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Title

1947 Investigations of Polinices and clams at  
Belliveau Cove, N.S.

Author

J. M. Wheatley

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1. INTRODUCTION

a) Polinices an enemy of commercially important shellfish. The works of several writers, among them Dr. J. C. Medcof of the Atlantic Biological Station, have shown the snail Polinices to be an enemy of commercially important shellfish.

b) Belliveau Cove visited in 1945. In 1945, Dr. Medcof, having twice visited the area that year, seems to have decided that Belliveau Cove, Nova Scotia, would offer a good opportunity to study the life history of Polinices and its effects upon the clam.

c) 1946 program. During the summer of 1946, Mr. R. H. Stinson spent three and a half months at Belliveau Cove investigating Polinices and aspects of its relationship with the soft shell clam and other bivalves. As may be seen from his report, some important findings were made by Stinson. He discovered that two species of Polinices, thought to be P. triseriata and P. heros, are present at Belliveau Cove (1); he investigated the growth rate of the snail, and the relationship between size-classes and age-classes, some aspects of reproduction and larval life, feeding habits, and other problems. Thus when continued study of Polinices and clams at Belliveau Cove was commenced by the present writer for the 1947 summer season, considerable work had already been accomplished, a fairly complete, if preliminary, survey of the field having been conducted.

d) 1947 program. The purpose of the 1947 investigation was 1) to continue some of the studies begun by Stinson, e.g., growth rate, including the relationship between size-class and age-class; feeding habits, including destructive capacity of the snail; reproduction and larval life; etc., and 2) to investigate the possibility of controlling Polinices on an industrial level, i.e., to consider whether such control would be both possible and worthwhile.

Work at Belliveau Cove in 1947 was begun on May 27 and terminated on August 27. Much of the program was carried out on the flat and therefore was largely governed by tidal movements. Some work could be accomplished during the day, while it was necessary to perform other duties nocturnally.

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(1) Although positive identification is lacking, the Polinices found at Belliveau Cove will be referred to in this report, with considerable justification, it is felt, as P. triseriata and P. heros.

## 2. BELLIVEAU COVE

a) Introduction. Belliveau Cove has already been described by Stinson, thus little need be said here. The cove is some twenty-four miles southwest of Digby, Nova Scotia, as reached by road on the main Digby to Yarmouth highway. Across St. Mary's Bay, part of the mainland shore of which is formed by mile-long Belliveau Cove, may be seen a portion of Digby Neck, about five miles away.

The soil in Belliveau Cove is for the most part sandy, becoming quite muddy near Piers 2 and 3 (see Stinson's figure 1) between two and five hundred feet seaward of high water mark. The tidal amplitude is large, about 18 feet, and the flat slopes gradually. The maximum distance between low and high tide marks at about the center of the cove being close to half a mile. The water at Belliveau Cove is warm, compared with other parts of the Bay of Fundy.

Stinson mentions that two large weirs were present on the flat during the summer of 1946. The following summer saw only one of the pair remaining, Stinson's "Weir 1", but several small weirs had been erected at higher levels and stood until mid-August, when some were dismantled. The large weir stands about eighteen hundred feet seaward of high water mark, quite close to the normal low tide line. At spring tide, a stretch of some five hundred feet more of sand is bared, affording a fine opportunity for diggers of bar clams (Mactra) to seek their prey.

b) Investigator's living and laboratory quarters. Stinson and the present writer obtained living accommodation at a hotel, the Bay Shore Inn, a small establishment situated a few yards from the piers as shown in Stinson's figure 1. Laboratory quarters were in the form of a fairly well lighted room (about 4 x 10') inclosed in a shed on the hotel premises. Electricity was available in the laboratory, though running water was lacking.

c) Local flora. Seaweeds are plentiful in the Belliveau Cove area, and include green, brown, and red algae. Also what remains of the once dense eel grass (Zostera marina) appears here and there on the flat, thicker at some points, non-existent at others.

d) Local fauna. Littoral invertebrate fauna in the area are varied and quite abundant. Judging from a cursory survey, there are several forms in addition to Polinices, Mactra, Mya, and the mussels Mytilus and Modiola. Other mollusks observed include representatives of the gastropod genera Purpura, Littorina (periwinkles), and Nassa. Crustacea such as amphipods (Gammarus?) which may be seen at night glowing a bright green, isopods (Chiridotaea?) and barnacles are plentiful, and a few crabs may be found at the lower levels. Polychete and other worms are quite commonly seen, and a few Asteroidea are noticeable at spring tide. Jellyfish

are abundant; about the end of July this year thousands of small specimens were to be seen mostly washed up near the piers. A few days later they had largely disappeared.

In addition to live forms, hundreds of shells of other mollusks were this year to be discerned among the beach wrack and elsewhere. These include Buccinum and Chrysodomus (found occasionally) and others among the gastropods, Ensis, etc., among bivalves. Brownish shells of one species, possibly belonging to the genus Littorina were found in considerable quantity in the soil at low levels. Most of these shells had been drilled and thus constitute evidence that the species they represent may be a major food of Polinices.

The great abundance of life at Belliveau Cove as at countless other locations may quite easily be overlooked by the casual observer walking the flats by day. At Belliveau Cove at least it becomes more difficult to overlook it on most nights, when hundreds, sometimes thousands, of Polinices, having emerged on the surface shortly after dark, may be seen crawling upon the sand, feeding, mating, etc., and attesting, in their profusion, to the vast extent of the living world beneath the surface of the soil.

e) Fossil shellfish found near Belliveau Cove. In August this year the present writer was shown several bivalve shells, quite well preserved, which inclosed solid rock. They had reportedly been found eight miles from Belliveau Cove by the blacksmith of that village, Capid (?) Comeau, embedded in the earth on the side of an embankment near the shoreline of St. Mary's Bay. The shells, whose growth lines showed clearly and which appeared very similar to present forms, e.g., Mya arenaria, are not the first to be collected by Comeau, who may have made a find of some importance. It has not been feasible to investigate the matter further as yet, but it is thought that this should be done.

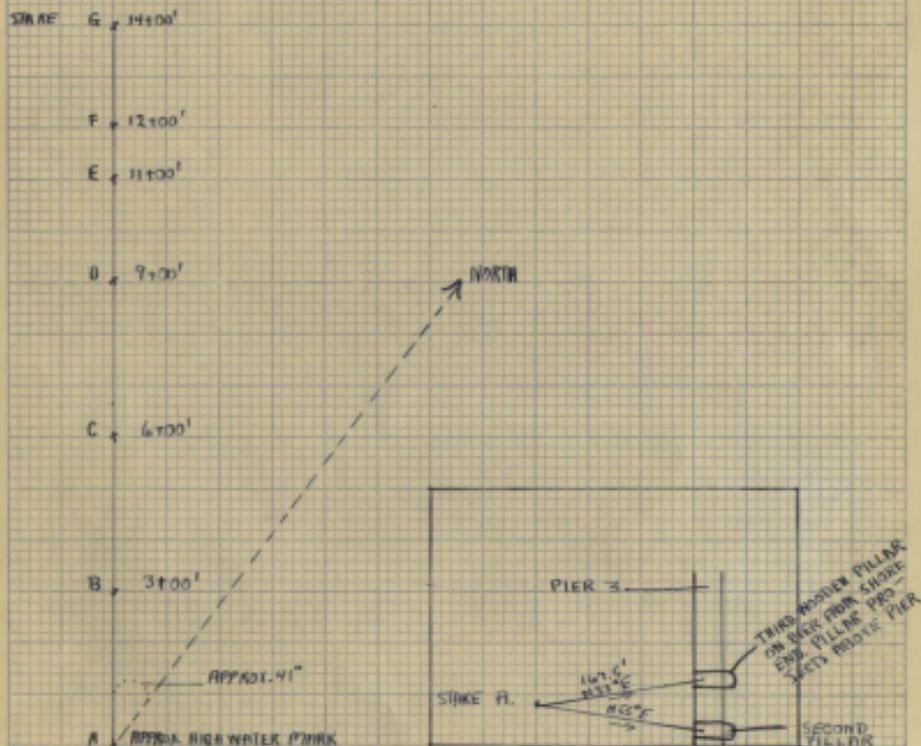
f) Weather at Belliveau Cove. The weather in the vicinity during the summer of 1947 was on the whole dry and warm, although fairly cool days with some rain were experienced in late May and in June. It is not thought that the air temperature went above 80°F. at all during the season, the breezes from the bay perhaps keeping the temperature from rising higher than it did. Fog and mist were often present, usually in the early morning and evening.

### 3. REFERENCE STAKES PLACED ON FLAT

On June 2, for purposes of reference and identification, a series of wooden stakes which were designated A through G was established on the flat, by use of chain and sighting compass, in a direction about 41° west of north, at intervals from high water mark seaward for fourteen hundred feet. As may be seen from figure 1, which shows the positions of the stakes, the line

Figure 1

SHOWING POSITION OF STAKES LAID ON FLAT  
BELLIVREAU COVE, 1947.



begins approximately 150 feet on the Major's Point side of Pier 3. A comparison with Stinson's line of stations may be made by comparing figure 1 mentioned above with Stinson's figure 1.

At the end of the season, the wooden stake at high water mark was replaced with a 36" length of lead piping.

#### 4. POLINICES AT BELLIVEAU COVE

a) Polinices appear on surface nocturnally. Polinices at Belliveau Cove begin to appear on the surface of the flat shortly after dark, some, possibly most, apparently remaining there until sunrise. It would seem (Table 2) although the evidence is not conclusive, that the number of snails on the surface tends to reach a peak about midnight.

A few Polinices may be seen on the surface before sunset and for a few hours after dawn. Also, on June 27, when it was raining, Polinices were noted in some numbers during the day<sup>(2)</sup>. However, as indicated in table 1, which compares the number of Polinices observed at various sites on the flat at night with the number observed at about the same sites on the following morning, activity by Polinices on the surface is almost wholly confined to nocturnal hours. Such activity on a given night is not thought to be affected by tidal movements.

b) Abundance of Polinices on surface. On some nights this summer, more Polinices were observed on the surface of the flat than on other nights (Table 2). It will be noted in table 2 that the greatest number of P. triseriata per square foot recorded on a single night within a certain 2500 square foot area situated some eight hundred feet seaward of high water mark is 0.6. On the other hand, estimations of the number of P. triseriata residing in the same area to a depth of six inches reveal a different picture. The lowest such estimate, obtained by screening part of the soil of the area in mid-June, is 12,000 or 4.8 per square foot (Table 7), the highest, based on mid-July sampling, is 48,750 or 19.5 per square foot. Thus the estimated population per square foot of soil six inches in depth varies from 4.8 to 19.5, and contrasts sharply with 0.6, that is, the greatest number per square foot observed on the surface at one time at the same site. This would suggest that to attempt to determine the Polinices population by means only of counting the number on the surface at night would not be fruitful.

Held by a few fishermen at Belliveau Cove is the belief that

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(2) On the basis of four areas 3 x 3' picked at random near stake D on June 27, it was found that the number of P. triseriata on the surface at 10:30 a.m. was nearly 6 per square yard. A few P. heros were noted on the surface shortly afterward near Weir 1.

Polinices appear on the surface in greatest number at the time of the new moon. Support for such a contention is largely lacking from the data as furnished by table 2. Possibly the belief has arisen because of the fact that the time of the new moon, tidal movements are such as to permit access to the flat during the hours of darkness before midnight, at which time the number of Polinices on the surface appears to reach its maximum for the night. Again, as may be seen from figures 2 and 3, the number of Polinices on the surface might seem to rise and ebb fairly regularly during the summer, but this too may be due to the time of night at which the various surveys were conducted. It should not be thought, however, that there may not be considerably more Polinices on the surface on one night than on some other night at a similar hour. For instance, it is felt that there were probably more Polinices on the surface at midnight on July 14 than at any other midnight during the summer.

c) Estimated abundance of Polinices per cubic unit of soil. It may be seen from table 7 that the average population of P. triseriata per square foot of soil six inches in depth within two 2500 square foot areas located eight hundred feet seaward from high water mark, as obtained by screening part of the soil therein at various times between June 10 and August 23, is 9.4. Similarly, the average population per square foot of soil about one inch in depth is 4.3. This suggests that slightly over 50% of the Polinices living within the top six inches of soil reside below the top inch.

The question as to the depth of soil at which Polinices reside by day was also investigated in another manner. It was wondered, because so few P. heros were encountered while screening to a depth of six inches even in parts of the flat well populated with P. heros nocturnally, whether that species resides deeper in the soil than P. triseriata. Although no satisfactory answer was obtained, it would seem as though that may be the case. At various sites selected at random the soil was screened to a depth of some twelve inches. Results of the screening are tabulated in table 3.

d) Reaction of Polinices to artificial light. Very weak evidence that Polinices may be sensitive to artificial light was obtained this summer. On June 9, a flashlight was held just above a P. triseriata travelling slowly on the surface and focussed on the region of the animal's protruding tentacles. As the light was moved first to the left and then to the right, the snail also shifted its path in those directions, as though reacting positively to the applied light. Only coincidence, of course, may have been involved, yet in a few other similar instances, the snail in question, as it either halted its crawl or altered its path, seemed vaguely to be aware of the light. In most cases, however, this was not true, the snail continuing on its way, apparently unaffected.

Fig. 2

SKETCH OF TRAP USED IN TESTS TO  
INVESTIGATE FEEDING RATE, ETC. OF  
POLINICES, BELLIVEAU COVE, 1947.

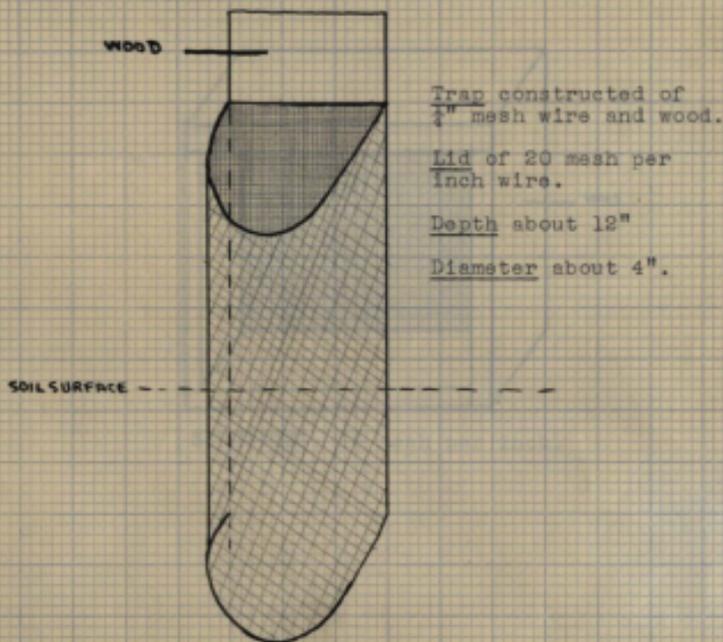


TABLE 1

SHOWING NUMBER OF POLINICES OBSERVED AT VARIOUS  
POINTS ON FLAT AT NIGHT AND THE NUMBER OBSERVED  
AT THE SAME POINTS THE FOLLOWING MORNING. (MAY 27-28)

<u>LOCATION</u>	<u>NO. OF POLINICES PER SQ. YD.</u>	
	<u>NIGHT (11:00 p.m.)</u>	<u>DAY (12 noon)</u>
Stinson's Station 2	2	0
Stinson's Station 3	7	1
Stinson's Station 4	5	0
Stinson's Station 5	11	0
1370' seaward of high water mark	18	0
	<hr/>	<hr/>
Total:	43	1

TABLE 2

SHOWING RELATIVE ABUNDANCE OF POLYCHAETS  
OBSERVED ON SURFACE OF VARIOUS FLATS

DATE 1947	TIME OF SURVEY	POLYCHAETS ON FLAT CATEGORIZED AS A WHOLE	<i>P. trilineata</i> NUMBER OF INDIVIDUALS OF THIS SPECIES AS DISTRIBUTED OVER THE WHOLE FLAT SURVEYED ON THIS DATE	<i>P. trilineata</i> AS PERCENT OF TOTAL AREA OF FLAT SURVEYED ON THIS DATE	REMARKS
May 27	11:00 pm	Plentiful	-	-	
June 2	5:00 am	None	-	-	
June 4	9:00 pm	Some	-	-	
June 9	9:00 pm	-	61	.004	
June 10	9:00 pm	Very few	0	.000	
June 11	11:00 pm	Very plentiful	80	.003	
June 12	11:00 pm	Plentiful	229	.006	LQ moon
June 13	10:30 pm	Plentiful	217	.007	
June 21	4:30 am	Plentiful	93	.001	
June 21	7:00 am	Some	-	-	
June 22	9:30 pm	Some	14	.000	First quarter moon
June 24	9:30 pm	-	23	.001	
June 27	11:00 pm	Very plentiful	220	.006	
July 7	7:30 pm	Very few	-	-	
July 8	10:00 pm	Some	1	.000	
July 10	10:00 pm	Very few	0	.000	See note "X" below
July 11	10:00 pm	Very few	0	.000	LQ moon
July 14	12 midnight	Very plentiful	1497	.242	New moon July 12
July 21	9:30 pm	Some	1	.000	
July 22	10:00 pm	-	61	.004	
July 23	9:30 pm	"	194	.002	First quarter moon
July 26	1:00 am	Very plentiful	509	.047	
Aug. 2	8:30 am	Some	-	-	
Aug. 3	9:30 pm	Some	12	.001	
Aug. 6	9:30 pm	-	120	.040	
Aug. 7	9:00 pm	Very few	26	.011	LQ moon Aug. 9
Aug. 11	11:30 pm	Some	20	.002	
Aug. 12	9:00 pm	Some - see note "X"	-	-	New moon Aug. 12
Aug. 19	9:00 pm	Very few	-	-	
Aug. 20	10:00 pm	Some	12	.001	
Aug. 21	10:30 pm	Some	110	.044	First quarter moon
Aug. 22	9:30 pm	Plentiful	141	.044	
Aug. 22	12 midnight	Plentiful	61	.004	
Totals:			4020	1.421	
Average:			142	0.042	

"X" - *P. barosa* on surface plentiful near Weir 1

"Y" - Tide prohibited survey of levels lower than 300' seaward of high water mark.

