Wildlife Afield 12(1):42-59, 2015

Food Habits of a Population of Black Turnstones and Rock Sandpipers Wintering in Southern British Columbia[1]

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[1]Edited by R. Wayne Campbell, Dennis A. Demarchi, and Spencer G. Sealy for publication in *Wildlife Afield.*

[2]Deceased February 8, 1993.

EDITOR'S NOTE: The following article is an edited and updated version of an undergraduate thesis written by William Glen Smith and submitted in April 1952 to the Department of Zoology at the University of British Columbia in Vancouver, British Columbia, in partial requirements for a Bachelor of Arts (Hons.) degree. The full text (51 pages) is available for download at www.wildlifebc.org (Figure 1).

Figure 1. Undergraduate bachelor's theses provide students an opportunity to work independently to develop a research topic, apply methodologies, process data, and incorporate relevant literature into a written peer-reviewed document. They also provide a good opportunity for the student to determine whether he or she is interested in conducting research and study in the future. Most universities do not retain copies of Bachelor's theses even though some, like Glen's, contain significant findings.

In the mid-1970s, Glen Smith's original unpublished thesis[1] was given to Wayne Campbell for inclusion in the bibliographies of British Columbia ornithology[2,3] and *The Birds of British Columbia* project.[4] These publications resulted in requests for Glen's thesis from researchers in North America interested in shorebirds, especially Black Turnstone (*Arenaria melanocephala*),[5] Rock Sandpiper (*Calidris ptilocnemis*),[6] and Surfbird (*Aphriza virgata*).[7]

Glen's research was the first quantitative analysis of food habits of the three species of rock-frequenting shorebirds and remains today as one of the few studies during the species' non-breeding seasons. Prior to 1952, most diet information for the province was incidental and was obtained from the stomachs of specimens. Glen's research during the winter of 1951/52 on the Iona Island jetty mainly involved stomach analysis by volumetric analysis for Black Turnstone and to a lesser degree Rock Sandpiper. He did, however, bring in additional information in his thesis from collectors who identified food items from specimens collected in the mid-1930s on Seal Islets at the north end of Baynes Sound and Ian McTaggart-Cowan at Iona Island in the late 1940s, which included Surfbird. These additional collections have been deleted from this article as the methods for analysis were dissimilar; however, results from them will be published later as a separate note.

Sixty-four years have lapsed since Glen's pioneering study. Taxonomy changes for species, shorebird populations fluctuated, habitats have been degraded or lost, food resources change, and migration patterns have been altered. Most of Glen's original text has been retained but some components are updated to make it more relevant to current conditions and knowledge. Repetitive material has been deleted. Also, some of the original format was altered but Glen's findings and results remain untouched.

Glen's contributions to natural history as a provincial wildlife biologist/game manager and bird artist are included in this issue of *Wildlife Afield* (pages 89-119).

It should be noted that during the late 1950s, after completion of Glen's study, the topography of Iona Island changed dramatically as the Greater Vancouver Regional District sewage treatment plant was constructed, and a causeway was built connecting Iona and Sea islands. The jetty was enlarged, wide enough for vehiclular traffic, and it was completed by 1963 (Figure 2).[8] A decade later the tip of the jetty was still being used as a foraging area by the three shorebirds in question.[9]

Figure 2. In the early 1950s, Glen Smith would have had to reach his study area at the tip of the Iona Island jetty, by walking over rock boulders, hugging the jetty by walking along soft mud flats, or by boat. By the mid-1960s public access was greatly improved and many birdwatchers and hikers enjoyed the 7.5 km round trip. *Photo by R. Wayne Campbell, Iona Island, BC. 24 August 1999.*

Photographs of intertidal plants and animals were provided courtesy of Lester B. Pearson College, Paul Norwood, and the Slater Museum of Natural History, University of Puget Sound. Permission to use sketches of marine life by the late Philip Croft, published in *Nature West Coast*[10], was received in the mid-1970s when it was first suggested by RWC that Glen Smith's thesis should be published.

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[10]Smith, K.M., N.J. Anderson, and K.L. Beamish (eds.). 1973. Nature west coast as seen in Lighthouse Park. Discovery Press, Vancouver, BC. 283 pp.

INTRODUCTION

This investigation was conducted with the hope that some knowledge may be added to the little known food habits of Black Turnstone (*Arenaria melanocephala*; Figure 3), Aleutian [Rock] Sandpiper (*Arquatyella* [*Calidris*] *ptilocnemis*), and Surf-bird [Surfbird] (*Aphriza virgate*; Figure 4) (American Ornithologists' Union 1931, 1998). These shorebirds characteristically frequent rocky shores of the coast and with this in mind the study was carried out in close relation to that habitat.

Figure 3. The principal species in Glen Smith's study of food habits of three species of rock-frequenting shorebirds was Black Turnstone, the only species common in the Vancouver area during the nonbreeding seasons. *Photo by R. Wayne Campbell.*

Figure 4. Surfbird is not included in this report of Glen's Smith's research on food habits as the species was absent during most of the study period. He did, however, include results from stomachs collected in the mid- 1930s on Seal Islets and the late 1940s from the same jetty on which he carried out his study. *Photo by R. Wayne Campbell.*

DESCRIPTON OF THE SHOREBIRD POPULATION

The population of birds studied consisted of an association of Black Turnstones and Rock Sandpipers, which frequented the distal end of a rock jetty projecting into the Gulf of Georgia in the mouth of the north arm of the Fraser River. The birds inhabited this place to feed upon the numerous marine organisms present on the rocks, and were generally absent from the area during high tides when much of the jetty was flooded.

Of the two species studied, only Black Turnstones consistently occurred and were present throughout the study period from 1 November 1951 to 30 March 1952. This species composed the greatest part of the community by numbers, averaging approximately 35 individuals. Rock Sandpipers were casual in occurrence and varied considerably in numbers. Of a total of 26 field trips, only on six (23%) were Rock Sandpipers seen, ranging from three to 15 individuals. The data gathered on the occurrence of Rock Sandpipers are insufficient to establish its status in the population. Data supplied by Cowan show that Rock Sandpipers wintered on the jetty in 1947, 1948, 1949, and 1950, which indicate that this species may be a regular but rare winter resident (see Campbell et al. 1972). Surfbirds did not appear in the area until February 16th when one individual was present with turnstones. On February 29th one more Surfbird appeared and is excluded from this study.

