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OBSERVATIONS ON SALTMARSH POOLS, MINAS BASIN, NOVA SCOTIA 1965-1977

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Two pools in the salt marshes of Kings Co., Minas Basin were studied from October 1965 to January 1967. Changes in temperature, salinity, ice cover, and floral and faunal composition were recorded. Relevant information gathered during subsequent field trips 1967 to 1977 has been added, and from this accumulated data several significant fluctuations in population density, local distribution, and maximum body size were discerned for 3 species of sacoglossan molluscs, 1 species of anemone, and 2 species of nemerteans.

There were irregular time periods when the tidal waters did not reach the study pools, the longest being 25 days. The highest water temperature recorded was 28.5° C and the lowest -1.5° C. Tidal water entering the pools had a salinity of near 29°/oo whereas average salinity at the bottom of the two pools was 33.4 °/oo and 32.4 °/oo. The average surface salinity was 31.4 °/oo and 30.2 °/oo. Salinities below 20 °/oo were unusual and only the pool surface water ever reached the minimum recording of 11.1 °/oo. Thus, these permanent saltmarsh pools are rather unusual lentic marine habitats, scarcely influenced by coastal marine temperatures, tides, or currents.

Ice formation is irregular but can cover these pools for periods exceeding 3 months. Measurements of ice thickness from 7 winters ranged from 19 cm to 68.5 cm. Nevertheless, algae remain green and many animals are active throughout the winter beneath substantial ice and snow covers.

The dominant species of macrofauna were 1 anemone, 2 nemerteans, 3 gastropods, 1 amphipod, 2 insects, and 1 fish.

Introduction

The initial examination of saltmarsh pools in Minas Basin by Acadia University staff and students began in 1965. Some of the subsequent accumulation of data has been published (Bailey & Bleakney 1966; 1967; Bleakney & Bailey 1967; Bleakney 1972; Frank & Bleakney 1976; 1978; Graves et al. 1979) but much information has remained in thesis form. With the current interest in Bay of Fundy environments and the desire to establish base line data for future comparisons, it was felt that our data should be made available through an appropriate journal. The purpose of this paper is to present information from theses, reports, and field notes which can contribute to our understanding of the physical and biotic features of Minas Basin marshes.

Although the literature concerning salt marshes is vast, saltmarsh pools have been largely ignored. Bromley and Bleakney (1979) compared reports from United States (Teal & Teal 1969; Nixon & Oviatt 1973) and British Isles (Hickson 1929; Lebour 1931; Nicol 1933; 1935; Brough et al. 1960) with Minas Basin marsh pool faunas. The evident relative paucity of species in other areas (Nixon and Oviatt, 14 species; Brough, 31 species) as compared with 76 taxa for Minas Basin (Bromley & Bleakney 1979) may help explain the lack of interest by estuarine biologists in other parts of the world.

Our local marsh pools are unusual qualitatively as well. Several of the most important marsh organisms in eastern United States such as ribbed mussel *(Guekensia demissa),* marsh snail *(Melampus lineatus),* and various crabs are absent or extremely rare in Minas Basin. However, other rare and unusual organisms such as the sacoglassan molluscs *(Alderia modesta, Elysia chlorotica,* and *Stiliger fuscata),* the burrowing anemone *(Nematostella vectensis),* and viviparous nemertine *(Prostomatella obscura)* are often abundant.

One of the characteristic features of these pools is the development of dense mats of filamentous algae in which reside many of the marsh pool animal species. Our first general survey in 1965 concentrated on determining the faunal community within these algal mats and the physical parameters of temperature, salinity, and ice formation.

Literature Review

In his study of the Minas Basin, Ganong (1890) failed to mention saltmarsh pools entirely and his later Bay of Fundy marsh report (Ganong 1903) referred briefly to the absence of life in marsh pools except for "a few simple algae". Bousfield and Leim (1960) devoted one sentence to pool inhabitants including *Gammarus mucronatus* and *Orchestia grillus,* a small corixid bug, the snail *Hydrobia totteni,* but beyond this their composite list of marine fauna of the Minas Basin lacks most of the pool fauna. Chapman (1937; 1960) summarized Ganong's previous findings adding some of his own observations on the Wolfville marshes but, as with Ganong, the emphasis was on the flora. The 1976-78 survey by Bromley (Bromley & Bleakney 1979) was limited to benthic organisms occurring in the soft sediments of marsh pools.

Study Area

Hydrographic details of Minas Basin were reported by Bousefield and Leim (1960), and local saltmarsh origin and build up was described by Ganong (1903). Minas Basin is a shallow, triangular body of water connected with the Bay of Fundy by the S-shaped Minas Channel. The red sand and mud so characteristic of the Basin were formed from an erosion of the Carboniferous and Triassic sandstone substratum. Tides having extreme ranges of 16 m make the Basin unique in this respect. This surge of tidal waters results in a heavy suspension of inorganic silt which is dropped by the check of the tide's quiet spread over the marshes. The extensive algal mats which develop over the mud in the *Spartina alterniflora* zone can be completely encased by 2 to 3 mm of red clay deposit on a single spring flood tide. In winter blocks of drift ice carry much clay, and often gravel and shells and even large basalt rocks. Many of these ice blocks, which average 1 m in thickness, are deposited on the marshes and marsh pools where they eventually melt leaving conspicuous mounds of sticky red clay. The larger Minas Basin ice blocks of 5 to 6 m thickness cannot be floated over the marsh, and thus their massive loads of entrapped sediments are simply returned to the muddy slopes of the creeks and flats. Ice can build up on the marshes and then be floated off by spring tides, tearing out the *Spartina* grasses. This bottom coating of *Spartina* on the ice sheets gradually works its way upwards through the ice (Medcof & Thomas 1974). The same block may ground several times on the marsh in the course of a winter season, and we have photographs on file showing 3 successive layers of *Spartina* within a 1 m-thick block of drift ice. If such a block settles on a marsh pool considerable organic detritus is added to that pool when the block melts.

The principal study area of 1965-67 was located along the Habitant Creek estuary southeast of Canning, Kings Co., N.S., in a *Spartina patens* and *S. alterniflora* marsh next to the old pilings of Pickett's Wharf (Fig. 1). Habitant Creek is dyked to the west of the saltmarsh area and fresh water flows out through an aboideau only at low tide, some 6 m below the level of the marsh. The marsh extends in width about 250 m from the adjacent roadbed to the creek bank at the wharf pilings.

