Factors affecting the success of Pigeon Guillemots on Whidbey Island, Puget Sound, Washington, during the 2009 breeding season.

By

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Abstract

Factors affecting the success of Pigeon Guillemots on Whidbey Island, Puget Sound, Washington, during the 2009 breeding season.

Kirsten A. Kreamer

Pigeon Guillemots (*Cepphus columba*) are colonial alcids that breed along the western coast of North America, extending from Alaska to California. While previous studies of breeding Pigeon Guillemots have taken place in remote areas, the current study investigated five colonies of Pigeon Guillemots on Whidbey Island, WA from 22 June, 2009 to 18 August, 2009. Whidbey Island is populated by 58,211 residents, 29,000 of whom live in rural areas, including beaches that are utilized by Pigeon Guillemots as nesting sites. Physical characteristics of burrows, feeding rates, behaviors, numbers of adults and human disturbances were all recorded. A total of 47 burrows were monitored, fifteen of which were determined to have supported chicks to fledging weight, and were considered successful. Burrow characteristics included size of entrance, type of vegetation within 15 cm of entrance, distance of burrow entrance above shore and distance of entrance from the top of the bluff. Human activities were determined to be disturbances when Pigeon Guillemots displayed agitated behaviors. None of the physical characteristics of burrows were significantly correlated with success, nor were human disturbances. Feeding rates were significantly correlated to success when all sites were grouped together (ANOVA, $p = 0.02$), with significant results at the largest site monitored (ANOVA, $p < 0.01$) Whidbey Island is an ideal location for monitoring projects to continue throughout the year to determine seasonal activities of Pigeon Guillemots. Further investigation on the success of Pigeon Guillemots breeding within close proximity to human activities is necessary to fully understand these complex interactions.

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Acknowledgments

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Introduction

Auks are marine birds that reside north of the equator and utilize shorelines as colonial breeding sites. Over 2 million pairs of Auks nest along the coastline of North America (Kaiser and Forbes, 1992), using a variety of nesting habitats, ranging from grassy slopes to bluffs. The breeding success of Auks (Alcidae) has been influenced by human disturbance (Pierce and Simons, 1986; Cairns, 1980; Drent, 1965), which has been both direct and indirect: disturbances from researchers have been directly correlated to nest abandonment by adults and marked declines in fledgling success (Pierce and Simmons, 1986; Cairns, 1980; Anderson and Keith, 1980; Carney and Sydeman, 1999). Indirect effects of human disturbances include the introduction of species which did not co-evolve with burrow-nesting species of birds (Jones et al. 2007; Vermeer et al. 1993b).

Abundance of prey items utilized to provision chicks has been correlated to success of Auks, as time spent foraging for prey items by adults directly influences provisioning rates to chicks (Litzow and Piatt, 2003). Lipid content of prey items, as well as size of prey items delivered to chicks have both been directly correlated to success of Auk chicks (Anthony et al. 2000, Golet et al. 2000, Wanless et al. 2005).

Changes in climate and other factors have caused declines in certain Auk populations (Kaiser and Forbes, 1992, Seiser at al. 2000), as well as environmental pollutants (Agler et al. 1999; Litzow et al. 2002;

Seiser et al. 2000). The effect of environmental contaminants has been well documented following the TV *Exxon Valdez* oil spill, which has been directly correlated to the decline of five species of Auks breeding in Prince William Sound, AK (Litzow and Piatt, 2003; Ewins, 1993; Golet et al. 2000; Oakley and Kuletz, 1996).

Interspecific competition for nesting sites and availability of nesting sites has been correlated to breeding success of Auks (Williams, 1975; Nelson, 1987), as well as the physical characteristics of burrows used as nests (Emms and Verbeek, 1989; Vermeer, 1979). Synchronized laying of eggs among adults (Birkhead, 1977; Hatchwell, 1991) effect breeding success, as well as the synchronized fledging of chicks (Hatchwell, 1975).

Pigeon Guillemots (*Cephus columba*) are semi-colonial alcids that breed on coastlines or islands of western North America extending from northwestern Alaska to southern California (Ewins, 1993). Breeding populations of Pigeon Guillemots are also present in the eastern portion of the Bering Sea, yet these populations have not been studied extensively (Konyukhov, 2000). Breeding success of Pigeon Guillemots has been studied in Alaska, British Columbia, Washington and California, with the aid of blinds and not within direct vicinity of human inhabitants (Nelson, 1987; Nelson, 1991; Vermeer, 1993).

Previous studies of Pigeon Guillemots have been conducted on islands, which support the largest breeding colonies of this species

(Ewins, 1993; Vermeer et al. 1993b). Islands have historically lacked mammalian predators, and offer access to shallow foraging areas, which enable breeding Pigeon Guillemots to provision more chicks than other Auks. This ability to provision offspring results in two egg clutches as opposed to a one egg clutch (Emms and Verbeek, 1991; Bradstreet and Brown, 1985). Islands located in Puget Sound, Washington, not only support breeding populations of Pigeon Guillemots, but are also inhabited by humans.

The purpose of this study was to determine if physical characteristics of burrows, feeding behaviors and anthropogenic disturbances affected the breeding success of Pigeon Guillemots on Whidbey Island, Puget Sound, WA during the 2009 breeding season. The human population of Whidbey Island in 2009 was 58,211 with half of this population residing in rural areas, including beaches and shorelines (2000 Census). Pigeon Guillemots utilize these shorelines that are easily accessible to humans as nesting habitat, providing a unique opportunity to observe behaviors and colony characteristics without the aid of blinds.

