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Title

Observations on the Natural History  
of Clam Drills

(Polinices) - - - - - 1946

Author

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revised

by

J. C. Medcof

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OBSERVATIONS ON THE NATURAL HISTORY

OF GLAM DRILLS

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## INTRODUCTION

During the summer and fall of 1945, Belliveau Cove was visited by Dr. J. C. Medcof, who found on the flat numerous egg cases of cockles (Polinices) and many drilled shells of seed clams -- evidence that the drills were there in considerable numbers. From this it was decided that the cove offered good opportunities for a study of their life history and industrial importance. This seemed desirable because in several of the areas in the Maritimes it appears to be a serious menace to the clam industry.

### I GENERAL OBSERVATIONS

#### 1. Belliveau Cove

The cove is formed about twenty miles southwest of Digby by a mile-long portion of the mainland shore of St. Mary's Bay in Digby County, Nova Scotia. The maximum width of exposed area (centre of cove) is a half mile. For the most part, the bottom is sandy, though the soil in Dock 2, through which a stream of fresh water flows over the flat, is a mixture of sand and mud. Off the more northerly point is a rocky area covered with rockweed. In the cove during the summer of 1946 were two large weirs.

The whole surface of the flat, including the mud of Dock 2, is heavily populated with small soft-shelled clams. This population extends from the shore down to the broken line shown in figure 1. It is thickest toward the piers,

and thins out toward the southwestern part of the cove. At the lower levels the clams often occur in small patches scattered between beds of eelgrass. The eelgrass is not more than one foot high and the beds are small and sparse. Brown streaking of the blades indicates that the grass is still diseased. At the level of weir 1 and beyond, large bar clams are found, but the maximum size of the soft-shelled clam, Mya arenaria over the whole area was not more than two inches in length and averaged one inch.

Although the cove once supported a heavy clam fishery, there has been no important production of soft-shelled clams there for several years. This is rather peculiar considering the present abundance of young clams. It is hoped that study will reveal the cause of this condition and indicate the remedy.

Local inhabitants seemed to agree that the larger soft-shelled clams disappeared from the flat about ten years ago. At that time, they claim, a man could dig  $1\frac{1}{2}$  to 2 barrels per tide, whereas now he is fortunate to get a bucketful. In their opinion the clam stocks were not depleted by over-fishing, but disappeared more or less suddenly from natural causes. Several relate the disappearance to the dying off of the eelgrass on the flat.

## 2. Classification and Nomenclature of Polinices

Polinices heros, the round whelk, has also been known by the generic names of Lunatia, Neverita and Natica. Borradaile

and Potts (1938) classify Natica as belonging to the order Prosobranchiata of the gastropods, and suborder Monotocardia due to the presence of just one auricle in the heart. Arnold (1903) mentions the family Naticidae and with regard to the genus, says "There has been much confusion in the generic nomenclature of this family. The old name Natica once did service for all the species; then the names Lunatia, Neverita and Polinices were applied to certain special forms, but it has been wisely proposed by conchologists to use the name Natica for those forms having a shelly operculum, and to adopt the name Polinices for those having a corneous operculum. Lunatia and Neverita have become subgenera of Polinices. Arnold describes five species of Polinices, the subgenus Neverita including two of these and being characterized by a thick brown or white callosity closing the umbilicus of the shell. The remaining three species, heros, triseriata and lewisi, the latter on the west coast, are grouped into the subgenus Lunatia. Arnold states of P. triseriata, "A small shell of exactly the same shape as P. heros, but decorated with three revolving series of bluish or chestnut spots. It is pretty well determined that this so-called species is only the young of P. heros?" Balding (1930) in mentioning L. triseriata states that it is "possibly erroneously considered to be the young of L. heros?" Gould, Binney (1870) describe in detail P. heros and P. triseriata as two distinct species. This point will be discussed later in the report.

### 3. Distribution

Ganong (1889) gives the distribution of P. heros as from low-water mark to forty fathoms and from Georgia to the southern coast of Labrador. Melville (1930) states they may be found from low-water line to a depth of 17 fathoms, and quotes Pratt (1927) that they may be found to a depth of 238 fathoms. It is one of the commonest shells on the coast north of Cape Cod. Ganong (1889) states that it is rarely found in rocky situations, preferring sand and mud bottoms. Even at the time of Champlain's explorations, the whelk was apparently present on the coast of the Bay of Fundy in sufficient numbers to be noticed by the explorers, for Champlain in 1604 mentions the occurrence at the present Weymouth Harbour, St. Mary's Bay, N.S. of "Many shellfish such as mussels, cockles and sea-snails" Ganong interprets this "sea-snail" to be the large whelks Buccinum undatum and P. heros. The explorer also observed the same at Dochet Island in the St. Croix River.

### 4. Previous Works

There has been little reported on the life history of Polinices heros and P. triseriata. Descriptions of the snail, its egg case, and feeding habits are given in Ganong (1889) and Arnold (1905). Melville (1930) has a report on the life history of specimens gathered around Passamaquoddy Bay, but makes confusing statements about the egg cases.

### 5. Description of the Snail

After studying many specimens the writer came to the conclusion that there were on the flat two varieties of Polinices

growing at different rates, and to different ultimate sizes. One was called "A" and the other "B". The "A" corresponds closely to the description given by Gould, Binney (1870) for P. triseriata and the "B" to the description for P. heros but assignment of the animals to these species should await their careful study by systematists.

"A" Snail: A small snail compared with "B". Its shell height never exceeds 30 mm. and the width measured at right angles to the longest diameter never more than 22 mm. The colour of the shell in the young varies from yellow to blue with three rows of chestnut spots on the whorls. In the older shells these rows become unbroken chestnut bands and the colour of the shell is an ashy-white. When the foot is extended it may be twice the length of the shell and of a flat white or yellowish colour. The mantle almost completely covers the shell. The snail moves along smoothly with the two tentacles directed anteriorly. When disturbed it quickly withdraws into its shell, the corneous operculum finally closing the aperture. See Figs. 2-5.

"B" Snail: Grows to a much larger size than "A", the height and width of a large one being 62 and 57 mm. respectively. In the young the colour of the shell is a pink or pale yellow, quite fragile and smooth, with a faint indication of 3 bands, but no sign of spotting. In the older shells the periostracum becomes yellowish-gray, and the bands cannot be

distinguished on the brown interior of the shell. The snail behaves much as the "A" type. See Figs 2-5.

The two most helpful distinguishing features for field work, besides size, are (1): the shape of the shell -- "B" snail being slightly wider than "A"; (2) the colour of the foot -- when that of the "B" snail is extended it has a pink colour and when retracted its upper surface is almost black. The foot of the "A" snail is always white in colour. This serves as a ready means of separating the two varieties in Belliveau Cove. A more detailed comparison of the two forms is to be formed in the table in section V entitled "Evidence of two Varieties".

#### 6. Habits

Both of these snail types are nocturnal. For the most part during the day they lie buried in the sand and no true idea of their abundance can be had from counts on the few that remain exposed. They come out on the surface of the flat in large numbers a few hours after sundown and go down again at the early morning light. At times in July the numbers of "A" observed on the surface during night surveys with a flashlight rose to four and five to the square yard. Toward the end of August not so many came to the surface at night and those which did seemed to come up later.

During the day they lived in the top six to eight inches of the flat, the smallest snails being nearer the surface. It will be noted that the clams on which the snails feed, distribute

themselves in the same way and at about the same depths.

Of the two, the "A" variety was much more abundant at Belliveau Cove and ranged all over the upper flat and down to the level of Stations 5 and 6 (Fig. 1). The "B" snail remained for the most part at the lower levels.

## II RATE OF GROWTH

### 1. Selection of Index to Size

For a proper study of growth it is necessary to have a reliable index to size and to changes in size. Several possible indices were tested. These are listed below with the criticism made of each.

a. Total weight of live snail in air: This varies greatly depending on the amount of water the animal extrudes as it withdraws into its shell.

b. Weight of shell alone: It was often impossible to remove the whole of the meat from the shell in preparing the specimens so this had to be abandoned.

c. Total volume: While this is theoretically the best index to size it was impossible with the equipment at hand to make accurate measurements of small animals.

d. Counts of numbers of whorls: Counts are hard to make accurately because in the prodissoconch region the shell is sometimes eroded so as to obscure the first whorl.

e. Length of operculum: The edge of the new growth was indefinite making it hard to measure and as soon as the whole operculum dried, it curled so that it could not be accurately

measured.

f. Width of shell: This involved measurement from the fragile outer lip of the shell which chipped so easily that exact measurement of specimens after a little handling was not reliable.

g. Height of shell aperture: This dimension may be as reliable an index to size as any but it is small and difficult to measure without considerable relative error.

h. Total shell-height: The linear distance from the tip of the spire to the lowest part of the lip was chosen because it is the greatest dimension and readily measured with the instrument available which was a vernier caliper reading to the nearest 0.1 mm. There is only slight erosion of the spire tip of most of the shells and the lower part of the lip is generally tough enough to resist breakage so this dimension is apparently the best to measure.

After a few trials it was decided that height measurement to the nearest mm. was fine enough for most purposes.

## 2. Size Composition of Population

Information on growth rate was sought from an analysis of the size-composition of the population based on height measurements.