The fall arrival of the three species was not observed. Black Turnstones were present when the study was initiated and Surfbirds had probably passed thorough by November 1, 1951, because they were not encountered until February. The occurrence of the Rock Sandpipers was too sporadic to speculate on fall arrival.

The spring departure of the three species was not observed because the project was completed before the birds had left. Munro (1935) observed that Black Turnstones and Rock Sandpipers were at their height in migration on the east coast of Graham Island between April 29 and May 11. Eight Surfbirds were collected by Cowan from the study area in April, 1948. The birds probably depart soon after the end of April.

LOCATION AND DESCRIPTION OF STUDY SITE

Location

Geographically, the jetty is situated parallel to the south shoreline of Point Grey, at an average distance of 0.52 miles (0.83 km) from shore. It arises from the end of Iona Island, which is situated in the north arm of the Fraser River, and extends a distance of 2.25 miles (3.62 km) northwest, ending in a point 0.77 miles (1.24 km) southwest of the tip of Point Grey (Figure 5).

The jetty serves as a breakwater, and confines the river within a dredged channel, which is immediately adjacent to it. Seaward, the jetty is flanked for its entire length by tidal sand flats which extend for a distance of several miles to the south.

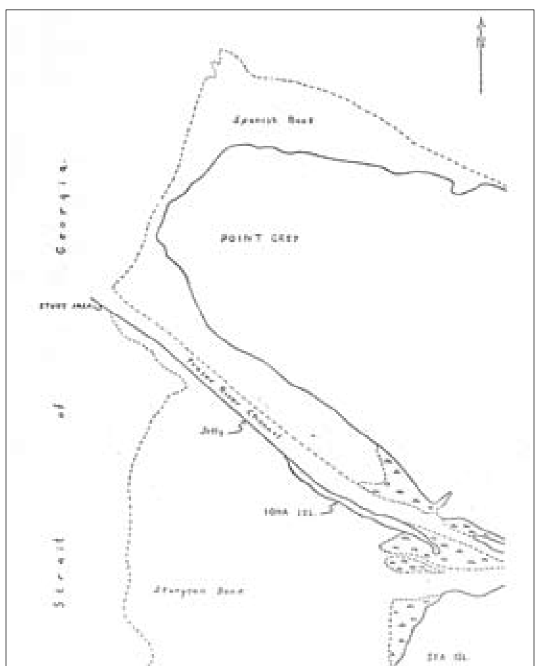

Figure 5. Map of the area of the Iona Island jetty and surrounding geographical features. Glen's study was located at the distal end of the jetty. *Reproduced from Smith (1952).*

Structure

The study area consisted of a jetty composed of granitic rocks ranging in size from several inches to four feet (1.2 m) in diameter, piled to an average height of seven feet (2.1 m) and a width of 20 feet (6.1 m) basally. The structure is built upon a sandflat, the level of which corresponds to approximately the eight-foot tide (2.4 m) level, hence, the upper level of the jetty lies along the 15-foot (4.6 m) tide mark. As shown in Figure 1 variations in the symmetry of the jetty occur, which causes certain areas to lie below the 15-foot tide level, and the distal section slopes progressively to the four-foot tide mark, which causes the upper part of the jetty to slope down to the 11-foot (3.4 m) tide level on the extreme end.

Vegetation

No vegetative cover is present on the jetty, but the crevices and hollows in the structure may substitute for this want. As a night roosting place the jetty would be of little value, as frequent high tides inundate the entire structure. Apart from this, winter storms keep the jetty drenched with spray and waves, thus rendering it undesirable as a roosting place. The habitat requirements for the shorebirds were not determined.

Ecological Classification of the Feeding Habitat

Since the three species frequented only the last 500 yards (457 m) of the jetty, further description of the habitat will refer to this part only. Within this area certain sections have become broken down, due, presumably to the action of waves and currents, to form three low portions with an average height of 12 feet (3.7 m) in relation to the tides, a difference of three feet from the remaining areas of jetty. The low areas extend a total distance of 150 yards (137 m), 30% of the length of the habitat. The extreme end of the jetty is slightly lower than the remaining low sections, but for convenience, will be classified as typical of the low parts.

According to the classification of littoral habitats of the Pacific coast, as described by Ricketts and Calvin (1939), the jetty is a rocky shore in the bay of an estuarine type of habitat characterized by the lack of heavy surf. The presence of fresh water from the Fraser River, however, tends to alter the associations of marine organisms typical of this substrate.

Distribution (Zones) of Marine Algae and Invertebrates

Three well-defined zones of algae and invertebrates were at the distal end of the jetty and were closely correlated with mean tide levels. These differ slightly from Ricketts and Calvin's (1939) description due to the close proximity of the river.

On the river side (east) of the jetty the numbers of mussels and barnacles decrease rapidly up-river. Mussels are entirely lacking at a point 600 yards from the end of the jetty, but barnacles occur on practically its entire length decreasing rapidly in numbers toward the proximal end, until only scattered individuals are found. The ocean side (west) supports diminishing populations of mussels and barnacles as the proximal end is approached. However, both organisms are more abundant than on a corresponding section of the "river side". Mussels cease to occur at a point midway along the jetty, due to a general elevation of the rocks and sand flats in relation to the tides. Barnacles are present throughout the entire length of jetty on the seaward side, but decrease in numbers and width of zonation proximally. Algae are present on the upper levels of the jetty throughout its entire length.

<u>ZONE 1</u> (Tide level range from 15 to 12 feet [4.6 to 3.7 m]): The upper zone consists of a 100% covering of green algae (75% a filamentous alga *Ulothrix* sp. and 25% a green leaf alga *Prasiola* sp.; Figure 6). The leaf alga occurs primarily on the relatively horizontal rock surfaces where it is the dominant of the two forms. The filamentous alga occurs on all rock surfaces, except where it has been eroded away by waves and debris. The leaf alga is most dense on the seaward side (west) of the jetty and extends below the 12-foot level to a point approximately corresponding to the 9-foot tide level.

A very sparse population of Acorn Barnacles (*Balanus glandula*) occurs along the lower level of zone 1, but is composed of small, scattered individuals, frequently buried under the green algae.

