BREEDING BIOLOGY OF THE COMMON MURRE AT TRIANGLE ISLAND, BRITISH COLUMBIA, CANADA, 2002–2007

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ABSTRACT—Triangle Island, the most westerly of the Scott Islands, supports the larger of 2 active Common Murre (*Uria aalge*) breeding colonies (about 3000 pairs) in British Columbia, Canada. However, little is known about the species' breeding ecology at this site. Here, we report on investigations of murre biology at Triangle Island between 2002 and 2007. Possibly indicative of their zoogeographic affinities, Triangle Island Common Murres are more similar in size to those that breed at colonies to the north than to the south. Murres were first seen on the colony between late March and early April. The 1st eggs were laid in mid- to late May, and latest eggs (1st or replacement) in mid-July. Median laying dates varied by about 25 d across 5 y (2003 to 2007). Despite differences in adult size, eggs laid at Triangle Island were similar in size to those at murre colonies across western North America. Breeding success for murres at Triangle Island ranged from 54% (2007) to 82% (2004) over 5 y, which is on the high end of the range for Pacific colonies. Adult Pacific Sand Lance (*Ammodytes hexapterus*) and juvenile rockfish (*Sebastes* spp.) combined formed the bulk (71 to 80%) of prey items delivered to nestling murres. Chick mass measured just prior to the start of fledging was notably reduced in 2005 compared to the other 5 y of the study, an obvious manifestation of the extreme oceanic conditions in the California Current system in that year. This report forms the most comprehensive account of the breeding biology of Common Murres in British Columbia, and should provide a benchmark against which future changes in this colony can be measured.

Key words: breeding biology, British Columbia, Common Murre, interannual variability, northeast Pacific, Triangle Island, *Uria aalge*

The Common Murre (*Uria aalge*) is one of the most abundant breeding seabirds in the northern hemisphere (Ainley and others 2002). The species has a rather disjointed distribution along the Pacific coast of North America. Hundreds of thousands of individuals breed on colonies in Oregon and California, and over a million on colonies from the Gulf of Alaska to the north and west, but fewer than 40,000 individuals breed on colonies from Washington State north to southeast Alaska (Manuwal and others 2001; Ainley and others 2002). That latter stretch includes the entire coast of British Columbia where murres breed in appreciable numbers at only 2 sites: the Kerouard Islands at the southern tip of the Haida Gwaii archipelago (about 200 breeding pairs), and on Puffin Rock at Triangle Island, the most westerly of the Scott Islands (about 3000 breeding pairs; Hipfner 2005). At present, information on murre breeding ecology in British Columbia is limited (Rodway 1990; Carter and others 2001).

The Common Murre is the most frequent victim of bycatch in commercial net fisheries operating off the British Columbia coast (Smith and Morgan 2006). It is also the species most frequently found oiled on beached bird surveys in the province (Burger 2002). In response to concerns about the potential population-level impacts of this mortality, we initiated detailed studies of murre biology and demography at Triangle Island in 2002. These data should pro-

vide a benchmark against which future changes can be measured. Here, we report our findings on adult morphometrics, egg size, timing and success of breeding, adult and chick mass, and nestling diets from 2002 to 2007, a period of extreme variation in environmental conditions off the coast of British Columbia (Mackas and others 2007). We also make comparisons with other northeast Pacific colonies, because while murre biology is well described throughout its range many basic facets tend to be colony-specific (Ainley and others 2002).

METHODS

Field crews were present on Triangle Island from late March until late August in each year between 2002 and 2007. That time period more than encompassed the murres' breeding season. We monitored the presence or absence of murres on the colony daily from the time we arrived on the island, and logged detailed, systematic observations when murres began to regularly attend the colony.