Study area and methods

Observations of five Pigeon Guillemot colonies were conducted on Whidbey Island, Washington (48° 08’11” N, 122° 34’ 57” W) from 22 June, 2009 to 18 August, 2009. One site per day was observed over an interval of five hours, during which number of adults, physical characteristics of burrows, behaviors, disturbances, burrow activity and chick feeding behaviors were all recorded. Pigeon Guillemot activity is highest at colonies between dawn and mid-morning (Drent, 1965; Vermeer et al. 1993b) therefore five hour intervals were used to monitor the most active periods of feeding and socializing. Observation periods began before sunrise in order to monitor the arrival of adult birds and to obtain an estimate of adult populations at peak attendance times (Vermeer, et al. 1993a). The five locations of study were Shore Meadows, Harrington South, Harrington North, Rolling Hills and Mutiny Sands, and were located on the southern, western and eastern portions of the island (Figure 1).

All colonies monitored were located in bluffs, where natural cavities were used as burrows by Pigeon Guillemots. These cavities were determined to be nesting sites or burrows when a prey item had been delivered to that cavity. Pigeon Guillemot chicks fledge at night (Ewins, 1993) when observations were not conducted, therefore success of the burrow was determined by using the number of consecutive weeks prey were delivered to burrows. Pigeon Guillemots reach fledging weights between 33-37 days after hatching (Thoresen and Booth, 1958), therefore burrows receiving deliveries of prey items for five weeks or longer were determined to be successful, indicating that the chick or chicks inside the burrow had reached fledgling weight .

Burrow characteristics

Breeding success of Pigeon Guillemots has been correlated to burrow structure (Emms and Verbeek, 1989) and concealment of the burrow entrance (Emms and Verbeek, 1989). Breeding Pigeon Guillemots in British Columbia avoided nesting near trees to evade predation (Ewins, et al. 1994). It was assumed that burrow placement on the bluff may have affected the ability of predators to gain access to eggs and chicks, as rats, raccoons and other mammalian predators could potentially gain access to burrows that were close to the tops of bluffs, as well as nests that were formed in the roots of trees (Ewins, et al. 1994). All of the following physical characteristics were recorded for all burrows at all colonies:

a. area of burrow entrance (cm^2),

b. height of burrow entrance above shore,

c. distance of burrow entrance from top of bluff,

d. type of vegetation within 15 cm of burrow entrance,

Vegetation types were categorized into five groups: no vegetation, grasses, shrubs, trees or roots. All distances were visual estimates; burrow entrance areas were based on bird body length.

Two-way ANOVA (SAS/STAT 9.2, SAS Inc.) were used to test for significant differences in the number of weeks fed based on physical characteristics of burrows. This determined if any or all of the physical characteristics documented were a function of success.

Feeding behaviors

Success of chicks has been significantly correlated to feeding rates within the first weeks after hatching (Cairns, 1981; Cairns, 1987; Emms and Verbeek, 1991), therefore careful observations of chick feedings were recorded during each five hour observation period. Feeding rates were calculated by summing total number of deliveries to individual burrows, then dividing total number of deliveries by total number of hours observed. Feeding rates were then compared to number of weeks fed to determine if correlations existed between the two variables.

Pearson's correlation (SAS/STAT 9.2, SAS Inc.) was used to test for correlations between feeding rates and numbers of weeks fed. Correlations were conducted twice: first on the overall data set and then by site.

One-way ANOVA (SAS/STAT 9.2, SAS Inc.) was used to determine if differences existed between number of weeks fed and site of colony. This analysis was completed in order to determine if any of the study sites was significantly different in the number of weeks fed.

Human disturbance

When disturbed, Pigeon Guillemots show agitation by sounding alarm calls, taking off en masse, rapidly leaving an area as individuals, or mobbing potential predators (Drent, 1965; Ewins, 1993; Nelson, 1985; Nelson, 1987.) If these behaviors were exhibited as a result of anthropogenic sources (dogs, boats, planes, etc.), the source was determined to be a disturbance. This included observer arrival or movements that caused changes in behaviors. Because all burrows monitored were within colonies and not independent nesting sites, all disturbances affected all nests within colonies.

One-way ANOVA was used to test the effects of human disturbance on the number of weeks fed (SAS/STAT 9.2, SAS Inc.). This analysis determined if a relationship existed between number of human disturbances and number of weeks fed at all sites.

Results

A total of 47 burrows were observed on Whidbey Island during the 2009 breeding season. The number of burrows at each site was as follows: Shore Meadows had eight burrows, Harrington South had seven, Harrington North had nine, Rolling Hills had 15, and Mutiny Sands had seven. Fifteen of these burrows received prey deliveries for five weeks or more, indicating that chicks within these burrows reached fledging size and were therefore successful. Shore Meadows had two successful burrows, Harrington South had two, Harrington North had four, Rolling Hills had six, and Mutiny Sands had one (Table 1). Burrows were restricted to cavities formed in the bluffs; no other nesting habitat was utilized by Pigeon Guillemots in this study.

Counts of adults arriving to colonies after dawn were counted to obtain a total population of both breeding and non-breeding adult Pigeon Guillemots. The numbers of adults present at colonies were: Shore Meadows 70, Harrington South 32, Harrington North 48, Rolling Hills 51, and Mutiny Sands had 52 (Table 1).

Burrow characteristics

Physical characteristics of burrows had no affect on Pigeon Guillemot success for the 2009 breeding season (Table 2). Entrance size of burrows had no affect on number of weeks fed (ANOVA, $p = 0.50$), nor did distance of entrance from the top of the bluff (ANOVA, $p = 0.62$), or distance of the burrow entrance from the shore (ANOVA, $p = 0.67$). Vegetation type within 15 centimeters of the burrow entrance also had no affect on success (ANOVA, $p = 0.50$). No site had distinguishing differences in mean entrance sizes (Figure 2), mean height above shore (Figure 3), or mean distance from the top of the bluff (Figure 4). Of the 47 burrows monitored, 24 had no vegetation within 15 cm of the entrance, eight had grass, six had shrubs, nine had roots, and no burrows had trees (Figure 5).

