

APPENDIX E

APEX: 95163 E

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KITTIWAKES AS INDICATORS OF CHANGE IN FORAGE FISH

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ABSTRACT

In 1990, the year following the *T/V Exxon Valdez* oil spill, productivity (fledglings/nest) of Black-legged Kittiwakes in Prince William Sound (PWS) decreased and has not recovered. Studies during this period indicated the decline in productivity resulted from decreased food availability and increased predation. Kittiwake productivity for 1995 was average at Shoup Bay, Eleanor Island, and Seal Island colonies, but overall productivity for kittiwakes in PWS (26 colonies) was low.

While foraging, kittiwakes from Shoup Bay traveled four times the distance and twice the duration of kittiwakes from Eleanor Island and still maintained productivity and chick growth rates similar to Eleanor Island. These results were similar to data collected in 1989 and indicated the potential for adult kittiwakes to buffer their chicks against variability in prey resources, although data from 1990 indicated a certain threshold point exists, beyond which adults can no longer buffer chicks.

Walleye pollock located offshore were a large portion of the forage fish biomass in PWS (APEX component A), however, adult kittiwakes foraged near shore (< 1 km) and fed their chicks primarily Pacific herring and Pacific sand lance (species of greater energy density than walleye pollock; APEX component G).

Surprisingly, kittiwakes often (> 50% of foraging) did not feed in foraging flocks and exhibited foraging site fidelity. These foraging behaviors are important in testing hypotheses of the APEX project.

Data collected during this study and Irons (1992) will allow us to model the relationship of prey availability, foraging effort, and productivity, and predict the effects of changes in oceanographic conditions and forage fish availability on population dynamics of kittiwakes in PWS.

INTRODUCTION

Seabirds have been recognized as potentially useful indicators of marine resources by many authors (Ashmole 1971, Boersma 1978, Crawford and Shelton 1978, Anderson and Gress 1984, Ricklefs et al. 1984, Cairns 1987, Croxall et al. 1988, Monaghan et al. 1989, Harris and Wanless 1990, Furness and Barrett 1991, Furness and Nettleship 1991, Hamer et al. 1991, Hunt et al. 1991). Availability of food resources affect foraging success, which in turn affects reproductive output. Several reproductive parameters have been proposed as useful indicators: breeding phenology, clutch size, breeding success, chick diets, chick growth rates, adult colony attendance, adult activity budgets, foraging trip duration, and adult mass (Cairns 1987, Croxall et al. 1988).

Although foraging behavior partially determines reproductive output, the nature of this relationship may be complex. Optimal foraging models predict precise behaviors that are assumed to maximize fitness (Schoener 1971, 1987, Pyke 1984, Stephens and Krebs 1986). In contrast to the idea of optimality, evidence indicates there is a range of foraging effort over which reproductive output is not affected (Costa and Gentry 1986, Burger and Piatt 1990, Irons 1992). For example, Cairns (1987) suggested that adult survivorship changes only when food is in very short supply while activity budgets change only during medium and high levels of food availability. The phenomenon responsible for this uncoupling of foraging effort and reproductive output above threshold levels of food abundance has been termed a "buffer" (Cairns 1987, Burger and Piatt 1990). A buffer can be defined as the surplus capacity to forage. Buffers can be used to compensate for periods of low food availability so that reproductive output is maintained even though food is less available. Cairns (1987) also pointed out that activity budgets may be better than reproductive parameters as indicators of changes in food supply; the effects of food supply changes on reproductive output may be reduced by parents altering their foraging behavior to compensate for shortages. Burger and Piatt (1990) and Irons (1992) found evidence of this in common murre (*Uria aalge*) and black-legged kittiwakes (*Rissa tridactyla*), respectively.

In addition to understanding how food shortages affect productivity of seabirds, it is important to understand how seabirds find their food in order to identify which processes break down during a food shortage. Many species of seabirds, including black-legged kittiwakes and marbled murrelets (*Brachyramphus marmoratus*), forage in flocks (Sealy 1973, Hoffman et al. 1981, Duffy 1983, Harrison et al. 1991) which apparently increases their foraging efficiency (Lack 1968, Morse 1970, Sealy 1973, Hoffman et al. 1981, Wittenburger and Hunt 1985, Gotmark et al. 1986, Harrison et al. 1991). The formation of seabird feeding flocks is enhanced by a form of information transfer termed "network foraging" (Wittenburger and Hunt 1985), which results in seabirds learning of and joining feeding flocks by observing the flight of other seabirds as they fly toward a feeding flock (Gould 1971, Sealy 1973, Hoffman et al. 1981). However, the importance of flock foraging has been questioned by Irons (1992), who found that much foraging by breeding kittiwakes occurred outside of foraging flocks.

During the 1995 nesting season, productivity, chick diets, and foraging of kittiwakes were monitored at three colonies in PWS and compared to data from a colony in lower Cook Inlet (the Barren Islands, APEX component K). Additionally, data were compared to previous years (Irons 1992 and USFWS unpubl. data). We addressed two of the ten APEX project hypotheses:

1. Seabird diet reflects changes in relative abundance and distribution of forage fishes around colonies.
2. Changes in seabird productivity reflect changes in availability of forage fishes as measured in foraging trips, chick meal size, and chick provisioning rates.

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METHODS

This study was conducted in PWS, a 10,000 km² inland marine/estuarine waterway located along the north coast of the Gulf of Alaska (Fig. 1). Prince William Sound has heterogeneous bathymetry and large tide height variation causing eddies and upwelling which likely affect the distribution of forage fishes and their availability to seabirds. Primary Black-legged Kittiwake colonies studied during the 1995 nesting season in PWS were located near Shoup Bay, Eleanor Island, and Seal Island. In 1995, Shoup Bay was the largest kittiwake colony (5628 nests, an increase of 4197 nests since 1984) in PWS, Eleanor Island was a relatively small colony (159 nests, relatively stable since 1984), and Seal Island was relatively small but increasing in size (270 nests, an increase of 185 nests since 1994). The Black-legged Kittiwake colony at the Barren Islands (Fig. 1) was much larger (> 10,000 nests) than colonies in PWS.

