Gastropods

of the

Tamishyacu-Tahuayo Communal Reserve
Peru, South America

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Photos by Dan Dourson unless otherwise stated

Developed in cooperation with
Amazonia Expeditions
Tahuayo Lodge and Amazon Research Center

Introduction

A cursory survey to document the diversity of land snails of the Tamishyacu-Tahuayo Communal Reserve was conducted in February of 2013. Principal investigator was Dan Dourson, biologist and malacologist with field assistance from Judy Dourson, and Alfredo Dosantos Santillan, resident biologist at the Amazon Research Center. The results of this rapid assessment are reported.

The phylum Mollusca is a diverse group of organisms that includes chitons, aquatic and terrestrial snails, slugs, clams, oysters, mussels, nautilus, squid and pulpos (Ramirez et al. 2003) and is second only to arthropods in terms of species diversity making this group one of the most successful on the planet (Bruggen 1995).

In general, understanding of land snail diversity, ecology and distribution is vastly incomplete, particularly in tropical regions of the world and South America is no exception. The first and only registered list of land snails study of land snails of the continent were conducted by Morelet in 1863 with 190 species recorded. In the past century, malacologists who have contributed significantly to the knowledge base of the terrestrial mollusks include Weyrauch who described 136 species from Peru between 1930-1970. He collaborated with other well-known malacologists of the day including Pilsbry. From the middle part of the 1900's till the present time, much of the collecting in Peru has been conducted by few private individuals and a handful of researchers. Most recently, Ramirez *et al*. (2003) conducted studies in western Amazonia in Peru of land snails in the genera, *Megalobulimulus* and *Systrophia* in 2001 as well as examination and compilation of the available literature both past and present in order to produce a list of mollusca for Peru. In their work, Ramirez et al, states that much work is still to be done, especially in the examination of private and past collections housed in various locations throughout the world.

Currently, the number of recorded land snail species (an estimated 800 taxa) from Peru is probably around 38% of the fauna (Ramirez *et al*. 2003; Thompson 2011); an estimated 62% of the total fauna remains undiscovered awaiting scientific description. Examination of collections mentioned above as well as targeting the micro snail fauna (less than 5mm in diameter) will no doubt yield new species to Peru and to science.

The preliminary rapid assessment of the Tamishyacu-Tahuayo Communal Reserve focused entirely on the macro snails greater that 5 mm in diameter and is likely the first study of the land snail fauna of this region. The inaccessibility of the densely and often flooded forests has no doubt been a deterrent to past collectors, leaving the reserve entirely unsampled for this interesting group of organisms. Future study of the area should focus on leaf litter collections (on higher ground that is not subject to flooding) and examination of bromeliads in order to include the micro snails.

STUDY AREA

Peru is a country rich in terms of both species diversity and habitats containing 84 of the 103 life zones of the Holdridge System (ONERN 1976). Located on the Pacific Coast of South America in the Neotropical Biogeographic Region, the presence of the Andes Mountain range and the Humboldt Current make Peru a country of contrasts (Tarazona *et al.* 1998).

Located in northeast Peru, the Area de Conservacion Regional Comunal de Tamshiyacu-Tahuayo(ACRCTT) exceeds 1.1 million acres, covering more than 1600 square miles it has more land area than does the state of Rhode Island (1045 sq. miles. South of Iquitos just off of the Amazon River, the reserve encompasses areas around the Tamshiyacu and Tahuayo Rivers eastward toward the border of Brazil. The reserve is currently adding a million acres of undisturbed forest onto its boundary, which will then include land all the way to Brazil's border.

Map of study area

The ACRCTT was designated in 1991 by the Peruvian government—in response to local concerns about resource rights and conservation concerns related to the presence of an exceptionally diverse primate species through a collaboration of local communities concerned about overexploitation of resources by commercial fishermen, loggers, and hunters from Iquitos, and biological researchers.

It is believed that the ACRCTT remained tropical forest during the Pleistocene era when the rest of the Amazon became a dry savannah. Known for its unprecedented mammal diversity, it is thought to be the greatest of any region of the Amazon. The highest number of primate species known to occur within a park or protected area in the world is within the ACRCTT. Scientists studying birds, amphibians, and plants have found the respective species assemblages to be "outstanding, unusual and exceptional."

Based on this brief survey of land snails of in a small portion of this area, it is expected that the diversity of land snails, especially endemic snails would match the finding of other taxa in terms of diversity. This remains to be seen.

SURVEY METHODS

In most regions of the world, land snails are typically surveyed by targeting specific habitats: arboreal epiphytes (bromeliads and orchids), leaf litter on the forest floor, rocky outcrops, rock crevices, and logs; under exfoliating bark of standing and/or down dead trees; hollow trees damaged trees oozing sap which attracts snails; under and on top of caps of fungi; under moss mats and the crotches of trees.

In the Amazon basin, the seasons play a pivotal role in a determining site selection and in particular ,survey methods. During the rainy season, land snails crawl up on vegetation in order to prevent drowning. Surveying for land snails normally done by foot on dry ground during the dry season is done predominantly by boat.

This cursory land snail inventory was conducted to gain general understanding regarding the possible habitats and the species diversity in targeted habitats near the Tahuayo Lodge and the Amazon Research Center in the flooded forest in a fraction of the total area of the ACRCTT.

The Tahuayo Lodge and the Amazon Research Center in conjunction with Amazonia Expeditions is the only organization permitted to conduct ecotourism on a limited basis within the ACRCTT.

The undersides of vegetation and tree trunks were targeted as the waters of the Tahuayo River continued to rise during the survey period from January 28-February 15, 2013 The other main habitat targeted in this survey was the terra firme (high ground 40 m or more above sea level). Tierra firme forest includes fairly well-drained nutrient rich soils and is usually very rich in tree species, with a dense upper canopy and a relatively dark, open interior.

