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The distribution, abundance and feeding ecology of birds associated with pack ice

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I. Summary of objectives, conclusions and implications with regard to oil and gas development.

As part of an environmental assessment of the outer continental shelf of Alaska the distribution, abundance and. feeding ecology of seabirds associated with pack ice are being studied. An attempt is being made to determine what factors are most important in determining distribution and abundance. This will allow the determination of which areas of the pack ice should be designated as critical habitat. Because of a complex set of variables bird distribution in the Bering Sea is hard to characterize. It appears that the area from the shelfbreak to the beginning of 8 oktas of ice cover is the most important for birds. This area corresponds to what is usually known as the "ice front". It is not known if the presence of ice plays a role in concentrating birds in the Bering Sea.

observations in the Beaufort Sea snow that distance from land is the most important variable in determining bird densities. The area from the mainland or barrier islands out to o-ne km has the most intensive bird use. Few birds are present at more than 20 km from shore.

Birds in the Bering Sea are feeding primarily on fish and zooplankton associated with a deep warm water layer. The presence of deep warm water may be important in determining which areas are important to large numbers of birds. In the Beaufort shoreline migrants are feeding primarily on zooplankton while pelagic species are feeding on fish.

For purposes of oil development all areas within 20 km of shore in the Beaufort can be considered critical habitat. The area within one km of land is the most intensively used part of this area. It is hard to designate critical habitat in the Bering due to the dynamic nature of the ice. Further oceanographic work is needed to determine why certain sections of the ice front support such large numbers of birds while other areas have very low densities.

II. Introduction

A. General nature and scope of study

Sea ice represents a unique marine habitat. Acting as a barrier between the air and water, it has a wide range of effects on seabirds. Ways in which sea ice decreases seabird numbers include:

1. Decreasing the amount of open water available for feeding and roosting.
2. Lowering primary productivity in the water column by decreasing the depth of the euphotic zone and preventing wind mixing.
3. Reducing benthic prey by scouring the bottom in shallow water.

Ways in which sea ice can enhance bird numbers include:

1. Providing a roosting space for species that normally roost on solid substrates.
2. Providing a matrix for an in-ice phytoplankton bloom.
3. In areas of multi-year ice, providing a substrate for an under-ice community of zooplankton and fish.
4. Decreasing wind speeds and sea surface disturbance in the immediate vicinity of ice.

B. Specific objectives

The specific objectives of this study are:

1. To determine the distribution and abundance of seabirds found in the open water south of the pack ice, at the ice edge and in the pack ice. Densities in the pack ice are analyzed with regard to ice type and amount of ice cover.
2. To determine the role that pack ice plays in the yearly cycles of seabirds and identify those species that are most dependent on the pack ice environment.
3. To determine the feeding habits of the seabird species associated with the pack ice,

C. Relevance to problems of petroleum development.

The ice environment of the Bering. Chukchi and Beaufort seas will present problems unique tc the exploitation of oil and gas reserves under these waters. Technical means have not. been developed to keep moving pack ice from affecting oil platforms. Underwater pipelines transporting oil to the mainland will be in danger of rupture by keels on ice floes. For these and a number of other reasons, the occurrence of an oil spill or similar major disturbance is more likely in the pack ice than in ice-free waters.

When a spill occurs the impacts on marine organisms associated with the pack ice probably will be more severe and longer-lasting than the impacts on biological systems in warmer waters. Water temperatures adjacent to the ice are usually near 0°C and biodegradation of oil occurs very slowly at such low temperatures. Oil spreading out on the underside of ice can be incorporated into it and affect the in-ice algae bloom and associated fauna. Oil spilled directly into leads will foul the limited amount of open water available to birds deep in the pack ice.

The birds found in and next to the pack ice will be severely impacted by oil spills. Birds are typically one of the most obvious and immediate victims of oil spills. Direct mortality is caused by oil fouling feathers resulting in loss of insulation, stress and possible ingestion of oil. More subtle effects are caused by the impacts of oil on the lower levels of trophic webs. Seabirds are at the terminal end of the marine food chain and thus are sensitive to any changes that occur at lower levels.

Research on seabirds in coastal areas (R.U. 3/4) has centered on delineating critical habitat so that precautions can be taken to minimize the impacts in these areas. The pack ice is too dynamic, however, to allow the designation of specific geographic areas as critical habitat. Critical habitat in the ice environment has to be defined in terms of distance to ice edge, amount and type of ice cover, water temperature, etcetera. These factors are constantly changing during ice formation and deformation. This project will provide pre-development information on the distribution and abundance of birds in relation to these parameters and allow the development of a predictive model. Impacts of development on pack ice birds can then be measured using the information gathered by this project.

III. Current state of knowledge

Previous studies that attempted to correlate ice with bird distribution are few. Frame (1973) reported on bird observations in the Beaufort Sea in summer. He only counted followers, however, and his work is not directly comparable to this project's. Watson and Divoky (1972) present information on birds next to and south of the pack ice in the Chukchi Sea in September and October. Irving et al. (1970) presented general information on birds at the Bering Sea ice edge in March.

Published accounts of pelagic observations in and next to the ice that do not deal specifically with iee in relation to bird distribution include Watson and Divoky's (1974) observations in the Beaufort and Jacque's (1930), Nelson's (1883) and Swartz's (1967) observations in the Chukchi. Unpublished pelagic observations deep in the Bering Sea pack ice were made by Divoky in March 1973.

The feeding habits of birds in and next to the pack ice are poorly known. The only applicable studies are those of Watson and Divoky (1972) and Divoky (1976) who report on prey items and feeding behavior of birds at the Chukchi ice edge in September.

IV. Study areas

The three seas covered by this project differ greatly in their amount and type of ice cover and their importance to seabirds. The following is a discussion of the marine and ice environment in each of these seas.

Bering Sea. Ice begins to cover the northern Bering Sea in late November. Ice coverage is at a maximum in February and March when the southern edge of the ice is usually found near the edge of the continental shelf. Decomposition of the pack ice begins in late April and continues until mid-June. This period (approximately six months) of ice cover is quite short compared to the Chukchi and Beaufort seas where some ice is present throughout the year. Because almost all of the ice in the Bering Sea is first year ice it lacks the extensive keels and pressure ridges found on ice in the Arctic. While the Bering Sea ice supports an in-ice photoplankton bloom (McRoy and Goering 1974) it is not known to have an under-ice fauna associated with its underside.

The Bering Sea ice "front" refers to the area of loose ice south of the more consolidated pack. It is composed primarily of bands of ice pans. Large floes are prevented from forming by swells on the open water to the south . When the wind is from the south the front is compacted against the main pack ice in a narrow band. When the wind is from the north the front becomes wider and more diffuse. In spring primary productivity is high in the water column under the ice front. At the same time productivity in the water column under the consolidated pack and south of the ice front is low (McRoy and Goering 1974). For this reason the ice front is an important biological area supporting large numbers of birds and mammals (Fay 1974).

Another feature of the Bering Sea pack ice of importance to birds is the open water associated with the islands found in the pack ice. These areas of open water (polynyi) are formed by the northerly winds which concentrate ice on the north side of islands and move ice away from the southern sides. These polynyi act as refugia deep in the pack ice.

The Bering Sea differs from the two Arctic seas studied by this project in that it has a high level of biological productivity. This is demonstrated by the large fishery the Bering Sea supports and by the large number of breeding and non-breeding birds present in summer.

Chukchi Sea. Ice covers the Chukchi Sea from November to May and coverage is almost complete during this period. Exceptions are the area of broken ice in the Bering Strait, a polynya associated with the shoreline in the Point Hope area (Shapiro and Burns 1975) and a lead system northwest of Point Barrow. In late May the ice in the southern Chukchi Sea begins to decompose and most of the area south of Cape Lisburne is ice free by July. The edge of the Arctic pack ice is present in the northern Chukchi throughout the summer occurring anywhere between 70° and 72° N.

The ice in the Chukchi Sea apparently supports an in-ice algae bloom similar to those found in the Bering and Beaufort seas. The multi-year ice in the Chukchi is known to support an under-ice fauna of zooplankton and arctic cod. The underside of multi-year ice has numerous keels and pockets which create a large surface area. Amphipods are known to concentrate on the ice underside presumably obtaining food from the plankton blooms occurring in and on the underside of ice (Mohr and Geiger 1968; MacGinitie 1955). Arctic cod prey on the amphipods and other zooplankton found next to the ice. The underside of multi-year ice is thus similar to a reef in that it has fish and invertebrate populations associated with a substrate. Little is known about this community. It is present in the spring and summer but nothing is known about the winter situation.

The water flowing north through the Bering Strait is a major influence on the Chukchi Sea. This water is warmer than Arctic waters and is the main reason for the rapid decomposition of ice in the southern Chukchi Sea. This water also supports high levels of primary productivity in summer (McRoy et al. 1972) and makes the southern portion of the Chukchi Sea the most biologically productive waters in the Arctic Ocean off Alaska.

Beaufort Sea. Ice covers much of the Beaufort Sea for almost twelve months of the year. The amount of open water present in the summer is dependent on wind and weather conditions. Adjacent to the coast strips of open water are present from approximately June to October; its width is dependent on the wind with south winds moving the ice offshore and north winds pushing the ice inshore. The pack ice present in the northern Chukchi and Beaufort seas in summer contains much open water between ice floes. Thus even in areas deep in the permanent pack ice there is open water available to birds in summer.

The Beaufort Sea supports an in-ice plankton bloom followed by a bloom in the open water. The Beaufort Sea is characteristic of arctic waters with productivity being reduced due to the lack of upwelling or mixing. Because of this the Beaufort is the least productive of the three seas studied by this project.

V. Sources, methods and rationale of data collection

A. Methods

1. Pelagic censusing

Pelagic censusing is conducted from the flying bridge during 15 minute observation periods. All birds seen in a 300-meter wide transect are recorded. Information is obtained on species, age, sex and activity. Ship followers are recorded once during each observation period but are not included in density computations. Information on oceanographic, meteorologic and ice conditions are recorded for each observation period. In 1977 all observations were put on coded sheets and sent to Michael Crane of AEIDC for punching, editing and conversion to magnetic tape.

All pelagic data collected by R.U. 196 has been handled in the manner described above since the project started in 1975. After one year it became obvious that the method of data processing was too cumbersome to allow rapid analysis of data by computer. The amount of person hours involved in coding the data, keypunching and editing was also large. It became obvious that after the data was on magnetic tape and sent to NODC (the National Oceanographic Data

Center) it was not possible to obtain sorted or analyzed data. These problems were dealt with in 1977 by developing a data entrY and analysis system.

The system consists of a S01-20 micro-computer, a Northstar Disc drive and a television monitor. An entry program written by Leo Karl of Custom Computing of Mill Valley, California, allows data to be entered directly from field forms and stored on a magnetic disc. The entry program is based on the “033” format used for all OCSEAP pelagic transect data. It is an interactive program in that the name of a parameter or data field appears on the screen and the operator enters the information from the field form. The entry program contains edits that prevent data from being entered that are not logical or do not fall within the values appropriate for a certain field.

The system was completed in the late summer of 1977 and was not used on any OCSEAP cruises during that year. The principal investigator of this project did use it, however, on a cruise from California to New Zealand to the Antarctic with David Ainley of the PRBO. Over 500 stations were entered on the cruise and, except for minor problems with power fluctuations caused by the ship’s generator, the entry system worked perfectly.

An analysis of variance program has been developed that allows the primary factors we correlate with bird densities (ice cover, distance from land, distance from shelfbreak, sea surface temperature, etcetera) to be stratified and the densities of certain species or total densities analyzed among the strata. This program has just been developed but the few tests that have been run on it show that it will be a very useful tool for the quick analysis of data at the end of a cruise. The program has the additional benefit of allowing data to be analyzed during a cruise so that sampling in the latter stages of a cruise can be based on the analysis of the data from the first part of the cruise.

The handling of large amounts of pelagic data has been a problem for this research unit as well as the U.S. Fish and Wildlife Service. The data processing system developed by the PRBO allows the quick entry of data on board ship. At the end of the cruise the observer has a set of floppy discs that can be run through a translation device and all of the information put on magnetic tape for NODC. The discs can also be used for analysis as soon as the cruise is over. The benefits of such a system are obvious and it is hoped that OCSEAP carries out most of its future pelagic work with the aid of such a system.

2. Specimen collecting and stomach contents analysis

Specimens are collected with a shotgun from a small boat. On board ship information on weight, molt, gonad, size and fat deposition are obtained. All food items present in the mouth, esophagus, and stomach are included in the analysis. All prey items are identified to the lowest possible taxonomic level and courted and measured. Weight of each prey group is determined.

VI. Results

An attempt is made in this report to portray graphically the densities of birds encountered on the cruises listed in Table 1. While all data will be analyzed with regard to ice, oceanographic and geographic conditions, it is recognized that much of what needs to be known by OCSEAP and BLM administrators is what birds are present where and in what densities. Some cruises conducted as part of R.U. 196 are not presented in this report. They are being mapped, however, and will be presented in a later report. A complete analysis of the data will be done using the computer programs discussed in the methods section of this report.

A. Bering Sea

1. Pelagic densities

Densities of birds seen on the three Bering Sea cruises in 1977 are presented in Tables 2 through 4. Figures showing densities of all species seen on five or more transects are presented on Figures 1-122.

2. Stomach contents

The prey found in the. stomachs of *Uria aalge*, *U. lonvia* and *Rissa tridactyla* are presented in Tables 5, 6 and 7 respectively.

B. Chukchi and Beaufort

1. Pelagic densities

Densities of all species seen on five or more transects in the Chukchi and Beaufort Seas are presented in Figures 124 through 230. Tables 8 and 9 show the density of birds by area for 1977 cruises. Tables 11 through 15 present bird densities in the Beaufort in relation to distance from land. This information is portrayed graphically in Figures 231-235.

2. Stomach contents

The stomach contents of Black-legged Kittiwakes collected in the Beaufort Sea are presented in Table 10.

VII. Discussion

A. Bering Sea

Pelagic bird distribution in the Bering Sea is determined by a complex set of parameters including distance from land, distance from shelfbreak, ice conditions, sea surface temperature and nature of the water column. As all of these factors have varying degrees of importance, the analysis of the Bering Sea data will be complex but extremely interesting. In last year's annual report an attempt was made to analyze the correlation of bird densities with distance from the northern and southern edge of the ice front. The analysis showed that certain species had affinities for specific parts of the ice front. Such an analysis is useful for predicting bird densities based on satellite photos. Cruises in 1977 snowed, however, that the primary factor in determining the abundance of birds in and near the ice front is the presence of a two layered system: a cold water layer above a warmer layer. Studies by R. T. Cooney and other personnel from R.U. 246 found the bottom layer oontained pollock (Theragra chlacogranna), capelius (Mallotus villosus), Parathemisto libellula and Neomysis rayi. Analysis of murre stomachs showed that the species mentioned above made up the bulk of the prey (Tables 5 and 6). A series of zooplankton tows taken during a 24-hour period by R.U. 246 showed that the fish and zooplankton migrate up into the water column at night. Because the layer of fish and zooplankton occurred at depths of 30 fathoms and more, murres may be feeding primarily in the early morning hours when prey are still present close to the surface with enough light to be visible. In order to test this assumption we collected bird specimens at three periods of the day: 800-1200, 1200-1600, 1800-2000 ADT. Common Murres (Uris aalge) fed most in the mid-afternoon (Table 5). Murres are visual feeders and can probably locate a maximum quantity of prey during maximum light penetration of the water column in early afternoon.

We now know that the concentrations of fish and zooplankton near the bottom of the water column are the major factors in producing high densities of birds at the ice edge but we do not know how the presence or absence of ice relates to these prey aggregations. Maybe the location of the shelfbreak is of critical importance and feeaing flocks of birds occur in the ice only because the ice front is found near the shelfbreak. We hope the University of Alaska PROBES study will shed some light on what determines the spatial and temporal distributions of prey items of birds in the Bering Sea.

B. Chukchi and Beaufort Seas

The distribution of birds in the northern Chukchi and Beaufort Seas is, unlike in the Bering Sea, largely determined by a single parameter, distance from land. Most of the birds in the Beaufort are tundra nesters that use the Beaufort as a migratory pathway and as a feeding area prior to the fall migration. Because of low productivity in the off-shore waters of the Beaufort, the nearshore waters have the highest concentrations of feeding birds. The importance of nearshore waters is increased by the large numbers of waterfowl that use the coast as a migratory pathway. In many areas the waterfowl do not roost or feed but simply pass overhead.

The densities of birds in the Beaufort Sea in relation to land are presented in Tables 11 through 15 and Figures 231 through 235. Figures 231 and 234 present data gathered on two August cruises on the Alumiak. On both cruises high average densities (over 100 birds per km^2 were found within 1 km of shore. From 2 to 10 km from shore densities averaged between 20 to 50 birds per km^2. Beyond 10 km the sample size was small but densities were low except for migrant waterfowl passing over areas of open ocean. Figures 232, 233 and. 235 show densities obtained on icebreaker cruises in the offshore Beaufort. Figures 232 and 235 show August densities of birds observed in the offshore Beaufort. In general densities average less than 20 birds per km^2. Areas with higher densities had either large flocks of phalaropes or eiders. During a September cruise in the Beaufort densities were higher than in August probably due to decreasing prey densities in nearshore waters.

The trophic relations' of birds in the Beaufort are also closely tied with distance from land. Nearshore species consume primarily zooplankton and pelagic species consume primarily Arctic Cod. Because Arctic Cod are closely associated with ice. offshore areas without ice have very low prey densities.

VIII. Conclusions

Bird densities in the Bering Sea need to be further studied with respect to the oceanographic conditions that cause concentrations of fish and zooplankton at the ice edge. Further cruises with biological oceanographers will allow bird densities to be correlated with prey abundance rather than those parameters that are most easily obtained by persons studying seabirds (i.e. distance from land, ice cover, sea surface temperature, etc.). The large numbers of birds found in the ice front in the Bering Sea may have little to do with the ice conditions. The location of the ice front may just happen to coincide with an area of prey abundance.

Cruises in the Beaufort Sea in 1976 and 1977 show that the offshore waters have very low densities of birds and that the area within 20 km of shore is most important to feeding and migrating birds. Further studies should center on the area within 20 km of shore in order to see what nearshore features or processes are most important *in* determining bird distribution and abundance within the zone.

The only pelagic area of the Beaufort found to regularly support high numbers of birds is the area just north of Point Barrow. Observations in 1977 showed that Bering Sea water north of Point Barrow had high densities of zooplankton at the surface. The high densities of birds found from Point Barrow along the shore to the eastern Plover Islands may be aue to the Bering Sea water offshore.

IX. Summary of 4th quarter operations

A. No field work was conducted during this quarter. The Pacific Seabird Group meeting and the Beaufort Synthesis were attended by the principal investigator.

B. None

C. Estimate of funds expended.

Salaries	$ 8000.
Travel	2200.
Equipment	-
Other direct costs	3000.
Overhead	3100.
Total	$16300.

X. Literature cited

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Table 1, Data reported in this report were gathered on the following cruises.

Ship	Date	Location	No. of 15 min. ohs.	Cruise Track Figure #
USCGC Burton Is.	22-28 July 1976	Chukchi and Beaufort Seas	88	125,191
USCGC Glacier	6 August - 3 Sept. 1976	Chukchi Sea	282	132
R.V. Alumiak	19-30 August 1976	Beaufort Sea	135	194
USCGC Glacier	5-17 Sept. 1976	Beaufort Sea	130	194
NOAA Discoverer	1o-24 Sept. 1976	Northern Bering and Southern Chukchi Sea	256	148,149
NOAA Surveyor	15 March - 6 April 1977	Bering Sea	271	1,2,3
NOAA Surveyor	14 April - 6 May 1977	Bering Sea	290	36,37,38
NOAA Discoverer	20 May - 10 June 1977	Bering Sea	357	77,78
USCGC Glacier	2-5 August 1977	Chukchi Sea	43	182
R.V. Alumiak	2-25 August 1977	Beaufort Sea	226	219
USCGC Glacier	6 August - 5 Sept. 1977	Beaufort Sea	462	219

Table 2. Bird densities by area in the Bering Sea, 15 March to 6 April 1977.

Area	# of transects	Avg. density per km2	Principal species	Avg. density per km^2
Unimak Pass	8	3230	*Uris* spp.	2550
			Aethia cristatella	666
Unimak Pass to St. George	13	5.3	*Uris* spp.	4
			Rissa tridactyla	0.9
Pribilofs to St. Matthew	17	4.2	*Uris* spp.	3.5
			Rissa tridactyla	0.3
Ice south of St. Matthew	34	591	*Uria* spp.	440
			Larus hyperboreus	139
Ice edge south of St. Matthew	14	9	*Uris* spp.	6.2
			Larus hyperboreus	1.9
Midway between Pribilofs and Cape Newenham	15	2.8	*Uris* spp.	1.9
Ice midway between Pribilofs and Cape Newenham	26	1.9	*Larus hyperboreus*	0.6
			Larus glaucescens	0.6
South of Cape Newenham	6	13	*Uris* spp.	13
Ice south of Cape Newenham	22	5.2	*Uria* spp.	2.4
			Eider	1
Approaching Unimak Pass from Bristol Bay	24	11	*Uris* spp.	10
Akutan Pass to Unimak Island	26	88	*Aethia cristatella*	44
			Uris spp.	21
			Somateria spectabilis	17

Table 3. Bird densities by area in the Bering Sea, 14 April to 3 May 1977.

Area	# of transects	Avg. density per km²	Principal species	Avg. density per km²
Unimak Pass	13	29	*Uris* spp.	16
			Anatid	5
Northwest of Unimak	6	32	*Uris* spp.	17
			Fulmarus glacialis	13
Unimak Pass to Cape Newenham	25	30	*Uris* spp.	18
			Fulmarus glacialis	6
Bristol	19	13	*Uris* spp.	7
			Clangula hyemalis	2
Leaving Bristol Bay	33	4.3	*Uris* spp.	2
			Rissa tridactyla	1
East of St, Paul	34	15	*Fulmarus glacialis*	6
			Somateria spectabilis	2
			Uris spp.	2
Ice north of St. Paul	27	17	*Uris* spp.	10
			Rissa tridactyla	3
			Larus hyperboreus	2
Ice edge south of St. Matthew	18	10	*Uris* spp.	5
			Fulmarus glacialis	2
Approaching Unimak Pass	14	12	*Uris* sp.	8
			Fulmarus glacialis	2
Unimak Pass	5	30	*Uris* spp.	21

Table 4. Bird densities by area in the Bering Sea 20 May to 10 June 1977.

Area	# of transects	Avg. density per km²	Principal species	Avg. density per km²
Leaving Unimak Pass	29	15	*Oceanodroma furcata*	5
			Rissa tridactyla	5
Southwest of St. Paul	12	58	*Phalaropus fulicarius*	27
			Uris sp.	17
			Fulmarus glacialis	8
Northwest of St. Paul	19	17	*Uris* spp.	8
			Aethis pusilla	3
Ice edge west of St. Matthew	13	116	*Aethia pusilla*	88
			Uris spp.	24
Ice west of St. Matthew	55	257	*Aethia pusilla*	169
			Uris spp.	33
			Rissa tridactyla	36
Ice west of St. Matthew	11	57	*Aethia pusilla*	25
			Aethia cristatella	15
			Uria spp.	6
Paralleling ice south of St. Matthew	29	89	*Uris* spp.	47
			Aethia cristatella	19
			Aethia pusilla	14
Ice between Nunivak and St. Matthew	26	47	*Uria* spp.	30
			Rissa tridactyla	4
			Fulmarus glacialis	3
Ice west of Nunivak	9	274	*Uria* spp.	213
			Fulmarus glacialis	21
			Rissa tridactyla	9.
West of Nunivak	7	9.4	*Uria* spp.	5
			Aethia pusilla	2
Ice edge west of Nunivak	21	26	*Uris* spp.	19
			Fulmarus glacialis	2

Table 4 (continued).

Area	# of transects	Avg. density per km²	Principal species	Avg. density per km²
Ice northeast of St. Matthew	18	55	*Uris* spp.	34
			Phalaropus fulicarius	5
			Aethia cristatella	4
Ice midway between St. Matthew and Nunivak	25	21	*Uria* spp.	14
			Rissa tridactyla	2
Southwest of Nunivak	10	14	*Uris* spp.	9

Table 5. Stomach contents of *Uris aalge* collected in the Bering Sea ice front.

	Pollock	Capelin	Herring	Unid. fish	*Parathemisto libellula*	Euphausids	*Neomysis rayi*
March 1976							
n=17 wt.=773.2g							
% wt.	56	38		6	tr.	tr.	
% freq.	100	41		35	29	6	
April 1976							
n=14 wt.=486g							
% wt.	60	tr.		3	8	20	
% freq.	21	7		7	29	57	
March 1977							
n=2 wt.=6.9g							
% wt.					100		
% freq.					100		
April 1977							
n=3 wt.=36.1g							
% wt.		26			34	39	
% freq.		33			67	33	
May 1977*							
n=48 wt.=568.6g							
% wt.	1	55	7	4	7	5	16
% freq.	5	40	2	19	37	26	30

*Additional information On May 1977 specimens

48 total birds collected

Time of collection	Number of birds	Number empty	Avg. vol.
0700 - 1000 ADT	19	4	2.1
1000 - 1500 ADT	12	1	24.o
1500 - 2100 ADT	17	0	16.2

Table 6. Stomach contents of *Uris lomvia* collected in the Bering Sea ice front.

	Pollock	Capelin	Unid. fish	*Parathemisto libellula*	Euphausids	Squid	Unid.
March 1976							
n=2 wt.=10 g							
% wt.				100			
% freq.				100			
April 1976							
n=9 wt.=486g							
% wt.	99		tr.	1		tr.	
% freq.	90		22	11		11	
March 1977							
n=8 wt.=255 g							
% wt.		9	tr.	59	21		10
% freq.		22	6	100	17		6
April 1977							
n=10 wt.=36.1g							
% wt.		26		34	39		
% freq.		33		67	33		
May 1977							
n=26 wt.=126.6g							
% wt.	tr.	tr.	tr.	79	17	tr.	3
% freq.	35	4	4	73	35	12	12

Table 7. Stomach contents of *Rissa tridactyla* collected in the Bering Sea ice front.

	Pollock	Capelin	Unid. fish	*Parathemisto libellula*	Euphausids	*Neomysis rayi*
March 1976						
n=2 st.=.8g						
% wt.	tr.	tr.	100			
% freq.	100	100	100			
April 1976						
n=1 wt.=41g						
% w-t.	95					
% freq.	100					
March 1977						
n=3 wt.=5.2g						
% wt.	100					
% freq.	100					
April 1977						
n=12 wt.=65.6g						
% wt.	6	54	37		1	
% freq.	75	75	80		17	
May 1977						
n=11 wt.=7.3g						
% wt.	96	tr.	tr.	tr.		4
% freq.	64	14	14	14		14

Table 8. Bird densities by area in the offshore waters of the eastern Chukchi and Beaufort Seas 1 August to 6 September 1977.

Area	# of transects	Avg. density per km^2	Principal species	Avg. density per km^2
Eastern Chukchi Sea	49	5.5	*Phalaropus fulicarius*	2.1
			Rissa tridactyla	1.0
Tangent Point to Oliktok Point	111	2.6	*Phalaropus fulicarius*	0.8
			Rissa tridactyla	0.3
Jones Islands to Brownlow Point	24	2.0	*Sterna paradisaea*	0.8
			Larus hyperboreus	0.6
			Phalaropus fulicarius	0.4
Ice edge off continental shelf	43	0.9	*Sterna paradisea*	0.3
			Rissa tridactyla	0.3
Approaching Demarcation Bay from north	46	3.8	*Clangula hyemalis*	2.5
Demarcation Bay to Cape Halkett (close to 10 fathom curve)	126	4.4	*Phalaropus fulicarius*	2.5
			Clangula hyemalis	0.8
Cape Halkett to Pt. Barrow	105	9.7	*Sterna paradisaea*	3.9
			Eider	2.1
			Phalaropus fulicarius	1.1

Table 9. Bird densities by area in the nearshore waters of the Beaufort Sea 3 to 26 August 1977.

Area	# of transects	Avg. density per km^2	Principal species	Avg. density per km^2
Barrow to Cape Simpson	26	81	Eider	38
			Phalaropus fulicarius	16
			Clangula hyemalis	8
			Stem paradisaea	6
Cape Halkett to eastern Camden Bay	84	49	Eider	34
			Clangula hyemalis	7
			Phalaropus fulicarius	5
Eastern Camden Bay to Halkett	57	10	Eider	6
			Phalaropus fulicarius	1.8
Cape Halkett to Tangent Point	59	36	*Clangula hyemalis*	18
			Sterna paradisaea	6
			Eider	6
			Phalaropus fulicarius	3

Table 10. Stomach contents of *Rissa tridactyla* collected in the eastern Chukchi and Beaufort Seas.

	Arctic Cod	Amphipods	Mysids	*Parathemisto libellula*	Shrimp
July to Sept. 1976					
n=25 wt.=112.4g					
% wt.	89	7			
% freq.	76	20			
August to Sept. 1977					
n=15 wt.=42.3g					
% wt.	73	7		8	12
% freq.	87	20		7	7

3AL876

Distance from land Km		≤ 1	2+3	4+5	6+7	8+9	10+11	12+13	14+15	16+17	18+19	20+21	22+23	24+25	26+27	28+29	30+31	32+33
Number of transects	n	28	40	18	11	17	5	3	2	1	1	0	1	2	2	1	2	1
Gavia arctica	x̄	0.2	1.3	0.2	0.5	0.4	1.1	0.3	1.4	0.0	0.0	---	1.0	4.7	1.1	0.0	2.3	1.2
	% freq	18	18	11	28	29	60	33	50	0	0	---	100	100	50	0	50	100
Gavia stellata	x̄	0.0	0.2	0.0	0.3	0.3	0.0	0.0	0.4	1.4	0.0	---	0,0	0.0	0.0	0.0	0.0	1.2
	% freq	0	13	0	17	6	0	0	50	100	0	---	0	0	0	0	0	100
All Gavia	x̄	1.3	1.0	0.2	0.8	1.4	1.9	0.5	1.8	1.4	0.0	---	1.0	4.7	1.6	0.0	2.7	2.4
	% freq	29	25	17	45	59	80	33	100	100	0	---	100	100	100	0	50	100
Clangula hyemalis	x̄	77.2	29.7	13.0	36.6	21.9	0.0	1.6	0.0	0.0	0.0	---	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	79	70	50	73	59	0	67	0	0	0	---	0	0	0	0	0	0
All Eiders	x̄	15.0	2.2	3.7	3.6	6.9	26.2	0.0	16.4	0.0	9.4	---	0.0	5.0	296.3	65.7	47.9	54.7
	% freq	11	13	22	18	24	20	0	50	0	100	---	0	100	100	100	100	100
All Phalaropes	x̄	49.1	3.6	22.8	4.3	2.9	0.6	0.0	0.0	0.0	0.0	---	0.0	0.0	0.0	0.0	0.0	2.4
	% freq	50	35	61	27	80	40	0	0	0	0	---	0	0	0	0	0	100
All Stercorarius	x̄	0.3	0.0	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0	0.0	0.9	0.0	0.0
	% freq	18	0	6	27	12	0	0	0	0	0	---	0	0	0	100	0	0
Larus hyperboreus	x̄	2.5	4.3	2.7	0.2	0.3	0.3	0.0	0.0	0.0	0.0	---	0.0	0.5	0.6	0.9	0.5	1.2
	% freq	11	23	39	18	29	20	0	0	0	0	---	0	50	50	100	50	100
Rissa tridactyla	x̄	0.8	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	18	13	0	0	6	0	0	0	0	0	---	0	0	0	0	0	0
Xema sabini	x̄	2.3	0.9	0.4	0.1	0.5	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	14	8	6	9	18	0	0	0	0	0	---	0	0	0	0	0	0
Sterna paradisaea	x̄	175.7	1.8	3.7	0.0	1.4	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0	0.6	0.0	0.0	0.0
	% freq	32	20	22	0	11	0	0	0	0	0	---	0	0	50	0	0	0
TOTAL DENSITY	x̄	310.7	45.8	46.3	46.3	35.6	29.0	1.9	18.2	1.4	9.4	---	1.0	12.2	299.5	67.5	51.1	60.7
	% freq	100	95	94	91	94	100	100	100	100	100	---	100	100	100	100	100	100
% transects with ice		86	82	89	64	47	40	100	100	100	100	---	100	100	100	100	100	100

Table 11. Densities of birds in relation to distance from Land in the Beaufort Sea in August 1976.

2GL876

Distance from land	Km	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Number of transects	n	3	3	11	-1	21	6	11	7	7	10	14	3	2	1	1	1	2	2	1
All *Gavia*	$\bar{x}$	0.1	0.0	0.0	0.0	0.2	0.3	0.3	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	33	0	0	0	10	17	18	0	0	0	7	0	50	0	0	0	0	0	0
Clangula hyemalis	$\bar{x}$	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.3	1.6	0.0	6.4	0.0	0.0	0.0	0.0	3.4	3.4	0.0
	% freq	0	0	0	0	0	0	18	0	14	10	0	33	0	0	0	0	50	50	0
All Phalaropes	$\bar{x}$	0.0	65.9	5.6	0.0	2.3	1.2	7.6	0.8	60.3	19.8	9.5	0.0	0.0	0,0	0.0	0.0	0.0	0,0	0.0
	% freq	0	100	18	0	10	17	18	14	57	20	14	0	0	0	0	0	0	0	0
All *Stercorarius*	$\bar{x}$	0.0	0.0	0.0	1.1	0.0	0.0	0.1	0.3	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
	% freq	0	0	0	29	0	0	9	14	14	10	0	0	0	0	0	0	100	0	0
Larus hyperboreus	$\bar{x}$	0.0	0.8	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.7	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	33	0	0	0	0	9	0	14	20	-1	33	0	0	0	0	0	0	0
Rissa tridactyla	$\bar{x}$	0.2	3.1	0.7	0.0	0.0	0.0	0.2	0.0	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	33	67	27	0	0	0	9	0	14	10	0	0	0	0	0	0	0	0	0
Xema sabini	$\bar{x}$	0.0	3.2	0.2	0.1	0.1	0.2	0.8	16.0	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
	% freq	0	67	9	14	5	17	29	14	29	0	0	0	0	0	0	0	50	0	0
Sterna paradisaea	$\bar{x}$	0.0	0.0	1.1	0.0	2.3	0.0	0.0	0.0	1.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	0	27	0	19	0	0	0	29	10	0	0	0	0	0	0	0	0	0
All *Uria*	$\bar{x}$	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DENSITY	$\bar{x}$	0.7	77.8	7.6	1.2	5.0	1.7	9.9	17.0	81.9	25.9	10.1	7.6	0.5	0.0	0.0	0.0	6.7	3.4	0.0
	% freq	67	100	45	29	33	50	27	14	57	40	21	33	50	0	0	0	100	50	0
% transects with ice		100	0	73	71	95	100	100	71	51	90	100	100	100	100	100	100	100	100	100

Table 12. Densities of birds in relation to distance from land in the Beaufort Sea in August 1976.

3GL976

Distance from land Km		1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Number of transects	n	0	5	3	1	0	1	4	4	5	2	3	11	12
All *Gavia*	x̄		10.8	2.3	0.0		0.0	0.8	0.0	1.2	0,0	0.0	3.8	1.4
	?. freq		80	100	0		0	50	0	20	0	0	18	11
Clangula hyemalis	x̄		36.5	11.5	0.0		0.0	0.0	5.4	13.1	0.0	2.7	0.2	1.1
	% freq		80	33	0		0	0	25	40	0	33	9	33
Puffinus tenuirostris	x̄		0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq		0	0	0		0	0	0	0	0	0	0	0
All Eiders	x̄		611.5	0.0	0.0		5,1	2.3	0.0	0.0	0.0	3.3	0.0	0.3
	% freq		80	0	0		100	25	0	0	0	33	0	8
All Phalaropes	x̄		0.4	0.0	0.0		20.6	37.8	54.9	23.2	2.9	2.1	1.3	2.5
	% freq		20	0	0		100	75	100	60	50	33	27	8
Stercorarius pomarinus	x̄		0.0	0.0	0.0		0.0	0.8	0.6	0,0	0.0	0.0	0.9	0.2
	% freq		0	0	0		0	25	50	0	0	0	9	8
Stercororius paras it icus	x̄		0.0	0.0	0.0		2.0	0.0	0.0	0.5	0.0	1.2	0.2	0.2
	% freq		.0	0	0		100	0	n	40	0	33	9	8
Stercorarius longicaudus	x̄		0.0	0.0	0.0		0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0
	% freq		0	0	0		0	0	?5	0	0	0	18	0
All *Stercorarius*	x̄		0.0	0.0	0.0		2.0	0.8	0.9	0.5	0.0	1.2	1.3	0.4
	% freq		0	0	0		100	25	75	40	0	33	36	17
Larus hyperboreus	x̄		0.4	1.8	2.4		1.0	1.0	4.2	3.4	1.5	0.9	2.4	1.5
	% freq		20	61	100		100	50	100	100	50	67	64	42
Rissa tridactyla	x̄		0.0	0.0	0.0		2.0	1.3	1.8	1.0	0.8	0.0	2.0	0.6
	% freq		0	0	0		100	50	75	40	50	0	55	17
________________	x̄		0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	2.1	0.5	0.0
	% freq		0	0	0		0	0	0	0	0	33	9	0
Xema sabini	x̄		0.0	0.0	0.0		0.0	8.2	18.2	?.2	0.0	0.0	2.7	0.4
	% freq		0	0	0		0	25	100	20	0	0	36	17
Sterna paradisaea	x̄		0.0	0.0	0.0		0.0	6.6	2.1	6.2	0.0	0.0	0.0	0.0
	% freq		0	0	0		0	83	23	20	0	0	0	0
TOTAL DENSITY	x̄		659.6	15.9	2.4		30.'7	58.7	88.6	50.8	5.1	15.2	14,2	8.5
	% freq		100	100	100		100	100	100	100	100	100	73	82
% transects with ice			0	0	0		0	0	100	60	100	67	100	100

Distance from land Km		66-70	71-15	16-80	81-83	86-90	91-95	96-100	101-103	106.110	111-115	116.120	121-125	126-130
Number of transects	n	5	7	9	11	5	10	14	6	1	1	0	6	2
All *Gavia*	x̄	8.8	0.0	0.0	1.3	0.2	0.8	0.6	1.6	1,8	0.0		0.0	0.0
	?. freq	20	0	0	27	20	50	36	33	100	0		0	0
Clangula hyemalis	x̄	0.0	1.0	0.2	0.2	0.0	0.6	2.7	0.0	0.0	0.0		2.8	0.0
	% freq	0	14	11	9	0	20	21	0	0	0		50	0
Puffinus tenuirostris	x̄	0.0	0.0	0.0	0,0	0.0	0.1	0.1	0.0	0.0	0,0		0.0	0.0
	% freq	0	0	0	0	0	10	7	0	0	0		0	0
All Eiders	x̄	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0		0.0	0,0
	% freq	0	0	0	0	0	10	0	0	0	0		0	0
All Phalaropes	x̄	0.3	0.0	3.3	18.1	10.6	14.5	7.9	0.0	0.0	35.0		0.0	10.5
	% freq	20	0	11	45	20	50	36	0	0	100		0	50
Stercorarius pomarinus	x̄	0.0	0.0	0.0	0.1	0.0	0,0	0.0	0.0	0.0	0.0		0,2	0.0
	% freq	0	0	0	9	0	0	0	0	0	0		17	0
Stercororius paras it icus	x̄	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0		0.0	0.0
	% freq	0	0	0	0	0	0	7	0	0	0		0	0
Stercorarius longicaudus	x̄	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.3	0.0
	% freq	0	0-	0	0	0	0	0	0	0	0		17	0
All *Stercorarius*	x̄	0.0	0.0	0.2	0.2	0.4	0.2	0.1	0.0	0.0	0.0		0.5	0.0
	% freq	0	0	11	18	40	10	7	0	0	0		33	0
Larus hyperboreus	x̄	0.0	0.5	1.5	0.8	0.0	2.3	1.2	0.6	0.0	0.0		0.3	0.9
	% freq	0	14	33	18	0	60	30	33	0	Q		17	50
Rissa tridactyla	x̄	0,0	0.0	0.5	0.2	0.4	1.9	0.4	0.9	0.0	0.0		0.7	1.8
	% freq	0	0	22	9	20	50	29	83	0	0		50	100
________________	x̄	0,0	0.0	0.0	0.0	0.0	1.0	0.6	0.4	0.0	0.0		0.0	0.0
	% freq	0	0	0	0	0	40	14	17	0	0		0	0
Xema sabini	x̄	0.7	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
	% freq	20	0	11	0	c	0	0	0	0	0		0	0
Sterna paradisaea	x̄	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
	% freq	0	0	0	0	0	0	0	0	0	0		0	0
TOTAL DENSITY	x̄	9.6	1.5	5.8	20.6	11.7	21.9	13.4	3.3	1.8	35.0		4.4	13.2
	% freq	60	29.	56	82	40	90	19	67	100	100		83	100
% transects with ice		100	100	89	A5	60	40	43	50	100	0		100	100

Table 13. Densities of birds in relation to distance from land in the Beaufort Sea i.n September 1976.

3AL877

Distance from land Km		≤ 1	2+3	4+5	6+7	8+9	10+11	12+13	14+15	16+17	18+19	20+21	22+23	24+25	26+27	28+29	30+31	32+33
Number of transects	*n*	14	21	55	47	17	18	7	21	10	3	2	3	3	2	0	2	1
Gavia arctica	$\bar{x}$	0.8	1.2	0.8	0.3	0.1	1.5	1.0	0.1	0.3	0.0	0.0	1.6	0.0	0.0	---	0.0	0.0
	% freq	29	24	16	4	6	11	29	5	20	0	0	33	0	0	---	0	0
Gavia stellata	$\bar{x}$	0.5	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0
	% freq	14	10	0	0	6	0	0	0	0	0	0	0	0	0	---	0	0
All Gavia	$\bar{x}$	1.3	1.3	0.8	0.3	0.4	0.3	0.6	0.1	1.2	0.0	0.0	2.9	0.9	0.0	---	0.0	0.0
	% freq	43	33	20	13	18	17	29	10	40	0	0	76	33	0	---	0	0
Clangula hyemalis	$\bar{x}$	33.4	15.2	14.4	2.7	0.4	10.4	0.0	0.0	0.0	0.0	0,0	0.0	0.0	0.0	---	0.0	0.0
	% freq	43	48	36	15	6	17	0	0	0	0	0	0	0	0	---	0	0
All Eiders	$\bar{x}$	74.9	3.1	0.1	12.1	3.6	16.1	0.0	117.8	0.0	0.0	0.0	0.0	0.0	42.2	---	0.0	0.0
	% freq	43	14	5	13	18	22	0	38	0	0	0	0	0	100	---	0	0
All Phalaropes	$\bar{x}$	16.6	2.2	2.8	9.4	7.0	4.2	0.2	0.4	3.9	0.0	0.0	0.0	0.0	2.5	---	0.0	0.0
	% freq	53	29	29	26	24	39	14	5	40	0	0	0	0	100	---	0	0
All Stercorarius	$\bar{x}$	0.5	0.5	0.0	0.1	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0
	% freq	21	5	2	4	0	6	0	0	20	0	0	0	0	0	---	0	0
Larus hyperboreus	$\bar{x}$	2.9	0.6	0.6	0.5	0.3	2.-1	0.0	0.3	0.8	0.0	1.2	0.8	0.8	1.9	---	1.2	0.0
	% freq	43	33	16	26	29	39	0	19	40	0	50	33	33	100	---	50	0
Rissa tridactyla	$\bar{x}$	0.7	0.5	0.1	0.0	1.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0
	% freq	14	14	4	2	12	0	0	0	10	0	0	0	0	0	---	0	0
Xema sabini	$\bar{x}$	0.3	0.0	0.1	0.3	1.2	0.0	0.0	0,0	0.0	0.0	0,0	0.0	0.0	0.0	---	0.0	0.0
	% freq	7	0	2	2	12	0	0	0	0	0	0	0	0	0	---	0	0
Sterna paradisaea	$\bar{x}$	2.9	0.6	5.4	3.5	2.1	2.3	0.0	0.3	0.0	3.5	4.8	0.0	0.0	0.0	---	0.0	0.0
	% freq	36	10	20	21	18	17	0	5	0	33	50	0	0	0	---	0	0
Uria species	$\bar{x}$	0.3	0.2	0.0	0.1	0.1	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	---	0.0	0.0
	% freq	7	5	0	4	6	11	14	0	0	0	0	0	0	0	---	0	0
TOTAL DENSITY	$\bar{x}$	133.8	30.0	24.3	32.4	16.7	41.0	1.0	119.0	7.2	3.5	6.0	3.7	1.7	46.6	---	1.2	0.0
	% freq	100	95	64	83	76	67	29	57	80	33	100	67	67	100	---	50	0
% transects with ice		57	52	25	28	35	17	29	48	33	100	100	67	100	100	---	100	100

Table 14. Densities of birds in relation to distance from land in the Beaufort Sea in August 1977.

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Distance from land	Km													
Number of transects	n	2	12	13	25	18	14	26	33	48	17	9	27	30
Gavia arctica	x	0.0	0.1	0.1	0.1	0.0	0.2	0.5	0.1	0.1	0.1	0.2	0.1	0.3
	% freq	0	8	8	12	0	14	23	9	8	0	11	4	13
All Gavia	x	4.2	0.5	0.6	0.1	0.1	0.2	0.6	0.3	0.1	0.3	0.4	0.1	0.3
	% freq	100	25	31	12	11	21	27	18	15	29	33	11	17
Fulmarus glacialis	x	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	% freq	0	0	0	0	0	0	4	0	2	0	0	0	0
Puffinus tennirostris	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
	% freq	0	0	0	0	0	0	0	3	0	0	0	0	3
____________	x	0.0	0.8	0.0	1.9	2.2	0.0	0.1	0.1	0.1	0.0	0.0	0.1	3.6
	% freq	0	25	0	16	33	0	12	3	2	0	0	4	3
All Eiders	x	0.0	9.3	8.6	0.0	0.0	0.0	0.1	0.2	1.2	0.0	0.0	1.1	0.0
	% freq	0	17	15	0	0	0	4	3	2	0	0	4	0
All Phalaropes	x	0.0	2.0	2.2	1.4	0.2	0.1	12.7	5.2	3.1	2.7	0.0	0.2	1.0
	% freq	0	8	15	12	6	7	15	42	19	24	0	11	7
Stercorarius pomarinus	x	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
	% freq	0	0	0	8	6	0	0	0	0	6	0	0	3
Stercorarius parasiticus	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.1
	% freq	0	0	0	0	0	0	0	12	6	0	0	8	3
Stercorarius longicaudus	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	% freq	0	0	0	0	0	0	0	0	0	0	0	0	3
All Stercorarius	x	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.3	0.1	0.1	0.0	0.1	0.2
	% freq	0	0	8	12	17	0	0	12	6	6	0	8	10
____________	x	0.7	0.6	0.4	0.4	0.4	0.5	0.6	0.3	0.3	0.1	0.1	0.3	0.3
	% freq	50	8	31	20	28	29	27	18	19	12	11	15	20
____________	x	1.5	0.1	0.1	0.1	0.2	0.3	0.6	1.0	0.6	0.2	0.1	0.3	0.3
	% freq	50	8	8	8	6	29	15	21	21	12	11	30	10
Xemi sabini	x	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.2	0.0	0.0	8.4	0.1	0.0
	% freq	0	0	0	4	0	0	4	3	0	0	22	4	0
Sterna paradisaea	x	0.0	0.3	0.3	0.0	0.0	0.2	1.4	9.5	1.0	0.0	8.6	0.0	0.0
	% freq	0	8	8	0	0	7	23	24	13	0	22	0	0
Uria species	x	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0
	% freq	0	0	0	3	6	14	4	3	2	0	0	11	0
Cepphus grylle	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	0	0	0	0	0	0	0	0	0	0	0	0
Small alcid	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0
	% freq	0	0	0	0	0	0	0	3	0	6	0	0	0
TOTAL DENSITY	x	59.0	4.2	12.8	4.7	3.2	1.4	5.5	17.2	7.5	3.7	17.5	2.2	5.7
	% freq	100	42	62	60	56	64	69	76	67	59	56	59	50
% transects with ice		50	17	62	28	11	21	31	15	31	29	22	33	47

Distance from land	Km														11-135
Number of transects	n	24	17	30	15	13	14	12	7	8	7	6	3	6	2
Gavia arctica	x	0.1	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	4	4	0	7	0	0	0	0	0	0	0	0	0	0
All Gavia	x	0.1	0.2	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	4	12	3	7	0	0	8	0	0	0	0	0	0	0
Fulmarus glacialis	x	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	% freq	4	0	0	0	0	0	0	0	13	0	0	0	0	0
Puffinus tennirostris	x	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	4	6	0	0	0	0	0	0	0	0	0	0	0	0
____________	x	0.1	0.3	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	% freq	8	12	3	7	0	0	0	0	0	0	0	0	33	0
All Eiders	x	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Phalaropes	x	0.1	2.9	0.3	0.0	0.1	0.5	0.6	0.0	0.0	0.3	3.6	0.0	0.0	0.0
	% freq	13	35	7	0	15	7	17	0	0	14	17	0	0	0
Stercorarius pomarinus	x	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	% freq	0	0	3	0	0	0	17	0	0	0	17	0	0	0
Stercorarius parasiticus	x	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
	% freq	0	6	3	0	8	0	0	0	13	0	0	0	17	0
Stercorarius longicaudus	x	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0
	% freq	0	0	0	0	0	0	8	0	13	0	0	0	0	0
All Stercorarius	x	0.0	0.1	0.1	0.0	0.1	0.0	0.4	0.3	0.2	0.0	0.3	0.0	0.1	0.0
	% freq	0	6	6	0	8	0	42	14	25	0	17	0	17	0
____________	x	0.5	0.1	0.1	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	13	12	13	0	0	14	0	14	0	0	0	0	0	0
____________	x	0.3	0.3	0.3	0.0	0.2	0.1	0.1	0.2	0.5	0.9	0.3	0.0	0.3	0.7
	% freq	25	29	20	0	15	7	17	14	13	43	17	0	17	50
Xemi sabini	x	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Sterna paradisaea	x	0.0	0.7	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	0	6	3	7	8	0	0	0	0	0	0	0	0	0
Uria species	x	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.9	0.3	0.5	0.0	0.0
	% freq	4	0	0	0	8	0	0	14	0	14	17	33	0	0
Cepphus grylle	x	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0
	% freq	0	0	7	0	0	0	0	0	13	0	0	0	17	0
Small alcid	x	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
	% freq	0	6	0	0	0	0	0	0	0	14	0	0	0	0
TOTAL DENSITY	x	1.0	5.4	1.0	0.7	0.7	0.8	1.2	1.0	1.1	2.5	4.5	0.5	0.8	1.2
	% freq	42	46	40	20	38	29	50	43	38	43	33	33	67	100
% transects with ice		58	41	37	47	46	43	92	29	50	86	83	33	33	50

15. Densities of birds in relation to di from land in the Beaufort in August 1977.

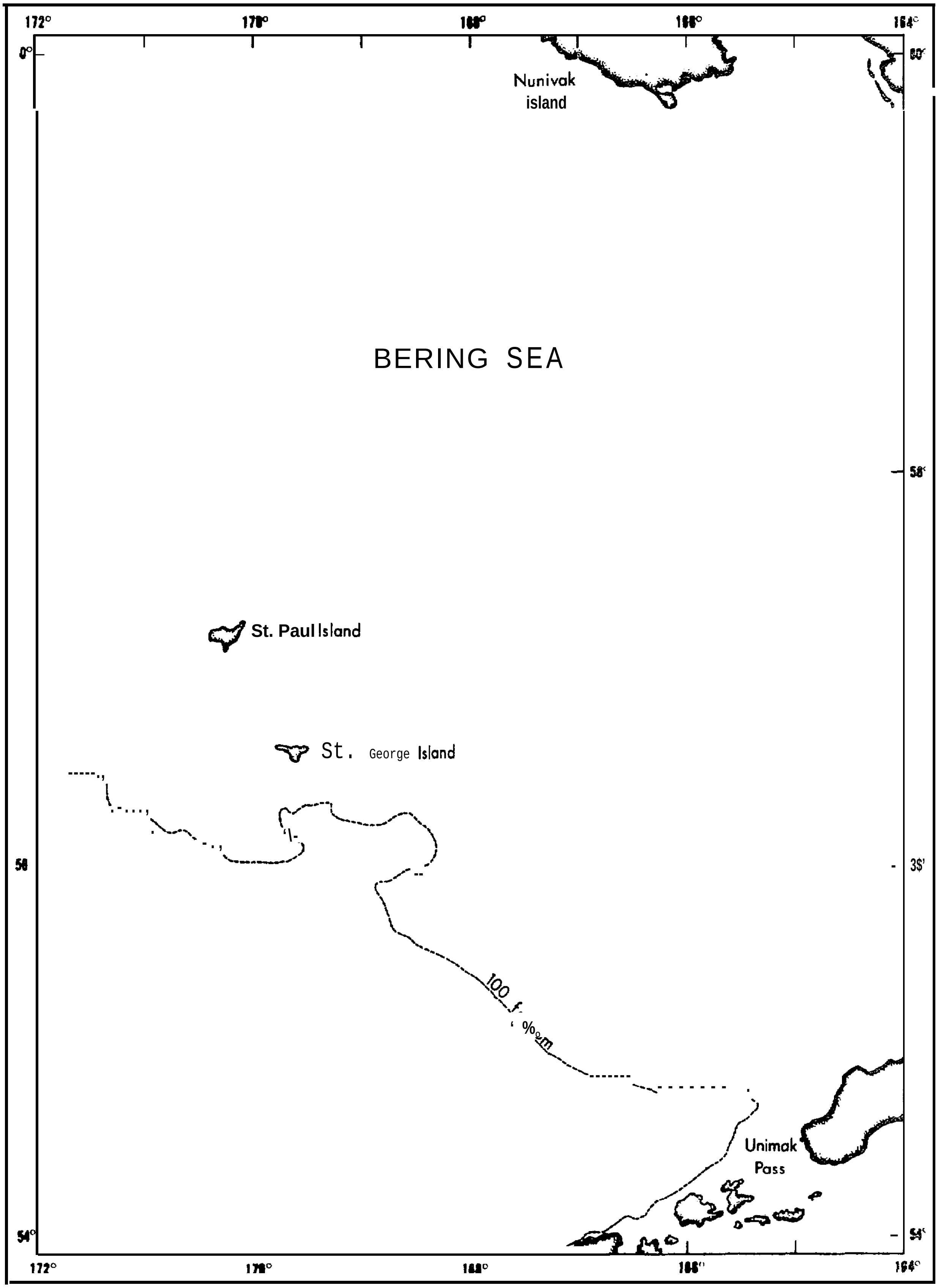


Figure 1. Southern Bering Sea showing localities mentioned in text.

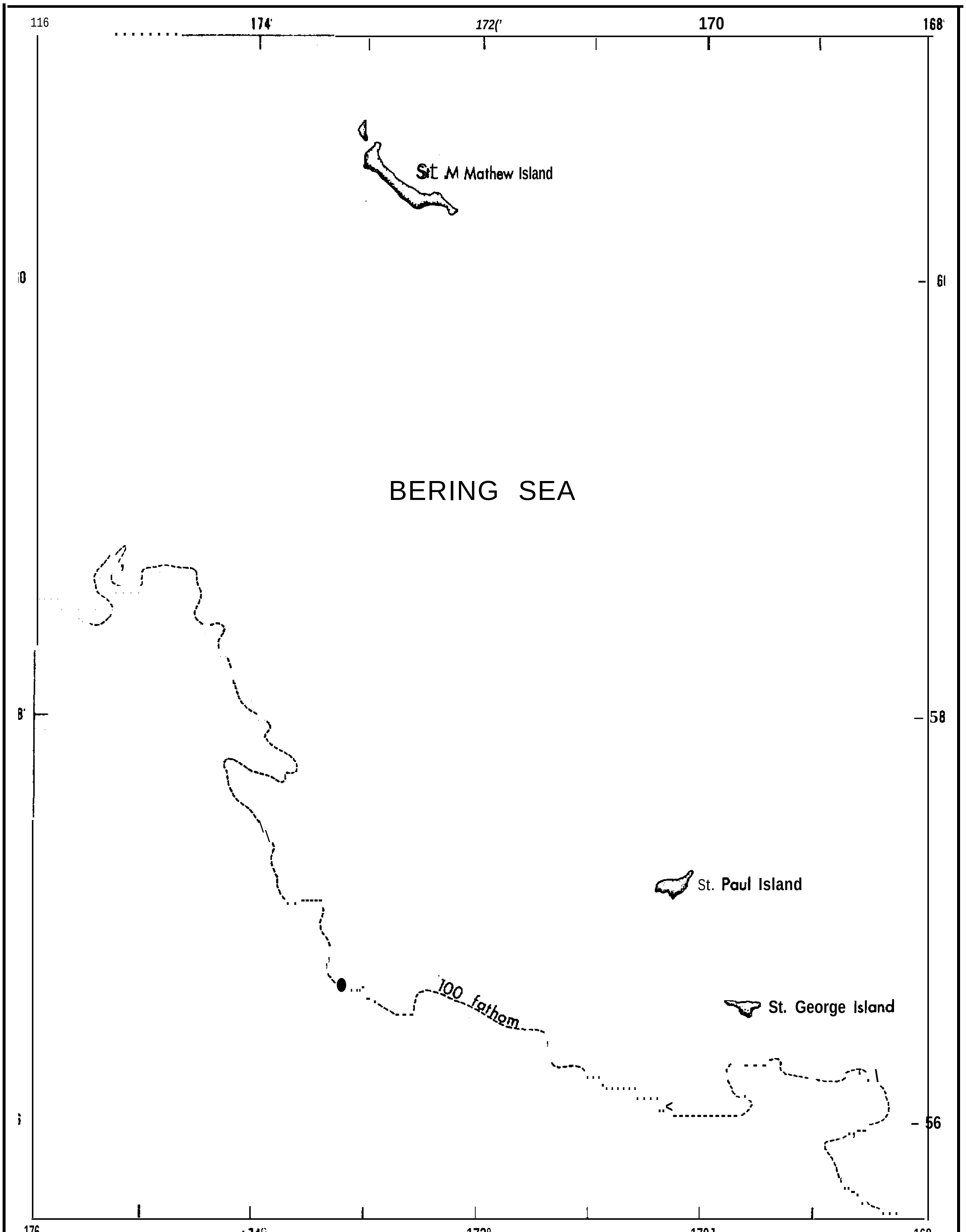


Figure 2. Central Bering Sea showing localities mentioned in text.

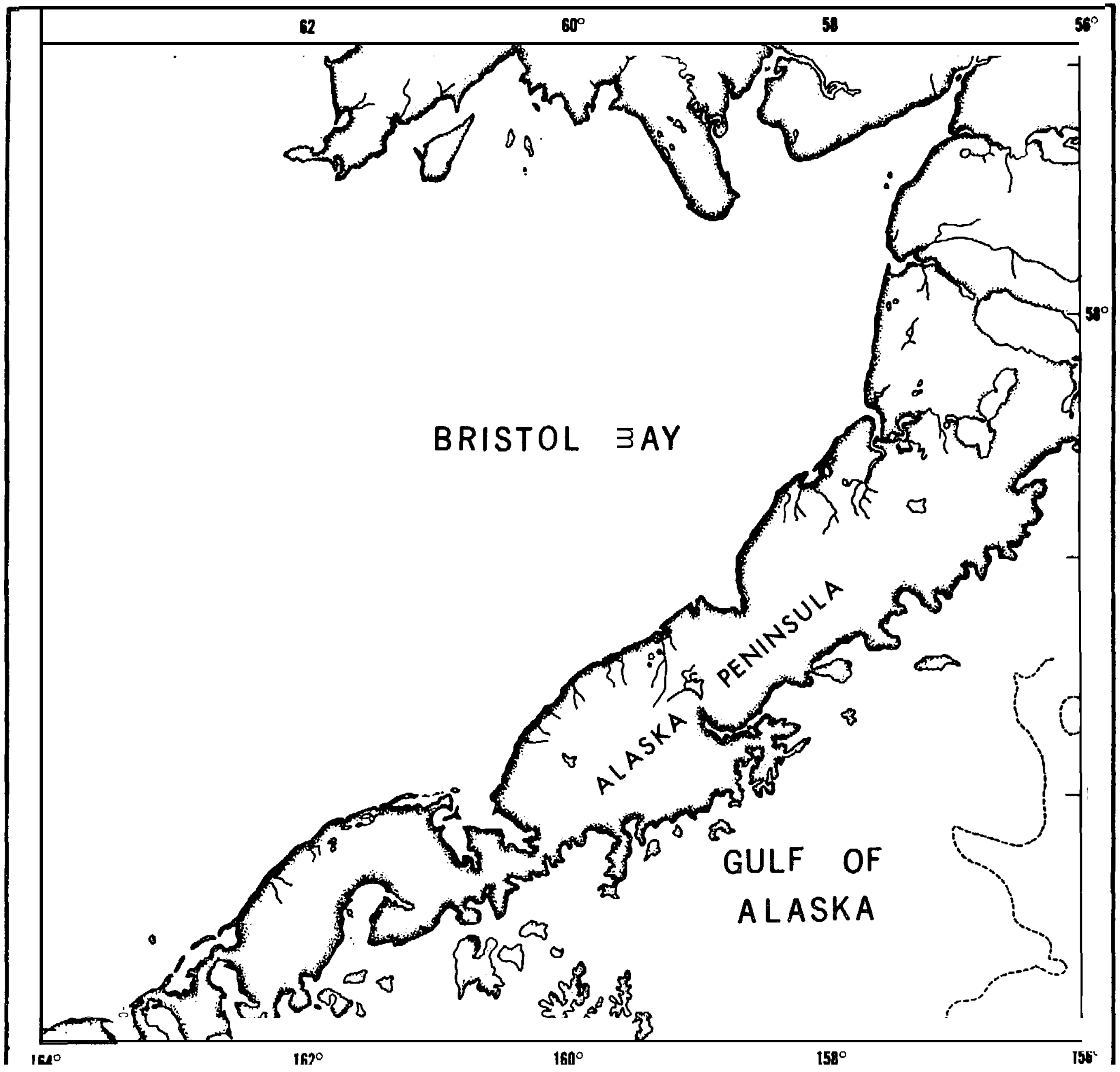


Figure 3. Bristol Bay showing localities mentioned in text.

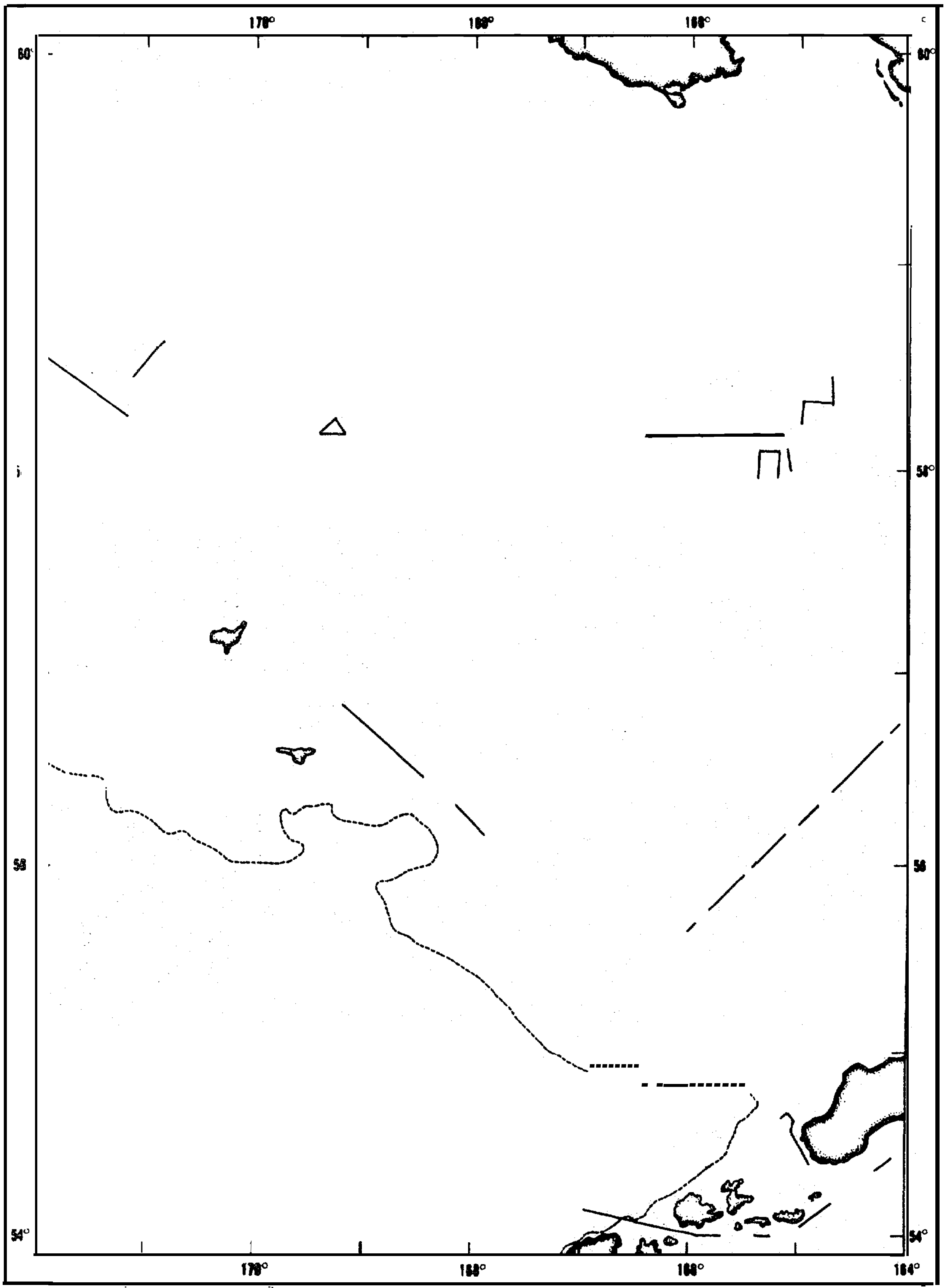


Figure 4. Cruise track during periods of observation in southern Bering Sea from 17 March to 4 April 1977.

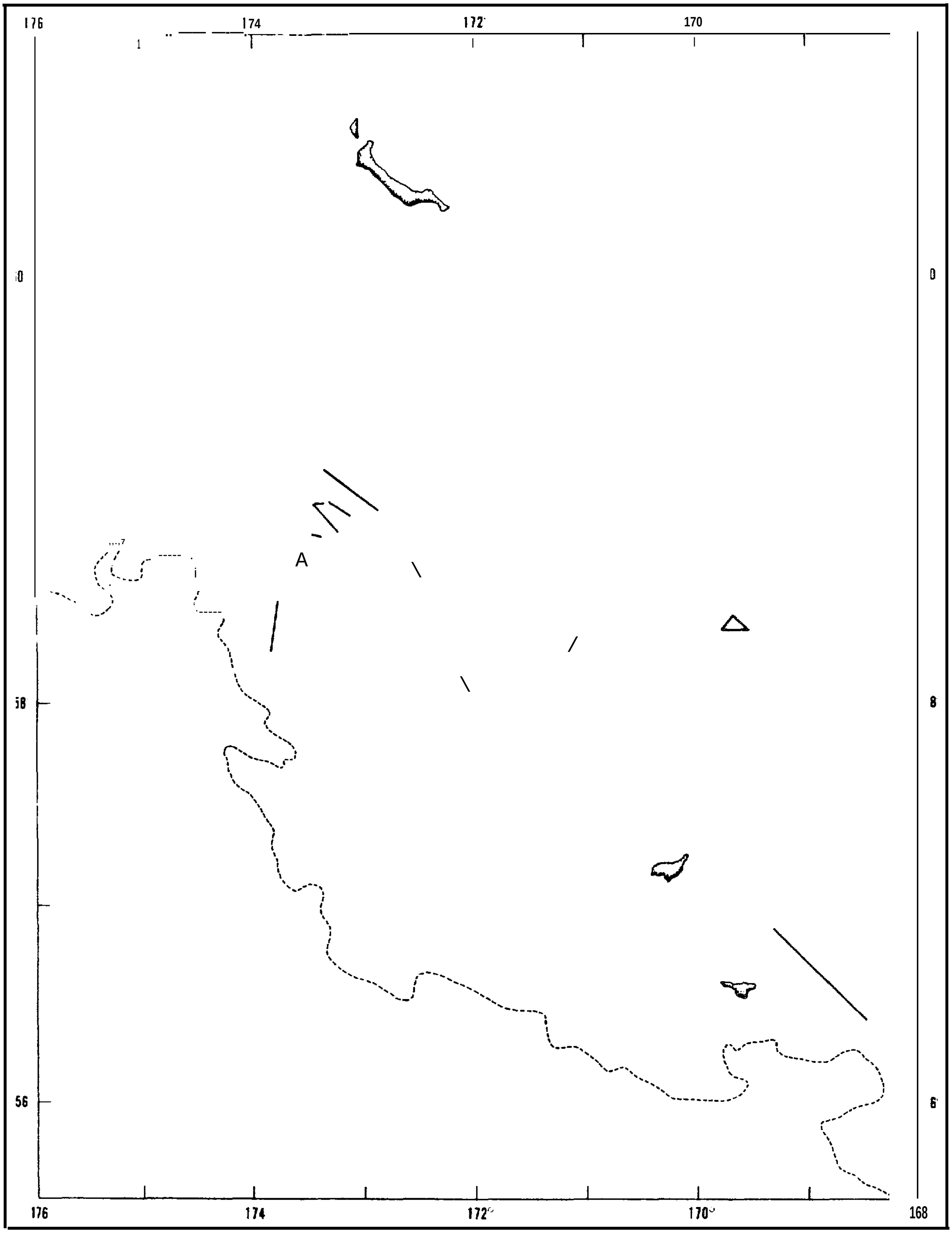


Figure 5. Cruise track during periods of observation in central Bering Sea from 18 March to 25 March 1977.

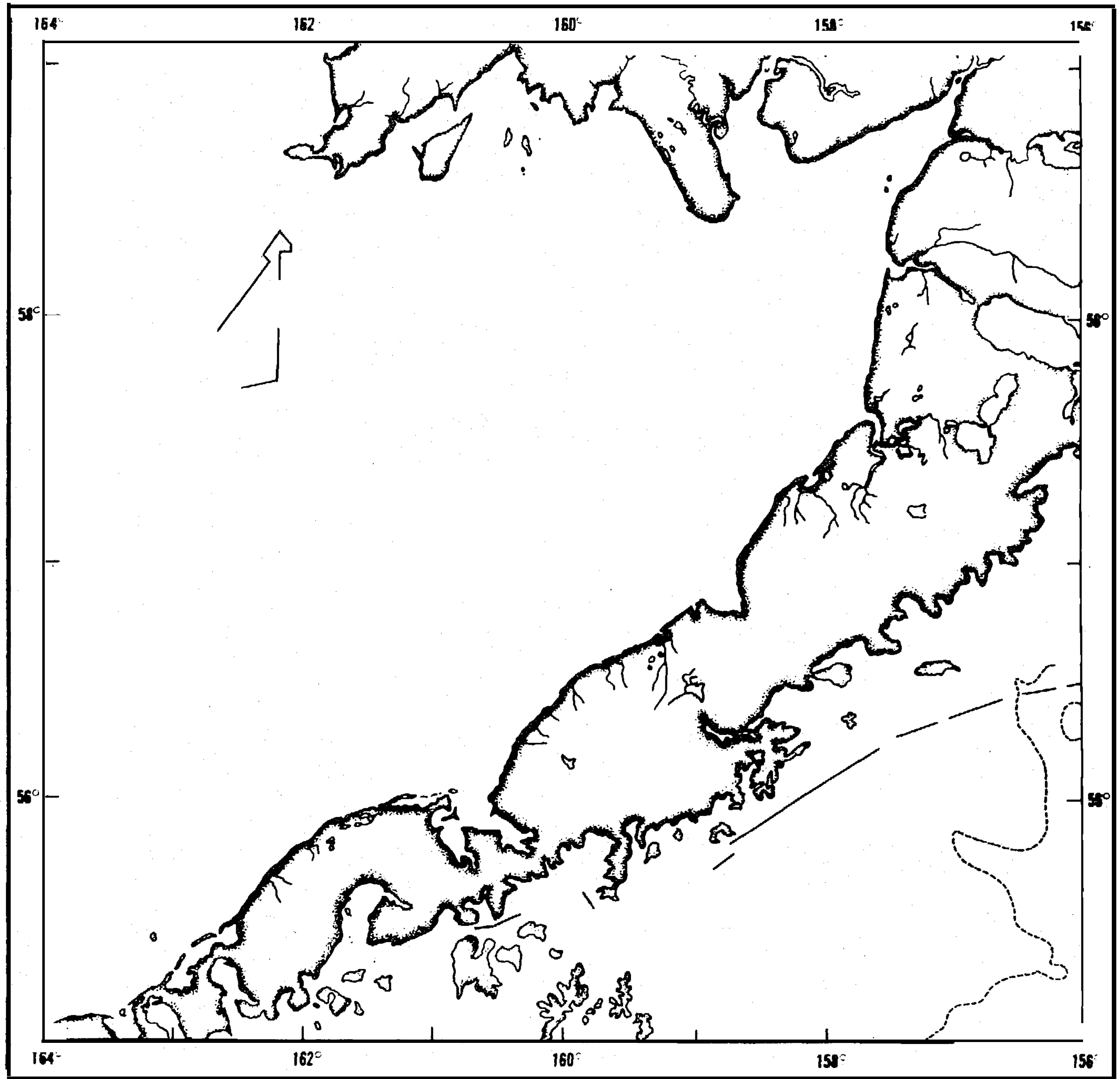


Figure 6. Cruise track during periods of observation in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 5 April 1977.

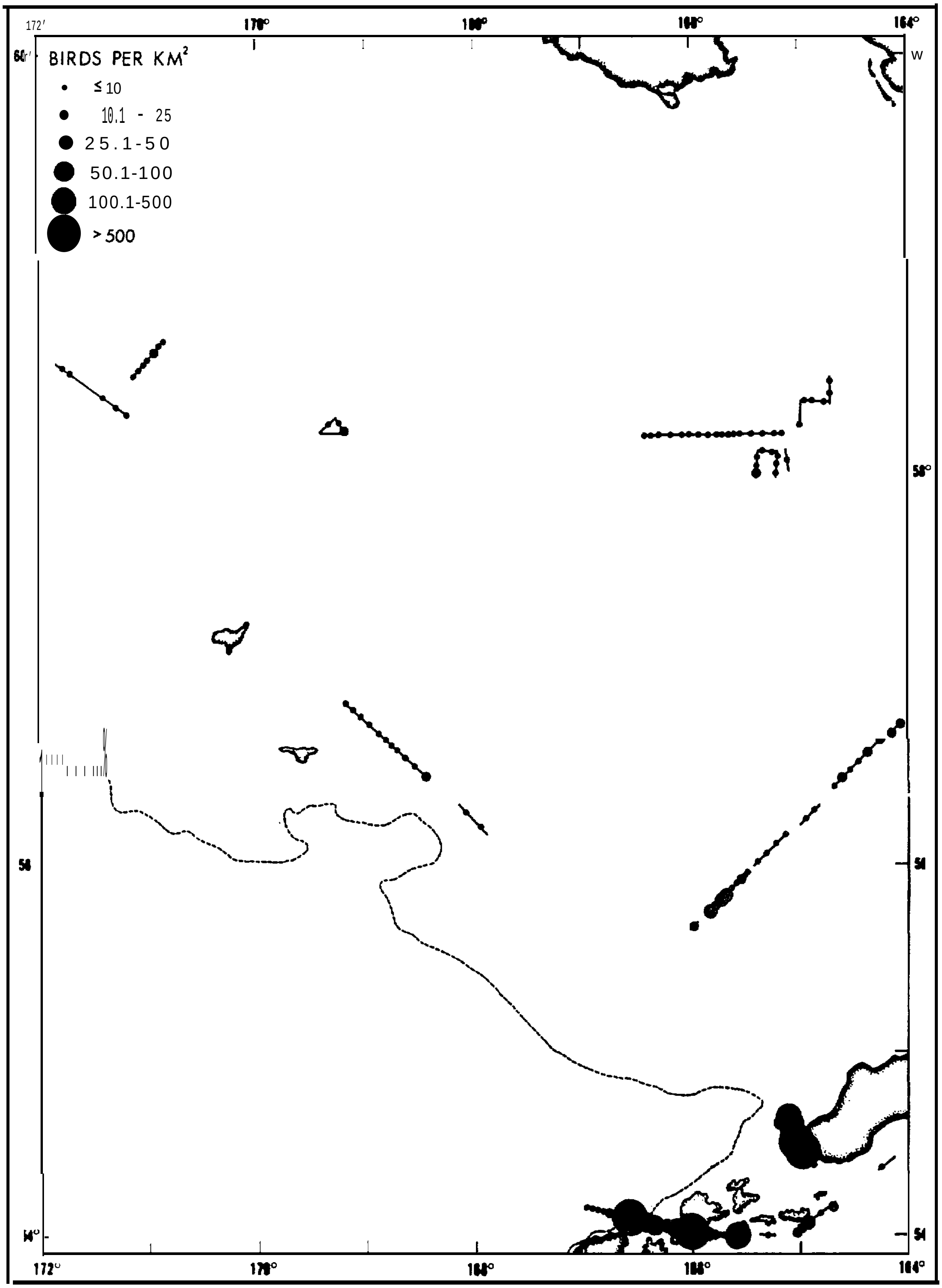


Figure 7. Distribution and abundance of seabirds in southern Bering Sea between 17 March and 4 April 1977.

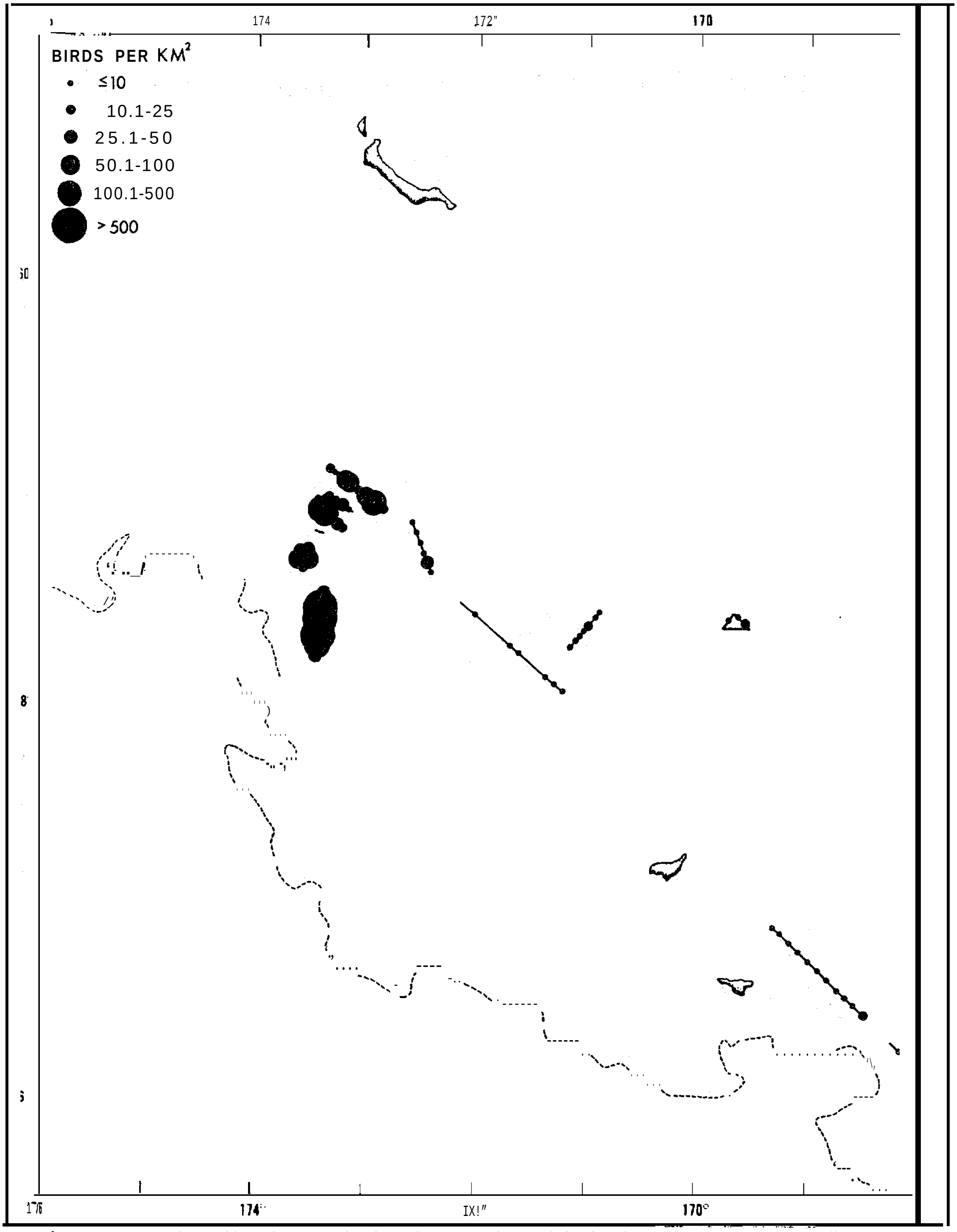


Figure 8. Distribution and abundance of seabirds in central Bering Sea between 18 March and 25 March 1977.

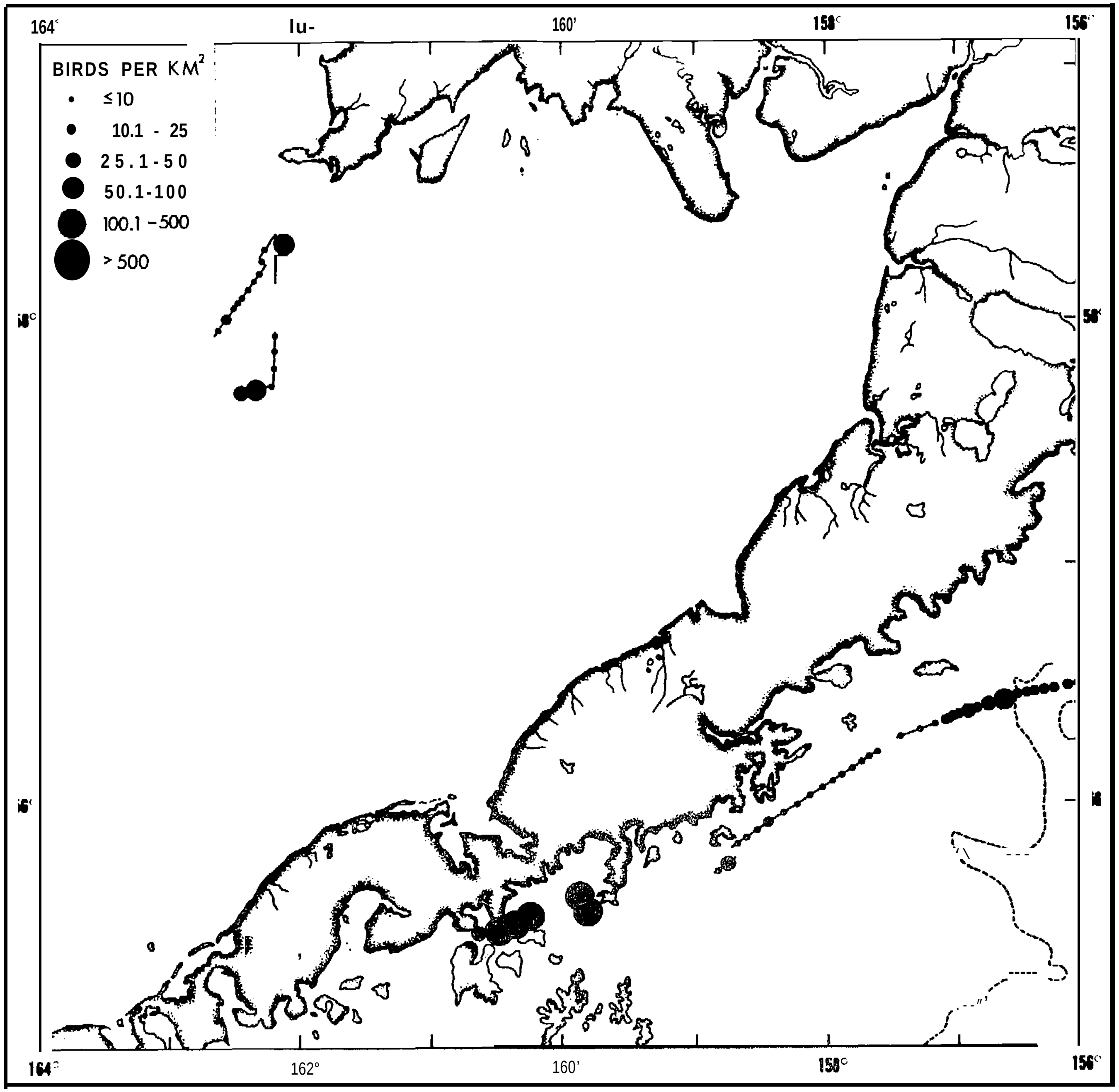


Figure 9. Distribution and abundance of seabirds in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 5 April 1977.

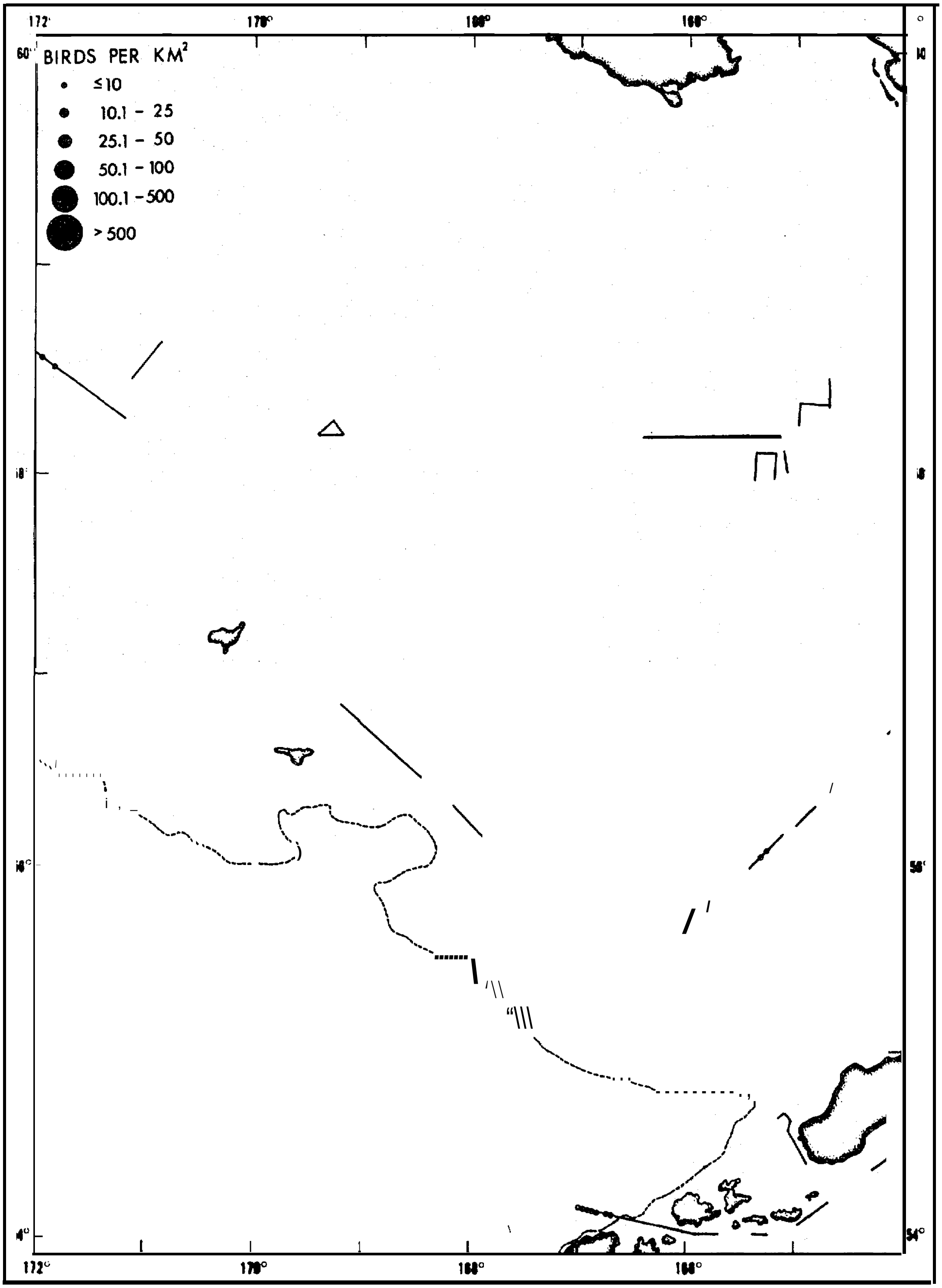


Figure 10. Distribution and abundance of Northern Fulmars in southern Bering Sea between 17 March and 4 April 1977.

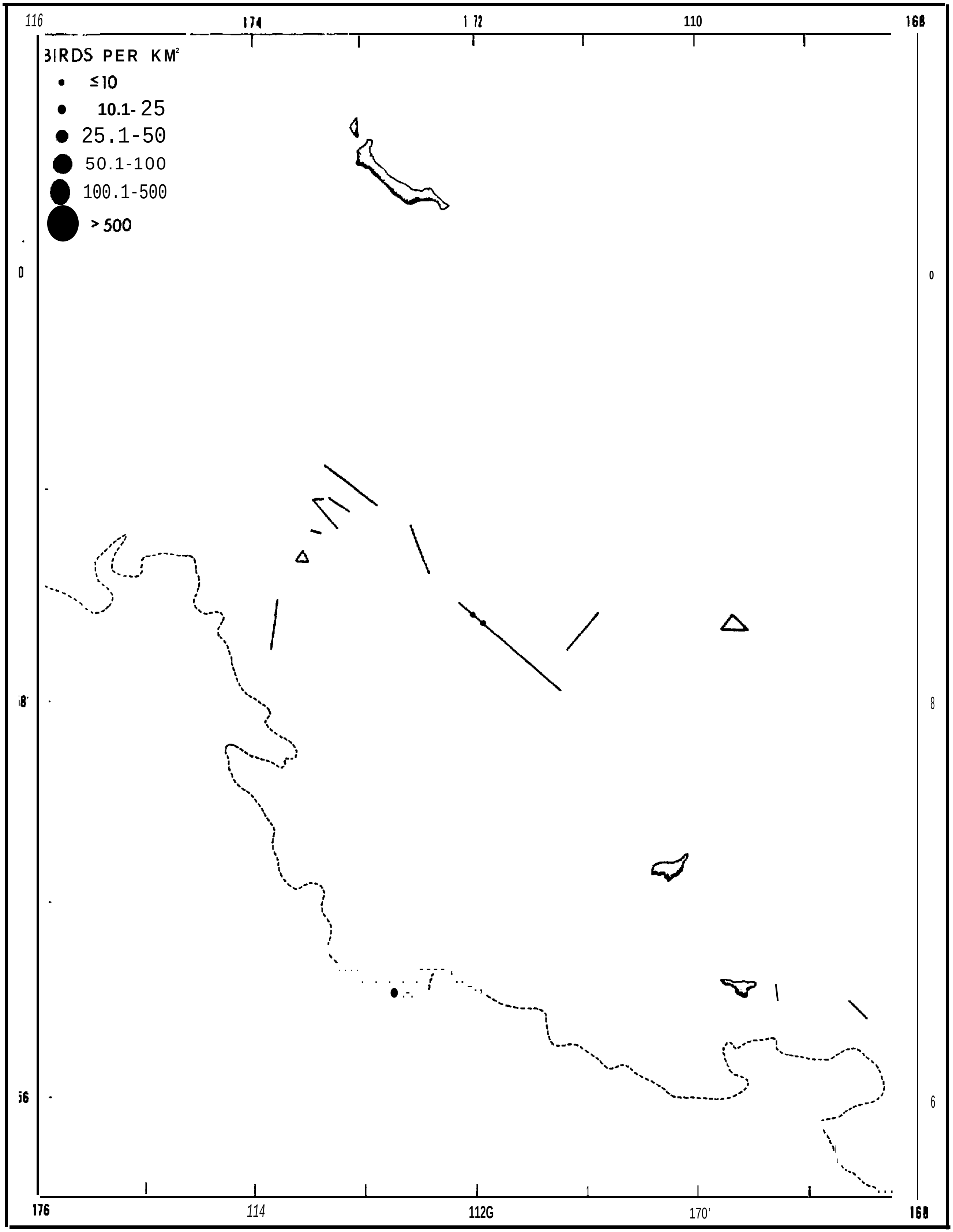


Figure. 11. Distribution and abundance of Northern Fulmars in central Bering Sea between 18 March and 25 March 1977.

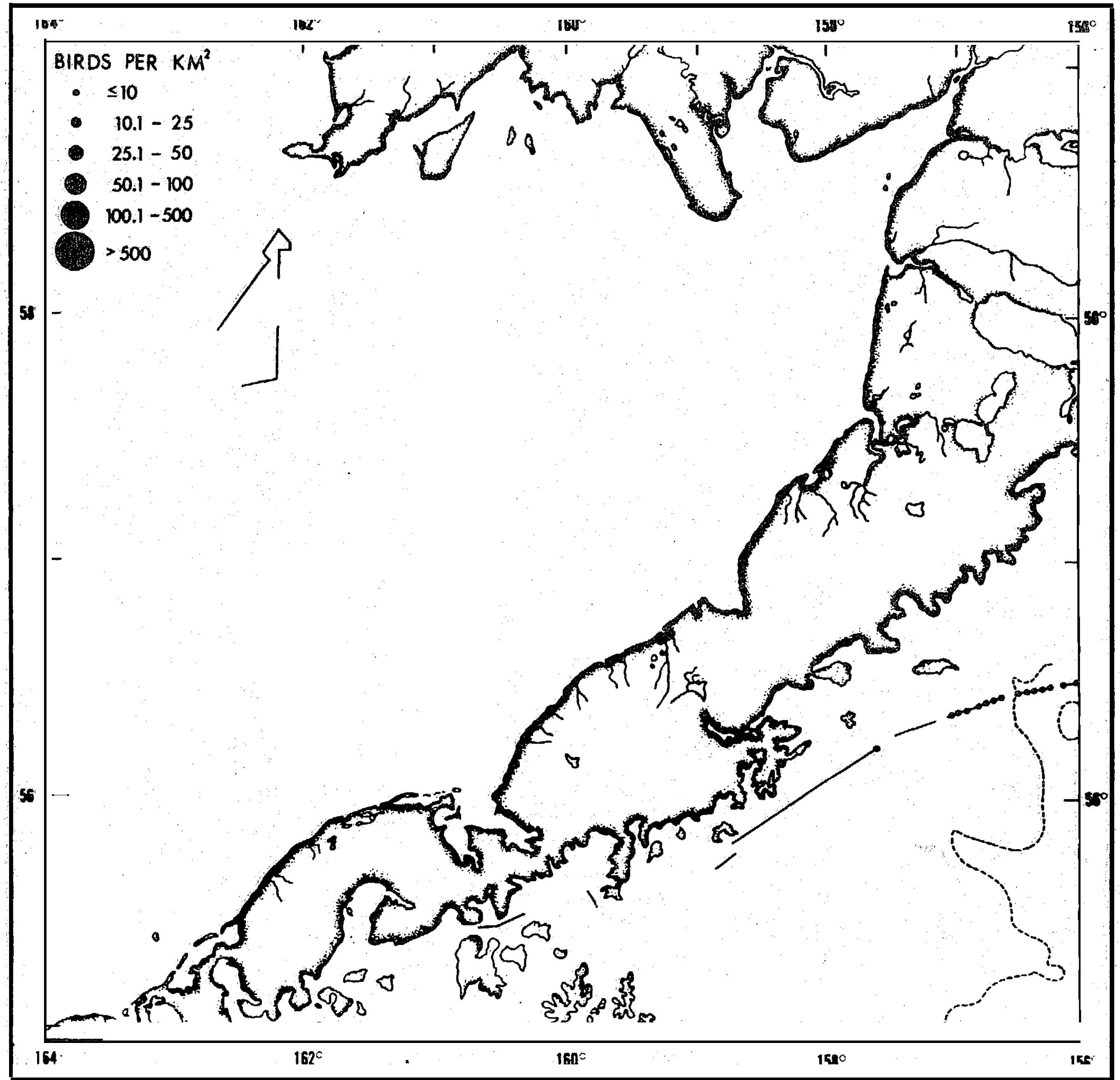


Figure 12. Distribution and abundance of Northern Fulmars in Bristol Bay from 1 to 2 April 1977 and in Gulf of Alaska on 16 March and 25 April 1977.

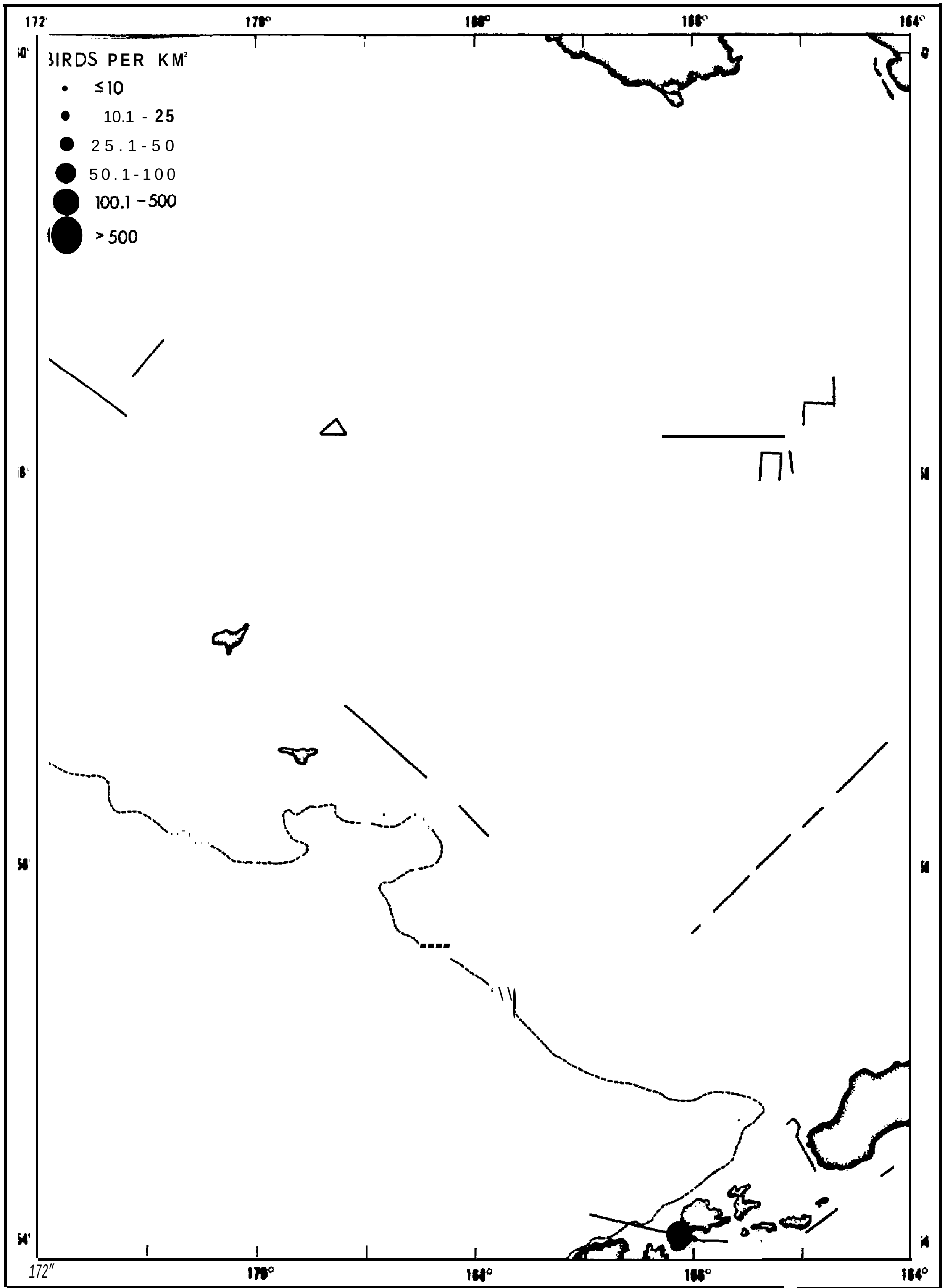


Figure 13. Distribution and abundance of eiders in southern Bering" Sea between 17 March and 4 April 1977.

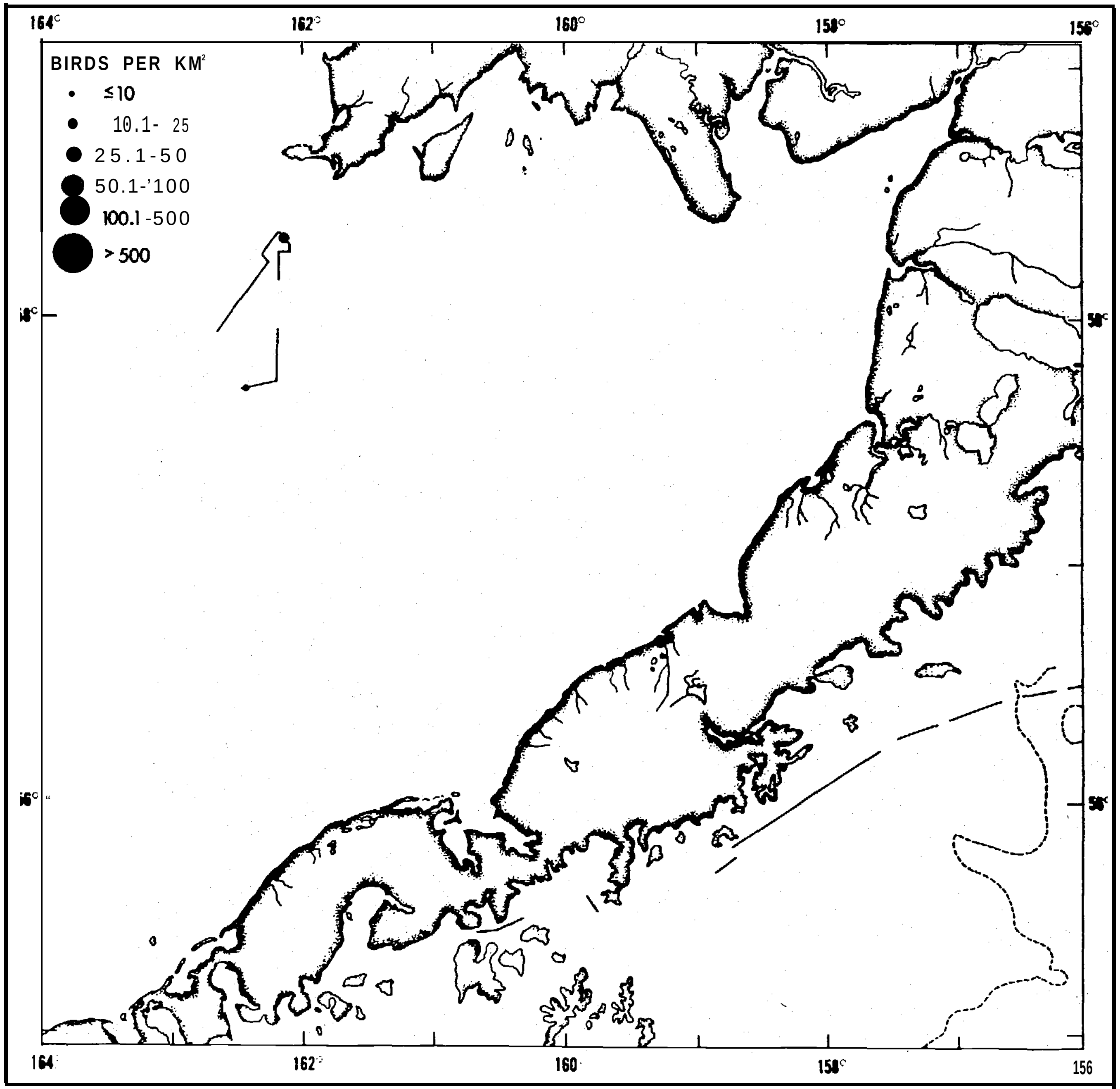


Figure 14. Distribution and abundance of eiders in Bristol Bay *from 1* to 2 April and in Gulf of Alaska on 16 March and 25 April 1977.

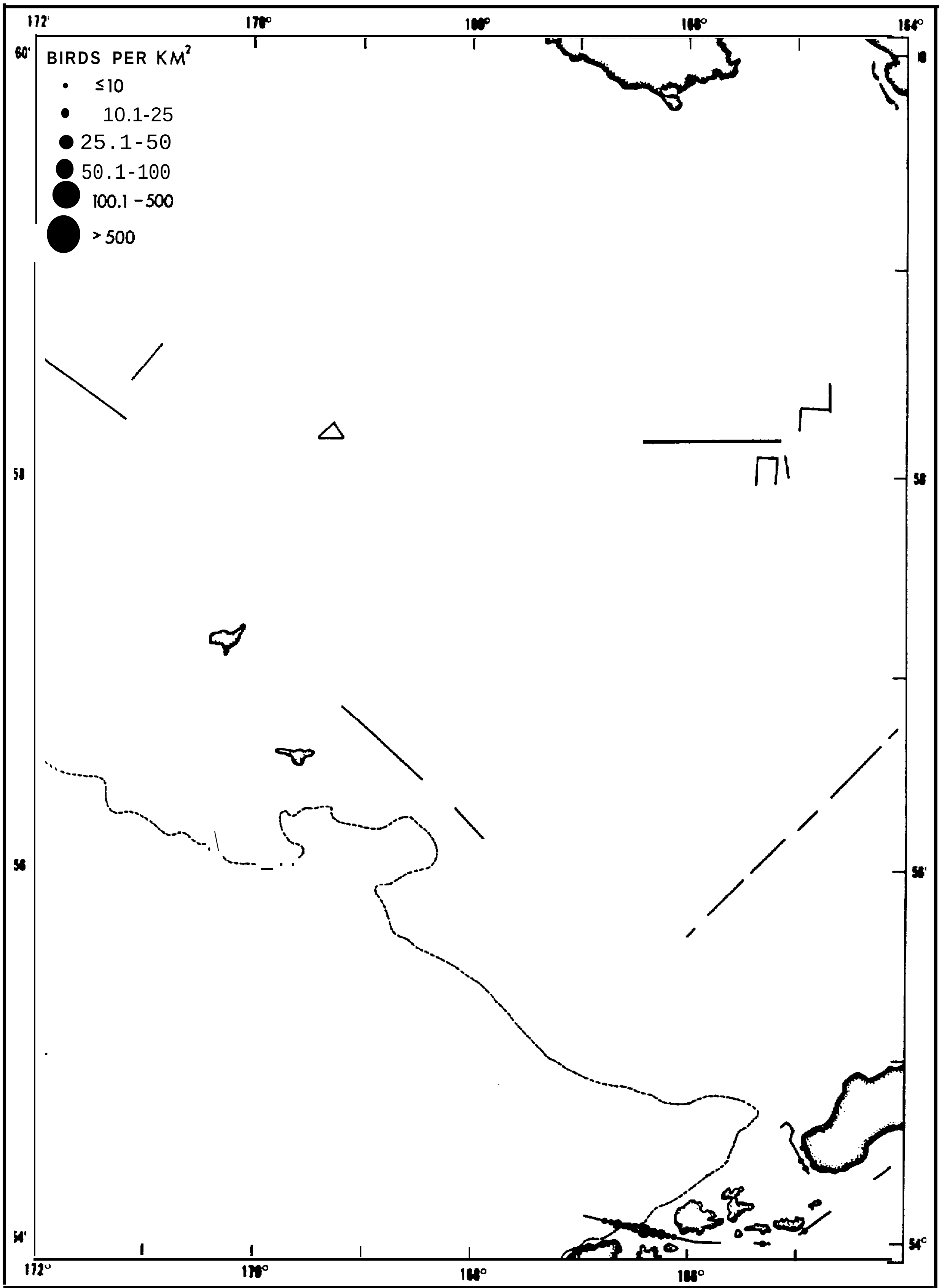


Figure 15. Distribution and abundance of cormorants in southern Bering Sea between 17 March and 4 April 1977.

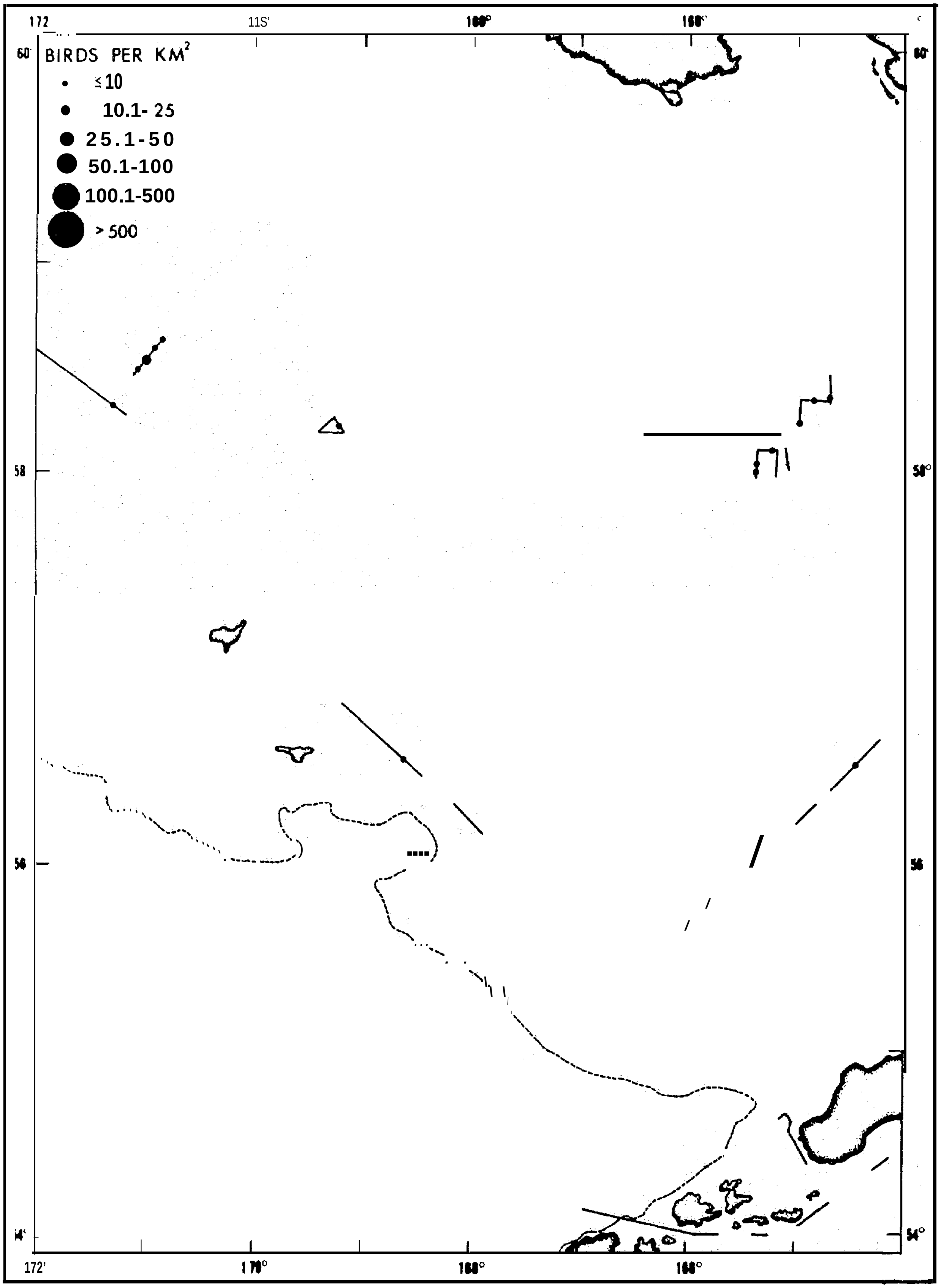


Figure 16. Distribution and abundance of Glaucous Gulls in southern Bering Sea between 17 March and 4 April 1977.

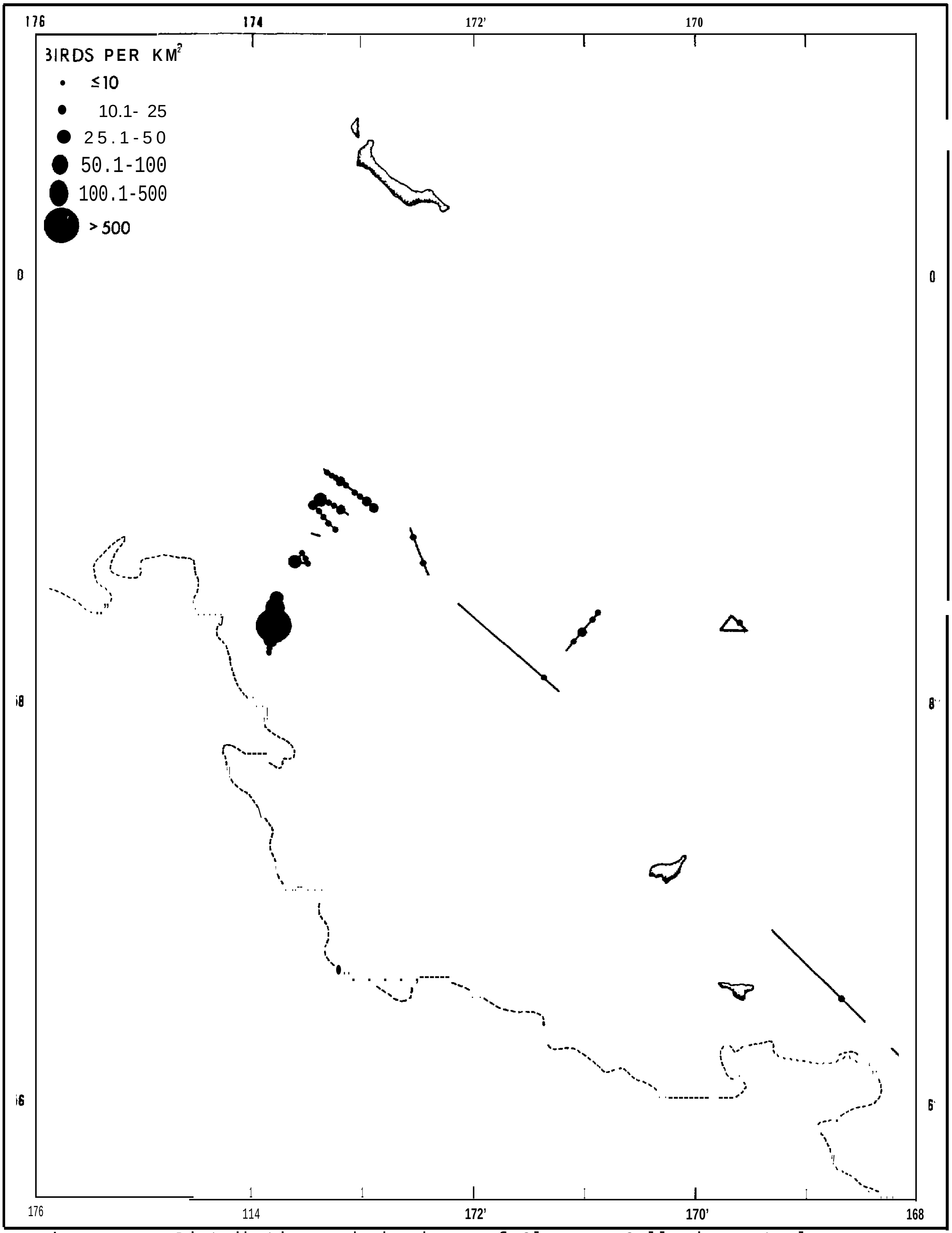


Figure 17. Distribution and abundance of Glaucous Gulls in central Bering Sea between 18 March and 25 March 1977.

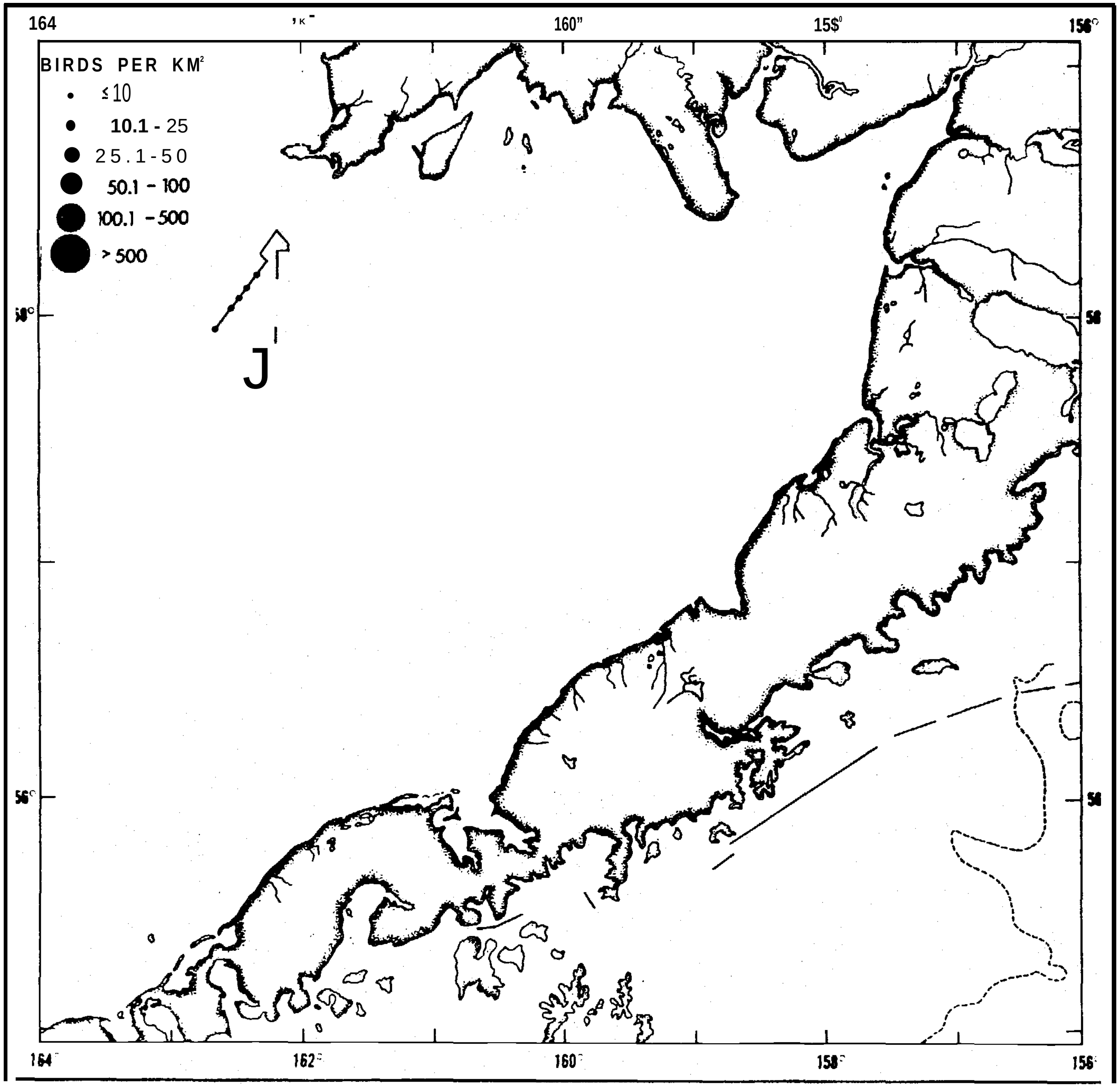


Figure 18. Distribution and abundance of Glaucous Gulls in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 25 April 1977.

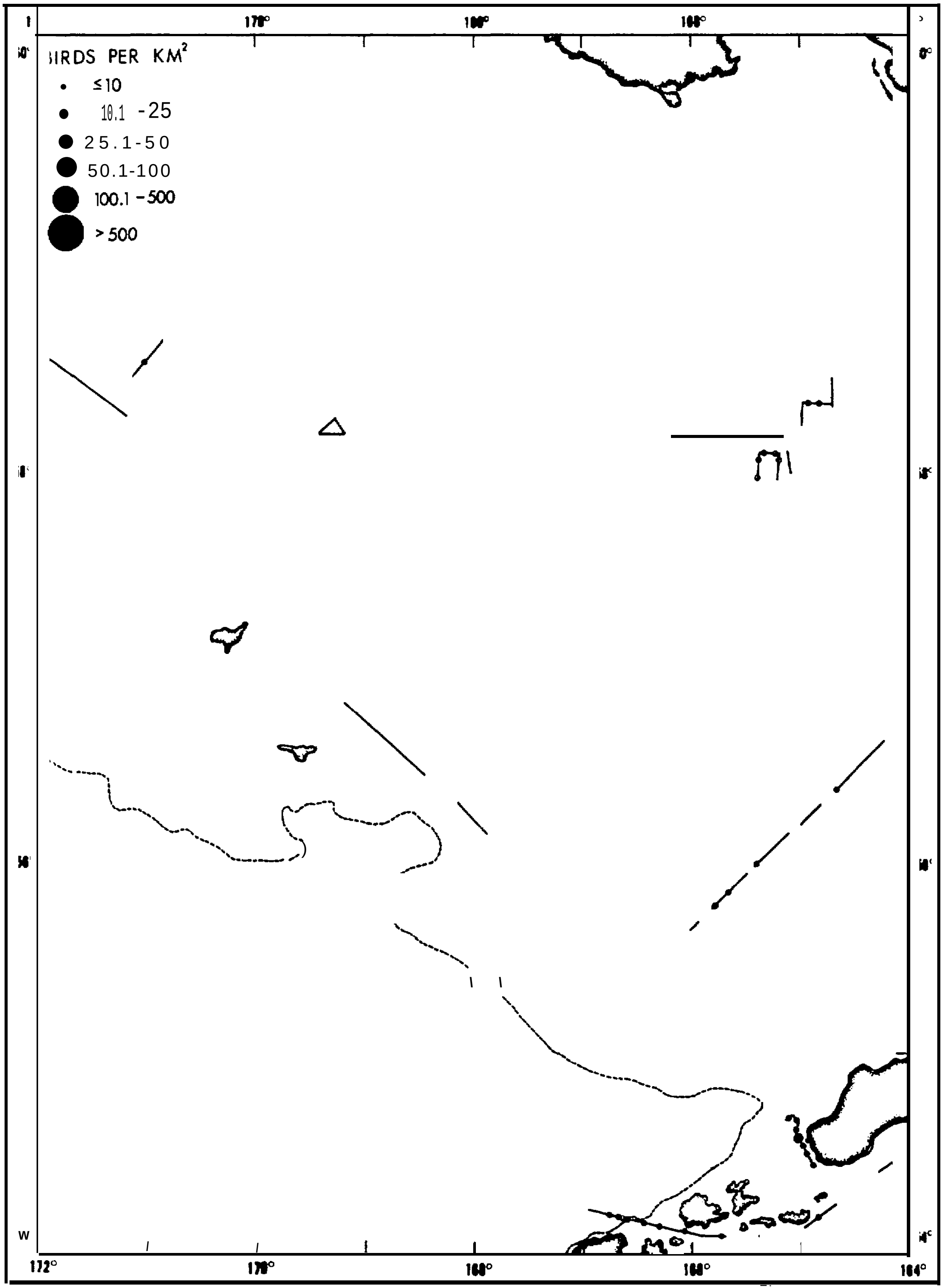


Figure 19. Distribution and abundance of Glaucous-winged Gulls in southern Bering Sea between 17 March and 4 April 1977.

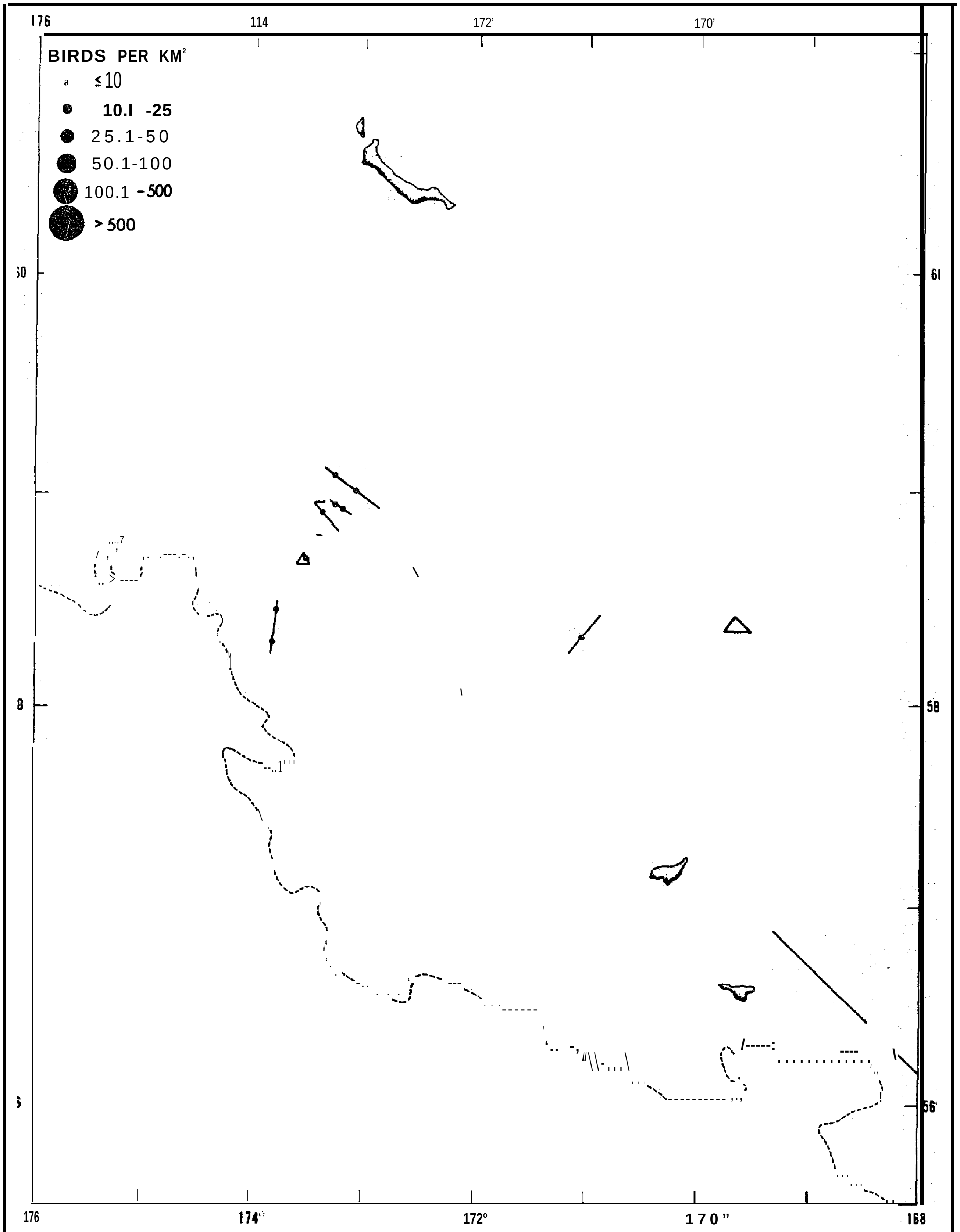


Figure 20. Distribution and abundance of Glaucous-winged Gulls in central Bering Sea between 18 March and 25 March 1977.

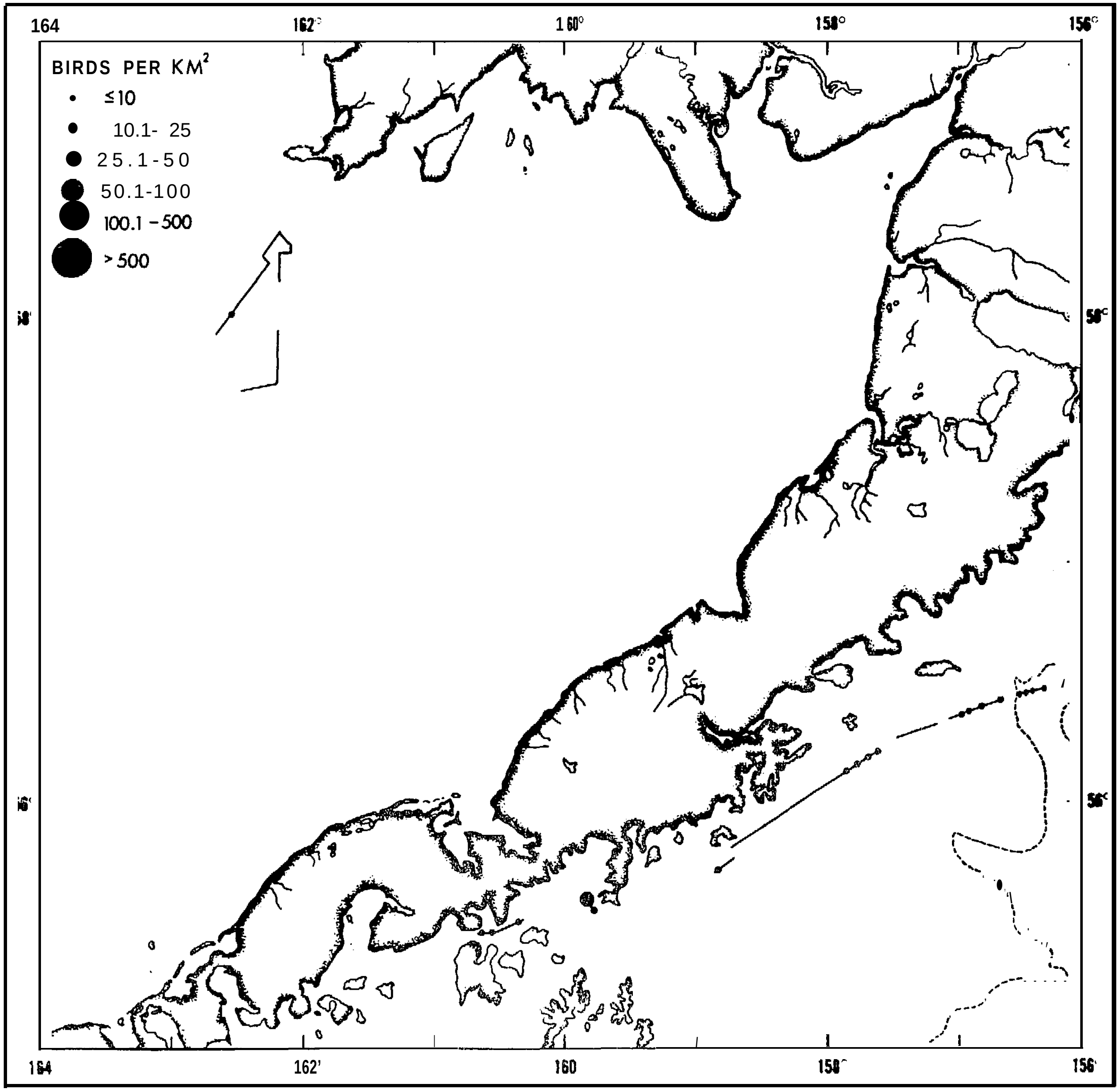


Figure 21. Distribution and abundance of Glaucous-winged Gulls in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 25 April 1977.

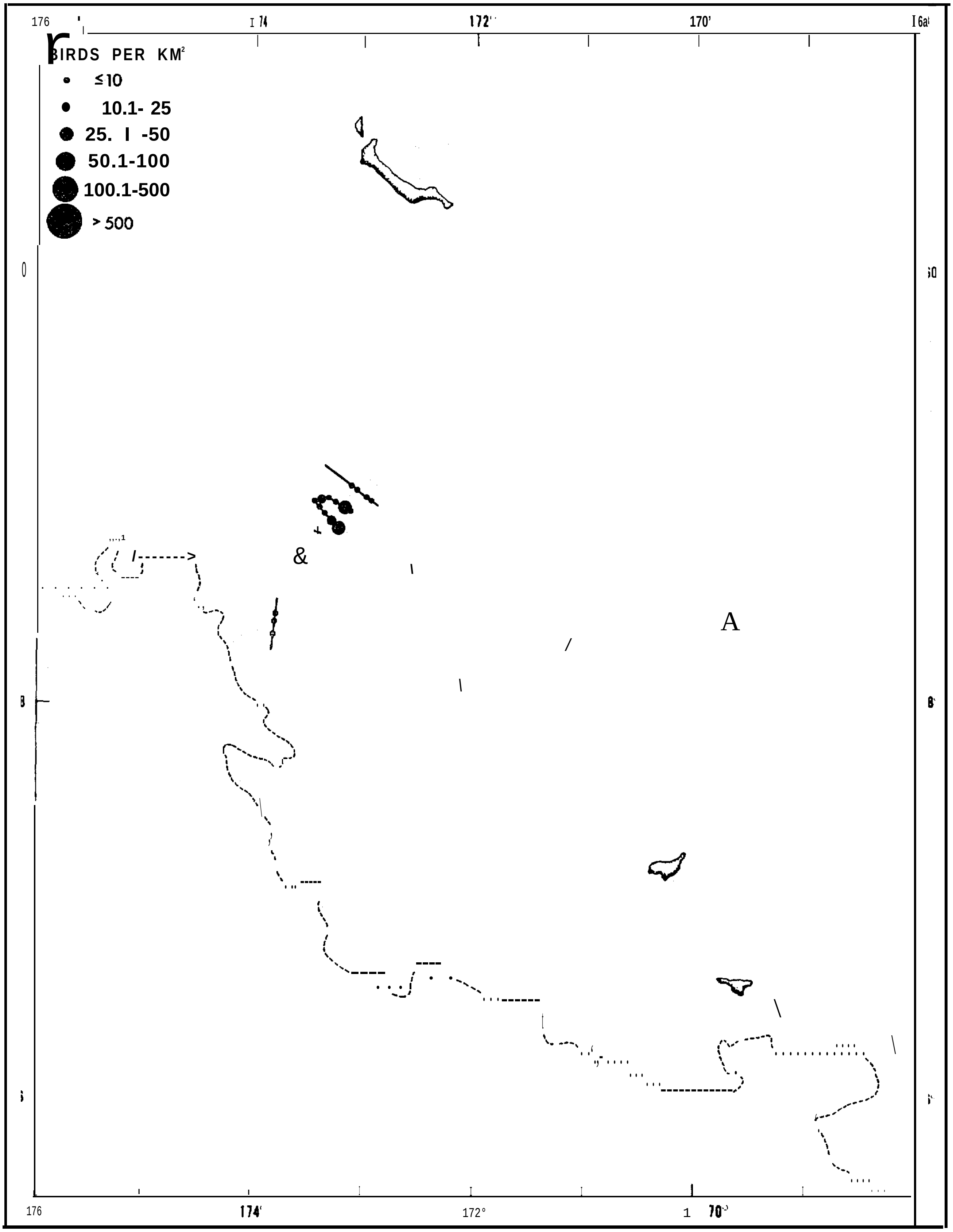


Figure 22. Distribution and abundance of Ivory Gulls in central Bering Sea between 18 March and 25 March 1977.

