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A TENTATIVE LIST OF THE LAND SNAILS OF GEORGIA, U.S.A.

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ABSTRACT

Because of their high ecological and conservation value, and because we know so little about the group, we compiled a systematic if tentative list of land snails from the state of Georgia. After gleaning a list of species from a monograph on the land snails of eastern United States, written by Leslie Hubricht in 1985, we realized that many species whose ecological requirements are found in Georgia had not been documented there. Therefore, we developed a qualitative model to predict the likelihood that these candidate species occur in Georgia and would eventually be documented. We tested the model with collections data from nine natural history museums and found that the model nonrandomly predicted the species that were collected after the publication of Hubricht's work. Our searches revealed 214 species of land snails collected in Georgia that exist in museums. Our model predicted that another 68 species are likely occur in the state and await documentation. There are at least 10 species of exotic snails within Georgia's borders, some of them invasive. We consider our list of land snails in Georgia tentative but useful because of our systematic approach. It is our hope that more researchers will consider Georgia land snails as a model for studying systematics, evolution, ecology, and conservation.

INTRODUCTION

Land snails, because of their high density and diversity, exhibit high ecological and conservation value. Land snails are a major prey item for numerous vertebrate species (Beissinger 1983; Gunzberger 1999), and can also serve as a major consumer of forest leaf litter (Mason 1974). Snails, because of their calcium-rich shells, are an important food source for passerine birds and, when snails decline, these birds can experience egg defects such as thin or porous shells (Graveland 1996; Graveland et al. 1994). Terrestrial mollusks also serve as food for organisms as diverse as platyhelminths, firefly larvae, and carabid beetles (Barker 2004). By transforming consumed lichens as well as limestone bedrock into feces, snails contribute significantly (>10% of total soil nitrogen) to nutrient cycles of some ecosystems (Jones and Shachack 1990). The diversity and abundance of land snails are positively related to levels of soil calcium in central Appalachians forests (Hotopp 2002). Snails are important dispersal agents for the seeds of certain plants (Turke et al. 2010) and can improve germination of ingested seeds (Calvino-Cancela and Rubido-Bara 2012). When introduced outside of their native range, land snails can cause extensive damage to plants, including rare species (Joe and Daehler 2008), to native animals, especially native land snails (Civeyrel and Simberloff 1996; Meyer and Cowie 2010), as well as economic damage to agricultural systems (Civeyrel and Simberloff 1996).

Globally, land snails, including slugs, reach high levels of diversity within a given ecosystem (e.g., De Winter and Gittenberger 1998; Douglas et al. 2014; Schilthuizen and Rutjes 2001), and the southern Appalachian Mountains are considered a diversity hotspot

for land snails based on overall species richness and diversity as well as on the large numbers of endemic species (Solem 1984). For example, we know a great deal about the biodiversity of the Great Smoky Mountains National Park thanks to the All Taxa Biodiversity Inventory (ATBI), which took place there (Nichols and Langdon 2007). The results of the ATBI (Dourson et al. 2013) revealed that the park contains more species (146) of snails and slugs than species of amphibians, reptiles, mammals, crayfishes, odonates, tardigrades, or orthopterans (Discover Life in America 2016). Of the 18 species of land snails listed as either *threatened* or *endangered* by the United States Fish and Wildlife Service, 10 species are found in the lower 48 states, and only five are found in the southeastern United States (USFWS 2015).

Considering these values, it is surprising how little is known about the land snail fauna of the Southeast. Georgia remains terra incognita in terms of its land snail inhabitants. The first published list of land snail species in the state of Georgia was by Hubricht (1964). Even at that time, the author remarked that less was known about the land snails in Georgia than almost any other place in the eastern United States. The list included a total of 123 species personally collected by the author. In his monograph on the distribution of eastern land snails, Hubricht (1985) listed a total of 150 species from within Georgia's boundaries. Since this time, research on Georgia land snails has focused almost exclusively on cave ecosystems. One study reported three land snail families containing nine species from caves in Georgia (Holsinger and Peck 1971), while another reported at least nine species from two families (Reeves et al. 2000). A review of the obligate cave fauna of Georgia listed two species of land snails—*Glyphyalinia specus* and *Helicodiscus barri* (Niemiller et al. 2012). Because of this knowledge gap, we summarized data on land snails collected in Georgia in order to compile a list of recorded and likely species for the state.

