Black Oystercatcher *(Haematopus bachmani)* foraging on varnish clams (*Nuttallia obscurata)* in Nanaimo, British Columbia

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Abstract: In this study, we investigated whether Black Oystercatchers (*Haematopus bachmani*) feed on the recently introduced varnish clam (*Nuttallia obscurata*), and whether they selectively feed on specific size classes of varnish clams. Surveys were conducted at Piper's Lagoon and Departure Bay in Nanaimo, British Columbia, between October 2013 and February 2014. Foraging oystercatchers were observed, and the number and size of varnish clams consumed were recorded. We also determined the density and size of varnish clams available at both sites using quadrats. Our results indicate that Black Oystercatchers consumed varnish clams at both sites, although feeding rates differed slightly between sites. We also found that oystercatchers consumed almost the full range of available clam sizes, with little evidence for size-selective foraging. We conclude that Black Oystercatchers can successfully exploit varnish clams and may obtain a significant part of their daily energy requirements from this non-native species.

Key Words: Black Oystercatcher, *Haematopus bachmani*, varnish clam, *Nuttallia obscurata*, foraging, Nanaimo.

Hollenberg, E.J.R. and E. Demers. 2017. Black Oystercatcher (*Haematopus bachmani*) foraging on varnish clams (*Nuttallia obscurata*) in Nanaimo, British Columbia. *British Columbia Birds* 27:35–41.

Introduction

The Black Oystercatcher (*Haematopus bachmani*) is a coastal shorebird found along the North American Pacific coast, from the Aleutian Islands and Southern Alaska to central Baja California (Jehl 1985; Sibley 2014). It typically inhabits rocky coastlines and islands, and forages on bivalve species and other intertidal invertebrates. With a small estimated global population size (8,900–11,000 individuals), Black Oystercatchers have been designated as a species of high concern by both the Canadian and U.S. Shorebird Conservation Plans (Donaldson *et al*. 2000; Brown *et al*. 2001). In addition to their small global population size and restricted range, conservation concerns for the Black Oystercatcher stem from threats to their preferred habitat, their susceptibility to alien species invasions, and a lack of baseline population data (Tessler *et al*. 2010).

Most Black Oystercatchers in British Columbia are considered to be year-round residents (Purdy and Miller 1988; Butler and Golumbia 2008). They form overwintering flocks from September to October, reaching peak group numbers by late October to early November (Andres 1994; Campbell *et al.* 1997). Flock sizes can range from a few to over 100 individuals (Campbell *et al*. 1997). The Black Oystercatcher feeds by using both visual hunting to glean prey from the surface and tactile sensation by probing with its long bill for prey buried in the substrate (Colwell 2010). Oystercatchers have strong bills compared to other shorebirds (Colwell 2010), enabling them to open and access the meat inside many species of bivalves.

Varnish clams (*Nuttallia obscurata*) are a relatively new species to British Columbia, thought to have been introduced in the early 1990's as larvae in ship ballast water (Gillespie 1995; Merilees and Gillespie 1995). Rapidly invading the British Columbia shoreline, varnish clams have spread over 500 km of coastline, have been recorded on over 100 beaches, and have been shown to reach densities of up to 800 clams / m^2 (Dudas 2005; Chan and Bendell 2013). This rapid invasion is due to several characteristics of the varnish clam, including a high fecundity and early sexual maturation, a lengthy planktonic phase which promotes dispersal, and its ability to exploit the upper intertidal zone (Dudas 2005; Dudas and Dower 2006). In coastal British Columbia, varnish clams can often be found with other bivalve species: the native Pacific littleneck

