ANNUAL REPORT

Contract No.: NA 81 RAC 00049
Research Unit No.: 612
Reporting Period: 1 January - 31 December 1982
Number of Pages: 43

Investigations of belukha whales in coastal waters of western and northern Alaska: marking and tracking of whales in Bristol Bay

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31 December 1982

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I. Summary

During 1982 a program was begun to develop techniques for the marking of belukha whales with visual and telemetric tags. Two types of visual-tag applications were developed: implantation of a Floy FH-69 stainless dart in the blubber, and sewing a length of plastic-coated stainless-steel wire through the dorsal ridge. The tags to be attached were brightly colored polyvinyl chloride streamers 3.8 cm wide and 32.0 cm long. Telemetric tags were 40-milliwatt Telonics radios with inconnel wire attachments (barnacle tags) and 250-milliwatt OAR radios mounted on a fiberglass backpack which can be attached by bolting through the dorsal ridge. All radios operated at VHF frequencies (164-165 MHz).

Field work was conducted in Nushagak Bay from 15 June through 11 July 1982, using the NOAA ship SURVEYOR as a principal logistics base, the NOAA Bell 204 helicopter 57RF for aerial support, and field camps on the Igushik, Snake, and Weary rivers. Attempts were made to catch whales in the rivers and on the mud flats near the Snake River mouth. One whale was captured in the latter area on 10 July and marked with two streamer tags attached to the dorsal ridge. Attempts to attach the OAR backpack radios were unsuccessful.

Tests of telemetry systems indicated that the OAR radio consistently provided better signals with both receivers (Telonics TR-2 and OAR ADFS-320). Reception of the Telonics radio was very poor with receivers on shore; however, adequate signals were obtained with the receiver in the helicopter, especially at higher altitudes.

Testing of tag attachments on a belukha carcass indicated that minor modifications are required to the Floy visual-tag attachments and the Telonics barnacle tags.

Sightings of belukha whales occurred mostly in the northern portion of Nushagak Bay near the Wood, Little Muklung, and Nushagak rivers, and off the mouth of the Snake River, with the majority of animals in the latter area. Whales were also seen in the Igushik, Snake, Nushagak, and Little Muklung rivers. The number of whales in Nushagak Bay in mid-July was approximately 400-600. Calves were born off the Snake River mouth beginning shortly after 1 July.

Carcasses of six dead belukha whales were located. Two were neonates, one was probably a yearling, one was an adult male, and two were probably subadults. One died due to entanglement in a net, four showed no apparent cause of death, and one was not examined. The stomach of one whale contained remains of recently ingested red salmon; that of another contained otoliths from smelt, sculpins, and a flatfish.

A variety of problems combined to prevent the capturing and tagging of more whales. Minor modifications to techniques should insure greater success in future field seasons.

II. Introduction

Since 1980 the Alaska Department of Fish and Game, with support from the Outer Continental Shelf Environmental Assessment Program, has been conducting a program of research on belukha whales (Delphinapterus leucas) in coastal waters of western and northern Alaska. Major components of this program have been studies of distribution, reproductive biology, age and growth, food habits, and characteristics of the subsistence harvest. Results of parts of these studies have been published (Seaman and Burns 1981, Seaman et al. 1982), and a comprehensive final report covering all biological studies is in preparation.

In 1982, an additional objective was added to the belukha research program which was to initiate marking efforts using both visual and radio tags in order to determine daily and short-term movements of belukhas. Initiation of such a study was deemed necessary for several reasons. Belukhas are a very important subsistence resource to Alaskan coastal residents. In recent years the total harvest in Alaska has ranged from 138 to 247 animals (Seaman and Burns 1981). During summer months, belukhas are very common in portions of the coastal zone (Frost et al. 1982), and their distribution in those areas appears to be affected to varying degrees by human activities (Burns et al., in prep.). Virtually the entire range of the Bering-Chukchi-Beaufort Sea population of belukha whales may be leased for oil and gas exploration and development, in spite of the fact that the effect of those activities, and others such as commercial fishing and sub-sea mineral extraction, cannot be assessed.

Marking of animals with visual and telemetric tags is essential in order to address many important aspects of belukha biology and ecology. Significant research problems that can only be answered through tagging include:

1) The interrelationships of the groups of belukhas that summer along the Alaskan coast. What degree of intermingling occurs during other times of the year, and what fidelity do individuals have to summering areas?

2) The sorts of small-scale movements that occur in local areas such as Bristol Bay. Are animals that occur in the various river systems discrete groups, or do they intermingle freely? Are local movements related to physical factors or biological circumstances such as food availability?

3) The normal behavior of belukhas in terms of the amount of time spent feeding, resting, socializing, etc. What are normal rates of movement, respiration patterns, surface and dive times, and dive depths?

4) The effects of disturbance on normal behavior patterns, and the nature and magnitude of the response.

Unfortunately, in spite of decades of research and development, standardized "off-the-shelf" techniques for marking of cetaceans are not available (Leatherwood and Evans 1979, White et al. 1981). Therefore, the principal objective during the first year of this research project has been the development of methods for live capture of belukhas in Alaskan waters and for the attachment of visual and radio tags. Field trials of methods and equipment were done in Nushagak Bay during June and July 1982.

III. Current State of Knowledge

The distribution of belukha whales is generally circumpolar in arctic and subarctic waters. In Alaska they occur in two discrete groups. A small group numbering 300-500 ranges principally in Cook Inlet, although they are occasionally seen elsewhere in the Gulf of Alaska (Klinkhart 1966, Harrison and Hall 1978, U.S. Department Commerce 1979). The majority of belukhas occurs in the Bering and Chukchi seas and ranges seasonally into the Beaufort and East Siberian seas (Seaman and Burns 1981).

Belukha whales in western Alaska are often associated with sea ice, and their movements are affected by the seasonal cycle of ice distribution. During winter they are excluded from most of the coastal zone by the formation of shorefast ice. Most sightings of whales during this season have been in the moving ice of the Bering and southern Chukchi seas, and it is presumed that the majority of the population winters in those areas (Seaman and Burns 1981). Some animals migrate northward in spring through

leads in the pack ice, passing Point Barrow in April and May, then moving eastward to the Mackenzie River delta and Amundsen Gulf (Seaman and Burns 1981, Braham et al. 1982). Other whales move into nearshore waters of the Bering and Chukchi seas shortly after ice breakup and concentrate in locations such as Bristol Bay, Norton Sound, Kotzebue Sound, and Kasegaluk Lagoon (Lensink 1961, Seaman and Burns 1981). Similarly, they move along the Siberian coast, although little data about these whales in western Bering and Chukchi seas are available. Although the relationships among groups summering in various locations are poorly known, the Bering-Chukchi population of belukhas is presently considered a single stock since the animals are thought to mingle during the breeding season in February-April (Burns et al., in prep.).

Due to their possible interactions with the commercial fishery for red salmon (Oncorhynchus nerka), belukhas summering in Bristol Bay have been comparatively well studied with respect to their use of river systems and predation on salmon (summarized by Lensink 1961). Investigations of the abundance of whales and their foods indicated that belukha predation could significantly impact red salmon stocks, primarily through consumption of smolt during their seaward migration in late May and early June. To reduce predation on smolts, attempts were made to displace belukhas from the Kvichak River, initially by harassing them using boats and small explosive charges (Lensink 1961). This method was later replaced by acoustic harassment devices which transmitted vocalizations of killer whales (Orcinus orca) (Fish and Vania 1971). Use of the acoustic system was discontinued after 1978, and organized attempts to displace the whales no longer occur. However, some consideration has recently been given to the possible effects of belukha predation on red salmon stock enhancement efforts in the Snake River (Fried et al. 1979).

During summer months it has been estimated that 1,000-1,500 belukhas are present in Bristol Bay (Lensink 1961). They are seldom seen anywhere except in Kvichak Bay and Nushagak Bay, and their associated river systems (Frost et al. 1982). Belukhas occur in the Kvichak River and Kvichak Bay from at least April to September (Frost et al. 1982), where they ascend 26-55 km up the river on flood tides and return to the bay on the ebbing tide (Lensink 1961). They are seen off the mouth of the Naknek River in April and May and sometimes move as much as 27 km upstream, past the town of King Salmon (Frost et al. 1982). They stop entering the Naknek in late May when boat traffic on the river becomes extensive (Lensink 1961). The distribution and movements of whales in Nushagak Bay appear more complex and are less well studied. They occur in the Bay and its estuaries from at least April to early October, with numerous sightings occurring near the mouths of the Snake River and Wood River (Frost et al. 1982). Fried et al. (1979) conducted a series of 11 surveys of the region from 28 May to 28 June 1979. In total, they sighted 280 whales; most of those were seen near the Snake River, and in northern Nushagak Bay near the junction of the Wood, Little Muklung, and Nushagak rivers. Some animals were also seen in the Igushik River and along the shores of Grassy Island. Fried et al. observed no significant relationship between

whale movements and tides or between whale abundance and numbers of outmigrating red salmon smolt.

The only censuses of whales in the Kvichak-Nushagak area were conducted in 1954 and 1955 (Brooks 1955). Results (Table 1) indicated an increase in abundance from May to August and considerably more whales in the area in 1954 than in 1955. The relationship among groups of belukhas in the Kvichak and Nushagak systems is unclear, although Brooks (1955) postulated a seasonal movement from the Kvichak to the Nushagak caused by changing abundances of prey (salmon). Lensink (1961) in 1959-1960 applied visual tags to 46 belukhas in the Kvichak Bay in an attempt to address this question. One tagged animal was recovered 1 month later from a gillnet near the mouth of the Naknek River, not far from where it was tagged.

In order to visually identify individual cetaceans, it is generally necessary to mark the animal with some sort of brand, tattoo, or tag. Marking and tagging of cetaceans have met with very variable success (White et al. 1981). Many of the tags that have been tried are designed for attachment through the dorsal fin and are therefore not applicable to belukhas. Lensink (1961) applied dart tags with heads similar to those made by Floy Tag and Manufacturing, Inc. to 46 belukhas in Kvichak Bay. Two resightings were made: one on the animal noted above and a second which was seen on a live animal at least 3 months after tagging. Sergeant and Brodie (1969) attached over 800 tags to belukhas in Hudson Bay. They attached 700 harpoon tags (Floy type FH-67) to the dorsal part of the body and 188 Petersen disc tags through the dorsal ridge. The only resightings were of animals tagged with harpoon tags. Two were caught 5-7 weeks after tagging, 300-800 km from the point of tagging. A third was seen on a live stranded whale 1 year later near the location of where it was tagged. The skin around the tag had completely healed, and the tag was in "excellent structural condition." Tests on captive animals confirmed the durability and safety of spaghetti-type tags attached with stainless-steel darts which toggle in the blubber or fascia (White et al. 1981).

The use of radio tags is considerably more complicated than visual tags. Successful radio tagging and tracking of cetaceans involves two relatively discrete components. First is the selection or development of appropriate electronic systems (telemetry) for transmitting and receiving signals. Second is the design of appropriate packaging for transmitters and mechanisms with which to attach them to and have them retained on the animal being tagged.

There are presently three general classes of telemetry equipment that are potentially suitable for tagging and tracking of cetaceans: HF (high frequency), VHF (very high frequency), and satellite-linked. Each system has its advantages and drawbacks (Hobbs and Goebel 1982). HF transmitters have long theoretical tracking distances but are comparatively large (due to battery requirements), have problems with antenna configuration, and are expensive. VHF transmitters are compact and

Table 1. Estimated numbers of belukha whales in inner Bristol Bay in 1954 and 1955 (Brooks 1955). Estimates were based on surface and aerial observations, and interviews with fishermen and local residents.

	May	Jun	Jul	Aug
1954				
Kvichak Bay	250	250-400	?	600
Nushagak Bay	?	250-400	400	400
Total, both bays, about 1,000				
1955				
Kvichak Bay	100	150-250	?	50-100
Nushagak Bay	?	250	250-500	450
Total, both bays, about 525				

inexpensive but provide poor surface reception due to line-of-sight transmission characteristics. Satellite-linked systems offer great potential for tracking but to date have had limited application for cetaceans due to size and configuration of transmitters and signal requirements of satellite receivers. In addition to appropriate antennas and logistics platforms, efficient tracking of cetaceans requires automatic direction finding (ADF) equipment to rapidly localize brief, infrequent signals, and scanners to monitor multiple frequencies if more than one animal is tagged in a particular area. At present, most development and testing of ADF systems has been done with HF transmitters, while VHF transmitters have well-developed scanning and data-processing systems available (Hobbs and Goebel 1982). Butler and Jennings (1980) did comparative tests of VHF and HF systems on free-ranging dolphins and concluded that the VHF system was the more reliable.

A number of techniques have been tried for attachment of telemetry packages to cetaceans. With the exception of the implanted Woods Hole Oceanographic Institute/Ocean Applied Research (WHOI/OAR) tag developed by Watkins (Watkins 1981, Watkins et al. 1981), all packages have been attached to the surface of the animal. Attachments have been made using belly bands, bolts which usually pass through the dorsal fin, sutures, or curved metal tines (umbrella stakes) (Leatherwood and Evans 1979, Mate and Harvey 1981, Hobbs and Goebel 1982). Important considerations in design and selection of attachments are whether the attachment will be "permanent" or incorporate a timed release, and whether it will be applied to animals that are in-hand and restrained, or remotely to free-swimming individuals.

Radio packages have been attached to a number of species of porpoises and whales in the wild. Bolted-on backpack-type transmitters have generally remained attached for 1 to 30 days and have proven useful for short-term observations of movements and behavior (Irvine et al. 1979, Leatherwood and Evans 1979). A common problem has been movement of the bolt(s) through the tissue at the point of attachment. Watkins et al. (1981) have tracked finback (Balaenoptera physalus) and humpback (Megaptera novaeangliae) whales tagged with the implanted WHOI/OAR tag in Prince William Sound, Alaska. They demonstrated minimum retention times of 16-17 days. Mate and Harvey (1981), using umbrella-stake attachments, applied tags to 19 gray whales (Eschrichtius robustus) in San Ignacio Lagoon, Baja California. Maximum documented retention time was 50 days. None of the gray whales showed any noticeable response to the tag attachment procedure. Similarly, Watkins (1981) observed little visible response to implantation of the WHOI/OAR tag in three species of large whales.

