

Population status of Kittlitz's Murrelet
Brachyramphus brevirostris
along the southern coast of the Alaska Peninsula



Final Report to U.S. Fish and Wildlife Service
U.S. Geological Survey Science Support Program
June 2005

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Cover photo: Survey vessel F/V *Alexandra* in Pavlof Bay, with summit of Pavlof Volcano (2,519 m) and southern slopes of Pavlof Sister in background. Photo by Kyle Juk.

TABLE of CONTENTS

ABSTRACT	page 4
INTRODUCTION	page 5
METHODS	page 7
RESULTS and DISCUSSION	page 10
CONCLUSIONS and RECOMMENDATIONS	page 12
ACKNOWLEDGEMENTS	page 16
LITERATURE CITED	page 17
TABLES	page 20
FIGURES	page 23
APPENDICES	page 37

ABSTRACT

The Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird that nests in alpine terrain and generally forages near tidewater glaciers during the breeding season. An estimated 95% of the global population breeds in Alaska, with some unknown proportion breeding in the Russian Far East. A global population estimate using best-available data in the early 1990s was 20,000 individuals. However, recent survey data from two core areas (Prince William Sound and Glacier Bay) suggest that populations have declined by 75-90% during the past 10-20 years. In response to these declines, a coalition of environmental groups petitioned the USFWS in May 2001 to list the Kittlitz's murrelet under the Endangered Species Act (ESA), and in 2004 Kittlitz's Murrelet was declared a candidate species under the ESA. In 2005, BirdLife International classified the species as "critically endangered".

In 2002, we began a three-year project to examine population status and trend of Kittlitz's Murrelets in areas where distribution and abundance were poorly known. Results from the 2002 field season, focused on the south coast of the Kenai Peninsula, suggested that the local population of Kittlitz's Murrelets has declined by ca. 74% since 1986, with a current population of ca. 500 individuals. Here we present results from the 2003 field season when we surveyed Kittlitz's Murrelets along the southern coast of the Alaska Peninsula. This is a large region that encompasses a substantial portion of the known range of the Kittlitz's Murrelet, yet has never been surveyed rigorously for murrelets or any other non-colonial marine birds.

During four weeks of surveys, we established a set of nearshore and offshore transects (over 825 linear kilometers in total) with a stratified sample design, combining random and systematically selected transects. From a total of 123 individuals seen on transects, we estimate a total population of 2265 (95% CI 1165-4405) Kittlitz's Murrelets along the south coast of the Alaska Peninsula. For comparison, we estimate the population size of the congeneric Marbled Murrelet (*Brachyramphus marmoratus*). We discuss broad-scale murrelet habitat relationships and species comparisons, and present recommendations for management and future work. Other species of marine birds and mammals were also surveyed; summarized information is included as an appendix.

INTRODUCTION

This report summarizes results from the second year of a three-year survey of Kittlitz's Murrelets (*Brachyramphus brevirostris*) in areas where significant populations were expected to occur, but where few data on populations are available. The Kittlitz's Murrelet is one of the rarest seabirds in North America, and most aspects of its biology remain obscure. A summary of limited data as of 1993 suggested a total world population of about 20,000 Kittlitz's murrelets (van Vliet 1993). Most of the global population breeds in Alaska, with some unknown number breeding in the Russian Far East. The most recent population assessment concluded that the current Alaska population of Kittlitz's Murrelets is between 9,000 and 25,000 birds, though that estimate was qualified as "speculative and dated" (U.S. Fish and Wildlife Service, 2003). In May of 2001, a coalition of environmental groups petitioned the USFWS to list the Kittlitz's murrelet under the Endangered Species Act, partly in response to available evidence from replicated Kittlitz's murrelet surveys showing indications of alarming declines in the species across their core geographic range. In 2004, the Kittlitz's Murrelet was declared a candidate species under the ESA. Adding to the recognition of concern for the species' future, BirdLife International (BLI) has recently classified Kittlitz's Murrelets as "critically endangered" owing to a variety of threats, joining the Eskimo Curlew (a species believed to be extinct) as the only two BLI "critically endangered" Alaska-breeding bird species (BirdLife International, 2005).

Preliminary analysis of surveys conducted in Glacier Bay (GLBA) in 1991 (Piatt et al. 1991) and 1999/2000 (Robards et al. 2003) suggest that populations declined by more than 80% during that period. Even greater declines have been observed in Prince William Sound (PWS) during the past 25 years (Kendall and Agler 1998; Agler et al. 1999; see also summarized reports referenced in USFWS 2003). Replicated surveys across similar time scales in other areas of Alaska have either not been carried out or remain unanalyzed. Because the species is rare and declining, accurate population estimates are needed to assess the true status of the species. In particular, we need to conduct broad-scale surveys in areas where the species is known to occur but has not been monitored in the past, and replicate surveys in core areas to produce more precise information on population trends.

Population status and trends for most seabird species are typically assessed from census counts at breeding colonies. However, the Kittlitz's murrelet is not colonial, and only around 20 nests have ever been documented across the species' entire range in the North Pacific and Bering Sea (Day et al. 1999). Kittlitz's Murrelets are also non-vocal over land, so unlike their congener the Marbled Murrelet (*Brachyramphus marmoratus*), they cannot be censused by their calls (Van Pelt et al. 1998). Kittlitz's Murrelet abundance must therefore be estimated from observations of birds at sea obtained during pelagic and coastal seabird surveys. While core population centers in PWS, GLBA, and Kenai Fjords (KEFJ) have been recently surveyed, some areas known to support significant populations of Kittlitz's murrelets have remained incompletely surveyed. Examples include the southern coast of the Alaska Peninsula, the Aleutian Islands, and northwest Alaska.

A broad-scale, rapid assessment of Kittlitz's murrelet populations across their range is critical for assessing population trends and for conservation planning. This would also allow us to evaluate some hypotheses about mechanisms that are driving population trends. Potential factors include direct mortality from oil spills and gill-net fishing (Wynne et al. 1991), and indirect effects such as natural changes in food abundance, loss of foraging habitat due to glacial recession, and vessel disturbance in core foraging areas (van Vliet 1993; van Vliet and McAllister 1994; Day et al. 1999). The impact of these factors is not evenly distributed across the species' range (e.g., vessel disturbance differs across glaciated areas of KEFJ, PWS, and GLBA, and extent of glaciation differs across the Gulf of Alaska and Bering Sea populations), and therefore if we evaluate population trends in light of these factors, we may be able to narrow our focus on the most likely mechanisms causing population declines.

It is useful to compare population trends of Kittlitz's Murrelet with other marine birds, particularly those that overlap in diet and share foraging habitats. For example, a number of piscivorous seabird species in the Gulf of Alaska have suffered population declines over recent decades due to climate-mediated changes in fish community composition (Agler et al. 1999; Piatt and Anderson 1996), and Kittlitz's Murrelets have likely also been affected by these broad-scale changes in trophic organization. Marbled Murrelets (*Brachyramphus marmoratus*), which have a high degree of dietary overlap with Kittlitz's Murrelets, have also declined in GLBA (Robards et al. 2003) and PWS

(Stephensen et al. 2001) lending support to the hypothesis that broader ecological changes have affected Kittlitz's Murrelets.

Here we present detailed findings from the second year of this three-year project, focusing on population status of Kittlitz's Murrelets along the south coasts of the Alaska Peninsula.

METHODS

Our overall approach in surveying for Kittlitz's Murrelets in poorly documented areas is to emphasize the spatial scale and accuracy of population estimates over the precision of those estimates. Ideally, surveys could be both broad-scale and precise, but this is difficult to achieve with limited resources (ship and personnel time). Relatively fine-scale monitoring efforts are ongoing in two core population centers (PWS and GLBA). Given the lack of basic information on populations elsewhere in the species' range, our objectives at this stage were not to increase the range of fine-scale monitoring but rather to broaden the geographical scope across which we will have current information about the status of Kittlitz's Murrelet populations.

Sampling protocol and statistics: There is large body of work on the application of at-sea surveys to population estimation for marine birds. Results of recent work on murrelets (Becker et al. 1997, Agler et al. 1998) indicate that surveys with high temporal replication and large spatial coverage are ideal for establishment of a monitoring program that will enable detection of population trends with acceptable statistical power. But given our immediate objective for surveying the Alaska Peninsula region (documentation of the meso-scale distribution and abundance of Kittlitz's Murrelets), we used a combination of stratified systematic and random sampling (without replication) for maximum spatial coverage. This sampling established a new set of nearshore and offshore transects that could be used in future years as the basis for a more intensive population monitoring program.

We surveyed a total of 826 linear kilometers (247.3 km²) along the south coast of the Alaska Peninsula, from Cape Douglas to Isanotski Strait (Fig. 1) during 18 June – 12

July 2003. We used standard FWS strip survey methods (Gould and Forsell 1989; Kendall and Agler, 1998; Agler et al. 1999; Irons et al. 2000) with a 300-m wide strip, counting from the flying bridge of a 42' seiner (F/V *Alexandra*, Babkin Charters, Anchorage AK; Appendix I). We counted all birds (on water and flying) within 150 meters to each side, ahead, and above the vessel and classified bird behavior for each record (e.g. "flying", "on water"). Flying birds were counted continuously. Data were recorded using DOS-based, real-time, GPS-integrated software that continuously wrote positional data to record the trackline ("dLOG" software; Glenn Ford Consulting, Inc., Portland, OR). For each bird observed, data were recorded on species, number, behavior, time, and GPS location.

Vessel speed was maintained at 6-8 knots. Surveys were conducted during periods without heavy precipitation, fog, glare, or seas with chop greater than 0.6 m. With the vessel carrying a typical load of fuel, water, and supplies, the observers' feet were about 2.5 m above the waterline. Two observers (one per forward quadrant) continually scanned the strip without binoculars, and used 10-power binoculars to confirm species identifications. Observers were trained in maintaining strip width and in species identification. Observations were called via radio to a third person entering data directly into a laptop running dLOG software and linked to the vessel's GPS.

We sub-sampled in strata that were defined from *a priori* knowledge of likely distribution, and with logistical considerations in mind. Outer, exposed shorelines were split into 5 km sections using GIS, and a sub sample of sections were then randomly selected (creating the stratum termed "outer nearshore" throughout this report). Embayments were systematically classified into two general types: "bays" (broad) and "fjords" (narrow). Whole bays and fjords were randomly selected (in proportional numbers), and systematic nearshore (observed area within ca. 500 m of coast) and offshore (observed area more than ca. 500 m from coast) transects were then run within the selected embayments, creating four additional strata termed "bay nearshore", "bay offshore", "fjord nearshore", and "fjord offshore". Some "nearshore" transects were run up to 1000 m from the coast when foul coastlines, shallow nearshore waters, or kelp concentrations forced deviations. However, the vast majority of transects are accurately binned into the five strata. See Appendix II for transects classified by strata, and Appendix III for transect numbering.

Species distributions were mapped using ArcMap (ArcGIS v. 8.2; ESRI) after flat data files were imported into a Microsoft Access geodatabase. Transects were buffered for the width of the surveyed strip (300 m), and the buffered area (equal to the total area sampled) was calculated for each stratum (Table 1). Total area per stratum was calculated using ArcMap with available shoreline GIS coverages (Appendix IV).

Estimators of density, abundance, and variance for each stratum and for pooled strata were calculated using model-based analyses within Program Distance (Thomas et al. 2002), under the assumptions that all objects within the strip were detected and that animals did not move off the strip in response to observers (Buckland et al. 2001). We used all murrelets seen (on water and flying) within the strip, since all “flying” murrelets recorded on the transect were concluded to have risen off the water within the transect (i.e. they were not traveling across the strip). Point values of densities and abundances calculated within Program Distance were similar to those calculated using the standard FWS ratio estimator approach (Klosiewski and Laing 1994; Cochran 1977), but variances were smaller and strata were pooled with weighted values and variances. Satterthwaite’s procedure for adjusting degrees of freedom for small sample sizes was used (Buckland et al. 2001). Confidence intervals are log-based, allowing for the asymmetric shape of the sampling distribution of density estimates generated from small sample sizes. Our survey lines were representative of the appropriate study area (i.e. nearshore lines were an unbiased sample of the nearshore environment, and offshore lines were an unbiased sample of the offshore environment), meeting the basic assumption for density and abundance estimation (Buckland et al. 2001).

Other marine bird and mammal species: While the specific aim of the present survey was evaluation of the status and distribution of Kittlitz’s Murrelets (key target species) and Marbled Murrelets (closely related species used for comparison), we were also interested in other marine bird and mammal species as comparative components of the same ecosystem, and for basic documentation of current population status. We therefore collected the same information for all other marine bird and mammal species, using the same methods as detailed above for murrelets. But we emphasize that no single survey design is equally effective for all species, since distribution, population size, and behaviors differ. Taxa that differ in temporal and/or spatial distribution generally require

a focused sample design and analysis; we have therefore not calculated densities or estimated population sizes for species other than the *Brachyramphus* murrelets. However, we present a table of total numbers observed for other species (Appendix V) that can be used for simple comparisons between years, and raw data will be made available for any future analyses.

RESULTS and DISCUSSION

Distribution: Kittlitz's Murrelet

Kittlitz's Murrelets were found mostly in protected bays and fjords, with highest densities found in "offshore" waters of open bays (more than ca. 500 m from shore). See Figures 2-6 for an overall map of distribution and accompanying larger-scale maps of distribution; see Appendix VI for detailed numbers by transect. Most of the 123 Kittlitz's Murrelets that we observed along our 826 kilometers of transects were in seven embayments, forming noteworthy "hotspots" for the species: Kinak, Dakavak, Puale, Nakalilok, Kujulik, Kuiukta, and Pavlof bays. Distinct gaps in distribution occurred between Puale and Nakalilok bays, and also between Ivanof and Pavlof bays.

Kittlitz's Murrelets were only rarely seen in the exposed waters of the outer coast; usually associated with a river outflow. For example, Kittlitz's Murrelets were seen off the eastern part of the Alaska Peninsula near the Swikshak River and other glacier-fed rivers and streams of the Fourpeaked Mountain / Mount Douglas massif (Fig. 3). Off the western part of the peninsula, Kittlitz's Murrelets were seen near the outflow of the Kamatolook River, part of the southern watershed of the glaciated slopes of Mount Veniaminof (Fig. 5).

Distribution: Marbled Murrelet

Marbled Murrelets were found both in protected waters and along some of the surveyed outer shoreline. See Figures 7-11 for an overall map of distribution and accompanying larger-scale maps of distribution; see Appendix VI for detailed numbers by transect. The highest densities were found in the nearshore waters (within ca. 500 m of coast) of the protected fjords, with two extraordinary concentrations in Kuiukta Bay

and Kinak Bay. There were no parallel gaps in distribution, but there were lower numbers of Marbled Murrelets in those two areas in which no Kittlitz's Murrelets were found (between Puale and Nakalilok bays, and between Ivanof and Pavlof bays).

Distribution: species comparison

At the mesoscale, the two *Brachyramphus* species generally exhibited a higher degree of overlap along the Alaska Peninsula than in more heavily glaciated parts of their range. In Prince William Sound, Glacier Bay, and Kenai Fjords, there are distinct marine areas, usually near tidewater glaciers or glacial outflows, where relatively high numbers of Kittlitz's Murrelets occur and few to no Marbled Murrelets occur. Along the Alaska Peninsula, Marbled Murrelets occurred nearly everywhere Kittlitz's Murrelets were found, and usually in higher numbers. It appears that the basic distribution of these two congeneric species is similar in this moderately glaciated habitat; there are simply more Marbled Murrelets than Kittlitz's Murrelets by a factor of about 3 to 1. However, there was a noticeable difference in the habitat supporting maximum concentrations of the two species: Kittlitz's Murrelet hotspots were both in open, shallow bays (e.g. Kujulik Bay) and narrow, deep fjords (Kinak Bay), while Marbled Murrelet hotspots were in deep fjords (Kuiukta and Kinak bays).

Population estimation: Kittlitz's Murrelet

From a total of 123 Kittlitz's Murrelets seen on transects in five strata, we estimate a pooled total population of 2265 (95% CI 1165-4405) Kittlitz's Murrelets along the south coast of the Alaska Peninsula (Table 2). We emphasize that this total population estimate must be regarded as a minimum benchmark for the region, since unidentified *Brachyramphus* murrelets (BRMU) were recorded on transect (BRMU comprised 7.1% of all murrelets seen on transect). Note also that our surveys focused only on waters closely associated with the mainland Alaska Peninsula; no surveys were conducted in open Gulf of Alaska waters or among the region's many offshore islands, where Kittlitz's and Marbled Murrelets have been seen on informal surveys in past years (T. Van Pelt and J.F. Piatt, pers. obs.) and where small numbers of Kittlitz's Murrelets were seen while traveling between transects during the current survey.

The large confidence intervals bounding our Kittlitz's Murrelet population estimate are not surprising, given the broad spatial coverage of the survey and clumped distribution and low densities that currently characterize the species. However, the overall pooled coefficient of variation (CV) of 33.4% is relatively low (e.g. compared to 71% in the Kenai Fjords region; Van Pelt and Piatt 2003) and indicates that Kittlitz's Murrelets are distributed relatively evenly within the selected strata. The fact that the highest densities occurred in the stratum with the lowest survey intensity and the largest stratum area ("bay offshore", density = 1.13 Kittlitz's Murrelets per square kilometer, 3.5% of stratum sampled; extrapolated area 1705 km² of 2592 total km²; Tables 1 and 2) means that the pooled population estimate is heavily weighted by this stratum. The CV in the bay offshore stratum was the lowest of the five strata (39%), contributing to the overall low CV.

Population estimation: Marbled Murrelet

From a total of 722 Marbled Murrelets seen on transects in five strata, we estimate a pooled total population of 7389 (95% CI 5291-10,319) Marbled Murrelets along the south coast of the Alaska Peninsula (Table 3). We emphasize that this total population estimate must be regarded as a minimum benchmark for the region, for the same reasons as listed above for Kittlitz's Murrelets.

Population trend

No previous data exist for quantitative measurement of population trend.