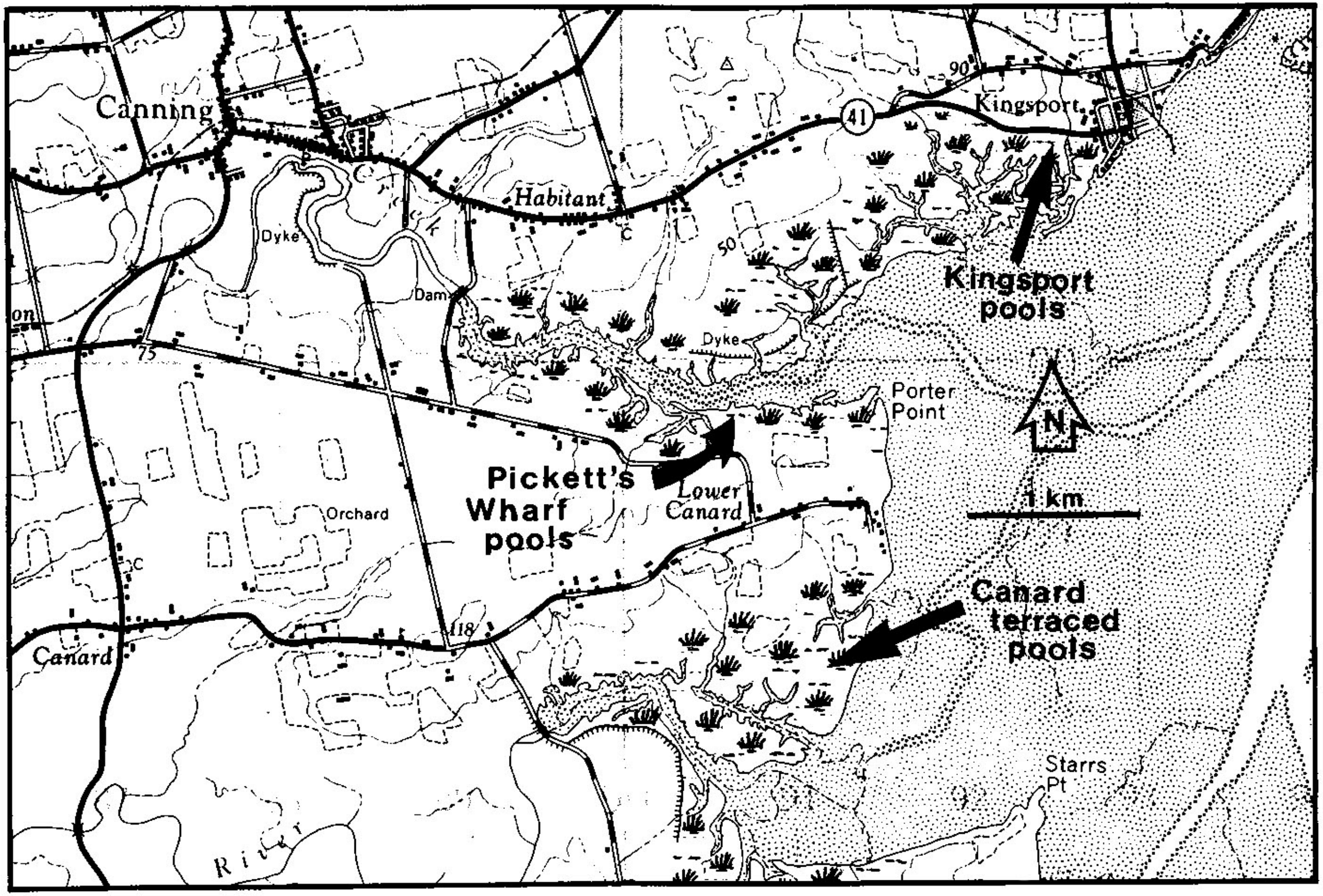


Fig 1. Topographic map of southwestern Minas Basin, Nova Scotia, showing location of principal study site at Pickett's Wharf and areas in Canard marsh and Kingsport marsh referred to in the text.

The 2 pools studied were immediately south of Pickett's Wharf. Pool No. 1 measured about 13 x 3 x 0.6 m. The northeast bank was steep, sandy and vegetated by *S. patens* (Fig 2). The southeast end of the pool was quite shallow (7.5 - 15 cm) and the tide entered here as it came through a small channel in the sand. The west bank merged gradually with the *S. alterniflora* and the tides also entered at this side of the pool.

Pool No. 2 was 32 m southwest of Pool No. 1 and was 30 cm higher thus being flooded less often by the tides. It measured 12.2 x 7.6 x 0.8 m with well defined banks except on the north side where it merged into the marsh and where the tidal waters entered. It was surrounded entirely by *S. alterniflora* (Fig 3).

Flora

The vegetation of Pool No. 1 was primarily *Cladophora, Chaetomorpha,* and the halophyte *Ruppia maritima*. However, distribution of these was not uniform. At the northwest end of the pool was *Chaetomorpha; Ruppia* occupied the western side; and *Cladophora* dominated the southern and central sections. The substratum was a black ooze rich in anerobic sulfur bacteria. In Pool No. 2 *Ruppia* occurred in scattered patches, but the algal covering was rather different. *Oscillatoria* dominated and was woven into felt-like mats with *Cladophora* and *Chaetomorpha*. On sunny days, with increased oxygen production, these mats rose to the surface in patches and partially or completely covered the pools. During dark dull days, they remained on the bottom. In Pool No. 2 the bottom was also the typical ooze, sometimes spotted by blooms of pink sulfur bacteria.

When high spring tides inundated the marsh, the study pools were momentarily covered by 0.4 to 0.6 m of water. Depending on the degree of wind action, this flooding had 2 effects. One was the deposition of silt as a thin layer over the pool vegetation. If there was little wind action on subsequent tides, this coating of clay remained undisturbed. The second wind effect was the dramatic removal from the pools through wave action of all free-floating algal mats. As these were washed away and the tide receded, they became entangled in marsh grass and soon were baked by the sun. Most of the contained fauna were also trapped and desiccated and scavenging marsh amphipods took over. After one such combination of factors in late June 1966, Pool No. 1 was surrounded by sheets of dry algae varying from 0.3 to 3.4 m^2 in area. The *Ruppia* plants, being firmly anchored, helped retain some of the filamentous algae and this served as a nucleus for replenishing the pool algae.

The algae made a feeble recovery from this washout in June only to die down during July, August, and September in Pool No. 1, but by October 17 the growth had recovered. Pool No. 2, however, maintained its algal coverage all summer until September 20 at which time most of it was gone, from unknown causes. Similar variability in dominant floral species was noted in pools of other local marshes. One pool under study by Frank and Bleakney (1976; 1978) was devoid of *Ruppia,* whereas an adjacent pool less than 4 m away was invariably choked with *Ruppia* by midsummer.

Several other marshes in the Wolfville and Canard areas were examined for comparative purposes and specimens collected, but no quantitative analyses were attempted. The Canard marsh 1.6 km south of Pickett's Wharf is unique in the diversity of pools and has yet to be studied. Most of its old dyke wall is extant but has been breached by several large creeks that permit tidal waters to inundate the extensive flat marsh area behind the dyke. There are large shallow pools on the marsh surface, deep pools in the creek channels, and long, narrow excavated pools paralleling both sides of the old dyke wall. In addition, the marsh gradually slopes

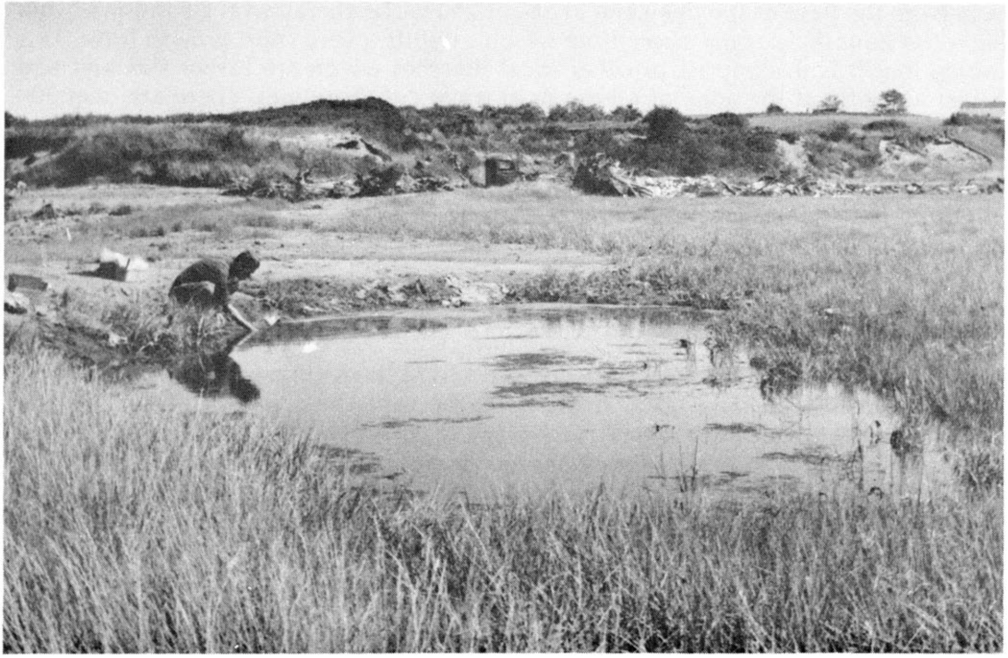


Fig 2. Photo of Pool No. 1 looking southeast. Note *Spartina patens* in lower left of picture, *Spartina alterniflora* in lower right, and algae on the pool surface.