Between 6 June and 23 August, the contents of Black-legged Kittiwake nests were recorded every three to seven days at colonies located near Shoup Bay (206 nests in 12 plots), Eleanor Island (159 nests, entire colony), and Seal Island (270 nests; entire colony). Only nests built before 20 June were included in the plots. Plots also were established and included nearly all nests at the Bay of Isles, Naked Island, and Eaglek Bay kittiwake colonies. Productivity for all kittiwake colonies in PWS (n = 26 colonies) was determined by conducting nest counts in mid June and chick counts in early August.

To determine growth rates, measurements of chicks were recorded every three to seven days from hatching to fledgling. Recorded measurements included length (± 0.1 mm) of culmen, headbill, tarsus, length (± 1 mm) of wingchord, fifth and tenth primaries, and total mass (g) of bird. Growth was calculated as weight gain per day during the near-linear growth phase of 60 to 300 g; producing results that are virtually identical to Ricklefs's (1967) maximum instantaneous growth rates (Galbraith 1983). Additional measures of growth will be evaluated during further data analyses.

Chick diet samples (regurgitations) were collected while handling chicks, weighed to the nearest 0.01 g on an Ohaus top-loading balance, and preserved in 70% ethyl alcohol or frozen. Typically, no more than one sample was collected per chick. Prey were identified using otoliths (all species) and scales (Pacific herring; *Clupea pallasii*).

Adult Black-legged Kittiwakes were captured at their nests using a noose pole and radio transmitters (Advanced Telemetry Systems, Inc (ATS), 166 – 167 MHz, 10 g) were attached to 23 birds at Shoup Bay, 18 birds at Eleanor Island, and 11 birds at Seal Island. Three transmitters for each frequency were differentiated by pulse widths of 145, 185, and 195 milliseconds. Transmitters were attached (using two plastic cable ties and Loctite 494 instant adhesive) to the ventral surface at the base of tail feathers (Anderson and Ricklefs 1987; Irons 1992). Head, breast, tail and underwings of radio-tagged kittiwakes were dyed (Nyanzol D, Rhodamine B, and Malachite Green Oxalate) one of three unique color combinations corresponding to the pulse width of the transmitter. The dye permitted easy identification of kittiwakes during tracking.

A remote receiving station (RRS) recorded the presence of radio-transmitted kittiwakes at Shoup Bay, Eleanor Island, and Seal Island colonies. A RRS consisted of an ATS data collection computer (DCC) connected to an ATS receiver and a two element "H" antenna. The RRS was powered by an 80 amp/hr deep cycle, lead-acid battery, which was charged by a three amp solar panel. The DCC continuously scanned each frequency for one minute every ten minutes. Data from the RRS's were useful in determining changes in foraging trip duration related to time of day, tides, and nest contents (eggs, chicks, fledglings, no nest).

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Foraging trip duration, distance, location, and behavior were determined while tracking radio-tagged kittiwakes from a 7.3 m Boston Whaler with an ATS receiver and a four element yagi antenna. Kittiwakes rearing chicks were selected for tracking. Observers waited near the colony until a radio-tagged bird left, then attempted to keep the kittiwake in view until it returned to the colony. Behaviors recorded included traveling (strait flight), searching for prey (back and forth flight), foraging (surface plunge or surface seize; Ashmole 1971), resting, and lost (bird out of view). Since duration of pursuit and handling of prey for kittiwakes is negligible compared to search time (Irons 1992), foraging was combined with searching in final analyses. Observers also recorded locations of foraging flocks and whether the radio-tagged kittiwake joined or passed the foraging flock. Foraging flocks included any seabird species and were divided into three categories; 1) foraging flock (≥ 2 birds flying back and forth with at least two surface plunge or surface seize locations less than 10 m apart), 2) dispersed foraging flock (≥ 2 birds foraging in an area > 10 m and < 500 m), and 3) potential foraging flock (≥ 2 birds flying back and forth with < 2 foraging attempts within a 500 m diameter). Locations of foraging kittiwakes, foraging flocks, and flight paths of radio-tagged kittiwakes were determined using a Lowrance LMS-350A geographic positioning system receiver (GPS). The computer program Atlas GIS was used to plot foraging trip locations and measure distance to shore for foraging kittiwakes, maximum foraging distance from colony (shortest distance without intersecting land), and total trip distance.

Reproductive parameters at all kittiwake colonies in PWS and diets of chicks at Shoup Bay for 1995 will be compared to historical data (1985 – 1994; U.S. Fish and Wildlife Service unpubl. data). Foraging parameters for kittiwakes at Shoup Bay and Eleanor Island colonies in 1995 will be compared to data collected in 1989 and 1990 (Irons 1992).

RESULTS

Analyses of data collected in 1995 are not complete and considered preliminary. Final results will be subjected to statistical analyses.

Productivity (fledglings/nest) was greater at Shoup Bay and Barren Islands than Eleanor and Seal Islands (Fig. 2a). Laying success (80 to 96% of nest structures had ≥ 1 egg) and mean clutch size (1.5 to 1.8 eggs) were similar among sites, therefore, reduced productivity at Eleanor and Seal Islands resulted from greater egg and chick mortality. Brood reduction (percent of two-chick broods reduced to one chick broods) was greater at Eleanor Island (57%) and Seal Island (44%) compared to Shoup Bay (36%). Mean chick growth rates were similar among sites in PWS and slightly greater at the Barren Islands (Fig. 2b). Overall productivity for kittiwakes in PWS was 0.19 fledglings/nest, continuing the trend of reduced productivity since 1990 (Fig. 3). Decreased productivity resulted in part from increased failure (≤ 0.10 fledglings/nest) of kittiwake colonies in PWS during 1990 to 1995 (mean = 50%, range = 46% – 54%) compared with 1985 to 1989 (mean = 79%, range = 63% – 89%), rather than low productivity throughout PWS.

Chick diets in 1995 were primarily Pacific herring and Pacific sand lance (*Ammodytes hexapterus*) at Shoup Bay, Pacific herring at Eleanor Island and Seal Island, and capelin (*Mallotus villosus*) and Pacific sand lance at the Barren Islands (Fig. 4). Walleye pollock (*Theragra chalcogramma*) was a small portion ($\leq 9\%$) of chick diets at all locations. Diets of kittiwake chicks from 1988 to 1995 at Shoup Bay also were dominated by Pacific herring and Pacific sand lance; two prey species that, except for 1988, alternate in greatest percent occurrence among years (Fig. 5).