CONCLUSIONS and RECOMMENDATIONS

Relatively thorough coverage of the south coastal waters of the Alaska Peninsula confirmed the presence of Kittlitz's Murrelets in segregated pockets along the coast where previous anecdotal or limited surveys had indicated some numbers. As expected, we found that both Kittlitz's and Marbled Murrelets are concentrated in embayments and not along exposed outer coasts of the Alaska Peninsula. Our work extends the

geographic range for which we have current knowledge of Kittlitz's Murrelet distribution, abundance, and broad-scale habitat preferences.

The minimum population estimate presented here of 2265 Kittlitz's Murrelets along the south coast of the Alaska Peninsula means that the region currently supports about 9-25% of the best-estimate total population (9,000 – 25,000; USFWS 2003).

Greatest concentrations of both murrelet species were found in the two parts of the peninsula dominated by the largest glaciated mountain massifs- Katmai and Veniaminof. At a finer scale, considering the spatial separation of the seven Kittlitz's Murrelet hotspots and their association with volcanic mountain massifs, we can broadly define four subpopulations:

- Katmai population (Puale Bay, Dakavak Bay, and Kinak Bay)
- Aniakchak/Chiginagak population (Kujulik Bay and Nakalilok Bay)
- Veniaminov population (Kuiukta Bay)
- Pavlof population (Pavlof Bay)

Absence of historical data means that we cannot measure population trend in this region, but we have established a set of transects that can be repeated in the future for analysis of population trend. It is important to note that the bulk of the Kittlitz's Murrelets on our transects were found in seven bays and fjords, meaning that a future survey could repeat only those selected transects, potentially achieving a robust comparison with dramatically reduced effort and vessel time. Given that relatively complete trend information available from Glacier Bay, Prince William Sound, and Kenai Fjords show population declines on the scale of 70-80 % over the past 10-20 years (Robards et al., 2003; USFWS, 2003; Van Pelt and Piatt 2003), we recommend that a monitoring plan be established for this substantial population along the south coast of the Alaska Peninsula.

One factor common to the three areas showing substantial population decline (Glacier Bay, Prince William Sound, and Kenai Fjords) is the presence of large ice fields and tidewater glaciers. Our surveys along the southern Alaska Peninsula showed that Kittlitz's Murrelets were generally found in broad-scale association with nearby glaciated mountain massifs or glacially-driven freshwater outflows. The association with glaciers

operates at a finer scale in the presence of tidewater glaciers, as in Prince William Sound (Kendall and Agler 1998; Day et al., 2000; USFWS, 2003; Kuletz et al., 2003), Glacier Bay (Kendall and Agler 1998; Robards et al. 2003), and Kenai Fjords (Van Pelt and Piatt 2003). Alaskan glaciers have been thinning and losing mass at a high rate over the past 50 years (Arendt et al. 2002), and it has been hypothesized that Kittlitz's Murrelet population declines are related in some way to glacier thinning and retreat. The mechanisms that link Kittlitz's Murrelet foraging and glacier-influenced marine waters remain unclear, however, and would be a fruitful area for further research. The Alaska Peninsula population may provide a useful comparison, given that substantial numbers of both species of murrelets occur here, with habitat associations that are not dominated by the presence of marine ice.

The still-uncharted Kuiukta Bay stands out as an important hotspot for both species of murrelets, and may warrant some special consideration by resource managers. Kujulik Bay and the other five embayments found to support most of the Kittlitz's Murrelets likewise might warrant special consideration.

Marbled Murrelets were more broadly distributed than Kittlitz's Murrelets, but there was no clear separation in habitat preference as has been documented in other more glacier-affected regions. Marbled Murrelets outnumbered the congeneric Kittlitz's Murrelet; the region supported an estimated 7389 Marbled Murrelets. But this comprises a proportion of the total Alaskan population of Marbled Murrelets that is lower than the Kittlitz's Murrelet proportion (Piatt and Naslund 1995). The non-forested terrestrial habitat that dominates the Alaska Peninsula may limit the Marbled Murrelet population by limiting preferred nesting habitat.

Recommended priorities for future work:

- A. Continue monitoring known concentrations in PWS and GLBA; initiate monitoring programs in other areas with accessible concentrations of Kittlitz's Murrelets (Alaska Peninsula, Kenai Fjords, Icy Bay, Kachemak Bay, Adak). Work with U.S. Fish and Wildlife personnel to build an effective and efficient monitoring program.

- B. Initiate surveys in peripheral or low-density Kittlitz's Murrelet populations in Alaska (e.g., Aleutians, Bering and Chukchi seas, Russia), to establish status of global population and to further investigate environmental correlates with population trends.
- C. Details of feeding ecology and habitat use should be examined, especially in relation to glacial influence and vessel traffic.
- D. Collate available anecdotal information on historical Kittlitz's Murrelet distribution and abundance along the Alaska Peninsula, for potential qualitative comparison to 2003 survey results.
- E. Conduct genetic analyses to decipher population and metapopulation structure across the whole range of the species, including the Russian Far East, to provide for clear management objectives for the species.
- F. Investigate population status in Russian territory via collaboration with or sponsorship of Russian specialists; support cooperative management of the global population.

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Table 1. Strata used for Kittlitz's Murrelet (KIMU) and Marbled Murrelet (MAMU) population estimations.

Stratum	# of transects	km ² surveyed	total stratum km ²	prop.sampled (%)	# KIMU	# MAMU
outer nearshore	66	110.8	265.3	41.8	20	126
bay nearshore	29	37.5	235.1	15.9	9	42
bay offshore	27	60.0	1705.0	3.5	68	111
fjord nearshore	15	20.4	114.2	17.9	16	308
fjord offshore	12	18.6	272.3	6.8	10	135
total	149	247.3	2591.9	21.4	123	722

Table 2. Kittlitz's murrelet density (D) and population (N) estimates for area along south coast of the Alaska Peninsula. See Methods for definition of strata and for explanation of estimate and variance calculations.

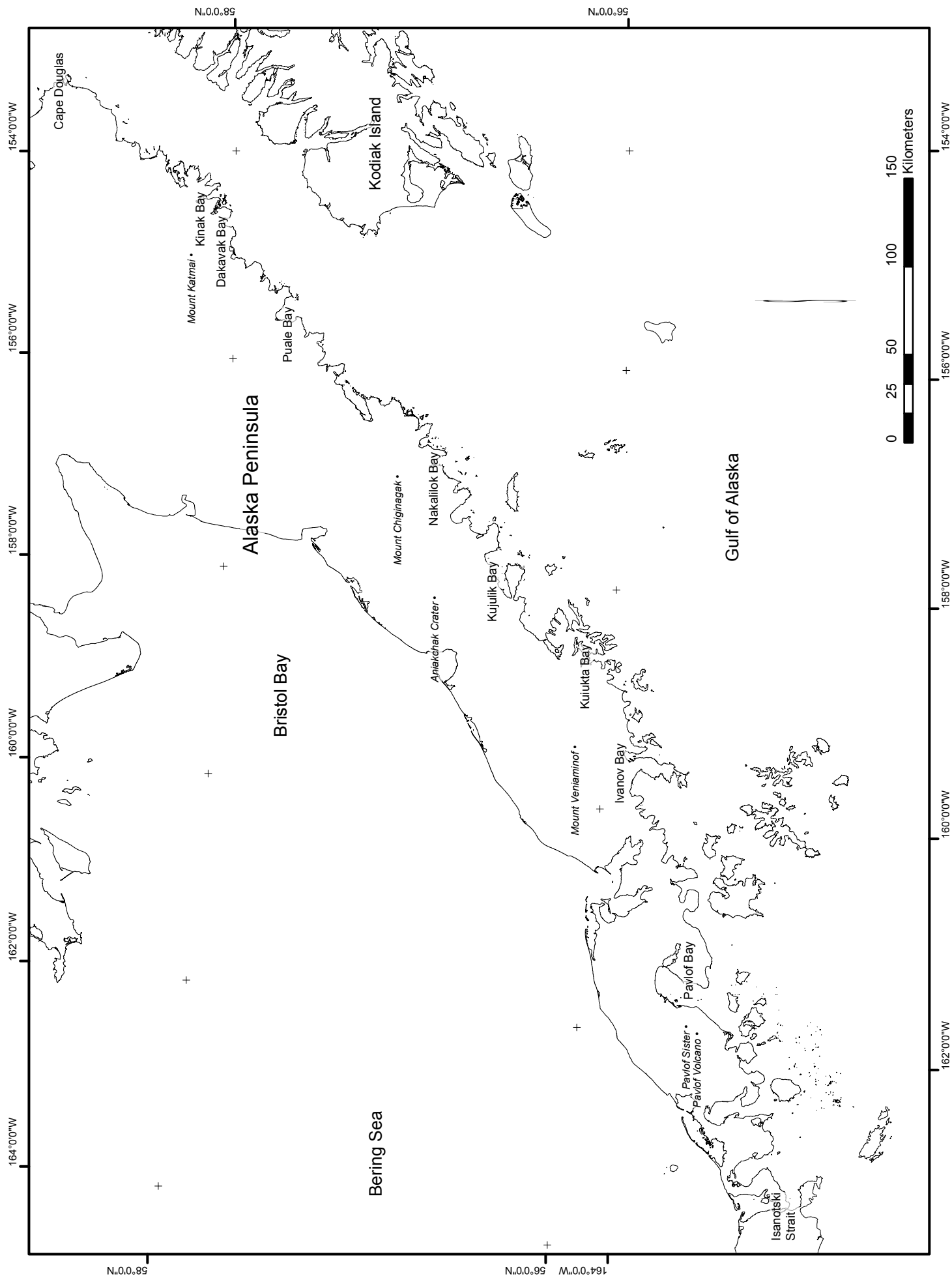
Stratum		Estimate	%CV	df	95% confidence interval	
outer nearshore	D	0.18	51.14	31.11	0.067	0.48
	N	48.0	51.14	31.11	18.0	127.0
bay nearshore	D	0.239	65.35	18.73	0.069	0.835
	N	56.0	65.35	18.73	16.0	196.0
bay offshore	D	1.13	38.92	28.18	0.524	2.438
	N	1927.0	38.92	28.18	893.0	4157.0
fjord nearshore	D	0.78	42.90	18.44	0.329	1.847
	N	89.0	42.90	18.44	38.0	211.0
fjord offshore	D	0.535	58.24	11.85	0.165	1.74
	N	146.0	58.24	11.85	45.0	474.0
all strata pooled		0.874	33.41	29.25	0.449	1.7
		2265.0	33.41	29.25	1165.0	4405.0

Table 3. Marbled murrelet density (D) and population (N) estimates for area along south coast of the Alaska Peninsula. See Methods for definition of strata and for explanation of estimate and variance calculations.

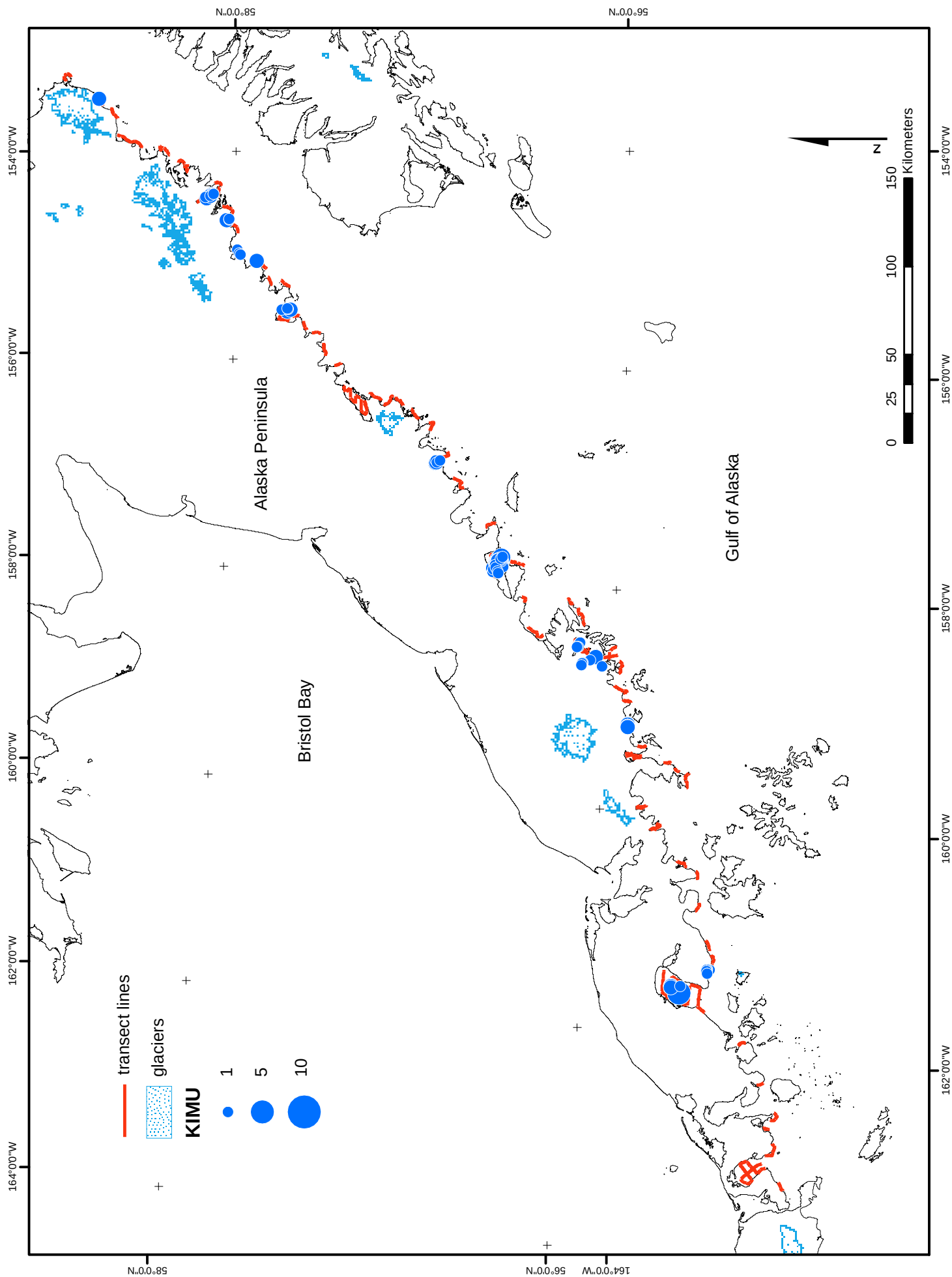
Stratum		Estimate	%CV	df	95% confidence interval	
outer nearshore	D	1.132	38.47	35.16	0.533	2.407
	N	300.0	38.47	35.16	141.0	639.0
bay nearshore	D	1.117	46.39	22.40	0.448	2.788
	N	263.0	46.39	22.40	105.0	655.0
bay offshore	D	1.844	25.41	45.69	1.115	3.052
	N	3145.0	25.41	45.69	1900.0	5204.0
fjord nearshore	D	15.017	31.8	23.83	7.913	28.502
	N	1715.0	31.8	23.83	904.0	3255.0
fjord offshore	D	7.223	39.22	19.85	3.28	15.907
	N	19.67	39.22	19.85	893.0	4331.0
all strata pooled		2.851	16.9	79.74	2.042	3.981
		7389.0	16.9	79.74	5291.0	10319.0