Feeding behaviors

No single site had significant differences in mean feeding rates (Figure 6). Feeding rates were significantly correlated to success for the entire dataset (Pearson's correlation, $p = 0.02$) (Table 3). When sites where looked at individually, only Rolling Hills, the largest site, had a significant correlation between feeding rates and number of weeks fed (Pearson's correlation, $p < 0.01$). Correlations were not significant at the Shore Meadows site (Pearson's correlation, $p = 0.09$), at Harrington North (Pearson's correlation, $p = 0.65$), Harrington South (Pearson's correlation, $p = 0.89$) or at Mutiny Sands (Pearson's correlation, $p = 0.30$) (Table 3).

A total of 47 burrows were monitored during this study, the majority of which were fed for four weeks (Figure 7). The number of weeks fed by site was not significantly different (ANOVA, $p > 0.05$); therefore one site was not more likely to have successful burrows than another (Table 4). This indicates that none of the observed sites was more likely to have more successful burrows than the others for this study.

Human disturbance

Human disturbances had no affect on number of weeks fed (ANOVA, $p = 0.97$, Table 5). There were also no significant results between number of disturbances and site (ANOVA, $p = 0.32$) (Table 6). This result indicates that no site in this study had significantly more disturbances than any of the others. Numbers of human disturbances were: Shore Meadows 11, Harrington South 12, Harrington North 15, Rolling Hills, 15 and Mutiny Sands 61 (Table 1).

Natural history observations

Direct observations of nests revealed egg failure due to avian predation (Figure 8), predation of a chick by an unknown predator (Figure 9), and a burrow which failed, and had collapsed (Figures 10 & 11). Observations also revealed that at least one burrow supported two chicks to fledgling size (Figure 12).

Discussion

Feeding behaviors

Feeding behaviors were found to effect success when all burrows were grouped together as well as for the largest site in the study. Feeding rates and success were significantly correlated for all sites(Pearson's correlation, $p = 0.02$), as well as for the Rolling Hills site (Pearson's correlation, $p < 0.01$).This was the largest colony with fifteen total burrows, six of which were successful. Rolling Hills had nearly twice as many burrows as the other colonies, which increase the chances of finding significant relationships between variables. Therefore, the total grouping of colonies gives a better insight as to the significance of feeding rates. The average hatching weight of Pigeon Guillemot chicks is 41.5 g (Thoresen and Booth, 1958), weight doubles five days after hatching, triples after 10 days, and chicks reach 411 g at fledging (Drent, 1965), which is reached

33-37 days after hatching (Thoresen and Booth, 1958). Pigeon Guillemot chicks on Farallon Island aged 1 to 30 days after hatching were fed more often than chicks aged 31 days and older (Nelson, 1987). This was also observed in colonies in British Columbia, where delivery rates were highest during the first half of the nestling period (Emms and Verbeek, 1991). In both studies, feeding then tapered off, due to the reduced need for provisioning by older chicks, or as a strategy by parents to encourage fledging (Emms and Verbeek, 1991). Black Guillemot (*Cepphus grylle*) chick provisioning decreased markedly when chicks had reached 30 days old (Peterson, 1981); these birds are closely related to Pigeon Guillemots and have similar breeding behaviors (Cairns, 1981).

Rapid feeding events were observed during this study, with at least two adults provisioning chicks at multiple burrows. Burrows receiving deliveries from two adults were apparent as one adult entered the burrow with a prey item, and was immediately followed into the burrow by a second adult with another prey item. Drent (1965) observed that both parents provisioned chicks, and these fast deliveries indicate that this was also the case for Pigeon Guillemots on Whidbey Island. These rapid deliveries could indicate that the chick or chicks in these burrows had not yet reached an asymptotic weight which is reached between day 30 and 40 after hatching (Ewins, 1993). Feeding rates decline rapidly after this asymptotic weight has been reached by the chicks and is indicative that chicks are approaching fledging age (Ewins, 1993).

Lipid contents of prey items have been found to correlate positively to Pigeon Guillemot success (Golet et al. 2000; Litzow et al. 2002).The availability of prey items has also been positively correlated to success(Litzow et al. 2002). A comprehensive study of colonial seabirds in the North Sea in Scotland concluded that Common Guillemots (*Uria aalge*) were particularly susceptible to low-quality prey items, as they deliver one prey item at a time to chicks (Wanless et al. 2005). Pigeon Guillemots also deliver one prey item at a time, and populations in Prince William Sound, AK, were determined to have slow recovery rates after the TV *Exxon Valdez* oil spill affected populations of oil-rich prey items (Litzow et al. 2000). Populations of prey species were also heavily affected by the climatic regime shift that occurred between 1976 and 1977 in the North Pacific (Agler et al. 1999). Lipid contents were not measured in this study, but may have affected growth rates and fledging success of Whidbey Island colonies; adults that provision chicks with high-lipid prey items are more likely to fledge two chicks, as opposed to one chick (Golet et al. 2000; Kuletz, 1986).

Specialization by adult Pigeon Guillemots also may have affected chick success. Adults that selected one type of prey item to deliver to chicks had higher success rates than those adults that did not specialize in Prince William Sound, AK (Golet et al. 2000). This was not because adults that specialized in prey selection chose higher-lipid prey items, but because they selected larger prey items, allowing for fewer deliveries and therefore fewer opportunities for predators to find burrows (Golet et al. 2000). Specialization was not examined during this study, as fishes such as Eulachon (*Thaleichthys pacificus*) are very difficult to decipher from Pacific Sand Lance (*Ammodytes hexapterus*), Surf Smelt (*Hypomesus pretiosus*), and Crescent Gunnels (*Pholis laeta*) unless the researcher has these prey items in hand. These species vary in lipid content from 20% in Crescent Gunnels to 50% in Eulachon (Anthony et al. 2000), and misidentification of prey items would lead to incorrect conclusions.

