FINAL REPORT

Contract No.: NA 81 RAC 00049
Research Unit No.: 612
Reporting Period: 1 January 1982 - 31 December 1983
Number of Pages: 104

Investigations of belukha whales in coastal waters of western and northern Alaska, 1982-1983: marking and tracking of whales in Bristol Bay

Kathryn J. Frost[1], Lloyd F. Lowry[1], and Robert R. Nelson[2]

[1] Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

[2] Alaska Department of Fish and Game
P.O. Box 1148
Nome, Alaska 99762

31 December 1983

Table of Contents

List of Figures

List of Tables

I. Summary

A 2-year study was conducted in Bristol Bay, Alaska, to develop and test techniques for marking belukha whales with visual and radio tags. Information was also gathered on belukha distribution and abundance, foods and feeding, and rates and causes of mortality.

Two types of radio packages were developed: an OAR "backpack" designed to be bolted through the dorsal ridge, and a Telonics "barnacle" tag with an umbrella-stake attachment. Testing of tags and attachments revealed that the more powerful OAR radio could be received at longer distances and lower antenna heights, and that the umbrella-stake attachment penetrated too deeply for reliable use on belukhas. Visual streamer tags were fabricated which were designed to be sewn through the dorsal ridge.

In 1982, one whale was caught in Nushagak Bay, tagged with visual streamer tags, and released. In 1983 in Kvichak Bay, two whales were tagged with OAR transmitters and visual tags. The radio-tagged whales each retained the radio for about 2 weeks. The packages were shed due to migration of the attaching bolts through the tissue.

During the time that they were monitored, movements of the radio-tagged whales were restricted to Kvichak Bay and the lower Kvichak River. Recordings of the pattern of surfacings and dives revealed the three following basic types: rolls that did not occur during restricted ventilation periods, rolls that were distinctly grouped into ventilation periods separated by soundings, and a pattern in which long to very long surfacings alternated with short to very short dives. These patterns were interpreted as representing traveling, feeding, and feeding or resting in very shallow water. For the first two respiration pattern types, the percentage of total time spent at the surface ranged from 2.6 to 7.2.

Observations of distribution indicate that although belukhas are widespread in both Nushagak and Kvichak bays, whales concentrate in certain areas at certain times. In Nushagak Bay, the largest concentration (400-600) occurs near the Snake River mouth in early July. In Kvichak Bay, the areas used most commonly are off the Naknek River mouth, the Halfmoon Bay area, and the lower portion of the Kvichak River. Tidally induced currents affected belukha movements in Kvichak Bay, but such effects were not evident in Nushagak Bay. Availability of prey appears to be the major factor influencing belukha distribution. Calves are born in both bays, principally in June and July.

Counts of belukha whales from aerial surveys ranged from 86 to 334. Correction factors were developed based on surface- and dive-time data and comparisons of counts from the air and small boats. Applying the correction factor to data from the most complete aerial survey yielded an estimate of 919 belukhas in the two bays on 29 June 1983. Correction for neonates and yearlings, which are dark colored and difficult to

count from the air, raises this estimate to 1,100, which is comparable to estimates made in the 1950's.

Stomach contents of five beach-cast belukhas were examined. Contents were remains of shrimp, isopods, mussels, and fishes, including flatfishes, smelt, sculpins, and red salmon. Data from earlier studies and observations of groups of feeding whales indicate that red salmon smolt are major prey from late May to early June, while adult salmon are the primary foods from mid-June to mid-August. Calculations based on belukha abundance and food requirements indicate that in Kvichak Bay in 1983 they consumed about 6 million smolt and 280,000 adult salmon. This was about 5% of the average smolt run, 1% of the commercial red salmon catch, and 9% of the catch of other salmon species.

During 1982, six belukha carcasses were found in Nushagak Bay. In 1983, 27-31 carcasses were located or reported in Nushagak and Kvichak bays. Most of the animals for which cause of death was determined were entangled in fishing gear. Seven of the dead whales were neonates. The incidence of entanglement has increased substantially since the 1950's.

This study has demonstrated the feasibility of attaching radios to belukha whales. Further work is required to develop long-lasting attachments. Techniques developed in this study should be applied to belukhas in other areas such as Kasegaluk Lagoon.

II. Introduction

Since 1980 the Alaska Department of Fish and Game (ADF&G), 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 addressed 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). Cetaceans have proven difficult to work with for a number of reasons, including the difficulty of capture, instrument packaging and attachment, signal transmission as affected by water, and tracking as complicated by large-scale movements of whales and the relatively short duration of time spent at the sea surface. Therefore, the principal objective during the 2 years of this research project was the development of methods for live capture of belukhas in Alaskan waters and for the attachment of visual and radio tags. Efforts by Sergeant and Brodie (1969) had shown that, in favorable geographic settings, belukhas could be marked after live capture by stranding in shallow water or by using tags delivered with a harpoon-type instrument. Lensink (1961) successfully applied dart tags to belukhas in Kvichak Bay. Field trials of methods and equipment done by this project in Nushagak Bay during June and July 1982 (Lowry et al. 1982) demonstrated the feasibility of capturing belukhas in Bristol Bay by herding them into shallow water and catching and restraining them during the attachment of tags. In that year, one belukha whale was captured and marked with visual streamer tags. Extensive testing was also done of transmitter-receiver systems and attachments for radio packages. Prior to the 1983 field season, minor modifications were made to capture and tagging techniques which later resulted in successful application of radio packages to two whales.

The river systems of Bristol Bay support the largest single-species salmon fishery in the world. In 1983 the catch of red salmon (Oncorhynchus nerka) was over 35 million fish, and the total run exceeded 45 million fish (C. P. Meacham, ADF&G, pers. commun.). Fishermen there have long considered belukha whales to be serious predators of salmon and in years of poor salmon returns have urged action to control the depredation of salmon. In response to that concern, in the mid-1950's the Alaska Department of Fisheries undertook studies of the natural history and ecology of belukhas, including detailed analyses of stomach contents (Brooks 1954, 1955). Those studies concluded that belukha predation on outmigrating red salmon smolt was a serious mortality factor which retarded the restoration of depleted salmon stocks and was costly to the greatly depleted fishery. Off and on from 1956 until 1978, various nonlethal harassment activities were conducted to displace whales from the Kvichak River during May and June. The "belukha spooker" program was discontinued after 1978, and organized attempts to displace whales no longer occur. In 1982, we began to consider the interaction of salmon fisheries and belukhas as part of our belukha whale studies.

In 1954 and 1955, it was estimated that about 1,000-1,500 belukhas spent the summer in inner Bristol Bay, with considerable annual variation in numbers (Brooks 1954, 1955). Since those early estimates, which were based mostly on observations from boats, airplanes, and talks with fishermen, no progress had been made in further refining estimates of the numbers of whales or annual variations in numbers until initiation of this project in 1982. In that year, regular observations were made of belukhas in Nushagak Bay only, and the peak number using that area in late June-early July was estimated at approximately 400-600. In 1983, a systematic effort was made to estimate the total number of belukhas in both Nushagak and Kvichak bays.

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-Beaufort 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, 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 (<u>Orcinus orca</u>) (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).

It has been estimated that 1,000-1,500 belukhas are present in Bristol Bay during summer months (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. Belukhas 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 indicated an increase in abundance from May to August and considerably more whales in the area in 1954 (approximately 1,000) than in 1955 (approximately 525). 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 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.

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 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 and 1983 was conducted in Nushagak and Kvichak bays, Alaska (Fig. 1). Both are large embayments in northcentral Bristol Bay. Nushagak Bay is approximately 65 km long and tapers from approximately 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. 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.

Kvichak Bay is approximately 60 km long and tapers from 40 km across the outer portion to approximately 4 km across at its upper end. Two major rivers flow into Kvichak Bay: the Naknek River on the east side and the Kvichak River to the north. The major human habitations are the towns of Naknek (1980 population 318) and King Salmon (population 545) approximately 20 km upriver from Naknek. There are several large canneries at and near the mouth of the Naknek River. Fishing camps line the shores of most of the bay in June and July during the red salmon fishery.

Both bays are 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 currents throughout both bays. Water in the bays is very muddy. In and near major rivers, visibility in the water is effectively zero.

During June and July, one of the world's largest salmon fisheries occurs in Bristol Bay. Fishing is done with gillnets, both from shore

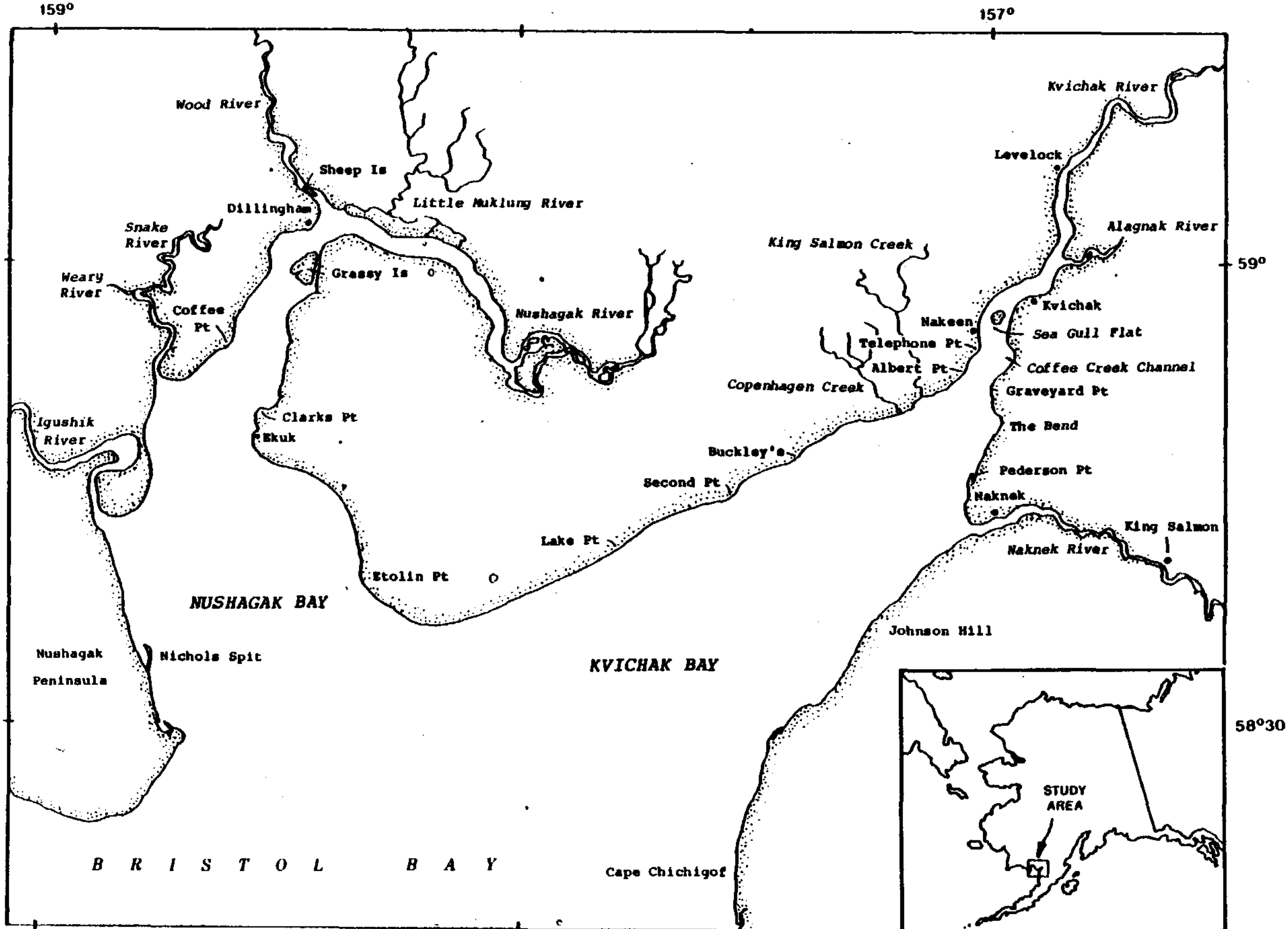


Figure 1. Map of Nushagak and Kvichak bays showing major locations mentioned in text.

(setnet) and boats (drift gillnet). During the peak fishing period in 1983, an estimated 1,000 drift-net boats and 344 setnet sites were fished in Kvichak Bay, and an additional 300-600 drift netters and up to 230 set-netters were in Nushagak Bay (ADF&G, unpubl.). Collectively, over 450 km of gillnet were fished in the two bays. The fishermen are supported by a fleet of tenders, processors, freighters, and air transports. The principal species harvested is 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 Kvichak and Nushagak bays combined in 1983 was approximately 27 million fish; 10 years earlier, in 1974, the catch was approximately 1.5 million fish.

V. Methods

Field work was conducted in Kvichak and Nushagak bays from 9 May through 15 July 1983. We used the ADF&G vessel Iliaska, a 32-ft (9.8-m) gillnet boat, as a base of operations. During most of the project, the Iliaska was anchored either off Naknek or in the Kvichak River off the abandoned Diamond J cannery. Project personnel lived aboard, and Iliaska was sometimes used for tracking radioed whales. The NOAA Bell 204 helicopter (57 RF) operated out of King Salmon from 24 May through 29 June and was used to transport personnel and supplies, conduct aerial surveys of whales, track radioed whales, locate beached carcasses, and coordinate whale-capture attempts.

Eleven people were primarily involved in the whale capture and tagging operations (Table 1). ADF&G contributed the time of eight of those at no cost to the project.

Table 1. Personnel directly involved in belukha whale capture, tagging, and tracking operations, Kvichak Bay, 1983.

Name	Dates	Affiliation
Lloyd Lowry	9 May-15 Jul	ADF&G, Fairbanks
Bob Nelson	9 May-28 Jun	ADF&G, Nome
Dick Tremaine	23 May-19 Jun	ADF&G, Fairbanks
Don Calkins	23 May-6 Jun	ADF&G, Anchorage
Kathy Frost	29 May-15 Jul	ADF&G, Fairbanks
Warren Ballard	29 May-11 Jun	ADF&G, Glennallen
Wayne Regelin	10 Jun-16 Jun	ADF&G, Fairbanks
Jack Whitman	11 Jun-24 Jun	ADF&G, Glennallen
Ken Taylor	May-Jun, intermittent	ADF&G, Dillingham
Dick Sellers	May-Jun, intermittent	ADF&G, King Salmon
Mark McNay	May-Jun, intermittent	ADF&G, King Salmon

In 1983, as in 1982 (see Lowry et al. 1982), 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). Our fleet of small boats included two Zodiac rafts (one 3.7-m and one 4.3-m) with 35-hp motors, one 6.4-m Boston whaler with 140-hp motor, and one 4.9-m aluminum riverboat with 35-hp motor. Other equipment included a 25-fathom (45.7 m) net which was 1.5 fathoms (2.8 m) deep, constructed of 6-inch (15.2-cm) stretch-mesh No. 48 thread nylon, and 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 m 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. A head net was constructed of 6-inch (15.2-cm) stretch-mesh webbing and was used to restrain the animal during tagging.

Visual tags and radiotelemetry packages were attached to two whales in 1983 (Fig. 2). Visual tags were constructed of brightly colored polyvinyl chloride fabric and measured 3.8 cm wide and 32.0 cm long. Each was numbered and preprinted with the words "RTN TO ADFG FAIRBANKS." Two pairs of visual tags were attached to each whale. They were applied by sewing a piece of plastic-coated stainless steel wire, to which one tag was attached, through the dorsal ridge and crimping the second tag onto the other side (see also Lowry et al. 1982).

The radio package (Fig. 2) consisted of an OAR (Ocean Applied Research Corp., San Diego, California) AB340 transmitter with 250-milliwatt power output, 100-millisecond pulse width, and a pulse rate of 120 per minute. Transmitter crystals were in the 164 MHz range. The transmitter was constructed as a pair of tubes, each 1.9 by 14.7 cm, with electronic components on one side and batteries on the other. A semi-rigid whip antenna 47.5 cm long was attached to the tubing which connected battery tube to electronics. Each radio operated with a saltwater switch located in the antenna and therefore transmitted only when the antenna broke the surface. The transmitter was attached to a fiberglass saddle, measuring 24 cm long by 11 cm wide by 7 cm high, and weighing approximately 575 g. The saddle was constructed by Dr. John D. Hall of Anchorage, Alaska, from a cast of a belukha dorsal ridge provided to us by Dr. Lanny Cornell, Sea World, Inc. The inner surface of the saddle was lined with 4-mm open-cell foam. Closed-cell foam was added to the top of the package to make the transmitter float with the antenna out of the water. The completed backpack transmitter was similar to that described and used by Gaskin et al. (1975) and Butler and Jennings (1980).

Packages were attached by means of a nylon rod inserted into a hole cored through the skin and blubber of each whale in the anterior portion of the dorsal ridge. Corrodible magnesium screws which were designed to release the package in approximately 6 weeks were passed through holes in the leading edge of the packages and threaded into the nylon rod.

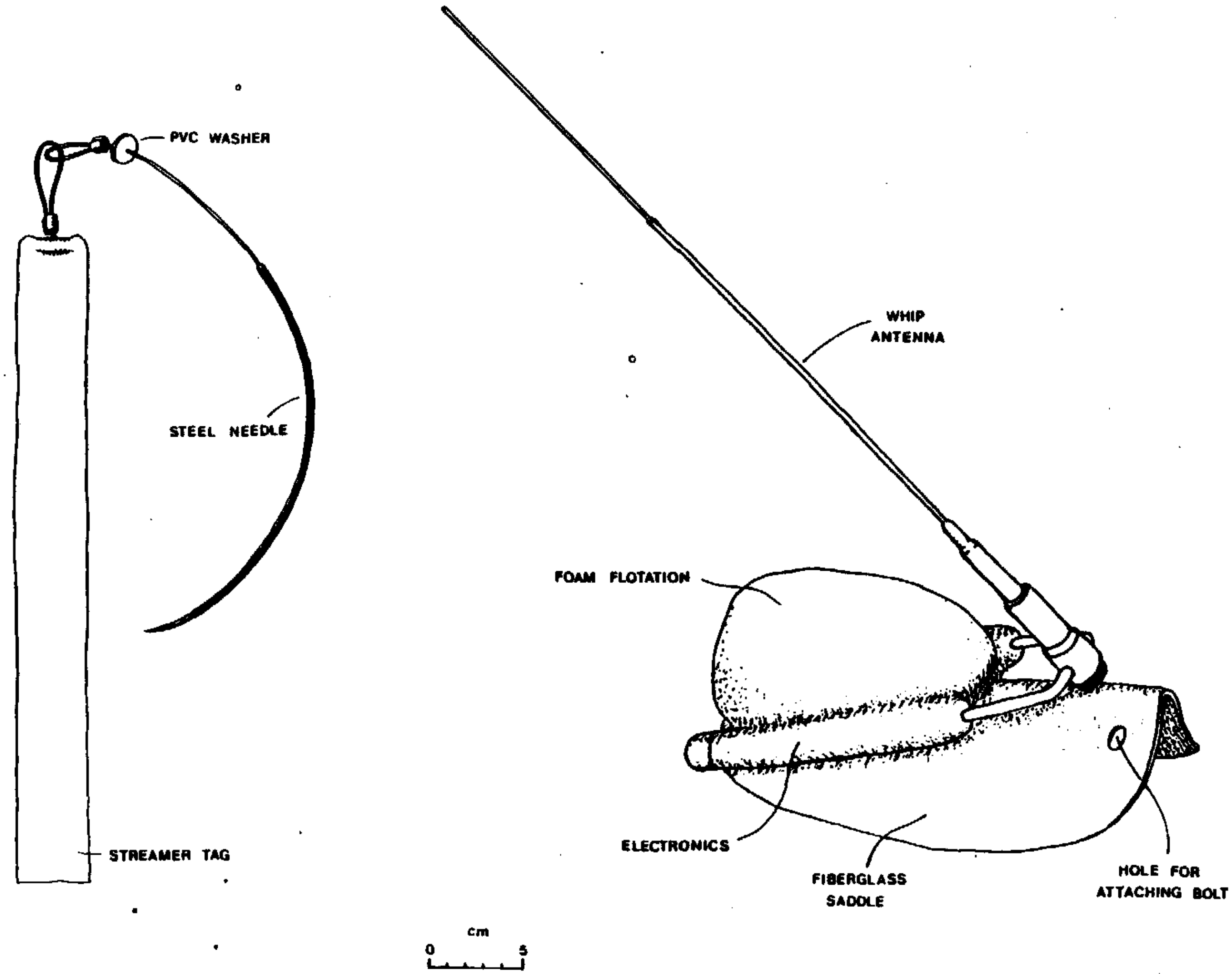


Figure 2. Illustration of visual streamer tag and OAR "backpack" radio tag.

Telonics barnacle tags as described by Mate and Harvey (1981) and Lowry et al. (1982) were taken into the field for additional testing. As a result of recalculations by the manufacturer on the frequency characteristics of the radios, antennas were cut 5 cm shorter in 1983 than they had been in 1982. It was anticipated that this would increase the effective range of the radios. The attachment tines were shortened to a length of 5.4 cm to decrease the depth of penetration. However, no Telonics radios were attached to whales.

Our primary receiving system consisted of a Telonics TR-2 receiver with automatic scanner which was connected to a two-element YAGI antenna. Antennas were either hand held (on land or in small boats), mounted at the end of a 3.7-m mast (in the Boston whaler), or mounted on the helicopter. When a helicopter was used to track, two antennas were used to more easily determine directionality of the signal. The antennas were affixed to either end of a 3-m piece of conduit secured horizontally to the nose of the aircraft. In addition to the Telonics system, we tested our ability to track radios using an OAR automatic direction finder (model ADFS-320) with an Adcock antenna. Although the ADF worked quite well at short range, it was only useful at distances of less than 1 km. In essence, by the time we were close enough to use the ADF, we already knew where the whales were and could track them more easily with hand-held YAGIs. We also attempted to use a Telonics digital data processor (model TDP-2) in combination with a two-channel strip chart recorder (American Analog Co.) as a remote data-acquisition station. We had hoped to acquire dive time:surface time data on a 24-hour basis through the use of this setup. However, due to a built-in 5-second lag in the response time of the recorder, this system proved unsuitable to the task at hand. The surfacings of the whales were closer together than the lag time of the equipment.

Dive times and surface times of the radio-tagged whales were recorded manually using digital stopwatches. Observers measured the length of all dives and recorded the number of signals per surfacing. Surface intervals were calculated by multiplying the number of signals received per surfacing by the pulse interval (0.5 sec).

Aerial surveys of Kvichak and Nushagak bays were conducted from fixed-wing aircraft or helicopter at approximately 2-week intervals from 15 April through 15 August (Table 2). Surveys were flown along the coastline approximately 0.5-0.9 km offshore at an altitude of 305 m and speeds of 183-274 km/hr. Observers did not survey a specified transect width but instead counted all of the whales they could see on their respective sides of the aircraft. When large groups of whales were encountered and a single observer was present, the aircraft sometimes circled the groups to obtain the best possible estimate. The single exception to this method was a line-transect survey on 29 July, when a predetermined grid of both bays was flown and observations were confined to a 0.9-km strip on either side of the aircraft.

Table 2. Aerial surveys of Kvichak and Nushagak bays, 15 April-14 August 1983.

Date	Time	Tide	Platform	Observer(s)
15 Apr	0912-1239	low - 1012	C-185	K. Taylor
2 May	1550-1628	low - 1357	C-185	K. Taylor
5 May	0925-1407	low - 1614	C-180	K. Taylor
17 May	0921-1204	low - 1329	C-185	L. Lowry/R. Nelson
31 May	1100-1400	low - 1332	helo	K. Frost/D. Calkins/ R. Tremaine
14 Jun	1535-1822	low - 1214	helo	K. Frost/W. Regelin
24 Jun	1318-1609	high - 1411 low - 2045	helo	K. Frost/L. Lowry
29 Jun	1034-1146 1340-1558	low - 1303	helo	K. Frost/L. Lowry
14 Jul	1206-1539	low - 1241	C-185	K. Frost/L. Lowry
14 Aug	1420-1642	low - 1402	C-185	K. Taylor

Beach-cast and floating dead belukhas were located from aircraft and boats. During 1982, most observations of beach-cast belukhas in Nushagak Bay were made on an opportunistic basis (Lowry et al. 1982). In 1983, systematic surveys were conducted in June and July. Aerial surveys were flown along the beach at altitudes of 25-50 m. Boat surveys were conducted by motoring along the shore, scanning the beach both visually and with the aid of binoculars. When a carcass was located, the animal was examined for cause of death and measured, its sex was determined, the lower jaw or several teeth were taken for age determination, and if condition permitted the stomach was examined for food remains. Additional information was obtained from ADF&G biologists in King Salmon and Dillingham and from salmon fishermen.

Fish remains in stomach contents were usually identified by their otoliths or characteristic bones. Information on probable foods was also obtained by observing feeding whales and by examining salmon caught in nets for the presence of belukha toothmarks.

VI. Results

A. Capture, Tagging, and Tracking of Whales

We conducted two field tests of the OAR and Telonics transmitters to determine the effect of partial submersion of the antennas on reception range, to compare different antenna lengths on Telonics transmitters, and to compare the range of the OAR and short-antenna Telonics transmitters. On 15 June, from 0900-1000 hours, testing was conducted from the Iliaska, which was anchored near the mouth of the Naknek River. The receiving system consisted of a Telonics receiver with a two-element YAGI antenna at approximately 5 m above sea level (ASL). A Boston whaler was used to take transmitters out to various distances. Positions were fixed by triangulation of sighting compass bearings to recognizable landmarks, and all test locations were in line of sight of the receiving antenna. One at a time at each test location, the transmitters were hand held in the water with 5 cm, half, or all of the antennas out of the water, and comparative signal strength was noted. Results (Table 3) indicated that the OAR transmitter emitted the strongest signals and was audible to 9 km with only half of its antenna emergent. The Telonics receiver had very limited range when the antennas were partly submerged. None of the transmitters emitted audible signals with 5 cm of the antenna exposed. In the case of the OAR, this was because the saltwater switch is activated at a point 16.5 cm down from the tip of the antenna.

On 5 July, testing was done in the lower Kvichak River at slack low water (Table 4). Sea state was flat calm. The short-antenna Telonics transmitter was mounted on a small board and floated in the river. The OAR package was floated approximately 6 m away to prevent interference between the two transmitters. A Boston whaler was used to transport the Telonics receiver various distances from the floating transmitters. Positions were fixed by triangulation of sighting compass bearings to prominent landmarks. Antennas were either handheld at approximately 1.5 m ASL or mounted on a mast 3.7 m ASL with the elements in vertical orientation. The OAR transmitter could be heard at all test locations; the maximum test distance was 20.1 km. The Telonics transmitter could be heard only at the 6.4- and 8.2-km locations. There was no detectable difference in signal strength between the two receiving antenna heights. The major factor affecting signal strength, other than distance, was orientation of the antenna. Maximum reception was obtained with the antenna elements vertical rather than horizontal.

We attempted to capture whales on 16 days between 27 May and 19 June (Table 5). Five of those attempts were made in the Kvichak River, four in Inner Kvichak Bay on Salmon Flats, five in eastern Kvichak Bay on the flats south of the Naknek River mouth, and two in Halfmoon Bay (Fig. 3). Whales were usually located from the helicopter. The four small boats, were then used to form a line behind the whales in an attempt to drive them, under direction of personnel in the helicopter, into shallow water over tidal flats. In most instances, the whales were difficult or impossible to drive for the distances required to reach adequately shallow water. On several days individual whales were herded for up to 90 minutes but could not be moved into water shallower than about 1.5 m. On two occasions, single whales swam into the net that was trailed behind the Boston whaler to act as a fence and close off one avenue of escape. However, in both instances the water was too deep for would-be capturers to jump in, and before the whales could be otherwise restrained they

Table 3. Comparative tests of OAR and Telonics transmitters, 15 June 1983.

