TECHNICAL REPORT NO. 03-02

SEASONAL MOVEMENTS AND HABITAT USE OF ARCTIC GRAYLING (*Thymallus arcticus*), BURBOT (*Lota Lota*), AND BROAD WHITEFISH (*Coregonus Nasus*) WITHIN THE FISH CREEK DRAINAGE OF THE NATIONAL PETROLEUM RESERVE-ALASKA, 2001-2002

by William Morris

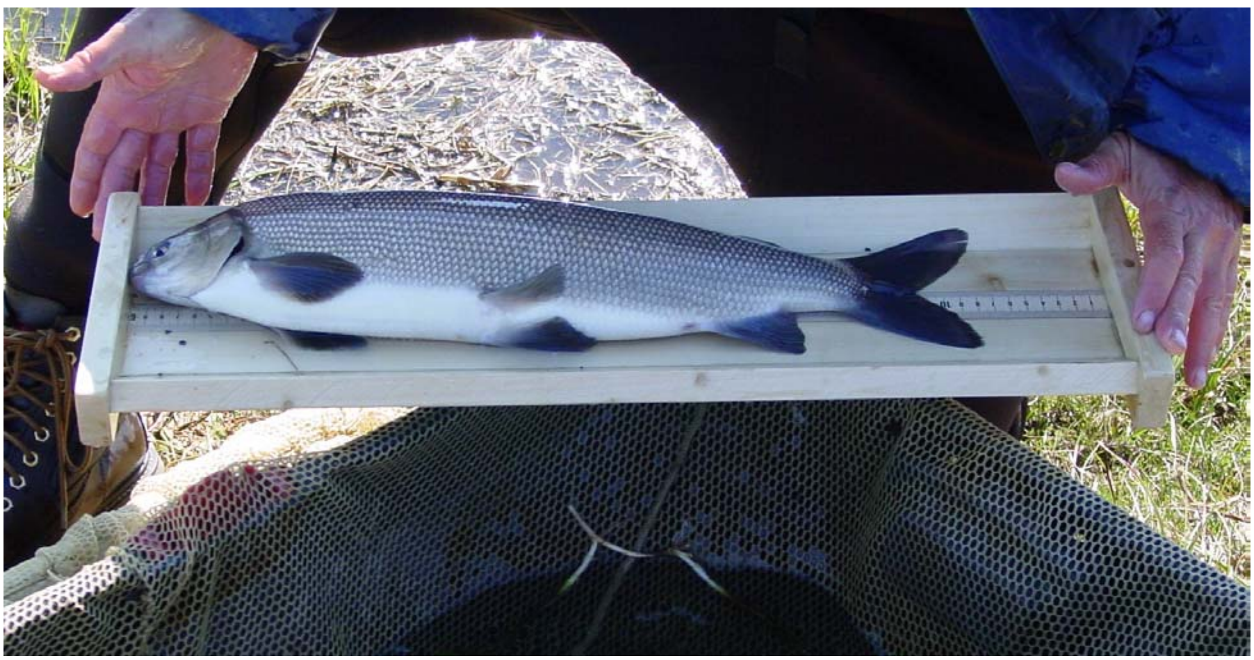

Photo by William Morris ADNR, OHMP

November 2003

Alaska Department of Natural Resources Office of Habitat Management and Permitting

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Seasonal Movements and Habitat Use of Arctic Grayling (*Thymallus arcticus*), Burbot (*Lota lota*), and Broad Whitefish (*Coregonus nasus*) within the Fish Creek Drainage of the National Petroleum Reserve-Alaska, 2001-2002

Technical Report No. 03-02

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Submitted to

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November 2003

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Introduction

In 2001, a collaborative effort among the North Slope Borough Wildlife Management Department, MJM Research, LLC., ConocoPhillips Alaska, Inc., and the Alaska Department of Natural Resources, Office of Habitat Management and Permitting (OHMP) (at the time Habitat Division, Alaska Department of Fish and Game) initiated a project to identify the seasonal movement patterns of fish and their use of specific habitats for wintering, spawning, and rearing within the eastern portion of the northeast planning area of the National Petroleum Reserve-Alaska (NPR-A). The North Slope Borough Wildlife Management Department provided project funding through the NPR-A Impact program and provided coordination with local communities to ensure that the fish studied and the area of focus were consistent with local needs. MJM Research, LLC. provided assistance during project planning and provided technicians for fish sampling and transmitter implantation procedures. ConocoPhillips Alaska, Inc. provided logistic support throughout the project, including camp, office and field equipment storage space at Alpine, as well as helicopter transport between sampling locations in the NPR-A and Alpine. The OHMP provided staff for the radio-telemetry aspect of the study and for final report writing and review.

Three species of fish, broad whitefish (*Coregonus nasus*), Arctic grayling (*Thymallus arcticus*), and burbot (*Lota lota*) were identified as the focus of this research effort. Broad whitefish (Aanaakliq) are a preferred subsistence fish in the NPR-A and are targeted within the eastern NPR-A and to a much higher degree in the Colville River. Arctic grayling (Sulukpaugaq) and burbot (Tittaaliq) are also important subsistence species and are harvested from the eastern NPR-A by residents of Nuiqsut. Three of the major river systems of the northeastern NPR-A, nearest Nuiqsut, flow north to northeast along the coastal plain and come together to form a delta 6 km west of the Colville River Delta Nigliq Channel. From west to east these systems are Fish Creek, Judy Creek and the Ublutuoch River (Figure 1).

Fish Creek is roughly 200 km long with an estimated drainage area of 4732 km^2 (Dietzmann *et al.* 2003). The river substrate consists almost solely of saturated sands and is highly susceptible to scour. The river has high cut banks on outside meander bends that experience significant

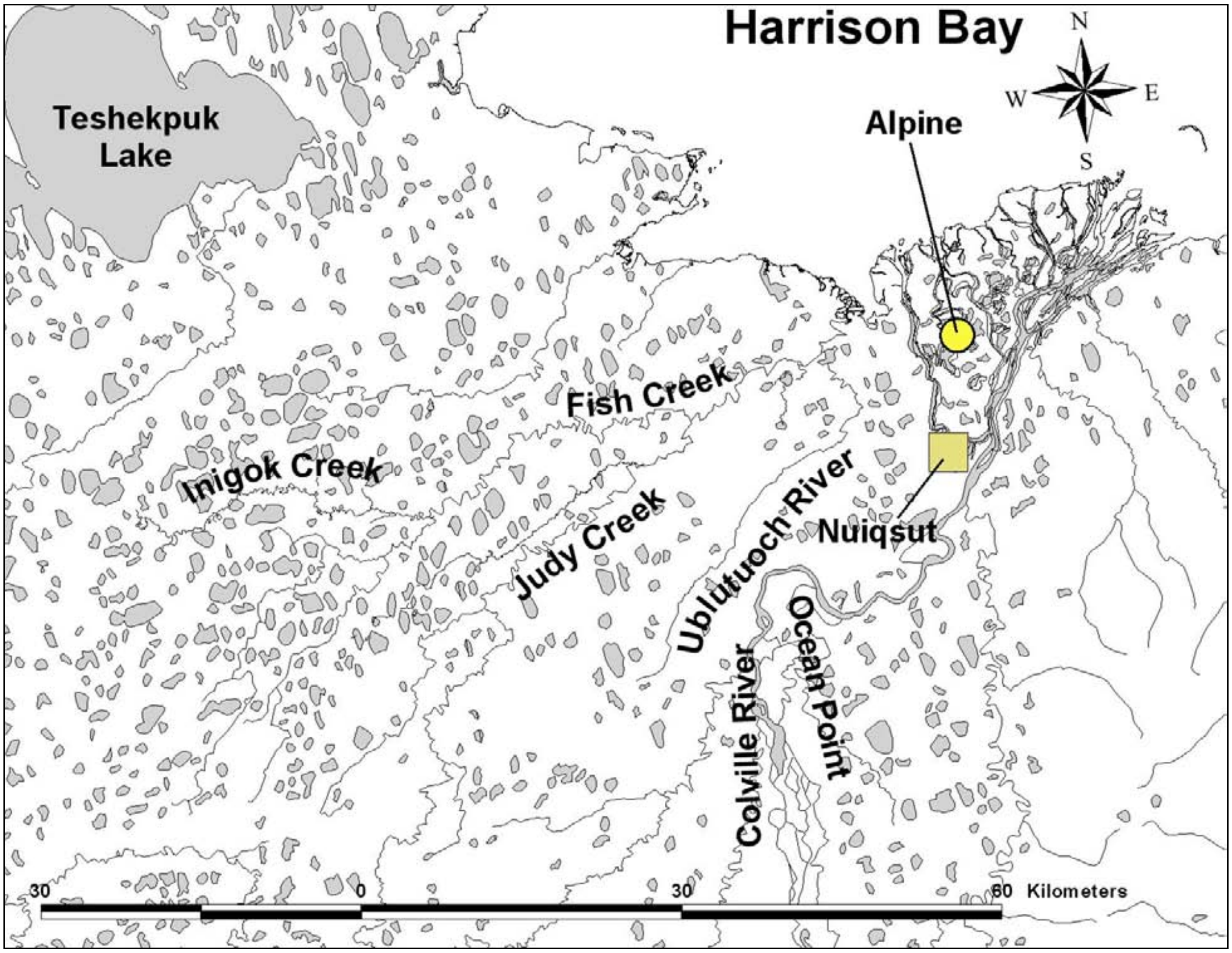

Figure 1. The principal project study area was located in the Fish Creek, Judy Creek, Ublutuoch River region of the easternmost portion of the NPR-A.

sloughing during the open water season and gentle sloping sand banks on inside meander bends (Figure 2a). The floodplain is wide over the majority of the river's length and on inside bends multiple sand terraces vegetated with willow are present. Numerous tundra stream/lake complexes flow into the river over most of its length; the highest concentration of these complexes occur within the lower river downstream from Inigok Creek (Figure 2b). Judy Creek is similar in configuration and substrate to Fish Creek but has a notably smaller drainage area of 1724 km^2 (Dietzmann *et al.* 2003) (Figure 3a). Judy Creek flows roughly 225 km from its headwaters into Fish Creek approximately 32 km upstream from Harrison Bay. Numerous tundra stream/lake complexes flow into Judy Creek along its length (Figure 3b).

Figure 2. a) High cut banks, gentle sloping inside meander bends and sand substrates characterize the lower Fish Creek Drainage (top). (Photograph ©MJM Research LLC.) b) The river channel is highly sinuous and fed by numerous small tundra drainages (bottom). (Photomosaic provided by ConocoPhillips Alaska, Inc.)

Figure 3. a) High cut banks, gentle sloping inside meander bends and sand substrates characterize the lower Judy Creek Drainage (top). (Photograph ©MJM Research LLC.) b) The river channel is highly sinuous and fed by numerous small tundra drainages (bottom). (Photomosaic provided by ConocoPhillips Alaska, Inc.)

The Ublutuoch River is the smallest of the three systems with a length of approximately 112 km and a drainage area of roughly 642 km^2 (Dietzmann *et al.* 2003). The river flows into Fish Creek approximately 13 km upstream from Harrison Bay. The river banks are vegetated with thick willow and sedge growth (Figure 4a). The river is characterized by a sinuous incised channel but the stream substrate is predominantly gravel (Figure 4b). Much of the river is less than 0.91 m deep but has areas of deeper water at meander bends. However; the lower 14 km of the river has areas with depths to 7.6 m (Moulton, pers. comm. 2002).

Figure 4. a) The Ublutuoch River is unique to the region in that it is incised, vegetated along its banks to the water's edge, and has a gravel substrate (top). (Photograph ©MJM Research LLC.) b) The river channel is sinuous and fed by somewhat fewer tundra drainages than other rivers in the region. The river is shallow with the exception of the lower 14 km upstream from the mouth (bottom). (Photomosaic provided by ConocoPhillips Alaska, Inc.)

To accomplish the goals set forth for this project, we determined that radio-telemetry techniques would be most effective. Our telemetry study was designed to complement fyke net work being conducted in lakes and major rivers of the region. Radio-tagged fish could be followed throughout the year to various habitats within the area during times of the year when instream sampling was not practical. Using relocation surveys and data from individual radio-tagged fish, it would be possible to sample large areas and many habitat types in a relatively short period of time. The method also would provide a means to investigate fish behavior on an individual basis to help determine if fish typically use the same areas year after year. The seasonal component was essential; we would be able to locate wintering areas and determine key periods of the year for fish migration to and from particular habitat types. Many of these goals can be accomplished with other methods but radio-telemetry seemed the most efficient method to achieve all of the goals.

Methods

Radio-tags

We determined that radio-telemetry was the best method available to investigate questions regarding fish fidelity to certain habitats and locations, and to investigate seasonal movements and habitat use during periods of the year when other sampling methods are not feasible. Additionally, the vast area available to fish in our transmittered population would be difficult to sample with other techniques. We determined that relocation efforts would be conducted via fixed wing aircraft in either a Cessna 185 or 206.

Key components of our study approach were to ensure that we had a high likelihood of detecting tagged fish during aerial surveys. First, we selected an area to focus our relocation effort. We determined that the most reasonable place to expend the majority of energy during relocation events would be the drainages of initial fish capture and the Colville River. The Colville River is known to be a high use system for broad whitefish and forms the eastern most boundary of the NPR-A. Broad whitefish are an amphidromous species, able to use both fresh water and brackish water habitats during the year. Broad whitefish from the study area easily could migrate the short distance along the coast to the Colville River as well as any of the proximate freshwater habitats of the area. This area, considered our core search area, consisted of over 5,500 km^2 of land dotted with lakes and scored with countless small tundra drainages (Figure 5). We further determined that if numerous broad whitefish went unlocated during surveys of our core area, that rivers to the west, including the Chipp and Ikpikpuk rivers, also known to support large broad whitefish populations, would be surveyed. This expansion was based primarily on the ability of broad whitefish to move long distances along the coast. This increased our potential survey area to over 16,000 km^2 with potential fish habitat (Figure 5). If fish still were unaccounted, the survey would be expanded east to the lower Sagavanirktok River where the easternmost known concentrations of broad whitefish occur.

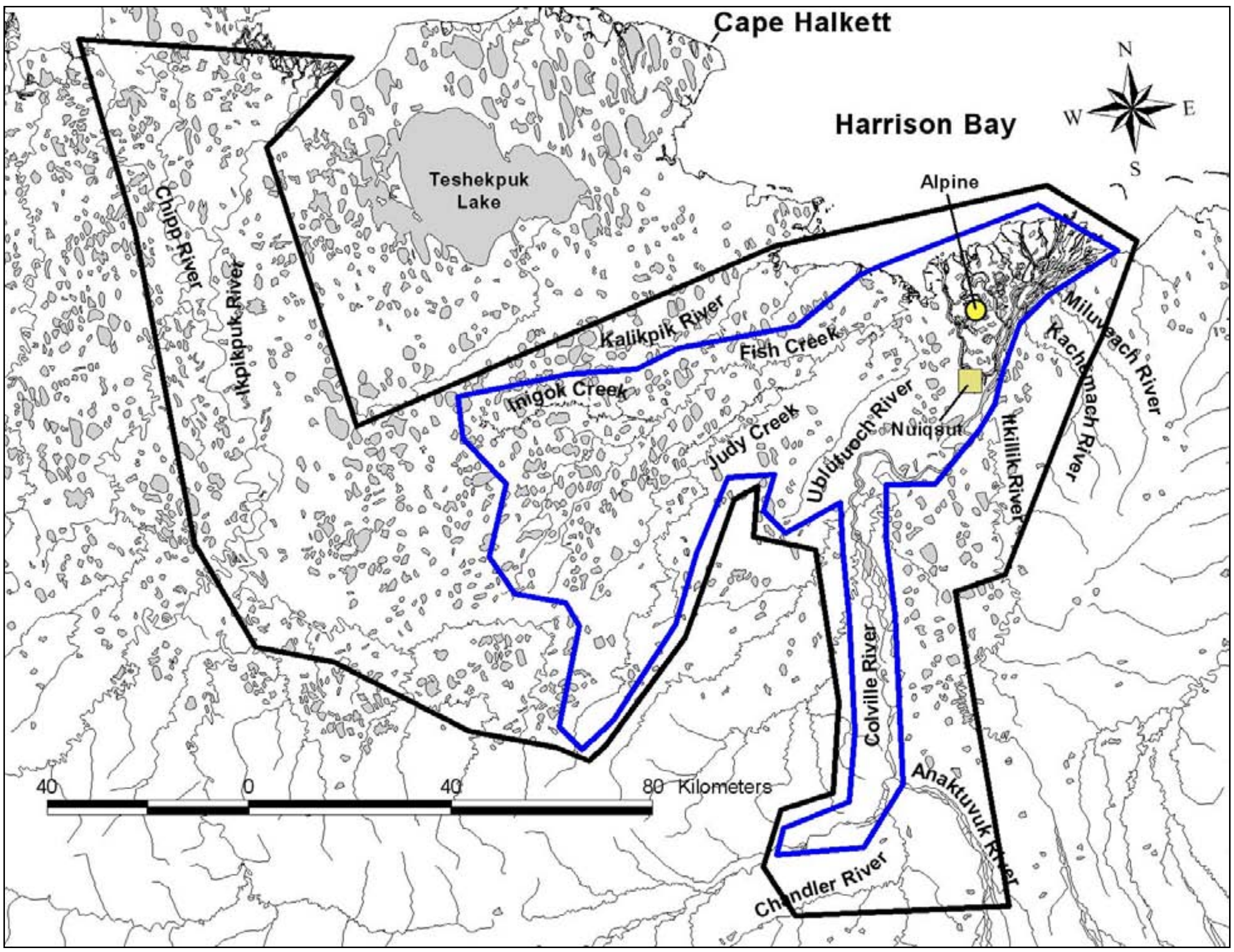

Figure 5. The core relocation survey area (in blue) consisted of the Ublutuoch River, Fish Creek, Judy Creek, Inigok Creek and the Colville River from the delta to upstream of Umiat. The expanded survey area included the lower 30 km of the major tributaries to the Colville River downstream from and including the Chandler River. Other streams surveyed in the expanded search area included portions of the Chipp River, the Alaktak Channel, the Ikpikpuk River to the headwaters of the Price River and Key Creek. The Kalikpik River, up to the Pik Dunes region, also was surveyed. The lower Sagavanirktok River, east and west channels, was surveyed on one occasion in May 2002 (not shown on map).

The effort and cost associated with complete surveys of areas this large are prohibitive. It was therefore critical to ensure that during our relocation efforts we detected fish if they were present in the core area to avoid costly excursions outside the core area on a regular basis when no such effort was actually required. To accomplish this goal we sought to decrease the amount of time our radio receiver would require to search for all fish with active transmitters. Until recently, each animal within a project required a unique frequency to be identified upon relocation. However, in our case, with 40 fish, the receiver would have required nearly three minutes to scan for all individuals. Given the minimum flight speeds of the aircraft available for tracking flights, we would cover a minimum of 4.8 km during a single scan and potentially more than 7.2 km. The likelihood of flying over a fish of frequency 1 and not detecting it, while listening for fish 2, 3 or 4 through 40 would be too high. By using coded wire tags with several different burst (beep) patterns per frequency, we were able to put eight fish on a single frequency and each would be uniquely identifiable to our receiver (Lotek SRX 400 Receiver). This technology allowed us to uniquely identify all 40 fish and use a scan time of 19 seconds, 9.5 times faster than with individual frequencies. Our likelihood of missing fish during our surveys and erroneously expanding the search area was dramatically reduced.

Our summer 2001 sampling goals were to catch and outfit 20 broad whitefish and 10 burbot with transmitters throughout the summer and to outfit 10 Arctic grayling with transmitters during late-August. The transmitters planned for use in the larger species, burbot and broad whitefish, were 11 mm diameter X 59 mm in length, 10 g Lotek MCFT-3M coded wire tags. Based on the frequencies and burst rates selected for these tags, the minimum battery life would range from 349 to 392 days, thereby allowing roughly one full year of tracking for each fish. Smaller Lotek MCFT-3B coded wire tags were used in Arctic grayling. The transmitters were 11 mm diameter X 43 mm long and weighed 7.7 g. The smaller size and weight of transmitters placed in Arctic grayling was accomplished with a smaller battery that created a transmitter with a shorter continuous life than the larger transmitters. To maximize the length of time we could track Arctic grayling, these smaller transmitters were programmed to transmit for a twelve hour period each day and then turn off. Additionally, the tags were programmed to be on from the date of activation (late-August) through early-January and then to reactivate in late-March and run into July 2002. This timing was desired to allow transmitters to function during the key periods of interest: fall, spring, portions of the summer to identify movement patterns and habitat use, winter to locate wintering areas and to allow tracking of fish for nearly a full year. By shutting the transmitters down during mid and late winter when tracking was not necessary because wintering areas would already have been selected by January, we were able to extend the life of the transmitter into the following spring and summer.

Fish Capture

During June and July sampling periods, fyke nets were set at various locations throughout the Fish Creek, Judy Creek and Ublutuoch River area. Nets were set from shore with as much lead net as possible given flow and depth conditions. Fyke nets were set as nearly perpendicular to the bank as possible. Figure 6 illustrates a typical fyke net set and illustrates how the gear relies on the movement of fish for capture. Fyke net sets at river sites were typically altered to orient the net downstream, with one wing running to shore and the center lead trailing downstream with the current. This became necessary to hold the nets in place given the soft bed material and high resistance on the net from mesh clogged with organic material and water flow. Nets were held in place with rebar and danforth anchors secured to the wings, lead, and cod.

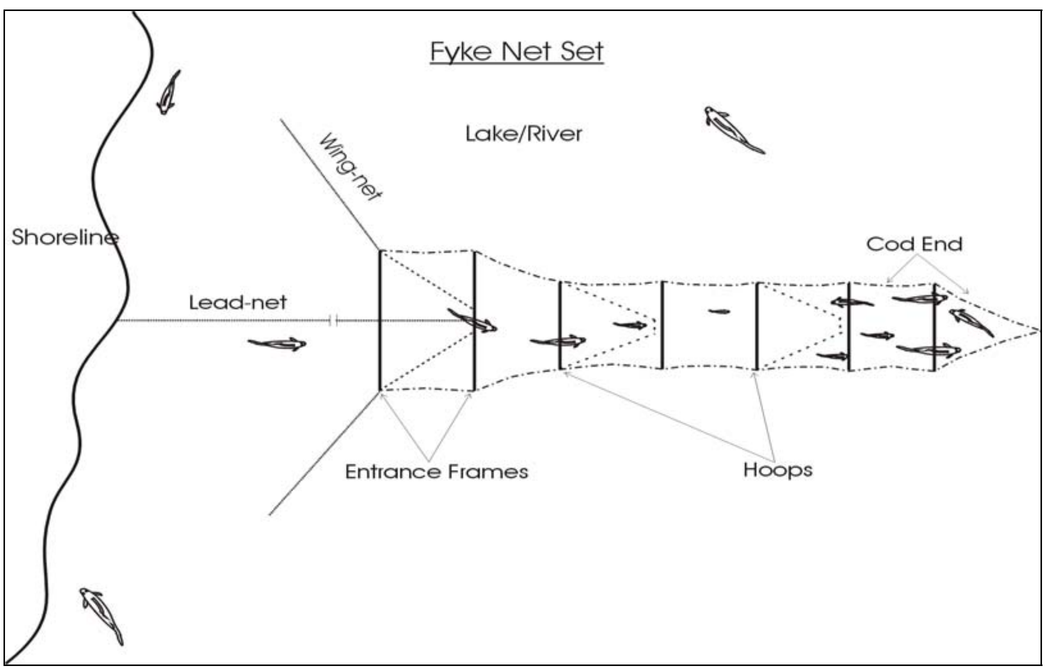

Figure 6. Fyke nets were used to capture broad whitefish and Arctic grayling and to a lesser extent burbot in 2001. Fyke nets are a passive gear type and rely on fish movement for capture. (© OHMP, ADNR)

During August/early-September sampling, fyke nets were set at about the same places as previous sampling sites. However, in response to extremely low catches of burbot during June and July, baited hoop traps were placed at locations proximate to fyke net sets. Each hoop trap was baited with frozen/chopped least cisco and/or humpback whitefish obtained from the previous year's Colville River commercial harvest; betadine treated salmon roe also was used. Hoop traps were set in habitats likely to be selected by burbot and within walking distance of the fyke nets. Traps were assembled, baited, placed in the water and secured to willows on shore with a rope. The hoop trap set near the net in Lake MC7916 was secured with a rebar set in the lake 50 m offshore. Figure 7 illustrates a typical lake habitat hoop trap set. This gear type was used specifically to increase the burbot catch as the method has proven very effective at capturing this predatory species that relies largely on olfactory cues for foraging. Nets were checked and reset at approximate 24-hour intervals after the initial set.

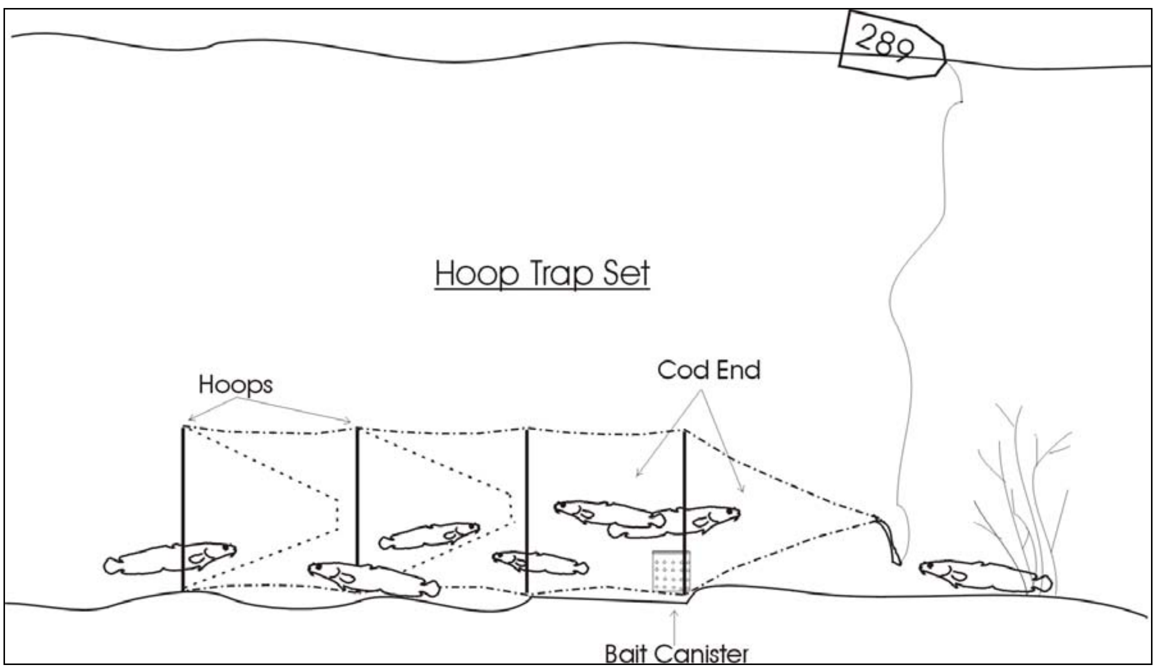

Figure 7. Baited hoop traps were placed near fyke net sampling sites to increase the burbot catch. Traps typically were set in areas with depths too deep for fyke nets. (© OHMP, ADNR)

All fish were lightly anesthetized using a clove oil extract solution, identified, measured to the nearest mm and released. Fish over 250 mm were tagged with a gray, uniquely numbered, T-bar anchor tag and released. During June, July, and August sampling, broad whitefish and burbot large enough to receive a transmitter were retained and implanted with a transmitter. During late-August/early-September sampling, Arctic grayling large enough to receive a transmitter also were retained and implanted with a transmitter.

Net Set History

Fyke netting was conducted with MJM Research, LLC. stream sampling efforts being conducted on behalf of ConocoPhillips Alaska, Inc. The OHMP helped check nets during the sampling program in return for assistance with capturing fish for radio-tag implantation and for assistance with the surgical procedures.

On 19 June, 2001, fyke nets were set at two locations in Fish Creek, one location in Judy Creek, and one location in the Ublutuoch River (Figure 8). Additional nets were set in lakes connected to the lower Fish Creek complex on 21 and 22 June. The net set on 21 June was placed in a large lake at the confluence of the Ublutuoch River and Fish Creek (Figure 8). The net set on 22 June was set in a lake off of Fish Creek, sampled previously by McElderry and Craig in 1979 (named MC7916). McElderry and Craig (1981) found broad whitefish, Arctic grayling and least cisco (*Coregonus sardinella*) using the lake. The 174 hectare, 2.4 m deep lake is the largest in a series of lakes joined by several small tundra drainages (Figure 8). A large ice pan was still present in the lake when we set the net. On 23 June the net set in the lake at the mouth of the Ublutuoch River was moved to Lake MC7916 as only juvenile fish were captured in the lake. During the first few days of sampling in Fish and Judy creeks, nets were routinely reoriented and some moved to backwater areas in response to extreme scour of the unconsolidated bed material and continual net clogging with organic material. The Ublutuoch River net also was moved slightly on a daily basis in response to receding water levels. The initial net set was on the low water floodplain terrace, as water receded the net was eventually moved into the main channel of the river (Figure 4). Early season radio-tagging efforts ended on 28 June.

Sampling to capture fish for radio-tagging was resumed in mid-July 2001. On 18 July the two Fish Creek and the lake MC7916 nets were reset. The Judy Creek and Ublutuoch River nets were set on 19 July (Figure 8). Similar to June sampling efforts, nets were adjusted frequently and occasionally moved to improve fishing efficiency. Mid-season radio-tagging efforts ended on 25 July.

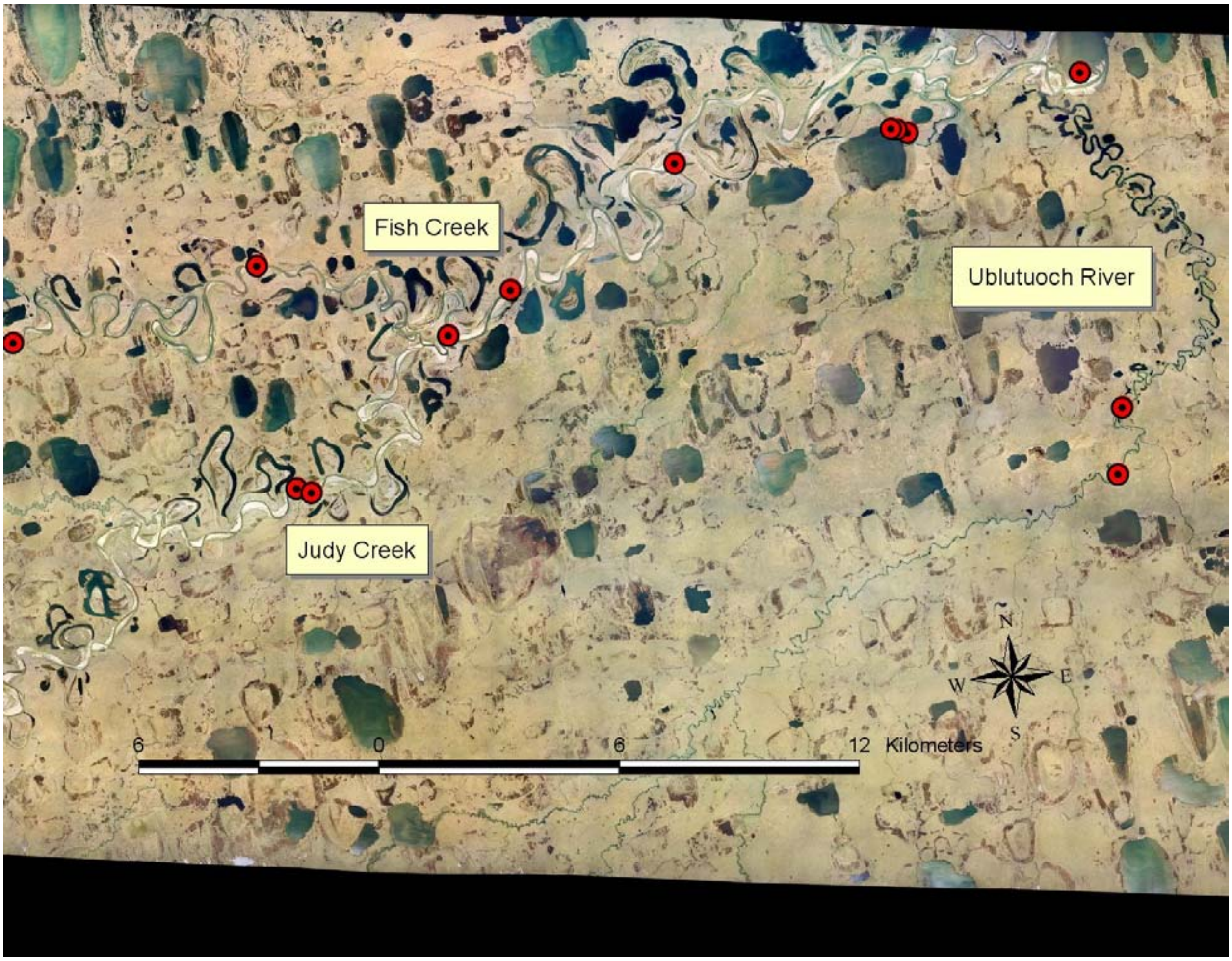

Figure 8. Nets were set at thirteen different locations within the Fish Creek, Judy Creek and Ublutuoch River drainages during summer 2001. (Photomosaic provided by ConocoPhillips Alaska, Inc.)

Both Fish Creek nets, the Judy Creek net, the Lake MC7916 net and the Ublutuoch River net were reset on 24 August (Figure 8). Hoop traps were set in the vicinity of each of the fyke nets. A hoop trap was placed downstream from the fyke net in Judy Creek in the outflow of a small tundra drainage entering the main channel; water depth was about 1m. One hoop trap was set near the uppermost Fish Creek net in the downstream most portion of a large backwater. Water depth was just over 1m. Two hoop traps were set in Fish Creek just below the confluence of Fish and Judy creeks. One trap was set off the inside meander bank on the east bank of Fish Creek in a deep eddy. The second net was set off the west bank, on the cut bank side of the river in considerably deeper water. A hoop trap was set near the Lake MC7916 fyke net, about 30 to 50 m offshore in the channel of a tundra drainage entering the lake. On 27 August the hoop trap on the east side of Fish Creek, downstream from the Judy Creek confluence, was moved to the west bank of the river to the upstream portion of the same large, deep hole the west bank hoop trap was fishing. A final hoop trap was placed just downstream of Judy Creek in Fish Creek along the west cut bank on 28 August. Sampling for the radio-tagging portion of the field effort ended on 2 September and nets were removed.

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, it is considered ideal to keep transmitter weight between 1 and 3% of body weight. These figures refer to the submerged weight of the transmitter versus the weight of the fish. 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. Broad whitefish and burbot were all implanted with transmitters weighing approximately 10 g. Accordingly, only broad whitefish and burbot over 500 g (2% of body weight maximum) were eligible for transmitter implantation; predominantly broad whitefish and burbot over 1000 g were implanted with transmitters. Review of broad whitefish length/weight relationship data and previous radio-telemetry work with the species from the North Slope were combined to set a minimum broad whitefish length of 390 mm. Two other research efforts with broad whitefish using telemetry on the North Slope had used an identical weight transmitter. Researchers in the previous studies had weighed fish prior to implantation; these data established a minimum size for broad whitefish. At the minimum, broad whitefish larger than 390 mm would weigh 700 g; however, this size also represents the smallest broad whitefish ever successfully outfitted with a 10 g transmitter. Space within the peritoneal cavity becomes the more restrictive issue for implanting this size transmitter in broad whitefish, not body weight. As a result, the weighing process was removed, leading to reduced time of handling during the procedure and, likely, reduced stress. No such data were available for burbot at the time of this research effort; therefore, burbot obviously less than 1000 g were weighed to ensure they were over 500 g, the 2% of body weight minimum. Arctic grayling were implanted with transmitters weighing about

7.7 g. Only Arctic grayling thought to weigh in excess of 385 g were selected for transmitter implantation. Data regarding the length/weight ratio for Arctic grayling on the North Slope were used to establish a minimum length criterion of 330 mm. Most fish were over 350mm long and likely weighed between 490 g and 539 g. Peritoneal space, as with broad whitefish, was far more limiting than the body weight/transmitter weight ratio. As a result, the smallest Arctic grayling implanted with a transmitter was 334 mm.

The next criterion used was related to the overall health and condition of fish. Only fish appearing healthy and relatively unstressed were selected. This assessment was subjective but several factors were considered. Fish with obvious external injuries, heavy parasite loads or fish in an obviously stressed condition (state of disequilibrium prior to anesthetic exposure) were not considered. Water temperature at the time of net checks also played a role in the decision to radio-tag fish. Previous studies have noted the severity of the additive effects of thermal stress and handling stress on broad whitefish. A research project investigating the seasonal movements of broad whitefish in the Prudhoe Bay region noted a maximum water temperature of 16.5 C for working with the species in small tundra lakes (Morris 2000). On one occasion water temperatures in the Ublutuoch River reached 18.0 C and several broad whitefish died during the process of removing them from the net. No surgeries were conducted at these temperatures. Similar extreme stress responses have been observed by burbot and Arctic grayling during periods of high water temperature. By assessing fish size, condition and ensuring fish were not predisposed to a lethal stress response from high water temperatures, we were able to increase the probability of fish survival over the course of the research program.

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 20 ppm 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 20 ppm were almost always adequate for broad whitefish and Arctic grayling regardless of water temperature; however, concentrations as high as 30 ppm were required for some broad whitefish. Burbot often required considerably higher concentrations of clove oil solution and typically required a longer period of exposure (some in excess of 20 minutes). Fish were held in the anesthetic solution until they had reached the desired state 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, fish were considered 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 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. A 3 to 4 cm long incision was made on the ventral side of the fish into the peritoneal cavity (Figure 9). Once the incision had been made, a transmitter was inserted into the cavity with the antenna end facing caudally (Figure 10). The antenna was then routed out of the body cavity caudal to the pelvic girdle. The routing of the antenna caudal to the girdle provided 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*. (1999) found that this procedure offered the best long term success for radio-tagged broad whitefish. The 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 (Figure 11). 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 (Figure 12). 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 (Figure 13). Once equilibrium had been regained, fish were released in the vicinity of the capture site.