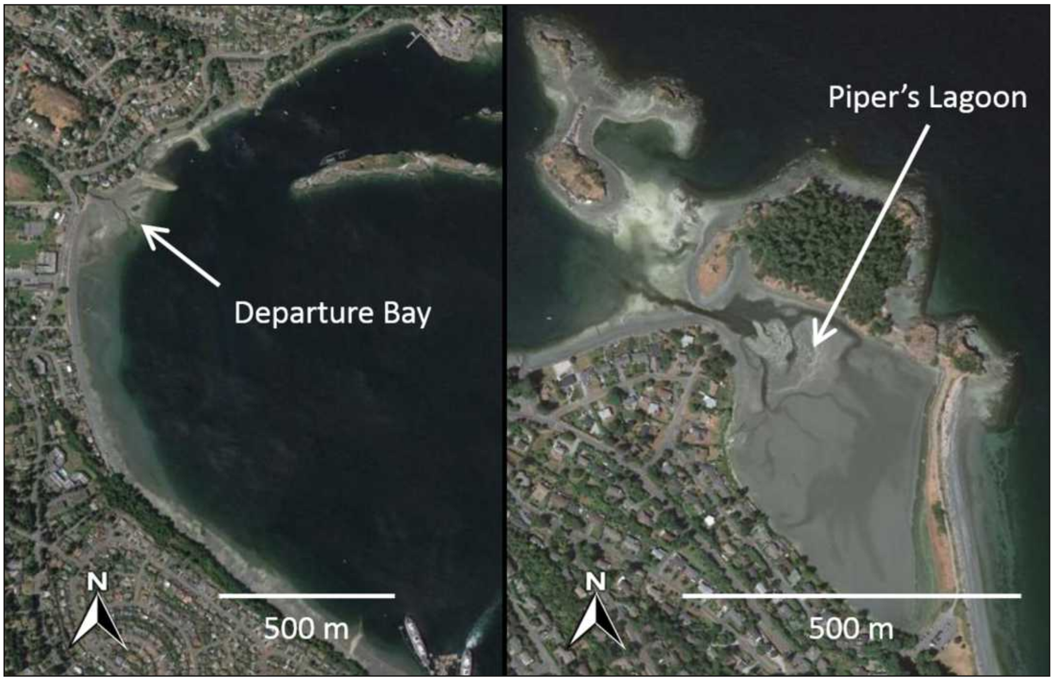

Figure 1. Aerial photographs of the study sites at Departure Bay and Piper's Lagoon in Nanaimo, B.C. The white arrows show the approximate locations where most observations of foraging Black Oystercatchers were made. Photographs from Google Earth Pro 7.1.5.1557 taken on June 7, 2015.

(*Protothaca staminea*) and the introduced Japanese littleneck or Manila clam (*Venerupis philippinarum*) (Dudas *et al*. 2005). Compared to these littleneck species, varnish clams have a thinner and flatter shell, possibly allowing easier consumption by predators (Dudas *et al*. 2005). Varnish clams primarily exploit the upper third of the intertidal zone, but when no other clam species are present, they can occupy the entire upper to lower intertidal zone (Dudas 2005).

Since the introduction and spread of varnish clam in the Black Oystercatcher's range, little is known about the extent to which the Black Oystercatcher may feed on varnish clams. Black Oystercatchers have previously been found to feed readily on another introduced species, the Pacific oyster (*Crassostrea gigas*) (Butler and Kirbyson 1979). In this study, we examined the interaction of the Black Oystercatcher with the non-indigenous and rapidly-spreading varnish clam. Specifically, we investigated: (1) whether and to what extent Black Oystercatchers feed on varnish clams; and (2) whether Black Oystercatchers forage selectively on specific size classes of varnish clam.

Methods

Study Sites

This study was conducted between October 2013 and February 2014 at two sites in Nanaimo, B.C.: Departure Bay and Piper's Lagoon (Figure 1). Departure Bay is an approximately 2-km crescent-shaped beach, located in a residential area. There is a steeper gradient in the upper intertidal zone of the beach, composed of coarse gravel, and a lower gradient in the middle and lower intertidal zone, where sand and fine gravel are the predominant substrate. The specific study site was located at the most northern end of the beach, near the outlet of Departure Bay Creek (49°12'22"N; 123°58'07"W).

Piper's Lagoon is a triangular and nearly enclosed shallow water lagoon of approximately 0.10 km^2 in size (Figure 1). The east shore of the lagoon is a treeless peninsula about 50–80 m wide that runs north-south to a forested land mass that forms the north shore. The western shore of the lagoon is residential waterfront. The gradient in the lagoon is shallow in the upper intertidal zone and relatively flat in the middle intertidal zone. The predominant substrates within the lagoon are sand and fine gravel. The specific study site was located at the northern end of the lagoon (49°13'37"N; 123°57'04"W). At both study sites, oystercatcher observation and sampling for varnish clams (see below) occurred at approximately 3–4 m above chart datum (maximum tidal range for Nanaimo, B.C.: 4.57 m).

