An Evaluation of the Use of External Radio Tags to Study the Migrations of Arctic Cisco in the Southeastern Beaufort Sea Region

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1991

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 2125

Fisheries and Oceans   Pêches et Océans

Canada

Canadian Manuscript Report of

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AN EVALUATION OF THE USE OF EXTERNAL RADIO TAGS TO STUDY THE MIGRATIONS OF ARCTIC CISCO IN THE SOUTHEASTERN BEAUFORT SEA REGION

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This is the 22nd Manuscript Report

from the Central and Arctic Region, Winnipeg

PREFACE

This study was funded by the Fisheries Joint Management Committee (FJMC). It was designed as a pilot project to test the feasibility of using radio transmitter tags to study the migrations of Arctic cisco in the southern Beaufort Sea coast and the Mackenzie River. The results of this study will contribute to an understanding of the strengths and limitations of this technology to enhance ongoing and future coastal studies conducted by the Department of Fisheries and Oceans.

Cat. No. Fs 97-4/2125E ISSN 0706-6473

Correct citation for this publication is:

Chang-Kue, K.T.J., and E.F. Jessop. 1991. An evaluation of the use of external radio tags to study the migrations of Arctic cisco in the southeastern Beaufort Sea region. Can. Manuscr. Rep. Fish. Aquat. Sci. 2125: iv + 27 p.

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Twelve Arctic cisco, taken in Tuktoyaktuk Harbour, were tagged with radio transmitters on 1-2 July 1990. Their movements were tracked with aircraft from 3 to 7 July and on 31 July 1990. A representative sample (N=19, 333-410 mm fork length), taken with the same gear, established that 42% of the Arctic cisco were mature and expected to spawn in 1990.

Ten radio-tagged fishes were detected at least once, with detection success varying from 17% to 67%. High conductivity and depth were factors limiting coastal detection success. Eastward migration occurred as far as Topkak Point. Five individuals migrated westwards to the East Channel of the Mackenzie Delta at a rate of 7-17 km per day. One fish was recaptured in mid-July in the Mackenzie Delta. Detection of another three in the Delta on 31 July suggested that a spawning migration into the Mackenzie River was in progress. If the criterion for tag weight and recommended procedures for capture and tagging are followed, existing radio tags can be used to study migrations of mature Arctic cisco

Keywords: migrations; anadromous species; radio tagging; coregonids; Arctic cisco; Tuktoyaktuk Harbour; Mackenzie Delta; East Channel; Beaufort Sea; coastal waters.

RÉSUMÉ

Chang-Kue, K.T.J., and E.F. Jessop. 1991. An evaluation of the use of external radio tags to study the migrations of Arctic cisco in the southeastern Beaufort Sea region. Can. Manuscr. Rep. Fish. Aquat. Sci. 2125: iv + 27 p.

Les 1 et 2 juillet 1990, on a installé des émetteurs sur douze ciscos arctiques capturés dans le havre de Tuktoyaktuk. On a suivi leurs déplacements par avion du 3 au 7 juillet ainsi que le 31 juillet 1990. Un échantillon représentatif (N=19, longueur à la fourche entre 333 et 410 mm), capturés avec le même engin de pêche, a permis d'établir que 42 p. 100 des ciscos arctiques étaient matures et probablement prêts à frayer en 1990.

On a détecté 10 poissons munis d'émetteurs au moins une fois, le taux de détection variant entre 17 et 67 p. 100. La conductivité élevée et la profondeur ont été des facteurs qui ont limité la détection dans la zone côtière. On a observé une migration vers l'est jusqu'à la pointe Topkak. Cinq poissons ont migré vers l'ouest en direction du chenal de l'Est du delta du Mackenzie à une vitesse variant entre 7 et 17 km par jour. À la mi-juillet, on a recapturé un poisson dans le delta du Mackenzie. La détection de trois autres poissons dans le delta le 31 juillet a suggéré qu'une migration de frai vers le fleuve Mackenzie était en cours. Lorsque l'on respecte le critère concernant le poids de l'émetteur et les méthodes recommandées de capture et de marquage, le système actuel de marquage avec des émetteurs peut être utilisé pour étudier la migration du cisco arctique mature.

Mots-clés: migrations; espèce anadrome; marquage avec des émetteurs; corégonidés; cisco arctique; havre de Tuktoyaktuk; delta du Mackenzie; chenal de l'Est; mer de Beaufort; eaux côtières.

INTRODUCTION

The Department of Fisheries and Oceans (DFO), Central and Arctic Region, has been studying coastal populations of coregonids in the southern Beaufort Sea and outer Mackenzie Delta since 1978. Recent projects examined populations at locations west of the Mackenzie Delta where particular attention was paid to Arctic cisco (Bond and Erickson 1987, 1989). Tagging studies provided evidence that Arctic cisco, inhabiting the Yukon and Alaska coastal regions, undertake eastward migrations to spawn in the Mackenzie River system (Bond and Erickson 1989). This transboundary migration aspect has given this species a high profile for future habitat and impact assessment studies. The current DFO project in the Liverpool Bay and Anderson River area includes an investigation of the life history of Arctic cisco east of the Mackenzie River (Mr. B. Bond, Department of Fisheries and Oceans, 501 University Crescent, Winnipeg, personal communication).

To support the Canadian coastal studies, we advocate the use of radio transmitter tags to delineate the coastal migration patterns of Arctic cisco in the southeastern Beaufort Sea coast. Radio tags have been used successfully to track the spawning migration of broad whitefish in the lower Mackenzie River (Chang-Kue and Jessop 1983). Since this type of tag has not been used specifically on Arctic cisco, this short term pilot study was designed to test the feasibility of mounting radio tags on selected Arctic cisco and tracking their subsequent movements.

STUDY OBJECTIVES

The study objectives were:

A. To establish that Arctic cisco can survive the radio-tagging procedure.

B. To determine the success rate of tracking radio-tagged Arctic cisco with aircraft.

C. To obtain preliminary information on migration routes, timing and rate of migration of Arctic cisco originating from a major coastal bay east of the Mackenzie Delta.

D. To observe the general condition and survival of Arctic cisco in a holding pen after capture and radio-tagging procedures.

E. To provide specific recommendations on capture, tagging and handling procedures if radio-tagging proves feasible.

DESCRIPTION OF STUDY AREA

The study area encompasses parts of two physiographic regions, the Mackenzie Delta and the Pleistocene coastal plain (MacKay 1963). The latter includes Richards Island, outer Islands of Mackenzie Bay and the coast of Tuktoyaktuk Peninsula (Fig. 1). The shoreline is characterized by numerous lagoons, embayments and offshore spits that provide shelter and fish habitat. Water depth along the Beaufort Sea coast is generally shallow with depths seldom exceeding three meters. An important feature is the zone of relatively fresh water that extends eastwards along the coast of the Tuktoyaktuk Peninsula. This phenomenon, formed by the outflow of the Mackenzie River, prevailing winds and the Beaufort gyre, provides a migration corridor for less saline-tolerant fish species. It also extends the area of coastal habitats available for feeding and overwintering.

Tuktoyaktuk Harbour is a unique coastal bay formed by flooding of an ancient river valley. With a shallow sill (4 m) at its narrow entrance and a maximum depth of about 26 m, its water characteristics are influenced by the action of tides and Mackenzie River flows. Under winter ice cover, a major surface layer of freshwater up to 6 m depth develops over a bottom layer of salt water (Barber 1968). These conditions contribute to suitable overwintering conditions for fishes, especially the Arctic cisco, which move in from coastal waters in the late summer and fall (Bond 1982).

The Mackenzie Delta covers an area of about 12 170 km^2 (Brunskill 1986). The Delta is a maze of lakes and channels spread over an area of low lying relief with an average elevation of 6 m. More detailed features of the physical geography of the area are described by Mackay (1963). Significant migrations of broad whitefish, lake whitefish, Arctic cisco, least cisco and inconnu occur in the main delta channels each year as mature fish proceed to spawning grounds in the Mackenzie watershed (Hatfield et al. 1972; Stein et al. 1973).

MATERIALS AND METHODS

RADIO TELEMETRY EQUIPMENT

The radio telemetry equipment was obtained from Advanced Telemetry Systems (ATS) of Bethel, Minnesota. Three sizes of low frequency radio transmitters, made for external mounting, were obtained (Table 1). Each epoxy-coated transmitter, complete with a nylon-coated whip antenna and two mounting wires, weighed 11 to 15 g. Tag size depended on the battery used to provide a transmitter life span of 30, 60 or 90 days. The specifications provided a tag of flat configuration to reduce chances of snagging on vegetation or gillnets and to minimize any negative effect on swimming performance. Each tag had a unique frequency in the 49.000 to 50.000 mHz range and was separated by at least 10 kHz from other tags to allow recognition of individual fish. The different sized tags were used to accommodate the varying sizes of fish. The general rule for tag size is that tag weight should not exceed 2% of the weight of the fish to minimize any negative effect on their natural buoyancy control and swimming ability (Mr. R. Huempfner, ATS Inc., 470 1st Avenue, Isanti, Minnesota, personal communication).

An ATS (Challenger 200 model) programmable scanning receiver was used, at ground level or with aircraft, to detect and locate radio-tagged fish. Two directional, 1/4 wavelength, loop antennae were mounted on the wing struts of a Cessna 185 aircraft for the flights on 7 and 31 July. The antennae were mounted such that the plane of one was parallel to the fuselage for maximum fore and aft detection range; the other antenna was mounted with its plane perpendicular to the fuselage for maximum sideways range. The coaxial cable for each antenna was attached to a left/right/both-side switchbox to allow for directional tracking while homing in on a transmitter. During the flights from 3 to 6 July, a Bell 206 helicopter was used for tracking. It was possible to use only one antenna clamped to the fore end of a pontoon and set parallel to the fuselage. This arrangement was sufficient for detection of transmitters but less effective for homing in on exact locations.

FISH CAPTURE LOCATION AND METHODS

Tuktoyaktuk Harbour was chosen as the site for tagging since overwintering Arctic cisco are known to be prevalent until their migrations out of the harbour shortly after ice-out (Bond 1982). A trapnet was set on mud substrate in a sheltered bay near the southeast end of Tuktoyaktuk Island (Fig.2, location TH001). This type of trap, used by Bond and Erickson (1989) in their coastal studies, has proven effective for the capture of coregonids migrating along the nearshore zone. The main box, 3.7 m long and 0.9 m deep, contained five internal stainless steel frames for structural support and two throats measuring 15 by 22 cm. The trap was constructed with #147 dark green nylon 1.27 cm mesh. The wings and leads, made with 2.54 cm dark gray #63 nylon mesh, were 1.7 m deep and constructed in 15.2 m sections that could be fastened together with zippers.

The trapnet was set on 30 June 1990 with a lead of 45.6 m and with wings 15.2 m in length. The trap was checked every 30 minutes to minimize possibility of stress or injury to the fish. The cod end of the trap was lifted and all fish emptied into a large tub of water. All other species were quickly returned to the harbour waters to allow immediate access to any Arctic cisco. Only active and uninjured Arctic cisco were retained for tagging.