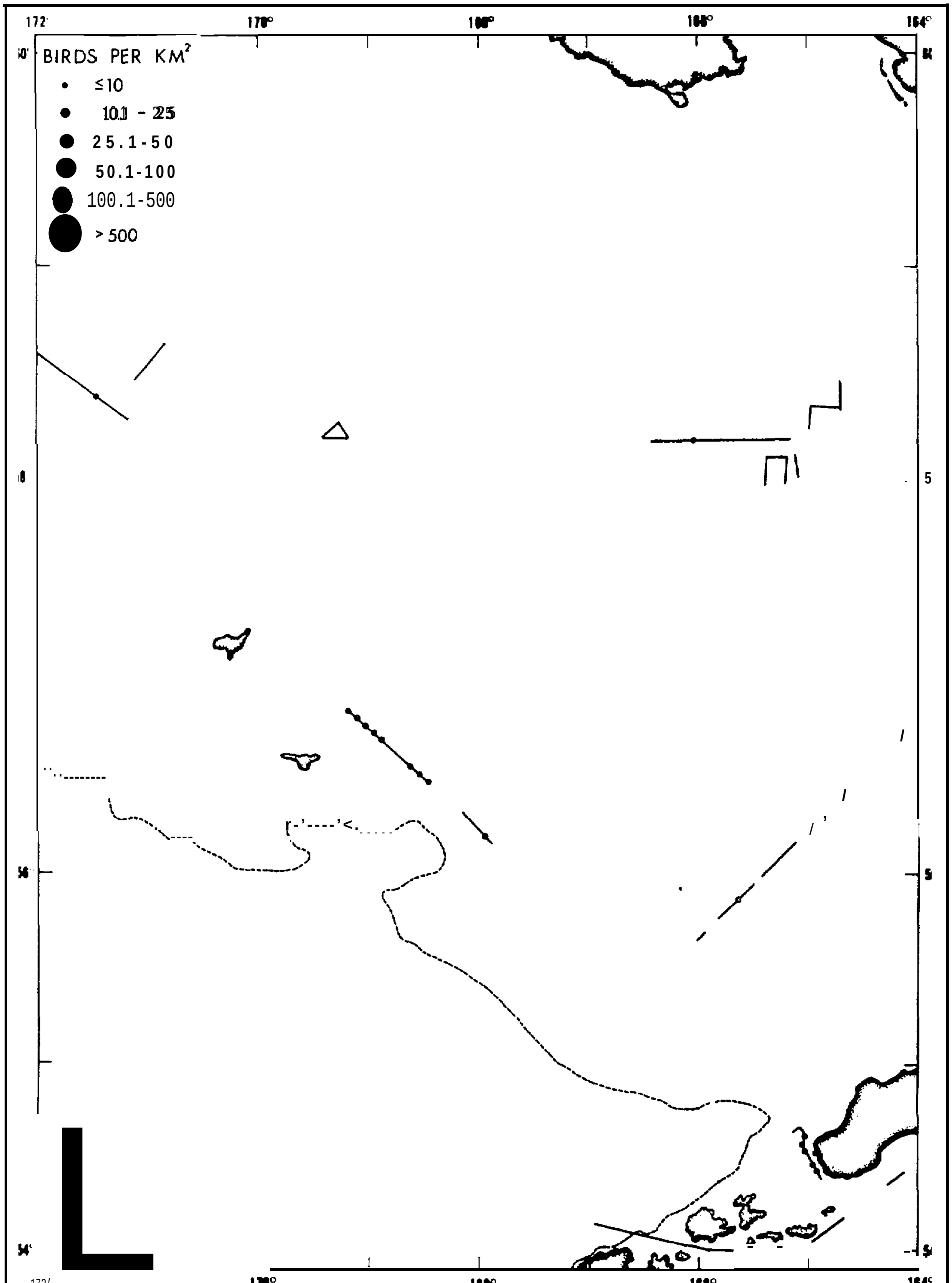


Figure 23. Distribution and abundance of Black-legged Kittiwakes in southern Bering Sea between 17 March and 4 April 1977.

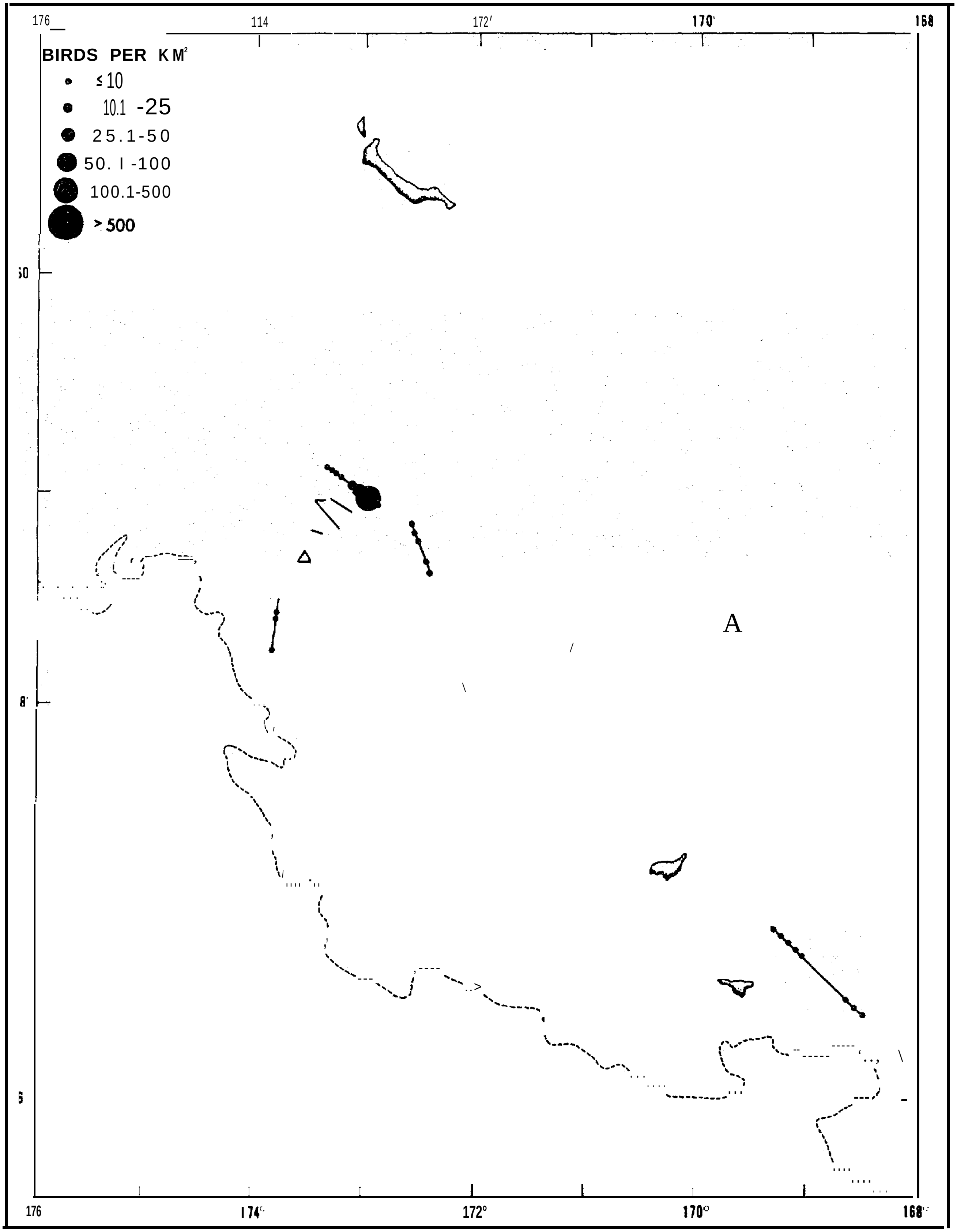


Figure 24. Distribution and abundance of Black-legged Kittiwakes in central Bering Sea between 18 March and 25 March 1977.

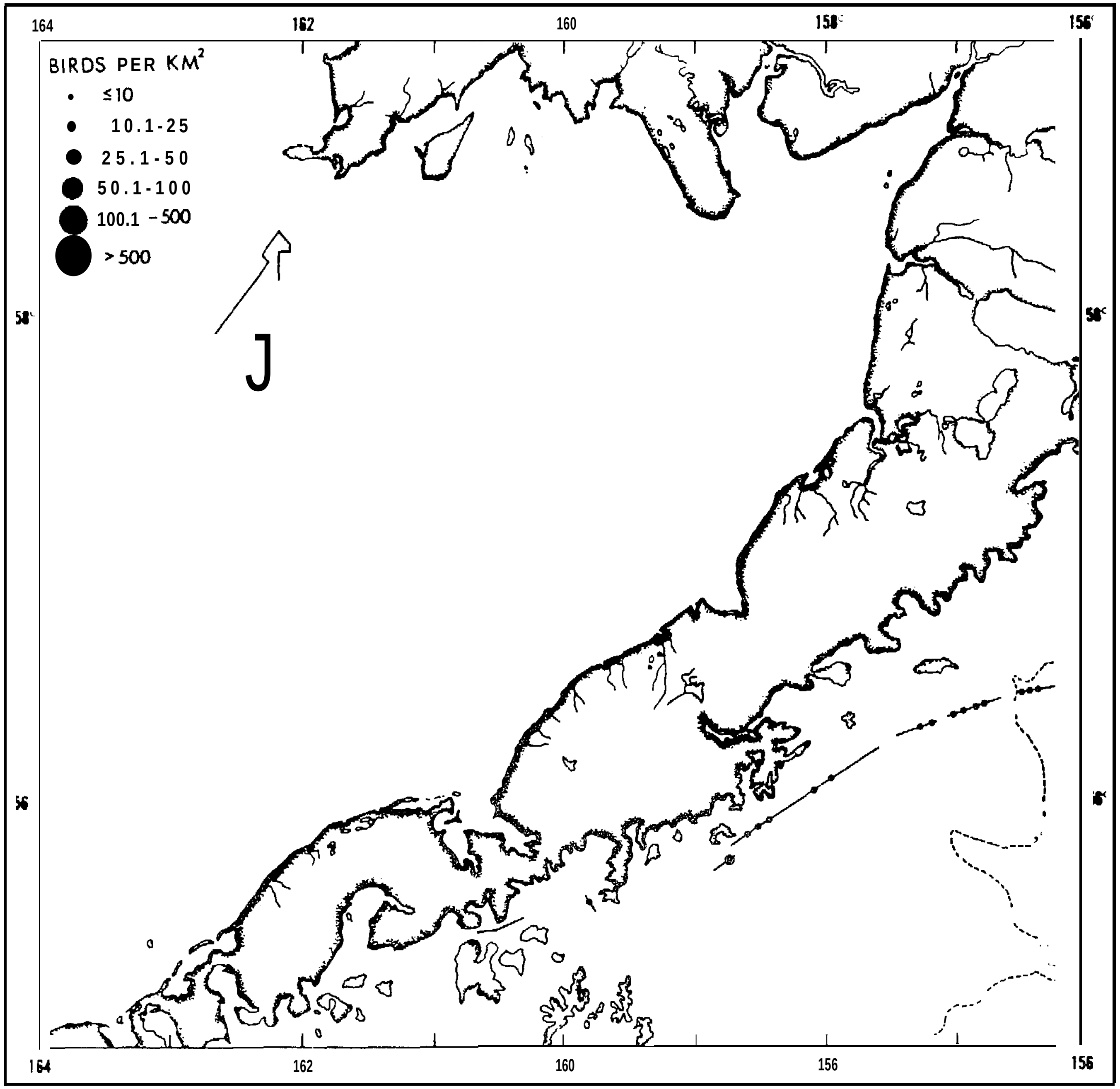


Figure 25. Distribution and abundance of Black-legged Kittiwakes in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 25 April 1977.

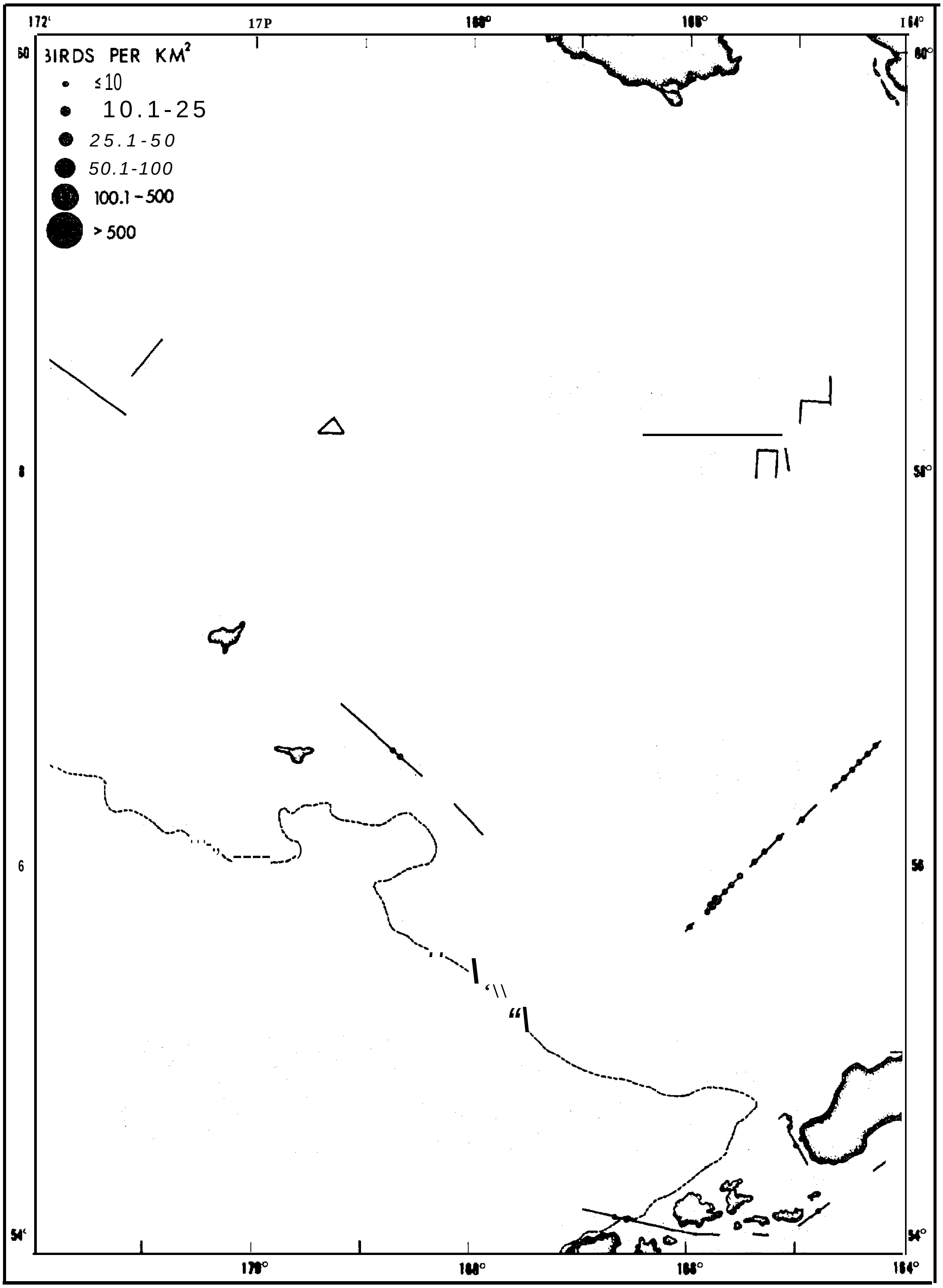


Figure 26. Distribution and abundance of Common Murres in southern Bering Sea between 17 March and 4 April 1977,

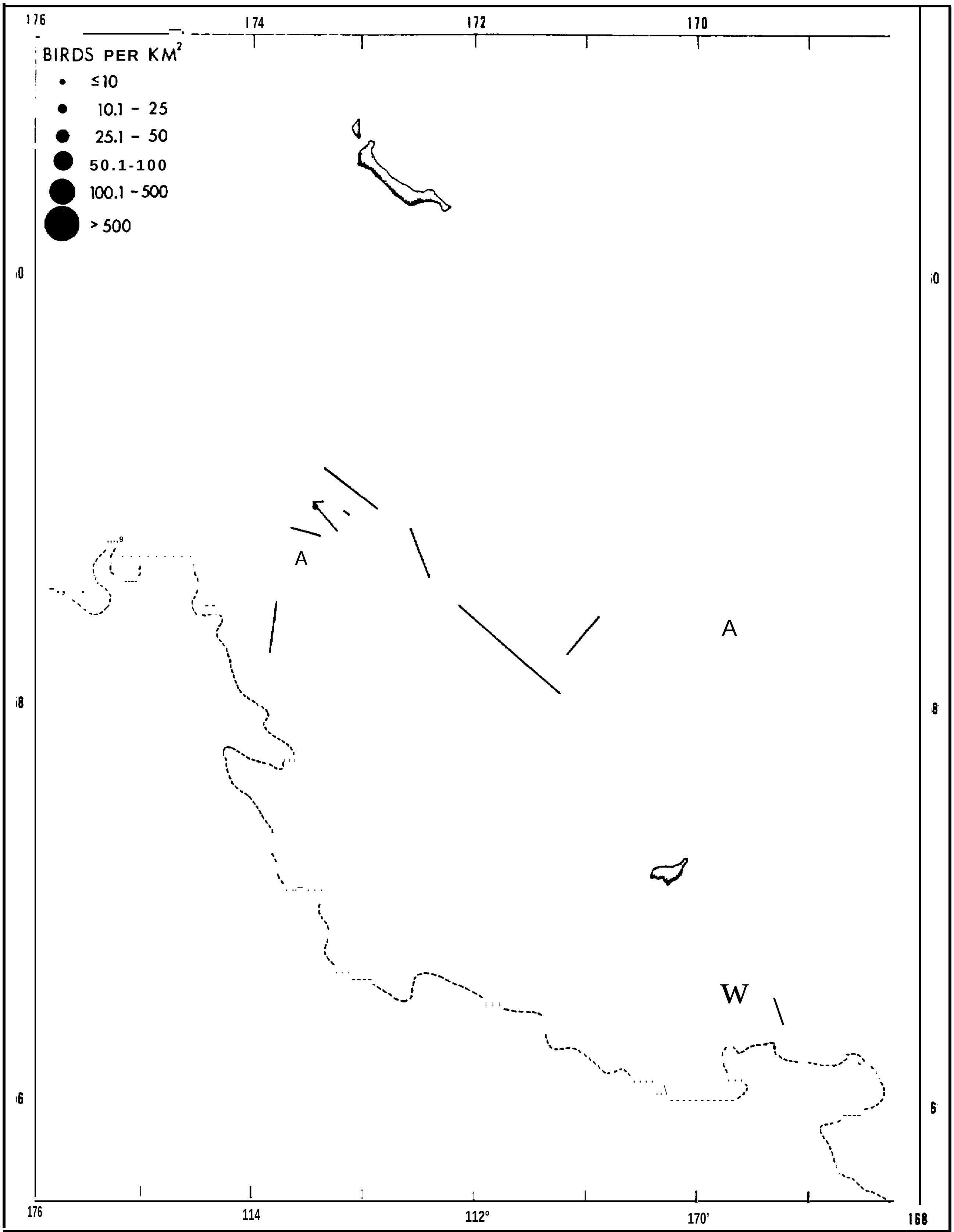


Figure 27. Distribution and abundance of Common Murres in central 'Bering Sea between 18 March and 25 March 1977.

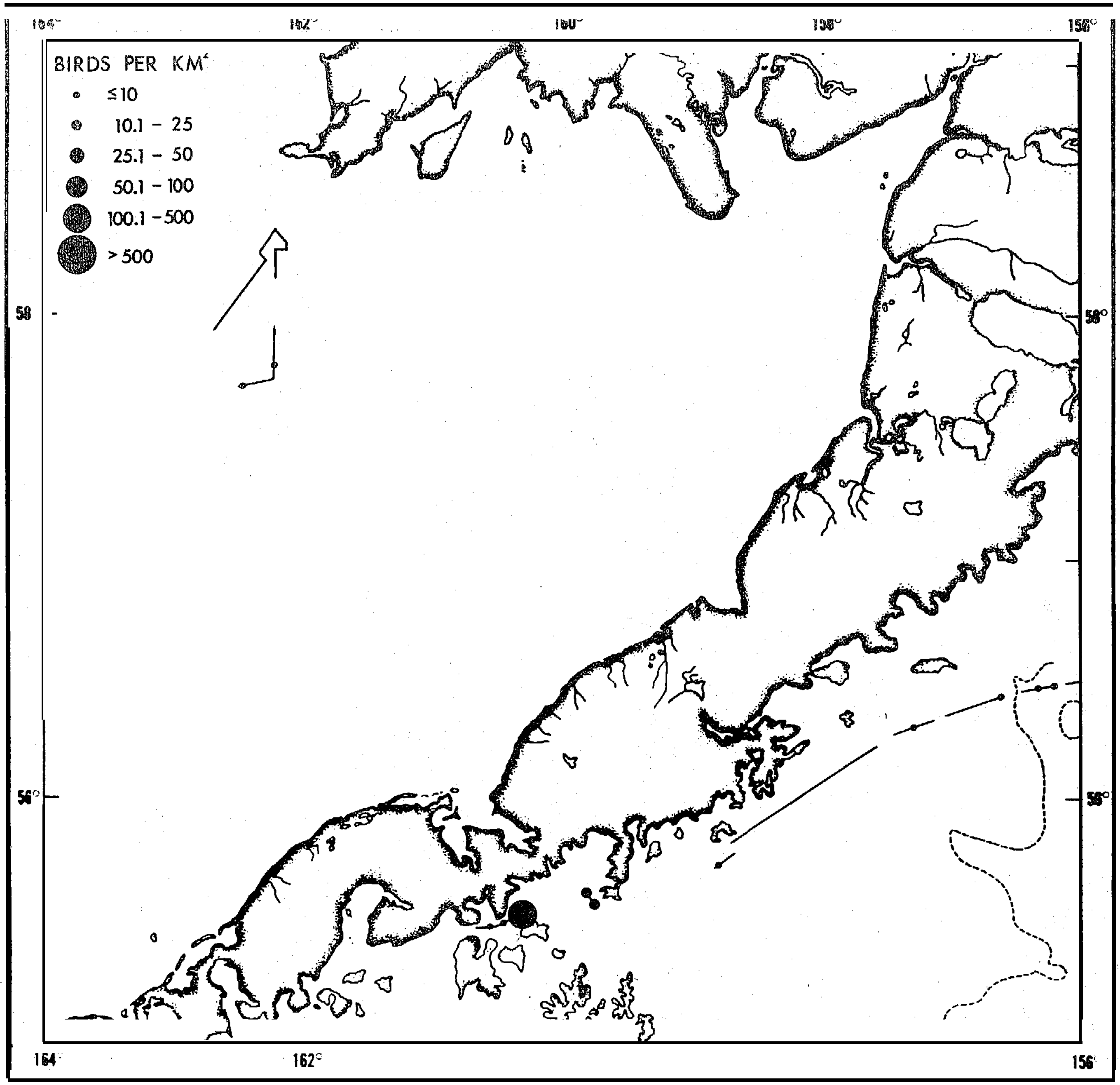


Figure 28. Distribution and abundance of Common Murres in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 17 March and 25 March 1977.

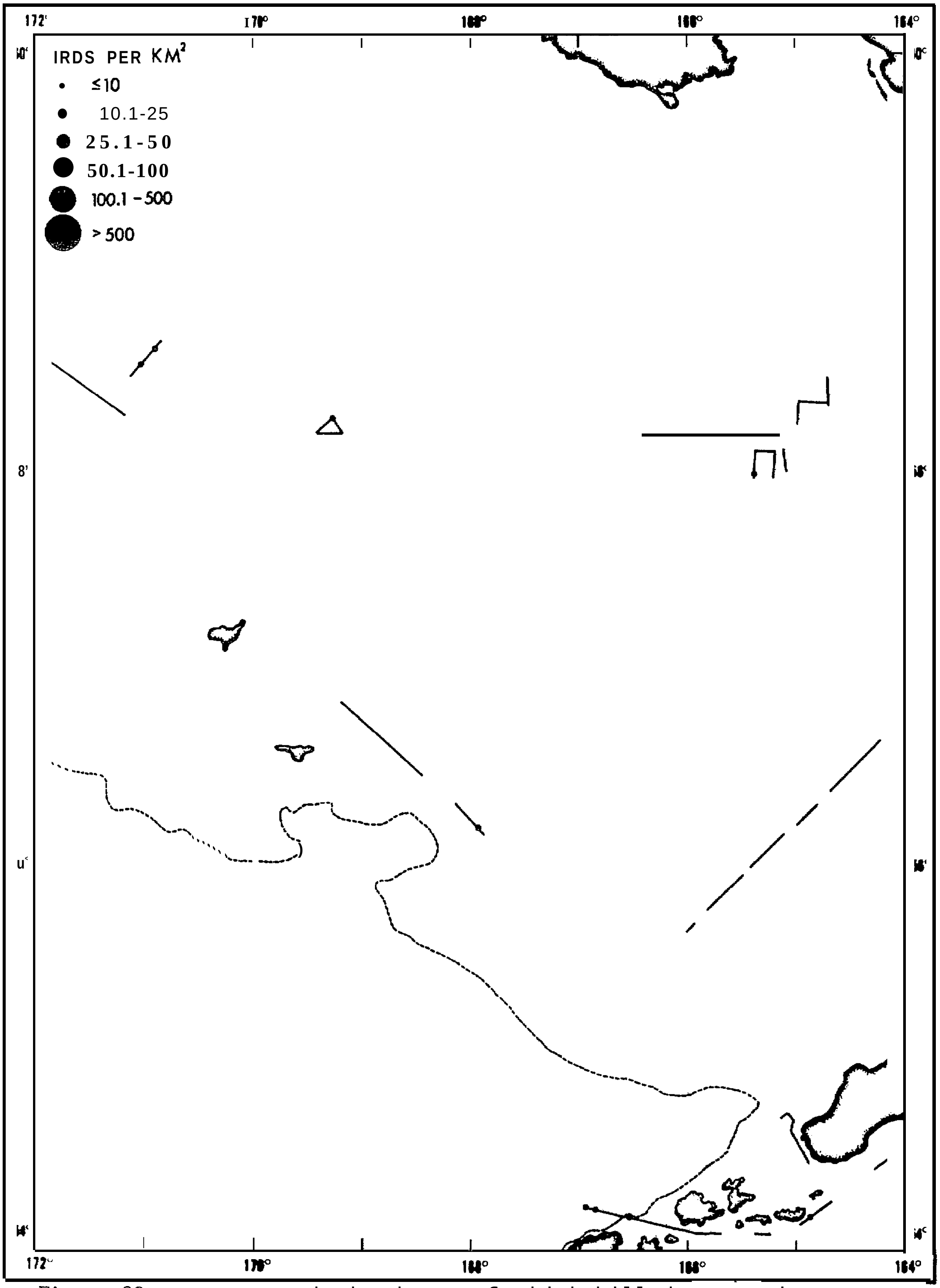


Figure 29. Distribution and abundance of Thick-billed Murres in southern Bering Sea between 17 March and 4 April 1977.

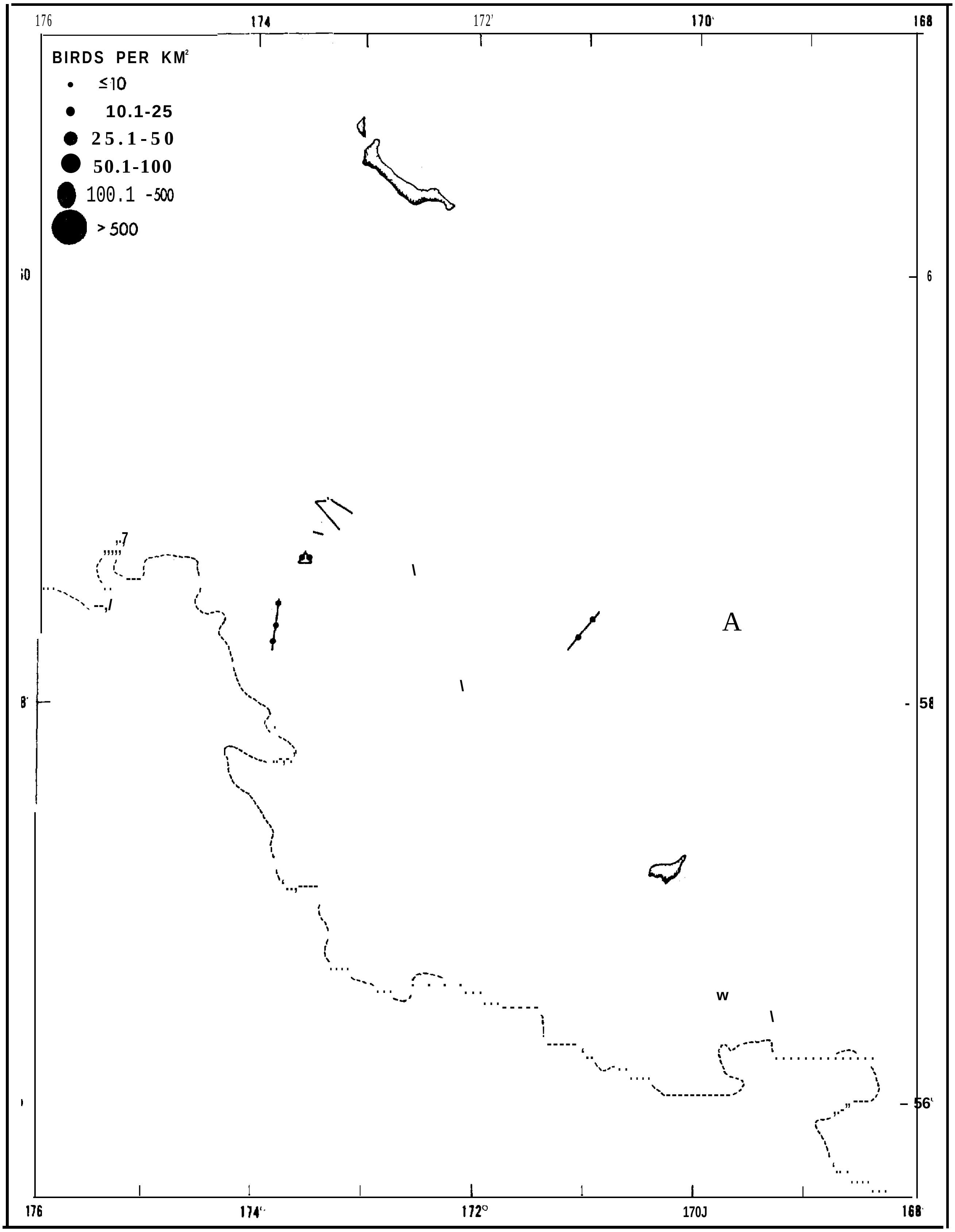


Figure. 30. Distribution and abundance of Thick-billed Murres in central. Bering Sea between 18 March and 25 March 1977.

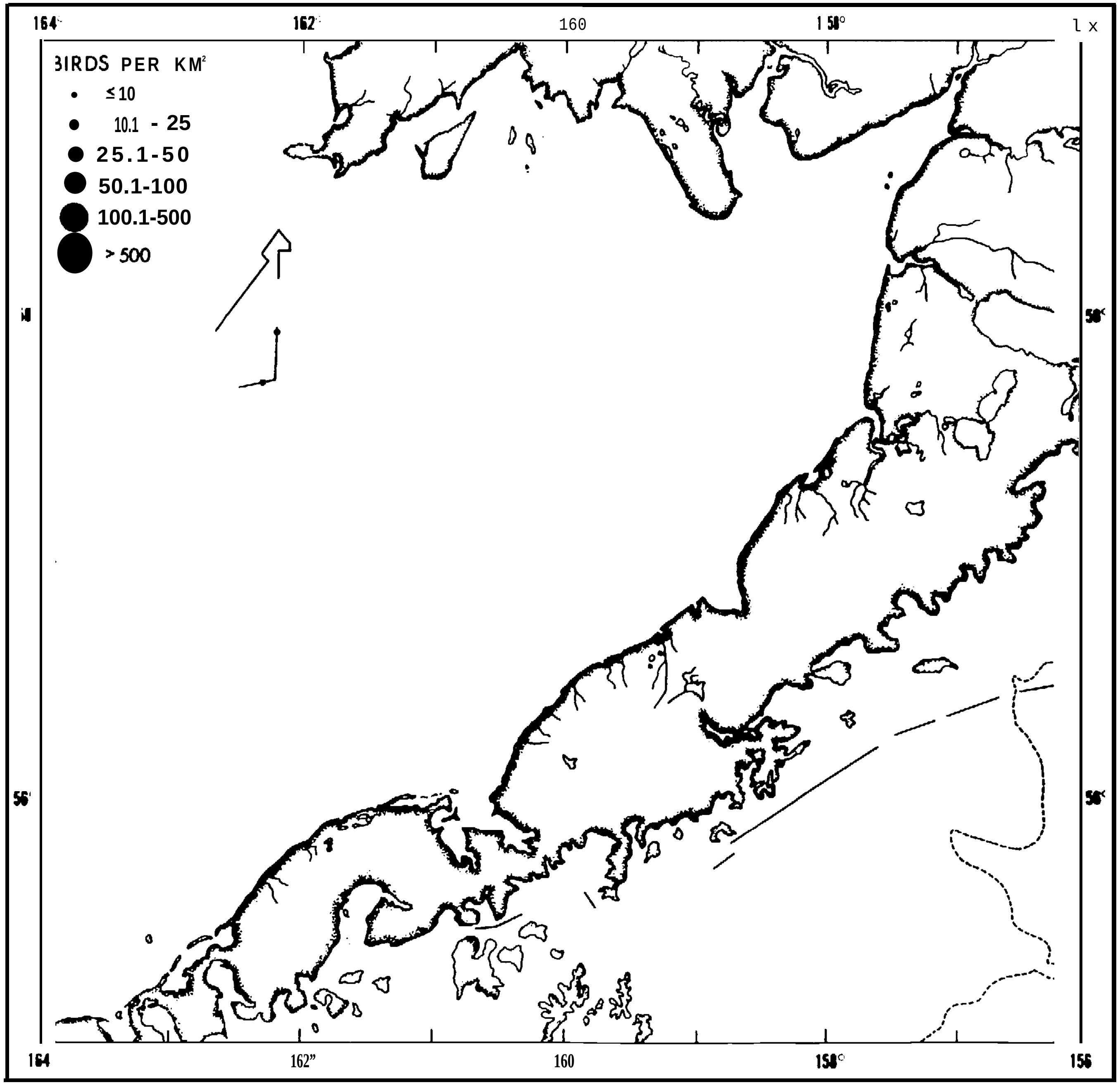


Figure 31. Distribution and abundance of Thick-billed Murres in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 25 March 1977.

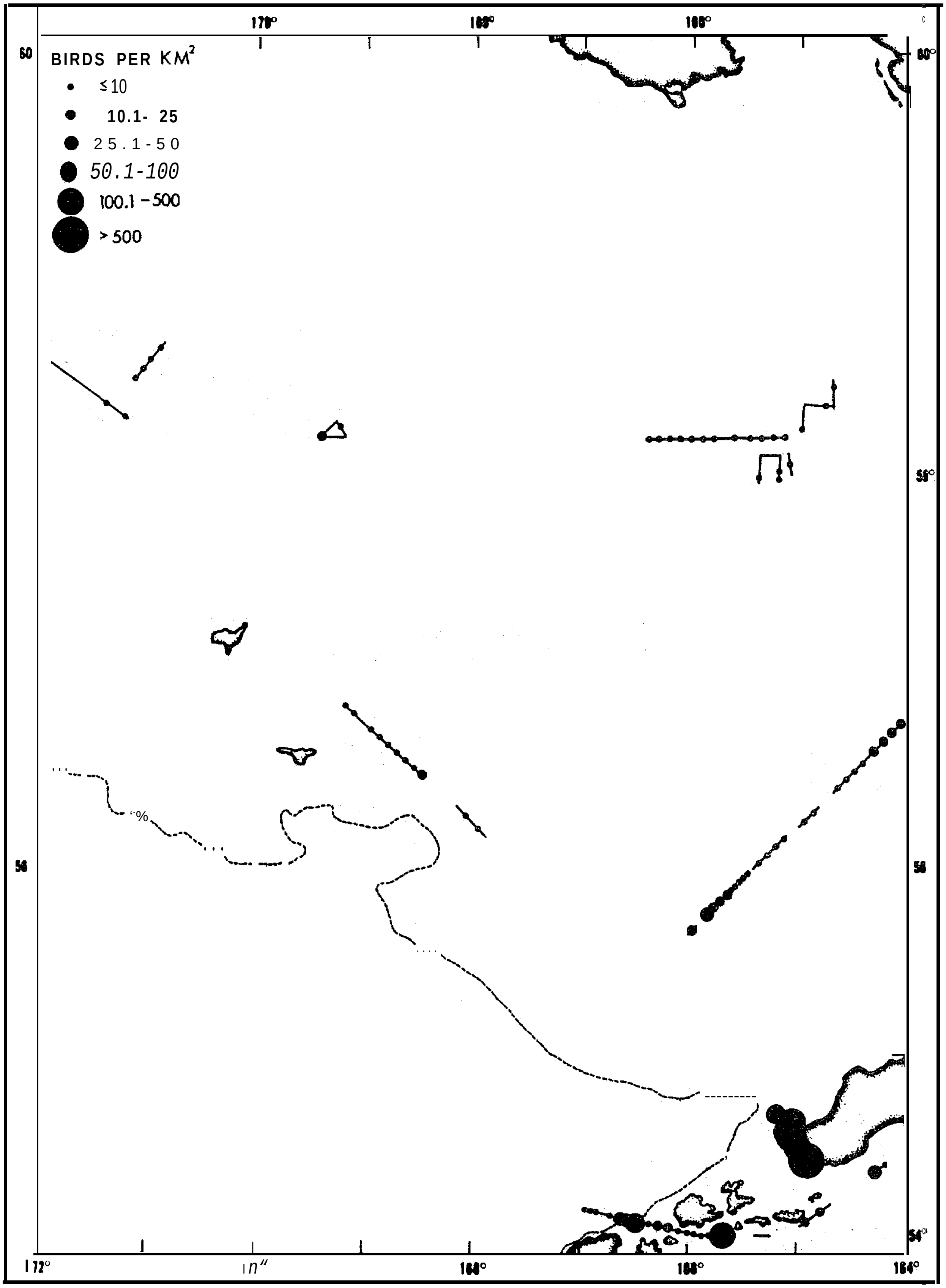


Figure 32. Distribution and abundance 'of all murres in southern Bering Sea between 17 March and 4 April 1977.

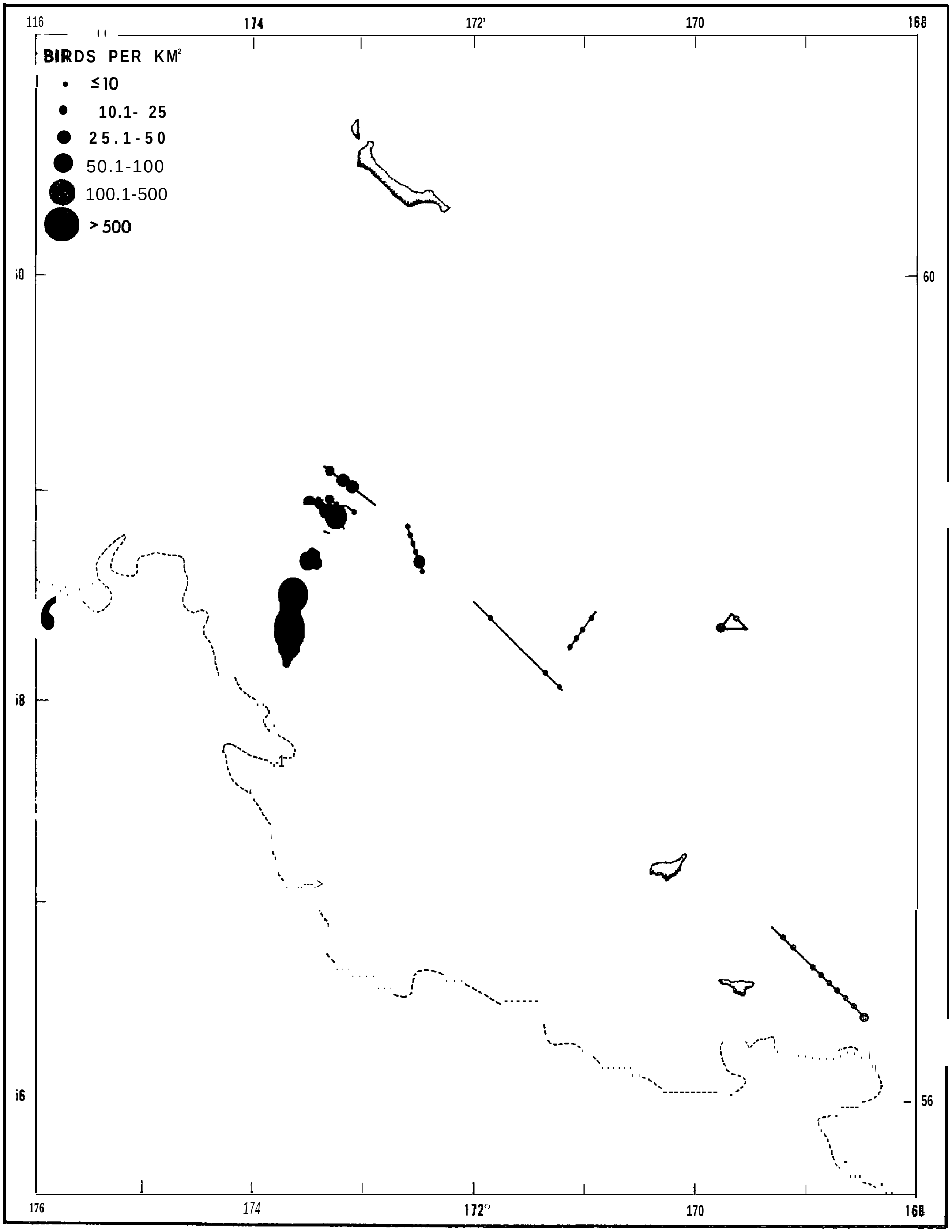


Figure 33. Distribution and abundance of all murres in central Bering Sea between 18 March and 25 March 1977.

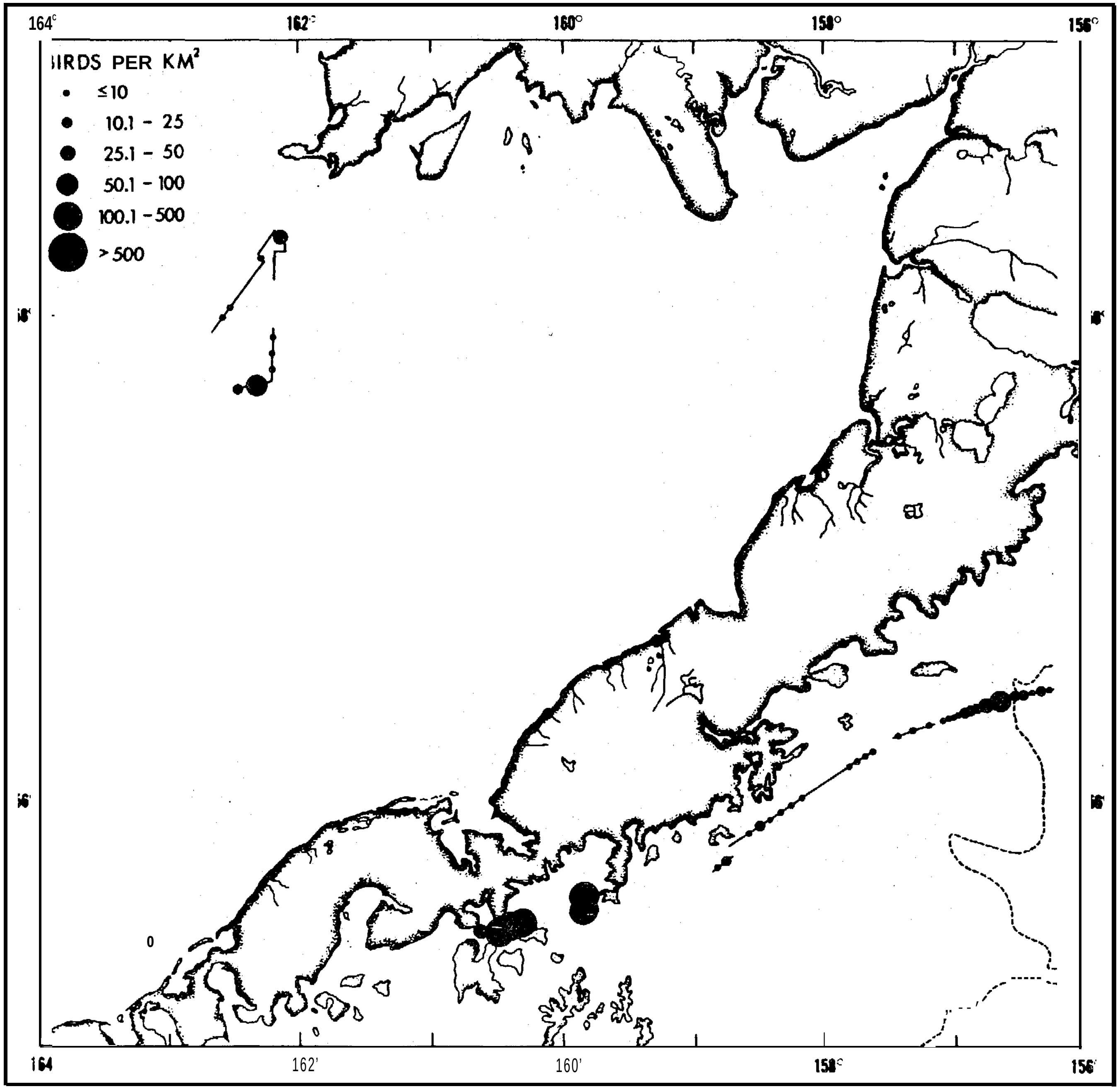


Figure 34. Distribution and abundance of all murres in Bristol Bay from 1 to 2 April and in Gulf of Alaska on 16 March and 25 April 19'77.

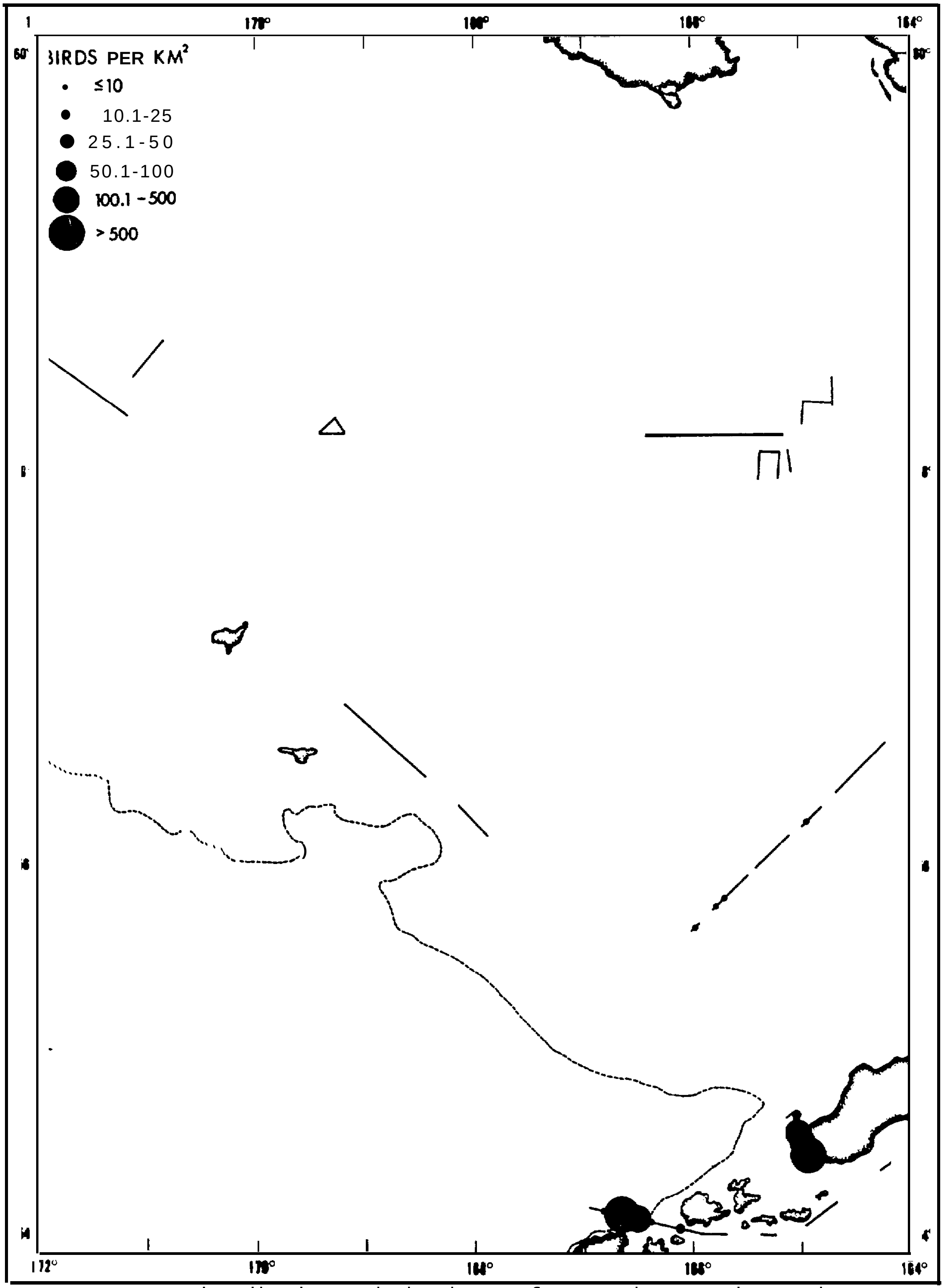


Figure 35. Distribution and abundance of Crested Auklets in southern Bering Sea between 17 March and 4 April 1977.

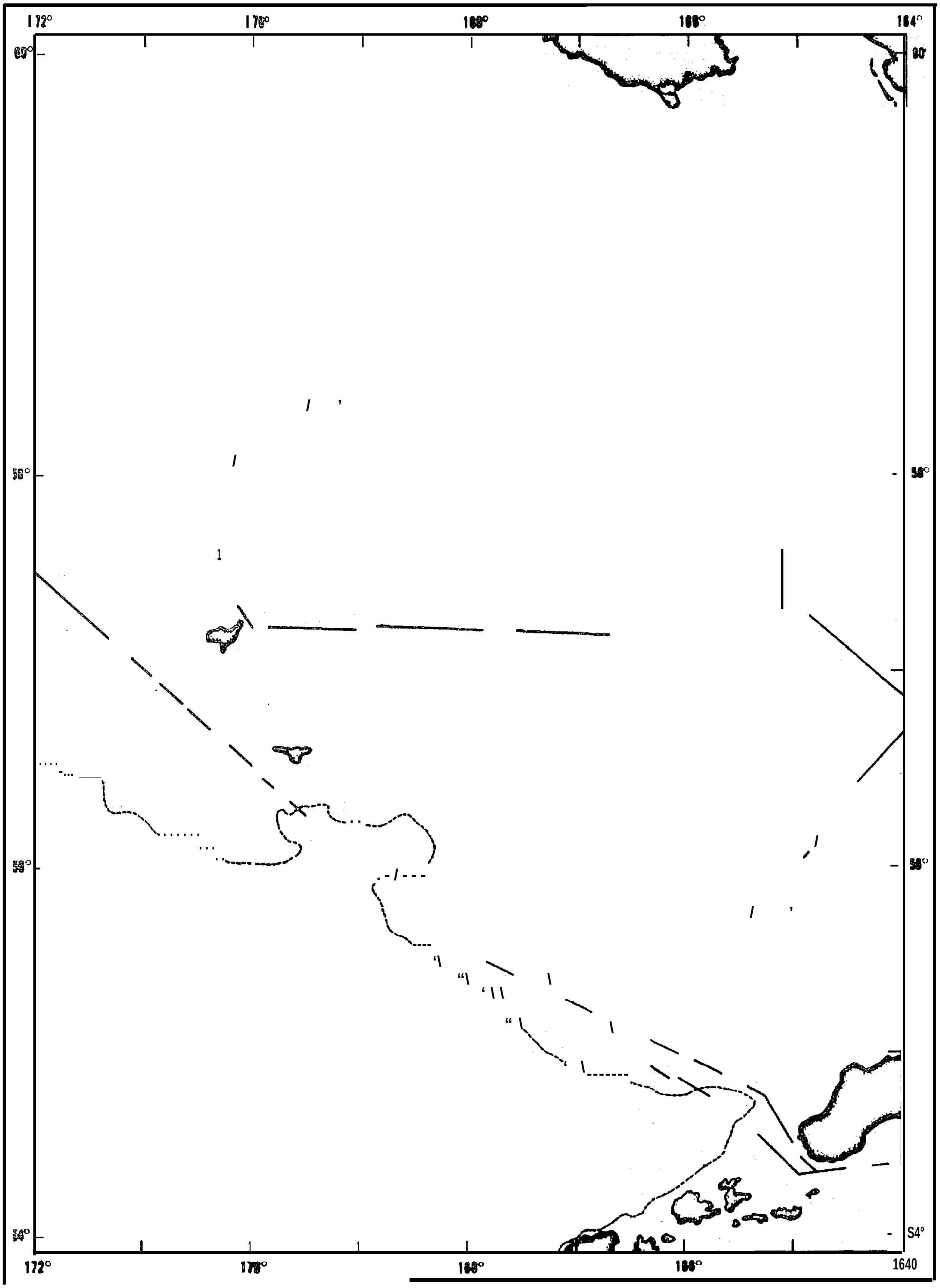


Figure 36. Cruise track during periods of observation in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April. to 1 May 1977.

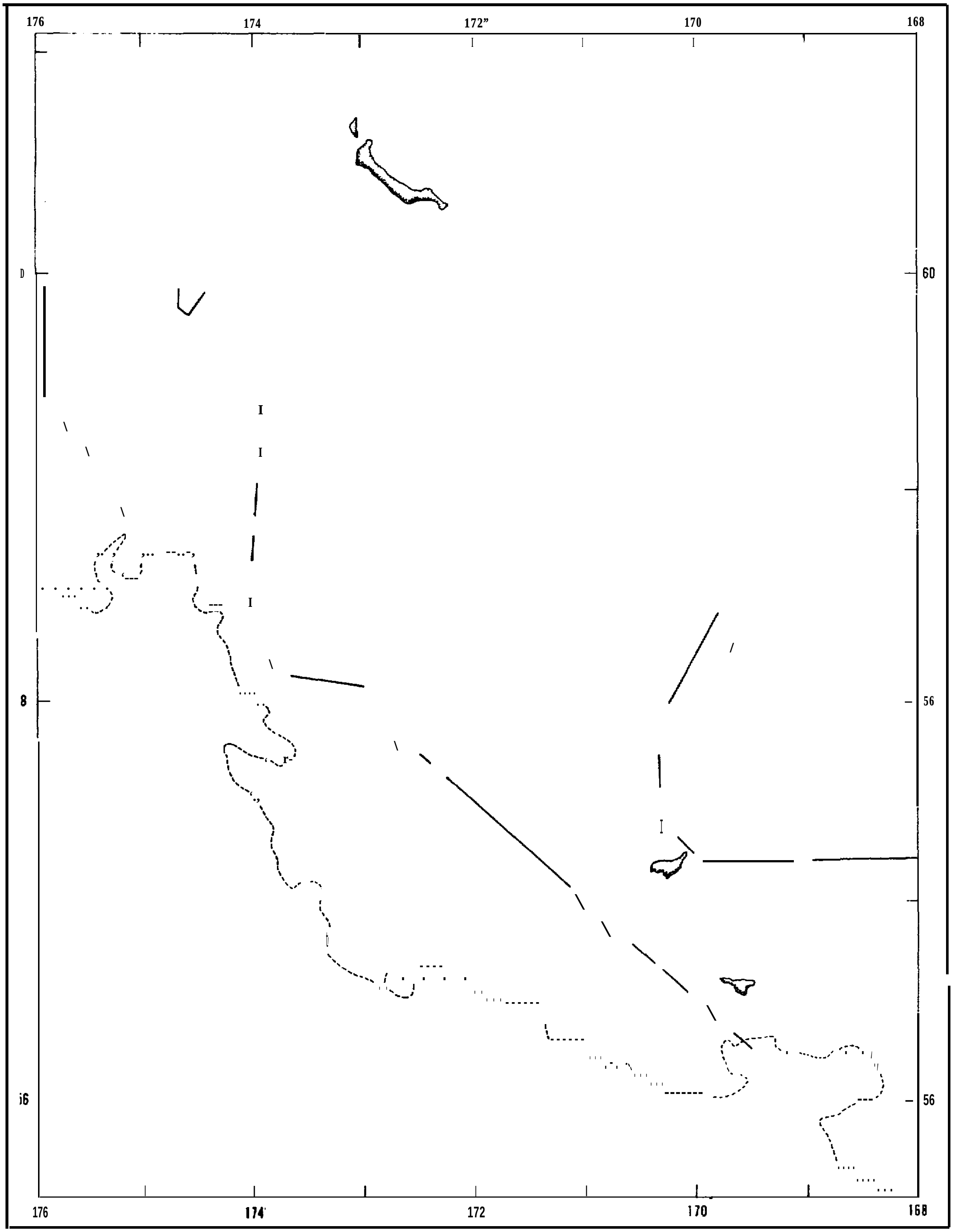


Figure 37. Cruise track during periods of observation in central Bering Sea from 22 to 30 April 1977.

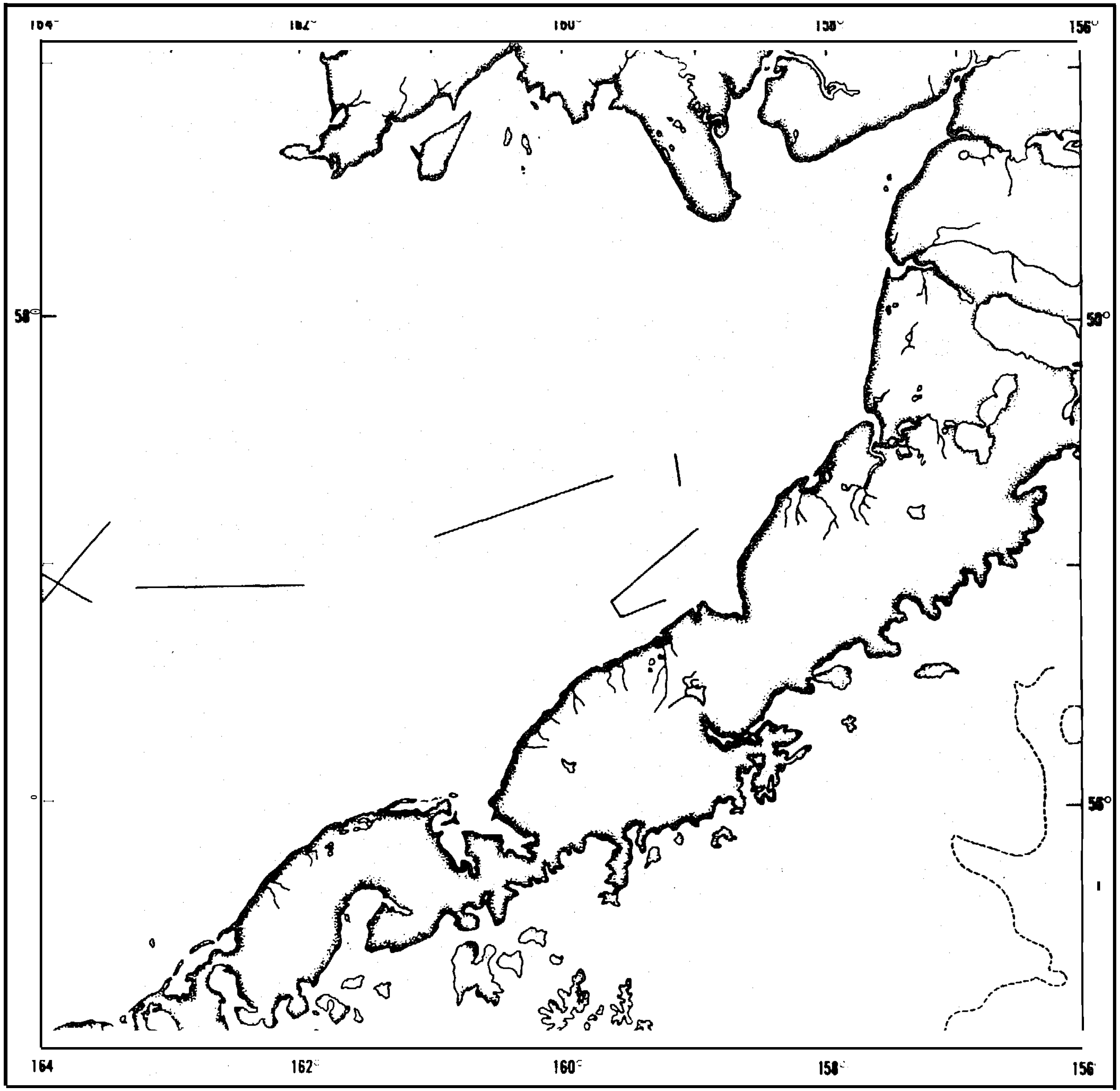


Figure 38. Cruise track during periods of observation in Bristol Bay from 17 to 19 April 1977.

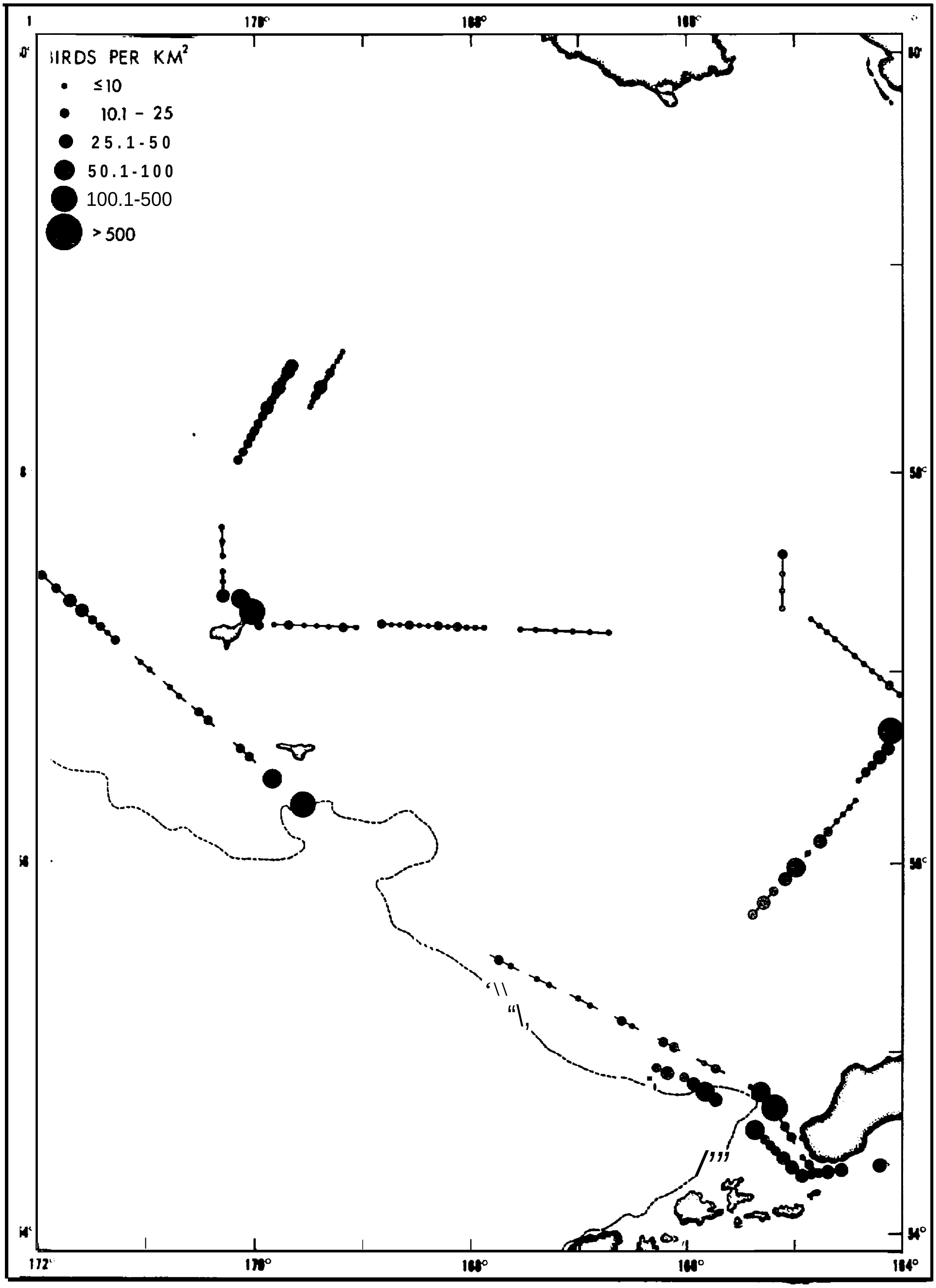


Figure 39. Distribution and abundance of seabirds in southern Bering" Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

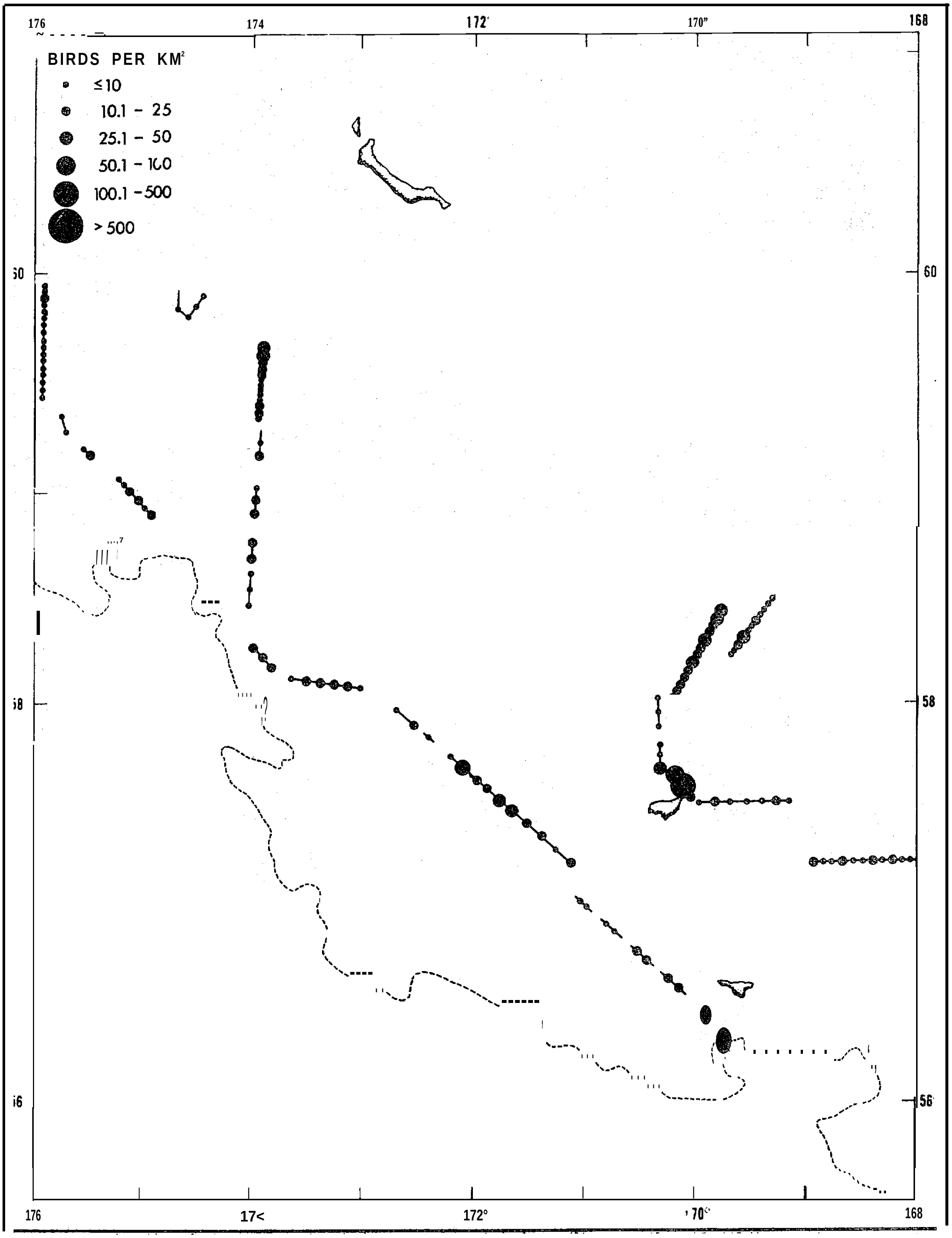


Figure 40. Distribution and abundance of seabirds in central Bering Sea from 22 to 30 April 1977.

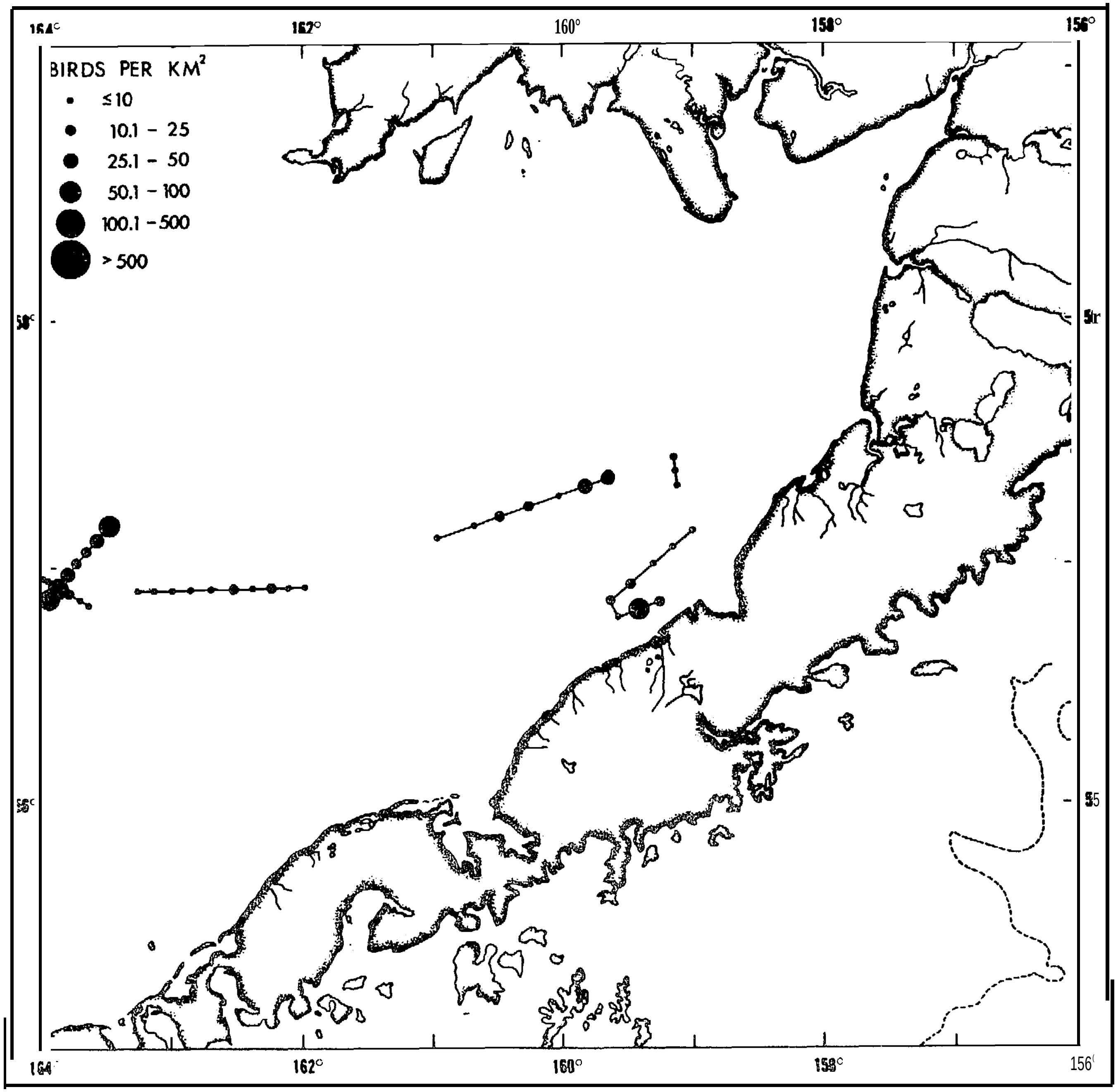


Figure 41. Distribution and abundance of seabirds in Bristol Bay from 17 to 19 April 1977.

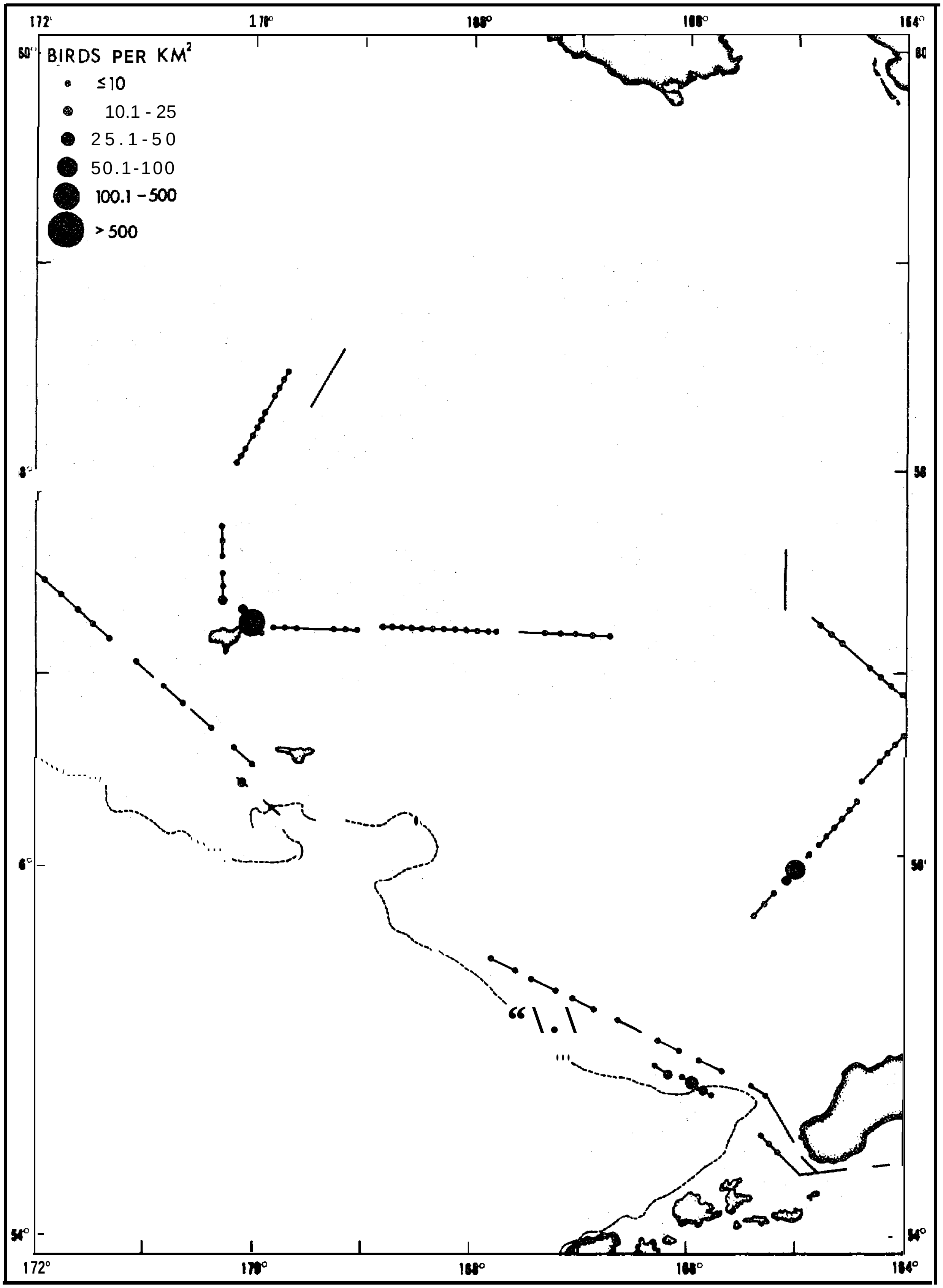


Figure- 42. Distribution and abundance of Northern Fulmars in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

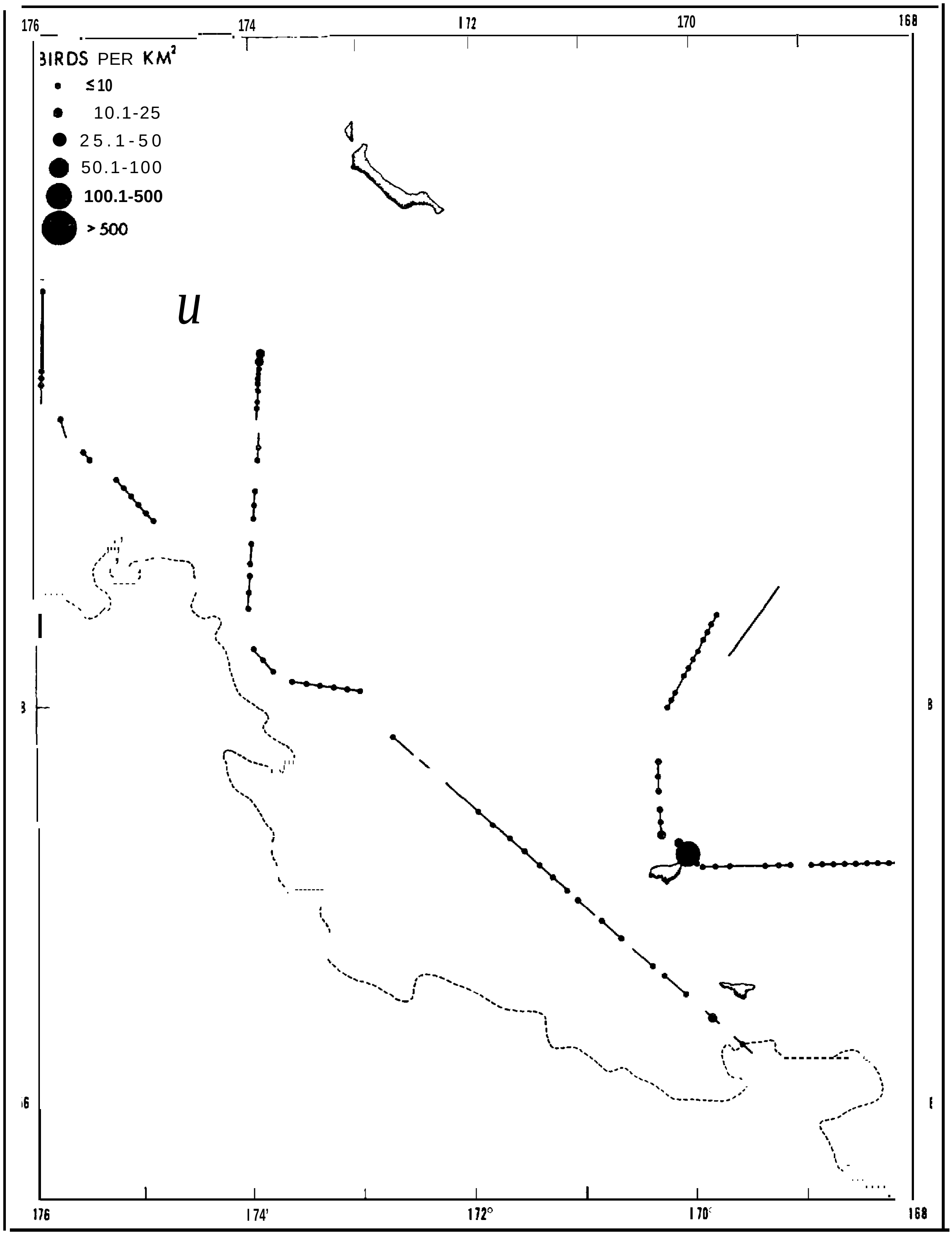


Figure 43. Distribution and abundance" of Northern Fulmars in central Bering Sea from 22 to 30 April 1977.

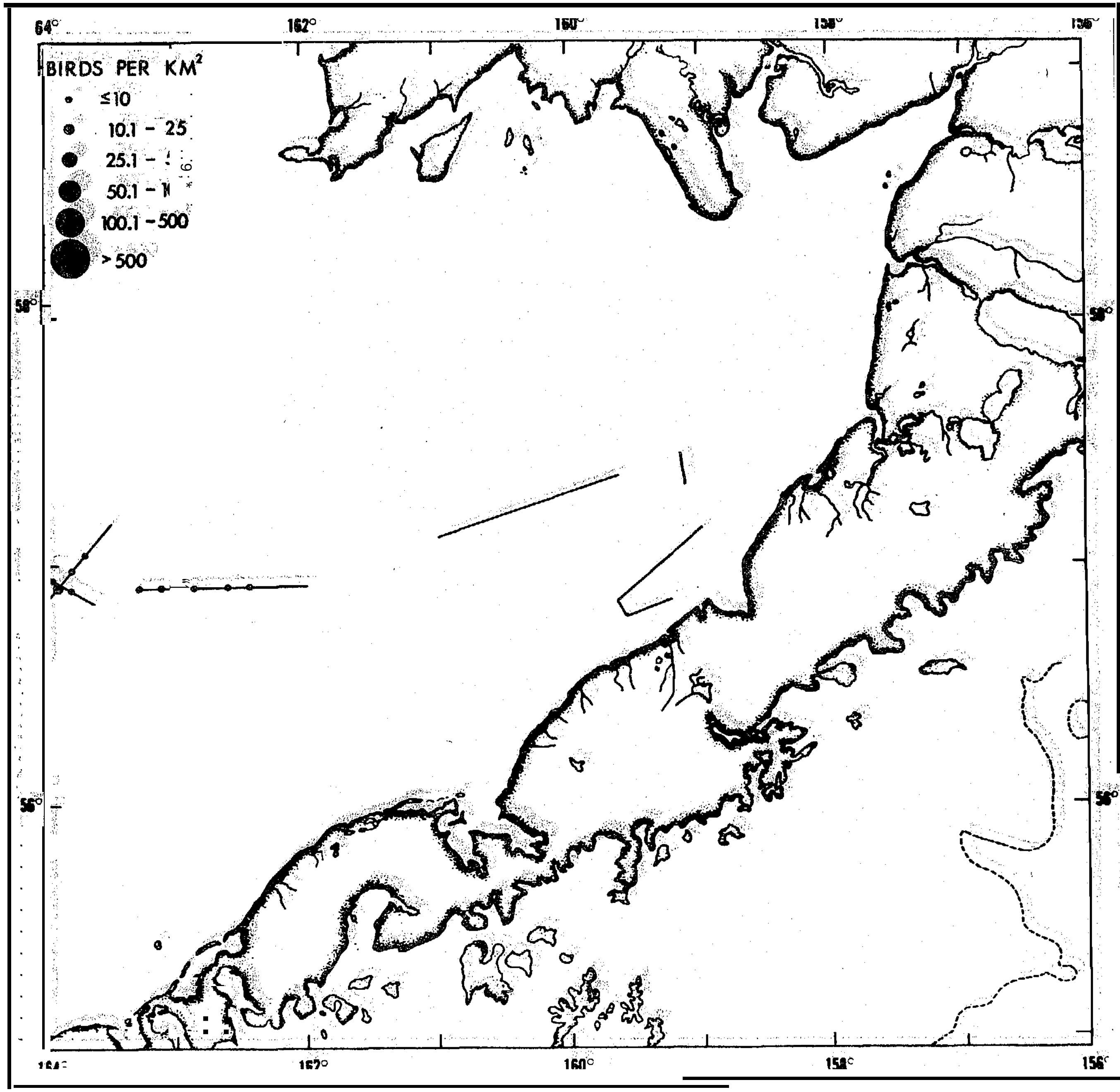


Figure 44. Distribution and abundance of Northern Fulmars in Bristol Bay from 17 to 19 April 1977.

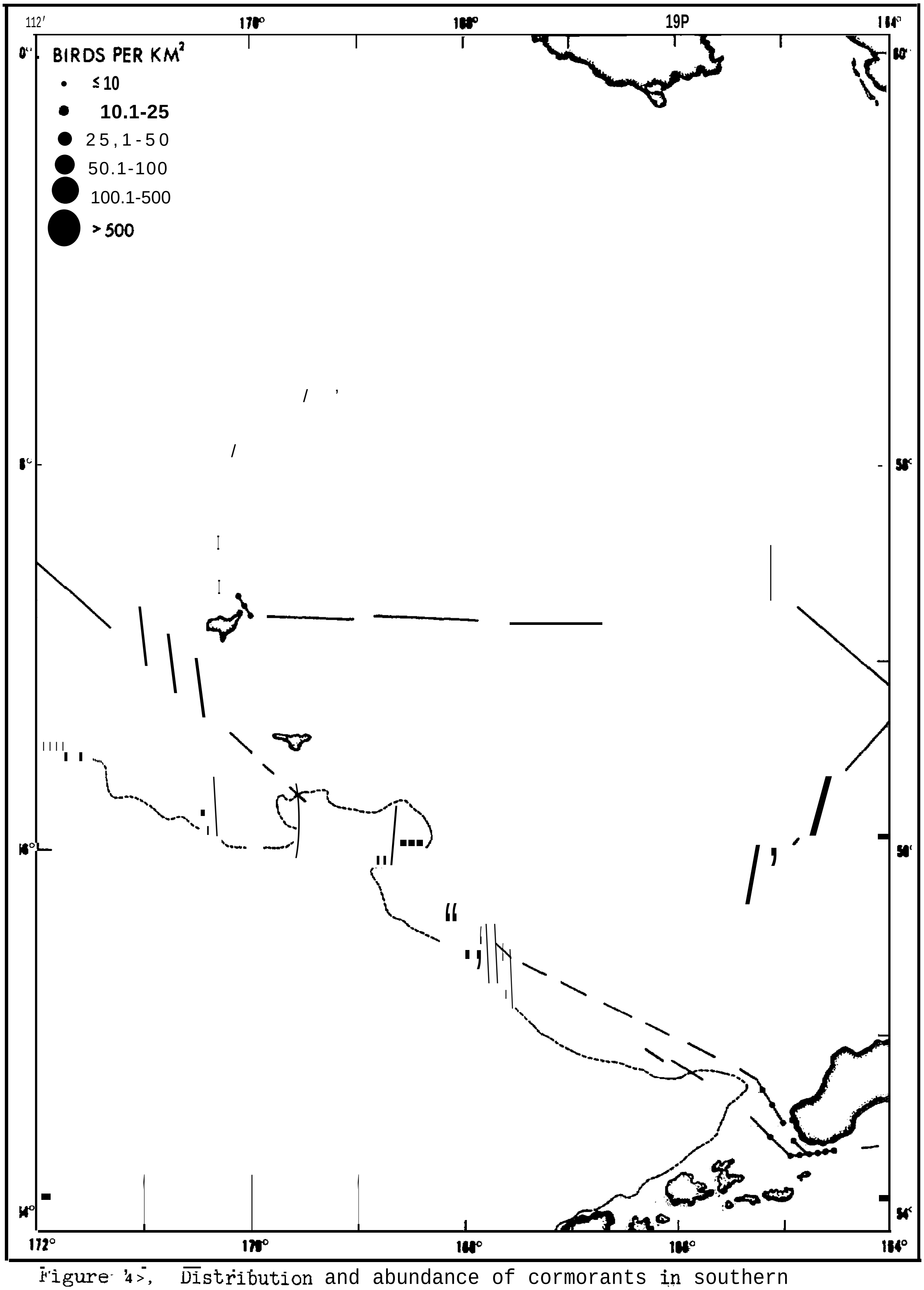


Figure 4>, Distribution and abundance of cormorants in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

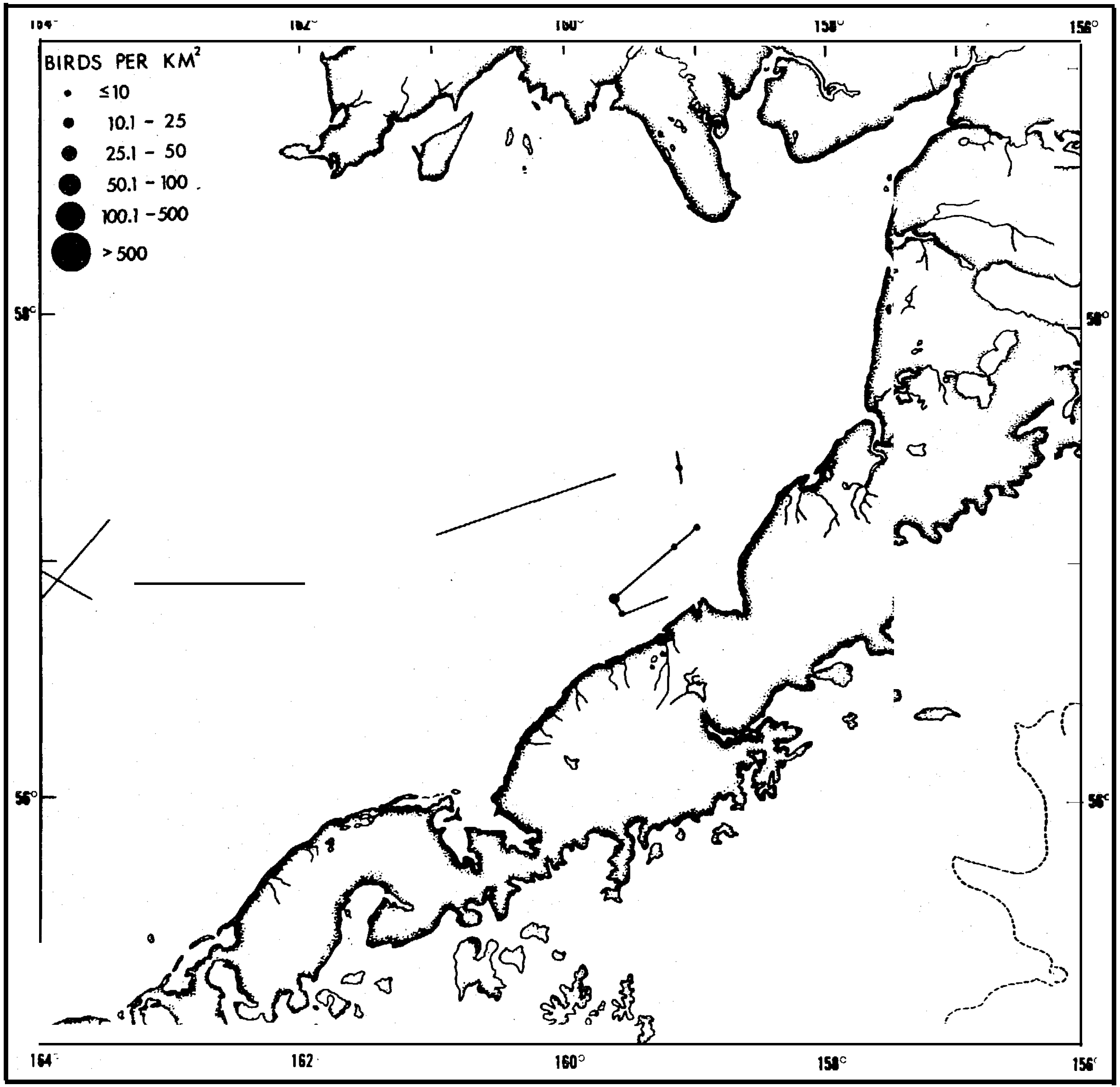


Figure 46. Distribution and abundance of cormorants in Bristol Bay from 17 to 19 April 1977.

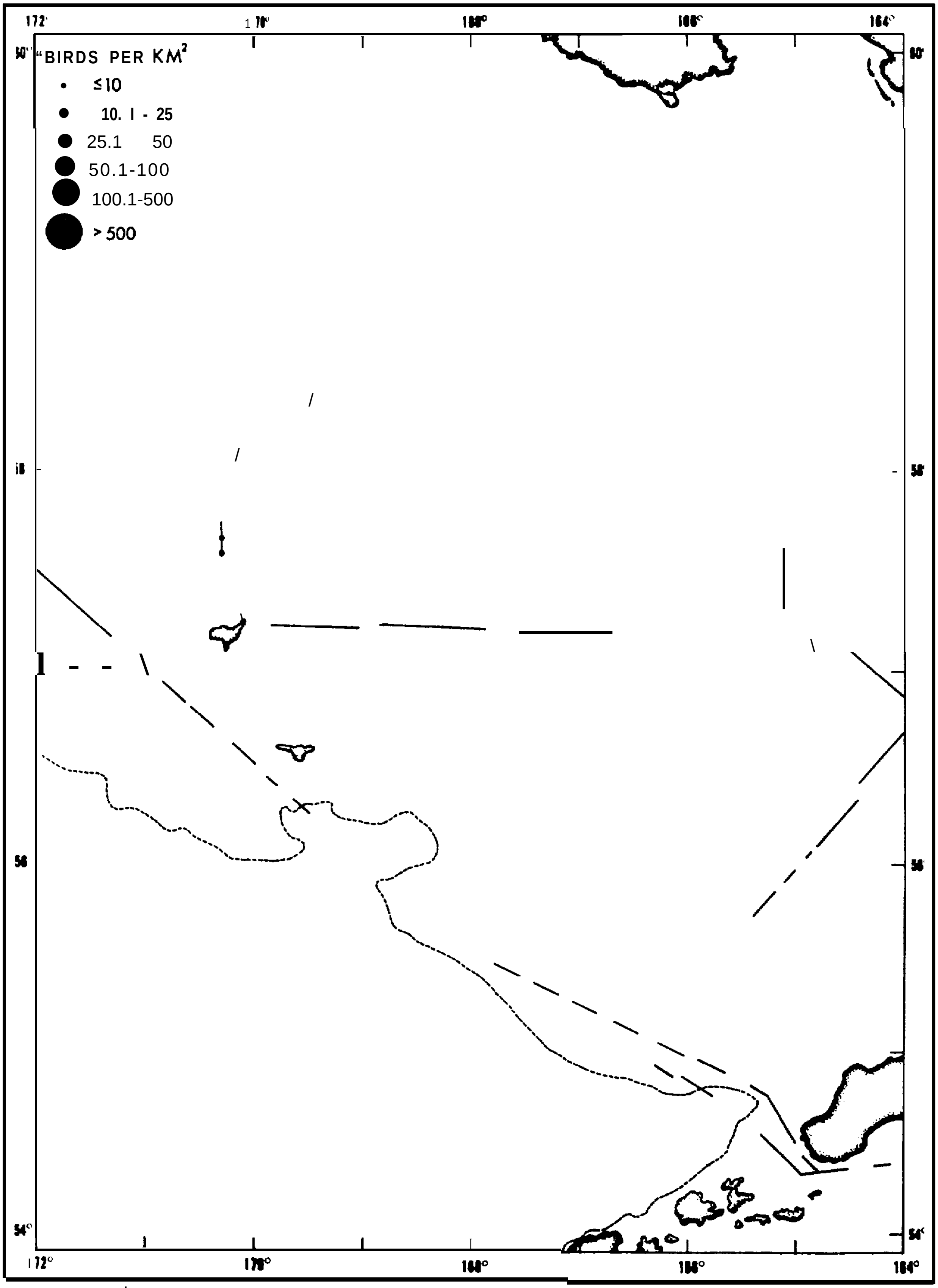


Figure 47. Distribution and abundance of Oldsquaws in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

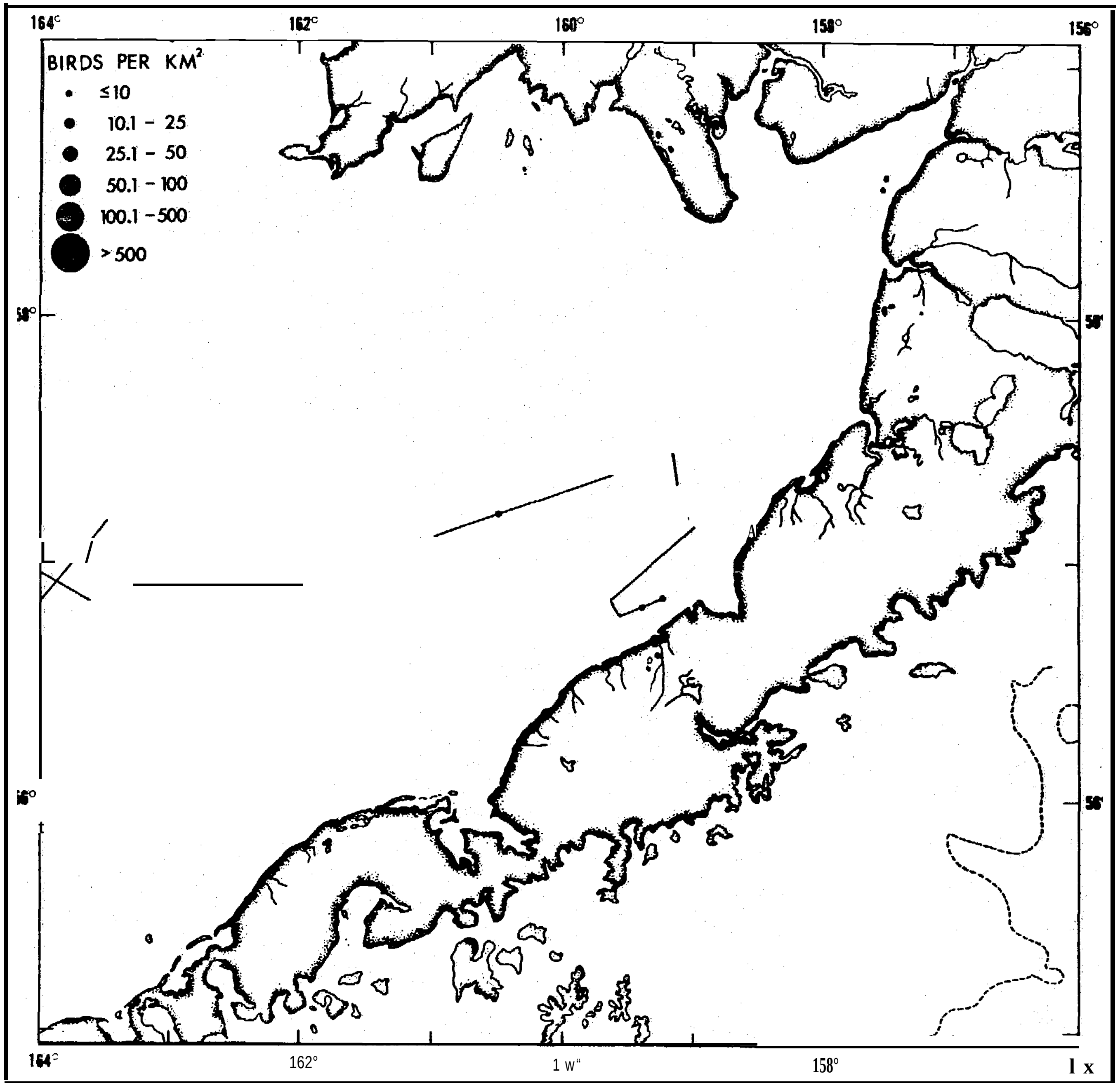
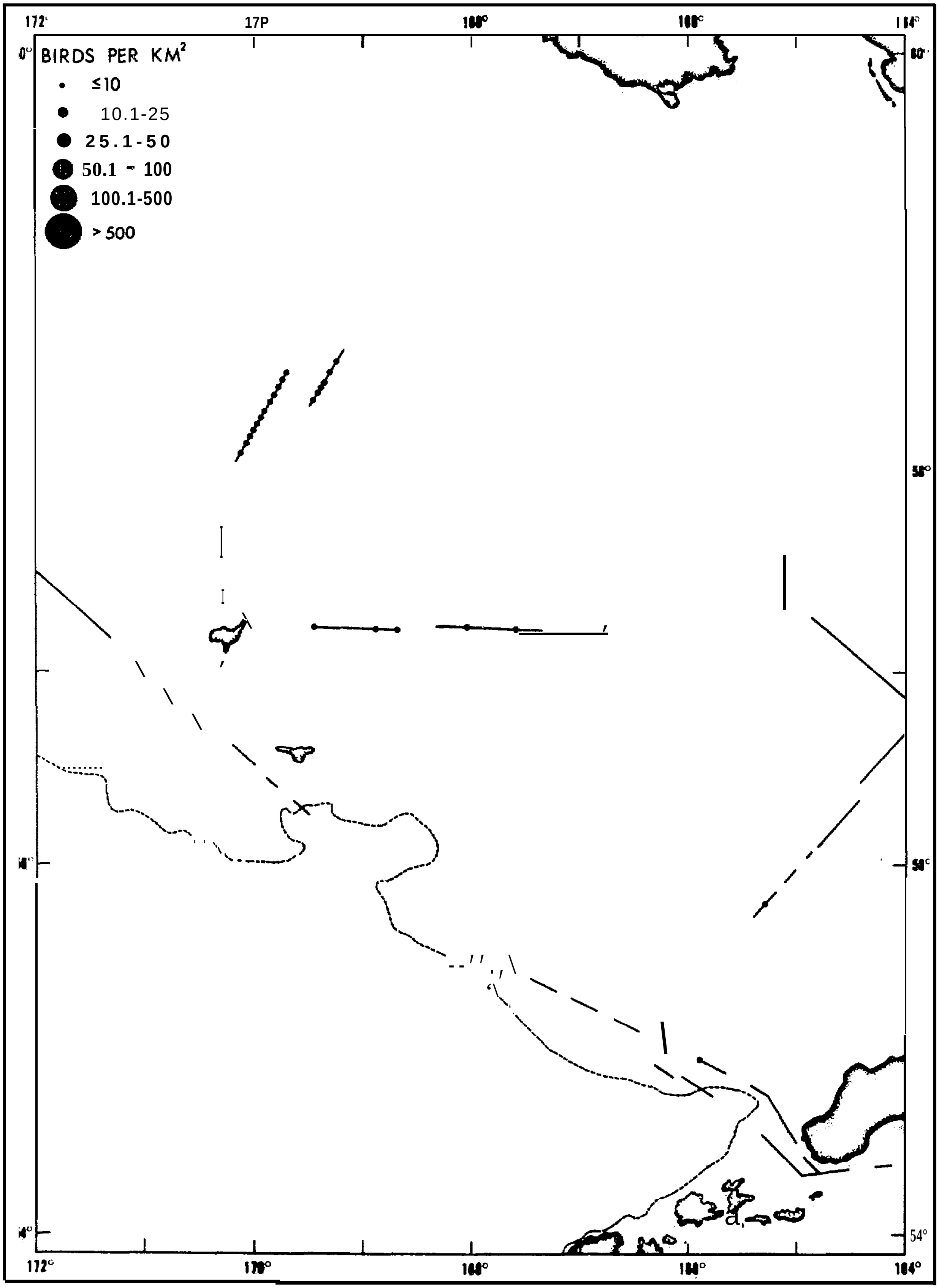


Figure 48. Distribution and abundance of Oldsquaws in Bristol Bay from 17 to 19 April 1977.



Figure" 49. Distribution and abundance of Glaucous Gulls in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

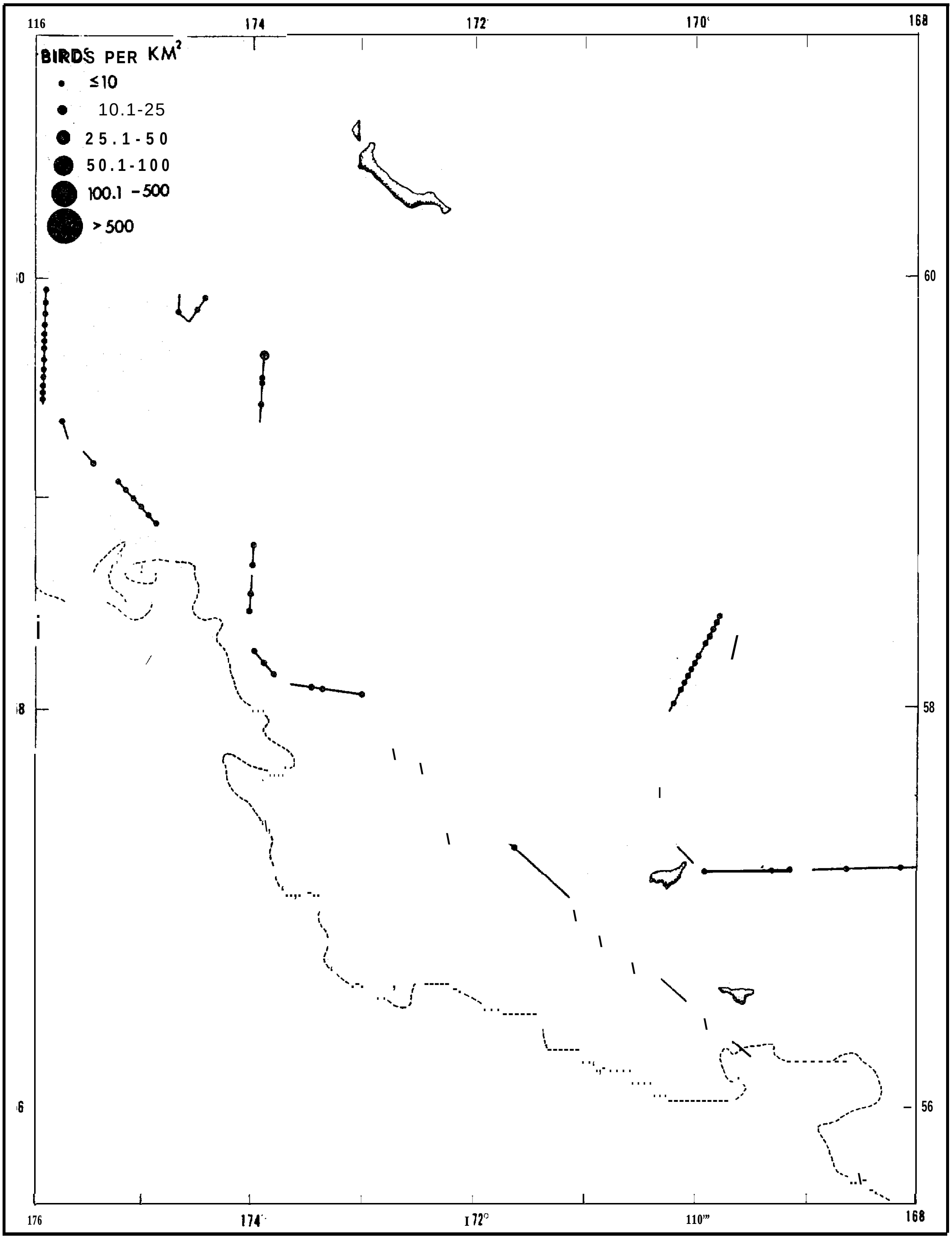


Figure 50. Distribution and abundance of Glaucous Gulls in central Bering Sea from 22 to 30 April 1977.

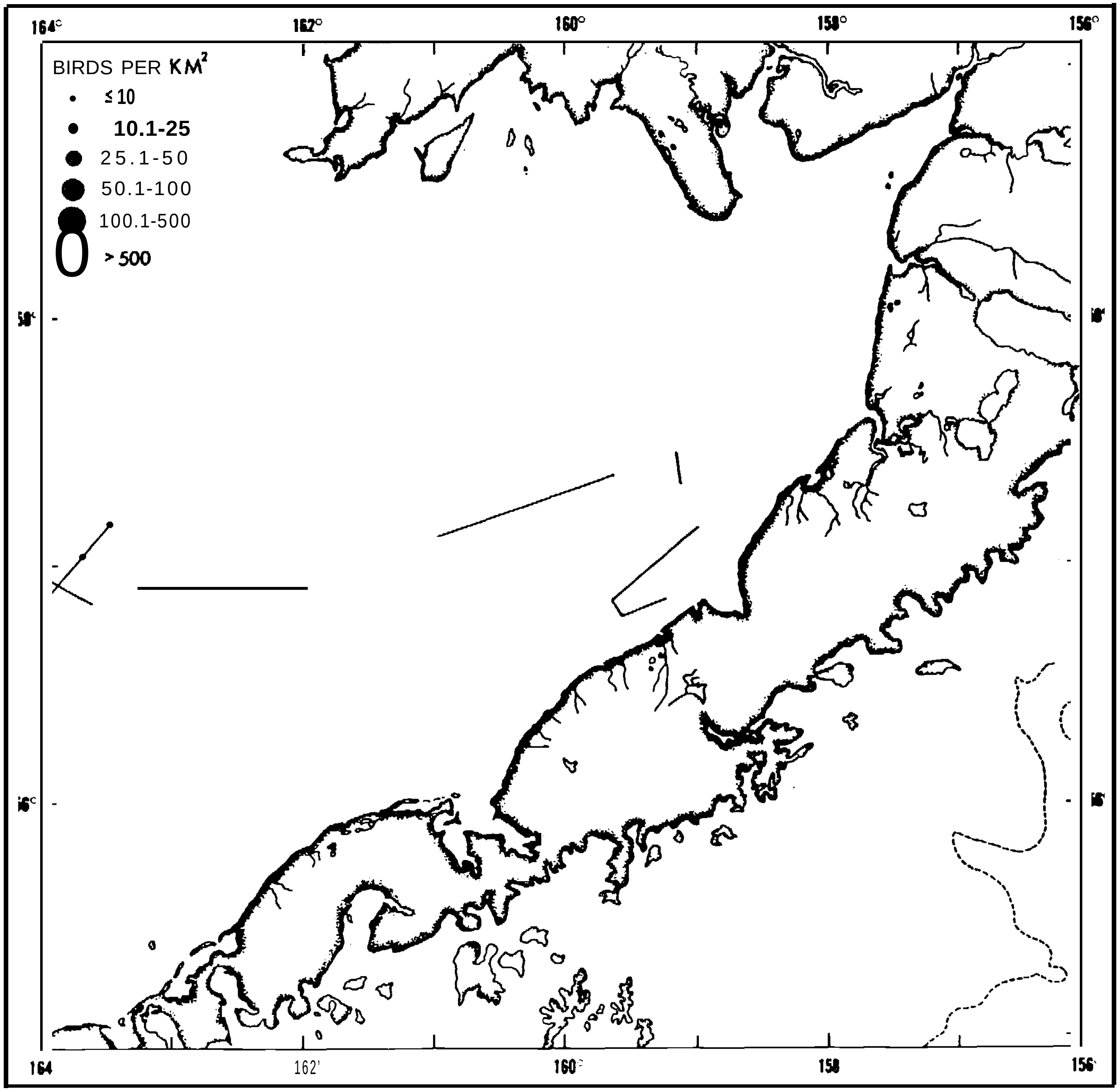


Figure 51. Distribution and abundance of Glaucous Gulls in Bristol Bay from 17 to 19 April 1977.

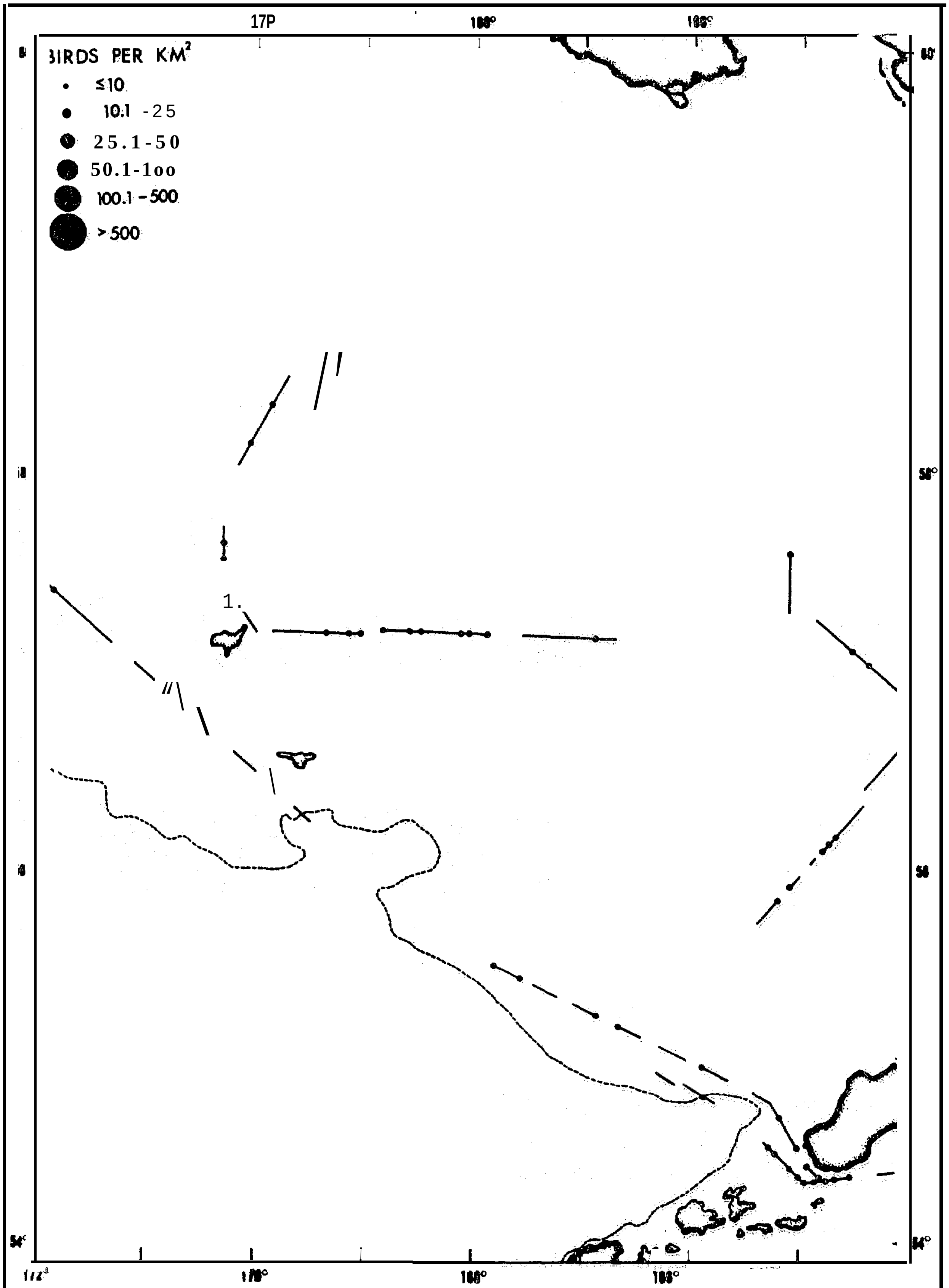


Figure. 52. Distribution and abundance of Glaucous-winged Gulls in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

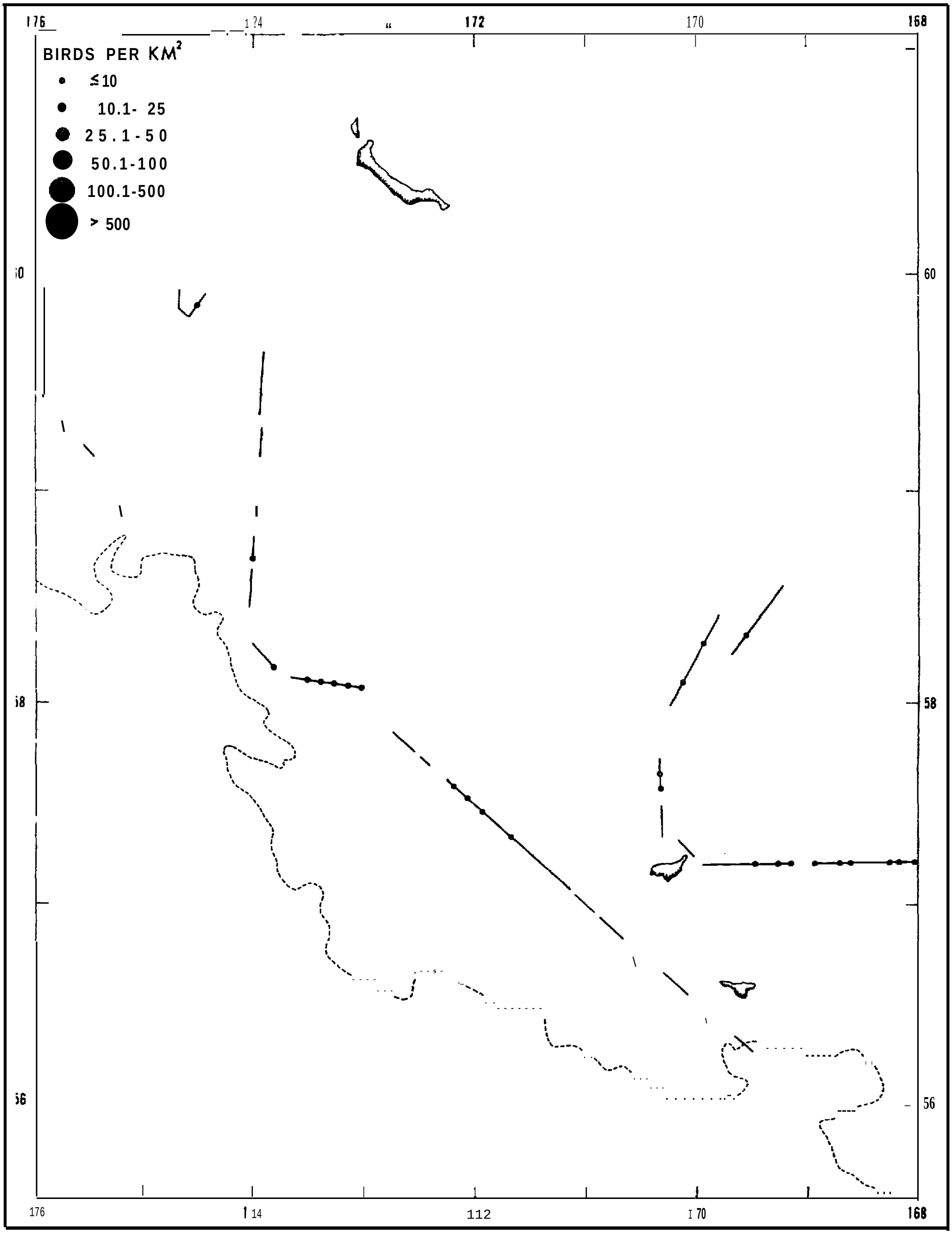


Figure 53 Distribution and abundance of Glaucous-winged Gulls in central Bering Sea from 22 to 30 April 1977.

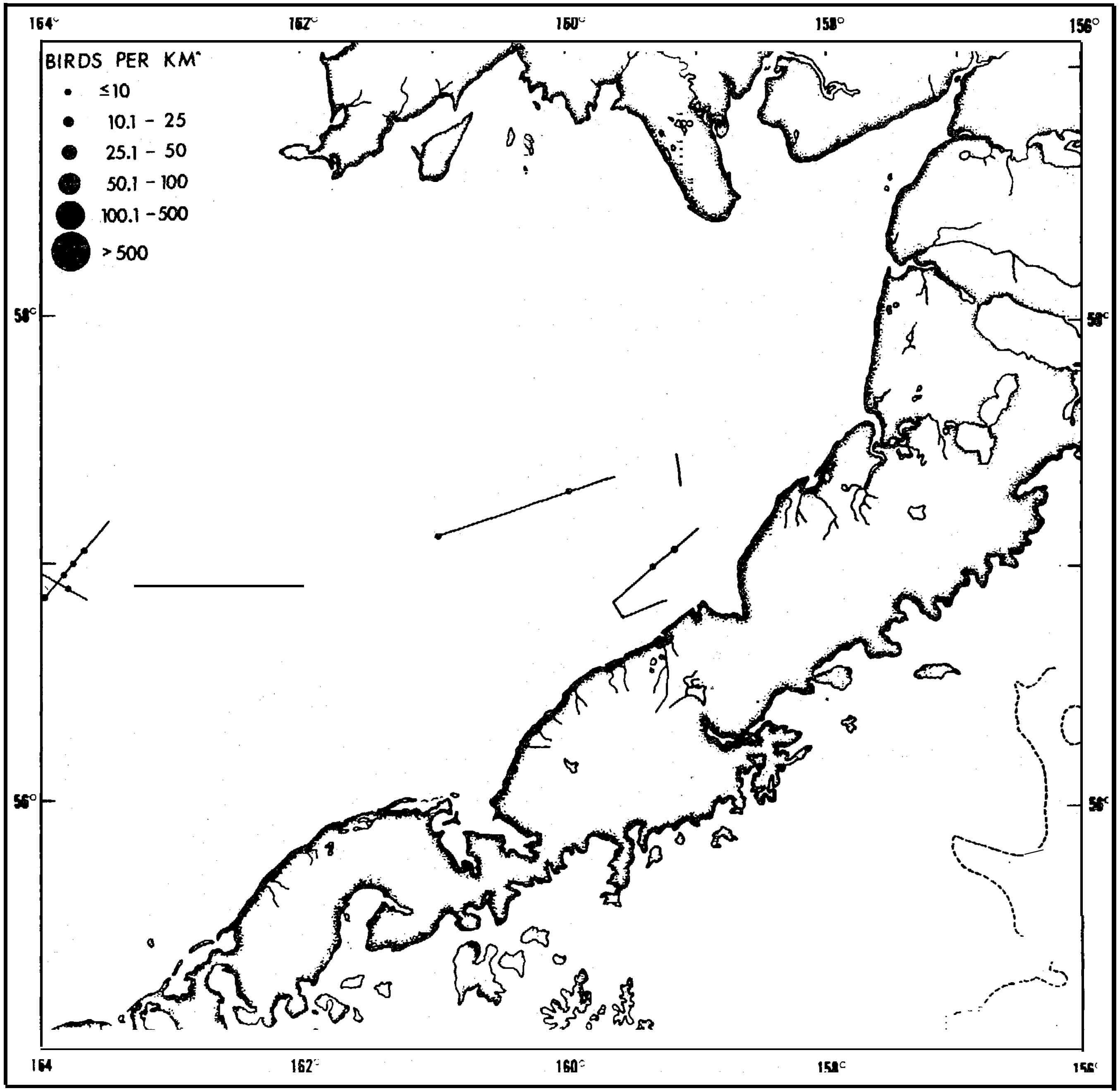


Figure 34. Distribution and abundance of Glaucous-winged Gulls in Bristol Bay from 17 to 19 April 1977.

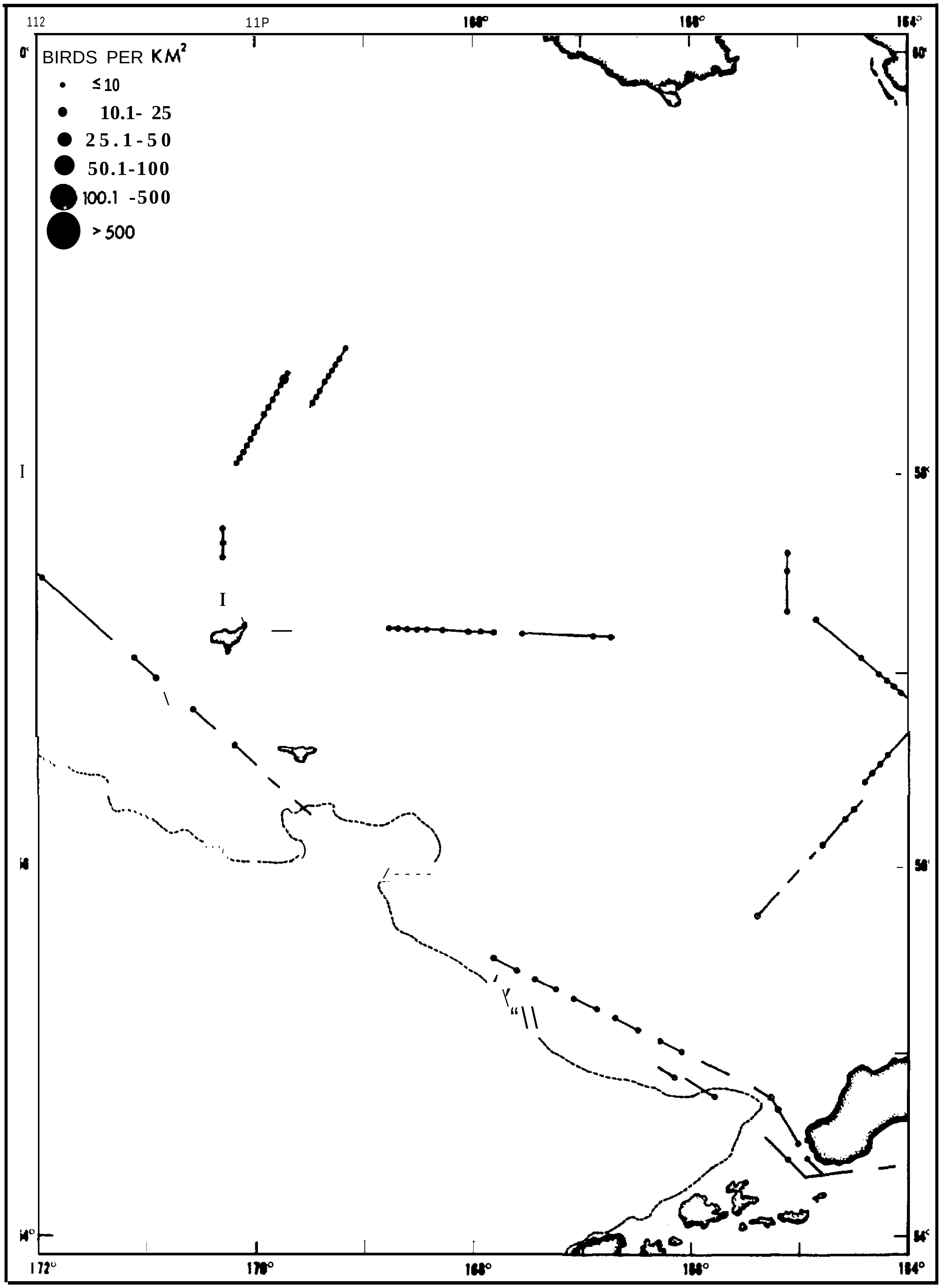


Figure. 55. Distribution and abundance of Black-1 egged Kittiwakes in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

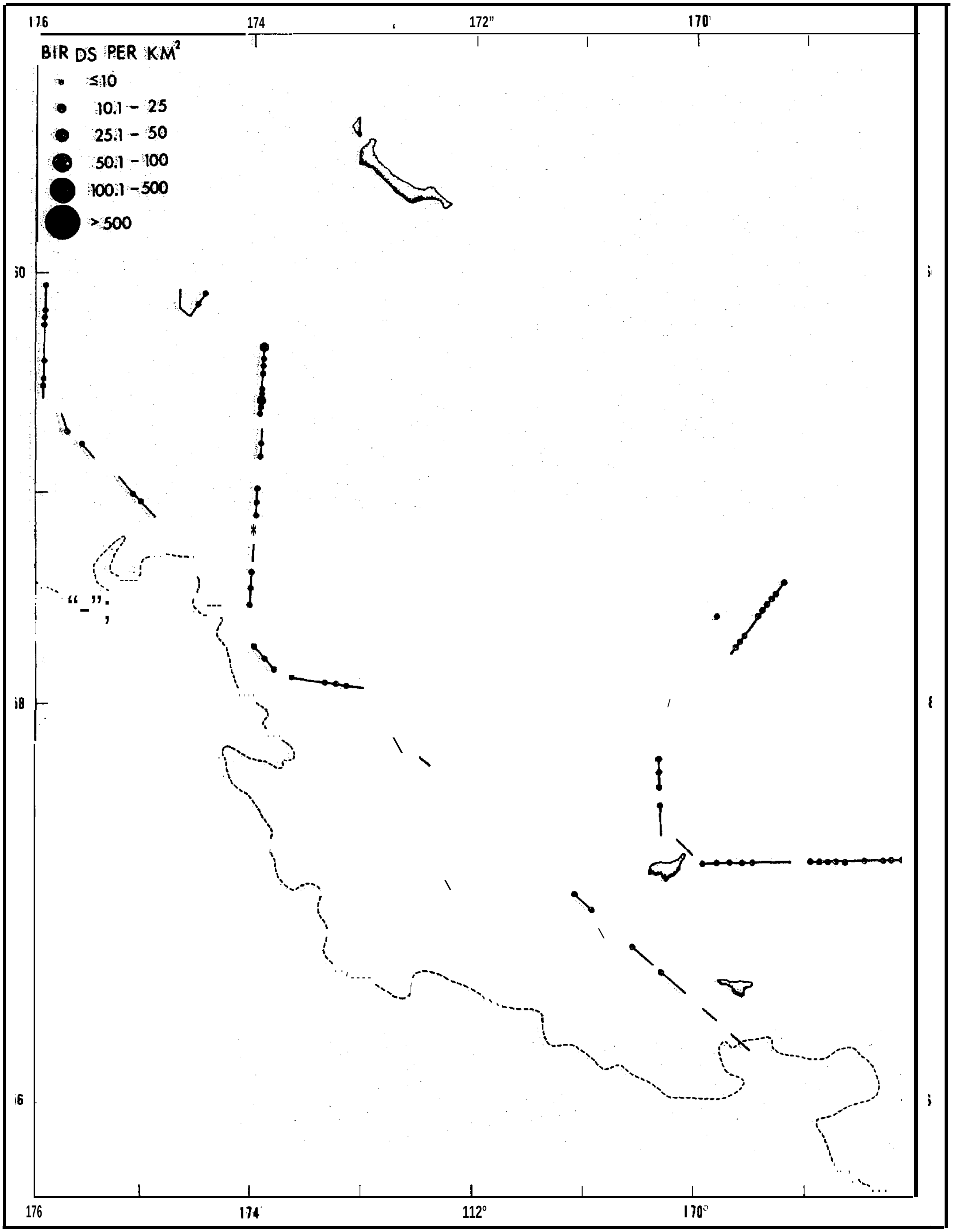


Figure -56. Distribution and-abundance of Black-legged Kittiwakes in central Bering Sea from 22 to 30 April 1977.

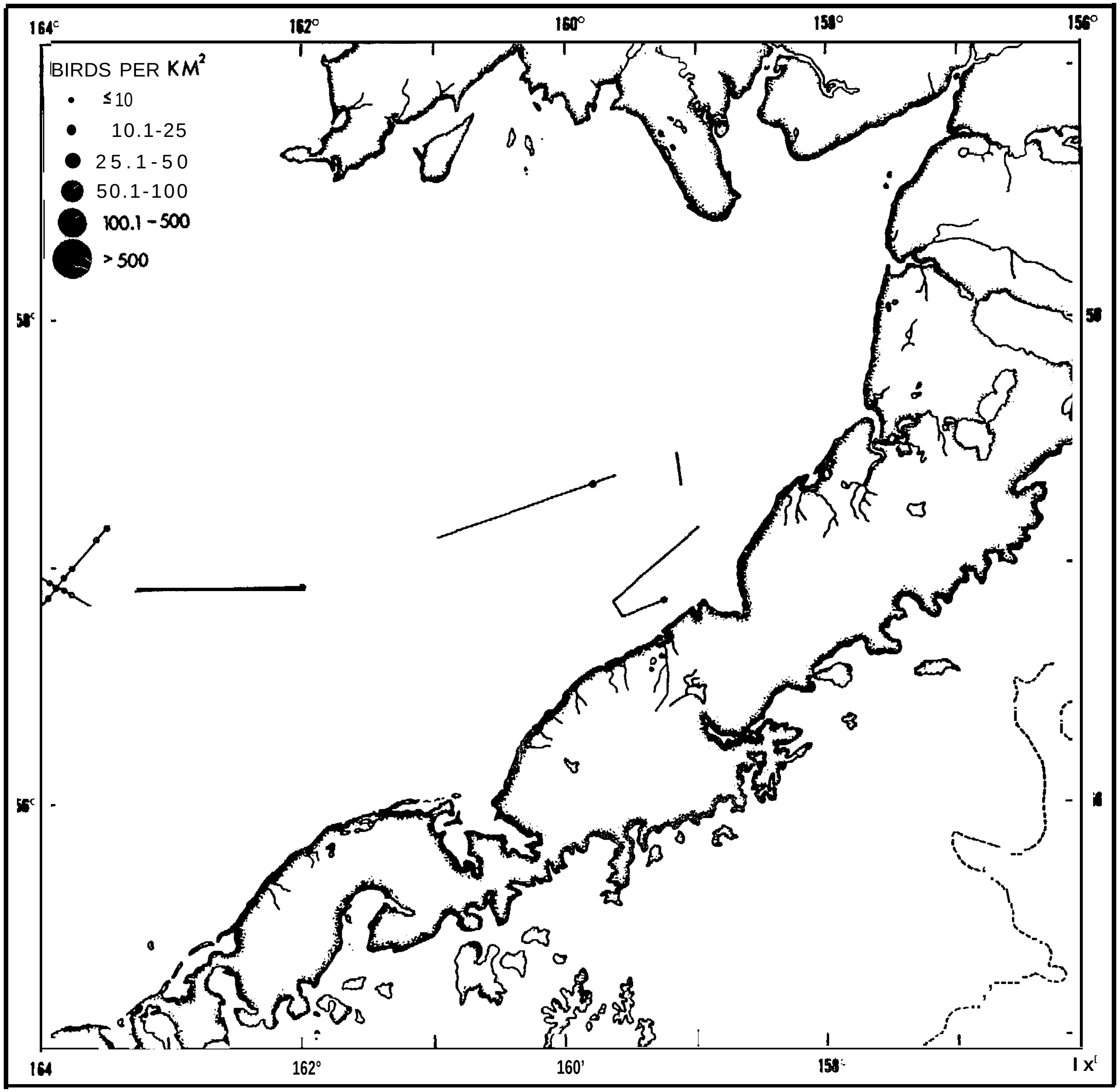


Figure 57. Distribution and abundance of Black-legged Kittiwakes in Bristol Bay from 17 to 19 April 1977.

