Movements and diet of gray whales (*Eschrichtius robustus)* off Kodiak Island, Alaska, 2002-2005

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ABSTRACT
Large feeding aggregations of gray whales, (*Eschrichtius robustus*), numbering 200-400 individuals have been documented near Ugak Bay off the northeast coast of Kodiak Island, Alaska, since at least 1999 (Moore et al., 2007). In 2002, 2003, and 2005, vessel surveys were conducted off Ugak Bay to photo-identify individual gray whales and to determine their foraging habits and prey consumption. Surveys were conducted in August or early September for a total of 15 days of survey effort. Eighty-four unique gray whales were identified from photographs taken near Ugak Bay from 2002 to 2005. Seventeen of these whales were matched to gray whales photographed in the Pacific Northwest from northern California to southeast Alaska, an area which is utilized by a portion of the eastern Pacific gray whale population often referred to as the Pacific Coast Feeding Group (PCFG). The timing of these sightings indicated that some of the gray whales seen at Kodiak Island spend time in the summer months foraging south of Alaska and that the home range of gray whales in the PCFG can extend from northern California all the way to Kodiak Island. Seven gray whales sighted around Kodiak Island in 2002-2003 returned and were identified there in 2005, which may indicate some level of site fidelity. It is believed that these movements are driven by food availability. During 2002 and 2005, 36 samples were collected from fecal plumes near surfacing gray whales. Ninety-two percent of the samples collected in 2005 contained exoskeletons of cumaceans, swarming epibenthic crustaceans which are present in the area in high densities. The gray whales off Ugak Bay were foraging in waters averaging 95 m deep (range 85-104 m). These depths are thought to be the deepest foraging locations known for gray whales south of the Bering Sea.

KEYWORDS: GRAY WHALE; PACIFIC OCEAN; DISTRIBUTION; MOVEMENTS; FOOD/PREY; PHOTO-ID

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INTRODUCTION

Eastern North Pacific gray whales (*Eschrichtius robustus*) migrate northward along the west coast of North America from wintering areas in lagoons off Baja California, Mexico to feeding areas off the Pacific Northwest and Alaska coasts (Rice and Wolman, 1971). The majority of the population migrates to Alaskan feeding grounds as far north as the Bering, Chukchi and western Beaufort Seas between May and October (Rice and Wolman, 1971; Swartz, 1986; Swartz *et al.*, 2006). A smaller percentage of the population remains south of the Bering Sea during the spring, summer and fall, feeding along the coast from northern California to southeast Alaska. These feeding groups have been referred to as "summer" or "seasonal" residents in the past (Pike, 1962; Darling, 1984; Darling *et* al., 1998; Calambokidis *et al*., 2002), as the Pacific Coast Feeding Aggregation (NMFS 2001), but more recently they have been described as the Pacific Coast Feeding Group (PCFG; IWC *in press*).

Since the late 1970's, research on the PCFG gray whales has focused primarily on the Pacific Northwest from northern California to northern Vancouver Island, British Columbia. These studies have examined the diet, range, movements, distribution, and abundance of gray whales in this region (Darling, 1984; Murison *et al*., 1984; Darling *et al*., 1998; Jenkinson, 2001; Calambokidis *et al*., 2002; Dunham and Duffus, 2002).

A large aggregation of feeding gray whales was observed by Kate Wynne off Kodiak Island, Alaska beginning in 1999 during aerial surveys for pinnipeds (Moore *et al*., 2007). In July 2000, 350-400 gray whales again were seen near Kodiak Island during aerial surveys. The whales were observed off Ugak Bay (Fig. 1) and sightings extended offshore as far as 100km (Moore *et al*., 2007). The whales appeared to be feeding in the vicinity because mud plumes were noted in the water near surfacing whales. These observations led to a more intensive survey effort beginning in August 2002 using vessels in and near Ugak Bay. The objectives during 2002 were to collect data on the relative abundance and distribution, document general foraging behavior and conduct photo-identification surveys of gray whales in the area. In addition, sampling of benthic and epibenthic fauna was conducted using a van Veen grab sampler in the vicinity of feeding gray whales. Extremely high densities of cumaceans (*Diastylopsis dawsonii*) were found in the grab samples (Moore *et al*., 2007). These cumaceans were the dominant fauna in the area and were in densities among the highest reported in the world (Moore *et al*., 2007).

