At-Sea Foraging Distributions of Radio-Marked Cassin's Auklet Breeding at Triangle Island, B.C.

W. Sean Boyd, John L. Ryder, Steven G. Shisko, & Douglas F. Bertram

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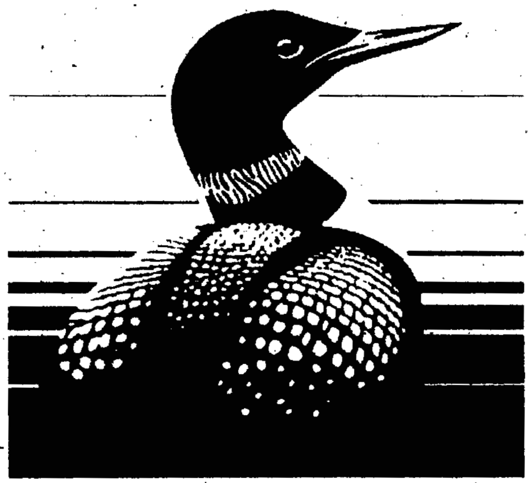

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AT-SEA FORAGING DISTRIBUTIONS OF RADIO-MARKED CASSIN'S AUKLETS BREEDING AT TRIANGLE ISLAND, B.C.

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ABSTRACT

We conducted a radio-telemetry study to determine the at-sea foraging distributions of Cassin's Auklets (*Ptychoramphus aleuticus*) breeding at Triangle Island, British Columbia. The information will help delineate the boundaries of a Marine Protected Area (MPA) around the Scott Island group, a region recently identified as an Important Bird Area (IBA). During the chick-rearing period in June 1999, 39 adults were captured and fitted with radio-transmitters. We conducted aerial surveys to locate the marked birds during two survey periods, 9-10 and 23-24 June. Most marked birds were detected in a relatively small area 40-75 km southwest of Triangle Island in waters >1000 m deep. This distribution pattern was consistent across the two survey periods and especially across days during the second period. Similar telemetry work will be conducted in June 2000 to verify if this pattern holds across years.

RÉSUMÉ

Nous avons effectué une étude radiotélémétrique visant à déterminer la distribution des stariques de Cassin (*Ptychoramphus aleuticus)* nichant sur l'île Triangle (Colombie-Britannique) alors qu'ils se nourrissent en mer. L'objectif était d'évaluer l'utilité de l'établissement d'une aire marine protégée autour de l'archipel de l'île Scott, région récemment reconnue comme étant une « région importante pour les oiseaux » (IBA). Un total de 39 adultes ont été capturés et équipés de petits émetteurs pendant la période d'élevage des oisillons, en juin 1999. Au cours de deux phases de comptage aérien (9-10 juin et 23 -24 juin), nous avons survolé la mer pour localiser les individus marqués. La plupart ont été repérés dans un secteur relativement restreint, entre 40 et 75 km au sud-ouest de l'île Triangle, sur des eaux dont la profondeur excédait 1 000 m, et bien en dehors des limites proposées pour l'air marine protégée. Ce type de distribution a été observé lors des deux phases de comptage et durant les deux jours de la seconde phase. Des travaux de télémétrie similaires seront effectués en juin 2000 pour vérifier si ce type de distribution se retrouve d'année en année.

ACKNOWLEDGEMENTS

We thank Carolyn Yakel and the other technicians and volunteers who assisted in the field. Lynn Lougheed provided advice on radio attachment techniques. The British Columbia Ministry of Environment Lands and Park granted permission to work on the Anne Vallée Ecological Reserve, Triangle Island. Steven Shisko provided GIS support made possible through the Career Edge federal internship program. Generous financial support was provided to DFB by the Nestucca Trust Fund, and the Canadian Nature Federation and their partners BirdLife International and Bird Studies Canada. Additional financial support was obtained from a Natural Sciences and Engineering Research Council operating grant to Dr. Fred Cooke and the CWS/NSERC Centre for Wildlife Ecology at Simon Fraser University (SFU). We benefited from discussions with Dr. Dave Mackas (Fisheries and Oceans Canada), Gary Kaiser (Canadian Wildlife Service) Dr. Cindy Hull (SFU), Hugh Knechtel (SFU), and Robert Suryan (USF&WS). Mark Drever (SFU/CWS) provided technical assistance in preparing this report.

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INTRODUCTION

To facilitate the protection of seabirds in British Columbia, information is needed on their at-sea foraging distributions during the breeding season (Drever 1999, Burger et al. 1997, Gaston 1996). Marine Protected Areas (MPAs) have been proposed in areas where marine species congregate in high numbers (Petrachenko and Thompson 1998, Dunn and Morgan 1999). The Scott Islands group is the most important site for breeding seabirds in British Columbia (Drever 1999) and it was nominated by the Canadian Wildlife Service (CWS) as an Important Bird Area (IBA) in 1997 (Drever 1999). The islands support an estimated 2.2 million breeding seabirds (Rodway et al. 1990, 1992), including ca. one million pairs of Cassin's Auklets (*Ptychoramphus aleuticus*) or 55% of the world's population (Rodway et al. 1990, Canadian IBA database 1998). Surveys in 1989 estimated 548 000 breeding pairs of Cassin's Auklets on Triangle Island (Rodway et al. 1992).

We conducted a telemetry study to determine the at-sea foraging distributions of Cassin's Auklets breeding on Triangle Island in 1999. This information may be used by stakeholders when delineating MPA boundaries for the Scott Island group. Cassin's Auklets were selected because they are one of the focal species for research, their burrow sites are readily accessible, they forage offshore during the daytime (Vermeer et al. 1985, Ainley et al. 1996) and they tolerate handling. An additional consideration was that Cassin's Auklets provision chicks primarily with zooplankton (Vermeer 1981, Burger and Powell 1989, D. Bertram, SFU/CWS, unpubl. data) and collaborative investigations on the distribution and abundance of zooplankton species are being undertaken with Fisheries and Oceans Canada.

METHODS

Study area

Triangle Island (50° 52'N; 129° 05'W) is northwest of Vancouver Island, 46 km off Cape Scott. It is the outermost island in the Scott Islands chain (Figs. 1A and B). Port McNeill and Port Hardy on the north-east coast of Vancouver Island were used as base camps for the telemetry flights (Fig. 1A).

Adult capture and transmitter attachment

From 6-19 June, 1999, 39 adult Cassin's Auklets were captured in West Bay at Triangle Island (Fig. 2) and fitted with radio-transmitters. Two capture methods were used. From 6-9 June, 26 adults were removed from burrows containing chicks, at approximately the mid-point of the 39-45 d chick rearing period. Of these, 10 birds were captured during the day while brooding young chicks and 16 were captured during the early morning hours just subsequent to their return to the colony. One parent from each burrow was radio-marked. The birds were returned to the burrow immediately after transmitter attachment. From 11-19 June, 13 adults were captured by soft plastic "pheasant" nets as they returned to the colony during the early morning hours. The net (approximately 15 m x 3 m) was erected vertically between two guyed polyvinyl chloride plastic poles at the base of the slope. Transmitters were attached only to adults carrying food-loads. Adults were sexed from bill depth measurements according to the criteria developed by Knechtel (H. Knechtel, SFU, unpubl. data). Individuals with bill depth > 9.9 mm were classified as males and < 9.7 mm as females. We did not attempt to assign sex to individuals with bill depth measurements in the 9.7-9.9 mm range.

Transmitters were affixed to Cassin's Auklets using the protocol described in Newman et al. (1999). Advanced Telemetry Systems (ATS) transmitters with anchors for subcutaneous attachment were used (Model 394; Advanced Telemetry Systems©, Isanti, Minnesota). Each transmitter weighed approximately 2.2 g (or < 2% of mean adult mass; Vermeer 1981) and had an expected lifespan of approximately 45 d. We used a sterilized 18- gauge hypodermic needle to perforate a small hole through the interscapular epidermis for anchor insertion. To limit handling time, birds were not anesthetized and they did not appear to suffer any ill-effects from the treatment. Marine epoxy (Marine epoxy #332©, Titan Corporation, Lynnwood, Washington) was applied to the transmitter and back feathers to hold the transmitter in place below the anchor site. Sutures were not used in the procedure. This protocol has been used successfully on Marbled Murrelets in Desolation Sound and Mussel Inlet, B.C. (L. Lougheed, SFU/CWS, unpubl. data, Kaiser and Keddie 2000).

Aerial detection of radio-marked individuals

Aerial telemetry surveys were conducted over two periods, 9-10 June and 23-24 June, 1999. During each survey, we flew at ca. 3000 m altitude and at ca. 130-140 km h^{-1} in a single-engine Dehaviland Beaver on floats. Each survey lasted ca. 4.5 h, including transit time to and from the base camp. Surveys were conducted during daylight hours when adults were foraging at sea and telemetry grids were established largely in east-west and north-south directions (Figs. 3 and 4).

We used two-element H-antennae, mounted to the airplane struts, during the 9-10 June surveys and 4-element Yagi antennae on the 23-24 June surveys. Radio frequencies were scanned at 2 s intervals using an ATS scanner/receiver (Model R4000; Advanced Telemetry Systems Ltd.©, Isanti, Minnesota). When a transmitter was detected, its signal strength and direction (with respect to flight path) were recorded along with the location (latitude, longitude) of the airplane using GPS. We did not attempt to pinpoint the exact location of each transmitter (eg., by flying tight circles around it) because such a procedure would have been too consuming of fuel and time.

During the first survey on 9 June (Fig. 3A), we flew in a tight grid pattern around Triangle Island to estimate the potential range of an identical reference transmitter in West Bay and to determine the number of transmitters present in the open ocean nearby. Using the information from 9 June, we flew a wider grid pattern on the morning of 10 June starting at Triangle Island and working east-west (Fig. 3B). Several transmitters were detected at the south and west edges of this grid. After re-fueling, we flew transects that were farther out to sea (up to ca. 70 km west and 90 km south of Triangle Island).

The distribution pattern of transmitters found on 10 June was used to design the route flown on 23 June (Fig. 4A). We wanted to determine if the at-sea distribution of marked birds changed across the 2-week period. In the morning of 23 June, we flew an east-west grid from just south of Triangle Island to 40-

50 km farther north. After refueling, we extended the grid to ca. 80 km west and 100 km south of the island. On 24 June, we flew a relatively small area that encompassed most of the transmitters detected during the previous day (Fig. 4B).

Colony detection of radio-marked individuals

Prior to each aerial survey, we scanned all frequencies to determine which transmitters were present at the colony. Manual scans were conducted on 9-10 June during the mid-morning hours after most adults had left the colony. From 14 June to 6 July, 1999, a remote telemetry recording system (DCC II, Model D5041; Advanced telemetry systems Ltd.©, Isanti, Minnesota) was positioned at the north end of West Bay (Fig. 2) to monitor the attendance behaviour of radio-marked birds at the colony prior to the chick fledging period (the first recorded fledgling in West Bay was on 23 June; D. Bertram, SFU/CWS, unpubl. data). The DCC II was linked to a receiver (Model R4000; Advanced Telemetry Systems Ltd. ©, Isanti, Minnesota) and an H-antenna and powered by a 12V deep-cycle battery connected to a solar panel (Model SM75, Siemens Solar Industries©, Camarillo, California). Frequencies were scanned at 5-10 s intervals to monitor arrival times. Following detection of a specific frequency the scanning interval was reduced to 15 min intervals until the bird departed the colony. The reference transmitter was used to confirm that the equipment functioned properly.

Mapping and analyses of foraging locations

At-sea locations were plotted in lat/long and were later converted to Albers projection for mapping and analysis using Arcview software. The inferred location of each radio-marked bird was determined by plotting airplane location and transmitter signal strength/direction using Arcview GIS (Version 3.1; Environmental Systems Research Institute Inc.©, Redlands, California). The most likely location for each bird was estimated using the available data; position accuracy was related to the number and strength of detections recorded for each transmitter (eg., birds with >10 strong signals would have been positioned more accurately than transmitters with only one or a few weak signals). For each survey, we used the data from radio-marked birds with multiple detections to compute the average distances from the airplane to inferred locations for each signal strength. These were then used to estimate the most likely location for transmitters that had one or only a few weak signals. Additionally, from 9-10 June we estimated the error associated with our positioning protocol. The positions of five radio-marked birds in burrows on Triangle Island were compared to their inferred locations derived from aerial surveys.

We estimated "modified" Jenrich-Turner home ranges for marked birds on 10 and 23 June using the Arcview GIS Animal Movement Analysis Extension (Jenrich and Turner 1969, Hooge and Eichenlaub 1997). Typically, home range analyses generate polygons for specific individuals detected on multiple occasions over time. In our "modified" approach, we used the inferred location of each marked bird as the sampling unit to calculate the arithmetic mean centre of activity. Distributions with 50% and 95% probability ellipses were generated and compared. The grids flown on 9 and 24 June were too small and specific to warrant this type of analysis.