Mean foraging trip duration was two times greater and distance was seven times greater for kittiwakes from Shoup Bay compared with Eleanor Island (Fig. 6). Foraging trip time budgets indicated the duration of travel, search, and rest for kittiwakes from Shoup Bay was at least twice

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that of kittiwakes from Eleanor Island (Fig. 7). Mean number of feeding attempts per foraging trip was greater for kittiwakes from Shoup Bay (mean = 22 attempts; SE = 5.35) than kittiwakes from Eleanor Island (mean = 10 attempts; SE = 3.05). Mean distance to shore of foraging locations for kittiwakes from Shoup Bay was 0.90 km (SE = 0.24; Fig 8a), 0.24 km (SE = 0.04; Fig 8b) for kittiwakes from Eleanor Island, and 0.28 km (SE = 0.09; Fig 8c) for kittiwakes from Seal Island. Forty-seven percent of feeding attempts of kittiwakes were not associated with foraging flocks when foraging flocks were present.

DISCUSSION

Reduced productivity of kittiwakes at Eleanor and Seal Islands compared to kittiwakes at Shoup Bay and the Barren Islands resulted from egg and chick mortality, possibly due to predation and weather (Seal and Eleanor Island colonies are more exposed to extreme swell and tide conditions than Shoup Bay). Brood reduction also was greater at Eleanor Island and Seal Island colonies than Shoup Bay, a potential indicator of decreased food availability near Eleanor and Seal Islands (Braun and Hunt 1983; Irons 1992). Brood reduction at Eleanor Island and Seal Island in 1995 was mid-way between brood reduction at Shoup Bay in 1989 (33 %, similar to 1995) when productivity and chick growth were average and 1990 (77%) when productivity and chick growth were reduced because of limited food availability (Irons 1992). These results indicated the potential for food to have been a greater limitation to productivity of kittiwakes at Eleanor Island and, to a lesser extent, Seal Island than at Shoup Bay.

Although kittiwakes from Shoup Bay traveled four times the distance and twice the duration while foraging compared with kittiwakes at Eleanor Island, productivity was greater at Shoup Bay and chick growth rates were similar. These results were consistent with data collected at the same colonies in 1989 (Irons 1992) and indicated the potential for adult kittiwakes to buffer their chicks against variability in prey resources. The ability of adults to buffer chicks against variable prey resources has also been reported for Common Murres (*Uria aalge*; Burger and Piatt 1990). Increased foraging trip duration and decreased chick growth for kittiwakes from Shoup Bay in 1990 compared to 1989 and 1995, however, indicated a threshold beyond which adults cannot buffer chicks (Irons 1992).

If decreased food availability did cause increased brood reduction at the Eleanor Island colony, it is interesting that kittiwakes did not increase foraging effort to the extent that kittiwakes at Shoup Bay were capable of maintaining. Irons (1992) reported kittiwakes nesting at Shoup Bay exhibited foraging site fidelity and suggested that predictable locations for finding food were learned, which is a possible explanation for low reproductive success of young kittiwakes compared with older, more experienced birds. Kittiwakes at Eleanor Island may not greatly change foraging effort unless there is a significant reduction in food due to foraging site fidelity and their reliance on locations of predictable (historically) food resources. There may be a range of food availability over which adult kittiwakes will not change their foraging effort if they can successfully raise at least one young. As with foraging effort and productivity, foraging effort and prey availability may not be a linear relationship. Data collected during this study and Irons (1992) will allow us to model the relationship of prey availability, foraging effort, and productivity, and predict the effects of changes in oceanographic conditions and forage fish availability on population dynamics of kittiwakes in PWS.

Cairns (1987) suggested that activity budgets may be better than reproductive parameters as indicators of changes in food availability. In addition to prey availability, predation is a significant factor affecting productivity of kittiwakes in PWS (Irons pers. obs.). Although foraging activity indicates changes in prey availability, the relationship to productivity is complicated by the effect of

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predation. Therefore, it is important to collect data on foraging activity and measures of productivity that are mostly independent of predation (e.g. brood reduction, chick growth rates, chick weight at fledging, adult body condition) to more accurately determine the relationship of prey availability to productivity.

For the past seven years at the Shoup Bay colony, Pacific herring and Pacific sand lance dominated chick diets and alternated annually in greatest percent occurrence. Kittiwake chick diets from the Barren Islands, Eleanor Island and Seal Island colonies in 1995 also indicated the importance of Pacific herring, Pacific sand lance, and capelin as prey items; all species of greater energy density than walleye pollock (APEX component G) which was a large portion of the forage fish biomass in PWS (APEX component A).

Kittiwakes primarily foraged within 1 km of shore indicating the importance of the natural history of forage fishes and nearshore oceanographic processes in affecting the availability of primary forage species. These results are consistent with locations of mixed species foraging flocks located by Ostrand (APEX component B)

Results of this study and Irons (1992) indicated kittiwakes, which have been thought to generally feed in flocks, often (> 50% of the time) fed alone, signifying the importance of considering foraging site fidelity when evaluating changes in foraging effort among sites and among years.

