Freshwater Molluscs of the United States Military Academy Drainages (West Point, NY) and Comparative Regional Biodiversity of Gastropods

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Abstract - Thirty-four species of molluscs have been found in the drainage systems of the United States Military Academy at West Point, NY. A few rare species were found as well as a single specimen of a presumed new gastropod taxon. Only two species of unionids, *Pyganodon cataracta* and *Elliptio complanata*, were found within the drainages. The largest drainage system, Popolopen Brook, contained the highest diversity of molluscs. Species redundancy between drainages aligned well as a function of the extent of lentic and lotic habitats with brooks and streams having a Bray-Curtis similarity index of ≈ 64.0 when compared to lakes and ponds. On the other hand, a number of species collected were found in only a single drainage. Total drainage area did not correspond well with diversity unless determined as total predicted usable habitat. Thus the drainages with the greatest number of discernible lakes, ponds, streams, and creeks, also had the highest molluscan diversity. On the whole, molluscan diversity of these drainages compared favorably to those of other regional New York sites, but relative abundance or population densities varied, with variations reflecting survey effort, time or season of collections, and incorporation of historic museum collections.

Introduction

The United States Military Academy (USMA) at West Point, NY, has an extensive drainage system comprising natural and variously manipulated ponds, lakes, and streams. Throughout the history of the Academy, several of the natural systems of the reservation have been altered by dams that have raised water levels and modified/controlled flow regimes. In addition, military training exercises on the USMA property have had the potential to degrade localized habitats, particularly through bank erosion. Training areas are especially heavily used in spring and summer, times of significant reproductive activity among regional molluscs. Amphibious maneuvers (for example amphibious assault training, confidence course, scuba diving, pontoon bridging) occur especially at Stilwell and Popolopen Lakes as well as Lake Georgina (USMA 1994). In light of these activities, the USMA has

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undertaken an extensive program to delineate the current status of the biota within the bounds of the Academy property.

E.A. Mearns (1898) conducted the first recorded molluscan survey for the West Point region yielding 10 species of freshwater molluscs plus several land snails. One hundred years later, a report to the USMA on the "Integrated Natural Resource Management Plan" (USMA 1998), reported only four species of molluscs in USMA waters. Those two are the extent of published reports uncovered for the molluscs of the USMA property prior to the current study. Clearly, this paucity of taxa noted in available reports represents under-sampling based not just on the findings of the current study, but based also on reports and publications from surrounding regions (see for example, Jokinen 1992). The molluscs reported more recently are from incidental collections made by J. Beemer from 1992 through 1998 (USMA Natural Resources Branch, J.A. Beemer, pers. comm.). The 1998 study did not have sampling protocols that allowed for the collection of smaller and less obvious molluscs within complex and often cryptic habitats, nor was it designed to encompass a serious molluscan survey.

Molluscs and other macroinvertebrates are often used to help assess an index of ecological quality of freshwater ecosystems (Rosenberg and Resh 1993). In order to do this assessment, however, there must be a substantive baseline so that a measure of relative ecological quality can be attained. Clarke et al. (1996), for instance, suggested that an assessment index, in part, could be defined by an understanding of the agreement of observed versus expected fauna in a particular river system. To better understand the malacofauna and ecological health of the large and variable array of habitats located within the drainages on USMA property, we undertook a study to garner a more complete appreciation of the molluscan fauna within the compound. In addition, we ran Bray-Curtis comparisons with molluscan communities in comparable habitats within the region based on other published works.

The five major surface drainage systems on the base (Fig. 1) appear, with few exceptions and within localized areas, well-established and the ponds and lakes appear to retain a diverse biota. These drainages, though only a portion of the total drainage system in the region, offer a good representation of habitats that reveal a rich molluscan fauna (> 30 species) with variable population densities and distinct distributions.

The Study Area

The United States Military Academy encompasses 16,000 acres in Orange County, NY, on the edge of the Hudson River. Many of the creeks, streams, ponds, and lakes of the USMA drainages have been variously manipulated or even created. The streams and lakes associated with Popolopen Brook represent the major drainage system on the property and include the single largest body of water on the base, Popolopen Lake. Popolopen Brook drainage contains 21 lakes and ponds > 4050 m^2 in size, 11 of which are on USMA property, and extensive tributaries composed mostly of narrow and shallow streams. The Mineral Springs drainage is a tributary of the much larger Woodbury Creek watershed, which is mostly outside the borders of the USMA property. Highland Brook drainage includes three tributaries of Highland Brook; all are cool water systems that are usually shallow and fairly narrow (< 3 m wide). Cragston Creek drainage is dominated by the relatively shallow impoundments that compose Cragston Lakes I–IV (two upper and two lower). Crows Nest Brook drainage contains two cool or coldwater streams, Crows Nest Brook and Sinclair Pond Brook, and an unnamed pond on the West Point Golf Course at the head of Sinclair Pond Brook. This could be the most anthropogenically impacted of the drainages on USMA property. Further descriptions of these water bodies are available in the Integrated Natural Resource Management Plan (USMA 1998). Many water systems on the USMA property are heavily used and manipulated for military maneuvers. To