Transmitter	Portion of antenna out of water	Distance from radio to receiver (km) 1.6	3.3	5.7	9.3
OAR 164.585	5 cm	no signal	no signal	no signal	no signal
	1/2	yes	yes	yes	faint
	all	strong	strong	strong	yes
Telonics 165.458 (18-cm antenna)	5 cm	no signal	no signal	no signal	no signal
	1/2	no or very faint	no signal	no signal	no signal
	all	yes	yes	yes	yes
Telonics 165.257 (23-cm antenna)	5 cm	no signal	no signal	no signal	no signal
	1/2	faint	faint	no signal	no signal
	all	strong	strong	yes	yes

Table 4. Comparative tests of OAR and Telonics transmitters, 5 July 1983.

Transmitter	Antenna height (m)	Distance from radio to receiver (km) 6.4	8.2	11.0	11.9	20.1
OAR 164.535	1.5	strong	strong	moderate	moderate	faint
	3.7	strong	strong	moderate	moderate	faint
Telonics 165.857 (18-cm antenna)	1.5	moderate	moderate-weak	no signal	no signal	no signal
	3.7	moderate	moderate-weak	no signal	no signal	no signal

Table 5. Dates and locations at which we attempted to catch whales in Bristol Bay during May-June 1983.

Date	Location	Comments
27 May	Alagnak R. mouth	20-25 whales in several small groups; chased 2 groups of 2 into shallow water, but they escaped downriver.
28 May	Sea Gull Flat	Chased 2 or 3 into shallow water but couldn't hold them there.
30 May	Telephone Pt.	20+ whales; 2 or 3 whales temporarily stuck on sandbar but got off. Too much deep water nearby.
31 May	S. Alagnak R. mouth	Moved 2 different gray animals into shallow water; worked for a while but couldn't catch them.
1 Jun	King Salmon Creek/ Copenhagen Creek	Followed/pushed group downstream; set net off spit but whales broke out and headed offshore; followed another group but they broke out between the boats to deep water.
2 Jun	Nakeen	Whales disappeared as soon as boats lined up.
3 Jun	Salmon Flats	Came really close; had 3 or 4 whales right along bar, tide dropping; wind came up quickly just as whales reached bottleneck in spit; lost whales because we couldn't see them.
4 Jun	Salmon Flats	10-15 whales in this area; moved 1 white animal up against bar, but it was a cut bank, water too deep, whale got away.
6 Jun	Salmon Flats	Tried to drive but water too rough.
8 Jun	Big Flat	70+ whales feeding; worked 1 large white animal for over 1-1/2 hr; it hit net, thrashed around, then swam under it; we kept it from going offshore, but couldn't move it into less than 1 m water; finally, helo ran low on fuel and tide was coming in, wind picked up.

Table 5. Continued.

Date	Location	Comments
11 Jun	Big Flat	Most whales offshore and moving upriver in deep water; we were unable to move them into shallower water.
14 Jun	Big Flat	Worked a big white animal until it turned offshore and ran hard upriver to the channel.
15 Jun	Big Flat	Whales in tight group; cut out a young 1- or 2-yr-old and worked it for >1 hr; pushed it into net but it got out; helo ran low on fuel, wind picked up, had to give up.
16 Jun	Big Flat	Whales very difficult to drive; would not be moved near to shore; water muddy, windy, too foggy to spot from helo.
18 Jun	Halfmoon Bay	SUCCESS! Tagged adult white female. Tide low and falling during capture; extensive flats in area, including long bars with no channels or breaks to allow escape; whale became disoriented, swam along a bar and was surrounded and captured.
19 Jun	Halfmoon Bay	Attempted to drive, futile; rain, wind, waves; no whales.

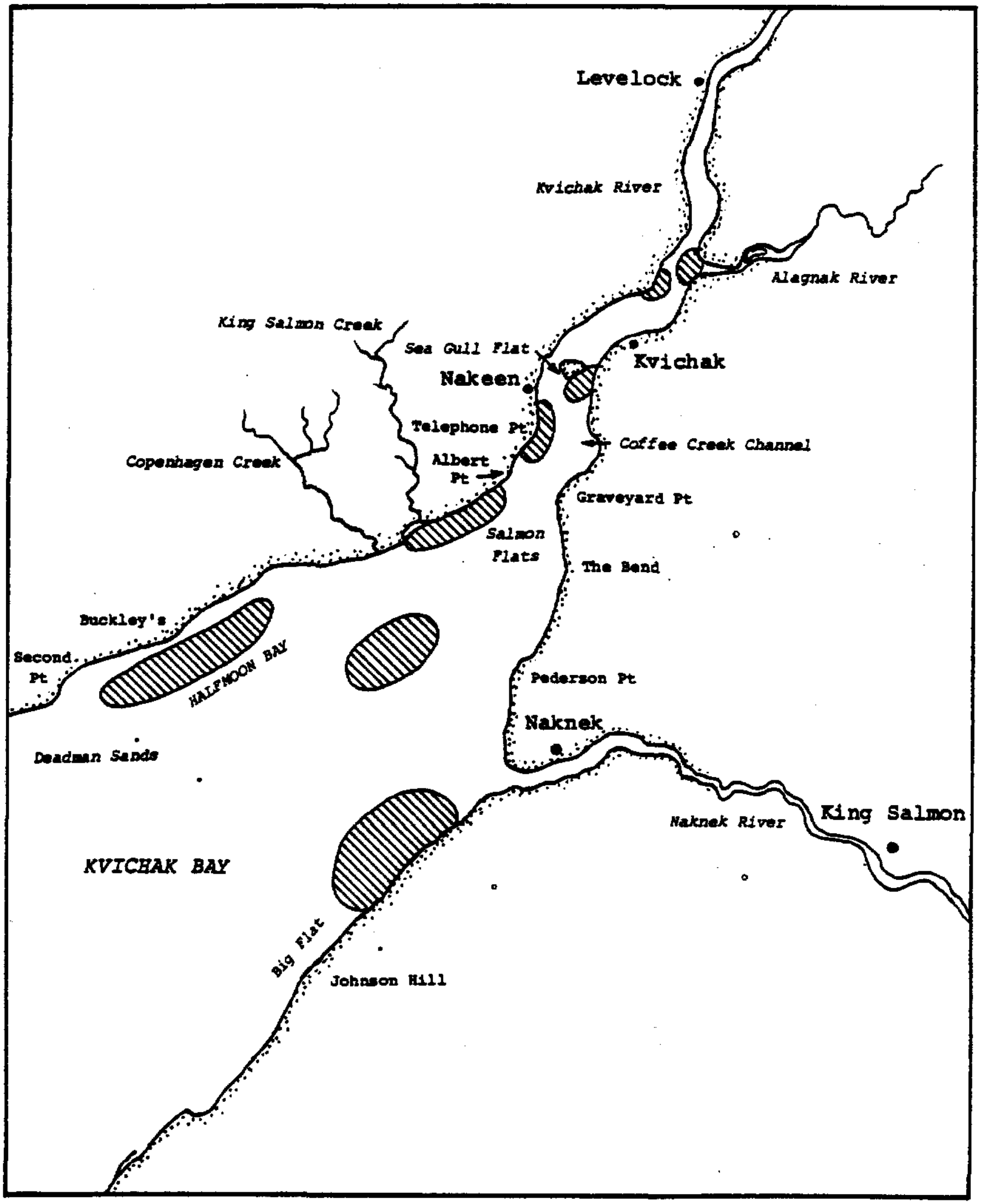


Figure 3. Map showing locations at which whale catching was attempted in May-June 1983.

swam under the net and escaped. Subsequent conversations with local Eskimo residents indicated that whales were sometimes driven for 2-3 hours or more before becoming sufficiently exhausted to catch.

Despite the difficulty in capturing, we successfully attached visual tags and radio transmitters to two whales (Table 6). The first whale to be tagged (later referred to as "BB") was caught between 1530 and 1930 hours on 9 June in a salmon setnet about 7 km south of the Naknek River mouth. Two employees of the Bumblebee Cannery disentangled this small belukha from the net and transported him by truck to the cannery, where he was covered with canvas and kept wet until our tagging crew was notified and arrived by helicopter. The whale had superficial net marks on the caudal peduncle and flukes but did not appear badly hurt. When we arrived, the whale was respiring regularly and lying quietly in the truck bed. It was transported by truck to the beach at the south side of the Naknek River mouth, where it was measured, tagged, and released at about 2145, using a stretcher and help from cannery workers to carry it into the water. As soon as the whale touched the water, it began to move and upon release swam away to the west in an apparently normal manner. The whale was monitored for 30 minutes after release to ensure proper functioning of the radio.

Table 6. Belukha whales captured and tagged in Kvichak Bay, June 1983.

Whale	Transmitter	Visual tags	Color	SL (cm)	Comments
"BB"	OAR 164.535	Red 11, 12 Blue 01, 02	dark gray	230	Caught in salmon setnet on 9 Jun
"Mama"	OAR 164.585	Red 13, 14 Blue 03, 04	white	370	Caught in Halfmoon Bay on 18 Jun

On 18 July, a second whale (later referred to as "Mama") was tagged. At approximately 1500 hours, approximately 1 hour before a +6-cm low tide, our four small boats assembled near Copenhagen Creek and moved south into central Halfmoon Bay where the helicopter had located 20-30 dispersed whales in very shallow water. Almost immediately upon arrival of the boats, the whales scattered and disappeared in the muddy water. However, one large white animal swam directly toward a long, shoaling sandbar. When the boats surrounded it and nets were set on one side, the whale submerged and laid on the bottom, invisible from either the boats or helicopter, for 5-10 minutes. Shortly thereafter, the wake of the whale appeared running offshore along the sandbar. Two boats blocked its retreat, and at approximately 1615 hours, when the other two boats arrived, the whale was physically captured. She struggled very little, and after a head net was put on she lay quietly, lifting her head to breathe every minute or so. The whale was restrained for 10-15 minutes while tags

were applied, after which the head net was removed and the whale swam away toward deeper water. As with the first whale, the radio was monitored for approximately 30 minutes after the release to ensure that it functioned properly.

Each of the whales to which we attached radio packages retained the radios for approximately 2 weeks. BB was last located with the radio attached on the 13th day after tagging. On the 14th day, the radio was discovered floating free, antenna upright, and emitting a constant signal approximately 3 km northwest of BB's last known location. Mama's radio remained on for 12-14 days. She was last located on the 11th day after tagging. On the 12th day, we did not attempt to locate her, and on the 13th and 14th days we were unable to locate her in the customary areas. On the 15th day, the radio was recovered approximately 20 km southwest of the last known location. The radio was lying on its side at the high-tide line with the antenna partially buried in the gravel. Both radios came off by working their way out of the tissue through which they were bolted. The magnesium screws, designed to last 4-6 weeks, were partially corroded but intact and were still in place in the nylon rod.

Determining the location of tagged whales was usually quite easy. The OAR radio worn by BB (frequency 164.535) emitted a very strong, clear signal that could be received over substantial distances (Table 7). With two YAGI antennas mounted on the front of a helicopter flying at 305 m, we routinely picked up moderate to strong signals over 30 km distant. On one occasion, a signal was received at 59 km. This signal was "moderate" in strength and could have been heard from considerably farther away. Using hand-held or mast-mounted YAGI antennas in a Boston whaler or on the Iliaska, we were able to receive and track BB from 20-30 km distant. As previously discussed and shown in Table 4, there was little apparent difference in reception between antennas hand held at 1.9-2.0 m and those mast mounted at 3-4 m.

The OAR radio worn by Mama (frequency 164.585), although supposedly identical to the one worn by BB, was considerably more difficult to track. The maximum reception distance from the helicopter (305 m antenna height) was 42 km, with a signal that was considered weak. Maximum recorded reception for Mama's radio from the Boston whaler (antenna height 2-3 m) was 23 km (signal strength moderate), and on at least several occasions we could not receive signals at a distance of 30 km.

During the 14 days that BB was radio-tagged, his position was determined on 16 occasions (Appendix I, Fig. 4). For the first 26+ hours after tagging, he remained in the Naknek River mouth area near where he was released. On the morning of 11 June, approximately 36 hours after his release and 9 hours after he was known to be off the Naknek River mouth, BB was visually relocated by an ADF&G fixed-wing pilot in the area of the Bend about 14 km to the north. Later that same day, he moved down the west side of Kvichak Bay against a flooding tide to near Second Point, a distance of about 30 km in approximately 6 hours.

Table 7. Distances at which signals were received from OAR radio 164.535 ("BB").

Date	Time	Antenna height (m)	Distance (km) to whale	Signal strength
10 Jun	1340	305	18	strong
	1706	2-4	7-8	weak
11 Jun	1250	2	20+	weak
12 Jun	1100	4	27	moderate
	2350	4	22+	weak
13 Jun	1100	2-4	31	moderate
14 Jun	1000	305	35	strong
	1725	305	37	moderate
	1800	305	59	moderate
15 Jun	1030	305	35+	strong
	1640	6-7	35+	weak
16 Jun	1510-1550	2	20	strong
21 Jun	1430	100	18+	moderate
22 Jun	1045	2-3	18+	moderate
23 Jun	1210	2-3	30+	weak
	1328	305	43	moderate-strong

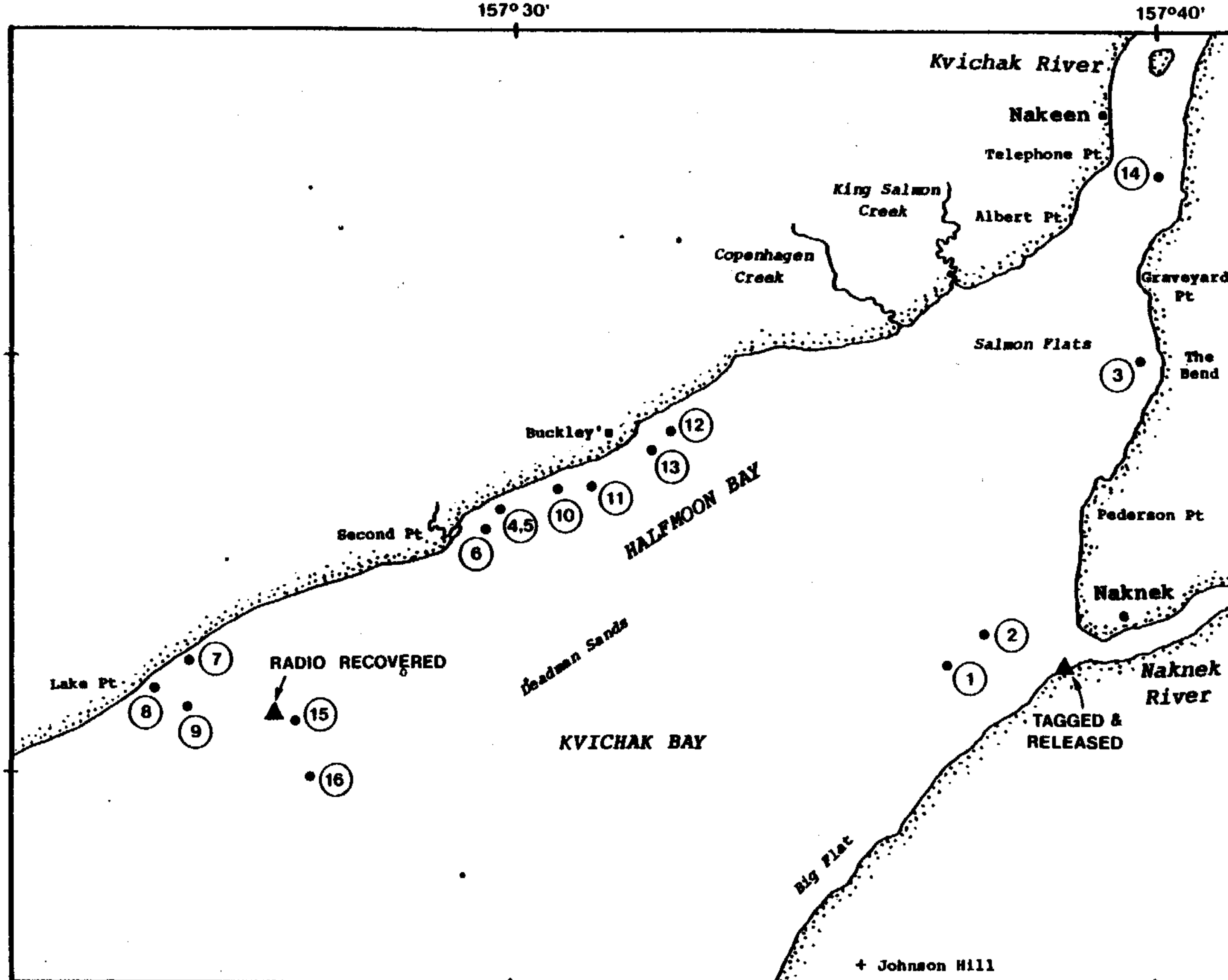


Figure 4. Relocations of the whale "BB" (frequency 164.535) from the time of tagging on 9 June at 2145 until recovery of the radio on 23 June 1983 at 1410. 1-10 June, 1630; 2-10 June, 2215; 3-11 June, 0830; 4-11 June, 1500; 5-12 June, 1150; 6-12 June, 1530; 7-13 June, 1200; 8-13 June, 1625; 9-14 June, 1600, 1745; 10-16 June, 1640; 11-18 June, 1000; 12-30 June, 1314; 13-20 June, 1730; 14-21 June, 1157; 15-22 June, 1319; 16-22 Jun, 1737.

During the subsequent 11 days, BB's location was determined on 12 occasions. Eleven of those positions were either in Halfmoon Bay or the Lake Point area and were within 30 km of each other. Between sometime before midnight on 20 June and about noon on the 21st, BB moved 25 km from mid-Halfmoon Bay to Graveyard Point and by later that afternoon back to Halfmoon Bay. On at least two other occasions, he moved to the northeast toward Graveyard Point and back to Halfmoon Bay in a 12- to 24-hour period. By noon on 22 June, he was 45 km from his location at noon the day before. Several times relocations were within 1-2 km of each other over 24- to 32-hour periods. It is unknown whether BB had remained in the same area for this duration or had moved from that area and returned.

During the 15 days from Mama's capture to the recovery of her radio, her position was determined on 14 occasions (Appendix II, Fig. 5). Within the first 25 hours after capture and release, she swam a minimum of 60 km and perhaps considerably more (based on a 20-km maximum range of her radio, which is probably quite conservative). On 20 June, she moved at least 20 km and probably over 30 km to the northeast in about 3 hours. One day later she was back again near her original position. Although fixes of her position are not frequent enough to determine daily movement patterns, they do demonstrate that substantial movements can and do occur over relatively short time periods. During most of the time Mama was radioed, she moved between the west side of Kvichak Bay and the mouth of the river near Graveyard. On several occasions, her signal was heard from the direction of the Naknek River mouth/Big Flat, but the position was not fixed.

The effect of tides on movements of radioed whales is unclear (Table 8). On seven occasions, BB's direction of movement over a period of several hours was known and could be compared to tidal stage. In five instances, he moved against either falling or flooding tides, while in two instances he moved with the tide. Mama's direction of movement in relation to the tide was also known for seven time periods. She moved with the tide three times, against it twice, and remained essentially stationary twice.

Prior to describing the respiration patterns of telemetered belukhas, some definition of terms is required. The terminology that we will use, which is similar to that of Watson and Gaskin (1983), is as follows:

roll - a single surfacing of a whale

surface period - the length of time a whale is visible above the air-water interface during a single roll

ventilation period - the total time from the beginning to the end of a series of rolls, with less than 30 seconds separating rolls within the series

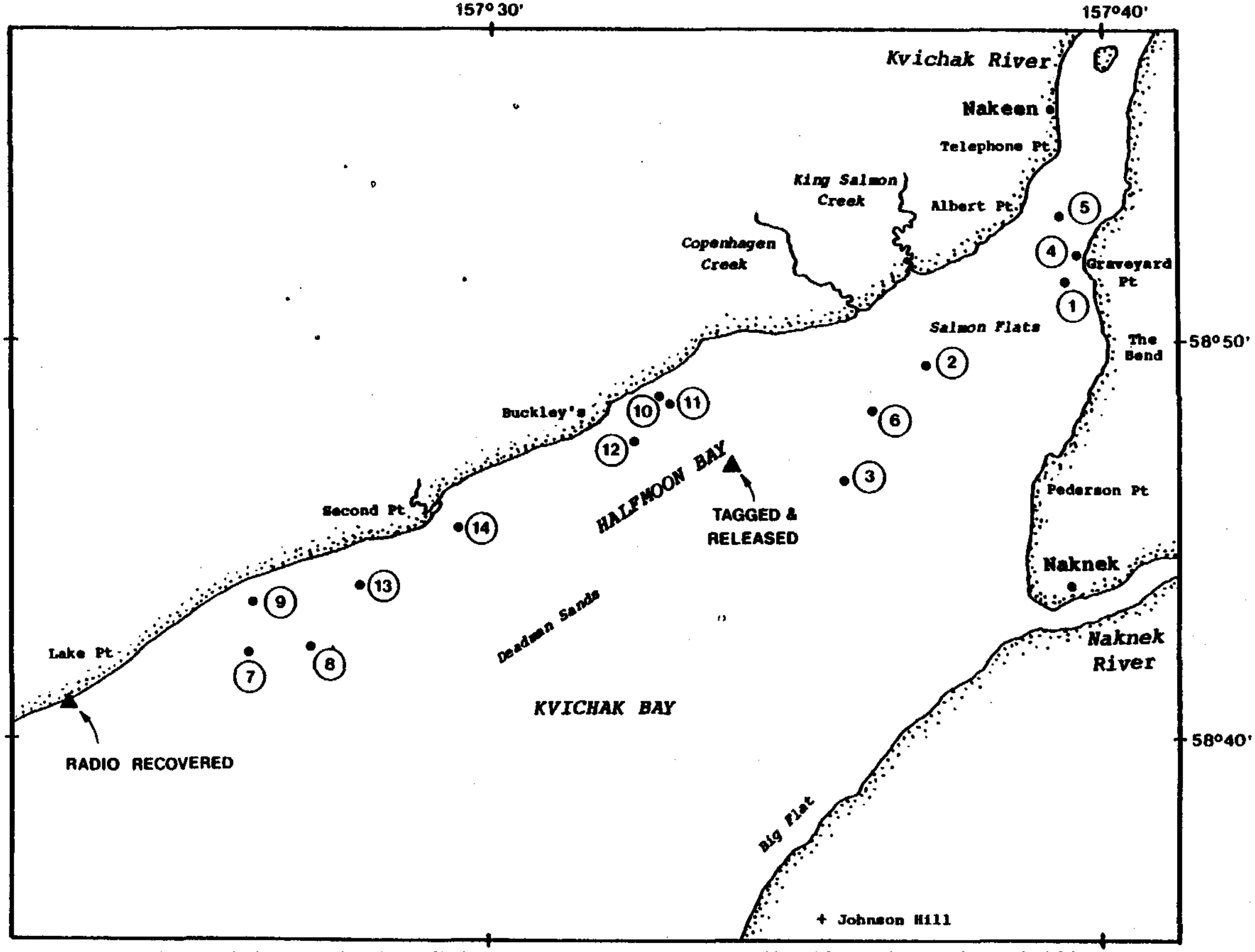


Figure 5. Relocations of the whale "Mama" (frequency 164.585) from the time of tagging at 1630 on 18 June until recovery of the radio at 1500 on 3 July. 1-19 June, 1800; 2-20 June, 1351; 3-20 June, 1730; 4-21 June, 1157; 5-21 June, 1232; 6-22 June, 1805; 7-23 June, 1405; 8-23 June, 1425; 9-23 June, 1648; 10-24 June, 1339; 11-27 June, 1255; 12-27 June, 1502; 13-28 June, 1110; 14-29 June, 1410.

Table 8. Movements of two radio-tagged whales in relation to tidal stage.

Date	Time	Tidal stage	Direction of whale	Relation to tide
"BB"				
11 Jun	1015-1530	flooding	out	against
13 Jun	1200-1625	flooding	out	against
17 Jun	1500-1900	flooding	in	with
	2200-2400	falling	in	against
18 Jun	0700-1000	flooding	out	against/slack
19 Jun	0400-1000	flooding	out	against
21 Jun	1200-1430	falling	out	with
"Mama"				
20 Jun	1350-1730	falling	out	with
21 Jun	1157-1430	high/falling	stationary	
22 Jun	1455-1805	falling	in	against
23 Jun	1405-1648	high/falling	stationary	
24 Jun	1230-1340	flooding	in	with
27 Jun	1255-1500	flooding	out (slightly)	against (slightly)
28 Jun	1110-1430	flooding	in	with

dive - a single submersion of a whale, either between rolls or between ventilation periods

sounding period - dives between sequences of rolls, almost always lasting greater than 30 seconds

In the following presentation of results we have assumed that the length of time during which a signal was received from the transmitter is equivalent to the surface period and, correspondingly, the dive period equals the length of time during which no signal was heard. Based on the placement of radio packages on the whales and our observations of swimming and diving patterns, we think this assumption is basically correct, with one exception that will be discussed.

We took respiration pattern data for the whale BB for a total of 726 minutes. Of that, 38 minutes of data taken on the day after capture were not used in the analysis, leaving 688 minutes of usable data which included 1,327 surfacings and 1,325 dives. All data were plotted graphically then grouped into similar patterns (Figs. 6-9). Following Watson and Gaskin (1983), we divided our data into two basic patterns: type A in which rolls did not occur during restricted ventilation periods, and type B in which rolls were distinctly grouped into ventilation periods separated by soundings. Each major type of pattern was further subdivided as follows: type A1 - surfacings irregular and often widely spaced; type A2 - surfacings irregular and frequent with few long dives; type B1 - surfacings clumped into a very regular series of ventilation periods; type B2 - surfacings generally clumped into ventilation periods but with some irregularities. For Mama we recorded respiration data for a total of 224 minutes, of which 64 were taken on the evening of capture and 18 were taken when signals were weak and not considered reliable, yielding 142 minutes of usable data. This included 325 surfacings and 323 dives. Two patterns were recognizable (Figs. 10 and 11): one corresponded to type A1, and the second, which we designated type C, consisted of long to very long surfacings alternated with short to very short dives.

The type C pattern observed for the whale Mama was unlike anything we expected. When we first recorded signals of this type, i.e., long periods of continuous signals with irregular short-to-moderate interruptions, we were concerned that either the radio package had been released from the whale or that Mama was somehow incapacitated. Therefore, immediately subsequent to recording the data of 23 June (Fig. 11), we followed the signal to its origin. After tracking shoreward from our data-recording position for about 10 minutes, the signal stopped and we saw four large wakes caused by whales passing by our boat to seaward. Water depth in that location was 1.3 m. We therefore interpret the type C pattern as indicative of feeding (or perhaps resting or socializing) in very shallow water where the antenna of the transmitter seldom goes below the surface. We did not actually see the whales when we located them, indicating that their backs were not necessarily above the surface for the entire time we recorded type C signals.