Photo-identification and prey sampling surveys were continued off Kodiak Island in 2003 and 2005. This paper reports the results of the Kodiak Island gray whale surveys from 2002-2005. The primary objective of this paper is to report on photo-identification matching of gray whales from Kodiak with those from the PCFG and to describe the prey and foraging behavior of gray whales in the area.

MATERIALS AND METHODS

Vessel transect surveys

Transect-type surveys for gray whales in 2002, 2003, and 2005 were conducted aboard the M/V *Mythos*, a 13.4m fishing and charter vessel. The transect surveys were not intended to be used to estimate true abundance, but only to document the spatial distribution of gray whales in the area. Survey watch was conducted by two observers

from the bridge of the *Mythos* where the eye height was approximately 4m above the water level. In 2002, the *Mythos* carried a Mark II Zodiac* with a 35hp engine. The Zodiac was launched in the vicinity of feeding gray whales so that closer approaches could be made to photograph whales. In 2003 and 2005, the Zodiac was replaced with a 5m aluminum seine skiff powered by a 115hp outboard engine. The skiff was towed behind the *Mythos* and launched when groups of whales were encountered. During the gray whale surveys from 2002-2005, the area between Gull Point in Ugak Bay and Ugak Island (Fig. 1) was the central survey location although additional surveys were conducted in other locations. The *Mythos* would generally anchor inside Ugak Bay at night at Gull Point or Pasagshak Bay. Transect surveys were conducted when the *Mythos* was in transit between Kodiak Harbor and Ugak Bay and also in and around Ugak Bay from Narrow Cape south to Kiliuda Bay and also each morning from Gull Point to the first aggregations of gray whales encountered (Fig. 1). A few offshore surveys were also conducted, transiting 10 – 20km offshore of Ugak Bay to determine the relative distribution of gray whale groups in the area. When groups of gray whales were encountered, their positions were recorded and photographs were taken, either from the *Mythos* or from the skiffs.

Photo-identification surveys

In 2002 and 2003, photographs were taken using 35mm single-lens reflex cameras equipped with telephoto lenses, such as a Canon EOS 630 with a 70-210mm zoom lens, a Canon EOS 3 with a 75-300mm image stabilized zoom lens, and a Nikon N90S with a fixed 300mm f/4 telephoto lens. Both Fuji Neopan 1600 black and white print film and Fuji Provia 100F and 400F color slide film were used for photographing the gray whales. The film was developed commercially and the negatives were sent to the Cascadia Research Collective (CRC) for cataloging and comparing the images with photographs in their collection.

In 2005, a Nikon D-70 digital camera with a 70-300mm zoom lens was used to photograph gray whales. The images were transferred to DVDs and sent to the CRC for identification and matching.

Gray whales are identified by their natural markings on the left and right sides of the whale, especially in the region around the dorsal hump, an area routinely exposed during the whale's surfacing. The photographs were compared with others taken that year in other locations and with a catalog maintained by CRC of gray whales photographed in previous years and in subsequent years up to 2008 along the west coast of the United States and British Columbia, Canada. At CRC, the photographs were compared by at least two matchers to identify the whale. As a final check on the matching, the relative spacing between the knuckles along the dorsal ridge behind the dorsal hump was measured and compared. The Kodiak gray whale photographic images were also analyzed by the Coastal Ecosystem Research Foundation who discovered additional matches.

Prey sampling

Fecal samples were collected from gray whales in 2002 and 2005. Fecal plumes were approached while onboard the *Mythos* in the vicinity of surfacing gray whales. A plankton net was used to scoop through the center of a plume. The net was then rinsed with seawater using a hose and the material was funneled into the codend. The material from the codend was collected in glass vials and preserved in 10% buffered formalin. Upon return to the laboratory, contents of all samples were identified to lowest possible taxon. All complete, identifiable organisms were measured and enumerated. Relative abundance of each taxon was noted within each sample.

In 2002, 10 samples were collected using a 2m plankton net attached to a salmon dip net frame. The mesh size of the plankton net was 0.15mm. One sample was also collected aboard the Zodiac by simply using a plastic bucket.

In 2005, a plankton dip net was specially constructed with a 65cm x 65cm opening in the frame and a handle length of 1.5m. The plankton net was 1m in overall length with a mesh size of 0.79mm. The mesh size of the collection bucket at the end of the plankton net was also 0.79mm.

