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Bill harnesses on nestling Tufted Puffins influence adult provisioning behavior

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ABSTRACT. For burrow-nesting seabirds, investigators have examined nestling diet by attaching harnesses to the bills of nestlings to intercept food delivered by the parent. To determine whether this method provides an unbiased estimate of nestling diet, we evaluated its effect on the provisioning behavior of Tufted Puffins (*Fratercula cirrhata*) nesting on Triangle Island, British Columbia. Adults delivering food to nestlings with bill harnesses always hesitated before entering a burrow with food, increasing their susceptibility to kleptoparasitism by gulls, and did not always leave the food intended for the nestling. These responses by adult puffins could lead to underestimates of energy intake rates of nestlings and unreliable comparisons with other species if prey left by adults in nest burrows were the only source of data. We also compared estimates of the species, number, and size of prey delivered by adult puffins as determined by direct observation from blinds to samples of prey collected directly from nest burrows and found that the two sampling techniques produced similar results. However, identifying rare prey species and gathering precise information about prey length, mass, and condition require collection of prey, and we recommend using a combination of techniques to obtain the most reliable estimates of nestling diet.

SINOPSIS. **Artefacto colocado en el pico de pichones de *Fratercula cirrhata* influye en la conducta de proveer alimento por parte de los adultos**

Los investigadores de aves marinas que anidan en cavidades o guaridas, han examinado la dieta de los pichones colocando artefactos en el pico de los polluelos que intercepta la comida que traen los adultos. Para determinar si el método provee de un estimado sin sesgo de la dieta de pichones, evaluamos su efecto en la conducta de *Fratercula cirrhata,* de aves que anidaron en Triangle Island, Columbia Británica. Los adultos que trajeron comida a pichones que tenían artefactos en el pico, tuvieron reservas para entrar en la cavidad, exponiéndose a kleptoparasitismo por parte de gaviotas. Además no siempre le dejaron comida a los pichones. La respuesta de los adultos, puede llevar a subestimar las necesidades energéticas de los pichones y hacer comparaciones poco confiables con otras especies si se utiliza únicamente como datos, las presas dejadas en las guaridas por los adultos. También comparamos las especies utilizadas para alimentar a los polluelos, número de presas y su tamaño comparando observaciones directas de lo que se llevaba a los nidos, con lo que se dejaba en las guaridas y encontramos que ambos métodos arrojan resultados similares. Sin embargo, la identificación de presas raras, obtener información precisa sobre la longitud de la presa, peso y condición de esta, requieren el examinar las misma. Recomendamos utilizar una combinación de ambos métodos para obtener estimados confiables de la dieta de polluelos.

Key words: diet, fish, *Fratercula cirrhata*, ligature, sampling prey, seabird

For marine birds, dietary information is often collected at breeding colonies where adults deliver food to their offspring. Methods include catching adults at the colony to induce regurgitation (Lance and Roby 2000, Hedd et al. 2002, Ainley et al. 2003) or intercept prey carried externally (Harris and Hislop 1978, Bertram and Kaiser 1993, Rodway and Montevecchi 1996, Sydeman et al. 2001), opportunistic collection of prey dropped near nest sites (Atwood and Kelly 1984, Ramos et al. 1998), direct observation of prey carried in the bill (Barrett et al. 1987, Rodway and Montevecchi 1996, Sydeman et al. 2001), and preventing nestlings from consuming prey (Hatch 1984, Bertram et al. 1991, Piatt et al. 1997, Reinhardt 1997). The best sampling methods should cause the

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least disturbance, but still provide reliable, unbiased, and repeatable estimates. Because human disturbance of adult Tufted Puffins (*Fratercula cirrhata*) can cause them to abandon nests (Pierce and Simons 1986), several investigators have used harnesses attached to the bills of nestlings to intercept prey delivered by parents (Hatch 1984, Baird 1986, 1990, 1991, Kitaysky 1996).

