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Source: Northwestern Naturalist, 97(3):237-245.
Published By: Society for Northwestern Vertebrate Biology
DOI: http://dx.doi.org/10.1898/NWN15-31.1
URL: http://www.bioone.org/doi/full/10.1898/NWN15-31.1

PIGEON GUILLEMOTS ON WHIDBEY ISLAND, WASHINGTON: A SIX-YEAR MONITORING STUDY

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ABSTRACT—Collecting long-term population trend data on indicator species contributes to our understanding of overall ecosystem health. The Pigeon Guillemot, a burrow-nesting piscivore, was identified as one of many indicators of health in Puget Sound, Washington. We observed the local guillemot population size, burrow occupancy, chick diet composition (identified as single fish carried in adult bills), and prey delivery rates to chicks on Whidbey Island, WA, between 2009 and 2014. Observations were conducted by trained volunteers from the Whidbey Audubon Society and the former Island County Beach Watchers (now Sound Water Stewards) who counted adults, verified burrow occupancy, and recorded prey delivery frequency and composition. Using the maximum counts across all Whidbey Island colonies, the index of abundance observed annually was an average of 991 individuals. A mean of 240 occupied burrows were observed each year. The peak rate of prey delivery occurred between the weeks of 12 July and 2 August, annually. Types of delivered prey consisted of 57.6% gunnel or prickleback (Pholidae or Stichaeidae), 25.6% sculpin (Cottidae), and 16.5% other or unknown prey. These data serve as a diet and reproductive baseline for assessing changes over time.

Key words: *Cepphus columba*, gunnel, long-term monitoring, nesting burrows, provisioning, Puget Sound, recovery, Salish Sea, sculpin, seabird

The Pigeon Guillemot (*Cepphus columba*) is a small diving seabird in the Alcidae (Auk) family. These birds breed along the coast from Southern California north to the Aleutian Islands and on both coasts of the Bering Sea, with an estimated global population of 200,000 to 300,000 individuals (Gaston and Jones 1998). Pigeon Guillemots are distributed widely in the greater Puget Sound region of Washington State, with 471 breeding colonies, primarily in sand-clay bluffs and rock cliffs, as documented by the Washington Department of Fish and Wildlife (Evenson and others 2003). Whidbey Island, Washington, is a 93.3 km long island of central Puget Sound, home to many guillemot colonies in the late spring and summer. As a result of their nearshore association, and as one of the few marine bird species that breed in Puget Sound, Pigeon Guillemot nesting season population trends are considered to be an indicator of biodiversity (Wahl and Speich 1984; Pearson and Hamel 2013; PSP 2014).

Breeding guillemot adults deliver single fish bill-loads to chicks in crevices adapted as burrows for approximately 30 d following hatching (Peterson 1981; Cairns 1987; Emms and Verbeek 1991). Previous studies have found variability in prey selection within colonies, and between nesting sites north of Puget Sound (Emms and Verbeek 1994; Golet and others 2000; Litzlow and others 2002, 2004). Litzlow and others (2004) concluded that the temporal and spatial variation in abundance of prey items causes this difference in adults' choice of prey for chicks. Schrimpf and others (2012) found that, except in times of exceptionally poor conditions, the Common Murre (*Uria aalge*), another Auk species, was able to adjust size and quality of prey delivered in response to variability in environmental conditions. Prey availability, prey size, and lipid content have been linked to breeding success in guillemot species (Golet and others 2000; Litzlow and others 2002; Wanless and others 2005). Information regarding diet composition and quality for Pigeon Guillemots in Puget Sound waters is limited, and has only been examined on Protection Island in the 1980s (Cyra 1982). This leaves researchers at a disadvantage in understanding the mechanisms driving population trends.

Breeding success in Pigeon Guillemot populations is additionally influenced by factors

beyond prey type, such as predation (Vilchis and others 2015). Pigeon Guillemots are more vulnerable to land predators (for example, Raccoon, *Procyon lotor*) than to marine predators (for example, Killer Whales, *Orcinus orca*) because, unlike most seabirds, they often use burrows on the mainland and not remote islands. As a result, they are vulnerable to a broader suite of mammalian predators (Vermeer and others 1993). They are also highly susceptible to gill netting and water pollution, especially in the form of oil spills (King and Sanger 1979; Vermeer and others 1993; Irons and others 2000). Concerns about the potential for oil spills in the Salish Sea (the body of water which includes Puget Sound) prompted a joint effort marine bird survey by the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. The results showed a high level of annual variation in marine bird populations, suggesting that long term monitoring is necessary for full understanding of baseline population trends (Wahl and others 1981).