RESULTS

Vessel surveys

In 2002, surveys were conducted from 14 to 19 August. Twenty-eight sightings of a total of 54 gray whales were made between the mouth of Ugak Bay and Ugak Island in water approximately 55 to 73m deep (Fig. 2). The average depth of 20 of these whale sightings was 66.4m.

In 2003, vessel surveys were conducted from 9 to 11 August. Three gray whales were photographed each day while the vessel transited between Kodiak Harbor and Ugak Bay. These whales were in the area between Cape

*****Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Greville and Sequel Point or Slope Peak Point to the north of Ugak Island (Fig. 2). On 10 August, only three gray whales were sighted between Ugak Bay and Ugak Island but were too far away to be photographed. The whales between Cape Greville and Slope Peak Point occurred in water between 19 and 27m deep, whereas those between Ugak Bay and Ugak Island were in water between 27 and 81m deep. In 2003, nine sightings of 11 gray whales were made, but only 4 gray whales could be identified.

In 2005, vessel surveys were conducted from 31 August to 5 September. A total of 240 gray whales were counted in 87 sightings. As in 2002, gray whales were sighted between the mouth of Ugak Bay and Ugak Island, but in an area to the south of the sightings in 2002. The average depth of the water off Ugak Bay where whales were sighted in 2005 was 90.2m (range= 54.9m – 103.5m).

Photo-identification

In August 2002, 42 individual gray whales were photographed and identified off Kodiak Island. Of these, four (#152, #232, #566, and #639) had been photographed previously off the west coasts of the United States and Canada during the summer and early fall (Table 1). The remaining 38 gray whales (#721 - #758) were identified for the first time at Kodiak Island in 2002. Gray whale #723 was later photographed off Everett, Washington, in northern Puget Sound in March and April 2004. It was photographed again in northern Puget Sound in April and May 2005.

In 2003, very few gray whales were sighted during a survey from 9 to 11 August. Only four gray whales were photographically identified at Kodiak Island and were sighted between Cape Greville and Slope Peak Point, an area north of Ugak Bay (Fig. 2). Three (#316, #684, and #691) of the four gray whales sighted in 2003 at Kodiak Island had been previously sighted off the west and south coast of Vancouver Island (Table 1).

Moore *et al*. (2007) reported that seasonal sightings of gray whales in that area are most frequent in September to November, so the main body of gray whales probably did not appear until later in the season.

In 2005, 45 gray whales were photo-identified during a survey from 31 August to 5 September. Of these animals, 13 were previously photographed one or more times off the west coasts of the United States and British Columbia; seven were in northern British Columbia; seven were off western and southern Vancouver Island; two each off the Washington and California coasts, and one each off the coasts of Oregon and Southeast Alaska.

Of the 45 gray whales that were identified in 2005, 7 (#152, #316, #566, #691, #737, #750, and 758) had previously been photographed off Kodiak Island in 2002 and 2003.

Of the 84 gray whales identified from Kodiak Island from 2002 to 2005, 17 had also been photographed at lower latitudes off the west coasts of the United States and Canada (Fig. 3). However, two of these gray whales were sighted in Washington waters from March to May

Local abundance estimate

During the six survey days between 31 August and 5 September 2005, 45 unique gray whales were photographed on one or more days. The program, CAPTURE, was used to fit a set of closed population models to the sighting history data in Table 2 to estimate the local abundance of gray whales in the area around Ugak Bay. Model M_t with time varying capture probabilities was selected as the most appropriate model. The estimate of abundance was 53 (SE=5.3; 95%CI=47-68).

Thus, after surveying the area around Ugak Bay for six days, an estimated 85% of the gray whales present in that local area were identified.

Foraging behavior and prey identification

A total of 10 fecal dip-net samples collected in 2002 and 26 samples in 2005 were used to characterize prey utilization by gray whales in the Ugak Bay region. All samples were collected in an area characterized by a relatively even soft-bottom substrate in depths ranging from 85 to 104m. The dominant identifiable component of 24 of the 26 samples from 2005 was exoskeletons of epibenthic cumaceans, likely of the genus *Diastylopsis.* The two other samples contained little identifiable organic material. Other invertebrates found in samples (*e.g.* polychaetes, ophioroids, decapod crabs) were characteristic of benthic soft-bottom communities and were likely byproducts of gray whales' indiscriminate 'benthic sucking' foraging behavior. Samples from both 2002 and 2005 contained small numbers of crab zoeae, which are known gray whale prey along Vancouver Island (Dunham and Duffus, 2002), although in this area off Ugak Bay they were likely recovered from the surface waters while dip-netting the fecal samples.

