Exxon Valdez Oil Spill
Restoration Project Annual Report

Harlequin Duck Population Dynamics

Restoration Project 00407
Annual Report

This annual report has been prepared for peer review as part of *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: Restoration Project 00407 begins a new phase of harlequin duck (*Histrionicus histrionicus)* studies initiated in 1991 by the Alaska Department of Fish and Game with Bird Study Number 11 (Assessment of Injury to Sea Ducks from Hydrocarbon Uptake in Prince William Sound and the Kodiak Archipelago, Alaska, Following the *Exxon Valdez* Oil Spill) and Restoration Study Number 71 (Breeding Ecology of Harlequin Ducks in Prince William Sound, Alaska). These earlier studies concluded that the number of harlequin ducks inhabiting oiled areas in western Prince William Sound (WPWS) declined as a result of the *Exxon Valdez* oil spill in 1989. The decline was attributed to direct mortality caused by oiling, and to subsequent low productivity of ducks that survived or avoided initial exposure. A Masters of Science thesis describing breeding habitat of harlequin ducks was also produced during the course of these initial studies (Crowley, D. W. 1994. Breeding habitat of harlequin ducks in Prince William Sound, Alaska. M. S. Thesis. Oregon St. Univ., Corvallis. 64pp.). Restoration Project (RP) 94427 (Experimental Harlequin Duck Breeding Survey) was initiated in 1994 in response to concerns that post-spill productivity by harlequin ducks in western Prince William Sound (WPWS) was not at a level necessary to maintain a viable population. The study developed criteria to differentiate harlequin ducks by age and sex to compare demographic characteristics of populations inhabiting oiled areas in WPWS with unoiled areas in eastern PWS (EPWS). Variation in population structure between locations would indicate dissimilar extrinsic influences affecting harlequin populations. A survey design was also developed to determine trends in harlequin abundance and production. Restoration Project /427 (Distribution, Abundance and Composition of Harlequin Duck Populations in Prince William Sound, Alaska), 1995-1997, utilized methods derived from RP 94427. Results from surveys conducted from 1995-1997 (Final Rept. 97427) found no major differences in population structure or timing of movements between WPWS and EPWS but did detect a decline in populations in oiled areas of WPWS and no significant change in population in unoiled areas of EPWS. The first winter survey, conducted in March 1997 (RP 97427), observed more harlequin ducks in oiled areas of WPWS and fewer in EPWS than indicated by spring and fall surveys.

Abstract: We compared numbers of breeding pairs, age and sex composition, and population trends to determine whether harlequin duck *(Histrionicus histrionicus)* populations in oiled areas of western Prince William Sound (WPWS) and unoiled areas of eastern Prince William Sound (EPWS), Alaska exhibited similar demographic characteristics. Similar demographics would indicate that populations in oiled areas had recovered from the 1989 *T/V Exxon Valdez* oil spill. Results are compared to our 1997 survey. We did not detect any major difference in population structure between EPWS and WPWS, except in the number of paired females. This suggests possible differences in breeding propensity but similar recruitment and survival rates. Numbers increased from 1997 to 2000 in both our WPWS (8.2%) and EPWS (29.8%) study areas. In 2000, we added transects along oiled shorelines of southwestern PWS and unoiled shorelines of Montague Island for regional comparisons. As this is only the second year of a four-year study we cannot draw conclusions about population trends and regional differences until we have additional surveys.

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

Project Data: *Description of data* - Data on sex, age, and location were recorded for each flock of harlequin ducks observed in PWS. *Format* - These data are in Microsoft Excel spreadsheet format and DBASE IV format. GIS coverage of PWS showing the location of each flock, survey transects, broods, and streams are presented in ARC VIEW format. *Custodian* - Archived at ADF&G regional headquarters in Anchorage. Contact Dan Rosenberg at ADF&G, 333 Raspberry Road, Anchorage, Alaska 99518 (907-267-2453) for information.

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EXECUTIVE SUMMARY

This study was initiated to determine whether the harlequin duck population in oiled areas of Prince William Sound (PWS), AK recovered or is in the process of recovering from the effects of the *T/V Exxon Valdez* oil spill (EVOS). In 1997, we began a transition from breeding season surveys (Rosenberg and Petrula 1998) to winter surveys to monitor the status of oiled and unoiled populations in PWS. We compared demographic characteristics of harlequin ducks *(Histrionicus histrionicus)* in the oil spill region of WPWS with reference areas (unoiled) in eastern Prince William Sound (EPWS). In 2000, we added transects along oiled shorelines of southwestern PWS and unoiled shorelines of Montague Island. This report summarizes results of surveys conducted in March of 1997 and 2000.

Harlequin ducks occur year-round in intertidal and shallow subtidal zones (nearshore waters) of PWS (Isleib and Kessel 1973). Relative to dabbling (Anatini) and diving (Aythyini) ducks, harlequin ducks and other sea ducks (Mergini) are considered *K* selected species in that they exhibit delayed sexual maturity, low annual recruitment, high adult survival and relatively low, but variable breeding propensity (Goudie et al. 1994). Long-term population stability depends on high adult survival coupled with a relatively few years of successful reproduction. High losses of adults may result in long recovery periods (Goudie et al. 1994).

In 1989, large numbers of harlequin ducks died in western PWS (WPWS) as a direct result of oil exposure following the *Exxon Valdez* oil spill (EVOS) (Ecological Consulting Inc. 1991). Harlequin ducks are particularly vulnerable to oil spills because 1) they exhibit fidelity to nearshore (marine) molting and wintering areas (Robertson 1999, Esler et al. 2000), 2) they utilize intertidal and shallow, subtidal zones exclusively for foraging for invertebrates (Dzinbal and Jarvis 1982), and 3) their nearshore habitats are subjected to the most severe and persistent effects of oiling (Highsmith et al. 1996, Short and Babcock 1996).

Prior to and coincidental to this study 1) invertebrate recovery in upper intertidal areas remained incomplete for some taxa (Hooten and Highsmith 1996), 2) oil persisted in mussel beds (Carls et al. 2001), 3) cytochrome P450 induction was greater in tissues of harlequin ducks captured in oiled areas than in reference areas (Trust et al. 2000), 4) overwinter survival was lower in oiled than reference areas (Esler et al. 2000), and 5) populations were declining in oiled areas and stable or slightly increasing in unoiled areas (Rosenberg and Petrula 1998).

We hypothesized that the population structure and trend in oiled and unoiled areas of PWS would be similar if the harlequin population in oiled areas had recovered or was in the process of recovering from the effects of oil exposure. We used the number of breeding pairs, and age and sex composition, as parameters to determine whether harlequin ducks in oiled and unoiled areas of PWS exhibit similar demographic characteristics. We used annual counts of harlequin ducks to compare population trends between oiled and unoiled study areas (treatments). Trends in abundance among study areas (WPWS, EPWS, SWPWS, MONT) and between treatments (oiled and unoiled) will be compared once we have three years of data. Variation among study areas or between treatments in population structure or growth would indicate dissimilar extrinsic influences acting on harlequin populations.

Harlequin ducks were counted along shoreline transects. Transects were established in areas surveyed in previous years (Patten et al. 1998a, Rosenberg and Petrula 1998) and known to support harlequin ducks. We counted 2,860 harlequin ducks along 550km of shoreline surveyed in our WPWS and EPWS study areas in 1997 and 4,823 harlequin ducks along 762km of shoreline surveyed in all 4 study areas in 2000 (Table 1).

The WPWS and EPWS study areas were surveyed in both 1997 and 2000. We counted more harlequin ducks in 2000 than 1997 in both areas (Table 1). Numbers increased substantially more between surveys in EPWS (29.8% increase) than in WPWS (8.2% increase), but more harlequin ducks were observed in WPWS in both years (Table 1). The proportion of males and females were similar between years and locations (Table 2) and consistent with sex ratios reported for other winter populations in British Columbia and Alaska. We observed 1.30–1.49 males for every female depending on study area and year (Table 3). We did not detect significant variation in sex ratios between WPWS and EPWS or between years (Table 4, Fig. 4). Males and females comprised 58.5% and 41.4% of the population, respectively, when both years and locations are pooled.

We used the proportion of paired females as an index of breeding propensity (Table 2). We assume that we can accurately identify breeding pairs and that only females determined to be part of a breeding pair will attempt to breed. We observed 0.37–0.41 non-paired females per breeding female in WPWS and 0.56–0.66 non-paired females per breeding female in EPWS depending on year (Table 3). The ratio of non-paired to paired females was significantly lower in WPWS than EPWS in both 1997 and 2000 (Table 4, Fig. 4) indicating a greater breeding propensity for females in WPWS. The ratio of non-paired to paired females observed in SWPWS and MONT were consistent with what we observed in WPWS and EPWS (Table 3).

We used the proportion of sub-adults as an index of recruitment (Table 2), and for comparison with other harlequin populations. We assume that the number of sub-adult males identified by plumage characteristics equals the number of sub-adult females, a cohort not identifiable during surveys. We observed 11.29–14.09 adult males for every sub-adult male in WPWS and 11.36–16.05 adult males for every sub-adult male in EPWS depending on year (Table 3). We observed 3.65–4.56 adult females for every sub-adult (male and female) in WPWS and 4.01-5.69 adult females for every sub-adult in EPWS depending on year (Table 3). The ratio of sub-adult males to adult males, and all sub-adults to females was similar in WPWS and EPWS, but significantly greater in 1997 than 2000 indicating lower recruitment in 2000 for both study areas (Table 4, Fig, 4).

The ratio of all sub-adults (males and females) to breeding pairs was similar between study areas and years, even though the number of breeding pairs was greater in WPWS. If our estimate of breeding pairs is biased low, this represent a maximum of 0.34 young/breeding pair and a minimum of 0.20 young/breeding pair for our WPWS and EPWS study areas combined. This level of productivity is insufficient to sustain population numbers given mortality rates reported by Esler et al. (2000).

We did not detect any differences in population structure between EPWS and WPWS that would indicate continued exposure to oil. Similar population structure indicates birds in oiled and unoiled study areas are not being influenced by different extrinsic factors. Based on population structure we believe the population in oiled areas is in a position to recover, or is recovering, from the effects of the *Exxon Valdez* oil spill.

