

APPENDIX B

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SEABIRD/FORAGE FISH INTERACTIONS

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ABSTRACT

We sought to determine if forage fish characteristics and/or interactions among seabirds limit food availability. We monitored seabird/forage fish interactions by conducting systematically arranged transects in three areas of Prince William Sound from 21 July-11 August 1995. The study sites were located at Valdez Arm, Naked and Knight Islands, and Jackpot and Icy Bays. Down- and side-looking hydroacoustic and bird-observation data were collected simultaneously. We collected separate data on foraging behavior and kleptoparasitism on 22 foraging flocks encountered during the survey. Walleye pollock (*Theragra chalcogramma*) made up a high proportion of the forage fish biomass; however, these schools were at depths greater than 15 m and were associated with few seabirds. Black-legged kittiwakes (*Rissa tridactyla*), pigeon guillemots (*Cephus columba*), and marbled murrelets (*Brachyrampus marmoratus*) were observed in shallow water near (<2 km) shore. Tufted puffins (*Fratercula cirrhata*) and glaucous-winged gulls (*Larus glaucescens*) were observed significantly farther from shore. We attempted to correlate the presence of forage fish schools observed in side viewing sonar with seabirds and found no relationship. Foraging flocks were associated with capelin (*Mallotus villosus*), sand lance (*Ammodytes hexapterus*), and juvenile herring (*Clupea harengus*).

Marbled murrelets and black-legged kittiwakes were positively correlated in foraging flocks suggesting that kittiwakes cue on marbled murrelets as a mechanism which concentrates and drives forage to the surface. Our observations suggest that glaucous-winged gulls' behavior may hinder kittiwake feeding in tightly grouped flocks. Kittiwakes lost 5% of their food catches to intraspecific and 7% to interspecific kleptoparasitism while foraging in mixed species flocks. Pomarine (*Stercorarius pomarinus*) and parasitic jaegers (*S. parasiticus*) attended the largest foraging flocks. Additional data and analysis is needed to determine if kleptoparasitism and aggressive behavior is limiting access to available forage.

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INTRODUCTION

The T/V *Exxon Valdez* oil spill resulted in extensive mortality of seabirds and damage to other resources in Prince William Sound (PWS) and the Gulf of Alaska (Piatt et al. 1990). Several of these resources had not recovered 5 years after the spill (Agler et al. 1990a&b, Klosiewski and Laing 1994). The APEX project was initiated in 1994 to determine if a shift in the marine trophic structure has prevented the recovery of injured seabirds. Seabirds interact with the marine system principally through foraging; therefore, a study of the seabird/forage fish interactions and foraging behavior is a necessary component of the APEX project.

This is an ongoing study that began with a pilot effort in 1994 to test field methods. In 1995, the study was expanded to look at seabird foraging in several habitats in 3 study sites within PWS. During 1995 we investigated the general supposition that forage fish characteristics and/or interactions among seabirds limit availability of prey. We limited the scope of this hypothesis to 2 working components:

- a. Forage fish are unavailable to seabirds because schools are too deep.
- b. Aggressive social interactions among seabirds limit access to prey.

METHODS

We collected data from 3 study areas within PWS (Fig. 1). We selected transects systematically with a randomly chosen point of origin. Each study area was sampled twice during 21 July-11 August 1995. We conducted seabird and marine mammal surveys simultaneously with hydroacoustic surveys (hydroacoustic survey methods were described in the report for 95163A) employing techniques similar to those used to conduct population surveys in PWS (Klosiewski and Laing 1994). Seabird data were collected during hydroacoustic sampling. All birds and mammals observed within 100 m of the starboard side of the vessel (that side which was scanned by side-viewing sonar) were identified and recorded. Observers calibrated their ability to estimate distances by viewing a duck decoy tied to the end of a fishing line three times during the survey. Calibrations were done for 100 and 300 meters. Bird observations were made by scanning ahead of the ship with binoculars.

Observations were made before the ship's presence influenced bird behavior. Data were entered when the ship was closest to the point at which the birds were first observed. The perpendicular distance to each bird from the transect line was estimated to the nearest meter. Bird behavior was recorded categorically as: (a) in the air, (b) on a floating object, (c) on the water, (d) following the boat, (e) foraging, or (f) potential foraging. Foraging (e) was defined as actual observation of foraging behavior such as diving for food or holding food in the bill. Potential foraging (f) was defined as >2 associated birds on the water or circling above. Data was directly entered in a computer file. The data entry system was programmed to record time and location of each observation. Locations were recorded directly from a geographical positioning system (GPS). Data were also collected on all foraging flocks on either side of the vessel. Three foraging piscivorous seabirds were used as the threshold number to define a flock. Data on estimated perpendicular distance to the flock, location, time of observation, and number of each species were recorded into a computer file.

We collected additional data on all foraging flocks and the associated fish schools seen while conducting boat surveys. This required diverting from the transect. After data were obtained from foraging sites the transect was resumed from the point of departure. For each sampled flock,

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hydroacoustic, GPS location, and behavioral data were collected. Flocks were assigned a classification based upon criteria developed by Hoffman et al. (1981). These classifications were: 1) small short duration flocks over tightly clumped prey; 2) larger persistent flocks over more broadly dispersed prey; 3) Flocks associated with sites where forage is concentrated by downwelling or other hydrophysical influence. The influence of structure, for ascribing type 3 classification, was determined by a subjective evaluation of oceanographic features rather than quantitative measurement of physical variables. Data were recorded by making auditory notes onto a cassette recorder and by video recording of behavior. Two additional foraging flocks not seen on transect were included in the analysis of behavioral data. Priorities for data collection were: 1) kleptoparasitic and piracy interactions with as much detail as possible; 2) foraging methods used by kittiwakes including number of dives, time between dives, success of dives, inter- and intraspecific interactions; 3) foraging methods of other gulls, or alcids as per #2. After behavioral data were collected, the vessel approached from a direction parallel to the transect to obtain a hydroacoustic profile of the forage. Vessel limitations, however, kept us from sampling many nearshore flocks in this manner. The species of forage fish associated with foraging flocks was determined by dip netting, pair-trawling, or trawling beneath the flocks.

We obtained data on distance to shore and distance to the nearest respective colony for each bird and flock observed with GIS software. We compared the mean distances to shore for black-legged kittiwakes, pigeon guillemots, and marbled murrelets, tufted puffins and glaucous-winged gulls with an analysis of variance (ANOVA) (Zar 1984). The distances to the nearest conspecific colony were also compared with an ANOVA for black-legged kittiwakes, pigeon guillemots, and tufted puffins. The acoustic data set has not yet been analyzed to determine collective or species specific forage biomass; however, qualitative comparisons were made by plotting the acoustic data and making visual observations. We compared acoustic and seabird data by plotting the locations of observed birds with the corresponding plots of hydroacoustic data and then made visual comparisons. Transects for which side-viewing sonar data were available, were partitioned into 10-min segments. We determined the number of piscivorous birds, number of fish schools, and total chord length of schools contained within each 10-min segment. We used Pearson Correlation (Zar 1984) to determine if there was a relationship between the number forage fish schools and the number of birds observed, and between the total chord length of fish schools and the number of birds observed within the 10-min segments.

We also used Pearson Correlation (Zar 1984) to determine the relationship between marbled murrelets and black-legged kittiwakes and between alcids and larids at foraging flocks. To determine differences in behaviors at the foraging flocks we used non-parametric statistics such as chi-square and Fisher's exact test (Zar 1984).

RESULTS

Marbled murrelets, pigeon guillemots, and black-legged kittiwakes were observed significantly closer to shore than were tufted puffins and glaucous-winged gulls ($n = 931$, $P < 0.05$) (Fig. 2). Black-legged kittiwakes were observed significantly farther from the nearest respective colony than were pigeon guillemots and tufted puffins ($P < 0.05$) (Fig. 3). Our visual review of the plots of the hydroacoustic data indicate that walleye pollock made up a large proportion of the biomass of schooling forage fishes (Fig. 4). We examined the graphical representations of the distribution of seabirds and hydroacoustic plots that contained pollock and determined that these schools were at depths greater than 15 m and were associated with few seabirds (Fig. 4). We found that there was no significant relationship between the number forage fish schools and the number of birds observed; and the total chord length of fish schools and the number of birds observed, within the 10-min segments ($P > 0.05$) (Fig. 5 and 6).

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During 18 days of running transects, foraging flocks were rarely encountered and ranged in size from 3 to 1065 birds ($= 135.8$; $SD = 291.5$; $n = 22$). In each of the 3 study areas, foraging flocks were located close to shore ($= 415$ m; $SD = 315.0$; $n = 22$) (Figs. 7, 8 & 9). A total of 15 different bird species participated in foraging flocks with 11 species in a single Type II flock. Black-legged kittiwakes ($= 56.45$; $SD = 132.94$) and marbled murrelets ($= 30.59$; $SD = 66.07$) were predominate species in all three flock types. Kittiwake presence in flocks was positively correlated with murrelet presence (Pearson correlation; $r = 0.65$; $P = 0.011$). Furthermore, numbers of all larids were positively correlated with all alcids combined (Pearson correlation; $r = 0.75$; $P < 0.001$). Tufted puffins were also a predominant species in Type I and II flocks.

Type I flocks were composed of a mean of 3.3 species ($SD = 1.45$) and 7 to 174 birds ($= 44.87$; $SD = 42.97$; $n = 15$). Trawls at these flocks revealed that herring (at 4 flocks) were the predominate fish being preyed upon but capelin (at 1 flock) and sand lance (at 1 flock) also appeared in some catches. The fish were held in tight balls for at least part of our observation time in 8 out of 15 Type I flocks by presumably by pursuit-diving birds that dived and resurfaced near the periphery of the flock (Hoffman et al. 1981, Mahon et al. 1992).

