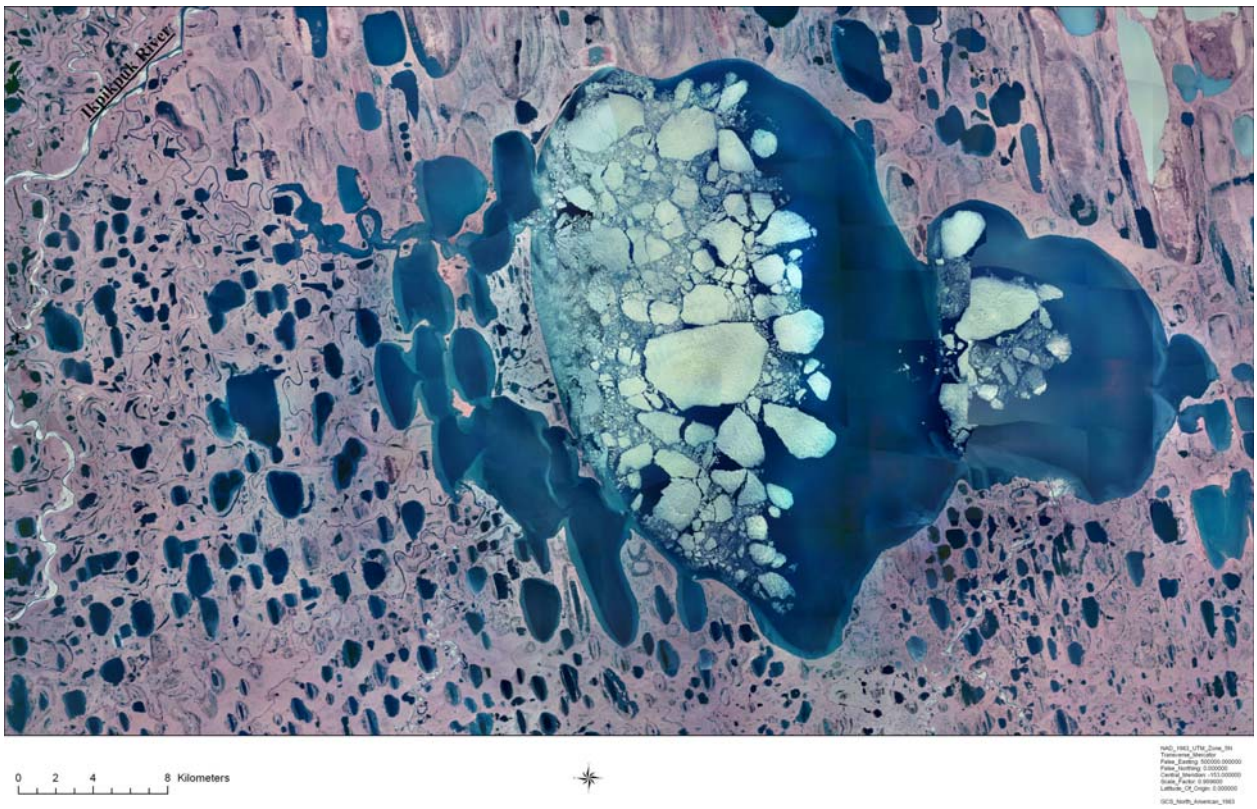
TECHNICAL REPORT NO. 06-04

SEASONAL MOVEMENTS AND HABITAT USE BY BROAD WHITEFISH (*COREGONUS NASUS*) IN THE TESHEKPUK LAKE REGION OF THE NATIONAL PETROLEUM RESERVE-ALASKA, 2003-2005

by William Morris



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Introduction

Teshekpuk Lake is located within the National Petroleum Reserve-Alaska in the northwestern portion of the North Slope of Alaska. The lake lies approximately 130 km southeast of Barrow Alaska and is accessible only by air or water during the open water season. The lake consists of a series of smaller lakes joined over time predominantly by wind generated bank erosion. As it exists today, including the large coalesced lakes making up the outlet portion of the lake (or the head waters of the Miguakiak (Mayoriak River)), the lake is roughly 45 km along its east-west axis and 32 km along its north-south axis. The lake is approximately 84,000 hectares in surface area with a maximum depth of around 24 ft. The littoral zone around the lake is extensive and in places extends well over 1 km into the lake. However, the vast majority of the lake is unvegetated as a result of heavy annual ice scour and open water season wave action.

The outlet from the lake is the Mayoriak River which drains the lake west into the Ikpikpuk River. The Ikpikpuk River is fed from the coastal hills between the Colville River and the Beaufort Sea Coast and numerous extensive tundra drainages. The Ikpikpuk River splits upstream from the confluence of the Mayoriak River approximately 54 km and forms the Chipp River flowing to the northwest. Downstream on the Ikpikpuk from the Chipp River, roughly 36 km upstream from the Mayoriak River confluence, the Alaktak River splits off and flows to the northwest. The area between the Chipp and Ikpikpuk rivers, including the Alaktak River, is extremely complex with numerous small distributary channels and hundreds of small and large lakes with varying degrees of stream connectivity. The Mayoriak River is similar in that several extensive and complex tundra stream/lake drainages flow into the river. In contrast, Teshekpuk Lake is fed by few drainages and with the exception of Kealok Creek, which flows into the southeastern basin of the lake, most streams are short and connected to few lakes.

This region of lakes and streams connected to Teshekpuk Lake via the Mayoriak River and the Ikpikpuk River has been and remains an area of substantial subsistence fishing for residents of Barrow and Atqasuk. Subsistence fishing and hunting cabins are numerous along the Chipp, Ikpikpuk, Alaktak and Mayoriak rivers. Additionally, the Meade River, which flows into the southwest side of Admiralty Bay, and the Topagoruk River, which flows into the south end of Admiralty Bay, support significant subsistence fisheries. Arctic grayling (*Thymallus arcticus*),

burbot (*Lota lota*), lake trout (*Salvelinus namaycush*), humpback whitefish (*Coregonus pidschian*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), and less frequently, sockeye(*Oncorhynchus nerka*) and Chinook (*Oncorhynchus tshawytscha*) salmon are captured throughout the summer fishing season which extends from ice-out through early freeze-up. However, broad whitefish (*Coregonus nasus*) are harvested most significantly by subsistence users. Broad whitefish are targeted throughout the open-water season but gravid females captured just prior to spawning in the fall are desired. The riverine fishery usually ends by early October as spawning progresses and gravid females are no longer caught in nets. Lake fishing for broad whitefish extends well into November. Studies of the fishery from Barrow conducted in the 1970's and 1980's reported harvests approaching 30,000 Kg (Underwood et al. 1978, Braund *et al*. 1988). Somewhere between 20,000 and 30,000 fish may be harvested between the summer and fall fisheries in some years (Craig 1989, Braund 1991).
Little fish research has been conducted in this region of the North Slope despite the apparent high level of harvest (Braund 1993). The work that has been done has focused specifically on broad whitefish life history and habitat use characterization. At present, there is circumstantial evidence based on our data, harvest records, and interviews with elders to suggest that the current level of harvest of the species is sustainable (Braund 1993; Fuller and George 1997).

Over the past decade the Bureau of Land Management has sold large exploration leases within the region, prompting interest in broad whitefish life history and habitat use research by both local subsistence users and government entities. In 2003, a cooperative research program including participants from the North Slope Borough Wildlife Management Department, the Alaska Department of Natural Resources Office of Habitat Management and Permitting, the Bureau of Land Management Arctic Field Office, MJM Research LLC., and Alaska Biological Research, Inc., was initiated to determine relative measures of abundance, distribution and population structure of fish species using the Mayoriak River and its tributaries, and to a lesser extent, Teshekpuk Lake. A primary objective of the study was to determine life history characteristics and seasonal habitat use patterns of broad whitefish using Teshekpuk Lake, the Mayoriak River and its tributaries using radio-telemetry. This report summarizes results from the radio-telemetry portion of the study and is designed to complement the fisheries resource report produced from the overall study effort. Data presented in this report include fish radio-

tagged in 2003, 2004 and 2005. However, fish tagged in 2005 in Teshekpuk Lake and in the Meade River will be tracked for an additional year and results reported at a later date (fish tagged in 2004 also will be tracked throughout 2006). Additional analyses and conclusions may be possible with incorporation of all tracking data from fish tagged in 2005 and additional data gathered from fish tagged in 2004.

This study was funded in part with the National Petroleum Reserve-Alaska grants funds made available through the Department of Commerce, Community and Economic Development.

Methods

Radio Tags

To investigate broad whitefish life history characteristics and seasonal habitat use, adult sized broad whitefish were outfitted with 2 basic types of transmitters. Generally, broad whitefish between 400 and 500 mm fork length, and all fish tagged in 2003, were outfitted with 10g Lotek Wireless (Newmarket, Ontario, Canada) MCFT3FM coded VHF tags. In 2004 and 2005, broad whitefish greater than 500 mm fork length were implanted with 29g Lotek Wireless MCFT7A coded VHF radio tags or the smaller -3FM tags. The heavier tags were placed only in larger fish. Radio tags in all years were programmed to maximize operational life by utilizing 12hr on/off cycling as well as by incorporating a period of tag shut down coinciding with the winter months when fish movements are not possible or are significantly reduced. Additionally, two lake trout captured in 2005 were implanted with the larger MCFT7A radio transmitters.

Net Set History

In June, July and August 2003 and 2004, nets were set at each of the major tributary creeks to the Mayoriak River (Figure 1). Not all sites were fished during each sampling event. In 2005, fish sampling was focused on the southern side of Teshekpuk Lake and its tributaries (Figure 1). Additionally, with guidance from local residents of Atqasuk and members of the Fish and Game Advisory Council, nets were also set in the Meade River (Figure 2).

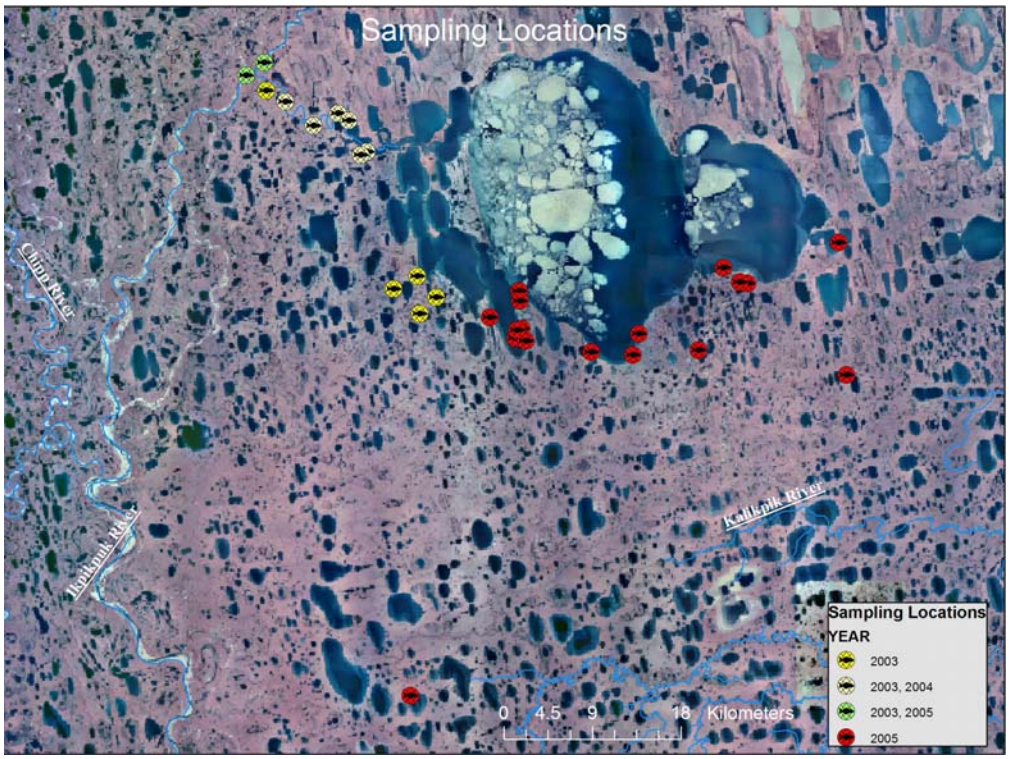

Figure 1. Nets were fished at various locations in the Mayoriak River and Teshekpuk Lake and tributary streams throughout 2003 to 2005.

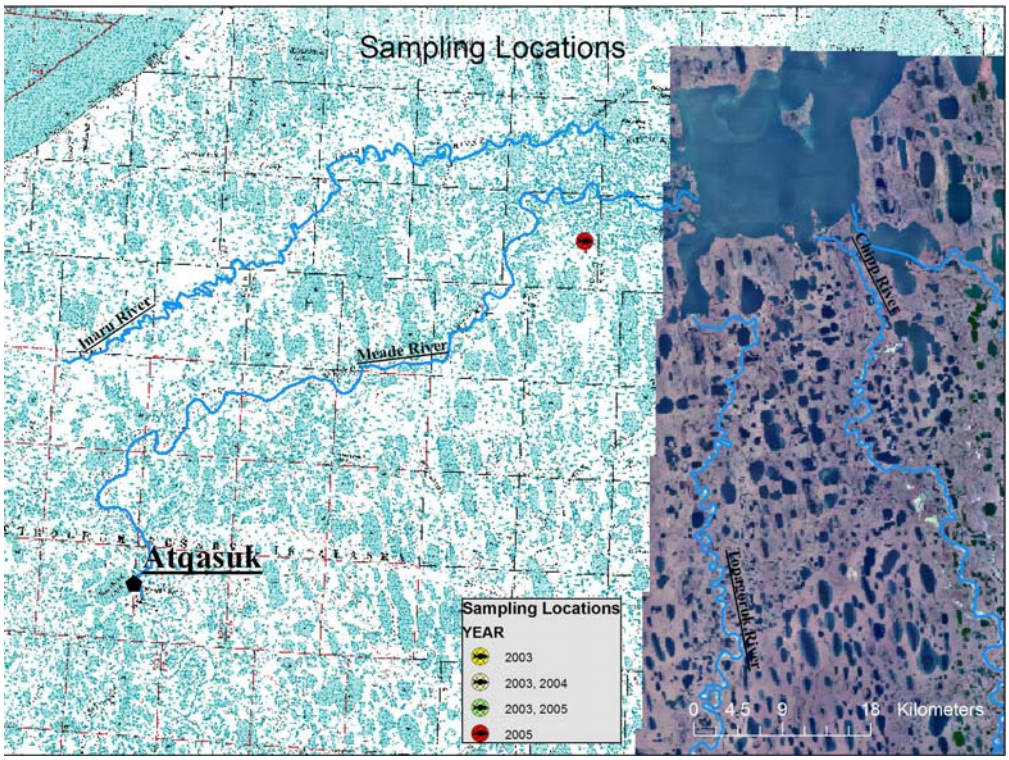

Figure 2. One net site was fished at the mouth of a small tributary to the Meade River in August 2005.

Fish Capture

All broad whitefish implanted with radio transmitters were captured in fyke nets, passive fish traps that rely on the directed movement of fish to capture them. In most cases, nets were set in small tributary creeks to Teshekpuk Lake and the Mayoriak River. Nets were set most often in pairs with one oriented to catch fish moving downstream and one to catch fish moving upstream; the creeks were blocked and most fish moving past the net site were likely captured (Figure 3).

Figure 3. Fyke nets were most often set to block small tributaries to Teshekpuk Lake and the Mayoriak River and to capture fish moving either up or down stream (top). Traditional lake type sets, utilizing a single net and a 100' lead net to shore were also used (bottom).

Some nets were set traditionally with a single lead running from shore to the fyke net (Figure 3). One of two lake trout implanted with radio transmitters in 2005 was captured in a gill net set in a

large bay on the southwest end of Teshekpuk Lake (eastern most coalesced lake in the upper Mayoriak area).

Transmitter Implantation

Fish Selection

Fish selection for transmitter implantation, and the decision to implant transmitters, was based on three major criteria; fish size, fish condition, and water temperature. Only fish large enough to survive with the added weight of the transmitter were considered as candidates. Generally, transmitter weight was kept between 1 and 3% of fish body weight. We computed minimum fish size considering only air weights for both the fish and the transmitters and a 2% of body weight maximum to ensure that fish would be able to handle the increased load. Generally, broad whitefish over 400mm in fork length were large enough to be outfitted with the 10g tags and broad whitefish larger than 500mm in fork length were large enough to be implanted with the larger 29g radio transmitters. One 358mm long broad whitefish was implanted with a 10g transmitter in 2003. Lake trout radio tagged were large enough to safely accept the 29g radio tags. Water temperature was measured prior to conducting surgeries to ensure that temperatures were below 15 C. Previous research with broad whitefish in the Arctic has indicated that the species experiences significant thermal stress and increased handling mortality at warmer water temperatures (Morris *et al*. 2000).

Anesthesia

Once a fish had been selected to receive a transmitter it was placed in a tub containing an anesthetic solution of 10% clove oil extract/90% pure ethanol and water from the sampling site. Starting concentrations of the anesthetic bath were 20ppm clove oil extract. Depending on fish response to the solution, concentrations of the anesthetic were adjusted upwards by adding additional 10% clove oil solution 1 ml to 0.5 ml at a time. Concentrations around 20ppm were almost always adequate regardless of water temperature; however, concentrations as high as 30ppm were required for some broad whitefish. Fish were held in the anesthetic solution until they had reached stage 3 of anesthesia which was evidenced by loss of equilibrium, loss of swimming response and a flaccid body condition. Once fish no longer responded to pressure

applied to the base of the anal fin, they were considered to be fully in stage 3 anesthesia and properly anesthetized for surgery. Throughout the surgical procedure either water or anesthetic solution was continually applied to the gills to keep the gills moist and to maintain the proper level of anesthesia. Just prior to completion of the surgical procedure, if not sooner, water was applied to the gills to begin fish recovery.

Surgical Transmitter Implantation

Fish were removed from the anesthetic bath and placed ventral side up in a surgical trough lined with a moist towel or moist foam. A 2.5 to 3 cm long incision was made on the ventral side of the fish into the peritoneal cavity. Once the incision had been made, a transmitter was inserted into the cavity with the antenna end facing caudally. The antenna was then routed out of the body cavity caudal to the pelvic girdle. The routing of the antenna caudal to the girdle provides an anchor point for the transmitter and helps reduce irritation caused by contact between the transmitter and soft tissue as drag, from water on the antenna, pulls the transmitter. Morris *et al*. (2000) found that this procedure offered the best long term success for radio tagged broad whitefish. Antenna routing was accomplished by inserting a needle guide into the incision and orienting the guide to the desired antenna exit point. A small horse catheter was then inserted through the body wall using the guide to protect internal organs from the catheter needle. The antenna was threaded through the catheter and out of the body. The catheter and then the needle guide were removed and the incision closed. Depending on the length of the incision three to four stitches (3-0 curved needle, monofilament) were made to close the incision. The incision area was dabbed with sterile gauze and VetBond surgical glue was applied to the incision area to provide a closed incision to aid in initial healing of the wound. Fish were then placed in a net pen at the capture site for recovery. Once equilibrium had been regained, fish were released in the vicinity of the capture site.

Radio Tracking

Radio tracking was conducted by air, primarily with a Cessna 185 or a Piper Super Cub fixed wing aircraft. Aircraft used to fly relocation surveys were outfitted with either two H-Antennas or two 3-element Yagi antennas, one mounted to each wing strut. Antenna coaxial cables were

routed through the wings to a switch box and from the switch box to a Lotek Wireless SRX-400 decoding receiver. The output from the receiver was routed through the aircraft noise suppressing audio system or into noise suppressing head-sets. Receiver output was audible through the aircraft headsets, allowing both the pilot and researcher to listen for signals.

The receiver was set to monitor each frequency for 4.0s to ensure the slowest burst rate transmitters would be detected if within range. The resulting total scan time to search for fish on the five frequencies used was about 20 seconds. Geographic positions for each relocated fish were recorded on the aircraft's on-board geographic positioning system and also recorded on a data sheet. Aerial surveys were flown periodically during June-August of each year of the study and then again in September through early October to locate spawning areas and wintering areas. November and then March surveys were also conducted to locate additional over-wintering fish.

Results

Fish Capture and Radio Tagging

2003 Fish

In 2003 a total of 40 broad whitefish were implanted with 10g radio-transmitters. All fish captured for radio tagging were caught in tributaries to the lower Mayoriak River (Figure 1). Fish ranged in size from 358mm to 590mm in fork length (N=39, mean = 495mm, mean does not include one 358mm long fish, the next smallest fish tagged was 428mm). The two smallest fish radio-tagged (358mm, 428mm) were judged to be immature fish based on size and general appearance. Based predominantly on physical appearance 8 fish were classified as post-spawning adults (fish that had spawned the previous fall and unlikely to spawn in the upcoming fall spawning season); and 11 were classified as pre-spawning adults (likely to spawn in the upcoming fall spawning season). The spawning condition of the remaining 19 radio-tagged fish was not determined, although all were likely mature adults based on size (481mm to 542mm). Figure 4 illustrates the extreme difference in body condition between fish in spawning condition and those judged unlikely to spawn. Gonadosomatic indices were not prepared, so these assessments are subjective but based on many years of combined experience. Additionally, fish not clearly fitting into one or the other group were placed in the undetermined category or

denoted as generally in good or poor condition with a questionable spawning condition. Table 1 provides a brief summary of fish radio tagged in 2003.

Table 1. A brief summary of broad whitefish radio tagged in 2003 is provided. Fish identification #, tagging date and general tagging locations are given. Fish size as measured from the tip of the snout to the fork of the tail is provided to the nearest mm as well as the assessed spawning condition of each fish at the time of capture. A brief summary of fidelity or likely fidelity is provided as well as the total number of relocations for each fish including the initial tagging event.

Fish ID#	Date Tagged		Capture Location	Fork Length (mm)	Spawning Condition	Summer Fidelity	Winter Fidelity	Number of Relocations
26	6/26/2003		Lower Mayoriak tributary	542	Undetermined?			5
27	6/26/2003		Lower Mayoriak tributary	488	Prespawner	x		4
28	6/26/2003		Lower Mayoriak tributary	505	Undetermined?	?	?	11
29	6/26/2003		Lower Mayoriak tributary	494	Postspawner	?	x	6
39	6/26/2003		Lower Mayoriak tributary	494	Postspawner			1
72	6/26/2003		Lower Mayoriak tributary	488	Postspawner			2
73	6/26/2003		Lower Mayoriak tributary	495	Prespawner			6
80	6/26/2003		Lower Mayoriak tributary	509	Prespawner			8
93	6/26/2003		Lower Mayoriak tributary	498	Prespawner	x		4
102	6/27/2003		Lower Mayoriak tributary	590	Prespawner			2
117	6/27/2003		Lower Mayoriak tributary	448	Undetermined?	?		5
131	6/27/2003		Lower Mayoriak tributary	495	Prespawner			2
151	6/27/2003		Lower Mayoriak tributary	506	Postspawner			4
221	6/27/2003		Lower Mayoriak tributary	428	Immature/post			4
222	6/27/2003		Lower Mayoriak tributary	467	Postspawner			9
223	6/27/2003		Lower Mayoriak tributary	584	Prespawner			4
224	6/27/2003		Lower Mayoriak tributary	565	Prespawner	?		6
238	6/27/2003		Lower Mayoriak tributary	525	Postspawner			4
250	6/27/2003		Lower Mayoriak tributary	569	Postspawner			4
422	8/24/2003		Middle Mayoriak Tributary	477	Prespawner			1
423	8/24/2003		Middle Mayoriak Tributary	470	Undetermined?			1
424	8/24/2003		Middle Mayoriak Tributary	495	Undetermined?	x		4
425	8/24/2003		Middle Mayoriak Tributary	482	Undetermined?	x		2
426	8/24/2003		Middle Mayoriak Tributary	480	Undetermined?			1
427	8/24/2003		Middle Mayoriak Tributary	468	Undetermined?	x		2
428	8/24/2003		Middle Mayoriak Tributary	490	Undetermined?	x		5
429	8/24/2003		Middle Mayoriak Tributary	485	Postspawner	x		4
430	8/24/2003		Middle Mayoriak Tributary	481	Undetermined?	x		3
434	8/24/2003		Middle Mayoriak Tributary	474	Prespawner	x		3
452	6/27/2003		Lower Mayoriak tributary	520	Prespawner	x	x	5
484	8/25/2003		Middle Mayoriak Tributary	440	Undetermined?	x	x	6
485	8/25/2003		Middle Mayoriak Tributary	488	Undetermined?	x		5
486	8/25/2003		Middle Mayoriak Tributary	498	Undetermined?			2
487	8/25/2003		Middle Mayoriak Tributary	485	Undetermined?	x		7
488	8/25/2003		Middle Mayoriak Tributary	469	Undetermined?	x	?	4
489	8/25/2003		Middle Mayoriak Tributary	358	Immature	x	?	3
491	8/25/2003		Middle Mayoriak Tributary	471	Undetermined?	x		6
493	8/25/2003		Middle Mayoriak Tributary	474	Undetermined?	x	x	6
494	8/25/2003		Middle Mayoriak Tributary	453	Undetermined?			1
496	8/25/2003		Middle Mayoriak Tributary	500	Undetermined?	x		6

Figure 4. Physical differences between pre-spawning (top) and post-spawning (bottom) adult broad whitefish were apparent in many cases. Note the robust, almost swollen appearance of the pre-spawning fish (top).

2004 Fish

In 2004 a total of 6 broad whitefish between 445 and 506mm in fork length were radio tagged with MCFT3FM, 10g tags, and 18 broad whitefish between 506 and 619mm in fork length were radio tagged with the larger MCFT7A, 29g radio tags. All fish tagged in 2004 were captured in the tributaries to the Mayoriak River. Fish radio tagged in 2004 ranged in size from 445 to 619mm in fork length with an average length of 550mm (N=24). Use of the larger tags lead to targeting larger sized fish for radio tagging when compared to fish radio tagged in 2003 with only the smaller tags. Seven broad whitefish radio tagged were classified as post-spawning

adults and 14 were classified as pre-spawning adults. Spawning condition of three fish between 460 and 480mm in fork length was undetermined. Table 2 provides a brief summary of fish radio tagged in 2004.

Table 2. A brief summary of broad whitefish radio tagged in 2004 is provided. Fish identification #, tagging date and general tagging locations are given. Fish size as measured from the tip of the snout to the fork of the tail is provided to the nearest mm as well as the assessed spawning condition of each fish at the time of capture. A brief summary of fidelity or likely fidelity is provided as well as the total number of relocations for each fish including the initial tagging event.

Fish ID#	Date Tagged		Capture Location	Fork Length (mm)	Spawning Condition	Summer Fidelity	Winter Fidelity	Number of Relocations
526	6/20/2004		Lower Mayoriak tributary	616	Prespawner			4
608	6/21/2004		Lower Mayoriak tributary	560	Prespawner			5
615	6/21/2004		Lower Mayoriak tributary	564	Prespawner			3
621	6/21/2004		Lower Mayoriak tributary	562	Prespawner with eggs			1
647	6/21/2004		Middle Mayoriak Tributary	582	Prespawner			3
663	6/23/2004		Lower Mayoriak tributary	506	Prespawner		?	3
664	6/23/2004		Lower Mayoriak tributary	524	Postspawner			7
721	6/22/2004		Lower Mayoriak tributary	568	Prespawner			1
722	6/22/2004		Lower Mayoriak tributary	619	Prespawner with eggs			
732	6/22/2004		Lower Mayoriak tributary	580	Postspawner			3
801	6/24/2004		Lower Mayoriak tributary	580	Prespawner with eggs			6
803	6/24/2004		Lower Mayoriak tributary	506	Postspawner	x	x	6
819	6/24/2004		Lower Mayoriak tributary	580	Postspawner			2
820	6/24/2004		Lower Mayoriak tributary	471	Undetermined?			2
821	6/24/2004		Lower Mayoriak tributary	565	Prespawner			4
822	6/24/2004		Lower Mayoriak tributary	506	Postspawner	x		2
823	6/24/2004		Lower Mayoriak tributary	445	Postspawner	x		4
830	6/24/2004		Middle Mayoriak Tributary	606	Prespawner			7
875	6/25/2004		Middle Mayoriak Tributary	551	Prespawner			5
878	6/25/2004		Middle Mayoriak Tributary	565	Prespawner	x	x	6
1260	6/25/2004		Middle Mayoriak Tributary	578	Prespawner	x		7
1261	6/25/2004		Middle Mayoriak Tributary	479	Good ?			2
1262	6/25/2004		Middle Mayoriak Tributary	462	Good ?	x		4
1263	6/25/2004		Lower Mayoriak tributary	618	Post Spawner with Residual eggs	x		5

2005 Teshekpuk Area Fish

In 2005, 10 broad whitefish ranging in length from 460 to 539mm were radio tagged with 10g MCFT3FM radio transmitters and 10 fish between 509 and 541mm in fork length were radio tagged with the larger MCFT7A tags. Fish radio tagged in 2005 ranged in size from 460 to 541mm in fork length with an average length of 502mm (N=20). All broad whitefish radio tagged were captured in late August in a small tributary flowing into the southeastern side of the southern bay of Teshekpuk Lake. Broad whitefish spawning condition and overall condition was notably different when compared to fish captured in June and July in the Mayoriak River tributaries in 2003 and 2004. Most fish appeared skinny for their length and for the first time since initiation of the study there were considerably fewer fish judged to be pre-spawning adults. Only 4 fish were judged to be pre-spawning adults while 9 were judged to be post-spawning

adults. Spawning condition of 7 fish was undetermined and of those up to 5 may have been immature or small post-spawning adults (460mm to 493mm in fork length).

One 685mm long lake trout was captured and radio tagged in June in a lake at the headwaters of Kealok Creek and a 780mm lake trout was captured and radio tagged in July in the southwestern-most bay of Teshekpuk Lake. Table 3 provides a brief summary of fish radio tagged in 2005.

Table 3. A brief summary of broad whitefish radio tagged in 2005 is provided. Fish identification #, tagging date and general tagging locations are given. Fish size as measured from the tip of the snout to the fork of the tail is provided to the nearest mm as well as the assessed spawning condition of each fish at the time of capture. Lake trout radio tagged in 2005 are denoted as Lake Trout in the table.

Fish ID#	Date Tagged		Capture Location	Fork Length (mm)	Spawning Condition
1575	7/29/2005	Lake Trout	Southwestern most bay of Teshekpuk Lake	780	
1580	8/22/2005		Lower Meade River	475	Good ?
1581	8/22/2005		Lower Meade River	446	Good ?
1582	8/22/2005		Lower Meade River	457	Good ?
1583	8/22/2005		Lower Meade River	557	Prespawner with eggs
1584	8/22/2005		Lower Meade River	506	Prespawner with eggs
1585	8/22/2005		Lower Meade River	488	Prespawner with eggs
1586	8/22/2005		Lower Meade River	467	Prespawner
1587	8/22/2005		Lower Meade River	431	Good ?
1588	8/22/2005		Lower Meade River	420	Good ?
1589	8/22/2005		Lower Meade River	436	Good ?
1597	8/27/2005		Teshekpuk Lake South Basin Western Tributary	520	Prespawner
1598	8/27/2005		Teshekpuk Lake South Basin Western Tributary	510	Prespawner
1599	8/27/2005		Teshekpuk Lake South Basin Western Tributary	518	Postspawner
1600	8/27/2005		Teshekpuk Lake South Basin Western Tributary	485	Postspawner
1601	8/27/2005		Teshekpuk Lake South Basin Western Tributary	510	Postspawner
1693	8/29/2005		Teshekpuk Lake South Basin Western Tributary	460	Immature/postspawner
1694	8/29/2005		Teshekpuk Lake South Basin Western Tributary	493	Immature/postspawner
1695	8/29/2005		Teshekpuk Lake South Basin Western Tributary	468	Immature/postspawner
1696	8/29/2005		Teshekpuk Lake South Basin Western Tributary	509	Undetermined?
1698	8/29/2005		Teshekpuk Lake South Basin Western Tributary	462	Immature/postspawner
1699	8/29/2005		Teshekpuk Lake South Basin Western Tributary	485	Postspawner
1700	8/29/2005		Teshekpuk Lake South Basin Western Tributary	475	Immature/postspawner
1718	6/21/2005	Lake Trout	Upper Kealok Creek lake	685	
1801	8/29/2005		Teshekpuk Lake South Basin Western Tributary	492	Postspawner
1802	8/29/2005		Teshekpuk Lake South Basin Western Tributary	516	Postspawner
1803	8/29/2005		Teshekpuk Lake South Basin Western Tributary	509	Postspawner
2062	8/29/2005		Teshekpuk Lake South Basin Western Tributary	525	Postspawner
2068	8/29/2005		Teshekpuk Lake South Basin Western Tributary	510	Prespawner
2076	8/29/2005		Teshekpuk Lake South Basin Western Tributary	515	Postspawner
2077	8/29/2005		Teshekpuk Lake South Basin Western Tributary	541	Good ?
2079	8/29/2005		Teshekpuk Lake South Basin Western Tributary	539	Prespawner

2005 Meade River Fish

On August 22, 2005, 10 broad whitefish ranging in length from 420 to 557mm in fork length were radio tagged at the mouth of a small tributary to the lower Meade River (Figure 2). The average size of fish radio tagged was about 470mm in fork length (N=10). Most fish were small and only one 29g radio tag was implanted in a 557mm long broad whitefish. Smaller, 10g radio

tags were placed in nine fish. Only 4 fish were classified as pre-spawning adults (eggs were visible when implanting transmitter in 3 fish); remaining fish either were immature or their spawning condition was not able to be determined (Table 3).

Fish Mortality and Relocation Success (2003 and 2004 radio tagged fish)

Relocation histories for individual fish within the 64 broad whitefish radio tagged in 2003 and 2004 indicate that mortality rates of radio tagged fish may have been as high as 15.6%. It is not clear whether any or all mortalities were the result of the surgical procedure, handling, or natural causes. It appears that at least some fish died of natural causes (winter killed from poor overwintering site selection) during winters 2003/2004 and 2004/2005. It is possible that some fish deemed mortalities actually were not dead fish but fish consistently located in the same general area at all successive relocations. Additionally, a minimum of four broad whitefish radio tagged in 2003/2004 were captured and killed in the local subsistence fishery (minimally, 6% of fish radio tagged). An additional six fish radio tagged were never relocated after release. Forty six (72%) individual fish radio tagged in 2003 and 2004 were successfully relocated more than once after release, and most were relocated on numerous occasions (Appendix I). Appendix I provides a complete relocation history for each fish relocated on more than one occasion.

Fish Mortality and Relocation Success (2005 and Meade River radio tagged fish)

Assessment of relocation rates and mortality for fish radio tagged in 2005, including lake trout, broad whitefish from the Meade River and broad whitefish from Teshekpuk Lake is not possible at this time. Fish radio tagged in 2005 will have active transmitters through late 2006 to early 2007 at which time mortality and relocation rates can be assessed.

General Relocation Results

Note: To view maps of individual fish relocation histories refer to Appendix I and locate the map corresponding to the fish of interest. Only histories for fish with multiple relocations are presented. Fish relocations presented in this section are labeled with the date of the relocation unless specified otherwise or if no label is present.

Broad whitefish radio tagged in the Mayoriak River in 2003 and 2004 ranged widely throughout the Chipp and Ikpikpuk River areas (Figure 5). Fish movements out of the Mayoriak River

commonly exceeded 50 and even 100 river km. Most river systems with freshwater connections to the Mayoriak River were used by fish radio tagged in the Mayoriak River. Systems used included the Ikpikpuk, Chipp, Oumalik, Titaluk, Alaktak and the Topagoruk rivers. Numerous fish used lakes within the major drainages of the region and there was extensive use of lakes and small tributary streams to the Mayoriak River. Although flown routinely, no fish radio-tagged in the Mayoriak River were relocated in the Inaru or Meade rivers. Some fish radio tagged in 2003 and 2004 were relocated in Teshekpuk Lake for periods of the year.

Broad whitefish captured in the Mayoriak River used hundreds of kilometers of riverine habitat throughout their annual movement cycle. Habitat use varied by season but was consistent between the fish radio tagged in 2003 and 2004. During the open-water season fish were widely dispersed while, during winter, fish tended to concentrate in areas of adequate depth for wintering (Figure 6 and Figure 7).

Fish relocations during 2005, and to a lesser extent in 2004 and 2003, were largely influenced by low water in the Ikpikpuk River. The Ikpikpuk downstream from the Chipp River often consists of a series of large isolated pools with little to no surface flow for much of the summer. Fish could not travel to the upper river from the Mayoriak by using the Ikpikpuk for most of the summer and all of the fall season in 2005. Similar to broad whitefish radio-tagged in other regions of Alaska's North Slope, long distance movements towards apparent spawning areas were observed during the middle of the open-water season from July to August in most years of tracking (Morris 2000, Morris 2003).

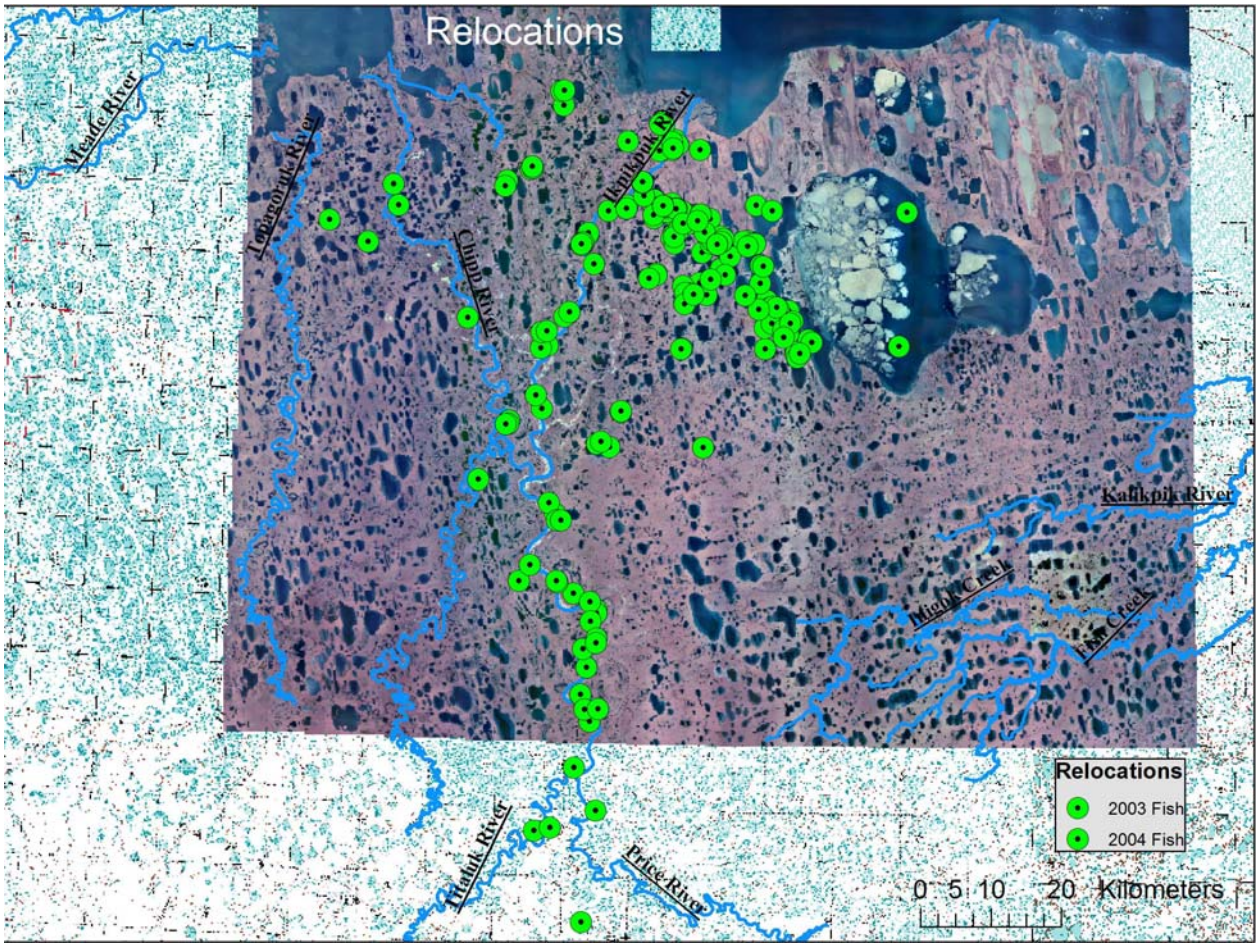

Figure 5. Map of all relocations of fish radio tagged in 2003 and 2004. Map illustrates the high degree of dispersal of fish radio tagged in the Mayoriak River and illustrates the high use of smaller drainages in and around the Mayoriak River and in the complex channels between the Chipp, Alaktak and Ikpikpuk rivers.