Pigeon Guillemots can be difficult to survey en masse, given their small size and dispersed populations. Additionally, it has been reported that in Prince William Sound the winter population is only 25 to 50% of summer numbers, demonstrating that counts of over-wintering Pigeon Guillemots might underestimate the breeding population size (Kuletz 1998). Currently, the most comprehensive survey monitoring seabirds in Puget Sound is conducted by Washington Department of Fish and Wildlife in the form of an aerial winter survey (Anderson and others 2009). Due to the timing of the survey and observation difficulties, this is not a successful method of determining Pigeon Guillemot population size, and the Washington Department of Fish and Wildlife has reported that the wide confidence limits of aerial surveys make this method ineffective for monitoring Pigeon Guillemots (Evenson and others 2003). The Department of Fish and Wildlife monitoring effort specific to Pigeon Guillemots was short lived, and involved just 3 population counts by boat in May of 2000, 2001, and 2002 (Evenson and others 2003). The survey was discontinued by the state and has only recently been considered for revival at a smaller scale (WDFW Wildlife Program Weekly Report 2015). In contrast, citizen-science projects have a high potential value for generating data at finer temporal and spatial scales than government-funded national or regional efforts to monitor breeding birds (Ward and others 2015).

In this 6-y study, we conducted field surveys with trained volunteers to record population metrics of Pigeon Guillemots in attendance at breeding colonies on Whidbey Island, Washington. The purpose was to establish a breeding season index of abundance by estimating the maximum annual population size of adult Pigeon Guillemots present at breeding colonies. We additionally aimed to determine the frequency, type, and relative abundance of prey delivered to chicks. By documenting the status of this species in Puget Sound, these data will serve as an index for comparison in the event of a change in the ecosystem.

Methods

We observed breeding colonies of Pigeon Guillemots from late June through late August, 2009–2014 (Fig. 1). Colonies were defined as aggregates of burrows in bluffs around Whidbey Island, Washington (48.13°N, 122.58°W), with the exception of 1 colony in a derelict wharf (Fig. 1). Surveys covered all known active breeding sites on the island, except in 2014 when we lost beach access to 1 colony. The total number of colonies fluctuated slightly between years based on the discovery of new breeding sites and, in some cases, declines in activity at previously recorded colonies. In a classroom and in the field, a group of 40 to 50 volunteers was trained annually before late June to conduct surveys and identify common prey items. Volunteer teams consisting of 1 to 5 individuals were assigned to collect data at each of the 23 to 27 colonies.

Volunteer teams arrived to complete a 1-h survey starting at or before 08:45, to capture peak hours of activity (Drent 1965; Vermeer and others 1993). Each team conducted 1 survey per week beginning in late June, and ending when all activity ceased, usually in late August. We did not attempt to coordinate simultaneous surveys between colonies to eliminate double-counting, but instead assumed that adults would show limited interest in bluff activity at multiple colony sites. Volunteers conducted surveys on the beach by observing the Pigeon Guillemots using spotting scopes or binoculars. Volunteers recorded the maximum number of