TABLE 3

SHOWING RESULTS OF SCREENING SOIL TO  
A DEPTH OF TWELVE INCHES IN ORDER TO  
CHECK ON THE SOIL DEPTH AT WHICH  
POLINICES RESIDE DIURNALLY

<u>DATE</u> 1947	<u>TIME OF</u> <u>SCREENING</u>	<u>SITE OF</u> <u>SCREENING</u>	<u>SPECIMENS OBTAINED</u> <u>BY THE SCREENING</u>	<u>DEPTH AT</u> <u>WHICH</u> <u>OBTAINED</u>	<u>REMARKS</u>
July 15	3 pm	Weir 1	6 large <u>P.triseri-</u> <u>ata</u>	Between 6" and 10" below surface	Screen 16-mesh-per-in. used.
July 15	3 pm	Weir 1	1 <u>P.heros</u> , 35 mm. in height	10" below surface	"
July 15	3 pm	Stake F	2 large <u>P.triseri-</u> <u>ata</u>	1" below surface	"
July 15	3 pm	Stake E	Nil	-	"
Aug. 26	1 pm	Stake G	1 <u>P.triseriata</u> , 15 mm. in ht., also 40 <u>Littorina</u> (?) shells, most of them drilled, many with spire tips corroded	Down to 12" below surface	1/4" mesh screen used
Aug. 26	1 pm	Stake F	1 <u>P.triseriata</u> , 10 mm. in height	"	"
Aug. 26	1 pm	Stake E	1 <u>P.triseriata</u> , 12 mm. in height	"	"
Aug. 26	1 pm	Stake D	2 <u>P.triseriata</u> , 15 mm. in ht., also 3 smaller <u>P.tri-</u> <u>seriata</u>	"	"

e) Mating habits. Fertilization among Polinices is internal. Mating pairs may be observed on the surface in season nearly any time during the night. Copulation has been observed on the surface this summer at times ranging from just after dusk until 5:00 a.m. In the daytime, mating may proceed slightly beneath the surface of the soil. It would seem that most mating, at least at Belliveau Cove, is carried on in June and early July, although to some extent it possibly occurs during most of the spring and summer months.

The two animals in a mating pair of P. triseriata travel slowly upon the soil surface. The female, the larger of the two, is situated in front, with the male at her right side and towards the rear. The penis, which is located at the base of the right tentacle is extended across the breadth of the male and inserted under the female shell. The length of time copulation continues in a given instance has not been ascertained. Presumably, it may go on for at least several minutes. For instance, one pair, already copulating when first noted, was observed to continue mating for five minutes. At the end of that time, the female did an about turn, taking her mate with her, and proceeded to burrow beneath the surface. Perhaps this signified the end of the act. After burrowing, the pair seemed to become detached.

The penis is an eggshell-white coloured structure, bearing a series of slight vertical grooves and ridges and terminating in a very fine point, very often observed bright red in colour. The penis has been noted to range in length, in the contracted state, from about 1.5 mm. in a 7 mm. P. triseriata to 7 mm. in a 19 mm. specimen (Table 4). The length of the penis in P. heros is correspondingly less. A 16 mm. P. heros was observed to have a penis 2 mm. in length, while a P. heros 36 mm. in length was seen to have a penis 12 mm. in length (Table 4). In the case of Polinices less than 7 mm. in height, it seems, the penis is poorly developed, and may not be noticed in gross dissection.

It has been observed this summer that the height of the female in a mating pair P. triseriata averages fifty per cent greater than that of the male. This is in accordance with Stinson's findings, which show the height ratio of male to female to be 1:1.4 (see Stinson's table 6).

## 5. FEEDING HABITS OF POLINICES - I

a) Introduction. It has long been known that in many cases snails eat their prey by drilling a circular, counter-sunk hole in the shell and then extracting the meat through that aperture.

b) Polinices may eat clams without drilling the shell. In some instances, it now seems, Polinices are able to consume clam meat without boring the shell. A hint of this was en-

TABLE 4

SHOWING SHELL HEIGHTS AND PENIS  
LENGTHS OF REPRESENTATIVES OF P.heros  
AND P.triseriata

<u>P.heros</u>		<u>P. triseriata</u>	
<u>Shell Height</u>	<u>Penis Length</u>	<u>Shell Height</u>	<u>Penis Length</u>
mm.	mm.	mm.	mm.
16	2	7	1.5
26	5	13	6.5
28	6	17	6.0
34	8	17	6.5
36	12	19	7.0

countered early in the present season at Belliveau Cove, when clam shells were found on the flat, undrilled, with their meat content gone, and later by an abundance of clam shells found at Belliveau Cove in an upright position in the sand with about half the shell above the surface. The contents of the shells were either wholly or partially gone, the valves were separated along the ventral margin, the mantle edge was on a stretch, and quite frequently a P. triseriata could be found an inch or less directly below the clam shell. Most of the shells so found measured about one inch in length. Other fairly good evidence that P. triseriata eat clams without boring the shells was observed. On August 5, a soft shell clam was seen on the flat with valves parted and mantle edge stretched. A snail was at each end apparently feeding through the foot and siphon holes in the mantle. One of the snails had its foot well extended inside the shell of the clam, about half the meat of which was gone when the operation was discovered. The snails measured about 10 mm. in height, the clam about 30 mm. in length. On August 21, a P. triseriata, 15 mm. in height, was noted firmly attached to the end of a soft shell clam 26 mm. in length. The clam had not been drilled and the snail seemed to be eating through a siphon hole in the mantle. The meat of the clam was mostly gone, a rim of mantle, a tip of siphon, a small part of the visceral mass, and a shred of an anterior muscle being all that remained.

The following may be considered as further evidence that undrilled clams are consumed by Polinices.

- 1) On June 21, an unbored soft shell clam was observed held in the foot of a P. triseriata. The valves of the former were separated ventrally about 5 mm., the mantle being stretched across the opening thus formed.
- 2) On June 27, an unbored clam in a condition similar to that just described was observed being taken below the surface of the soil by a P. triseriata.
- 3) On July 3, as a result of soil screening, a clam 1 1/2" in length was discovered. Unbored, its meat was largely gone, with only part of the mantle and siphon remaining.
- 4) On July 22, two unbored clams (27 and 30 mm. in length) were noted on the surface at 10:00 p.m. Most of the meats were gone. One of the clams was near a group of P. triseriata one of which seemed attached to the foot hole in the mantle.
- 5) On August 2, a P. heros, 25 mm. in height, was encountered firmly attached to the posterior end of an unbored clam 45 mm. in length. At that end the valves were slightly parted, the P. heros possibly ready to extract the clam meat there. When the pair was found, the clam, in an upright position, was almost wholly buried in the sand, while the snail

was on the surface.

6) On August 11, two unbored clams 30 mm. in length were observed on the surface apparently being eaten. Five P. triseriata were attacking one, two the other.

7) On August 25, unbored clams were discovered on the surface apparently being eaten by groups or individuals of P. triseriata. It seemed the clam meat was being extracted through the foot and siphon holes in the mantles of the clams. One of the clams, 30 mm. in length, was being attacked by a P. triseriata 17 mm. in height. All of the clam meat remaining was a rim of mantle, siphon tip, shreds of muscle, and part of the visceral mass.

It is interesting to note that Stinson reported finding clam shells with the meat content "gone" but with the shells undrilled (see Stinson's table 17). It is not suggested by him that the meat had been eaten, as it is in cases where the shells were found bored, nor is any explanation offered as to the disappearance of the meat from the unbored clam. It now seems reasonable to suppose that it may have been eaten by Polinices.

c) Evidence of eating-without-drilling found at Pinette. Further evidence of Polinices' feeding without boring was discovered this summer at Pinette, Prince Edward Island, by Dr. Medcof. There, Medcof reported, bar clams were being eaten by Polinices, somewhat larger than those found at Belliveau Cove, without being bored. The clams when found were completely inclosed in a mucilaginous sheath and buried in the foot of the snail, which seemed to have entered the clam between the shells along the mid-ventral margin and to have devoured first the parts nearest that point. In one case, there was nothing left but the siphon tip and a rim of mantle, marginal to the pallial line. In another specimen, there were a few shreds of the two adductor muscles and a small amount of the visceral mass adjacent to the hinge line, besides the siphon tip and the mantle rim. These bar clams measured 90 and 89 mm., in length, respectively, and were being eaten by snails 87 and 98 mm. in height.

d) Feeding by Polinices at the Sissiboo river. On the Federal government flats at Sissiboo river four miles from Belliveau Cove, very little damage seems to be caused among the clam population by Polinices, probably because the latter are present in only small numbers. However, both P. heros and P. triseriata are found there, and drilled clam shells occasionally are encountered.

#### 6. FEEDING HABITS OF POLINICES - II

- a) Tests conducted at Belliveau Cove to determine feeding rate and predominant method of feeding of P. heros and P. triseriata.

I. Introduction As a result of work done last year,

Stinson came to the conclusion that one P. triseriata 20 to 30 mm. in height destroys a clam every two days, at the time of year the tests were made (August). P. heros, he felt, may not be so voracious. Further tests were conducted this year designed to increase the knowledge of the rate of consumption of soft shell clams by Polinices and the latter's methods of attacking the clam.

II. Procedure. On August 4, three "traps" (Figure 2) as described by Stinson under his "Feeding Habits - Rate of Drilling", were placed in Dock 1 (Stinson's figure 1) partially submerged in the soil, and in them were placed certain Polinices and soft shell clams. From time to time the stock in the traps was changed, and a series of checks provided indication of how and the rate at which the clams were being consumed.

III. Results. Tables 5a and 5b summarize the results.

IV. Discussion and Conclusions. It may be noted from the data summarized in those tables that more extensive results were obtained in the case of P. heros than in that of P. triseriata. Polinices of the former species seemed more inclined to attack the clams in the caged condition than did P. triseriata.

Despite meager results in the case of P. triseriata, the data may indicate that the method of attack without boring is more popular among that species than among P. heros: of the three clams attacked by P. triseriata all were unbored, while of the eleven clams attacked by P. heros all but two were bored.

Perhaps it is interesting to consider here the fate, described below in the section entitled "Clam Relays at Bellevue Cove", of some seven thousand soft shell clams relayed this summer to a level below weir 1, i.e., to an area not naturally populated with Mya but quite highly productive of P. heros and to a lesser extent, P. triseriata. The clams, in good condition, were planted there at the end of June, while a check in August on the number of survivors indicated that all of the clams had been destroyed. Some of the destruction is believed to have been caused by gulls, but Polinices are thought to be mostly responsible. The check in August also indicated that two-thirds of the shells had been bored.

The results for P. triseriata, recorded in Table 5b, suggest that a snail between 12 and 18 mm. in height attacks one clam every thirteen days. This is in contrast to the findings of Stinson, who, as noted above, judged the rate to be one clam every two days. He also states that P. heros "may not be so voracious". Now assuming the rate at which P. triseriata attack to be one clam every two days, that statement is in accordance with this year's findings, which indicate a P. heros 14 to 38 mm. in height attacks one clam about every four-and-a-half days. Belding, however, reports

Stinson, has claimed that a two-inch snail, presumably P. heros, kills 26 clams per month, or nearly one clam per day.

It may be interesting to consider whether there exists any difference in destructive capacity between male and female Polinices regardless of species. Information about such is largely lacking. Stinson suggests that females may outnumber other P. heros (though this summer's findings fail to indicate that they do to a considerable extent) and also that P. heros may be less voracious than P. triseriata. It might be well in the future not only to investigate the questions of female preponderance in P. heros and the relative destructive capacities of that species and P. triseriata, but also the question of whether such a preponderance, if actual, has any causative effect on the destructive capacity of the species.

It may be seen that no clam over 40 mm. in length was attacked in spite of the fact that clams 56 and 63 mm. in length were among those caged (Table 5a). This accords with a statement attributed by Stinson to Belding to the effect that a 1 $\frac{1}{2}$ " (38 mm.) Lunatia cannot operate on a clam over two inches (51 mm.) in length.

On the basis of this year's observations, the following conclusions may be drawn:

- 1) Both P. heros and P. triseriata eat soft shell clams having either bored the shell or not.
- 2) The method of attacking without drilling is more popular among P. triseriata than among P. heros. The latter usually drill in the case of soft shell clams, but this may not be so when bar clams are involved.
- 3) The rate at which P. heros (average height 33 mm.) attack soft shell clams is about one per four-and-a-half days. (The results obtained in investigating the rate at which P. triseriata attack were too meager to justify a general statement. Stinson concluded that it is one clam every two days).
- 4) Soft parts of the clam most frequently left uneaten by Polinices are the mantle rim and siphon tip.

b) Tests conducted with young snails and clams.

I. Introduction. It appeared to Stinson that a small snail (about 1 mm. in height) kills a clam spat every third day. Further testing to obtain data on the destruction of soft shell clam spat by young P. triseriata was conducted this summer.

II. Procedure. On August 25, five soft shell clam spat which ranged in length from 4 to 7 mm. were placed together with three P. triseriata, 3 and 4 mm. in height, into a vial (Vial A) containing about  $\frac{3}{4}$ " of sand wet with salt water. Into a second

vial (B) also containing sand and salt water, were placed three spat (4 to 7 mm. in length) and two P. triseriata (3 and 4 mm. in height). The vials were checked on August 27.

III. Results. Only one spat, 5 mm. in length and in Vial A, appeared to have been attacked. Its valves had been separated ventrally and the meat content was about half gone. The shell showed no sign of drilling. The remaining seven spat and the five snails seemed to have undergone no change during the two days.

IV. Discussion and Conclusion. It would seem that the most important conclusion which might be drawn from the results just described is that Polinices as small as those used in the tests (3 and 4 mm. in height) apparently may resort to the method of attacking clams without drilling the shell, even when the latter is as soft as it would be in the case of a spat 5 mm. in length.

c) Of feeding observed at and below the surface of the soil.

I. Polinices Feeding on Soft Shell Clams. Many feeding operations were observed on the flat throughout the summer during both day and night. Some of them have been described in another section (see 5 - c). During the day, while soil was being screened on various occasions, P. triseriata were dug up attached to clams on which they were feeding or apparently preparing to feed. On June 16, for example, at 4:15 p.m., a snail was dug up from about three inches beneath the surface clasping in its foot a drilled soft shell clam with its meat partially consumed. Similar cases were observed on other days. At night and in the early morning when Polinices were to be observed on the surface, cases were noted in which a P. triseriata had a soft shell clam partially inclosed in its foot and was dragging the victim along the sand as described by Stinson. Usually in such cases, the clam, when rescued, showed no evidence of drilling. At other times, clams, more completely inclosed in the foot of a P. triseriata, and not being dragged, were taken from the snail and seen to be drilled. As Stinson found, P. heros seem not to travel about on the surface with their victims, but rather, as Stinson says, to roll up into a ball with the cupped foot curved round inclosing the clam.