DISCUSSION

During their northbound migration, most gray whales travel from Baja California, Mexico, to feeding grounds in the Bering and Chukchi Seas (Rice and Wolman, 1971). However, some gray whales migrate only as far as foraging areas along the west coasts of California, Oregon, Washington, and British Columbia. These whales are referred to as the Pacific Coast Feeding Group (PCFG). Gray whales seen near Kodiak Island that have also been sighted at lower latitudes in the summer should also be considered to be part of the PCFG.

From 2002 to 2005, 84 gray whales were identified off Kodiak Island. Twenty percent of these animals have been sighted off the Pacific Northwest, British Columbia and Southeast Alaska. Fifteen of these animals were sighted in the southern feeding areas after June 1st after the northbound migration. Six animals sighted at Kodiak Island were re-sighted in subsequent years off the west coasts of the United States and Canada. Two gray whales were photographed off southern and northern Vancouver Island in June and July before being resighted at Kodiak Island later in the same year. It is believed that as more gray whales are identified from the Kodiak group, more matches to animals from the Pacific Northwest will result.

This paper addresses the sightings of Kodiak Island gray whales in other areas. It does not address the proportion of gray whales from other areas that appeared at Kodiak Island. Table 1 shows that Kodiak Island gray whales were sighted mostly in northern British Columbia, west Vancouver Island, and southern Vancouver Island. The amount of effort expended searching for gray whales in each of these areas differed.

Of the 45 gray whales identified in 2005, 16% had previously been photographed near Kodiak Island in 2002-2003. This indicates that some gray whales return to the area off Ugak Bay at least on one or more years. Gray whale #316 was photographed by Brenda Rone (NOAA, NMML) during the 2005 SPLASH[1] Cruise off Kodiak Island on 13 August, indicating that the whale remained in the waters off Kodiak Island for around a month and was not just passing through.

Fecal samples collected in 2002 and 2005 indicate that gray whales were foraging over soft bottom sediment in deep waters (85-104m) off Ugak Bay. Samples contained a variety of invertebrates commonly associated with these soft bottom communities (polycheates, ophioroids, decapod crabs) but were dominated by the presence of cumaceans, likely of the genus *Diastylopsis*. Foraging by gray whales at depths greater than 50m has not been documented within the PCFG south of Alaska. Perhaps the energetic expense of repeated foraging dives to great depths needs to be balanced with the metabolic reward for finding dense prey patches.

It appears that epibenthic cumaceans are the primary prey resource utilized by gray whales around Ugak Bay, Kodiak Island. Moore *et al*. (2007) noted this area to have the highest measured density of cumaceans ever reported. The distribution and density of cumaceans along the Pacific Northwest coast is typically patchy (Lie and Kisker, 1970), although in areas of high cumacean densities such as the Klamath River, California (Jenkinson, 2001), Chukchi Sea (Kim and Oliver, 1989) and Sea of Okhotsk (Sobolevskii *et al*., 2000) large numbers of gray whales are known to utilize this resource for extended periods of time. Within the region encompassed by the PCFG, cumaceans should likely be incorporated into the commonly cited prey preferences along with burrowing amphipods and mysids. These prey allow for extended summer foraging south of the primary feeding grounds in the Bering and Chukchi Seas.

The abundance of gray whales off Ugak Bay during the 6 day survey in 2005 was estimated to be only 53 animals although Moore *et al*. (2007) reported that as many as 350-400 gray whales have been present here in other years. These changes in abundance suggest there is an inconsistent use of this foraging area. Although some authors (e.g., Darling *et al.*, 1998) have thought that gray whales exhibit strong site fidelity, returning to the same feeding areas year after year, it may be that this "fidelity" is driven primarily by prey abundance. Gray whales may travel to areas where food has been abundant in the past, but if food is no longer available in sufficient quantities, they will forage in other areas.

It appears then that some gray whales feed opportunistically in local areas as they move northward, spending more time in areas where feeding conditions are suitable, and that the north-south geographic extent of the PCFG may change from year to year, extending on occasion as far north as Kodiak Island, Alaska, as whales move to exploit patchy prey resources.