Since the rate of capture of Arctic cisco with the trapnet was slow, a gillnet, 23 m long with 64 mm mesh (stretch measure), was used on 2 July as a preferred method for capturing the largest size ranges of Arctic cisco for tagging. The net was set at location TH002 in the east entrance of Tuktoyaktuk Harbour (Fig.2). With the shore end of the net set at the water surface, it was possible to detect fish capture so that Arctic cisco could be removed immediately for tagging. By cutting the gillnet mesh around an entangled fish, Arctic cisco were retrieved with a minimum of injury and handling time.

FISH TAGGING

Fish selected for tagging were anaesthetized in a tub containing a solution of tricaine methane-sulfonate. Each fish was measured for fork length (±1.0 mm) and weighed (±1.0 g) on an Alsep model 5000 electronic balance. A scale sample was taken for age determination. Tag placement followed the sub-dorsal mounting procedure described by Winter et al. (1978). A 14 gauge stainless steel hypodermic needle was inserted through the supporting tissue in two places under the dorsal fin to allow threading of the radio tag's mounting wires through the pterygiophores and out one side. The wires were threaded through plastic backing discs and an overhand knot was used to hold each disc firmly against the side of the fish. The tag was thus secured in place on the opposite side beside the dorsal fin with its whip antenna trailing parallel to the body and extending towards the tail. The tagged fish was then hand-held in shallow water close to shore and allowed to revive. Recovery, which usually took 1-2 minutes, was judged by the fish's ability to resist further handling by swimming away actively.

Dummy radio tags

Ten Arctic cisco (Table 2), tagged with externally mounted dummy radio transmitters, were retained in a holding pen for general observation. These tags were manufactured by ATS to match the three different sizes of radio tags used in this study (Table 1). This holding pen, secured in a sheltered area near the trapnet site, consisted of a fine-mesh trapnet (Beamish 1973) modified by removal of the throats to allow the fish to move around freely without danger of entanglement. By raising the bottom of the trapnet toward the surface, the condition and survival of the fish were observed without handling. Holding pen observations were discontinued on 6 July and fish were retrieved for dissection.

Radio tags

Twelve Arctic cisco were tagged with externally mounted radio transmitters (Table 3). After recovery, all fish were carried in a holding tub to a release site in the east entrance of the harbour to avoid recapture in our gillnet. Scanning with the receiver confirmed that each transmitter was functional at release time.

FISH TRACKING

Tracking was done with aircraft flying at 250-400 m altitude. All radio tag frequencies were stored in the scanning receiver's memory and scanned at a rate of 2 seconds per frequency. The coastal area scanned daily between 3 and 7 July included the nearshore waters between Tuktoyaktuk Harbour and Mason Bay (on Richards Island) to the west, and eastwards to McKinley Bay. After a three-week break, one final tracking flight was made on 31 July to locate possible spawners in the Delta. Tracking in the Delta covered the East Channel to Tununuk Point, along Neklek Channel and up the Middle Channel to Horseshoe Bend (Fig.1).

Project funding limited the extent and frequency of tracking flights. The main emphasis of the project was to determine our ability to detect tagged fish and to confirm their survival indirectly by tracking along presumed coastal and Delta migration corridors.

A reference tag was placed at 0.3 m depth at location TH001 to check the receiver's function and reception range at the start of each day's flight. This tag was repositioned at a depth of 0.8 m at the same site on 6 July to determine the general effect of depth on detection range.

FISH SAMPLING

A sample of 19 Arctic cisco were taken with the gillnet at location TH002 within 40 minutes after the last fish in our radio-tagging sample was released. All were preserved by freezing and sent to Winnipeg. Fork length, weight, sex and gonad maturity were recorded when fish were dissected 2 months later (Dr. J. D. Reist, Department of Fisheries and Oceans, 501 University Crescent, Winnipeg, personal communication). Sex and maturity were recorded according to the following code:

Female	Male	
0	0	sex unknown
1	6	immature
2	7	maturing
3	8	mature
4	9	ripe
5	10	spent

Ages were determined from fish scales. The gonadosomatic index (GSI), used as a measure of gonad development, was calculated for each fish with the formula:

$$GSI = \frac{\text{Gonad weight}}{\text{Fish round weight}} \times 100$$

RESULTS AND DISCUSSION

FISH TAGGING

The trapnet at location TH001 captured large numbers of broad whitefish, lake whitefish and least cisco; a small number of Arctic cisco, inconnu, burbot, northern pike and starry flounder were also caught. Over a period of 48 hours only 10 Arctic cisco were captured, eight of which were retained for tagging. Scale loss and trauma to fish were unavoidable during trapnet maneuvering and fish retrieval. The gillnet set at location TH002 in the east entrance to the Harbour proved to be more effective in capturing uninjured Arctic cisco for the purpose of tagging. The quick retrieval of fish minimized scale loss significantly. All Arctic cisco selected for tagging recovered from the tagging procedure and appeared in good condition on release into the harbour or holding pen.

Dummy-tagged fish

The fork lengths for the ten dummy-tagged fish ranged from 315-390 mm; the age range was 5 to 9 years (Table 2). Fish number D001 to D005 came from the trapnet while D006 to D010 came from the gillnet. The conditions of these fish were monitored by checking the holding pen at least twice a day from 30 June to 6 July. Subcutaneous hemorraging became visible within 24 hours for six fish. Three of these six (D001, D003 and D004) expired within 3 days after showing progressive hemorraging, loss of buoyancy control, body swelling and stiffness. The other three fish (D005, D006 and D008) were in poor condition by 6 July and would likely have expired within a few days. The remaining four fish (D002, D007, D009 and D010) were swimming actively and showed no evident body deterioration. These fish were classified to be in good condition when we concluded observations on 6 July.

It was not possible to make firm conclusions on survival of these dummy-tagged fish because of the interplay of different factors. While all tagged fish appeared healthy at release, 60% showed progressive deterioration in appearance and swimming ability within a few days. Arctic cisco captured in the gillnet appeared to fare better than those taken from the trapnet since only one of five trapnetted fish were in good condition while three of the five gillnetted fish were in good condition by the end of the study. The three fish that died during the observation period had been taken in the trapnet where the chance of physical injury and handling stress prior to tagging was greater.

The tag weight, expressed as a percentage of fish weight, varied for this group of fish. The range was 2.3% to 2.9% for fish that survived in good condition, 2.2% to 3.0% for those in poor condition, and 3.7% to 4.8% for the three that expired (Table 3). Although the results seem to suggest that tag weight had an effect on survival, the data are inconclusive because of the limited scope and incidental nature of the holding pen observations. It seems advisable to follow the general recommendation for tag weight versus fish weight. The available choices of tag size to meet the weight criterion ($\leq 2\%$ of fish weight) will set limitations in transmitter lifespan and minimum fish size in any future Arctic cisco studies.

Confinement of Arctic cisco in a holding pen may have been the most critical influence on survival. Under natural conditions, Arctic cisco are either feeding actively along the coast or migrating towards spawning areas. With only a short time frame for summer foraging before returning to overwinter in September, any holding pen experiment may jeopardize growth and survival. Confinement of this coregonid species in the pen probabably exacerbated any physiological responses associated with stress from capture and handling, thereby contributing to a failure to recover completely (Mr. S. Brown, Department of Fisheries and Oceans, 501 University Crescent, Winnipeg, personal communication). These observations affirmed our pre-study decision that the best way to evaluate Arctic cisco recovery and survival in the field was to follow the behaviour of tagged fishes left free to continue with their normal summer activities.

Radio-tagged fish

The 12 Arctic cisco, radio-tagged on 1-2 July, ranged in fork length from 358 to 410 mm and were 6-10 years old (Table 3). Fish number 90-1, 90-5 and 90-7 were trapnetted fish while the rest were from the gillnet. The tag weight to fish weight percentage ranged from 1.5 to 2.6%. It was expected that potential spawners for the year would migrate into the Mackenzie River on a spawning migration. On the other hand, non-spawners were expected to feed along the coast during July and August before returning to overwintering areas such as Tuktoyaktuk Harbour.

FISH TRACKING

Six tracking flights were made between 3 and 31 July (Table 4). Detection success was measured as the number of positive detections out of the six scanning attempts. Only two fish, 90-2 and 90-6, were never detected after release. For the remaining 10 fish, we recorded at least one fix (17% detection success) on four fish, two fixes (33%) on four fish, and four fixes (67%) on two fish. Individual maps showing the dates and locations of each tagged fish are included in Figures 3 to 12. Figure 13 shows the last recorded location for seven of the radio-tagged Arctic cisco.

Four Arctic cisco, (90-1, 90-5; 90-7, 90-11 [Fig. 3, 6, 7 and 11, respectively]), stayed in the vicinity of Tuktoyaktuk Harbour for two to three days after release. Fish 90-7 was recaptured on the east side of the harbour by a domestic fisherman on 4 July while 90-1 and 90-5 were never detected again. These three individuals were the only fish in the radio-tagged sample that were originally taken in the trapnet. Although fish 90-11 was not detected in subsequent flights along the coast, it was detected on 31 July in Neklek Channel in the Mackenzie Delta.

Four Arctic cisco (90-3, 90-4, 90-8, 90-10 [Fig. 4, 5, 8 and 10, respectively]), which were not detected in Tuktoyaktuk Harbour on 3 July, were found to have moved eastward to the vicinity of Topkak Point by 4 July. Fish 90-10 escaped further detection while 90-8 was still at Topkak Point on 5 July before it too was lost. Fish 90-3 and 90-4 reversed their direction by moving westward towards the Mackenzie Delta; fish 90-3 was followed for three consecutive days until it reached the mouth of the East Channel by 7 July, its last day of detection. Fish 90-4 was not detected along the coast during subsequent coastal scans; however, it was found in the Middle Channel of the Mackenzie Delta on 31 July.

Two other Arctic cisco (90-9, 90-12 [Fig. 9 and 12]) also left Tuktoyaktuk Harbour by 3 July. Unlike the previous group, no initial eastward movement occurred since both were initially detected moving westwards. Fish 90-12 was followed over three consecutive days as it moved along the coast, reaching the mouth of the East Channel by 6 July; it was next located on 31 July near Pete's Creek in the East Channel. Fish 90-9 moved 17 km west of its release site by 3 July. Although there was no further detection, this fish was recaptured on 19 July by a domestic fisherman at Tununuk Point in the East Channel (Fig. 9).

The preceding tracking results showed that five of the tagged Arctic cisco (90-3, 90-4, 90-9, 90-11 and 90-12) displayed movements that suggested the actions of mature fish on spawning migrations (Fig. 13). Three of these fish, 90-4, 90-11 and 90-12, were detected on 31 July in the East and Middle Channel of the Mackenzie Delta. Fish 90-4 made the furthest point of upstream migration when it was located on 31 July just south of Horseshoe Bend, about 207 km from its release site (Fig. 5 and 13). Fish 90-9 was in the East Channel when recaptured on 19 July. Fish 90-3 reached the mouth of the East Channel via Whitefish Bay (Fig. 4). Although its path suggested upstream migration, this fish was not recorded in the Delta on the 31 July tracking flight. It may have moved further upstream in the Mackenzie Delta beyond our area of scanning or else remained in coastal waters.