Population growth from 1997 to 2000 was much greater in EPWS than WPWS. The population increase we observed in WPWS and EPWS was reflected equally in all sex and age classes. The change between 1997 and 2000 represents an average annual increase of 9.9% in EPWS and 2.7% in WPWS. This represents just 2 non-consecutive years of data so it must be viewed cautiously. Detecting trends with time-series data will require a minimum of 3 years of surveys. With two more winter surveys we will have a measure of variability within the entire survey area that will greatly improve our ability to assess the status of PWS harlequin ducks, predict future needs for monitoring and evaluate the most efficient and effective survey design.

If population structure remains similar, then population status relative to the recovery process will be determined by comparing population trends between oiled and unoiled sites. If population trends for oiled areas are not increasing at an equal or greater rate than for unoiled areas, extrinsic factors, such as increased oil exposure, may be suppressing population growth equally among age and sex classes, in oiled areas.

INTRODUCTION

This study was initiated to determine whether the harlequin duck population in oiled areas of Prince William Sound (PWS) recovered or is in the process of recovering from the effects of the *T/V Exxon Valdez* oil spill (EVOS). In 1997, we began a transition from breeding season surveys to winter surveys (Rosenberg and Petrula 1998) to monitor oiled and unoiled populations in PWS. This report compares population structure (breeding pairs, age, and sex ratios), between oiled and unoiled areas from data gathered during winter surveys in 1997 and 2000. We will compare population trends when we have completed additional surveys.

Harlequin ducks *(Histrionicus histrionicus)*, a sea duck *(Mergini)*, occur year-round in PWS (Isleib and Kessel 1973) and were the most abundant waterfowl species in nearshore habitats prior to the EVOS (Irons et al. 1988). On March 24, 1989, the *T/V Exxon Valdez* ran aground in northern PWS. Oil spread southwest, oiling 563 km of PWS shoreline before spreading to the Gulf of Alaska (Galt et al. 1991, Piper 1993) (Fig. 1). Within oiled areas, the harlequin duck wintering population was at risk of exposure because the EVOS occurred prior to movements to breeding areas. Post-spill studies estimated that a minimum of 423 harlequin ducks died in PWS as a direct result of the EVOS (Ecological Consulting, Inc. 1991).

Harlequin ducks are particularly vulnerable to oil spills because 1) they exhibit fidelity to nearshore (marine) molting and wintering areas (Robertson 1999, Esler et al. 2000), 2) they utilize intertidal and shallow subtidal zones exclusively for foraging for invertebrates (Dzinbal and Jarvis 1982), and 3) their nearshore habitats are subjected to the most severe and persistent effects of oiling (Highsmith et al. 1996, Short and Babcock 1996).

Prior to or coincidental to this study 1) invertebrate recovery in upper intertidal areas remained incomplete for some taxa (Hooten and Highsmith 1996), 2) oil persisted in mussel beds (Carls et al. 2001), 3) cytochrome P450 induction was greater in tissues of harlequin ducks captured in oiled areas than in reference areas (Trust et al. 2000), and 4) overwinter survival was lower in oiled than reference areas (Esler et al. 2000).

Several post-spill surveys and damage assessment studies were designed to measure the extent and severity of injuries to the PWS harlequin duck population from the EVOS (see Rosenberg and Petrula 1998). Results of longer-term monitoring surveys (Irons et al. 2000, Lance et al. 2001) are equivocal with respect to the effects of oil contamination on the population level of harlequin ducks in summer, although recovery was occurring in the winter population (Lance et al. 2000). From 1995–1997 populations were declining in oiled areas and stable or slightly increasing in unoiled areas (Rosenberg and Petrula 1998). Lower female survival in oiled areas (Esler et al. 2000) and evidence of exposure to residual oil (Trust et al. 2000) supported the conclusion that harlequin duck populations had not recovered from the spill.

A significant decline in numbers resulting from an acute increase in adult mortality potentially predisposes a population of sea ducks to a relatively long recovery period. A reduction in prey or indirect exposure (ingestion of contaminated foods) may further increase adult mortality or reduce productivity, extending the recovery process. Relative to dabbling (Anatini) and diving (Aythyini) ducks, sea ducks are considered *K* selected species because: (1) first breeding occurs later than 1 year of age; and (2) their life history is characterized by (a) low rates of annual recruitment, (b) high adult survival, and (c) relatively low and variable breeding propensity (Goudie et al. 1994). Sea ducks are sensitive to catastrophic causes of mortality because long-term population stability depends on high adult survival (Goudie et al. 1994).

In 1997, we began a transition from spring, summer, and fall surveys to winter surveys. March is a period when pair bonds are well formed (Robertson et al. 1998) and there is relative stability in both numbers and movements of harlequin ducks (Breault and Savard 1999, Robertson et al. 2000). In 2000, we conducted a second winter survey and expanded our coverage in order to make population structure and trend comparisons within treatment areas as well as between treatment areas (oiled versus unoiled). Once we complete three years of surveys we will be able to compare seasonal and annual trends in abundance and composition between study areas.

OBJECTIVES

1. Compare population structure of harlequin ducks (number of breeding pairs, subadults, adult males, and females) between oiled and unoiled areas during March.

2. Estimate density of harlequin ducks for oiled and unoiled survey sites.

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

4. Compare annual changes in density and population structure *within* oiled and unoiled survey sites.

5. Compare results with EVOS project /427 Harlequin Duck Recovery Monitoring (Rosenberg and Petrula 1998).

We hypothesized that the population structure and trend in oiled and unoiled areas of PWS would be similar if the harlequin population in oiled areas had recovered or were in the process of recovering from the effects of oil exposure. We used the number of breeding pairs, and age and sex composition, as parameters to determine whether harlequin ducks in oiled and unoiled areas of PWS exhibit similar demographic characteristics. We used annual counts of harlequin ducks to compare population trends between each area (oiled vs. unoiled).

Measures of composition and productivity reveal more about the status of a population than total numbers alone, and when combined with annual changes in density, provides a more comprehensive measure for comparison between oiled and unoiled sites. Annual variation between areas in population structure or growth rate would indicate dissimilar extrinsic influences acting on harlequin populations.

STUDY AREA AND METHODS

The study was conducted in Prince William Sound (PWS) (ca. 60°30'N, 147°00'W), a marine water body located on the southcentral coast of Alaska (Fig. 1). PWS is a large estuarine embayment of the northern Gulf of Alaska characterized by fjord-like ports and bays surrounded by steeply rising mountains. Highly irregular in shape, it is approximately 160km east to west and 140km north to south. Tides can exceed 4.5m and water depth can reach 870m. Total shoreline (including islands) is approximately 5,000 km (Irons et al. 1988). A general description of the physiography, climate, oceanography, and avian habitats of PWS was described by Isleib and Kessel (1973). After running aground on Bligh Reef in northern PWS, oil from the *T/V Exxon Valdez* spread southwest, oiling 563 km of shoreline in PWS before spreading to the Gulf of Alaska (Galt et al. 1991) (Fig. 1).

In 1997 and 2000 we surveyed harlequin ducks in areas of WPWS oiled by the EVOS and in areas of EPWS geographically distant from oiled areas (Fig. 1). Study areas were separated by a minimum of approximately 35km. In 2000, 2 additional study areas were included to broaden the geographic scope of the survey. Transects were established in southwestern Prince William Sound (SWPWS) along oiled shorelines of Bainbridge, Evans and LaTouche islands and in unoiled portion of Montague Island (MONT) (Fig. 2). Shoreline transects were subjectively chosen for each study area.

In WPWS, transects were established in selected areas extending from the north end of Culross Island, southeast to Dangerous Passage, southwest to Squire Island, and northeast to Green Island. Additional surveys in oiled portions of southwestern PWS were established along the shorelines of Bainbridge, Evans, and LaTouche islands. Transects varied relative to the extent and amount of oil they received. Transects included nearshore habitats and concomitant offshore rocks.

All transects located in the EPWS study area were known to support relatively high densities of harlequin ducks. Surveys in unoiled areas included portions of Hinchinbrook Island, Sheep Bay, Port Gravina, Landlocked Bay, Bligh and Busby islands, Galena Bay and Valdez Arm in northeastern PWS. An additional survey in unoiled portions of eastern PWS was conducted along the shoreline of northwestern Montague Island (Fig. 2).

Transects were surveyed in March (Table 1). Surveys were conducted from open skiffs (ca. 6m long) traveling at 2-10 km/hr within 100 meters of shore at a pace, course, and distance that assured complete coverage of the survey area. Two skiffs worked simultaneously on different transects or different portions of the same transect. This included circling all exposed rocks, and scanning shallow lagoons from shore when boat travel was not possible. Boating distance from shore depended on light, weather, and tide conditions. One full-time observer and an observer/boat operator continuously surveyed nearshore habitats using 10X binoculars. When possible we observed large flocks of resting ducks from vantage points on shore using a 20X-60X spotting scope. No surveys were conducted when wave height, weather, or light conditions compromised accuracy.

During all surveys, we recorded the number, sex, and age of all harlequin ducks observed in each flock, their pair status, and the location of the flock (GPS coordinates). We also marked flock locations on nautical charts (National Ocean and Atmospheric Administration).

Males were classified as adult or sub-adult based on plumage patterns (Rosenberg 1995, Smith 2000). We use the term sub-adult to refer to birds still in their first-year of life but in their second calendar year (e.g., hatched in July 1999, and observed in March 2000) unless otherwise noted.

Sub-adult females could not be visually differentiated from adults. Harlequin ducks that could not be identified by sex were recorded as unclassified.

We classified an adult male and female as a breeding pair when they were 1) physically closer to each other than either was to the next closest duck when roosting, swimming or in flight; or 2) their behavior suggested that a pair-bond had formed (Inglis et al. 1989, Gowans et al. 1997). Paired females were considered adults.

We doubled the number of sub-adult males to estimate the total number of sub-adults in the population. We assumed the number of sub-adult males equals the number of sub-adult females because 1) juvenile sex ratios are similar on the breeding grounds (Ashley 1998) and 2) broods migrate with adults to the wintering areas (Smith 2000). We assume similar survival and dispersal rates. The number of adult females was calculated by subtracting sub-adult females from total females.