Burrow characteristics

Burrow characteristics have been shown to have significant effects on success in previous studies in colonies of alcids (Emms and Verbeek, 1989; Vermeer, 1979; Vermeer et al. 1993b), yet no strong correlations were found in this study. Burrow placement on the bluff was assumed to have a possible effect on predation by mammals, as Pigeon Guillemots utilize cavities that are inaccessible to mammalian predators (Ewins et al. 1993) yet there were no significant correlations between variables recorded and number of weeks fed. Pigeon Guillemots have been noted to nest in a variety of materials, including discarded pipes and nest boxes (Nelson, 1987) tires, empty buildings, ferry terminals, root balls, abandoned nests of other seabirds and rabbits, driftwood piles (Ewins, 1993), and old bomb casings (Speich and Wahl, 1989). All burrows included in this study were cavities in bluffs, and no burrows had trees near the burrow entrance, which both indicate that presence of mammalian predators were a factor in nest site selection.

Thermoregulation of burrows could have a significant effect on chick development on Whidbey Island. Drent (1965) observed that adult Pigeon Guillemots brooded chicks longer in cooler weather, exposing themselves to greater chances of predation. Conversely, Black Guillemot chicks suffered an increase in mortality rates from 2% in 1975 to 11% in 1977 due to heat (Asbirk, 1979). Stable microclimates reduce energy expenditures for parents, increasing foraging opportunities for prey items and increasing chances of survival for chicks (Kaiser and Forbes, 1992.) Regulated temperatures within nesting materials could eliminate the risk of both cold temperatures and overheating, and could be a factor for selection of nesting sites as well as success rates.

Human disturbance

Human disturbances have been shown to have adverse effects on breeding colonies of birds that frequently nest near human habitations (Carney and Sydeman, 1999). It is, however, possible that interactions with humans do not affect Pigeon Guillemots in an adverse way on Whidbey Island. The populations monitored during this study may have been able to adapt to human interactions more readily than populations previously studied. Laysan Albatross (*Diomedea immutabilis*) adults and chicks that were frequently visited by humans were less aggressive than those that were not visited, indicating that interactions had decreased sensitivity to human disturbances (Burger and Gochfeld, 1999). This phenomenon may be occurring on Whidbey Island with Pigeon Guillemots that are frequently exposed to human disturbances.

It is also possible that observer influence had a greater effect than realized or reported during this study. Because sites were monitored once a week, birds may not have had time to acclimate to a constant presence of a human, and burrows may not have been provisioned while the researcher was present. Use of blinds could have eliminated this distraction for the breeding Pigeon Guillemots. Tufted Puffin (*Lunda cirrhata*) success on Barren Island, Alaska was reduced from 94% (15 fledglings from 16 eggs laid) to 18% (6 fledglings from 34 eggs laid) based solely on disturbances caused by researchers (Pierce and Simmons, 1986). Tufted Puffins left nests for longer periods of time in the highly disturbed area, exposing chicks to inclement weather, and longer periods between feedings (Pierce and Simmons, 1986).

Human presence may have had an indirect effect on success, as some predators of Pigeon Guillemots are commensal with humans. Rats (*Ratus* spp.) prey on eggs, chicks and adult Pigeon Guillemots and are responsible for seabird population declines (Atkinson, 1985). Burrow nesting alcids are believed to be particularly at risk from rat predation, as rats frequently forage for food and build nests in crevices, which Pigeon Guillemots use as nests (Jones et al. 2007). Invasive species are considered to be the largest terrestrial threat to seabird colonies (King, 1985); this was supported by a study in British Columbia, which found that non-native Raccoons (*Procyon lotor*) were the main predator of Pigeon Guillemot eggs and chicks (Vermeer et al. 1993b). Northwestern Crows (*Corvis caurinus*) have been documented to follow researchers and later prey upon chicks that had been examined by humans (Vermeer et al. 1993b). Evidence of predation was found at Mutiny Sands, Harrington North, Harrington South and Shore Meadows. A predated egg was found at Mutiny Sands, most likely from an avian predator (Figure 8). A wing from a juvenile Pigeon Guillemot was found at the Harrington North site (Figure 9), and an easily accessible burrow at the Harrington South site was also predated (Figures 10 &11). None of these predations were witnessed by the observer.

Predation has been deterred by synchronized breeding in alcids, as adults will group together and mob potential predators (Williams, 1975). Chicks that fledge in groups are also more likely to survive than single chicks fledging alone (Williams, 1975). Synchronized breeding is likely to have occurred at the Harrington North site, as no burrows at that site received deliveries after 29 July, 2009, a full two weeks before burrows at other colonies stopped receiving deliveries. Other colonies in this study may have also been synchronized, but not as clearly as the Harrington North colony.

Ecological implications

The small number of successful burrows during the 2009 season leads to several possible explanations: the breeding population of Pigeon Guillemots on Whidbey Island for that season was affected by unobserved variables, observations for the season did not start early enough and the reported number of burrow receiving deliveries is incorrect, or success should have been measured by a variable other than number of weeks fed. It is also possible that 2009 was an extreme low in reproductive success for Pigeon Guillemots at these colonies.

Research for this project commenced on 22 June, 2009, and deliveries of prey items were already taking place at all five colonies; this indicates that some of the burrows may have been receiving deliveries for longer periods of time than reported, and more than fifteen total burrows were successful. Seventeen burrows were recorded to have been fed for four weeks (Figure 7); eight of which had been receiving deliveries during the first week of observation. Correlations between early laying times and success have been reported for Pigeon Guillemots, as well as other alcids (Asbirk, 1979; Cairns, 1981; Divoky, 1982; Drent, 1965; Ewins, 1993) Adults that breed later are typically inexperienced, have lower success rates, and do not lay as many eggs (Ainley et al. 1990; Asbirk, 1979). It is possible that successful nests that started earlier in the season were determined to be unsuccessful, and the majority of observations were on burrows that were utilized by inexperienced adults. Because research for this study began after eggs had been laid, and in some cases, after chicks had hatched, it is difficult to report with certainty that success was determined accurately due to the timing of the project.