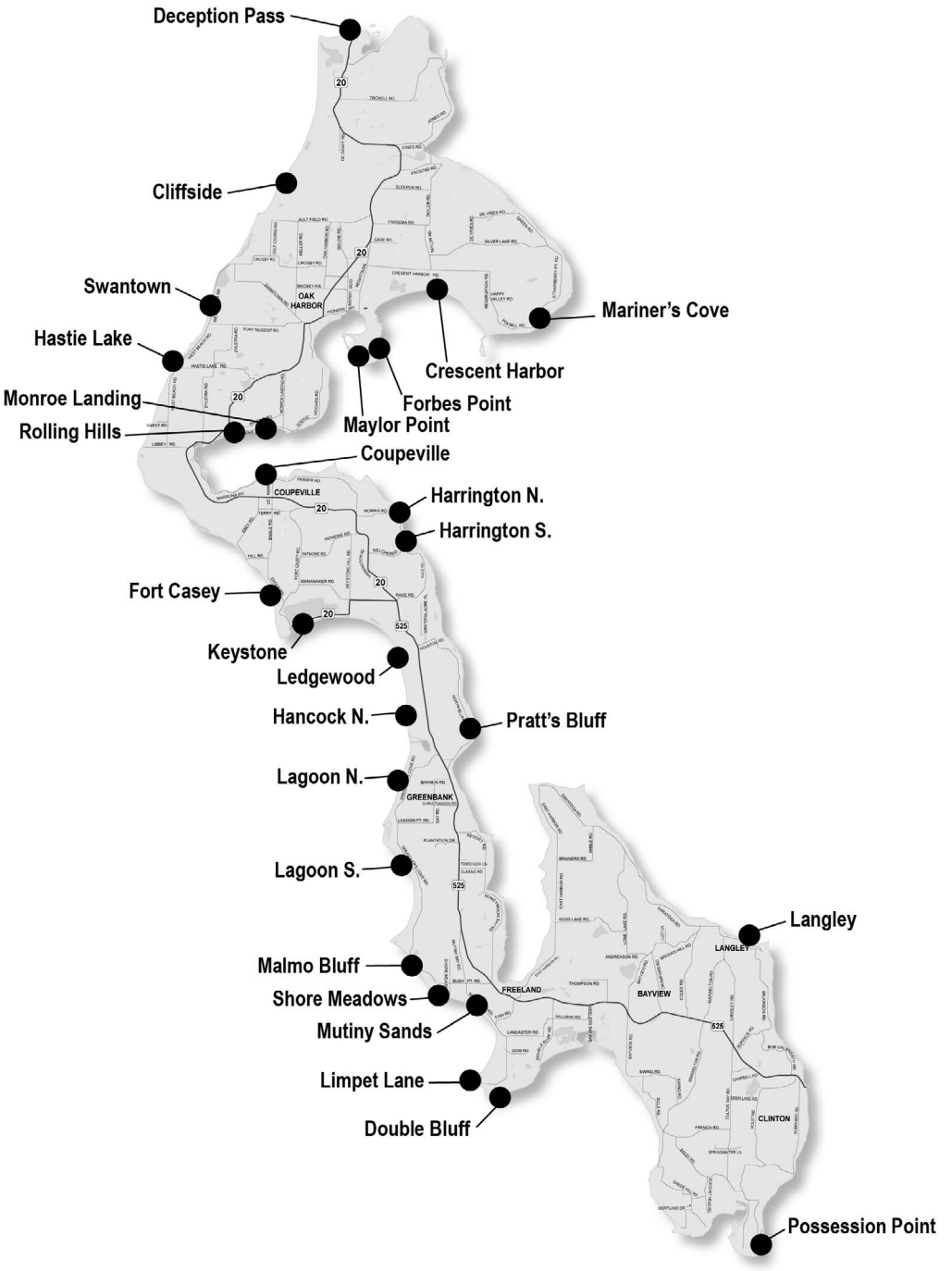

FIGURE 1. Whidbey Island, Washington, showing colony sites of breeding Pigeon Guillemots. The Keystone colony is housed in a derelict wharf.

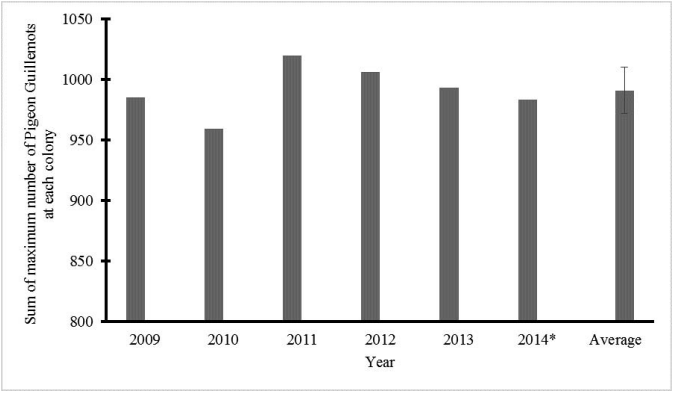

FIGURE 2. Annual sum of maximum index of abundance of Pigeon Guillemots at each colony during June to August, 2009 through 2014 on Whidbey Island (2009: $n = 23$; 2010: $n = 24$; 2011: $n = 26$; 2012: $n = 25$; 2013: $n = 27$; 2014: $n = 27$). Error bar shows standard deviation. * indicates one year where 1 colony was not accessible (see text).