Survey Coverage

Shoreline length (km) of transects was 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.

We surveyed 2 study areas in 1997 and 4 study areas in 2000, consequently we surveyed less shoreline in 1997 (550.3 km) than in 2000 (762.6 km) (Table 1). Variation in survey coverage within study areas existed among years because, on occasion, poor weather or ice conditions precluded the completion of some (or portions of) transects (Table 1).

We selected more transect locations in EPWS (n=25) than WPWS (n=18), SWPWS (n=12) and Montague Island (n=7), but total shoreline length was greatest in WPWS (Table 1). Transect length varied (range = 1 to >70 km) (Appendix A1) and averaged 16.7 km (SD=19.6) in WPWS, 10.0 km (SD=7.5) in EPWS, 12.4 km (SD=6.5) in SWPWS, and 10.5 km (SD=2.2) in MONT.

Statistical Methods

Population Structure

We used a generalized logit model (Agresti 1990) to test for annual differences between study areas (EPWS and WPWS), for the following ratios: (1) male to female; (2) adult males to sub-adult males; 3) sub-adults (both sexes) to adult females and (3) non-paired to paired females. A test of the hypothesis of no interaction between main effects (i.e., study area and year) was based on a likelihood ratio test (Stokes et al. 1995). Non-significant interaction terms were excluded from the model and a reduced model was used to test for significant study area or year effect. We used the natural logarithm of ratios (logit) to interpret the differences between years and locations (study areas). Because SWPWS and MONT were only surveyed in 2000, these study areas were not included in our annual comparisons.

Trend Analysis

Once we have three years of surveys, we will use the number of harlequin ducks to compare trends in abundance among study areas. We will analyze our data at a regional spatial scale using simple linear regression (Rosenberg and Petrula 1998). To estimate the rate of change among years for oiled and unoiled study areas we regress density of harlequin ducks against year to generate a slope and variance for each transect within a region during each survey period. A mean slope for each region will be calculated by weighting the slopes for each transect by the total number of ducks counted during the survey period in all years combined.

For each treatment (study area) we will compare the average rate of change between regions (ANOVA). This will allow us to identify regional differences within the oiled or unoiled study areas. A two-sample t-test will be used to test for differences in the rate of change in duck density between study areas. We will calculate the power to detect differences in slopes between study areas.

Absolute Measures

The number of harlequin ducks classified as unknown varied among our surveys. To avoid erroneous interpretation when comparing the absolute abundance of specific components of the population, we partitioned unknown birds among the appropriate age, sex, and breeding categories based on observed proportions.

RESULTS

Abundance and Distribution

We did not compare total counts of harlequin ducks between study areas because survey effort deliberately varied (Table 1). Density comparisons are also inappropriate because transect locations were arbitrarily selected and harlequin ducks, for the most part, used particular segments of transects (e.g., emergent rock, rocky point) with a high degree of regularity, creating a patchy rather than uniform distribution throughout PWS.

We counted a total of 2,860 harlequin ducks along 550.3km of shoreline in our WPWS and EPWS study areas in 1997 and 4,823 harlequin ducks along 762.6km of shoreline in our 4 study areas in 2000. The total number of harlequin ducks, the number of adult males, females and sub-adult males, and the number of breeding pairs were greater in WPWS than EPWS during our surveys in 1997 and 2000 (Table 2).

Numbers increased from March 1997 to March 2000 in both WPWS (+08.2%) and EPWS (+29.8%)(Table 6). This increase was reflected equally in both sexes. However, the number of sub-adult males declined slightly in both areas (Table 2, Appendix A3).

Harlequin ducks were observed on all transects surveyed (Appendix A2). Distribution and relative abundance are presented in Appendix B for the 2000 survey and in Rosenberg and Petrula (1998) for the 1997 survey. Transects which supported a large proportion of the total number of harlequin ducks in WPWS included Green Island, Naked Island, Foul Bay, and Falls

Bay. Green Island accounted for 33% and 35% of the total ducks counted in WPWS in 1997 and 2000, respectively. Large proportions of harlequin ducks counted in EPWS were observed on transects in Port Gravina and Sheep Bay. Birds in SWPWS and Montague Island were more equally distributed, in part, due to smaller survey areas (Appendicies A2 and B).

Population Structure

Sex Ratios

We observed 1.30-1.49 males for every female during winter surveys in our 4 study areas (Table 3). Sex ratios were not significantly different between study areas or years for our comparison between WPWS and EPWS (Table 4, Fig. 4).

Sex ratios were skewed towards males in all surveys and study areas (Tables 2 and 3). For all study areas combined, males comprised 58.7 percent of the population and females 41.3 percent. Montague Island had the lowest percentage of males among the four survey areas while WPWS had the highest (Table 2).

Breeding-Pair Ratios

We observed 0.37–0.66 non-paired females for every paired female depending on study area and year (Table 3). The non-paired:paired ratio was significantly lower in WPWS than EPWS in both 1997 and 2000 (Table 4, Fig. 4). Thus, the proportion of paired females was significantly greater in WPWS in both 1997 and 2000.

Combining all surveys, 67.7% of the female population was paired in 2000. Comparing the 1997 survey with comparable areas surveyed in 2000, 68.5 percent and 67.2 percent of females were paired respectively. In 2000, WPWS (oiled) and Montague Island (unoiled) had the highest percentage of paired females (73.0% and 71.4% respectively), while EPWS (unoiled) and SWPWS (oiled) had the lowest (60.7% and 65.8% respectively).

Age Composition

In our model, annual differences in ratios of adult to sub-adult males was best explained by a year effect and not by location (Table 4). Sub-adult males comprised a significantly greater proportion of the male population in 1997 than 2000 in both WPWS and EPWS (Table 4, Fig. 4). The number of adult males observed for every sub-adult male varied from 11.29 in WPWS in 1997 to 28.69 in SWPWS in 2000 (Table 3).

We also compared the ratio of sub-adults (both sexes) to adult females. The number of sub-adult males were doubled to obtain the number of total sub-adults and used to obtain a sub-adult to adult female ratio. In our model, annual differences in ratios of all sub-adults to adult females was best explained by year and not by location (Table 4). Total sub-adults comprised a significantly greater proportion of the adult female population in 1997 than 2000 in both WPWS and EPWS (Table 4, Fig. 4). We observed from 3.65–10.58 adult females for every sub-adult depending on study area and year (Table 3).

We compared the number of sub-adults to breeding pairs, although we did not run this in our model. In 1997, we observed 0.34 sub-adults per breeding pair in both WPWS and EPWS. In 2000, the overall ratio of sub-adults to breeding pairs declined to 0.27, but again was the same for WPWS and EPWS. In 2000, Montague Island and SWPWS had the lowest sub-adult to breeding pair ratios we recorded. We observed 0.13 and 0.14 sub-adults per breeding pair respectively.

Population Trends

Once we have completed three years of surveys in all four study areas we will compare seasonal and annual trends in abundance between treatments and among study areas.

DISCUSSION

Abundance and Distribution

We compared demographic characteristics of harlequin duck populations in oiled areas and unoiled areas of PWS to determine whether variation exists between populations. Similarity in both composition and similar positive trends in abundance would indicate that the harlequin population in WPWS is recovering or has recovered from the effects of the EVOS. Before variation between populations can be fully interpreted with respect to recovery, we must determine the relationship, if any, between treatment effect and geographic variation.

In 2000, we increased the geographic scope of the survey by adding a study area in oiled areas of SWPWS and unoiled areas of Montague Island. We will not be able to make comparisons among study areas and years until we have completed 3 surveys in all locations. Therefore, we primarily compare 1997 and 2000 data for the WPWS and EPWS study areas.

Within our 2-week survey period during the winter we believe the number of harlequin ducks in PWS remains relatively constant. Once the annual molt is completed and pair-bonds form, birds on wintering areas are philopatric to relatively small geographic areas (Holland-Bartels et al.1998, Robertson et. al 2000). Although some dispersal and mortality occurs throughout winter (Cooke et al. 2000), it is a period of relative stability compared to the large-scale and asynchronous movements that occur during migration to and from breeding grounds. On an annual basis, harlequin ducks observed during our surveys likely represent many of the same birds because a high percentage of males and females return to the same wintering areas (Robertson et. al. 2000).

During the winter survey in 1997 and 2000, we counted substantially more harlequin ducks in WPWS than EPWS (Table 1). However, during previous surveys conducted in the spring, summer and early fall we counted more harlequin ducks in EPWS (Rosenberg and Petrula 1998). This suggests that at some point between molt (early fall) and the following March harlequin ducks immigrated to WPWS and emigrated from EPWS. Post-molt dispersal to different wintering sites is especially common among unpaired males but also occurs in adult males and females (Robertson et al. 1999, Cooke et al. 2000, D. Esler, pers. comm.). Although we do not have fall surveys to compare with our 2000 data, this post-molt redistribution may be the normal pattern. Whether this seasonal influx into WPWS is from EPWS, a different but limited geographical region, or a much broader region, is unknown.

Population Structure

Sex ratios skewed toward males are typical for sea ducks (Goudie et al. 1994). As expected, we consistently observed more males than females. Sex ratios did not change from 1997 to 2000. Pooling data from all winter surveys, we recorded 58.7% males and 41.3% females (Table 5). Sex ratios in PWS approximate proportions for harlequin ducks on other coastal wintering sites (Table 5). Geographic difference in sex ratios may reflect long-term differences in productivity or survival, but this is not apparent in our comparisons. However, our numbers are more skewed towards males than reported for wintering populations in Kodiak and Amchitka islands (Table 5). The ratios reported in the latter two studies are similar to what we observed when comparing ratios of adult males to females (Table 2).