Only macro snails (>5mm) were documented during this survey. No leaf litter samples to survey for micro snails were taken.

No live animals were collected and all snail shells were deposited with Alfredo Dosantos Santillan, biologist, at the Amazon Research Center. Images of each snail encountered were taken by the author or Alfredo then identified using a combination of resources including Thompson's *Annotated Checklist and Bibliography of the Land and Freshwater Snails of Mexico and Central America* (2011), *Inventario preliminar de los moluscos terrestres y de agua dulce del área de la Reserva Los Amigos* (Ituarte *et al.* 2008), Pilsbry's Land Mollusca (1940, 1946, 19480 with taxonomy following Bouchet and Rocroi (2005).

RESULTS

A total of 15 species representing 11 families with two species of terrestrial mollusks that could not be assigned to genus or species (including one slug) and two species that could not be assigned to species were recorded.

Table 1. Species Documented

FAMILY	COMMON NAME	GENUS	SPECIES
Orthalicidae	Painted Cone	*Sultana*	*sultana*
Orthalicidae	(juvenile)	Unknown	unknown
Liguus	Speckled Cone	*Hemibulimus*	*dennisoni*
Spiraxidae	Amazon Hunting Snail	*Euglandina*	*striata*
Subulinidae	Pale Funnel	*Leptinaria*	*unilamellata*
Subulinidae	Glossy Subulina	*Subulina*	*octona*
Helincinidae	Angled Dome	*Helicina*	*carinata*
Helincinidae	Hairy Dome	*Helicina*	*species (undetermined)*
Pleurodontidae	Tahuayo Disc	*Labyrinthus*	*diminutus*
Pleurodontidae	Striped Tree-climber	*Solaropsis*	*incarum*
Succineinae	Dusky Amber Snail	*Succinea*	*species (undetermined*)
Veronicellidae	Amazonian Tree Slug	Unknown	unknown
Bulimulidae	Striated Cone	*Drymaeus*	*expansus*
Streptaxidae	Clear Button	*Tamayoa*	*trinitaria venezuelensis*
Scolodontidae	Orange Crawler	Unknown	unknown

The following plates represent the gastropods documented. The scale bars represent actual size of the shell of each species. When possible, images of the live animal were included. Three standard views of shells that are heliciform in shape were represented while conical shells were photographed with a front and side view for diagnostic purposes.

A brief introduction to gastropods, and in particular, the land snails, is included immediately following the plates. This is provided as a framework for understanding the importance of this lower order organism to the overall function of a healthy ecosystem.

~Species Accounts~

Painted Cone ***Sultana sultana***

Painted Cone, *Sultana sultana* (Dillwyn, 1837)

Top view


Painted Cone


Painted Cone

Speckled Cone, *Hemibulimus dennisoni* L. A. Reeve, 1848


Speckled Cone


Speckled Cone

Amazon Hunting Snail, *Euglandina striata*

Juvenile shell

An Amazon hunting snail attacking and eating a juvenile Striated cone, *Drymaeus expansus*.

Amazon Hunting Snail ***Euglandina striata***

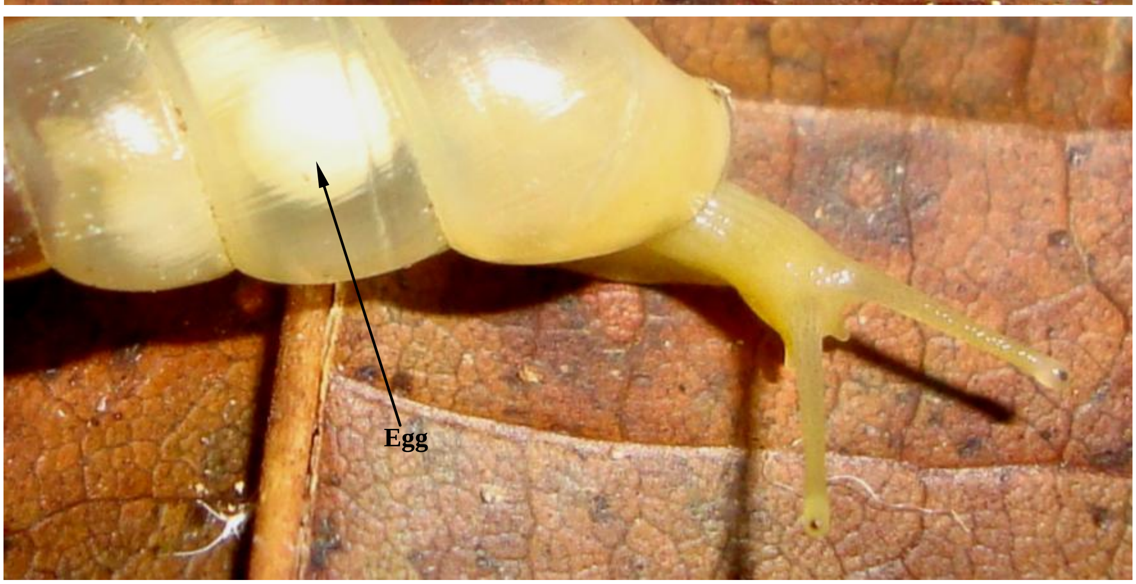
Alfredo Dos Santos

Alfredo Dos Santos

A juvenile Amazon hunting snail feeding on the eggs and new born hatchlings of the aquatic apple snail.