Samples of snails were collected at intervals from May 10 to late August. These were as nearly as possible "representative" of the population. Several of them were gathered simply by picking by hand all the snails that could be found in a limited

area. Other samples were gathered by screening the sand through copper fly netting. The latter are considered the more reliable.

All together measurements were made on about 2,500 snails but only about 1900 of these are considered pertinent. The reason for this is that on June 18 it was certainly established that there were two varieties of snails present on the flats and that in both varieties the males and females grew at different rates and attained different ultimate sizes. These facts were established after it was found that two types of egg cases were being formed and that in mating pairs of snails, the female was almost invariably larger than the male.

The data applying to these earlier collections are summarized in table 1. From this it appears that there were only two certain size-classes with modes at about 6 and 16 mm. and a doubtful third at 3mm.

Without further information the 3 mm. class may be regarded as representing the 1945 "set" of snails since the first 1946 egg cases were just appearing at the time these samples were gathered and the 6 mm. group the 1944 set.

The 16 mm. group is assumed to be composite of several year classes.

After June 18 attempts were made to classify all specimens according to variety and sex. There was little difficulty in classifying the snails according to variety. No young of the "B" type were found. Separation according to sex was simple

Table 1. Size-composition of Polinices samples taken from Belliveau cove May 10 to June 18, 1946.

Shell height mm.	Date and Source of Collection			Total Collection
	Whole Cove May 10-June 5	Dock 1 June 4-7	Whole Cove June 13-18	
1				
2	4	3		7
3	13	6	12	31
4	10	5	3	18
5	7	13	7	27
6	9	9	6	24
7	15	6	5	24
8	8	5	2	15
9	4	5	6	15
10	5	4	6	15
11	2	10	2	14
12	3	17	7	27
13	5	14	8	27
14	3	21	13	37
15	4	22	14	40
16	9	27	31	67
17	4	25	13	42
18	7	3	10	20
19	1	3	9	13
20	4	1	5	10
21	4	2	11	17
22	1	2	5	8
23	1	1	10	12
24	3	2	7	12
25	5		4	9
26	1	1	5	7
27			5	5
28	1		1	2
29				
30			1	1
31	1			1
32	1			1
33				
34				
35			1	1
36				
37			1	1
38				
39				
40	1			1
Total	134	207	210	551

with larger snails on the basis of characteristics described in the section "Reproduction and Larval Life" but was impossible in snails below 6 mm. because at this size the sex organs were not well formed. It seems safe to assume that at this age the difference in size between males and females is slight enough to be neglected in size-composition studies and data on these small snails have all been included in table 2. Tables 2 and 3 summarize all the other data on size-frequency distribution in samples from the Belliveau Cove area. (In the unrevised long-hand manuscript these data are supplied by Mr. Stinson according to several sub-areas which have not been separately analyzed. J. C. M.)

In that manuscript several measurements of snails from Petpeswick, N.S. and St. Andrews, N.B. are recorded. These indicate that the "E" type is relatively more abundant than "A" at Petpeswick. Both species are present in the St. Andrews collection but it was too small to justify any statement as to the relative abundance of the two varieties. Neither collection is considered sufficiently representative or extensive to justify any statement on growth rates which might be based on analysis of size-composition.

Judging from the totals for the three principal Belliveau Cove collections the males and females were about equally abundant throughout the summer although the males may have been the more conspicuous in June and the less in August. Allowance must be made in the June collections for the very

small snails whose sex was indeterminable.

"A" snails (1) Males:

There is some doubt as to how the data on size composition (Table 2 and figures 6 and 8) should be interpreted. The June data suggest three distinct size classes with modes about 3, 6.5 and 16 mm. The July distribution is bi-modal with maxima at about 6 and 16 mm. The August measurements do not fall clearly into size classes.

The data listed under "Other Times" and "Total" can be interpreted in much the same way as those for June and are good supporting evidence for the conclusions drawn from the study of the smaller individual samples.

It seems probable that the size class with its mode at 16 mm. is composite, embracing several year classes and that the ultimate size of "A" males seldom exceeds 18 mm. This assumption is strengthened by the observation that snails of this size-class showed much variety in shell and body characteristics. Some had new-looking shells with thin lips. These usually had a penis that was only moderately developed. Others of about the same size had old-looking worn shells that were much thickened at the lip. Their recent shell secretions seemed to have added very little to the shell height. The penis in these animals was so large that they may be regarded as truly mature males. It was only males of this size class that were found mating (Table 6).

Many dead shells of about this size with thickened lips were found on the beach. Although the meats were gone it seems reasonable to assume that they had belonged to old males that had reached their maximum size and died because females do not develop this thick-lipped appearance until they are much larger.

The two size classes of smaller males probably represent year classes and the statement might be ventured that at the beginning of 1946 season the 1945 set of snails averaged 3 mm. in height and the 1944 set 6 to 7 mm.

None of the 1946 year class were represented in these samples since they did not hatch from their egg cases until August.

There is no reliable basis for judging the life-span of males but it is certainly not less than two and probably more than three years.

(2) Females:

The data on females in the June collections (Table 3 and figures 7 and 9) suggest at least three and if the data from table 2 applying to snails below 6 mm. are included, possibly four size classes with modes at 3, 7-9, 17-19, and 23 mm. The July figures suggest three. The first is ill-defined and may be composite of the first two indicated in the June sample. The second and third have their modes at about 19 and 24 mm. respectively. The August sample shows one group with a mode at 10 mm. and what appears to be a

Table 2. Size-composition of male population of "A" and "B" snails at Belliveau Cove on various dates, 1946.

Frequency

sex known	Mt. 15-21 June		16-22 July		21-22 Aug.		Other times		Total	Total	Total
	A	B	A	B	A	B	A	B	A	B	A+B
(1	0										
(2	2						14		16		16
(3	11						63		74		74
(4	5						50		55		55
(5	5		6				36		47		47
6	8						4		12		12
7	7	1	4				6		17	3	20
8	6		2		2		7	2	17	2	19
9	3				2	1	3	1	8	2	10
10	4		1		4		3		12	1	13
11	4		1		5	1	4	1	14	2	16
12	7		7		6	3	1		21	3	24
13	15		12	1	10	4	11	1	48	6	54
14	17		10		8		17	2	52	2	54
15	29	1	25		21	5	18	1	93	7	100
16	28		19		21	10	18		86	10	96
17	25		24		21	3	17	1	87	4	91
18	11		15		20	4	10	1	57	5	62
19	8		5	1	10	2	2	1	25	4	29
20	2		3		5	1	1	1	10	3	13
21	1		1				1	2	3	6	9
22	1						1	2	2	6	8
23							1	1	1	3	4
24							2	1	1	3	3
25							3			4	4
26				4			2	1		6	6
27				3			5	1	1	8	9
28		1		3			6			10	10
29		1		3			3			12	12
30				5			6			11	11
31				4			2		1	7	7
32				6				1	1	7	7
33		1		4		1				6	6
34		1		6		2				9	9
35				3		3		1		7	7
36				3		2		2		7	7
37		1		2		2		1		6	6
38				7		3				10	10
39				1		1		1		3	3
40				1		1		1		3	3
41				1		1				2	2
42						1				1	1
43				1						1	1
44				1						1	1
Totals	199	7	135	71	135	87	288	28	758	193	951

Table 3. Size-composition of female population of "A" and "B" snails at Belliveau Cove on various dates, 1946.

Ht. mm.	18-21 June		18-22 July		21-22 Aug.		Other times		Total	Total	Total
	A	B	A	B	A	B	A	B	A	B	A+B
6			1				5		14		14
7	8		3	1	2		11	2	24	3	27
8	3		1		4		12		20		20
9	9	1	3		4		6	3	22	4	26
10	6	3	2	1	6	1	2	1	18	6	24
11	2		1		5		3	1	11	1	12
12	3		3		3	1		1	9	2	11
13	5		1	1	2	4	1	5	9	10	19
14	1		4		3	2	8	2	16	4	20
15	6		2	1	4	9	2		14	10	24
16	9		3		1	3	7	2	20	5	25
17	8		5		6	3	8	2	27	5	32
18	8		6		14	4	10	2	36	6	42
19	5		10		14	4	18	2	47	6	53
20	3		11		15	3	12	2	41	5	46
21	4		7	1	18	2	21		50	3	53
22	8		9		23	2	14	1	54	3	57
23	12		17	1	19	3	10	2	58	6	64
24	9		20		12	1	12	2	53	3	56
25	6		15	1	10	2	10	4	41	7	48
26	8		12		5		4	3	29	3	32
27	2	2	7	1		3	3	1	12	7	19
28	1		1	1	1	3		1	5	5	10
29		1	3	3	1	2		3	2	9	11
30	1		2	2		3	1	1	1	6	7
31			1	1		2	2	2		5	5
32		1	8			1		1		11	11
33		1	7			3		2		13	13
34		2	4			2		2		10	10
35			6			2		2		10	10
36			2			1		1		4	4
37		1	3			2		1		7	7
38			5			7		2		14	14
39		2	2			4				8	8
40			2			2				2	2
41			5			2				7	7
42			2			1				3	3
43			1							1	1
44		1	6			4				11	11
45			6							6	6
46			2			2				4	4
47			3			2				5	5
48			3			2				5	5
49			2			3				5	5
50			1			1				2	2
51			3			2		1		6	6
52			3					1		4	4
53			2			1				3	3
54						1				1	1
55				1		1				2	2
56						2				2	2
57				2		2				4	4
58											
59						1				1	1
60											
61				1						1	1
62						1				1	1
Totals	137	15	145	97	172	107	179	58	633	277	910

fusion of the two classes (19 and 24 mm.) of larger snails in the July collection with a mode at 22.