The percentage of sub-adult males (and absolute numbers) was greater in 1997 than 2000 for both oiled and unoiled sites, indicating better recruitment in 1996-1997 and no direct oil effect on this parameter. Our ratios of sub-adult males to *all males* for WPWS and EPWS survey areas in 1997 and 2000 (0.059–0.081) are within the range observed in wintering populations in British Columbia over five winters (0.042–0.082) (Smith 2000). They overlap the low end of the range of winter ratios (1999–2001) from Kachemak Bay, Alaska (0.072–0.100) (Petrula and Rosenberg 1999, 2000, 2001) and are below those reported from Iceland (0.09) (Gardarsson in Smith 2000). Our lowest male age ratios of 0.034 and 0.035 for SWPWS and Montague Island respectively were similar to lows reported for harlequin ducks in Maine where sub-adult ratios ranged from 0.03 – 0.22, over an 11 year period, averaging 0.11 (n=1,700, ±0.008) (Mittelhauser in Smith 2000). As a reminder, in our tables we present ratios of sub-adult males to *adult* males. We did not present ratios of sub-adult males to *all males* but include it here for comparison with other studies.

Age ratios are similar in oiled and unoiled areas and appear to be within normal ranges for harlequin duck populations. As sex ratios are similar between study areas, differences in age ratios would indicate recent differences in breeding propensity, breeding success, or juvenile survival between oiled and unoiled populations. We found no evidence to indicate that different extrinsic factors in WPWS and EPWS are affecting age ratios.

To maintain a stable population, recruitment, from all sources, must be equal to adult mortality. Esler et al. (2000) estimated winter survival rates in PWS between 0.780 (± 0.033 SE) and 0.837 (± 0.029 SE) for adult females in oiled and unoiled areas respectively. As adult males and females exhibit similar winter survival rates (Cooke et al. 2000), the low proportion of sub-adults we record are insufficient to compensate for adult mortality and sustain populations. Nor can it explain the population increase we observed between 1997–2000 unless in the interim years, 1) recruitment was much better than observed, 2) survival rates were greater than Esler et al. (2000) observed from 1995–1998, or 3) immigration exceeded emigration. Otherwise, 1) plumage patterns of sub-adults males may vary more than recognized, making it an unreliable technique 2) the number of sub-adult males does not approximate the number of sub-adult females, or 3) sub-adults are not distributed equally among wintering populations.

We believe our results approximate recruitment rates of sub-adults. Smith (2000) reported no marked change in plumage patterns that would make sub-adult males more difficult to distinguish from females or adult males as winter progressed. Juvenile sex ratios are similar on the breeding grounds (Ashley 1998) and fledged young accompany adult females to wintering areas (Smith 2000). Similar male age ratios in western Canada and southcentral Alaska, supports relatively equal distribution of sub-adults throughout the population, although we did find lower ratios in SWPWS and Montague Island. Additional surveys will help us confirm if this is a persistent pattern resulting from unequal geographic distribution or annual variation.

The number of sub-adult males was lower in both WPWS and EPWS in March 1997 than the following spring. This is consistent with an influx of birds, mostly non-paired males, in spring (Robertson et al. 1999). We do not know if this pattern was repeated in 2000. Whether any of these birds remains through the following winter is unknown.

The ratio of sub-adults/adult females varied by year but not by location. This also reflected the lower recruitment rates observed in 2000 (as previously indicated by the ratio of sub-adult males to adult males). This index is likely a better indicator of reproductive success than male age ratios. Population growth rates are female limited (Goudie et al. 1994), females exhibit relatively little movement between molting and wintering sites (D. Esler, pers. comm), and dispersal rates of females may be less variable than adult males.

We used the ratio of non-paired to paired females as an index of breeding propensity; assuming that only paired females will attempt to breed. Most females have formed pair bonds by December although first-time breeders may not establish pair bonds until April (Robertson et al 1998). We would expect to find most females paired in March, thus, our estimate of the number of paired females in winter may be biased low and account for the higher percentage of unpaired females we observe during winter than spring surveys (Rosenberg and Petrula 1998). Pairs may also behave differently in winter than spring, making pair assessment more difficult and less accurate (Robertson et al. 1998).

The significantly greater percentage of paired females we observed in WPWS than EPWS in 1997 and 2000 is difficult to explain. If correct, we would predict greater breeding propensity in the WPWS population but this is not consistent with the similar age ratios we observed. This discrepancy is possibly a function of survey conditions. Poorer survey conditions or shoreline topography may have required us to approach birds more closely, creating greater disturbance and disruption of normal behavior, making it appear that fewer birds were paired. The much greater percentage of unclassified birds we recorded in EPWS in both years (Table 2), and records of survey conditions, supports this explanation. Future surveys may help us determine if we are detecting a higher percentage of paired females in WPWS or this is weather related.

The ratio of all sub-adults (males and females) to breeding pairs was nearly identical in EPWS and WPWS in 1997 and 2000 even though the number of breeding pairs was greater in WPWS. We are reluctant to emphasize this until we are confident that our assessment of the number of breeding pairs is comparable (see above). If the number of breeding pairs we observe is biased low, this represents a maximum of 0.34 young/breeding pair for our WPWS and EPWS study areas combined (1997 data). Assuming all adult females were paired, this would represent a minimum of 0.20 young/breeding pair for the same area (2000 data).

Population Trends

The rate of population growth from 1997 to 2000 was much greater in EPWS than WPWS. The change between 1997 and 2000 represents an average annual increase of 9.9% in EPWS and 2.7% in WPWS. This represents just 2 non-consecutive years of data so it must be viewed cautiously.

Factors Affecting Counts

Several factors account for variation in the number and composition of harlequin ducks we observed in PWS. Actual differences between years in abundance and composition are related to variation in productivity, mortality, and rates of immigration and emigration. Although we did not quantify these specific parameters, we made inferences about their contribution to annual variation observed in the harlequin population.

Measurement error may contribute to variation in our harlequin counts. We believe, however, that because the same observers participated in surveys, surveys were conducted at the same time each year and transects were thoroughly searched, any bias in our data resulting from measurement error is minimal and accounted for in our interpretation of the results.

CONCLUSIONS

This study was designed to assess the recovery status of harlequin duck populations after the *Exxon Valdez* oil spill by comparing population trends and structure between oiled and unoiled areas. In future years, we will test for geographical differences within PWS that may affect population change independent of treatment (oiled or unoiled). As this is just the second year of a longer-term monitoring study it is premature to draw conclusions about all of our hypotheses.

We did not detect any substantial differences in population structure between EPWS and WPWS that would indicate continued exposure to oil. We observed similar age and sex ratios between EPWS and WPWS. Similar population structure indicates that the oiled population is in a position to recover, is recovering, or has recovered from the effects of the *Exxon Valdez* oil spill. Where populations are in this recovery process will be determined by comparing population trends between oiled and unoiled sites. If population trends in oiled areas are not increasing at an equal or greater rate than unoiled areas, then extrinsic factors, such as increased oil exposure, may be suppressing population growth equally among age and sex classes, in oiled areas.

In 2000 we observed a greater population in both EPWS and WPWS than in 1997, but detecting trends with time-series data will require a minimum of 3 years of surveys. The overall population increase was greater in EPWS. The population increase we observed in WPWS and EPWS was reflected equally in all sex and age classes. The summer of 1996 and following fall and winter were a better year for recruitment than 1999–2000. Sex ratios are skewed towards males but are similar to other wintering populations. Age ratios are also within ranges reported for other wintering populations.

We observed similarities in distribution and habitat use from year to year. As in 1997, WPWS had a greater wintering population than EPWS. The WPWS population increased from early

September, while the EPWS population decreased. Winter is the only season when we observe more ducks in WPWS than EPWS (Rosenberg and Petrula 1998).

We need additional years of surveys before we can assess geographic differences within oiled and unoiled areas. Thus, we did not include these areas in our ratio models nor can we compare population change. We observed relatively fewer sub-adults in SWPWS and Montague Island then we observed in our WPWS or EPWS study areas, but it is premature to draw conclusions with only one year of data.

With two more winter surveys we will have a measure of variability within the entire survey area that will greatly improve our ability to assess the status of PWS harlequin ducks, predict future needs for monitoring and evaluate the most efficient and effective survey design.

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Table 1. Survey dates, kilometers of shoreline surveyed, and numbers of harlequin ducks in oiled areas of western (WPWS) and southwestern (SWPWS) and unoiled areas of eastern (EPWS) Prince William Sound and Montague Island, Alaska in 1997 and 2000.

	Year	
	1997	2000
Survey Dates	March 13-19	March 20-31
Shoreline Surveyed (km)		
WPWS (oiled)	301.1	301.1
EPWS	249.2	244.4
SWPWS (oiled)	DNS[a]	143.3
Montague Island	DNS[a]	73.8
Total	550.3	762.6
No. of Harlequin Ducks		
WPWS (oiled)	1677	1814
EPWS	1183	1535
SWPWS (oiled)	DNS[a]	691
Montague Island	DNS[a]	783
Total	2860	4823

[a] Did Not Survey

Table 2. Number and composition of harlequin ducks in oiled areas of western (WPWS) and southwestern (SWPWS) and unoiled areas of eastern (EPWS) Prince William Sound and Montague Island (MONT), Alaska for winter surveys in 1997 and 2000. Numbers in parenthesis indicate % of total birds that were classified by age or sex.

Study Area	Year	Adult Males	Sub-adult Males	Unk.[a] Males	Total Males	Females	Un-classified[b]	Pairs [c]	Total
WPWS	1997	892 (54.8)	79 (4.8)	3 (0.2)	974 (59.8)	655 (40.2)	48 (2.9)	465 (57.1)	1677
WPWS	2000	986 (55.5)	70 (4.0)	2 (0.1)	1058 (59.9)	709 (40.1)	47 (2.7)	517 (58.5)	1814
EPWS	1997	511 (52.8)	45 (4.7)	5 (0.5)	561 (58.0)	406 (42.0)	216 (22.3)	261 (54.0)	1183
EPWS	2000	706 (54.5)	44 (3.4)	0 (0.0)	750 (57.9)	545 (42.1)	240 (18.5)	329 (50.8)	1535
SWPWS	2000	373 (55.5)	13 (1.9)	6 (0.9)	392 (58.3)	280 (41.7)	19 (2.8)	184 (54.8)	691
MONT	2000	334 (54.6)	12 (2.0)	0 (0.0)	346 (56.5)	266 (43.5)	171 (27.9)	189 (61.8)	783

[a] Age of males unknown.
[b] Not included in ratio analysis.
[c] Included in adult male and female totals.