Pale Funnel, *Leptinaria unilamellata* (Potiez & Michaud, 1838)

Glossy Subulina, *Subulina octona* (Brugiere, 1792), with eggs



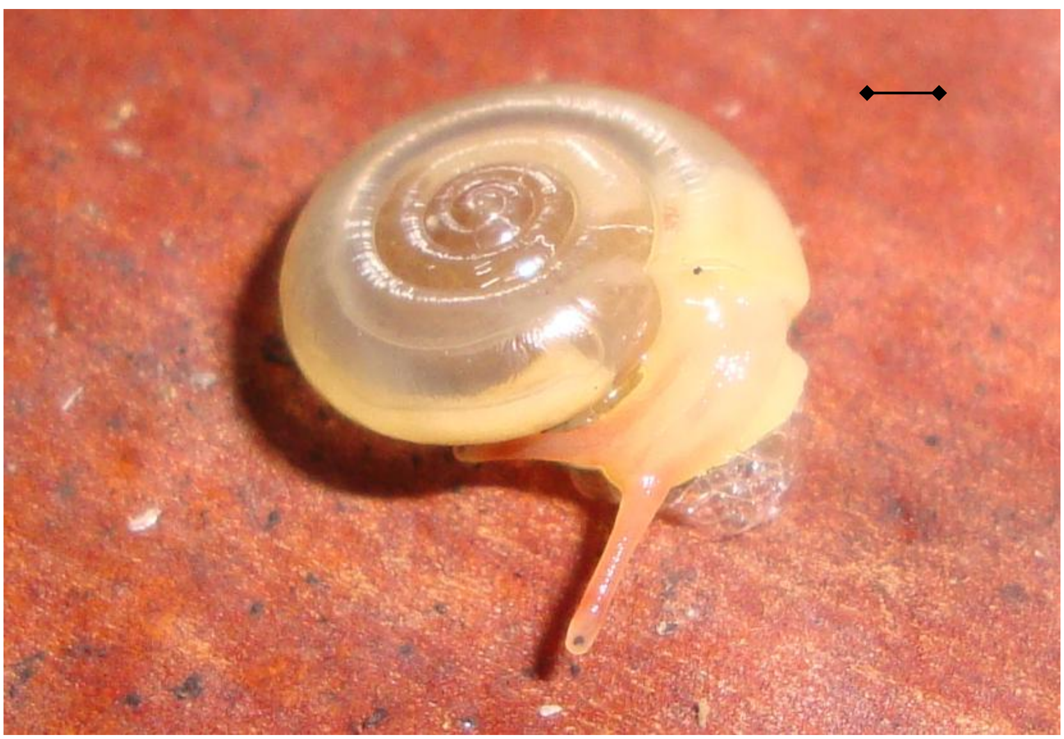
Angled Dome, *Helicina carinata* d'Orbigny, 1835


Angled Dome


Angled Dome

Hairy Dome, *Helicina* species (undetermined)

Clear Button, *Tamayoa* aff. *trinitaria venezuelensis* Baker, 1925



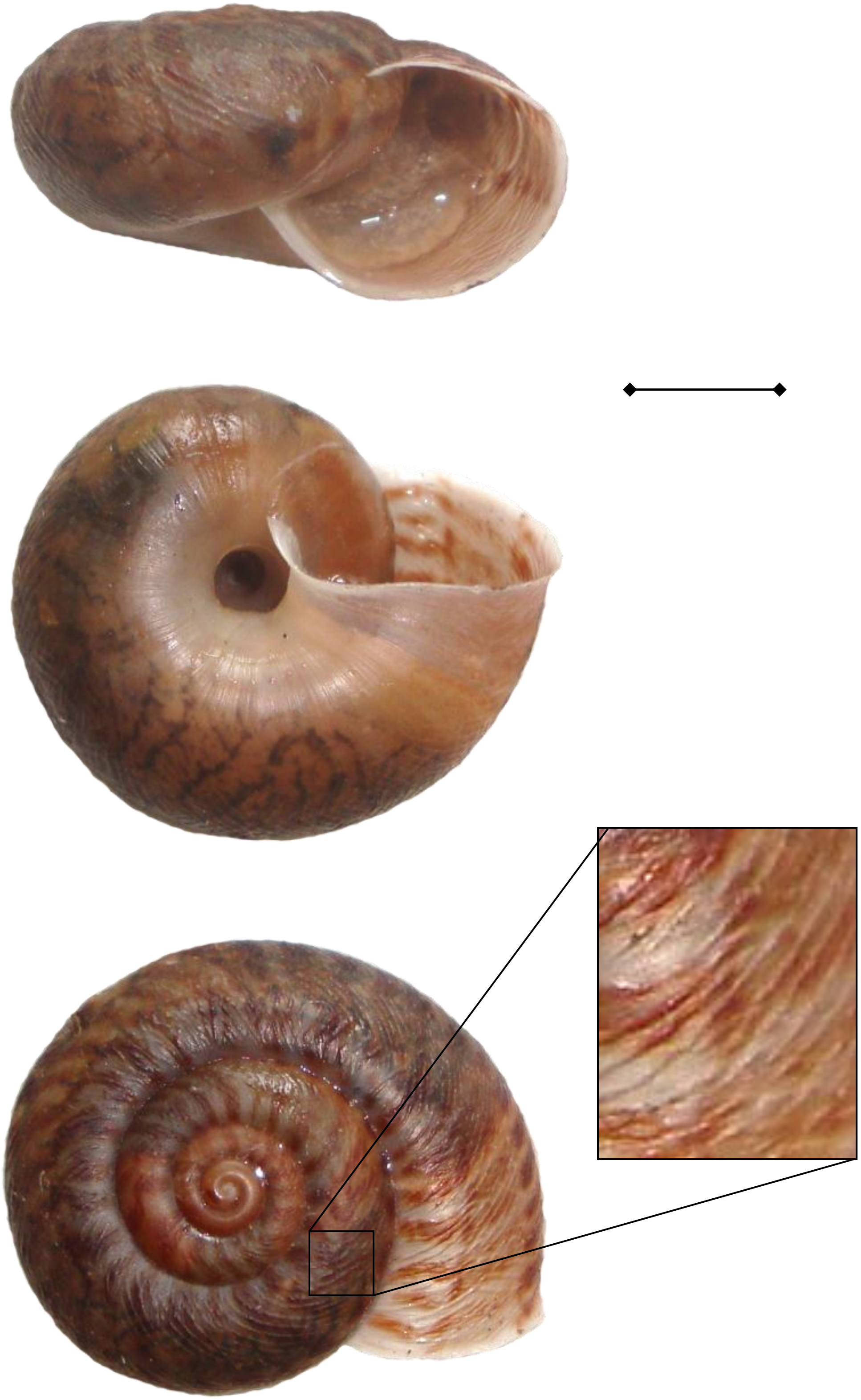
Tahuayo disk, *Labyrinthus diminutus* Gude, 1903