[1]SPLASH=Structure of Populations, Levels of Abundance, and Status of Humpbacks

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Table 1. Month and year of resightings of Kodiak gray whales in the Pacific Northwest.

ID Number	Kodiak Island	SE Alaska	Northern British Columbia	West Vancouver Island	South Vancouver Island	Northern Washington	Northern Puget Sound	Oregon Coast	Northern California
CRC-232	8/2002			7/2000 7/2001	7-8/1998 7/2001 6-7/2003				
CRC-639	8/2002								10/2001
CRC-723	8/2002						3-4/2004 4-5/2005		
CRC-152	8/2002 9/2005		8/1995 7-8/1996 7-9/1997	7-9/1999					
CRC-566	8/2002 9/2005				8/2004				7/2000
CRC-684	8/2003			8/2002	7/2002				
CRC-316	8/2003 9/2005			7-8/1998					
CRC-691	8/2003 9/2005			6/2004	7/2002 6-7/2003 6/2004				
CRC-126	8-9/2005		7/1994 8/1995 7/1996 7-9/1997 7-8/1998 8-9/2004 8/2008		9-10/1998				7/2001
CRC-530	9/2005					5/2000			
CRC-538	9/2005		8/1998 9/2001 8/2002 8/2003 7-9/2004					8/2000	
CRC-604	9/2005				6-8/2003	6/2001			
CRC-323	9/2005		7-8/1995 7-9/1996 7-9/1997 7-8/1998 8/2002 7-8/2003 7-9/2004 9/2006	7/1998					
CRC-760	9/2005		8-9/2002 7-8/2003 7-8/2004 6/2005						
CRC-772	9/2005	6/1999							
CRC-801	9/2005		7/2003 8/2004						
CRC-899	9/2005		7-8/1995 6-8/1997 8/2002 8/2004						

Table 2. Gray whales identified each day at Kodiak Island in 2005.

Date of survey	No. of gray whales identified	Identification numbers
31/8/05	2	126, 896
1/9//05	10	538, 604, 737, 750, 760, 871, 887, 889, 890, 898
2/9/05	27	152, 316, 566, 604, 758, 772, 801, 867, 871, 898, 899, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 917, 918, 919, 920, 921
3/9/05	6	323, 538, 772, 868, 898, 912
4/9/05	17	316, 538, 604, 691, 737, 750, 760, 868, 870, 871, 887, 892, 893, 895, 896, 897, 898
5/9/05	9	126, 316, 530, 538, 691, 868, 892, 893, 897

Table 3. Gray whale fecal samples collected off Ugak Bay in 2002 and 2005. Primary prey items were determined via estimates of total abundance and biomass.

Sample No.	Collection date	Depth (m)	Primary prey item	Secondary prey item
ER02AK-01	20/8/2002	101	crab larvae	
ER02AK-02	20/8/2002	98	crab larvae	
ER02AK-03	20/8/2002	99	crab larvae	unknown
ER02AK-04	20/8/2002	100	crab larvae	cumacean carapace
ER02AK-05	20/8/2002	-	cumacean carapace	crab larvae
ER02AK-06	20/8/2002	101	crab larvae	
ER02AK-07	20/8/2002	104	cumacean carapace	
ER02AK-08	20/8/2002	101	cumacean carapace	crab larvae
ER02AK-09	20/8/2002	100	cumacean carapace	
ER02AK-10	20/8/2002	85	cumacean carapace	crab larvae
ER05AK-01	3/9/2005	95	cumacean carapace	crab larvae
ER05AK-02	3/9/2005	97	*Diastylopsis* spp.	crab larvae
ER05AK-03	3/9/2005	-	unknown	cumacean carapace
ER05AK-04	3/9/2005	90	cumacean carapace	majidae crab
ER05AK-05	3/9/2005	90	cumacean carapace	unknown
ER05AK-06	3/9/2005	85	unknown	
ER05AK-07	3/9/2005	85	cumacean carapace	unknown
ER05AK-08	3/9/2005	85	cumacean carapace	
ER05AK-09	3/9/2005	93	*Diastylopsis* spp.	polychaete spp
ER05AK-10	3/9/2005	98	cumacean carapace	
ER05AK-11	3/9/2005	-	*Diastylopsi*s spp.	polychaete spp
ER05AK-12	3/9/2005	94	unknown	fish larvae
ER05AK-13	3/9/2005	94	cumacean carapace	majidae crab
ER05AK-14	3/9/2005	93	cumacean carapace	gammeridian amphipod
ER05AK-15	3/9/2005	93	cumacean carapace	majidae crab
ER05AK-16	3/9/2005	97	cumacean carapace	crab larvae
ER05AK-17	3/9/2005	-	cumacean carapace	crab larvae
ER05AK-18	3/9/2005	99	cumacean carapace	polychaete spp
ER05AK-19	3/9/2005	94	cumacean carapace	paguroid crab
ER05AK-20	3/9/2005	-	unknown	
ER05AK-21	4/9/2005	-	cumacean carapace	*Diastylopsis* spp.
ER05AK-22	4/9/2005	91	cumacean carapace	unknown
ER05AK-23	5/9/2005	93	cumacean carapace	*Diastylopsis* spp.
ER05AK-24	5/9/2005	91	cumacean carapace	
ER05AK-25	5/9/2005	88	cumacean carapace	unknown
ER05AK-26	5/9/2005	-	cumacean carapace	Copepod

