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GRAY WHALE OCCURRENCE AND FORAGE SOUTHEAST OF KODIAK, ISLAND, ALASKA

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Although the Bering and Chukchi seas are commonly cited as the principal summer feeding grounds of Eastern North Pacific (ENP) gray whales (*e.g.*, Highsmith *et al.* in press, Swartz *et al.* 2006), records indicate that this population actually feeds opportunistically throughout its range from the lagoons of Baja California, Mexico, to Alaskan waters (Nerini 1984). Specifically, recent reports suggest that whales may routinely feed in the Gulf of California (Sánchez-Pacheco *et al.* 2001) and Bahia Magdalena, Baja California Sur (Caraveo-Patino and Soto 2005), whereas Clapham *et al.* (1997) noted that feeding gray whales occurred offshore California even in the 1920s when population numbers were very low. The dynamic nature of foraging in this population is best described from coastal study sites along the southeastern shore of Vancouver Island, Canada, where whales shift among pelagic, epi-benthic, and benthic prey within and between years (Darling *et al.* 1998; Dunham and Duffus 2001, 2002).

In the 1980s the southern Chukchi Sea and the Chirikov Basin in the northern Bering Sea were considered the primary feeding grounds for ENP gray whales, based on reported high densities of both whales (Braham 1984, Kim and Oliver 1989, Moore *et al.* 2000) and their ampelicid amphipod prey (Grebmeier *et al.* 1989, Highsmith and Coyle 1990). However, by 2002, benthic productivity in the Chirikov Basin had declined precipitously, due to either whale foraging (Highsmith *et al.* 2006), ecosystem change (Grebmeier *et al.* 2006), or both, and only the southern Chukchi Sea supported dense aggregations of gray whales (Moore *et al.* 2003). Indeed, the

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decline in benthic biomass in the Chirikov Basin (Highsmith and Coyle 1992) was suggested as causal to the 1999–2000 gray whale mortality event (Le Boeuf *et al.* 2000), although other factors, such as disease, could not be ruled out (Moore *et al.* 2001).

Since 1999 gray whales have been observed feeding year-round near Ugak Bay, Kodiak Island, Alaska, in the course of surveys for pinnipeds (Wynne 2005). These "Kodiak" gray whales have not been described in terms of distribution, relative abundance, behavior, or diet. One reason for this oversight is that waters southeast of Kodiak Island have long been considered simply a portion of the migration corridor for gray whales passing to and from northern seas (*e.g.*, Braham 1984) and not a part of the feeding or overwintering range. Conversely, the distribution and feeding behavior of the Pacific Coast Feeding Aggregation (PCFA; formerly called "summer resident" whales) have been investigated offshore Vancouver Island, British Columbia since 1984 (Darling *et al.* 1998; Calambokidis *et al.* 1999; Dunham and Duffus 2001, 2002). The PCFA has been the focus of photo identification surveys extending from northern California to southeastern Alaska, with mark-recapture estimates of 261–298 whales from photos taken from 1998 to 2003 (Calambokidis *et al.* 2004).

Here we present a compilation of opportunistic gray whale sightings noted between 1999 and 2005 in waters southeast of Kodiak Island, Alaska, accompanied by results from 6 days of benthic sampling conducted in 2002 near feeding whales at the entrance of Ugak Bay. Although these data are limited in scope, they provide evidence of year-round occurrence and a noteworthy feeding area for ENP gray whales in the northern Gulf of Alaska. Building a record of seasonal distribution, relative abundance, and feeding areas is key to interpreting the response of this population to environmental variability and carrying capacity.

Gray whale sightings were recorded opportunistically during aerial surveys for Steller sea lions (*Eumetopias jubatus*) and harbor seals (*Phoca vitulina*) conducted in the Kodiak Island archipelago (Fig. 1: inset). Monthly surveys of Steller sea lion haul-outs were conducted throughout the archipelago from September 1999 through July 2005, whereas surveys of harbor seal haul-outs focused on the east and south side of Kodiak Island and were conducted only in late August each year from 1993 to 2002 and in 2004. Although the sea lion and seal survey routes differed somewhat, both included waters between Long Island and Cape Barnabas along Kodiak's southeast coast, including the entrance to Ugak Bay. In addition, on 25 July 2000, a single aerial survey was conducted along a transect southwest and roughly parallel to Kodiak Island (Fig. 1: inset) to search for North Pacific right whales (*Eubalaena japonica*). This survey was flown in a high-wing aircraft with two primary observers seated at bubble windows and a downward looking high-format camera aboard to photograph whales (for details, see Perryman *et al.* 2002).