Aperture view showing the calcareous teeth


Tahuayo disk


Tahuayo disk

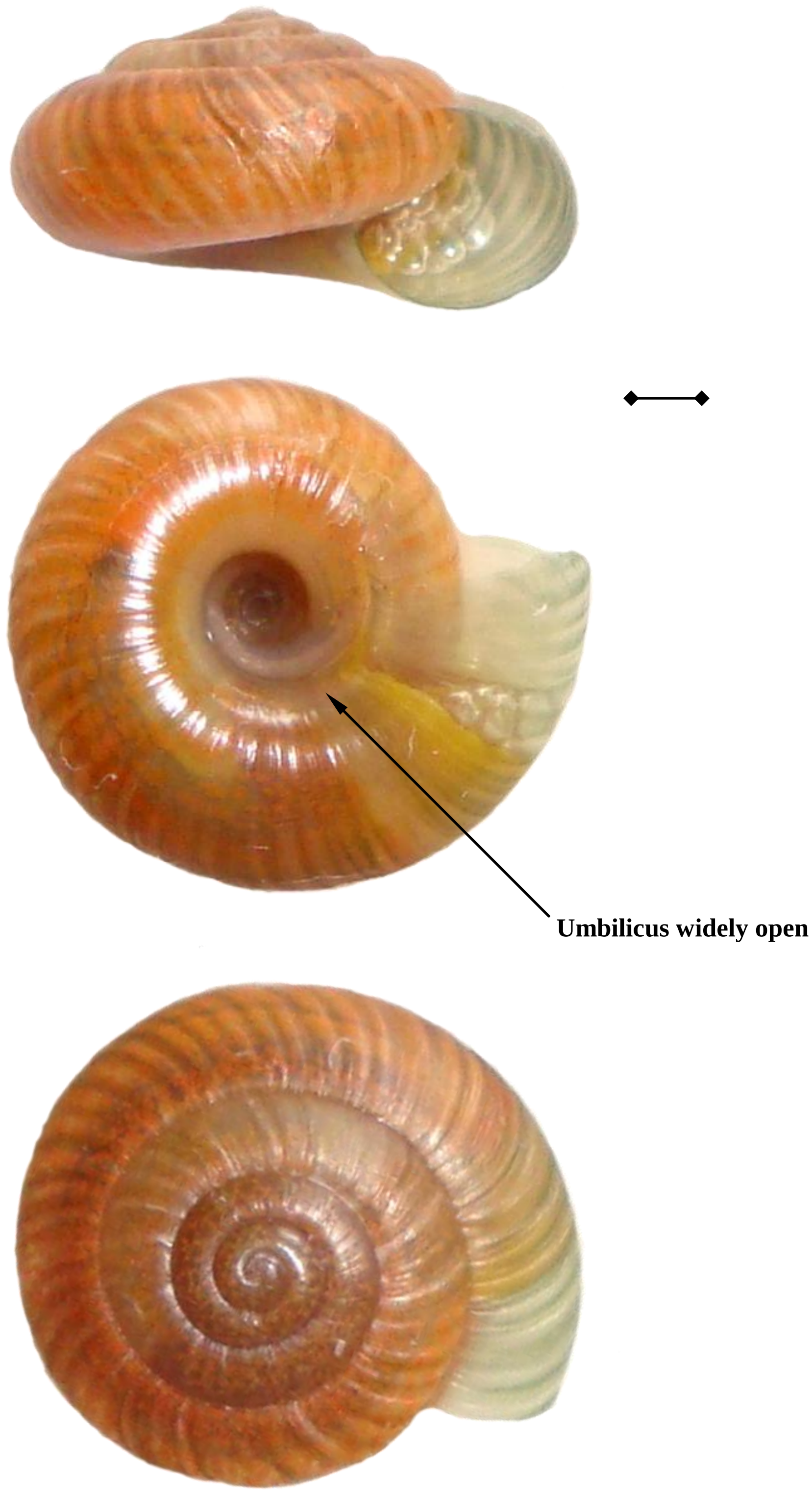
Striped Tree-climber, *Solaropsis incarum* Philippi, 1869




Striped Tree-climber


Striped Tree-climber

Orange Crawler, Scolodontidae, genus and species unknown)




Orange Crawler

Dusky Amber Snail, *Succinea* species (undetermined)

Juvenile Land Snails

Alfredo Dos Santos

Juvenile Land Snails

Alfredo Dos Santos


Juvenile Orthalicidae

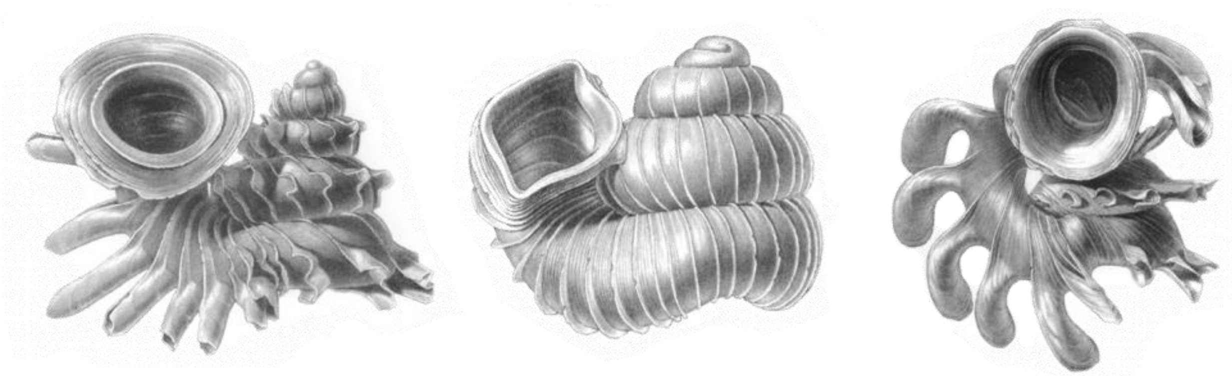

Juvenile Orthalicidae

Amazonian Tree Slug, Family Veronicellidae (genus and species undetermined)