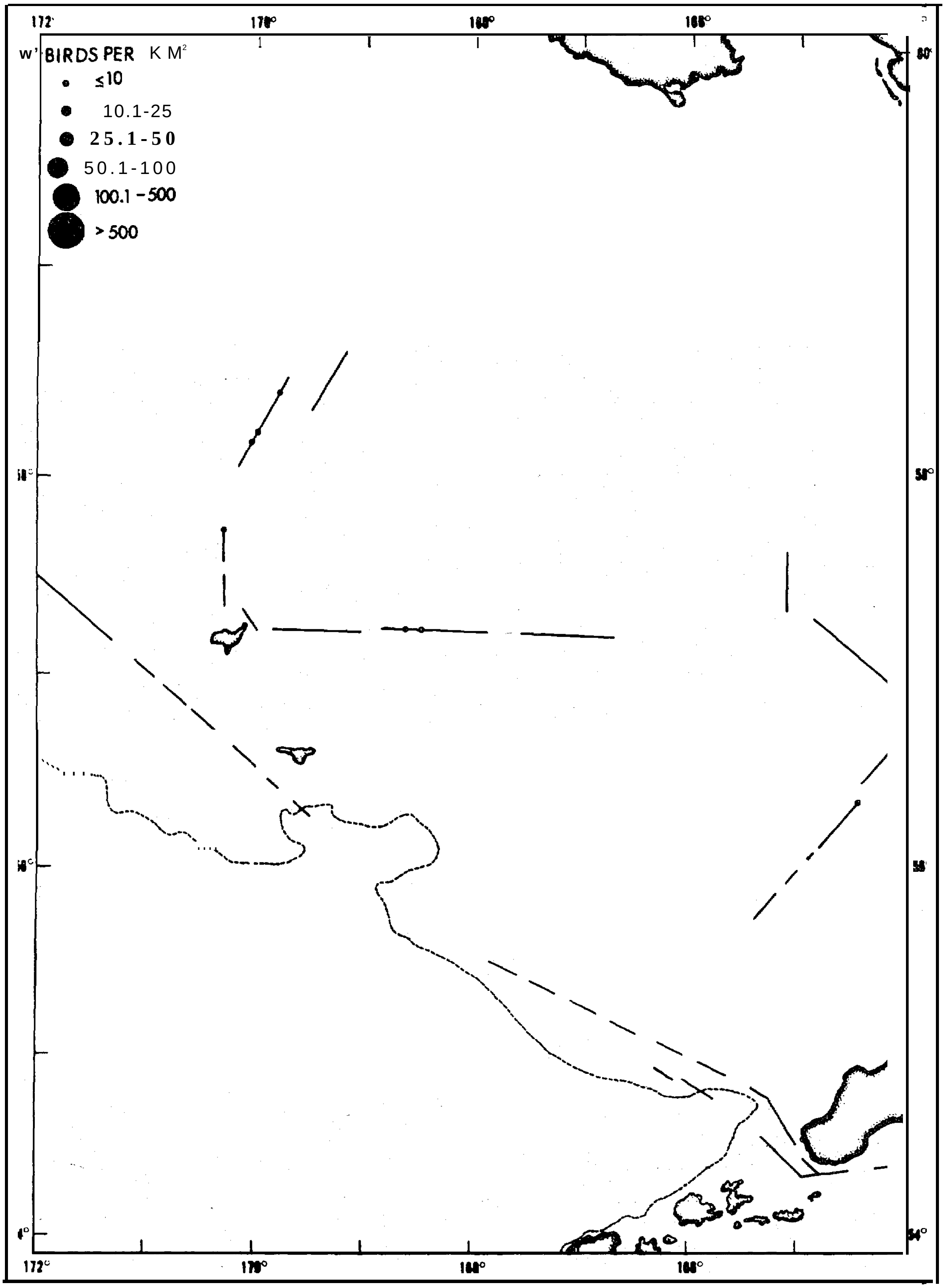


Figure 58. Distribution and abundance of Red-legged Kittiwakes in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

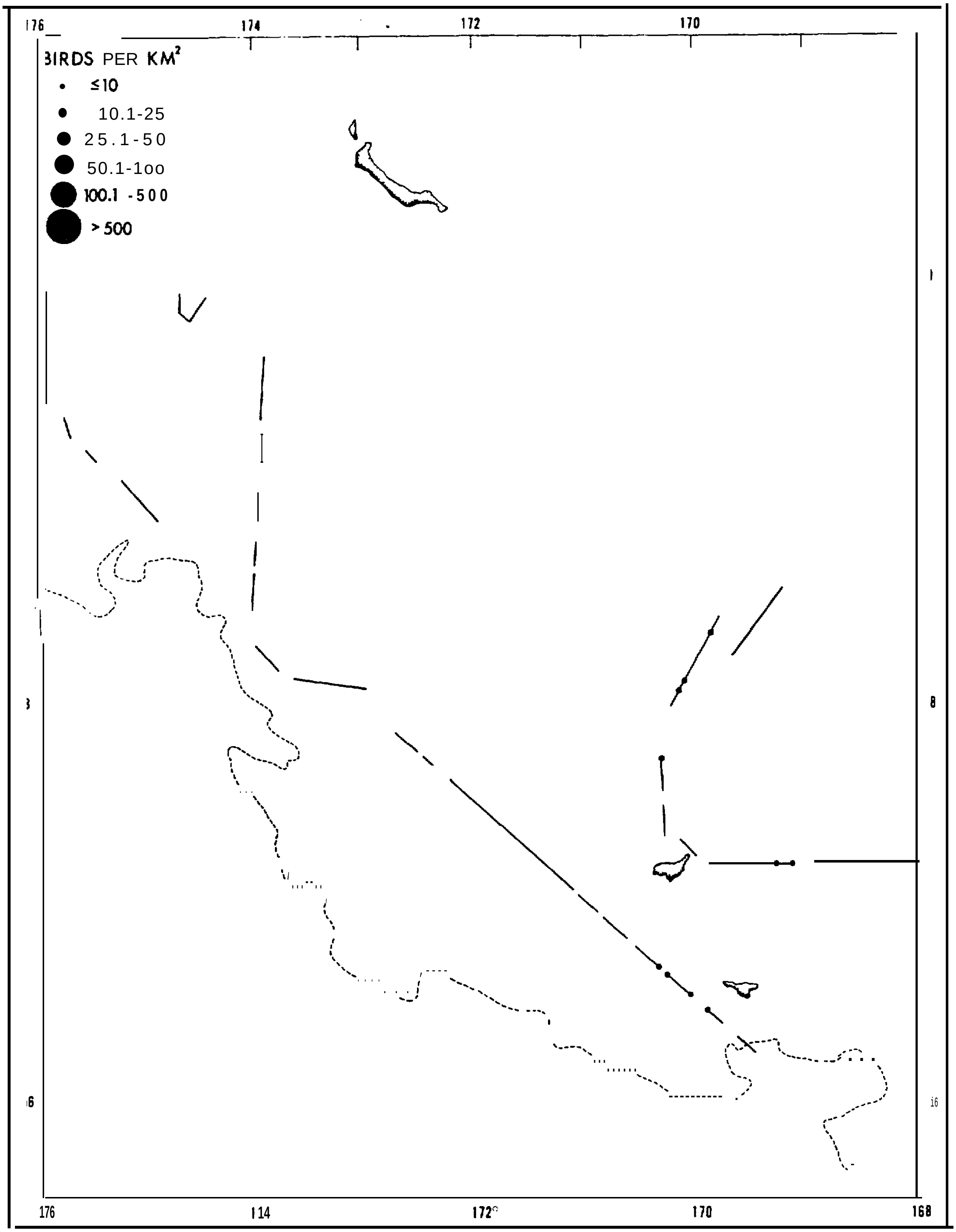


Figure 59. Distribution and abundance of Red-legged Kittiwakes in central Bering Sea from 2? to 30 April 1977.

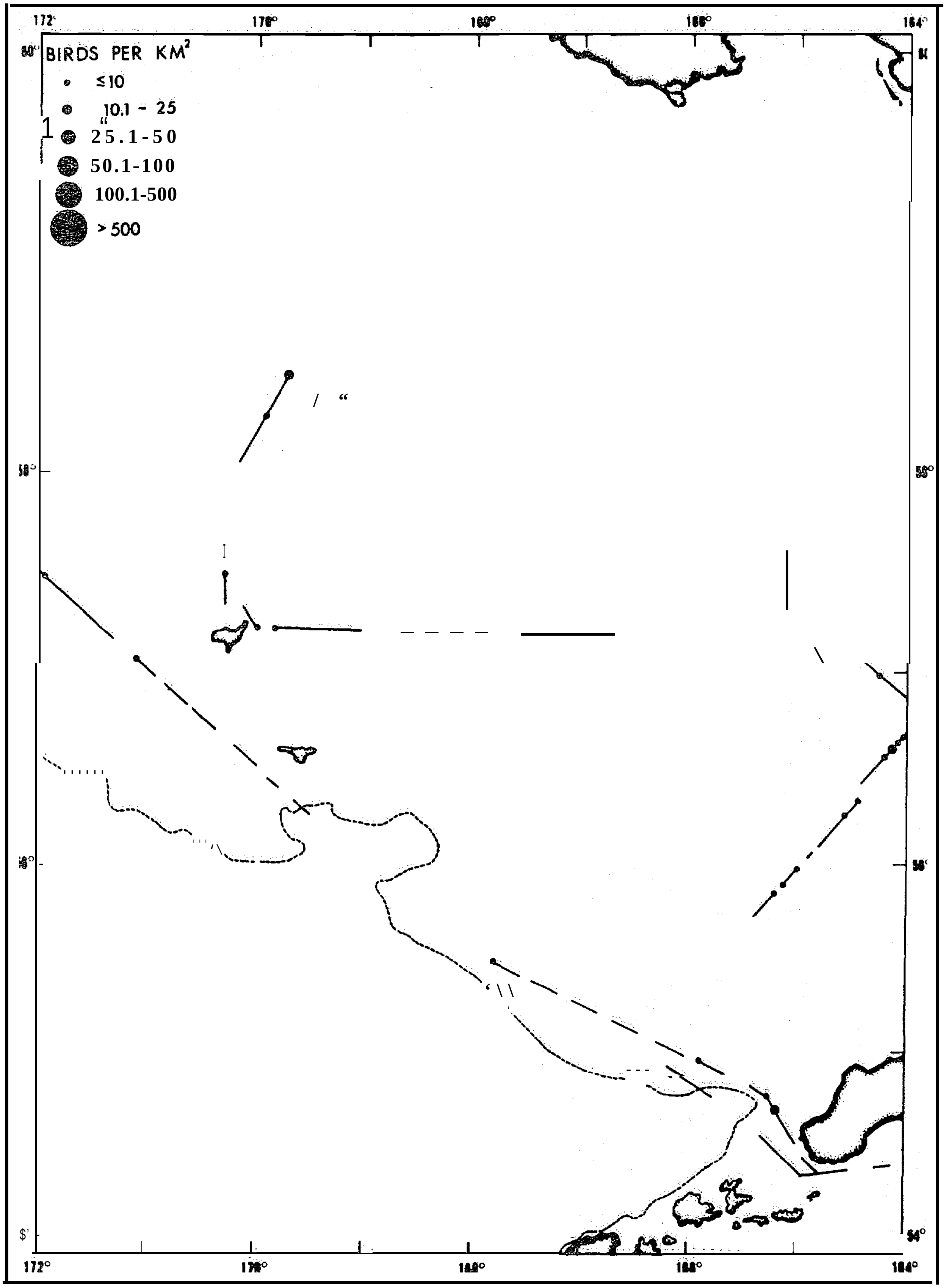


Figure 60. Distribution and abundance of Common Murres in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

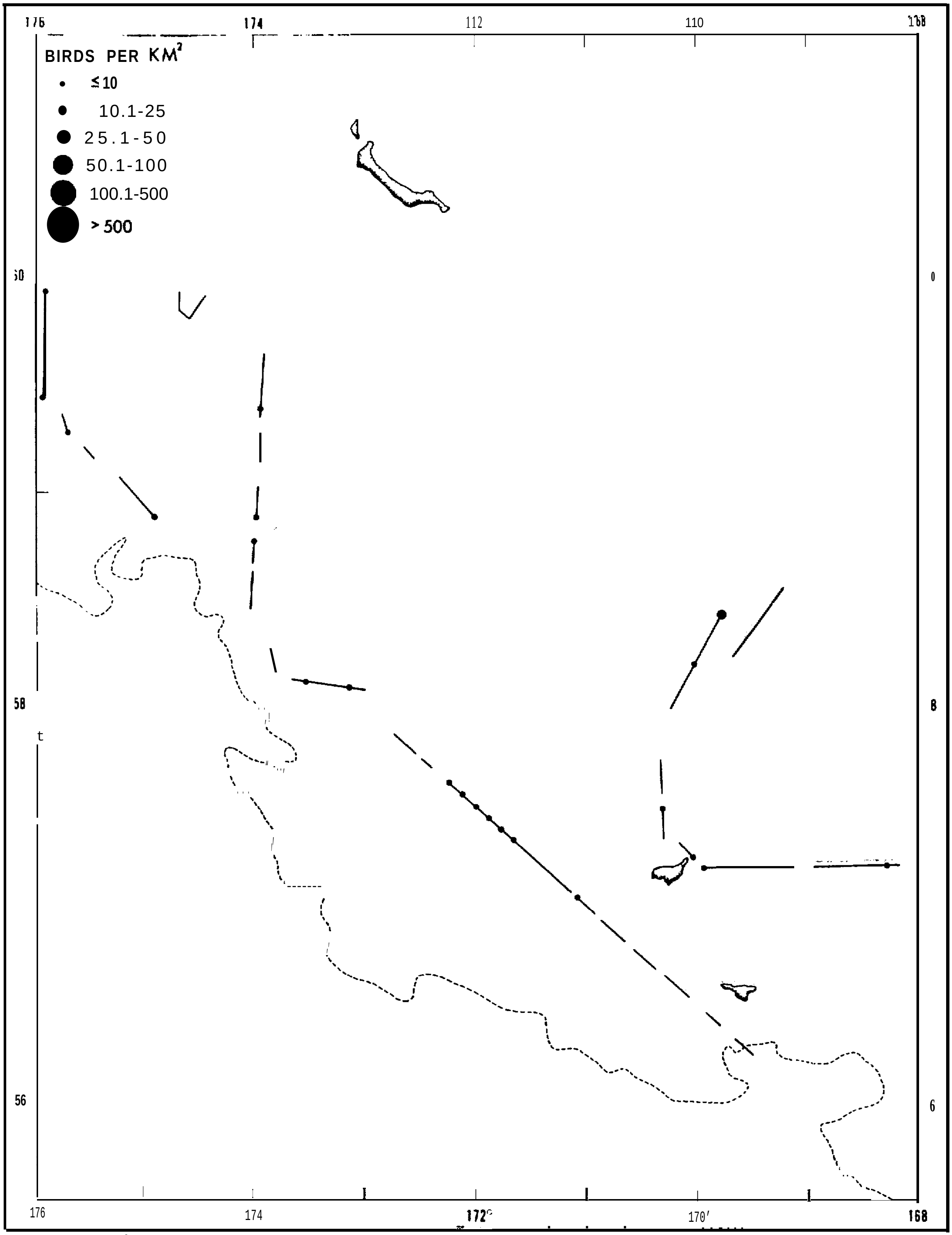


Figure 61. Distribution and abundance of Common Murres in central Bering Sea from 22 to 30 April 1977.

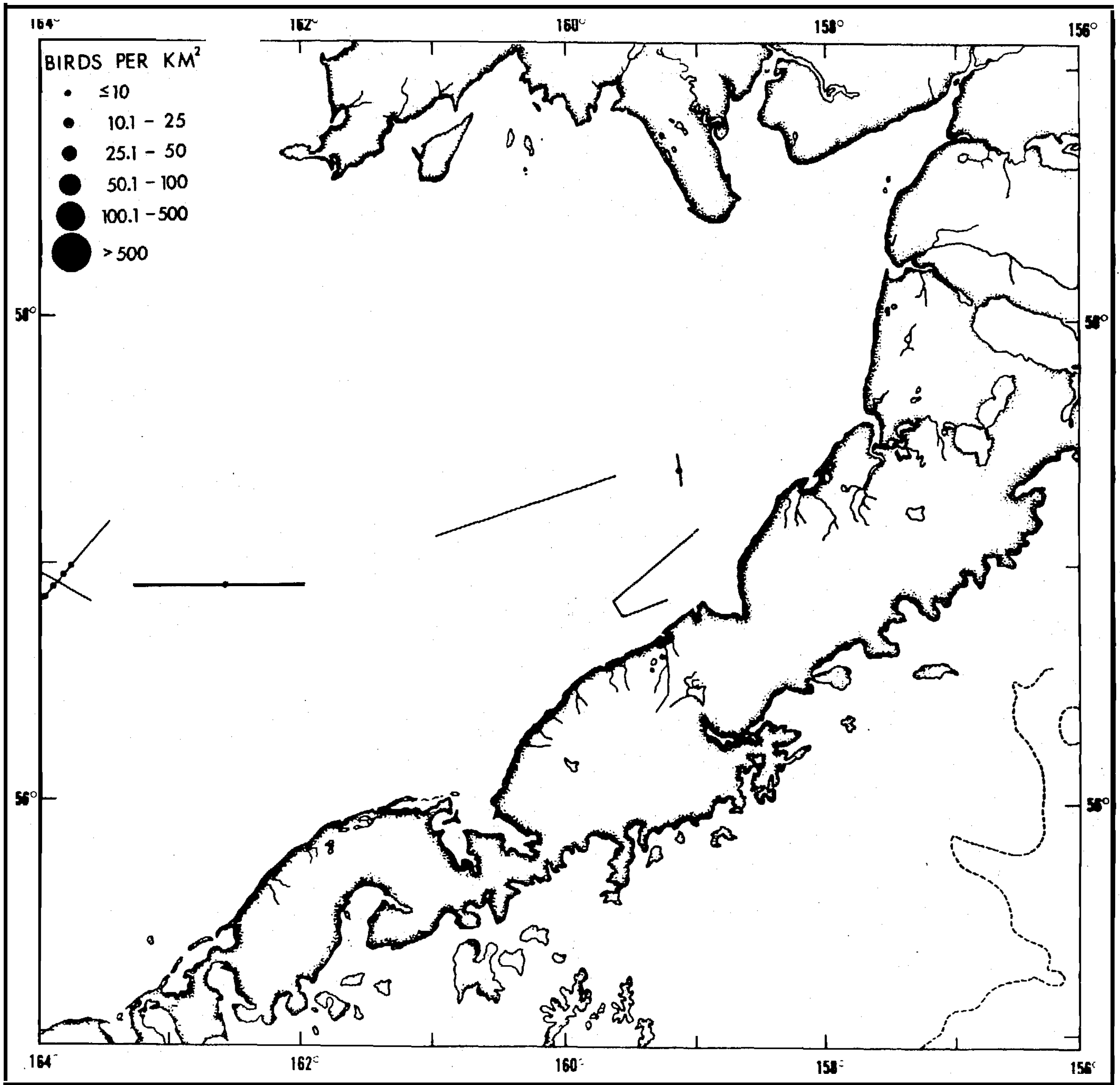


Figure 62. Distribution and abundance of Common Murres in Bristol Bay from 17 to 19 April 1977.

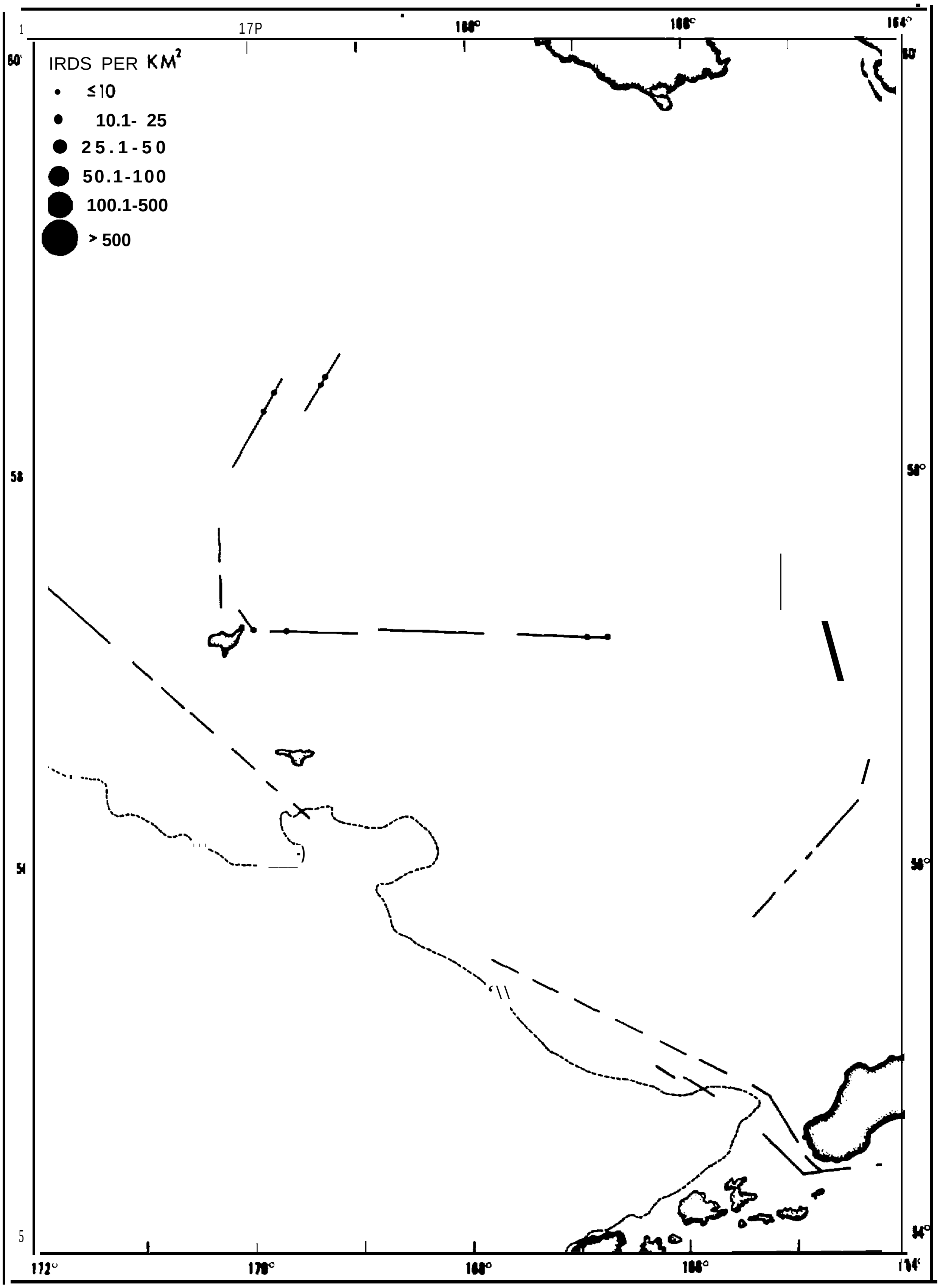
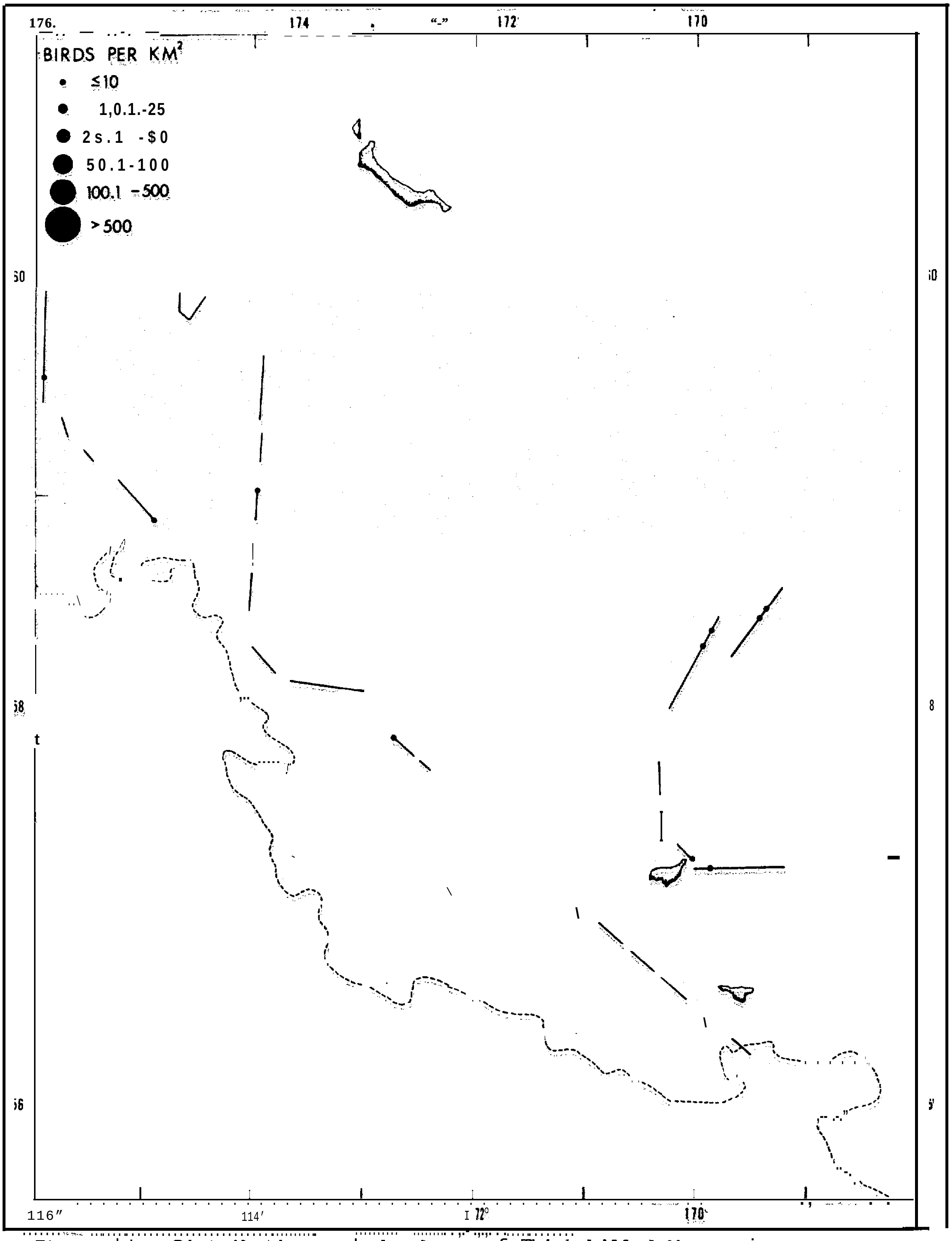


Figure 63. Distribution and abundance of Thick-billed Murres in southern Bering Sea from 4 to 17 April, 19 to 2.5 April and 30 April to 1 May 1977.



Fi gure b!+, Distribution and abundance of Thick-billed Murres in central Bering Sea "from 22 to 30 April 1977.

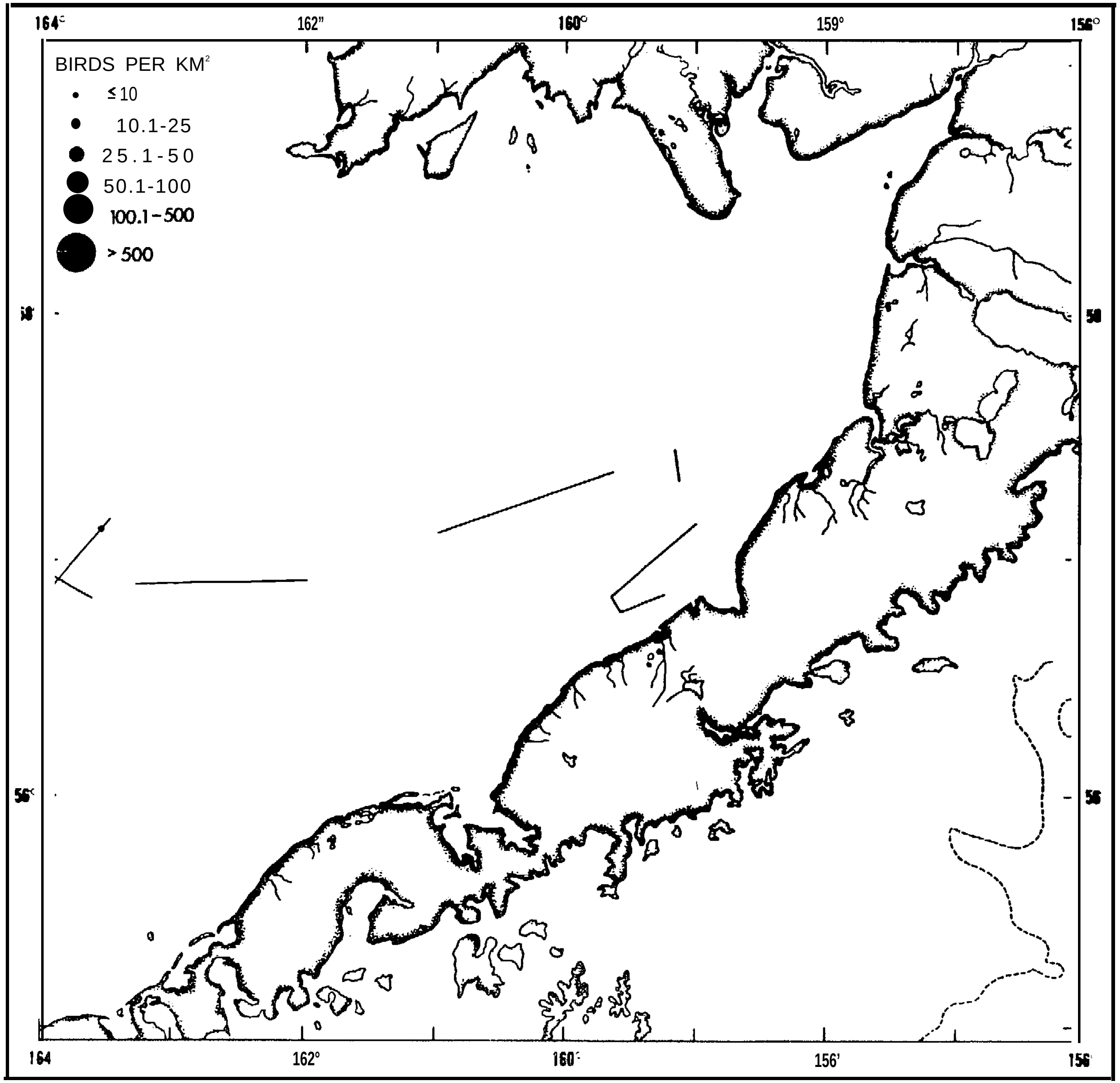


Figure 65. Distribution and abundance of Thick-billed Murres in Bristol Bay from 17 to 19 April 1977.

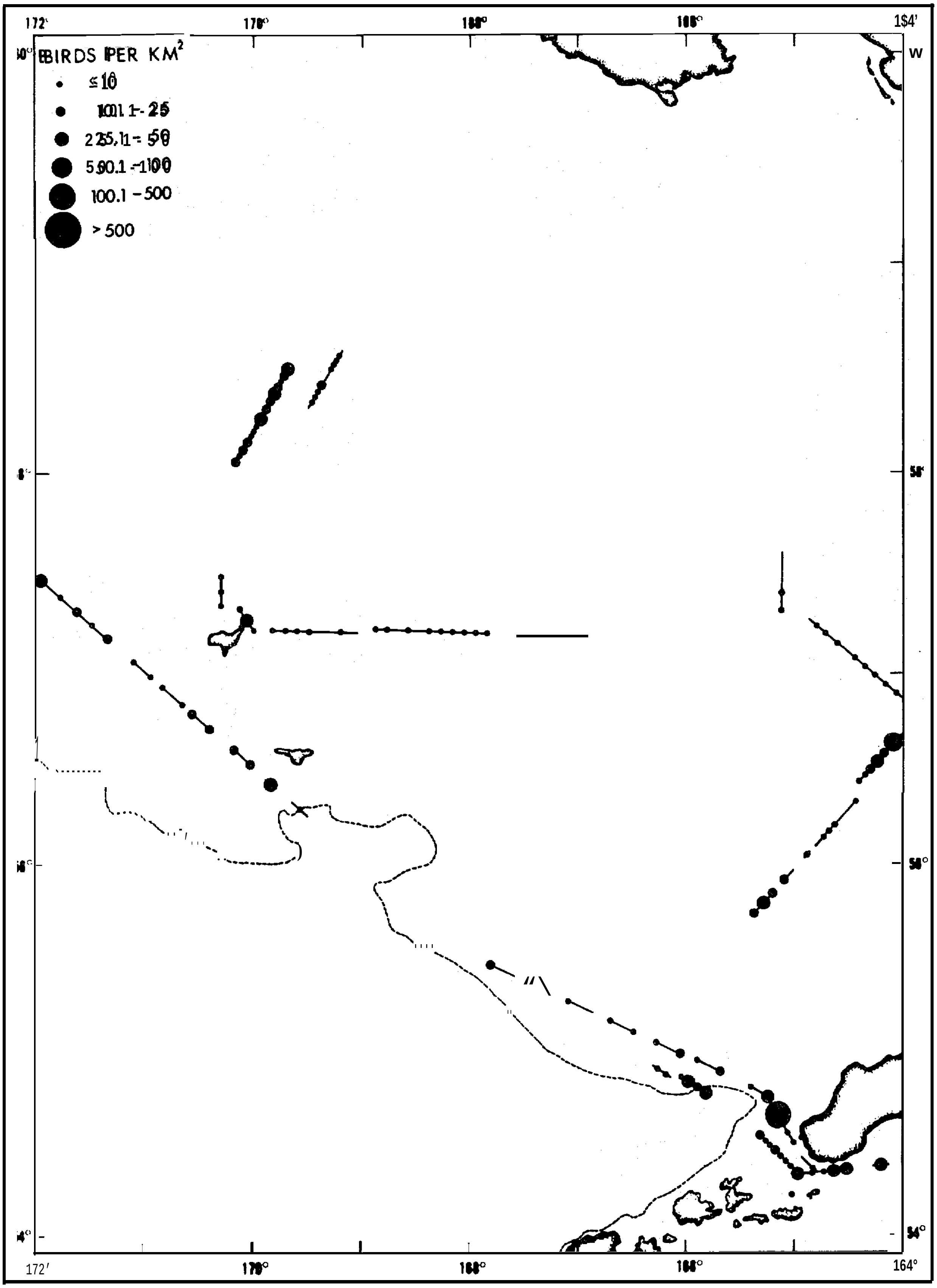


Figure 66, Distribution and abundance of all murres in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

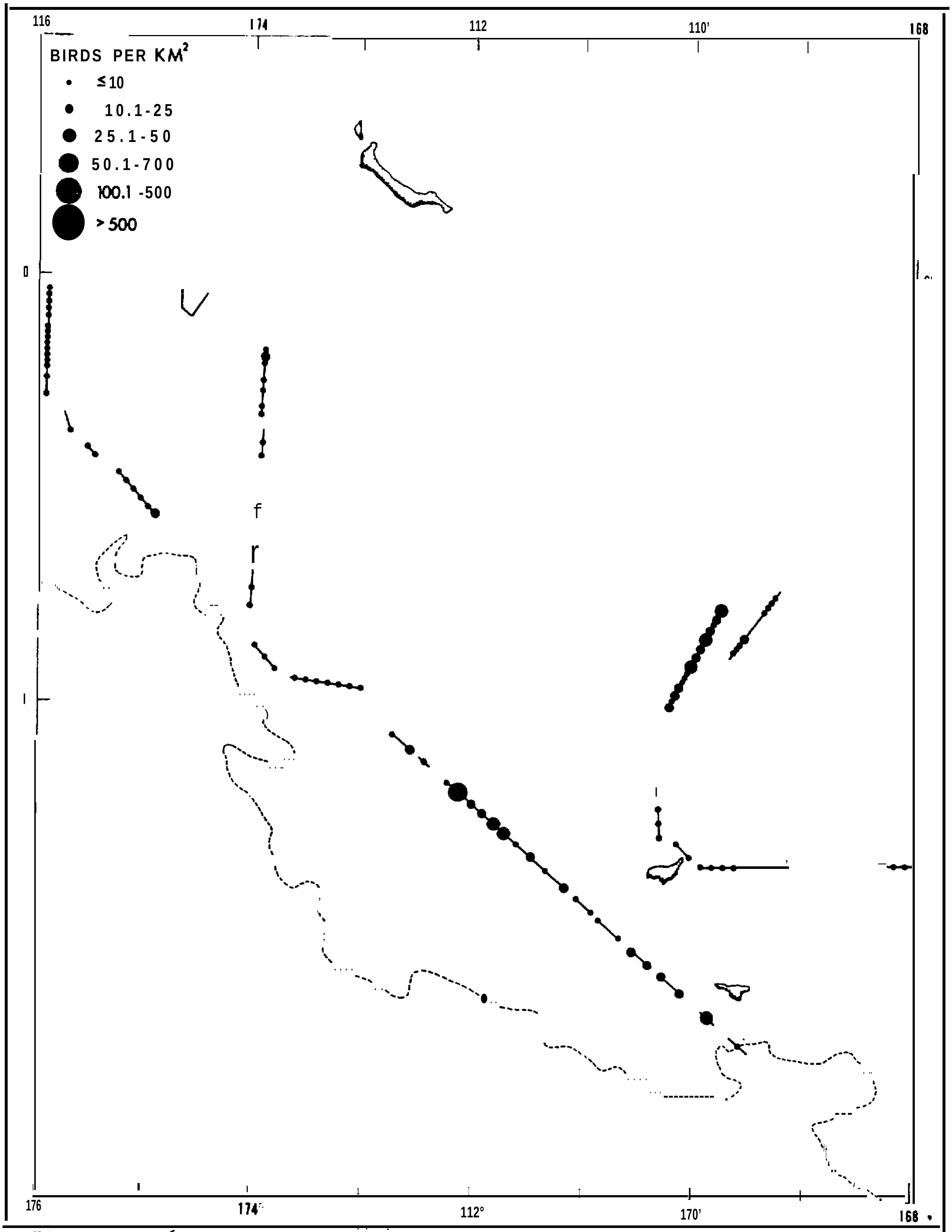


Figure 61. Distribution and abundance of all murres in central Bering Sea from 22 to 30 April 1977.

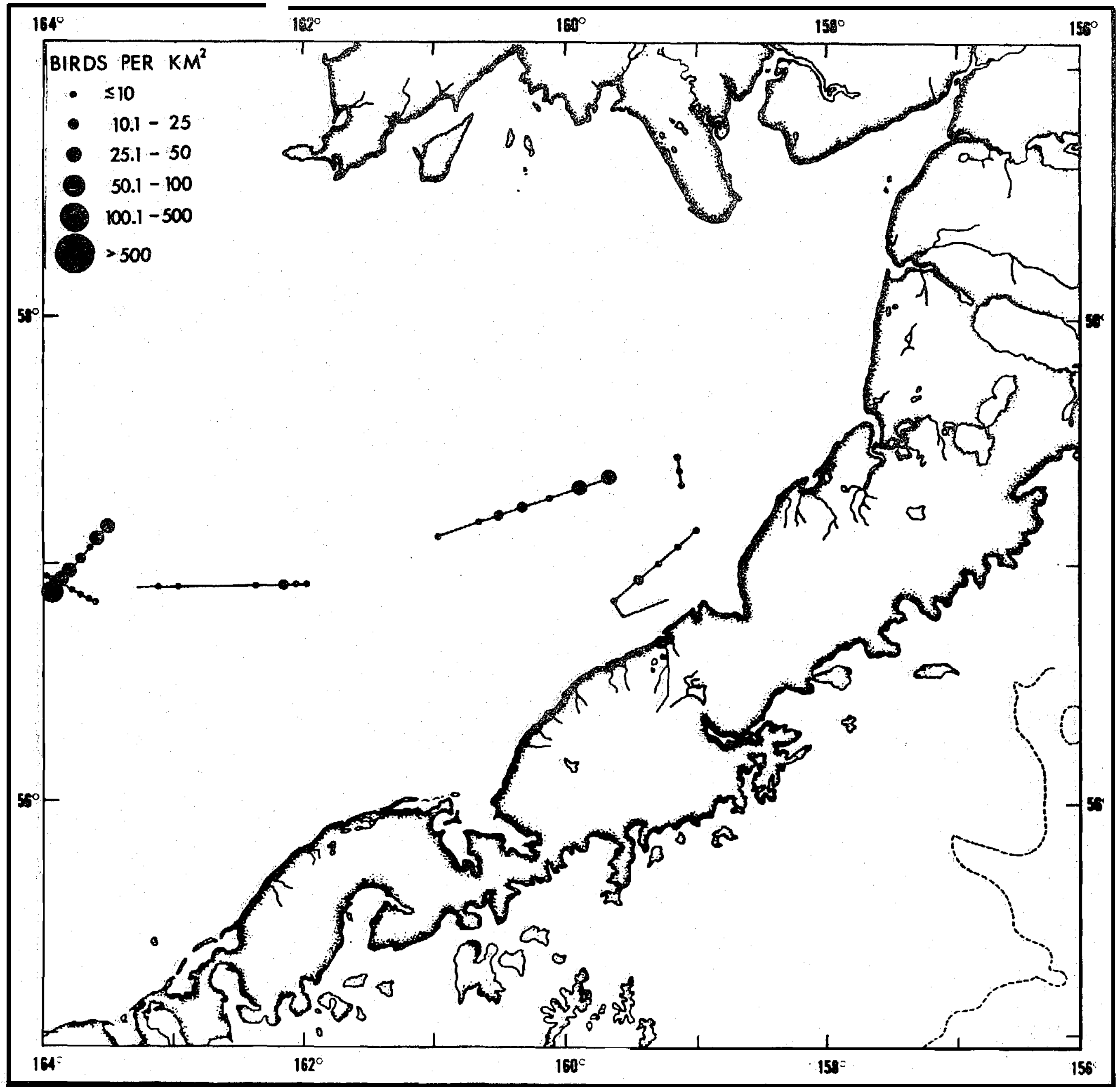


Figure 68. Distribution and abundance of all murres in Bristol Bay from 17 to 19 April 1977.

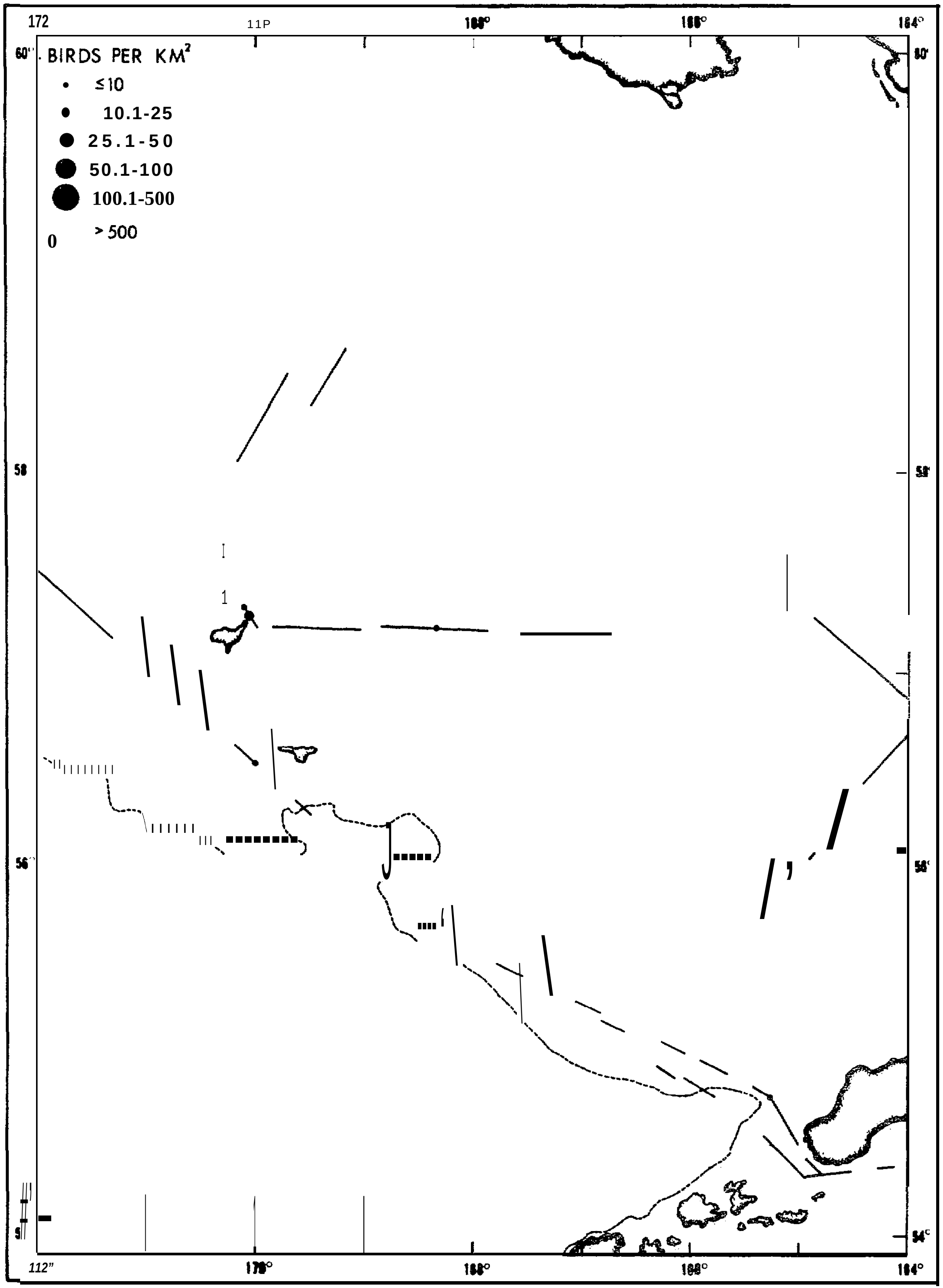


Figure 69. Distribution and abundance of Parakeet Auklets in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

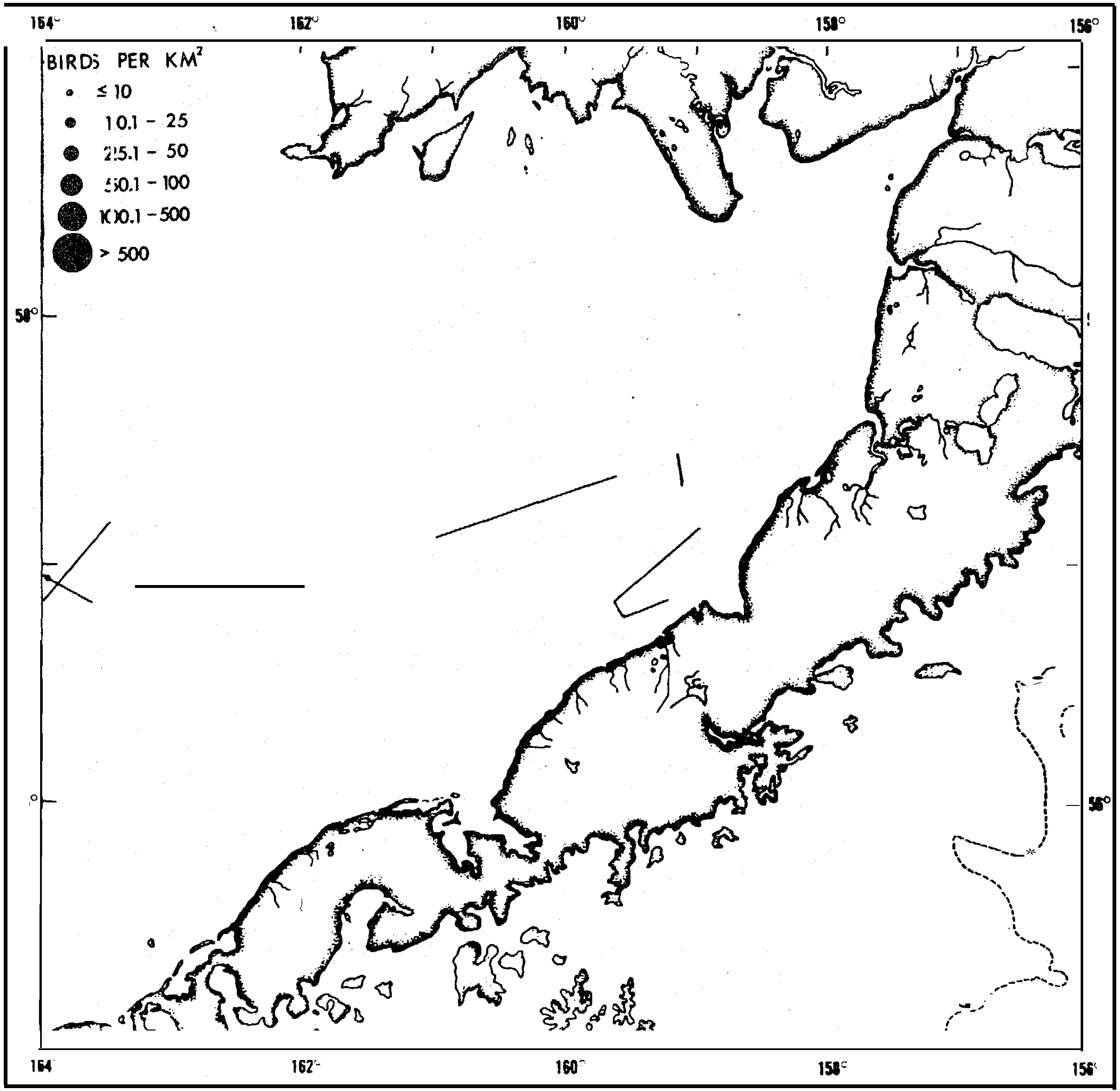


Figure 70 Distribution and abundance of Parakeet Auklets in Bristol Bay from 17 to 19 April 1977.

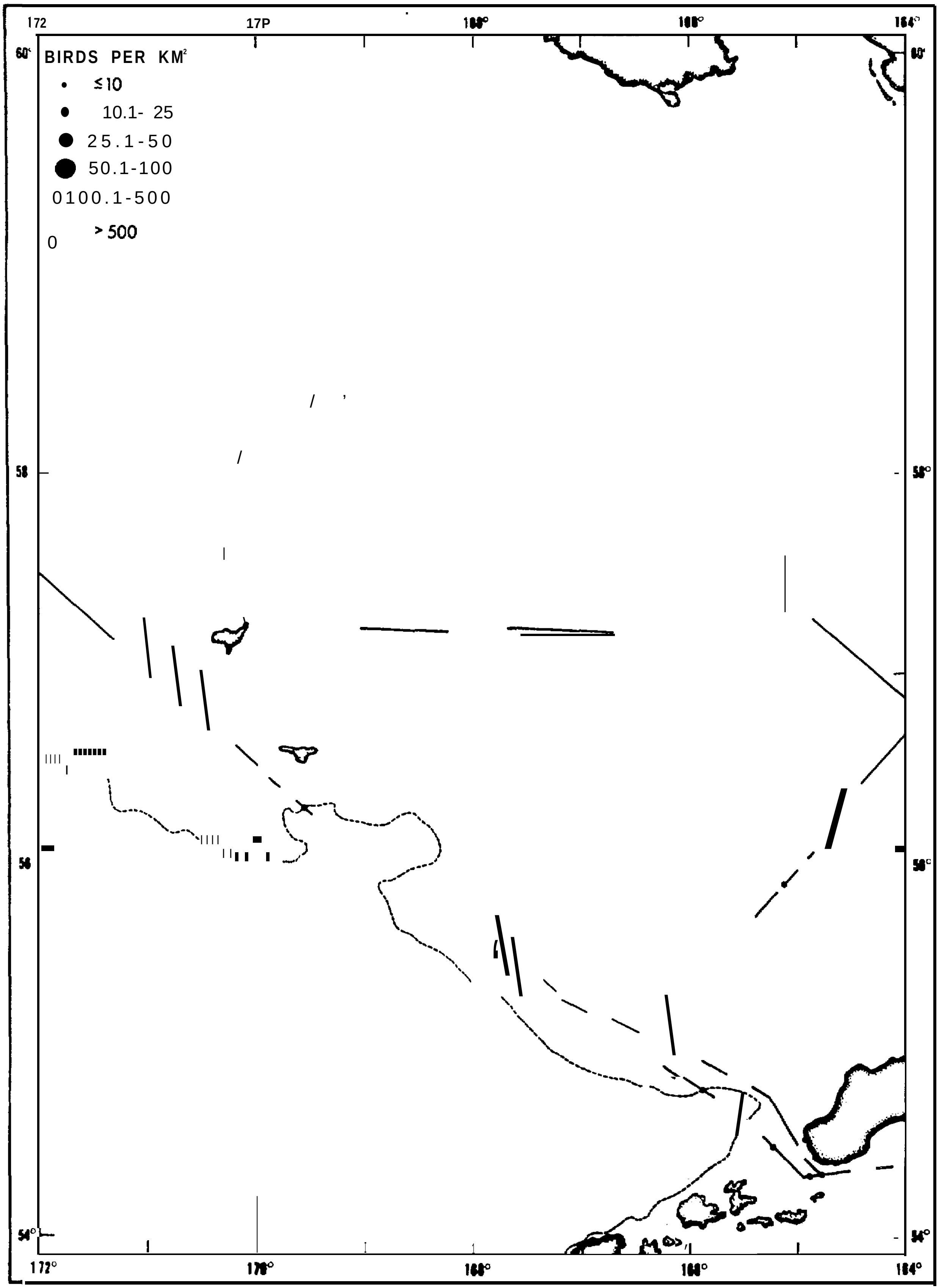


Figure 71. Distribution and abundance of Crested Auklets in southern Bering Sea from 4 to 17 April, 19 to 25 April, and 30 April to 1 May 1977.

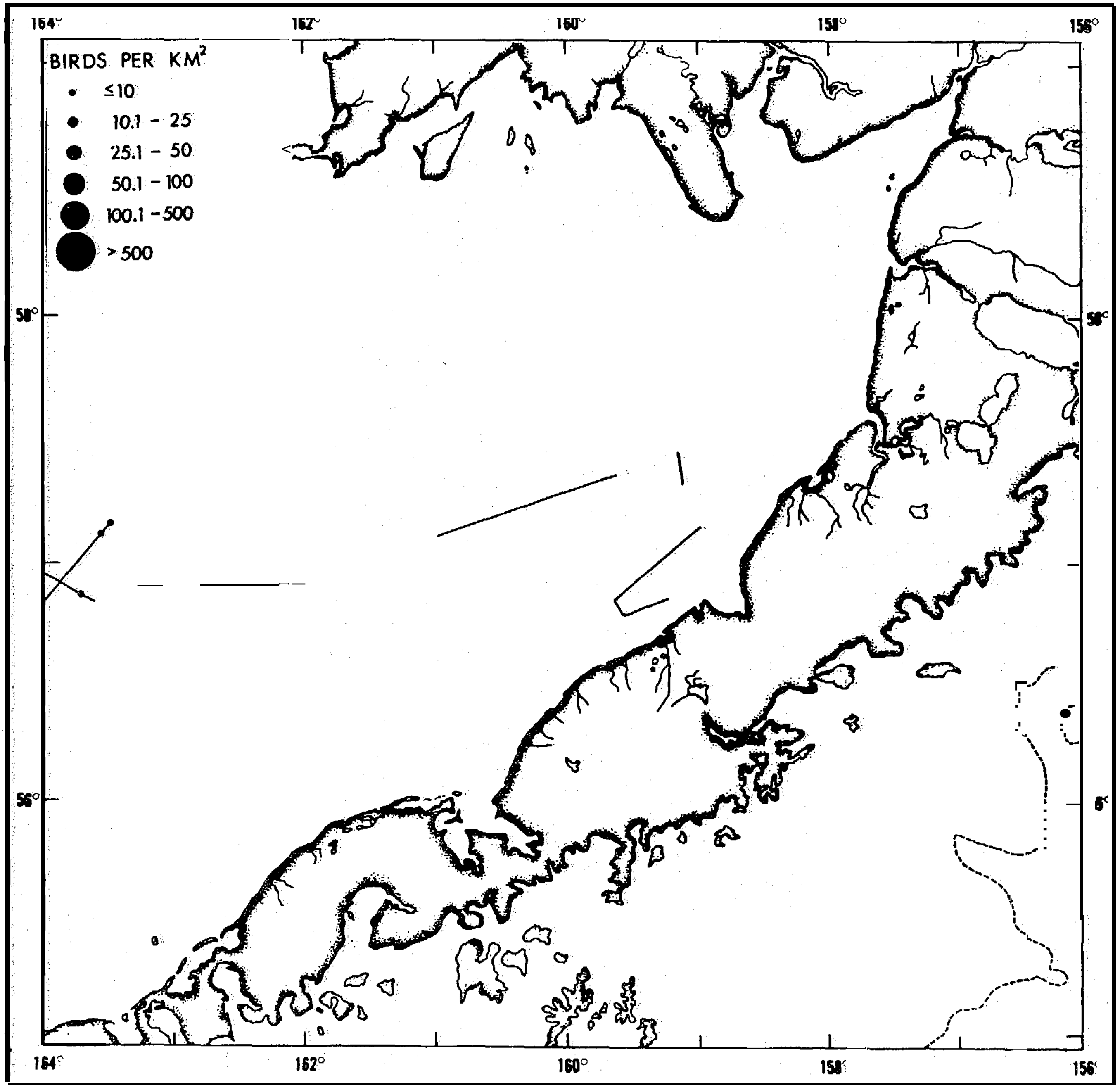


Figure 12. Distribution and abundance of Crested Auklets in Bristol Bay from 17 to 19 April 1977.

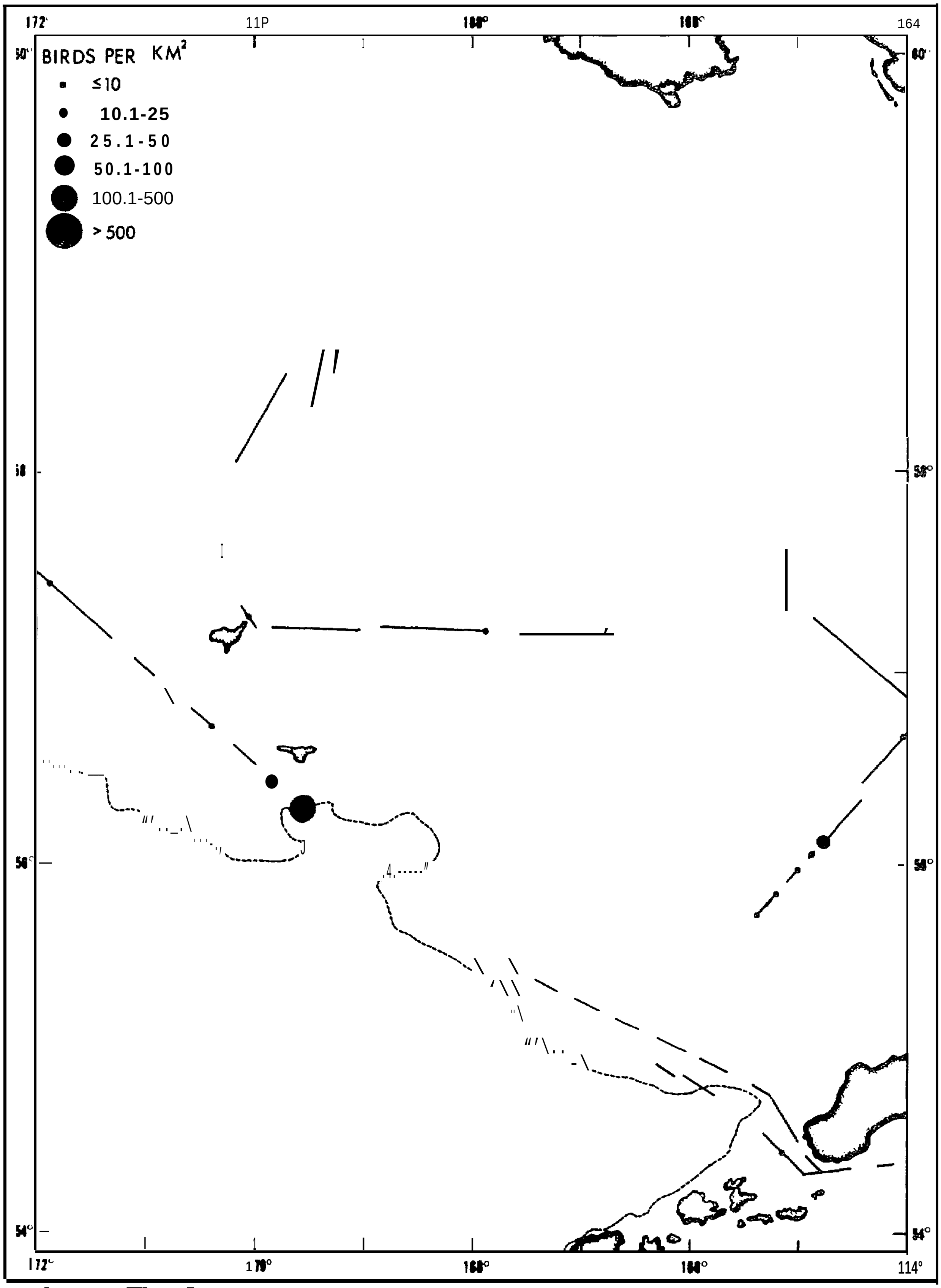


Figure 73. Distribution and abundance of Least Auklets in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

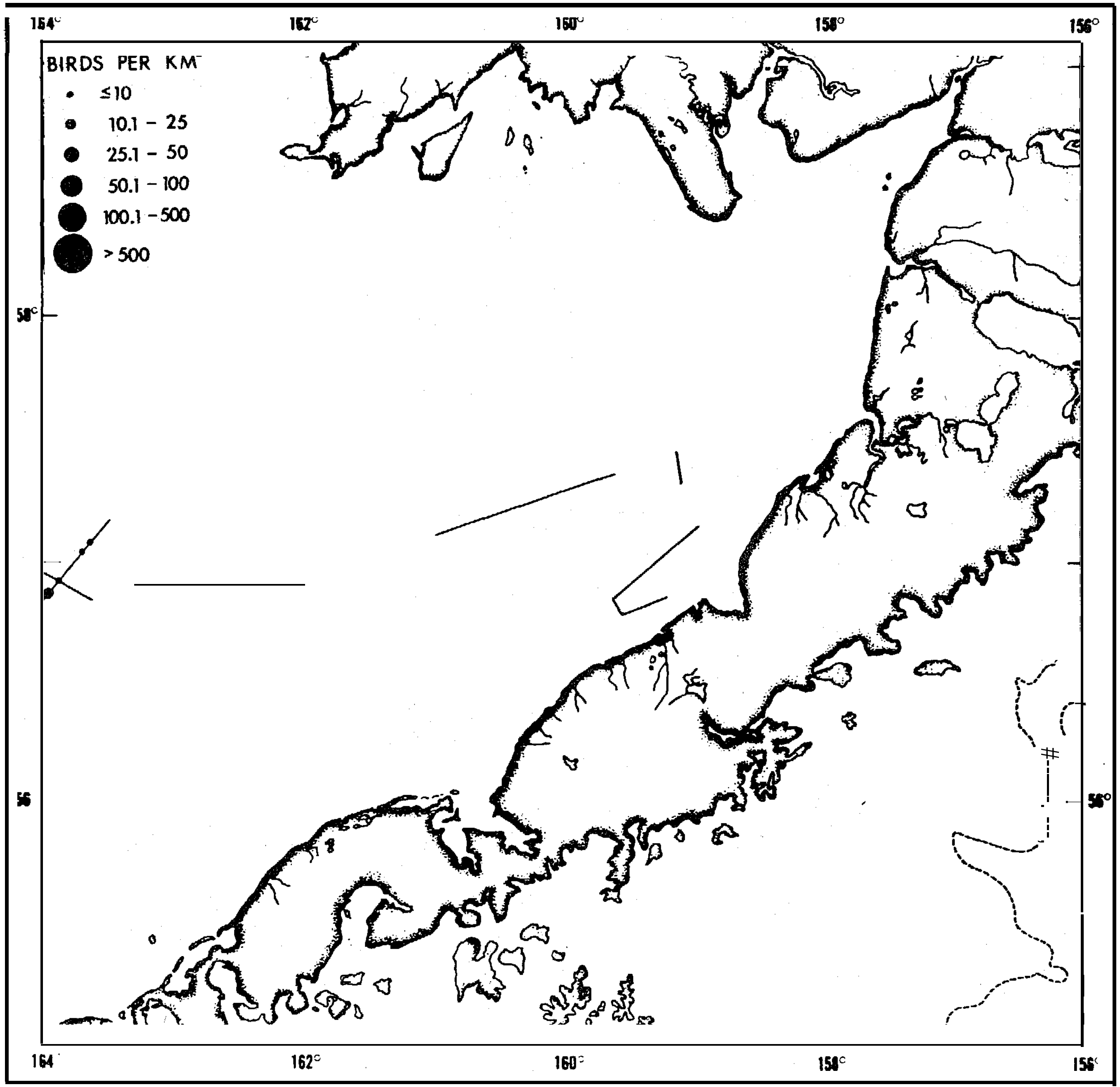


Figure 74. Distribution and abundance of Least Auklets in Bristol Bay from 17 to 19 April 1977.

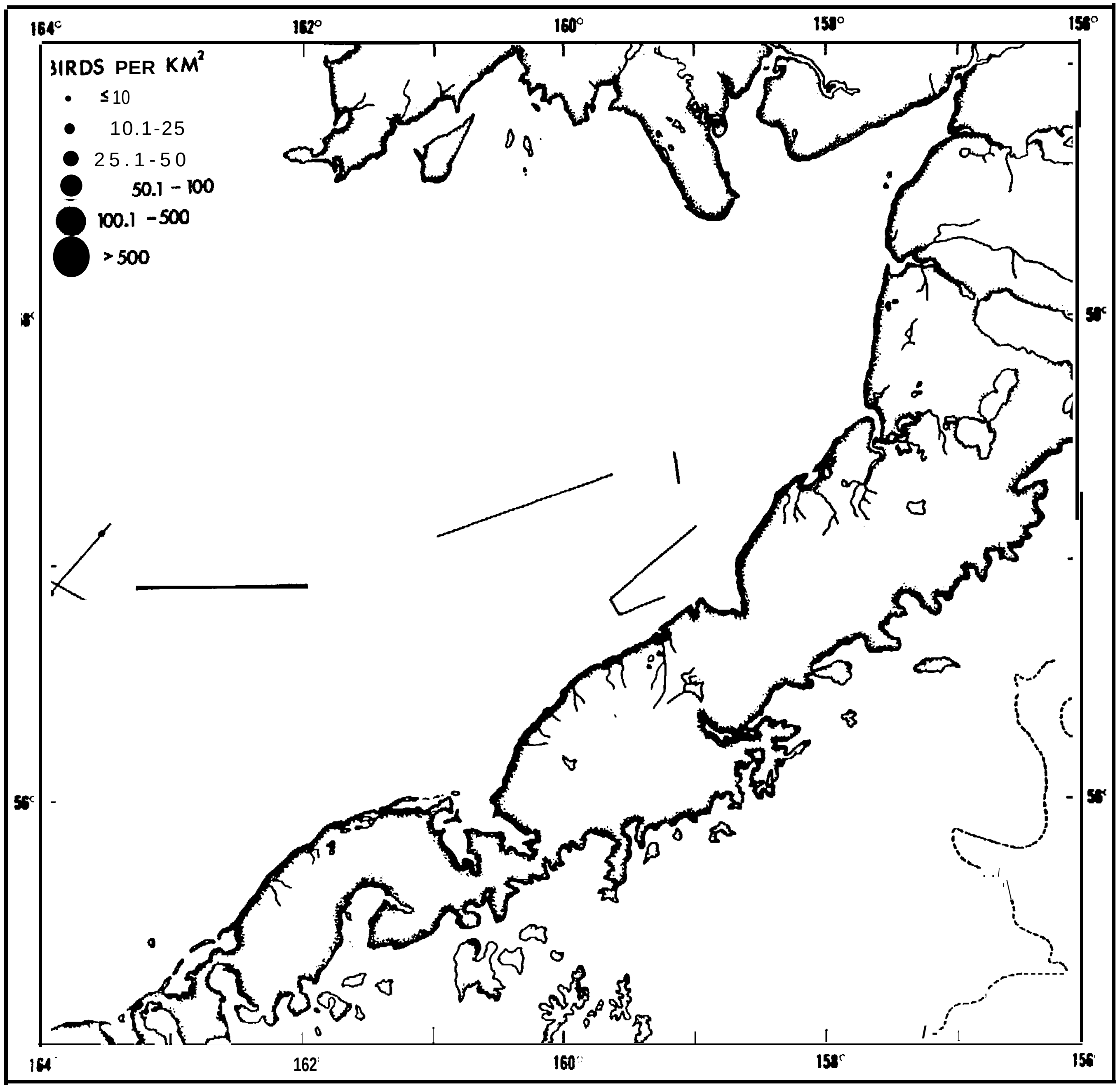


Figure 76. Distribution and abundance of unidentified small dark alcids in Bristol Bay from 17 to 19 April 1977.

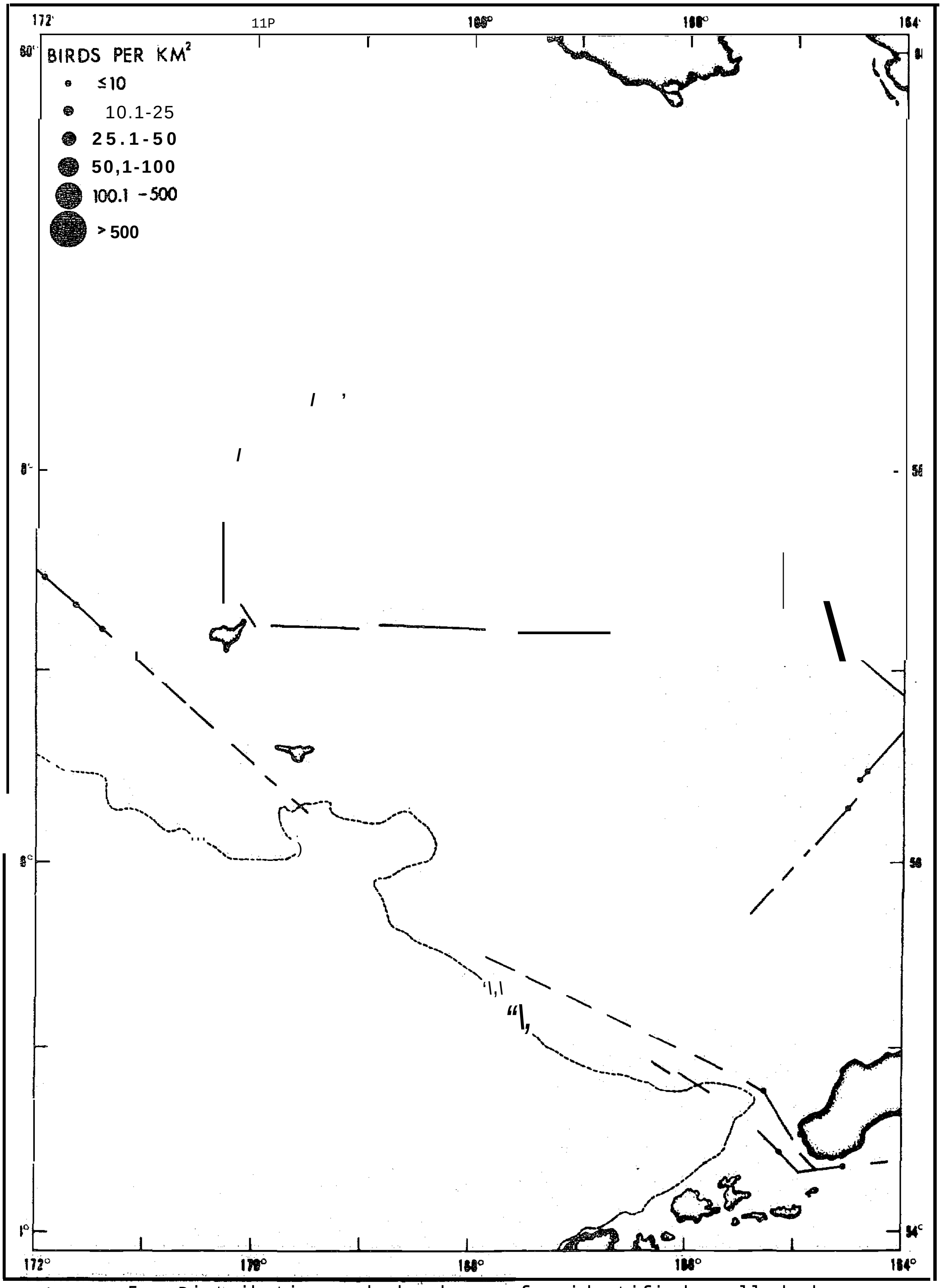


Figure- 7 5. Distribution and abundance of unidentified small dark alcids in southern Bering Sea from 4 to 17 April, 19 to 25 April and 30 April to 1 May 1977.

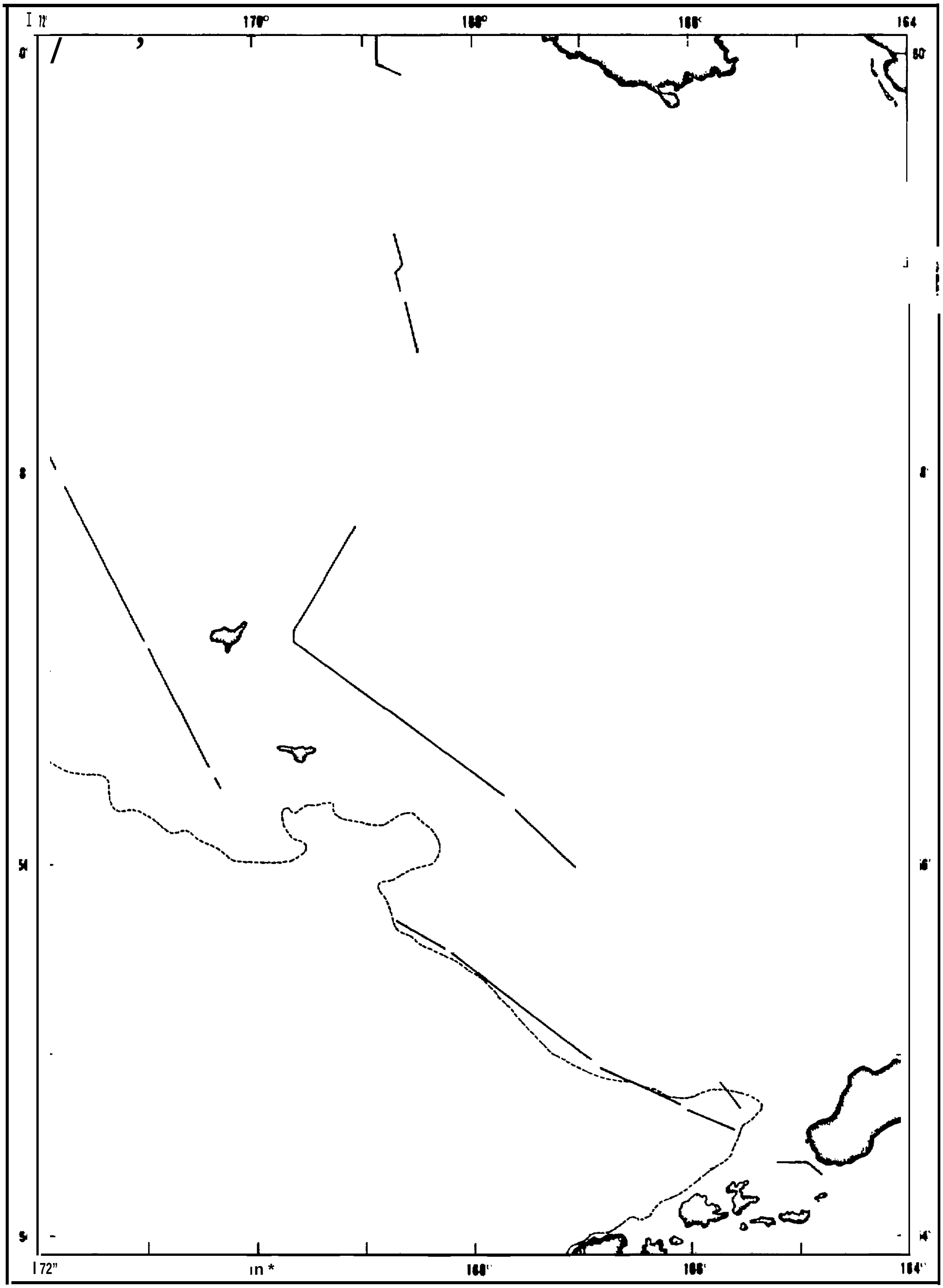


Figure 77. Cruise track during periods of observation in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June. and from 8 to 10 June 1977.

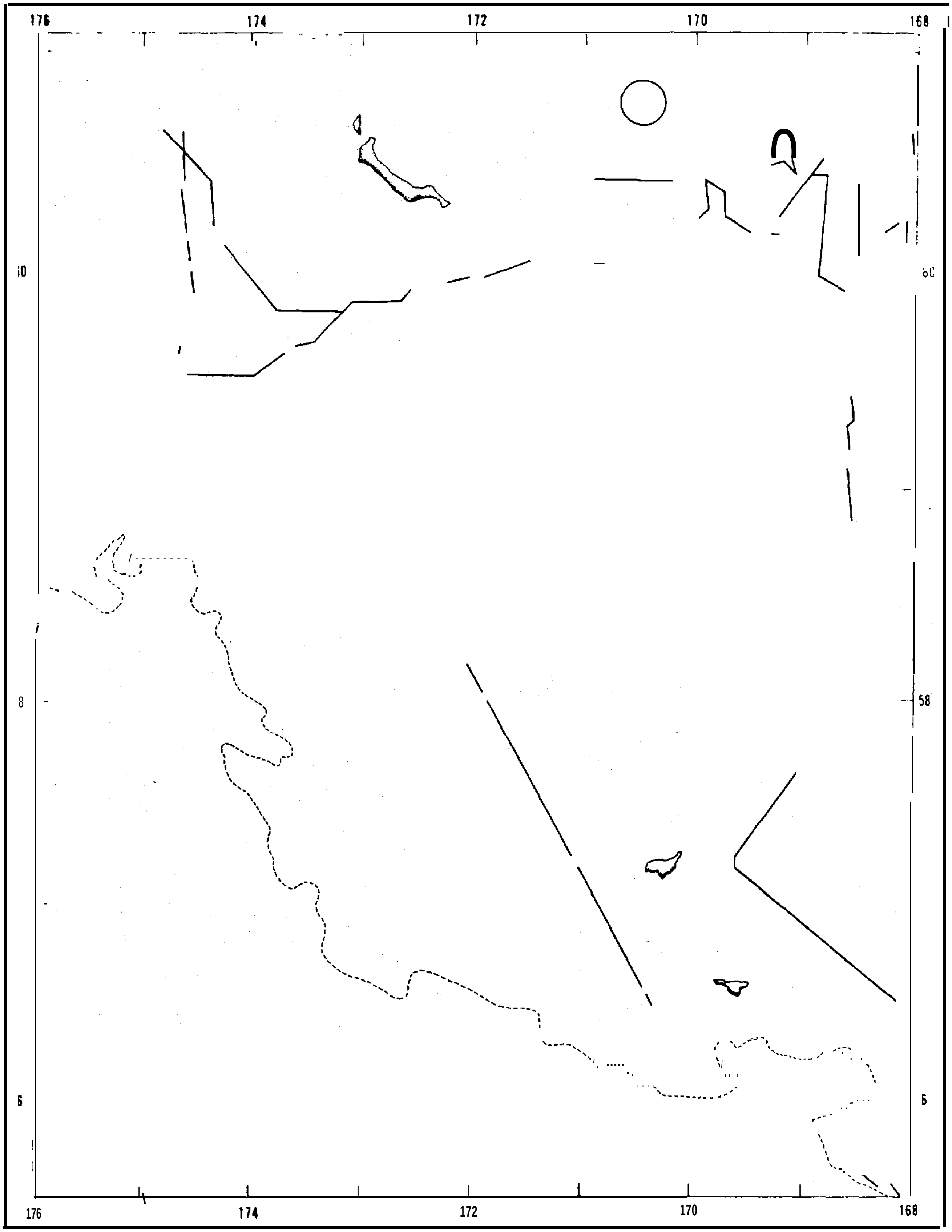


Figure 78. Cruise track during periods of observation in central Bering Sea from 23 May to 9 June 197'7.

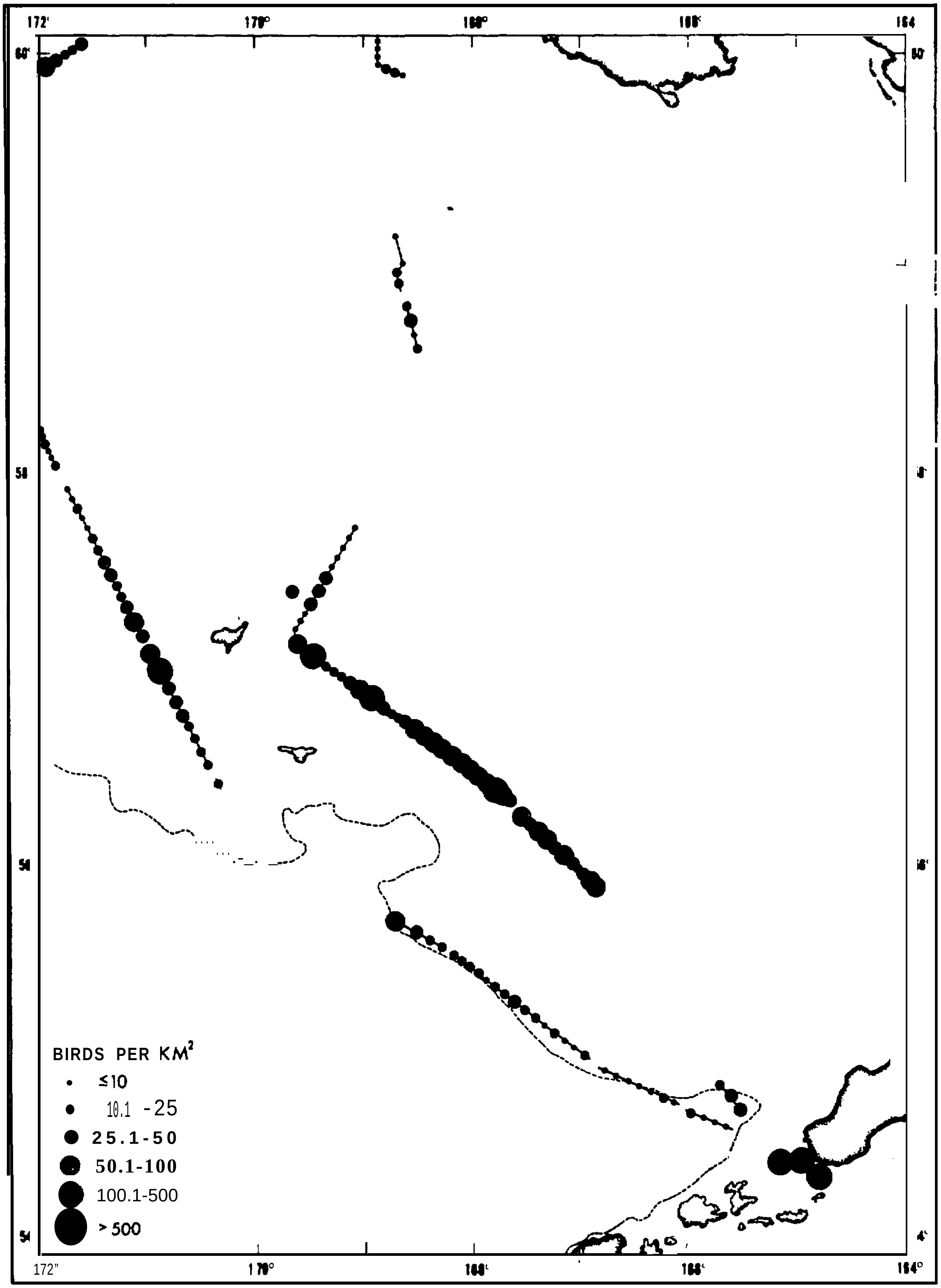


Figure 79. Distribution and abundance of seabirds in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

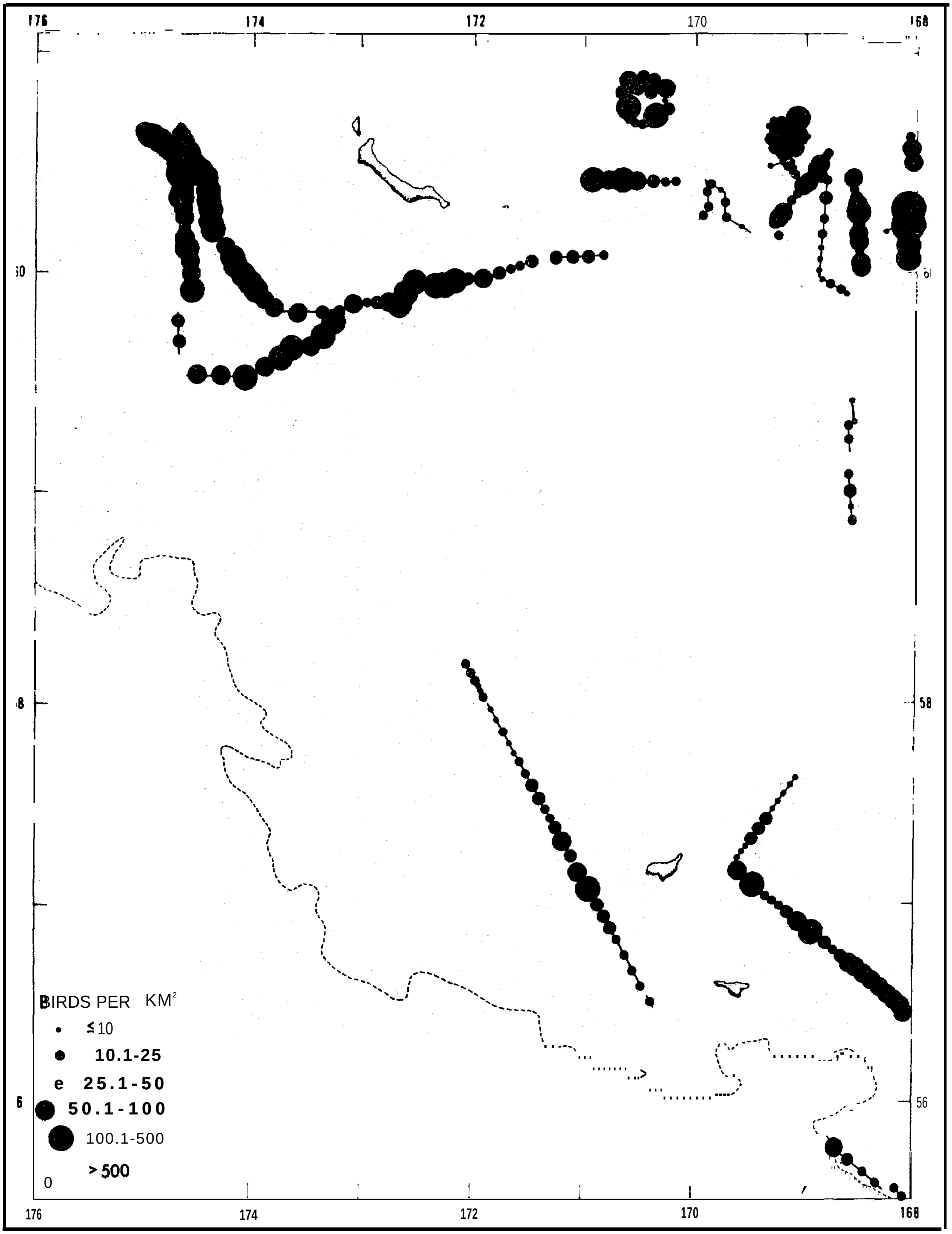


Figure 80. Distribution and abundance of seabirds in central Bering Sea from 23 May to 9 June 1977.

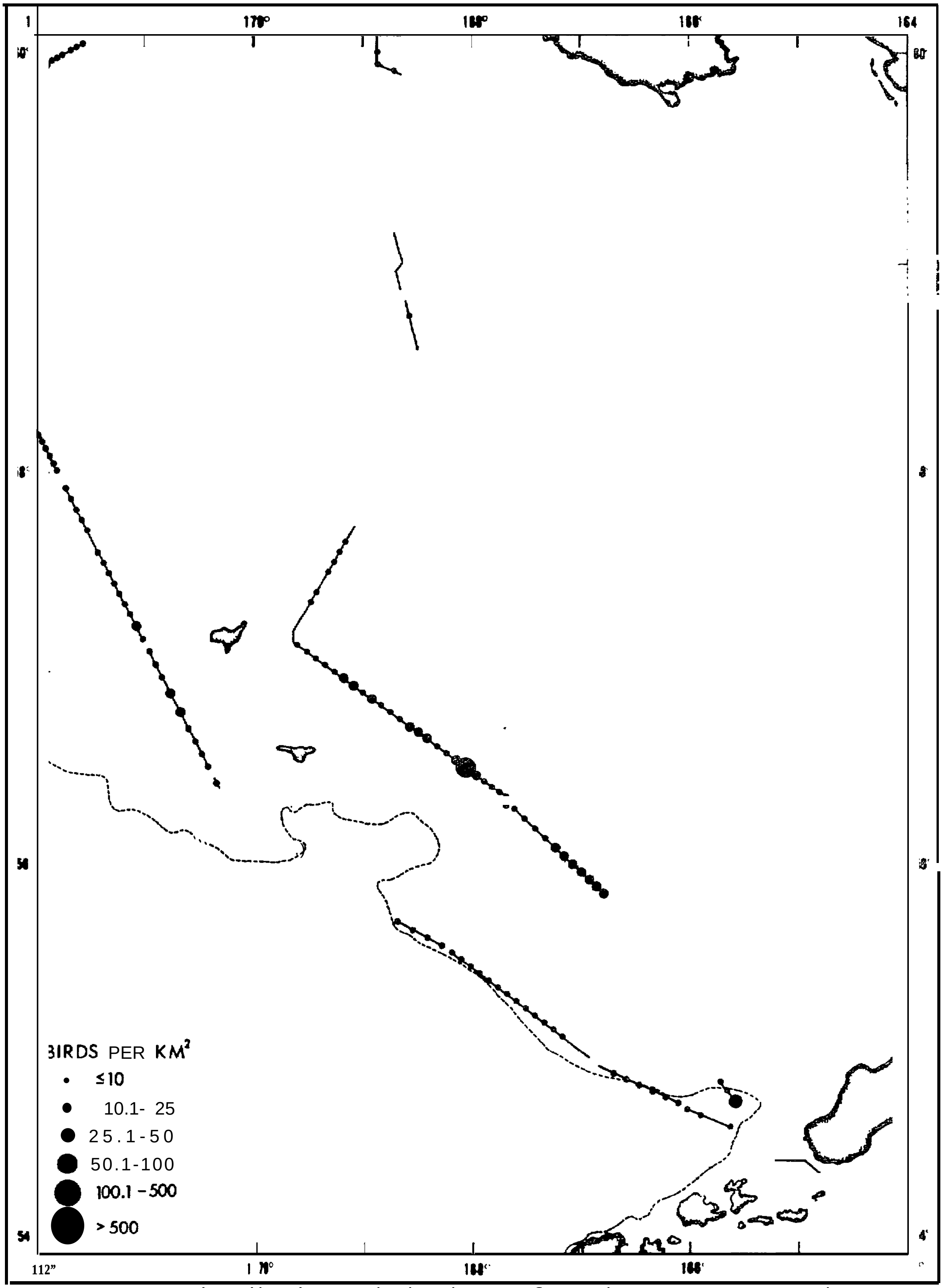


Figure 81. Distribution and abundance of Northern Fulmars in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

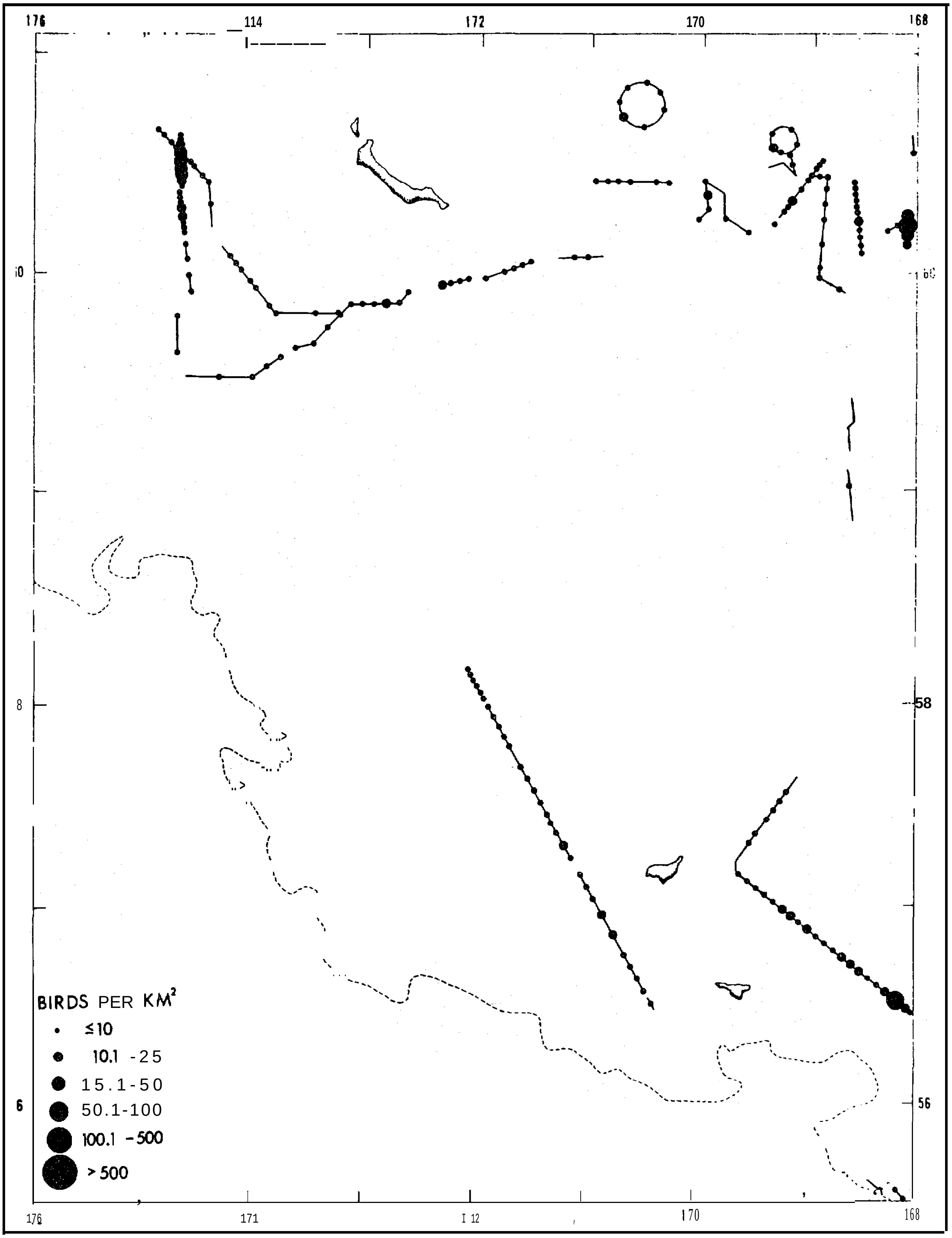


Figure 82. Distribution and abundance of Northern Fulmars in central Bering Sea from 23 May to 9 June 1977.

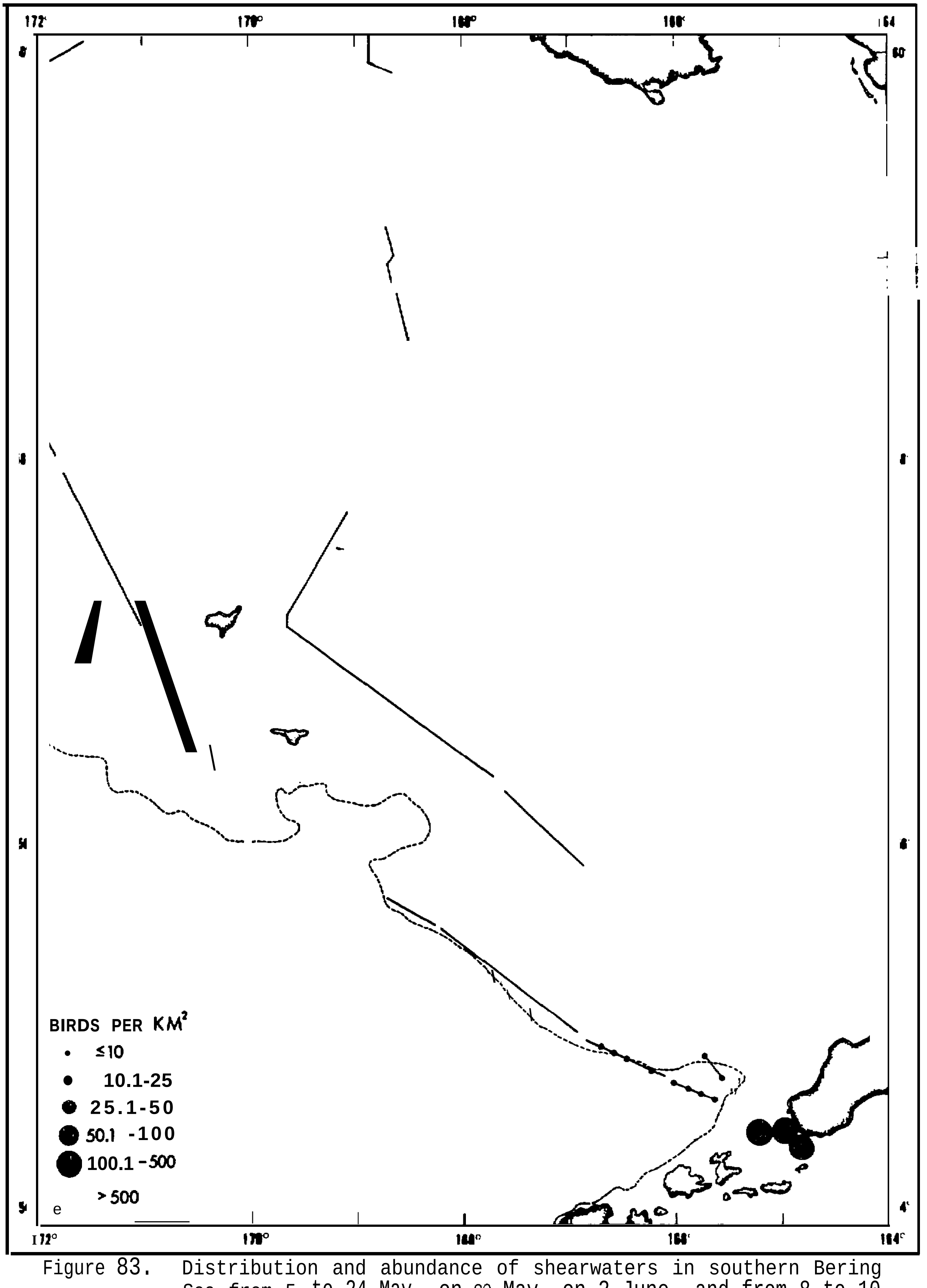


Figure 83. Distribution and abundance of shearwaters in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 19'77.

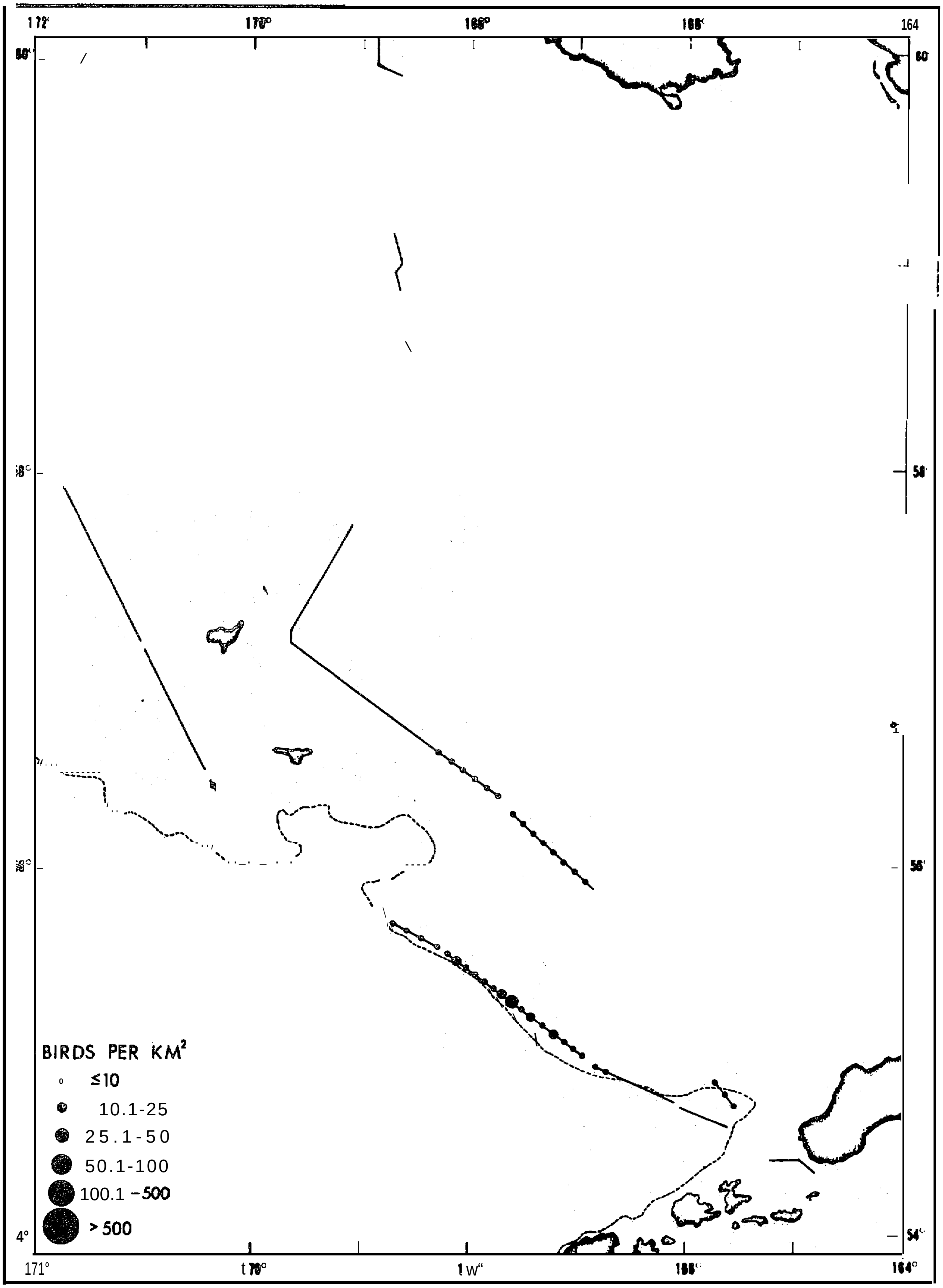


Figure 84. Distribution and abundance of Fork-tailed Storm Petrels in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

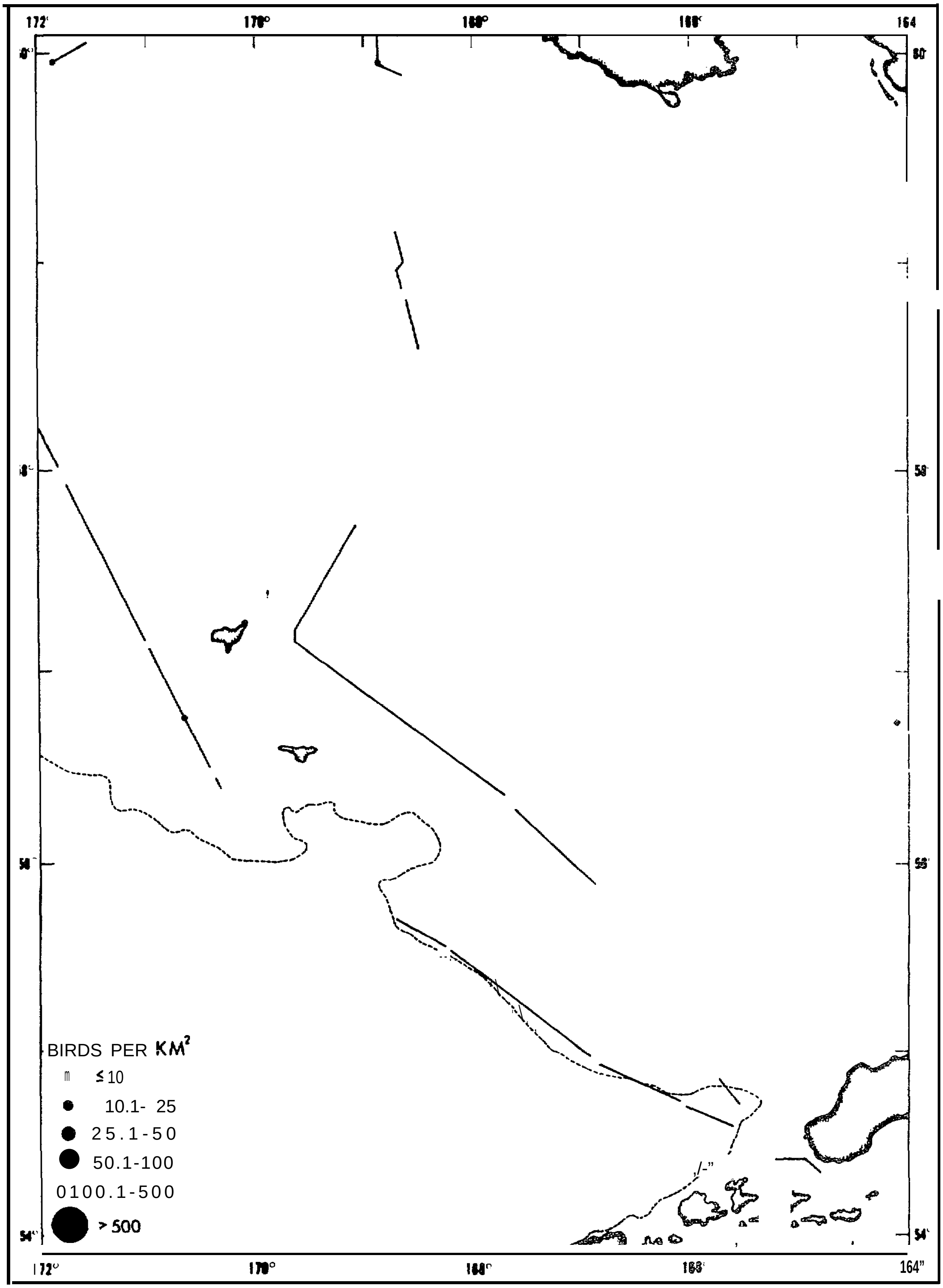


Figure 85. Distribution and abundance of cormorants in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 19'77.

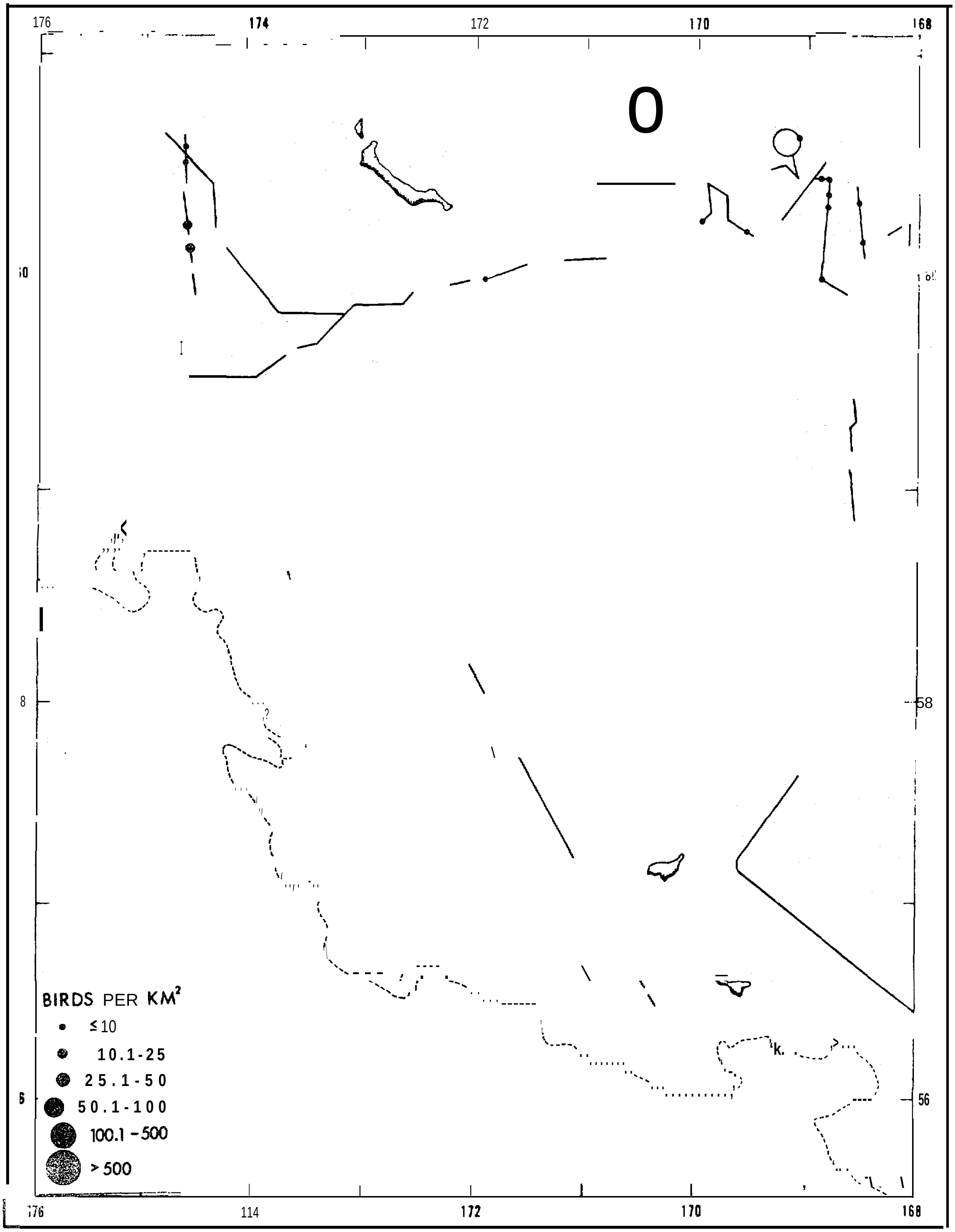


Figure 86. Distribution and abundance of cormorants in central Bering Sea from 23 May to 9 June 1977.

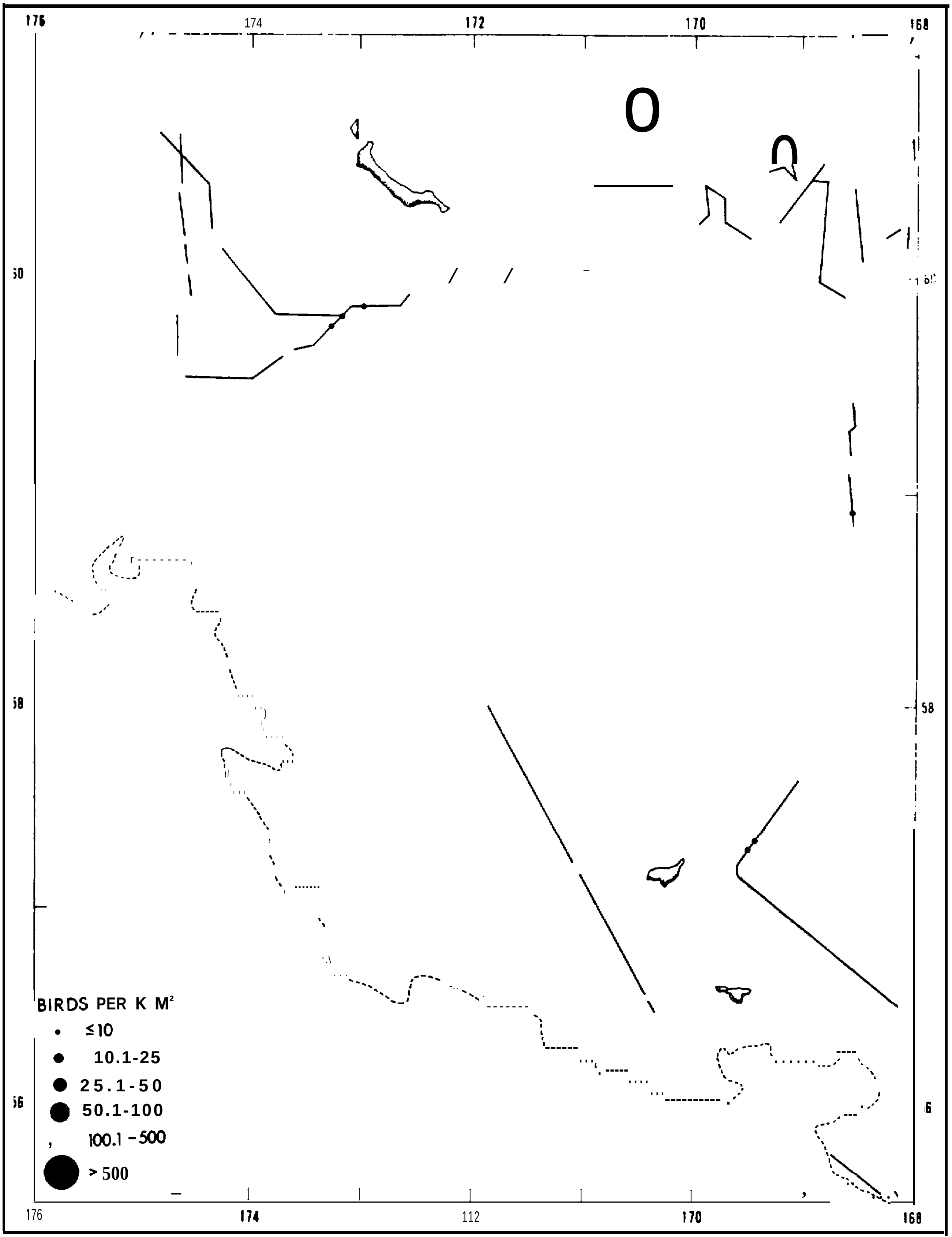


Figure 87. Distribution and abundance of Harlequin Ducks in central Bering Sea from 23 May to 9 June 1977.

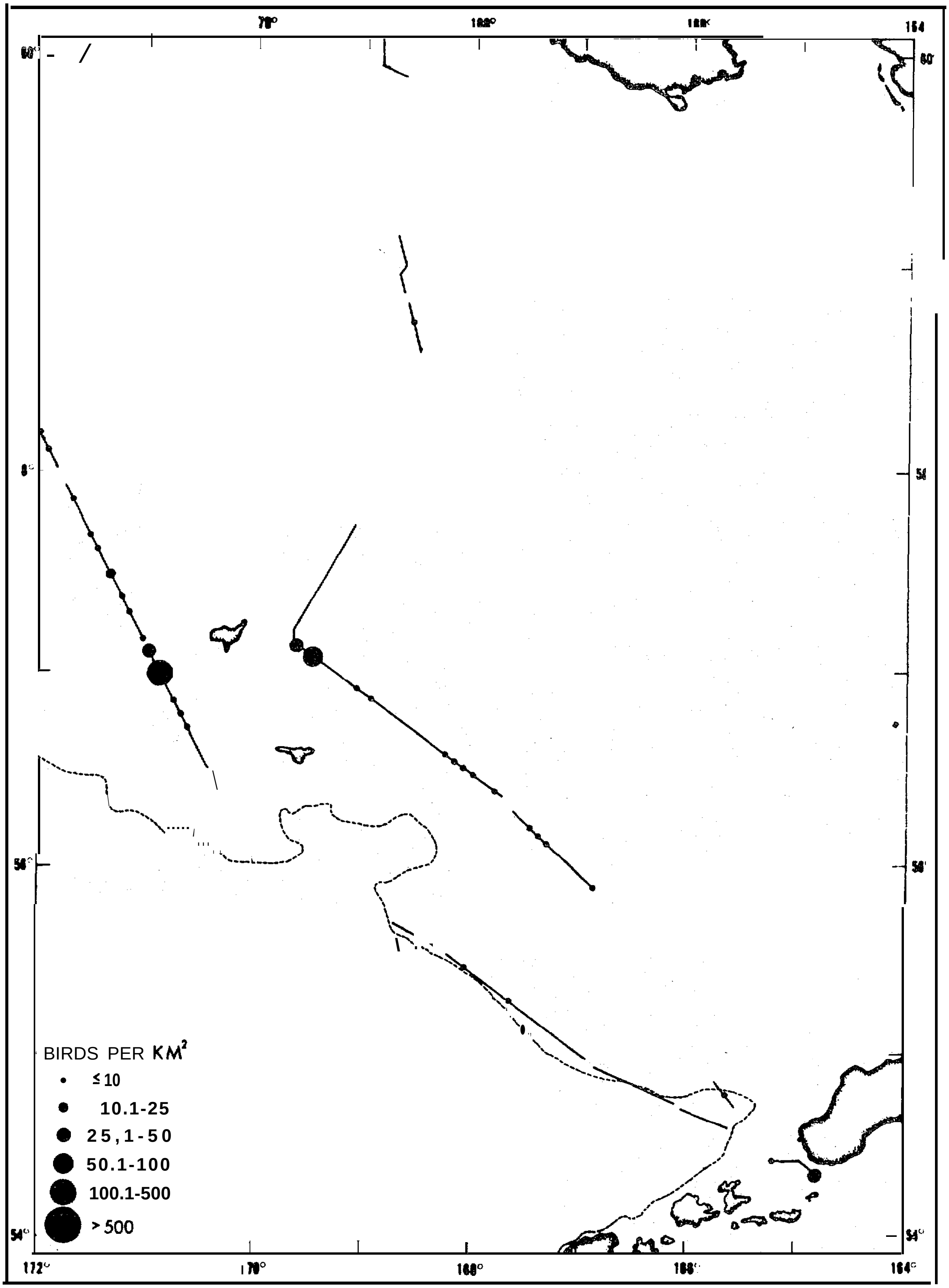


Figure 88. Distribution and abundance of phalaropes in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

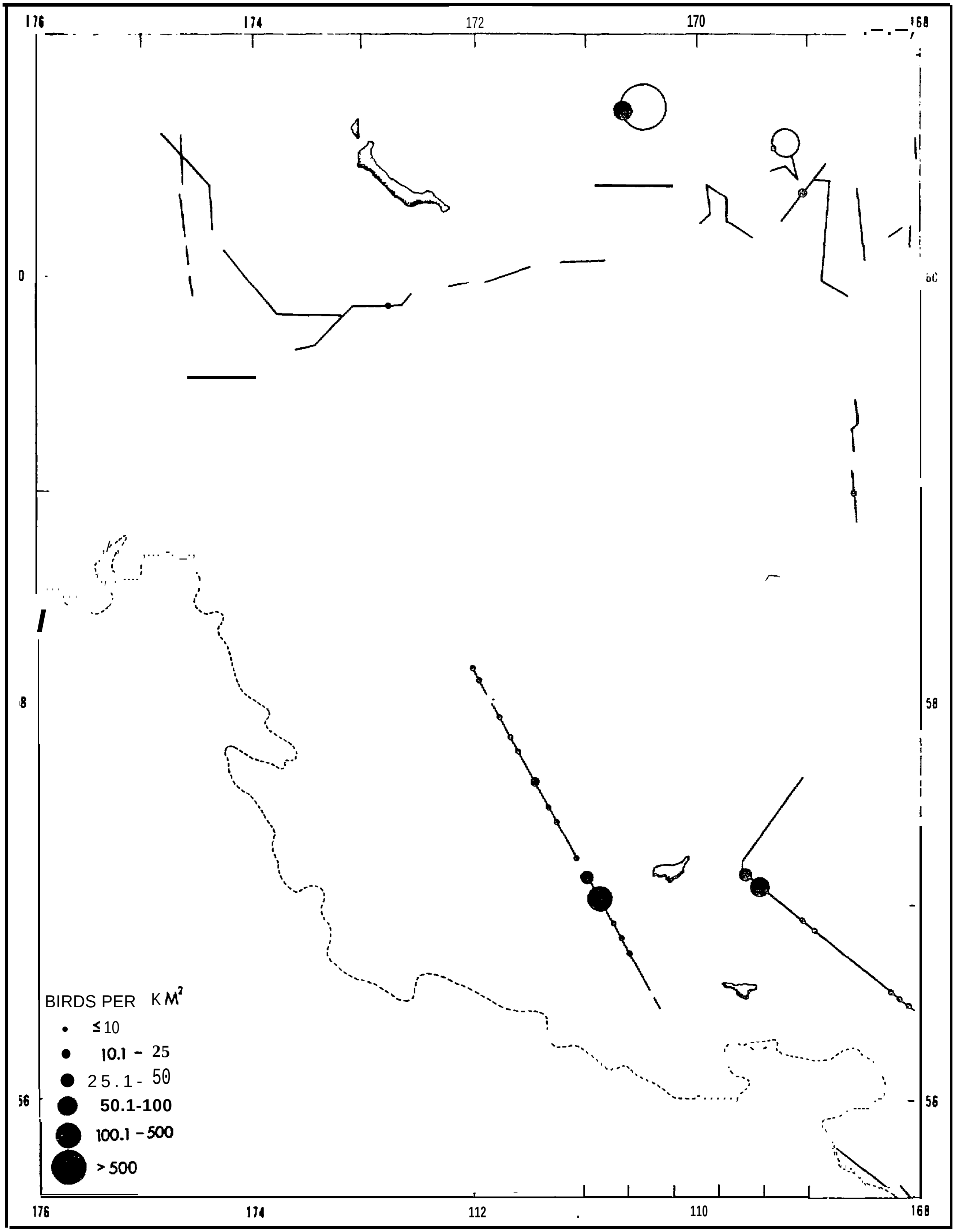


Figure 89. Distribution and abundance of phalaropes in central Bering Sea from 23 May to 9 June 1977.

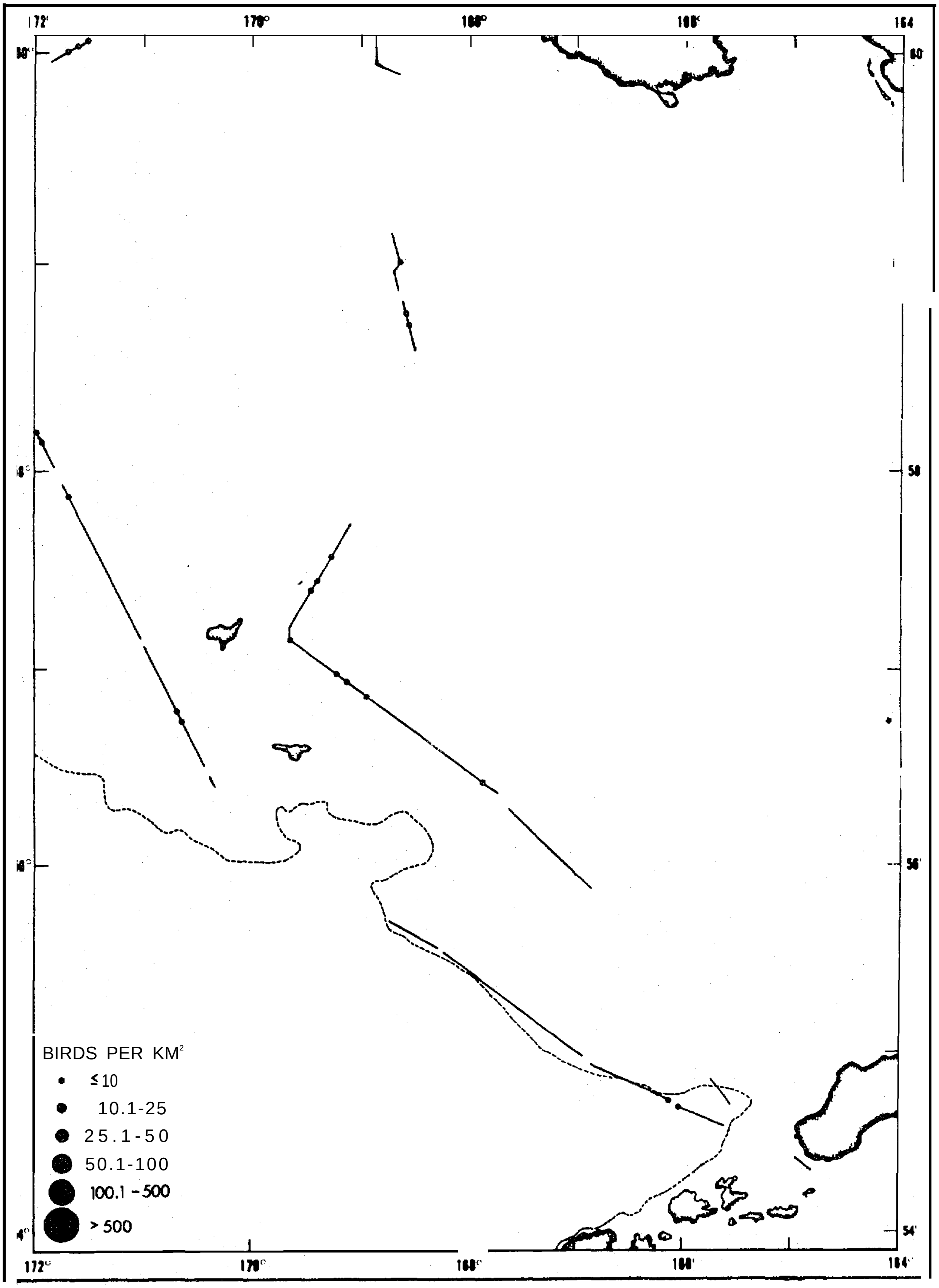


Figure 90. Distribution and abundance of Pomarine Jaegers in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June, and from 8 to 10 June 1977.

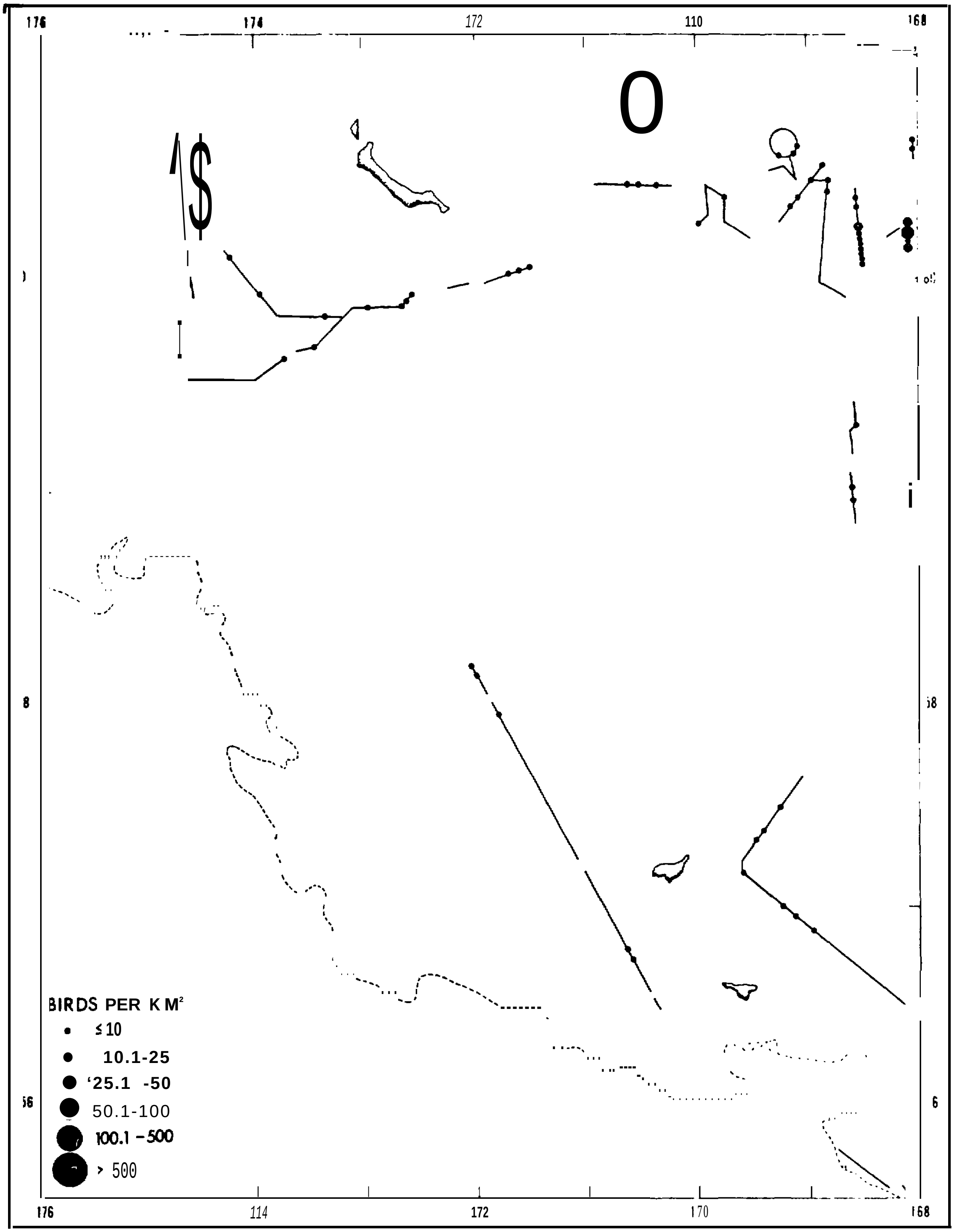


Figure 91. Distribution and abundance of Pomarine Jaegers in central Bering Sea from 23 May to 9 June 1977.