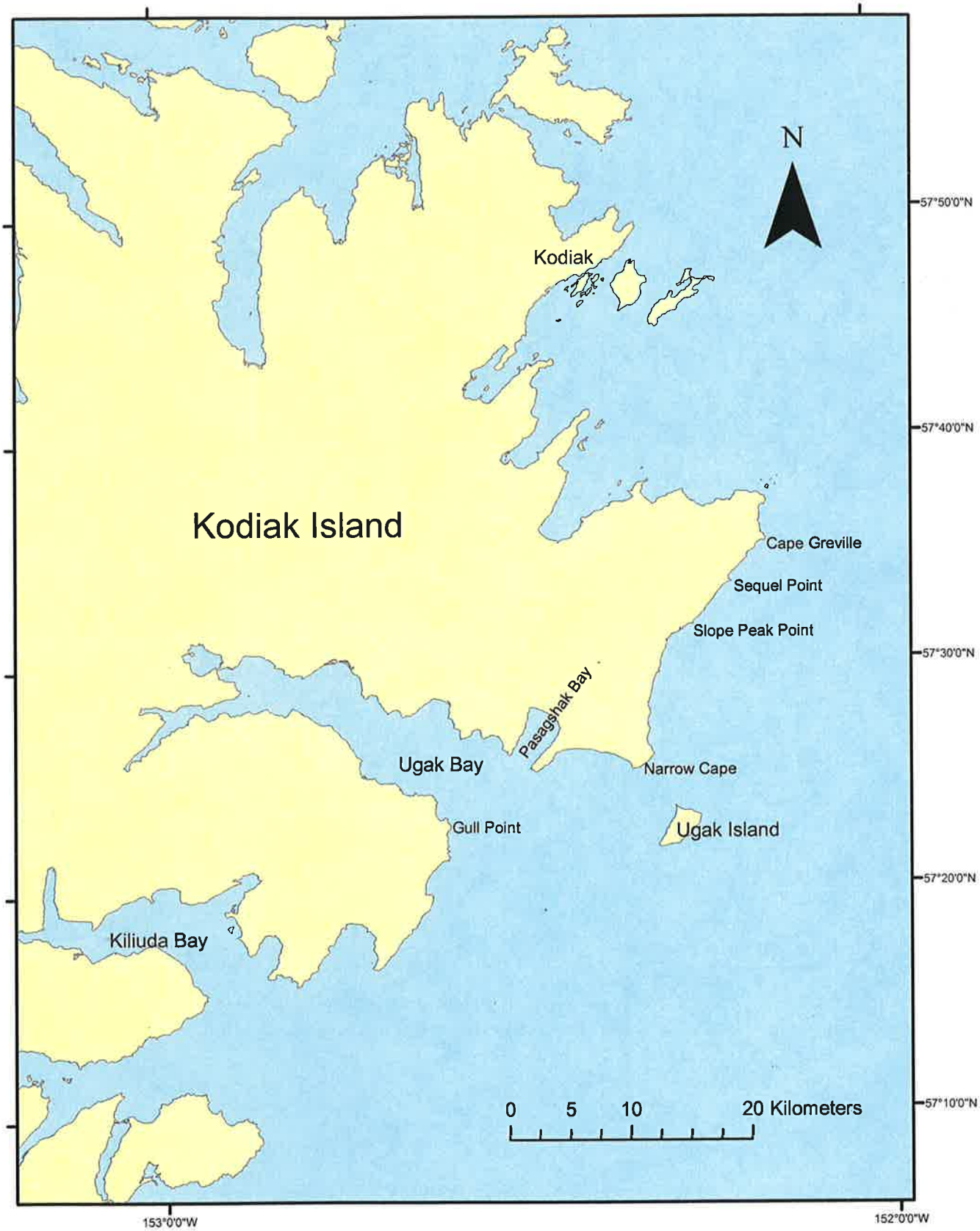

Fig. 1. Areas surveyed for gray whales off Kodiak Island, Alaska, 2002-2005.