Apple snail, *Pomacea levior* Sowerby, 1909 (**Aquatic)**

Apple snail with eggs

Introduction to the Gastropods (snails)



Land snails come in every color, form and size imaginable (some beyond belief). Take for example terrestrial gastropods in the genus *Opisthostoma* (above images). These land snails have taken calcium carbonate sculpturing to a whole new level of architecture. No less complicated than a Roman Cathedral, they represent spectacular achievements in convoluted evolution! Illustrated below are nine species of *Opisthostoma*, a group of highly restricted land snails found only on limestone outcrops and in caves of Borneo. (Illustrations by Jaap Verneulen, used here with permission).

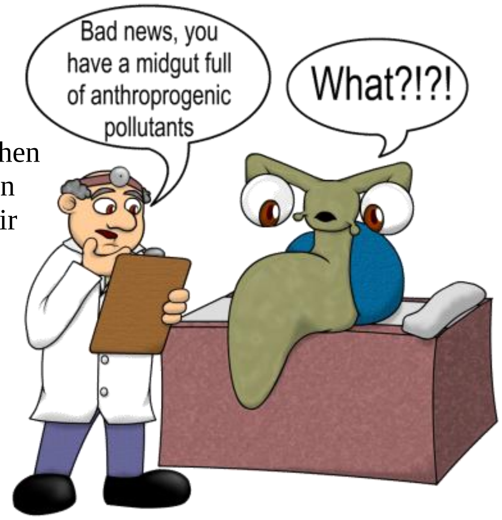
Land snails are part of a large and diverse family of organisms known as Gastropods, all belonging to the enormously diverse Phylum MOLLUSCA. Nearly 100,000 described species occur world-wide and include both land and fresh water snails, terrestrial and sea slugs, marine snails such as conchs, sea-hairs, limpets, bivalves (clams, oysters, and mussels), squids, octopuses, and the infamous nautiluses of deep oceans. Octopuses are considered the most highly evolved of the mollusks having feet divided into a number of prehensile and skillful tentacles capable of twisting the lid off a glass jar to access the food within. Although snails and slugs are slow moving, squids are among the fastest animals known, exceeding underwater speeds of more than 70 mph in short bursts, a result of their jet propulsion. Mollusks are also reported as the longest living multicellular organisms on earth, some species of marine clams reported to be over 500 years old.

There is scarcely a place on the dry surface of the world, outside the polar regions, where one cannot find at least a few examples of land snails (Abbott 1989). From hot, nearly waterless deserts to snow-capped mountain tops, land snails are thriving. Despite such biological and physiological limitations, land snails have developed efficient mechanisms for coping with freezing, starvation and desiccation. For example, when conditions become increasing dry, snails cover the aperture of their shells with an epiphragm, a mucous sheet that hardens, sealing in critical moisture and preventing desiccation. Some snails can remain dormant for years, resuming activity during wet weather. Land snails in Peru are typically nocturnal animals and are largely active in warm, rainy weather.

Even though mollusks rank as one of the most numerous and speciose groups of organisms on Earth, they remain largely unstudied. As a result, little is known of their importance's in many ecosystems and land snails, like most invertebrates, suffer from being a conservation “blind-spot”. As snail research moves forward, however, our understanding of the value of these organisms is increasing. Research has shown, for example, that land snails play an important role in micronutrient cycling in terrestrial ecosystems (Dallinger et al. 2000), disperse plant seeds and fungal spores (Richter 1980) and have been shown to predict vertebrate conservation priorities (Moritz et al. 2001). Further, live snails and their vacant shells provide a food and calcium carbonate source to many systematic groups. These include but are not limited to ants, firefly larva, snail-killing flies (Foote 1959); *Cychrine* beetles, which feed chiefly on land snails (Symondson 2004), Arachnids including harvestmen, carnivorous snails, numerous species of salamanders (Petranka 1998), turtles and frogs (Burch 1962), a variety of small mammals including shrews, mice, and moles (Reid 2006), snakes (Lee 1994, Dourson 2012), a variety of passerine birds (Graveland et al. 1994; Graveland 1996), thrushes, ruffed grouse and wild turkey (Martin et al. 1951), bats, (Bonato et al. 2004; Thabah et al. 2007) and primates including humans.

While a building body of evidence suggests the importance of mollusks in present-day ecosystems, their historical value is less well known; namely their contributions made to existing plant communities, animals and, in particular, caves. In the past, the colossal accumulation of deceased mollusks, corals, and tiny creatures known as Foraminifera (that have calcareous skeletons), provided the necessary building material to create limestone, where caves are essentially formed. Many species uniquely adapted to caves, roost or otherwise live in these vast underworlds, a number of these species occurring nowhere else. These ancient shells have also provided the necessary limestone in cement to form the foundations of our cities and homes.