RESULTS AND DISCUSSION

Colony detections

Twenty-six of the 39 birds (67%) regularly attended the colony on a daily or bi-daily basis (12 males, 12 females, and 2 undetermined). Of the 26 birds, 24 (96%) were detected during aerial surveys on at least one occasion (Table 1). One of the two undetected birds (frequency 164.103) departed the colony on the morning of 15 June and its chick was discovered dead in the burrow on 17 June. The other undetected bird (164.882) abandoned the colony on 16 June but the status of its chick was unknown because the adult was captured at the net. Eight adults (21%) were not detected at the colony or during the at-sea surveys (Table 1). Their transmitters may have failed, the birds may have died, or they may have left the study area. The nestling of one of these adults (164.094) was discovered dead in the burrow on 18 June. The estimated failure rate of the same ATS transmitters attached to Marbled Murrelets in Desolation Sound and Mussel Inlet, B.C., was 11-13% (Hull et al. 2000, Kaiser and Keddie 2000). Two adults (164.162 and 164.853) abandoned the colony but were later detected during the at-sea surveys (Table 1). Another bird (164.903) was absent at the colony from 12-22 June, present at the colony from 23-26 June, and absent again from 27 June-5 July. This individual was caught at the net and may have been a non-breeder, or alternatively it may have been nesting outside the detection area and was recorded occasionally (colony attendance patterns for all individuals will be treated elsewhere).

Prior to DCC activation, the manual (hand-held) scan conducted on 9 June preceding the first aerial survey recorded one adult present at the colony at 11:00h (164.843). On 10 June, four adults were present at the colony on a manual scan conducted at 07:00h (164.094, .773, .783, and .792). DCC data showed that no adults were present at the colony on 23 June and one adult was present on 24 June (164.922).

We tested for the effect of capture technique and capture time on subsequent detection of individuals in the colony. For birds detected at the colony, the proportion of adults taken from burrows (0.62 ± 0.19) was not significantly different than for those caught at the net (0.77± 0.23 (95% C.I)) (2-tailed t-test, $t = 0.94$, $df = 37$, $p = 0.34$). The proportion of subsequent detections of adults taken from burrows during the day (from 12:00 to 16:30 h) was 0.40 ± 0.31, while for adults taken during the late evening/early morning (from 23:00 to 04:00 h) was 0.75 ± 0.22. This difference was not significant (2-tailed t-test, $t = 3.45$, $df = 24$, $p = 0.09$).

Handling time did not appear to affect the colony attendance behaviour of individuals. Average handling time was 24 min for each bird removed from the burrow (range 16-37 min) and 28 min for birds captured at the net (range 19-51 min). The subsequent detections of adults that were handled for ≤ 25 minutes (0.68 ± 0.19) was not significantly different than the proportion of adults handled for > 25 minutes (0.64 ± 0.26) (2-tailed t-test, $t = 16.67$, $df = 37$, $p = 0.82$).

At-sea detections

An example of high quality/quantity telemetry data collected for one bird (164.133) on 23 June is provided in Figure 5. The relative signal strength and direction for each detection are shown along with the inferred location of the bird. Four birds were detected only once on 10 June (Fig. 6A) but all birds were detected more than once on 23 June (Fig. 6B). The difference in number of detections per individual between surveys can be attributed largely to the fact that different antennae were used (see above). Other factors that can affect the probability of detection include: transmitter strength, position of antenna on the bird, submerged (diving) activity, etc.

The error associated with estimating locations was low; for five transmitters on Triangle Island the mean distance from the true location to the inferred location was 4.5 km (SE=2) with a maximum error of 6.8 km. Four of the five transmitters were detected only once during this ground truthing exercise, suggesting that the locations for transmitters detected on several occasions would be predicted accurately.

We used distances from the airplane to inferred locations to estimate total coverage during the surveys (Figs. 7A and B). The mean and maximum potential areas covered on 10 June were 1.3 million ha and 2.1 million ha, respectively. For 23 June, the areas were 2.6 million and 5.1 million ha. Coverage on 10 June was less than on 23 June due to the type of antennae used (see above).

Foraging ranges and distributions

The patterns found on 10 June (Fig. 8B) and 23 June (Fig. 9A) represent the at-sea distributions of Cassin's Auklets nesting on Triangle Island during the 1999 chick rearing period. Survey coverage was the most extensive and unbiased on these two survey dates. On 10 June, 16 of 22 (73%) marked birds were detected at-sea (Fig. 10A; mean distance from Triangle Island = 59 km (SE=5), maximum = 93 km). Seven of these individuals were male, 8 female, and 1 undetermined (Fig. 9C). On 23 June, 24 of 27 (89%) marked birds were detected at-sea (Fig. 10B; mean distance = 54 km (SE=3), maximum = 80 km). Thirteen of these individuals were male, 9 female, and 2 undetermined (Fig. 9D). There were no apparent sex-specific differences in the patterns of distribution. At-sea distributions for dates with biased survey coverage on 9 June (Fig. 8A) and 24 June (Fig. 9B) are presented for comparison.

A concurrent telemetry study conducted at San Miguel Island, California, found that Cassin's Auklets were concentrated approximately 10-20 km off the colony (J. Adams, USGS-BRD, unpubl. data). Marbled Murrelets in British Columbia commuted 12-102 km from nest sites to foraging sites in 1998 (Hull et al. 2000). Least Auklets breeding in the Bering Sea had foraging radii of 5-56 km (Obst et al. 1994), and Crested Auklets traveled 55-110 km to forage (Hunt et al. 1993). Foraging distributions for Common Murres, Razorbills and Atlantic Puffins were reported to range from 2 to >10 km from colonies (Wanless et al. 1990).

The Jenrich-Turner ellipses differed in area covered but they were centered over approximately the same area of open ocean. The 95% probability ellipse for 10 June covered an area of ca. 900,000 ha with an arithmetic mean point 52 km southwest of Triangle Island. The 95% probability ellipse for 23 June covered an area of ca. 330,000 ha with an arithmetic mean point 53 km southwest of Triangle Island (Figs. 11A,B and 12A,B).

Marked Cassin's Auklets foraged 35-50 km seaward of the 200 m shelf break isobath. On 10 June and 23 June, only 1 of 16 (6%) and 2 of 24 (8%) adults were found at the continental shelf margin between the coast and the 200 m isobath, respectively; all other marked birds were in water 1500-2000 m deep. In contrast to our findings, other studies in California (Briggs et al. 1987, Ainley et al. 1996, J. Adams, USGS-BRD, unpubl. data), Alaska (Sanger, 1987) and British Columbia (Vermeer et al. 1985) suggested that Cassin's Auklets foraged near the continental shelf during the breeding season. Previous studies have documented aggregations of Cassin's Auklets and other seabirds in the vicinity of offshore seamounts (Vermeer et al. 1985, Haney et al. 1995); however, no such features occur where we located marked birds.

Ten radio-marked birds were detected on both 10 June and 23 June (Fig. 13). These birds moved mean and maximum distances of ca. 31 km (SE=6) and 62 km, respectively, between periods. As with the Jenrich-Turner home range distributions discussed above, the area over which these ten marked birds were distributed was greater on 10 June compared to 23 June, but the centre of their 95% probability ellipses shifted only 13 km to the northwest (Figs. 11A, 12A). Across days (ie., from 23 to 24 June), the movements of 20 marked individuals were less pronounced. Mean and maximum distances moved were only 15 km (SE=2) and 34 km, respectively (Fig. 14).

In summary, the majority of marked birds detected in June 1999 were found in a relatively small area 40-75 km southwest of Triangle Island in waters >1000 m deep. This pattern of distribution was consistent across the two survey periods, and especially across days during the second period. Similar telemetry work will be conducted in June 2000 to verify if this pattern holds across years.

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Table 1: Summary of transmitter attachment dates and post-release detections on the colony and at-sea.

Frequency[1]	Attachment date (in June) and time		Capture method	Adult Sex	Detected at colony[2]	Detected on ocean	
					Detected (x)	Detected (x)	Detection date(s) in June
.022	6	12:42	BURROW	M			
.042	6	13:38	BURROW	F	x	x	10,23
.063	6	14:05	BURROW	M	x	x	10,23,24
.074	6	14:32	BURROW				
.082°	6	15:09	BURROW	F			
.094	6	15:44	BURROW	M			
.103	7	00:13	BURROW	F	x		
.113	7	00:48	BURROW	F		x	10
.124	7	01:28	BURROW		x	x	10,23,24
.133	7	02:04	BURROW	F	x	x	10,23,24
.142	7	02:33	BURROW	F	x	x	10,23,24
.153	7	03:03	BURROW	M	x	x	23,24
.162	7	03:38	BURROW	M		x*	10,23
.173	8	00:17	BURROW	M	x	x	9,10,23,24
.193	8	00:51	BURROW	M	x	x	10,23,24
.762	8	02:21	BURROW	M	x	x	10,23,24
.773	8	15:20	BURROW	F	x	x	23,24
.783	8	14:53	BURROW				
.792	8	15:50	BURROW	M	x	x	23,24
.802	8	01:41	BURROW	F	x	x	9,10
.813	8	16:25	BURROW	F		x	10
.822	9	00:06	BURROW	F	x	x	23,24
.832	9	00:32	BURROW	M		x	9,10
.843	9	01:06	BURROW	M	x	x	23,24
.853	9	01:29	BURROW	F		x*	10,23,24
.862	9	01:59	BURROW	F	x	x	9,10
.873	11	23:40	NET	M	x	x	23,24
.882	12	23:38	NET	F	x		
.893	13	23:24	NET	F	x	x	23,24
.903	12	00:08	NET	M	x	x	23,24
.913	12	00:41	NET	F			
.922	12	01:00	NET	M	x	x	23
.933	12	01:25	NET				
.943	13	23:38	NET	M	x	x	23,24
.952	13	00:11	NET		x	x	23,24
.964	14	00:29	NET	F	x	x	23;24
.973	18	00:01	NET	M	x	x	23
.983	19	00:04	NET				
.993	19	00:10	NET	F	x	x	23,24

[1] frequency prefix is 164 (Mhz)
[2] colony detection of radio-tagged individuals based on data collected from 14 June to 6 July, 1999. Individuals undetected at ≥1d post-attachment were considered to have abandoned the colony and/or the transmitter failed (detected = x). Attendance behaviour prior to 14 June were not verifiable due to infrequent scans.
° noisy frequency; transmitter may have malfunctioned
* adult detected on ocean following confirmation it had abandoned the colony (no longer feeding the nestling)

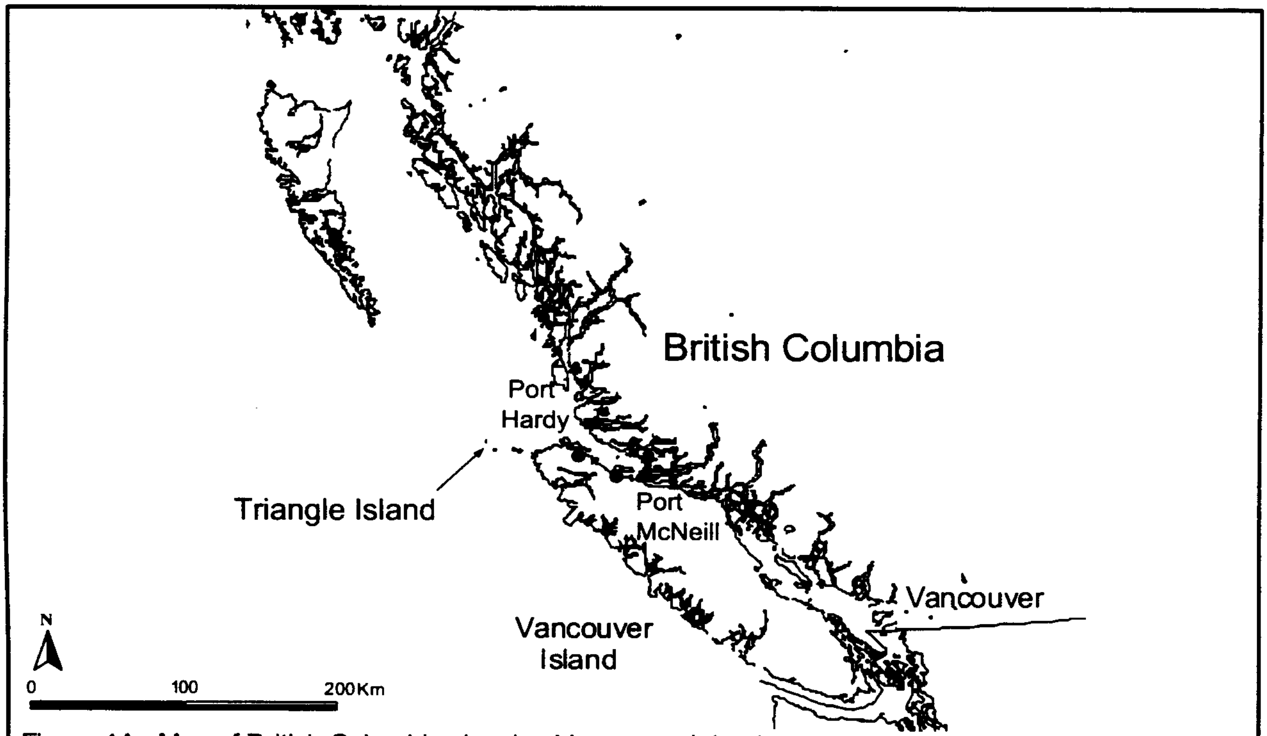


Figure 1A. Map of British Columbia showing Vancouver Island and Triangle Island.