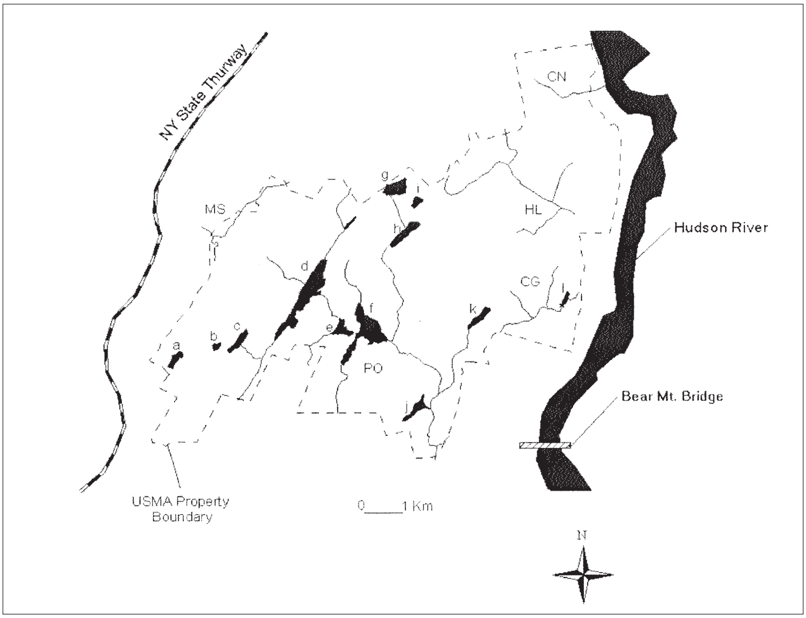

Figure 1. Major creeks and lakes sampled on USMA property. Abbreviations for drainages are MS = Mineral Springs, PO = Popolopen, CN = Crows Nest, HL = Highland, and CG = Cragston. All ponds and lakes found within the survey area are labeled, a = Lake Frederick, b = Lake Georgina*, c = Bull Pond, d = Popolopen Lake, e = Mine Lake, f = Stilwell Lake, g = Wilkins Pond, h = Long Pond*, i = Round Pond, j = Weyants Pond, k = Cranberry Pond, and l = Cragston Lakes (I–IV). * = not sampled.

control algal growth some sites receive periodic copper sulfate treatments, which can be toxic to molluscs. Stilwell Lake, for instance, is a local water supply and receives regular treatments.

Our survey entailed a study of only the truly aquatic molluscs. Our survey also did not include any part of the Hudson River proper (this is not on Academy property) nor the marshy border areas of the river. Thus, we eliminated terrestrial and semiterrestrial gastropods from the survey, even though after heavy rains we would occasionally find these species submerged along stream banks. We calculated area of available aquatic habitat on the USMA property as a function of stream, creek, lake, or pond area and did not include the surficial drainage area that surrounds these bodies of water. An evaluation of total drainage systems versus our calculations of available habitats gives an example of the fraction of drainage areas available to our survey. For instance, the total Popolopen drainage encompasses an area of 77,599 km^2, whereas we determined the available, perennial, aquatic habitat area comprising the 22 lakes, ponds, streams and creeks for this drainage on USMA property as only 1786 km^2. Additional details of our specific collection sites can be found in Prezant and Chapman (2002) and in Tables 1 and 2.

Methods

Sampling occurred from August 2000–June 2002 in water bodies shown in Figure 1. Streams, creeks, and ditches were sampled using fine-meshed dip nets. Molluscs recovered, except unionids, were immediately preserved in 70% ethanol. In cases where the substratum was composed of fine adhesive sediments that would not easily pass through a fine-meshed net, samples were taken by shovel and run through a 0.5-mm mesh sieve. We collected samples along the periphery of lakes and ponds using dip nets and sieves. In deeper lakes and ponds, we also used hand collection by SCUBA divers to recover samples, especially of unionids and larger gastropods. SCUBA dives followed predetermined transects across the width and margins of the lakes. Where floating or submerged aquatic vegetation was found, we also collected specimens from the plants using a fine-meshed net or sieve by running the sampling device through the plants. To avoid oversight of smaller specimens, submerged aquatic vegetation samples were also collected for examination under a dissecting microscope in the laboratory.

An Oakton® Model WD-35615 meter was used to determine temperature and pH. A Secchi disk was used to measure turbidity in lakes and ponds. Sampling dates, substratum types, average depth, approximate area or length, and habitat notes for each site sampled can be found in Tables 1 and 2. We used a Garmin® GPS Map 12 unit to determine site locations (latitude and longitude) for future reference and repetitive sampling.

We compared similarities of the molluscan communities, both within and external to the boundaries of the USMA property. Similarities were calculated using a Bray-Curtis Index found in the statistical program PRIMER. Data were transformed into presence/ absence counts for all comparisons allowing species to be equally weighted. When data are transformed in this manner the resulting similarity indices are identical to the Sorenson coefficient (Clarke and Warwick 1994). The resulting data

Table 1. Area or length for ponds/lakes or streams, respectively, and depths for sample sites. Area of ponds and lakes is in km^2, length of creeks and brooks is linear km and the ditch is in m.

Water body	Area/length	Max depth
Beaver Pond	32.40 km^2	< 2.0 m
Bull Pond	117.00 km^2	25.0 m
Bull Pond Road Ditch	2.00 m	< 1.0 m
Cascade Brook and Ditch	2.12 km	< 1.0 m
Cragston Creek	1.85 km	1.0 m
Cragston Lakes (I–IV)	79.00 km^2	3.0 m
Cranberry Pond	97.10 km^2	3.0 m
Crows Nest Brook	2.25 km	1.0 m
Highland Brook	5.91 km	2.0 m
Johnson Meadow Brook	1.87 km	< 1.0 m
Lake Frederick	64.70 km^2	7.6 m
Mine Lake	93.10 km^2	5.0 m
Mineral Springs Brook	2.50 km	< 1.0 m
Popolopen Brook	4.01 km	2.5 m
Popolopen Lake	603.00 km^2	10.0 m
Round Pond	52.60 km^2	10.0 m
Sinclair Pond Brook	2.30 km	0.3 m
Stilwell Lake	526.00 km^2	15.0 m
Stoney Lonesome Brook	1.20 km	< 1.0 m
Trout Brook	0.74 km	< 1.0 m
Weyants Pond	105.00 km^2	3.0 m
Wilkins Pond	142.00 km^2	2.5 m
Unnamed tributary to Stilwell Lake	0.47 km	1.0 m

Table 2. Qualitative substratum composition and mussel species presence or absence from each USMA SCUBA-collected site. *E.c.* = *Elliptio complanata, P.c.* = *Pyganodon cataracta,* + = presence, - = absence of mussel species.

Site	Drainage	Sediment	*E.c.*	*P.c.*
Beaver Pond	Popolopen	Silt/organics	-	-
Bull Pond	Popolopen	Sand/gravel	+	+
Mine Lake	Popolopen	Silt/organics	-	-
Popolopen Lake	Popolopen	Sand/gravel	-	+
Round Pond	Popolopen	Sand/silt	-	+
Stilwell Lake	Popolopen	Silt/sand	-	+
Weyants Pond	Popolopen	Rock/silt/organics	-	-
Wilkins Pond	Popolopen	Algal mat/silt	-	-
Cragston Lake I	Cragston	Silt/gravel/organics	Valves only	-
Cragston Lake III	Cragston	Muck/heavy vegetation	-	+
Lake Frederick	Mineral Springs	Sand/gravel	-	+

set was then compared, using the CLUSTER function, to survey results of Jokinen (1992) and Strayer (1987), the only other comparable published studies for the region. A representative collection of all taxa collected has been deposited into the State Museum of New York, Albany.