Table 3. Ratios of the harlequin duck population in oiled areas of western (WPWS) and southwestern (SWPWS) Prince William Sound and unoiled areas of eastern (EPWS) Prince William Sound and Montague Island (MONT), Alaska during winter surveys in 1997 and 2000.

		Ratios			
Study Area	Year	Males: Females	Non-Paired: Paired Females	Adult Males: Sub-Adult Males	Adult Females: Sub-Adults
WPWS[a]	1997	1.49	0.41	11.29	3.65
WPWS	2000	1.49	0.37	14.09	4.56
EPWS[b]	1997	1.38	0.56	11.36	4.01
EPWS	2000	1.38	0.66	16.05	5.69
SWPWS[a]	2000	1.40	0.52	28.69	10.27
MONT[b]	2000	1.30	0.41	27.83	10.58
All Unoiled Sites	2000	1.35	0.57	18.57	6.81
All Oiled Sites	2000	1.47	0.41	16.37	5.46
All Sites[c]	1997	1.45	0.46	11.31	3.79
All Sites	2000	1.41	0.48	17.26	6.05

[a] Oiled
[b] Unoiled
[c] EPWS and WPWS

Table 4. Logit analysis used to test for differences in demographic parameters of the harlequin duck population between western and eastern Prince William Sound, Alaska.

Ratio	Survey period	Source	DF	Chi-square	Prob.
Males: Females	Winter	Intercept	1	184.7	<0.001
		Year	1	00.0	0.993
		Study Area	1	1.98	0.159
		Year*Study Area	1	00.0	0.946
Non-paired : Paired females	Winter	Intercept	1	254.3	<0.001
		Year	1	0.05	0.818
		Study Area	1	25.3	<0.001
		Year*Study Area	1	2.09	0.148
Adult : Sub-adult males	Winter	Intercept	1	1447.4	<0.001
		Year	1	4.06	0.044
		Study Area	1	0.23	0.629
		Year*Study Area	1	0.20	0.654
Females : Sub-adults	Winter	Intercept	1	833.42	<0.001
		Year	1	7.58	0.006
		Study Area	1	2.28	0.131
		Year*Study Area	1	0.36	0.550

Table 5. Comparisons of winter sex ratios reported for harlequin ducks in western North America. Data from several years, when available, are pooled.

Location	Males (%)	Females (%)	n	Source
PWS, AK	58.7	41.3	7,683	This Study
British Columbia	58.3	41.9	9,439	Smith 2000
Kachemak Bay, AK	60.5	39.5	2,366	Petrula and Rosenberg 1999, 2000, 2001
Kodiak Island, AK	54.4	45.6	489	Zwiefelhofer and Forsell 1989
Amchitka Island, AK	53	47	Unknown	Byrd et al. 1992

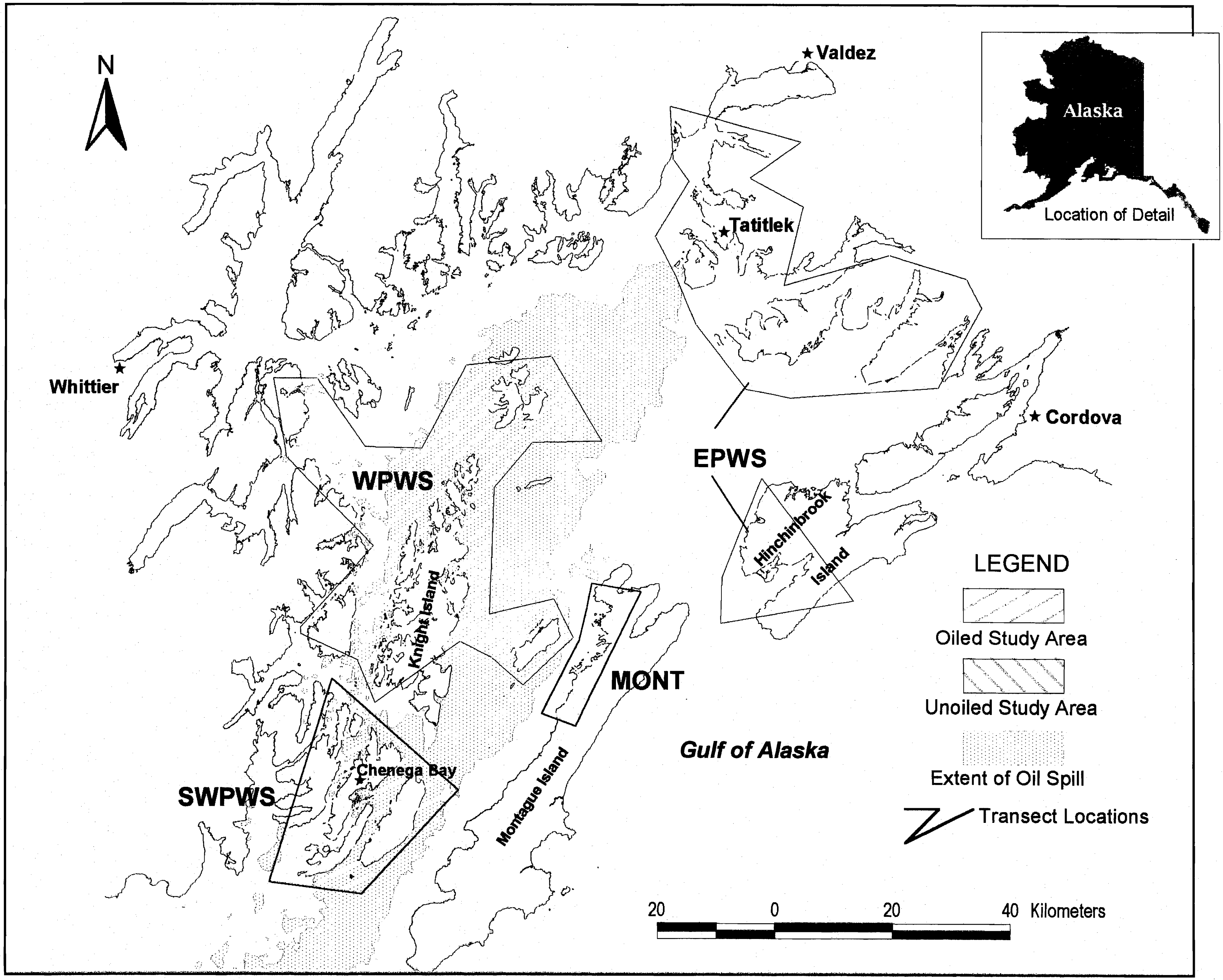


Figure 1. Map of Prince Wiliam Sound, Alaska showing general location of the western (WPWS), southwestern (SWPWS), eastern (EPWS), and Montague Island (MONT) study areas superimposed over the Exxon Valdez oil spill.

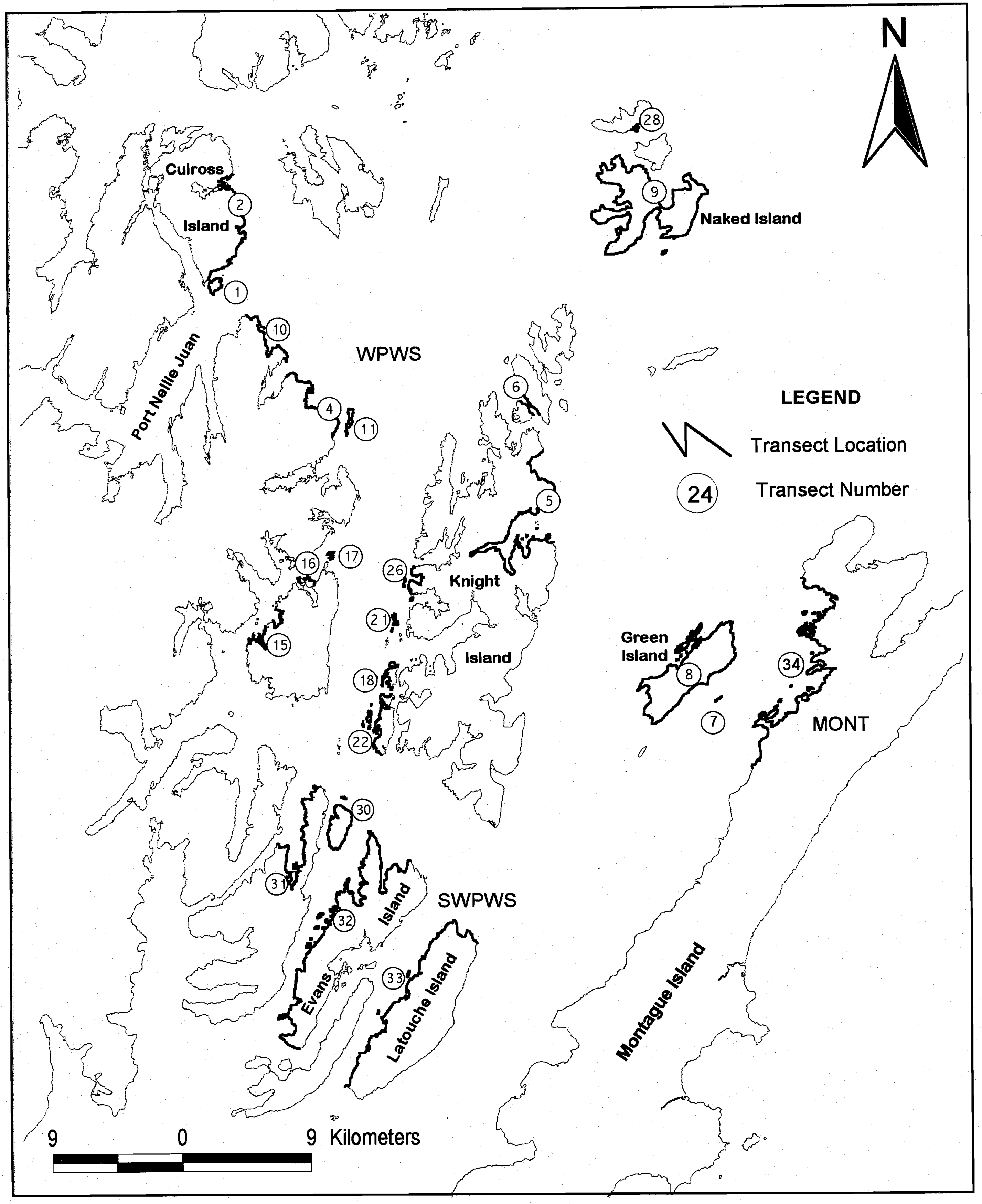


Figure 2. Location of oiled transects surveyed for harlequin ducks in western (WPWS) and southwestern (SWPWS), Prince William Sound, Alaska and unoiled transects on Montague Island (MONT). Transect numbers are referenced in tables.