Figure 6. The green leaf alga *Prasiola* sp. appears as a green fuzzy mat in the upper intertidal zone on Iona Island jetty. Its distribution in British Columbia is closely associated with the guano of marine birds such as Glaucous-winged Gulls (*Larus glaucescens*) roosting near the end of the jetty. *Photo courtesy of Lester B. Pearson College.*

Associated with the alga are insect larvae of the families Tipulidae (Crane Flies) and Chironomidae (non-biting midges). They occur frequently; as many as 93 per square feet ($8.6m^2$) having been found. The Checkered Periwinkle (*Littorina scutulata*) was casual in occurrence.

<u>ZONE 2</u> (Tide level range from 12 to 10.5 feet [3.7 to 3.2 m]): The mid-zone is composed primarily of Acorn Barnacles (Figure 7). The lower levels of the zone support a small population of Blue Mussels (*Mytilus edulis*), which occur only in the most protected areas.

About 24% of the exposed rock surface is covered with a mixture of barnacles and mussels of which barnacles cover 21% and mussels 3%. Only barnacles occurred on the exposed rock surfaces, their percentage of covering increasing at the lower levels of the zone. Very few barnacles were found on the upper rock surfaces, particularly in the upper regions of the zone.

Associated with the mussel and barnacle populations are numerous free-living animals, including Oregon Pill Bug (*Exosphaeroma* [*Gnorimosphaeroma*] *oregonensis*; Figure 8), which

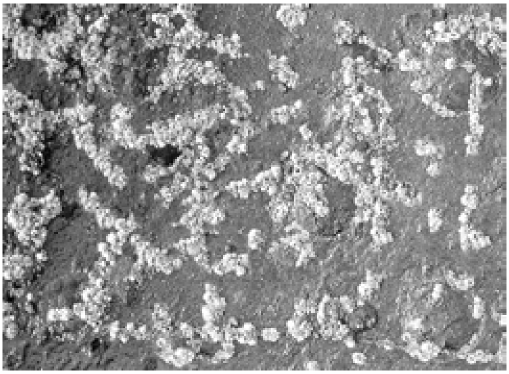

Figure 7. The small, dirty white or gray-coloured Acorn Barnacle is most common in the mid-zone and is one of the few barnacles in British Columbia that can tolerate brackish waters. *Photo by R. Wayne Campbell.*

averages 20 per square foot (0.09m). Larvae of the families Tipulidae and Chironomidae occurred at approximately 75 per square foot and were frequently found applied to the barnacles, in the groove between the scutes and shell. The Checkered Periwinkle was numerous, at 30 per square foot, and the Marine Beetle (*Liparocephalus brevipennis*) occurred erratically, ranging between 4 and 15 per square foot.

Figure 8. The Oregon Pill Bug, a species tolerant of fresh water in estuarine conditions, is most commonly found in the mid-zone on the Iona Island jetty. In some Black Turnstone stomachs it was a major source of food when foraging occurred at mid-tides. *Photo courtesy Paul Norwood.*

Algae from zone 1 overlapped slightly into zone 2, particularly on the barnacle-free upper rock surfaces. The green leaf algae is most intrusive in this respect, particularly on the seaward side of the jetty.

ZONE 3 (Tide level range from 10.5 feet to Base): The lower zone consists primarily of a barnacle-mussel association covering 42% of the exposed rock surfaces. Barnacles were the dominant species and covered 36% of the rocks, whereas mussels covered 12% (Figure 9). As in zone 2, only barnacles occurred on the upper rock surfaces, however, the covering was considerably more complete. Mussels occurred to the exclusion of barnacles on the under surfaces, and in the protected crevices in the rocks. The lateral surfaces of the rocks were partially covered with small mussels, particularly on the lower levels of the zone, a feature not observed in zone 2. Small numbers of limpets were present, especially on the sea-ward side, and at the extreme end of the jetty.

Figure 9. Although Blue Mussels appeared in zone 2, the species was more abundant in in deeper water in zone 3. A few Little Brown Barnacles (*Chthamalus dalli*) are growing on the mussel shells. *Photo by R. Wayne Campbell.*

Associated with the encrusting organisms of this zone, the Checkered Periwinkle occurs in large numbers, as many as 85 per square foot (Figure 10). Almost every empty Acorn Barnacle shell contained from one to several of this species, and it was readily observed creeping over the rock surfaces, or clustered in the shelter of the barnacles. The larvae of the insect families Tipulidae and Chironomidae were casually distributed amongst the barnacles and mussels, approximately 40 per square foot. Oregon Pill Bug averaged 70 per square foot and the Marine Beetle was found only rarely in this zone, averaging six per square foot of encrusted marine organisms.

Figure 10. Typical aggregations of Checkered Periwinkle that reached their abundance of 85 per square foot in intertidal zone 3 on Iona Island jetty. *Photo courtesy Slater Museum of Natural History, University of Puget Sound, Tacoma, WA.*

METHODS

Attempts to study the food habits of the shorebirds on the basis of direct field observations proved impossible, because of the difficulty of approaching the birds to within a distance where the small food items could be identified. Fecal analysis was also considered but the highly liquid state of the feces eliminated this method as a quantitative means of study. The only reliable method was to collect the birds for stomach analysis. The general technique employed was essentially that described by Martin (1949) with modifications designed to accommodate the material worked with. Certain items varied by as much as 40% by volume, depending upon whether they were wet or dry. Hard parts were not subject to this variation. Since the stomach contents were measured by water displacement, all items were measured wet, care being taken to ensure the same degree of moisture throughout. Because of the described variation in volume, the results obtained are not an accurate measure of the actual quantity of food eaten, but should only serve as a reliable index to the relative quantities of food items found.

Since various shell fragments probably act as grit, and because the quantity of rock fragment was so small, all items of this sort are included in the analysis as food. The greatest portions of the shell parts are probably ingested with, or as part of the food; hence, they cannot be considered as pure grit.

All measurements were made in a 5 cc pipette, which contained a known volume of water. The food items were placed in the pipette, and forced down by a glass rod that exactly fitted the interior diameter of the pipette. Before the food material was paced in the pipette, it was found to be expedient to place a glass bead in the pipette, which served to prevent small particles of food from becoming lodged in the constricted tip, and which forced the food out when the apparatus was inverted, thus speeding the operation. It was checked by measuring lead shot in a 1 cc pipette. The method of measuring volumes used was found to be accurate to within one hundredth of a cc.