Results and Discussion

Total species summary

We found thirty-four species of molluscs including one listed subspecies, one taxon that is apparently new to science, and two or three considered rare in New York by Jokinen (1992) and the New York

Table 3. Occurrence of species found in each habitat type at USMA. Numbers indicate how many times each species was collected in a given, non-overlapping habitat type.

Species	Pond/lake	Stream/brook	Ditch
Amnicola cf. *grana* (Say, 1822)	1	0	0
A. limosus (Say, 1817)	6	3	0
Aplexa elongata (Say, 1821)	1	0	1
Campeloma decisum (Say, 1817)	2	1	0
Bellamya (*Cipangopaludina*) *chinensis* (Gray, 1834)	1	0	0
Elliptio complanata (Lightfoot, 1786)	2	1	0
Ferrissia californica (Rowell, 1863)	0	2	0
F. walkeri (Pilsbry & Ferriss, 1907)	1	0	0
Fossaria obrussa (Say, 1825)	2	1	0
F. rustica (I Lea, 1841)	0	1	0
Gyraulus circumstriatus (Tryon, 1866)	0	2	1
G. parvus (Say, 1817)	2	1	0
Helisoma anceps (Menke, 1830)	5	1	0
Micromenetus dilatatus (Gould, 1841)	0	2	0
Musculium partumeium (Say, 1822)	6	2	1
M. securis (Prime, 1851)	4	1	0
Physa acuta Draparnaud, 1805	4	3	1
P. ancillaria (Say, 1825)	2	2	0
P. gyrina (Say, 1821)	3	4	0
Pisidium casertanum (Poli, 1795)	7	1	2
P. ferrugineum Prime, 1852	1	0	0
P. henslowanum (Sheppard, 1825)	1	0	0
P. cf. *insigne* Gabb, 1868	0	1	0
P. ventricosum Prime, 1851	1	0	0
P. ventricosum rotundatum Prime, 1852	3	0	1
Planorbella trivolvis (Say, 1817)	5	2	0
Planorbid sp. novo	0	1	0
Probythinella lacustris (Baker, 1928)	1	0	0
Pseudosuccinea columella (Say, 1817)	4	3	1
Pyganodon cataracta (Say, 1817)	7	1	0
Sphaerium nitidum Westerlund, 1876	1	0	0
S. simile (Say, 1817)	1	1	0
Valvata tricarinata (Say, 1817)	2	1	0
Viviparus georgianus (Lea, 1834)	1	0	0
Total species	27	23	7
Gastropods	17	16	4
Bivalves	10	7	3

Table 4. Presence/absence of all species of molluscs collected at USMAWest Point sites. B1 = Beaver Pond, B2 = Bull Pond, B3 = Bull Pond Road Ditch, C1 = Cascade Brook Ditch, C2 = Cragston Creek, C3 = Cragston Lake I, C4 = Cragston Lake III, C5 = Cragston Lake IV, C6 = Cranberry Pond, C7 = Crows Nest Brook , C8 = Crows Nest Target, H = Highland Brook, J = Johnson Meadow Brook, L = Lake Fredrick, M1 = Mine Lake, P1 = Popolopen Lake outlet, M2 = Mineral Springs Brook, U = unnamed tributary of Stilwell Lake, P2 = Popolopen Brook, P3 = Popolopen Lake, R = Round Pond, S1 = Stilwell Lake, S2 = Stony Lonesome Brook, T = Trout Brook, W1 = Weyants Pond, and W2 = Wilkins Pond.

	B1	B2	B3	C1	C2	C3	C4	C5	C6	C7	C8	H	J	L	M1	P1	M2	U	P2	P3	R	S1	S2	T	W1	W2
Amnicola cf. *grana*						X																				
A. limosus							X	X					X			X			X	X	X	X			X	X
Aplexa elongata		X	X																							
Campeloma decisum		X																	X	X						
Bellamya (*Cipangopaludina*) *chinensis*																					X					
Elliptio complanata		X				X							X						X							
Ferrissia californica																X			X							
F. walkeri									X										X							
Fossaria obrussa						X				X											X					
F. rustica																	X									
Gyraulus circumstriatus			X													X			X							
G. parvus						X	X	X											X		X					
Helisoma anceps	X												X	X								X			X	X
Micromenetus dilatatus										X		X														
Musculium partumeium			X			X	X		X				X			X				X	X	X				X
M. securis	X						X																X		X	X
Physa acuta	X			X			X			X				X			X					X	X		X	
P. ancillaria							X											X				X		X		
P. gyrina							X	X			X					X			X	X	X		X			

Table 4 cont. Presence/absence of all species of molluscs collected at USMAWest Point sites. B1 = Beaver Pond, B2 = Bull Pond, B3 = Bull Pond Road Ditch, C1 = Cascade Brook Ditch, C2 = Cragston Creek, C3 = Cragston Lake I, C4 = Cragston Lake III, C5 = Cragston Lake IV, C6 = Cranberry Pond, C7 = Crows Nest Brook Camp, C8 = Crows Nest Target, H = Highland Brook, J = Johnson Meadow Brook, L = Lake Fredrick, M1 = Mine Lake, P1 = Popolopen Lake outlet, M2 = Mineral Springs Brook, U = unnamed tributary of Stilwell Lake, P2 = Popolopen Brook, P3 = Popolopen Lake, R = Round Pond, S1 = Stilwell Lake, S2 = Stony Lonesome Brook, T = Trout Brook, W1 = Weyants Pond, and W2 = Wilkins Pond.