Tufted Puffins breed on islands along the Pacific Rim from California to Hokkaido, Japan, and are most abundant in British Columbia, Alaska, and in the Sea of Okhotsk (Piatt and Kitaysky 2002). Females lay a single egg in a burrow, and both parents feed the nestling several times a day with prey carried crosswise in the bill. Nestling diets are dominated by fish, although there are regional and interannual differences in prey size and species composition (Vermeer 1979, Wehle 1983, Hatch 1984, Baird 1990, 1991, Hatch and Sanger 1992, Piatt et al. 1997, Kitaysky and Golubova 2000, Gjerdrum 2004).

To reliably estimate nestling diet, the effect that a harnessed chick has on parental provisioning behavior needs to be evaluated. Our specific objectives were to (1) describe any behavioral differences between adult Tufted Puffins delivering food to nestlings with and without bill harnesses, and (2) compare visual estimates of bill loads (prey in the bill of adults being delivered to nestlings) to samples collected from burrows.

METHODS

We studied puffins in the Puffin Rock subcolony on Triangle Island, British Columbia, Canada (50°52′N, 129°05′W), during the breeding seasons of 1999 and 2000 when fledging success was unusually high (Gjerdrum et al. 2003). In both years, as part of a larger study on nestling growth and parental provisioning behavior, approximately 100 burrows were marked with a flag that could be read from an observation blind located 50–100 m from the burrows. If the nestling could not be reached from the entrance of the burrow, an access hole was dug and covered with a cedar shingle, dirt, and grass.

On 23 July, 29 July, and 2 August 1999, harnesses made of twist ties and cotton string were attached to the bills of 10 nestlings, and the same nestlings were manipulated each time. Twist ties were securely fastened around the bill, distal to the nares, and held in place with the string tied around the back of the head (Baird 1986). Harnesses remained on the nestlings for 4 h and prevented them from swallowing food, but not from vocalizing. On each sampling date, harnesses fell off 2 of the 10 nestlings before the end of the observation period and, as a result, our sample size of harnessed nestlings for each sampling period was 8. Harnessed nestlings occupied burrows located among an additional 62 active burrows.

We monitored all burrows from an observation blind, and counted feeding visits and recorded parental behavior from 06:00 to 10:00. After the observation period, harnesses were removed and prey were identified, weighed, measured, and then returned to the nestling. Prey mass was measured to the nearest 0.1 g using a spring scale (Pesola, Baar, Switzerland) and fish length was measured from the caudal peduncle to the end of the snout (standard length) using dial calipers (±0.1 mm).

In 2000, we compared visual estimates of bill loads to samples collected from burrows. Between 13 July and 17 August, we estimated bill load size and composition from an observation blind using 8 × 30 binoculars. When possible, we estimated the number, size, and species of prey in food deliveries during 13 4-h observation periods. Lengths of fish were estimated based on their relationship to the size of the puffin bill. Two distinct size-classes of sand lance (*Ammodytes hexapterus*; juvenile <105 cm < adult) and one size-class of rockfish (*Sebastes* spp.; juvenile <60 cm) were identified. The mass of bill loads was estimated using species-specific length-to-mass relationships determined from collected samples (Gjerdrum 2001). When fish species could not be determined, we assigned weight based on an average mass for all fish collected in that size class.

To compare visual estimates of bill load size and composition to prey samples collected from burrows, we attached bill harnesses to chicks on 13 July ($N = 10$), 20 July ($N = 16$), 27 July ($N = 16$), and 4 August ($N = 9$). Harnesses were left on for 24 h to maximize the probability that parents would leave food intended for the chicks. The same nestlings were harnessed on each date. We identified and measured prey found in the burrows and subsequently fed them to the nestlings. Prey either dropped by puffins being chased by Gulls or left in burrows (when nestlings were pulled from burrows to be

measured and weighed) between 13 July and 17 August were also measured ($N = 29$).

We used χ^2 analyses to determine if the relative proportion of prey species delivered by parents differed between samples estimated visually during delivery and those that were intercepted. We present means ± 1 SD. SYSTAT 8.0 (SPSS Inc. 1998) was used for all analyses.