Pigeon Guillemots utilize natal cavities for rearing chicks (Drent, 1965; Nelson, 1991); if natal cavities are not available, males will secure burrows within 200 m of natal sites (Nelson, 1991). This site fidelity indicates that the adults present at each colony were likely hatched within close vicinities of that colony, and could indicate past success of the colony as a whole. In order for populations of Pigeon Guillemots to remain stable, 40% of chicks must survive to breeding age (Nelson, 1991). Breeding Pigeon Guillemots pairs fledge an average of one chick per season (Nelson, 1991); this study found that 15 burrows supported chicks to fledgling weights, which falls far below the required 40% needed to sustain the population. It is evident by the number of breeding and non-breeding adults present at all colonies that Pigeon Guillemots have been successful in the past and that the 2009 season may have had unusually low success rates. It is also possible that this study did not begin early enough in the season to accurately account for all feedings to all burrows; 2009 was an unusually warm year for Whidbey Island, and nesting could have begun earlier than previous seasons, when observations were not taking place.

Conclusions

A total of 47 burrows were observed during the 2009 breeding season on Whidbey Island; 15 of which were determined to be successful based on number of weeks fed. The implications of this low number are not consistent with the numbers of adult Pigeon Guillemots that were observed during this study. The number of adults within the five colonies is indicative of successful breeding seasons in previous years, as Pigeon Guillemots return to natal nesting sites during the breeding season (Drent, 1965; Nelson, 1991). Of all factors observed, significant correlations were found between number of weeks fed and feeding rates for one site, Rolling Hills (Pearson's correlation, $p < 0.01$), and when all sites were analyzed together (Pearson's correlation, $p = 0.02$). No other significant correlations were found, which indicates that success may have been a function of unknown variables. It is also possible that Pigeon Guillemots began the breeding season earlier than usual in 2009, before this study commenced.

Whidbey Island is a unique habitat in which to study Pigeon Guillemot breeding biology; burrows are accessible to researchers, and human interactions are prevalent. The ease of access to colonies on this island provides opportunities for future research projects, exploring variables that were not looked into for this study. Burrow characteristics including complexity of the inner cavity, and thermoregulation of burrows could be looked into, as well as the substrate composition of the bluffs. Other possible projects include type of prey and lipid rates of prey items delivered to chicks using mist nets, and the banding and tracking of adults to determine fluctuations in attendance and site fidelity. Further research is needed on this island in order to determine definitively if success rates of these populations of Pigeon Guillemots differ from conspecifics nesting on uninhabited islands. Year round monitoring of Pigeon Guillemots on Whidbey Island could provide insight into seasonal behaviors, changes in population throughout the year, and patterns in breeding characteristics. Future studies should be conducted on one colony, starting earlier in the season with observations taking place daily with the use of a blind, and continuing for consecutive seasons. Further investigation on the success of Pigeon Guillemots breeding within close proximity to human developments is necessary to fully understand these complex interactions.

Table 1. Characteristics of Pigeon Guillemot colonies on Whidbey Island in 2009. Number of all active burrows, successful burrows, number of adults present, and number of human disturbances for each colony.

Site	Burrows (n)	Successful Burrows (n)	Adults (n)	Human Disturbances (n)
Shore Meadows	8	2	70	11
Harrington South	7	2	32	12
Harrington North	9	4	48	15
Rolling Hills	15	6	51	15
Mutiny Sands	8	1	52	61
Totals	47	15	253	114
Mean	9.4	3	50.6	22.8
Standard Deviation	3.2	2	13.5	9.6

Table 2. Summary of results using two-way ANOVA, examining differences between number of weeks fed and physical characteristics of all monitored burrows of Pigeon Guillemots on Whidbey Island.

Characteristic	n	Mean ± SD	Min	Max	MSE	F	p
Entrance size cm^2	47	324.47 ± 354.43	24.0	2230.0	2.6	1	0.5
Distance from bluff top (m)	47	2.40 ± 3.83	0	18.3	2.8	1	0.6
Height above shore (m)	47	9.25 ± 4.80	3.1	21.3	2.7	1	0.6
Vegetation	47	n/a	n/a	n/a	2.8	1	0.5

Table 3. Correlations coefficients (R) between number of weeks fed and mean feeding rates of Pigeon Guillemots on Whidbey Island, for all sites combined and as single units

Site	Shore Meadows	Harrington South	Harrington North	Rolling Hills	Mutiny Sands	All Sites
n	8	7	9	15	8	47
R	0.63	-0.06	0.18	0.66	0.63	.34
p	0.09	0.89	0.65	**<0.01**	0.09	**0.02**

Table 4.Colonies of Pigeon Guillemots on Whidbey Island showed no differences in weeks fed and site. Results of one-way ANOVA revealed no significant differences ($p > 0.05$), as no site was fed for a longer or shorter amount of time during this study.

Number of Burrows	MSE	df	F	p
47	2.62	4,47	0.07	> 0.05

Table 5. Success of Pigeon Guillemots on Whidbey Island was not affected by human disturbances. Results of one-way ANOVA test to find differences between total number of disturbances and total number of weeks fed revealed no significant differences ($p = 0.9656$). Results indicate that no site in this study had significantly more or less disturbances than any other site.

n	df	MSE	F	p
47	3,3.43	2.564	0.09	0.9656

Table 6.The five colonies of Pigeon Guillemots studied on Whidbey Island did not vary significantly in number of human disturbances. Results from two-way ANOVA show that no site had a significant difference in disturbances (p = 0.3156).