We encountered two Type II flocks of 984 and 1065 birds with 11 and 8 different species participating in them, respectively. These were much smaller than the Type II flocks described by Hoffman et al. (1981) who characterized such flocks as ranging in size from 5,000 to 50,000 individuals. However, we considered them Type II flocks because: (1) they were significantly larger than flock types I and III ($2 = 1696.1$, $d.f. = 2$, $P < 0.001$), (2) both of them lasted for at least two days, and (3) they were loosely aggregated assemblages feeding on spawned out male capelin in one case and either capelin or herring in the second case.

Type III flocks were composed of a mean of 4.2 species ($SD = 2.68$) and 11 to 168 birds ($= 53.00$; $SD = 64.84$; $n = 5$). These flocks were concentrated around points of land or at the entrances to shallow passages. A trawl at one of these flocks disclosed herring of various age groups.

In Type I flocks, where the fish were in a tight ball, glaucous-winged gulls sat on the water above the fish while kittiwakes sat outside the gulls or hovered above. To maintain their position in this flock type, the gulls hop-plunged as opposed to plunge dived. The latter foraging method was used more often in Type II and III flocks (Fisher's exact test; $P < 0.0001$). Kittiwakes also hop-plunged more often in Type I flocks than in Type II and III flocks ($2 = 14.356$; $P < 0.001$). Yet, in all flock types, greater than 78% of their foraging attempts were plunge dives (Figure 10).

Kittiwakes had a foraging success of 80.6% ($n = 129$) and lost 4.8% of their captures to intraspecific piracy and 6.7% to interspecific piracy (Fig. 11). Kleptoparasitism against kittiwakes was most intense in the tightly aggregated Type I flocks compared to Type II and III flocks ($2 = 83.55$; $P < 0.001$).

Interspecific kleptoparasitic attempts by glaucous-winged gulls were directed toward kittiwakes in Type I and II flocks and toward alcids in Type I flocks (Figure 12). Intraspecific kleptoparasitism by kittiwakes was observed most often in Type I flocks while attempts directed against alcids were more commonly seen in Type III flocks (Figure 13). Together, glaucous-winged gulls and black-legged kittiwakes kleptoparasitized alcids less than expected in Type I flocks ($2 = 15.32$, $d.f. = 1$, $P < 0.001$) but not in Type III flocks ($2 = 1.780$, $d.f. = 1$, $P = 0.182$; Table 1). Parasitic and pomarine jaegers preferentially chased kittiwakes in Type II flocks (Figure 14). In flocks where jaegers were present, the number of kleptoparasitic attempts by them increased with the number of larids present in the flock (Figure 15).

DISCUSSION

Black-legged kittiwakes, pigeon guillemots, marbled murrelets were associated with nearshore habitats. These piscivorous species were all arguably injured by the spill (*Exxon Valdez* Oil Spill Trustee Council 1994, Irons, U. S. Fish and Wildl. Serv., Anchorage, Alas., unpublished data); whereas tufted puffins and glaucous winged gulls were located significantly farther from shore and were not classified as injured by the *Exxon Valdez* Oil Spill Trustee Council (1994). These injured seabird share a lifehistory linkage to nearshore habitats with many nonbird species listed as injured by the *Exxon Valdez* Oil Spill (Exxon Valdez Oil Spill Trustee Council 1994). This linkage implies that the major long term impact of the spill has been nearshore and this portion of the ecosystem has not recovered. Alternatively, long term fisheries monitoring of the Gulf of Alaska has demonstrated major trophic shifts that include an increase in walleye pollock abundance (Anderson et al. 1994). It is probable that these shifts also occurred in PWS and that the high proportion of walleye pollock in the total fish biomass is a recent result from these shifts. Wespestad and Fried (1983) demonstrated a negative relationship between herring and pollock biomass in the Bering Sea. Data collected by APEX indicates that pollock and herring school together during the fall (L. Halderson, Univ. of Alas. Fairbanks, unpublished data) and their diets overlap (M. Sturdevant, US Nat. Marine Fish. Ser., unpublished data) suggesting that direct competition does occur and that a negative relationship between the species is probable in PWS. Our data suggest that the injured seabirds are not foraging on walleye pollock and have not adapted to the ecological shift. Had the spill not occurred, a decline in the injured seabird species may have been inevitable. We suggest that the current condition in PWS is the result of both broad scale ecological change and the localized long term impact of the spill. The oil spill may have directly reduced the populations of preferred nearshore prey species giving a competitive edge to an increasing pollock population, thereby exacerbating an on going decline. We suggest that the large scale ecological shift will prevent or delay a recovery of the injured seabirds until the Gulf of Alaska returns to previous conditions.

Our finding of an insignificant correlation between bird and fish abundance is consistent with previous studies that found correlations between seabird and fish abundance became less significant at decreasing scale (Obst 1986, Heinemann et al. 1989, Schneider and Piatt 1986, Erikstad et al. 1990, Hunt et al. 1990, Piatt 1990). We suggest that at smaller scales birds observed loafing and in transit to and from foraging sites confounded the correlation between birds and fish. This has led us to consider reanalyzing our data using fish schools as our sampling unit and examining additional environmental variables to explain resource selection by seabirds. Through a GIS and the down- and side-looking hydroacoustic data we will derive depth of school, total depth of water, and distance to shore. Additionally, we intend to examine the role of time of day, and state of tide. The probability of school selection will be modeled statistically through the use of a multivariate resource selection function (Manly et al. 1993).

In PWS flocks are generally smaller than those encountered in more oceanic regions (e.g. Hoffman et al. 1981, Duffy 1983). Foraging flocks of murrelets, kittiwakes, gulls, puffins, and guillemots fed on schools of herring, capelin, and sand lance that were nearshore. Conspecifics and congeners of these birds have also been found distributed nearshore in other boreal environments (Vermeer et al. 1989, Stone et al. 1995) to obtain easy access to their prey. Our observation of only 22 foraging flocks during 18 days was likely the result of spending a much greater proportion of time on offshore portions of transects.

Seabird prey can be concentrated by upwelling or downwelling in both oceanic and coastal regimes (e.g. Wahl et al. 1989, Schneider et al. 1990, Coyle et al. 1992). Such flow gradients are often

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found around islands and points of land (Hamner and Hauri 1981, Kinder et al. 1983). In PWS these processes may be associated with concentrations of herring that are vulnerable to seabird predation. Sand lance are also common nearshore and in shallow waters that have sandy substrates and relatively high bottom current velocities (Auster and Stewart 1986). These conditions occur around many land masses in PWS. The capelin concentrations discovered nearshore appeared to be post spawning aggregations that are known to attract alcids (Piatt 1990) and many other seabirds (Hoffman et al. 1990). Preliminary analysis of the hydroacoustic data suggests that the predominant concentration of capelin in these schools reside near the bottom of the water column. Alcids appear to be the driving force in Type I flocks where capelin and other forage fish are concentrated in tight balls near the surface and hence become accessible for gulls and kittiwakes (Grover and Olla 1983). In the large Type II flocks individual capelin apparently become confused and swim to near the surface where they are vulnerable to plunge-diving birds.

Research in British Columbia suggested that marbled murrelets may have been the catalyst in the formation of foraging flocks (Mahon et al. 1992). Murrelets may have made forage available to kittiwakes by forcing schools into tight balls and driving them to the surface. This is a likely cause for the strong association between murrelets and kittiwakes at foraging flocks. Our observations of murrelet participation in flocks were consistent with observations made within intercoastal waters of British Columbia (Mahon et al. 1992) and inconsistent with the low murrelet participation in flocks of outside waters (Porter and Sealy 1981, Chilton and Sealy 1987).

Glaucous-winged gulls may deter smaller gulls and kittiwakes from feeding at densely aggregated foraging flocks. Porter and Sealy (1982) observed that smaller California gulls usually hovered over flock and plunge dived while glaucous-winged gulls flew right into the center and hop-plunged or dipped for prey. These behaviors are similar to what we have observed with kittiwakes and gulls in PWS foraging flocks. We encountered one foraging flock that had 12 glaucous-winged gulls sitting on the water over a tight ball of capelin and occasionally plunge diving. Kittiwakes were entirely absent from this flock though many were seen within just a few kilometers. Glaucous-winged gulls are unable to dominate the more loosely aggregated fish at Type II and III flocks. Unfortunately, foraging success is difficult to determine in tightly clumped feeding flocks, therefore comparison with type II and III flocks is not viable. The rates of kittiwake plunge-dives at densely aggregated fish schools with glaucous-winged gulls over them compared to those without glaucous-winged gulls are presently being analyzed.

Densely aggregated Type I flocks promoted kleptoparasitism within the gulls and kittiwakes but did not facilitate piracy by jaegers perhaps because of a low success rate in this flock type (Hoffman et al. 1981). Alcids were also attacked less frequently in Type I flocks because of their ability to dive and resurface around the outer edge of these flocks and avoid the attacking kittiwakes (Hoffman et al. 1981, Chilton and Sealy 1987). The inability to keep fish tightly balled as in Type II and III flocks causes diving birds to resurface randomly. Without the focal point of a tight fish school, kittiwakes may cue on the resurfacing alcids for feeding opportunities.