IV. Study Area

Field work during 1982 was conducted in Nushagak Bay, Alaska. Nushagak Bay is a large embayment in northcentral Bristol Bay (Fig. 1). The embayment is approximately 65 km deep and tapers from approximately

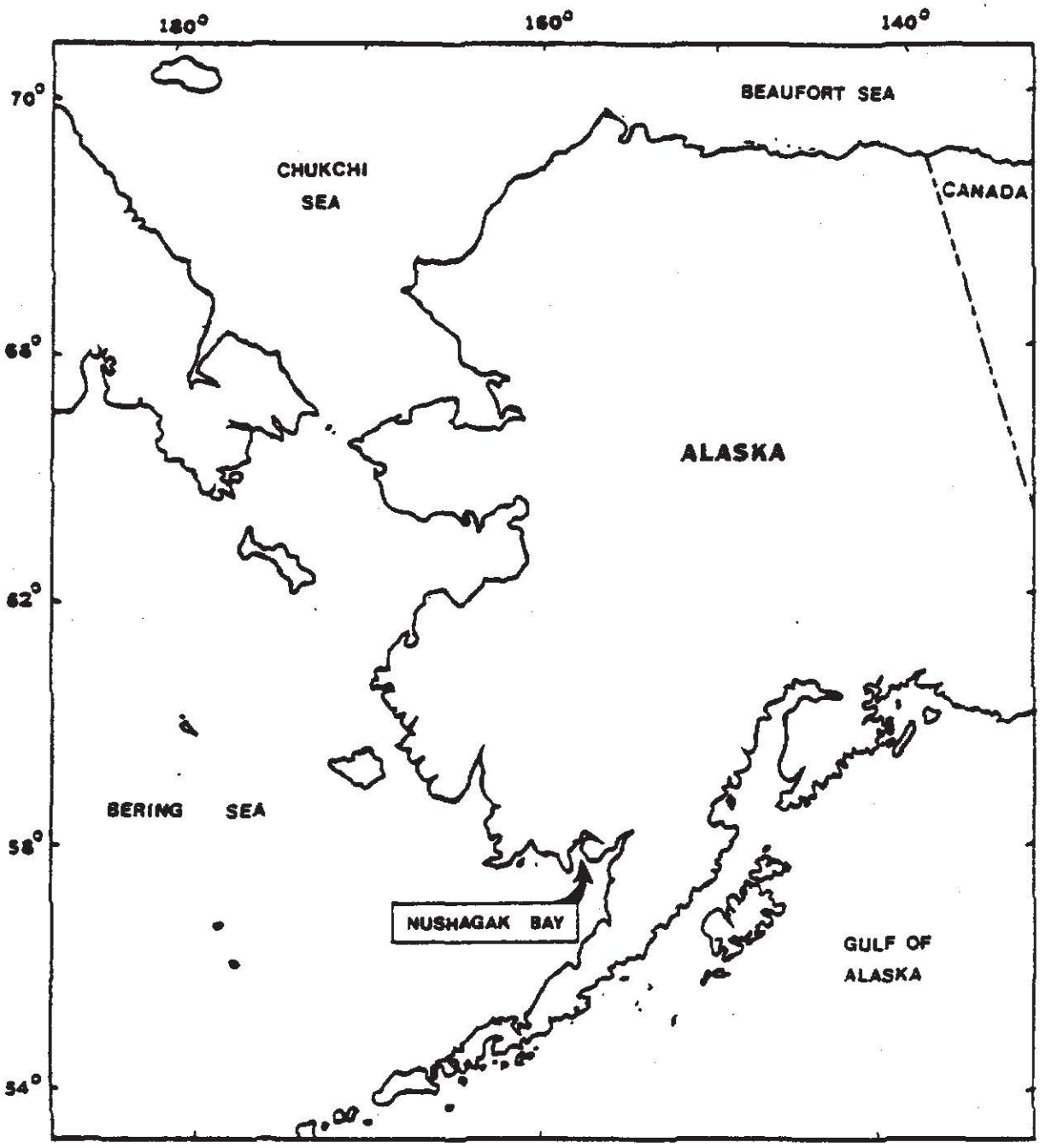

Figure 1. Map of the Bering Sea showing Nushagak Bay.

30 km across in the outer portion to 3-6 km across at its upper end. Four major rivers flow into Nushagak Bay: the Igushik and Snake rivers on the west side and the Wood and Nushagak rivers in the north (Fig. 2). The major human habitations in the area are the city of Dillingham (1980 population 1,563) at the north end of Nushagak Bay and a small village at Etolin Point near the southeast portion of the entrance to the Bay. Several canneries are located on the east side of the Bay, particularly near Clarks Point.

Nushagak Bay is generally shallow, with water depths (at low tide) seldom exceeding 15 m. The area is characterized by numerous sand and mud flats which are exposed during low tides. During June and July, daily tidal ranges vary from 4.8 to 8.6 m. River outflow and tides combine to produce strong current throughout the Bay. Water in the Bay itself is very muddy, with visibility in the water effectively zero in and near major rivers.

During June and July, one of the world's largest salmon fisheries occurs in Bristol Bay. Fishing is done with gillnets, both from shore (set net) and boats (drift gillnet). In 1981 there were approximately 595 permit holders registered in the drift gillnet fishery and 279 set net permits in Nushagak Bay. The fishermen are supported by a fleet of tenders, processors, and air transports. The principal species harvested is the red salmon, although chum salmon (Oncorhynchus keta), pink salmon (O. gorbuscha), king salmon (O. tshawytscha), and silver salmon (O. kisutch) are also taken. Red salmon runs in Bristol Bay have fluctuated greatly in strength during past years. The catch in Nushagak Bay in 1981 was 7.7 million fish, which is approximately 5.2 million above the average for the previous 5 years.

V. Methods

Prior to field work in Bristol Bay, several months were devoted to design and fabrication of visual and radio tags. Two experts were subcontracted to assist in development of tags: Dr. Bruce Mate, Oregon State University, Corvallis, Oregon and Dr. John Hall, Solace Enterprises, Anchorage, Alaska.

Visual tags were designed to be brightly colored and recognizable at a distance. The material chosen was 10-mil thickness polyvinyl chloride (PVC) safety-flag fabric (provided by Floy Tag and Manufacturing, Inc.), colored red, yellow, and blue. Finished tags measured 3.8 cm wide and 32.0 cm long. Tags were indelibly pre-printed with the words "RTN TO ADFG FAIRBANKS" and sequentially numbered with permanent marking pens. Tags were also numbered by means of holes punched through the tags with a hot needle. One end of each tag was attached to a piece of 1.5-mm-diameter (60 kg test) plastic-coated stainless-steel wire (7-Strand), by means of a 6.8-mm-diameter, 19.0-mm-long PVC rod through which the wire was passed and a steel crimp attached. The wire was then passed through a hole approximately 2.0 cm from the end of the tag, and the tag material was

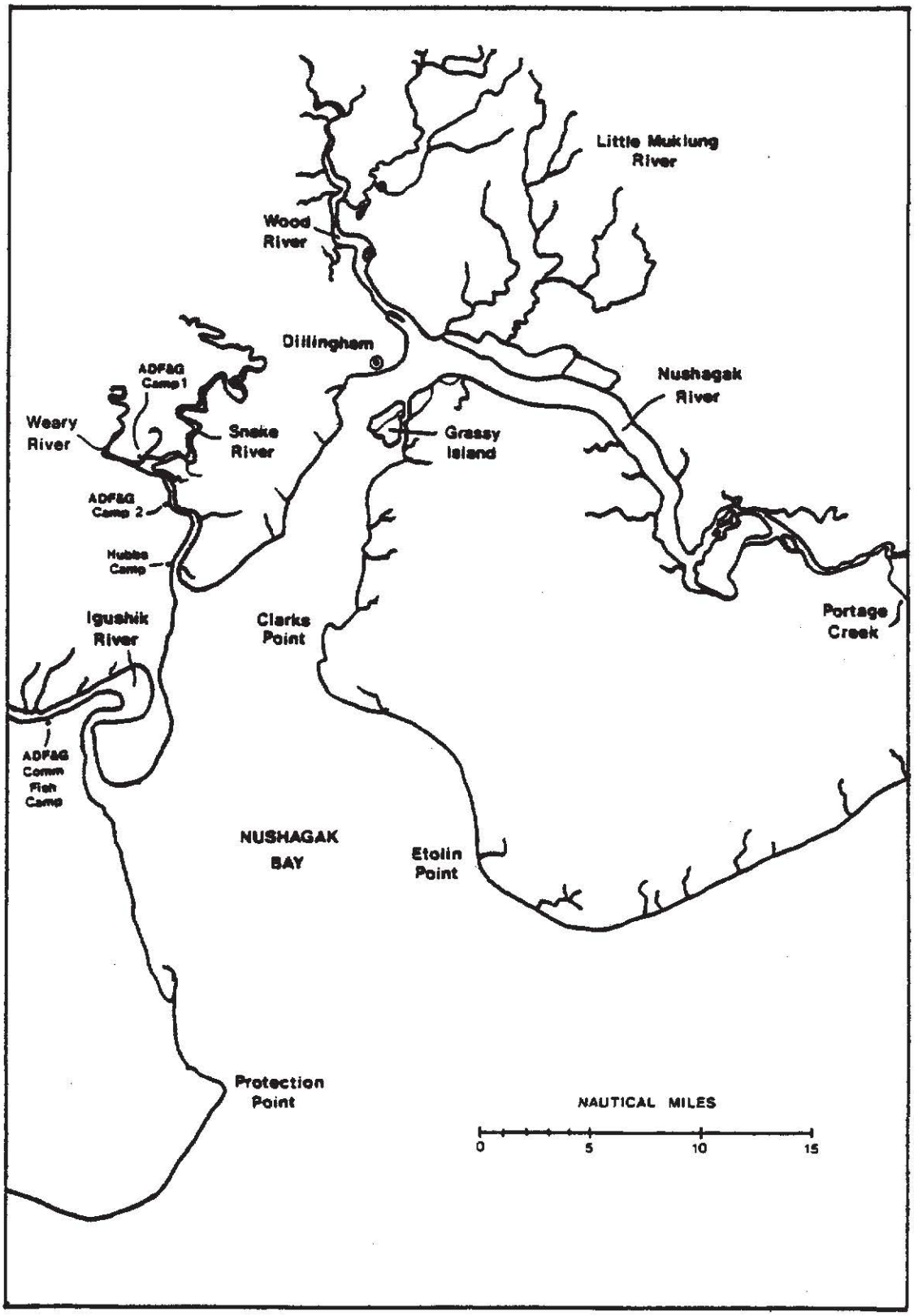

Figure 2. Map of Nushagak Bay showing major locations referred to in this report.

folded around the PVC rod and glued to itself with vinyl cement. Two hundred and fifty streamer tags were constructed.

We designed two methods to use for attaching visual tags to belukhas. One method attaches two tags to a piece of plastic-coated stainless-steel wire sewn through the dorsal ridge by using a curved steel needle 3.2 mm in diameter and 23.0 cm long (Fig. 3a). For application, one tag is attached to the wire which is passed through the dorsal ridge, at which point a second tag is attached on the other side. A PVC washer 1.3 cm in diameter is to be threaded on the wire on each side of the dorsal ridge to prevent the crimps from abrading the skin. The second type of tag application uses a Floy FH-69 stainless-steel dart (2.7 cm long by 0.8 cm wide), which is attached to a length of coated stainless-steel wire by means of a crimped stainless-steel nut (Fig. 3b). The streamer tag is then attached to the wire connected to the dart head. The tag is designed to be applied by means of a jab stick which will insert the dart head to a depth limited by a stop on the applicator.

We also prepared two types of radio packages for attachment to belukhas, Telonics "barnacle" tags and OAR "backpacks."

The Telonics barnacle tags (Fig. 4) were described in detail by Mate and Harvey (1981). We selected transmitters with 40-milliwatt power output, 35-millisecond pulse width, and a pulse rate of 120 per minute. They are equipped with high-shock crystals. The electronics are encased in a polyurethane hemisphere 6.8 cm in diameter and 5.4 cm high. The antenna protrudes approximately 22 cm from the top of the package and is constructed of coiled stainless steel encased in polyurethane. To the bottom of the transmitter is attached a stainless-steel baseplate (6.4 cm diameter) onto which are welded eight inconnel wire legs (tines). The wire legs are 3.4 mm in diameter and 8.0 cm long and are somewhat curved. Spring tension causes the legs to be about 8.0 cm apart at the tips prior to application. A teflon retaining-collar serves to line up the bases and tips of the legs prior to application. For application, the antenna of the tag slides inside a handle which rests firmly against the top of the polyurethane hemisphere. When deployed, the teflon ring slides upward, releasing the tips of the legs which splay outward. Total package weight is approximately 312 g. Transmitter crystals are in the 165 MHz range.