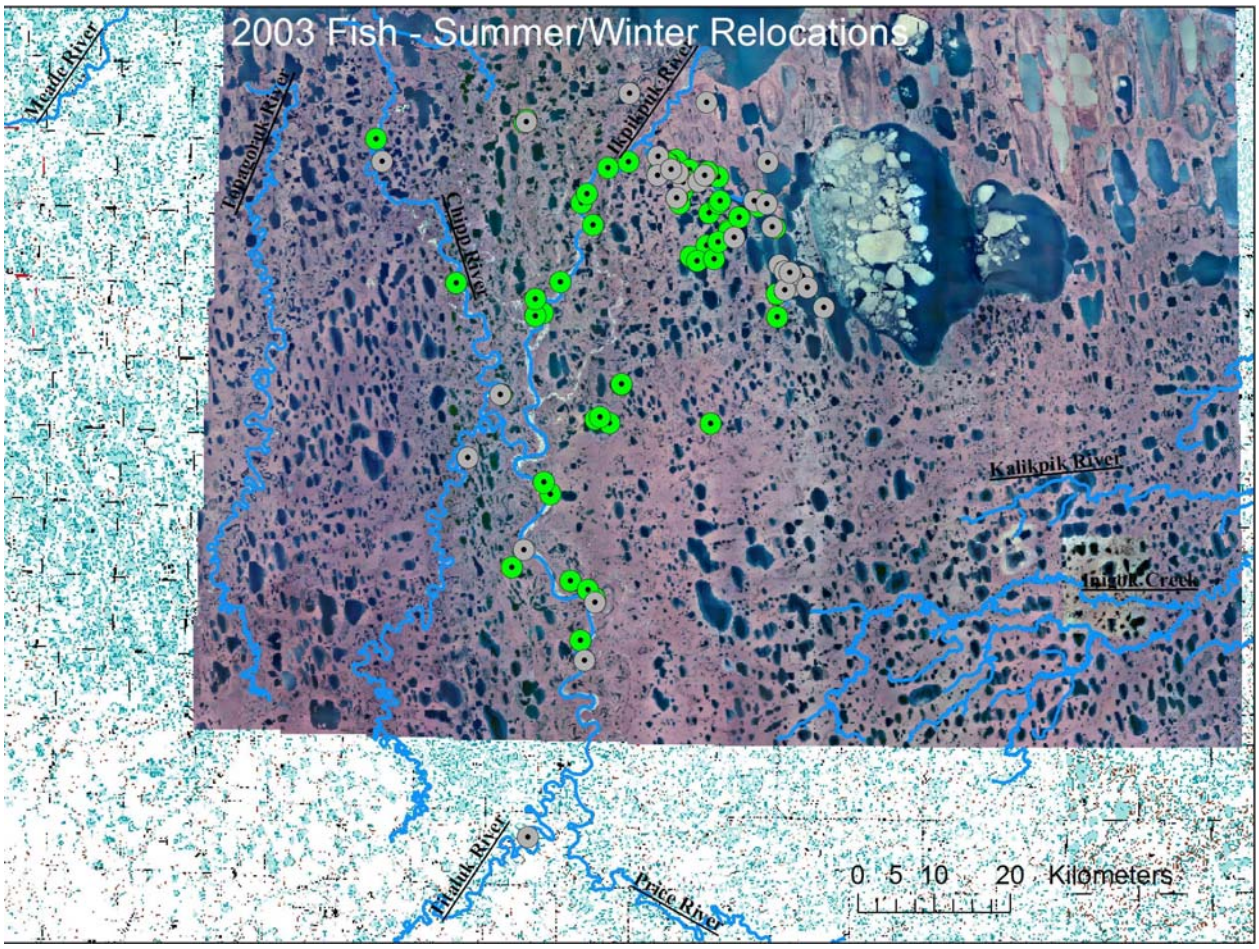

Figure 6. Map of all relocations for fish radio tagged in the Mayoriak River during 2003. Winter relocations are in grey and summer in green. The figure illustrates the dispersion of fish observed while illustrating the concentration of fish that occurs in certain areas during the overwintering season (also See Figure 7).

Spawning

Fish relocations during late August through September to early October show a strong pattern of fish migration to upper reaches of the Ikpikpuk River, presumably for spawning. Bendock and Burr (1986, 1985) had identified pre-spawning broad whitefish downstream from this area in past survey efforts. Fish judged to be post-spawning adults and pre-spawning adults in 2003 used the upper Ikpikpuk River.

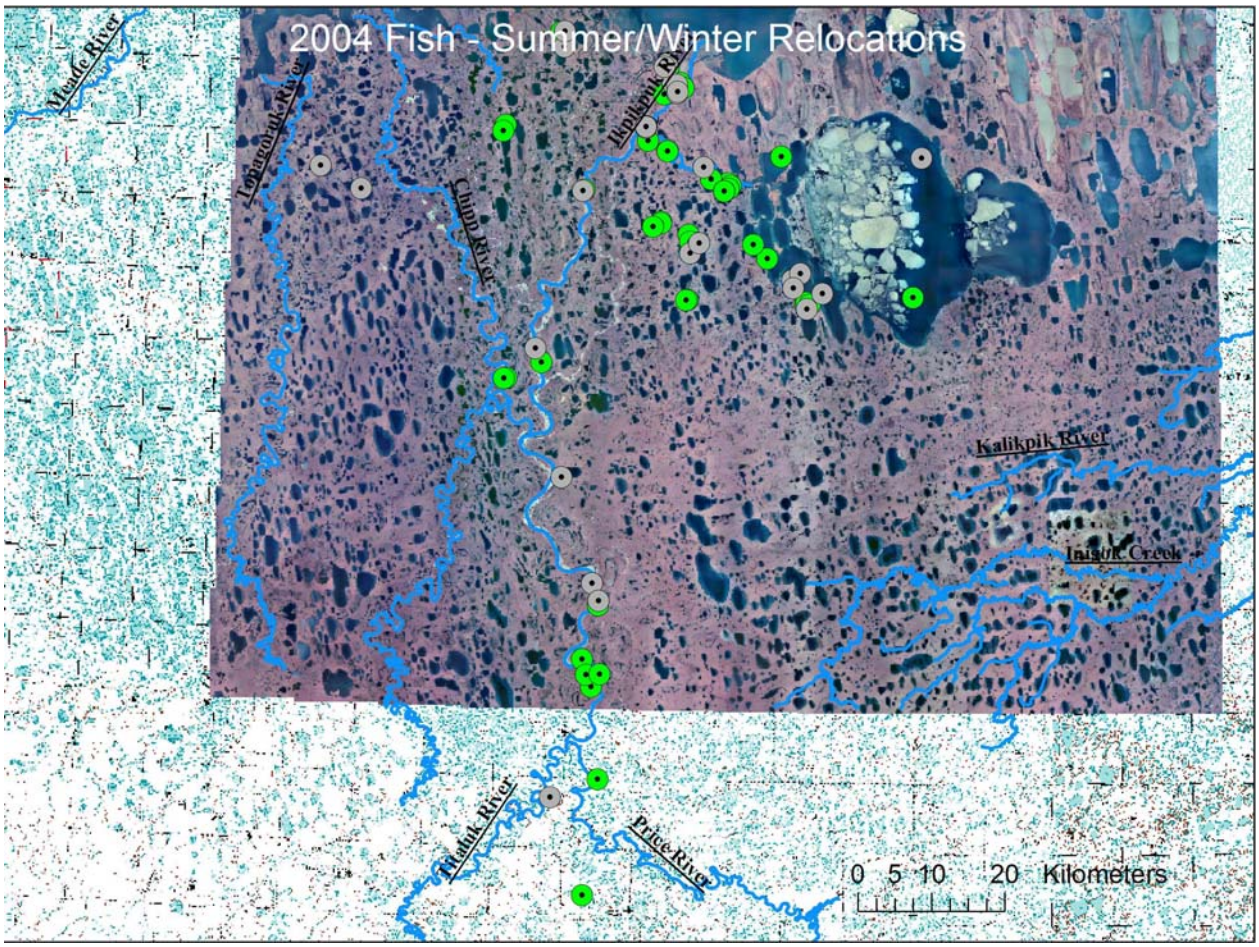

Figure 7. Map of all relocations for fish radio tagged in the Mayoriak River during 2004. Winter relocations are in grey and summer in green. The figure illustrates the dispersion of fish observed while illustrating the concentration of fish that occurs in certain areas during the overwintering season (also See Figure 6).

However, of those that remained in the upper river into the spawning seasons (late September through early October) of 2003 and 2004 almost all were fish likely to have been in spawning condition during the year they were located in the upper river. Of the 2004 radio-tagged fish, virtually all fish that used the upper river during late summer and early winter were fish judged to be likely spawners. However, a mixed group of fish including pre- and post-spawners and immature and undetermined spawning condition fish moved into the coalesced lakes that form the western-most basin of Teshekpuk Lake or the headwaters of the Mayoriak River during the spawning season and for wintering (Figure 8). It is possible that some spawning occurs in this region of the lake/river. Lake spawning for broad whitefish has never been observed and it is likely that if spawning is occurring in this area that fish are actually orienting to the water flowing out of the lake in the deep channels that flow though the coalesced lakes; essentially

spawning in a riverine environment within this portion of the lake. Additionally, one fairly isolated distributary channel, at times carrying water from both the Alaktak and Ikpikpuk rivers, was used by four radio tagged fish (#73,#250, #424 and #430), some during the spawning period and some for overwintering (See Appendix I, Individual Map 9). It has long been speculated by local subsistence users that some broad whitefish move to portions of the lower river for spawning. From the tracking results, it would appear that a limited number of fish may indeed spawn in discrete locations in the lower rivers of the region.

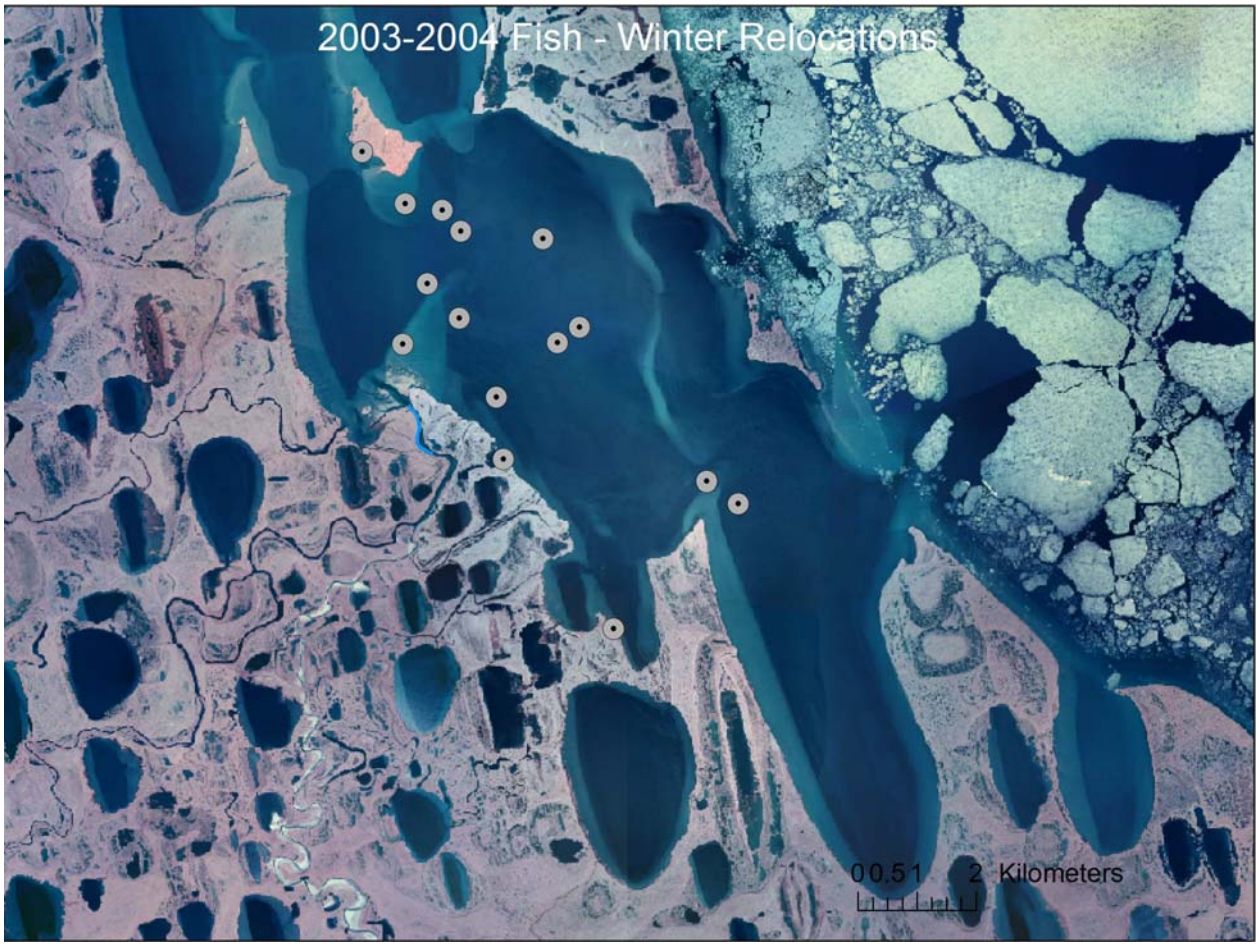

Figure 8. Map of the area of coalesced lakes that forms the headwaters of the Mayoriak River or the westernmost bays of Teshekpuk Lake. Broad whitefish radio tagged in the Mayoriak River in 2003 and 2004 as well as broad whitefish radio tagged in the south bay of Teshekpuk Lake in 2005 used this area for overwintering and possibly for spawning. Several apparent pre-spawning adult fish from all years moved into this region during the spawning season and for wintering.

Winter Relocation Results

Broad whitefish radio tagged in the Mayoriak River used widely dispersed overwintering areas in the Teshekpuk Lake area relative to conspecifics observed in other areas of the North Slope (Figure 9). However, patterns of movement and winter site selection are evident. Many fish

radio tagged in the Mayoriak River overwintered in the Mayoriak River where depths often exceed 15'. As discussed previously, many fish found in the area also used the coalesced lakes at the headwaters of the Mayoriak River (Figure 8 and Figure 9). Similar to broad whitefish overwintering behavior in other drainages of the North Slope, some broad whitefish in the Teshekpuk area appear to winter in deep pools of rivers, typically near suspected spawning areas. However, several fish moved considerably downstream from suspected spawning areas into the lower reaches of the Chipp River either in the river or to connected lakes for wintering. Given the relative reduction in relocation success that occurred during most winter surveys, it is likely that many fish moved into the myriad connected lake systems for wintering.

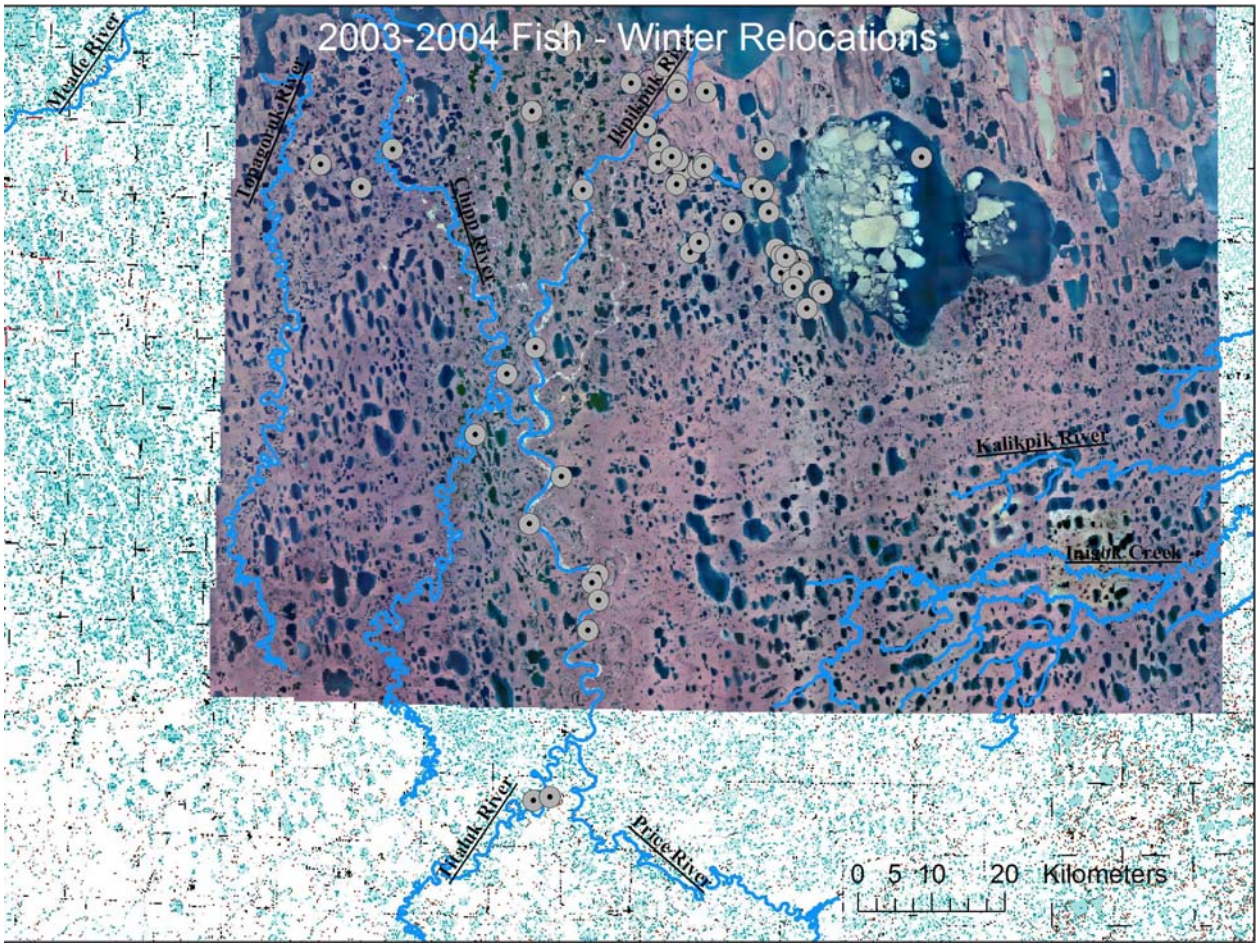

Figure 9. Map of overwintering locations used by broad whitefish radio tagged in 2003 and 2004 in the Mayoriak River. Broad whitefish overwintered in numerous locations and were considerably dispersed from their tagging sites. Fish judged to be likely spawners tended to be dispersed the furthest during the winter of their suspected spawning run. Nonetheless, concentrations of fish can be seen in areas around the Mayoriak and the upper Ikpikpuk River. Fish that moved to the upper Ikpikpuk for spawning commonly dropped out into the lower reaches of the Chipp River or to lakes connected to distributary channels of the Chipp and Alaktak rivers or even to the Titaluk and Oumalik rivers.

Fidelity

Approximately 39% of fish radio tagged in 2003 and 2004 showed some degree of summer feeding site fidelity (see individual fish maps Appendix I). The majority of fish consistently using the Mayoriak River and Teshekpuk Lake areas for wintering and feeding tended to return to the same drainages of initial capture during summer (Figure 10). However, fish that moved out of the Mayoriak River and into portions of the upper Ikpikpuk River tended not to return during the course of this study; however, there were exceptions (Figure 11).

Winter site fidelity for the broad whitefish tagged in 2003 and 2004 ranged from 9 to 15% over the course of this study. Overwintering site fidelity was more difficult to assess given the complexity of the drainages involved and the time frame of the study. Winter site fidelity was limited predominantly to fish that most often were relocated in some portion of the Mayoriak River (Figure 12), or to fish that moved to smaller drainages and appear to have become entrained in lake systems (Figure 13).

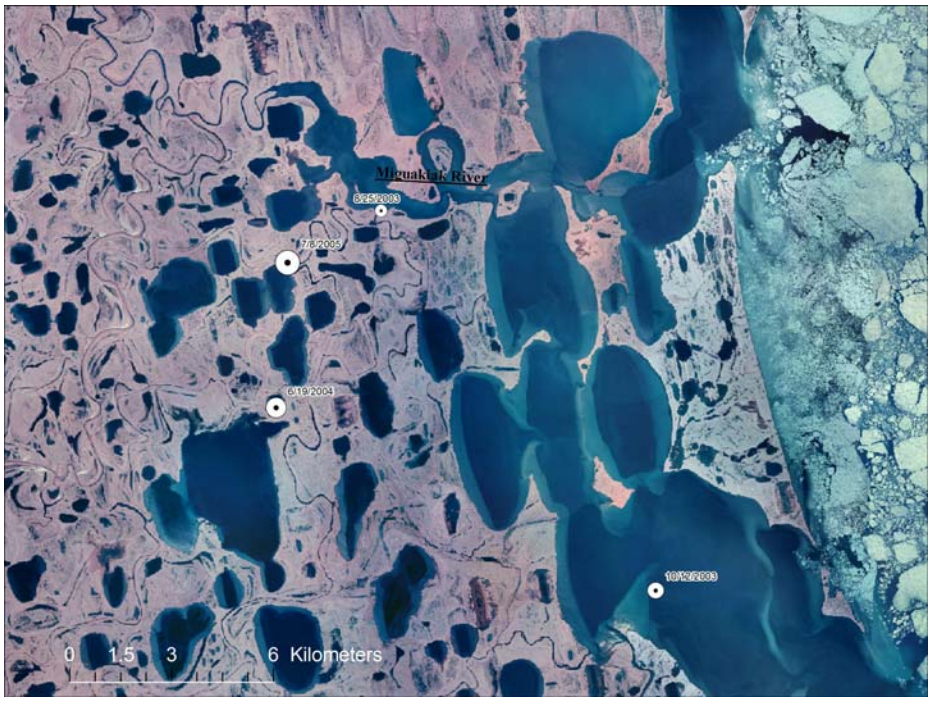

Figure 10. Map of broad whitefish #488 relocations provides an example relocation history of a fish that exhibited clear summer feeding site fidelity. Fish #488 used the same tributary of the Mayoriak in 2003, 2004 and 2005 and likely never dispersed far from the Mayoriak River during the course of this study.

Figure 11. Map of the relocation history for broad whitefish #424. The fish exhibited summer feeding site fidelity despite overwintering a considerable distance away in another drainage. Few other fish returned to the Mayoriak River area after overwintering in the channels or lakes of the other drainages in the area during the course of our study.

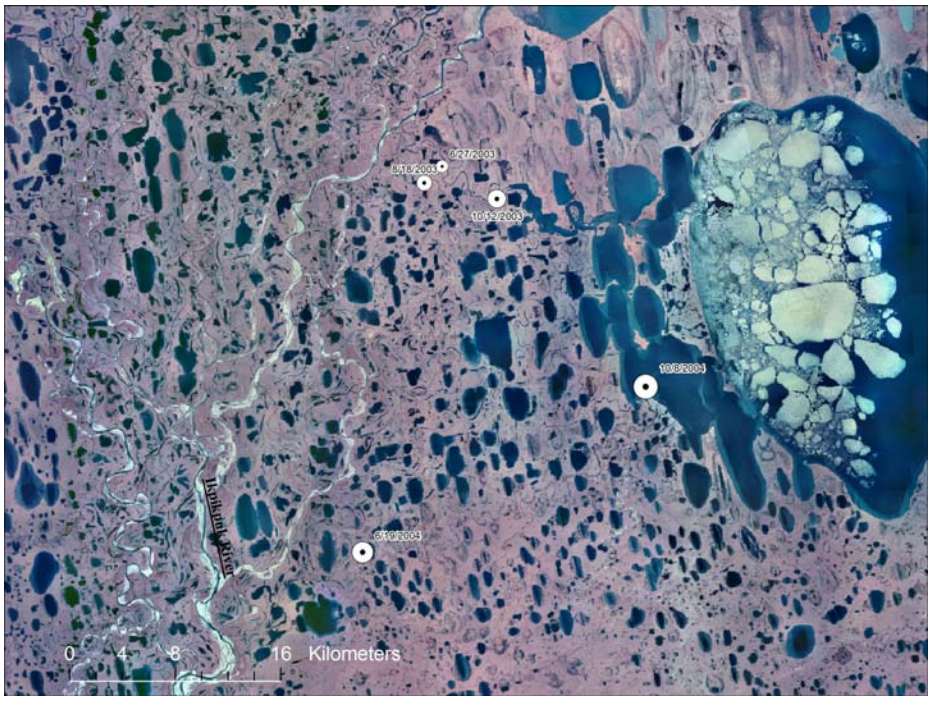

Figure 12. The relocation history for broad whitefish #452 illustrates feeding site fidelity to the Mayoriak River system but not necessarily to any given tributary, however; the fish consistently overwintered in some portion of the Mayoriak River.

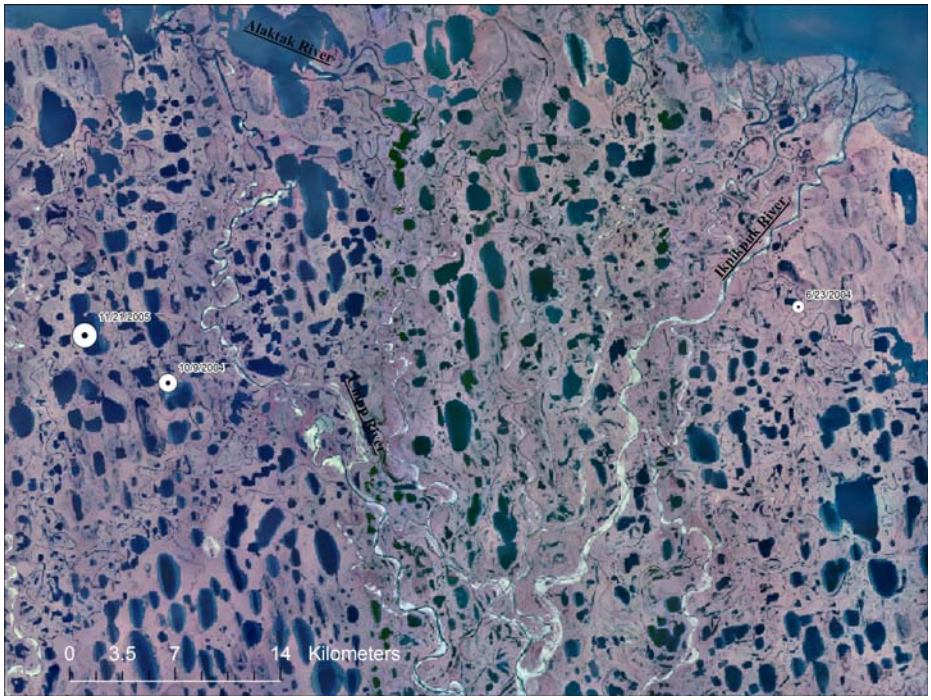

Figure 13. The relocation history for broad whitefish #663 illustrates winter site/system fidelity to some degree as the fish overwintered within the same drainage for consecutive years. However, it is likely that the fish has become entrained in this lake system and will remain there until flow conditions permit return access to main channel habitats.

Degrees of fidelity to both summer and winter habitats are likely somewhat higher over the lifespan of individual fish than documented during the short time frame of this study. It is likely that fish moving into spawning areas or moving out of the lower Ikpikpuk River, in general, have a high likelihood of entering lake systems within the complex drainages of the area and remaining there for extended periods of time. It is also likely that at some point, as fish are able to leave these lakes, they return to specific habitats used in prior years. The distribution of fish throughout the complex systems of the area probably led to the lack of relocations for many fish with low relocation rates.

Use of Lakes and Small Tundra Drainages

Broad whitefish radio tagged in this study were all captured at or near the mouths of small tundra drainages. Catch rates of broad whitefish are routinely higher at such locations during the summer feeding season than at other available habitats. Broad whitefish research on the North Slope has consistently indicated that the species depends on small drainages during the summer months. Considerable time is spent in small drainages and particularly in those with connected lakes during the summer season (Moulton 2000, Moulton 2002, Morris 2000, Morris 2003).

Broad whitefish radio-tagged in this study exhibited similar behavior, as the majority of radio tagged fish were relocated in small tributaries to the Mayoriak River at some point during the year. Lakes in several of the tributaries to the Mayoriak River were used extensively by tagged broad whitefish (Figure 14). Radio tagged fish tended to be found in lakes with other radio tagged fish.

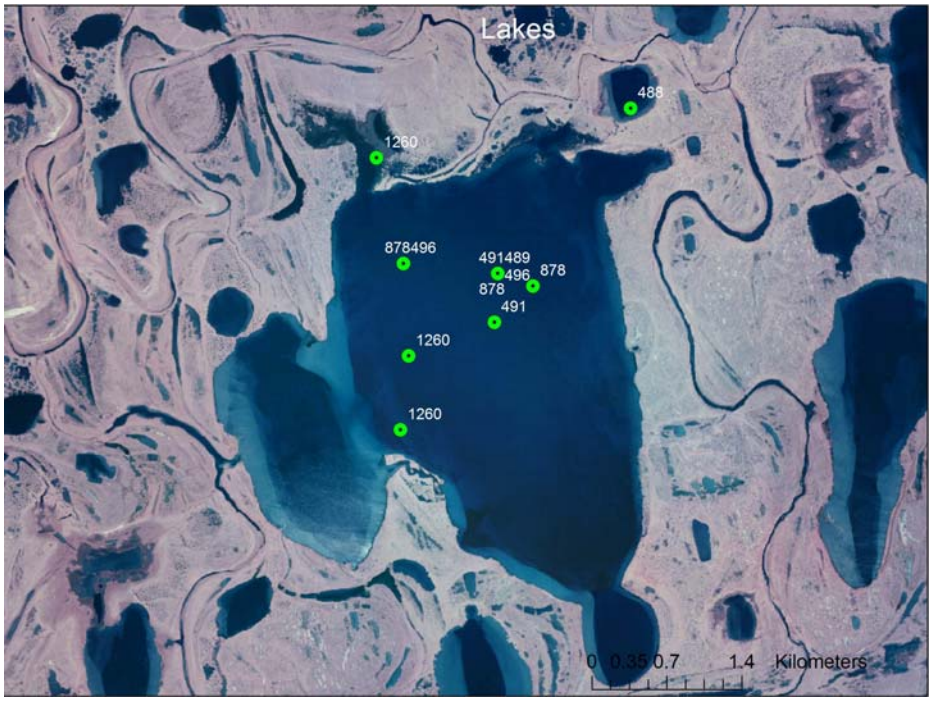

Figure 14. A detailed map of a lake in one of the middle Mayoriak tributaries used by broad whitefish #489, #491, #496, #878 and #1260. The lake was used in both summer and winter but not by all fish. Broad whitefish #488 used a smaller lake downstream in the system.

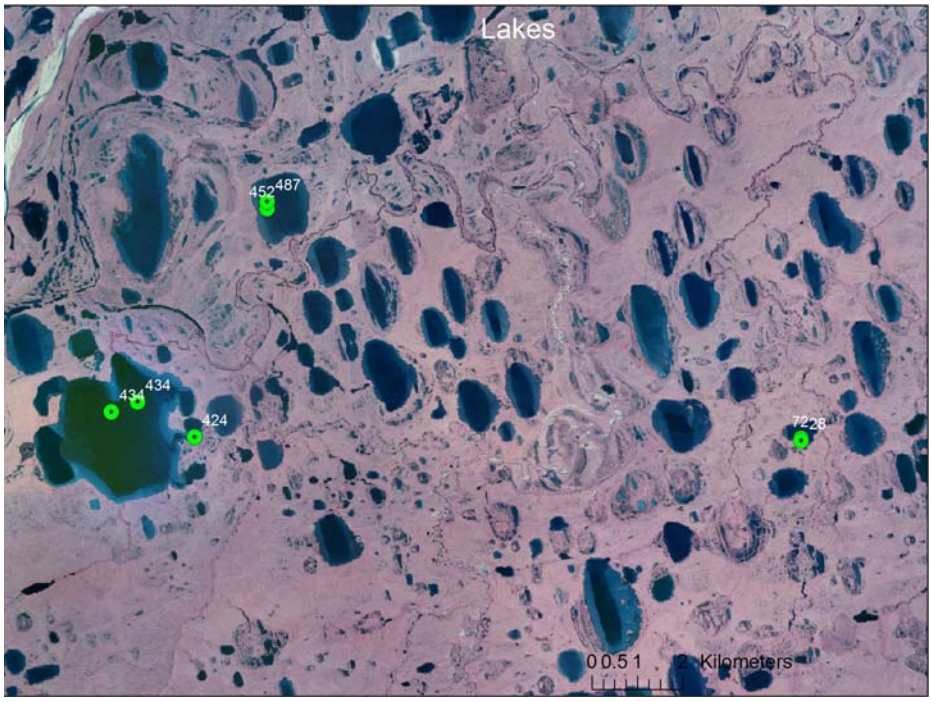

Figure 15. Map illustrating three additional lakes in Mayoriak River tributaries used by several radio tagged fish during this study (fish identification numbers are given).

Most lakes used in summer months were used by more than one radio tagged fish but for differing lengths of time. In some cases fish spent a month or less in the lakes while other fish spent up to the entire summer in a lake and then wintered there (see Appendix I, Individual Map 60). Many of these lakes are connected to streams and rivers only during periods of high water, usually in the spring and during significant rainfall events in late summer. During some years of the study, several heavily used lakes had stream surface water connections throughout the summer and in some years the lakes became isolated. In years where fish become isolated total depth of the lake is critical to allow for winter survival. In this study, few fish became entrapped in lakes where winter survival was unlikely. However, some did become trapped in very shallow isolated portions of some tributaries and even in the Ikpikpuk River.

2005 Radio Tagged Fish

Teshekpuk South Basin Radio Tagged Broad Whitefish

Radio-tracking of broad whitefish radio tagged in the southern basin of Teshekpuk lake is ongoing and only tracking results through November 2005 are fully evaluated. Few 2005 tagged fish were relocated during winter 2005. However, some fish were wintering in the main lake

basin and others in the coalesced lakes area of the upper Mayoriak River; an area commonly used for wintering by fish tagged in the lower and middle Mayoriak (Figure 16). While not yet fully evaluated, several fish were relocated during summer 2006 using the same small lake system they were tagged in during summer 2006. Additionally, some fish were also relocated in portions of the upper Ikpikpuk River used in previous years by fish tagged in the lower and middle Mayoriak.

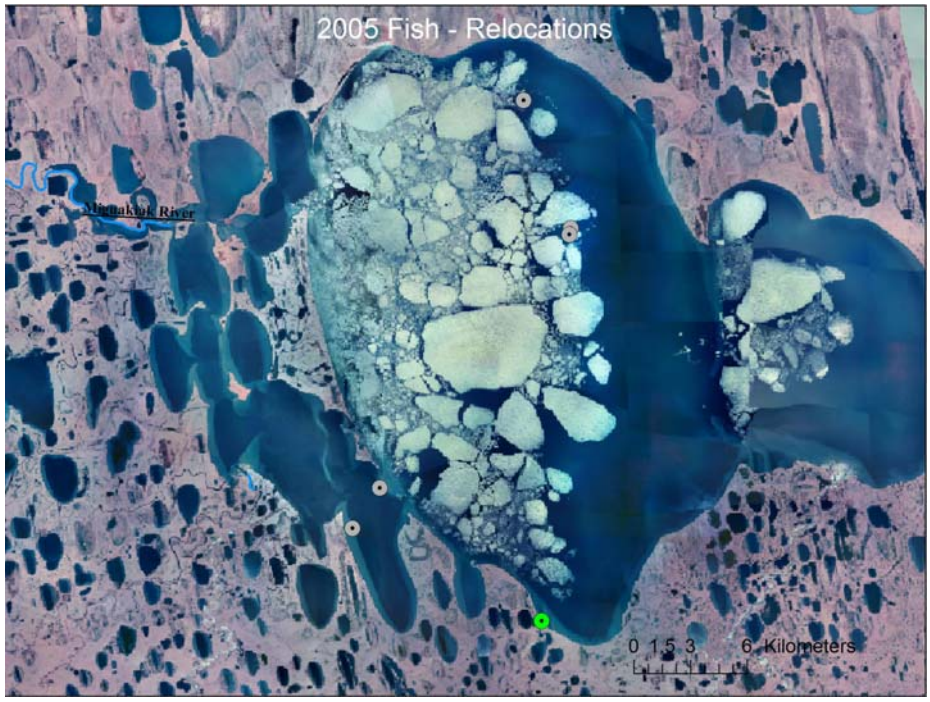

Figure 16. Broad whitefish radio tagged in the south basin of Teshekpuk lake overwintered in Teshekpuk lake and in the coalesced area of the upper Mayoriak River in winter 2005/2006 (tagging site is in green).