For this paper, we used an approach that combined the use of literature with a search of museum records to compile a list of terrestrial snail species, including native and exotic species, for which a vouchered specimen collected from the state of Georgia exists. We also developed and tested a qualitative model to predict species that have not been found in Georgia yet, but are likely occur here based on the proximity of known populations and ecoregional affinities. The same model was used to identify species that have vouchered Georgia specimens, but that we are doubtful occur in the state. This effort is the type of basic research needed for us to properly understand regional patterns in land snail diversity, and for managers to pinpoint locations for conservation efforts (Lydeard et al. 2004).

MATERIALS & METHODS

Our first step was to compile a list of the species shown in Hubricht (1985) as occurring in at least one county in the state of Georgia. This monograph remains the most extensive work on land snail distributions in the eastern United States to date. One impression that we gained during this process was that the state of Georgia was not well-represented in the sampling, and that many species whose ecological requirements should be met within Georgia ecosystems were not recorded there as of the time of Hubricht's 1985 publication. Therefore, we constructed a qualitative model to predict which species might eventually be recorded in Georgia based on their geographic proximity and level III ecoregional associations (US EPA 2006). Using this model we classified every species not recorded by Hubricht 1985 in any Georgia counties as likely, possible, or unlikely to actually occur in

Georgia. The following are the rules of the model: If a species is not found in any adjacent states, and Georgia is not included in gaps between known sites, then the species was classified as *unlikely*. If the species is found in one adjacent state, but not within three counties of Georgia (excluding species restricted to Florida Keys); or is found in two or more surrounding states (one or more being nonadjacent), and Georgia is in the gap between known sites; or is found in two or more adjacent states in ecoregions not found in Georgia, and Georgia is in gap between these states; then the species is classified as *possible*. If, on the other hand, the species is found in one or more adjacent states within three counties of Georgia; or is found in two or more adjacent states in ecoregions found in Georgia, and Georgia is in a gap between these states; then the species was classified as *likely*.

On 01/23/12, a request was sent to the following museums for all digital records from the state of Georgia for all families of land snails included in Hubricht 1985: United States National Museum, Washington (USNM); Academy of Natural Sciences Museum, Philadelphia (ANSP); Museum of Comparative Zoology, Cambridge (MCZ); Field Museum of Natural History, Chicago (FMNH); University of Michigan Museum of Zoology, Ann Arbor (UMMZ); Carnegie Museum of Natural History (CMNH); Auburn University Museum of Natural History, Auburn (AUM); Delaware Museum of Natural History, Wilmington (DMNH); Florida Museum of Natural History, Gainesville (UF); American Museum of Natural History, New York (AMNH); Ohio State University Museum of Biological Diversity (OSU); and North Carolina State Museum of Natural History (NCSM). These collections include all of those listed used by both Hubricht (1985) and Minton and Perez (2010). All records received were compiled into a common spreadsheet and taxonomic names were all updated for consistency. Taxonomy followed Turgeon et al. 1988 at the species level in most cases. Exceptions were accounted for by literature such as Emberton (1988, 1991). Taxonomy followed Bouchet et al. 2017 at the family level with some exceptions; we chose to follow Hausdorf (1998) and Slapcinsky (2018) in assignment of the genera *Glyphyalinia*, *Nesovitrea*, *Paravitrea*, *Pilsbryna*, and *Mesomphix* to Oxychilidae.

We used museum data, particularly those collected after the publication of Hubricht (1985), to test the validity of our predictive model. All species listed in Hubricht (1985), but not reported in Georgia by the same, were considered as candidate species for eventual discovery within the state. We used Chi-square to test the null hypothesis that, for the species documented in Georgia in museum collections but not in Hubricht (1985), the proportion found in the different likelihood categories is random. For random, or expected, values we used the proportions of all 372 candidate species found in the three likelihood categories. If, alternatively, our model was useful, then more candidate species that our model classified as likely to occur in Georgia would be found in museum collections than expected at random, and, on the other hand, fewer candidate species that our model classified as unlikely would be found in museum collections than expected at random.