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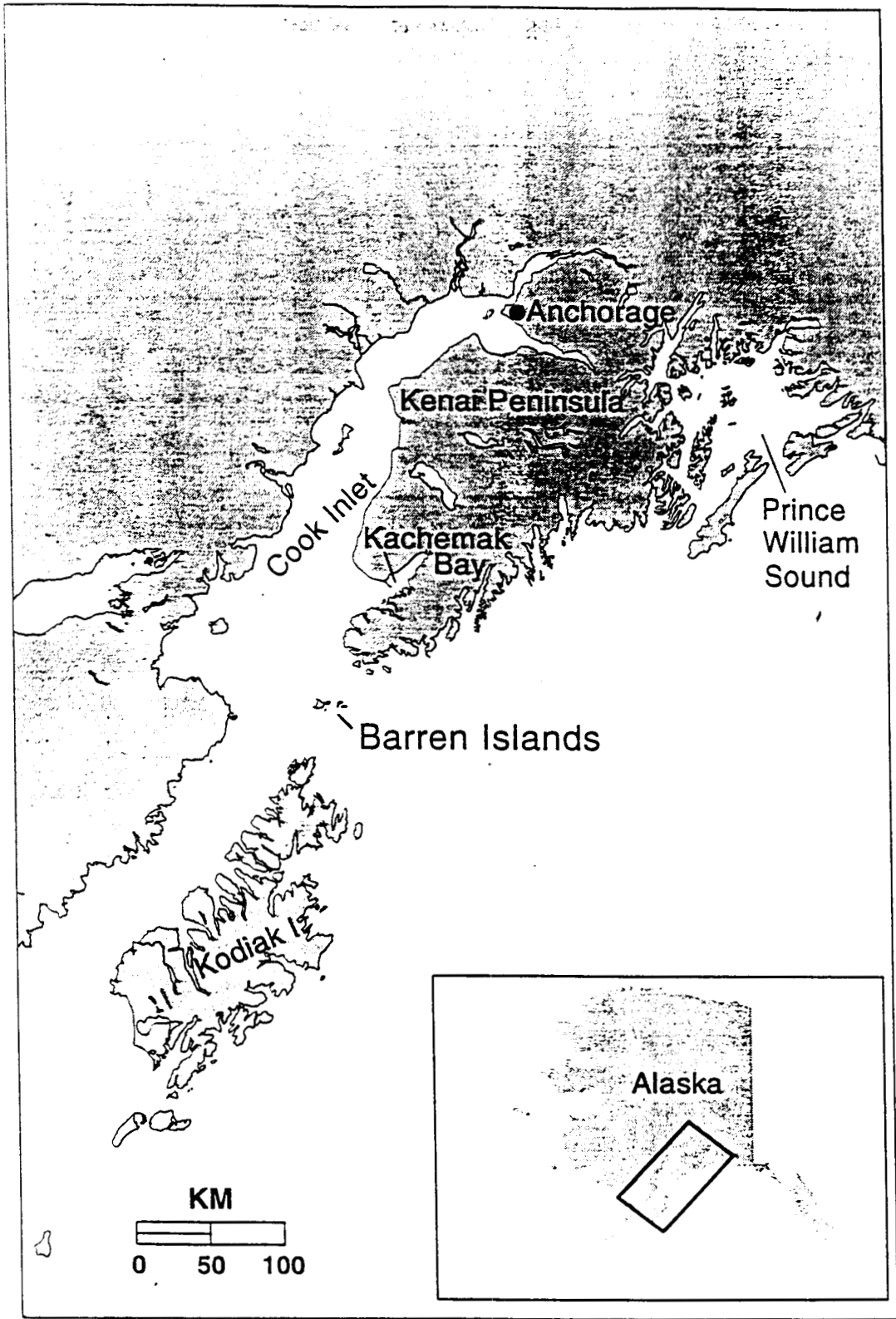
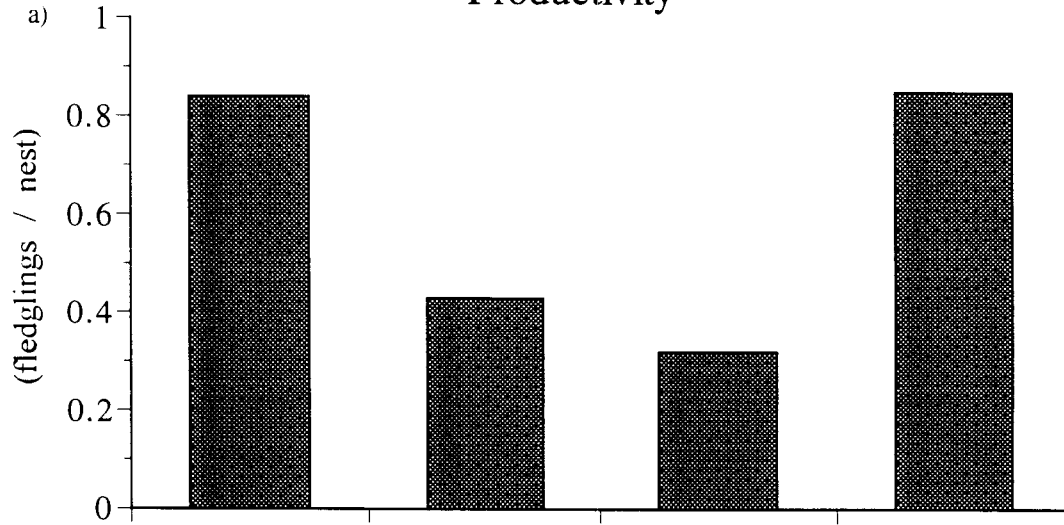


Figure 1. Location of Prince William Sound and the Barren Islands, Alaska.

1995

Productivity



Chick Growth Rates
Mean (+ SE)

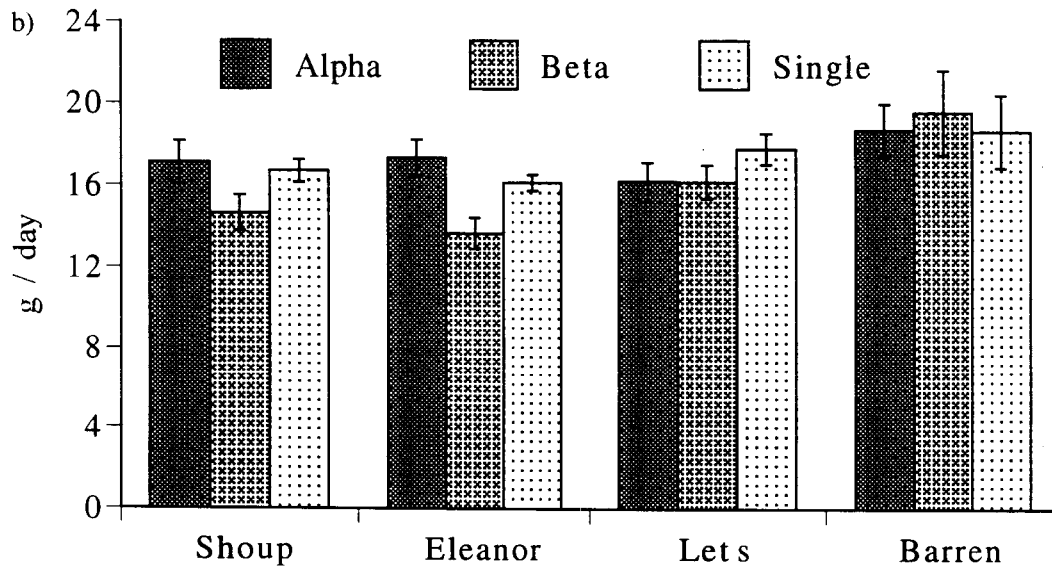


Figure 2. Productivity (a; fledglings/nest) and mean chick growth rates (b; \pm SE; g/day; alpha, beta, and single chicks) for Black-legged Kittiwakes nesting at Shoup Bay, Eleanor Island, and Seal Island, Prince William Sound and the Barren Islands, lower Cook Inlet, Alaska, June - August 1995.