From 2003 to 2007, we made daily observations of about 50 to 60 pairs of Common Murres breeding on a small part of the colony on Puffin Rock. Observations were made from a viewing blind situated about 50 m away from the murres using 7× binoculars and a 25 to 60× spotting scope. We used standardized methods (Birkhead and Nettleship 1980) to determine dates of laying (1st and replacement eggs), hatching, and nest departure, and used these 3 indices to determine hatching success (the proportion of eggs laid that hatched), fledging success (the proportion of hatched chicks that survived at least 15 d before they disappeared), and breeding success (the proportion of eggs laid that produced chicks that survived to departure). We have no way of knowing what proportions of chicks survived the period at sea after nest departure and before true fledging, during which they are attended by their father. As it was difficult to determine an exact laying date for some pairs due to the fact that murres breed very densely and do not build nests, we in some cases assumed that the laying date was 32 d prior to the hatching date (Ainley and others 2002).

After hatching began, we made daily observations of prey delivered to murre chicks. Adult murres provision their chicks with single fish, or occasionally large invertebrates, held lengthwise in the bill. Observations on diets spanned most or all of the chick-rearing period in each year. Prey items were visually identified to the lowest possible taxonomic level.

In every year, murre adults (13 to 51 birds) and large chicks (10 to 20 birds) were captured from above the colony with a noose pole (a stout, 3 m long fishing rod with a monofilament noose attached to its end) over a 2-d period in late July or early August. This took place just prior to the start of chick departures in each year. All captured birds were weighed (±5 g with a 2.5 kg Pesola spring scale for adults; ±1 g with a 300 g Pesola spring scale for chicks) and measured (tarsus, culmen and bill depth to ±0.1 mm with vernier calipers; maximum flattened wingchord to ±1 mm with a wingbar), then banded and released (adults tossed into the air, chicks returned to their site). Adult murres returned to their breeding sites within a few minutes of their release. To assess interannual variation in chick growth rates, we examined masses of chicks with wing lengths >60 mm long, a measure indicating that departure is imminent. Early in the laying period in 2002, we also measured a total of 15 murre eggs (length and maximum breadth to within 0.1 mm using vernier calipers). These were the only times when we approached, handled, or otherwise disturbed murres breeding on the colony.

RESULTS AND DISCUSSION

Nesting Population

The Common Murre colony at Triangle Island declined by about 25% between 1989 and 2003, and satellite sites were abandoned so that murres now breed exclusively on Puffin Rock. The reasons for the apparent decline are unknown, however the contraction may be related to an increasing population of Peregrine Falcons (*Falco peregrinus*) providing a more secure nesting environment for murres on Puffin Rock by excluding Bald Eagles (*Haliaeetus leucocephalus*; Hipfner 2005).

Adult Morphometrics

Linear measurements indicate that murres at Triangle Island are more similar in size to those breeding at colonies further north than further south (Table 1). These northern birds, considered a distinct subspecies (*U. a. inornata*), have considerably longer wings than southern

TABLE 1. Morphometric measurements (mean ± 1 *s*) of breeding Common Murres at Triangle Island. Linear measurements from the Kerouard Islands, British Columbia (JM Hipfner, unpublished data), and the range of averages (for adult males and females) from Alaska and California (Ainley and others 2002) are shown for comparison.

Site	*n*	Wing cord (mm)	Culmen (mm)	Bill depth (mm)	Tarsus (mm)
Triangle Is.	75	216.4 ± 3.9	47.1 ± 2.6	14.7 ± 0.7	40.4 ± 1.6
Kerouard Is.	20	218.0 ± 6.3	46.8 ± 3.0	15.2 ± 1.0	41.8 ± 1.7
Alaska	—	215–218	44.2–47.7	13.6–15.2	38.0–42.3
California	—	208–209	47.1–49.3	13.6–14.9	37.8–39.6

birds (*U. a. californica*), as well as longer tarsi, yet shorter bills (Ainley and others 2002). The validity, however, of the subspecific split and the affinities of Triangle Island murres remain to be determined using molecular techniques.

