BEETLES AS INDICATORS FOR FOREST CONSERVATION IN CENTRAL AMERICA

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Summary

Accelerated rates of deforestation, species loss and global threat to biodiversity make imperative increasing conservation efforts such as establishment of biological reserves, based on studies of biodiversity indicators. However, in developing regions such as Central America, the time, economic resources and taxonomic expertise are scarce. Therefore, the use of bioindicator groups such as passalid beetles (Coleoptera: Passalidae) dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) and leaf litter-inhabiting weevils (Coleoptera: Cucujidae), and rove beetles (Coleoptera: Staphylinidae) can be cost-effective, rapid, contrasting, and strong tools to produce objective and confident criteria to prioritize the establishment and evaluation of protected areas. It has been possible to use these groups because they are well studied in the region, are speciose, highly endemic (especially in mountains) and are easily collected and identified. Three cases (in Honduras, Guatemala and Costa Rica) are summarized which demonstrate that beetles can readily identify regions for conservation, maximizing diversity in minimal area for each region.

1. Introduction

Central America (Figure 1) is a tropical region formed by seven countries (Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama), with a territory of near 523 000 km$^2$ and a population of near 39 million. Geologically, Central America can be divided in three regions. The northern region from Guatemala (including Chiapas in México) to mid Nicaragua, consists of two terranes, the Chortis Block (southern Chiapas, southern Guatemala, El Salvador, Honduras and northern Nicaragua), and the Mayan Block (Yucatan Peninsula, northern Chiapas, northern Guatemala, and Belize). These two blocks collided near the end of Cretaceous. The southern region of Central
America (southern Nicaragua, Costa Rica and Panama) is a more recent territory that, at first, consisted of oceanic volcanic islands which coalesced in the Pliocene (3 million years ago) to form the Panama isthmus, permitting the great biotic interchange of megafauna between North and South America.

![Figure 1. Central American countries and geomorphology. Courtesy of NASA.](image)

Landscape topography is dominated by a pacific volcanic chain extending from Tacana volcano on the Guatemalan-Mexican border to west of the Sierra de Talamanca of Costa Rica and Panama. A series of almost continuous mountainous regions is present in southern Belize (Mayan mountains), Guatemala, Honduras, northern El Salvador and northwestern Nicaragua (see Figure 1). Lowlands are present in the Caribbean and Pacific versants of the region. Relevant inter-montane valleys and other dry areas (generally considered biogeographic barriers for wet montane species) include the dry Motagua valley in Guatemala, the valleys of San Pedro Sula and Yoro in Honduras, the area around Lake Guija in Guatemala and El Salvador, northeast Golfo de Fonseca, the areas west of Lake Nicaragua, Guanacaste and Peninsula de Nicoya in Costa Rica and east of Peninsula de Azuero in Panama.
Vegetation (Figure 2) includes coniferous forests dominated by pines in the mountainous areas in Guatemala, Honduras, El Salvador and northern Nicaragua (forests of *Pinus caribaea* occurs in lowlands of Belize, Guatemala, Honduras and Nicaragua); pine-oak montane forests; cloud forests; lowland rain forests; dry forests; mangrove forests and a type of paramo in Cerro de la Muerte highlands of Costa Rica. The Holdridge Life Zone system maps (Figure 3) are widely used to designate vegetation types in Central America. Central America includes at least 50 tropical and subtropical life zones. Life zones are delimited on basis of mean annual bio-temperature (temperature favorable to living plants, 0-30°C), potential evapotranspiration, annual precipitation, latitude and altitude.

The region has a highly concentrated diversity, although estimates of species richness and endemism are certainly biased by differences in intensity of study and exploration among the countries. Floral diversity has been estimated at approximately 18,000 species of vascular plants (21% endemics). Also, animal diversity is high, especially amphibians, reptiles, freshwater fishes, small mammals, and some groups of well studied arthropods. Interestingly, data from different taxa demonstrate that Central America possesses at least two centers of diversification: The Costa Rica and Panamá cluster and the northern Central America cluster (Guatemala, El Salvador, Honduras, northern Nicaragua and adjacent Chiapas). For example Guatemala share with Costa Rica only 11% of june beetle species (*Phyllophaga*) and 2% of species of jewel beetles genus *Chrysina*.