As with the males the 1946 year class is not represented in these collections because the hatching had not begun by the time the samples were taken.

If it is assumed that four size classes actually existed in June and that they represented different year classes it may be said that 1945, 1944, and 1943 snails had respectively attained heights of 3, 9, and 17 mm. by the start of the 1946 season. The size class composed of the largest females (mode about 24 mm.) shows a wide range in sizes and is probably composite of several year classes. Few ever exceed a height of 26 or 27 mm. and the life span may be judged to be at least 4 and probably 5 or 6 years. As with males the largest females tend to expend their limey secretions in thickening the shell rather than in adding to its length. They develop the "old look" that goes with scarred shells that have little of the glossy appearance of young animals. These are the truly mature females which were common in mating pairs (Table 6). The larger dead shells on the beach all showed these features.

"B" snails:

Females of this species seem to be consistently more abundant than the males. Their greater size may make them more conspicuous and account for the greater numbers in the samples or they may be actually more numerous.

The numbers of males of this variety were too small to permit any deductions as to growth rate from the size-composition. Very few of the animals ever attain a height greater than 39 mm.

The small numbers of females gathered makes it impossible to deduce much about growth rate from the size-composition of the population. Few of them exceed a height of 50 mm. Their shells have a pink tinge up to 30-35 mm. and thereafter become grayish.

In both sexes the ultimate size seems to be indeterminate in the sense that while the shell is thickened after 30-35 mm. the height-growth is not greatly interrupted. The largest shell observed during the study was bought in Digby at a souvenir shop. It measured 77 mm.

In this discussion of size composition of the population it will be observed that there was no attempt to trace the changes in the positions of the various modes from month to month. Presumably these do shift progressively with season and it should be possible to map the regular course of their changes and thereby get some idea of seasonal growth rates and thus determine whether the size-classes observed actually represent year-classes. Failure in this is attributed to the inadequacy of the sampling and the mergence of the various size classes due to differences in their relative growth rates in height. It may be possible to remedy this in 1947 by better sampling. In the meantime, corroboration of the identity of age and size classes must depend on observations on the growth of individual marked specimens.

3. Growth of Marked Specimens:

Difficulty was encountered in putting on the shell a mark which would resist the wearing action of the snail's environment. The thin outer lip was so fragile that an attempt to notch it resulted each time in a portion of the lip breaking away. When the snail moves about, part of the mantle comes up over the shell almost completely covering it from behind and coming up over the outer lip in front. Thus it seemed that a waterproof substance applied to this lip on the outside would be protected from the sand by the mantle. Dark red nail polish was tried. Sixty-seven "A" snails of varying sizes were marked and numbered so that they could easily be spotted, and released near a marker in Dock 1. Most of them were never seen again, perhaps because they moved out of the area, or were not on the surface during the nights when the search for them was conducted, or, most likely, because the polish came off. Observations on the few that were recovered are listed in table 4. On numbers 1 and 2 the polish was intact but came off when touched.

Specimen no.	Date released at marker	Height on release mm.	Date recovered	Distance from marker	Height on recovery mm.	Growth Data			
						Increase in no. of whorls	Shell added lip-width mm.	Height increase	Interval between measurements (days)
1	5 June	16	18 June	16'	---	---	3	---	13
		16	22 Aug.	18'	19	1/4	18	3	77
2	5 " "	10	17 Aug.	12'	13.6	1/3	15	3.6	72
3	8 " "	16	18 June	18'	16	0	0	0	10
4	8 " "	21	19 "	18'	21	0	0	0	11
5	8 " "	15	18 "	16'	15	0	0	0	10
6	8 " "	19	18 "	1'	19	0	0	0	10

Table 4. Summary of information on the release and recapture of marked "A" snails (sex not determined).

From several points of view this experiment was not well designed. The fact that sexes were not determined is probably its greatest short-coming. The failure of specimens #5 to #6 to grow could possibly have been explained if sex had been determined. They may have been mature males.

The fact that a 10 mm. or 16 mm. "A" snail was able to add 3-3.6 mm. to their heights in 10-11 weeks strongly suggests that in the entire season they could grow enough to carry them from the 2nd to the 3rd size class of males or from the 3rd to the 4th of females which appeared in the June samples (Tables 2 and 3). To this extent the meagre results of this study accord with those from the analysis of size-composition and support the idea that the size classes are also year classes.

The animals in their wanderings showed a maximum movement away from the point of release of 1.8' per day and an average of 0.6' per day. There is an obvious need for a better method of marking the animals for studies of this sort. More detailed records, (e.g. data on sex) of the marked specimens should be kept in future work of this sort.

#### 4. Lines of growth on the shell:

Well-marked, growth-interruption lines are frequent on the shells of "A" snails but no consistent series of growth lines could be found on the shells, and many of the lines observed were not well marked. No clear relation could be shown between the sizes at which growth lines were formed and

the size classes revealed by the study of size-composition although these might be expected.

With the "B" snails, the shell is quite smooth up to the 30-40 mm. size. Some have no marks of arrested growth anywhere on the surface. Accordingly less might be expected from a study of shell annuli in this species. It was concluded that in the time available, a study of growth-interruption lines was not likely to contribute much to our knowledge of growth rate although further study of larger samples may be warranted.

#### 5. Lines of growth on the operculum:

The operculum has the outline shown in figure 10. In life, the end with the nucleus occupies that part of the shell aperture away from the spire tip. The operculum apparently grows by additions to its margin as suggested in figure 11. As in the shell study no regular sequence of growth lines was found which might be useful in age determinations.

In some shells, particularly of the larger "B" snails, the lip had been broken at one time and the snail had taken time to mend the lip evenly before going on with new growth. In such cases there was a well marked line on the operculum.

It may be that there is no winter interruption in growth that is great enough to leave a mark on the shell or operculum.

#### 6. Shell whorls:

There was so little erosion at the spire tip of the shells, that it was easy to count the whorls in the majority of cases. Table 5 lists the number of whorls in several shells of different heights for males and females of both types. Figure 12 shows

curves plotted from these data (females only) of the "A" and "B" varieties. The first five points on the curve, up to the break, are for snails whose sex is unknown. The tabulated data suggest little or no difference in the whorl no./height ratio for the two sexes within any one variety. There are, however, slight differences between varieties. The data are not extensive enough to permit more elaborate generalizations.

The rate at which new whorls are added changes greatly with size and age so that counts of numbers of whorls in shells are not likely to be helpful in growth studies.

Table 5. Showing the number of whorls in the shells of snails of different varieties, sexes, and heights.

Ht. mm.	No. of Whorls					
	Sex Unknown	A Snail			B Snail	
		M	F	M	F	
1	1.5			"		
2	2.75			"		
3	2.9			"		
4	3.25			"		
5	3.7			"		
6			4.1	"		
7			4.3	"		
10		4.7	4.7	4.6	4.7	
15		4.9	5.3	5.3	5.2	
20		5.3	5.5	5.4	5.6	
25			5.4	5.6	5.9	
30			5.3	6.0	6.0	
35				5.7	6.0	
40				6.0	6.0	
45					6.0	
50					5.8	
55					5.8	
62					6.4	

### III REPRODUCTION AND LARVAL LIFE

#### 1. Mating habits:

The male of both varieties of Polinices studied is equipped with a prominent penis situated at the base of the right tentacle. For all sizes greater than 5 mm. in height, this serves as a ready means of determining sex; below 5 mm. the penis is quite small and often not easily distinguishable. Dissections were not carried out on small snails to determine sex but this might be a means of identification.

Mating was first observed at sunset on June 3, the same date that it was discovered that the snails were nocturnal. Some mating must have taken place earlier than this because one egg case was found on the flat in late May. Mating was still going on at the end of August though not nearly to so great an extent as earlier in the season. By night mating took place on the surface of the flat, and by day just below the surface of the sand.

The positions in mating are such that the male, which is usually smaller, is in a position on the right and slightly to the rear of the female. The propodium of the male is extended around as a narrow band with the penis extended, and is inserted under the shell of the female. Fertilization is therefore internal.

The duration of mating was not determined. During the process, when it occurs on the surface, the male and female move along together slowly. Occasionally a small clam has been observed held in the posterior portion of the foot of the female while mating was in process.

Individual heights of male and female "A" type snails found as mating pairs both on and under the surface of the sand are listed in table 6. The females range from 16 to 25 mm. in height, with an average of 21 mm. and the males ranged from 9 to 19 mm. with an average height of 15 mm. In all cases these snails, males and females, had a thickened outer lip margin. All of the snails described in the table were of the "A" type. No "B" snail mating pairs were found.

Table 6. The sizes of mating pairs of "A" snails.