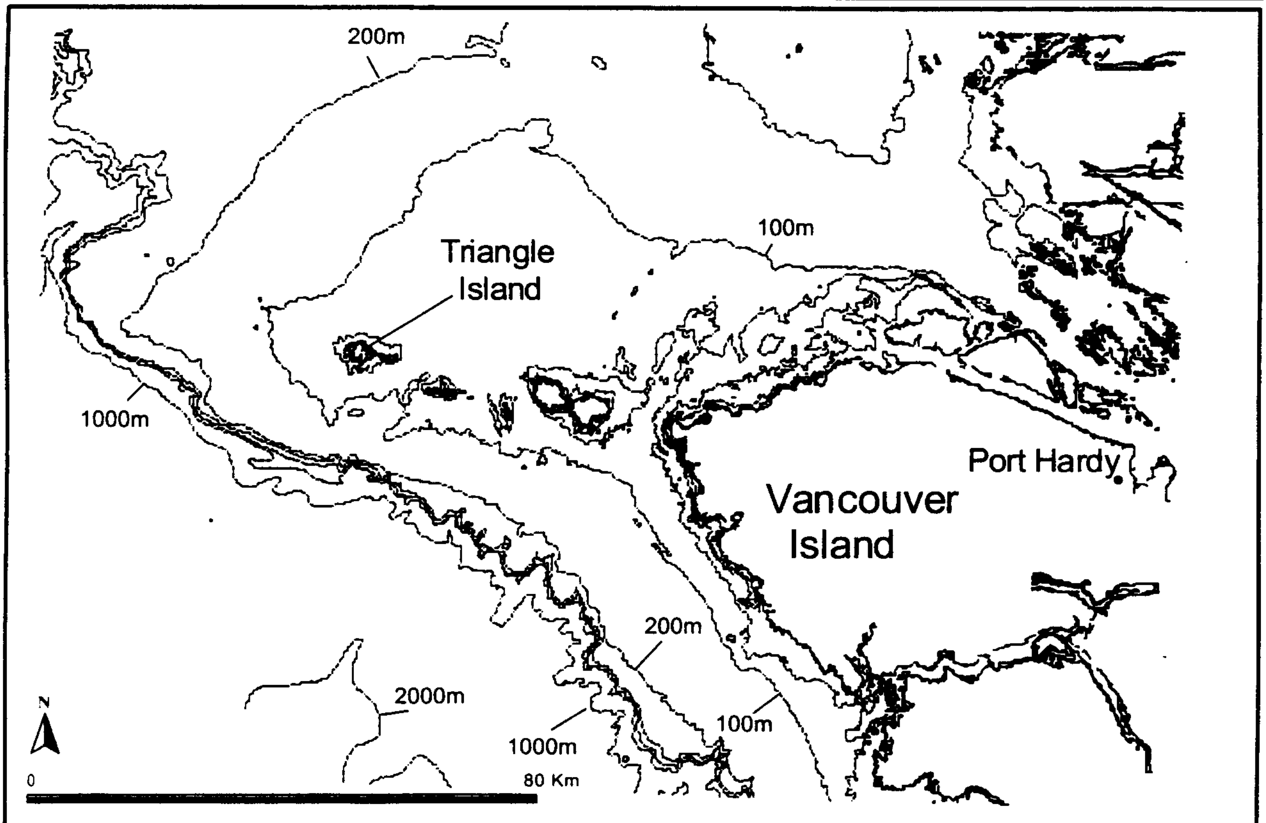


Figure 1B. Map of study area showing the North coast of Vancouver Island, Triangle Island and ocean bottom contours.

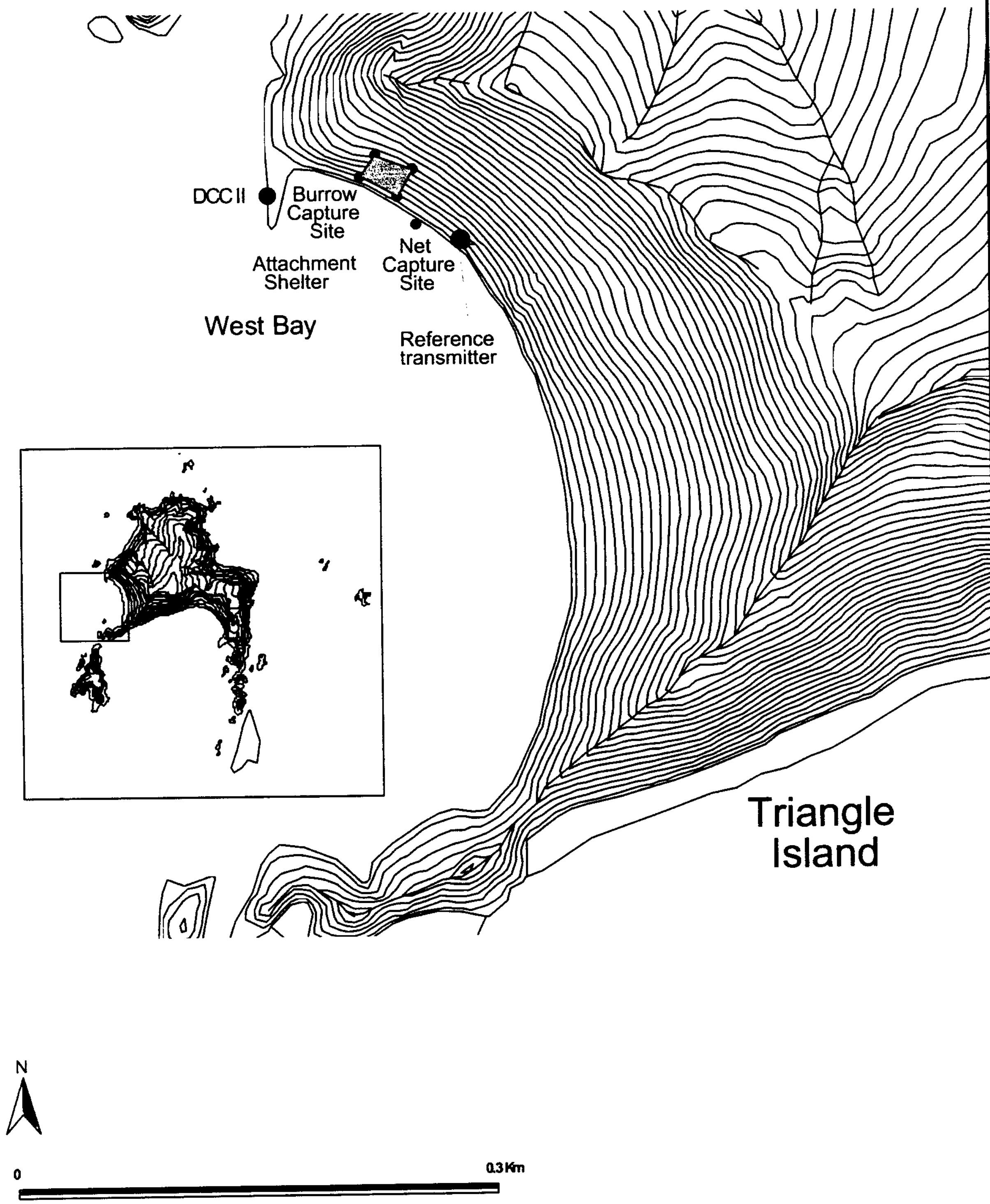


Figure 2. Map of Triangle Island West Bay showing key sites.

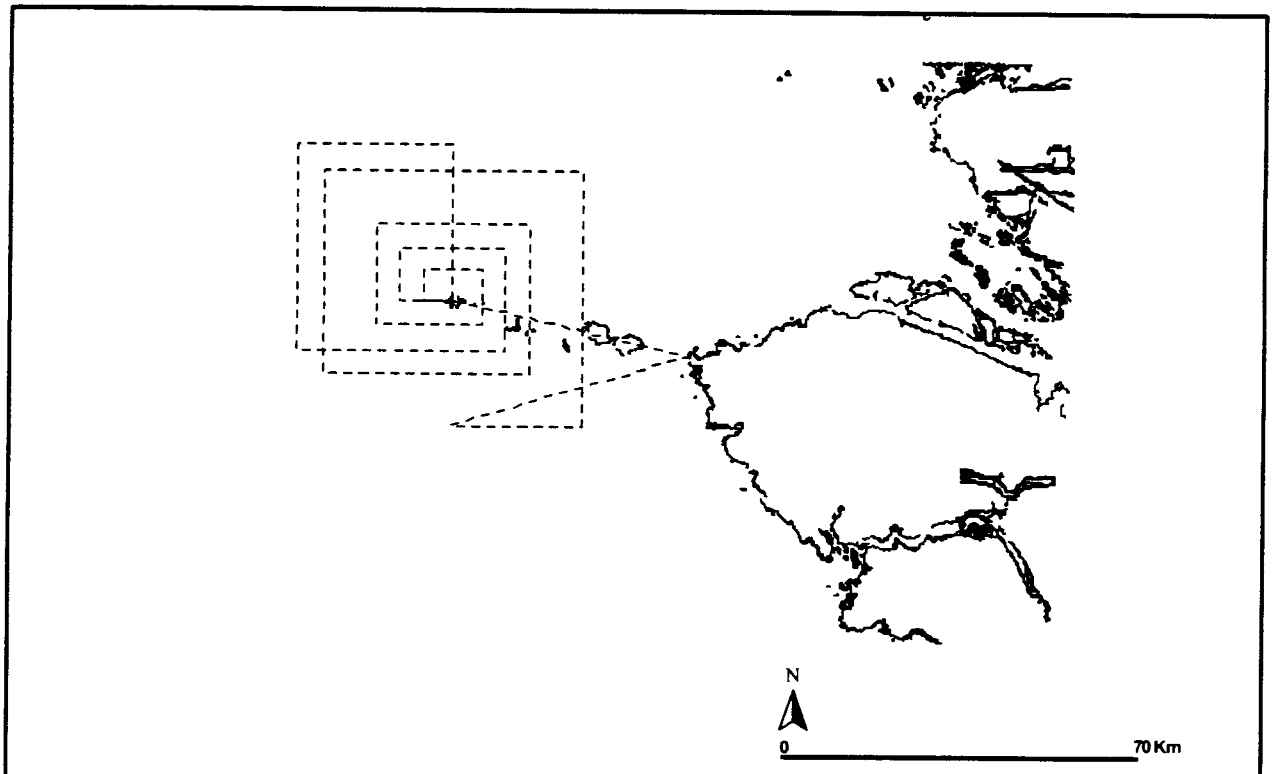


Figure 3A. Telemetry route covered on 9 June, 1999.

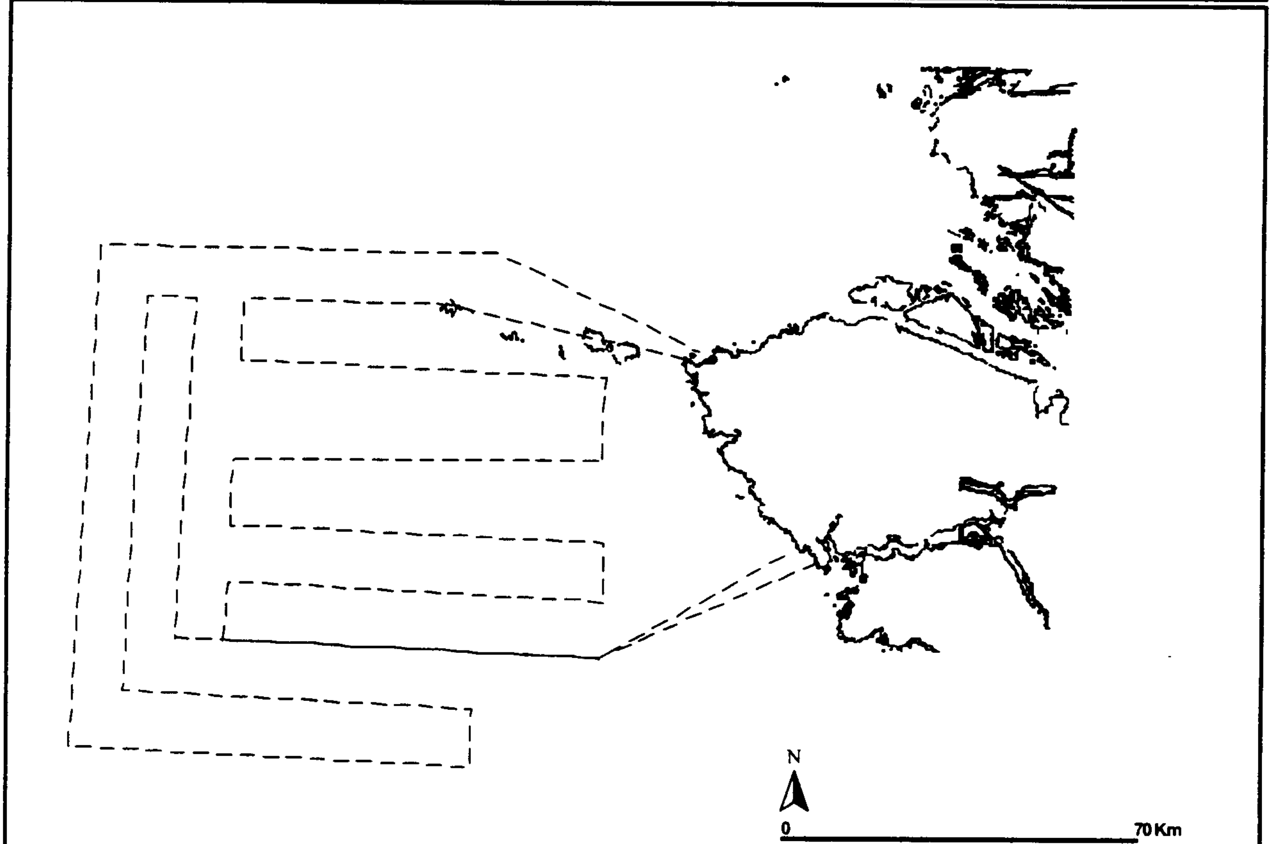


Figure 3B. Telemetry route covered on 10 June, 1999.