Several countries in Central America have been through turbulent political periods and were politically unstable as recently as 1996. As a consequence, high levels of poverty...
and direct dependence of agriculture and renewable resources have produced or sustained the major threats to region’s biodiversity: slash and burn agriculture, cattle ranching, illegal logging, invasions of protected areas, narcotraffic, large-scale use of pesticides, water pollution, environmentally aggressive industrial development, and petroleum exploitation. Increasing conservation efforts are thus crucial to preserve Central America's wealth of ecosystems. In 1992 produced what was probably the most important set of international agreements to date on the preservation, investigation, and sustainable use of biodiversity – the Rio Convention on Biological Diversity (CBD). Article 7 (identification and monitoring) of the CBD to which the Central American countries are signatories, states that “each contracting party shall, as far as possible and as appropriate, identify components of biological diversity important for its conservation and sustainable use”. Among the recommended categories of such listed components (Annex I, CBD), are “ecosystems and habitats containing high diversity and large numbers of endemic or threatened species” and those with importance for research into the conservation and sustainable use of biodiversity, as indicator species.

2. Forest Conservation in Central America

Although establishment of municipal forest reserves date from 1870 in Guatemala, biological conservation in Central America begin in 1923 when the Barro Colorado Island in the Panama Canal was declared natural monument. In 1928 the British administration of Belize declared Half Moon Cay as a Crown Reserve (now, National Monument), the oldest reserve in Belize. In 1952 Honduras declared San Juancito in Tegucigalpa as a Forest Reserve, which in 1980 became to be “La Tigra” National Park. In 1955 the volcanic craters in Costa Rica were declared National Parks. Between 1955 and 1956 Guatemala declared 38 protected areas, including the first National Park, Tikal. Panama declared the Altos de Campana National Park in 1966.

The decades of 1970s and 1980s were significant for the conservation in Central America (see Figure 4). In Nicaragua, the first National Park, Volcán Masaya, was declared in 1979 and the Ministry of Environment and Natural Resources was created in 1994, based on the Constitution of 1987. Costa Rica proclaimed in 1983 the Law of Conservation of Wild Fauna, when wild fauna refuges were created and, in 1997, its Law of Creation of the National Parks Service. In 1981 Belize passed its Laws of Protected Areas (The Wildlife Protection Act 1981 (No. 4) and National Parks Systems Act 1981 (No. 5)). El Salvador declared its three legally protected areas in 1987 (Montecristo National Park), 1989 (El Imposible National Park) and 1996 (El Jocotal Lagoon); the Law of Wildlife Conservation was passed in 1994, although the Law of Protected Natural Areas was approved in 2005. Guatemala proclaimed its Law of Protected Areas in 1989. By the parliamentary act No. 87 of 1987, Honduras declared 37 protected areas mostly of cloud forest. Panama, between 1980 and 1988, declared protected 14 of the 20 more important areas of the country, corresponding to 95% of protected land, and in 1992 created the National System of Protected Areas (Ugalde and Godoy 1992).

During this time most reserves were established based on opportunity (most were national lands), and a few were designed based on biological criteria (particularly endangered and charismatic species). Protected areas have incremented in numbers but not much in area since 1990s (Figure 4).
Figure 3. Life zones of Central America. Data courtesy of Comision Centroamericana de Ambiente y Desarrollo (CCAD).

Figure 4. Accumulated number and area of biological reserves in Central America. Numbers may be different according to published data or different criteria applied by national authorities. Some areas are still not clearly delimited and others are “virtual reserves”.