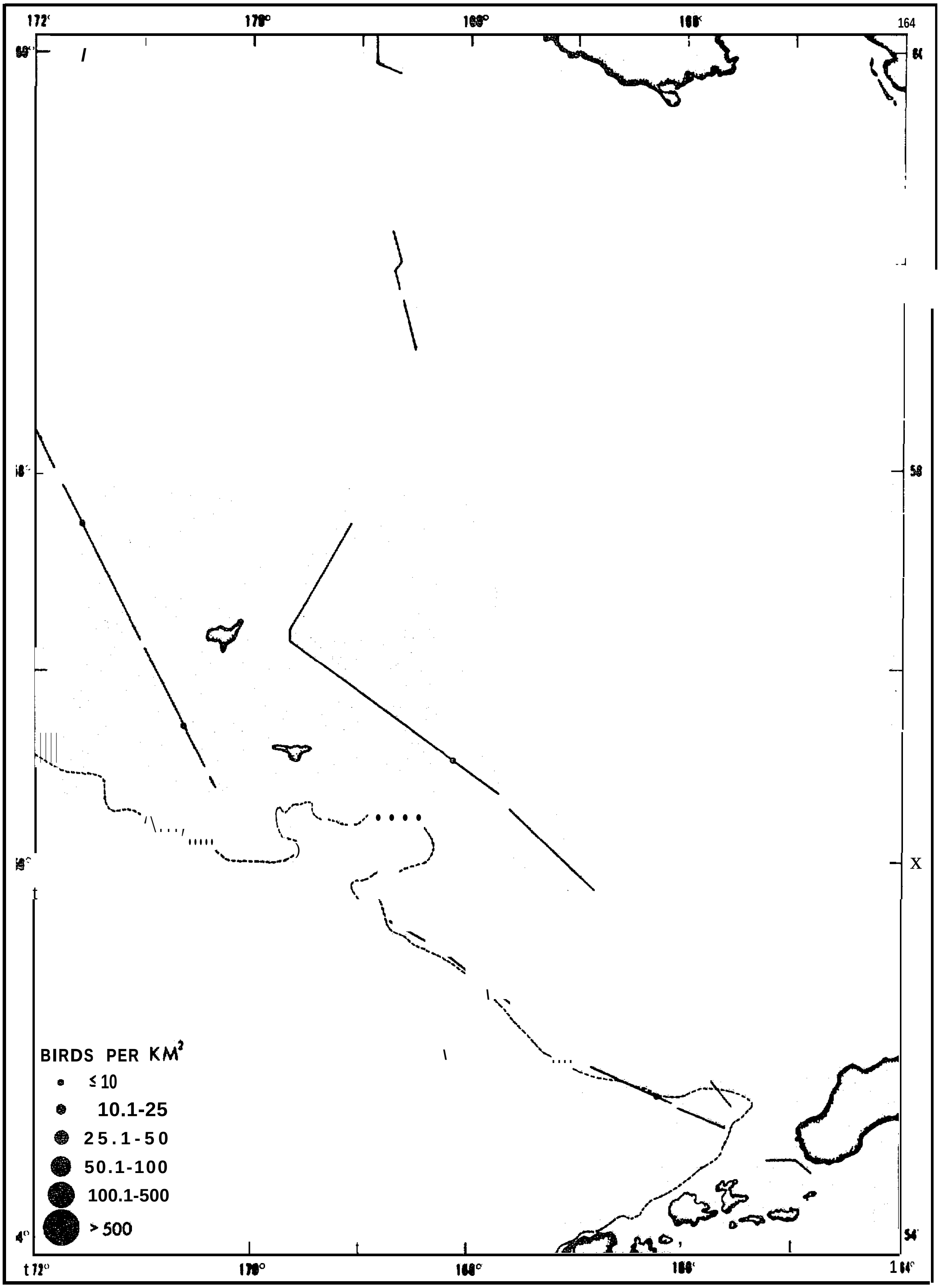


Figure 92. Distribution and abundance of Parasitic Jaegers in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

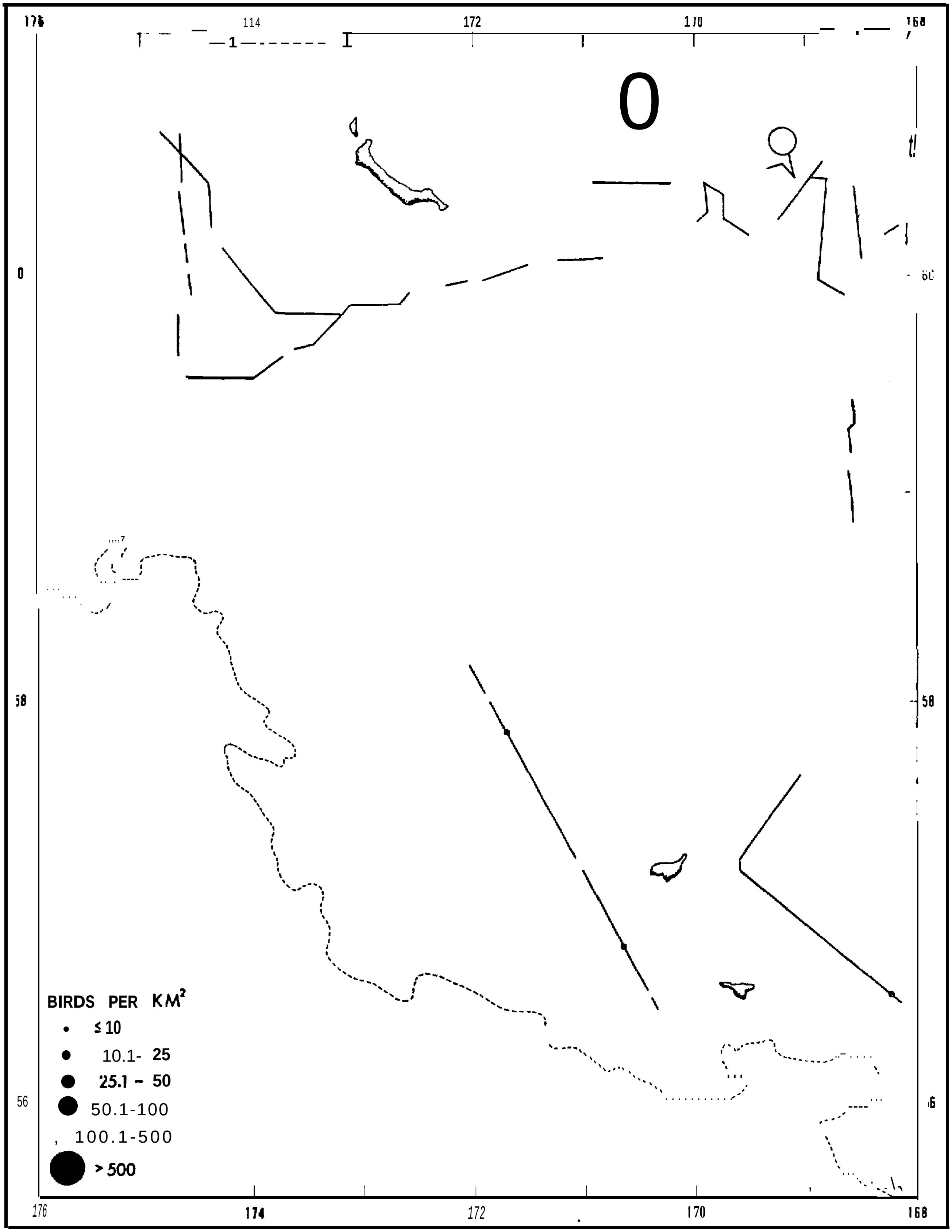


Figure 93. Distribution and abundance of Parasitic Jaegers in central Bering Sea from 23 May to 9 June 1977.

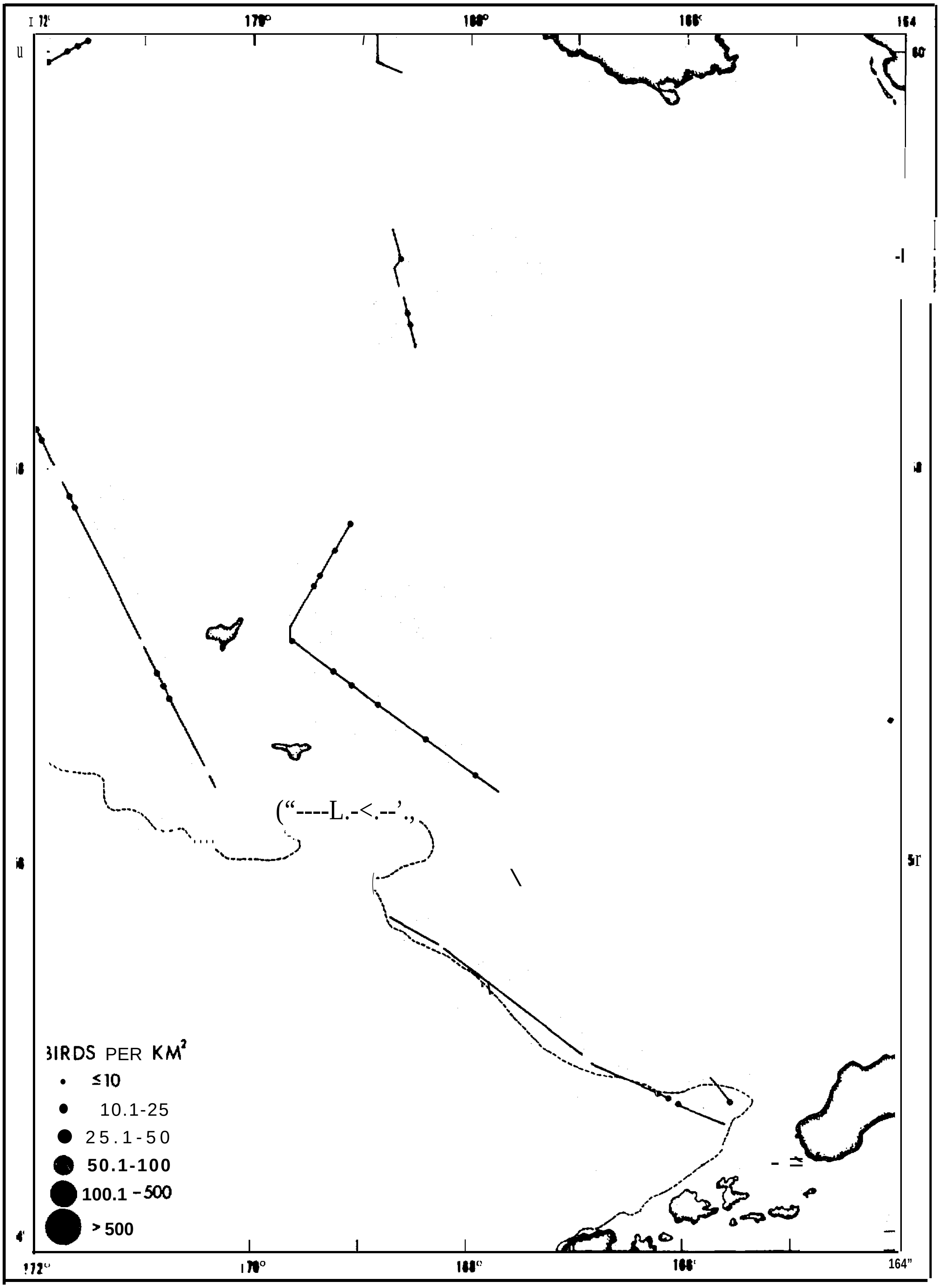


Figure 94. Distribution and abundance of all Jaegers in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June, and from 8 to 10 June 1977.

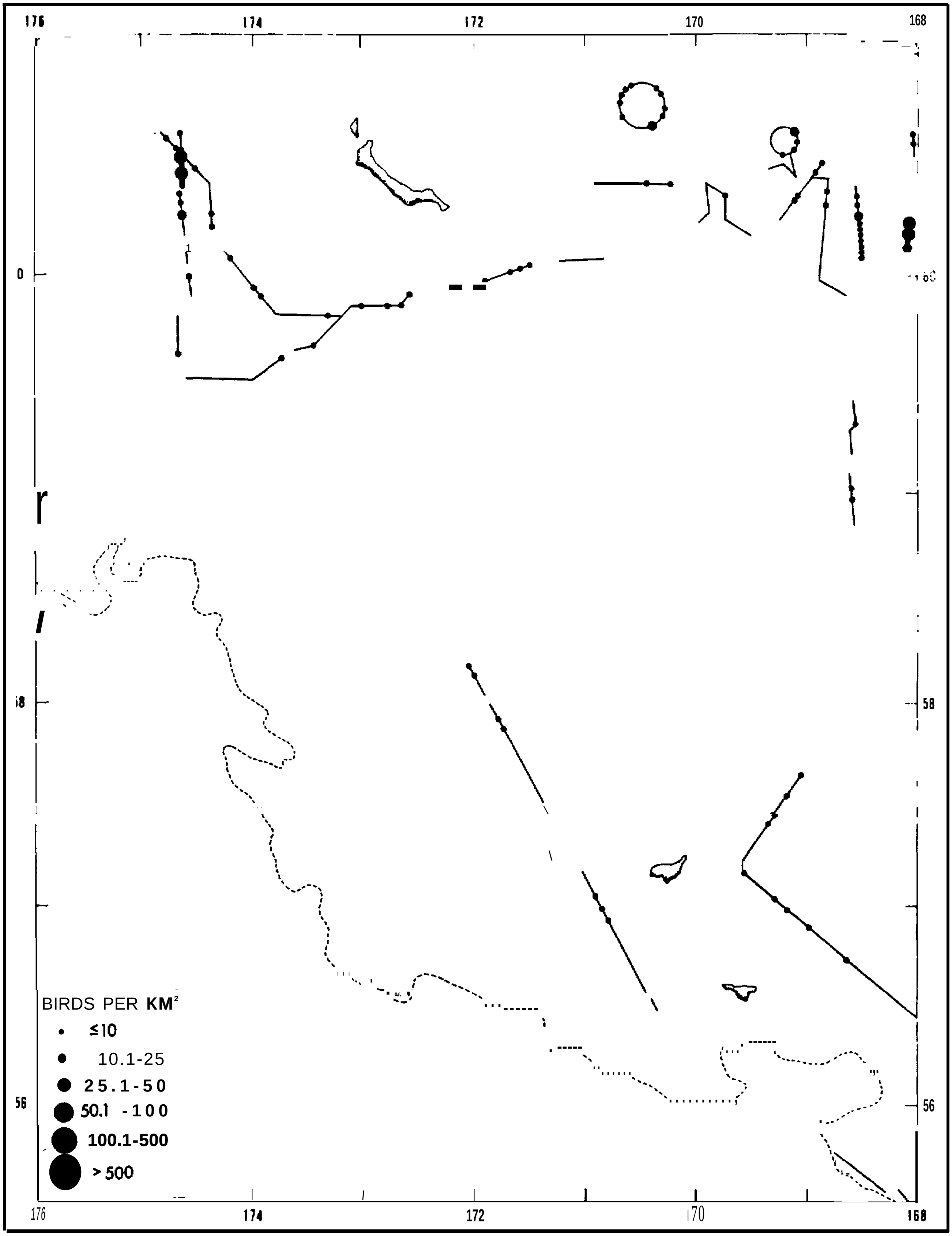


Figure 95. Distribution and abundance of all jaegers in central Bering Sea from 23 May to 9 June 1977.

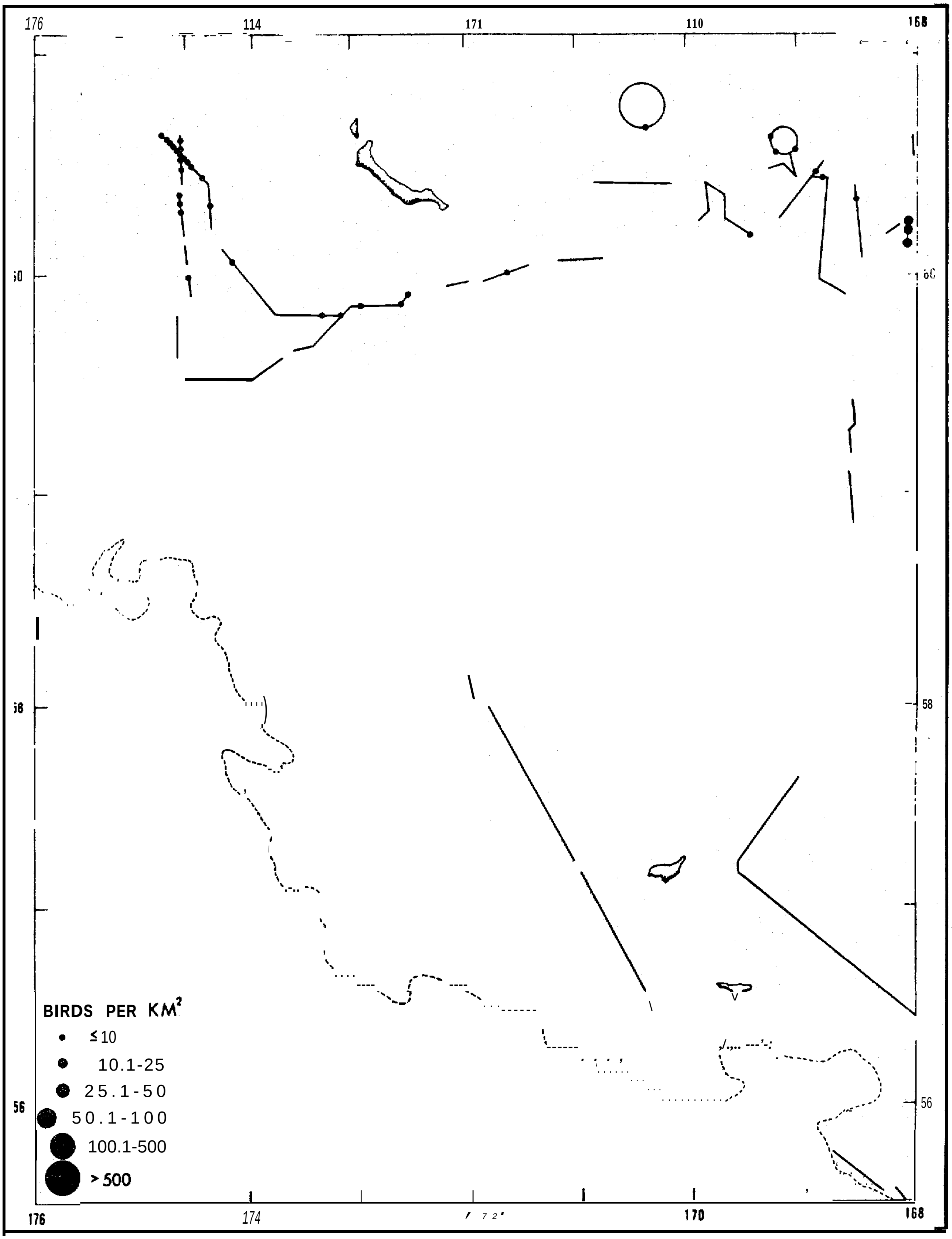


Figure 96. Distribution and abundance of Glaucous Gulls in central Bering Sea from 23 May to 9 June 1977.

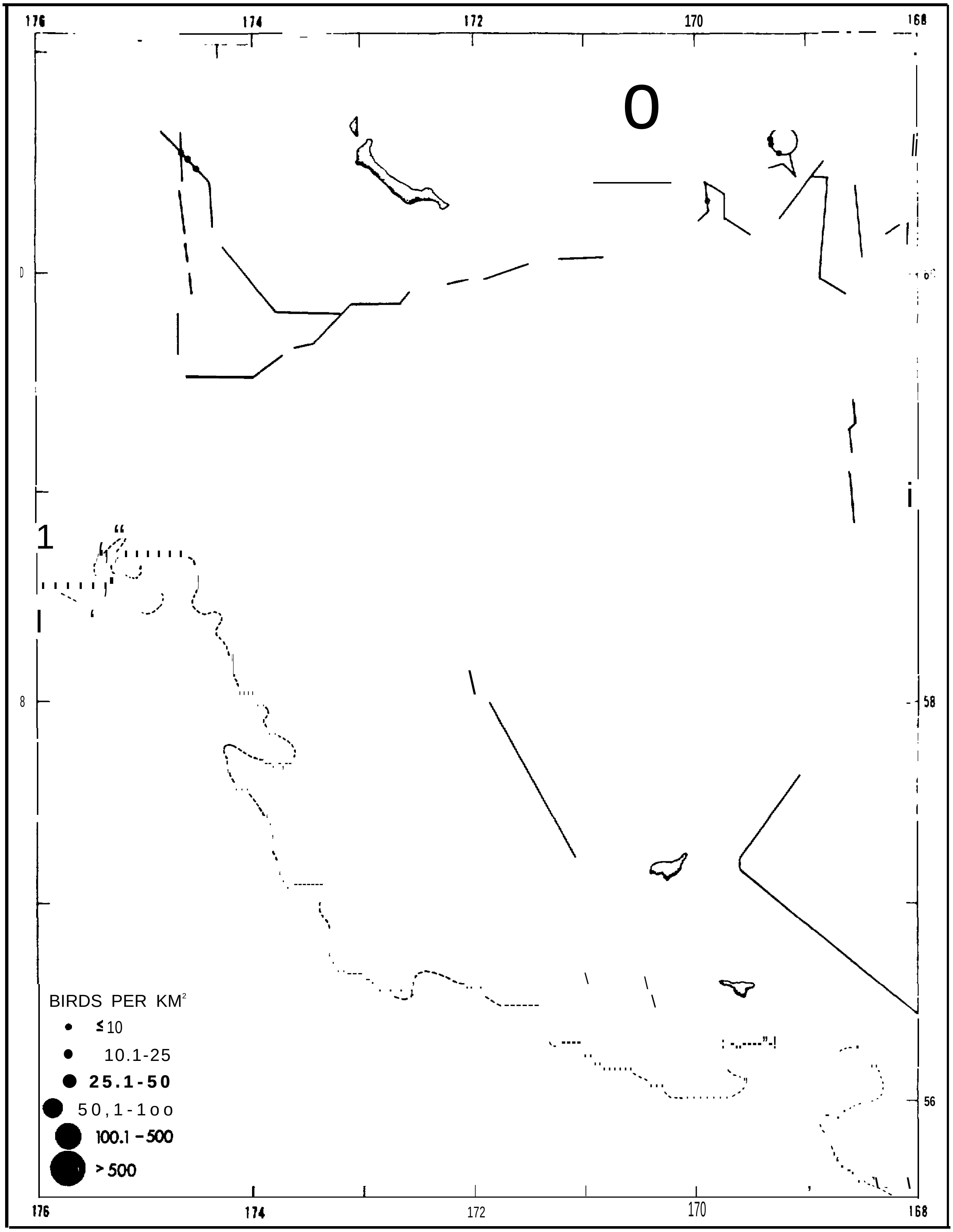
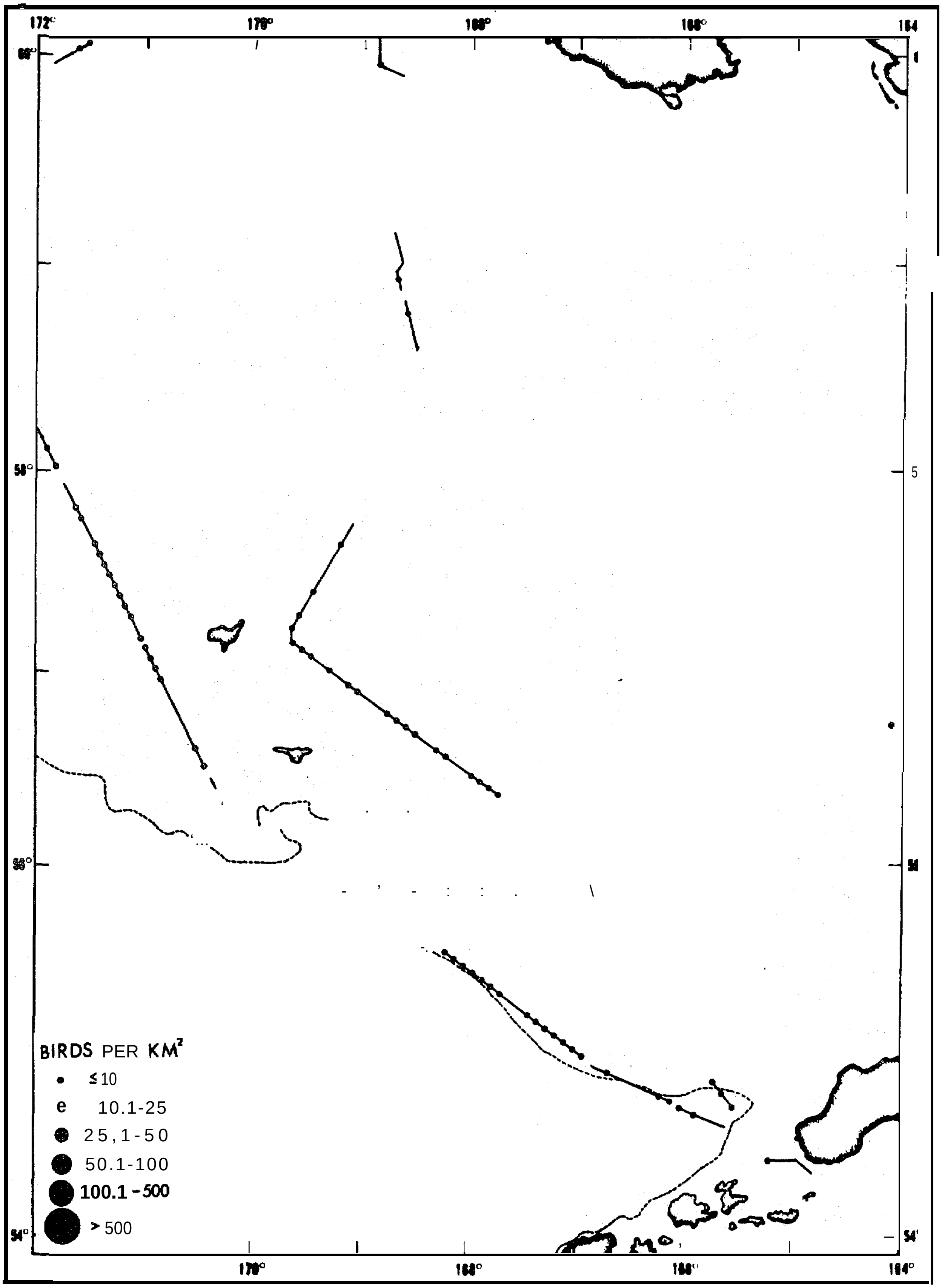


Figure 99. **Distribution and abundance** of Herring Gulls in central Bering Sea from 23 May to 9 June 1977.



igure 100. Distribution and abundance of Black-legged Kittiwakes in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

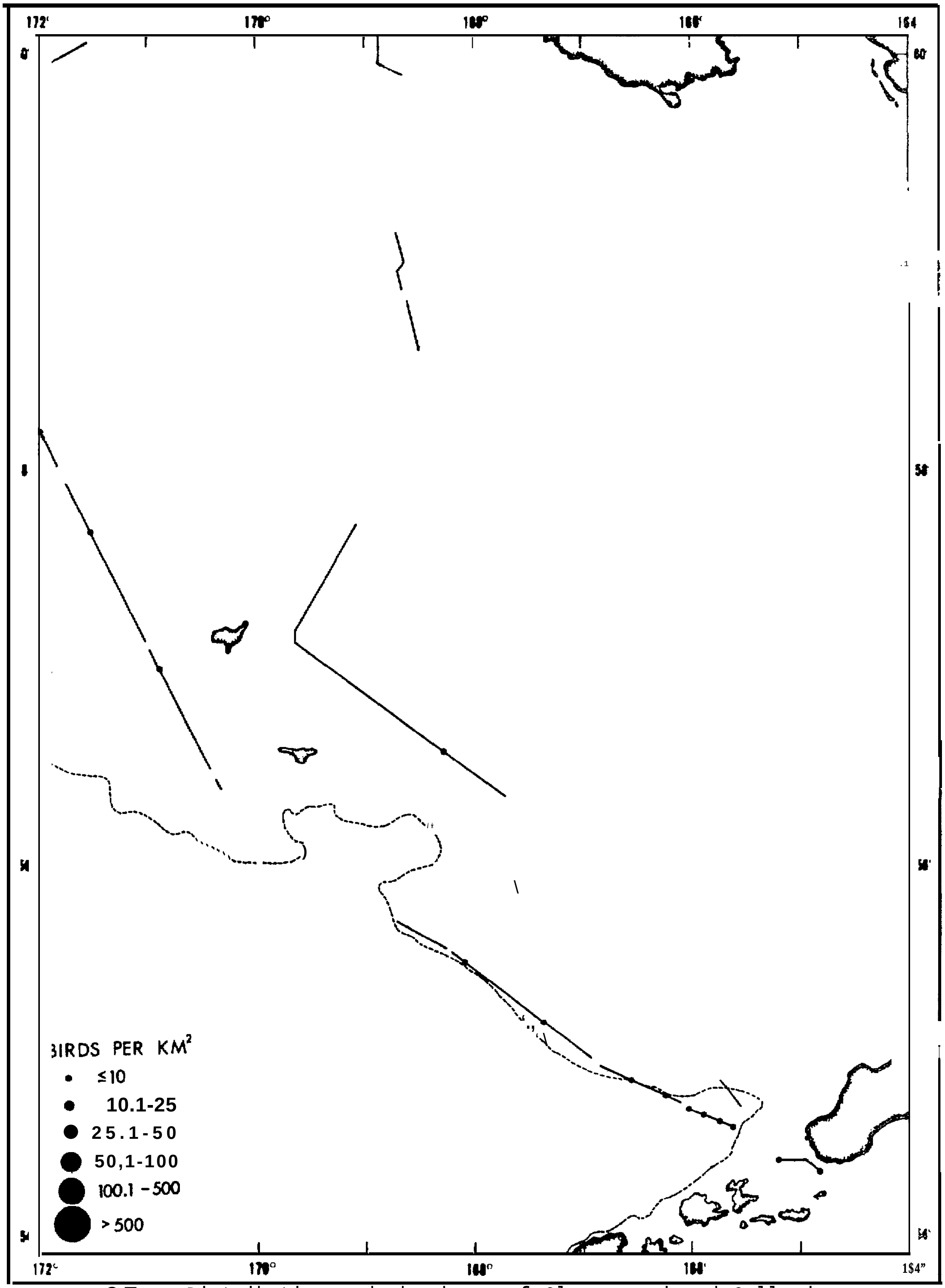


Figure 97. Distribution and abundance of Glaucous-winged Gulls in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

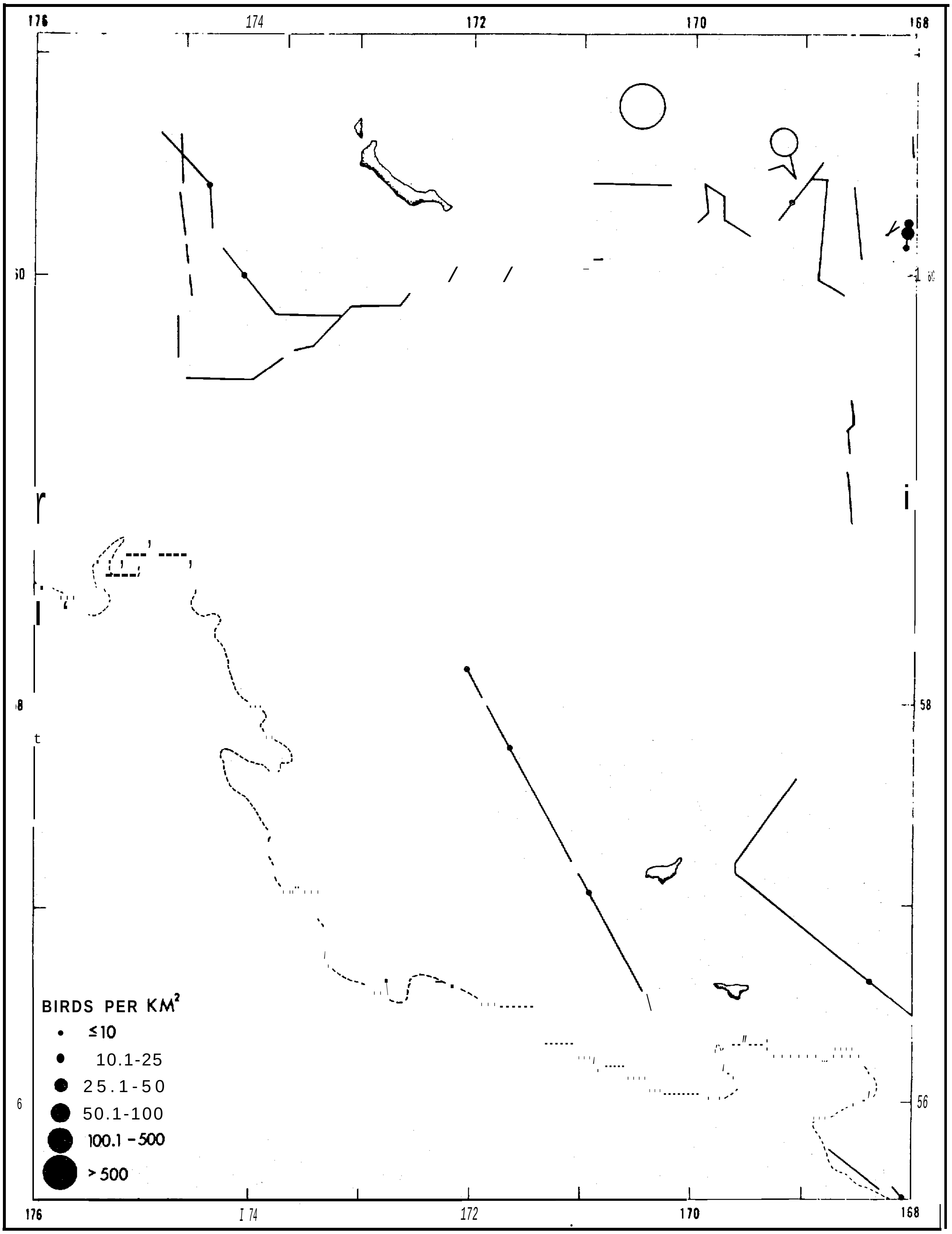


Figure 98. Distribution and abundance of Glaucous-winged Gulls in central Bering Sea from 23 May to 9 June 1977.

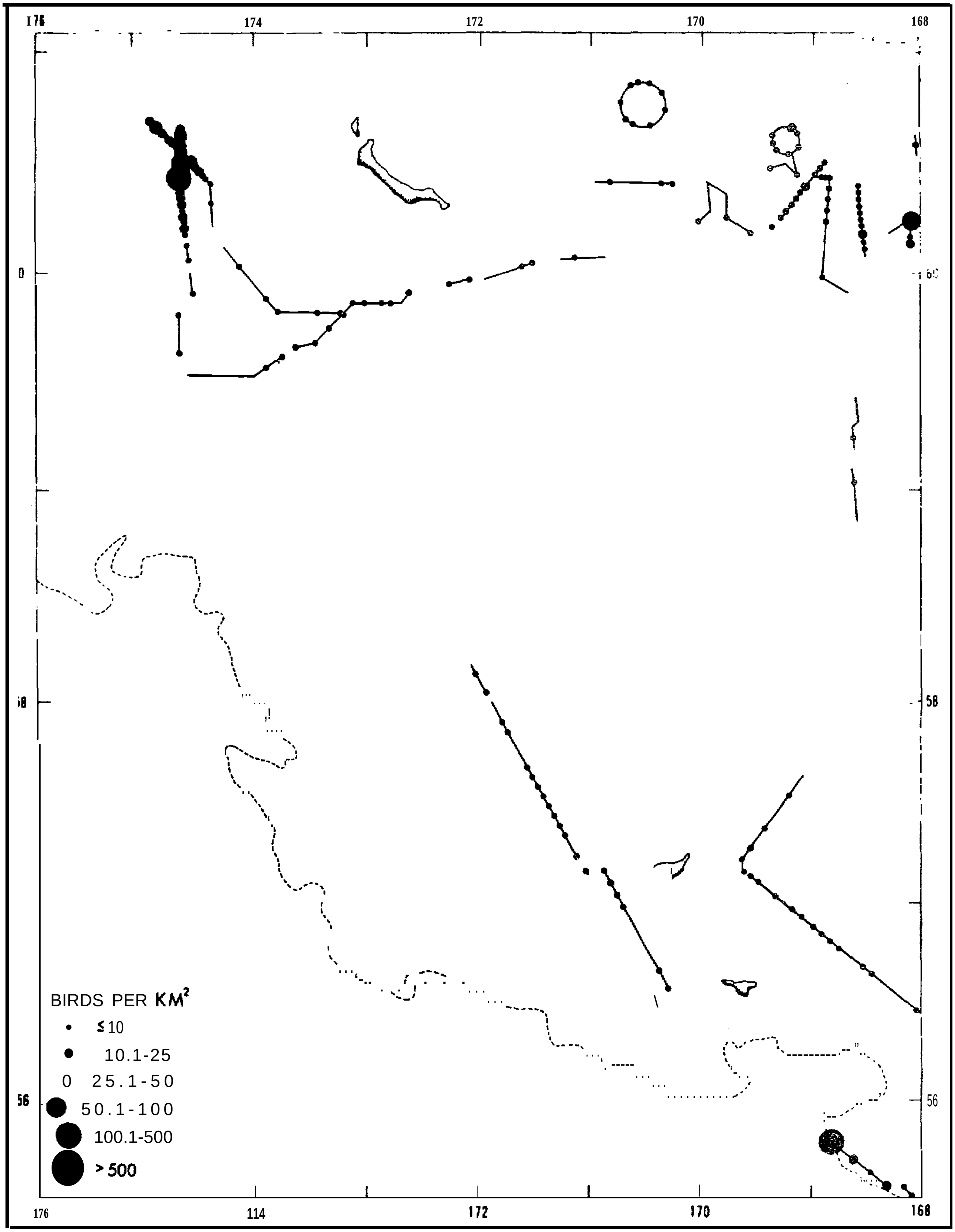


Figure 101. Distribution and abundance of Black-legged Kittiwakes in central Bering Sea from 23 May to 9 June 1977.

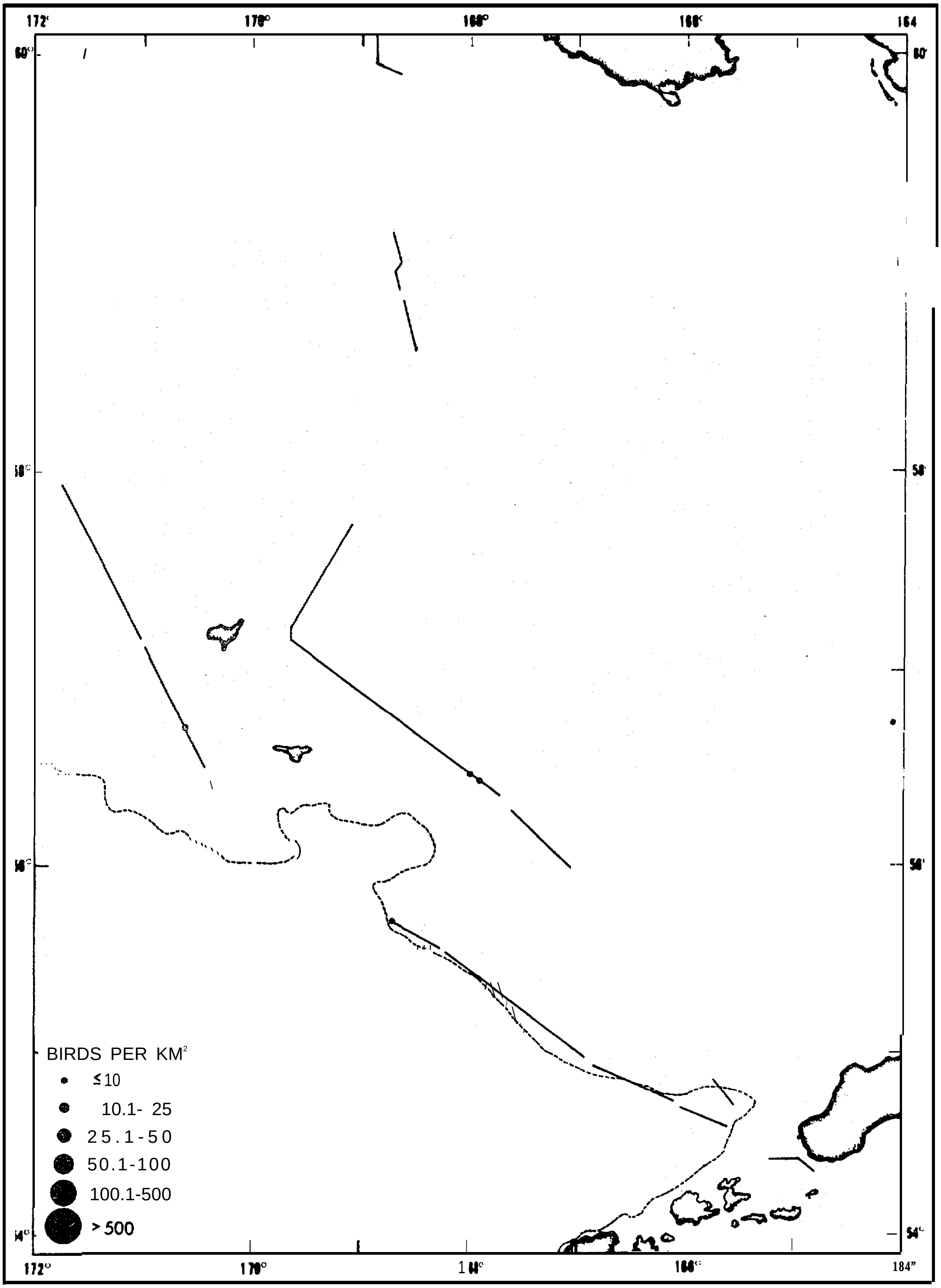


Figure 102. Distribution and abundance of Red-legged Kittiwakes in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

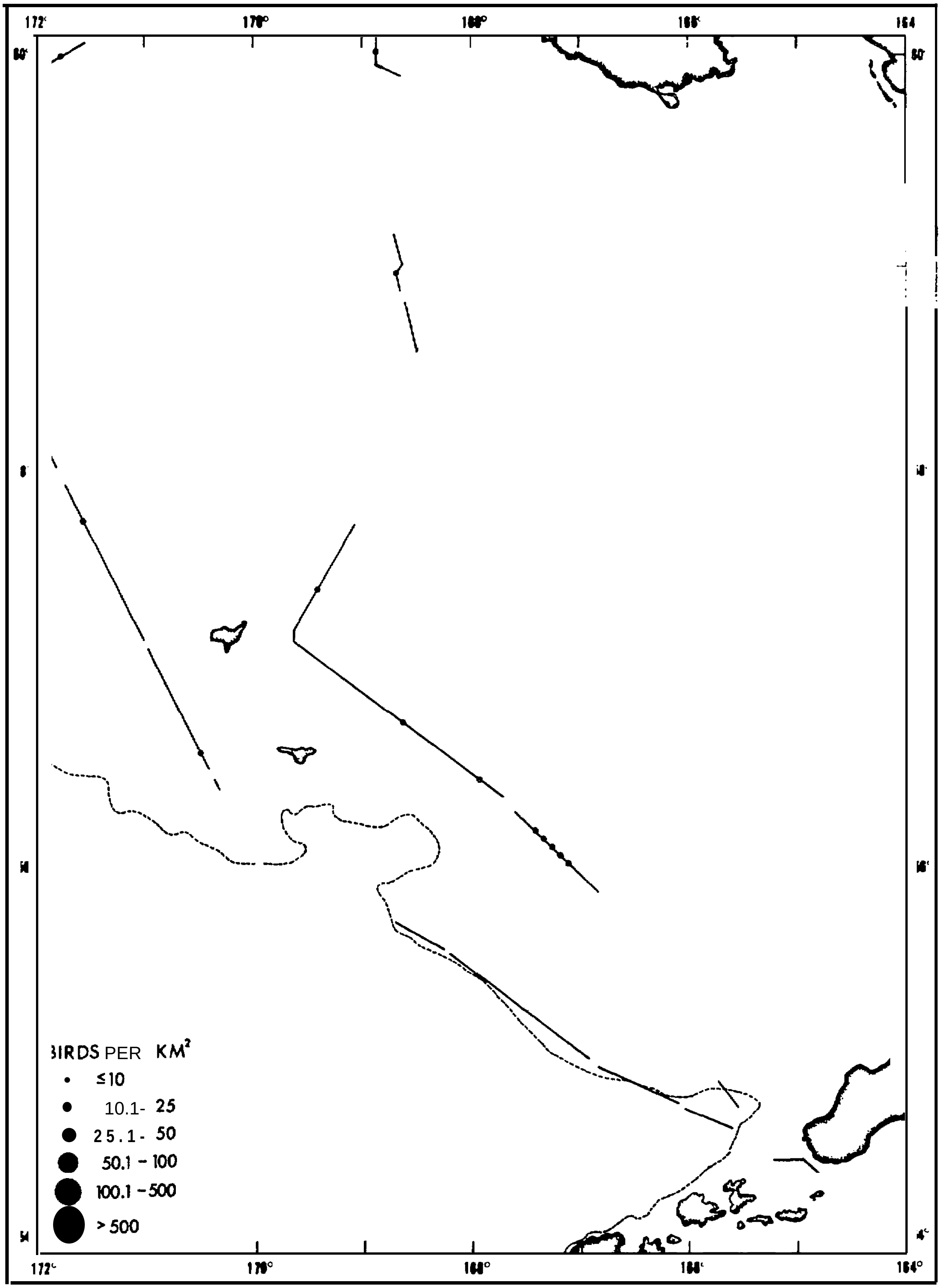


Figure 103. Distribution and abundance of Common Murres in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

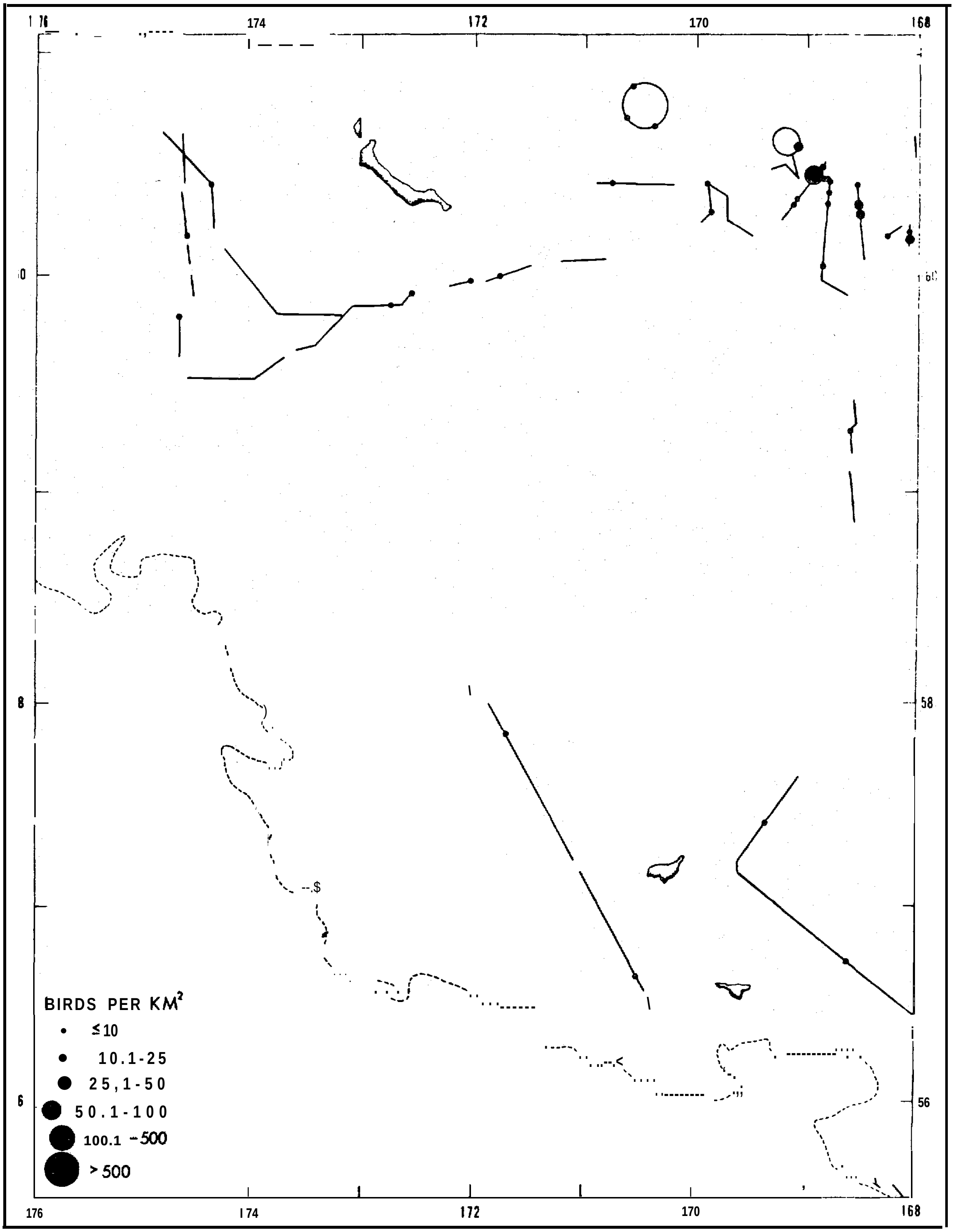


Figure 104. Distribution and abundance of Common Murres in central Bering Sea from 23 May to 9 June 1977.

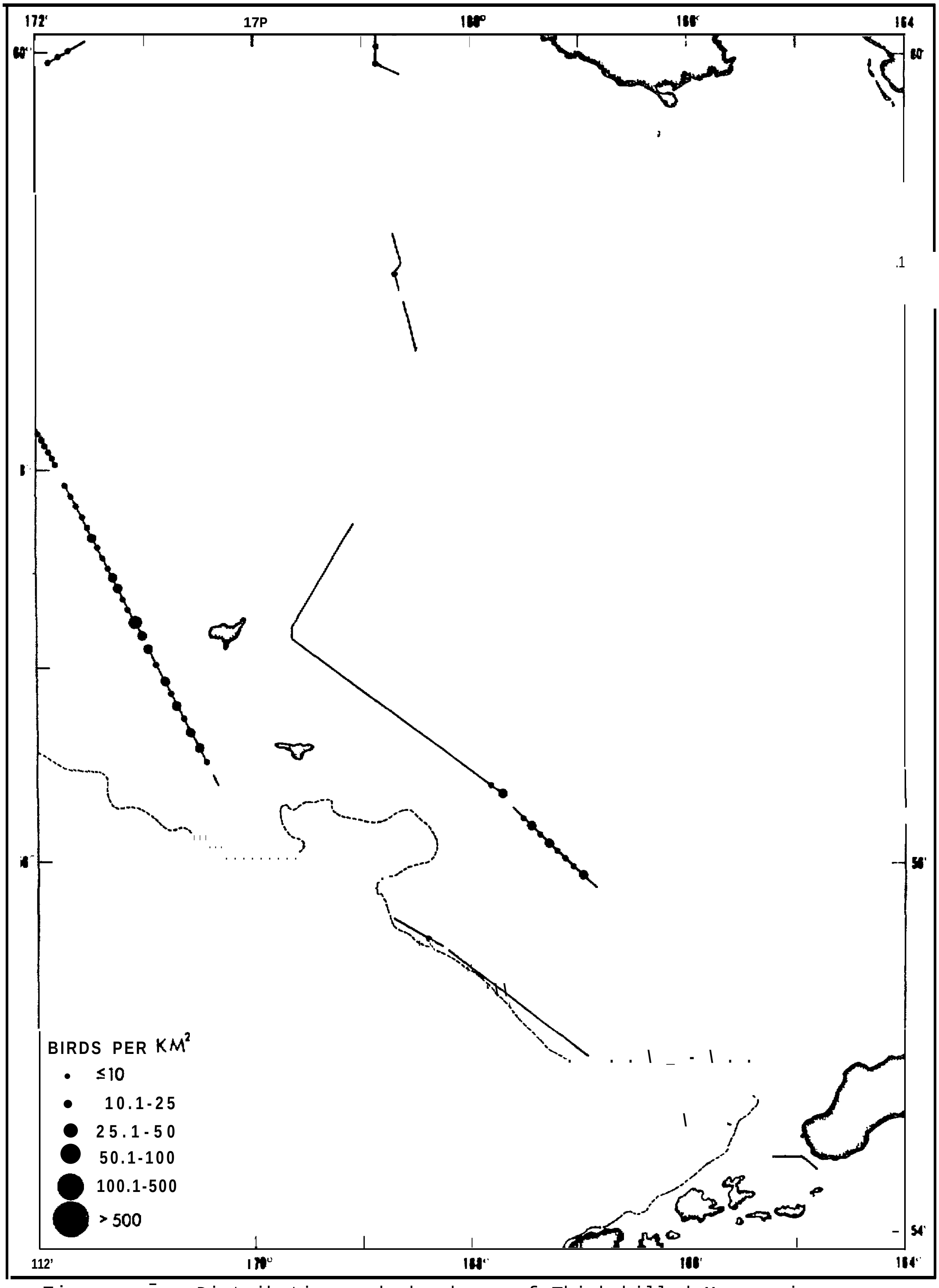


Figure 105. Distribution and abundance of Thick-billed Murres in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

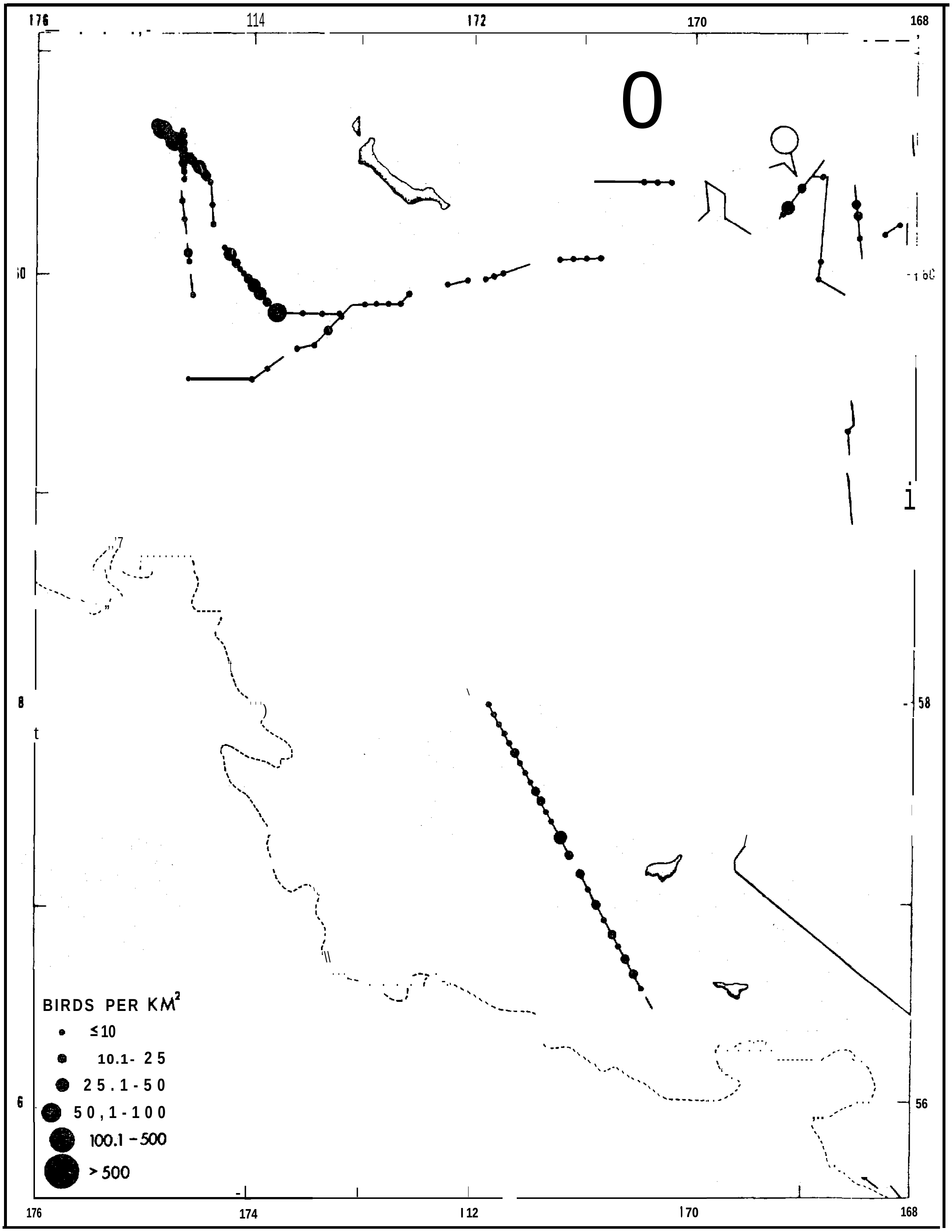


Figure 106. Distribution and abundance of Thick-billed Murres in central Bering Sea from 23 May to 9 June 1977.

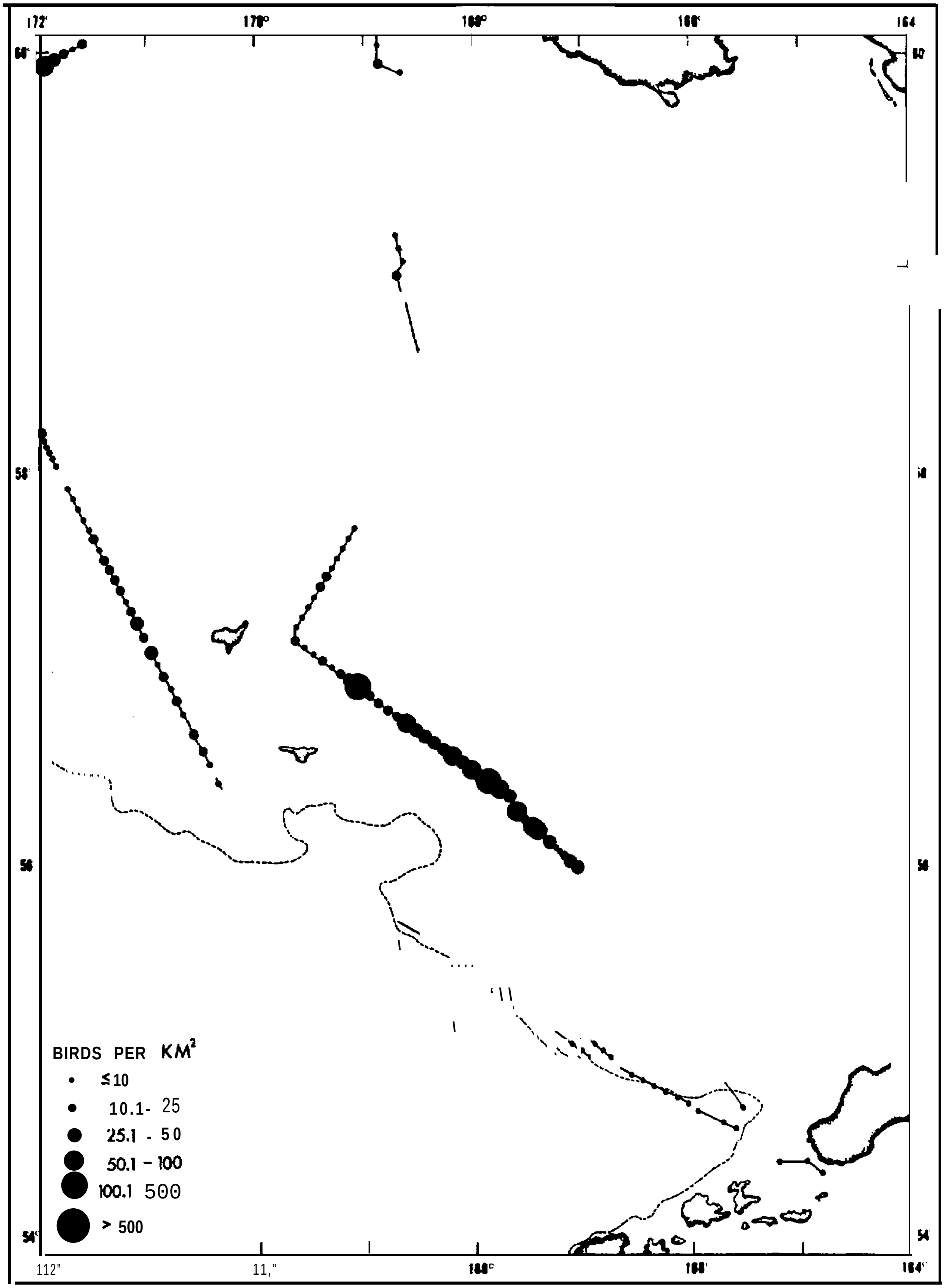


Figure 107. Distribution and abundance of all murres in southern Bering Sea from 5 to 24 May, on 29 May on 2 June and from 8 to 10 June 1977.

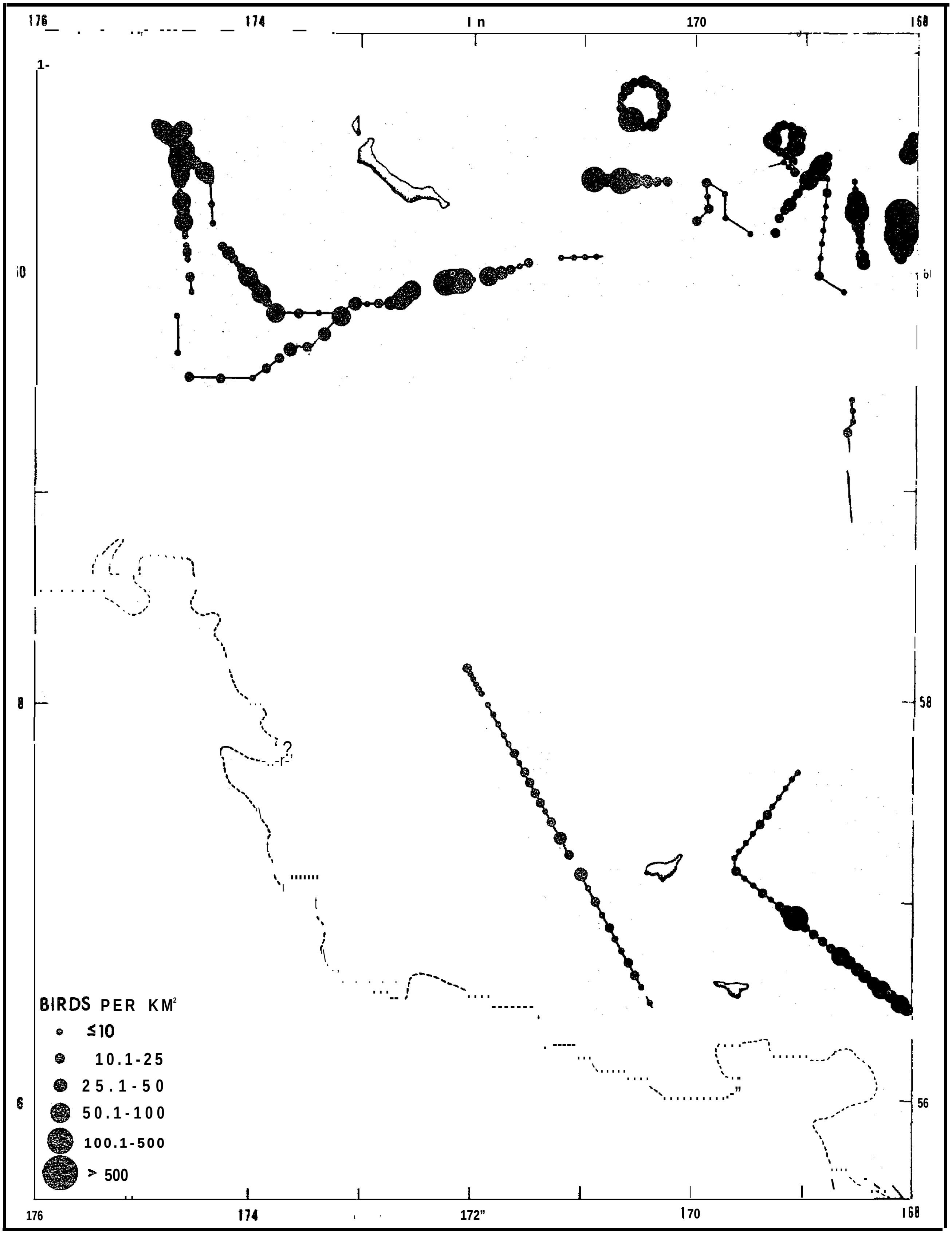


Figure 108. Distribution and abundance of all murres in central Bering Sea from 23 May to 9 June 1977.

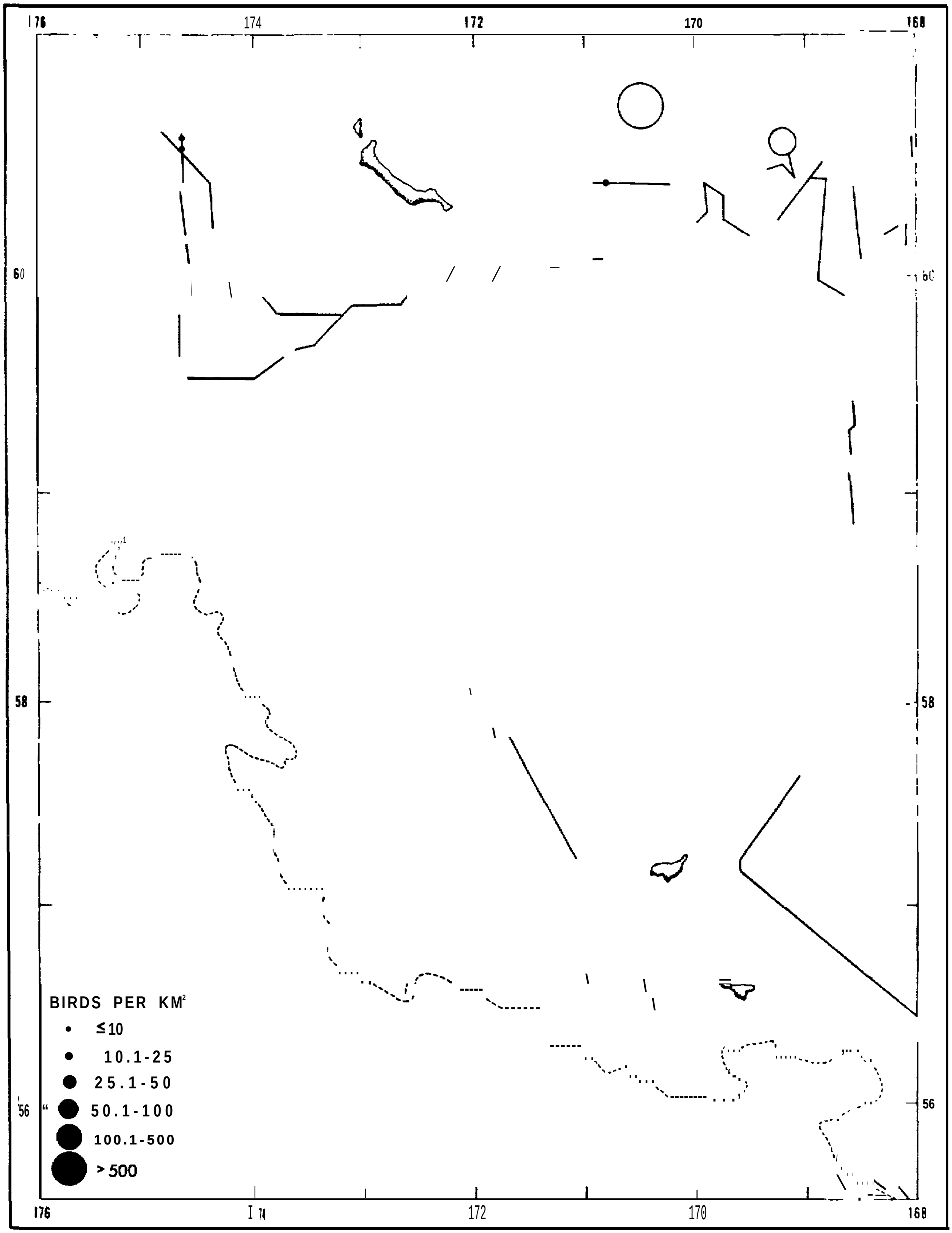


Figure 109. Distribution and abundance of Black Guillemots in central Bering Sea from 23 May to 9 June 1977.

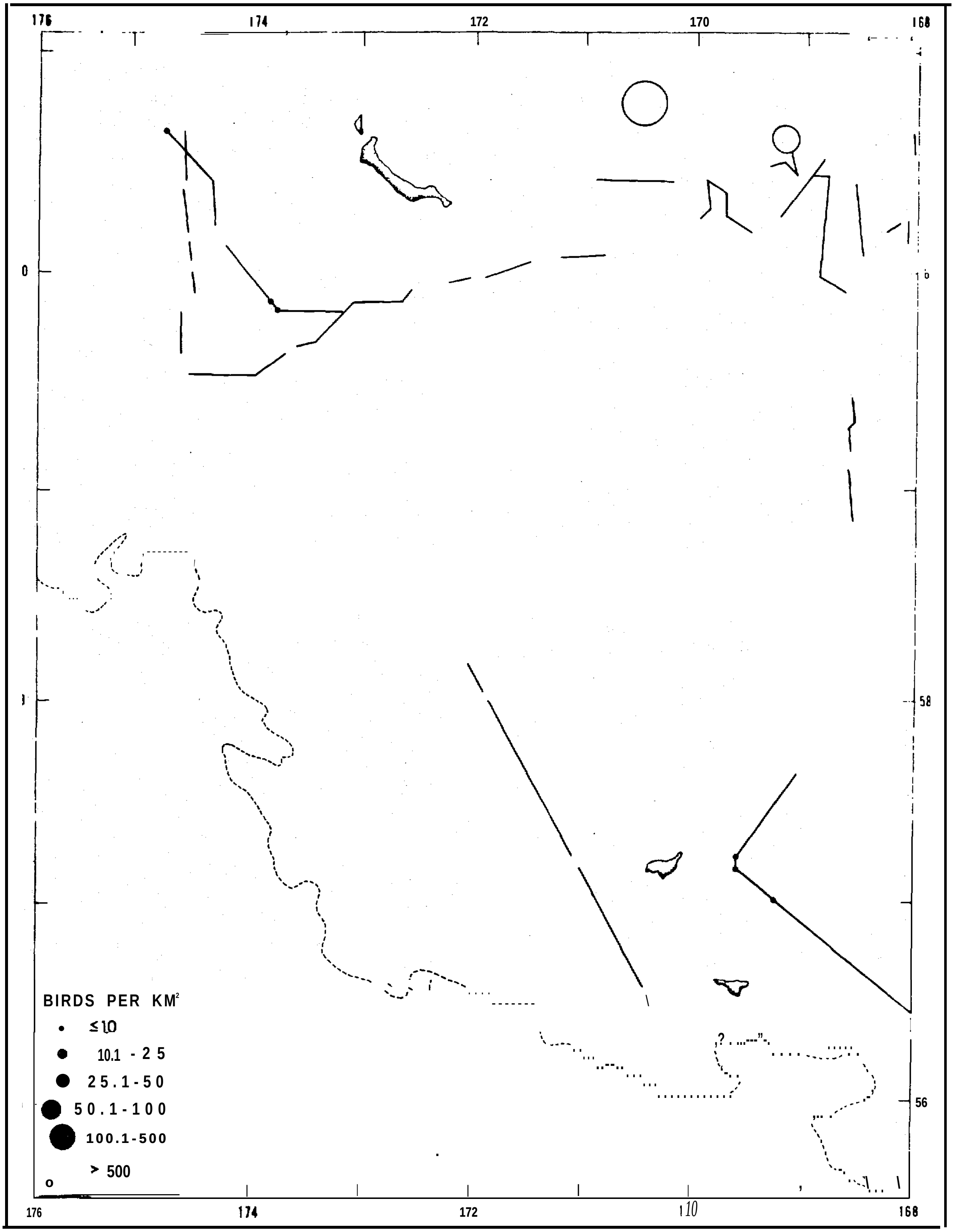


Figure 110. Distribution and abundance of Pigeon Guillemots in central Bering Sea from 23 May to 9 June 1977.

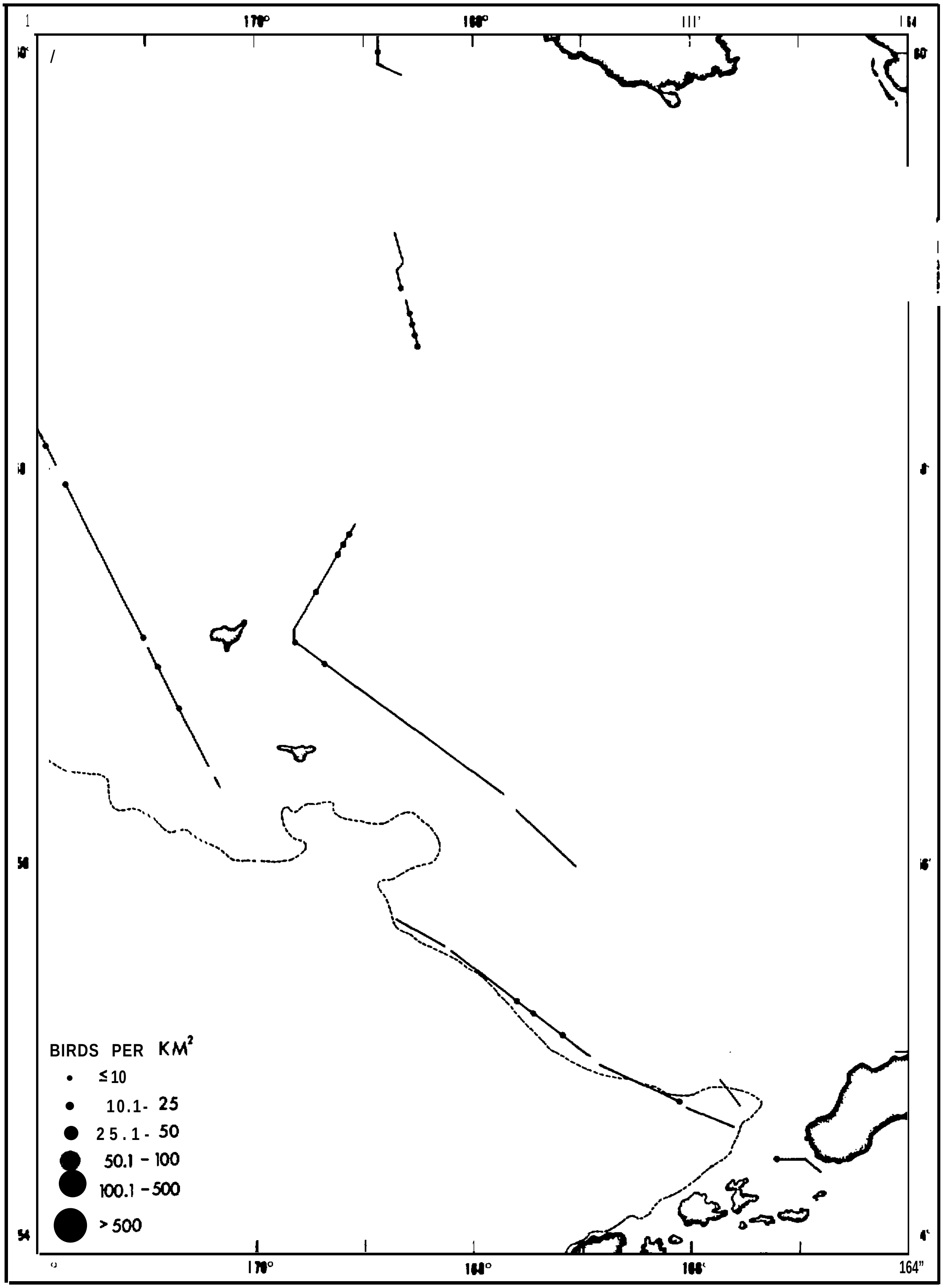


Figure 111. Distribution and abundance of Parakeet Auklets in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and' from 8 to 10 June 1977.

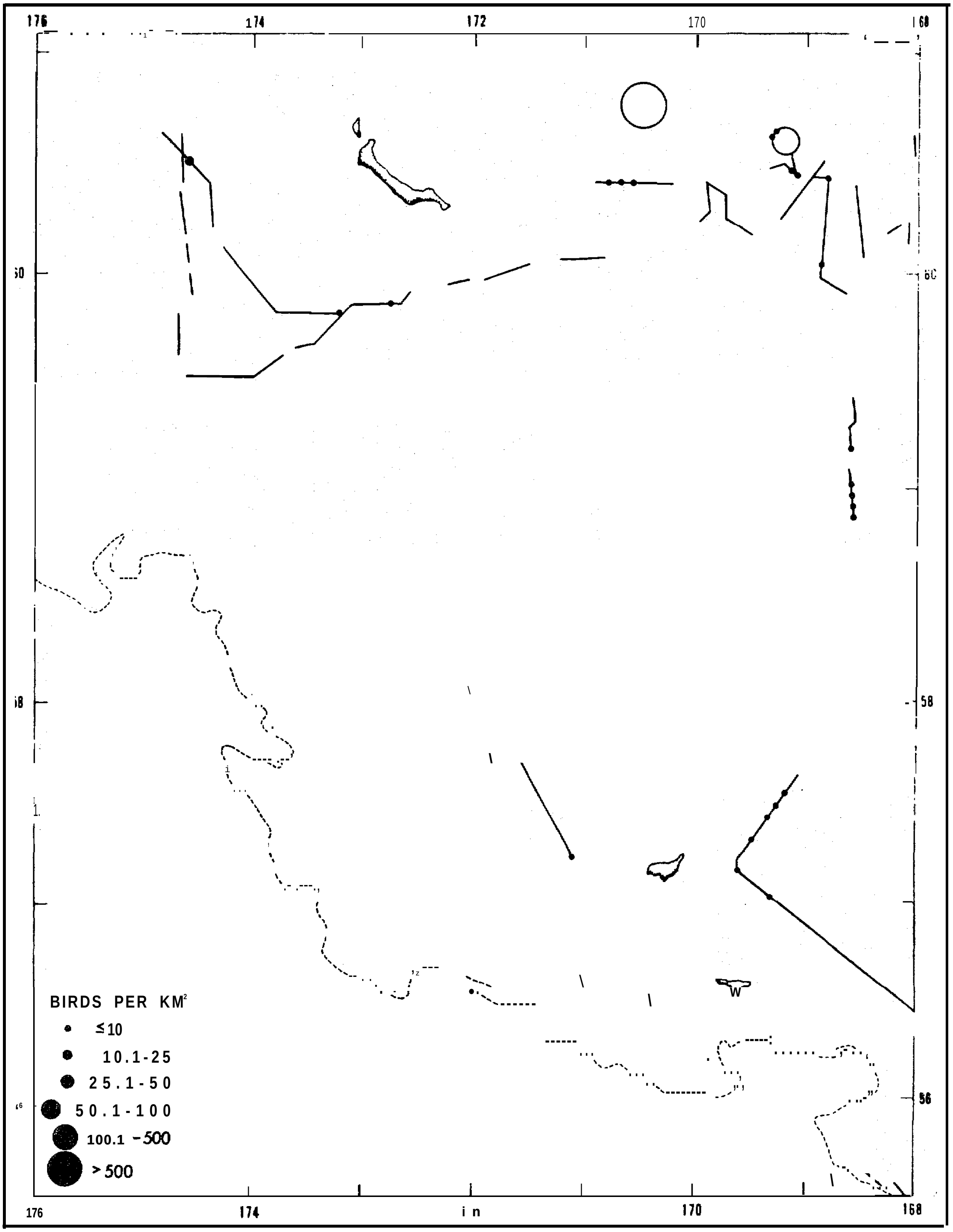


Figure 112. Distribution and abundance of Parakeet Auklets in central Bering Sea from 23 May to 9 June 1977.

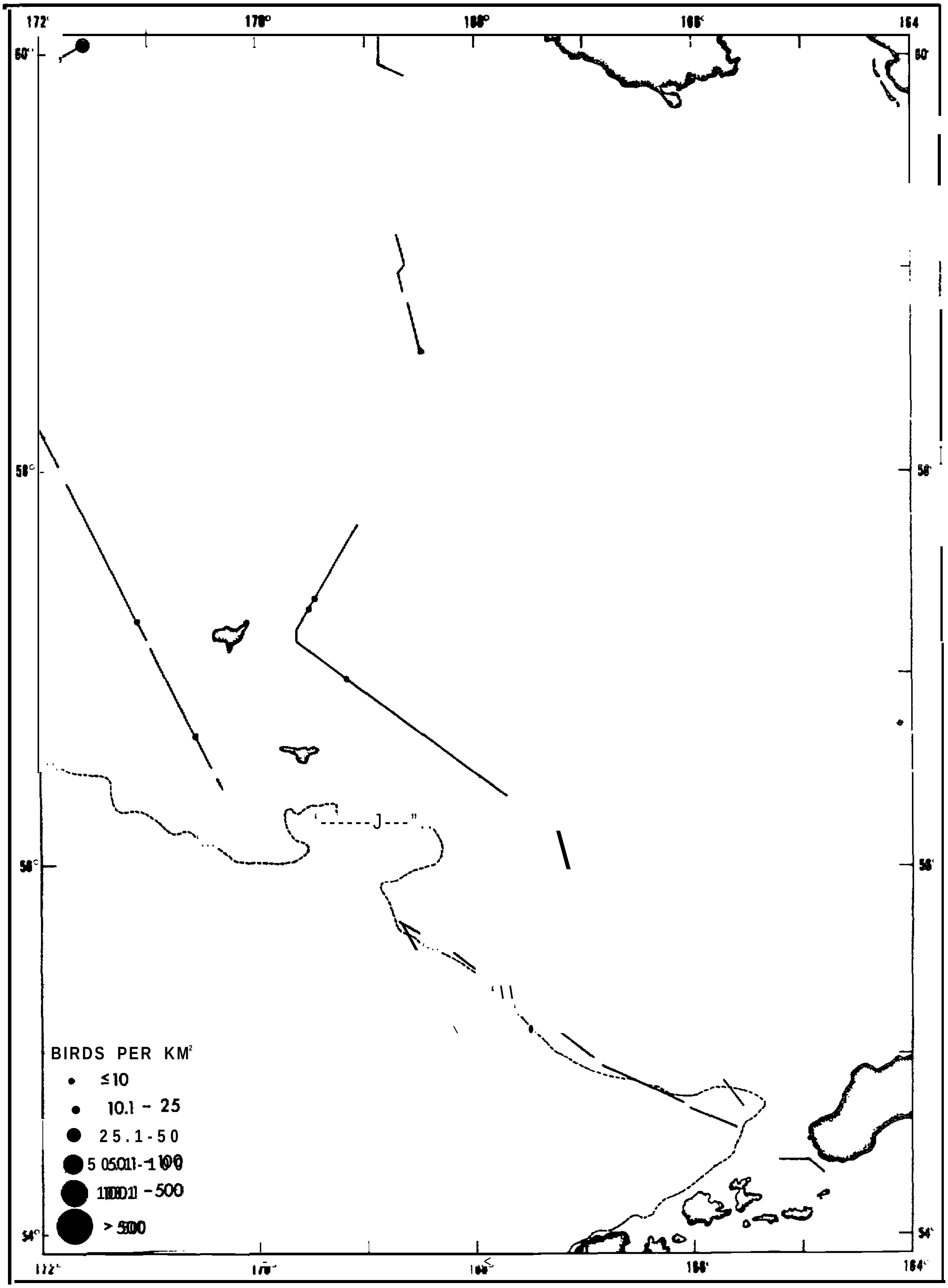


Figure 113. Distribution and abundance of Crested Auklets in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

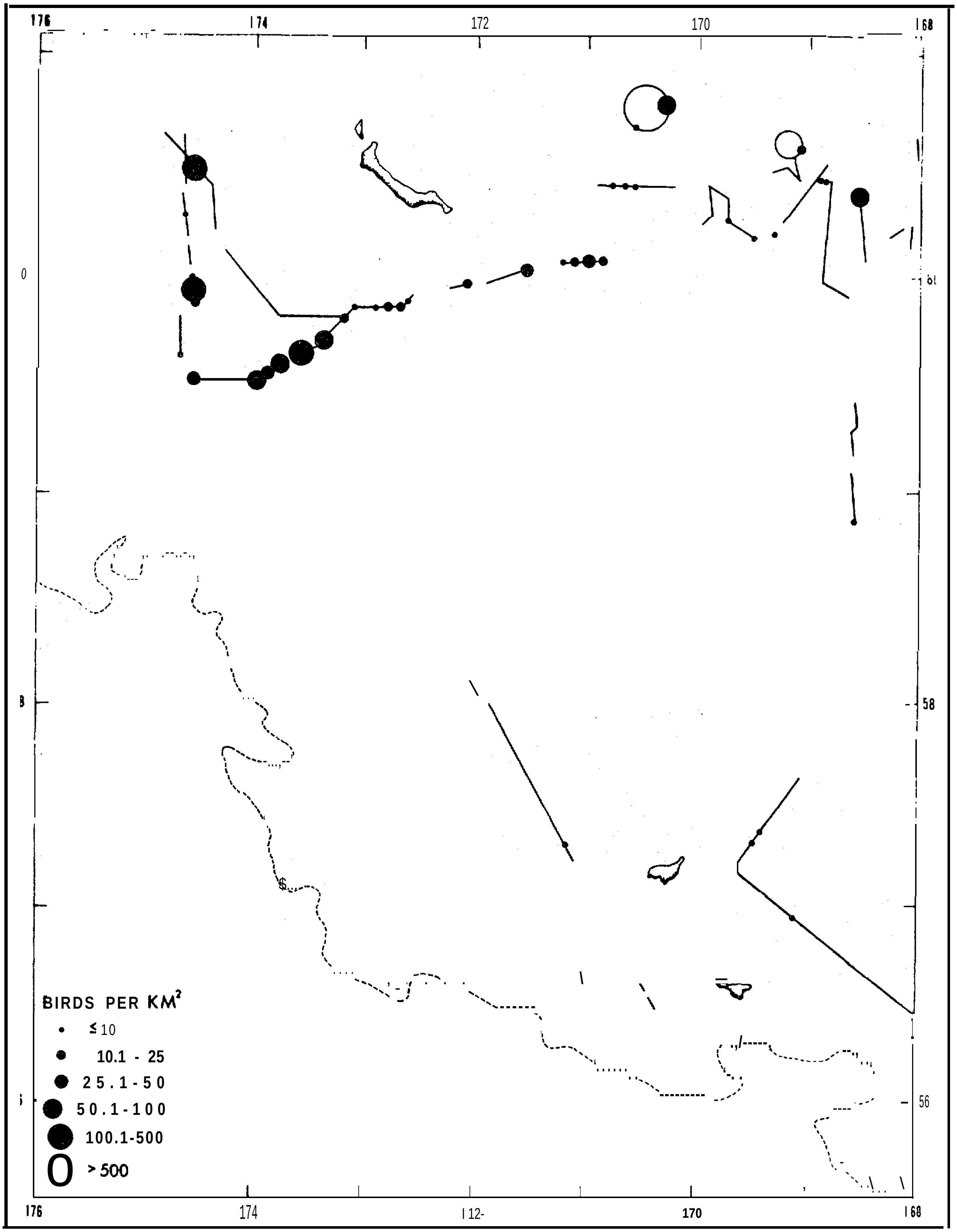


Figure 114. Distribution and abundance of Crested Auklets in central Bering Sea from 23 May to 9 June 1977.

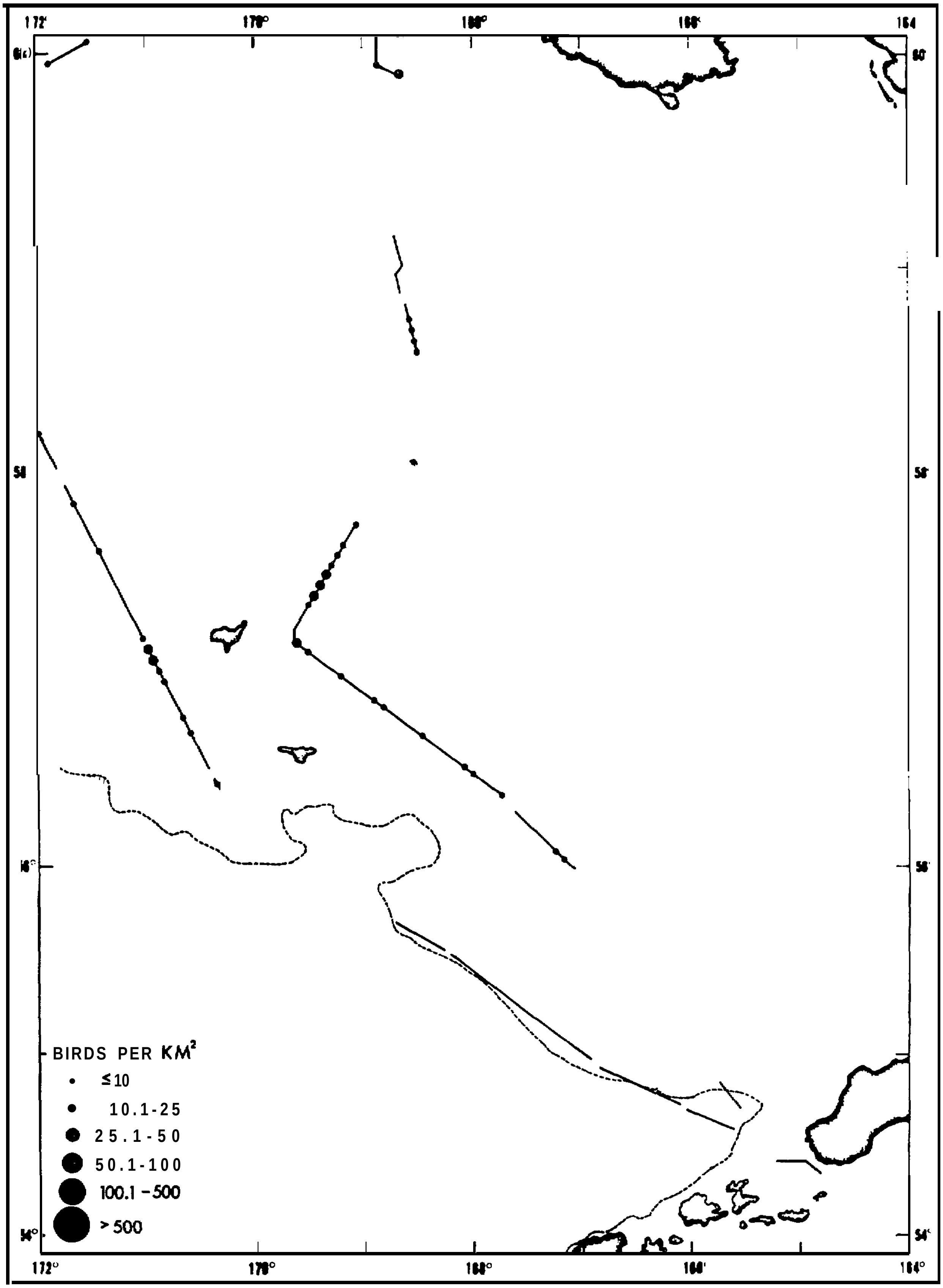


Figure 115. Distribution and abundance of Least Auklets in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

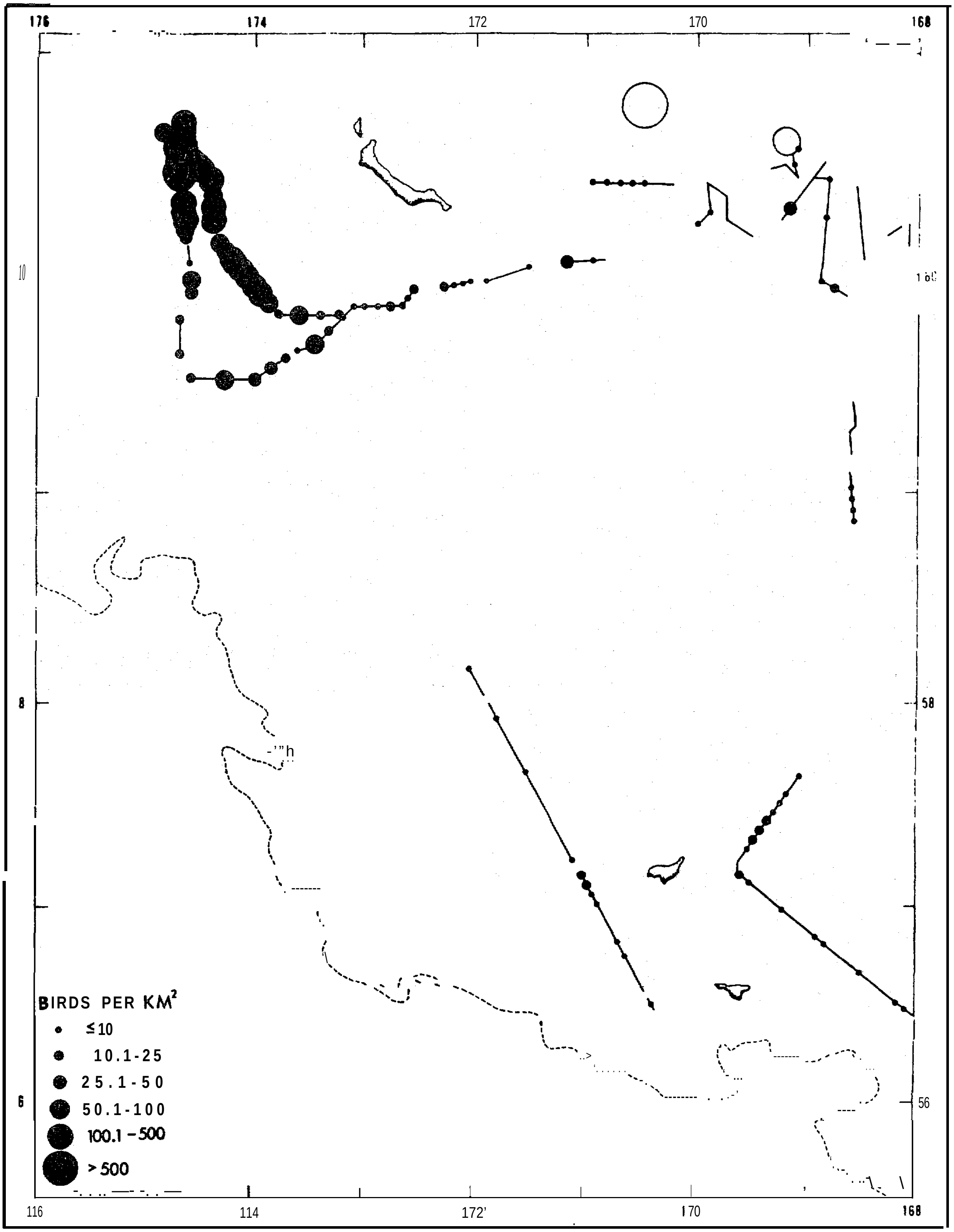


Figure I-16. Distribution and abundance of Least Auklets in central Bering Sea from 23 May to 9 June 1977.

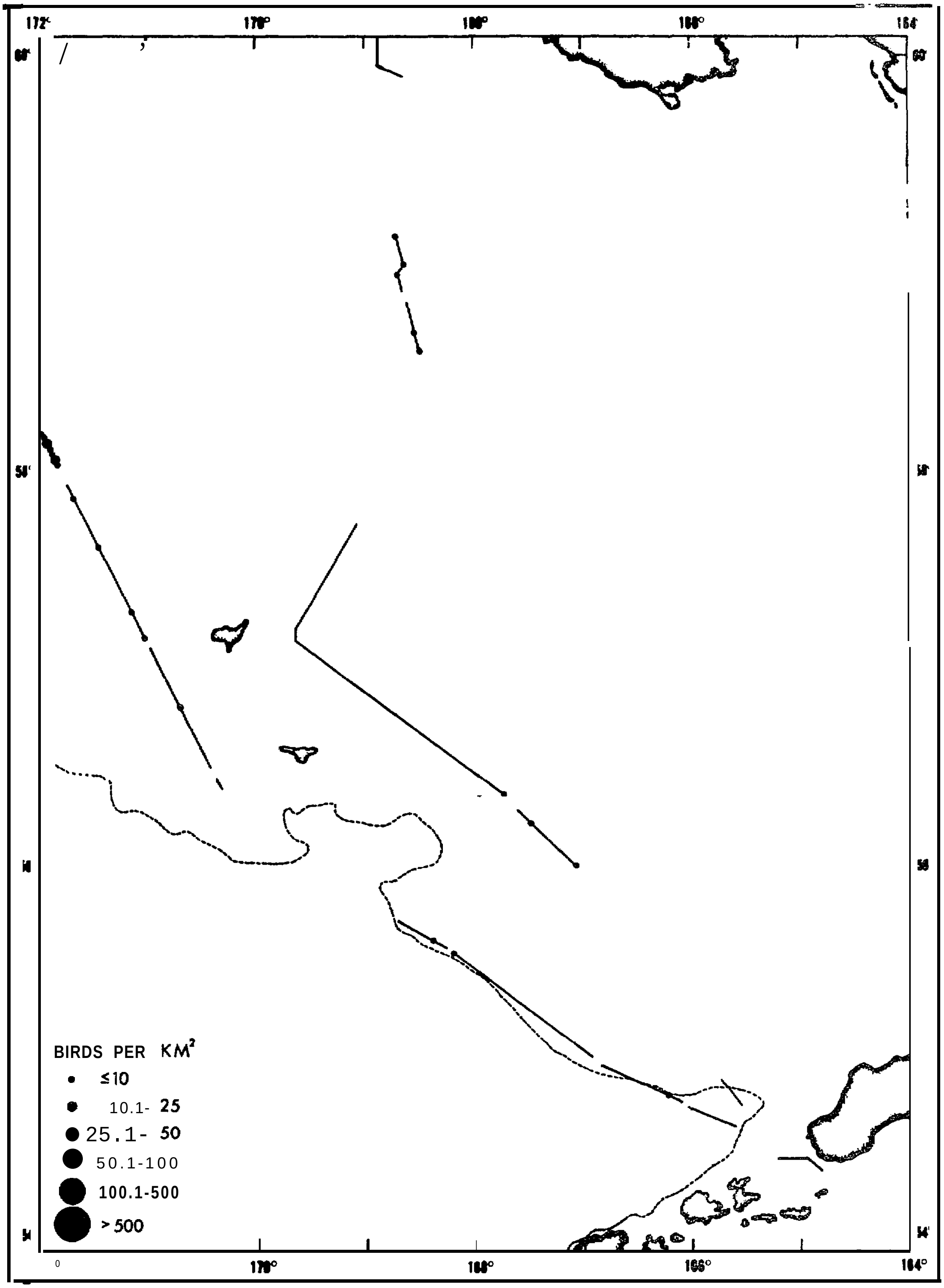


Figure 117. Distribution and abundance of unidentified small dark alcids in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

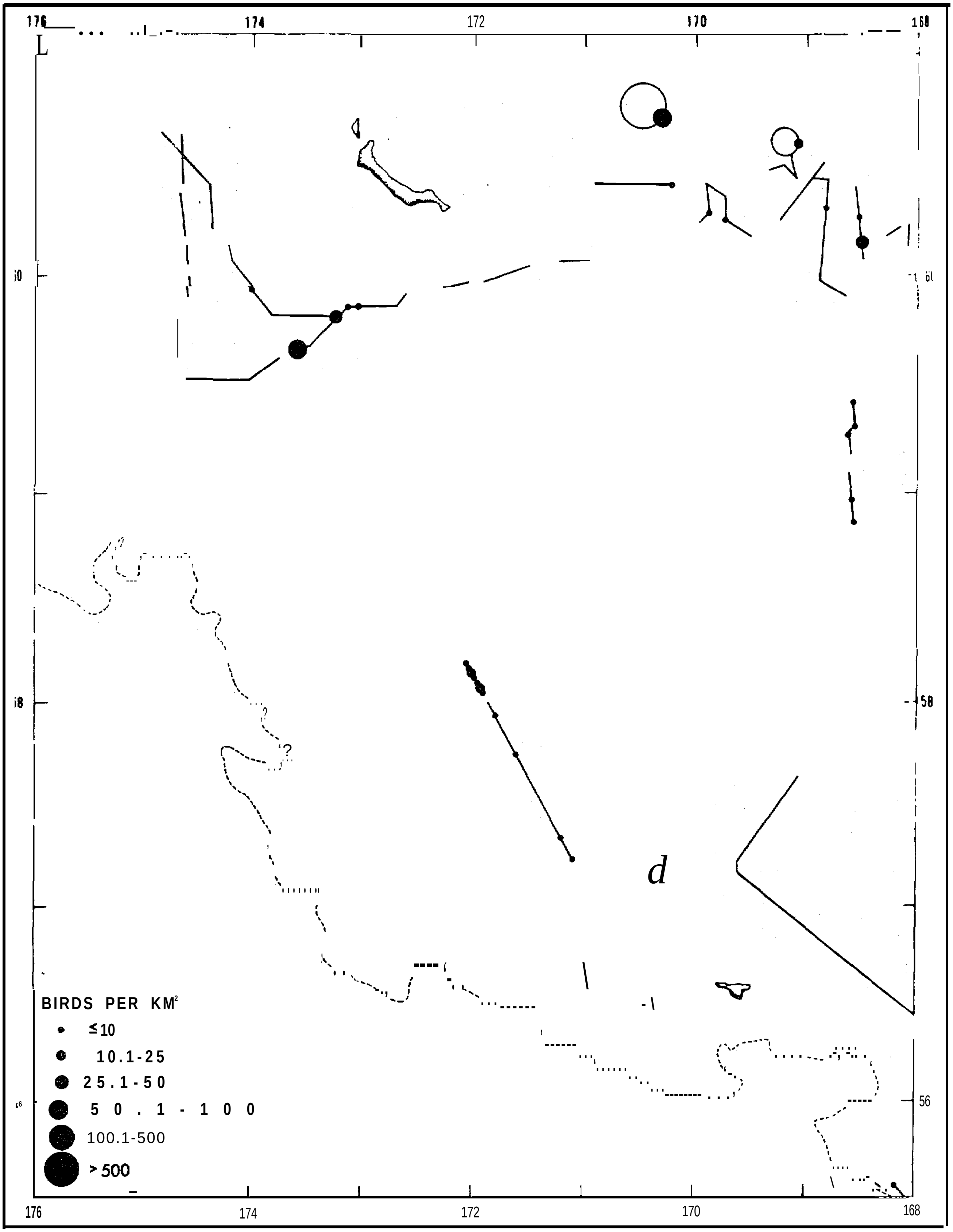


Figure 118. Distribution and abundance of unidentified small dark alcids in central Bering Sea from 23 May to 9 June 1977.

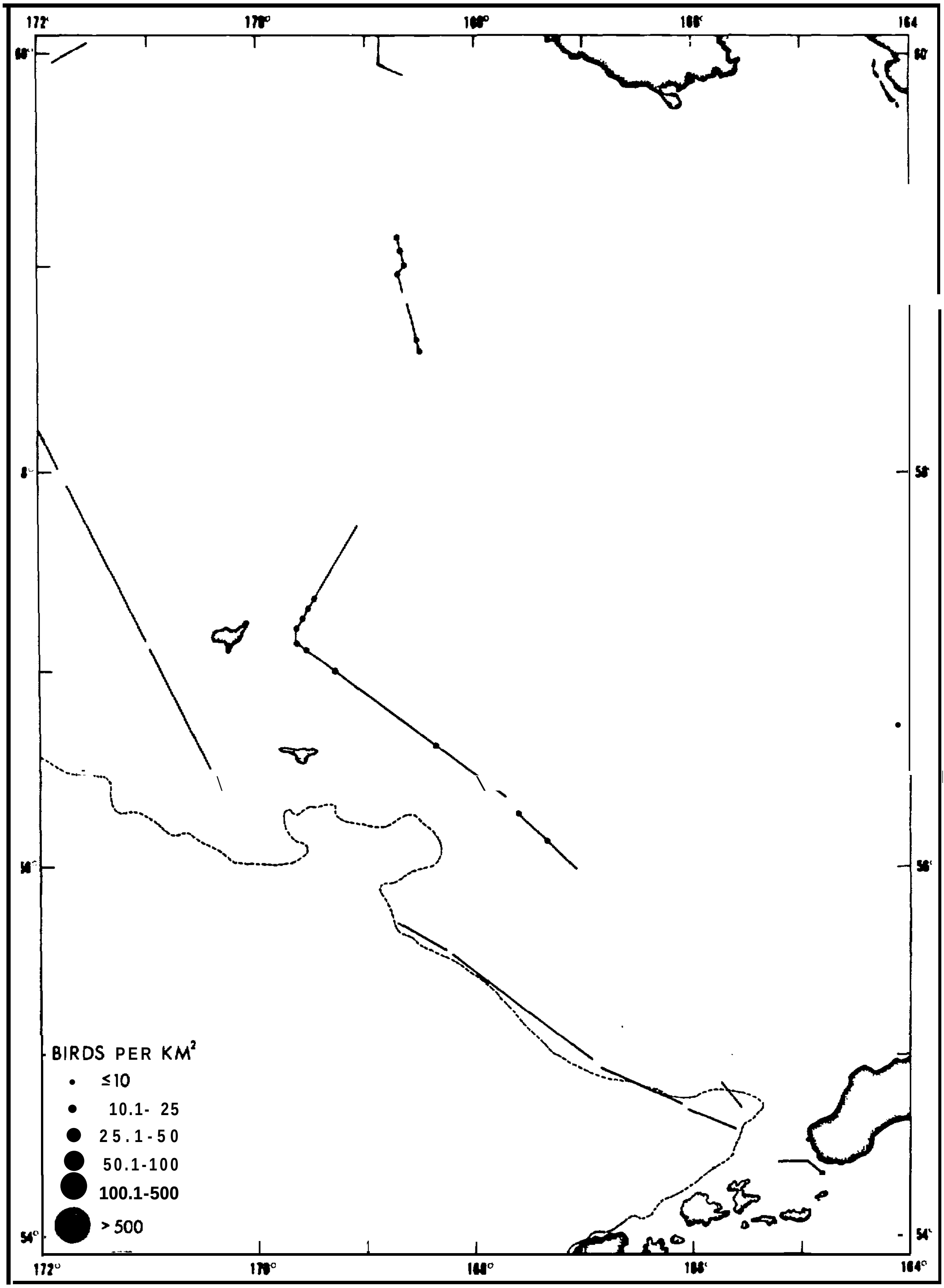


Figure 119. Distribution and abundance of Horned Puffins in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

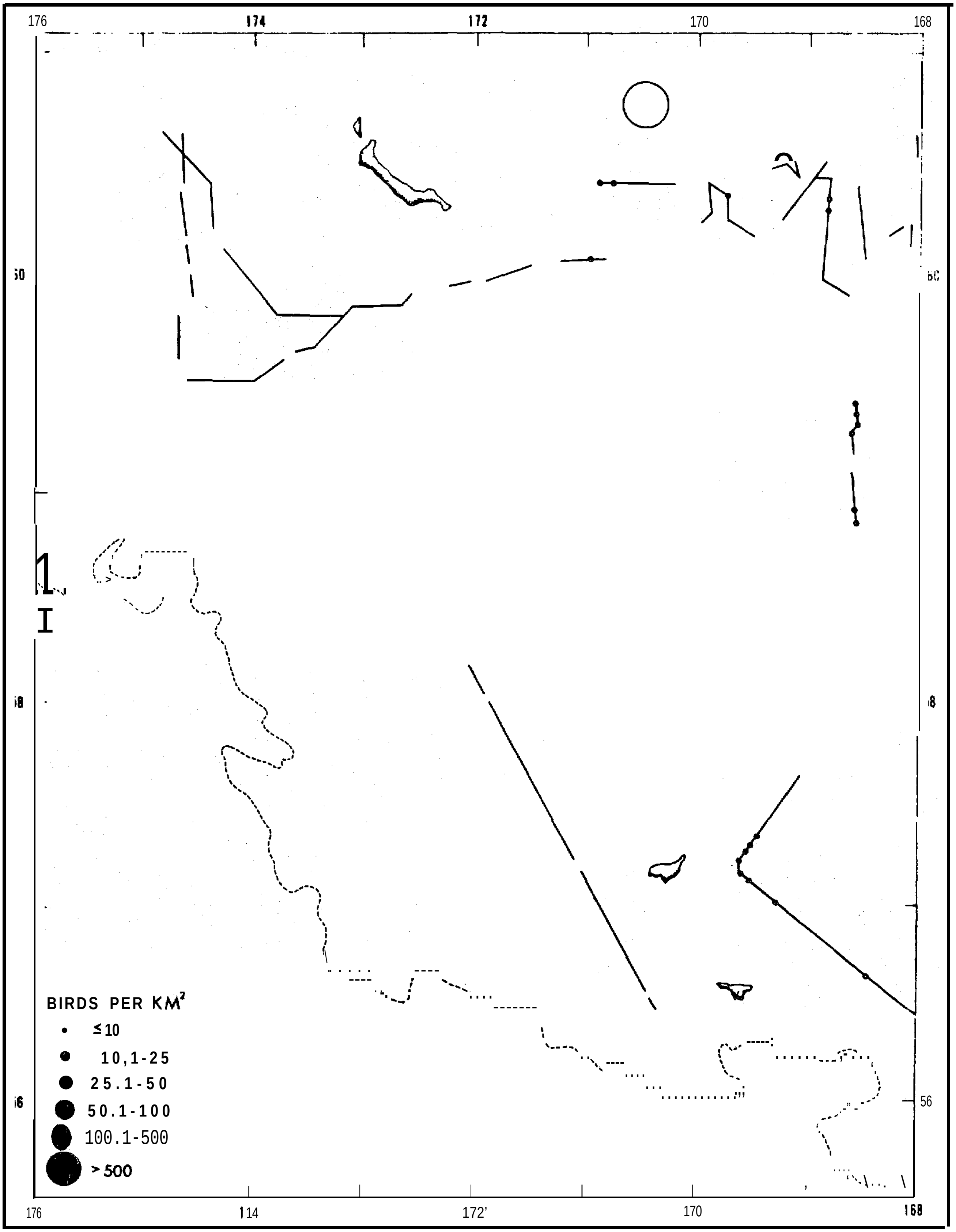


Figure **120.** Distribution and abundance of Horned Puffins in central Bering Sea from 23 May to 9 June 1977.

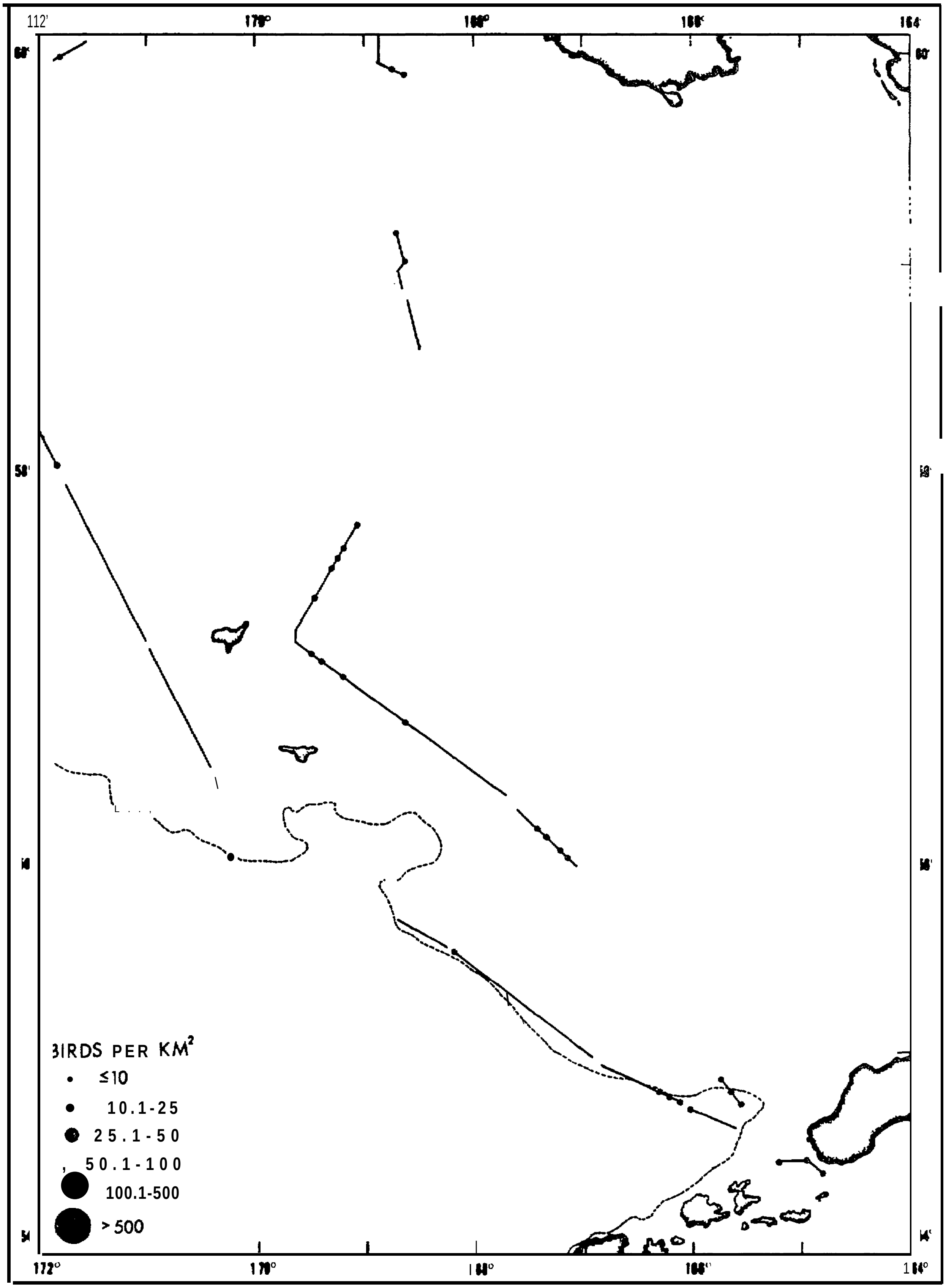


Figure 121, Distribution and abundance of Tufted Puffins in southern Bering Sea from 5 to 24 May, on 29 May, on 2 June and from 8 to 10 June 1977.

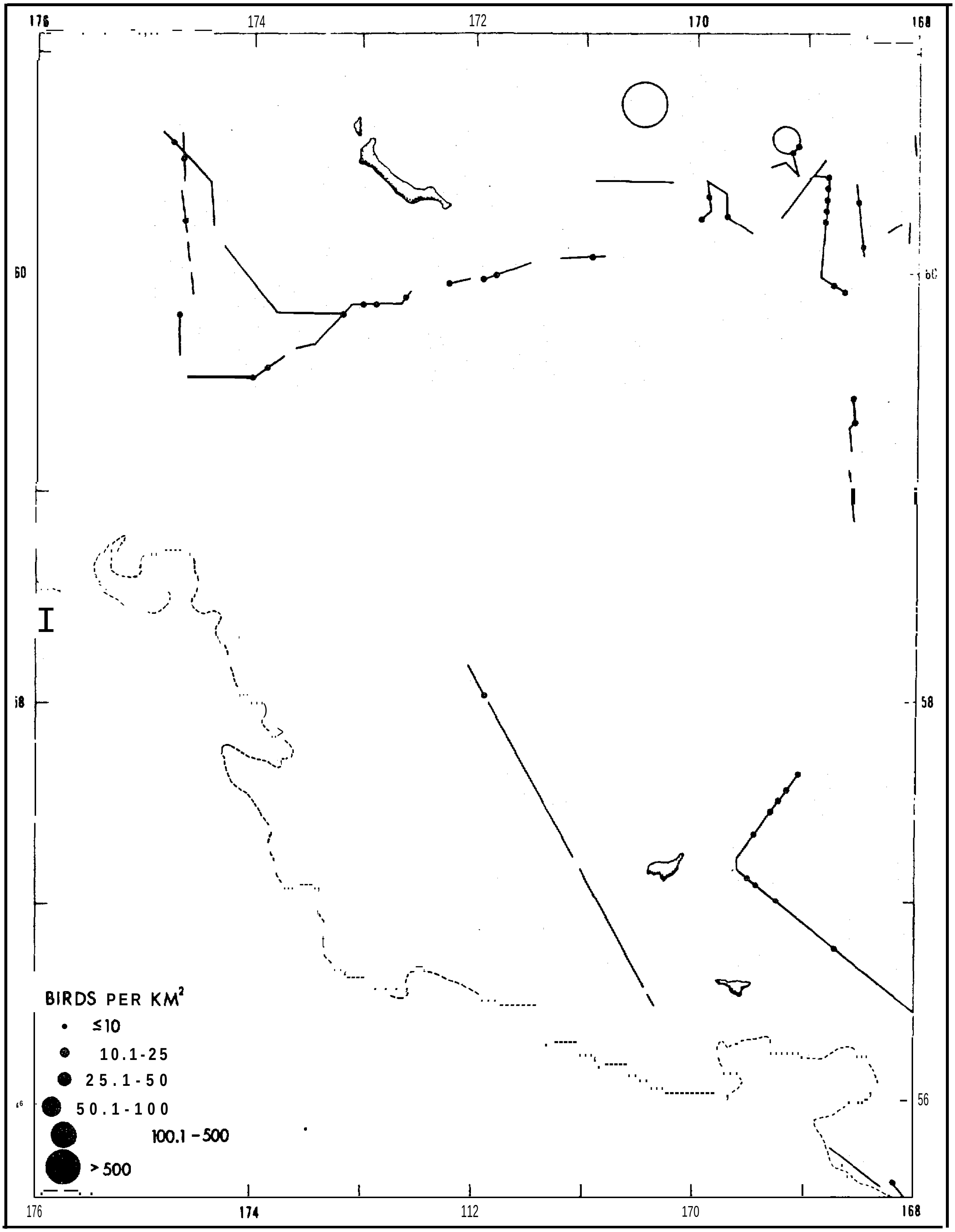


Figure **122.** Distribution and abundance of Tufted Puffins in central Bering Sea from 23 May to 9 June 1977.

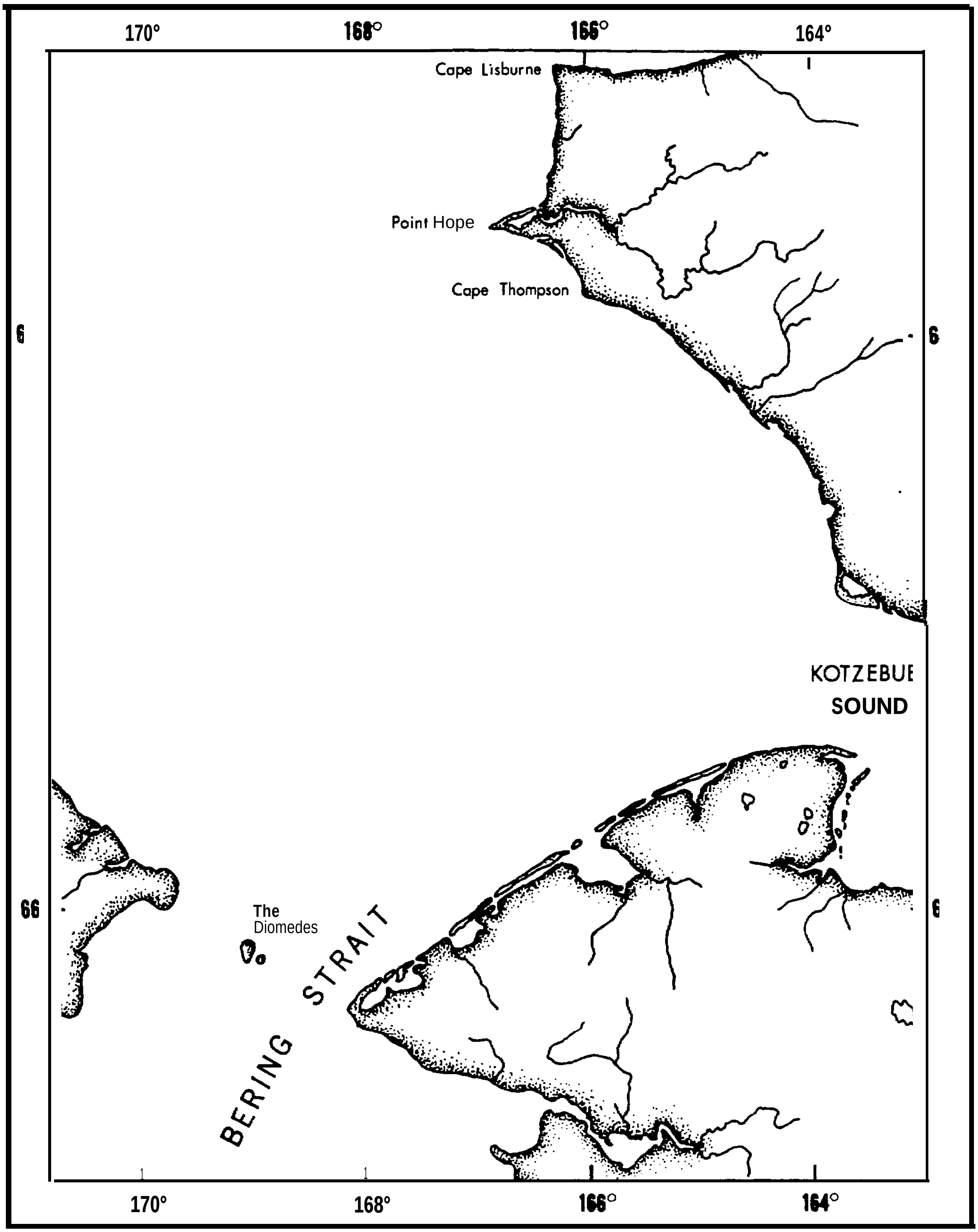


Figure 123. Bering Strait and southern Chukchi Sea showing localities mentioned in text.

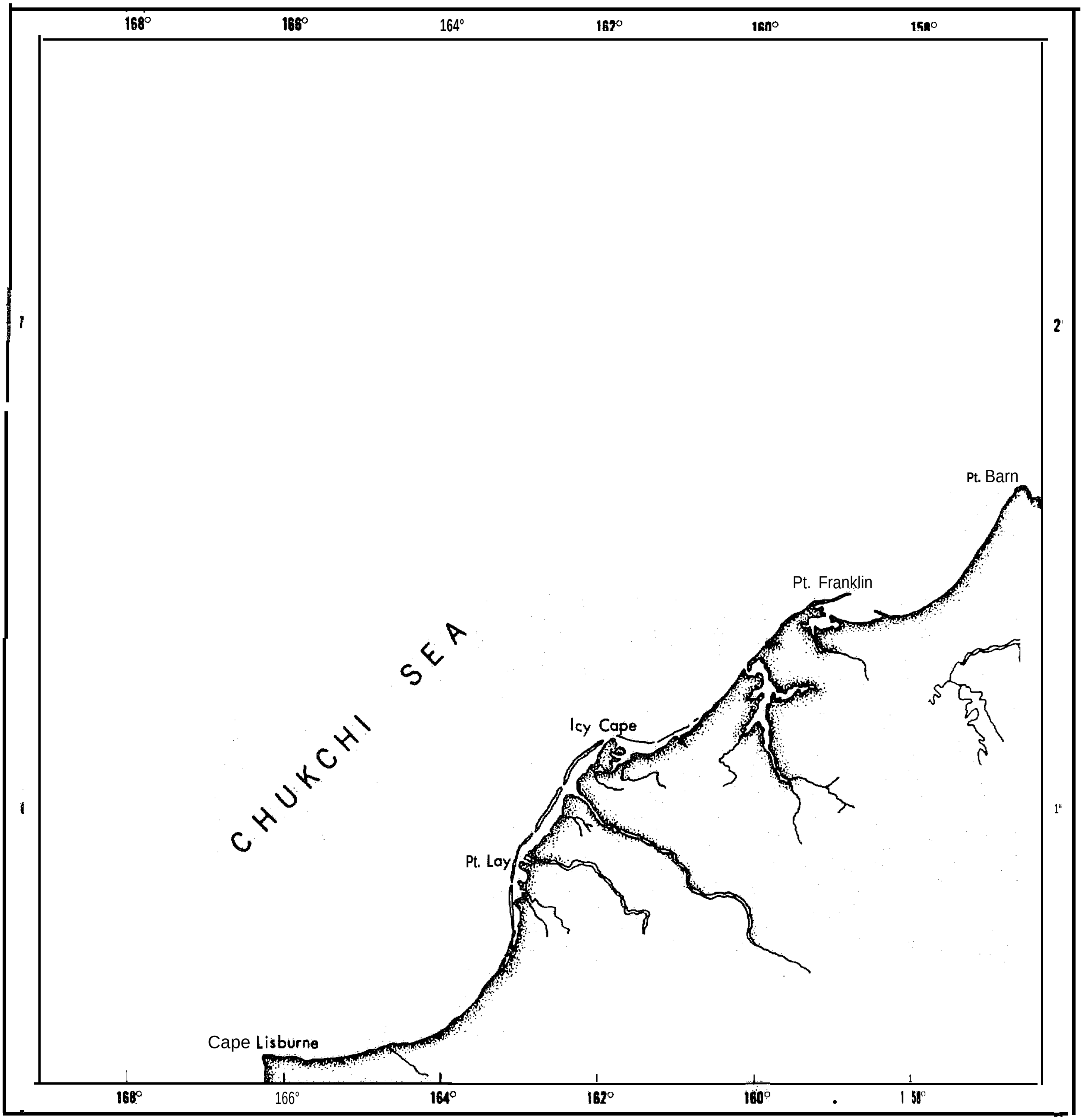


Figure 124. Northern Chukchi Sea showing localities mentioned in text.

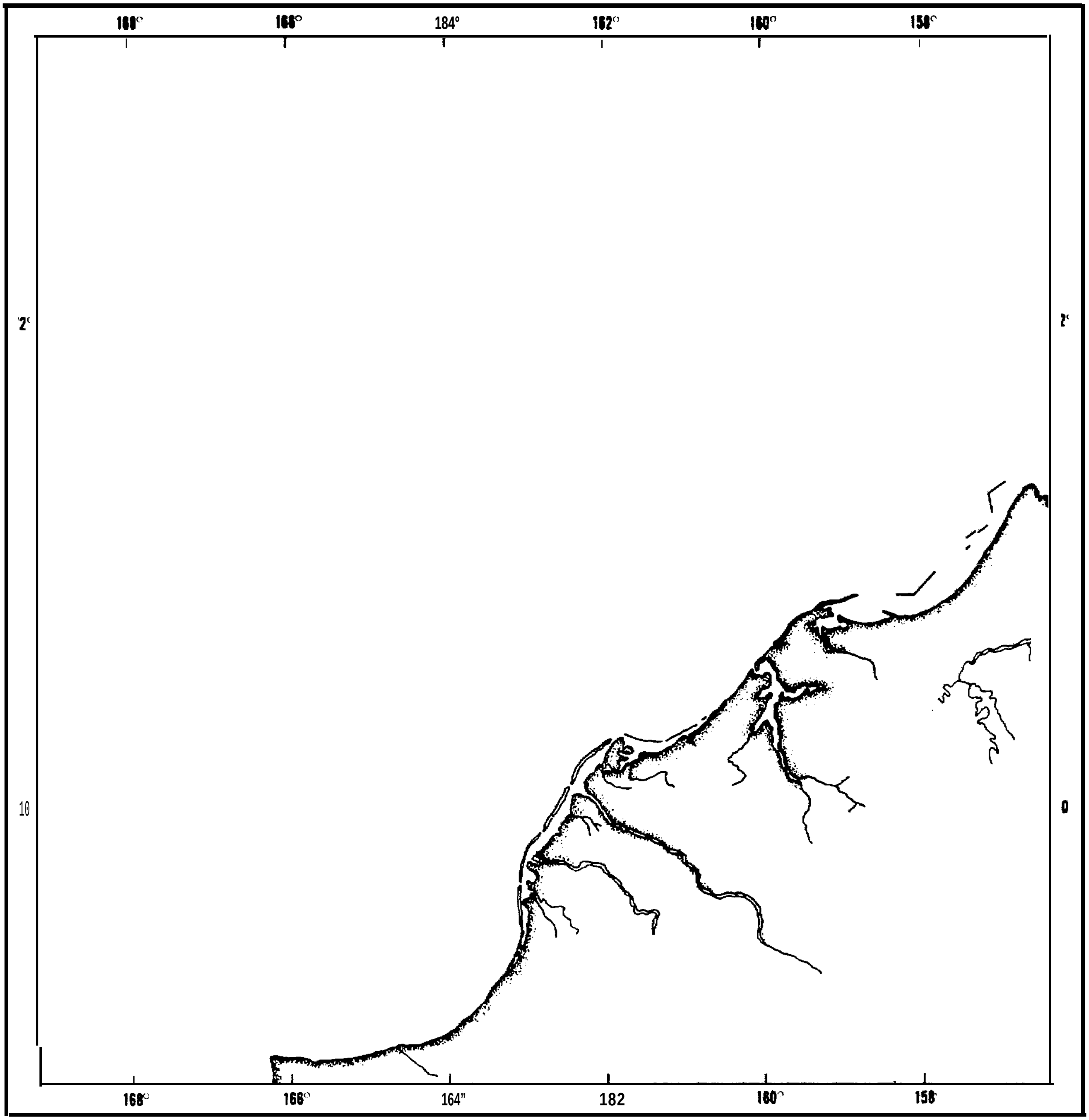


Figure 125. Cruise track during periods of observation in northern Chukchi Sea from 23 to 25 July 1976.

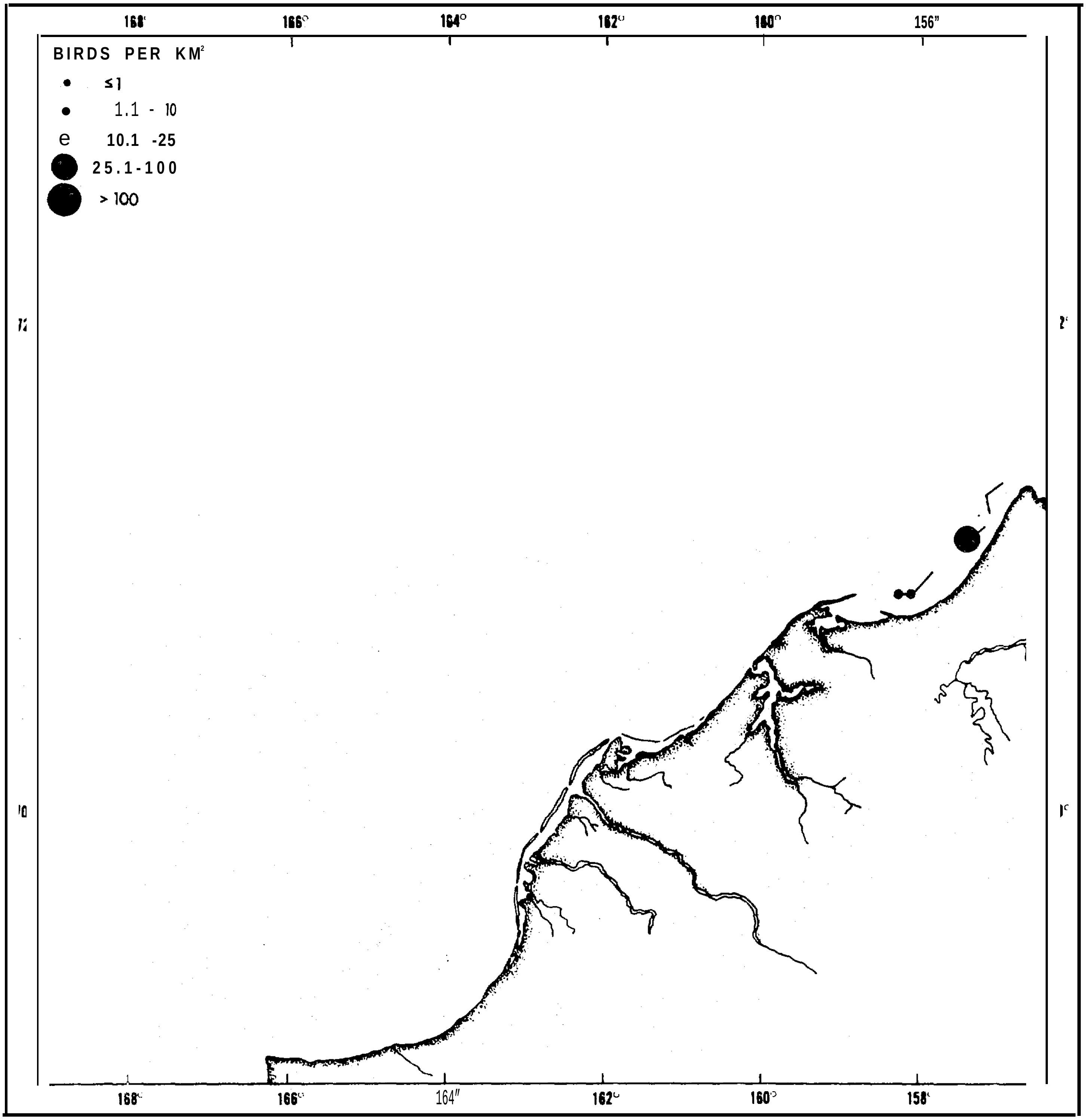


Figure 126. Distribution and abundance of seabirds in northern Chukchi Sea from 23 to 25 July I-976.

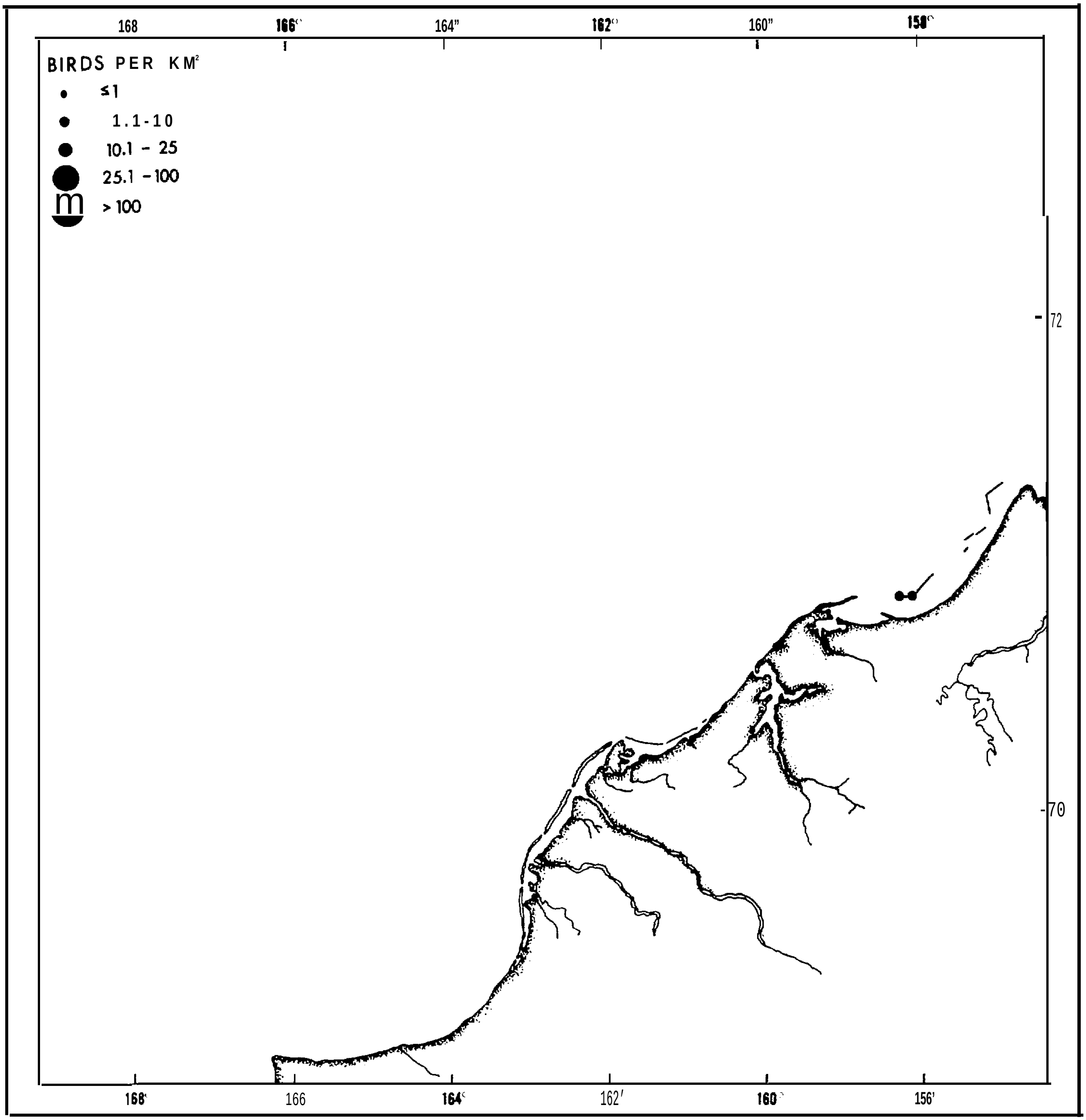


Figure 127. Distribution and abundance of loons in northern Chukchi Sea from 23 to 25 July 1976.