Foraging Observations

Observations of Black Oystercatchers were conducted between 08:00 and 18:00 (Pacific Standard Time), using Nikon Monarch 10X42 binoculars and a Vortex Razor HD 85-mm spotting scope from a minimum distance of 20 m. Observations were usually made during a rising tide (range: 2.3–4.3 m) since preliminary observations indicated that oystercatchers were most likely to be present under these conditions. Upon arrival at a study site, the area was scanned for the presence of Black Oystercatchers. If no oystercatcher was observed, sampling was discontinued at that site. If at least one Black Oystercatcher was present, focal animal sampling (Altmann 1974) was carried out to record the number and species (or taxon if not identifiable to species) of prey items eaten by an individual bird in a 5-minute observation period. If more than one oystercatcher was present, the focal bird was randomly selected. After each 5-minute observation period, an instantaneous scan was conducted to record the number of Black Oystercatchers present and the activity of each individual (feeding, preening, resting, vocalizing). Observational periods of Black Oystercatchers were repeated until all Black Oystercatchers left the area.

Black Oystercatchers were generally observed to forage within a small area, making it easy to keep track of their discarded shells. Varnish clams were identifiable at a distance by their shiny brown periostracum. To determine the size of varnish clams consumed by Black Oystercatchers, discarded shells were collected and measured once the feeding birds left a feeding area or the study site. The discarded shells recently eaten by oystercatchers were easily identified because part of the abductor muscle was usually still attached, the shells were still wet (if not underwater), and the shells were not cracked like the shells of clams eaten by gulls and crows. The discarded shells were measured with calipers to the nearest millimetre along their longest axis. After the discarded shells were measured, they were placed back on the beach as close as possible to where they were found.

Varnish Clam Distribution and Size

The availability of varnish clams to Black Oystercatchers was determined once at each study site (Departure Bay: January 21, 2014; Piper's Lagoon: January 23, 2014) by measuring the abundance and size of clams. Sampling occurred in accordance with Fisheries and Oceans Canada license to "Fish for Experimental, Scientific, Educational or Public Display Purposes issued under Section 4 of the Management of Contaminated Fisheries Regulations" (license number: XMCFR 14 2013). A transect was established with a measuring tape laid out perpendicular to the edge of a dropping tide at each study site. Six 0.25-m^2 (0.5 m × 0.5 m) quadrats were sampled in a random stratified manner at 0.3-metre tidal interval at the tide range of 3.1–3.7 m, where Black Oystercatchers were observed feeding on varnish clams. Quadrats were placed randomly from 0.0 to 5.0 metres of the transect. Each quadrat was dug to a depth of 0.1 m using a hand trowel. Although varnish clams can bury to a depth of 0.3 m (Dudas *et al.* 2005), this excavation depth was deemed representative for a typical Black Oystercatcher with a maximum bill length of 8.1 cm (Marchant *et al.* 2010) and accounted for substrate roughness. The sediment within each quadrat was examined for varnish clams and other bivalve species, which were counted and measured with calipers to the nearest millimetre along their longest axis. All clams were returned to the sediments after processing.

Data Analysis

The mean number of varnish clams and other prey eaten at each site was calculated by taking the average number of prey items consumed per 5-minute observation period across all observed birds. Mean varnish clam density (clams / m^2) at each site was calculated using the average density from the six quadrats. Feeding rates and varnish clam densities were compared between sites using a Mann-Whitney U test.

Average sizes (length; mm) of available and eaten varnish clams at each study site were compared with Welch's *t*-test to assess size-selective foraging by Black Oystercatchers. For each study site, the size data were pooled for available varnish clams across all quadrats and for eaten varnish clams across all observed birds. For all statistical tests, significance was determined with $\alpha = 0.01$, which included a Bonferroni correction to account for multiple comparisons (Zar 2010).

Results

Observations of Black Oystercatcher foraging were attempted on 17 days at Departure Bay and 10 days at Piper's Lagoon between October 26, 2013 and February 6, 2014 (Table 1). Oystercatchers were present during four and three of these dates at Departure Bay and Piper's Lagoon, respectively. Absence of oystercatchers on some dates may have been a result of disturbance by people or dogs, which frequently used these public sites. A total of 33 observational periods were conducted, with 22 at Departure Bay and 11 at Piper's Lagoon. The number of individuals present (*i.e.* flock size) at Departure Bay (2–9 birds) was typically higher than at Piper's Lagoon (1–2 birds). Black Oystercatchers were observed at similar tide levels at both sites (Departure Bay: 3.0–3.7 m; Piper's Lagoon: 3.1–3.7 m). At both sites, oystercatchers were most frequently observed near the water line (~0–5 m), during a rising tide. They usually departed the area once the tide level reached >3.8 m and the exposed beach or lagoon area was minimal.