The confirmed departure of radio-tagged Arctic cisco into the coastal zone was an indication that seven of the 12 tagged fish released in Tuktoyaktuk Harbour (90-3, 90-4, 90-8, 90-9, 90-10, 90-11 and 90-12) had recovered sufficiently from the effects of tagging and were able to proceed, to some extent, with summer coastal activities. Tag weight to fish weight percentage for these fish ranged from 1.5 to 2.6% (mean = 2.2±0.4%). As for the remaining five, one fish (90-7) was taken out of circulation by its recapture in the harbour while the remaining four fish, with limited or no detection results, may have been missed because of fish mortality, tag failure or fish movement outside the area and range of scanning.

Two fish provided data on the rate of Arctic cisco migration. Fish 90-3 moved 30 km from the tagging location to a site 2.5 km east of Whitefish Station (Fig. 4) between 2 July and 5 July, a rate of approximately 10 km per day. This fish moved a further 7 km from 5 to 6 July and another 15 km from 6 to 7 July when it reached the East Channel. Fish 90-9 moved approximately 17 km west along the coastline between 2 July and 3 July on route to the Mackenzie River. A high rate of migration may have resulted in some fish moving beyond the area covered by later tracking flights.

Questions regarding mortality and long term survival could not be addressed fully in this time-limited pilot study. Additional scanning flights, not possible in this study, might have located missing fish to establish whether tagged Arctic cisco were still alive two to three months after tagging. The last flight on 31 July suggested that some Arctic cisco survived for at least one month after tagging. More extensive aircraft tracking in the lower Mackenzie River in August might have established if migrations continued upstream or up major tributaries such as the Peel or Arctic Red River. Similarly, more coastal tracking might have revealed more details on the coastal movement patterns of non-spawners or immature Arctic cisco. Detection of a return to overwintering sites like Tuktoyaktuk Harbour might have also been possible if tracking was conducted in September. Accommodation of such an expanded scope, however, would have required a significant level of funding for aircraft tracking.

Data on the sample of 19 fish, taken from the gillnet on 2 July at location TH002, are summarized in Table 5. These fish, ranging from 333 to 410 mm fork length, were 7-10 years old and consistent with the largest size ranges seen in the harbour in previous studies (Bond 1982; Hopky and Ratynski 1983). The age of Arctic cisco, sampled by the authors in 1980 and 1981 during spawning migrations in the Delta, ranged from 6 to 12 years in age (unpublished data). The gonadosomatic index (GSI) provided indications of the number of potential spawners among our sample of cisco from 1990. There were six females with a GSI range of 0.56 to 5.97. Four of these could be considered potential spawners for the year with a GSI range of 3.00 to 5.97 (W. Bond, personal communication). There were 13 males with a GSI range of 0.29 to 1.61. Only four of these fish could be considered potential spawners for the year with a GSI range of 1.21 to 1.61. Overall, the sample consisted of 42% potential spawners for the year with ages ranging from 7 to 9 years.

It was clear that detection success was not always guaranteed for each radio-tagged fish. Zero detections can be attributed to tag malfunction or to early mortality of a tagged fish which, on sinking into deeper waters, made detection impossible. Two important factors known to affect the transmission of radio tag signals are high water conductivity and immersion depth of the transmitter. High levels of conductivity decreases transmission range. Four surface conductivity readings taken at the entrance of the harbour between 2 and 4 July ranged from 1040 to 1670 $\mu S \cdot cm^{-1}$; these levels are considered high for radiotelemetry. Detection range of radio-tagged fish in the freshwater of the Delta, ranging from 1 to 3 km, was obviously greater than the general range of 0.2 to 1 km experienced in coastal waters. The effect of depth was observed with the reference tag at location TH001. With the reference tag at 0.3 m depth, reception distance from the helicopter ranged from 1 to 1.5 km. Reception distance was reduced to less than 0.5 km with the tag set at an immersion depth of 0.8 m. Intermittent high salinity conditions along the coast, active fish movements into deep water or fish movement out of the range of detection during tracking periods were therefore the most likely factors influencing detection success in this study.

We observed that most gillnet caught Arctic cisco were moving within 10 m from shore in less than 3 m depth. A few fish, however, were also caught further offshore up to approximately 5 m depth. During their coastal gillnet survey at Phillips Bay, Yukon, Bond and Erickson (1989) found that among the anadromous coregonid species, Arctic cisco was the species most likely to venture offshore to the 5 m isobath, where it was captured both at the surface and at the bottom.

When a radio-tagged Arctic cisco ventures further offshore into deeper waters, detection range would decrease substantially or be reduced to zero. A similar effect on detection is assumed if wind or flow conditions result in coastal waters becoming more brackish during a fish's passage in shallow, nearshore waters.

The task of tracking immature Arctic cisco would be more difficult than tracking the mature adults. Immature cisco inhabit coastal waters where salinity and depth limit detection success. Detection of mature Arctic cisco is more assured since they appear to migrate, close to the shoreline, towards their freshwater spawning grounds soon after leaving a coastal overwintering area. With the greater detection range of radio tags in freshwater, the major emphasis of a radiotelemetry study is best directed at following the migration behaviour of mature fish.

Commercially available low frequency radio transmitters and associated scanning receivers and loop antennae can be used to track Arctic cisco migrations. Tag sizes with a useful lifespan of 60-100 days favour the large size ranges of Arctic cisco. The smallest tag used in this study, with a lifespan of 30 days and weighing 11-12 g, should not be used for fish smaller than 550-600 g if the 2% weight rule is to be followed. Smaller tags can be obtained for immature fish but at a reduction of useful lifespan. The mean weight of the five presumed spawning migrants was 638 ± 137 g while the mean percent tag weight to body weight for the same fishes was $2.1 \pm 0.5\%$. The type RW-48 and type RM675 tags, suitable for fish in the 550-700 g size range, were the most suitable tags for the Arctic cisco taken in this study.

SUMMARY AND CONCLUSIONS

1. Twelve Arctic cisco were tagged with radio transmitters in Tuktoyaktuk Harbour and their movements were tracked with aircraft on 3, 4, 5, 6, 7 and 31 July. Ten fish were detected at least once with only two having no detections. Detection success for each fish ranged from 17% to 67%.

2. Arctic cisco recovered rapidly from the anaesthesia and sub-dorsal tagging procedures. The tag weight for seven cisco moving into coastal waters averaged 2.2% of fish weight.

3. Detection success in this pilot study was affected by the limited area of tracking coverage and a short study timespan. Detection range was restricted by saline conditions of coastal waters and probable fish movements into deeper waters.

4. Arctic cisco migrated along the coast at a rate of 7 to 17 km per day. Five out of twelve tagged fish (42%) appeared to be potential spawners for the year as indicated by their direct migration toward the Mackenzie River's East Channel. Four fish moved eastward to Topkak Point although two reversed direction and also moved westward in subsequent detections.

5. The locations of four fish in the Delta by 31 July suggested the behaviour of mature fish on a spawning migration into the Mackenzie watershed.

6. A sample of Arctic cisco (N = 19), taken in the same gillnet used during radio-tagging, had fork lengths ranging from 333 to 410 mm and were 7 to 10 years old. Gonadosomatic index data indicated 42% of this sample were potential spawners for the year.

7. Ten Arctic cisco, tagged with dummy radio transmitters, were kept for 6 days in a holding pen for incidental observations. Three fish expired within three days. Four fish survived in good condition while three were in poor condition. Gillnet-captured fish seemed to survive in better condition than trapnet-captured fish. While excessive tag weight may be another factor in affecting survival, confinement in the holding pen could have been the overriding cause of incomplete recovery and ill health.

8. We conclude that radio transmitter tags and our present tracking equipment can be used to study migrations of mature Arctic cisco.

RECOMMENDATIONS

Tracking the migrations of Arctic cisco from coastal waters can be accomplished with the use of radio tags and aircraft tracking. The main emphasis of such a study is best directed at following mature fish since their behaviour and rapid migration towards estuarine and freshwater habitats ensure greater success for a radiotelemetry study.

The total weight of an external mount radio tag should not exceed 2% of the weight of the fish. Small tags for the size range of fish encountered would have a lifespan of 30 to 60 days. Implant type radio tags may not be suitable for this species because of the Arctic cisco's relative sensitivity to additional handling required for the surgical procedure.

The anaesthesia and external mounting techniques followed in this study were appropriate for Arctic cisco. The preferred method of capture is to use a shore set gillnet with the appropriate mesh size for the target size range of fish. Individual Arctic cisco should be retrieved moments after capture to minimize injury.

By radio-tagging mature Arctic cisco emerging from other major coastal overwintering sites, the hypothesis that southern Beaufort Arctic cisco originate exclusively from the Mackenzie River watershed can be tested. Tagging of Arctic cisco at the mouth of the Anderson River, the first major drainage east of the Mackenzie, is recommended. The study may address a hypothesis that the Anderson River functions only as a nursery, feeding and overwintering area and that no upstream spawning run of Arctic cisco exists.

Mackenzie River Arctic cisco constitute a resource shared by both commercial and domestic fisheries in Alaska. It is also an important part of the domestic fishery in Tuktoyaktuk and Mackenzie Delta communities. Arctic cisco migrations are known to cover the greatest distances among coregonid species in the region. Unlike some coregonid species that use the coastal waters mainly as a migratory corridor, Arctic cisco use these waters as important feeding habitat. Since these considerations may make this species sensitive to future offshore oil and gas production in the Beaufort Sea, life history studies of this species in its coastal habitat should be considered a high priority.

ACKNOWLEDGMENTS

Primary funding for this project was provided by the Fisheries Joint Management Committee (FJMC). The authors would like to thank the Polar Continental Shelf Project of the Department of Energy, Mines and Resources for logistical support provided in Tuktoyaktuk. Mr. V. Gillman, Area Manager, Department of Fisheries and Oceans, Inuvik, provided additional funding for tracking flights on 7 and 31 July. We also thank Mr. L. Dahlke for processing tag returns and recapture infomation from subsistence fishermen. The manuscript was reviewed by Mr. G. Lacho and Mr. D. Chiperzak.

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Table 1. Specifications of radio transmitters used to tag Arctic cisco in Tuktoyaktuk Harbour, July 1990.

Manufacturer's Code	RW-48	RM-675	RM-625
Length (cm)	3.0-3.2	3.8-4.0	4.1-4.5
Width (cm)	0.8-0.9	1.1-1.2	1.5-1.7
Depth (cm)	0.6-0.7	0.6-0.7	0.7-0.8
Weight (g)	11-12	13-14	15
Antenna Length (cm)	19-20	19-20	19-20
Battery Model	393 (mercury)	357 (mercury)	355 (mercury)
Battery Voltage (v)	1.4	1.4	1.4
Battery Rating (mah)	74.4	180	350.4
Pulse Rate (pulse/min)	59-63	60-62	57-74
Pulse Width (millisec)	15-19	15-16	14-20
Current Drain (ma)	0.07-0.10	0.07-0.10	0.07-0.10
Lifespan (approx.days)	30	60	100

Table 2. Data on Arctic cisco tagged with dummy radio tags in Tuktoyaktuk Harbour, July 1990.