RESULTS

During the 4-h observation period, adults delivered food during 25%, 67%, and 71% of all feeding visits on the three sampling dates, respectively (Table 1). All adults hesitated for at least 30 s at the burrow entrance before entering. For the failed feeding attempts, adults quickly left burrows still carrying food, and three food loads were subsequently kleptoparasitized by Glaucous-winged Gulls (*Larus glaucescens*). On 2 August, one food load was delivered to the nestling only after two previous attempts (i.e., the parent came out of the burrow twice still carrying the food), and another was only a partial bill load because the parent flew away with some of the prey items. In contrast, we recorded 48–50 feeding visits to control nestlings on each of the sampling dates and only one adult failed to leave food for the nestling; the food-laden adult was chased by a Glaucous-winged Gull before entering its burrow.

We obtained 11 complete bill loads from the 21 feeding attempts (52% success) in 1999 (Table 1). The mean number of prey in a bill load was 4.7 ± 2.3 (range 2–8). The mean mass of a bill load was 8.0 ± 3.9 g (range 3.1–15.7 g).

Table 1. Behavior of Tufted Puffin parents feeding nestlings ($N = 8$) with bill harnesses during three sampling periods in 1999.

	Sampling date		
	23 July	29 July	2 August
Approached by adult with food[1]	8	6	7
Failed feeding attempt[2]	6	2	2
Kleptoparasitism event	2	0	1
Complete bill load obtained	2	4	5

[1]Number of sampling burrows approached by a feeding adult during the 4-h observation period.

[2]Adult entered the burrow, but left without leaving the food for the nestling.

In 2000, we visually estimated bill load size and composition for 341 food deliveries (Table 2). Juvenile rockfish dominated both in numbers and mass, followed by sand lance. An average of 4.3 ± 1.5 (range 1–8) prey items were counted per bill load, weighing an estimated 8.6 ± 4.5 g (range 1.6–40.7 g). During the same period, we collected 40 burrow loads from 51 chicks using bill harnesses (80% success). Because adults were not observed making these food deliveries, these samples do not equate to bill loads, but instead represent prey delivered to a nestling over a 24-h period. An additional 29 samples were collected opportunistically, resulting in a total of 69 samples and 257 prey items (Table 2). We collected juvenile rockfish, sand lance, sablefish (*Anoplopoma fimbria*), squid (*Loligo* spp.), an unidentified octopus, and several larval fish (Table 2). We found no difference in species composition either by numerical abundance ($\chi^2_5 = 3.9$, $P = 0.56$) or mass ($\chi^2_5 = 8.04$, $P = 0.15$) between samples collected from burrows and visually estimated samples.

DISCUSSION

Our results demonstrate that adult Tufted Puffins may not deliver food to nestlings with bill harnesses or may only leave a partial bill load. The parents of manipulated nestlings always hesitated before entering the burrow and sometimes took more than one trip into the burrow before leaving food, increasing their susceptibility to kleptoparasitism by Glaucous-winged Gulls. Similarly, Hatch (1984) found that adult puffins delivered reduced food loads to harnessed chicks in Alaska, or ceased feeding altogether, although adults were not observed during sampling periods. As part of a larger study of Tufted Puffin provisioning behavior in 2000, we classified 1057 provisioning visits as direct (no hesitation at entrance of burrow), paused (hesitation at entrance between 1 and 15 s), delayed (>15 s but <1 min), or extended delay (>1 min) and found that only 6% of parents hesitated more than 15 s (CG, unpubl. data). In over 4000 feeding visits observed in 1999 and 2000 to nestlings without harnesses, we never observed an adult leave its burrow with food.

Table 2. Bill load composition of Tufted Puffins expressed as percentages (numerical abundance and wet mass for major prey species) of all items delivered.

	Bill harness		Observation	
Prey	% abundance	% mass	% abundance	% mass
Sand lance (0)[1]	8.2	7.8	8.6	7.7
Sand lance (1+)[2]	4.3	15.9	4.6	16.8
Rockfish[3]	84.0	65.3	84.8	66.9
Squid[4]	1.2	3.3	0.7	0.2
Other invertebrates[5]	1.6	0.5	0.6	0.1
Other fish[6]	0.8	7.3	0.8	6.6
Number of samples	69		341	
Total prey items	257		1450	
Total mass (g)[7]	519.6		2938.8	

Data were obtained using bill harnesses and observation of provisioning adults from 13 July to 17 August 2000.