Numerator DF	Denominator DF	F	p
4	713	1.19	0.3156

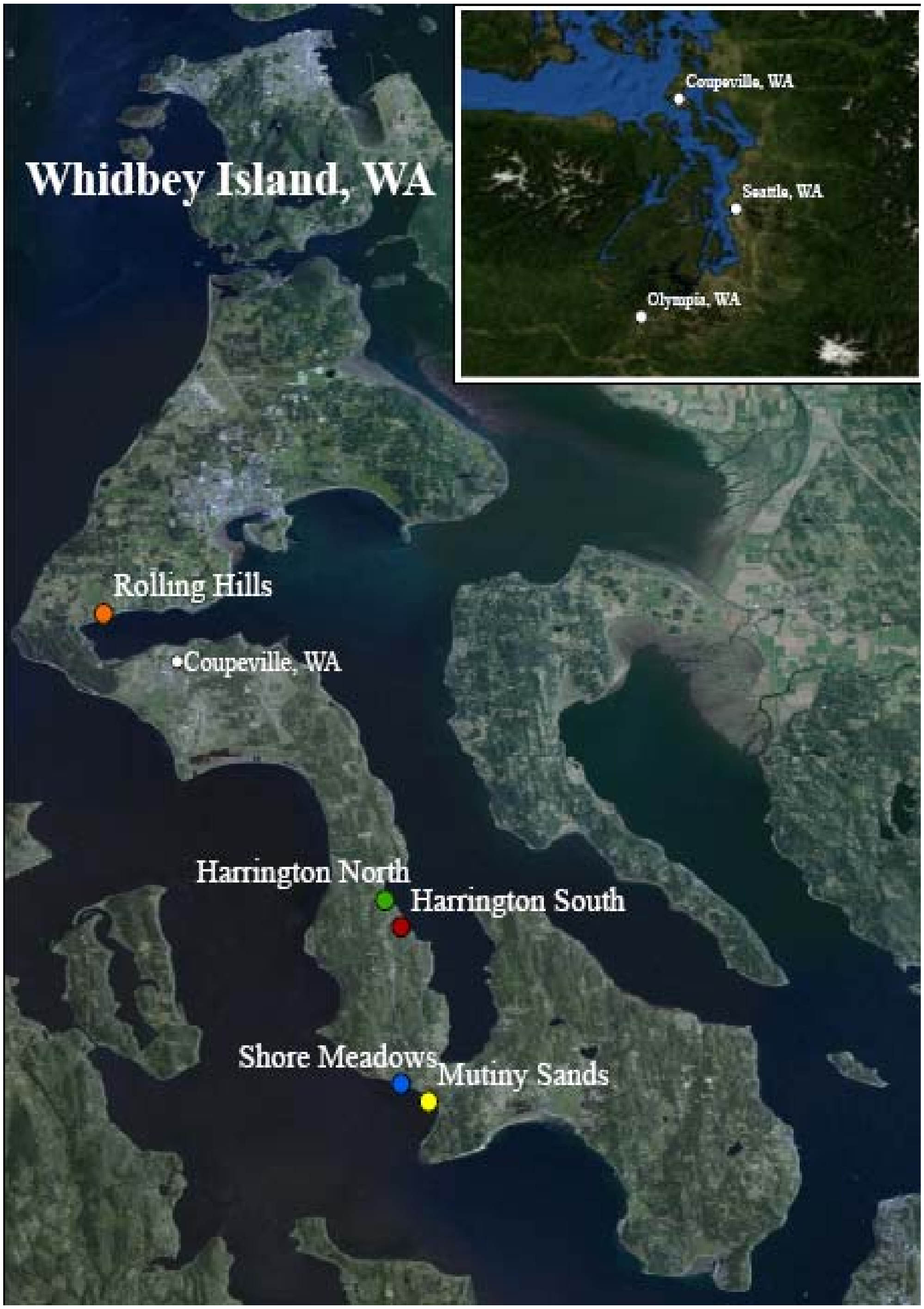

Figure 1. Map of Whidbey Island showing the sites where Pigeon Guillemot colonies were studied. Inset shows the location of Whidbey Island within the Puget Sound.

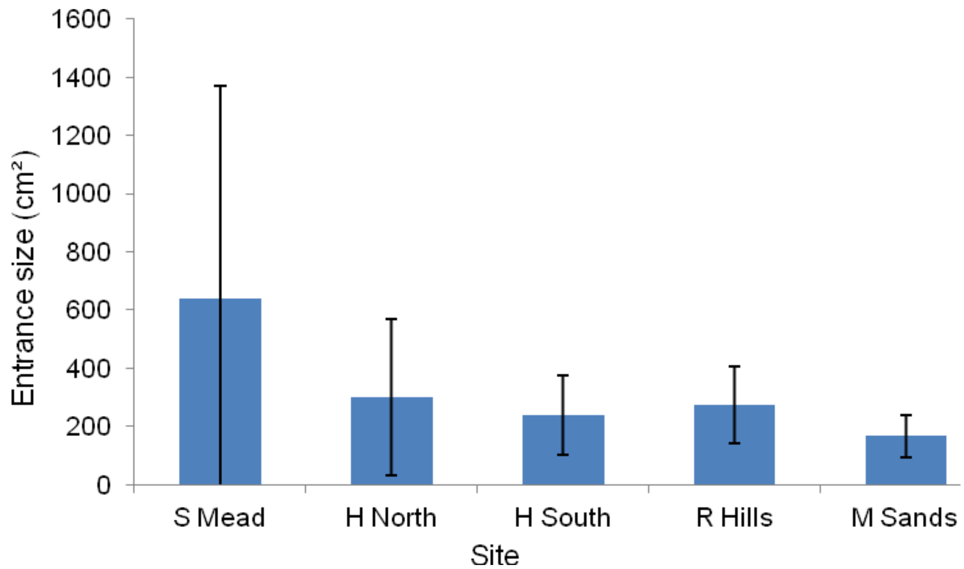

Figure 2. Mean entrance size (± SD) for burrows of Pigeon Guillemots at all colonies on Whidbey Island (n = 47). No single colony had significantly different entrance sizes (ANOVA, p = 0.5). The greatest variation existed within the Shore Meadows site, and the least in the Mutiny Sands site. Study sites are shown in Figure 1.