All pinniped surveys were conducted from a fixed-wing aircraft at altitudes between 220 and 472 m (700 and 1,500 ft) and speeds of 165–200 km/h (90–110 km). One to three observers (plus the pilot) scanned for blows and whales at the surface ahead of and on either side of the aircraft. When whales were seen, the plane was diverted to (1) confirm species identity; (2) mark the location, either *via* a global positioning system or a position relative to coastal landmarks; (3) estimate number

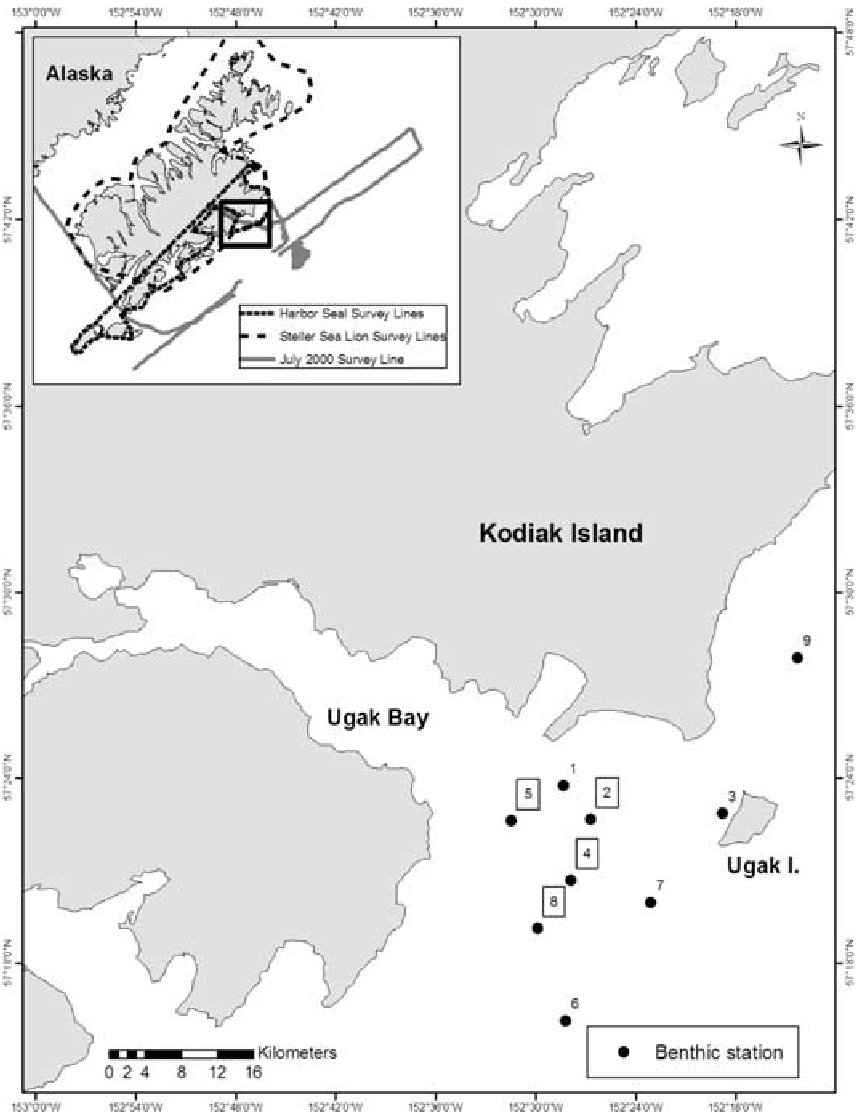

Figure 1. Benthic sampling stations near the entrance to Ugak Bay. Boxes indicate stations with extremely high cumacean densities (see Table 1). Inset: Routes for aerial surveys for pinnipeds around Kodiak Island (Wynne 2005), and trackline for the July 2000 aerial survey offshore the southeastern coast of Kodiak Island, Alaska. Gray whale sightings were recorded opportunistically during surveys for Steller sea lions (dashed line) and harbor seals (solid line) from September 1999 through July 2005.