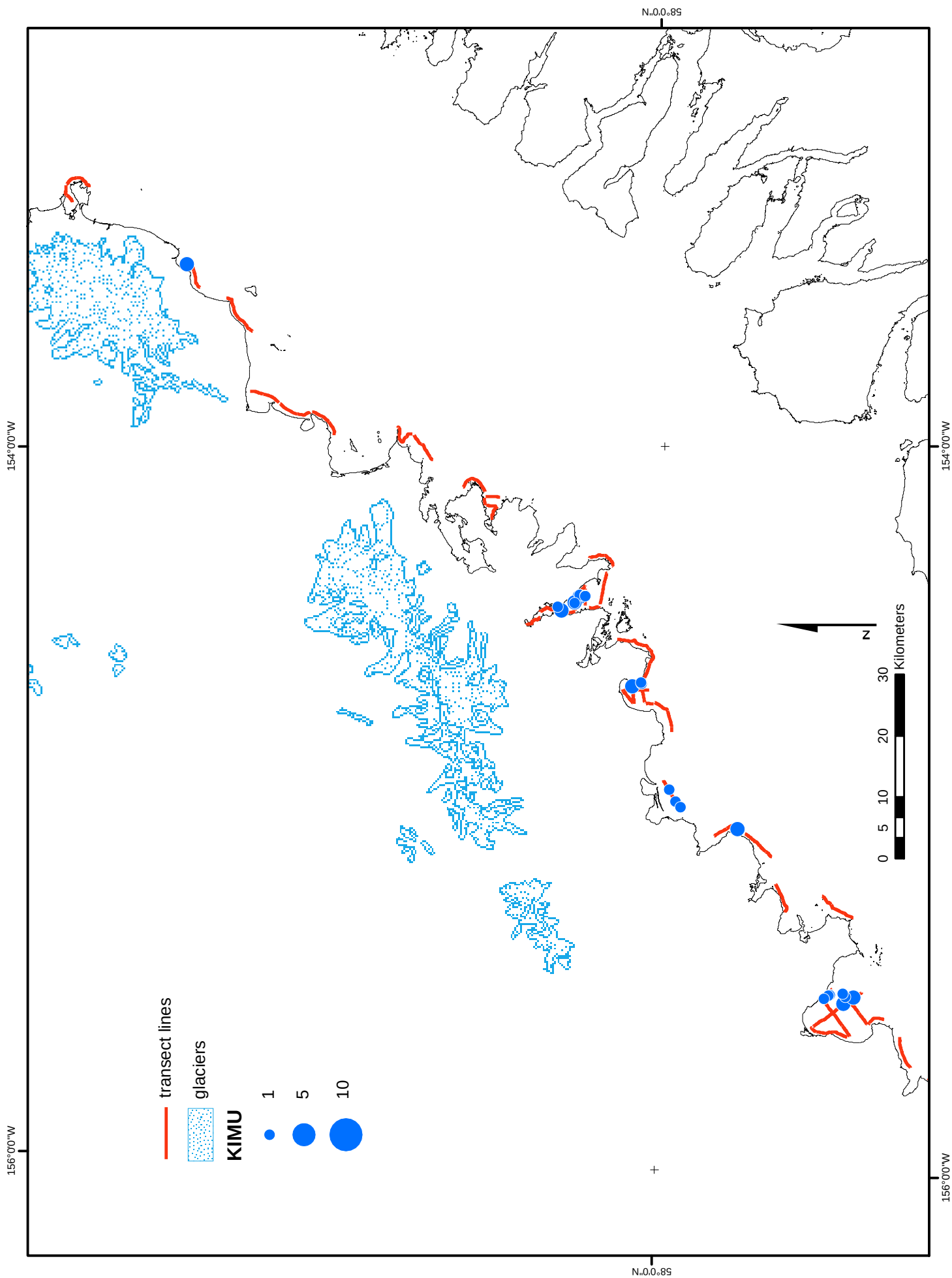
FIGURES

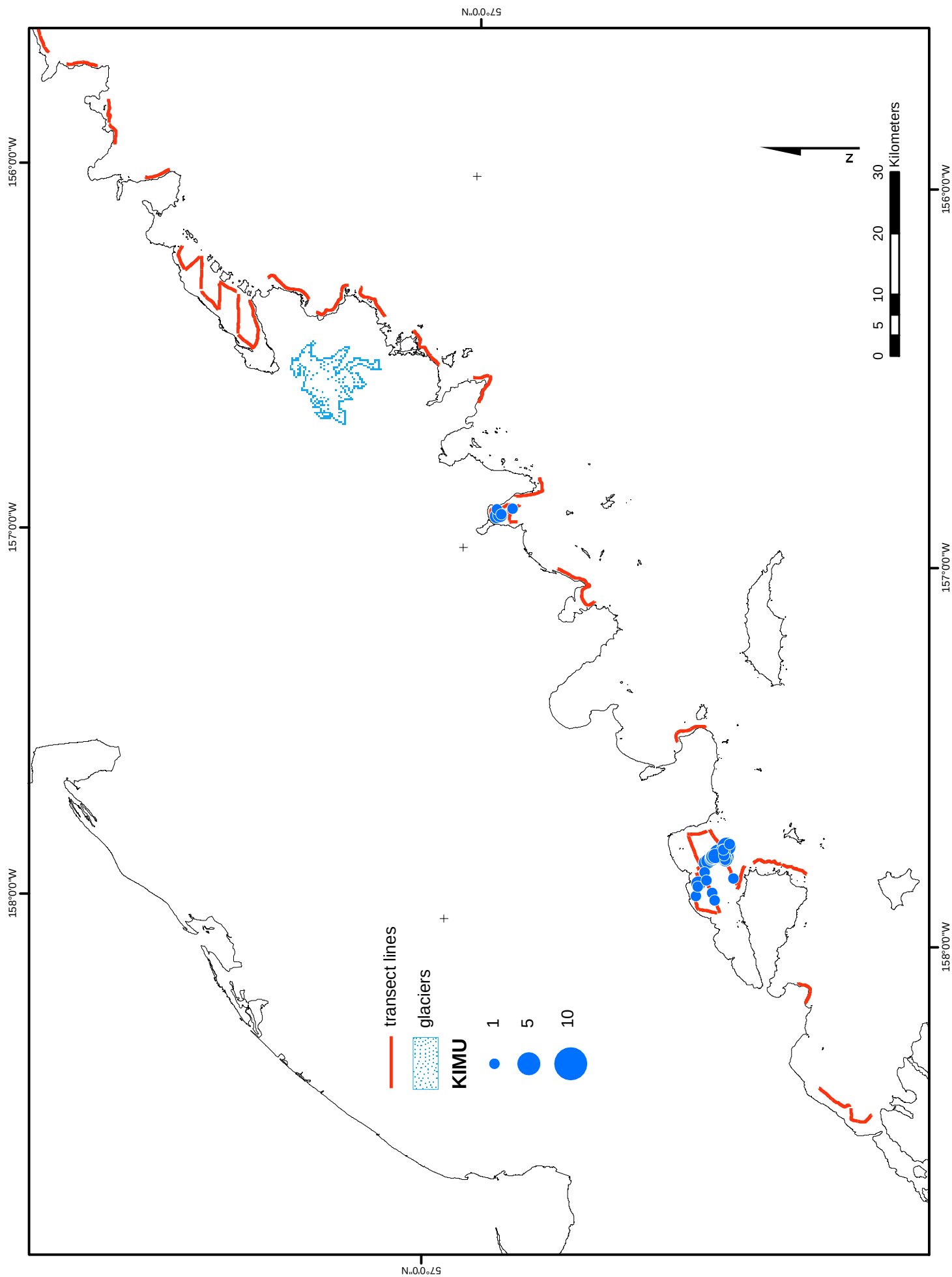
Figure 1. Map of the study area along the southern coast of the Alaska Peninsula, showing names and locations of major features.

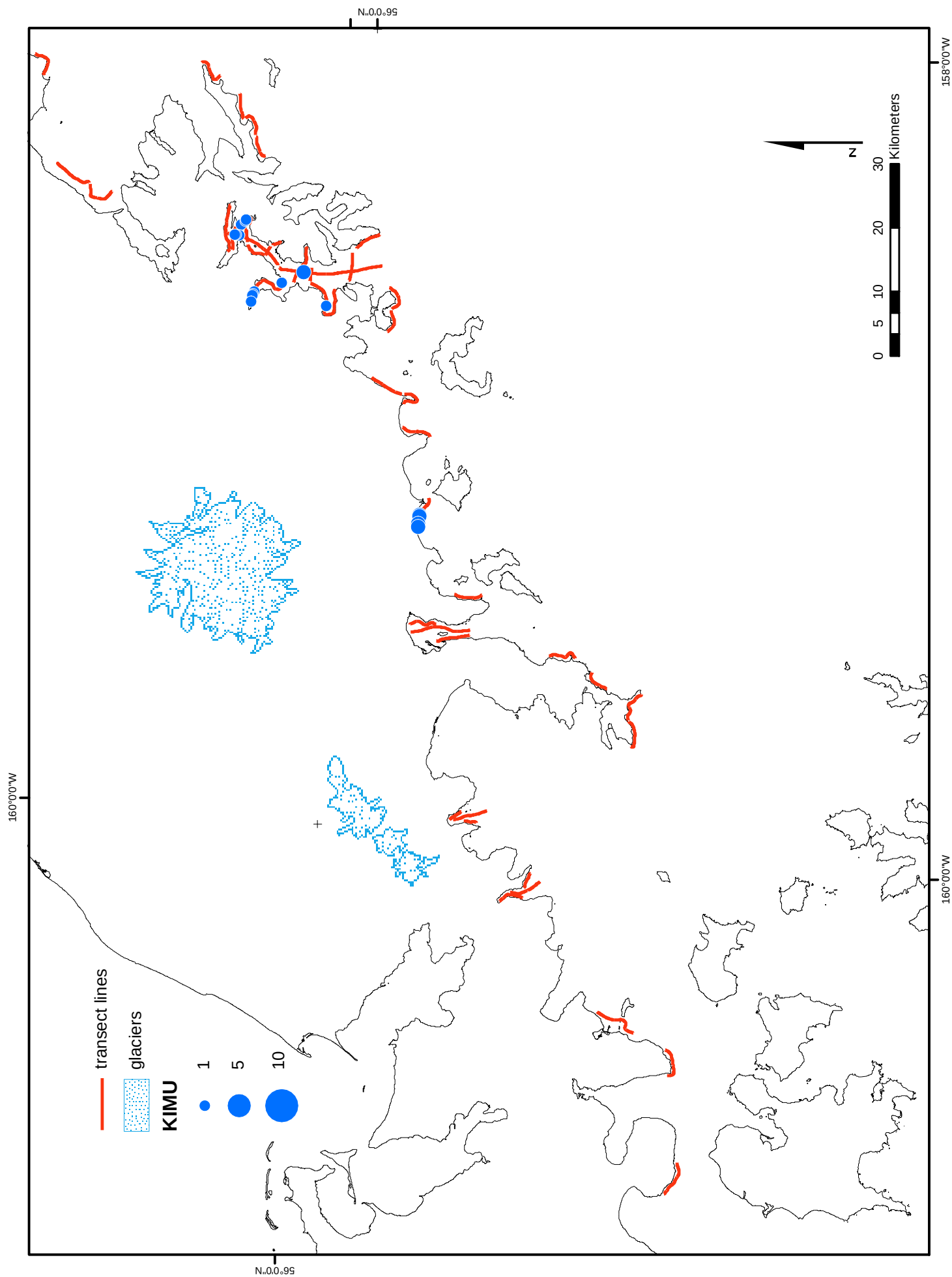


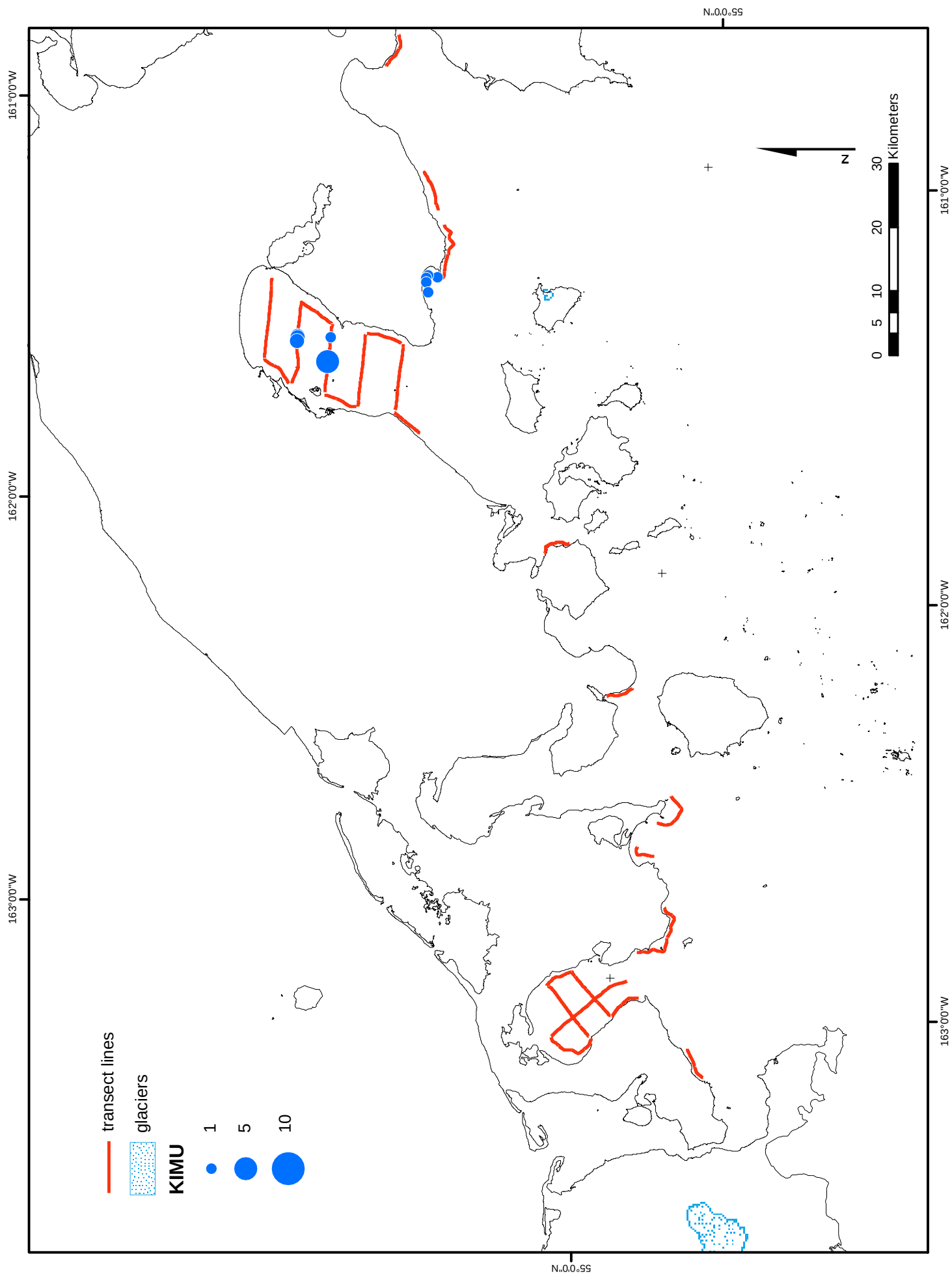
Figures 2-6. Distribution and abundance of Kittlitz's Murrelets seen on transects along the southern coast of the Alaska Peninsula, 18 June – 12 July 2003. **Figure 2** shows the entire study area. **Figures 3-6** show quadrants of the study area at larger scale, beginning at NE end of the peninsula and ending at SW end of the peninsula. See Methods and Appendices for detail of survey methods and sample design.