Teshekpuk Lake and Kealok Creek Radio tagged Lake Trout

The lake trout tagged in Teshekpuk Lake in 2005 was relocated only once, a few days after it was released. The fish had moved into the south basin of Teshekpuk Lake (Figure 17). The lake trout radio tagged in a lake in upper Kealok Creek was most frequently relocated in the same lake it was first captured. However, by early August 2005, it had moved downstream to a smaller lake. The lake trout returned to the initial lake of capture for wintering (Figure 18).

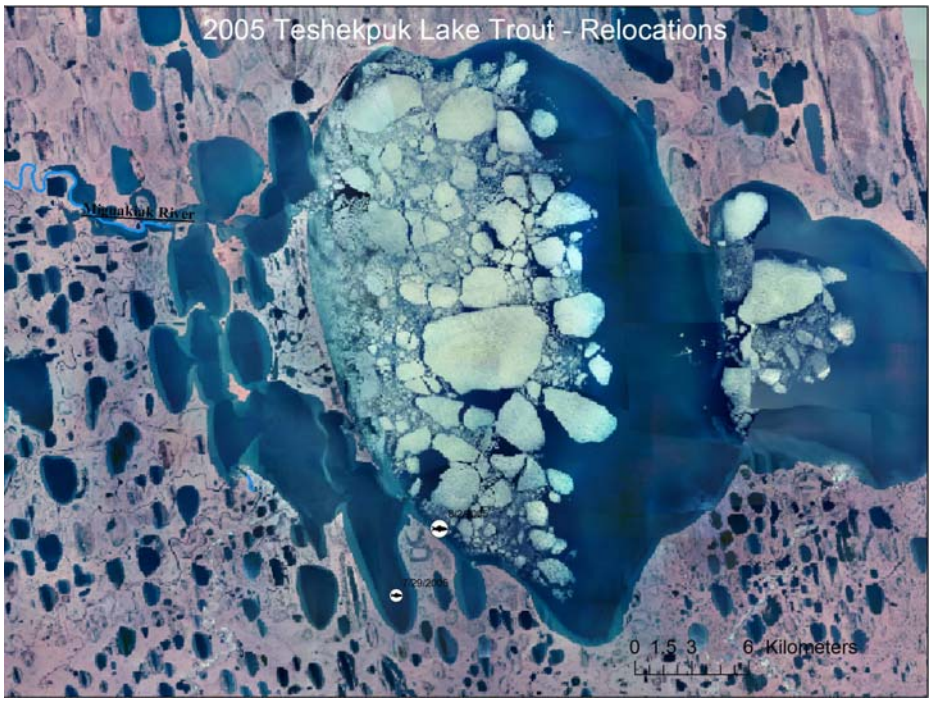

Figure 17. Map of the only relocation to date for the lake trout radio tagged in the first coalesced lake of the upper Mayoriak/western Teshekpuk basin. The fish moved into the main lake almost immediately after tagging and has not been relocated since.

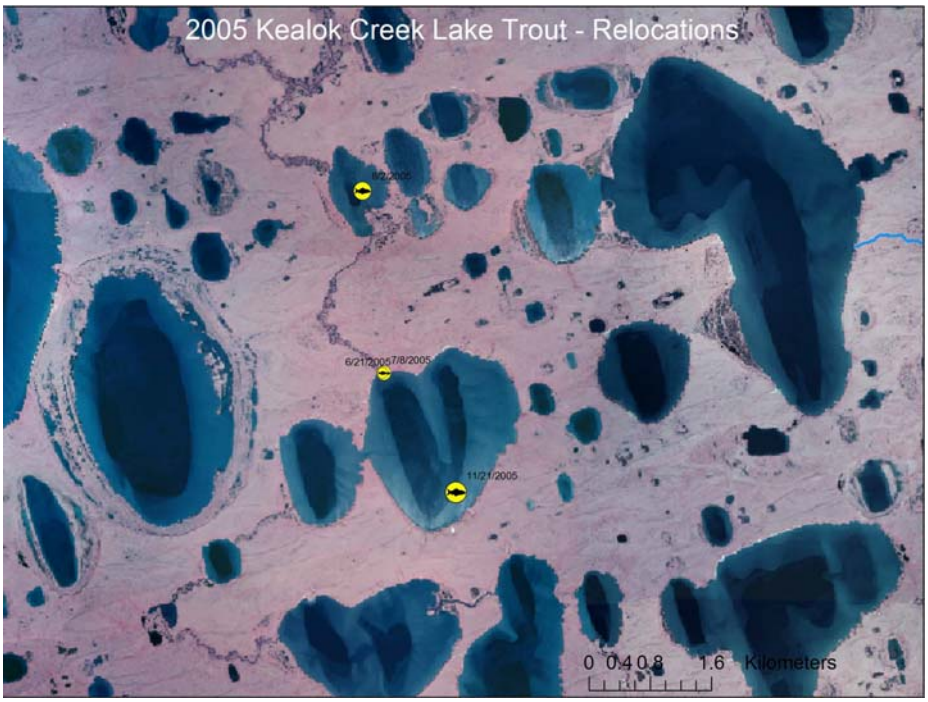

Figure 18. Map of the relocation history for the upper Kealok Creek lake trout radio tagged in 2005. Summer 2006 relocations (not shown) indicated the fish had again moved downstream to the lower lake, subsequent radio tracking has failed to relocate this fish after early summer 2006.

Radio tracking in 2006, while not fully evaluated, indicates the fish again moved to the downstream lake and then either its transmitter battery went dead or the fish left Kealok Creek.

Meade River Radio tagged Broad Whitefish

Preliminary tracking results from the Meade River tagged broad whitefish are presented in Figure 19. A total of seven fish were relocated in October 2005. Two broad whitefish classified as pre-spawners when tagged were relocated in the lower Meade River, while one fish classified as a pre-spawner was relocated roughly 20 km downstream from Atqasuk. On November 21, 2005 7 fish were relocated in a 10 km reach of the Meade, beginning approximately 20 km downstream from Atqasuk. Several of the fish relocated further down river in October had moved upstream into this reach of the river. Five fish were located in the same spot, one slightly upstream and one roughly 10 km upstream.

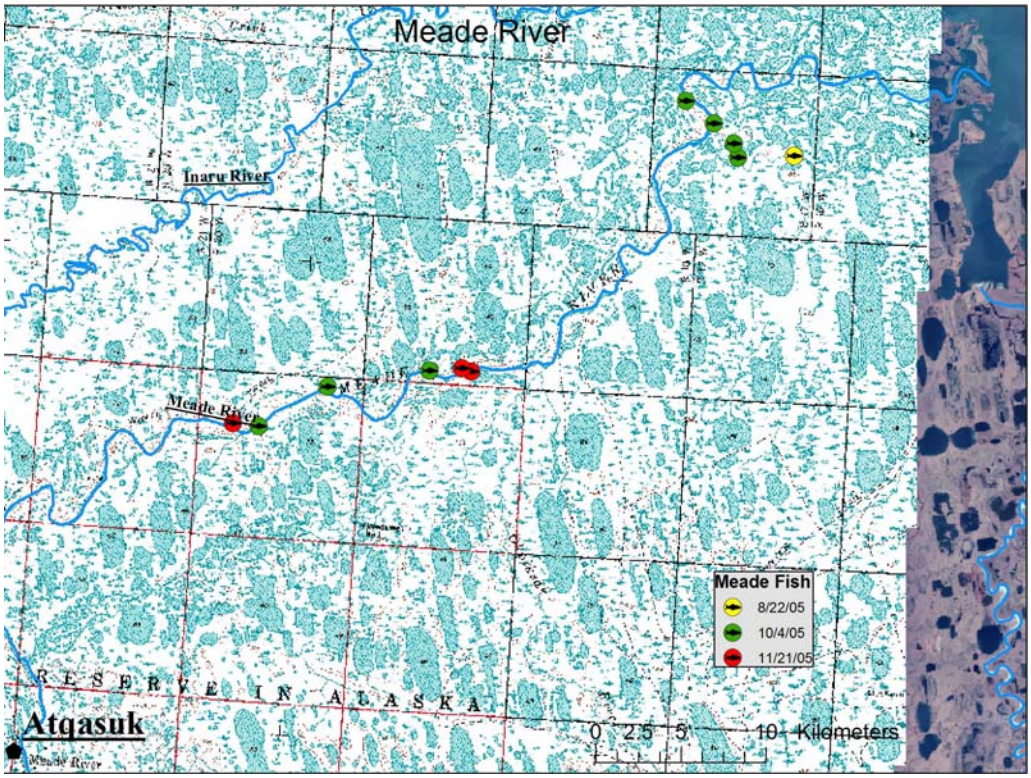

Figure 19. Map of broad whitefish relocations for fish tagged in the Meade River in 2005. The yellow marker shows the tagging location.

Subsequent radio tracking in 2006, while not fully evaluated, has identified one Meade River broad whitefish in the upper Topagoruk River and one in the upper Ikpikpuk River with several broad whitefish radio tagged in Teshekpuk Lake in 2005. The location of this particular fish in

the Ikpikpuk River, while not surprising, represents the first documented movement of broad whitefish between the two drainages. Additionally, several of the fish have moved into areas of the upper Meade River and into lake systems.

Discussion

Radio tracking of broad whitefish in the Teshekpuk Region from 2003 to 2005 has lead to a clearer picture of the species use of the area and has also contributed information as to how the species can be harvested at reasonably high levels from the drainages around Teshekpuk Lake with no apparent detriment to the population. It is clear that broad whitefish from the Mayoriak River and probably Teshekpuk Lake rely heavily on small tundra lake systems for summer feeding to regain condition prior to wintering and/or spawning. The Mayoriak River broad whitefish appear to be split into two groups; those that spend much of their time in the Mayoriak River and its small tributaries for both wintering and feeding (and possibly for spawning), and those that feed in the system and leave for spawning. Of those that left during our study only a few returned. Given the complexity of the systems adjacent to the Mayoriak River, this result is not surprising, and likely contributes to the species ability to survive significant harvest as well as annual variations in weather.

Once fish leave the Mayoriak and travel into upper portions of the Ikpikpuk drainage it is unlikely that they will be able to return to the Mayoriak in the same year. Most of the flow in the upper Ikpikpuk is routed down the Chipp River, resulting in fairly limited opportunities for return movement to the Mayoriak River after August. It appears that in many years, migrations of broad whitefish out of the Mayoriak River to spawning areas in the upper Ikpikpuk, Chipp, Oumalik and Titaluk rivers, in mid to late summer (during high or relatively high water), is a one way trip during any given year. By the end of the spawning season, in late September to early October, little flow remains in the Ikpikpuk River and travel back to the lower river and to the Mayoriak is often not possible. Instead, fish locate deep channels in the rivers or, frequently, distribute to deep water lakes in the lower reaches of the Chipp River or one of the many distributary channels of the Chipp or Alaktak rivers. It appears that once entrained in these smaller stream systems with deep lakes, fish may spend extended periods of time before making their way to a main channel where access back to the Mayoriak is possible. Similarly, fish using

the small drainages tributary to the Mayoriak River may spend multiple seasons and years within lakes associated with those drainages. Based on these data, it is apparent that the population of broad whitefish is so widely dispersed at any given time that significant portions of the population are not available for harvest during any one year, and therefore, over harvest is unlikely. After spawning or other migrations out of the Mayoriak River, fish may distribute to areas not accessible to or areas not often fished by subsistence fishers, partially as a result of their inability to return to the Mayoriak River. Flow in the Chipp/Ikpikpuk river system appears to be shifting towards the Chipp River portion of the drainage, which, if it continues, will lead to a further reduction in flow in the lower Ikpikpuk. If this trend continues, access to upper river spawning areas for broad whitefish in the Teshekpuk Lake drainage may become considerably more difficult and less frequent.

Broad whitefish from our study population used numerous areas for wintering and several areas for spawning. Based on multiple relocations during multiple years it appears that most spawning activity occurs in the Ikpikpuk River in a 20 km reach from above the Chipp River to the confluence with the Price River. However, more recent and as yet unevaluated tracking results suggest that some spawning may occur upstream from the Price River. Additionally, some fish may spawn in the coalesced lakes area of the Mayoriak River. Teshekpuk Lake and particularly the area of coalesced lakes at the head waters of the Mayoriak River appears to be of significance as a potential spawning area but more so as a wintering area. The deep channels through this portion of the lake/river probably carry enough flow late enough into the fall to allow for some spawning; actual lake spawning is not implied as fish likely spawn in the flowing waters of the deep channels. A significant proportion of fish radio tagged in 2003, 2004, and 2005 has been identified using this area of the lake for wintering. Some fish have also been identified using the main basin of the lake during winter and, given the size and depth of the lake, it is likely that more radio tagged fish than detected were using the lake during winter in any given year.

As a direct result of the complexity of the habitats available for use in the region, broad whitefish life history in the region is extremely complex. Broad whitefish distribute widely throughout area drainages and use virtually all habitats available during some period of the year. Several migration strategies seem to exist in the region. Some fish remain relatively sedentary and reside

within the same proximate drainages most of each year. Others are considerably more wide ranging and travel in excess of 100 km annually to spawning areas and then to wintering areas. Of fish that traveled extensively to spawning areas, some winter near their spawning areas in main river channels while others move downstream to distant pools in river channels. Others make their way to lake systems for wintering and often for subsequent summer feeding. There is even separation in habitat selection for fish that remained within the same general drainage of initial tagging, where some moved far upstream to lakes and others remained in lower portions of small drainages and the Mayoriak itself. Ultimately, the population of fish using the areas is separated into many different habitats at any given point in time in their life history. This strategy helps ensure survival of the species in the region as no single event would be likely to decimate the entire population. Similarly, it is unlikely that a population so dramatically spread out would suffer from harvest as over harvest would be unlikely. Localized short term over harvest could occur, but the population would almost always have source fish from other areas to replenish the loss.

Fish radio tagged in 2005 and even some in 2004 still have active transmitters and surveys will be flown to relocate those fish during the 2006 spawning season. High water in August 2006 has provided good access to the upper river for fish radio tagged in Teshekpuk Lake and it is likely that additional spawning area relocations or refinements to those identified will occur. Similarly, fish tagged in the Meade River will be relocated during the fall spawning season and additional distribution and spawning area data gathered. An additional report containing full analysis of all data collected to date will be prepared once radio tracking of 2005 tagged fish is complete, sometime in 2007.

Management Implications

This study has confirmed several key aspects of broad whitefish ecology on the North Slope pertinent to fish and fish habitat management in areas likely to see varying degrees of Oil and Gas exploration and development in the years to come. As with other populations of broad whitefish on Alaska's North Slope, the population using the Teshekpuk Lake region appears dependant on small tundra drainages and lake systems both for feeding and to some extent for overwintering. Given the variable flow patterns and extreme complexity of the drainages of the

area it will be important to ensure unimpeded fish passage in streams of the region especially in stream/lake complexes. Our study also identified potential spawning areas in reaches of the upper Ikpikpuk River as well as identified use of numerous deep water pools for wintering in the Ikpikpuk, Chipp, Oumalik, and Titaluk rivers. These areas are of particular significance to the population of fish using the region and are sensitive to perturbations that may alter flow or reduce riverine pool volumes. Additionally, the coalesced lakes of Teshekpuk Lake appear to receive considerable use by wintering and possibly spawning broad whitefish captured in the Mayoriak River and in Teshekpuk Lake.

Availability and use of multiple habitats appears to be a very successful strategy used by the broad whitefish of the area. Most habitats available at some point in the year are used by some fish during most years. The complexity of the drainages associated with the Mayoriak River, Chipp River and Ikpikpuk River, and use of all available habitats, leads to a wide distribution of fish during most times of most years. This ability to disperse widely into all available habitats is likely key to the species ability to withstand considerable harvest and variations in weather. It is very unlikely that a significant proportion of the areas' broad whitefish are susceptible to harvest in any given year. Additionally, extreme weather conditions that may kill numerous fish in river pools in any given year, likely will not harm fish distributed into lakes. Mortality from natural events and from harvest can easily be replenished over time by individuals not susceptible to the same cause of mortality in that year. However, this strategy can only be successful as long as access to most available habitats is maintained. Through careful and rigorous hydrological data collection and applying those data to site selection and design of roads and other industrial facilities, habitat connectivity, availability and fish use can remain largely intact.

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APPENDIX I Complete Relocation History Maps for Individual Fish Radio tagged in 2003 and 2004.

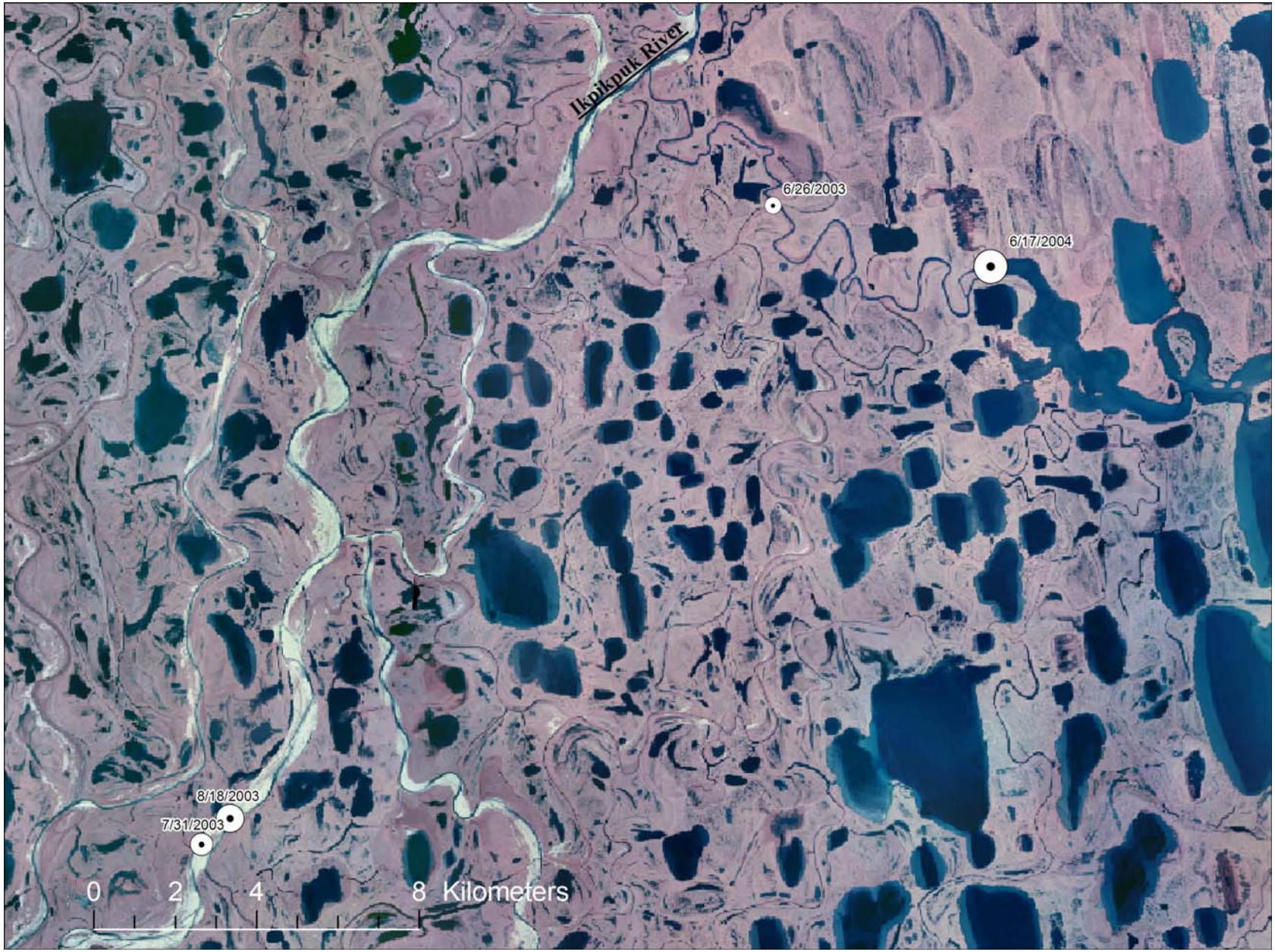
Fish with two or fewer relocations in their history typically are not included in this appendix. Fish radio tagged in 2005 are not included in this appendix as radio tracking of these fish will continue into 2007.

Individual Maps are arranged in order of fish identification number by year. Fish tagged in 2003 appear first followed by those tagged in 2004. Symbol size on each map increases with time. The smallest symbol indicates the fish location on the date of tagging while the largest represents the last relocation of the fish. Dates for each relocation are presented on each map.

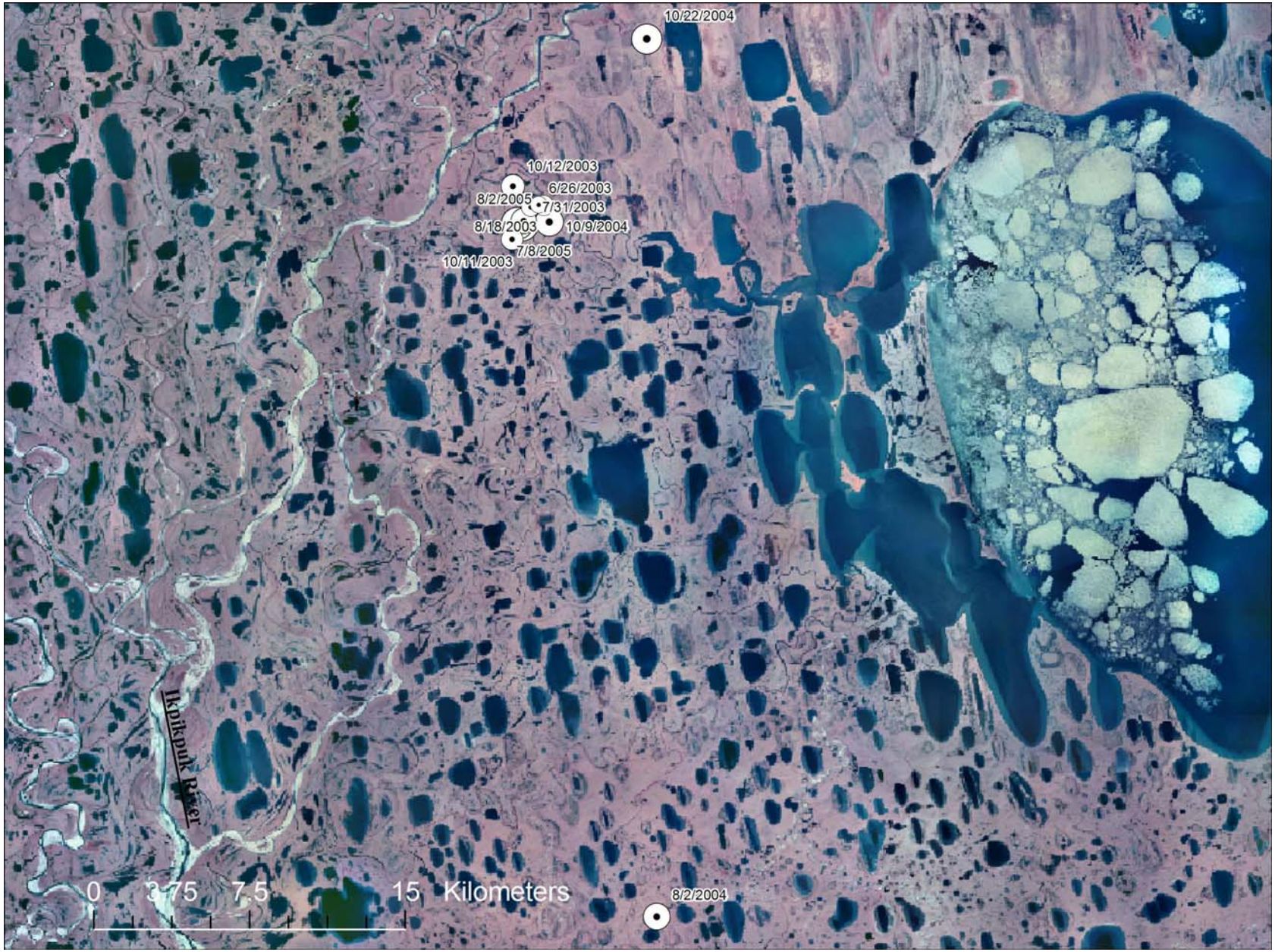
Relocations that appear to occur over land can be inferred to correspond with the nearest point of water in most cases unless specified otherwise.

2003 Radio Tagged Broad Whitefish

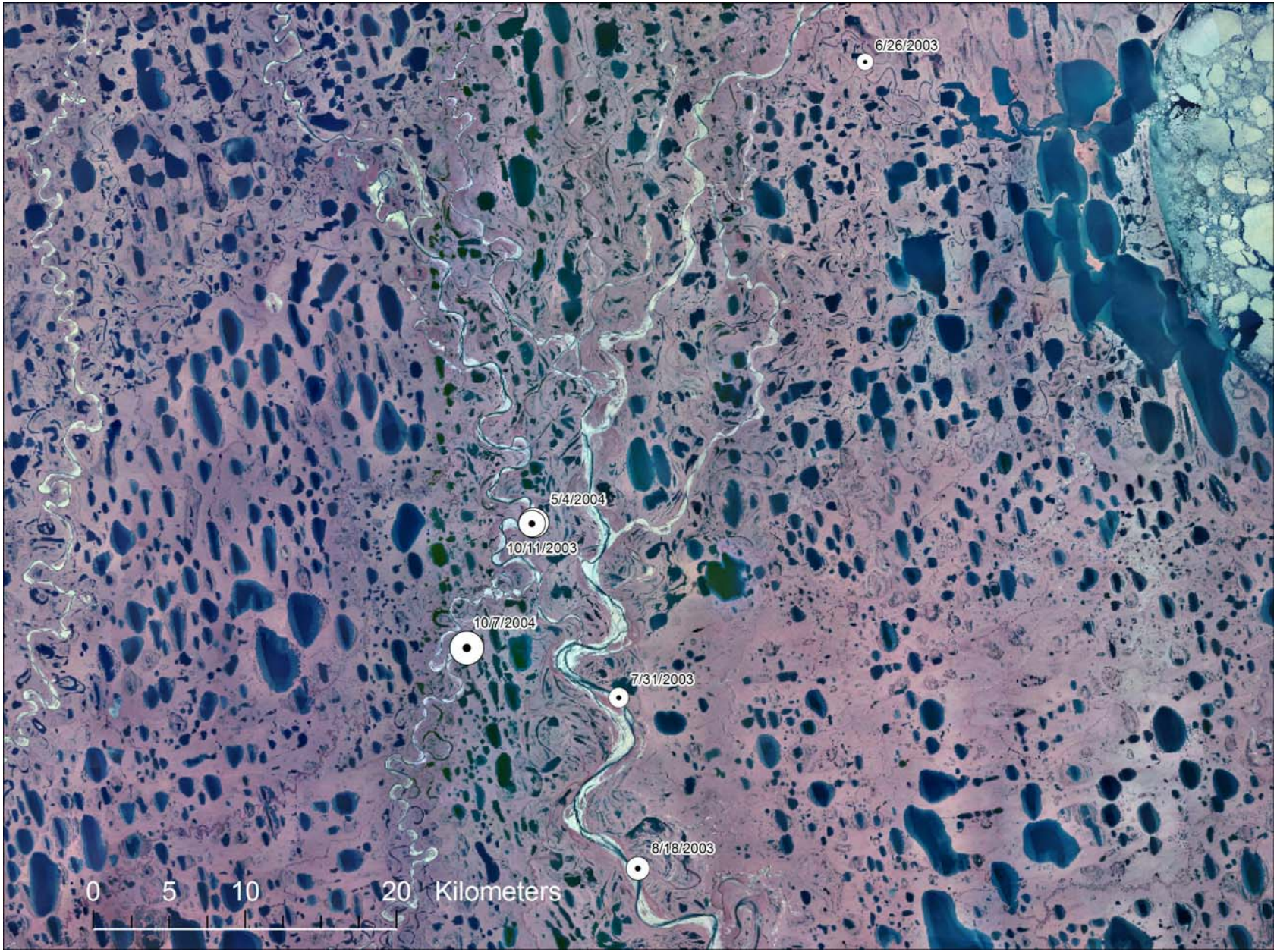
Individual Map 1. Broad Whitefish #26 moved into the upper Ikpikpuk River area by July 2003 but was relocated in the lower Chipp River after the spawning season. The fish was last relocated moving back upstream in the Chipp River in August 2004.



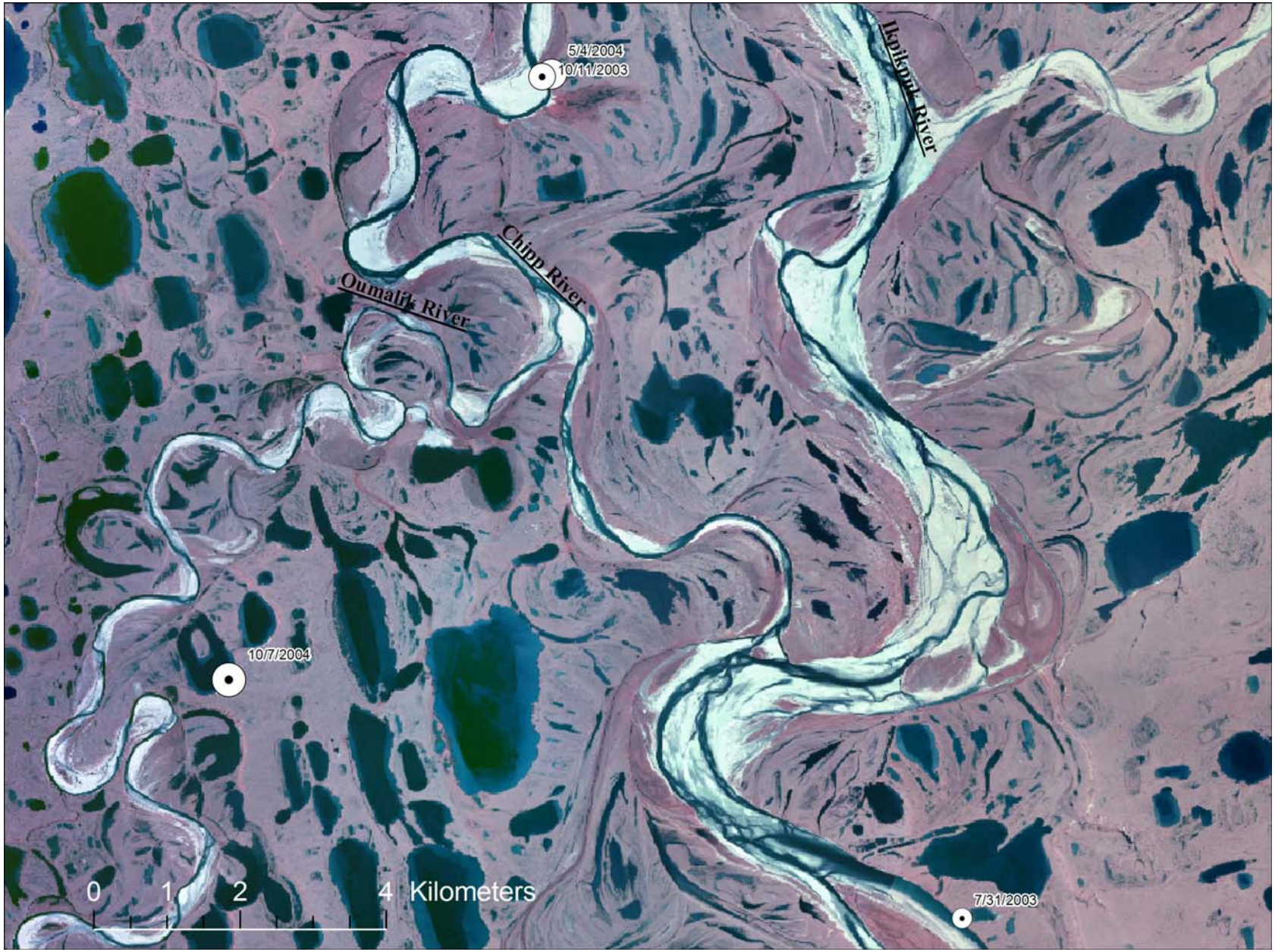
Individual Map 2. Broad whitefish #27 moved out of the Mayoriak River and upstream into the Ikpikpuk River during summer 2003. The fish had returned to the Mayoriak some time before mid June 2004 when it was relocated at the mouth of a middle Mayoriak area tributary.



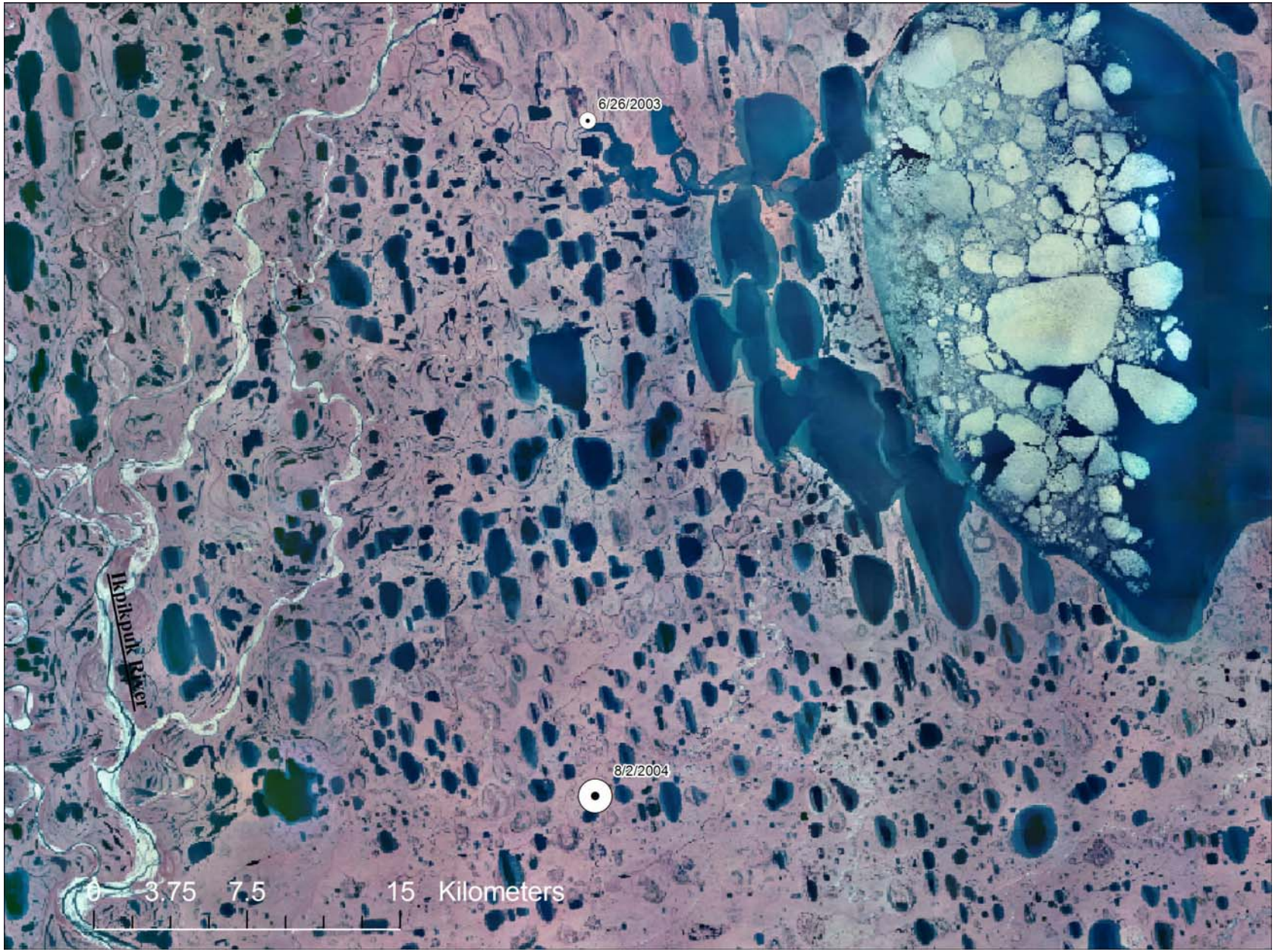
Individual Map 3. Broad whitefish #28, is a likely mortality, however some long distance movements were recorded for this fish.



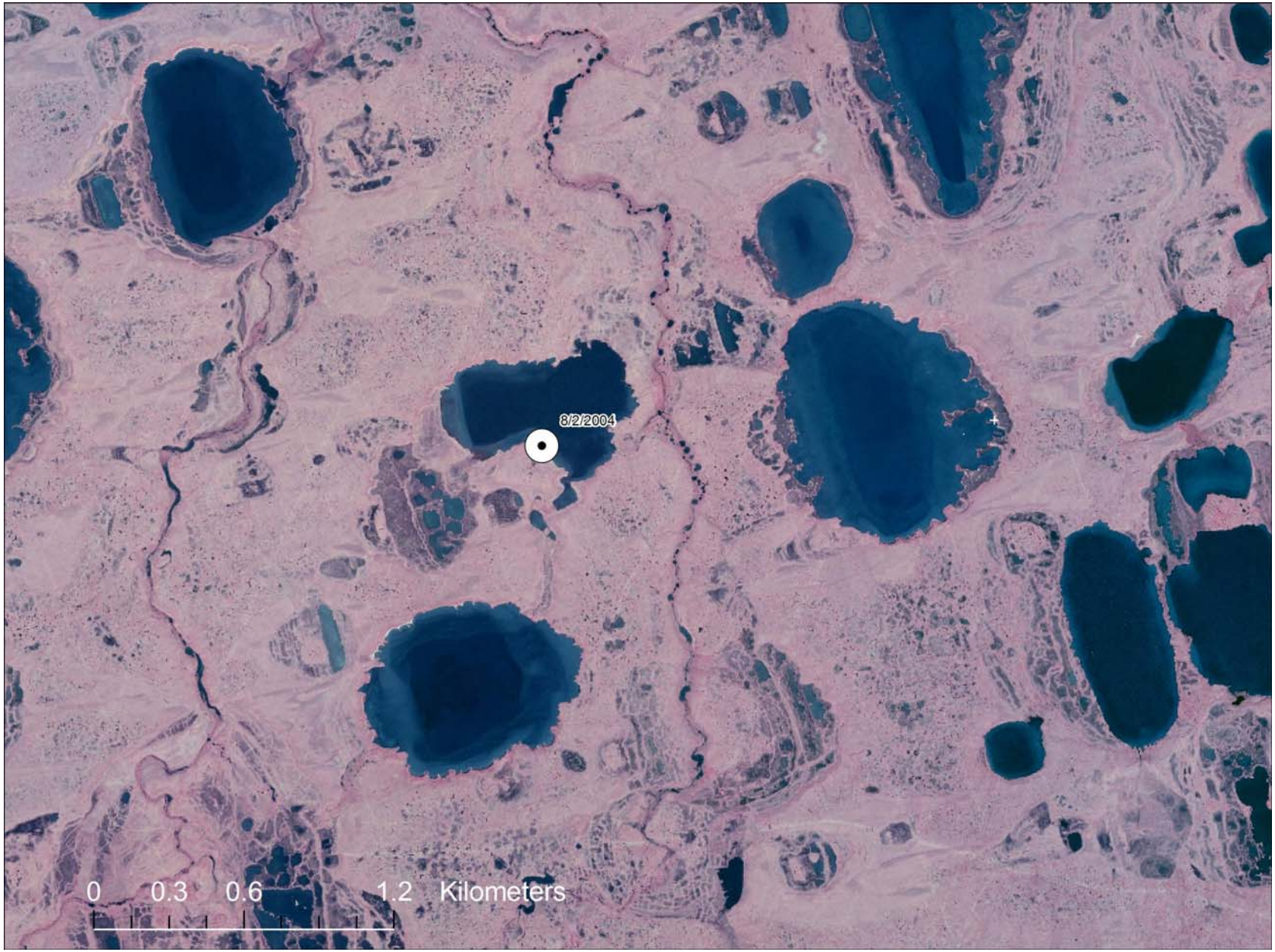
Individual Map 4. Broad whitefish #29 moved into the upper Ikpikpuk and Oumalik River area and successfully overwintered in the Chipp River in winter 2003/2004. The fish was later relocated in a lake off of the Oumalik River in winter 2004/2005.