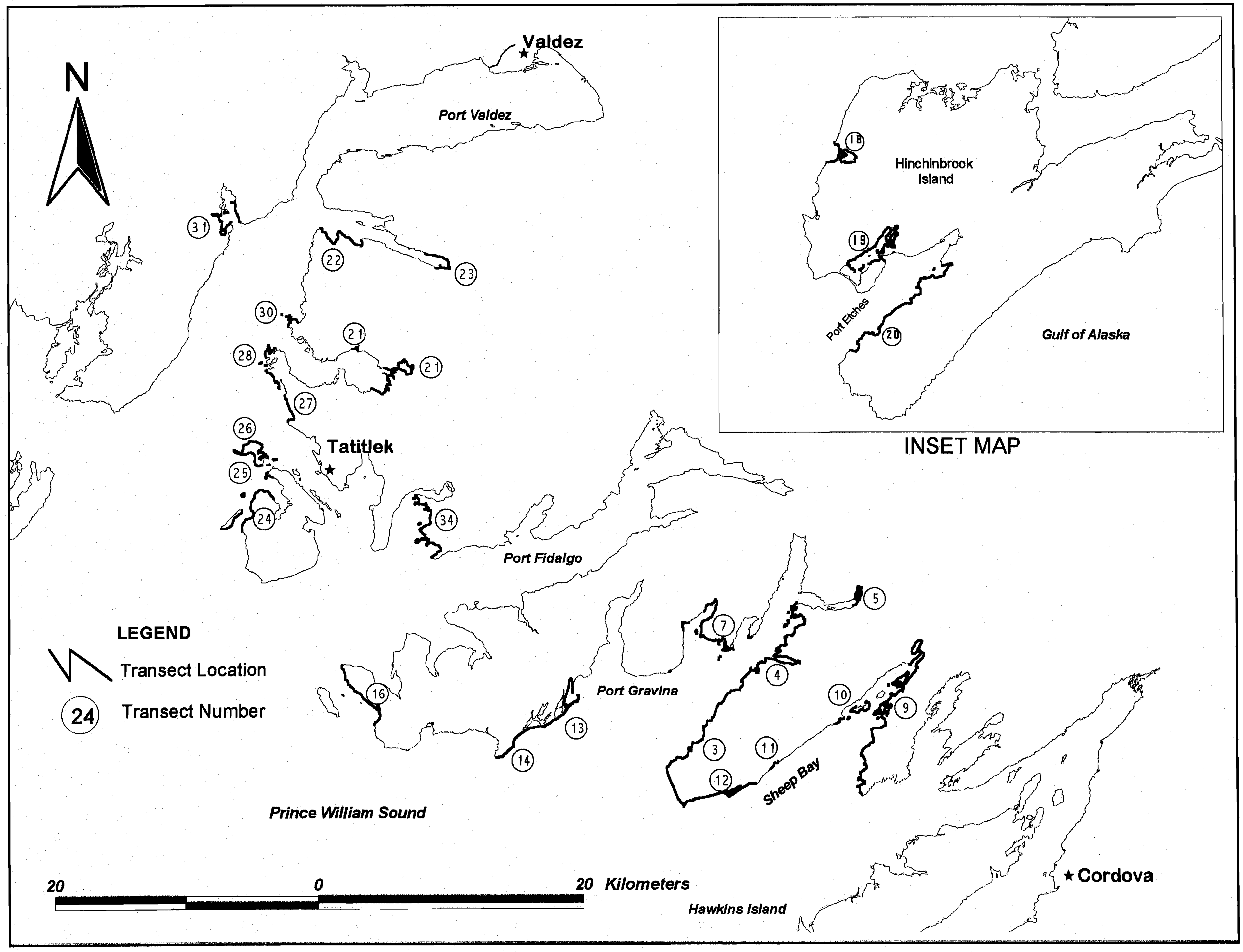


Figure 3. Location of transects (unoiled) surveyed for harlequin ducks in eastern Prince William Sound (EPWS), Alaska. Transect numbers are referenced in tables.

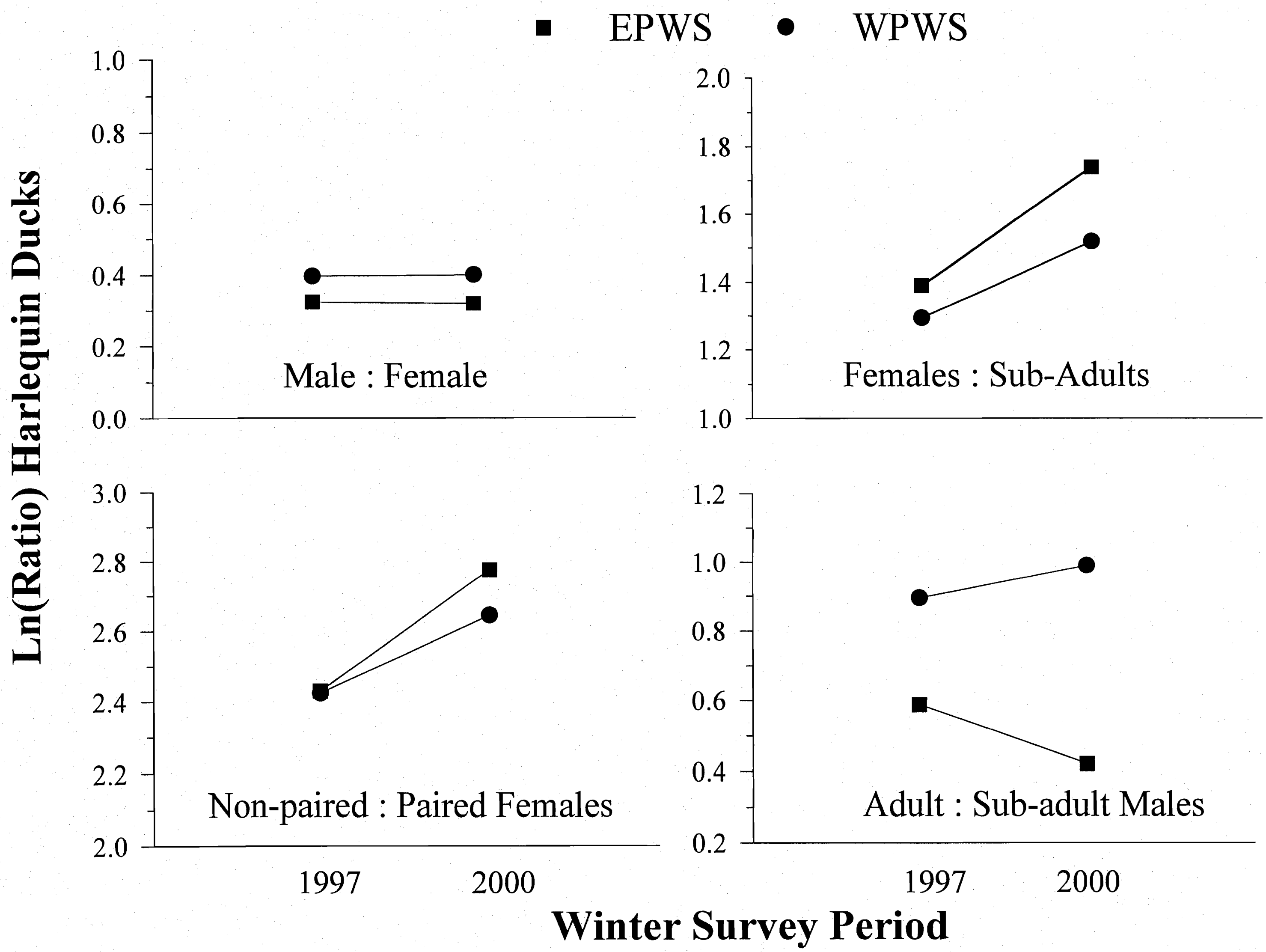


Figure 4. Natural logarithm of ratios observed for harlequin ducks for sex, breeding pair status, and male age structure, in oiled areas of western (WPWS) and unoiled areas of eastern (EPWS) Prince William Sound, Alaska during March surveys in 1997 and 2000

Appendix A 1. Transect, region, and study area spatial scales (see Methods) used to compare trends in harlequin ducks observed in oiled areas of western (WPWS) and southwestern (SWPWS) and unoiled areas of eastern (EPWS) Prince William Sound and Montague Island (MONT), Alaska in March 1997 and 2000. SWPWS and MONT transects were not surveyed in 1997.