The backpack radio package consists of an OAR-type AB340 transmitter with 250-milliwatt power output, 100-millisecond pulse width, and a pulse rate of 120 per minute. The transmitter is constructed as a pair of tubes, each 1.9 by 14.7 cm, with electronic components in one side and batteries in the other (Fig. 5). A semi-rigid whip antenna 47.5 cm long is attached to the tubing which connects the battery tube to the electronics. The transmitter is attached to a fiberglass saddle, approximately 21 cm long, 12.5 cm wide, and 5.2 cm high. The saddle was constructed from a cast of a belukha dorsal ridge provided to us by Dr. Lanny Cornell, Sea World, Inc. The inner surface of the saddle is lined with 4-mm open-cell foam. Closed-cell foam was added to the top of the

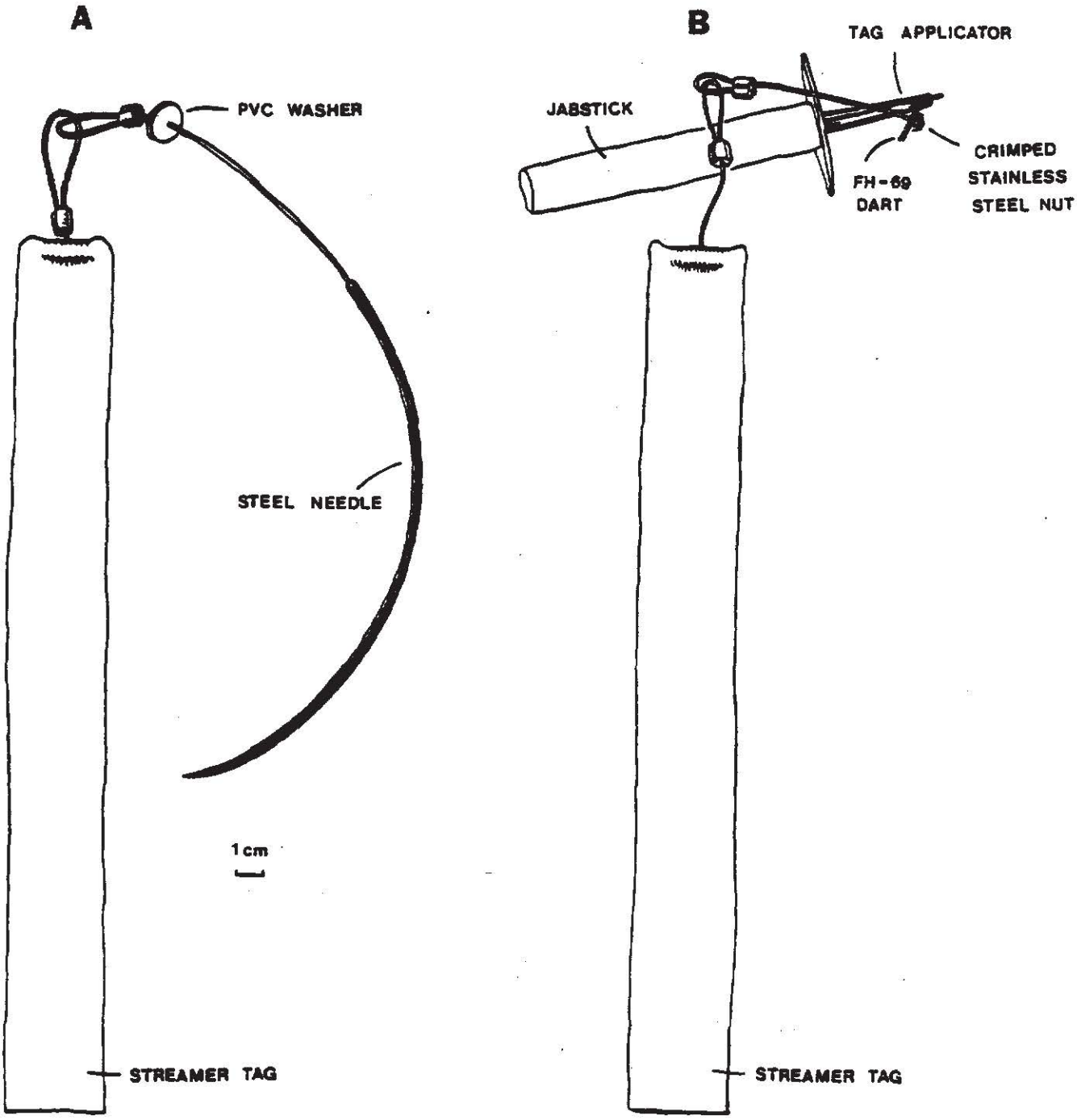

Figure 3. Visual streamer tags and attachments. A-dorsal ridge attachment B-Floy dart attachment

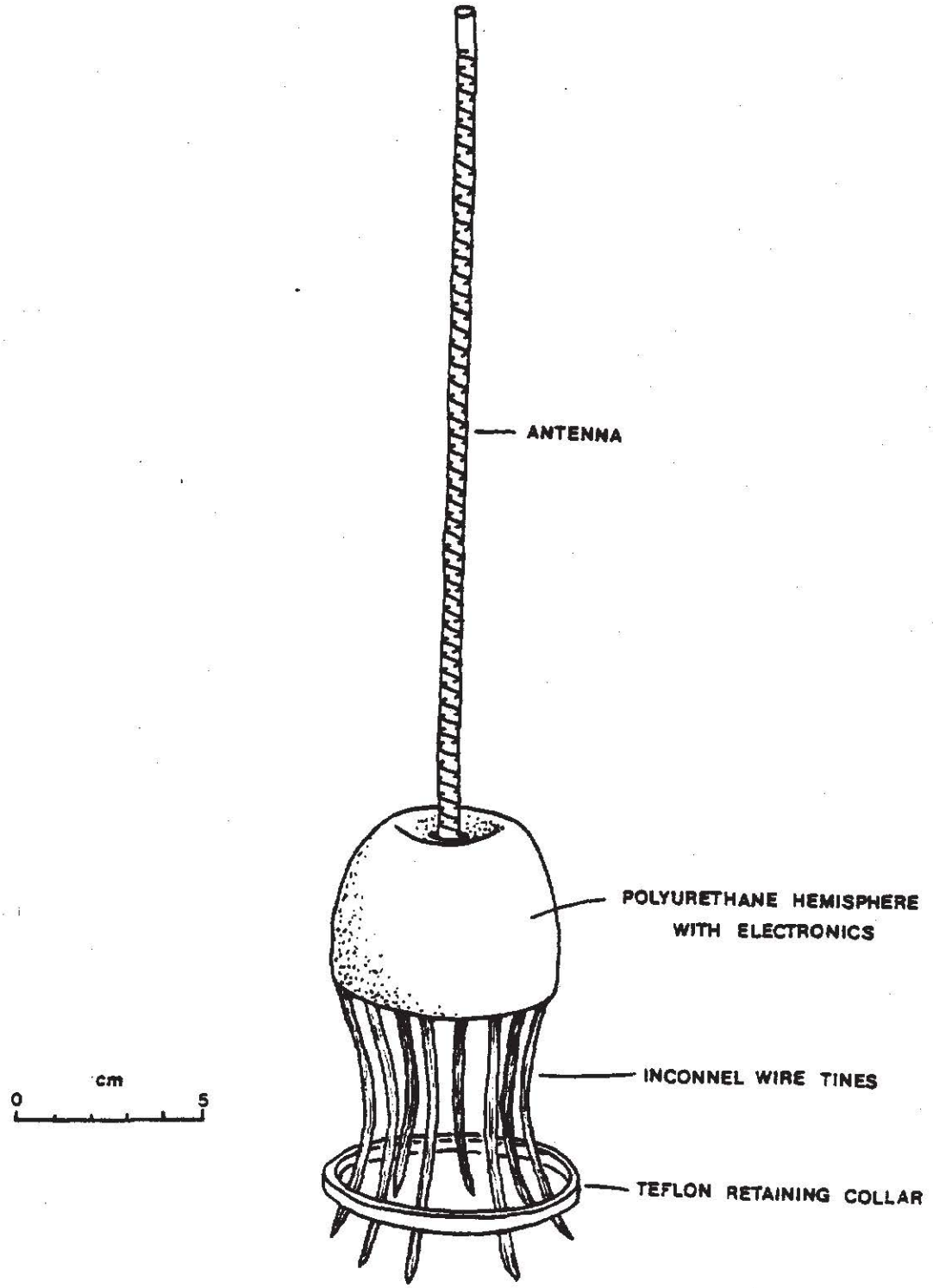

Figure 4. Telonics "barnacle" radio tag.

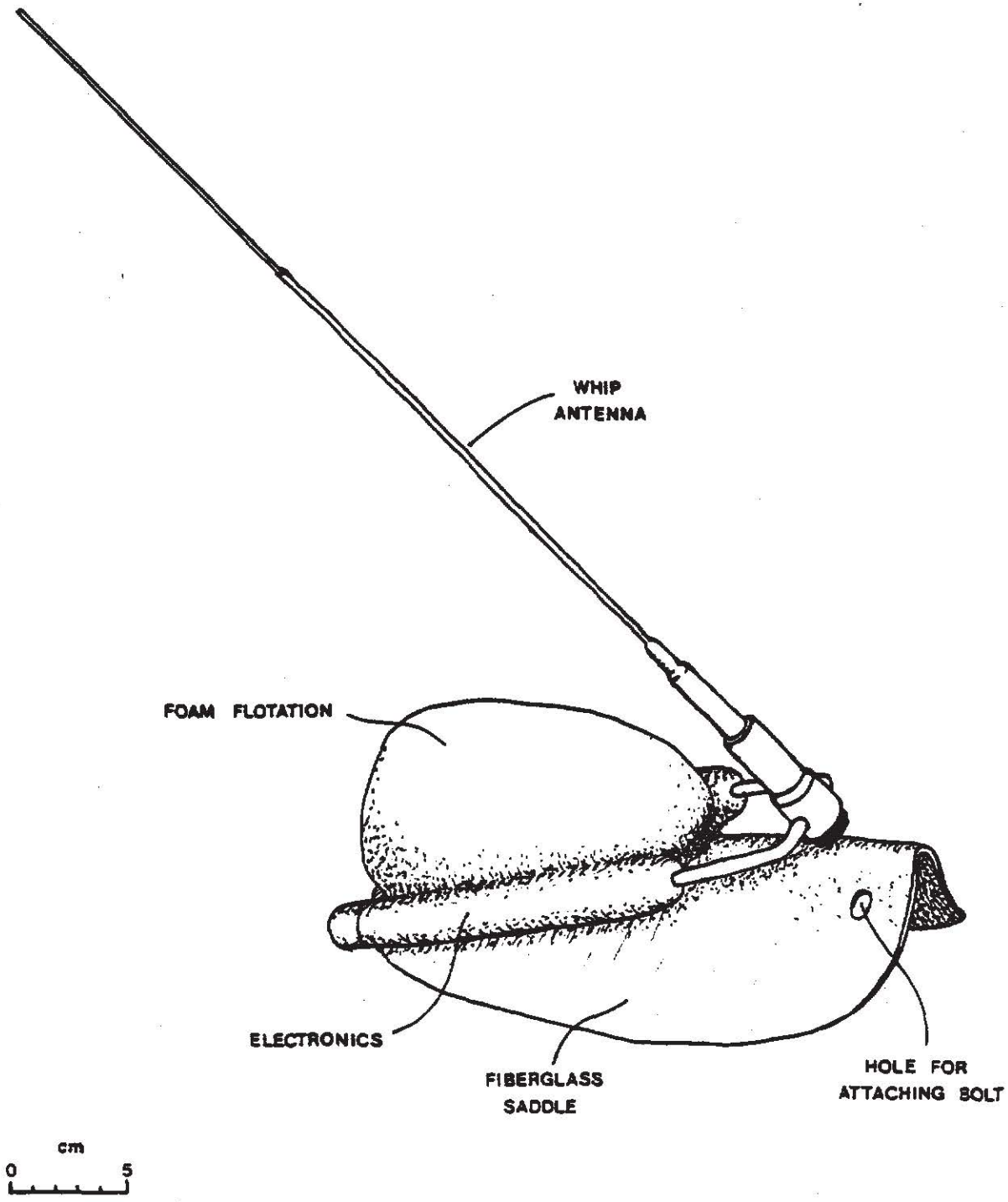

Figure 5. OAR "backpack" radio tag.

package in order to make the transmitter float with the antenna out of the water. The completed backpack transmitter was similar to that described and used by Butler and Jennings (1980). Packages are designed to be attached by means of a nylon bolt passed through holes in the leading edge of the package and the dorsal ridge of the whale. A trocar needle 4.8 mm in diameter was to be used to make the hole for a bolt 5.6 mm in diameter so that the bolt would fit snugly to prevent bleeding from the hole. Total package weight is approximately 454 g. Transmitter crystals are in the 164 MHz range.

Our primary receiving system consisted of a Telonics TR-2 receiver with automatic scanner which can be connected to an omni-directional whip antenna, a two-element YAGI antenna, or a five-element YAGI. In addition, we used an OAR automatic direction finder (model ADFS-320) with an Adcock antenna. These receiving systems are similar to those used by Butler and Jennings (1980).

We planned to catch whales by driving them with small boats until they stranded themselves in shallow water. This technique, in combination with the use of nets, can be very effective for catching belukha whales (e.g., Ray 1962, Sergeant and Brodie 1969). The NOAA research vessel SURVEYOR supplied several small boats (one 4.3-m Zodiac raft with 35-hp motor, one 5.2-m Boston whaler with 55-hp motor, one 5.2-m Boston whaler with 35-hp motor, and one 6.4-m Boston whaler with 140-hp motor), and two more (one 4.9-m aluminum riverboat with 50-hp motor and one 3.7-m Avon raft with 25-hp motor) were provided by ADF&G Dillingham. Other equipment included three sections of net, each 25 fathoms (45.7 m) long and 3 fathoms (5.5 m) deep, constructed of 6-inch (15.2 cm) stretch-mesh No. 48 thread nylon, hung like a gillnet with net floats and lead line. The net was intended to be detectable (acoustically and perhaps visually) by the whales so that they would not become entangled and was to be used as a fence to direct or contain the animals. A stretcher 3.0 by 1.5 m was constructed of sturdy nylon fabric with several rope hand-holds and was to be used to transport stranded animals into the water after tagging.

Field work was conducted in Nushagak Bay from 15 June through 11 July 1982. The SURVEYOR was anchored in the mouth of the Bay from 18 June until 12 July and served as a primary base of operations. The NOAA Bell 204 helicopter (57RF) was on scene from 16 June until 12 July, operating from King Salmon on 16 and 17 July and from the SURVEYOR thereafter. The helicopter was used to transport personnel and equipment, observe the distribution of whales, and coordinate whale capture attempts. Field camps were set up at two locations (Fig. 2). The Weary River camp was in place from 18 to 30 June and served principally as an emergency shelter and for storage of equipment. The ADF&G camp on the lower Snake River was set up on 30 June and used until 11 July as a primary base for whale capture operations. In addition, an ADF&G camp (used for fishery research projects) on the Igushik River was used from 22-26 June for observations of whales and storage of equipment.

Eleven people were primarily involved in the whale capture and tagging operations (Table 2). Other personnel from the SURVEYOR and Hubbs Sea-World at times provided considerable assistance.

VI. Results

A. Telemetry Tests

We conducted several tests to determine the adequacy and effective range of our transmitter-receiver systems. For all tests, radio packages were mounted on small pieces of plywood and put into the water. The plywood and transmitters floated in such a way that the orientation of radios and antennas closely simulated that which would occur when a tagged whale surfaced to breathe. The setup of receiving systems varied among tests, which are individually described below.

From 1000-1430 hours on 20 June, testing was conducted from the SURVEYOR, which was anchored in the mouth of Nushagak Bay (58°21.1'N, 158°22.1'W). Receiving systems were set up on the ship: a Telonics receiver with two-element YAGI antenna at approximately 9 m above sea level (ASL), and an OAR ADFS-320 with an Adcock antenna in the ship's mast at about 30 m ASL. A motor whaleboat was used to take transmitters out to various distances from the ship. Range and bearing to the motor whaleboat were determined using the ship's radar, and reception of transmitters was tested with each receiving system. Weather was partly cloudy, seas 0.6-1.2 m, and air temperature 7.5-9.0°C. Results (Table 3) indicated that signals from the OAR radio were considerably stronger, especially with the OAR ADF. At a distance of 3.2 km, the ADF received signals from the Telonics radio as weak but readable; at 3.7 km they were very weak and no relative bearing could be determined. At 3.7 km the OAR transmitter was still being clearly received by the ADF, and good directional information could be obtained. Tests were terminated due to a malfunction in the motor whaleboat.