Interestingly, there are similar latitudinal trends in Common Murre morphology across the northeast Atlantic (Storer 1952), although the tendency for increasing body size with latitude (''Bergmann's Rule''; Ashton 2002) is not consistent across the Alcidae as a whole (Bédard 1985). This suggests that there is a more complex ecological underpinning. In the congeneric Thick-billed Murre (*U. lomvia*), populations that breed in Canada's High Arctic are smaller than those that breed across most of the Low Arctic (Gaston and Hipfner 2000). While breeding, high arctic Thick-billed Murres also eat more planktonic invertebrates and less fish than do low arctic birds, although both deliver mostly fish to offspring (Gaston and Bradstreet 1993). Stable isotope analyses suggest that Common Murres in the Gulf of Alaska (Hobson and others 1994) and at Triangle Island (Davies and others, unpubl. data) tend to feed at a higher trophic level than at the Farallon Islands, California (Sydeman and others 1997), at least early in the season. We suggest that the larger body size, longer wings, and shorter bills of northern murres may be particular adaptations for pursuing and capturing fish.

Timing and Success of Breeding

We did not study daily and seasonal patterns of murre colony attendance at Triangle Island in detail, but based on Rodway (1990), patterns there are similar to those reported elsewhere (Hatch and Hatch 1989). In all years of this study, hundreds to thousands of murres were seen on the ocean in the vicinity of Triangle Island from late March onwards, and murres were first seen on the colony between late March (in 2005 to 2007) and early April (in 2002 to 2004).

Common Murres began to lay eggs in mid- to late May in each year, with latest eggs (1st or replacement) laid in early to mid-July; overall, the laying period spanned about 2 mo (Fig. 1; note that we saw a few eggs laid outside of our monitoring plot in the last 10 d of May 2007). Median laying dates varied by about 25 d across the 5 y of this study. The timing of breeding at Triangle Island is intermediate between that at the Farallon Islands, California (1st egg dates late April to late May up to 1983; Boekelheide and others 1990) and in the Gulf of Alaska (1st egg dates early to mid-June; Hatch and Hatch 1990). Thus, timing of murre breeding becomes later with latitude, and presumably related to delays in phenologies at lower trophic levels (Carter and others 2001).

There has been a clear advance in the timing of Common Murre breeding at Triangle Island since 1980 (Fig. 2). Based on available evidence (Carl and others 1951; Vallee and Carter 1987; Rodway 1990), it appears that the peak of laying typically fell at the end of June up to the late 1980s, or up to 4 to 5 wk later than recorded during this study. Similar advances occurred in other species of seabirds at Triangle Island, including species that feed at a variety of trophic levels (Bertram and others 2001). This phenomenon presumably was related to phenological advances at lower trophic levels driven by oceanographic conditions (Mackas and others 2007). Of note, the timing of murre breeding has advanced over the last few decades at the Farallon Islands as well as at Triangle Island (Boekelheide and others 1990; Miller and Sydeman 2004).

Fifteen Common Murre eggs measured at Triangle Island in 2002 differed by less than 4% in mean volume index (length × breadth^2) from those laid at colonies to the south and to