adult Pigeon Guillemots observed directly in front of the bluff. The highest number of birds seen at any one time throughout the season became the maximum value for each colony. This number does not account for birds that may have been in their burrows for the entire 1-h survey, nor does it exclude non-breeding individuals that may travel between colonies. We therefore refer to this number as an index of abundance rather than as a breeding population estimate. The average annual index of abundance was calculated by adding the maximum counts across all colonies for each year, and then averaging those values across all years of the study.

Each team of volunteers agreed on a system for numbering active burrows at their colony, and assigned designations to burrows describing the nature of observed activity. A burrow was designated as an "occupied burrow" as soon as an adult Pigeon Guillemot was observed entering that burrow. We assumed that an occupied burrow indicated an attempt to breed, whether or not fish deliveries were later observed. When an adult Pigeon Guillemot delivered prey into the burrow, it was designated as a burrow with at least 1 chick ("chick burrow").

Prey were identified as either sculpin (Cottidae) or gunnel-prickleback (Pholidae and Stichaeidae, respectively). All remaining prey, and prey that could not be identified, were reported as other. Sand Lance (*Ammodytes personatus*) deliveries were not observed frequently enough to warrant a separate category for volunteer identification. Pigeon Guillemots typically held prey in their beaks for several minutes while sitting on the water before flying to their burrows. Observers were able to identify the prey held by adults using binoculars, but difficulty in making positive observations at a distance limited species identification in this study. Following Koelink (1972) and Golet and others (2000), gunnel and prickleback are reported together due to difficulty of distinguishing between those families.

Results

The average yearly index of abundance was 991 individuals ($s = 19.12$; Fig. 2). Double Bluff North was the largest colony, with a mean annual abundance of 92 Pigeon Guillemots observed by volunteers. Monroe Landing was the smallest colony, with a mean annual abundance of 16 birds. The average mean index of colony abundance was 41 birds colony^{-1} year^{-1} ($s = 1.45$). In 2014, we lost shoreline access to the Limpet Lane colony, which had previously hosted an average abundance of 31 guillemots per year. Because of this, we were unable to account for the adults nesting in that area in the index of abundance for 2014. We observed no trends or significant difference in Pigeon Guillemot abundance among the 6 y studied (one-way ANOVA $F_{5,\ 146} = 0.18$, $P = 0.968$; Table 1).

We observed the 1st prey deliveries to burrows in June each year (Fig. 3). The number of occupied burrows recorded ranged between

TABLE 1. Increases (+) and decreases (-) in maximum observed adult abundance at each site after the 1st survey year (2009). All symbols represent change relative to previous year. Blank spaces denote lack of survey data.

Sites	2010	2011	2012	2013	2014
Cliffside	-	-	-	no change	+
Coupeville Wharf				+	-
Crescent Harbor	-	+	-		
Double Bluff North	-	-	-	-	+
Double Bluff South			-	+	-
Forbes Point	-	+	-	-	-
Fort Casey	-	+	-	+	-
Hancock North/Lake Hancock		+	+	-	-
Hancock South					+
Harrington Lagoon N		-	+	-	+
Harrington Lagoon S		-	+	-	+
Hastie Lake North			+	-	no change
Hastie Lake (South)	+	-	-	-	+
Keystone	+	no change	+	-	-
Lagoon North, Site 0				+	+
Lagoon North, Sites 1A & 1B	-	+	+	+	-
Lagoon North, Site 2	-	+	-	+	-
Lagoon North, Site 3	+	+	+	-	
Lagoon South	-	+	-	-	-
Ledgewood	+	+	-	+	+
Limpet Lane	+	-	-	+	
Malmo Bluff	+	+	+	-	-
Maylor's Point	+	+	-	+	+
Monroe Landing	-	-	+	+	-
Mutiny Sands	-	+	-	-	+
Possession Point	-	+	+	-	-
Pratt's Bluff	+	-	-	+	-
Rolling Hills – Section 1					+
Rolling Hills – Section 2	+	+	-	+	-
Rolling Hills – Section 3					+
Shore Meadow	-	-	+	-	+
Swantown	+	+	+	-	-