Sensitive to changes in their environment, native land snails could provide an early warning to impending habitat deterioration, similar to the way that freshwater snails found in streams and rivers are used to determine the quality of waterways. For example research has shown that when snails feed on contaminated foods such as mushrooms, green vegetation and forest litter, environmental toxins are ingested and sequestered in their tissues (Dallinger and Wieser 1984a), the midgut gland being the main accumulation site of these trace elements (Dallinger 1993). Further laboratory experiments by Dallinger and Wieser(1984) have shown that land snails fed on lettuce laced with Zinc, cadmium, lead, and copper easily sequestered these elements. More concerning however, snails quickly become poisoned when simply raised on soils contaminated with cadmium, raising fear that toxins in polluted soils may be more bio-active than previously believed (Scheifler et al., 2003a).



Declining land snail populations can have ripple effects to surrounding ecosystems. The great tit, *Parus major* in the Netherlands, for example, has declined precipitously with declining land snails as a result of acid rain (Graveland et al. 1994; Graveland 1996). A lack of snail shells in the bird's diet causes egg shells to thin and break, therefore reducing reproductive success rates of the species. In North America, Hames et al. (2002) have documented a correlation between a reduced number of wood thrushes and acid rain, hypothesizing a connection to reduced land snail populations.

A Human Connection

Mollusks are providing a number of life-supporting contributions to humans. For example, marine mollusks may help fight cancer. The drug Kahalalide F, a protein extracted from a species of mollusks that eat sea slugs in the Pacific Ocean, has shown great promise as chemotherapy for the treatment of liver cancer. Lethal toxins produced by cone snails are used to develop a drug called Ziconitide for patients with cancer and AIDS who suffer from chronic pain that cannot be relieved by opiates and they are not addictive. Slime from the land snail, *Helix aspersa* (one of the commonly eaten snails referred to as escargot) is now used to treat many different types of skin disorders. The snail slime is used to repair skin damage from overexposure to the sun and reduces scarring caused by severe acne. The mucus of snails is known to contain antibacterial properties but remains largely unstudied. In Central America, the Maya use gastropods to treat a number of ailments including skin disorders, warts, glaucoma and whooping cough.

Parasites and Gastropods

Although nearly every kind of mollusk is inhabited by some form of parasite, only a few gastropods are of medical or veterinary importance (Burch 1962). Of these, almost all live in fresh water environments. Snails are required hosts in the life cycles of parasitic trematode worms. A few land snails such as *Cochlicopa lubrica* are vectors of lancet liver flukes in sheep, cattle, deer, and groundhogs (Burch 1962). *Zonitoides arboreus* a native snail to Belize, are implicated in the spread of lungworms in domestic sheep. *Veronicellid* slugs (found in Belize) are intermediate hosts for *Angiostrongylus costaricensis*, a rat parasite that can cause Morera's disease in humans. The parasite is transferred to people when the infected juvenile slugs (sometimes found on lettuce and other vegetables) are inadvertently consumed or during the handling of the infected gastropods. The parasite has been observed in Costa Rican children since the early 1950's. Many other parasite connections are yet to be discovered.

Land Snails as Pests

Land snails, including slugs can be agricultural pests. By and large, snails and slugs that are problematic in gardens however are those species that are non-native introductions. Most have been accidently released into Belize by way of plants, potting soils or shipping crates. Introduced gastropods can naturalize quickly and multiply. Degrading Belize's native habitats only makes things worst by providing the conduit for their dispersal and movement into new, uninfected areas of the country. These exotics carry molluscan diseases and problematic parasites that can effect domestic animals, livestock, native wildlife and even humans. Exotic slugs can be especially damaging pests in greenhouses and agricultural lands, costing millions of dollars worth of damage. In contrast, native snails and slugs are rarely trouble and most species actually become scarce or disappear entirely in areas where the natural vegetation has been eliminated. The giant African land snail (pictured below) is a major pest on agriculture crops including bananas, causing millions of dollars of damage every year. This species (the size of an orange) is spreading across the globe and is now reported from several Caribbean islands including Barbados, where it is a major crop nuisance. if seen in Peru, these invasive pest snails should be quickly eliminated. HOWEVER, before destroying this snail, ensure that the identity is not that of native land snail species, M*egalobulimus* (below image).

The giant African land snail (exotic)

Megalobulimus species **(native)**

Reproduction

Land snails are either hermaphrodites, each individual snails having two sets of sex organs; testes, sperm and penis; ovaries, eggs, an oviduct or dioecious, species having the male and females organs separate. In the latter case, shells can be different between male and female, female shells averaging a slightly larger size. The genus *Philomycus* (native slugs to North America) are characterized by the presents of a dart sac and dart (Fairbanks 1998). The slugs plunge these calcareous "love darts" into their mates to evoke heightened sexual excitement. Cupid does exist, if only in the world of land snails! After mating, eggs are typically laid under logs or in deep, moist leaf litter.

Defense Strategies used by Land Snails

Land snails use a variety of strategies to protect themselves from harm. The shell is the first line of defense and works well to ward off a number of predators. Conversely, there are animals such as small mammals, birds, insects and carnivorous land snails that routinely hunt and consume snails. Snail predators such as birds and small mammals will consume the entire shell, chew through the shells to extract the snail flesh or, in the case of the beetle larva, drill a hole though the side of the shell to extract to feed on the live animal. Other defense strategies include the hairs found on *Trichodiscina* species which help camouflage already cryptic shells by picking up forest debris. The defense strategy that has stood the test of time are teeth or lamellae barriers located in and around the snail's aperture. These structures have evolved to prevent *Cychrine* beetles from entering the shell, keeping the snail safe from harm. Teeth and aperture barriers may also provide a calcium storehouse to repair damaged shells or act as pivotal points for balancing the shell during the snails movement forward Although slugs are without protective shells they are not defenseless. Slugs are well-endowed with copious and stickier mucus than shelled snails, their slime containing repugnant substances that repel predators. For this reason, there are few animals eager to grab and dine on a gummy-slug.