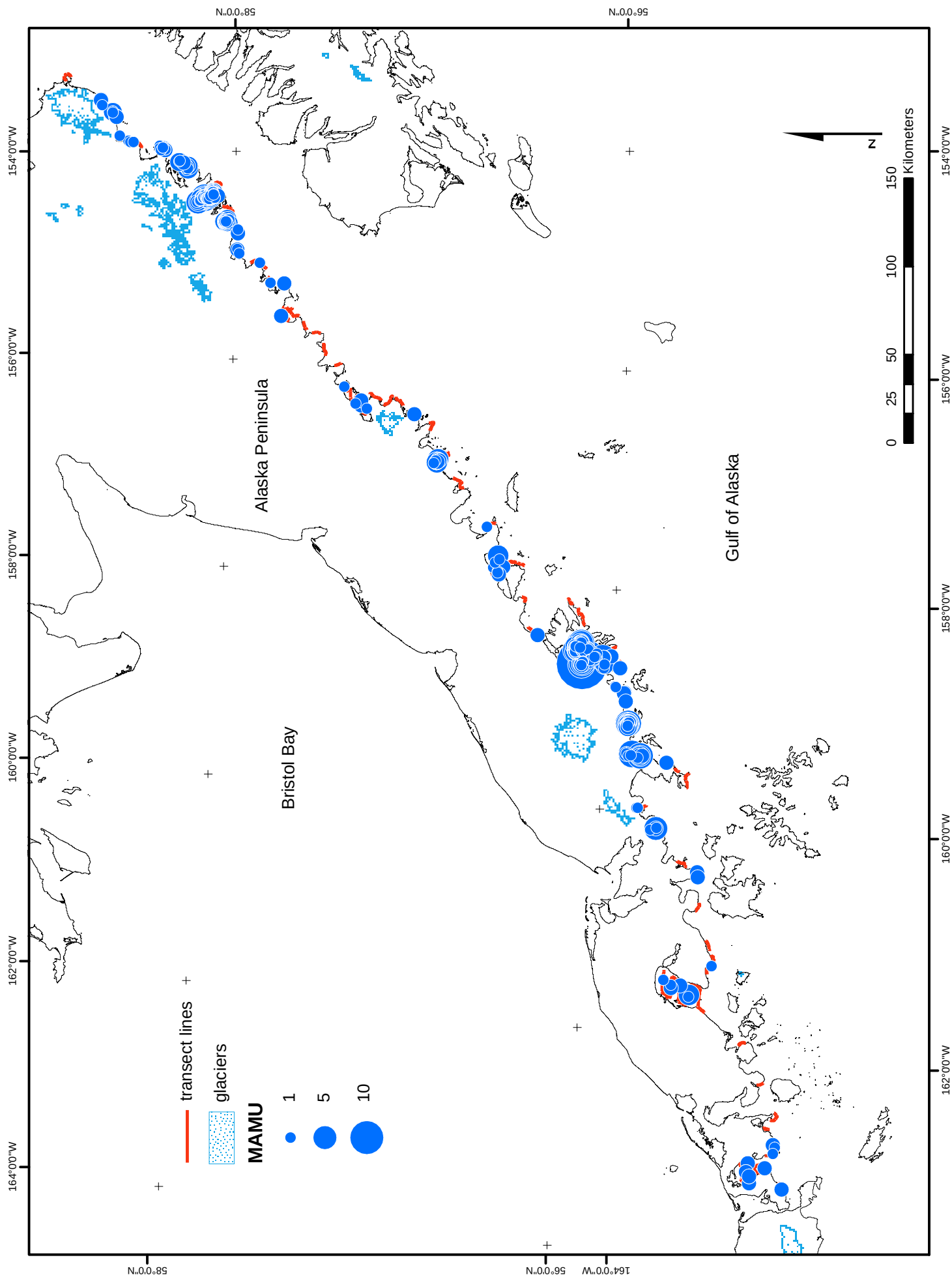


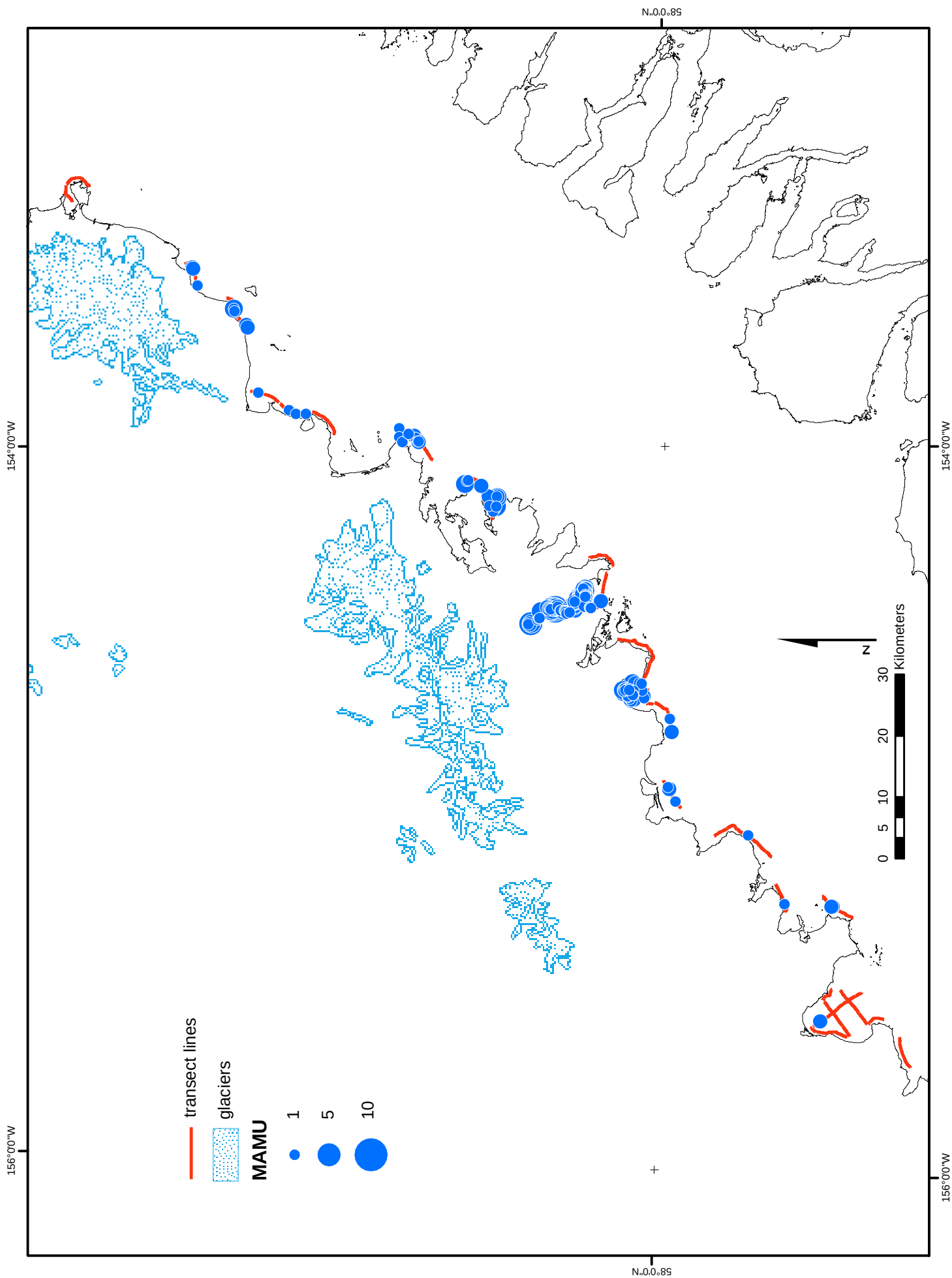


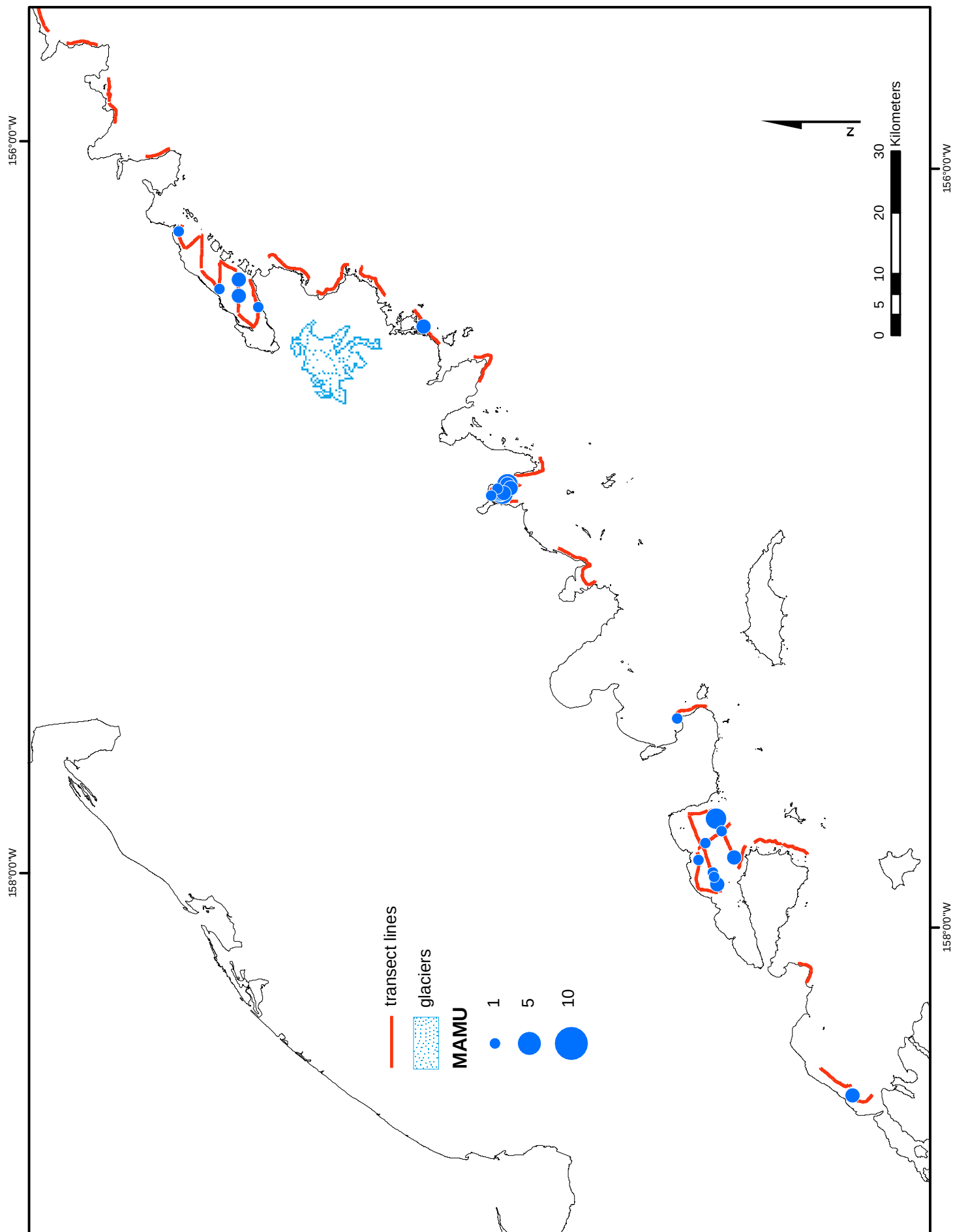


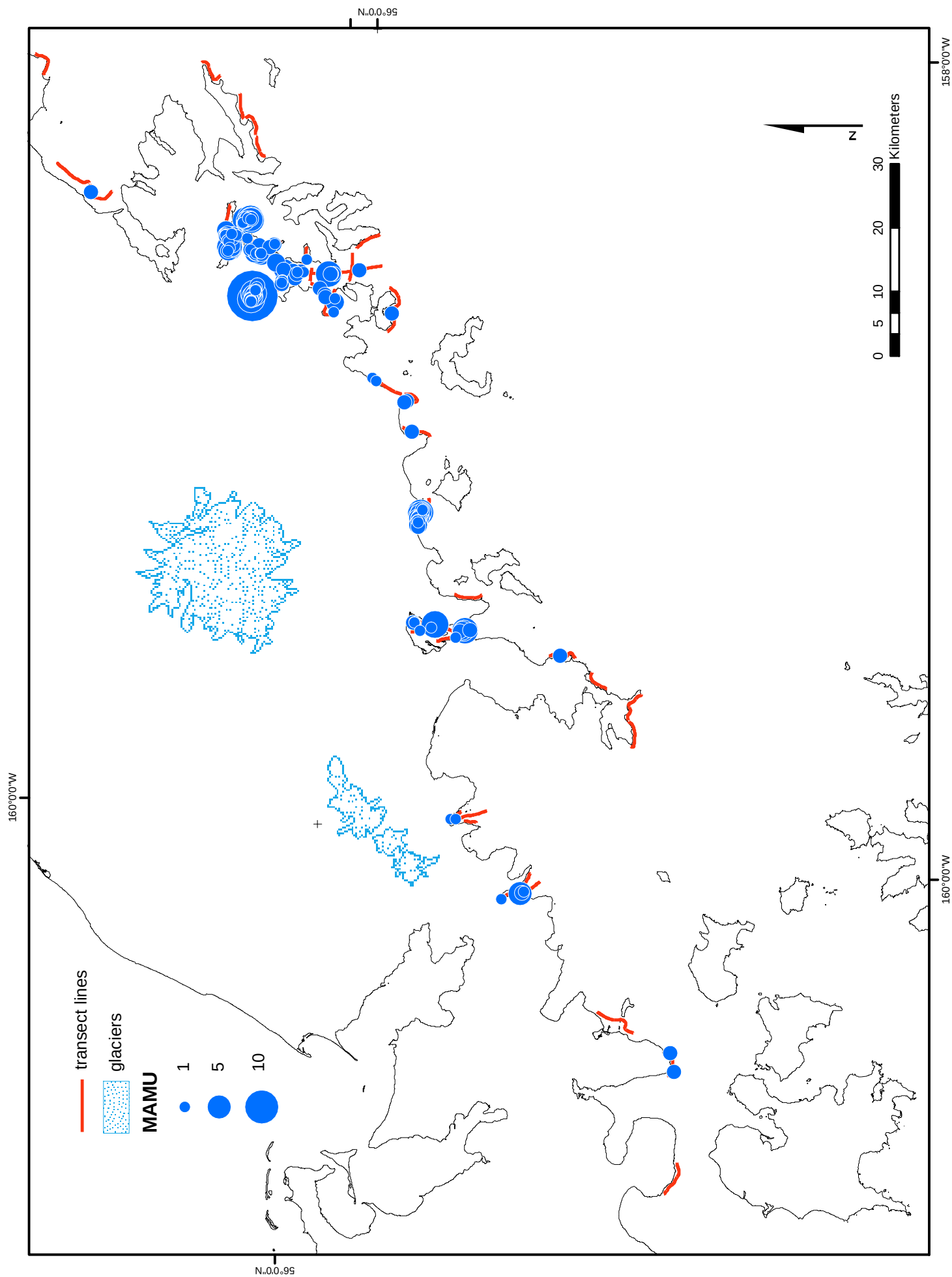


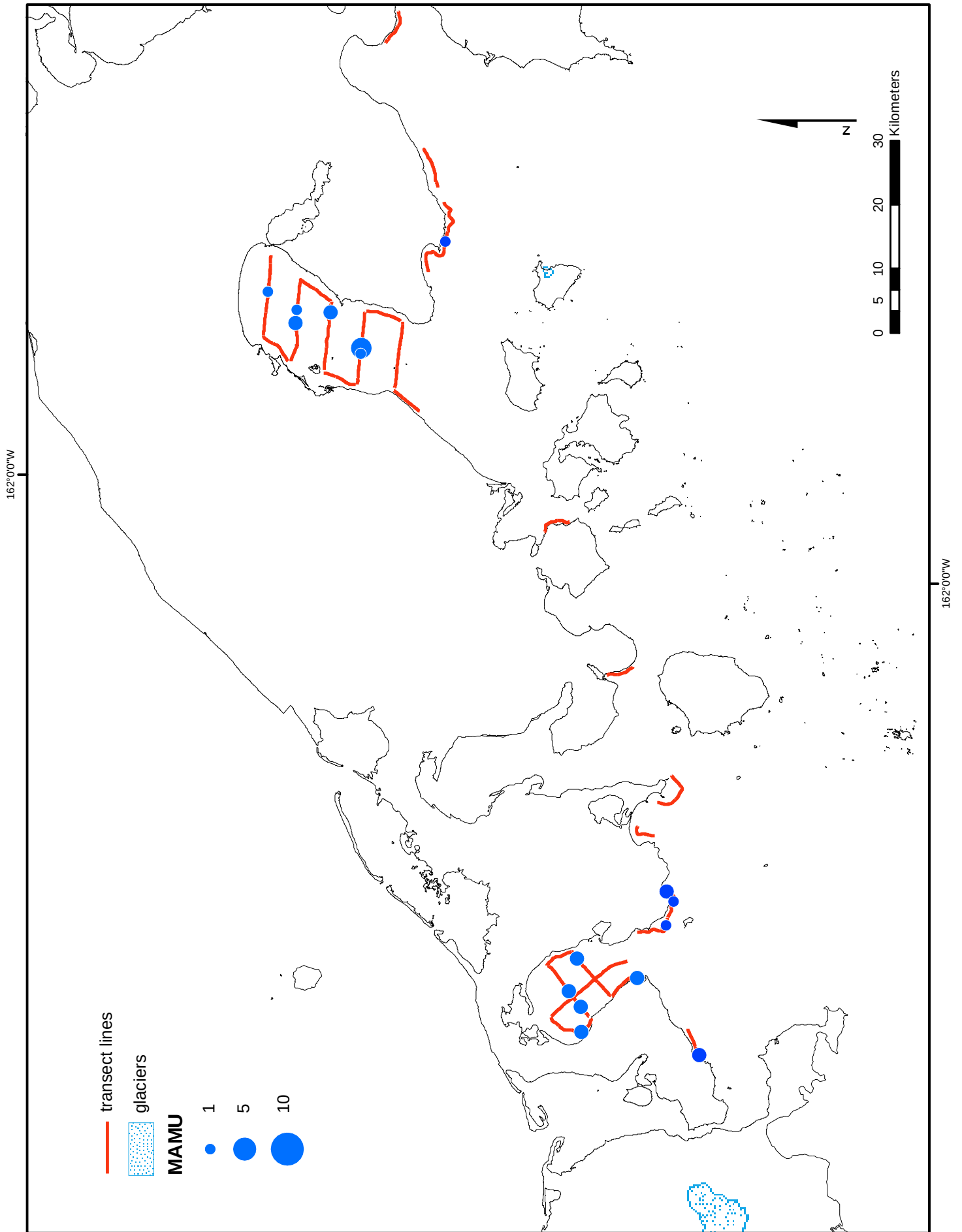
Figures 7-11. Distribution and abundance of Marbled Murrelets seen on transects along the southern coast of the Alaska Peninsula, 18 June – 12 July 2003. **Figure 7** shows the entire study area. **Figures 8-11** show quadrants of the study area at larger scale, beginning at NE end of the peninsula and ending at SW end of the peninsula. See Methods and Appendices for detail of survey methods and sample design.