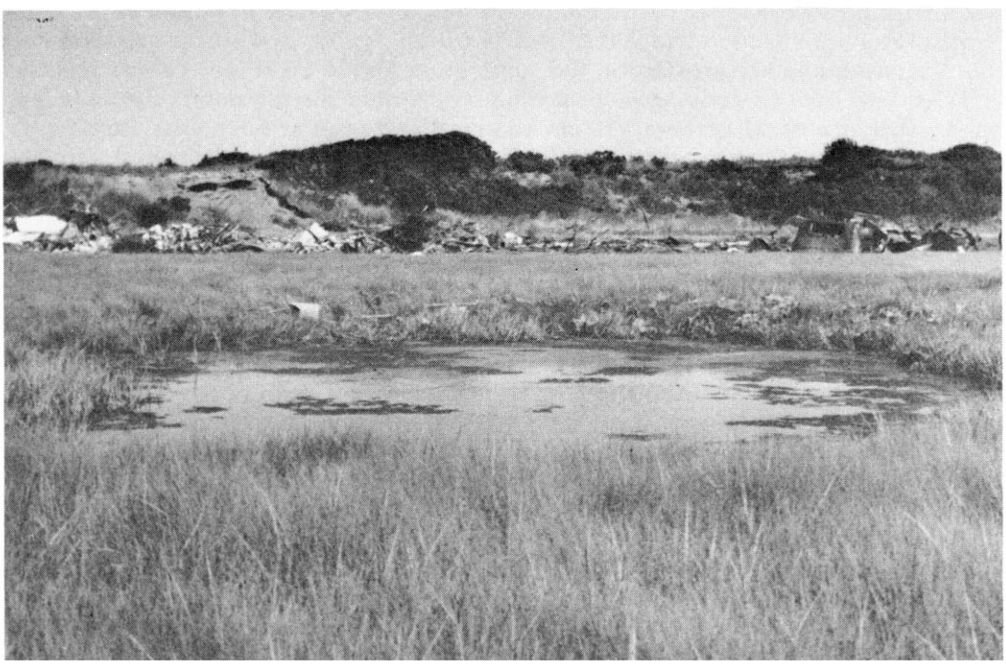


Fig 3. Photo of Pool No. 2 looking east. Note floating algal mats and on opposite bank stranded mats swept out of pool by high tides.

away from the base of the dyke and at about 240 m the elevation is 2.6 m lower, and this is the limit of *Spartina alterniflora* which exhibits a very short growth form. This sloping marsh is in contrast to other local marshes which are rather flat and end almost abruptly at the edge of creeks or at wave cut shorelines. There are over 300 pools in the area, situated at every elevation along this slope and the lowest are submerged twice daily by as much as 3 m of water, whereas the upper pools are flushed only during spring tides. These terraced pools often have marshpool species present in abundance at times when we cannot find these same species at pools in nearby 'table-top' marshes. They may, therefore, serve as an important reservoir for marsh species.

Materials and Methods

The vagaries of tide and weather were deemed to be the most severe environmental stresses to which these pools could be subjected. Therefore, in order to document the conditions under which marshpool organisms exist, the flora and fauna were sampled at various extremes in physical factors such as dry periods, just before and after rains, and at certain tidal phases. A total of 27 trips were made to the study area beginning 14 October 1965 and ending 16 January 1967. The number of trips made per month were: October 1965, 3 trips; January 1966, 1; February, 1; March, 2; May, 3: June, 2: July, 7: August, 1: September, 2; October, 1; November, 2; December, 1; and January 1967, 1. During 1965 preliminary examination of the pools took place with a few unmeasured amounts of algae brought into the laboratory from Pool No. 1 for sorting. Beginning January 1966, general observations of marsh conditions, algal growth, conspicuous animals, air and water temperatures, ice thickness, salinities, weather conditions, and other pertinent information were recorded.

Temperatures were taken with a Yellow Springs Model 43 TD or Model 42 SC telethermometer with 3 interchangeable probes for air, water, and surface determinations. Occasionally temperature in the substratum and in algal masses was recorded. From late June to early August maximum-minimum thermometers were placed in the pools at a depth of about 15 cm and read and reset at each visit. Zerbe and Taylor's (1953) density temperature reduction tables were used to determine salinity from the hydrometer and temperature readings taken in the field.

Estimation of the frequency with which the marsh area was flooded involved determining critical heights from comparisons with heights listed in the Canadian Government *Tide and Current Tables* for the matress at Walton, 30 km away. Reference points were nailed into the wharf pilings at Pickett's Wharf during peak high tides and the height in the tide table noted. On subsequent high tides the process was repeated and the difference between those tides as listed in the tables and actual measurements between the 2 reference points on each post noted. Several such calculations proved that there was little consistency. To the contrary, at times the actual height was 15 cm higher, and at other times 18 cm lower for the same Tide Table height prediction. However, as nearly as could be determined under these circumstances, tides at 6.9 m on the Tide Tables entered Pool No. 1 and tides of about 7.2 m entered Pool No. 2.

From 1966 to 1979 we have witnessed several peculiar (and biologically significant) tidal phenomena in the western Minas Basin. In general the times of high tides agree closely with the official tide tables, but the height can be much higher or lower than anticipated from our considerable past experience with previous similar tide table predictions. This can happen on clear days and does not require strong winds nor extremes in barometric pressure. An apparently unrelated phenomenon is the unusual duration of high slack tide and low slack tide. A tide usually floods in over the marsh, then stops all movement and within 2 or 3 minutes dramatically reverses its flow, but it may unexpectedly hold the high level mark for as much as 10 minutes. We have observed the same phenomenon during extreme low tides when instead of a quick reversal of flow, the slack water holds its level for periods we have noted in one instance of 20 minutes and in another of 35 minutes. Such unusual extended exposure periods at the sublittoral fringe may account for the death of many adult *Cancer irroratus* in January 1970 (Bleakney 1972).

The first weighed algal samples were taken May 31, 1966, and the last on November 21. Wet algae samples of 0.91 kg (2 lb) were weighed in a fiberglass screen suspended from a spring scale. At each pool samples were taken at three areas (indicated as "a", "b", and "c") to determine whether there was any variation within 1 pool. In the laboratory each sample was sorted and species tabulated.

At first, all the *Hydrobia totteni* were counted but, as the actual numbers per 0.91 kg sample at times exceeded 2000 individuals, densities were calculated from 0.11 kg (0.25 lb) subsamples.