Empty snail shells

When snails die, the shells do not immediately decompose. Some research suggests that shells can remain intact for years (Pearce 2008) and empty shells in some limestone locations can reach exceptional numbers. But these discarded shells are anything but vacant and actually provide secure and protected refuge for a whole host of living micro-invertebrates including pseudoscorpians, ants, millipedes, tardigrades and, on occasion, other smaller land snails. Some invertebrates species even deposit their eggs to be incubated in the security of shells.

Land Snail Benefits to Local Wildlife

Among the largest freshwater snails in the world, apple snails, *Ampullaria* species are an important food source to otters, crocodiles (caimans), freshwater turtles, a variety of egrets, herons and the well-known snail kites. The bulky gastropods (roughly the size of a lime) are found throughout Americas in still water lagoons, oxbows and slow moving rivers. A study in Belize by Platt et.al (2006) found that as much as 70% of the diet of adult Morelet's crocodiles was that of apple snails. It was discovered that the apple snail was found in the stomach contents of 22.1% of all of the animals studied (over 450 individuals). Surprisingly, consumption of snails increased with an increase in body size of the crocodile. The smaller-sized crocodiles fed primarily on insects and arachnids, while the medium-sized crocodiles broadened their diet to include apple snails, fish and other vertebrates, and larger crocodiles fed primarily on apple snails, fish, and crustaceans. In fact, the largest adult crocodiles studied were found to have 70.8 % of their total diet to consist of apple snails (Platt *et. al* 2006). The loss of aquatic gastropods such as apple snails due to water pollution, dredging, or other forms of habitat degradation would clearly threaten a host of wildlife species.

Another intriguing relationship between gastropod and predator is one with bats. What could be considered no less than remarkable bat feeding behavior on gastropods takes place deep within the Maya Mountains of Central America. Along massive outcrops of limestone are scattered overhanging rock-ledges used by bats to feed on land snails. The evidence includes multiple shell fragments containing puncture marks from bat canines along with bat guano that hold fragments of snail shells. Snail species that are being consumed at these bat night-feeding roosts include *Orthalicus princeps* (a), *Helicina rostrata*, *Chondropoma kusteri*, *Euglandina ghiesbreghti* and *Neocyclotus dysoni*. Interestingly, the first four species are largely arboreal snails while *N. dysoni* is a species found living on the ground. Live *Chondropoma kusteri* are usually found on vertical or overhanging limestone rock structure whereas *Orthalicus princeps* and *Helicina rostrata* are snails typically found on trees. *Euglandina ghiesbreghti* can be found on the ground or in trees searching for its diet of live snails. The overall evidence suggests multiple bat species that glean snails from trees, hard to reach (for non-flying mammals) cliff-faces and an appetite for snail flesh. The distance between canine puncture marks on several shells suggests a fringe-lipped bat, an optimistic feeder that eats a variety of foods including frogs, lizards and even small rodents (pers. comm. Price Sewell 2012). But puncture marks have varied considerably (in their spacing) on other snail shells recovered, so a variety of bat species are suspected. The snail shells found also indicate that the bats are con-

suming the snail flesh only, not the entire shell that has been reported in other studies (Bonato *et al.* 2004; Thabah *et al.* 2007). Besides bats praying on land snail there are birds that hunt snail flesh as well. In Great Britain, song thrushes can be a major predator on adult wood snails, *Cepaea nemoralis*, crushing their shells on stones to get at the soft snail within (Whitson 2005).

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Dipsadine snakes within the genus *Sibon* (below image) are generally referred to in the literature as feeding exclusively on slugs and snails (Peters 1960). However, there is little or no information available regarding which species of gastropods these snakes eat. Furthermore, there is some suspicion that the diets of several snakes in the genus *Sibon* occasionally include non-molluscan prey (Montgomery *et al.* 2007). During a 2009 study (Dourson et al. 2011) in Belize, Central America, various native foods were offered to eight individuals of the spectacle snailsucker, *Sibon nebulata* (image on next page). Feeding habitats were observed and recorded for each snake. Although the behavior witnessed was based on a meager 25 feeding events, certain characteristics remained surprisingly consistent, especially when the snakes fed on land snails in the genus *Drymaeus*. For example, before making grabs for the snail flesh, *S. nebulata* make deliberate and calculated assessments of prey size, movement and position. If the snail is on the move, the snake uses its tongue to delicately touch the snail, stopping all movement forward (pers. comm. Richard Foster 2012). Occasionally the snail withdraws into its protective shell, but the snake simply waits with great patience until the snail re-emerges. At this point, the snake begins to hover over the snail turning its head in contorted angles as it searches for an ideal strike angle, being careful not to make premature contact with the gastropod.

Spectacle snailsucker feeding on a sulfur cone

Next the snake aligns its lower jaws with the lower opening of the snail aperture (this taking a few minutes). A strike then follows with the precision of a thread passing through the eye of a needle. Only the lower mandible of the snake enters the aperture while the snake's upper mandible comes to rest on the outer surface of the last body whorl of the shell (see image on next page). Without delay, the snake makes a few lower and upper mandible adjustments before seizing down on the live snail flesh, holding the snail securely until it ceases to struggle. The snake begins extracting snail flesh only when all snail movement has ended, which may last upwards of an hour or more for *Drymaeus* species. The hesitation to eat the snail immediately is thought to be a direct response to the effectiveness of the snake's saliva. Actual feeding and extraction of the gastropods meat takes around five minutes or less and 80 to 90% of the snail flesh is usually retrieved by the snake. The shell remains intact and largely undamaged.

When eating land snails such as the larger *E. ghiesbreghti*, *S. nebulata* execute the usual strikes (as seen in other snake species), grabbing, yet sometimes missing, whatever portions of the snail remain outside the shell. Upon securing the snail's body, the snake holds its prey without moving, upwards to 24 hours or more until the snail ceases to struggle at which time it is then consumed. Slugs eaten by *S. nebulata* (below image) are seized promptly and eaten without the hesitation seen in shelled species with whole feeding events usually lasting only a few minutes.