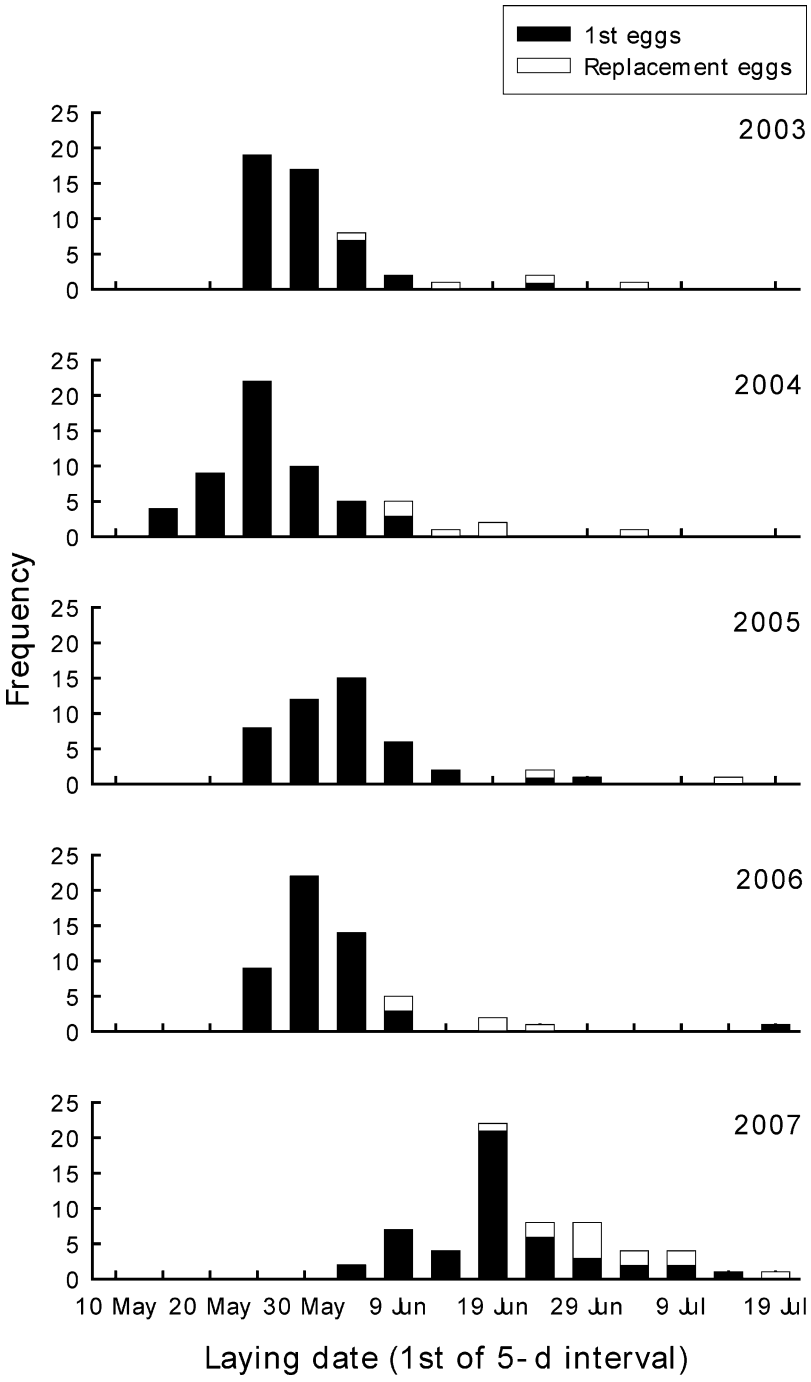

FIGURE 1. Five day frequency distributions of laying dates for 1st and replacement Common Murre eggs at Triangle Island, 2003–2007.

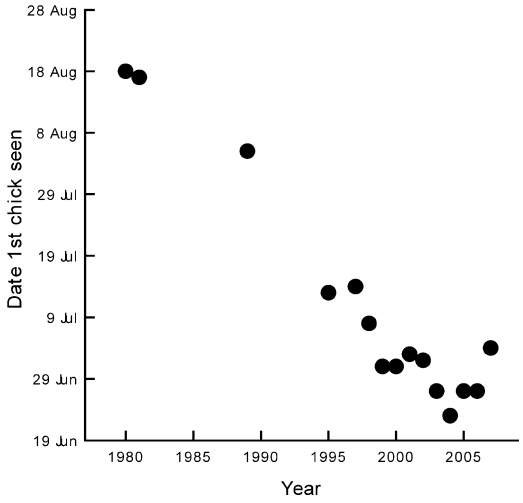

FIGURE 2. Dates on which Common Murre chicks were first seen on the colony at Triangle Island, 1980–2007. This is the only measure of phenology available for all years through the whole of that time period (Bertram and others 2001). Note that data from 1980 and 1981 probably represent hatching dates of replacement eggs; Vallée and Carter (1987) reported that the bulk of egg-laying occurred between 25 and 30 June in those years, thus 1st chicks would have been expected between late July and early August.

the north (Table 2). The consistency is surprising, given that latitudinal differences in adult body size are closely parallelled by variation in egg size in Thick-billed Murres (Gaston and Hipfner 2000).