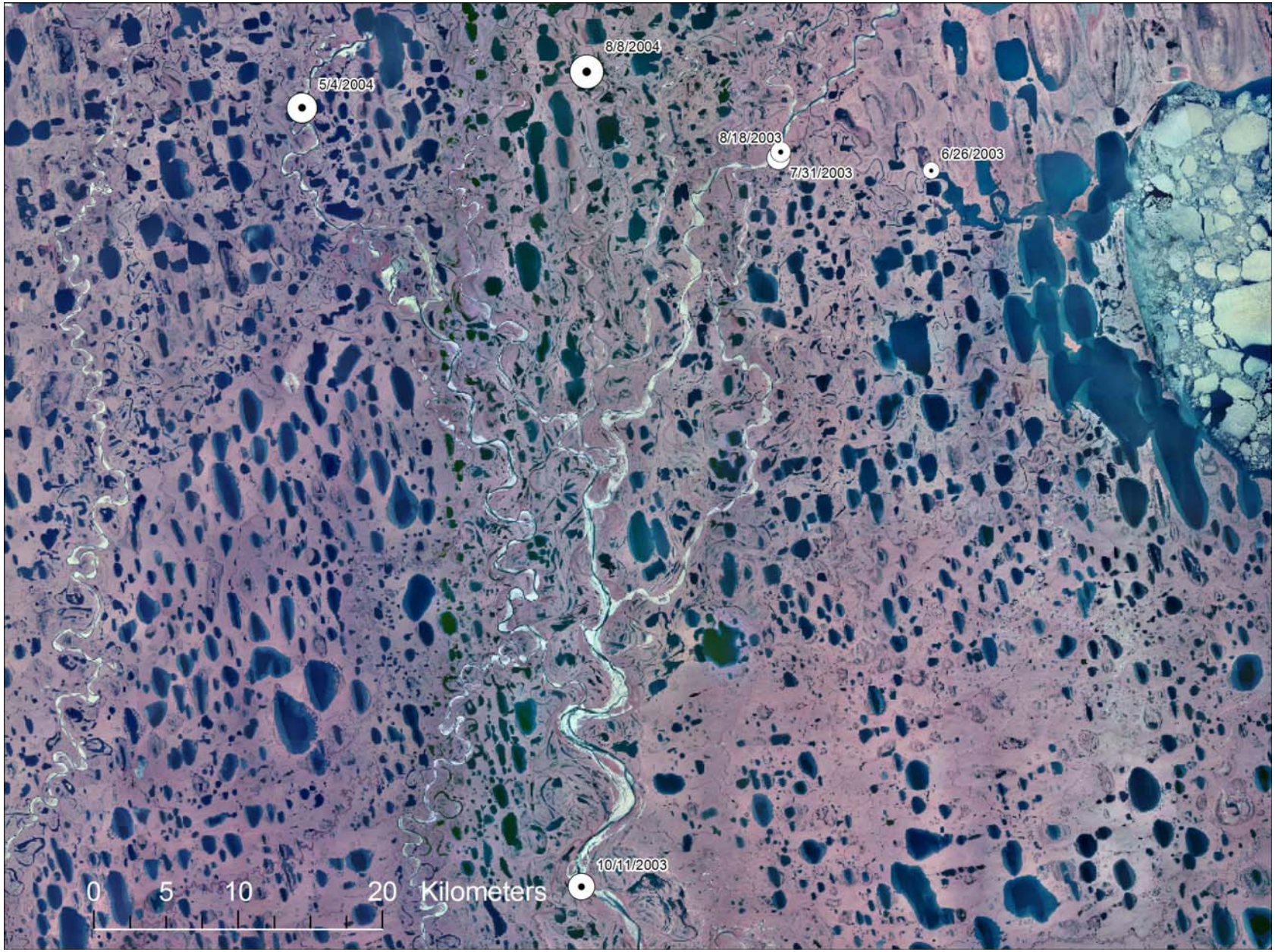
Individual Map 5. Broad whitefish #29 Oumalik River and Chipp River overwintering relocations are shown in detail.



Individual Map 6. Broad whitefish #72 was never relocated outside of the Mayoriak River or its tributaries. The fish did however; make significant movements to the upper reaches of a tributary to the Mayoriak River.

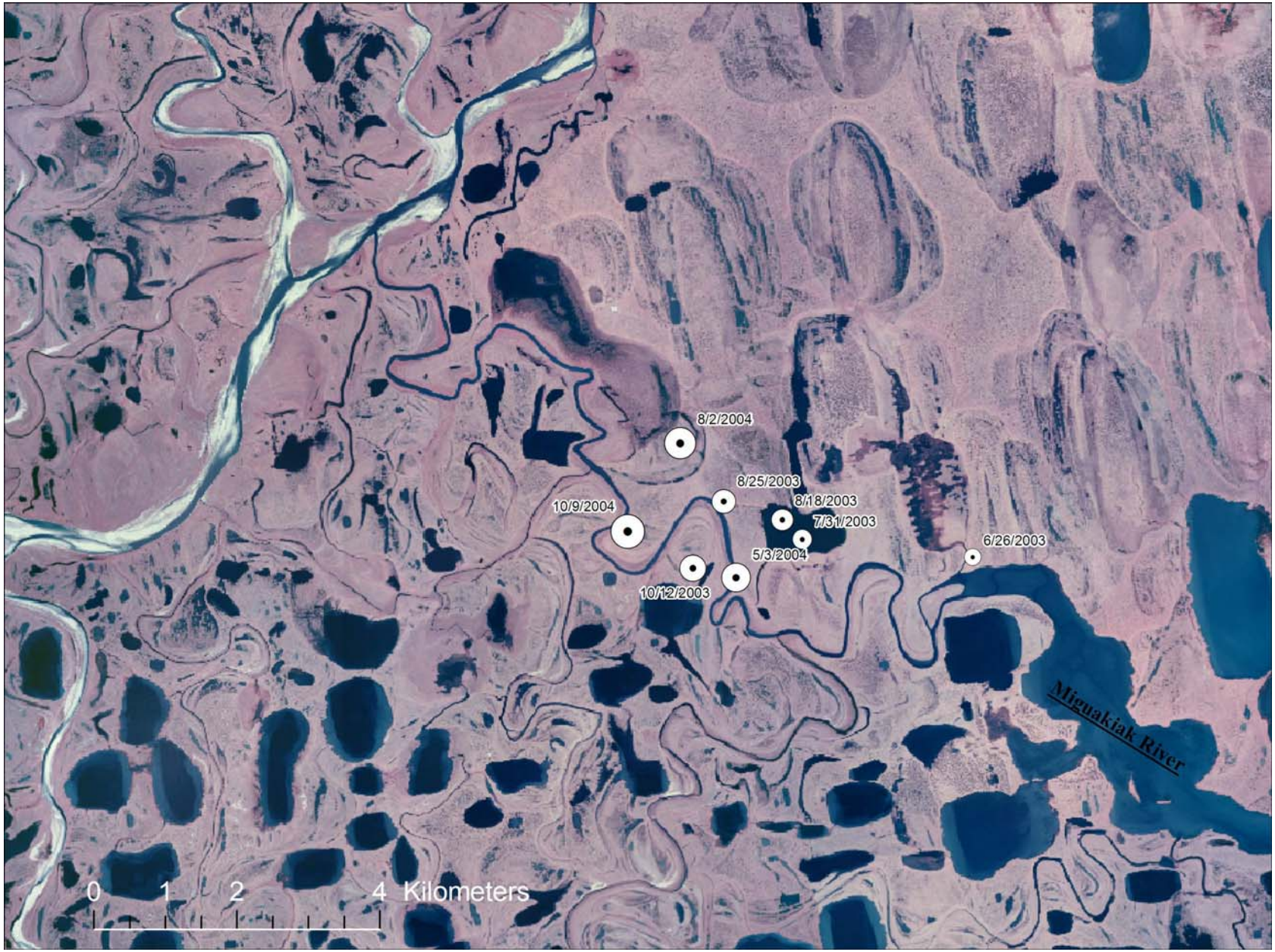


Individual Map 7. Detail of upper Mayoriak River tributary lake used by broad whitefish #72. The lake is small, appears relatively deep but has only seasonal surface water connections to adjacent streams.

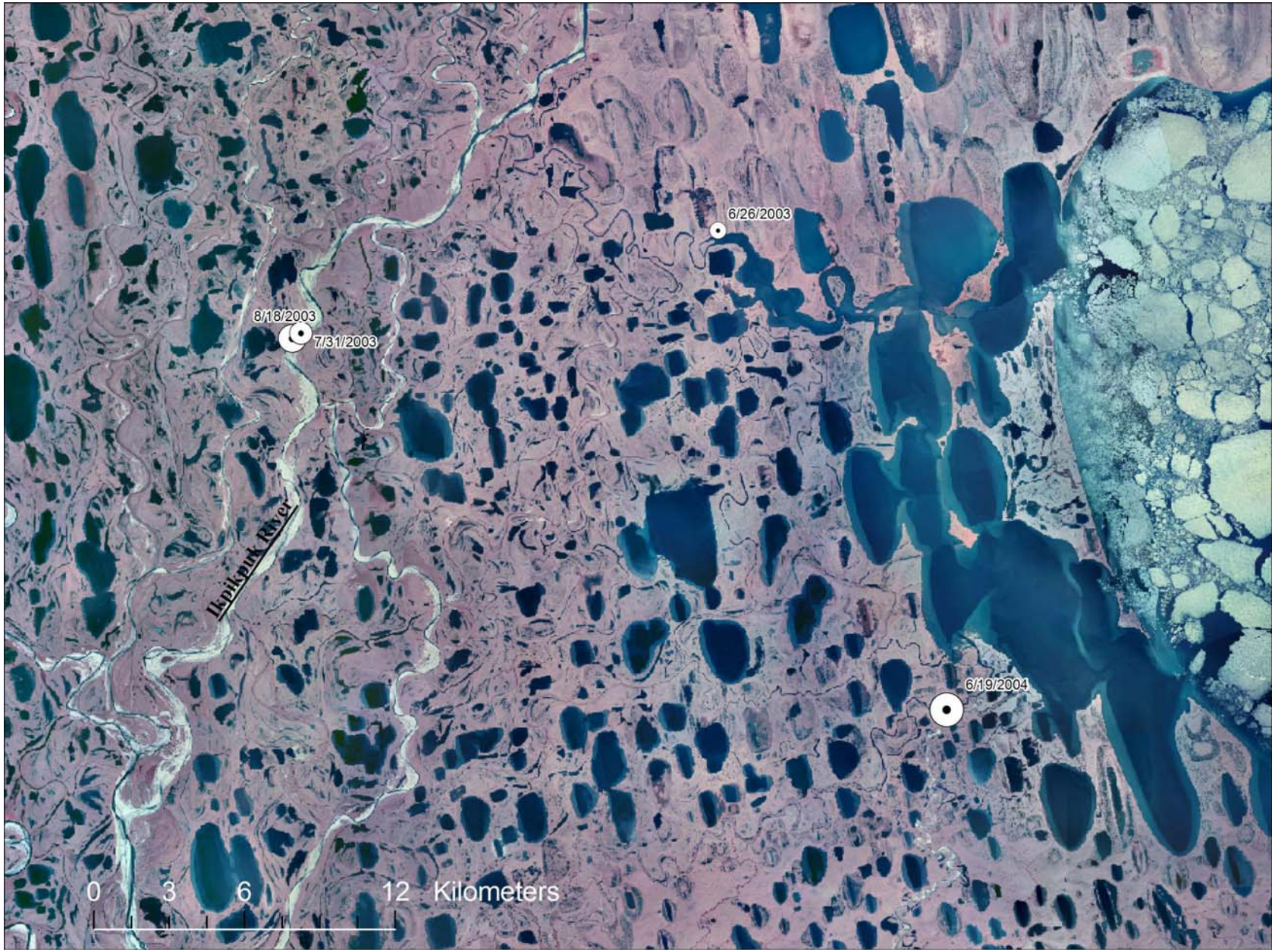


Individual Map 8. Broad whitefish #73 moved into the upper Ikpikpuk during the spawning period in 2003 then wintered in the lower Chipp River. During 2004 summer and fall tracking the fish was relocated in a distributary channel/deep paleochannel in a location used by several other fish.

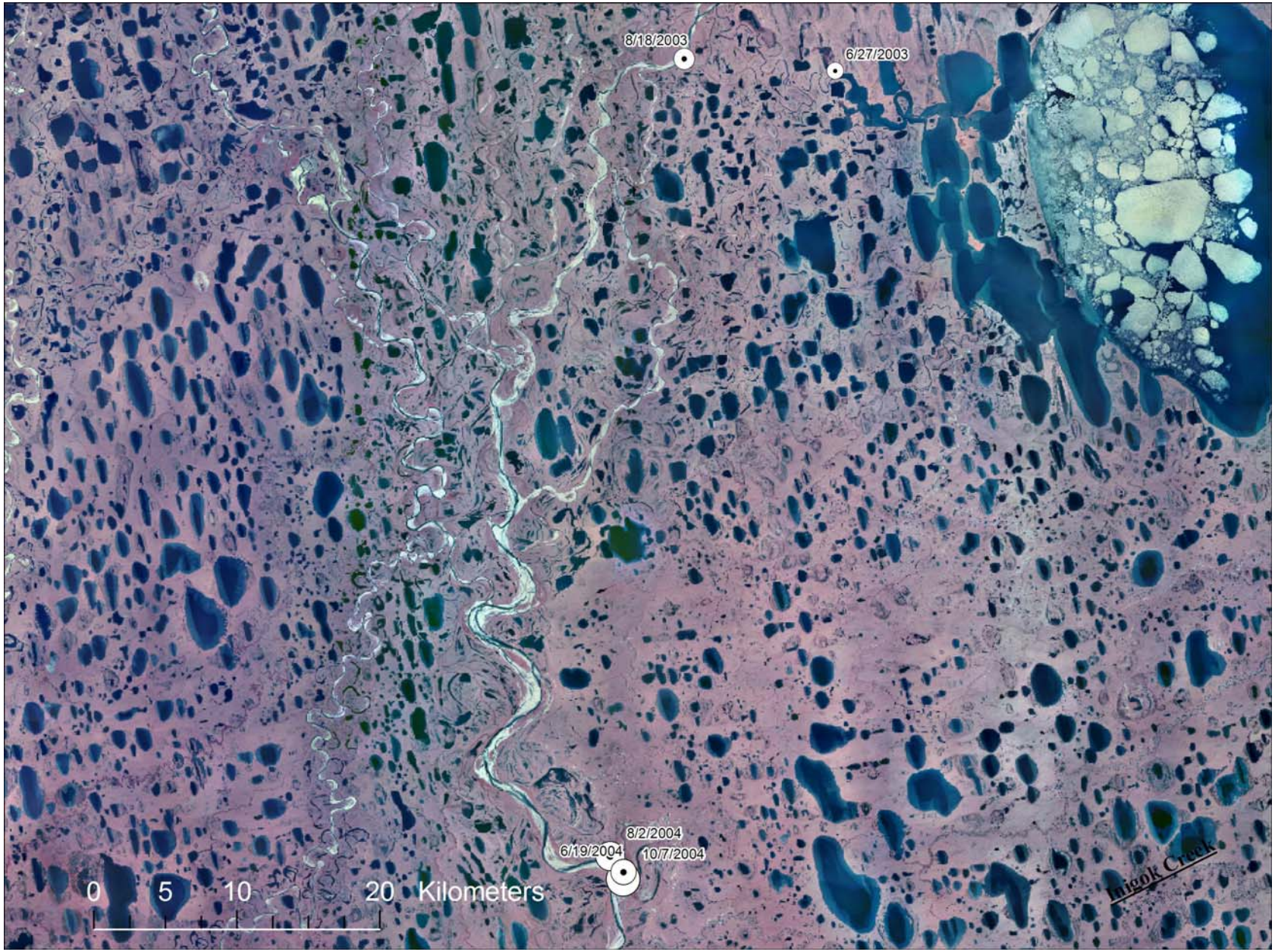
Individual Map 9. Detail of channel used by broad whitefish #73 in August 2004 and broad whitefish #250, #430 and #424 (#424 not labeled) for wintering and also during the spawning period. Spawning is not inferred for this fish as it appears to have spawned the previous fall in the upper Ikpikpuk River. Relocation dates and fish identification numbers are provided on the map.



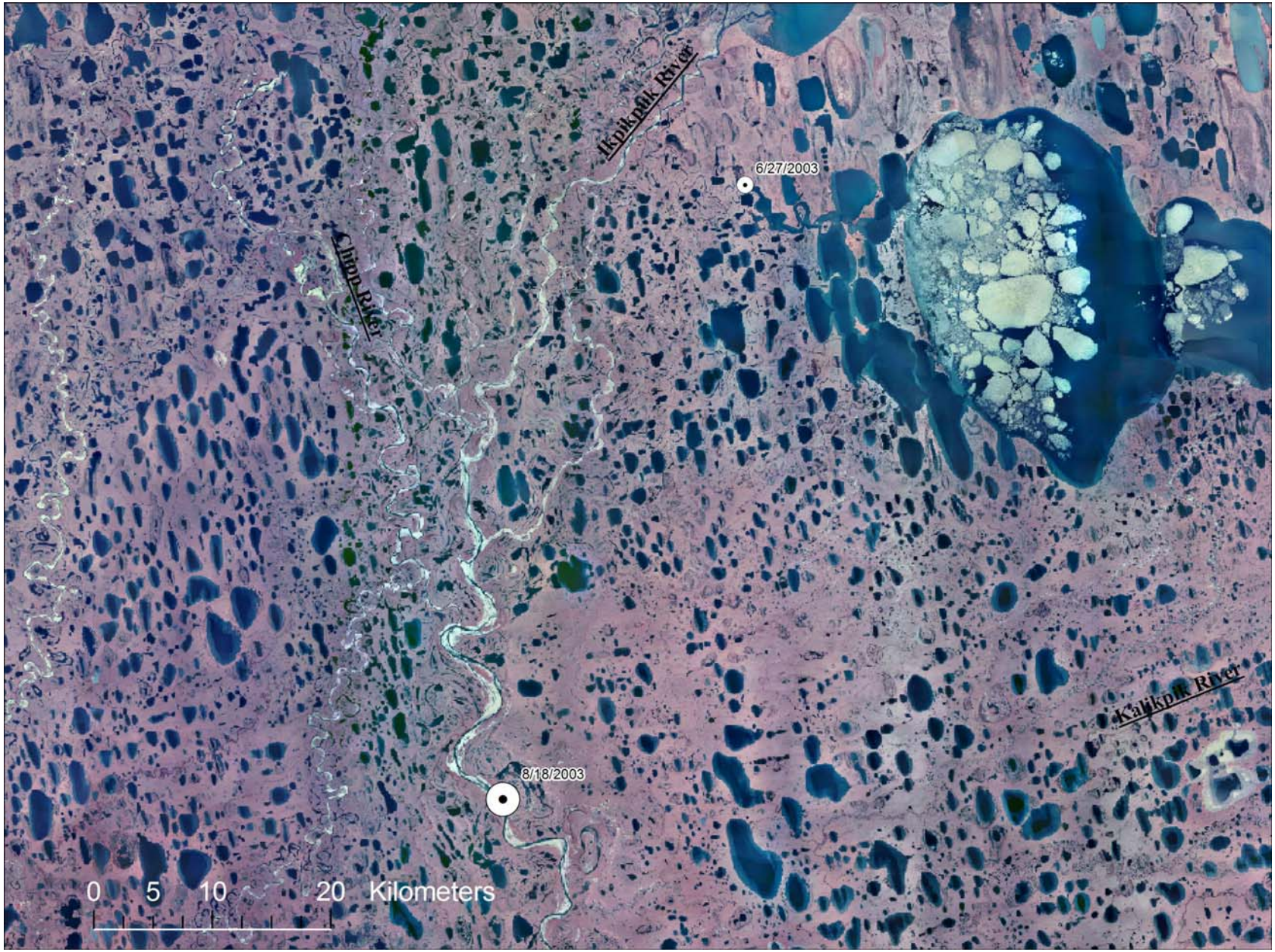
Individual Map 10. Broad whitefish #80 used the lake headwater lake of the Mayoriak River tributary it was tagged in and then moved to the Mayoriak River where it may have died (locations not on water do not indicate the fish was out of the water, this phenomenon is attributable to GPS and relocation error possibly based on poor signal).



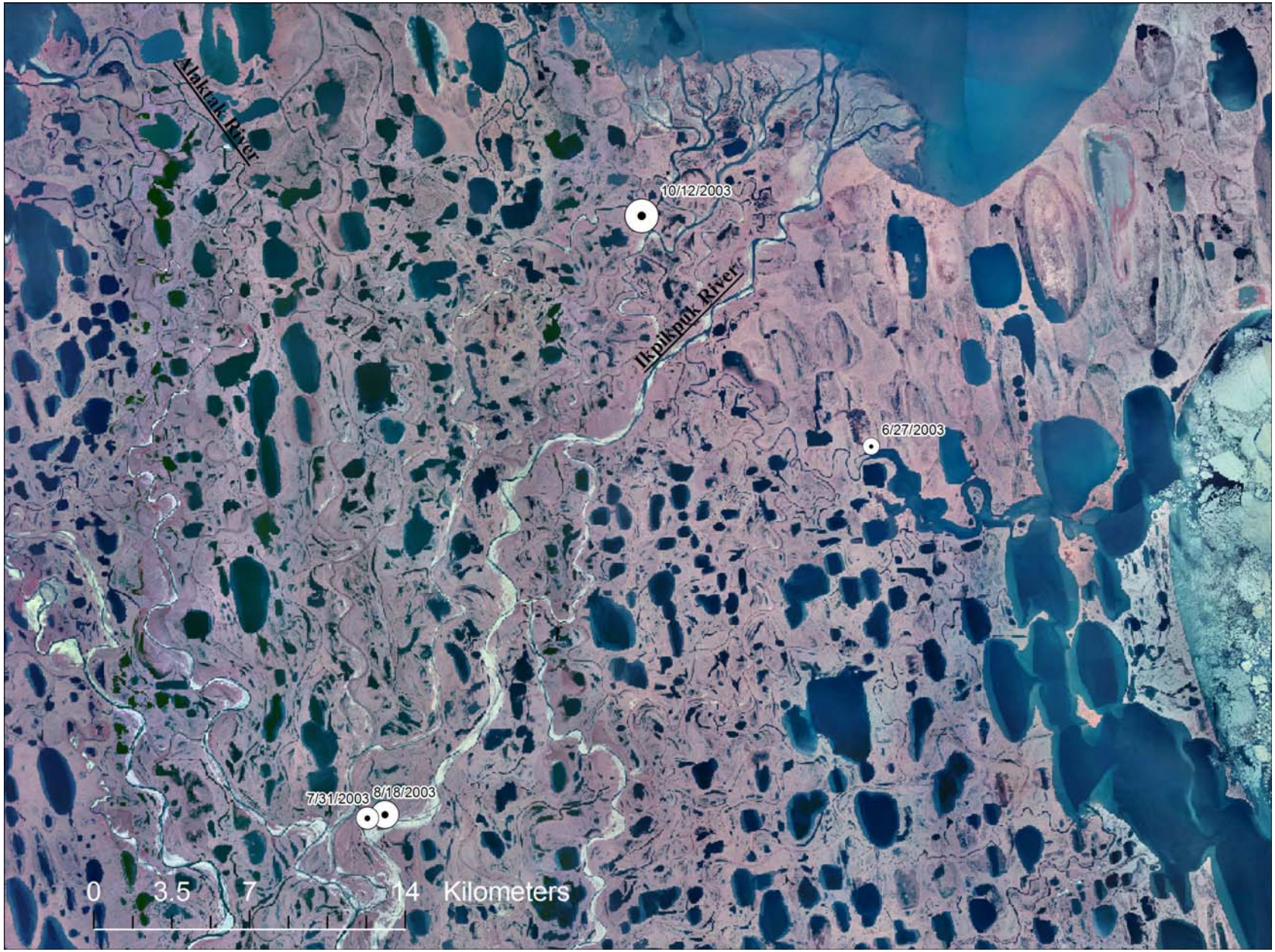
Individual Map 11. Broad whitefish #93 moved into the Ikpikpuk River where it appeared to have been in an isolated pool. The fish subsequently moved into a tributary of the upper Mayoriak River by the following June.



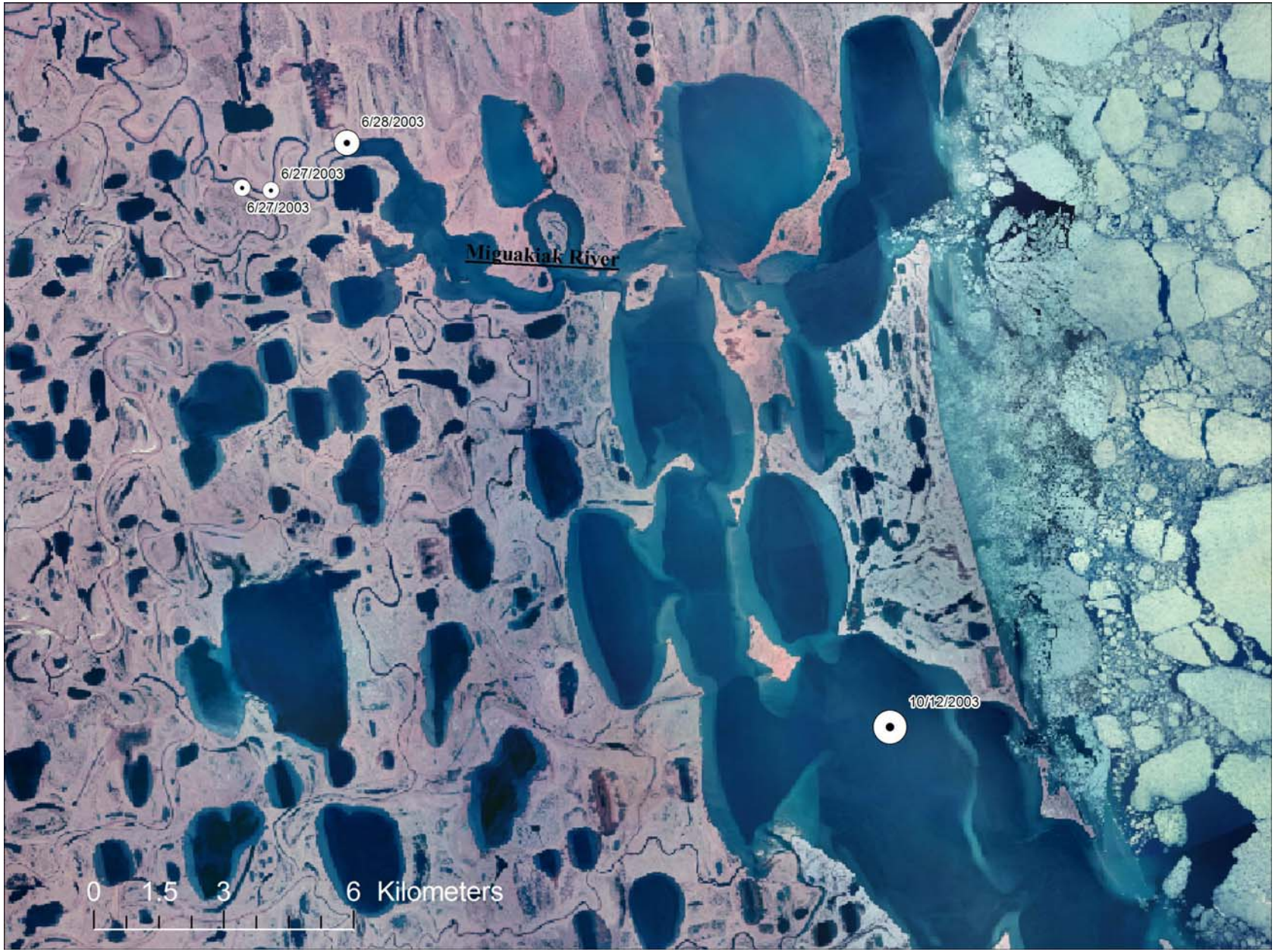
Individual Map 12. Broad whitefish #117 moved to the upper Ikpikpuk during the spawning season and over wintered there in winter 2003/2004 and was again in the area by early August 2004.



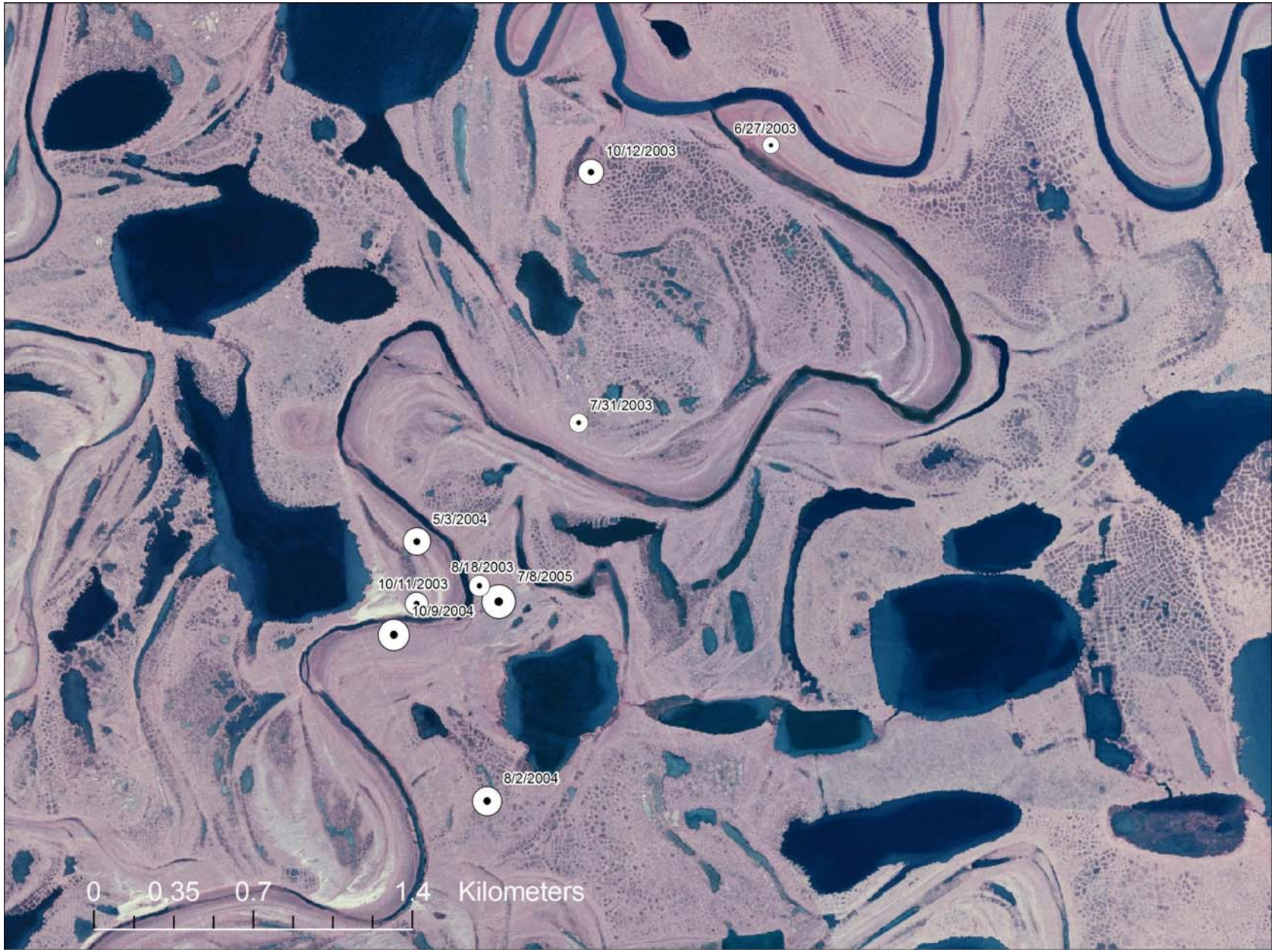
Individual Map 13. Broad whitefish #131 moved into the upper Ikpikpuk River prior to spawning and was not relocated after mid August 2003.



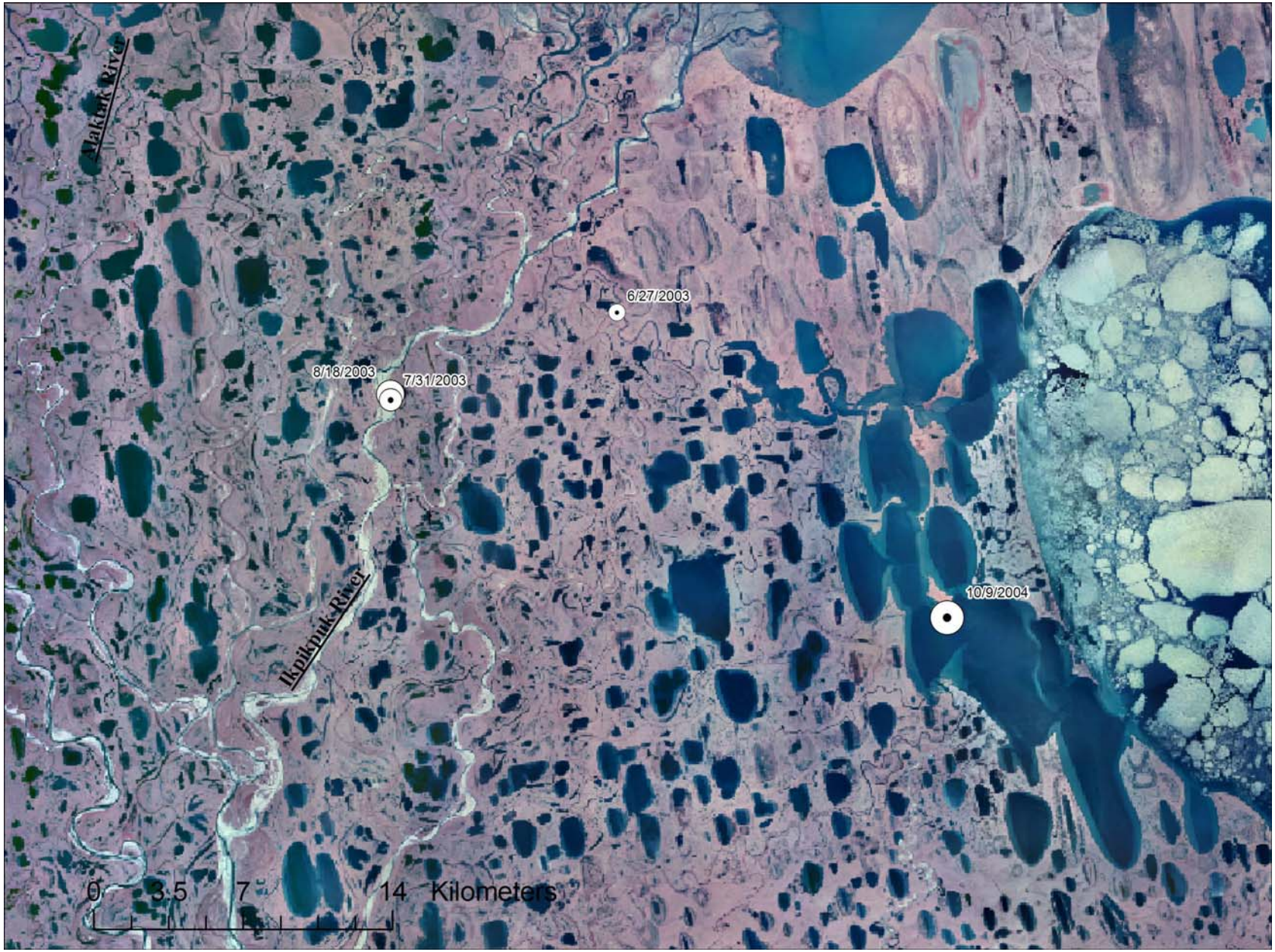
Individual Map 14. Broad whitefish #151 moved into Ikpikpuk River just below the fork that forms the Chipp River. The fish was later relocated wintering in a distributary of the lower river.