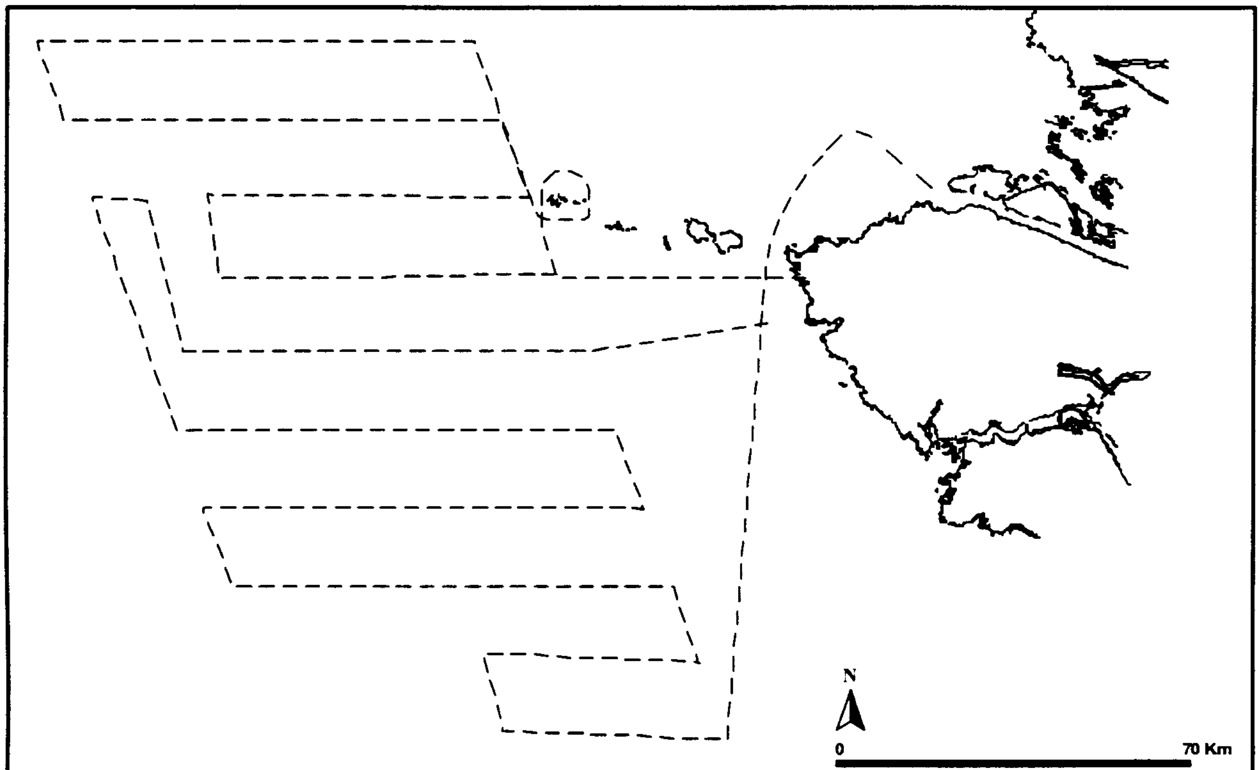


Figure 4A. Telemetry route covered on 23 June, 1999.

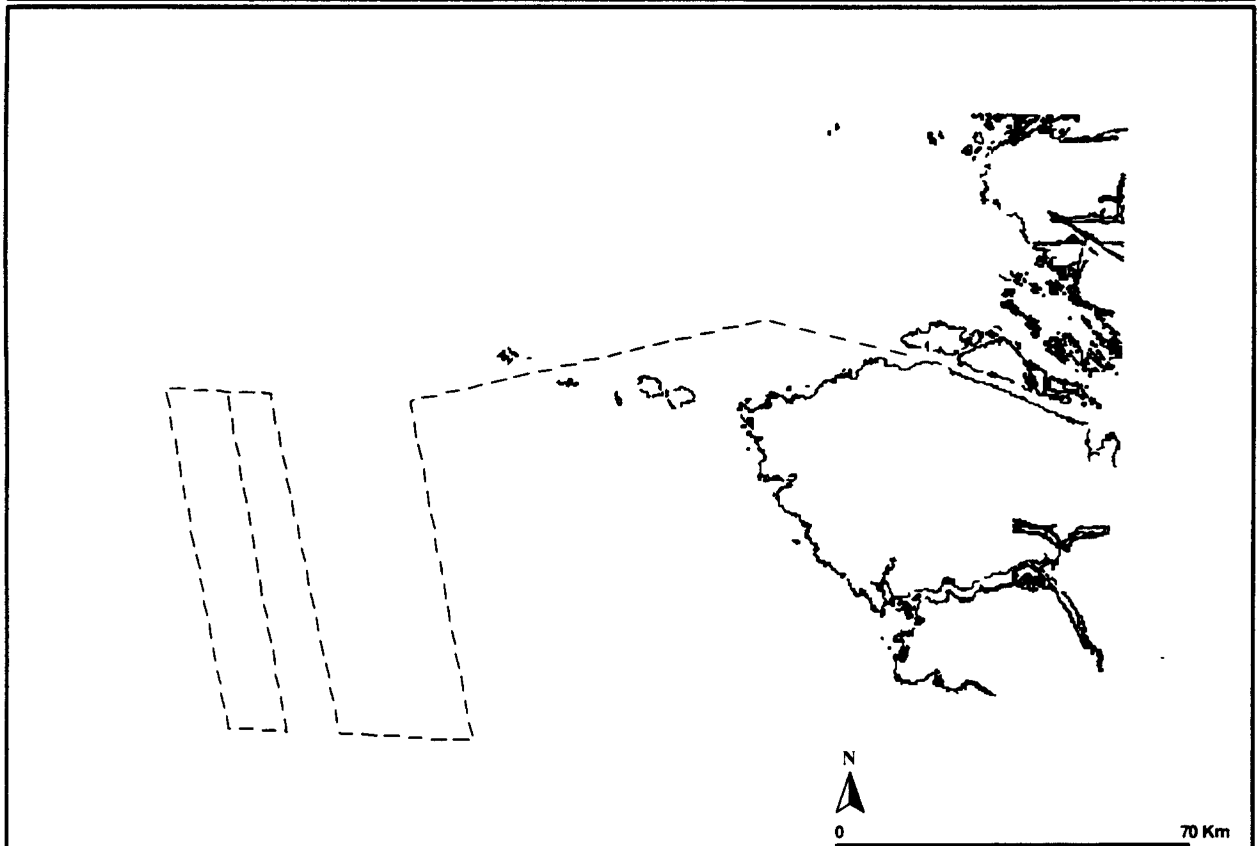


Figure 4B. Telemetry route covered on 24 June, 1999.

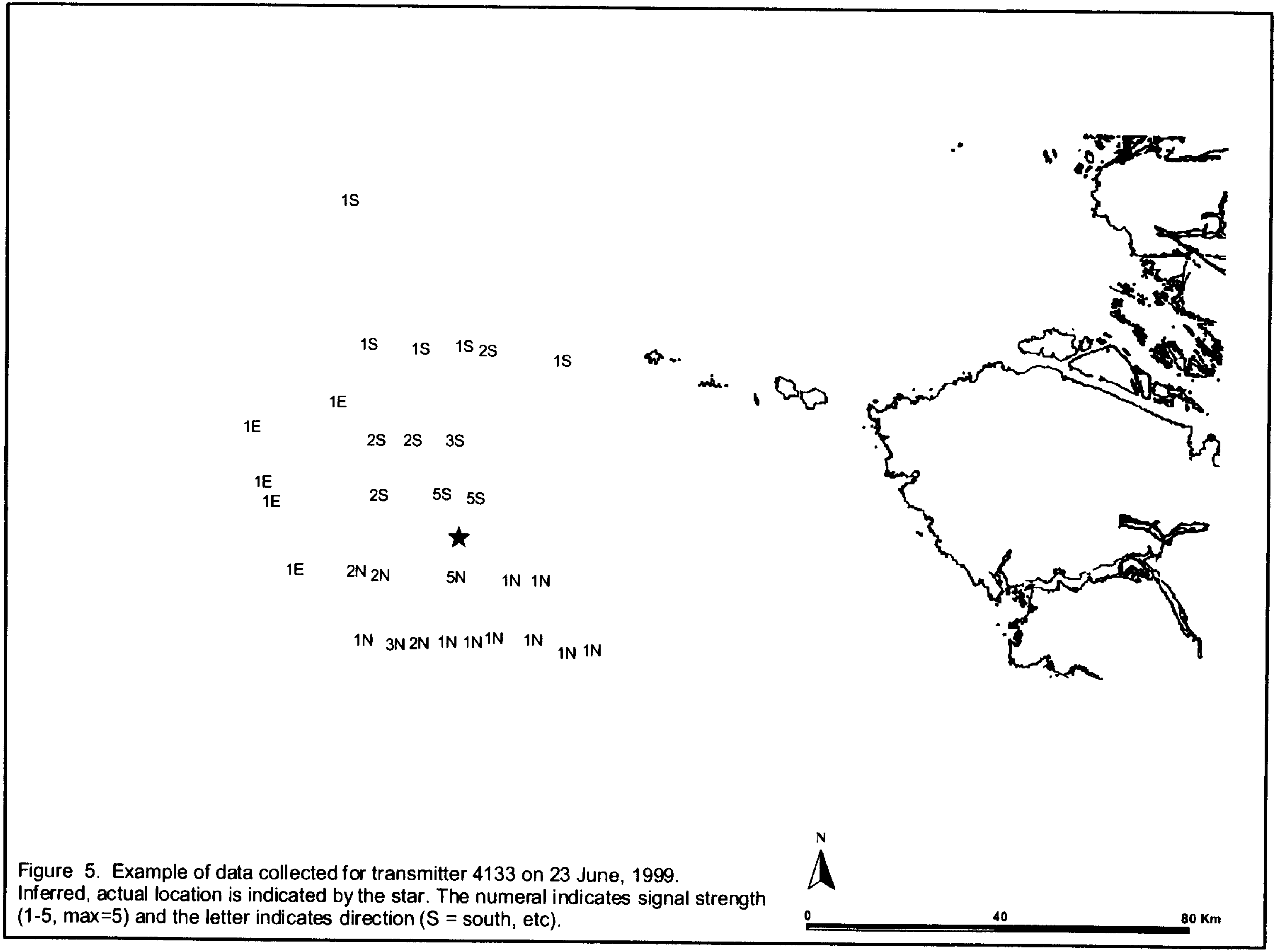


Figure 5. Example of data collected for transmitter 4133 on 23 June, 1999. Inferred, actual location is indicated by the star. The numeral indicates signal strength (1-5, max=5) and the letter indicates direction (S = south, etc).