MATING PAIRS

No.	Date Collected	Time of Day	Location	Height female mm.	Height male mm.
1	June 11	2 pm	just under	25	14
2	"	"	sand	23	15
3	"	"	"	21	15
4	"	"	"	18	15
5	"	"	"	21	19
6	"	"	"	20	17
7	June 14	5 pm	under surface	21	16
8	"	"	"	19	9
9	July 1	8 pm	"	21	18
10	"	"	"	25	18
11	"	"	"	19	19
12	"	"	"	24	18
13	July 3	9 pm	on surface	25	15
14	"	"	"	18	10
15	"	"	"	21	13
16	"	"	"	22	16
17	"	"	"	16	17
18	"	"	"	23	15
19	"	"	"	23	14
20	"	"	"	24	15
21	"	"	"	17	16
22	"	"	"	22	14
23	"	"	"	22	14
24	"	"	"	19	16
25	"	"	"	20	15
26	"	"	"	21	16
27	Aug. 22	12 pm	"	25	15
Mean Height				21	15

2. The egg case:

Two types of egg cases (sand collars) were found on the flat. Both were constructed on the same general plan and of the same materials, but they differed in size, shape, texture, colour, and content. They will be described as "A" and "X" types.

The type "A" collar (Fig. 13-20) is laid by the "A" snail and was found everywhere in Belliveau cove, the greatest concentrations being out from piers 1 and 2, and in the eel-grass region (Fig. 1). Table 7 shows some data on the heights of female snails found making "A" collars.

Table 7. Showing the sizes of females discovered making egg cases.

No.	Date	Height of Female	Type of Collar	Type of Snail
1	July 9	38	"X"	"B" (Snail 4" below it buried in sand.)
2	" 12	26	"A"	"A"
3	" 12	24	"A"	"A"
4	" 12	22	"A"	"A"
5	" 18	26	"A"	"A"
6	" 22	24	"A"	"A"
7	Aug. 16	22	"A"	"A"

The type "X" collar (Fig. 19 and 20) was rather scarce, being found in greatest numbers about the level of weir 1, in the rocky region on the northerly edge of the cove, and

about 100 yards in from weir 2 (Fig. 1). Its area of occurrence corresponded roughly with that inhabited by the "B" snails. See figure 19.

Samples of both "A" and "X" types were obtained from St. Andrews on July 16.

(a) Type "A" Egg Case. Although a complete construction of an "A" collar was not observed, "A" snails were observed making them. Some ideas of the sizes of the snails involved may be had from Table 7. The egg case is made of a mixture of sand and jelly hardened to a pliable layer 1-2 mm. thick, in which is deposited a single layer of egg capsules. These are small clear globes of jelly producing slight bulges on the inner and outer surfaces of the collar (Fig. 56). The collar is characteristic in form resembling an inverted basin with the bottom out and a portion missing from one side or an old-fashioned detachable shirt collar. The collar always lies with its widest diameter on the surface of the sand.

In figure 15 the end of the collar labelled "a" is invariably thickened and jagged, and is apparently formed first. Its capsules appear in a row just inside its border.

The end labelled "b" tapers off usually into a thin layer, often of just clear jelly or with widely and irregularly spaced capsules. This is the end which is found attached to the snail when the collar is being made. The wide spacing of the capsules would indicate that this was the end at which they were inserted into the jelly layer

and that the snail lays all its mature eggs in one collar.

The arc of most of the completed collars ranged from 180° to 360°. A small number of collars had overlapping ends, and others were less than 180°. It is possible that the latter were sometimes fragments of larger collars. Later in the season, many collar fragments were seen in the eelgrass region.

The upper rim of the collar is straight, and capsules are present almost to the edge. The lower rim is irregularly wavy with a rim about 1/4 " wide in which no capsules are present. An occasional collar was found in which the snail had not secreted sufficient sand; the clear jelly of the capsules was visible and the egg within.

Some writers have described the making of the collar, though the process seems to take such a time that none have been able to see it from beginning to end. Most collar-formation was observed in the early morning and in these cases the collars were almost complete, indicating that the snail probably does most of the work in a single night. During collar-formation the snails were found partially buried in the sand. The collar came up and out from the snail, the plane of the collar being perpendicular to the sand surface. When a collar was finished before an incoming tide it remained in this position and could easily be noticed on the flat. The tide moved it into the normal position (Fig. 17).

The egg capsules are packed tightly together in irregular order, not in rows; they vary in diameter from less than one to almost two mm. There is usually a single egg in a capsule (Fig. 24) but frequently capsules with two, and rarely with three and four eggs were found. The larger capsules are sometimes found in the rows along the bottom rim of the collar; these, however, contained no more eggs than those of normal size.

Table 8 shows the calculated numbers of capsules and eggs contained in a series of "A" collars.

Since the height of the collar varies around its circumference that given in table 8 is the average height. Under "eggs per capsule" a figure with a plus sign indicates that capsules were found in that collar which contained more than one egg. Capsules per collar would also give the minimum number of eggs per collar. The "A" collars examined varied from 0.9 to 2.3 cm. in height from 4 to 40 sq. cm. in area and from 180 to 1200 in number of capsules.

The area of collars from St. Andrews, N.B. was less than those from Belliveau Cove, but the Capsules were smaller and therefore the number per square cm. higher and the total count about the same as in other areas (Fig. 16). These collars were also more brittle, of a rougher texture, and often with reddish particles in them. These differences could be due to the difference between the soil at St. Andrews and Belliveau Cove.

(b) Type "X" Egg Case: This egg case is constructed on the same general plan as the "A" type. Although it has a turned down lower margin and a turned up upper margin compared with the "A" which tends to be straight-sided (Fig. 19 and 20). It lies on the sand with the wide diameter down but is far less inclined to be buried than the "A". Its surface is smoother and grayer in colour than the "A" collar. It is also more flexible and thinner, seldom being over 1 mm. in thickness. The capsules are small in diameter with higher numbers per cm.<sup>2</sup> of the collar. They do not show as bulges on the collar surface as the "A" capsules do (Fig. 15 and 36). The sand grains appear to be fewer than those used in the "A" collar. The upper rim is again smooth with the capsules right up to the edge; the lower rim is irregular (Fig. 19 and 20).

Unlike the "A" type, the capsules in the "X" collar are packed together as closely at the end last formed as at the beginning. The number of capsules per cm<sup>2</sup> of collar was high compared with "A" collars (Table 9).

The formation of this collar was never observed. However, one was observed one afternoon in the position of a newly laid collar as described for the "A" snail. It was in an area 25 yards from high water mark between piers 1 and 2. This area was dotted with "A" collars and heavily populated with "A" snails. No other "X" collars were found there. About 4" below this collar was found a female snail of the "B" variety and this snail is assumed to have produced this

collar. When examined later the eggs were found to be in the 2-4 cell stage of development.

Table 9 shows some of the physical characteristics of the "X" collar, and Table 10 compares the two collars. There is a great difference in their size and number of eggs they contain.

(c) Collar Distribution: An attempt was made to study the distribution and concentration of the "A" collars on the flat. At different times, the collars in an area of 100 square yards were counted at different levels (stations) on the beach, and the concentration calculated. Figure 1 shows the positions of these stations. This was undertaken as a regular program beginning June 11 and the observations are summarized in table 11.

Table 8. Summary of observations on 50 egg cases of the "A" type.

No.	Date collected	Av. Ht. collar cm.	Area of collar cm. <sup>2</sup>	Capsules per cm. <sup>2</sup> Av no.	Eggs per capsule Av. no.	No. of capsules per collar (calculated)	Where collected
1	June 19	1.6	15	36	1	540	Belliveau cove
2		1.8	13	37	1+	480	
3		1.7	16	44	1+	700	
4		1.9	18	37	1	670	
5		1.8	18	32	1+	580	
6		1.7	14	38	1+	530	
7		1.8	24	43	1	1030	
8	June 21	1.5	15	35	1+	530	Major's Pt.
9		1.8	14	43	1	600	
10		1.7	12	40	1	480	
11		2.0	18	27	1	490	
12	June 26	1.7	15	33	1	500	
13		1.5	14	40	1	560	
14		1.3	9	39	1	350	
15		1.4	12	45	1	540	
16		1.4	12	46	1	550	
17		0.9	5.3	47	1	250	
18		1.7	15	42	1	630	
19		1.4	11	43	1	470	
20		1.3	8.6	48	1	410	
21		1.2	7.5	45	1	340	
22		0.9	4.8	47	1	230	
23		1.4	13	49	1	640	
24		0.9	6.2	38	1	240	
25		1.4	8.4	48	1	400	
26		0.9	6.0	44	1	260	
27		0.9	5.3	40	1	210	
28		1.2	8.5	45	1	380	Belliveau cove
29		1.6	15	44	1	660	
30		2.0	21	40	1	840	
31		1.4	10	35	1+	350	
32		1.8	25	30	1+	750	
33		1.9	25	38	1+	950	
34		2.0	25	38	1	870	
35		2.0	19	37	1	700	
36		1.6	21	42	1	880	
37		1.9	26	45	1	1200	
38	July 16	1.5	10	55	1	550	St. Andrews A.B.S. Flat
39		1.5	9.6	49	1	470	
40		1.9	18	45	1+	810	
41		1.5	10	48	1	480	
42		1.1	5.6	55		310	
43		1.3	6.9	40	1	280	
44		1.4	5.3	50		470	
45		1.6	10	47		470	
46		1.5	10	45	1	450	
47		1.5	11	47	1	520	
48		1.2	6.9	43	1	300	
49		1.0	4.1	43	1	180	
50	Aug. 3	2.3	40	18		720	Belliveau cove
Average		1.5	13.5	42	1	540	

Table 9. Summary of observations on 12 egg cases of the "X" type.