The study pools could not be poisoned; therefore, fish species were obtained with rotenone from other pools on the Canning marsh and on the Canard marsh (1.6 km to the south).

An obvious shortcoming of the algal method of population density determinations was that the algae and fauna were removed from the same site each time depleting that area rather drastically. However, no appreciable local effect was evident over the entire sampling period, and usually no more than 1 or 2 samples were taken per month. Also, as certain spring tides coupled with strong winds were found to sweep out much of the algae on occasion, the damage done by the sampling was minimal. Several times after the algae had been swept out by wind action, some algal-covered *Ruppia maritima* was added to the sample in order to make up a 0.91 kg sample. This created an unfortunate inconsistency in the sampling since not all species common to the algae, *H. totteni, L. saxatilis, E. chlorotica,* and *A. modesta* for example, were found in the *Ruppia*. However, the *Ruppia* did harbor populations of the bryozoan *Bowerbankia gracilis* and the tube dwelling ciliate *Semifolliculina gigantea,* 2 animals which were considered accidentals by Brough et al. (1960/1961).

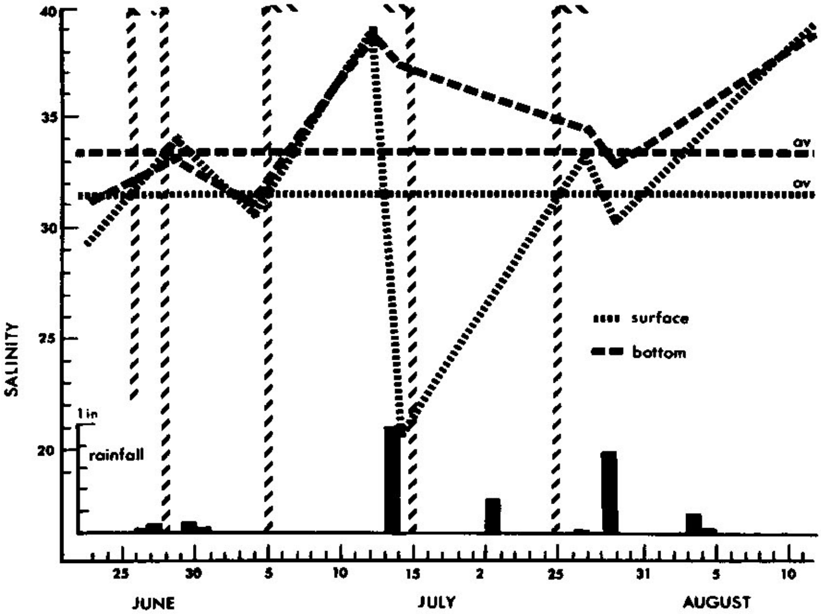
Results and Discussion

Physical Factors

I. Salinity: Salinity variation within the pools was determined by 4 factors: tides, rainfall, evaporation, and algal coverage. The diagonal-dash lines in Figures 4 and 5 indicate as nearly as could be estimated from tide tables, periods between which tides did not enter Pools No. 1 and No. 2 during the days between June 23 and August 13. In Pool No. 1 tides did not inundate the pool during the periods 26-27 June (2 days), 5-15 July (10 days), and 25 July to 13 August (20 days). In Pool No. 2 the periods of non flooding were longer: from 23 June to 18 July (24 days) and 24 July to 18 August (25 days).

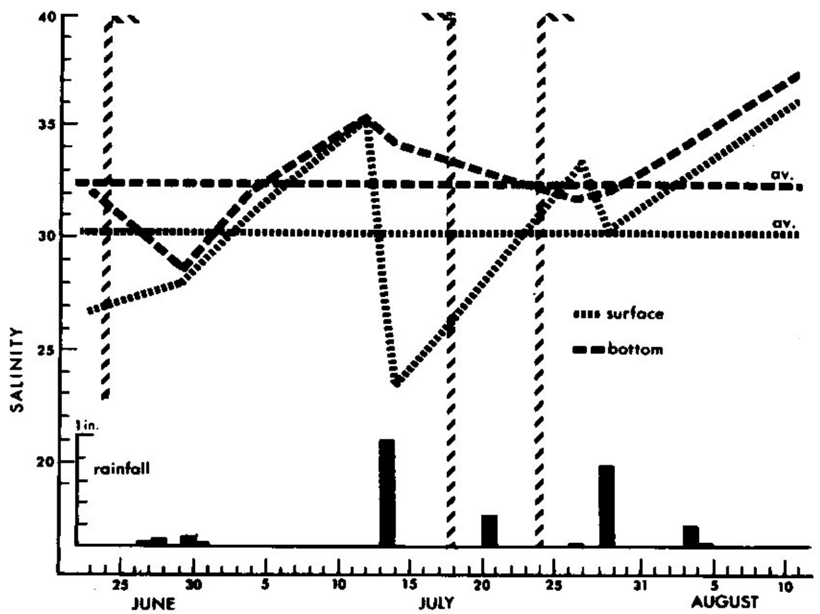
Water entering the pools in June had a salinity of 29 °/oo. The average surface salinity of Pool No. 1 (Fig 4) was 31.4 °/oo with bottom salinities averaging 33.4 °/oo. The respective values for Pool No. 2 were 30.2 °/oo surface and 32.4 °/oo bottom.

Rainfall data in Figures 4 and 5 were obtained from the Kentville Research Station, 11 km southwest of the study area. During periods of daily tidal flooding, heavy rains cause a decrease in salinity until the next tide. During periods of non flooding the effects of lowered salinity were prolonged. If there was no wind during



POOL 1

Fig 4. Surface and bottom salinity readings (‰) for Pool No. 1 from 23 June to 11 August 1966. Horizontal lines indicate average salinity. Time periods bracketed by tall vertical broken lines are those when tides did not enter the pool. Solid vertical bars record amount of rainfall reported at Kentville Agricultural Research Station 11 km away.



POOL 2

Fig 5. Surface and bottom salinity recordings (‰) for Pool No. 2. Explanation as in Fig 4.

a heavy rain, a stratification of the water took place as illustrated in Figures 4 and 5. The surface and bottom salinities of both pools were nearly the same on 12 July just previous to a day of heavy rainfall. Measurements taken 14 July just after the rain show little change in the bottom salinities (decrease of 1.8 °/oo in Pool No. 1 and 1.1 °/oo in Pool No. 2) but large change in surface salinity (decrease of 13.5 °/oo in Pool No. 1 and 11.3 °/oo in Pool No. 2) as the colder but less dense freshwater remained on top of the warmer, denser saline water. Strong winds soon create a mixing of bottom and surface salinities.

In Pool No. 1 surface salinities rose above bottom salinities on 3 occasions (29 June, 12 July, 11 August) possibly resulting from evaporation. Runoff surface waters after light rains can also increase salinity from first dissolving salt crystals on the substratum and *Spartina* leaves before trickling into the pool. This probably explains the increased salinity of the surface of Pool No. 1 on 29 June.

Pool No. 2, although less exposed to the equilibrating influence of the tide, showed less relative fluctuation in salinity between surface and bottom waters, except after the 2 periods of heavy rain, and also had a lower average salinity than Pool No. 1 (Fig 4). This may have resulted from extensive algal coverage which would have reduced evaporation keeping surface salinities lower than the bottom salinity thereby lowering average salinity in the pool. The higher surface salinity of 27 July may have resulted from the wind blowing the algae to one end of the pool exposing a larger surface area to evaporation.