	B1	B2	B3	C1	C2	C3	C4	C5	C6	C7	C8	H	J	L	M1	P1	M2	U	P2	P3	R	S1	S2	T	W1	W2
Pisidium casertanum		X	X	X		X		X						X				X		X	X	X				X
P. ferrugineum																				X						
P. henslowanum									X																	
P. cf. *insigne*																			X							
P. ventricosum																										X
P. ventricosum rotundatum		X	X						X																	X
Planorbid sp. novo										X																
Planorbella trivolvis						X	X	X										X	X	X	X	X				X
Probythinella lacustris																										X
Pseudosuccinea columella			X									X				X		X		X	X	X				X
Pyganodon cataracta		X					X							X	X			X		X	X	X				
Sphaerium nitidum																										X
S. simile													X								X					
Valvata tricarinata																		X	X			X				
Viviparus georgianus														X												
Total No. Species	3	6	6	2	0	7	9	5	4	4	1	2	5	5	1	6	2	6	11	9	11	10	3	1	4	11

Natural Heritage Program (2002). Gastropod species outnumbered bivalve species. These include 22 species of gastropods and 12 species (plus one subspecies: *Pisidium ventricosum rotundatum* Prime, 1852) of bivalves (2 unionids and 10 sphaeriids). The complete list of taxa collected with specific general and site locations can be found in Tables 3 and 4.

The most abundant species in our collections included (in order of abundance): *Amnicola limosus* (Say, 1817), *Planorbella trivolvis* (Say, 1817), *Pisidium casertanum* (Poli, 1795), *Sphaerium partumeium* (Say, 1822), and *Pyganodon cataracta* (Say, 1817). The small hydrobiid *A. limosus* was the most common species of mollusc found within USMA waters, accounting for almost 50% of the 1117 total individuals collected. The rarest included the undescribed, presumed planorbid, gastropod plus *Micromenetus dilatatus* (Gould, 1841) and *Sphaerium nitidum* Clessin, 1876. Eleven of the thirty-four taxa collected comprised only 2% of the total individuals found, whereas the three most abundant species comprised 67% of all molluscs collected.

There were slightly more species of molluscs found in USMA lakes and ponds than in streams and brooks (Table 3). Not surprisingly, the largest drainage, Popolopen, held the highest number of species (Fig. 2). This relationship is supported by work near Lake Winnipeg by Pip (1987), who found a strong correlation between gastropod species richness and size of water body. There is a significant decrease in total number of species in the Popolopen drainage vs. any of the other drainages sampled. For instance, 29 species were found in the Popolopen drainage whereas the next highest number was for the Cragston drainage with 11 species.

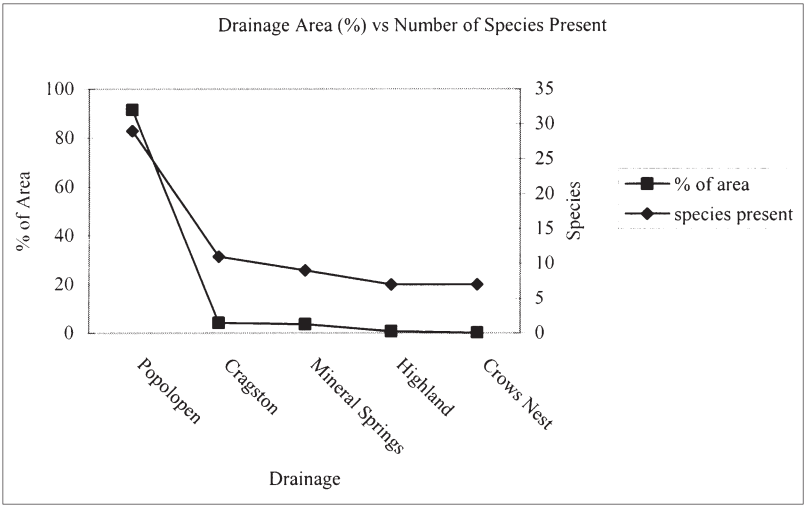

Figure 2. Total number of mollusc species collected in each drainage versus individual drainage areas.

There is a strong correlation between not only drainage size and species found, but also the correlative diversity of habitats within the drainage. A Pearson correlation comparing drainage size and number of species present yielded a value of 0.984. This represents a strong linear relationship between size of drainage and number of species present. Drainage area was calculated for all available water at West Point (Table 5). The areas of lakes and ponds were calculated from historical survey data (USMA 1998), whereas areas of streams, brooks, and ditches were calculated based on average width and total length. The Popolopen system contains over 91% of the total drainage area on the reservation, roughly 1786 km^2 of water surface. Popolopen also contained 29 of the 34 species of molluscs collected in this study. The next largest drainage system was Cragston, with a water-coverage area of about 81 km^2, roughly 4% of the total aquatic area on the reservation. The three remaining drainage systems combined accounted for only 4.49% of total aquatic habitat found on the property. The magnitude of the Popolopen system in comparison to the other drainages from within the USMA property accounts for the diversity of potential habitats and high species count. Many of the species found in this drainage were found nowhere else on the academy property.

The New York Natural Heritage Program (2002) considers *Aplexa elongata* (Say, 1821) "very vulnerable" in New York. Jokinen (1992) performed an extensive survey of the molluscs of New York and did not find *Probythinella lacustris* (Baker, 1928). Based on our survey, we also consider this species to be rare in New York.

Drainage, habitat, and community similarities

Comparing total species overlaps (similarities and differences), we can speculate on habitat similarities between the various USMA drainages. The highest similarity occurred between Popolopen and Cragston drainages (Fig. 3) with a similarity of 46%. Highland drainage had a similarity of 38% with Cragston and Popolopen; Mineral Springs drainage a similarity of 38% with the former three drainages; and Crows Nest was least similar to the other drainages (approximately 28%). Extremely abundant taxa such as *Pisidium casertanum* and *Amnicola limosus* have

Table 5. The relative total drainage area versus on-site aquatic habitats. Total impoundments are defined as all permanent and ephemeral waters composing the five drainages found on USMA property.