Parasitic and Pomarine jaegers were most commonly observed in the largest foraging flocks (Type II). Although most studies of jaeger piracy have been conducted near colonies (e.g. Andersson 1976, Birt and Cairns 1987) these birds are not common raiders at colonies in PWS (David Irons, pers. comm.). One large capelin feeding flock had a group of 15 pomarine and 2 parasitic jaegers sitting on the water about 1 km away. They appeared to be making occasional sorties (usually alone) into the foraging flock. Their method of attack in Type II flocks appears to concentrate efforts on kittiwakes that have recently caught a fish (Hoffman et al. 1981). We also observed many cases where jaegers chased kittiwakes with fish visible in the bill. These behaviors may increase the robbing success of jaegers. Kittiwakes may also be preferentially chased over the

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larger gulls because of size differences or the delayed swallowing of prey or a combination of both. On the St. Lawrence River smaller common terns were chased more often by parasitic jaegers than black-legged kittiwakes and almost half the chased terns had fish dangling from the bill whereas none of the chased kittiwakes had a visible fish (Belisle and Giroux 1995). A review by Furness (1987), however, suggests that the parameters regarding a bird's susceptibility to chase remain equivocal.

Evolutionary-stable kleptoparasitic interactions deprive hosts of about 1% of their food (Furness 1987). We determined the estimated loss of secured prey by kittiwakes to interspecific kleptoparasitism is close to 7%. If our sample of foraging kittiwakes was representative of the PWS population this may be great enough to cause feeding stress in their populations. Puffins robbed of only 4% of their food deliveries to chicks in Iceland during 1973 had unusually poor breeding success that year (Arnason and Grant 1978). A significant change in rates of kleptoparasitism in PWS in the coming years may indicate an unstable ecosystem.

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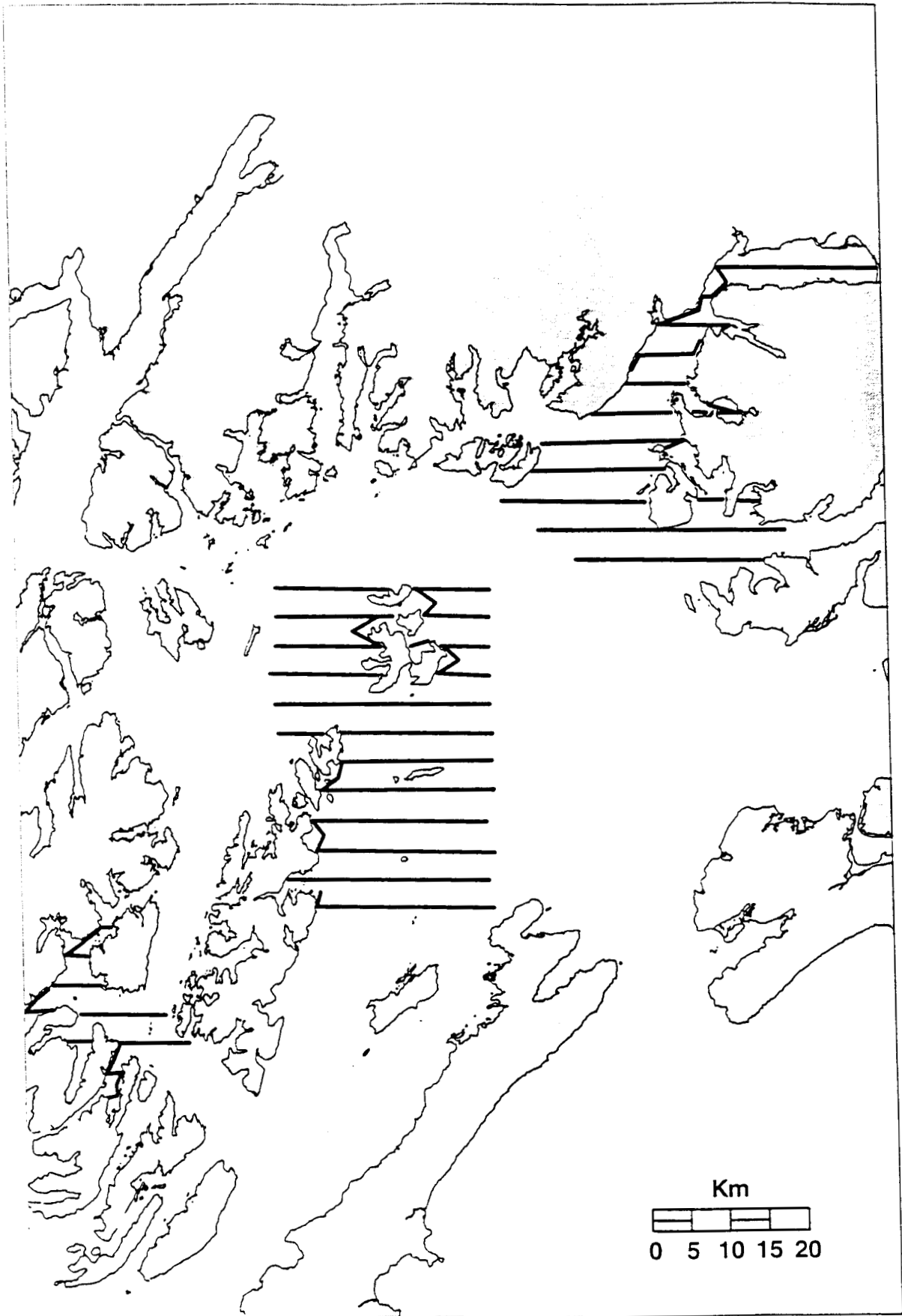
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Table 1. Relative abundance and observed vs. expected number of chases against alcidids in type I and type III flocks encountered during the 1995 APEX cruise.

Flock Type	Host	total abundance	relative abundance	expected chases	observed chases
I	ALCID	180	0.4286	12.43	2
	BLKI	240	0.5714	16.57	27
III	ALCID	143	0.6272	10.66	8
	BLKI	85	0.3728	6.34	9

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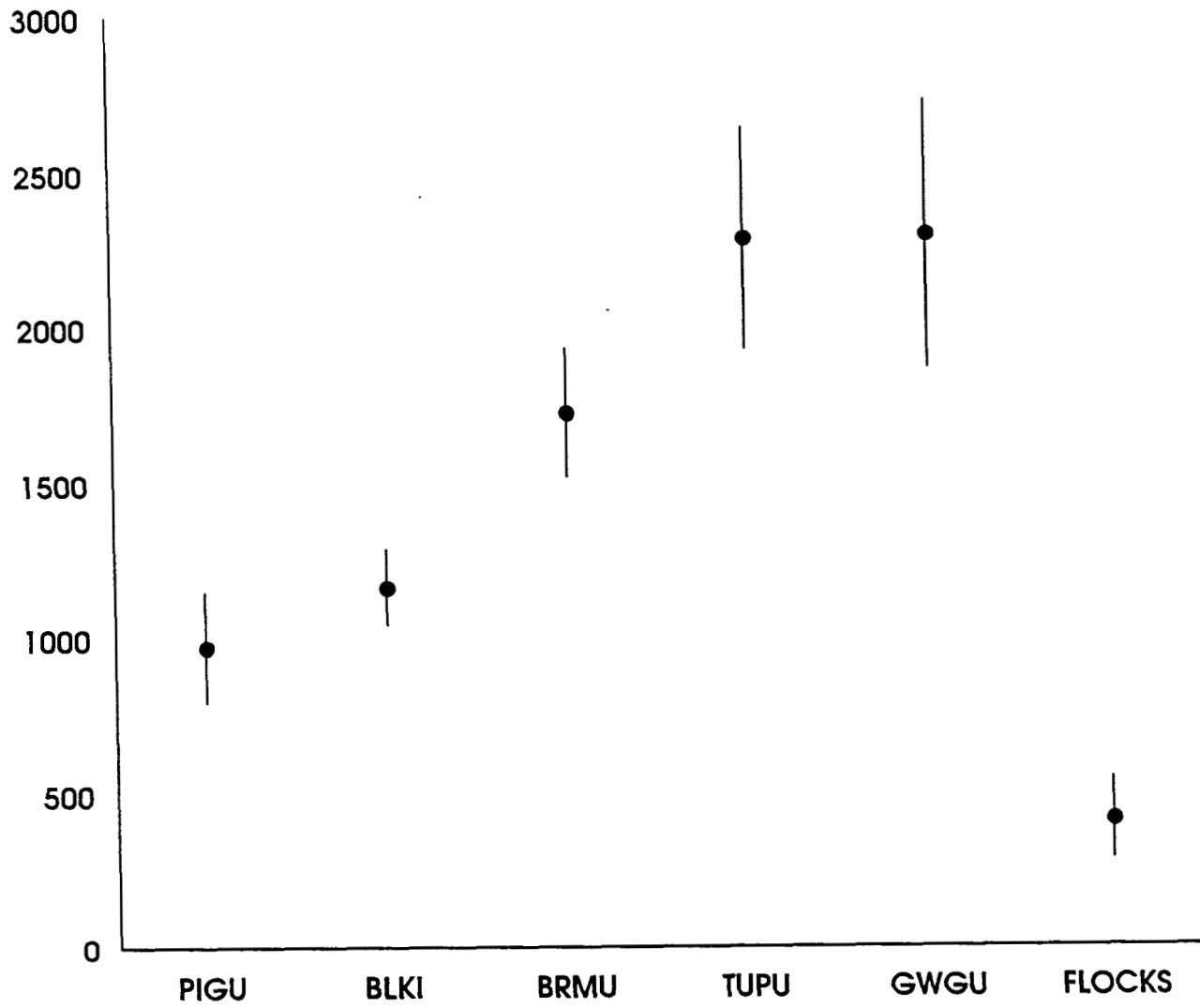
Fig. 1. Prince William Sound and the location of transects used in 3 study sights for the 1995 APEX cruise.



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Fig. 2. The mean distance to shore from where seabirds and foraging flocks were observed during the 1995 APEX cruise. Error bars indicate 95% confidence intervals.