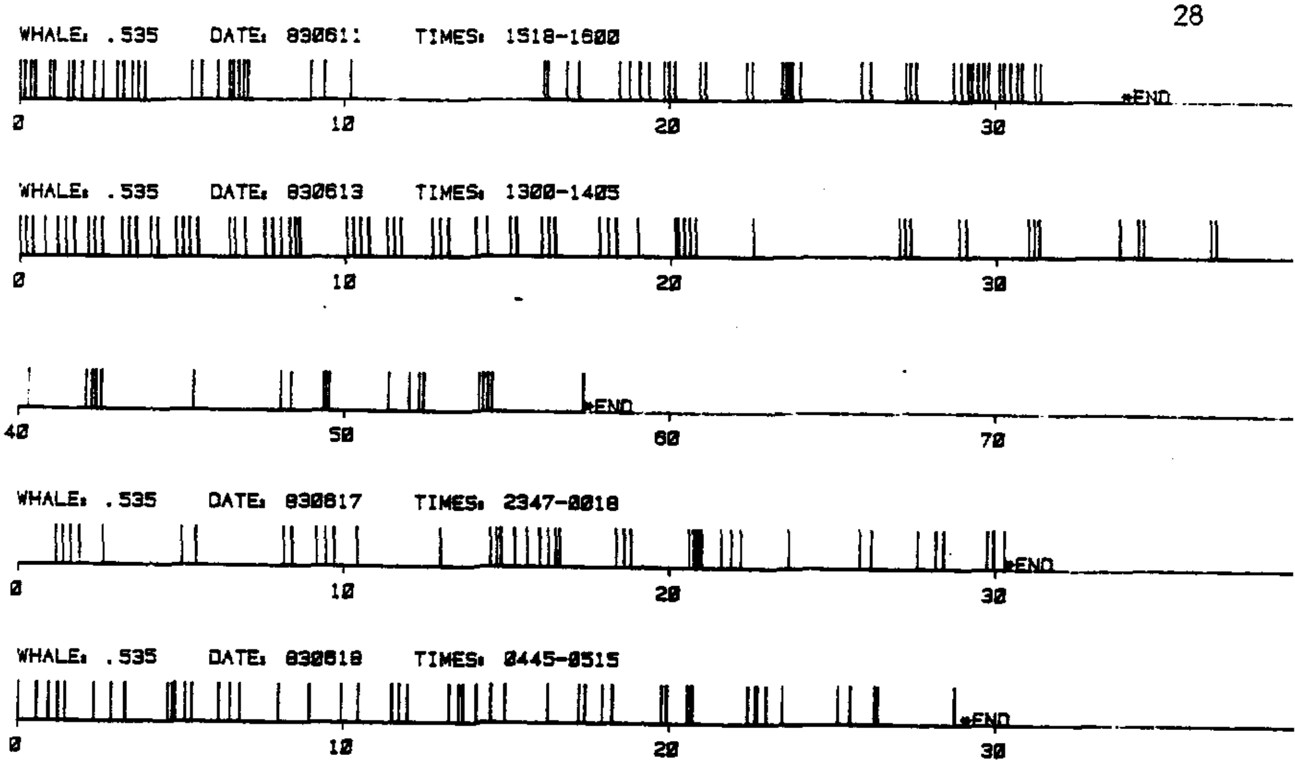


Figure 6. Type A1 respiration pattern for the whale BB.

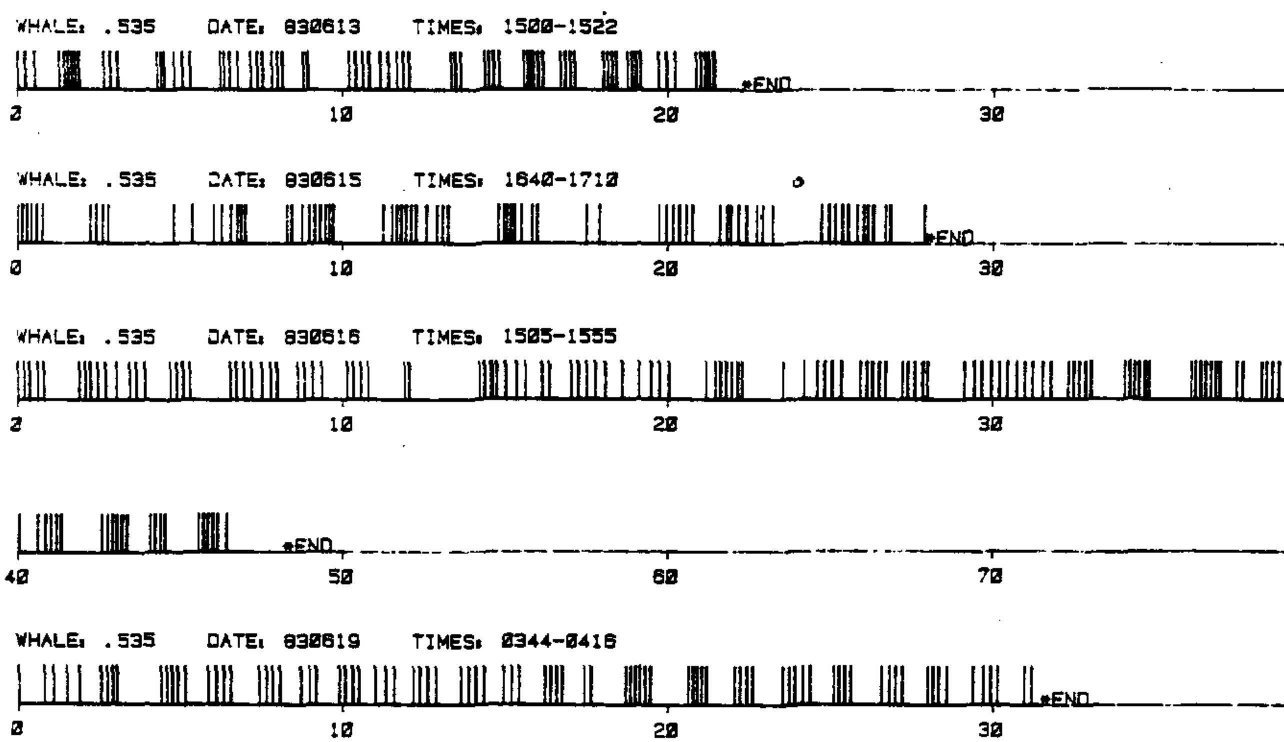


Figure 7. Type A2 respiration pattern for the whale BB.

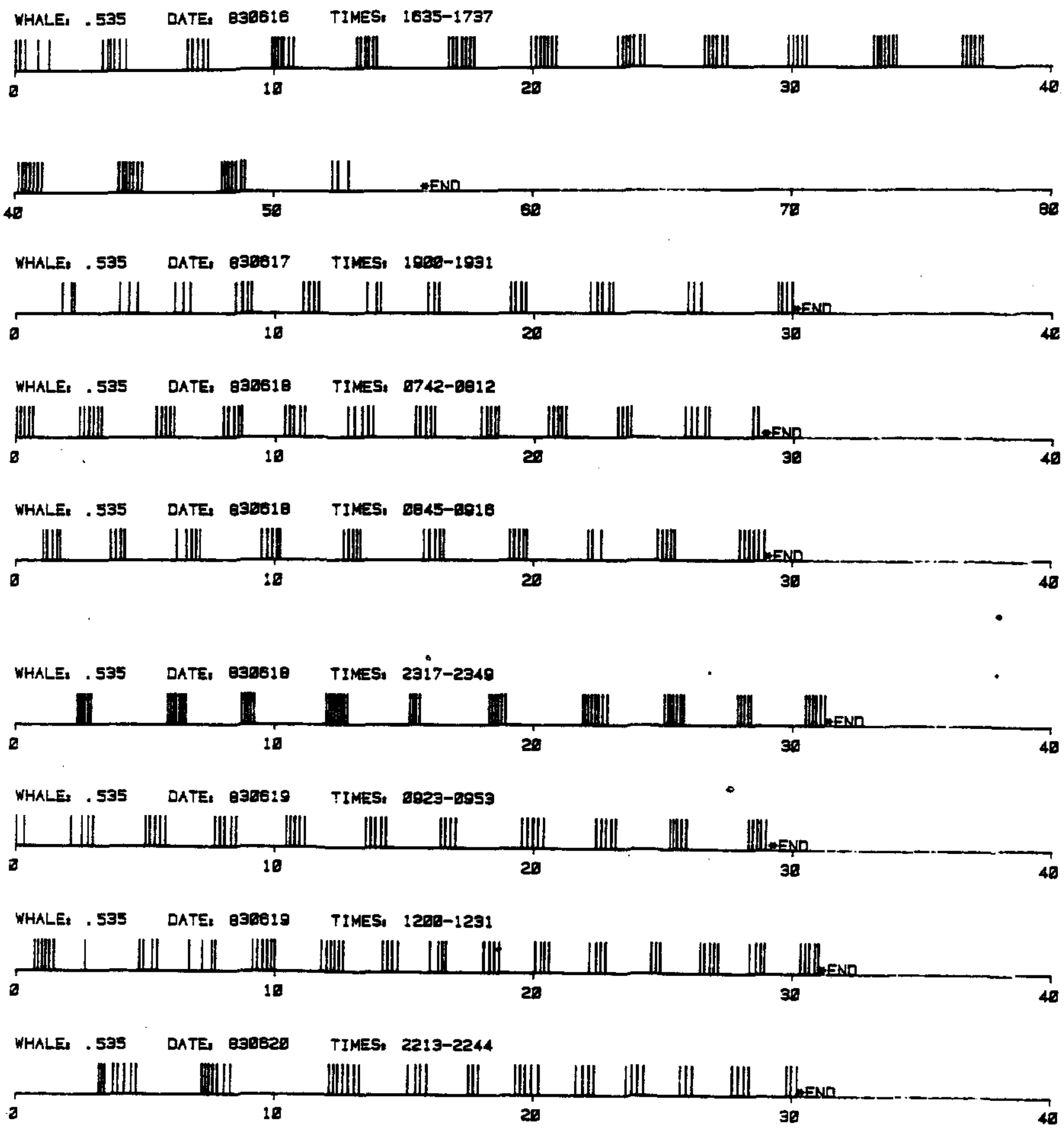


Figure 8. Type B1 respiration pattern for the whale BB.

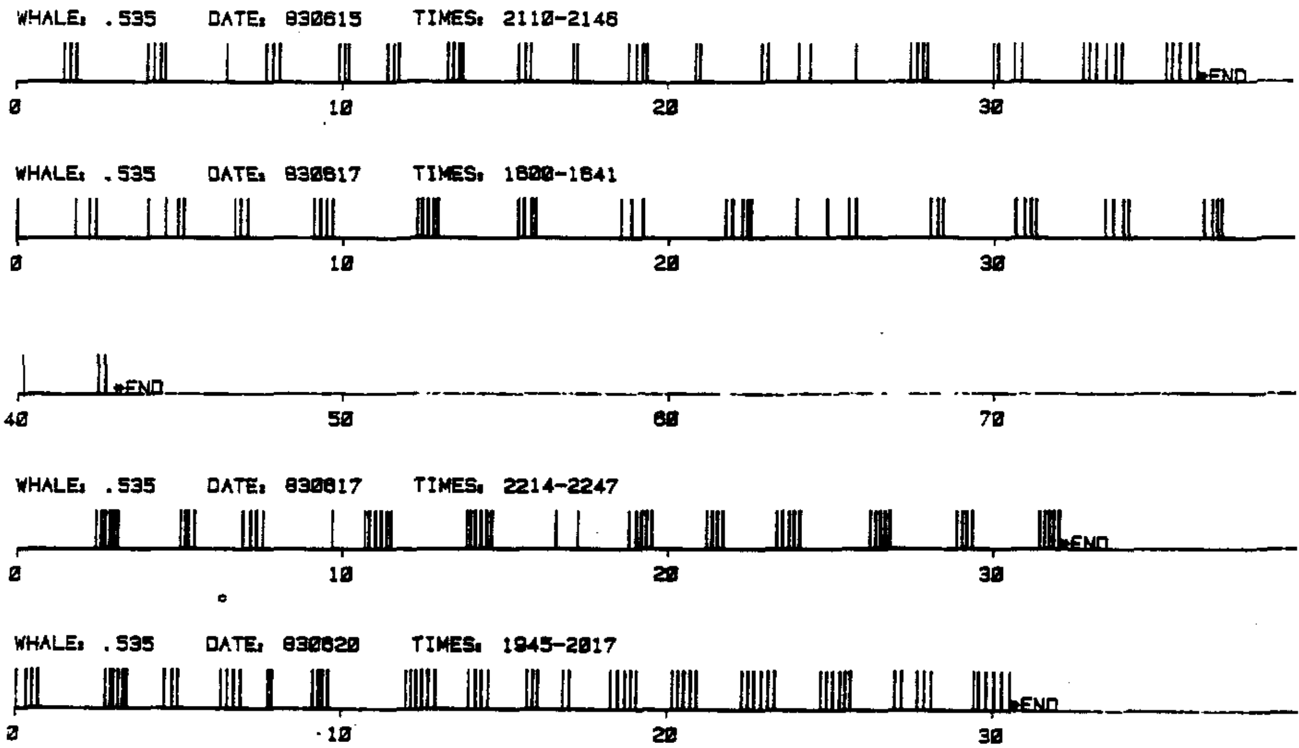


Figure 9. Type B2 respiration pattern for the whale BB.

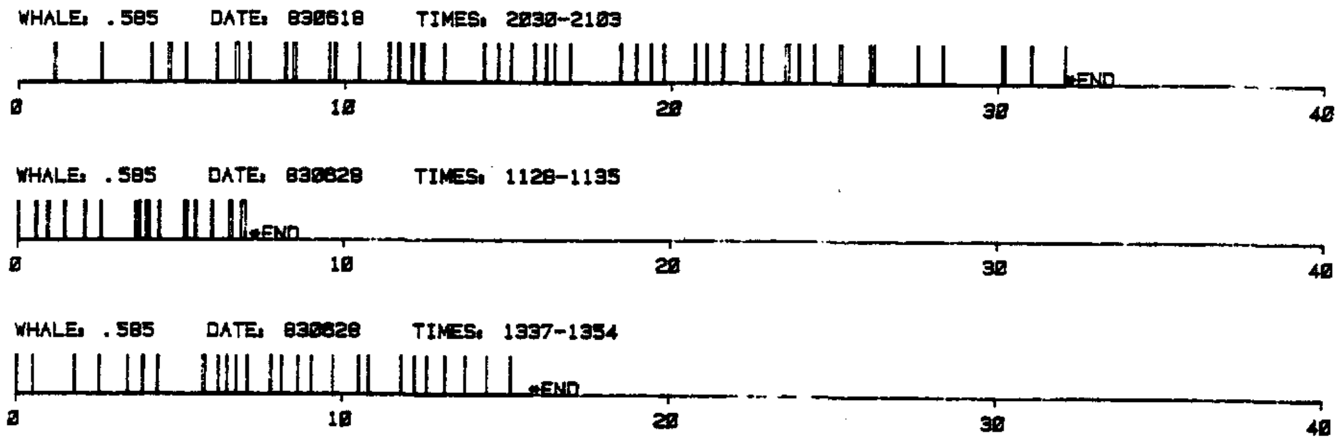


Figure 10. Type A1 respiration pattern for the whale Mama.

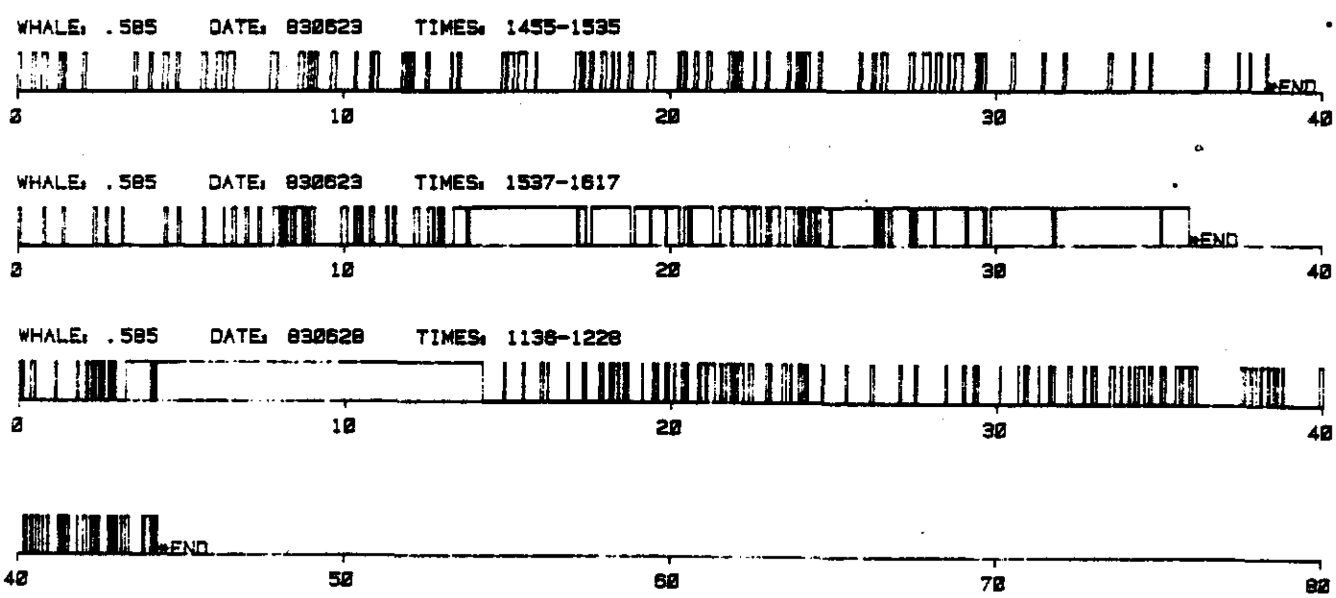


Figure 11. Type C respiration pattern for the whale Mama.

Characteristics of the respiration patterns of telemetered whales are shown in Table 9. Pattern A was recorded for 41% of the total observation time of BB. Types A1 and A2 differed in terms of the surfacing rate and the relative amounts of time spent above and below the surface. This is not surprising since differences in those characteristics were used to select the data sets. In pattern A1, the mean surface interval (0.94 sec) was significantly shorter than in type A2 (1.50 sec; $t = 15.06$, $p < 0.01$), and the mean length of dive was significantly longer (36.07 vs. 19.55 sec; $t = 5.59$, $p < 0.01$), which suggests that these two patterns are actually discrete. Due to the greater frequency of surfacings, the proportion of time spent at the surface was almost three times as great in pattern A2 as in A1. For BB, pattern B occurred during 59% of the data collection periods. Types B1 and B2 were very similar except for the higher incidence of single rolls during type B2 (Figs. 8 and 9). There was no significant difference in the mean length of surfacings (1.150 vs. 1.151 sec; $t = 0.03$, $p > 0.90$) or of dives (32.68 vs. 34.16 sec; $t = 0.41$, $p > 0.50$), and the surfacing rates and proportions of time spent above and below the surface were virtually identical. In pattern B1, the respiration sequence consisted of a ventilation period averaging 4.9 rolls (range 1-8), separated by dives lasting about 10 seconds, followed by a sounding which lasted an average of 2 minutes and 5 seconds (range 1 min 3 sec to 3 min 48 sec).

Pattern A1 for Mama was recorded during 16% of the usable data. Although the surfacing rate was similar to type A1 for BB, the proportion of time spent at the surface was considerably greater due to a significantly greater average surface interval (2.22 vs. 0.94 sec; $t = 10.62$, $p < 0.01$). The average length of dives of BB (36.07 sec) and Mama (29.78 sec) was not significantly different ($t = 0.89$, $p > 0.30$). Pattern type C for Mama was unlike all others and differed most notably in that signals were received during 40% of the monitoring periods. The longest recorded dive for BB was 5 minutes 56 seconds, which was over twice as long as for Mama (2 min 8 sec).

B. Distribution, Abundance, and Movements

Observations of the distribution and movements of belukha whales in Nushagak and Kvichak bays were made during systematic aerial surveys flown at approximately 2-week intervals, in the course of whale capture attempts, and on an opportunistic basis from locations onshore, from the Iliaska while anchored in Kvichak River, and during transit in the helicopter and small boats.

All observations from Nushagak Bay are listed in Appendix III and summarized in Table 10. In summarizing those observations, we divided the bay into six geographical subareas: Igushik and Snake rivers, Snake River mouth - Clarks Point, Wood River, and central part and outer Nushagak Bay (Fig. 12). Belukhas were seen in the Nushagak on all aerial surveys except the last in mid-August (Table 10). Maximum numbers were observed in late June and mid-July. Most sightings in Nushagak Bay were

Table 9. Characteristics of the respiration patterns of telemetered whales.

Whale	Pattern type	Mean no. of surfacings per min	% time at surface	% time diving	No. rolls per ventilation period	Mean length of vent. period (min)	Mean length of sounding period (min)	% of total observation time
BB	A1	1.63	2.6	97.4				22
BB	A2	2.86	7.2	92.8				19
BB	B1	1.77	3.4	96.6	4.9	0.73	2.09	38
BB	B2	1.70	3.3	96.7				21
BB	overall	1.91	3.8	96.2				
Mama	A1	1.88	6.9	93.1				16
Mama	C	2.38	40.5	59.5				84
Mama	overall	2.31	34.7	65.3				

Table 10. Summary of whale observations in Nushagak Bay, April-August 1983.

Date	Igushik River	Snake River	Snake R. mouth-Clarks Point	Central Nushagak	Wood River	Outer bay
	Number of whales sighted					
15 Apr	37	3	14	0	0	5
2 May	0	7	5	0	--	0
5 May	--	--	--	0	0	6
17 May	12	11	0	0	0	0
31 May	0	0	0	2	8	0
3 Jun	--	--	20+	--	0	--
14 Jun	10	2	4	0	2	0
24 Jun	0	0	50	3	12	1
27 Jun	15	--	54	0	24+	--
29 Jun	17	0	107	2	0	0
12 Jul	--	--	90+	--	--	0
13 Jul	--	25+	87+	--	--	--
14 Jul	0	15	119	0	0	0
14 Aug	0	0	0	0	--	0

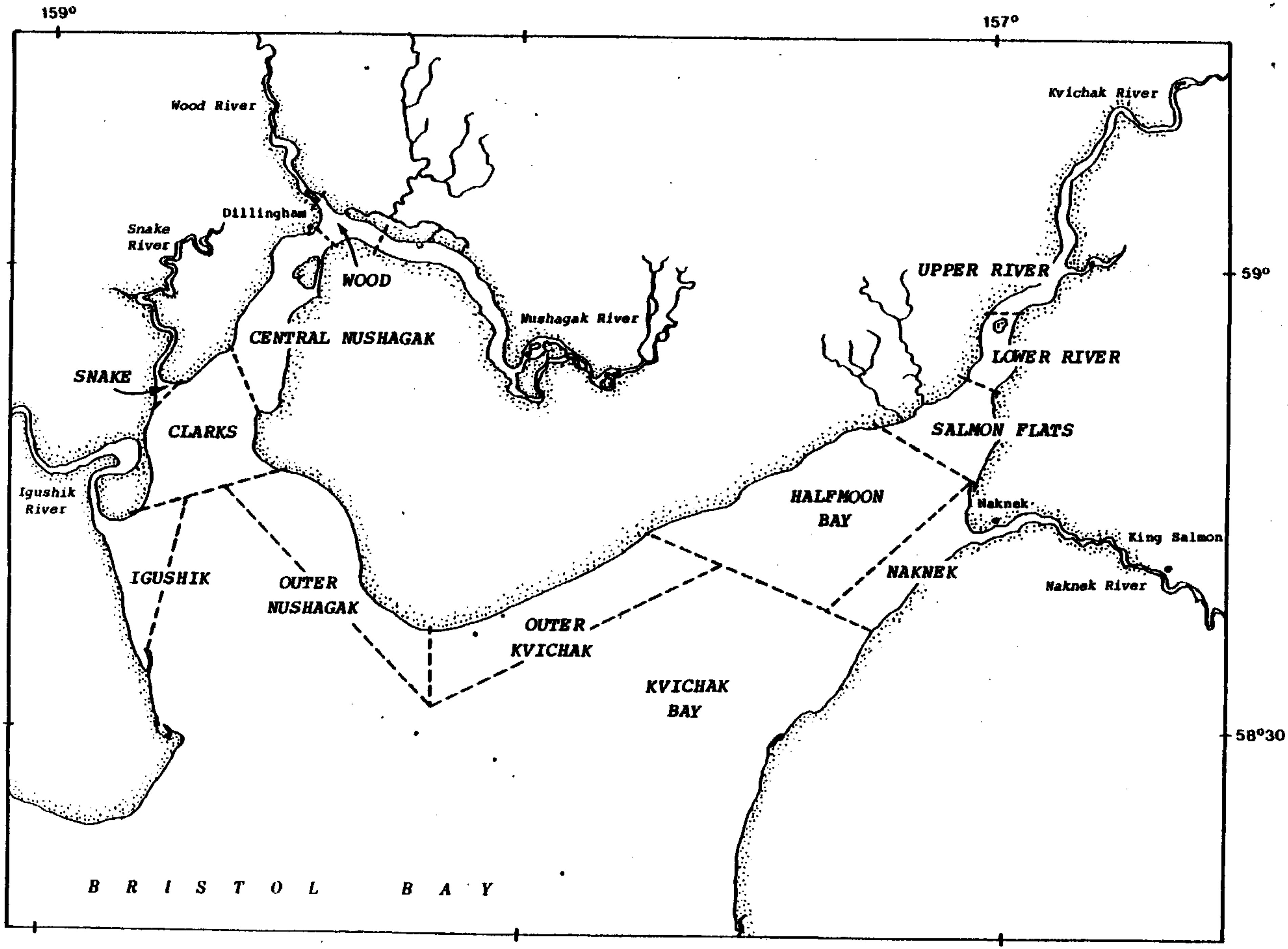


Figure 12. Map of the study area showing geographical subareas referred to in summarizing information on distribution of belukha whales.

near the Snake River mouth or between the Snake River mouth and Clarks Point. From mid-April to mid-June, sightings were of fewer than 20 whales. In late June to mid-July, 50-120 were counted. Whales were regularly seen in the Snake River and on two occasions in May were found approximately 12 km upstream at the confluence of the Snake and Weary rivers.

Small numbers of whales, usually fewer than 20, were present in the Igushik River on four occasions in April-June. In only one instance in mid-May were they seen above the first large bend in the river, approximately 18 km from the river mouth.

Belukhas were sighted near the mouth of the Wood River and the Little Muklung or in the central Nushagak area once in late May and three times in mid- to late June. The largest number counted was 24 on 27 June between Sheep Island and the bar at the mouth of the Little Muklung. In three instances, one to four whales were sighted in outer Nushagak Bay near Etolin Point.

Since Kvichak Bay was our base of operations for tagging whales in 1983, observations there were more extensive than those in Nushagak Bay. From mid-May through mid-July, we made over 150 sightings of whales in Kvichak Bay and the Kvichak River (Appendix III). Figure 12 shows the geographical subareas used in summarizing that distributional information (Table 11). The use of the six areas changed markedly during the study period.

During surveys conducted from mid-April to mid-May, belukhas were present in Halfmoon Bay and outer Kvichak Bay, Salmon Flats, and near the mouth of the Naknek River. The group at the mouth of the Naknek consisted of 70 or more whales on five occasions. After 19 May, belukhas were not seen again near the mouth of the Naknek for over 2 weeks. Between 25 May and 4 June, up to 225 whales were seen in the upper Kvichak River each day. Twice daily, groups of whales moved upriver on the flooding tides, usually traveling at least to the mouth of the Alagnak River (18 km upstream), and downriver on ebbing tides. They were usually seen traveling in mid-river or feeding in rips or current eddies, probably on the smelt (*Osmerus mordax*) and salmon smolt present in the river during this period.

Prior to 25 May, we did not make regular observations in the Kvichak River and thus were unable to determine when regular use of the river began. During the same 2-week period that belukhas used the upper Kvichak River on high tides, they were common in the lower river, Salmon Flats, and Halfmoon Bay. After 6 June, the whales were not again seen in large numbers in the Kvichak River. When they were seen, it was in small groups of fewer than 10 whales. These whales were usually swimming close to the riverbank and appeared to be feeding on adult salmon. From 6-16 June, belukhas were present off the mouth of the Naknek and southward toward Johnson Hill. Over 100 were present on several days, feeding at low tide over Big Flat. At high tide they moved upriver toward Salmon Flats, and at least some were present in Halfmoon Bay. After about

Table 11. Summary of whale observations in Kvichak Bay, April-August 1983.