FEEDING BEHAVIOUR

The observed feeding habits of Black Turnstone and Rock Sandpiper were different. Surfbirds were not observed feeding.

Black Turnstone

The wary nature of the turnstones rendered detailed observations of their feeding behaviour exceedingly difficult. However, the few occasions when observations could be made indicated that the foraging and feeding method employed was a random search (Figure 11). In this fashion the birds searched for food by a series of movements with no particular direction, from rock to rock, pausing only momentarily to eat an article of food. On a few occasions birds stood in one place for a minute or two feeding over a group of barnacles. The actual object of such feeding could not be identified with great certainty as approach to within less than 15 yards (13.7 m) of the birds was not possible. By all indications the turnstones plucked the contents out of barnacles, an act that was effected only with considerable effort. Thus, it appeared the bill was inserted into the top of the barnacle and used lever-fashion to pry loose the protective scutes, thereby exposing the fleshy contents that were then ingested.

Figure 11. The uniquely shaped bill of the Black Turnstone is used primarily to turn over small stones, seaweeds, flotsam, bits of driftwood, and other marine debris in search of food items. *Photo by R. Wayne Campbell.*

Close study of the barnacle remains found later in the stomachs indicated that most of this food is obtained in this fashion as discussed in the following section on foods.

Further evidence of this method of feeding was obtained by inspecting areas where the birds had been feeding. Thus numerous barnacles were found that had been emptied of their contents with no damage to the shell. Empty barnacles (Figure 12) were found most frequently upon the uppermost rock surfaces, or upon areas that the turnstones could reach with ease. Relatively few empty barnacles were found upon vertical and under surfaces on the rocks despite a much denser population of this organism in these places.

The movements of the feeding birds indicated that the upper rock surfaces were most frequented, and feeding birds were seldom observed on very steep rock surfaces or under the rocks, which were suspended at all angles upon one another. Probably the difficulty of applying sufficient force to open a barnacle while standing upon steep rock surfaces account for the absence of feeding on such areas, and the fear of being trapped by incoming waves prevents feeding in the numerous crevices and under-surfaces

Figure 12. On the Iona Island jetty, Glen Smith described the method Black Turnstones employed to feed on soft tissue inside barnacles in the early 1950s. Thirty-four years later, Marsh (1984) described this feeding behaviour as a "staccato" or "hammering" peck. In this sketch, the dark areas in the cluster of Acorn Barnacles indicate that their innards have been extracted by rock-frequenting shorebirds. *Sketch courtesy of Philip Croft.*

of the rocks. As a result of the apparent avoidance of the sides and under-surfaces of the rocks during feeding, much of the invertebrate population on the rocks appear to be unused by the turnstones.

Feeding Black Turnstones showed a distinct preference for certain sections of the habitat, and this preference in relation to the tide levels tended to control the activity of the birds. The preferred areas of the jetty were those parts that were lowest, and almost invariably were first encountered the birds would be found in one of these places. Correlation of the numbers of feces found on the various parts of the jetty with the selection of preferred areas showed that by far the greatest density of feces was on the low parts of the jetty. It was further observed that the greatest number of feces were present on the upper surfaces of the rocks, and only rarely were any found between or under the rocks.

Feeding turnstones could be approached most readily when the tides were receding from a high, after most of the jetty had been flooded. Birds that were encountered while the tide was low were by contrast very difficult to approach, which suggests that feeding was most intensive as the jetty was being exposed after a period of inundation.

Rock Sandpiper

Feeding was observed only four times due to the general absence of this species from the study area. However, several points in the behaviour were noticed. While feeding, Rock Sandpipers were easy to observe and did not flush unless approached to within about five yards (4.6 m). However, if in the company of Black Turnstones, the sandpipers assumed that species' wariness, making observations difficult.

When feeding apart from turnstones, Rock Sandpipers worked very slowly along the rocks frequently spending several minutes in one location before flying to the next rock. Birds feeding thus selected algae-coated rocks but only if the rocks were wet. Feeding was executed by "cropping" through the wet alga, an act that consisted of a persistent series of bites as the bill was run along the surface of the rocks. In this fashion an individual bird walked slowly over a rock for up to a foot without once lifting its head. On one occasion while this feeding behaviour was being watched, three birds were on one rock, all feeding for a period of five minutes before one of the group flew to an adjacent rock. Black Turnstones were never observed feeding in this fashion, nor as persistently.

When feeding with turnstones, Rock Sandpipers behaved markedly differently. Apart from the apparent increase in wariness, feeding appeared to be more erratic, and was characteristic of the turnstone's feeding habits. Thus, the sandpiper moved from rock to rock picking up specific items of food. Field observations suggested that the food eaten on these occasions was identical with that eaten by the turnstones, but stomach analysis did not confirm this observation.

RESULTS AND DISCUSSSION

Because the population of birds studied was small, only a few stomachs could be obtained. However, the food habits of the population of Black Turnstones and Rock Sandpipers studied should be well represented.

Table 1 shows the occurrence of all food items found in the stomachs of 12 Black Turnstones. Each item is given as a percentage of the total volume of the individual stomach contents. The tide level at the time of collection, and the total volume of each stomach, are also included.

Black Turnstone

The various foods are grouped into five general categories in the following discussion, namely invertebrates, marine algae, marine plants, accidental items, and miscellaneous items. Further, each food/item identified is listed as a percent of the total volume for each stomach analyzed (Table 1).

Table 1. Percent by volume of all items removed from 12 Black Turnstone stomachs collected on the Iona Island jetty, British Columbia, between 1 November 1951 and 30 March 1952.