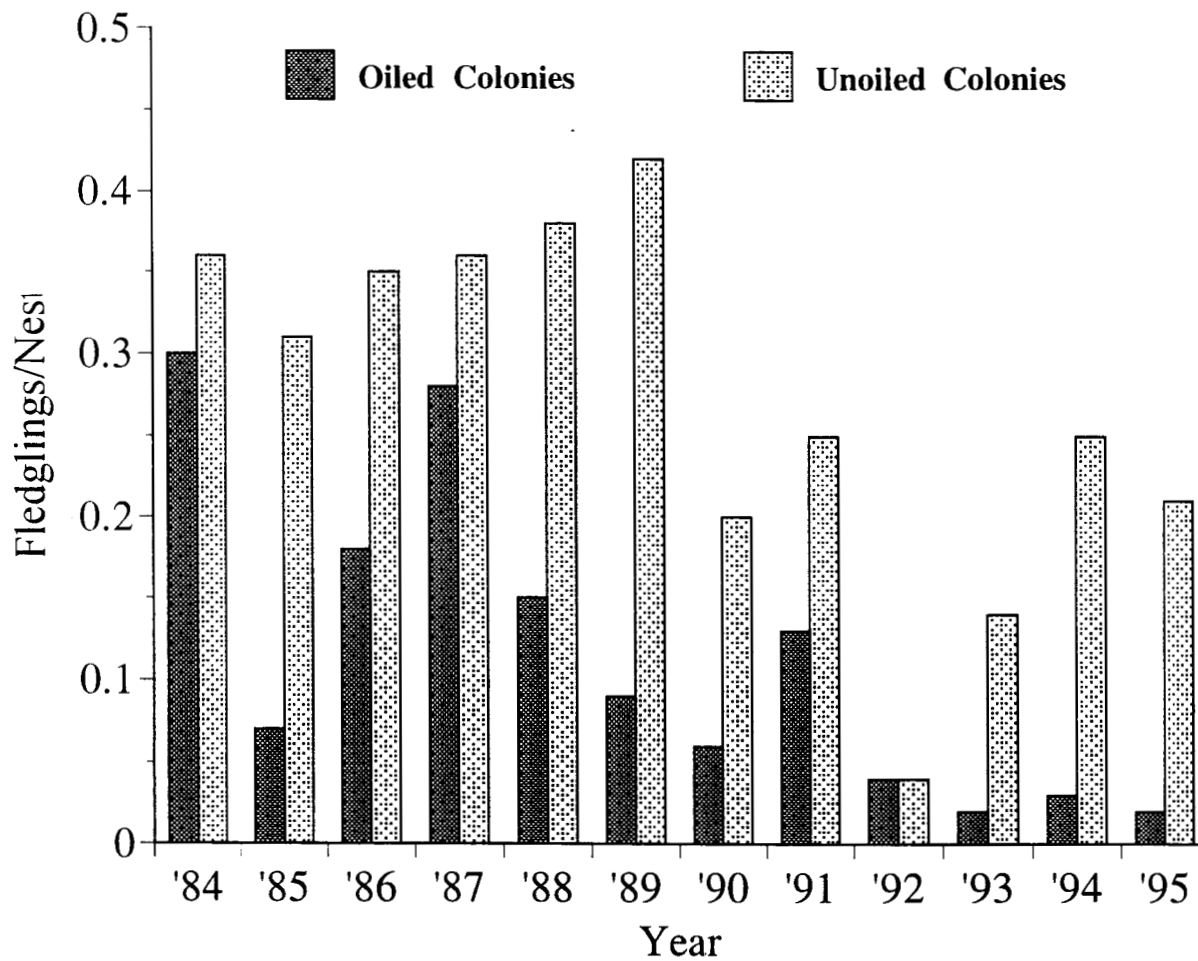


Figure 3. Productivity (fledglings/nest; 1984 to 1995) of Black-legged Kittiwakes at colonies where foraging ranges contained oil or were not oiled by the T/V Exxon Valdez oil spill, 24 March 1989, in Prince William Sound, Alaska.