Drainage	Total area (km^2)	Aquatic habitat on USMA (km^2)	Total impoundments
Popolopen	77,599	1786	40
Mineral Springs	13,610	70	6
Highland	11,300	15	10
Crows Nest	5277	2	4
Cragston	4759	81	12

no skewing effect on these results due to the transformation of data to mere presence or absence. The similarities are thus based solely on species similarity indices and no other factors but can reflect similarities in habitat including potential anthropogenic influences. Popolopen drainage on USMA property is composed of eleven lakes and ponds, including the two largest lakes, Popolopen and Stilwell. These two large lakes have extensive shallows with dense populations of submerged aquatic vegetation. Many of the smaller lakes and ponds are very shallow throughout and also extensively vegetated. Bull Pond and Round Pond have relatively little in the way of dense submerged plants. The Popolopen Brook drainage also has several tributaries, most of which are cool water with variable substrata. The Cragston drainage overlaps the Popolopen drainage in terms of similarity of habitat, including cold water Cragston Creek with a boulder and gravel substratum with silt interstices and extensively vegetated upper and lower impoundments.

As would be expected, there is minimal overlap in occurrence of species found in "ditches" compared to other permanent habitats. "Ditches" diverge from both lakes/ponds and brook/streams when analyzed using PRIMER (Fig. 4). The similarity coefficient comparing brooks/streams and lakes/ponds is 64.0 whereas ditches show a coefficient of only 25.0 for lake/ponds and 26.7 for brooks/streams. The low similarity exhibited for the "ditches" compared to other aquatic habitats is recognized as a reflection of their ephemeral character.

Nineteen species were unique to a single drainage, Popolopen Brook, on the USMA campus (Fig. 5). Eight species occurred in two drainages, whereas four were represented in three different drainages. The snail *Physa acuta* Draparnaud, 1805 and the bivalve *Pisidium*

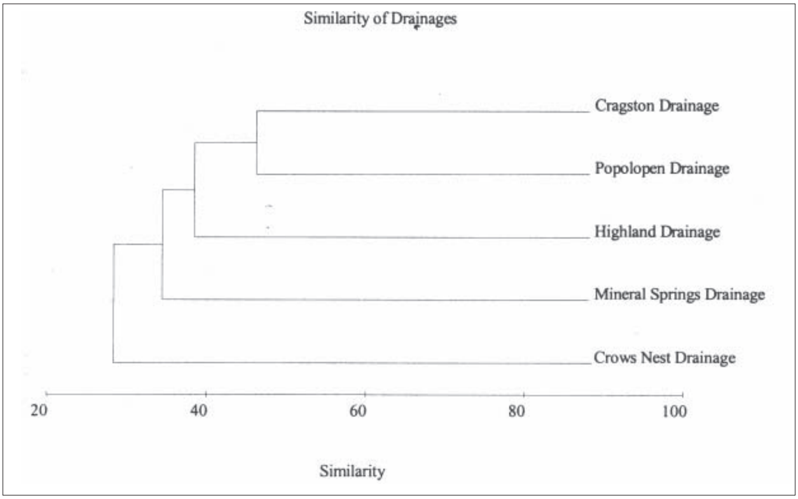

Figure 3. Dendrogram demonstrating the overlap of molluscan species among various drainages on the Academy property.

casertanum were both found in four of the five drainages surveyed. *Physa gyrina* (Say, 1821) was found in all five of the drainages making it the most ubiquitous molluscan species on the academy property. The absence of various molluscs from seemingly available habitats could be a result of microhabitat preferences, water chemistry variations, predator/prey interactions, and, in a few cases, the ephemeral nature of the uppermost drainages (e.g., Crows Nest).

Strayer (1987) suggested, "the drainage basin is, in many ways, the ideal unit for ecological and zoogeographical studies." He further noted that the basin frequently will "correspond to distributional boundaries of

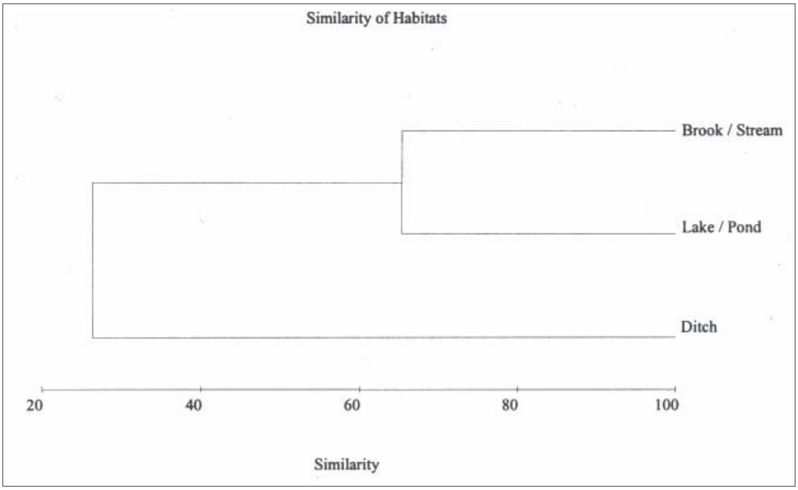

Figure 4. Dendrogram comparing mollusc species similarities between particular aquatic habits (pond, lake, stream, ditch) using a Bray-Curtis analysis.

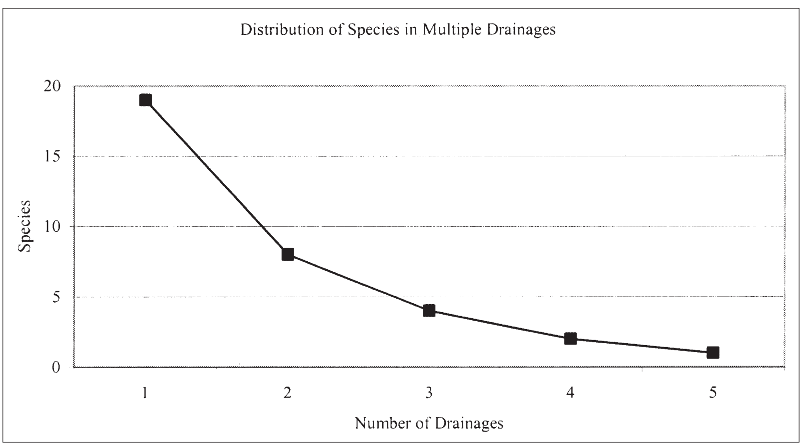

Figure 5. Graph showing the number of species of molluscs similarly inhabiting one, two, three, four, or all five of the USMA drainage systems. *Physa gyrina* was the only mollusc found in all five drainages.