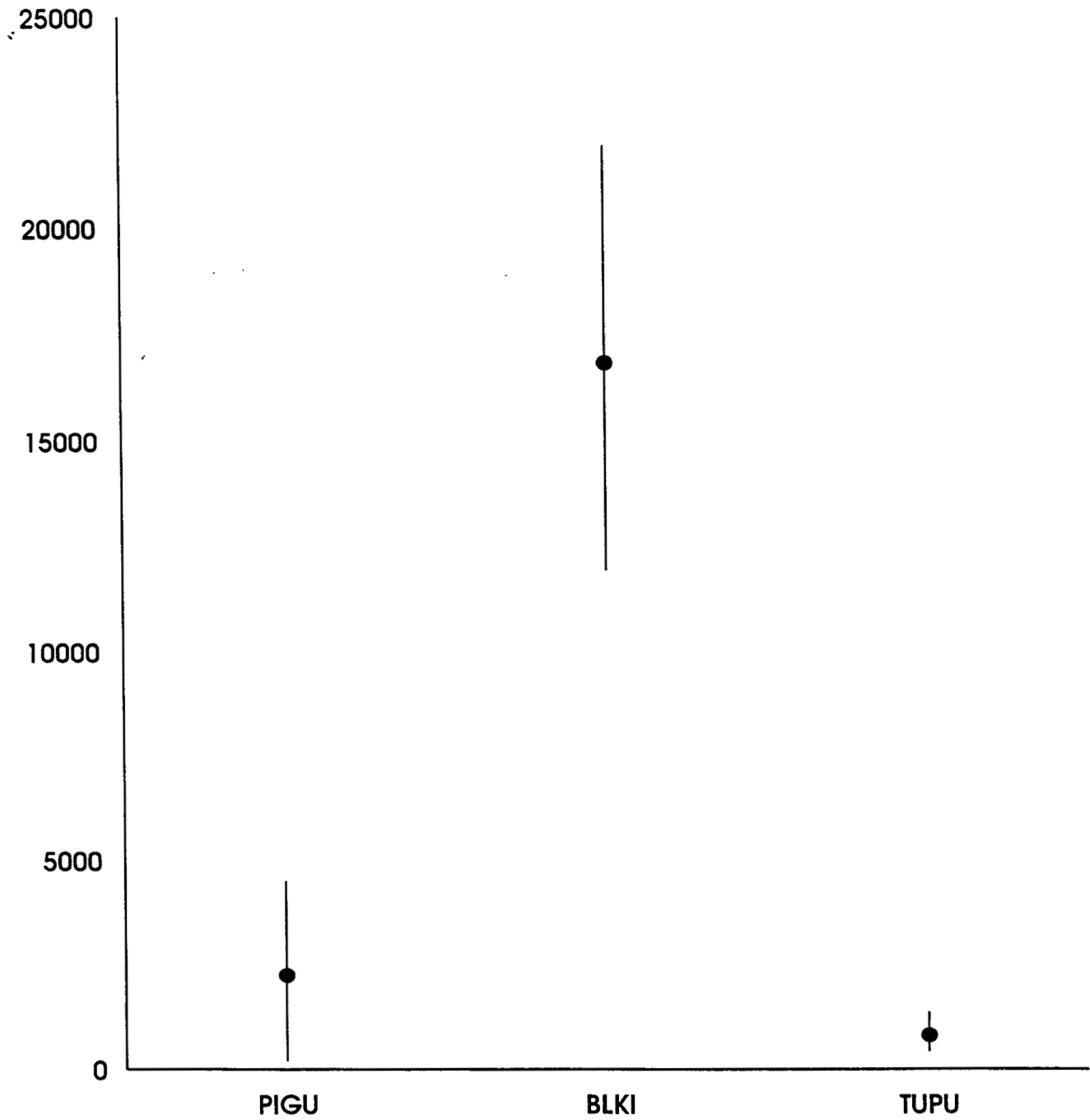
Distance From Shore



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Fig. 3. The mean distance to the nearest respective colony from where seabirds were observed during the 1995 APEX cruise. Error bars indicate 95% confidence intervals.

Distance From the Nearest Colony for Members of Foraging Flocks

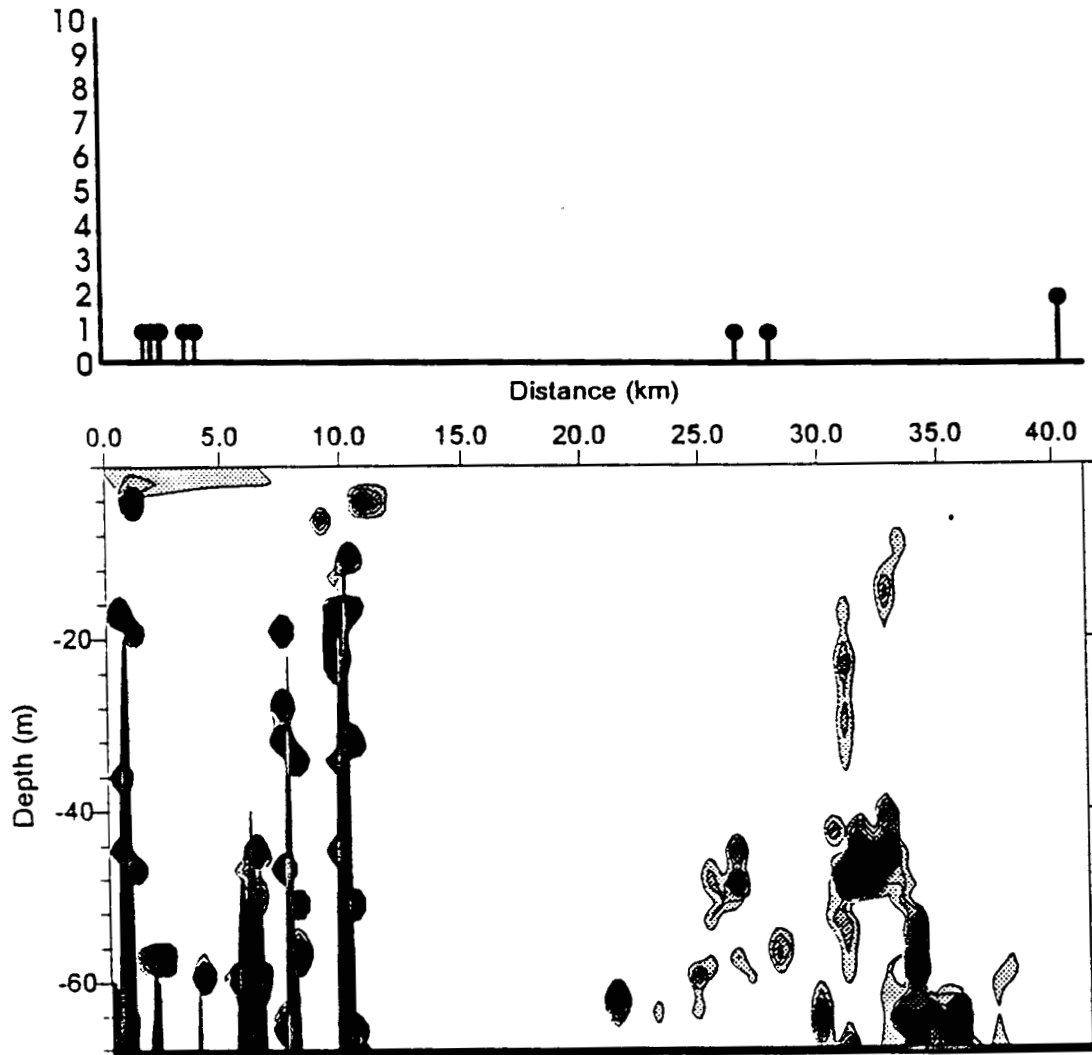


Appendix B-14

Fig. 4. The number of black-legged kittiwakes, marbled murrelets, and pigeon guillemots observed on a representative transect of the central study area is depicted above. The corresponding hydroacoustic data are depicted below. Polygons on the right were determined to be pollock schools. Data were collected during the 1995 APEX cruise.