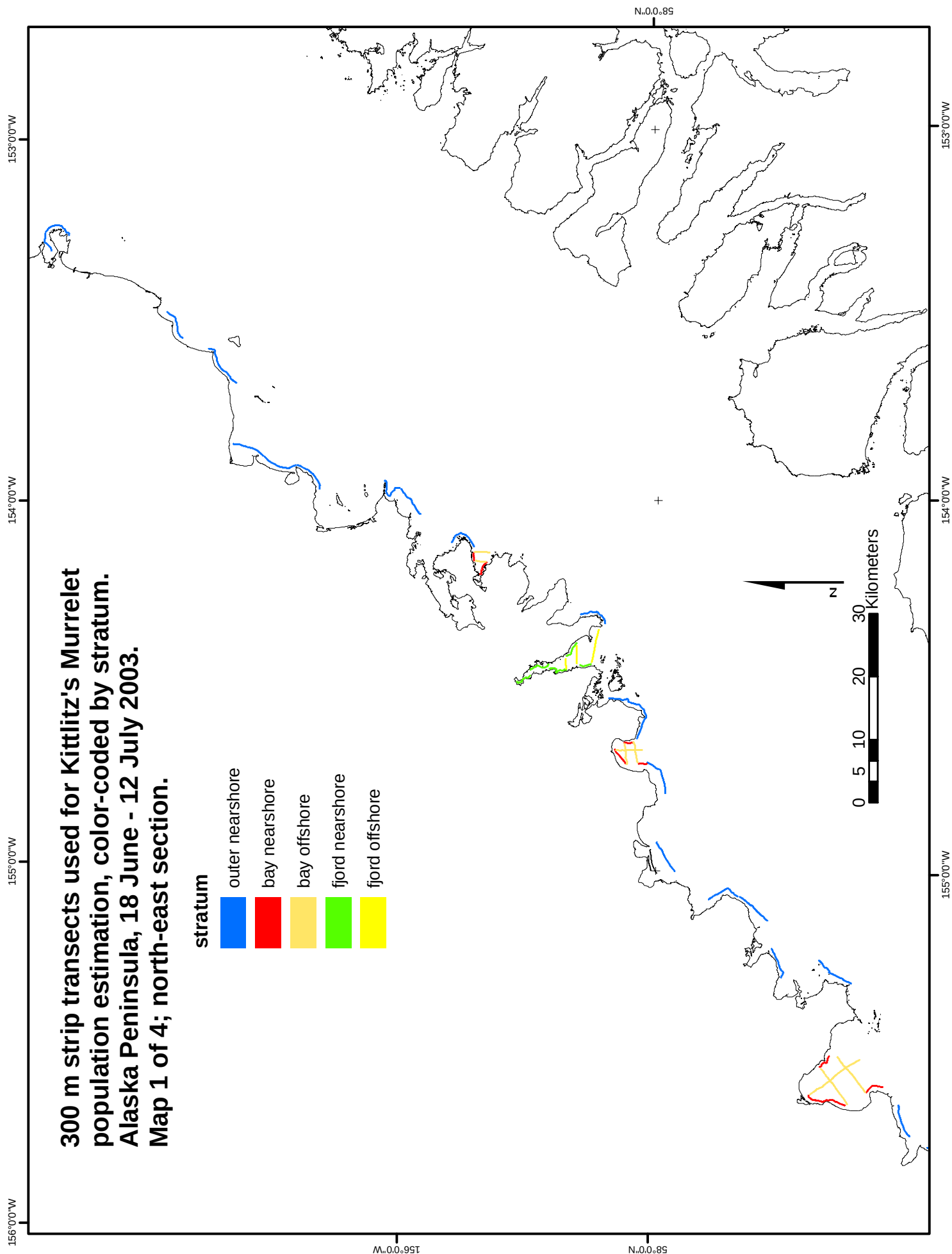


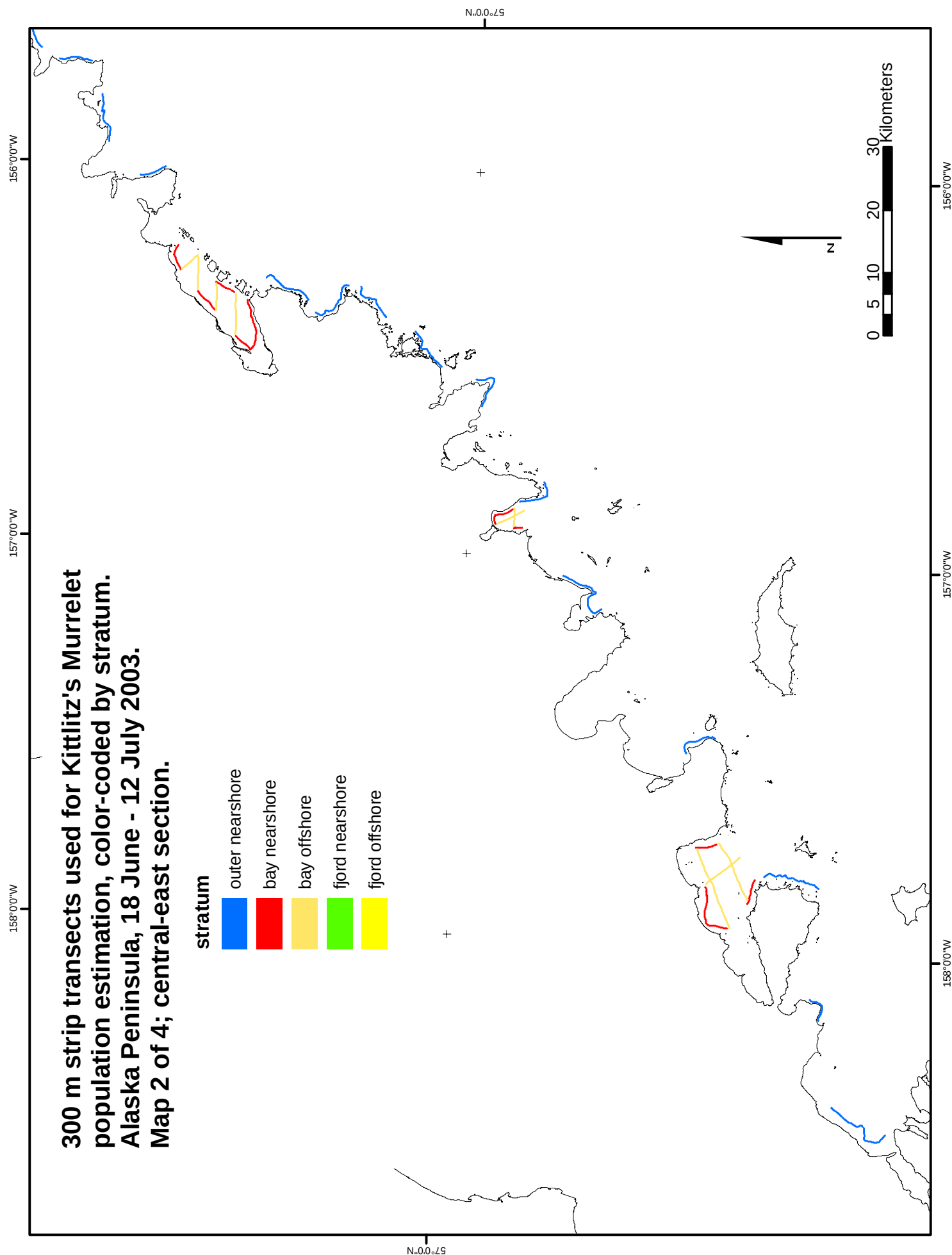
APPENDICES

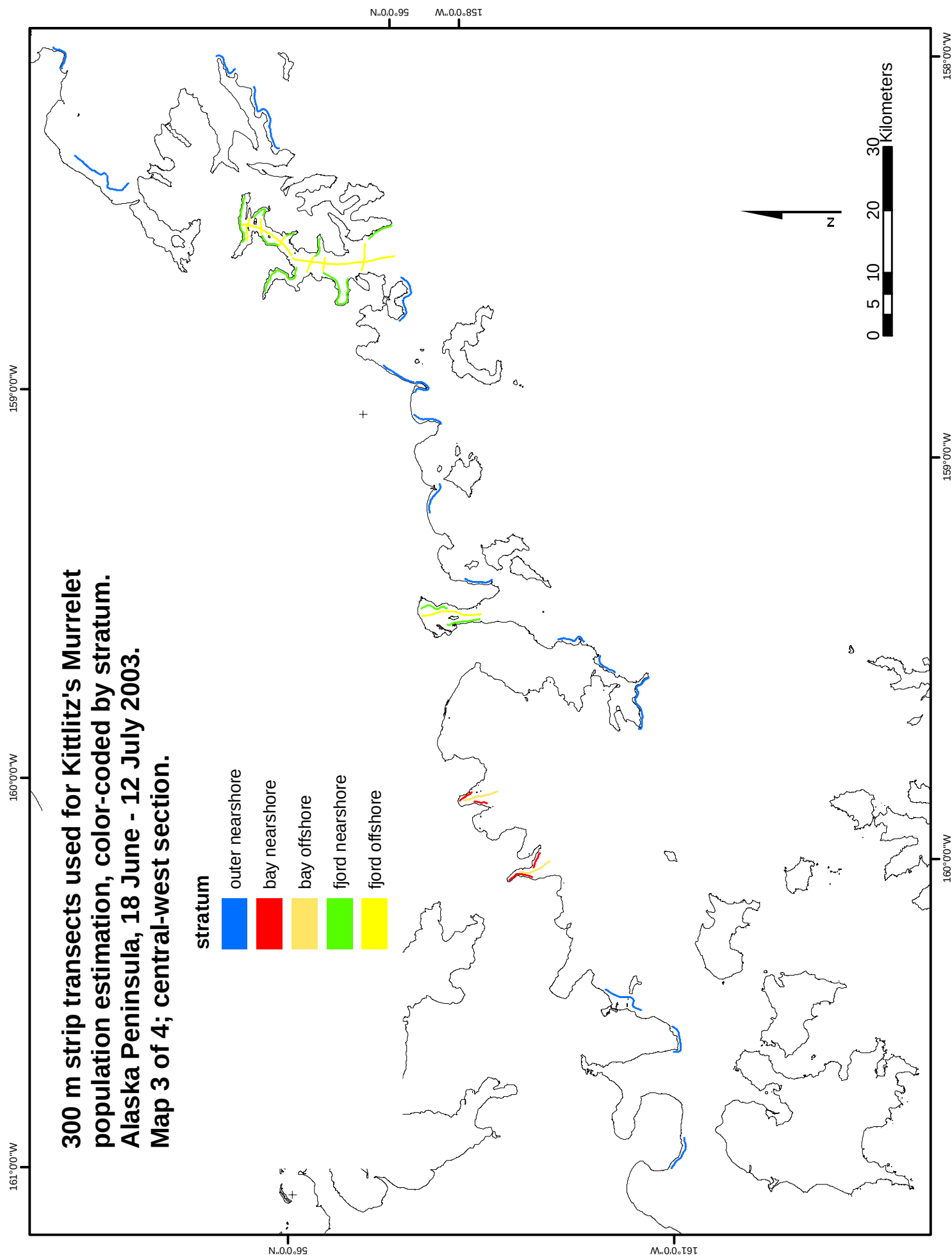


Appendix I. Survey vessel F/V *Alexandra*.

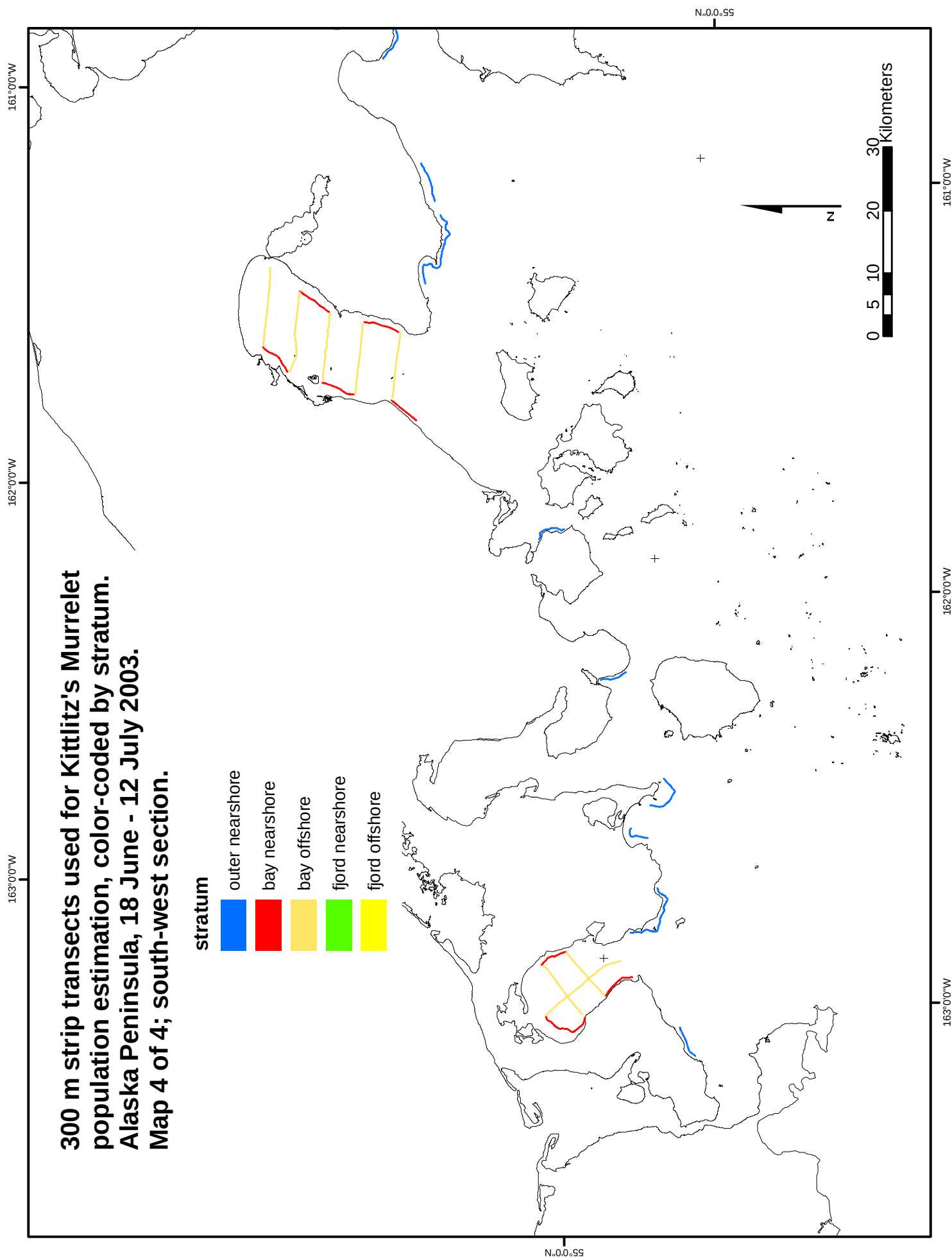
Appendix II. Survey transects classified by strata (see Methods).