species." Although we have not studied the entire basin (i.e., the Hudson River proper was not included nor were sites in drainages off USMA properties), we have studied large areas of specific drainages to garner insight into molluscan community structure. We are able to discern communities using information on species found in-habitat, but we have limited environmental data (temperature, pH, and qualitative information on substratum and cover). Pip (1987) examined over 400 sites near Lake Winnipeg between 1972 and 1985, including lakes, ponds, rivers, and creeks. Over that time she monitored many environmental parameters. She reported 40 species of gastropods from all sites combined, with a mean species richness of 4.58 (i.e., 4.58 species per site examined). Her highest values were from lakes (5.22) and lowest from creeks (3.35) with rivers (4.66) and ponds (4.12) in between. Similarly we found highest total species numbers for all molluscs (gastropods and bivalves) in lakes and ponds. Looking just at level of occurrence (i.e., occurrence of a given species in a habitat type), we found a similar number of species of molluscs in ponds/lakes and streams/brooks (Table 3). Similarly, we found that among the gastropods, 18 and 16 species, respectively, were found at least once in both ponds/lakes and streams/brooks. Bivalves, however, were more commonly found in lakes and ponds than in streams and brooks (10 to 7 occurrences). The latter pattern is partially explained by substratum preference (i.e., soft, finer sediments needed for infaunal habitat), water flow regimes, occurrence of unionid host-fish for glochidial dispersal (especially centrarchids in lentic habitats), and the relatively sedentary nature of adults. In addition, the brooding habitats and direct development of the sphaeriid bivalves allows for localized release of young in "appropriate" lentic habitats. Species richness in Pip's Canadian sites varied with substratum and aquatic macrophytes. She also found a positive correlation for all sites with phosphorus, chloride, total alkalinity, total dissolved solids, and pH. These varied between ponds and lakes, with a negative correlation for dissolved organic matter in lakes. Overall, she found water chemistry less critical in lotic habitats. Dillon and Benfield (1982) found a correlation among abundance of pulmonate snails and alkalinity and drainage area in streams of North Carolina and Virginia. Many other studies have shown correlations between various chemical parameters and freshwater mollusc distribution (e.g., Dussart 1976, 1979; McKillop and Harrison 1972; Saunders and Kling 1990; Williams 1970). The similarity indices used in this study can, we suggest, reflect and predict habitat preference. It is, however, difficult to tease apart the various possible synergistic parameters that could be involved in discerning community structure and species distribution. Therefore, it is critical that all variables be examined and viewed together when evaluating community dynamics. With sufficient environmental data from a given site and a backdrop of correlating information showing community similarities from a given geographic region, predictions of comparable but unexamined freshwater communities could be made.

Communities of molluscs can be extremely localized and possibly short-lived. Densely vegetated ditches with temporary standing water can be an important habitat for freshwater molluscs. We found six species in a single small ditch beside the road to Bull Pond. Killeen et al. (1998) discussed the importance of conserving ditch populations in Britain. They recognized that, as is true in the present study, these temporary pools can act as refugia for relatively rare species (in our case *Gyraulus circumstriatus* (Tryon, 1866)). Killeen et al. (1998) devised a Molluscan Conservation Index (MCI) to help regulate development near relevant ditches. They noted that time of year is critical for quantitative analysis and encouraged surveys at times other than during molluscan reproductive phases (for their study this meant late summer, well past the prime spring breeding period). At the USMA, road surfaces vary from paved to fairly primitive dirt and gravel, as does usage, which varies with time of year and operational exercises. Careful evaluation must be made of the potential impact of erosion caused by road traffic into these ephemeral aquatic habitats. Sites with particularly heavy military exercise activity, such as Stilwell Lake and Popolopen Lake, show, respectively, 10 and 6 species of molluscs. It is difficult to determine the exact impact that the exercises might have in these lakes as the numbers are comparable to other sites on the USMA property. Specifically, the lakes are also large enough that the physical damage that these activities might cause are likely to be localized with only minimal impact to the relatively large populations of the more common molluscan taxa.

Table 3 shows the distribution of mollusc species found in lakes and ponds, and in streams and brooks, on USMA drainages. Using this table allows us to tease apart the distribution of these taxa by combining lakes and ponds as lentic systems, and streams and brooks as lotic systems. Ephemeral standing water in ditches is home to both lentic and lotic species. The majority of species we collected can be found in both lotic and lentic systems. Water flow is not the sole determinant factor involved in mollusc distribution. It is, in fact, impossible to distinguish a single feature of a habitat as being the controlling factor in community or population structure; instead, all possible variables must be examined and taken into account. Thus, as a simple example, the presence of huge numbers of *Amnicola limosus* in ponds and lakes is likely not a direct reflection of the lentic structure of the water body per se, but instead a reflection of the presence of highly branching and filamentous submerged vegetation as this snails preferred substratum. The higher occurrence of species found in lentic habitats probably reflects the relative stability, especially in terms of hydrodynamics, of these habitats compared to the small streams and brooks. Stability of habitat is a key feature towards stability of community structure and, over time, stability of species occurring within a particular habitat.

Total drainage systems in this region encompass a much larger area than we surveyed. These drainages envelop the ephemeral wet surfaces and subterranean systems that rarely hold a diverse molluscan fauna. We have instead sampled (with the exception of a few roadside ditches) the permanent and more usable (i.e., not subterranean, aquifer, below soil, etc.) aquatic habitats composing variously impounded waters. If we re-rank the drainages by total area encompassed, the highest molluscan diversity remains within the Popolopen drainage system followed by Cragston (Table 5). This also correlates with the total number of lakes, ponds, streams, and creeks in each of the drainages (40 and 12 respectively). The Crows Nest drainage, with the lowest on-site usable aquatic habitat area surveyed, is ranked fourth in total drainage area (5277 km^2),but has the fewest (a total of four, all located on-site) permanent impoundments (lakes, streams, etc.) of the five drainages examined. The Crows Nest and Highland drainages each held < 10 molluscan species, the fewest found in this survey. The drainages with the highest number of permanent water bodies (Popolopen and Cragston) held the highest diversity of molluscs. Conceptually, the species-area relationship is well documented with increased richness directly related to increased area (Lomolino 2001). Very recently, Johnson et al. (2003) cautioned that habitat diversity could play an important role in species richness and that topography or heterogeneity of habitat must be considered. In our studies we accounted for only lotic habitat length or lentic habitat area; it must be recognized that there are interesting habitat complexities to be examined in either case that could deal with temporal changes in pond/lakes (e.g., seasonal turn-over, etc.) and changes with distance from headwaters in lentic systems. Correlations between these changes and species richness have yet to be documented in this region.