217 and 273 annually, and the number of chick burrows ranged between 147 and 183 (Table 2). There was no significant variation in annual number of burrows for either type between years (one-way ANOVA occupied burrows: $F_{5,\ 154} = 0.27$, $P = 0.930$; chick burrows: $F_{5,\ 154} = 0.43$, $P = 0.829$). A mean of 240 occupied burrows was observed each year. Of the occupied burrows, an

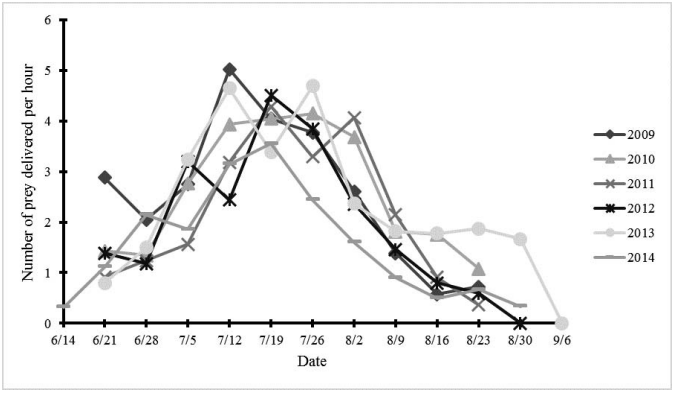

FIGURE 3. Weekly rates of total prey delivery to Pigeon Guillemot chicks throughout the season (June through August, 2009 through 2014), on Whidbey Island. Each date represents data collected that day and the subsequent 6 d averaged across all sites.

TABLE 2. The number of occupied burrows and chick burrows by colony 2009 through 2014 on Whidbey Island. Number of burrows is designated as "O" for occupied or "C" for chick. Dashes indicate that no adult guillemots were showing nesting activity during that breeding season. NA: No site access.

	2009		2010		2011		2012		2013		2014	
Sites	O	C	O	C	O	C	O	C	O	C	O	C
Cliffside	13	11	4	4	7	7	7	1	9	6	7	6
Coupeville Wharf	–	–	–	–	–	–	–	–	4	2	–	–
Crescent Harbor	3	3	–	–	–	–	–	–	–	–	–	–
Double Bluff North	37	16	34	19	28	18	15	9	21	17	19	11
Double Bluff South	4	3	–	–	2	2	2	1	3	1	3	2
Forbes Point	–	–	5	2	8	4	6	4	4	3	5	4
Fort Casey	8	8	11	6	6	5	10	8	8	7	15	9
Hancock North/Lake Hancock	10	8	16	3	12	10	27	11	23	16	13	8
Hancock South	–	–	–	–	–	–	–	–	–	–	4	3
Harrington Lagoon N	7	7	10	3	4	3	5	5	3	2	2	2
Harrington Lagoon S	9	9	7	3	7	3	6	5	3	2	6	1
Hastie Lake North	–	–	–	–	–	–	4	3	3	3	3	1
Hastie Lake (South)	9	2	6	4	2	2	5	3	8	6	11	9
Keystone	5	5	9	8	10	10	7	7	7	7	5	5
Lagoon North, Site 0	–	–	–	–	–	–	–	–	2	1	11	2
Lagoon North, Sites 1A & 1B	13	11	7	3	7	7	11	8	13	10	10	4
Lagoon North, Site 2	3	3	2	2	3	2	2	2	2	2	1	1
Lagoon North, Site 3	5	5	5	1	5	0	5	1	–	–	–	–
Lagoon South	10	6	7	7	18	11	19	10	20	4	17	3
Ledgewood	12	9	5	5	2	2	9	6	12	7	13	6
Limpet Lane	3	3	5	3	6	6	8	7	4	3	NA	NA
Malmo Bluff	12	12	10	9	13	12	11	7	16	10	21	11
Maylor's Point	5	5	7	6	5	5	–	–	3	3	6	4
Monroe Landing	5	3	3	3	3	3	1	1	2	2	1	1
Mutiny Sands	9	9	13	10	11	11	11	4	11	10	13	12
Possession Point	6	5	6	6	6	5	7	6	6	3	3	2
Pratt's Bluff	8	6	7	7	11	8	11	9	17	13	15	11
Rolling Hills - Section 1	14	6	15	8	12	9	14	11	12	10	14	12
Rolling Hills - Section 2	12	9	7	4	6	6	2	1	12	8	8	5
Rolling Hills - Section 3	–	–	–	–	–	–	–	–	–	–	3	3
Shore Meadow	27	14	23	21	22	13	14	14	17	13	37	10
Swantown	6	5	3	3	1	1	3	3	4	3	7	7
Total	255	183	227	150	217	165	222	147	249	174	273	155