At 1800 hours on 6 July, testing was conducted from the SURVEYOR with receiving systems as described above. The ship was anchored at approximately 58°31.3'N, 158°26.8'W. Transmitters were in the Snake River at "Hubbs Camp" (58°53.3'N, 158°46.4'W) approximately 44 km away. Weather was partly cloudy, air temperature 14°C, and the tidal height approximately + 2.2 m. Neither transmitter could be heard with either receiving system.

On 8 July testing was done in mid-Nushagak Bay. The receiving system was a Telonics receiver with two-element YAGI antenna on land at approximately 12 m ASL. A Boston whaler was used to move the transmitters to several locations in the Bay (Fig. 6). Locations of the transmitters were determined by triangulation of sighting compass bearings to prominent landmarks. Weather was clear; seas were 0-0.6 m. Results (Table 4) indicated that the OAR transmitter could be received all the way across

Table 2. Personnel directly involved in belukha whale capture and tagging operations, Nushagak Bay, 1982.

Name	Dates	Affiliation
Lloyd Lowry	15 June - 12 July	ADF&G Fairbanks
Robert Nelson	15 June - 12 July	ADF&G Nome
Ken Taylor	15 June - 12 July	ADF&G Dillingham
Guy Oliver	18 June - 12 July	OMPA Juneau
John Hall	18-24 June	Solace Ent., Anchorage
Mark McNay	18-24 June	ADF&G, King Salmon
Dick Sellers	18-24 June	ADF&G, King Salmon
Al Franzmann	18-27 June	ADF&G, Soldotna
Bruce Mate	22-27 June	Oregon State University
Kathy Frost	1-12 July	ADF&G Fairbanks
Steve Peterson	8-12 July	ADF&G Juneau

Table 3. Results of tests of OAR and Telonics transmitters, 20 June 1982. See text for explanation of methodology.

Transmitter-receiver distance (km)	relative bearing	Transmitter type	Receiver system: Telonics w/YAGI gain setting[1]	Receiver system: OAR ADF w/Adcock relative bearing	Receiver system: OAR ADF w/Adcock signal strength[2]
1.8	353°	OAR	4.5	350°-020°	--[3]
		Telonics	5.0	350°-000°	0.05
3.2	342°	OAR	4.5	340°-015°	0.15
		Telonics	5.0	345°	0.00
3.7	093°	OAR	5.4	080°-110°	0.10
		Telonics	6.5	not readable	0.00

1 Minimum gain setting on receiver at which signal was audible.
2 Relative units as indicated on the signal strength meter of the ADFS-320.
3 Signal was too strong to be read on the meter.

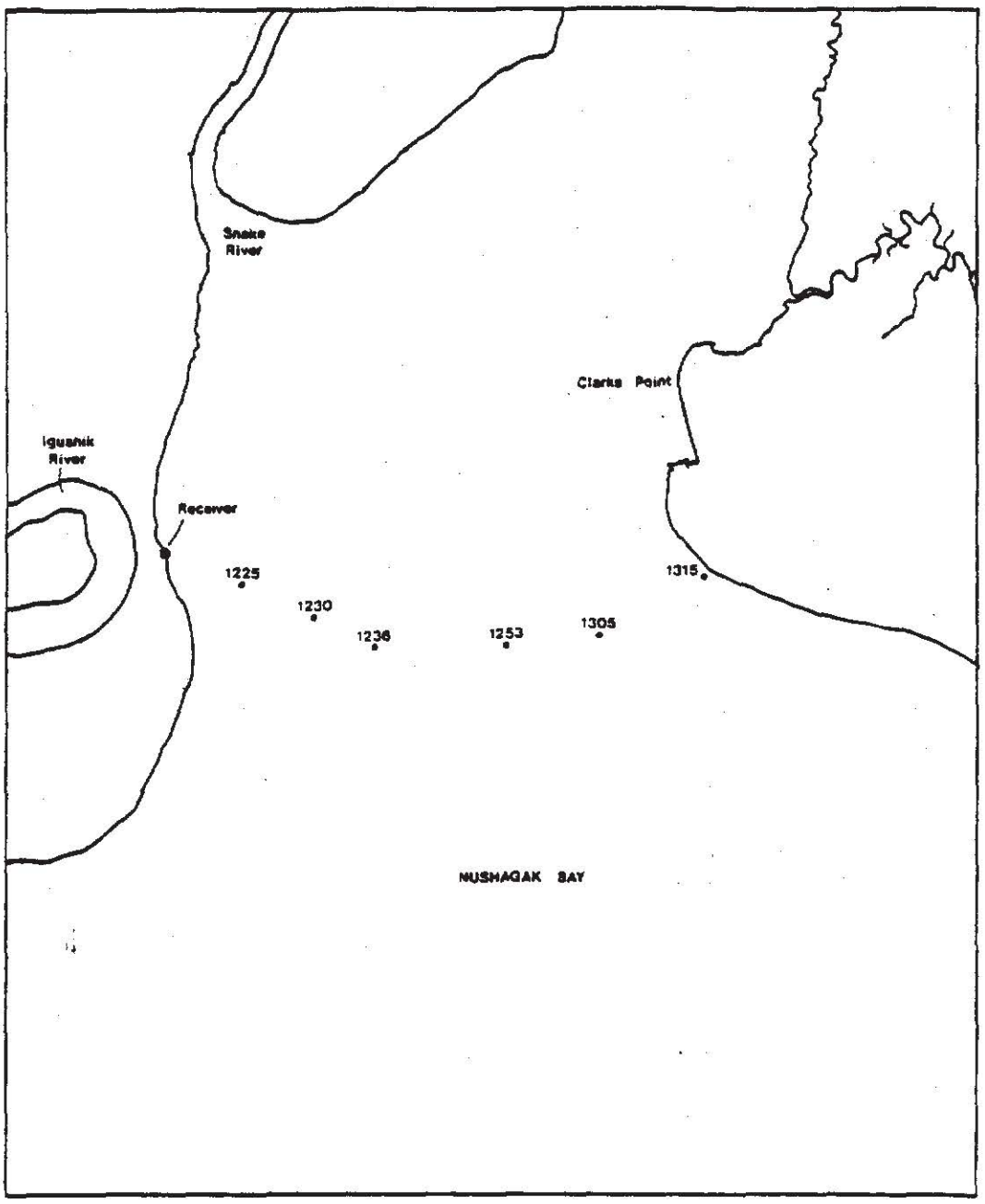

Figure 6. Locations of transmitter tests in Nushagak Bay, 8 July 1982. Numbers refer to times shown in Table 4.

Table 4. Results of tests of OAR and Telonics transmitters, 8 July 1982. See text for explanation of methodology and Figure 6 for locations.

Time	Distance (km)	Transmitter type	Gain setting	Comments
1225	2.2	OAR	6	very clear
		Telonics	6	very clear
1230	4.2	OAR	6	very clear
		Telonics	7	faint
1236	5.9	OAR	7	clearly readable
		Telonics	--	no signal received
1253	9.0	OAR	7	clearly readable
		Telonics	--	no signal received
1305	11.2	OAR	7	clearly readable
		Telonics	--	no signal received
1315	13.7	OAR	7+	faint
		Telonics	--	no signal received

the Bay (13.7 km), while signals from the Telonics radio were lost at between 4.2 and 5.9 km from the receiver.

On 8 and 9 July tests were conducted in the Snake River. The receiving system was a Telonics receiver connected via a switch box to an omnidirectional whip antenna and a two-element YAGI antenna. Antennas were mounted on a mast at the ADF&G camp and were approximately 12 m above the mean low water level. Transmitters were moved with a Boston whaler to the locations shown in Figure 7. Conditions on 8 July were steady light rain, air temperature 13°C, 0.1-0.2 cm waves, tidal height + 3.8 m (antenna 8.2 m above the water). On 9 July weather was very clear and calm, air temperature was approximately 15°C, and tidal height was + 3.3 m. Results (Tables 5 and 6) indicate a maximum reception distance of 3.1 km with the omnidirectional whip antenna, and at times signals could not be heard when the transmitter and antenna were less than 1.5 km apart. With the YAGI antenna, the OAR transmitter could generally be heard at all locations except off Belukha Point (Fig. 8), while the Telonics transmitter could be received at only half of the locations (Fig. 9), with reception appearing to be much more sensitive to obstructions.

Our final telemetry tests were done on 12 July 1982. Transmitters were in the water near the SURVEYOR, which was anchored at 58°31.1'N, 158°26.3'W. Weather was cloudy, air temperature was 13.4°C, and sea state was calm with no waves or swells. The receiver was on the helicopter, connected to a two-element YAGI antenna mounted on the left strut. Reception tests were made at several locations and altitudes (Table 7). The OAR transmitter could be heard at all locations and altitudes tested. The Telonics transmitter could not be heard at test distances of 57.2 and 57.0 km. At 44.2 km the Telonics transmitter could be received at altitudes of 305 and 229 m but not at 213 m.

B. Testing of Tag Attachments

We had an opportunity to test the attachment of our radio and visual tags on a dead belukha whale which was found in the Snake River near Hubbs Camp on 29 June. The animal was a recently dead male, 296.5 cm standard length, in what appeared to be normal physical condition. The animal was necropsied, and the combined thickness of skin and blubber on the dorsal midline was measured at several locations as follows: above pectoral fins - 4.1 cm, in front of dorsal ridge - 6.2 cm, midway between the front of the dorsal ridge and the flukes - 6.3 cm.

Three visual tags were applied with the Floy dart heads and applicator. Application was simple and fast, and the dart heads toggled properly in the blubber just at or above the fascia. However, it was found that when given a strong, sharp pull the tag separated from the dart head. This was due to the crimped nut at the dart stripping the plastic coating off the wire, allowing the wire to slip free. Visual tags applied by sewing through the dorsal ridge appeared very satisfactory, and the application

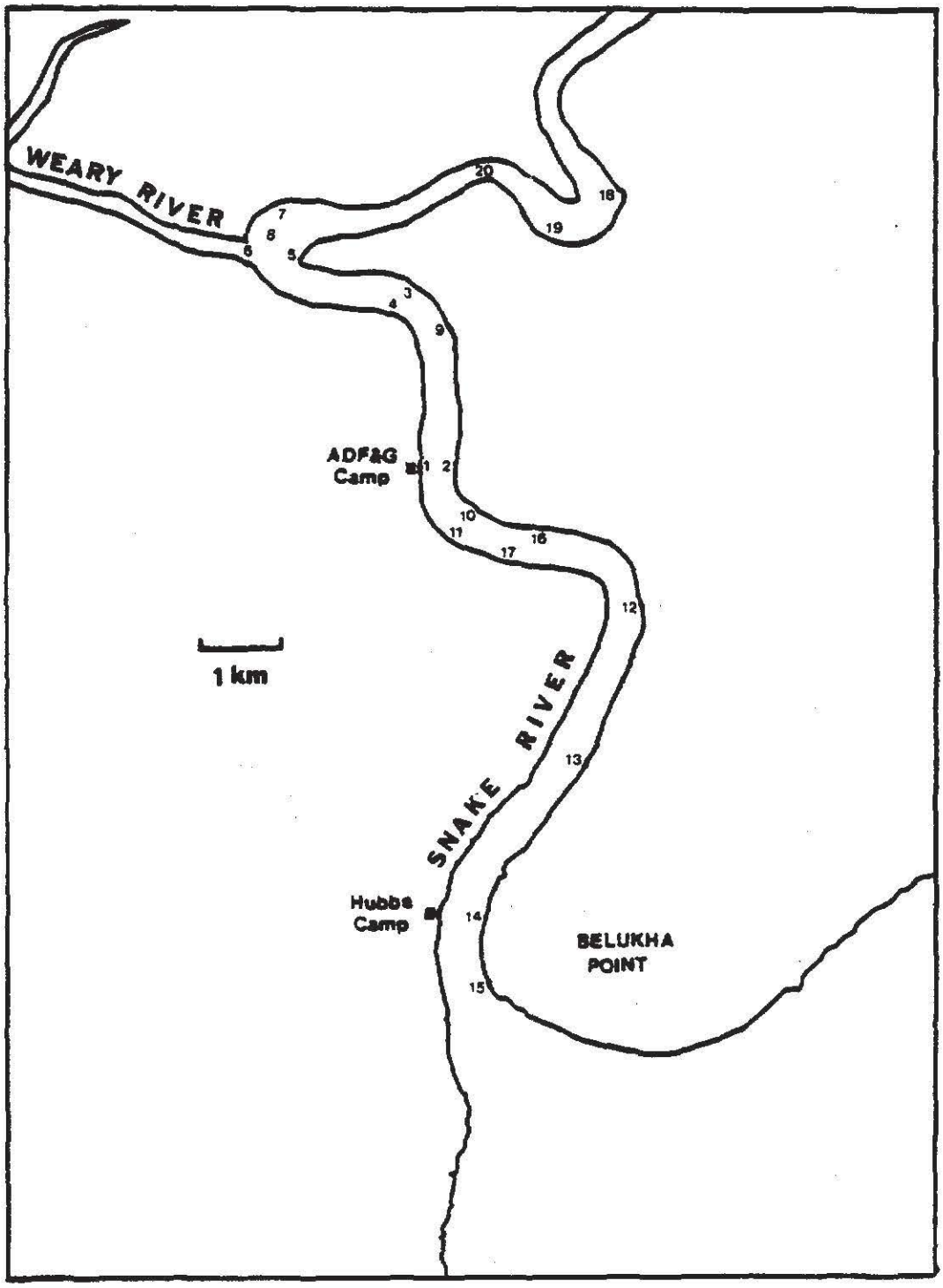

Figure 7. Locations of transmitter tests in the Snake River, 8-9 July 1982.

Table 5. Results of tests of OAR and Telonics transmitters in the Snake River, 8 July 1982. See text for explanation of methodology and Figure 7 for locations.