Both P. heros and P. triseriata were frequently observed on the surface apparently eating the meat of clams whose shells had been broken while screening or relaying had occurred.

In table 6 are listed the heights of some P. triseriata observed eating or apparently preparing to eat soft shell clams, together with the lengths of the latter. It will be noted that the average height:length ratio is 1:1.2, while

the data tabulated in table 5b suggest that P. triseriata tend to attack clams of length about 50% greater than the snail height. The more representative and therefore more reliable data, as far as that ratio is concerned, would seem to be those given in table 6. The 1:1.2 ratio is similar to that suggested by Stinson's figure 46. Table 5a indicates that P. heros tend to attack clams of length equal to the snail height or slightly less.

## II. Polinices Feeding on Other than Soft Shell Clams.

In addition to soft shell clams Polinices feed on such forms as bar clams, mussels, gastropods, worms, etc.

Observations made by Dr. Medcof at Pinette this summer of P. heros attacking bar clams (Maetra) have been mentioned. At Belliveau Cove, too, such attacks were frequently noted. On August 2, for instance, a P. heros 45 mm. in height was observed dragging below the surface a bar clam 115 mm. in length. The latter, held in the snail's foot, was enveloped by a slimy sheath save for a circular spot where presumably the shell was to be drilled.

Mussels are very commonly attacked by Polinices, and many of the latter may usually be found at night near or upon the mussel beds on the flat at Belliveau Cove.

Mentioned above are the numerous drilled Littorina (?) shells found in the soil at the lower levels of the flat. In a random count made on August 26, the density of those shells, many with their spire tips corroded and most of them bored, was found to be 80 per cubic foot of soil near Weir 1. Thus the species may be quite extensively eaten by Polinices.

On June 27, a P. heros, 27 mm. in height, was observed apparently soon to consume a P. triseriata, 10 mm. in height. The latter, still unbored, was completely inclosed in the foot of its captor. Both snails were males.

d) Use of anesthetizing secretion to facilitate feeding. The question of whether a Polinices, before consuming its victim, secretes some type of anesthetic or poison which facilitates the feeding operation, has been raised from time to time. For instance, use of an anesthetic by Polinices seems suggested by Ganong, who writes:

"The writer saw last summer, at Oak Bay, a large Buccinum undatum which had been attacked by a Lunatia a little larger than itself. Though the boring had not commenced, the former was completely enclosed by the foot of the latter and had its aperture quite covered with a sticky slime. It at first seemed dead, but on being placed in water revived and seemed none the worse for its adventure." (3)

TABLE 24

SHOWING RESULTS OF TESTS CONDUCTED TO DETERMINE THE RATE AT WHICH LABORER ATTACKS SOFT SHELL CLAMS AND WHETHER DRILLING IN THE FOREMOST RING OF SHELL

TEST NO.	PERIOD OF TEST, DATE	NO. OF LABORER AT TEST AT START	NUMBER OF LABORER	LABORER NO.	NO. OF SHELLS BORED	LABORER BORED	SHELLS DRILLED	DIAMETER OF BORE, OTHER LINE		PARTS OF CLAM REMAINING IN ADDITION TO SHELL	NO. OF CLAMS REMAINING IN SHELL FROM TEST	
								mm.	mm.			
1	Aug. 4-11	2, 2	20, 20, 40	22, 24, 26, 28, 30, 40, 44, 42	2	24, 26	No, both cases	-	-	Manile rim and part of siphon in both clams	0.10	
2	Aug. 11-14	2, 2	20, 20, 40 (see "x")	22, 27, 20, 40, 20, 22	1	20	Yes	2	2	Small portion of mantle rim near hinge	0.17	
3	Aug. 14-15	2, 2	20, 40	22, 27, 40, 24, 22	2	27, 20	Yes, both cases	2	2	None (27 mm. clam)	0.22	
4	Aug. 18-22	1, 4	20	21, 24, 24, 22	2	24, 24, 22	Yes, all cases	2	2	24 mm. clam; None, 24 mm. clam; small portion of mantle rim	0.72	
5	Aug. 18-22	1, 4	40	22, 40, 20, 22	1	22	Yes	2	2	Small portion of mantle rim	0.25	
6	Aug. 22-24	2, 2	14, 20	22, 20	0	-	-	-	-	-	0.00	
7	Aug. 22-24	1, 2	20	21, 24	2	22, 20	Yes, both cases	4.5	2.5	Small portion of mantle rim in both clams.	0.20	
8	Aug. 24-27	1, 1	20	22	0	-	-	-	-	-	0.00	
9	Aug. 24-27	1, 2	20	40, 22	0	-	-	-	-	-	0.00	
					No. of clams attacked, bored:	9						
					No. of clams attacked, not bored:	2						
						11						
											Average:	0.224

"x" - The 20 mm. small escaped during the test period. It was not considered when column 11 (the last) of this table was calculated.

"y" - These figures refer to the 27 mm. clam; drilling of the other clam had not been completed.

"z" - These figures refer to one of the 24 and the 20 mm. clams; drilling of the other clam had not been completed.

TABLE 2a

SHOWING RESULTS OF TESTS CONDUCTED TO DETERMINE THE RATE AT WHICH *P. brissoni* ATTACKS SOFT SHELL CLAMS AND WHETHER DRILLING IS THE PREDOMINANT MODE OF ATTACK

TEST PERIOD NO. OF TESTS 1947	NO. OF <i>P. brissoni</i> ATTACHED AND REPRODUCING IN TEST AT START OF TEST	LENGTHS OF <i>P. brissoni</i> mm.	LENGTHS OF CLAMS mm.	NO. OF TESTS ATTACHED	LENGTH OF CLAM ATTACHED	MODE OF ATTACK	DIAMETER OF BORE:		PARTS OF CLAM REMAINING IN ADDITION TO SHELL	NO. OF CLAMS ATTACHED PER SHELL PER 100
							INNER	INNER		
							mm.	mm.		
1 Aug. 6-11	1, 3	12	28,29,31	1	31	Dr	-	-	Bore	0.14
2 Aug. 6-11	2, 3	12, 18	30,31,31, 34,34,38	1	31	Dr	-	-	Mantle rim and part of siphon	0.27
3 Aug. 11-14	2, 3	12, 15 see "xx"	30,31,34, 34,38	1	30	Dr	-	-	Mantle rim, part of siphon, part of visceral mass	0.53
4 Aug. 13-14	2, 3	12,15,15	30,30	0	-	-	-	-	-	0.00
5 Aug. 14-15	2, 3	12, 15	30,30	0	-	-	-	-	-	0.00
6 Aug. 15-22	1, 2	12	30,30	0	-	-	-	-	-	0.00
7 Aug. 22-27	2, 3	12,12,14	30,30	0	-	-	-	-	-	0.00
No. of clams attached, bored: $\frac{0}{3}$ No. of clams attached, not bored: $\frac{2}{3}$										Average: 0.277

"xx" - The 15 mm. clam was observed dead at the conclusion of the test. It was not considered when column 11 (the last) of this table was calculated.

TABLE 6

SHOWING HEIGHTS OF SOME *P. triseriata*  
OBSERVED EATING OR APPARENTLY PREPARING  
TO EAT SOFT SHELL CLAMS AND LENGTHS OF  
THE LATTER.

<u>DATE</u> 1947	<u>TIME</u>	<u>CONDITION OF CLAM WHEN</u> <u>OBSERVED</u>	<u>LOCATION</u> <u>AND</u>	<u>HEIGHT</u> <u>OF</u> <u><i>P. tri-</i></u> <u><i>seriata</i></u> <u>mm.</u>	<u>LENGTH</u> <u>OF CLAM</u> <u>mm.</u>
June 12	Night	Held in snail's foot. Not drilled.	On surf	25	29
June 13	"	Held in snail's foot. Not drilled.	On surf	24	29
June 13	"	Held in snail's foot. Drilled.	On surf	25	29
June 16	Day	-	Beneath	18	9
June 21	4.30 am	-	On surf	25	29
Aug. 21	Night	Posterior end firmly held by snail which seemed to be eating through siphon hole in mantle. Not drilled.	On surf	15	26
Aug. 25	"	-	On surf	17	30
				<u>Average: 21.3</u>	<u>25.7</u>

This summer, in two instances of a P. triseriata feeding upon an isopod (Chiridotea?), the action of some sort of anesthetic was suggested. In both cases, the isopod, when first noted, was partially inclosed by the cup of the snail's foot. When rescued, the victim appeared very sluggish, almost lifeless. It was then placed on the sand. Gradually, life seemed to return to it. Within ten minutes, much of the usual vigor was apparent and the isopod was able to burrow beneath the surface quite rapidly.

## 7. TRIAL CONTROL OF POLINICES

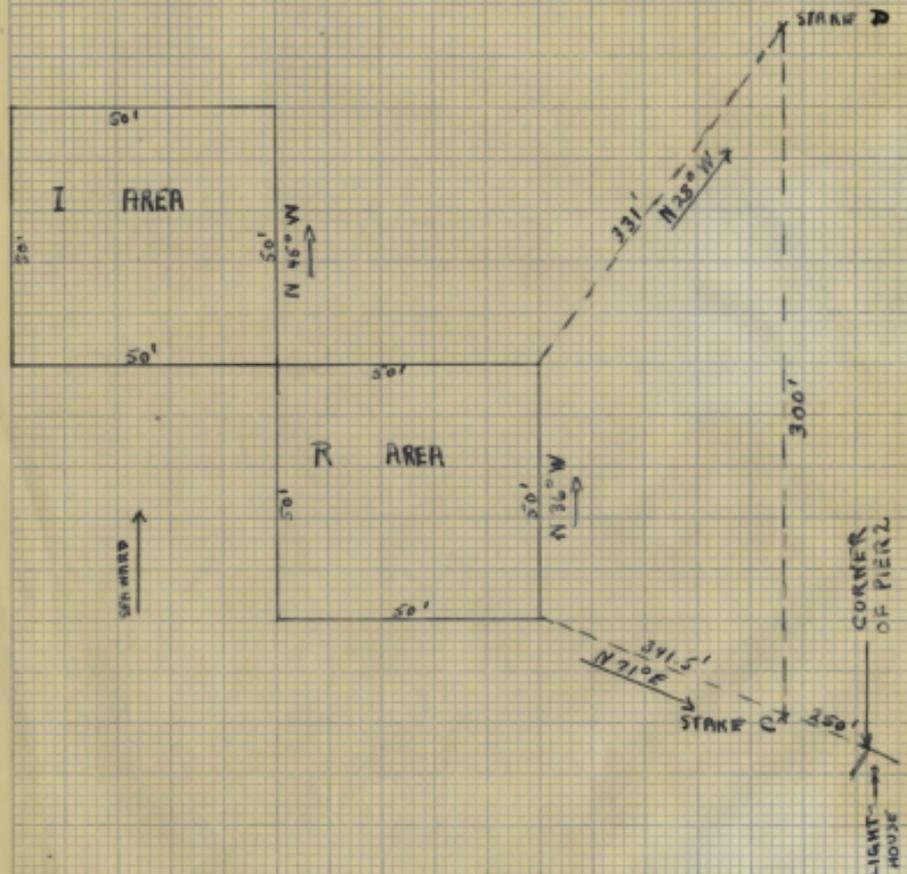
a) Introduction. It was desired to investigate this summer the possibility of controlling the numbers of clam drills in a given area. It was decided that a suitable way to do this might be to select two similar areas, determine the populations of Polinices and soft shell clams in each area, decrease the population of the former in one of the areas, increase it in the other, and maintain a regular check upon the populations in each area. If the clam population in the area of increased snail population were to show a marked drop between the start of the season and the end, while in the other area to remain more or less stationary, it would seem that the control of Polinices would be valuable. It was decided also that removal of egg cases of Polinices from one of the areas would be a satisfactory means of controlling the number of Polinices seed-of-the-year to hatch in that area.

b) Preliminary procedure. On June 3, two areas each 50 x 50' were staked off in positions as shown in figure 1a, between the levels represented by Stakes C and D. The site was chosen because night surveys had shown Polinices to be plentiful in the vicinity and Stinson's records indicated a good supply of soft shell clams there, and because tidal movements permitted access to it for a good part of the time. It was thought that having the areas joined by one common stake (figure 1a) would permit them to be close enough together so that very similar conditions would prevail in each, while avoiding a situation whereby crawling Polinices could readily pass from one area to the other. — Such a situation would have prevailed had the areas been placed on the same level and joined by two common stakes.

c) Selection of sampling method.— The question of how best to sample the areas in order to calculate populations arose. It was early realized that two distinct "classes" of soft shell clams, based on size, were to be encountered. These classes were designated "spat" (maximum length 12 mm.) and "larger clams" (all clams over 12 mm. in length). At first, both classes were counted in any given sample. Later, only one class in a certain sample was counted, the other ignored. That scheme was decided upon after several different sizes of samples

Fig. 1a

SHOWING POSITION OF I AND R AREAS  
IN RELATION TO LINE OF STAKES, ETC.  
BELLIVEAU COVE, 1947.



which were obtained by screening the soil through a box screen (figure 3) were considered. The matter of how deep to make the samples of soil was also investigated. A depth of four inches was first tried. Next, rather than a certain depth, it was chosen to sample a certain number of shovelfuls of soil. Used was an ordinary ash shovel, the sides of the scoop of which had been altered so that the approximate volume in a single shovelful could be calculated. With a length of 6", an average width of  $4 \frac{1}{8}$ ", and an average height of  $1 \frac{1}{16}$ ", each level shovelful would contain about 26 cubic inches of soil. In a square foot area nine shovelfuls of sand were screened, which meant that a volume of soil about  $12 \times 12 \times 1 \frac{1}{2}$ " was being screened. Then samples  $12 \times 12 \times 3$ " were obtained. Still the method seemed unsatisfactory. It was felt that sufficient numbers of spat could be obtained by sampling, say, the top one inch of soil, though such a shallow sample, of course, would not be adequate as regards the larger clams; indeed, in their case, three inches even was not thought deep enough. Therefore another system was adopted. Instead of ten square-foot samples within each of the 50 x 50' areas being obtained, both classes of clams in every sample being counted, now twenty samples would be screened. Ten would be dug to a depth of six inches and would be for the larger clams, while the other ten would be for the spat class. The ten for the larger clams were to be samples of soil  $12 \times 12 \times 6$ "; and it was decided in the case of spat to screen three shovelfuls of top soil for each sample (26 cubic inches per shovel). Thus in obtaining spat, areas  $12 \times 6$ " and nearly 1" in depth would be sampled. This is the method employed throughout the season.

d) Population checks by screening the soil. Before attempting to determine the soft shell clam and Polinices population of the areas (figure 1a) it was decided arbitrarily to make the area on the higher level the one in which the Polinices population would be reduced. This area will be referred to hereafter as R area. The other area had its Polinices population increased by transfer to it of nearly all Polinices found in R. The second area will be referred to as I area.

In sampling the population of larger clams in I and R areas, ten square-foot sites in each of those areas were randomly selected. They were chosen as far as possible so that all parts of the 2500 square foot areas would be represented, they were dug to a depth of six inches. The Polinices and soft shell clams in the half cubic foot of soil which were secured by means of the screen (figure 3) were counted in each of the ten cases and the average multiplied by 2500 to obtain an estimated population of the area's top six inches of soil.

Polinices, if found in R area, were transferred to I<sup>(4)</sup>, and if found in the latter, were left there. Soft shell clams were always left in their own area.

In sampling for clam spat, ten sites in each of I and R areas were selected, as in the case of larger clams. At each site, three shovelfuls (i.e., 78 cubic inches) of top soil were screened to secure the clam spat and Polinices therein. Usually the latter were placed into or left in I area, and the young clams were taken to the laboratory for counting.

Between June 10 and August 26, inclusive, eight population checks were made of I and R areas. In four of those checks, both size-classes of Mya were counted; in two, only the larger clams were counted; and in two also, only the spat. Results of the checks are tabulated in table 7 and discussed below in this section under "Discussion and conclusions".

e) Nocturnal checks of I and R areas. On twenty-six occasions between June 9 and August 25, inclusive, I and R areas were visited after dark (average time: 10:30 p.m.) and the P. triseriata on the surface within R area collected and placed into I<sup>(5)</sup>. By the end of the final such inspection, on August 25, 4063 P. triseriata had been collected nocturnally from R area. The dates and times of the checks are listed in table 7. The number of snails transferred from R to I area on each date is given in Column 4 of that table, for the 50 x 50' area referred to therein is R area<sup>(6)</sup>.