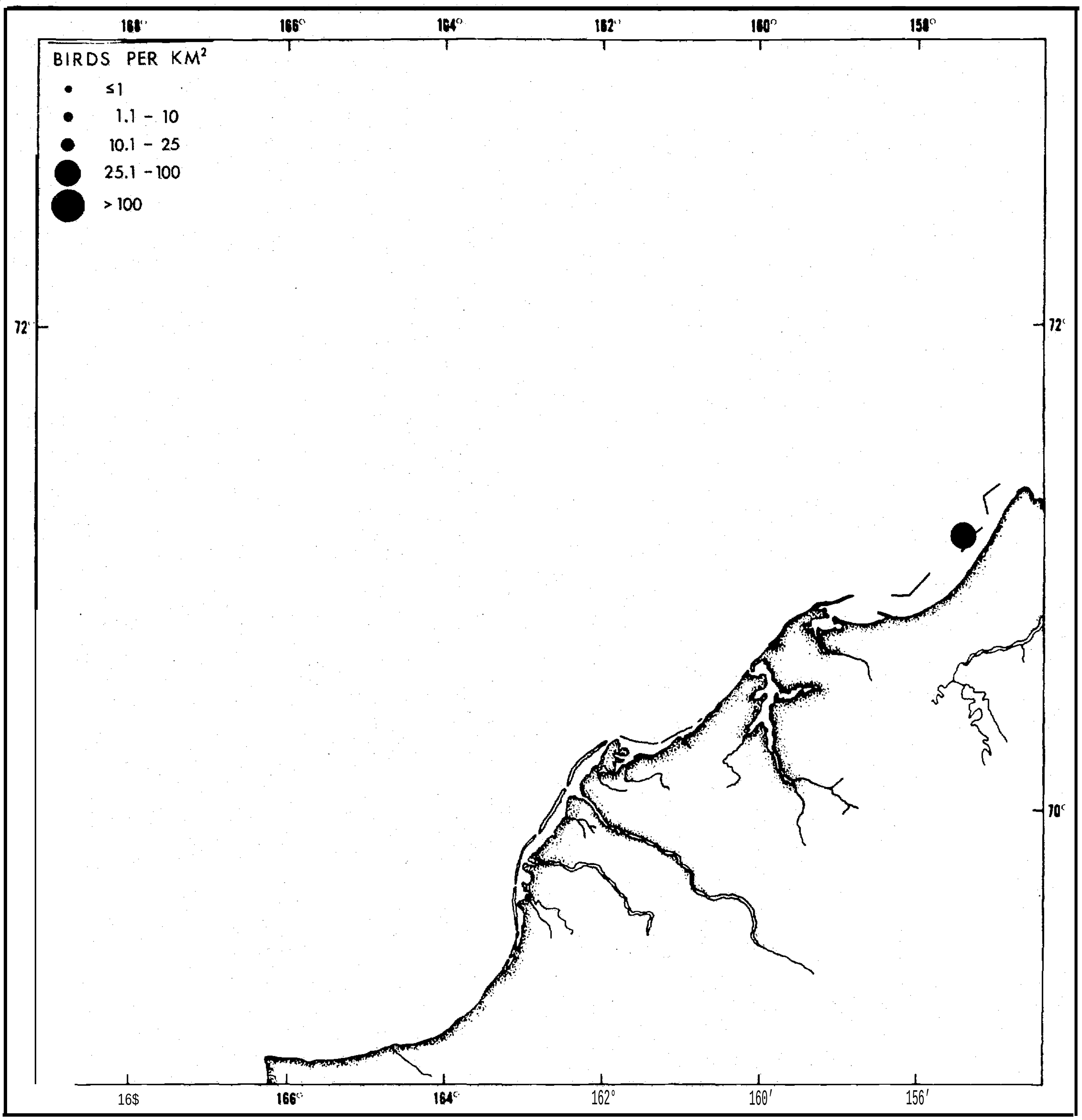


Figure 128. Distribution and abundance of eiders in northern Chukchi Sea from 23 to 25 July 1976.

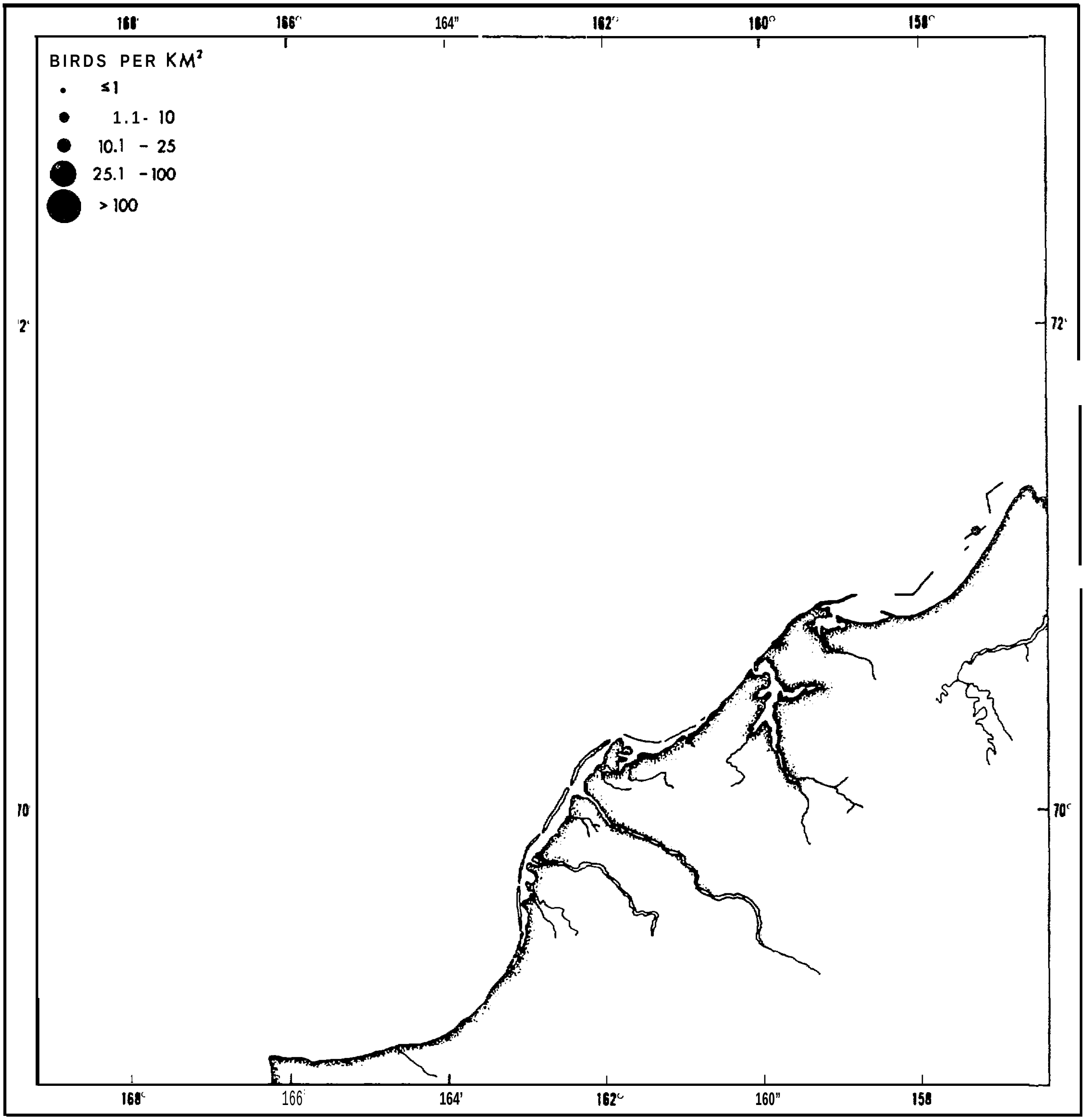


Figure 129. Distribution and abundance of Pomarine Jaegers in northern Chukchi Sea from 23 to 25 July 1976.

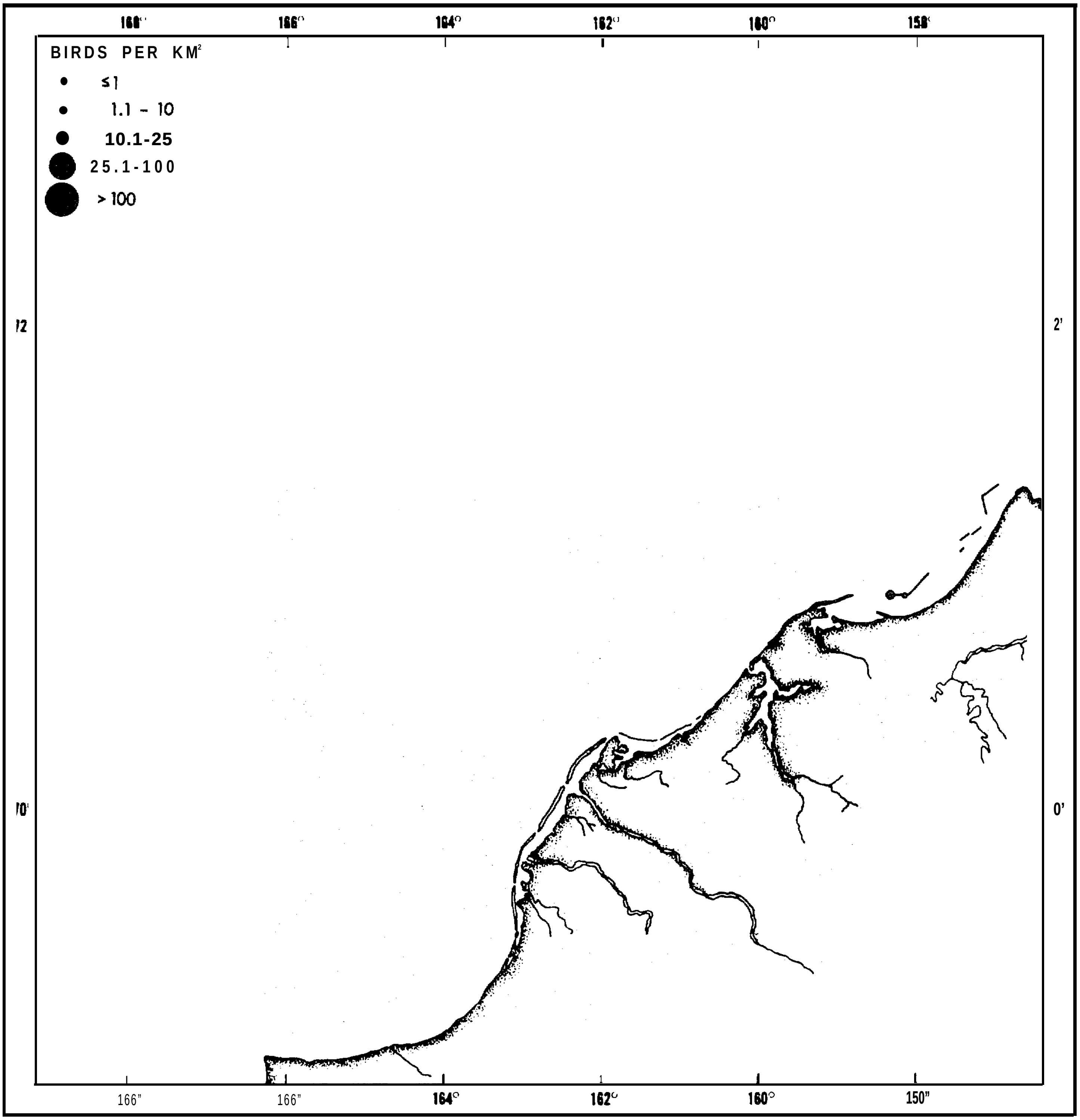


Figure 130. Distribution and abundance of murres in northern Chukchi Sea from 23 to 25 July 1976.

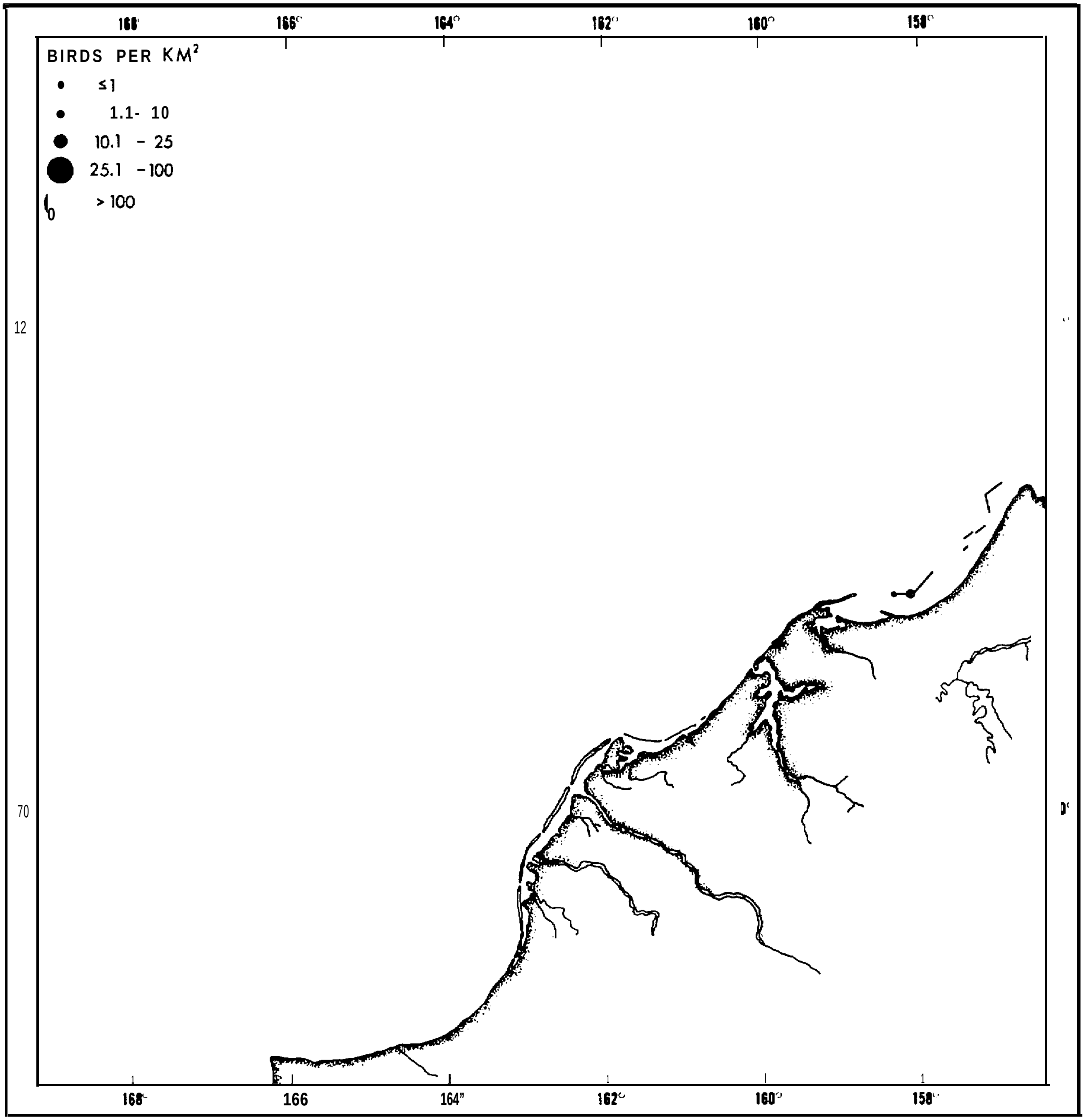


Figure 131. Distribution and abundance of Black Guillemots in northern Chukchi Sea from 23 to 25 July 1976.

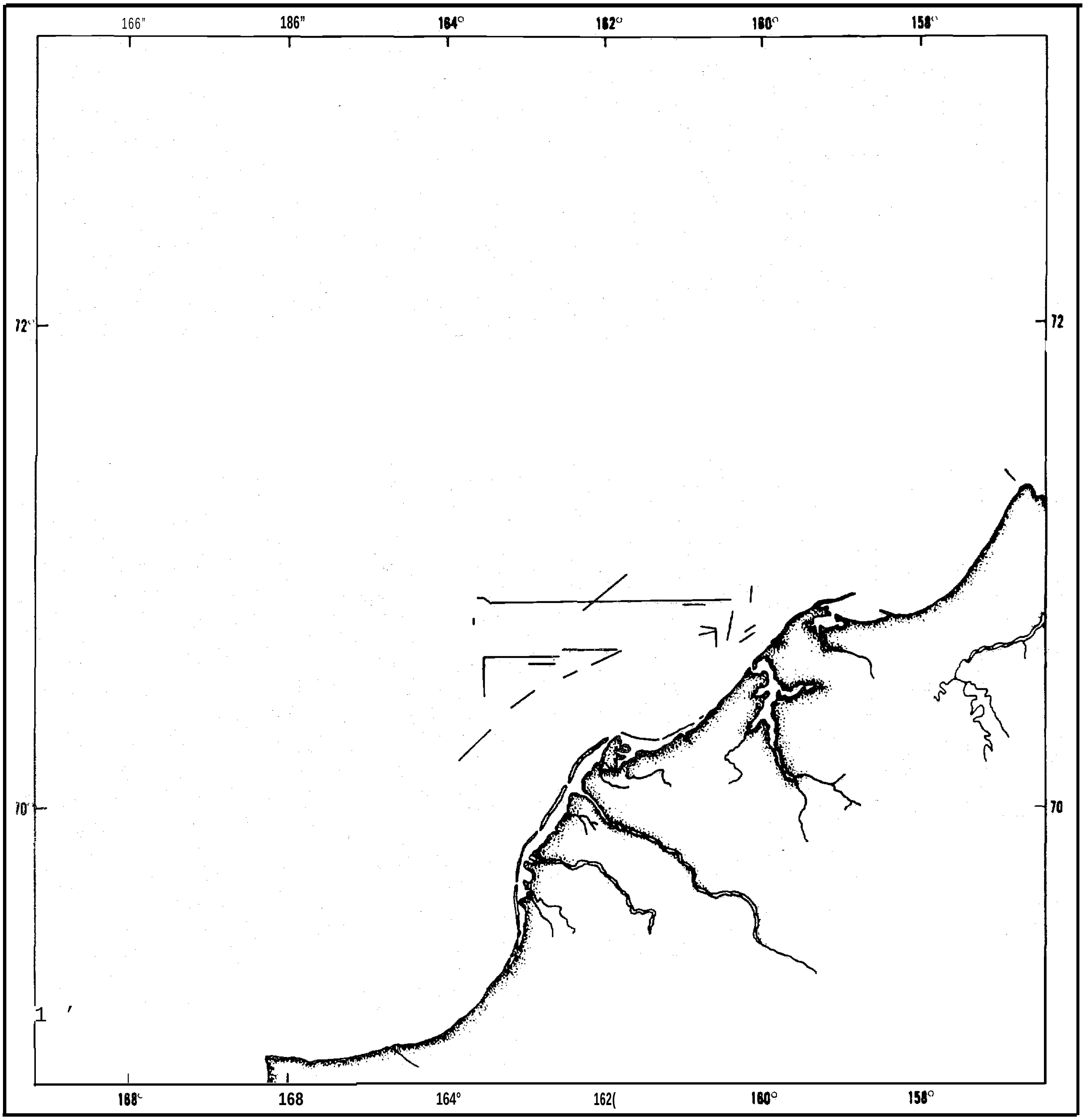


Figure 132. Cruise track during periods of observation in northern Chukchi Sea from 7 to 17 August 1976.

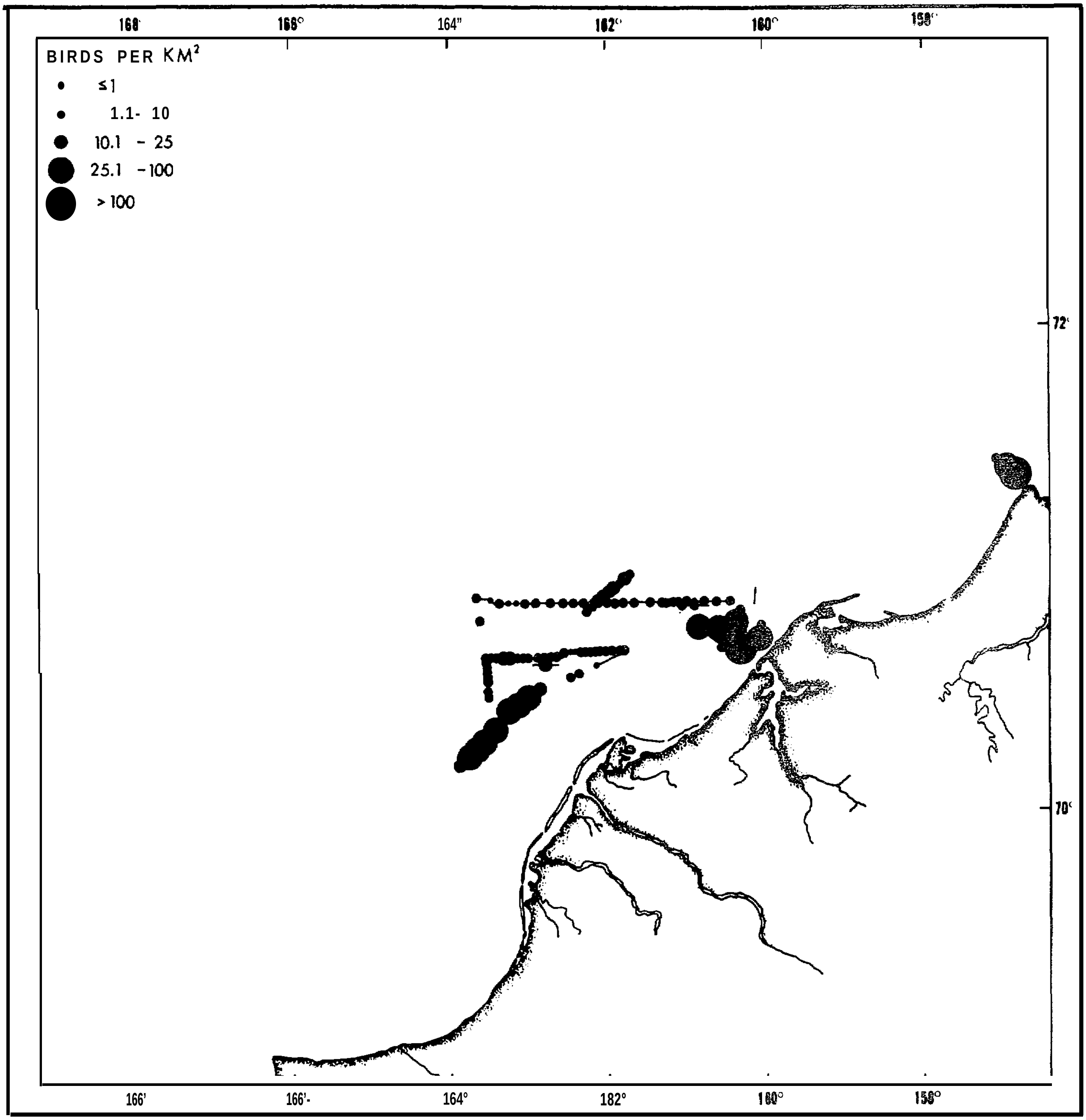


Figure 133. Distribution and abundance of seabirds in northern Chukchi Sea from 7 to 17 August 1976.

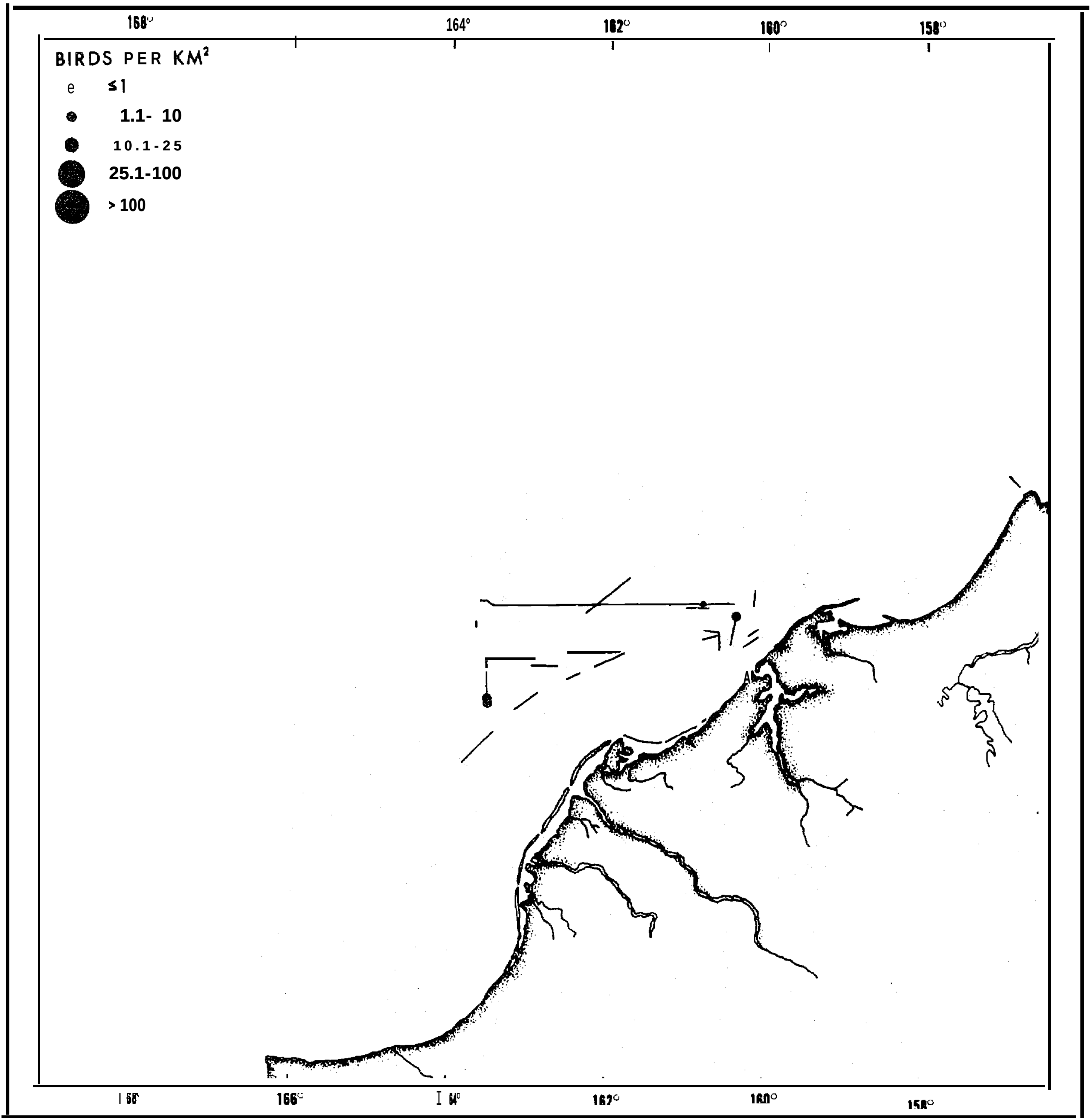


Figure 134. Distribution and abundance of loons in northern Chukchi Sea from 7 to 17 August 1976.

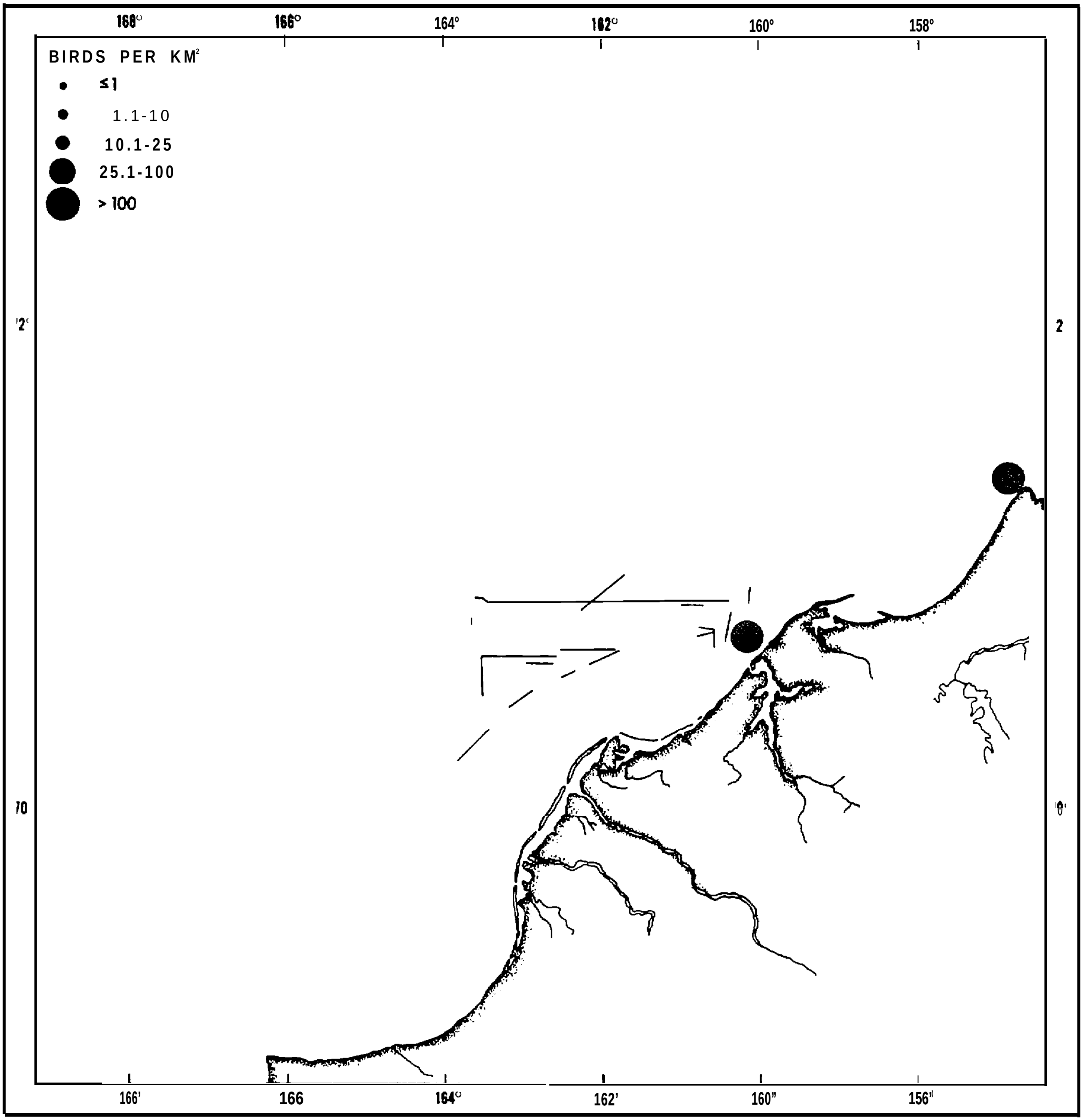


Figure 135. Distribution and abundance of eiders in northern Chukchi Sea from 7 to 17 August 1976.

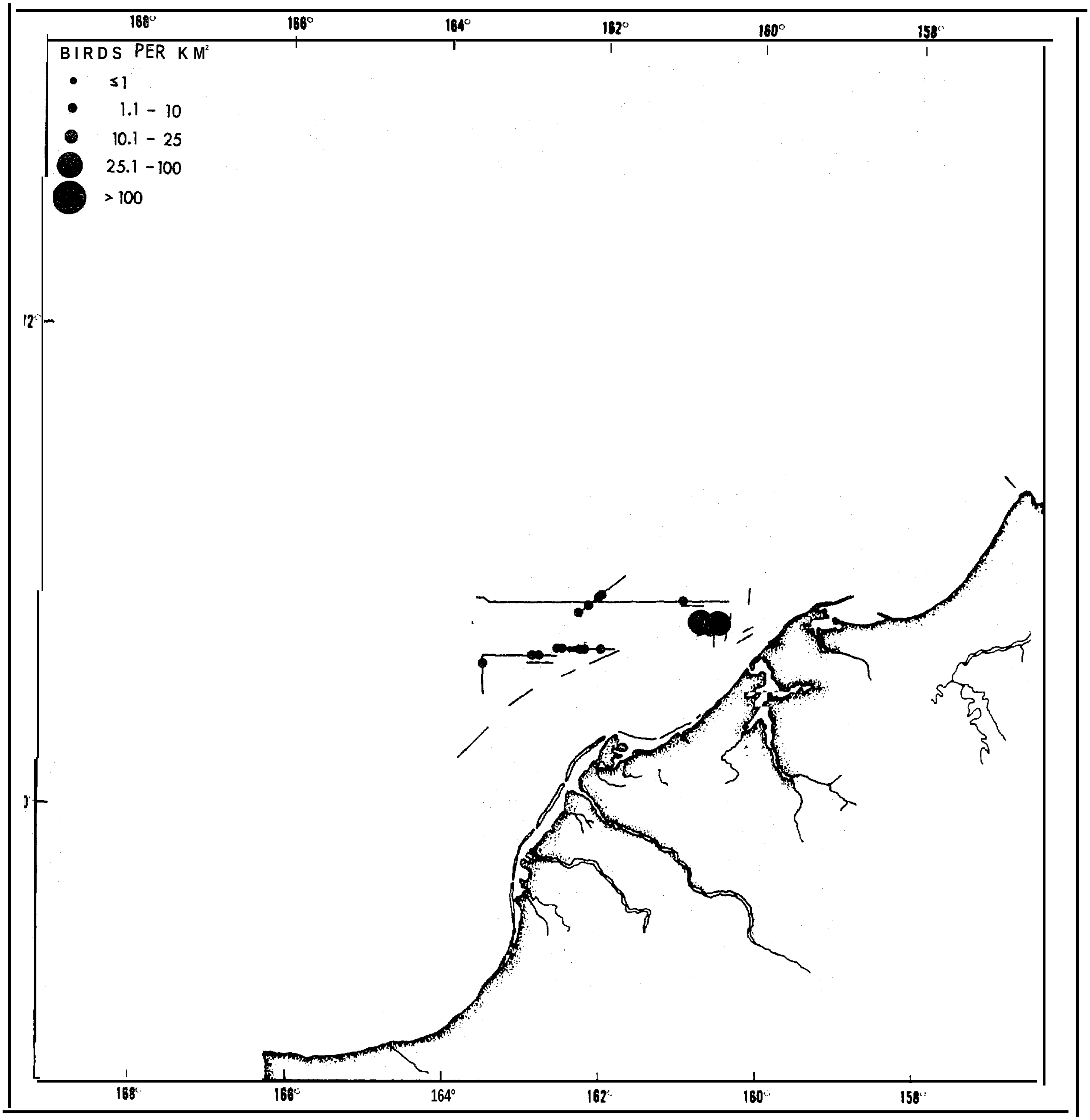


Figure 136. Distribution and abundance of phalaropes in northern Chukchi Sea from 7 to 17 August 1976.

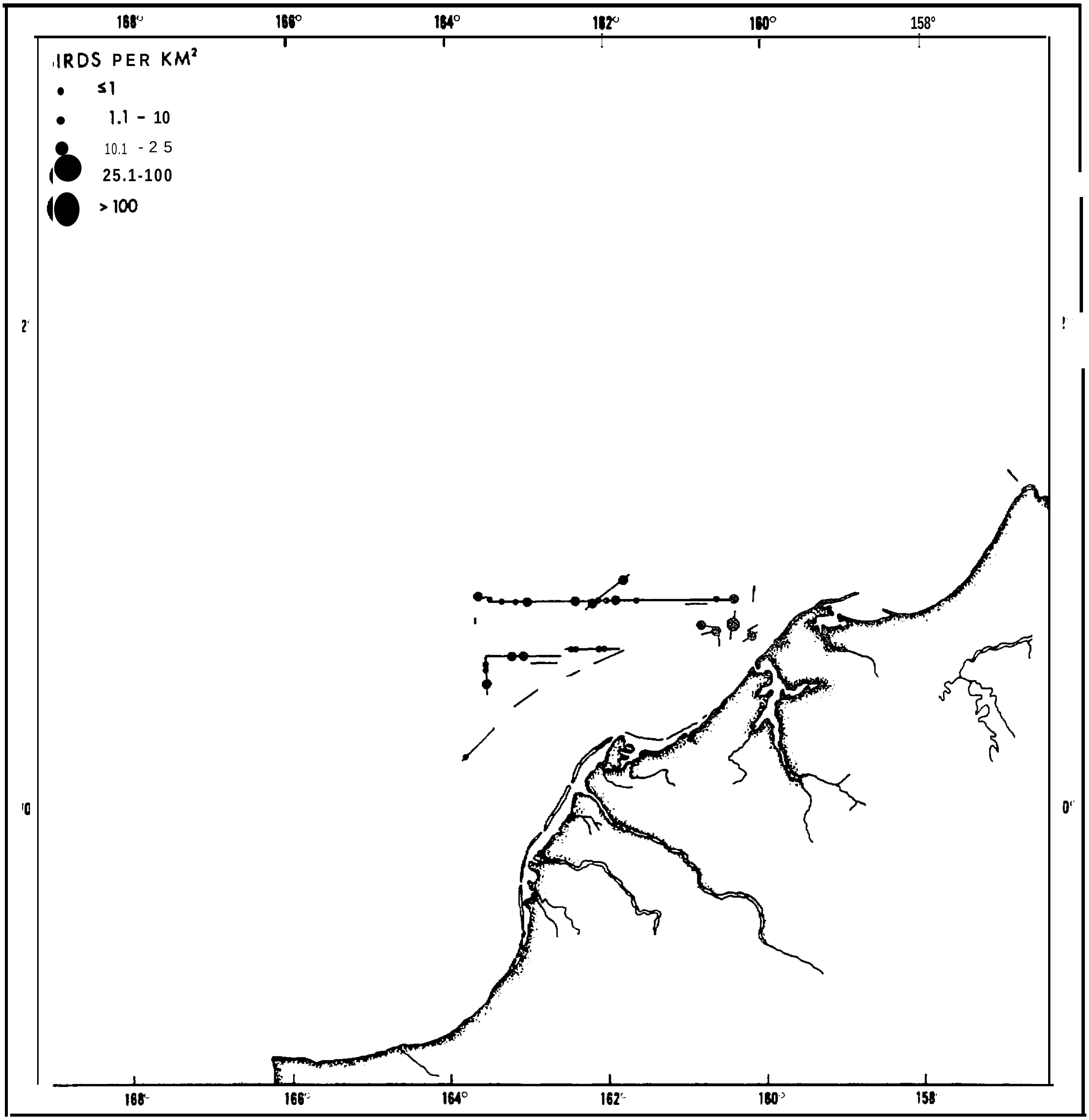


Figure 137. Distribution and abundance of jaegers in northern Chukchi Sea from 7 to 17 August 1976.

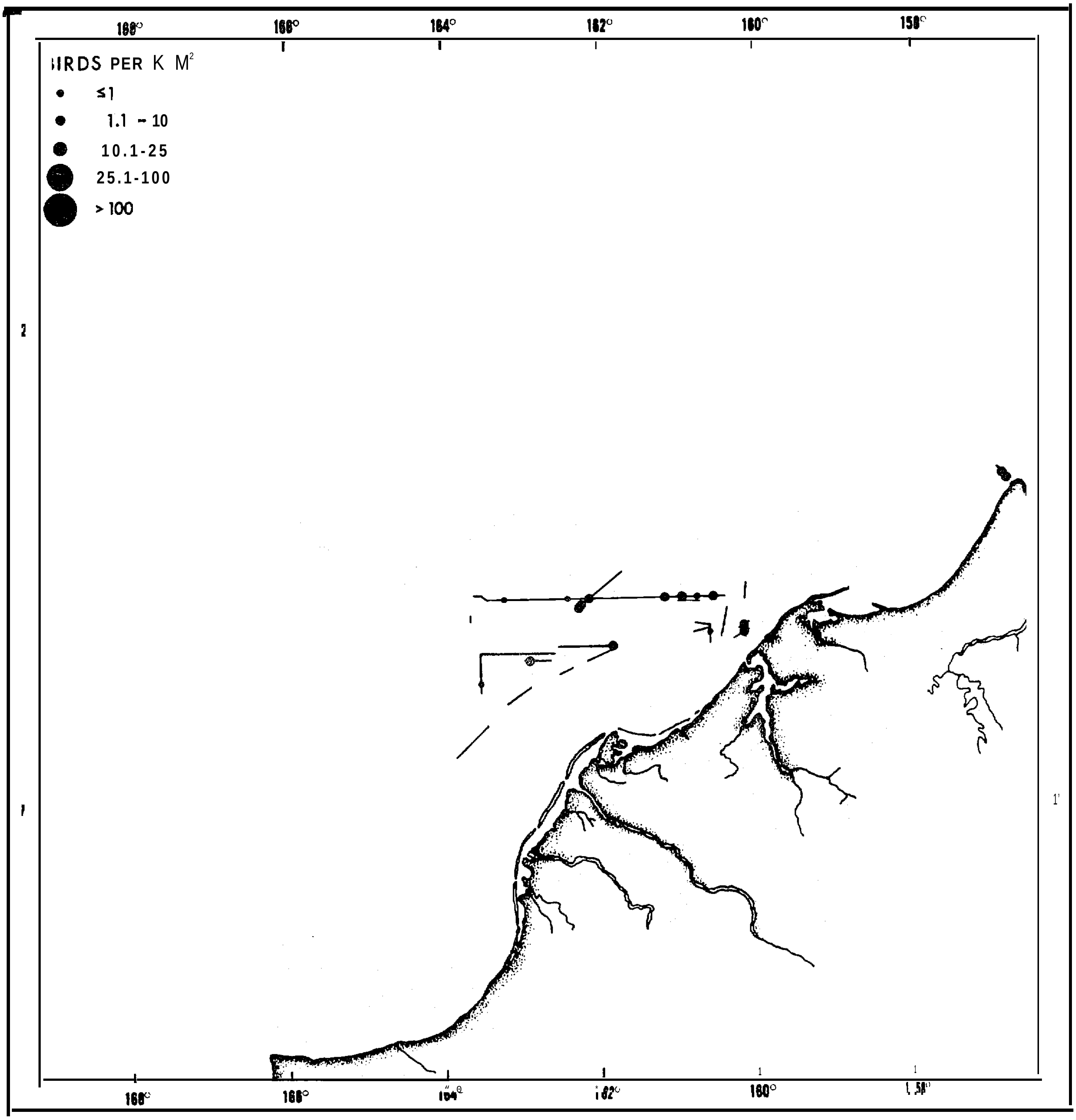


Figure 138. Distribution and abundance of Glaucous Gulls in northern Chukchi Sea from 7 to 17 August 1976.

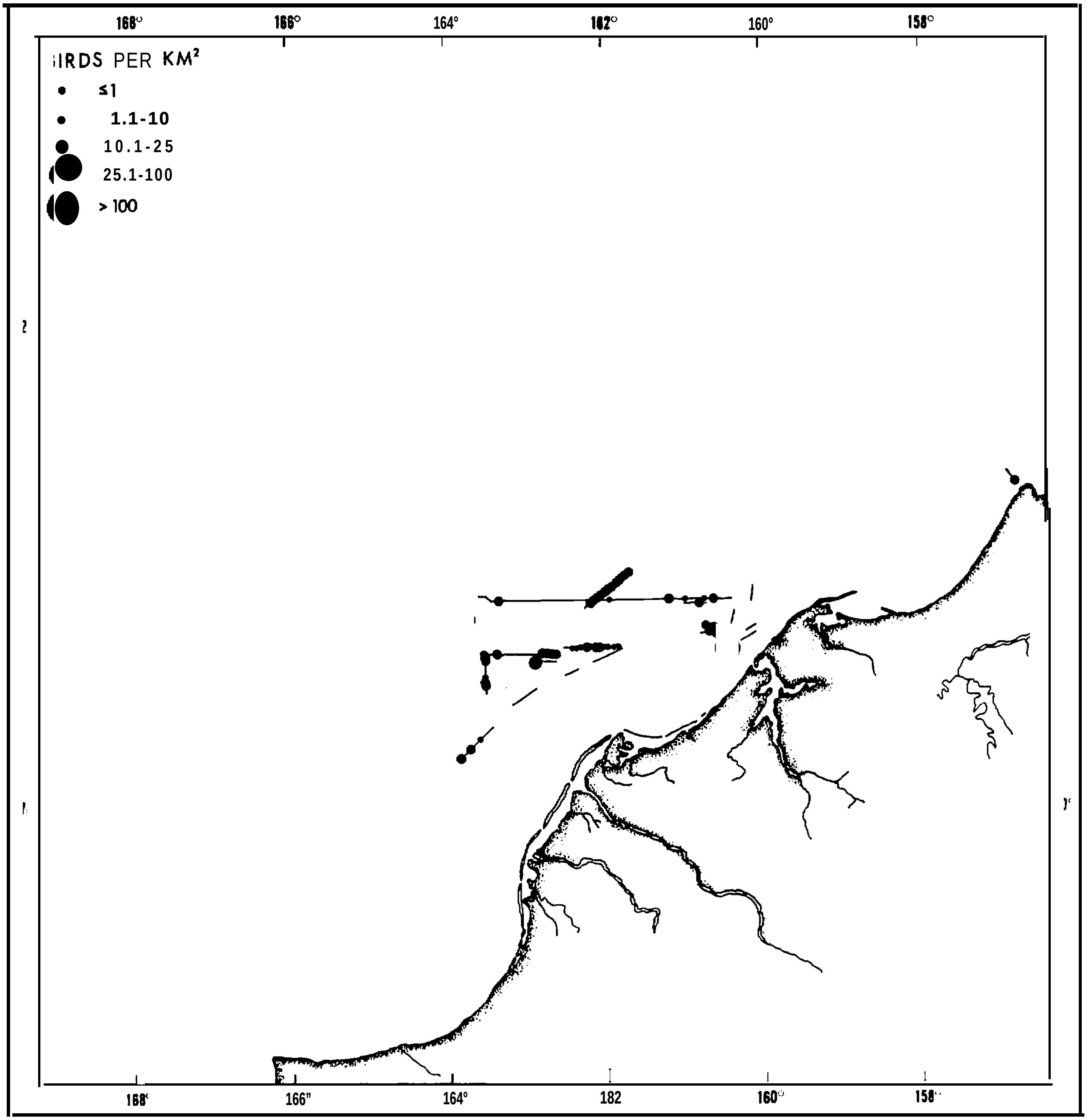


Figure 139. Distribution and abundance of Black-legged Kittiwakes in northern Chukchi Sea from 7 to 17 August 1976.

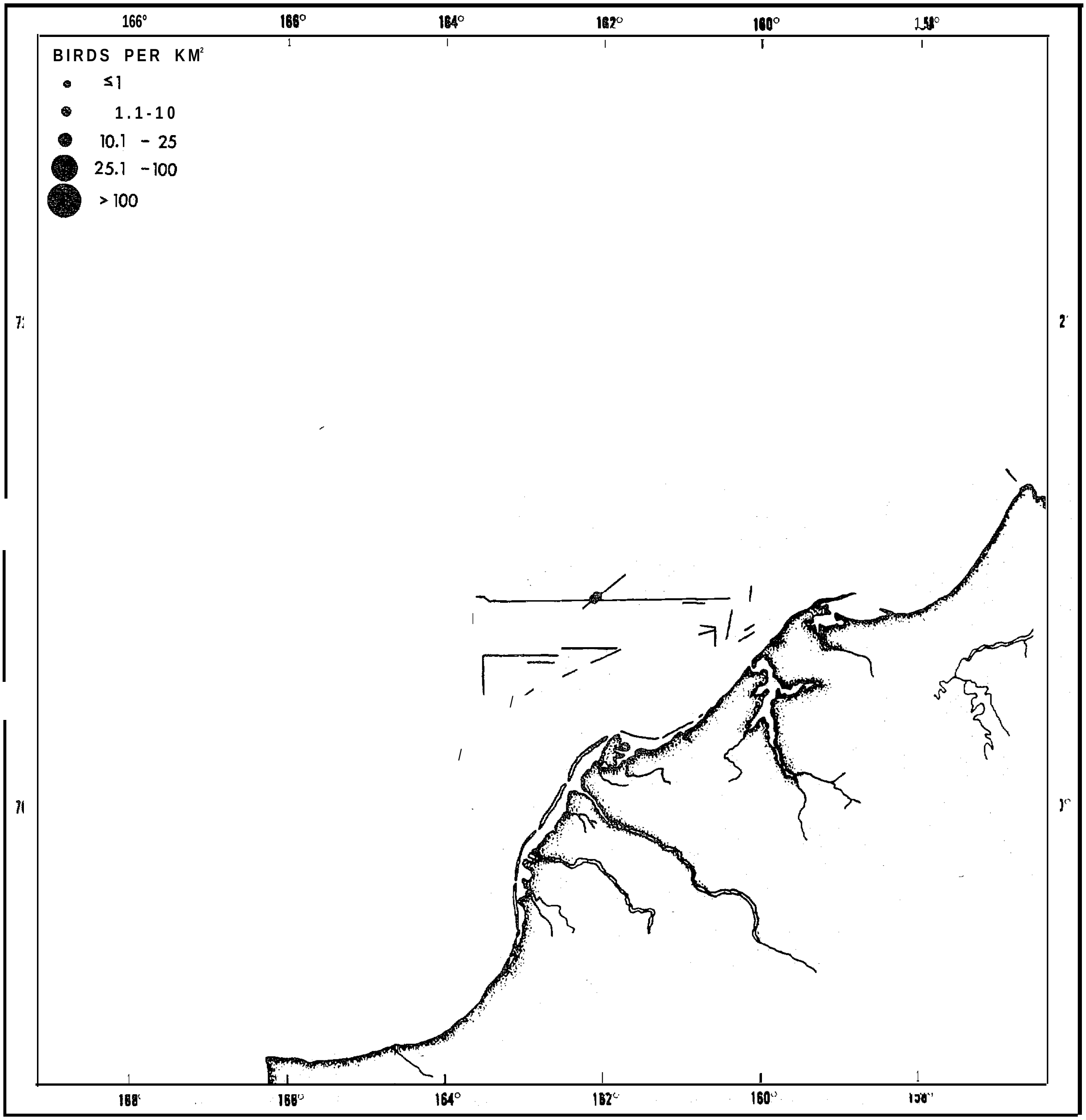


Figure 140. Distribution and abundance of Ross' Gulls in northern Chukchi Sea from 7 to 17 August 1976.

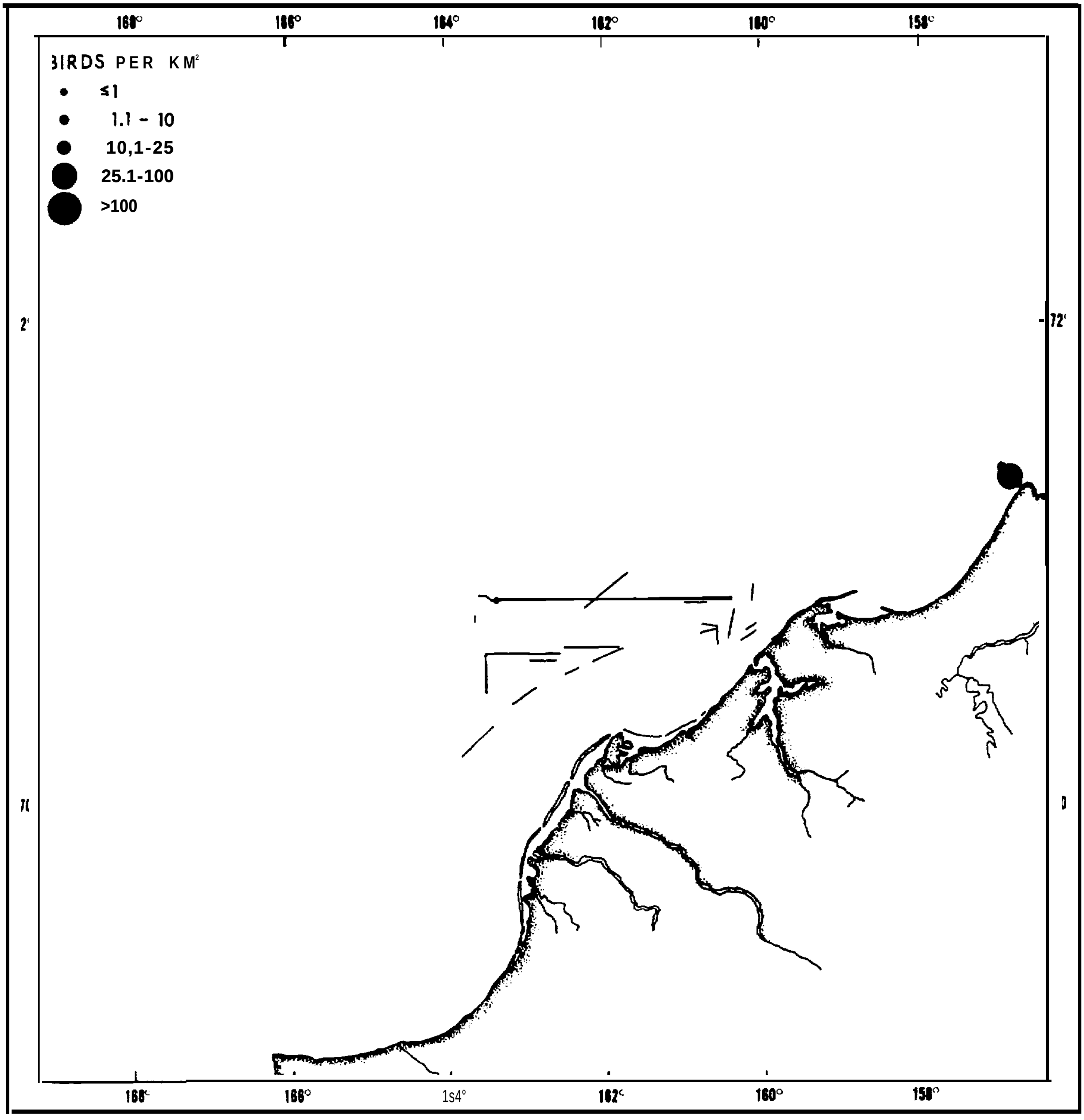


Figure 141. Distribution and abundance of Sabine's Gulls in northern Chukchi Sea from 7 to 17 August 1976.

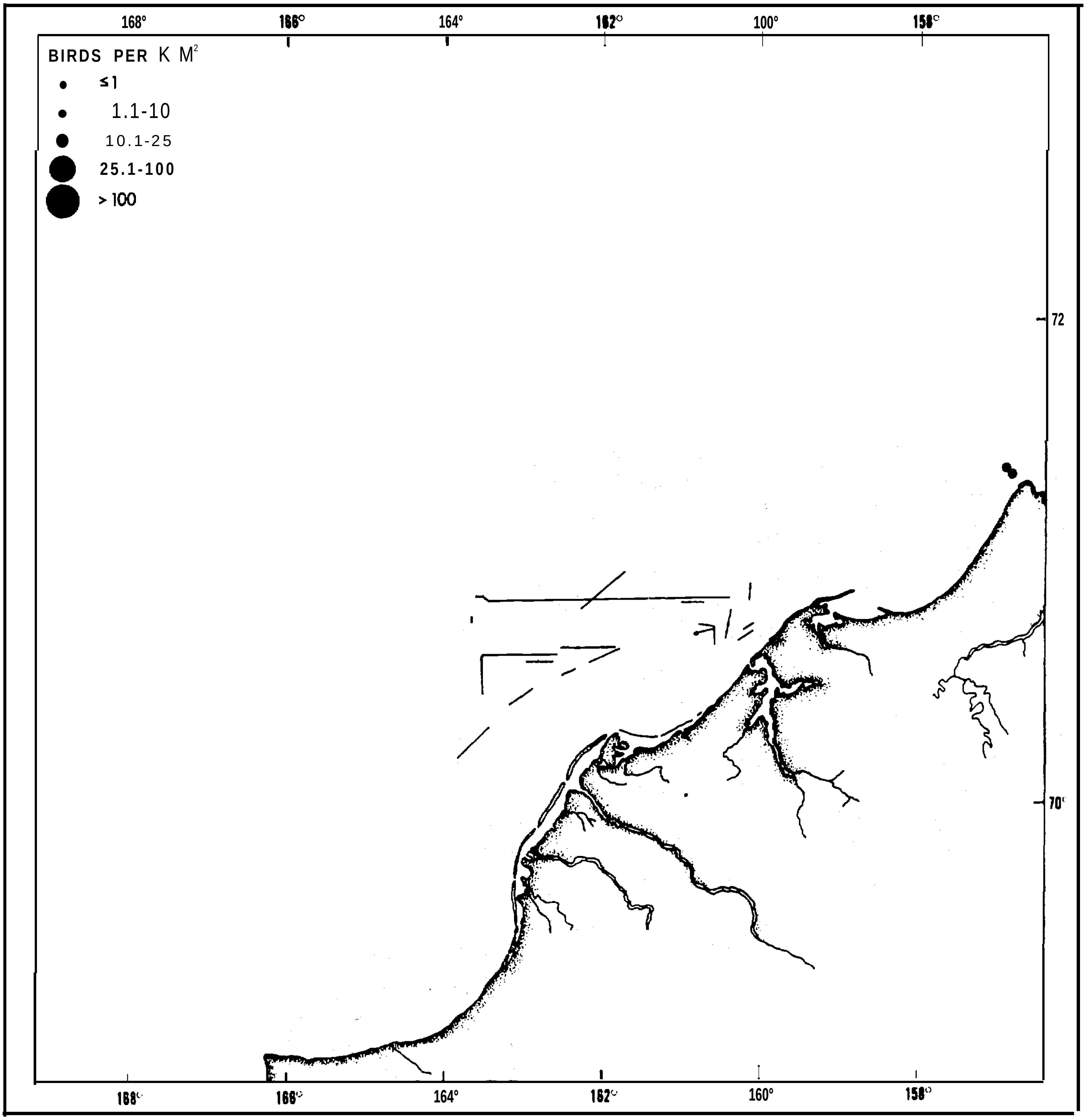


Figure 142. Distribution and abundance of Arctic Terns in northern Chukchi Sea from 7 to 17 August 1976.

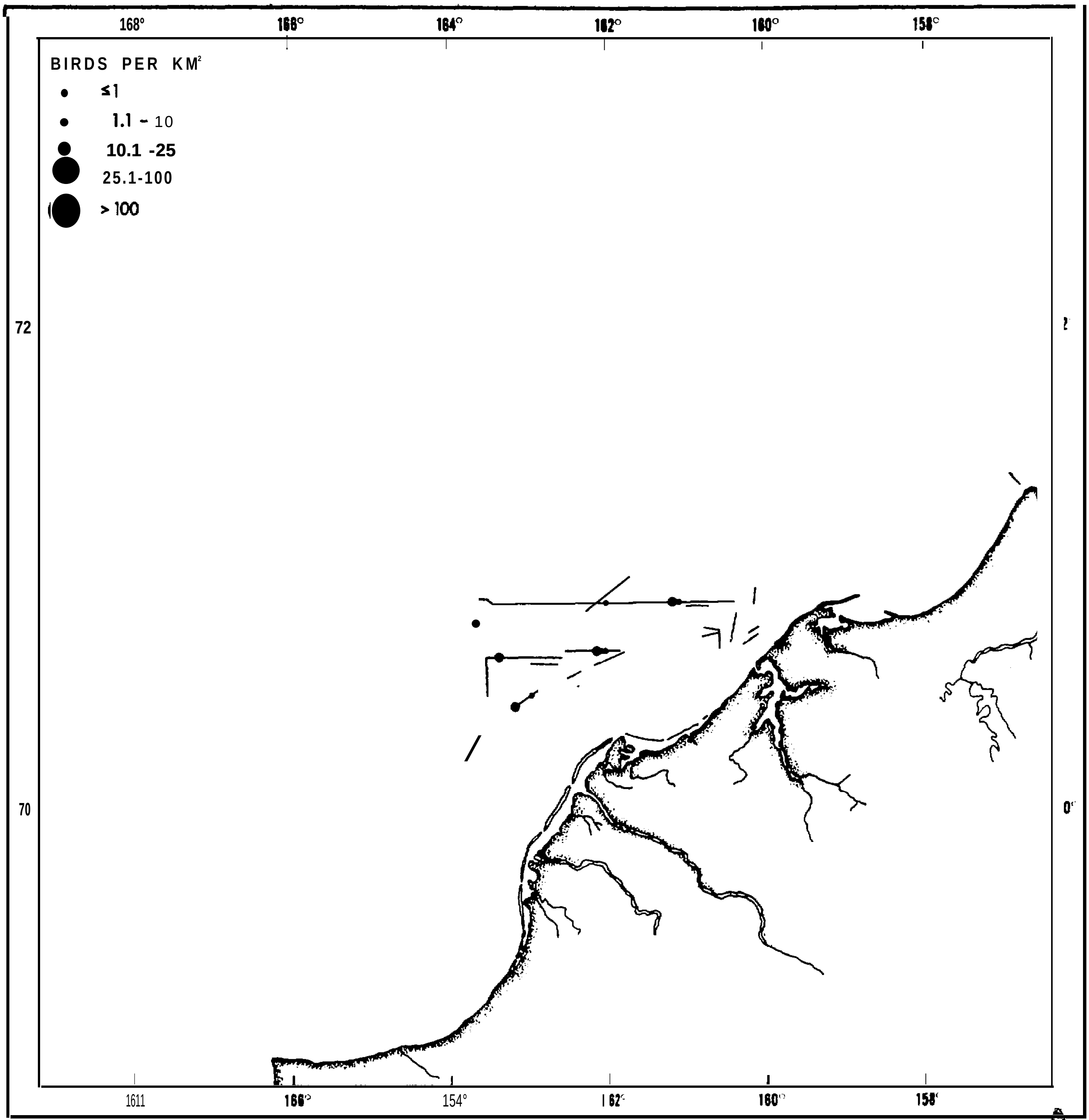


Figure 143. Distribution and abundance of Common Murres in northern Chukchi Sea from 7 to 17 August 1976.

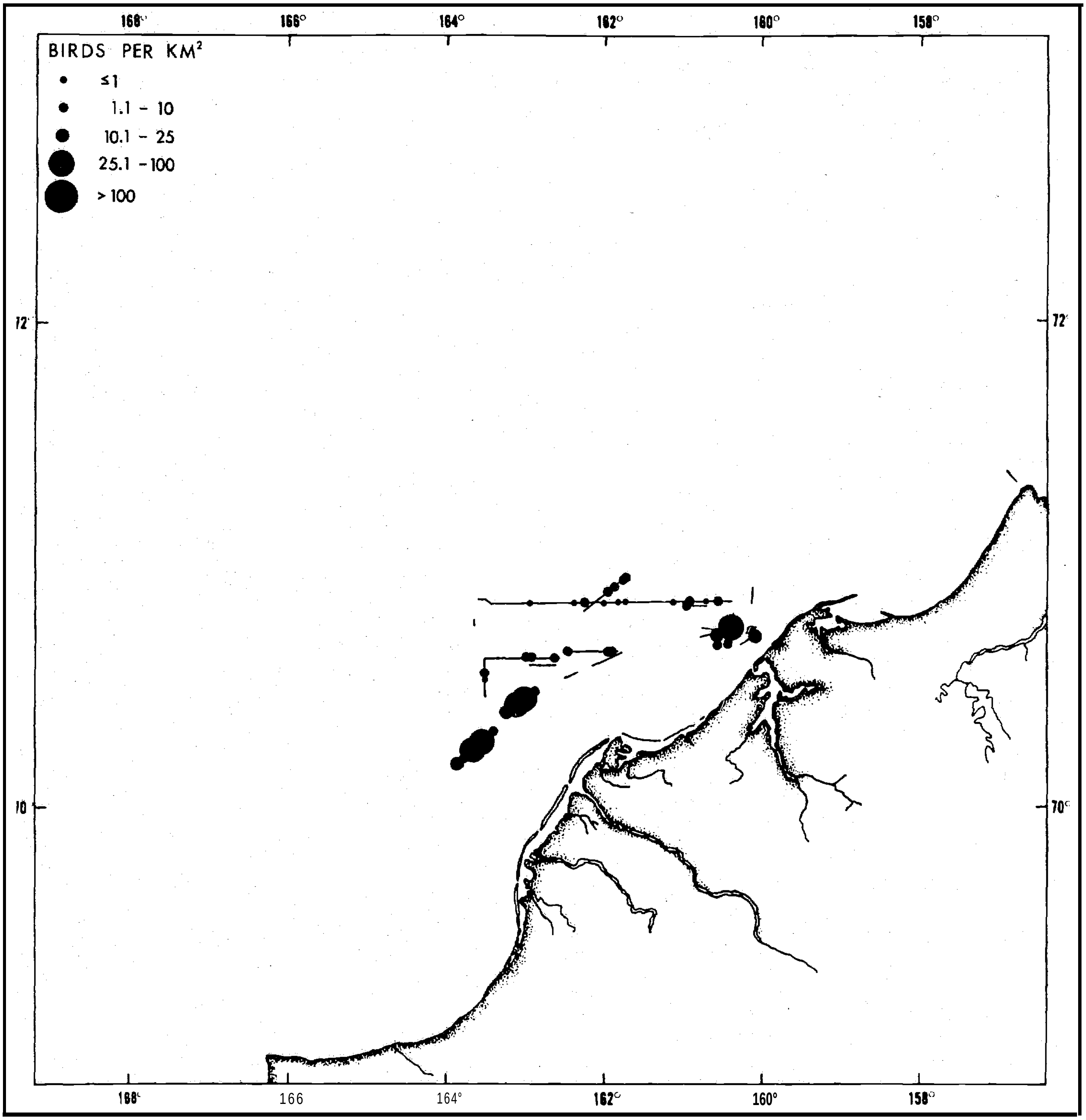


Figure 144. Distribution and abundance of Thick-billed Murres in northern Chukchi Sea from 7 to 17 August 1976.

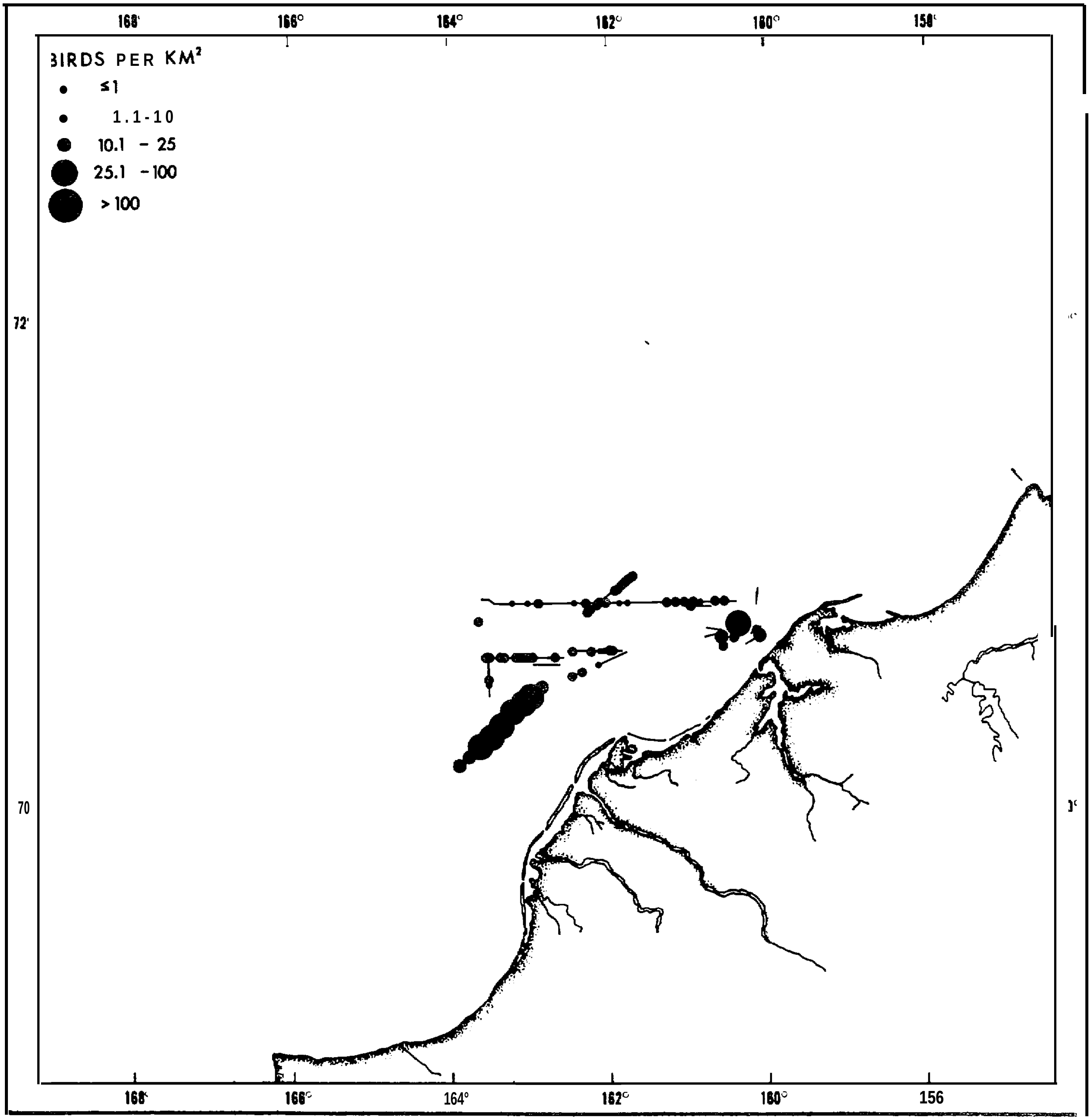


Figure 145. Distribution and abundance of all murres in northern Chukchi Sea from 7 to 17 August 1976.

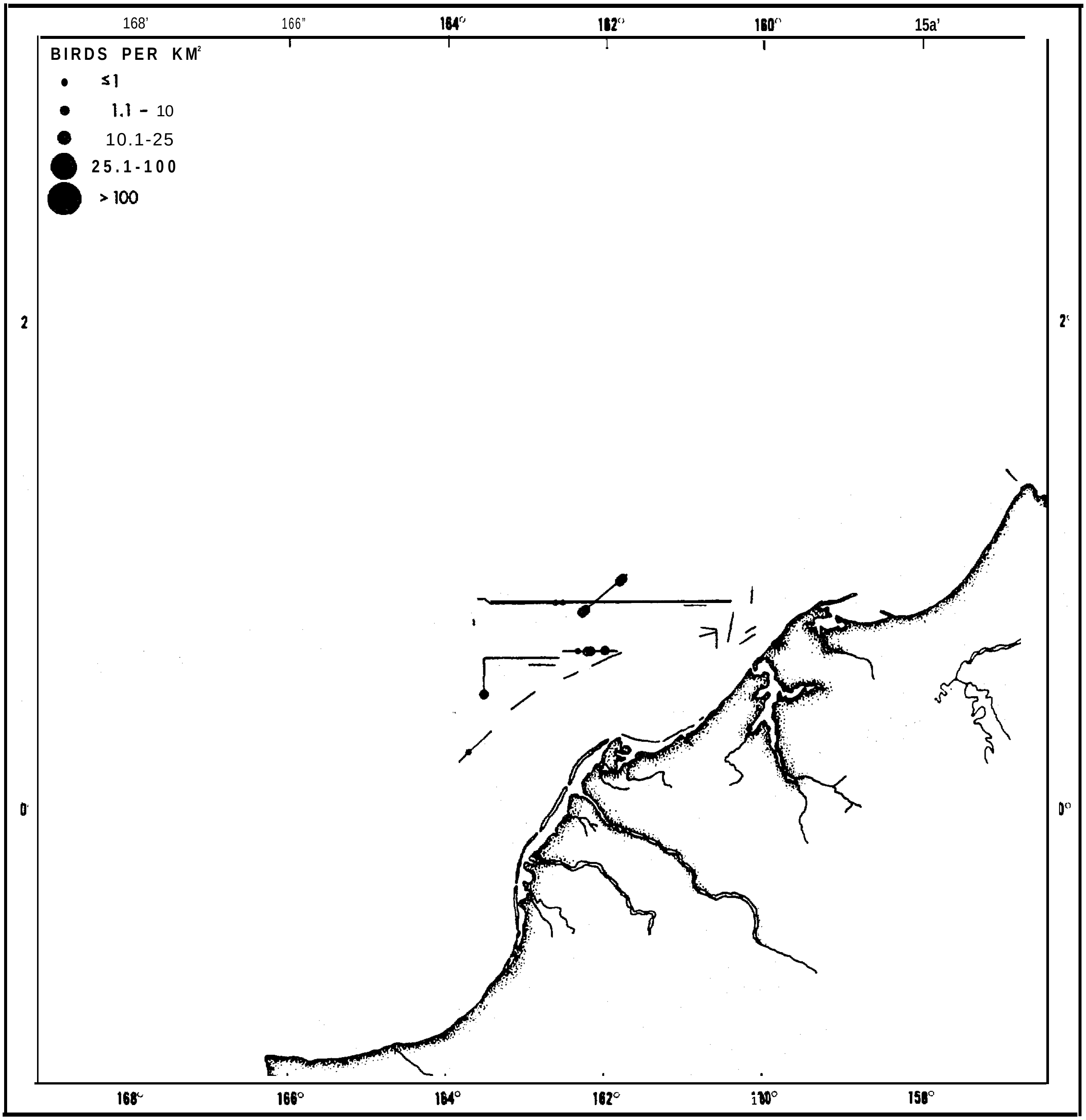


Figure 146. Distribution and abundance of Black Guillemots in northern Chukchi Sea from 7 to 17 August **1976.**

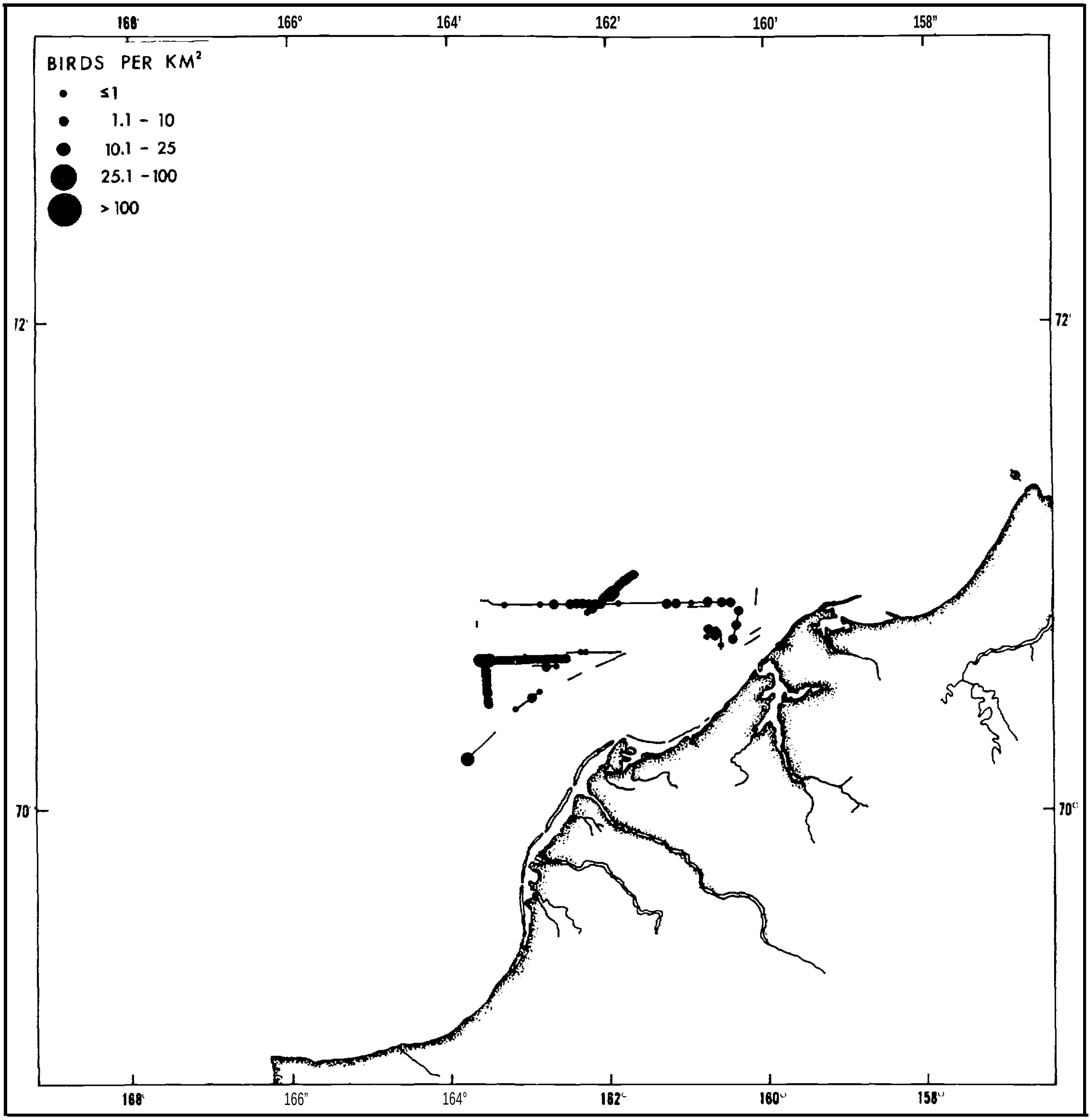


Figure 147. Distribution and abundance of ship followers in northern Chukchi Sea from 7 to 17 August 1976.

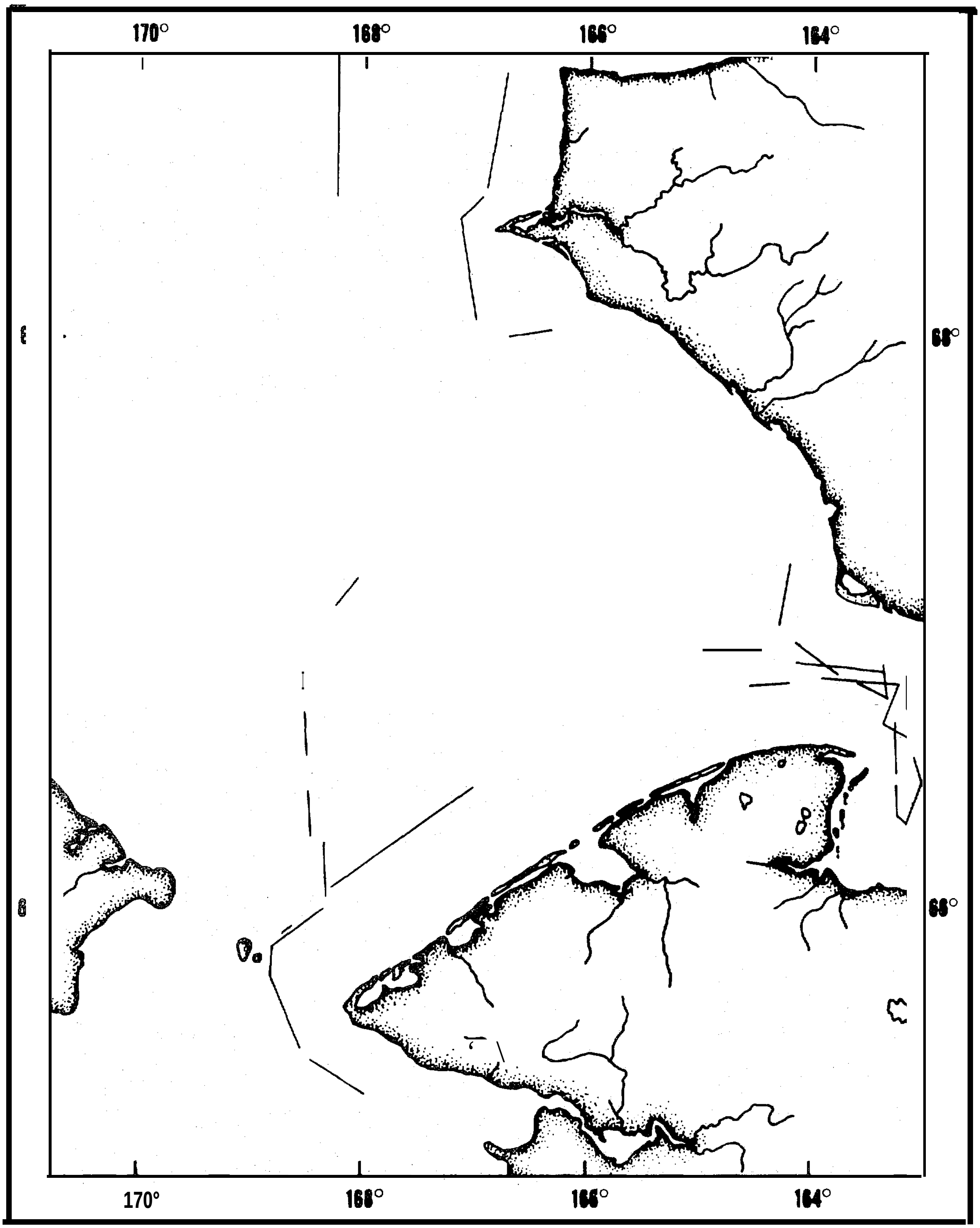


Figure 1.48. Cruise track during periods of observation in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

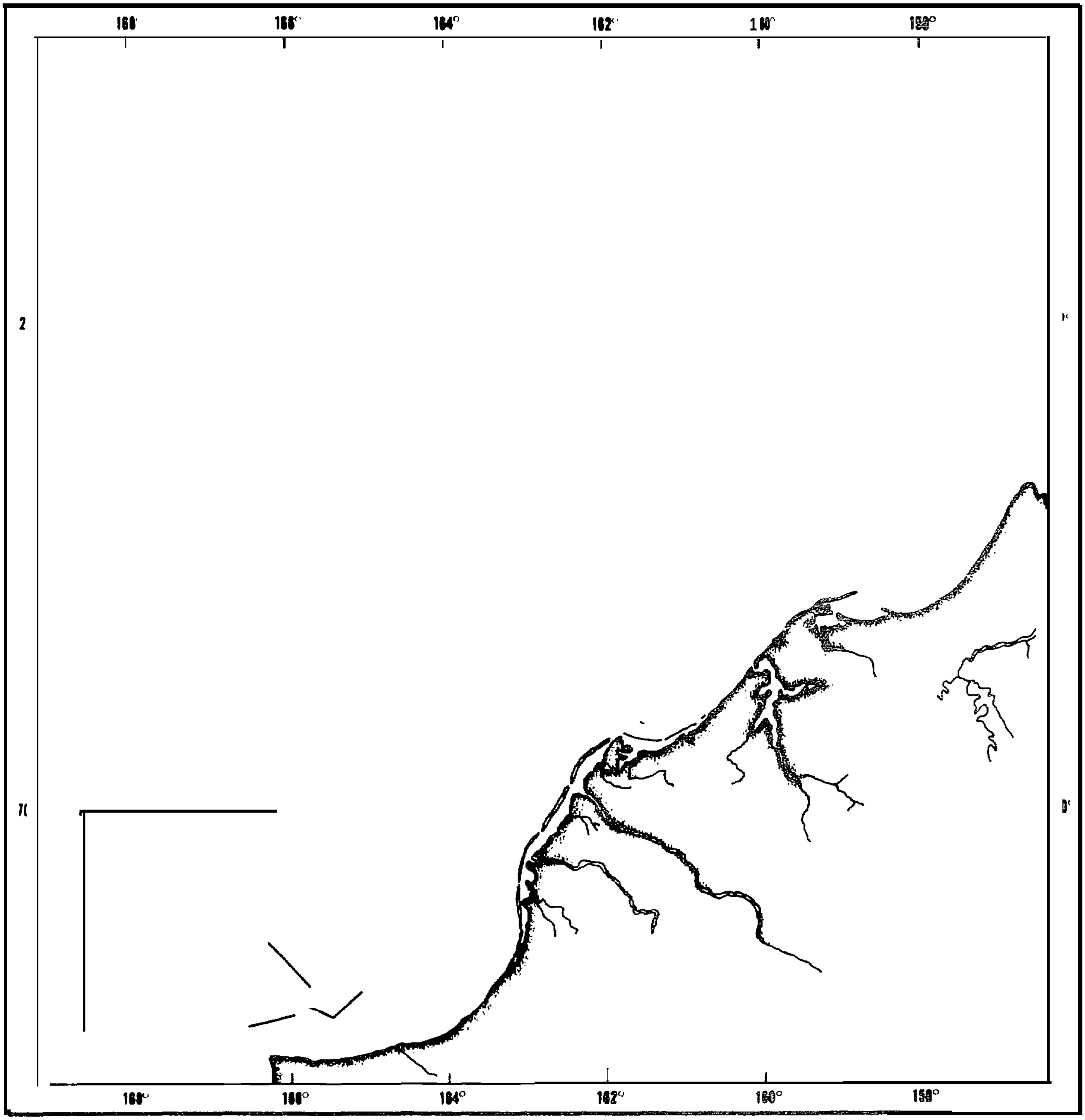


Figure 149. Cruise track during periods of observation in northern Chukchi Sea from 20 to 22 September 1976.

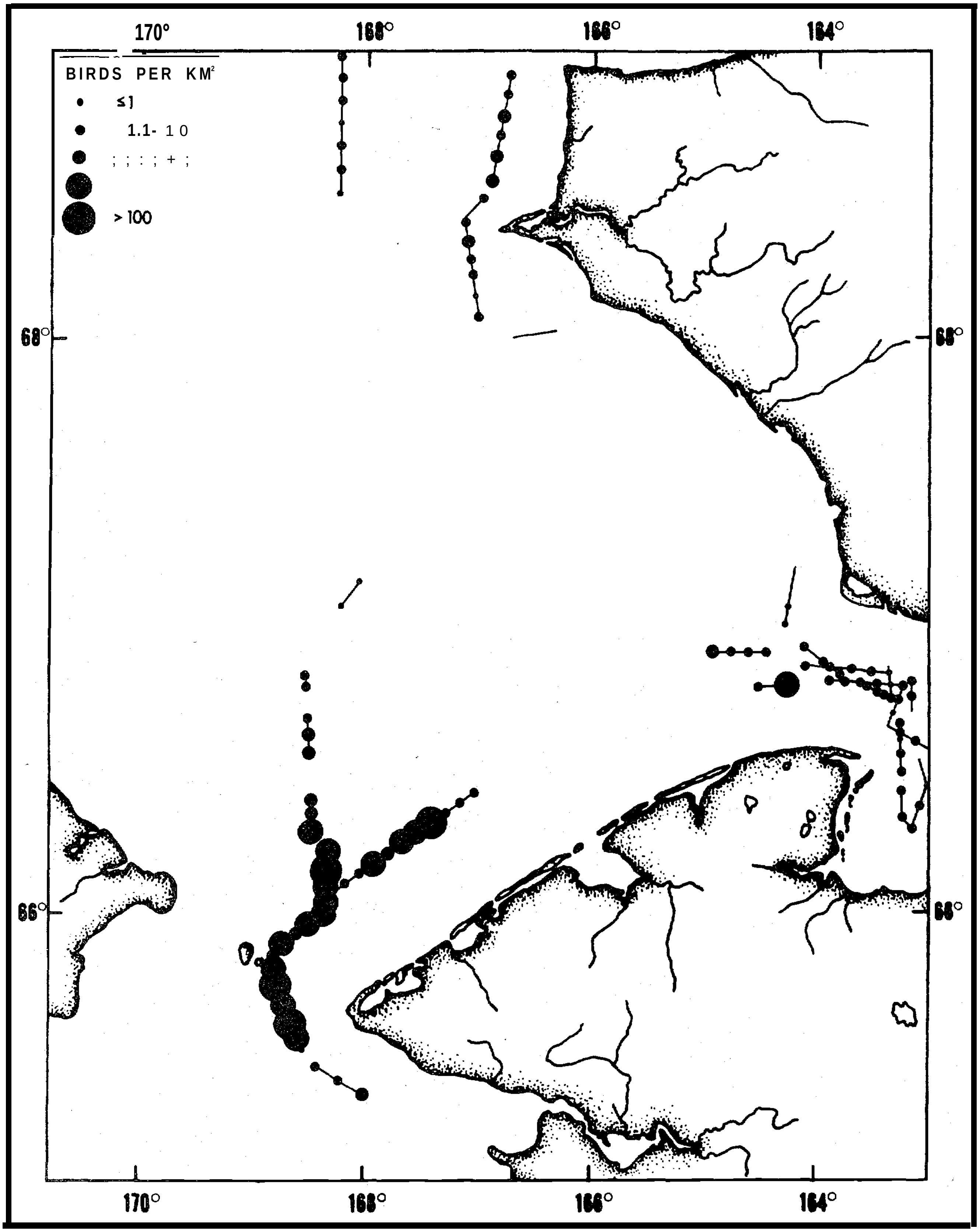


Figure .150. Distribution, and abundance of seabirds in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

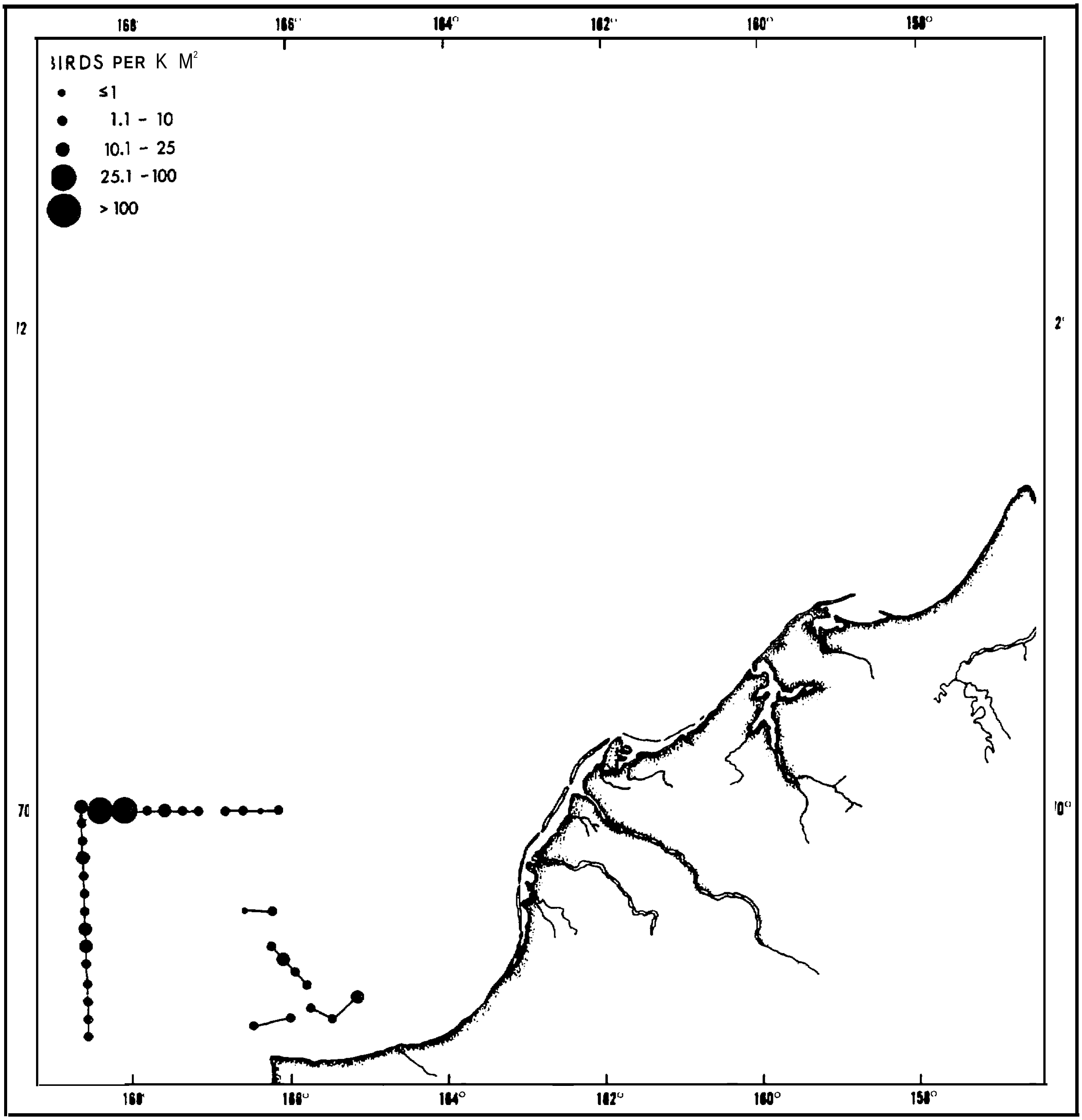


Figure 151. Distribution and abundance of seabirds in northern Chukchi Sea from 20 to 22 September 1976.

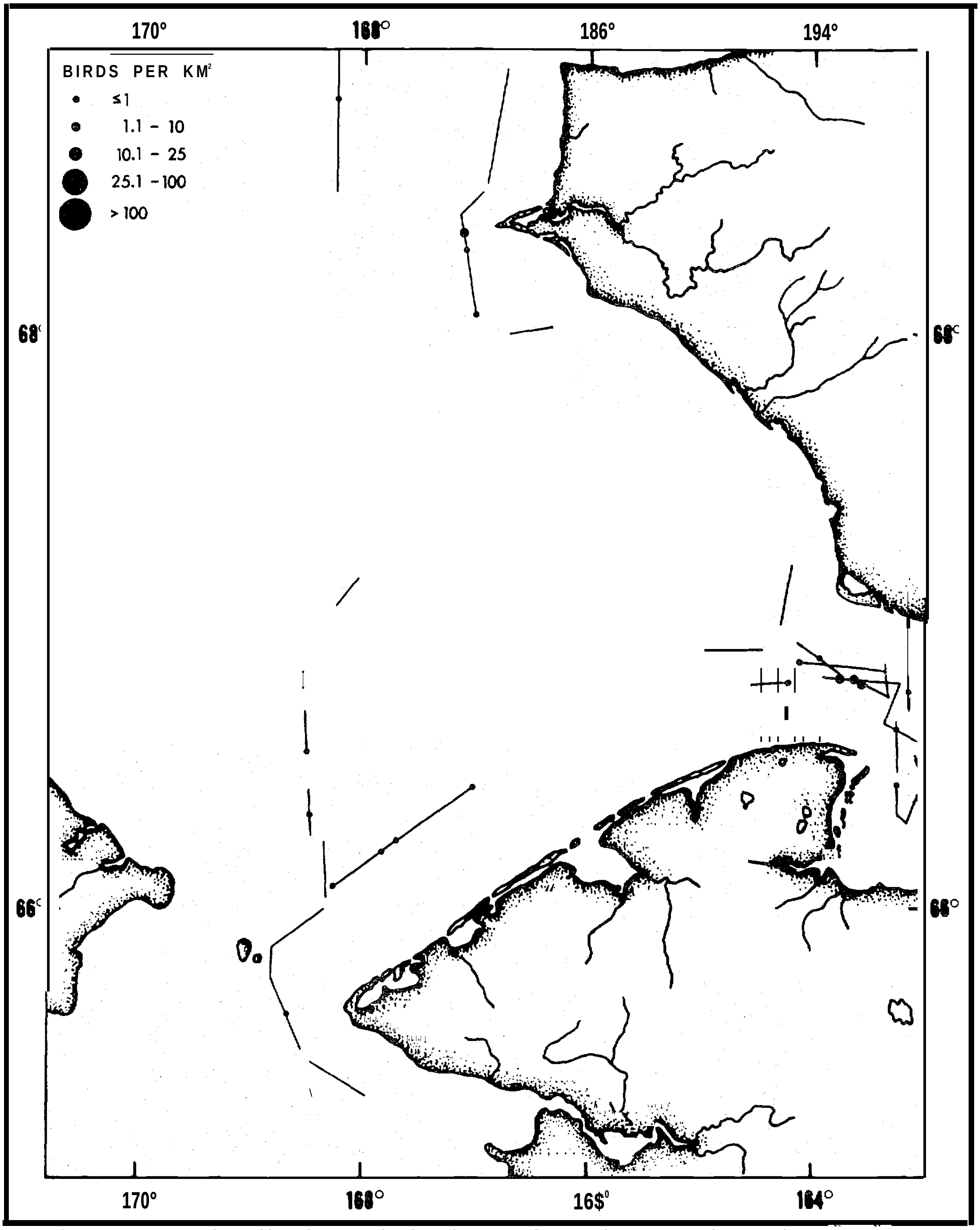


Figure 152. Distribution and abundance of Arctic Loons in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

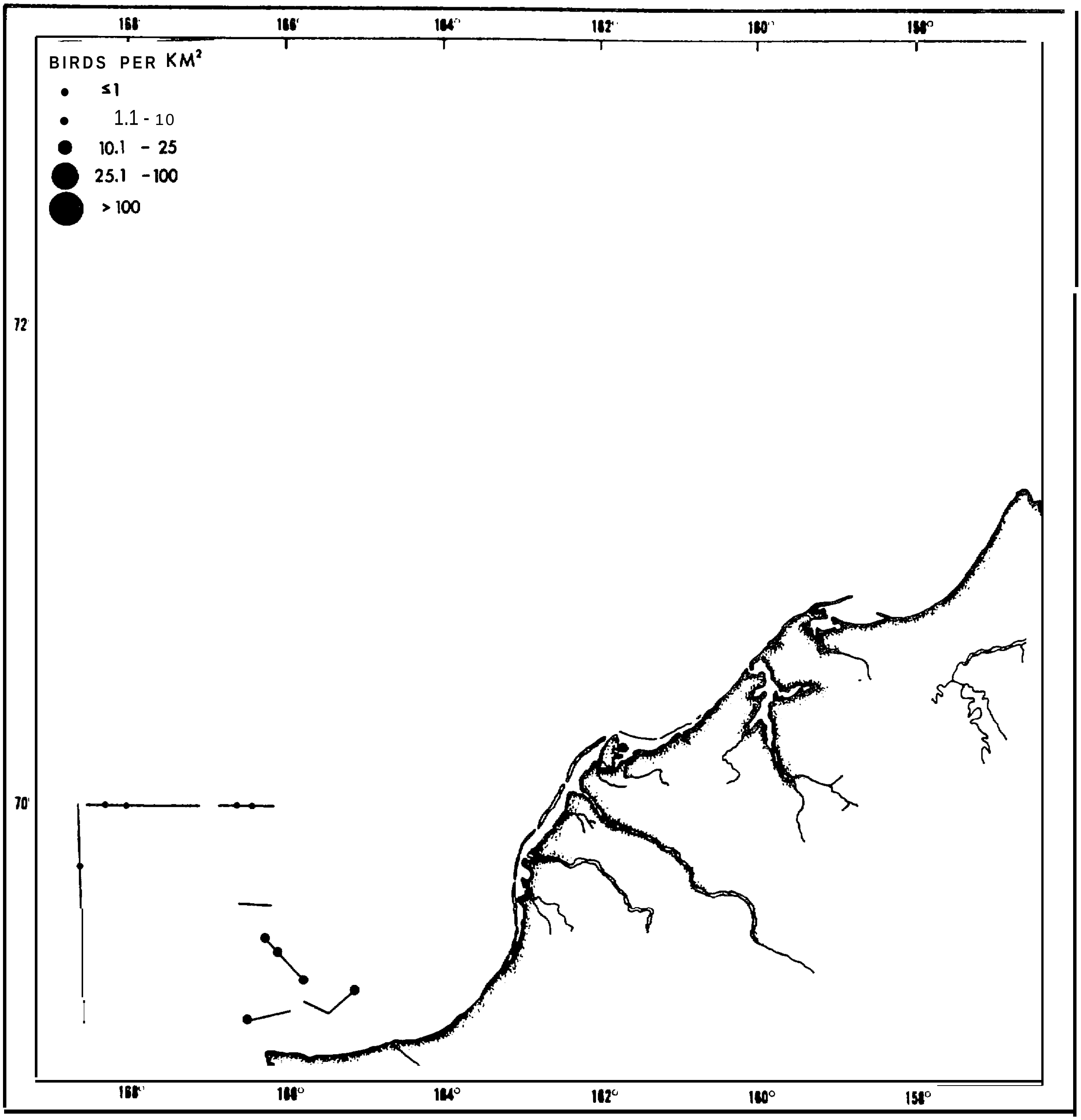


Figure 153. Distribution and abundance of Arctic Loons in northern Chukchi Sea from 20 to 22 September 1976.

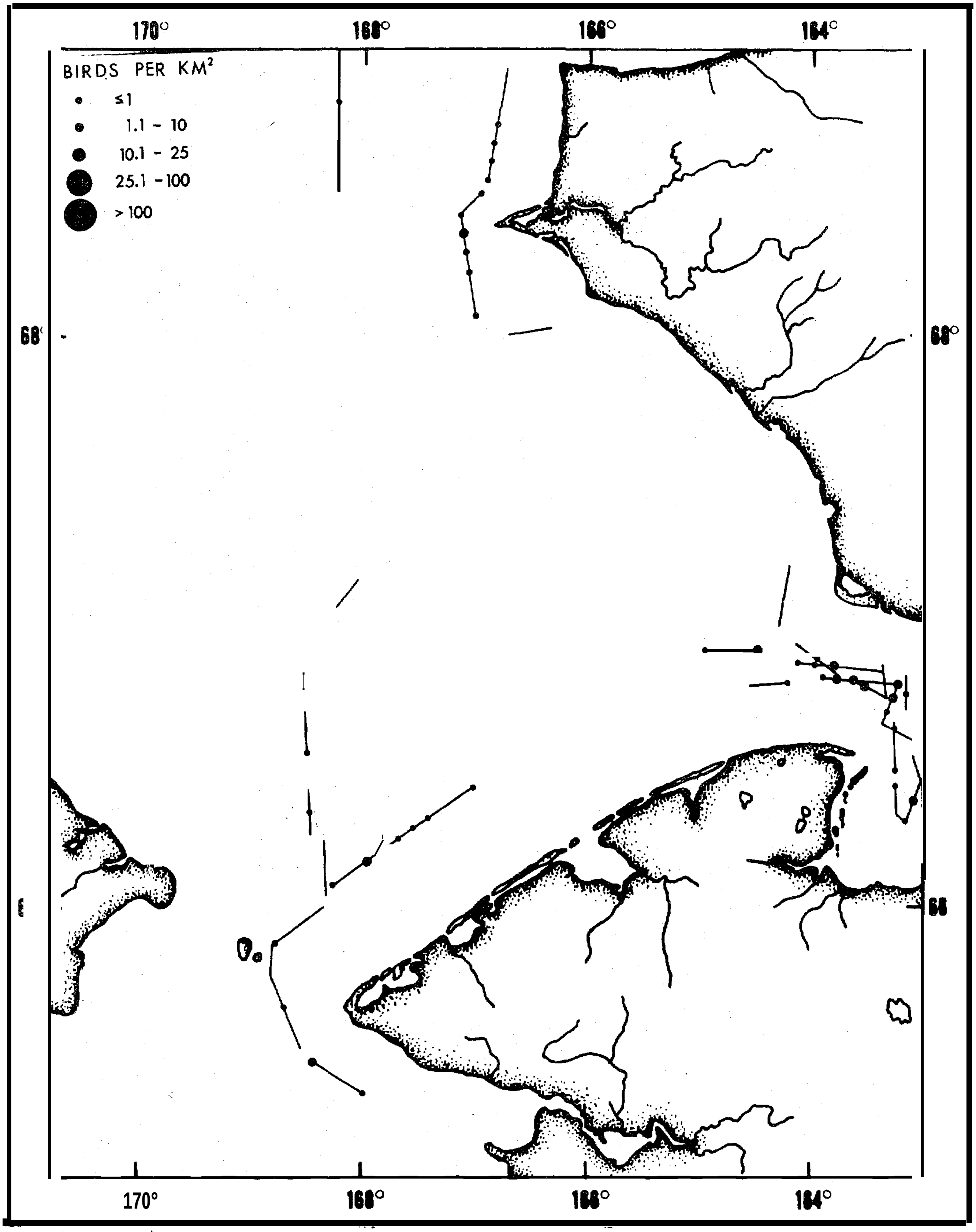


Figure 154. Distribution and abundance of" all loons in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

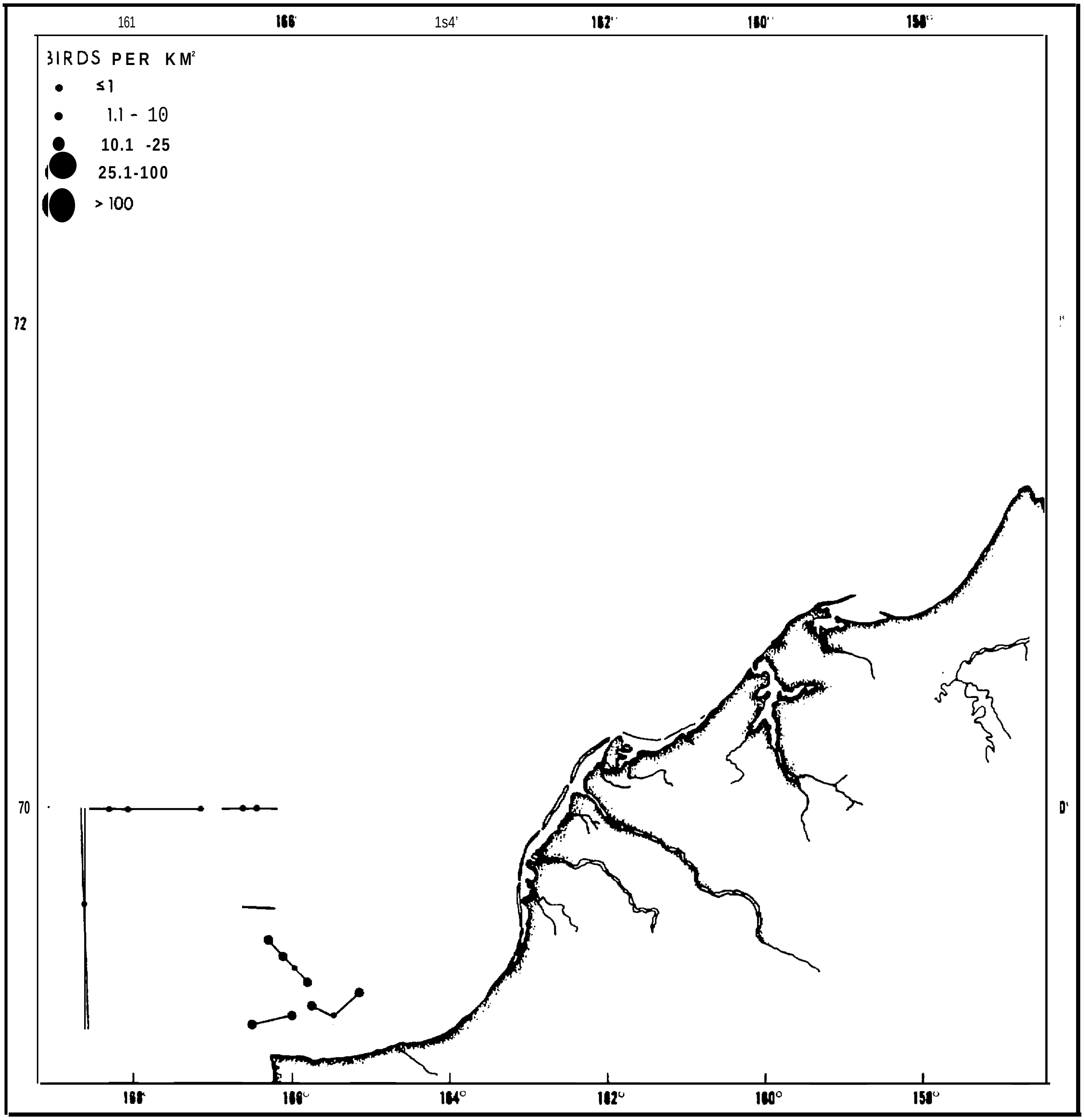


Figure 155. Distribution and abundance of all loons in northern Chukchi Sea from 20 to 22 September 1976.

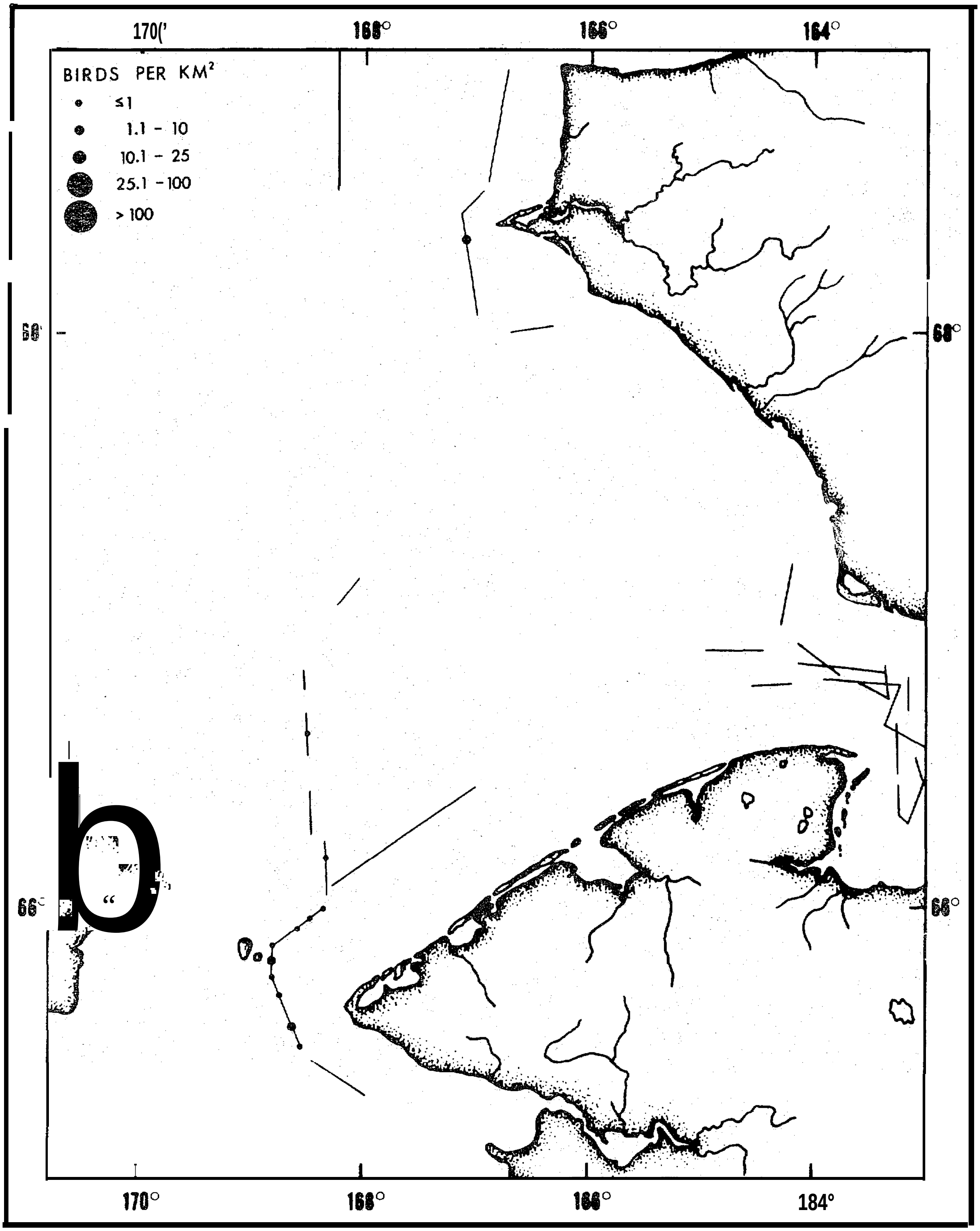


Figure 156. Distribution and abundance of Northern Fulmars in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

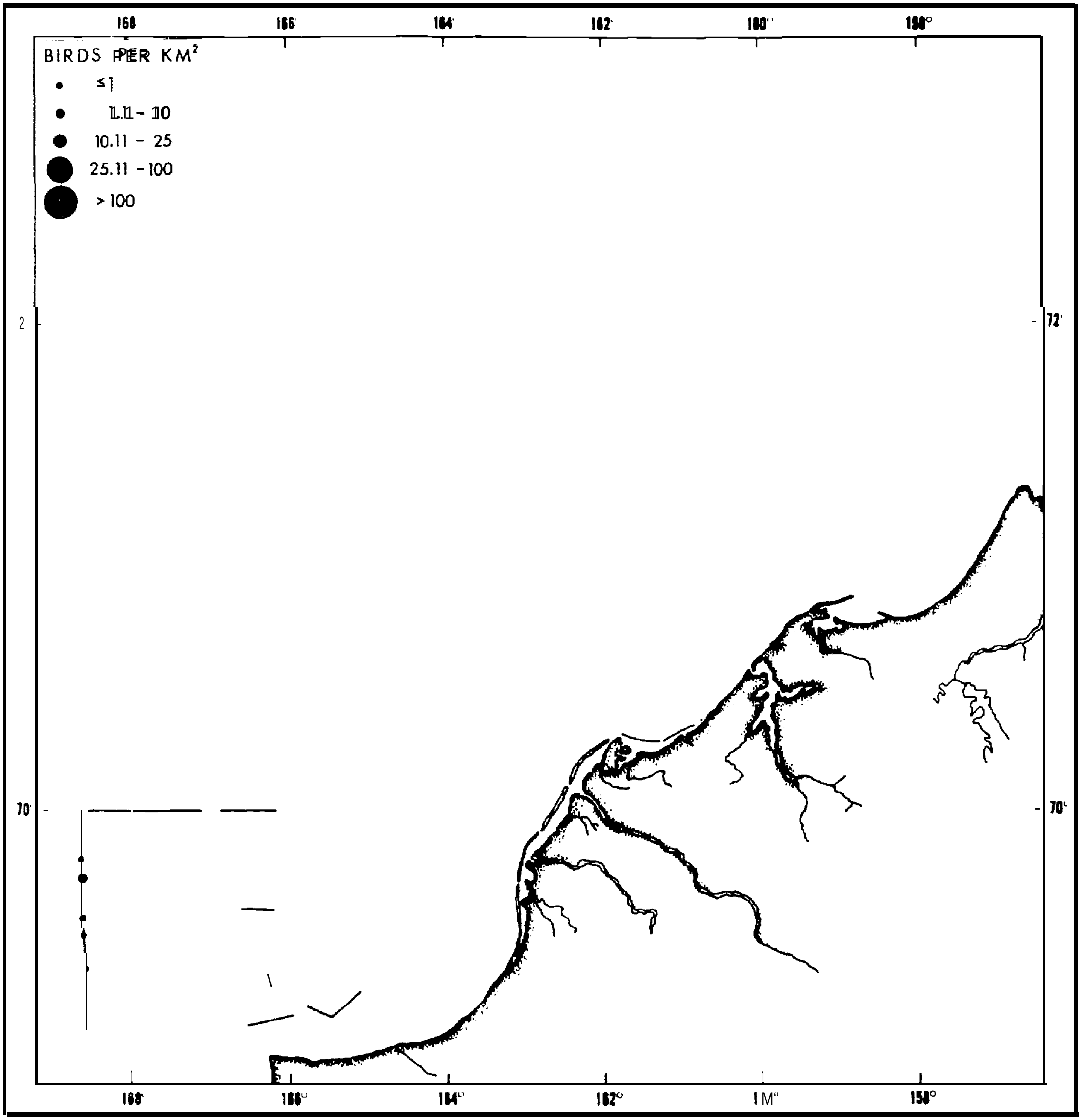


Figure 157. Distribution and abundance of Northern Fulmars in northern Chukchi Sea from 20 to 22 September 1976.

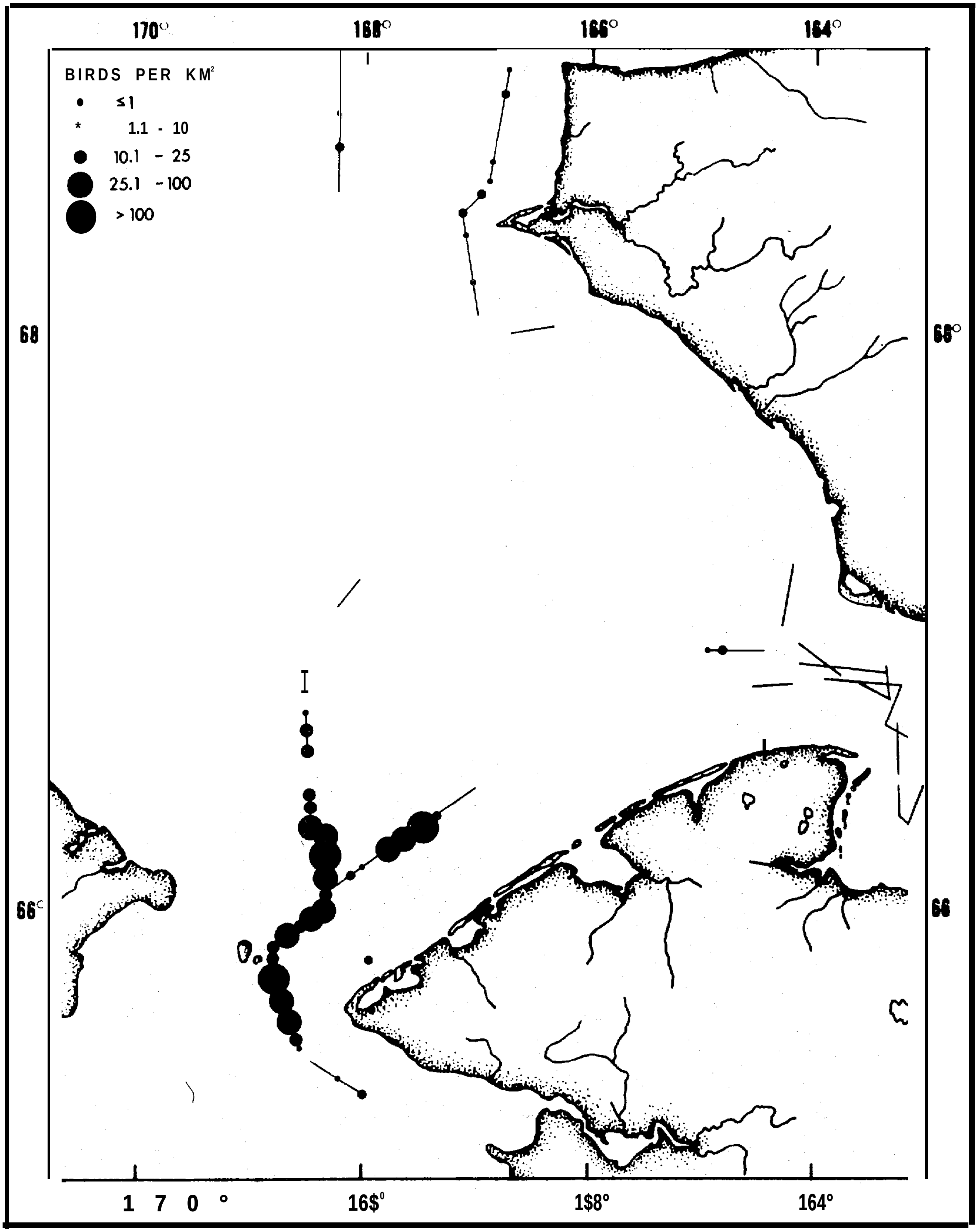


Figure .158. Distribution and abundance of shearwaters in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

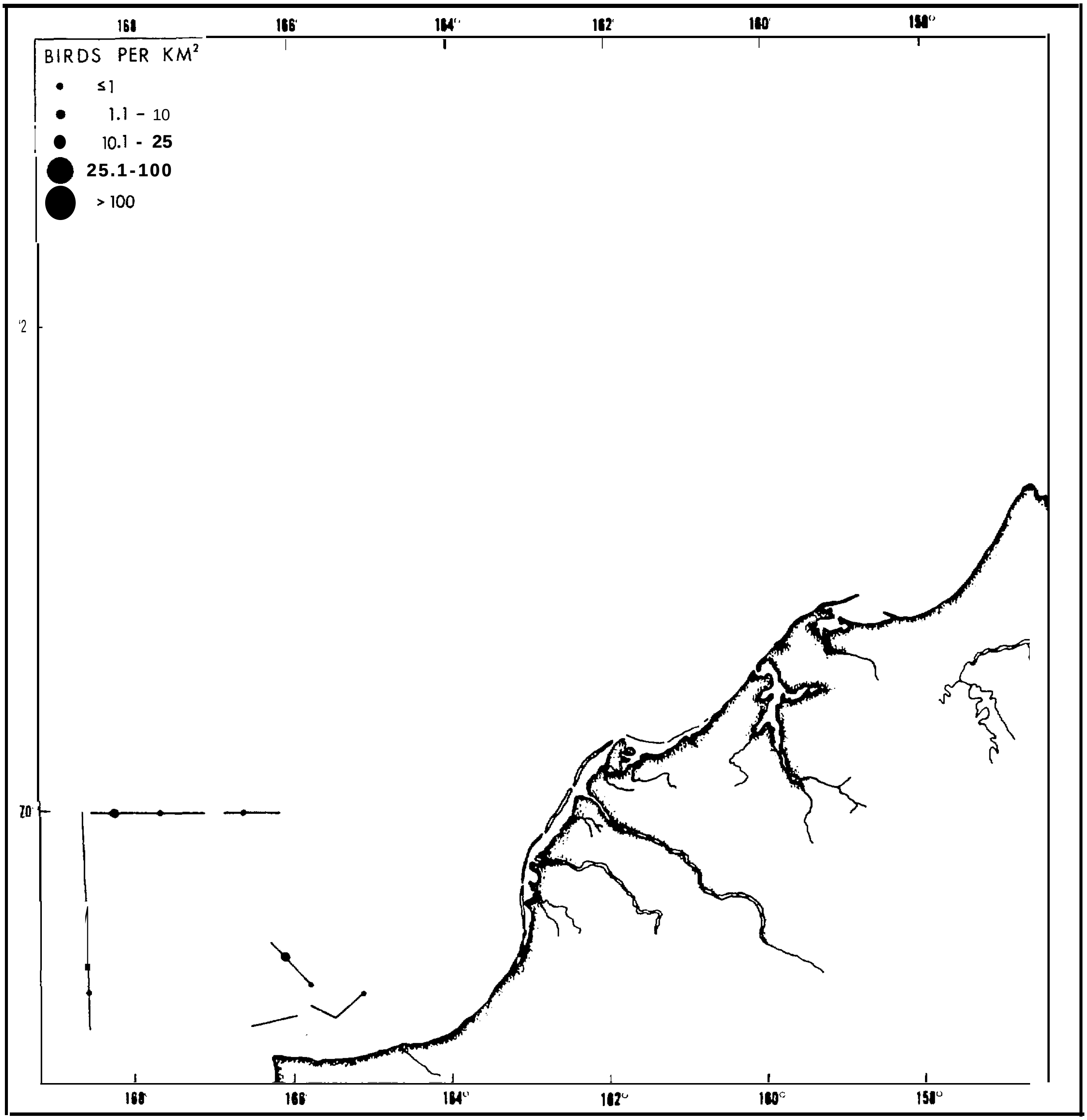


Figure 159. Distribution and abundance of shearwaters in northern Chukchi Sea from 20 to 22 September 1976.

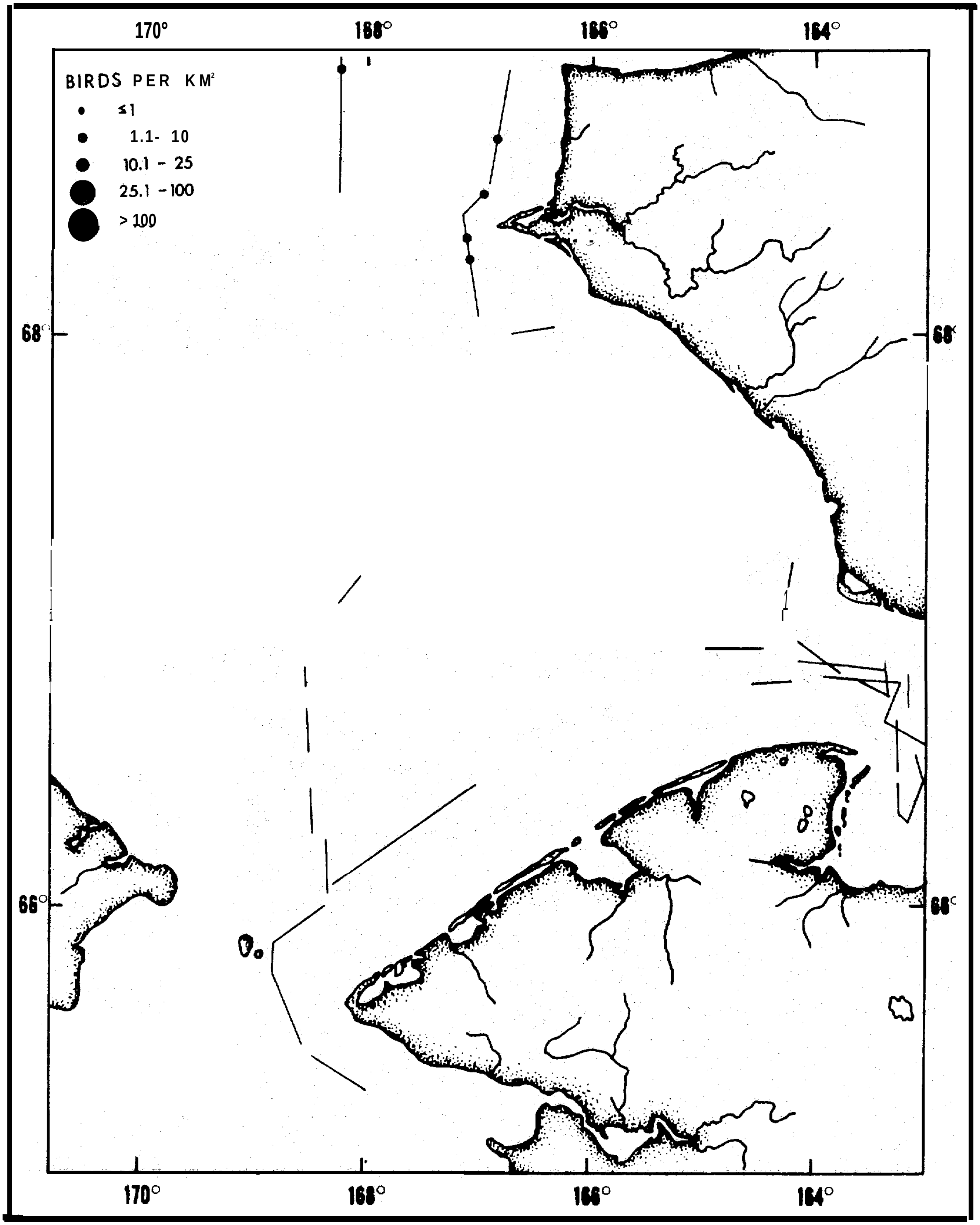


Figure 160. Distribution and abundance of Oldsquaws in Bering Strait and southern Chukchi Sea from 15 to 20 September and-on 22 September 1976.

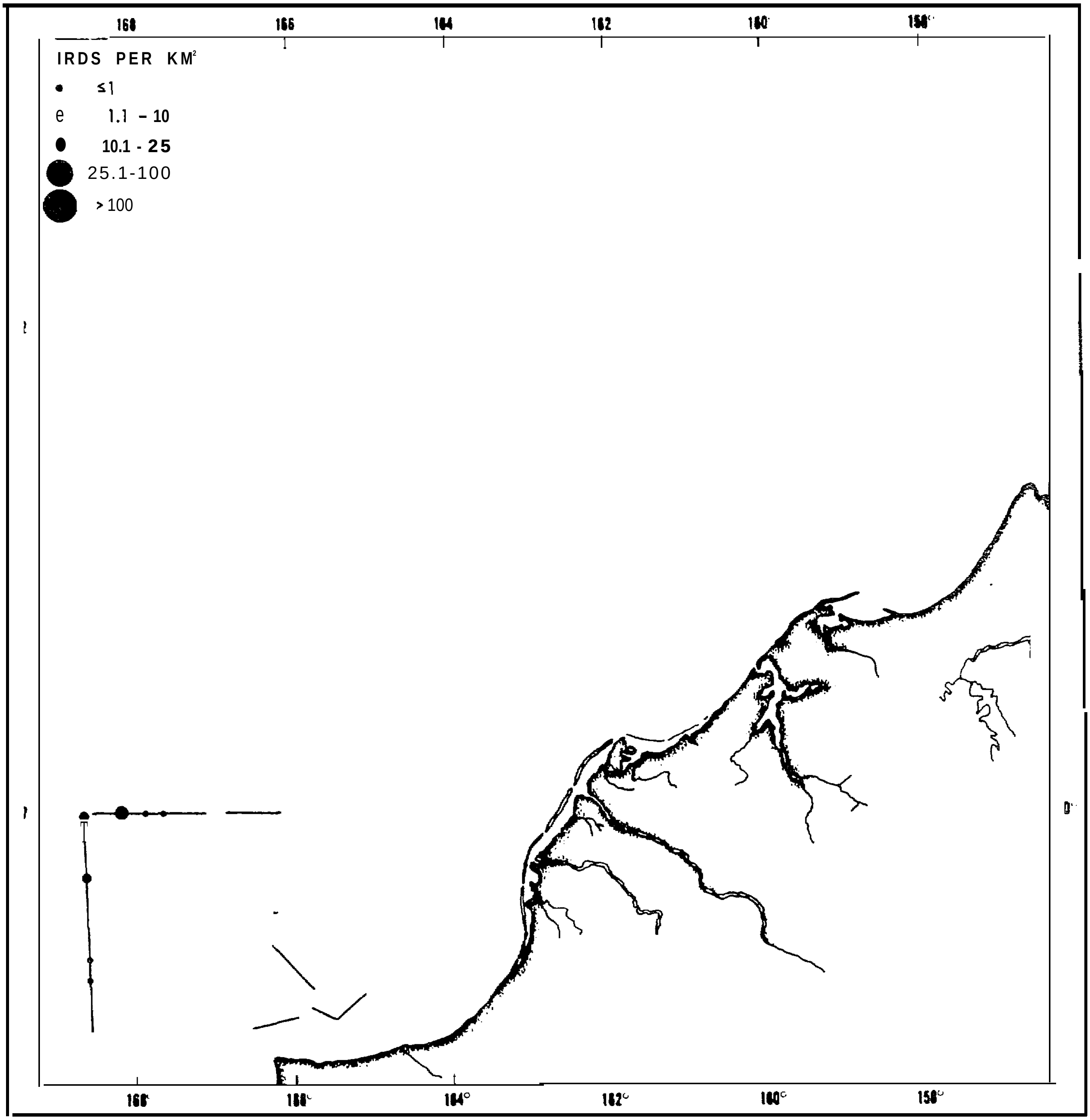


Figure 161. Distribution and abundance of Oldsquaws in northern Chukchi Sea from 20 to 22 September 19'76.