Date	Number of whales sighted					
	Upper river	Lower river	Salmon Flats	Naknek River	Halfmoon Bay	Outer Kvichak
15 Apr			14	60-70	3	43
5 May			31	2	88	37
17 May			4	70		
19 May				many		
25 May	75-80	60			16	
26 May	40+	6				
27 May	20-25					
28 May	45	38	150-200	0	150-200	
29 May	150+	50-100				
30 May	80-100	100-150				
31 May	223	12	29		1	
1 Jun	104		20+			
2 Jun	10-15	few	± 20		100+	
3 Jun	120+	10-20	30-50			
4 Jun	200+	16	10-15			
6 Jun	few			30-50	12+	
7 Jun		100+				
8 Jun		3		75+	few	
9 Jun				± 10	10-15	
10 Jun			10+	2-3		
11 Jun			some	50-100+	10-20+	
12 Jun					50-100	
13 Jun				1	few	20+
14 Jun		20-30		100+	22	40+
15 Jun				125-200+		
16 Jun		3+		100+	100's	
17 Jun		23+				
18 Jun	6	30-50	86+		30-50	
19 Jun	1	1			few	
20 Jun	few					
21 Jun		50+	20+	present		
22 Jun	several	1			few	
23 Jun	several		20+			many
24 Jun		few			many	2
27 Jun			few 35+		present	
28 Jun			57		124	
29 Jun					202	6
30 Jun		25+				
2 Jul		present				
3 Jul			100+			20+
4 Jul		100+	30+			

Table 11. Continued.

Date	Number of whales sighted					
	Upper river	Lower river	Salmon Flats	Naknek River	Halfmoon Bay	Outer Kvichak
5 Jul		10-20	80-100			
6 Jul			few			
7 Jul			400+			
12 Jul		200+	present			
14 Jul			50+			
14 Aug				3	179	127

16 June, belukhas were no longer seen in the Naknek River-Big Flat area. Instead, from then until our studies terminated in mid-July, they apparently moved between the lower Kvichak River-Salmon Flats area, mostly at high tide, and Halfmoon Bay, or in some instances outer Kvichak Bay at low tide.

For all observations (n = 73) in which the whales' direction of movement was known, we compared the tidal stage and direction of flow with the direction the whales were moving (Table 12). In 77% of the observed cases, the whales were found to move with the direction of the tide ($chi^2 = 20.84$; $p < 0.01$). The number of observations of whales moving with the flood (37%) versus with the ebb (63%) is in proportion to the total amount of time the tide was flooding (35%) and ebbing (65%). Of the whales that moved against the tide, only 18% of those moved against a flooding tide, whereas 82% moved against an ebbing tide ($chi^2 = 12.6$; $p < 0.01$). All movements against the tide occurred within 2 hours of a tidal change, and 85% were within 1.5 hours of a change. Movements with the tides occurred throughout the tidal cycle.

Our best information on abundance of whales came from systematic aerial surveys in which we attempted to cover all areas of Kvichak and Nushagak bays where whales regularly occurred (Table 13, Figs. 13-21). However, when counting from the air, not all whales are at the surface where they can be enumerated during the passage of the aircraft. Consequently, a correction factor (CF) was developed and applied to the counts in order to estimate actual abundance. We have used two independent methods to derive correction factors to apply to our surveys.

During early June, large numbers of belukhas were predictably moving up and down the Kvichak River. The river was generally less than 2 km across in this area and the surface conditions were usually calm. On 4 June, three observers in two Zodiac rafts counted 201 belukhas passing downstream in the vicinity of the Alagnak River mouth from 1105-1155 hours. Since the whales were moving rapidly downstream with the ebbing tide, it was easy to track individuals and avoid duplicate counts. It is, however, likely that some whales passed unseen downriver past the rafts. From 1032-1034, prior to the downstream movement, two observers in the helicopter counted 85 whales in the region upstream from the rafts, using standard aerial-survey techniques. If all whales were seen and counted by the observers in the rafts, the correction factor derived from these data is 2.4 (i.e., total whales = whales counted from the air X 2.4). If, as was estimated at the time, observers missed 20% of the whales passing by the boats, the total number of whales in the group was about 241, and the actual correction factor would be 2.8.

A second method for correcting aerial survey counts involves estimating the probability that a given whale will be at the surface where it can be seen at the time an observer scans the area, based on the length of surfacings and dives, and the length of time a particular spot is in the field of view. This method has been applied to surveys of bowhead whales (*Balaena mysticetus*) (Davis et al. 1982) and gray whales

Table 12. Movement of belukha whales in Kvichak Bay, summer 1983, in relation to tidal stage. Numbers represent the number of observations of one or a group of whales.

Direction of movement (n = 73)	Hours after change in tide								
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	>4.0
with flood (n = 20)	1	6	4	6	1	2			
with ebb (n = 36)	1	10	7	2	6	4	2	3	1
against flood (n = 3)	1	1		1					
against ebb (n = 14)	6	1	4	3					

Table 13. Aerial survey counts of belukha whales in Nushagak and Kvichak bays, April -August 1983.

Date	Wood River	Central Nushagak	Clarks Point	Snake River	Igushik River	Outer Nushagak	Total Nushagak	Outer Kvichak	Halfmoon Bay	Naknek River	Salmon Flats	Lower river	Upper river	Total Kvichak	TOTAL
15 Apr	0	0	14	3	37	5	59	43	3	68	14	fog	fog	128	187
2/5 May	0	0	5	7	0	6	18	37	88	2	31	--	--	158	176
17 May	0	0	0	11	12	0	23	0	0	70	4	0	0	74	97
31 May	8	2	0	0	0	0	10	0	1	0	29	12	35	77	87
4 Jun	--	--	--	--	--	--	--	--	1	0		15	85	101	--
14 Jun	2	0	4	2	10	0	18	29	31	0	3	31	0	94	112
18 Jun	--	--	--	--	--	--	--	0	32	0	86+	0	8	126	--
24 Jun	12	3	50	0	0	1	66	5	11	0	0	4	--	20	86
27 Jun	24+	0	54	--	15	--	93	--	--	--	--	--	--	--	--
29 Jun	0	2	107	0	17	0	126	6	202	0	0	0	0	208	334
14 Jul	0	0	119	15	0	0	134	0	0	0	49	0	--	49	183
14 Aug	--	0	0	0	0	0	0	127	179	3	0	--	--	309	309

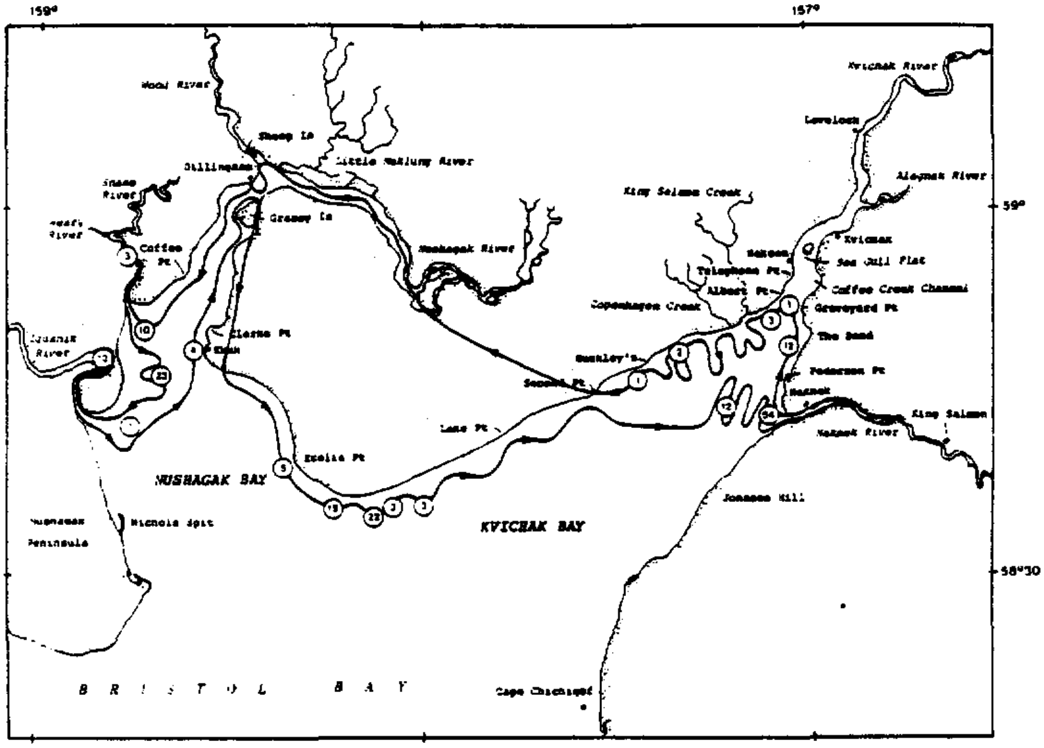


Figure 13. Aerial survey of Nushagak and Kvichak bays, 15 April 1983. Numbers along survey track lines indicate the number of belukhas counted.

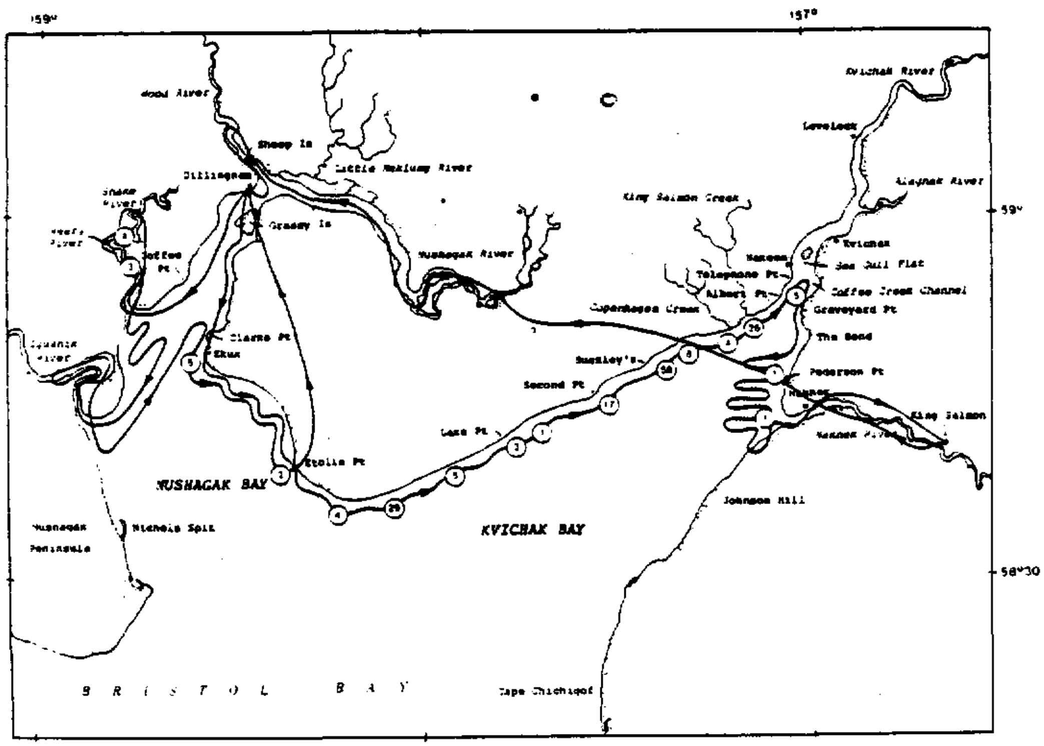


Figure 14. Aerial survey of Nushagak and Kvichak bays, 2 and 5 May 1983. Numbers along survey track lines indicate the number of belukhas counted.

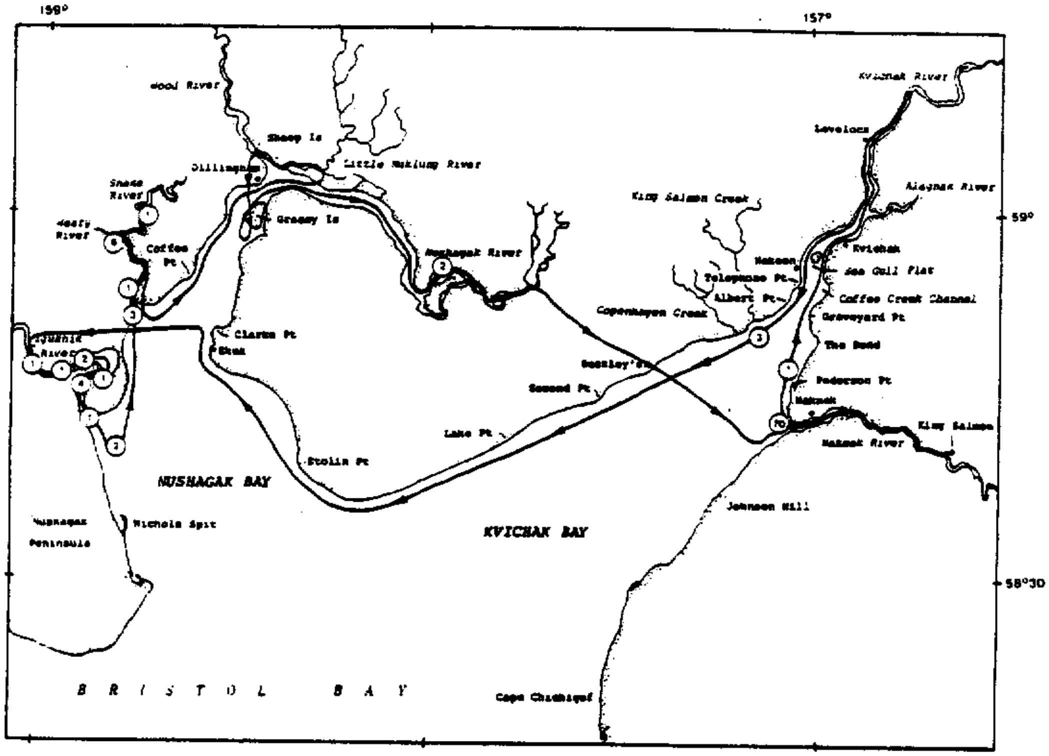


Figure 15. Aerial survey of Nushagak and Kvichak bays, 17 May 1983.

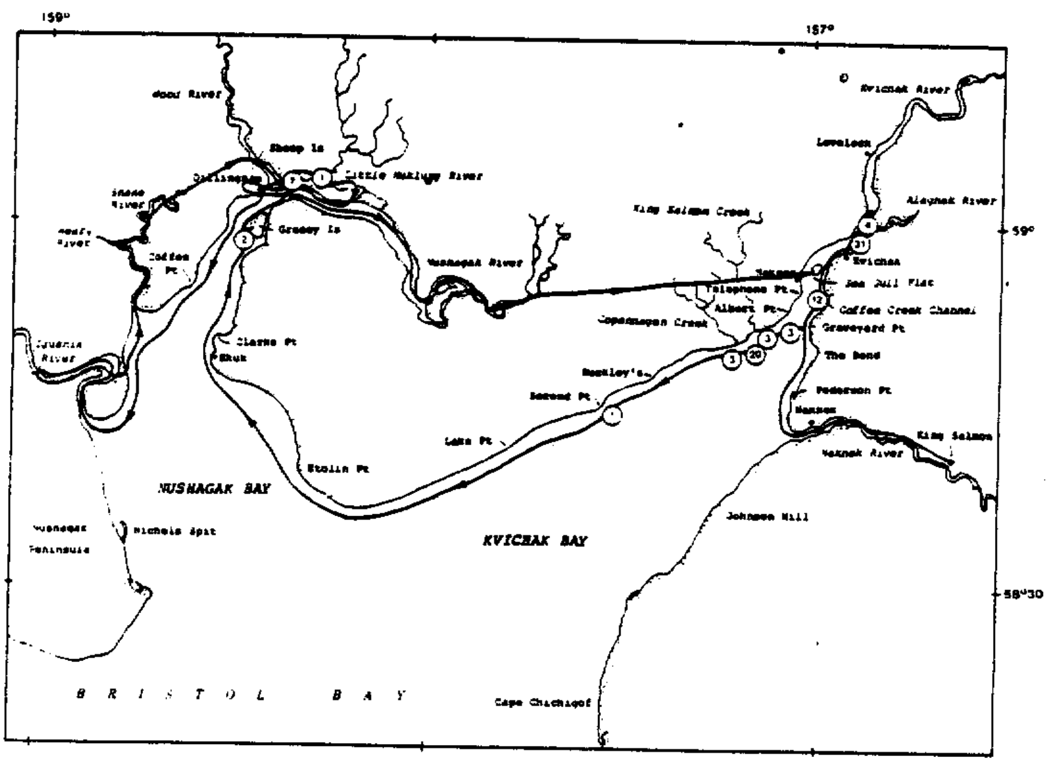


Figure 16. Aerial survey of Nushagak and Kvichak bays, 31 May 1983.

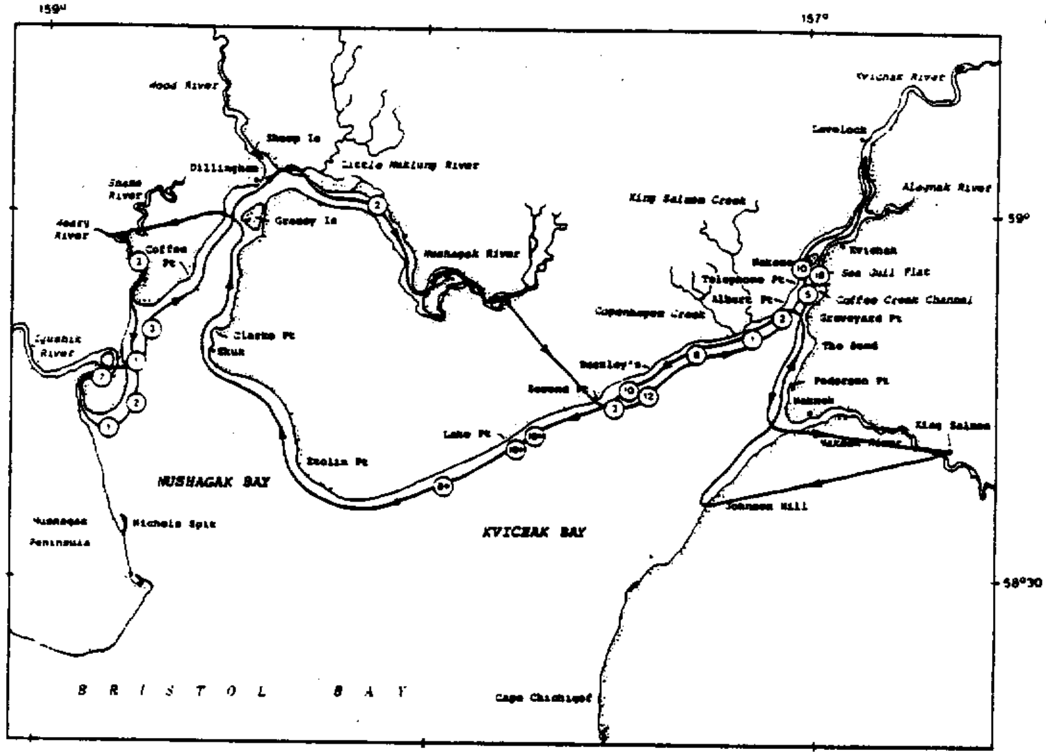


Figure 17. Aerial survey of Nushagak and Kvichak bays, 14 June 1983.

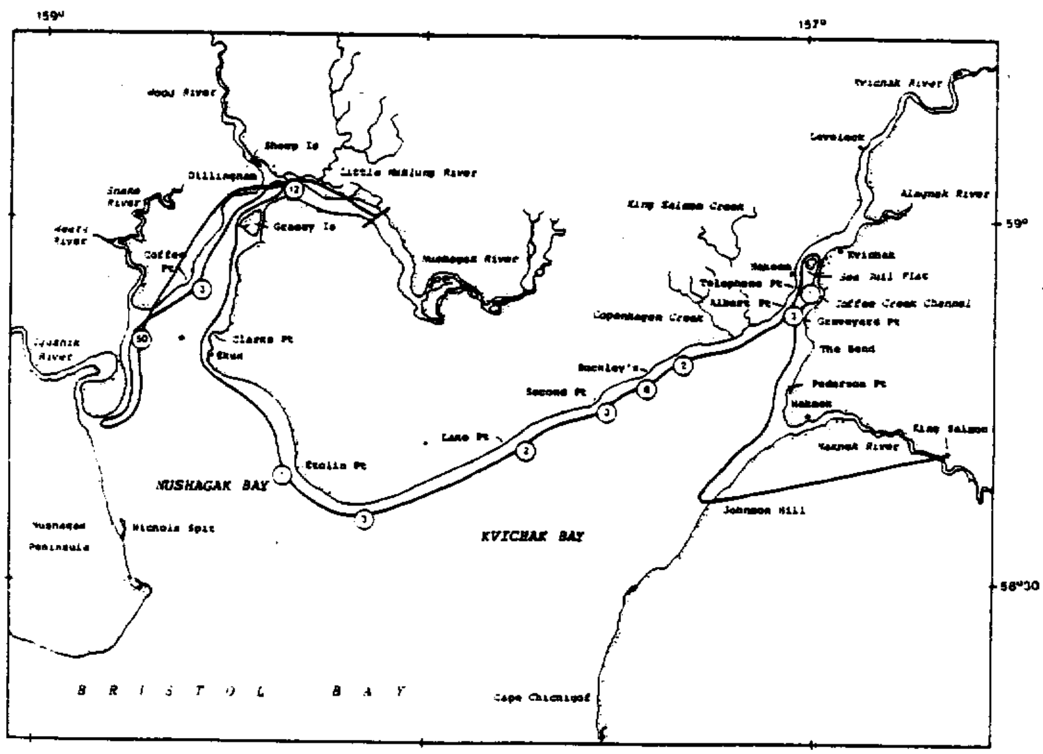


Figure 18. Aerial survey of Nushagak and Kvichak bays, 24 June 1983.

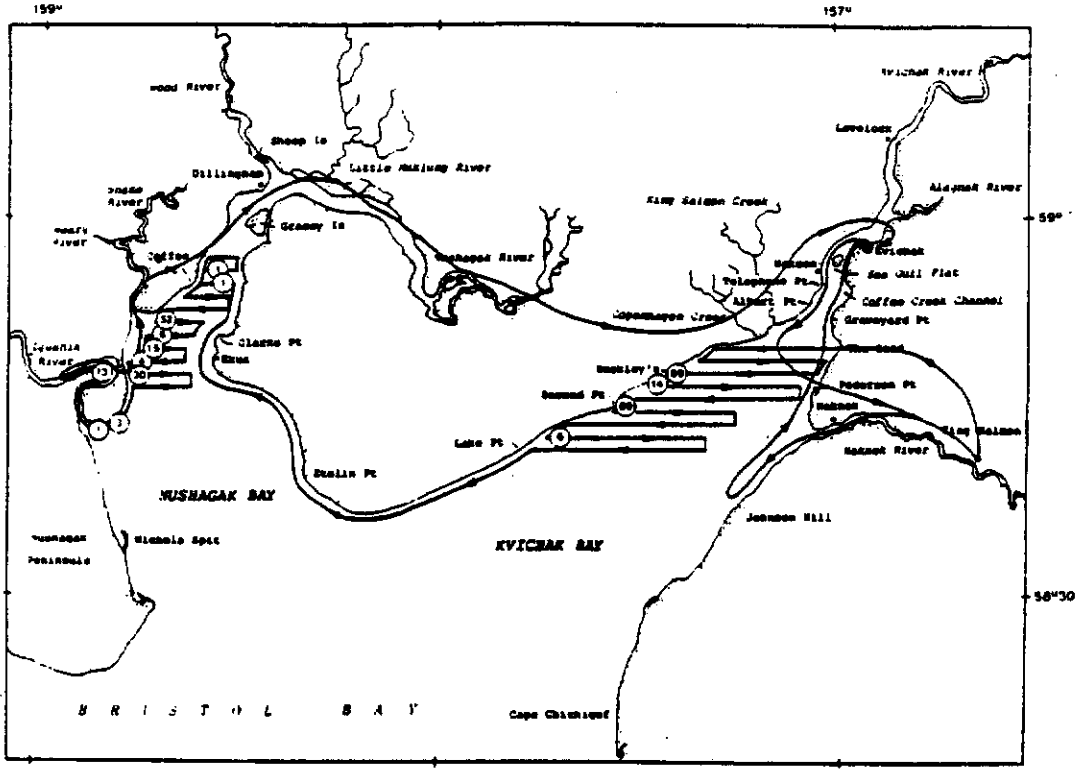


Figure 19. Aerial survey of Nushagak and Kvichak bays, 29 June 1983.

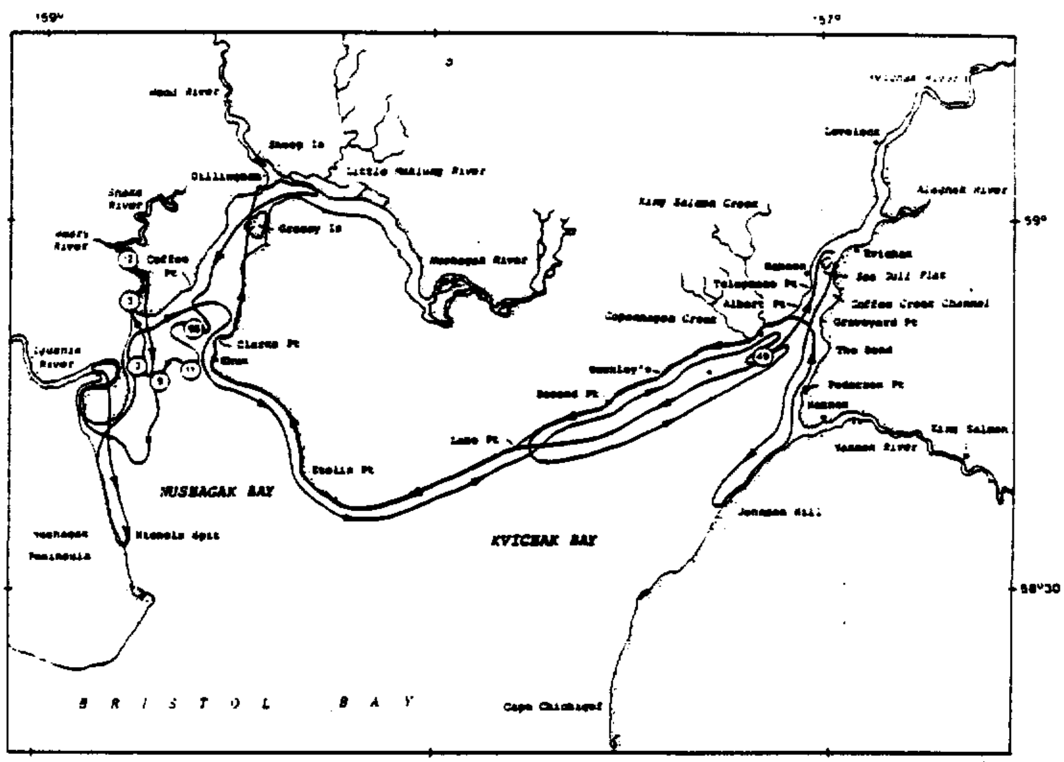


Figure 20. Aerial survey of Nushagak and Kvichak bays, 14 July 1983.