The range of salinity for Pool No. 1 was from 20.5 °/oo to 39.3 °/oo surface and from 28.2 °/oo to 38.9 °/oo bottom. For Pool No. 2 the range was surface 32.5 °/oo to 36.3 °/oo and bottom 28.5°/oo to 37.2 °/oo. Thus the average salinities of these pools were quite unlike the average low salinities reported by Nicols (1935) in Scotland. She divided pools into 2 groups, those having a low average salinity of less than 5 °/oo, and those having an average salinity of 15 to 20 °/oo. During hot weather salinities rose as high as 40 °/oo and in wet weather dropped as low as 8 °/oo. Naylor and Slinn (1958) studied the flora and fauna of pools at Scarlett Point, Isle of Mann. Only 6 visits were made over a period of 3 years, however. The highest salinity recorded was 38.6 °/oo while the lowest of 1.0 °/oo to 4.1 °/oo were recorded just after a rain. Table I summarizes miscellaneous salinity and temperature data from Minas Basin marsh pools, 1966 to 1977. These pools are, on an average, hypersaline to the waters in the immediate Minas Basin. Thus, in summer, they constitute a warm lentic environment of near oceanic salinities. The lowest salinities recorded, just over 11 °/oo, were surface readings and 1 of these followed a 10 day period of rainy weather (Table 1).

II. Temperature. The shallowness of the pools result in temperatures warmer during the day than the air temperatures. Bottom temperatures tended to be lower than surface temperatures except in the case of Pool No. 1 after the rain of 13 July (Fig 6). The solar radiation on 14 July, although insufficient to significantly warm the surface water of Pool No. 1, was sufficient to raise the algal mats (through oxygen production) from the bottom of Pool No. 2 thus warming the surface through greater heat absorption by the algae (Fig 7).

During winter the pools may be covered by ice by varying thickness. On 5 December 1965, 15 January, and 24 February 1966, the ice on Pool No. 1 was 5 cm, 24 cm, and 14.5 cm thick respectively, whereas Pool No. 2 was covered with 1.3 cm, 10 cm, and 20 cm of ice on the same dates. Why should two adjacent pools in the same habitat show an inverse relationship in thickness of ice cover and by factors as large as 2 and 4? On 24 February, large blocks of drift ice were noted scattered over

Table I. Miscellaneous temperature, ice, and salinity measurements at salt marsh pools, Kings County, Minas Basin, 1966-1977. Norenburg's work included small shallow pools not considered by the other authors.

Data Source	Dates	Temperature Range °C	Ice Thickness cm	Salinity (°/oo) Bottom	Salinity (°/oo) Surface
BAILEY (1967)	Jan-Nov 1966	-1.5 to 28.5			
	June-Nov 1966			28.5-38.9	20.5-39.3
	12 Jan 1967		50		
BLEAKNEY (unpubl)	25 Jan 1970		30		
	27 Jan 1971		46-50		
FRANK (1974)	9 Jan-15 Nov 1973	-1.0 to 26	19	22.6-39.3	11.9 (10 days rain)
NORENBURG (1976)	Sept 1974 to Feb 1976	-1.5 to 28	30	19.7-31.9	11.1-23
BLEAKNEY (unpubl)	8 March 1977		68.5		

Table II. Dominant animal forms found in pools of the *Spartina* marshes in Kings Co., N.S. 1965-67. Species marked with asterisk were often abundant.

PROTOZOA		**ARTHROPODA**	
Ciliata:	*Semifolliculina gigantea* Dons	Acarina:	Red Mites
CNIDARIA		Crustacea:	**Gammarus mucronatus* Say *Orchestia grillus* Bosc
Actinaria:	**Nematostella vectensis* Stephenson		
NEMERTEA:	**Lineus viridis* (Fabricius) *Prostomatella obscura* (Schultze)	Insecta:	*Enochrus hamiltoni* Horn **Ephydra riparia* Fallen *Tabanus nigrovittatus* Macq. *Corixids
MOLLUSCA			
Gastropoda:	**Hydobria totteni* Morrison *Littorina saxatilis *(Olivi)* *Littorina littorea* (Linné) *Ilyanassa obsoleta* (Say) *Alderia modesta* (Lovén) **Elysia chlorotica* (Gould)	**ECTOPROCTA**	*Bowerbankia gracilis* Leidy
		CHORDATA	
		Pisces:	*Anquilla rostrata* (Le Sueur) **Fundulus heteroclitus* (L.) *Gasterosteus aculeatus* L. *Apeltes quadracus* (Mitchill) *Pungitius pungitius* (L.)
Pelecypoda:	*Geukensia demissa* (Dillwyn) *Gemma gemma* (Totten)		

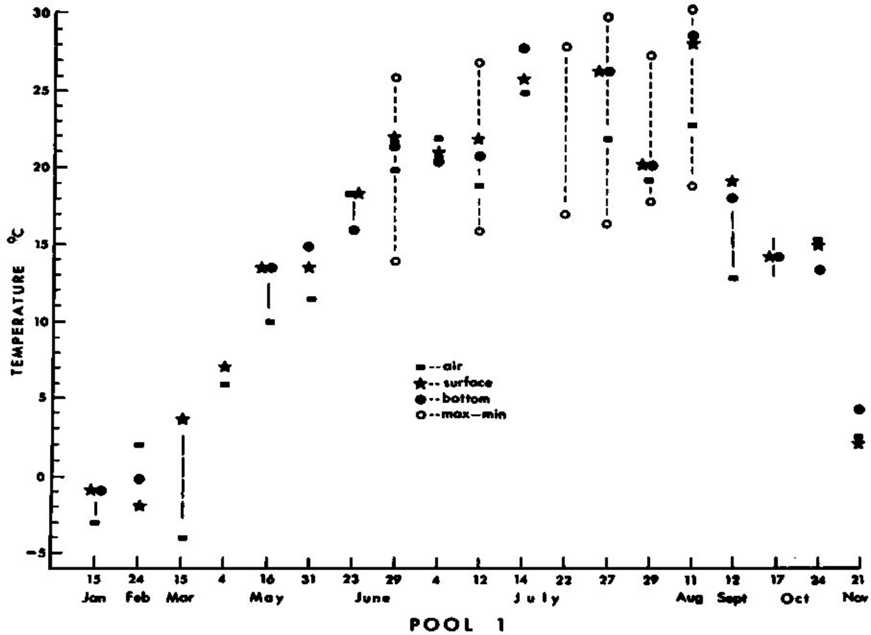


Fig 6. Temperature fluctuations recorded at Pool No. 1. Air temperatures taken near 1.5 m above ground. Pool temperatures taken within 2 cm below surface, and within 2 cm above bottom. Each maximum and minimum range recorded (late June to early August) covers entire period from previous visit and at water depth of 10-20 cm.