CHICK DIETS - 1995

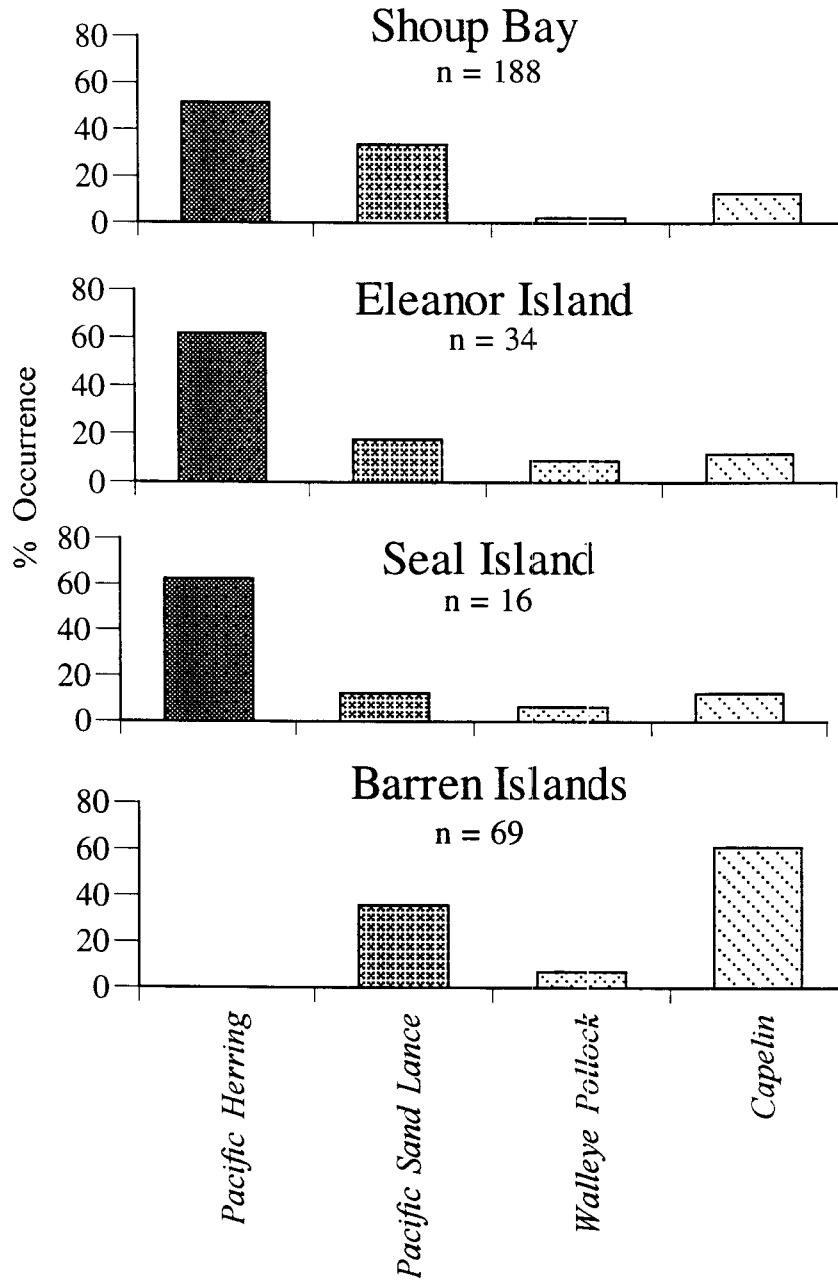


Figure 4. Percent occurrence of primary prey in Black -legged Kittiwake chick diet samples collected during 1995 at Shoup Bay, Eleanor Island, and Seal Island, Prince William Sound, and the Barren Islands, Lower Cook Inlet, Alaska.

CHICK DIETS AT SHOUP BAY

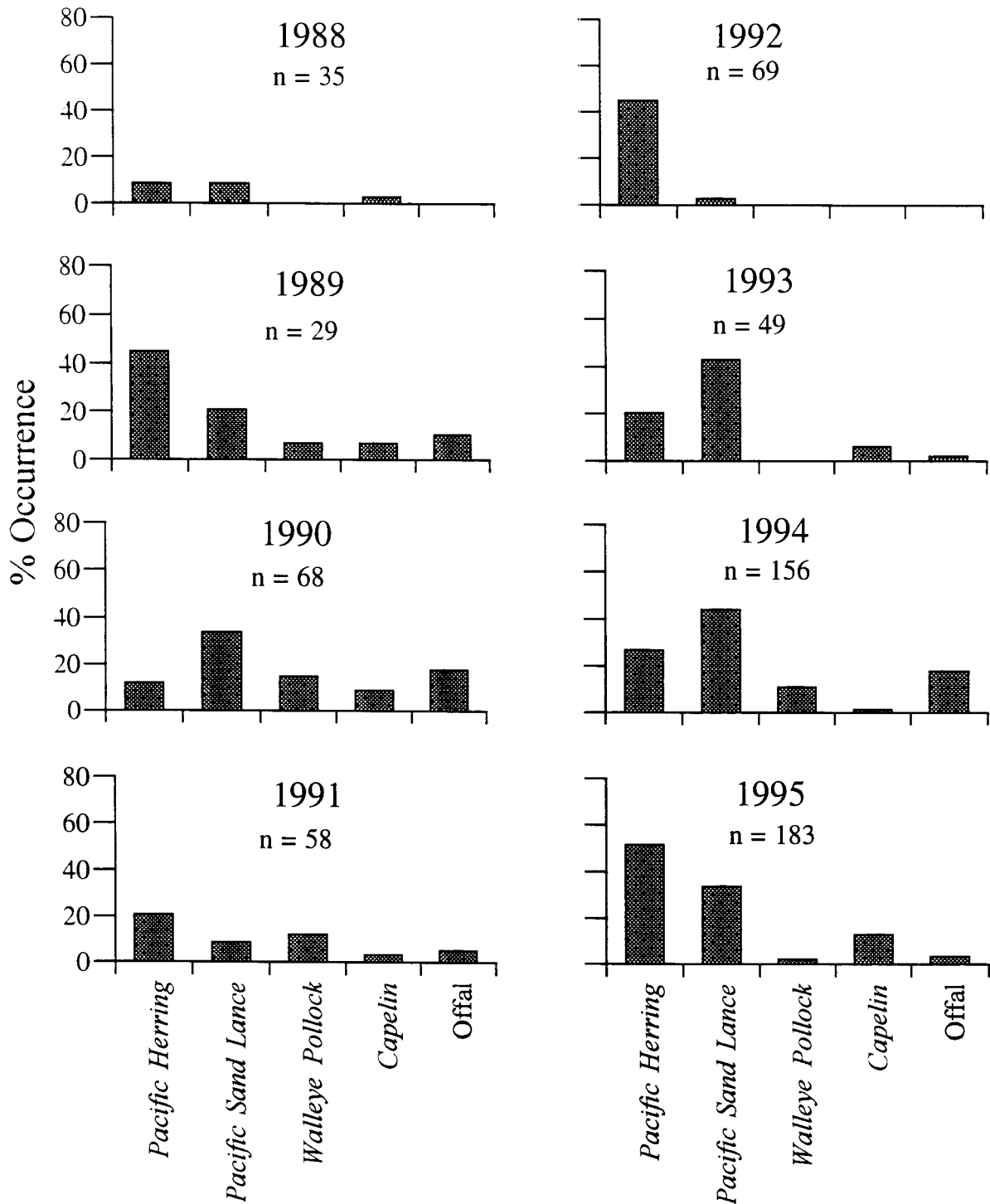
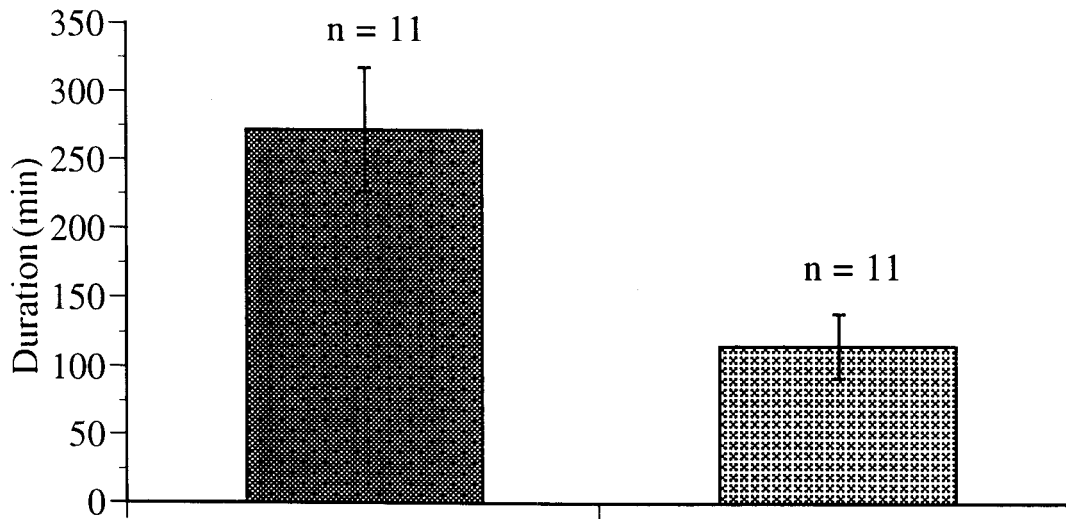