			Invertebrates[1]							Marine Algae and Plants[2]		Misc[3]
Specimen Number	Tide Level (ft)	Total Volume (cc.)	*Balanus* scutes	*Balanus* tissue	Isopods	*Littorina*	*Mytilus* shell fragments	*Mytilus* tissue	Limpets	*Ulotrhix sp.* filamentous algae	*Prasiola sp.* Leaf algae	Unidentified
10	4	0.7	14.2	30.0	42.8	3.0	2.0	-	8.5	-	-	-
11	4	0.55	9.1	65.4	25.4	-	tr[4]	-	-	-	-	5.0
12	7.5	0.4	2.2	2.2	90.0	tr	tr	-	-	-	-	-
6	8	0.85	47.0	51.7	-	tr	-	-	-	-	-	1.2
9	8.5	0.85	47.1	52.9	tr	tr	-	-	-	-	-	-
5	11	1.35 +	11.1	51.3	-	-	-	-	-	18.5	14.6	7.0
1	11.5	2.0	50.0	35.0	-	tr		-	-	-	-	15.0
2	11.5	0.75	38.6	21.3	-	26.6	-	6.6	-	-	-	6.0
8	12	0.1	90.0	10.0	-	-	tr	-	-	-	-	-
7	12	0.7	57.1	40	-	-	-	-	-	-	tr	-
3	12.2	1.0	15.0	-	-	7.0	tr	-	-	63.0	12.0	3.0
4	12.2	0.5	20.0	25.0	tr	-	10.0	-	-	23.5	11.5	6.0

[1]Current common and scientific names are: Acorn Barnacle (*Balanus glandula*), Oregon Pill Bug [Isopod] (*Gnorimosphaeroma oregonensis*), Checkered Periwinkle (*Littorina scutulata*), insect larvae (Tipulidae and Chirononidae, Blue Mussel (*Mytilus edulis*), Limpets (Gastropoda), filamentous algae (*Ulothrix* sp.), sedge (*Carex* sp.), green leaf algae (*Prasiola* sp.).

[2]Also includes 0.7% *Carex* seeds.

[3]Also 2.9% wood fragments.

[4]tr = trace <1%.

Each category is discussed separately.

Invertebrates – Acorn Barnacles: Barnacle parts composed 65.4% of the total stomach contents and occurred in 100% of the samples (Figure 13). Of the 64.5%, 32% consisted of soft parts and 33.4% was scutes. Only a trace of hard parts other than scutes was present (Table 1).

Figure 13. Black Turnstone probing a barnacle to extract the soft inner food that is the most important item in their diet during the nonbreeding seasons. *Photo by R. Wayne Campbell.*

The scutes were frequently found attached to the soft parts of the barnacles, and were thus part of the food eaten. Measurements of the scutes were taken to determine a predilection by the birds for certain size classes of barnacles.

Table 2 shows the occurrence of scute sizes in the turnstone's stomachs, arbitrarily designated as small, medium, and large, correlated with a similar grouping of barnacles as they occurred in zones 2 and 3 of the jetty. The results reveal a preference by the turnstones for barnacles of the medium-sized class, with a greater selection of large than small sizes. Thus medium-sized barnacles composed 71.5% of this organism eaten, whereas only 6.5% of those eaten were the smaller individuals, and 22% were of the larger size class.

Table 2. The percent of distribution of scute sizes of Acorn Barnacles found in 12 Black Turnstone stomachs as correlated with the scute sizes of arbitrarily classed small, medium, and large collected at Iona Island, BC, between 1 November 1951 and 30 March 1952.

Scute Sizes (mm)	Category	% Occurrence in Stomachs
0.5 to 1.5	Small	6.5
1.5 to 3.5	Medium	22
3.5 to 5.5	Large	71.5

The presence of whole scutes, almost to the exclusion of other barnacle shell fragments, is indicative of the feeding habits of the birds: 100% of the stomachs contained scutes and only 8.3% contained other shell fragments. This suggests that the birds feed on barnacles by extracting the contents from the shell, rather than feeding upon barnacles that have been damaged by debris. Field observation supports this finding. Initially, the writer thought that perhaps this choice of rocky coastal habitat by the species was a behavioural characteristic developed in conjunction with the damaging effect of waves and debris upon organisms encrusting the rocks in such habitat. The effect of erosive forces upon the barnacles and mussels was considerable, and many of these organisms were crushed or loosened, thus exposing the fleshy contents.

Soft parts of barnacles occurred in 91% of the stomachs, and averaged 32% of the stomachs' volume, thus composing the main nutrient eaten by the turnstones (Table 1). Freshly eaten barnacles were found in several of the stomachs examined, and the groups of cirri could be counted. The greatest number was 17, which showed a complete gradation of digestion from very fresh to well disintegrated. This observation gives some idea of how many barnacles may be eaten during one feeding bout, and indicates that digestion is rapid.

Barnacles formed the dominant species of food organism in the environment in terms of the area of rock covered, particularly the upper surface area. Mussels, although more numerous, covered only a small portion of the rocks. In relation to the food habits of the turnstones, the evident preference of barnacles may be based on the greater availability of this organism, and the fact that receding tides expose them before other food items are exposed. Field observations on the feeding habits indicated that the birds fed most intensively on a receding high tide. Munro (1935) observed this phenomenon, which may account for the choice of barnacles as the main food item.

The effect of tides is reflected in the quantity of barnacle parts found in the stomachs (Table 3). Birds that were taken on the higher tides (11.5 feet [3.5 m] and above) contained an average of 60.9% barnacle parts, consisting of 42.7% scutes, and 18.2% soft parts. Birds taken on lower tides averaged 68% barnacle parts by volume, of which 26.8% were scutes and 41.9% were soft parts. The presence of a larger quantity of scutes in the stomachs of birds taken on the higher tides suggests that more barnacles are eaten under such circumstances than when the tide is lower, thus correlating with the observed intense feeding during a receding tide. However, scutes may be retained in the stomachs as grit, and thus the passage of this item cannot be used as a criterion of the quantity of food eaten. Soft parts, because they disintegrate during digestion are a more reliable index to the amount of food eaten during a feeding bout, and the greater quantity of this item present in these stomachs taken on the lower tides indicates that more barnacles are eaten during such periods.

Table 3. Primary and secondary Black Turnstone food items in relation to tide level at Iona Island, BC. Stomach samples (n = 12) collected between 1 November 1951 and 30 March 1952.

	Primary Food Item (% of Volume)[1]			
Tide Level (m)[2]	Acorn Barnacle (Scutes)	Acorn Barnacle (Soft Tissue)	Oregon Pill Bug (Isopods)	Filamentous Algae (*Ulothrix* sp.)
1.22	-	65.4	25.4	-
1.22	-	30.0	42.8	-
2.29	-	-	90.0	-
2.44	47.0	57.1	-	-
2.59	47.1	52.9	-	-
3.35	-	51.7	-	-
3.35	-	51.3	-	-
3.51	50.0	35.0	-	-
3.51	38.6	-	-	-
3.66	90.0	-	-	-
3.72	-	25.0	-	23.5
3.72	-	-	-	63.0

[1]Primary and secondary food items with highest percentage of volume in relation to tide level.
[2]Listed from lowest (most exposed) to highest (least exposed) tide level.