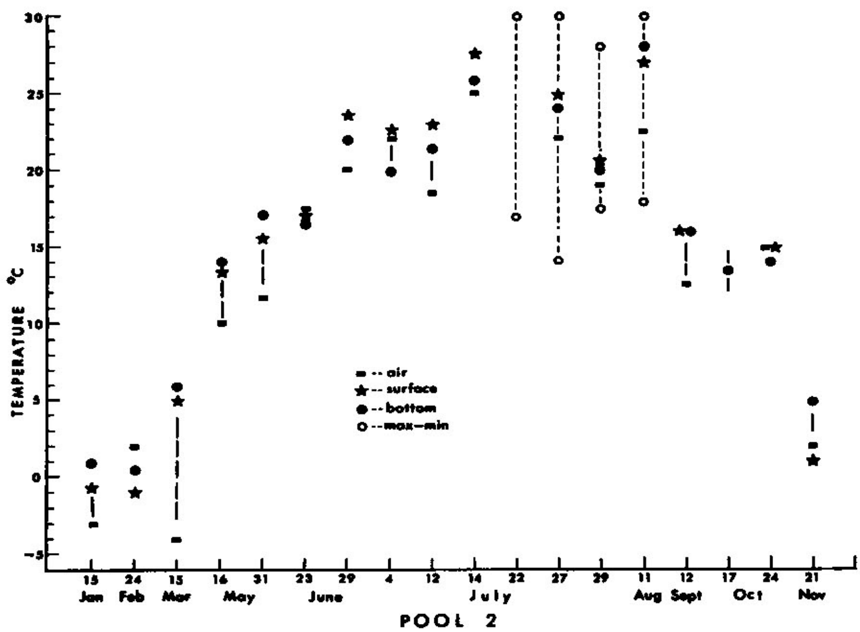


Fig 7. Temperature fluctuations recorded at Pool No. 2. Explanation as in Fig 6.

the marsh. Observations on 16 January 1967 revealed the phenomenon of 'ground ice'. Pool No. 2 had 18 cm of hard ice, 32 cm of slushy ice, and a thin ice layer of 1.3 to 2.5 cm lining the bottom. Pool No. 1 was in a similar condition with a total of 50 cm of ice and slushy ice from mud bottom to snow cover.

Maximum and minimum temperature variations during any one time period between pool visits are indicated in Figures 6 and 7 and are summarized in Table I with additional data from 1970-77. The low temperatures of February 1977 froze shallow marsh pools to the bottom, but the deepest pool on Kingsport marsh had 18 cm of water beneath 68.5 cm of ice. Measurements were taken of this ice cover until it disappeared on 3 April. Figure 8 shows that the pool water depth remained stable and that the ice block remained fixed, but by 28 March the ice had lost 29 cm from its upper surface and only 4 cm from its submerged surface. Yet 5 days later, this very persistent massive ice cover was reduced to a floating block 4 cm thick and the following day it was gone.

Fauna

Harsh though the conditions seem, many organisms inhabit these pools summer and winter. Gastropods were the dominant inhabitants represented by 6 species. There were 2 pelecypods; the ribbed mussel, *Geukensia demissa,* a common inhabitant of the Tantramar saltmarshes of New Brunswick, but certainly rare in Minas Basin marshes, and *Gemma gemma.* The latter species was common in the marsh pools of Canard but was not found at the Canning study pools 1.6 km to the north. Several insect species frequent these pools and their larvae as well as the abundant amphipods were prey for 5 species of fish. A semi-sessile anemone, *Nematostella vectensis,* the sessile bryozoan *Bowerbankia gracilis,* and the large tube-dwelling protozoan *Semifolliculina gigantea* were common. A list of the fauna compiled from 1965 to 1967 field studies is presented in Table II. Several of these species received special attention, and pertinent observations and updated comments are presented here.

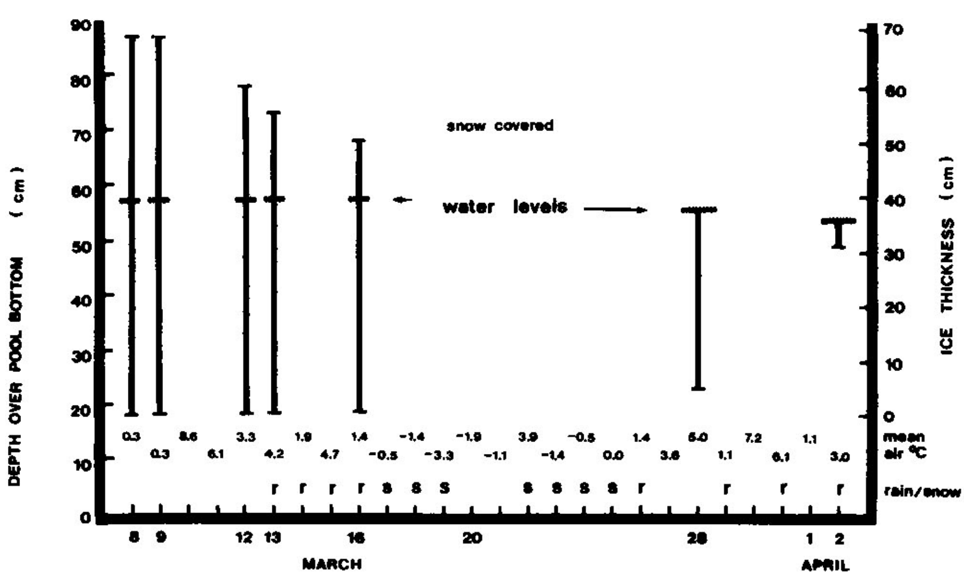


Fig 8. Ice melt sequence in a 12 x 5 m pool on Kingsport marsh March 8 to April 2, 1977. From beneath the 68.5 cm of ice on March 8, a pool bottom sample contained green filamentous algae and new green shoots of *Spartina alterniflora.*

Phylum Protozoa

Semifolliculina gigantea: This large tube-swelling ciliate was found on the stalks of *Ruppia maritima*. The colonies were intermingled with those of *Bowerbankia gracilis*.

Phylum Nemertea

During the summer of 1966, all the algal samples contained an abundance of green nemertines. During autumn, this handy source was used routinely in laboratories for live demonstration but by 1970 they had disappeared from these same marsh pools. Collections preserved in 1966 were identified by Jon Norenburg (Northeastern University, Marine Science Institute, Nahart, Mass., in litt. 1979) so we know that most were *Lineus viridis,* but 2 specimens of *Prostometella obscura* were also present. In January and October of 1970 only *P. obscura* were extracted from the algal samples employing the same technique of allowing the algae to stand in open trays at room temperature for several days until all the animals had surfaced. When Norenburg surveyed these same pools specifically for nemerteans during 1974 to 1976, he found both species but *L. viridis* was rare and, although difficult to locate, *P. obscura* was common enough to risk a thesis commitment (Norenburg 1976).

Phylum Cnidaria

Nematostella vectensis: This small anemone was first observed on 14 October 1965. Subsequent sampling always revealed this cnidarian, even beneath ice on 15 January 1966. It commonly occurred imbedded in bottom ooze with only its tentacular whorl exposed, or stretched out on the substratum, or entwined in floating algae (Bailey & Bleakney, 1966). Specimens collected June, July and August 1966 were larger than those taken at other seasons and far exceeded the largest (15 mm) reported by Hand (1957) from California. Measurements of relaxed specimens ranged from 1 to 60 mm, averaging 25 mm. However, of 518 specimens measured in 1973 by Frank (1974) the largest was only 47.4 mm.

The variations we have noted over the past decade relative to distribution and population density will have to be taken into consideration by workers conducting short-term environmental impact studies. For example, in 1972 the 1966 study pools at Pickett's Wharf were devoid of *Nematostella,* so a new study site was established (October 1972 - January 1974) on the Kingsport marsh (Frank 1974). One particular pool, in a close group of 4, invariably had *Nematostella* present, summer and winter, even beneath heavy ice cover. On 1 occasion (12 October 1973) 181 *Nematostella* were extracted from a single 15 cm x 15 cm x 2 cm sample of pool bottom silt. However, in the summer of 1975 there was none in this pool, but an adjacent pool, which produced but a single specimen in 1973 samples, was now the major site for *Nematostella*. Previous to 1975 the average density per sample was near 45 specimens (max. 181) and the greatest densities were always in September or October and the least in June and July. This "established pattern" in our minds was dramatically shattered when on 9 July 1975, in a small Wolfville marshpool, the count from a 15 cm^2 sample (ca. 225 cm^3) was an unprecedented 1,816 *Nematostella*.