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<table>
<thead>
<tr>
<th>Territory (sq.km)</th>
<th>Guatemala</th>
<th>Belize</th>
<th>El Salvador</th>
<th>Honduras</th>
<th>Nicaragua</th>
<th>Costa Rica</th>
<th>Panama</th>
<th>Central America</th>
</tr>
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<tr>
<td></td>
<td>108,889</td>
<td>22,966</td>
<td>21,040</td>
<td>112,492</td>
<td>130,682</td>
<td>51,100</td>
<td>75,517</td>
<td>522,686</td>
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<tr>
<td>Population (thousand)</td>
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<td>266.4</td>
<td>6,500</td>
<td>6,900</td>
<td>5,484</td>
<td>4,262</td>
<td>3,253</td>
<td>38,665.40</td>
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<tr>
<td>Forest cover</td>
<td>37.2%</td>
<td>79%</td>
<td>9.6%</td>
<td>48%</td>
<td>24.5%</td>
<td>40%</td>
<td>45%</td>
<td>39.06%</td>
</tr>
<tr>
<td>Number of protected areas</td>
<td>123</td>
<td>74</td>
<td>3</td>
<td>64</td>
<td>26</td>
<td>155</td>
<td>50</td>
<td>545</td>
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<td>Protected territory</td>
<td>29.40%</td>
<td>47.20%</td>
<td>0.33%</td>
<td>21.70%</td>
<td>17%</td>
<td>25.20%</td>
<td>26%</td>
<td>23.35%</td>
</tr>
</tbody>
</table>

Table 1. Relevant data of Central American countries.
Actually in Central America it has been legally declared that more than 545 protected areas, occupying approximately 23.35% of the terrestrial surface of the region (see Table 1 and Figure 5). Guatemala, Nicaragua, Costa Rica and Panama protect almost 29.40%, 17%, 25.20% and 26% of their territory, respectively. Astonishingly Belize protects the 47.20% of its territory, whereas El Salvador with only 9.6% of its natural forest remaining protects only 0.33% of its territory in just three legally declared protected areas.

Figure 5. Protected areas of Central America. Data courtesy of CCAD.

3. The Knowledge of Entomological Diversity in Central America

The first modern contribution to the knowledge of the Central American entomological diversity was the 67-volume *Biologia Centrali-Americana* (http://www.sil.si.edu/digitalcollections/bca/) published over several decades, beginning in 1879, as a result of the British expeditions of Frederick Ducane Godman and Osbert Salvin. Insects were collected by Salvin and Godman or by contacted collectors in Central America (particularly, A. Salle, M. Boucard, J.J. Rodriguez, L. Conradt and F. Sarg (Guatemala), P. Blanchaneaux (Belize), T. Belt, E.M. Janson and W.B. Richardson (Nicaragua), H. Rogers, P. Bioley, Van Patten, C.F. Underwood and H. Lankester (Costa Rica), E. Trötsch, H. Ribbe and A. Boucard (Panama)), but most of the collecting work was due to George C. Champion who spent four years (from March 16, 1879 to May 23, 1883) collecting in Guatemala and Panama (Godman 1915, Champion 1907). Forty-three volumes deal with insects, arachnids, and myriapods, 38 of which are dedicated solely to insects, covering 30,802 species. Most groups of organisms, and certainly insects, have received little or no attention since then and the “*Biologia*” continue to be used by young taxonomists.
At present, we recognize the development of moderate-sized insect collections in Guatemala (Universidad del Valle de Guatemala), El Salvador (Museo de Historia Natural de El Salvador), Honduras (Escuela Agrícola Panamericana El Zamorano), Nicaragua (Museo Entomológico de Leon), Costa Rica (CATIE and the University of Costa Rica) and Panama (Museo de Invertebrados G.B. Fairchild de la Universidad de Panama). However, the more than 3 million of insect specimens collected and stored by the Instituto Nacional de Biodiversidad de Costa Rica (INBio) represent the most coordinated and efficient effort toward the knowledge of entomological biodiversity in any country of Central America in the last 20 years.

As a result of contributions from all countries, several publications dealing with insects of Central America have been realized. Of particular interest are regional taxonomic guide-style publications such as “The dynastine scarab beetles of Costa Rica and Panama” (Ratcliffe 2003), “The dynastine scarab beetles of Honduras, Nicaragua and El Salvador” (Ratcliffe and Cave 2006), “Insects of Panama and Mesoamerica” (edited by Quintero and Aiello in 1992), “Orchid bees of tropical America: Biology and field guide” (Roubik and Hanson 2004), “Dragonflies and damselflies of Middle America and the Caribbean” (Esquivel 2006), and “Treehoppers of tropical America” (Godoy et al. 2006), as examples.