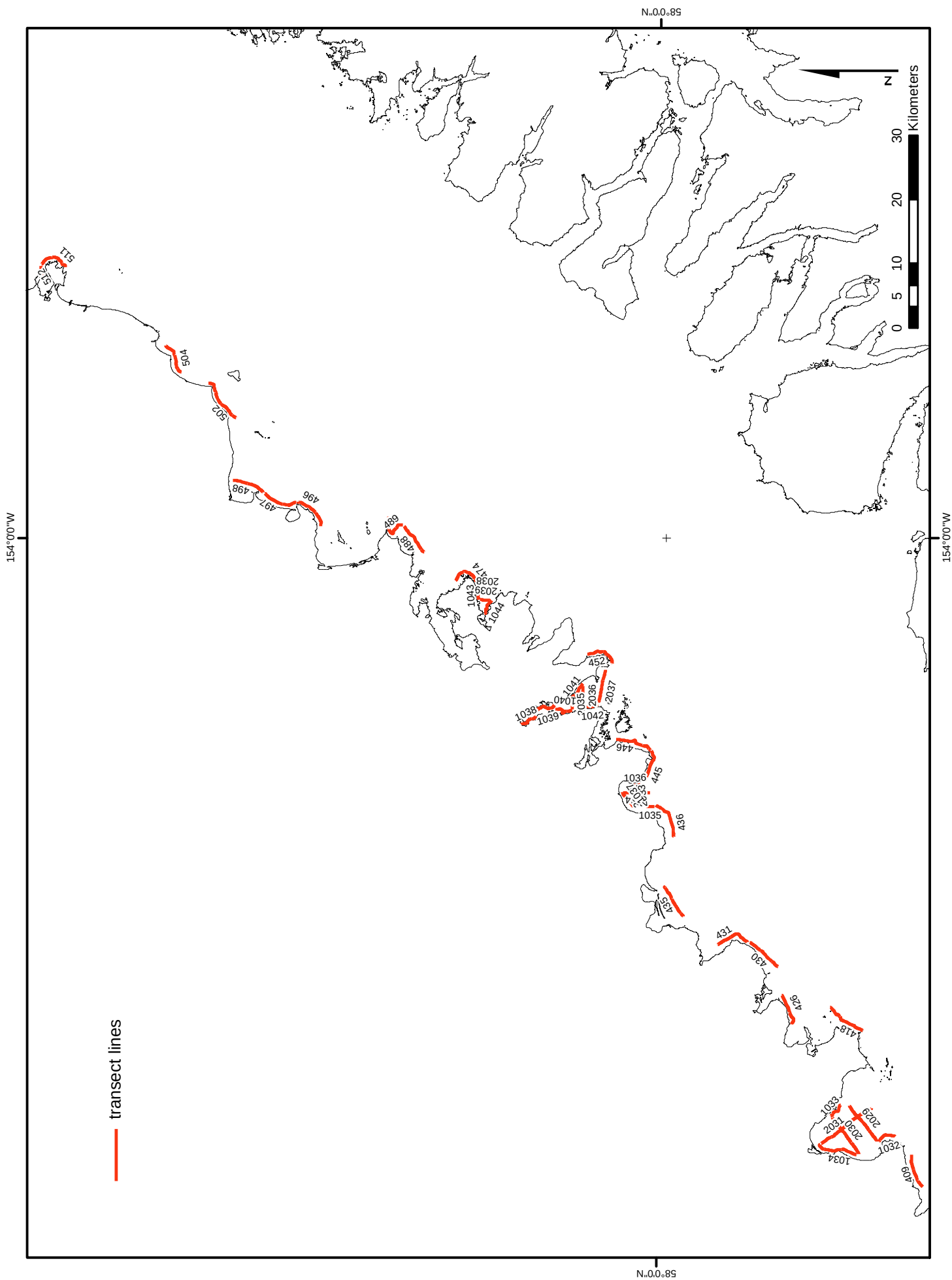


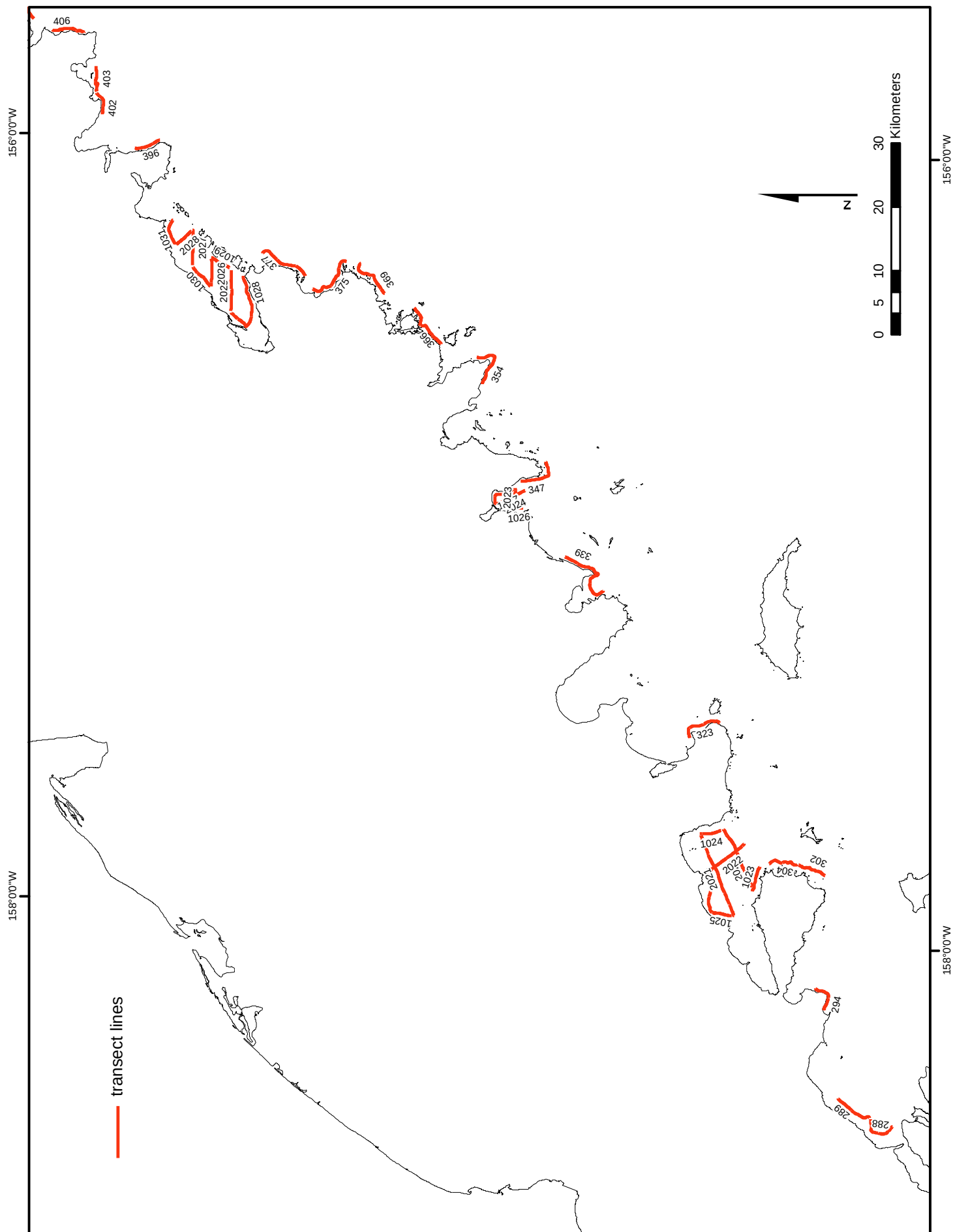


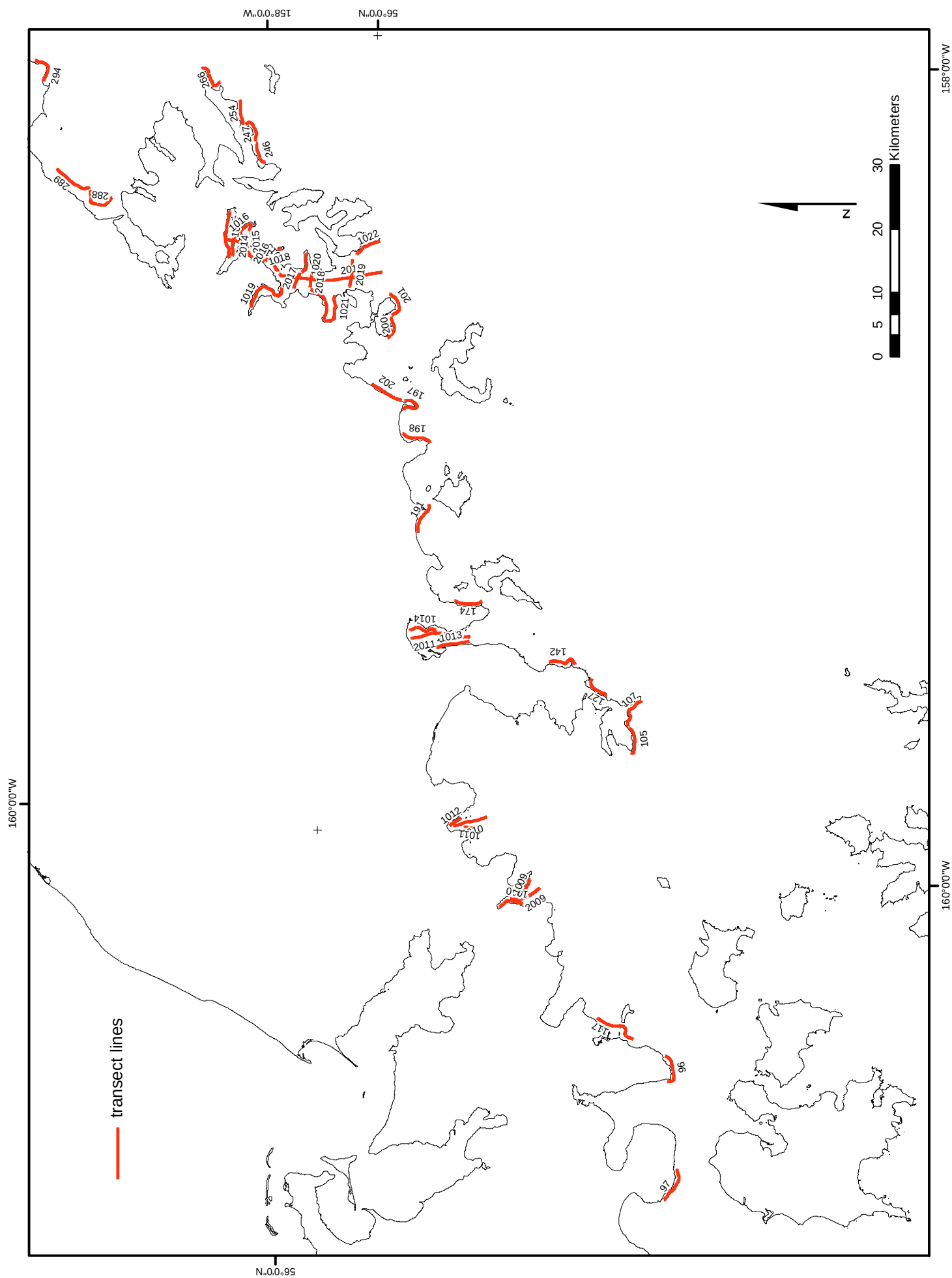
**300 m strip transects used for Kittlitz's Murrelet
population estimation, color-coded by stratum.
Alaska Peninsula, 18 June - 12 July 2003.
Map 4 of 4; south-west section.**

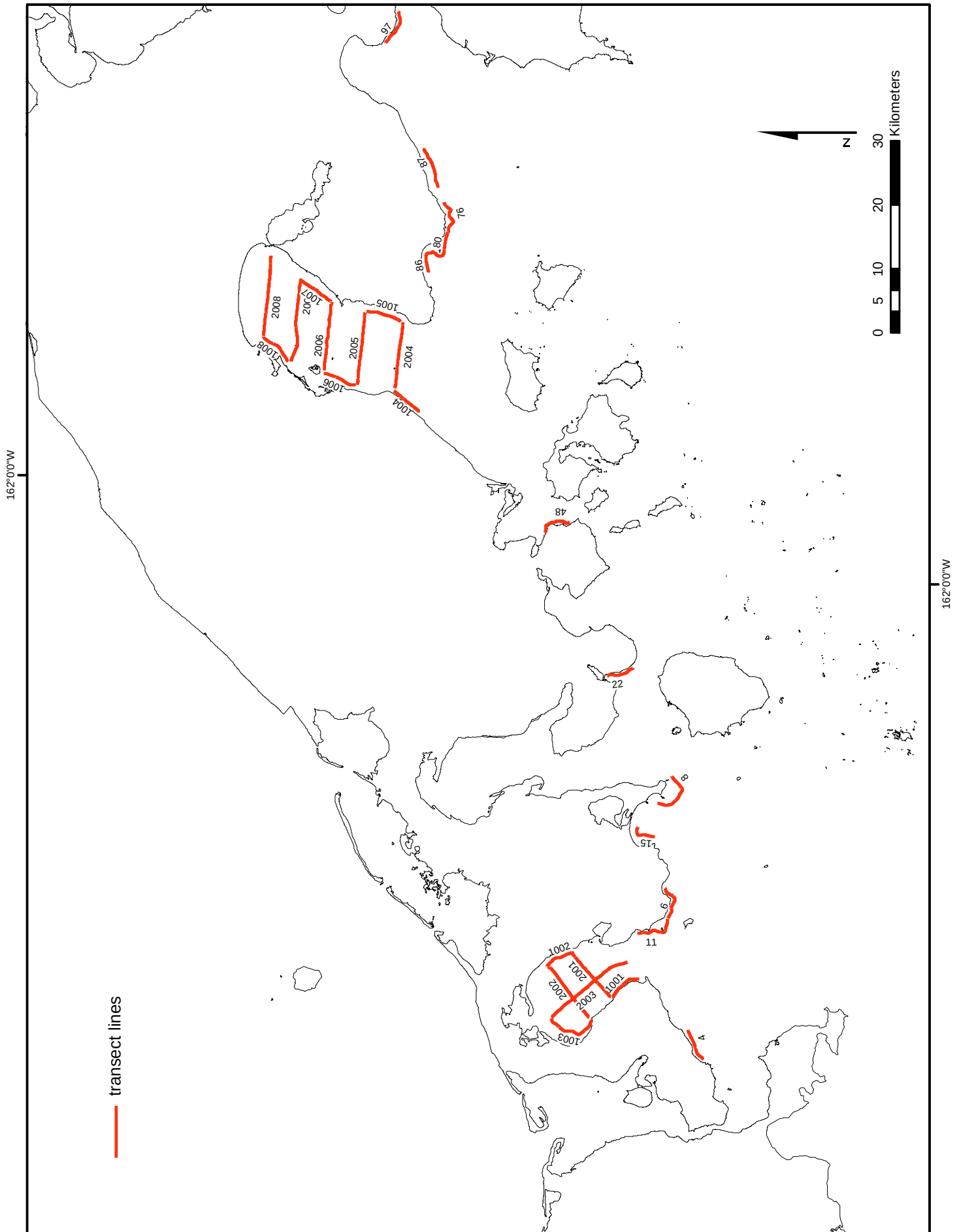


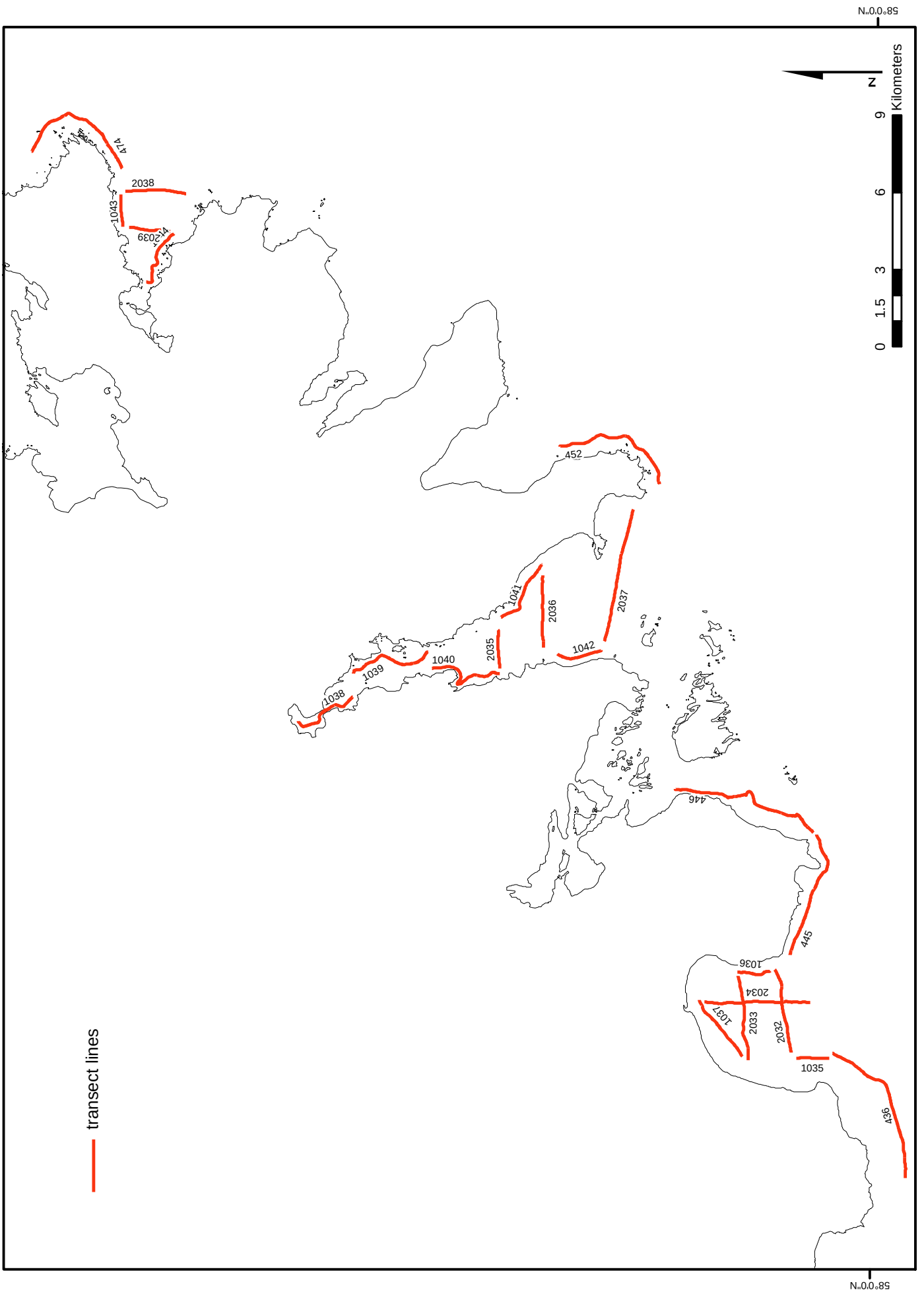
Appendix III. Numbered survey transects. Four maps cover the entire survey area; supplemental maps show areas with high density of transects.

