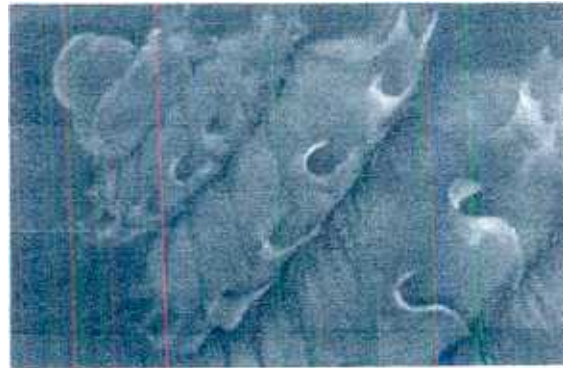
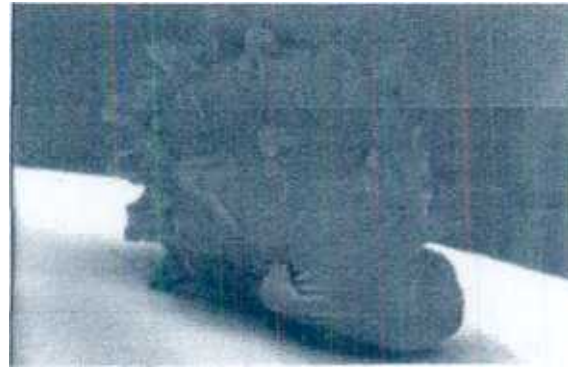
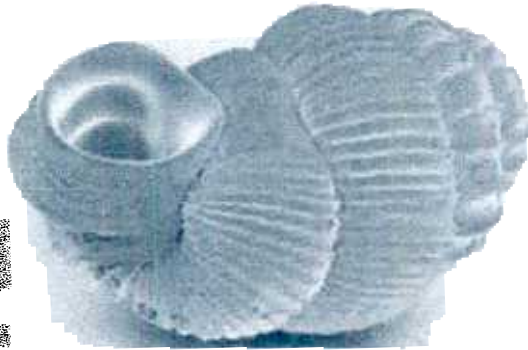


# The Land Snails of Belau: Survey of the 16 States



*By*  
**Rebecca J. Rundell**

Committee on Evolutionary Biology, 1025 East 57<sup>th</sup> Street,  
University of Chicago, Chicago, IL 60637, USA and  
Department of Zoology, Field Museum, 1400 South Lake Shore  
Drive, Chicago, IL 60605, USA; [rundell@uchicago.edu](mailto:rundell@uchicago.edu)

April 2005

Timarong Sisior (Peleliu) and Ms. Laura Ierago (Sonsorol). The people within each of these states were extremely welcoming and helpful, and for that I thank them.

Ms. Lori Colin and Mr. Pat Colin of the Coral Reef Research Foundation kindly provided laboratory space and occasional use of dissecting microscopes. Their help and advice was very much appreciated. Dr. Ron Crombie was also extremely helpful, and I am grateful for his advice and support. I thank the following individuals for assisting with some of the survey work: Mr. Emilio Basilius, Mr. William Carlos and Ms. Mandy Etpison. I thank Dr. Joel Miles of the Office of Environmental Response and Coordination for his ongoing support and interest in the project.

I thank Dr. Robert Cowie (University of Hawai'i at Mānoa), Dr. Barry Smith (University of Guam), Dr. Fred Thompson (Florida Museum of Natural History), Dr. Carl Christensen and Dr. Michael Hadfield (University of Hawai'i at Mānoa) for their collective advice on and interest in the land snails of Palau. Reports written by two of these individuals (Smith, 1993; Cowie *et al.*, 1996) were especially important resources.

Funding and support for this survey was kindly provided by the Department of Zoology's Field Fund (Field Museum, Chicago, Illinois), under my advisors Dr. Rüdiger Bieler and Dr. Paul Goldstein, the American Malacological Society, and the Hinds Fund (University of Chicago). I thank Ms. Regina Kawamoto (Bishop Museum, Honolulu, Hawai'i) and Ms. Virginie Héros (Museum National d'Histoire Naturelle, Paris, France) for providing diplommatinid type and comparative material. Thanks to Ms. Betty Strack (Field Museum) for technical assistance with the Scanning Electron Microscope (SEM).

Last, but certainly not least, I am forever grateful to my two field assistants, Ms. Ann Marie Gawel and Mr. Chris Carroll, both undergraduates at the University of Chicago, who volunteered their time, efforts and airfare(!) to this project. They were quick-learning, enthusiastic, smart and able, and I could not have asked for two better people to work with me in the field.

## Table of Contents

<b>Goals of the Belau Land Snail Project</b>	<b>1</b>
<b>Acknowledgments</b>	<b>1</b>
<b>Summary</b>	<b>3</b>
<b>List of Land Snail Species Recorded in Survey</b>	<b>4</b>
<b>Summary of Land Snail Families</b>	<b>7</b>
<b>Land Snail Species Recorded from Each State</b>	<b>11</b>
<b>Conclusions</b>	<b>16</b>
<b>Detailed Listing of Species Found in Each Locality</b>	
<b>Literature Cited and Further Reading</b>	
<b>Appendix 1. Details of Sites Sampled for Land Snails</b>	

Cover: Diplommatinid land snail species known only from Belau. *Palaina albata* (Peleliu; left); *Hungerfordia* sp. 1 (an undescribed species from Airai State; right and below). Photos by Rebecca J. Rundell.