Black Oystercatchers consumed varnish clams at both study sites (Table 1). The mean rate of consumption of varnish clam was higher at Piper's Lagoon (PL) than at Departure Bay (DB) (0.9 vs. 3.0 clams per 5 minutes, respectively), although these rates were not statistically different ($U = 4$; nDB = 7, nPL = 6; $P = 0.015$). The mean rate of consumption of other prey items was higher at Departure Bay than at Piper's Lagoon (4.7 vs. 0.5 prey per 5 minutes, respectively), although these rates were not statistically different ($U = 7$; nDB = 7, nPL = 6; $P = 0.046$).

Other prey items consumed by oystercatchers included: blue mussel (*Mytilus* sp.), unidentified bivalve, barnacle and limpet at Departure Bay; unidentified bivalve and polychaete at Piper's Lagoon.

Black Oystercatchers were observed foraging on varnish clams near the water line, where they would probe the substrate with their bill. They either consumed an individual clam where it was excavated, or they wedged it beneath a rock to pin the shell before gaining access to the meat inside. As many as three discarded varnish clam shells could be found stacked within each other and wedged beneath a rock. All discarded varnish clam shells were found intact and with half-shells pried apart but still attached together. The majority of the meat was consumed from each varnish clam although there were often traces of abductor muscle still attached to the discarded half-shells.

Varnish clams were present in all quadrats excavated at both study sites, and numbers per quadrat ranged from 15 to 90 clams at Departure Bay and 2 to 117 clams at Piper's Lagoon. Mean varnish clam density was higher at Piper's Lagoon (212 ± 177 clams / m^2) than Departure Bay (163 ± 118 clams / m^2), although the difference was not significant (U = 16; nDB = 6, nPL = 6; P = 0.81) (Table 1). Other bivalve species found in quadrats included Manila clams, butter clams (*Saxidomus gigantea*), and Pacific oysters (*Crassostrea gigas*), although their densities were typically low (<2.0 clams / m^2). One exception was a high density of Manila clams in two of the six quadrats taken at Piper's Lagoon (24–76 clams / m^2).

Mean size of available varnish clams excavated at Departure Bay was significantly larger than for varnish clams at Piper's Lagoon (38.1 ± 6.1 mm vs. 35.0 ± 3.7 mm, respectively; t = 7.07; df = 377; P < 0.001) (Table 1; Figure 2). Similarly, mean size of varnish clams eaten by Black Oystercatchers at Departure Bay was significantly larger than at Piper's Lagoon (39.3 ± 3.9 mm vs. 33.0 ± 4.8 mm, respectively; t = 5.17; df = 43.8; P < 0.001) (Table 1; Figure 2).

At Departure Bay, we found no significant difference between mean size of varnish clams eaten by Black Oystercatchers and mean size of available varnish clams (t = 1.26; df = 25.4; P = 0.220) (Table 1; Figure 2). Qualitative examination of the size frequency data suggests that oystercatchers at Departure Bay appeared not to eat the smallest (<30 mm) and largest (>45 mm) sizes of available varnish clams. At Piper's Lagoon, mean size of varnish clams eaten by Black Oystercatchers was slightly smaller than mean size of available varnish clams (t = 2.28; df = 37.4; P = 0.029), although the difference was not significant. At this location, oystercatchers consumed the full range of sizes of varnish clams available (22–42 mm), but with a bimodal distribution with larger proportions of clams around 30 mm and 36 mm in size.

Discussion

Our results indicate that Black Oystercatchers consumed varnish clams in the intertidal zones of Departure Bay and Piper's Lagoon in Nanaimo, B.C. Results from

Table 1. Summary of observations of Black Oystercatcher feeding on varnish clams and other prey at Departure Bay and Piper's Lagoon in Nanaimo, B.C.

Parameter	Departure Bay	Piper's Lagoon
Number of observation days	17	10
Days with Black Oystercatchers present (percentage)	4 (24%)	3 (30%)
Number of 5-min observation periods	22	11
Mean number (±SD) of individual Black Oystercatchers present (range)	5.8 ± 2.9 (2 – 9)	1.4 ± 0.5 (1 – 2)
Mean tide level (m; ±SD) when Black Oystercatchers were present (range)	3.2 ± 0.2 (3.0 – 3.7)	3.3 ± 0.2 (3.1 – 3.7)
Mean number (±SD) of varnish clams eaten per 5-minute period (range)	0.9 ± 1.2 (0 – 3)	3.0 ± 1.1 (1 – 4)
Mean number (±SD) of other prey[1] eaten per 5-minute period (range)	4.7 ± 4.5 (0 –10)	0.5 ± 0.8 (0 – 2)
Mean density (number / m^2; ±SD) of available varnish clams (range)	163 ± 118 (60 – 360)	212 ± 177 (8 – 468)
Mean length (mm; ± SD) of available varnish clams (range)	38.1 ± 6.1 (18 – 55)	35.0 ± 3.7 (20 – 42)
Mean length (mm; ± SD) of varnish clams eaten by Black Oystercatchers (range)	39.3 ± 3.9 (31 – 45)	33.0 ± 4.8 (22 – 42)