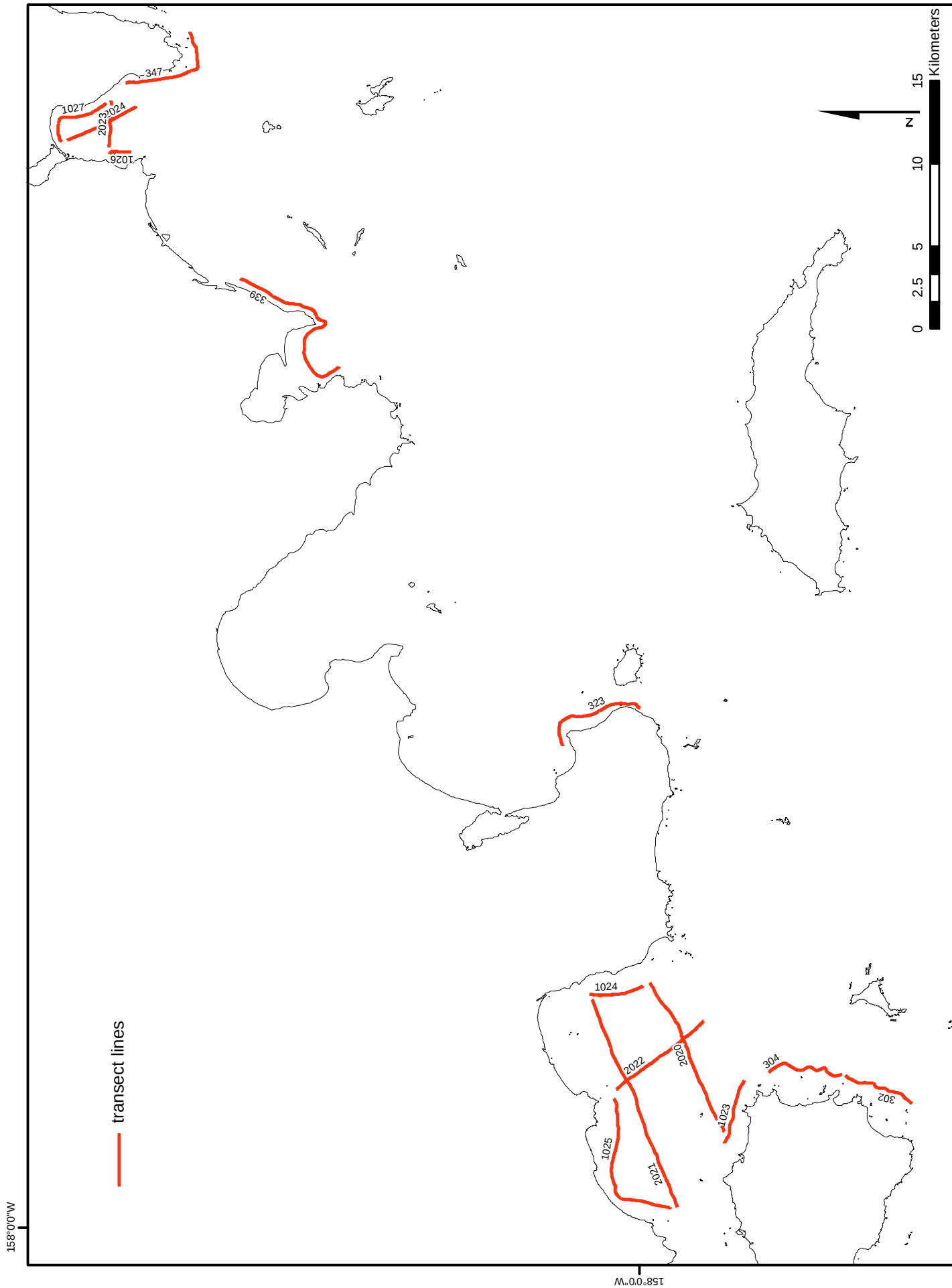


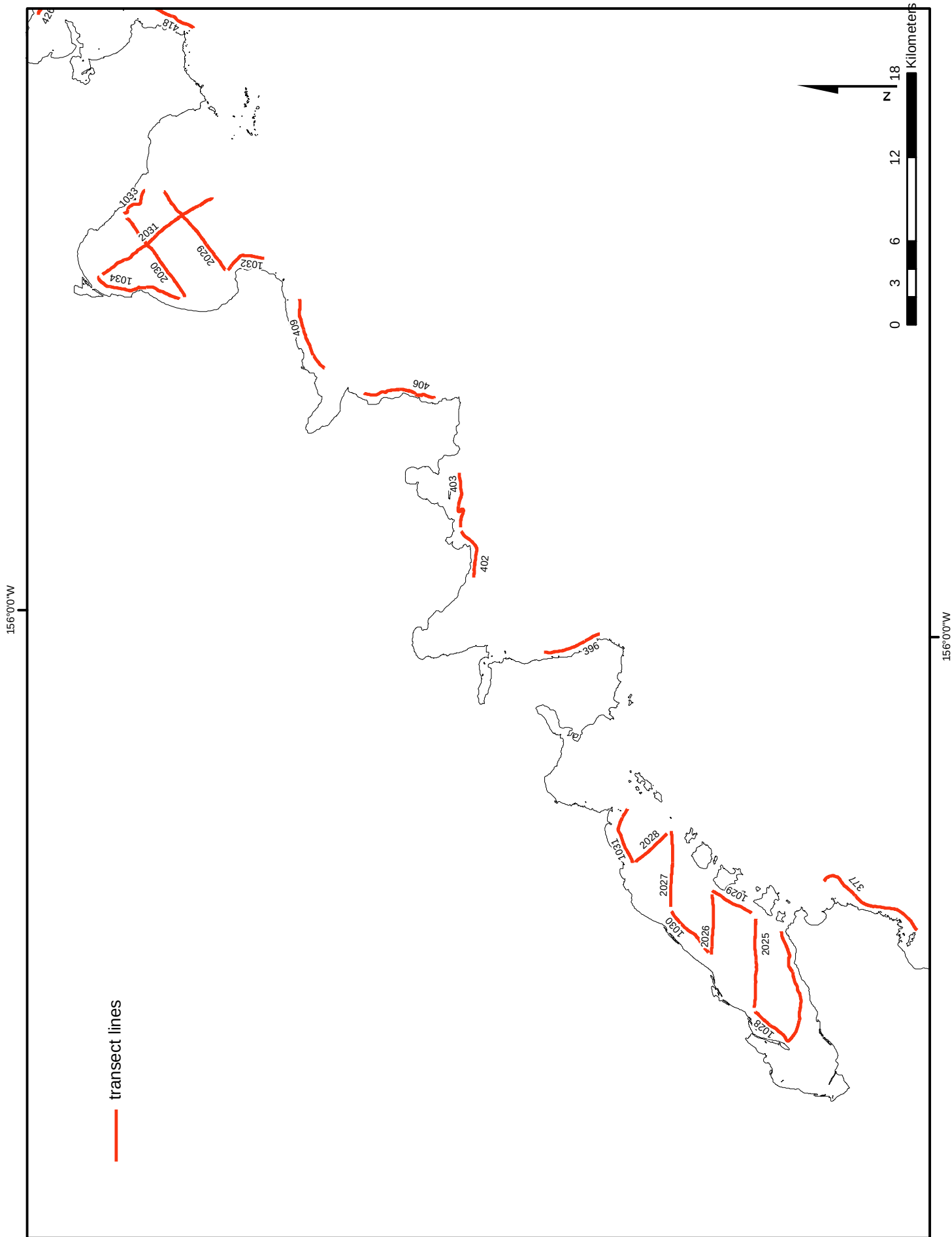


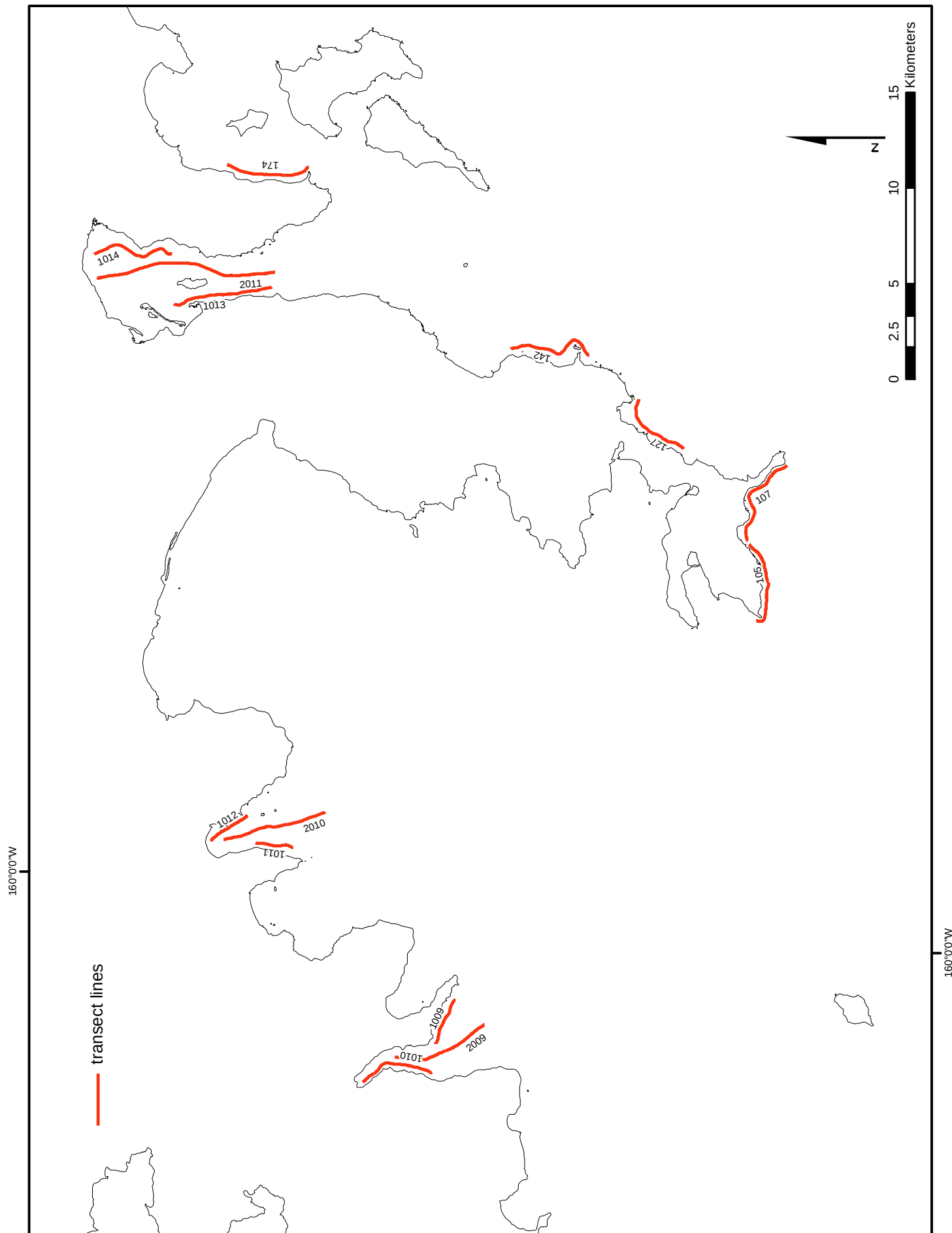


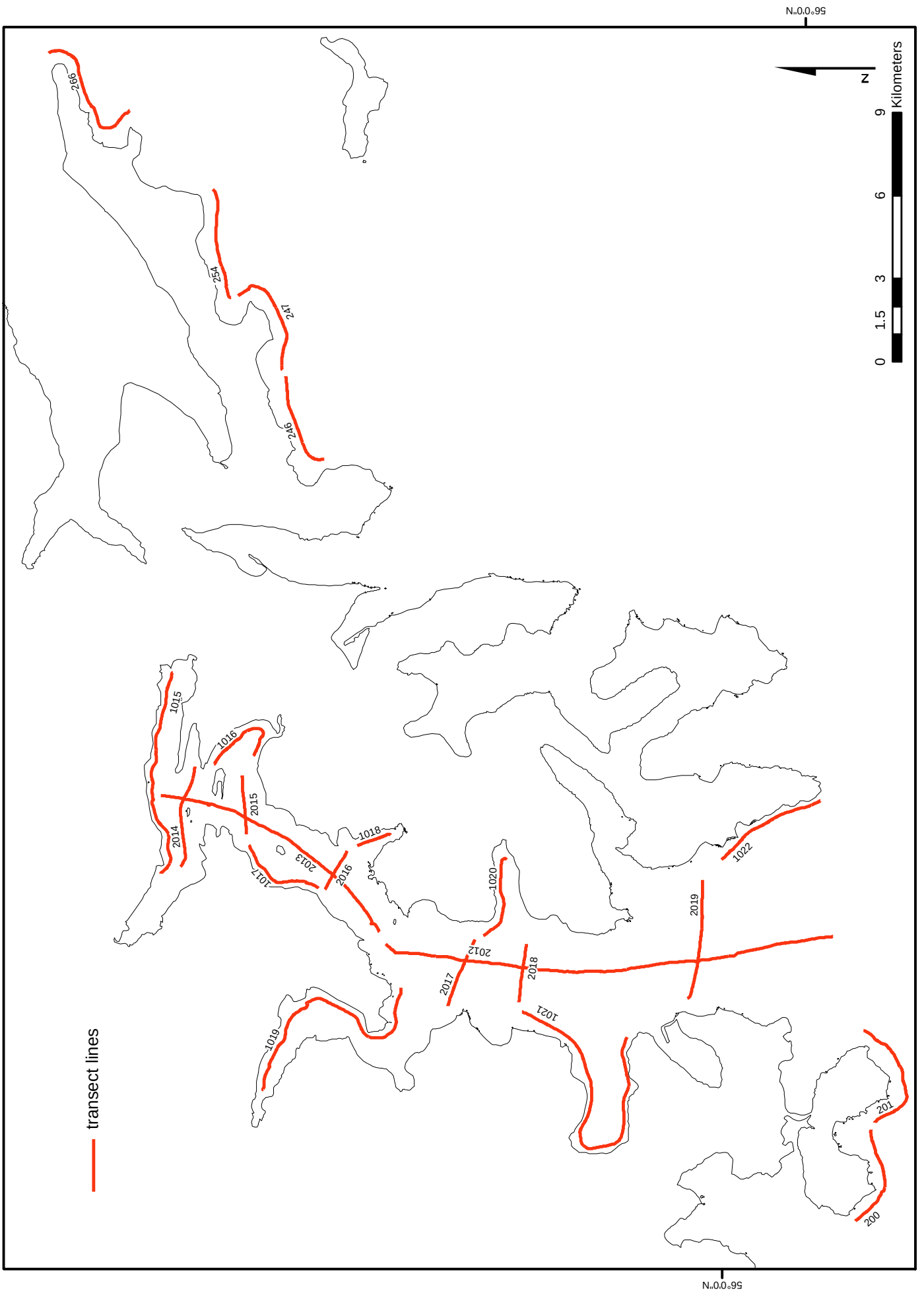




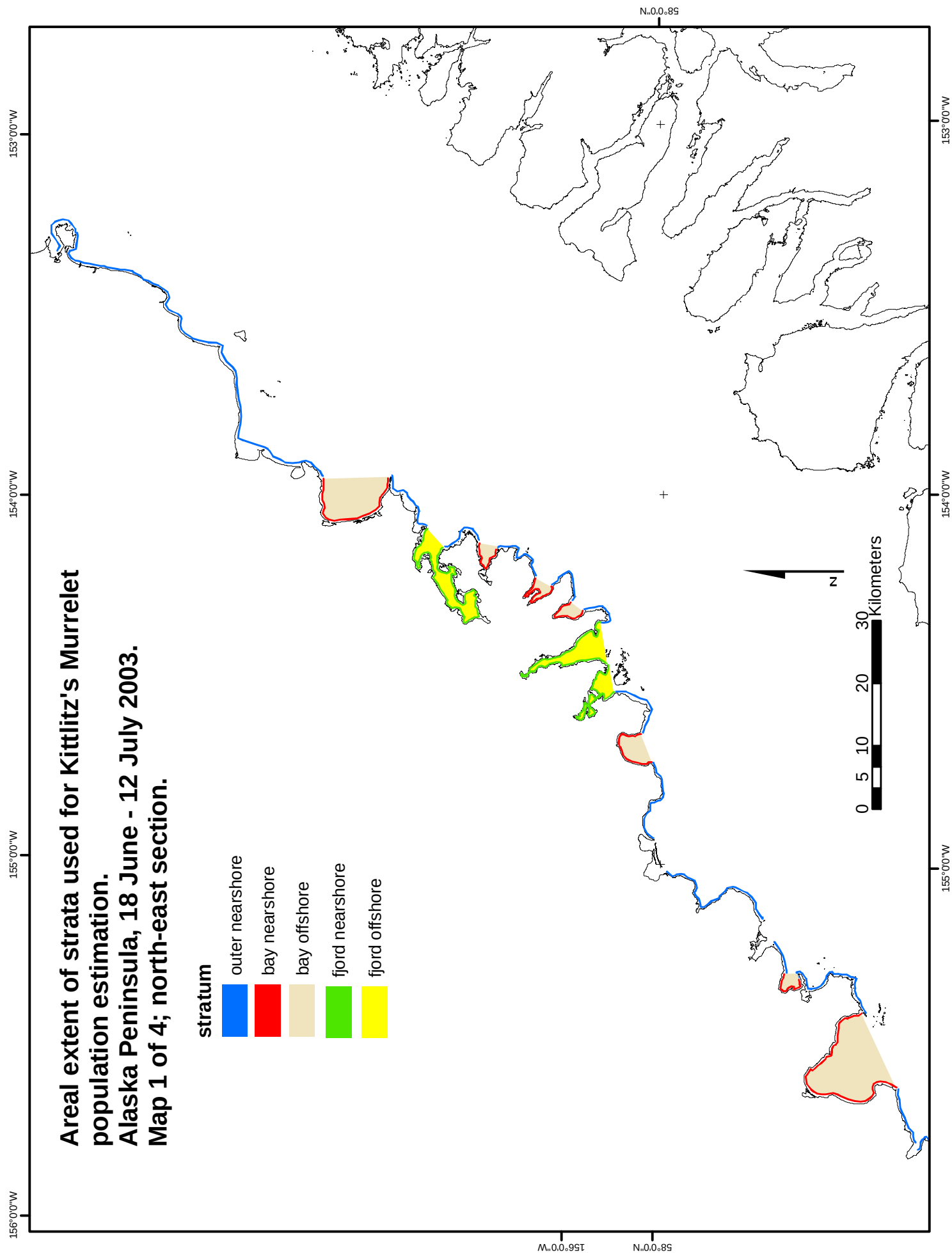


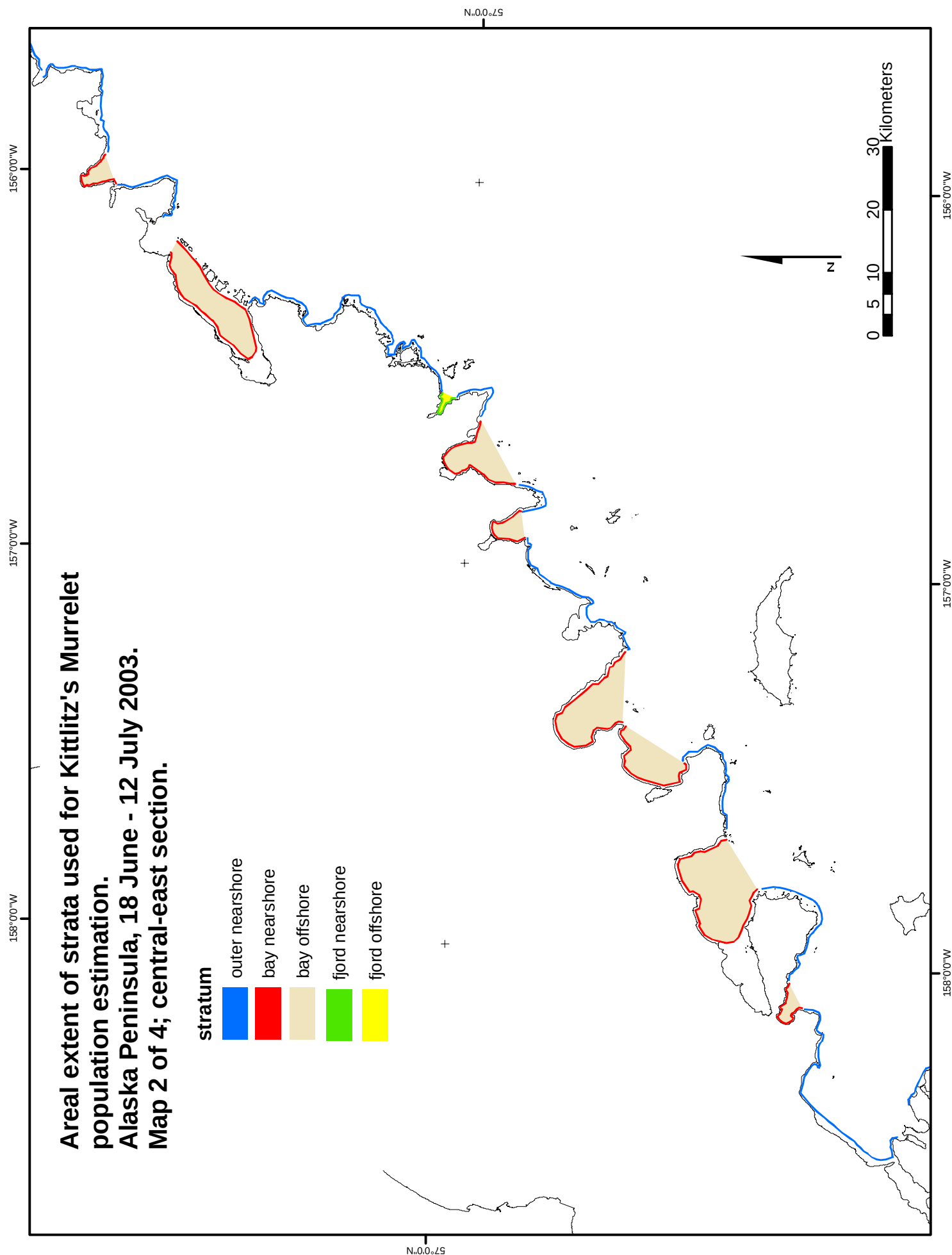


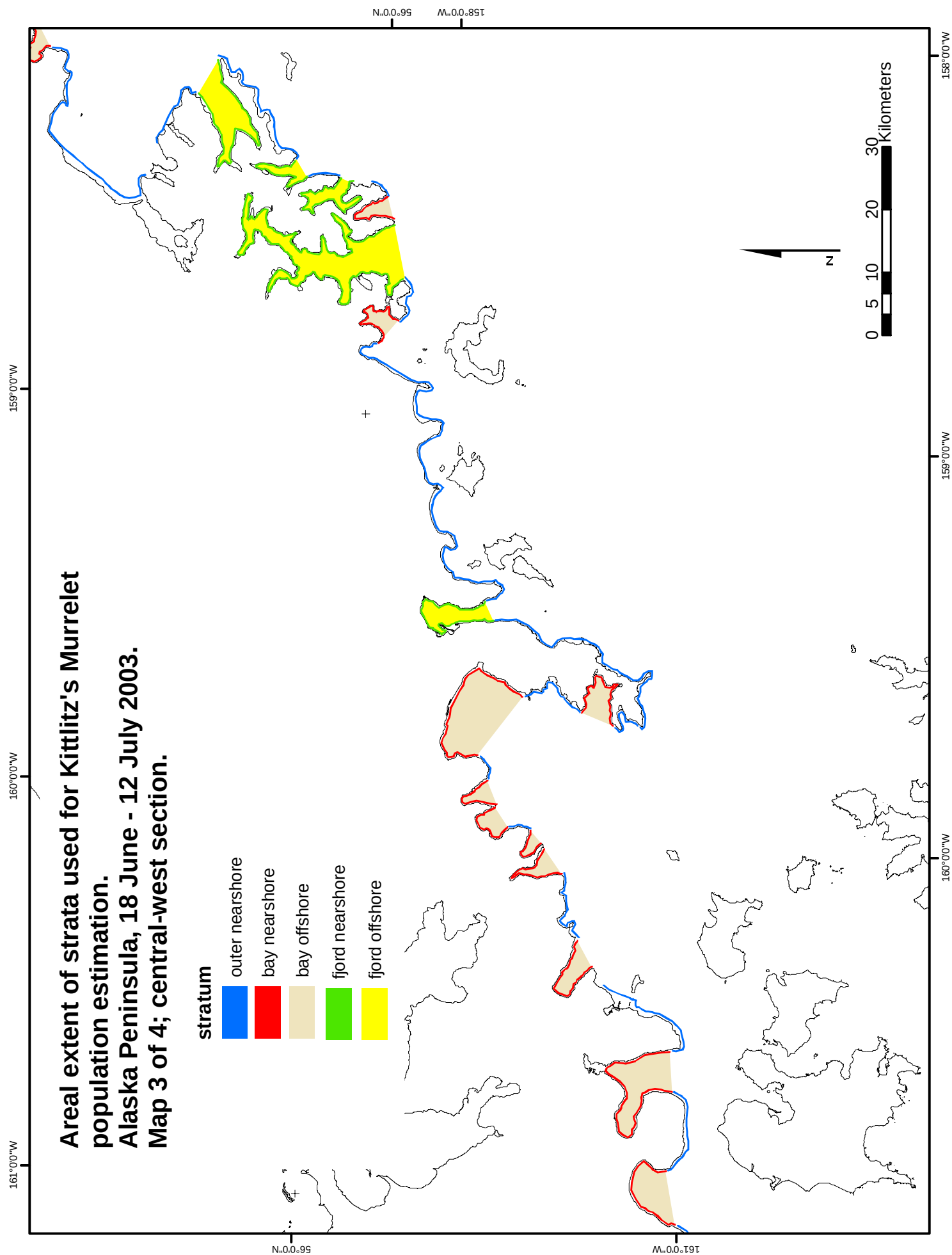




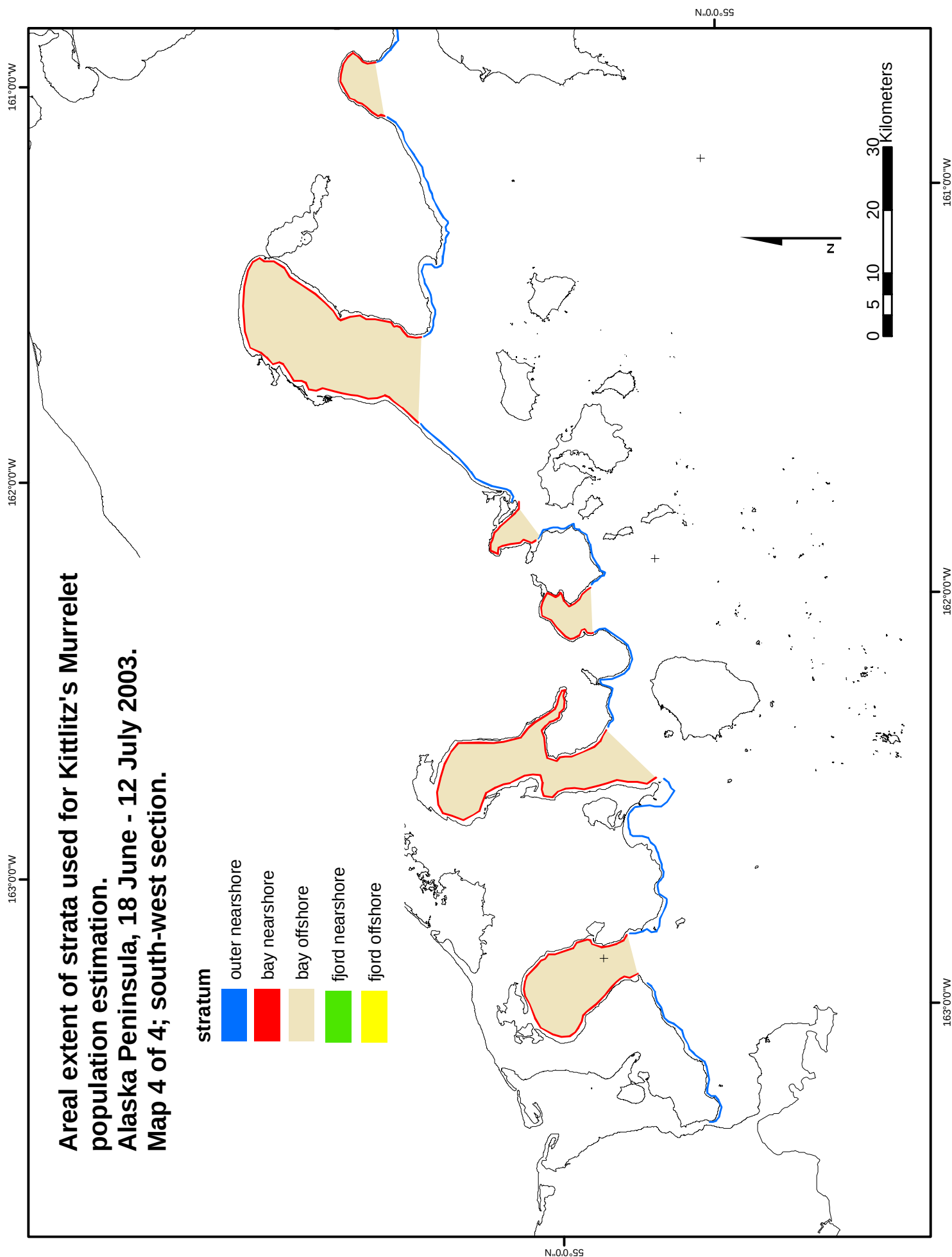
Appendix IV. Color-coded total area per stratum, used to extrapolate total estimated population from surveyed area (see Methods and Appendix II).







**Areal extent of strata used for Kittlitz's Murrelet
population estimation.
Alaska Peninsula, 18 June - 12 July 2003.
Map 4 of 4; south-west section.**



Appendix V. Total numbers of birds and mammals observed on all transects along the south coast of the Alaska Peninsula, Alaska, from Cape Douglas to Isanotski Strait, 18 June - 12 July 2003. Species are listed in taxonomic order. Species totals include only those animals observed while on transect (i.e. not those observed while travelling between transects) and within the strip transect (300 m width), except for Brown Bears, for which totals represent all individuals seen on land while on transect. See Methods for further details of observation protocol and transect locations.

Order	Family	Common name	Scientific name	Species code	Total
<u>Birds</u>					
Gaviiformes	Gaviidae	Common Loon	<i>Gavia immer</i>	COLO	3
		Pacific Loon	<i>Gavia pacifica</i>	PALO	6
		Red-throated Loon	<i>Gavia stellata</i>	RTLO	2
		Yellow-billed Loon	<i>Gavia adamsii</i>	YBLO	2
		Unidentified Loon	<i>Gavia</i> spp.	UNLO	7
Procellariiformes	Procellariidae	Northern Fulmar	<i>Fulmarus glacialis</i>	NOFU	1
		unidentified Shearwater spp.	<i>Puffinus</i> spp.	UNSH	66
		Least Storm-Petrel	<i>Oceanodroma microsoma</i>	LESP	1
		Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	FTSP	5
Pelecaniformes	Phalacrocoracidae	Double-crested Cormorant	<i>Phalacrocorax auritus</i>	DCCO	22
		Red-faced Cormorant	<i>Phalacrocorax urile</i>	RFCO	367
		Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	PECO	40
		Unidentified Cormorant	<i>Phalacrocorax</i> spp.	UNCO	249
Anseriformes	Anatidae	King Eider	<i>Somateria spectabilis</i>	KIEI	2
		Harlequin Duck	<i>Histrionicus histrionicus</i>	HADU	117
		Surf Scoter	<i>Melanitta perspicillata</i>	SUSC	29
		Black Scoter	<i>Melanitta nigra</i>	BLSC	37
		White-winged Scoter	<i>Melanitta fusca</i>	WWSC	603
		Unidentified Scoter	<i>Melanitta</i> spp.	UNSC	256
		Common Merganser	<i>Mergus merganser</i>	COME	167
		Bald Eagle	<i>Haliaeetus leucocephalus</i>	BAEA	6
Falconiformes	Accipitridae		<i>Haematopus bachmani</i>	BLOY	5
		Black Oystercatcher			
Charadriiformes	Scolopacidae	Red-necked Phalarope	<i>Phalaropus lobatus</i>	RNPH	3
		Unidentified Phalarope	<i>Phalaropus</i> spp.	UNPH	33
		Parasitic Jaeger	<i>Stercorarius parasiticus</i>	PAJA	6
		Pomarine Jaeger	<i>Stercorarius pomarinus</i>	POJA	2
	Laridae	Mew Gull	<i>Larus canus</i>	MEGU	15
		Glaucous-winged Gull	<i>Larus glaucescens</i>	GWGU	1358

continued next page

Appendix V (continued). Total numbers of birds and mammals observed on all transects along the south coast of the Alaska Peninsula, Alaska, from Cape Douglas to Isanotski Strait, 18 June - 12 July 2003. Species are listed in taxonomic order. Species totals include only those animals observed while on transect (i.e. not those observed while travelling between transects) and within the strip transect (300 m width), except for Brown Bears, for which totals represent all individuals seen on land while on transect. See Methods for further details of observation protocol and transect locations.

Order	Family	Common name	Scientific name	Species code	Total	
Passeriformes	Alcidae	Black-legged Kittiwake	<i>Rissa tridactyla</i>	BLKI	3204	
		Arctic Tern	<i>Sterna paradisaea</i>	ARTE	3	
		Aleutian Tern	<i>Sterna aleutica</i>	ALTE	22	
		Common Murre	<i>Uria aalge</i>	COMU	3622	
		Thick-billed Murre	<i>Uria lomvia</i>	TBMU	29	
		Unidentified Murre	<i>Uria</i> spp.	UNMU	2730	
		Pigeon Guillemot	<i>Cepphus columba</i>	PIGU	791	
		Ancient Murrelet	<i>Synthliboramphus antiquus</i>	ANMU	331	
		Marbled Murrelet	<i>Brachyramphus marmoratus</i>	MAMU	722	
		Kittlitz's Murrelet	<i>Brachyramphus brevirostris</i>	KIMU	123	
	Unidentified <i>Brachyramphus</i> Murrelet	<i>Brachyramphus</i> spp.	BRMU	65		
	Parakeet Auklet	<i>Aethia psittacula</i>	PAAU	4		
	Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	RHAU	4		
	Horned Puffin	<i>Fratercula corniculata</i>	HOPU	2467		
	Tufted Puffin	<i>Fratercula cirrhata</i>	TUPU	1129		
	Bank Swallow	<i>Riparia riparia</i>	BASW	1		
Mammals	Carnivora	Sea Otter	<i>Enhydra lutris</i>	SEOT	217	
		Steller Sea Lion	<i>Eumetopias jubatus</i>	STSL	6	
		Harbor Seal	<i>Phoca vitulina</i>	HASE	5	
		Brown Bear	<i>Ursus arctos</i>	BRBE	38	
		Humpback Whale	<i>Megaptera novaeangliae</i>	HUWH	1	
		Killer Whale	<i>Orcinus orca</i>	KIWH	2	
		Harbor Porpoise	<i>Phocoena phocoena</i>	HAPO	6	