Before the Polinices from R were placed in I, the number of them on the surface in the latter area on most nights was quite close to the number in the former.

f) Removal of egg cases from R area. Throughout the season, egg cases of Polinices found within R area were collected and placed in I. On June 3, when the first collection was made, there were ten egg cases or collars in and transferred from R area. Between June 3 and August 22, after which no collars were noted in R, a total of 214 egg cases, including many doubtless produced by P. triseriata within that area and others washed into it from elsewhere on the flat, were taken from R and laid on the surface within I. Many remained in I to hatch, while others were washed outside.

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(4), (5) Very few were taken to the laboratory.

(6) Table 2 omits mention of three P. triseriata transferred on August 19, when only 2/3 of R area was inspected for Polinices on its surface.

TABLE 7

SHOWING SUMMARY RESULTS OF THE CHECKS ON THE POPULATION OF *P. trilineata* AND SOFT SHELL CLASS IN I AND N AREAS

NO. OF DATE	AREA	LARVAE CLASS: POPULATION OF Larvae per 100 sq. ft. of soil	LARVAE CLASS: POPULATION OF Larvae (2000 to 750) per 100 sq. ft.	CLAS. SPAT INDEXED Larvae per 100 sq. ft. of soil	CLAS. SPAT INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	CLAS. SPAT INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	NO. OF CHECKS	<i>P. trilineata</i> INDEXED Larvae per 100 sq. ft. of soil	<i>P. trilineata</i> INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	<i>P. trilineata</i> INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	<i>P. trilineata</i> INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	<i>P. trilineata</i> INDEXED Larvae (2000 to 750) per 100 sq. ft. of soil	% OF INDEXED Larvae per 100 sq. ft. of soil
1	June 10-16	I	8.9	37,350	178.6	800,000	17.0	6.7	6.7	1.5	16,750	6,000	50
2	June 10-16	I	28.1	60,350	198.7	800,000	18.0	6.8	6.8	1.5	18,000	7,000	50
3	June 17-23	I	11.5	50,350	188.0	840,000	17.0	18.0	6.8	1.7	17,000	14,000	82
4	June 17-23	I	23.4	60,500	188.8	800,500	18.0	6.4	6.8	1.8	17,000	6,000	65
5	June 27-30	I	14.8	50,000	-	-	-	-	14.0	-	50,000	-	-
6	June 27-30	I	14.9	40,000	-	-	-	-	17.1	-	40,700	-	-
7	July 18-19	I	7.7	19,000	17.8	60,500	47.0	73.0	19.0	4.5	28,500	27,000	11
8	July 18-19	I	24.9	57,000	15.1	70,500	38.0	70.8	19.8	4.8	48,700	21,000	27
9	July 24-30	I	-	-	6.7	20,000	27.0	60.0	-	1.5	-	7,000	-
10	July 24-30	I	-	-	18.0	81,000	28.5	28.8	-	1.5	-	6,000	-
11	Aug. 1-7	I	11.2	36,000	-	-	-	-	4.2	-	10,000	-	-
12	Aug. 1-7	I	28.6	64,000	-	-	-	-	6.8	-	18,500	-	-
13	Aug. 20-23	I	6.8	31,000	8.0	67,000	2.5	40.7	7.8	2.0	18,500	10,000	48
14	Aug. 20-23	I	19.1	47,750	6.1	30,000	7.8	24.2	6.8	1.2	14,000	7,500	48
15	Aug. 28	I	-	-	10.5	67,000	6.8	27.8	-	1.8	-	6,000	-
16	Aug. 28	I	-	-	20.2	101,000	7.8	28.0	-	1.8	-	6,000	-
17	Aug. 28	I	-	-	10.9	-	24.5	70	-	2.8	-	-	-
18	Aug. 28	See	-	-	28.6	-	20.2	44	-	1.2	-	-	-

"xxx" - only complete shells counted.

"yyy" - Except in this check, the top inch of soil was screened in sampling clay spot. In this check, however, the soil was screened one inch below the surface inch, as it was desired to determine the spot frequency at that depth.

\* - Undisturbed flat near I area based on 2 samples.

cc -

Most of the 214 collars mentioned above were found in R area before the end of June.

Because of the control program, it is thought that no P. triseriata collars released young snails within R area this year.

g) Discussion and conclusions. The data given in table 7 do not indicate the occurrence in the period of time involved of any marked drop in the population of larger clams in I area. Indeed, the initial check indicated a population of 21,250. The final check on the larger clam class, one of 21,000. The other checks suggest a greater population. The population in I area failed to shrink markedly, despite the fact that the Polinices population therein was increased, possibly because that increase was too slight to cause an appreciable effect during the period involved, namely, two-and-a-half months. The average estimate of the P. triseriata population in I area, as derived from data in table 7, is 22,000. The number of specimens transferred to that area from R was about 4700 or some 21% of the estimated population. The final check on the population of P. triseriata in I area, completed August 23, indicates a population of 18,500, i.e., about 10% greater than that indicated by the initial check, concluded June 16. The corresponding increase (a decrease might have been expected) in R area was 16%. It seems questionable whether such an indication is accurate in view of the fact that 4785 (7) P. triseriata were taken from R area during the season.

A drop of 27% from the start of the tests until the conclusion is suggested in the population of larger clams of R area. The first check on that population, concluded June 16, indicated a population of 62,250; the last, completed August 23, one of 47,750. The decrease was not gradual nor the rate of decrease consistent. In fact, except for the third and last checks, the population seems to have remained nearly constant.

It is suggested by the data in table 7 that the ratios of the population of larger clams of I area to that of R area were successively: 1.0:3.1, 1.0:1.7, 1.0:1.1, 1.0:3.5, 1.0:1.7, 1.0:2.3, the average being 1.0:2.70.

Perhaps the most striking development to show among the data in table 7 is the pronounced drop in the soft shell clam spat population of both I and R areas. Between the second

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(7) Including 4063 obtained by picking from the surface nocturnally, and 722 obtained by screening the soil.

check on that population, concluded June 23, and the third, commenced July 16, there apparently occurred a drop of 91% in the unbored spat population of I area and one of 92% in that of R. At the same time, the relative abundance of drilled spat seems to have increased from 12.9% to 71.3% and from 8.4% to 70.8% in I and R areas, respectively (8) (figure 4).

About the time these changes seem to have occurred, the peak was reached in numbers of P. triseriata egg cases observed on the flat (see Section 11). After July 12, the young snails began to hatch in increasing quantity. However, to attribute those changes in I and R areas to the 1947 class of P. triseriata seems unjustified for at least two reasons:

1) The increase in the percentage of bored spat and the decrease in numbers of unbored spat in R area were even greater than they were in I, yet it is not thought that young P. triseriata hatched in the former area. Nor is it thought the young of that species undergo a free-swimming stage.

2) By July 12, the downward trend in the frequency of unbored spat and the opposite trend in the percentage of bored spat seem to have been well under way. However, it seems unlikely that hatching occurred to a great extent before mid-July, for on July 12 the peak in collar frequency was noted (Section 11).

Now if the changes may not be attributed to 1947-hatched Polinices, to what can they be ascribed? It is suggested that the 1946 class of P. triseriata may be responsible for the changes. If they are, similar changes may be observable in I area next year, possibly at the same time, while in R area next year, due to the removal this summer of egg cases, no such changes should occur (9). Hence it is submitted that samples of the spat population in I and R areas should be taken next year periodically from, say, mid-June until the end of July or later if necessary.

It is interesting to note that the last check on the clam spat population, conducted on August 26, revealed a new upswing in spat numbers, as well as a continuation of the

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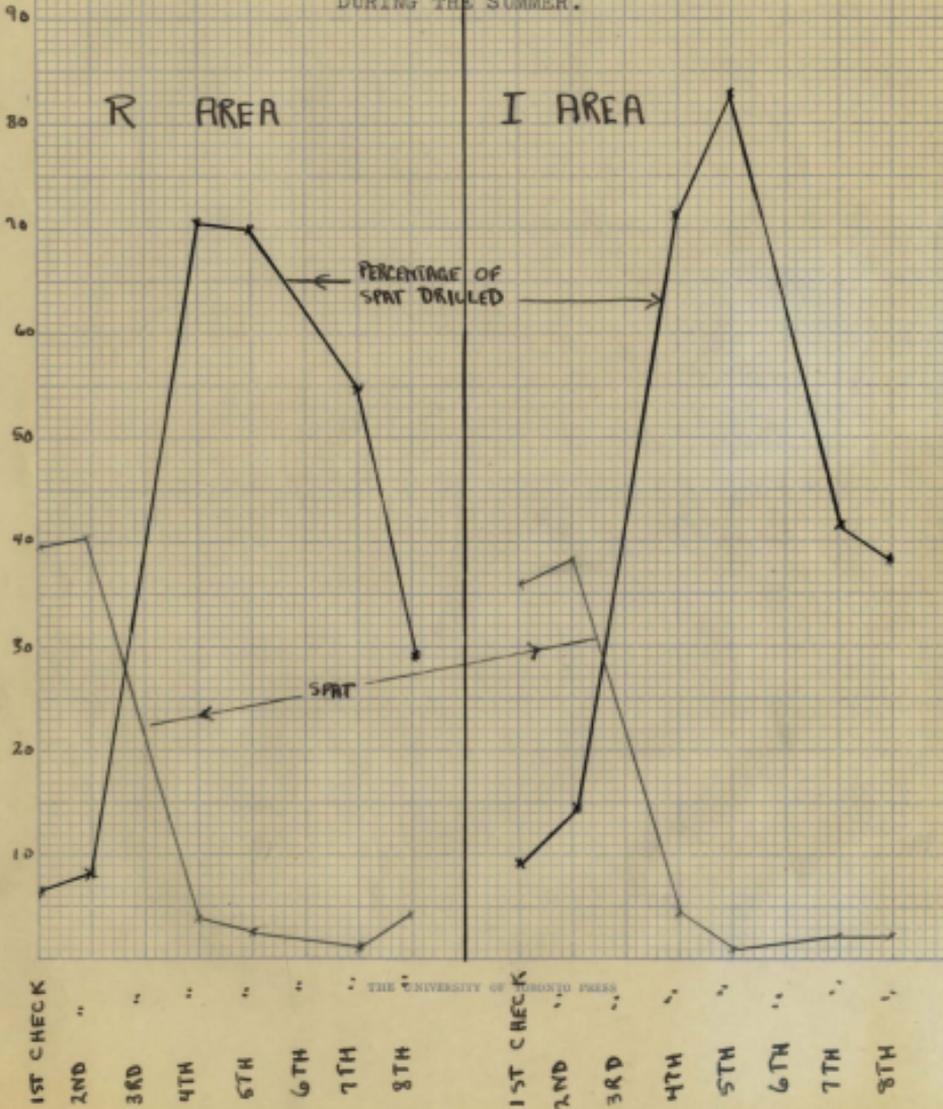
(8) It may be asked why the total number of bored spat and unbored spat, despite the great change in their ratio, did not equal about the same as it had earlier. It may be that many drilled shells, emptied of their meat, became washed away. *Table 7 supports this idea. In 3 weeks the no. of drilled spat shells dropped from 21.5 to 5.5 per 1/2 sq'.*

(9) In I area, because many egg cases were placed there this summer, changes even more pronounced than those noted this year might occur next summer.

FIG. 4

SHOWING 1) ONE-TENTH OF THE SOFT SHELL CLAM ("SPAT" CLASS) POPULATION PER SQUARE FOOT OF SOIL ABOUT 1" DEEP.

2) PERCENTAGE OF SPAT OBSERVED TO BE DRILLED IN TOP INCH OF SOIL AT THE SUCCESSIVE POPULATION CHECKS IN I AND R AREAS MADE DURING THE SUMMER.



decrease, apparently begun about mid-August, in the percentage of bored specimens. As an abundance of very small spat occurred in the samples screened during the latter part of August, it is thought that seed-of-the-year clams were beginning to appear and thus raising the spat population which reached its lowest ebb, due to the attacks of Polinices, about the end of July (figure 4).

The average ratio of the estimated P. triseriata population of I area to that of R, despite the transfer of specimens from the latter area to the former, was 1.0:1.1. On the basis of the first check, in June, the estimated P. triseriata population of I area to a depth of six inches, was 18,750 or 4750 greater than that of R area; while on the basis of the final check, in August, that population of I area was 18,500, or 4500 greater than that of R.

A great increase in the P. triseriata population of both areas is recorded by the third and fourth checks. In R area, by far most of this increase was centered in the top inch of soil, for by the end of the fourth check, only 11% of the P. triseriata in the upper half-foot of soil in that area was found to be living below the top inch. As has been said, it may be inferred from the data given in table 7 that usually a little over 50% of the P. triseriata living within the top half-foot of soil reside below the surface inch. The smallest P. triseriata (i.e., those up to 6 mm. in height) mostly were found this summer to occur within the top inch of soil.

That P. triseriata crawled into R area at night thus interfering with efforts to reduce the numbers of that species in the area, is suggested by the fact that it was found very often on nocturnal inspections that the greatest density of Polinices on the surface within R area was near the periphery of the area.

Together with consideration of the trial control of Polinices and the extent to which Polinices may destroy the clam stock of an area, must be remembered the fate of the seven thousand soft shell clams relayed to a part of the flat seaward of Weir 1. These clams were destroyed within two months, largely, it is felt, by P. heros and P. triseriata.

On August 25 it was decided to compare the spat, class clam population inside the I and R areas with that just outside. It was thought that the frequent digging might have altered the conditions sufficiently to have upset the picture. For this purpose five samples 12 x 6 x 1" were taken at various parts near each area which showed the following mean frequencies per half-square foot:

	Seed clams under 12 mm. Unbored	Bored	<u>Polinices</u> <u>triseriata</u>
Near I	10.8(10.5)	24.6(6.3)	2.8(1.8)
Near R	25.8(20.3)	20.2(7.9)	1.6(1.8)

The values bracketed are the corresponding values listed for areas within the plots on August 26 (see table 7).

From these data it would seem that the intermittent digging for samples inside the areas had not seriously affected the results of sampling.

In summary, the following conclusions may be tabulated:

1) P. triseriata of the 1946 seed may be responsible for the remarkable decline in the number of clam spat, and the accompanying increase in the percentage of bored spat, noted in I and R areas about mid-July this summer (figure 4).

2) In an attempt to determine whether the yearling snails were responsible, to investigate whether the extensive early summer attacks upon the spat is an annual occurrence, and to test the results of the removal this summer of P. triseriata egg cases from R area and their transfer to I, checks on the clam spat population of both areas should be taken periodically next year in a manner similar to that followed this summer. Sampling should commence in mid-June and proceed until the end of July or later if necessary.

3) The clam stocks in I and R areas did not seem noticeably affected by the transfer of P. triseriata from the latter area to the former. Perhaps the number of specimens transferred (21% of the population) was not great enough to be effective during the period involved (less than three months). Possibly in sampling both the spat and larger clams stocks next year, more pronounced results will be revealed.

4) That Polinices are probably capable of destroying completely a given stock of clams is indicated by the outcome when some seven thousand clams were relayed to a low level of the flat. The clams apparently were all killed, mostly by P. heros and P. triseriata.

5) Slightly over 50% of the P. triseriata residing in the top half-foot of soil reside below the top inch.

6) The smallest P. triseriata (i.e., 6 mm., and under, in height) tend to be found most frequently in the top inch of soil.

7) Clam spat are most abundant in the top inch of soil, but also occur below that.

Supplementary observations by J. C. Madcof.

On October 23 five half-square-foot samples 1' deep were screened from the I and R areas with the following total catches of *P. triseriata* seed clams less than 12 mm. long. About 95% of the clams were of the 1947 set averaging 3 - 5 mm. Many were too small to be retained by the screen and therefore were not counted.

Area	Clams per $\frac{1}{2}$ sq. ft.		Snails per $\frac{1}{2}$ sq. ft.	
I	1.	169	1.	2
	2.	145	2.	0
	3.	12	3.	0
	4.	144	4.	1
	5.	72 Av. 103	5.	1 Av. 0.8
R	1.	36	1.	3
	2.	105	2.	0
	3.	59	3.	3
	4.	35	4.	0
	5.	75 Av. 61	5.	0 Av. 1.2

Comparisons with data in table 7 shows that the relative abundance of seed clams in the two plots did not change in the period August to October but that the numbers retained by the screen increased about five times. The increase may have resulted from late sets of clams or simply from the growth of seed to such a size as to be retained on the screen.