Invertebrates – Oregon Pill Bug [Isopods]: This food ranked second in importance by volume, averaging 13.2% of the stomach contents, and occurred in 41.6% of the stomachs (Table 1). This organism was found only on the lower levels of the jetty, and the effect of tide upon the occurrence of isopods in the stomach is obvious. Of five stomachs containing this item, four were taken on tides below 8.5 feet (2.6 m). Table 3 shows that the four stomachs taken below 8.5 feet (2.6m) contained a larger volume (52.7%) of isopods than barnacle soft parts (23.5%), and because both items probably disintegrate at a comparable rate during digestion, suggests that isopods are equally or more sought as food than are barnacles, provided they are available.

Invertebrates – Checkered Periwinkle: This small snail ranked third in importance among the animal foods, composing 3% of the stomach volumes, and occurred in 50% of the stomachs. This organism is exceedingly abundant in the environment, practically every empty barnacle shell on the rocks contains from one to several of these snails. Because of the small quantity of *Littorina* eaten by the birds, and the large numbers present in the environment, this animal apparently is not a favoured food. Of the *Littorina* found in the stomachs, few exceeded 3 mm in length, the smallest individuals of the population; this suggests further that this prey is not taken.

Invertebrates - Blue Mussels: This bivalve ranked fourth in importance on the basis of percent occurrence but composed only 1.5% of the stomach contents (Table 1). Shell fragments were most frequently found, occurring in 50% of the stomachs, and composing 1% of the stomach contents. Soft parts of this organism were rare, and were found in 8.5% of the sample, composing only 0.5% of the stomachs' volume. Because of the large numbers of mussels in the environment, and their infrequent presence in the stomachs, it is evident that this organism is not sought as food. The occurrence of only a very small quantity of soft parts gives further indication that this prey item is unimportant. If mussels were eaten to any extent, there should have been some indication of small whole individuals in the stomachs, but this was not the case, except for one very small mussel found in one stomach. In view of this evidence, it is obvious that mussels are not sought as a food item by the turnstones.

Invertebrates – Limpets: These gastropods occurred only in one stomach, and composed 8.5% of its volume (Table 1), thus indicating this prey is not important to the population, although individuals may feed largely upon them (Figure 14). Insect larvae of the families Tipulidae and Chironomidae occurred in 33.5% of the stomachs examined but because of their small size constituted only a trace of the total stomach volumes. This organism is relatively common in the environment, particularly on the upper zones of the jetty. From the data obtained, it is impossible to determine whether these larvae were ingested accidentally or whether they were sought out as a food item. Since these larvae were frequently found applied to barnacles, they may have been eaten incidentally to the barnacles. The data presented in Table 1 show that larvae were generally found in the stomachs containing alga, which suggests they were sought as prey during high tides, or were ingested incidentally.

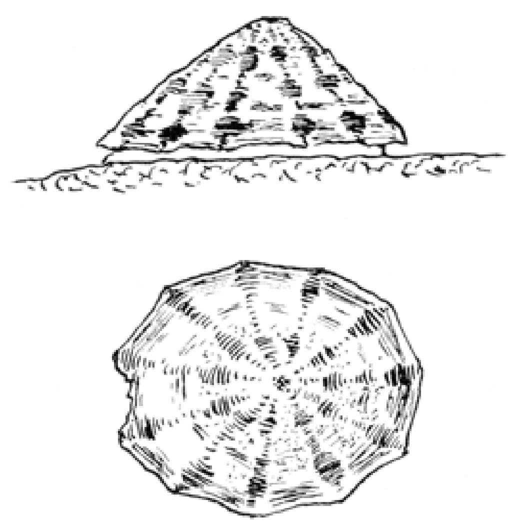

Figure 14. Small limpets were found in only one turnstone's stomach suggesting that individual birds may depend on them occasionally. *Sketch courtesy of Philip Croft.*

Marine Algae and Plants: Algae and plant material composed 12% of the turnstone diet, and consisted of filamentous alga *Ulotrix* sp., leaf alga, *Prasiola* sp., and *Carex* sp., seeds. Table 1 lists these items.

Filamentous alga occurred in 25% of the stomachs and composed 8.7% of the total volume of food. Of the stomachs in which filamentous algae were present, they composed an appreciable part of the contents, and appear to be related to the tide level. The tidal level at the time these stomachs were obtained was generally higher than when other stomachs were obtained, and was on the ebb flow. This evidence suggests high tides force the turnstones to feed upon alga, or organisms associated with it. Concurrent with the occurrence of alga, data in Table 1 show generally fewer barnacle parts than what is present in the stomachs that contain no alga. This emphasizes the effect high tides have on the food habits, and seems to suggest that the thinly applied barnacles along the upper regions of zone 2 are not eaten.

Leaf alga composing 3.1% of the stomach contents occurred only in the stomachs containing filamentous alga, except for a trace in one other stomach. The presence of this item appears to be correlated with the tide level in the same manner as filamentous alga, and is thus eaten out of necessity rather than choice.

Carex sp. seeds, which occurred only casually in the stomachs, consisted of trace volumes. One stomach contained 8 seeds, 0.7% of the stomach contents, possibly selected by that individual. In general seeds did not compose a significant portion of the turnstone diet.

Accidental Items – Wood Fragments and Feathers: The occurrence of wood fragments and feathers is believed to be accidental. Small fragments of wood are exceedingly numerous in the environment, and are readily visible as thin lines on the wave-washed sand. All the feathers found were down and their presence probably results from preening.

Miscellaneous Items – Grit: The occurrence of rock particles was infrequent in the turnstones, and composed only a trace of the stomach volumes. The presence of large numbers of shell fragments probably substitutes for grit, and for this reason, rock may be included accidentally.

Unidentified items composed 3% of the total stomach contents, and consisted largely of an inseparable pulp of animal and vegetable matter, mixed with sand and tiny fragments of shell. No attempt was made to separate these items but probably animal tissue constituted the main part.

Rock Sandpiper

The stomach contents of Rock Sandpiper differed somewhat from those of Black Turnstone (Table 4).