2F N02A

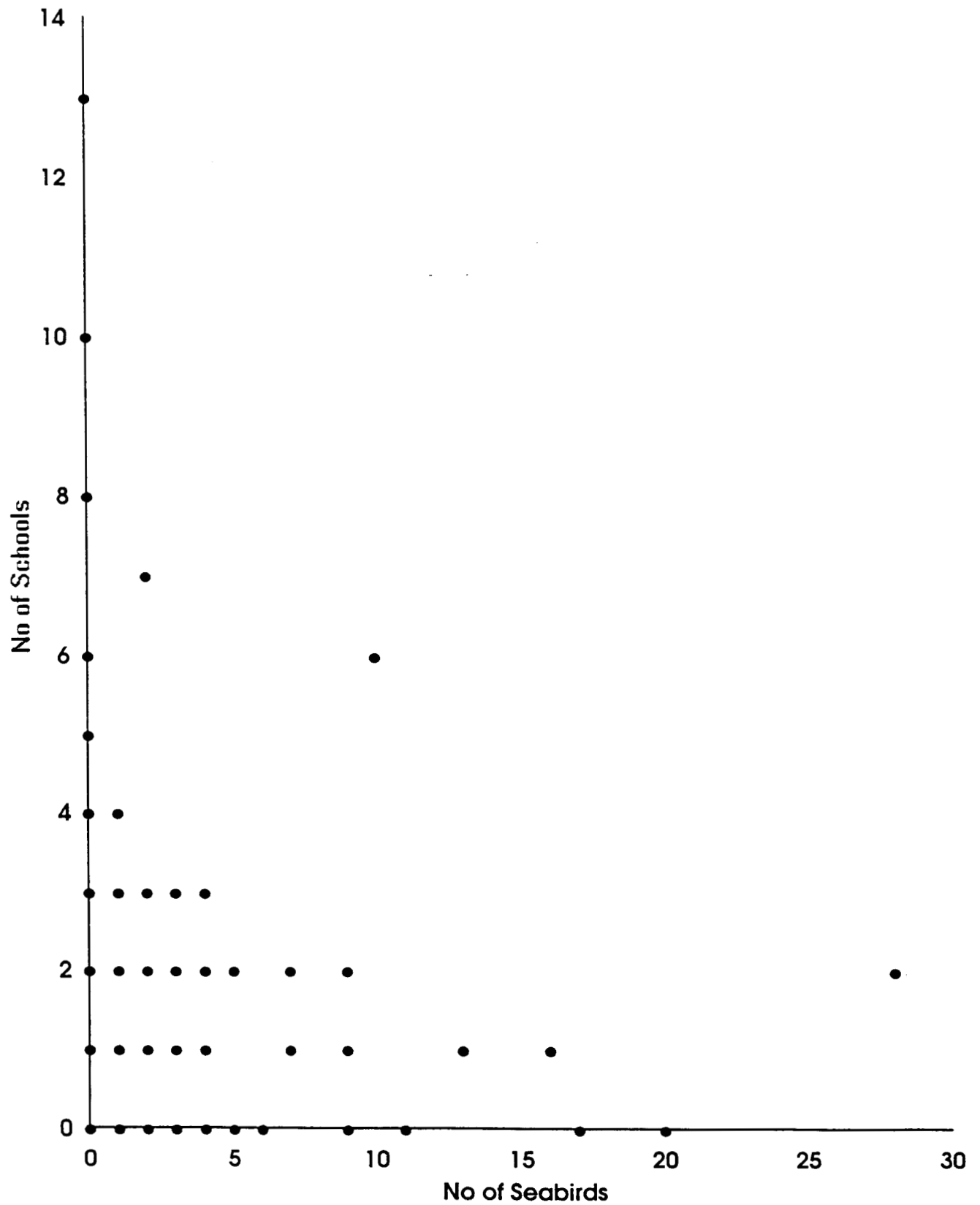
KIT IWAKES, GUILLEMOTS, AND MURRELETS



Appendix B-15

Fig. 5. The lack of correlation between piscivorous seabirds and fish schools observed during 10-min segments in side-looking hydroacoustics during the 1995 APEX cruise.

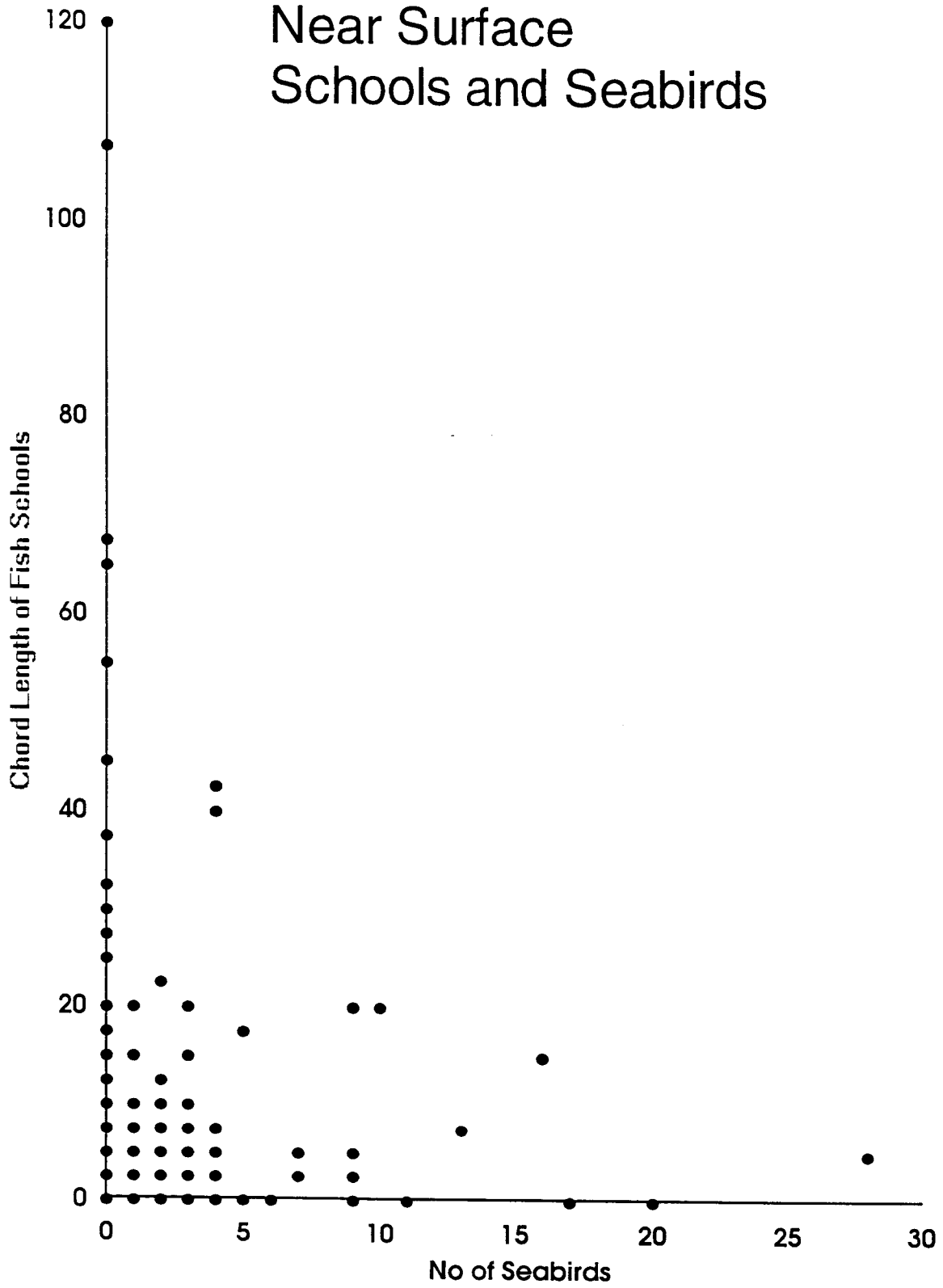
Relationship Between the No of Near Surface Schools and Seabirds



Appendix B-16

Fig. 6. The lack of correlation between piscivorous seabirds and total chord length of fish schools observed during 10-min segments in side-looking hydroacoustics during the 1995 APEX cruise.

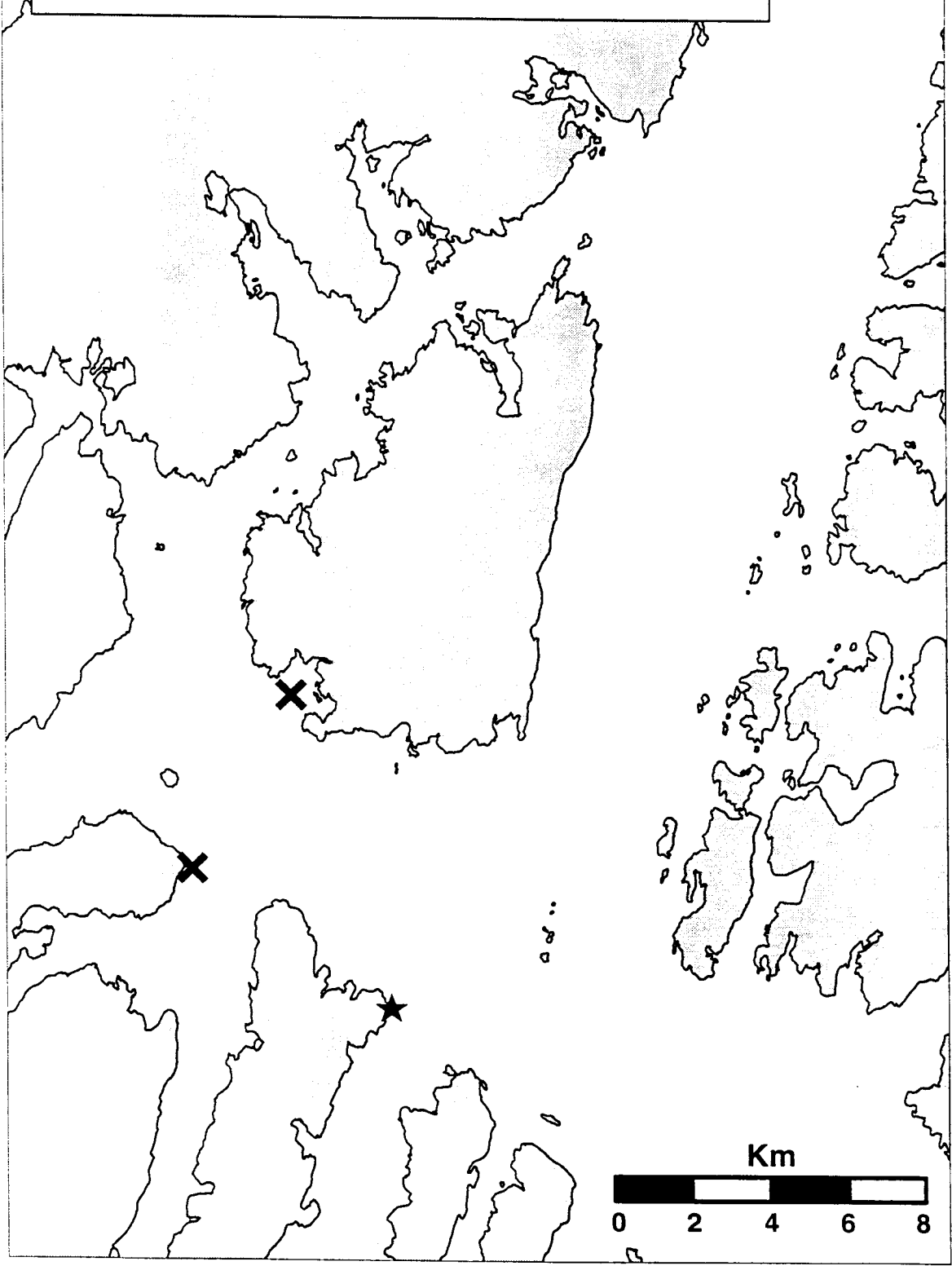
Relationship Between Near Surface Schools and Seabirds