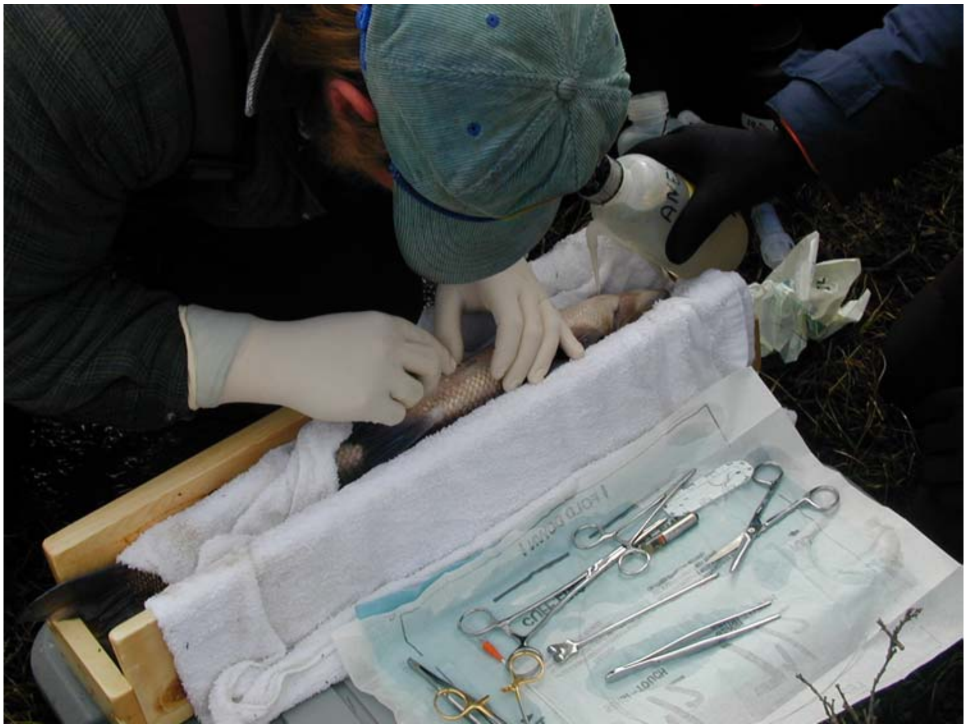

Figure 9. Once anesthetized, a 3 to 4 cm incision was made into the peritoneal cavity on the ventral surface of the fish, cranial to the pelvic girdle. Anesthetic water is being applied to the gills. (© MJM Research, LLC.)

Figure 10. Transmitter was inserted into the peritoneal cavity with the antenna facing caudally. Anesthetic water is being applied to the gills. (© MJM Research, LLC.)

Figure 11. The antenna was routed out of the body cavity caudal to the pelvic girdle using a needle guide and a small horse catheter. Anesthetic water is being applied to the gills. (© MJM Research, LLC.)

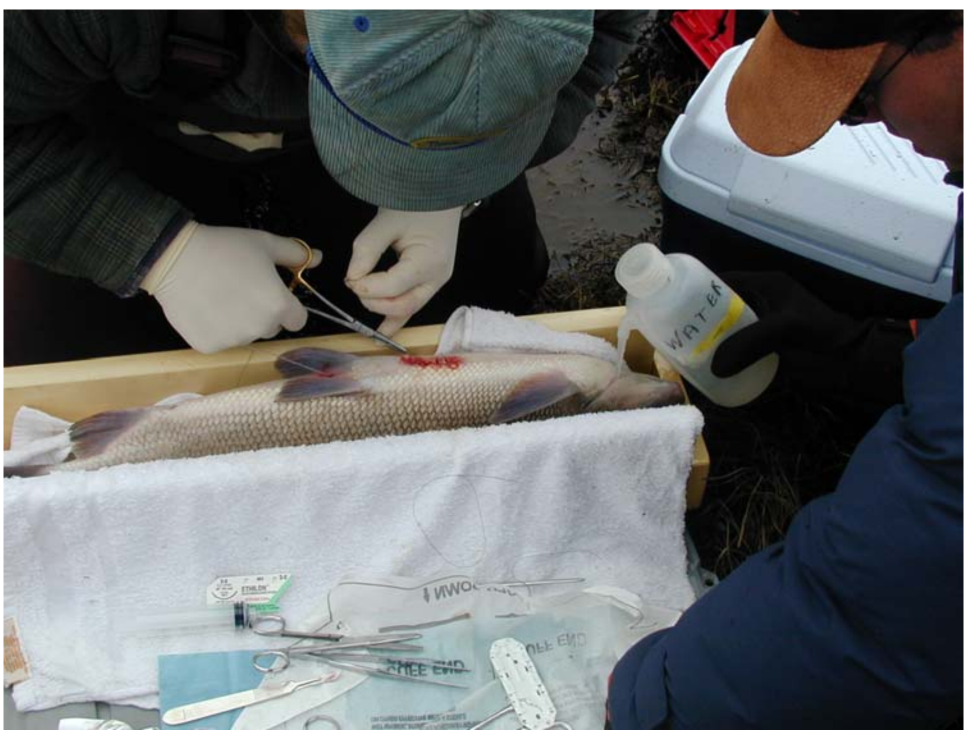

Figure 12. Three to four monofilament sutures were used to close the incision and VetBond® surgical glue was added topically to provide a sealed incision to aid in initial healing. Water is being applied to the gills. (© MJM Research, LLC.)

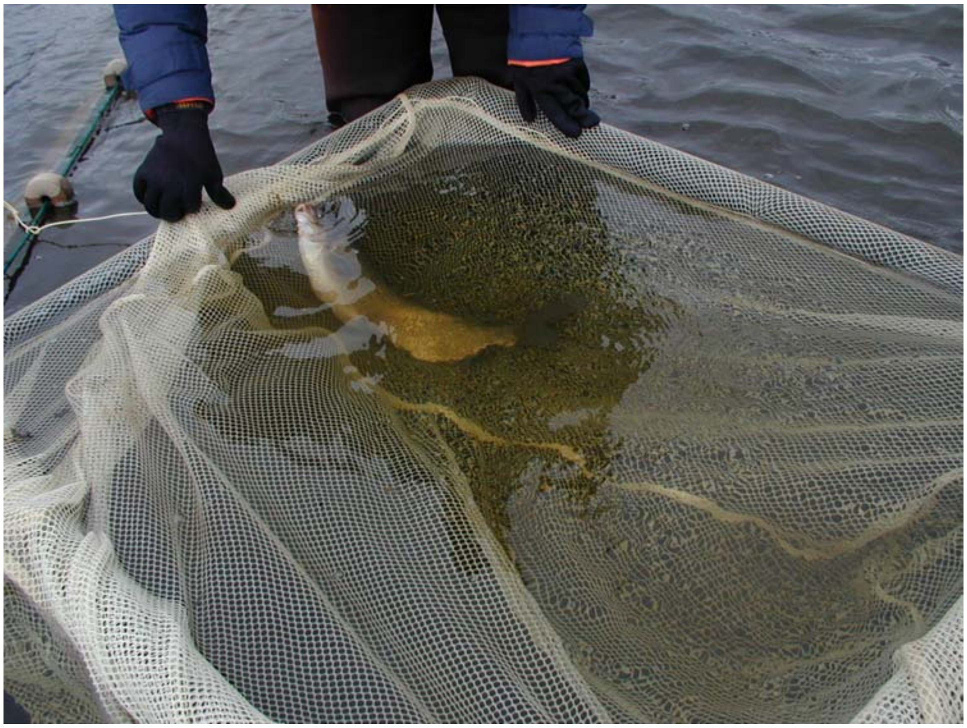

Figure 13. Fish were moved to a holding pen near the capture site and held until they had regained equilibrium, then were released. (© MJM Research, LLC.)

Burbot anatomy dictated that a slightly altered surgical procedure be used. Burbot are considerably more dorso-ventrally compressed over the portion of their body from head to vent. The peritoneal cavity is considerably larger in burbot relative to similar length fish of other species. Burbot also have a pelvic girdle considerably different from the salmoniform body plan of Arctic grayling and broad whitefish. The girdle is extremely reduced and has migrated cranially to near the pectoral fins and therefore was not a viable structure to anchor the transmitter. As a result of the above anatomical differences, a similar size incision was made into the peritoneal cavity just cranial and lateral to the vent. The transmitter was inserted into the body cavity and, using the same procedure as with broad whitefish and Arctic grayling, the antenna was routed out of the body cavity. However, the antenna was routed out of the body cavity through 3 to 6 cm (fish size dependant) of muscle tissue near the terminus of the cavity just lateral to the vent. Figure 14 illustrates the differences in procedure discussed above for burbot transmitter implantation.

Figure 14. Burbot transmitter implantation required modification of the surgical procedure. Transmitters were inserted closer to the terminus of the body cavity and antennas were routed out of the body through several centimeters of muscle tissue in the caudal portion of the fish (top). (© MJM Research, LLC.) One burbot recaptured in an Interior Alaska lake 1 year after receiving a transmitter with the procedure above illustrates the location of implantation, antenna routing and suggests that the procedure is safe for burbot (bottom).

Radio-tracking

Radio tracking was conducted by air, primarily with a Cessna 185 or Cessna 206 fixed wing aircraft. On one occasion, in late-June 2001 just after radio-tagging the first group of fish, limited tracking was conducted with a Bell 206 Jet Ranger helicopter. Fixed wing aircraft used to fly relocation surveys were outfitted with two H-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 SRX-400 decoding receiver. The output from the receiver was routed through the aircraft noise suppressing audio system. Receiver output was then audible through the aircraft headsets, allowing both the pilot and researcher to listen for signals.

The receiver was set to monitor each frequency for the length of the slowest burst rate transmitter (3.5 plus 0.3 s), to ensure a signal would be detected if present. The resulting total scan time to search for all five frequencies was about 20 seconds. Each time a signal was detected the pilot maneuvered to gain adequate reception to decode the signal, providing a positive identification for each fish. Once the position of the strongest signal from any given transmitter was established, a GPS location was recorded on the onboard GPS system of the aircraft and also recorded on the data sheet. A sample data sheet is included in Appendix I. Occasionally, depending on the number of signals being detected at a given location and occasional decoding difficulties, multiple passes of an area or circling of an area was required to discern the individual identification of fish. Unlike traditional pulsed transmitter/receiver units where each frequency is on a separate channel and can be removed upon relocation, all five frequencies were continually monitored because numerous fish were transmitting on each. This was only a slight hindrance relative to the 132 second scan time required had each fish been on a separate frequency.

Beginning in late-June 2001, aerial surveys of the core search area were conducted roughly once every 15 to 20 days through late-September. After September tracking, one early-winter survey was conducted in November and one late-winter survey in early-May. Tracking was conducted again in late-May at break-up, and then again in mid-June. The final tracking event was conducted in mid-August 2002. Table 1 provides a log of each relocation event.

Table 1. Relocation log for 2001/2002 radio-tracking with a key to areas surveyed during each event; aircraft type is also presented.

Survey Dates		Aircraft	Area Surveyed
6/28/2001		Bell 206/Ground	1,2,3,4
7/12/2001		Cessna 185	7,6,5
7/25/2001		Cessna 206	5,6,7,8
8/16/2001		Cessna 206	5,6,7,8
8/30/2001		Cessna 206	5,6,7,8
9/20/2001		Cessna 206	5,6,7,8,10
11/23/2001	11/24/2001	Cessna 206	5,6,7,8
5/4/2002		Cessna 206	5,6,7,8
5/22/2002		Cessna 206	5,6,7,8,14,13,12
6/25/2002	6/26/2002	Cessna 206	5,6,7,8,9,11,13
8/15/2002	8/16/2002	Cessna 206	5,6,7,8,11,15

After 8/15/02 only 11 total tags should have been on the air and only for a short period of time

Key to Areas Surveyed

1	Lower Fish Creek
2	Lower Judy Creek
3	Lake MC7916
4	Lower Ublutuoch to net set areas
5	Fish Creek to headwaters
6	Judy Creek to headwaters
7	Ublutuoch River to Headwaters
8	Colville River, Delta to upstream Umiat
9	Ikpikpuk, Chipp, Alaktak to headwaters
10	Inigok Creek
11	Inigok Creek to headwaters
12	Sagavanirktok River Delta
13	Kachemach and Miluveach rivers
14	20 miles up Anaktuvuk, Chandler, Itkillik rivers
15	Kalikpik River

Results

Fish Capture and Radio-Tagging

Thirty-nine fish were implanted with radio-transmitters during 2001. During late-June, six broad whitefish were radio tagged in Lake MC7916 and one was radio-tagged in the Ublutuoch River. A large burbot also was tagged during late-June efforts in Judy Creek. Catch rates of broad whitefish eligible for radio-tagging increased considerably in the Ublutuoch River during late-July; 12 additional broad whitefish were tagged at this time. Efforts to capture and tag Arctic grayling in late-August/early-September were successful and all 10 Arctic grayling transmitters were placed in fish. We spread the transmitters between drainages roughly proportionate to fish capture in the three rivers. Arctic grayling were most numerous in the Ublutuoch River and five were outfitted with radio tags. The remaining five fish were tagged in Judy (3 fish) and Fish creeks (2 fish). An additional five burbot, captured with hoop traps, were implanted with transmitters in Fish Creek, along with two in Judy Creek. Burbot catches, even with the introduction of hoop trap fishing, were low and only 8 burbot out of our goal of 10 were implanted. Only nine burbot were captured during summer 2001 sampling; eight of these fish were large enough to receive a transmitter. Two additional broad whitefish were radio-tagged in late-August in the Ublutuoch River, bringing the number of tagged broad whitefish to 21, one more than our goal. Table 2 provides a history of the summer 2001 radio-tagging efforts by date, species and location.

Arctic grayling captured and radio-tagged during 2001 sampling ranged from 334 to 401 mm fork length. Mean length of Arctic grayling captured was 367 mm (N= 10, SE = 6.4) and the median size of fish tagged was 370 mm. While only 10 Arctic grayling were implanted with radio-transmitters, differences in fish size between the 3 drainages were observed. Generally, fish from Judy Creek were larger than those captured in the Ublutuoch River. Comparison of mean ranks suggests that Arctic grayling from the Ublutuoch River were the smallest group of Arctic grayling adults, whereas fish from Judy Creek were the largest; Arctic grayling from Fish Creek were not different in size from the other two sites (Appendix II). The sample of 10 fish is inadequate to detect true statistical differences; however, the detected difference is consistent with empirical data from the rivers for adult Arctic grayling.

Eight burbot were tagged with radio-transmitters in 2001. Burbot ranged from 455 to 710 mm total length, with a mean total length of 565 mm (N=8, SE=31.6). Although only eight burbot were outfitted with transmitters, significant differences were observed between fish captured in Judy and Fish creeks. The three burbot tagged in Judy Creek were larger than those in Fish Creek ($\overline{X}$ Judy Creek = 650 mm, $\overline{X}$ Fish Creek = 514 mm); however, given the small sample size, statistical differences were not detected (Wilcoxin Rank Sum, Exact p = 0.1429). Appendix II contains descriptive and comparative statistics for burbot radio-tagged during 2001.

Table 2. Radio-tagging log for summer 2001 tagging events. Data regarding species, tagging date, T-bar tag number, fish size, and tagging location are presented.

Species	T-Bar Tag #	Tagging Date	Sex	Fork Length (mm)	Tagging Location
Broad Whitefish	MJM 01 0091	6/25/2001		405	Lake MC7916
Broad Whitefish	MJM 01 0105	6/25/2001		580	Lake MC7916
Broad Whitefish	MJM 01 0103	6/25/2001		456	Lake MC7916
Broad Whitefish	MJM 01 0104	6/25/2001		440	Lake MC7916
Broad Whitefish	MJM 01 0102	6/25/2001		492	Lake MC7916
Broad Whitefish	MJM 01 0154	6/26/2001		573	Lake MC7916
Burbot	MJM 01 0176	6/27/2001		710	Judy Creek
Broad Whitefish	MJM 01 0184	6/27/2001		523	Ublutuoch River
Broad Whitefish	MJM 01 0518	7/20/2001		505	Ublutuoch River
Broad Whitefish	MJM 01 0519	7/20/2001		431	Ublutuoch River
Broad Whitefish	MJM 01 0520	7/20/2001		459	Ublutuoch River
Broad Whitefish	MJM 01 0200	7/20/2001		540	Ublutuoch River
Broad Whitefish	MJM 01 0548	7/21/2001		434	Ublutuoch River
Broad Whitefish	MJM 01 0725	7/24/2001		414	Ublutuoch River
Broad Whitefish	MJM 01 0726	7/24/2001		392	Ublutuoch River
Broad Whitefish	MJM 01 0727	7/24/2001		451	Ublutuoch River
Broad Whitefish	MJM 01 0847	7/25/2001		497	Ublutuoch River
Broad Whitefish	MJM 01 0776	7/25/2001		475	Ublutuoch River
Broad Whitefish	MJM 01 0777	7/25/2001		402	Ublutuoch River
Broad Whitefish	MJM 01 0778	7/25/2001		485	Ublutuoch River
Arctic Grayling	MJM 01 0581	8/25/2001	M	371	Ublutuoch River
Arctic Grayling	MJM 01 01331	8/25/2001	F	338	Ublutuoch River
Arctic Grayling	MJM 01 01330	8/25/2001	F	334	Ublutuoch River
Arctic Grayling	MJM 01 01329	8/25/2001	M	365	Ublutuoch River
Arctic Grayling	MJM 01 01302	8/26/2001	M	374	Judy Creek
Arctic Grayling	MJM 01 076	8/26/2001	F	388	Judy Creek
Arctic Grayling	MJM 01 01306	8/26/2001	M	401	Judy Creek
Burbot	MJM 01 01326	8/26/2001		462	Fish Creek
Burbot	MJM 01 01301	8/26/2001		640	Judy Creek
Broad Whitefish	MJM 01 01315	8/26/2001		555	Ublutuoch River
Arctic Grayling	MJM 01 01317	8/27/2001	F	375	Fish Creek
Arctic Grayling	MJM 01 01318	8/27/2001	F	368	Fish Creek
Burbot	MJM 01 01324	8/28/2001		455	Fish Creek
Burbot	MJM 01 01352	8/28/2001		555	Fish Creek
Burbot	MJM 01 01370	8/29/2001		600	Judy Creek
Burbot	MJM 01 01380	8/30/2001		598	Fish Creek
Burbot	MJM 01 01386	8/31/2001		500	Fish Creek
Arctic Grayling	MJM 01 01505	9/2/2001	F	360	Ublutuoch River
Broad Whitefish	MJM 01 01506	9/2/2001		432	Ublutuoch River

Broad whitefish captured and implanted with transmitters ranged in size from 392 to 580 mm fork length. The mean size of broad whitefish tagged during summer 2001 was 473 mm (N= 21, SE = 12.3 mm) and the median length of the group of tagged fish was 459 mm. No significant differences in fish sizes between radio-tagged broad whitefish from Lake MC7916 and the Ublutuoch River were observed (Wilcoxin Rank Sum, Mean Rank MC7916 = 12.7, N = 6, Mean Rank Ublutuoch = 10.3, N = 15, Exact Permutation 2-tailed p = 0.63). However, the mean size of fish from Lake MC7916 ($\overline{X}$ = 491 mm, min = 405, max = 580) was larger than that observed in the Ublutuoch River ($\overline{X}$ = 466 mm, min = 392, max = 555). Differences in broad whitefish lengths between the three sampling periods were not statistically different (KW AOV = 1.8482, p = 0.3969). However, sample sizes of radio-tagged broad whitefish were markedly different between periods (June = 7, July = 12, August = 2). Generally, larger broad whitefish were present and tagged in spring. Appendix II contains descriptive and comparative statistics between net locations and sample periods.

Relocation Success

Radio tracking, initiated just after the first group of fish were tagged in June 2001, yielded varying degrees of relocation success between seasons by species (Table 3). Immediately after tagging and through 20 September 2001, Arctic grayling relocation success ranged from 77 to 80%. Winter tracking success for Arctic grayling was poor. Late-November 2001 and early-May 2002 Arctic grayling relocation rates were only 10% (1 of 10 fish, the same fish relocated at the same place in early- and then late-winter). Relocation success improved slightly upon break-up to 20% (2 of 10 fish) on 22 May, 2002. Late-June 2002 relocation success increased dramatically to 80% (8 of 10 fish).

Broad whitefish radio-tracking success also was variable by season, but was consistently higher than that for Arctic grayling. After tagging in 2001, broad whitefish relocation rates ranged from 89 to 52% during the first open water season of tracking. Relocation rates during winter 2001/2002 were between 52% and 42%. After break-up 2002, relocation rates increased to 66% and remained at that level through the open-water tracking season in 2002.

Burbot relocation rates were consistently high. The one burbot tagged in June 2001, was relocated during all open-water tracking surveys with the exception of the 16 August survey in 2001. Once additional burbot were tagged in August 2001, relocation rates ranged from 75 to 100% prior to freeze-up. Burbot relocation rates decreased during the winter season, similar to tracking success with the other two species. Early-winter tracking in late-November 2001 located 37% of tagged burbot whereas late-winter tracking found only 25% of the burbot tagged in 2001. Mid- and post-break-up tracking rates in 2002 were consistently 87% successful.

Table 3. Radio tracking-success varied by species and by season. A summary of relocation rates by survey date and species is presented.

		Relocations						Number of Fish Tagged		
Survey Dates		Arctic Grayling	% Relocated	Broad Whitefish	% Relocated	Burbot	% Relocated	Arctic Grayling	Broad Whitefish	Burbot
6/28/2001				6	85.7	1	100.0	0	7	1
7/12/2001				4	57.1	1	100.0	0	7	1
7/25/2001				17	89.5	1	100.0	0	19	1
8/16/2001				10	52.6	0	0.0	0	19	1
8/30/2001		7	77.8	11	55.0	7	100.0	9	20	7
9/20/2001		8	80.0	11	52.4	6	75.0	10	21	8
11/23/2001	11/24/2001	1	10.0	11	52.4	3	37.5	10	21	8
5/4/2002		1	10.0	9	42.9	2	25.0	10	21	8
5/22/2002		2	20.0	14	66.7	7	87.5	10	21	8
6/25/2002	6/26/2002	8	80.0	14	66.7	7	87.5	10	21	8
8/15/2002	8/16/2002	0		14	66.7	7	87.5	0	21	8

After 8/15/02 only 11 total tags should have been active, and only for a short period of time.

Relocation histories of individual fish offered a much better picture of fish use of the area and provided a better metric for habitat use by species and by season. However, well over 200 individual relocations were made, and each will not be treated independently. Instead, movement histories are presented in map form for each fish in Appendix III. While all fish were not relocated on each tracking event, most fish were relocated numerous times throughout the study and during both years.

General Relocation Results

Note: To view maps of individual fish relocation histories refer to Appendix III and locate the map corresponding to the fish of interest. Maps are organized from Arctic grayling to burbot to broad whitefish and fish within each group are in numerical order.

Arctic grayling

Arctic grayling within the study group readily moved between the Judy, Fish and Ublutuoch drainages and used main channel habitats in the Ublutuoch River, Judy Creek, Fish Creek and Inigok Creek. Arctic grayling were relocated in Inigok Creek as far as 40 km upstream from the mouth, in Fish Creek up to 80 km upstream from the mouth, in Judy Creek or its tributaries up to 50 km upstream from the mouth, and as far upstream in the Ublutuoch River and its tributaries as 20 km from the mouth (Figure 15). At least 60% of Arctic grayling tagged used small tributaries and lakes. Arctic grayling used well over 200 km of stream and lake habitats within the region between late-August 2001 and mid-June 2002 (Figure 15).

Most Arctic grayling were readily relocated during the open water seasons of 2001 and 2002. All fish were located immediately after release in late-August and early-September and typically were very near their release sites (Appendix III). On 20 September, 8 of the 10 tagged Arctic grayling were relocated; most fish were near their previous location earlier in the month. However, one Arctic grayling had moved downstream in the Ublutuoch River to near the mouth of the river. Another Arctic grayling had moved out of Judy Creek and moved upstream in Fish Creek a few kilometers from the Fish Creek and Judy Creek confluence by 20 September. Two Arctic grayling were not relocated during late-September 2001 and were subsequently never found again. Late-November 2001 and early-May 2002 surveys yielded very poor relocation success for Arctic grayling; one fish was relocated in Fish Creek. In late-May, one additional Arctic grayling was relocated. By 25 June, the eight fish successfully relocated in late-September were again found.

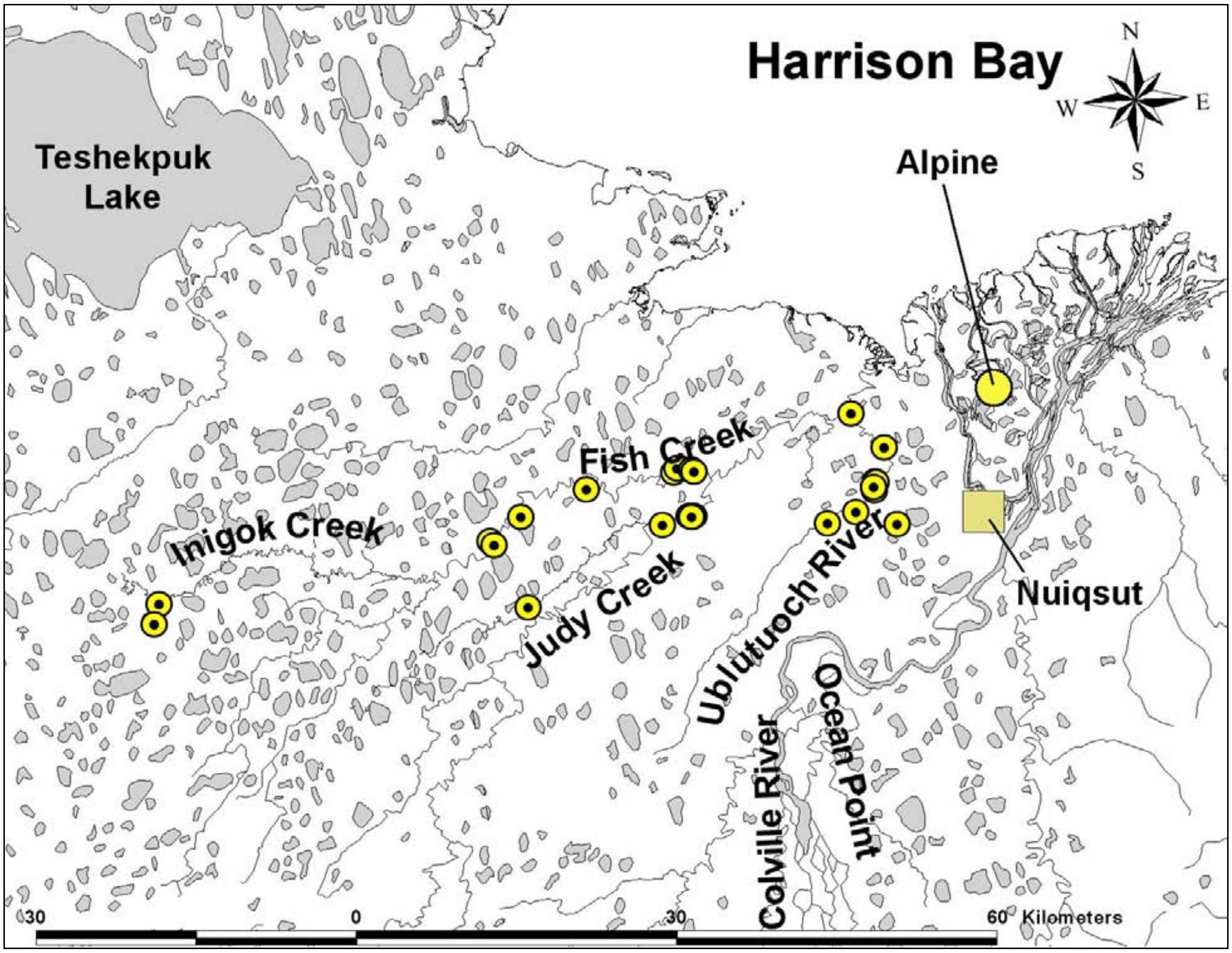

Figure 15. Map of all Arctic grayling relocations from August 2001 through June 2002. The map illustrates the geographic areas and the extent of system use by the tagged population of Arctic grayling in the study program.

Arctic grayling locations from June 2002 suggested two probable causes for the low relocation rates observed during winter; technological problems with ice-induced signal attenuation or migration of fish to areas not surveyed. Arctic grayling 1505 was located near the mouth of the Ublutuoch River during late-September 2001 and likely spent the winter in that vicinity, undetected during winter surveys. The fish was in the Ublutuoch River in late-May a few kilometers downstream from its tagging location the previous year. Between late-May and late-

June 2002, the fish moved from the Ublutuoch River to a small tributary of Judy Creek some 60+ kilometers away. Given the long movements made by Arctic grayling within the study area, it is difficult to say for certain where the fish wintered, but it is likely that the fish wintered in the Ublutuoch River and then proceeded, during break-up in late-May 2002, to the Judy Creek tributary, probably for spawning. Other fish moved far greater distances throughout the study. Arctic grayling 1306 was located in lower Judy Creek during late-September 2001 and was not relocated again until late-June 2002. The fish was well over 77 km upstream in Inigok Creek in a small off-channel lake with Arctic grayling 1317. Both fish exhibited identical relocation patterns, each was in the lower Judy Creek/Fish Creek confluence area in late-September and each was relocated next in the small Inigok Creek lake in June 2002. Aerial surveys did not cover upper Inigok Creek during winter and would have missed these fish if they wintered somewhere in the Inigok Creek area.

Thirty percent of Arctic grayling tagged showed fidelity at least to summer rearing areas and were relocated in summer 2002 within the same drainages they were initially captured in during summer 2001 (Appendix III, Arctic grayling 1302, 1329, 581). Eighty percent of Arctic grayling used the Ublutuoch River at some point during the study period although only 50% were tagged in the Ublutuoch River. Perhaps most interesting was the use of a small drained lake by three Arctic grayling during summer 2002 (Appendix III, Arctic grayling 1329, 581, 1318). One of the Arctic grayling found in the lake was tagged in Fish Creek during summer 2001, upstream from the confluence with Judy Creek, while the other two were tagged in the Ublutuoch River. It is likely that these three fish wintered in the lower Ublutuoch River, along with another Arctic grayling (1505) located in the Ublutuoch River at break-up, as the Ublutuoch appears to provide the only near-by wintering habitat. Arctic grayling 076, tagged in the Ublutuoch River in late-August was relocated at the tagging location in late-September, but by late-November 2001, was more than 30 km upstream of the Fish Creek/Judy Creek confluence in Fish Creek. Subsequent movements suggest the fish either moved slowly downstream after break-up or died during winter and simply drifted downstream until relocated in June 2002, some 20 km downstream from its wintering location (with broad whitefish 0518).

Burbot

Burbot within the study group used the Fish Creek, Judy Creek, Inigok Creek and Ublutuoch River systems but used tributary streams and lakes less frequently than Arctic grayling (Figure 16). However, burbot readily moved long distances within the main channel habitats of Inigok Creek, Fish Creek, Judy Creek and one small meandering tributary of Judy Creek. Burbot also used the lower several kilometers of the Ublutuoch River within the lowest gradient reach of the system; habitats upstream from the deepest portion of the Ublutuoch River were not used by burbot (Figure 16). Burbot were relocated as far upstream in Inigok Creek as 30 km from the mouth; however, the majority of relocations for burbot occurred within the lower 10 km of Judy Creek and the 40 km stretch of Fish Creek upstream from the mouth of the Ublutuoch River. Burbot were relocated in a small tributary of Judy Creek, roughly 35 km upstream from its confluence with Judy Creek, in both 2001 and 2002 (Figure 16).

Burbot relocation rates were reasonably high throughout the study and although each fish was not relocated during each tracking event, all burbot were relocated during at least one tracking event after break-up 2002. Most notable from the burbot tracking conducted during 2001/2002 were the expansive movements throughout the systems. Burbot 1352 remained in the same 10 km stretch of Fish Creek, upstream from Judy Creek, from the time it was tagged in August 2001 through late-June 2002. By mid-August 2002, the fish was 25 km farther upstream in Fish Creek from its June location. This fish represents the most sedentary burbot of the eight tagged. Some fish made extensive movements up nearby drainages. Burbot 1326, for example, was relocated 30 km upstream in Inigok Creek in June 2002. Upon its last relocation in late-September 2001 the fish was downstream 10 km from Judy Creek in Fish Creek. This fish moved minimally 100 km between freeze-up 2001 and mid-June 2002. The first burbot tagged in the study (Burbot 0176) on 27 June 2001, moved several kilometers upstream in Judy Creek and by 20 September 2001 was over 35 km upstream in a small tributary to Judy Creek. Late-November radio-tracking relocated the same burbot some 70 km away in the lower Ublutuoch River. By mid-August 2002 the fish had moved upstream of Judy Creek in Fish Creek, another 30 km movement from its November 2001 location. Burbot 1380 exhibited similar movements up the same small Judy Creek tributary during summer 2002, moving minimally 30 to 40 km between

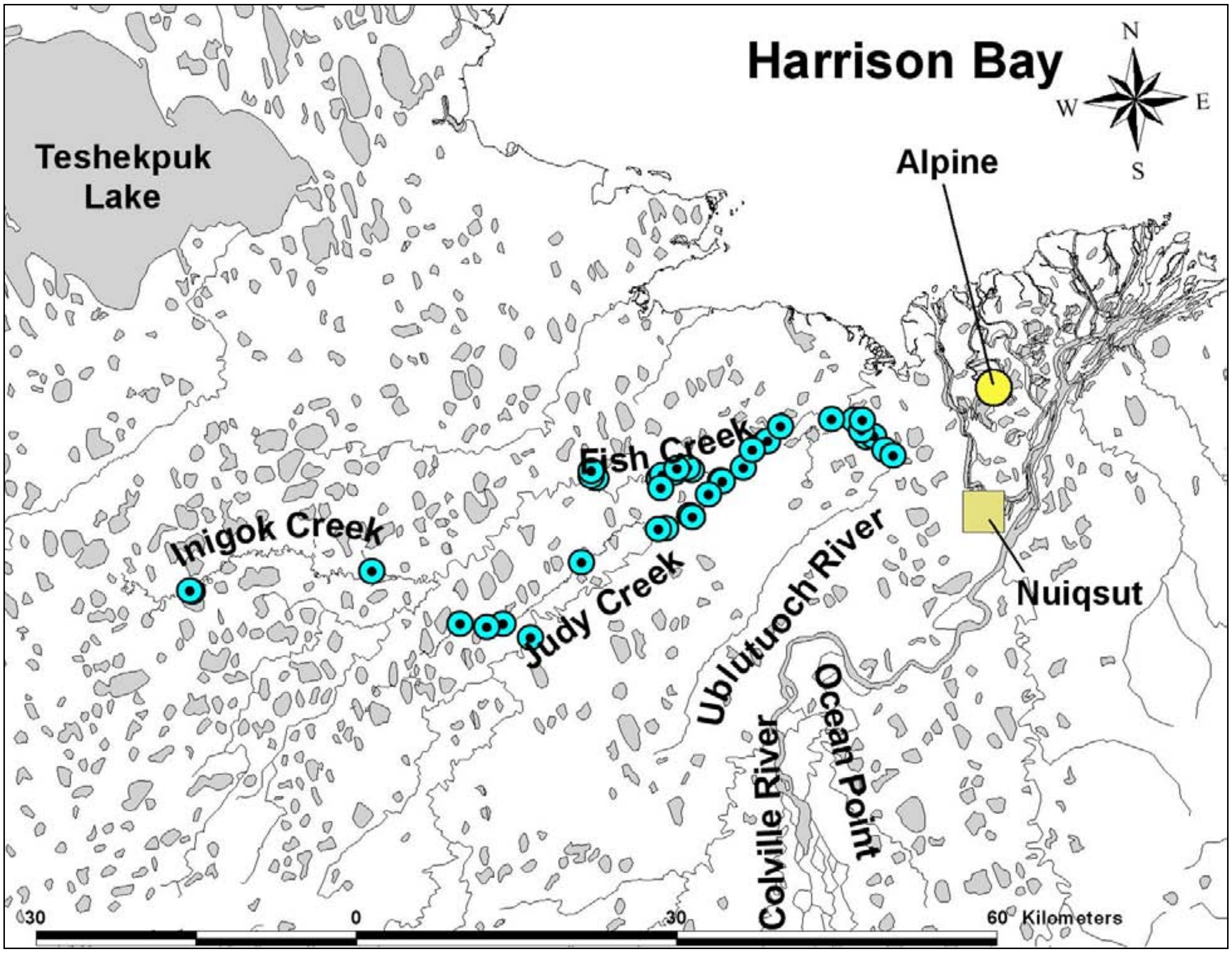

Figure 16. Map of all burbot relocations from June 2001 through June August 2002. The map illustrates the geographic areas and the extent of system use by the tagged population of burbot in the study program.

relocations in summer 2002. While no burbot were outfitted with transmitters in the Ublutuoch River, four of the eight radio-tagged burbot used the Ublutuoch River during the study. Complete movements histories are provided for each fish in Appendix III.

Broad Whitefish

Broad whitefish within the study group exhibited the most diverse movement patterns, readily using main channel habitats, small off-channel systems and numerous lakes within the study area (Figure 17). Broad whitefish movements within the Fish Creek/Judy Creek complex exhibited similar movements to radio-tagged burbot and Arctic grayling and upstream relocation extremes were nearly identical. The majority of broad whitefish relocations occurred within the lower 15 km of the Ublutuoch River and that portion of Fish Creek upstream from the Ublutuoch River roughly 5 km. Most relocations in lower Fish Creek occurred within the drainages associated with Lake MC7916. Unlike movements of burbot and Arctic grayling, broad whitefish used freshwater habitats within the Colville River as well. This movement required a short easterly migration into Harrison Bay to enter one of the Colville River delta's distributaries. Most fish moved upstream of the delta head towards or to Ocean Point. All Colville River relocations were from just downstream of the Itkillik River to Ocean Point (Figure 17).