Between 2003 and 2007, murres generally bred successfully at Triangle Island: 44 to 78% of 1st-laid eggs hatched, and 90 to 98% of these chicks survived to depart the colony; including replacement layings, 54% to 82% of pairs succeeded (Table 3). We rarely knew the cause of breeding failure. However, we did on occasion see both eggs and chicks being taken by Glaucous-winged Gulls (*Larus glaucescens*) and Ravens (*Corvus corax*). Other eggs were either lost accidentally or failed to hatch, and a few chicks apparently starved to death. In 2007, which was the only year in which Peregrine Falcons did not breed above the murre colony, we several times saw gulls take murre eggs early in the laying period after the murres were flushed by Bald Eagles. This activity largely explained the murres' low hatching success in 2007. Annual success at Triangle Island during our study was on the high end of the range compared to Common Murres breeding at other north Pacific colonies (27 to 77%, with 9 of 10 site estimates <70%; Byrd and others 1993).

Nestling Diets

Despite marked interannual variation in oceanographic conditions off the British Columbia coast (Mackas and others 2007), we observed little interannual variation in Common Murre nestling diets between 2003 and 2007 (Table 4). Adult Pacific Sand Lance (*Ammodytes hexapterus*) and juvenile rockfish (*Sebastes* spp., almost exclusively 1 or more of the orange-coloured species) combined formed the bulk (70 to 80%) of diets in each year. Among less common species, Pacific Herring (*Clupea harengus*) were important in 2003, 2004 and 2007; Pacific salmon (*Onchorhynchus* spp.) in 2006; and 1 or more species of squid in 2003 and 2006. The only other taxon identified to species was Pacific Saury (*Cololabis saira*). On occasion, murres delivered fish and crustacea that we were unable to identify.

With the exception of 2003 and 2007, when rockfish increased as Pacific Sand Lance decreased through the season, there was little consistent within-year variation in nestling diets (Fig. 3). The relative consistency in murre

TABLE 2. Measurements (mean ± 1 *s*) of Common Murre eggs at Triangle Island in 2002. Egg measurements from the Kerouard Islands, British Columbia (JM Hipfner, unpublished data), the Farallon Islands, California (Gress and others 1973), and Tatoosh Island, Washington, and 6 colonies in the Gulf of Alaska (both Vander Pol and others 2003) are shown for comparison.

Colony	*n*	Length (cm)	Breadth (cm)	Volume index (cm^3)[1]
Triangle I., BC	15	8.55 ± 0.35	5.05 ± 0.12	218.1 ± 15.1
Farallon Is., CA	66	8.25 ± 0.78	5.05 ± 0.37	210.4
Tatoosh I., WA	14	8.24 ± 0.23	5.08 ± 0.19	213.0 ± 17.4
Kerouard Is., BC	38	8.21 ± 0.42	5.04 ± 0.20	209.8 ± 24.9
Gulf of Alaska	189	8.31 ± 0.47	5.12 ± 0.27	218.7 ± 23.0

[1] Egg volume index (length × $breadth^2$).

TABLE 3. Reproductive parameters for Common Murres at Triangle Island, British Columbia, Canada, 2003 to 2007.

	1st eggs				Replacement eggs				
Year	*n*	Hatched (%)	Fledged (%)	Successful (%)	*n* (%)[1]	Hatched (%)	Fledged (%)	Successful (%)	Total Successful (%)
2003	46	35 (76)	33 (94)	33 (72)	4 (36)	3 (75)	2 (67)	2 (50)	35 (76)
2004	55	43 (78)	42 (98)	42 (76)	6 (50)	4 (67)	3 (75)	3 (50)	45 (82)
2005	48	34 (71)	31 (91)	31 (65)	2 (14)	0 (0)	0 (–)	0 (0)	31 (65)
2006	52	40 (77)	37 (93)	37 (71)	6 (50)	2 (33)	1 (50)	1 (17)	38 (73)
2007	48	21 (44)	19 (90)	19 (40)	13 (48)	7 (54)	7 (100)	7 (54)	26 (54)

[1] Percentage of 1st eggs that failed to hatch that were subsequently replaced.

chick diets contrasts sharply with the marked changes usually seen within and among years at Triangle Island in the zooplankton-based diets fed to Cassin's Auklet (*Ptychoramphus aleuticus*) chicks (Hedd and others 2002), and the fish-based diet fed to Rhinoceros Auklet (*Cerorhnica monocerata*) chicks (Hedd and others 2006).