Fish No.	Tag Type	Fork Length (mm)	Weight (g)	Age (yr)	Maturity	Tag [1] Weight (%)	Date Tagged	Final Condition
D001	RW-48	315	290	5	6	4.1%	30 June	died 2 July
D002	RM-625	380	582	7	6	2.6%	30 June	good 6 July
D003	RM-675	340	382	7	6	3.7%	1 July	died 4 July
D004	RM-675	318	294	5	6	4.8%	1 July	died 2 July
D005	RM-625	390	649	9	3	2.3%	1 July	poor 6 July
D006	RM-675	370	465	8	6	3.0%	2 July	poor 6 July
D007	RM-675	370	480	8	6	2.9%	2 July	good 6 July
D008	RW-48	378	450	6	1	2.7%	2 July	poor 6 July
D009	RM-625	380	558	9	2	2.7%	2 July	good 6 July
D010	RM-625	382	600	9	3	2.5%	2 July	good 6 July

[1] Tag weight expressed as a percentage of fish weight

Table 3. Data on Arctic cisco tagged with radio tags in Tuktoyaktuk Harbour, July 1990.

Fish No.	Tag Freq. (mHz)	Tag Type	Fork Length (mm)	Weight (g)	Age (yr)	Release Date	Tag Weight (%) [1]
90-1	49.020	RM-675	364	565	8	1 July	2.5%
90-2	49.040	RM-675	388	719	8	2 July	1.9%
90-3	49.080	RM-675	370	580	7	2 July	2.4%
90-4	49.100	RM-675	379	540	8	2 July	2.6%
90-5	49.180	RM-625	385	625	9	1 July	2.4%
90-6	49.230	RM-625	386	639	8	2 July	2.3%
90-7	49.310	RM-625	410	745	10	1 July	2.0%
90-8	49.340	RM-625	395	686	8	2 July	2.2%
90-9	49.400	RW-48	400	807	8	2 July	1.5%
90-10	49.460	RW-48	367	507	6	2 July	2.4%
90-11	49.490	RW-48	393	762	9	2 July	1.6%
90-12	49.538	RW-48	358	502	8	2 July	2.4%

[1] Tag weight expressed as a percentage of the fish weight.

Table 4. Schedule for radio tracking and summary of detection success for Arctic cisco tagged in Tuktoyaktuk Harbour, July 1990.

Date	Fish Number											
	90-1	90-2	90-3	90-4	90-5	90-6	90-7	90-8	90-9	90-10	90-11	90-12
3	No	No	No	No	No	No	Yes	No	Yes	No	Yes	No
4	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes
5	No	No	Yes	No	No	No	[1]Rec.	Yes	No	No	No	Yes
6	No	No	Yes	No	No	No	-	No	No	No	No	Yes
7	No	No	Yes	No	No	No	-	No	No	No	No	No
31	No	No	No	Yes	No	No	-	No	[2]Rec.	No	Yes	Yes

[1] Rec. = Recapture by domestic fisherman, 4 July.
[2] Rec. = Recapture by domestic fisherman, 19 July.

Table 5. Data on a sample of Arctic cisco retained for analysis during radio tagging in Tuktoyaktuk Harbour on 2 July 1990.

Fish Number	Fork Length (mm)	Weight (g)	Age (yr)	Sex	Maturity Code	Gonad Weight (g)	G.S.I.
32335	410	739	10	M	7	4.5	0.61
32336	350	490	7	M	8	6.1	1.24
32337	354	429	7	F	1	2.4	0.56
32338	363	497	9	F	2	8.9	1.79
32339	359	489	8	F	3	21.1	4.31
32340	377	636	8	M	7	3.0	0.47
32341	360	547	7	M	7	1.3	0.24
32342	376	595	8	M	7	4.2	0.71
32343	348	463	7	M	7	1.4	0.30
32344	351	453	8	M	7	2.0	0.44
32345	333	405	8	M	8	5.3	1.31
32346	366	457	8	M	7	2.2	0.48
32347	351	519	8	M	7	2.9	0.56
32348	355	486	7	M	8	5.9	1.21
32349	395	766	9	F	3	23.0	3.00
32350	376	612	8	M	7	1.8	0.29
32351	363	547	9	M	8	8.8	1.61
32352	395	642	8	F	3	37.5	5.84
32353	373	590	8	F	3	35.2	5.97

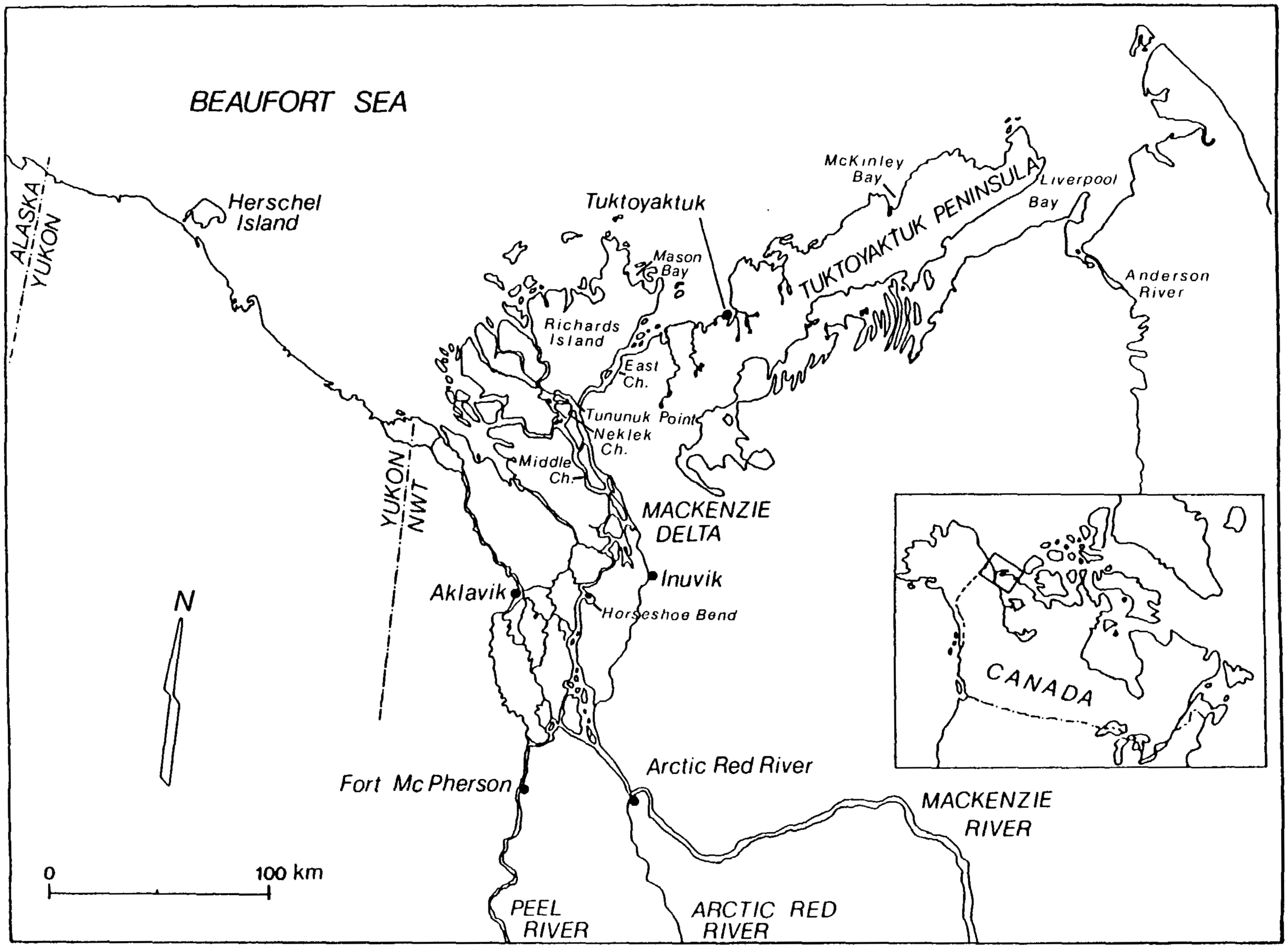


Fig. 1. The Mackenzie Delta-Tuktoyaktuk study area, July 1990.

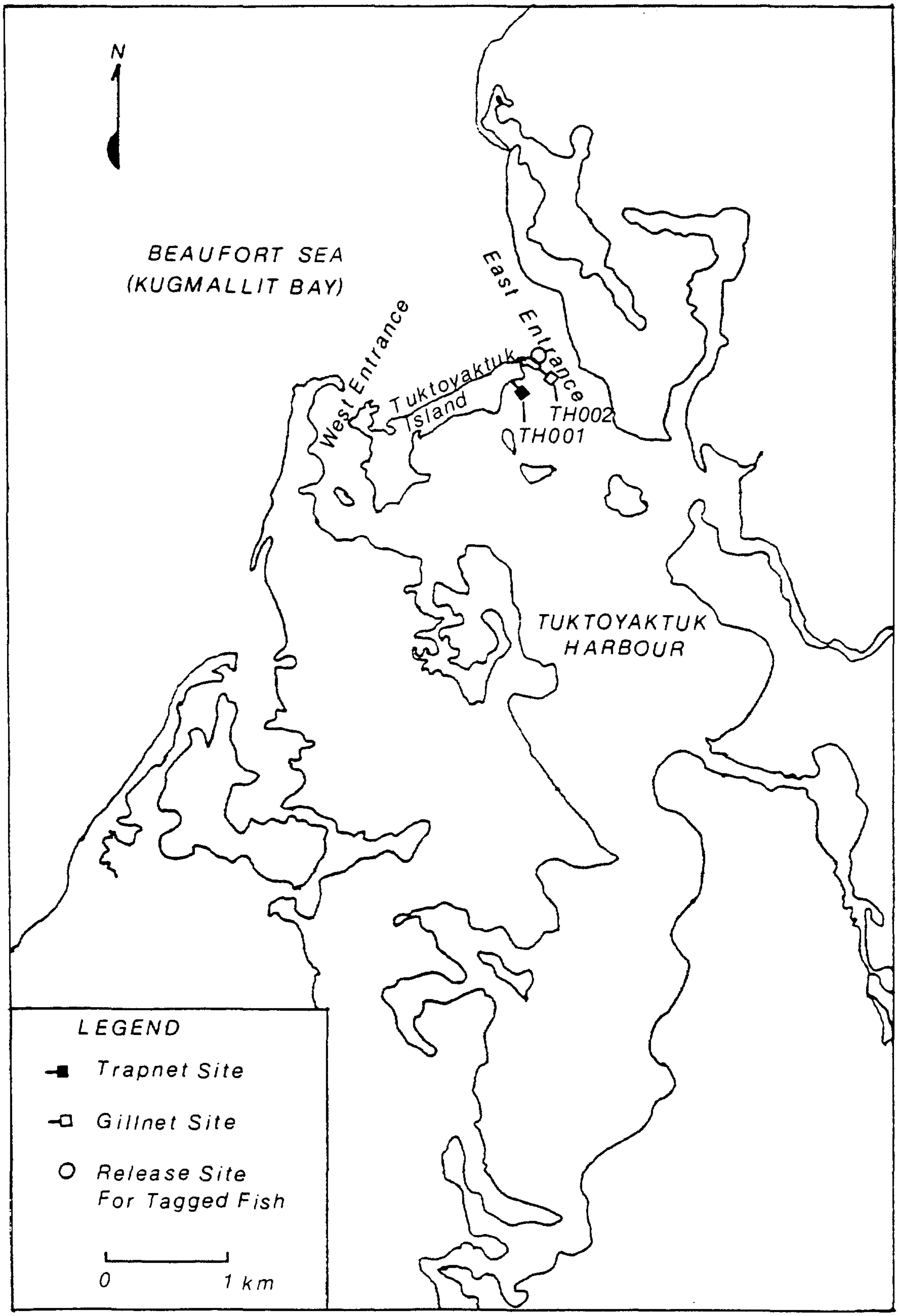


Fig. 2. Tuktoyaktuk Harbour showing trapnet and gillnet sites.