RESULTS

A total of 5232 records were returned from each of these respective collections: AMNH (314), ANSP (395), AUM (33), CMNH (311), DMNH (157), FMNH (2723), UF (1000), MCZ (282), NCSM (18). From these records, we found a total of 214 unique species that were collected in the state of Georgia from 27 families and 63 genera. There were three

species listed in Hubricht (1985) that were not represented in the museums that we surveyed, thus bringing the total number of land snail species recorded in Georgia to 217 (Table I).

We found that 64 species uncovered in our survey of museum specimens were not listed as occurring in Georgia by Hubricht (1985). Twenty-three of these species were not found in Hubricht at all and represent either exotic species not considered by Hubricht in his work or species that have been described since the publication. Our model nonrandomly predicted the 41 other species that were found in Georgia after the publication Hubricht (1985) from the list of 372 candidate species not recorded in Georgia by Hubricht ($P < 0.001$, $X^2 = 41.95$, $df = 2$). Only 101 of the 372 (27%) of the candidate species were predicted as *likely*, whereas 29 of the 41 species subsequently found in Georgia (71%) were predicted as *likely* by our model. On the other hand, 200 of the 372 candidate species not recorded in Georgia by Hubricht (54%) were predicted as *unlikely* by our model, whereas only five (1.3%) of the species recorded in museums additional to Hubricht were those that were predicted as *unlikely*. For those species predicted as *possible*, there were 71/372 candidates (19%) and 7/41 (17%) subsequently recorded. These results lend some support to our predictions of which species will eventually be found in Georgia. After considering the species found in our museum survey, this leaves 69 species of snails that our model classified as likely to occur in the state but have still never been documented (Table II).

The following 12 species of exotic snails have been documented in the state of Georgia (Table I): *Allopeas clavulinum*, *Allopeas gracile*, *Arion circumscriptus*, *Cochlicopa lubrica*, *Hemicycla plicaria*, *Limax maximus*, *Opeas pumilum*, *Opeas pyrgula*, *Otala lactea*, *Otala punctata*, *Oxychilus draparnaudi*, *Rumina decollata*, *Subulina octona*.

Table I. Species of land snails collected in Georgia and the minimum number of specimens found in various museum collections. Specimen numbers are minimums in some cases because if museum records did not contain data on specimen numbers we recorded "≥1" for this field. AMNH = American Museum of Natural History, ANSP = Academy of Natural Sciences of Philadelphia, AUM = Auburn Museum of Natural History, CMNH = Carnegie Museum of Natural History, DMNH = Delaware Museum of Natural History, FMNH = Field Museum, UF = Florida Museum of Natural History, MCZ = Museum of Comparative Zoology at Harvard, NCSM = North Carolina State Museum.

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Achatinidae									
Allopeas clavulinum[ε]						≥1			
Allopeas gracile[ε]		10				46			
Opeas pumilum[ε]							1		
Opeas pyrgula[ε]						31			
Rumina decollata[ε]		18		57		112		12	
Subulina octona[ε]								2	
Agriolimacidae									
Deroceras laeve	7						3		
Arionidae									
Arion circumscriptus[ε]						≥1			

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Cochlicopidae									
Cochlicopa lubrica[ε]			16						
Cochlicopa morseana						9			
Discidae									
Anguispira alternata		94		42	1	5		110	
Anguispira fergusoni						101			
Anguispira mordax				1					
Anguispira strongylodes						265	23		
Discus patulus		88		57	18	854	7	45	
Discus whitneyi				≥1					
Ellobiidae									
Carychium clappi						217			
Carychium exiguum						99			
Carychium exile						481			
Carychium mexicanum	3					1026			
Carychium nannodes						110			
Euconulidae									
Euconulus chersinus	4	23				280	1		
Euconulus dentatus						3			
Euconulus trochulus	5					33			
Guppya sterkii						4			
Gastrocoptidae									
Gastrocopta armifera				5		111			
Gastrocopta clappi						115			
Gastrocopta contracta	1	1				168			
Gastrocopta corticaria		7				1			
Gastrocopta pellucida	42	4		12		57			
Gastrocopta pentodon	10	16		11		57			
Gastrocopta procera				2		16			
Gastrocopta rupicola	18	30		9		159		3	
Gastrocopta tappaniana	7			1		138			
Gastrodontidae									
Gastrodonta interna		115	30	92		544	47	123	4
Striatura meridionalis	13		2	1		183			
Ventridens acerra		11		53		94	15	17	
Ventridens arcellus						4			
Ventridens cerinoideus	136	77				1006	6	21	
Ventridens collisella						3			
Ventridens decussatus						17			
Ventridens demissus		13	2			333			
Ventridens gularis		88	2	117		500		202	
Ventridens intertextus		14	1	13		301	6	17	
Gastrodontidae									
Ventridens lawae						436			
Ventridens ligera		5		1			7	2	1