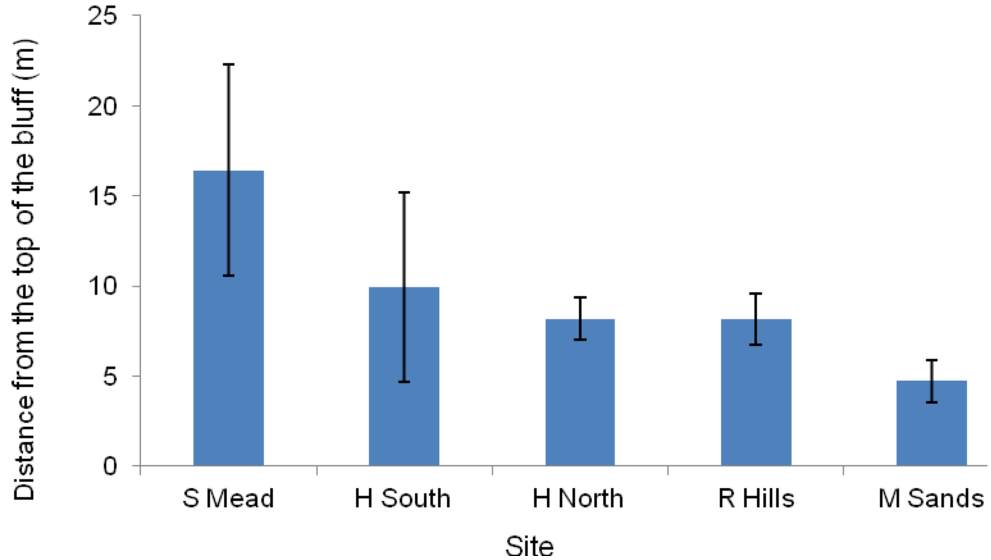

Figure 3. Mean distance of all Pigeon Guillemot burrows (n = 47) from top of bluff (± SD) on Whidbey Island. No colony displayed significant differences in distance from the top of the bluff in which burrows were located (ANOVA, p = 0.6). Study sites are shown in Figure 1.

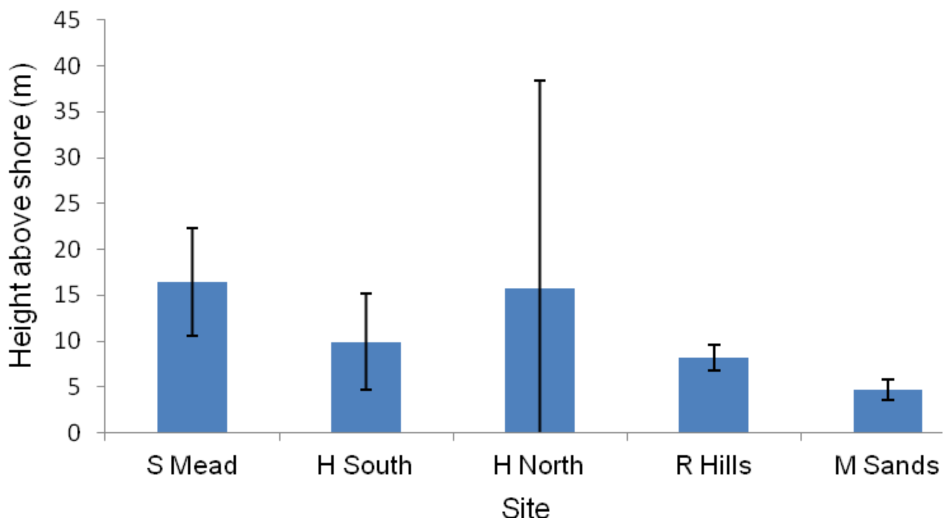

Figure 4. Mean distance of all Pigeon Guillemot burrows (n = 47) above the shore in meters (±SD) on Whidbey Island. No colony had burrows that were significantly different in height (ANOVA, $p = 0.6$).The Harrington North site had the most variation. Study sites are shown in Figure 1.

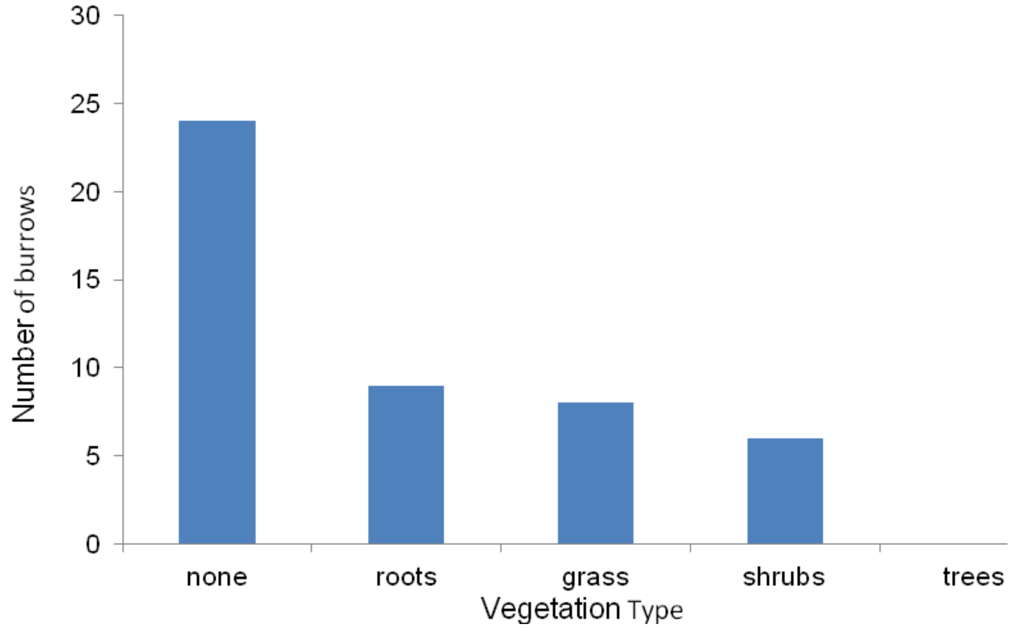

Figure 5. Types of vegetation within 15 cm of Pigeon Guillemot burrow entrances for all monitored burrows on Whidbey Island. Twenty four burrows had no vegetation, nine had roots, eight had grasses, six burrows had shrubs, and no burrows had trees near the entrance. Study sites are shown in Figure 1.