Figure 5. Percent occurrence of primary prey in Black-legged Kittiwake chick diets from 1988 to 1995 at the Shoup Bay colony, Prince William Sound, Alaska.

Foraging Trip Duration Mean (+ SE)



Maximum Distance From Colony Mean (+ SE)

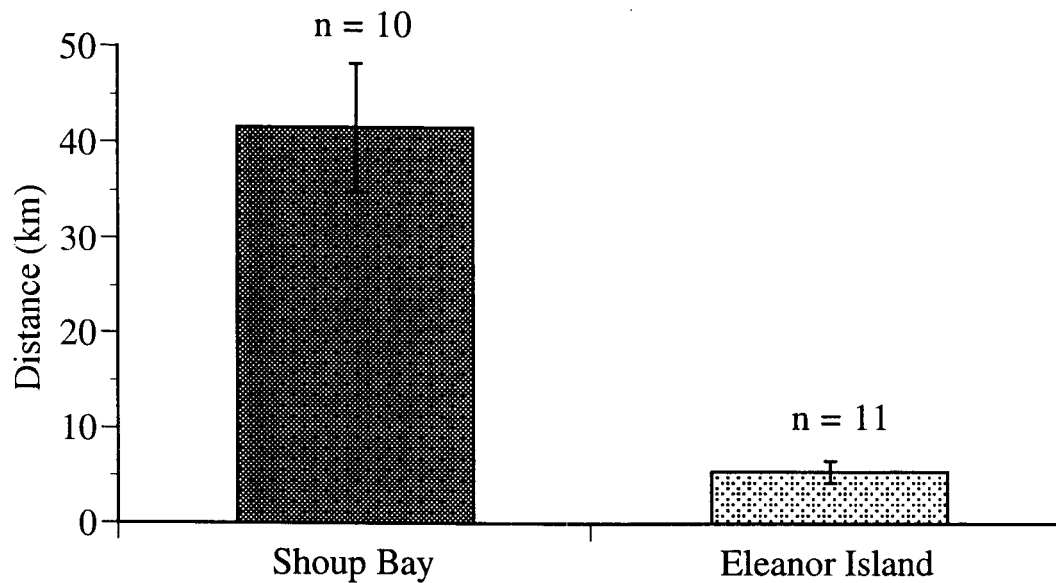


Figure 6. Mean foraging trip duration and mean maximum foraging trip distance for Black-legged Kittiwakes nesting at Shoup Bay and Eleanor Island colonies, Prince William Sound, Alaska, in 1995.

Foraging Trip Time Budgets

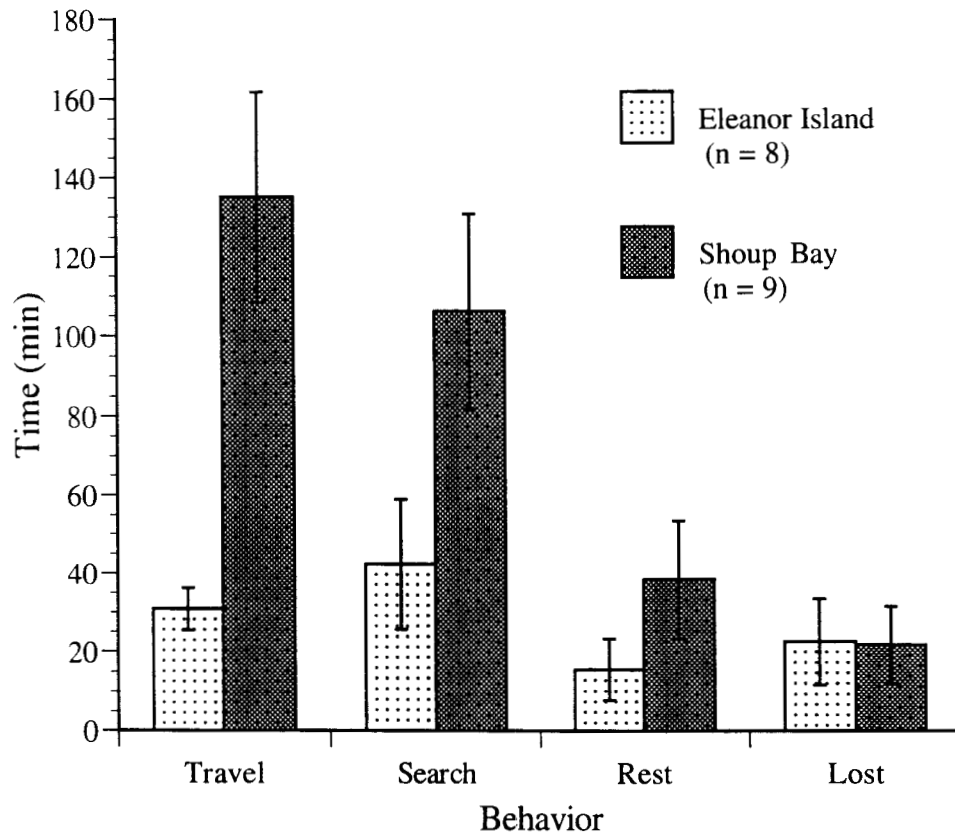


Figure 7. Mean (+ SE) duration of travel, search (including pursuit and handling times), rest, and lost from observer's sight during foraging trips of radio-tagged Black-legged Kittiwakes from Eleanor Island and Shoup Bay, Prince William Sound, Alaska, 1995.