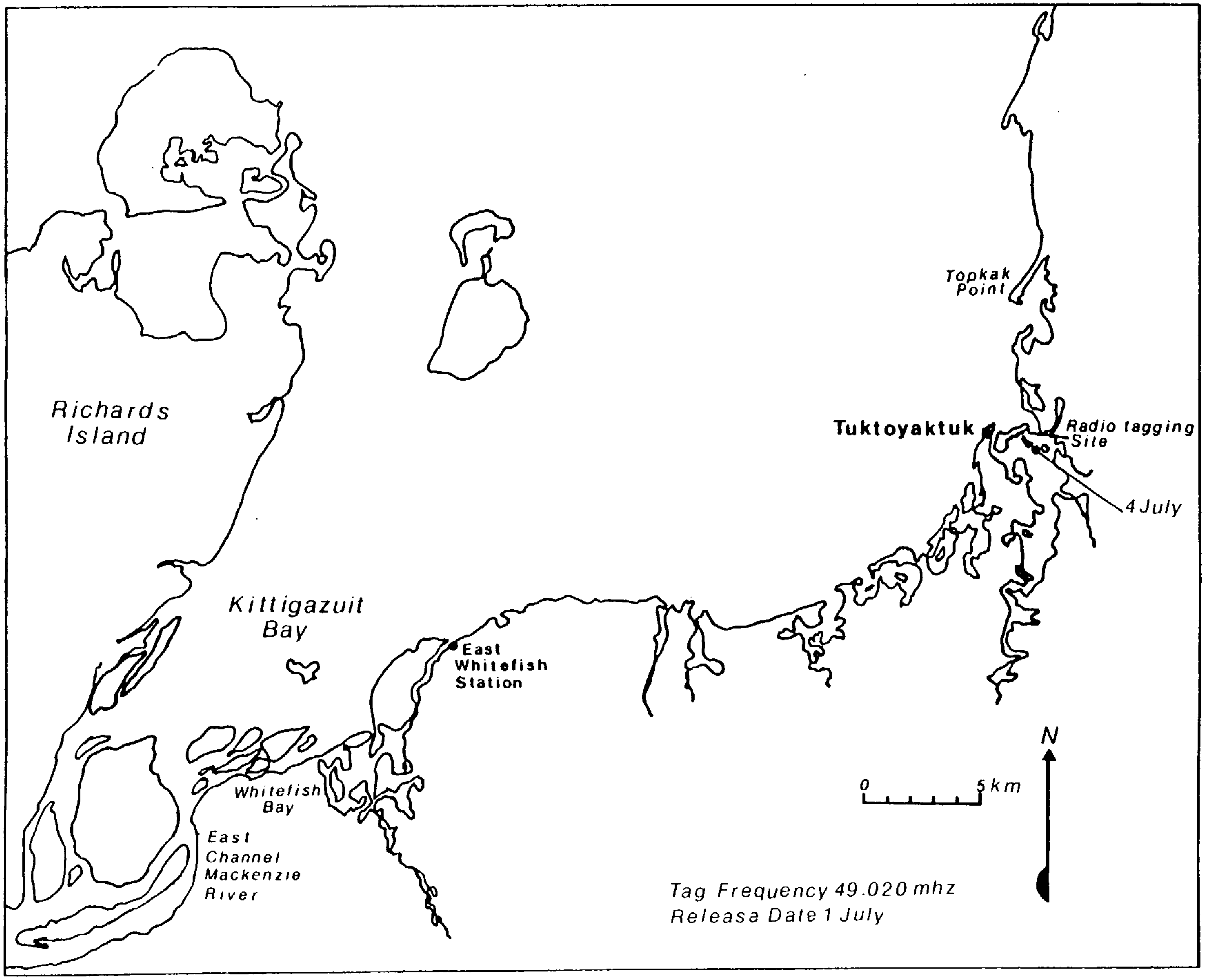


Fig. 3. Tracking locations of radio-tagged fish No. 90-1.

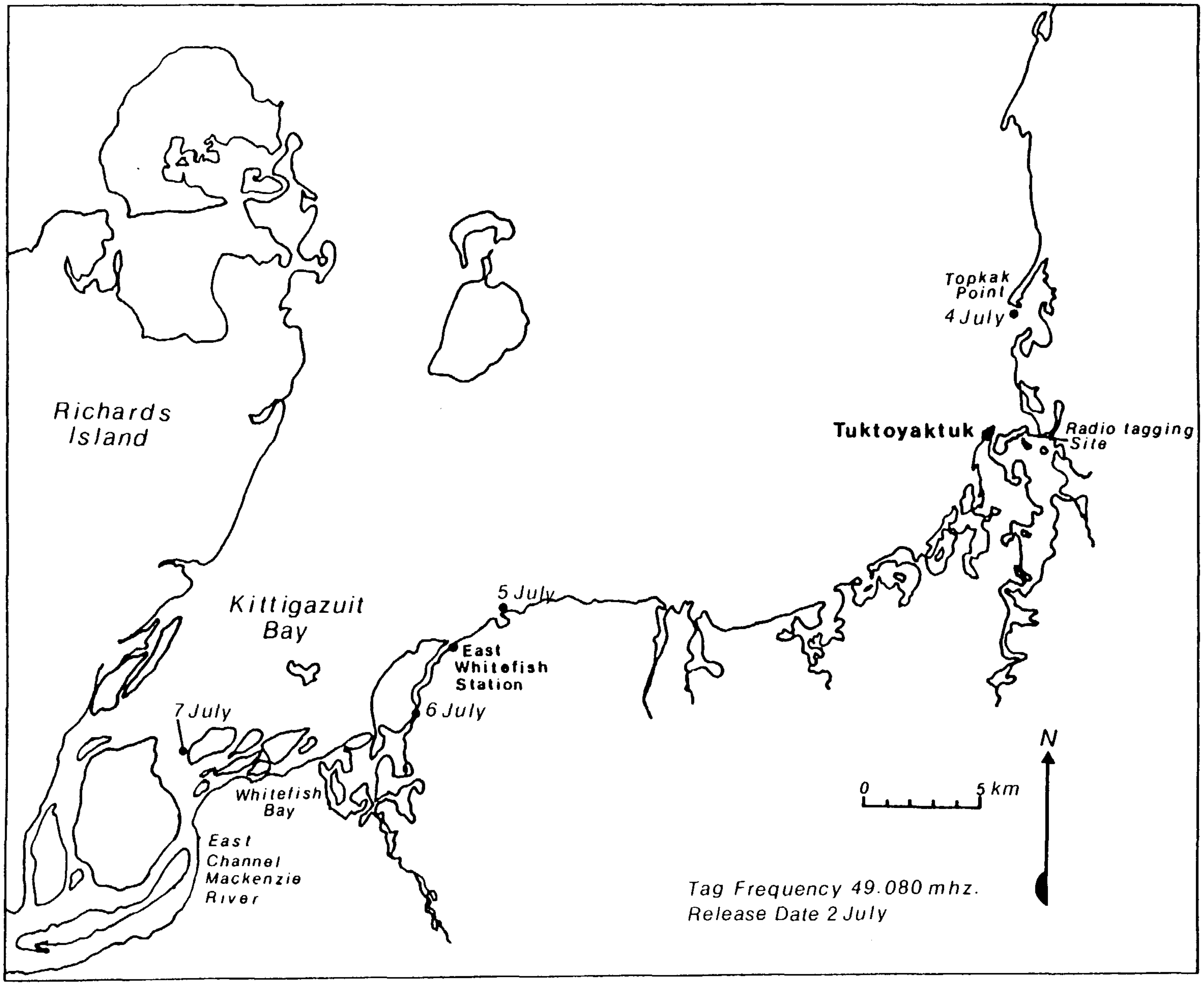
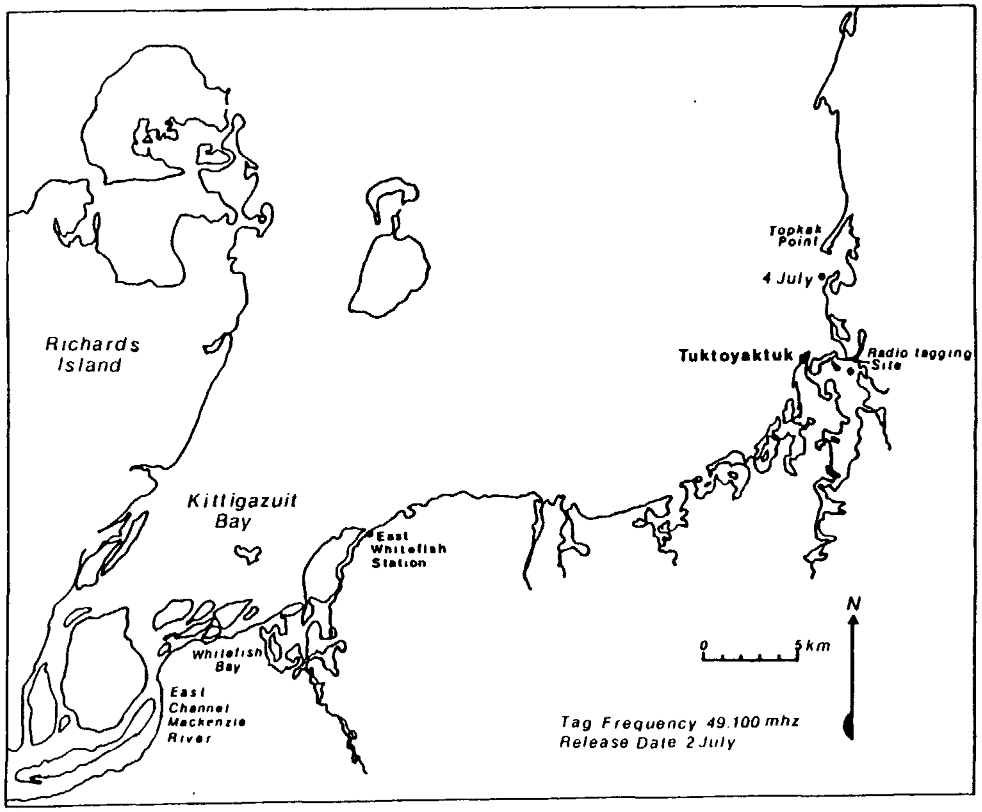


Fig. 4. Tracking locations of radio-tagged fish No. 90-3.