Fish Creek and Judy Creek Broad Whitefish

Broad whitefish relocation success rates were consistently high (Table 3), even though the amphidromous life style of the species enables them to move between freshwater systems along the coast. Four broad whitefish likely moved to distant river systems along the coast shortly after being tagged. Broad whitefish 1315 and 0725 were tagged in the Ublutuoch River during summer 2001; both were relocated successfully within a few days of tagging and then left the study area. Two broad whitefish tagged on 25 June 2001 in Lake MC7916 also left the study area within a few days of being tagged (0103 and 0091). Broad whitefish 0103 had moved into Fish Creek a few kilometers upstream from the lake by 28 June 2001, and was never relocated again. Broad whitefish 0091 was relocated within Lake MC7916 on 28 June 2001; the fish was never relocated after that date. These four fish immediately left the study area and represent 19% of our radio-tagged broad whitefish. Two broad whitefish appeared relatively sedentary and never were relocated outside of the Ublutuoch River. Broad whitefish 0548 and 0200 were both tagged in July 2001 and subsequently made movements into the lower portion of the Ublutuoch River during winter. They made only slight upstream movements within the drainage during summer 2002. However, the two fish may have moved more extensively than their tracking results indicated. Broad whitefish 0520 also was tagged in July 2001 within the Ublutuoch River and typically was relocated within the Ublutuoch River during tracking events, although on one occasion the fish ventured 25 kilometers upstream in Fish Creek. The fish remained in the Ublutuoch River through 25 July; however, by 16 August 2001 the fish had moved some 12 km downstream in the Ublutuoch River and then upstream in Fish Creek roughly 25 km. Subsequent tracking on 20 September 2001 relocated the fish back within the lower 10 km of the Ublutuoch River. The two fish showing more sedentary movements may have made similar and undetected movements between relocation events.

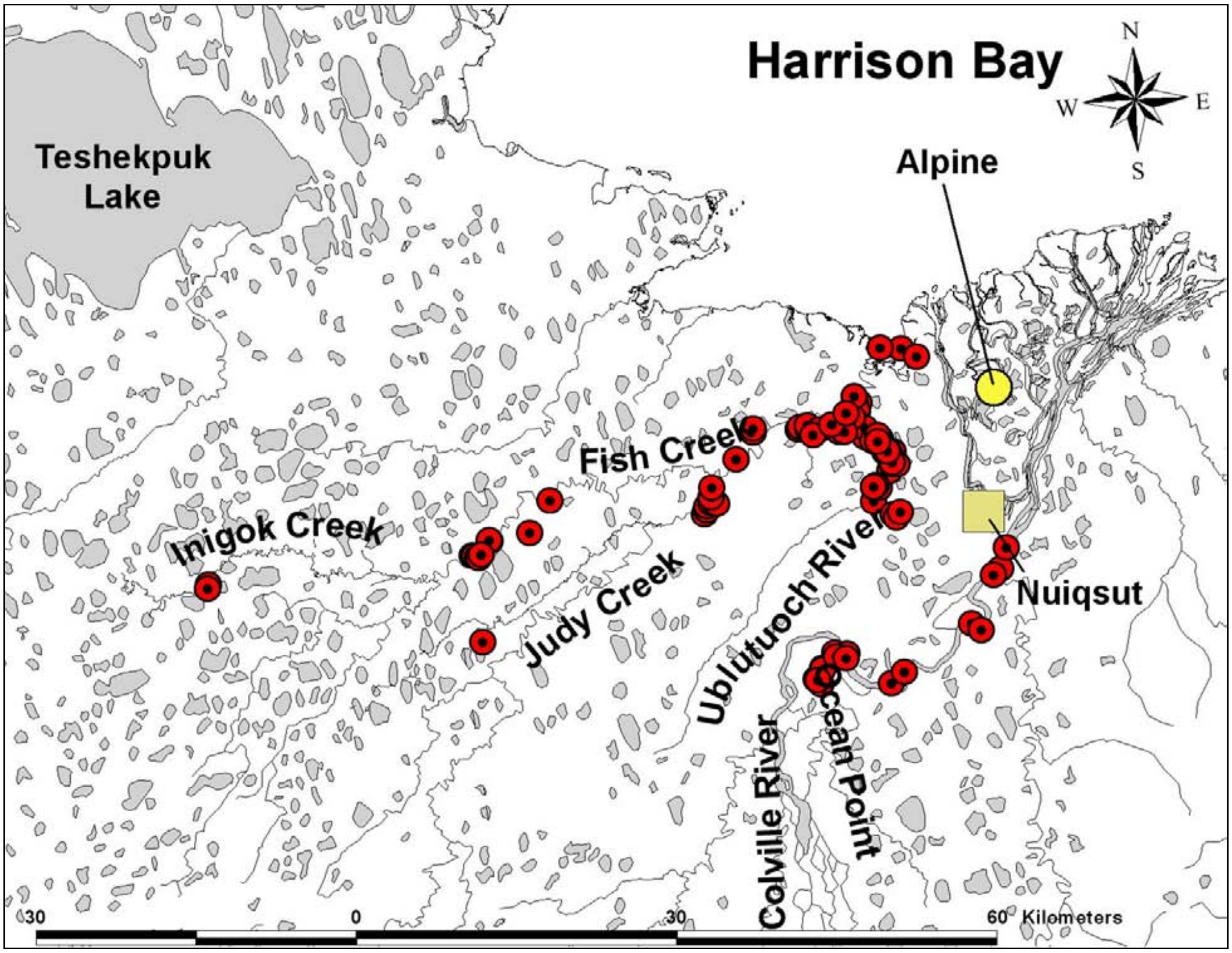

Figure 17. Map of all broad whitefish relocations from August 2001 through June 2002. The map illustrates the geographic areas and the extent of system use by the tagged population of broad whitefish in the study program.

The majority of broad whitefish within the study group remained within the freshwater systems of the Fish Creek/Judy Creek/Ublutuoch River complex (Appendix III). Many made extensive movements within the main channels and to lakes and tributary systems.

Areas of use and extents of upstream movements were similar to those observed with Arctic grayling and burbot. Broad whitefish 0519 was tagged in the Ublutuoch River during June 2001 and remained there until sometime after break-up 2002. It was relocated on 15 August 2002 some 70 km away in a lake off-channel from the small Judy Creek tributary that was also used by tagged burbot and Arctic grayling. Broad whitefish 0184 illustrates a within season nomadic movement pattern observed with several broad whitefish in the study and observed with broad whitefish studied in the Sagavanirktok River region near Prudhoe Bay (Morris 2000). The fish was tagged in the Ublutuoch River in June 2001, moved to Lake MC7916 off of Fish Creek by 12 July 2001, returned to the Ublutuoch River by 30 August 2001, and finally proceeded to the lower 4 km of Judy Creek for wintering. This fish almost certainly did not survive the winter in lower Judy Creek; all mid- and post-break-up relocations occurred slightly farther downstream as the season progressed, suggesting downstream drifting of the carcass (see map in Appendix III). Broad whitefish 0518 moved the furthest distance within the study area in the shortest time period when it moved 75 km from the Ublutuoch River to upper Fish Creek between 20 July and 25 July 2001. The fish subsequently moved upstream in Fish Creek to winter; wintering survival was not conclusively determined for this fish. Similar to Arctic grayling and burbot in the region, broad whitefish used off-channel and main channel habitats within Inigok Creek. Broad whitefish 1506, tagged in the Ublutuoch River, appeared to winter within the Ublutuoch River during winter 2001/2002 and then moved into the Inigok Creek drainage where it was relocated in a small off-channel lake during June and August 2002 surveys..

Colville River Broad Whitefish

A group of five broad whitefish migrated from the Fish Creek/Judy Creek/Ublutuoch River area to winter in the Colville River during winter 2001/2002. These five broad whitefish (~24%, [0847, 0778, 0776, 0104 and 0102]) each returned to systems within the northeast NPR-A the following open water season. Broad whitefish 0847 was tagged in the Ublutuoch River in June 2001, was first relocated in a small inside channel at Ocean Point in the Colville River (a channel system located just east of the inside meander of the main channel) on 20 September 2001, wintered just downstream of Ocean Point, moved to Lake MC7916 in lower Fish Creek by 25 June 2002 and by 15 August 2002 had returned to the Ublutuoch River and was relocated in a small off channel lake. This same small lake was used by three Arctic grayling and another broad whitefish during summer 2002. Another broad whitefish tagged in the Ublutuoch River during late-June 2001 was not relocated again until 4 May 2002, when it was relocated in the Colville River between the mouth of the Itkillik River and Ocean Point. During break-up the fish was relocated just downstream from the Itkillik River; however, by June 2002 the fish had returned to the lower Ublutuoch River and was relocated in the same general area of the

Ublutuoch River during mid-August 2002. Broad whitefish 0776 was tagged in the Ublutuoch River in July 2001 and was next relocated roughly one month later in the Colville River downstream from Ocean Point. By 20 September 2001 the fish had moved to the same inside channel of Ocean Point as fish 0847. The fish subsequently was relocated in June and August 2002 in a small off-channel lake off the Ublutuoch River with fish 0847 (and three Arctic grayling). Broad whitefish 0102 also used the Colville River during winter 2001/2002. The fish was tagged in June 2001 in Lake MC7916 and was not relocated again until 23 November 2001 when it was relocated in the Colville River near the mouth of the Itkillik River. Break-up surveys again relocated the fish in generally the same area of the Colville River; however, by late-June 2002 the fish had moved back into Fish Creek but was located roughly 50 km upstream in a lake at the head of a small 4 km long tundra drainage.

Broad whitefish 0104 is perhaps the most interesting of the Colville River broad whitefish as the fish made multiple movements between the Fish Creek area and the Colville River. The fish was initially tagged in Lake MC7916 in late-June 2001 where it remained until at least 12 July 2001. By 25 July 2001 the fish was relocated in the Colville River in the small inside channel used by other broad whitefish (discussed above). This broad whitefish spent the entire fall and winter within the small channel of the Colville River and was relocated there on 22 May 2002. Late-June surveys later relocated the fish in a small lake adjacent to Lake MC7916 within the same drainage system in lower Fish Creek. Surveys flown in August 2002 relocated the fish back in the same channel at Ocean Point in the Colville River. This same channel was used during winter 1998/1999 by at least one broad whitefish radio-tagged in the Prudhoe Bay area near the Sagavanirktok River during 1998. Additionally, another broad whitefish from that study was captured in a subsistence net likely just downstream from Ocean Point (Morris 2000).

Statistically significant differences in the size of fish between broad whitefish using the Colville River and other broad whitefish within the study group were not detected (Wilcoxin Rank Sum Mean Rank Colville = 12.4, Mean Rank non-Colville = 10.6, Exact $p = 0.72$). Sample sizes were markedly different with only five fish going to the Colville River and 17 fish never going to the Colville River. Median size for broad whitefish relocated in the Colville River was 485 mm whereas the median size for the remaining broad whitefish was 454 mm; however, the mean lengths were nearly identical (Colville = 478 mm, non-Colville = 472 mm). Information on fish condition, while noted for many fish, was inadequate to perform any additional comparative analyses. Appendix II presents descriptive and comparative statistics for Colville River broad whitefish.

Wintering Areas

Location of wintering areas throughout this region of the northeast NPR-A was identified as a major goal for this research. Several have been identified as significant for fish using the Fish Creek/Judy Creek/Ublutuoch River drainages. Determination of wintering areas first concentrated on winter relocation data for each species (Figures 18 – 20). Only two Arctic grayling were definitively relocated at wintering areas; one in the lower Ublutuoch River and one in Fish Creek (Figure 18). Burbot winter relocations were similar. Three were found within the lower Ublutuoch River between November 2001 and May 2002, and one burbot successfully overwintered in Fish Creek just upstream from Judy Creek (Figure 19). Broad whitefish winter relocations were more numerous but generally were located within the same areas with some exceptions (Figure 20). Broad whitefish used the Ublutuoch River, Fish Creek, Judy Creek and the Colville River for wintering. The Colville River was used by 24% of broad whitefish tagged while the lower Ublutuoch River was used by 33% of broad whitefish tagged in 2001. Additionally, several deep lakes off of Fish, Judy and Inigok creeks were likely used for wintering by fish. Some broad whitefish tagged in 2001 moved to deep off-channel lakes in summer 2002. It is unknown if these fish wintered in the lakes during winter 2002/2003.

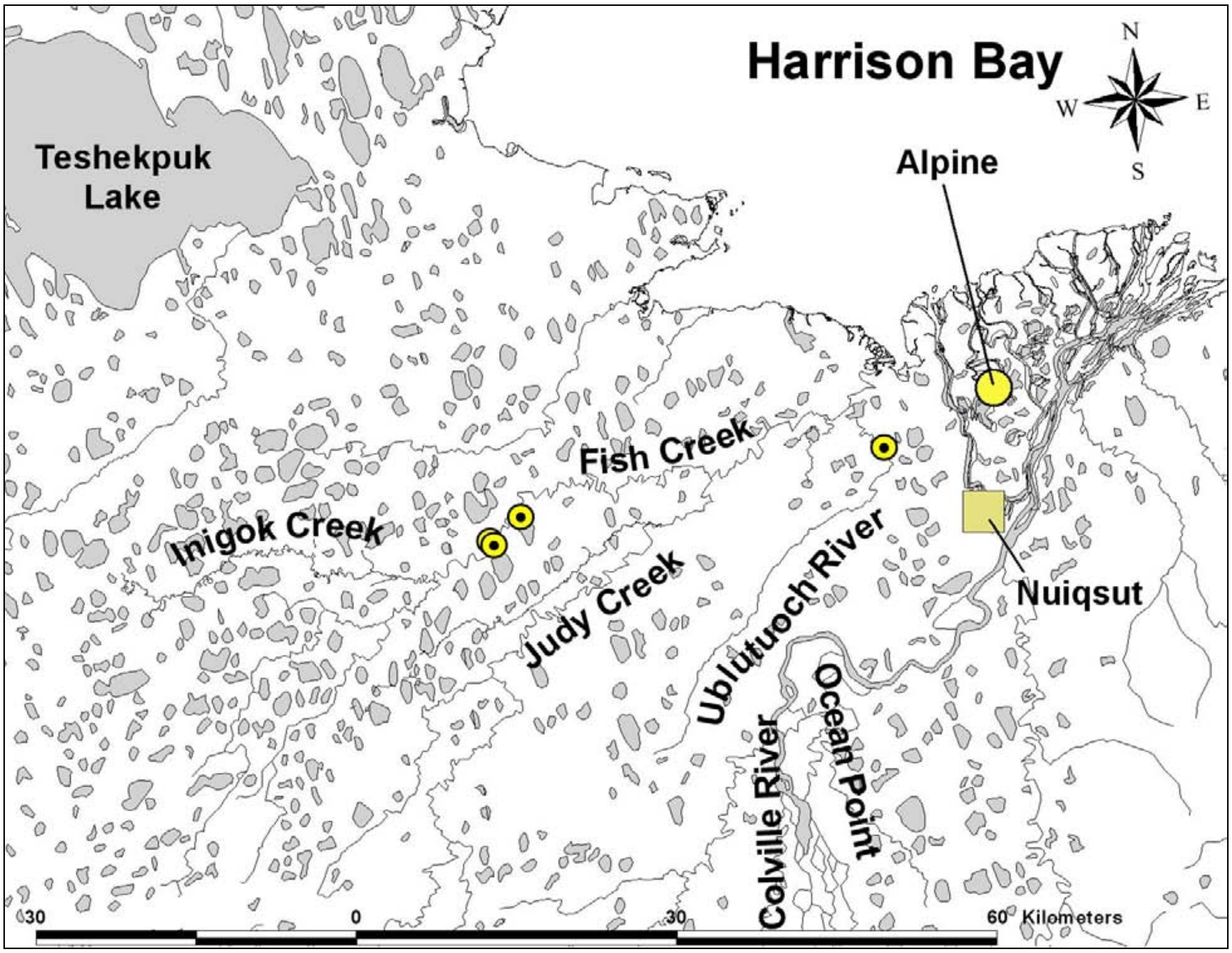

Figure 18. Arctic grayling November 2001/May 2002 relocations were limited and occurred only in the Ublutuoch River and in upper Fish Creek. However, the Arctic grayling using upper Fish Creek may not have survived winter 2001/2002.

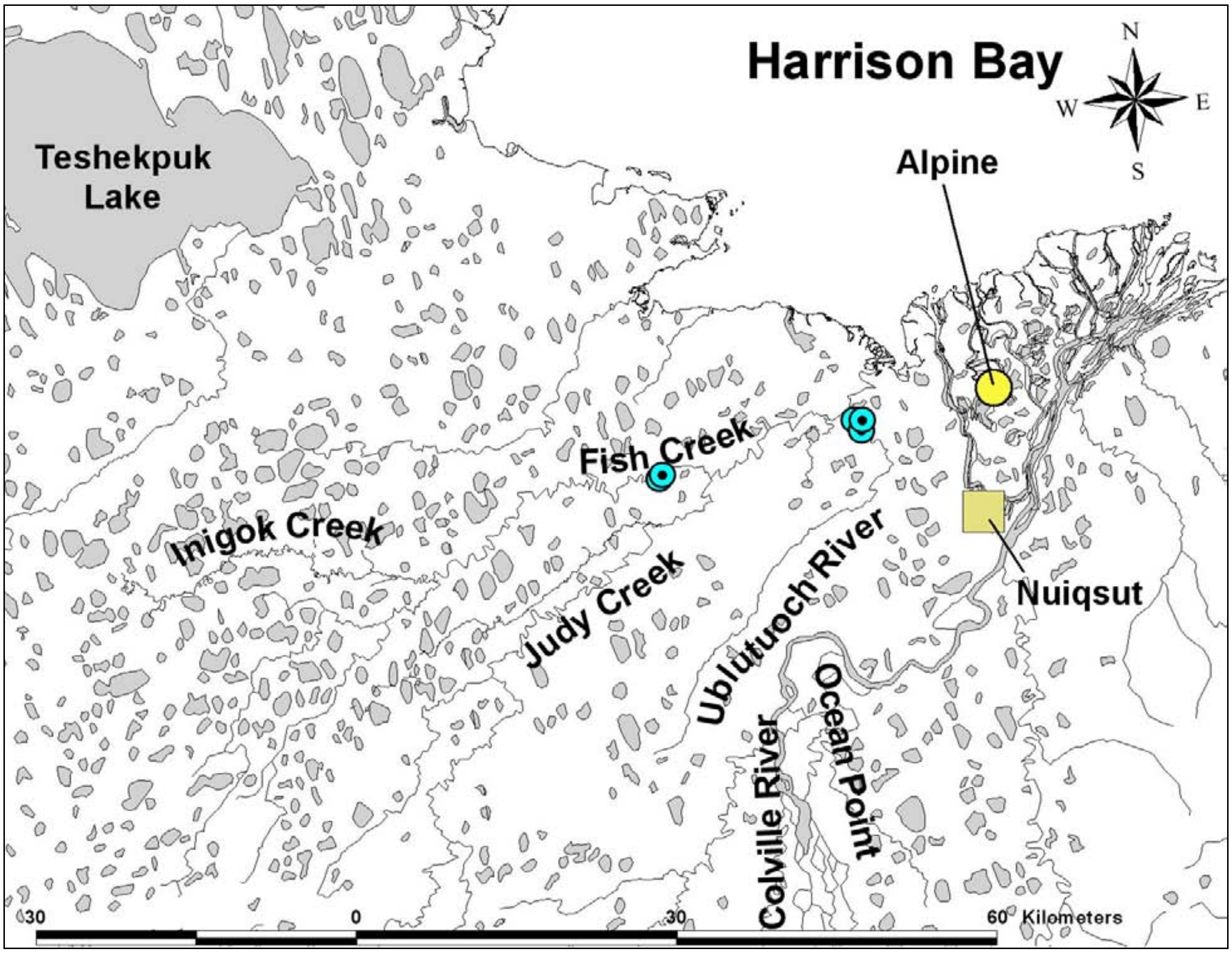

Figure 19. Four burbot were relocated during November 2001/May 2002 surveys. Wintering areas occurred in the Ublutuoch River and proximate to the confluence of Fish and Judy creeks. All burbot appeared to survive winter.

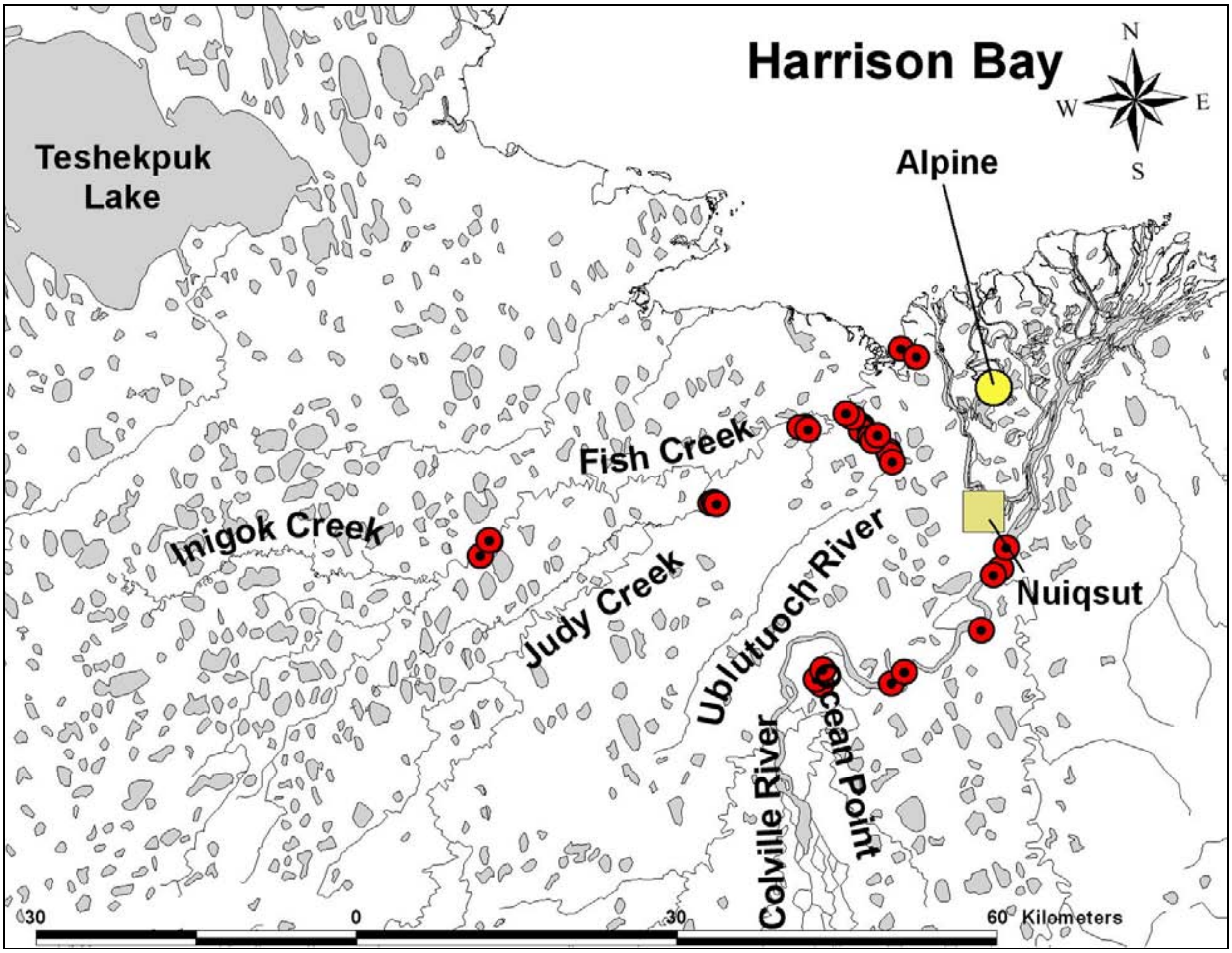

Figure 20. Over 50% of broad whitefish tagged in 2001 were relocated during November 2001/May 2002 surveys. Twenty four percent of broad whitefish relocated on wintering grounds were in the Colville River, 33% in the Ublutuoch River, and some fish were relocated in Fish Creek, Judy Creek, a small lake upstream of Lake MC7916 and in the Fish Creek delta. Relocation histories suggested that survival of the fish that wintered in Fish Creek, Judy Creek, the small lake, and in the Fish Creek delta was unlikely.

Relocation data just prior to freeze-up and just after break-up for Arctic grayling and burbot were examined to deduce areas likely used for wintering. However, ice-induced signal attenuation and/or water depth limited the number of fish detected at these times. Arctic grayling relocations from late-September 2001 and mid-June 2002, offered some insight to potential wintering areas. It is likely that the two Arctic grayling (1306 and 1317) located upstream in Inigok Creek wintered somewhere in that region; mid-winter surveys did not include habitats in upper Inigok Creek. Numerous deep lakes are tributary to Inigok Creek and easily could, and likely did, harbor these fish during winter. It is unknown if the lakes the two Inigok Creek Arctic grayling were relocated in during summer 2002 had adequate depths to winter the fish. Additionally, the location of three Arctic grayling in a small lake connected to the Ublutuoch River offered some insight as to where they may have wintered. Two of the Arctic grayling (1329 and 0581) relocated in the lake during summer 2002 were positively relocated within the Ublutuoch River on 20 September 2001. It is likely these fish wintered in the lower river and were not detected. Arctic grayling 1318, also relocated in the lake during summer 2002, was last relocated on 20 September 2001, in Fish Creek near the confluence with Judy Creek. This fish may have wintered in the area of the confluence where deepwater habitat is available or it may have wintered in the lower Ublutuoch River. Further evidence for potential Arctic grayling wintering in the Fish Creek/Judy Creek confluence area was provided by fish 1302 which was located just upstream of the confluence in Fish Creek in late-September 2001 and just upstream of the confluence in Judy Creek in June 2002.

Burbot relocation histories also were used to define potential wintering areas not definitively located with winter relocation data. Burbot 1380, was located near the confluence of Fish and Judy creeks in Fish Creek in August 2001 and upstream in Judy Creek in June 2002. Although little relocation history exists for this fish, it is possible that it wintered in the vicinity of the confluence (similar to burbot 1352, documented to successfully overwinter near the confluence in Fish Creek). Burbot 1370 and 1386 both were relocated in lower Inigok Creek on 20 September 2001. Each was next relocated during summer 2002 at locations that required they pass though the Fish and Judy Creek confluence. Summer relocation data found burbot 1370 upstream 30 km in Fish Creek and burbot 1386 in the lower Ublutuoch River. These fish may have wintered within the Fish and Judy creeks confluence area or in the Ublutuoch River. Similar movements to those hypothesized above were documented by burbot 0176, when at some point after 20 September 2001, the fish migrated out of a small Judy Creek tributary about 60 km to winter in the lower Ublutuoch River. Burbot 1326 was relocated in the lower Ublutuoch River on 20 September 2001 and then again in June and August 2002 many kilometers upstream in Inigok Creek; this fish may have wintered within Inigok Creek, Fish Creek or the Ublutuoch River.

Given the number of successful wintering relocations of all species and the movement patterns observed before and after winter by Arctic grayling and burbot, it was possible to generate a map of wintering areas and potential wintering areas (Figure 21). Fish survival at known wintering locations also was used to assess the potential for wintering. One lake upstream from Lake MC7916 was eliminated as the fish, along with all water in the lake, froze. An area just off the Fish Creek delta in Harrison Bay also was eliminated, although winter survival of the fish at that location was not determined, it likely did not survive the winter. It is noteworthy that 17 to 23% (excludes the four fish that left the study area in 2001) of the broad whitefish relocated at wintering areas probably failed to survive the winter at their selected sites because water was too shallow. Similar numbers of fish failed to survive in the Prudhoe Bay Study; 19% of broad whitefish relocated at wintering sites failed to survive winter (Morris 2000).

Potential wintering areas were delineated from relocation data suggesting that fish selecting those locations during winter 2001/2002 may not have survived. The fish located in lower Judy Creek almost certainly failed to survive winter because relocations during summer 2002 where each successively slightly farther downstream from the wintering location (drifting carcass). Summer 2002 relocation data for the broad whitefish and Arctic grayling that wintered in upper Fish Creek were inconclusive. Nonetheless, in some years fish may survive the winter within these reaches. No attempt was made to find wintering areas within Inigok Creek, although it appears that some tagged fish must have wintered either in Inigok Creek or connected lakes. Data were too limited to select specific areas within the drainage. Generally, the deeper portions of the lower 11 river kilometers (7 linear kilometers) of the Ublutuoch River were the most heavily used habitat for wintering in the study (Figure 22).

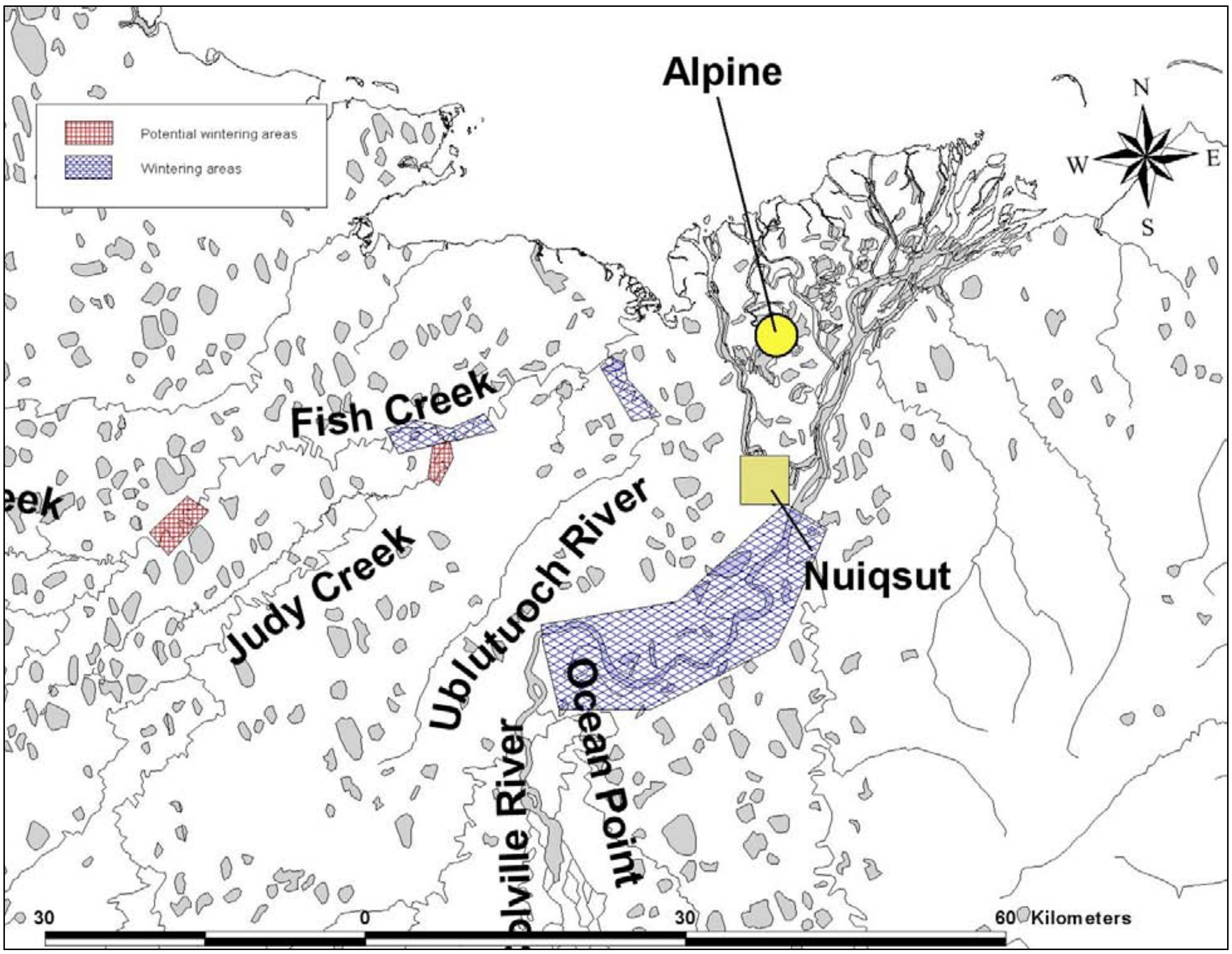

Figure 21. Successful wintering areas were identified for all species in the lower Ublutuoch River and for Arctic grayling and burbot in the area around the confluence of Fish and Judy creeks and just upstream from the confluence in Fish Creek. The Colville River was successfully used for wintering by five radio-tagged broad whitefish. Marginal or potential wintering areas may exist in Judy Creek above the confluence with Fish Creek and in upper Fish Creek in some years.

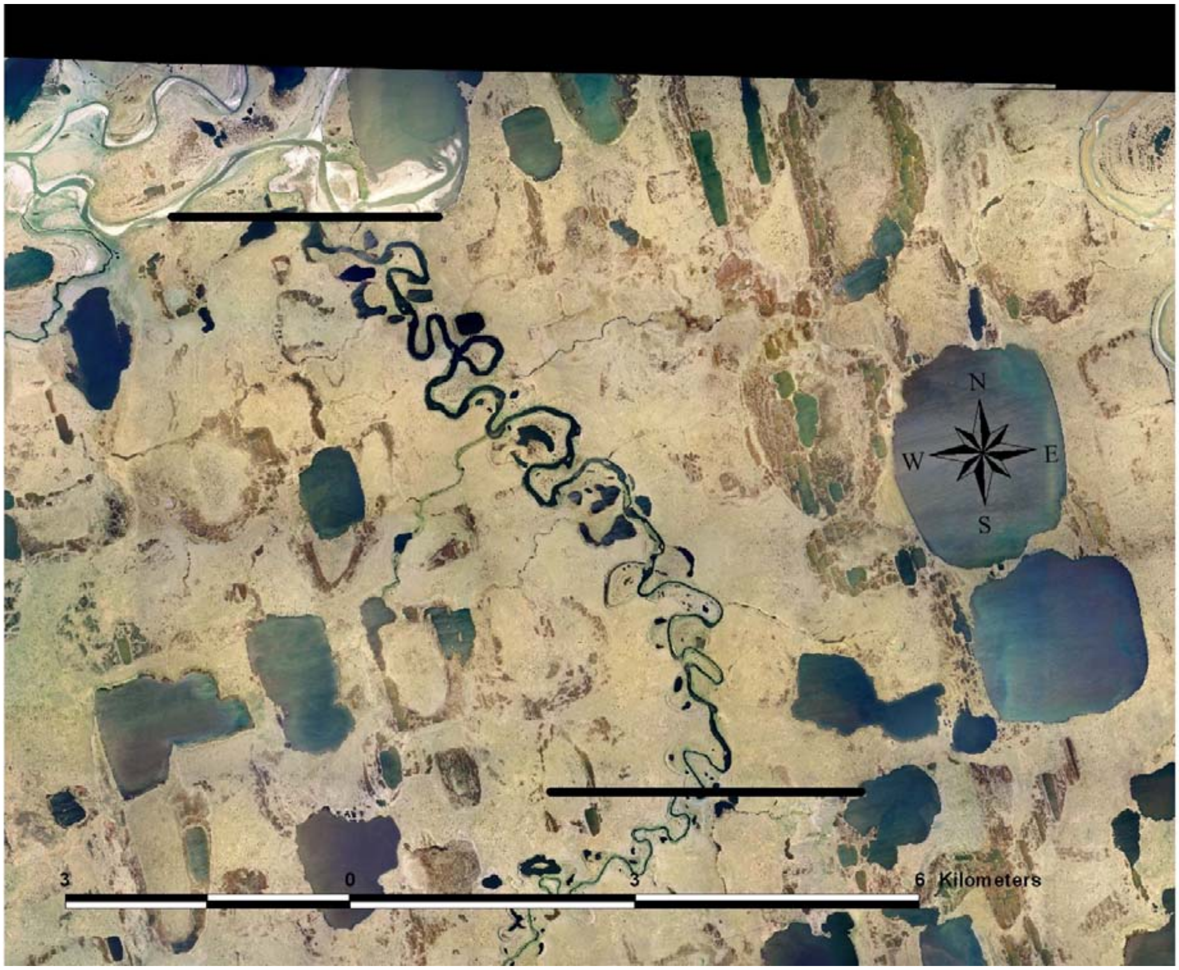

Figure 22. The lower Ublutuoch River between the two marked delineators was used by all species for wintering during winter 2001/2002. The increase in depth at the southernmost (bottom) delineator is apparent. Much shallower channel conditions exist downstream from the northernmost delineator and likely prevent salt-water intrusion to the deep habitats of the lower river.

Small Tundra Drainages and Off-Channel Lakes

Use of off-channel lakes, in this case, defined as lakes with connections to the main channels of Fish, Judy, and Inigok creeks and the Ublutuoch River, and small tundra drainages was very common for Arctic grayling and broad whitefish. June 2002 surveys relocated 50% of Arctic grayling tagged in 2001 in small lakes or off-channel tributaries. Additionally, the three Arctic grayling tagged in Judy Creek were attempting to move upstream into a small tundra drainage when captured and tagged. Broad whitefish relocations in 2001/2002 and 2001 fyke net work in Lake MC7916 found that over 80% of radiotagged broad whitefish used lake and off-channel stream systems. Two burbot (25%) tagged during summer 2001 were relocated 30 or more kilometers upstream of Judy Creek in a small, but extensive, tributary system. Burbot in the study group never were relocated in lake habitats.

Lake types used by Arctic grayling and broad whitefish varied from shallow to deep lakes and from well connected to ephemerally connected lakes. Summer 2002 surveys located two broad whitefish and three Arctic grayling using a small drained lake 4 km upstream from the Ublutuoch River at the head of an ephemeral drainage (Figure 23). These fish were dependent on spring high water to enter the lake and were likely dependant on fall high water to exit the lake if they were to survive winter 2002/2003. Two broad whitefish were relocated during June and July 2002 surveys in a lake system connected to Fish Creek (Figure 24). The lake system appeared to be connected to Fish Creek through an outlet channel at the easternmost lake. Connections may not exist year-round between all of the lakes but the system was relatively well connected in July and deep enough to winter fish if they were not able to leave the lake in fall.