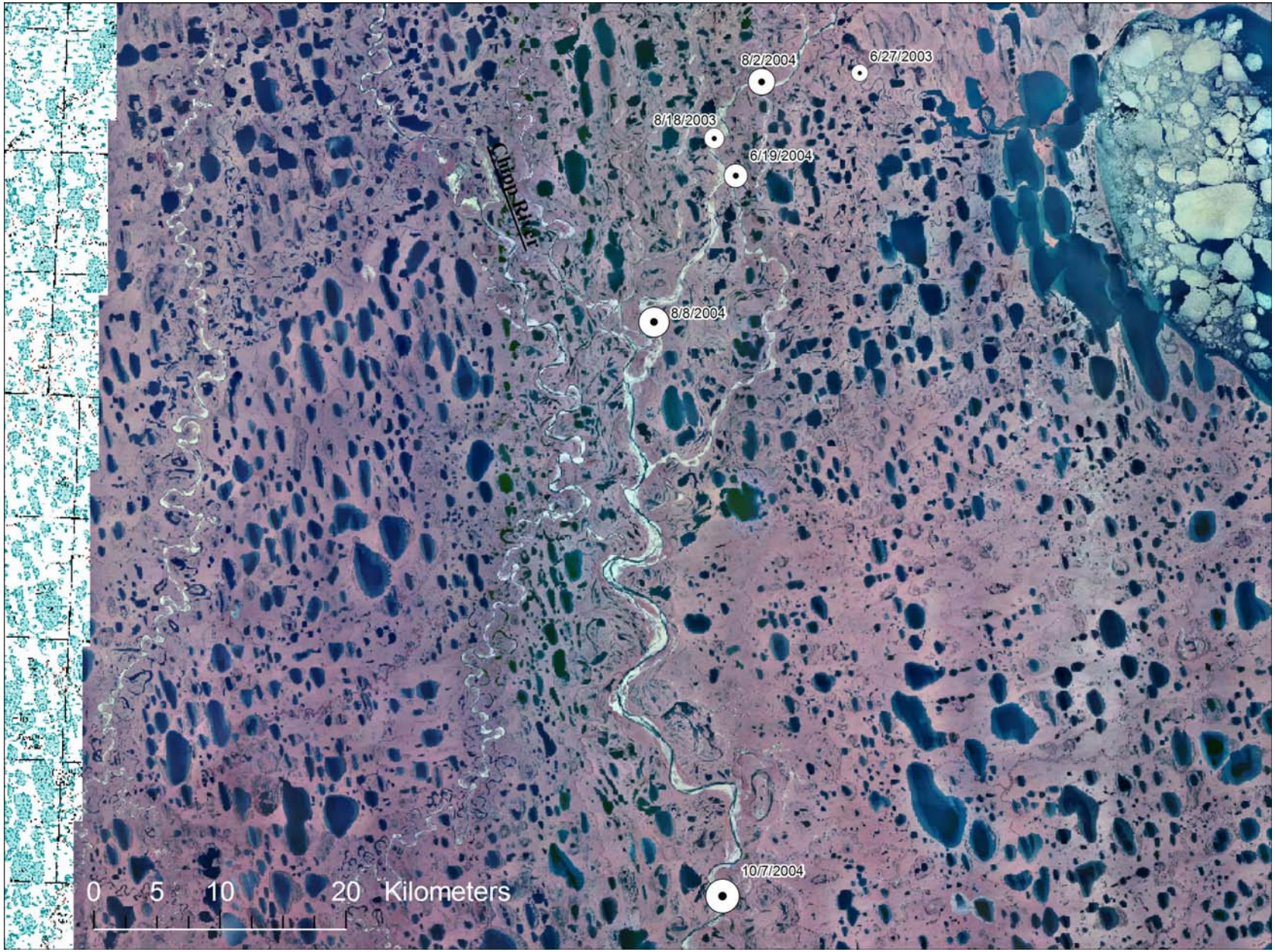
Individual Map 15. Broad whitefish #221 wintered in the coalesced lakes region of the Mayoriak River in 2003 and was not relocated after winter 2003/2004.



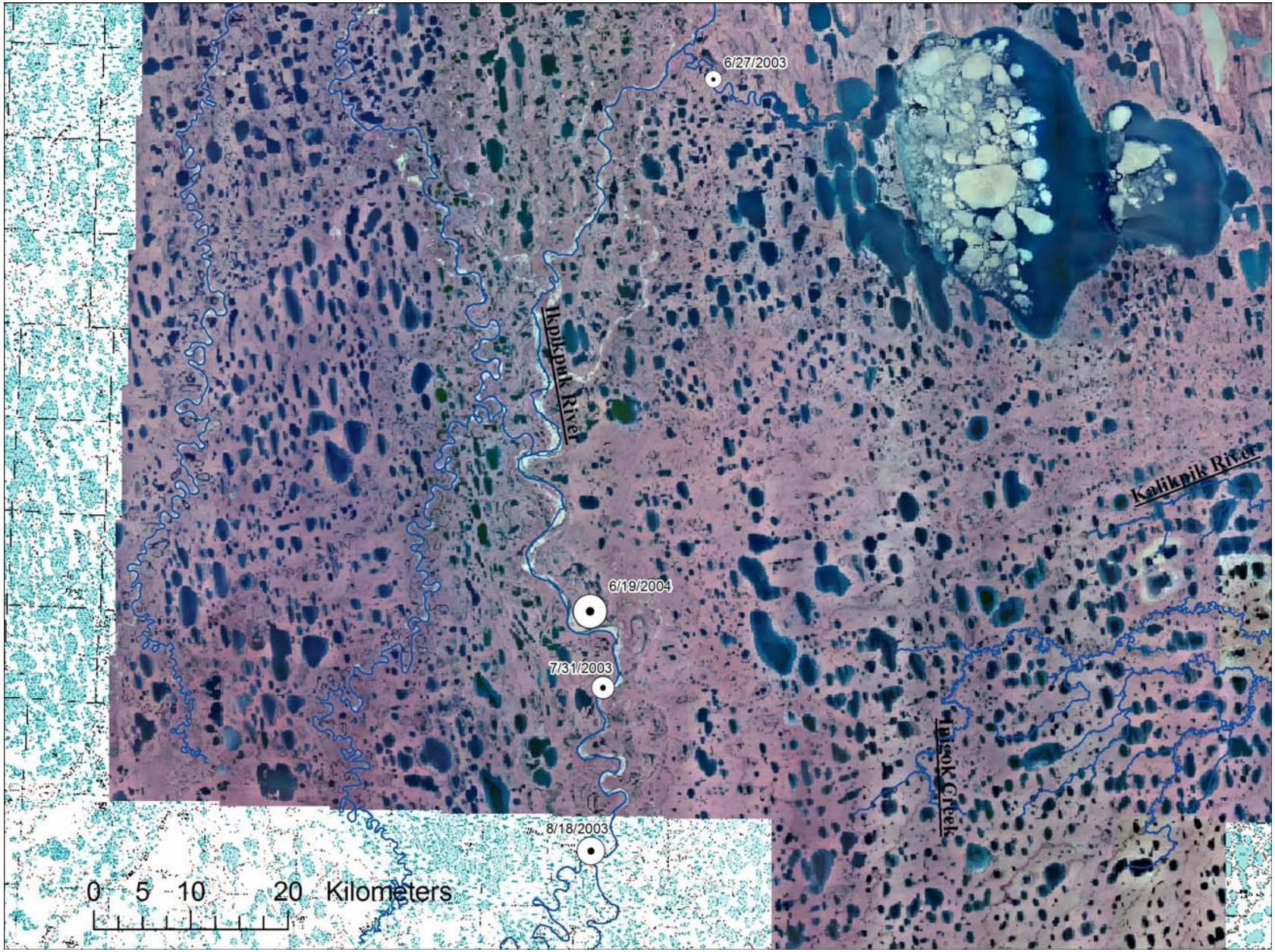
Individual Map 16. Broad whitefish #222 was a post spawning adult at the time of capture and died up-river in the tributary it was tagged in either as a result of the tagging event or its general poor condition after spawning. This tag may have been out of water making pinpointing its location difficult from the air.



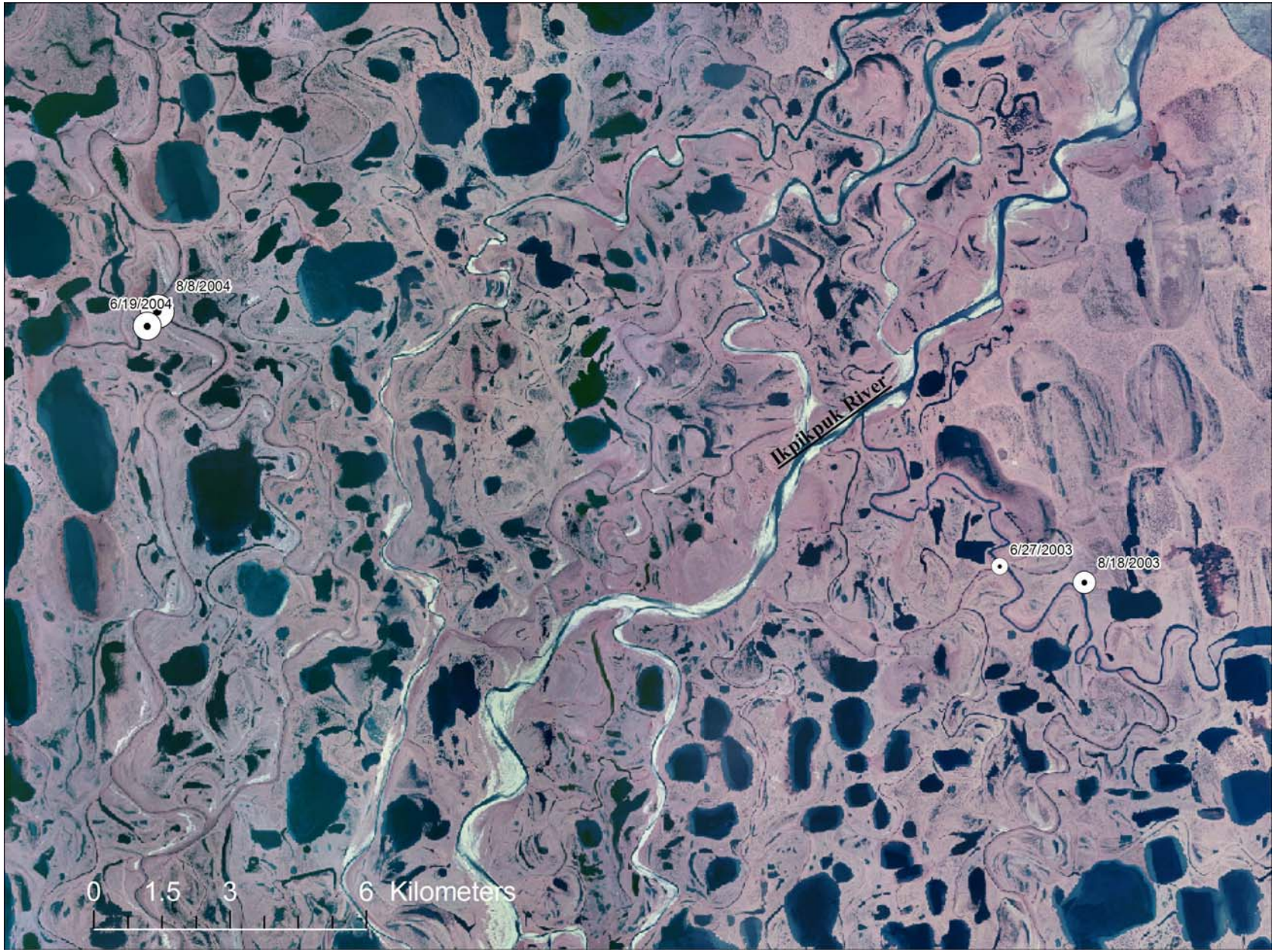
Individual Map 17. Broad whitefish #223 moved into the Ikpikpuk River after tagging and then was not relocated until the following year when it was found overwintering in the coalesced lakes region of the upper Mayoriak River in 2004.



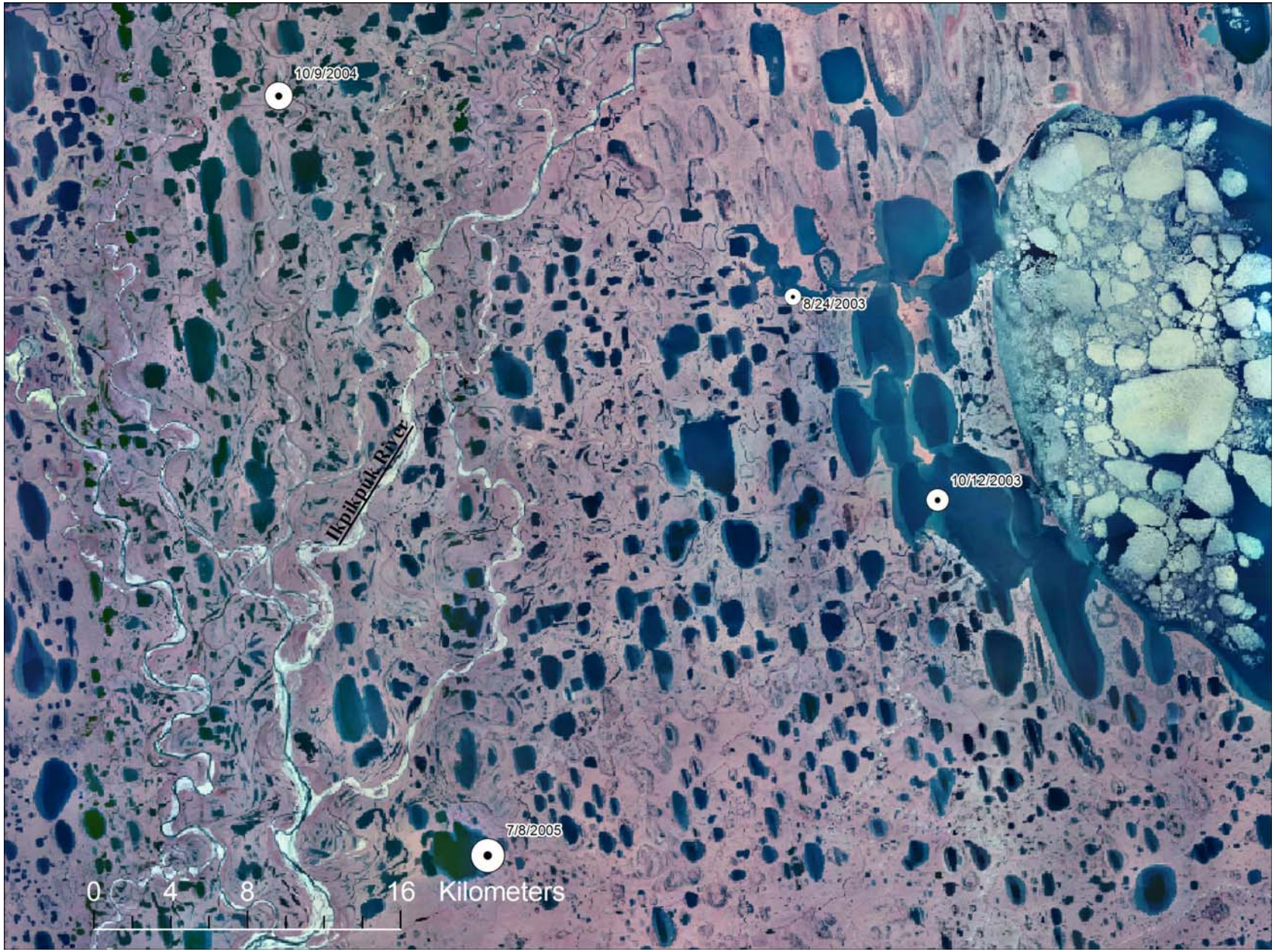
Individual Map 18. Broad whitefish #224 moved into the Ikpikpuk River during 2003 and was in the same area of the river in 2004. The fish was in the upper Ikpikpuk River during or just after the spawning season in early October 2004.



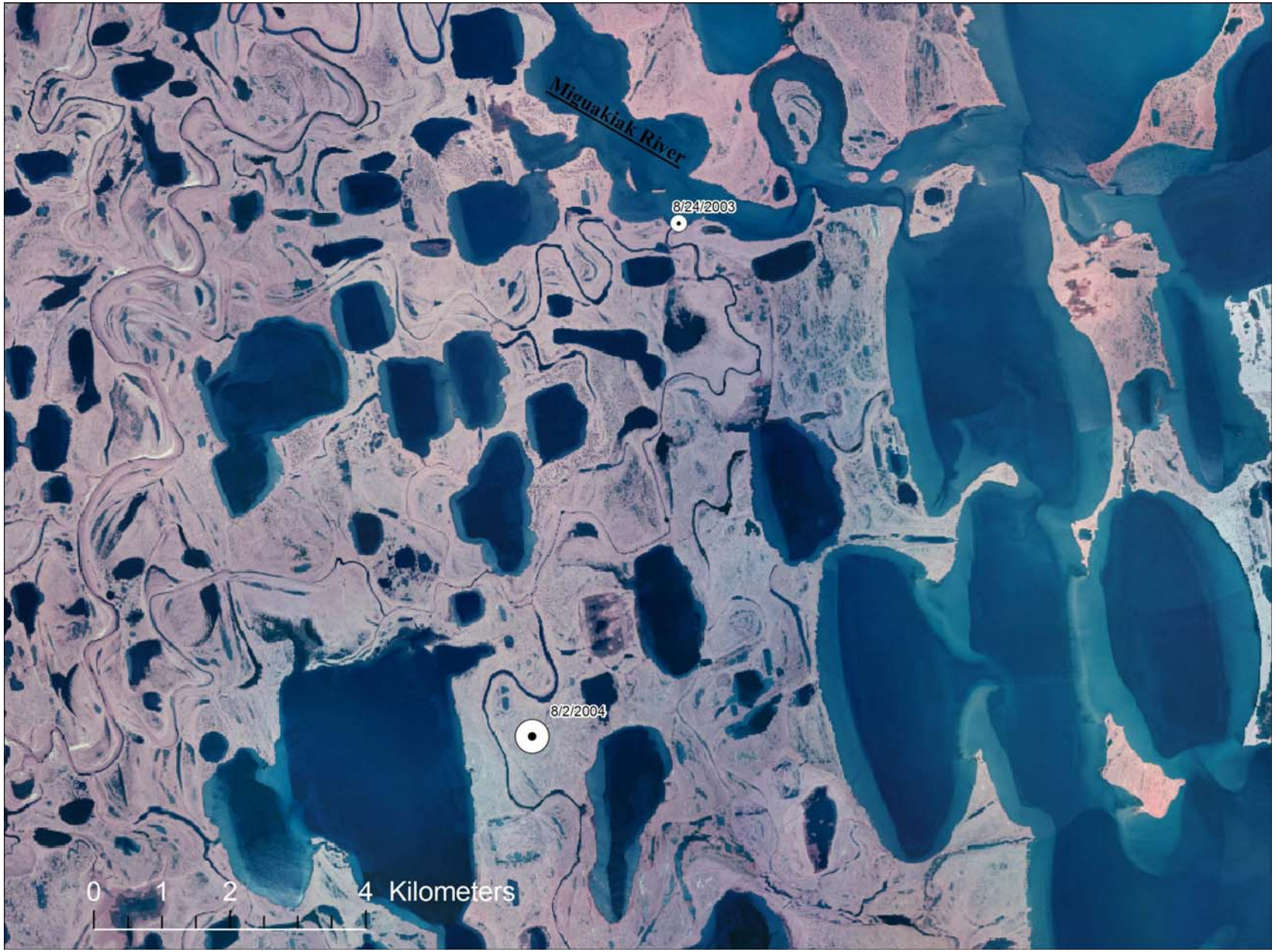
Individual Map 19. Broad whitefish #238 moved into the upper Ikpikpuk River just below the Price River prior to the spawning season in 2003. The fish was still in the upper part of the Ikpikpuk in early summer 2004; the fish was classified as post-spawning adult in June 2003 and would not have been expected to spawn in 2003.



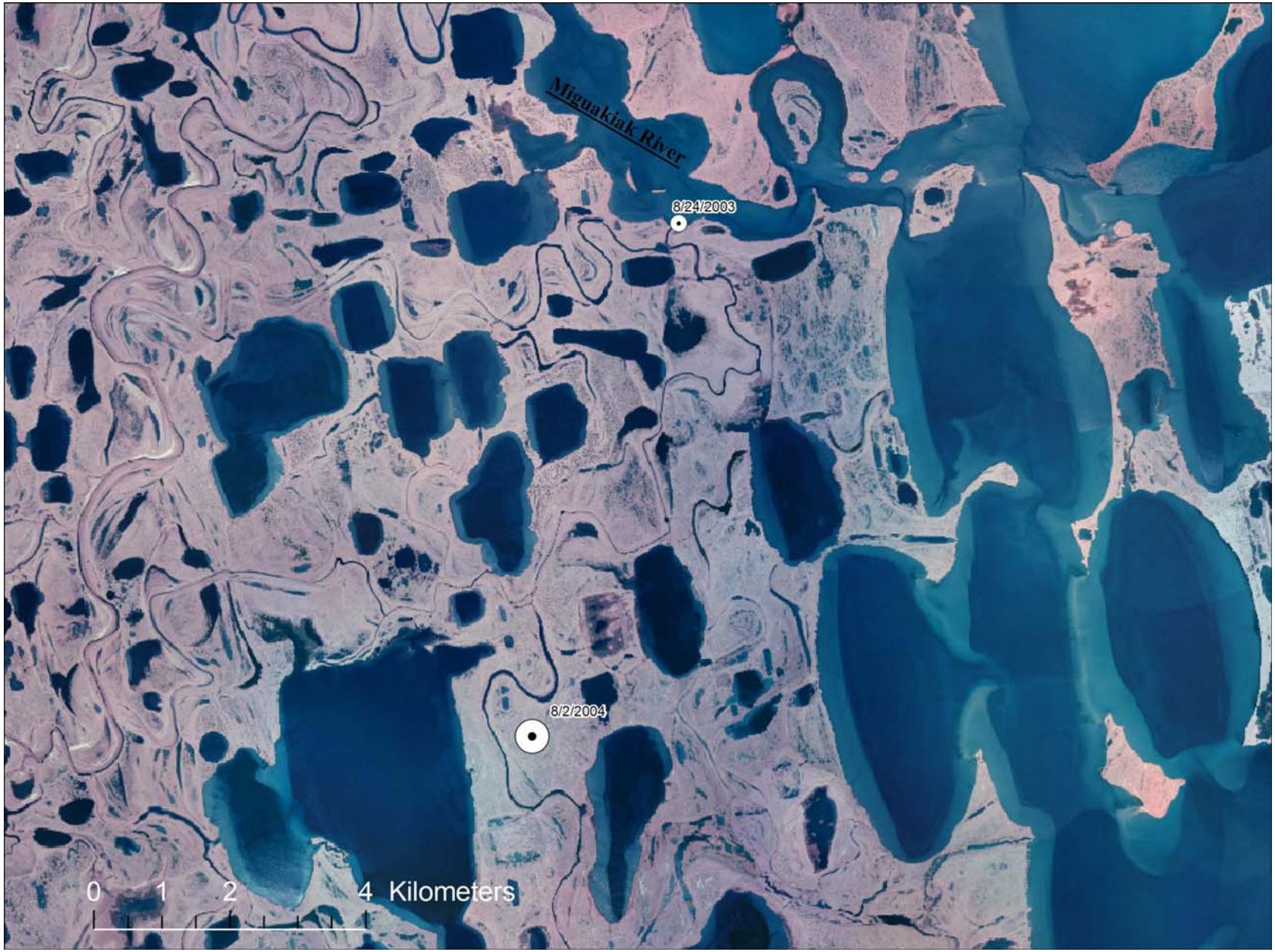
Individual Map 20. Broad whitefish #250 was in the Mayoriak River in June and August 2003 and was later relocated in a distributary channel of the Alaktak River in June and August 2004 in the same location as broad whitefish #73, #424 and #430 (See Individual Map 9).



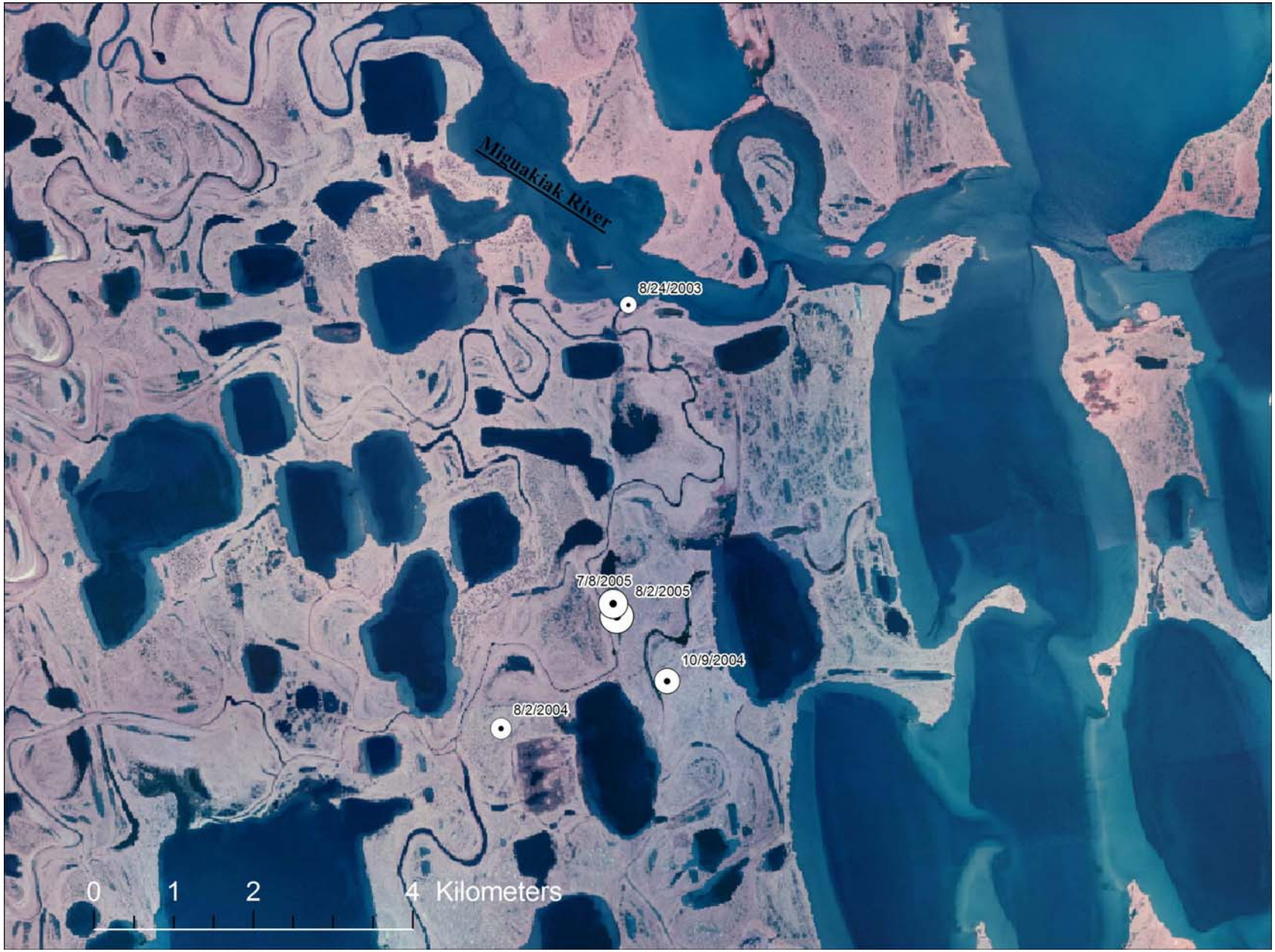
Individual Map 21. Broad whitefish #424 overwintered in the coalesced lakes region of the upper Mayoriak River in 2003 and was not relocated again until October 2004 when it was found in a distributary channel of the Alaktak or Ikpikpuk rivers also used by fish #73, #250 and #430. The fish later returned to the Mayoriak River area and was relocated in a tributary lake with another radio tagged fish in 2005 (See Figure 15).



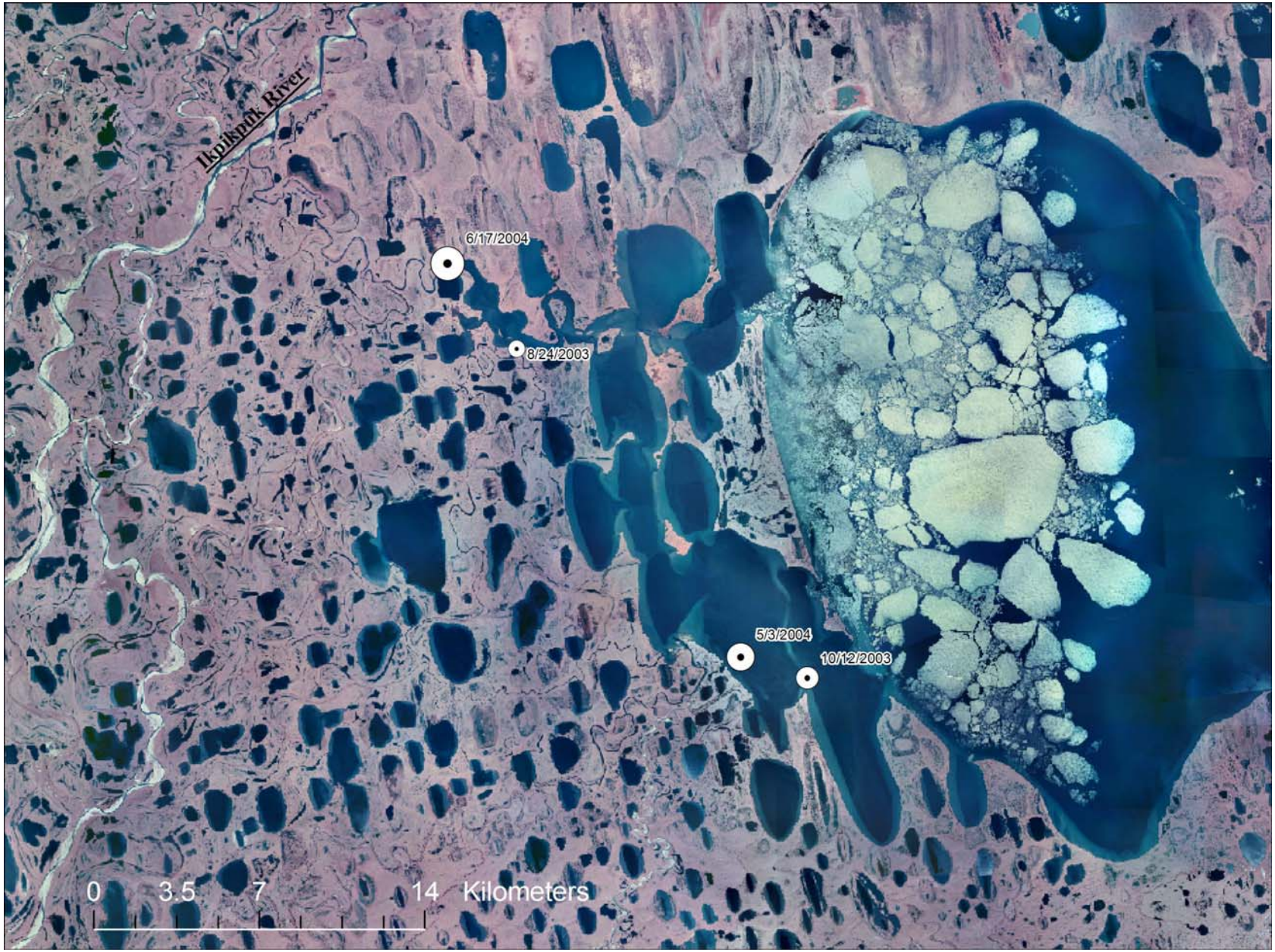
Individual Map 22. Broad whitefish #425 was relocated in a tributary to the Mayoriak adjacent to a large lake used by numerous radio tagged fish (See Figure 14).



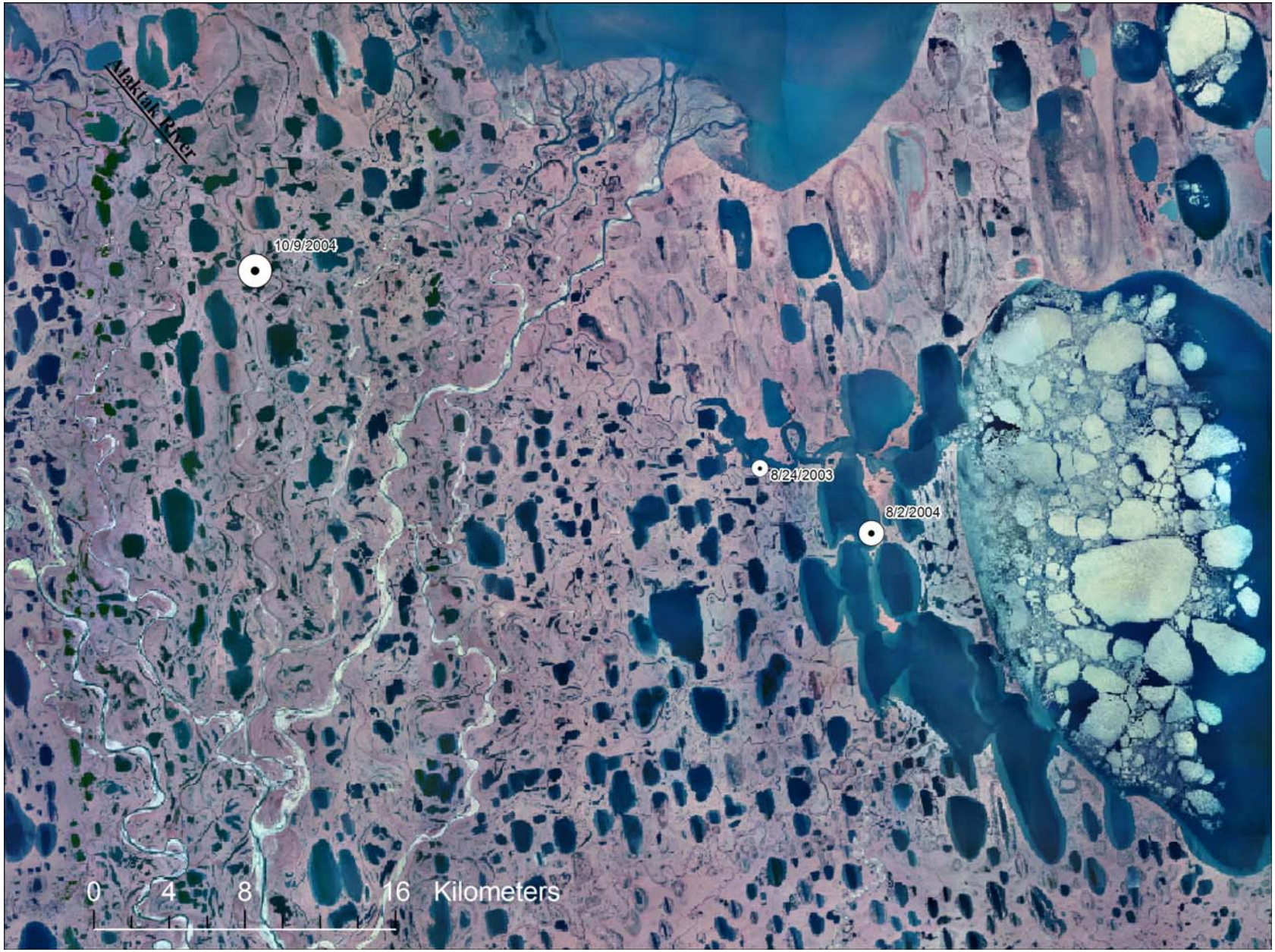
Individual Map 23. Broad whitefish #427 had an identical relocation history to broad whitefish #425 above.



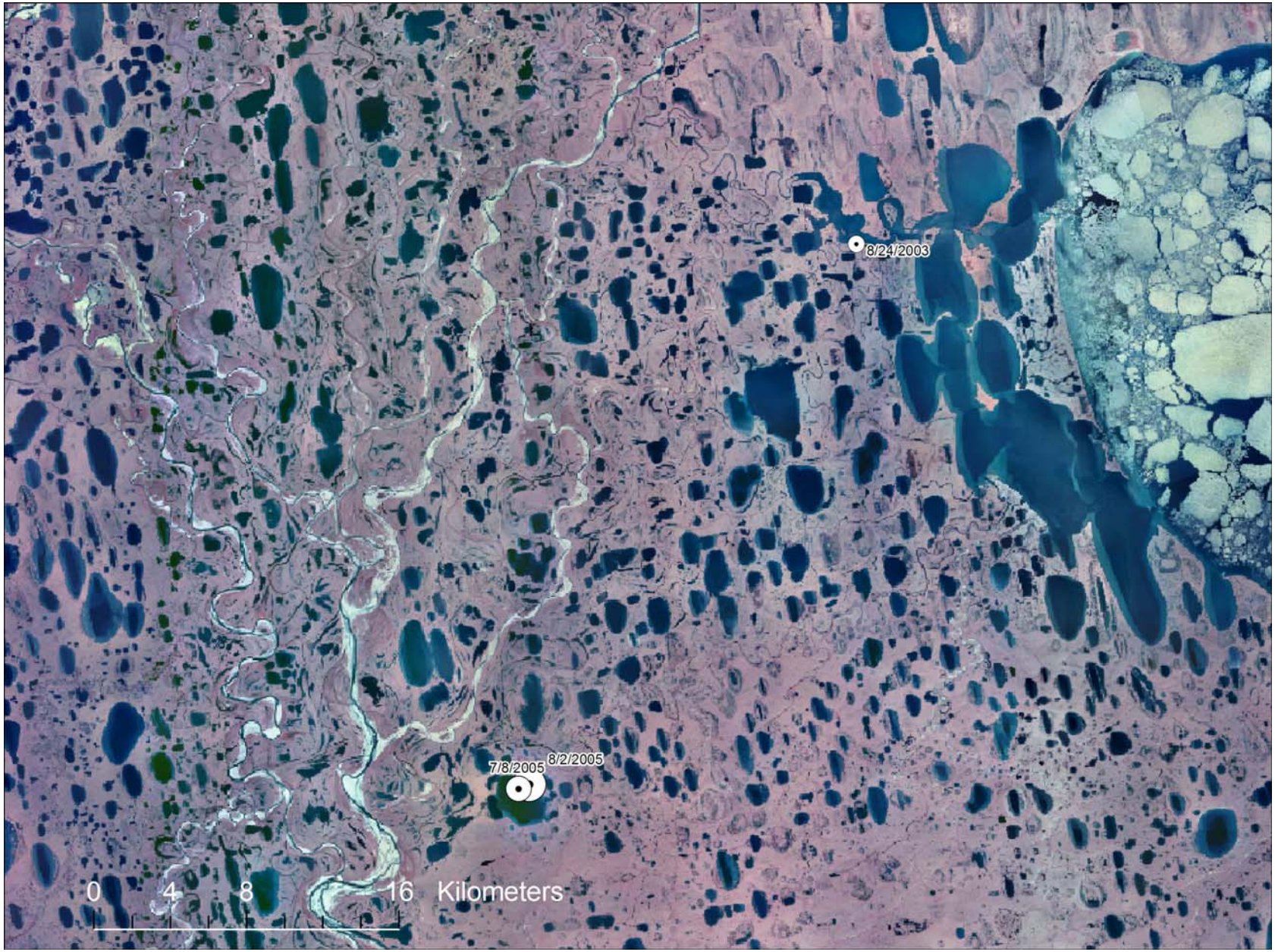
Individual Map 24. Broad whitefish #428 moved into the same area as fish #425 and #428 in 2004 but was later relocated in the shallow outlet channel of a small lake. The fish was next relocated in the tributary of initial tagging in a small deep lake in summer 2005. The lake had no obvious surface water connection to the creek at the time of the relocations.