Figure 6A. Frequency histogram showing the number of transmitters versus number of detections per transmitter on 10 June, 1999

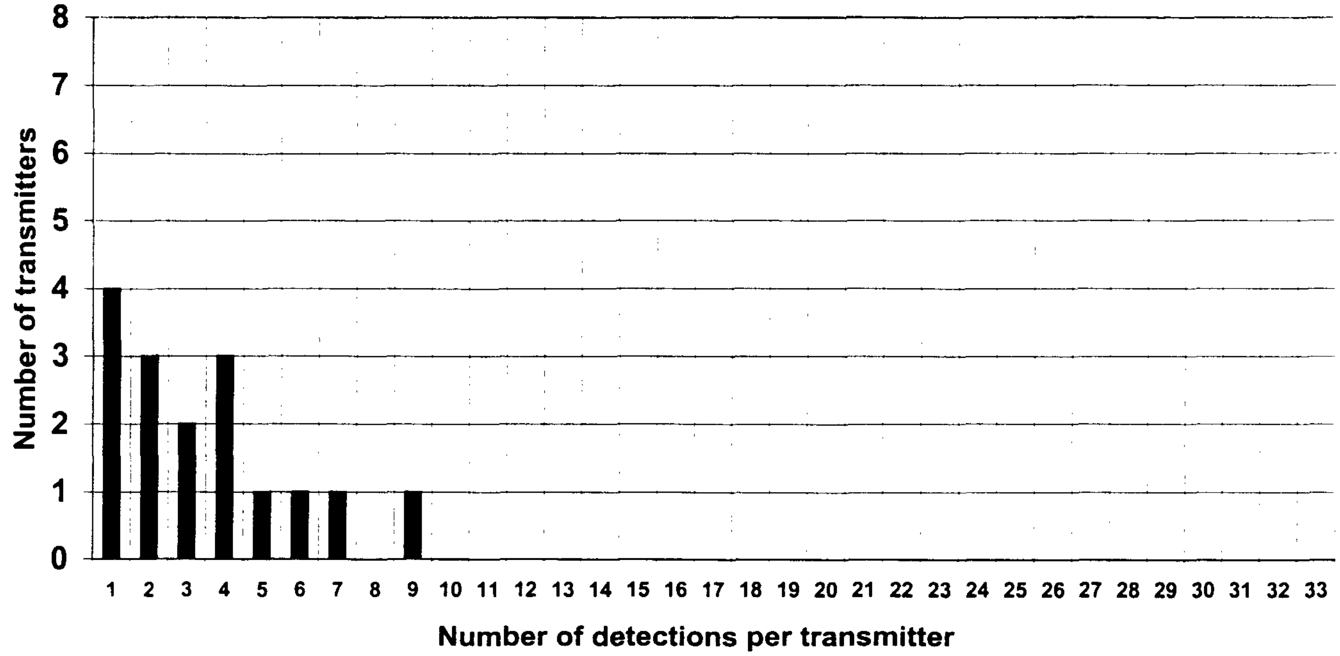
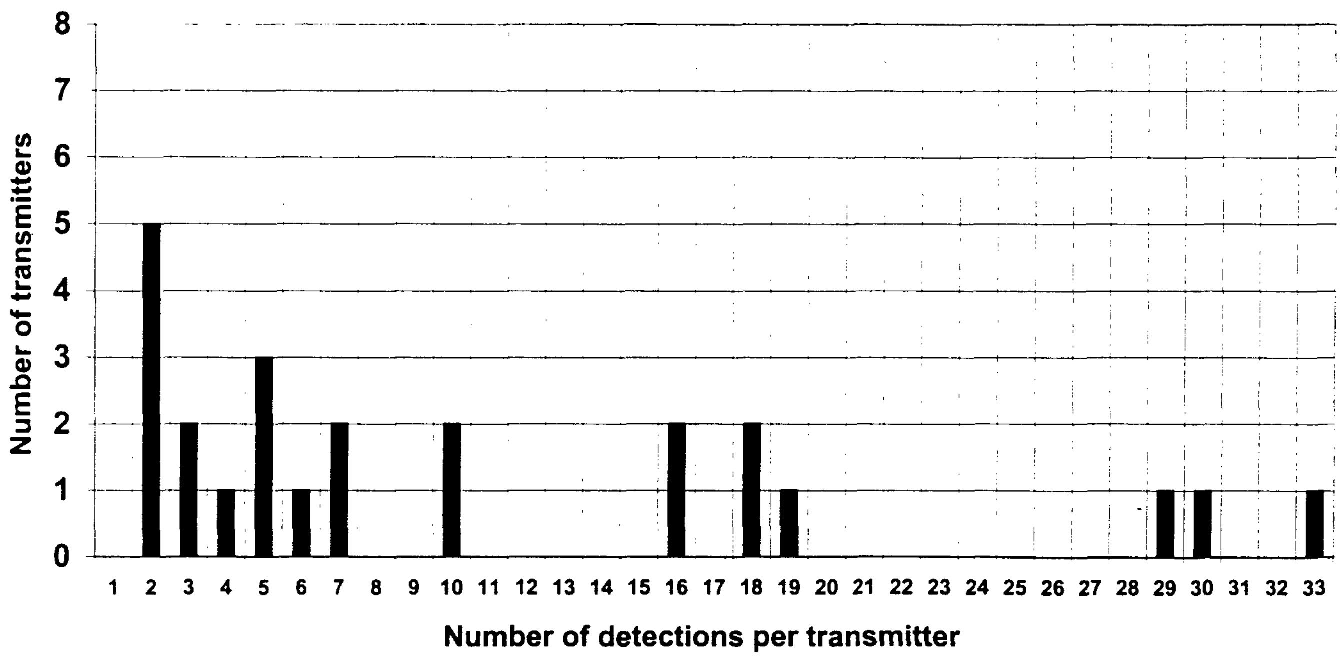


Figure 6B. Frequency histogram showing the number of transmitters versus number of detections per transmitter on 23 June, 1999



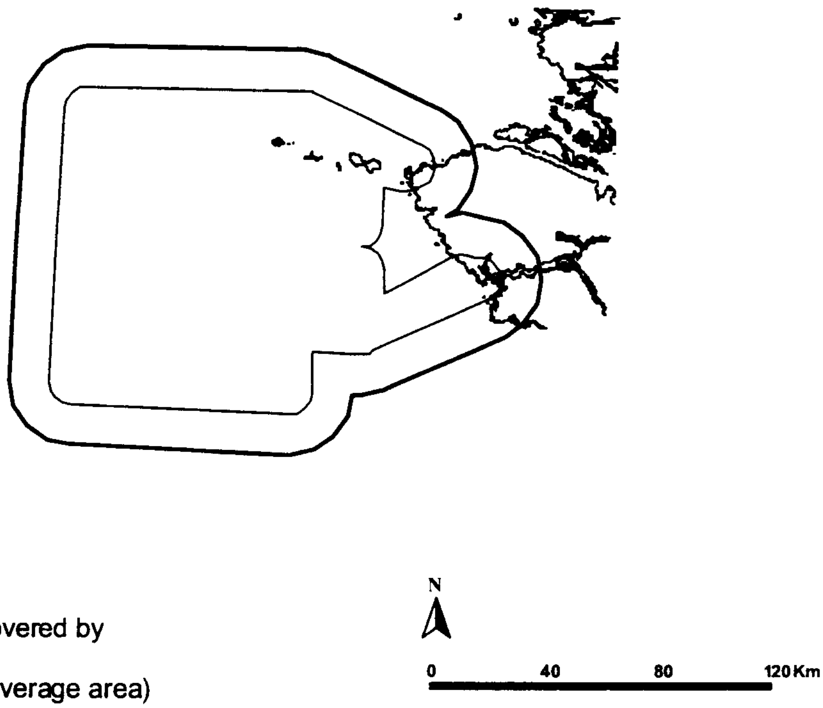


Figure 7A. Estimated area covered by telemetry on 10 June, 1999.
(— = maximum area; — = average area)

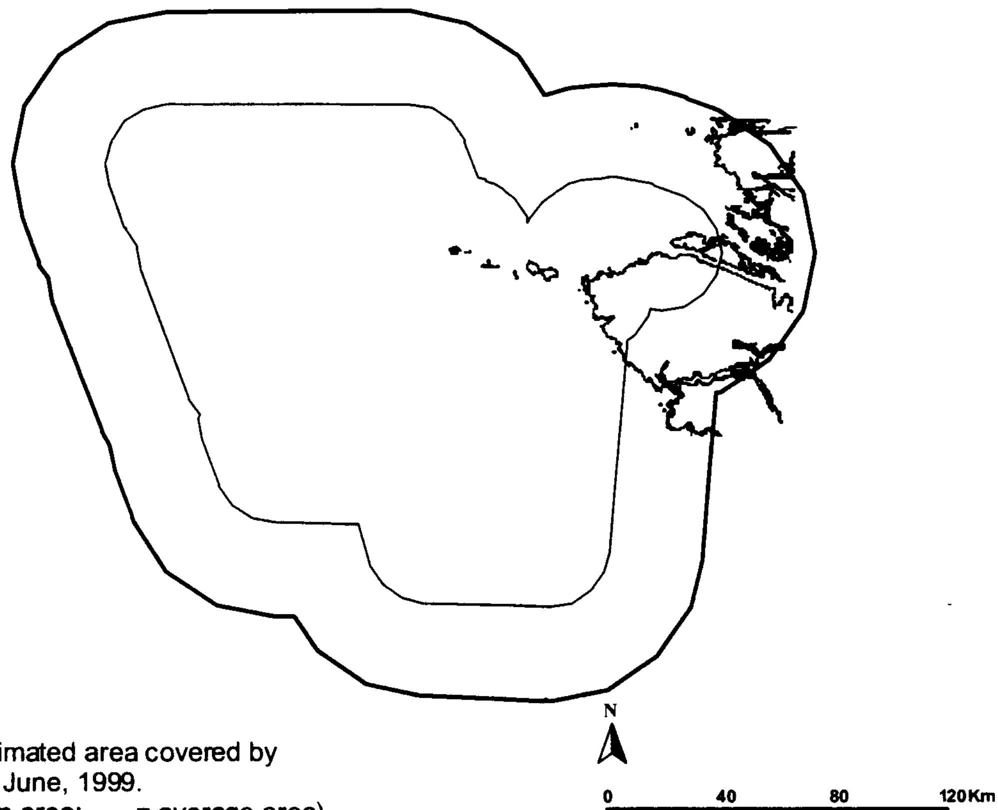


Figure 7B. Estimated area covered by telemetry on 23 June, 1999.
(— = maximum area; — = average area)

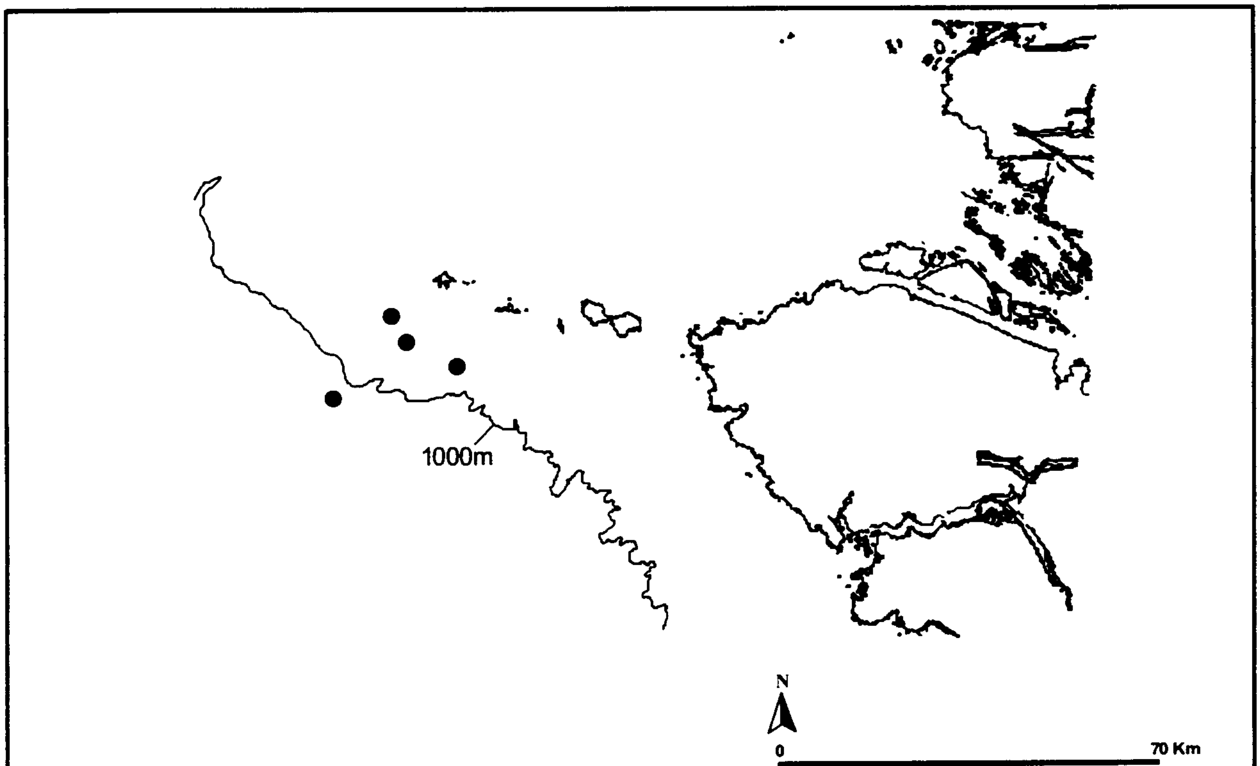


Figure 8A. Transmitter locations on 9 June, 1999.