of whales; and (4) determine general behavior—feeding was recorded whenever mud plumes were seen near whales. Sighting locations were subsequently plotted by season: winter (December–February), spring (March–May), summer (June–August), and autumn (September–November) and "rough-order" sighting rates (number of sightings/survey hour) calculated by dividing the number of gray whale sightings by the average time spent surveying between Long Island and Cape Barnabas on the pinniped surveys. These indices must be considered provisional, as there was no attempt to account for variable survey conditions, nor counts of individual whales in the derivation of sighting rates. In addition, due to the opportunistic nature of these surveys, no effort was made to delineate the full extent of gray whale distribution, detail behavioral interactions, or to derive population estimates from the sightings.

Gray whales were seen year-round along the east side of the Kodiak Island archipelago, most frequently and in greatest numbers near the entrance to Ugak Bay (Fig. 2). Whales were seen with mud plumes in each month, suggesting year-round feeding. Seasonal sighting rates were highest from September to November, declined during December to February and March to May periods, and reached lowest levels during the June to August period. Monthly sighting rates exceeded 100 sightings/h in January, June, September, and November, with >20 sightings/h in all other months except March (Fig. 3A). Annual sighting rates were highest in 2000 and 2001 (>70 sightings/h), lowest in 2003 (<20 sightings/h), with rates >30 sightings/h in 2002 and 2004 (Fig. 3B).

Roughly 350–400 gray whales were counted along the aerial survey transect flown on 25 July 2000. Distribution extended from the mouth of Ugak Bay, where 40–50 whales were seen, to roughly 100 km east-southeast of Ugak Island (Fig. 2: June–August). Overall, the feeding aggregation covered roughly 240 km^2 (*ca.* 80 km × 30 km); actual limits to the distribution were difficult to determine due to low fog over portions of the survey area. Whales were clustered in groups of 10–20 animals, with most associated with conspicuous mud plumes and surface feces trails indicative of active feeding. Most whales appeared to be large adults, with one trio involved in sexual behavior; no small juvenile whales or calves were noted.

To investigate gray whale prey availability, benthic samples were collected at nine stations where whales were seen feeding near the entrance to Ugak Bay (Fig. 1), from 15 to 20 August 2002. Four grab samples were collected at each station using a 0.1-m^2 van Veen grab weighing 88.7 kg (including a 32-kg lead weight), except for station 3 where only one sample was collected due to very large sediment grain size. Each sample was placed on a screen with mesh size of 1 mm and washed with seawater to remove sediment. Samples were preserved in 10% seawater buffered formalin for post-cruise laboratory analysis. To investigate gray whale prey selection, ten fecal samples were collected using a modified small-mesh plankton net with a cod end, attached to a fishing dip net by an extended handle. Samples were collected from the benthic sampling vessel by trolling through water where whales had deposited fecal plumes. One additional fecal sample was collected using a plastic bucket.

Thirty-six benthic samples were collected (Table 1), with potential gray whale prey summarized by station as abundance (individuals/m^2) and carbon biomass (g C/m^2). Cumaceans (*Crustacea: Diastylidae*) were the dominant fauna (93.6%–98.4% of the sampled abundance) at stations 2, 4, 5, and 8 (Fig 1: boxed stations), where biomass ranged from 31 to 67 g C/m^2. Abundance and carbon biomass measures were roughly an order of magnitude lower at stations 1, 6, 7, and 9 (Table 1). The single sample at station 3 revealed moderately high faunal abundance (33,060 individuals/m^2),