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Gastrodontidae, continued									
Ventridens pilsbryi						1275	32		
Ventridens suppressus		5				7			
Ventridens theloides						936			
Vitrinizonites latissimus						8			
Zonitoides arboreus	137	138		86		615		12	2
Zonitoides elliotti		25	1	98		98	17	107	
Zonitoides nitidus				12					
Zonitoides patuloides						1			
Haplotrematidae									
Haplotrema concavum		8		10	4	96	3	7	10
Helicidae									
Hemicycla plicaria[ε]					8				
Otala lactea[ε]					2				
Otala punctata[ε]		16				345			
Helicinidae									
Helicina orbiculata	23	16		18		112			
Helicodiscidae									
Helicodiscus barri						2			
Helicodiscus fimbriatus		10		3		19		12	
Helicodiscus inermis	1					36			
Helicodiscus notius						256			
Helicodiscus parallelus	41	25	1	3		643		4	
Limacidae									
Limax maximus[ε]						1			
Oxychilidae									
Glyphyalinia carolinensis		9		44	4				
Glyphyalinia cryptomphala		4		3		9			
Glyphyalinia cumberlandiana		2				21	2		
Glyphyalinia indentata		51		19	9	297	4	3	
Glyphyalinia junaluskana						1			
Glyphyalinia luticola						17			
Glyphyalinia pentadelphia		1		2		1			
Glyphyalinia praecox		2				4	1		
Glyphyalinia rhoadsi						13			
Glyphyalinia sculptilis		24		32		41	4		
Glyphyalinia solida	3					105			
Glyphyalinia specus						7			
Glyphyalinia umbilicata	17					154			
Glyphyalinia wheatleyi				1		206			
Mesomphix andrewsae		7			3		2		

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Oxychilidae, continued									
Mesomphix anurus						5			6
Mesomphix capnodes		8		6	6	54	7	4	2
Mesomphix cupreus		2		7				1	
Mesomphix globosus						488	4		
Mesomphix latior		4			2	32	1		
Mesomphix perlaevis			2	33	1	112	8	23	
Mesomphix pilsbryi		8	1	5	3	59			
Mesomphix rugeli						1			
Mesomphix subplanus						1		4	
Mesomphix vulgatus		51		25	12	50		28	
Nesovitrea dalliana	4					245	4		
Nesovitrea electrina				24					
Oxychilus draparnaudi[ε]						2			
Paravitrea amicalola						44			
Paravitrea capsella						99		8	
Paravitrea diana						19			
Paravitrea lamellidens									
Paravitrea multidentata						≥1			
Paravitrea petrophila								50	
Paravitrea placentula				5					
Paravitrea umbilicaris						2			
Philomycidae									
Megapallifera mutabilis							1		
Pallifera fosteri	7								
Pallifera unicolor	1								
Philomycus carolinianus	2							2	
Philomycus togatus							2		
Polygyridae									
Allogona profunda								1	
Appalachina sayana					2				
Daedalochila auriculata							≥1		
Daedalochila auriformis		23		17		12	4	38	
Daedalochila avara				2				2	
Daedalochila delecta							6		
Daedalochila leporina		9				4			
Daedalochila postelliana	2	5		9	6	11		29	
Daedalochila subclausa						3			
Daedalochila uvulifera		1							
Euchemotrema fraternum		2		2	6	6	3		
Euchemotrema leai		2		1	4	7			
Fumonelix archeri						3			
Fumonelix christyi						100			