Other broad whitefish were relocated in off-channel lakes of Inigok Creek (Figure 25), upper Fish Creek (Figure 26) and a small tributary to Judy Creek (Figure 26). The upper Fish Creek lake was located at the head of a small 4 km tundra drainage that likely had a continuous connection to the river. One Arctic grayling also was relocated in a small lake connected to Inigok Creek in summer 2002. Another Arctic grayling appeared to be in the same system, downstream of the lake, near the confluence with Inigok Creek (Figure 25). The small tributary of Judy Creek was used by all species tagged during summer 2002 and by a burbot in 2001 (Figure 26). Fish moved 30 or more kilometers upstream in the tundra drainage; one broad whitefish moved into a small off-channel lake, with a marginal connection to the channel; one burbot moved a few kilometers farther upstream of the lake in 2001; and a burbot was relocated just upstream of the lake in 2002 (Figure 26). An Arctic grayling also used the system in 2002 and was relocated 5 km downstream from the lake in June (Figure 26).

Figure 23. A small ephemerally connected shallow lake off of the Ublutuoch River was used by three Arctic grayling and two broad whitefish during summer 2002. This lake would not support overwintering of fish; spring and fall high water events would likely be required for access and escape. (Photomosaic provided by ConocoPhillips Alaska, Inc.)

Figure 24. A large lake complex with good seasonal connection to lower Fish Creek was used by two broad whitefish during June and August 2002. The lake likely could overwinter fish if emigration were not possible during fall. (Photomosaic provided by ConocoPhillips Alaska, Inc.)

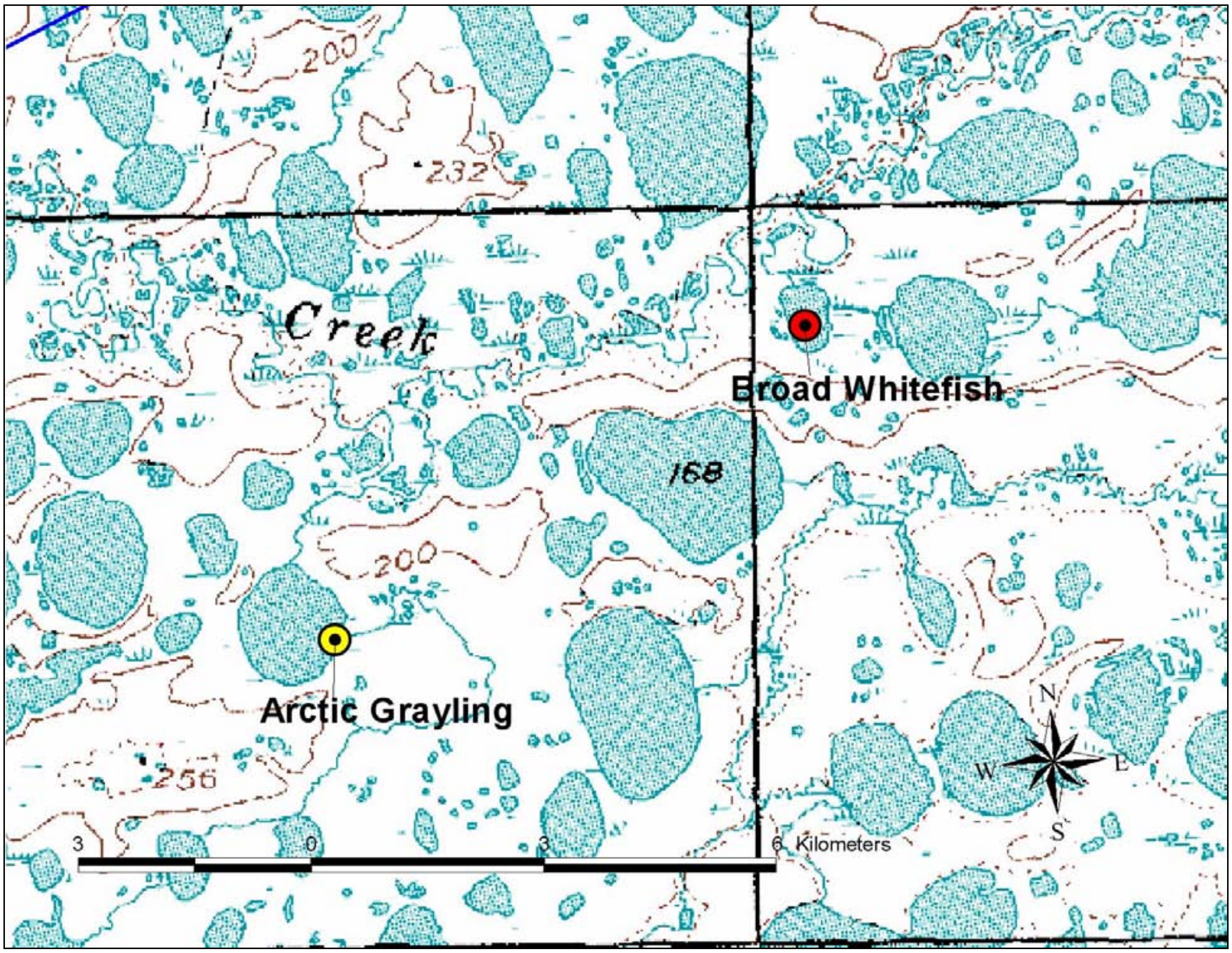

Figure 25. Arctic grayling and broad whitefish used small tundra drainages and lake systems in Inigok Creek during summer 2002.

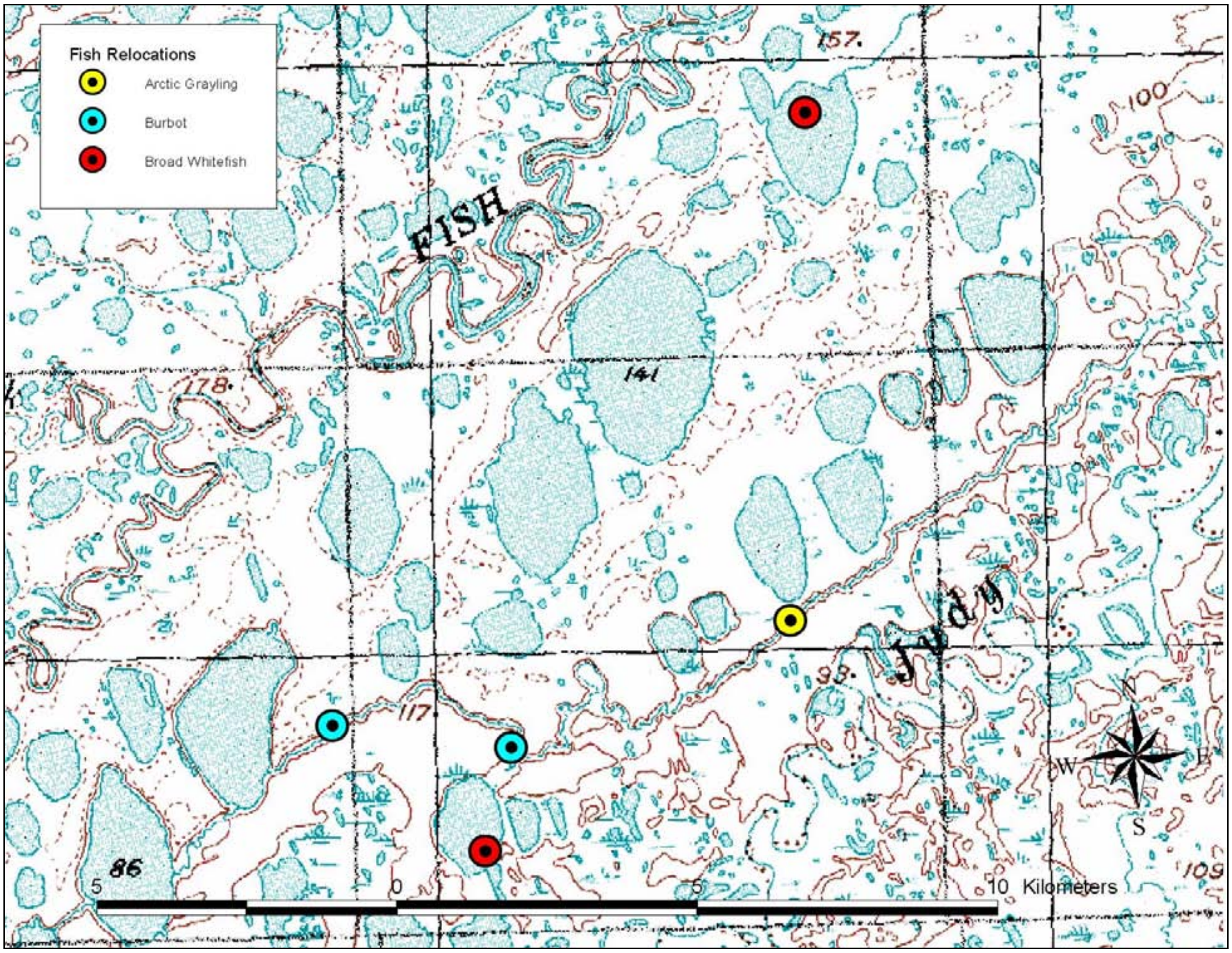

Figure 26. Broad whitefish used a small 4 km tundra drainage and its headwater lake off of Fish Creek in 2002 (top of map). An extensive low gradient tundra drainage, and at least one of its lakes, off of Judy Creek was used by burbot in 2001 and 2002 and by Arctic grayling and broad whitefish in 2002.

Lake MC7916 and the lake immediately downstream to the east were used heavily by broad whitefish within the study. Six broad whitefish were tagged in the lake and several returned to the lake or the nearby lake the following summer season. Besides the six fish tagged in the lake, three fish tagged in the Ublutuoch River also used the lake at some point during the open water seasons in 2001 and 2002. Figure 27 illustrates the Lake MC7916 complex most used by broad whitefish during summers 2001 and 2002.

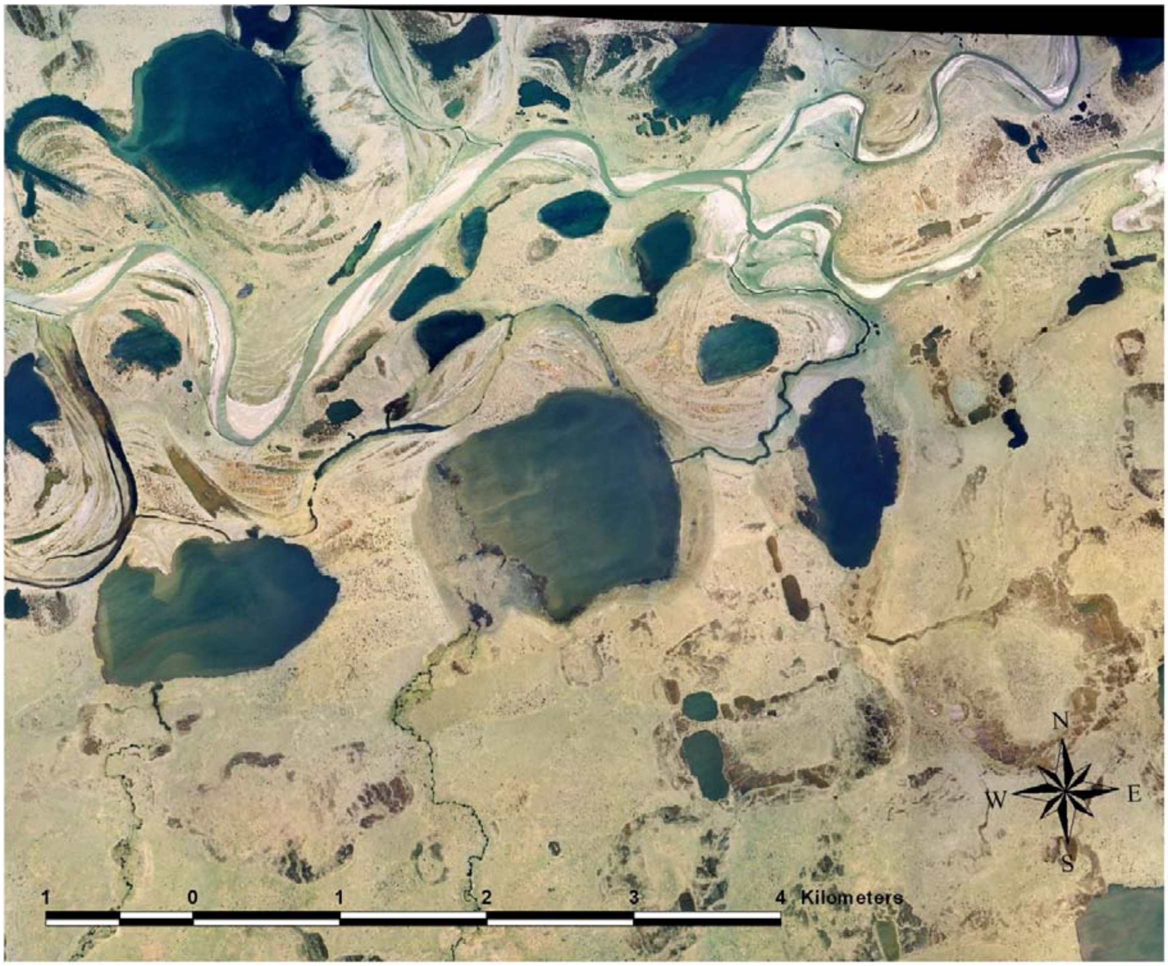

Figure 27. Lake MC7916 (center) and its associated lake/stream complex is ideal broad whitefish summer habitat and was used more extensively by the species than any other lake system in the study area. Forty three percent of broad whitefish radio-tagged in the study used this lake system at some point during 2001/2002. (Photomosaic provided by ConocoPhillips Alaska, Inc.)

Discussion

Biological Interpretations and Implications

Radio-telemetry proved to be an effective tool for seasonal habitat use assessment and life-history characterization for Arctic grayling, broad whitefish, and burbot. Specific areas of significance for rearing and, perhaps more critically, for wintering were identified. Observations of the timing of fish movements between habitats within the open-water season were made as well as determination of the significance of the near freeze-up and near break-up periods of the year for fish movement.

Specific limitations with our program also were identified. Relocation success rates dropped significantly during winter. Apparently ice thickness and depth of wintering habitat limited our ability to detect fish. This limitation was minor for burbot and broad whitefish (outfitted with larger tags) but caused a significant problem with Arctic grayling wintering area determinations. While it is possible to hypothesize likely areas for Arctic grayling wintering locations based on pre-freeze-up and post-break-up relocation data, it is more desirable to use winter relocation data. Selection for the largest Arctic grayling available in an area and the use of the larger tags used in burbot and broad whitefish should produce better relocation data for Arctic grayling during winter.

Use of tundra lakes and small tundra drainages was significant for all species investigated. This pattern reflects the relatively lower productivity of Fish and Judy creeks compared with small tundra drainages and lakes during mid summer. Fall subsistence fishers from Nuiqsut in the 1980's identified Fish Creek as one of the most productive drainages (J. George, unpublished notes). This pattern of use is consistent with use of main channel habitats primarily for migration as seen in this study. All broad whitefish radio-tagged during the study were captured in Lake MC7916, a shallow lake, or in the Ublutuoch River, a gravel bed system. Few large broad whitefish were captured at other net sites within Fish and Judy creeks (Moulton 2002). Burbot tagged in the study were in main channel habitats but their numbers were extremely low. Only nine burbot were captured throughout the entire summer and seven of those were from baited hoop traps. Most Arctic grayling captured during summer 2001 were from the Ublutuoch River where high numbers of all species were present throughout most of the summer. Large Arctic grayling were uncommon in Fish Creek and only after a significant effort were two Arctic grayling captured and radio-tagged. All Arctic grayling tagged in Judy Creek were near the outfall from a small tundra drainage and were attempting to enter the tundra system or were feeding on drift from the system when captured. Relocation results reflected the relative productivity of each system and offered insight into the role each system and respective habitat type plays in the annual ecology of fish in the region.

Arctic grayling

Results from Arctic grayling suggest that the Ublutuoch River is one of the most important drainages for this species in the study area. Catch rates of adult and sub-adult Arctic grayling were considerably higher in the Ublutuoch River during 2001 sampling than in Fish and Judy creeks. Age-0 Arctic grayling were not captured in the Ublutuoch River (Moulton 2002). Fifty percent of Arctic grayling radio-tagged in this study were tagged in the Ublutuoch River. One Arctic grayling radio-tagged in Judy Creek also used the Ublutuoch River in 2002. Relocation results suggested that several of the fish may have wintered in the Ublutuoch River, including one fish that was relocated there in May and possibly one fish tagged in Judy Creek the previous summer. Generally, Arctic grayling exhibited lower open-water season fidelity to the river. Numerous fish tagged in the Ublutuoch River moved to small tributary streams and lakes in Judy and Inigok creeks during summer 2002. It is likely that mature Arctic grayling (all radio-tagged Arctic grayling were spawning-sized fish) moved into the smaller tundra drainages in spring 2002 to spawn. However, the three Arctic grayling relocated in the small ephemeral drainage lake off the Ublutuoch River during June 2002, suggested that limited Arctic grayling spawning might have occurred within the system. Moulton (2002) reported high numbers of large humpback whitefish (*Coregonus pidschian*) and some large round whitefish (*Prosopium cylindraceum*), known opportunistic predatory species, in the Ublutuoch River during 2001. Moulton surmised that the high density of these species likely makes the Ublutuoch River less favorable for Arctic grayling spawning. If spawning occurs within some limited areas of the system, few age-0 Arctic grayling probably survive. This was reflected in the lack of age-0 Arctic grayling in our fyke net catches, also, it is likely that any age-0 Arctic grayling captured in fyke nets would be consumed by the larger predatory species prior to being checked.

Arctic grayling movements, after tagging in August, were generally minimal in 2001 until sometime after 20 September when some Arctic grayling began to leave river habitats near their tagging locations. Arctic grayling radio-tagged in the Ublutuoch River generally moved the least distance during the 2001 season. Fish tagged in Fish and Judy creeks appeared to make movements away from the areas in which they were tagged during early-winter. Some probably moved to the Ublutuoch River for wintering but relocation data suggest that one or two fish may have moved into the upper Inigok Creek area and into the vicinity of the Fish Creek/Judy Creek confluence. Relocation data indicate that at or near break-up, Arctic grayling (in this region) make significant movements to small tundra drainages within all systems in the larger drainages. This is likely a spawning migration. Five of the eight Arctic grayling were still in small systems or lakes during June 2002 when their transmitters expired. One fish was back in Judy Creek near the mouth of the same tundra drainage and one fish (whose winter survival is uncertain) was in Fish Creek. Although our data set for Arctic grayling is limited, due to short transmitter life and poor winter relocation rates, it is possible to hypothesize general movements within the drainages studied and to identify critical periods for migration.

Major movements for Arctic grayling occur during late-fall/early-winter and then again at or near break-up. These are critical periods for survival; access to spawning grounds and subsequent access to high productivity areas for recovery from spawning. Several Arctic grayling were located in lakes or systems that require high-water conditions for access in the spring, but more critically in some instances, for escape prior to freeze-up as these systems do not provide adequate depths for overwintering. Figure 28 provides a stylized diagram of typical movement patterns exhibited by Arctic grayling during the study.

Figure 28. A simplified diagram outlining typical Arctic grayling seasonal movements throughout the Fish Creek, Judy Creek and Ublutuoch River drainages.

Burbot

Data on burbot movements also supported the relative significance of the Ublutuoch River. While only eight fish were radio-tagged, none were tagged in the Ublutuoch River, but four of the burbot used the Ublutuoch River at some point during the study. Three burbot were relocated in the lower Ublutuoch River during winter 2001/2002 and one additional burbot may have wintered in the lower Ublutuoch River or possibly in Fish Creek. At least two burbot used the lower gradient portion of the lower Ublutuoch River during significant portions of the 2002 summer season.

Burbot movements throughout the summer season in 2001 and 2002 were extensive and likely reflect the low productivity conditions in the main channel habitats within Fish and Judy creeks. Post break-up movements in 2002 again suggested that burbot of the area move long distances to find adequate food resources. Burbot are winter spawners that spawn over clean gravels sometime between January and February (Morrow 1980). Burbot probably use the lower Ublutuoch River for spawning. No suitable burbot spawning areas outside of the Ublutuoch River have been identified within the Fish Creek and Judy Creek drainages. At least two burbot used small tundra systems in 2001 and in 2002 and two were first captured attempting to enter small tundra drainages in 2001. Burbot made long movements in late-fall from shallower main channel habitats upstream from the confluence of Fish and Judy creeks to the Ublutuoch River for wintering and potentially for spawning. At least one tagged burbot and potentially others wintered near the confluence of Fish and Judy creeks. Figure 29 provides a stylized diagram of typical movement patterns exhibited by burbot during the study.

Figure 29. A simplified diagram outlining typical burbot seasonal movements throughout the Fish Creek, Judy Creek and Ublutuoch River drainages.

Broad whitefish

The Ublutuoch River was clearly significant habitat for broad whitefish within our study group. Seventy-one percent of broad whitefish were initially tagged in the Ublutuoch River during summer 2001. Some of the broad whitefish never left the system during the entire study period and made only minor up- and downstream movements within the system. However, some broad whitefish left the system; some briefly, but some left for the entire winter. Most fish that left the river for wintering grounds in the Colville River returned to the system the following year. Additionally, numerous fish tagged in Lake MC7916 were ultimately relocated at some point in the Ublutuoch River.

The Ublutuoch River appears to be a significant wintering area for broad whitefish, but also may be used for spawning by the species. Six broad whitefish spent the entire summer/fall and winter

2001/2002 within the lower Ublutuoch River. Four of these fish made extensive movements upstream in the Fish/Judy Creek drainages to lakes the following spring. It is probable that some of these fish were congregating in the lower river for spawning. Broad whitefish have been identified moving to spawning areas or to staging areas near spawning areas, considerably earlier than the known spawning or spawning migration periods (Chang-Kue and Jessop 1992, Morris 2000). Some fish in the Prudhoe Bay Study moved to wintering/spawning areas as early as mid- to late-July (Morris 2000). A review of the radio-tagging log and data presented by Moulton (2002) indicates that most spawning sized broad whitefish in the Ublutuoch River during 2001 were captured in late-July and in late-August (Table 2).

Broad whitefish on the North Slope spawn in late-fall/early-winter, likely beginning in September and lasting into October (Bendock and Burr 1986, Morris 2000). Broad whitefish spawn on gravel substrates in areas with flow that remain thawed throughout the winter. The Ublutuoch River fits this description and was used by several tagged broad whitefish during the spawning period. The Ublutuoch River contained the only suitable broad whitefish spawning habitat identified within the Fish and Judy creek drainages. Additionally, age-0 broad whitefish were captured during a brief sampling period in June in Lake M0142 located at the mouth of the Ublutuoch River, as well as in Lake MC7916, just a few kilometers upstream from the Ublutuoch River off Fish Creek (Moulton 2002). However, since this drainage is just west of the Colville River, it is also possible that a portion or even the majority of the age-0 broad whitefish found in the lakes were from known broad whitefish spawning areas located upstream from the head of the Colville River delta to Ocean Point.

Broad whitefish within the study group showed a high propensity for movement out of the Fish Creek drainage. Forty-two percent of broad whitefish radio-tagged did not spend the entire year within the Fish Creek/Judy Creek drainages. Four broad whitefish left the study within days of being tagged. Five broad whitefish were relocated in the Colville River during winter 2001/2002. With the exception of one of these fish, all had left the Fish Creek area by August 2001 (one fish left sometime between 30 August 2001 and 20 September 2001). By late-September, 2001 three of the fish were relocated in the Colville River, and by late-winter 2002, five of the broad whitefish were in the Colville River. Similar early season movements out of summering habitats towards more distant wintering and spawning habitats have been observed in broad whitefish from the Sagavanirktok and Mackenzie rivers (Morris 2000, Chang-Kue and Jessop 1992). In the Sagavanirktok River, broad whitefish used a small tundra drainage for a relatively short period of time after break-up and subsequently moved to wintering/spawning areas in the Sagavanirktok River (and Colville River), often by early-August. Chang-Kue and Jessop (1992) found similar pre-spawning runs in the Mackenzie River where fish left summering areas and moved to areas below spawning reaches well in advance of spawning. Results from our study suggest a significant proportion of broad whitefish rely on the Fish/Judy Creek area for summer rearing before migrating to other local coastal rivers for spawning and/or wintering.

Each of the five broad whitefish relocated during winter 2001/2002 in the Colville River showed fidelity to the Fish Creek/Judy Creek drainages for summer feeding and most to the same locations they were first captured in 2001. Fidelity to summering areas was similarly observed by broad whitefish radio-tagged in the Sagavanirktok River area near Prudhoe Bay (Morris 2000). However, the four fish using the area that left shortly after tagging, with no evidence that they returned to the area, suggests that a portion of the fish using the Fish Creek/Judy Creek drainages may not be tied to the area on an annual basis. In that respect, the Fish Creek/Judy Creek drainages appear to contribute to broad whitefish populations coastally by providing foraging habitat to fish that spawn in other river systems. One fish also showed signs of fidelity to the Colville River as well as the Fish Creek area. Broad whitefish 0104 moved from Lake MC7916 to the Colville River by late-July 2001, likely spawned, wintered, and then returned to a lake adjacent to Lake MC7916 in the same small drainage in summer 2002. By mid-August 2002, the fish had returned to the Colville River to the same location it had spent the previous fall and winter, spending perhaps a month or two in Fish Creek habitats during summer 2002. Similar movement and timing patterns were observed with some fish in the Prudhoe Bay study (Morris 2000).

The area upstream of the Colville River delta head to Ocean Point is a well known spawning area within the river. In combination with the Prudhoe Bay project and the Fish Creek/Judy Creek project, this reach of the Colville River begins to appear regionally significant for broad whitefish spawning. Three broad whitefish from this study used small inside channels of the Ocean Point area of the Colville River during fall 2001 around the spawning period and one or two for wintering. Broad whitefish 0104 used the channel in two successive years, arriving at nearly the same time each year. One broad whitefish tagged in the Prudhoe Bay area in 1998 moved to this same inside channel, and an additional broad whitefish tagged in the study was harvested in the subsistence harvest in the Colville River, presumably while on or on route to this portion of the Colville River (Morris 2000).

Broad whitefish exhibited the most complex movement patterns of the species radio-tagged in this study. Broad whitefish movements during the open-water season were composed of two general patterns; nomadic/sedentary and coastal migratory. The movement patterns of nomadic/sedentary fish can be characterized as having a nomadic period of extensive in-river movement early in the year followed by a more sedentary period of lake habitat use. Movement patterns were associated with habitat type and were not mutually exclusive. During summer, most broad whitefish in the study group were associated with lakes with high summer productivity. A group of these fish moved many kilometers within the Fish Creek and Judy Creek drainages before finally entering lake or small tundra stream/lake habitats. Several fish were identified that had made movements into more than one lake during summer.

A group of broad whitefish was also identified that appeared considerably more reliant on the Ublutuoch River, with some remaining for extended periods through multiple seasons. However, several of the fish residing in the river during summer/fall 2001 and winter 2001/2002 made significant movements to other systems in spring 2002. These movements may be related to spawning during 2001 and may represent a movement away from spawning areas to lake habitats for recovery the following spring. Fish potentially spawning in the Ublutuoch River in 2001 were at least in the river by mid-summer 2001, consistent with timing of arrival at spawning areas in other drainages on the North Slope, and some subsequently dispersed from the river the following spring. Most fish in the Ublutuoch River may have little reason to leave this productive system from an energetic basis. However, the high numbers of large fish in the system may also induce some fish to search out productive habitats with less competition for food resources.

The more "coastal migratory" summer behavior, is likely associated with fish moving to other natal streams (in different drainages) along the Beaufort Sea coast for spawning and/or wintering. This group of fish generally moved out of the high productivity freshwater systems of the Fish Creek area by late-August and most by early-August. Some relocated coastal migratory fish arrived in the Colville River from Fish Creek drainages by late-July and most between mid-August and late-September. All radio-tagged broad whitefish from the Fish Creek drainages spawning and/or wintering in the Colville River dispersed immediately at break-up and returned to the Fish Creek drainages.

Three basic movement periods were identified for broad whitefish: spring movements to small stream or productive riverine habitats, summer movements to locate productive habitats, and summer/fall movements to spawning and wintering areas. Figure 30 provides a stylized diagram of typical movement patterns exhibited by broad whitefish during the study. While the diagram presents general details of the movements of broad whitefish, discussions above clearly indicate some individuals may exhibit much more intricate patterns of movement and habitat use.

Figure 30. A simplified diagram outlining typical broad whitefish seasonal movements throughout the Fish Creek, Judy Creek and Ublutuoch River drainages.

Summary

Generalized use of the systems within the region can be categorized from the combination of relocation histories for all species radio-tagged. The Ublutuoch River is unique to the area in its stream morphology and its level of use by fish in the Fish Creek drainages. The Ublutuoch River is used by all species for wintering, feeding, and likely for spawning by burbot and broad whitefish. Main channel habitats within Fish and Judy creeks are used most heavily as migration routes to lakes and small tundra drainages by broad whitefish and Arctic grayling, and as migration routes to and from wintering and spawning areas. Moulton (2002) categorized the water bodies of the region using fyke net data from main channel and lake habitats and came to similar conclusions. Burbot, in contrast, use expansive lengths of the main channel rivers for foraging, but their numbers are very low. The Fish Creek/Judy Creek confluence area appears to provide wintering habitat for a limited number of fish, but potentially for all species. Small tundra drainages receive use by all species, particularly by broad whitefish and Arctic grayling. Burbot used one low gradient tundra stream in the Judy Creek drainage. Several systems used by broad whitefish and Arctic grayling require high water events in spring for access and again in fall for escape. Movements to these high productivity systems are common and certainly provide enhanced reconditioning after spawning and wintering. However, there is a significant risk associated with such movements. Several lakes identified with fish in them during summer 2002, while certainly highly productive, did not have adequate depths to winter fish. Emigration from these water bodies would be required for winter survival. Relatively dry fall seasons on the coastal plain, which may produce insufficient stream flow for fall emigration, likely kill many fish located in such systems. One fish tagged in 2001 moved into such a lake in summer 2001, failed to emigrate in fall, and died. The area is used by broad whitefish from other coastal river systems and in that respect appears to play a role in broad whitefish populations coastally. Direct exchange of broad whitefish between the Colville River and the Fish Creek area was well documented throughout the study.

Recommendations for Future Work

Additional work with Arctic grayling should be conducted in the area using the shortfalls encountered during this research effort as a guide to improve the knowledge base for Arctic grayling use of the Fish Creek/Judy Creek/Ublutuoch River drainages. Larger radio tags, offering higher output and additional battery life should be used. Additionally, to increase the likelihood of attaining adequate relocation histories for a number of fish, a minimum of 20 fish should be outfitted with radio-tags. Given the low density of burbot in the area and the adequate rate of relocation success during most seasons, additional work in the area is probably not necessary. However, a similar program using similar tags, but 20 burbot would provide higher likelihood for numerous, more complete relocation histories on more individuals. Broad whitefish relocation success was generally high so we were able to construct numerous comprehensive relocation histories. With the exception of the four fish that left the study area almost immediately, all fish were relocated after release in 2001 and then again during 2002. Additional netting during fall in the Ublutuoch River and the inside channel of Ocean Point in the Colville River should be conducted and gonadosomatic indices for the fish determined. This work would confirm or refute the apparent use of these specific areas by broad whitefish for spawning.

Management Implications

Radio-telemetry results for broad whitefish, burbot, and Arctic grayling from the northeastern NPR-A provide a basis for making management decisions regarding future development activities that may occur in the region. The Ublutuoch River provides essential habitat to fish throughout the year. Smaller drainages within the region receive extensive use by fish and cumulatively, small drainages and associated lake complexes, represent the productivity base for Arctic grayling, broad whitefish, and burbot of the region. Thus, it is imperative to maintain natural flow conditions in these smaller systems to allow for fish movement during spring and, more importantly, fall, as fish move to and from rearing, spawning, and overwintering habitats. Although the sand bottomed systems are not necessarily essential for fish feeding, with the exception of burbot, unrestricted spring flow is necessary for fish to access both adjacent and distant high productivity streams and lakes. In short, this study confirms that maintaining natural flow patterns in these small drainages is extremely important in providing fish access to productive summer habitats as well as access to critical overwintering habitats.

The most likely industrial activity in the area is oil and gas exploration and development. Information on fish use combined with hydrological data will be needed for planning and design of oil field related facilities such as roads, material sites, and water sources. These research efforts, combined with results obtained by Moulton (2001 and 2002) on behalf of ConocoPhillips Alaska Inc., provide clear evidence of the significance of Fish Creek, Judy Creek and the Ublutuoch River and the small drainages and associated lake complexes to fisheries resources in the region. Acquisition and utilization of these types of data and their use in making decisions regarding future development activities should help ensure the proper protection of the fisheries resources in the region.