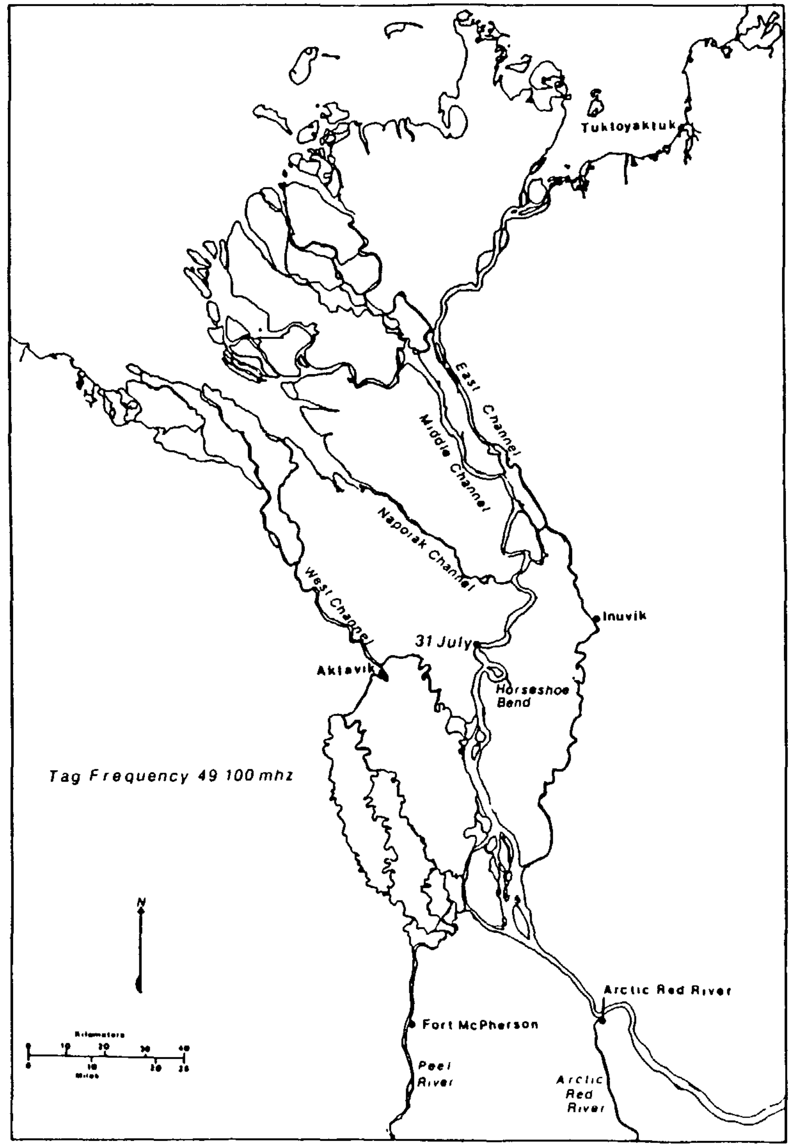


Fig. 5. Tracking locations of radio-tagged fish No. 90-4.

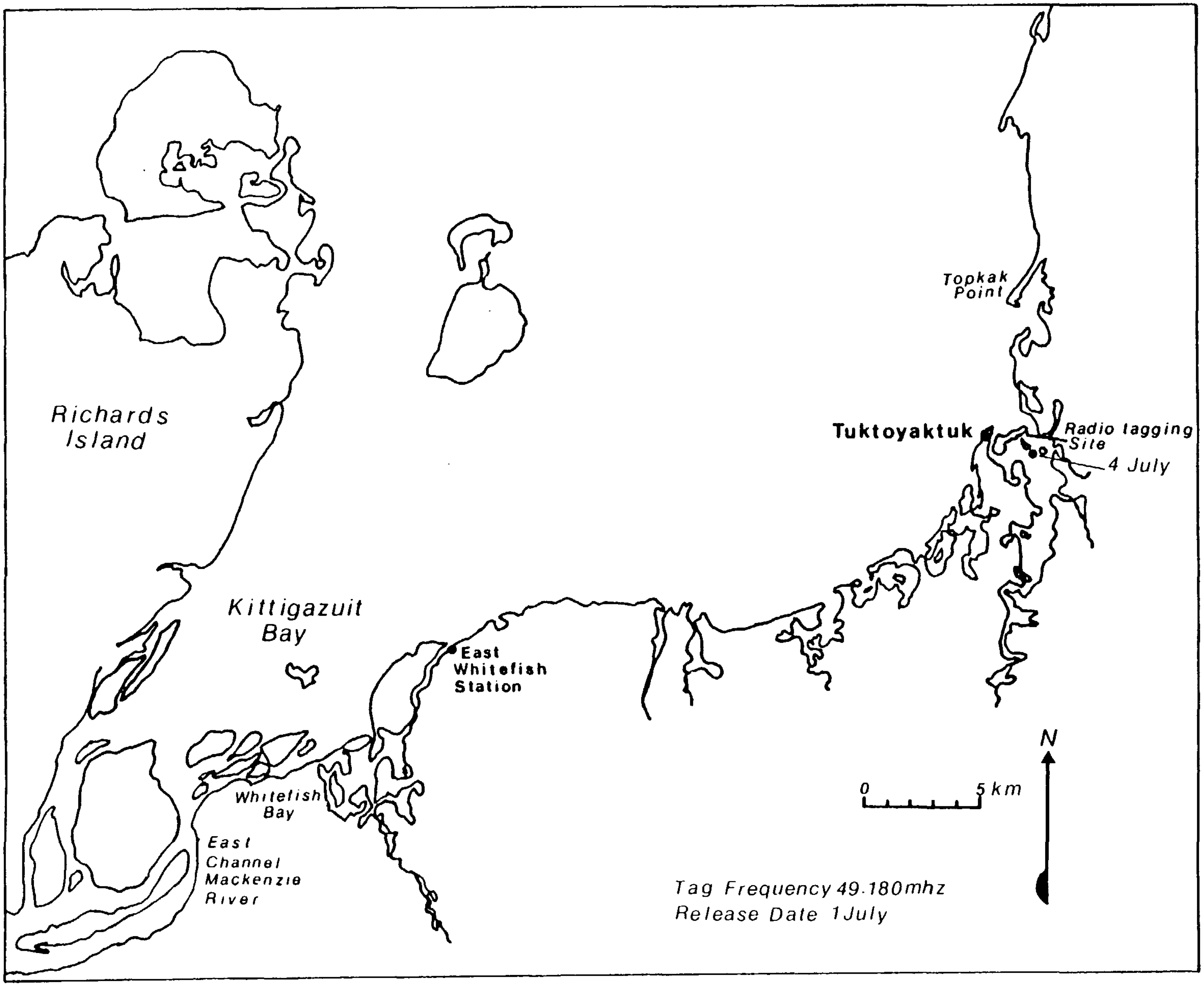


Fig. 6. Tracking locations of radio-tagged fish No. 90-5.

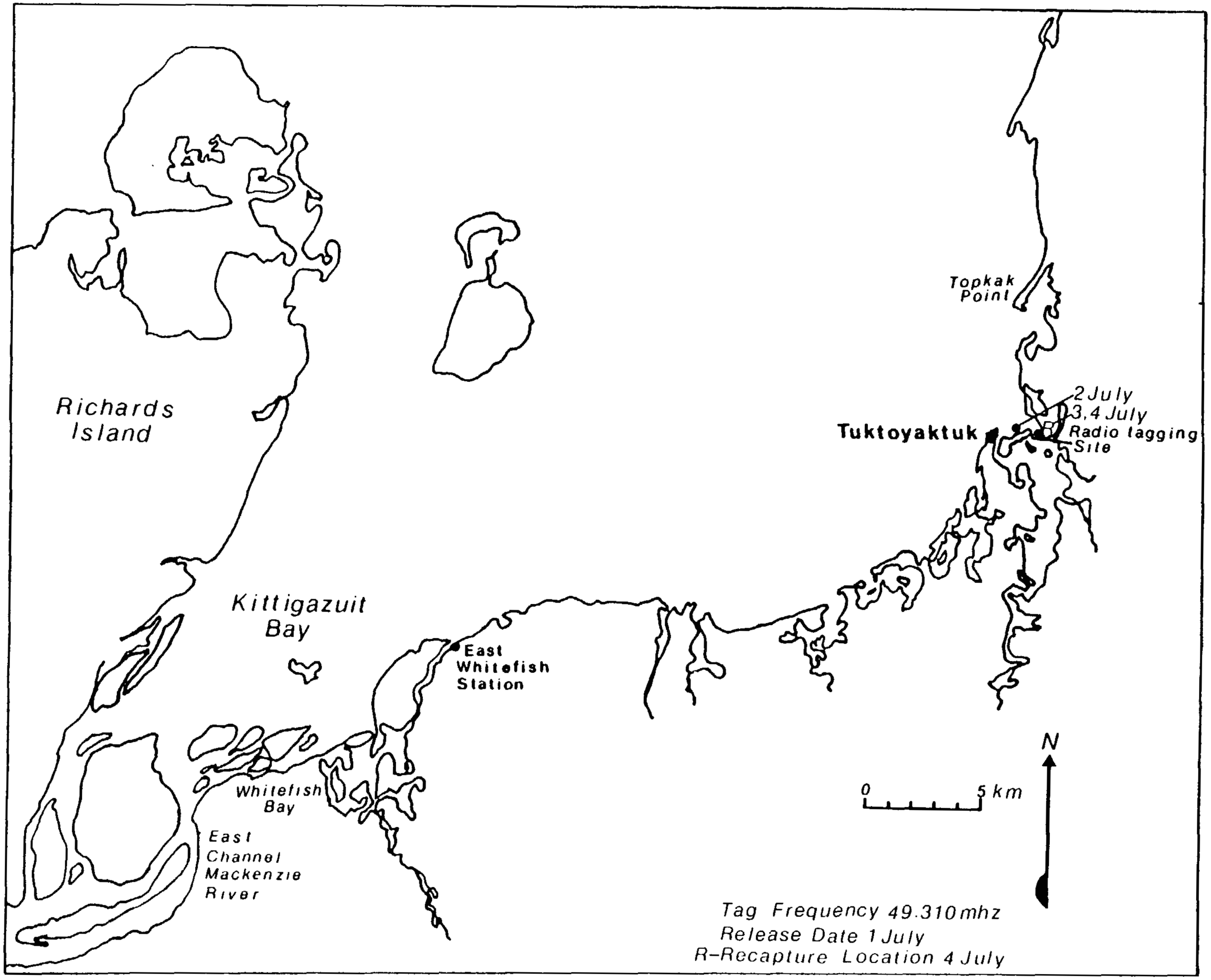


Fig. 7. Tracking locations of radio-tagged fish No. 90-7.