No.	Date collected	Av. Ht. of collar (cm.)	Area of collar (cm <sup>2</sup> )	Av. No. capsules per cm <sup>2</sup>	Av. No. eggs per capsule.	No. capsules per collar (calculated)	Eggs per collar	Where collected
1	June 18	4.5	70	90	40	6300	250,000	Belliveau Cove
2	July 9	3.7	66	100	33	6600	220,000	Dock 1
3	" 19	3.7	41	100	21	4100	86,000	Seagrass region
4	" 20	3.5	53	90	21	4800	100,000	Off pier 1.
5	" 22	2.8	28	80	21	2200	46,000	Near Weir 2
6	" 22	4.8	86	90	24	7700	185,000	
7	" 22	3.5	40	85	19	3400	65,000	
8	" 22	4.5	61	80	33	4900	160,000	
9	" 22	4.5	88	100	31	8800	270,000	
10	" 22	5.0	105	85	42	8900	370,000	
11	" 22	4.8	93	80	47	7400	350,000	
12	" 22	4.7	77	90	33	6900	230,000	
<u>Average</u>		4.2	67	89	30	6000	194,000	

Table 10. Comparison of collars of "A" and "X" types.

Collar	Av. Ht. (cm.)	Av. area (cm <sup>2</sup> )	No. capsules per cm <sup>2</sup>	Av. No. eggs per capsule	Av. No. capsules per collar	Av. No. eggs per collar
A	1.5	13.5	42	1	540	540
X	4.2	67	89	30	6000	194,000

Table 11. Showing results of surveys of abundance of collars at various stations at various times during the summer.

Sta. No.	Collars per sq. yd.				Description of eelgrass in vicinity
	June 11 1946	June 26	July 19	August 16	
1 (Near H.W.M.)	0.0018	0	0	0.01	None
2	0.15	0.23	0.37	0.33	None
3	0.05	0.19	0.35	0.25	Sparse
4	0.14	0.555	1.1	1.3	Thick
5	0.0252	2.00		0.14	Sparse
6		1.4		0.67	None
7 (Near L.W.M.)		0.20		0.12	None

General observations carried on previous to June 11 showed that collars began to appear in important numbers about June 5. Few newly laid collars were found after the middle of August, though at the end of August a few were still appearing. From table 11 it may be seen that there was an increase in the concentration up to at least the third week in July. By this time most of the season's crop of collars appears to have been laid. In other words most of the egg laying took place in 2-2½ months. Few collars were found on the open flat at the level of Station 1 which was close to the shore in an area densely populated with clams. However, between piers 1 and 2 they came to within thirty yards of high water mark. Many snails were observed at station 4 in the eelgrass at night, but the abundance of collars there was lower than expected perhaps as a result of breakage which seems to have been unusually high there. It was often difficult to tell whether a collar was whole or a fragment of the original.

So few of the "X" type of collar were found that no conclusion can be made as to the time of their appearance. The first was found on June 18, and the remainder throughout July. In August those seen on the flat were breaking up. One was discovered 50 ft. from shore in dock 1, but the remainder were found in the rocky area of the cove and at the level of stations 7 and 8. There was no heavy concentration in the eelgrass area. Most of them were found either in rocky places or on the bare sand.

### 3. Larval Development.

#### (a) Larval Development in "A" Type.

(1) Embryology: This was not studied in great detail, but the general development from the time the eggs were laid until the release of the larvae was followed.

The egg is a spherical yellow body about 0.35 mm. in diameter suspended in the clear, transparent, firm jelly of the capsule. Each capsule is separated from those around it by a thin hardened layer of sand and clear jelly, so it is possible to study the development of individual eggs microscopically without resort to special devices except occasionally paring away the upper faces of capsules with a razor blade to clarify vision.

Shortly after being laid the egg goes through the two and four cell stages, then cell division becomes irregular with a small plate of cells forming on top of three or four large cells (Fig. 21-26). After this stage development became so complex that no definite form could be distinguished until the shelled veliger stage shown in figure 27. This form has a height of about 0.5 mm.; the velum moves constantly; the cilia beat rapidly and the larva if removed from the capsule and placed in sea water will swim about slowly. From this stage onward the shell develops a reddish-brown colour. By this time a half whorl of shell has developed, the dextral twisting (Fig. 29, 30 and 43) is quite clear. The operculum which was present in figure 27 is now well formed so that when the foot and velum are withdrawn into the shell it

completely fills the shell aperture. The velum disappears when about  $\frac{3}{4}$  whorl of shell has developed. By the time the larva has  $1 \frac{1}{3}$  to  $1 \frac{1}{2}$  whorls it is ready to leave the capsule. At this stage it is 0.9 - 1.0 mm. in height and of a reddish-brown colour. The foot is quite active now so when a snail that has just emerged is placed on sand, it begins to burrow at once. At this time it is able to drill clam spat as long as itself and devour the contents (Fig. 32-35). Apparently this variety normally has no free-swimming phase in its life cycle.

An attempt was made to determine the length of time required for development from the egg to the 1 mm. size by identifying individual collars that could be kept under observation. The waves shift loose collars considerable distances which makes it impossible to keep track of them by positions alone. Tethering selected collars to a stake by three-foot lengths of cotton thread was unsuccessful because the thread cut through the collars as a result of wave action. Finally covered wire cages were constructed of  $\frac{1}{4}$ " mesh wire cloth. The sides of these were set into the sand, deep enough to anchor them firmly, and still leave a space  $\frac{3}{4}$ " deep between the surface of the sand and the top of the cage. Several collars studied were marked by cutting identifying notches into the upper and lower margins. Provided the notches were not deep enough to weaken the collars seriously they proved satisfactory identification marks.

The wire cages did not provide an environment identical with that of the open flat, for it had a tendency to silt up, thus burying the collars. However, this effect is not considered to have seriously affected the development of the eggs. Seven "A" collars from Belliveau cove in the 1-4 cell stage and three "A" collars from St. Andrews judged to be about 2 weeks old were placed in a cage on July 18. By August 12, the larvae of the Belliveau cove collars had the form shown in figure 26. The collars originally gray in colour were beginning to turn brown and become soft. On close examination it was found that the eggs in many of the capsules had failed to develop. Instead, these capsules appeared to contain filaments of a brown alga. Tufts of filaments were found on the outside of the cases. On the 28th of August the observations had to be terminated at which time the Belliveau cove embryos were just beginning to develop the reddish shell and the St. Andrews collars had  $1/3$  whorl of shell. Considering these times, it took about six weeks for the embryo to grow from the egg to a snail with  $1/3$  whorl of shell. Probably another 2-3 weeks are needed for the addition of another complete whorl at which time the larva is ready to leave the collar. Thus the total development period for the "A" snail larva is estimated as at least two months and possibly three months. At no time during that period is it <sup>free-</sup>swimming.

The collars when they first appear on the flat are firm gray structures lying on the surface of the sand. In the following weeks they developed a brown shade and grew soft, as a brown alga appeared on them. At the same time they were partly buried in the sand. That part of the collar below the surface was often the most solid. Many of the older collars may be almost completely covered with sand. In the end they crumbled away, releasing the small snails. The first collar was observed releasing snails onto the surface of the sand on August 26 (Fig. 18), so none of the 1946 age class were represented in the samples studied for size-composition.

Throughout the season the collars were observed on different parts of the flat to see if there was any great differences in rate of development. The tide left the upper part of the flat for 4 hours at a time, but as it receded enough water was left lying on the sand that very few of the collars ever completely dried up, although their upper  $\frac{1}{2}$ " would dry out. No remarkable differences were observed in the rate of development at different beach levels.

(11) Collar Rot: Larval Mortality:

It was found that in most collars, only a small percentage of capsules ever succeeded in producing snails. At a maximum this is estimated at 30%. Most of the embryos degenerate about the time the brown alga attacks collars. A degenerate capsule often assumes a bright yellow colour (Fig. 36 and 37).

This "rot" was most noticeable in the upper parts of the collars, which were subject to drying at low tide. The greatest number of healthy embryos appeared to be at the level where the collar entered the sand.

About 550 embryos per collar begin development (Table 8) but on the average probably not more than 160 survive. Taking 0.25 per square yard, a rough estimate of abundance of collars in the area just east of weir 1 on August 16, the annual recruitment to the snail population would be about 40 per square yard or about 200,000 per acre.

(b) Larval Development in "X" Type.

(1) Embryology: The egg is a spherical white body about 0.1 mm. in diameter and there are usually about 30 eggs per capsule. The capsule itself has a transparent membranous wall and the contents flow out if the membrane is broken.

Shortly after being laid, the eggs begin to divide and develop in a manner similar to that described for the "A" type embryos until they can be seen moving within the capsules. This stage is illustrated in figure 31. When first released into salt water after artificial rupture of the capsule they appeared inactive. However, in a few minutes they began to swim about quickly moving in short arcs, the velum extended. This form has a very thin transparent shell and an agile foot. When disturbed it quickly withdraws foot and velum into the shell. It is at this half-shorl stage that the larvae are presumed to

to escape from the capsule (Fig. 39 to 42), since no more advanced larvae were found in any of the collars studied.