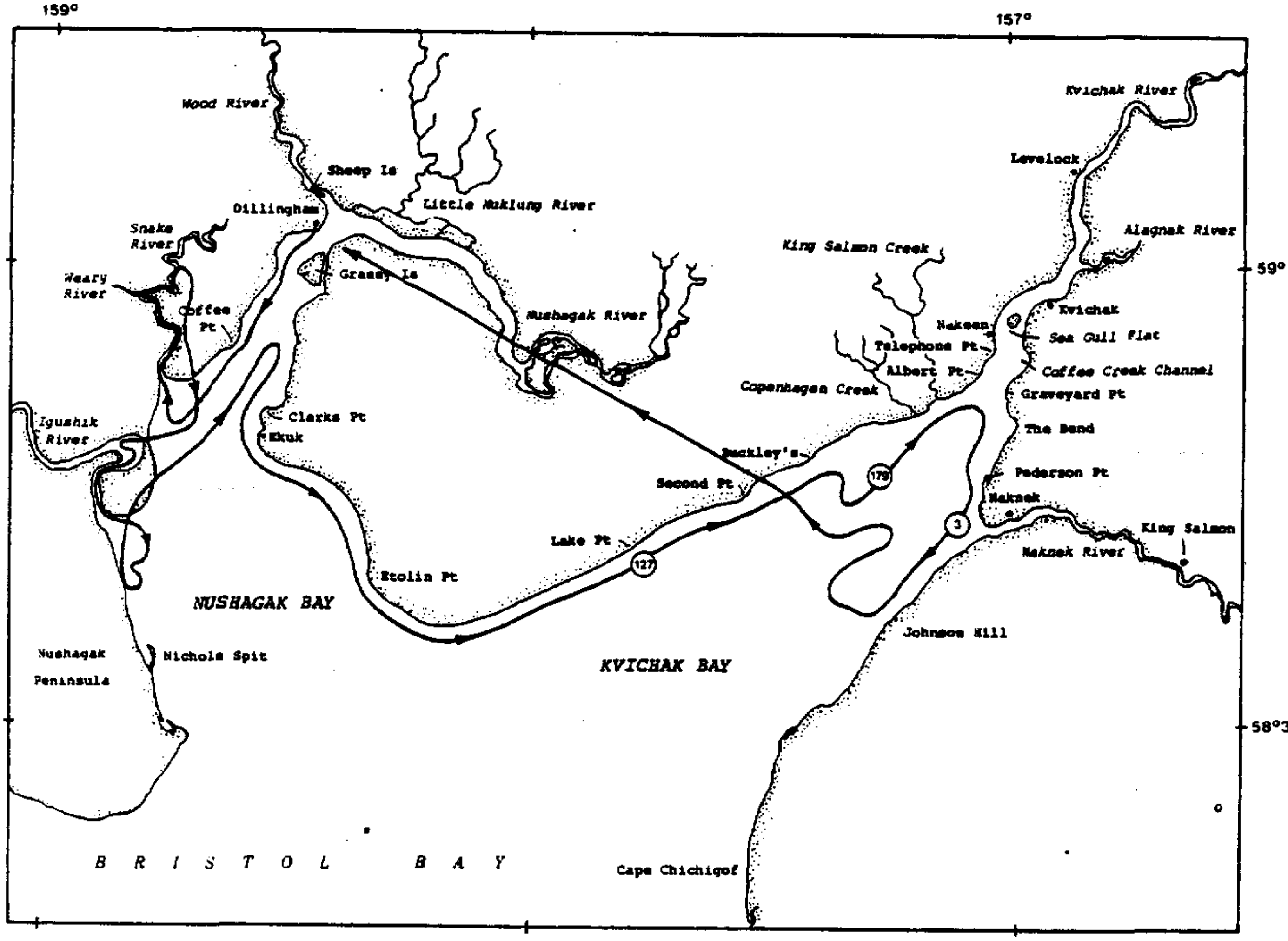


Figure 21. Aerial survey of Nushagak and Kvichak bays, 14 August 1983.

(Miller 1983). The formula for calculating the probability that a whale will be at the surface where it can be seen is:

$$P = \frac{S + t}{S + u}$$

where S = the mean surface interval, u is the mean dive interval, and t is the length of time an area is within the field of view of an observer. The correction factor by which aerial counts can be multiplied to derive the actual abundance of whales is the reciprocal of this probability (i.e., CF = 1/P).

The value of t can be determined based on the angular field of view of the observer (Ø), the median distance from the flight track to sighted whales (X), and the velocity of the aircraft (v), using the following formula (Miller 1983):

$$t = \frac{2 \tan \frac{\emptyset}{2} \cdot X}{v}$$

We have assumed that the median sighting distance occurred at a point halfway across the strip transect (i.e., 457 m). The angular field of view is difficult to determine accurately since it does not equate to the maximum angle that can be seen from inside the aircraft, but rather to the angle that is included in the normal scan of the observer. We estimate that angle to be approximately 60°. Parameters used to estimate t for the two survey aircraft used are given in Table 14.

Table 14. Parameters used to estimate the period of detectability (t).

Aircraft type	c Ø	x(m)	v(m/sec)	t(sec)
Bell 204 helicopter	60°	457	50.8	10.4
Cessna 185	60°	457	76.2	6.9

We also determined the value of t empirically by timing the period during which floating objects passed through the normal field of observation during surveys from the helicopter. Objects from 228 to 457 m from the trackline passed by in 4.5-6.2 seconds with an average time of 5.8 seconds (N = 15). Corrected to a median sighting distance of 457 m, this indicates a value of t of 7.3 sec. Although this empirically derived value may be the most realistic, we will use the values of t in Table 14 since, being larger, they will underestimate the correction factor and result in a population estimate that is conservative (i.e., smaller than the true population).

The values for S and u which are needed for calculations are measurements of the time during which a whale is visible from the air and the time during which it cannot be seen, which, depending on the turbidity of the water, may or may not be equivalent to actual surfacing and dive times. In the muddy waters of Kvichak and Nushagak bays where we surveyed, whales were invisible unless their bodies were actually breaking the surface. Therefore, our telemetry data on lengths of surfacings and dives can be used to approximate S and u. Type C data from Mama was not included since during those periods she was in shallow water with the antenna, but not her body, breaking the surface. An exception occurred off and to the south of the Naknek River mouth. On several occasions whales were seen there in clear, shallow water, and, since our counts probably included all individuals, no correction factor was applied to them.

As noted by Davis et al. (1982) and Miller (1983), calculations of probability of detection must treat instances where the dive time is less than the detection time separately from those where $u > t$. Taking that factor into account, and using all data for BB and type A1 data for Mama, the appropriate correction factors for each survey aircraft are shown in Table 15.

Table 15. Correction factors for aerial counts based on surface times, dive times, and the duration of potential detectability.

Aircraft type	BB	Mama	Mean
Bell 204 helicopter	2.9	2.6	2.75
Cessna 185	3.8	3.6	3.7

These correction factors were applied to aerial survey counts to estimate the number of belukhas present in Nushagak and Kvichak bays during spring and summer 1983 (Table 16). The most complete survey was flown on 29 June from a helicopter and was an aerial strip-transect survey of known concentration areas combined with a coastal survey of other areas (Fig. 19). On that day we counted 126 belukhas in Nushagak Bay and 208 in Kvichak Bay, for a total of 334 whales. When the mean CF for BB and Mama of 2.75 is applied to those counts, it yields estimates of 347 whales in the Nushagak and 572 in the Kvichak, for a total of 919 whales. Total counts on all other days were lower and yielded corrected estimates of 237-692 whales. In Nushagak Bay, the highest estimated number of whales, 496, occurred on 14 July in the Snake River mouth-Clarks Point area. Numbers increased steadily between mid-June and mid-July. In Kvichak Bay, there was no clear trend in abundance. Maximum corrected counts occurred on 5 May and 29 June.

Table 16. Aerial survey counts and corrected estimates of abundance for belukha whales in Nushagak and Kvichak bays, April-August 1983. Dashes indicate no or incomplete aerial survey coverage.

	Nushagak Bay		Kvichak Bay		Total	
Date	Counted	Corrected estimate	Counted	Corrected estimate	Counted	Corrected estimate
15 Apr	59	218	128	474	187	692
5 May	11	41	158	584	169	625
17 May	23	85	74	274	97	359
31 May	10	27	77	212	87	239
4 Jun	--	--	101	278	--	--
14 Jun	18	49	94	259	112	308
18 Jun	--	--	126	347	--	--
24 Jun	66	182	20	55	86	237
27 Jun	93	256	--	--	--	--
29 Jun	126	347	208	572	334	919
14 Jul	134	496	49	181	183	677
14 Aug	0	0	309	n/a	309*	n/a

* CF not considered applicable to these counts as whales were in very shallow water and the observer considered that more than the usual proportion was counted.

C. Foods and Feeding

Information on belukha whale feeding was obtained in three ways: through analysis of stomach contents of beach-cast whales, observations of apparent feeding behavior, and examination of net-caught salmon. During our 1982 and 1983 field seasons, we examined five whales in which the stomachs were suitably fresh for examination and contained food (Table 17). The three 1983 whales had all died in May. Two had mostly flatfish remains in their stomachs, while the third contained primarily rainbow smelt with lesser amounts of flatfish and shrimp. The shrimp may have been from the stomachs of the flatfish that were eaten. None of the stomachs were full; the largest volume of contents was 163 ml. Of the 1982 whales, one had probably died in late May or early June; its stomach contained otoliths from smelt and a few from sculpins (F. Cottidae). The other whale died in late June and had eaten entirely red salmon. Its stomach was the fullest of the five and contained 415 ml.

During 1983, apparent feeding behavior was observed throughout the study period (Table 18). From mid-May until early June, whales were regularly seen 10-25 km up the Kvichak River, often accompanied by flocks of feeding birds (seagulls, _Larus_ spp., and kittiwakes, _Rissa tridactyla_) in areas where many small fish dimpled the surface. In general, the whales moved upriver on rising tides and back down on falling tides. In some instances, they worked localized areas (such as tide rips at Nakeen or the Alagnak River mouth), remaining in those areas for some time. Their activity consisted of many short dives with lots of turning; in blowing, they exposed only their heads. While in the rivers during this early period, they were also observed to swim fairly rapidly upstream or downstream (with the tide) until they found a concentration of fish (smelt or smolt), then drift along in that concentration with the current and feed. During feeding, it was more typical for whales to blow by raising their heads up, or by exposing only their blowholes, than by rolling and raising their backs out of the water. Consequently, it was often possible to hear whales in an area where they were feeding but to see them only occasionally through very careful observation and under ideal viewing conditions (calm water).

After the first week in June, large groups of belukhas were no longer seen moving up and down the Kvichak River. From about 6 June until 18 June, they moved at least once and perhaps twice (one tide was during the night when observation was precluded) daily on the ebbing tide to the Big Flat area south of the Naknek River mouth to feed. Compact groups (within a 0.5- to 1.0-km^2 area) of up to 100 whales were seen on several occasions. About 2-3 hours before low tide, the whales could be seen moving toward Big Flat from the Kvichak River mouth area. At that time they were quite widely dispersed. As slack tide approached, the whales began to concentrate in large groups (100+) containing smaller groups of 30 or more. Within these smaller groups, clusters of usually four to eight individuals (both gray and white) lined up parallel and so close they appeared to be almost touching. The whales within the clusters would simultaneously dive to the bottom and stir up clouds and trails of mud. In several

Table 17. Stomach contents of belukha whales collected in Bristol Bay in June-July 1982 and May 1983.

SPECIMEN #	BBD-1-82		BBD-3-82		BBD-1-83		BBD-2-83		BBD-3-83	
DATE WHALE DIED	29 Jun		early Jun?		11 May		11 May		26 May	
PREY ITEM	% Vol.	% No.	% Vol.	% No.	% Vol.	% No.	% Vol.	% No.	% Vol.	% No.
Shrimp	0	-	*	-	4	-	11	-	0	-
Isopod	0	-	0	-	1	-	1	-	0	-
Mussel	0	-	0	-	1	-	0	-	0	-
TOTAL INVERTEBRATE	0	-	*	-	6	-	12	-	0	-
Rocks and Pebbles	0	-	0	-	1	-	0	-	100	-
TOTAL FISHES	100	-	*	-	92	-	88	-	*	-
Flatfishes	-	0	-	1	-	90	-	13	-	100
Rainbow smelt	-	0	-	87	-	0	-	83	-	0
Salmon	-	100	-	0	-	0	-	0	-	0
Sculpins	-	0	-	9	-	0	-	0	-	0
Other fish	-	0	-	3	-	10	-	4	-	0
VOLUME OF CONTENTS (ml)	415		*		163		142		20	
NUMBER OF IDENTIFIED FISHES	4		78		20		71		4	

* Trace (< 1 ml).

Table 18. Observations of feeding whales made in May-July 1983.

Date	Location	Time	Number of whales	Comments
5 May	Copenhagen Cr.	1020	32	feeding
17 May	just N of Naknek R. mouth	1109	70	milling/feeding; many gulls feeding nearby
25 May	Branch R. - Levelock	1119-1123	75-80	some feeding at river mouth
25 May	Nakeen	1209-1330	± 60	working the tide rip; obviously feeding; short dives; lots of turning and blowing by exposing only heads
26 May	Nakeen	1355	6	"
26 May	Coffee Cr. - Kvichak	1320-1351	41-43	some feeding
27 May	Kvichak	2000	12 +	50 gulls with them; big group of smolt at surface
27 May	Branch R.	1200	20-25	feeding
31 May	Kvichak	1807-1916	223 +	milling/feeding in river
4 Jun	Kvichak	0700-0800	± 30	lots of smolt at the surface
6 Jun	Naknek R. mouth	1630	30 +	feeding
8 Jun	Big Flat	2000-2200	75 +	milling and feeding
14 Jun	Big Flat	1000-1200	100 +	feeding; diving to bottom; stirring up mud clouds
15 Jun	Big Flat	1230-1330	125 +	"
16 Jun	Big Flat	1230-1330	100 +	"
18 Jun	Graveyard Pt.	1043	86 +	feeding
23 Jun	Halfmoon Bay	1400-1420	many	milling

Table 18. Continued.

Date	Location	Time	Number of whales	Comments
24 Jun	Halfmoon Bay	$\pm$ 1200	many	feeding
29 Jun	Lake Pt.	1430	6	feeding
30 Jun	Nakeen/ Sea Gull Flat	0400-0700	25 +	feeding; some moving against floodtide
3 Jul	Sea Gull Flat to Telephone Pt.	1115-1125	100 +	feeding/milling
3 Jul	Lake Pt. area	1620	20 +	feeding on salmon on flats
4 Jul	Copenhagen Cr.	1015	30 +	feeding; in among nets
7 Jul	Copenhagen Cr.	1320-1350	400 +	most traveling; some stopped to feed on salmon

instances, groups of 30 or more whales would be diving together in a very small area, sometimes with eight to 12 in "rosette" formation (forming a circle with heads pointed inward). Sometimes a single whale could be seen swimming round and round in tight circles, stirring up mud in the midst of the others. They may have been feeding on flatfishes or some other demersal prey.

After about 18 June, we no longer saw large groups of whales on Big Flat. Instead of making twice-daily movements between the Kvichak River mouth and Big Flat, they began moving en masse between the river mouth at high tide and Halfmoon Bay or Deadman Sands at low tide. This change coincided with the arrival of adult red salmon in the Bay. (A few reds were caught in setnets in Halfmoon Bay on 18 June; drift netters had been catching a few earlier that week.) The whales were often seen in very shallow water within 10 m of the shoreline or over the extensive tidal flats but seldom in deeper, offshore waters. They could be seen chasing fish, making rapid turns, and lunging through the water. When feeding on salmon, they swam into the current (against the tide) more often than they did at other times. Although most feeding on salmon took place in the lower river or in the Bay, some whales did move upriver to feed. In contrast to earlier in the season during the smelt and smolt runs when they were common in mid-river, they worked close to the riverbank. They often breathed by lifting only the tops of their heads and blowholes out of the water and were frequently audible but not visible.

On several instances we examined salmon caught in gillnets for signs of belukha tooth marks. Although not all catches contained marked fish, one catch of seven fish had two with tooth scrapings across the posterior third of the body, and another catch of 11 had three marked fish. Most fishermen we talked to were familiar with the marks we described, although some thought they were seal bites. The incidence of such marks was apparently not high enough to cause many complaints, nor were the fish usually scraped very deeply. The tooth marks look as if someone had raked the fingernails of one hand across the tail end of the fish. The scales were removed and the flesh bruised, but the skin was rarely broken. If there was ever any doubt about the identity of these marks, it was dispelled when a belukha bit one of us and the tooth marks left on a hipboot matched those on the fish.

D. Mortality

During June and July 1983, we conducted 856 km of systematic aerial or boat surveys for beach-cast, dead belukhas (Table 19). During these surveys we located 25 carcasses, of which 19 were original sightings and six were resightings. Of the 19, 15 were recently dead (within the past 2-3 months) and four probably had been dead for over 6 months. Six additional dead belukhas were located in the course of other activities. Most carcasses were found along the high-tide line of gently sloping beaches. Very old, highly decomposed carcasses were usually located at the extreme high-tide line and often were partially covered by sand.

Table 19. Surveys for beach-cast, dead belukha whales conducted in Kvichak and Nushagak bays, May-July 1983.

Date	Area surveyed	Platform	Observer(s)	km	Number of beach-cast belukhas	Other
3 Jun	Telephone Pt. to Etolin Pt. to Ekuk; Igushik to Dillingham	helicopter	Frost; Ballard	161	1	
4 Jun	Johnson Hill to Naknek R. mouth	helicopter	Frost; Calkins	18	Ø	
18 Jun	Johnson Hill to Egegik	helicopter	Lowry; Frost	46	Ø	1 walrus, 1 seal
21 Jun	Johnson Hill to Naknek R. mouth; Telephone Pt. to Grassy Is.; Bradford Pt. to Nichols Spit	helicopter	Frost; Nelson; Whitman	210	6*	1 minke whale, 1 harbor porpoise
28 Jun	Telephone Pt. to Etolin Pt.; Naknek to Graveyard	helicopter	Lowry; Nelson	82	3	
4 Jul	Telephone Pt. to Second Pt.	whaler	Lowry; Frost	33	2	
5 Jul	Telephone Pt. to Lake Pt.	whaler	Frost; Lowry	46	Ø	
7 Jul	Copenhagen Cr. to Second Pt.	whaler	Lowry; Frost	22	Ø	
14 Jul	Nichols Spit to Snake R. mouth; Clark's Pt. to Telephone Pt.; Naknek R. to Johnson Hill	fixed-wing	Frost; Lowry	156	6[a]	1 gray whale
15 Jul	Clark's Pt. to mid-Halfmoon Bay	fixed-wing	Lowry; Frost	82	7[b]	1 walrus
			TOTAL	856	25	

* Four of these very old (probably greater than 1 year).
[a] One was a duplicate of a 28 June sighting.
[b] Four of these were duplicates of 14 July sightings; 1 was a duplicate of a 4 July sighting.

Fresher carcasses were sometimes found farther down the beach, depending on the height of the most recent high tides. One animal was found floating dead about 7 km up the Kvichak River. Another was found in the marsh grass in an area flooded only by exceptionally high tides. Two were caught by setnet fishermen and reported to the local ADF&G office.

Carcasses were found in both Kvichak and Nushagak bays, with the greatest number on the exposed beaches of Etolin Point, Halfmoon Bay, and near the Igushik River mouth (Fig. 22). It is probable that most carcasses flushed out with the tide, then washed back onshore with incoming tides and onshore winds.

Measurements were taken and sex was determined for 21 carcasses (Appendix IV). Of those, one was probably an abortus and seven were recently born calves. Standard length for the seven neonates ranged from 137 cm to 150 cm, with a mean of 141 cm. The remaining animals ranged from 192 cm to 410 cm standard length (Fig. 23). All of those shorter than 300 cm were gray in color, and those longer than 350 cm were white. One 320-cm individual was gray; color was indeterminable for the other three carcasses between 300 and 350 cm.

Sex ratio for all 21 carcasses was 13 males:7 females (1 unknown). Of the eight neonates (including the abortus), six were males and two females. Of those 1 year or older, seven were males and five were females.

In addition to conducting aerial and boat surveys, we interviewed fishermen and fisheries biologists to gather information on belukha whale mortality in Kvichak and Nushagak bays during spring and summer (Appendix V). By combining information from all sources, we compiled an estimate of the rates and causes of mortality (Table 20). In general, it was difficult to ascertain cause of death of beach-cast carcasses unless fishermen were present nearby to tell us whether or not the whales had been caught in nets. In some instances net marks in the form of superficial cuts around the caudal peduncle and flukes were obvious. The flukes had been cut off of one large whale and a pectoral flipper from each of two neonates, presumably in order to disentangle carcasses from nets. However, in at least two instances when whales were known to have been killed in setnets within the previous few days, no net marks or other indications of cause of mortality were obvious. Rapid degradation of the skin upon exposure to wind and sun aggravated this problem.

Hunting mortality was determined through interviews with ADF&G biologists and with local residents. One of the deaths attributed to hunting in Table 20 was a beach-cast carcass with obvious bullet wounds in the mid-body region. It could have been a hunting loss or possibly an animal shot at for some other reason.

One of the remaining carcasses was probably an abortus. The others had no obvious marks, bullet holes, or wounds indicating cause of death.

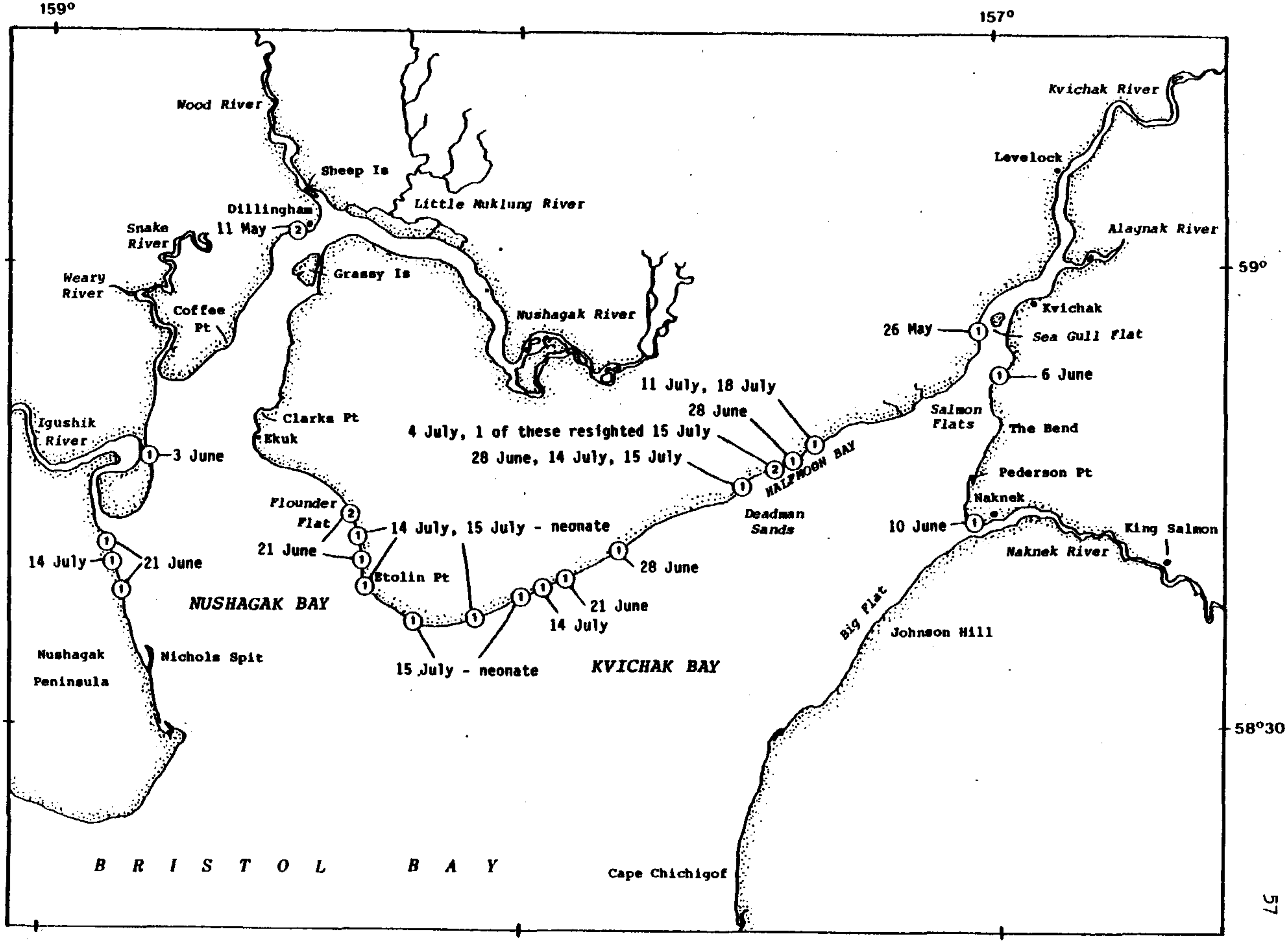


Figure 22. Locations of beach-cast belukha carcasses found in Nushagak and Kvichak bays, May-July 1983.

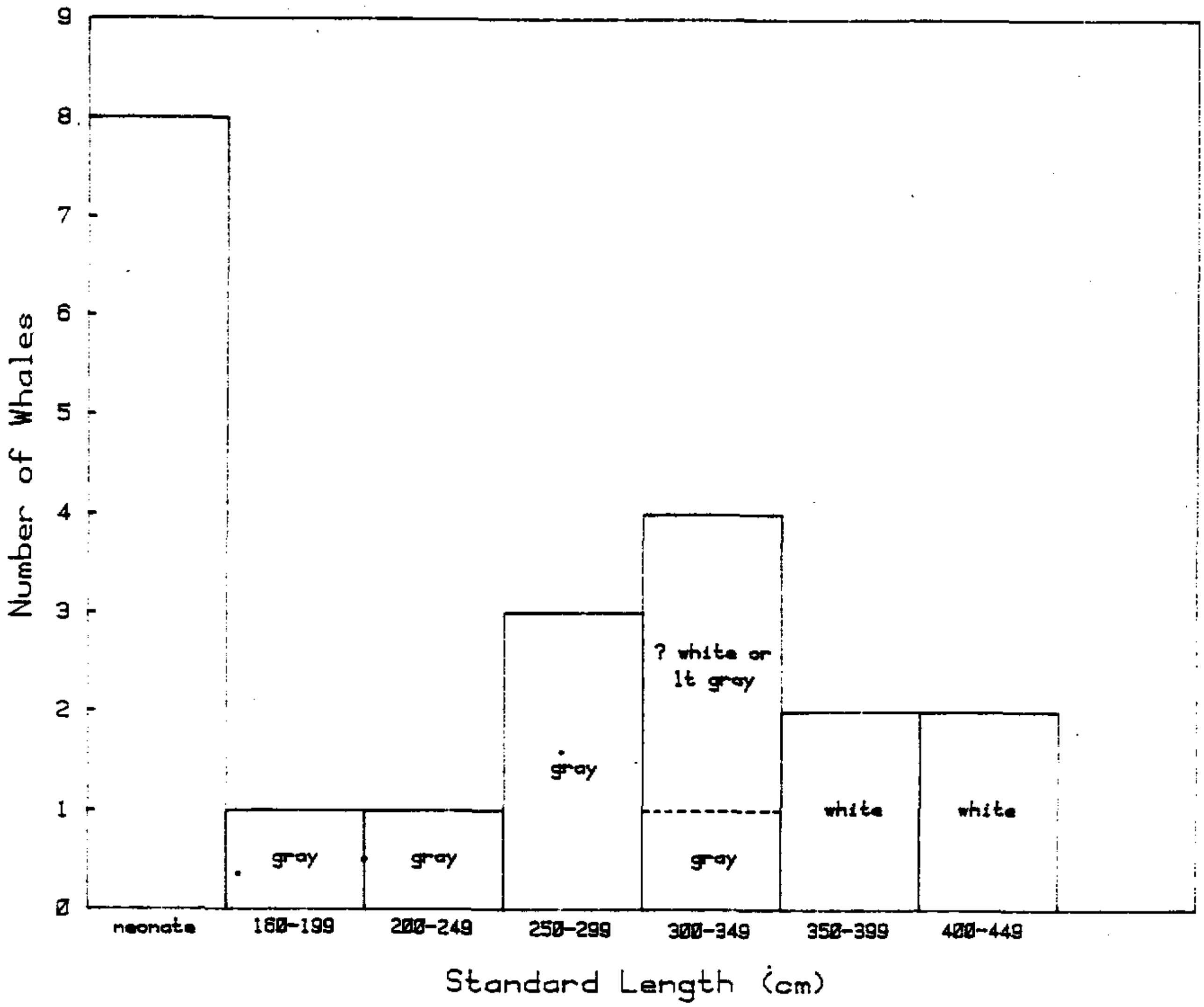


Figure 23. Length distribution of 21 beach-cast carcasses from Nushagak and Kvichak bays, summer 1983.