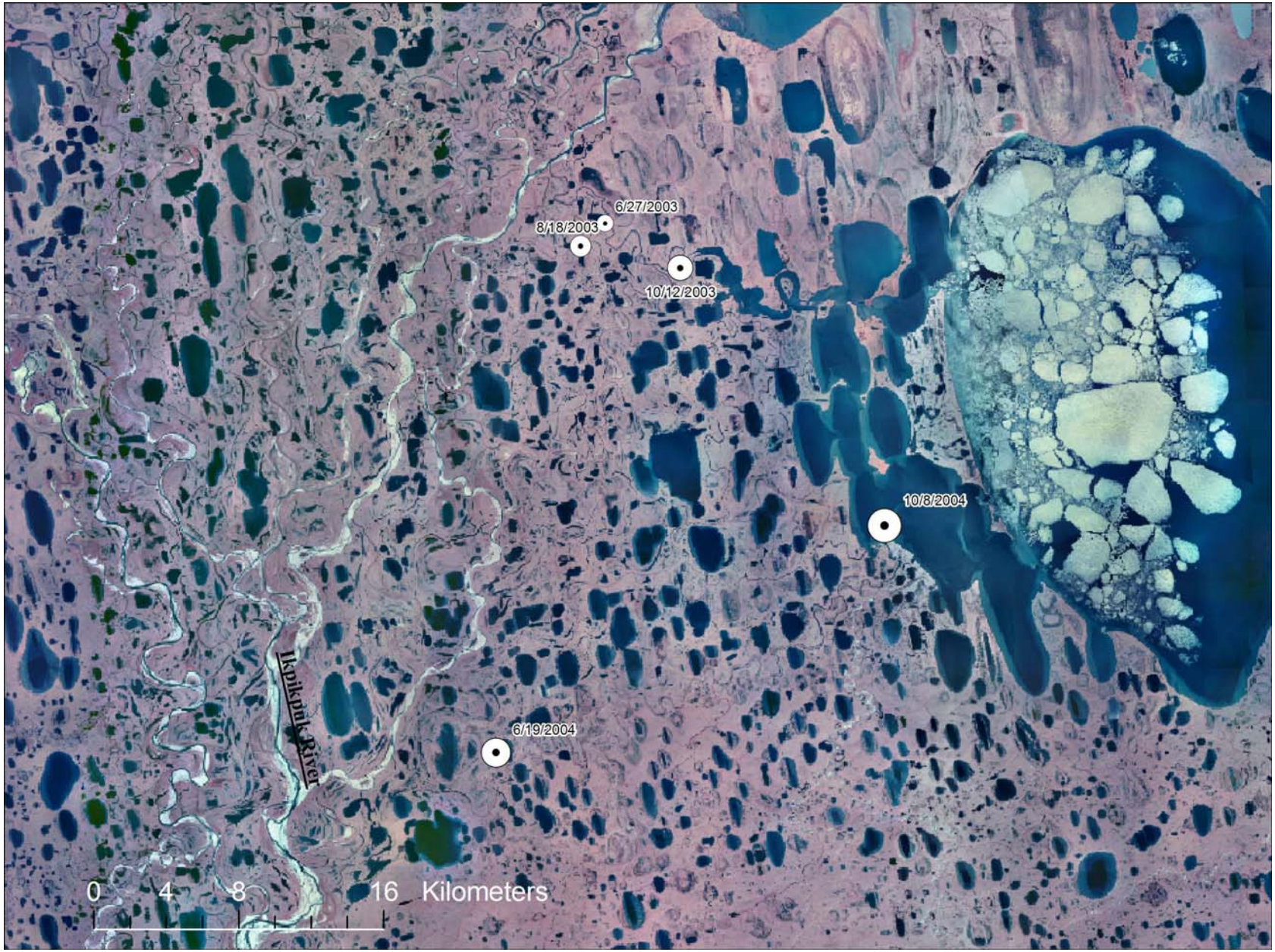
Individual Map 25. Broad whitefish #429 overwintered in the coalesced lakes region of the upper Mayoriak River during winter 2003/2004. The fish was captured in a subsistence net in June 2004 at the mouth of a Mayoriak River tributary.



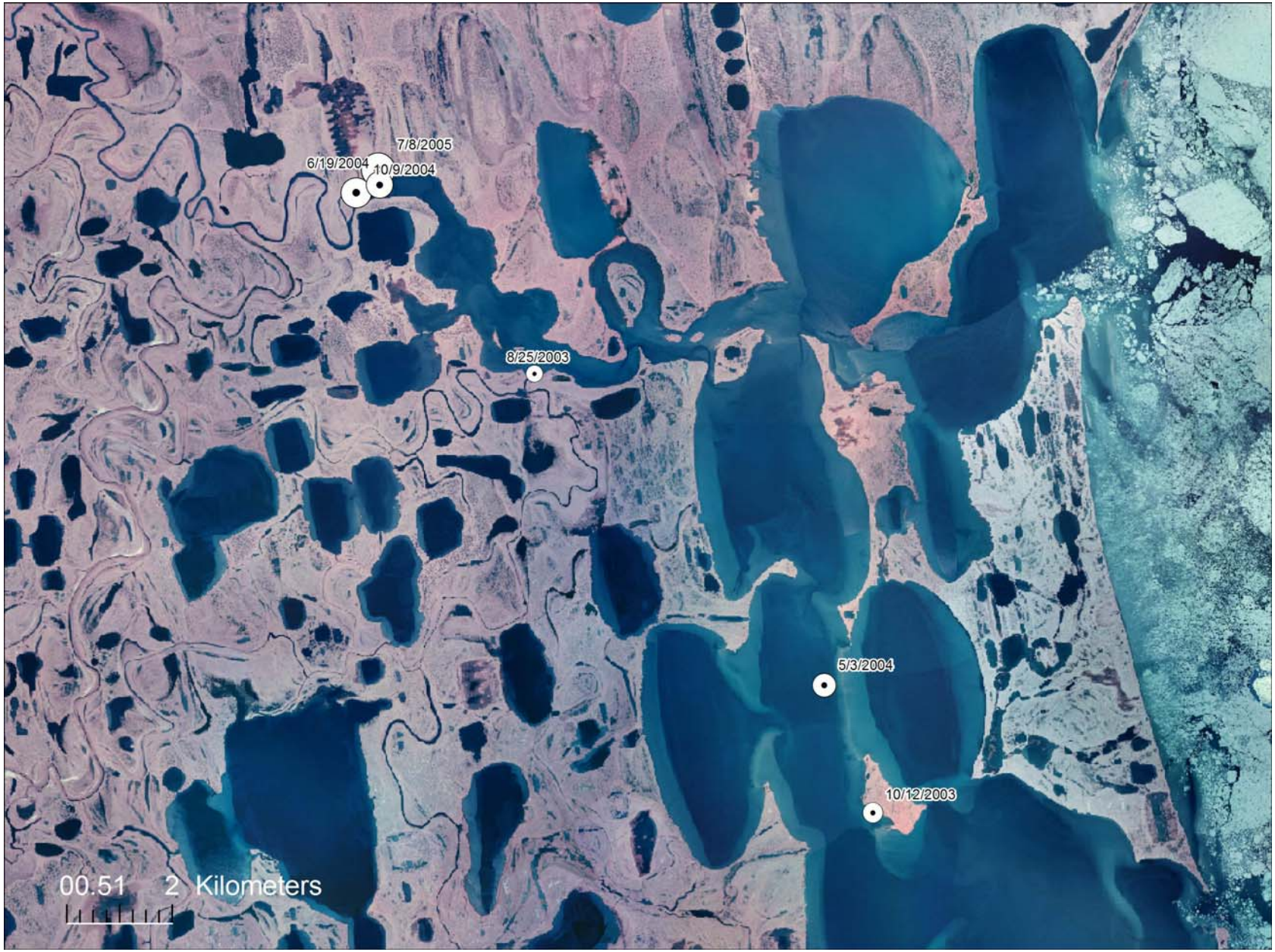
Individual Map 26. Broad whitefish #430 was in the Mayoriak River area for at least some portion of 2004, the year following tagging. However, in two months time in 2004 the fish moved out of the Mayoriak and into a distributary channel of the Alaktak/Ikpikpuk complex. The fish was relocated in the same location as fish #424, #373 and #250 in October 2004 (See Figure 15 and Individual Map 9).



Individual Map 27. Broad whitefish #434 was first relocated nearly two years after it had been tagged. The fish was relocated in July and August 2005, in a lake in the upper reaches of a Mayoriak River tributary with fish #424 (See Figure 15).

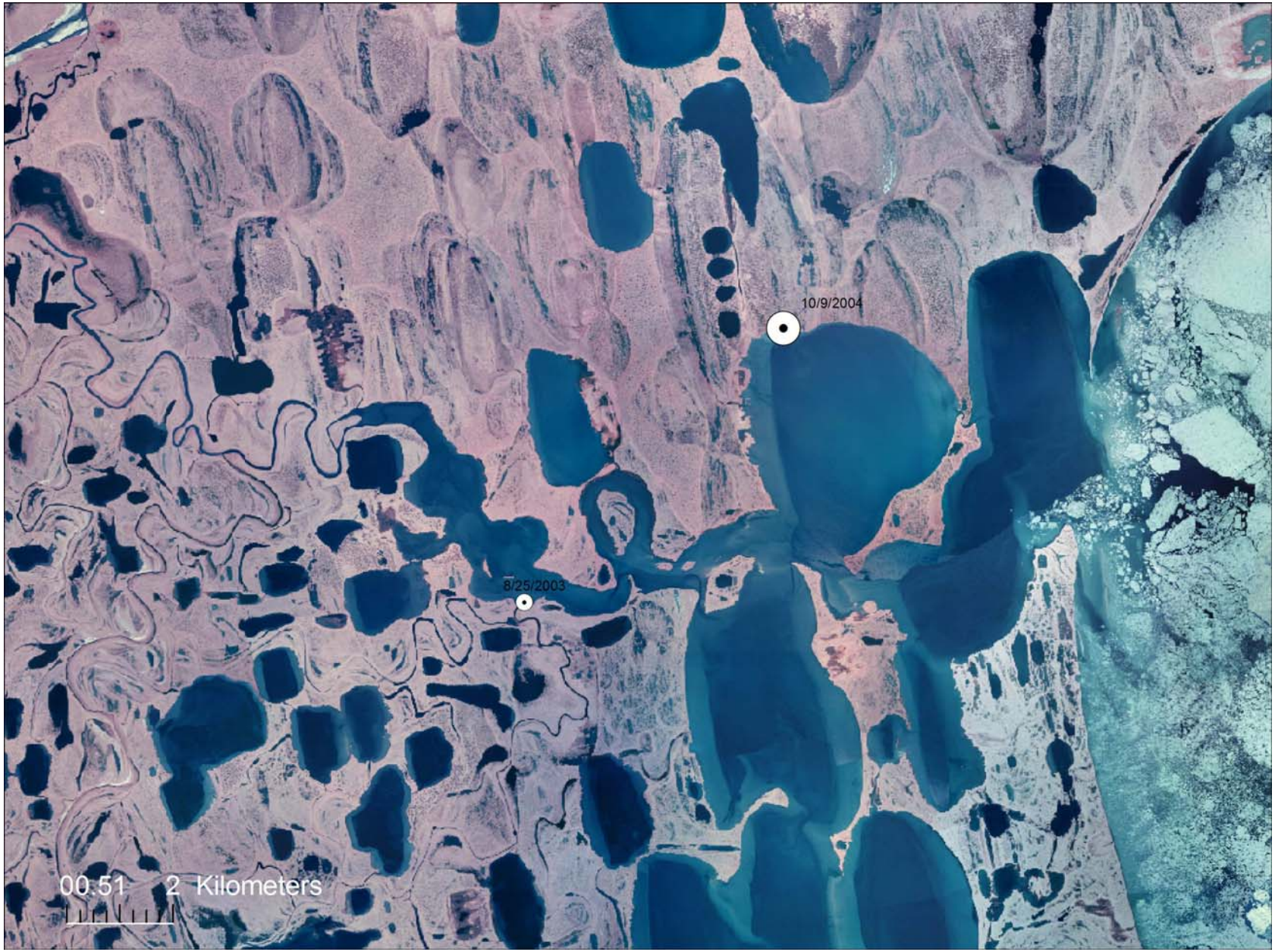


Individual Map 28. Broad whitefish #452 was judged to be a pre-spawning adult when captured in 2003. The fish appears to have spent the spawning season and winter 2003/2004 in the Mayoriak River. The fish moved into a lake with fish #487 in the upper reaches of a Mayoriak River tributary for summer 2004 (See Figure 15) and wintered in the coalesced lakes region in winter 2004/2005. The lake used in 2004 has a very limited period of surface water connection to the creek.

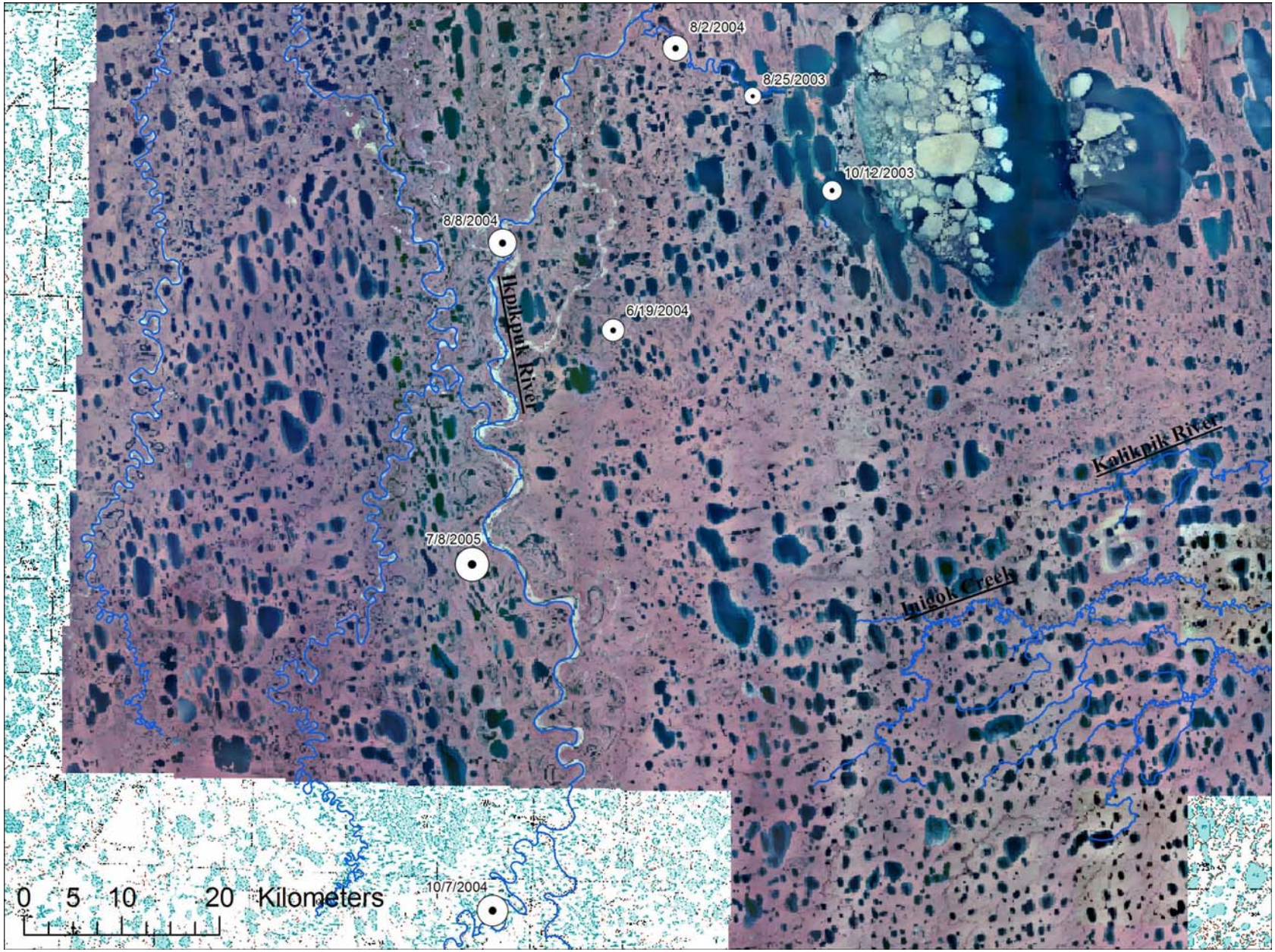


Individual Map 29. Broad whitefish #484 wintered in the coalesced lakes area of the Mayoriak river in winter 2003/2004. The fish moved to the middle Mayoriak during summer 2004 where it may have been captured at a subsistence net location or died. It is believed that the transmitter was not in water after July 2004.

Individual Map 30. Broad whitefish #485 wintered in the coalesced lakes area of the upper Mayoriak River in winter 2003/2004. The fish returned to the same Mayoriak tributary where it had been tagged in both 2004 and 2005.

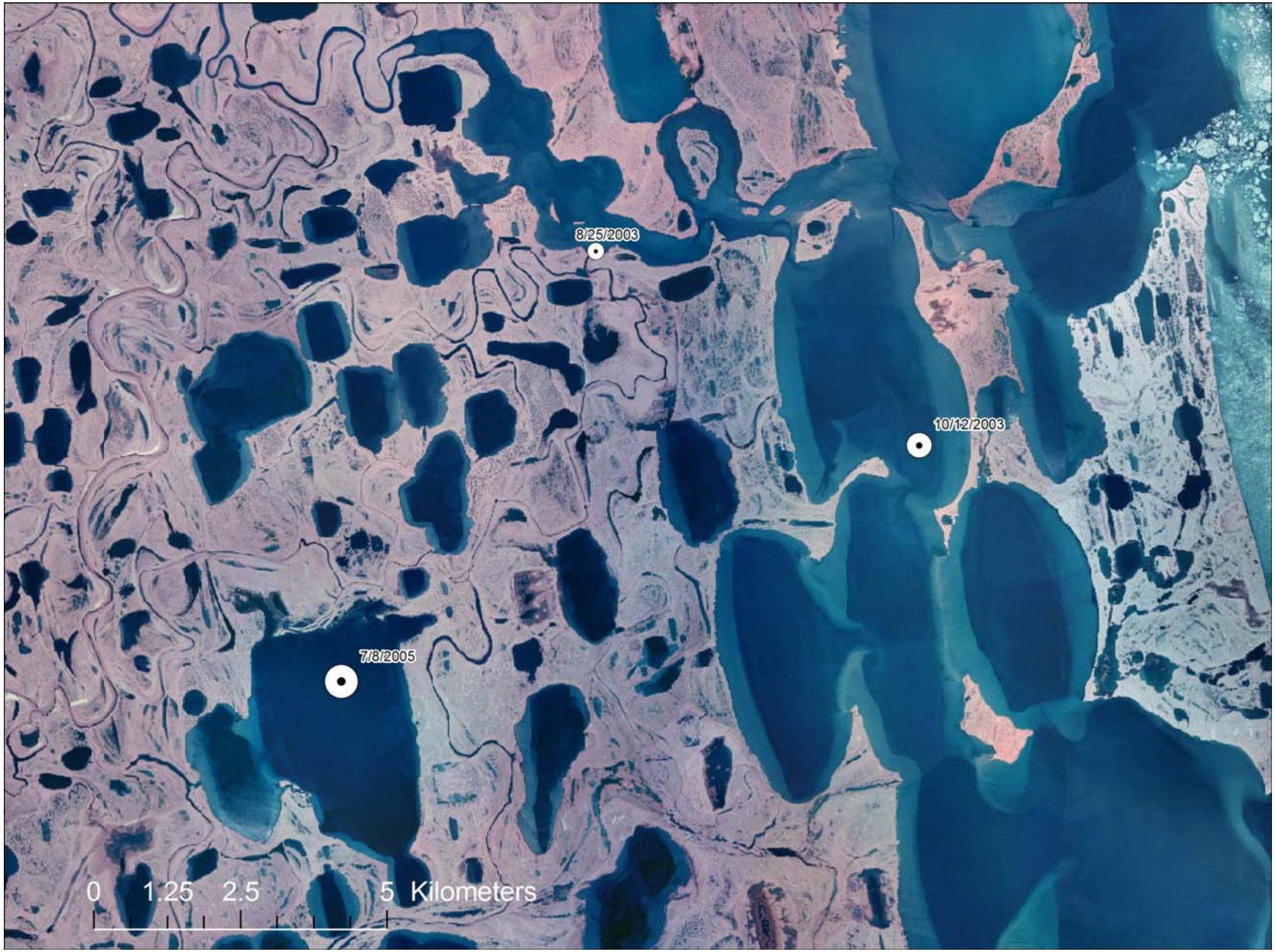


Individual Map 31. Broad whitefish #486 was relocated only once after it was radio tagged, however; the fish was relocated in a northern lake of the coalesced lakes area in the upper Mayoriak the year after it was tagged.

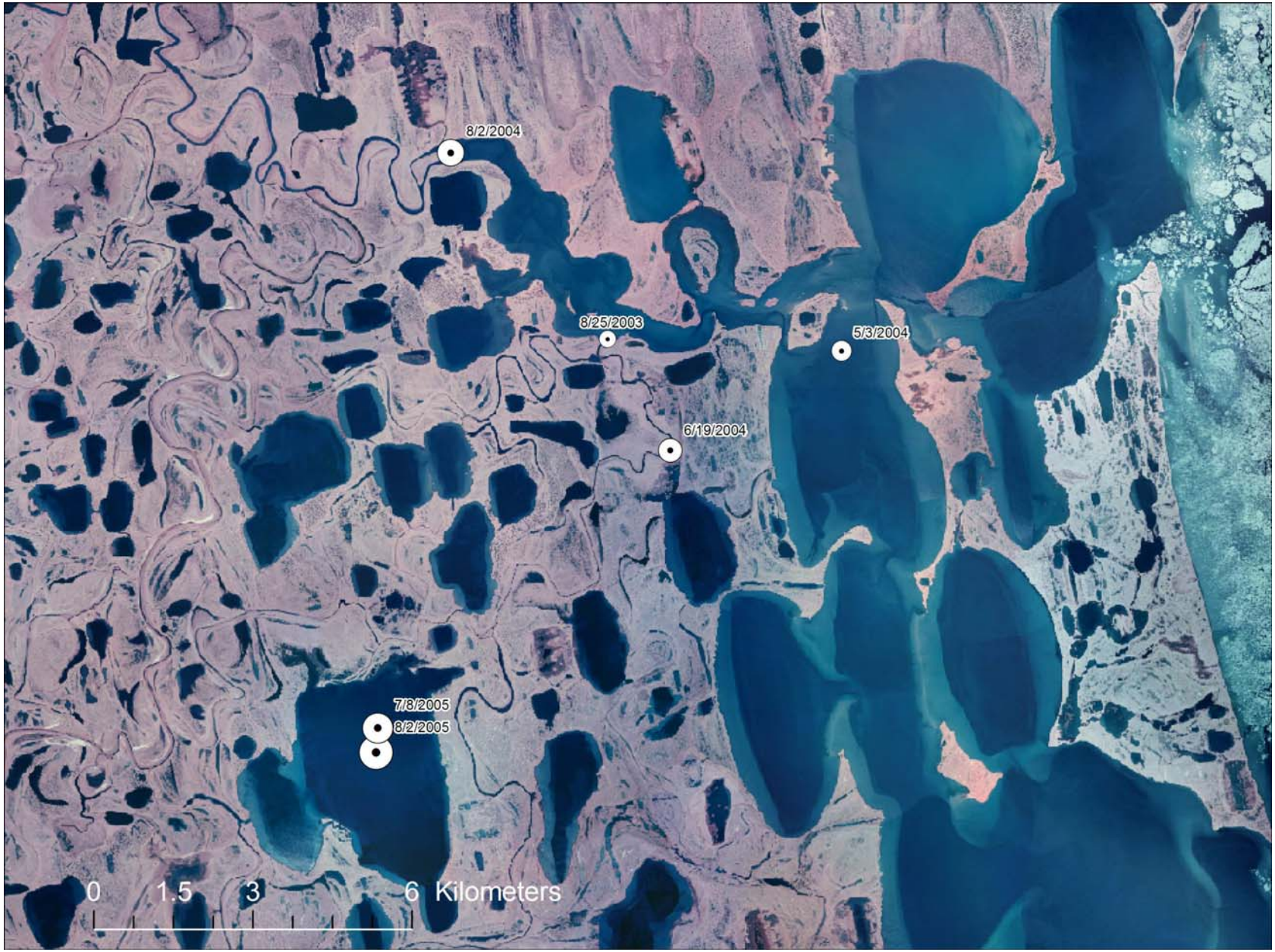


Individual Map 32. Broad whitefish #487 wintered in the coalesced lakes region of the Mayoriak River in winter 2003/2004. The fish was in a small lake in the upper reaches of a Mayoriak River tributary with fish # 452 in June 2004 (See Figure 15). In August 2004, the fish was rapidly moving upstream in the Ikpikpuk River and was relocated in a bend of the lower Titaluk River in October 2004. In July 2005, the fish was relocated in a small lake in a small tributary to the upper Ikpikpuk River.

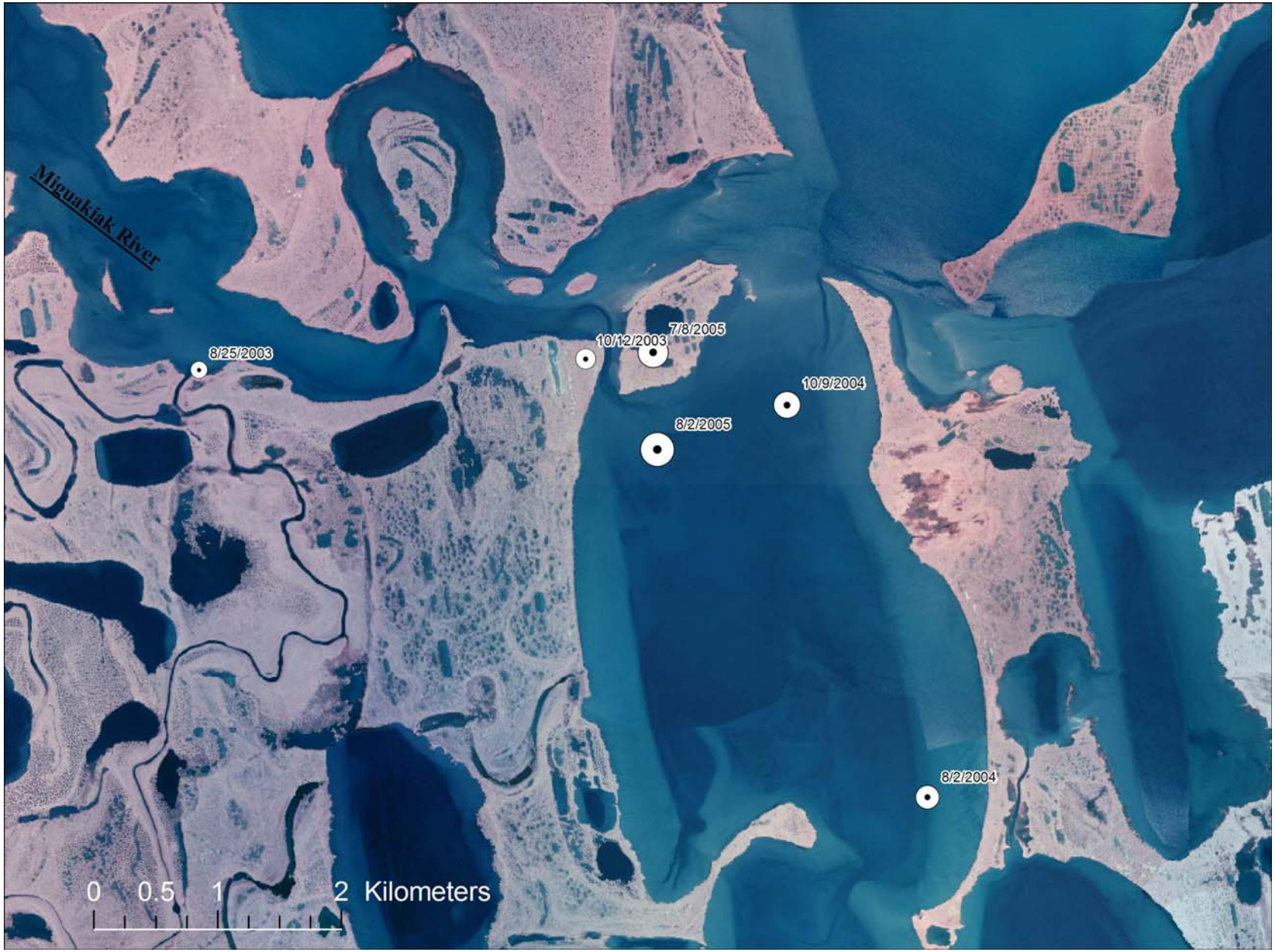
Individual Map 33. Broad whitefish #488 wintered in the coalesced lakes region of the Mayoriak River in winter 2003/2004. The fish returned to the drainage it was tagged in 2004 and was relocated in a lake within the system. The lake is just downstream from a lake used by numerous radio tagged fish (See Figure 14). In July 2005, the fish was again relocated in the same drainage it had been radio tagged nearly two years before.



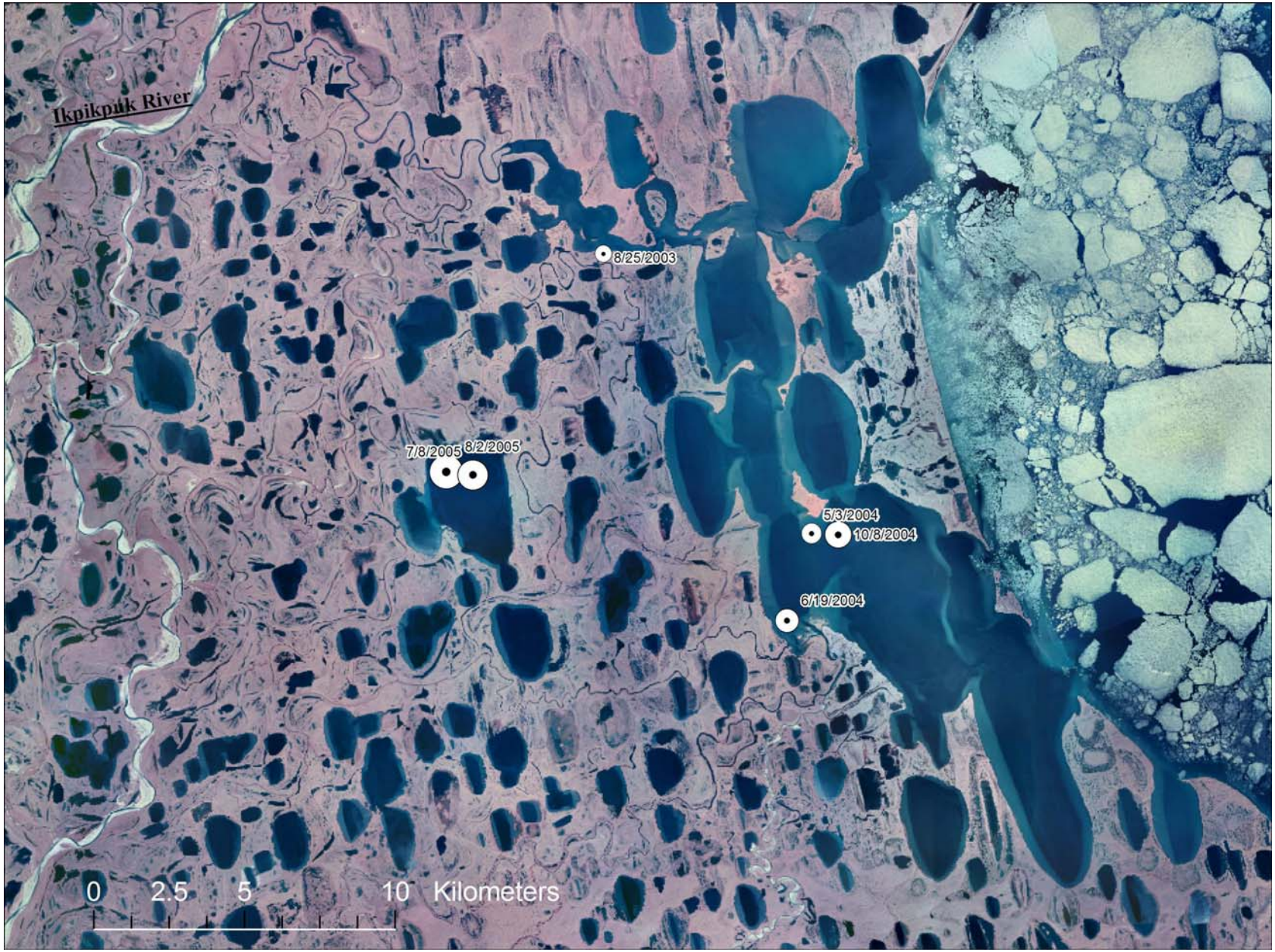
Individual Map 34. Broad whitefish #489 was 358mm long when tagged in 2003 and was the smallest fish tagged in this study. The fish wintered in the coalesced lakes area in winter 2003/2004. The fish returned to the drainage of initial tagging, at least in 2005, and was relocated in a lake used by numerous other radio tagged fish (See Figure 14).



Individual Map 35. Broad whitefish #491 wintered in the coalesced lakes area of the Mayoriak River in winter 2003/2004. The fish returned to the system it was tagged in during both 2004 and 2005. In 2005 the fish was in a lake used by several other radio tagged fish (See Figure 14).

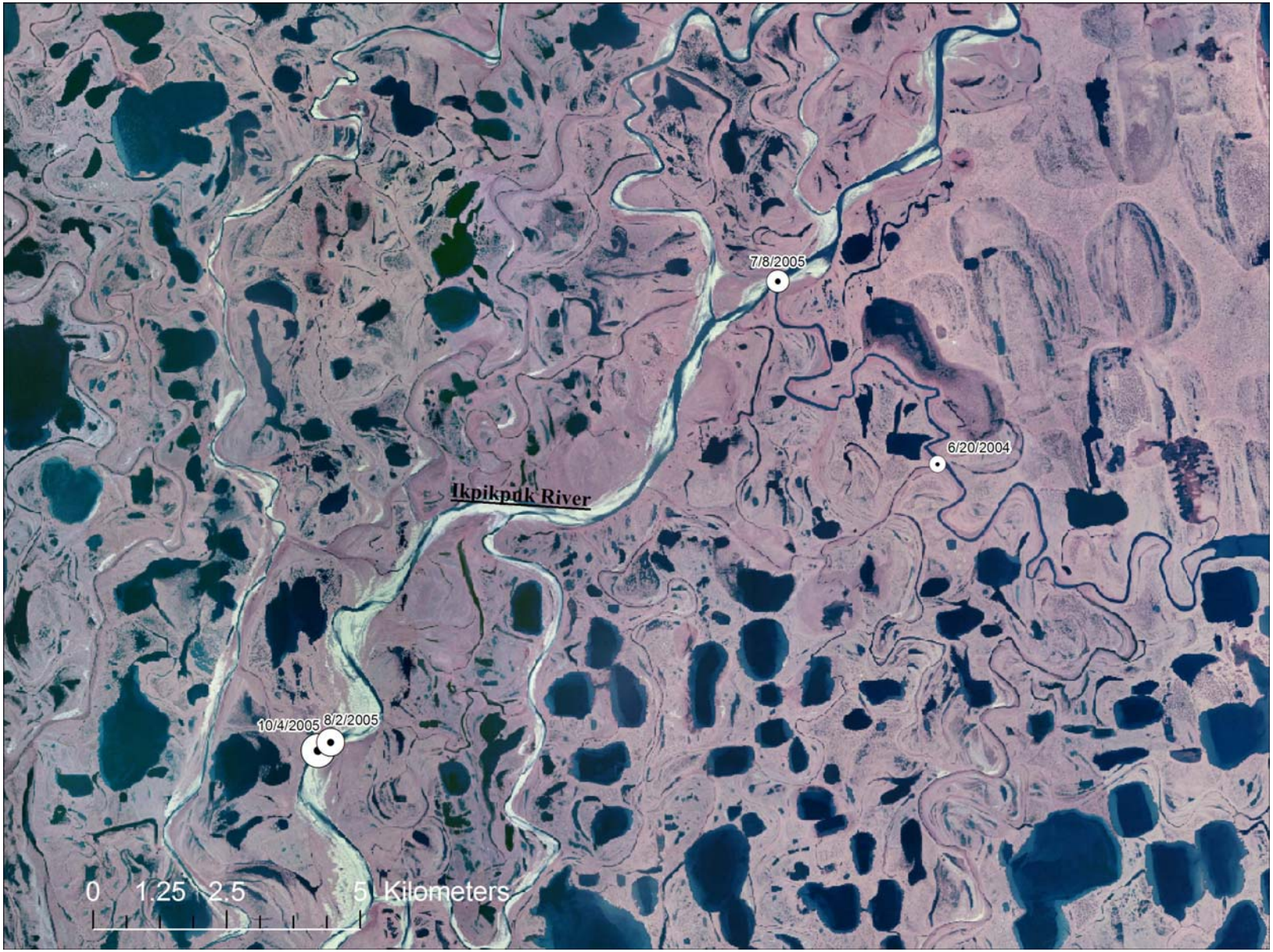


Individual Map 36. Broad whitefish #493 wintered in the coalesced lakes region of the Mayoriak River in winter 2003/2004. It appears likely that this fish did not survive the winter.