		Dall's Porpoise	<i>Phocoenoides dalli</i>	DAPO	8	
Sharks	Lamniformes	Salmon Shark	<i>Lamna ditropis</i>	SASH	4	

Appendix VI. Numbers of *Brachyramphus* murrelets (Kittlitz's [KIMU] and Marbled [MAMU]) seen on strip transects along the south coast of the Alaska Peninsula, 18 June - 12 July 2003, grouped by transect number and behavior, and with number that were holding fish when seen indicated in parentheses. Blanks represent zero. See Appendices for delineation of transects and Methods for explanation of strata.

Transect number	Stratum code*	Count by species and behavior								
		KIMU			MAMU			unidentified <i>Brachyramphus</i>		
		flying	on water	total	flying	on water	total	flying	on water	total
4	0					2	2			
6	0					3	3			
8	0									
11	0					1	1			
15	0									
22	0									
48	0									
76	0									
80	0		1	1	1		1			
86	0		4	4				1	1	2
87	0									
96	0					4	4			
97	0									
105	0									
107	0									
117	0									
127	0									
142	0					2	2			
174	0									
191	0		8	8		46	46		2	2
197	0					4	4			
198	0					2	2			
200	0					2	2			
201	0									
202	0					2	2			
246	0									
247	0									
254	0									
266	0									
288	0					2	2			
289	0									
294	0									
302	0									
304	0									
323	0					1	1 (1)			
339	0									
347	0									
354	0								1	1
366	0					2	2			
369	0									
375	0									
377	0									
396	0									
402	0									
403	0								1	1
406	0									
409	0									
418	0					4	4		3	3
426	0				1		1			

*0 = outer nearshore; 1 = bay nearshore; 2 = bay offshore; 3 = fjord nearshore; 4 = fjord offshore

Appendix VI (continued). Numbers of *Brachyramphus* murrelets (Kittlitz's [KIMU] and Marbled [MAMU]) seen on strip transects along the south coast of the Alaska Peninsula, 18 June - 12 July 2003, grouped by transect number and behavior, and with number that were holding fish when seen indicated in parentheses. Blanks represent zero. See Appendices for delineation of transects and Methods for explanation of strata.

Transect number	Stratum code*	Count by species and behavior								
		KIMU			MAMU			unidentified <i>Brachyramphus</i>		
		flying	on water	total	flying	on water	total	flying	on water	total
430	0					1	1		1	1
431	0		2	2				1		1
435	0	1	2	3	1	3	4	2	2	4
436	0				1	2	3			
445	0									
446	0									
452	0									
474	0					7	7			
488	0					9	9	2		2
489	0					5	5			
496	0									
497	0				1	2	3			
498	0					1	1	1		1
502	0					9	9			
504	0		2	2		5	5		6	6
511	0								5	5
512	0									
1001	1					2	2			
1002	1									
1003	1					2	2			
1004	1									
1005	1									
1006	1									
1007	1									
1008	1									
1009	1									
1010	1				1		1			
1011	1									
1012	1					1	1			
1013	3					1	1			
1014	3					11	11 (2)			
1015	3					32	32 (1)			
1016	3		3	3	5	38	43		2	2
1017	3				1	29	30	3		3
1018	3					3	3			
1019	3	3	2	5	8	65	73	1	1	2
1020	3					1	1			
1021	3		1	1		11	11			
1022	3									
1023	1									
1024	1									
1025	1		4	4 (3)		1	1			
1026	1									
1027	1		1	1	1	9	10			
1028	1				1		1			
1029	1									
1030	1								1	1
1031	1					1	1			
1032	1									

*0 = outer nearshore; 1 = bay nearshore; 2 = bay offshore; 3 = fjord nearshore; 4 = fjord offshore

Appendix VI (continued). Numbers of *Brachyramphus* murrelets (Kittlitz's [KIMU] and Marbled [MAMU]) seen on strip transects along the south coast of the Alaska Peninsula, 18 June - 12 July 2003, grouped by transect number and behavior, and with number that were holding fish when seen indicated in parentheses. Blanks represent zero. See Appendices for delineation of transects and Methods for explanation of strata.

Transect number	Stratum code*	Count by species and behavior								
		KIMU			MAMU			unidentified <i>Brachyramphus</i>		
		flying	on water	total	flying	on water	total	flying	on water	total
1033	1		4	4						
1034	1									
1035	1									
1036	1					6	6			
1037	1				1	14	15			
1038	3				6	8	14			
1039	3		1	1	4	45	49		3	3
1040	3		2	2	2	12	14	1		1
1041	3		4	4		23	23		1	1
1042	3				1	2	3			
1043	1									
1044	1					2	2			
2001	2					2	2			
2002	2					8	8	6		6
2003	2									
2004	2									
2005	2					5	5		2	2
2006	2		6	6		2	2			
2007	2	2	4	6		3	3		2	2
2008	2					1	1			
2009	2					8	8			
2010	2					1	1			
2011	4					19	19			
2012	4		2	2	2	23	25			
2013	4		3	3 (3)	1	17	18 (1)			
2014	4					12	12			
2015	4					1	1 (1)		1	1
2016	4				2		2			
2017	4				2	3	5			
2018	4									
2019	4								2	2
2020	2		14	14 (1)		6	6			
2021	2		4	4 (2)		4	4		2	2
2022	2		2	20		2	2 (1)		2	2
2023	2					2	2			
2024	2		6	6		12	12			
2025	2					4	4			
2026	2					1	1			
2027	2									
2028	2									
2029	2	1	3	4						
2030	2								3	3
2031	2		4	4		2	2			
2032	2		2	2		5	5	1		1
2033	2	2		2		16	16 (2)			
2034	2					13	13		2	2
2035	4	2	1	3 (1)	4	16	20			
2036	4		2	2	4	27	31			
2037	4					2	2			
2038	2					8	8			
2039	2					6	6			

*0 = outer nearshore; 1 = bay nearshore; 2 = bay offshore; 3 = fjord nearshore; 4 = fjord offshore