## **1. Goals of the Belau Land Snail Project**

The goals of this project were twofold. The overarching goal of this project was to provide the Republic of Belau, local conservation agencies and state governors with an up-to-date assessment of the land snail species found within Belau's many islands. Understanding what species are present and where is a vital first step for guiding all future management decisions. Through my collaboration with the Palau Conservation Society my aim is to continue this survey work, thereby increasing our knowledge (and indeed, the world's knowledge) of this spectacular land snail fauna.

The second goal of the project was to collect data for my doctoral dissertation work at the University of Chicago (Chicago, Illinois U.S.A.), which focuses on the evolution and biogeography of Belau's diplommatinid land snails. Despite the fact that the diplommatinids were most important in terms of my dissertation work, all the snails that comprise Belau's land snail fauna received equal attention for the purposes of this survey. I felt that this was vital to the project, since all species and specimens recorded in this survey would represent important data for generations to come. Few malacologists have visited Belau, and therefore the land snail fauna is in serious need of detailed study.

## **2. Acknowledgments**

There are many individuals who contributed to the overall success of this project and I owe them each my deepest gratitude. First, I thank Mr. Belhaim "Bena" Sakuma, Director of the Palau Conservation Society (PCS) at the time of this survey, for opening his arms to both myself and my field assistants. I could not have imagined a better first field season in Belau, and I am incredibly grateful for his unwavering support of the project. I thank the Palau Conservation Society and all of its dedicated staff members for their wonderful support as well. The Palau Conservation Society was a fundamental part of the project, as they provided boat transportation, an incredible boat captain, as well as assisting with logistics and important contacts. Sulang, Bena and PCS.

I thank Mr. Herman Francisco, Director of the Bureau of Agriculture's Ministry of Resources and Development, for granting my national permit (no. ROP03-002) and Mr. Adalbert Eledui, Director of Conservation and Law Enforcement in the Koror State Government, for granting my Koror State Permit. A wide representation of islands was vital to the success of this project, and for the utility of the data for future conservation efforts, and so I am indebted to both of these individuals.

I also thank each one of the Governors of the States of Belau for supporting collecting within their states. These governors are: Mr. Demei Obak (Aimeliik), Mr. Tmeuang Rengulbai (Airai), Mr. Horace Rafael (Angaur), Mr. Sabino Sakarias (Hatohobei), Mr. Harris Kambalang (Kayangel), Mr. Johnny Gibbons (Koror), Mr. Lazarus Kodep (Melekeok), Mr. Tadashi Sakuma (Ngaraard), Mr. Brownly Salvador (Ngarchelong), Mr. Sabo Esebei (Ngardmau), Mr. John Skebong (Ngaremlengui), Mr. Shallum Etpison (Ngatpang), Mr. Florencio Adelbai (Ngchesar), Mr. Elmis Masubed (Ngiwal), Mr.

### **3. Summary**

The Republic of Belau is home to an extraordinary land snail fauna. In contrast to many other Pacific island groups, the islands of Belau still boast relatively intact rainforests in most areas, which gives us the unique ability to uncover a diversity of native species living in fairly natural ecosystems.

The geology of the islands also provides fascinating grounds for learning how animals have evolved and dispersed. First, the sheer number of islands (~350) suggests that dispersal and evolution of species among these islands may be complex (Crombie and Pregill, 1999). Second, many of the islands are very small (*e.g.* < 1 km<sup>2</sup>), yet harbor land snail species that may be endemic to single islands. Third, the variable compositions of the islands (coralline or limestone versus volcanic, and combinations of the two) and the variability of island types throughout the archipelago (everything from high volcanic islands to atolls, and the distinctive limestone Rock Islands), provide the differing habitats that may fuel explosive evolution.

Although land snails are generally an inconspicuous part of the forests, and may go completely unnoticed to the casual hiker, land snails are without a doubt both ecologically and evolutionarily significant. Many of Belau's land snails are leaf litter-dwelling, and by helping to break down decomposing material they are likely a vital part of nutrient cycling in a healthy forest. Some land snail species may also indirectly influence the diversity of fungi and lichens in an area through their grazing activities.

Evolutionarily speaking, Belau's land snail fauna is incredibly rich. The Diplommatinidae in particular, have radiated extensively within the islands. Forty-two (42) out of the 80 species found in this survey are diplommatinids. There are often several diplommatinid species present within a single locality, dividing themselves amongst rock and leaf-litter habitats. They have a wide variety of shell sculpture patterns, from variable ribs to striking white spines.

The land snails of Belau present a unique opportunity for conservation. Whereas many Pacific island groups have already lost a large proportion of their land snail faunas to extinction (Cowie, 1992; Cowie, 1996; Hadfield 1986; Hadfield *et al.*, 1993), Belau is still at a point where very few non-indigenous species have invaded, and many indigenous and endemic species still flourish. With careful planning and decision-making, it is possible to prevent further species introductions and ensure that Belau's spectacular endemic land snail fauna is around for generations to come.