Attempts were made to determine the length of larval period and to study hatching in caged collars. Unfortunately, an accident to the wire basket resulted in the loss of all but one of the "X" type collars that were under observation. The only record of hatching is from the first collar collected. This was kept in a salt-water aquarium in the laboratory at an average temperature of 20°C. Judging from the form of the embryo this collar was only a few days old when collected. Eight days later it began to crumble and the free swimming larvae escaped in clouds into the jar. Together with observations on the time it took "X" collars to break up on the flat, it is probable that the incubation period averages one month to six weeks; that is, only half the time required for the "A" type.

In an effort to collect naturally-produced free-swimming "X" larvae a #18 mesh plankton net was towed repeatedly in water directly over collars which were breaking up. Many tows were made near weir 2 where the greatest number had been found, but no larva was ever picked up in this way. Of course, only a few collars of this type were present even here which may explain the futility of the trials.

On one occasion the sand from around the base of an "X" collar which was breaking up was examined in a watch glass filled with seawater. Numbers of half-whorl larvae were found

on the sand (Fig. 42). They extruded their vela and rotated slowly but did not swim up actively as they did in the aquarium, nor did they burrow as the "A" type were observed to do. From these observations there is still doubt as to whether or not the "X" collar produces <sup>under natural conditions,</sup> a truly free-swimming veliger larva. This point warrants further study.

(ii) Collar Rot: Like "A" collars, the "X" type were at first firm gray structures although considerably larger and more flexible. They, too, began to turn brown a week or two after deposition as a result of algal growths which appeared first on the bottom half of the collar. The part remaining above the surface of the water at low tide retained its lighter gray colour. When "X" collars were kept in the laboratory aquarium the same differentiation appeared even though they were completely immersed at all times. The brown alga also appeared in small colonies on the inside of the aquarium. It may be Ectocarpus.

Most of the larvae in the upper parts of the collars degenerated, even while those in the lower half were developing vigorously. The boundary in the collar separating dead and living embryos corresponded roughly with the boundary between the gray and brown areas. On the flat the brown alga spread eventually throughout the whole "X" collar.

Unlike the "A", the "X" type collar always remained on top of the sand, sometimes in a depression, but never buried in sand.

It was difficult to calculate the percentage of "X" capsules producing live embryos. Fifty per cent would be a rough estimate. On this basis each collar would yield about 90,000 embryos presuming 100% survival of all embryos in those capsules which came through.

#### 4. Association With *Nassa trivittata*.

This gastropod was found in great numbers on the flat, some by day and many more by night. It was never seen drilling a shellfish, but appeared to be a scavenger. On June 19 and for the remainder of June, July and August, the egg case of this snail appeared on the "A" and "X" collars, and occasionally on the blades of eelgrass. They were 2-3 mm. high, of the shape illustrated in figure 28. The wall is tough and gelatinous with sharp spines and angles enclosing about fifty eggs. The cases were laid in a double row or irregularly on outer or inner surface of the collar, sometimes in such numbers as to cover the surface completely (Fig. 38). In August the young began to emerge in the veliger stage, swimming out of a small round hole in top of the case. This larva was so like that of the "X" type *Polinices* that the two were often confused. The only noticeable difference was that the surface of the first half-whorl of the "X" larva appeared roughened. In *Nassa* this appeared perfectly smooth.

IV EVIDENCE OF TWO VARIETIES.

There is no doubt in the writer's mind as to the specific distinctness of the two snails described in this report as types "A" and "B". The two are compared summarily in table 12 below. They should be identified by a competent conchologist.

Table 12. Comparison of the two types of Polinices.

Character	Type "A" ( <i>P. triseriata?</i> )	Type "B" ( <i>P. heros?</i> )
<u>Shell</u>		
1. Shape	Spire relatively obtuse; Aperture relatively wide.	Spire relatively acute; Aperture relatively narrow.
2. Colour	Young has triple row of dots; older animals have three unbroken bands of colour.	Young, faint bands but no spots; old, no colour bands apparent.
3. Ultimate size	About 30 mm. for females.	60+ for females.
4. Lip character	The lip thickens after a height of 16 mm. is reached by males and 24 mm. by females.	The lip does not thicken to the same extent as in the "A" type.
5. Growth in height	After the lips begin thickening growth in height practically ceases.	Growth is indeterminate.
<u>Soft Parts</u>		
1. Foot colour	Normally the extended foot appears white and is white when contracting.	Normally the foot appears pinkish and is black when contracting.
2. Penis	16 mm. males have a large penis.	16 mm. males have a small penis.
<u>Mating Behaviour</u>	"A" mates only with "A".	"B" mates only with "B".
<u>Egg Cases</u>	(Type "A")	(Type "X")
1. Size	Small, average area 13.5 sq. cm.	Large, average area 67 sq. cm.
2. General character	Thick; brittle; opaque; contains much sand; cap- sules protrude on both sides making the surface humpy.	Thin; pliable; translucent; less sand in texture; surface quite smooth.

Table 12. (Continued)

Character	Type "A"	Type "X"
3. Burial of collars	Collars bury in sand.	Collars never bury in sand.
4. Number of capsules per cm. of surface	42	89
5. Eggs	Large (Diameter 0.35 mm.); 1 per capsule.	Small (Diameter 0.1 mm); 30 per capsule.
6. Laying activity	"A's" often observed making "A" collars but never "X" collars.	Circumstantial evidence that "B's" make "X" collars; no evidence that they make "A" collars.

Development

1. Incubation period.	Roughly 6-8 weeks.	Roughly 4 weeks.
2. Larva	Veliger stage passed in capsule; velum lost before emergence.	Emerges as a veliger that can swim.

V AGENTS DESTRUCTIVE OF SNAILS AND EGG CASES.

1. Of Snails

(a) Mechanical Damage: Occasionally a snail is found with the shell so badly broken in the lip area that some of the soft body parts are exposed even after the animal has retreated as far as possible into its shell. In this condition the exposed parts are attacked by small crustaceans which eventually destroy the snail. This type of breakage is not frequent and causes of it are unknown.

(b) Surf: Occasionally after a storm live snails are found in the windrows of shells that are thrown up with other wrack to dry out above high water mark. These snails are nearly always of small size constituting those which live in the upper inch or two of sand. Presumably some of these return to their former positions after the storm especially if the blow takes place at low water and does not drive them too far up the beach. From what was seen in 1946 the number of snails killed in this way is seldom if ever large.

(c) Birds: Gulls, like owls, have the habit of swallowing their food whole and later regurgitating pellets of indigestible matter which work forward from the stomach into the gullet during digestion. Examination of pellets often provides information on the food habits of these animals. In some districts pellets may be collected from rocks where the birds roost after feeding. At Belliveau cove, however, the gulls stand around on the flats a good

deal at low tide and their pellets may be found on the sand. In most cases they were found to be composed almost entirely of fragments of shells of soft-shelled clams, but several were found to contain Polinices. Three of these had the following composition:

(1) 66 Polinices (type "A") from 2 to 10 mm. in height; small fragments of crab shell; 36 of the snails were entire with the opercula still attached; the other 30 showed varying degrees of breakage.

(2) 48 Polinices, from 2 to 9 mm. in height; of these 10 were entire.

(3) 8 Polinices - one 23 mm. and three 15 mm. high; the others were small. The larger snails showed shell fracture and torn opercula as if the gull had tried to pick out the meat before swallowing the snail. From observations made so far it is not considered that gulls are important enemies of Polinices because they feed during the day when the snails are buried and because so few pellets contain their remains. The feeding of gulls on the flats should be more carefully studied.

(d) Man: At one time Polinices was collected at night by lantern light and used as bait for line trawl, but it is several years since any quantity has been taken for this purpose. Man has consequently ceased to be an enemy. Probably P. heros was the species most used because of the larger size.

## 2. Of Collars

(a) Algae: Without doubt the most important agent destructive of snails is the brown alga (Ectocarpus?) which attacks the egg cases. By invading the collar and destroying the eggs it greatly reduces the number of young that hatch. Furthermore, the presence of the filaments apparently fosters the burial of the egg cases by sand and may possibly lead to smothering and death of the eggs and larvae developing in the capsules.

(b) Crustacea: Two small Crustaceans, Gammarus (?) and Chiridota, are often found on the inner surface of collars which are rotting. Although they were not observed destroying collars, they may have some damaging effects.

(c) Surf: Collars are often washed up on the beach in the surf, and the eggs are killed by drying out. On August 2 after a heavy blow, 66 newly dried out collars were found at high water mark on a hundred-foot stretch of beach near pier 1 (Fig. 1). No attempt was made to estimate what proportion this constituted of the total number of collars on the beach opposite.

(d) Birds: Though there are many gulls on the flat during the summer there is no evidence that they disturb the collars in any way.

(e) Man: The local people did not know what the collars were, and did them no harm.

VI FEEDING HABITS

1. Type of Food:

Polinices feeds on soft-shelled clams, bar clams, common mussels, other bivalves, and numerous gastropods including its own kind. At Belliveau Cove drilled Purpura and Littorina shells were found in great numbers.