[1] Other prey items included: blue mussel (*Mytilus* sp.), unidentified bivalve, barnacle, and limpet at Departure Bay; unidentified bivalve and polychaete at Piper's Lagoon.

our quadrat sampling indicate that varnish clams were the main bivalve species available in the shallow sediments of the upper intertidal zone, which is consistent with previous research that found varnish clams are often the only bivalve species present at tidal heights greater than 2.5 metres (Dudas 2005). Our results also suggest slight differences in feeding rates by Black Oystercatchers between the two study sites, although these differences remain speculative given our small sample sizes.

Basic foraging theory predicts that when prey are less abundant, a predator should expand its preferred diet to also eat less profitable prey sizes, and when valuable prey are abundant, the predator should reject less profitable prey sizes (Werner and Hall 1974). Hartwick (1976) found that Black Oystercatchers tend to select prey (especially mussels) that are larger than average size. We did not find a strong indication of size-selective foraging by Black Oystercatchers in this study. Although at Piper's Lagoon there was a slight difference between the mean sizes of available clams and those eaten, oystercatchers still consumed the full range of available clam sizes at that site. At Departure Bay, oystercatchers consumed most sizes of available varnish clams, with the exception of the smallest and largest size classes. Maximum size of varnish clams eaten by oystercatchers at both study sites was 45 mm. This may suggest an upper size limit for oystercatchers to feed on varnish clams, possibly imposed by the handling time required to excavate and open the largest varnish clams, although further observations are needed to confirm this. It must be noted that our analysis is limited by the small number of quadrats examined for available clams (n = 6) at each site. In addition, it is probable that the same individual oystercatchers were observed repeatedly over the course of this study since the birds were unmarked. Nevertheless, it appears that Black Oystercatchers can effectively feed on a large proportion of the abundant varnish clams available in the intertidal zone at these sites.

In this study, we observed that Black Oystercatchers fed on varnish clams mainly during the relatively brief window of opportunity that occurs in daytime during a rising tide (1–2 hours, usually once a day in winter). The fact that oystercatchers were rarely observed feeding on varnish clams during lower or falling tides suggests that feeding on clams is most effective for these predators during rising tides. The rising waters may increase the likelihood of detecting the presence of clams or water flow as they resume filter-feeding. Therefore, although varnish clams may represent an abundant prey resource for oystercatchers