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Polygyridae, continued									
Fumonelix clingmanicus						1			
Fumonelix wheatleyi		1				9		2	
Inflectarius approximans		3							
Inflectarius downieanus		1							
Inflectarius edentatus						2			
Inflectarius inflectus		45		56	51	753	30	90	
Inflectarius rugeli		16	1	14	6	198	26	11	
Inflectarius smithi					4				
Lobosculum pustula	64	28		4		233	1	12	
Lobosculum pustuloides		9		8	6	382		33	
Mesodon andrewsae				1		1		4	
Mesodon clausus		1	1			3			
Mesodon normalis		4	1	31	27	196	4	3	
Mesodon thyroidus		39		37	7	260	16	45	
Mesodon zaletus		1		1		7	4		
Millerelix dorfeuilliana				3				1	
Millerelix plicata		27		17	73	140	1	18	
Millerelix troostiana					5				
Neohelix albolabris		70		17	25	11		55	
Neohelix dentifera							≥1		
Neohelix divesta					2				
Neohelix major			2	32		199	2	8	
Neohelix solemi						≥1			
Patera appressa			2	9	10	99		34	
Patera clarki		6		9	5	117	9	3	
Patera laevior						17			
Patera perigrapta		20	8	23	16	213	2	16	14
Polygyra cereolus	15	80		21	2	553	20	85	
Polygyra septemvolva	136					138		6	
Praticolella jejuna	30	7		22	2	7	21	4	
Praticolella lawae		4		5	20	29			
Praticolella mobiliana		4		1					
Stenotrema altispira					1				
Stenotrema barbatum						1			
Stenotrema barbigerum		20		28	4	98	10	61	
Stenotrema cohuttense		4	56	39	65	127	3	37	
Stenotrema edvardsi				35		4		15	
Stenotrema exodon		6							
Stenotrema florida						6			
Stenotrema hirsutum		3						17	
Stenotrema magnifumosum		15		1	19	212	7		
Stenotrema maxillatum		23	10	3	4	109		19	
Stenotrema spinosum		9		12		19	20	4	1
Stenotrema turbinella						4			

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Polygyridae, continued									
Triodopsis affinis						659			
Triodopsis alabamensis				10		260			
Triodopsis fallax		39		2	81	44		19	
Triodopsis fraudulenta								1	
Triodopsis hopetonensis	179	155		35		1298	5	59	3
Triodopsis juxtidens		1				6		2	
Triodopsis messana						198			
Triodopsis palustris						61			
Triodopsis tennesseensis			3			2			
Triodopsis tridentata		9		24	1	226	5	23	
Triodopsis vannostrandi		23	8	39		312	1	50	
Triodopsis vulgata					7	9	1		
Xolotrema caroliniense		17		3	17	25	3	3	
Xolotrema denotatum				1	2				
Xolotrema fosteri					6				
Xolotrema obstrictum				6				3	
Pomatiopsidae									
Pomatiopsis lapidaria						323			
Pristilomatidae									
Hawaiia alachuana	2								
Hawaiia minuscula	51	51		7		320	10		
Punctidae									
Punctum blandianum						13			
Punctum minutissimum	3					152			
Punctum vitreum		1							
Pupillidae									
Pupoides albilabris				20		246		67	
Pupoides modicus	65	67		82	3	17	15	3	
Spiraxidae									
Euglandina rosea	40	21	2	14	9	35		76	3
Strobilopsidae									
Strobilops aeneus	84			1	4	306			
Strobilops hubbardi	4					1			
Strobilops labyrinthicus		3			2	60			
Strobilops texasianus	10	1				63			
Succineidae									
Catinella oklahomarum						41			
Catinella pugilator						1			
Catinella vermeta		12				128			
Novisuccinea ovalis					37	14		13	
Succinea campestris	46	60		16		232		48	
Succinea indiana		12			2	127			
Succinea unicolor	39					216			
Succinea wilsonii	3	9			4	113	8		

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table I (*continued*)

Family and species	AMNH	ANSP	AUM	CMNH	DMNH	FMNH	UF	MCZ	NCSM
Truncatellinidae									
Columella simplex						100			
Valloniidae									
Pupisoma dioscoricola	11					246			
Pupisoma macneilli	5					21			
Pupisoma minus						≥1			
Vallonia excentrica						8			
Vallonia pulchella								14	
Vertiginidae									
Vertigo milium						457			
Vertigo oralis	6	1				220			
Vertigo oscariana						1			
Vertigo ovata				5		12			
Vertigo rugosula		1							
Vertigo teskeyae						101			

[ε] denotes species that are considered exotic relative to the state of Georgia.