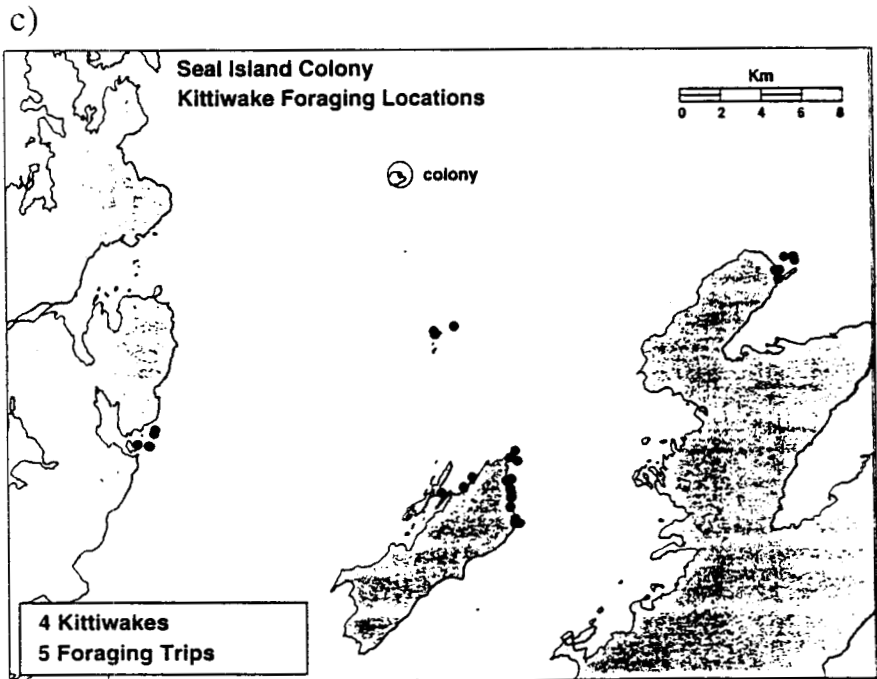
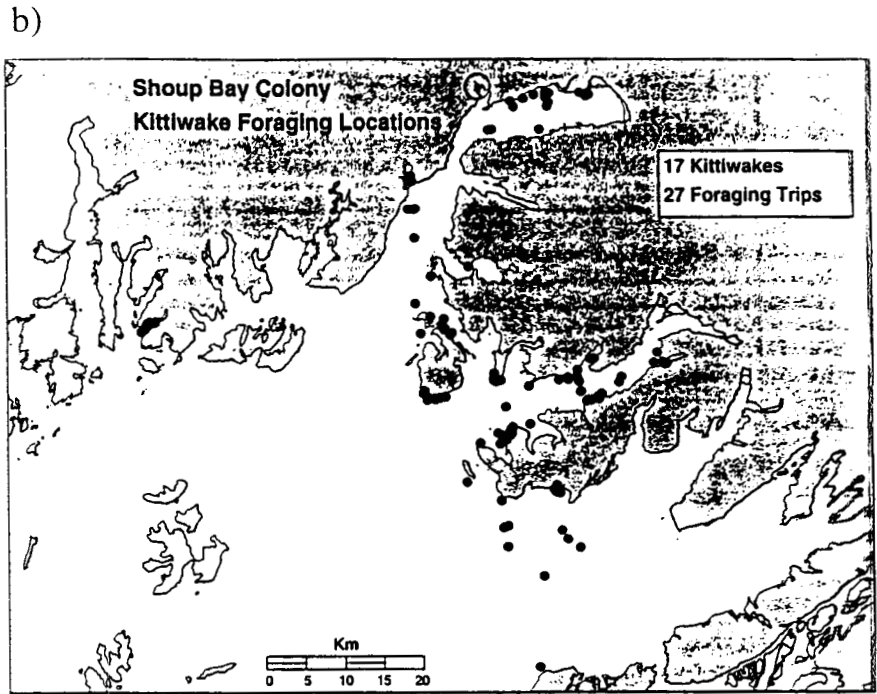
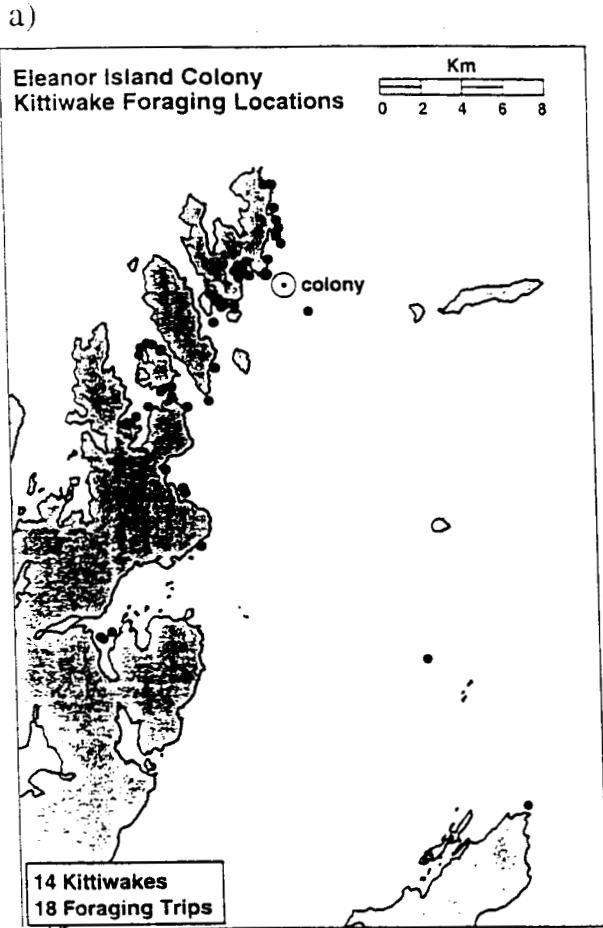


Figure 8. Foraging locations of adult Black-legged Kittiwakes (with 1 or 2 chicks) at colonies located near Shoup Bay (a), Eleanor Island (b), and Seal Island (c) during the 1995 nesting season in Prince William Sound, Alaska.