Only one of the snails taken was small enough to be considered as belonging to the 1947 set. The others were of various sizes up to 25 mm.

8) Clam seed-of-the-year were revealed in the spat samples taken in the latter part of August.

9) P. triseriata, in their nocturnal wanderings on the surface of the soil, frequently passed into R area and thus interfered somewhat with efforts to reduce their numbers therein.

#### 8. AGENTS DESTRUCTIVE OF POLINICES

a) Destruction on the egg case level. Polinices at Belliveau Cove seem to have few natural enemies once they have survived the incubation period within the egg case. It is during that period when they seem most liable to attack by one agent or another, for example the following.

1) Wind. Stinson indicates that the wind is responsible for causing a good many collars to be washed up on shore and thus dried out, their living contents perishing.

2) Crustaceans. Stinson mentions that Crustaceans such as isopods and amphipods are frequently found on the inner surface of a collar and may have damaging effects. It is not suggested here that those animals do or do not damage the collars, but it is agreed that their occurrence on egg cases of Polinices is very frequent.

During the latter part of August, when capsules of several P. triseriata egg cases were examined microscopically, there appeared in some of the capsules no snail embryo, but what at first seemed to be a white, slush-like material. Under closer examination it became obvious that the material was scores of small organisms, which resembled tiny isopods, some of which were moving vigorously. It was wondered whether possibly they had resulted from isopod eggs laid in or on the capsule and whether the organisms had fed upon the Polinices embryo. On occasions earlier in the summer, the "slush-like material" had been seen in some capsules, in one or two a snail embryo being also present. Examined microscopically on August 26 was a P. heros egg capsule in which appeared to be hundreds of organisms, judged to be about 0.03 mm. in length. They seemed spindle shape, and frequently darted about within the capsule where no P. heros were observed.

3) Algal growths. As Stinson was led to believe last year, the danger greatest by far to the collars seems to be infectious growth which appears on a large number of egg cases after they have lain on the sand for some time. Stinson says, "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."

What Stinson took to be Ectocarpus, and which since

has been identified by H. P. Bell<sup>(10)</sup> as such, appears brown or olive green and consists on the egg case largely of feathery tufts. It seemed to the present writer that not all the growth which infects Polinices egg cases was Ectocarpus. Indeed, collars were frequently encountered that were infected with a green growth quite different in appearance from the feathery, brown Ectocarpus. The other growth is bright green and more strand-like, sometimes almost stringy. It has since been identified by Bell as Enteromorpha.

A few collars all infected with one or the other growth, were preserved in formalin.

It is interesting to note that of Enteromorpha and Ectocarpus Bell, who identified the genera but not the species, says, "These are... Epiphytes and there is no evidence of their being parasitic but they do often kill by smothering."

b) Destruction on the post-egg case level. Gulls seem to be the only agent constituting an appreciable menace to Polinices on this level. There is evidence found by examining several gull pellets<sup>(11)</sup> noted on the flat from time to time that Polinices are not infrequently attacked by the birds.

On May 28, nine pellets were examined and of these, five contained parts of Polinices shells. Otherwise the pellets were composed of fragments of the shells of clams, a few fish bones and vertebrae, etc.

On July 16, one pellet was examined which contained no less than thirteen P. triseriata (all but one were whole) which ranged in height from 4 to 15 mm.

On July 17, two more pellets were examined. One contained six P. triseriata, all but one whole, the other contained parts of about thirty P. triseriata shells, none whole.

On July 21, one or two pellets were examined. They contained only fragments of Mya shells.

On August 26, three pellets were examined. One contained parts of about thirty P. triseriata shells, nine of them whole with opercula in place. The other pellets comprised only clam shell fragments.

## 9. DISTINGUISHING SEXES OF POLINICES

a) P. triseriata over 6 mm. in height. The most convenient way of identifying sex in P. triseriata over 6 mm. in height (and in P. heros about 15 mm. in height and larger) is to determine whether a penis is present. The position of that organ and a description of it have been given in Section 4 - e

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(10) Professor Bell is an algologist and Head of the Department of Biology, Dalhousie University.

(11) Gulls regurgitate pellets of indigestible matter having previously swallowed their food whole.

Fig. 8a

Fig. 8b

HEIGHT-FREQUENCY DISTRIBUTION  
OF *P. triseriata* IN ALL SCREENED  
SAMPLES (JUNE, JULY, AUGUST) COM-  
BINED (The 2-3 mm. size-class  
frequencies have been "adjusted").

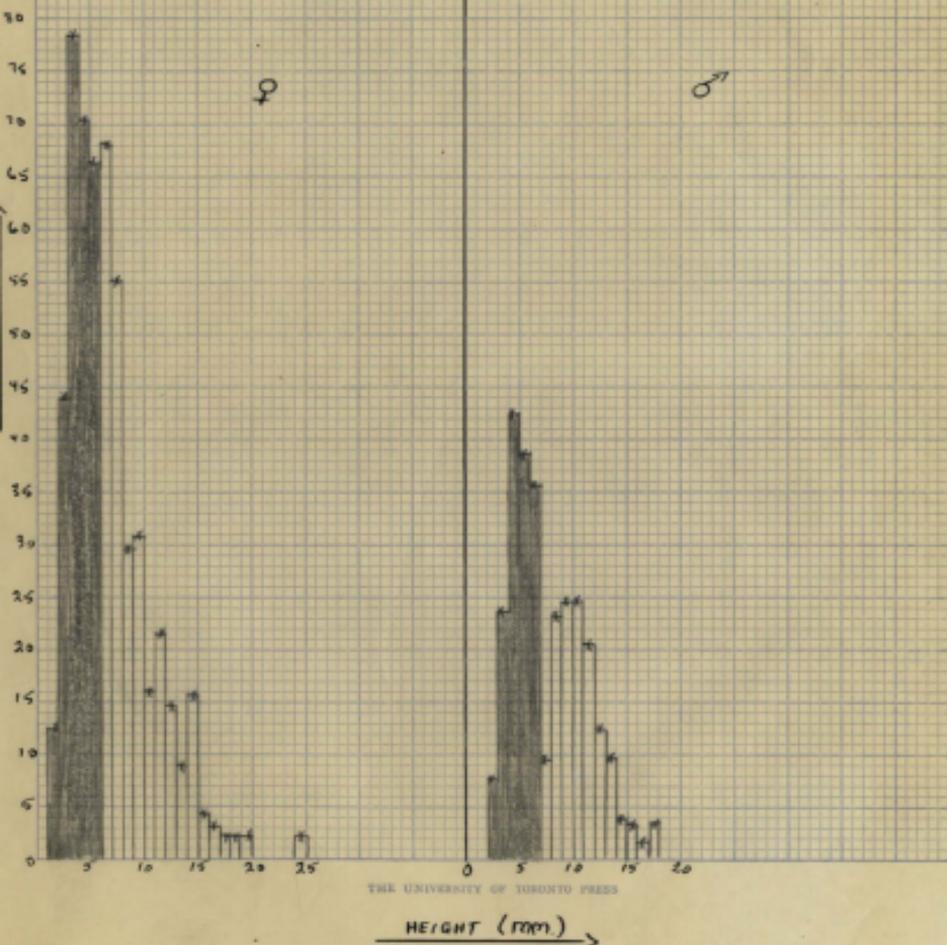
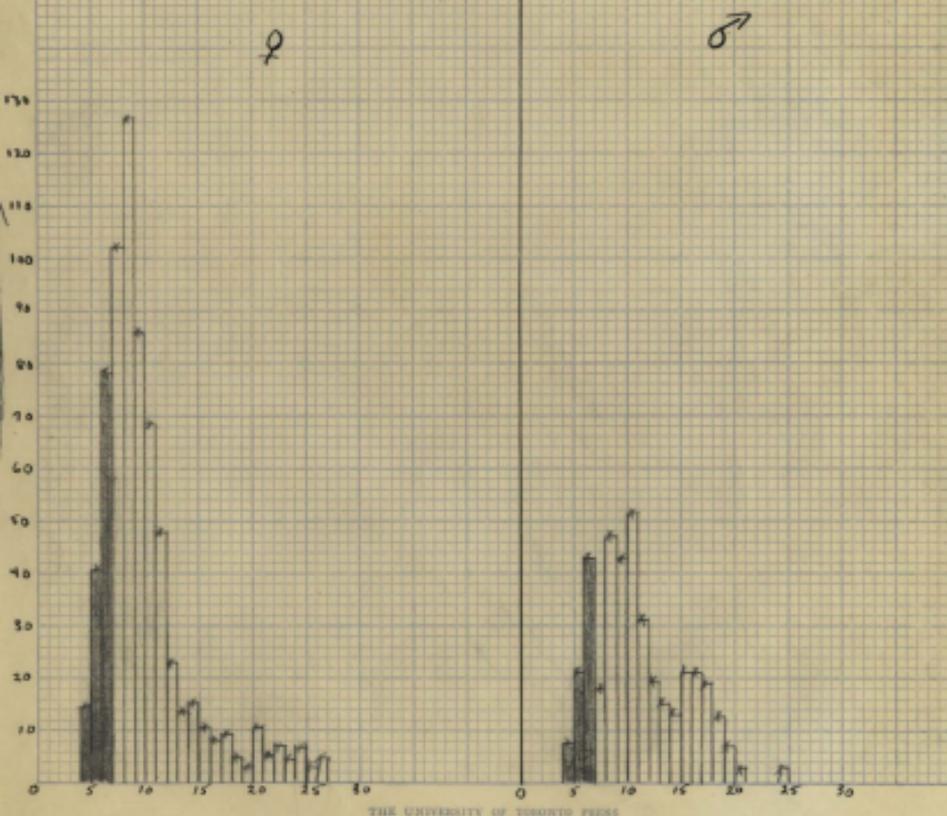


Fig. 9a

Fig. 9b

HEIGHT FREQUENCY DISTRIBUTION OF  
*P. triseriata* IN ALL PICKED-FROM-  
 SURFACE SAMPLES (JUNE, JULY, AUG.)  
 COMBINED (The 2-6 mm. size-class  
 frequencies have been "adjusted").



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HEIGHT (mm)  
 →

(Polinices at Belliveau Cove - Mating habits"). To locate the penis it is of course necessary to remove the meat from the shell. The procedure adopted this summer was to place the snails in boiling water for one or two minutes and then to extract the meat with a dissection needle.

In the larger specimens, the penis is very prominent. Some P. triseriata 7 mm. in height have a penis about 1.5 mm. in length (Table 4) while other specimens of that species and such height have a penis too small to be noticed in gross dissection. Those specimens must be considered below together with Polinices less than 7 mm. in height.

In the case of P. heros, the minimum height at which the penis may be observed would probably be about 14 mm. (see table 4).

b) Smaller specimens. Because the penis of a P. triseriata 6 mm. in height and under, and of a P. heros under, say, 14 mm., is very slightly developed and may well be overlooked in gross dissection, it is not practical to determine the sex of such specimens by determining the absence or presence of a penis.

Perhaps other differences may readily differentiate the sexes of Polinices. If they are discovered they may well eliminate the difficulty, indeed, the present impossibility, of readily ascertaining the sex of very small specimens.

c) Other means of determining sex. In some larger female specimens of Polinices, at least at certain times of the year, e.g., June and July, the ovaries may be seen packed with tiny light-coloured eggs, apparently hexagonal. The ovaries seem to be in the dark brown tip of the body. In males, on the other hand, the corresponding region is light brown and possibly contains sperm.

#### 10. SIZE COMPOSITION OF P. triseriata POPULATION AT BELLIVEAU COVE

a) Introduction. To further the study of the growth rate of P. triseriata at Belliveau Cove, the relationship between size-class and age-class, annual mortality, life span, etc., representative collections of P. triseriata were made this summer. The specimens were sorted as to height and sex except the smallest, which were sorted only as to height. In order to study the differences in the size-composition of the population as the season advanced, the sampling was divided into three parts, namely, June, July, and August.

b) Collecting specimens for study. It would seem that the most reliable method of obtaining representative samples of Polinices is by screening the soil rather than by picking by hand from its surface. However, if all the snails in a given

area were to be picked, and the danger of selecting the larger specimens while overlooking the smallest to be avoided, the latter method is perhaps almost as satisfactory as screening, assuming that snails of all size groups emerge on the surface from time to time. Both methods were employed this summer.

The June sampling was conducted at times between June 11 and July 8, inclusive. 1269 P. triseriata were collected, 811 being picked nocturnally from the surface at various distances seaward of high water mark, and 458 being obtained by screening at various distances from that mark (see table 8).

The July sampling was conducted on July 15, when 62 specimens were obtained by screening (Table 8).

The August sampling occurred at times between August 20 and August 26, inclusive. 521 specimens of P. triseriata were collected, including 372 obtained by picking from the surface nocturnally, and 149 by screening diurnally (Table 8).

c) Sex of specimens under 7 mm. in height estimated. It was thought desirable, for purposes of considering height-frequency distribution in both sexes of P. triseriata, to make some attempt to judge the sex of the specimens in cases where it could not be determined experimentally. The number of specimens, collected in the June, July, and August sampling of that species, whose sex was ascertained, is 1255. 813 or about 65% of them were females. Thus 65% of the specimens of unknown sex were considered to be females, the rest males.

The question of whether the 3 mm. class (i.e., 2 to 4 mm., inclusive, in height) and the 6 mm. class (5 and 6 mm. in height) respectively, represented males and females of the same age (year) class was considered. That may be the case, but it seems unlikely for at least two reasons. First, that many females in their initial year of life should grow to twice the height attained by many males during the same period, does not seem probable. Second, although it was not unusual to observe specimens of the 6 mm. class crawling on the surface after dark, it was quite rarely that snails of the 3 mm. class were noted there. Yet if both classes represented the same year group, why should females have appeared on the surface far more frequently than males of the same age?

d) Height-frequency distribution tables. Tables 9a, 9b, and 9c show the heights and sexes (where determined) of P. triseriata collected in the June, July, and August sampling, respectively. Table 9d is a summation of the three.

e) Discussion and conclusions.