Study Area	Location	Transect number[a]	Transect length (km)	Region[b]	Study Area	Location	Transect number	Transect length (km)	Region
WPWS	Aguliak Island	26	9.0	7	WPWS	Green Island	8	51.5	4
WPWS	Applegate Island	1	5.9	1	WPWS	Junction Island	17	2.7	3
WPWS	Bay of Isles	5	41.9	6	WPWS	Masked Bay	16	2.6	3
WPWS	Channel Island	7	1.6	4	WPWS	Mummy Island	18	10.8	7
WPWS	Crafton Island	11	6.8	2	WPWS	Naked Island	9	73.2	5
WPWS	Culross Island	2	21.0	1	WPWS	Squire Island	22	21.3	7
WPWS	Falls Bay	4	15.1	2	WPWS	Squirrel Island	21	4.5	7
WPWS	Foul Bay	10	11.7	2	WPWS	Storey Island	28	2.8	5
WPWS	Foul Pass	6	5.5	6	WPWS	Totemoff Creek	15	13.2	3
SWPWS	Bainbridge Bay[c]	31a	13.2	1	SWPWS	Latouche Is. (N)	33a	18.5	1
SWPWS	Bainbridge Pt. [c]	31b	13.1	1	SWPWS	Latouche Is. (S)	33c	2.8[e]	1
SWPWS	Danger Island	33d	2.9[e]	1	SWPWS	Latouche Is. (SW)	33b	16.1	1
SWPWS	Flemming Island	30a	12.6	1	SWPWS	Prince of Walesd[d]	32c	20.2	1
SWPWS	Gage Island	30b	1.2	1	SWPWS	Shelter Bay[d]	32a	17.7	1
SWPWS	Iktua Bay[d]	32b	15.9	1	SWPWS	Squirrel Bay[d]	32d	14.7	1
EPWS	Beartrap Bay[f]	5	4.8	1	EPWS	Port Etches	20	17.0	3
EPWS	Black Creek	27	2.6	5	EPWS	Port Gravina(NE)	4	20.6	1
EPWS	Busby Island (N)	26	6.2	5	EPWS	Port Gravina(SE)	3	17.3	1
EPWS	Busby Island (S)	25	6.2	5	EPWS	Redhead	14	8.8	1
EPWS	Close Island	10	4.8	2	EPWS	Reef/Bligh Islands	24	7.1	5
EPWS	Constantine Harbor	19	19.7	3	EPWS	Rocky Pt./Galena Is.	28	6.1	5
EPWS	Galena Bay	21	12.6	5	EPWS	Sawmill Bay	31	7.4	5
EPWS	Galena Rocks	30	2.5	5	EPWS	Sheep Bay(E)	9	35.0	2
EPWS	Hell's Hole	13	6.4	1	EPWS	Sheep Bay(SW)	12	8.8	2
EPWS	Jack Bay	22	5.7	5	EPWS	Shelter Bay	18	9.0	3
EPWS	Landlocked Bay	34	13.3	4	EPWS	Surf Creek	11	1.0	2
EPWS	Olsen Bay	7	14.9	1	EPWS	Vladnoff River	23	4.0	5
EPWS	Porcupine Bay	16	7.4	4					
MONT	Gilmour Point	34d	9.9	1	MONT	Port Chalmers (S)	34f	10.7	1
MONT	Graveyard Point	34a	11.2	1	MONT	Stockdale Harbor	34b	14.8	1
MONT	Moose Lips	34g	10.4	1	MONT	Wilby Island	34e	8.9	1
MONT	Port Chalmers (N)	34c	7.8	1					

[a] **Transect numbers referenced in Fig. 2 and Fig. 3.**

[b] **Regions are discreet for each study area**

[c] **Bainbridge Island**

[d] **Evans Island**

[e] **Did not survey in 2000**

[f] **Did not survey in 1997**

Appendix A 2. Number of harlequin ducks counted on transects surveyed in oiled areas of western (WPWS) and southwestern Prince William Sound (SWPWS), unoiled areas of eastern Prince William Sound (EPWS) and Montague Island (MONT), Alaska in March 1997 and 2000.

			Number of Harlequin Ducks	
Transect location	Transect Number	Transect Length (km)	1997	2000
WPWS				
Aguliak Island	26	9.0	37	67
Applegate Island	1	5.9	40	33
Bay of Isles	5	41.9	86	81
Channel Island	7	1.6	33	31
Crafton Island	11	6.8	79	71
Culross Island	2	21.0	96	62
Falls Bay	4	15.1	154	167
Foul Bay	10	11.7	146	193
Foul Pass	6	5.5	6	13
Green Island	8	51.5	559	644
Junction Island	17	2.7	20	18
Masked Bay	16	2.6	3	6
Mummy Island	18	10.8	51	48
Naked Island	9	73.2	168	221
Squire Island	22	21.3	105	79
Squirrel Island	21	4.5	59	34
Storey Island	28	2.8	6	15
Totemoff Creek	15	13.2	29	31
Total		301.1	1677	1814
SWPWS				
Bainbridge Bay[b]	31a	13.2	DNS[a]	9
Bainbridge Pt.[b]	31b	13.1	DNS[a]	72
Danger Island	33d	2.9	DNS[a]	DNS[a]
Flemming Island	30a	12.6	DNS[a]	55
Gage Island	30b	1.2	DNS[a]	7
Iktua Bay[c]	32b	15.9	DNS[a]	64
Latouche Is. (N)	33a	18.5	DNS[a]	151
Latouche Is. (S)	33c	2.8	DNS[a]	123
Latouche Is. (SW)	33b	16.1	DNS[a]	DNS[a]
Prince of Wales[c]	32c	20.2	DNS[a]	56
Shelter Bay[c]	32a	17.7	DNS[a]	64
Squirrel Bay[c]	32d	14.7	DNS[a]	90
Total		143.3	------	691

[a] Did not survey
[b] Bainbridge Island
[c] Evans Island

Appendix A 2 (Cont).

Transect location	Transect Number	Transect Length (km)	Number of Harlequin Ducks 1997	2000
EPWS				
Beartrap Bay	5	4.8	0	DNS[a]
Black Creek	27	2.6	4	6
Busby Island(N)	26	6.2	44	74
Busby Island(S)	25	6.2	35	81
Close Island	10	4.8	107	107
Constantine Harbor	19	19.7	27	49
Galena Bay	21	12.6	0	DNS[a]
Galena Rocks	30	2.5	0	18
Hell's Hole	13	6.4	65	68
Jack Bay	22	5.7	21	31
Landlocked Bay	34	13.3	42	82
Olsen Bay	7	14.9	95	67
Porcupine Bay	16	7.4	30	83
Port Etches	20	17.0	55	86
Port Gravina(NE)	4	17.3	39	34
Port Gravina(SE)	3	20.6	189	149
Redhead	14	8.8	59	185
Reef/Bligh Islands	24	7.1	23	9
Rocky Point/Galena Is.	28	6.1	54	16
Sawmill Bay	31	7.4	0	8
Sheep Bay(E)	9	35.0	181	148
Sheep Bay(SW)	12	8.8	55	152
Shelter Bay	18	9.0	34	52
Surf Creek	11	1.0	24	30
Vladnoff River	23	4.0	0	DNS[a]
Total		249.2	1183	1535
MONT				
Gilmour Point	34d	9.9	DNS[a]	23
Graveyard Point	34a	11.2	DNS[a]	135
Moose Lips	34g	10.4	DNS[a]	144
Port Chalmers (N)	34c	7.8	DNS[a]	32
Port Chalmers (S)	34f	10.7	DNS[a]	95
Stockdale Harbor	34b	14.8	DNS[a]	86
Wilby Island	34e	8.9	DNS[a]	268
Total		73.8	---	783

[a] Did not survey

Appendix A 3. Number and composition of harlequin ducks in oiled areas of western (WPWS) and southwestern (SWPWS) and unoiled areas of eastern (EPWS) Prince William Sound and Montague Island (MONT), Alaska after unknown birds were partitioned among the appropriate age, sex, and breeding categories based on observed proportions. Numbers are presented for March 1997 and 2000 surveys.

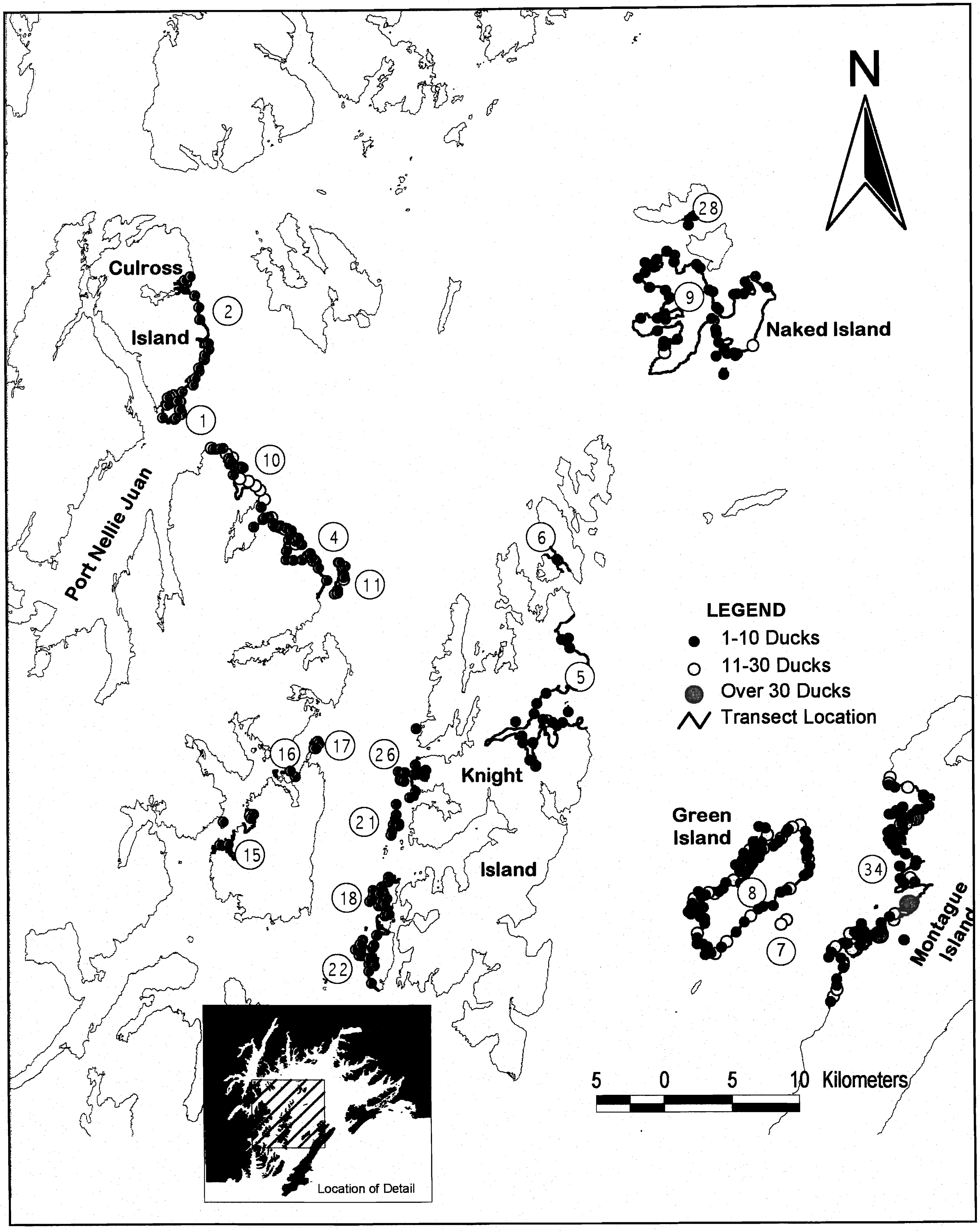
	Number of Harlequin Ducks							
	WPWS				EPWS			
Classification	Original Count 1997	Corrected Count 1997	Original Count 2000	Corrected Count 2000	Original Count 1997	Corrected Count 1997	Original Count 2000	Corrected Count 2000
Adult Males	892	918	986	1,012	511	625	706	837
Sub-adult males	79	81	70	72	45	55	44	52
Unknown males[a]	3	4	2	2	5	6	0	0
Females	655	674	709	728	406	497	545	646
Unclassified	48	0[c]	47	0[c]	216	0[c]	240	0[c]
Breeding Pairs[b]	465	478	517	531	261	319	329	392
Total	1677	1677	1814	1814	1183	1183	1535	1535