#### 4. List of Land Snail Species Recorded in the Survey

Eighty (80) species total from 17 families were recorded in this survey. Sixty-nine (69) out of 80 species are endemic, 5/80 are indigenous, and 6/80 are introduced species. Forty-three (43) out of the 80 species are undescribed (new) species; most of these are diplommatinids. This substantially increases the number of species recorded from Belau. Smith (1993) lists 69 described species (including both native and introduced species), 37 of which were recorded in the present survey. The species that were not found may be located on islands not included in this survey, or may be exceedingly rare or extinct. Cowie *et al.* (1996) suggest that there may be 40-50 indigenous/endemic species in Belau, based on a survey of the literature and a scan of the Bishop Museum (Honolulu, Hawai'i) collections. The present total of 74 indigenous/endemic species exceeds this number.

Land snails can be roughly divided into two groups: the “prosobranchs,” which frequently have more heavily calcified shells and opercula covering the aperture or opening of their shells and the pulmonates, which often lack opercula. Worldwide, pulmonates represent a far greater percentage of total land snail species, though interestingly, “prosobranch” species have radiated extensively within Belau.

Genus and species names are given in italics under the family name, which is in capital letters, with the ending *-ae*. The authority responsible for describing a particular species, and the year in which that species was described, is given after the species name. Habitat data are based on collection data in the locality spreadsheet, though it should be noted that a few species were found only as dead shells, and therefore would be recorded only as “ground-dwelling.” This is not likely to be problematic, since most species were indeed found alive in either ground or rock habitats. “Ground” refers generally to the leaf litter, “vegetation” (veg.) refers to live emergent leaves and branches (including, but not restricted to trees), and “rock” refers to limestone cliff and boulder faces, as well as occasionally limestone rubble.

Under the category of “status,” *endemic* refers to species that are native to only the Belau islands. The term *indigenous* refers to species that are native to Belau, but also found elsewhere. The terms *introduced* and *invasive* are used interchangeably, and refer to all species that are non-indigenous to Belau, having been introduced either accidentally or deliberately.

Finally, species marked with an asterisk are listed in the *1994 Red List of Threatened Animals* (Groombridge, 1993; IUCN 2004). These species deserve special attention, with regard to conservation and management. Surveys such as this one are important for helping to assess the current conservation status of such species.

Family	Species	Habitat	Status
<u>“Prosobranchia”</u>			
ASSIMINEIDAE			
	<i>Kubaryia pilikia</i> Clench, 1948	Ground	Endemic
	<i>Omphalotropis cheynei</i> (Dohrn & Semper, 1862)	Ground/Veg.	Endemic
	<i>Omphalotropis</i> sp. 1	Ground/Veg.	Endemic
	Unidentified species 1	Ground	Endemic
DIPLOMMATINIDAE			
	<i>Diplommatina lutea</i> Beddome, 1889*	Ground/Rock	Endemic
	<i>Diplommatina</i> sp. 1	Rock	Endemic
	<i>Diplommatina</i> sp. 2	Rock	Endemic
	<i>Diplommatina</i> sp. 3	Rock	Endemic
	<i>Diplommatina</i> sp. 4	Ground/Rock	Endemic
	<i>Diplommatina</i> sp. 5	Rock	Endemic
	<i>Diplommatina</i> sp. 6	Ground/Rock	Endemic
	<i>Diplommatina</i> sp. 7	Rock	Endemic
	<i>Palaina albata</i> (Beddome, 1889)*	Ground/Rock	Endemic
	<i>Palaina dimorpha</i> Crosse, 1866)*	Ground/Rock	Endemic
	<i>Palaina inflatula</i> (Crosse, 1866)*	Ground/Rock	Endemic
	<i>Palaina moussoni</i> Crosse, 1866*	Ground	Endemic
	<i>Palaina patula</i> (Crosse, 1866)*	Ground/Veg.	Endemic
	<i>Palaina polymorpha</i> (Crosse, 1866)*	Ground	Endemic
	<i>Palaina ringens</i> (Crosse, 1866)*	Ground/Rock	Endemic
	<i>Palaina rubella</i> (Beddome, 1889)*	Rock/Veg.	Endemic
	<i>Palaina strigata</i> Crosse, 1866*	Ground	Endemic
	<i>Palaina striolata</i> Crosse, 1866*	Ground	Endemic
	<i>Palaina</i> sp. 1	Rock	Endemic
	<i>Palaina</i> sp. 2	Rock?	Endemic
	<i>Palaina</i> sp. 3	Rock	Endemic
	<i>Palaina</i> sp. 4	Ground	Endemic
	<i>Palaina</i> sp. 5	Ground	Endemic
	<i>Palaina</i> sp. 6	Ground	Endemic
	<i>Palaina</i> sp. 7	Rock	Endemic
	<i>Palaina</i> sp. 8	Rock	Endemic
	<i>Palaina</i> sp. 9	Ground	Endemic
	<i>Palaina</i> sp. 10	Ground	Endemic
	<i>Palaina</i> sp. 11	Ground	Endemic
	<i>Palaina</i> sp. 12	Ground/Rock?	Endemic
	<i>Palaina</i> sp. 13	Ground	Endemic
	<i>Palaina</i> sp. 14	Ground	Endemic
	<i>Palaina</i> sp. 15	Ground	Endemic
	<i>Palaina</i> sp. 16	Ground	Endemic
	<i>Palaina</i> sp. 17	Ground	Endemic
	<i>Hungerfordia</i> sp. 1	Rock	Endemic