At other northeast Pacific colonies, Common Murres also provision mainly with fish, although species composition differs from that at Triangle Island. At the Farallones, the main prey species are rockfish, Anchovy (*Engraulis mordax*), and Pacific Sardine (*Sardinops sagax*), their relative importance varying among years (Miller and Sydeman 2004). At Tatoosh Island, in Washington State, Surf Smelt (*Hypomesus pretiosus*), Pacific Sand Lance, Pacific Herring, and Eulachon (*Thaleichthys pacificus*) combine to form over 80% of items in murre chick diets (Parrish and Zador 2003). Further north, in the Gulf of Alaska, important prey items include Capelin (*Mallotus villosus*), Pacific Sand Lance, and juvenile Walleye Pollock (*Theragra chalcogrammus*) (Zador and Piatt 1999).

Body Mass of Adults and Chicks

Adult mass measured just prior to the start of chick departures, and chick masses at that same time, varied among years (Fig. 4). Of particular note, chick masses were substantially lower in 2005 than in any other year, which constituted the most obvious manifestation for murres of the anomalous oceanographic conditions in the California Current system in that year (Sydeman and others 2006). There is little information pertaining to growth rates of murre chicks at colonies to the south of Triangle Island. However, compared to mean fledging masses reported at colonies in Alaska (175 to 205 g; Ainley and others 2002), growth rates at Triangle Island are probably on the high end of the range in most years.

Conclusions

Results of our study indicate that conditions for breeding by Common Murres at Triangle Island in recent years have been generally favorable; most pairs successfully raise chicks that survive to depart the colony. In addition, the relative constancy in chick diets within and across years, and the apparently good growth rates of chicks in most years, suggest that feeding conditions in waters around Triangle Island are adequate for breeding murres. The continued advance in the timing of breeding is noteworthy, though the reasons for this advance are unknown. We hope that the data presented here can serve as a baseline against which any future changes, should they occur, can be measured.

TABLE 4. Diets fed to Common Murre chicks (as percentage of all prey items delivered in each year) at Triangle Island, British Columbia, Canada, 2003 to 2006.

	Year (*n*)				
Species	2003 (212)	2004 (367)	2005 (307)	2006 (172)	2007(582)
Pacific Sand Lance	44	31	40	41	39
Rockfish spp.	29	49	32	36	32
Other	27	20	28	23	29