		Gain setting				
		OAR		Telonics		
Time	Location	Omni	YAGI	Omni	YAGI	Comments
1559	1	5	5	6	6	clear line of sight (LOS)
1601	2	6	6	7	6	clear LOS
1607	3	--	6+	--	--	clear LOS
1615	4	--	6+	--	--	obstructed by low bank
1620	5	--	7+	--	--	probably obstructed
1625	6	--	--	--	--	probably obstructed
1630	7	--	--	--	--	probably obstructed
1635	8	--	7+	--	--	probably obstructed
1645	9	6+	6	--	7+	clear LOS
1653	10	6	6	--	7	clear LOS
1657	11	6	6	--	7	clear LOS below bank
1705	12	7+	6+	--	--	obstructed by low bank
1710	13	--	6+	--	--	obstructed
1715	14	--	7+	--	--	obstructed by high bank
1720	15	--	--	--	--	obstructed by ridge
1732	16	6+	6	--	--	obstructed by low bank
1737	17	6+	6	--	7+	clear LOS

Table 6. Results of tests of OAR and Telonics transmitters in the Snake River, 9 July 1982. See text for explanation of methodology and Figure 7 for locations.

Time	Location	Gain setting				Comments
		OAR		Telonics		
		Omni	YAGI	Omni	YAGI	
1515	2	6	6	6	6	clear LOS
1520	3	6+	6	--	6	trees in way
1522	4	6+	6	--	6+	obstructed by low bank
1529	5	--	7	--	--	obstructed by low bank
1532	8	--	7	--	--	obstructed by low bank
1536	6	--	7	--	--	obstructed by low bank
1541	7	--	7	--	--	obstructed by low bank
1555	18	--	6	--	6+	mid-river
1603	19	--	6+	--	7+	near low bank
1608	20	--	6+	--	--	midstream near mud bank
1619	9	6+	6	6+	6	clear LOS

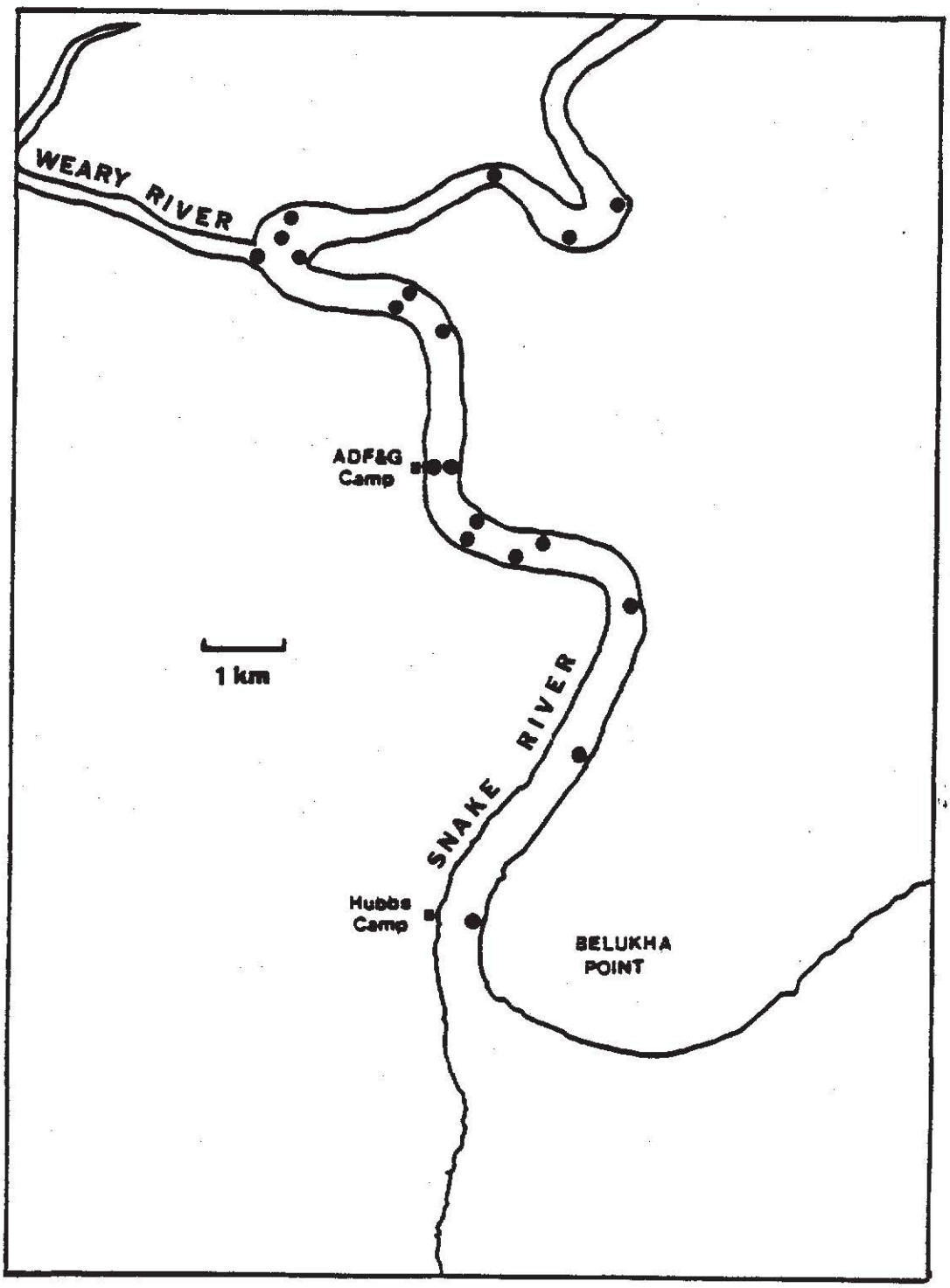

Figure 8. Results of transmitter tests in the Snake River. Dots indicate locations at which OAR transmitters were received.

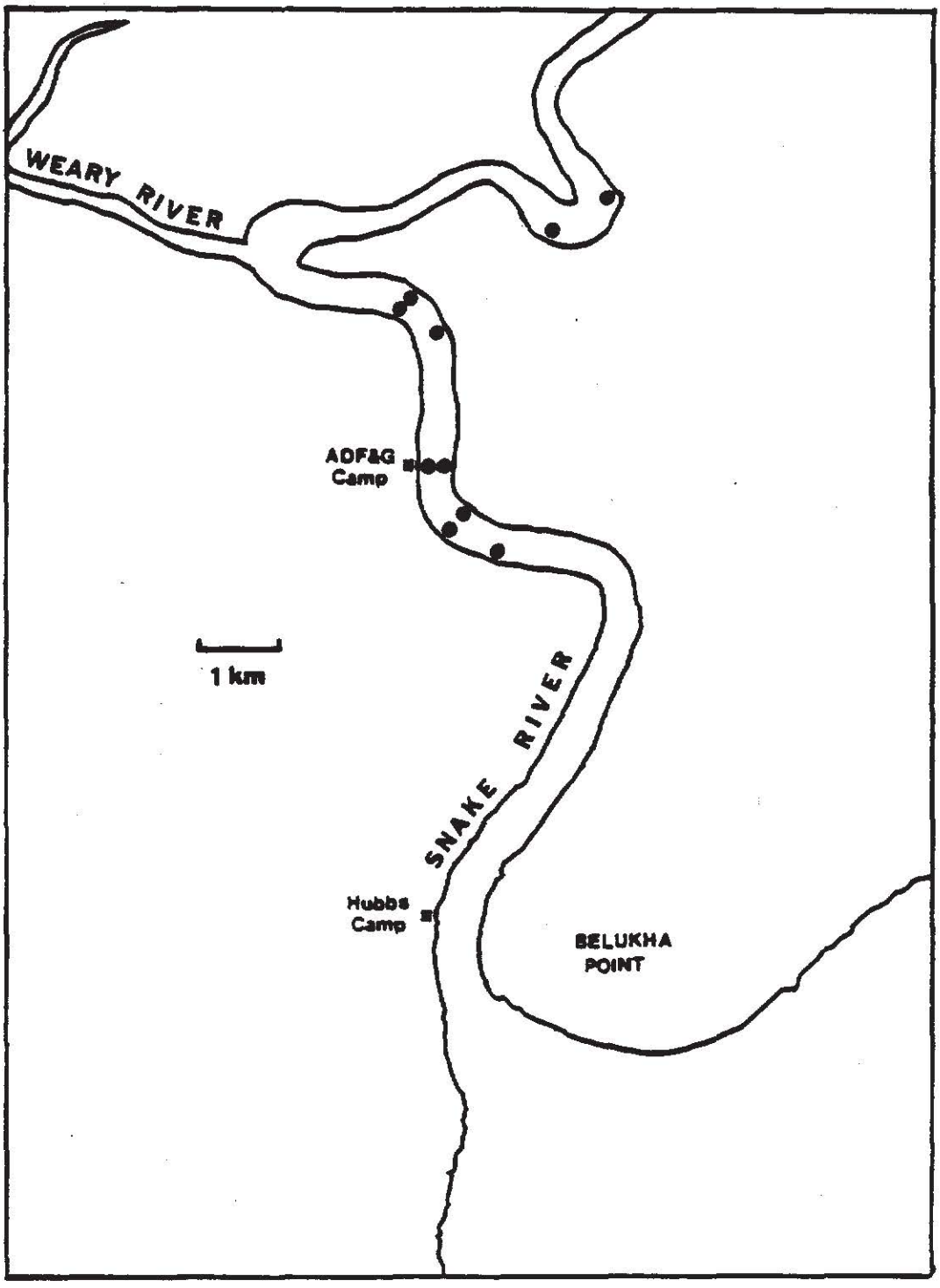

Figure 9. Results of transmitter tests in the Snake River. Dots indicate locations at which Telonics transmitters were received.

Table 7. Results of tests of OAR and Telonics transmitters in Nushagak Bay, 12 July 1982.

Receiver location	Distance (km)	Altitude (m)	Transmitter	Reception	Comments
9 km east of Little Muklung River	57.2	305	OAR	yes	signal not directional
		152	OAR	yes	
		61	OAR	yes	signal more directional
		305	Telonics	no	
		152	Telonics	no	
		61	Telonics	no	
off Dillingham	57.0	152	OAR	yes	signal directional
		152	Telonics	no	
Snake River mouth	44.2	305	OAR	yes	strong signal
		229	OAR	yes	
		213	OAR	yes	
		305	Telonics	yes	signal directional
		229	Telonics	yes	barely audible
		213	Telonics	no	

procedure, although involving more time and handling of more parts, was quite simple. Moderate force applied to the tags did not cause any apparent problems to the whale's skin or to the tags. Breaking strength of tag components was subsequently measured using a vise and spring scale. Three dart heads with attached wires were tested; they failed at an applied force of 5.5-6.8 kg. Three streamer tag assemblies with wire attachment loops were tested; they failed at an applied force of 18-23 kg. In all cases, failures were due to the steel crimp or crimped stainless-steel nut pulling off the wire, taking with it the plastic coating.

The OAR backpack transmitter fit very well on the dorsal ridge of the animal. The trocar needle easily produced an incision through the dorsal ridge; however, some difficulty was encountered in alignment of holes in the backpack and dorsal ridge and installation of the nylon bolt.

A Telonics transmitter was applied to the whale in the mid-dorsal region. Observations of the attachment indicated that the tines did not splay adequately and penetrated the blubber and fascia into the muscle. The transmitter was pulled off the animal with relative ease.

Further test applications of Telonics transmitters were done on 30 June. Two transmitters were used, one of which had the tines in standard configuration and a second on which the curvature of the tines was slightly increased by bending them in the middle. Radios were firmly jabbed onto the carcass in the area just lateral to the dorsal midline in front of the dorsal ridge, where the skin was 1.1 cm thick and the blubber 4.0 cm. Both radios appeared to attach well. In both instances the teflon tine-retaining ring broke off, and the base plate of the transmitter seated all the way against the skin. When the skin and blubber in the area were removed, it was observed that all eight tines on the standard attachment had penetrated the blubber and fascia into the muscle, while on the modified attachment six of the tines were completely in the blubber and two had penetrated through the blubber, into the fascia, but not into the muscle. Measurements of the attachments after they were dissected from the blubber and skin showed that the modified tines splayed to a substantially greater degree and penetrated 1.8-2.0 cm less deeply than the standard tines (Table 8).

On 1 July, another recently dead belukha whale was found and necropsied. The animal was a male, with a standard length of 390.0 cm. After necropsy, a series of measurements was made of the thickness of the skin and blubber in the region between the blowhole and the dorsal ridge (Fig. 10). Results indicated a general thickening of the skin and blubber from a combined minimum of 4.1 cm at a point 20 cm behind the blowhole to 9.5 cm just in front of the dorsal ridge. The combined thickness of skin and blubber was greater than 5.0 cm in the entire region from 40 to 140 cm behind the blowhole.

Table 8. Measurements of Telonics transmitter attachments and depth of penetration on a belukha carcass, 30 June 1982.