Appendix B-17

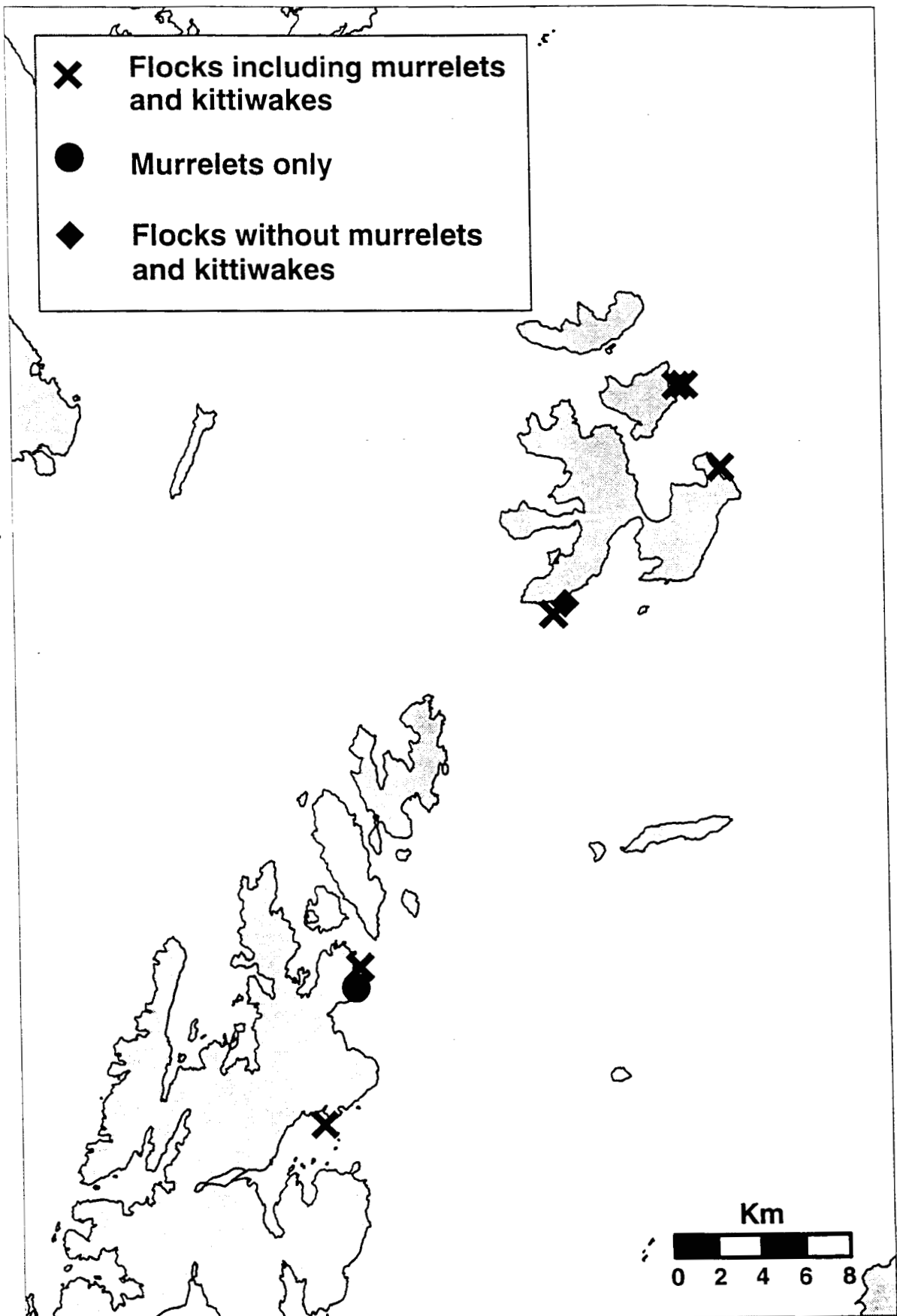
Fig. 7. Locations of foraging flocks observed in the Southwestern area during the 1995 APEX cruise.

- ✕ Flocks including murrelets and kittiwakes
- ★ Flocks including murrelets and terns



Appendix B-18

Fig. 8. Locations of foraging flocks observed in the Central area during the 1995 APEX cruise.

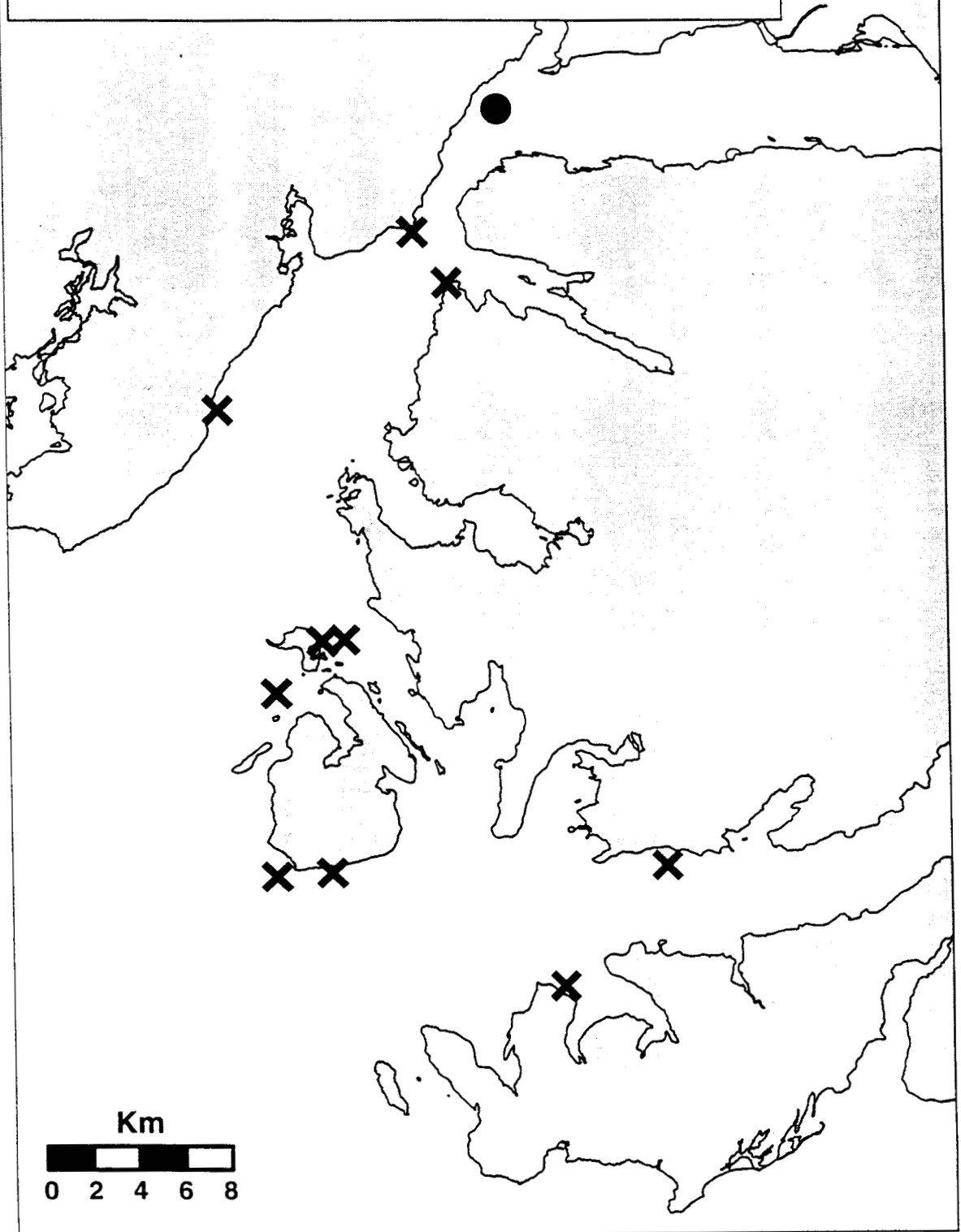


Appendix B-19

Fig. 9. Locations of foraging flocks observed in the Northeastern area during the 1995 APEX cruise.