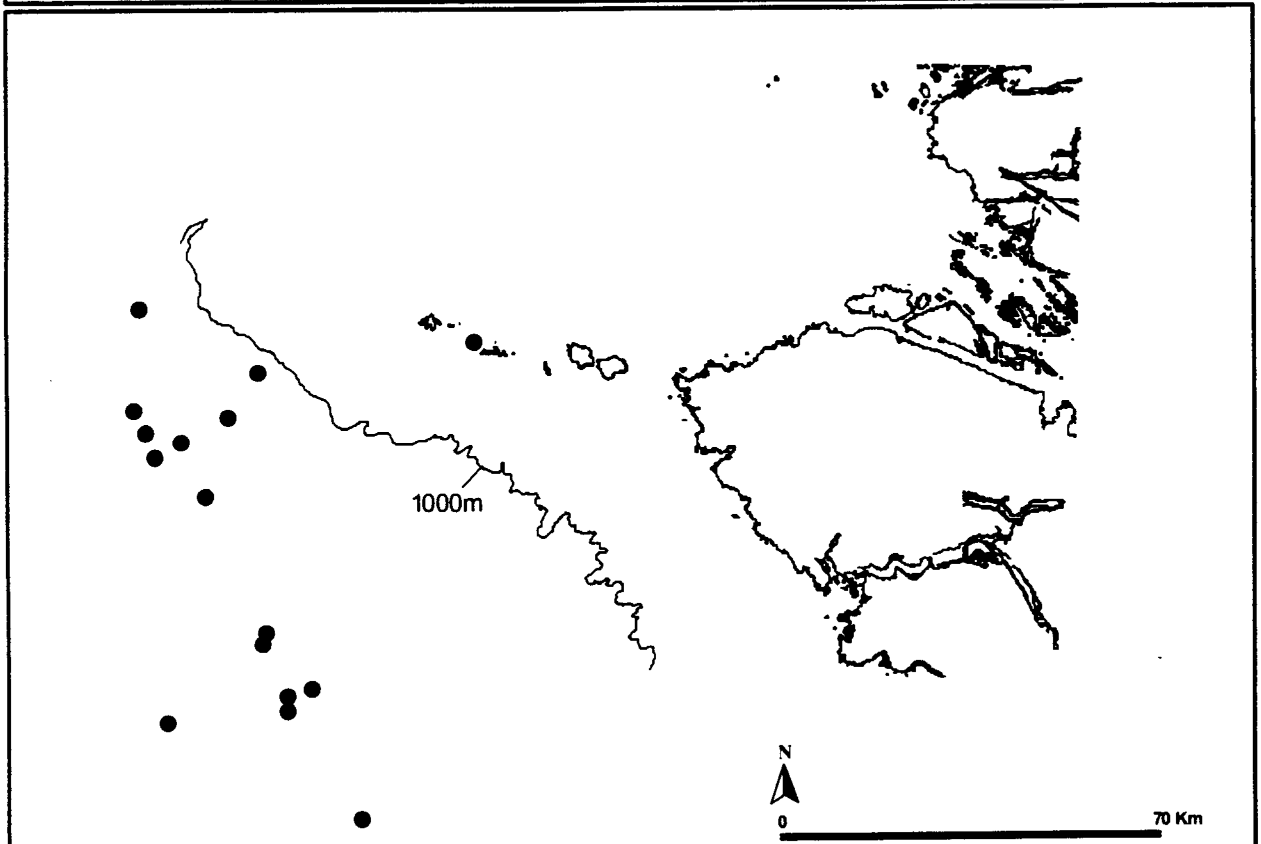


Figure 8B. Transmitter locations on 10 June, 1999.

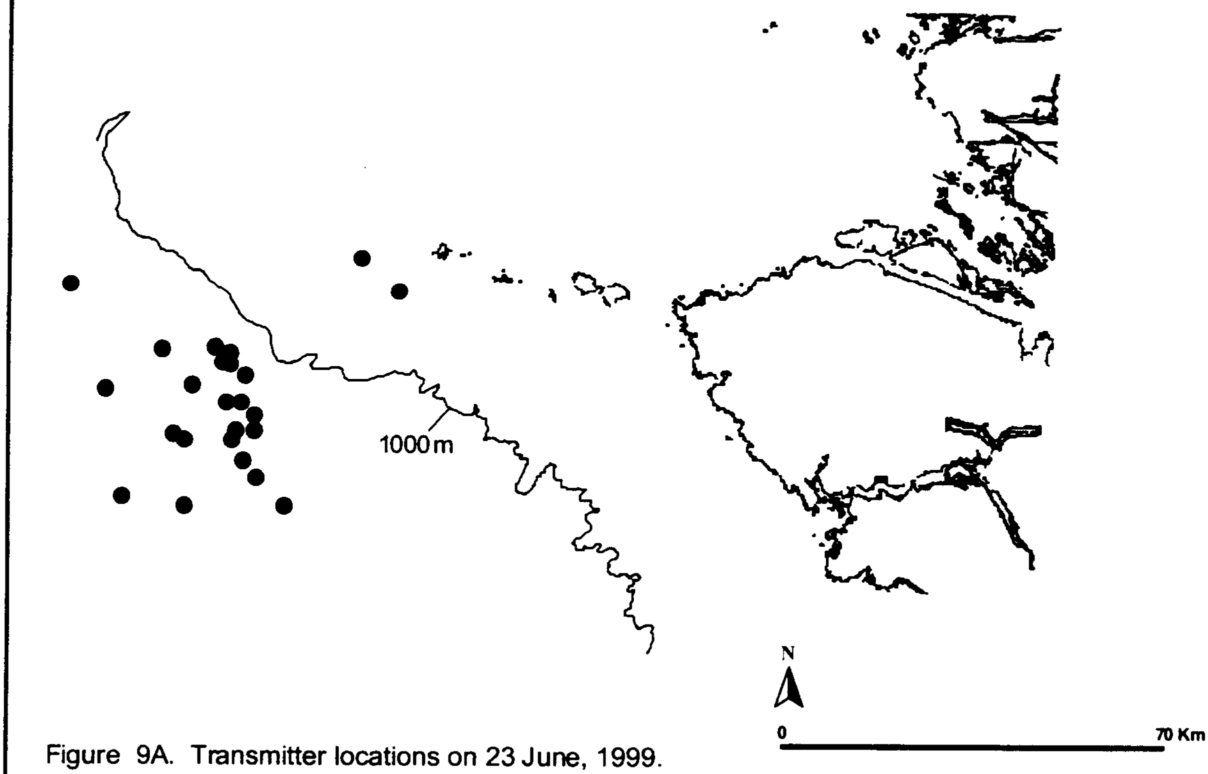


Figure 9A. Transmitter locations on 23 June, 1999.

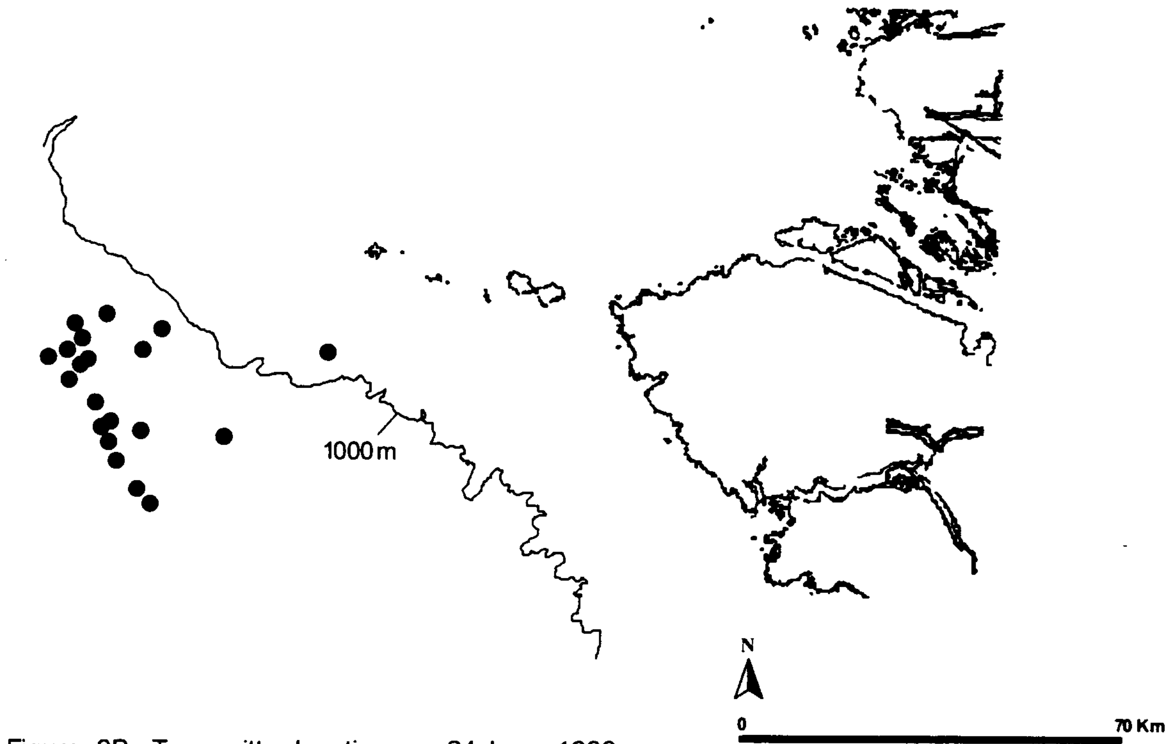


Figure 9B. Transmitter locations on 24 June, 1999.

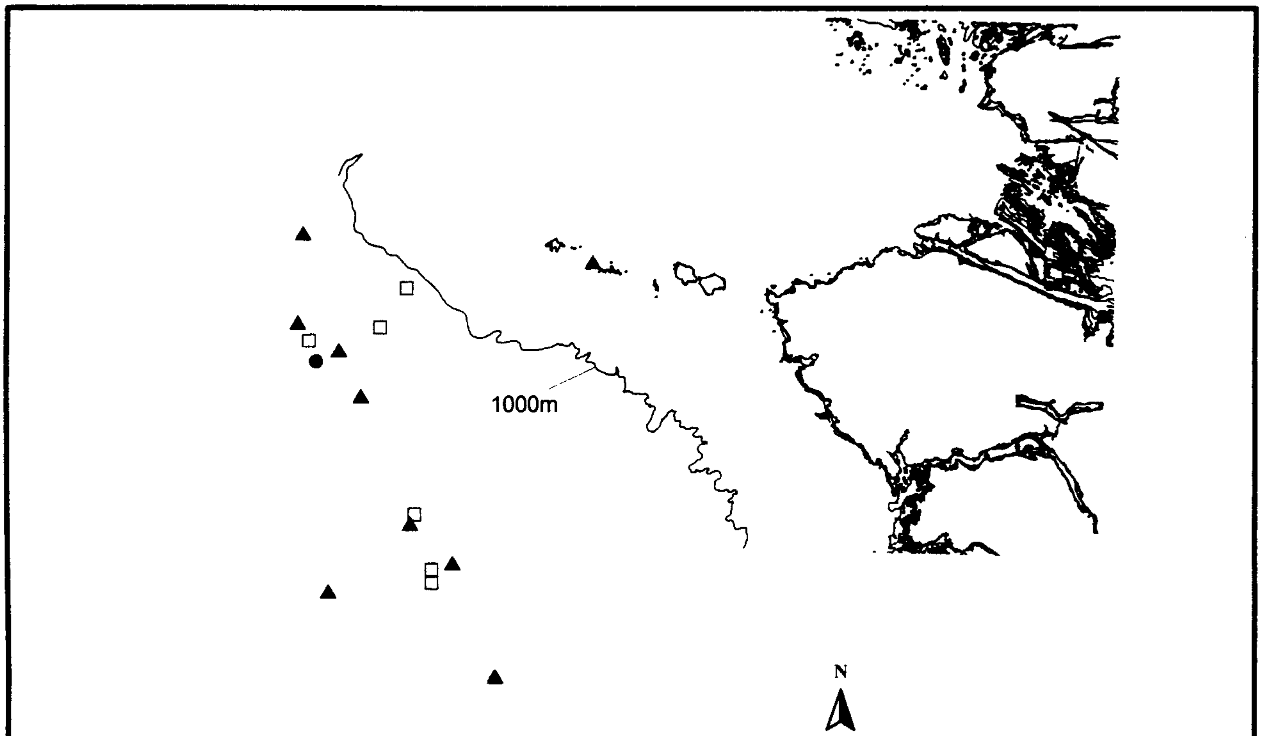


Figure 9C. Sex specific transmitter locations on 10 June, 1999.
(Female = ▲, Male = □, Undetermined = ●)