average of 68% had observed food deliveries ($s = 5.98$), designating those burrows as having chicks. Adult Pigeon Guillemots delivered prey to an average annual count of 162 burrows during the study period.

We recorded a total of 3872 prey deliveries over 6 breeding seasons. The peak rate of prey delivery occurred between the weeks of 12 July and 2 August each year, with an average rate of 3.54 deliveries h^{-1} $colony^{-1}$ (Fig. 3). Deliveries began during the week of 21 June with an average of 1.41 deliveries h^{-1} $colony^{-1}$, and ended during the week of 23 August with an average rate of 0.88 deliveries h^{-1} $colony^{-1}$. Gunnels and pricklebacks were the primary prey, accounting for 57% of the average annual observed deliveries (Fig. 4). Sculpin made up 26% of prey deliveries to nests, and other fish genera made up the final 17% of prey. The types of prey listed as other were not easily recognized or routinely recorded by the majority of volunteers, but regularly consisted of perch (Embiotocidae), flatfish (Pleuronectiformes), and Sand Lance. Unidentified prey, also recorded as other, likely included some gunnel-prickleback and sculpin which were delivered too quickly, or at too great a distance, for positive identification.

Discussion

A volunteer-based study of Pigeon Guillemots has allowed us to supplement previous population counts by government agencies at a low

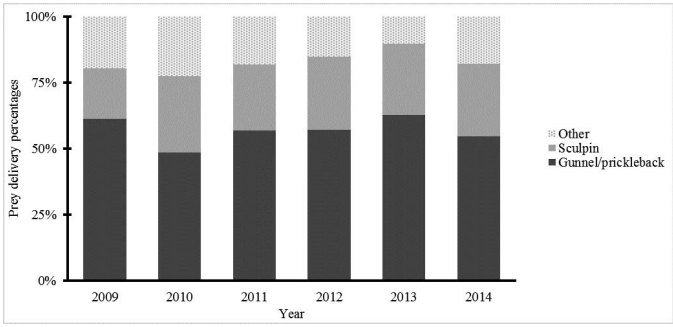

FIGURE 4. Annual composition of prey type delivered to Pigeon Guillemot chick burrows on Whidbey Island, June through August, 2009 through 2014.

cost, with a high resolution, over several years. The goals of this study were to establish a baseline for the annual index of abundance of adult Pigeon Guillemots in attendance at breeding colonies on Whidbey Island, Washington, and collect information about the type and frequency of prey delivered to guillemot chicks in the study area. Using maximum counts per colony, we estimated there were potentially as many as 991 adult birds in attendance at breeding colonies each summer, with very low annual variability. The prey delivery rate was highest during mid-summer and deliveries stopped in late August each year. Gunnel and prickleback were the most common prey items delivered to chicks, followed by sculpin.

Wahl and Speich (1984) surveyed marine birds within Puget Sound in May–June of 1982 at variable tides and times of day by boat, small aircraft, foot, and ferries. They counted a Puget Sound-wide population of 1159 breeding Pigeon Guillemots, but only 166 were in the waters surrounding Whidbey Island. Compared with our results, this number could underestimate the population of Pigeon Guillemots using Whidbey Island for breeding, or, conversely, show that the number of adult guillemots was much lower in the 1980s. Between 2000 and 2002, the Washington Department of Fish and Wildlife survey of maximal Puget Sound Pigeon Guillemot counts added an additional 350 nesting sites to those recorded by Wahl and Speich (1984), and recorded a population of >14,000 individuals, with variation in sub-regions ranging from 5 to 153% (Evenson and others 2003). The index of abundance calculated using data recorded by our volunteers had a high level of inter-annual consistency, though it could overestimate the actual number of adult Pigeon Guillemots surrounding Whidbey Island due to the possibility of double-counting. Our results, however, suggest a stable adult bird population and inferred proportion of breeding adults.