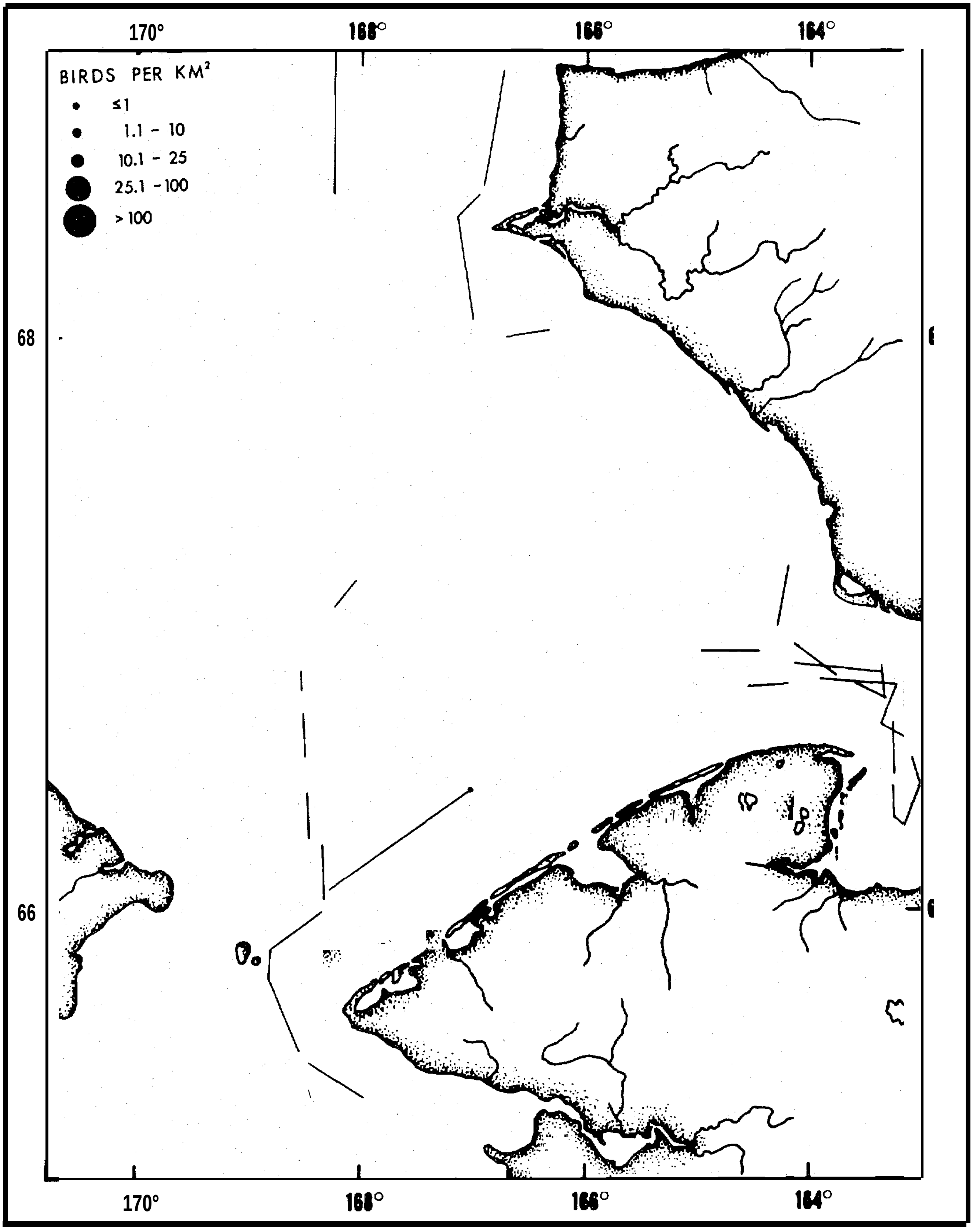


Figure I-62. Distribution and abundance of eiders in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

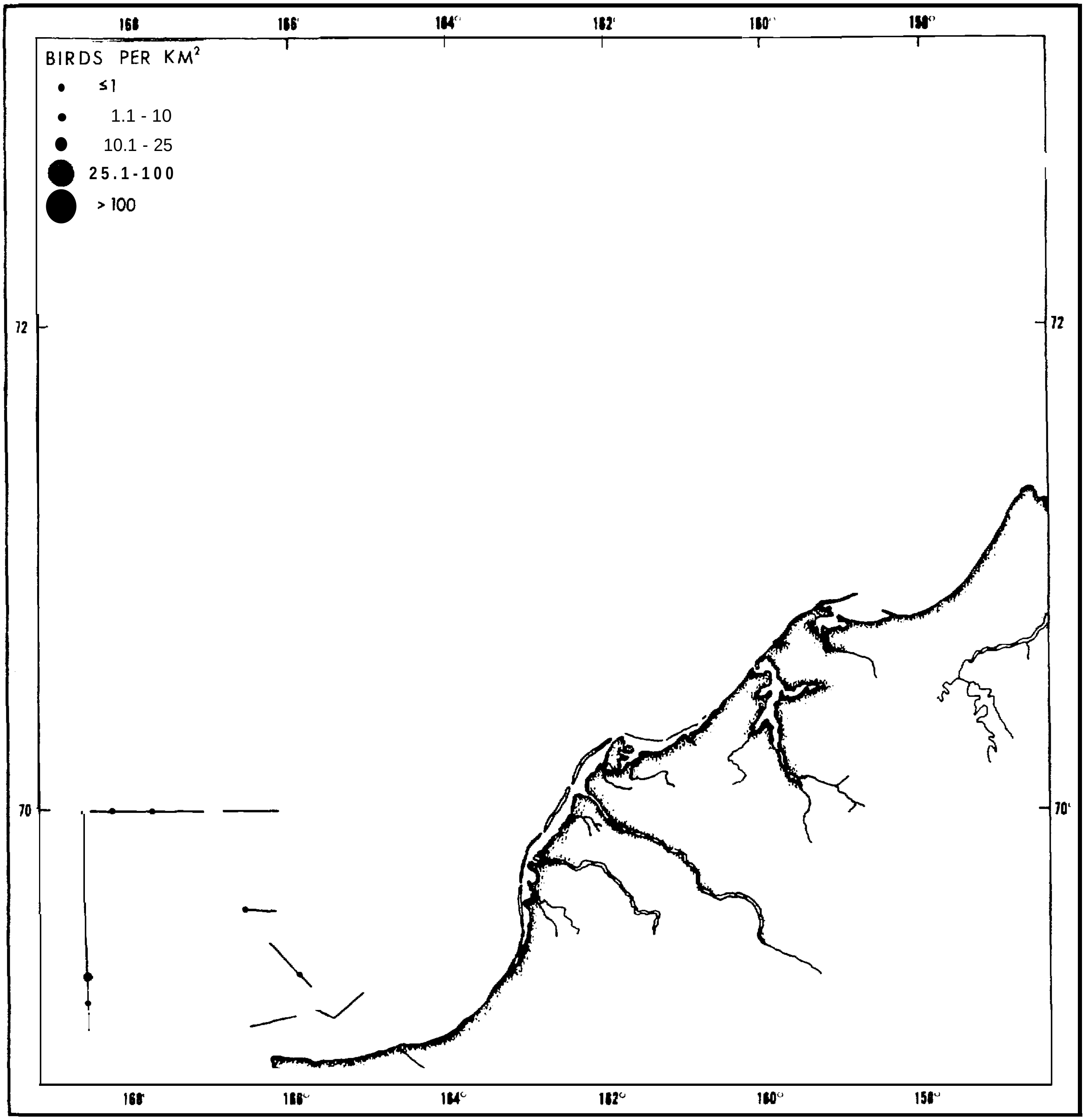


Figure 163. Distribution and abundance of eiders in northern Chukchi Sea from 20 to 22 September 1976.

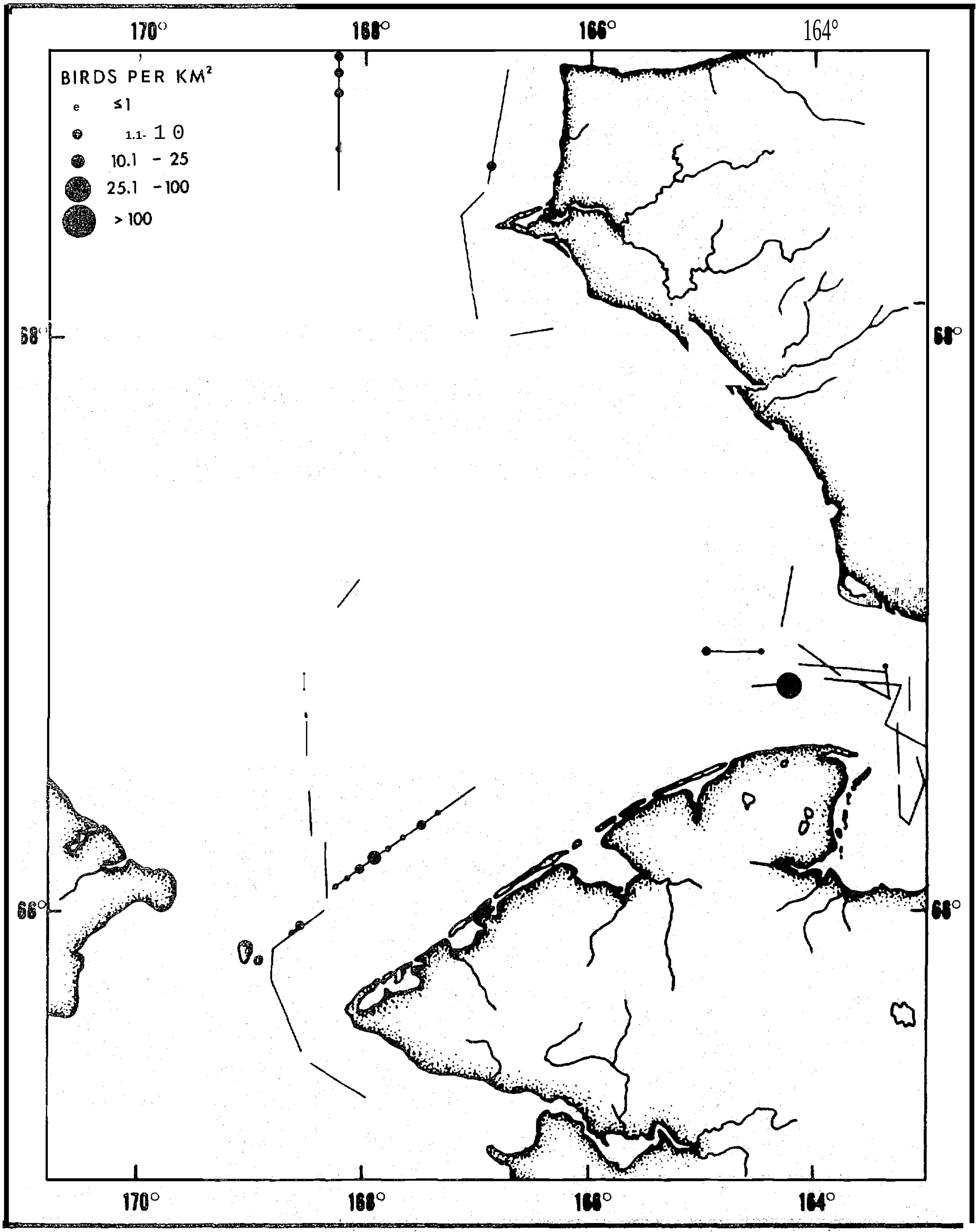


Figure 164. Distribution and abundance of phalaropes in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

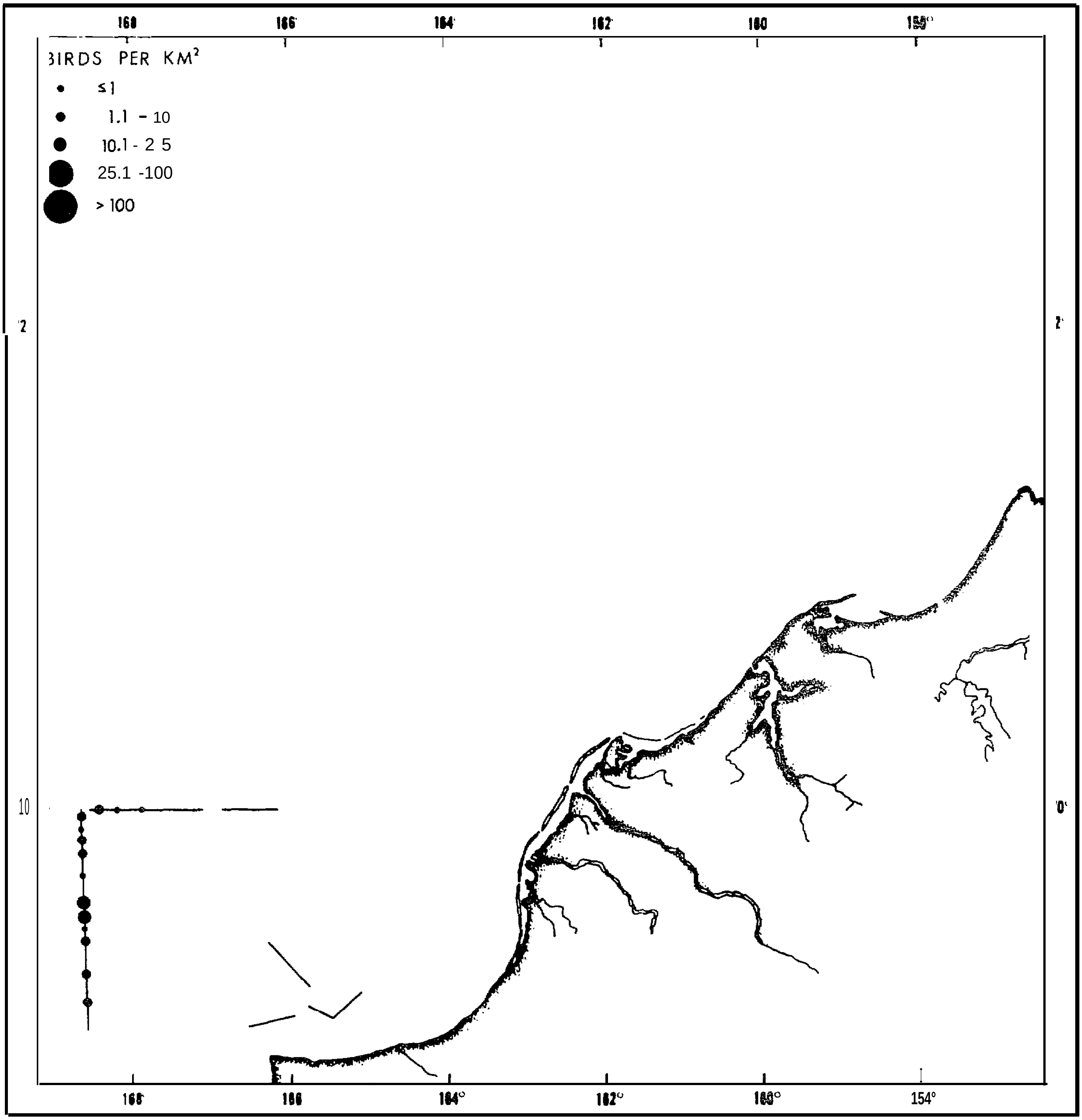


Figure 165. Distribution and abundance of phalaropes in northern Chukchi Sea from 20 to 22 September 1976.

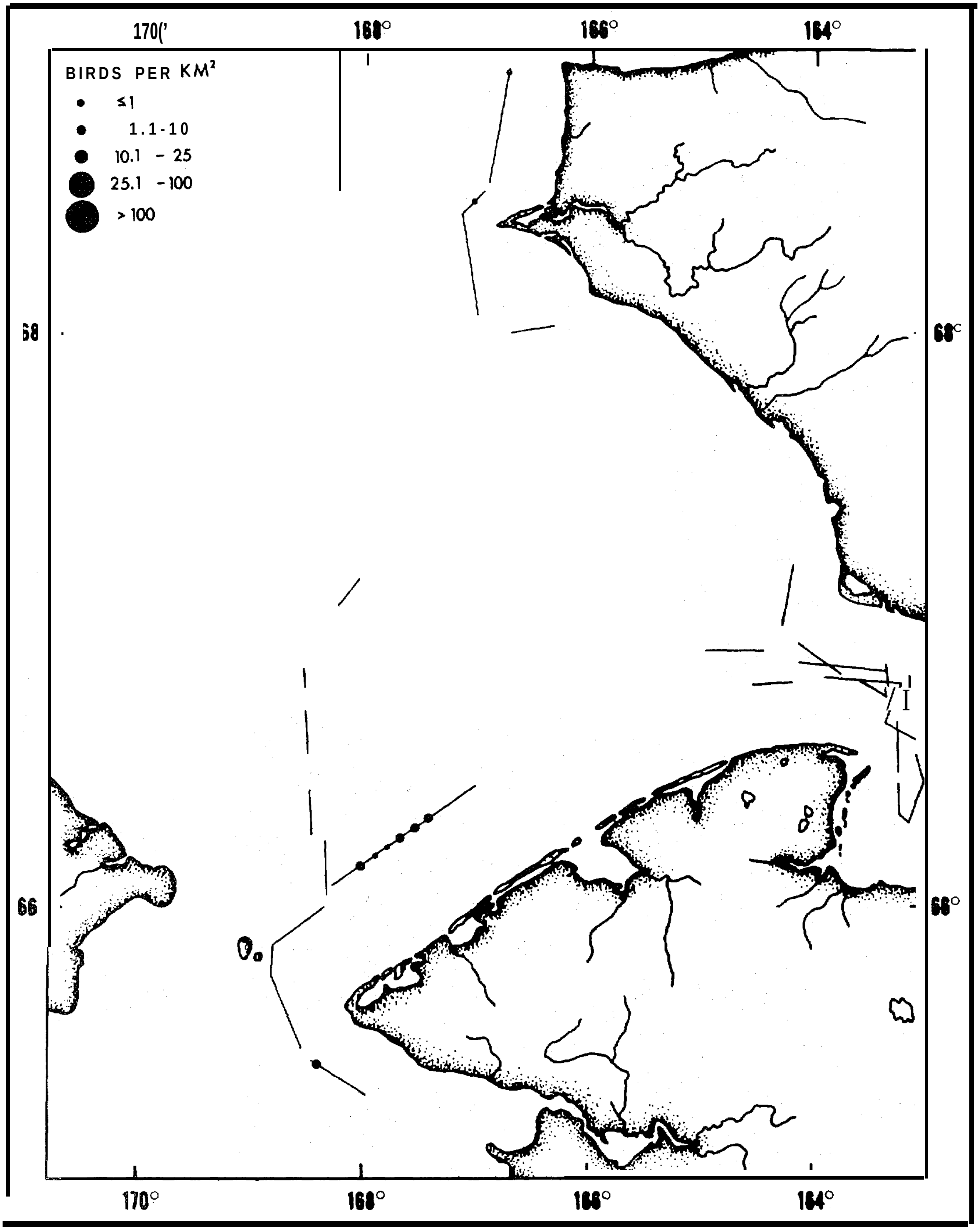


Figure 166. Distribution and abundance of jaegers in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

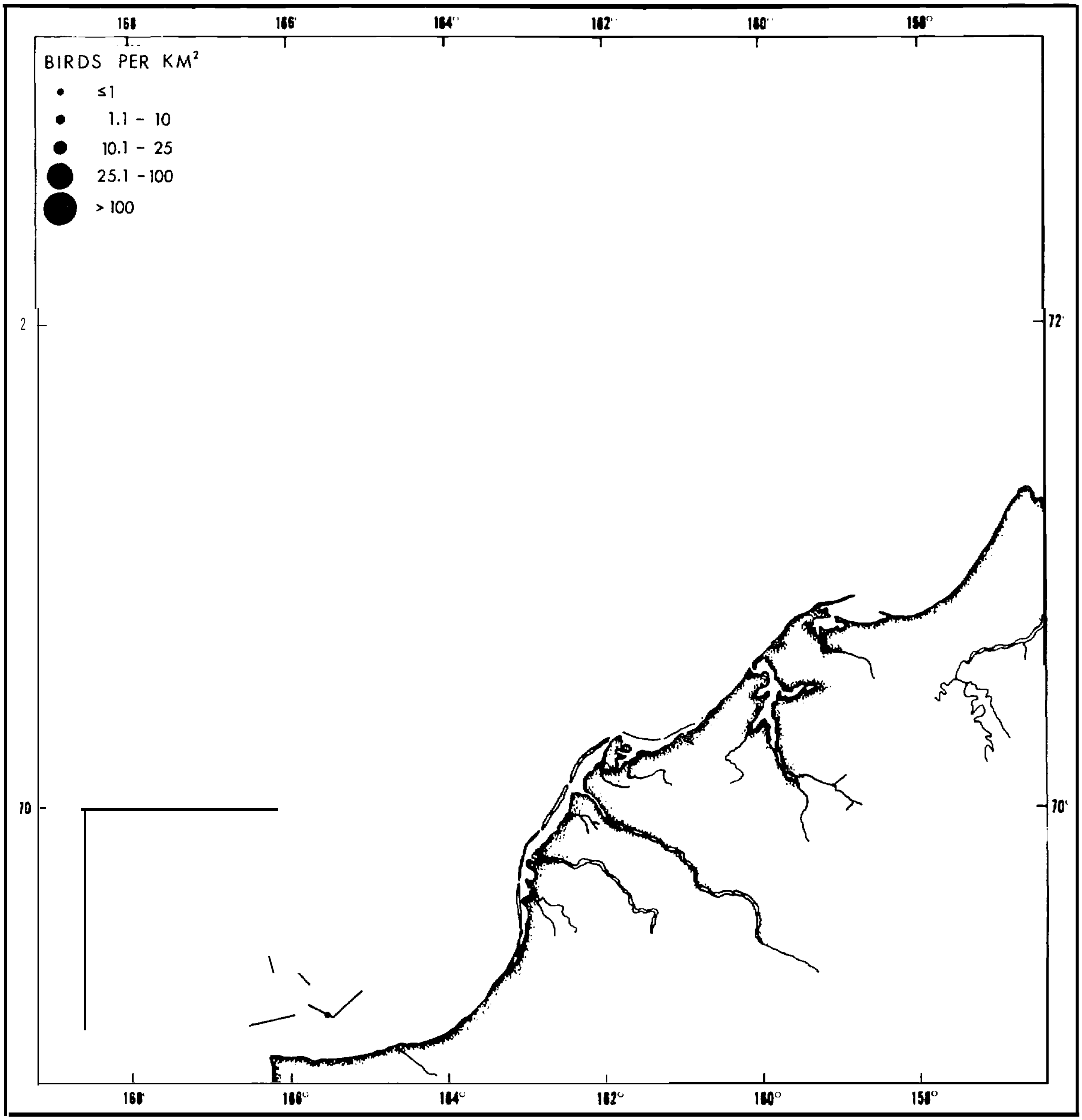


Figure 167. Distribution and abundance of jaegers in northern Chukchi Sea from 20 to 22 September 1976.

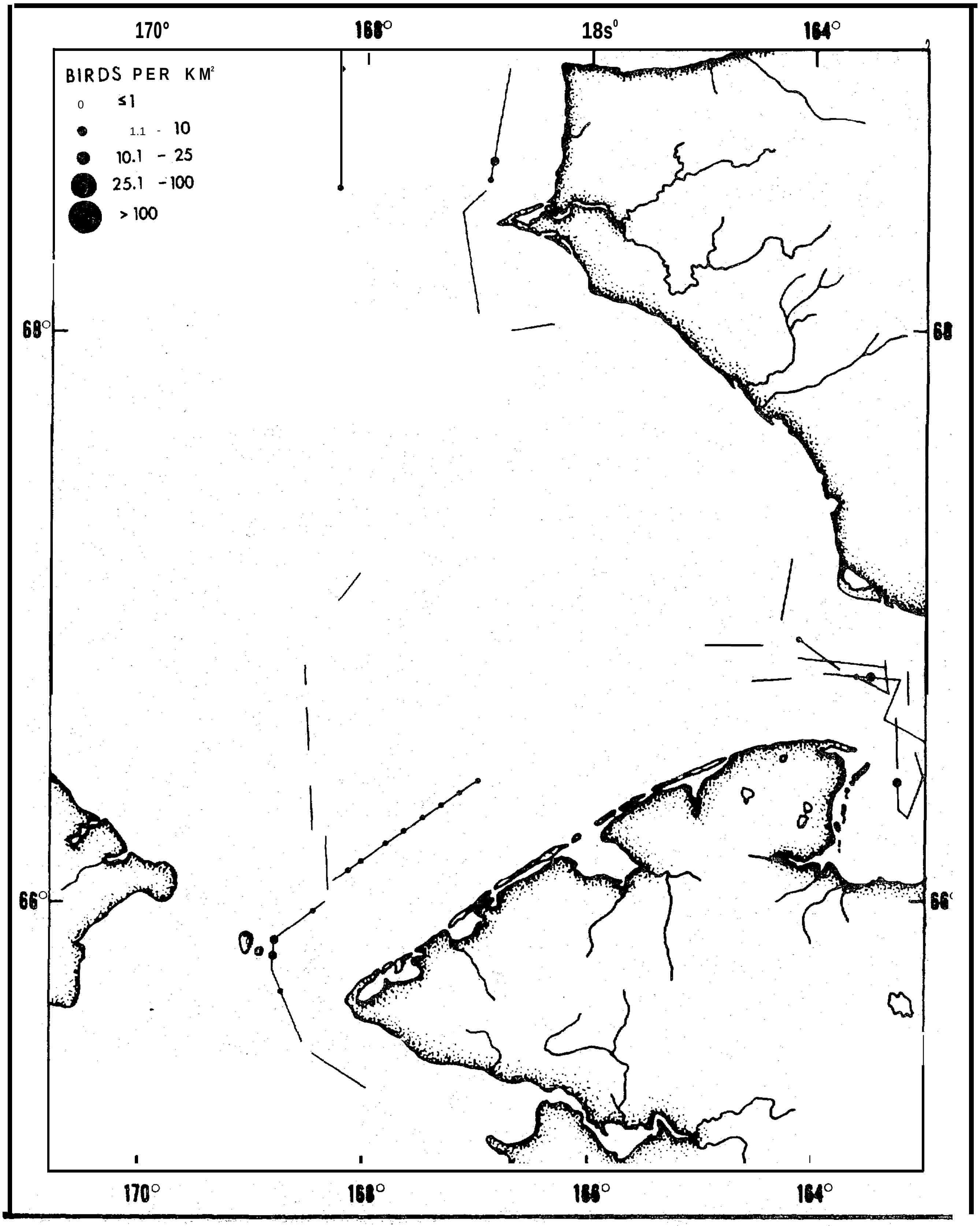


Figure 168. Distribution and abundance of Glaucous Gulls in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

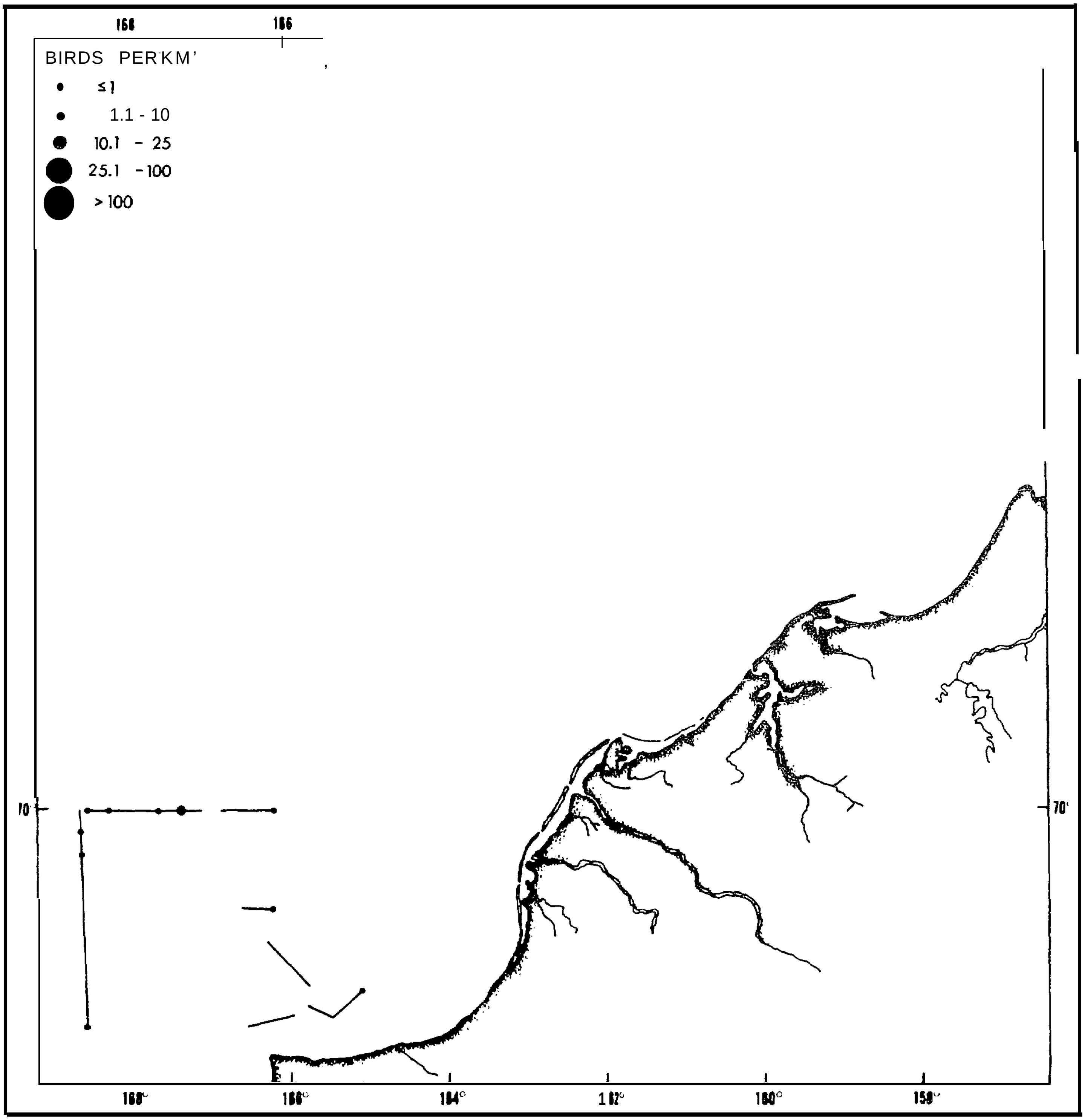


Figure 169. Distribution and abundance of Glaucous Gulls in northern Chukchi Sea from 20 to 22 September 1976.

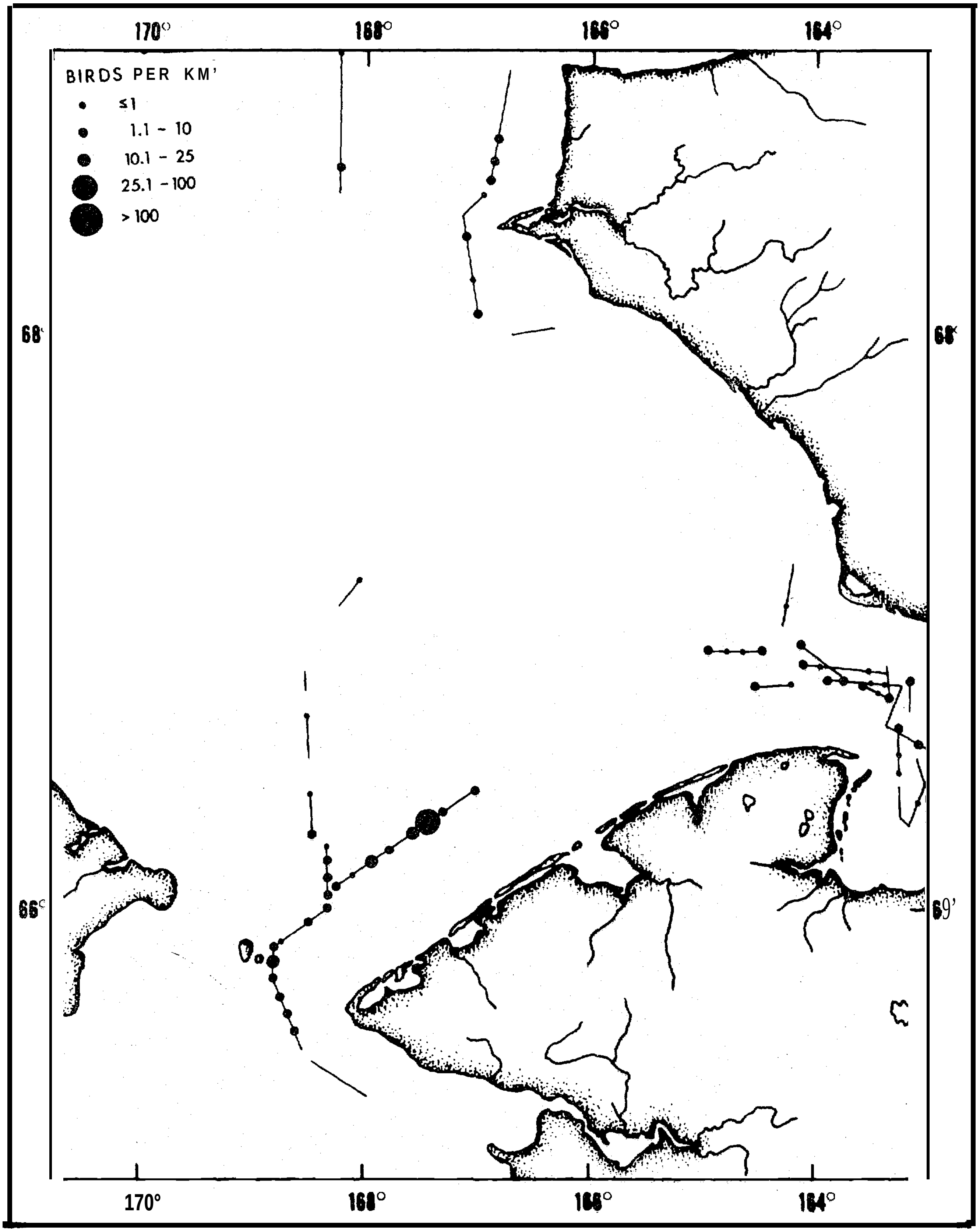


Figure 170. Distribution and abundance of Black-legged Kittiwakes in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

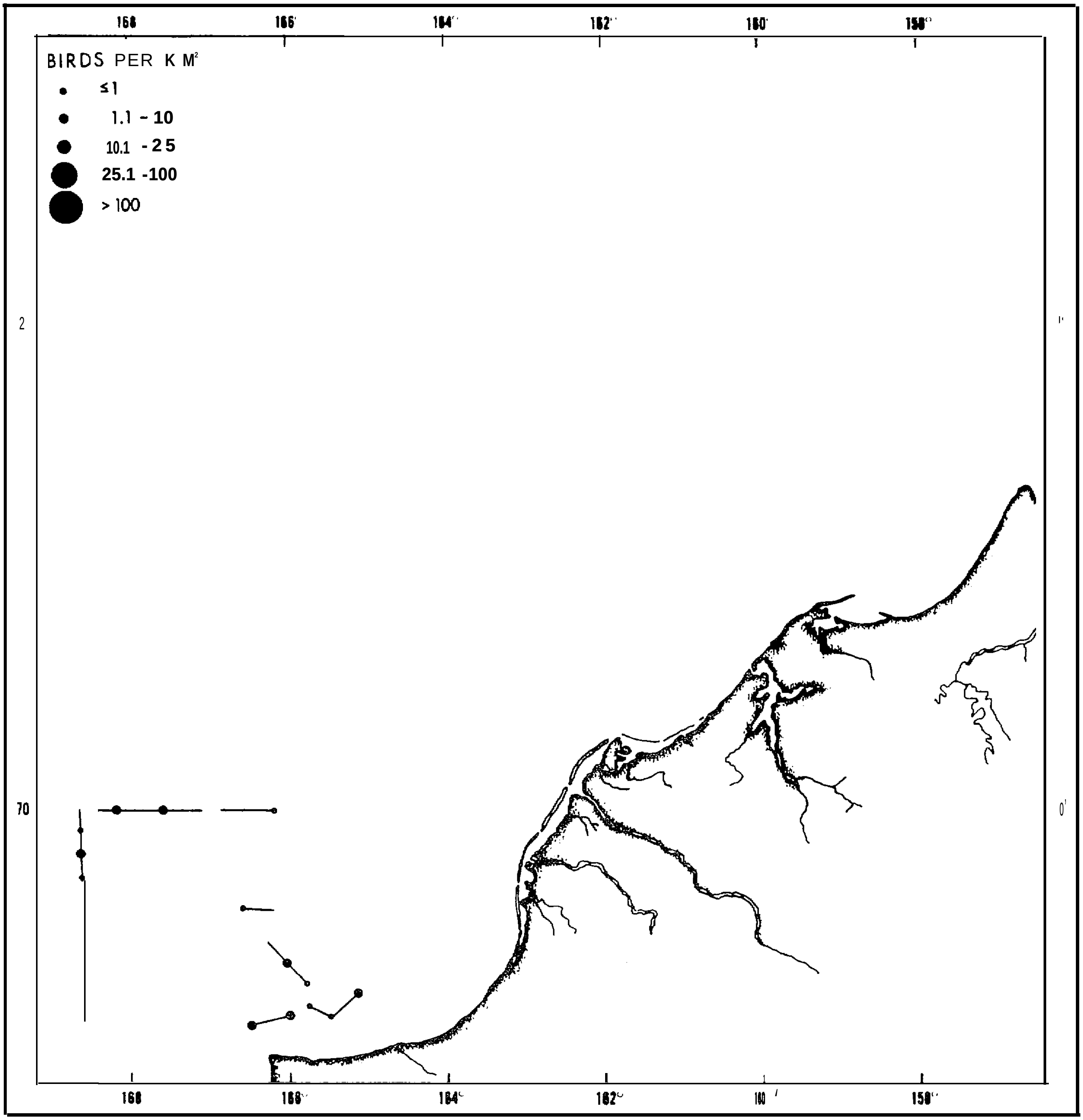


Figure 171. Distribution and abundance of Black-1egged Kittiwakes in northern Chukchi Sea from 20 to 22 September]976.

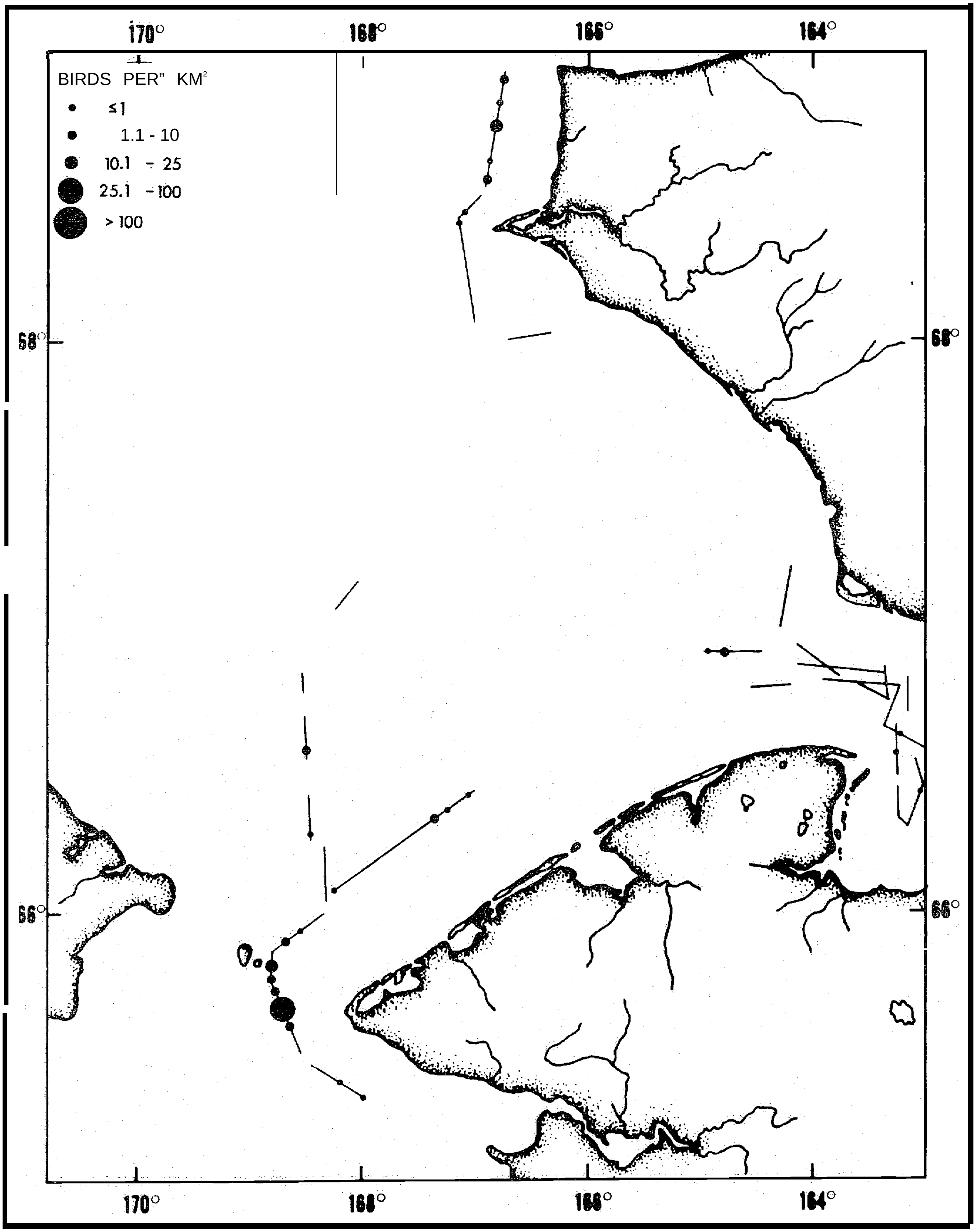


Figure 172. Distribution and abundance of. murres in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

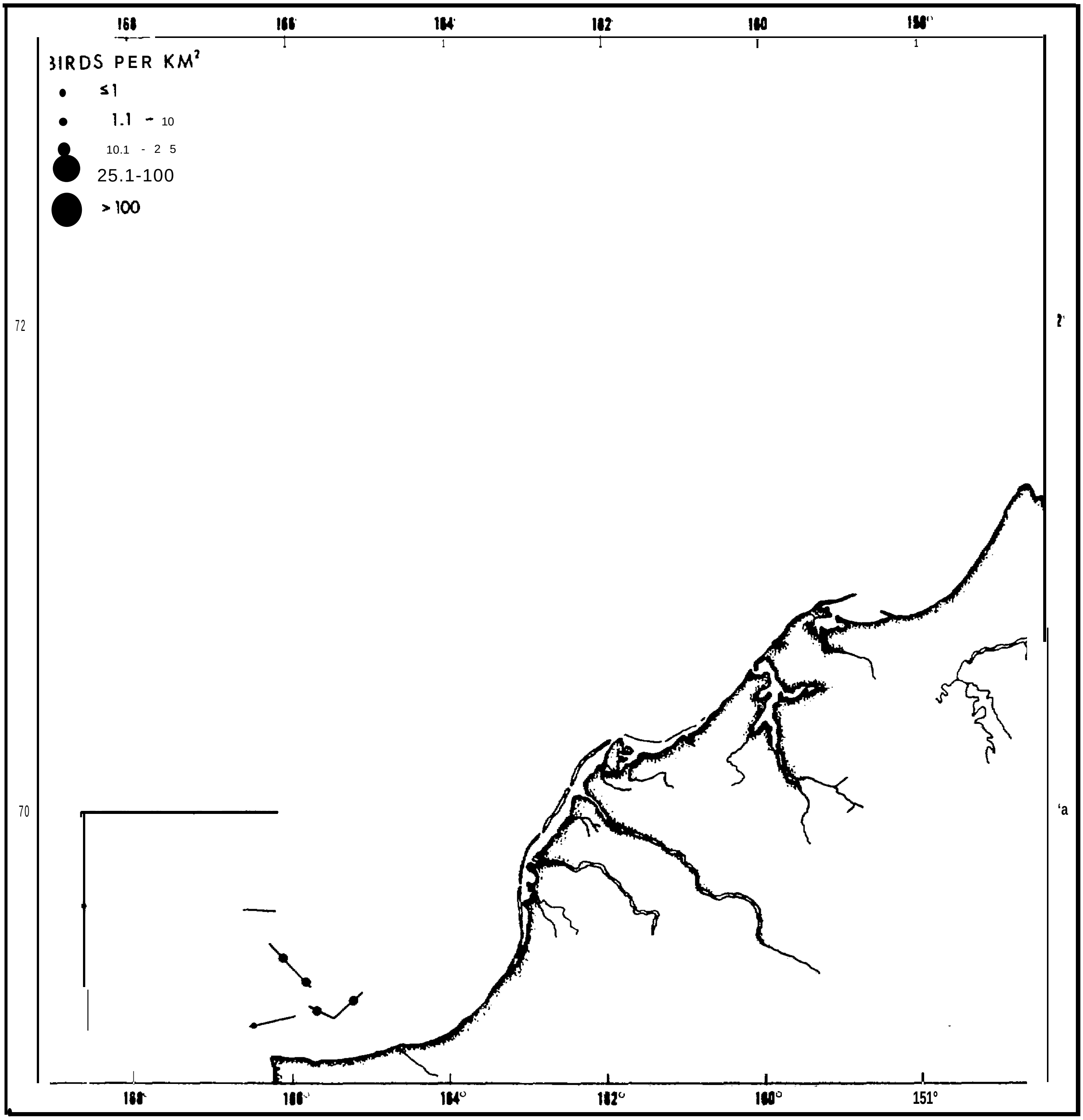


Figure 173. Distribution and abundance of murres in northern Chukchi Sea from 20 to 22 September 1976.

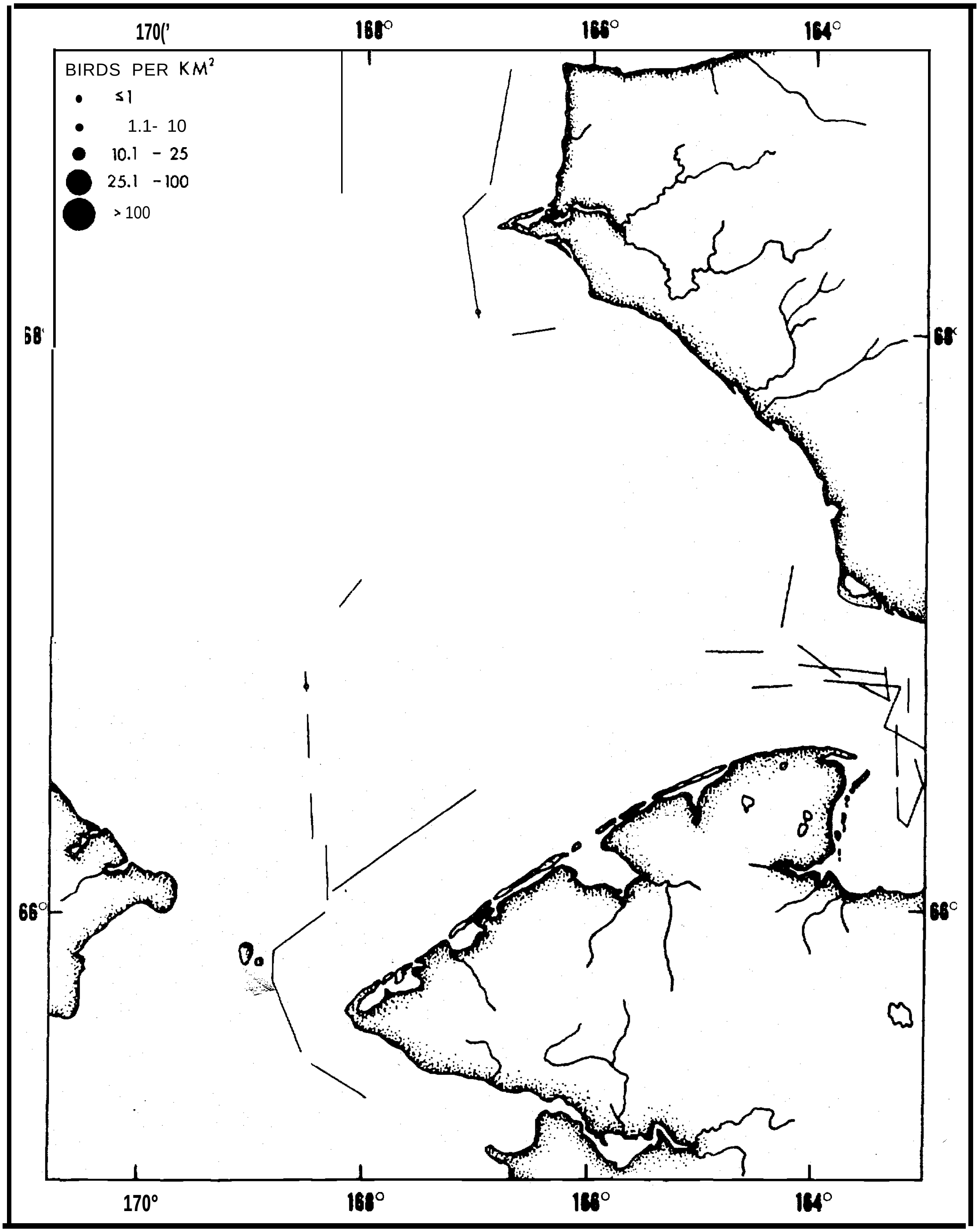


Figure .174. Distribution and abundance of Parakeet Auk-Lets in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

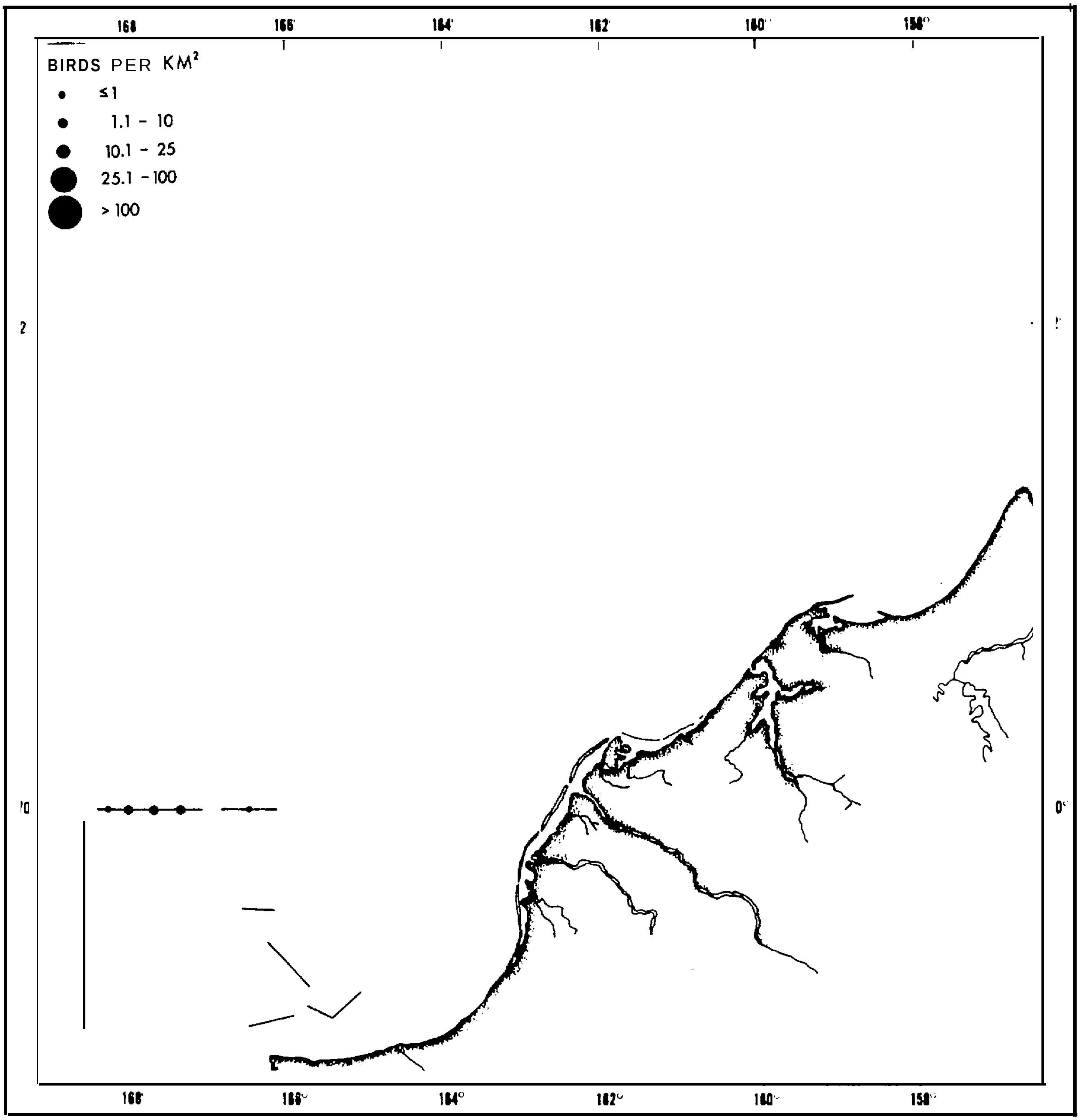


Figure 175. Distribution and abundance of Parakeet Auklets in northern Chukchi Sea from 20 to 22 September 1976.

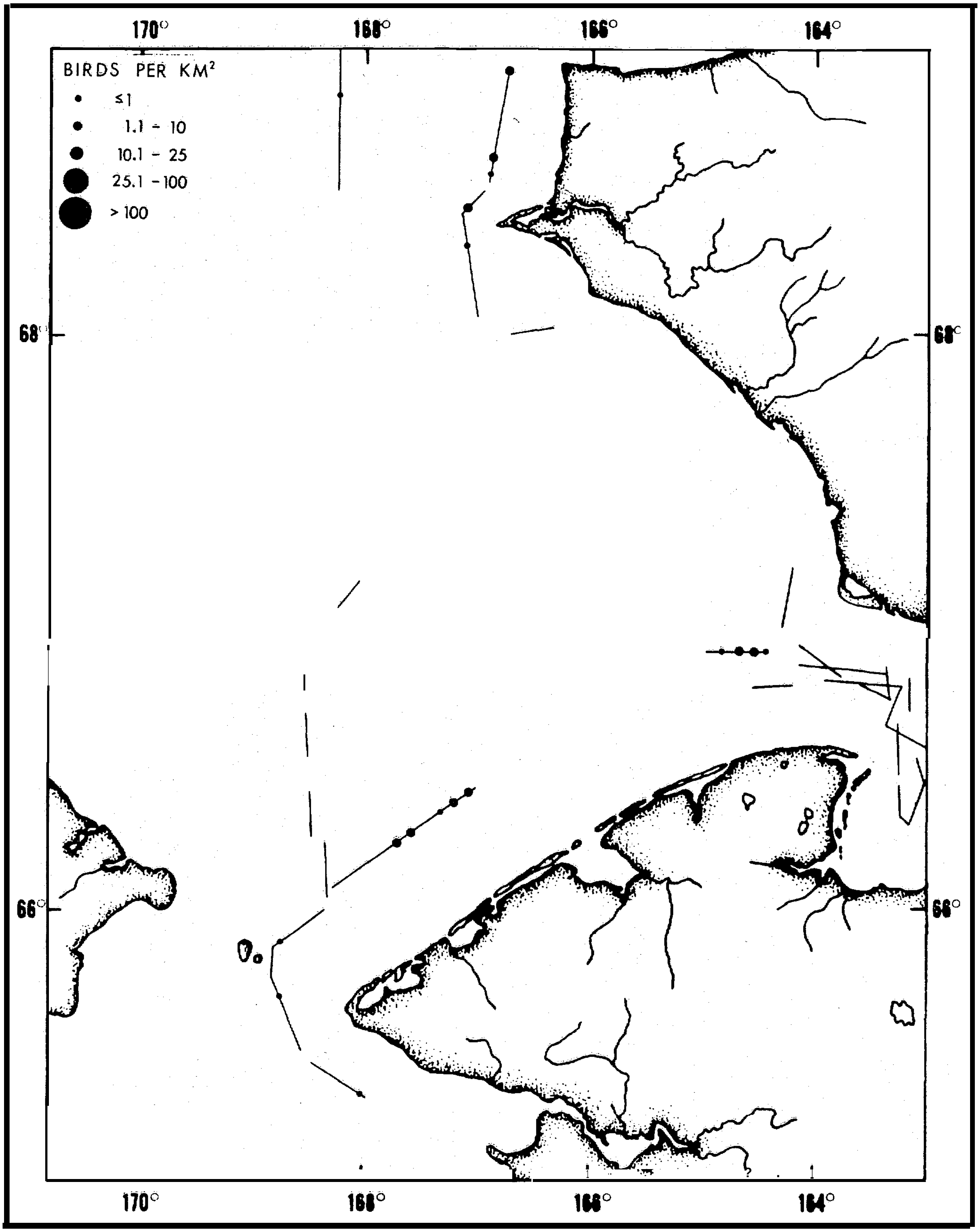


Figure 176. Distribution and abundance of unidentified small dark alcids in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

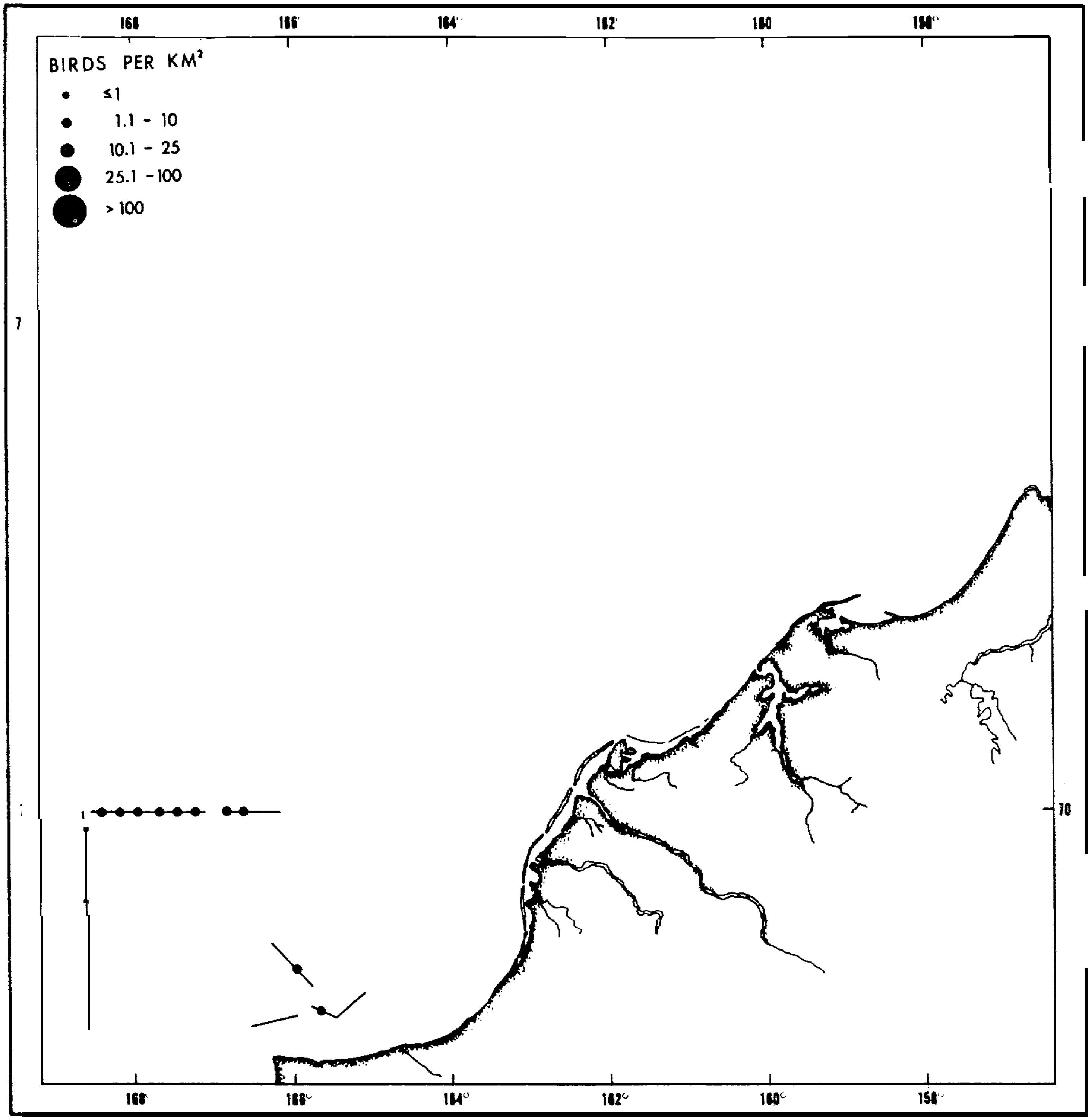


Figure 177. Distribution and abundance of unidentified small dark alcids in northern Chukchi Sea from 20 to 22 September 1976.

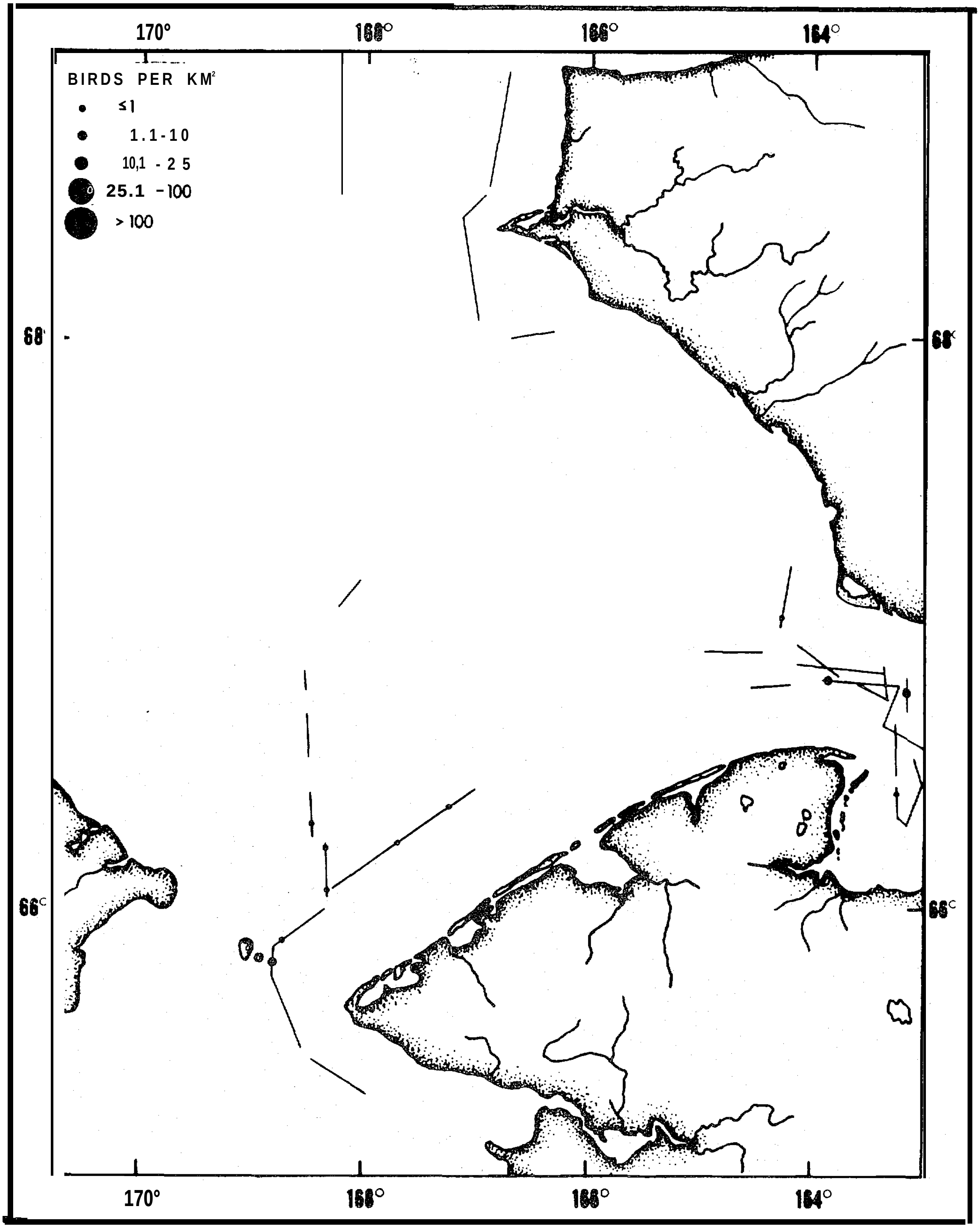


Figure .178. Distribution and abundance of Horned Puffins in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

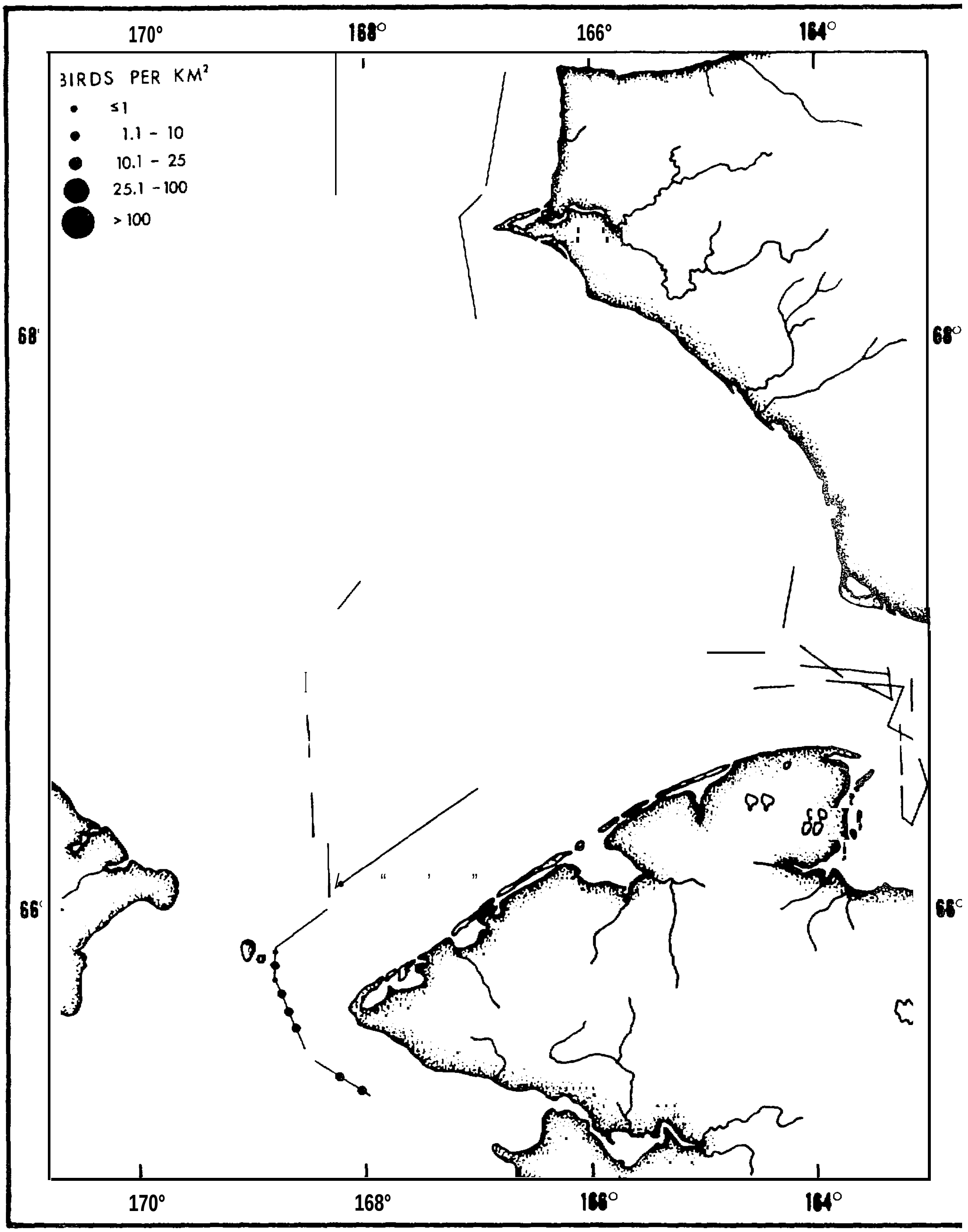


Figure 179. Distribution and abundance of Tufted Puffins in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

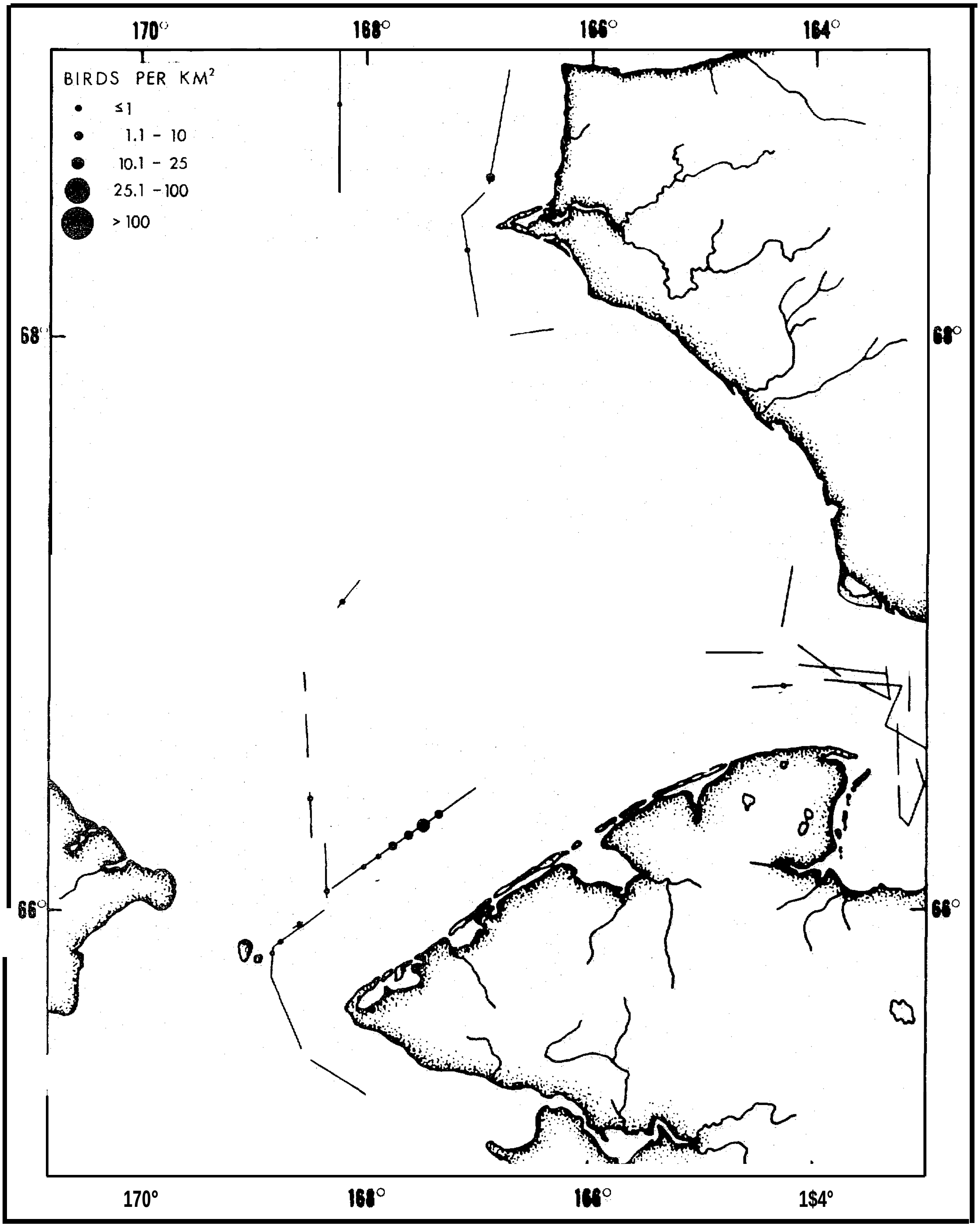


Figure 180. Distribution and abundance of unidentified alcids in Bering Strait and southern Chukchi Sea from 15 to 20 September and on 22 September 1976.

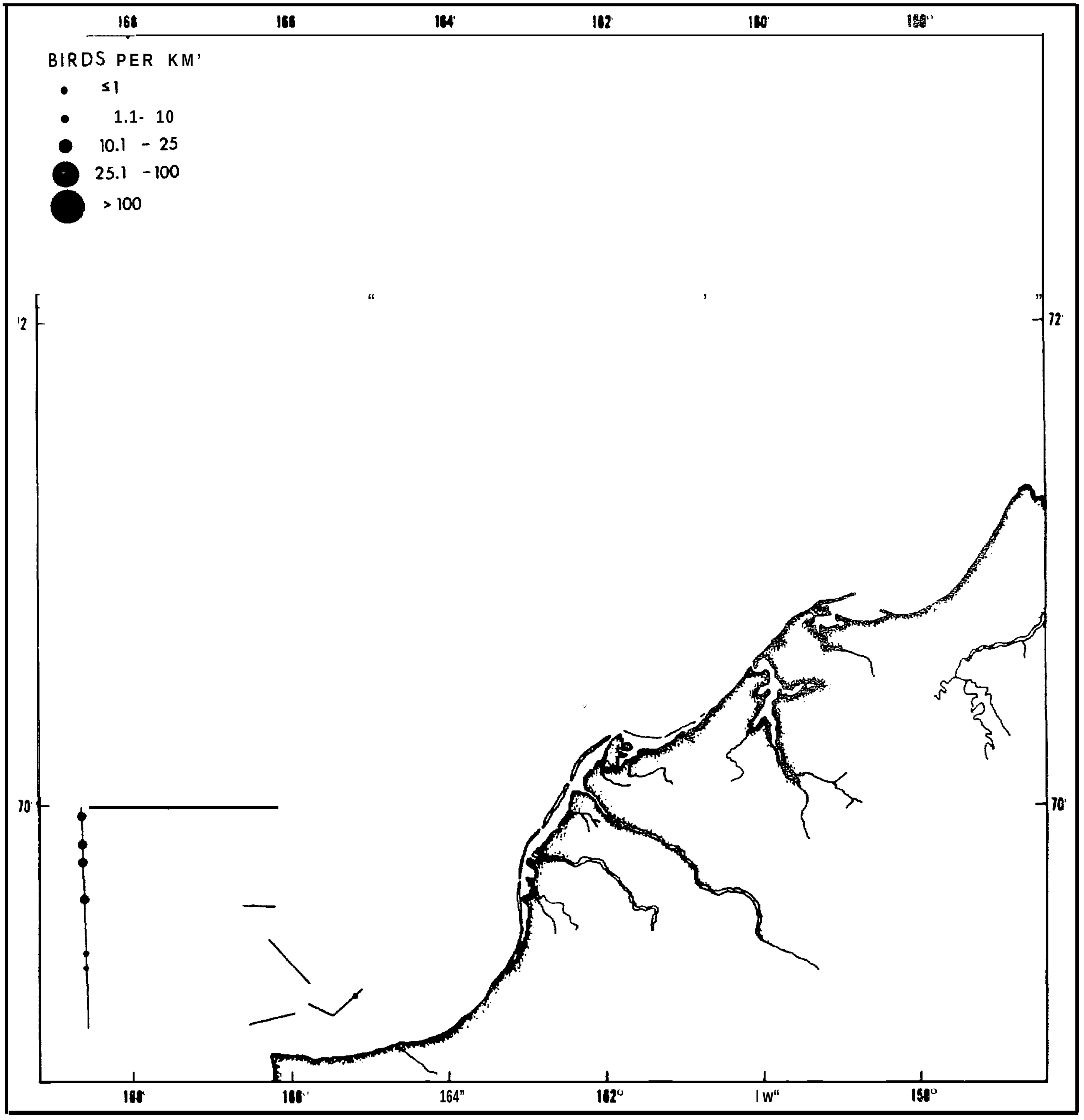


Figure 181. Distribution and abundance of unidentified alcids in northern Chukchi Sea from 20 to 22 September 1976.

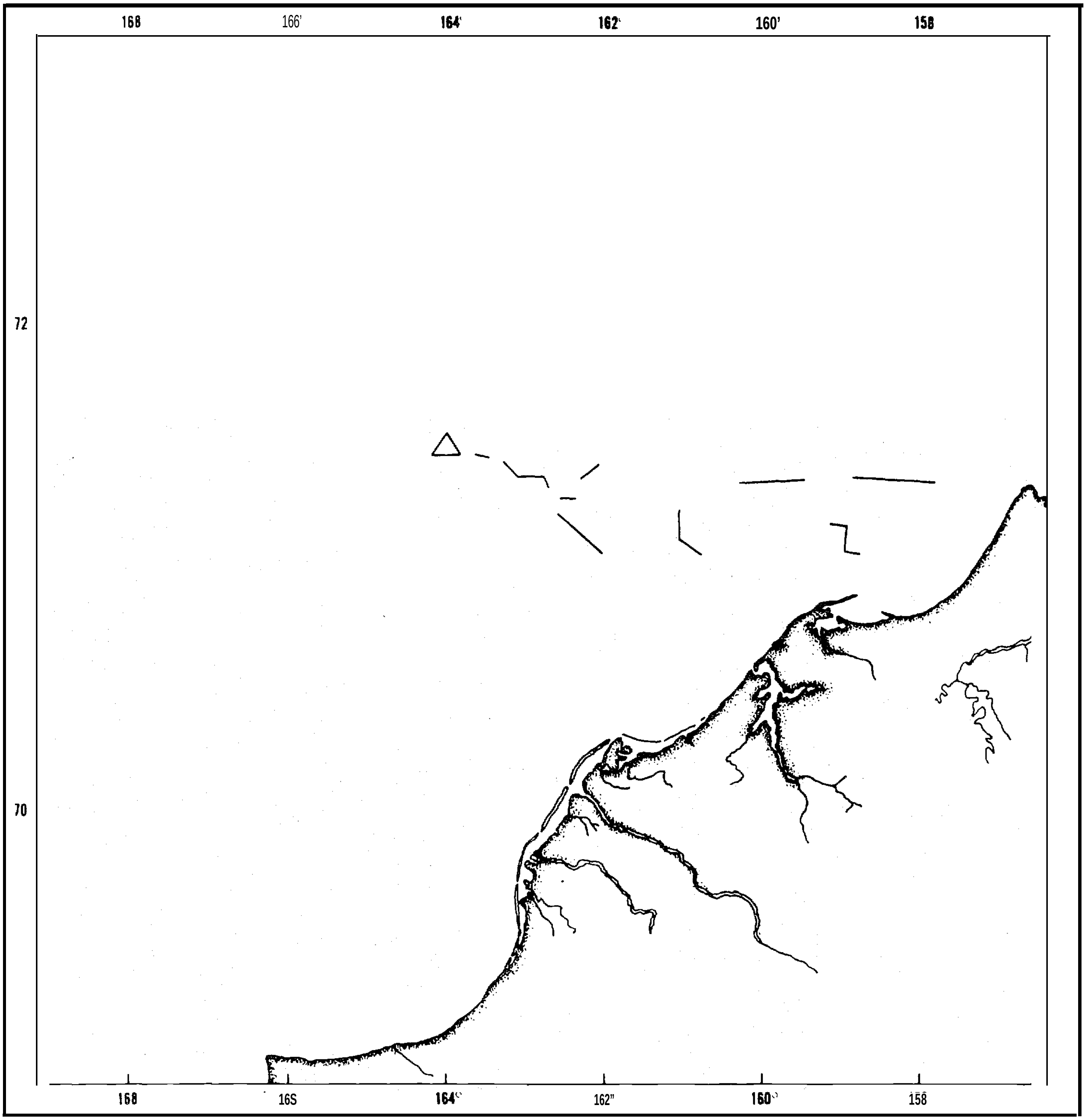


Figure 182. Cruise track during periods of observation in northern Chukchi Sea from 2 to 5 August 1977.

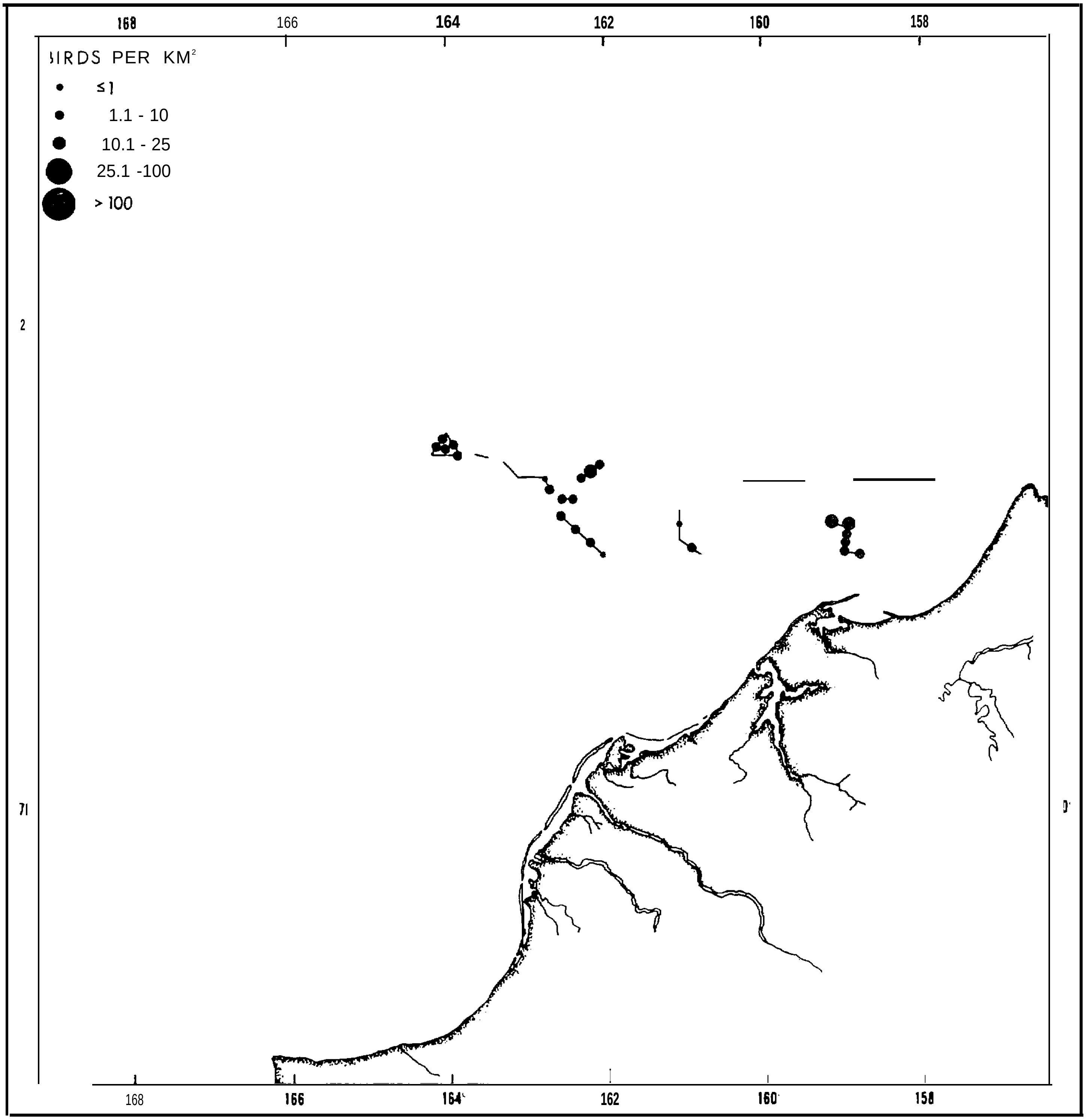


Figure 183. Distribution and abundance of seabirds in northern Chukchi Sea from 5 to 8 August 1977.

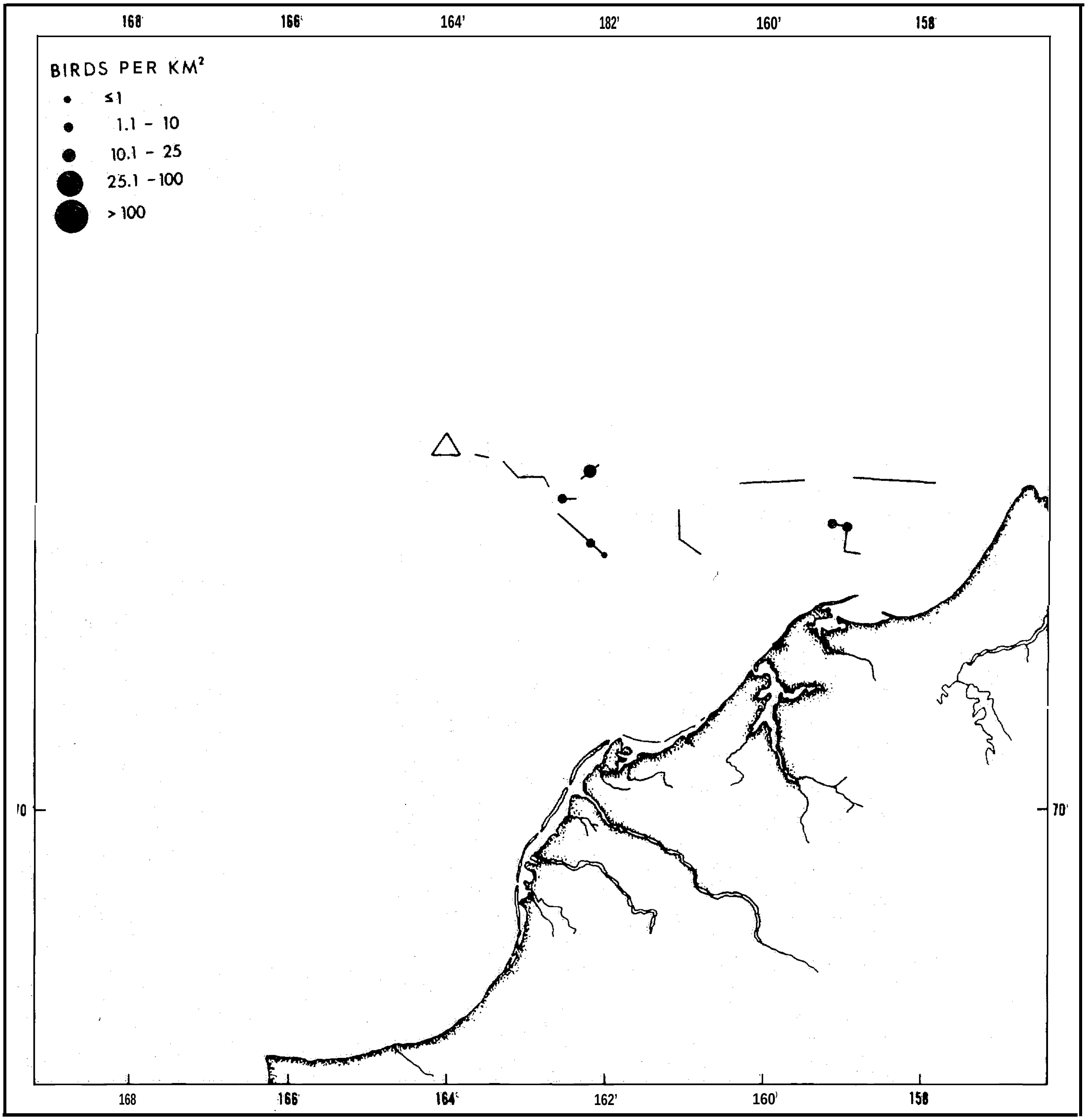


Figure 184. Distribution and abundance of phalaropes in northern Chukchi Sea from 5 to 8 August 1977.

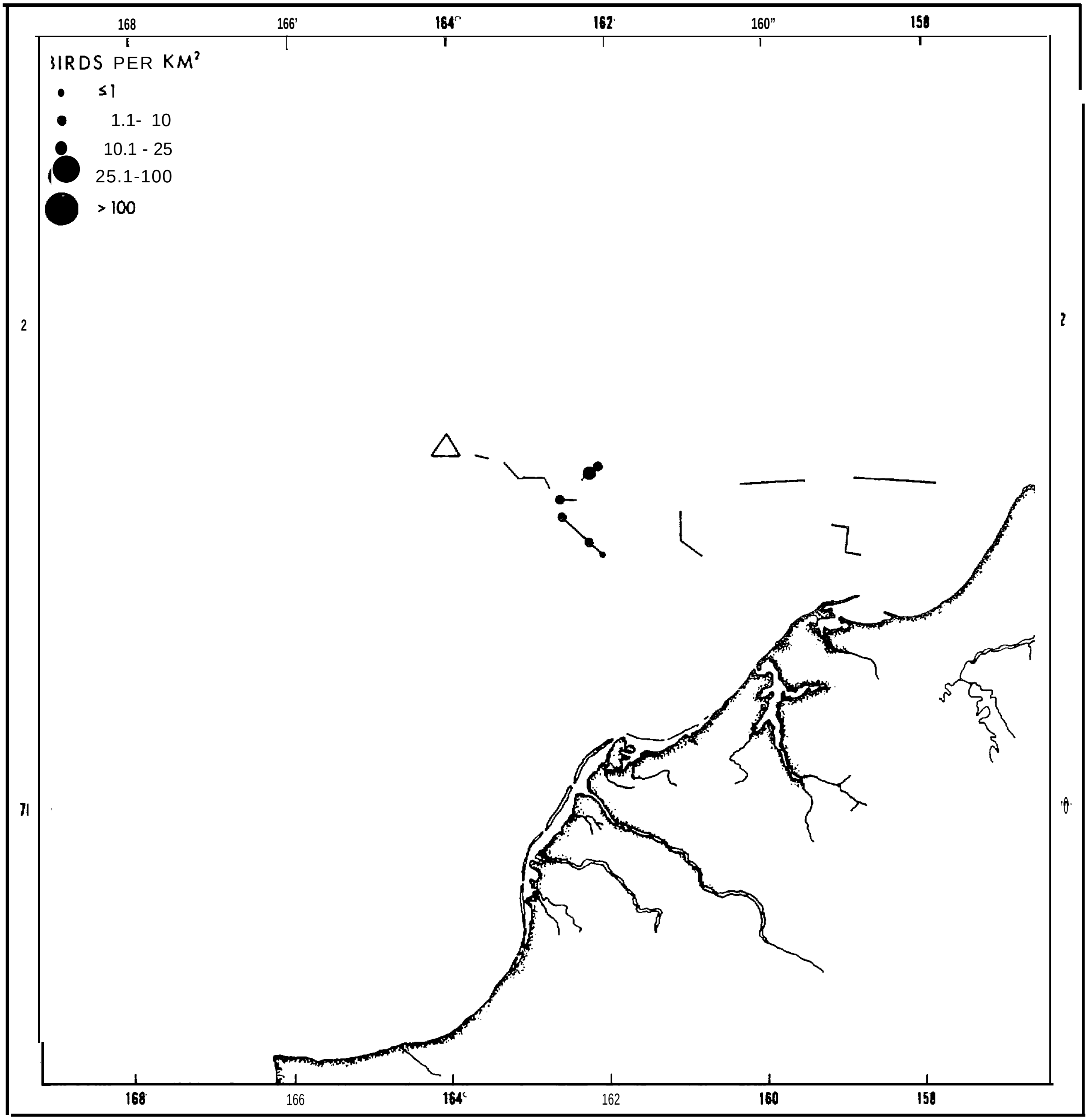


Figure 185. Distribution and abundance of jaegers in northern Chukchi Sea from 5 to 8 August 1977.

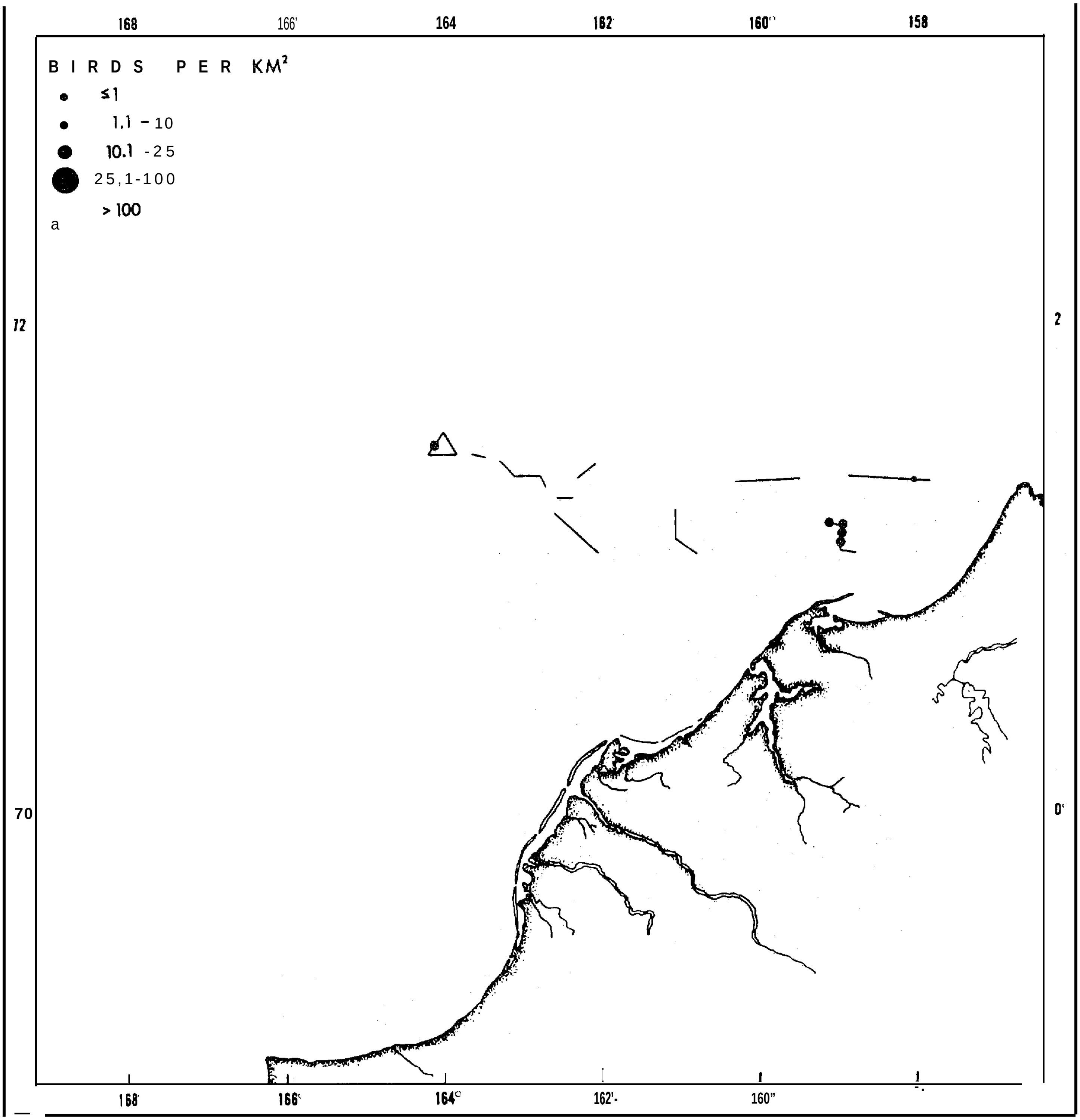


Figure 186. Distribution and abundance of Glaucous Gulls in northern Chukchi Sea from 5 to 8 August 1977.

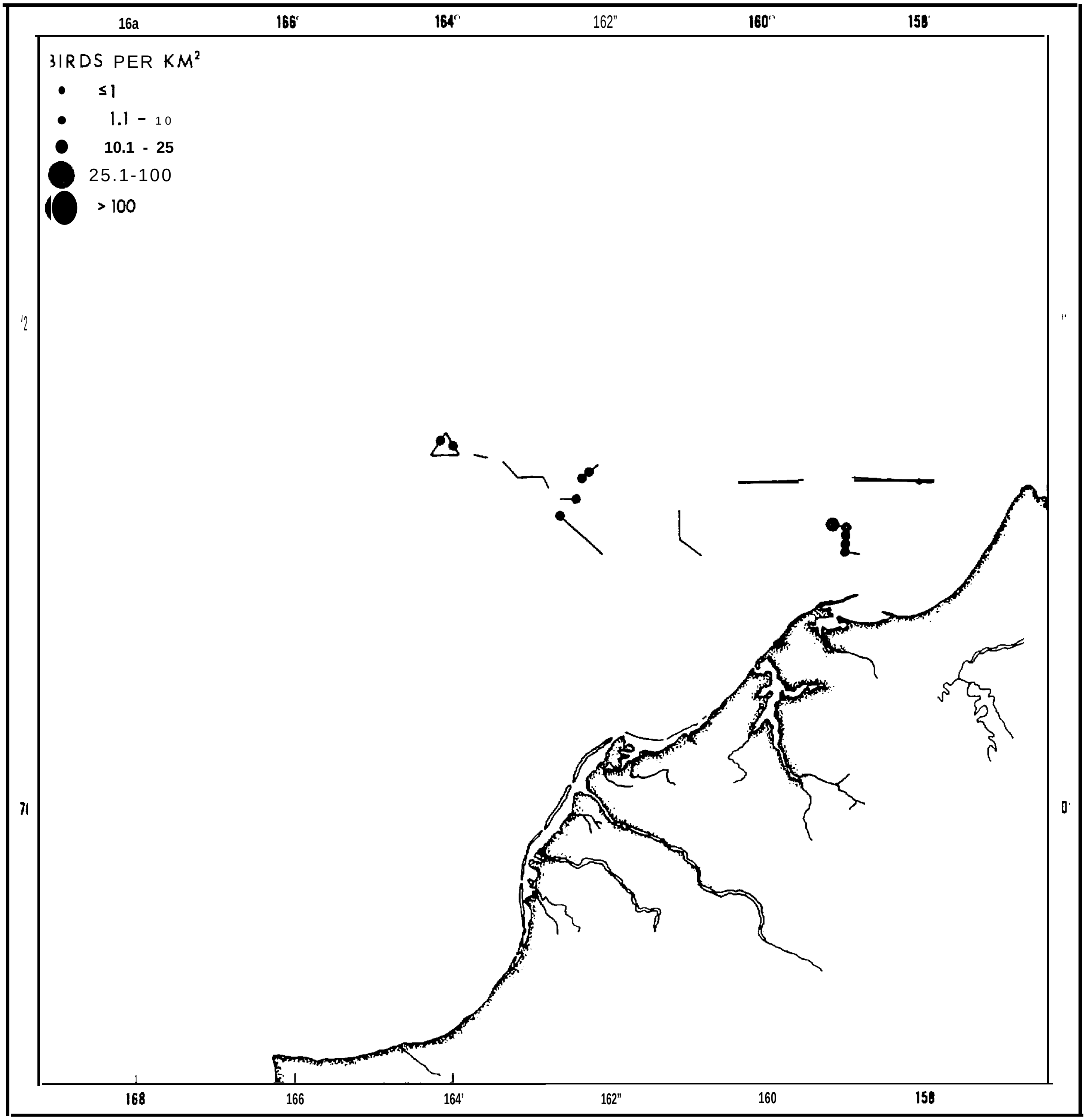


Figure 187. Distribution and abundance of Black-legged Kittiwakes in northern Chukchi Sea from 5 to 8 August 1977.

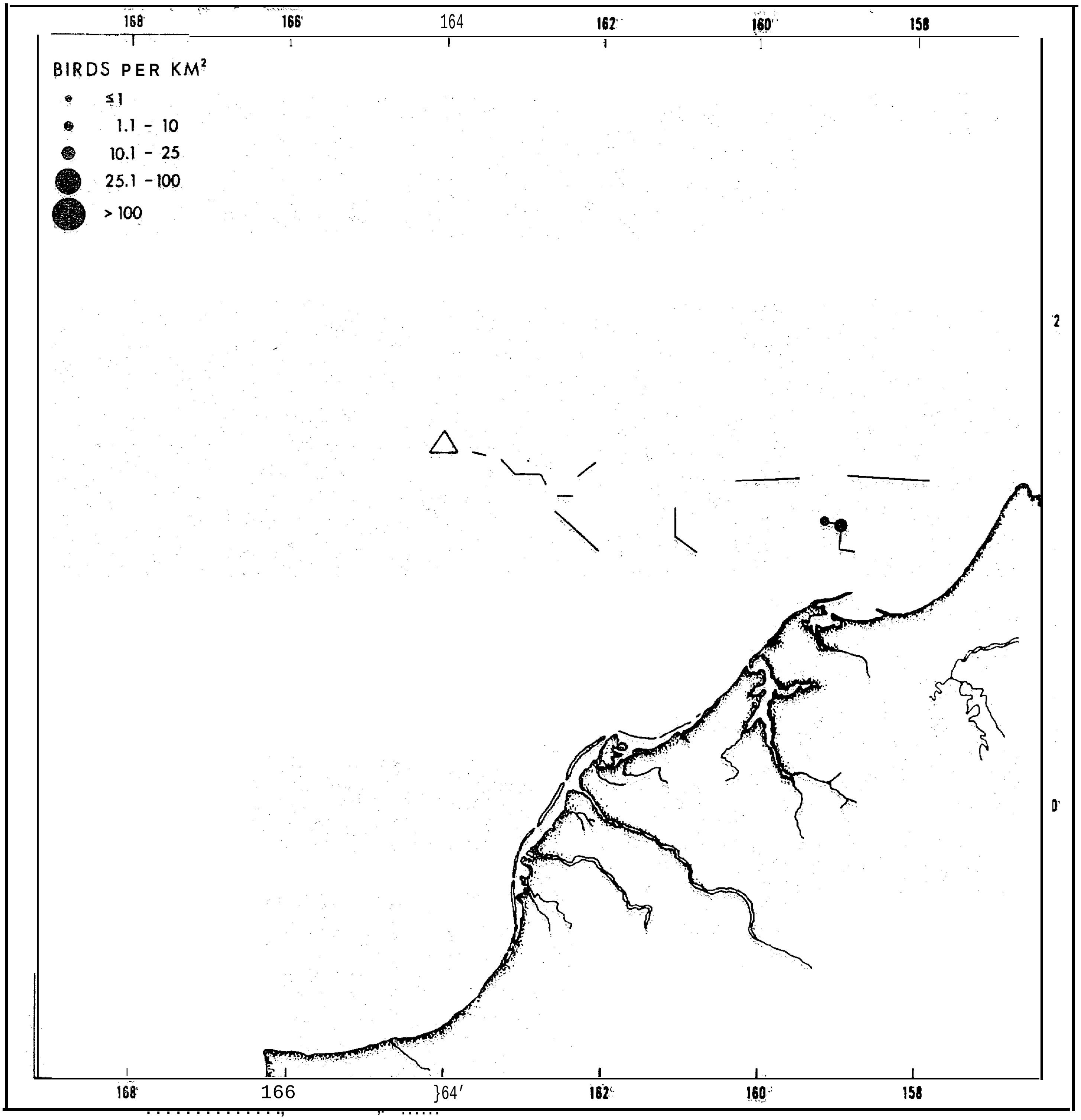


Figure 188. Distribution and abundance of Arctic Terns in northern Chukchi Sea from 5 to 8 August 1977.

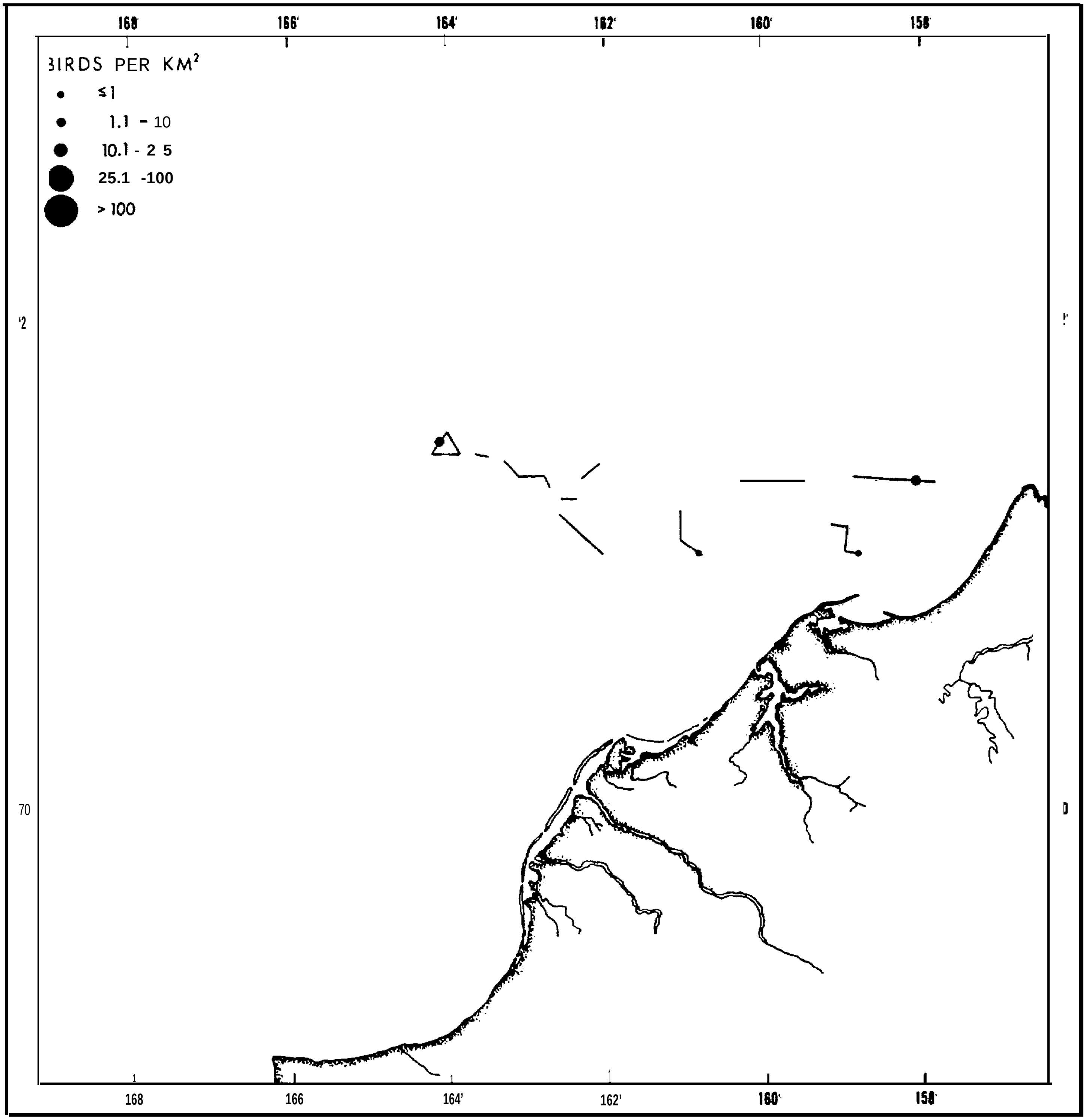


Figure 189. Distribution and abundance of ship followers in northern Chukchi Sea from 5 to 8 August 1977.

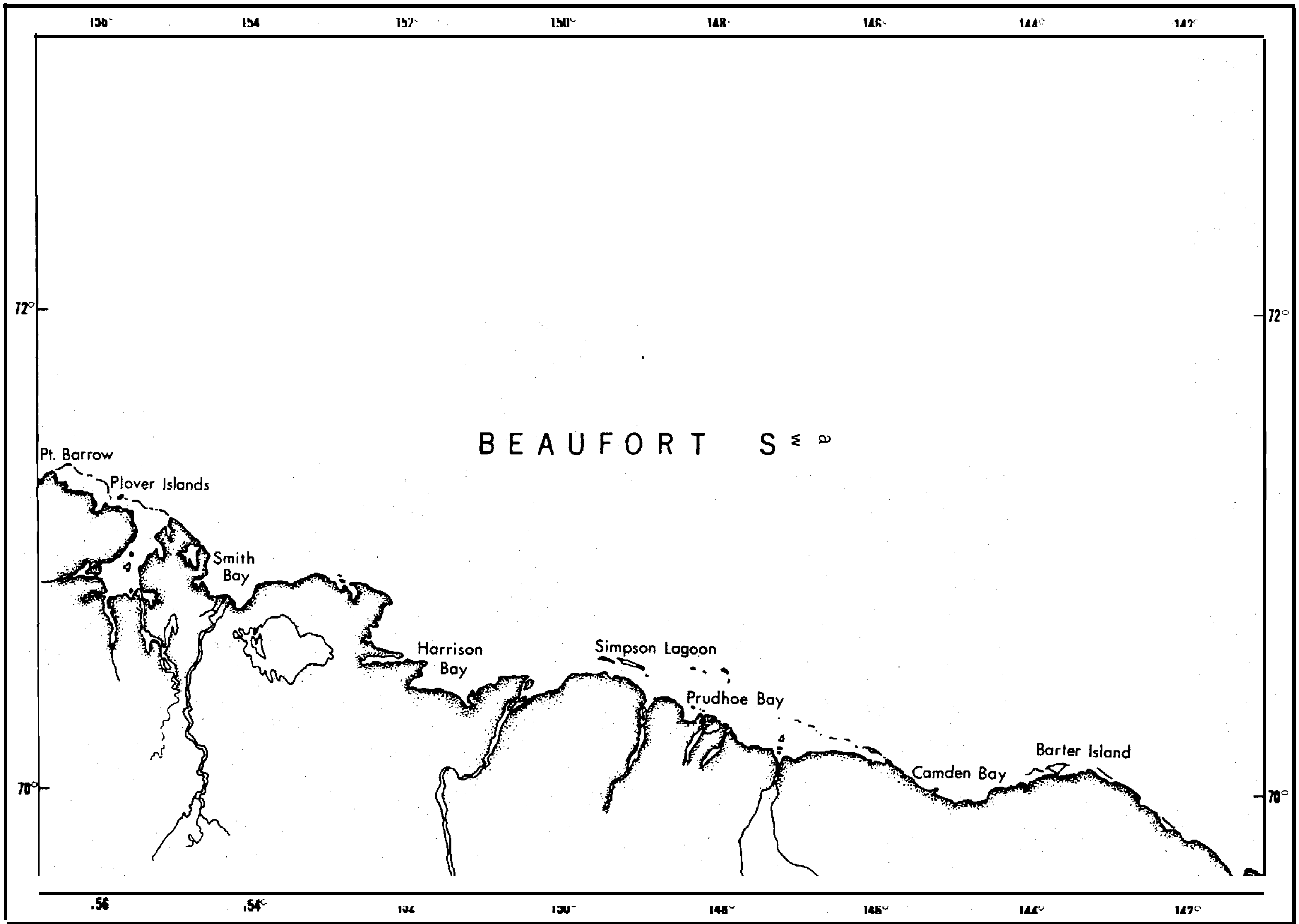


Figure 190. Beaufort Sea showing localities mentioned in text.

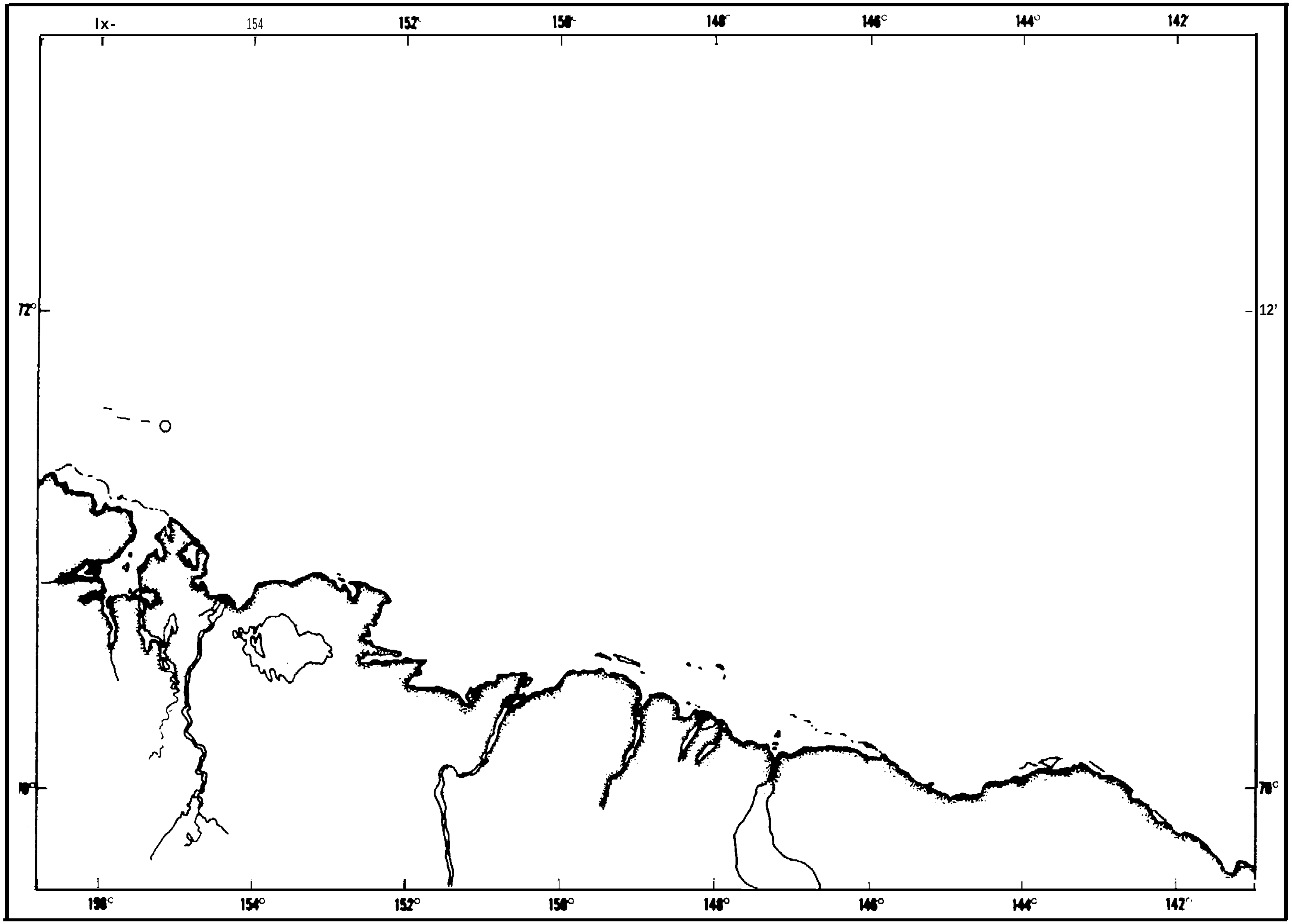


Figure 191. Cruise track during periods of observation in Beaufort Sea from 26 to 28 July 1976.

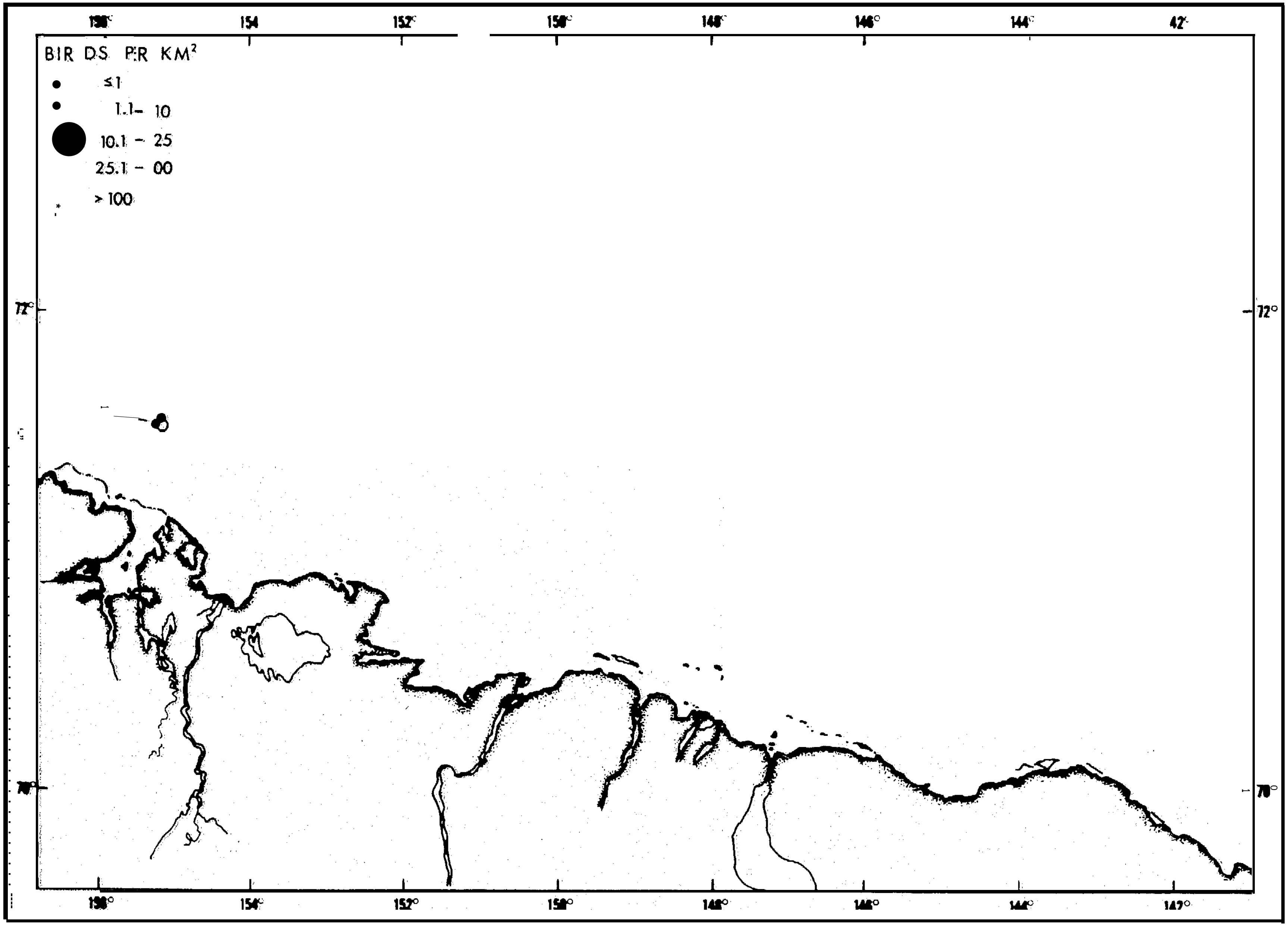


Figure 192. Distribution and abundance of seabirds in Beaufort Sea from 26 to 28 July 1976.

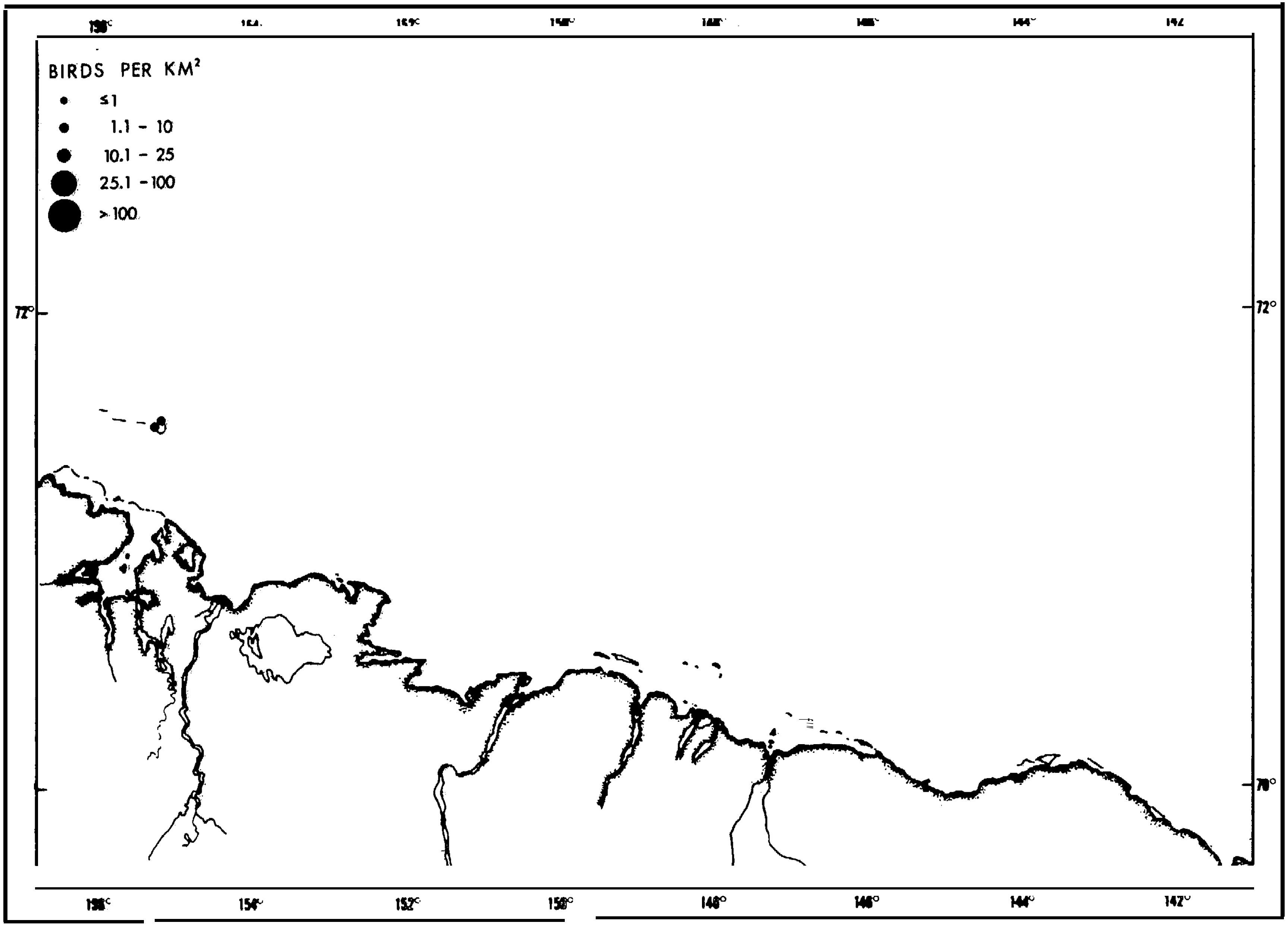


Figure 193. Distribution and abundance of murres in Beaufort Sea from 26 to 28 July 1976.

Figure 194. Cruise track during periods of observation in Beaufort Sea from 17 August to 3 September 1976.

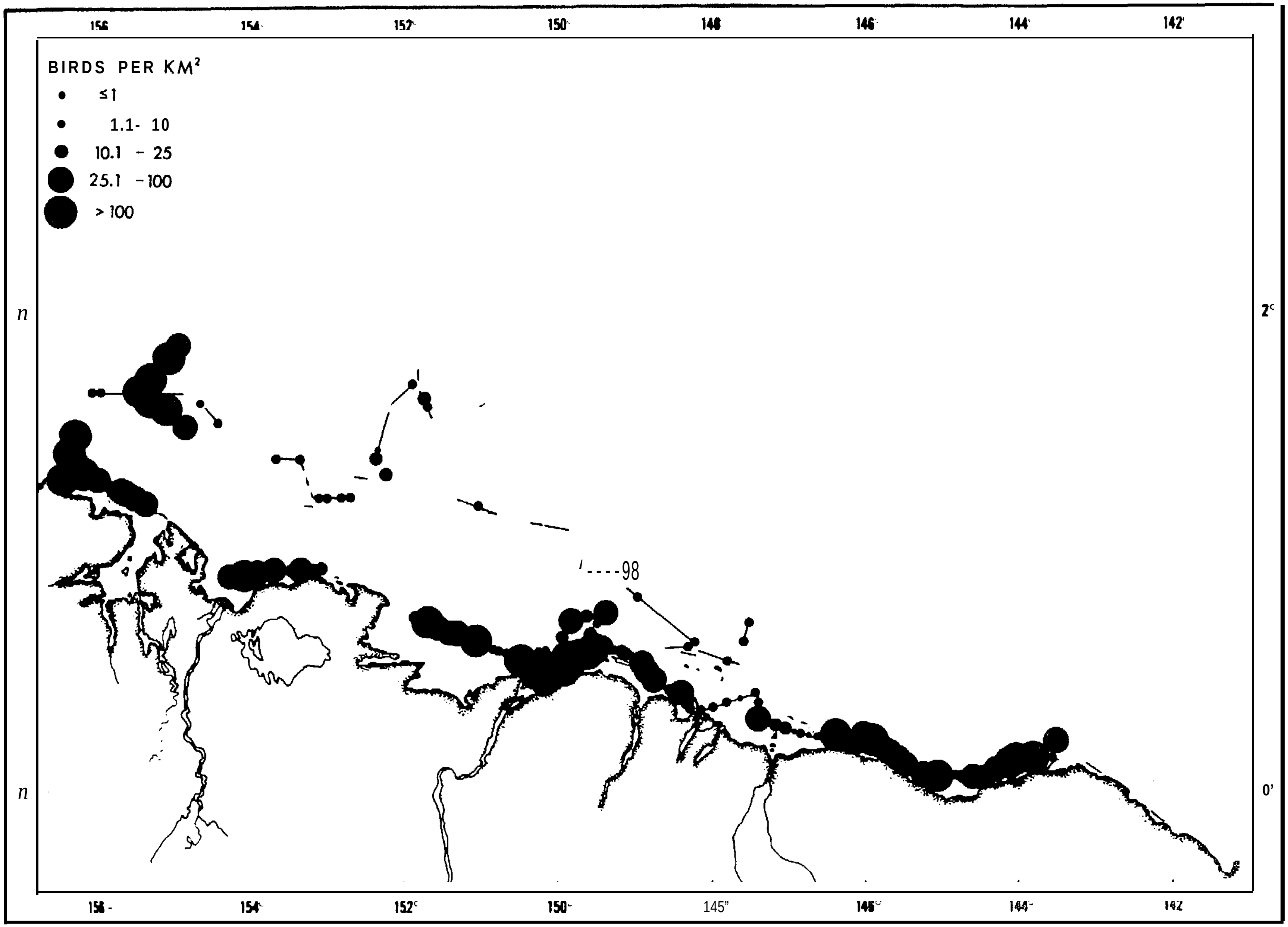


Figure 195. Distribution and abundance of seabirds in Beaufort Sea from 17 August to 3 September 1976.

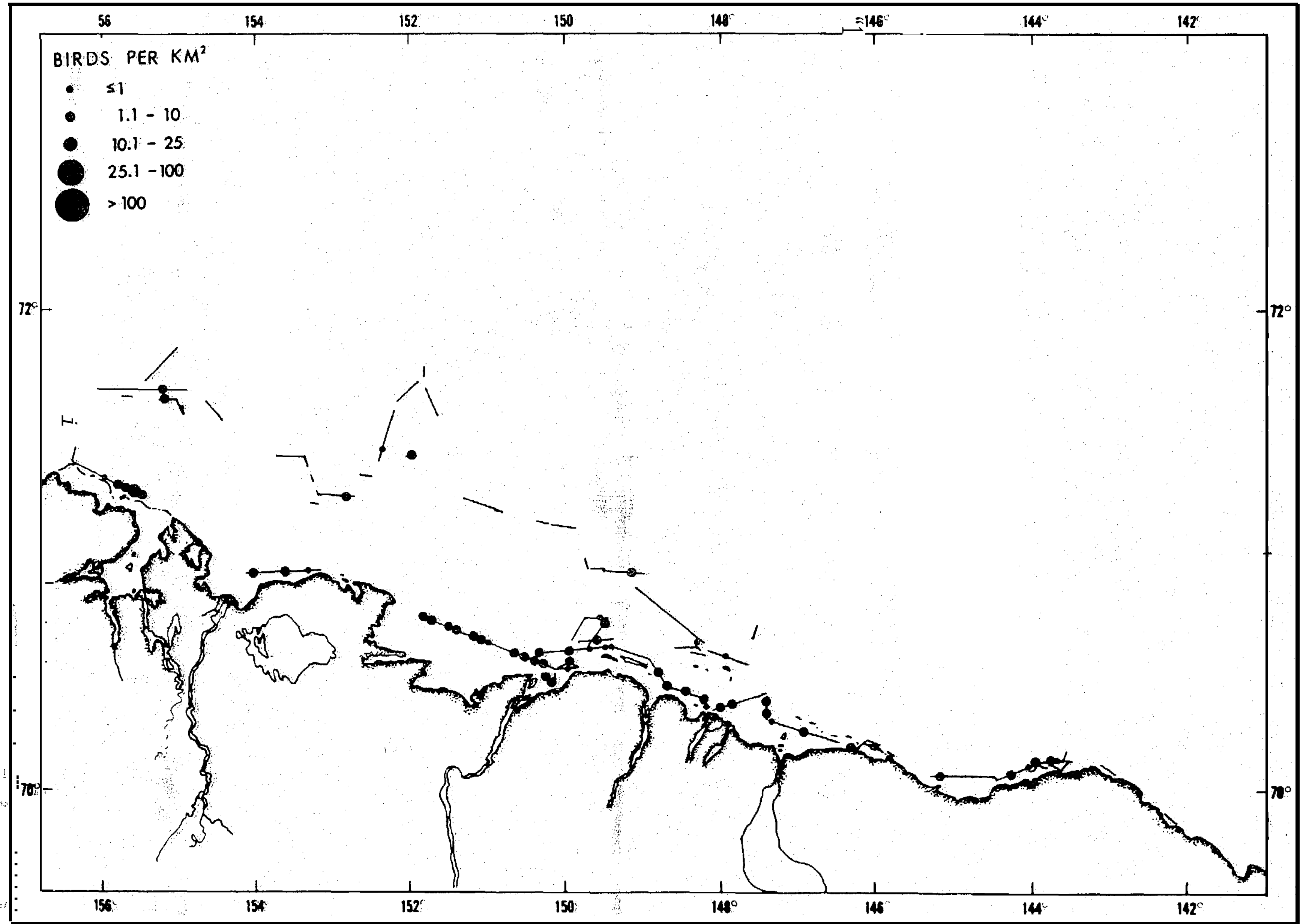


Figure 196. Distribution and abundance of loons in Beaufort Sea from 17 August to 3 September 1976.

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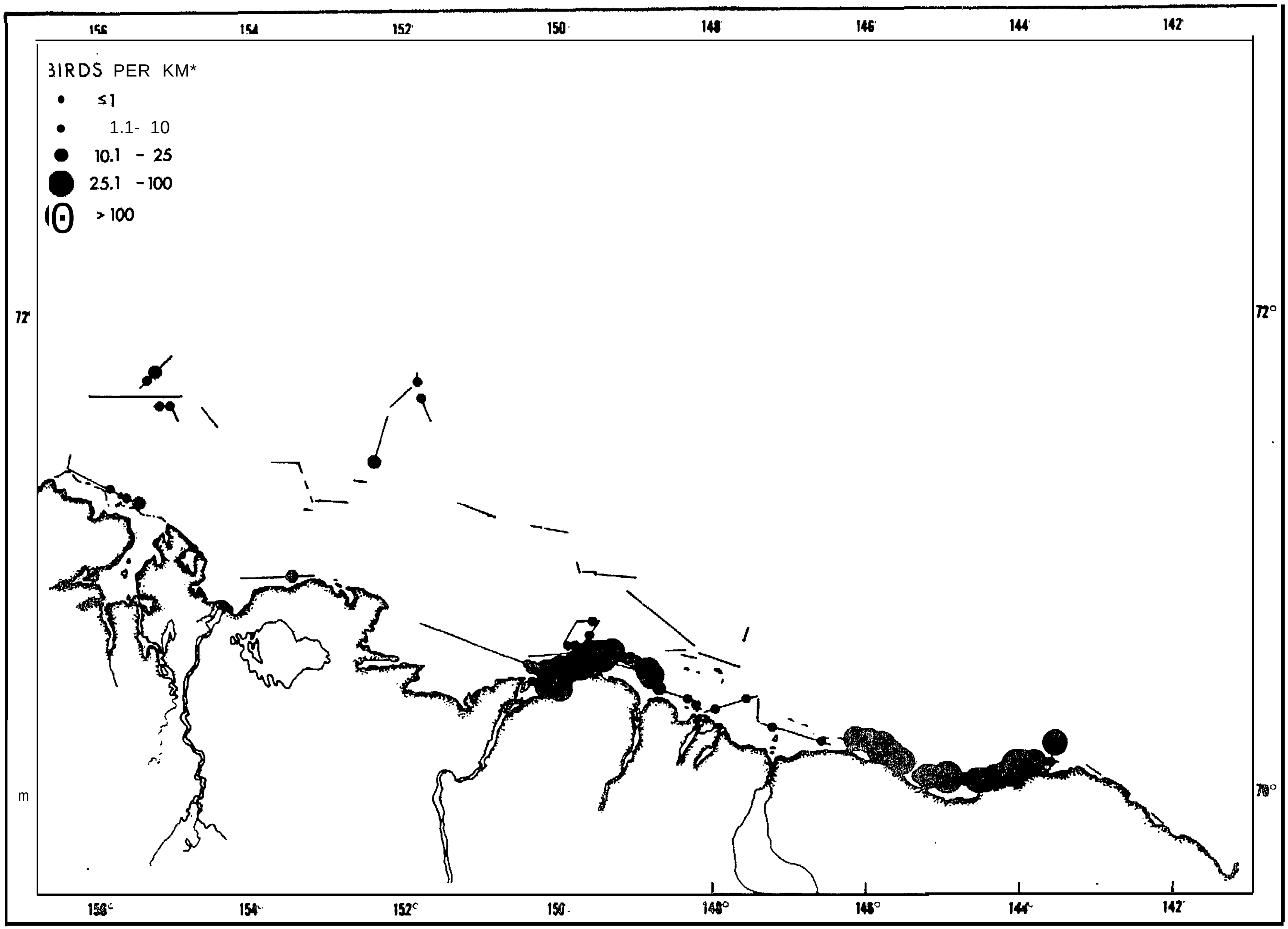


Figure 197. Distribution and abundance of Oldsquaws in Beaufort Sea from 1.7 August to 3 September 1976.

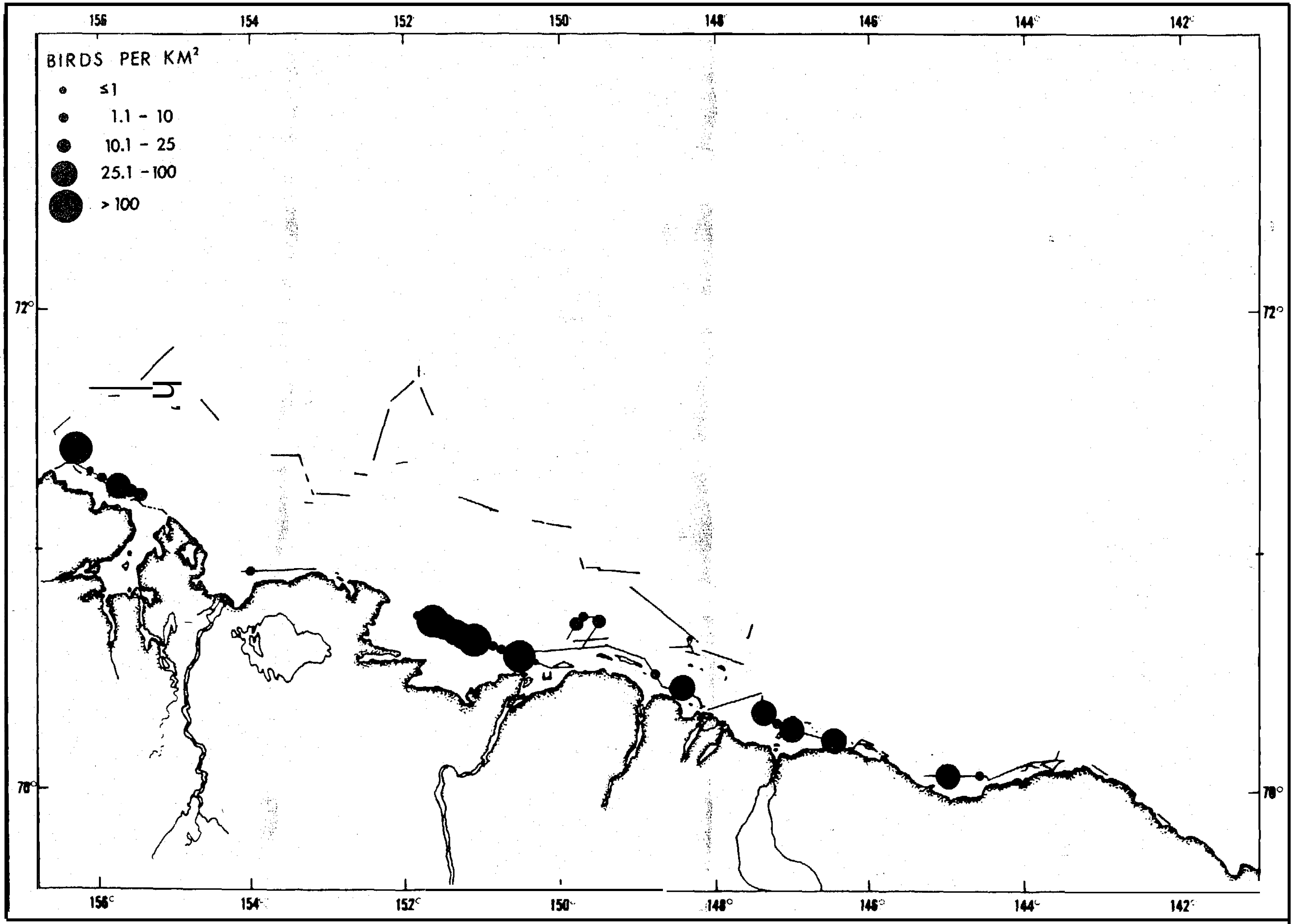


Figure 198. Distribution and abundan◦e ◦f eiders in Beaufort Sea from 17 August to 3 September 1976.