Phylum Mollusca

Hydrobia totteni: This small gastropod was always present in large numbers in the algae and on the bottom of the pools. Figure 9 records adult population fluctuations

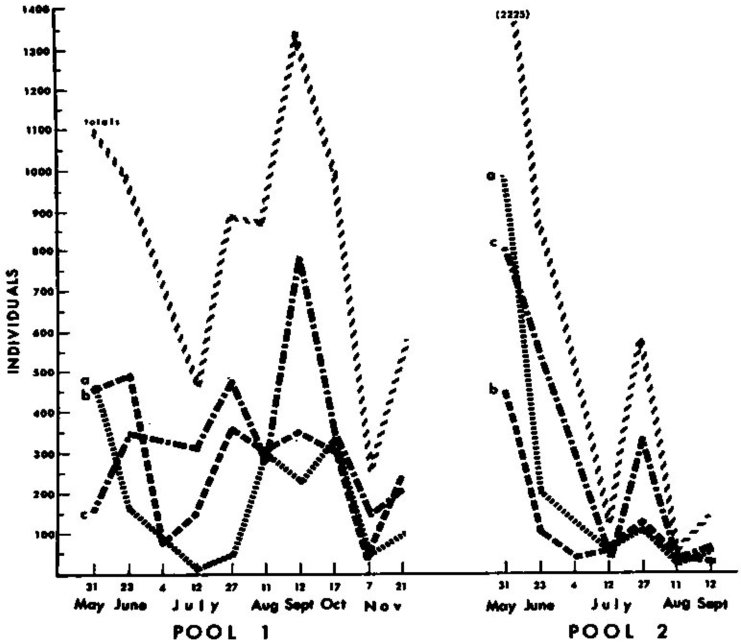


Fig 9. Population density fluctuations of *Hydrobia totteni* in areas "a", "b", and "c" of Pool No. 1 and Pool No. 2 based on 0.11 kg (0.25 lb.) algal samples. Upper line represents number of individuals in combined samples.

in 1966 between 31 May and 21 November (12 September in the case of Pool No. 2) per 0.11 kg (0.25 lb) algal samples. Numbers of adults varied from as few as 7 individuals on 12 July (area "a" of Pool No. 1) to about 1000 individuals on 31 May (area "a" of Pool No. 2). However, when the number of individuals was low in one area, it could be high in an adjacent area.

Littorina saxatilis: The Northern Rough Periwinkle was relatively common in the algae. Numbers of individuals varied from 4 shells in area "c" of Pool No. 1 to 235 shells in area "a" of the same pool on October 17 per 0.91 kg (2 lb) sample of algae (Fig 10). Numerous young appeared between 12 July and 11 August and the adults in "c" and "b" of pool No. 1 tended to decrease in number.

Littorina littorea: Although common on rocks of the intertidal region and on the nearby wharf pilings, the Common Periwinkle was rarely found in the pools. When present, individuals varied in size from small to medium. In contrast, this species occurred regularly in the Canard pools on *Ectocarpus* sp. (an alga absent from the Canning pools) and attained much larger size.

Ilyanassa obsoleta: The detritus rich mud around the lower reaches of the *Spartina alterniflora* zone and the mud below that region was densely carpeted by the Mud Snail, but in the study pools it occurred sparsely. Eggs were found attached to *Ruppia* stalks on 31 May. However, in some of the lower terraced pools of the Canard area it was found in densities of up to 537/m^2.

Alderia modesta and *Elysia chlorotica:* These 2 sacoglossan gastropods were of

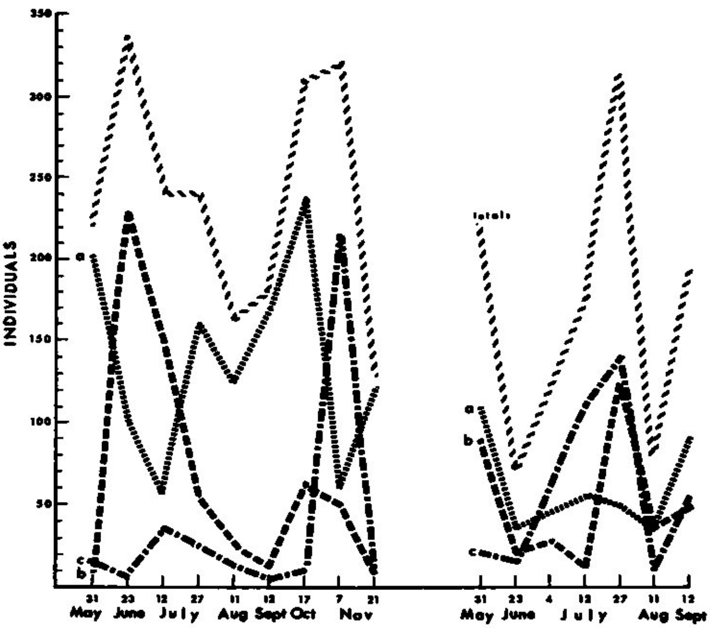


Fig 10. Population density fluctuations of *Littorina saxatilis* in areas "a", "b", and "c" of Pool No. 1 and Pool No. 2 based on 0.91 kg (2 lb.) algal samples. Upper line represents number of individuals in combined samples.

special interest since very little was known of their life histories and ecology. In addition, this was the first *E. chlorotica* record for Canada and the second Canadian report of *A. modesta*, the other being Grand Manan Island (Bailey & Bleakney 1967; Bleakney & Bailey 1967).

Recent studies by Graves et al. (1979) have established that *E. chlorotica* and *A. modesta* both consume *Vaucheria*, but that *E. chlorotica* incorporates the *Vaucheria* chloroplasts as functional photosynthetic units within its digestive tract cells.

Alderia were also present at Canard extending into the upper marsh where *Spartina patens* predominates and above the reach of all but the highest tides. Sixteen specimens 4 mm to 8 mm were collected 5 August 1966, from one area on the Canard Marsh. They were found in grass tunnels amongst the feces of the meadow mouse, *Microtus pennsylvanicus*, adjacent to an orchard. The abundant insects and mouse tunnels of the upper marsh provide an unusual contrast to the winter-pool habitat of this "marine" organism. On the high marsh this slug must withstand the abrupt salinity changes of tides and rain as well as potential desiccation by sun and wind. On the Wolfville marsh I recorded temperature taken on a sunny day with a tele-thermometer disc on an *A. modesta* 'basking' on a *Vaucheria* mat cushion was 25.5° C.

The size of specimens from algal samples in 1966 range between 2 and 15.5 mm, the latter figure being much larger than the maximum of 8 mm reported by Hand and Steinberg (1955) and Abbott (1975). It is interesting that no specimens greater than 8 mm were ever found on the *Vaucheria* outside the pools.

The largest *A. modesta* and *E. chlorotica* have been found only in the pools. The puzzling aspect was their sudden appearance in the pools in autumn and their sudden disappearance from the pools in spring. Large 15 mm *A. modesta* were not collected again until the winter of 1969-70 when they were unusually common in some pools. Not until the winter of 1975-76 were large ones observed again, and these were 12 mm not 15 mm.