2. Method of Feeding:

The snail eats its victim by first boring a neat, counter-sunk hole through the shell. Good photographs of drilled shells have been published by Mead (1903 and 1904), see also figure 45 of this report. After completing the hole the snail presumably inserts the proboscis and devours the flesh. The hole is bored by rasping <sup>with</sup> the slender file-like tongue, or radula, perhaps aided by acid in the saliva. In eating shellfish other than mussels, the snail cups the ventral surface of the posterior part of its foot firmly about the victim. The foot is then doubled forward ventrad so the radula can come to play on the shell. If the snail is disturbed when feeding, the "cup" of the foot enclosing the victim quickly unrolls and the shellfish drops out, it is then found to be completely covered with a slimy envelope except for a bare spot where the radula has been rubbing against the shell (Fig. 45).

When the snail attacks mussels the method of feeding is usually different since they are attached to some substrate by the byssus and cannot be freely enclosed by the gastropod's

foot. Instead, the snail forms the foot into the shape of a disc and apposes this to the side of the mussel. By holding on with the disc it is able to keep the radula over the same spot and drill the shell. In this way any size of mussel may be attacked by any size of snail. This is shown by the fact that large mussel shells are often found perforated with very small holes. The largest holes observed were 2 mm. in diameter. The snails regularly congregate about beds of small mussels which are consequently excellent places to collect the snails at night.

Either valve of the shellfish was chosen for the boring (Table 13). In the soft-shelled clam and the mussel, the drill hole is usually slightly posterior to the umbone and closer to the umbone than the free margin of the shell. With bar clams over 2 inches in length, the hole is often on the umbone of either valve. Belding (1930) states that the point of perforation varies but is usually toward the siphon end (posterior).

Feeding took place both by day and night (Table 13). Snails were dug up from 1 to 6 inches below the surface during the day with clams grasped firmly in the foot. At night feeding took place extensively on the surface. Often snails were observed lying on the surface with clams they were drilling enclosed in the foot, but just as often, particularly with snails 17 to 24 mm. high, they travelled along the surface with the clam held in the posterior part of the foot, the lower valve of the clam shell thus dragging

Table 13. Summary of field observations on drills and their prey.

No.	Date	Time of Day	Shell-fish	Shell- Length mm.	Shell Height mm.	Drilling	Diam. of Hole mm.	Valve	Remarks
1	May 26	?	S.S.	20	23	Comp.	2	?	
2	29		Mussel	26	23	Nil			
3	June 5		S.S.	13	20	Comp.	2	R	
4	13		Mussel	32	25		3	R	
5	13		S.S.	26	22		2	L	
6	13	?	Mussel	25	24	Comp.	2	R	S.S. = Soft-shelled clam
7	18	Night	S.S.	20	13	Inc.	1	R	Bar = Bar clam
8	18		...	21	21	Inc.	2	L	Comp. = Complete
9	18			24	20	Nil			Inc. = Incomplete, not perforated.
10	18			18	20	Inc.	2	R	
11	18			23	16	Nil			
12	19	Morning		24	25	Nil			
13	19	Night		20	21	Inc.	2	R	
14	19			19	17	Comp.	1	R	
15	19			19	16	Nil			
16	20	Morning		22	19	Nil			
17	22			18	15	Inc.	1	R	
18	July 1		S.S.	24	17		1	L	
19	1	Night	Mussel	9	7	Inc.	.5	R	Mussel grasped in foot.
20	1		Bar	8	17	Nil			
21	3		Bar	41	33				
22	3		S.S.	26	23				
23	3			19	15	Nil			
24	3			25	18	Comp.	2	L	All eaten but siphon, digestive gland.
25	3			19	17	Comp.	1	R	All eaten but posterior 2/3 of mantle.
26	3			23	15	Nil			All gone but mantle and digestive gland.
27	3			27	20	Comp.	2	R	All eaten but siphon, digestive gland.
28	3			17	15	Nil			All gone but siphon, digestive gland.
29	3			20	19	Nil			
30	3			21	13	Comp.	1	R	All eaten but siphon, digestive gland, mantle, anterior suctor muscle.
31	3			21	19	Nil			
32	3			21	16	Nil			
33	3			24	20	Comp.	2	R	See 30.
34	3			22	21	Inc.	2	L	
35	3			24	15	Nil			
36	3			21	16	Comp.	2	L	See 30.
37	3		S.S.	20	16	Nil			
38	July 3	Night	S.S.	20	14	Nil			All gone but siphon, stomach.
39	10	Day		18	14	Inc.	2	R	Found 1/2 inches below surface.
40	12			20	25	Comp.	2	L	Found 1 inch below surface, all eaten but siphon.
41	12			19	20		2	L	Found 1/2 inches below surface, all eaten but siphon.
42	12			18	18		1	R	Found 3 inches below surface, all eaten but siphon.
43	12			23	22		2	R	Found 3 inches below surface, un eaten.
44	Aug. 23	Night	S.S.	37	38	Comp.	4	L	All eaten but siphon tip.
45	25	Morning	Mussel	27	29	Nil			Mussel held in the foot.
46	25		S.S.	35	35	Comp.	4	R	
47	25			31	24	Nil			On surface.
48	25			26	23	Nil			On surface.
49	25			25	18	Inc.	2	L	On surface.
50	25			19	21	Nil			On surface.
51	25			21	20				On surface.
52	25			21	21				On surface.
53	25			16	17				On surface.
54	25			23	18				On surface.
55	25			26	19				On surface.
56	25			25	19	Nil			On surface.
57	25			20	22	Inc.	1.5	L	Paint outline of boring.
58	25			18	18	Nil			On surface.
59	25			22	19				On surface.
60	25			24	19				On surface.
61	25			25	18				On surface.
62	25			24	18				On surface.
63	25			23	17				On surface.
64	25			20	21				On surface.
65	25			21	21				On surface.
66	25			15	15				On surface.
67	25			17	20				On surface.
68	25			20	21				On surface.
69	25			17	14				On surface.
70	25		S.S.	20	17				On surface.
71	19	Day	Bar	36	43				On surface.
72	25	Night	Bar	79	66				On surface.
73	25		Mussel	54	48	Nil			On surface.

along the sand. Occasionally snails were observed burrowing into the sand with a clam held in this way as if retiring to feed. In most cases clams rescued from this position had not yet been bored. This behaviour of holding clams in the back part of the foot while moving along was observed only in the "A" snail. The larger "B" type always were rolled up into a ball with the cupped foot curved round enclosing the shellfish and never travelled about with their victims.

From table 13 it may be seen that usually certain parts of the clam meat were not eaten. Most often untouched were the tough ends of the siphon and the mantle-edge. The dark digestive gland was frequently left alone and perhaps the adductor muscle.

### 3. Destructive Capacity:

(a) Estimates from screened samples: Efforts were made to determine roughly the importance of drills in regulating the size of populations of bivalves by counts of the numbers of living and dead specimens in the upper six inches of sand. Samples of the upper three inches of sand from several areas inshore from wier 1 were screened and the shells and shellfish contained were separated into the several categories shown in table 14. Most of the specimens ranged from 1 to 3 cm. in length.

Table 14. Summary of observations on screened samples of clams and shells, August 8, 1946.

Condition of clams	Variety of Clam			Total
	Soft-shelled Bar	Tellina	Unknown	
Alive	0	4	1	5
Dead, not bored	12	1	0	13
Dead, bored	176	9	0	186

The results indicate:

- (1) Drills are responsible for a high proportion (up to 90%) of the deaths of small bivalves in Belliveau Cove.
- (2) Of the several species studied, soft-shelled clams are the hardest hit in proportion to their numbers.
- (3) It is possible for the drills to completely eliminate soft shells before turning to other prey.
- (4) Nevertheless, 9 out of 10 dead bar clams were killed by drills.

It should be borne in mind that the above conclusions are based on the assumption that the samples included all the living clams in the areas sampled, and that the shells of all the dead shellfish remain intact and buried in the sand. No observations were made to determine how long empty shells persist in the sand before disintegration. Consequently, the basis is lacking for an estimate of the time interval during which the observed destruction took place. Limited

experience suggests that for small shells of this size it is not more than two years, and often less.

(b) Estimates from study of shells from beach wrack: There is a great abundance of soft-shell clams of the 1943 "set" on the flats and almost none of earlier year classes. By 1946 these had attained an average length of 2.5 cm. A random sample of 100 empty shells of this size whose valves were still joined and unbroken, was taken from beach wrack. From their general appearance these were assumed to be from clams that had set in 1943 and died during the current year. Similar counts were made on a sample of 50 mussel shells. The results appear in table 15.

Table 15. Summary of observations on samples of shells in beach wrack.

Kind	NUMBERS		
	Examined	Bored	Not Bored
Soft-shelled clams	100	33	77
Mussels	50	42	8

These records indicate:

(1) That in clams of "seed" size at least one third of the mortality can be attributed to destruction by Polinices.

(2) Comparing this estimate with that from the study of screened shells which were on the average much smaller, it would appear that large clams are less subject

to attack by the snail than the small.

(3) Of the agents that kill mussels without destroying or removing the shells from the flats, Polinices is by far the most important. From the point of view of the clam industry it is fortunate that the snail kills mussels because they are regarded as pests which would soon cover the flats if unchecked.