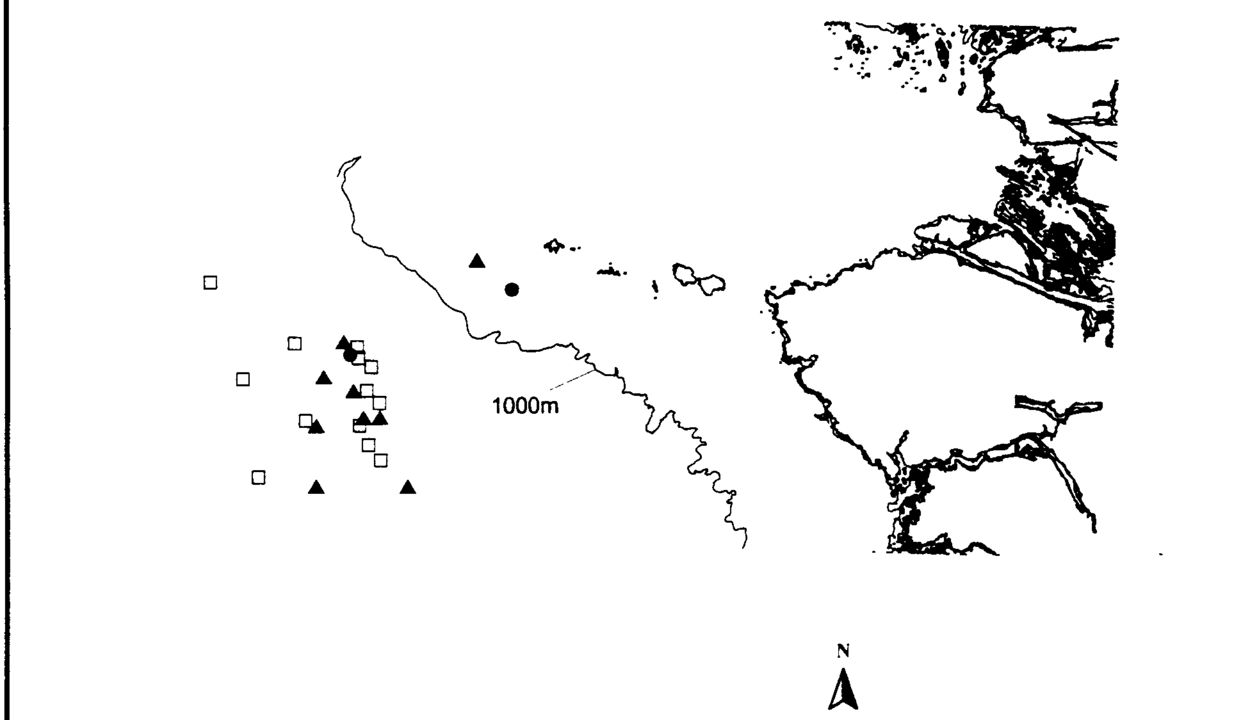


Figure 9D. Sex specific transmitter locations on 23 June, 1999.
(Female = ▲, Male = □, Undetermined = ●)

Figure 10A. Frequency histogram showing the number of transmitters versus distance from Triangle Island to inferred location on 10 June, 1999

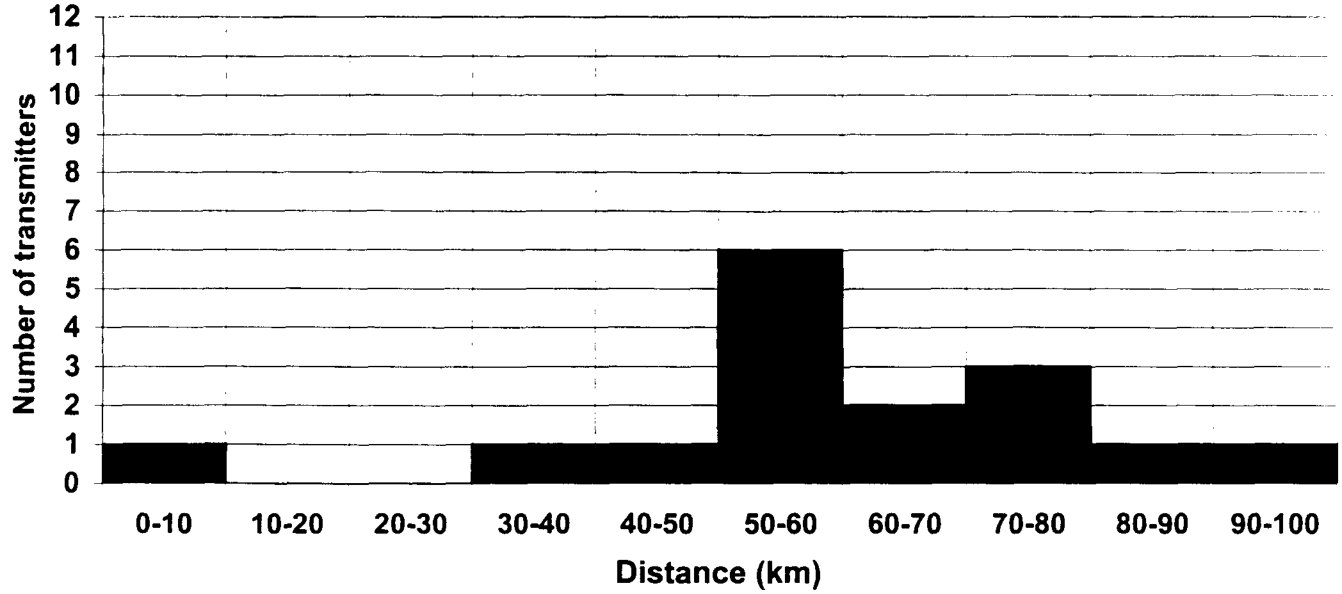
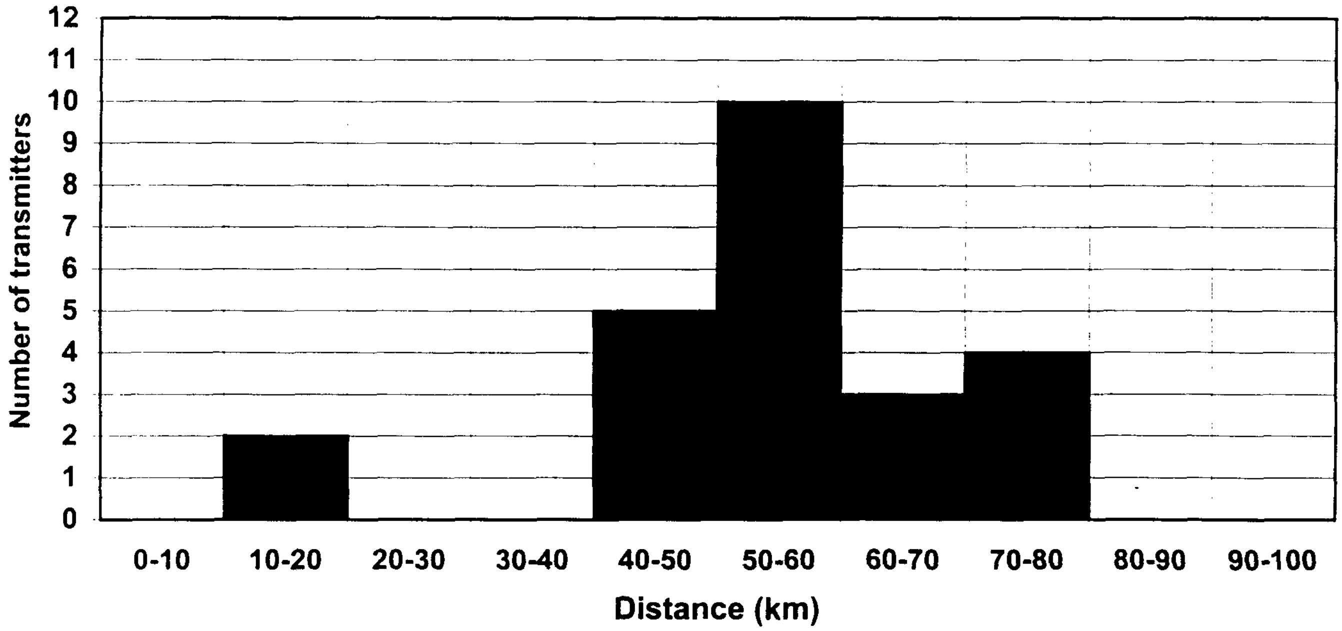


Figure 10B. Frequency histogram showing the number of transmitters versus distance from Triangle Island to inferred location on 23 June, 1999



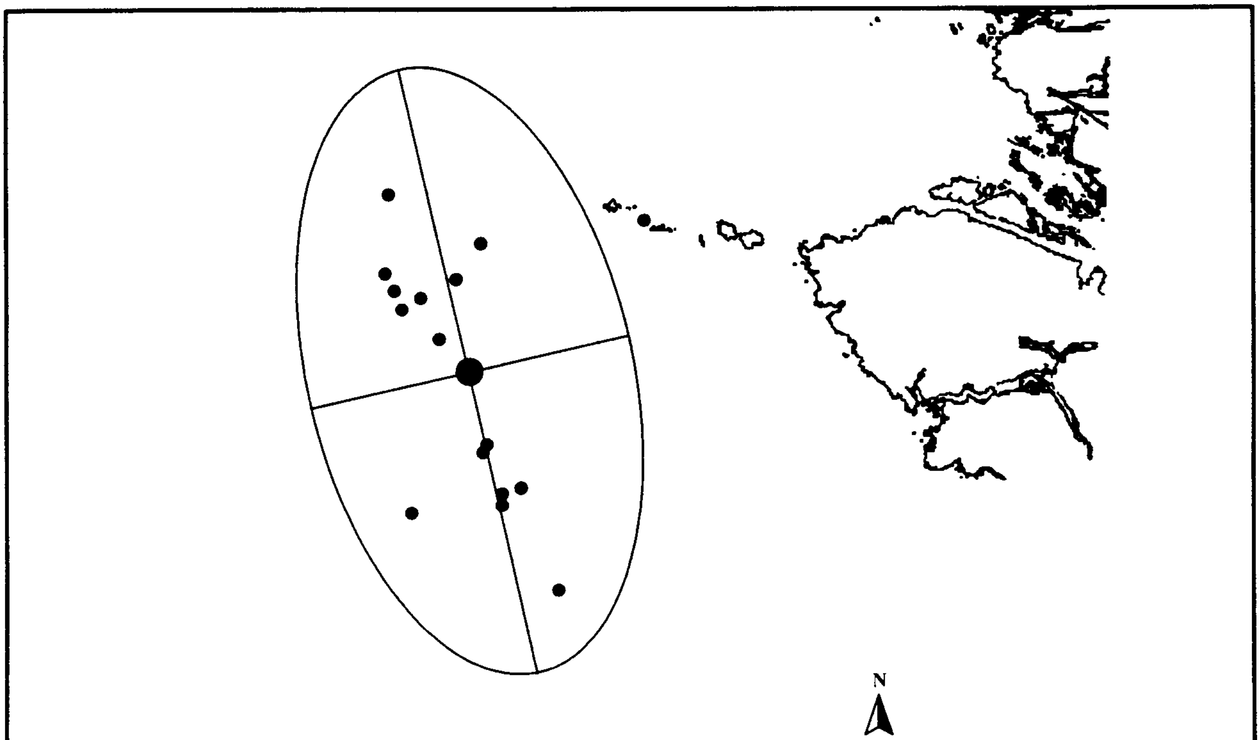


Figure 11A. Jenrich-Turner distribution (95% probability) estimated for 10 June, 1999.

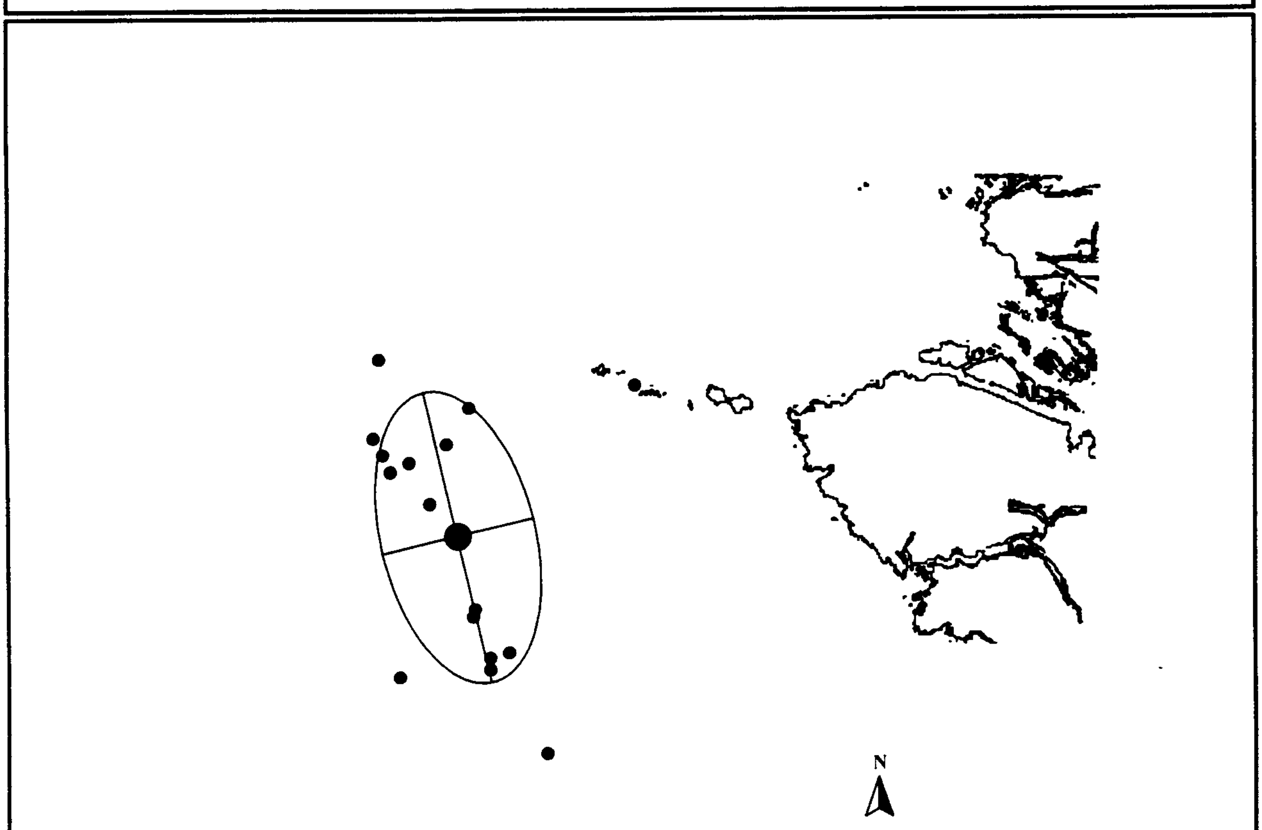


Figure 11B. Jenrich-Turner distribution (50% probability) estimated for 10 June, 1999.