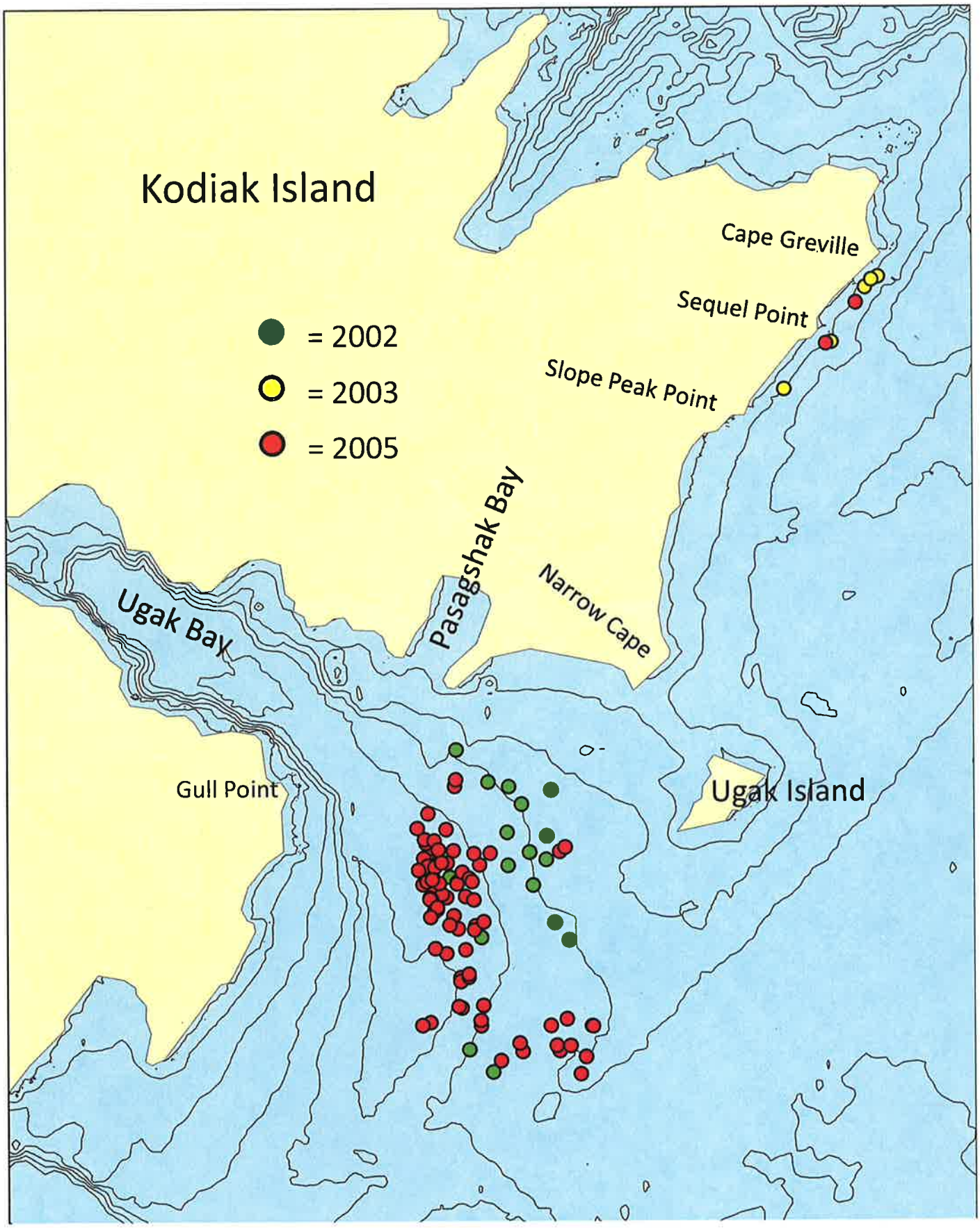

Fig. 2. Sightings of gray whales by year at Kodiak Island.