4. Insects as Bioindicators

Recently, insects, due to their small length, diversity and sensitivity to environmental stress have been considered as good indicators of habitat heterogeneity, ecosystem diversity and environmental stress. Insects have been used as indicators (or surrogates) of biodiversity and endemism, prioritization for establishment of protected areas, biogeographic relationships, bioindicators of anthropogenic changes in the forest, water quality and areas of importance for bioprospecting. Insects are the most diverse group of living organisms in the world with more than 1 million described species of a total of perhaps 5-10 or more. There are so many insect species that to study all is impossible when the time, resources and taxonomic expertise are so scarce but the forest destruction is accelerated. In this sense, the utilization of indicator taxa is recommendable to identify the key regions for forests conservation or to prioritize them when economic resources are limited.

Although the use of the term bioindicator or biodiversity indicator has been used in different ways, McGeoch (1988) suggests that the use of insects as bioindicators can be apportioned into three categories: environmental indicators, ecological indicators and biodiversity indicators. An environmental indicator is a species or group of species that responds predictably, in ways that are readily observed and quantified, to environmental disturbance or to a change in environmental state. An ecological indicator is a characteristic taxon or assemblage that is sensitive to identified environmental stress factors, which demonstrates the effect of these stress factors on biota, and whose response is representative of the response of at least a subset of other taxa present in the habitat. A biodiversity indicator is a group of taxa (e.g. genus, tribe, family or order, or a selected group of species from a range of higher taxa), or functional group, the diversity of which reflects some measure of the diversity (e.g., character richness, species richness, level of endemism) of other higher taxa in a habitat or set of habitats.
For the purpose of this work we follow this definition of biodiversity indicator.

Accelerated rates of deforestation and predictions about species loss and global threat to biodiversity make imperative increasing conservation efforts such as establishment of biological reserves. Various methods of prioritization have been published and applied to conservation of forests. These methods require deep knowledge about species richness per site, phylogenetic relationships of the indicator groups, well known geographic distribution and systematic sampling. Nevertheless, for most of Central American countries where the biological information is scarce, the use bioindicator groups (well studied in the region) such as passalid beetles, dung beetles and leaf litter-inhabiting weevils and rove beetles, can be cheap, rapid, contrasting, and strong at the moment to give objective and confident criteria to prioritize the establishment and evaluation of protected areas, especially when destruction is accelerated and the call for conservation is critical.

5. The Experiences in Central American Countries

Prioritization for conservation is the selection of the least number of areas that includes most of the biodiversity of a region, with the purpose of legally declaring and establishing biological reserves, within budget limitations. Prioritization is based on calculation of values of species richness, endemism, rarity and complementarity or GIS analysis. Complementarity refers to the need, once a representative target has been set, for new reserves to complement previous ones as fully as possible in the features they contain rather than to duplicate features unnecessarily (Pressey et al. 1996). A widely used approach, the Greedy principle, is to select a reserve site at each step in such a way that the largest number of ‘under-represented’ species will be added to the set of species jointly represented by previously chosen reserve sites (Önal 2003). Also endemism or rarity of species can be used or added to the analysis.

GAP analysis is a technique based on Geographical Information System (GIS) when abundant samples and distributional data are available. It consists in assessments of georeferenced databases overlaying different maps or data layers, in order to obtain the optimal solutions to elucidate gaps in biodiversity conservation systems, by the use of algorithms.

In Central America we known only three studies that deal with beetles as indicators for establishment of biological reserves; one by Anderson and Ashe (2000) using rove beetles and weevils, others by Schuster et al. (2000) with passalid beetles and Kohlmann et al. (2007) using dung beetles.

Case 1. Leaf Litter Weevils (Curculionidae) and Rove Beetles (Staphylinidae) in Honduras

Weevils (“picudos” or “gorgojos” in Spanish) are beetles of the family Curculionidae (Figure 6) that have an elongate rostrum (snout) with biting mouthparts situated at the apex and with geniculate antennae having a compact antennal club. They live in plants, soil or in freshwater and both adults and larvae are phytophagous. Adults of forest litter species are flightless and have reduced eyes, characters associated with highly endemic
groups (Anderson and Ashe 2000). Curculionidae is the largest family of beetles, and indeed perhaps the largest of any taxonomic group of living organism in the world, with over 60,000 worldwide described species. Most species (and genera) of weevils inhabiting leaf litter in Central America are new to science and in consequence there is a problem in the correct taxonomic identification of species. Nevertheless, until these species may be described, the problem can be avoided by the use of the morphospecies methodology and comparisons with voucher specimens of the Central American collections. At present, the most useful key to identification of Central American genera of weevils, prepared by Robert Anderson, is contained in the Volume 2 of the American Beetles, edited by Ross Arnett Jr. and collaborators.