<i>Hungerfordia</i> sp. 2	Rock	Endemic
<i>Hungerfordia</i> sp. 3	Rock	Endemic
<i>Hungerfordia</i> sp. 4	Rock	Endemic
<i>Hungerfordia</i> sp. 5	Rock	Endemic
<i>Hungerfordia</i> sp. 6	Rock	Endemic
<i>Hungerfordia</i> sp. 7	Rock	Endemic
<b>HELICINIDAE</b>		
<i>Palaeohelicina heterochroa</i> (Ancey?)	Ground/Veg.	Endemic
<i>Pleuropoma pelewensis</i> (Sykes, 1901)	Gr./Rock/Veg.	Endemic
<b>HYDROCENIDAE</b>		
<i>Georissa</i> sp. 1	Ground/Veg.	Endemic
<i>Georissa</i> sp. 2	Ground	Endemic
<i>Georissa</i> sp. 3	Ground	Endemic
<i>Georissa</i> sp. 4	Ground	Endemic
<i>Georissa</i> sp. 5	Ground	Endemic
<b>PUPINIDAE</b>		
<i>Pupina difficilis</i> Semper, 1864*	Ground	Indigenous
<b>TRUNCATELLIDAE</b>		
<i>Truncatella guerinii</i> A. & J.B. Villa, 1841	Ground	Indigenous
 <u>Pulmonata</u>		
<b>ACHATINELLIDAE</b>		
<i>Elasmias ovulatum</i> (Möllendorff, 1900)	Vegetation	Indigenous
<i>Elasmias</i> sp. 1	Ground	Endemic?
<b>ACHATINIDAE</b>		
<i>Achatina fulica</i> Bowdich, 1822	Ground	Introduced
<b>CHAROPIDAE</b>		
<i>Semperdon xyleborus</i> Solem, 1982*	Ground/Rock	Endemic
<b>ELLOBIIDAE</b>		
<i>Pythia scarabaeus</i> (Linnaeus, 1758)	Ground	Indigenous
<b>ENDODONTIDAE</b>		
<i>Aadonta constricta</i> (Semper, 1874)*	Ground	Endemic
<i>Aadonta kinlochi</i> Solem, 1976*	Ground	Endemic
<b>HELICARIONIDAE</b>		
<i>Coneuplecta turrata Belauensis</i> Baker, 1941	Ground	Endemic
<i>Kororia palaensis</i> (Semper, 1870)	Ground/Rock	Endemic
<i>Liravidena lacerata</i> (Semper, 1974)	Ground/Rock	Endemic
<i>Palaua minor</i> (Semper, 1873)*	Ground/Rock	Endemic
<i>Palaua</i> sp. 1	Ground/Veg.	Endemic
<i>Palaua</i> sp. 2	Ground	Endemic
<i>Palaua</i> sp. 3	Ground	Endemic
<i>Videna electra</i> (Semper, 1873)*	Gr./Rock/Veg.	Endemic
<i>Videna oleacina</i> (Semper, 1873)*	Ground/Rock	Endemic
<i>Videna pagodula</i> (Semper, 1873)*	Ground/Rock	Endemic
<i>Videna pumila</i> (Semper, 1873)*	Ground	Endemic
<b>PARTULIDAE</b>		



<i>Partula calypso</i> Semper, 1865*	Veg.	Endemic
<b>STREPTAXIDAE</b>		
<i>Gonaxis kibweziensis</i> E.A. Smith, 1894	Ground	Introduced
<i>Gulella bicolor</i> (Hutton, 1834)	Ground	Introduced
Unidentified species 1	Ground	Introduced
<b>SUBULINIDAE</b>		
<i>Subulina octona</i> (Bruguière, 1789)	Ground	Introduced
<b>SUCCINEIDAE</b>		
<i>Succinea philippinica</i> Möollendorff, 1893*	Ground	Indigenous?
<b>VERONICELLIDAE</b>		
<i>Vaginululs plebeius</i> Fischer	Ground	Introduced

## 5. Summary of Land Snail Families Found During Survey

### ASSIMINEIDAE

*Omphalotropis cheynei*, a dark, conical species with variable mottling and striping, was found at most localities throughout Belau, in a variety of habitats. It is suspected to be a species endemic only to Belau (Cowie *et al.*, 1996; Barry D. Smith, pers. comm.). There may be more species than the single one included under the name *O. cheynei*, given the variability of shell patterns and color among populations. However, there was insufficient evidence to divide the species into different groups, with the exception of the *Omphalotropis* sp. 1 found in the Southwest Islands, which is smaller, and may therefore be an undescribed species. The other two assimineids found during this study were fairly rare and restricted in distribution.

### DIPLOMMATINIDAE

The diplommatinids are exceptionally diverse in Belau, and were the focus of this study. Only 25 species (and one subspecies) have been described from Belau (Smith, 1993). However, during this survey 42 species were found, 31 of which are likely undescribed species, new to science. All specimens were compared with extensive type and comparative material from the Museum National d'Histoire Naturelle (Paris, France) and the Bishop Museum (Honolulu, Hawai'i), as well as original species descriptions. Therefore it is likely that very few of these undescribed "morphospecies" can be ascribed to previously identified species.