Table 20. Known mortality of belukha whales in Nushagak and Kvichak bays, May-July 1983.

Date	Comments	Cause of death: Fishing	Hunting	Unknown	Possible duplicate
4-8 May	Whale shot at Black Pt. - Nushagak R.		1		
11 May	Whales caught in king salmon setnets - Nushagak Bay	2			
11-20 May	Whales hunted at Levelock - Kvichak R.		2		
26 May	Floating dead whale - Nakeen, Kvichak R.			1	
1 Jun	Dead whale reported by F/V Pluto - Kvichak Bay				1
1-6 Jun	Whales caught in king salmon drift nets - Nushagak Bay	4			
3 Jun	Beach-cast whale S of Snake R. mouth - Nushagak Bay				1
6 Jun	Beach-cast whale - near Kvichak R. mouth			1	
17 Jun	Dead whale reported by set-netter S of Johnson Hill - Kvichak Bay			1	
21 Jun	Beach-cast whales - Nushagak Bay		1	1	
28 Jun	Beach-cast whales - W side of Kvichak Bay	1		2	
4 Jul	Whales caught in setnets, W side of Kvichak Bay	2			
6 Jul	Report of dead whale in Kvichak Bay, W side				1
11 Jul	Whale drowned in drift net - Kvichak Bay	1			
14 Jul	Beach-cast whale near Igushik Beach - Nushagak Bay			1	
14 Jul	Beach-cast whales - Etolin Pt.			3	
14 Jul	Beach-cast whale - W side Kvichak Bay			1	
15 Jul	Beach-cast whales - Etolin Pt.	2			
18 Jul	Beach-cast whale - W side Kvichak Bay				1
	TOTAL	12	4	11	4

There were four instances in which it was not possible to positively correlate carcasses found with reports of dead whales. In Nushagak Bay, four whales were reported as taken in drift nets from 1-6 June. On 3 June, a large, fresh carcass which may have been one of those four was found on the west side of that bay. Dead whales were reported by setnet fishermen in Kvichak Bay on two occasions, but we did not find the carcasses when we searched for them in the specified areas. It is possible that the animals washed off the beach with a high tide or in stormy weather and came onshore at another location, to be discovered on later surveys. On 11 July, the crew of a drift-net boat in Kvichak Bay told us about a white or very light gray whale that became entangled and drowned in their net a few days earlier. To disentangle it, they cut off the tail flukes. On 18 July, a large whale with the tail flukes missing washed up on the beach in Halfmoon Bay. It was estimated to have been dead a week or more and was probably the same whale.

When belukhas are caught in nets, they become entangled in two ways. Some, especially neonates and juveniles because of their small size, become tangled in the web of the net, catching pectoral flippers or tail flukes. In at least some instances, fishermen are able to disentangle and release these individuals before they drown. The small male animal that we tagged on 9 June had been caught in a net. He had superficial cuts in the skin and blubber and slightly dry skin but apparently suffered no long-term damage when set free. Several days later he was over 20 km from the release site and swimming with other whales. Larger individuals are able to break through net webbing but sometimes become entangled in the lead and cork lines. They roll and thrash when hitting the net, wrapping themselves so tightly that they have to be cut out. The tail flukes may be cut off in the process.

Approximate time of entanglement was known for six whales, five of which were caught by set-netters and one by a drift-netter. All but one (the small whale that was rescued and radio-tagged) were caught at night or on early-morning tides.

VII. Discussion and Conclusions

A. Capture, Tagging, and Tracking

The choice of radio transmitters for application to marine mammals requires consideration of multiple factors, including signal strength and therefore range, battery life, package size and design, attachment mechanism, cost, and availability. One of the aims of this project was to compare two types of transmitters, the OAR model AB340 backpack-style radio, and the Telonics barnacle-type tag. During both years of our study, we conducted comparative field tests of signal strength and range. Signals from the more powerful OAR radios (250 vs. 40 milliwatts) were consistently received at distances up to four times greater than the Telonics radios. Maximum range for a Telonics transmitter emitting a constant signal from a known direction was approximately 9 km when the receiving antenna was hand held at ground or water level. In contrast, signals from OAR radios attached to whales and transmitting intermittently were received at distances of 20-35 km. From aircraft, the range of the Telonics transmitter increased to over 40 km but was highly dependent on altitude, whereas signals from OAR radios had greater range and could be heard at low altitudes. The extra power output of the OAR produces a greater drain on the battery, but this is compensated for by a switching mechanism which causes the radio to transmit only while the whale is at the surface. Although the OAR radios were six times more powerful than the Telonics radios, they probably transmitted for less than one-tenth of the time they were on the instrumented whales.

Because of range limitations and concern over penetration depth of the tines, Telonics barnacle tags were not applied to the two captured whales. The OAR package was successfully attached by bolting through the dorsal ridge. The whales showed no apparent reaction to being tagged in this manner and subsequently appeared to behave normally. The packages came off the whales after approximately 2 weeks, in contrast to the desired 6-week duration. When recovered, neither of the radio packages or antennas showed any signs of damage that would indicate attempts at removal by the whales. We assume that hydrodynamic drag on the package caused the bolt to migrate through the hide and blubber. Irvine et al. (1982) applied similar radio packages to dorsal fins of bottlenose dolphins, Tursiops truncatus, and noted problems with migration of bolts through the tissue which resulted in a maximum tracking period of 22 days. The amount of tissue above the nylon sleeve was a triangle about 4.5 cm across the base and 1.5 cm high on the belukhas we tagged. In spite of the fact that belukhas are thicker skinned than true porpoises and dolphins (Sergeant and Brodie 1969), the radio packages were shed quite quickly. There appeared to be no difference in duration of attachment between the subadult (BB) and adult (Mama) belukha.

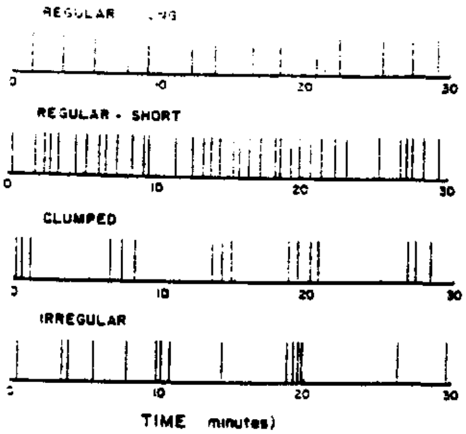
Two modifications to radio packages would be likely to substantially increase the retention time. First and simplest would be to reduce the amount of drag exerted by the package. At least half of the cross-sectional area of the OAR package we used was the result of foam flotation. If it was not necessary or desirable to recover radios, the flotation could be eliminated. Alternately, the smaller Telonics transmitter could be installed on a backpack and would exert correspondingly less drag. Secondly, different or additional methods could be used to attach the radio packages to the whales. The dorsal ridge attachment we used appeared very good in terms of production of signals and effects on the whales. Elimination of flotation from the package and use of two bolts could perhaps increase attachment duration to 2 or 3 months. Mate et al. (1983) have used an attachment consisting of two sets of umbrella stakes on gray whales. They received signals from whales 50 days after tagging (Mate and Harvey 1981) and recorded a sighting of a whale with at least part of the package still attached at least 27 months after tagging (Mate et al. 1983). We think the umbrella-stake attachment has great promise for use on belukhas but requires modification so that the depth of penetration can be reliably controlled.

Clearly, in terms of signal strength, the OAR is the preferred radio. 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 (A. 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 (packaged and ready to apply) for $800 each. If reacquisition of signals is to be done principally from aircraft, the Telonics radios should be adequate; however, the OAR transmitters are far more preferable if animals are to be detected and tracked principally from boats or shore.

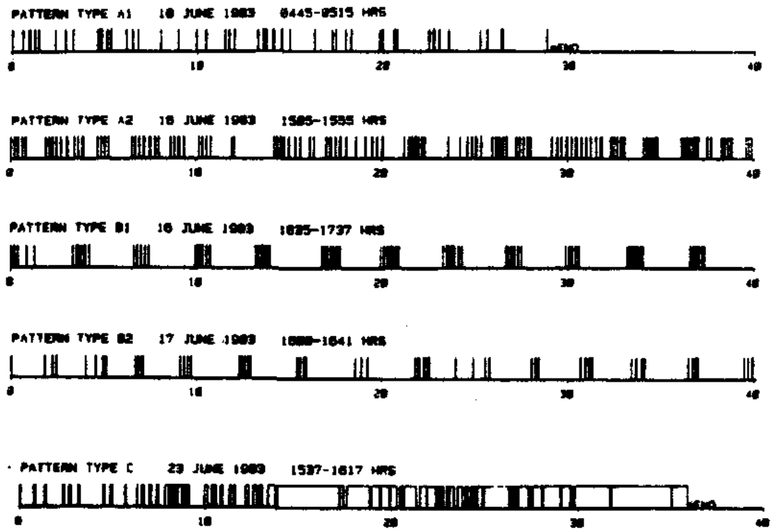
Three main respiration patterns were identified from the surface and dive-time data collected from the two telemetered belukhas. Similar respiration patterns have been described for other cetaceans (Fig. 24). Each of the species shown in Figure 24 exhibits a pattern of clumped ventilations separated by short dives, resembling what we termed pattern type B. Similarly, all five species show a variation of pattern type A where ventilations do not occur in clumped ventilation periods but are more widely spaced with short dive intervals between. Since we seldom visually resighted tagged whales, it was difficult to correlate those respiration patterns with behavior and activity. Pattern type B, with rolls clumped into discrete ventilation periods, has been interpreted to represent feeding in harbor porpoises, Phocoena phocoena (Watson and Gaskin 1983), and in spotted dolphins, Stenella attenuata (Leatherwood and Ljungblad 1979).

Pattern type A for belukhas resembles patterns associated with traveling in Phocoena and Stenella. The significance of the different surfacing frequency in types A1 and A2 is unclear. Leatherwood and Ljungblad (1979) associated frequent surfacings in Stenella with "running" and periods of less frequent surfacings with "traveling or exploratory diving." Watson and Gaskin (1983) reported a higher surfacing frequency in harbor porpoises trapped in weirs or carrying radio transmitters as compared to other free-ranging animals. Mate and Harvey (1981) suggested that surfacing frequency increased for gray whales holding their position against a strong current. We speculate that patterns A1 and A2 for belukhas may represent traveling with versus against the current, although it is equally possible that they may represent different behaviors such as resting and traveling.

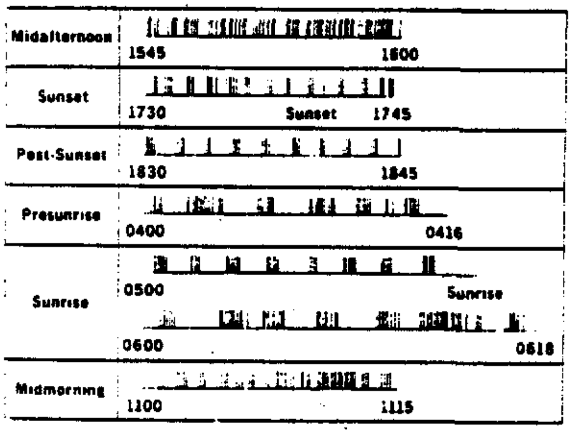
The respiration pattern for Mama which we called type C was characterized by very long periods of continous signals with irregular interruptions. When we first received these continuous signals, we thought that the radio had come off or some other malfunction had occurred. However, when we tracked the signal to its source, we located a group of whales in water slightly more than a meter deep, and the signals stopped as the whales moved rapidly to deeper water. We interpret this pattern as indicative of whales feeding or resting in very shallow water.



Examples of dive patterns of gray whales (from Mate and Harvey 1981).

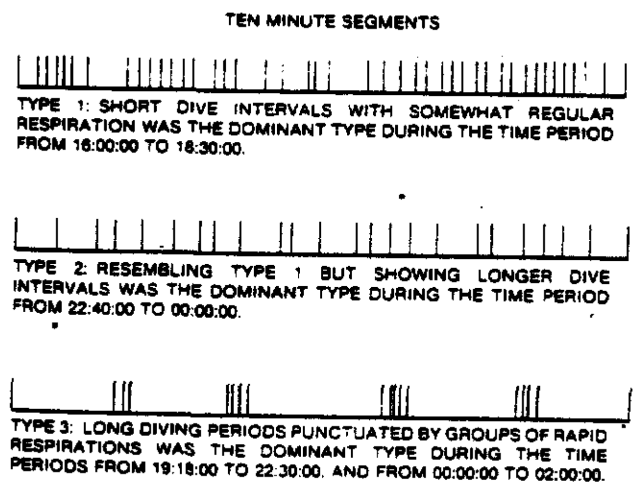


Examples of respiration patterns of belukha whales (this report).



Respiration patterns of Delphinus delphis (from Evans 1971).

Respiration patterns of harbor porpoises, Phocoena phocoena (after Watson and Gaskin 1983).



Examples of 3 diving patterns of a spotted dolphin, Stenella attenuata (from Leatherwood and Ljungblad 1979).

Figure 24. Respiration patterns of five species of cetaceans.

Near-continuous signals were also reported for harbor porpoises traveling or feeding very near the surface (Watson and Gaskin 1983).

Caution should be used in assigning behaviors to respiration patterns. In gray whales, Mate and Harvey (1981) noted that patterns are not exclusive to a particular behavior but include a variety of activities. For example, in gray whales, clumped respirations occur during migration and probably also during feeding and milling in moderate currents. Although Watson and Gaskin (1983) assigned traveling and foraging behavior to pattern types A and B, Read and Gaskin (1983 and pers. commun.) have subsequently cautioned that harbor porpoise behavior is highly variable and cannot always be clearly assigned to a particular pattern.

Characteristics of the ventilation and sounding periods for belukhas were very similar to those for harbor porpoises, with the exception of a longer mean sounding period in the former (2.09 vs. 1.44 min). The average ventilation period of belukhas was about one-third the length of the sounding period, which suggests they may be somewhat better divers than harbor porpoises in which ventilations were one-half as long as soundings (Watson and Gaskin 1983). The longest dive we recorded was almost 2 minutes longer than that reported for harbor porpoises. Watson and Gaskin suggested the possibility of a common maximum-to-mean dive ratio for all odontocetes, based on killer whales and harbor porpoises with ratios of 2.7 and 2.8. Dive data for BB give a maximum-to-mean ratio of 2.8 and thus support that suggestion.

B. Distribution, Abundance, and Movements

The distribution of belukha whales in Nushagak Bay was similar in 1982 and 1983. Most whales were seen in four areas: the Igushik River, the Snake River, between the Snake River mouth and Clarks Point, and near the junction of the Wood, Little Muklung, and Nushagak rivers (Fig. 12). Small numbers of whales, usually fewer than 20, were present in the lower Igushik River during June 1982 and from April-June 1983. Belukhas were not sighted in the Igushik in July of either year, although surveys were flown there on several occasions.

Whales were regularly seen in the Snake River and in both 1982 and 1983 were seen upriver as far as the junction of the Snake and Weary rivers, approximately 12 km from the river mouth. The largest sightings were of 15-25 whales on 13 and 14 July 1983. All others were of fewer than 10 individuals. No whales were seen in the Weary River.

The largest observed concentration of belukhas in Nushagak Bay occurred between the Snake River mouth and Clarks Point. Although the number seen there varied considerably, there was a clear trend of increasing abundance from late June to mid-July. From mid-April to mid-June, sightings were of fewer than 20 whales. In late June to mid-July, the number estimated to be in this area ranged from 30 or 40 to 400 to 600 in 1982 and from 150 to over 400 in 1983. In 1979, belukhas were also reported to be concentrated near the Snake River mouth in late June (Fried et al. 1979). Fried et al. and others have suggested that whales may gather near the Snake River to avoid boat activity since that area is closed to commercial fishing. Indeed, there was very little boat activity there in June and July 1982-83. However, that same group of whales apparently moves regularly between the Snake River mouth and the east side of the bay near Clarks Point, where there is constant boat activity and where most of the processing fleet is anchored. On several occasions, we observed a large group of whales swimming among the boats at Clarks Point. Local ADF&G biologists also have reported that belukhas are frequently numerous around Clarks Point (K. Taylor, pers. commun.). Thus, it seems unlikely that the absence of boat activity entirely explains the whales' preference for the Snake River mouth. Topography may be one of the factors affecting the suitability of the area. Although several rivers flow into Nushagak Bay, the most extensive mud flats occur at the mouth of the Snake River and extend south to the mouth of the Igushik River. The red salmon run in the Snake River is smaller than that in any of the three other major rivers, but the extensive shallows may make those salmon easier to catch.

Belukhas were sighted near the mouth of the Wood River and the Little Muklung River during May through early July. The number seen there varied considerably but was usually fewer than 50 in 1982, and in 1983 it was never more than 24. In both years we received reports of belukhas at Portage Creek, approximately 50 km up the Nushagak River from the Wood-Little Muklung area. Fried et al. (1979) also reported that belukhas regularly occurred off the mouth of the Little Muklung.

Observations on the distribution of belukha whales in Kvichak Bay were made only in 1983. The use of different areas within the bay changed markedly from April through August. From mid-April to mid-May, belukhas were present along the west side of the bay and near Salmon Flats, and large groups were sometimes seen near the mouth of the Naknek River. Frost et al. (1982) also listed sightings near the mouth of as well as in the Naknek River in April and May. The whales are thought to be feeding on smelt in the river at this time. In late May through the first week in June, up to several hundred whales were seen in the upper Kvichak River each day. Twice daily, groups of whales moved upriver on the flooding tides and returned downriver on ebbing tides. Brooks (1954, 1955) and Lensink (1961) also reported that from early May until mid-June, belukhas swam up the Kvichak on each incoming tide and returned to the bay on ebbing tides. Brooks estimated that about 250 whales used the river in 1954 and about 100 in 1955. Fish and Vania (1971) reported that 50-500 moved daily up and down the Kvichak.

The period during which belukhas make daily movements up and down the Kvichak River coincides with the seaward migration of post-spawning smelt and with the peak outmigration of red salmon smolt. Smelt spawn in the rivers of Kvichak Bay from late March to early May and then return to the bay. Red salmon smolt migrate from Lake Iliamna and Naknek Lake to the sea during the last 2 weeks in May and the first 2 weeks in June, with the peak migration occurring from about 22 May to 3 June (Meacham 1981; Huttenen 1982). In 1983, belukhas were last seen in large numbers in the Kvichak River on 6 June. By that date, approximately 90% of the smolt outmigration had occurred. Between 21 May and 3 June, from 1 to 14 million smolt moved down the river each day, with the number dropping rapidly after 3 June.

Between the end of the smolt outmigration and the beginning of the red salmon run, belukhas moved twice daily between the western or upper part of Kvichak Bay at high tide and the Big Flat area south of the Naknek River mouth at low tide. The whales were almost certainly feeding over Big Flat, but we were unable to determine what they were eating. Possibilities include flatfish, smelt, smolt, or shrimp.

After 16-18 June, distribution shifted away from the Big Flat area. From then until our study terminated in mid-July, the whales moved between the west side of Kvichak Bay and the mouth of the river between Sea Gull Flat, Nakeen, and Graveyard. They were particularly numerous there after 28 June. This change coincided with the beginning of the red salmon run. Red salmon were first caught in numbers during the week of 13-18 June, and between the 23rd and the 28th the catch increased from 170,000/day to 1.8 million/day. Escapement of fish upriver past the open fishing area increased 50 fold between the 27th and the 28th.

In the Kvichak in 1983, we observed a strong correlation between tidal stage and the direction of movement of the whales. Other studies have reported variable results when comparing tide and whale movements. Brooks (1954) and Lensink (1961) found, as we did, that belukhas generally swam up the Kvichak on flooding tides and down on the ebb. In Nushagak Bay, Fried et al. (1979) found that belukha movement patterns were independent of tide stage. Our observations in the Nushagak in 1982 and 1983 were too few to test for significance, but we also noted that whales moved with and against the tide with about the same frequency. We have no explanation for the apparently different behavior in the two areas.

Our telemetered whales showed substantial movements up and down the bay but were also sometimes relocated in particular areas over periods of several days. Because relocations were often almost a day apart, it was not possible to determine whether the radioed whales had moved to other areas and returned, or remained in the same area for the entire time. Based on our observations of other whales, which appeared to move between the inner bay and outer bay on a fairly regular twice-daily basis, it is likely that the radioed whales did the same. Large tides in the area result in currents of several km/hour flowing both up and down the bay. Because of river influence, the tide ebbs about 65% of the time so the net movement of a passive floating object would be out to the ocean. Although in most of the observed instances whales were moving with the direction of the tide, occasional movements against the tide, which were predominantly up the bay against ebbing tides, serve to maintain their relative position from day to day. The overall pattern of movements and utilization of various areas appears to be influenced largely by the distribution and movements of prey.

Although it has been assumed by previous investigators that belukhas move back and forth between Nushagak and Kvichak bays, we are unable to confirm such movements based on observations of radio-tagged whales or from aerial surveys. The two whales we radioed and tracked appeared to remain in Kvichak Bay throughout the 2 weeks during which they were tagged. We regularly observed whales moving between the Kvichak River mouth and Lake Point on the west side but seldom saw them along the coast between Nushagak and Kvichak bays. The two surveys in which they were seen in substantial numbers along the outer coast, and perhaps moving between areas, were on 15 April and 5 May. Lensink (1961) put visual tags on 46 belukhas in Kvichak Bay in 1959 and 1960. Only two tags were recovered or resighted: the first 1 month after tagging and the other approximately 3 months after tagging, both in Kvichak Bay. Brooks (1955) stated that there was some movement between Kvichak and Nushagak bays but presented no evidence to that effect. We consider it highly likely that such movements do indeed occur, but further radio-tagging studies are required to delineate their frequency and timing.

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). In 1982, we observed very small calves from boats and the helicopter, found two dead neonates near the Snake River mouth during the 1st week in July, and received a report of four floating belukha placentas there on 9 July. In 1983, in the Nushagak, we found a single dead neonate, with an estimated birth date of about 10 June. We observed a substantial increase in the number of belukhas using the Snake River mouth area in late June-early July 1982 and 1983, with an estimated 400+ whales present in mid-July of both years. We conclude that the area near the mouth of the Snake River is a calving area and that most calving occurs in late June or early July. In 1983, similar observations were made in the Kvichak. One of us (LFL) observed what was thought to be a birth of a belukha on 31 May in the Kvichak River. A local setnet fisherman found a placenta on 28 June in Halfmoon Bay. Six beachcast neonates were found between Halfmoon Bay and Etolin Point from 3 to 15 July, and an abortus was found on 28 June. We noticed a group of 20-30 or more females with new calves on 7 July in the inner bay. It is obvious from this summer's observations that calving also occurs in Kvichak Bay, probably with a peak in late June and early July. Lensink (1961) reported that near-term fetuses were collected on 11 and 17 June and that in 1958 the first newborn calves were seen on 14 June.

A recurrent problem in the enumeration of cetaceans which spend a considerable portion of time under water, and therefore are not visible, has been how to estimate the total number of animals present based on the number observed at any one time. Consequently, one of the primary applications of radiotelemetry has been to provide quantitative data with which to interpret and extrapolate aerial survey counts. In this project, surface-time to dive-time information obtained from radioed whales was used to calculate an average correction factor of 2.75 by which to multiply our aerial survey counts. A comparison of simultaneous aerial and boat counts also suggested a multiplier of 2.4-2.8. Similar correction factors have been used by others. Sergeant (1973) observed that ventilation periods during which the whales were visible lasted 20-30 seconds and dives during which they were not visible lasted 60-100 seconds, therefore indicating a correction factor of 3. Fraker (1977, 1980) suggested a correction factor of 2 rather than 3 since an aerial surveyor's view is not instantaneous. He also believed that neonates and yearlings were for the most part not visible at altitudes of 300 m and more, and further stressed that it was unknown at what age juveniles became light enough to count. Brodie (1971) used a correction factor of 1.4 for belukhas in Cumberland Sound; however, the water there is clear, and the whales were visible for a greater proportion of the time. He added 18% to the corrected estimate to account for neonates (10%) and yearlings (8%).

Multiplication of our aerial survey counts by a correction factor of 2.75 yielded an estimate of 919 belukhas in Nushagak and Kvichak bays in late June 1983. If we correct that estimate by 18%, as Brodie did, to account for neonates and yearlings, the total estimated number of whales would be 1,100. We believe that is a minimum estimate, as the number of gray animals other than neonates and yearlings was probably also somewhat underestimated, and survey coverage was not complete, although it did include known concentration areas. A similar estimate of 1,000-1,500 was made by Brooks (1955). Thus, it appears that the number of whales using Nushagak and Kvichak bays is approximately the same now as 30 years ago.

C. Foods and Feeding

Stomachs examined in 1982-83 and observations of whales that appeared to be feeding on salmon smolt and adult salmon agreed well with the more extensive data collected in the 1950's and 1960's (Brooks 1954, 1955; Lensink 1961; ADF&G 1969). Those studies found that during May and early June, belukhas fed in the rivers, particularly the Kvichak, on smelt and red salmon smolt (Table 21). Smelt were eaten in the greatest numbers in the earliest May samples from a given year, followed later by red salmon smolt. The whales congregate in the rivers and at river mouths to feed on smelt during and after they spawn. In mid- to late May, the red salmon smolt outmigration begins, and almost immediately the diet of belukhas switches to primarily smolt. Brooks (1955) proposed that smolt, which travel downstream in large, dense schools, moving within about a meter of the surface, are more easily caught than smelt, which also may be abundant but swim closer to the bottom.

The first adult red salmon appear in Kvichak and Nushagak bays around mid-June, with peak numbers usually present from the last week in June through the first 2 weeks in July. A few king salmon are present in early June. After mid-July, the red salmon run tapers off and other species of salmon (chums, pinks, and silvers) are present, although

Table 21. Stomach contents of belukha whales from the Kvichak River and its estuary, May and June 1954, 1955, 1965, and 1966. (Brooks 1955; ADF&G 1969).

Date	Mean number per stomach			
	Smelt	Salmon smolt	Shrimp	Other fish
26-28 May 1954 n = 3	501	*		
22-24 May 1955 n = 2	548	73		
20-22 May 1966 n = 3	62	0	2	*
31 May-6 Jun 1954 n = 5	17	983	*	
26-31 May 1955 n = 8	29	607	6	*
29-31 May 1965 n = 3	0	283		
1-7 Jun 1955 n = 9	20	873		*
11-17 Jun 1954 n = 4	3	399	*	7
8-14 Jun 1955 n = 6	90	201	4	*
11-12 Jun 1965 n = 4	0	125	*	

* Trace (average of < 1 per stomach).

their runs are much smaller than that of the red salmon (Nelson 1981). Brooks (1954, 1955) collected no belukhas between mid-June and 1 July. By 1 July, smelt and red salmon smolt had disappeared entirely from the whales' diet and had been replaced by adult salmon, which composed the bulk of the diet for the subsequent 7 weeks (Table 22). During the first 3 weeks of July, reds were the predominant species of salmon eaten. After that, chums, pinks, and silvers became relatively more important. Chums first showed up in the diet during the 2nd week of July, pinks in the 3rd week, and silvers in the 4th week. Only a very few kings were eaten. After the 15th of August, stomachs contained very few salmon. Some had small quantities of shrimp or other fish such as sculpins, flounder, or lampreys (Lampetra japonica), as did stomachs of eight belukhas taken in September 1959 and 1960 (Lensink 1961).