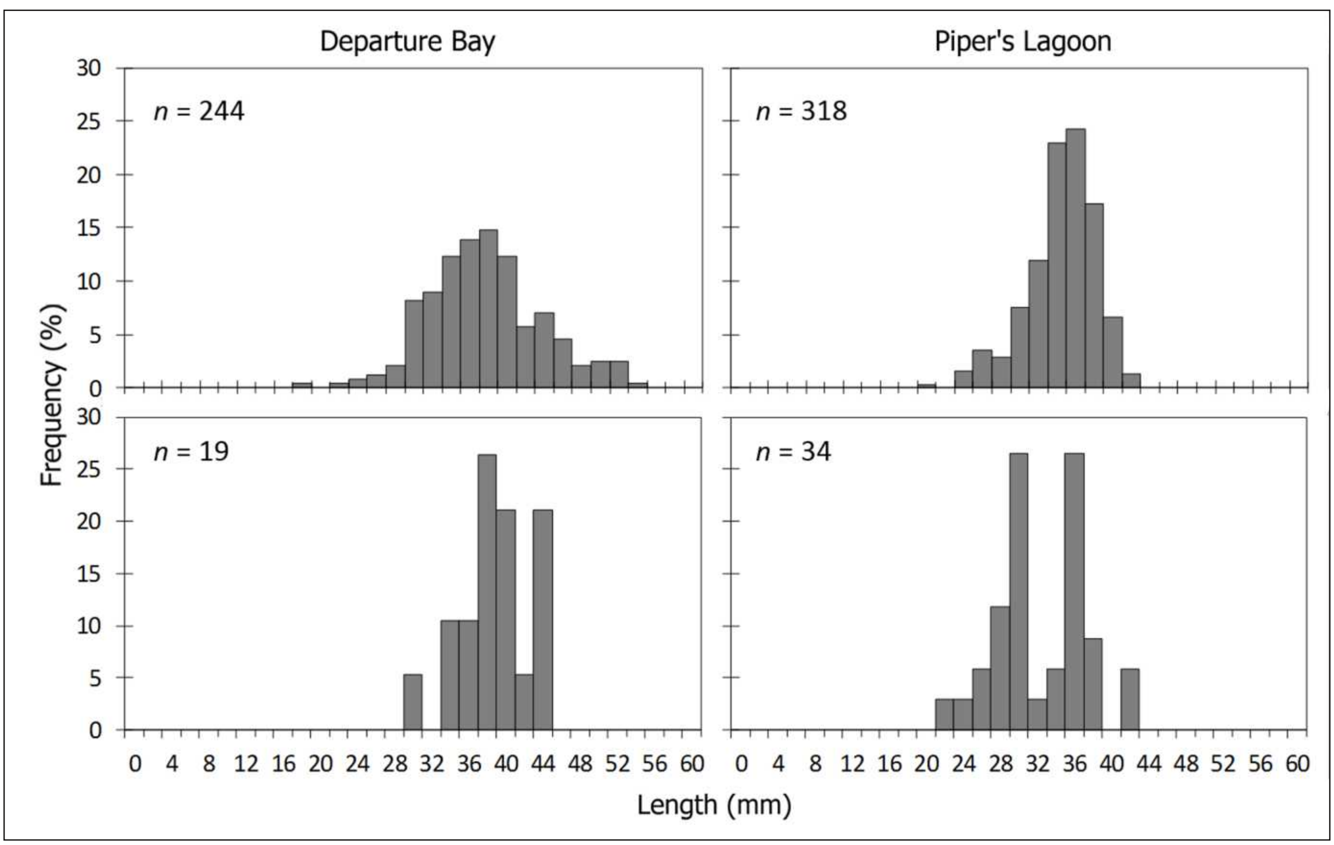

Figure 2. Size distribution of varnish clams available (top) and eaten by Black Oystercatchers (bottom) at Departure Bay (left) and Piper's Lagoon (right).

in the upper intertidal zone, foraging opportunities may be limited by access.

The contribution of varnish clams to the overall diet and daily energy needs of Black Oystercatchers was not determined in this study. However, it is possible to calculate the approximate energetic contribution for a Black Oystercatcher feeding on varnish clams at Piper's Lagoon for 30 minutes. Assuming a metabolic and assimilation rate typical of a medium-sized shorebird, a 600-g oystercatcher has an estimated daily basal metabolic requirement of 251 kJ and an assimilation rate of 85% (estimates from Kersten and Piersma (1987) for the Eurasian Oystercatcher (*Haematopus ostralegus*)). In a study of racoon (*Procyon lotor*) feeding on varnish clams, Simmons *et al.* (2014) estimated that a 36-mm clam provides a net energetic value of 4.64 kJ. Thus, an oystercatcher eating an average of 0.6 clams / min could acquire approximately 2.78 kJ / min, which, when adjusted for assimilation, could represent 28.3% of its daily basal metabolic needs in 30 minutes. This estimate suggests that introduced vanish clams may represent a high-quality food resource for Black Oystercatchers. Further studies should be conducted to evaluate the contribution of varnish clams as part of the annual energy budget of Black Oystercatchers, and the potential effects on their status and productivity in the Salish Sea.

Acknowledgements

Many thanks to Nathan Hollenberg, Kim Wetten, and Stephanie Wetten who provided assistance in the field. Karen Barry, Jane Watson, Liz Demattia, Rosemarie Ganassin, Neil Bourne, Rob Butler, and Art Martell provided advice, help, or editorial comments. This research was part of an undergraduate thesis by Emily Hollenberg and funding was provided by the Biology Department of Vancouver Island University (VIU). Travel funding was provided by the VIU Research & Scholarly Activity Office to present a poster of this research at the Pacific Ecology and Evolution Conference in February 2014.

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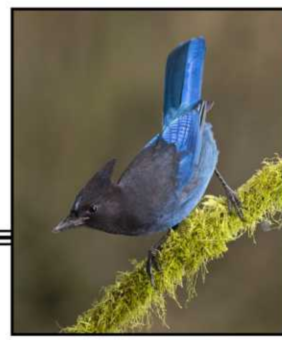

Tim Zurowski