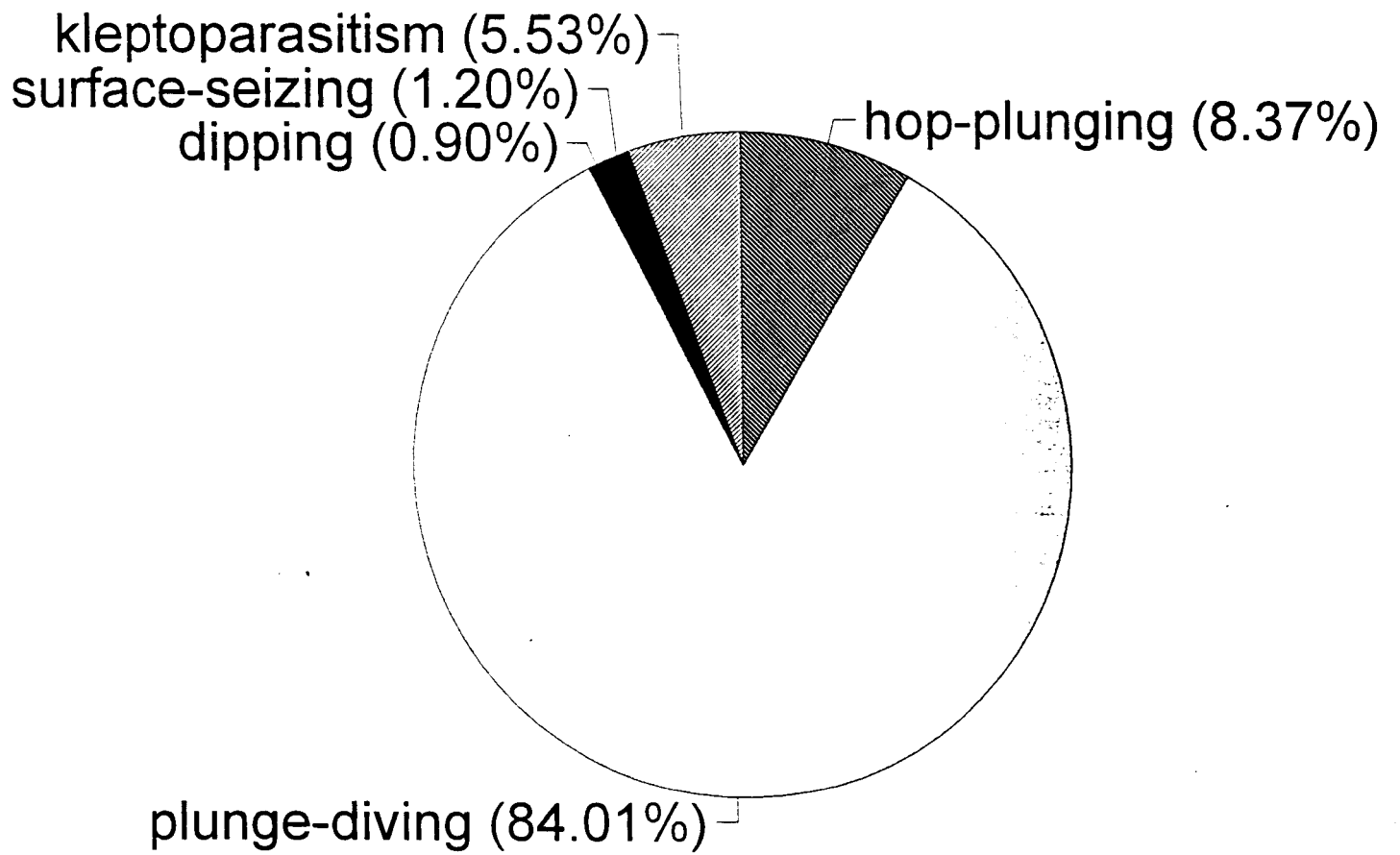
✕ Flocks including murrelets and kittiwakes

● Murrelets only



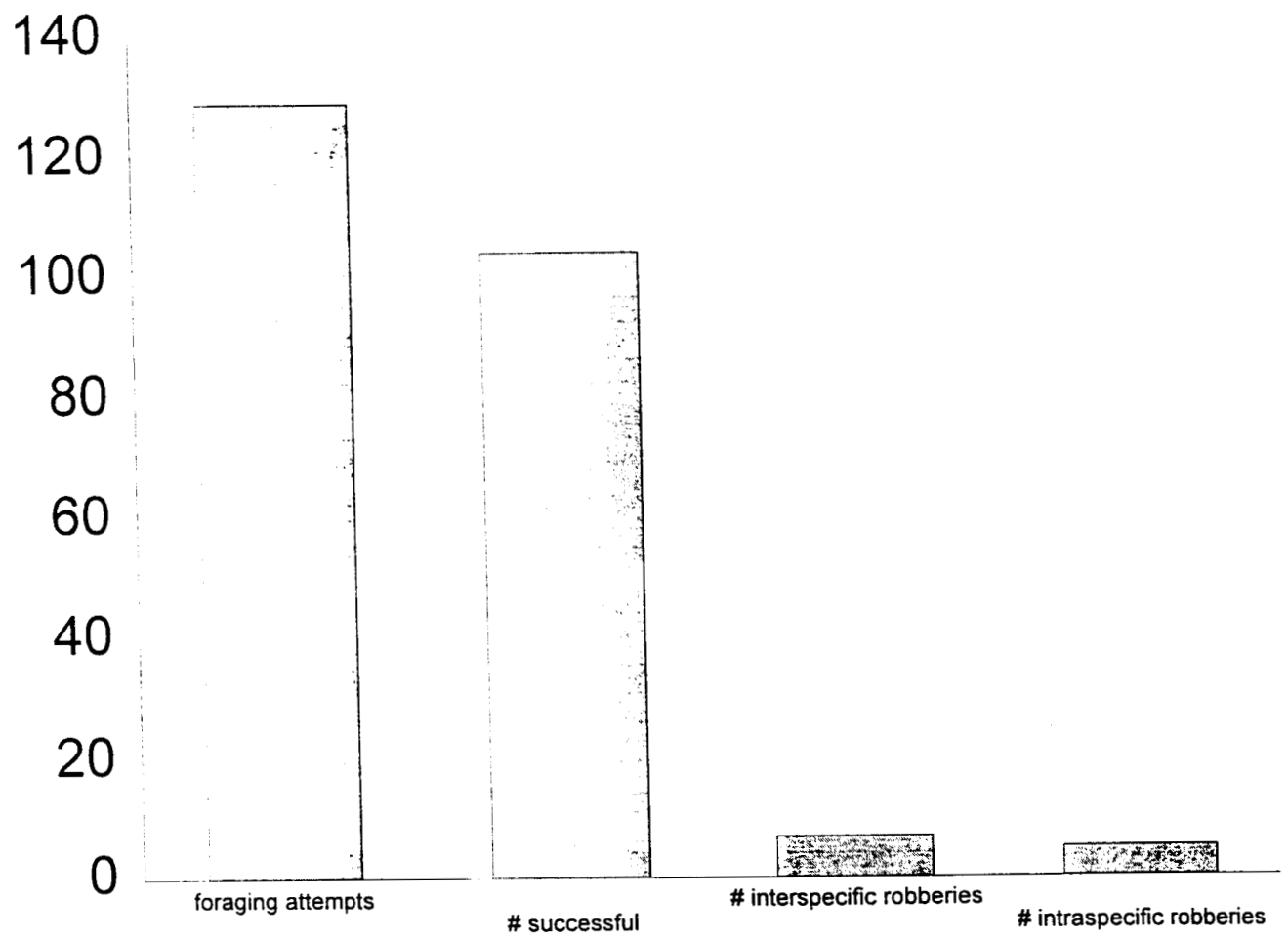
Appendix B-20

Fig. 10. Foraging methods used by black-legged kittiwakes in foraging flocks during the 1995 APEX cruise.