TABLE 8

DATA RELATING TO COLLECTIONS OF POLINICES MADE IN ORDER TO STUDY THE SIZE-COMPOSITION OF THE POPULATION

<u>DATE OF SAMPLING</u> 1947	<u>LOCATION OF SAMPLING</u>	<u>METHOD OF SAMPLING</u>	<u>NO. OF SNAILS OBTAINED</u>	<u>SPECIES OF SNAIL OBTAINED</u>
June 11	Stake B	Screened	20	<u>P. triseriata</u>
June 11	" B	Picked from surface	28	"
June 11	" C	"	112	"
June 11	" D	"	14	"
June 12	" B	"	39	"
June 13	" B	Screened	30	"
June 13	" B	Picked from surface	38	"
June 13	" G, 300' seaward	Screened	43	"
June 14	" C	"	53	"
June 14	" D	"	53	"
June 14	" E &	"	10	"
	Stake F			
June 14	" G	"	6	"
June 16	" E &	"	42	"
	Stake F			
June 16	" G	"	45	"
June 16	" G, 300' seaward	"	8	"
June 23 & 24	Stake D	Picked from surface	185	"
June 23 & 24	" E	"	140	"
June 23 & 24	" F	"	127	"
June 23 & 24	" G and seaward	"	50	<u>P. heros</u>
June 23 & 24	" G and seaward	"	78	<u>P. triseriata</u>
June 30	I area	Screened	6	"
June 30	R "	"	15	"
July 3	I "	"	17	"
July 3	R area	"	14	"
July 5	I "	"	24	"
July 5	R "	"	26	"
July 7	I "	"	29	"
July 7	R "	"	59	"
July 8	I "	"	57	"
July 8	R "	"	51	"
July 15	Weir 1	"	3	"
July 15	Stake B	"	16	"
July 15	" C	"	33	"
July 15	" D	"	3	"
July 15	" E	"	4	"
July 15	" F	"	1	"
July 15	" G	"	2	"
Aug. 20	R area	"	36	"
Aug. 20	Stake B	Picked from surface	50	"

(Continued on P. 34)

TABLE 8 - CONTINUED (from P.33)

<u>DATE OF SAMPLING</u> 1947	<u>LOCATION OF SAMPLING</u>	<u>METHOD OF SAMPLING</u>	<u>NO. OF SNAILS OBTAINED</u>	<u>SPECIES OF SNAIL OBTAINED</u>
Aug. 20	Stake C	Picked from surface	50	<u>P. triseriata</u>
Aug. 20	" D	"	50	"
Aug. 21	I area	Screened	51	"
Aug. 21	Stake E	Picked from surface	50	"
Aug. 21	" F	"	50	"
Aug. 21	" G	"	50	"
Aug. 22	I & R areas	Screened	43	"
Aug. 22	Stake B	Picked from surface	12	"
Aug. 22	" C	"	12	"
Aug. 22	" D	"	12	"
Aug. 22	" E	"	12	"
Aug. 22	" F	"	12	"
Aug. 22	" G	"	12	"
Aug. 26	" B	Screened	4	"
Aug. 26	" C	"	10	"
Aug. 26	" D	"	2	"
Aug. 26	" E	"	1	"
Aug. 26	" F	"	2	"

TABLE 9a

HEIGHT-FREQUENCY DISTRIBUTION OF *P. triseriata* OBTAINED  
IN JUNE SAMPLING BY PICKING FROM THE SURFACE AND SCREENING  
THE SOIL

<u>HEIGHT</u> mm.	<u>SCREENED SAMPLES</u>			<u>SAMPLES FROM SURFACE</u>		
	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>
1	0			0		
2	18			0		
3	61			0		
4	96			7		
5	80			21		
6	73			67		
7		54	6		65	12
8		41	12		88	28
9		21	16		52	21
10		21	18		43	34
11		10	9		30	21
12		15	7		12	15
13		7	6		9	10
14		7	2		11	13
15		13	1		8	20
16		1	1		8	18
17		1	0		7	17
18		1	0		4	12
19		0	0		3	4
20		1	0		10	1
21		0	0		5	0
22		0	0		6	0
23		0	0		4	0
24		0	0		6	1
25		0	0		3	0
26		0	0		4	0
	328	193	78	95	378	227

TABLE 9b

HEIGHT-FREQUENCY DISTRIBUTION OF *P. triseriata* OBTAINED  
IN JULY SAMPLING BY PICKING FROM THE SURFACE AND  
SCREENING THE SOIL

<u>HEIGHT</u> mm.	<u>SCREENED SAMPLES</u>			<u>SAMPLES FROM SURFACE</u>		
	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>
1	0			N I L		
2	0					
3	0					
4	5					
5	10					
6	8					
7		7	0			
8		6	3			
9		2	5			
10		4	1			
11		2	0			
12		2	1			
13		1	0			
14		0	0			
15		0	1			
16		1	0			
17		1	1			
18		0	0			
19		0	0			
20		0	0			
21		0	0			
22		0	0			
23		0	0			
24		1	0			
<hr/>						
	23	27	12	N I L		

TABLE 9c

HEIGHT-FREQUENCY DISTRIBUTION OF *P. triseriata*  
OBTAINED IN AUGUST SAMPLING BY PICKING FROM THE  
SURFACE AND SCREENING THE SOIL

<u>HEIGHT</u> mm.	<u>SCREENED SAMPLES</u>			<u>SAMPLES FROM SURFACE</u>		
	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>	<u>SEX</u> <u>UNKNOWN</u>	<u>FEMALE</u>	<u>MALE</u>
1	0			0		
2	1			0		
3	6			0		
4	19			14		
5	18			39		
6	20			52		
7		6	3		37	6
8		7	8		37	19
9		6	3		33	21
10		5	5		25	17
11		3	11		18	9
12		4	4		10	4
13		6	3		5	4
14		1	1		4	0
15		2	0		2	1
16		1	0		0	3
17		0	1		2	1
18		0	0		0	0
19		1	0		0	1
20		0	0		0	0
21		0	0		0	0
22		0	0		0	0
23		0	0		1	0
24		0	0		1	0
	64	42	39	105	175	86

TABLE 9d

HEIGHT-FREQUENCY DISTRIBUTION OF *P. triseriata* OBTAINED  
IN ALL SAMPLING (JUNE, JULY, AUGUST) BY PICKING FROM  
SURFACE AND SCREENING THE SOIL

HEIGHT mm.	SCREENED SAMPLES			SAMPLES FROM SURFACE		
	SEX UNKNOWN	FEMALE	MALE	SEX UNKNOWN	FEMALE	MALE
1	0			0		
2	19			0		
3	67			0		
4	120			21		
5	108			60		
6	101			119		
7		67	9		102	18
8		54	23		125	47
9		29	24		85	42
10		30	24		68	51
11		15	20		48	30
12		21	12		22	19
13		14	9		14	14
14		8	3		15	13
15		15	2		10	21
16		3	1		8	21
17		2	2		9	18
18		1	0		4	12
19		1	0		3	5
20		1	0		10	1
21		0	0		5	0
22		0	0		6	0
23		0	0		5	0
24		1	0		7	1
25		0	0		3	0
26		0	0		4	0
	415	262	129	200	553	313

## I. June Sampling.

A) FEMALES. It may be seen from figure 5a, which shows the height-frequency distribution in screened female samples for June (specimens 6 mm. and under in height have been divided between the sexes on a 65% - 35% basis, as mentioned above, in all the bar graphs) that at least two height-classes are indicated, with modes at 4 and 7 mm. Possibly a third mode is fused with the second and would otherwise have appeared to represent a composite age group of older snails. The 4 mm. mode possibly represents yearling snails, the 7 mm. mode, two-year-olds. This accords roughly with the findings of Stinson, who assumed that females attained heights of 3 and 9 mm., respectively, by about the end of their first and second years.

B) MALES. Figure 5b clearly reveals two maxima at 4 and 10 mm., respectively. It would appear that either the one- or two-year-class is not manifested in the graph (the 4 mm. mode doubtless represents one of those classes) and that either the three-year-old group or a composite age group is represented by the 10 mm. mode.

## II. July Sampling.

A) FEMALES. Little change seems to have occurred between the June and July screenings (12). However, the 4 mm. mode indicated by June figures has become a 5 mm. mode in July (Figure 6a). The 7 mm. mode is still evident.

B) MALES. Modes at 5 and 8 mm. are apparent (Figure 6b). It may be that the 8 mm. class represents 1945 snails. If so, 1945 females must have attained a height greater than 7 mm., at least if it is assumed that females are larger than males the same age. Possibly they are not, although the opposite is indicated. For one thing, the female in a mating pair is always considerably larger, and, also, few males over 17 mm. in height are found, while females over 20 mm. in height are quite common. On the other hand, such evidence is not conclusive: possibly the female in a mating pair is usually older, or females may grow at the same rate for a longer period than do males.

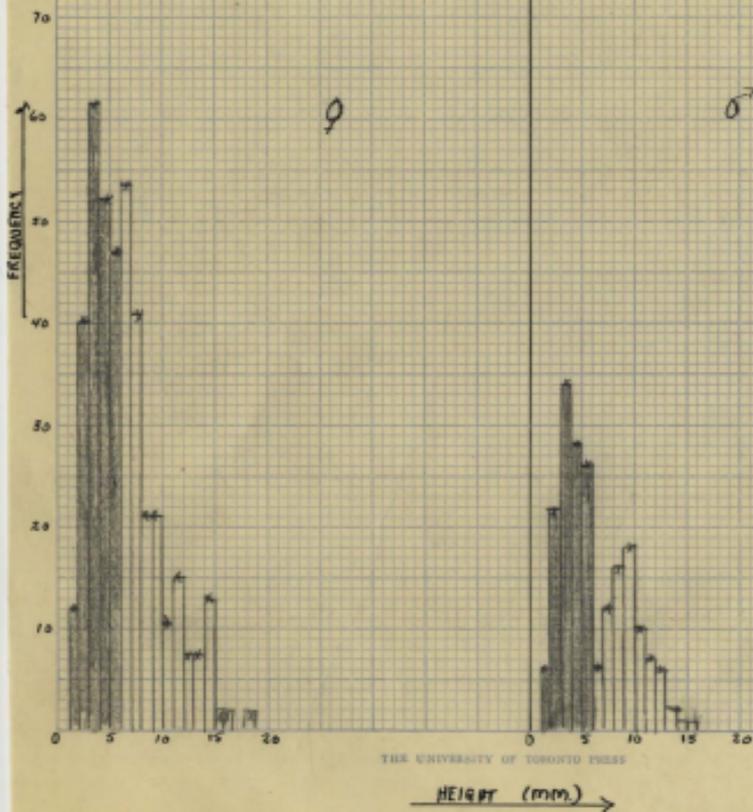
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(12) Actually only one week elapsed between the end of the June sampling and the start of the July sampling (see above, Section 10 - b).

Fig. 5a

Fig. 5b

HEIGHT-FREQUENCY DISTRIBUTION OF  
*P. triseriata* IN JUNE SCREENED  
SAMPLES (The 2-6 mm. size-class  
frequencies have been "adjusted").



### III. August Sampling.

A) FEMALES. The 4 mm. mode exhibited by the June graph which became a 5 mm. mode in July has by August shifted to 6 mm. (Figure 7a)(13). The 7 mm. mode has become an 8 mm. mode, and a new one is evident at 13 mm.

B) MALES. Frequency maxima in the male samples for August occur at 4-6, 8 and 11 mm. (Figure 7b). The 11 mm. mode is very prominent.

IV. June, July, and August Sampling. Figures 8a and 8b are height-frequency distribution graphs combining the graphs for the individual months' sampling as considered above.

It may be noted that among the snails 4 to 6 mm., inclusive, in height, the 4 mm. specimens were the most frequently obtained at the start of the season, while towards the end, there was a slight preponderance of 6 mm. specimens. It may be that at the start of this season, the 4 mm. group represented 1945 snails, while at season's end, those snails had attained an average height of 6 mm. Now suppose 1946 snails, at the start of the season had reached an average height of 3 mm. or less (many of the smaller ones not being secured in a 16-mesh-per-inch screen) and during the summer grew to an average height of 4 mm. Thus the 4 mm. group would represent 1945 and 1946 snails at the start and end of the season, respectively. That would mean, however, two-year-old specimens have an average height of 6 mm., whereas Stinson was led to think that they reach a height of 9 mm. even before their second year is complete. Again, in view of the facts that specimens over 20 mm. in height are common and that the life span is thought to be only five or six years, 6 mm. height does not seem sufficient for an average two-year-old specimen.

V. Samples Picked from the Surface. The greatest difference between the samples obtained from the surface and those by screening, seems to be that the relative number of specimens 6 mm. and under in height is less in the former samples. Figures 9a and 9b, which show the height-frequency distribution in all samples picked from the surface (June, July and August) may be noted in comparing the results of the two methods of sampling.

VI. P. heros Samples. In June, specimens of P. heros were obtained by picking from the surface, but not enough were collected to warrant discussion here, it is felt. Table 10

(13) If more time had elapsed between the June and July sampling and an equal period between the latter and the August screenings, it might be considered that this gradual shifting of the mode represents the summer growth in females. Possibly it does.

Fig. 6a

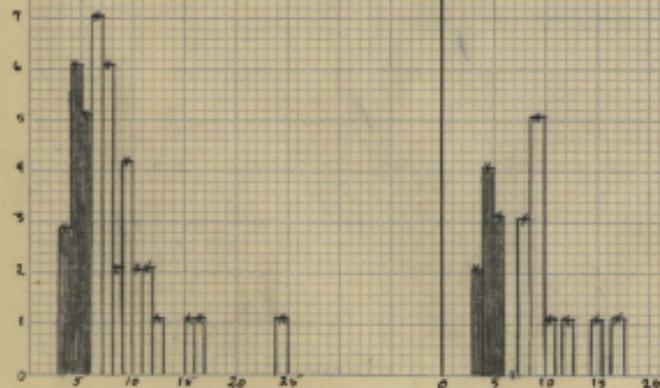
Fig. 6b

HEIGHT-FREQUENCY DISTRIBUTION OF  
*P. triseriata* IN JULY SCREENED  
 SAMPLES (The 2-6 mm. size-class  
 frequencies have been "adjusted").

FREQUENCY

♀

♂



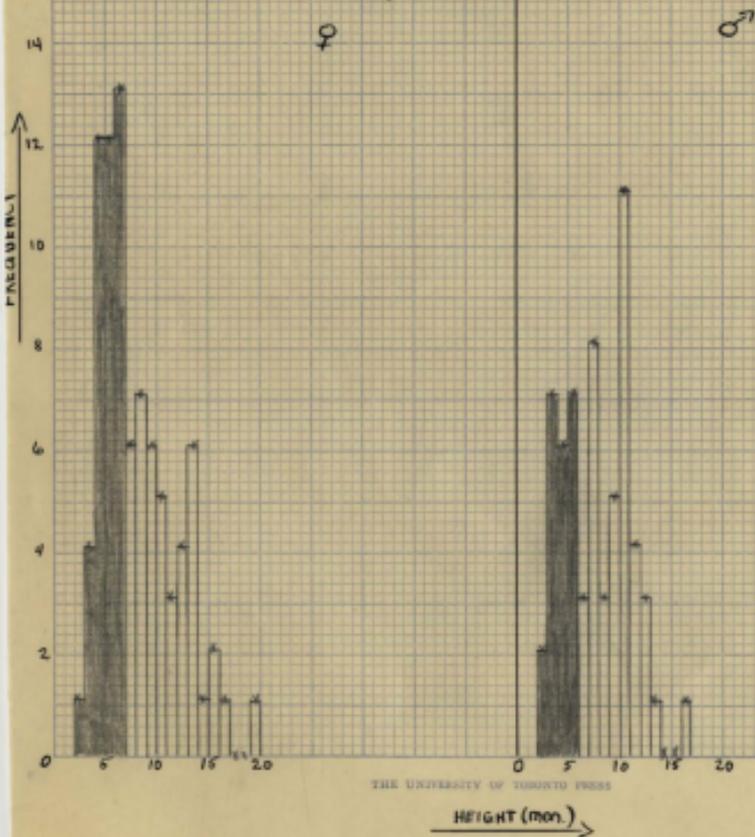
THE UNIVERSITY OF TORONTO PRESS

HEIGHT (mm)

Fig. 7a

Fig. 7b

HEIGHT-FREQUENCY DISTRIBUTION OF  
*P. triseriata* IN AUGUST SCREENED  
 SAMPLES (The 2-6 mm. size-class  
 frequencies have been "adjusted").



shows the height-frequency distribution of the P. heros obtained.

#### VII. Conclusions.

1) It would be well if a practical method of determining experimentally the sex of P. triseriata 6 mm. and under in height were found as it is felt a more accurate picture of height- and age-class, and of the relationship between the two, would then be possible.

2) The average height of one-year-old P. triseriata may be 4 mm., that of two-year-olds 6 mm.

3) The 4 mm. group may have represented 1945 and 1946 snails at the start and end of this season, respectively.

4) In the case of female P. triseriata, a year group (probably second or third) seems represented by snails 7 and 8 mm. in height, as the frequency of those heights produces maxima in the bar graphs. Similarly, in the case of males, a year group (probably third or fourth) may be represented by snails 9-11 mm. in height, or perhaps that height range comprises a composite age group.

5) A smaller percentage of P. triseriata 6 mm. and under in height is found in samples obtained by picking from the surface than in screened samples.

#### 11. FREQUENCY OF POLINICES EGG CASES

a) Introduction. A program was organized at the start of this season to measure the relative abundance of Polinices egg cases on the flat at various distances from high water mark throughout the season. Stinson made such a survey, though perhaps not as comprehensive as that conducted this year. The results of Stinson's survey are tabulated in his table 11.

b) Procedure. On June 7, an area of 50 x 50 feet was marked off at seven levels on the flat selected to correspond with the sites of Stinson's observations last year (see his table 11) and a count of the number of collars in each area was made. Frequently thereafter, similar counts were made at approximately the same sites on the flat. Also, a 50 x 50 feet observation area (to be referred to as CF (collar frequency) area) was staked out in Deck 1. A count of the collars in CF area was made on June 7 and about once weekly afterwards.

c) Results. Results of the collar surveys are given in table 11. Figure 10 shows the number P. triseriata egg cases occurring at all the various sites on the flat as the season advanced. Figure 11 shows the number occurring in CF area alone as the season advanced.