Figure 6. Different curculionid species inhabiting leaf litter in Central America. a. *Tylodinus piazurus*; b and c are new species of undescribed genus; c. *Tylodinus* new species.

The rove beetles (Figure 7), although highly variable in aspect, are small-elongated insects mostly with short elytra exposing part of a flexible abdomen; they have contiguous procoxae. Most species live in leaf litter and many types or decaying organic matter, rotten logs, fungus, mosses, flowers, shorelines of aquatic ecosystems and in rodent hair. Most species are predators of invertebrates with exceptions feeding on fungus or decomposing organic matter. Staphylinidae is the second largest family of beetles with more than 46,000 described species. Presently, the most useful keys to rove beetle identification in Central America are the “Illustrated guide to the genera of Staphylinidae of Mexico” by José Luis Navarrete and collaborators and the key to Neartic genera of Staphylinidae of Alfred Newton and collaborators, contained in

Curculionidae and Staphylinidae are the two most species-rich and most numerically dominant taxa in the leaf litter community (Anderson and Ashe 2000). Anderson and Ashe (2000) characterized the community structure for the leaf litter Curculionidae and Staphylinidae, of 17 cloud forests localities in Honduras and El Salvador (two localities). Using these results they realized a priority-areas analysis for selection of reserves, based on non-parametric estimation of species richness (Sobs and Chao2 of the EstimateS Program, by R.K. Colwell (2006)), number of endemic species and complementarity (using Greedy principle) of sites. In the complementarity method the site with the highest Sobs is the first ranked; subsequent priorities are based upon maximizing the number of new species added by the addition of any one site (Anderson and Ashe 2000). Sites with species shared with other previously selected sites, may be low ranked; sites with most exclusive species will be highly ranked. In each locality they sampled forest floor debris which was vigorously sifted until approximately 4.5 liters of sifter litter had accumulated. Beetles were extracted during six hours from each sample (replica) by placing 1.5 liters of litter in three Berlese funnels with a layer of cheesecloth placed on 1 cm hardware cloth with a 60 W light bulb as source of heat, and a bottle of 90% alcohol under the funnels. Replicates varied from 4 to 18 per site. Specimens were sorted, mounted, labeled and identified as morphospecies by the authors.

Figure 7. Staphylinid species inhabiting leaf litter in Central America.
Weevils

The results for weevils of Anderson and Ashe shown that Montecristo National Park (a tri-national reserve in the Guatemalan-Honduras-El Salvador limits) was the most diverse site (62 species), followed by Güisayote Biological Reserve (49 species), and Santa Barbara National Park (48 species) (see Honduras in Figure 8 for localities). Nevertheless, the performance of the estimator Chao 2 predicts bigger species richness for La Muralla National Park in elevation between 1430-1450m, than Güisayote.


Endemism was greater at Santa Barbara National Park (27 species), followed by Montecristo National Park (23 species).

In their priority-areas sequences Anderson and Ashe (2000) ranked Montecristo as the first priority but the second priority differed largely due to low complementarity (high number of shared species) between Montecristo and Güisayote. When the Greedy principle is used, the Santa Barbara National Park is ranked two and La Muralla (1430-1450m) is ranked as the third priority. When the Chao 2 method is used, Montecristo also ranks first, La Muralla ranks second and Güisayote the third. When the priority-
areas sequence is based on number of endemics Santa Bárbara (27 endemics) ranks first, Montecristo ranks second and Comayagua National Park and Cusuco National Park (1960-2080 m), rank third.

Rove Beetles

The results for rove beetles of Anderson and Ashe (2000) show that La Muralla National Park (1430-1450m) was the most diverse site (61 species), followed by Montecristo (46 species), and Santa Barbara (43 species) (see Honduras in Figure 8 for localities). However, based on Chao 2 estimator the sites of Güisayote and Montecillos ranks first and third respectively (because large numbers of species represented by only one individual), with La Muralla (1430-1450m) ranked second.