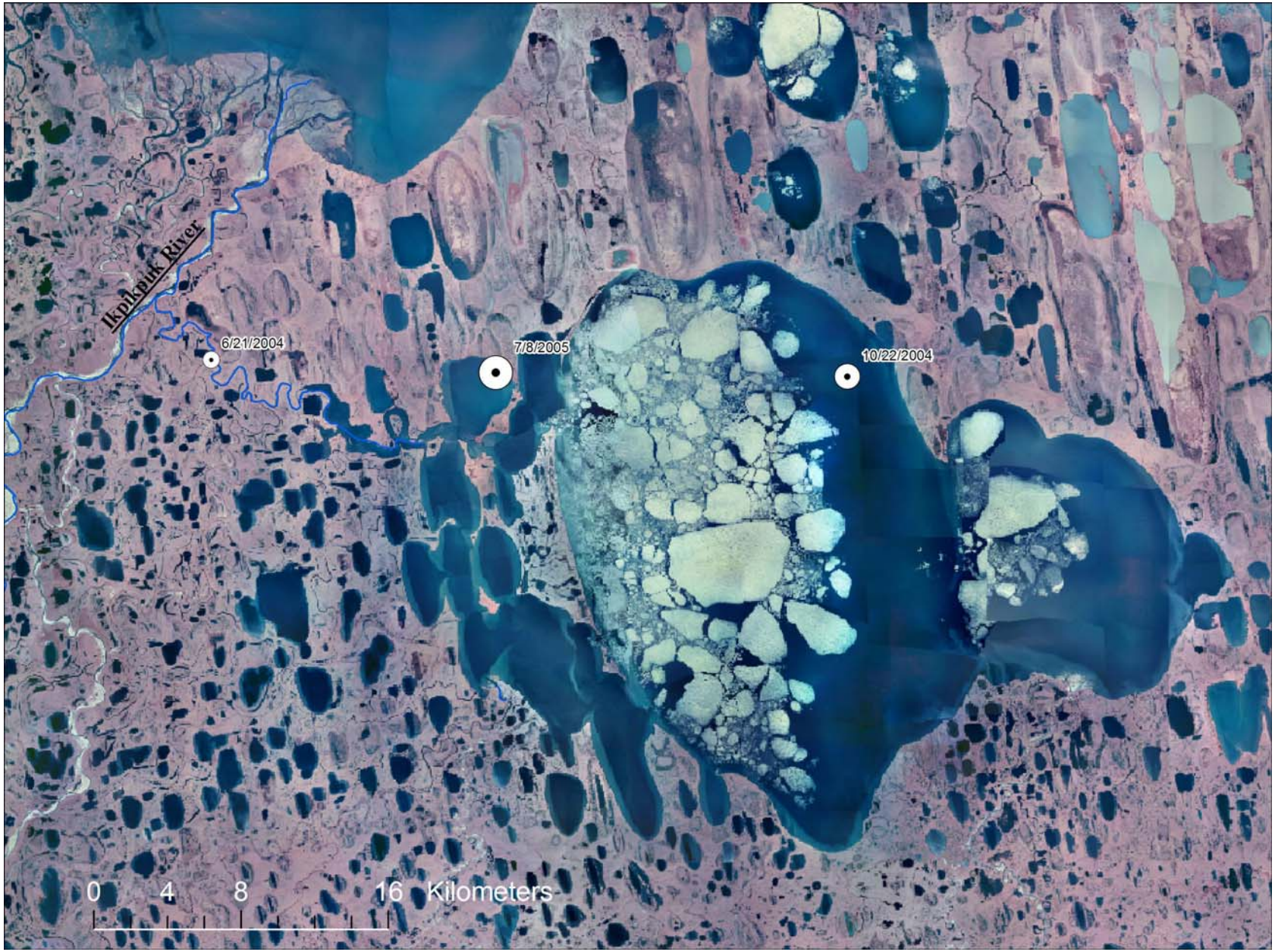
Individual Map 37. Broad whitefish #496 appears to have remained in the Mayoriak/Teshekpuk Lake area throughout our study. The fish wintered in the coalesced lakes area in winters 2003/2004 and 2004/2005 and then, in 2005, returned to the drainage it was tagged in. The fish was relocated in the same lake as several other fish radio tagged in our study (See Figure 14).

2004 Radio Tagged Broad Whitefish

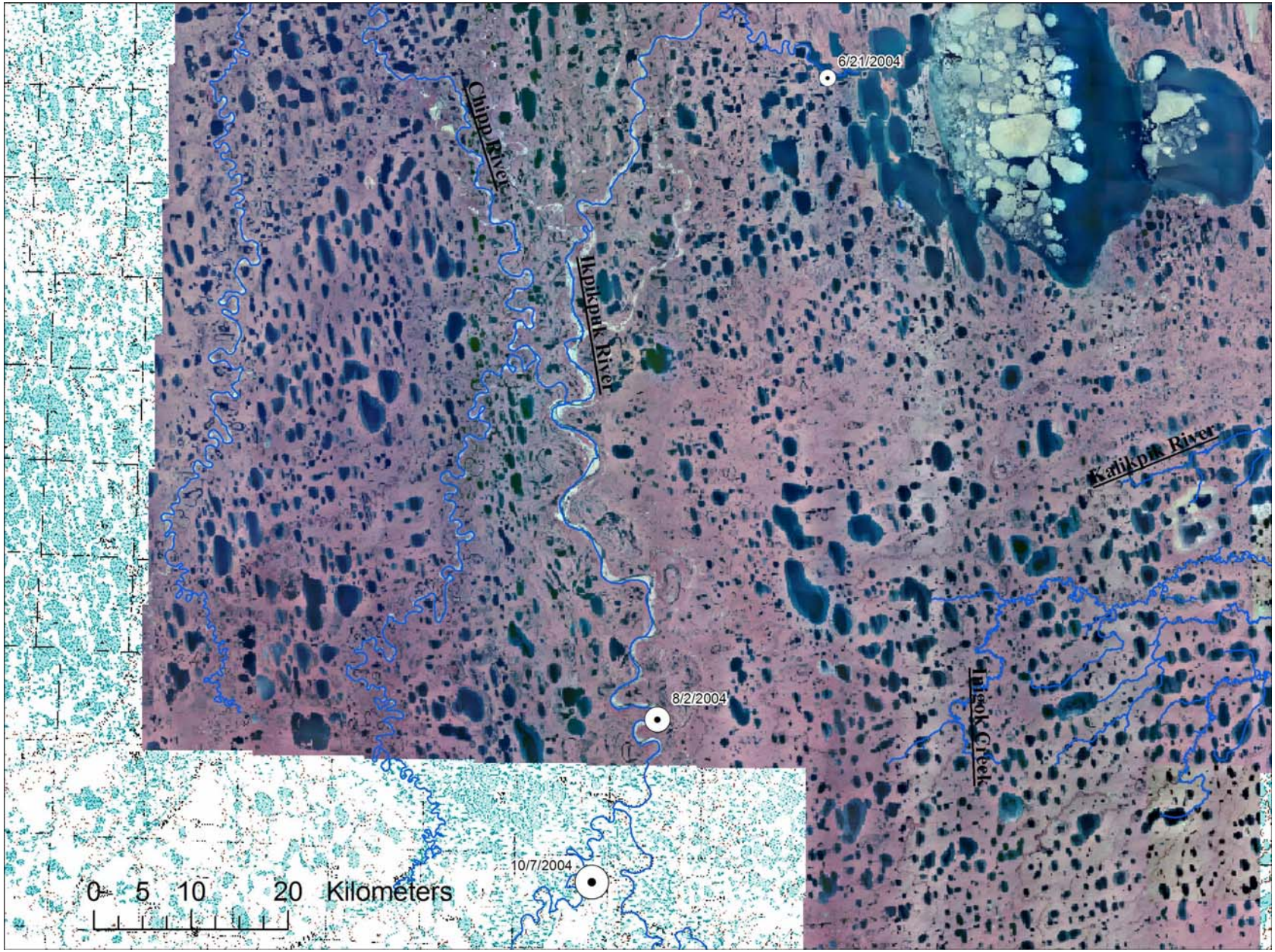


Individual Map 38. Broad whitefish #526 overwintered in an unknown location in winter 2004/2005. The fish moved into the Ikpikpuk River during early summer 2005 and was in what appeared to be an isolated pool in the Ikpikpuk in August 2005. The fish was still in the same area in early October 2005.

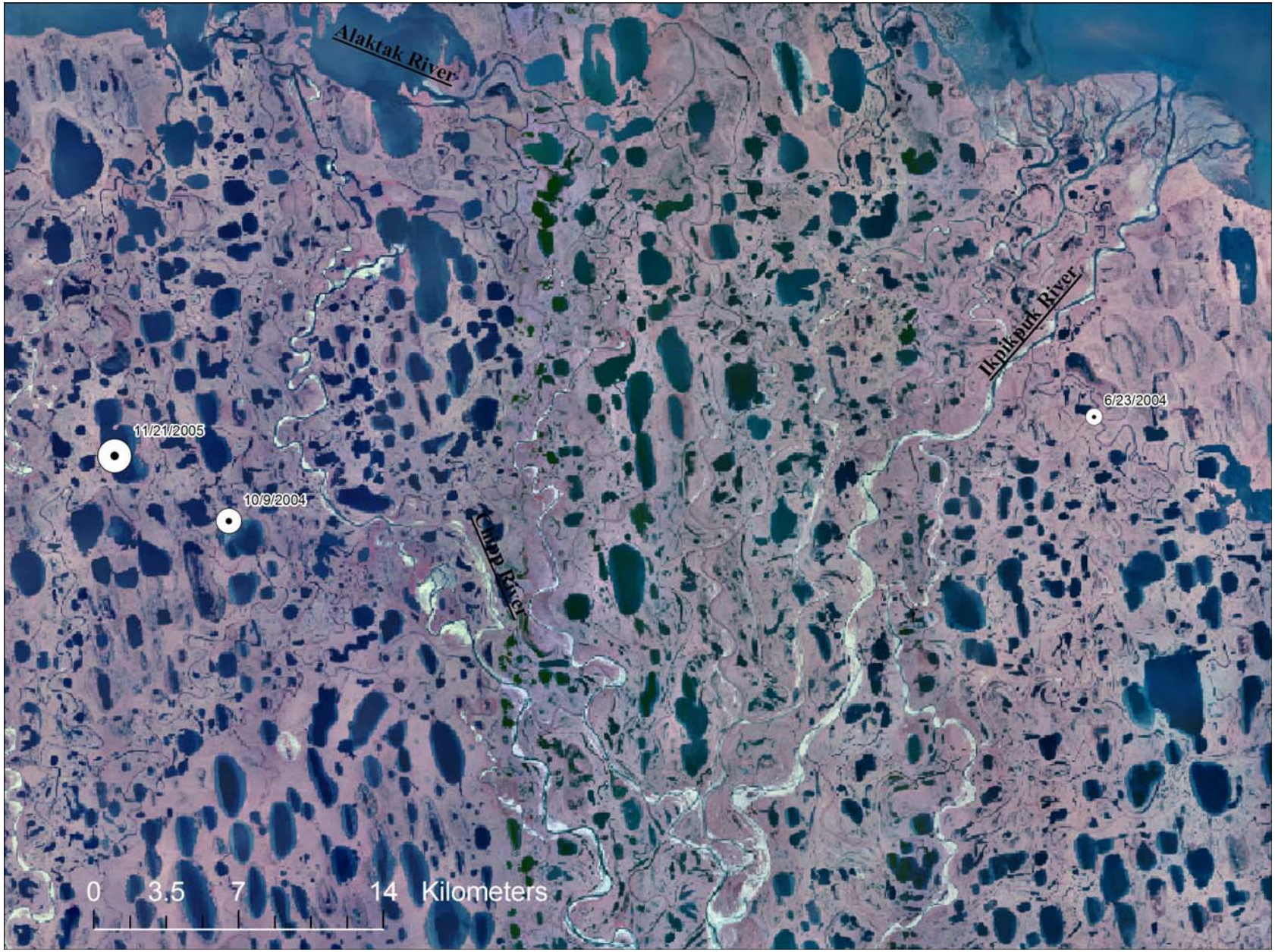
Individual Map 39. Broad whitefish #608 was located downstream from the Mayoriak River in the Ikpikpuk in the same general location each time it was relocated. It is our interpretation that fish likely died.



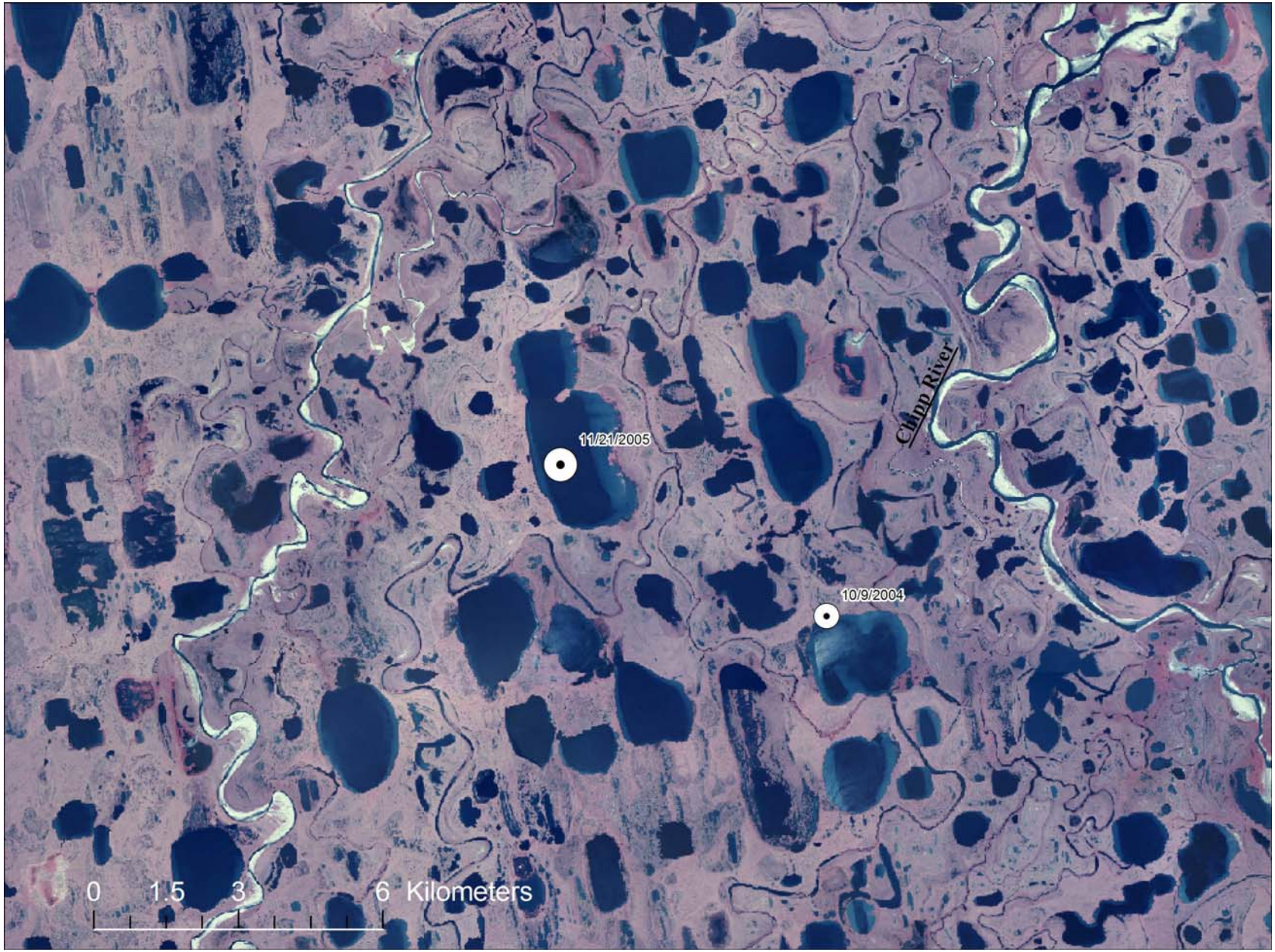
Individual Map 40. Broad whitefish #615 wintered in Teshekpuk lake during winter 2004/2005. By July 2005 the fish had moved into the area of the coalesced lakes in the upper Mayoriak. This fish was judged to be a pre-spawning adult in June 2004.



Individual Map 41. Broad whitefish #647 was a pre-spawning adult with visible eggs in June 2004. By August 2004 the fish was in the upper Ikpikpuk River and by early October was relocated in the lower Titaluk River.



Individual Map 42. Broad whitefish #663 was judged to be a pre-spawning adult in June 2004. In October 2004 the fish was relocated in a lake within a tributary to either the Chipp River or Topagoruk River. The fish was relocated in winter 2005 in a lake within the same tributary system further downstream from its previous location. This fish likely remained in this small lake system for the entire period between relocations.

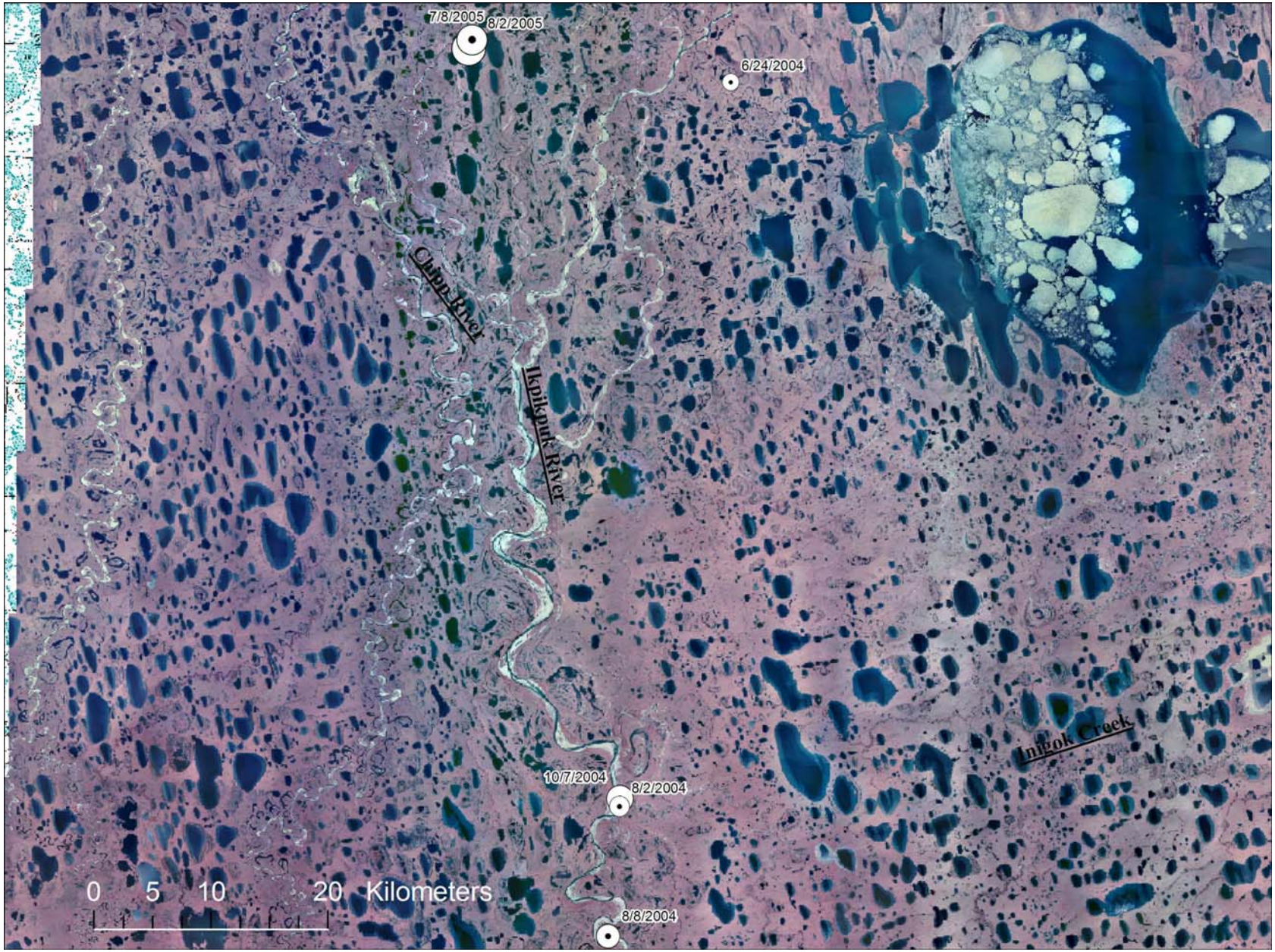


Individual Map 43. Broad whitefish #663 likely became entrained in this lake system. Connections between the lakes and creeks are minor and in the case of the larger lake appear to be ephemeral. This system appears to have connections to both the Topagoruk (to the west) and Chipp (to the east) rivers at times.

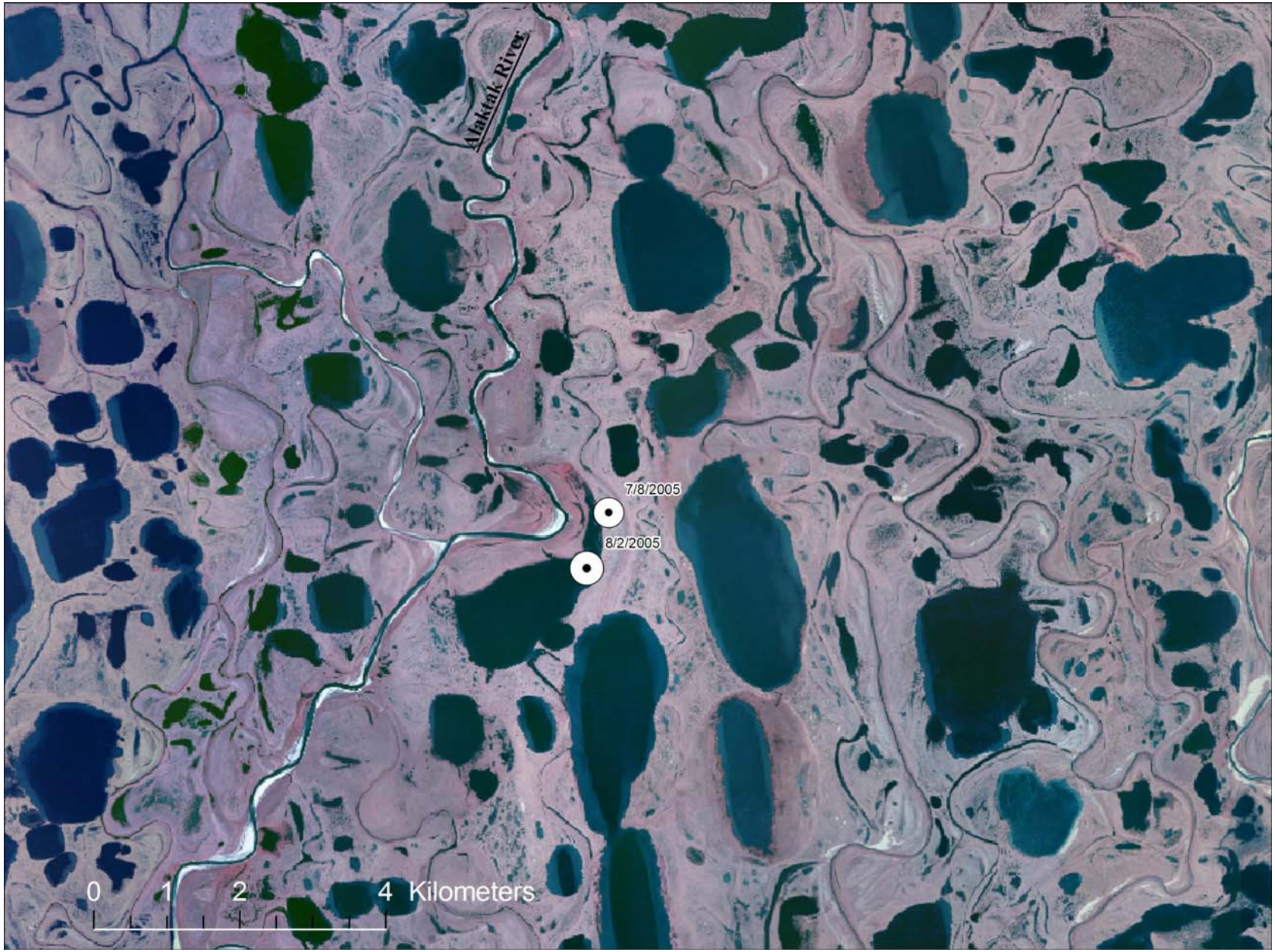
Individual Map 44. Broad whitefish #664 moved out of the Mayoriak River by August 2004 and was generally relocated in a small distributary channel of the Ikpikpuk River. Even with numerous over fights of this location it was difficult to ascertain the exact location of this fish. On several occasions it appeared most likely that this fish was in the large lake just off the distributary channel, if not, it is likely that this fish died during winter 2004/2005.

Individual Map 45. Broad whitefish #722 died either in the subsistence fishery or from the stress of the surgical procedure shortly after tagging and remained at the same location throughout the study.

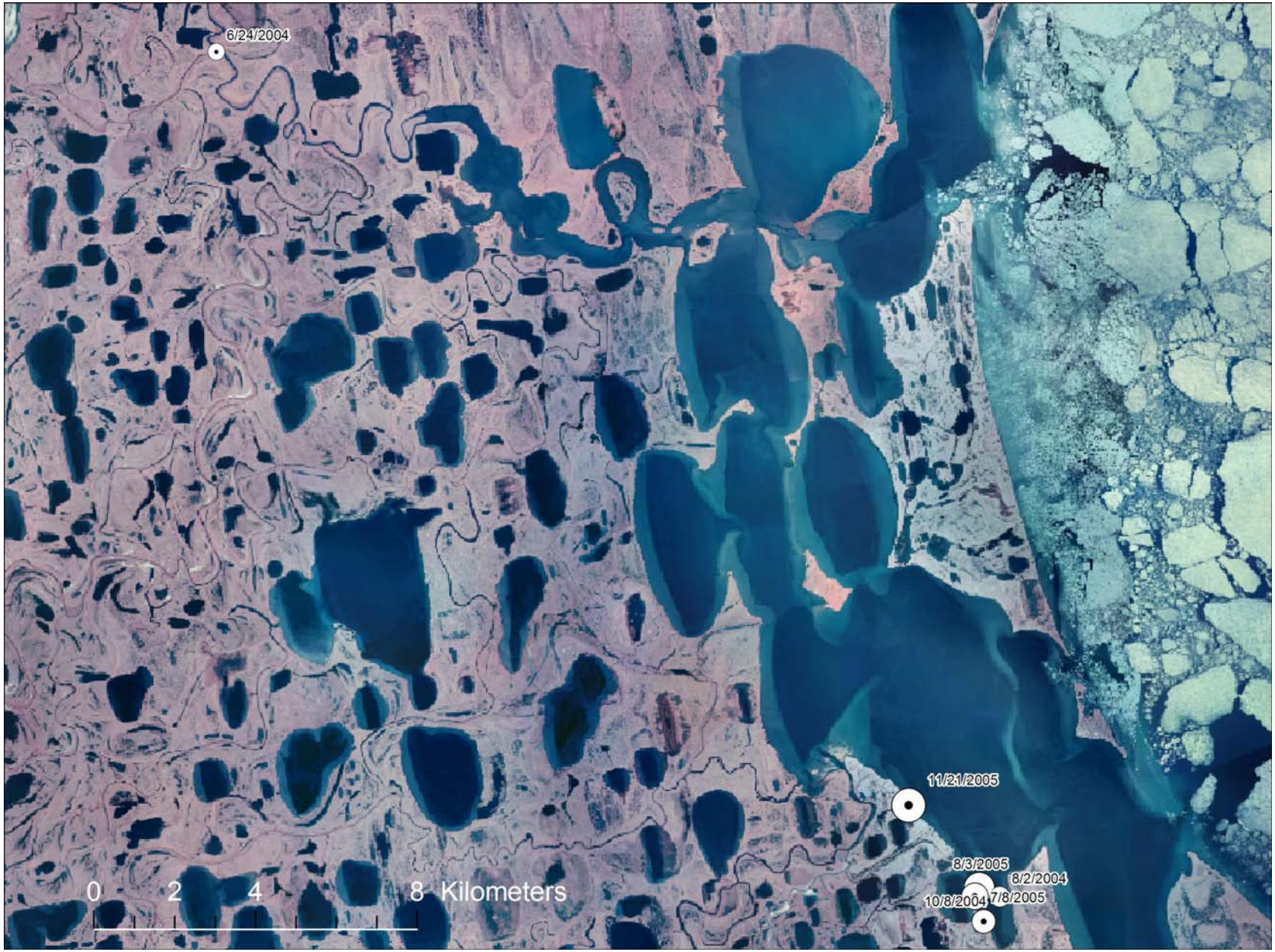
Individual Map 46. Broad whitefish #732 was relocated twice after it was tagged, both times in 2005 and in the lower Ikpikpuk River.



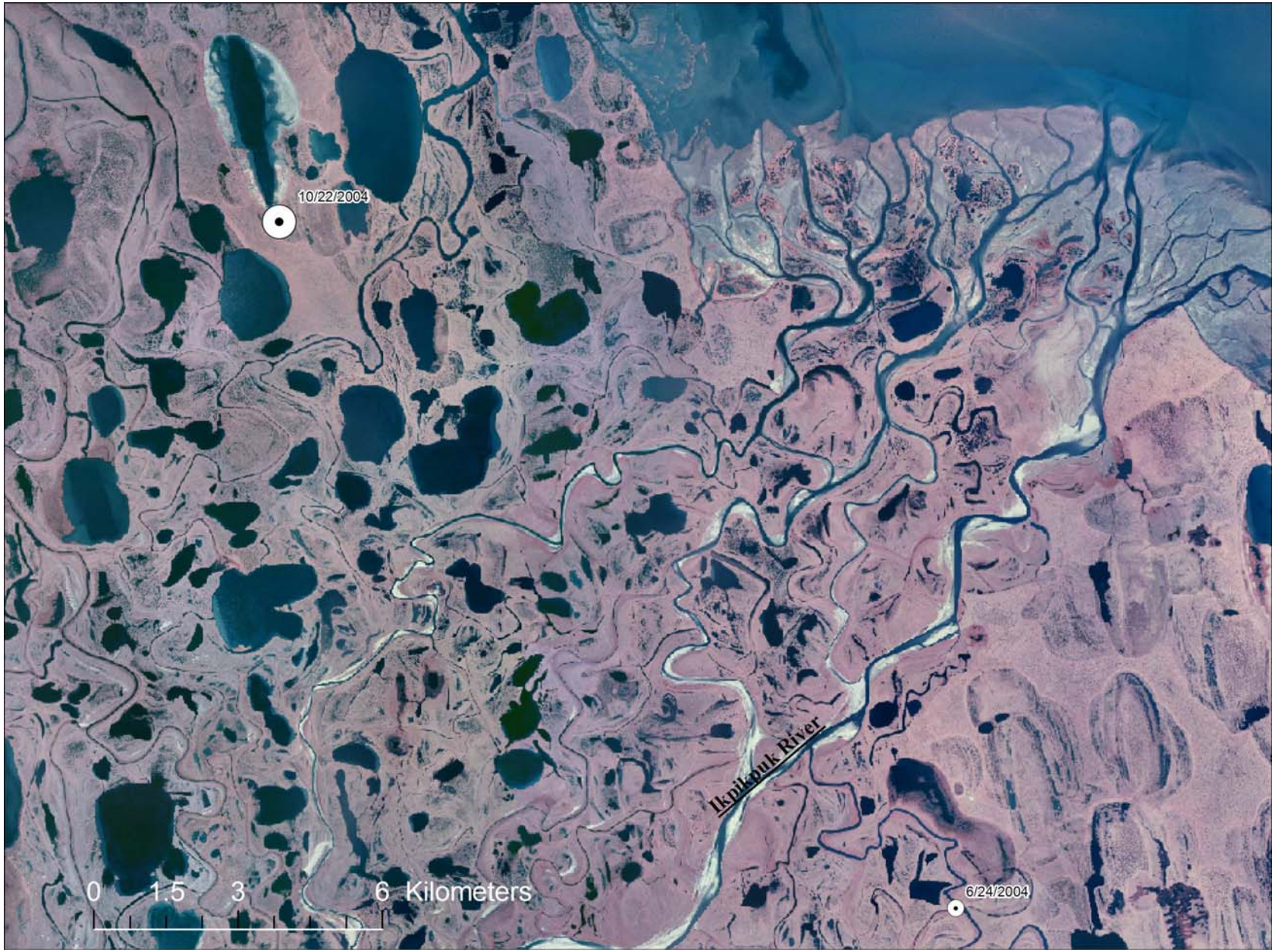
Individual Map 47. Broad whitefish #801 was identified as a pre-spawning adult with visible eggs in June 2004. The fish rapidly moved to the upper Ikpikpuk by August 2004. Just post spawning-period in 2004 the fish was still in the upper Ikpikpuk River. By July 2005 the fish had been relocated in a lake off of the Alaktak River. It is uncertain where this fish wintered but it was not relocated in November surveys of the main river channels.



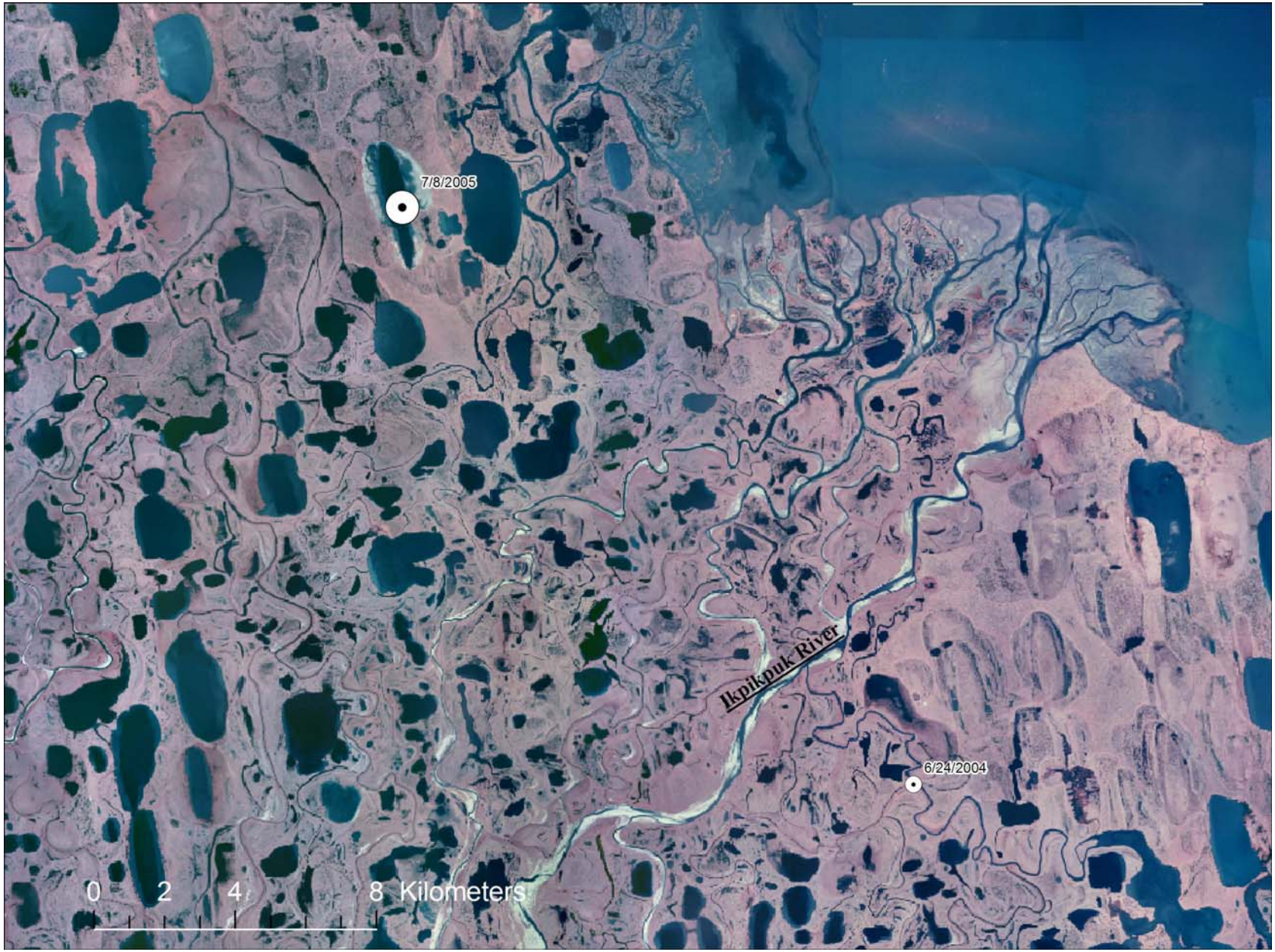
Individual Map 48. Detailed map of lower Alaktak River lake used by Broad whitefish #801 in 2005 after its apparent spawning run in 2004.



Individual Map 49. Broad whitefish #803 was relocated on numerous occasions after initial tagging. The fish was almost always relocated in a small southern bay of the coalesced lakes region of the Mayoriak River. It is possible that this fish died during winter 2004/2005.



Individual Map 50. Broad whitefish #819 was relocated in a lake connected during high water to a distributary channel of the Alaktak River. Broad whitefish #820 and #821 were also relocated in this lake although at different times.

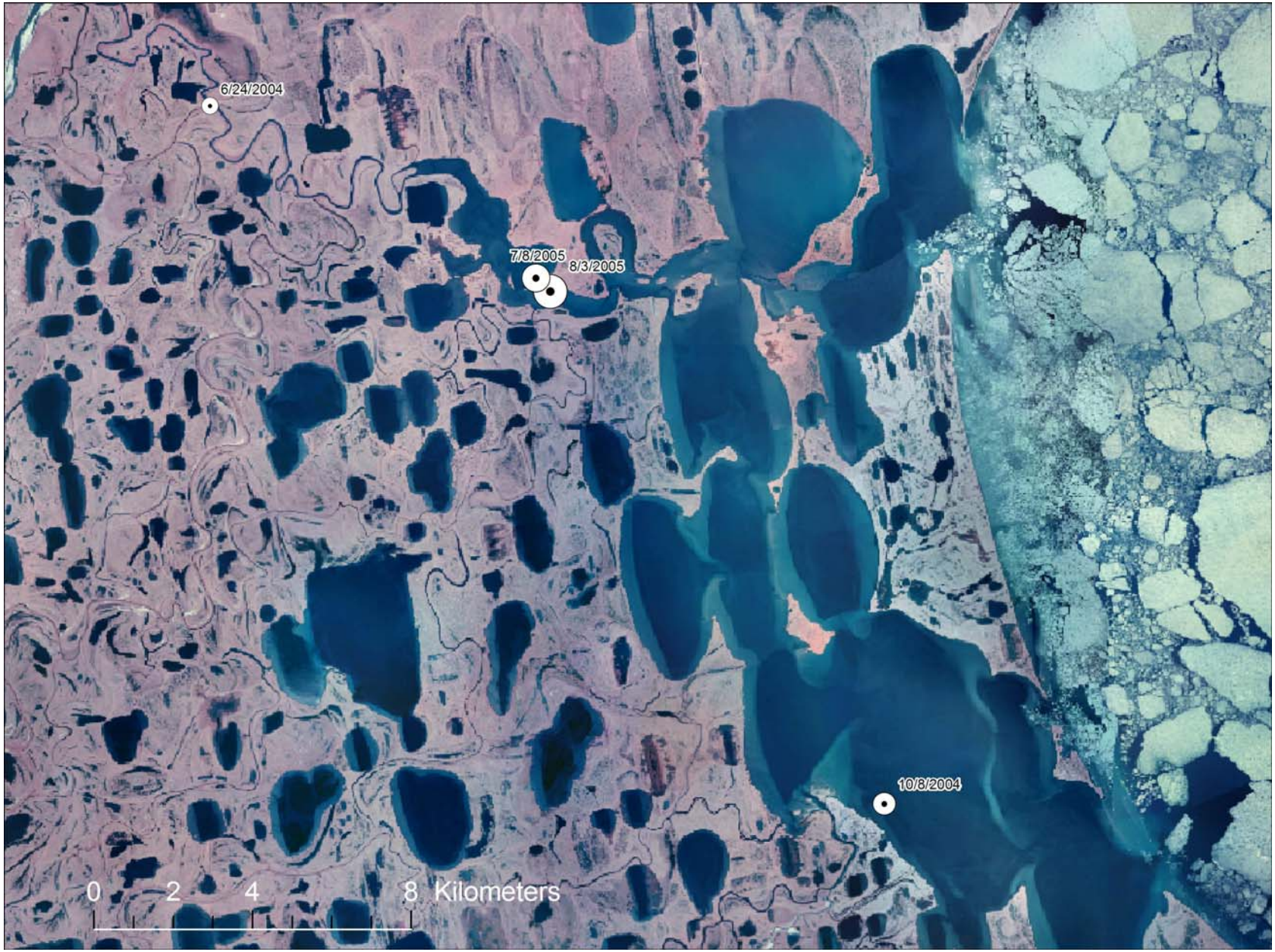


Individual Map 51. Broad whitefish #820 was relocated in a lake connected to a distributary channel of the Alaktak River during periods of high water in July 2005. Fish #819 and #821 also have been identified using this lake.