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APPENDIX I Sample Tracking Log Data Sheet

NPRA Telemetry Radio-Tracking Log Sheet

Recorder:

Date: **Time:**

Area Surveyed:

Freq	Cd.	Sp.	Tag	Position	Freq	Cd.	Sp.	Tag	Position
500	10	BWF	91	N W	680	3	AG	581	N W
620	9	BWF	105	N W	320	3	AG	1331	N W
680	5	BWF	103	N W	400	4	AG	1330	N W
400	7	BWF	104	N W	620	4	AG	1329	N W
320	7	BWF	102	N W	320	8	BB	1326	N W
320	9	BWF	154	N W	680	9	BB	1301	N W
620	5	BB	176	N W	500	4	AG	1302	N W
400	9	BWF	184	N W	320	4	AG	76	N W
320	10	BWF	518	N W	500	3	AG	1306	N W
620	10	BWF	519	N W	320	5	BWF	1315	N W
680	7	BWF	520	N W	400	3	AG	1317	N W
400	6	BWF	200	N W	620	3	AG	1318	N W
500	7	BWF	548	N W	400	8	BB	1324	N W
680	8	BWF	725	N W	620	6	BB	1352	N W
500	6	BWF	726	N W	400	10	BB	1370	N W
620	7	BWF	727	N W	500	5	BB	1380	N W
320	6	BWF	847	N W	400	5	BB	1386	N W
680	10	BWF	776	N W	500	9	BWF	1506	N W
500	8	BWF	777	N W	**Key:**	1	Fish Cr		
620	8	BWF	778	N W		2 3	Judy Cr. Ublutuoch		
680	4	AG	1505	N W		4	Colville		

APPENDIX II Descriptive and Comparative Statistics

Arctic Grayling Descriptive Statistics – all fish 2001

	LENGTH
N	10
LO 95% CI	352.88
MEAN	367.40
UP 95% CI	381.92
SD	20.299
VARIANCE	412.04
SE MEAN	6.4191
MINIMUM	334.00
MEDIAN	369.50
MAXIMUM	401.00

Burbot Descriptive Statistics – all fish 2001

	LENGTH
N	8
LO 95% CI	490.23
MEAN	565.00
UP 95% CI	639.77
SD	89.441
VARIANCE	7999.7
SE MEAN	31.622
MINIMUM	455.00
MEDIAN	576.50
MAXIMUM	710.00

Broad whitefish Descriptive Statistics – all fish 2001

	LENGTH
N	21
LO 95% CI	447.63
MEAN	473.38
UP 95% CI	499.13
SD	56.568
VARIANCE	3199.9
SE MEAN	12.344
MINIMUM	392.00
MEDIAN	459.00
MAXIMUM	580.00

APPENDIX II Continued

Ublutuoch River Arctic grayling Descriptive Statistics

	LENGTH
N	5
LO 95% CI	333.00
MEAN	353.60
UP 95% CI	374.20
SD	16.592
VARIANCE	275.30
SE MEAN	7.4202
MINIMUM	334.00
MEDIAN	360.00
MAXIMUM	371.00

Judy Creek Arctic grayling Descriptive Statistics

	LENGTH
N	3
LO 95% CI	354.12
MEAN	387.67
UP 95% CI	421.21
SD	13.503
VARIANCE	182.33
SE MEAN	7.7960
MINIMUM	374.00
MEDIAN	388.00
MAXIMUM	401.00

Fish Creek Arctic grayling Descriptive Statistics

	LENGTH
N	2
LO 95% CI	M
MEAN	371.50
UP 95% CI	M
SD	4.9497
VARIANCE	24.500
SE MEAN	3.5000
MINIMUM	368.00
MEDIAN	371.50
MAXIMUM	375.00

APPENDIX II Continued

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV FOR Arctic grayling LENGTH BY Capture Site

Capture Site	MEAN RANK	SAMPLE SIZE
Ublu	3.2	5
Judy	8.7	3
Fish	6.5	2
TOTAL	5.5	10

```
KRUSKAL-WALLIS STATISTIC                        6.3855
P-VALUE, USING CHI-SQUARED APPROXIMATION        0.0411
```

PARAMETRIC AOV APPLIED to RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	2	58.5333	29.2667	8.55	0.0132
WITHIN	7	23.9667	3.42381		
TOTAL	9	82.5000			

```
TOTAL NUMBER OF VALUES THAT WERE TIED    0
MAX. DIFF. ALLOWED BETWEEN TIES    0.00001

CASES INCLUDED 10    MISSING CASES 0
```

COMPARISONS OF MEAN RANKS OF Arctic Grayling LENGTH BY Capture Site

Capture Site	MEAN RANK	HOMOGENEOUS GROUPS
Judy	8.6667	I
Fish	6.5000	I I
Ublu	3.2000	.. I

```
THERE ARE 2 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.

REJECTION LEVEL    0.050
CRITICAL Z VALUE    2.39
CRITICAL VALUES OF DIFFERENCES VARY BETWEEN
COMPARISONS BECAUSE OF UNEQUAL SAMPLE SIZES.
```

Judy Creek Burbot Descriptive Statistics

	LENGTH
N	3
LO 95% CI	511.69
MEAN	650.00
UP 95% CI	788.31
SD	55.678
VARIANCE	3100.0
SE MEAN	32.146
MINIMUM	600.00
MEDIAN	640.00
MAXIMUM	710.00

Judy Creek Burbot Descriptive Statistics

	LENGTH
N	5
LO 95% CI	437.67
MEAN	514.00
UP 95% CI	590.33
SD	61.478
VARIANCE	3779.5
SE MEAN	27.494
MINIMUM	455.00
MEDIAN	500.00
MAXIMUM	598.00

WILCOXON RANK SUM TEST FOR Burbot LENGTH BY Capture Site

Capture Site	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
Judy	21.000	3	15.000	7.0
Fish	15.000	5	0.0000	3.0
TOTAL	36.000	8		

EXACT PERMUTATION TEST TWO-TAILED P-VALUE 0.1429

NORMAL APPROXIMATION WITH CORRECTIONS FOR CONTINUITY AND TIES 2.087
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.0369

TOTAL NUMBER OF VALUES THAT WERE TIED 0
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 8 MISSING CASES 0

APPENDIX II Continued

Ublutuoch River Broad whitefish Descriptive Statistics

	LENGTH
N	15
LO 95% CI	438.44
MEAN	466.33
UP 95% CI	494.23
SD	50.372
VARIANCE	2537.4
SE MEAN	13.006
MINIMUM	392.00
MEDIAN	459.00
MAXIMUM	555.00

Lake MC7916 Broad whitefish Descriptive Statistics

	LENGTH
N	6
LO 95% CI	415.52
MEAN	491.00
UP 95% CI	566.48
SD	71.928
VARIANCE	5173.6
SE MEAN	29.364
MINIMUM	405.00
MEDIAN	474.00
MAXIMUM	580.00

June Broad whitefish Descriptive Statistics

	LENGTH
N	7
LO 95% CI	433.82
MEAN	495.57
UP 95% CI	557.32
SD	66.765
VARIANCE	4457.6
SE MEAN	25.235
MINIMUM	405.00
MEDIAN	492.00
MAXIMUM	580.00

July Broad whitefish Descriptive Statistics

	LENGTH
N	12
LO 95% CI	428.51
MEAN	457.08
UP 95% CI	485.66
SD	44.970
VARIANCE	2022.3
SE MEAN	12.982
MINIMUM	392.00
MEDIAN	455.00
MAXIMUM	540.00

August/September Broad whitefish Descriptive Statistics

	LENGTH
N	2
LO 95% CI	M
MEAN	493.50
UP 95% CI	M
SD	86.974
VARIANCE	7564.5
SE MEAN	61.500
MINIMUM	432.00
MEDIAN	493.50
MAXIMUM	555.00

WILCOXON RANK SUM TEST FOR Broad whitefish LENGTH BY Capture Site

Capture Site	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
Ublu	155.00	15	35.000	10.3
MC7916	76.000	6	55.000	12.7
TOTAL	231.00	21		

```
EXACT PERMUTATION TEST TWO-TAILED P-VALUE    0.6306

NORMAL APPROXIMATION WITH CORRECTIONS FOR CONTINUITY AND TIES   0.740
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION                    0.4596

TOTAL NUMBER OF VALUES THAT WERE TIED         0
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001
CASES INCLUDED 21    MISSING CASES 0
```

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV FOR Broad whitefish LENGTH BY Sampling Period

PERIOD	MEAN RANK	SAMPLE SIZE
June	13.3	7
July	9.4	12
Aug/Sep	12.5	2
TOTAL	11.0	21

KRUSKAL-WALLIS STATISTIC	1.8482
P-VALUE, USING CHI-SQUARED APPROXIMATION	0.3969

Colville River Broad whitefish Descriptive Statistics

	LENGTH
N	5
LO 95% CI	449.63
MEAN	477.80
UP 95% CI	505.97
SD	22.687
VARIANCE	514.70
SE MEAN	10.146
MINIMUM	440.00
MEDIAN	485.00
MAXIMUM	497.00

Non-Colville River Broad whitefish Descriptive Statistics

	LENGTH
N	16
LO 95% CI	437.79
MEAN	472.00
UP 95% CI	506.21
SD	64.193
VARIANCE	4120.8
SE MEAN	16.048
MINIMUM	392.00
MEDIAN	453.50
MAXIMUM	580.00

APPENDIX II Continued

WILCOXON RANK SUM TEST FOR LENGTH BY Colville vs. Non-Colville River Broad whitefish

COLVILLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
1	62.000	5	47.000	12.4
2	169.00	16	33.000	10.6
TOTAL	231.00	21		

EXACT PERMUTATION TEST TWO-TAILED P-VALUE 0.7221

NORMAL APPROXIMATION WITH CORRECTIONS FOR CONTINUITY AND TIES 0.537
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.5915

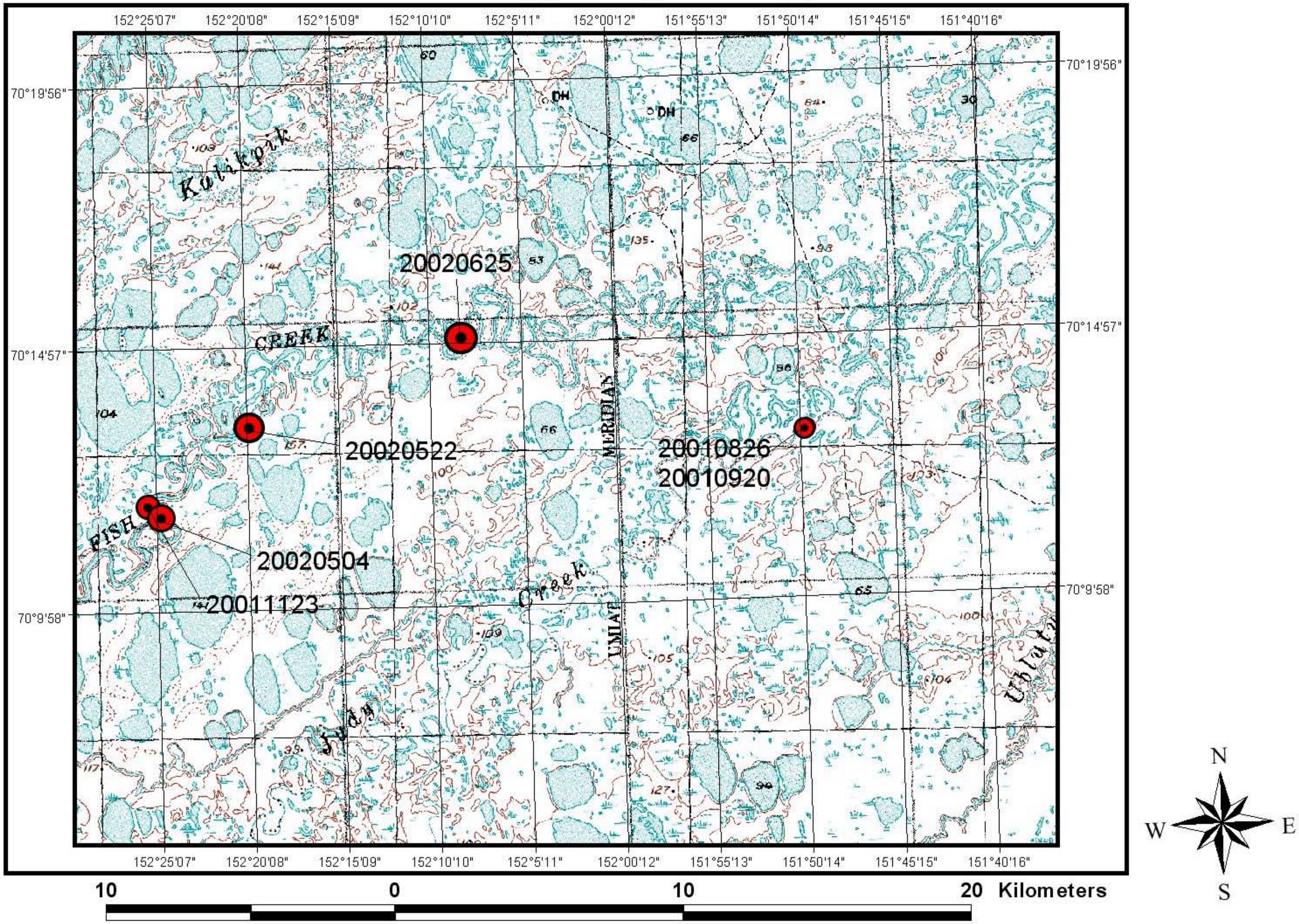
TOTAL NUMBER OF VALUES THAT WERE TIED 0
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 21 MISSING CASES 0

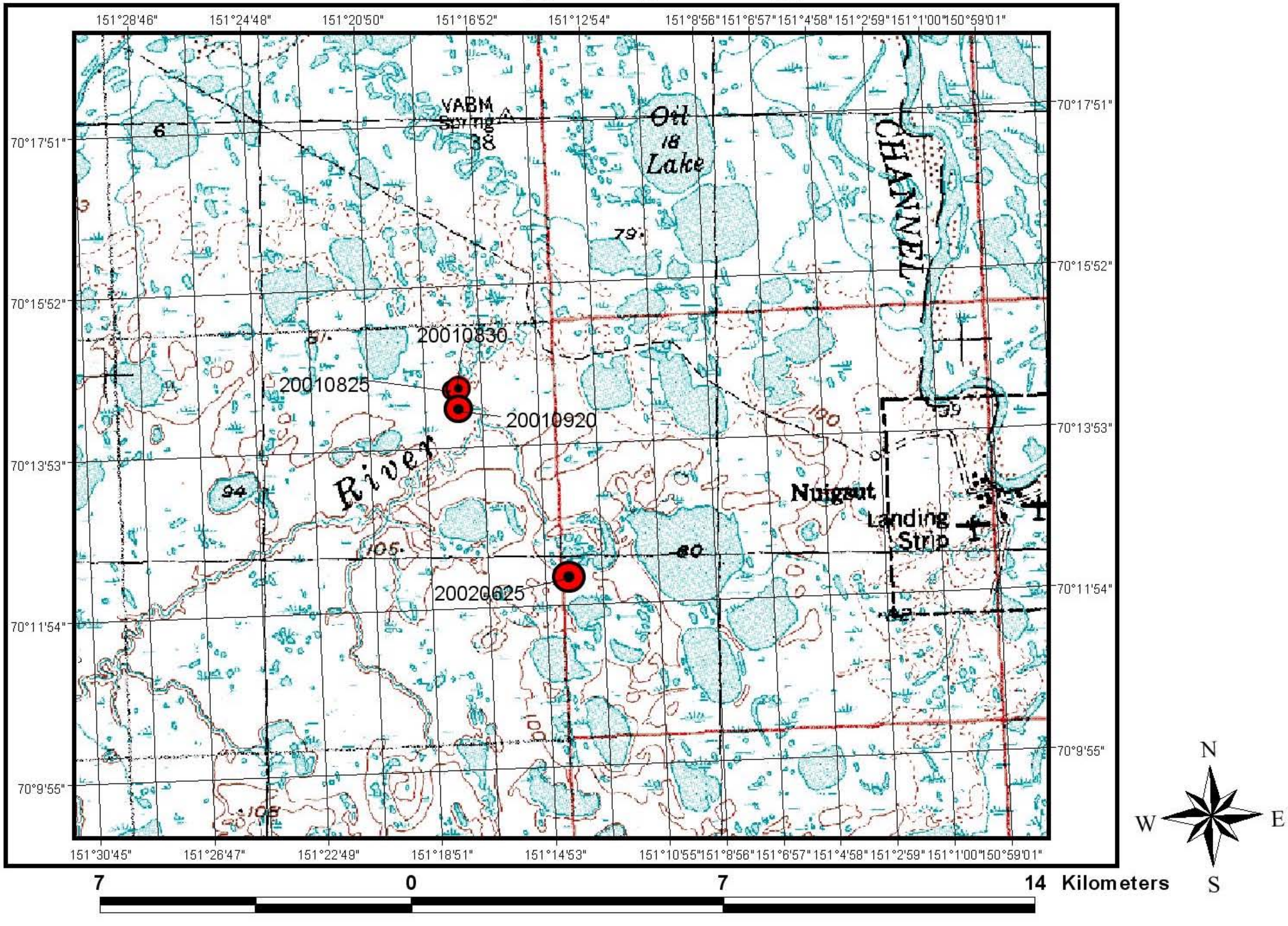
APPENDIX III Complete Relocation History Maps for Individual Fish

Maps presented in Appendix III are arranged in order from Arctic grayling to burbot to broad whitefish. Maps are in order of increasing fish identification number within each species. 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.