Table 22. The occurrence of adult salmon in belukha stomachs on a weekly basis from 1 July-18 August 1954-55 (Brooks 1955).

Date	No. of belukhas (excl. calves)	No. of salmon		Average/belukha	
		red	all species	red	all species
1-7 Jul	6	32	34	5.3	5.7
8-14 Jul	10	33	45	3.3	4.5
15-21 Jul	14	41	74	3.0	5.3
22-28 Jul	5	5	50	1.0	10.0
29 Jul-4 Aug	10	8	31	0.8	3.1
5-11 Aug	15	10	59	0.7	4.0
12-18 Aug	10	8	21	0.8	2.1

In 1955, Brooks estimated the consumption of red salmon smolt in the Kvichak River using the following assumptions, which were based on his 1954-55 field studies: an average meal consisted of 685 smolt; each whale averaged 1.5 meals/day and fed on smolt for 19 days; and 150 belukhas fed in the river each day during the smolt run. Based on these assumptions, he calculated that belukhas ate approximately 3 million salmon smolt per season.

The consumption of smolt by belukhas in 1983 was estimated in the following manner. During late May and early June, the number of whales estimated to be in Kvichak Bay ranged from 210 to 280. We regularly counted groups of 75-225 in the river and consider 200 to be a reasonable estimate of the average number feeding there during this time. The large groups of whales were in the river for 14 days from 25 May through 7 June, after which we did not see them there. We made no observations in the Kvichak prior to 25 May. In recent years, the smolt run in the Kvichak has lasted for about 30 days from approximately mid-May to mid-June (Meacham 1981). Since whales clearly did not use the river after mid-June, and since they probably did use it before 25 May, 19 days seems a reasonable approximation of the period spent feeding on smolt.

Daily ration can be calculated as a product of predator size and consumption rate. Brooks (1954, 1955) and Lensink (1961) collected and measured 82 belukhas of all ages from Nushagak and Kvichak bays. Mean length of those animals, excluding calves, was 326 cm. Similar mean lengths were reported by Nelson (1887), who found that the average adult in the Yukon-Kuskokwim area was 305-366 cm long, and by Doan and Douglas (1953), who found that the average length of 1,077 belukhas from Churchill, Northwest Territories, was 308-325 cm. Weight data are not available for belukhas from Bristol Bay. However, Sergeant and Brodie (1975) plotted a length-weight regression for belukhas from Churchill, which are similar in size to those from Bristol Bay. On the basis of Sergeant's and Brodie's data, a whale averaging 326 cm in length will weigh about 350 kg.

Sergeant (1969) summarized data on the daily ration of six captive belukhas and found that they consumed 4-7% of their body weight per day. The average for four of those measuring 300-400 cm in length was 5.1% per day; therefore, a 350-kg whale will consume about 18 kg per day. Based on estimated weight of prey items, we calculated that the stomach of an average whale collected during the smolt run in 1954-55 contained 7-8 kg. Estimated numbers of smolt, and therefore weight of food per stomach, are almost certainly low due to the difficulty of counting partially digested fishes. During the peak of the adult salmon runs, that average was 15 kg per stomach and, later in the season, 6-11 kg. Assuming two meals per day, daily consumption (based on stomach contents) would therefore be about 15 kg of smolt or 12-30 kg of adult salmon, which is very close to the calculated consumption of 18 kg. Using data on the number of fishes eaten, and information on the average size of fishes, it was estimated that smolt composed 73% of the diet during the 19 days when the whales ate them, or approximately 13 kg (of a total 18 kg) eaten per whale per day. That number can then be divided by the average weight per smolt ($\pm$ 8 g, taking into account the ratio of age I and II smolt and their mean sizes based on the 20-year average provided in Meacham 1981) to estimate the number of smolt eaten per whale per day. Using the above assumptions, the consumption of red salmon smolt can be calculated as follows:

200 belukhas X 1625 smolt/day X 19 days = 6,175,000 salmon smolt

The average annual smolt run in the Kvichak from 1971-1980 was approximately 122 million (Meacham 1981). Consumption by belukhas represents about 5% of that average. If no predation had occurred and 10% of these smolt survived to spawn (Huttenen 1982), they would number about 618,000, or approximately 3% of the 1983 commercial salmon catch in Kvichak Bay. Belukha predation on salmon smolt undoubtedly also occurs in the Nushagak, but we do not have the information necessary to make calculations for that area.

Brooks (1955) calculated the predation on adult salmon based on the average number of salmon per stomach for the whales he collected (2.1 reds, 5 total), a 49-day period of eating salmon, and an estimated 800 whales in 1954 and 450 in 1955. In 1954, estimated consumption was 196,000 (82,320 reds), and in 1955 it was 99,225 (41,674 reds).

Based on observations of feeding and data on the duration of salmon runs in 1983 (ADF&G, unpubl.), we consider 70 days as a more realistic estimate of the period during which belukhas prey on adult salmon. Brooks's data indicate that fewer salmon are taken in August than in July and that even during the peak salmon run other prey are eaten. By multiplying data on the number and kinds of salmon and other species eaten per day over a 7-week period by average fish size, and assuming a total daily consumption of 18 kg per whale, the average daily consumption of salmon from 17 June through 25 August was estimated as 13 kg. Based on our most complete aerial survey in late June 1983, we consider 920 whales to be a reasonable estimate of the number of belukhas (older than calves and yearlings which do not eat adult salmon) present during the adult salmon runs. Using these assumptions, then, the estimated 1983 consumption of adult salmon by belukhas is:

920 whales X 70 days X 13 kg salmon/whale/day = 837,200 kg adult salmon

If the total amount of salmon is allocated by species according to Brooks's data, excluding pinks since there were essentially none present in 1983, then the 837,200 kg represents approximately 182,000 red salmon and 101,000 salmon of other species. The catch of red salmon in Kvichak and Nushagak bays in 1983 was close to 27 million, out of a run of slightly over 33 million, so that belukha predation was the equivalent of less than 1% of the commercial catch and just over 0.5% of the total run. Catch of other species was approximately 1.1 million, with belukha consumption equaling about 9% of that number.

D. Mortality

From May-July 1983, 27-31 dead belukha whales were located or reported in Nushagak and Kvichak bays. In 1982, only six belukha carcasses were found; however, search effort was much less systematic and was confined to the Nushagak area (Lowry et al. 1982). Of the 27-31 whales found in 1983, at least 12 and perhaps several more were fishing-related mortalities. One of the six 1982 carcasses was definitely a fishing-related death. This represents an apparent change in the incidence of entanglement of whales in nets over the last 3 decades. In the 1950's, Brooks observed no net-caused mortality (J. Brooks, National Marine Fisheries Service, Juneau, pers. commun.). Since then, some mortality has been known to occur in conjunction with the king salmon fishery but not, generally, with the red salmon fishery (J. J. Burns, ADF&G, pers. commun.). Of the 12 known fishing-related mortalities in 1983, six were killed in king salmon nets, four in red salmon nets, and two in nets of unknown type.

The cause of this apparent increase in entanglement warrants further study. Possible factors could include changes in gear type, particularly the switch from cotton to nylon webbing; the increase in the number of setnets in areas such as western Kvichak Bay, where many whales concentrate to feed; and the increased amount of time gear is in the water.

If the number of belukhas present in Nushagak and Kvichak bays in summer 1983 (including neonates and yearlings) is estimated at 1,100, the number extrapolated from maximum aerial survey counts on 29 June, then the 27-31 dead animals located in May-July represent 2.5-2.8% of that total group of whales. Gross productivity for belukhas has been estimated at 10% (Brodie 1971), which means in a group of 1,100 whales, 110 would be calves. The seven dead neonates located by us in summer 1983 would represent 6% of that year's calf production. Actual mortality is undoubtedly greater as our mortality figures are based only on carcasses we personally located or happened to hear about. We did not systematically interview fishermen, yet heard of at least four dead belukhas through casual conversation. Although aerial survey efforts were considerably more extensive in 1983 than in 1982, carcasses were probably missed in the Nushagak system which we surveyed less frequently and less intensively. In 1982, three of the six carcasses we found were located up the Snake River in the grass along the riverbank. Such carcasses are extremely difficult to see from the air and probably would not have been noticed on the 1983 aerial surveys.

VIII. Needs for Further Study

This project was initially designed as a 3-year study, the first 1-2 to be spent developing and testing tags and techniques in Bristol Bay, after which techniques were to be used in other areas such as Norton Sound, Kotzebue Sound, and Kasegaluk Lagoon. For a number of reasons, the first field season was not productive in terms of capturing and tagging whales. In the second year, although we did not attach radios to as many whales as we intended, our results were comparable to other successful studies involving radiotelemetry of free-ranging cetaceans.

With respect to belukhas in Bristol Bay, our study has resulted in a reasonably comprehensive description of distribution, abundance, and movements. The issue in this area that merits further investigation is the present level of interaction between belukhas and the commercial fishery for red salmon. Although we have estimated the consumption of salmon by belukhas, our estimates are extrapolations based on old data and numerous assumptions. In truth, we have only a general idea of the predator-prey interactions between belukhas and salmon, and it would be difficult, for example, to suggest means by which to reduce the effects of belukha predation. Of particular interest is the present level of entanglement of belukhas in fishing gear. The reason for the increase in entanglement since the 1950's is unknown, and therefore it would be impossible to suggest means by which to reduce the present level. The actual amount of mortality caused by entanglement is not known nor are the costs to fishermen in terms of damaged gear and lost fishing time.

Our intentions were to develop telemetry as a tool which could be used for studies of belukha movements and behavior. As demonstrated in this report, the OAR backpack radios we used are adequate for short-term studies of that nature. Long-term studies will require development and modification of transmitter packages and attachment mechanisms. Such development should be continued and telemetry applied to whales in other areas in order to describe habitat use, respiration patterns, movements, abundance, and interrelationships among groups of whales. A description of these aspects of belukha whale biology is needed prior to proceeding with oil and gas exploration and other such activities in important parts of their range.

IX. Literature Cited

ADF&G. 1969. A report on beluga whales in Alaska. Unpubl. ms. prepared for the Board of Fish and Game meeting, Anchorage, AK, 1969. 12pp.

Braham, H. W., B. D. Krogman, and G. M. Carroll. 1982. Bowhead whale (Balaena mysticetus) migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975-1978, with notes on the distribution and life history of white whales (Delphinapterus leucas). NOAA Tech. Memo. NMFS SSRF-000. In press.

Brodie, P. F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale (Delphinapterus leucas) with reference to the Cumberland Sound, Baffin Island, population. J. Fish. Res. Board Can. 28:1309-1318.

Brooks, J. W. 1954. Beluga. Pages 51-57 in Annual Report for 1954. Alaska Dep. Fish., Juneau.

Brooks, J. W. 1955. Beluga investigation. Pages 98-106 in Annual Report for 1955. Alaska Dep. Fish., Juneau.

Burns, J. J., K. J. Frost, G. A. Seaman, and L. F. Lowry. In prep. Biological investigations of belukha whales in waters of western and northern Alaska. Final Rep. Contract NA 81 RAC 00049, NOAA, Outer Continental Shelf Environmental Assessment Program.

Butler, R. W., and J. G. Jennings. 1980. Radiotracking of dolphins in the eastern tropical Pacific using VHF and HF equipment. Pages 757-759 in C. J. Amlaner, Jr. and D. W. MacDonald, eds. A Handbook on Biotelemetry and Radio-Tracking. Pergamon Press, New York.

Davis, R. A., W. R. Koski, W. J. Richardson, C. R. Evans, and W. G. Alliston. 1982. Distribution, numbers and productivity of the western arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Unpubl. rep. by LGL Ltd., Toronto, for SOHIO Alaska Petroleum Co., Anchorage, and Dome Petroleum Ltd., Calgary. 134pp.

Doan, K. H., and C. W. Douglas. 1953. Beluga of the Churchill region of Hudson Bay. Fish. Res. Board Can. Bull. 98. 27pp.

Evans, W. E. 1971. Orientation behavior of delphinids: radio telemetric studies. Ann. N.Y. Acad. Sci. 188:142-160.

Fish, J. F., and J. S. Vania. 1971. Killer whale, Orcinus orca, sounds repel white whales, Delphinapterus leucas. Fish. Bull. 69:531-535.

Fried, S. M., J. J. Laner, and S. C. Weston. 1979. Investigation of white whale (Delphinapterus leucas) predation upon sockeye salmon (Oncorhynchus nerka) smolts in Nushagak Bay and associated rivers:

1979 aerial reconnaissance surveys. Unpublished rep. Project 11-41-6-340, Alaska Dep. Fish and Game, Dillingham. 15pp.

Frost, K. J., L. F. Lowry, and J. J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. Final Rep. Contract NA 81 RAC 00050 submitted to NOAA, Outer Continental Shelf Environmental Assessment Program. 166pp.

Gaskin, D. E., G. J. D. Smith, and A. P. Watson. 1975. Preliminary study of movements of harbor porpoises (Phocoena phocoena) in the Bay of Fundy using radio telemetry. Can. J. Zool. 53:1466-1471.

Harrison, C. S., and J. D. Hall. 1978. Alaskan distribution of the beluga whale, Delphinapterus leucas. Can. Field-Nat. 92:235-241.

Hobbs, L. J., and M. E. Goebel. 1982. Bowhead whale radio tagging feasibility study and review of large cetacean tagging. NOAA Tech. Memo. NMFS F/NWC-21. 68pp.

Huttenen, D. C. 1982. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Dep. Fish and Game Tech. Data Rep. No. 73. 63 pp.

Irvine, A. B., J. H. Kaufmann, M. D. Scott, R. S. Wells, and W. E. Evans. 1979. A study of the activities and movements of the Atlantic bottlenosed dolphin, Tursiops truncatus. Final Rep. U.S. Mar. Mammal Comm., Contract Nos. MM4AC004 and MM5AC0018. 34pp.

Irvine, A. B., R. S. Wells, and D. M. Scott. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fish. Bull. 80: 135-143.

Klinkhart, E. G. 1966. The beluga whale in Alaska. Fed. Aid Wildl. Rest. Proj. Rep., Vol. VII: Proj. W-6-R and W-14-R, Alaska Dep. Fish and Game, Juneau. 11pp.

Leatherwood, S., and W. E. Evans. 1979. Some recent uses and potentials of radiotelemetry in field studies of cetaceans. Pages 1-31 in H. E. Winn and B. L. Olla, eds. Behavior of Marine Mammals, Vol. 3. Plenum Publ. Corp.

Leatherwood, S., and D. K. Ljungblad. 1979. Nighttime swimming and diving behavior of a radio-tagged spotted dolphin, Stenella attenuata. Cetology 34:1-6.

Lensink, C. J. 1961. Status report: beluga studies. Unpubl. ms., Div. Biol. Res., Alaska Dep. Fish and Game, Juneau. 20pp.

Lowry, L. F., K. J. Frost, and R. R. Nelson. 1982. Investigations of belukha whales in coastal waters of western and northern Alaska: marking and tracking of whales in Bristol Bay. Annu. Rep. Contract

NA 81 RAC 00049, NOAA, Outer Continental Shelf Environmental Assessment Program. 43pp.

Mate, B. R., and J. T. Harvey. 1981. An evaluation of three radio tags applied to gray whales and their utility in assessing whale movements and dive characteristics. Final Rep. Contract AA 730 794120 0109 submitted to BLM, Anchorage, Alaska. 68pp.

Mate, B. R., J. T. Harvey, L. Hobbs, and R. Maiefski. 1983. A new attachment device for radio-tagging large whales. J. Wildl. Manage. 47:868-872.

Meacham, C. P., ed. 1981. 1980 Bristol Bay sockeye salmon smolt studies. Alaska Dep. Fish and Game Tech. Data Rep. No. 73. 63pp.

Miller, G. W. 1983. Distribution and abundance of gray whales. Pages 13-45 in D. H. Thomson, ed. Feeding ecology of gray whales (Eschrichtius robustus) in the Chirikof Basin, summer 1982. Unpubl. rep. by LGL Alaska Res. Assoc., Inc., Anchorage, for NOAA, Juneau, AK.

Nelson, E. W. 1887. Report upon natural history collections made in Alaska between the years 1877 and 1881. H. W. Henshaw, ed. Congressional Ser., U.S. Public Doc. No. 2349, U.S. Gov. Printing Off., Washington, DC.

Nelson, M. L. 1981. Annual management report 1981 - Bristol Bay area 1981. Unpubl. rep., Alaska Dep. Fish and Game, Anchorage. 175pp.

Ray, C. 1962. Three whales that flew. Natl. Geogr. 121(3):346-359.

Read, A. J., and D. E. Gaskin. 1983. The application of radio tracking techniques to the study of harbour porpoises (Phocoena phocoena) in the Bay of Fundy. Pages 346-352 in D. G. Pincock, ed. Proc. Fourth Int. Conf. Wildl. Biotelemetry, Halifax, Nova Scotia.

Seaman, G. A., and J. J. Burns. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. Rep. Int. Whaling Comm. 31:567-574, SC/32/SM 13.

Seaman, G. A., L. F. Lowry, and K. J. Frost. 1982. Foods of belukha whales (Delphinapterus leucas) in western Alaska. Cetology 44: 1-19.

Sergeant, D. E. 1969. Feeding rates of Cetacea. Fisk. Dir. Skr. Ser. Hav Unders. 15:246-258.

Sergeant, D. E. 1973. Biology of white whales (Delphinapterus leucas) in western Hudson Bay. J. Fish. Res. Board Can. 30:1065-1090.

Sergeant, D. E., and P. F. Brodie. 1969. Tagging white whales in the Canadian Arctic. J. Fish. Res. Board Can. 25:2201-2205.

Sergeant, D. E., and P. F. Brodie. 1975. Identity, abundance, and present status of white whales, Delphinapterus leucas, in North America. J. Fish. Res. Board Can. 32:1047-1054.

U.S. Department of Commerce. 1979. Taking of certain Alaska marine mammals: waiver of the moratorium, final rule. Pages 2539-2554 in Federal Register, Vol. 44, No. 8.

Watkins, W. A. 1981. Reaction of three species of whales Balaenoptera physalus, Megaptera novaeangliae and Balaenoptera edeni to implanted radio tags. Deep-Sea Res. 28A:589-599.

Watkins, W. A., K. E. Moore, D. Wartzok, and J. H. Johnson. 1981. Radio tracking of finback (Balaenoptera physalus) and humpback (Megaptera novaeangliae) whales in Prince William Sound, Alaska. Deep-Sea Res. 28A:577-588.

Watson, A. P., and D. E. Gaskin. 1983. Observations on the ventilation period of the harbour porpoise Phocoena phocoena (L.) in coastal waters of the Bay of Fundy. Can. J. Zool. 61:126-132.

White, M. J. Jr., J. G. Jennings, W. F. Gandy, and L. H. Cornell. 1981. An evaluation of tagging, marking, and tattooing techniques for small delphinids. NOAA Tech. Memo. NMFS-SWFC-16. 142pp.

Appendix I. Radio-tracking record for the whale "BB," frequency 164.535, 9 June-23 June 1983. Numbers in circles correspond to those in Figure 4.

Date	Time	Listening location		Signal received	Comments
9 Jun	2145-2215	Naknek R. mouth		strong	whale released after tagging
	2330-2345	Kvichak		no	from Iliaska
10 Jun	0800	Kvichak		no	from Iliaska
	1000	Nakeen		no	from whaler
	1015	S end Albert Channel		no	"
	1021	mid-Salmon Flats		no	"
	1255	Kvichak		no	from Iliaska
	1340	Halfmoon Bay		strong	from helo at 305 m; BB probably near Naknek R. mouth
	1355	S of Naknek R.		strong	from helo at 152 m; BB between Naknek R. and Johnson Hill
	1556-1647	3.7 km S Naknek R.	1	strong	from whaler; 3-6 signals per surfacing; BB here
	1706-2200	Naknek R. mouth		weak	from whaler and Iliaska
	2215-2315	off Naknek R. mouth	2	strong	from whaler; BB 4-5 km W of Naknek R. mouth

Appendix I. Continued.

Date	Time	Listening location		Signal received	Comments
11 Jun	0830	off the Bend	3	visual	seen by fixed-wing aircraft
	1015	Naknek R. mouth		weak	from whaler; BB toward Copenhagen Cr.
	1250	1.8 km W Naknek R.		weak	from whaler; BB toward Halfmoon Bay
	1444-1500	S Halfmoon Bay	4	strong	from whaler and helo; BB very close but no visual
12 Jun	1100	Naknek R. mouth		moderate	from Iliaska; BB in Halfmoon Bay
	1150	S Halfmoon Bay	5	strong	from whaler and Iliaska; BB in area; same location as yesterday
	1530	"	6	strong	whale very close; with other whales
	2350	Naknek R. mouth		weak	from Iliaska; signal from across bay
13 Jun	± 1030	Naknek R. mouth		no	from Iliaska and whaler
	± 1100	mid-Kvichak Bay		yes	from Iliaska and whaler; BB in Lake Pt. area
	1200	Lake Pt. area	7	strong	from Iliaska and whaler; BB here
	1625	"	8	strong	BB sighted visually nearshore
14 Jun	1000-1200	Naknek R. mouth		strong	from helo; BB on W side of bay

Appendix I. Continued.

Date	Time	Listening location	Signal received	Comments
14 Jun, cont.	1600/1745	near Lake Pt. 9	strong	from helo; BB here
	1725	Lewis Pt.	moderate	from helo; BB near Lake Pt.
	1800	Alagnak R. mouth	moderate	"
15 Jun	1030	Naknek R. mouth	strong	from helo; BB on W side of bay
	1640-1710	S side Naknek R. mouth	weak	from bluff; BB on W side
16 Jun	1000	Naknek R. mouth		from <u>Iliaska</u>; BB on W side
	1510-1550	3.7 km W Naknek R. mouth	strong	from W side of bay
	1640-1700	S Halfmoon Bay 10	strong	from helo; BB here (circled and located)
17 Jun	1200-1500	Buckley's	no	BB out of range to the SW
	1600-1630	"	mod-strong	from bluff
	1900-1931	"	strong	from bluff; whale nearby
	2214-2247	Buckley's	mod-strong	from bluff; whale to NE toward Graveyard
	2347-0018	"	weak-mod	"

Appendix I. Continued.

Date	Time	Listening location	Signal received	Comments
18 Jun	0445-1515	Buckley's	strong	from bluff
	0742-0815	"	strong	from bluff; signal from the E
	0845-0916	"	mod-strong	from bluff
	1000	" 11	strong	from helo; BB here
	1323	Graveyard	weak	from helo; BB to S
	2030-2103	Buckley's	strong	from bluff
	2317-2349	"	moderate	"
19 Jun	0344-0415	Buckley's	weak	from bluff; signal from E
	0923-0953	"	moderate	"
	1105-1115	Kvichak	no	from Iliaska
	1200-1231	Buckley's	weak	from bluff
	1230-1330	Kvichak to Copenhagen Cr.	no	from whaler
	1800	mid-Halfmoon Bay	weak	from whaler; signals to the SW
	1900	4 km SE Copenhagen Cr.	no	from whaler
	2020	Sea Gull Flat	no	"

Appendix I. Continued.

Date	Time	Listening location		Signal received	Comments
19 Jun, cont.	2130-2140	Kvichak		no	from Iliaska
	2240-2245	"		no	"
20 Jun	1300-1400	Halfmoon Bay	12	strong	from helo; BB here
	1310-1320	Kvichak		no	from Iliaska
	1730	Halfmoon Bay	13	strong	from helo; BB here
	1945-2017	Buckley's		strong	from shore
	2213-2244	"		strong	"
21 Jun	1157	S Coffee Cr. channel	14	strong	from helo; BB here
	1430	Naknek R. mouth		moderate	from helo; BB in Halfmoon Bay area
	2300	Graveyard		no	from whaler
22 Jun	1045	N of Graveyard		no	from whaler
	1108	3 km W Graveyard		no	"
	1129	3-4 km E Copenhagen Cr.		no	from whaler
	1150	3-4 km S Copenhagen Cr.		no	"
	1217	2-3 km off Buckley's		moderate	from whaler; BB to S

Appendix I. Continued.

Date	Time	Listening location	Signal received	Comments
22 Jun, cont.	1237	4 km ESE Second Pt.	moderate	from whaler; BB to S
	1307	5 km SW Second Pt.	mod-strong	from whaler; BB to S toward Lake Pt.
	1319	11 km SW Second Pt. 15	strong	from whaler; BB in Lake Pt. area
	1737	12 km SW Second Pt. 16	strong	from helo; whales seen in area
23 Jun	1131	1 km S Graveyard	no	from whaler
	1150	5-6 km WNW Bristol Bay cannery	no	"
	1210	mid-Kvichak Bay off Naknek R.	weak	from whaler; BB to SW
	1230	7-8 km E Buckley's	moderate	from whaler; signals steady
	1328	Graveyard	mod-strong	from helo; signal continuous, BB's radio near Lake Pt.
	1410	E Lake Pt.	mod-strong	radio recovered by whaler-floating

Appendix II. Radio-tracking record for the whale "Mama," frequency 164.585, 18 June-3 July 1983. Numbers in circles correspond to those in Figure 5.

Date	Time	Listening location	Signal received	Comments
18 Jun	1630	N Halfmoon Bay	strong	whale released; headed to the S
	1852-1945	Buckley's	strong	from bluff; whale at surface for $\pm$ 40 min
	2030-2103	"	strong	from bluff; whale to S
	2242-2315	"	very strong	"
19 Jun	0341-0953	Buckley's	no	whale out of range to S
	1105-1115	Kvichak	no	from Iliaska
	1240	Sea Gull Flat	no	from whaler
	1310-1320	Kvichak	no	from Iliaska
	1330	Copenhagen Cr.	no	from whaler
	1800	Graveyard 1	strong	from helo; Mama here
	1800	mid-Halfmoon Bay	moderate	from whaler; Mama toward Graveyard
	1900	3-4 km SE Copenhagen Cr.	moderate	"
	2020	Sea Gull Flat	no	from whaler
	2130-2140	Kvichak	no	from Iliaska
	2240-2245	"	no	"

Appendix II. Continued.

Date	Time	Listening location		Signal received	Comments
20 Jun	1351	4 km SE Copenhagen Cr.	2	strong	from helo; Mama here; 3 whales seen in area
	1730	8 km S Copenhagen Cr.	3	strong	from helo; Mama here
	1945/2020	Buckley's		no	from bluff
	2210/2245	"		no	"
21 Jun	1157	1.8 km W Graveyard	4	strong	from helo; Mama here; whales seen in area
	1232		5	strong	from helo; Mama here
	1430	Naknek R. mouth		strong	from helo; Mama in Graveyard area
	2310	W of Graveyard		weak	from whaler; Mama toward Johnson Hill/Naknek R.
22 Jun	1045	N of Graveyard		no	from whaler
	1108	3 km W Graveyard		no	"
	1129	3-4 km E Copenhagen Cr.		no	"
	1150	3-4 km S Copenhagen Cr.		no	from whaler
	1217	2-3 km off Buckley's		weak	from whaler; Mama to S toward Johnson Hill

Appendix II. Continued.

Date	Time	Listening location		Signal received	Comments
22 Jun, cont.	1237	4 km ESE Second Pt.		no	from whaler
	1307	5 km SW Second Pt.		no	"
	1319	11 km SW Second Pt.		no	"
	1455	3-4 km W Naknek R.		weak	from whaler; Mama on W side somewhere
	1523	5-6 km SSW Graveyard		weak	from whaler; Mama on W side toward Copenhagen Cr.
	1805	4-5 km S Copenhagen Cr.	6	strong	from helo; Mama here
23 Jun	1131	1 km S Graveyard		no	from whaler
	1150	5-6 km WNW Bristol Bay cannery		no	"
	1210	mid-Kvichak Bay off Naknek R.		no	"
	1230	7-8 km E Buckley's		no	"
	1328	S Graveyard		weak	from helo; Mama to SW
	1405	6 km E Lake Pt.	7	strong	from helo; Mama here
	1425	9 km E Lake Pt.	8	strong	"

Appendix II. Continued.