Endemism was greater at La Muralla (1430-1450 and 1510-1550 m) with 31 species, Santa Barbara (11 species) and Montecristo (10 species). Endemism was present, at different levels, in all sites.

In their priority-areas sequences Anderson and Ashe (2000) ranked La Muralla (1430-1450m) as the first priority, and Montecristo as the second priority area, independent of the method. Using the Greedy principle Yuscaran Biological Reserve ranks as third priority and Santa Barbara fourth (third in terms of Sobs). When Chao 2 is used, Güisayote is the first priority, La Muralla (1430-1450 m) is the second and Montecillos is the third.

When the priority-areas sequence is based on number of endemics, La Muralla (24 endemics) ranks first, Santa Barbara (11 endemics) ranks second and Montecristo is ranked third together with Güisayote (both with 10 endemics).

Prioritization with Combined Data

Combining results of Staphylinidae and Curculionidae, Anderson and Ashe (2000) obtained four highly ranked sites (very high priority), to be considered as conservation priorities (see Honduras in Figure 8): Montecristo National Park, La Muralla National Park, Santa Barbara National Park and Comayagua National Park. A second priority level (high priority) includes the Güisayote Biological Reserve, La Tigra National Park and Cusuco National Park (see Honduras in Figure 8).

The results show that different monophyletic taxa produce relatively similar results (with some exceptions) and that rapid systematized inventories may be helpful and practical for countries with scarce biological studies.

Case 2. Bess Beetles (Passalidae) in Guatemala

Passalids or bess beetles (Figure 9) are moderate to large size (13-80 mm length), black scarabiods that live in family groups in tunnels of rotten logs, although a few species live in decaying plant material among the rhizomes of epiphytic ferns or in detritus chambers of leaf-cutter ants (Atta spp.). In some species occurring in montane forests adults have reduced eyes and are flightless and, in consequence, are markedly endemic.
Passalids are distributed in the tropics of the world with more than 600 described species, a few reaching the United States, Canada and Japan. The most important works for the taxonomic study of passalids in Central America are the scarab volume of the *Biologia Centrali-Americana* by Henry Walter Bates (http://www.sil.si.edu/digitalcollections/bca/navigation/bca_12_02_02/bca_12_02_02select.cfm), revisions of the Neotropical family by Pedro Reyes-Castillo in 1971 and Stephane Boucher in 2005, and the online “Key to American genera of Passalidae” by Schuster and Cano (http://www-museum.unl.edu/research/entomology/Guide/Scarabaeoidea/Passalidae/Passalidae-Key/Passalidaekey.pdf). Taxonomic determination to species level is easy but, except for Panama (Reyes-Castillo and Castillo 1992), a key or guide to the species in Central America is lacking and many species are awaiting description. Published revisions of highly endemic genera such as *Spurius*, *Petrejoides*, *Oileus*, *Odontotaenius*, *Ogyges*, *Xylopasassaloides*, *Proculus*, *Veturius*, *Arrox* and ongoing revisions of *Popilius* and *Verres* may be helpful for taxonomic identification. The most important collections with Central American passalids are in the Instituto de Ecologia, Xalapa, Veracruz, Mexico; Universidad del Valle de Guatemala, Guatemala; Instituto Nacional de Biodiversidad, INBio, Costa Rica; Muséum Nationale d’Histoire Naturelle, Paris, France; The Natural History Museum, London, England and the U.S. National Museum of Natural History (Smithsonian) in Washington.

Passalid beetles have been intensively studied in Central America for more than 30 years by Jack Schuster. One of the best sampled regions was the Sierra de las Minas in Guatemala and, due to the high diversity and endemism (similar Herpetofauna data by Jonathan Campbell), were used to justify the establishment of the Sierra de las Minas Biosphere Reserve, recognized by UNESCO. It has been possible to use passalids due to the existence of local facilities for taxonomic identification such as collections, publications and experts. Geographical distribution and areas of endemism of species are well known, at least in the northern portion of Mesoamerica (Figure 10). Endemism is common principally in cloud forests above 800 m in elevation and in most cases endemic species are frequently collected. As flightless species, they are not migratory as are butterflies or birds and, due to the presence of adults all year, it is possible to evaluate an area in any time of the year. Collecting is easy looking for rotten logs during at least 3 hours per site with two persons, one with an axe an the other with a machete.