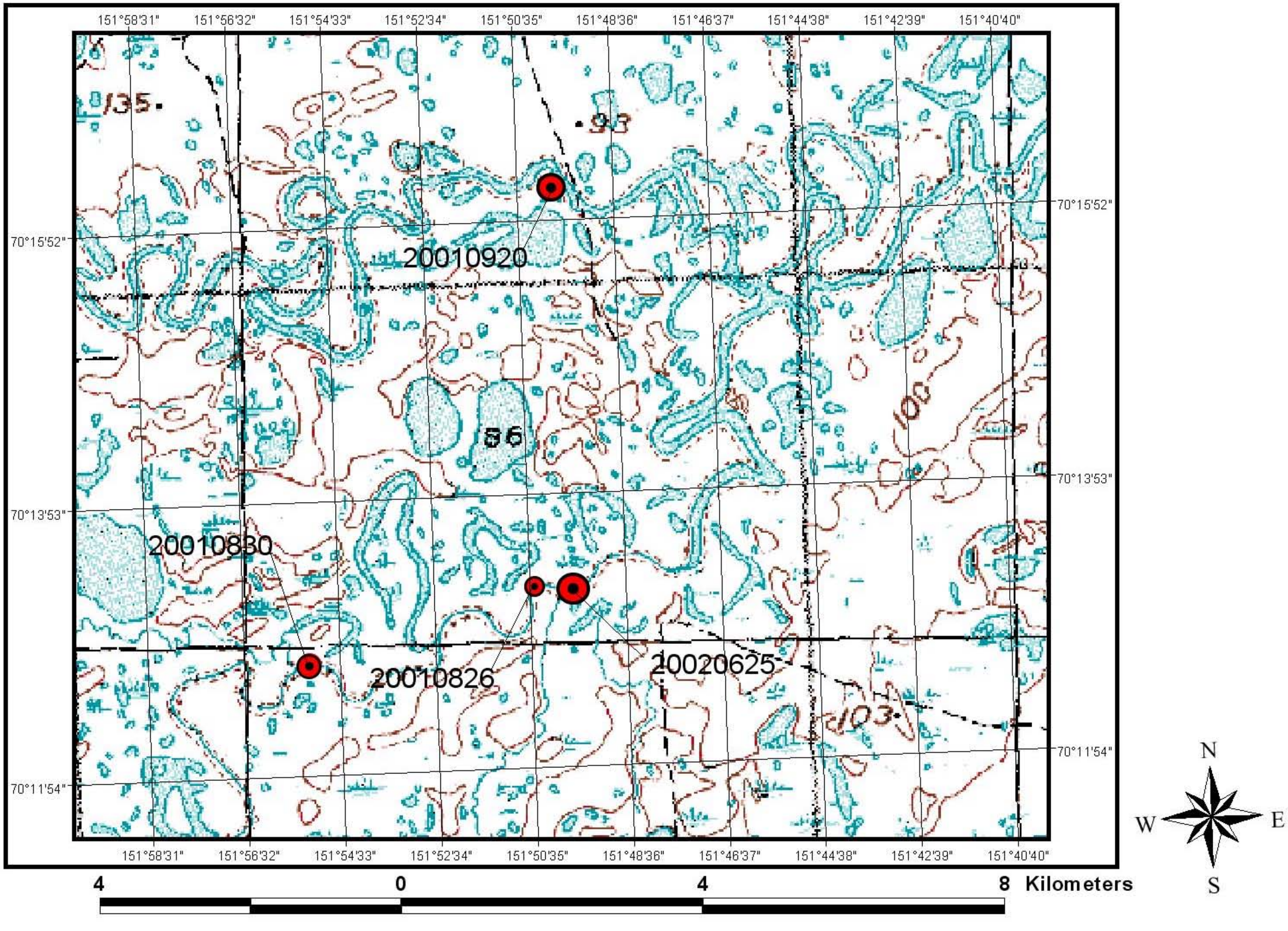
Arctic grayling 076



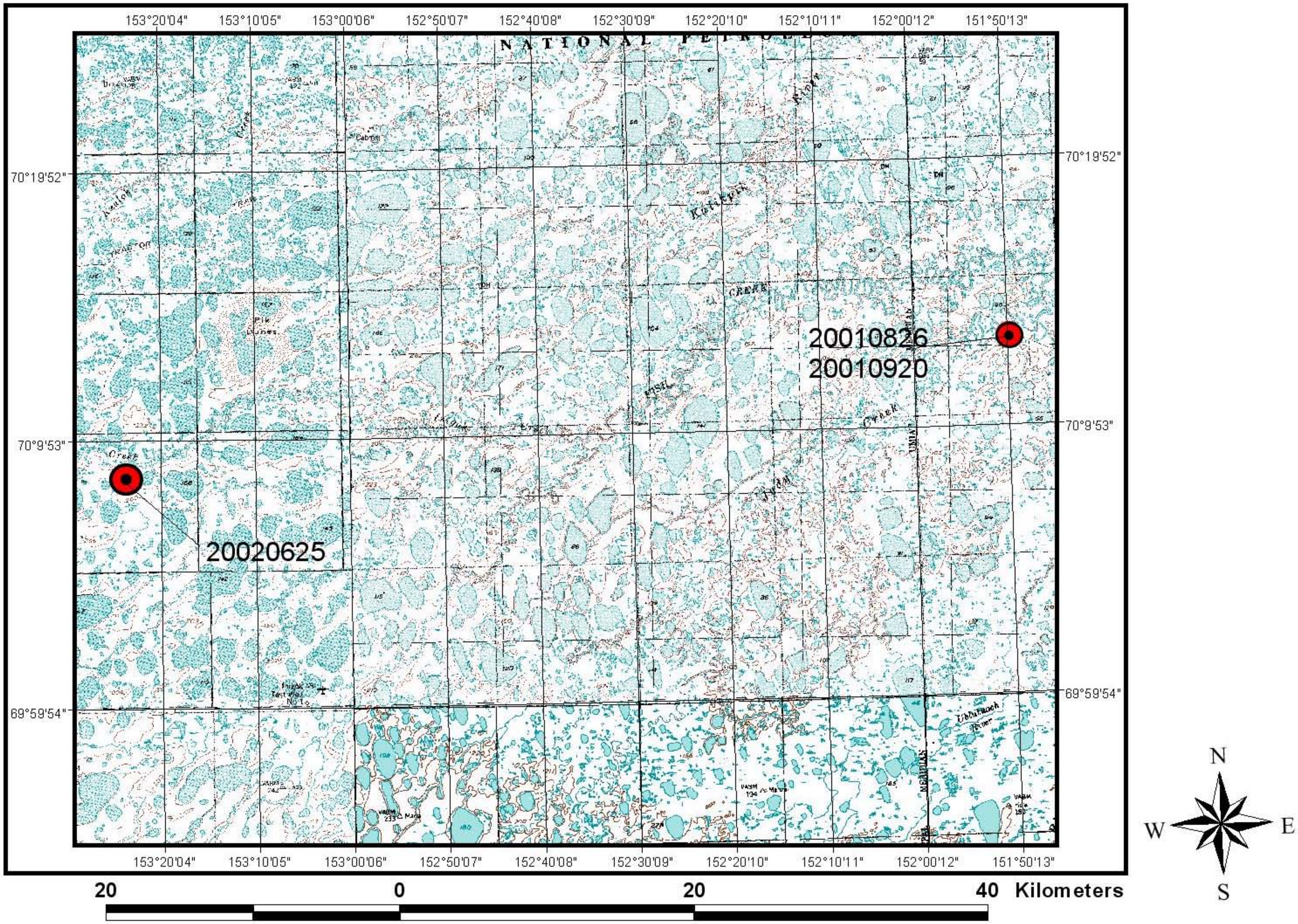
Arctic grayling 581



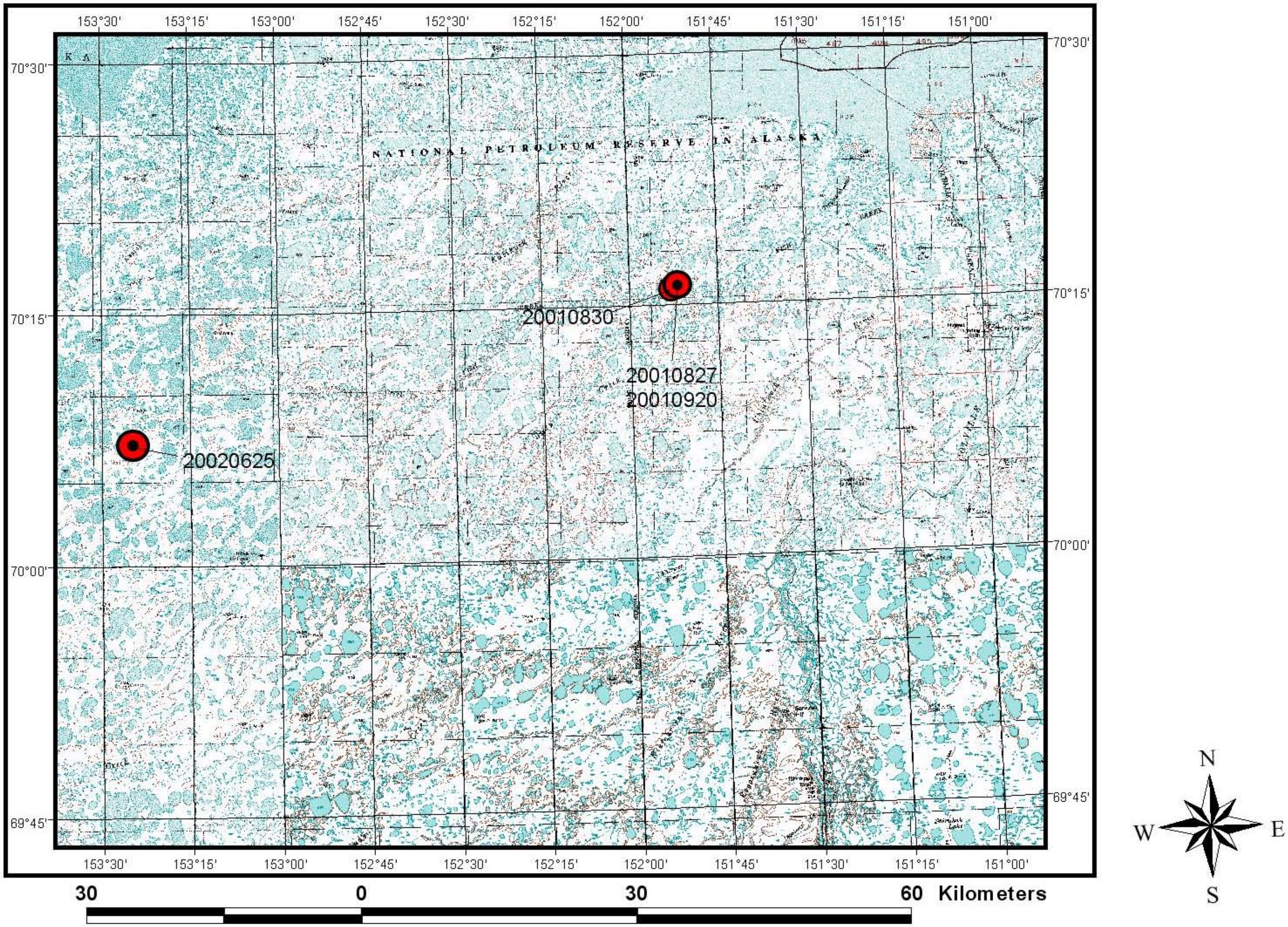
Arctic grayling 1302



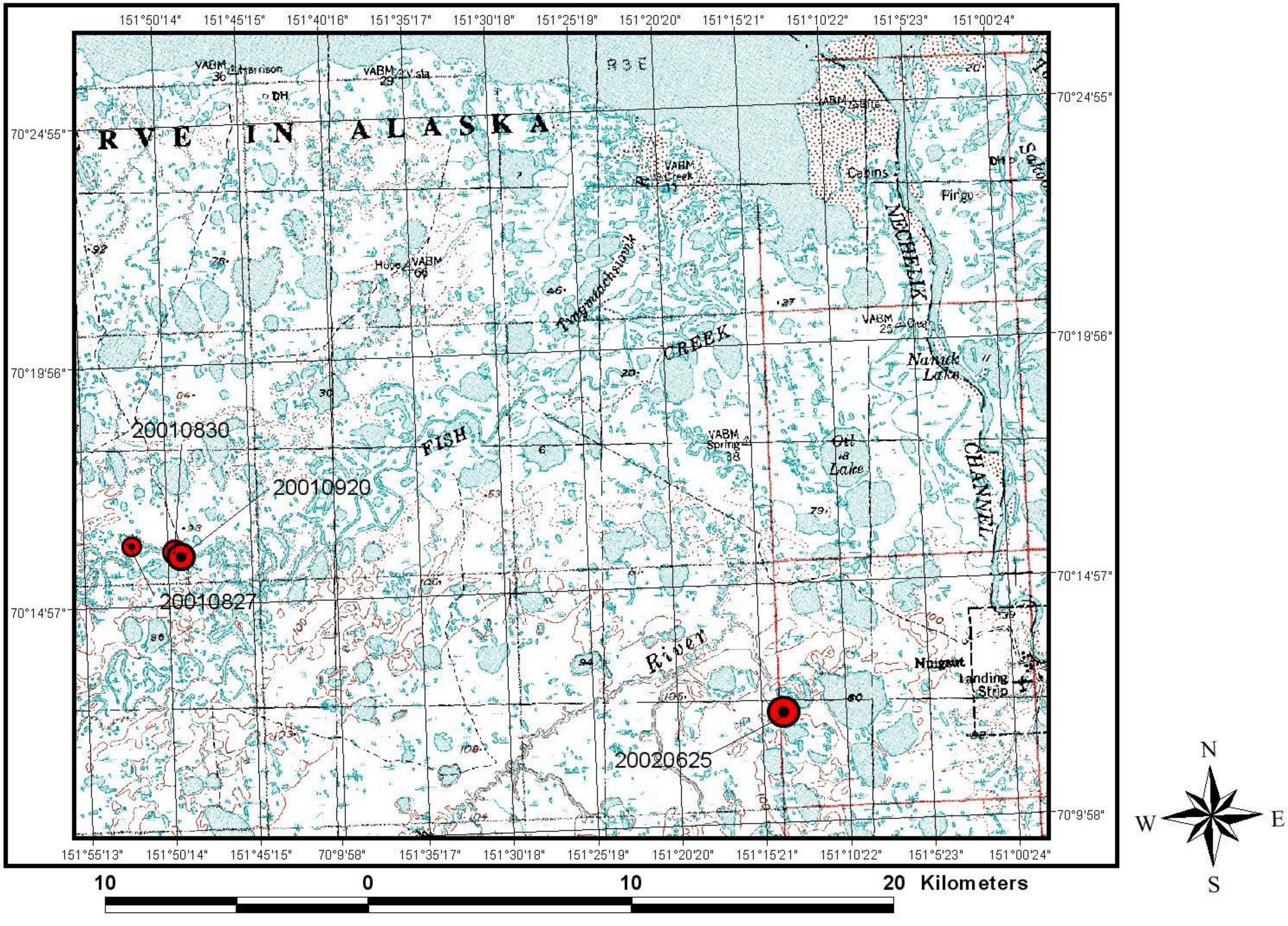
Arctic grayling 1306



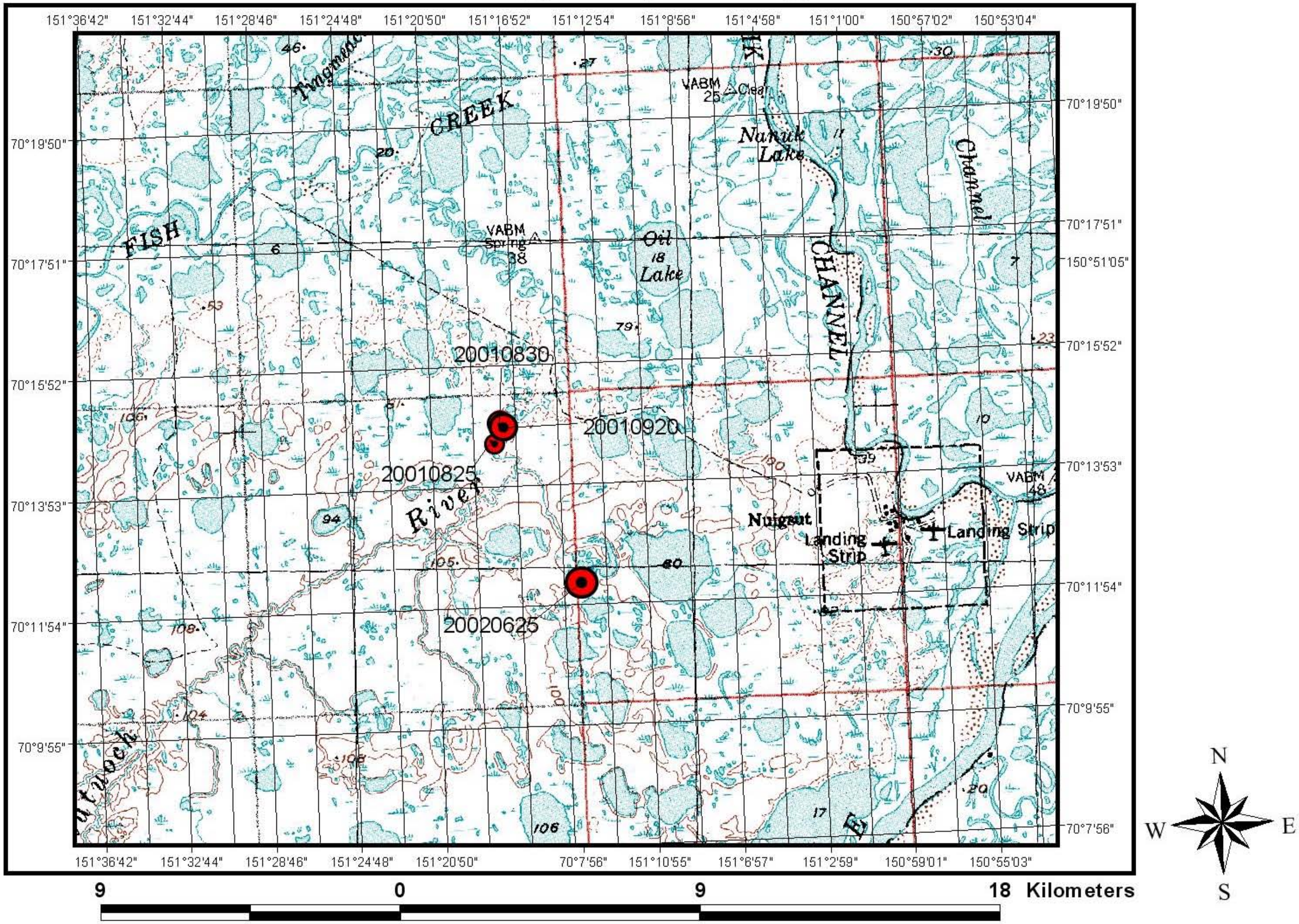
Arctic grayling 1317



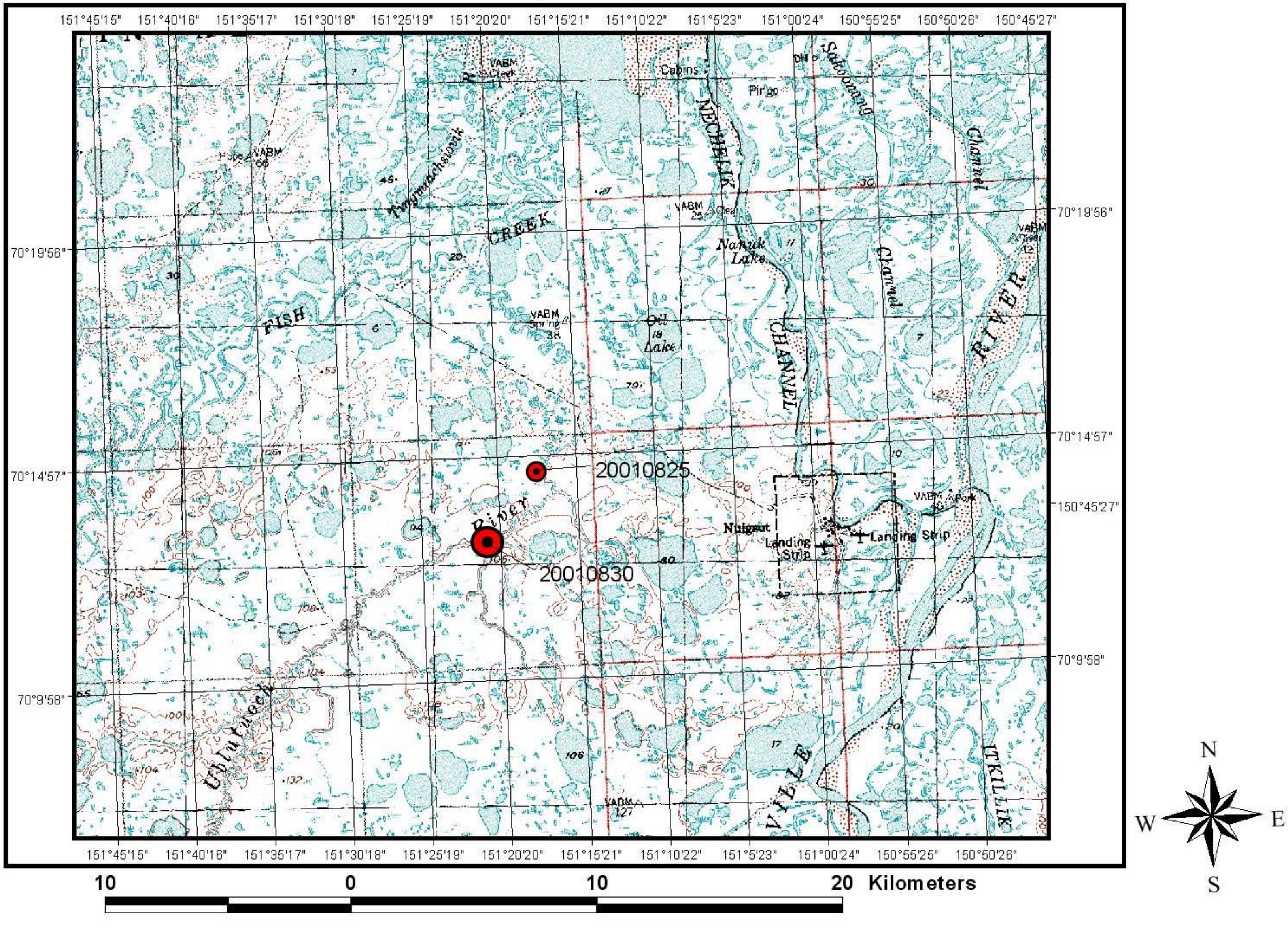
Arctic grayling 1318



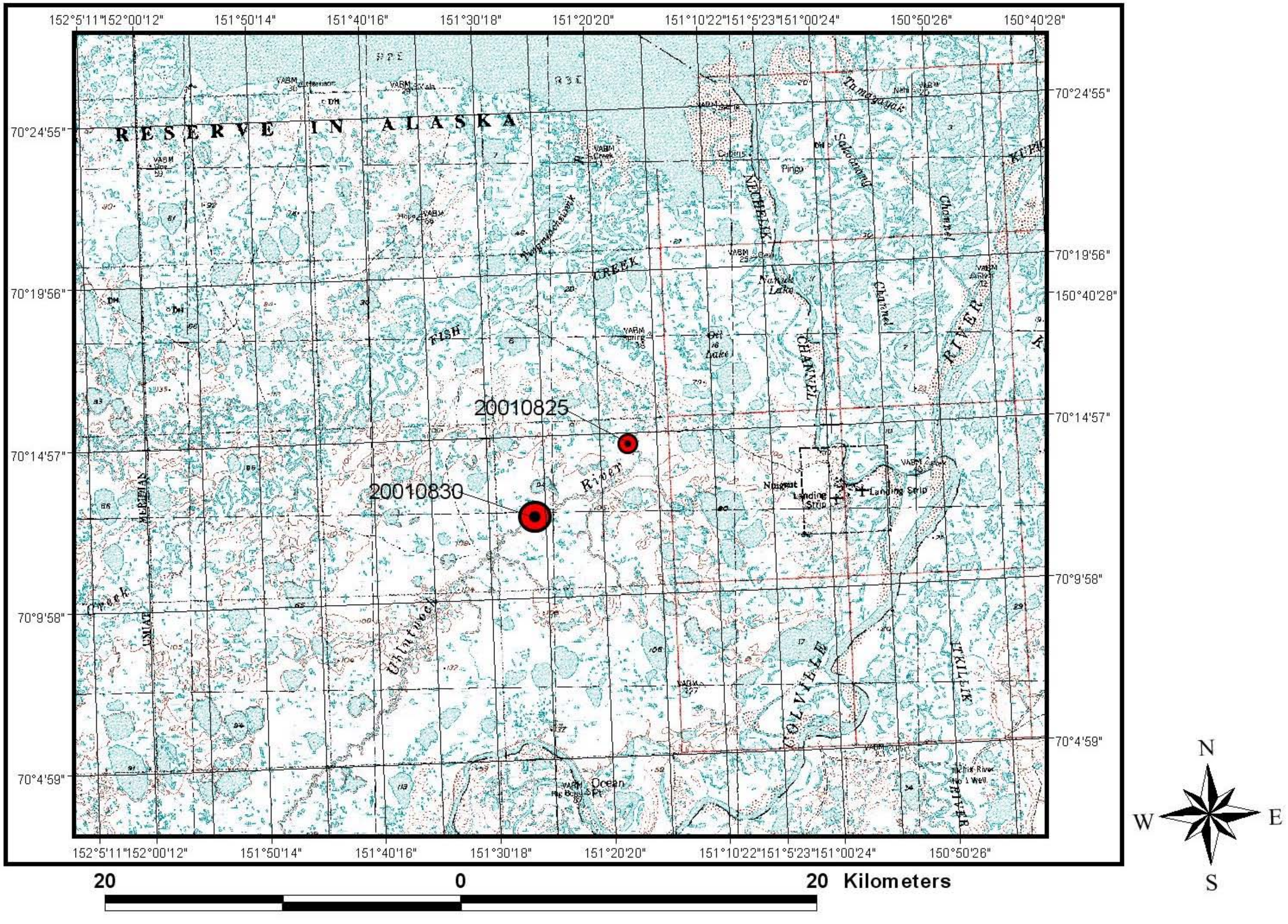
Arctic grayling 1329



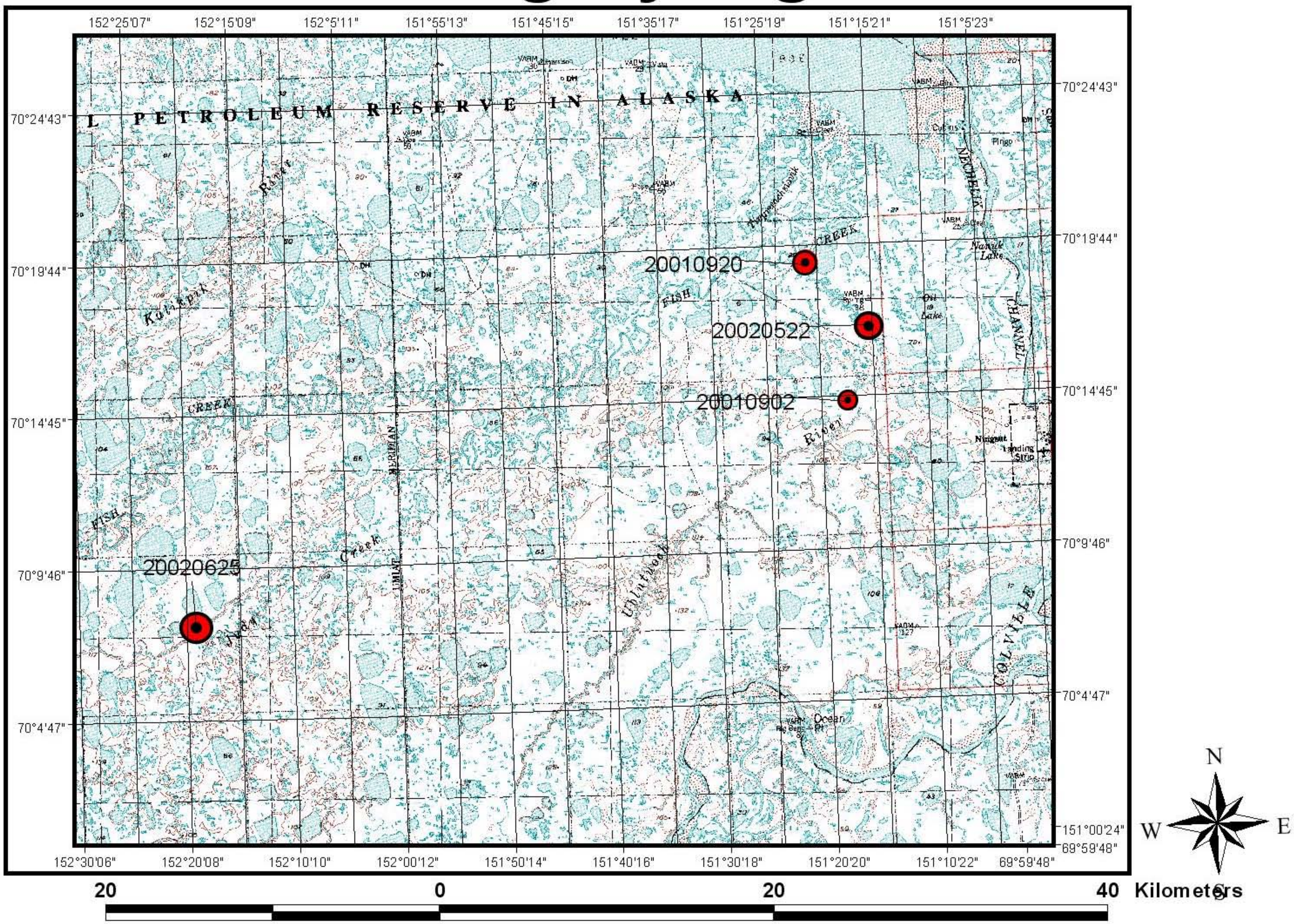
Arctic grayling 1330



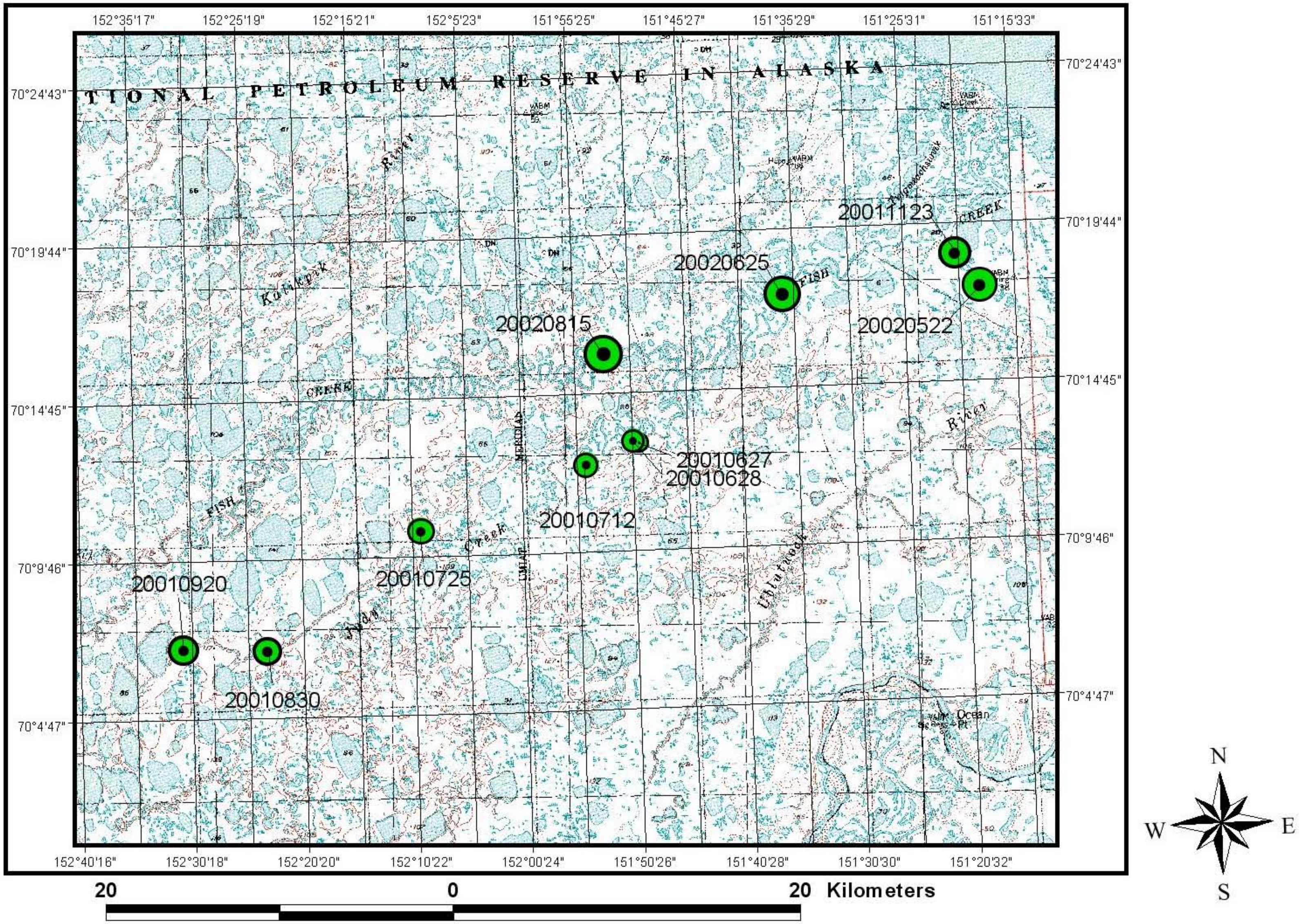
Arctic grayling 1331



Arctic grayling 1505



Burbot 0176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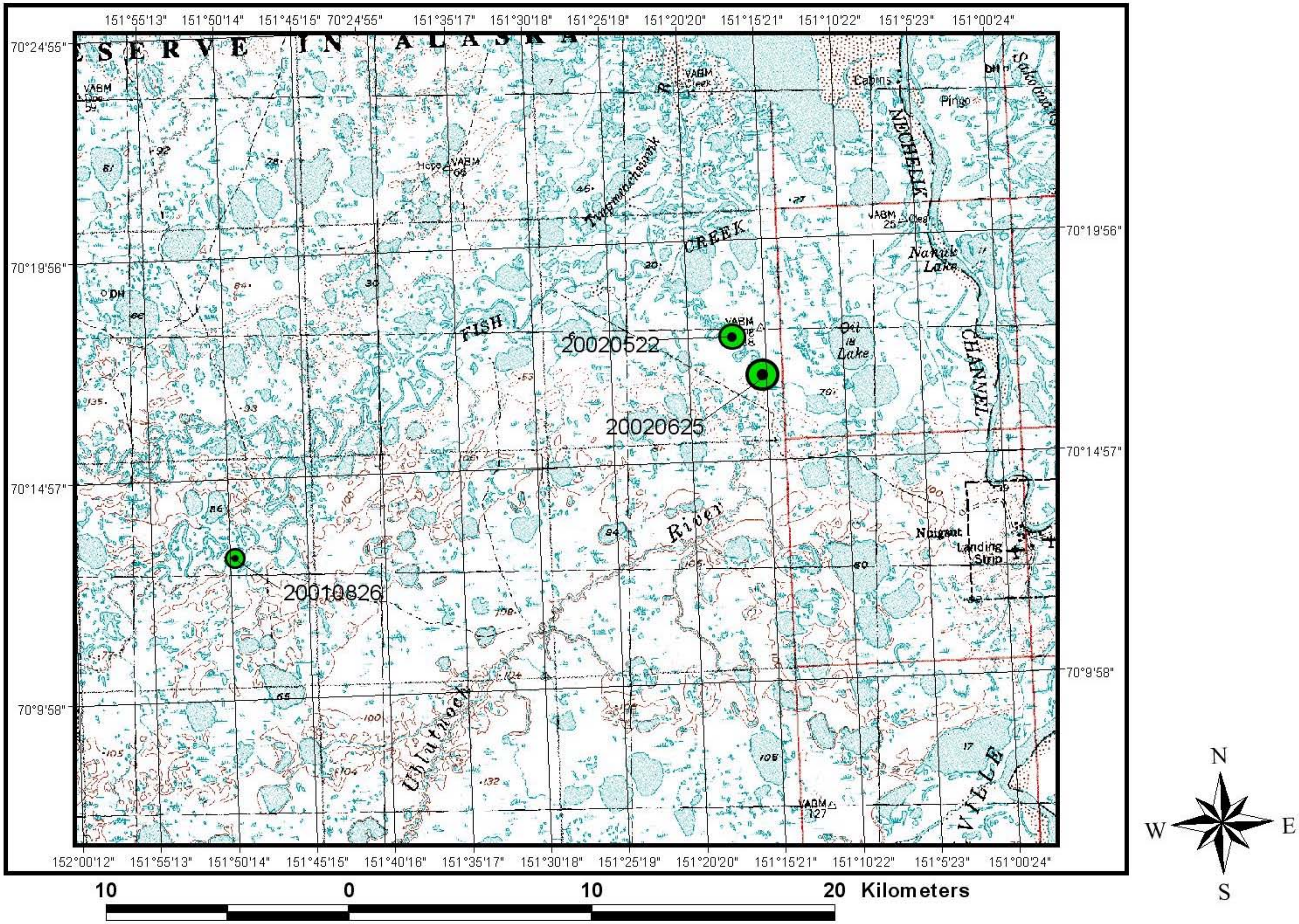
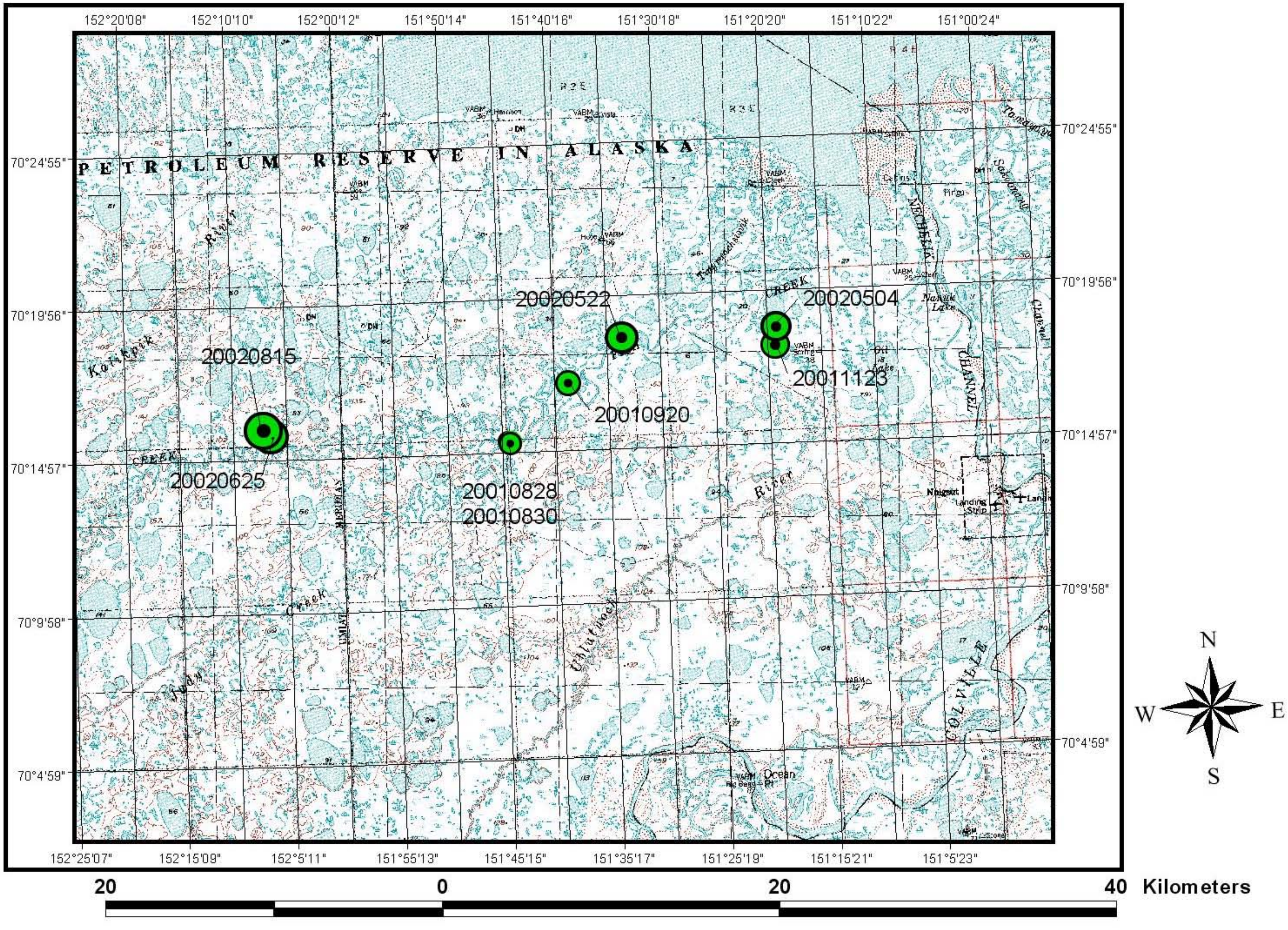
152°15'21"
152°5'23"
151°55'25"
151°45'27"
151°35'29"
151°25'31"
151°15'33"
70°24'43"
70°19'44"
70°14'45"
70°9'46"
70°4'47"
152°40'16"
152°30'18"
152°20'20"
152°10'22"
152°00'24"
151°50'26"
151°40'28"
151°30'30"
151°20'32"
20011123
20020625
20020522
20020815
20010627
20010628
20010712
20010725
20010920
20010830
20 0 20 Kilometers
N
W
E
S

Burbot 1301



20020522
20020625
20010826
FISH
CREEK
River
NECHELIK
CHANNEL
Nanuk Lake
Oil Lake
Cabins
Pingo
Nuiqsut
Landing Strip
Ublutuoch
70°24'55"
70°19'56"
70°14'57"
70°9'58"
152°00'12"
151°55'13"
151°50'14"
151°45'15"
151°40'16"
151°35'17"
151°30'18"
151°25'19"
151°20'20"
151°15'21"
151°10'22"
151°5'23"
151°00'24"
10
0
10
20 Kilometers
N
W
E
S

Burbot 1324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152°10'10"
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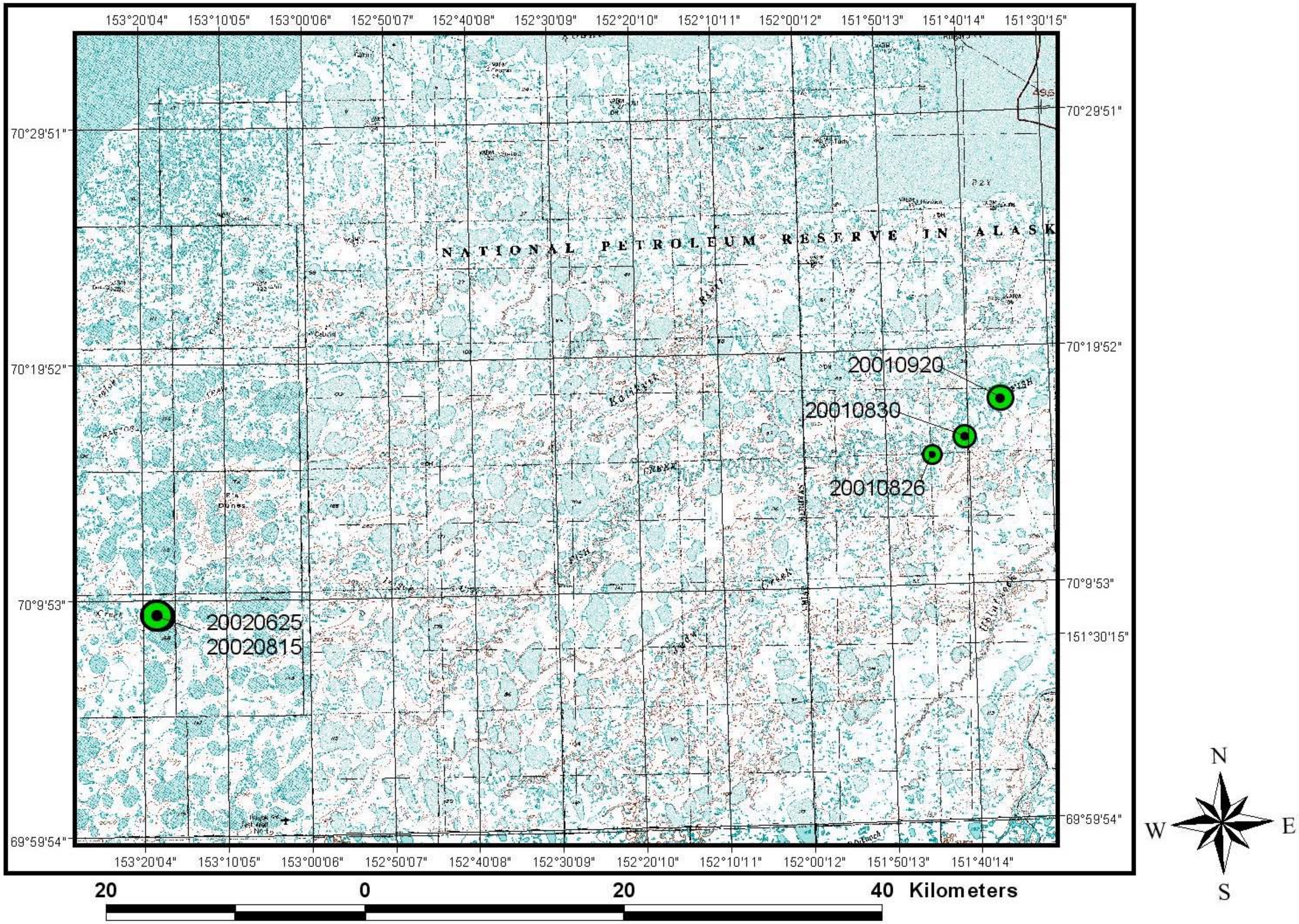
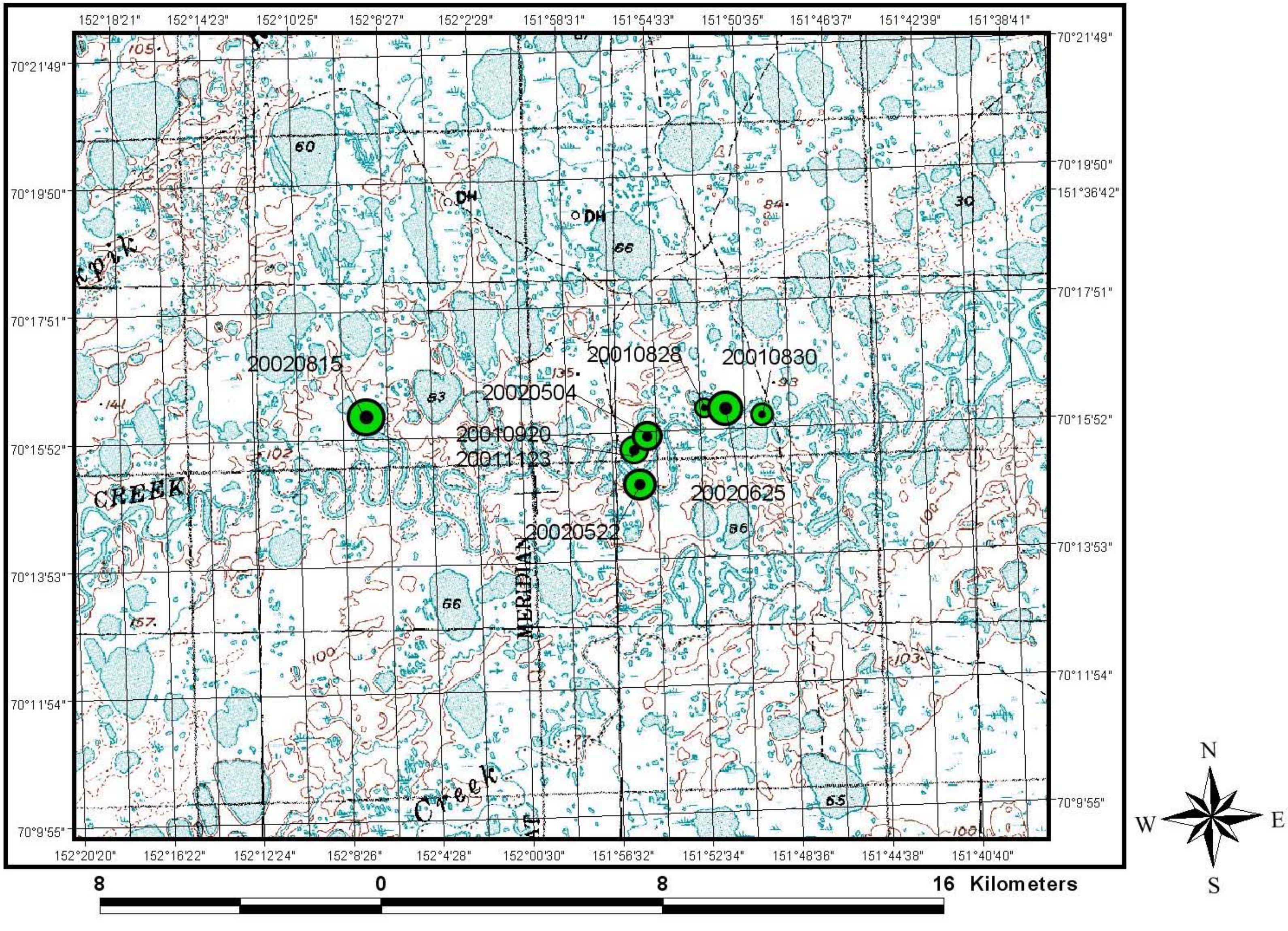
151°50'14"
151°40'16"
151°30'18"
151°20'20"
151°10'22"
151°00'24"
70°24'55"
70°19'56"
70°14'57"
70°9'58"
70°4'59"
152°25'07"
152°15'09"
152°5'11"
151°55'13"
151°45'15"
151°35'17"
151°25'19"
151°15'21"
151°5'23"
PETROLEUM RESERVE IN ALASKA
20020522
20020504
20020815
20011123
20010920
20020625
20010828
20010830
20
0
20
40 Kilometers
N
W
E
S

Burbot 1326



153°20'04"
153°10'05"
153°00'06"
152°50'07"
152°40'08"
152°30'09"
152°20'10"
152°10'11"
152°00'12"
151°50'13"
151°40'14"
151°30'15"
70°29'51"
70°19'52"
70°9'53"
69°59'54"
NATIONAL PETROLEUM RESERVE IN ALASK
20010920
20010830
20010826
20020625
20020815
20
0
20
40 Kilometers
N
S
E
W

Burbot 1352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152°14'23"
152°10'25"
152°6'27"
152°2'29"
151°58'31"
151°54'33"
151°50'35"
151°46'37"
151°42'39"
151°38'41"
70°21'49"
70°19'50"
70°17'51"
70°15'52"
70°13'53"
70°11'54"
70°9'55"
151°36'42"
152°20'20"
152°16'22"
152°12'24"
152°8'26"
152°4'28"
152°00'30"
151°56'32"
151°52'34"
151°48'36"
151°44'38"
151°40'40"
20020815
20010828
20010830
20020504
20010920
20011123
20020625
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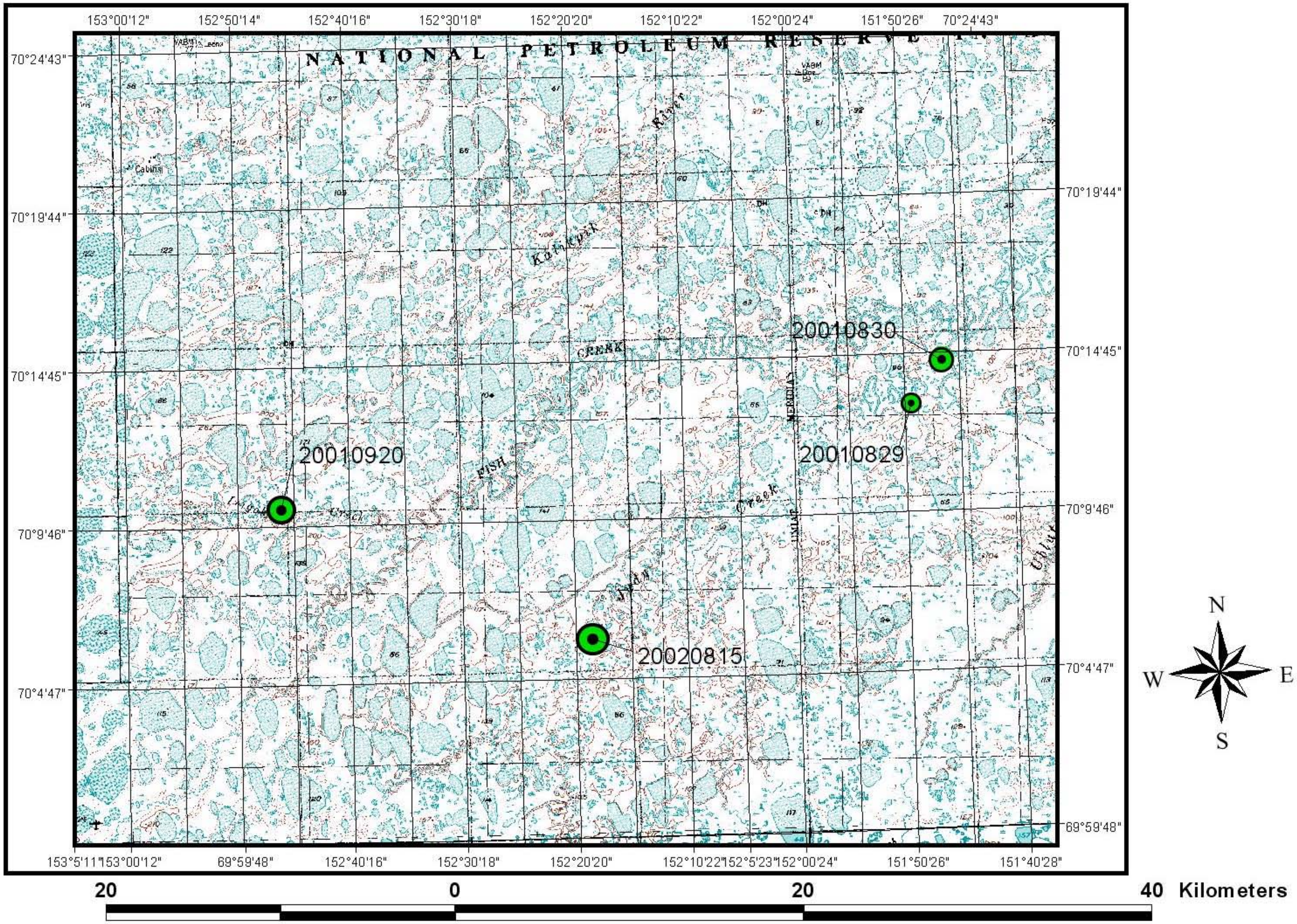
CREEK
MERIDIAN
Creek
DH
8
0
8
16 Kilometers
N
W
E
S

Burbot 1370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152°40'16"
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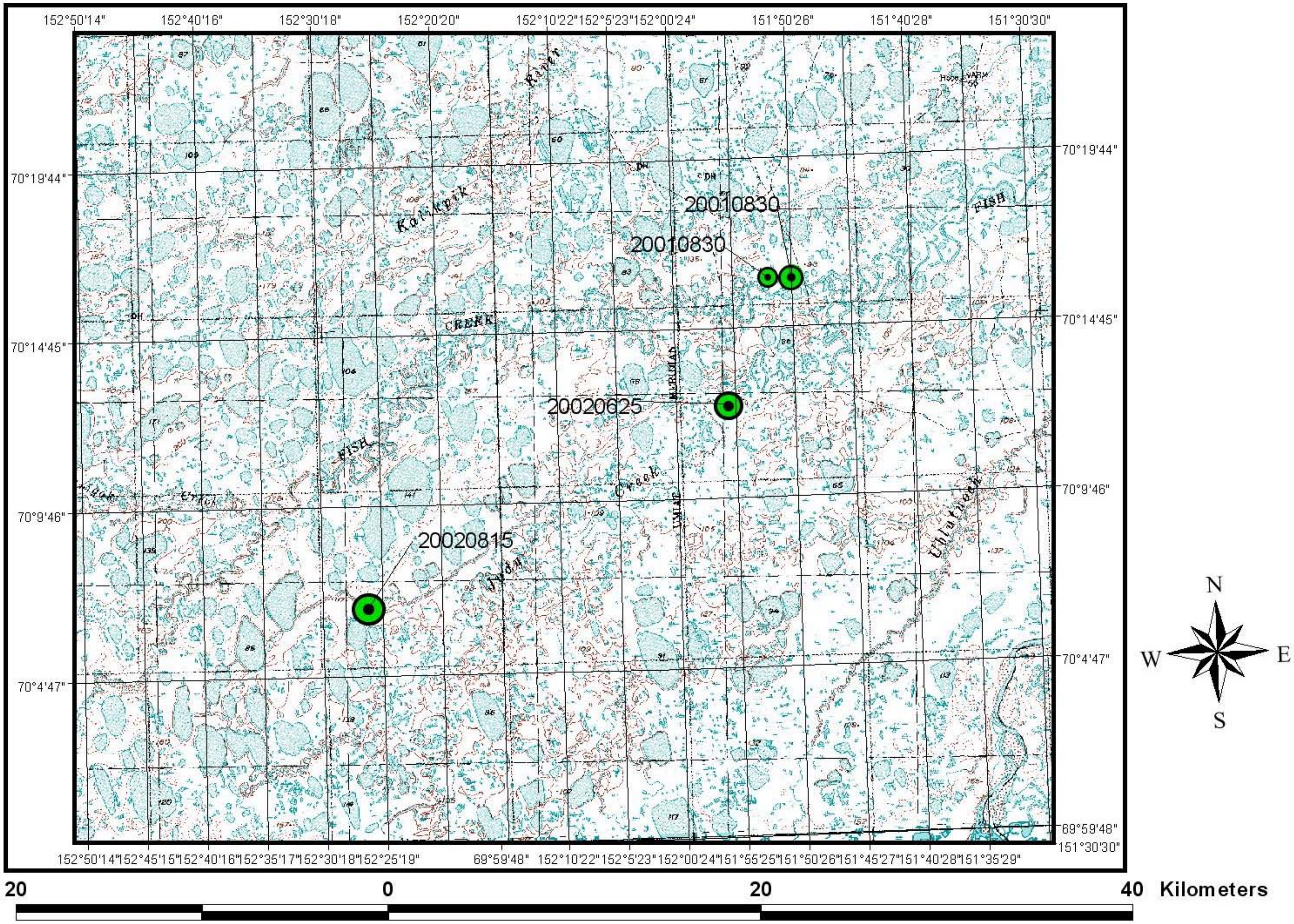
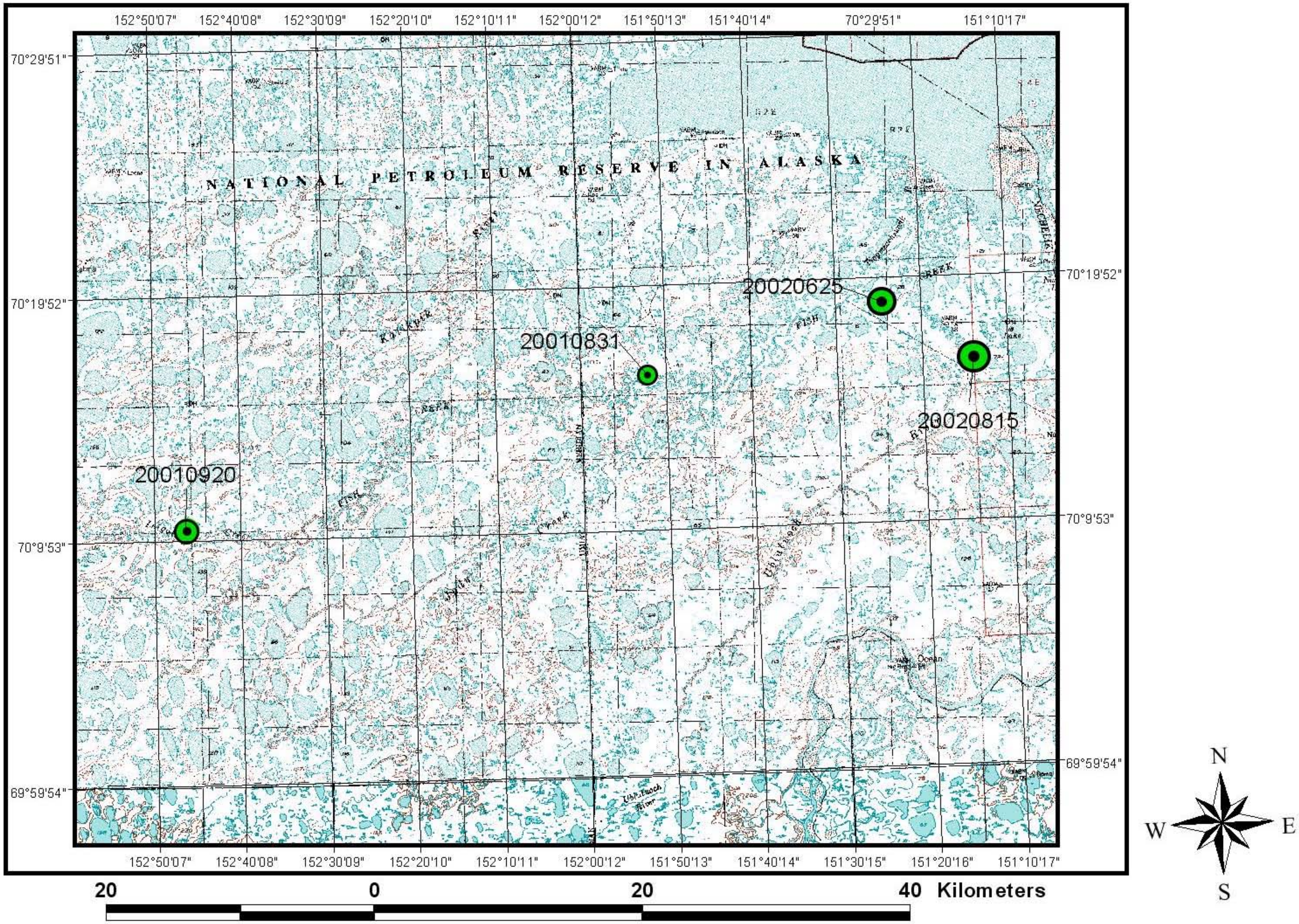
152°00'24"
151°50'26"
70°24'43"
70°19'44"
70°14'45"
70°9'46"
70°4'47"
69°59'48"
NATIONAL PETROLEUM RESERVE
20010830
20010829
20010920
20020815
153°5'11"
69°59'48"
152°5'23"
151°40'28"
N
W
E
S
20
0
20
40 Kilometers

Burbot 1380



152°50'14"
152°40'16"
152°30'18"
152°20'20"
152°10'22"
152°5'23"
152°00'24"
151°50'26"
151°40'28"
151°30'30"
70°19'44"
70°14'45"
70°9'46"
70°4'47"
69°59'48"
152°50'14" 152°45'15" 152°40'16" 152°35'17" 152°30'18" 152°25'19"
69°59'48"
152°10'22" 152°5'23" 152°00'24" 151°55'25" 151°50'26" 151°45'27" 151°40'28" 151°35'29"
151°30'30"
20010830
20010830
20020625
20020815
CREEK
FISH
Creek
N
S
E
W
20
0
20
40 Kilometers