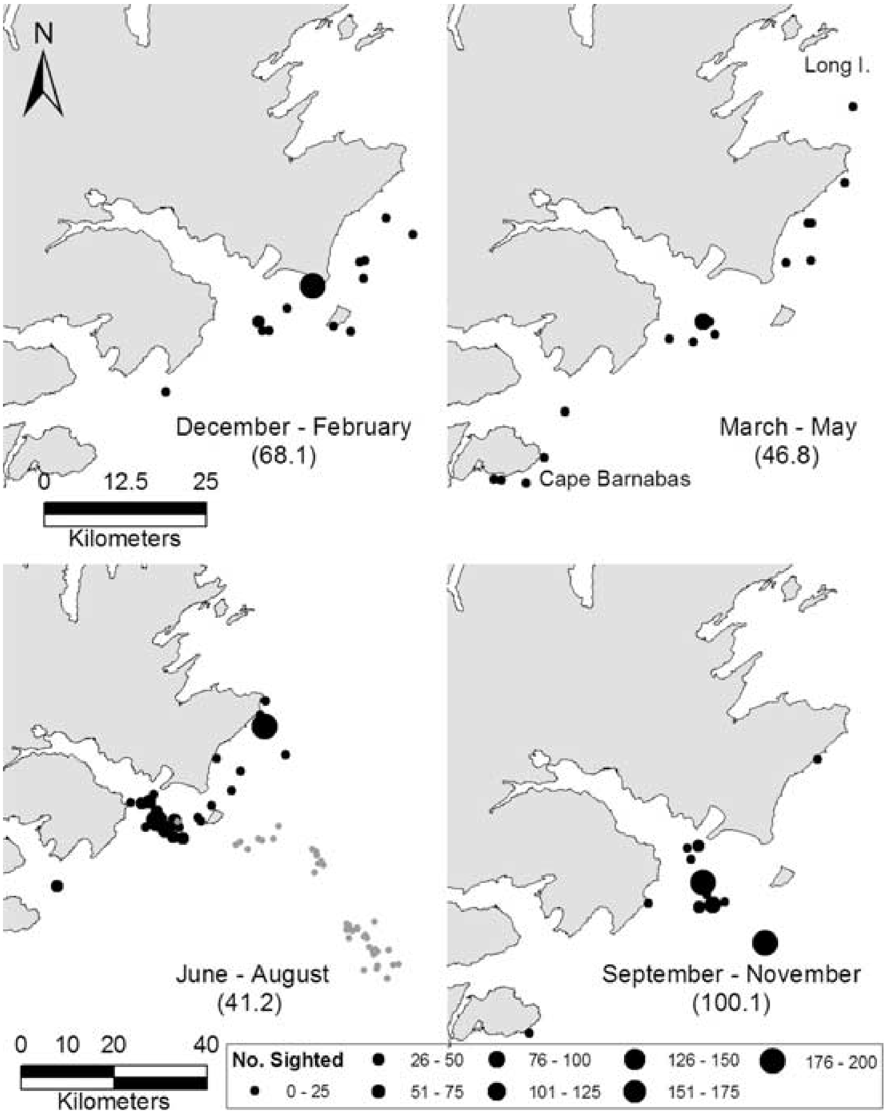

Figure 2. Cumulative gray whale distribution and provisional sighting rates by season: December–February (winter); March–May (spring); June–August (summer), and September–November (autumn). Note difference in spatial scale for the June–August panel, required to show data from the July 2000 survey.

consisting of polychaete worms (*Phyllodocidae* = 54.3%) and bivalves (*Tellinidae* = 33.6%), which resulted in the highest biomass measures (3,950 g/m^2; 125 g C/m^2) of all the stations. Evidence that gray whales were consuming cumaceans resulted from gross examination of the fecal samples, which contained voluminous quantities of (usually partially digested) Diastylidae. Notably, amphipods (*Ampelisca* spp.), a