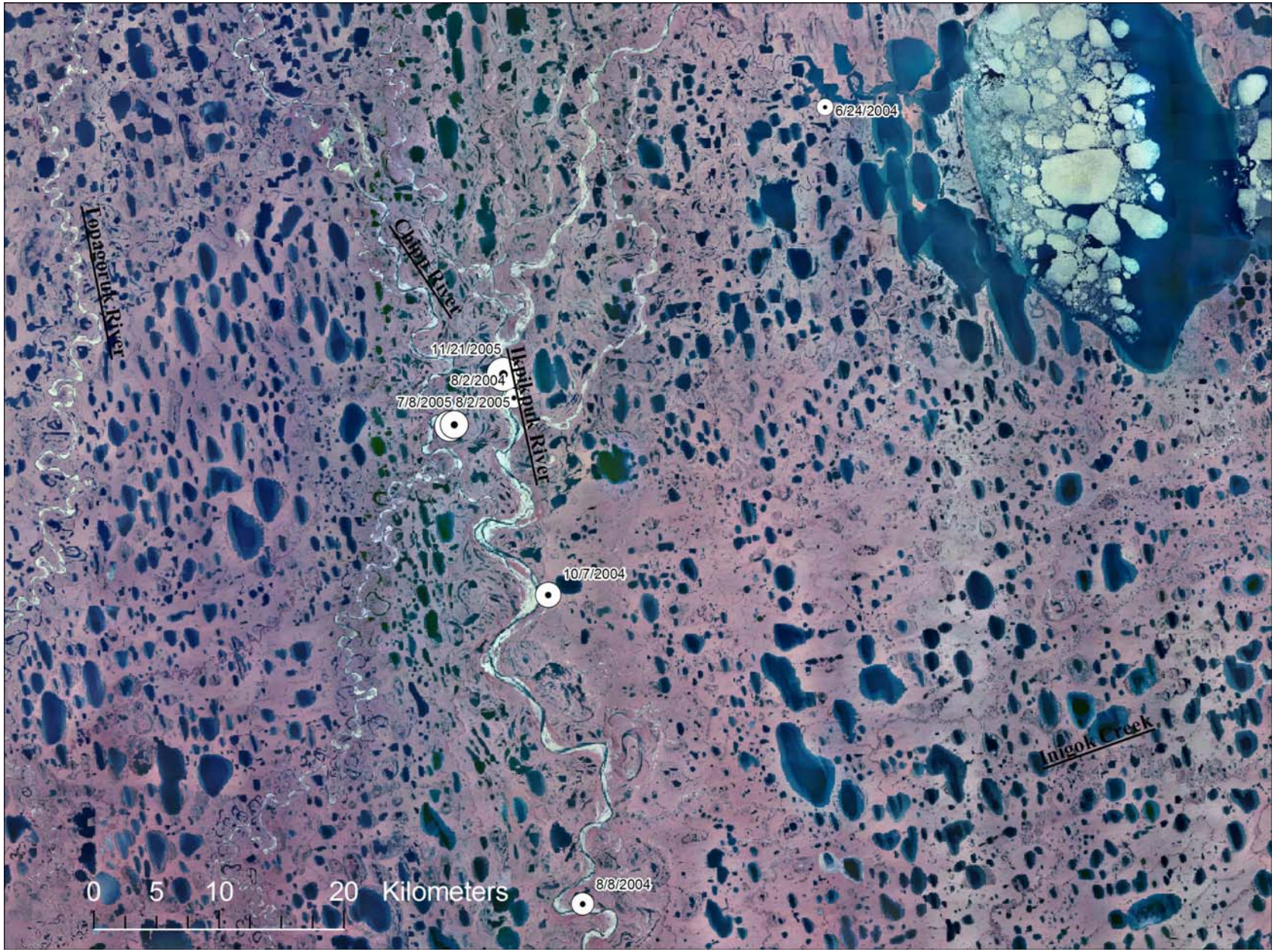
Individual Map 52. Broad whitefish #821 moved from the coalesced lakes area of the Mayoriak River to the upper Ikpikpuk over a period of 6 days. The fish was later relocated in November 2005 in a lake ephemerally connected to a distributary channel of the Alaktak River, a lake also used by fish #819 and #820 at different times of the year. This fish was judged to be a pre-spawning adult at the time of tagging and would likely have spawned in fall 2004.

Individual Map 53. Detail of the lake off of the Alaktak River used by broad whitefish #819, #820 and #821 at different times of the year in 2004 and 2005.

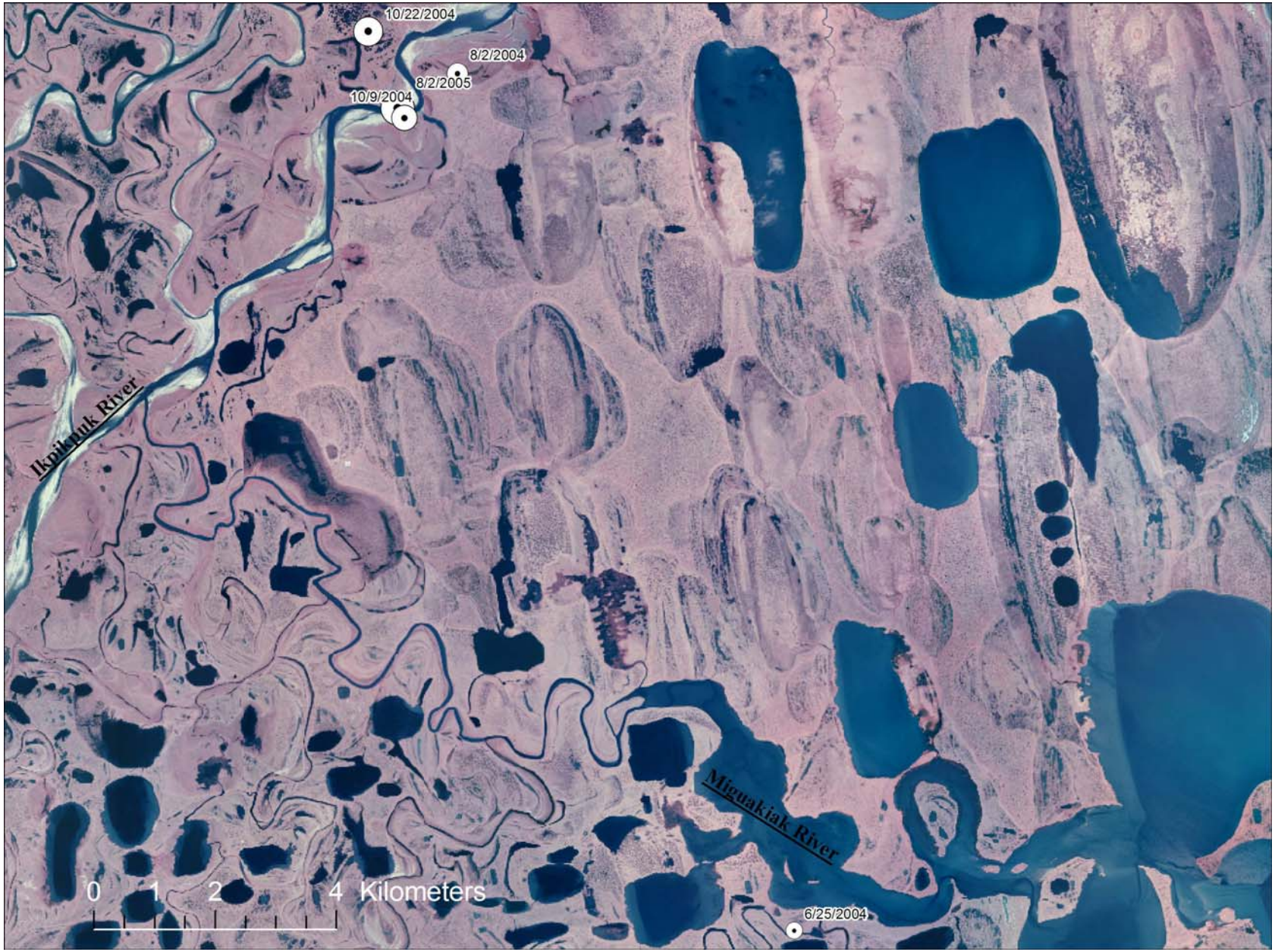
Individual Map 54. Broad whitefish #822 was only relocated once after it was tagged. The fish was relocated in a bay of the middle Mayoriak River in July 2005.



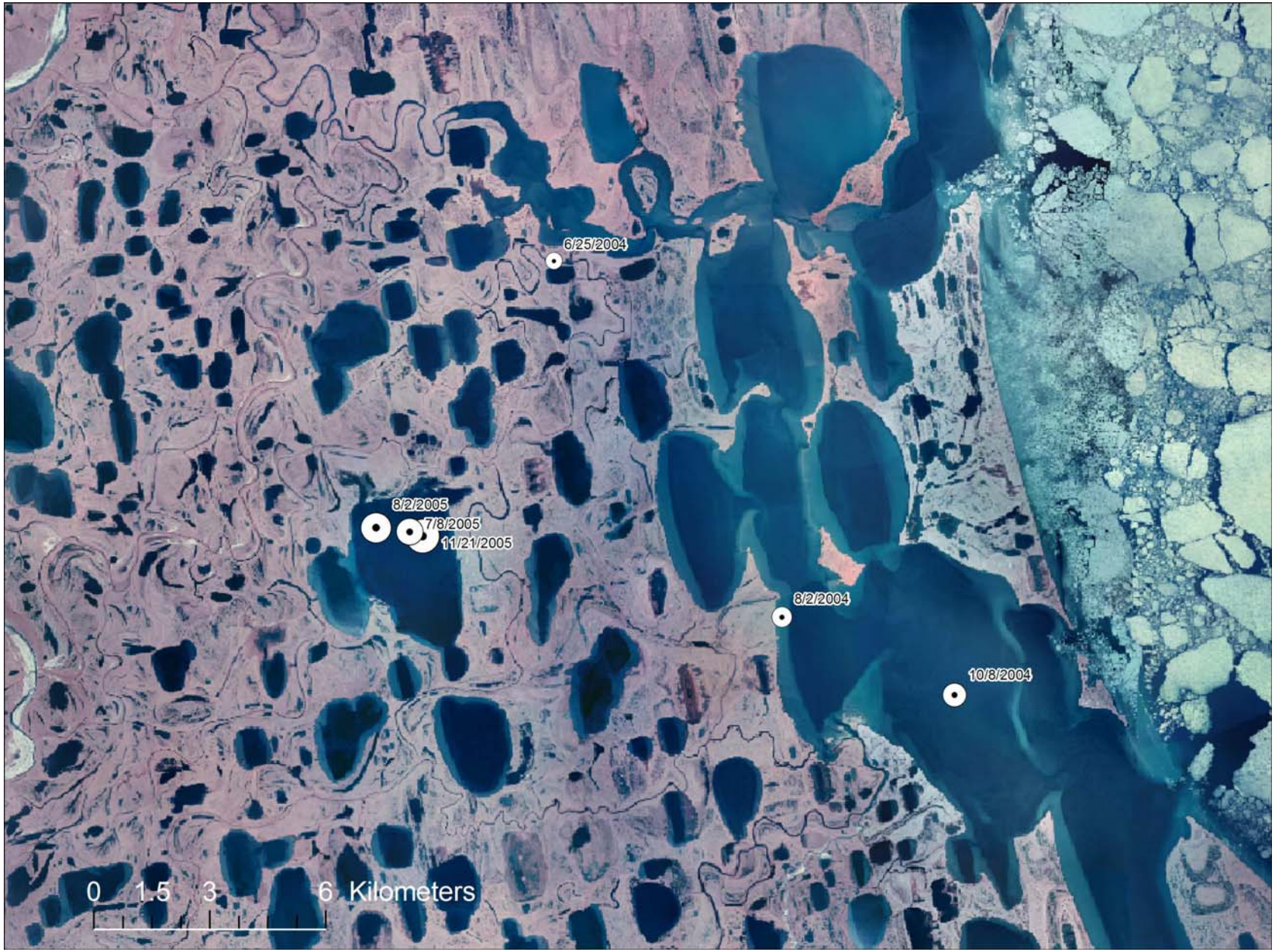
Individual Map 55. Broad whitefish #823 overwintered in the coalesced lakes region of the Mayoriak River in winter 2004/2005. The fish used the middle Mayoriak area in summer 2005 and has not been relocated since.



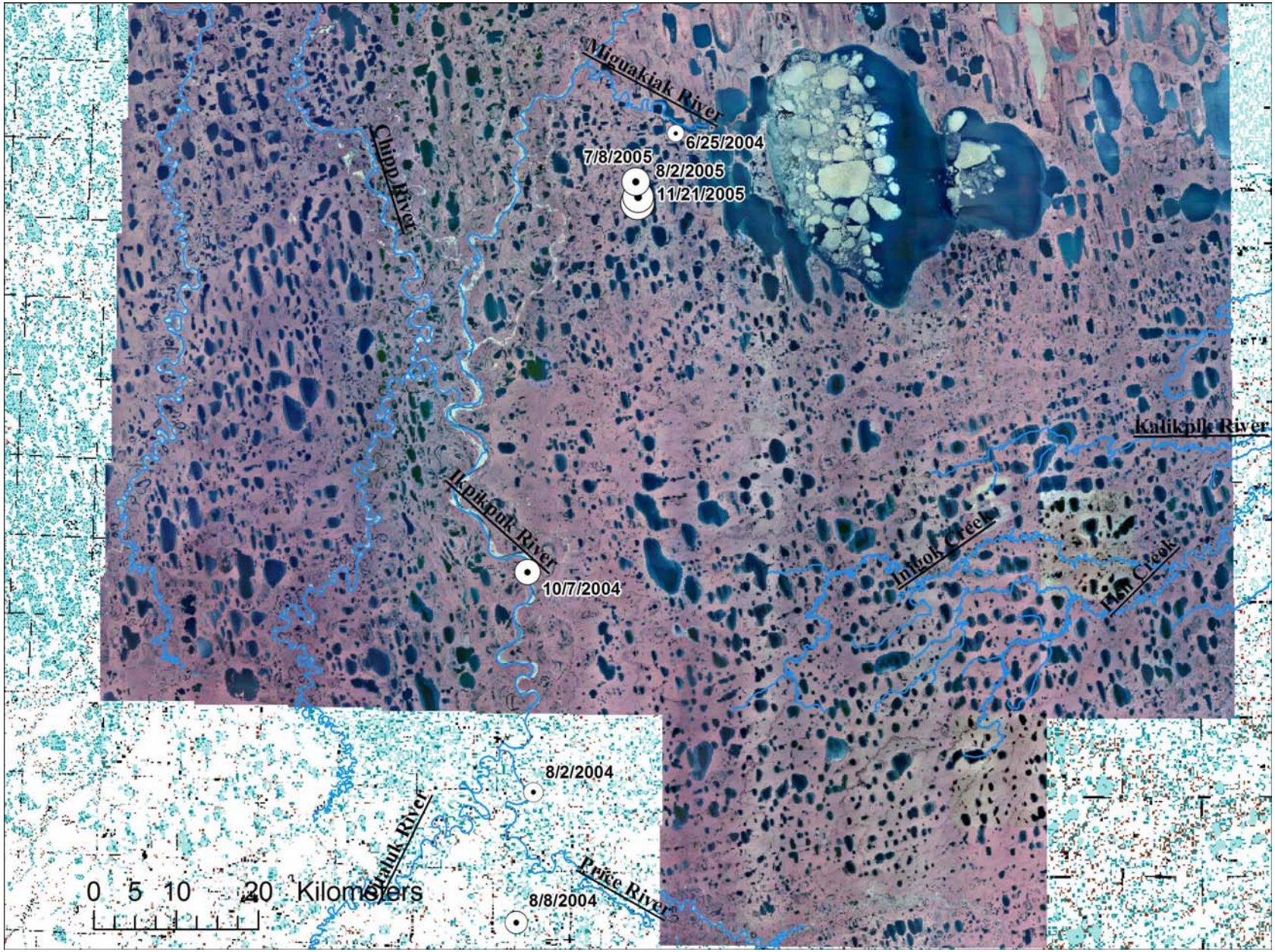
Individual Map 56. Broad whitefish #830 was judged to be a pre-spawning adult when tagged in June 2004. The fish moved into the upper Ikpikpuk River in August 2004 and was still in the upper river during early October 2004. The fish moved into the lower Oumalik River in summer 2005 but appears to have overwintered during winter 2005/2006 in the Ikpikpuk River.



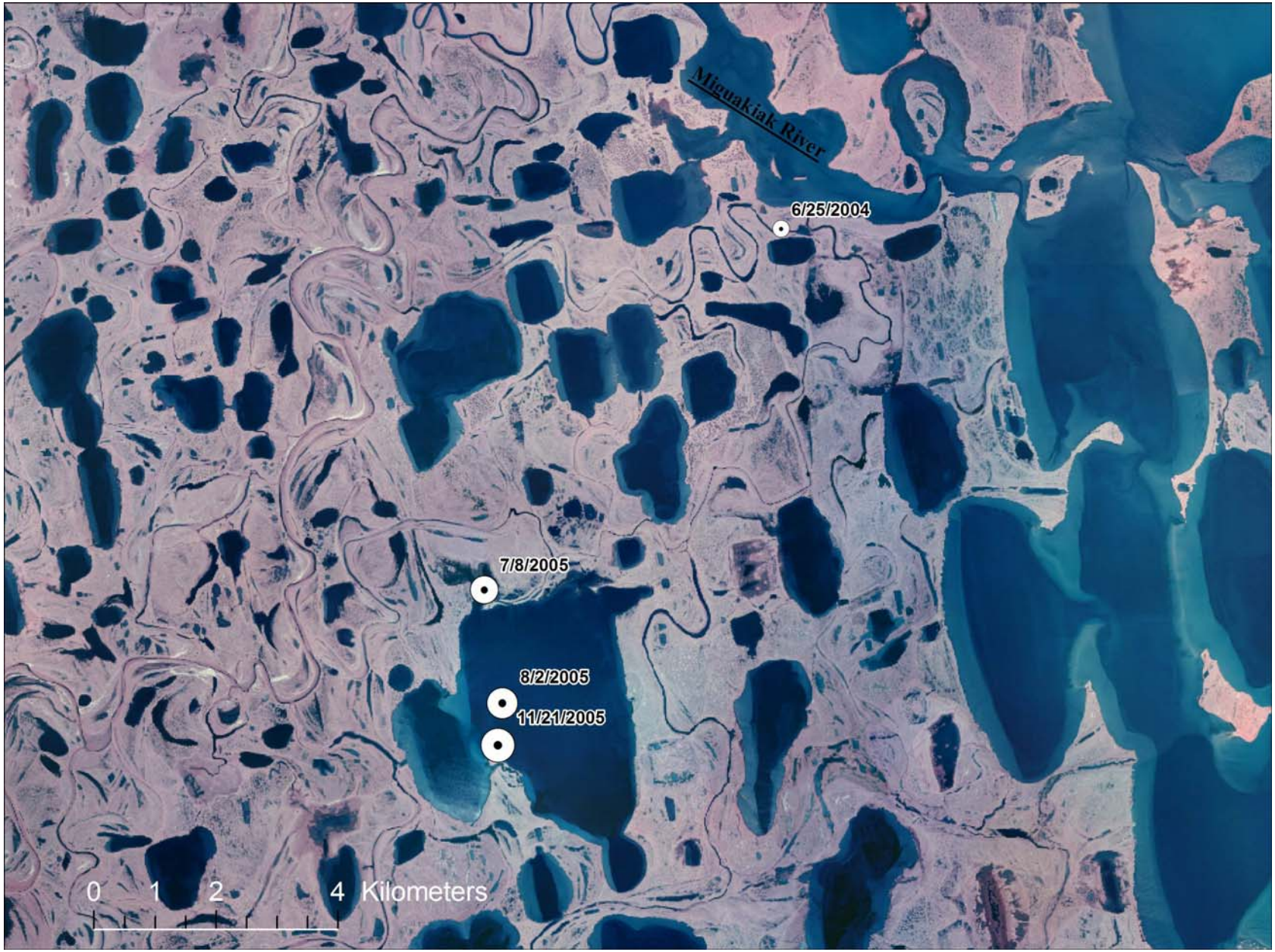
Individual Map 57. Broad whitefish #875 moved into the lower Ikpikpuk River and, similar to fish #608 that moved to the same area at the same time, appears to have died during winter 2004/2005. Both fish were judged to be pre-spawning adults and may have attempted spawning and overwintering in the lower river and were winter killed.



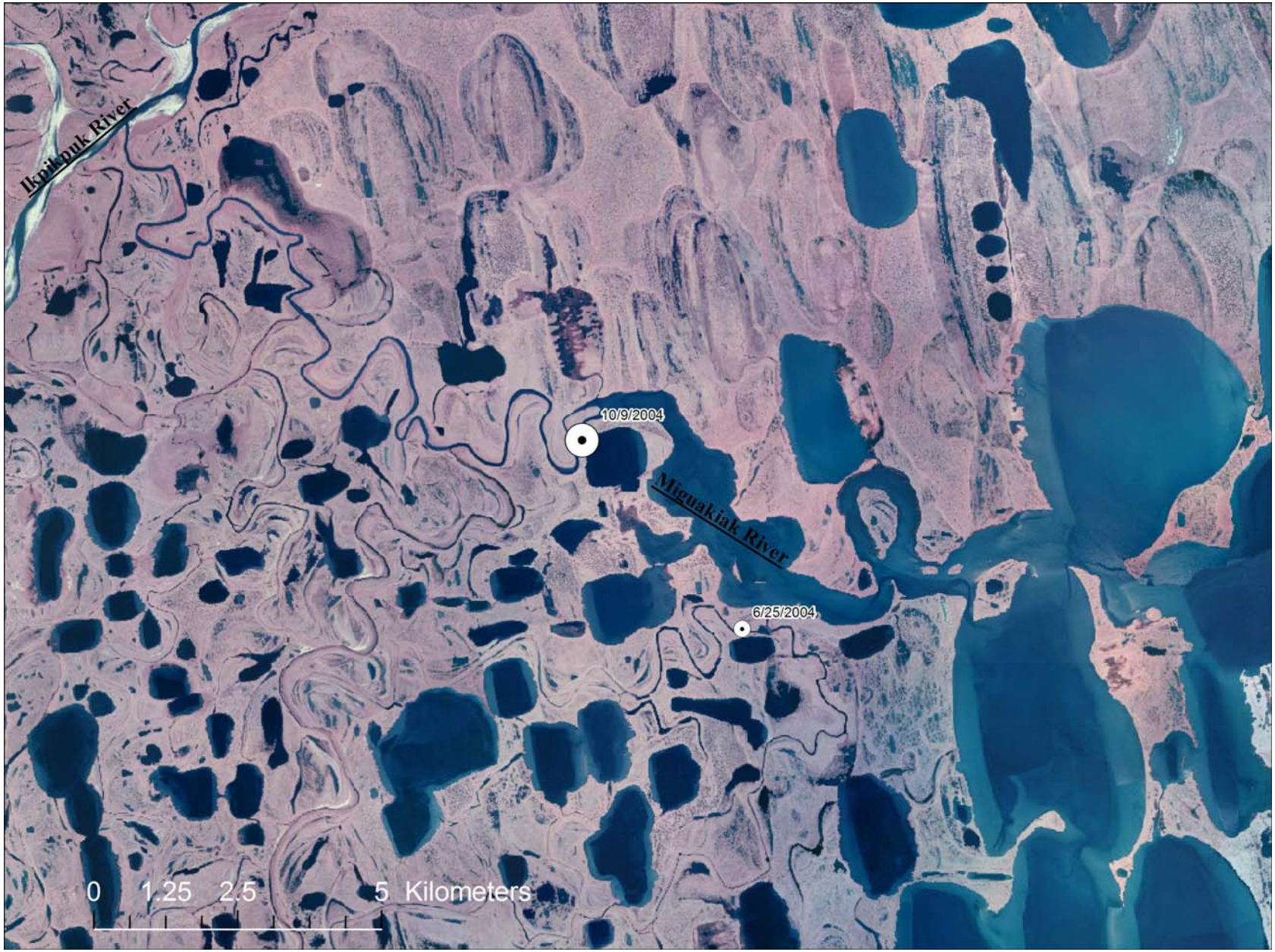
Individual Map 58. Broad whitefish #878 overwintered and spent the 2004 spawning season in the coalesced lakes area of the upper Mayoriak River. The fish was judged to be a pre-spawning adult in June 2004. The fish returned to the drainage of initial tagging in 2005 and spent the summer and overwintered during winter 2005/2006 in a lake used by numerous radio tagged broad whitefish (See Figure 14).



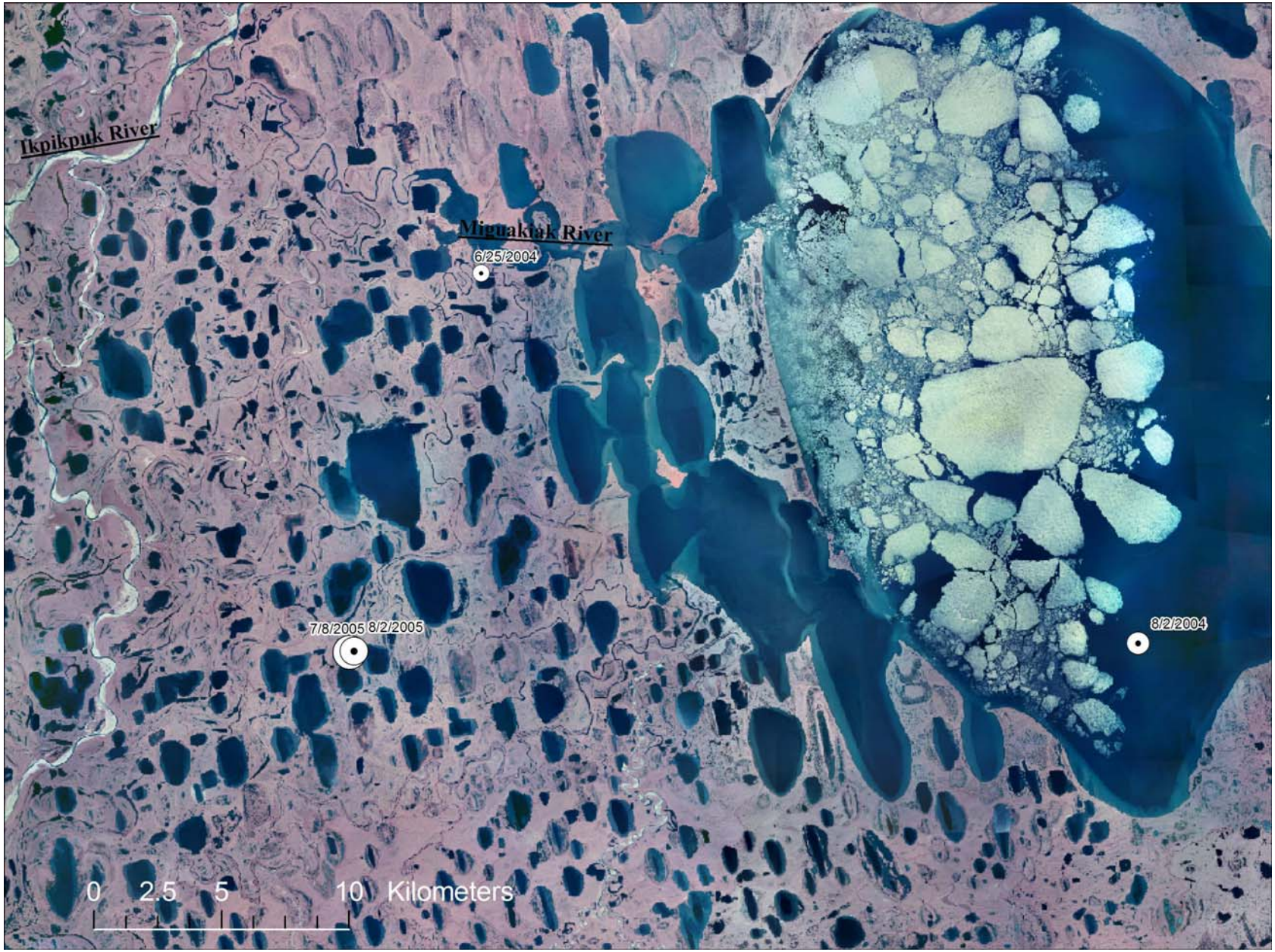
Individual Map 59. Broad whitefish #1260 was identified as a pre-spawning adult in June 2004. The fish moved upstream to the upper Ikpikpuk just downstream from the Price River and upstream from the Titaluk River in August 2004 and was in the upper river just after the spawning season in 2004. The fish was not relocated again until summer 2005 when it was relocated back in the same Mayoriak River tributary it was tagged in. The fish was using the same lakes used by numerous tagged broad whitefish in the drainage.



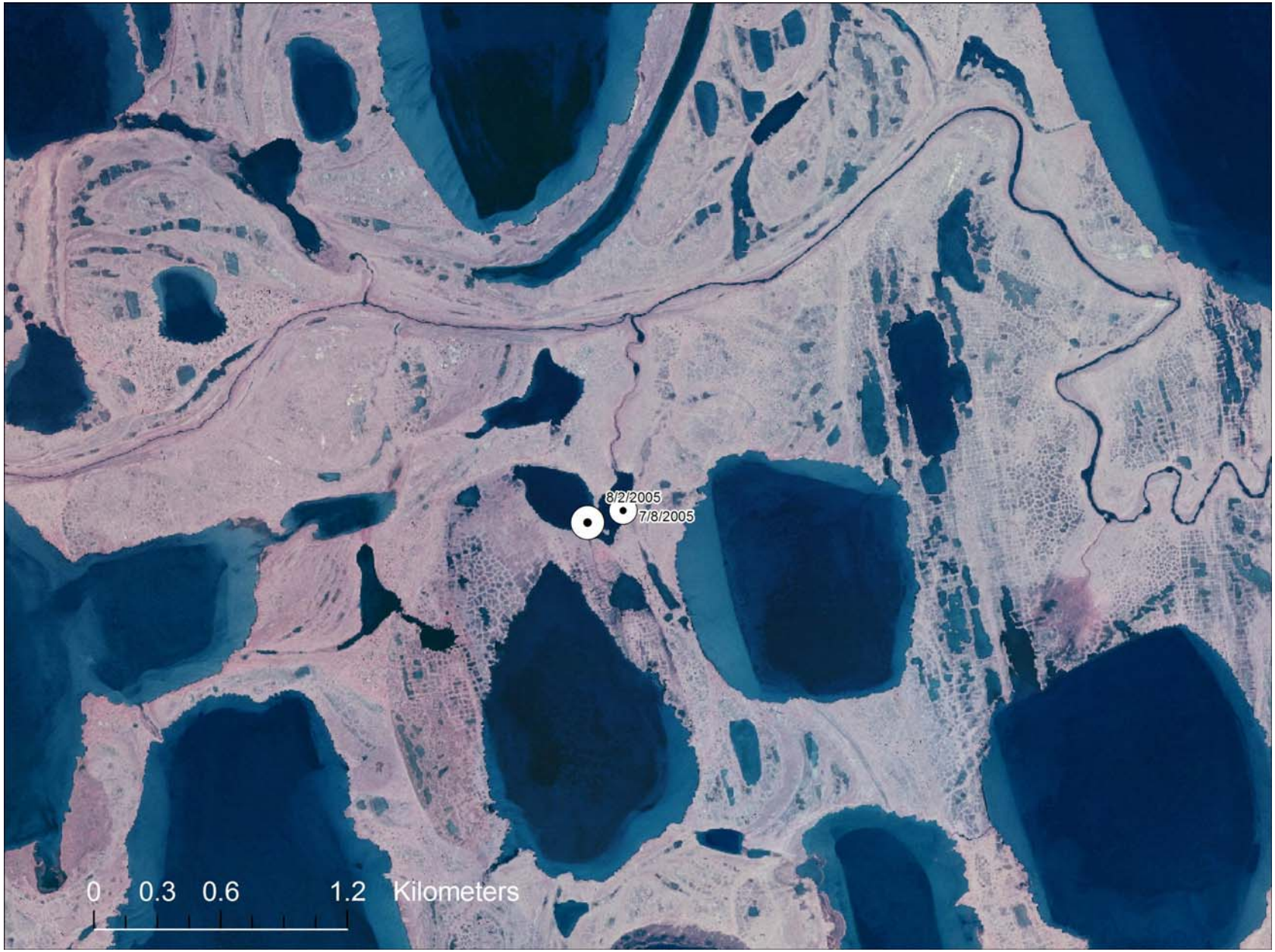
Individual Map 60. Detail of lake used by broad whitefish #1260 in summer 2005 and winter 2005/2006, the season after its apparent spawning run to the upper Ikpikpuk River. Numerous radio tagged fish used this same lake for summer feeding and overwintering (See Figure 14).



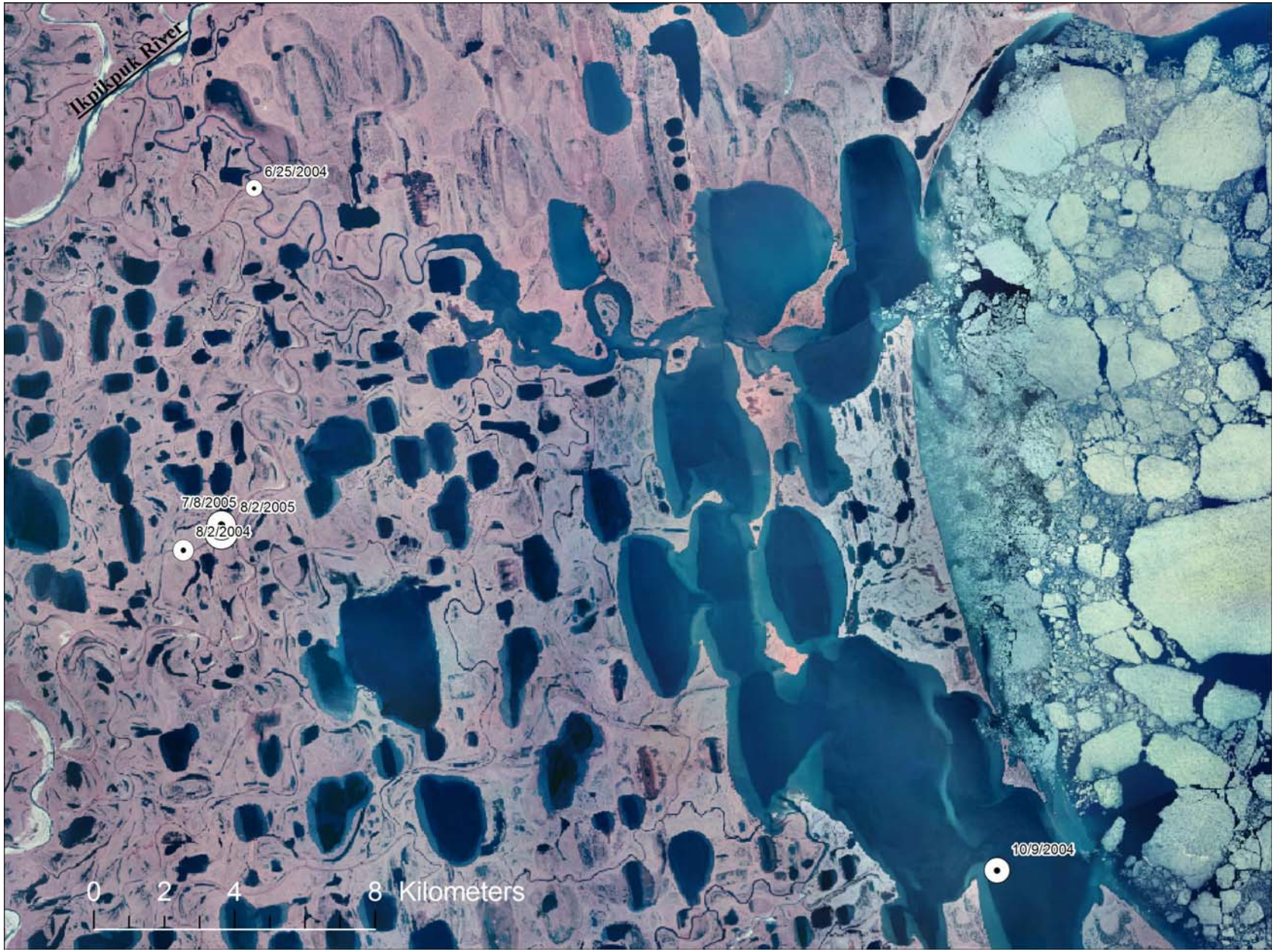
Individual Map 61. Broad whitefish #1261 apparently overwintered in the middle Mayoriak River during winter 2004/2005. The fish was never relocated after October 2004.



Individual Map 62. Broad whitefish #1262 was relocated in the southern bay of Teshekpuk Lake in August 2004. The fish was later relocated in summer 2005 in a lake off of a tributary to the Mayoriak River.



Individual Map 63. Detail of lake used by broad whitefish #1262 during summer 2005. The lake was relatively small but appeared considerably deeper than adjacent lakes. The lake was weakly connected to the nearest creek at the time of both over flights.



Individual Map 64. Broad whitefish #1263 was judged to be a post spawning adult in June 2004 and residual eggs from the previous year's spawning were visible. The fish moved into a tributary of the Mayoriak River upstream from its tagging location during summer 2004. The fish overwintered during winter 2004/2005 in the easternmost bay of the coalesced lakes area of the upper Mayoriak River. The fish spent the summer of 2005 in the same area of its last relocation in August 2004.