Elysia chlorotica: This large emerald-green sacoglossan was first noticed in Pool No. 1, 14 October 1965, when 4 were observed and collected. Since then it has been observed at most of the local marshes. On the same day it can be found on *Vaucheria* cushions, on mud at the base of *Spartina alterniflora,* on the overhanging sides of creeks, submerged in pools along the drainage creeks, and in pools on the high marsh. At Pool No. 1, on 16 January 1967, live specimens were found in pockets on the underside of 18 cm of ice cover. The greatest density to date was recorded (and photographed) at Pool No. 1, 24 October 1966, when 75 m^2 were on the submerged algal mats. The largest individuals in any year occurred in the pools and were in the 26 to 46 mm size range which certainly exceeds Abbott's (1974) limits of 20 to 30 mm. However, specimens observed on the open marsh were rarely over 12 mm in length. The extremely large individuals were common on 9 December 1969 and 23 November 1970 at Kingsport marsh pools, but in 1972 and 1973 there were none although 3 km to the south in the Canard pools they were common on 22 October 1972. At Pickett's Wharf the dense populations of 1966 were gone by 1970 and specimens were not seen there again until 30 November 1976; further demonstration of natural fluctuations in marsh pool populations.

Stiliger fuscata: This sacoglossan is relatively small, 6 to 8 mm, but its black color renders it most conspicuous on green algae and on the brown substrate of the pools. We can say with assurance that it was not in the marshes of the western Minas Basin in 1966. On 21 October 1970, a single specimen was observed, collected, and photographed. Not until September 1972, was another found in spite of our diligent efforts in the interim. This 'rare' species suddenly increased in 1973 and 1974 to such densities that a small sample of pool algae, enough to half fill a 16 oz jar, would produce over 120 *S. fuscata.* The population declined in 1975 and by autumn of 1977 we considered them rare.

Gemma gemma: In July and August 1966 this small pelecypod was found in numbers as high as 50 to 96 per 0.91 kg algal sample from the Canard marshes, but was never found in the Canning pools.

Phylum Arthropoda

Gammarus mucronatus: Reported as a "warm water endemic" by Bousfield and Leim (1960), this amphipod was present in great numbers throughout the sampling period, reaching a peak in July and August at which time young were present. On 9 November 1966 the count from a 0.91 kg algal sample was 122 specimens. They were found active even beneath the ice, although on 24 February 1966, winter kill of both algae and animals was observed in Pool No. 2.

Bousfield (1956; 1973) reported this species occurring in Nova Scotia in salinities ranging from 4 ‰ to 28.7 ‰. The highest salinities of our study pools, 39.3 ‰, indicate that this species can live at salinities much above those previously recorded.

Orchestia grillus: This second "warm water" amphipod was most often found in the moist *Vaucheria* mats and was observed only once in the pools, at a time when a high tide was just receding from the marsh. On 12 July 1966 many live individuals were found in folds of algal mats swept out of the pools by the June high tides. Bousfield (1956) reported habitat salinities ranging from 18.0 ‰ to 28.7 ‰.

Enochrus hamiltoni: Throughout the period from May to August this water beetle occurred regularly in the samples.

Ephydra riparia: Larvae and pupae of these shore flies were abundant throughout the summer but disappeared by September.

Tabanus nigrovittus: Only 1 larva was found.

Corixidae: Water boatmen were first observed 27 July 1966, at which time they occurred in great numbers in algal samples of both pools. High numbers of 15 to 68 individuals per 0.91 kg algal sample, which persisted through August, gradually decreased to only 2 specimens in November. In 1973, instars were common in benthic samples in spring and early summer and progressively increased in size. Adults of summer were derived from this overwintered population of eggs or instars.

Acarina: Red mites were common from May to August disappearing completely from the algal samples by September.

Phylum Chordata

Fundulus hetroclitus: Killifish were seen throughout the summer in both study pools. Eggs and young were taken in algal samples and young persisted through to 20 September. On the Canard marsh, *F. heteroclitus* was seen as late as 9 November. During 1 particular high tide in 1966 when the *Spartina* near Pickett's Wharf was flooded to a depth of about 0.45 m, schools of this fish were observed leaving the pools and feeding actively as they worked their way through this submerged 'hay field'. In some instances they appeared to let the flood of the tide carry them along. Whether these groups of foraging fish return to their home pools was not determined, but the absence of stranded fish on the marsh and the presence of the usual complement of killifish in the pools after the tide had receded would indicate the probability of homing behavior. From observations at the Kingsport marsh in 1973, there were two categories of killifish foraging patterns in the *Spartina* during extreme highwater spring tides. As tidal waters flooded over the marsh from the creeks, discrete schools of *Fundulus* come in with this flood and these feeding units were particularly conspicuous on dead-calm days. When the rising waters finally reach the upper marsh pools, the resident killifish were observed to school away into the *Spartina* where they become indistinguishable from the groups already there. There was, then, a sporadic but intense utilization of invertebrates of the marsh vegetation (insects, spiders, mites) by fish resident in the pools and by schools from the Basin proper.

Gasterosteus aculeatus, Gasterosteus wheatlandi, Apeltes quadricus, and *Pungitius pungituis:* All 4 species of sticklebacks were collected from poisoned Canard terraced pools on 28 June 1966, but on 9 November only *P. pungitis* was present. Rotenone treatment of a marsh pool (8.3 x 1.5 x 0.5 m) on the Kingsport marsh on 26 August 1975 produced 379 fish specimens: 335 *F. heteroclitus* (52 gm), 38 *Anguilla rostrata* (262 gm) and 6 *Apeltes quadricus* (1.4 gm). Two of the larger eels (length 32 and 33 cm) emerged and fled across the marsh surface.

Anquilla rostrata: The American eel was never seen in the Canning pools but on 14 July 1966, the shallow gully draining that part of the marsh was poisoned (rotenone), and eels quickly emerged from the bottom silt and escaped downstream.

Conclusions

The uniform appearance of Minas Basin *Spartina* marshes could easily lead to the assumption that pools in such a monotonous habitat would be equally uniform. The evidence from this study is to the contrary for even 2 adjacent pools showed variations in species composition, population densities, and physical factors. Although just 30 m distant, Pool No. 1 showed algal characteristics different from Pool No. 2. Population densities of areas "a", "b", and "c" of Pool No. 2 showed more coincidence in fluctuations than did those in Pool No. 1. Average salinities were higher in Pool No. 1. *Alderia modesta* and *Elysia chlorotica* were more abundant in Pool No. 1. *Gemma gemma* of the nearby Canard Marsh were altogether absent from the Canning marshes. Further, within 1 pool, areas only 3 m apart were distinct from month to month. Bromley's 1976 to 1978 survey of 5 Minas Basin estuarine marshes adds further evidence of surprising faunal diversity between contiguous similar marshes (Bromley 1978).

Over this 12-year period (1965-1977), significant natural fluctuations in densities, local distribution, and even average sizes were observed for 3 species of sacoglossans, an anemone, and two nemerteans.

The diversity and instability of environmental parameters are an essential characteristic of these marsh pools. When tides do not enter the pools for 20 days or more, there may be periods of cool, rainy weather or a persistent summer heat wave. Also, at such a time, the diurnal periodicity of day-night temperature changes may be strongly felt. However, then the tides are flooding these pools twice daily, but at different times, such diurnal patterns would be robbed of their periodicity. As the precise height and action of these spring tides are unpredictably affected by wind and/or barometric pressure and as there is no regular seasonal pattern in flooding sequence of the marsh pools (Bleakney 1972), then tidal cycles are of little consequence in establishing rhythms to which marsh pool animals could adapt and synchronize any intrinsic biorhythms.

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