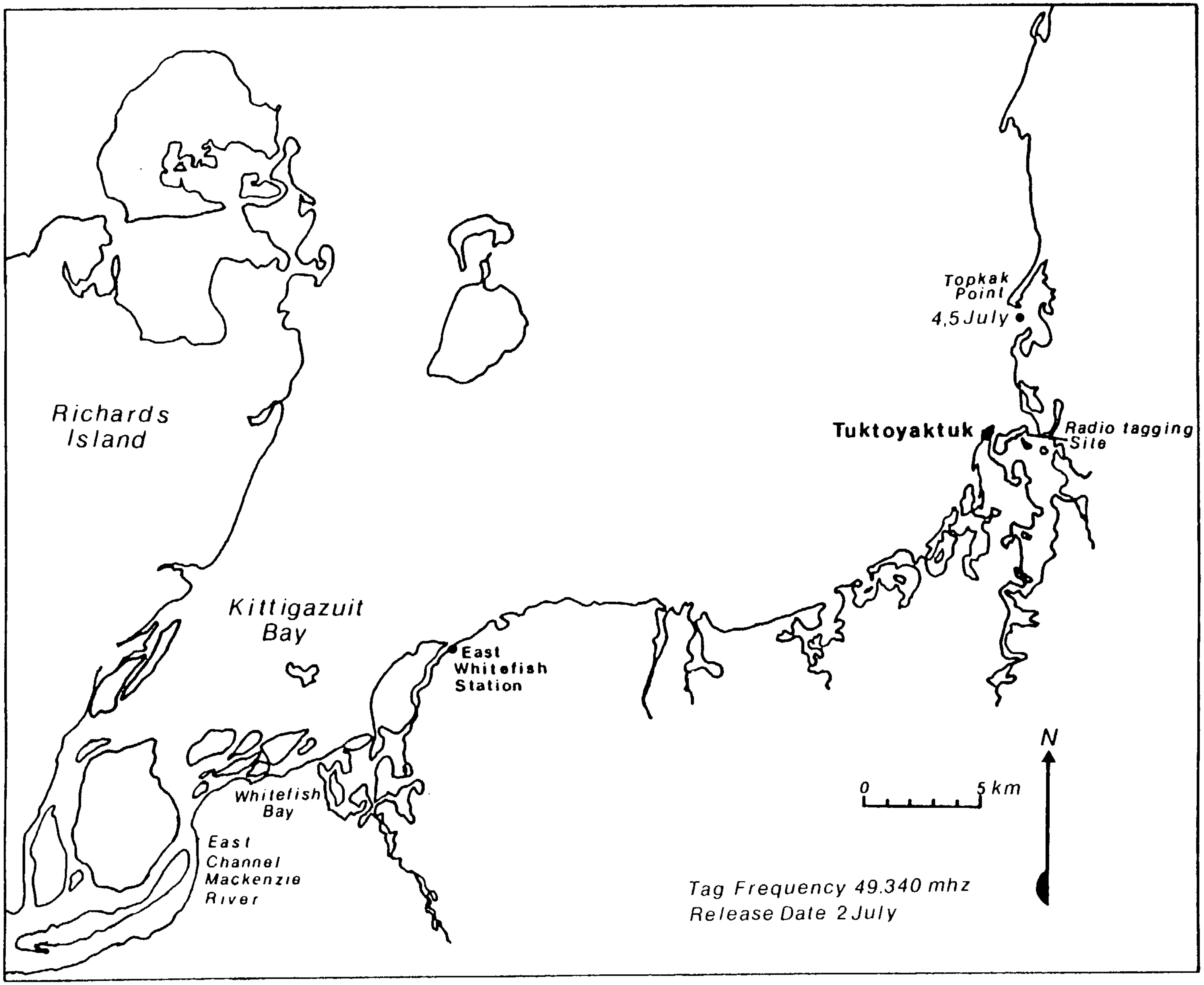


Fig. 8. Tracking locations of radio-tagged fish No. 90-8.

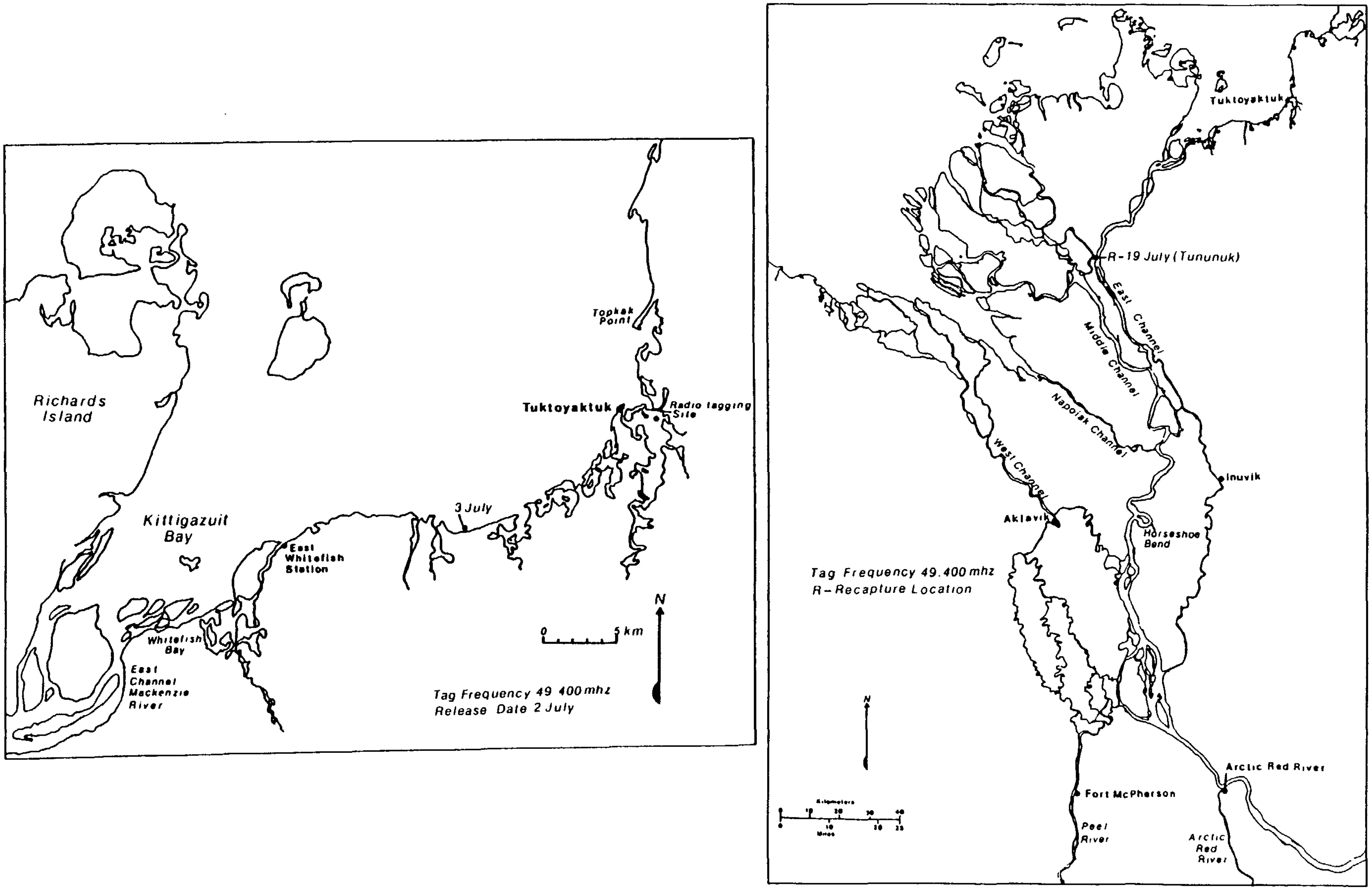


Fig. 9. Tracking locations of radio-tagged fish No. 90-9.

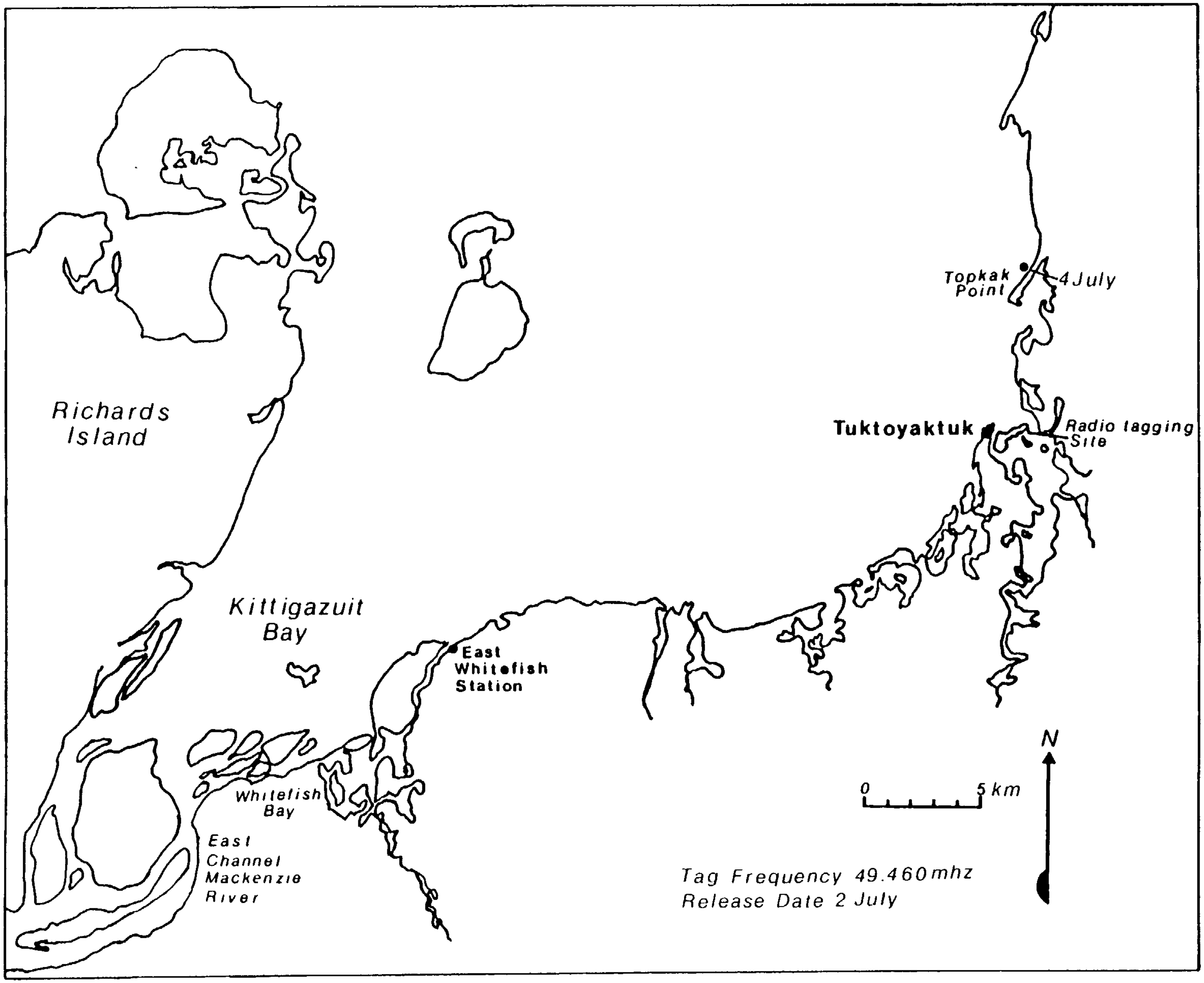


Fig. 10. Tracking locations of radio-tagged fish No. 90-10.