Table II. Species of land snails not found in any of the museum collections that we searched, but which our qualitative model predicts as likely to actually occur in the state of Georgia, USA

Family and species of land snails		
Bulimulidae	*Helicodiscus saludensis*	*Daedalochila hausmani*
Drymaeus dormani	Haplotrematidae	*Daedalochila peninsulae*
Rabdotus dealbatus	*Haplotrema kendeighi*	*Fumonelix jonesianus*
Discidae	Oxychilidae	*Fumonelix orestes*
Anguispira alabama	*Glyphyalinia latebricola*	*Fumonelix wheatleyi*
Anguispira cumberlandiana	*Glyphyalinia lewisiana*	*Inflectarius smithi*
Anguispira jessica	*Glyphyalinia ocoae*	*Mesodon elevatus*
Anguispira knoxensis	*Paravitrea bidens*	*Mesodon sanus*
Discus nigrimontanus	*Paravitrea calcicola*	*Millerelix fatigiata*
Euconulidae	*Paravitrea clappi*	*Neohelix alleni*
Dryachloa dauca	*Paravitrea conecuhensis*	*Patera sargentiana*
Euconulus fulvus	*Paravitrea lacteodens*	*Stenotrema calvescens*
Guppya gundlachi	*Paravitrea metallacta*	*Stenotrema deceptum*
Gastrocoptidae	*Paravitrea pilsbryana*	*Stenotrema depilatum*
Gastrocopta servilis	*Paravitrea tantilla*	*Stenotrema edgarianum*
Gastrodontidae	*Paravitrea tiara*	*Stenotrema pilula*
Striatura ferrea	*Paravitrea toma*	Punctidae
Ventridens lasmodon	*Paravitrea variabilis*	*Punctum smithi*
Ventridens percallosus	*Pilsbryna castanea*	Succineidae
Ventridens volusiae	Philomycidae	*Catinella hubrichti*
Helicinidae	*Megapallifera wetherbyi*	*Oxyloma effusa*
Hendersonia occulta	*Pallifera hemphilli*	*Succinea chittenangoensis*
Helicodiscidae	*Pallifera secreta*	*Succinea urbana*
Helicodiscus aldrichianus	*Philomycus sellatus*	Valloniidae
Helicodiscus bonamicus	*Philomycus venustus*	*Vallonia perspectiva*
Helicodiscus hadenoecus	Polygyridae	Vertiginidae
Helicodiscus hexodon	*Appalachina chilhoweensis*	*Vertigo gouldi*

DISCUSSION

We will say up front that this work, with all of its limitations, is a starting point for a complete and exhaustive list of land snails in the state of Georgia. One major limitation of our data is the general dearth of collecting in the state, and another is that we had to rely only on digitized museum records that were unverified. Some museums that provided data for Hubricht (1985), including Ohio State University, University of Michigan Museum of Zoology, and the United States National Museum, could not provide any digitized records for the present investigation. However, because our species list includes information from Hubricht (1985), a study that used data from these same collections, our species list appears to be representative of what is found in museum collections; it is notable that only three species listed as occurring in Georgia by Hubricht (1985) were not represented in the digitized museum records. Land snails are notoriously difficult to identify, and there have been many taxonomic changes in the past within this group (J. Slapcinsky, personal communication). Some species in our list have since been split into multiple taxa, and others are almost certainly misidentified. In fact, we used our qualitative model results to categorize species for which a Georgia specimen can be found in museum collections, but that which we doubt actually occur here. Accordingly, our list of 217 species includes five doubtful species (*Appalachina sayana*, *Millerelix dorfeuilliana*, *Neohelix divesta*, *Triodopsis fraudulenta*, and *Zonitoides nitidus*), for which Georgia seems to fall outside of their native range. Interestingly, all but one of these species, *Millerelix dorfeuilliana*, are represented in only one collection; this suggests that these could be misidentified or mislabeled. Future research should reexamine the identifications and verify or refute the legitimacy of these specimens' provenance.