Invertebrates – Acorn Barnacles: As in the Black Turnstone diet, barnacles were the most important food item, composing 41.7% of the volume of food eaten and occurred in 100% of the stomachs. Scutes were the main body part present, with an average volume of 28.9% of the stomach contents and occurring in all three stomachs. Soft tissues occurred in one stomach composing 10.6% of the contents. Hard parts other than scutes composed 2.3% of the food volume and occurred in one stomach (Table 4).

The scutes that occurred in the sandpiper stomachs were seldom found to be recently ingested and in most cases most scutes were worn. This condition suggests that, unlike Black Turnstone, barnacles are not eaten extensively and the scutes may be retained as grit. A comparison of the scute contents of the two shorebird species shows that the quantity is comparable. If the sandpipers consumed large quantities of barnacles and yet retained the scutes, then these items would be expected to accumulate in the stomachs. The smaller quantity of barnacle soft parts in the sandpiper stomachs, coupled with the relatively large quantity of scutes, suggests scutes accumulate in the stomach and that barnacles are less important as food to the sandpipers than the turnstones. The scutes found in the sandpiper stomachs were measured and classified into the same arbitrary groups as was done with those found in the turnstones. On this basis it was found that the sandpipers selected medium-sized barnacles to the greatest extent, and consumed more of the small than the large classes. Table 5 illustrates this selection of scute sizes, showing that 71.4% of the scutes were of the medium size class, 22.1% small, and 9.3% were large.

Table 4. Percent by volume of all items found in stomachs of Rock Sandpipers collected on the Iona Island jetty, British Columbia, between 1 November 1951 and 30 March 1952 (n=3).

			Invertebrates[1]							Marine Algae and Plants		Accidental	Misc.
Specimen Number	Total Volume (cc.)	Tide Level (ft)	*Balanus* scutes	*Balanus* tissue	*Balanus* shell framents	Isopods	*Littorina*	Larvae	*Mytilus* shell fragments	*Ulotrhix* sp. filamentous algae	*Prasiola* sp. Leaf algae	Grit	Unidentified
3	0.45	9.5	31.1	-	6.6	-	15.5	tr[2]	2.2	36.8	2.0	4.4	1.0
2	10.5	0.7	5.7	-	-	-	-	7.1	14.2	64.3	-	7.1	1.4
1	11.5	0.4	50.5	31.8	-	10.7	-	-	tr	-	-	tr	7.5

[1]Current common and scientific names: Acorn Barnacle (*Balanus glandula*), Oregon Pill Bug [Isopod] (*Gnorimosphaeroma oregonensis*), Checkered Periwinkle (*Littorina scutulata*), insect larvae (Tipulidae and Chironomidae, Blue Mussel (*Mytilus edulis*), Limpets (Gastropoda), filamentous algae (*Ulothrix* sp.), sedge (*Carex* sp.), green leaf algae (*Prasiola* sp.).
[2] tr = trace <1%.

Table 5. Occurrence of Acorn Barnacle scute sizes in 3 Rock Sandpiper stomachs collected at Iona Island, BC, between 1 November 1951 and 30 March 1952.

Scute Sizes (mm)	Category	% Occurrence in Stomachs
0.5 to 1.5	Small	22.1
1.5 to 3.5	Medium	71.4
3.5 to 5.5	Large	9.3

Shell fragments of the barnacles occurred in one of the stomachs and composed 6.6% of its volume. The occurrence of this item reveals this bird may have fed upon damaged barnacles. However, because the sandpipers apparently consume considerable quantities of grit, these shell fragments may have been ingested for that purpose. Sandpipers were not observed feeding upon barnacles, but their presence in the stomach contents suggests they do, without having to rely upon damaged barnacles as their source of this food item.

Barnacle soft parts occurred in one of the three stomachs, composing 31.8% of its contents. No shell fragments were found, but 50% of its volume consisted of scutes. The contents of this stomach provide evidence that Rock Sandpipers can extricate the contents of barnacles despite the soft tips of the mandibles. The presence of barnacle soft parts in the single stomach provides little evidence of the importance of barnacles in the sandpiper diet. However, the large quantity of scutes, and general absence of soft parts, suggests barnacles are not eaten regularly.

Invertebrates – Checkered Periwinkle: This snail was found in one stomach, composing 15.5% of its volume. Five individuals occurred in this stomach, all very small. Apparently this bird used these organisms as a food item, but the data are too limited to form any generalizations on the importance of this item.

Invertebrates – Oregon Pill Bug [Isopods]: These crustaceans ranked third in volume, but were found in only one stomach, composing 10.7% of its contents. This suggests that individual birds eat this organism extensively, but no generalizations can be made.

Invertebrates – Blue Mussel: Shell fragments occurred in all three stomachs and composed 5.4% of the total stomach contents. Mussel soft parts or small entire shells were not found in the stomachs examined, which indicate that this item is not important (Figure 15). The presence of shell fragments suggests that this item was ingested as grit, or eaten incidentally to other foods.

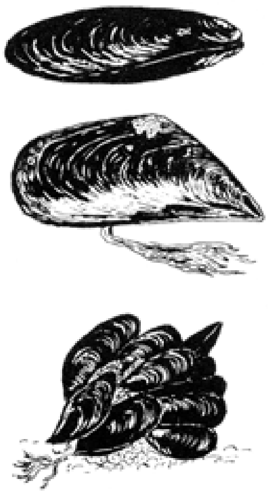

Figure 15. Blue Mussel, although a common intertidal invertebrate on the Iona Island jetty, was unimportant as a food item in the diet of both Black Turnstone and Rock Sandpiper. *Sketch courtesy of Philip Croft.*

Invertebrates – Insect Larvae: The families Tipulidae and Chironomidae composed 2.3% of the stomach contents and occurred in two of the three stomachs (Table 5). The presence of these organisms in two stomachs suggests that it may be sought by Rock Sandpipers as a food item. The stomachs containing larvae also contained a large quantity of alga, which may indicate that either the larvae were eaten incidentally to algae, or the converse. A total of 202 individual larvae were found in the two stomachs, which is strong evidence that the larvae were sought as a food item by cropping the algae. If this is the case, then the larvae of this species of insect constitutes a food item of major importance to the sandpipers feeding on the jetty.