Many of these species have incredibly restricted distributions, based on these preliminary data, often comprising a single small Rock Island, or limited patch of rainforest on Babeldaob. The habitat specializations and complexity of shell shapes among the species are also remarkable. Diplommatinids live on rocks and in the leaf litter, and their shell morphologies roughly correlate with these habitats. The rock-dwelling species (*e.g.* *Hungerfordia* spp.) have dramatic white spines on their shells, while the leaf litter-dwelling species have an enormous variety of different rib patterns.

## HELICINIDAE

These species, particularly *Palaeohelicina heterochroa*, were found throughout the islands. *P. heterochroa* has a heavily calcified planispiral (“flattened” rather than conical) shell with brightly colored, often variable spiral striping. This distinctive species is frequently found on all sorts of emergent vegetation.

## HYDROCENIDAE

Hydrocenids are very tiny, poorly known snails, found throughout the Pacific (Thompson and Huck, 1985; Cowie *et al.*, 1996). All of the species found during this survey are most likely undescribed and endemic to Belau.

## PUPINIDAE

*Pupina difficilis* was the only species found during this study, and was often abundant where it was found. It seems to prefer moist habitats such as rotting logs.

## TRUNCATELLIDAE

The single species found during this survey, *Truncatella guerinii*, is found throughout the Pacific, typically close to beaches. They have tall, heavily calcified shells, often decollate at the apex (“chopped off”), with heavy ribbing. They are often the preferred homes for small hermit crabs.

## ACHATINELLIDAE

This family is endemic to Pacific islands, and the genus *Elasmias* comprises very small conical species that may be easily dispersed among islands. The two species found during this survey were fairly rare.

## ACHATINIDAE

*Achatina fulica* (the Giant African Land Snail) is an invasive species that has unfortunately been introduced throughout the Pacific. The species is native to Africa, and unlike most or all of Belau’s indigenous and endemic species, *A. fulica* is herbivorous, and therefore may be considered a crop pest. Efforts should be made to avoid spreading this species. However, under no circumstances should predatory species be introduced to control *A. fulica*. Predatory snails such as the Rosy Wolf Snail *Euglandina rosea* and various streptaxids (two of which were recorded in this survey) have been introduced to other Pacific islands, such as Hawai‘i and the Society Islands (Cowie, 1992), where they have contributed to cataclysmic extinctions of native tree snails. It was later found that these predatory species *did not* help to control *A. fulica* populations; instead, it is likely that *A. fulica* declined on its own (Cowie, 2001).

*A. fulica* was found at only 5 sites, all of which were in Airai and the island of Koror. *Euglandina rosea*, a smaller, predatory snail with a conical/oval cream to beige shell often with a slight "rosy" tone (especially in the juvenile) was not found during the survey; however, this species is often fairly cryptic. Since a single *E. rosea* individual can consume a huge number of snails, and because this species is virtually impossible to exterminate once it is present in a habitat, it is important that care be taken to never further the spread of this species.

#### CHAROPIDAE

Four species and three subspecies of charopids are described from Belau (Solem, 1982; Smith, 1993). Only one species, *Semperdon xyleborus* was found during this survey. This species was very rare, and found only on the islands of Ngeruktabel and Peleliu (in the current survey). It is a small, planispiral, distinctive species with pronounced ribbing on its shell. The charopids, as well as the endodontids (below), have unfortunately suffered extinction throughout the Pacific.

#### ELLOBIIDAE

*Pythia scarabaeus* is an indigenous species found in moist habitats, often near beach areas. This species has a dark, mottled, heavy conical shell with a keel, and is found on islands throughout the Pacific.

#### ENDODONTIDAE

Endodontids are tiny, distinctive ground-dwelling species, similar to the charopids. Five endodontid species (and five subspecies) are described from Belau. Two of these species, *Aadonta constricta* (which has prominent striping) and *Aadonta kinlochi*, were found in the survey, at a very limited number of sites. These species are both rare and threatened, like the charopids (above).

#### HELICARIONIDAE

The Helicarionidae were previously known as families Euconulidae (genera *Comuplecta*, *Kororia* and *Palaua*) and Trochomorphidae (*Videna* and *Liravidena*). Eight euconulinine species are described from Belau. Three of these described species were found in the survey; three other undescribed species, tentatively assigned to the genus *Palaua*, were also found.

Five trochomorphinine species are described from Belau, and all of these were found in the survey. *Videna electra*, a flattened, large planispiral snail with a keel and dark spiral stripe on its shell, is particularly distinctive, and was found alive at several localities.

#### PARTULIDAE

The Partulidae are endemic to Pacific islands, and the family comprises mainly large tree-dwelling species in a variety of colors. Partulids are flagships for conservation on many Pacific islands, known for both their beauty and, unfortunately, their susceptibility to extinction. They have been all but exterminated on many islands in French Polynesia and many species survive only in captivity (Cowie, 1992).

Three species, *Partula calypso*, *Partula thetis* and *Partula leucothoe* are described from Belau, and only one species, *Partula calypso*, was found alive in this survey. Although it appeared to be thriving in the few localities where it was found, its geographical distribution is extremely restricted, and therefore care should be taken to conserve this species. Partulids generally are very slow to reproduce, and therefore are particularly susceptible to extinction pressures, such as predation by introduced predators (e.g. invasive predatory snails and rats) and habitat destruction.