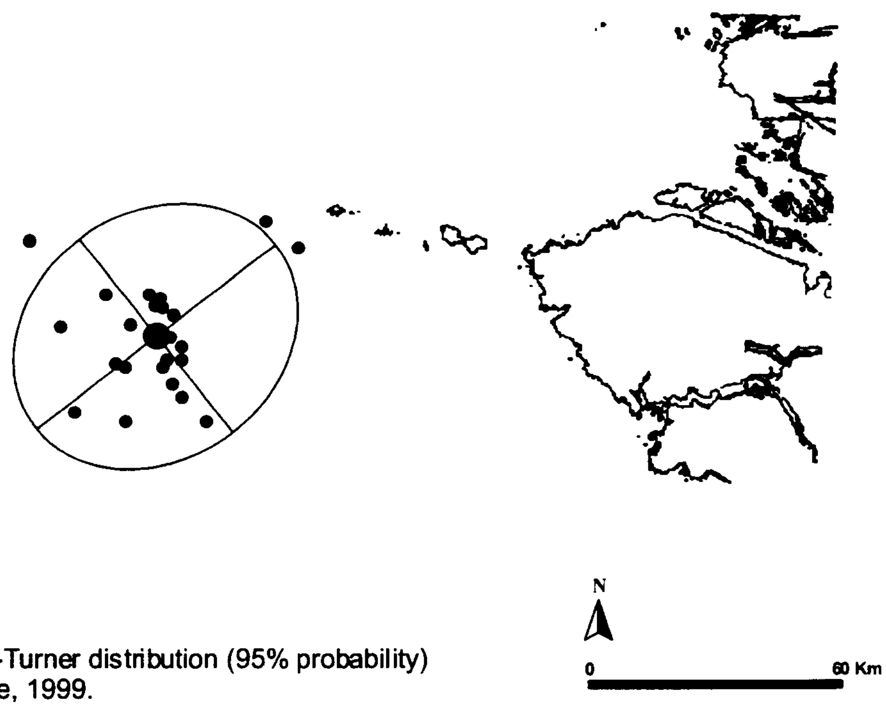


Figure 12A. Jenrich-Turner distribution (95% probability) estimated for 23 June, 1999.

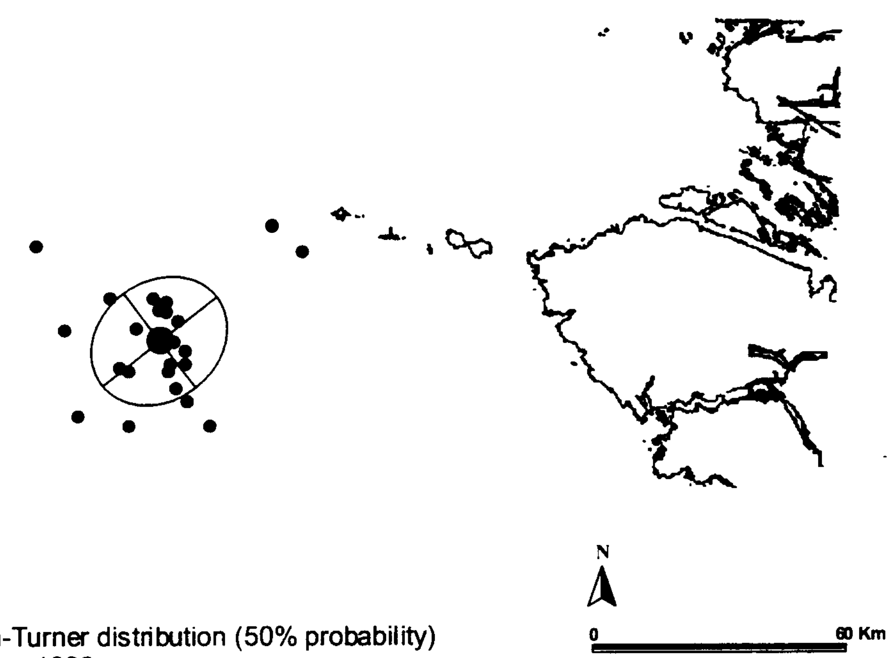


Figure 12B. Jenrich-Turner distribution (50% probability) estimated for 23 June, 1999.

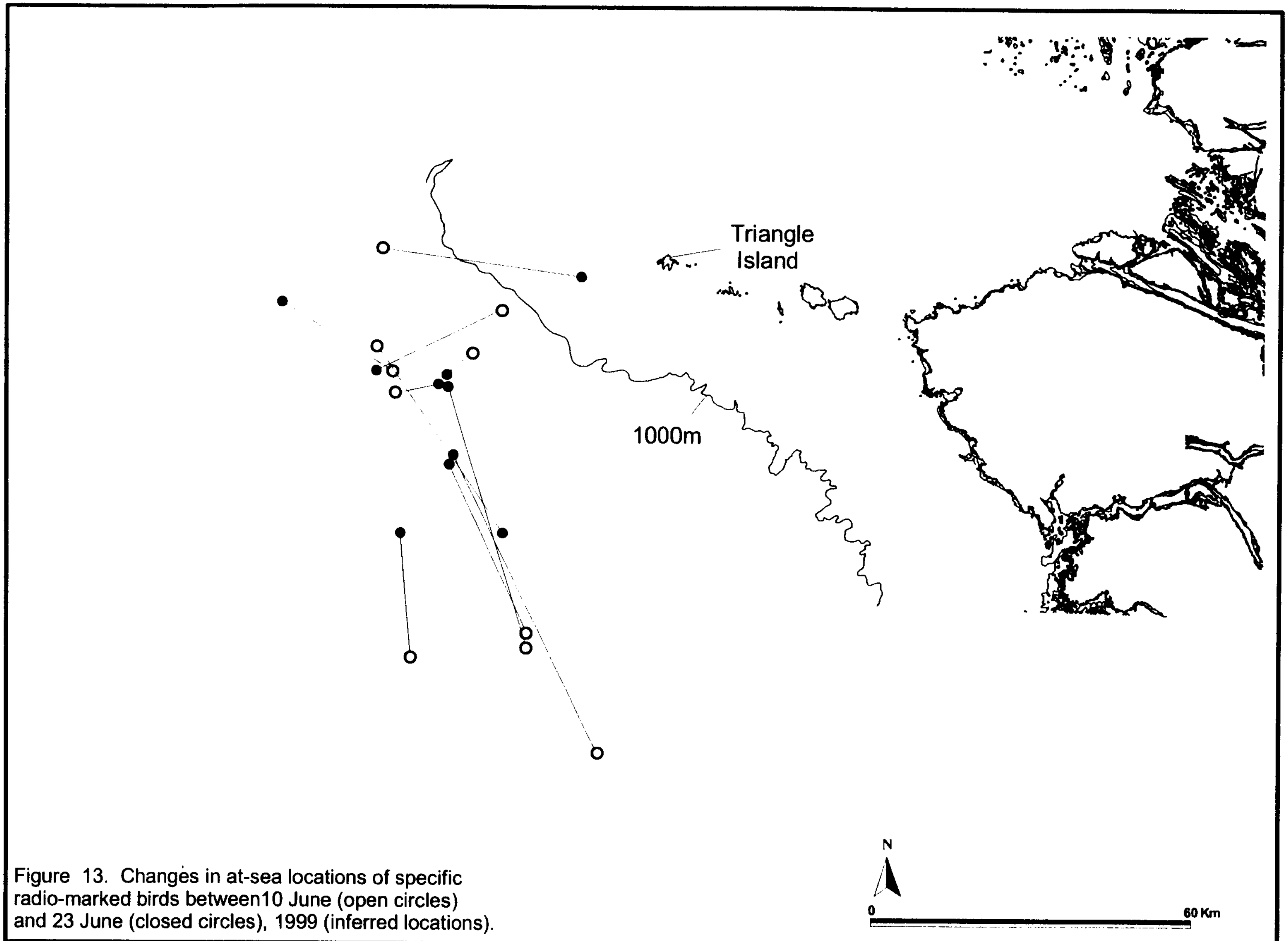


Figure 13. Changes in at-sea locations of specific radio-marked birds between10 June (open circles) and 23 June (closed circles), 1999 (inferred locations).

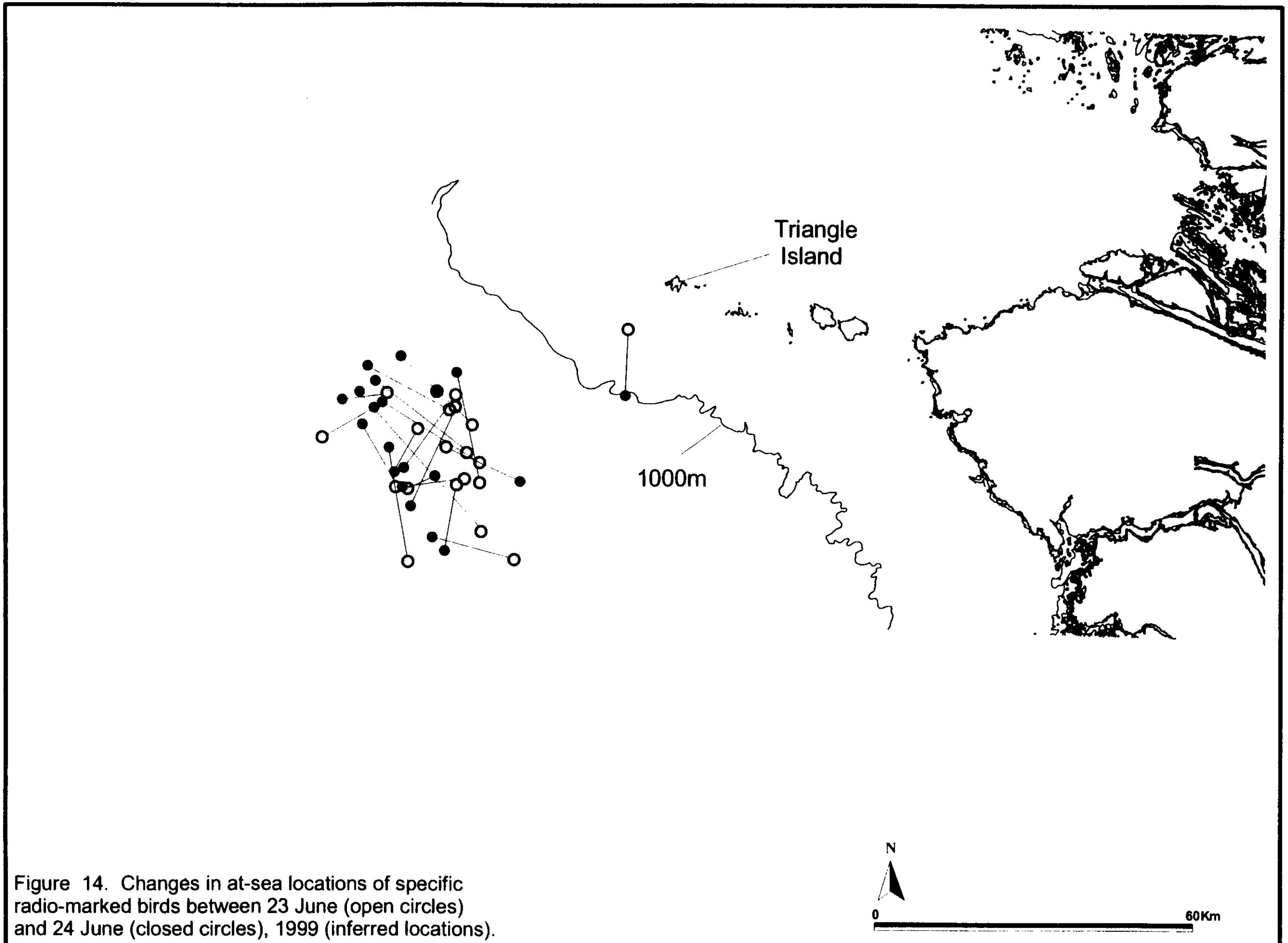


Figure 14. Changes in at-sea locations of specific radio-marked birds between 23 June (open circles) and 24 June (closed circles), 1999 (inferred locations).