Burbot 1386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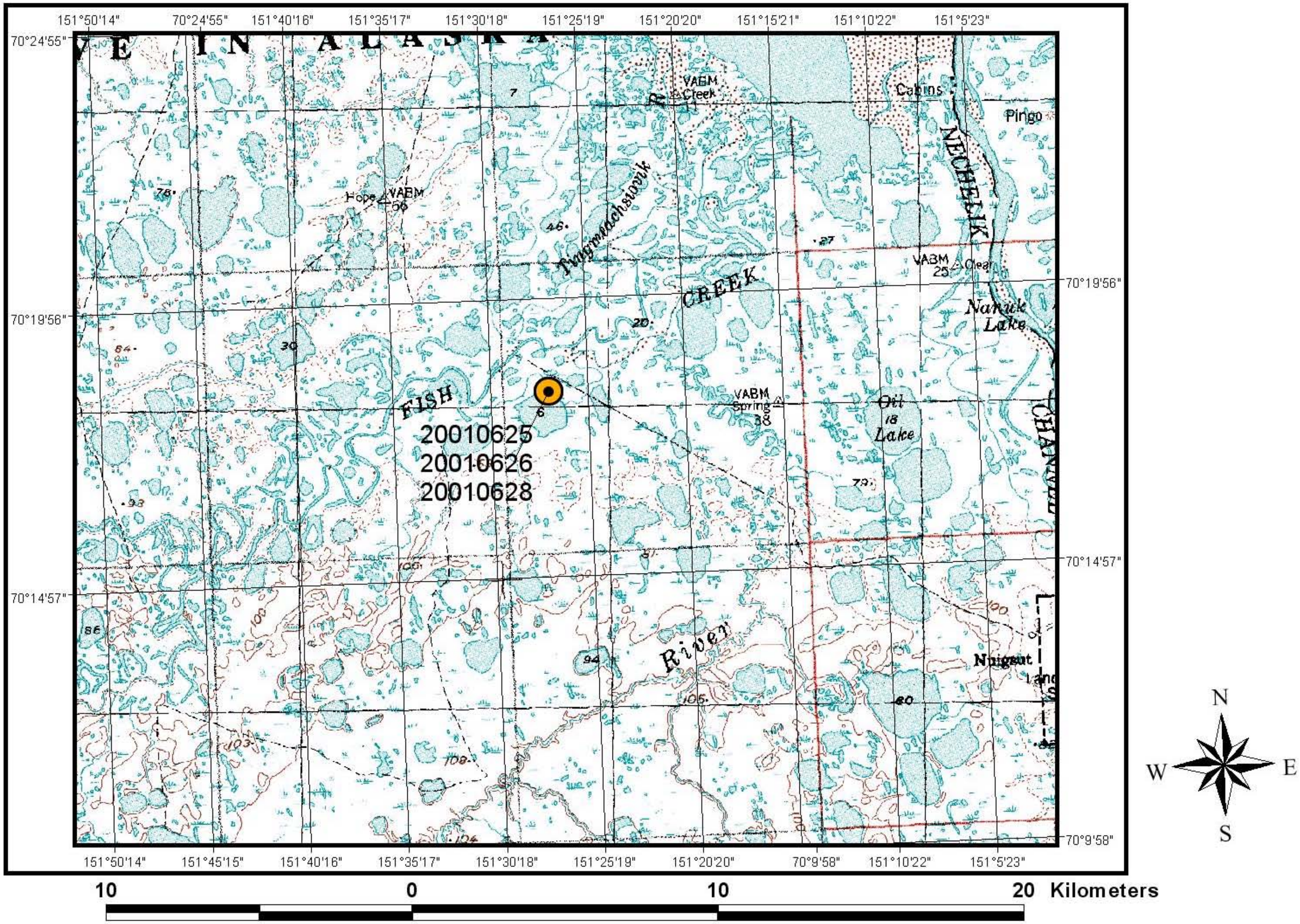
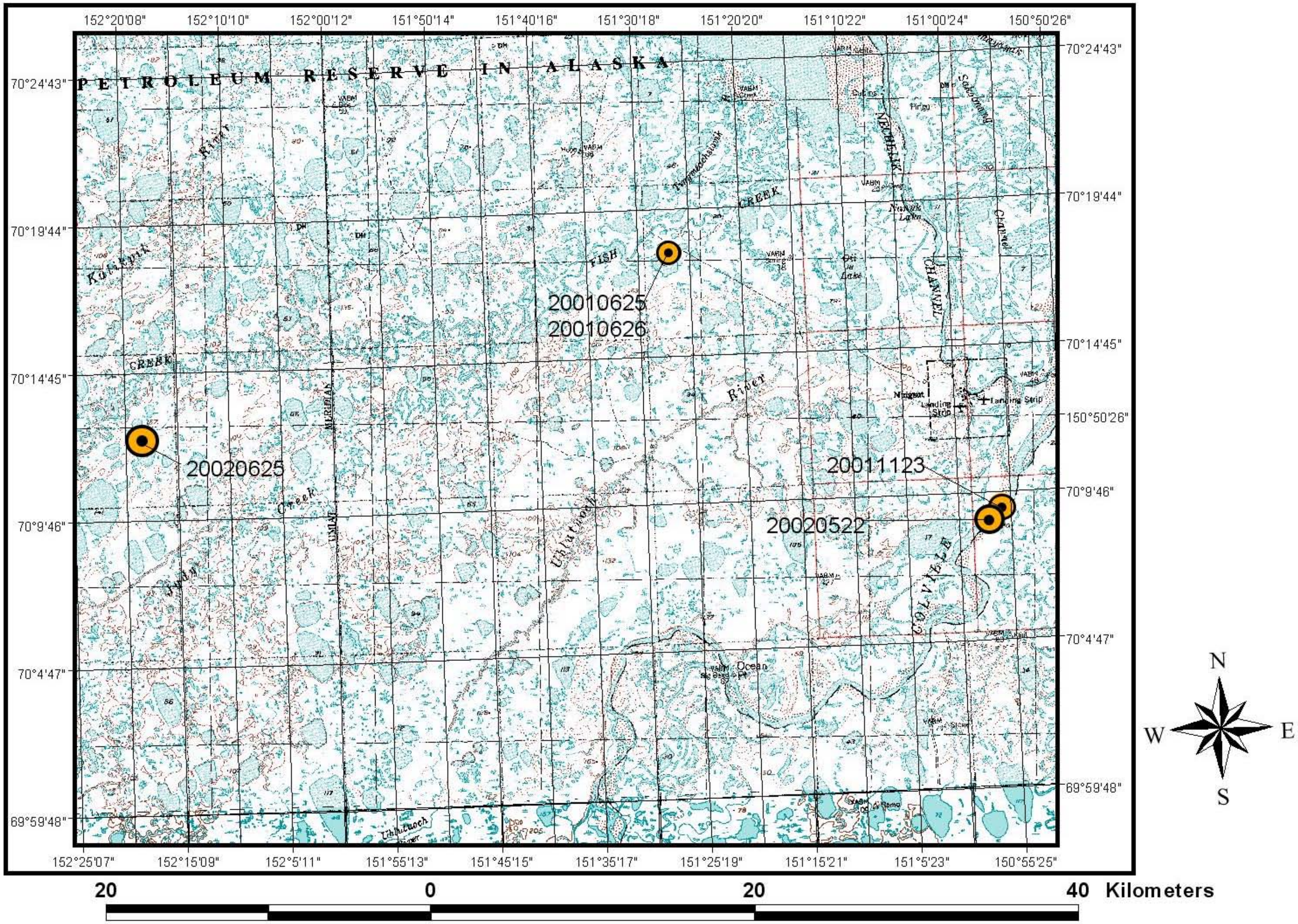
151°50'13"
151°40'14"
70°29'51"
151°10'17"
70°29'51"
70°19'52"
70°9'53"
69°59'54"
NATIONAL PETROLEUM RESERVE IN ALASKA
20020625
20010831
20020815
20010920
151°30'15"
151°20'16"
20
0
20
40 Kilometers
N
W
E
S