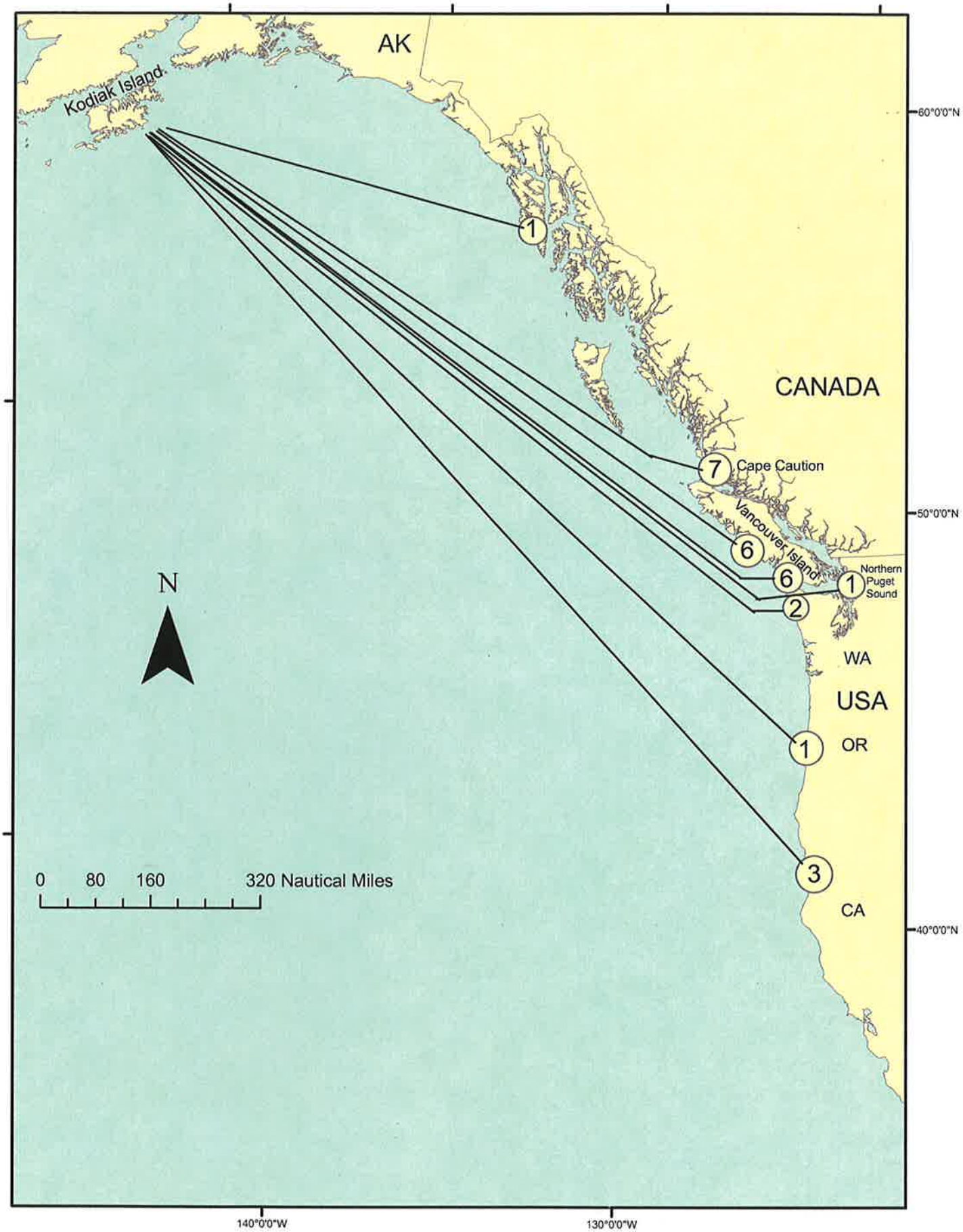

Fig. 3. Location of Kodiak Island gray whale resightings in the Pacific Northwest.