Measurement (cm)	Standard attachment	Modified tines
Pre-application:		
width across tines at transmitter base	6.0	6.0
width across tines at tips (without retaining ring)	8.1	8.3
Post-application:		
width across tips of tines	16.5	18.5 - 19.0
depth of penetration on carcass	6.7 - 6.8	4.8 - 5.0

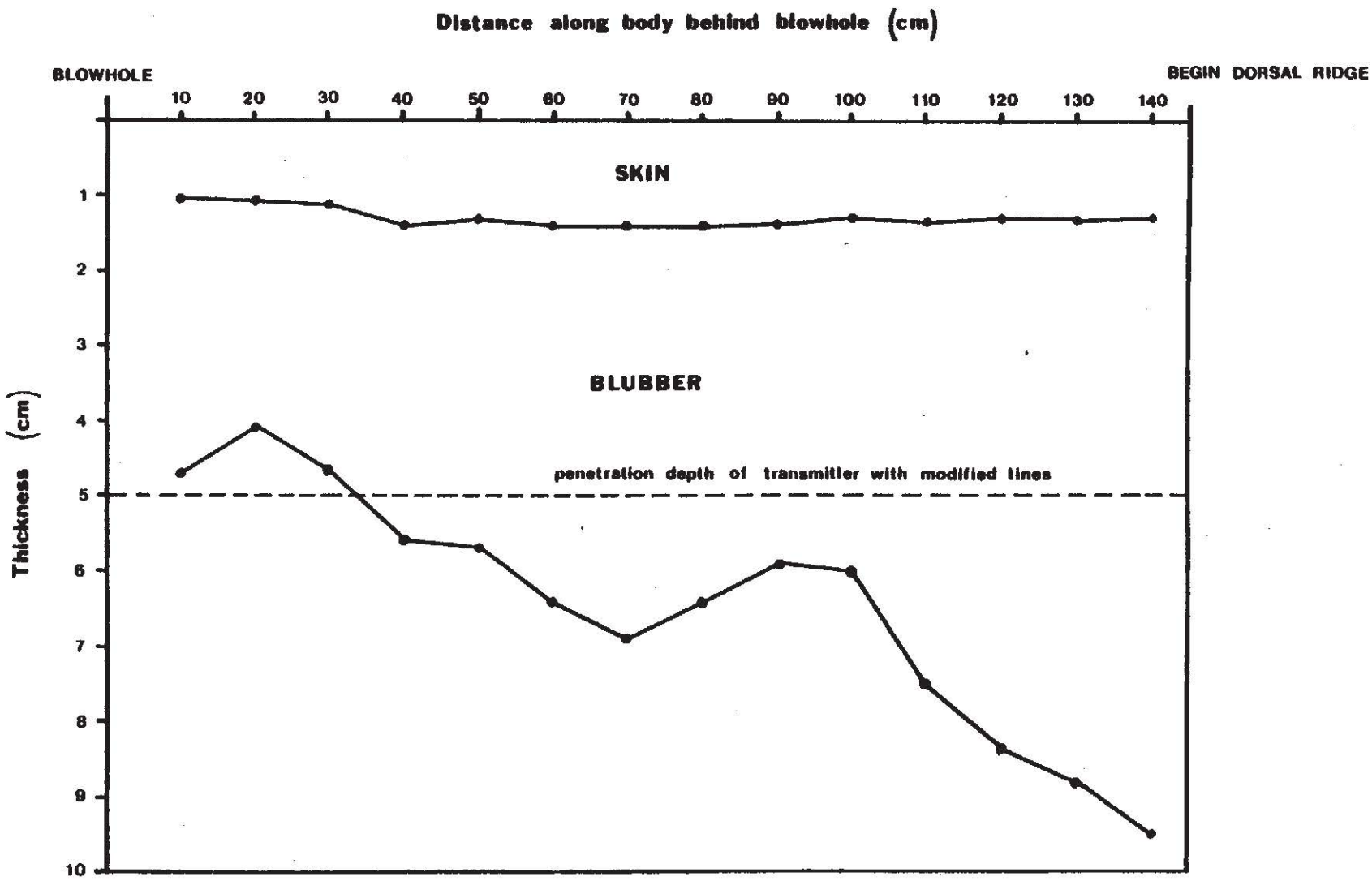

Figure 10. Measurements of skin and blubber thickness along the dorsal midline of a 390 cm long male belukha whale.

C. Capture and Tagging of Whales

We tried several different methods for capturing belukha whales. During the early portion of our field work, whales were regularly seen in the lower part of the Igushik River. We attempted to capture whales in that area (Location 1 in Fig. 11) on 23, 24, and 25 June. Operations are described as follows:

23 June - Whales were first observed in the river at about 1130 h. Three boats were in the river downstream of the whales when the first capture attempt began at 1400 h. A 50-fathom length of net was anchored perpendicular to the current on the cutbank side of the river. Two boats moved to a point upstream from a group of 8-10 whales, then headed downriver moving the whales toward the net. The third boat was positioned at the midstream end of the net to try and move whales onto the mud flats on the other side of the river. Whales moved steadily downriver ahead of the boats until about 200 m from the net, at which time they dove and were not seen again.

24 June - At 1700 h a capture attempt was made using techniques identical to those described above. A group of 6-8 whales was herded downstream to a point about 200 m upstream from the net, where the animals again disappeared. One surfaced again about 50 m from the net but dove and disappeared when approached by the boats.

25 June - At 1500 h a capture attempt was made using techniques similar to the previous 2 days except that the net was set on the mud flat side of the river. However, the current was flooding strongly, and the net could not be held perpendicular to shore and wound up virtually parallel to the mud flat. The group of 10-15 whales present in the river at the time passed by the boats and downstream along the cutbank side.

From 27 June through 5 July we attempted to catch whales in the Snake River. Initially we scouted the river with two boats, hoping to locate whales in a narrow portion of the Snake River or Weary River where we could block the main channel with our nets. We did not locate any animals in an area where capture attempts were feasible. Reports from observers at Hubbs Camp indicated that a few whales had been seen on previous days at high tides in the small sloughs on the east side of the Snake River. We therefore set up an "ambush" at a slough above Hubbs Camp (Location 2, Fig. 11). A 25-fathom section of net was anchored and piled up on the south bank of the slough, and a length of rope, supported above the water, was run across the north bank. The rope was tied to the free end of the net and could be used to pull it across the mouth of the slough. Two persons watched from the north bank during the daylight high tides of 3, 4, and 5 July. No whales moved into the slough, and none were seen in the adjacent portion of the Snake River.

On 7, 9, and 10 July we attempted to catch whales by driving them onto the mud flats outside the mouth of the Snake River. Operations were

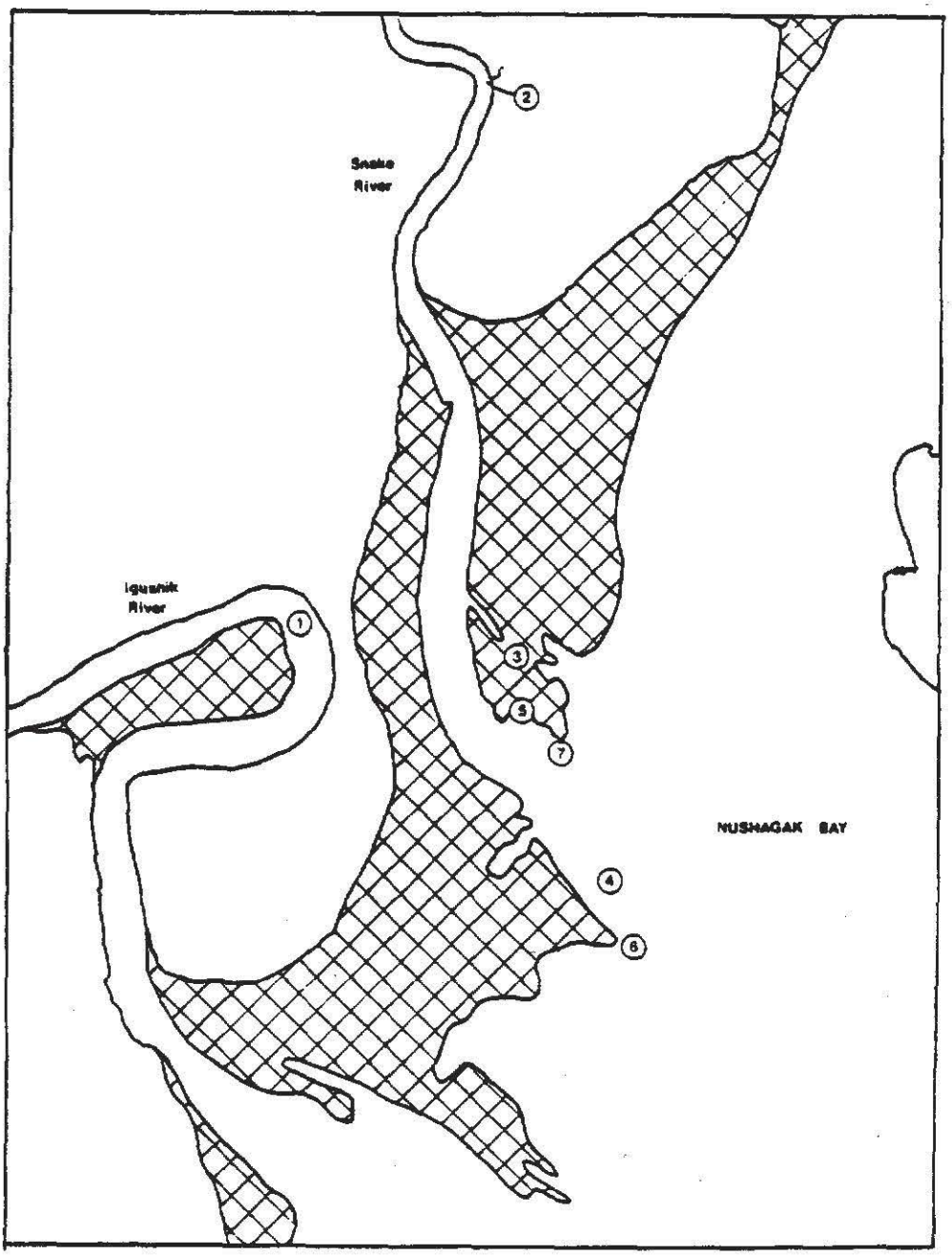

Figure 11. Locations of belukha whale capture operations in the Igushik River and Nushagak Bay, 23 June-10 July 1982. Numbers refer to locations mentioned in the text.

as follows:

7 July - Six boats drifted and motored out the mouth of the river at approximately 1100 h. A group of 15-20 whales was sighted north of the boats, and four boats (two had broken down) formed a line spaced about 100 m apart and started moving toward the mud bar on the east side of the river. All the animals except a large animal accompanied by a juvenile disappeared quickly. Those two animals moved ahead of the boats until they were over a shallow area with water 1.0-1.2 m deep (Location 3, Fig. 11), at which point they began circling and were surrounded by the boats. No exposed mud flats were in sight. Fifty fathoms of net were deployed, and we attempted to move the whales toward it. They approached no closer than 50 m and then eventually located deeper water and moved away. The other two boats were repaired, and the helicopter arrived and spotted a group of 300-400 whales off the river mouth (Location 4, Fig. 11). At 1345 h the boats were south of most of the whales and headed north in a line with intervals of about 100 m between them. Some of the whales moved eastward to the main part of the Bay; however, many moved north ahead of the boats. Whales were initially in groups of 4-10 animals which coalesced in front of the boats until they formed a compact group of about 20. The boats and whales moved north for approximately 40 minutes and toward the mud flats (under direction of personnel in the helicopter). When the whales reached shallow water (Location 5, Fig. 11), they began to circle, double back, and escape between the boats. The boats closed in on a group of about four animals; however, they also escaped before they could be captured. The helicopter spotted another two animals nearby in shallow water and directed the boats to them. Four persons entered the water and attempted to encircle the whales. However, the whales located deeper water in a drainage channel and disappeared.

9 July - Six boats motored out to the river mouth at 1700 h and attempted to drive whales as described on 7 July. Whales did not respond satisfactorily to attempts to move them toward the mud flats, and no real drives were made.

10 July - Six boats moved out of the river mouth at 1030 h to a point south of a group of 300-400 whales which had been spotted from the helicopter (Location 6, Fig. 11). Boats were deployed as on 7 July, and two attempts were made to drive whales toward the mud flats to the west. In both cases, whales moved around the boats to the north or south and then east. At about 1400 h with five boats (one was returned to the SURVEYOR), we began to move northward with a group of 200-300 whales between the boats and the Snake River mouth. Orientation and direction of boats was maintained by personnel in the helicopter. Most whales moved eastward into the main portion of the Bay. A group of about 10 animals stayed ahead of the boats until they reached shallow water (Location 7, Fig. 11). One animal was encircled by boats and people in the water and was physically

captured at approximately 1440 h. The animal was a light-gray female, approximately 3.0 m long. Four to six persons restrained the animal by holding onto the flukes, front flippers, and neck/head region. Water depth was about 1.2 m, and the tide was rising rapidly. Two visual tags (Red, Nos. 01 and 02) were attached by sewing through the dorsal ridge. The OAR backpack transmitter was placed over the dorsal ridge, which was then punctured with the trocar needle. It proved impossible to get the nylon bolt through the resulting hole, and the animal was released without a transmitter. Throughout the tagging operation the animal was difficult to restrain and struggled at intervals of about 45 to 60 seconds, actually breaking free on two occasions. No response was observed to puncturing the dorsal ridge for the visual tag and transmitter bolt, and virtually no bleeding was observed from the holes.

On 11 July, four boats with a total of eight observers motored and drifted through a group of 400-600 whales off the Snake River mouth. Observers scanned the whales with binoculars in an attempt to locate the tagged animal. The tagged whale was not seen.

D. Distribution and Movements of Whales

All observations of belukha whales made by personnel working with this project are listed in Appendix I. Observations were made during systematic reconnaissance surveys, whale capture attempts, and on an opportunistic basis from locations on shore and during transit in the helicopter and small boats. Additional sightings were sometimes obtained from local residents, particularly air taxi pilots.

Observations indicate four principal areas where belukhas were regularly seen (Table 9). Whales were seen in northern Nushagak Bay near the junction of the Wood, Little Muklung, and Nushagak rivers and off the Snake River mouth during the entire period of field work (15 June-12 July). The number of whales seen in the Wood-Little Muklung area varied considerably but was generally less than 50. Animals were most common along the northern shore and were on a few occasions reported or seen in the lower portion of the Little Muklung River. On 4 July the presence of whales was reported at Portage Creek, approximately 50 km up the Nushagak River from the Wood-Little Muklung area. The number of whales seen off the Snake River mouth also varied considerably. However, a clear trend of increasing abundance was seen from late June to mid-July. Whales were seen off the Snake River mouth on every occasion when observations were made of that area.

Our observations indicate small numbers of belukhas in the Snake River itself. Whales were seen on two occasions (16 and 28 June) near the junction of the Snake and Weary rivers, approximately 12 km upstream from the river mouth. No whales were seen in the Weary River.

Table 9. Summary of whale observations in Nushagak Bay, June-July 1982.

Date	Number of whales sighted				
	Wood River-Little Muklung River	Snake River	Snake River mouth	Igushik River	Other
15 June	1	0[1]	12		
16 June	6	3			
18 June					1 near Grassy Is.
19 June	2	0	37		
20 June	0	0		12	
22 June	100[2]	0	8	7	
23 June				20	
24 June				12	
25 June				12-15	
27 June		2			
28 June	several[2]	3			
1 July		0			
2 July		3	6-10		
3 July			50-100		
4 July	15-20	0	50-60	0	some at Portage Creek[2]
5 July	30+	0	30-40	0	
6 July	50-60	0	30-40	0	
7 July	15-20		300+		
8 July			300+		
9 July		4	100		
10 July			400-600		
11 July			400-600		
12 July	2		26[3]		115[3] - central Nushagak Bay off Clarks Point

1 Indicates observations of the area were made but no belukhas were seen.
2 Not observed by scientific party but reported by reliable observers.
3 Actual counts from aerial survey.

Small numbers of whales were regularly seen in the lower portion of the Igushik River from 20 to 25 June. They were never seen passing the ADF&G camp, which is located approximately 18 km upriver. No whales were seen in the Igushik River during reconnaissance surveys on 4, 5, and 6 July.