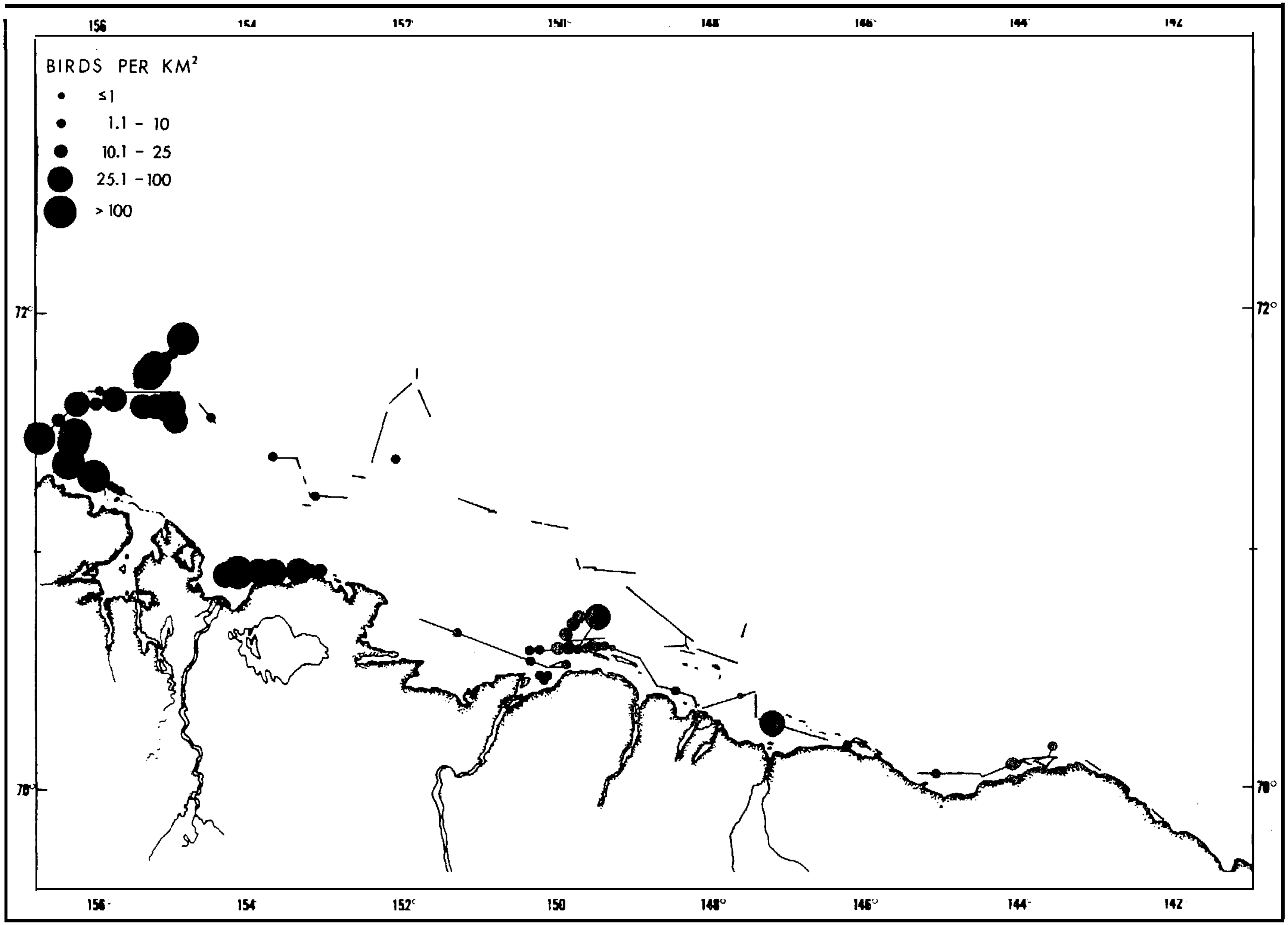


Figure 199. Distribution and abundance of phalaropes in Beaufort Sea from 17 August to 3 September 1976.

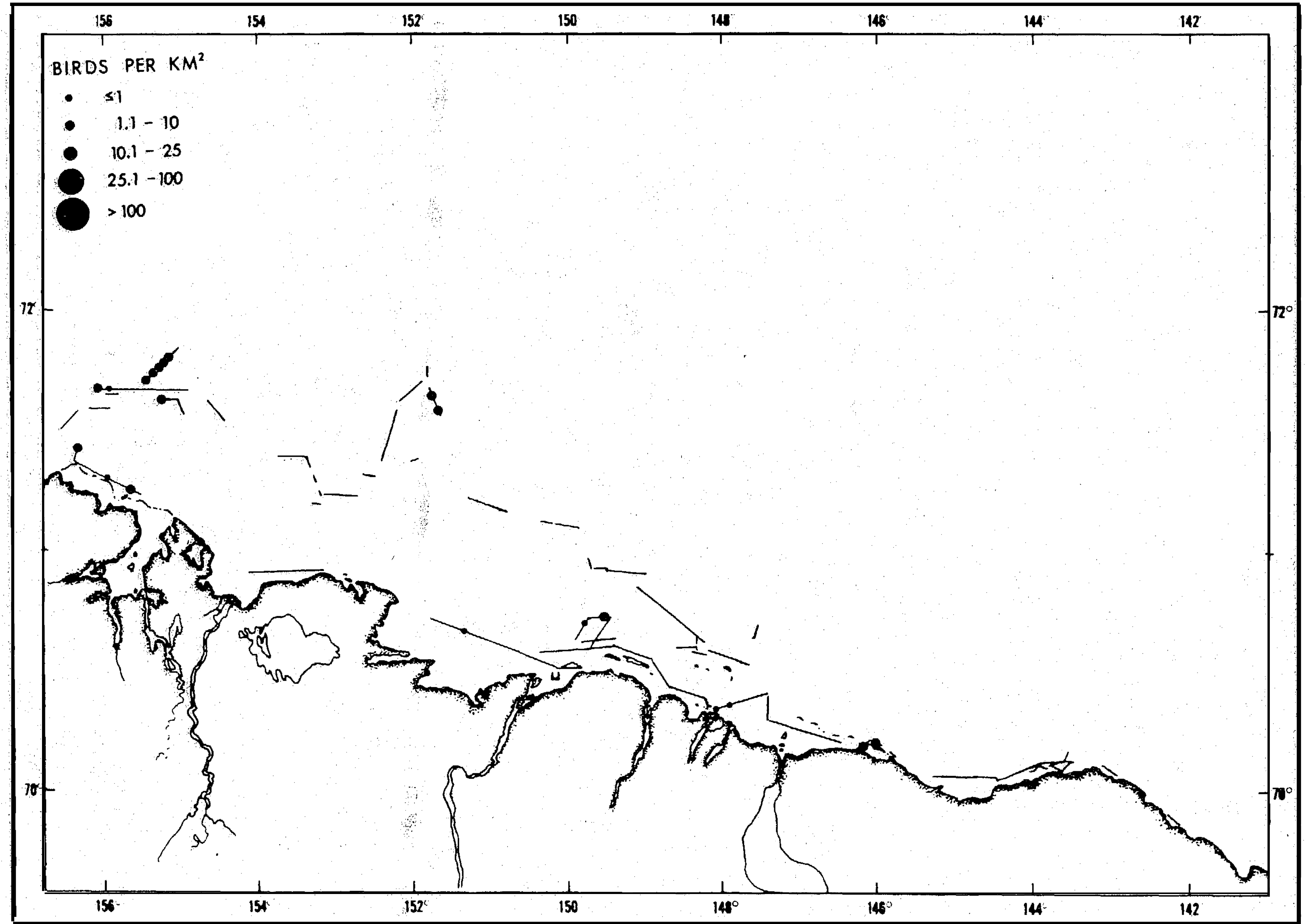


Figure 200. Distribution and abundance of jaegers in Beaufort Sea from 17 August to 3 September 1976.

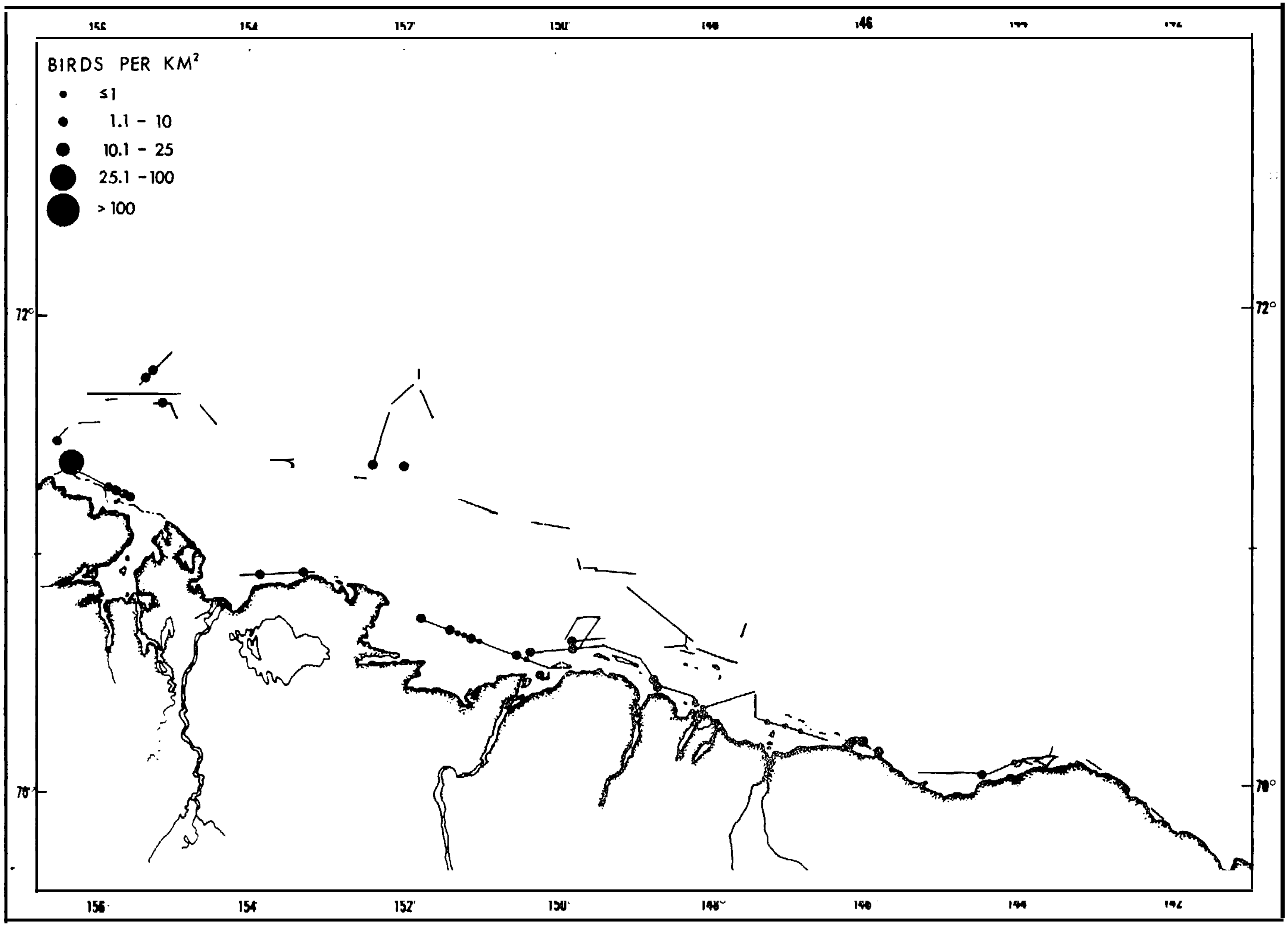


Figure 201. Distribution and abundance of Glaucous Gulls in Beaufort Sea from 17 August to 3 September 1976.

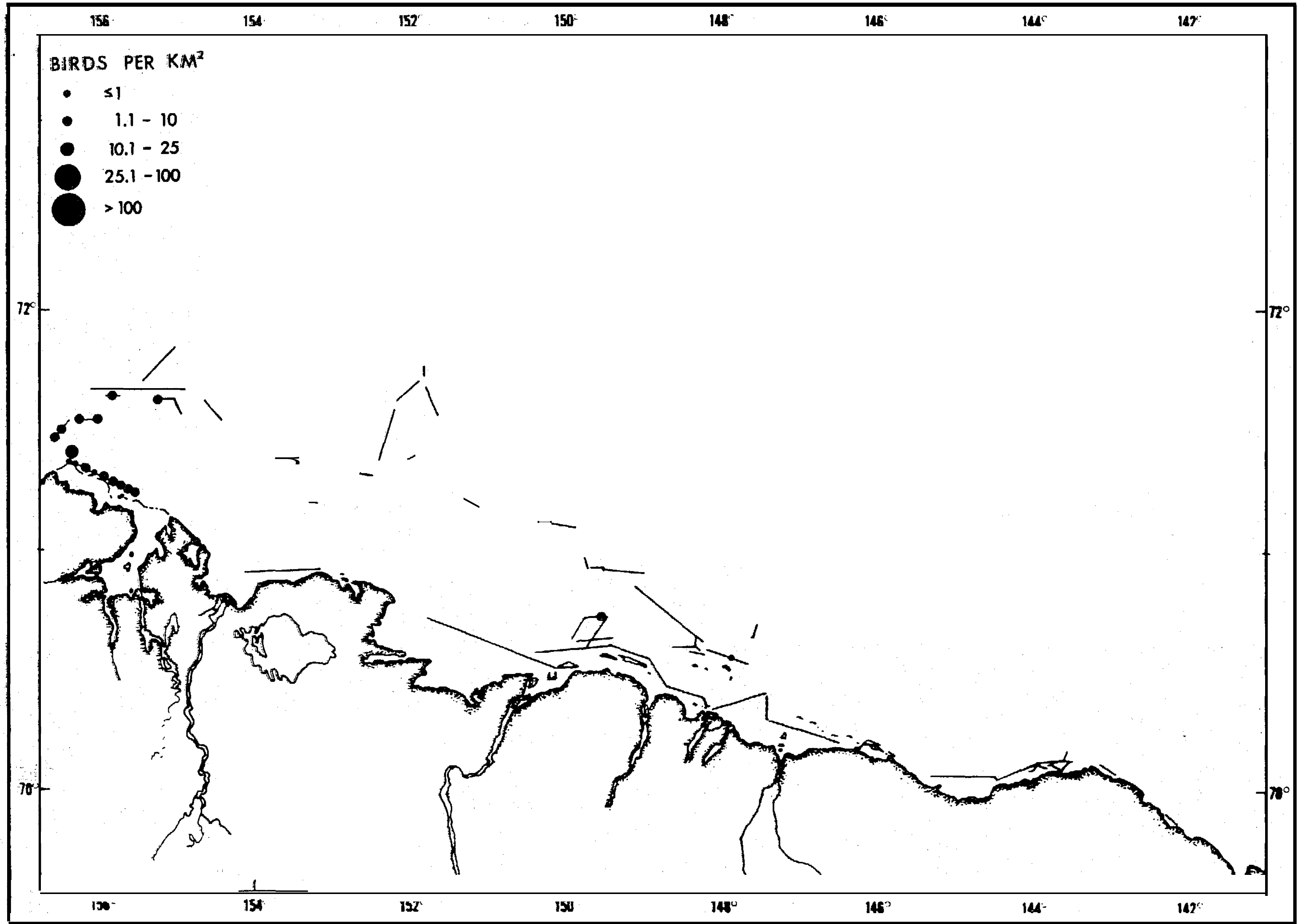


Figure 202. Distribution and abundance of Black-legged Kittiwakes in Beaufort Sea from 17 August to 3 September 1976.

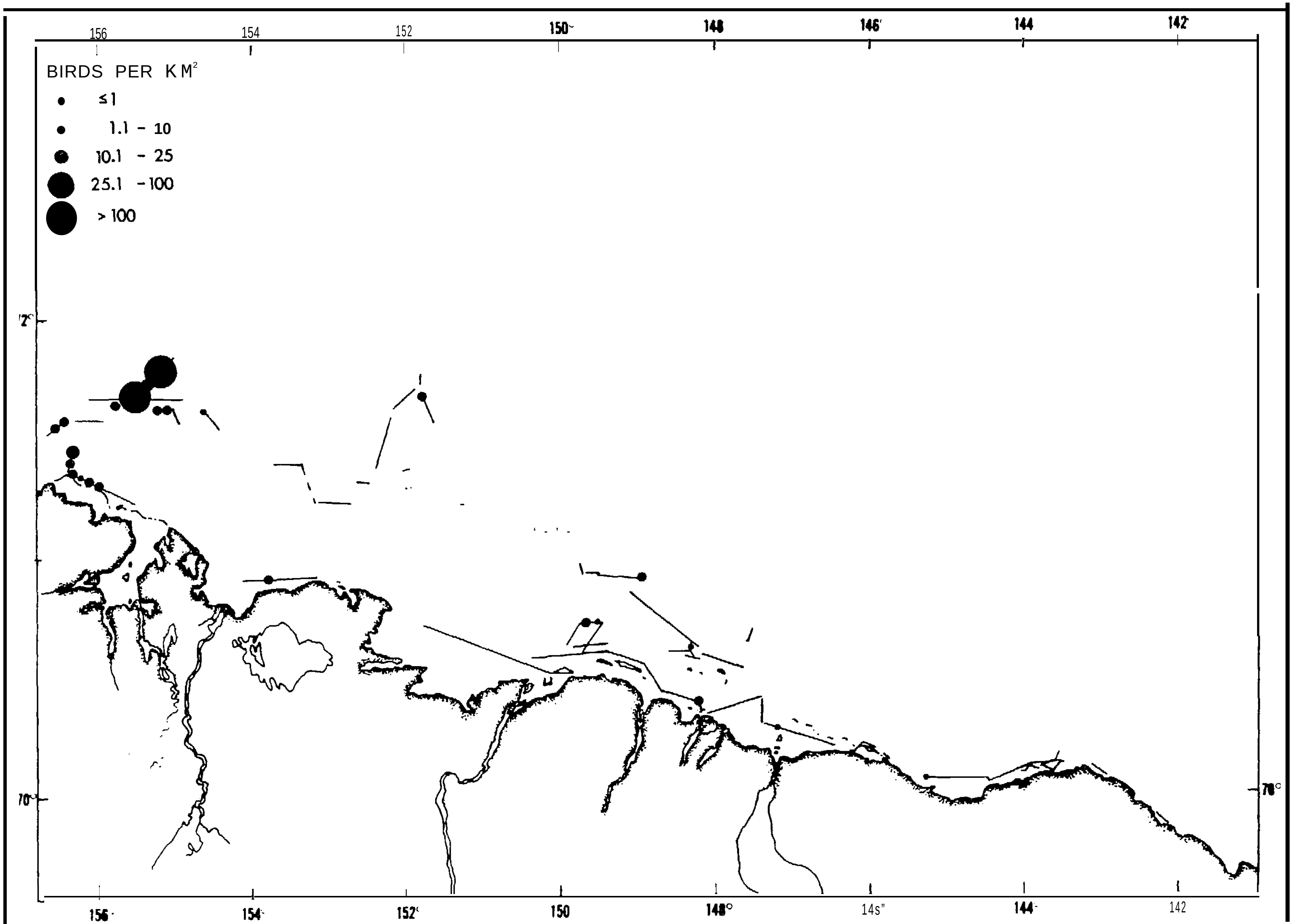
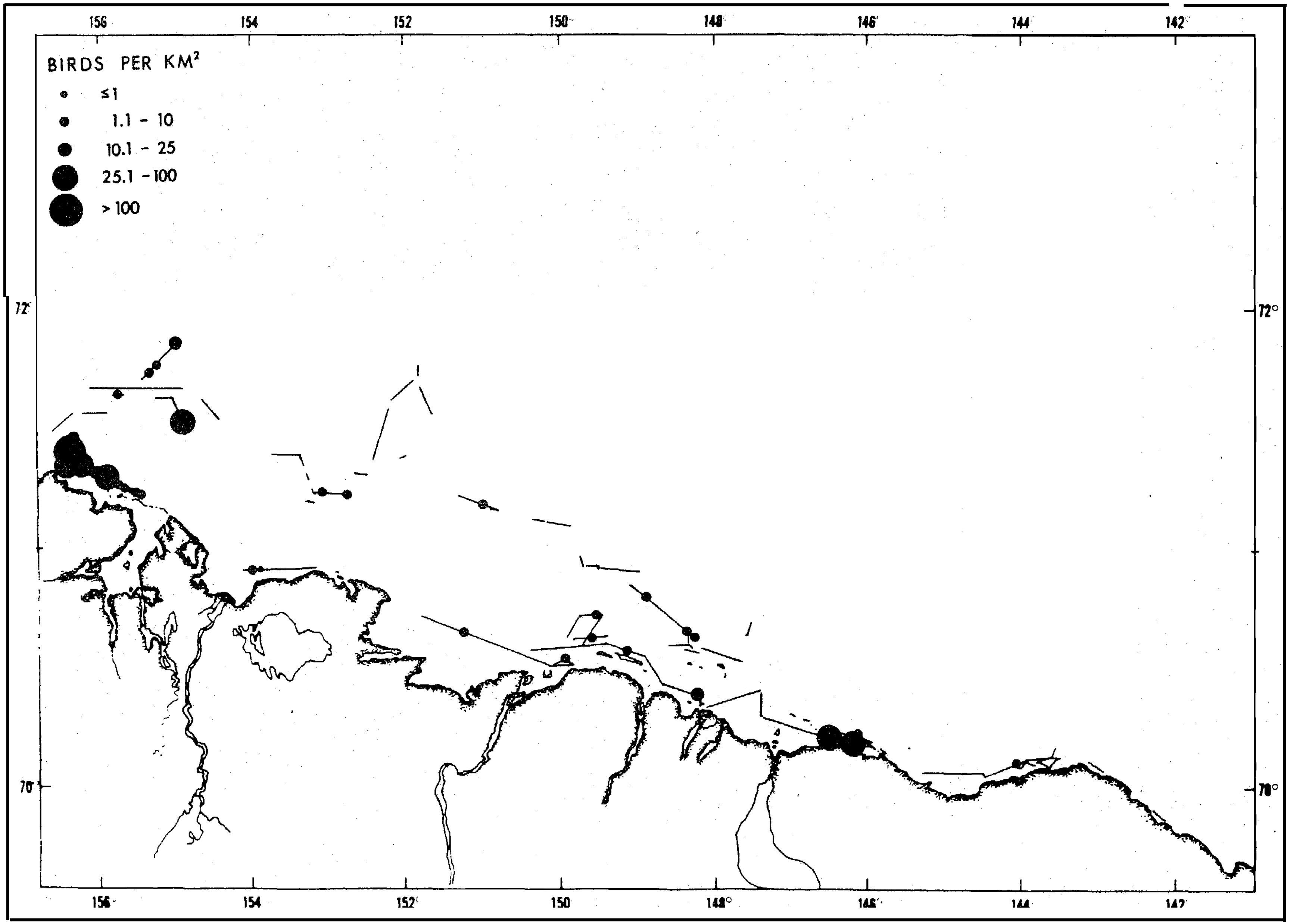


Figure 203. Distribution and abundance of Sabine's Gulls in Beaufort Sea from 17 August to 3 September 1976.



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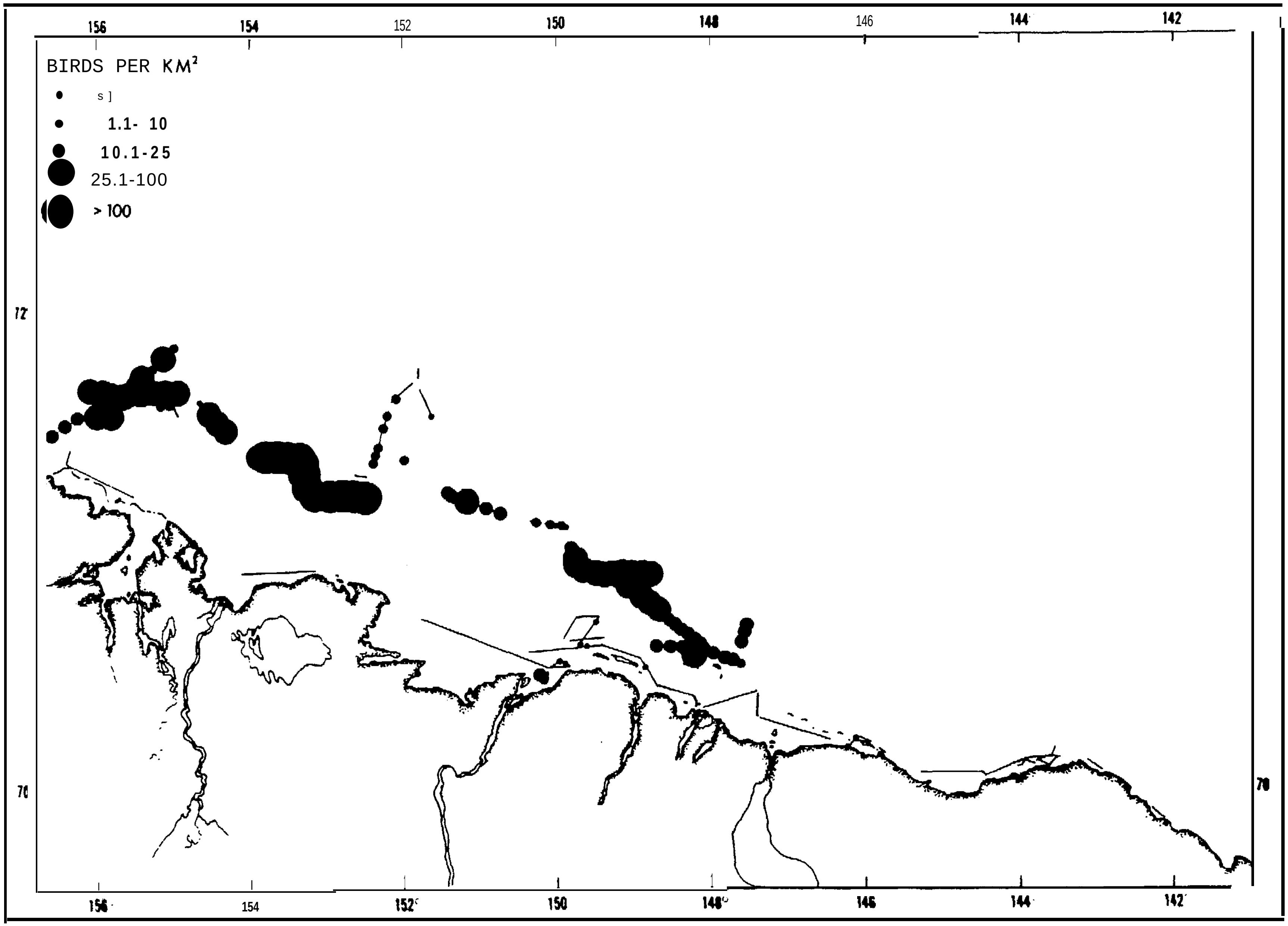

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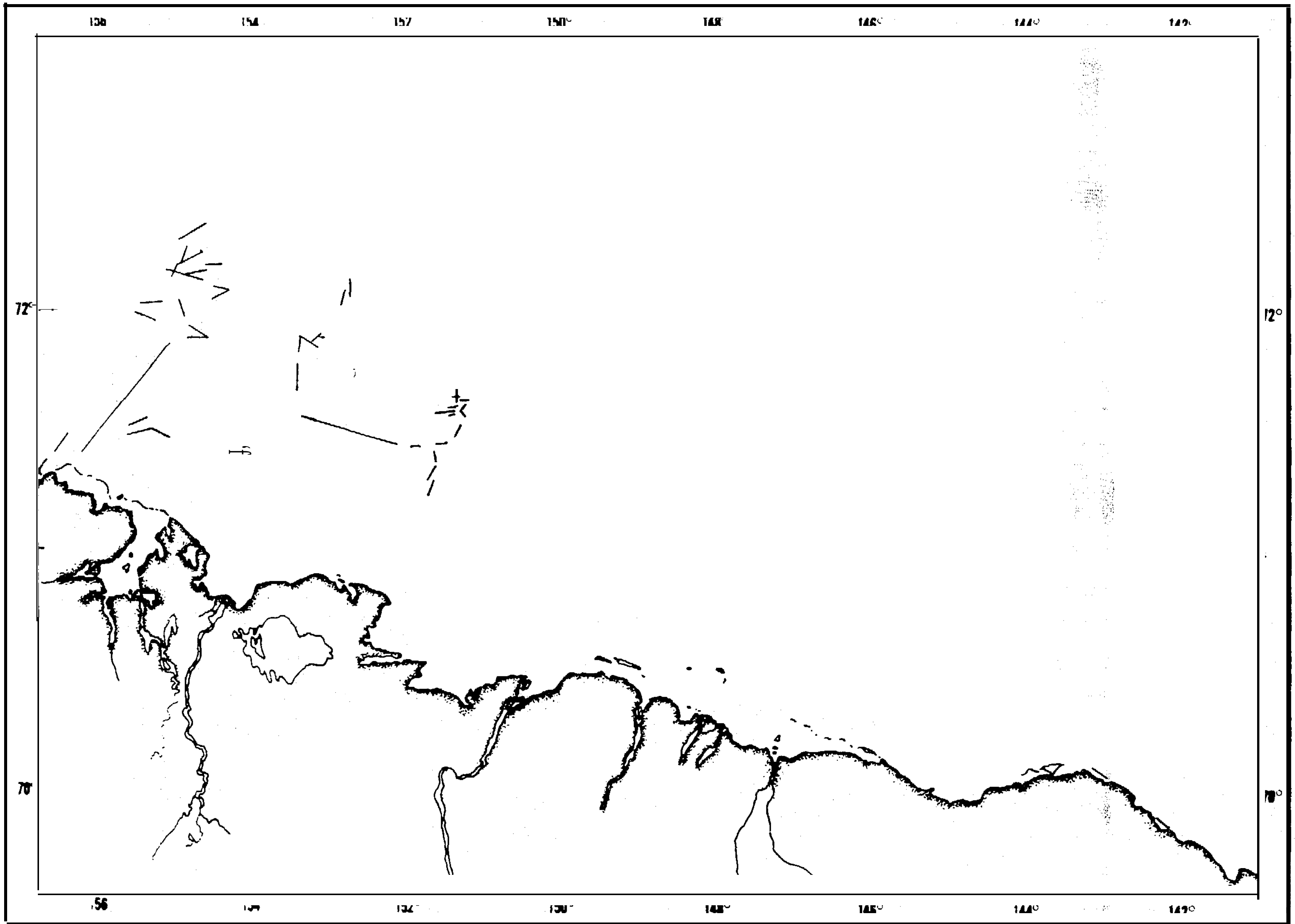

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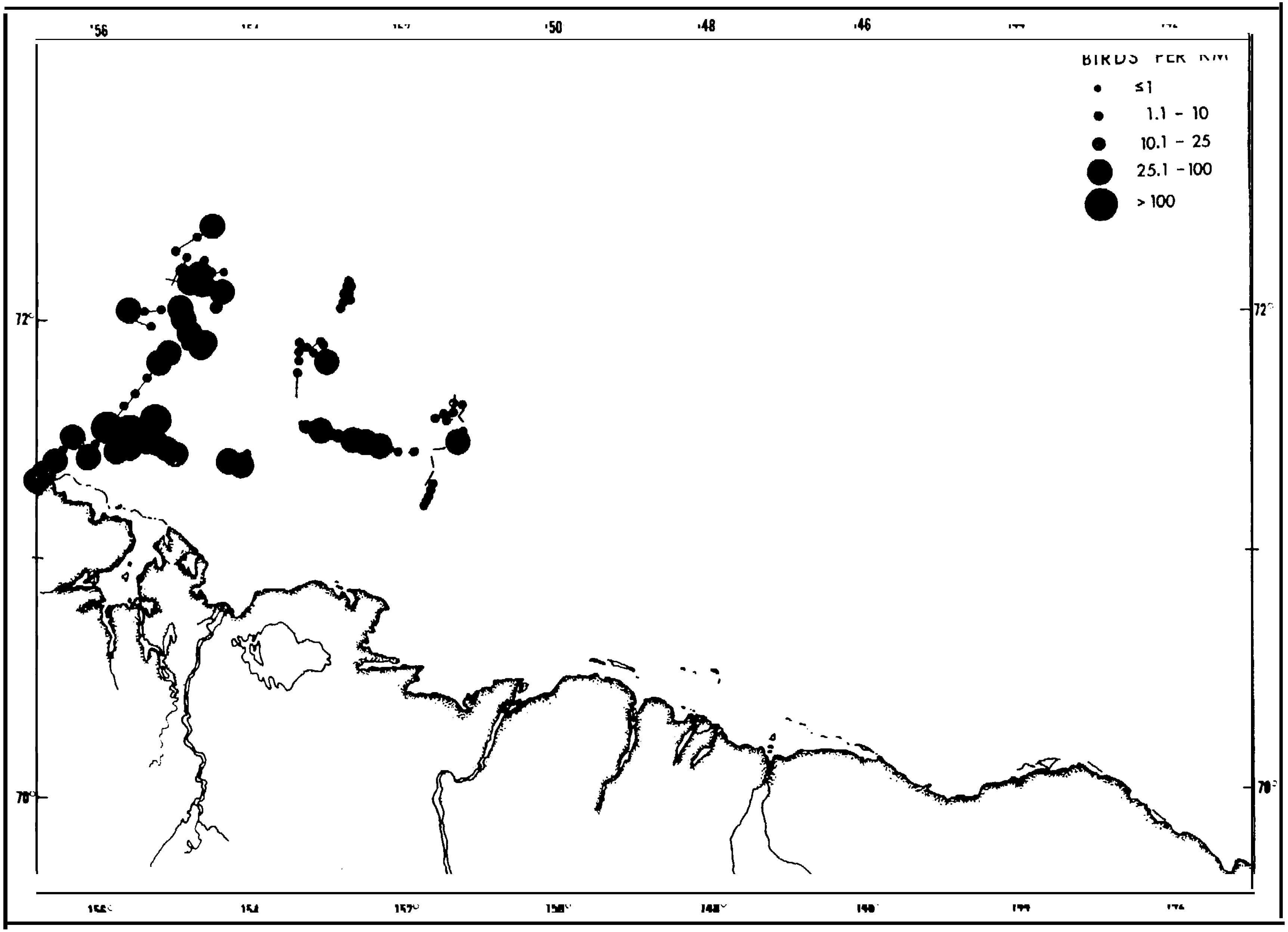

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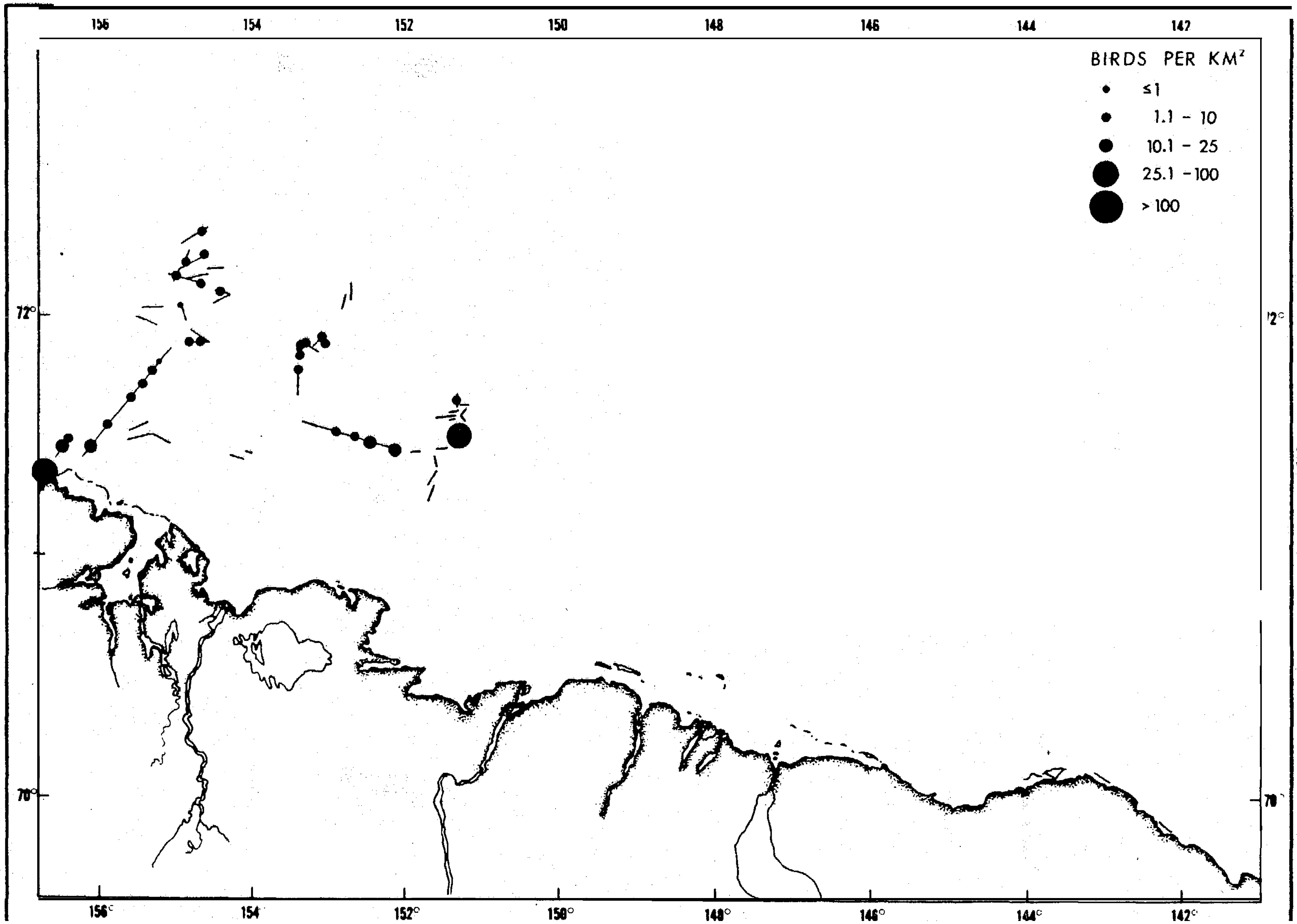

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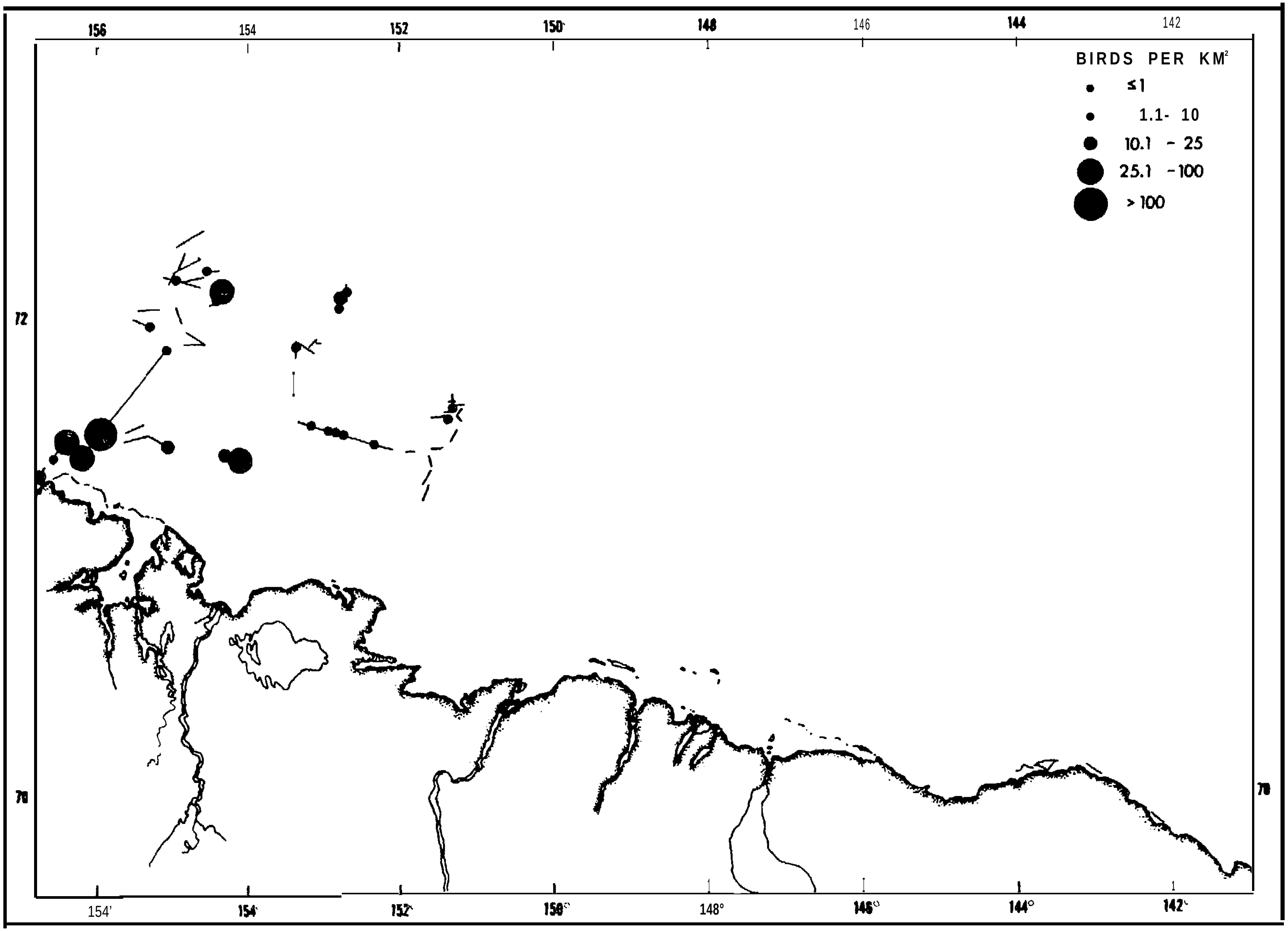

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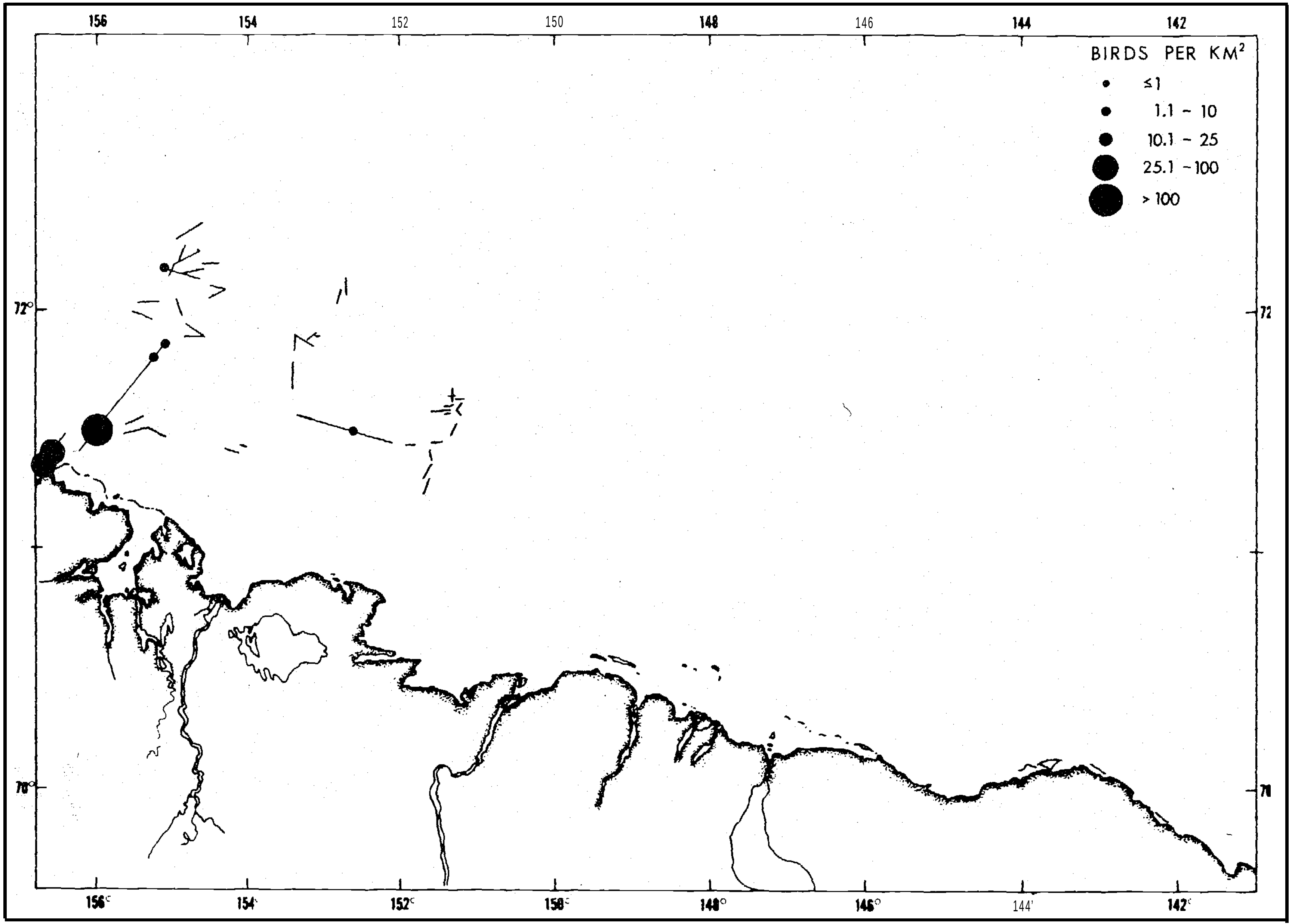

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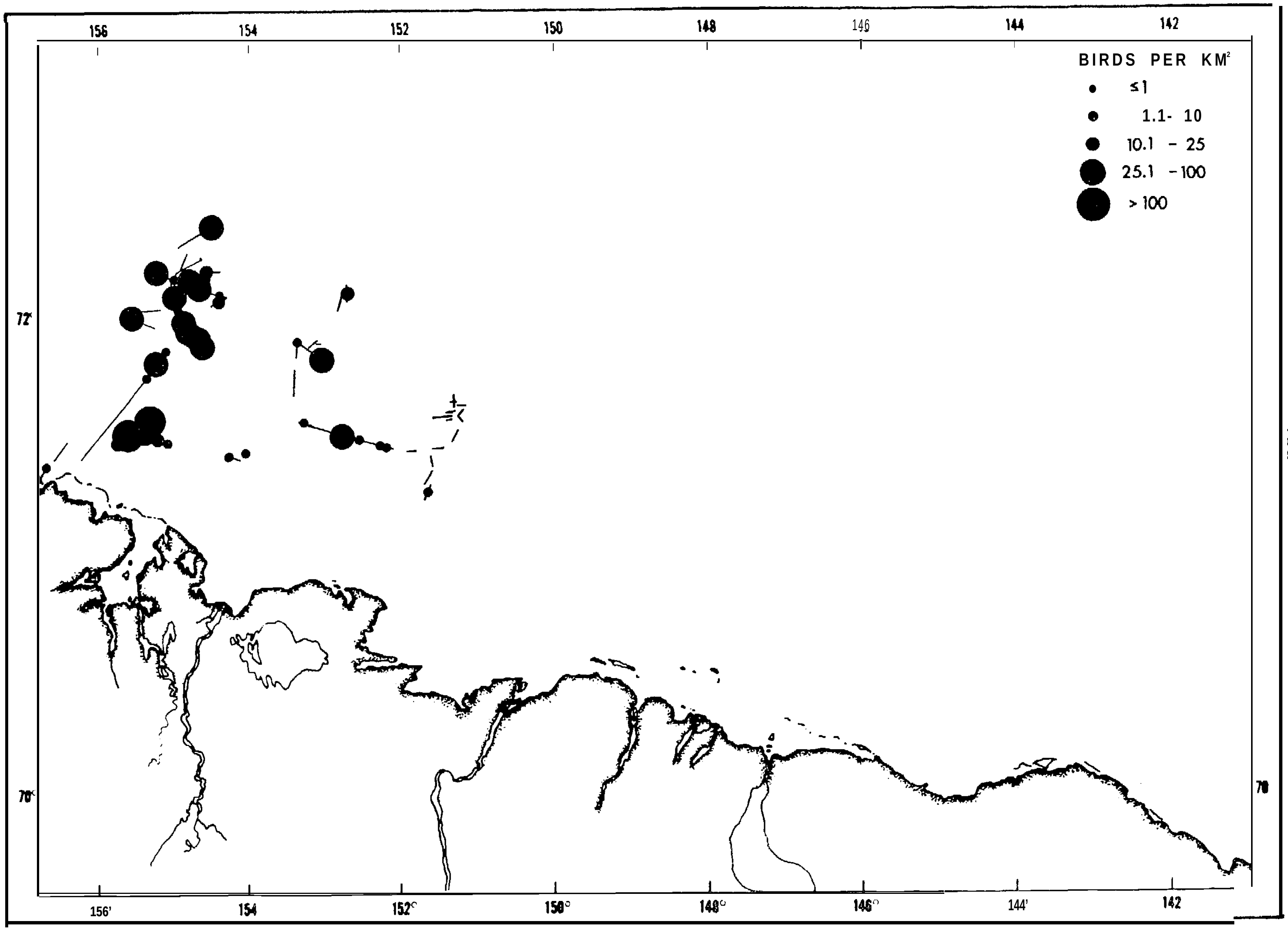

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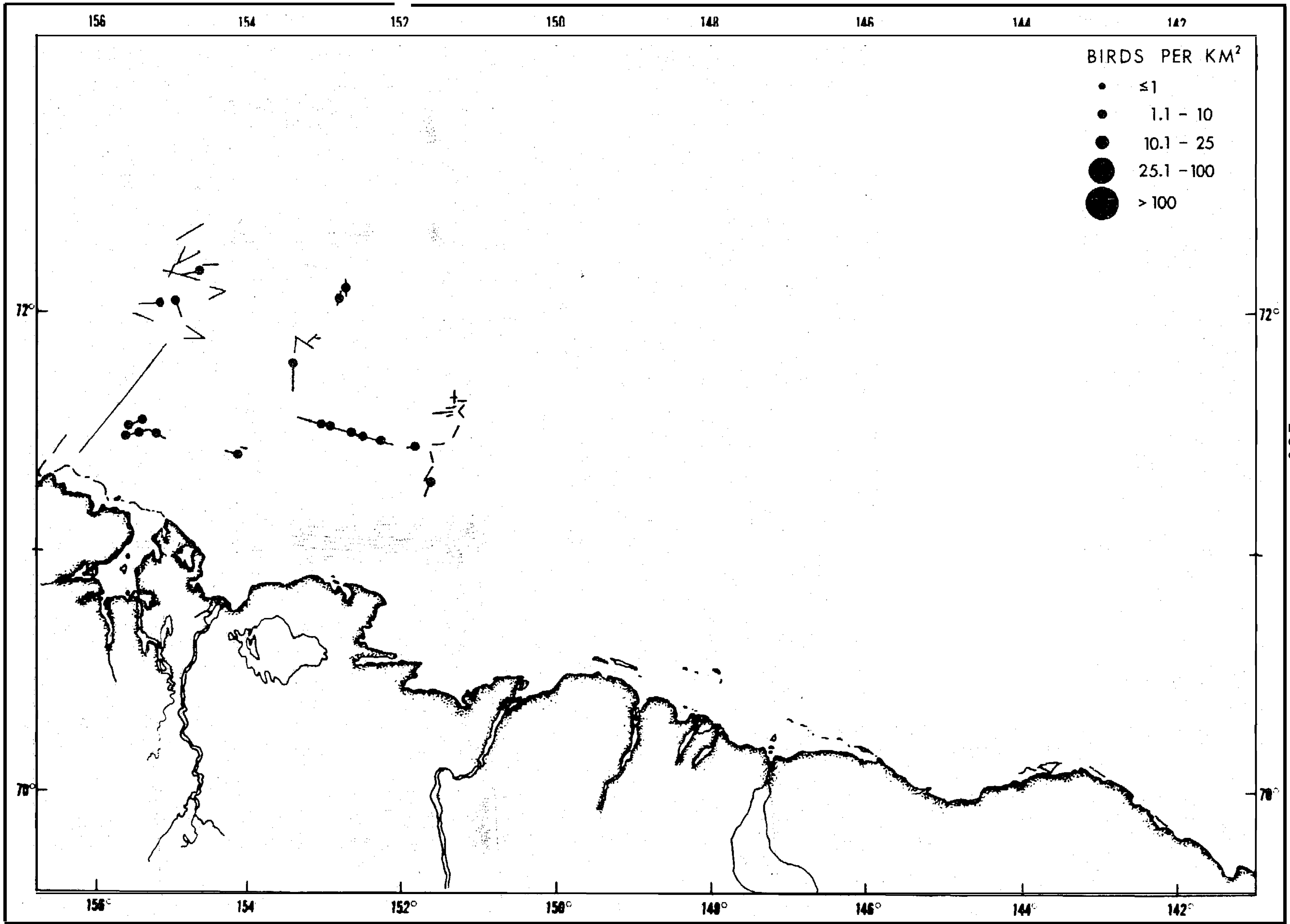

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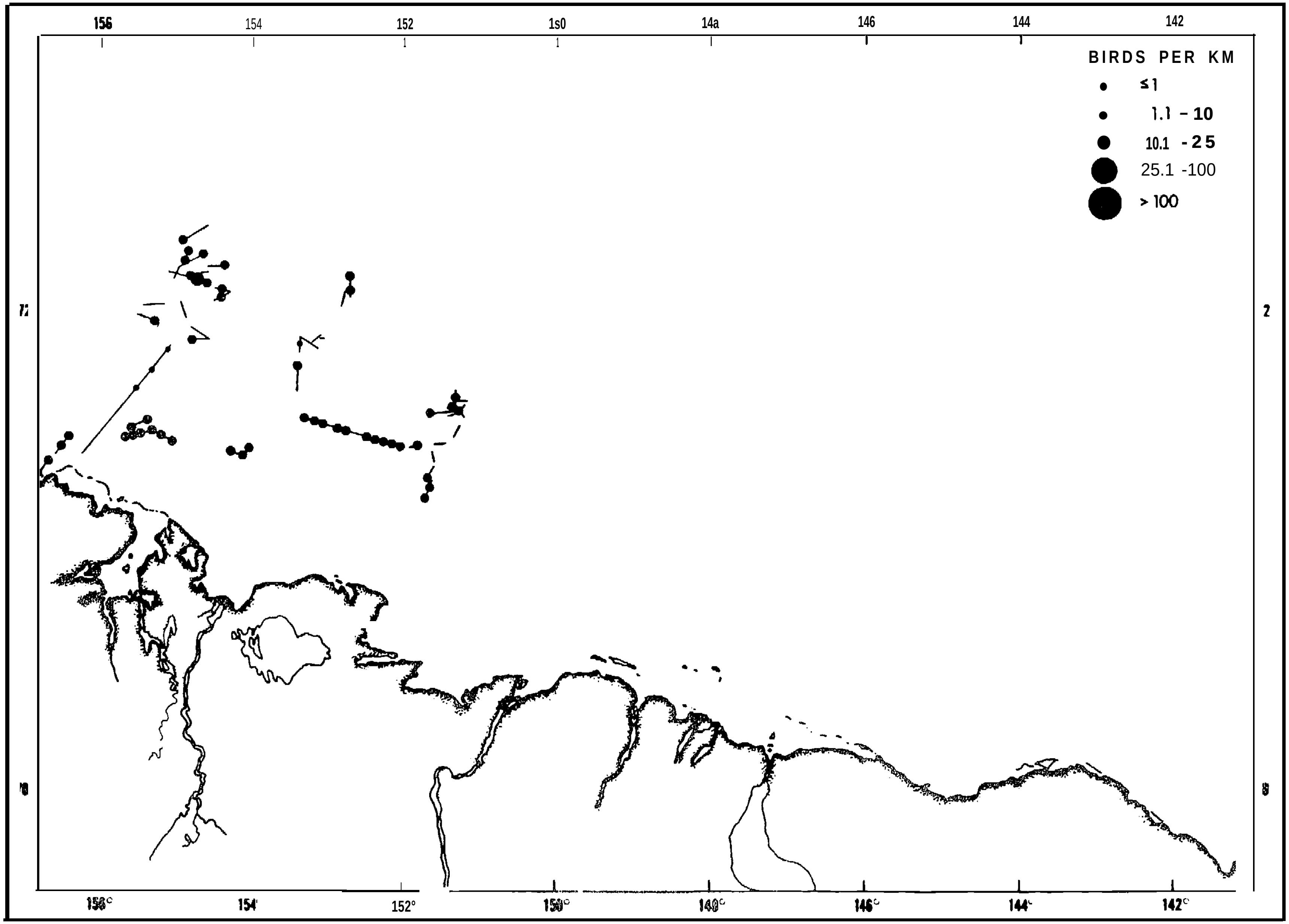

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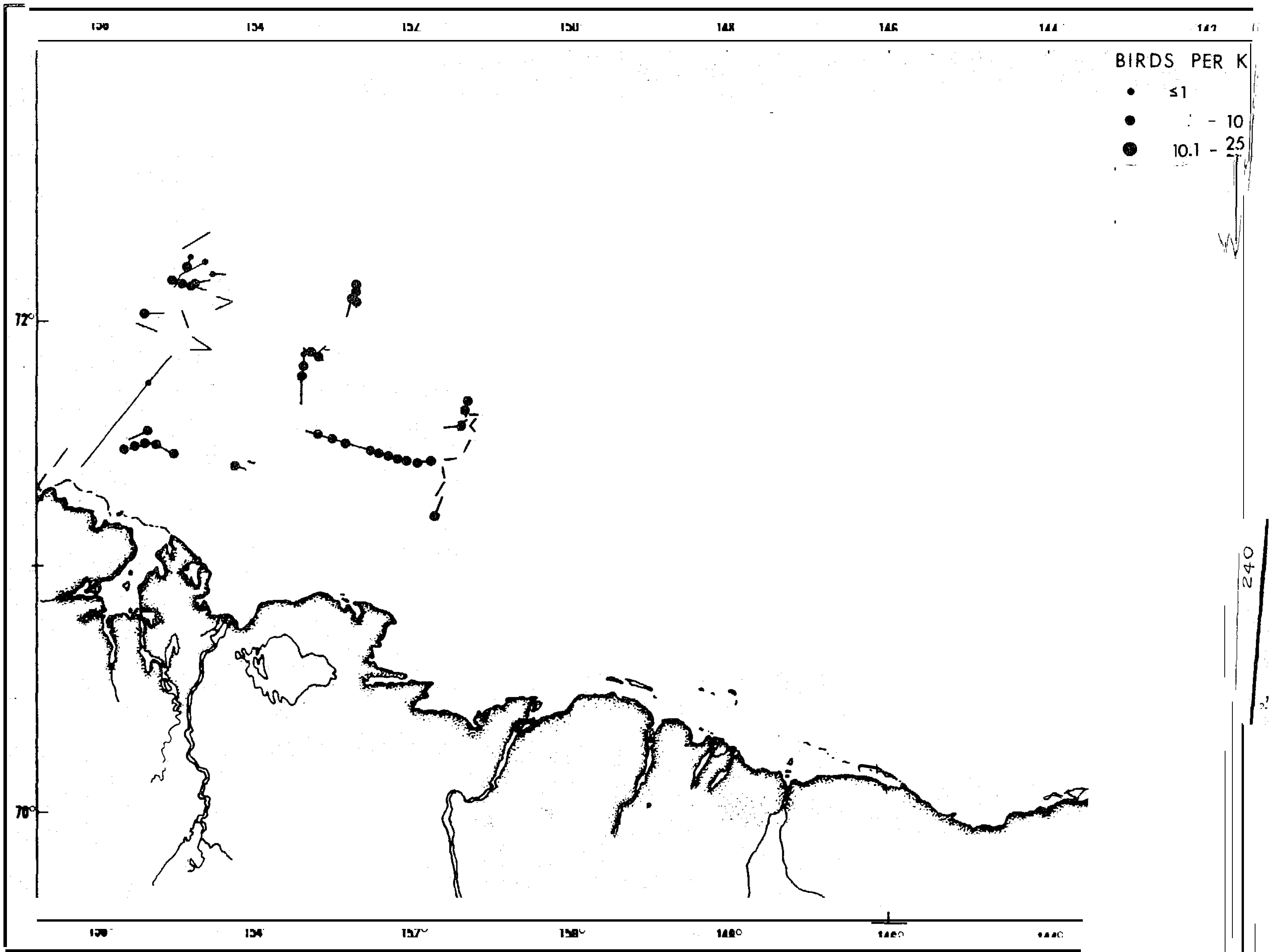

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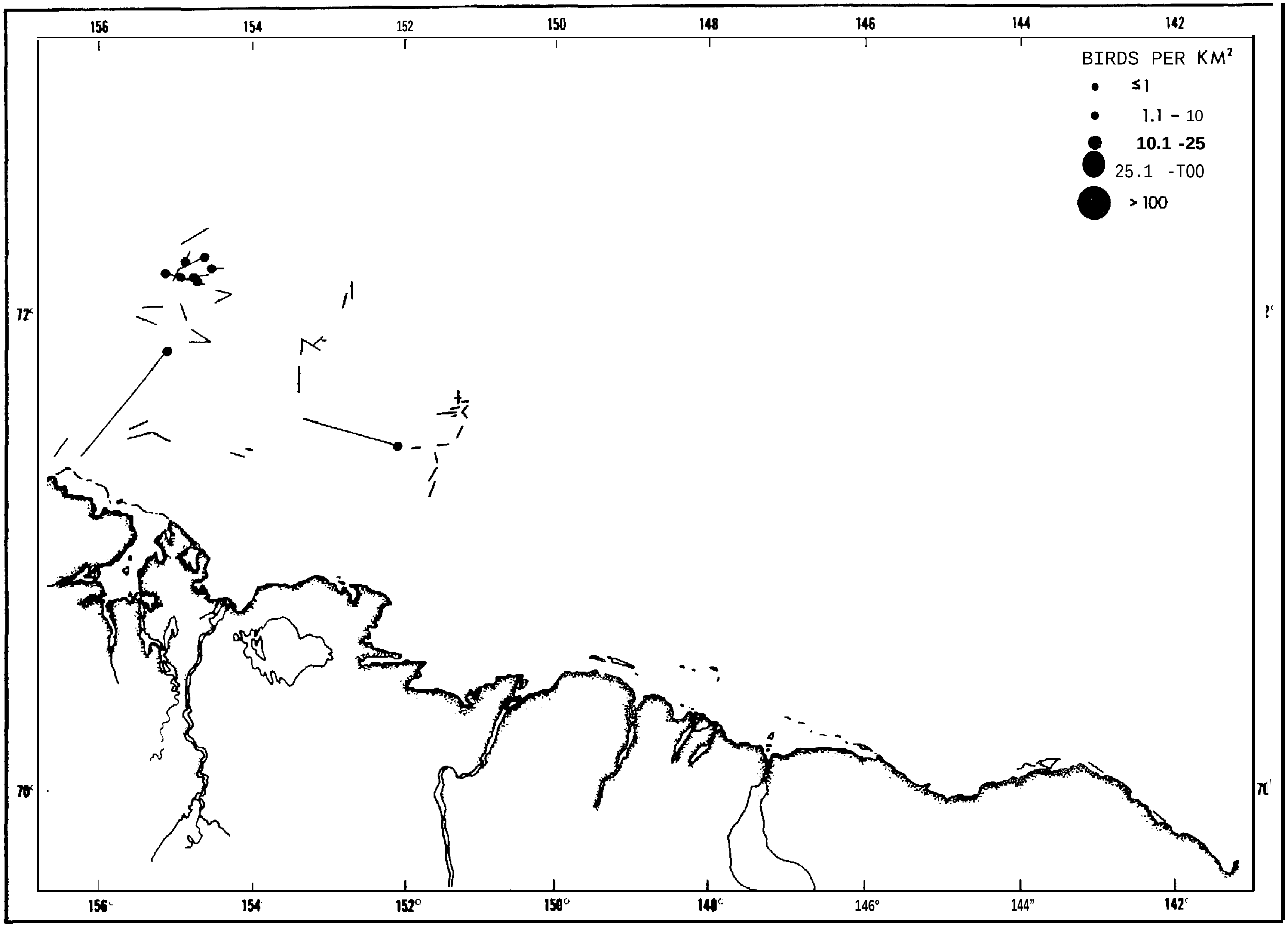

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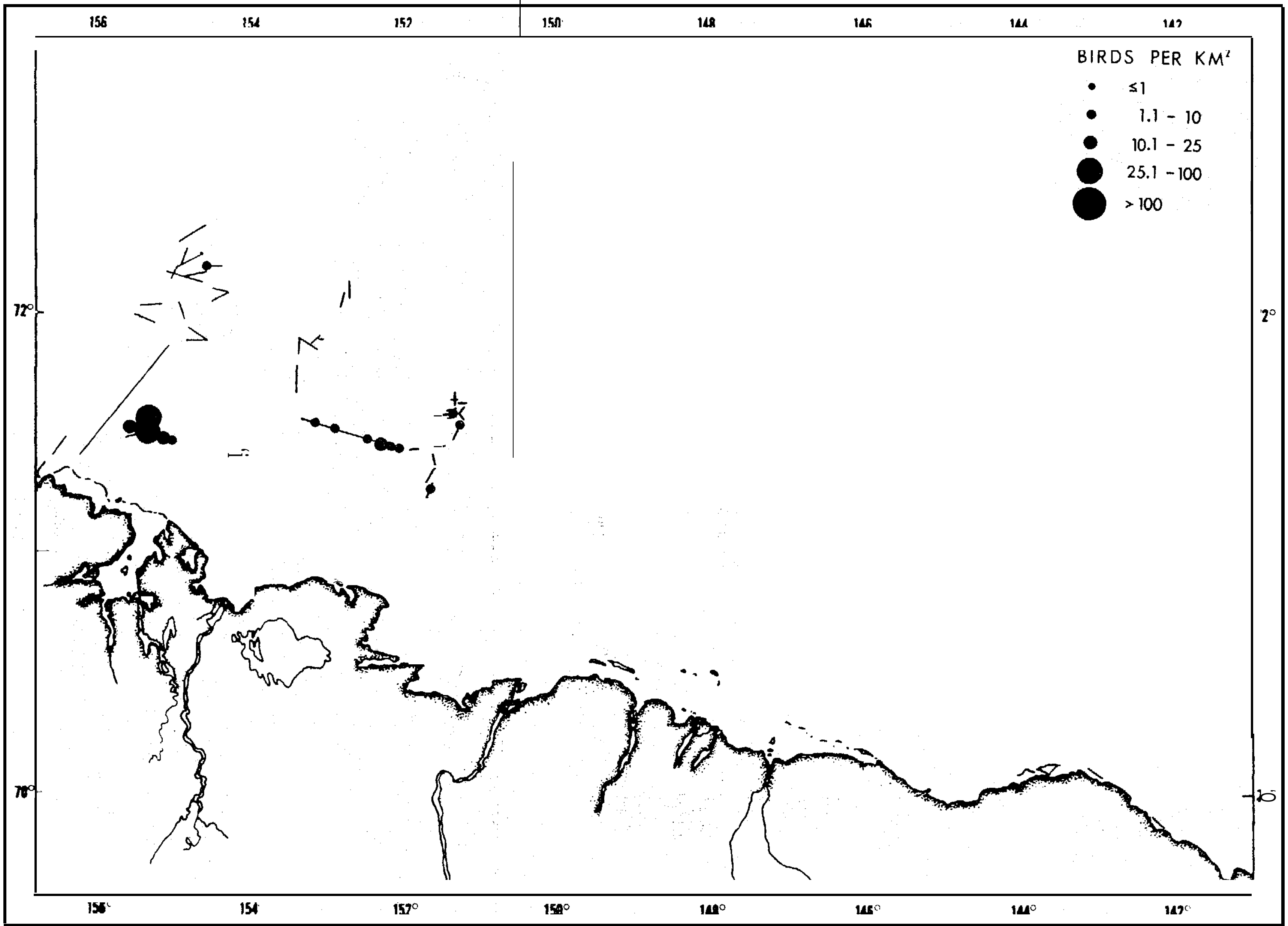

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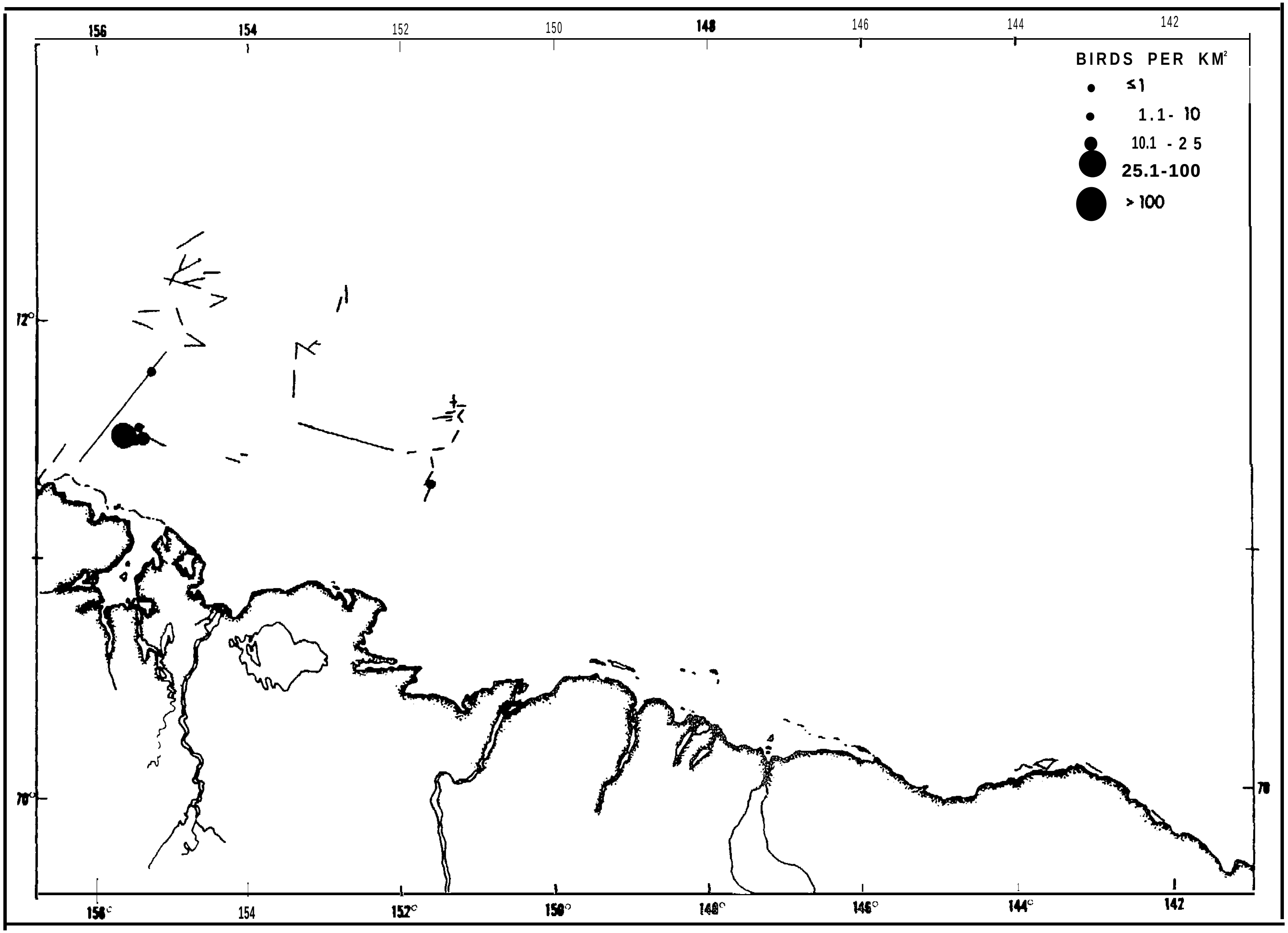

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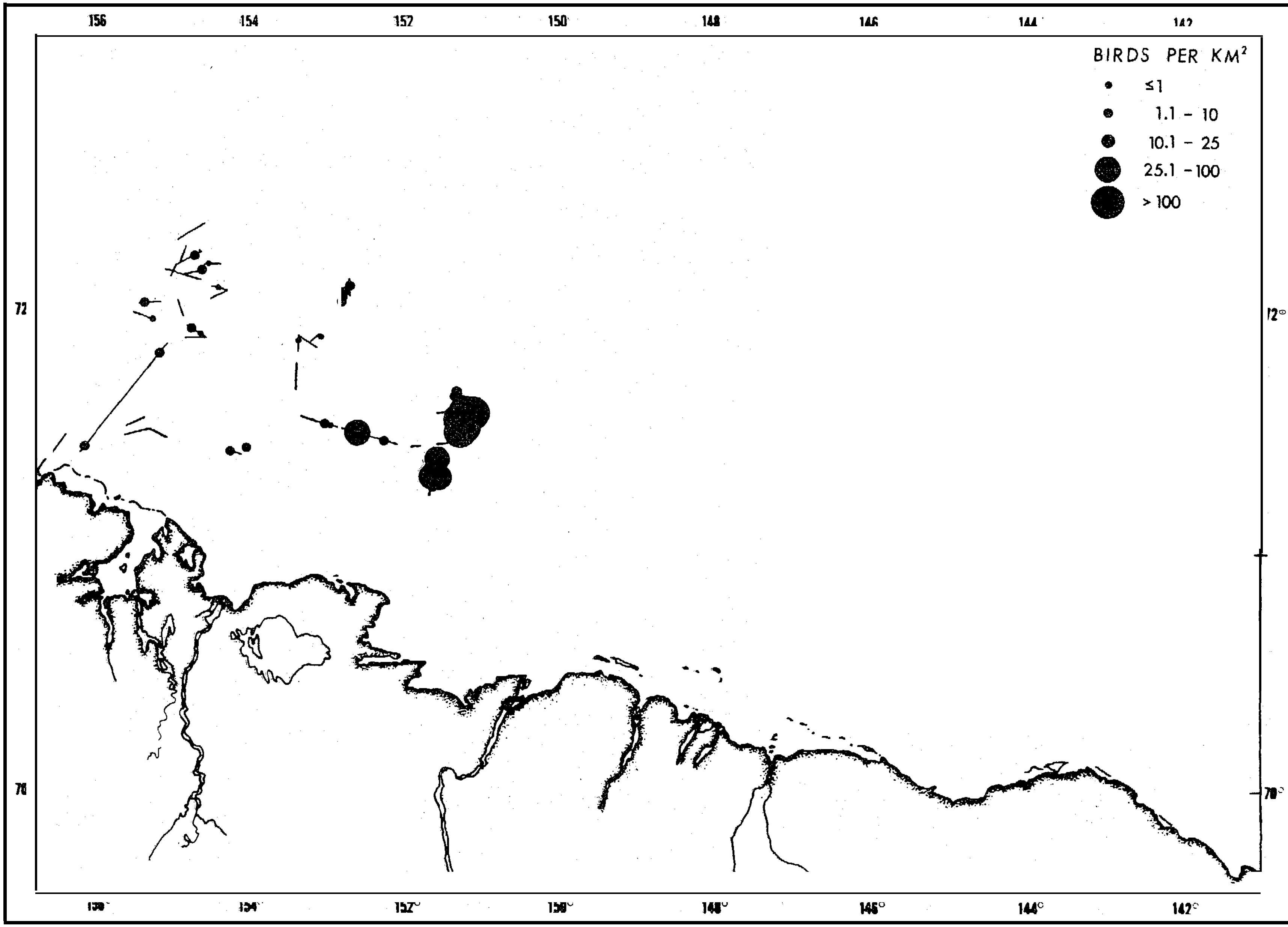

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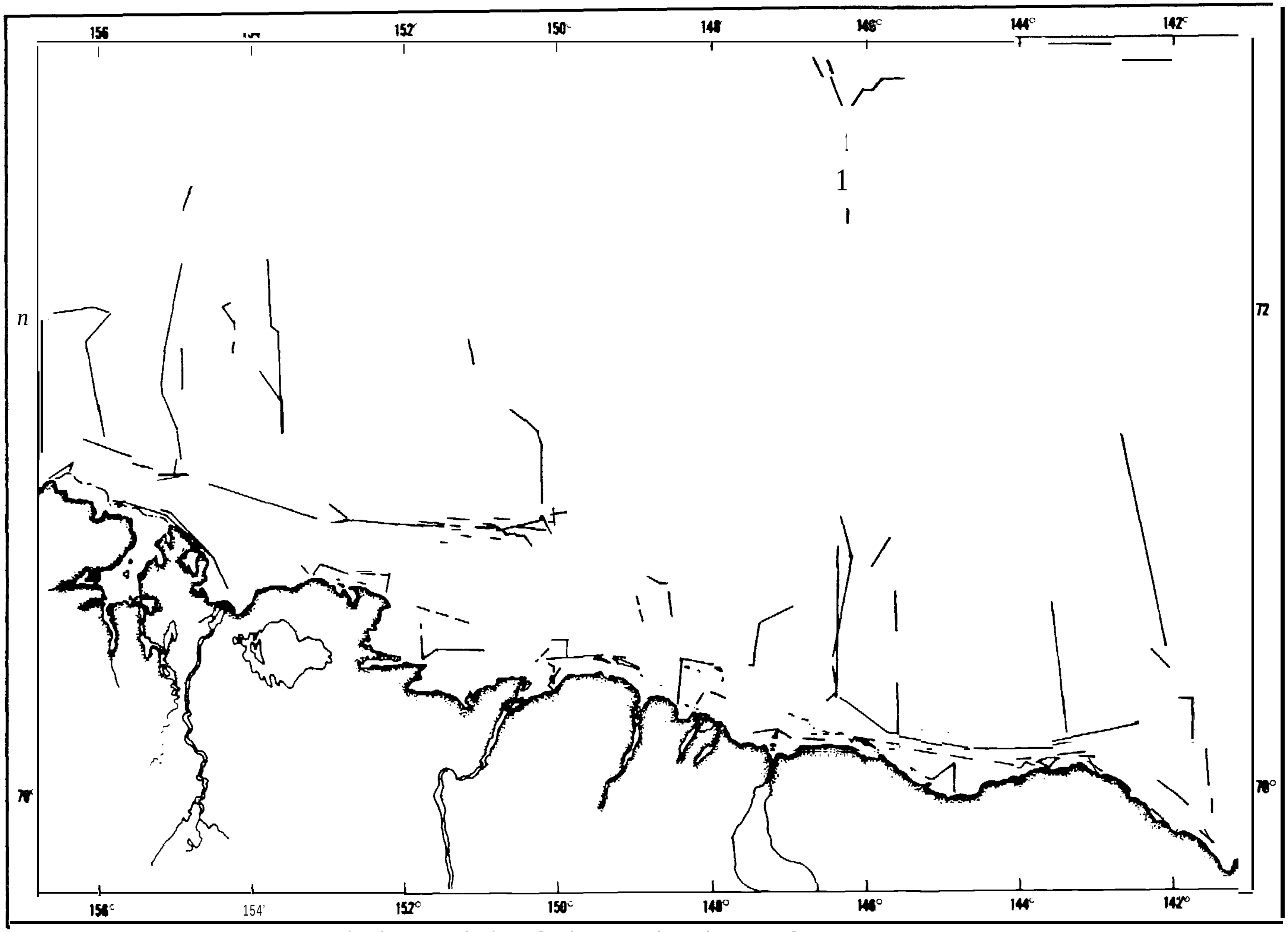

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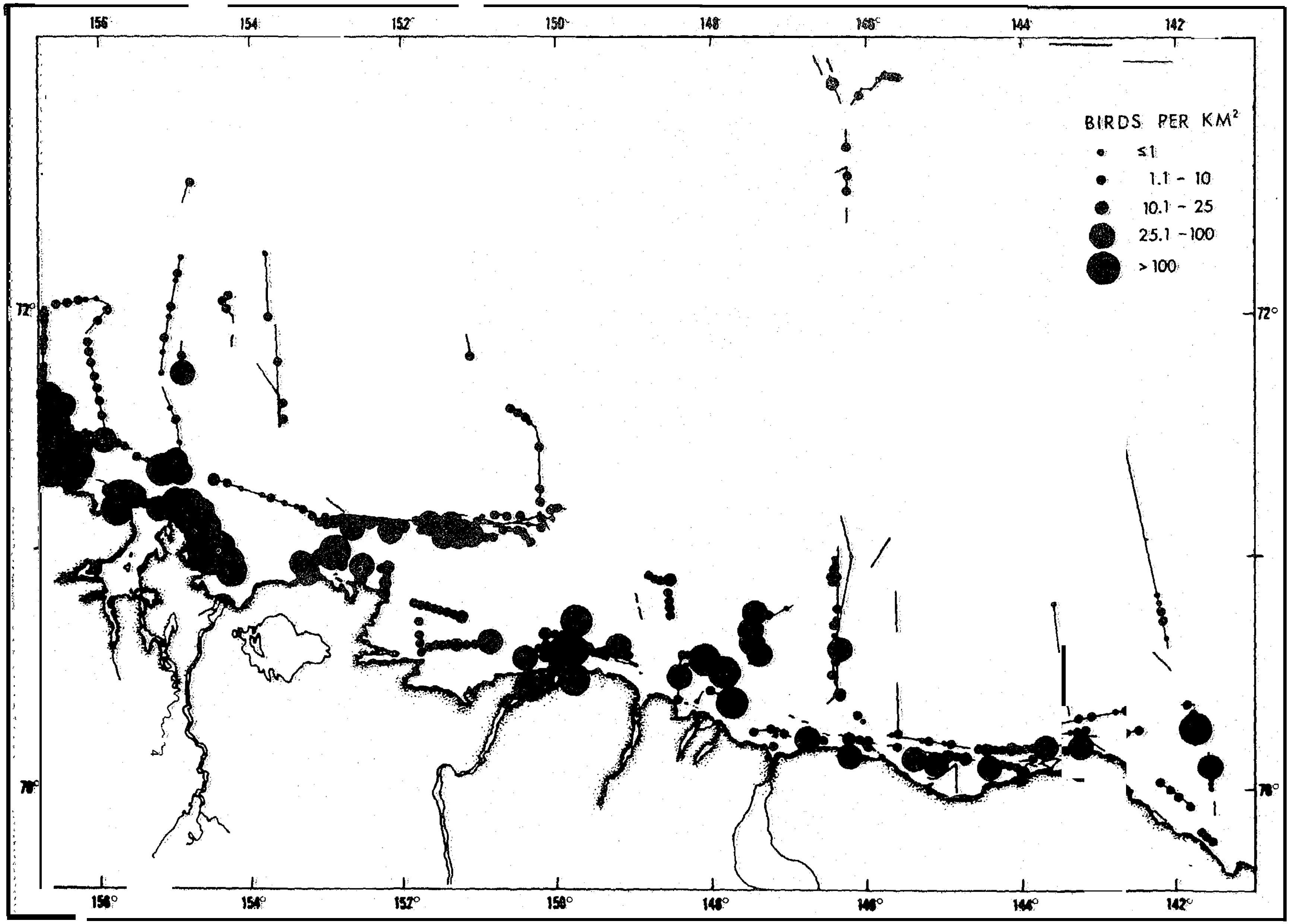

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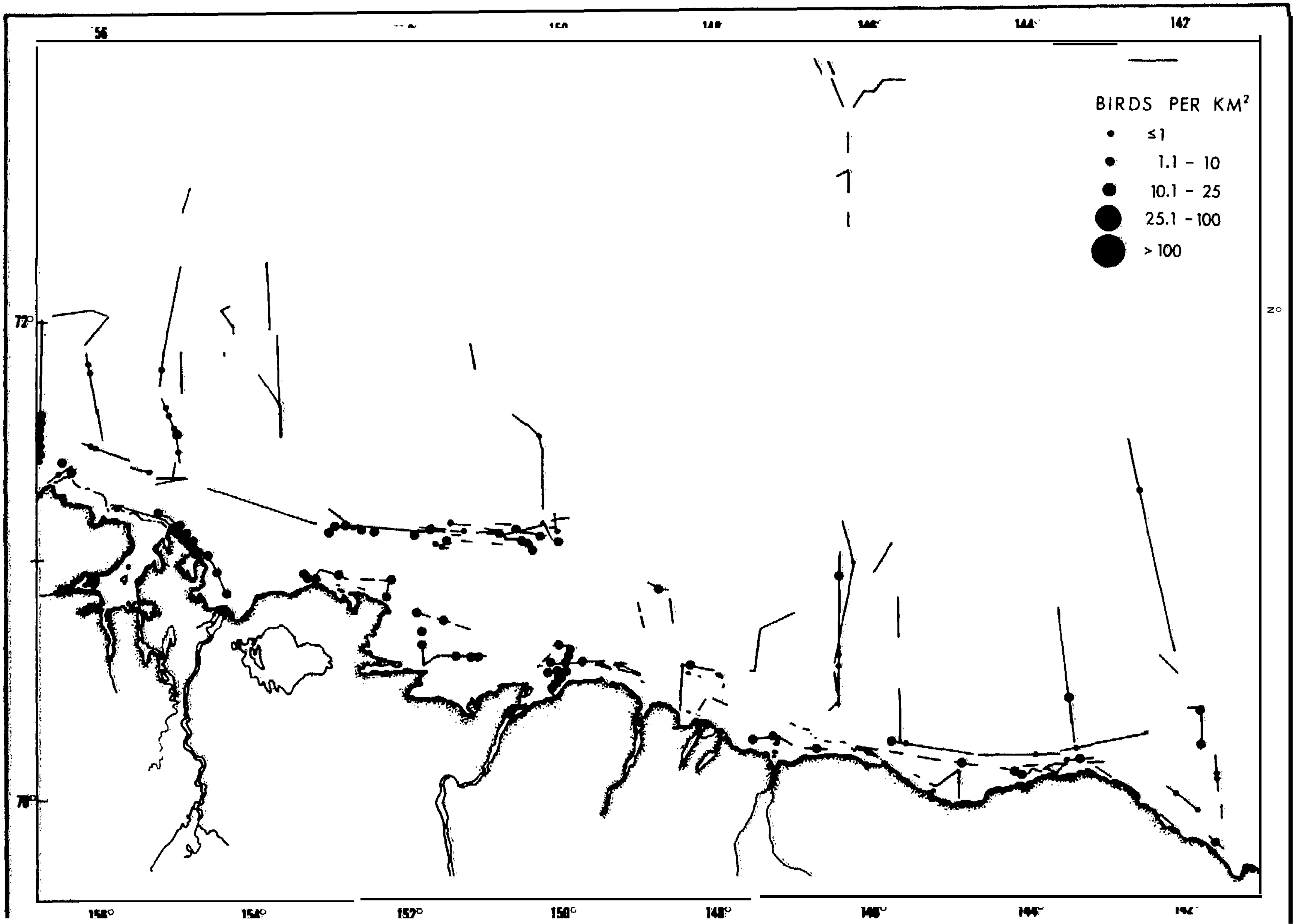

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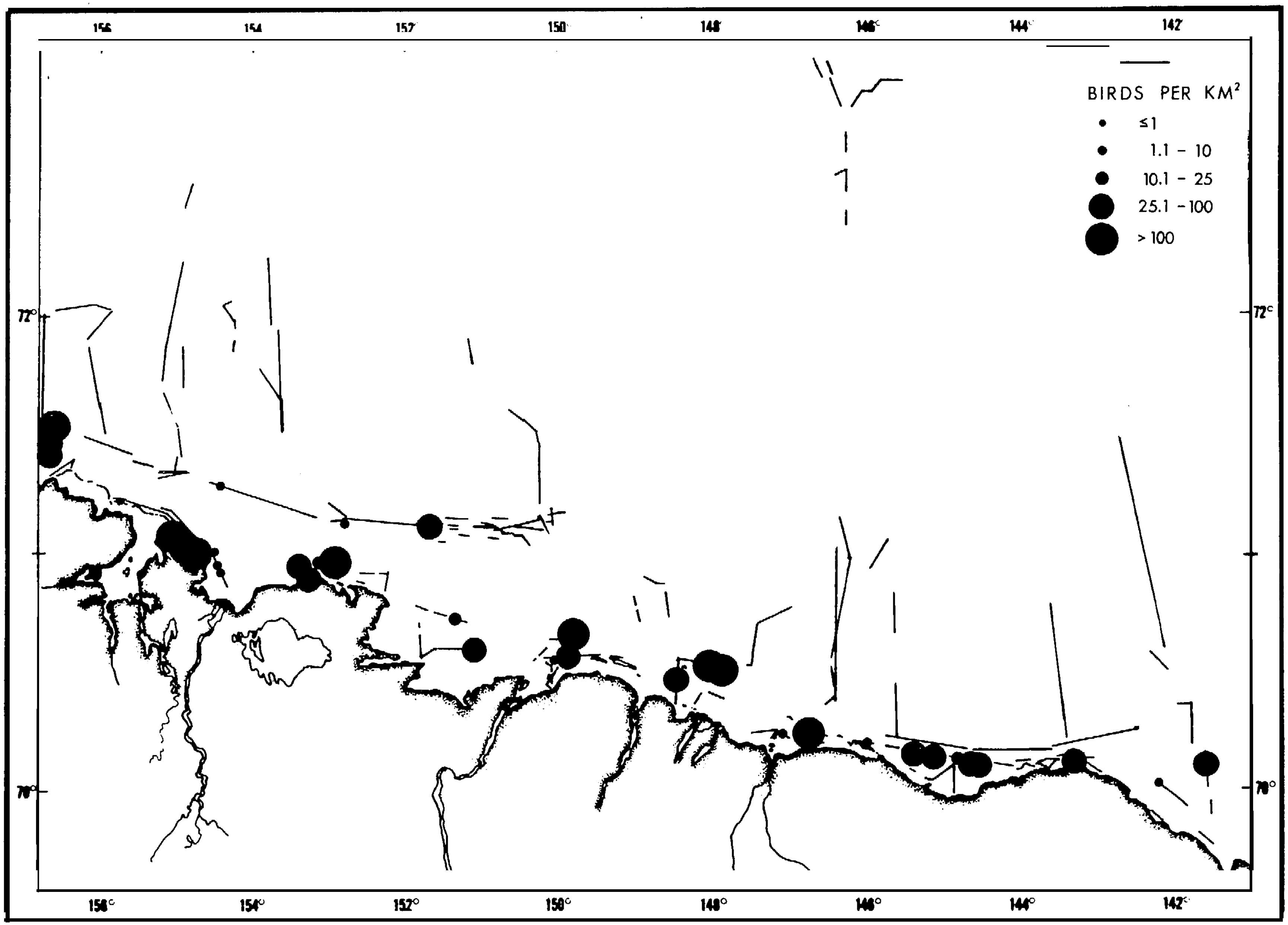

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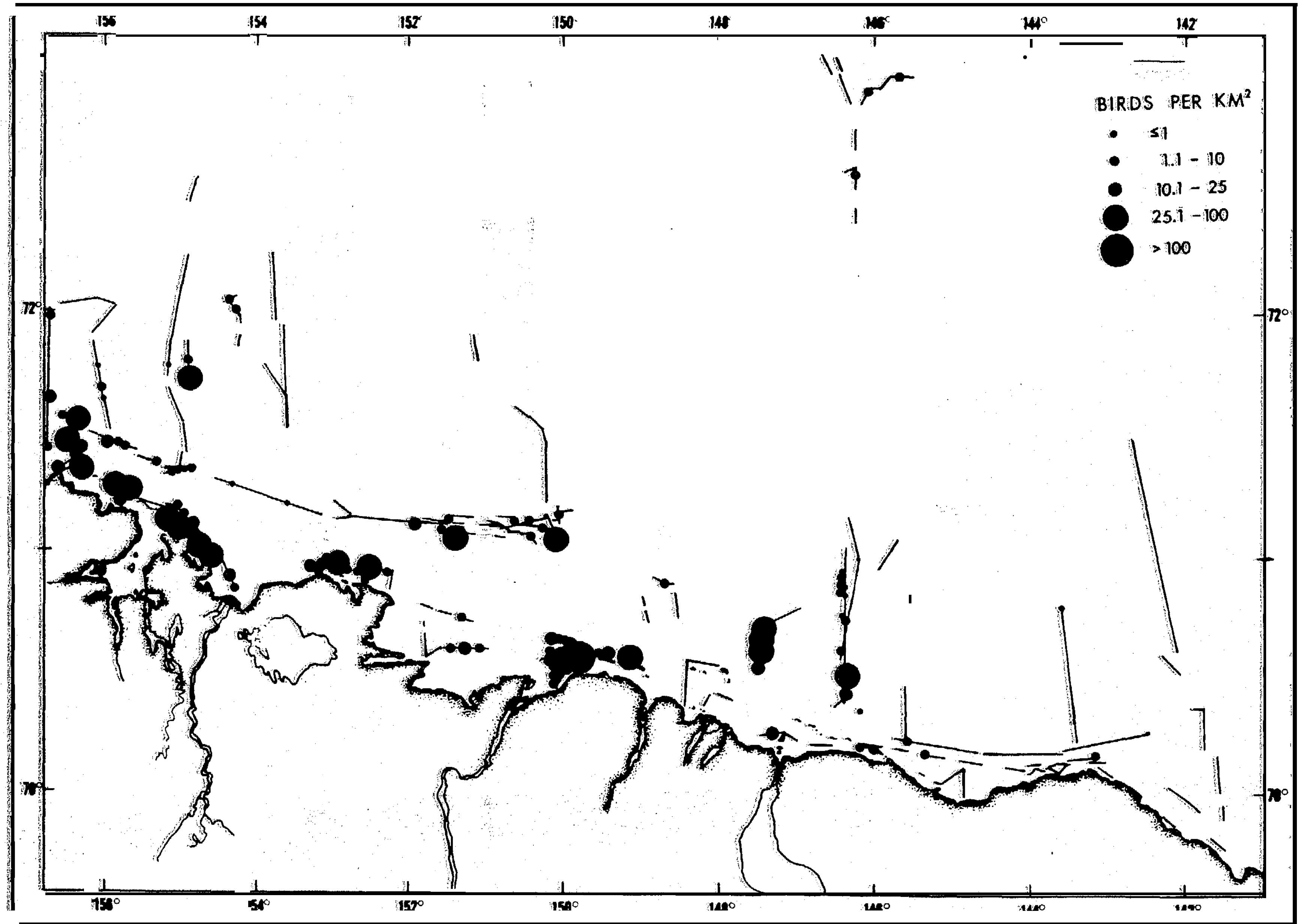

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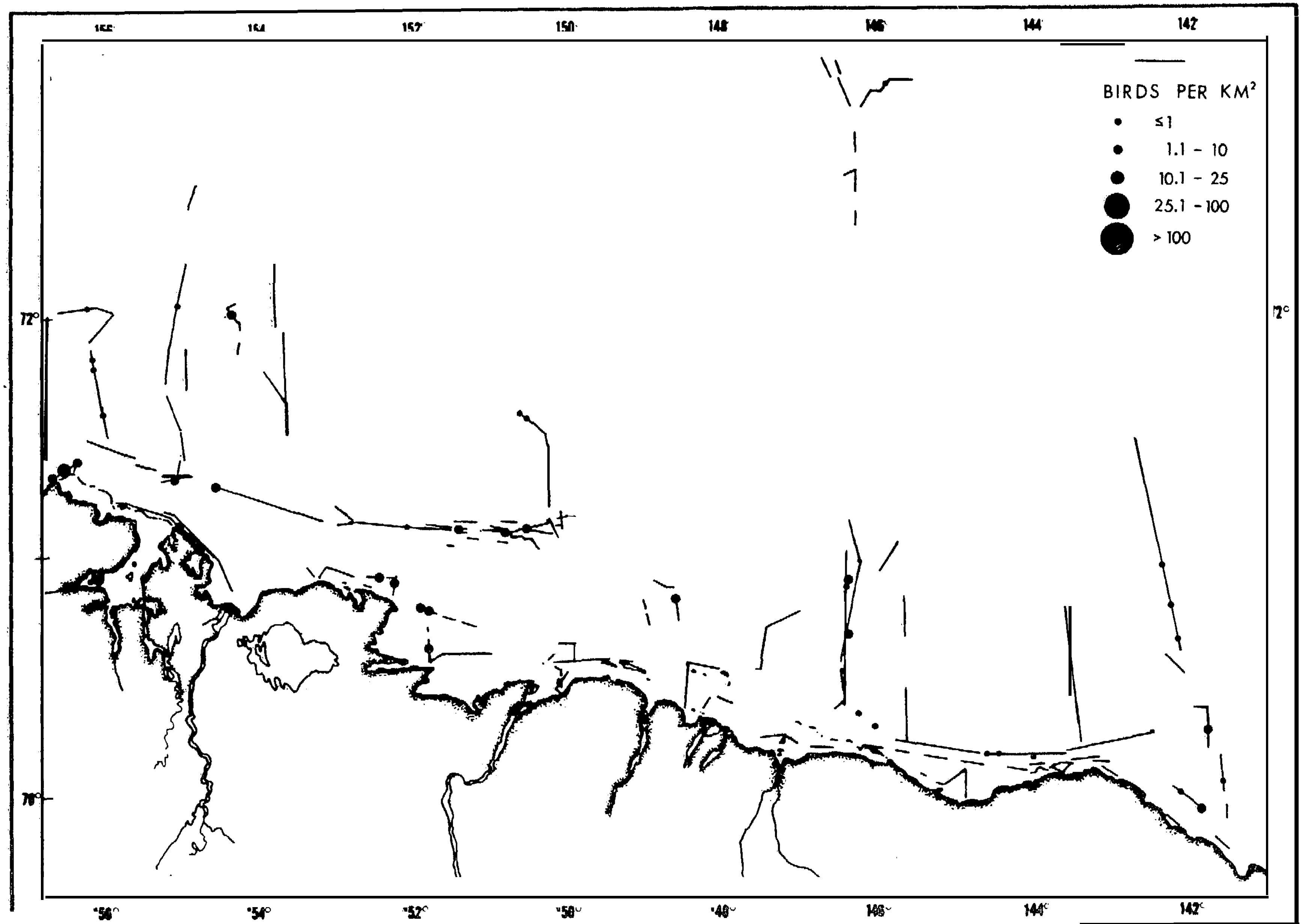

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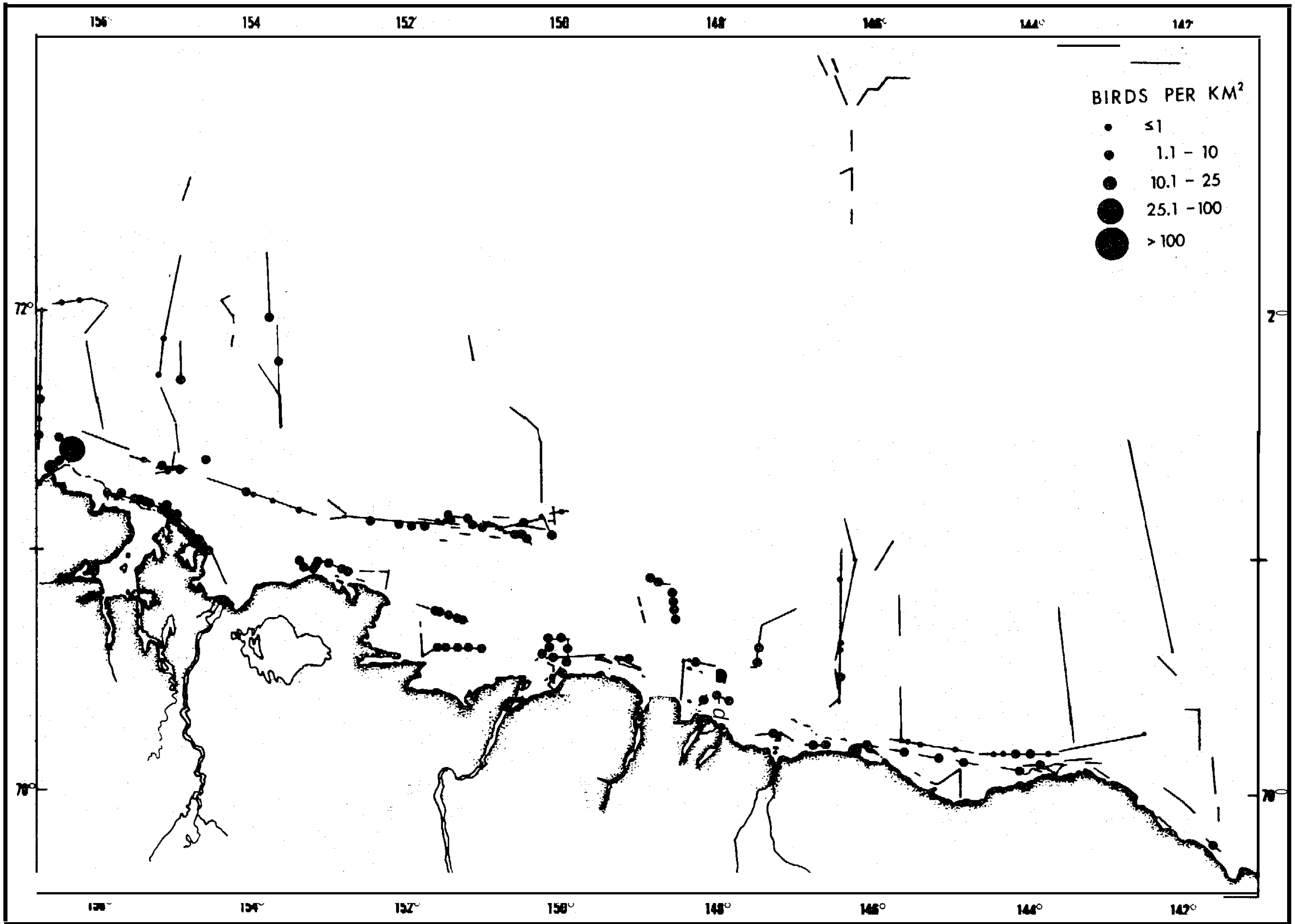

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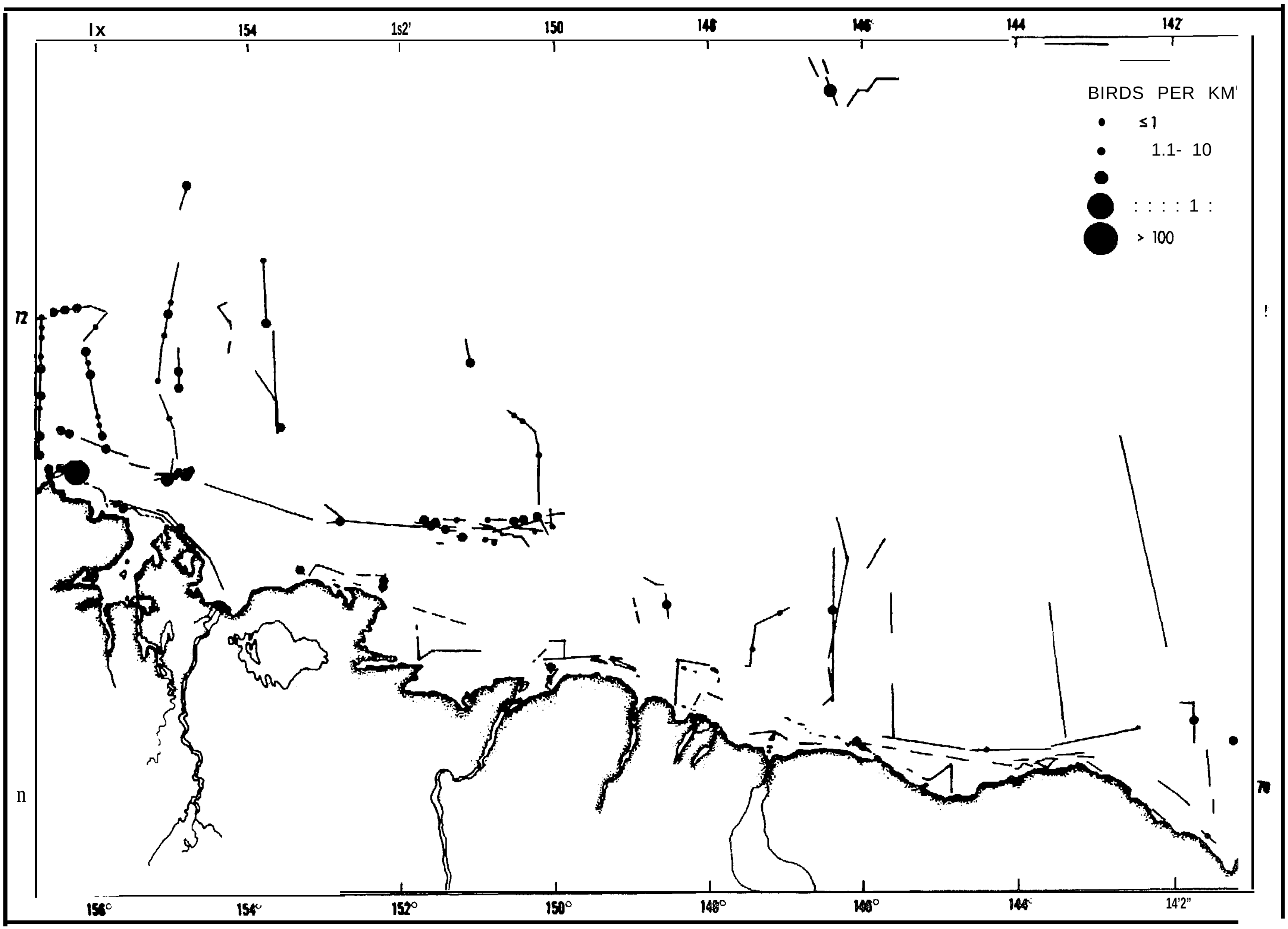

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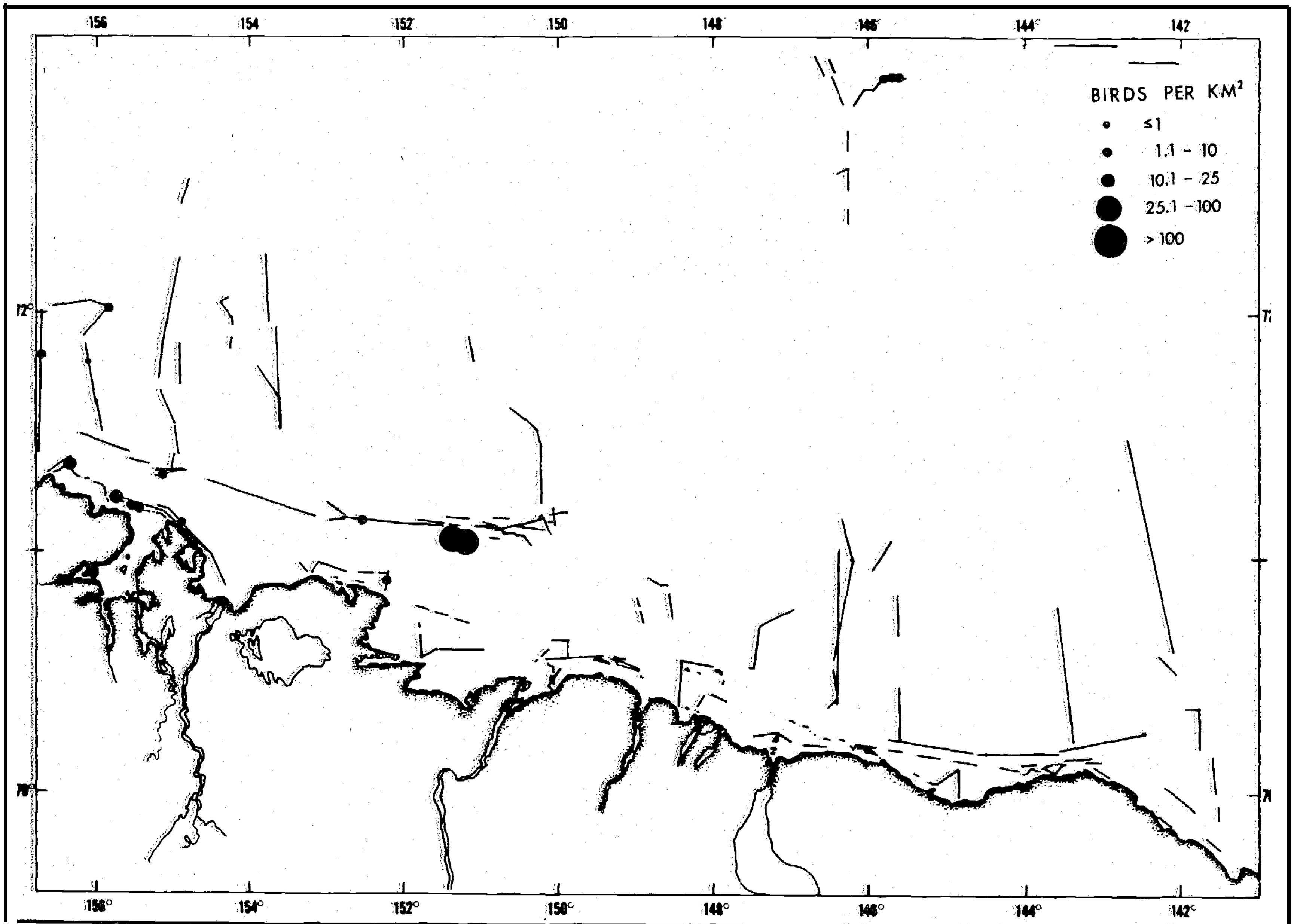

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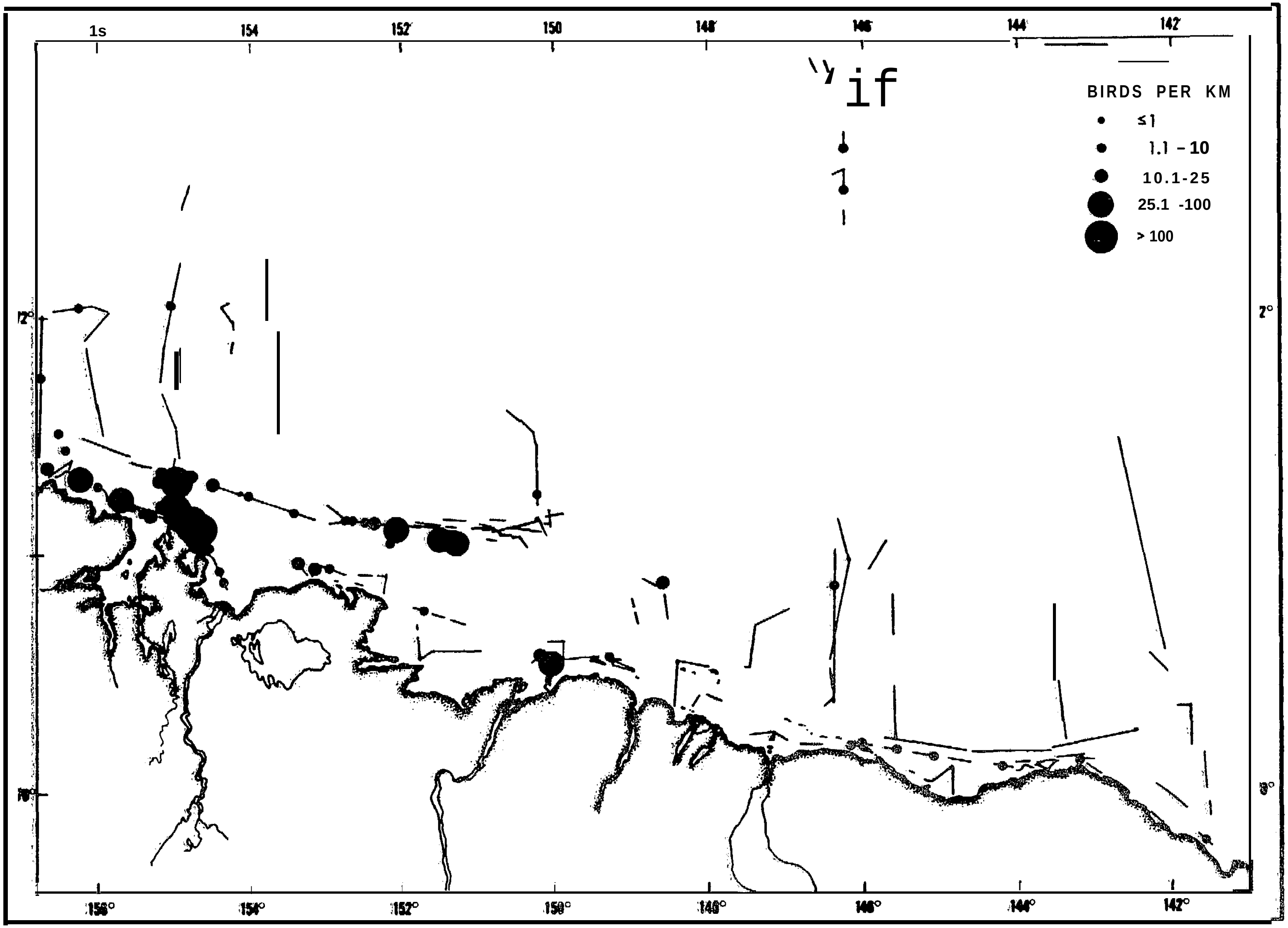

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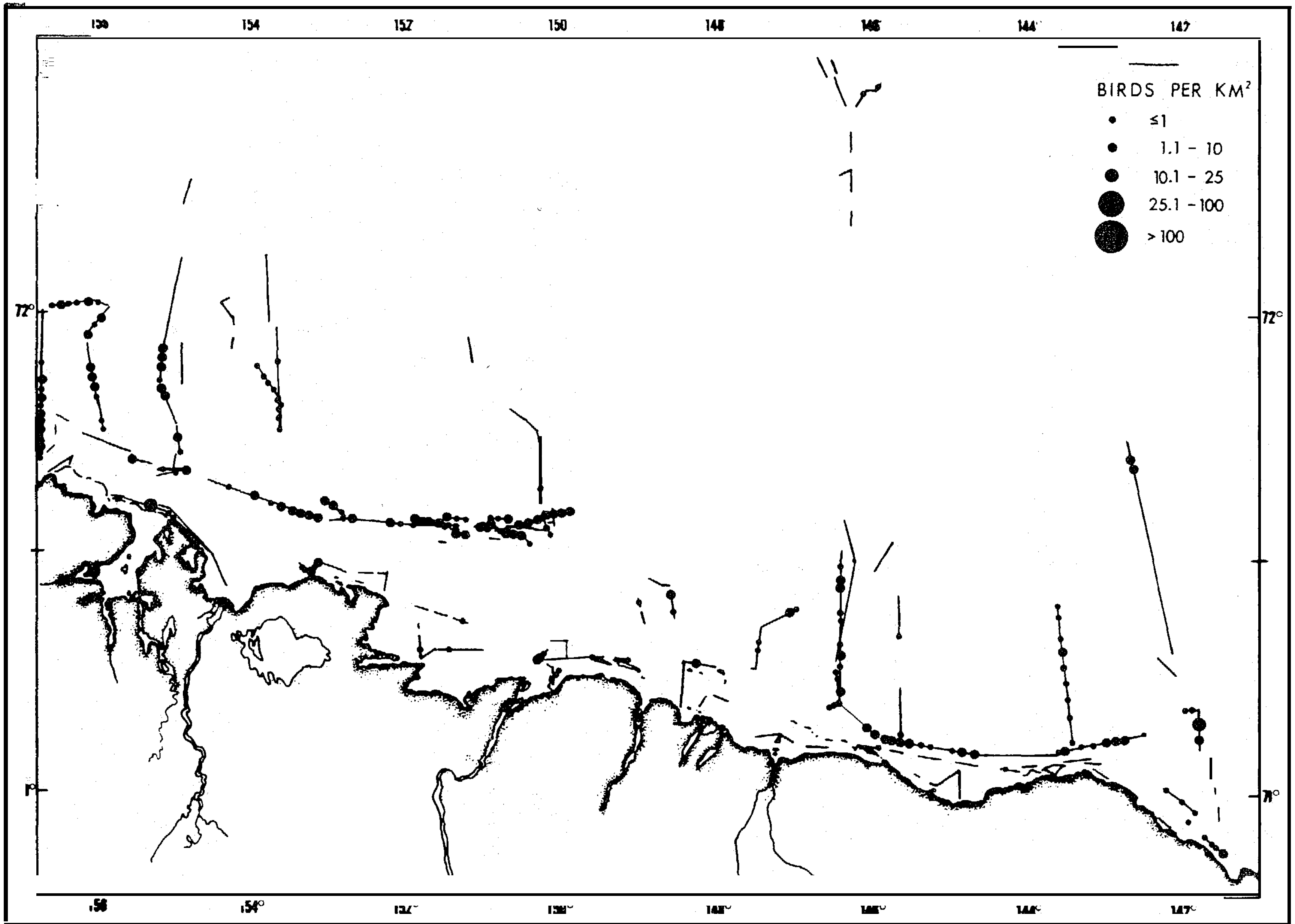

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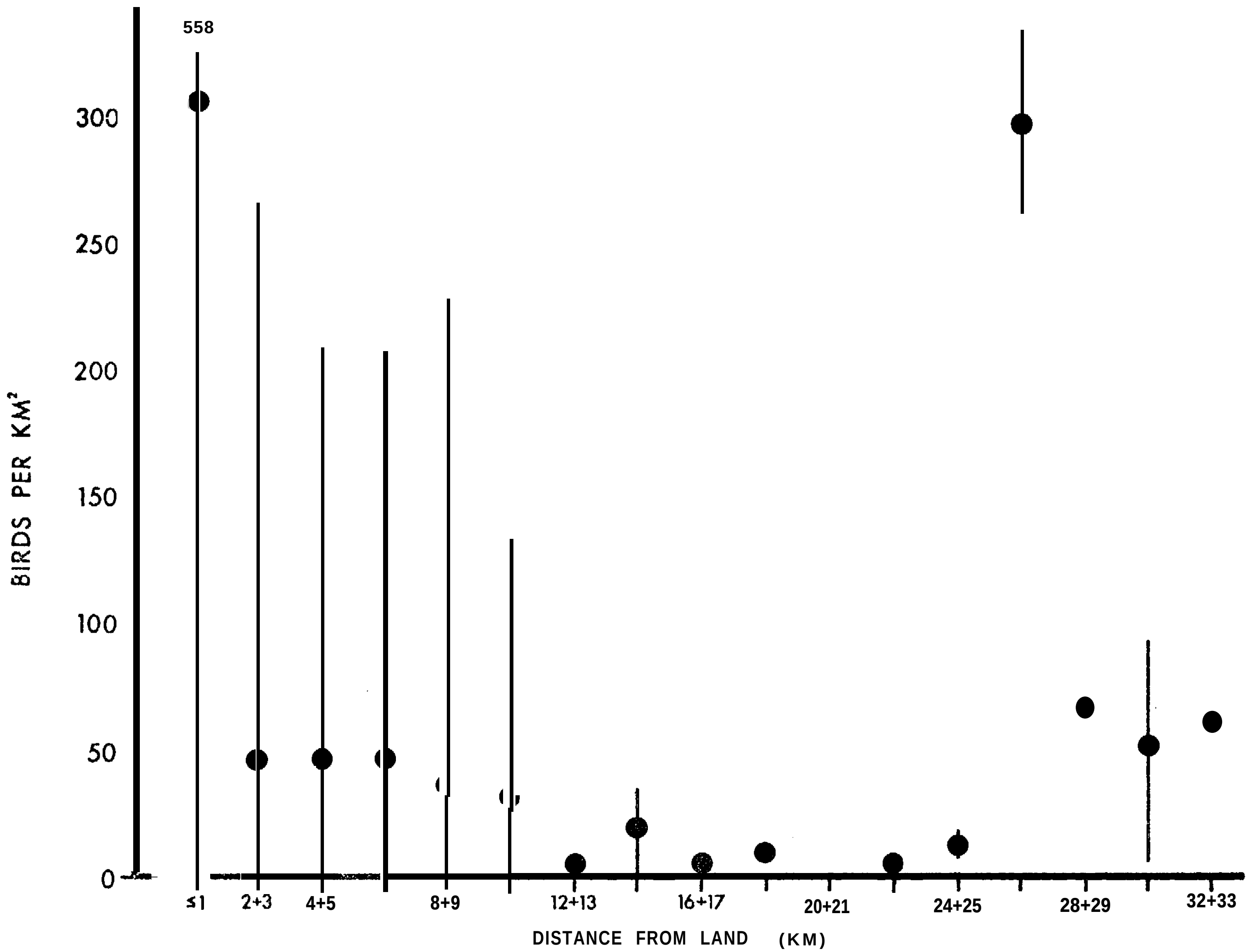

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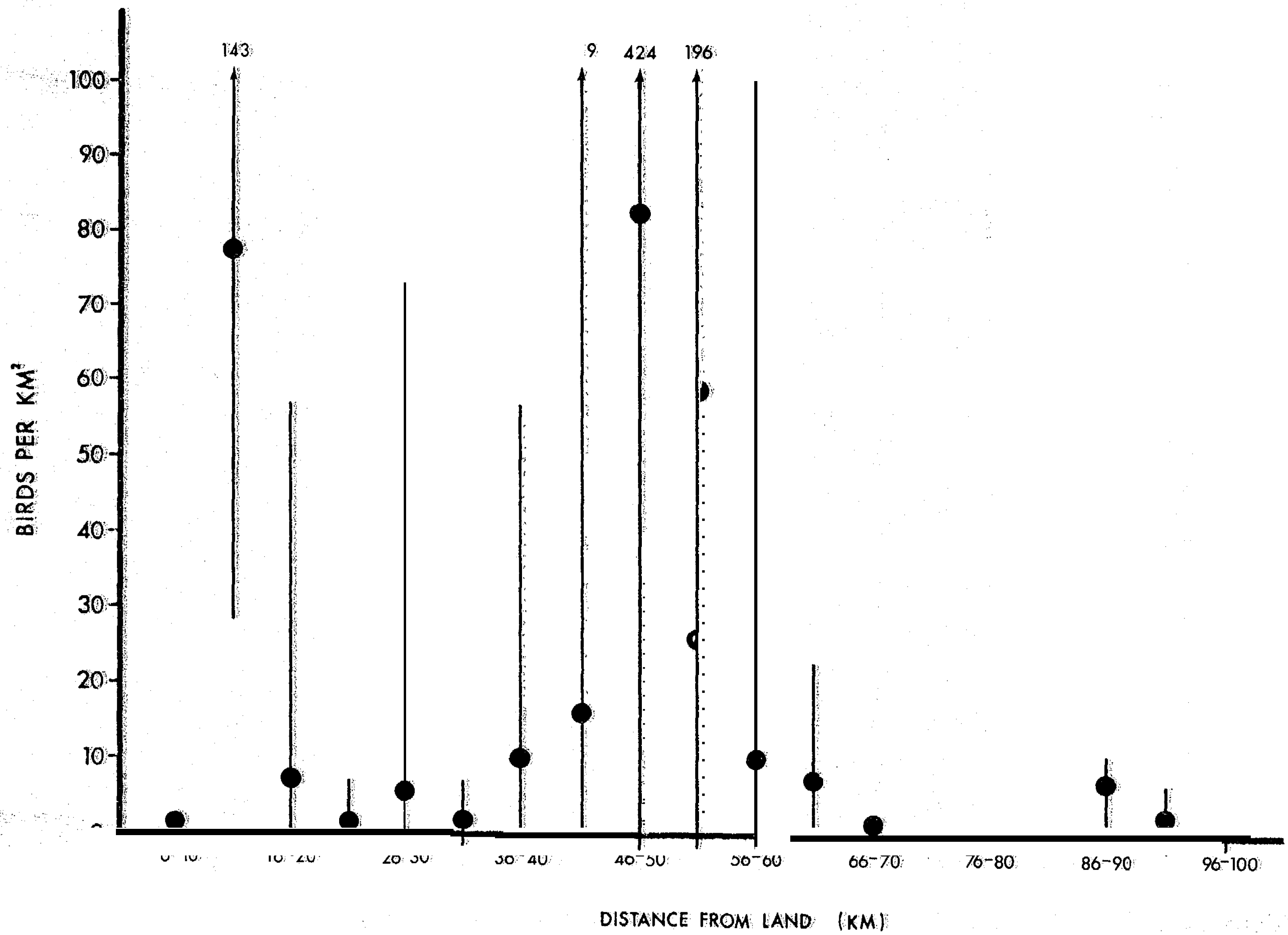

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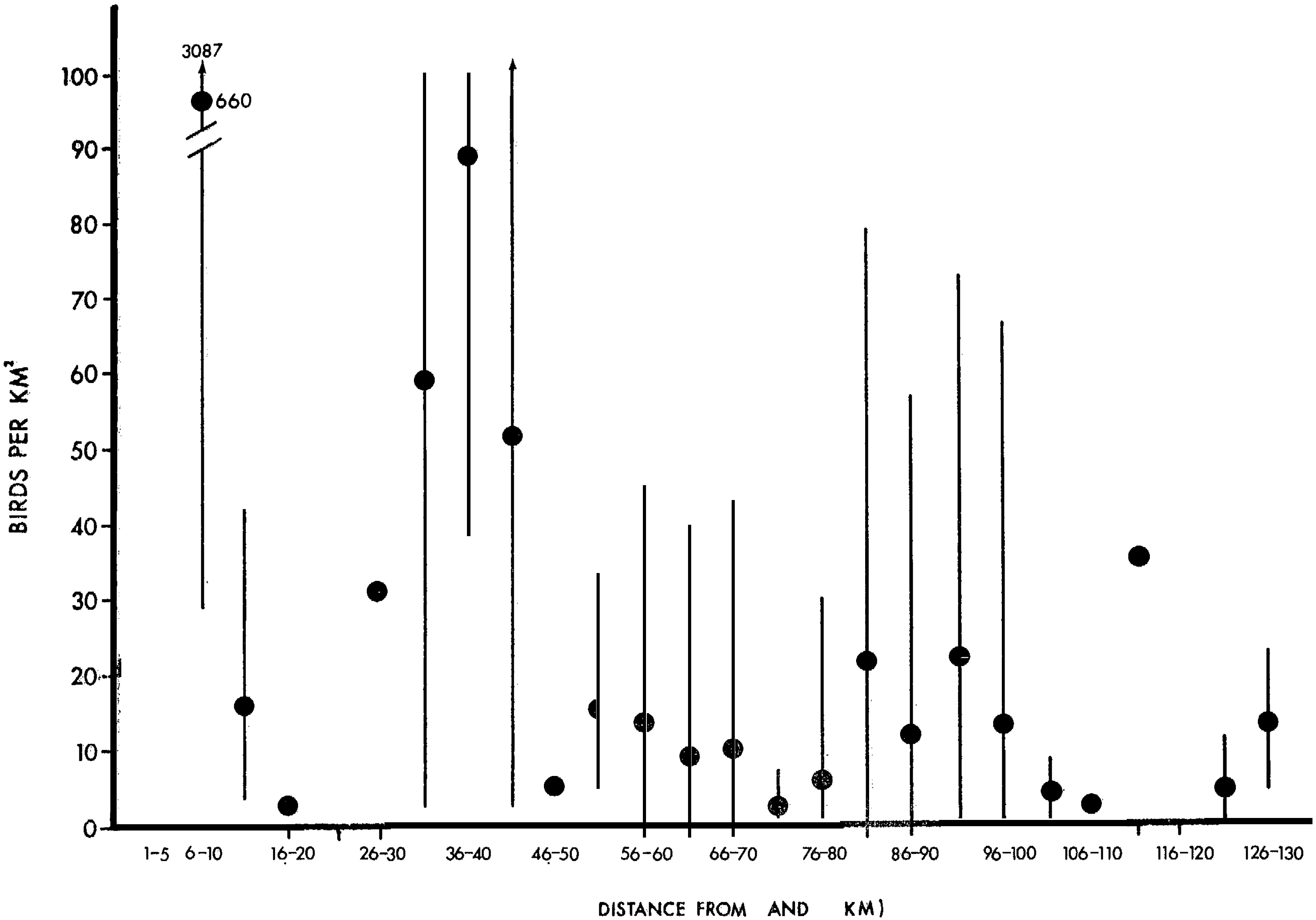

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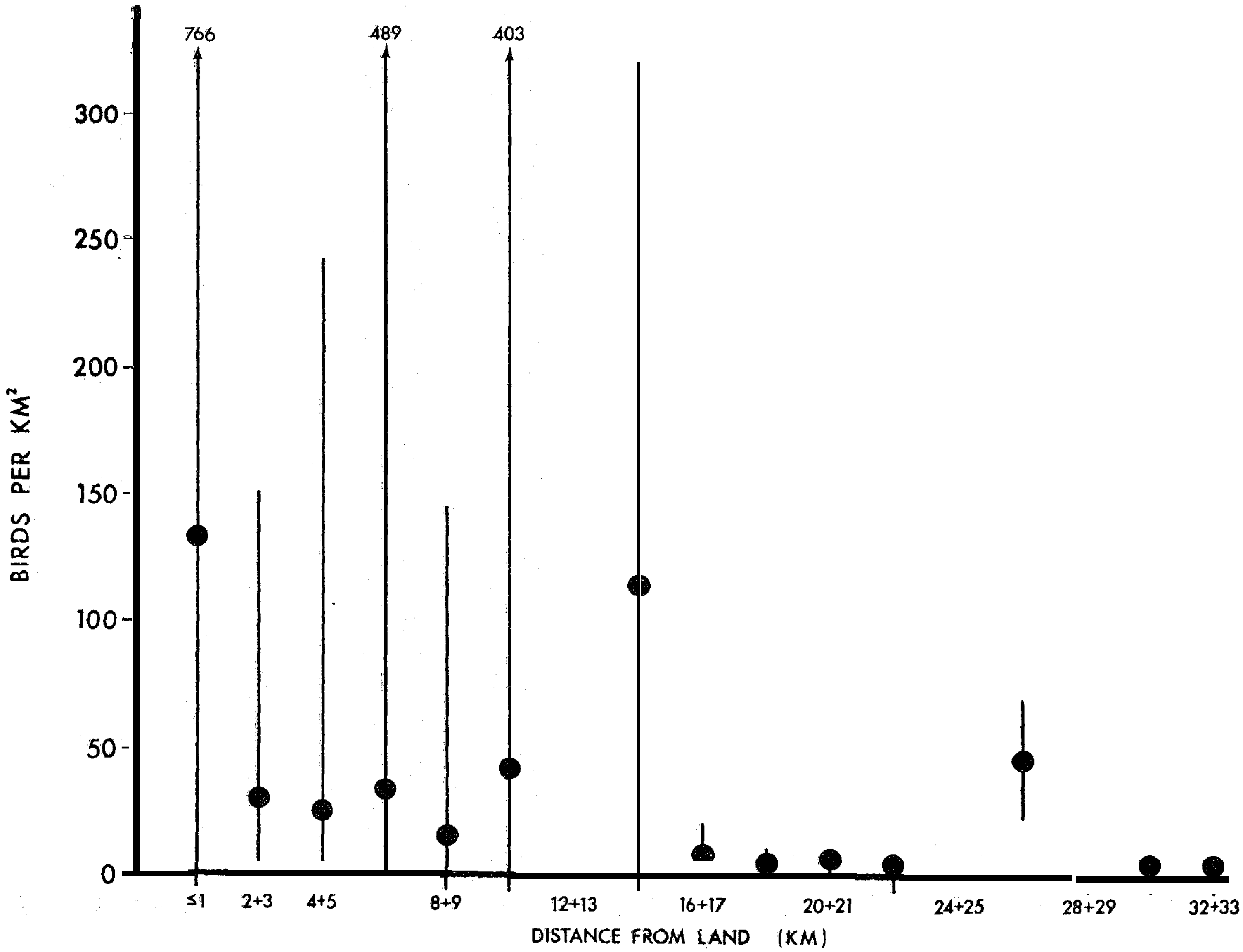

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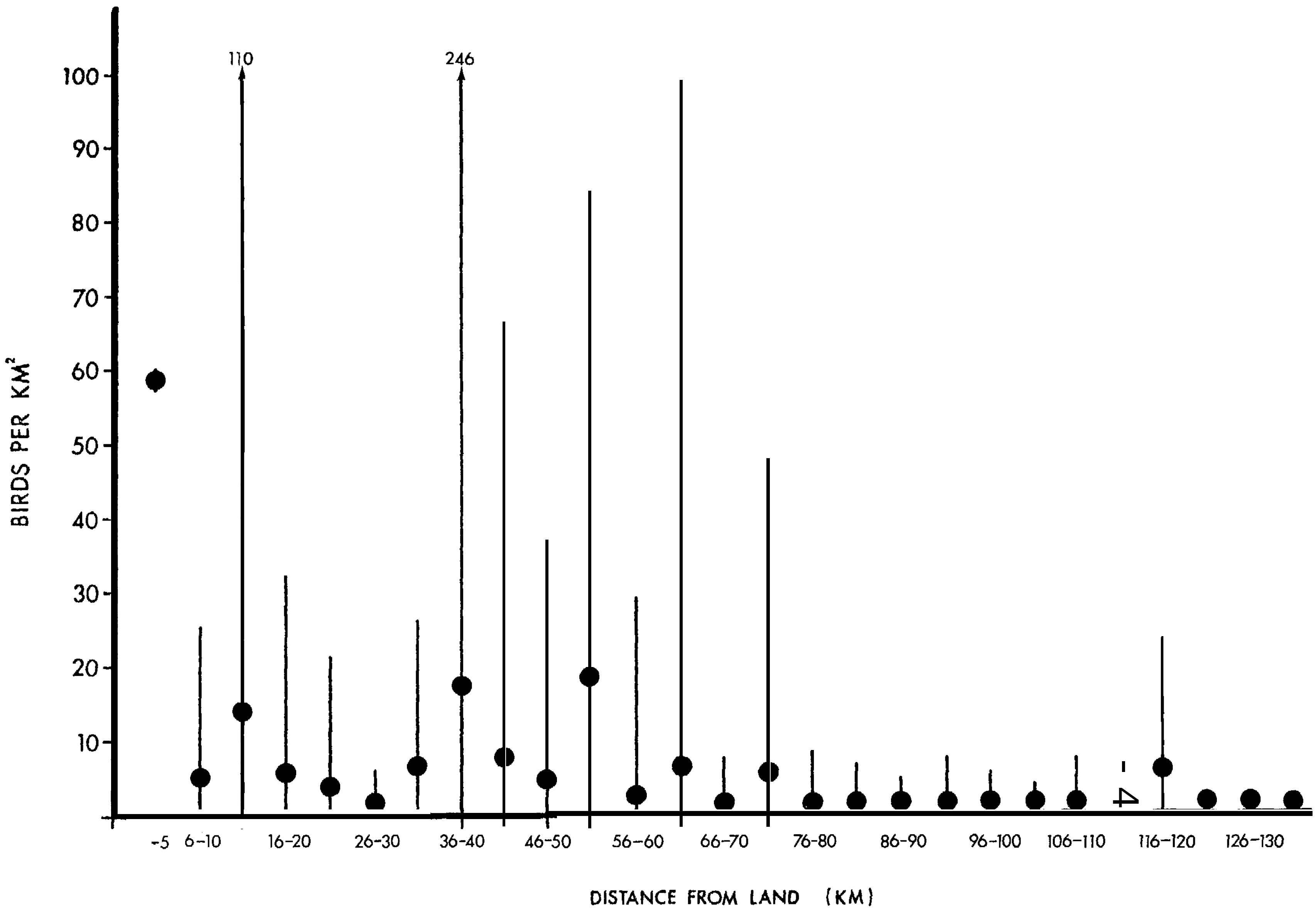

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Cooper Island Supplement

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COOPER ISLAND ANNUAL REPORT - supplement to RU 196, Divoky.