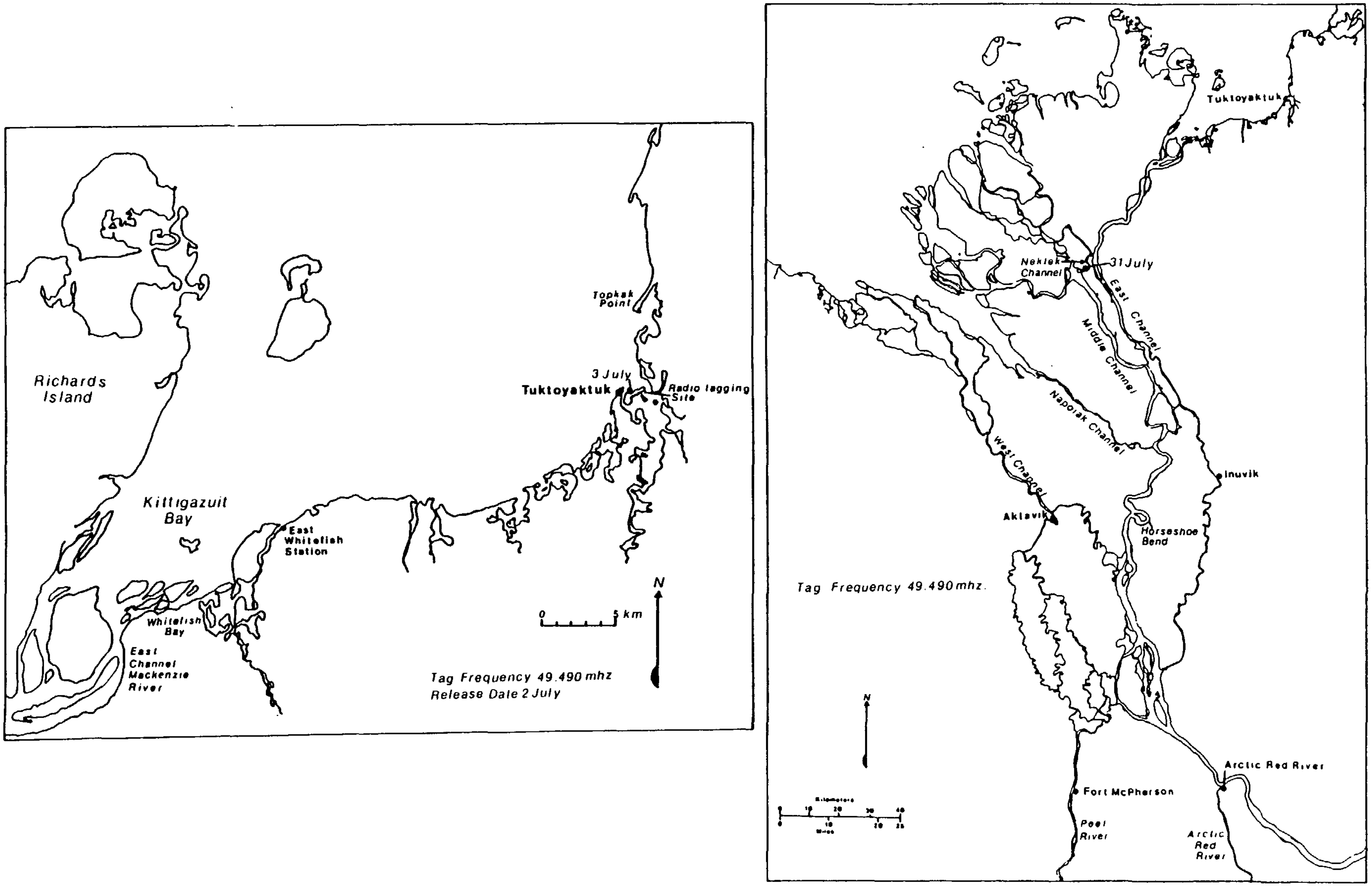


Fig. 11. Tracking locations of radio-tagged fish No. 90-11.

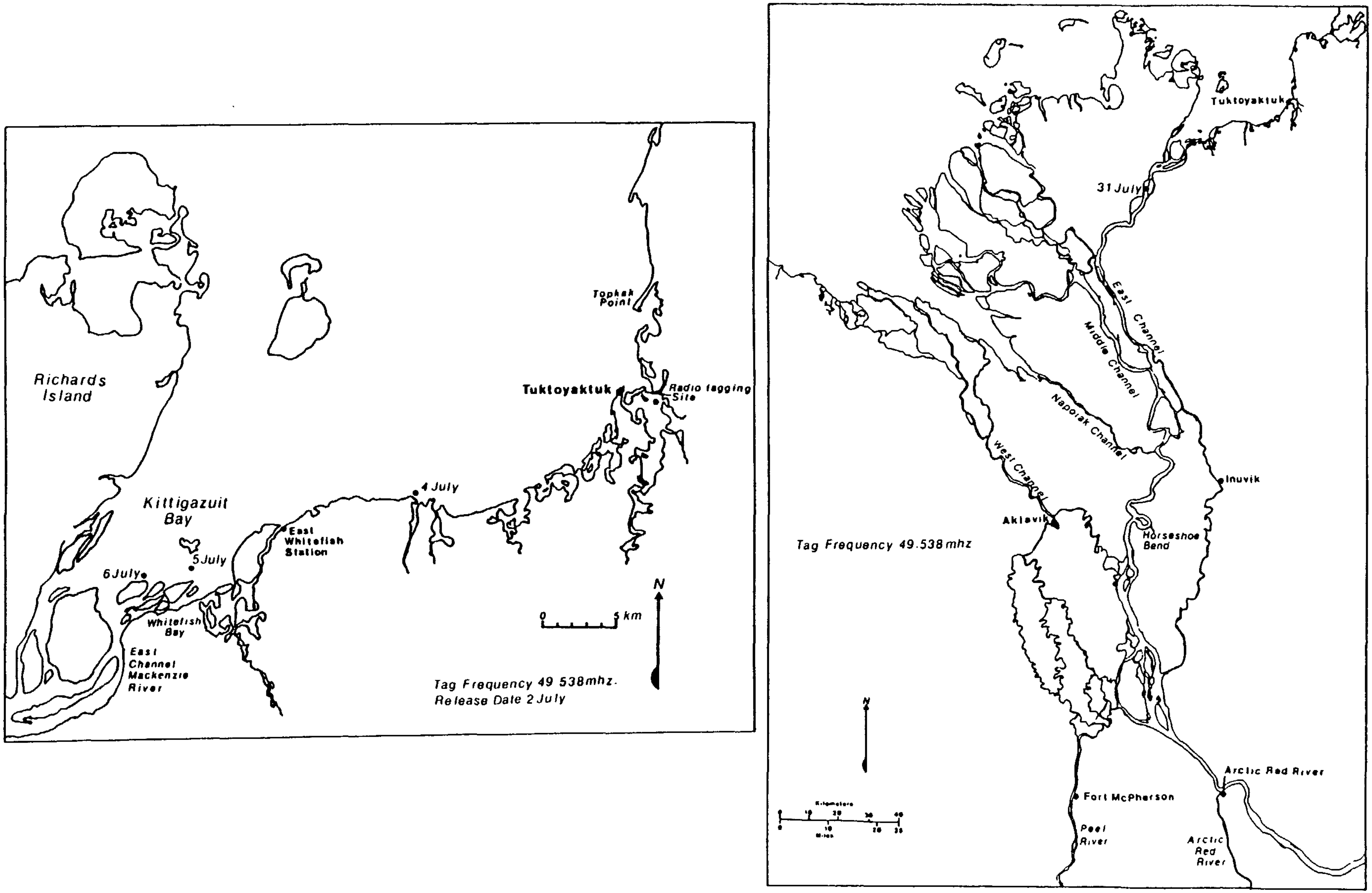


Fig. 12. Tracking locations of radio-tagged fish No. 90-12.

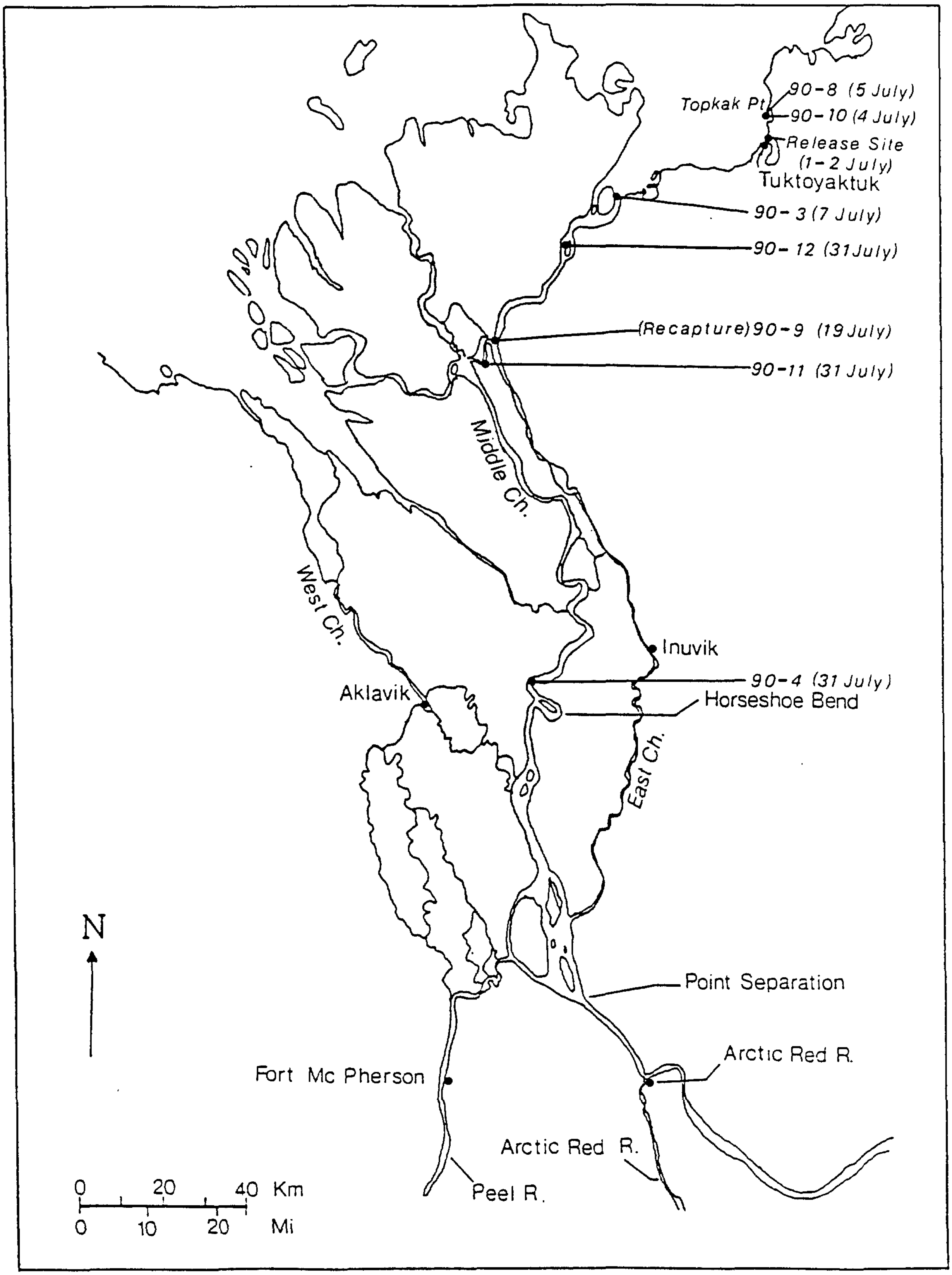


Fig. 13. The last recorded location of seven radio-tagged Arctic cisco released on 1-2 July at Tuktoyaktuk Harbour.