No correlation was obvious between whale movement in the rivers and the stage of the tidal cycle.

On 12 July we conducted a strip-transect aerial survey of the Snake River mouth and the adjacent portion of Nushagak Bay (Fig. 12). Principal transect lines were run in an east-west direction at intervals of 1.8 or 3.6 km. Three observers were on the aircraft, with the two primary observers in the window seats in the rear of the helicopter. Each observer counted whales in a strip 0.9 km wide along the transect. Sightings were recorded by 1-minute intervals. A total of 141 whales was counted, some (26) off the Snake River mouth and most (115) east of there in Nushagak Bay off Clarks Point.

E. Other Observations

On a number of occasions, we made observations of the responses of belukhas to potential sources of disturbance. Whales generally showed little if any response to anchored or drifting small boats. However, when approached by slowly moving boats, the animals invariably moved away and where possible headed toward deeper water. On 8 July, while doing telemetry tests, we ran at high speed in a Boston whaler through a large group (100 +) of whales milling off the mouth of the Snake River. Whales showed no apparent response to the fast-moving boat, and a similar-sized group was observed milling in the same location when the boat returned about 1 hour later.

At 1300 h on 9 July, while observing from a small boat anchored about 1 km upstream from Hubbs Camp, we saw a group of four belukhas moving up the river on the west side. After the animals had passed around a bend in the river, we started our outboard and motored slowly upriver to the ADF&G camp, where we anchored the boat on shore and shut off the engine. At that time the whales were milling in the river just above the camp. The whales continued milling for several minutes, then began to move downriver along the opposite (east) bank of the river. They moved very close to the bank and were barely visible when surfacing to breathe. They were last seen moving downstream around a bend in the river. We made similar observations on 2 July. A group of three whales was seen at the bend in the river below the ADF&G camp. After a boat motored past the whales to Hubbs Camp to get fuel, they were not seen again that day.

As noted previously, whales were seen in the lower Igushik River from 20 to 24 June but not on 3, 4, or 5 July. During the days that whales were seen, there was virtually no vessel activity in the river mouth. However, in early July there were usually four to six boats

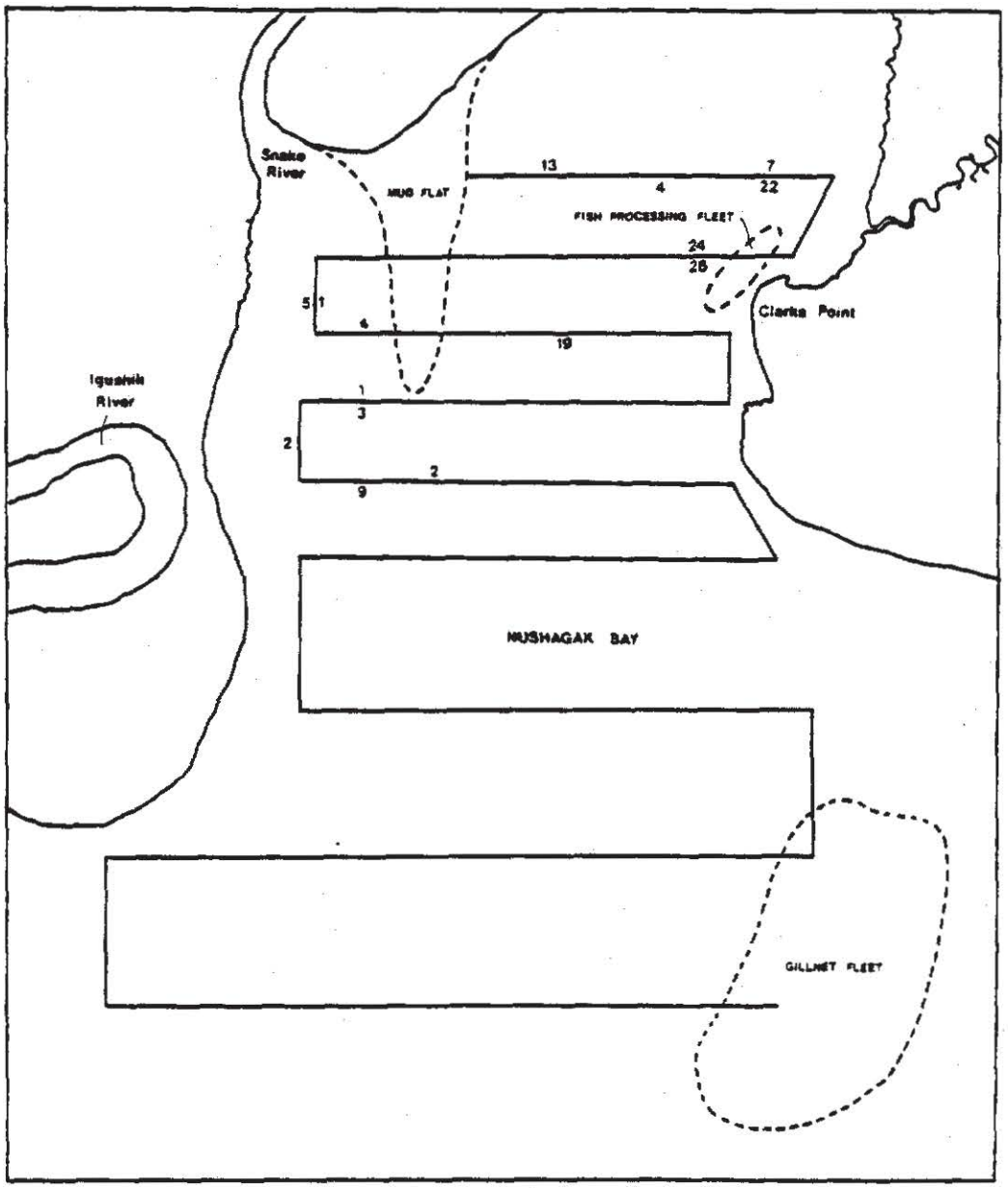

Figure 12. Aerial survey of central Nushagak Bay, 12 July 1982. Numbers along transect lines indicate the number of belukhas sighted in one minute intervals.

(processors, transports, tenders, and fishing boats) anchored in the river just above the mouth.

Other general observations indicate variable effects of disturbance on belukha distribution. Whales were never seen in the vicinity of the drift gillnet fleet. However, on 12 July many animals were seen within 1 km of a fleet of processors anchored off Clarks Point (Fig. 12). Whales were regularly seen in the Wood-Little Muklung area, in spite of the fact that it is near and upriver from Dillingham, which is the center of activity in Nushagak Bay. Whales in that area and in transit must be almost constantly exposed to noise from onshore sources, vessels, and aircraft.

During the course of our operations, we located the carcasses of six dead belukhas in the Snake River and vicinity. Details of each are given in Appendix II. Of those, two were neonates, one was probably a yearling, one was an adult male, and two were probably subadults. One animal (the yearling) apparently died due to entanglement in a net. No cause of death was obvious for the other four animals examined.

Food remains were found in the stomachs of two of the dead belukhas. Specimen BBD-1-82 was recently dead, and when found in the Snake River near Hubbs Camp it was spewing flesh and bones of red salmon. Remains of four salmon were found in its stomach; based on sizes of otoliths, two of the fishes were 54.9 and 73.8 cm long and weighed approximately 1,715 and 5,240 g. The other specimen (BBD-3-82) had been dead for several days prior to necropsy, and, since it had been caught in a net, it had probably died somewhere in Nushagak Bay and not in the Snake River where it was found. In its stomach were a few fragments of a shrimp, and otoliths from 68 rainbow smelt (Osmerus mordax), 2 pond smelt (Hypomesus olidus), 7 sculpins (family Cottidae), and 1 flatfish (family Pleuronectidae).

On several occasions we caught red salmon in our whale nets and in a small test gillnet. Whenever a net was set perpendicular to shore in a river, virtually all the salmon caught were in the 5 m of the net closest to the bank. Observations of undisturbed belukhas in rivers indicated that they also usually swam within a few meters of the banks. On 9 July 1982, eight red salmon were caught in a 10-minute set of a test gillnet at the ADF&G camp. One of those, a 66.5-cm male, had several fresh scrapes on the posterior portion of each side of the body which were obviously the result of attempted predation by a belukha.

VII. Discussion and Conclusions

Results of field work conducted in 1982 confirmed the occurrence of belukhas in Nushagak Bay. In 1982 they were present in the area from at least mid-June through mid-July. Other observations (Frost et al. 1982) and conversations with local residents indicate that belukhas are present in the Bay from at least April through October. The peak in abundance coincides with the peak of the red salmon run in early July.

Our observations indicate that during June and July belukhas occur primarily in two portions of Nushagak Bay: the northern end near the junction of the Wood, Little Muklung, and Nushagak rivers; and the west-central area near the mouth of the Snake River. Fried et al. (1979) and others have suggested that whales may gather near the Snake River to avoid boat activity since that district is closed to commercial fishing. Indeed, there was very little boat activity in the area in June and July 1982. However, it is difficult to explain the regular occurrence of whales in the northern part of the Bay near Dillingham, an area with extensive on- and over-water activity. The degree of interchange and patterns of movement of whales between these two areas are not known. Whales also move into the Nushagak, Little Muklung, Snake, and Igushik rivers. When in the confines of these rivers, they appear to react strongly to disturbance from boats.

Fried et al. (1979) noted that local residents reported belukhas calving in the Snake River area. However, they did not observe any neonates during their surveys (26 May-28 June). Our findings of dead neonates, plus sightings of newborn young from boats and the helicopter, confirm that many calves are born while belukhas are concentrated off the mouth of the Snake River. Calving in the area appears to begin shortly after 1 July.

It is difficult to estimate the number of whales that were present in Nushagak Bay during our field work in 1982. We estimated the number of whales in the Snake River area on 10 and 11 July at 400-600. On the 12 July aerial survey, 141 whales were counted. All observers on the survey agreed that the group of animals counted on that day was much smaller than groups seen on 10 and 11 July. Nonetheless, 141 individuals visible at the surface undoubtedly represent a large group of whales. Sergeant (1973) estimated that in turbid waters in western Hudson Bay belukhas were visible at the surface for about one-third of the time, and he therefore increased his actual counts of whales by a factor of 3 to estimate abundance. If a similar factor is applied to our survey, it would result in an estimate of about 423 whales in central Nushagak Bay on 12 July.

In order to elucidate further the distribution, abundance, and movements of belukhas in Nushagak Bay, radio tagging of animals is necessary. By using radio tags it will be possible to rapidly locate groups, which can then be counted, and it will also be possible to obtain accurate surface and dive-time data with which to determine proper extrapolation factors. Tagged animals are needed in order to investigate rates of movement, patterns of occurrence in concentration areas and corridors used between them, and interrelationships of groups of animals in the various areas.

We have demonstrated that it is possible to live capture, tag, and release belukhas in Nushagak Bay. A number of factors combined to prevent us from capturing more than a single animal. First, using the SURVEYOR as a base of operations was inefficient due to time lost in transit to

and from the ship. Ideally, the field party should work from a moderate-sized boat (10-12 m) with field camps set upon shore as necessary. Secondly, our objectives and those of another belukha research project were largely in conflict, which resulted in our spending less time attempting to catch whales than would otherwise have been possible. Third, several days were spent trying to catch whales in rivers. We learned that, due to strong currents, deep channels, and the wariness of animals, catching them while in rivers is generally not feasible. Lastly, a number of minor methodological and equipment problems combined to prevent us from catching more animals. Minor modifications to boats, motors, whale nets, and equipment for restraining animals should greatly increase future effectiveness.

Both types of visual tag applications appeared adequate when tested on dead belukhas. Due to the problem with failure of the attachment of tags to dart heads, the method of sewing through the dorsal ridge is probably preferable in circumstances when animals are restrained and handling time is not critical. The problem we encountered with crimps tearing the plastic coating off attaching wires can be easily remedied.

The adequacy of attachments for telemetry packages is more difficult to assess. Although we encountered difficulty in attaching the OAR package with a bolt, improvements in technique will remedy the problems encountered. In the future we will not attempt to attach radio packages until animals are actually grounded in shallow water and restrained as necessary by head nets and straps. In addition, a hole will be cored in the dorsal ridge (as opposed to the trocar needle which merely splits the tissue), with a diameter adequate to allow easy passage of the bolt. Results of our testing showed that increasing the curvature of the tines remedied the problem with penetration and splay of the barnacle tag, as was noted by Hobbs and Goebel (1982). With modification, the metal tine attachments on the Telonics barnacle tags appear adequate provided they are carefully placed well behind the blow hole, just in front of the dorsal ridge, and are used only on larger whales.

We found major differences in the effective range of the Telonics and OAR transmitters. This may largely be explained by differences in power output (40 versus 250 milliwatts), although antenna configuration may also be a factor. Generally speaking, an animal equipped with an OAR transmitter could be easily detected, even at low altitudes, from an aircraft anywhere in the Nushagak Bay region. Reception was also adequate, both in rivers and the open Bay, with receivers and antennas at locations on shore. In contrast, the Telonics transmitter could be heard at a maximum distance of 4-5 km with the receiver on shore. With the receiver in the helicopter, the Telonics transmitter was picked up at 44.2 km but only at an altitude of 229 m or greater. If the two transmitters were equivalent in terms of cost and convenience of packaging, the OAR would be the obvious choice. However, the model AB340 transmitter is no longer being manufactured, and considerable development and modification would be required to adapt currently produced OAR transmitters for application to belukhas. The resulting radios would probably cost

approximately $2,000 each (Art Wiggins, OAR, pers. commun.), which does not include the cost of construction of the backpack. The Telonics transmitters use currently produced, standard components and were purchased, with attachments and ready to apply, for $800 each. If reacquisition of signals is to be done principally from aircraft, the Telonics radios are adequate; however, the OAR transmitters are preferable if animals are to be detected and tracked principally from shipboard or shore.

VIII. Needs for Further Study

A large number of belukha whales, probably 1,000-1,500, summers annually in the Bristol Bay area, primarily in Kvichak and Nushagak bays. In this area, belukhas coexist with a substantial amount of human disturbance, although their movements and distribution are undoubtedly affected in various ways. The area offers an excellent natural laboratory in which to study the interactions between human activities and belukha whales. Such studies will require more accurate determination of abundance, distribution, movements, and behavior of whales in the area. In order to accomplish that, systematic aerial surveys and tagging and tracking of whales will be required.

In future years, distribution and abundance studies should include both Kvichak and Nushagak bays since both areas are important for belukhas, and the interrelationships among animals in them are unclear. Distribution and abundance studies will benefit greatly from marking animals with visual and radio tags.