Sibon nebulata was offered and fed on the live snail species, *Bulimulus unicolor*, *Euglandina ghiesbreghti*, *Veronicella floridana* and *Veronicella moreleti* (both slugs), *Drymaeus serperastrum* and *Drymaeus sulfureus*. Other land snail species offered but rejected included *Orthalicus princeps*, *Helicina rostrata, Helicina amoena, Chondropoma kusteri, Choanopoma radiosum*, and *Neocyclotus dysoni* (the last 5 snail species possessing operculum's). Perhaps species equipped with operculum structures (snail doors) act as a deterrent to the snakes, preventing the snakes lower jaw from entering the aperture of the shell. This however remains to be investigated. Non-mollusk organisms offered the snakes included frogs, lizards, small snakes, earthworms, beetle larva and other invertebrates, all of which were declined. All foods presented were found locally and native to Belize with the exception of *V. floridana* (a native slug to Florida, USA and Cuba).

These feeding behaviors suggest that *S. nebulata* is able to distinguish shelled and non-shelled gastropods (slugs) and is able to differentiate shelled snail species based on size and aperture shapes, perhaps through visual or olfactory senses. Clearly, *S. nebulata* uses different feeding strategies for dissimilar snail species. Further, these sequences of events strongly suggest that the snakes use immobilizing saliva to relax or even kill shelled snails before consumption. This is thought to make extraction of the muscular and slippery snail flesh easier for the taking. One more interesting fact. *Sibons* are reported to have a greater number of teeth in their lower right jaw than their lower left jaw, an evolutionary response to land snails in this region having right-sided apertures (openings). This allows the snake to reach deeper into the shell, resulting in removal of a higher percentage of snail flesh.

Collecting Land Snails, Selecting Sites to Survey

These instructions are designed for use predominantly in the USA. However, many of the same techniques are applicable for collecting land snails in other parts of the world.

When surveying for land snails, there are specific habitats that should be targeted in order to comprehensively cover an area. These habitats include: under leaf litter, rocky outcrops, rock crevices, and logs; under exfoliating bark of standing and/or down dead trees; hollow trees damaged trees oozing sap, which attracts snails; under and on top of caps of fungi; under moss mats; crotches of trees; human-made features such as roadsides, steep banks, retaining walls, cement structures, discarded bottles; cliffline features, caves, and rock talus. (**In the tropics and flooded forests, epiphytic plants as well as the trunks of trees and the undersides of vegetation, including palm leaves).**

Field and Lab Equipment Needed

- Ziploc bags
- Permanent marker
- GPS unit
- Field notebook
- Hand lens
- Quart-size drying bags

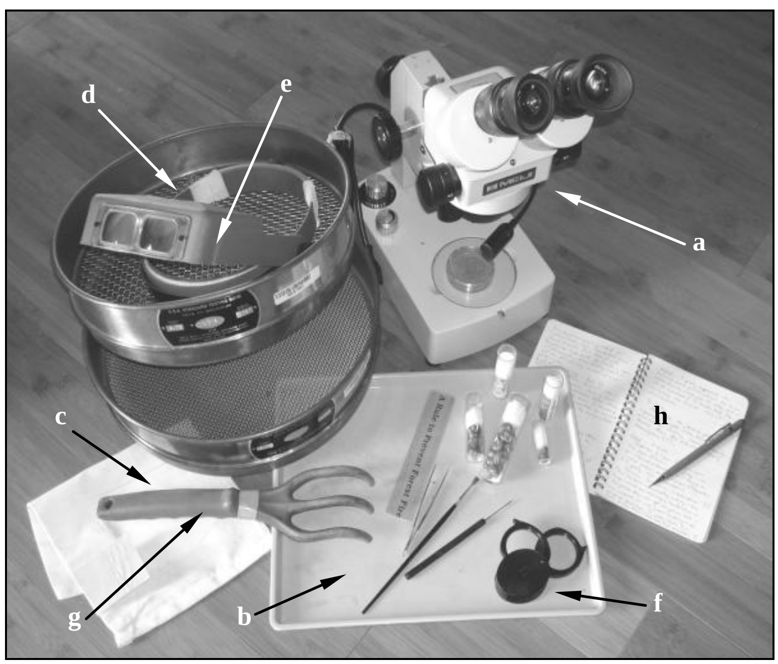
Collecting Methods

Samples of larger (macro) specimens from 5mm and greater should be collected and placed in Ziploc bags with date, site number, GPS coordinates, and collector name (preferably on the outside with a Sharpie). Do not put paper labels in bags with live snails. They will eat the paper.

Samples of smaller (micro) specimens are best collected from leaf/soil collections. Sites that yield increased numbers of snails include the bases of large mature hardwood trees, tree crotches and leaf litter along the edges of seeps. Optimal sites can be determined by collecting a handful soil/leaf litter then scanning the litter with a hand lens for evidence of micro specimens. If any snails are observed, a quart-sized cotton drying bag is filled with the material from the site, labeled with the date, site number, collector's name and GPS coordinates.

These leaf samples are taken back to the lab and dried for approximately two weeks. Dried samples should be sifted through a series of sieves ranging from 4.76 mm down to 500 micrometers. The subsequent debris that remains after this sifting process is then searched with the aid of an Optivisor or other magnification device. It will be necessary to use a zoom microscope to determine the species of these small snails. Many of them have microscopic ornamentation that can be seen only under high magnification.

Necessary equipment for land snail work includes: a dissecting microscope (a), sorting tray (b), 1-liter litter bags (for the soil and leaf litter collections) (c), a series of soil sieves sizes #4 (4.75mm), #10 (2.00mm), #18 (1.00mm), #14 (1.40mm) (d), magnifying head loop (e), forceps, vials, labels, paintbrush to pick up and transfer small snails (all pictured on tray), hand lens (f), hand rake (g), and notebook (h).



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