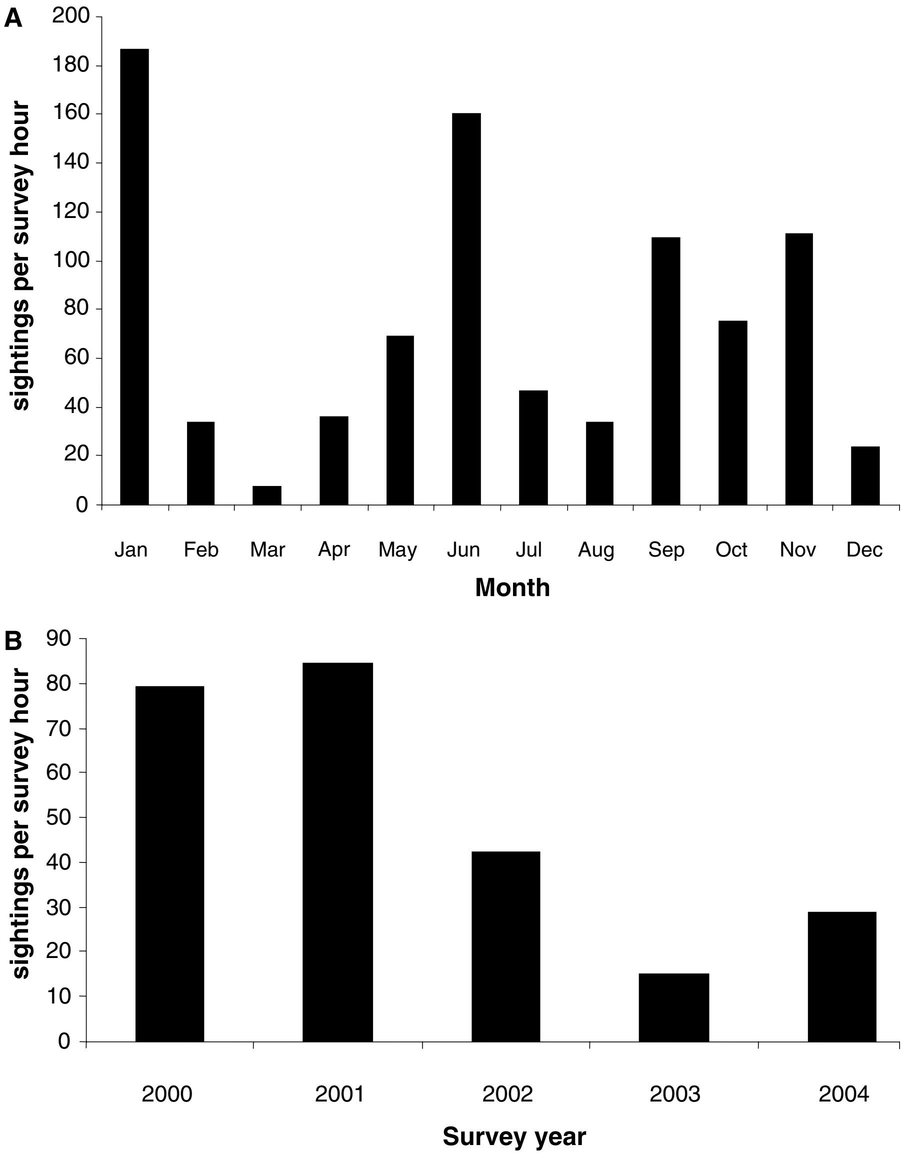

Figure 3. Provisional sighting rates for gray whales seen during pinniped-related surveys along southeastern Kodiak Island, by month (A) and year (B). Annual rates were not calculated for 1999 or 2005 because surveys were conducted only during part of those years.

common gray whale prey, were found only at station 2 and in low densities (0.7% of 57,210 individuals/m^2) and station 6 (15.6% of 1,105 individuals/m^2).

Although many of the gray whales seen near Ugak Bay since 1999 may be migrating through the area, some clearly stop to feed there, perhaps for much of the year. The

Table 1. Summary of benthic samples at nine stations near the entrance to Ugak Bay, Kodiak, Alaska. Abundance (individuals/m^2) and carbon biomass (g C/m^2) provided for each station and for the dominate families (top 3) at each station; bold indicates stations with cumacean abundance >93% (Fig. 1 inset: boxed stations).

Station number	Depth (m)	Abundance (individuals/m^2)	Biomass (g C/m^2)	Abundance: top 3 (individuals/m^2)	%	Biomass: top 3 (g C/m^2)	%
1	52	4,163	7.14	Diastylidae	51.8	Diastylidae	23.0
				Spionidae	20.3	Pharidae	12.6
				Rhyncocoela	2.2	Ophiuridae	9.3
2	62	57,210	45.28	Diastylidae	**94.4**	Diastylidae	84.5
				Lysianassidae	1.4	Pharidae	7.2
				Spionidae	0.7	Rhyncocoela	1.7
3	13	33,060	124.87	Phyllodocidae	54.3	Tellinidae	86.7
				Tellinidae	33.6	Glycymerididae	8.3
				Polygordidae	6.4	Opheliidae	2.7
4	84	55,030	49.21	Diastylidae	**96.2**	Diastylidae	81.1
				Thyasiridae	0.7	Ophiuridae	4.3
				Ophiuridae	0.5	Ophiuroidea	4.2
5	89	91,995	66.70	Diastylidae	**93.6**	Diastylidae	85.0
				Thyasiridae	1.7	*Macoma sp.*	8.0
				Lumbrinereidae	0.9	Lumbrinereidae	2.7
6	72	1,105	8.21	Ampelicidae	15.6	Pharidae	58.4
				Diastylidae	13.6	Lumbrinereidae	13.6
				Thyasiridae	12.9	Ophiuridae	6.5
7	55	1,450	3.25	Spionidae	47.2	Amphiurida	20.9
				Phyllodocidae	7.6	Rhyncocoela	15.5
				Tellinidae	5.5	Spionidae	10.8
8	101	49,478	30.83	Diastylidae	**98.4**	Diastylidae	97.9
				Macoma sp.	0.6	Gastropoda	0.8
				Lumbrinereidae	0.4	Lumbrinereidae	0.5
9	58	8,218	10.72	Spionidae	43.0	Pharidae	20.9
				Cirratulidae	13.4	Mactridae	19.6
				Magelonidae	8.7	Ampharetidae	16.5