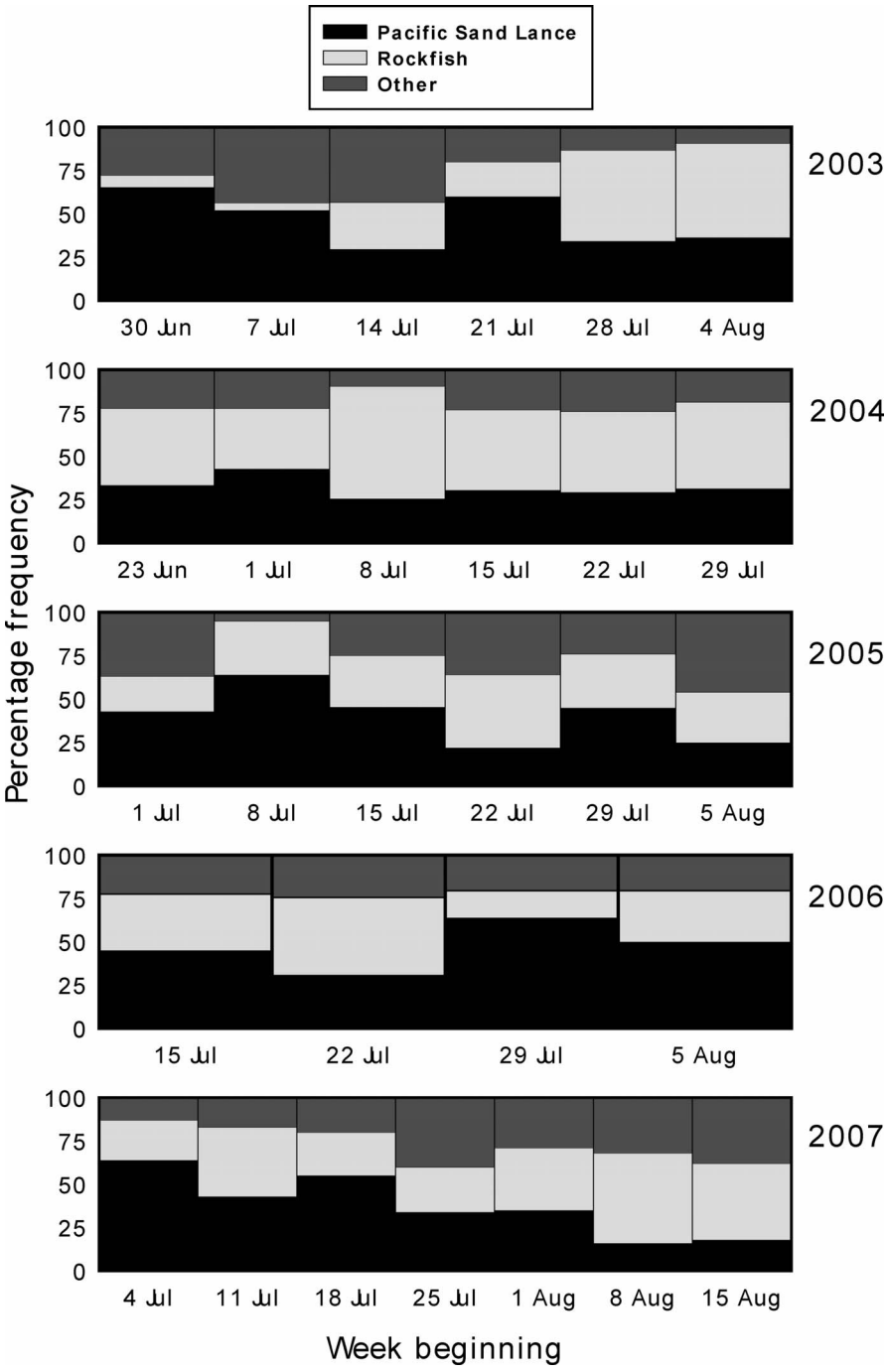

FIGURE 3. Weekly frequency distributions (as percentage by number) of prey species delivered by adult Common Murres to their chicks at Triangle Island, 2003–2007. ''Other'' includes Pacific Herring, unidentified species of Pacific salmon, squid, Pacific Saury, and items not identified but known not to belong to any of these other groups.

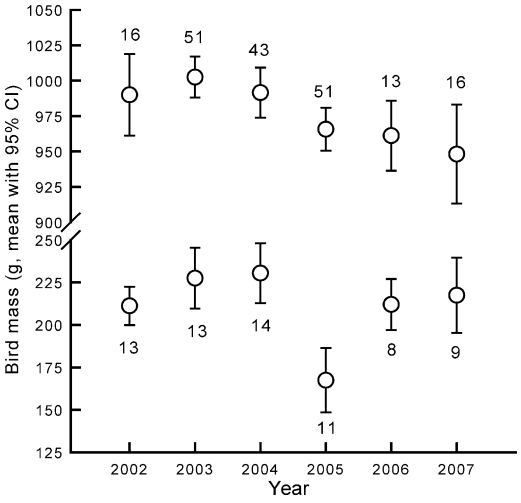

FIGURE 4. Mean (with 95% confidence intervals) adult and chick Common Murre body masses at Triangle Island, 2002–2007. Measurements were taken just prior to the start of fledging. Only chicks with wing lengths >60 mm (those near to fledging) are included.

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