Comparisons to other regional studies

Very few comparable studies of the freshwater malacofauna are available for the Hudson River drainage. It is important to note that the sites described in the comparative literature appear relatively pristine with no indications of significant anthropogenic impacts. Thus, with relatively localized physical impact in our collecting sites at West Point, we assume equitable comparisons as follows.

The most extensive report on molluscs of the region is found in a review paper by Strayer (1987). The gastropods of New York have also been reviewed and extensively collected by Jokinen (1992). In order to use historic data from these papers for comparative purposes, we electively eliminated the malacofauna from rivers from the Strayer paper and compared only our gastropod findings to those of both authors. Similarly, we compared the total (diversity) finding of gastropods between Jokinen and Strayer using Bray-Curtis Similarities. The highest similarity between studies for gastropods was between Strayer and Jokinen at 73.9 (Fig. 6). We found 5 species not found by either Jokinen or Strayer, while Jokinen found 2 and Strayer 7 species that neither of the other studies recovered (Table 6).

Similarities and differences in taxa collected between and among studies reflect one or more scenarios. Geographic range can, of course, differ between collections. Strayer (1987) and Jokinen (1992) covered a much larger area than the current study, which was limited to the waters localized within the USMA property boundaries. Even subtle differences that have significant variations due to headwater impacts, natural or otherwise, can produce community change. The duration of individual collection periods or entire survey studies can, of course, vary considerably between research protocols. The present collection entailed about 12 weeks of concerted effort over various seasons, whereas Jokinen's study extended over a much longer period of time. At any given site in our qualitative survey, we spent a considerable number of hours (3–8 h, depending on area or length) carefully sampling all available aquatic habitats. Metcalfe-Smith and Di Maio (2000) note that substantial time is needed in qualitative surveys when searching for rare (mussel) species. Earlier, Vaughn et al. (1997) and Strayer et al. (1997) also suggested that timed searches were more effective methods for recovering rare species (of mussels) than, for instance, transect and quadrat methods. In addition, various

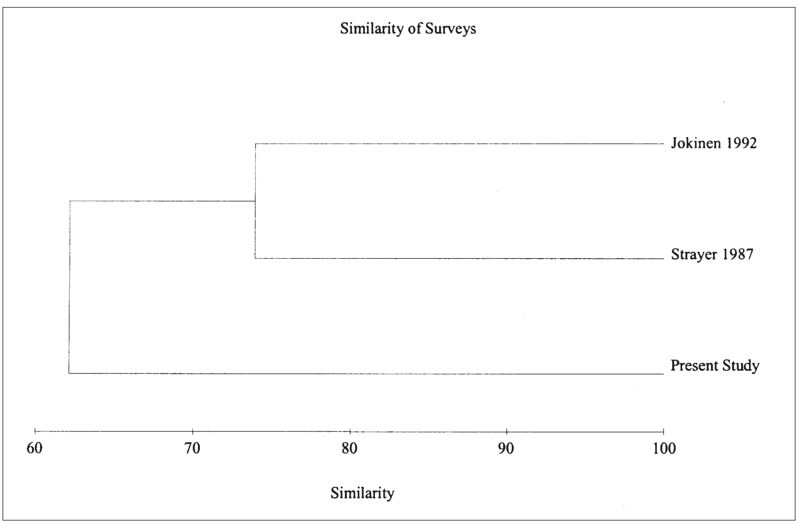

Figure 6. Bray-Curtis generated dendrogram comparing similarity of gastropod collections of the present study with that of Jokinen (1992) and Strayer (1987).

published surveys mix current live/shell collections with museum collections that extend over considerable past periods. Our current study included only specimens collected live from the field during the study period. Strayer (1987) amassed a species list that included museum collections. In addition, the exact definition of terms was somewhat vague in differentiating, for instance, the rapidly moving streams (or rivers); thus, there may not have been a perfect overlap in habitat types (nomenclature) considered. And lastly, the USMA watersheds are recognized as manipulated systems, variably modified through extensive usage over time (beach creation, military training

Table 6. Comparison of overlapping gastropod taxa among three studies. Taxa represented were collected from similar habitats (i.e., lakes, ponds, ditches, and small lotic habitats). Species collected by Strayer (1987) or Jokinen (1992) from non-comparable sites (e.g. riverine) are not listed.

	Strayer (1987)	Jokinen (1992)	Present Survey
Amnicola grana	X		X
A. limosus	X	X	X
A. pupoidea (Gould, 1841)	X	X	
Aplexa elongata		X	X
Bithynia tentaculata (Linnaeus, 1758)	X		
Campeloma decisum	X	X	X
Bellamya (*Cipangopaludina*) *chinensis*	X	X	X
B. (*C.*) *japonica* (von Martens, 1861)		X	
Elimia livescens (Menke, 1830)	X		
Ferrissia californica			X
F. rivularis (Say, 1817)	X	X	
F. walkeri			X
Fossaria obrussa		X	X
F. rustica			X
Gyraulus circumstriatus	X		X
G. deflectus (Say, 1824)	X	X	
G. parvus	X	X	X
Helisoma anceps	X	X	X
Laevapex fuscus (C.B. Adams, 1841)	X		
Marstonia lustris (Pilsbry, 1890)	X		
Micromenetus dilatatus	X	X	X
Physella ancillaria	X	X	X
P. gyrina	X		X
P. heterostropha	X	X	X
P. integra	X	X	
Planorbid sp. novo			X
Planorbella trivolvis	X	X	X
Probythinella lacustris			X
Pseudosuccinea columella	X	X	X
Stagnicola elodes (Say, 1821)	X	X	
S. catascopium (Say, 1867)	X	X	
Valvata tricarinata	X	X	X
Viviparus georgianus	X		X
Number of Species	25	20	22

maneuvers, water depth control, etc.) These activities, in addition to the regular international travel and return to the USMA base by military personnel, could have led to introductions, relocations, or even localized extirpation of species.