Figure 9. *Paxillus leachi*, a common lowland passalid beetle.
Studies of jewel scarabs (genus *Chrysina*), the june beetles genus *Phyllophaga*, Plethodontid salamanders and small mammals (rodents and shrews), shown similar endemism patterns as those of Passalidae. As a consequence, in Guatemala, passalids now are being used as a major component of Technical Studies for Declaration of Protected Areas in cloud forests for the Parque Nacional Cerro El Amay, Quiche department and Reserva de Vida Silvestre Volcan Lacandon, Quetzaltenango department. Evaluation of the Montecristo Trinational Protected Area shared between Guatemala, El Salvador and Honduras, also included the study of passalid beetles.

![Figure 10. Map of areas of endemism of the north of Central America. White area is above 800 m altitude. Numbers indicate areas of endemism: 1. Northern Chiapas; 2. Southern Chiapas; 3. West Sierra de los Cuchumatanes; 4a. West volcanoes; 4b. East volcanoes; 5a. Sierra de las Minas; 5b. South Sierra de Chama; 5c. East Sierra de los Cuchumatanes; 6. Trifinio (Cerro Montecristo); 7a. El Portillo region (Honduras); 7b. La Union, Zacapa; 7c. Tecuamburro region; 7d. Santa Barbara (Honduras); 8. Sierra del Merendon.](image)

For these reasons Passalidae were proposed by Schuster and collaborators in 2000 as good bioindicators to determine what regions of cloud forest are more similar or complementary, what areas have most endemic species and/or species richness. Based on these data areas could be prioritized for conservation.

**Methods**

Data for prioritization of Guatemalan cloud forests were formerly published by Schuster et al. (2000). Since, new data were added in the same format. Passalid assemblages from 32 cloud forests of Guatemala of elevation between 900-3100 m were analyzed. To prioritize, a “Priority Value” (PV) was obtained based on the sum of endemism, species richness and state of forest conservation, adjusting the maximum value in each item to 5. Maximum value of species richness (13) and endemism (5) was adjusted to 5.
and the minimum value was adjusted to 0. Areas officially protected and with personnel and management plan were ranked as 0 and areas without any protection were ranked as 5. A species was considered as endemic if it is present only in one of the endemism areas of Figure 10. The adjusted value of richness of endemism was calculated as a simple proportion. For example, for a richness of 10 species, the adjusted species richness rank is 3.85 (in other words, (5/13) x10 = 3.85). This way the species richness rank could not be greater than 5. With these values forests were classified as localities of Very High Priority, High Priority, Medium Priority and Low Priority (Table 2). If conflict exists, cluster analysis based on similarity index of passalid assemblages (Figure 11) may help to take a decision.

![Cluster analysis of Passalidae assemblages of 32 cloud forests in Guatemala. Rescaled distance cluster combined, index is Dice (= Sorensen), grouping is UPGMA.](image)

Figure 11. Cluster analysis of Passalidae assemblages of 32 cloud forests in Guatemala. Rescaled distance cluster combined, index is Dice (= Sorensen), grouping is UPGMA.
<table>
<thead>
<tr>
<th>Locality</th>
<th>Species Richness</th>
<th>Adjusted richness</th>
<th>Endemic species</th>
<th>Protection grade</th>
<th>Priority value</th>
<th>Type of priority</th>
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<td>3.46</td>
<td>3</td>
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<td>La Fraternidad, San Marcos 1800m</td>
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<td>3</td>
<td>5</td>
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Table 2. Passalid beetle prioritization for Guatemala. RBSM= Sierra de las Minas Biosphere Reserve.
Results

The sites with highest species richness are Purulhá, Baja Verapaz (13 species), Laj Chimel, Uspantán (11), La Unión, Zacapa (10), Sierra de Caral (10), Río Zarco (9) and Yalambojoch (9) (see Table 2). Forests with high endemism are San Lorenzo 2260-2400m, (5 species) and Cerro Pinalon, 2400-2500m (4 species) (see Table 2). Four of these mentioned localities are included in two biological reserves (Río Zarco, San Lorenzo and Cerro Pinalon in the Sierra de las Minas Biosphere Reserve and Biotopo del Quetzal).