seasonal variability in gray whale distribution and sighting rates offshore Kodiak may be related both to migration timing (Rugh *et al*. 2001) and to whale responses to prey availability and composition, as demonstrated elsewhere on their range (Darling *et al*. 1998, Dunham and Duffus 2001, Moore *et al*. 2003). The high counts of gray whales near Kodiak in 2000 and 2001 may have been related somehow to the 1999–2000 mortality event (Gulland *et al*. 2005), or to feeding opportunities resultant from ecosystem responses to the 1997–1998 El Nino in the North Pacific, although specific mechanisms for this remains unexplored. We note that Benson *et al*. (2002) report gray whales feeding on large surface swarms of euphausiids (*Thysanoessa spinifera*) in Monterey Bay, California, during May 1999, which they interpret as a short-term response to prey availability linked to the 1997–1998 El Nino and 1999 La Nina.

The cumacean densities sampled at the entrance of Ugak Bay are among the highest reported anywhere in the world. Cumaceans are usually considered atypical gray whale prey (Nerini 1984, Darling 1998, Dunham and Duffus 2002) and have a low dry weight energy content (14.33 J/mg) compared to amphipods (16.37 J/mg; Cauffope and Heymans 2005). In a prey sampling effort co-located with feeding gray whales at fourteen sites along the Alaskan coast from Wainright south to Dutch Harbor, cumaceans were the dominant species only at Icy Cape in the Chukchi Sea (Kim and Oliver 1989). Core samples from that site resulted in wet weight biomass values of roughly 169 g/m^2, 51% of which was attributed to cumaceans. In contrast, at our sampling site 5 in outer Ugak Bay, wet weight biomass was 1024 g/m^2, 75% of which was attributed to cumaceans. Because sampling methods differed between the two studies, these specific measurements must be compared with caution; however, the extreme densities of prey suggest that the Ugak Bay site offered gray whales an exceptional opportunity to feed on swarming cumaceans, at least during August 2002.

Available records suggest pockets of gray whales can be found, often feeding, from Kodiak to northern California. These records include (1) gray whales reported here; (2) the report of approximately ninety feeding whales near Yakutat Bay in May 2000 (Moore, unpublished data); (3) summertime occurrence of roughly 30–50 gray whales feeding along the outer coast of Southeast Alaska since the mid-1990s;[2] and (4) whales routinely photo-identified at various sites between Kodiak and northern California (Calambokidis *et al*. 2004). Although the gray whales offshore Kodiak may simply represent a reoccupation of former feeding areas, there appears to be now some consistency in their use of these waters. When combined with observations of localized aggregations reported in Calambokidis *et al*. (2004), a pattern similar to that described for white-bearded wildebeests (*Connochaetes taurinus mearnsi*) is suggested wherein roughly 3,000 animals out of a population of 14,000 behave as "residents" that forage and breed in localized areas that are unused by the main migratory population (Estes 2006).

In summary, we suggest that (1) as flexible foragers, gray whales are responsive to feeding opportunities along their entire range; (2) an expanding ENP population may be meeting with new and more variable forage challenges in the wake of alteration of marine ecosystems associated with global climate warming; and (3) research focus on this population may provide novel insight into large whale population dynamics, behavioral ecology, and the capacity of a mysticete species to exploit disparate forage opportunities and respond to environmental changes.

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