#### STREPTAXIDAE

Both of the streptaxid species known from Belau were found (as dead shells only) in this survey. They are both predatory, invasive species that have been introduced throughout the Pacific.

#### SUBULINIDAE

One introduced species, *Subulina octona*, is known from Belau; this species is found throughout the Pacific. It was found alive at several localities in this survey, including the Southwest Islands. However, the Southwest Islands individuals were smaller, with more pointed apices, and therefore may represent a distinct species.

#### SUCCINEIDAE

The succineids have radiated extensively throughout the Pacific, and are found in a variety of habitats, including rainforest (Cowie, 1996; Rundell *et al.*, 2004). They have flattened, amber-colored shells with little coiling. A single species, *Succinea philippinica*, is known from Belau (Smith, 1993), and a single specimen, tentatively ascribed to this name was found as a dead shell on the Southwest island of Tobi. It is possible that this species is incidental in Belau rather than indigenous, having arrived attached to cargo; but given that only one specimen was found, little can be assumed about its distribution.

#### VERONICELLIDAE

A single introduced veronicellid slug was recorded in the survey. Since the collection of slugs was not a focus for this survey, few conclusions can be drawn about the distributions of invasive slugs in Belau. Anecdotally, however, few slugs were noted during this survey. The species we collected is tentatively identified as *Vaginulus plebeius*, though it is possible that the species is actually *Veronicella cubensis*, which is commonly collected in Hawai'i (R. Cowie, pers. comm.).

## **6. Land Snail Species Recorded from Each State**

The following sections list the species recorded from each state during the survey. Due to the limits of time and funding, different amounts of time were spent in each state, and therefore some of the lists are incomplete. Absence of a species on a list does not necessarily indicate the absence of a particular species within a state; for example, *Omphalotropis cheynei* was found at most sites, and therefore it is suspected that it is also found in Aimeliik. Further survey work in these states will likely serve only to increase the number of species in the species lists.

### **AIMELIIK**

(surveyed near Aimeliik, but not within Aimeliik proper)

#### **AIRAI**

*Omphalotropis cheynei*  
*Diplommatina lutea*  
*Diplommatina* sp. 6  
*Palaina dimorpha*  
*Palaina albata*  
*Palaina patula*  
*Palaina rubella*  
*Palaina* sp. 1  
*Palaina* sp. 2  
*Palaina* sp. 3  
*Palaina* sp. 4  
*Palaina* sp. 5  
*Palaina* sp. 6  
*Palaina* sp. 7  
*Hungerfordia* sp. 1  
*Palaeohelicina heterochroa*  
*Georissa* sp. 1  
*Pupina difficilis*  
*Pythia scarabaeus*  
*Kororia palaensis* (Semper, 1870)  
*Palaua minor*  
*Palaua* sp. 3  
*Videna electra*  
*Videna oleacina*  
*Liravidena lacerate*  
*Partula calypso*  
*Subulina octona*  
*Achatina fulica*

#### **ANGAUR**

*Omphalotropis cheynei*  
*Diplommatina* sp. 7

*Palaina strigata*  
*Hungerfordia* sp. 6  
Unidentified diplommatinid  
*Palaeohelicina heterochroa*  
*Pleuropoma pelewensis*  
*Truncatella guerinii*  
*Pythia scarabaeus*  
*Kororia palaensis*  
*Palaua minor*  
*Videna oleacina*  
*Subulina octona*

#### **HATOHOBEL**

*Omphalotropis* sp. 1  
*Georissa* sp. 4  
*Kororia palaensis*  
*Palaua* sp. 2  
Unidentified streptaxid sp. 1  
*Subulina octona*  
*Succinea philippinica*

#### **KAYANGEL**

*Omphalotropis cheynei*  
*Palaina moussoni*  
*Pleuropoma pelewensis*  
*Georissa* sp. 2  
*Pupina difficilis*  
*Truncatella guerinii*  
*Elasmias ovulatum*  
*Pythia scarabaeus*  
*Kororia palaensis*  
*Palaua* sp. 1  
*Subulina octona*  
*Gulella bicolor*

#### **KOROR**

*Omphalotropis cheynei*  
Unidentified assimineid 1  
*Diplommatina lutea*  
*Diplommatina* sp. 2  
*Diplommatina* sp. 3  
*Diplommatina* sp. 5  
*Diplommatina* sp. 6  
*Palaina albata*  
*Palaina inflatula*

*Palaina dimorpha*  
*Palaina patula*  
*Palaina striolata*  
*Palaina* sp. 4  
*Palaina* sp. 6  
*Palaina* sp. 7  
*Palaina* sp. 8  
*Palaina* sp. 12  
*Palaina* sp. 16  
*Palaina* sp. 17  
*Hungerfordia* sp. 1  
*Hungerfordia* sp. 2  
*Hungerfordia* sp. 3  
*Hungerfordia* sp. 4  
*Hungerfordia* sp. 5  
*Hungerfordia* sp. 7  
*Georissa* sp. 1  
*Georissa* sp. 2  
*Georissa* sp. 5  
*Palaeohelicina heterochroa*  
*Pleuropoma pelewensis*  
*Pupina difficilis*  
*Elasmias ovulatum*  
*Elasmias* sp. 1  
*Achatina fulica*  
*Semperdon xyleborus*  
*Pythia scarabaeus*  
*Aadonta constricta*  
*Aadonta kinlochi*  
*Kororia palaensis*  
*Liravidena lacerate*  
*Palaua minor*  
*Palaua* sp. 3  
*Videna electra*  
*Videna oleacina*  
*Videna pagodula*  
*Videna pumila*  
*Partula calypso*  
*Subulina octona*