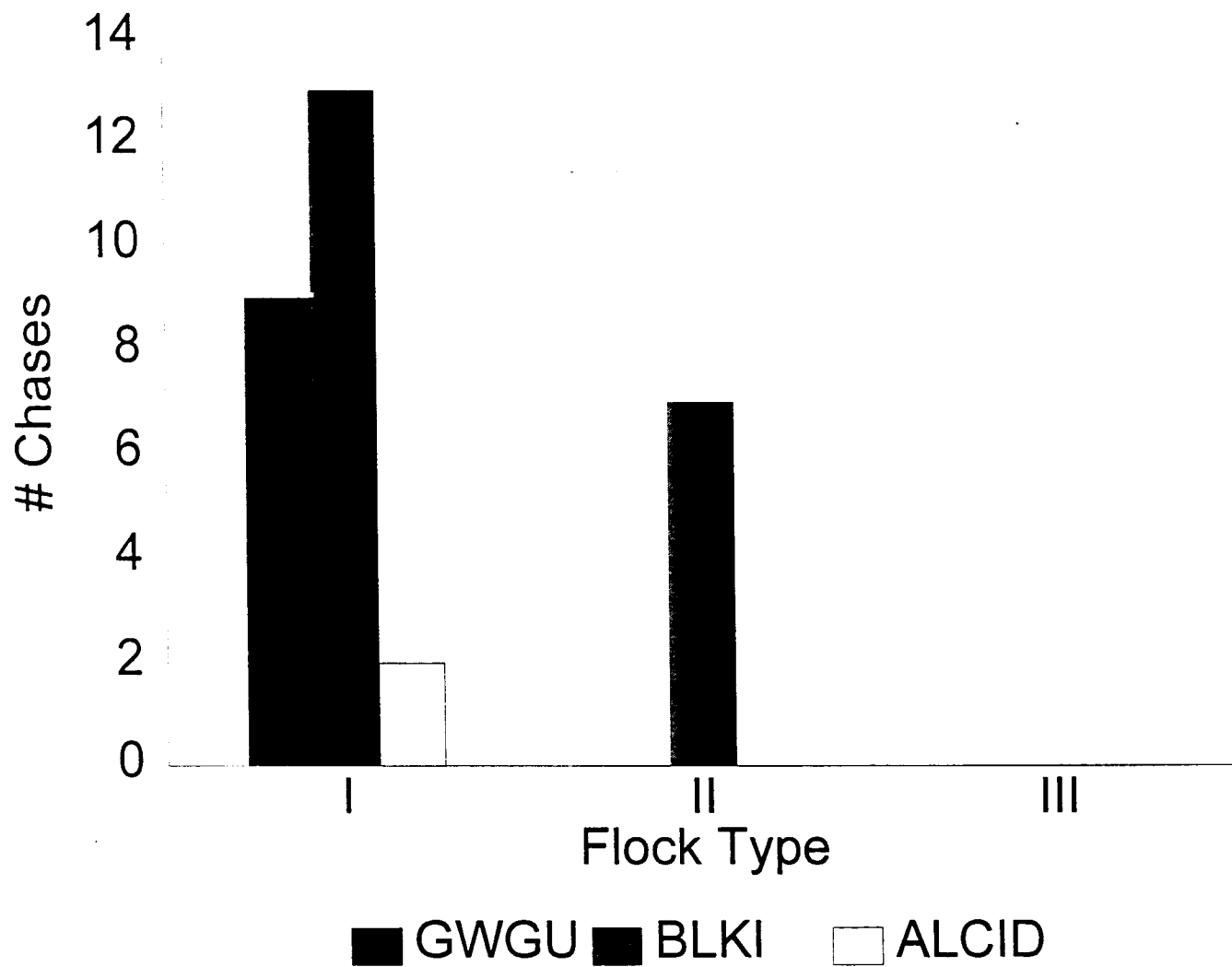
Appendix B-21

Fig. 11. Foraging attempts made by black-legged kittiwakes observed in foraging flocks and the number of successful kleptoparasitic attempts directed against them during the 1995 APEX cruise.



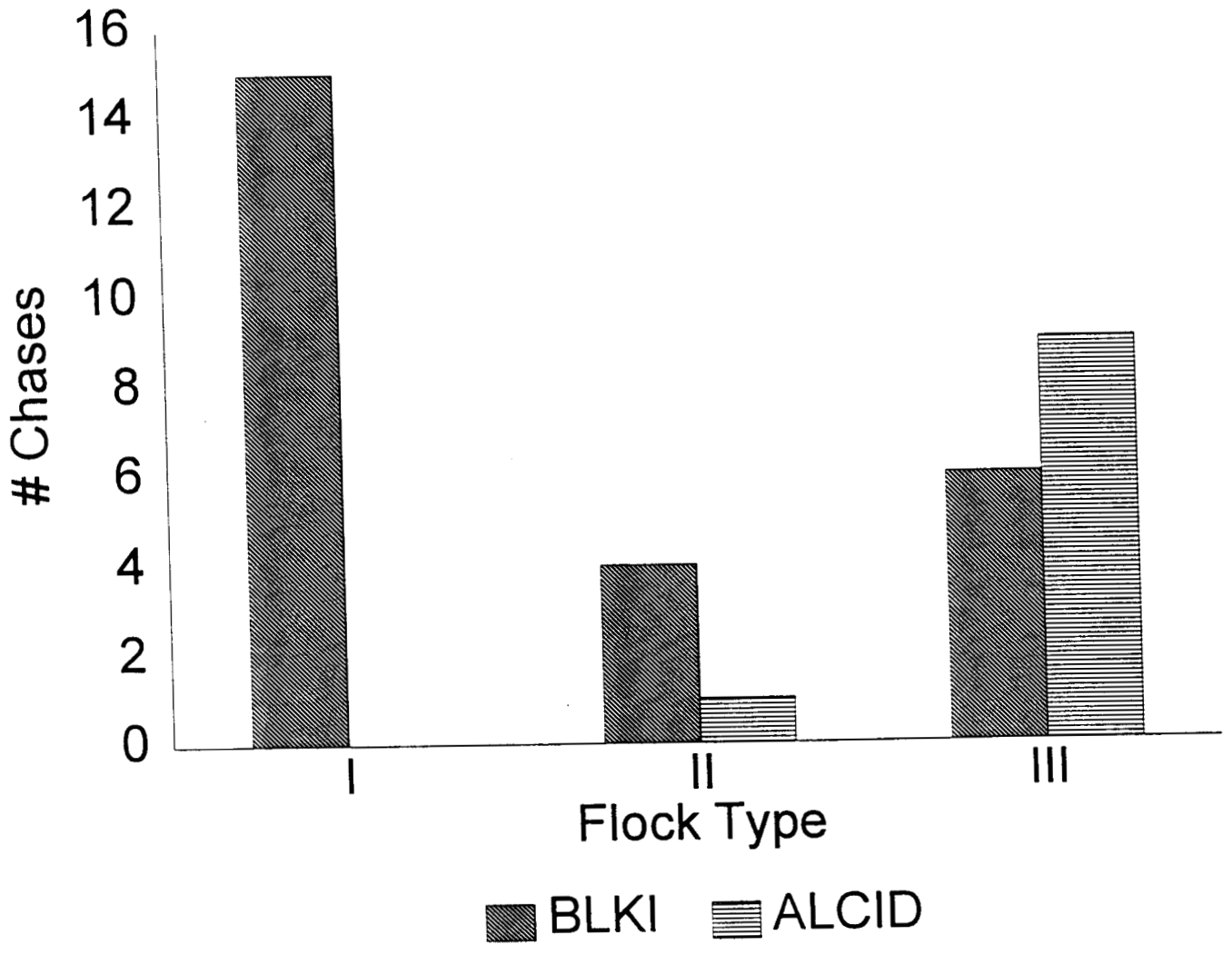
Appendix B-22

Fig. 12. Victims of kleptoparasitism by glaucous-winged gulls in foraging flocks during the 1995 APEX cruise.



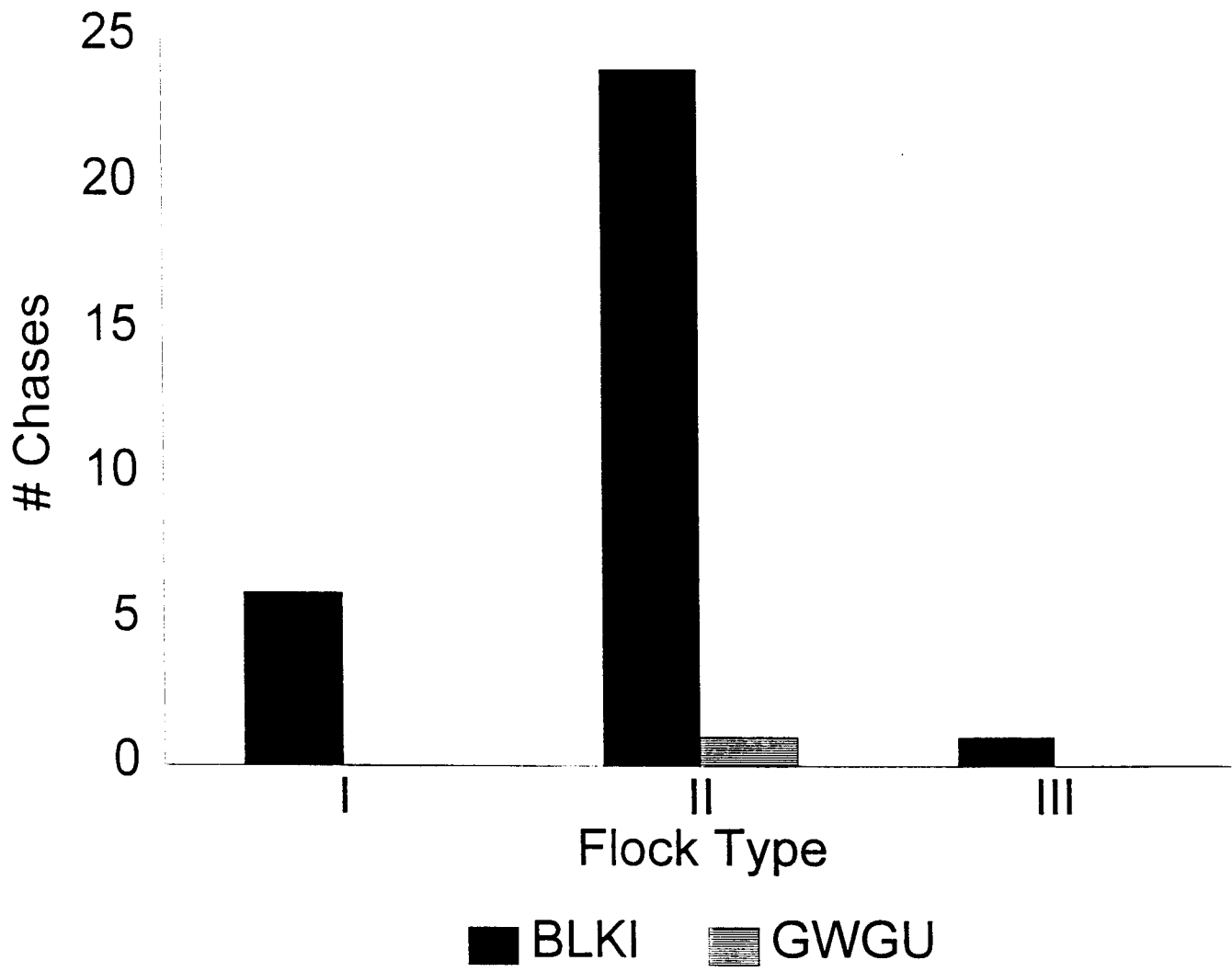
Appendix B-23

Fig. 13. Victims of kleptoparasitism by black-legged kittiwakes in foraging flocks during the 1995 APEX cruise.



Appendix B-24

Fig. 14. Victims of kleptoparasitism by jaegers in foraging flocks during the 1995 APEX cruise.



Appendix B-25

Fig. 15. Number of attempted robberies by jaegers compared with numbers of larids present in the flocks with jaegers during the 1995 APEX cruise.