TABLE 10

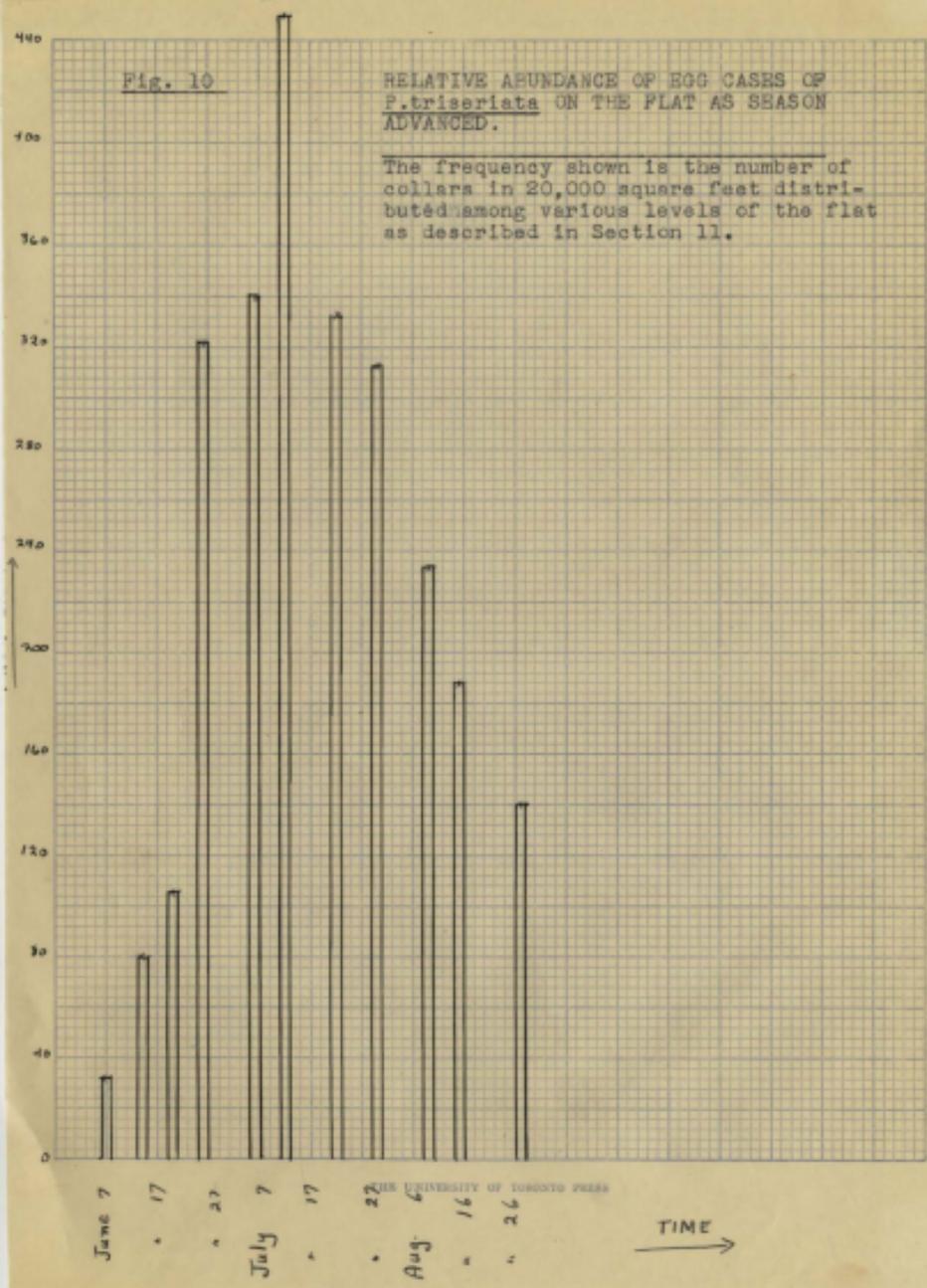
HEIGHT-FREQUENCY DISTRIBUTION OF *P. heros* OBTAINED  
IN JUNE SAMPLING BY PICKING FROM THE SURFACE OF THE  
SOIL AND SCREENING.

HEIGHT mm.	SCREENED SAMPLES		SAMPLES FROM SURFACE	
	FEMALE	MALE	FEMALE	MALE
10	0	0	1	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	3	0
15	0	1	0	1
16	1	0	0	1
17	0	0	0	0
18	0	0	2	1
19	0	0	0	1
20	0	0	3	2
21	0	0	0	0
22	0	0	3	2
23	0	0	2	0
24	0	0	2	3
25	0	1	0	3
26	0	0	2	1
27	0	0	2	2
28	0	0	0	2
29	0	0	3	1
30	0	0	2	0
31	0	0	0	1
32	0	0	0	0
33	0	0	1	1
34	0	0	0	0
35	0	0	0	0
36	0	0	0	0
37	0	0	0	0
38	0	0	0	0
39	0	0	0	0
40	0	0	0	0
41	0	0	0	0
42	0	0	0	0
43	0	0	0	0
44	0	0	0	0
45	0	0	0	0
46	0	0	1	0
	1	2	27	22

Fig. 10

RELATIVE ABUNDANCE OF EGG CASES OF  
*P. triseriata* ON THE FLAT AS SEASON  
ADVANCED.

The frequency shown is the number of  
collars in 20,000 square feet distri-  
buted among various levels of the flat  
as described in Section 11.



TIME →

Fig. 11

RELATIVE ABUNDANCE OF *P. triseriata*  
EGG CASES IN CP AREA AS SEASON ADVANCED.

The frequency shown is the number of collars counted on various dates in the 2500 square foot area of the flat known as CP area (See Section 11)

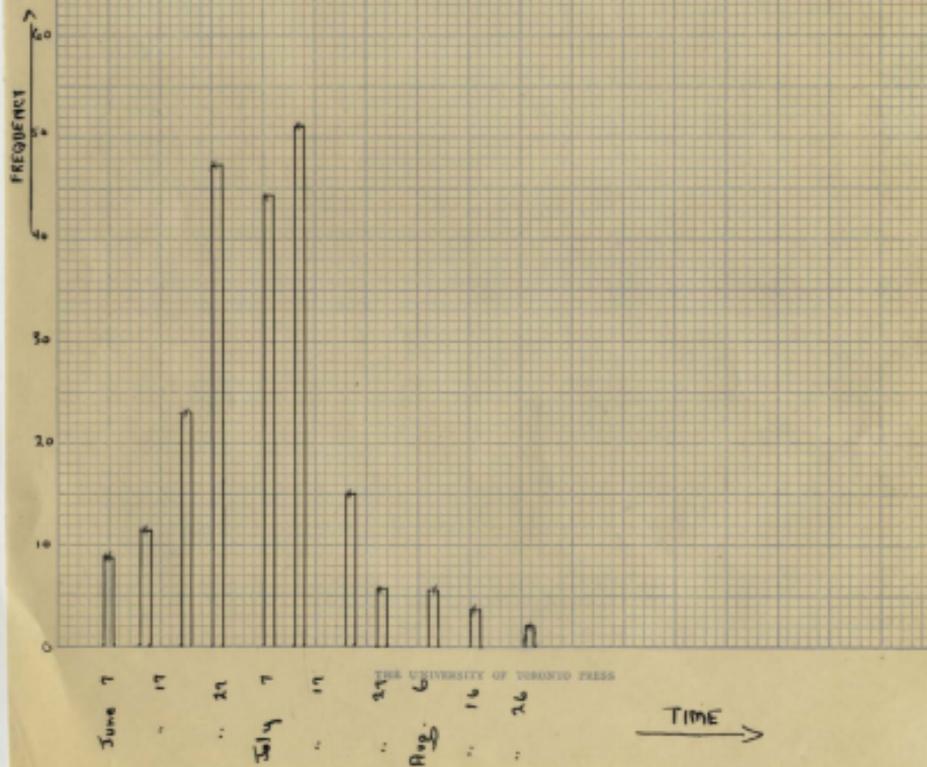


Table 11 is not suggestive of the number of P. heros egg cases on the flat as a whole as it is in the case of P. triseriata collars. Stinson mentions seeing the first P. heros egg case of the season on June 18. This year it was noted on June 23, when a small collar was found near Weir 1. Apparently it was not quite new, as it bore egg cases of Nassa trivittata on both sides. No more were observed until July 7, when a large P. heros collar was noted also near Weir 1.

On July 12 five P. heros collars were found, four near Weir 1, one in Dock 1, into which the tide had likely carried it.

On July 17, eleven P. heros collars were counted between Weir 1 and Major's Point.

On August 2, five collars of that species were observed near the remains of Weir 2 (see Stinson's figure 1) and two near Weir 1.

A few such collars were noted near Weir 1 and seaward from time to time between August 2 and 18.

d) Discussion and conclusions. The data pertaining to CF area may possibly be more reliable than those pertaining to the other observation sites. The latter were but approximately the same each week, being marked out anew each time, while CF area was staked out in June and used all season. However, as may be seen by comparing figures 10 and 11, the pattern of relative abundance upon the various dates observed in CF area is very similar to that observed on the flat as whole.

The frequency of P. triseriata egg cases reached its maximum for the season about July 12 and thereafter declined steadily. During the latter part of the season, a good many of the collars remaining on the flat were infected with alga growths (see above, Section 8 - a - 3) and likely would have hatched the snails already had it not been for the infection.

Thus the period of maximum frequency and of hatching occurred earlier this year than in 1946. Stinson's table 11 weakly suggests a peak on July 19, but the ensuing drop between then and August 16 seems not nearly so great as that between July 12 and one month later this year.

Up until early July at least, as may be noted by comparing table 11 with Stinson's table 11, there seems to have been fewer P. triseriata egg cases on the flat this year than in 1946.

Maximum frequency of P. heros collars seemed to occur this summer during the latter part of July. Stinson mentions



that most were seen last year in that month.

The following conclusions are submitted:

1) Collar production this year by P. triseriata, beginning in late May, increased steadily until mid-July when most of the collars began to break up, releasing the young snails. After mid-July, collar production dropped heavily until season's end.

2) The maximum frequency of the collars and the hatching period occurred earlier this year than in 1946.

3) Collar production by P. heros this year, as in 1946, began in June and increased through most of July, when the peak was reached.

4) Fewer P. triseriata egg cases appeared on the flat this year than in 1946, at least until early July.

5) The development of many, perhaps most, of the collars appearing on the flat towards season's end this year, seemed to have been arrested by algal growths which infected them.

## 12 LARVAL LIFE AND INCUBATION PERIOD

a) Introduction. It may be recalled that Stinson suggested, on the basis of tests made by him last year, that "the total development period for the 'A' snail (P. triseriata) larva is at least two months and possibly three" while "it is probable that the incubation period (of P. heros averages one month to six weeks". It was decided this year to keep under observation several collars of both species. Some of the P. triseriata collars were to be placed under observation when the embryos therein had reached the shelled veliger stage of development<sup>(14)</sup> and be examined from time to time until the young snails hatched, while observations on other P. triseriata collars and on P. heros collars were to begin just after the collar was produced, i.e., while the ova were still in the 1-4 cell stage, and continue at intervals until the escape of the larvae from the collar.

The question of how best to keep collars under observation while investigating larval life is somewhat difficult to answer. If they are kept in an aquarium in the laboratory

(14) In connection with larval development reference should be made to Stinson's Section III - 3 ("Reproduction and Larval Life - Larval Life"). Microscopic examinations made this year of egg cases of Polinices corroborated much of what Stinson has said concerning the successive stages of larval development, and failed to contradict any.

(as in fact a few were, for purposes of comparison) the eggs obviously are not developing among natural surroundings. If the collars are caged on the flat, the same applies to some extent, for they are likely to become completely buried in sand. If they are tethered, by means of a thread through a small hole in the collar, to some object on the flat, they tend to collect about the object, becoming buried at its base in sand and seaweed. Possibly the best method is to stake out a small area on the flat, placing therein the collars to be observed. Regrettably, however, quite a few are washed away. Of them, some may be recognized by their small identifying notches and returned to the area.

b) Procedure adopted to investigate incubation periods.

On July 12, two small areas (about 5 x 5') were staked out in Dock 1. In one were placed six P. triseriata egg cases whose embryos just previously had been found to be in the 1-4 cell stage of development. In the other area were placed five P. triseriata collars whose embryos had reached the shelled veliger stage, and four P. heros collars. Of the latter, two had embryos in a multicellular, non-veliger stage of development, one had bicellular ova, and the fourth had veligers, possessing a half-whorl of shell, which were moving within the capsules.

Other egg cases whose embryos were at either a 1-4 cell level of development or the shelled veliger stage were later placed in one or the other area, depending on the extent of development, and were re-examined periodically.

c) Results. Many of the collars, including most of those placed on July 12, were lost. Two P. heros collars were retained until they began to crumble, presumably releasing young snails. One of the collars, 58 mm. in height, was observed on July 12 to have embryos in a multicellular, non-veliger stage of development. It is not known how old the collar then was. On July 26, when it was observed crumbling, embryos in a portion of the collar were examined and seen to possess semi-transparent shells, rapidly beating cilia, and opercula. Vela appeared to be present. When loosed in sea-water, some frequently moved their opercula, extending what appeared to be ciliated vela. Swimming was not observed. The other P. heros collar which crumbled while under observation did so on August 7, eight days after its embryos were seen to be at a multicellular level, not having reached the shelled veliger stage. On August 7, the veligers seemed to possess half a whorl of transparent shell. In most cases the apertures were closed. Beating cilia were observed in a few instances. The height of the veligers was judged to be about 0.3 mm.

On August 1, two egg cases of P. triseriata were placed under observation. The eggs of one were unicellular, of the other, just past the four cell stage. By August 13, all of the embryos seemed to have advanced to a multicellular stage, a few had developed vela, and in one instance at least, a reddish colored shell had been wrought.

d) Possible free-swimming stage of *P. heros*. Stinson suggests, though he adds that the question is still doubtful, that there is a free-swimming veliger larval phase in the development of *P. heros*. He presumed that when the larvae are ready to leave the capsule they have developed a half-whorl of very thin and transparent shell, an agile foot, and a velum which they retain for a period after leaving the capsule. The larvae within the two *P. heros* collars that began to crumble during the period of investigation (see above, this section), which were examined at the time the collar was crumbling, seemed to fit Stinson's description. The shells of those larvae, however, appeared darker and less transparent than was the case with embryos noted at a supposedly earlier stage of development. No swimming was noted, it may be remembered, when the larvae from the crumbling egg case were loosed into sea-water.

The question of whether *P. heros* do develop a free-swimming larva is still not answered definitely. However, it appears that the larvae hatch from the capsules still equipped with a velum and cilia.

e) Examination of egg cases. On two occasions this summer, a series of collars was collected and examined. Findings, which generally agree with those of Stinson, are tabulated in table 12. (cf. Stinson's tables 8 and 9).

f) Larvae of *Polinices* obtained at Pinette. The eggs in one or two collars produced by *Polinices* at Pinette appeared on microscopic examination to be similar to those *P. heros* at Belliveau Cove. Figure 12 shows photomicrographs of the ova of such a collar. They apparently were killed while still unicellular. They may be compared with those produced at Belliveau Cove last year as shown in Stinson's photomicrographs.

g) Time involved in production of an egg case. It has not, it is thought, been ascertained how much time is consumed in the production of an egg case by a *Polinices*. Often a collar is completed in the early morning, and on the basis of what was observed this summer, it is thought that production is an all-night task. On a few occasions on and after June 27, at times ranging from about 7:00 to 10:30 p.m., *P. triseriata* were observed in what was possibly the beginnings of collar production. The snails seemed to be reposing on their sides, with the feet barely in contact with the sand. When picked up, they were noted to be attached to a string of jelly-like material about four to six inches in length. The clear, slimy jelly often contained many grains of sand.

h) Microscopic technique in examination of embryos. The capsules in a collar, usually containing one egg (in the case of *P. triseriata*) and about thirty eggs (in the case of *P. heros*) are separated from one another by sand and jelly, and thus individual capsules and their contents can easily be studied.