1. Introduction

A. General nature and scope of study

The general nature of studies concerning breeding bird populations dealt with preferred habitats, nest site selection, chronology of breeding, breeding success and causitive factors, and trophic relationships during chick feeding. Major emphases dealt with how these events, especially chronology, success, and feeding, varied with seasonal ice conditions in inshore waters. We sought the influence of critical factors, such as changing ice conditions and apparent variation in availability of preferred prey species, on the breeding biology of these populations.

Non-breeding bird studies centered on migration chronology and abundances of migrant birds using inshore habitats. We sought to determine why migrant species use various habitats and what prey species are preferred or critical for non-breeding birds. An additional goal, one we hope to further pursue in future research, is to determine factors concentrating particular prey species in inshore waters near barrier islands.

B. Specific objectives

Marine bird research on Cooper Island, Alaska, was devised to provide information on four topics:

1) General bird use of a northwest Alaska barrier island during the reproductive and post-reproductive seasons, especially in response to variations in seasonal sea-ice conditions.

2) Breeding phenology, success, and feeding patterns of breeding sea-bird populations on an arctic Alaska barrier island affected by sea-ice during reproductive periods.

3) Patterns of migration in inshore waters of the Beaufort Sea.

4) Responses of avian populations to environmental and biotic effects, such as weather, ice, oceanographic conditions, predation, and food resources, during reproductive and post-reproductive seasons.

C. Relevance to problems of oil development

The Plover Islands, of which Cooper Island is part, lie adjacent to National Petroleum Reserve 4. Development in the area seems likely within the next ten years. Barrier islands such as Cooper Island suffer potential oil development impact by two possible methods: 1) as a platform site for drilling operations, and

2) as a gravel source for tundra or artificial island drilling operations. Both these forms of development could adversely affect marine bird populations by destroying nesting habitat or inhibiting nesting through disturbance. To minimize future impacts, pre-development knowledge of critical factors affecting bird populations is essential.

Catastrophic events after development, such as oil spills, threaten not only marine birds with immediate mortality, but also substantially reduce or make inaccessible prey species on which these birds depend. As will be discussed, the Plover Islands appear especially critical for migrant bird populations which feed at the surface on patchy zooplankton species. Such prey could be effectively depleted in the event of oil spills.

Cooper Island is somewhat unique in that one breeding species, the Black Guillemot, solely uses artificial materials (wooden boxes, plywood, oil barrels) for nesting cavities. This illustrates how certain species, through plastic behavior patterns, can possibly benefit from human activities. The maintenance and enhancement of barrier island marine bird populations appears possible through well-planned development, minimal on-site disturbance, and concern for trophic dependencies.

II. Study area

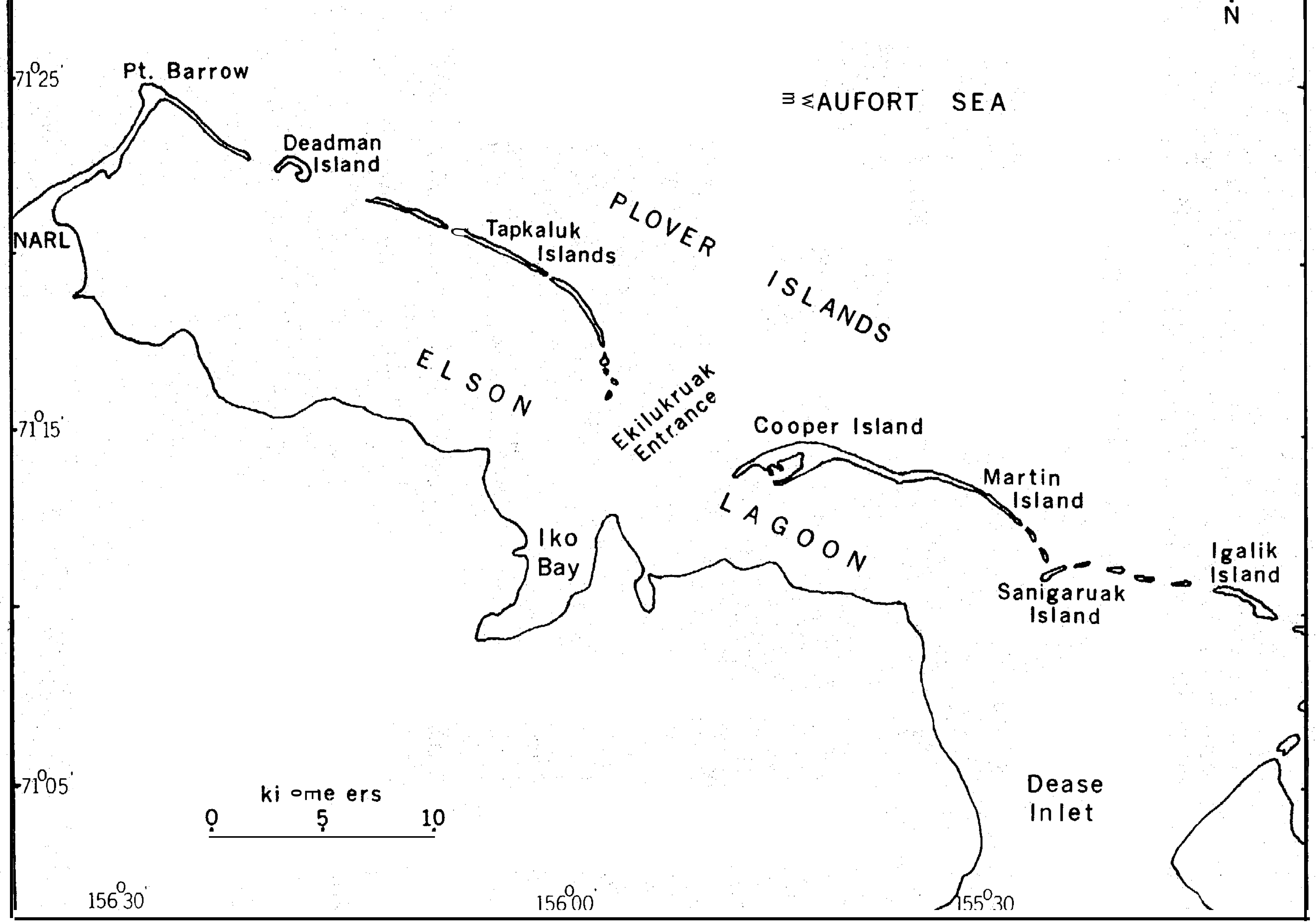
The bulk of our observations were made on Cooper Island, a barrier island lying 35 km E of Barrow Alaska (Fig. 1). The nearest mainland site is Tulageak Point, 3.5 km S of the island. Cooper Island is 4.5 km long and averages less than 0.5 km wide, but is 0.8 km at its widest point. The highest elevation is approximately 3 m above sea level.

Major substrates are sand and gravel, although small areas of tundra appear to contain sandy loams. A small. approximately 20 ha, tundra patch encircles several small brackish ponds at the island's greatest width. The tundra patch is little used by breeding species other than Baird's Sandpiper and Oldsquaw.

The island's origin, similar to other eastern Plover Islands, appears due to sediment transport from the vicinity of Tangent Point (D. M. Hopkins, pers. comm.). Sediment transport occurs primarily during the open water period in late August and September. The dynamics of sediment transport are illustrated by Cooper Island's present connection to Martin Island, an adjacent barrier island. Maps from the 1950s show these islands separated by as much as 1 km.

Major plant species include *Carex subspathacia, Puccinellia* spp., *Stellaria humifusa, Elymus arenarius, Honckenya peploides,* and *Cochlearia officianalis*. Most island substrates are not vegetated, and most nesting activity occurs in unvegetated areas (Fig. 2).

FIGURE 1. ELSON LAGOON AND ADJACENT BARRIER ISLANDS, BARROW TO TANGENT POINT



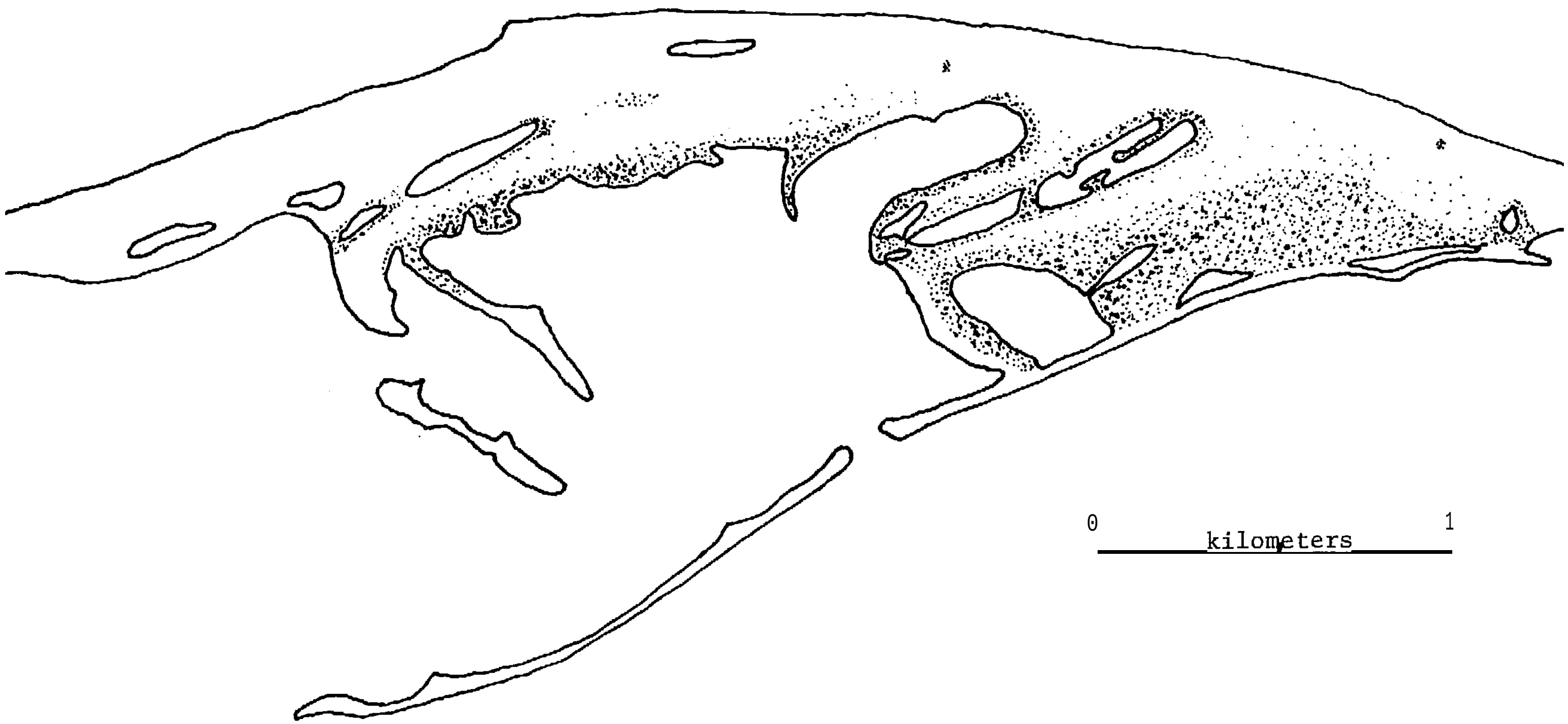


FIGURE 2. VEGETATION PATTERNS ON COOPER ISLAND, ALASKA. Stippled areas are vegetated primarily by Puccinellia and Carex spp. Unstippled areas are primarily sand and gravel.

Past human use of Cooper Island appears extensive. At least two collapsed sod huts lie on the island's east side. An eskimo family visiting the island in 1976 claimed their parents trapped Arctic Foxes on the island. Luther Leavitt, an Inupiat hunter using Cooper Island as a base-camp in 1976, stated Barrow hunters used the island to hunt Polar Bears after fall freeze–up.

Large amounts of natural and man-related driftwood and metal occur on the island. Sources of natural drift possibly include Yukon and Mackenzie river drainages. Man-related artificial drift includes boxes, sleds, wallboards, oil barrels, and assorted other debris. Sources of artificial drift possibly include waifed materials from Barrow and cargo dumped at sea by shipping. Three barges grounded on nearby Plover Islnds are possible additional sources. Several breeding species, most notably Black Guillemot, use artificial debris for nest sites.

An extremely important factor affecting marine bird populations on Cooper Island is sea-ice. Sea-ice chronology during an average season appears to be:

1. Shorefast ice period

   Shorefast ice surrounds the island nearly 10 months every year, from October to July. Surface deterioration of shorefast ice begins in late May to early June and continues through mid-July. Progression of shorefast ice melt is: 1) surface melt pond formation, 2) thaw hole formation as melt ponds erode through to the water column below the ice, and 3) thaw channel formation as thaw holes widen and connect. During this period, the effects of solar radiation in shallow waters melts ice immediately adjacent to island and mainland shorelines, forming narrow "moats" of open water.

2. Shorefast ice breakup period

   As shorefast ice deterioration continues, thaw channels connect and form sizable leads. Ice cakes of varying sizes split off from the shorefast ice mass and drift with winds and currents in leads. This condition continues until all shorefast ice is decomposed and removed from inshore waters, usually in late July.

   In 1976, following the extremely heavy ice year of 1975, shorefast ice breakup occurred from 25 July to 1 August. In 1977, a year of relatively light ice conditions, shore-fast ice breakup occurred from 9 to 20 July.

3. Drifting pack ice period

With the removal of shorefast ice, offshore drifting pack is pushed inshore by predominant NE winds. Ice concentrations vary during this period from 1 to 7 oktas, depending upon wind conditions and offshore pack concentrations. This condition continues until the first major storm in August or September with wind direction and magnitude capable of blowing ice far offshore.

Such storms occurred on 20 to 22 August in 1976 and 8 to 11 August in 1977. Ice remained nearshore throughout all of summer, 1975, due to a lack of major storms and persistent heavy ice in inshore waters.

4. Open water period

Open water persists until freeze-up in late September or early October. Occasional drifting cakes, usually of multi-year ice, appear in inshore waters during this time.

River outflow does not significantly affect inshore ice conditions in Elson Lagoon, in contrast to other lagoon systems, such as Simpson Lagoon, on the arctic Alaska coastline (S. R. Johnson, pers. comm.).

Inshore oceanographic patterns are not well known. Large-scale offshore currents are dominated by the clockwise-rotating Beaufort Gyre and the Chukchi Coastal Current, which flows northeastward past Point Barrow (Sater et al., 1971). Small-scale oceanographic events, such as convergence at entrances between barrier islands and Langmuir spirals in nearshore waters, seem most important as factors concentrating prey for neritic marine birds.

III. Methods of data collection

Visits to Cooper Island occurred on 30 June to 23 July, 26 August, and 1 to 5 September, 1975; 16 June to 30 July and 2 August to 16 September, 1976; and 21 June to 13 August, 19 to 20 August, 30 August, 3 September, and 10 September, 1977. Six major methods of data collection were used during these visits:

A. Shoreline transects

In 1976 six numbered transects were staked along geographically distinct sections of Cooper Island shoreline. Three transects censused the island's north shoreline facing the Beaufort *Sea.* The three remaining transects censused the south shoreline and inshore waters of Elson Lagoon,

We censused all transects every day in 1976 and 1977 except during unfavorable weather conditions. One observer walked each transect, using notebook and pen to record sightings. Most birds were sighted by eye, but identified and counted using 7 or 8 power binoculars. All birds observed were counted regardless of their distance from the observer. When possible, sightings of birds included age, sex, plumage, molt conditions, behavior, and habitat occupied at the time of observation. Data were totaled as number of birds sighted per kilometer walked. Environmental data collected during each transect included weather and ice conditions.

B. Habitat watches

Two hour stationary habitat watches were usually conducted twice daily during periods in 1975, 1976, and 1977. Two observers conducted each watch; one observer on the north shoreline recording bird passages north of the island and. one observer on the south shoreline recording bird passages over inshore lagoons and bays. This method also separated breeding bird feeding movements to and from the island to the north and south.

Eight hours of watch data were collected on an average day (2 watches X 2 observers X 2 hours/observation period). Habitat watches were staggered so over time observations included all daylight hours.

We recorded all birds sighted during habitat watches except local breeding bird movements within the breeding colony. We recorded breeding bird flights away from the colony as well as all non-breeding bird movements over the island and adjacent waters. 7 or 8 power binoculars were used to search out distant migrants. When possible, habitat watch data included age, sex, plumage, molt condition, behavior, and habitat occupied at the time of observation. Environmental data collected during each watch included weather and ice conditions.

C. Breeding bird surveys

Breeding bird surveys were usually held every two days. Surveys comprised of locating new nest, sites, checking conditions of known nests (number of eggs and number of living and" dead chicks), collecting chick growth data, and noting other pertinent information such as distances to nearest neighboring nest in meters and nest substrates. Chick growth data included weight measured to the nearest gram by Pesola scale, and flattened wing chord measured to the nearest mm by metric ruler.

D. Colony watches

We periodically observed numbered Arctic Tern and Black Guillemot nests from a blind in the breeding colony. Information recorded at the blind included time of departure and arrival at nest sites, time of nest reliefs, and type and size (in bill lengths) of prey returned to nests. An average blind watch lasted about two hours per person, although back-to-back watches extending several hours were often held.

E. Plankton tows

In 1976 plankton tows were taken approximately once a week at a series of ten shoreline stations. The towing methods consisted of wading with hip boots until water reached above the knee (0.5 to 0.7 m deep), throwing the net out a distance of 3 m, and returning the net as slowly as possible yet fast enough to maintain the desired water column depth (approximately ½ m/see.), The diameter of the net's mouth was 0.254 m, consequently each tow sampled 0.152 m^3 of water. Five surface tows were made at each station with each tow series from June to September. Two additional bottom tows were made at each station from mid-July to September.

After each tow, specimens were identified, counted, and grossly measured to the nearest mm. Only microorganisms (>2 mm) were identified. Voucher specimens were kept to confirm identification.

F. Specimen collections

Birds were periodically collected with 12 guage shotgun for stomach sample analysis. Stomachs and esophagi were removed after collection and stored in 10% formalin. Results of these collections are reported with other stomach analyses of RU 196.

IV. Results

A. Breeding

Six species nested on Cooper Island in 1975, 1976, and 1977. These included Arctic Tern (Sterna paradisaea), Black Guillemot (Cepphus grylle), Oldsquaw (Clangula hyemalis), Sabine's Gull (Xema sabini), Baird's Sandpiper (Calidris bairdii), and Snow Bunting (Plectrophenax nigalis).

1. Chronology of breeding

All species began breeding activities in June. Egg laying for all commenced in mid- to late June. Most species completed breeding activities in August, although late Black Guillemot chicks did not fledge until mid-September.

The bulk of Arctic Tern egg laying occurred in late June and early July (Fig. 8). Modal peak of laying for years 1975 to 1977 was 29 to 30 June. Egg hatching primarily occurred in the last two weeks of July, with modal peak of hatching for 1975 *to* 1977 occurring on 22 to 23 July. Average incubation period was 26.3 days (N=16) in 1976 and

and 21.6 days (N=65) in 1977. Dates of fledging centered in mid-August, but ranged from 2 to 28 August. Modal peak of fledging was 17 to 18 August.

Peak egg laying-for terns in 1977 was about one week later than peak egg laying in 1976, despite lighter ice conditions in 1977. The difference in these two years appears due to Arctic Fox activity on Cooper Island. In 1976, tern eggs began disappearing on 30 June, and two foxes were eventually shot on 12 and 13 July. During this two week period, in which the foxes came ashore only intermittently, they consumed 52 tern eggs, 12 Sabine's Gull eggs, 58 Oldsquaw eggs, and 3 Baird's Sandpiper eggs. Egg laying by terns in 1976 concentrated in the last week of June prior to fox activity on the island, and essentially ceased while foxes worked the island in early July. In 1977, however, one fox intermittently raided nests on the island from 24 June until it was shot on 28 June, and another was shot on 7 July before it apparently took eggs. The first fox in 1977 ate 4 tern eggs, at least 12 guillemot eggs, and a minimum of 9 Oldsquaw eggs, The pattern of tern laying in 1977 was the reverse of 1976, in that laying was slow in late June while the fox occupied the island and peaked in early July during a period of no fox activity. Clutch sizes were substantially reduced in 1977 (Table 3). This strongly suggests the fox's presence in late June, 1977, inhibited egg laying and decreased the overall egg production of Cooper Island terns.

Black Guillemot egg laying for years 1975 to 1977 ranged from 22 June to 22 July, with modal peak on 30 June to 1 July (Fig. 9). The egg laying period was substantially lengthened in 1977, apparently due to Arctic Fox activity in late June and the number of inexperienced birds occupying nest sites for the first time. We suspect at least 3, and possibly 5, guillemot pairs relayed in July after losing their clutches to an Arctic Fox in June. Hatching dates ranged from 23 July to the third week in August , with modal peak occurring on 28 to 29 July. Average incubation period was 28.2 days in 1976 and 27.6 days in 1977. Although exact observations of guillemot fledging dates were not possible, we estimate that fledging ranges from the last week in August to the third week in September, peaking around 31 August.

Breeding chronologies of other species are only generally known, as emphasis was placed on numerically important breeding species.

Oldsquaw

Egg laying period - last two weeks of June and first two weeks of July.

Observed brood departure dates - two on 20 July, one on 29 July, one on 1 August, two between 3 and 6 August, and one on 12 August.

Sabine's Gull

Egg laying period - last two weeks of June.

Observed hatching period - third week of July.

Fledging period - mid-August.

Baird's Sandpiper

Egg laying period - late June.

Hatching period - mid-July.

Last observation of fledged young - 11 August.

Snow Bunting

Egg laying period - mid-June.

Hatching period - early July.

Final departure of island fledged young - late August to early September.

2. Nest site selection

Primary nesting areas of exposed nesting species, such as Arctic Tern. Sabine's Gull, and Oldsquaw, centered around vegetated shorelines of small brackish ponds and open areas of sand-gravel substrate. Cavity nesters, such as Black Guillemot and Snow Bunting, out of necessity restricted their nest sites to suitable driftwood and metal covers.

Arctic Tern nesting habitat included open sand-gravel areas and sparsely vegetated margins of island ponds (Fig. 3 and 4). Sand, gravel, and sand and gravel in combination were primary mest substrates (Table 1). Similar nesting habitats are reported by Hawksley (1957) on Machias Seal Island in New Brunswick. 76% (N=55) of 1977 Cooper Island nest sites were located by driftwood or similar objects.

Many unused nest scrapes existed on the island, suggesting nest sites were not limiting for Arctic Terns. Distances to nearest neighboring nests were quite far in 1976 (mean distance = 50.8 ± 9.4 (95% C. L.), N= 56) and 1977 (mean distance = 53.9 ± 10.6 (95% C. L.), N = 55), also suggesting that terns did not breed at maximum densities. By comparison, Pettingill (1939) estimated 2000 tern nests in 7.5 acres on Machias Seal Island, New Brunswick. His density observations equal approximately 15 m average distance to nearest neighboring nests, assuming uniform spacing of nest sites.

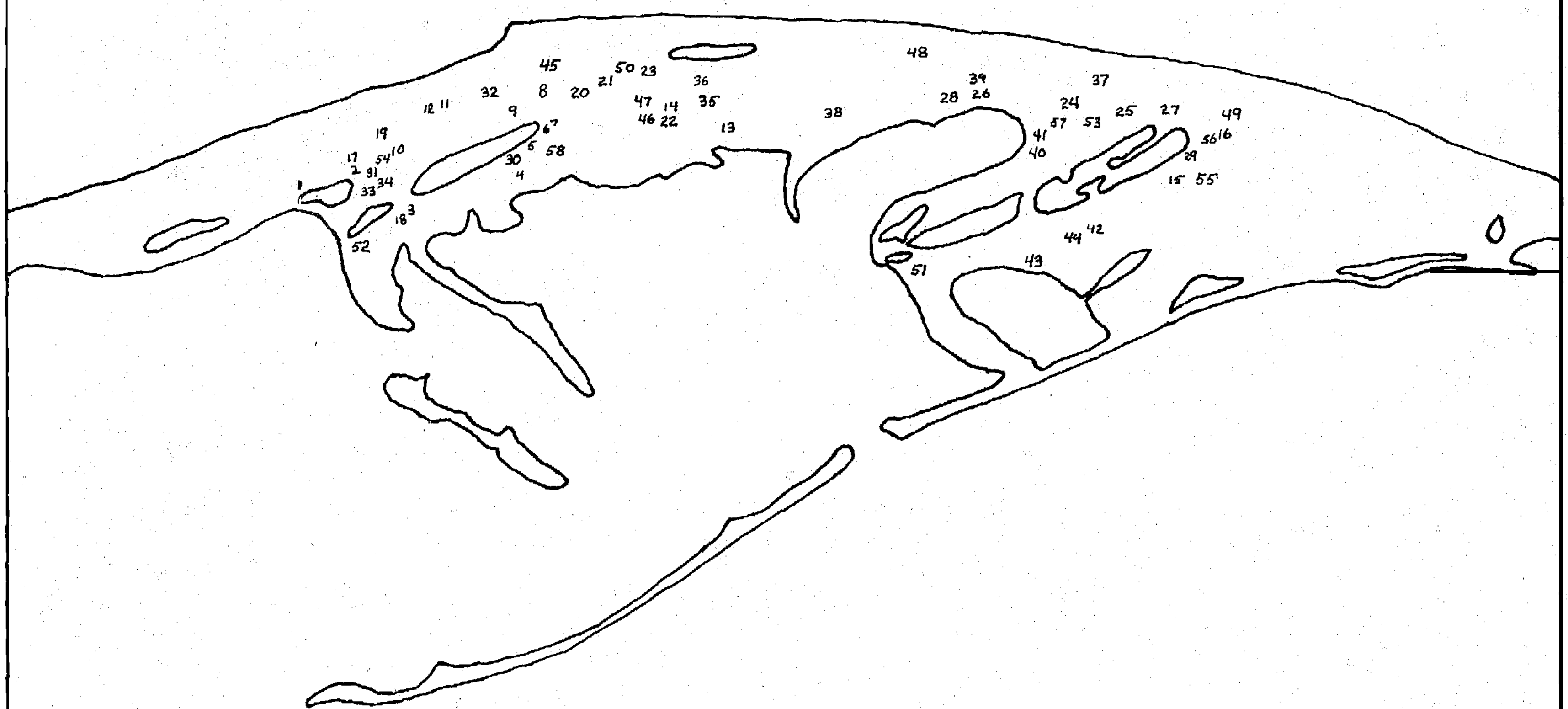


FIGURE 3. ARCTIC TERN NEST SITES, COOPER ISLAND, 1976

FIGURE 4. ARCTIC TERN NEST SITES, COOPER ISLAND, 1977

TABLE 1. ARCTIC TERN NEST SUBSTRATES, COOPER ISLAND, 1976 and 1977

SUBSTRATE	1976		1977	
	NUMBER	PERCENT	NUMBER	PERCENT
Sand	5	9	15	27
Gravel	9	16	14	26
Sand and gravel	36	63	18	33
Vegetation	2	3	0	0
Vegetation, sand, and gravel	5	9	3	6
Other (wood chips, feathers)	0	0	4	7

Cooper Island Black Guillemots solely used man-related artificial covers for nest cavities, consequently their nests concentrated where covers were available (Fig. 5). Nest site covers included prone and inclined wooden boards and boxes and a punctured oil barrel (Table 2). The expansion of the Cooper Island guillemot breeding population is due in part to our creation of nest cavities from available wood on the island [see Divoky et al., 1974). At least 68% of occupied nest sites in 1977 were created by us from 1972 to 1976.

Oldsquaw nested exclusively in driftwood windrows (36% of sites in 1976, 55% in 1977) and patches of Lyme Grass, Elymus arenarius (64% in 1976, 45% in 1977). Most nests clustered near shorelines of island ponds (Fig. 6).

Of the three remaining species, Sabine's Gull also nested primarily along sparsely vegetated margins of island ponds (Fig. 7). All three Baird's Sandpiper nests were located on the island's tundra patch in short-grass tundra. Lastly, Snow Bunting nest covers included oil barrels, plywood, and other debris providing suitable nesting cavities.

3. Breeding success

Breeding success of non-passerine populations is presented in Tables 3 to 7. Tremendous year to year variation in breeding success occurred in all species. Primary factors increasing mortality of eggs and chicks were Arctic Fox predation, Glaucous Gull predation, and starvation due to decreased food availability. Greatest breeding success for all species occurred in 1975, a Year of zero fox predation and persistent pack ice in inshore waters of the Beaufort Sea. Poorest breeding success for most species occurred in 1976, primarily due to heavy fox predation of open nesting species.

Arctic Tern breeding success in 1975 compares favorably with very successful years observed in other populations (see discussion). Ice associated prey species appeared readily available well into September, 1975. 1976 success was very poor, due to fox predation during the egg period and high mortality of very young chicks (Table 8). In 1976 parent terns deserted their nests during diurnal periods while foxes worked the island. This resulted in extended incubation periods (26.3 days in 1976 vs. 21.6 in 1977), possible depletion of yolk reserves in eggs prior to hatching, and increased mortality of chicks during the first days of life. 1977 success was fair, decreased in part due to fox predation of eggs in late June. A large storm in early August, 1977, blew the drifting pack ice far offshore during

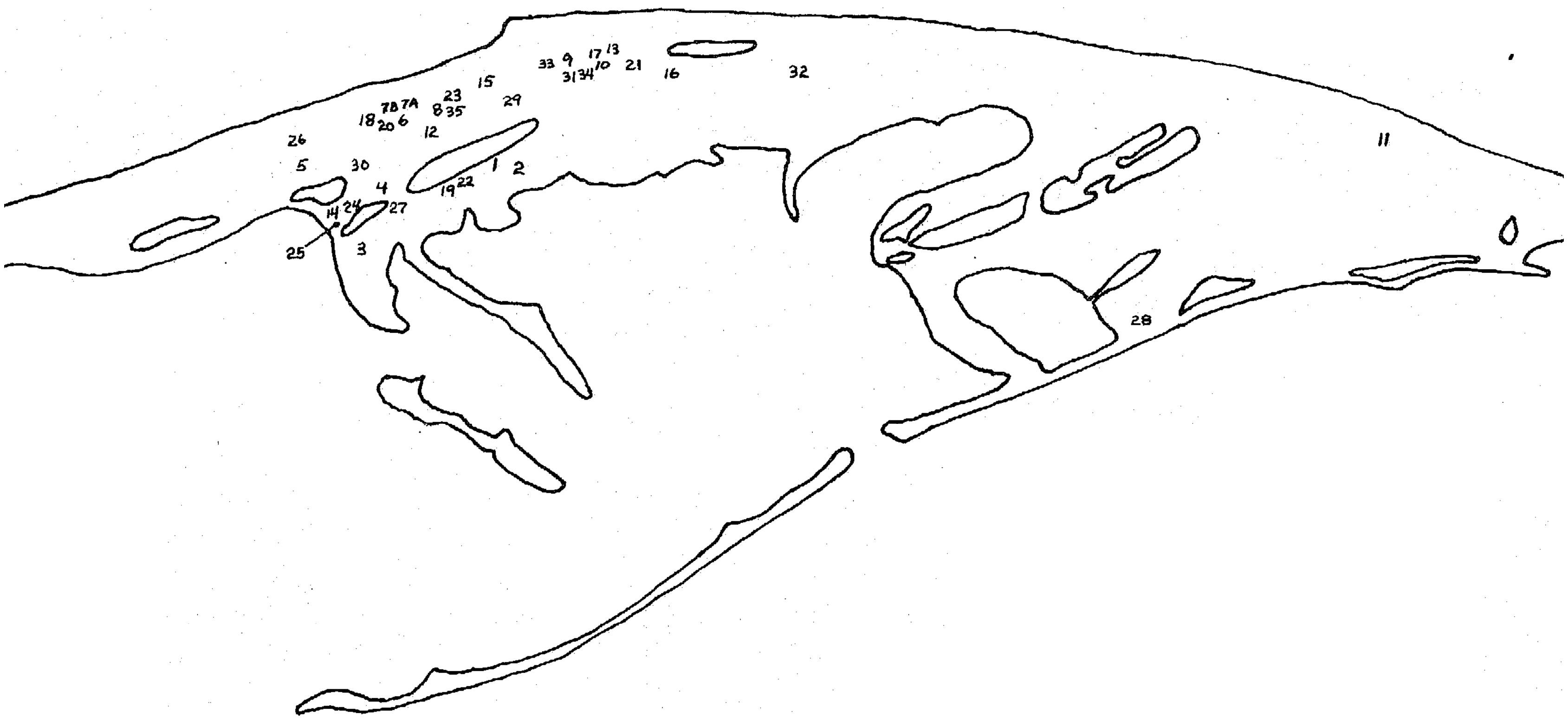


FIGURE 5. BLACK GUILLEMOT NEST SITES, COOPER ISLAND, 1975 - 1977

NEST USE: 1975 - 1-7A, 8-18; 1976 - 1-17, 19-21; 1977 - 1-17, 19, 21-35

TABLE 2. BLACK GUILLEMOT NEST COVERS, COOPER ISLAND, 1975 - 1977

COVER	NUMBER USED	PERCENT	CUMULATIVE USE 1975 - 1977	PERCENT
Plywood	17	47	28	38
Box	8	22	20	27
Wallboard	6	16	15	21
Wood sled	3	8	8	11
Door	1	3	1	1
Oil barrel	1	3	1	1

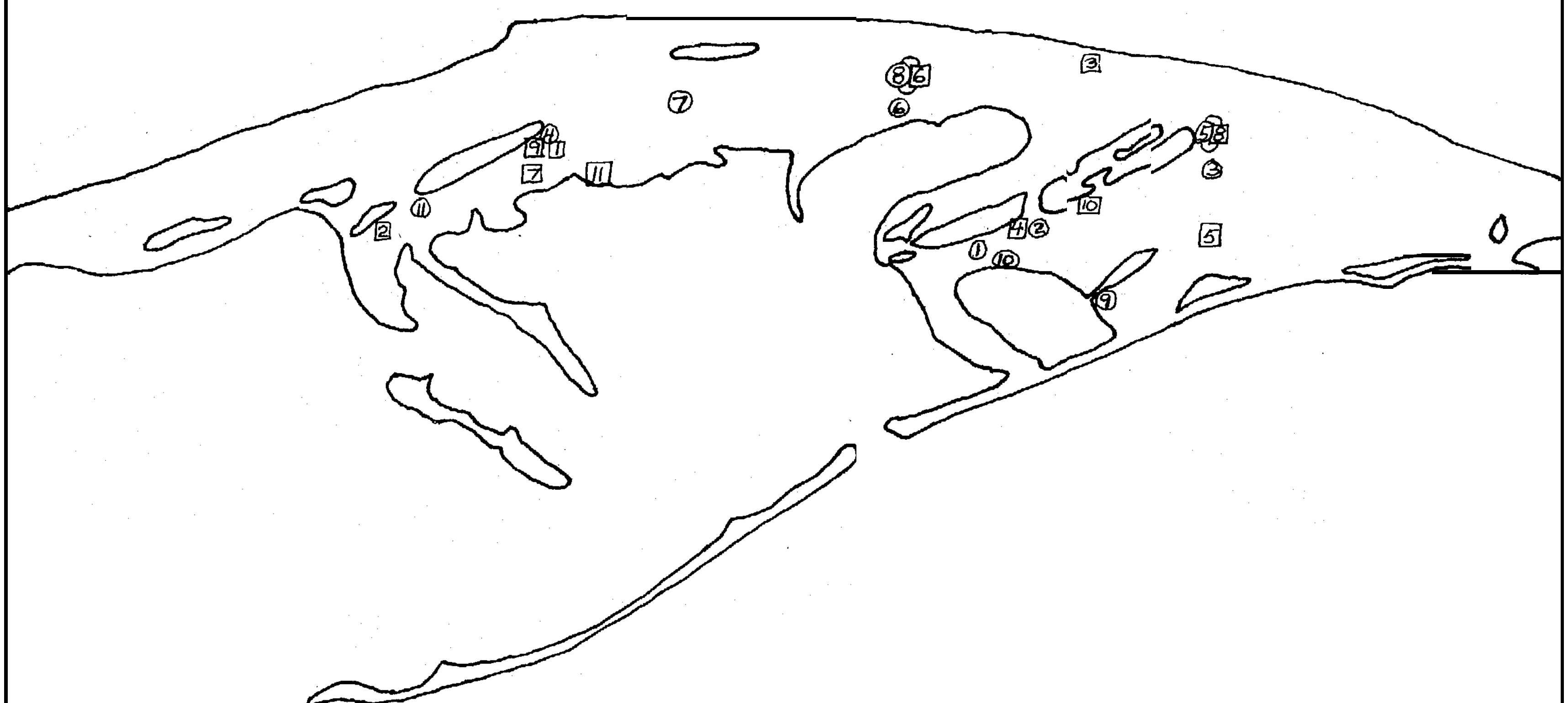


FIGURE 6. OLDSQUAW SITES, COOPER ISLAND, 1976 (CIRCLES) AND 19 7 (SQUARES

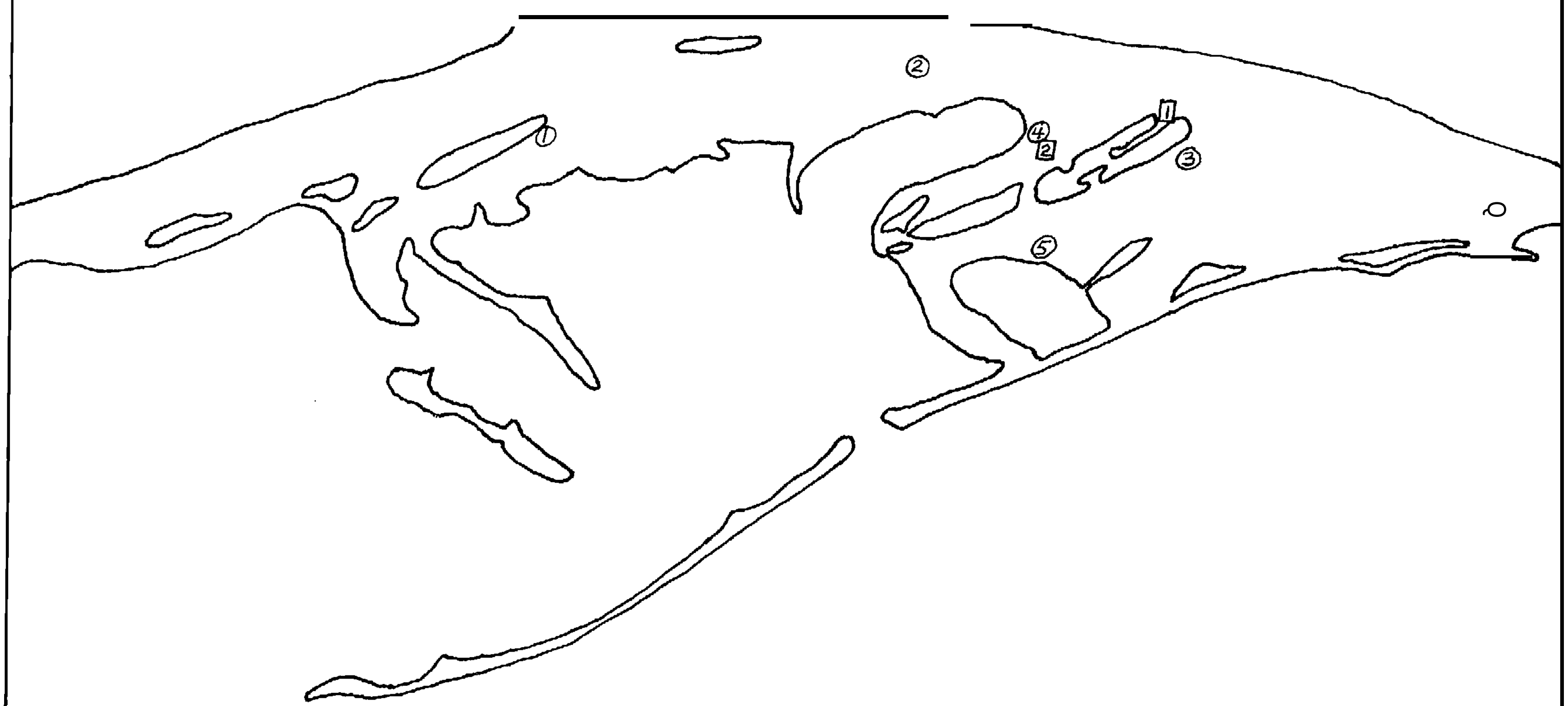


FIGURE 7. SABINE'S GULL NEST SITES, COOPER ISLAND, 1976 (CIRCLES) AND 977 (SQUARES)

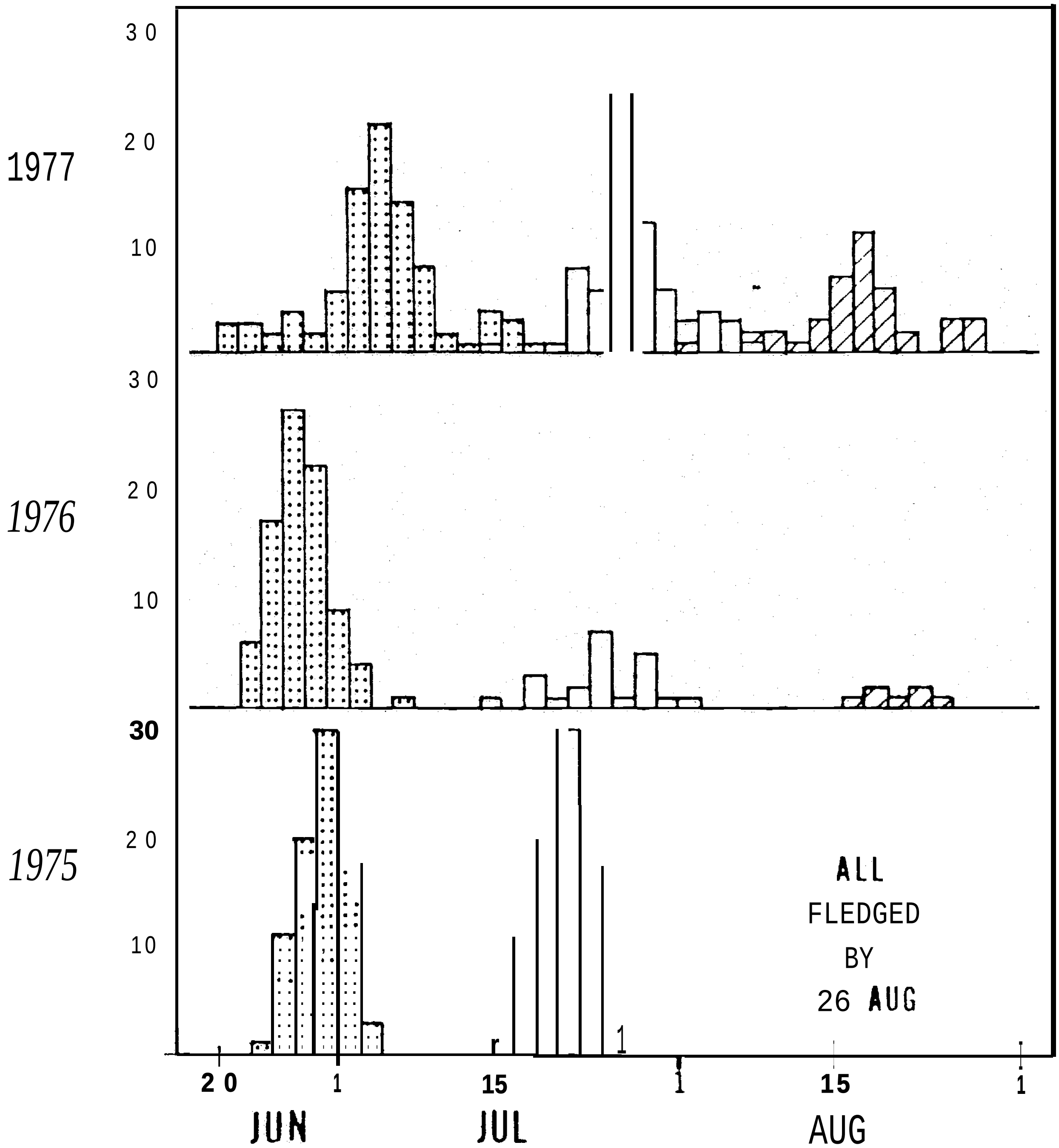


FIGURE 8. ARCTIC TERN BREEDING CHRONOLOGY, 1975 - 1977, COOPER ISLAND. Ordinate denotes numbers of eggs or chicks. Dotted columns are laying dates,. open columns are hatching dates, and barred columns are dates of first flight. 1975 laying dates based. on 22 day incubation period prior to observed hatching dates. ,

the chick period. This apparently had great effect on the availability of ice-related prey species used by terns for chick feeding, leading to starvation of old chicks prior to fledging (Table 8).

Black Guillemots had near perfect breeding success in 1975. 1976 and 1977 saw decreased success due to Arctic Fox predation and mortality factors as yet unexplained. A possible cause of decreased overall success in 1976 and 1977 was the increased number of new nest sites, hence the number of previously inexperienced and unpaired birds, in the Cooper Island colony. At least 38% of guillemot nest sites in 1977 were occupied for the first time, and one additional site not used in 1975 and 1976 was previously occupied in 1972. First time nest sites had smaller clutches (1.6 VS. 1.8 eggs) and poorer breeding success (29% vs. 36%) than previously used sites, despite the fact that all fox predation occurred at previously used sites. Increased chick mortality in 1976 and 1977 may also be due to Horned Puffin disturbances. Several guillemot chicks died of crushed skulls and body lacerations at nest sites frequented by a lone Horned Puffin, but only circumstantial evidence suggests the puffin caused these deaths.

Arctic Fox and Glaucous Gull predation had greatest impact on the breeding success of other species (Tables 5 to 7). Open nesting species, particularly Oldsquaw and Sabine's Gull, were especially vulnerable to Arctic Fox predation on the island.

4. Feeding

Prior to breakup of shorefast ice in July, marine prey were largely inaccessible in inshore waters for Cooper Island breeders. Before breakup Black Guillemots flew north from the island, presumably to feed in leads beyond the shorefast ice margin. Most Arctic Terns and Sabine's Gulls flew south to the mainland on a daily basis during the shorefast ice period, presumably to feed on tundra arthropods. One tern collected in 1975 while returning to the island from the south had Diptera larvae in its stomach, a prey item obtainable at the mainland. The major shift to marine prey did not occur until the shorefast ice had begun substantial deterioration.

The principle and probably preferred prey species of Cooper Island Arctic Terns during chick feeding was Arctic Cod (Boreogadus saida) (Table 9). Arctic Cod seemed readily available in inshore waters during the shorefast ice breakup and drifting pack ice periods. Crustaceans also made up a significant portion of tern chick diets, depending on availability. For three days in early August, 1976, a

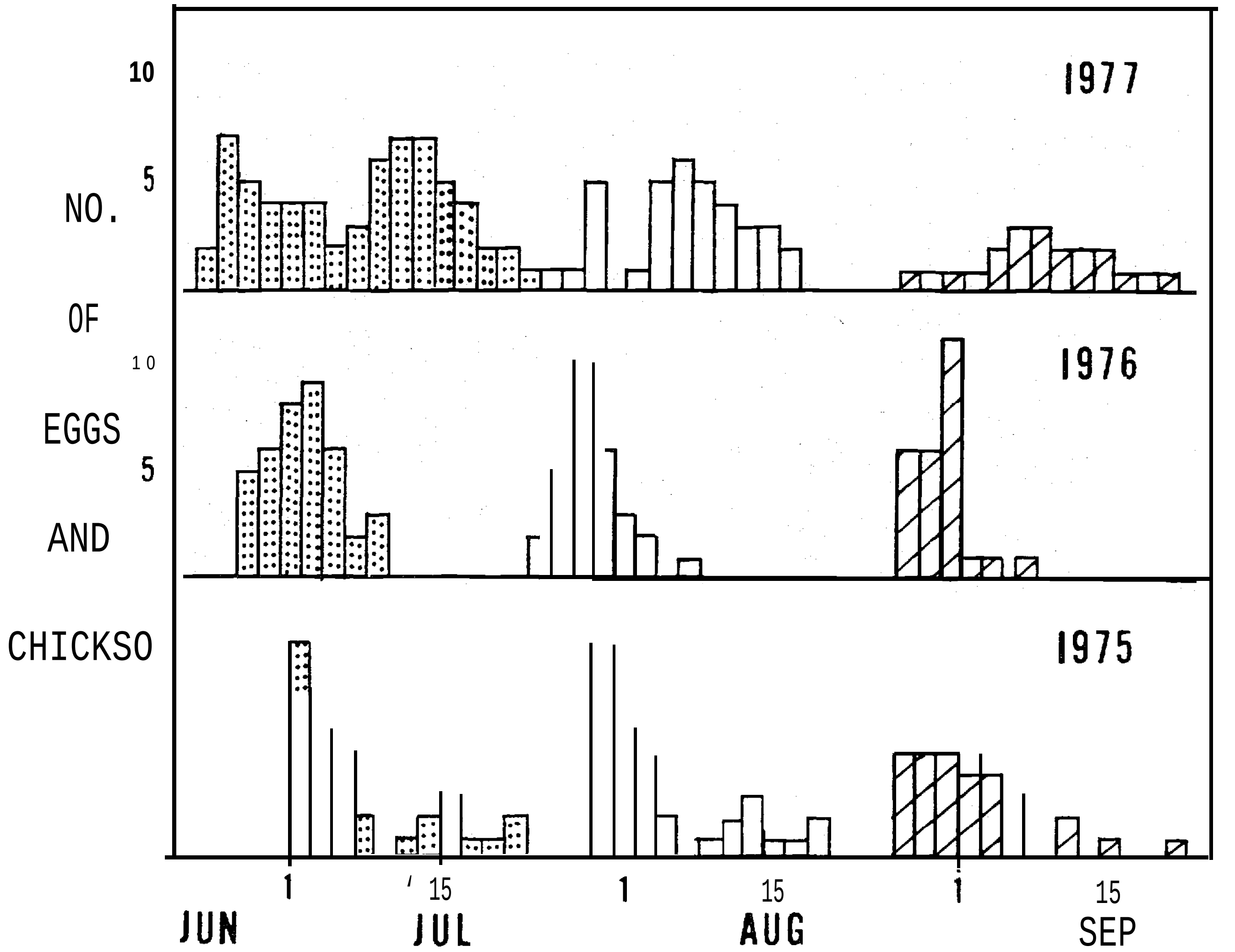


FIGURE 9. BLACK GUILLEMOT BREEDING CHRONOLOGY, 1975 - 1977, COOPER ISLAND, ALASKA. Dotted columns are laying dates, open columns are hatching dates, and barred columns are nest desertion dates. Several nest desertion dates are estimates based on late season, visits to Cooper Island. 1975 hatching dates based on 28 day incubation period after observed laying dates.

TABLE 3. ARCTIC TERN BREEDING SUCCESS, COOPER ISLAND, ALASKA

Year	1975	1976	1977
Number of Nests	51	58	61
Average Clutch Size	1.9	1.7	1.4
% Hatching Success	86	21	79
% Eggs Taken by Arctic Fox	0	53	5
Number of Eggs Hatched/Nest	1.6	0.4	1.1
% Fledging Success	79*	33	57*
Number of Chicks Fledged/Nest	1.3*	0.1	0.7*
% Breeding Success	68*	7	46*

* Estimates based on number of dead chicks found during late-season visits to Cooper Island.

TABLE 4. BLACK GUILLEMOT BREEDING SUCCESS, COOPER ISLAND, ALASKA

	1975	1976	1977
Number of Nests	18	21	392
Average Clutch Size	1.8	1.95	1.75[3]
% Hatching Success	97	78	59
% Eggs Taken by Arctic Fox	0	0	17
Number of Eggs Hatched/Nest	1.8	1.5	1.0
% Fledging Success	97[1]	84	56
Number of Chicks Fledged/Nest	.7[1]	1.3	0.6
% Breeding Success	94[1]	66	33

1. Assuming remaining chicks fledge (4 remaining on 5 September).

2. 39 attempted clutches in 34 nest sites.

3. Data for known completed clutches only. Average clutch for all nests, including those suffering Arctic Fox predation before completing clutches, 1.69.

TABLE 5. OLDSQUAW BREEDING SUCCESS, COOPER ISLAND, ALASKA

	1975	1976	1977
Number of Nests	9	11	11
Average Clutch Size (completed cluches only)	7	6.4	6.4
% Hatching Success	[1]	10	82
% Eggs Taken by Arctic Fox		83	13
% Nests Taken by Arctic Fox		82	45
Number of Eggs Hatched/Nest		0.6	2.8
% Departure Success		9	71

1. 1975 information unavailable

TABLE 6. SABINE'S GULL BREEDING SUCCESS, COOPER ISLAND, ALASKA

	1975	1976	1977
Number of Nests	4	5	2
Average Clutch	3.0	2.4	2.5
% Hatching Success	83	0	40
% Eggs Taken by Arctic Fox	0	100	0
% Eggs Taken by Glaucous Gull	0	0	60
Number of Eggs Hatched/Nest	2.5	0	1.0
% Fledging Success	60[1]	0	50[1]
Number of Chicks Fledged/Nest	1.5[1]	0	0.5[1]
% Breeding Success	50[1]	0	20[1]

1. Estimates based on number of dead chicks found in late season.

TABLE 7. BAIRD'S SANDPIPER BREEDING SUCCESS, COOPER ISLAND, ALASKA

	1975	1976	1977
Number of Nests	2	2	1
Average Clutch	[1]	3.5	3.0
% Hatching Success		57	100
% Eggs Taken by Arctic Fox		43	0
Number of Eggs Hatched/Nest		2.0	3.0
% Fledging Success		25	0
Number of Chicks Fledged/Nest		0.5	0
% Breeding Success		14	0

1. 1975 information unavailable

TABLE 8. AGE OF ARCTIC TERN CHICK MORTALITY, COOPER ISLAND, ALASKA

Year	1975	1976	1977
% Chicks Dead <1 week old	19	52	4
% Chicks Dead 1-2 weeks old	0	10	6
% Chicks Dead >2 weeks old	1*	5	33*
% Fledging Success	79*	33	57*

* Estimates based on number of dead chicks found during late-season visits to Cooper Island

TABLE 9. PREY RETURNED TO COOPER ISLAND BY ARCTIC TERNS DURING CHICK PERIOD, 1976 AND 1977

PREY	% OF TOTAL PREY ITEMS 1976 N=264	1977 N=261	MEAN SIZE* (mm) ± 95% C.L. 1976	1977
Arctic Cod (Boreogadus)	21.6	31.4	79 ± 10	81 ± 8
Unknown Fish	2.3	21.5	N<5	69 ± 10
Large Amphipod	3.8	2.3	26 ± 4	28 ± 6
Small Amphipod	15.2	3.4	11 ± 2	14 ± 2
Euphausid (Thysanoessa)	53.0	0.0	Not Sizable	
Isopod (Saduria)	0.8	0.0	N<5	
Pteropod (Limacina)	0.0	3.4		12 ± 2
Unknown Invertebrate	3.4	37.9	16 ± 10	13 ± 7

* Based on estimated bill lengths of prey items observed with binoculars.

large patch of Euphausiids (Thysanoessa spp.) washed ashore on the island's south shoreline. Terns fed frantically at this patch, sometimes returning prey to chicks every 45 seconds. Due to observations during this frantic feeding activity Euphausiids appear numerically important in 1976 chick diets; over the entire chick period, however, their importance was probably slight. Nevertheless, concentrations of superabundant invertebrate prey may at times provide an important food source for chick feeding Arctic Terns.

Similar to terns, Black Guillemots seem to have overwhelmingly preferred Arctic Cod during chick feeding (Table 10). Arctic Cod was apparently quite available in inshore waters near Cooper Island, as most feeding during the shorefast ice breakup and drifting pack ice periods occurred within 1 km of the island. Adult guillemots captured and returned cod on feeding trips lasting as little as five minutes. Four-horned Sculpin did not become a major prey species for guillemots until the removal of drifting pack ice from inshore waters.

B. Non-breeding bird use

Migratory patterns were fairly similar in 1976 and 1977 (Fig. 10 and 11). During June and the- first half of July sightings primarily included breeding species. The first significant influx of non-breeding birds occurred in the last half of July, and in both years migrant numbers peaked in August. Several migrant species, however, occupied Cooper Island habitats 5 to 10 days earlier in 1977 and in 1976, most notably shorebirds and small Larids. The departure of these species also took place earlier in 1977, apparently due to poor weather conditions and the associated removal of pack ice and its prey fauna from the Cooper Island vicinity in early to mid-August. In 1976 migrant densities of over 1000 birds per kilometer of shoreline occurred in the third week of August, mostly Red Phalaropes, Arctic Terns, and Sabine's Gulls feeding on under-ice amphipods. In 1977, however, with the removal of pack ice from inshore waters 11 to 12 days earlier, migrant densities decreased to less than 100 per kilometer by 19 August. Thus the presence of drifting pack ice and its associated prey seem to have an important influence on the timing of departure by several species from the Plover Islands and the Beaufort Sea.

A summary of major species follows:

1. Loons

Loons were regular visitors to inshore waters near Cooper Island (Fig. 12). Prior to shorefast ice breakup, loons,

TABLE 10. PREY RETURNED TO COOPER ISLAND BY BLACK GUILLEMOTS DURING CHICK PERIOD, 1976 AND 1977

PREY	% OF TOTAL PREY ITEMS 1976 N=71	% OF TOTAL PREY ITEMS 1977 N=37	MEAN SIZE* (mm) ± 95% C.L. 1976	MEAN SIZE* (mm) ± 95% C.L. 1977
Arctic Cod	83	54	73 ± 6	70 ± 10
Four-horned Sculpin	1	19	N· 5	139 ± 11
Capelin	0	3		N·5
Unknown fish	16	22	unable to size	67 ± 11
Large amphipod	0	3		N 5

* All sizes except sculpin based on estimated bill lengths of prey items observed with binoculars. Sculpin sizes based on fish found at nest sites or in dead chicks.

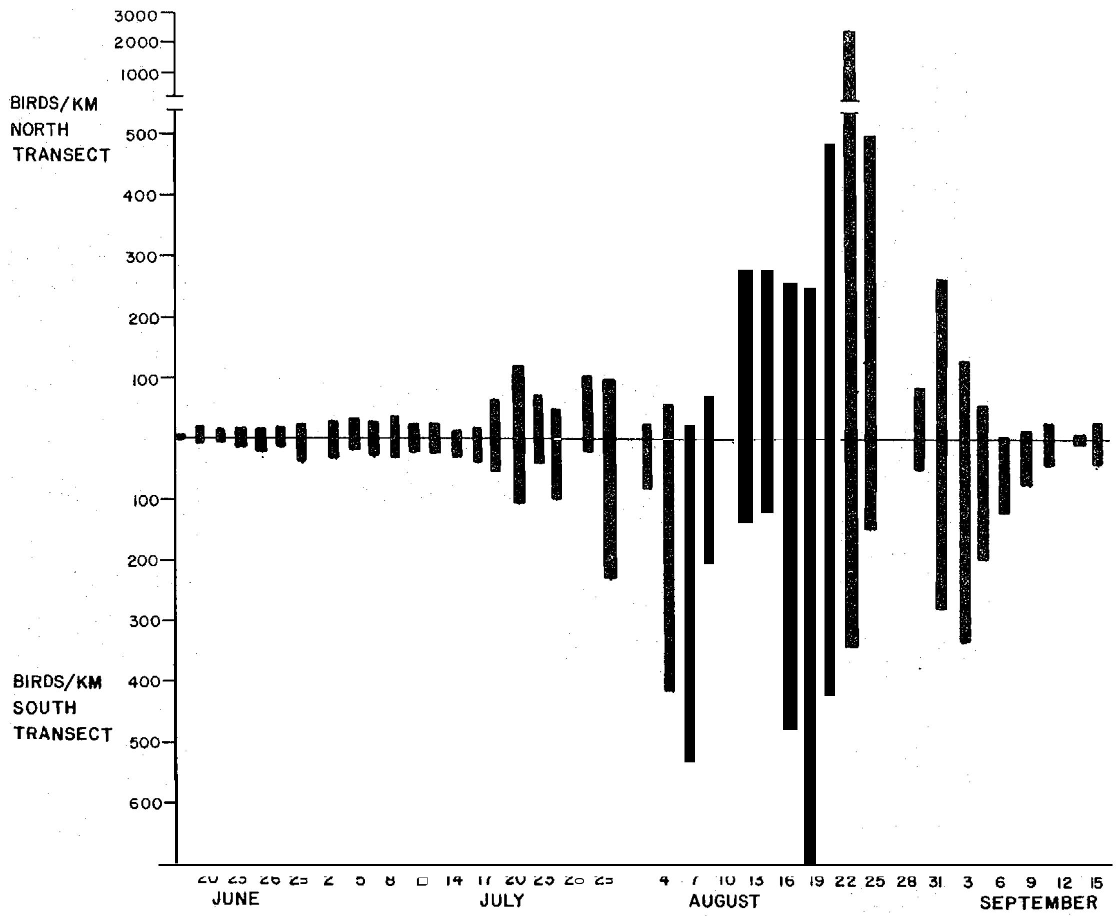


FIGURE [illegible]. TRANSECT DENSITIES, BIRDS USING COOPER ISLAND HABITAT, 1976 (BIRDS OBSERVED/KM WALKED)

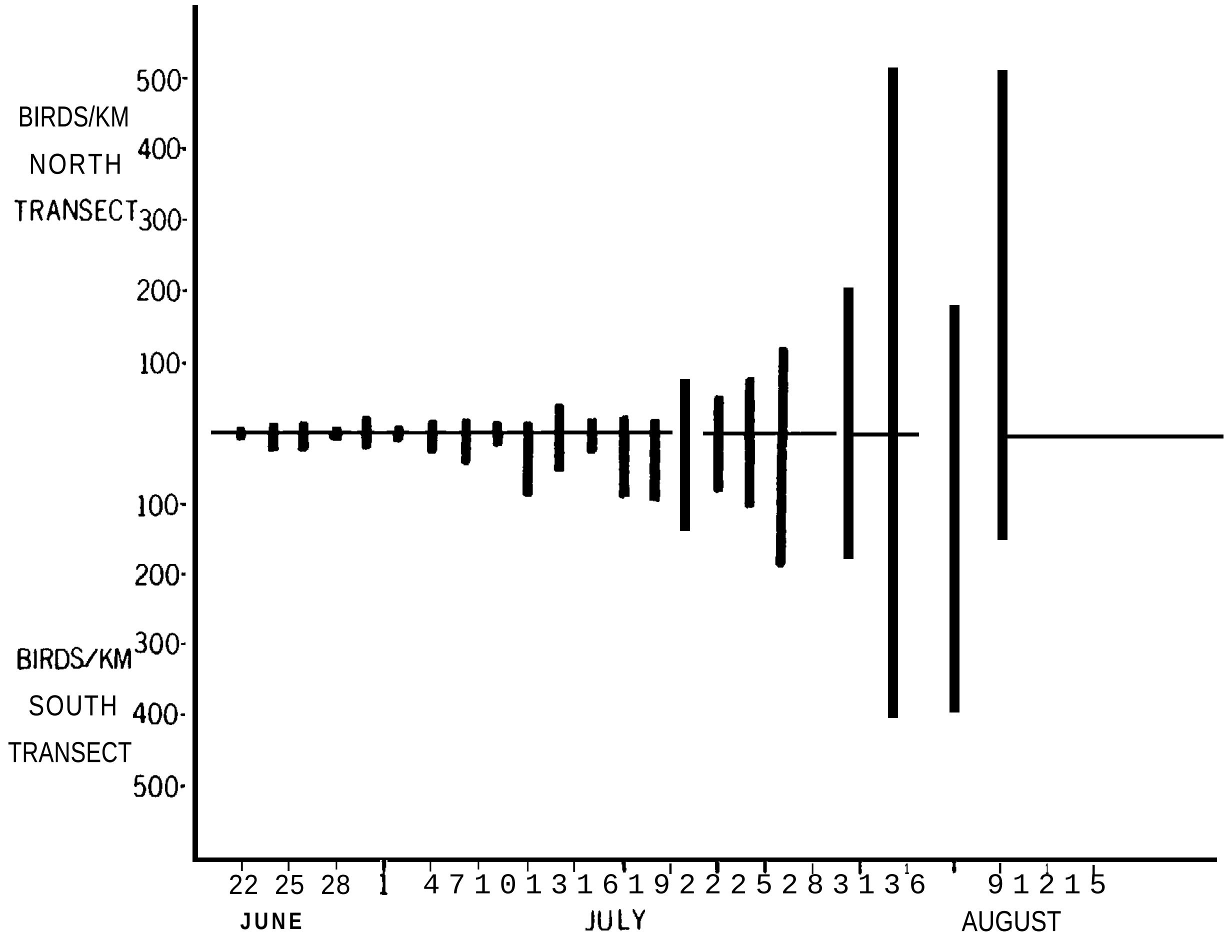


FIGURE 11. TRANSECT DENSITIES, BIRDS USING COOPER ISLAND HABITAT, 1977 (BIRDS OBSERVED/KM WALKED)

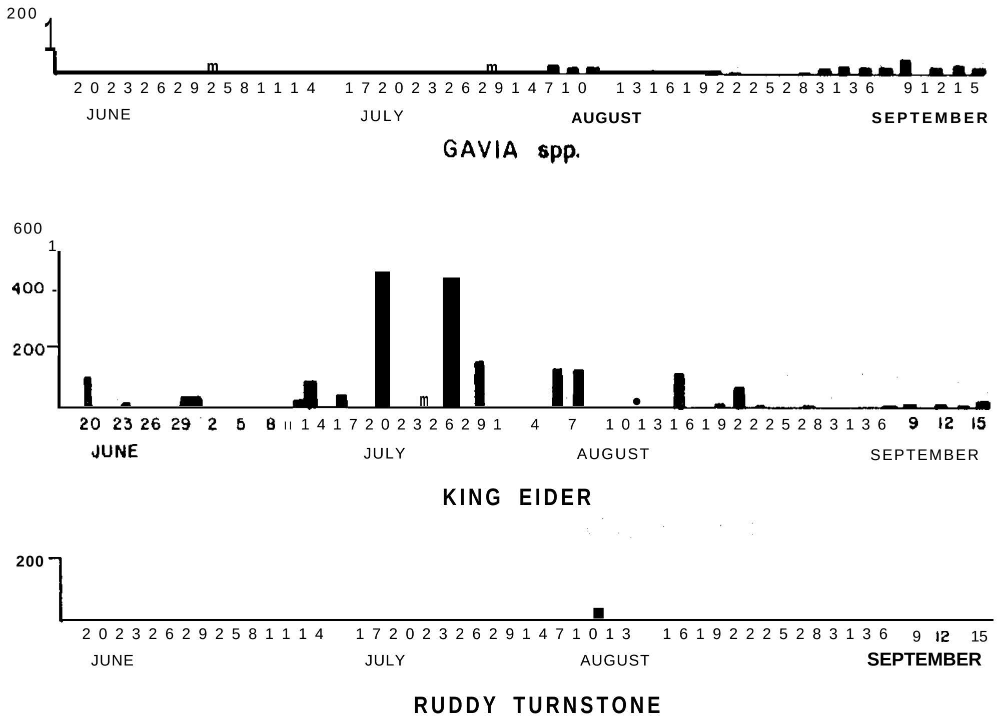


FIGURE 12. LOON, KING EIDER, AND RUDDY TURNSTONE ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

particularly Arctics, swam and clove in moats surrounding the island. The birds preferred the west end of the island, swimming in mid-moat or near the shorefast ice edge.

After breakup loons often swam solitarily or in pairs near light concentrations of ice, such as Ekilukruak Entrance and waters north of the island. Most individuals, however, flew over the island in north–south directions without stopping, suggesting these were mainland nesters flying to offshore marine waters for food. Yellow-billed Loons did not become abundant until the drifting pack ice period of late July and August.

Post-breeding migration of loons was heaviest in September, 1976. Frequent flocks of 5 to 15 birds passed from east to west during this time.

2. Brant

Small groups of Brant were common on the island during late June and early July, 1976 and 1977, and September, 1976, Individuals in the early summer were one of the few non-breeding users of Cooper Island terrestrial habitats prior to post–breeding migration. All Brant flocks restricted their activities to Carex patches on the island's south side. September flocks sighted in 1976 contained both adults and juveniles.

3. Pintail

Pintails were infrequent in 1976. In 1977, however, they were common during most of the summer, peaking at 118 on 2 August. Females comprised almost all flocks. Few birds dabbled in shallow waters of Elson Lagoon and Ekilukruak Entrance, but most merely roosted on vegetated shorelines of island ponds.

4. Eiders

Few eiders used the island or surrounding habitats. Occasionally a migrating eider flock landed in mid-Elson Lagoon, especially on late summer evenings. Perhaps these birds roosted overnight on the water. Up to 15 King and Common Eiders, primarily sub-adult males and females, used the Cooper Island north shoreline in August and September for possible wing molt. These birds quietly roosted on the beach, entering the water only when disturbed. A small flock of female Stellar's Eiders roosted on the island's south shoreline for several days in September, 1976.

Passing flocks of migrating eiders were visible almost daily in both 1976 and 1977, all flying west. King Eiders far outnumbered other species, although most flocks were too distant for identification (Fig. 12). Many large eider strings were visible over the mainland coastline, suggesting these birds predominantly flew over the mainland coast rather than the barrier islands while migrating. It appears this section of coastline is of little value to eiders other than as a migratory route.

5. Oldsquaw

Oldsquaw was the most consistent and abundant species near the island (Fig. 13). 1000 to 2000 males underwent wing molt in Elson Lagoon near Cooper Island in both 1976 and 1977. Their period of flightlessness stretched from about 20 July to 20 August. Many other Oldsquaw occupied adjacent sections of Elson Lagoon at this time. Molting birds roosted in large flocks on lagoon shorelines of barrier islands. These birds fed primarily in mid-lagoon 200 m to 2 km offshore,

Heaviest post-breeding migration of Oldsquaws occurred during September, as observed in 1976. Intense flights of Oldsquaw occurred in the evening at this time. From about 1600 to 1900 flocks numbering 50 to 1000 appeared far offshore to the northeast, flew directly south over the barrier islands, and landed in Elson Lagoon. On following mornings from 0600 -to 080″0, large flocks took off from the lagoon, crossed the islands, and proceeded offshore in a west to northwest direction. Peak numbers visible on one evening were 12,650 $\pm$ 500 on 9 September, 1976. We observed no feeding behavior after these birds landed, merely great rafts of ducks which persisted until darkness.

6. Ruddy Turnstone

Ruddy Turnstones were regular migrants in August (Fig. 12). The first turnstone arrivals occurred about 10 days earlier in 1977 than in 1976, in the last week of July rather than the first week of August. They fed on beaches by walking and pecking, apparently on invertebrates beached by wave action. Highest counts occurred in early August, 1976, but several individuals remained into September of that year.

7. Semipalmated Sandpiper

In both 1976 and 1977 a large wave of juvenile Semipalmated Sandpipers occurred in the last week of July and the first week of August (Fig. 14). These birds fed primarily on mud shorelines of tundra ponds, although many walked and pecked on beaches with other shorebirds. Numbers rapidly declined in August, although few individuals remained past mid-August.

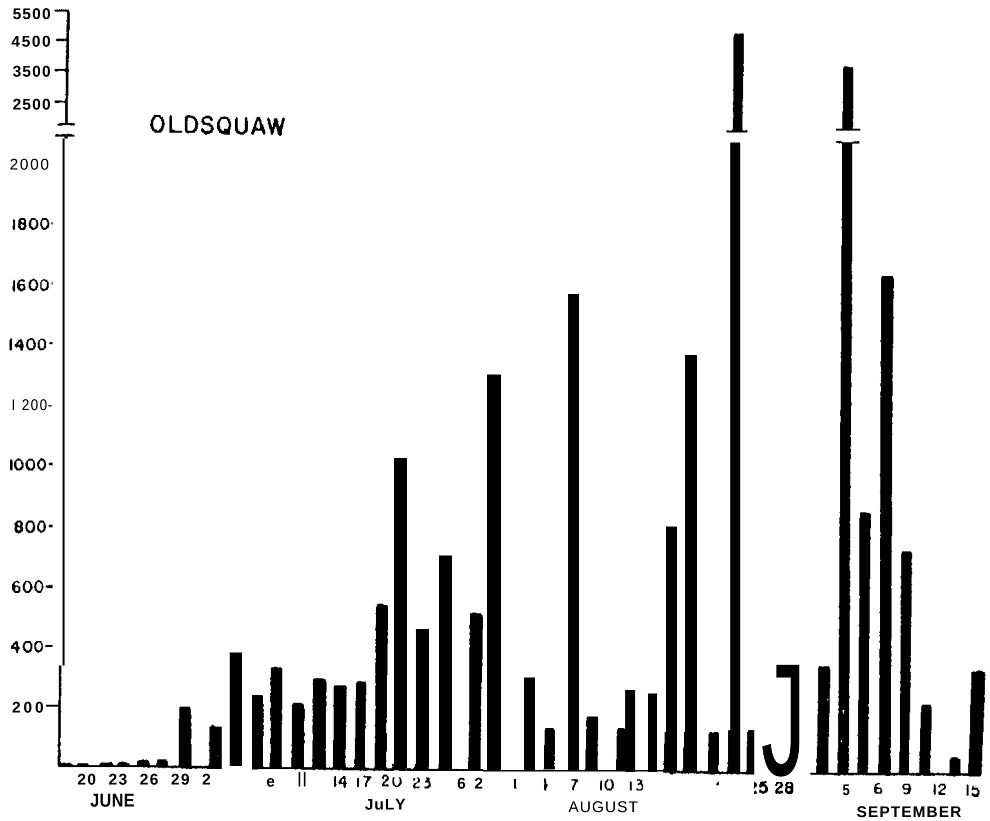


FIGURE 13. OLDSQUAW ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

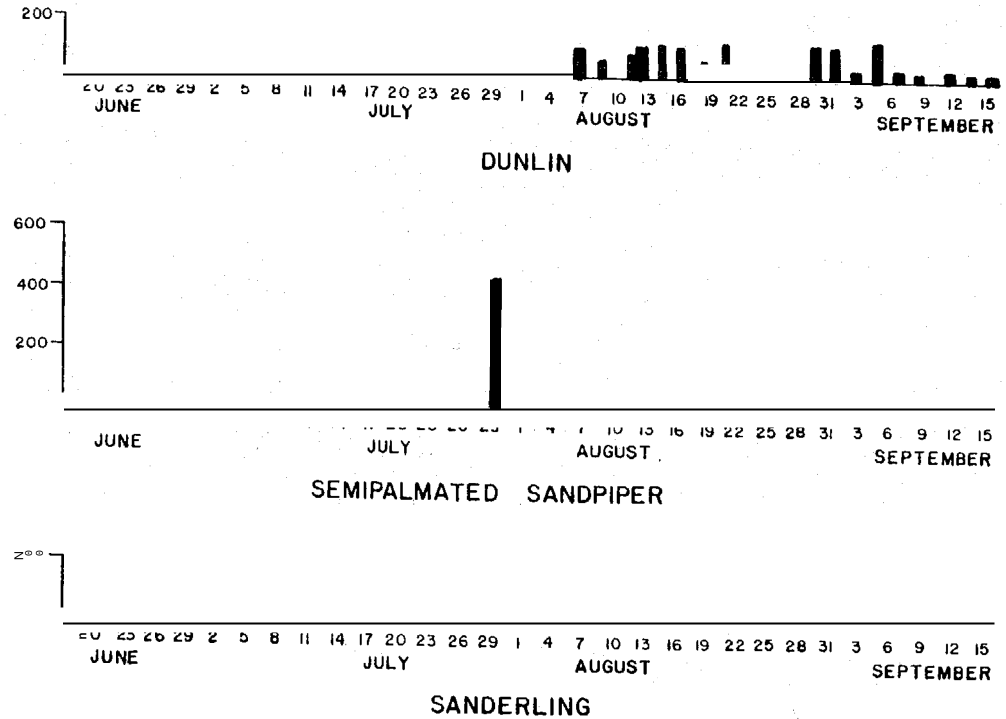


FIGURE 14. DUNLIN, SEMIPALMATED SANDPIPER, AND SANDERLING ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

8. Western Sandpiper

Scattered Western Sandpipers fed along beaches and mud shorelines of tundra ponds during the first two weeks of August in both 1976 and 1977.

9. Pectoral Sandpiper

Pectorals were sighted infrequently in both 1976 and 1977. Most birds roosted with other shorebirds in terrestrial habitats, and none remained on the island for extended periods.

10. Dunl in

Adult Dunlin began arriving in mid- to late July (Fig. 14), although they arrived at least a week earlier in 1977 than in 1976. The first juvenile birds were sighted in late July. Over 100 birds were present on several days in August and September, 1976. They fed with Ruddy Turnstones and Sanderlings by walking and pecking where beached invertebrates washed ashore.

11. Sanderling

Migrant Sanderlings were infrequent in early August of 1976 and 1977. Numbers peaked at 25 during the last week in August in 1976, but they continued conspicuous until mid-September (Fig. 14). Sanderlings fed individually at plankton washups on sand and gravel beaches.

12. Red Phalarope

This species occurred throughout 1976 and 1977 seasons (Fig. 15). Low numbers, primarily adult females, occupied mud shorelines of tundra ponds and Elson Lagoon in June and early July. Some jousting occurred between females as they chased males over the island and the lagoon. A small influx of males occurred in mid- to late July in both 1976 and 1977.

Juvenile phalaropes arrived in large numbers in late July and early August, and continued abundant until the first large storm in August. Peak numbers in one transect series were over 8000 in 1976 and nearly 3500 in 1977. In both 1976 and 1977 the greatest juvenile phalarope feeding flocks occurred where Apherusa glacialis, an under-ice amphipod, was the dominant available prey. Large flocks roosted on the island, especially on unvegetated flat areas near the breeding bird colony. Numbers quickly dwindled when the pack ice blew offshore, Several late season aggregations of feeding

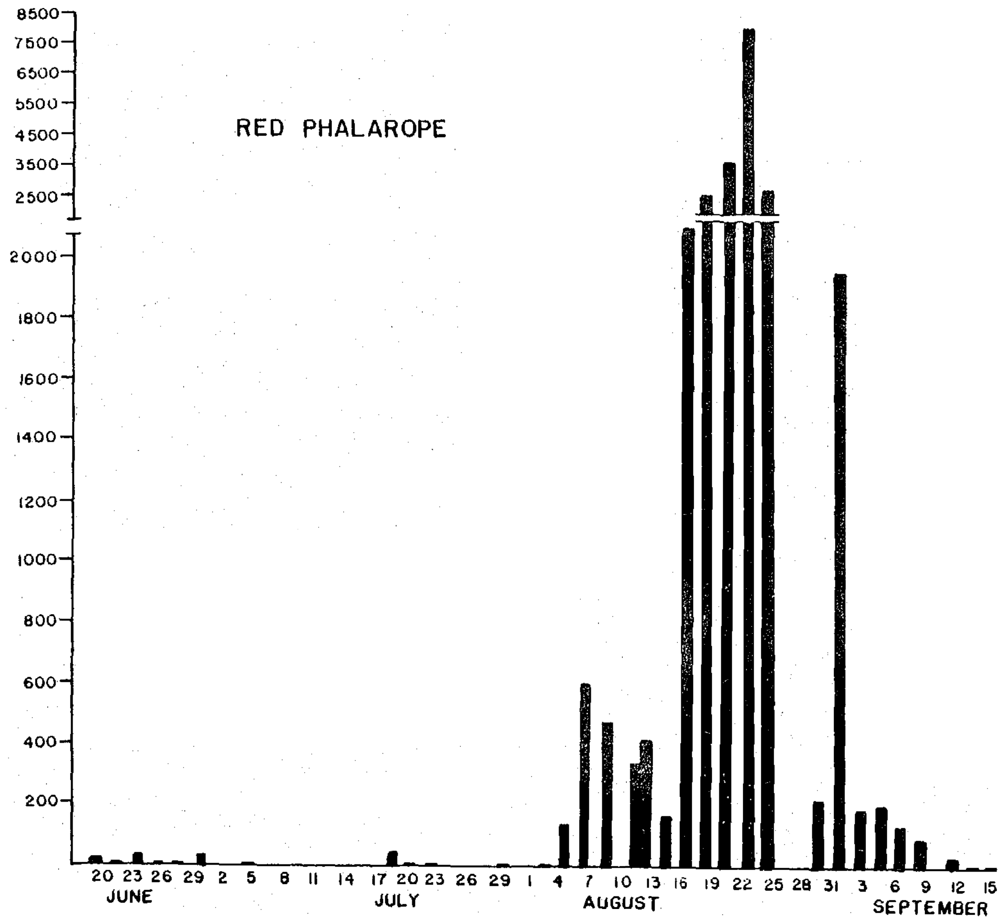


FIGURE 15. RED PHALAROPE ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

phalaropes occurred during the open water period in 1976 when patches of zooplankton washed on barrier island beaches.

13. Jaegers

Passing jaegers were sighted nearly every day in 1976 and 1977. Pomarine Jaegers were common in June and early July, but were infrequent later in the summer. Parasitic Jaegers were the most abundant jaeger of late July and August, oftentimes parasitizing terns returning fish to the island. Long-tailed Jaegers were seen steadily only during early to mid-July, although rare individuals fed in feeding flocks of Arctic Terns, Sabine's Gulls, and Red Phalaropes associated with *Apherusa glacialis*. Few jaegers used island habitats, as breeding Arctic Terns vigorously mobbed most passing jaegers.

14. Glaucous Gull

We observed Glaucous Gulls daily (Fig. "16). Most were individuals or small groups which flew over the island without stopping. Buildups of feeding gulls occurred whenever patches of suitable plankton species, especially Euphausiids and Copepods, washed onto shallow beaches. After feeding activity slowed or stopped at a feeding flock site, perhaps due to depletion of prey or changes in conditions decreasing food availability, Glaucous Gulls often roosted onshore for several hours or days before departing the island. These roosting birds were very wary of human activity, taking flight with minimal disturbance.

15. Sabine's Gull

The Plover Islands lie along a major migratory route of this species (Fig. 16). Sabine's Gulls were a major component of August feeding flocks associated with *Apherusa glacialis* and other plankton species. Habitats used by Sabine's Gulls for feeding included almost all shorelines of the island and entrances between barrier islands. Feeding methods of these birds were quite flexible, icluding dipping, surface siezing, and walking and pecking on beaches. Many Sabine's Gulls, however, flew by the island in large flocks without feeding.

Prior to 1 August, all birds were either breeding adults or speckled-headed non-breeders (subadult one year olds?). The first juveniles arrived with their parents in early August. Sabine's Gulls rapidly decreased in numbers after the pack ice blew offshore in August of both 1976 and 1977.

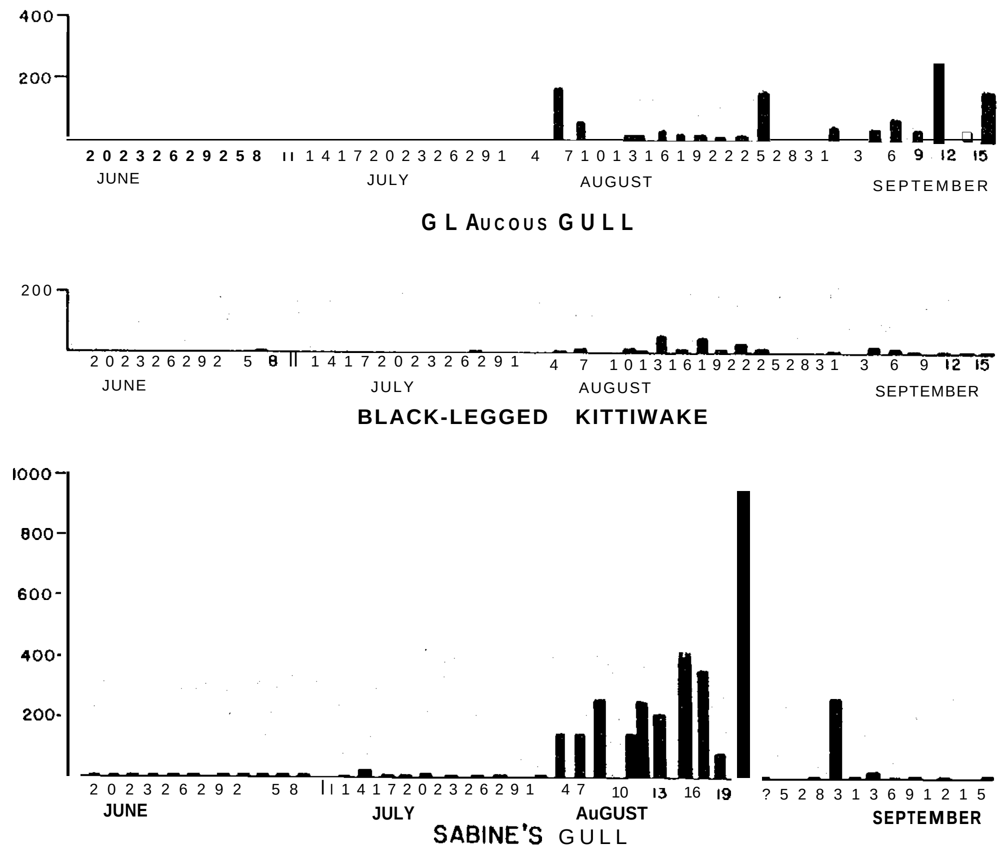


FIGURE 16. GLAUCOUS GULL, BLACK-LEGGED KITTIWAKE, AND SABINE'S GULL ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

17. Arctic Tern

Like Sabine's Gulls, Arctic Tern migration patterns suggest the Plover Islands lie along a major tern migratory route (Fig. 17). Beginning in late July, and depending upon the continued presence of prey into September, large numbers of terns used Cooper Island habitats for feeding and roosting. Major tern feeding habitats were shallow waters at barrier island beaches and at entrances between barrier islands where patchy zooplankton concentrations washed ashore, The largest buildups of terns occurred at feeding flocks associated with Apherusa glacialis and Thysanoessa spp.

The first flocks of non-breeding terns, all adults, arrived in mid-July in both 1976 and 1977. Juveniles first arrived with their parents in late July, but the bulk of tern migration occurred during the first three weeks of August in 1976 and early August in 1977. Numbers of birds in feeding flocks decreased rapidly after the removal of sea-ice from inshore waters , but terns also joined feeding flocks during the open water period when patches of Euphausiids and other zooplankters washed ashore.

18. Lapland Longspur

A wave of 100 to 200 immature longspurs occurred in mid-August in both 1976 and 1977. These birds occupied the island’s tundra patch, usually milling in small groups, but also pecking around vegetation as if feeding.

C. Plankton tows

Surface plankton tow results are presented in Figures 18 - 22. These tows were intended to provide seasonal trends in relative plankton abundances in nearshore waters of Cooper Island. Many sampling errors are inherent in such tows, consequently, depending on the species, such information may be an incomplete representation of real conditions. Major problems encountered are patchiness of plankton species, net avoidance, and the fact that we cannot perceive and capture prey items similarly to feeding marine birds.

1. Plankton species present in inshore waters during the entire summer season

The only species present in ample numbers throughout all ice periods were amphipods occupying primarily benthic habitats, such as Gammarus spp. and Onissimus Spp. “These animals did not display overt patchiness, but instead seemed evenly dispersed in suitable

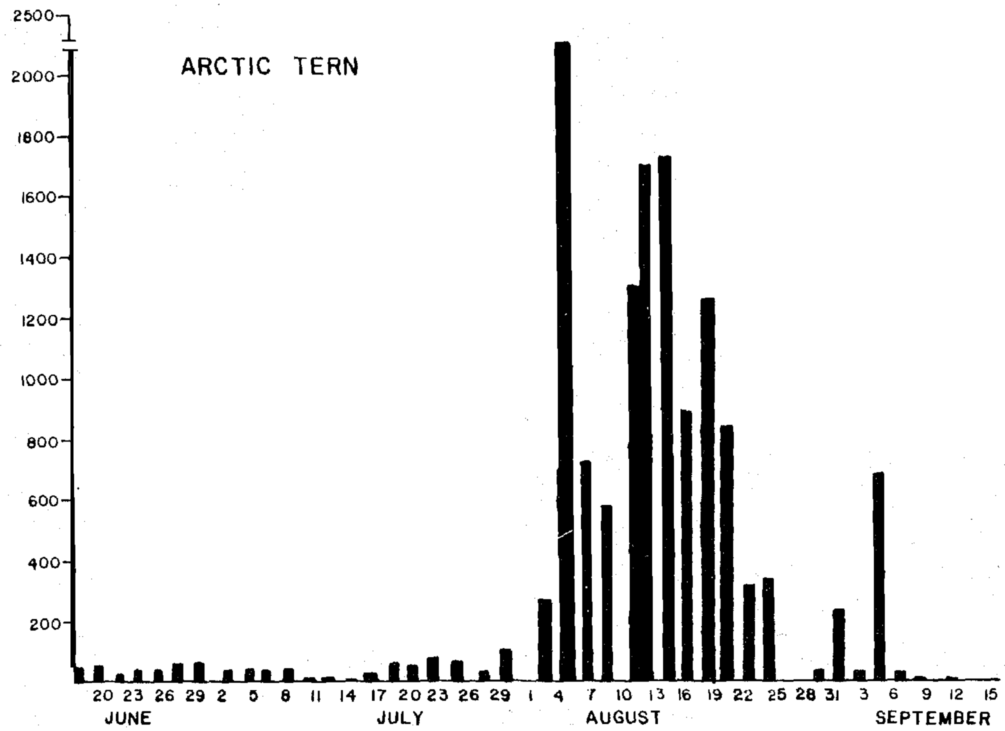


FIGURE 17. ARCTIC TERN ABUNDANCES ON SHORELINE TRANSECTS, COOPER ISLAND, 1976

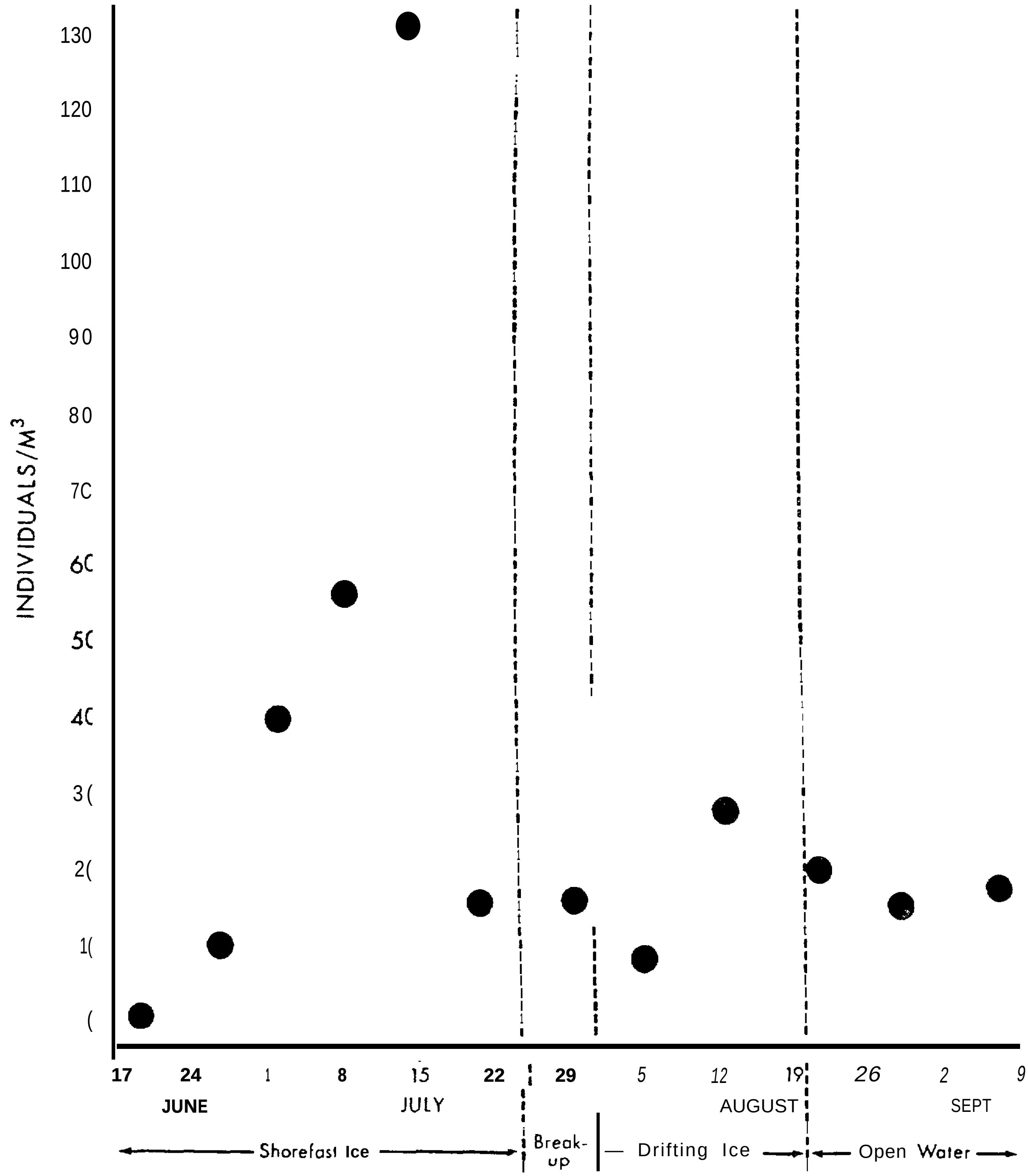


FIGURE 18. ZOOPLANKTON DENSITIES, ALL SPECIES, COOPER ISLAND, 1976

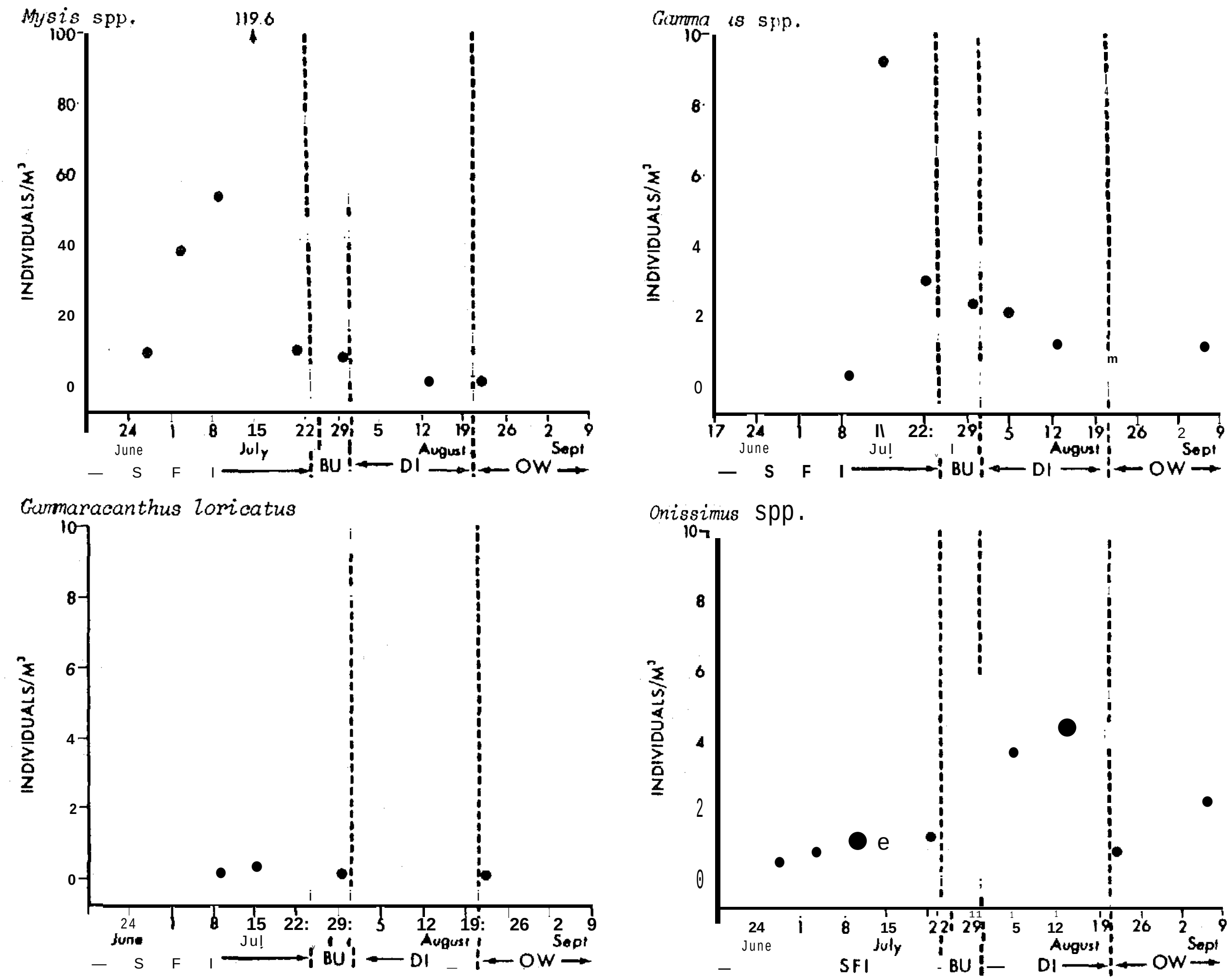


FIGURE 19. DENSITIES OF MYSIS SPP ., GAMMARUS SPP ., GAMMARACANTHUS LORICATUS, AND ONISSIMUS SPP ,

CAPTURED IN PLANKTON TOWS, COOPER ISLAND> 1976

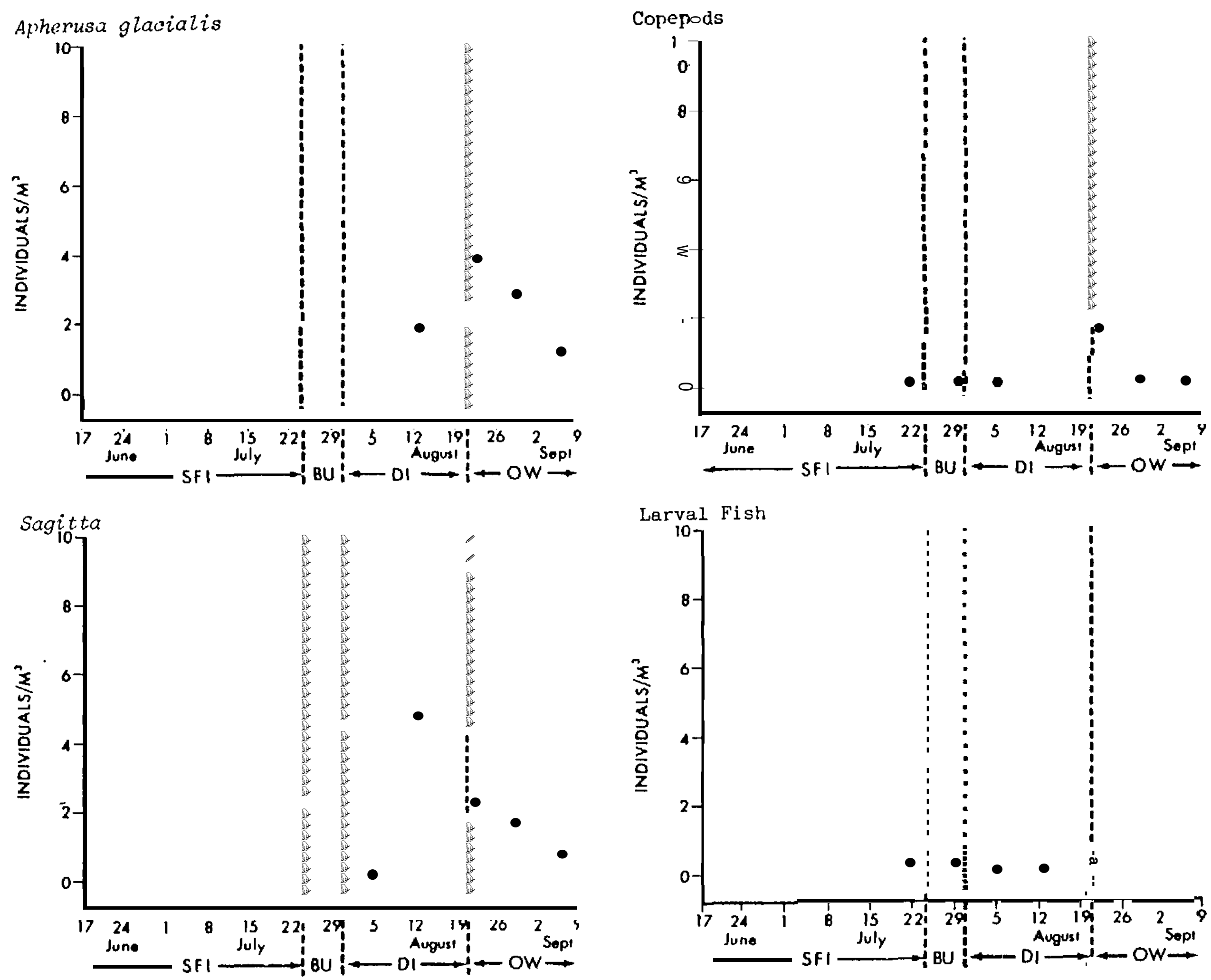


FIGURE 20. DENSITIES OF <u>APHERUSA GLACIALIS</u>, COPEPOD SPP., <u>SAGITTA ELEGANS</u>, AND LARVAL FISH CAPTURED IN PLANKTON TOWS, COOPER ISLAND, 1976

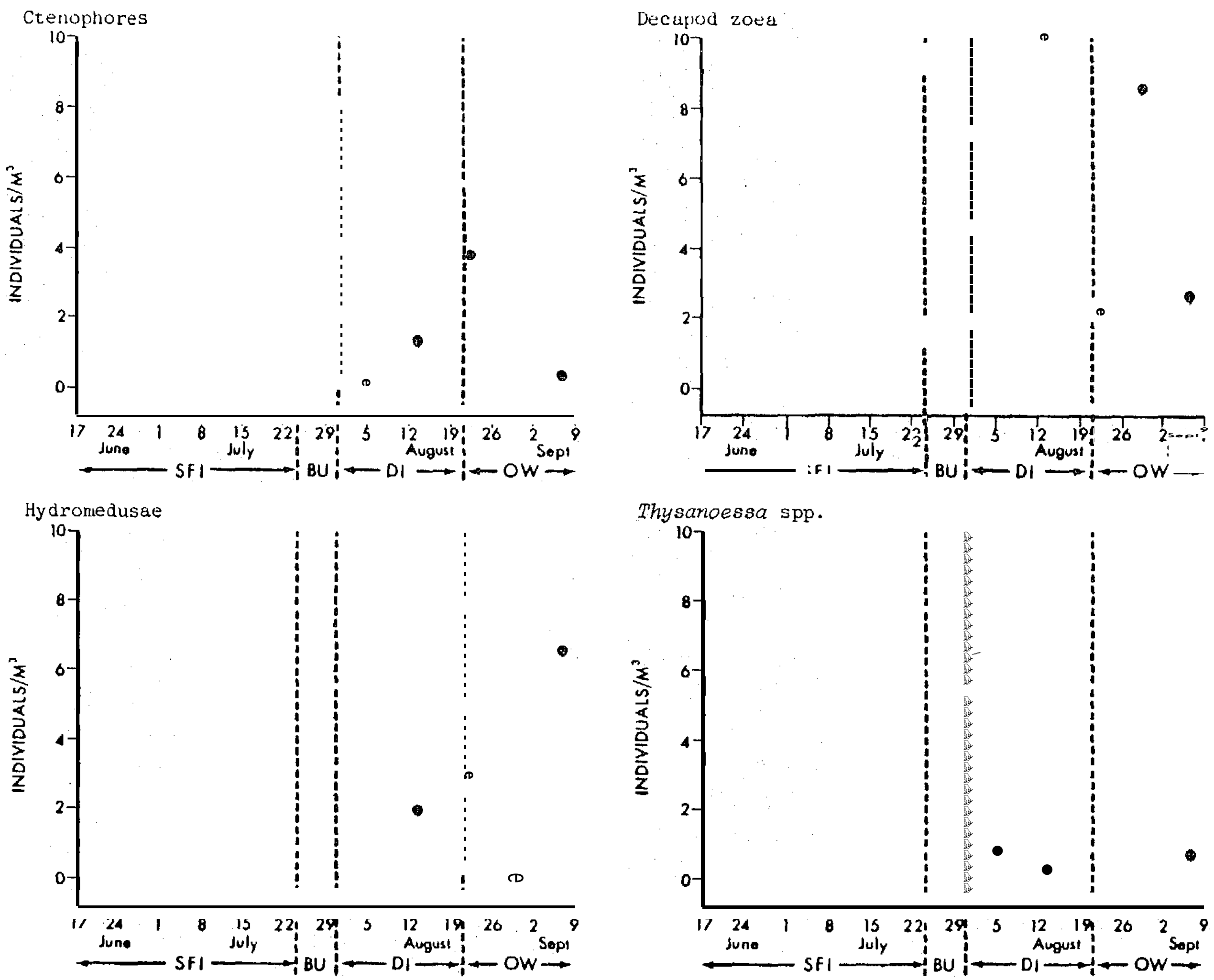


FIGURE 21. DENSITIES OF CTENOPHORES, DECAPOD ZOEA, HYDROMEDUSAE, AND <u>THYSANOESSA</u> SPP. CAPTURED IN PLANKTON , <OOPER ISLAND, 1976.

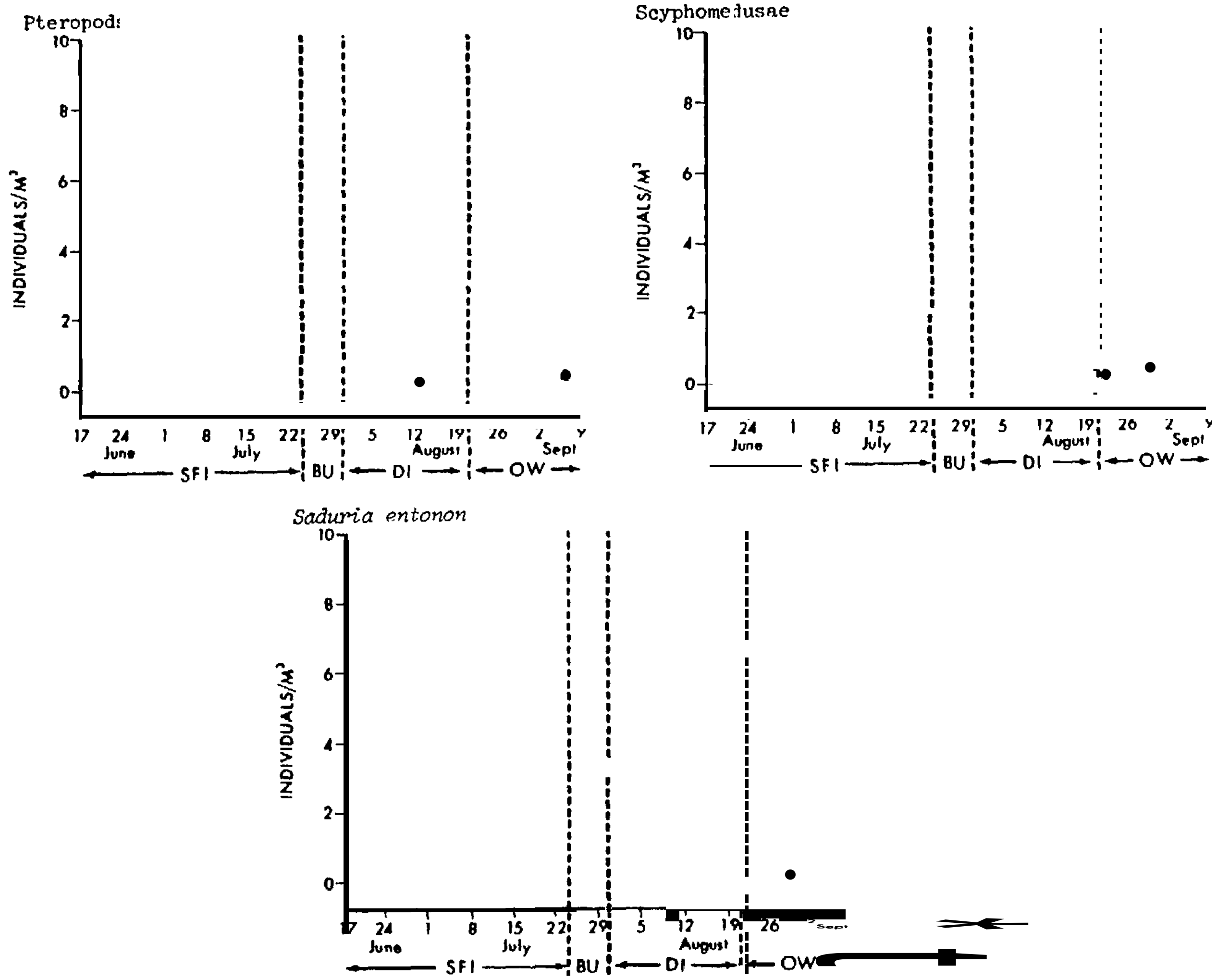


FIGURE 22. DENSITIES OF PTEROPODS, SCYPHOMEDUSAE, AND SADURIA ENTOMON CAPTURED IN PLANKTON TOWS, COOPER ISLAND, 1976

habitats. Both these genera were captured at all plankton collection sites, although Gammarus appeared most abundant in gravel substrates north of the island and Onissimus appeared to prefer mud substrates of Elson Lagoon.

During the shorefast ice and shorefast ice breakup periods Arctic Terns and Sabine's Gulls fed where these species were readily visible in shallow water. They were less important to breeding bird species later in the summer, as most birds fed at patchy concentrated prey after breakup of shorefast ice.

2. Species abundant in shorefast and shorefast ice breakup periods, but decreasing in densities later in the summer

Dense masses of juvenile Mysis spp. (most <10 mm) occupied inshore waters during the shorefast ice period. These individuals reached greatest densities near the bottom, although they also made excursions into the water column. Several times we noticed benthic amphipods (Gammarus and Onissimus spp.) with small Mysids in their mouthparts, suggesting these animals provided some input into the trophic structure of inshore waters. Larger Mysids were present, most about 15 to 30 mm long; it appears as if these larger individuals were captured by dipping Arctic Terns during the shorefast ice period. Mysids markedly decreased in plankton tows after breakup of shorefast ice.

Gammaracanthus loricatus was noticably conspicuous during the shorefast ice breakup period near the island's west end. Several large individuals (20 to 40 mm) were found on the underside of ice cakes when these cakes were inverted. Small feeding flocks of Arctic Terns occurred at West End at this time, suggesting Gammaracanthus was a likely prey species for these birds.

3. Species with noticable affinities to certain ice types during the drifting pack ice period

Apherusa glacialis reached its greatest abundance under multi-year ice cakes. These amphipods became available to surface feeding birds when the multi-year cakes they adhere to grounded and deteriorated on shorelines or in entrances between barrier islands. Apherusa was extremely patchy, obviously concentrating where cakes deteriorated onshore. Consequently our sampling techniques at fixed shoreline stations do not convey their true overall abundances.

The most persistent feeding flocks of surface feeding migrants were associated with Apherusa. Red Phalaropes, Arctic Terns, and Sabine's Gulls fed extensively on these prey items in inshore waters. Apherusa and feeding flocks associated with it were most numerous in 1976, a year of abundant multi-year ice. The great amounts of multi-year ice in this year was undoubtedly due to the extremely heavy ice conditions in 1975.

4. Species with no strong ice affinities reaching greatest abundances during drifting pack ice and open water periods

Several species apparently not associated with specific ice types, and in fact reaching greatest abundances away from ice, appeared on Cooper Island shorelines as current waifs in single and mixed species patches. These included Euphausiids (Thysanoessa spp.), Chaetognaths (Sagitta elegans), Copepods (Uritoma canadensis ?), Pteropods (Limacina and Clione), Decapod zoea, Ctenophores, and Hydromedusae. These species appeared concentrated by small-scale oceanographic conditions in nearshore waters, such as convergence between barrier islands, collisions of patches with barrier island shorelines, and Langmuir spirals. Many individuals in these patches appeared lifeless, possibly due to inhospitable environmental conditions such as abrupt temperature and salinity changes in shallow inshore waters.

Several of these species, most notably Thysanoessa, Sagitta, Uritoma, and Limacina became the focus of late season feeding flocks of marine birds. Arctic Terns, Sabine's Gulls, Glaucous Gulls, and Red Phalaropes constituted the bulk of these feeding flocks.

D. Human use

Several Eskimo groups used Cooper Island during our study, all reaching the island by boat. All appeared to be family groups containing adults and children. Most used the island as a rest stop for a few hours while traveling between Barrow and mainland campsites. One group using a site adjacent to the island's breeding colony shot one adult Arctic Tern and turned over a Black Guillemot nest site without harming the chicks. Another family of one man, one woman, and two sons, became trapped by heavy ice in Elson Lagoon and camped on the island's south shoreline for two days. This group never entered seabird breeding areas, as far as we know.

During 1976 and 1977 only two Eskimo families intentionally camped extended periods on Cooper Island. One of these was a family of one man, one woman, and two sons who camped two nights on the island's north shoreline. They stated they were vacationing away from Barrow for several days. The family frequently walked about the seabird colony, turning over several Black Guillemot nest sites. They also used a plywood guillemot nest cover as a windbreak for their tent. No apparent chick mortality resulted from these activities. A second family camped in the middle of the breeding colony for four days, waiting for improved ice conditions so they could hunt Bearded Seals to outfit their umiak. One 8 year old boy in their party shot several non-breeding birds, especially Glaucous Gulls, with a .22 rifle. One breeding adult Arctic Tern was shot near their camp, presumably because it annoyed people by attacking them near its nest. The family disturbed no guillemot nest sites, even though nests with young chicks lay less than 50 m from their camp.

Overall, Eskimo impact on Cooper Island breeding birds was slight. Deteriorating shorefast ice surrounding Cooper Island until late in the birds' incubation periods seems to preclude egging of the island by Barrow residents.

Cooper Island lies along a busy aircraft route from Barrow to points east. Many aircraft, particularly small planes and helicopters, fly very low over barrier islands. These low flights invariably scare Cooper Island breeding birds off their nests, but most return soon after disturbances subside. The quick return to nest sites after disturbance may be characteristic of species breeding on Cooper Island. Species using other barrier islands, such as eiders and geese, may remain off nest sites for extended periods, making their nests vulnerable to predation in their absence.

Aircraft disturbance has not been a regular problem during the the last two summers, although increased traffic associated with development could potentially decrease breeding success. The greatest disturbance during the last two years appears to have been due to Coast Guard helicopters constructing a radar deflection tower and NARL aircraft outfitting our field camp. Only one guillemot nest located outside the major nesting colony possibly failed due to this disturbance. Such disturbance can be avoided by eliminating over-flights of breeding areas.

The greatest potential disturbance to Cooper Island breeding birds occurred when a cleaning crew contracted by Naval Petroleum Reserve 4 attempted to burn unnatural driftwood and remove oil barrels at Cooper Island in June, 1976. Although well meaning, this cleanup attempt-ignored the fact that some bird species may adapt over time to using human associated debris for nest sites. What at one time was unnatural litter has now become essential breeding habitat for certain bird populations, Obviously, the Cooper Island Black Guillemot population would be extirpated if cleanup operations destroyed its nest cavities. Our presence on the island prevented this from occurring in 1976, but future development must be closely observed to limit the threat of well-intentioned cleanup operations.

V. Discussion

A. Breeding chronology

Cooper Island breeding birds initiate egg laying in late June when shorefast ice still lies onshore, Due to nearly 100% ice cover at this time, marine food is minimally accessible near the island. This forces terns and gulls to fly several kilometers to feed on the mainland and guillemots to fly similar distances to feed in offshore leads. The potential for predation by Arctic Foxes is also highest at this time, as foxes have easy access on the island by shorefast ice. Breeding birds, however, could avoid essentially all fox predation if they delayed egg laying two to three weeks, permitting substantial deterioration of inshore ice and effective isolation of the island from foxes. This assumes foxes would not remain on the island prior to inshore ice breakup if no food in the form of eggs were available. A basic question arises concerning why breeding birds begin egg laying at a time when food is essentially inaccessible near the island and predation pressure is the greatest.

For Arctic Terns, the answer seems to lie with Arctic Cod, the principle prey species used for chick feeding. Arctic Cod is a cryopelagic species associated with the Arctic pack ice (Andriashev, 1970). It is readily accessible for a brief period each year during the shorefast ice breakup and drifting pack ice periods. What becomes of cod after ice is blown offshore in late summer is unclear, but it appears it may either be removed with the ice or may become inaccessible due to changes in its distribution in the water column once it has lost its ice refuges. Alverson and Wilimovsky (1966) captured large numbers of adult cod in otter trawls north and west of Cape Lisburne in open water, but none in mid-water trawls. This suggests these fish descend to depth in open water. Quast (1974) also showed that cod were uncommon in surface waters away from ice. At any rate, it appears the timing of breeding in Cooper Island Arctic Terns is adapted to take advantage of this cryopelagic species in nearshore waters during chick feeding. On average, the chick period in the population begins early in the shorefast ice breakup period and concludes near the end of the drifting pack ice period, the seasonal periods in which cod and other cryopelagic fauna are readily available for these birds.

The chick period of Black Guillemots, on the other hand, usually extends into the open water period in September. There is some evidence that other fish species in guillemot diets, most notably Four-horned Sculpin, increase in importance relative to Arctic Cod during open water. Sculpin, due to their benthic habits, may not be as accessible for terns as for guillemots. Of interest is the fact that guillemots had phenomenal fledging success (97%) in 1975, an extremely heavy ice year in which drifting pack ice, and presumably Arctic Cod, remained inshore well into September. In contrast, 1977, a very light ice year in which drifting pack ice blew far offshore by mid-August, was also a year of relatively poor guillemot fledging success (56%). Consequently, it appears that guillemots also rely to a great extent on cod as a prey species during chick feeding, and have potentially greater fledging success when cod remains available throughout the chick period.

B. Arctic Fox predation

There is no doubt that Arctic Foxes have tremendous impact on the reproductive success of island bird populations. Two foxes intermittently worked Cooper Island in each of 1976 and 1977, yet none appeared in 1975. The explanation for yearly differences in fox predation may lie with abundances and availability of alternate prey sources used by foxes in early summer (Larson, 1960). Low lemming years on the mainland, such as 1977, may force foxes onto barrier islands and offshore ice in search of food. Offshore oil development may have the same result if foxes switch from natural prey to scavenging human encampment s'.

The condition of foxes collected on Cooper Island. gives a clue to the status of foxes working barrier islands. The stomach of one fox in 1977 contained a female Oldsquaw, whereas the other fox's stomach was packed full of seal blubber. Both animals had adequate fat and appeared quite healthy. This suggests Cooper Island was not a last resort for potentially starving animals, but instead was probably only one of several feeding sites used periodically within their home ranges. Prey preferences and foraging areas of Arctic Foxes in coastal areas need closer attention to adequately assess their impact on breeding birds in relation to OCS development.

The activity of a predator at a colony may not only decrease breeding success through overt predation of eggs and chicks, but also by inhibiting egg production, inducing parental neglect, and upsetting the chronology of breeding events (Emlen et al., 1966). All these occurred on Cooper Island during the study. Subtle effects such as this are difficult if not impossible to perceive without knowledge of breeding patterns in years of little or no predator activity.

C. Arctic Tern breeding success

As stated, much variability existed in year to year breeding success of Cooper Island breeders, especially Arctic Terns. This is attributed to variation in Arctic Fox predation and the availability of prey species associated with specific ice conditions during the chick period. Other studies also show variation in year to year success of Arctic Terns at various latitudes. Bengtson (1971) and Norderhaug (1964) report breeding success at Spitsbergen colonies ranging from 14% to 78%. Pettingill (1939) and Hawksley (1957) report breeding success at Bay of Fundy in New Brunswick ranging from 16% to 35%. Causes of mortality included Arctic Fox predation (Bengtson, 1971), starvation due to food shortages (Bengtson, 1971), weather (Gollop et al., 1974) and intrinsic colonial disturbances such as chicks killed by adults, chick disappearances, and abandonment (Pettingill, 1939). It appears, therefore, that high variation in breeding success is typical of Arctic Terns, depending upon predation and environmental factors. Once these factors are reasonably understood the impacts of increased human disturbances associated with oil development are possible.

D. Zooplankton concentrations

The most important prey source for migrant surface feeding birds in inshore waters of the Plover Islands is patchily distributed zooplankton species. As stated, the Plover Islands lie along a major migratory route for barrier island and tundra nesting Arctic Terns, Sabine's Gulls, and Red Phalaropes. Feed ing flocks of these and other species numbering several thousand individuals aggregate when and where plankton patches appear inshore.

Conditions promoting concentrations of zooplankton during the migratory period seem extremely important for these birds. One key plankton species, Apherusa glacialis, is consistently more abundant when the multi-year drifting pack ice it adheres to is pushed inshore by predominant NE winds. As ice deteriorates in shallow water Apherusa is robbed of its refuge, enters the water column, and becomes accessible to surface feeding birds. Year to year variation in the amount of multi-year ice obviously affects Apherusa abundance. Folowing the heavy ice year of 1975, multi-year ice was present over an extended period during the drifting iced period in 1976. Surface feeding birds fed abundantly at Cooper Island shores and at entrances between barrier islands at that time. The multi-year ice period was short-lived and relatively unspectacular in 1977, resulting in infrequent, yet at times intense, feeding on this prey.

Other patchy zooplankton species not associated with particular ice types showed greater affinities to open water. These species (Thysanoessa spp., Sagitta elegans, Copepods, Pteropods, Ctenophores, and Hydromedusae) appeared passively concentrated and transported in inshore waters by various small-scale oceanographic conditions, such as convergence of water types between barrier islands and Langmuir spirals. Their initial appearance nearshore may be regulated by large-scale water mass movements offshore.

Ctenophores and Hydromedusae make up the bulk of many patches, sometimes so abundant as to create a thick soup of protoplasmic jelly. Human skin sometimes feels prickly and irritated when dipped in water containing large numbers of these organisms, perhaps due to released nematocysts in the water. The sluggish and "lifeless activity of organisms in these patches may also be due to high nematocyst concentrations, or, as previously suggested, to abrupt temperature and salinity differences at convergence of water types.

At this time it appears two primary factors have greatest "impact on concentrations of zooplankton near the Plover Islands:

1) The effects of shorelines and shallow water concentrating prey species near the surface, hence accessible to surface feeding birds.

2) Local oceanographic factors creating boundary conditions which passively concentrate zooplankton in the water column,

Additional possibilities are biotic factors inherent in the populations themselves, although the lack of basic natural history facts of these populations precludes any speculation in this regard. Much more information is needed to accurately predict the spatial and temporal occurrence of zooplankton patches, and thus feeding aggregations of marine birds.

E. Human use

Human activities from 1975 to 1977 did not play a major role in the breeding success of Cooper Island birds. Increased human disturbance, however, may increase egg and chick mortality even though no overt predation, such as egging, takes place (Gillett et al., 1975; Robert and Ralph, 1975). Most eskimos used the island as a temporary stopover while traveling to and from Barrow, but few intentionally camped on the island during the breeding season. These family groups seemed curious but generally indifferent about the breeding bird populations. Ice conditions seem to limit access to the island when birds are most prone to predation by humans through egging.

Increased activities associated with oil development pose a much greater threat to breeding birds. Helicopters are a preferred mode of transportation to barrier islands because they require little runway, yet helicopters are noisy and cause intense disturbance of breeding birds when flying at low altitudes. Aircraft disturbance could easily be minimized by avoiding low over-flights of areas with high densities of breeding birds. Pilot education is perhaps the best method to decrease unnecessarily low over-flights, as many pilots seem unaware of the havoc caused by their aircraft to colonial bird populations. Permanent structures and intentional or unintentional disturbances associated with them may also substantially reduce breeding productivity, but careful monitoring of human activities near breeding colonies can do much to limit overt disturbances.

Catastrophic events associated with oil developments are possibly the greatest threat to breeding and migrant populations. Oil spills near Cooper Island could result in high immediate mortality of bird species spending large amounts of time afloat on the water's surface, such as Oldsquaw and Black Guillemot. Small-scale oceanographic conditions which concentrate drifting zooplankton at shorelines and in entrances between barrier islands may also concentrate floating oil at sites used by feeding birds, killing prey organisms and preventing access to prey. Marine invertebrates in the arctic are slow growing (Dunbar, 1968), thus impacts of oil spills may be long lived if prey species are affected. Additionally, cleanup operations in ice affected areas are extremely difficult, as oil trapped below ice eludes cleanup operations (Glaeser and Vance, 1971). Also, biological degradation of oil in cold arctic regions requires long periods, upwards of 10 years (Hoult et al., 1975). It appears, therefore, that effects of oil spills near the Plover Islands can be immediately devastating yet seriously prolonged by the nature of the arctic environment.

As suggested by Vermeer and Anweiler (1975), lagoon systems inside of barrier islands are possible protected sites for ducks and other surface resting seabirds if offshore spills are prevented from entering between islands. They suggest the use of oil-blocking booms across lagoon entrances to isolate lagoons in case of spills. Such arrangements are possible in the Plover Islands area and other lagoon systems on the arctic coast. These measures could protect the sizable Oldsquaw population in the event of offshore spills during its most vulnerable wing molt period in July and August. Oil spills within lagoons, however, could cause devastating mortality to these ducks.

An additional problem deals with unnatural driftwood and metal used by cavity nesting birds for nest sites. As stated, these breeding populations, particularly Black Guillemots, can be enlarged by the placement of suitable structures in breeding colonies. Conversely, excess human materials strewn about barrier islands are potentially unsightly. Perhaps a trade-off must be made between increased populations of breeding birds and increased debris on the islands. Perhaps populations should increase only as chance events allow, such as large storms depositing much debris on islands suitable for nesting. The conditions are perfect, however, for experimentation in a field situation of populations limited in size by available nest sites. Ecological questions such as variable reproductive success of inexperienced versus experienced nesting pairs and social factors affecting populations in a saturated environment can be approached in experimental situations as presented on Cooper Island. So few people visit the barrier islands that the unsightliness of controlled amounts of litter is immaterial compared with the benefit gained by certain bird populations.

VI. Conclusions

Despite the relatively small size of Cooper Island breeding populations compared with colonial seabirds in southern Alaska, these populations are a unique aspect of marine birds in the state. The island's Black Guillemot population is the largest in Alaska. The Arctic Tern population is the largest barrier island tern colony in the Chukchi and Beaufort Seas (G. J. Divoky, 1977 Annual Report). The importance of the island for breeding species is primarily due to its available nesting habitat and the accessibility of prey organisms in nearshore waters during the chick period. The availability of principle prey species, especially Arctic Cod, is closely tied to patterns of pack ice conditions near the island.

The Plover Islands are also an important feeding and roosting habitat for post-breeding migrants. Thousands of migrating birds pass the islands in July, August, and September. The islands and the Elson Lagoon system are especially critical for molting male Oldsquaw and several surface 'feeding planktivores such as Red Phalaropes, Arctic Terns, and Sabine's Gulls. The geographical arrangement of the islands, their inshore topography, and wind, ice, and current factors affect local oceanographic conditions to concentrate zooplankton and make them accessible to these birds.

Breeding and non-breeding bird use during the summer season will be summarized by ice period:

1) Shorefast ice period - June to mid-July

During this period the island is surrounded by eight oktas of shorefast and grounded first year ice. Narrow inshore moats of open water widen continually during the period, from O to 10 m in mid-June to 20 to 200 m mid-July.

Little breeding bird use of inshore waters occurs during this period, other than occasional foraging by Arctic Terns and Sabine's Gulls. The prey of these birds appears to be two gammarid amphipods, Onissimus Spp. and Gammarus spp. , and a mysid, Mysis spp. Terns and Sabine's Gulls fly south to feed at mainland habitats during this time. Guillemots rarely feed in the moats, as their feeding areas at this time appear to be offshore leads in the Beaufort Sea.

Non-breeding bird use of the island and surrounding waters is low at this time. Oldsquaw and loons regularly use moats for feeding and loafing. Red Phalaropes and Brant occasionally occupy terrestrial habitats, especially the island's tundra patch.

2) Shorefast ice breakup period - mid-July to late July

Early in the period rotten first year ice near the island begins splitting along thaw channels, releasing cakes and floes into moats and leads. General ice coverage is O to 2 oktas nearshore and 6 to 8 oktas beyond. Extensive thaw holes and channels exist beside the moats and leads. Deterioration continues until the shorefast ice disappears and drifting pack ice is pushed into inshore waters. The lagoon south of the island becomes free of ice during this period.

Small Arctic Tern feeding flocks, primarily of breeding birds, occur regularly, concentrating in areas of decomposing ice. Tern feeding trips south of the island decrease, and trips north of the island increase as terns begin foraging in thaw channels offshore. Black Guillemots begin feeding closer to the island, especially along ice margins in moats and leads. Guillemots and terns begin feeding on Arctic Cod in inshore waters. The timing of inshore ice breakup appears to be an important transitional period for breeding species beginning chick feeding.

Oldsquaw males occupy the island and lagoon waters in large numbers throughout the period, feeding in moats and leads and roosting on shorelines and ice beside moats. Several species, such as Semipalmated Sandpiper, Dunlin, Red Phalarope, Arctic Tern, and Sabine's Gull begin arriving as post-breeding migrants, utilizing the island's shorelines and adjacent waters for feeding.

3) Drifting pack ice period - late July and early August until the first major storm with winds strong enough to blow ice far offshore.

Persistent NE winds push drifting small to medium cakes and floes onshore and into lagoons during this period. Cakes and brash ice concentrate at shorelines. Ice coverage on the island's north side varies from 1 to 7 oktas depending on wind and current conditions. Multi-year ice and its cryopelagic fauna becomes plentiful near the island within this period.

Breeding birds feed close to the island throughout the period. Black Guillemots feed on the north side within 1 km of shore. Arctic Cod appear easily caught, as birds are often gone from nest short periods during successful fishing trips. Breeding Arctic Terns return both fish and available planktonic crustaceans, particularly a Euphausiid, Thysanoessa spp., and numerous Amphipods to their chicks.

Throughout the period non-breeding species form variable feeding flocks near the island. The most abundant species are Red Phalaropes (nearly all juveniles), Arctic Terns, and Sabine's Gulls. Jaegers, Glaucous Gulls, and Black-legged Kittiwakes are present in lesser numbers. Patchily dispersed zooplankton populations are the major prey items for these feeding flocks. Apherusa glacialis is especially abundant under deteriorating multi-year ice. Feeding flocks associated with Apherusa occur primarily near cakes and brash ice and in entrances between barrier islands where ice deteriorates as it enters Elson Lagoon.

Dunlins, Sanderlings, and Ruddy Turnstones feed intensively on beaches during this period. Oldsquaw, undergoing wing molt at this time, regularly raft and feed in large flocks south of the island.

4) Open water period - continues from ice retreat to freeze-up in early fall.

Ice conditions are less than one okta of drifting small to medium multi-year cakes.

Seabird feeding flocks associated with zooplankton species having less affinity for certain ice types and conditions occur during this period. Most migrants leave the island at this time. By mid-September Oldsquaw and Glaucous Gulls are the only species commonly using the island and surrounding waters, but passing migrations of Loons and Oldsquaw also take place.

OCS petroleum development potentially threatens these breeding and non-breeding bird populations. Initial development will increase human activity, which in turn may have deleterious impact on reproductive success of island breeders. Human activities may concentrate predators, such as Arctic Fox, which in turn may increase predation on breeding birds. Increased air traffic over the islands and increased foot and machinery traffic on the islands may upset breeding and non-breeding birds and force abandonment of habitat. Oil spills and alterations of shorelines may decrease prey availability. Obviously, the threat to wildlife in the Plover Island area is great if unthinking petroleum development occurs in the area.

Alternatives to disturbances are possible. Human activities can be limited to areas away from breeding colonies. Aircraft overflights can be prevented by pilot knowledge of critical nesting areas and by realization of the potential damage caused by their aircraft. Seabird species are generally long lived, consequently they can possibly recover from short term disturbances or reproductive failures. This was shown by Cooper Island Arctic Terns following a year of high Arctic Fox predation and near total breeding failure. Overt pollution caused by catastrophic oil spills can hopefully be rapidly contained and recovered, and barrier island – lagoon systems may provide some shelter for birds in the event of an oil spill. At best, OCS development in this inshore area should consider special measures to insure, or at least to not limit, conditions promoting use of these habitats by marine birds and related organisms.

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