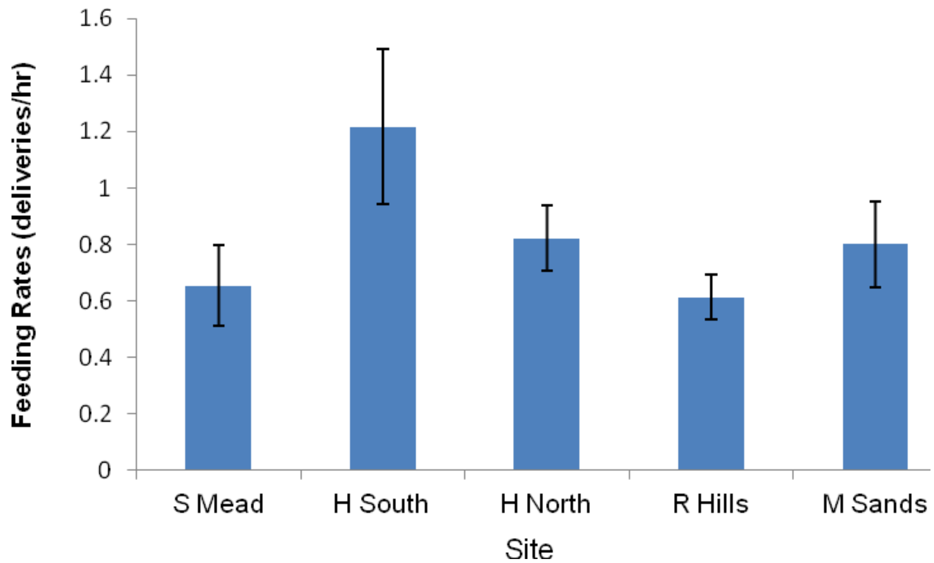

Figure 6. Mean feeding rates (± SE) for all colonies of Pigeon Guillemots on Whidbey Island. Rates were obtained by dividing total number of deliveries by total hours observed. No site was significantly different in feeding rates from other sites (ANOVA, $p = 0.5$). Study sites are shown in Figure 1.

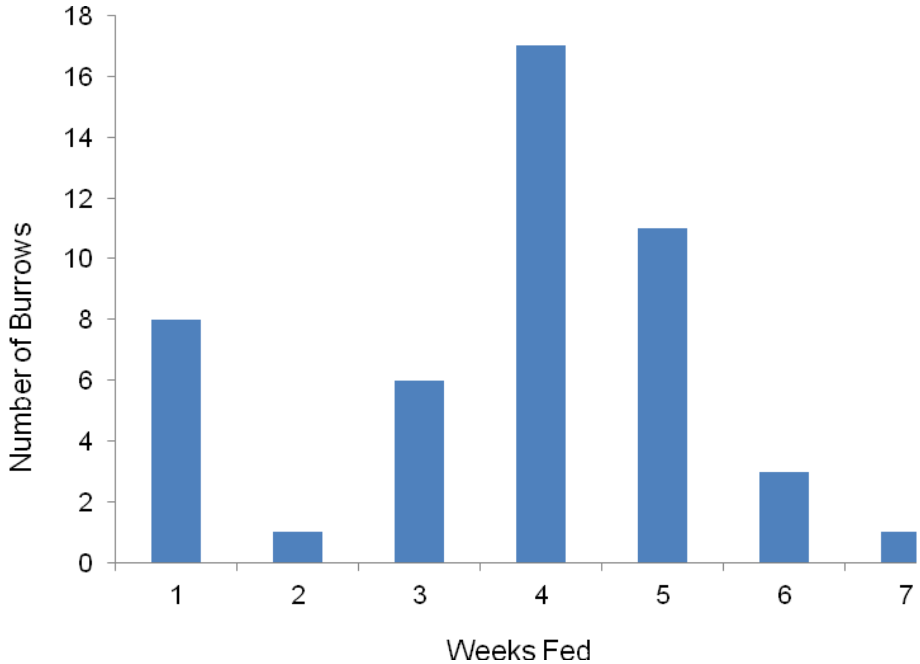

Fig
ure 7. Number of weeks fed for all Pigeon Guillemot burrows at all sites on Whidbey Island. Study sites are shown in Figure 1.

Figure 8.Pigeon Guillemot egg shells at the Mutiny Sands site on Whidbey Island. Egg shell on the right was predated by a bird, apparent by the opening at the top and the residue left in the shell. Egg on left was broken open by hatching chick; no residue was left in the shell, and it was no longer intact. Study sites are shown in Figure 1.

Figure 9. Evidence of predation of a chick at the Harrington North site on Whidbey Island. This is a wing from a juvenile Pigeon Guillemot, apparent by downy feathers and lack of distinct coloration. Study sites are shown in Figure 1.

Figure 10. Pigeon Guillemot chick photographed inside the burrow at the Harrington South site on Whidbey Island on 14 August, 2009. Chick is located in the center of the photo, covered in black down. Exact age of chick is unknown. Study site is shown in Figure 1.

Figure 11. The same Pigeon Guillemot burrow as in Figure 10, four days later on 18 August, 2009 on Whidbey Island. Chamber had collapsed and deliveries had ceased; this was believed to be a predated nest.

Figure 12.Two Pigeon Guillemot chicks at fledgling age resting within a burrow at the Mutiny Sands site on Whidbey Island. This was the single burrow at this site to have deliveries of prey items for five weeks, and the only successful burrow at the Mutiny Sands site.

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