TABLE 12

SHOWING THE RESULTS OF THE EXAMINATION  
OF SEVERAL POLINICES EGG CASES (cf.  
Stinson's Tables 8 and 9)

COLLARS ARE THOSE OF P. triseriata UNLESS OTHERWISE STATED

<u>DATE</u> <u>COLLECTED</u>	<u>AVERAGE</u> <u>HEIGHT</u>	<u>APPROX.</u> <u>AREA</u>	<u>NO. OF</u> <u>CAPSULES</u>	<u>NO. OF</u> <u>CAPSULES</u>	<u>EGGS PER</u> <u>CAPSULE</u>	<u>REMARKS</u>
1947	cm.	cm. <sup>2</sup>	<u>PER SQ.</u> <u>CM.</u>	<u>PER</u> <u>COLLAR</u>		
			(APPROX.)	(APPROX.)		
June 27	2.3	31	42	1300		
June 27	2.1	29	50	1450		
June 27	2.2	33	57	1880		
June 27	1.9	17	43	730		
June 27	1.9	22	40	880		<u>Ectocarpus</u> Collar infected
June 27	1.7	20	38	760		with/ do (x)
July 30	2.0	21	40	840		
July 30	2.4	32	25	800	1 †	
July 30	1.8	15	50	750	1	green alga
July 30	1.8	23	28	640	1	Collar infected with/
July 30	2.0	24	48	1150	1 †	
July 30	1.7	18	36	650		
AVERAGE	2.0	23.5	41.5	975		
July 30	3.6	79	120	9480	20	<u>P. heros</u> collar

(x) - A few capsules were yellow and degenerate.

It was found best to slice off the tops of a patch of capsules, i.e., a section of collar, by means of a scalpel, and thus expose the ova lying suspended in the small jelly-filled craters. For much work, 56x magnification was found suitable, and at times 120x was used.

1) Discussion and conclusions. As has been said, the examinations made this summer lent support to Stinson's findings that P. triseriata undergo the following stages in developing within the capsule. The unicellular egg experiences cleavage and becomes successively bicellular and four-celled. Next a plate of small cells forms on top of the four larger cells, development then becoming complex. The next stage to emerge clearly is the shelled veliger, cilia and a velum being evident. The velum later disappears, the reddish shell develops further, and the larva is then ready to leave the capsule. In the case of P. heros, early development appears to be similar. The P. heros veliger has a thin, transparent shell, not reddish in color. It may be at this veliger level of development that the larvae leave the capsules.

With regard to the incubation period, Stinson concludes that in the case of P. triseriata two or three months are involved. Nothing was observed this year seeming either to support or gainsay such a conclusion, although it is true that at least one embryo (as has been noted) developed from the 1 - 4 cell stage to a shelled stage within about thirteen days, whereas Stinson held that about six weeks are required for the embryo to develop 1/3 whorl of shell.

In the case of P. heros, Stinson suggests that the incubation period probably averages one month to six weeks, but may it not be even less? Stinson himself records the following: "The only record of hatching (in the case of P. heros) 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." Again, as has been mentioned, two P. heros collars on the flat crumbled, presumably releasing their larvae, fourteen and eight days, respectively, after they were placed under observation. It is true that the age of the collars when first observed is not known, but in both cases the embryos were at a multicellular stage, no sign of vela or shells being apparent.

In connection with larval development, it may be interesting to refer again to Section 8 - a - 2 above ("Agents Destructive of Polinices - Crustaceans").

The following conclusions may be indicated by the foregoing:

1) It still seems likely that the incubation period P. triseriata is two or three months.

2) The incubation period of P. heros may be less than one month.

3) Whether P. heros larvae undergo a free-swimming stage remains uncertain (though it seems probable that they do) and the matter should be further investigated.

4) P. triseriata may commence production of an egg case in the evening, completing it the following morning.

### 13. MARKED SNAILS

On a few occasions during the summer, P. triseriata were marked with red or black Volger's ink and replaced on the flat. Although none of the forty-seven snails marked have yet been recovered, it is hoped that some may be encountered next year or later and furnish information about growth rate, migration, etc. Should these specimens be found, it is submitted that a record be kept of where they are found and that they be measured for height and sexed, this information when obtained being compared with that given in table 13. The latter tabulates the data relating to the snails marked during the summer.

### 14. CLAM RELAYS

a) Introduction. Apparently a large part of the flat at Belliveau Cove - much of the great expanse of nearly pure sand found at the lower levels - is unpopulated by soft shell clams. Stinson indicates (see his figure 1) that the seaward limit of the soft shell clam population about the center of the cove is some 1570 feet from high water mark. Beyond this, is a large area of smooth, sandy surface which might prove satisfactory for clam production.

To provide information on the possible usefulness of the low flats which are not populated naturally, it was decided to relay at or near low tide mark a few hundred soft shell clams taken from the stock at Sissiboo River four miles away, and from the stock at Belliveau Cove itself.

b) Procedure - First relay. The first relaying operation was done on June 20. About 7200 soft shell clams from the Sissiboo stock, judged to average about  $1\frac{1}{2}$  inches in length, were planted a few hundred feet seaward of Weir 1, that is, about 2250 feet seaward of high water mark. They were spread by hand, a cultivator also being used, over an area approximately 30 x 30'. The area, designated Observation Area I, was staked off with metal piping.

c) Later observations. The plot was visited at 5:00 a.m. on June 21, that is, twelve hours after the relay. The density of clams on the surface seemed to have diminished, many

TABLE 13

SHOWING DATA RELATING TO P. triseriata MARKED  
WITH VOLGER'S INK AND RELEASED ON FLAT THIS SUMMER

<u>DATE</u>	<u>WHERE RELEASED</u>	<u>HEIGHT</u>	<u>MARK ON</u>	<u>COLOR OF</u>	<u>REMARKS</u>
<u>SPECIMEN</u>		<u>OF SNAIL</u>	<u>SHELL</u>	<u>INK</u>	
<u>MARKED &amp;</u>		mm.			
<u>RELEASED</u>					
1947					
June 23	Within 1' of stake at NW corner of R area	6 to 15	X	Red	12 specimens in- volved in this series (See note 1 below)
June 27	Within 1' of stake at SW corner of I area	23	X1	Red	
June 27	do	10	X2	Red	
June 27	do	12	X3	Red	
June 27	do	10	X4	Red	
June 27	do	13	X5	Red	
June 27	do	10	X6	Red	
June 27	do	10	X7	Red	
June 27	do	4	X8	Red	
June 27	do	10	X9	Red	
June 27	do	9	10	Red	
June 27	do	8	11	Red	
June 27	do	10	12	Red	
June 27	do	9	13	Red	
July 15	Center of I area	22	I	Black	
July 15	do	18	2	Black	
July 15	do	16	3	Black	
July 15	do	17	5	Black	
July 15	do	16	6	Black	
July 15	do	16	7	Black	
July 15	do	14	9	Black	
July 15	do	17	10	Black	
July 15	do	15	11	Black	
July 15	do	16	12	Black	
Aug. 26	I area	16	II	Black	(See note 2 below)
Aug. 26	do	12	III	Black	
Aug. 26	do	13	IV	Black	
Aug. 26	do	16	V	Black	
Aug. 26	do	8.5	VI	Black	
Aug. 26	do	13.5	VII	Black	
Aug. 26	do	14	VIII	Black	
Aug. 26	do	15.5	IX	Black	
Aug. 26	do	12.5	X	Black	
Aug. 26	do	11	XI	Black	
Aug. 26	do	14.5	XII	Black	
Aug. 26	do	14	XIII	Black	

Note 1 - Unlike the specimens marked after June 23, which were taken to the laboratory for marking, the 12 specimens marked on that date were marked on the flat where found and released.

Note 2 - The 12 specimens marked on August 26 were evenly distributed when being released, over I area.

of the clams having buried themselves during the night, others having uprighted themselves in preparation for burrowing. Gulls had seemingly taken a small toll as evidenced by emptied shells lying about with their valves well apart. Several Polinices were in the relay plot. Bunching of the clams by wave action had occurred hardly at all.

On June 26 the plot was again visited. It was under a foot of rather opaque water, though something of the situation could be seen. It appeared that most of the clams had gone below the surface, though several, quite evenly distributed within the area, were still visible. Wave action resulting in bunching or carrying the clams landward still seemed negligible.

On July 17 (Observation Area I, because of its location, is uncovered only at spring tide) the plot was again examined. About thirty or forty opened shells were on the surface evidencing gull action. No bored shells were found on the surface, but when a few spots were selected at random for sampling, three bored shells as well as three living clams were noted about three inches beneath the surface. About a dozen clams, apparently alive, were on the surface. One feeding operation was observed: a P. heros 34 mm. in height had inclosed in its foot a soft shell clam 48 mm. in length. When the latter was rescued, it was seen to be already drilled and enveloped in a slimy sheath.

The relay ground was next visited on August 16. Hardly any clams or shells of clams were seen on the surface. A few drilled mussel shells, 8 mm. in length and longer, were noted on and beneath the surface, as well as one drilled F. triseriata shell. A dozen Polinices egg cases were removed from the observation area.

Information, considered quite important, was obtained as a result of an attempt made on August 16 and 18 to ascertain the remaining population of soft shell clams in Observation Area I. It may be remembered that 7200 clams were planted there on June 20. Twenty square-foot samples of soil six inches in depth were selected within the observation area, the soil being sifted through a  $\frac{1}{2}$ " mesh screen. No living soft shell clams were found. Rather, the following was secured by the screen:

Soft shell clams (Empty)		<u>P. triseriata</u>	<u>P. heros</u>	<u>Bar clams</u>
<u>Drilled</u>	<u>Not Drilled</u>			
40	20	9	2	1

The largest of the drill holes in the clam shells measured 8 mm. in outer diameter, some were much smaller. The latter may have been made by P. triseriata.

As has been said (see Section 6 - a - IV above), some of the clams had doubtless been attacked by gulls, but it is felt that most of the destruction was due to attacks by Polinices.

d) Procedure - Second relay. On August 1, a second relay was conducted. 2500 soft shell clams, taken from the vicinity of the piers at Belliveau Cove, were transferred to a lower level, that is, to about forty feet southwest of Weir 1. They were spread over an area about 18 x 17', called Observation Area II, at the corners of which stakes were placed. The clams were judged to average between 1 and 1½" in length.

e) Later observations. At 5:30 a.m. on August 2, i.e., about thirteen hours after the clams were relayed, the area was visited. It seemed that over 75% of the clams remained on the surface. A few were in process of burrowing. Gulls had apparently taken a small toll. Wave action resulting in bunching and washing away the clams had been negligible. Three P. heros were noted devouring the meat of clams with shells broken in handling.

At 6:30 p.m. on August 4, about 72 hours after the relay, Observation Area II was again visited. Gulls seemed to have done some damage, fifty or more emptied shells with valves well apart being noticeable. There remained on the surface, too, about 3.5 clams per square foot, i.e., nearly one thousand in all. Hence some 58% had probably gone below the surface within the 72 hours. Wave action had apparently been negligible. One P. heros was noted emerging onto the surface.

Observation Area II was next examined on August 7. Some clams were still to be seen on the surface. A few among them were picked at random and examined for drilling, but none was seen. One P. triseriata was on the surface in the area.

On August 9 the plot was again inspected. The number of clams remaining on the surface seemed to have diminished since the previous visit.

f) Inspection in 1948 suggested. It is suggested that Observation Area II be inspected next summer and samples of soil there screened in order to discover the following:

1) Percentage of clams to survive the winter within the relay plot.

2) Approximate growth of the survivors since the relay.

3) Percentage of the clams apparently attacked by Polinices.

4) Whether Observation Area II possibly represents a more favorable location to which to relay soft shell clams than does Observation Area I, nearly five hundred feet seaward.

#### 15. BRIEF HISTORY OF CLAM PRODUCTION, ETC., AT BELLIVEAU COVE

a) Belliveau Cove once had large clam stocks. At present, the soft shell clam population at Belliveau Cove is very much smaller than apparently it once was. In former years, perhaps up to two or three decades ago, large clams of good eating quality were abundant. It was possible, the villagers relate, for a single digger then to secure a barrel or more of good-sized clams during one low-tide period, whereas now it is not possible for him to obtain more than a bucketful. The quality, too, has reportedly deteriorated.

In addition to the large stocks of clams, great quantities of mussels, it is said, practically covered the whole flat.

Commercial digging of clams and mussels was not, it seems, carried on, save that the latter were used in soil fertilization.

b) Physical and biological changes in the flat. It may be asked, what were some of the features of the flat when clams were abundant, and how have they changed? The principal change is that the once dense eel grass (Zostera marina), which grew quite long and blanketed large parts of the flat, has mostly disappeared. About 1930, it is recalled, a disease swept up the Atlantic coast from Cape Hatteras to Labrador, wiping out, within two or three years, nearly all of the eel grass in its path.

The soil at Belliveau Cove, as far as has been learned, has undergone no considerable change at least within the past few decades.

c) Decline in the shellfish population. The downward trend of the clam population at Belliveau Cove seems to have commenced shortly before the destruction of the eel grass and afterwards to have continued markedly. It is understood that since shortly after the disappearance of the grass the numbers of soft shell clams at Belliveau Cove have been about at their present low. Again, compared to its former magnitude, the quantity of mussels on the flat is now negligible.

d) White's Cove. At White's Cove, about one mile east of Belliveau Cove, the clam stocks may be somewhat better than at the latter. It is understood that some commercial digging is conducted at White's Cove, a small quantity of soft

shell clams being exported from the district periodically.

e) Comeauville. Mention should possibly be made of the situation at Comeauville, about six miles west of Belliveau Cove. There, where the eel grass also disappeared about 1930, the once large stocks of mussels have depleted so that now practically none of those shellfish are found. On the other hand, it seems, on the flats adjacent to Comeauville, mussel stocks have undergone improvement.

f) Discussion. It would seem that the disappearance of the eel grass and the decline in the clam population at Belliveau Cove are closely connected. It has been suggested that the grass had a stabilizing influence upon the soil which was beneficial to clam production. On the other hand, it may be wondered whether the eel grass had any inhibitory effects on the production of Polinices. A local inhabitant has said that when the grass on the flat was thick, snails seemed to attach themselves to it. Indeed, on one or two occasions this summer, small P. triseriata were noted partially floating on shallow water near a patch of eel grass, having, it seemed, attached themselves to the blades of grass.

Casual efforts to discover whether the clam population has recently shown any sign of increasing have met with conflicting reports. One or two local diggers, for example, advised that an upswing does seem to be underway, while another digger reported that the clam stocks have decreased considerably over the past six years.

#### 16. RECOMMENDATION FOR A FUTURE PROGRAM.

a) At Belliveau Cove. It is felt that a program should be carried out at Belliveau Cove next year which would include at least the following:

1) Sampling the population of soft shell clams, especially those in the "spat" class, or I and R areas, as discussed above in Section 7 - g.

2) Sampling the population of clams remaining in the relay plot, Observation Area II, as discussed above in Section 14 - f.

3) A further relay of soft shell clams to the lower levels of the flat not populated naturally. See Section 14 above.

4) Further investigation of the rate at which P. triseriata and P. heros attack soft shell clams. (The investigation, which might be patterned after that described above in Section 6, should also include an attempt to discover the percentage of cases in which drilling is employed by the snail.)

5) Checking the number of egg cases, of both species of Polinices found on the flat at various times. See Section 11 above.

6) Continued investigation to ascertain whether P. heros undergo a free-swimming stage during larval development. See Section 12 - d above.

7) Careful watch for P. triseriata marked this year with Volger's ink and the measurement and sexing of any such specimens found. See Section 13 above. (It might be worth while to mark more Polinices next year).

8) Sampling the soil to various depths and at various locations on the flat to determine the depth at which P. heros reside diurnally. See Section 4 above.

b) Elsewhere. If investigations of Polinices and their effects upon the soft shell clam were to be made at several of the clam fishing grounds in the Maritime Provinces, not only would they prove valuable for their own sakes, but also they would enhance the value of the work conducted at Belliveau Cove in 1946 and 1947. A picture of the relationship between Polinices and soft shell clams more nearly representative of the Maritimes as a whole would result, thus affording wider application of the results from Belliveau Cove studies as well as an opportunity for comparing them with similar data obtained elsewhere.

Much information could be obtained by the spending of a relatively short period during the summer at each of several areas selected. In every case, it is thought, it should be endeavoured to discover at least the following:

1) The population of soft shell clams, P. triseriata and P. heros.

2) Whether the clams are much affected by the Polinices as evidenced by the quantity of drilled shells on the beach; etc.

3) The effect of Polinices on very small clams, by examining samples of the latter.

4) The feeding rate and the predominant method of attack as described above in Section 6. (Perhaps the investigation could be similar to that conducted at Belliveau Cove, as described in Section 6).

5) The number of egg cases of both species on the flat.

6) The number of Polinices on the surface nocturnally.

7) The size frequency distribution of Polinices.  
(A brief investigation only, of course, would be possible at each location. For that reason, it might be thought a study of size frequency distribution had better be omitted.)

If it becomes feasible to conduct an investigation at Belliveau Cove during the winter, some interesting information might be obtained with regard to the behaviour, growth rate, etc., of Polinices during that season.