It may be noted here that many drilled mussel shells are pierced by more than one hole. Apparently two or more snails often attack the same mussel. This is possible because the byssus prevents the mussel from being completely surrounded by the foot of a single attacker.

4. Size-relationships of Drills and Prey:

On August 6, newly-emerged young of "A" snails which are approximately 0.9 mm. high and have about 1 1/3 whorls, were observed to drill newly-settled clam spat about 1 mm. in length that were held in the laboratory. The actual process was not observed but it is presumably the same as that involving <sup>large</sup> snails. It is presumed that these clams are the newly-settled seed-of-the-year. Table 16 summarizes information on these.

Table 16. Summary of observations on newly-emerged snails and their prey.

<u>No.</u>	<u>Ht. mm.</u>	<u>Length of spat mm.</u>	<u>Diameter of hole mm.</u>
1	0.9	0.75	0.16
2	0.9	0.85	0.2
3	0.95	0.8	0.15
4	0.9	1.0	0.15
5	0.9	0.8	0.15
6	0.9	0.85	0.16
7	1.1	1.2	0.15
8	0.9	0.9	0.2
9	0.9	1.0	0.17
10	0.9	0.95	0.15
11	0.95	1.5	0.15
12	0.95	1.5	0.16
13	0.9	1.2	0.15
14	0.9	1.0	0.18

Other records on the size-relationship of prey and predator were compiled from observations on the flats (Table 13).

Combining the two sets of data it appears that the size of the hole drilled varies directly as the size of the snail making it.

Using data from tables 13 and 16 the curve in figure 46 was constructed. From the curve it may be seen that over the whole range the size of shellfish attacked varied directly with the size of snail and that snails generally attack clams whose lengths are 1.1 to 1.2 times their own height.

During the study of feeding habits it appeared that there was a maximum to the size of clam that could be attacked by a snail of a given size because it would be physically impossible for a small snail to wrap its foot around a large clam. The unusual feature of the relationship is the slight tendency for large snails to attack small clams though there would appear <sup>to be</sup> nothing to prevent this. The fact that it occurs to some extent accounts in some measure for the scattering of the points about the curve in figure 46. All shellfish mentioned in table 13, including the mussels, were found either completely enclosed in the foot or held in the posterior portion.

It is not known whether the small snails referred to in table 16 completely enclose the spat or not. They fed below the surface of the sand in vials and were not observed directly because at the slightest disturbance they withdrew into their shells.

For a given size of "A" snail the size of clam attacked varied somewhat. For a 17 mm. snail it ranged as much as from 15 to 25 mm., for smaller snails it seldom varied this much.

Belding (1930) reports that a  $\frac{1}{2}$ " Lunatia can destroy a clam 1" long. (See point in figure 46.) Our evidence indicates that this seldom happens. He also states that a  $1\frac{1}{2}$ " (38 mm.) Lunatia cannot operate on a clam over 2" (51 mm.) in length, which accords with our findings.

5. Rate of Drilling:

(a) With small snails: In studying rates of boring by snails of different sizes many attempts were made to observe them directly by keeping them in aquaria with sand in the bottom and frequent changes of sea water. Running water was not available. Different sizes of aquaria from battery jars down to vials were used. With the exception of the freshly-hatched snails which fed on clam spat as described below, these attempts were unsuccessful. The snails would merely bury themselves in the sand.

On August 6, eleven "A" snails 1 mm. in height were put on sand in a watch glass and covered with water, and several spat 0.8 to 1.5 mm. long were added. The snails burrowed below the surface. The watch glasses were left undisturbed without a change of water for 11 days. When the sand was then examined six clam spat of about 1 mm. in length were found bored. This is a mean destruction of 0.05 clams per snail per day but the test was not critical.

An attempt was then made to see how many clam spat a newly hatched snail could kill per unit of time. Dried sand to a depth of  $\frac{1}{2}$ " and sea water to 1" were put into a number of <sup>small</sup> vials, to which were added several soft-shelled

clam spat of sizes varying from 0.9 to 1.5 mm., and one newly-hatched "A" snail. Often some of the spat were found climbing up the sides of the vials to the level of the water, sometimes at the rate of 2" in 10 minutes which, of course, made them inaccessible to the snails. Table 17 summarizes the results.

Table 17. Summary of data on destruction of clam spat by newly-hatched "A" snails.

Vial no.	Spat per vial	Snail height mm.	No. of spat bored	Time days	Length of spat mm.	Clams destroyed per day per snail
1	5	0.95	1	4.0	0.8	0.25
2	5	0.9	1	4.0	1.0	0.25
3	5	1.1	1	4.5	1.2	0.2
4	10	0.95	2	4.0	1.3, 1.5	0.5
5	10	0.9	2	4.0	1.05 1.2	0.5
Average						<u>0.34</u>

From these records it appears that a small snail kills 0.34 clams per day.

(b) With large snails: Older snails did not feed actively in a tank in the laboratory, probably due to the difficulty in simulating their natural environment. This limited the study of feeding habits to tests conducted on the flat.

At first, older snails and clams were placed together in large, flat wire baskets sunk in the flat. These trials were unsuccessful until a narrow wire cage of  $\frac{1}{4}$ " mesh, 4" in diameter and 12" deep with wire cover and wooden bottom was developed in mid-August. The cage was placed vertically in the soil with only the upper 4" exposed. Clams 18 to 22 mm. long were placed in the cage to a density of 1 per square inch of soil surface along with a single snail. The snails were selected for size so that the clams they were caged with were suitable, as regards size, for food (Fig. 46). The data accumulated are summarized in table 18. From these it appears that an "A" snail 20 to 30 mm. in height may destroy 0.2 to 0.7 clams every day at this time of year. This is a slightly higher rate of destruction than that observed in laboratory tests with very young snails. The "B" type may not be so voracious. More elaborate studies of this activity should be conducted.

Belding (1930) claims that a 2" snail presumably the "B" type, is the most destructive and kills 26 clams per month (0.8 per day). Present observations indicated that 20 mm. snails of the "A" type are not so destructive with a capacity of about 10-15 per month.

Table 18. Summary of observations on feeding of 6 individually caged snails.

Type of snail	Snail ht. mm.	Clams per cage	Days	No. of clams bored	Length of bored clam mm.	Clams destroyed per day per snail
A	20	6	3	2	18, 20	0.7
A	32	6	3	1	21	0.3
B	40	8	3	0	--	0.0
A	20	10	5	4	20, 21, 21, 22	0.2
B(?)	32	6	3	0	--	0.0
B	40	6	3	0	--	0.0

#### VII ECONOMIC ASPECTS

The basis for estimating the total destructive effects of the snails throughout the year is lacking because observations were limited to the warmest months of the year when feeding is probably at its peak. It is reasonable, however, to calculate what the "A" snails alone may have done in the summer months (June to September inclusive) in 1946, assuming a diet exclusively of soft-shelled clams, a uniform feeding rate and an abundant supply of food. The "B" type inhabited the lower part of the beach and appeared to feed chiefly on mussels and bar clams and will be neglected in this section of the report.

At times the abundance of snails observed on the surface at night was 4 to 5 per square yard over a good part of the

Belliveau clam flats. These drilling at a rate of 0.5 clams per day for four months would account for 270 per square yard.

The 1946 brood of snails was late emerging, appearing in numbers in middle and late August. Although these had only one and a half summer months left to operate, they were present in very large numbers estimated at 40 per square yard. In a forty-five-day period, killing seed clams at a rate of 0.3 per day, these could destroy 600 clam spat-of-the-year per square yard if they made clams their only diet. Probably both the above estimates are low because caged snails and snails in the laboratory tended to be less active in general than those in their natural habitats. Together, the large and small snails could account for close to 900 clams per square yard or 100 per square foot during the four-month summer season.

Considering these figures as they stand it is reasonable to assume that Polinices could be, and probably has been responsible for the low clam productivity of Belliveau cove during the past ten years. Such a condition warrants a thorough search for effective and practicable control measures.

More information is required on the food preferences of the snails and their activity at different seasons. It is not certain whether it is the young or old snails which are the most destructive because little is known about natural mortalities of seed clams during the first winter.

VIII CONTROL MEASURES

1. Control of "A" Type:

Of the two species present in the cove, the "A" variety seems to be the more destructive, but it might be relatively easy to keep down its numbers and thus reduce the damage it does by the two devices listed below.

(a) Collecting snails:

This could best be done manually at night using a light. The movements of the animals are so slight that it should be reasonably possible to keep the ground free of the larger snails by occasional systematic collections.

(b) Collecting egg cases:

This work could be done in the daytime and need not begin until late July because the brood-of-the-year do not emerge in numbers until August. The collecting of cases should continue until after deposition is over -- late August. Because small snails cannot move far and because "A" snails have no free-swimming larvae, any area is likely to remain free of young-of-the-year if the cases are gathered. This should protect the clam seed-of-the-year and have a good carry-over effect into the next season.

2. Control of "B" Type:

The control of the "B" type which is assumed to produce "X" type egg cases should be attempted in the same way. While the collection of adults would probably be helpful, it seems doubtful that "X" type egg-case collection would be as

effective as with the "A" variety. The "B" type free-swimming veliger larvae are probably transported a great distance by tidal currents and spread from area to area.

The effectiveness of these two control measures for the two varieties could be readily subjected to test and this should be done at the earliest opportunity.

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