[1] *Ammodytes hexapterus* <105 mm fork length (Hatch and Sanger 1992).

[2] *Ammodytes hexapterus* >105 mm fork length (Hatch and Sanger 1992).

[3] *Sebastes* spp.

[4] *Loligo* spp.

[5] Includes octopus and larval fish.

[6] Includes Sablefish (*Anoplopoma fimbria*) and any unidentified fish species.

[7] Bill load mass for observational samples was estimated using species-specific length-to-mass relationships (Gjerdrum 2001).

The delayed entry of adults into burrows with harnessed nestlings, and the rapid departures of adults still carrying food, suggest that parent-offspring communication facilitates successful feeding. Because nestlings with harnesses could vocalize, parents were likely reacting to calls that may have signaled alarm or distress. An audio recording of one harnessed nestling revealed persistent calling for the duration of a 60-min tape. By comparison, recordings revealed that nestlings without harnesses vocalized only when parents arrived with food (CG, unpubl. data). In general, parent-offspring communication in Tufted Puffins is not well understood. The function of chick vocalizations, variation among calls, and the environmental effects on communication require further study.

Previous investigators have assumed that placing bill harnesses or hoods on nestlings did not affect the behavior of parents (Baird 1990, 1991, Bertram et al. 1991, Bertram and Kaiser 1993, Kitaysky 1996). We have shown that food intended for nestlings is not always left by adults, and that the use of harnesses may increase the success of kleptoparasites. This bias could lead to underestimates of energy intake rates and unreliable comparisons among species or age classes. If parents provision based on nestling nutritional requirements (Hamer and Hill 1994, Bertram et al. 1996, Harding et al. 2002, Gjerdrum 2004) and chicks vocalize to signal their nutritional needs to parents (Harris 1981), bill harnesses may also influence what parents bring to nestlings on subsequent feeding visits. Because we manipulated the same nestlings on each sampling date, parents may have habituated to the disturbance and been more willing to leave food for nestlings in the later sampling periods. Habituation to the method could introduce bias in analyses of the possible effects of season or nestling age on diet.

Visually estimating bill load size and composition causes the least disturbance and data we collected by observing adult puffins from blinds did not differ from that based on prey collected from burrows. Similarly, Rodway and Montevecchi (1996) found that visual observations of prey delivered by adult Atlantic Puffins (*Fratercula arctica*) provided reliable estimates of prey species composition. In 2000, rockfish and sand lance dominated the diet of Tufted Puffins on Triangle Island and could easily be distinguished using binoculars. However, a more diverse diet may have made it difficult to get reliable estimates

using this technique. For example, rare prey species such as herring (*Clupea pallasi*) or greenling (*Hexagrammos* spp.) could be misidentified in bill loads with multiple species because these species are difficult to recognize from a distance. Squid, larval fish, and large euphausids could be visually identified in the bill of puffins in this study, but smaller prey items make it more difficult to count individuals. Although larger sample sizes can be obtained by direct observation than by more disruptive and time-consuming interception methods, information on prey length and mass, prey condition, and identification of rare species require the collection of prey (Rodway and Montevecchi 1996).

Despite the effect bill harnesses had on the behavior of feeding parents, the technique is reliable for sampling species composition and for comparisons among years or colonies or areas of the same colony. This technique should also provide adequate sample sizes because the number of samples obtained per harnessed nestling is relatively high, depending on the length of time nestlings are left harnessed. However, several adult Tufted Puffins in Alaska stopped feeding their harnessed nestlings, and the technique led to high rates of nestling mortality (Hatch 1984). Because we found a high degree of similarity between visual and harness samples, we suggest using observations to estimate nestling diet, and supplementing the information with more invasive methods. This will minimize the potentially negative effects of harnesses, especially in years when food availability is low, on species of conservation concern like the Tufted Puffin.

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