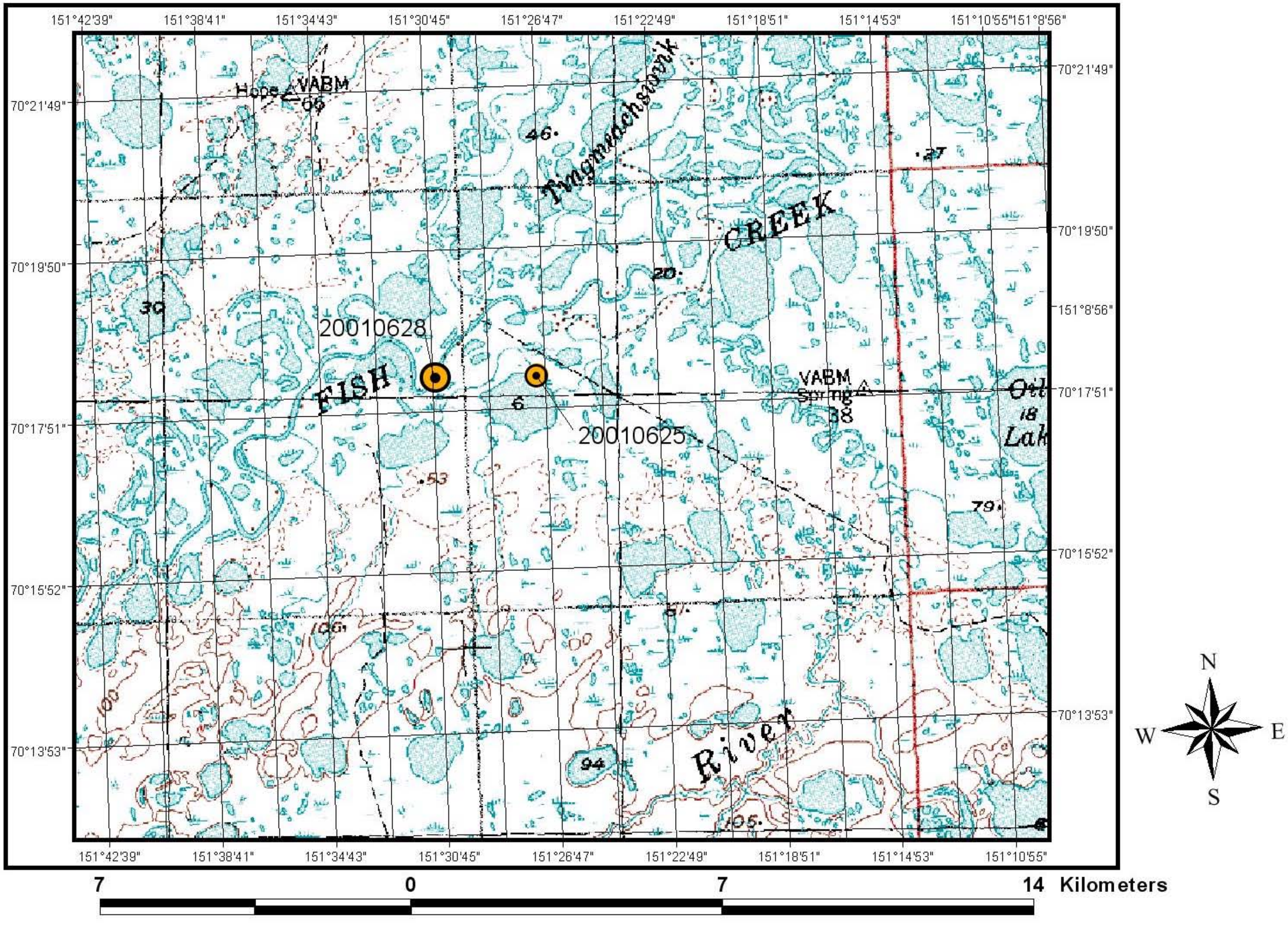
Broad whitefish 0091



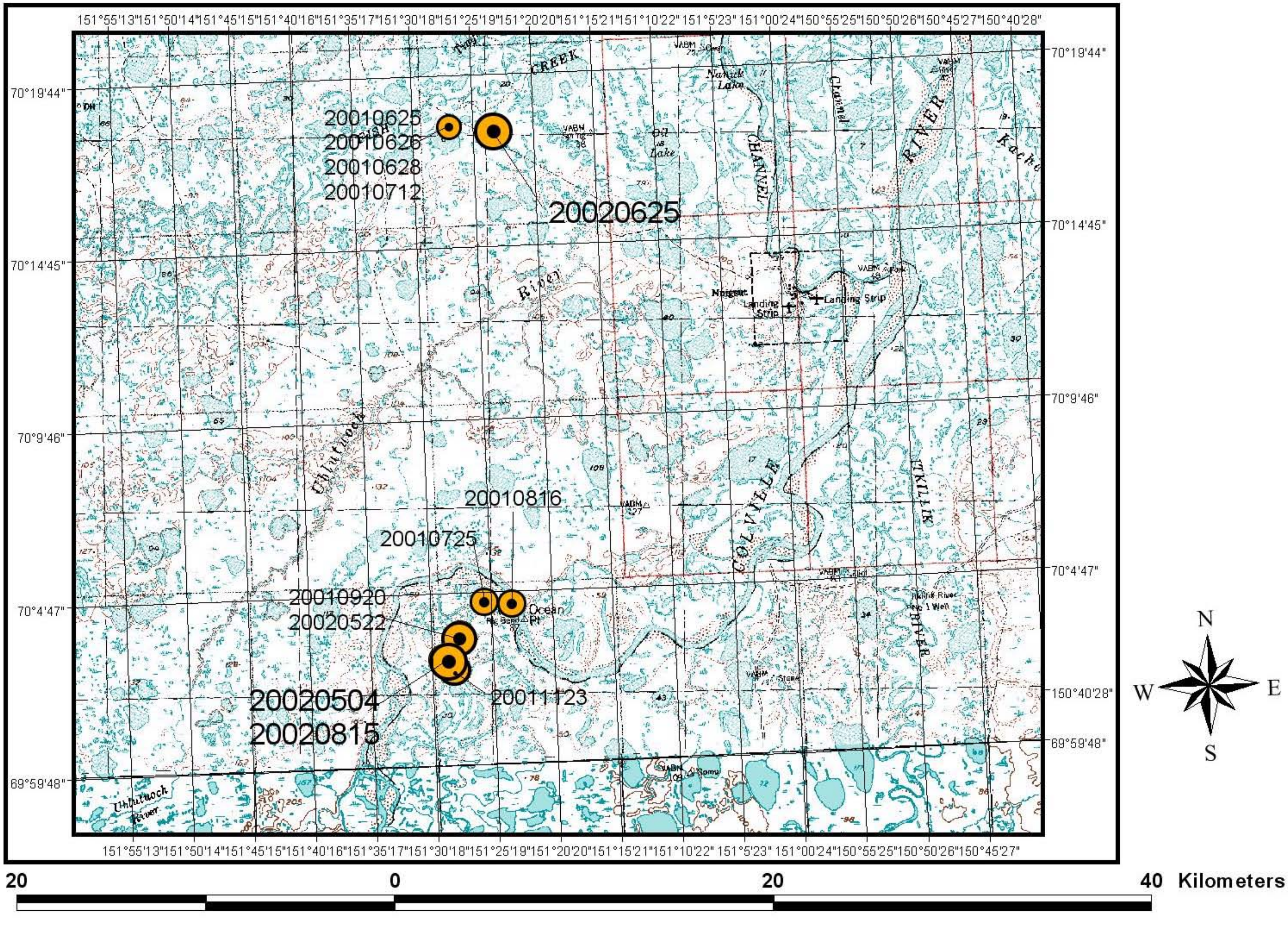
Broad whitefish 0102



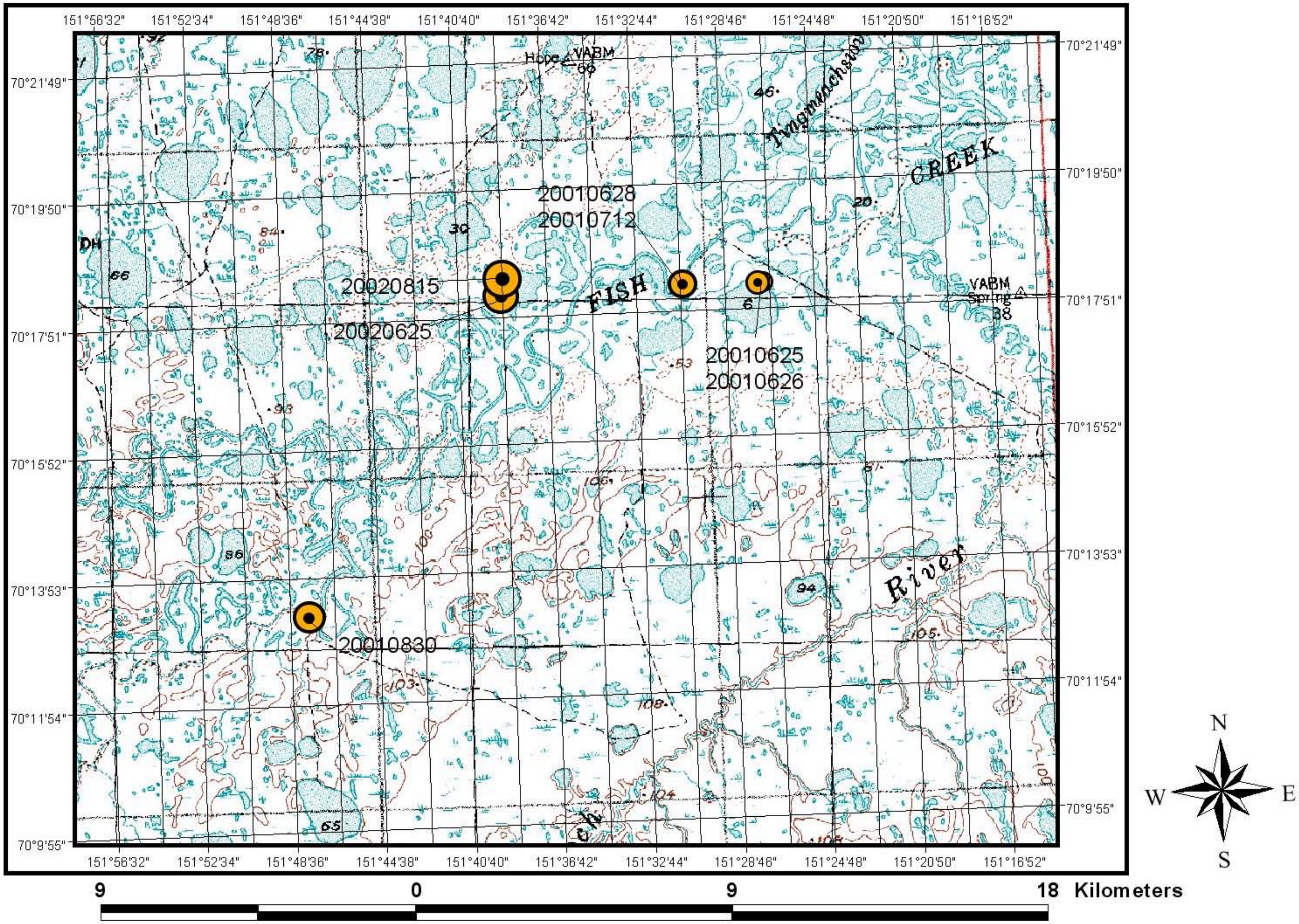
Broad whitefish 0103



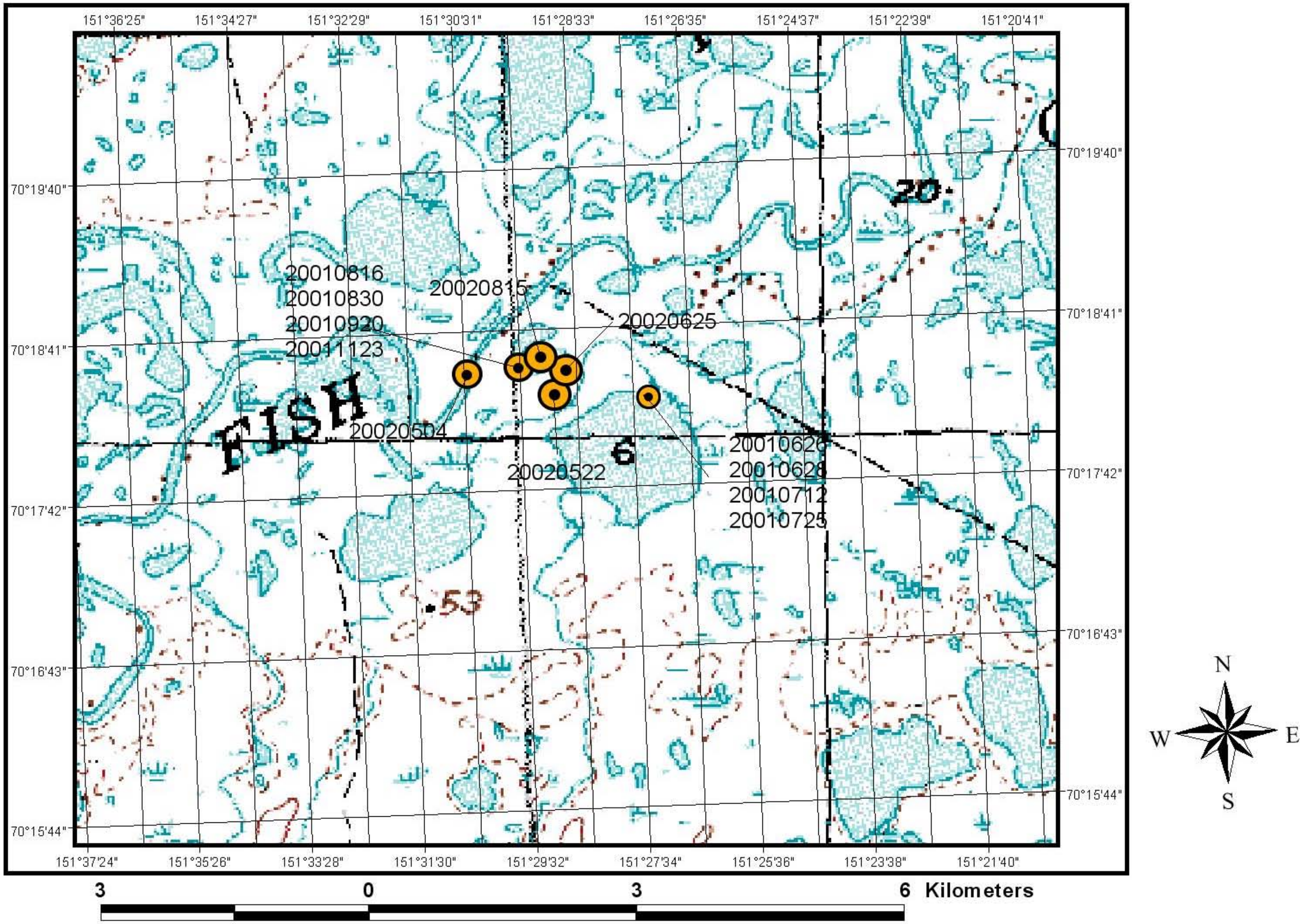
Broad whitefish 0104



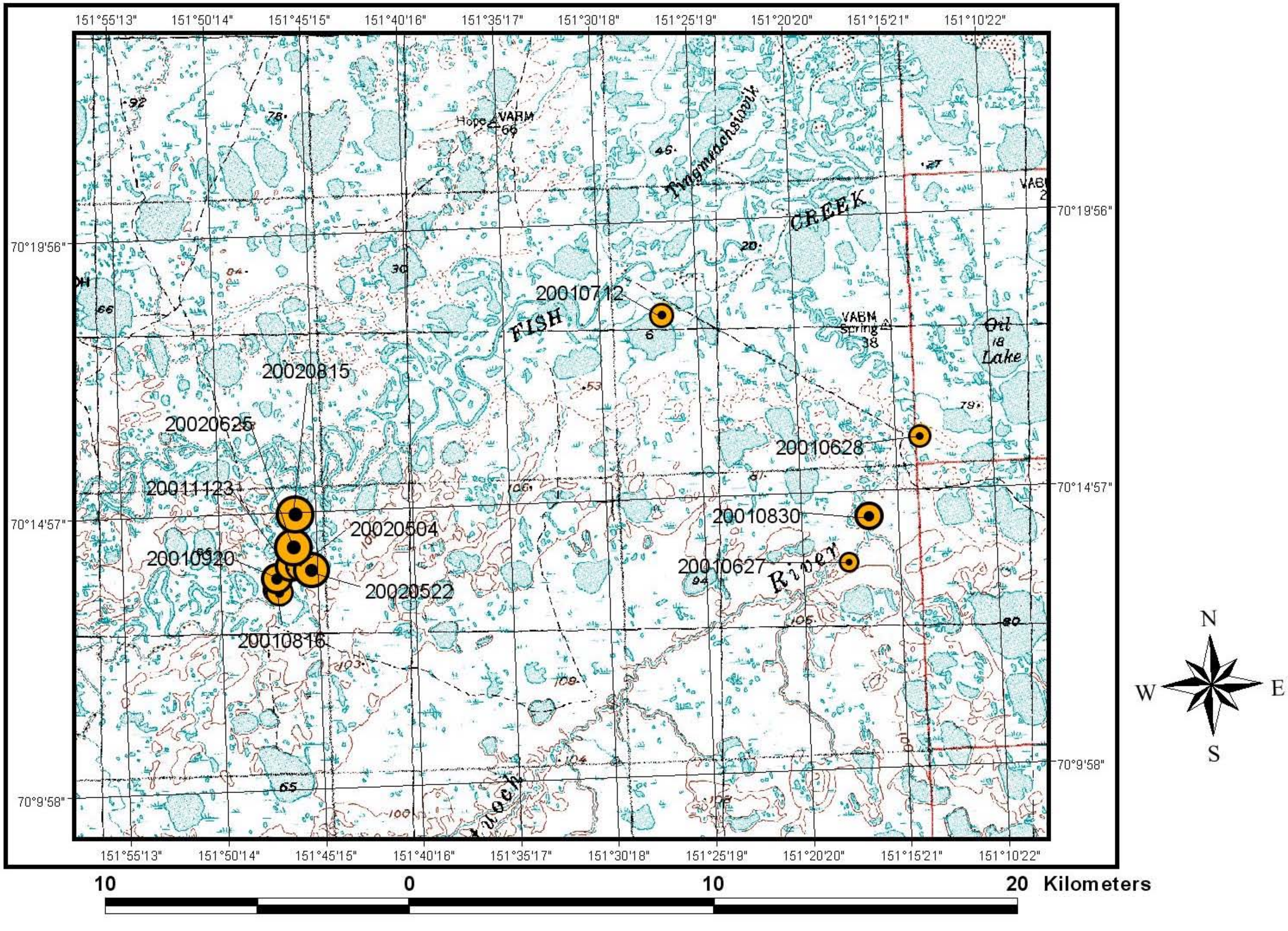
Broad whitefish 0105



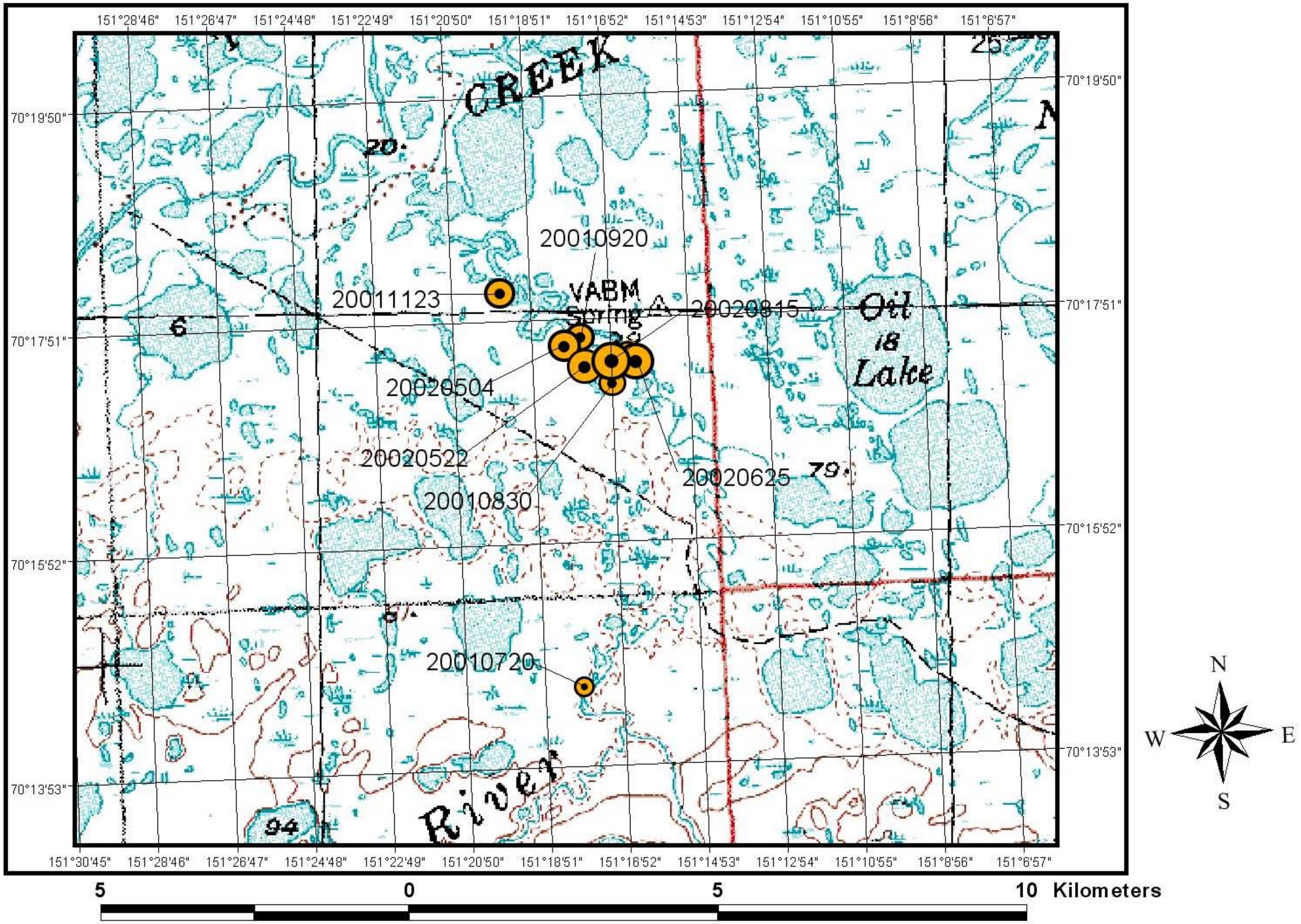
Broad whitefish 0154



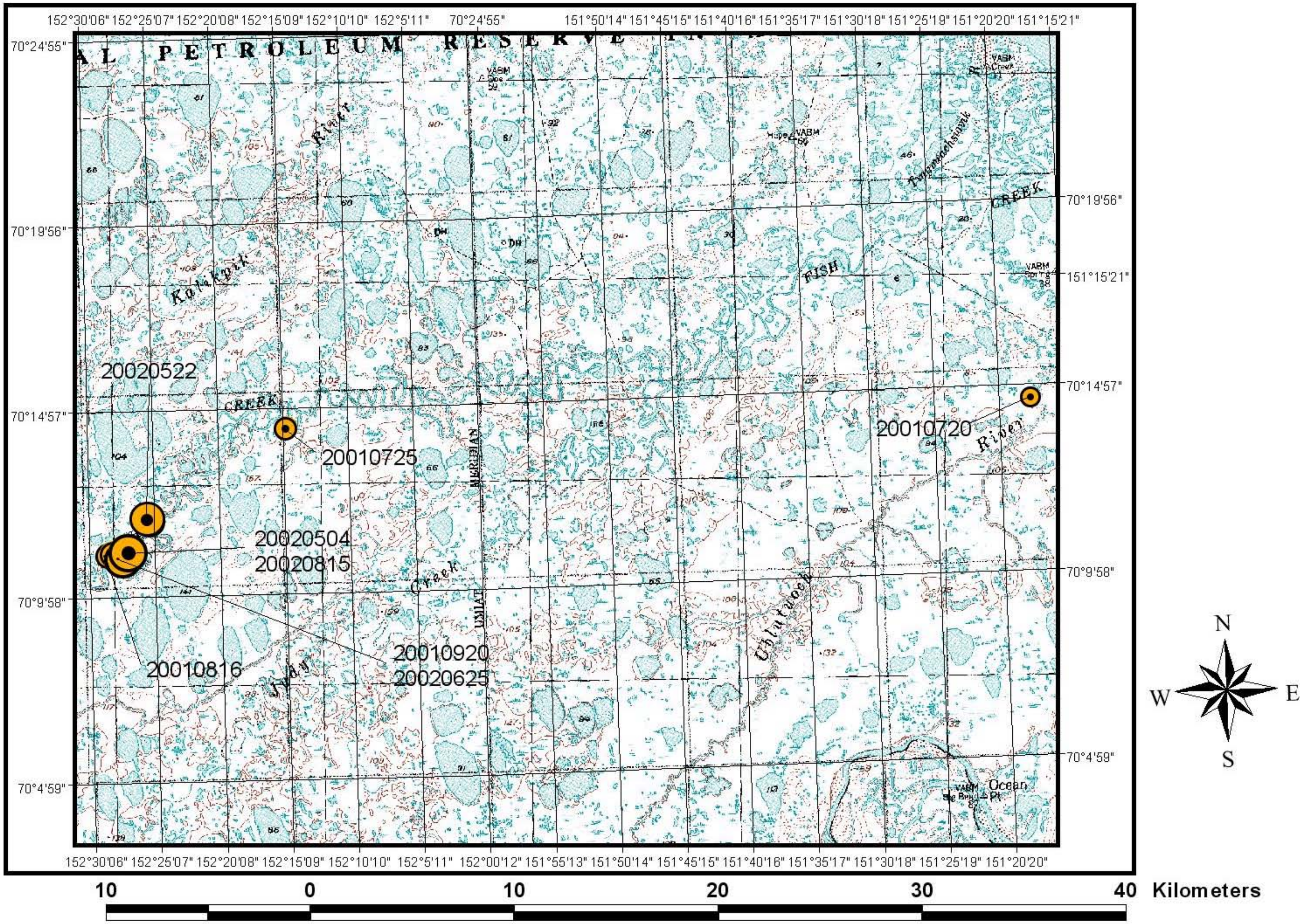
Broad whitefish 0184



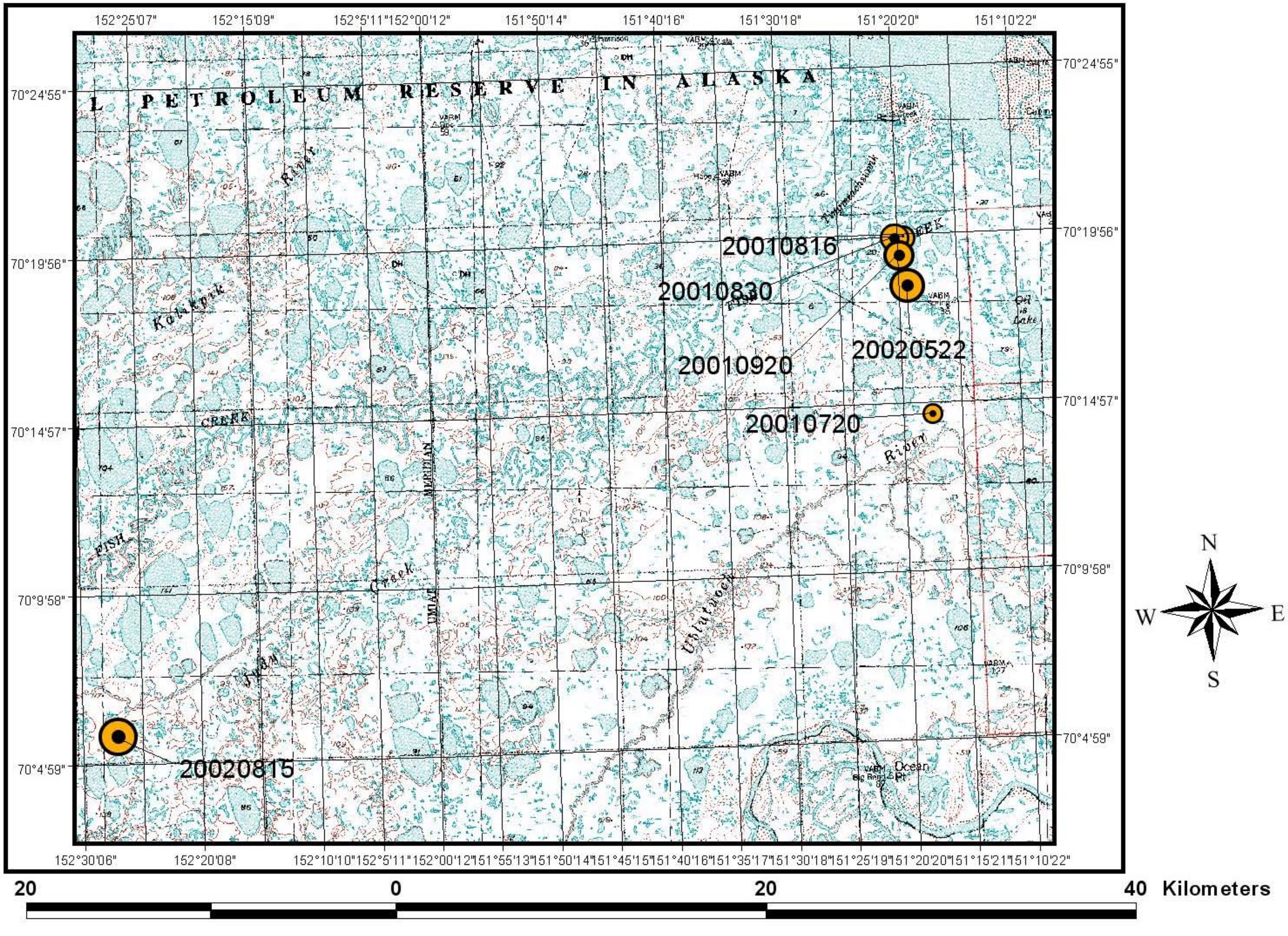
Broad whitefish 0200



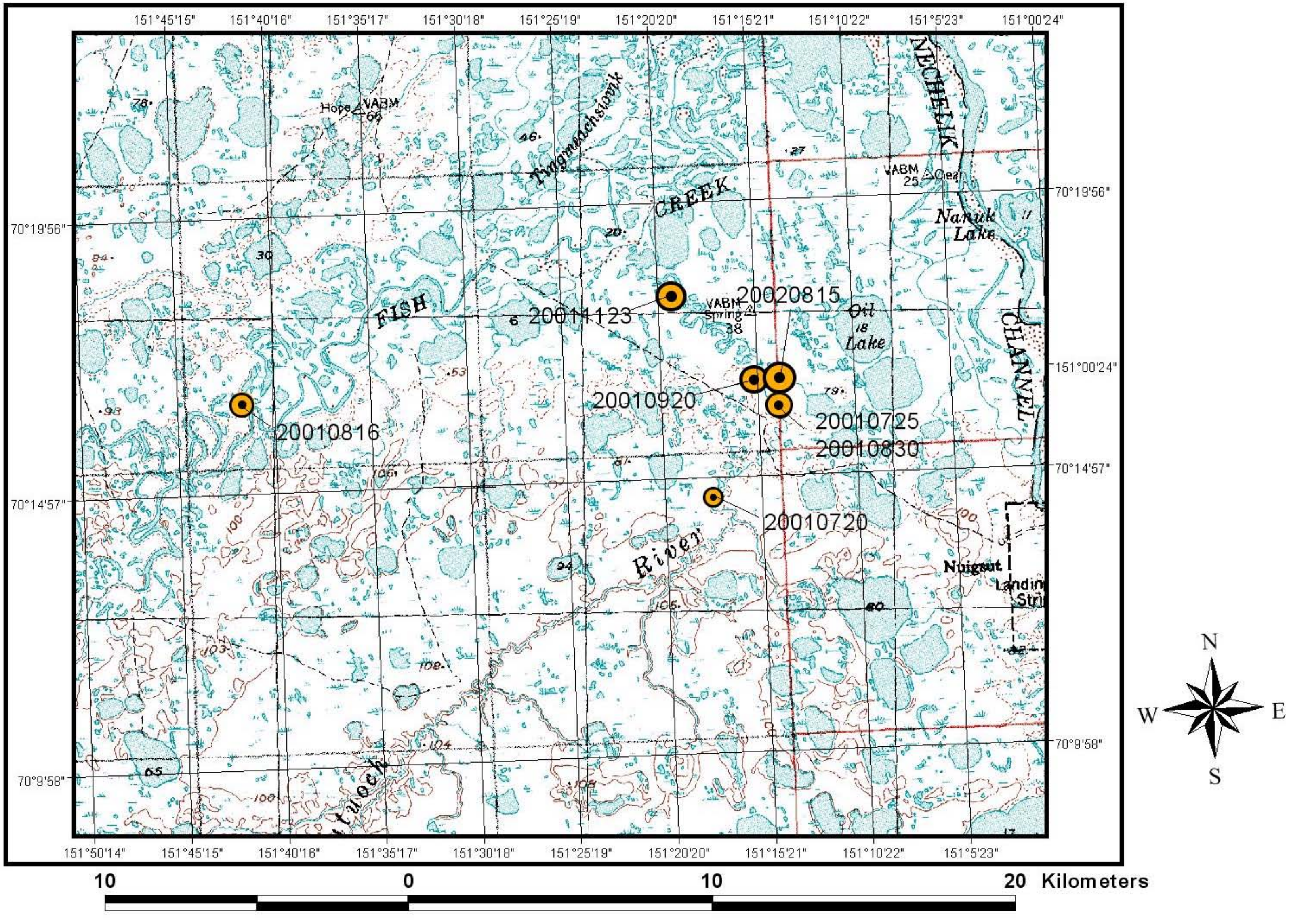
Broad whitefish 0518



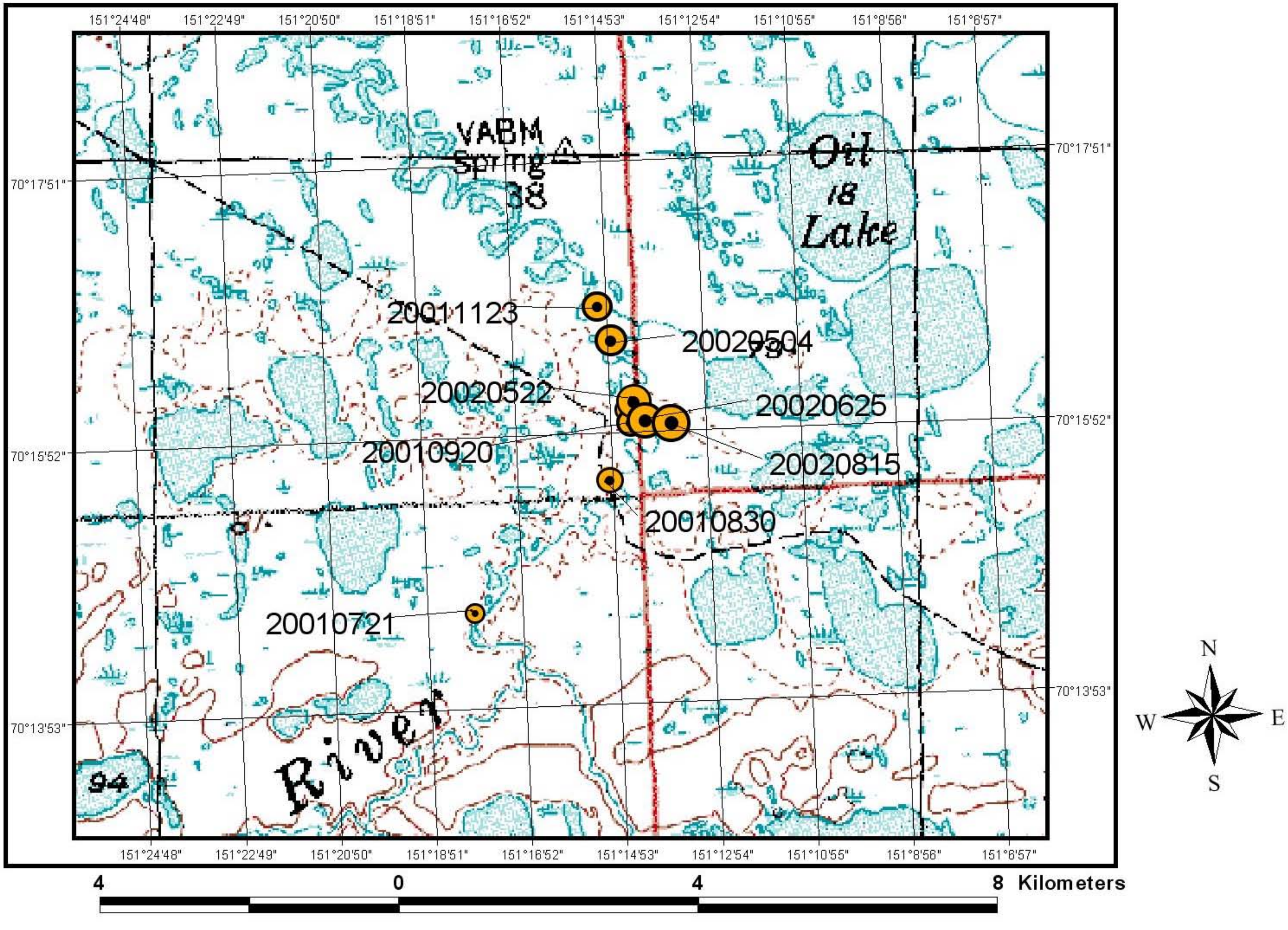
Broad whitefish 0519



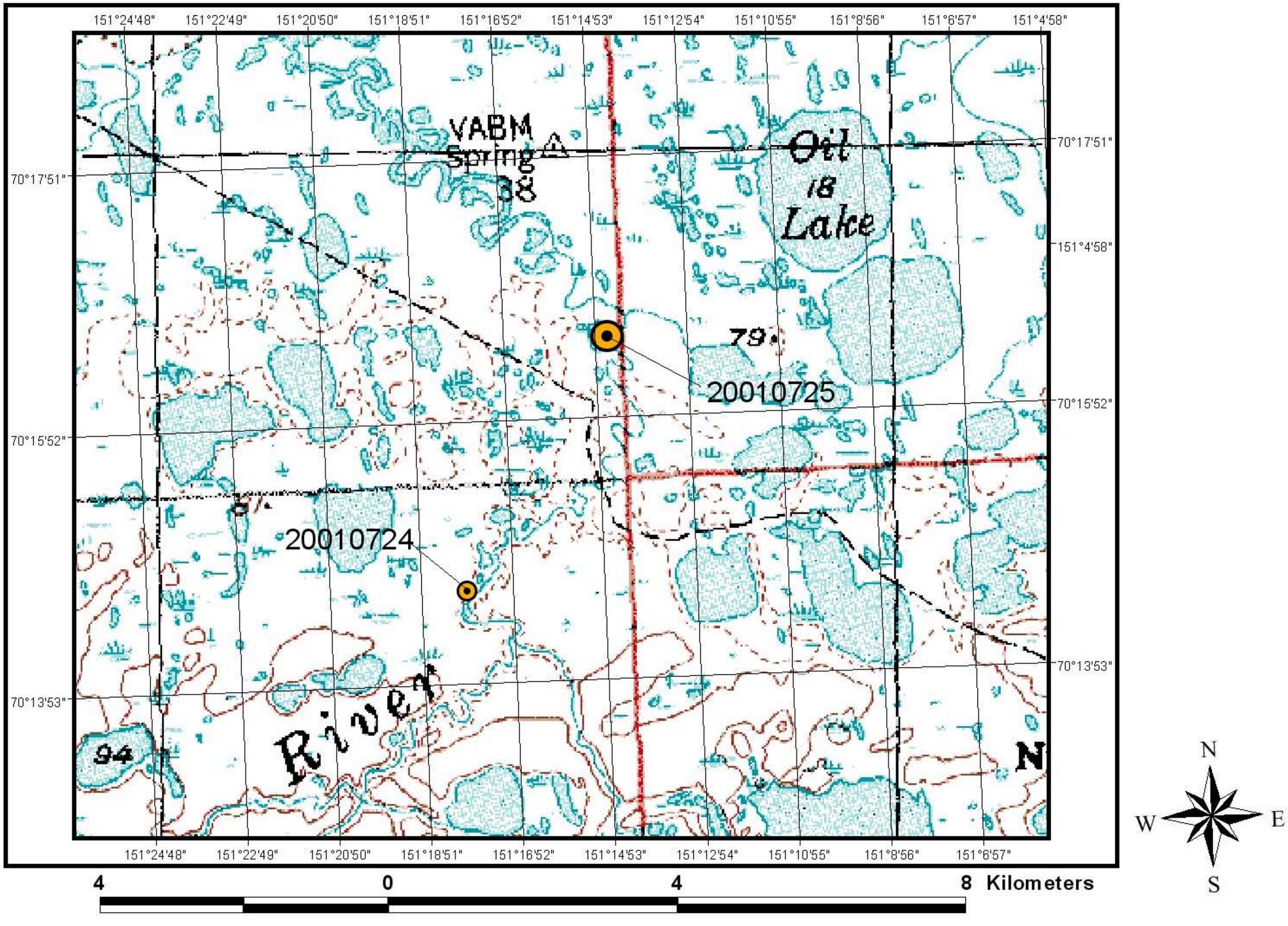
Broad whitefish 0520



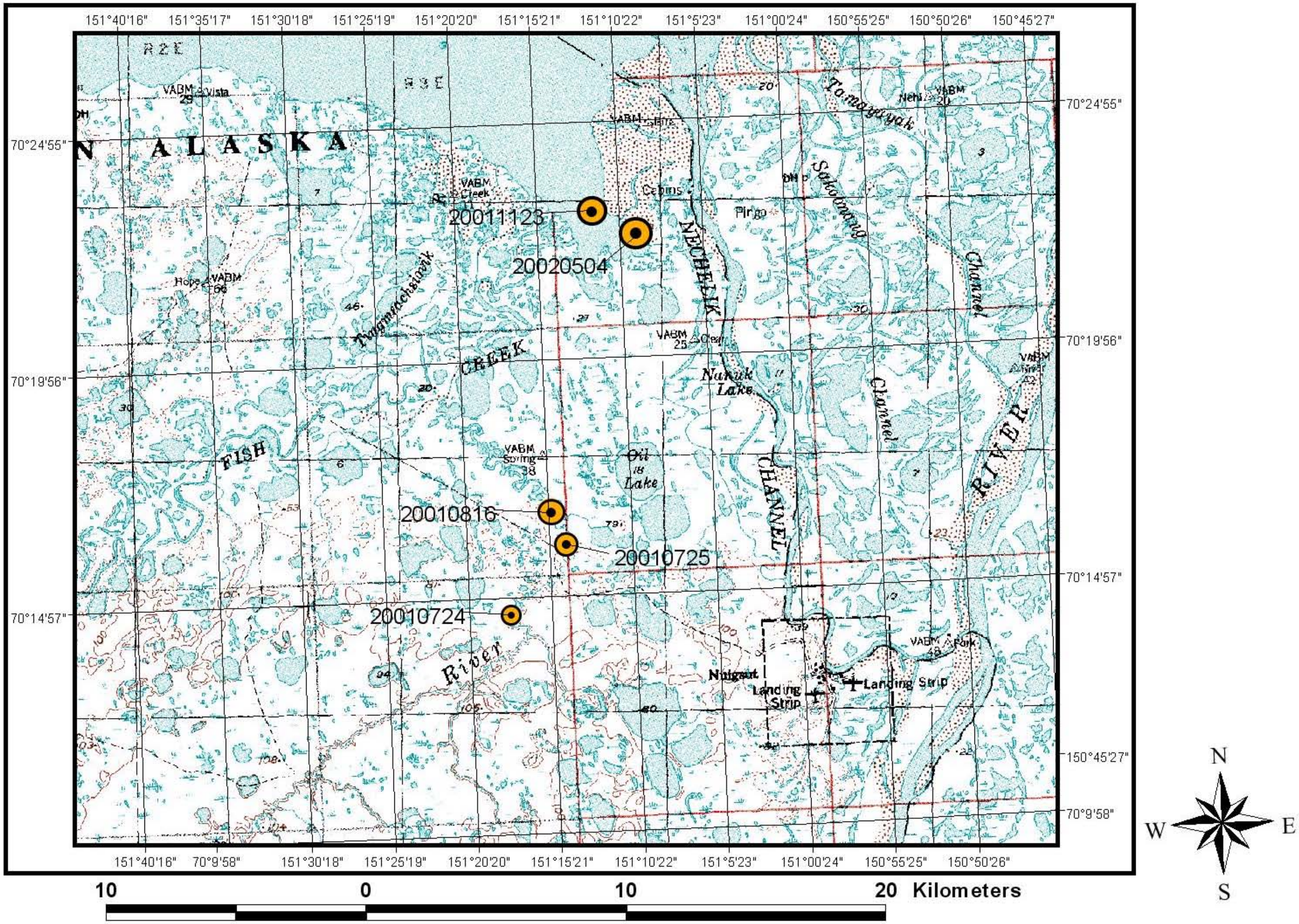
Broad whitefish 0548



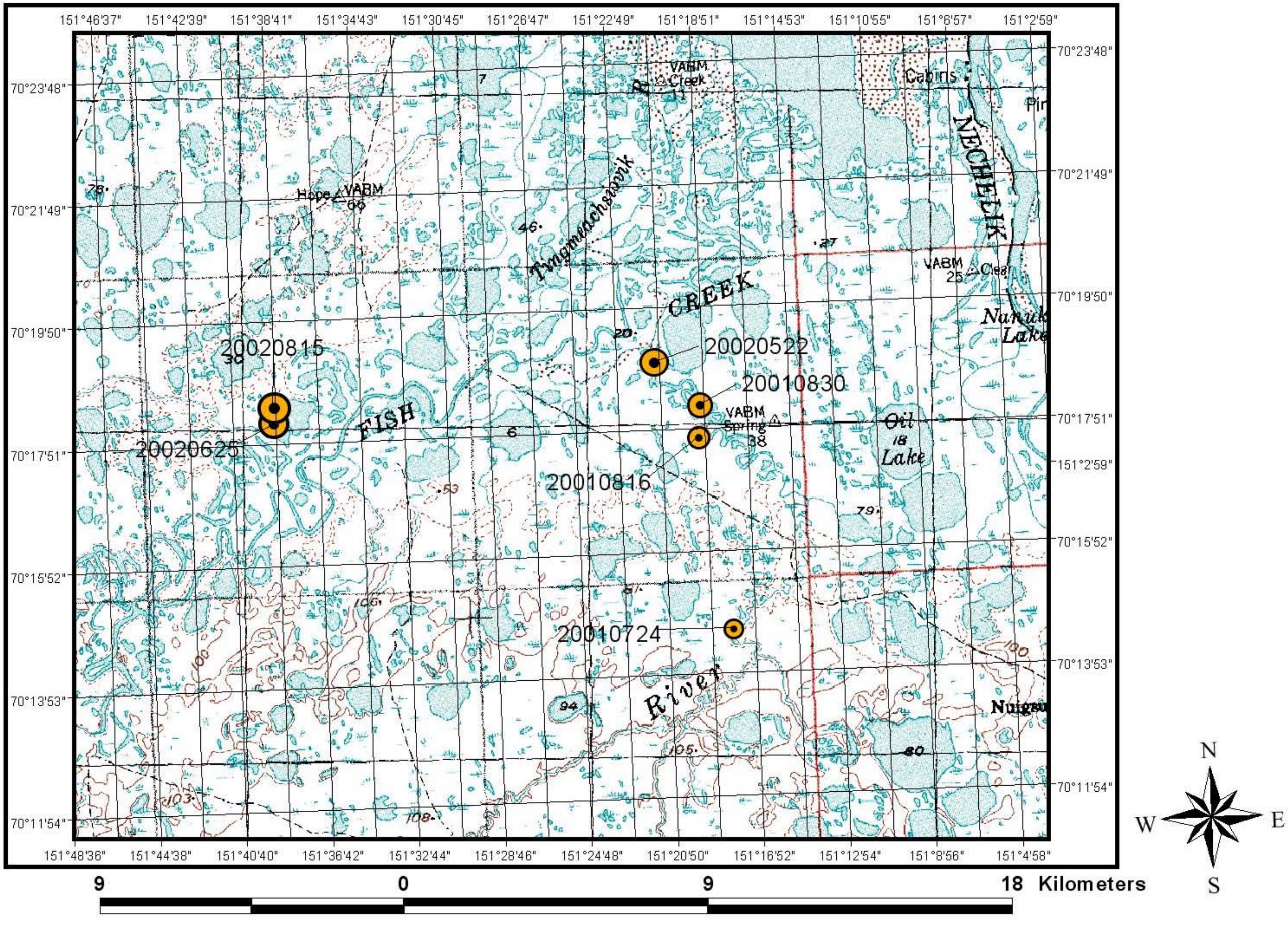
Broad whitefish 0725



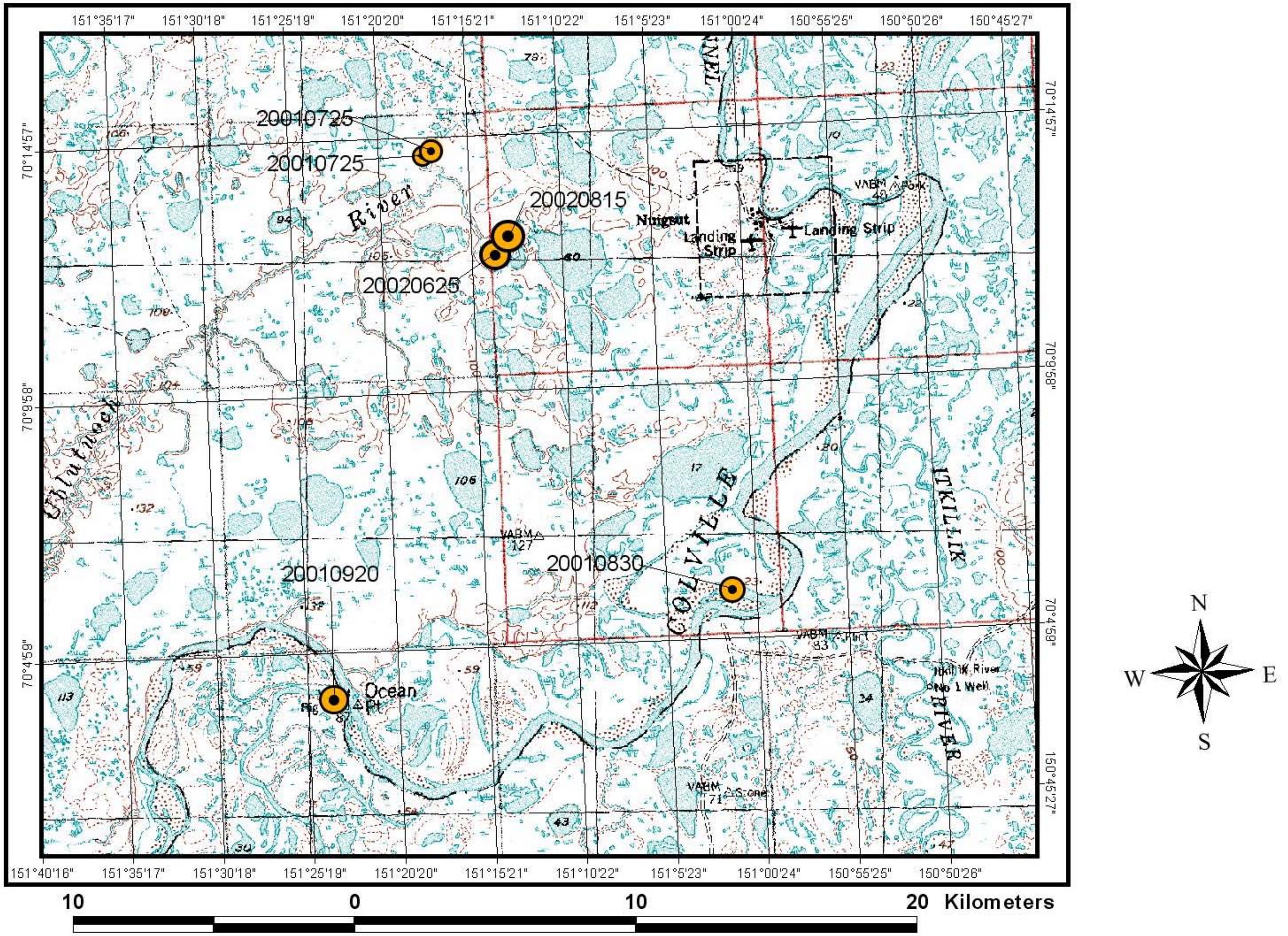
Broad whitefish 0726



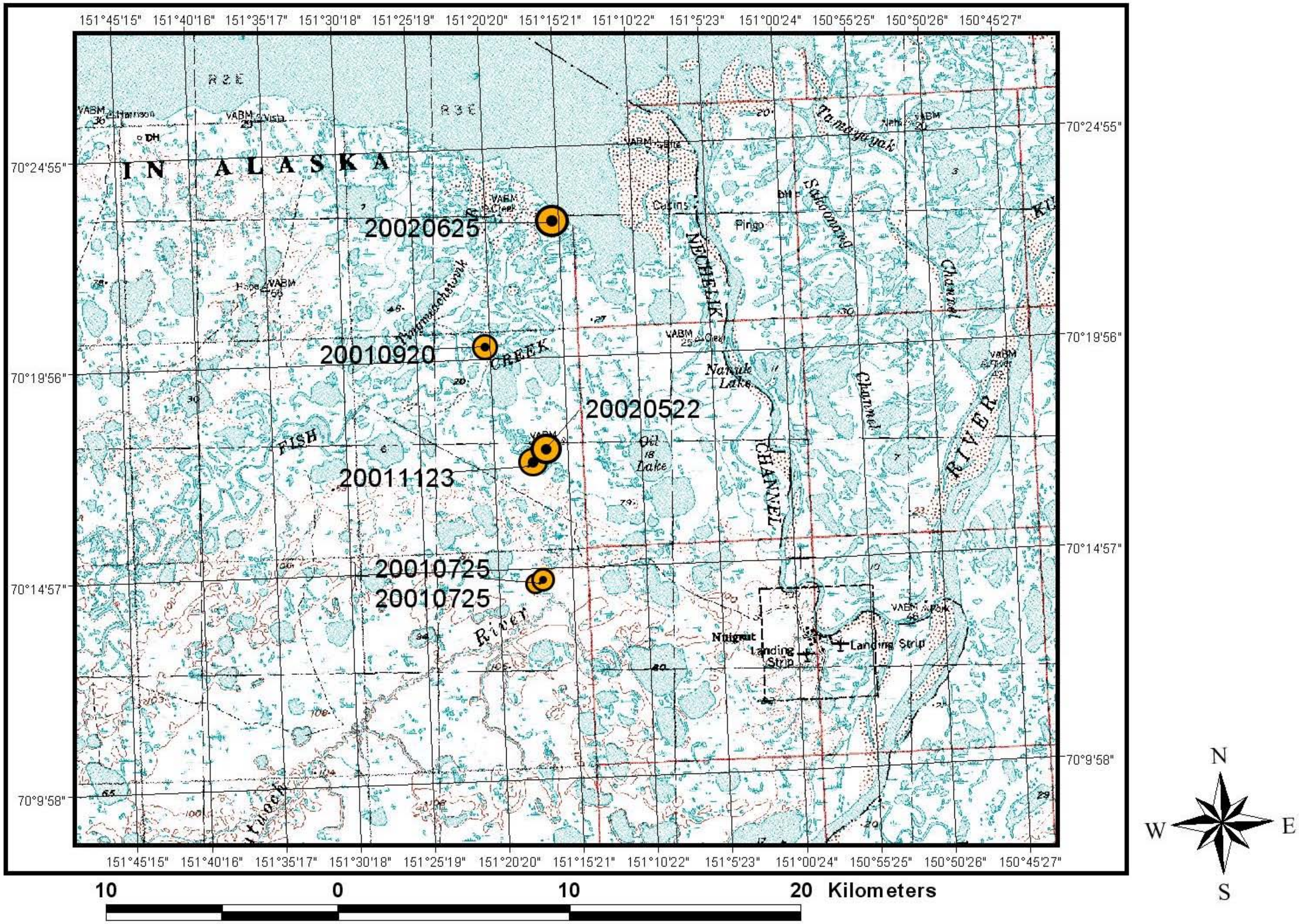
Broad whitefish 0727



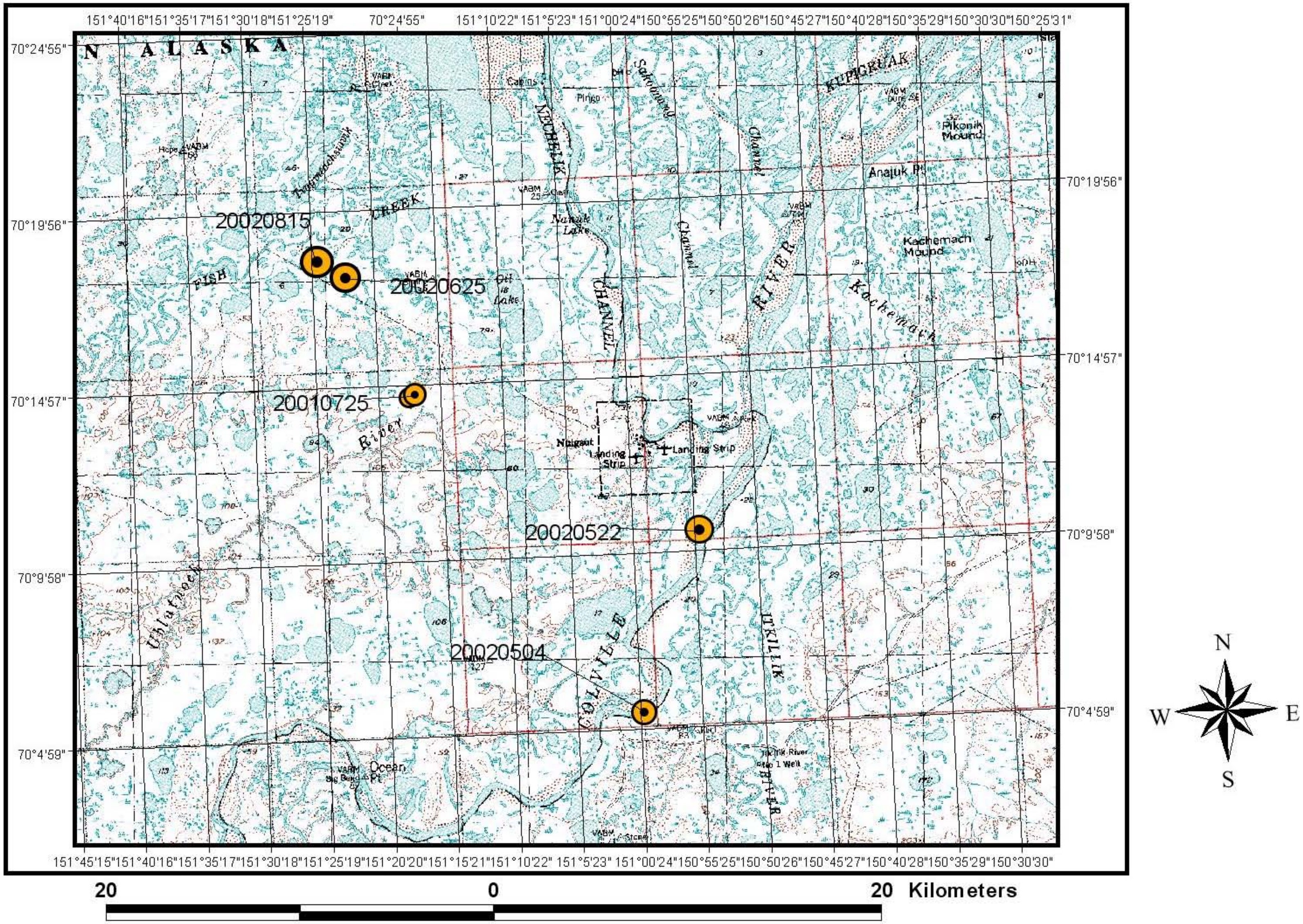
Broad whitefish 0776



Broad whitefish 0777



Broad whitefish 0778



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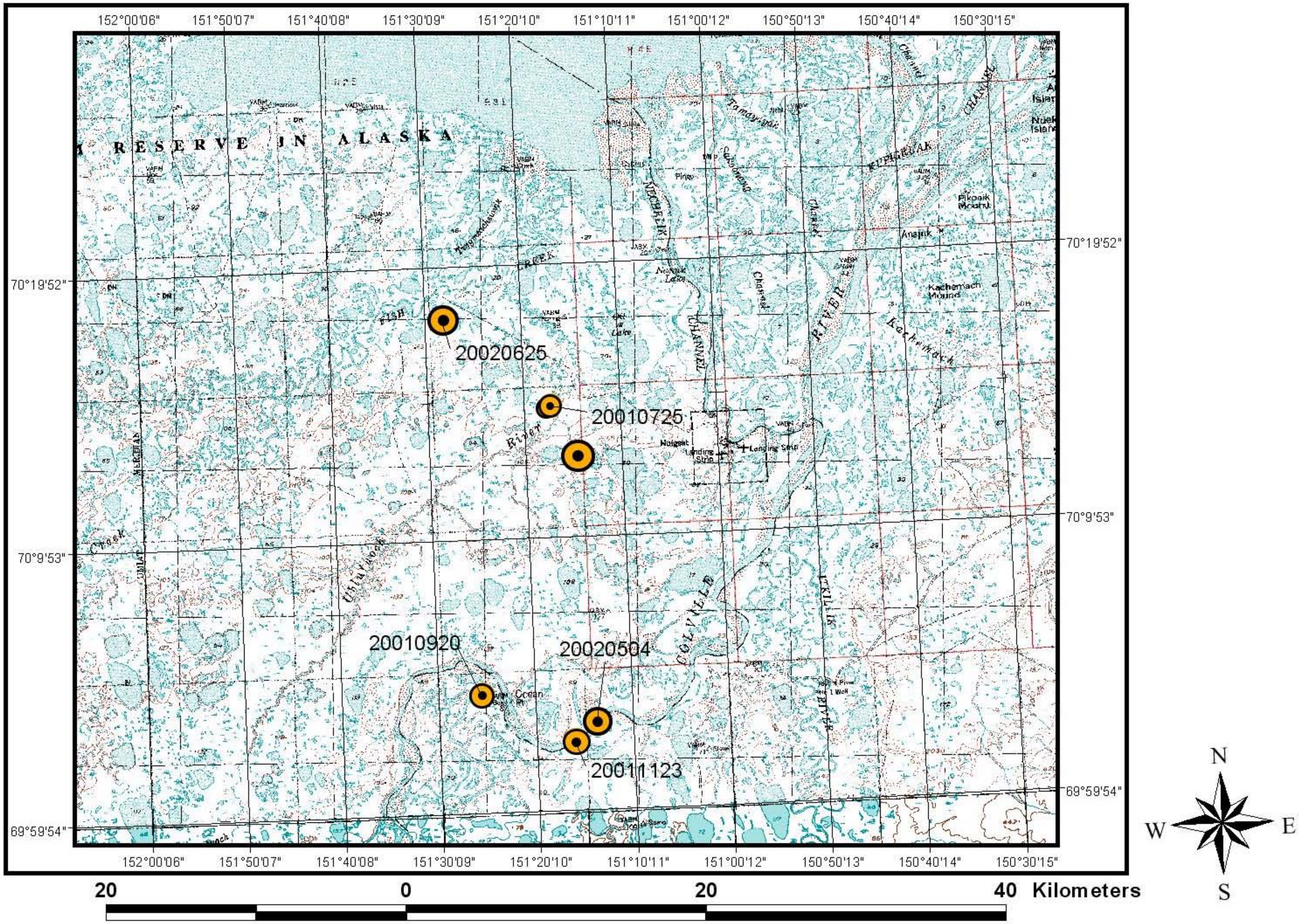
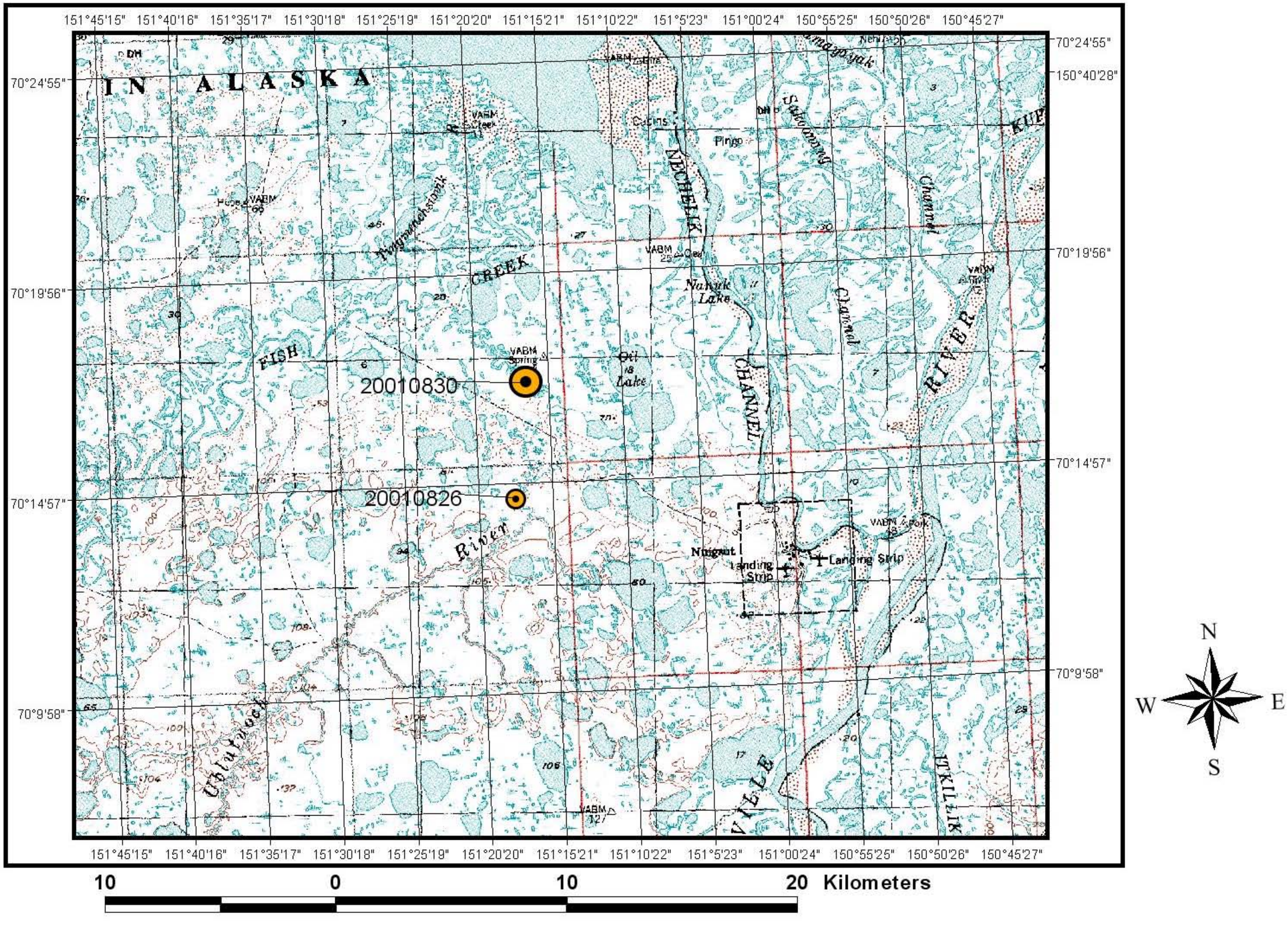


Broad whitefish 1315



Broad whitefish 1506