Date	Time	Listening location		Signal received	Comments
23 Jun, cont.	1648	halfway Lake Pt. to Second Pt.	9	strong	from whaler; Mama here
24 Jun	1230	Buckley's		moderate	from whaler; Mama to S
	1339	N Halfmoon Bay	10	strong	from helo; Mama here
27 Jun	1255	N Halfmoon Bay	11	strong	from helo; Mama here
	1502	mid-Halfmoon Bay	12	strong	"
28 Jun	1110	4-5 km SW Second Pt.	13	strong	from helo; Mama here
	1345	4 km W Second Pt.		moderate	from bluff; Mama to NE toward Graveyard
	1430	4 km W Second Pt.		no	from bluff; Mama out of range to N
29 Jun	1143	King Salmon Cr.		moderate	from helo; Mama to SW
	1410	S Halfmoon Bay	14	strong	from helo; Mama here
1 Jul	1200-1300	Naknek R. mouth		no	from bluff
2 Jul	1200-1600	Buckley's to Lake Pt.		no	from whaler; listened every 1/2 hr down and back
3 Jul	1037-1400	Telephone Pt. to Lake Pt.		no	from whaler; listened every 1/2 hr

Appendix II. Continued.

Date	Time	Location	Signal received	Comments
3 Jul, cont.	1410	2 km S Lake Pt.	mod-weak	from whaler; radio to W
	1500	4.6 km SW Lake Pt.	mod-strong	radio recovered on beach with antenna partially buried

Appendix III. Listing of belukha sightings and observations in Bristol Bay, May-July 1983.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
KVICHAK BAY						
6 Apr	1215	King Salmon-Naknek R.	ebb	2	down	seen by King Salmon residents
5 May	1000-1015	Halfmoon Bay	ebb/H 0945	83	up	traveling
	1020-1025	Copenhagen Cr.	ebb/H 0945	32		feeding
	1158	Naknek R. mouth	ebb/H 0945	1		feeding
17 May	1043	Copenhagen Cr.	ebb/H 0703	3		
	1109	Naknek R. mouth	ebb/L 1330	70		feeding
19 May	±1230-1300	Naknek R. mouth	ebb/L 1513	many	down out	traveling
25 May	1119-1123	Branch R. to Levelock	ebb/L ±1145	75-80	up	some feeding at river mouth
	1230	Nakeen - off dock	flood/H 1315	60		feeding
	1352-1356	Halfmoon Bay	H 1351	16		
	1404	Albert Pt.	slack or just ebb/ H 1351	6	down	
26 May	1320-1351	Coffee Cr. to N of Kvichak	flood/H 1515	41-43		some feeding
	1400	Nakeen	flood/H 1440	6		feeding
27 May	±0900	Branch R.	ebb/H ±0500	present		
	± 1200	Branch R.	ebb/L ±1340	20-25	down	feeding
	2000	Kvichak	ebb/H ±1600	12+	down	many gulls and 3-4" fishes (smolt) at surface
28 May	0630-0800	Kvichak	ebb/H ±0530	25	down	
	0800-1000	Kvichak	ebb/H ±0530	20		
	±0900	Branch R. mouth	ebb/H ±0600	20-25		
	±1030	Coffee Cr. channel	ebb/H ±0500	38		
	1045	Graveyard to Deadman Sands	ebb-slack/ L 1107	150-200		none Naknek-Graveyard
	±1200	S Sea Gull Flat	slack-flood/ L 1107	some		
29 May	0730-1100	Kvichak	ebb/H 0615	150+	down	calm
	±0830	Coffee Cr. channel	ebb/H ±0600	50-100		
	1630-1730	Kvichak	flood/H 1740	8-10	up	choppy

Appendix III. Continued.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
29 May, cont.	1730-1830	Kvichak	ebb/H 1740	4	up	choppy
	± 1900	Kvichak	ebb/H 1740	± 2	up	choppy
30 May	1030-1045	Kvichak	ebb/H 0700	8-10	down	choppy
	±1000	Salmon Flats to Branch R.	ebb	present		
	±1400	Telephone Pt. area	flood/L 1248	30-50		choppy
	1500-1600	off & N of Graveyard	flood/L 1248	100-150		from helo
	1655-1740	Kvichak	flood/L 1600	80-100	up	calm
	1740	Kvichak	flood/L 1600	8	down	
	2033	Kvichak	ebb/H 1830	2	up	
31 May	0620	Kvichak	flood/H 0740	2	up	calm
	0915-1020	Kvichak	ebb/H 0740	40-60	down	rough
	±0900	Coffee Cr. channel	ebb/H ±0710	12	up	
	±0900	Kvichak to Branch R.	ebb/H ±0800	35	up	
	1101-1104	Graveyard-Copenhagen Cr.	ebb/H 0710	29		
	1112	S end Halfmoon Bay	ebb/L 1330	1		
	1807-1916	Kvichak	flood/H 1915	223	up	calm; at end milling/feeding
	2045-2055	Branch R. mouth	ebb/H 1940	20-25	down	choppy
	2140	Coffee Cr. channel	ebb/H 1840	8	down	choppy
1 Jun	0930-1050	Kvichak	ebb/H 0815	104	down	mod. calm; 1 side of boat only
	1300-1400	Albert Pt.-Copenhagen Cr.	ebb/L 1416	20+	down	
	1925-1945	Kvichak	flood/H ±2000	14	up	
2 Jun	0725	Kvichak	flood/H 0900	1 or 2	up	choppy
	1310-1345	Kvichak	ebb/H 0940	few (10-15)	down	calm
	±1330	Coffee Cr. channel	ebb/L ±1500	few	down	
	±1400	Albert Pt.	ebb/L ±1500	few		
	1430-1500	Copenhagen Cr. area	ebb-slack/ L 1500	±20	up	
	1430-1500	Halfmoon Bay	ebb-slack/ L 1500	100+	up	about 2 mi out

Appendix III. Continued.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
3 Jun	0728	Kvichak	flood/H 0935	2	up	choppy
	1055	Copenhagen Cr.	ebb/H 0902	12+		
	1046-1111	Branch R. mouth + 1 mi	ebb/H 1010	36+	down	
	1230	Branch R. mouth	ebb/H 1010	6	down	
	1140-1225	Kvichak	ebb/H 0940	86	down	to W of Iliaska only
	1305-1340	Kvichak	ebb/H 0940	34	down	to W of Iliaska only
	1352-1355	Copenhagen Cr.-Nakeen	ebb/L 1540	19-21	down	
	2015	Kvichak	flood/H 2140	5	up	
	1430-1630	Salmon Flats	ebb/L 1540	30-50	down	
4 Jun	0720-0805	Kvichak	flood/L 0600	30+	up	smolt activity at surface; feeding
	1032-1034	Branch R. & above	ebb/H ±1030	85	down	helo count
	1105-1155	Branch R. mouth area	ebb/H ±1030	201	down	boat count (both sides)
	1054-1057	Nakeen-Albert Pt.	ebb/H 0940	16	down	
	1142-1144	Graveyard	ebb/H 0940	12		
	1145-1149	Kvichak to Branch R.	ebb/H ±1000	22		helo
	±1400	King Salmon Cr.-Copenhagen Cr.	ebb/L 1620	10-15+		
	±1600	Telephone Pt.	ebb-slack/ L 1620	few		
5 Jun	1410	1/2-3/4 mi off Peterson Pt. area	ebb/H 1050	30-50	down	
	1515	Halfmoon Bay	ebb/L 1740	12+		
	1630	Naknek R. mouth	ebb/L 1740	30+		feeding
	1700	4 mi off Halfmoon Bay	ebb/L 1740	8		choppy
	2330-0000	Kvichak	flood/H ±0025	some		heard but didn't see
7 Jun	2205-2235	Graveyard	flood/H 0045	100+	up	
	2235-2330	Nakeen	flood/H 0045	5-10+ some	up	same ones seen 1 hr earlier at Graveyard
8 Jun	0905-0930	Telephone Pt.-Graveyard	flood/L 0640	3		conditions poor
	1330-1900	Halfmoon Bay	ebb-slack/ L 1900	few		light chop

Appendix III. Continued.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
8 Jun, cont.	2000-2200	Big Flat - 1-2 mi S of Naknek R.	flood/L 1900	75+ (prob. 100-200)		milling/feeding
9 Jun	1920	mid-Halfmoon Bay	ebb-slack/ L 1940	3-5		choppy
	1925	mid-Kvichak Bay	ebb-slack/ L 1940	10-15		
	1940	Naknek R. mouth	slack/L 1940	±10		milling; choppy
10 Jun	1337	Copenhagen Cr. to King Salmon	slack/H 1330	10+		
	2000	Naknek R. mouth	slack/L 2020	2-3		poor conditions; milling
11 Jun	0650	The Bend	ebb/L 0930	present		
	1030-1130	Big Flat/Naknek R.	flood/L 0930	50+ (prob. 100+)	up	in deep water
	1400-1600	central Halfmoon Bay	slack-ebb/ H 1430	10-20+ present		
12 Jun	1630-1700	mid-Halfmoon Bay	ebb/H 1520	50-100; many	up	light chop
13 Jun	1035	Naknek R. - 1 mi W	ebb/L 1120	1		choppy; milling
	1140	mid-Halfmoon Bay	slack/L 1120	few		
	1630-1650	Lake Pt. area	slack-ebb/ H 1615	20+	up	calm
14 Jun	1000-1200	Big Flat	ebb/L 1214	100+		milling/feeding
	1607-1617	Halfmoon Bay-Lake Pt.	flood/H 1720	40+	up	traveling very close to shore
	1745-1748	Halfmoon Bay	ebb/H 1720	22	up	
	1758-1759	Nakeen-Sea Gull Flat	ebb/H 1720	10+		
	1812-1814	Sea Gull Flat-Graveyard	ebb/H 1720	21	down	
15 Jun	1030-1330	Big Flat	ebb/L 1310	>125 (prob. ± 200)	down	swimming here from E; feeding toward end
	1640-1710	Big Flat	flood/H 1823	present		chop
16 Jun	1200	Naknek R. mouth	ebb/L 1400	10-20	down	
	1230-1330	Big Flat	ebb/L 1400	100+		milling/feeding
	± 1500	Halfmoon Bay	flood/L 1400	several 100's		

Appendix III. Continued.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
16 Jun, cont.	1630-1700	Halfmoon Bay	flood/L 1400	70+	up	chop; some milling
	1833	Graveyard	flood/H 1930	3+	up	
17 Jun	A.M.	Leader Cr.	H 0830	6 or 7		in river; report by fisherman
	1911-1918	Graveyard/Coffee Cr. channel	flood/H 2040	23+	up	
	2130	Nakeen-Sea Gull Flat	ebb/H 2040	20-25	down	
18 Jun	0943-0944	Branch R.	slack-flood/ H 1010	6	down	
	0943-0956	Nakeen - Graveyard - Sea Gull Flat	H 0910	30-50	down	
	0958	King Salmon Cr.	ebb/H 0910	1		
	1004-1033	Halfmoon Bay	ebb/H 0910	30+	down	some milling
	1043-1046	Graveyard-Libbeyville	ebb/H 0910	86+	down	feeding
	1530	Halfmoon Bay	ebb-slack/ L 1550	30-50+		
19 Jun	1252	Telephone Pt.	ebb/H 1003	1	down	
	1430-1530	Halfmoon Bay	ebb/L 1640	few		
	2150	Kvichak	flood/H 2330	1	up	
20 Jun	1310	Kvichak	ebb/H 1130	1	down	
	evening	Kvichak dock	flood/L 2020	few		reported by Commercial Fish Div.
21 Jun	1000	Coffee Cr. channel	flood/H 1140.	1		
	1115-1200	Nakeen - Sea Gull Flat - Graveyard	flood-slack/ H 1140	50+	up	
	1232	W of Graveyard	ebb/H 1140	20+	down	
	2255	Telephone Pt.	flood/H 0108	2		
	2300	Naknek R. area	flood/H 0108	present		
22 Jun	1045	Graveyard	flood/L 0700	1 or 2		choppy
	1730	Deadman Sands	ebb/L 1910	small group		
	2214	Coffee Cr. channel	flood/L 1910	1	up	
	2330	Kvichak	flood/L 2200	several		

Appendix III. Continued.

				Whales		
Date	Time	Location	Tide	No.	Dir.	Comments
23 Jun	0010	Kvichak	flood/L 2200	several	up	
	1320-1330	Graveyard-Bend	slack-ebb/ H 1320	20+	down	
	1400-1420	Halfmoon Bay-Lake Pt.	ebb/H 1330	many		milling
24 Jun	± 1200	Halfmoon Bay	flood/H 1410	many		feeding
	1330-1331	Graveyard	flood/H 1410	2		
	1336	Albert Pt.	flood/H 1410	2+		
	1339-1343	Halfmoon Bay	flood/H 1410	10+		
	1347	Lake Pt., N of	flood/H 1410	2		
27 Jun	1250	Copenhagen Cr.	flood/L 1135	few present		
	1255	Halfmoon Bay	flood/L 1135	present		none on E side of Bay
	1505	King Salmon Cr.	flood/H 1630	35+		
28 Jun	1057	Copenhagen Cr.	ebb/L 1221	57		
	1100-1146	Halfmoon Bay	ebb/L 1221	124	up	feeding
	±1900	Halfmoon Bay	ebb/H 1720	±60	up	300 m offshore
29 Jun	A.M.	E side Graveyard & Kvichak R.	ebb/H 0637	0		surveyed
	1353-1410	Halfmoon Bay	flood/L 1303	202	up-113 down-89	
	1429	Lake Pt. area	flood/L 1303	6		feeding
30 Jun	0400-0700	Nakeen/Sea Gull Flat	flood/H 0713	25+		feeding
2 Jul	A.M.	Sea Gull Flat		present		
3 Jul	1115-1125	below Graveyard	ebb/H 0852	100+		milling/feeding
	1520	S of Lake Pt.	flood/L 1540	20+		feeding
	1820	Copenhagen Cr.	flood/L 1540	5+		
	1830-1900	S of Graveyard	flood/L 1540	present		
4 Jul	0945	Nakeen-Sea Gull Flat	slack-ebb/ H 0930	100+		
	1015	N Copenhagen Cr.	ebb/H 0930	30+	down	feeding; in among nets
	2100	Coffee Cr. channel	flood/H 2230	5-10		

Appendix III. Continued.

				Whales		
Date	Time	Location	Tide	No.	Dir.	Comments
5 Jul	1005	Nakeen- Sea Gull Flat	slack/H 1000	10-20		
	1300	King Salmon Cr.	ebb/H 1000	80-100	down	
6 Jul	±1145	S of Graveyard	ebb/H 1040	few		
7 Jul	1320-1350	King Salmon-Copenhagen Cr.	ebb/H 1120	400+	down	some stopped to feed
12 Jul	±0100-0200	Graveyard	flood/H 0434	present		
	0558	S Nakeen	ebb/H 0434	2		
	0615	N Graveyard	ebb/H 0434	200+	up	
14 Jul	1345-1450	King Salmon-Copenhagen Cr.	flood/L 1240	50+		milling
14 Aug	1525	SW of Halfmoon Bay	flood/L 1401	127		in very shallow water
	1546	Halfmoon Bay	flood/L 1401	179		resting or feeding
	1557	Naknek R. mouth	flood	3	up	traveling
NUSHAGAK BAY						
15 Apr	0923	Snake R. mouth	ebb/L 1012	10	down	all adults
	0932	Snake R., near Weary R.	ebb/L 1012	3		feeding, up as far as ice permitted
	0945	Igushik R. mouth, N of	ebb/L 1012	24	N	feeding in very shallow water
	0956	Igushik R., big bend	ebb/L 1012	13		feeding in shallows
	1004	Clarks Pt.	ebb/L 1012	4		
	1012	Etolin Pt.	ebb or slack/ L 1012	5		feeding
2 May	1601-1605	Snake R.	flood/L 1357	7	up	
5 May	0932	Ekuk	flood/H 0945	5		traveling
	0939-0944	Etolin Pt. area	flood-slack/ H 0945	2		traveling
15 May		Nushagak R., Black Pt.		present		from Doug McCart of Armstrong Air
17 May	0935-0937	Snake R., near mouth	ebb/H 0703	4	down	
	±0940	Snake R., near Weary R.	ebb/H 0703	7		
	0951	Igushik R. mouth	ebb/H 0703	2		

Appendix III. Continued.

Date	Time	Location	Tide	Whales No.	Whales Dir.	Comments
17 May, cont.	0952-1005	Igushik R., in river	ebb/H 0703	10		
31 May	1141	Grassy Is.	ebb/L 1332	2		
	1145-1250	Little Muklung R. mouth	ebb/L 1332	8		
3 Jun	1310	mid-Bay, Igushik to Ekuk	ebb/L 1538	20-30	NW	grays and whites
14 Jun	1647	Snake R.; in river	flood/H 1719	2		
	1650-1710	Snake R. mouth & S	flood/H 1719	6		
	1655	Igushik R. mouth	flood/H 1719	?		
	1700	Igushik R., near big bend	flood/H 1719	7		
	1724	Nushagak R., Lewis Pt.	slack/H 1719	2		
24 Jun	1359	Etolin Pt.	flood/H 1411	1		very close to shore
	1422-1423	Coffee Pt.	slack or ebb/ H 1411	3		
	1426-1433	Snake R. mouth	ebb/H 1411	50+		feeding/milling
	1602	Little Muklung R. mouth	ebb/H 1411	12		
27 Jun	1320	Little Muklung R. mouth	flood/L 1135	24+		milling, very close to shore
	1330-1400	Snake R. mouth to Coffee Pt.	flood/L 1135	54		
	1337-1338	Igushik R. mouth, N of	flood/L 1135	15		
29 Jun	1508-1510	Coffee Pt.	flood/L 1303	2		
	1520-1530	Snake R. mouth	flood/L 1303	107		
	1540	Igushik R. mouth	flood/L 1303	4		
	1546	Igushik R., near big bend	flood/L 1303	13		
12 Jul	1440-1450	Clarks Pt.-Ekuk	flood/H 1559	90+	down	among and W of processor fleet
13 Jul	1145-1255	Snake R., in river	slack-flood/ L 1148	25+	up	very close to bank
	1400	Snake R. mouth, E of bar toward Clarks Pt.	flood/L 1148	87+		conditions poor for counting
	1445	Grassy Is.	flood/H 1705	1		
14 Jul	1225	Snake R. mouth	ebb-slack/ L 1241	12		

Appendix III. Continued.

				Whales		
Date	Time	Location	Tide	No.	Dir.	Comments
14 Jul, cont.	1230	in Snake R.	ebb-slack/ L 1241	15	up	
	1315	Clarks Pt.	flood/L 1241	96		
	1321	Ekuk	flood/L 1241	11		

Appendix IV. Beach-cast belukha carcasses found in Nushagak and Kvichak bays, May-July 1983.

Specimen number	Location	Date	Sex	Std. length	Girth	Fluke width	Comments
BBD-1-83	Scandinavian Landing, Nushagak Bay	11 May	F	259.1	157.5	55.9	caught in king salmon net; color-gray; saved skull, stomach, repro; hide and blubber at sternum-5.1 cm
BBD-2-83	"	11 May	F	280.7	156.2	66.0	caught in king salmon net; color-gray; saved skull, stomach, repro; hide and blubber at sternum-7.9 cm
BBD-3-83	Nakeen Cannery, Kvichak River	26 May	F	320	173	65.0	found floating; dead for several days; no obvious cause of death; color-gray; saved skull, stomach, repro
BBD-4-83	Between mouths of Snake and Igushik rivers	3 Jun	M	310	-	-	recently dead; stomach empty; no obvious cause of death; saved skull
BBD-5-83	1-2 km below S end of Coffee Cr. channel	6 Jun	M	380	-	-	found high up in grass; estimated dead 3+ weeks; saved skull
BBD-6-83	near Etolin Point village	21 Jun	M	410	-	-	very old carcass, probably >1 year; upper jaw missing, lower one broken (saved)

Appendix IV. Continued.

Specimen number	Location	Date	Sex	Std. length	Girth	Fluke width	Comments
BBD-7-83	Flounder Flat, about halfway between Etolin Pt. and Ekuk	21 Jun	M	230	-	-	bullet holes mid-body; dead several weeks; saved lower jaw
BBD-8-83	"	21 Jun	U	-	-	-	very old carcass, probably >1 year; posterior 1/3 to 1/2 gone; very large
BBD-9-83	Igushik Beach camp	21 Jun	M	139	-	-	estimated 30 kg; 3" umbilicus; on beach about 1-1/2 weeks
BBD-10-83	1-2 km S of Igushik Beach camp	21 Jun	M	± 360	-	-	old carcass, on beach last year
BBD-11-83	mid-Halfmoon Bay	28 Jun	M	343	-	-	old carcass; jawbone exposed; skin dried; skull saved
BBD-12-83	near Lake Point	28 Jun	M	127.3	-	-	fetus or premature calf, too small for normal newborn; carcass 1-2 weeks old
BBD-13-83	southern Halfmoon Bay	28 Jun	F	192	-	-	yearling, no erupted teeth; caught 23 Jun by set-netter Jim McDade; gray

Appendix IV. Continued.

Specimen number	Location	Date	Sex	Std. Length	Girth	Fluke width	Comments
BBD-14-83	mid-Halfmoon Bay	4 Jul	F	250	-	-	caught in setnet by Jim McDade on night of 2 Jul; gray; stomach empty; teeth erupted
BBD-15-83	"	4 Jul	M	150	94.5	31.5	washed up on beach 3 Jul, fresh; neonate; caught near flukes in net
BBD-16-83	southern Flounder Flat	15 Jul	F	137.2	-	25.1	neonate with umbilicus
BBD-17-83	near Etolin Point village	15 Jul	M	139.1	-	26.7	neonate without umbilicus
BBD-18-83	Etolin Point	15 Jul	M	138.4	-	-	neonate; missing right pectoral; maggots
BBD-19-83	"	15 Jul	M	139.4	-	29.8	neonate; umbilicus rotted out; no obvious cause of death
BBD-20-83	halfway between Lake Pt. and Etolin Pt.	15 Jul	F	143.5	-	-	umbilical scar not healed; missing left pectoral
BBD-21-83	mid-Halfmoon Bay	18 Jul	M	est. 335	-	-	probably dead ≥ 1 week; flukes cut off; tooth taken from lower jaw; possibly the whale reported by the Silver Surfer on 11 Jul

Appendix V. Information on belukha whale mortality in Bristol Bay, May-July 1983.

4-8 May	One belukha taken, probably by shooting, near Black Point, Nushagak River. The carcass was given to Stepan Pat in Dillingham.
11 May	*Two small gray female belukhas* (BBD-1-83; BBD-2-83) caught and drowned in king salmon setnets at Scandinavian Landing, Nushagak Bay.
10-20 May	Two belukhas taken (hunted) by people at Levelock, according to Dick Russell of Commercial Fisheries Division, King Salmon. According to John Wright of Subsistence Division, Dillingham, the villages of Clark's Point and Manokotuk each take about 2 belukhas per year.
26 May	Dead gray female belukha (BBD-3-83) found floating near Nakeen. Dead for several days, no obvious cause of death.
1 June	Report received by ADF&G from Bumblebee Cannery that the fishing vessel <u>Pluto</u> had a dead belukha. No further details available. We were unable to contact the <u>Pluto</u>.
1-6 June	Four belukhas caught in commercial king-salmon drift nets in Nushagak Bay, according to Ken Taylor, Game Division, Dillingham.
3 June	On a survey of Kvichak and Nushagak bays for beach-cast carcasses, one white male belukha (BBD-4-83) was found on the beach between the Snake and Igushik rivers. The carcass was fresh, cause of death was not obvious.
6 June	Dead male belukha (BBD-5-83) found on tundra north of Graveyard Point. Whale had been dead for quite a while (3+ weeks), bear tracks all around it.
9 June	Small male belukha caught in king-salmon setnet about 7 km south of Naknek River mouth at 1530-1930. This whale (BB) was rescued and subsequently tagged and tracked for 2 weeks until the radio came off.
10 June	A small (2.5-2.75 m) dead belukha was found on the beach near the north point at the entrance to the Naknek River. This was a very old, long-dead carcass, badly decomposed and beaten up. The lower jaw was missing.

Appendix V. Continued.

17 June	Employee at Bumblebee Cannery reported a dead belukha on the beach about 18 km south of Johnson Hill. We surveyed this area on 18 June and did not find it.
21 June	Aerial survey flown of Kvichak and Nushagak bays for beach-cast carcasses. Six belukha carcasses were found, 4 of which may have been dead for over (or up to) 1 year. One was located about 5 km southwest of Lake Point. The skull was smashed and mostly gone; probably dead over a year; no specimens taken. Two other very old carcasses were found near Etolin Point and Flounder Flat (BBD-6-83; BBD-8-83) and another (BBD-10-83) about 2 km south of Igushik Beach. This one was known to be dead over 1 year (local set-netters had seen it last year). A gray juvenile male (BBD-7-83) dead several weeks, with bullet holes in the mid-body region, was found about halfway from Ekuk to Etolin Point village. A male neonate (BBD-9-83), umbilicus attached, was found at Igushik Beach. Local residents said it had been there about 1-1/2 weeks.
28 June	Aerial survey for beach-cast carcasses was flown of Kvichak Bay. Three dead belukhas were found on the west side. One (BBD-11-83) was a very old carcass of a male, lower jaw exposed and skin very dry. One was a premature male calf (BBD-12-83), dead at least 1-2 weeks, and the third (BBD-13-83) was a yearling female. We subsequently found out this one was caught at night on 23 June by a set-netter (Jim McDade) on the west side. It was covered with sand by the local folks on 3 July. On 15 July it had washed out of the sand and moved north about 1-2 km, where we located it on an aerial survey.
4 July	Two carcasses were found on the west side of Kvichak Bay in central Halfmoon Bay. One (BBD-14-83) was a subadult female that had been caught in a setnet the night of 2 July by Jim McDade. The other was a neonate (BBD-15-83) with umibilicus that washed up on the beach on 3 July. Both of these carcasses were towed offshore into deep water after examination.
6 July	Dick Russell received a call about another dead belukha on the west side of Kvichak Bay. We looked for it on the 7th but did not find it.
11 July	Crew of the <u>Silver Surfer</u> told us they caught a 3.4-3.7-m belukha sometime the previous week. The whale was caught at night, in the distal 2-3 m of their drift net. It was tangled in the web and float and lead lines. They cut the flukes off to get it out of the net and threw it overboard. It was white when it came aboard but later turned gray.

Appendix V. Continued

14 July	An aerial survey for beach-cast carcasses was flown of Kvichak and Nushagak bays. Six belukha carcasses were located: 1 small ($\leq$ 3 m) animal about 2 km south of Igushik Beach; 3 neonates around Etolin Point; and 2 subadults, 1 in mid-Halfmoon Bay and 1 south of Lake Point.
15 July	An aerial survey was flown from Clark's Point to northern Halfmoon Bay to relocate and take specimens from belukha carcasses seen on 14 July. Five neonates (BBD-16 to 20-83), 3 presumably the same as the 3 seen on the 14th, were located between Flounder Flat and Lake Point. In addition, 1 juvenile without a head was seen south of Buckley's (probably BBD-14-83), and the carcass we examined on 28 June (BBD-13-83) was seen about 1 km north of Buckley's.
18 July	An adult male, estimated 335 cm, was found in mid-Halfmoon Bay. It had been dead a week or so; the flukes were missing. This may have been the dead whale caught by the <u>Silver Surfer</u> and reported to us on 11 July.