Emms and Verbeek (1991) found that prey delivery rates increased during the first half of the breeding season, then decreased in the second half. Nelson (1987) similarly found that prey delivery rates increased up to 15 d after hatching occured, which is about half the time it takes chicks to fledge. Deliveries decline when chicks are only halfway to fledging as a result of factors which likely extend beyond prey availability, such as adults encouraging chicks to fledge at an optimal weight (Shultz and Sydeman 1997). Guillemots provisioned chicks at an average rate of 0.81 fish parent^{-1} h^{-1} and 0.55 fish parent^{-1} h^{-1} on Southeast Farallon Island, California, in 1979 and 1980, respectively, adjusting for chick age using an analysis of covariance (Nelson 1987). Our results show a higher unadjusted average of 2.25 deliveries h^{-1} across all survey seasons, although surveys began during the week of 21 June between 2009 and 2014 had an unadjusted average of 1.41 deliveries h^{-1}. Our data did not capture delivery rates at the very beginning of the breeding season, resulting in a higher overall average of delivery rates. A future change in the prey delivery rate to Whidbey Island Pigeon Guillemot chicks may signal the response of the adults to a change in prey quality, type, or availability.

Studies in Prince William Sound, Alaska, and the Strait of Georgia, British Columbia, have found that adults provision chicks with a

primary diet of gunnel-prickleback (blennies), and sculpin (Drent 1965; Koelink 1972; Emms and Verbeek 1991; Golet and others 2000). Our data support the conclusions reported by Vermeer and others (1993), with gunnel and prickleback as the main prey items. Drent (1965) and Koelink (1972) both found that 75% or more of prey delivered to chicks were either sculpins or "blennies", a category that included gunnel and prickleback, among other families. Unknown deliveries were grouped into the "other" category in our study, so it is likely that our numbers underestimate the proportion of deliveries that were sculpin or gunnel-prickleback. Even so, at 26% of total deliveries to chicks, sculpin deliveries made up a higher proportion of prey in our study compared to Koelink (1972) who observed 63.8% of food deliveries as blennies and only 13.2% sculpin in British Columbia.

In the Salish Sea, birds like the Pigeon Guillemot that include demersal fish in their diet are less likely to exhibit declining populations when compared to species that focus on small, schooling pelagic fish like herring (Clupeidae) and Sand Lance (Vilchis and others 2015). Golet and others (2000) hypothesized that this phenomenon of trading nutrient content for consistent availability may explain the relative success of specialized Pigeon Guillemots, which choose to exploit primarily demersal fishes for delivery to chicks. Current Pigeon Guillemot prey choices suggest that Sand Lance is not a reliable food source for adult guillemots delivering prey to chicks on Whidbey Island. This is supported by Rice and others (2012), who reported that the most common fish types in waters surrounding Whidbey Island were Pacific Herring (*Clupea pallasii*), Surf Smelt (*Hypomesus pretiosus*), and Threespine Stickleback (*Gasterosteus aculeatus*). In the event of an abrupt change in the Puget Sound ecosystem, for example an oil spill, our results suggest that Pigeon Guillemots on Whidbey Island will be useful as indicators of demersal fish population stability, rather than of the population trends of lipid-rich schooling fish, within the range of guillemots foraging for prey to deliver to chicks on Whidbey Island. Continued monitoring of Pigeon Guillemot populations will expand these results and provide a baseline data set in the event of such an ecosystem or prey- choice shift in Puget Sound.

Acknowledgments

This project is supported by the Whidbey Audubon Society the Washington Audubon Chapter Grant program, and the Island County Marine Resources Committee through the Northwest Straits Marine Conservation Initiative. We thank the editors who provided valuable feedback, and the interns who contributed to this project: H Flores, K Krammer, J Svetco, and K Zupich. Special thanks go to all the Guillemot Research Group volunteers for their many years of contributions. This project has been funded wholly or in part by the United States Environmental Protection Agency. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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WDFW WILDLIFE PROGRAM WEEKLY REPORT MAY 18–24, 2015. Available from http://wdfw.wa.gov/about/wildlife_weekly/.

Submitted 25 September 2015, accepted 4 April 2016. Corresponding Editor: D Max Smith.