Marine Algae and Plants: Algae occurred in two of the three stomachs, comprising 33.9% of the total stomach contents. Filamentous alga (*Ulothrix* sp.) accounted for 33.9% of this volume, whereas green leaf alga (*Presiola* sp.) composed 0.6% (Table 5). Filamentous alga constituted the greatest bulk of food eaten by the sandpipers and on this basis appeared to be a major food item. However, the presence of larvae in the filamentous alga of zone 1 and the lack of this organism in the leaf alga on the jetty, correlated with the presence of much filamentous alga, and very little leaf alga in the stomachs indicates that filamentous alga is eaten as a result of searching for larvae. Further evidence for this is indicated by the absence of larvae from the stomach that contained no alga. Although the data are limited, it would seem that algae are a relatively unimportant food item in the sandpiper diet, except when taken incidentally to other more palatable items.

Accidental Items – Grit: Rock Sandpipers consume appreciable quantities of grit, an average of 3.9% of the stomach contents by volume, and occurred in all stomachs (Table 5). Despite the presence of grit, the various hard parts of animals eaten could probably function as grit in the absence of rock particles and as shown in Table 5, the smaller the quantity of animal hard parts, the greater the amount of grit. This suggests rock fragments were eaten to compensate for the lack of animal hard parts in the stomachs. Unfortunately, the sample was too small to illustrate a definite trend in this respect, but in view of the high plant contents of the sandpiper diet, grit is probably eaten purposely, not ingested accidentally, as in the turnstones.

Unidentified Items: Occurred in all the stomachs but composed a small part of the total contents (Table 5). Probably a large part of this material was finely macerated filamentous alga that had been eaten by the larvae. Considerable amounts of sand and very fine shell fragments also occurred but separation was impractical.

The number of sandpiper stomachs taken was small but the level of the tide does not warrant discussion (Table 6). An exception, however, may be that the stomachs containing alga were taken on relatively low tides, which suggests insect larvae occurring in zone 1 are a more attractive food than the organisms present in the lower zones of the jetty.

Table 6. Primary food items for Rock Sandpiper in relation to tide level at Iona Island, BC. Stomach samples ($n = 3$) collected between 1 November 1951 and 30 March 1952.

Tide Level (m)[2]	Primary Food Items (% of Volume)[1]			
	Acorn Barnacle (Scutes)	Acorn Barnacle (Soft Tissue)	Oregon Pill Bug (Isopods)	Filamentous Algae (*Ulothrix* sp.)
2.90	-	-	-	36.8
3.20	-	-	-	64.3
3.51	50	-	-	-

[1]Primary food items with highest percentage of volume in relation to tide level.
[2]Listed from lowest (most exposed) to highest (least exposed) tide level.

SUMMARY

From the results of this study, the following points are noted:

Environment

- Marine alga and invertebrates in the study area were distributed in three zones, which closely correlated with the average tide levels.
- Acorn Barnacles (*Balanus glandula*), Blue Mussels (*Mytilus edulis*), and filamentous alga (*Ulotrhix* sp.) were the dominant organisms forming the three zones. Oregon Pill Bug [Isopods] (*Gnorimosphaeroma*] *oregonensis*), Checkered Periwinkle (*Littorina scutulata*), and insect larvae (families Tipulidae (Crane Flies) and Chironomidae (non-biting midges) were the most conspicuous forms found in association with the encrusting barnacles.
- The food habits of Black Turnstone and Rock Sandpiper differed, with the turnstones apparently preferring the lower parts of the jetty.
- Feeding by both species appeared to be most intense on receding tides.
- The topography of the lower areas of the jetty facilitated an increase in the quantity of barnacles and mussels present compared to an area of normal jetty, and promoted a concentration of feeding effort by the Black Turnstones on these lower areas (Figure 16).

Figure 16. Black Turnstone preferred to feed at the lower limits of the intertidal zone where barnacles were more abundant. *Photo by R. Wayne Campbell.*

Black Turnstone

- The tides, in relation to the height of the lower areas of the jetty, governed the presence and activity on the jetty.
- Acorn Barnacles were the most important food item; more invertebrates were eaten than marine alga.
- The barnacle remains indicated this species can extract the contents from the shell, and that damaged barnacles are not necessarily sought.
- Since barnacles form the dominant species of organism by area of coverage, and since this organism is exposed before mussels by a receding tide, the selection of barnacles may be due to their greater availability.

- Of the several species of invertebrates, Oregon Pill Bug occurred frequently and was the most important food in this category. Checkered Periwinkle occurred frequently but was less important as a food item. Blue Mussels were not an important food. Limpets occurred in only one stomach. Insect larvae were of little importance.
- Algae (*Ulothrix* sp. and *Prasiola* sp.) comprised a small part of the turnstone diet and seemed to be eaten only during high tides.
- *Carex* sp. seeds occurred occasionally in the Black Turnstone diet.

Rock Sandpiper

- Appreciable quantities of grit were consumed.
- Acorn Barnacles composed the most important animal food eaten but the scutes may be retained in the stomach as grit; hence, the hard parts are a poor indicator of the food habits. For this reason, barnacles in the diet were probably not related to choice and quantity.
- Of the invertebrates, Checkered Periwinkles were the most important by volume but by occurrence were relatively unimportant. Isopods were not important, whereas insect larvae were of major importance and occurred concurrently with considerable quantities of alga. Only the filamentous alga (*Ulothrix* sp.) occurred to any extent in the diet, but its significance as food item is doubtful.

ACKNOWLEDGEMENTS

The author is much indebted to Dr. I. McT. Cowan of the Department of Zoology, University of British Columbia, for supplying some of the data used in this study, and under whose direction this work was conducted. Gratitude is also tendered Dr. W.A. Clemens, head of the same department, for supplying data, and for assistance with problems arising from the study of marine invertebrates that occurred in the study area.

Identification of insects removed from stomachs was made by Professor G.J. Spencer, Department of Zoology. Algae were identified by Mr. R.W. Pillsbury, Assistant Professor, Department of Biology and Botany. Assistance on problems concerning tides was obtained from Dr. W.M. Cameron, Associate Professor of Oceanography, Department of Zoology. The assistance of these people is gratefully acknowledged.

Particular gratitude was expressed to the author's wife, Lillian Joyce (Joy) Elvidge, without whose help and cooperation much of this work would not have been possible.

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ABOUT THE AUTHOR

See pages 89-119 in this issue of *Wildlife Afield* for a comprehensive biography of W. Glen Smith.