#### **MELEKEOK**

*Palaina* sp. 14  
*Pleuropoma pelewensis*  
*Pupina difficilis*  
*Pythia scarabaeus*  
*Kororia palaensis*

*Palaua minor*  
Unidentified partulid  
*Subulina octona*

**NGARAARD**

*Palaina* sp. 12  
*Pleuropoma pelewensis*  
*Georissa* sp. 3  
*Kororia palaensis*

**NGARCHELONG**

Unidentified diplommatinid  
*Pleuropoma pelewensis*  
*Palaeohelicina heterochroa*  
*Georissa* sp. 3  
*Kororia palaensis*  
*Palaua minor*

**NGARDMAU**

(surveyed near Ngardmau, but not within Ngardmau proper)

**NGATPANG**

*Palaina* sp. 9  
*Palaina* sp. 10  
*Palaina* sp. 11  
*Palaina* sp. 14  
*Palaina* sp. 15  
Unidentified diplommatinid  
*Pleuropoma pelewensis*  
*Pupina difficilis*  
*Pythia scarabaeus*  
*Aadonta constricta*  
*Kororia palaensis*  
*Palaua minor*  
*Gonaxis kibweziensis*  
*Subulina octona*  
*Vaginulus plebeius*

**NGCHESAR**

*Palaina* sp. 11  
*Pleuropoma pelewensis*  
*Pythia scarabaeus*  
*Palaua minor*

**NGEREMLENGUI**

(surveyed near Ngeremlengui, but not within Ngeremlengui proper)



### **NGIWAL**

*Palaina* sp. 12

*Palaina* sp. 13

*Pleuropoma pelewensis*

*Pythia scarabaeus*

*Pupina difficilis*

*Kororia palaensis*

### **PELELIU**

*Kubaryia pilikia*

*Omphalotropis cheynei*

*Hungerfordia* sp. 1

*Hungerfordia* sp. 4

*Diplommatina* sp. 4

*Palaina albata*

*Palaina inflatula*

*Palaina polymorpha*

*Palaina ringens*

*Palaina* sp. 4

*Palaina* sp. 6

*Palaina* sp. 7

*Palaina* sp. 8

*Palaeohelicina heterochroa*

*Pleuropoma pelewensis*

*Georissa* sp. 1

*Elasmias ovulatum*

*Pythia scarabaeus*

*Semperdon xyleborus*

*Coneuplecta turrita*

*Kororia palaensis*

*Palaua minor*

*Videna electra*

*Videna oleacina*

*Videna pagodula*

*Subulina octona*

### **SONSOROL**

*Omphalotropis* sp. 1

*Georissa* sp. 4

*Pupina difficilis*

*Truncatella guerinii*

*Kororia palaensis*

*Palaua* sp. 2

*Subulina octona*

Unidentified streptaxid 1

## **7. Conclusions**

Eighty (80) species total from 7 families were recorded in this survey. Sixty-nine (69) out of 80 species are endemic, 5/80 are indigenous, and 6/80 are introduced species. Forty-three (43) out of the 80 species are undescribed (new) species; most of these are diplommatinids. This substantially increases the number of species recorded from Belau. Given the number of islands remaining to be surveyed, and the high levels of endemism of diplommatinid species in particular, it is expected that additional survey work will only increase the number of species known from Belau.

The Rock Islands and Babeldaob should receive special attention, in terms of future survey efforts. Land snails tend to gravitate toward limestone areas, and the large number of snails found in Koror State verify this claim. Species diversity is incredibly high there, even given the small relative proportion of Koror State islands covered by the present survey.

The island of Babeldaob should also be surveyed more thoroughly. Many species new to science were found there, indicating that the land snail fauna is poorly known. With the inevitable increasing development brought on by the completion of the Compact Road around the island, pristine rainforest habitats may be destroyed, which could lead to the extinction of many of Belau's endemic land snail species. Land snails are sensitive to small changes in microclimate and plant species composition, which are often brought about through edge effects and the invasion of non-indigenous plant species, accidentally carried as seeds via roadways.

Furthermore, given the small geographical range sizes of many of Belau's land snail species, cutting down even small tracts of rainforest could severely impact some land snail populations. The partulid tree snails and the rare endodontid and charopid ground-dwelling snails are particularly deserving of conservation attention, since species in these families have rapidly gone extinct throughout the Pacific islands.

However, a substantial proportion of Belau's land snail fauna is currently intact. Given the fact that almost all of Belau's land snail species are found only in Belau, this fauna is completely unique in the world, and worthy of preservation. Obviously, development will occur within the Republic of Belau. But with wise decision-making, and consideration for future generations, the land snails of Belau may continue to thrive for years to come.