Clarke et al. (2002) quantitatively confirmed the influence of "inter-operator variability" in the results of biodiversity studies. Despite these possible differences in sampling protocol, there remains a considerable overlap of similarity coefficients between any two sites we compared, ranging from 60.5 to 73.9. The overlap (similarity) between molluscan communities in various regional studies gives credence to a relatively consistent regional freshwater molluscan fauna in this region. All three studies commonly found *Amnicola limosus*, *Planorbella trivolvis*, *Helisoma anceps* (Menke, 1830), and *Gyraulus parvus* (Say, 1817) in ponds and lakes. There were, on the other hand, fewer commonalties among the three studies for lotic environments, perhaps indicating the less stable environments found in these moving waters. Stretches of lotic waters are vulnerable to anthropogenic and natural changes that can occur along long distances of shallow water originating at their headwaters or at point sources at specific sites along their lengths.

With the large number of lakes and ponds available, we might have predicted a higher diversity of unionid mussels. Based on the cumulative collection reports by Peckarsky et al. (1990), Strayer (1987), and Strayer and Jirka (1997) for this region,there are ptentially 10–20 species of unionids that could have been found at West Point . The paucity of unionid taxa in the current study could be a result of long-term development and dredging in lentic systems as well as stream and creek alteration and regulated water impoundment. It is not unusual, in this geographic region, to find large monospecific populations of *Elliptio complanata* (Lightfoot, 1786) (e.g., in some impacted creeks south of Philadelphia; A. Bogan, pers. comm.). Similarly, sand, as in the artificial beaches on the Academy property, is a common substratum for shared communities of *E. complanata* and *Pyganodon cataracta* (A. Bogan, pers. comm.). Hanson and Richardson (2000) found only *P. cataracta* and *E. complanata* in the impacted Petitcodiac Headpond in New Brunswick, Canada. This headpond underwent a series of drawdowns in the late 1990s that correlated with a notable change in the benthic fauna including serious losses to these mussel communities. Over the three years these authors monitored this site, the population density of *P. cataracta* was reduced from 14 individuals/m^2 to 0.22 individuals/m^2. These authors suggested that mussels such as *P. cataracta* are vulnerable to aerial exposure caused by these drawdowns and may succumb in as few as 8 hours under emerged conditions.

Very few juvenile unionids were collected in the current study, although we found a large number of recently dead specimens of

Pyganodon cataracta during a significant drawdown in Stilwell Lake. Hanson and Richardson (2000) found no mussels smaller than 50 mm in their study in Petitcodial Headpond and suggested that all smaller individuals may have been "eliminated from the system by the 1999 drawdown." The authors, however, also affirm that small sampling size could have resulted in missed cohorts. The variation in cohort distribution in the USMA mussel populations between different local sites demands additional study. Also, among the bivalves, high densities of some sphaeriids were found. The viviparous fingernail or pea clams often dominate in creeks and small ponds and can have a similarly dominating influence on the overall ecology (water quality, substratum turn-over, etc.) of the habitat. As such, they represent an excellent group of organisms for biomonitoring (Korniushin and Glaubrecht 2002).

Conclusions

The lotic and lentic waters composing the various drainages found on the USMA West Point property reveal a high diversity of molluscs compared to the initial recording of four species by the 1998 report on the "Integrated Natural Resources Management Plan" for West Point and an earlier account by Mearns (1898) of 10 freshwater species. A few of the gastropod species we found within the drainages are variously considered rare in New York, but are not on the Federal list of endangered species to date. Specifically, the New York Natural Heritage Program (2002) lists *Aplexa elongata* as "very vulnerable in New York State," with S2 status (i.e., "Typically 6 to 20 occurrences, few remaining individuals"). In addition, Jokinen (1992) did not find *Probythinella lacustris* in her extensive survey and, in fact, questioned whether it was extirpated from New York State. We found this gastropod in Wilkins Pond but in only very small numbers. There is also one exceptionally rare species of undescribed mollusc (i.e., Planorbid sp.) found in Crows Nest Brook. Only a single specimen of this gastropod has been found and it is presently undergoing evaluation for taxonomic status. Two species of limpets, previously unrecorded for the West Point area, have also been found during this study. The small hydrobiid snail *Amnicola limosus* is the most widely distributed mollusc in these drainages, being found in nine different collection sites (about 1/3 of all sites sampled). To date, only two species of unionid mussels have been confirmed on the USMA base.

In their entirety, the drainages of the USMA at West Point contain a relatively high diversity of malacofauna distributed in an extensive array of streams, brooks, lakes, ponds, and ephemeral habitats. Juvenile unionids were found in only some ponds/lakes, while in most habitats we found only adult cohorts with apparently minimal recent successful recruitment. The human-made swimming beaches of some of the USMA lakes and ponds also offered an extended habitat for various fish and were often densely populated by centrarchid nests. These fish nests were found in shallow, sandy areas, the same areas also inhabited by unionids. If we extrapolate breeding behaviors and seasons found in comparable populations within the region, it is likely that many of the molluscs found within the watersheds of the USMA are reproducing at times of peak military activity. A longer term and differently focused study is required to determine potential impacts of these activities. There does not appear, however, to be a significant impact to overall malacofauna judging from sheer comparative molluscan diversity and the large numbers of regionally abundant species found in most USMA locations. It is possible that some USMA drainage sites have been impacted by human activity (drainage changes, road-runoff, physical incursions including dams and maneuvers, etc.) leading to some sites with relatively low diversity (for instance, portions of Crows Nest Brook within the housing development or various brooks impacted by golf course run-off). Other sites, however, could benefit from modified areas that have opened additional habitat for unionids (artificial sand beaches with relatively shallow waters, plus stocking of fish that could act as hosts for glochidia). Overall, however, the similarity of malacofauna diversity and communities found in this study compared favorably to the very few other available studies. There are only a few aquatic systems on the USMA sites examined that could be showing changes reflecting anthropogenically induced environmental modifications.

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