The visual and telemetric tags developed during 1982 appear to be basically suitable for use on belukhas. Minor modifications to capture techniques and tag attachments should be tried during the next field season. Also, short- and long-term durability of tags and their possible effects on the whales should be determined.

Once techniques for capturing and tagging whales are thoroughly developed and tested, those techniques will allow us to investigate many other questions regarding belukha whales in western Alaska. Tagging should be done in several areas to examine the interrelationships of groups of belukhas which summer in various locations along the Bering, Chukchi, and Beaufort Sea coasts. By attaching satellite radios, data can be gathered on migration routes and wintering areas. Tagged animals may prove extremely useful for studies of quantitative behavior and the responses of whales to various disturbance factors.

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APPENDIX 1. Summary of belukha sightings and observations.

15 JUNE 1982

Aerial observations in fixed-wing C 180 - Lowry, Nelson

Flew along the coast from Dillingham to Snake River mouth, up Snake River 4 miles past Weary River, up the Weary River to Gnarled Mountain, down the Wood River from Aleknagik to the mouth, up the Little Muklung 3 miles and back, across the Nushagak River to Picnic Point, up the Nushagak River to Scandinavian Slough, and back to Dillingham.

0949 - 12 belukhas observed milling off the mouth of the Snake River (58°49.2'N, 158°40.3'W).

1035 - 1 belukha observed at the mouth of the Little Muklung River (59°03.6'N, 158°22.7'W) swimming south into the Nushagak River.

16 JUNE 1982

Aerial observations in Helo 57RF - Lowry, Nelson

Flew up Little Muklung River 2 miles and back, across Nushagak River to Grassy Island, across Nushagak River to mouth of Snake River, up Snake River to 3 miles past Weary River, back down Snake River to just below Weary River.

1218 - 6 belukhas sighted at mouth of Wood River (59°03.1'N, 158°24.0'W), headed upriver (east).

1313 - 3 belukhas sighted in Snake River just below junction with Weary River (58°57.7'N, 158°48.1'W), headed upriver.

18 JUNE 1982

Helo observations - Lowry

1350 - 1 belukha just south of Grassy Island (58°59.2'N, 158°30.6'W), headed south.

19 JUNE 1982

Ground observations, Weary River - Lowry, Hall, Nelson, Franzmann

1030-2000 - no belukhas sighted.

19 JUNE 1982 (continued)

Ground observations, Little Muklung River - Sellers, McNay
Observed from 1100-1730 - 2 belukhas sighted in Nushagak River about 1 mile offshore from Little Muklung River (59°02.8'N, 158°22.8'W), headed upstream.

Helo observations - Oliver, Lowry
1030 - 35 belukhas south of the Snake River mouth (58°43.6'N, 158°48.0'W), headed north.

1032 - 2 belukhas south of the Snake River mouth (58°44.8'N, 158°47.5'W), headed north about 100 yards offshore.

20 JUNE 1982

Ground observations, Weary River - Nelson, Sellers
0930-1630 - no belukhas sighted.

Ground observations, Little Muklung River - McNay, Franzmann
1300-1600 - no belukhas sighted.

Helo observation - Sellers
1230 - Igushik River (58°47.9'N, 158°48.5'W) - approximately 12 belukhas sighted, headed upstream.

22 JUNE 1982

Small boat observations - Nelson, Hall
Left Weary River camp at 1200, down Snake River, south along west side Nushagak Bay to ADF&G camp on Igushik River. Shore observations there and boat observations around to south of big mud bar and back until 1800 - no belukhas seen.

Helo observations
afternoon - Miles Croon
8 belukhas in the mouth of the Snake River (58°50.6'N, 158°44.5'W).

1810 - Hall, Nelson, McNay
7 animals including 1 juvenile sighted along the southeast bank of Igushik (58°46.8'N, 158°49.0'W) swimming upstream along the deep bank of the river.

Other observations
early morning - 100 belukhas reported at the mouth of the Wood River by air taxi pilot to Ken Taylor.

23 JUNE 1982

Small boat observations - Lowry, Nelson, Hall
Pursued and attempted to catch whales in the Igushik River (58°47.0'N, 158°49.0'W) from 1415-1630 - they were sighted in the big bend at about 1200 but were not seen passing the lower stretch of the river from 0906-1200 (Lowry observing). At least 20 animals in the group.

24 JUNE 1982

Small boat observations - Lowry, Nelson, Hall
Pursued and attempted to catch whales in the lower Igushik River (58°47.0'N, 158°49.0'W) - 8-10 animals sighted at 1100, about 12 present at 1700-1900.

25 JUNE 1982

Small boat observations - Lowry, Nelson
Three whales sighted in lower Igushik River at 0745 (58°45.0'N, 158°53.5'W).

Pursued and attempted to capture a group of 12-15 whales from 1300-1500 at big bend of Igushik (58°48.0'N, 158°49.0'W).

27 JUNE 1982

Ground observations - Lowry
1215 - 2 whales passing Hubbs Camp (58°53.7'N, 158°45.9'W) headed downstream.

28 JUNE 1982

Helo observations - Lowry
0940 - 3 whales at junction of Snake and Weary rivers (58°58.0'N, 158°49.0'W).

Other observations
early morning - pilot from Armstrong reported several whales at mouth of Little Muklung River (59°03.6'N, 158°22.7'W).

1 JULY 1982

Small boat observations - Lowry, Nelson, Oliver
Boated up Weary River 4 miles and up Snake River almost to Nunavagaluk Lake - no whales sighted.

2 JULY 1982

Helo observations - Lowry, Frost, Nelson
0900 - flew from the ship up to Weary camp, saw 6-10 whales near the point below Hubbs (58°52.3'N, 158°45.5'W), and about 3 off the point below Weary camp (58°55.7'N, 158°44.2'W).

3 JULY 1982

Ground observations - Nelson, Frost
Observed from slough on Snake River about 1 mile from Hubbs Camp (58°55.7'N, 158°43.9'W)
1200-1700 - no belukhas seen.

Helo observations - Oliver
Saw 50-100 whales southeast of the Snake River mouth about 2 miles (approximately 58°50.0'N, 158°44.0'W)

4 JULY 1982

Ground observations - Nelson, Oliver
Observed from slough on Snake River (58°55.7'N, 158°43.9'W)
1100-1650 - no belukhas seen.

Helo observations - Frost, Lowry
Flew Sheep Island, Wood River, Little Muklung area, down the Snake River beginning 5-6 miles above the Weary River, 2-3 miles up Weary River, the Igushik River mouth and lower Igushik River.

1219 - 15-20 belukhas (white) 1/4-3/4 mile off Little Muklung (59°03.6'N, 158°22.7'W), oriented south but milling.

1258 - Saw 50-60 belukhas within 1/2 mile area 1-1/2 miles south of Snake River mouth (58°51.2'N, 158°44.7'W); most were white, milling.

Other observations
Air taxi pilot reported to Lowry that some whales were seen at Portage Creek (58°52.8'N, 157°50'W) today about 0930.

4 JULY 1982 (continued)

Air taxi pilot (Doug) saw a group of some ten's of belukhas off the Black Slough/Little Muklung area (59°03.6'N, 158°22.7'W) but none up inside the slough.

5 JULY 1982

Small boat observations - Lowry, Oliver

Observed from small lagoon below Hubbs Camp (58°53.3'N, 158°46.6'W) 1100-1530 - no belukhas sighted.

Helo observations - Frost, Nelson

Flew 3-5 miles up Wood River, several miles up Black Slough/Little Muklung, up Nushagak River to 1 mile above Portage Creek, the Little Muklung-Wood River-Picnic Point triangle, then about 6-8 miles of the lower Snake, 1 mile up the Weary, out the Snake River mouth, south to the Igushik, up Igushik River to the ADF&G Commercial Fish camp - saw no whales in any of the rivers.

1319 - 30+ whales 1/2-2 miles off mouth of Little Muklung (59°03.3'N, 158°22.7'W) but none in the slough.

1443 - 30-40 (some gray animals) whales 2-3 miles south of spit at entrance to Snake River (58°50.0'N, 158°44.0'W).

Other observations

People at Wien told Budd Christman that whales were seen in Little Muklung River today.

6 JULY 1982

Helo observations - Frost, Oliver

Flew the mouth of the Little Muklung/Black Slough, up the slough, up the Nushagak River to 3-5 miles upstream from Portage Creek, back down river, looked at Black Slough to the mouth of the Wood River again, up the Wood River approximately 3 miles, over to and down the Snake River (lower 6-8 miles), out mouth of Snake to Igushik River and up the Igushik to the ADF&G Commercial Fish camp. Flew over the Little Muklung area again later in the afternoon.

1204, 1254, and 1520 - belukhas seen at the mouth and offshore of Little Muklung/Black Slough (59°03.3'N, 158°22.7'W), at least 20-30, probably 50-60+ in triangle from Black Slough-Wood River-Picnic Point. Saw 2 or 3 within 10 yards of beach on west side of Black Slough.

6 JULY 1982 (continued)

1335 - saw 30-40 whales south of Snake River mouth (58°51.0'N, 158°44.0'W).

Helo observations - Nelson, Lowry, Frost
Flew out over Snake River mouth at 1630 - 100-120 (white and gray) whales in area from Belukha Point to 2 miles south (58°52.7' to 58°50.0'N, 158°45.0' to 158°45.7'W). Many whales very close to shore, milling, some moving up small drainage channels.

7 JULY 1982

Helo observations - Frost
Flew the mouth of the Wood River/Little Muklung at 1020 - saw 15-20 belukhas off the Little Muklung River (in close) (59°03.6'N, 158°22.7'W) and 1 or 2 inside the river mouth.

Whales were driven up on the spit south of the Snake in the afternoon. The helo spotted and directed from the air. An estimated 300+ (probably more like 500-600) whales were seen in the area from about 2 miles south of Belukha Point to the north side of the mouth of the Igushik. Some whales were in very shallow (3-4 feet) water within 3/4 mile of the beach.

Ground observations - Frost
1200 - 200-300 whales seen from shore, most moving south, while helo was on beach (58°47.3'N, 158°47.0'W). Vocalizations clearly audible from beach.

8 JULY 1982

Small boat observations - Lowry, Frost
Saw an undetermined number of whales (at least 300) along the west shore between the Snake and Igushik rivers. Whales were within sight of shore and could be seen rolling and blowing in shallow water.

9 JULY 1982

Small boat/shore observations - Lowry, Frost
1400 - 4 belukhas swam upriver past Weary camp (58°56.3'N, 158°46.9'W), turned, and swam back downstream.

9 July 1982 (continued)

Helo observations - Frost

1800 - saw 100-200 whales south of Snake River mouth, well offshore from previous days' sightings (58°49.0'N, 158°42.0'W).

10 JULY 1982

Helo observations - Frost, Christman

Belukhas were spread out from about 1 or 2 miles south of Belukha Point to the Igushik River mouth. We estimated at least 400 whales, probably more like 600+, in an area several miles wide by 4 or 5 miles long. There were all sizes and colors, many very dark new calves today.

11 JULY 1982

Small boat observations - Frost, Lowry

Many belukhas were seen in the area from 2 or 3 miles south of Belukha Point to the mouth of the Igushik River. Abundance was similar to 10 July. They were present in water as shallow as 3-4 feet deep, as well as offshore. Saw grays, whites, plus quite a few very dark gray neonates, several with gray females.

12 JULY 1982

Helo observations - Frost, Lowry

Flew the mouths of the Little Muklung and Wood rivers, off Dillingham and over to the Snake, the Snake River mouth and the Igushik River mouth in the early afternoon.

1300 - 2 belukhas at the mouth of the Little Muklung River (59°03.6'N, 158°22.7'W).

1642-1727 - Flew an aerial survey in the area from Clark's Point to the Snake River mouth and south to the mouth of the Igushik River. Saw 141 whales, most in the deep water on the east side near Clark's Point and a few in the mouth of the Snake River.

Appendix II. Dead belukha whales, Nushagak Bay, 1982.

BBD-1-82 - found 29 June 1982

- 296.5 cm standard length, male, light gray in color
- found in small pool off west side of Snake River near Hubbs Camp (58°54.3'N, 158°45.5'W)
- the animal was freshly dead; nematodes in the stomach were still alive
- external and internal examination revealed no obvious abnormalities--cause of death unknown
- stomach contents consisted of remains (415 g) of 4 salmon; much of contents was expelled prior to necropsy
- skull retained by Guy Oliver

BBD-2-82 - found 1 July 1982

- 390.0 cm standard length, male, white in color
- found floating in the mouth of the Snake River at approximately 58°52.7'N, 158°46.0'W
- the animal was slightly bloated but not putrid--it had been dead for perhaps 24 hours
- external and internal examination revealed no obvious abnormalities--the animal looked like a healthy adult
- stomach was empty
- skull retained by ADF&G

BBD-3-82 - found 1 July 1982, necropsied 6 July 1982

- 187.0 cm standard length to caudal peduncle, male, gray in color
- found at the high tide line on the west side of the Snake River - 58°56.5'N, 158°46.9'W
- the animal was bloated and somewhat putrid--it had been dead for several days and probably washed up during high tide on or about 28 June

BBD-3-82 (continued)

- cause of death was obvious--the flukes had been cut off at the caudal peduncle, and there was a bleeding hole in the left orbital area and hemorrhaged area in the right postorbital region
- the stomach contained otoliths from smelt and sculpins, as well as some very tiny otoliths and fragments of a shrimp
- skull retained by ADF&G

BBD-4-82 - found 6 July 1982

- found up a slough on the west side of the Snake River just below Hubbs Camp at 58°53.7'N, 158°46.2'W
- the animal was small to medium sized, gray in color
- it was spotted from the air on 6 July but was gone the following day when we went to the location to necropsy it
- from the air it appeared to be intact and several days old

BBD-5-82 - found 7 July 1982

- 152.0 cm standard length, female, neonate, dark gray
- found on the beach south and west of the Snake River mouth at the high tide line (approximately +17 ft) at 58°47.3'N, 158°47.0'W
- the animal was intact, had the umbilicus attached and putrid, and had been dead for at least several days
- no apparent injuries or cause of death

BBD-6-82 - found 10 July 1982

- 145.0 cm standard length, male, neonate, dark gray
- found floating in the mouth of the Snake River at approximately 58°47.0'N, 158°44.3'W
- the animal was intact, had the umbilicus attached
- it had been floating for at least 2 or 3 days and was decomposing on the exposed side--slightly bloated and putrid
- no apparent injuries or cause of death