[a] Age of males unknown.
[b] Included in adult male and female totals.
[c] Distributed among other categories based on relative percent.

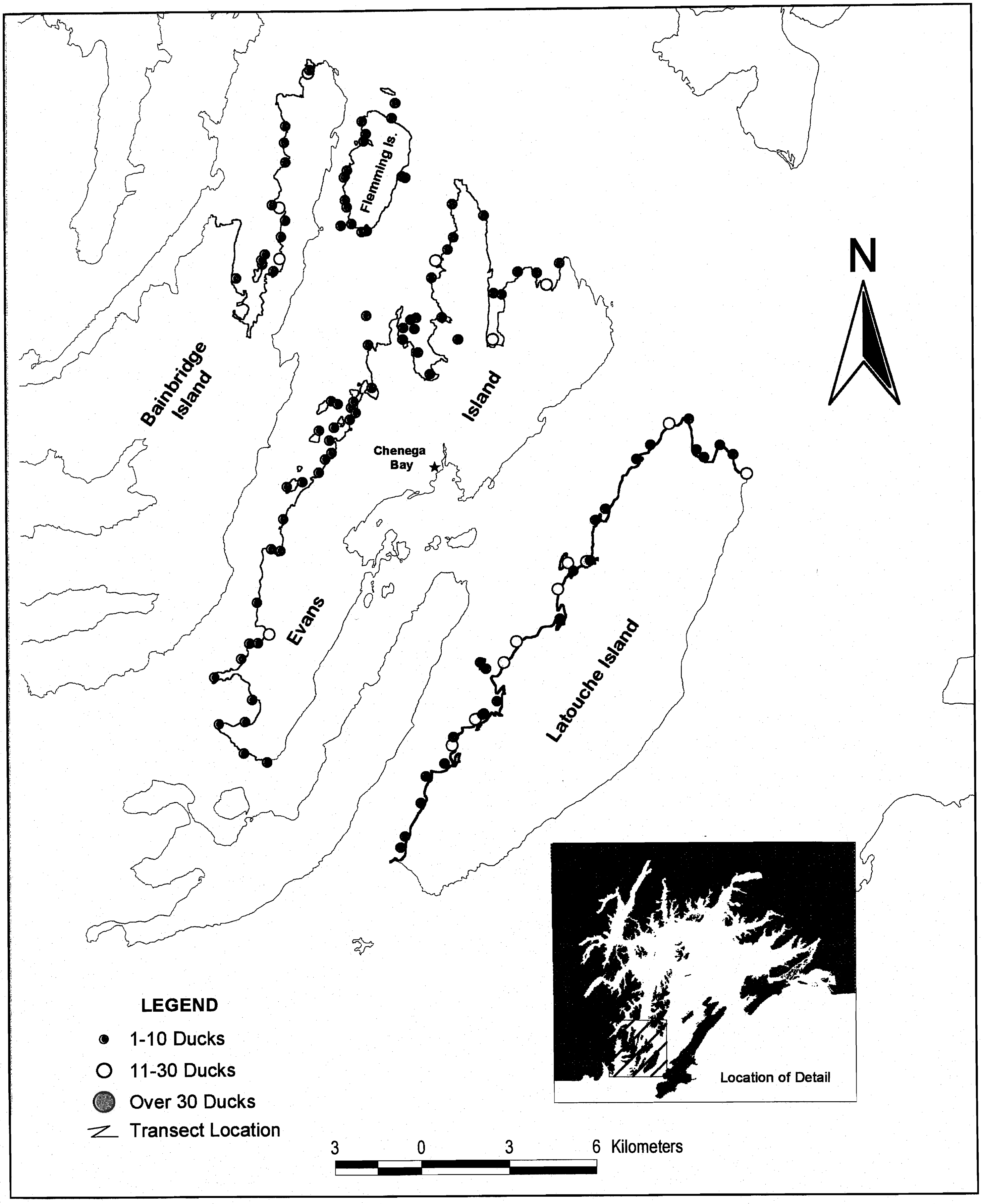
Appendix A 3 (Cont).

	Number of Harlequin Ducks			
	SWPWS		MONT	
Classification	Original Count 2000	Corrected Count 2000	Original Count 2000	Corrected Count 2000
Adult Males	373	384	334	427
Sub-adult males	13	13	12	16
Unknown males[a]	6	6	0	0
Females	280	288	266	340
Unclassified	19	0[c]	171	0[c]
Breeding Pairs[b]	184	189	189	243
Total	691	691	783	783

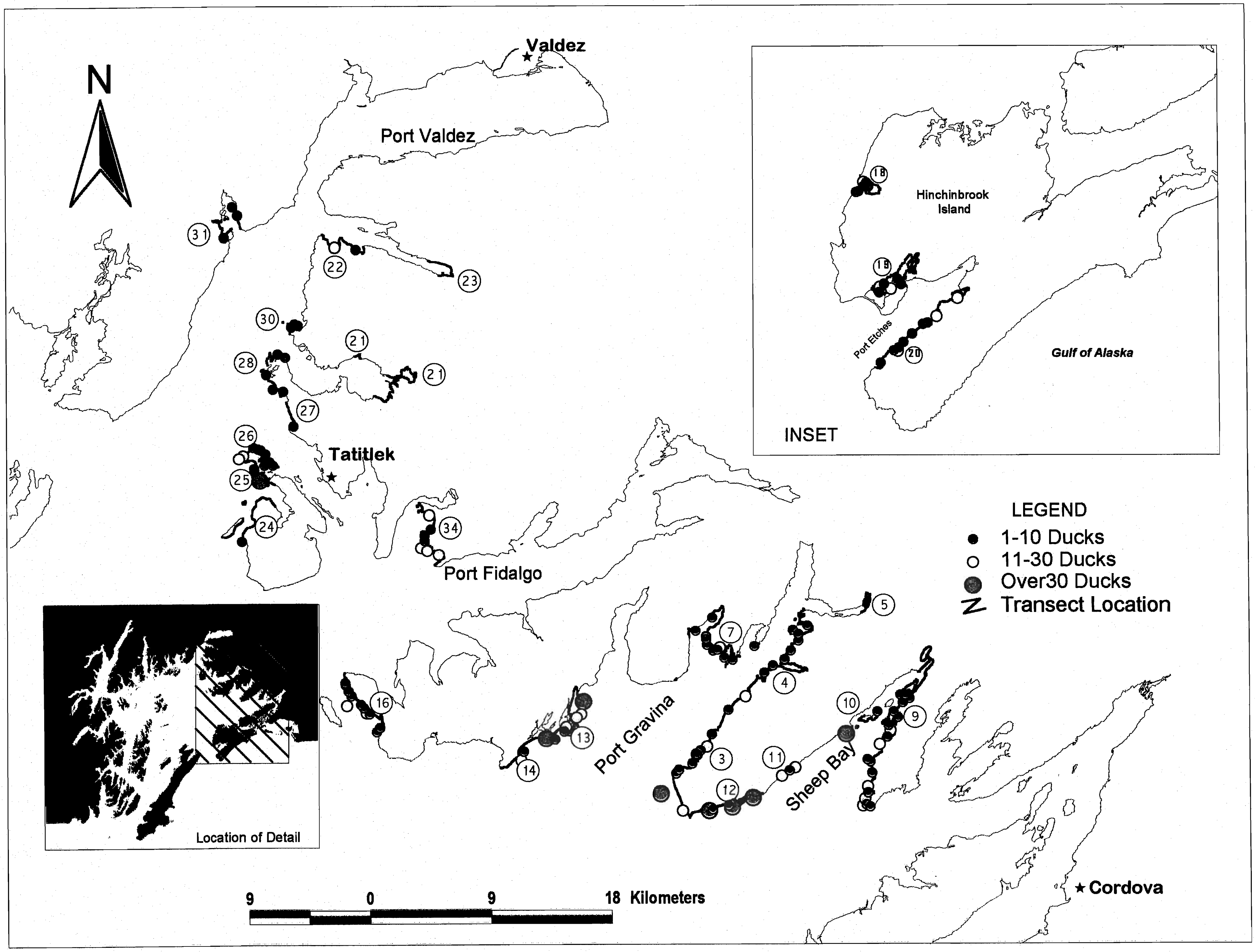
[a] Age of males unknown.
[b] Included in adult male and female totals.
[c] Distributed among other categories based on relative percent.



Appendix B1. Distribution of harlequin ducks during March 2000 on oiled transects in western Prince William Sound (WPWS) and unoiled transects on Montague Island (MONT).



Appendix B2. Distribution of harlequin ducks observed on oiled transects in southwestern PWS (SWPWS) during the March 2000 survey.



Appendix B3. Distribution of harlequin ducks on unoiled transects in eastern Prince William Sound (EPWS), Alaska during March 2000 surveys.