The number of land snails documented here as occurring in Georgia, 217, is on par with the number of species in surrounding states. Minton and Perez (2010) documented 226 species of terrestrial mollusks in neighboring Alabama in a similar analysis of museum records. At the time of publication, the list of land snails for North and South Carolina included 262 and 102 species, respectively (A. VanDevender, personal communication). The true number of species of land snails in Georgia is almost certainly higher than 217, and our best estimate considering the 69 species that our model categorized as likely to occur in Georgia would be 270–290 species. A high number of land snail species for Georgia is not surprising considering the high ecological diversity found within Georgia's borders (Edwards et al. 2013). Our model may overpredict the presence of some high-elevation southern Appalachian species with restricted ranges but, then again, we predict that our state harbors similar undescribed species.

Many of the exotic taxa, e.g., *Allopeas*, *Otala*, *Deroceras*, *Opeas*, that we uncovered as living in Georgia are common invasives globally (Brodie and Barker 2011; Cowie 2001; LaPierre et al. 2010). In California grasslands, *Otala lactea*, an established nonnative snail, prefers to feed on *Brassica nigrans*, a nonnative plant that co-occurs with *O. lactea* in its native range, suggesting that this exotic snail may slow the progress of an invasive plants (LaPierre et al. 2010); however, this is certainly an exception, and most invasive land snail species almost certainly have an overall detrimental effect on indigenous ecosystems. The *O. lactea* specimens found in our query of museum records may be misidentified *Otala punctata*, a species known to have invaded coastal islands near Savannah, and it seems unlikely that the narrowly endemic *Hemicycla plicaria* records are accurate (J. Slapcinsky, pers. comm.). Considering the potential ecological and

economic impacts that exotic land snails could have in Georgia, we suggest that the list of exotic land snail species presented here can serve as the nucleus of an organized surveillance program for the study of the spread of these species, and as a baseline for detection of newly introduced species.

One of our major goals in this investigation was to spur interest in research on land snails in the state of Georgia. Accordingly, an important finding was the estimation that there are 68 species of land snail that are likely to occur in Georgia but have not been documented (Table II). If all of these species were eventually found in the state, the species list for Georgia would increase by 32% compared to the list from the current study, suggesting that sampling effort for this important taxon has been grossly inadequate till present. Though it is unlikely that all likely species will be discovered in Georgia, the results of our model validation indicate that this list is useful in guiding targeted surveys for additions to the state species list. The list of species likely to occur in Georgia contains both macro- and microscopic snails from a variety of families, but certain genera, e.g., *Paravitrea*, *Fumonelix,* and *Helicodiscus*, contain several species to be targeted. Surveys that are designed to add new species to the state list should take place on the limestone outcroppings and seepages on the Cumberland Plateau or in the Blue Ridge Mountains in the northern part of the state, as many of the undocumented species have been found just north of Georgia in these ecoregions. Swamps, wet prairies, and hammocks in south Georgia would also be promising places for malacological exploration. Because of the small size of many snail species, surveyors would do well to sift through leaf litter and look for shells of these minute creatures (Dourson et al. 2013).

We encourage all ecologists, biogeographers, and systematists to consider adopting this fascinating group as a model for their research. With 20 or more species occurring in the same forest floor habitats here in Georgia, these communities offer tremendous opportunities to study topics like niche partitioning, competition, nutrient cycling, and trophic relationships. The sensitivity of land snails to environmental change (Baur and Baur 1993; Bezemer and Knight 2001), and their small home ranges (Edworthy et al. 2012), combined with Georgia's unique geographic position at the end of the Appalachian Mountains, all make Georgia land snails a perfect model to study the rate and nature of distributional shifts in response to climate change (Fortunato 2016). Work needs to be done for us to achieve a better understanding of the evolutionary relationships among the many land snail taxa, and especially of the taxonomy of these groups. Recent molecular genetic studies suggest that many nominal taxa are not monophyletic and require a new taxonomic scheme that more accurately reflects the evolution of the groups (Perez et al. 2014). Based on this same research it is likely that numerous cryptic species of land snails await description within our borders. Many states have more systematically assessed the conservation status of their land snails and assigned protective status to certain species. Georgia is far behind in this regard, and it is our hope that our preliminary list here can serve as a seed for a larger effort to assess and protect this important natural resource.

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