## **Literature Cited and Further Reading**

(including works used for comparative/taxonomic purposes)

- Abbott, R.T., 1989. *Compendium of landshells*. American Malacologists, Inc., 240 p.
- Baker, H.B., 1941. Zonitid snails from Pacific islands. Parts 3 and 4. 3. Genera other than Microcystinae. 4. Distribution and Indexes. *Bernice P. Bishop Museum Bulletin* 166, 201-370.
- Beddome, R.H., 1889. Descriptions of land-shells from the island of Koror, Pelew Group. *Proc. Zool. Soc. Lond.* 1889, 112-116.
- Clench, W.J., 1948. Two genera and a new species of Synceridae from the Caroline Islands. *Occasional Papers of the Bernice P. Bishop Museum* 19(8), 191-194.
- Cooke, C.M., Jr., and Kondo, Y., 1960. Revision of Tornatellinidae and Achatinellidae (Gastropoda, Pulmonata). *Bernice P. Bishop Museum Bulletin* 221, 1-303.
- Cowie, R.H., 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. *Phil. Trans. R. Soc. Lond. B* 335, 167-191.
- Cowie, R.H., 1996. Pacific island land snails: Relationships, origins and determinants of diversity, In: Keast, A., Miller, S.E. (Eds.), *The origin and evolution of Pacific Island biotas, New Guinea to Eastern Polynesia: patterns and processes*, SPB Academic Publishing, Amsterdam, pp. 347-372.
- Cowie, R.H., 2001. Can snails ever be effective biocontrol agents? *Int. J. Pest Management* 47, 23-40.
- Cowie, R.H., Allison, A., Howarth, F.G., Samuelson, G.A., Evenhuis, N.L., 1996. Impacts of construction of the Palau Compact Road: survey of the non-marine fauna of the Island of Babeldaob, unpublished report, Will Chee Planning, Honolulu, Hawaii, 43 p.
- Crombie, R.I., Pregill, G.K. 1999. A checklist of the herpetofauna of the Palau Islands (Republic of Belau), Oceania. *Herpet. Mono.* 13, 29-80.
- Crosse, H., 1866. Note sur les Mollusques operculés terrestres des îles Pelew ou Palaos. *Journal de Conchyliologie* 14, 346-350.
- Groombridge, B. (Ed.), 1993. *1994 Red List of Threatened Animals*. IUCN, Gland, Switzerland and Cambridge, U.K. 1vi + 286 p.
- Hadfield, M.G., 1986. Extinction in Hawaiian achatinelline snails. *Malacologia* 27, 67-81.

- Hadfield, M.G., Miller, S.E., Carwile, A.H., 1993. The decimation of endemic Hawaiian tree snails by alien predators. *Amer. Zool.* 33, 610-622.
- IUCN 2004. *2004 IUCN Red List of Threatened Species*. [www.redlist.org](http://www.redlist.org)
- Rundell, R.J., Holland, B.S., Cowie, R.H., 2004. Phylogeny and biogeography of the endemic Hawaiian Succineidae (Gastropoda: Pulmonata). *Molecular Phylogenetics and Evolution* 31, 246-255.
- Semper, O., 1865. Notice preliminaire sur la famille des Diplommatinacées. *Journal de Conchyliologie* 18, 289-294.
- Semper, O., 1865. Addition au catalogue des Diplommatinacées. *Journal de Conchyliologie* 18, 294-296.
- Semper, O., 1865. Description de trois especes nouvelles du genre Partula. *Journal de Conchyliologie* 18, 417-422.
- Smith, B.D., 1993. Working list of the terrestrial gastropods of Palau, Caroline Islands. Working List No. 4, Dickinson Memorial Mollusc Collection, Marine Laboratory, University of Guam, 5 p.
- Solem, A., 1976. *Endodontoid land snails from Pacific islands (Mollusca: Pulmonata: Sigmurethra), Part I, family Endodontidae*. Field Museum of Natural History, Chicago, Illinois, xii + 508 p.
- Solem, A., 1983. *Endodontoid land snails from Pacific islands (Mollusca: Pulmonata: Sigmurethra), Part II, families Punctidae and Charopidae, Zoogeography*. Field Museum of Natural History, Chicago, Illinois, ix + 336 p.
- Thiele, J., 1927. Über die Schneckenfamilie Assimineidae. *Zool. Jahrb. Abt. Syst.* 53, 113-145.
- Thompson, F.G., Huck, E.L., 1985. The land snail family Hydrocenidae in Vanuatu (New Hebrides Islands), and comments on other Pacific island species. *The Nautilus* 99(2), 81-84.
- Wagner, A.J., 1905. Helicinenstudien. *Denkschrift der Kaiserlichen Akademie der Wissenschaften Wien. Mathematisch-Naturwissenschaftliche Klasse* 77, 357-450, pls. 1-9.

## **[APPENDIX 1. DETAILS OF SITES SAMPLED FOR LAND SNAILS]**

For details on land snail species collected and locality information, please contact Rebecca Rundell directly at [rundell@uchicago.edu](mailto:rundell@uchicago.edu) or 1-(312)665-7810. I would be happy to discuss any questions or concerns relating to the information contained in this report or regarding Palau land snails in general. Thank you very much.

Sincerely,  
Rebecca J. Rundell  
Chicago, June 2005