Areas with very high conservation priority (priority value from 11.85 to 10.46) in Guatemala (see Table 2 and Guatemala in Figure 8) are Sierra de Caral, Izabal (900-1200m) (PV=11.85); Yalambojoch, Huehuetenango (1800 m) (PV=11.46); La Fraternidad, San Marcos (1800 m) (PV=11.08); La Unión, Zacapa (1500 m) (PV=10.85); Santa Eulalia, Huehuetenango (2500-2700 m) (PV=10.69); Trifinio (Cerro Montecristo, 1600-1900 m) (PV=10.69); Laguna Maxbal (PV=10.69); and Chiblac, Barillas, Huehuetenango (1200-1400 m) (PV=10.46).

Very highly prioritized sites are located in endemism areas 3, 4, 6, 7 and 8 (Figure 10) showing the importance of establishment of reserves in each endemism area in Guatemala. Actually these areas do not have real protection in Guatemala. Nevertheless, helped by these data, Sierra de Caral is near to being established as biological reserve, under administration of Fundacion para el Ecodesarrollo (FUNDAECO). Cerro Montecristo, although unprotected in Guatemala and Honduras, has an excellent level of protection in the El Salvador. Private reserves were recently established near La Fraternidad forests and a governmental technical study for reserve declaration of joined forest of Lacandon “volcano” was recently published and is expecting approval of the Guatemalan Congress (CONAP 2005).

A second level of priority (priority value between 10.31 to 9.08), named high priority (see Table 2 and Guatemala in Figure 8) includes the Fuentes Georginas, Quetzaltenango (2400-2500 m); Santa Eulalia, Huehuetenango (1800-2060 m); Laj Chimel, Uspantán, Quiché (2100 m); Cerro Nylon, Izabal (1100 m) and Cerro Miramundo, Santa Rosa (1800 m).

A complementary criterion based on a cluster analysis (Figure 11) of passalid assemblages was proposed when forests obtain the same priority value. For example, localities Atitlán volcano southern slope (2250-2500 m) and Acatenango volcano (2200-2500 m) have the same priority value (8.92) (Table 2); if the similarity dendrogram is analyzed (Figure 11), Atitlan volcano seems similar to Fuentes Georginas (2400-2500 m), therefore Acatenango volcano will be prioritized because it has a Passalidae assemblage more unique.

Case 3. Dung Beetles (Scarabaeidae: Scarabaeinae) in Costa Rica

Dung beetles (Figure 12) are scarabs of the subfamily Scarabaeinae, small to large (2-60 mm), round or oval in appearance, with clypeus expanded, covering the mouthparts. Although many species feed on mammalian dung, others feed on carrion, rotting fruit,
mushrooms and dung of other animals such as turtles or terrestrial snails. More than 5,000 species has been described in the world.

Figure 12. *Onthophagus landoldti* (female), a common dung beetle of Central American pastures.

Dung beetles have been proposed by Halffter and Fávila (1993) as indicators for the study of the basic aspects of biodiversity in tropical forest and for monitoring the effects of anthropogenic landscape alteration. Dung beetles constitute a well-defined guild and, in recent years, have been demonstrated to be very sensitive to destruction of tropical forests in Latin America (e.g. Howden and Nealis 1975, Peck and Forsyth 1982, Klein 1989, Halffter et al. 1992). The biology is relatively well known from classic works such as those of Halffter and Matthews (1966) and Hanski and Cambefort (1991). Also, dung beetles are easily collected with cheap pitfall traps baited with human, pig or cow feces, supplemented with traps baited with carrion (rotten fish, meat or chicken).

A general key to Central American species of dung beetles is lacking but the “clave para determinar a los taxones genéricos y supragenéricos de Scarabaeoidea Latreille, 1802 (Coleoptera) de México” by Delgado and Blackaller (2000), and the keys included in the synthesis of the Scarabaeinae of Panama by Howden and Young (1981) are still useful. As in passalid beetles, scarab volume of the *Biologia Centrali-Americana* by Henry Walter Bates (http://www.sil.si.edu/digitalcollections/bca/navigation/bca_12_02_02/bca_12_02_02se...
lect.cfm is vital for the study of dung beetle taxonomy. Information of taxonomic works useful for Central American material was summarized by B. Kohlmann et al. (2007).

Methods

Bert Kohlmann et al. (2007) using geographic information system (GIS), analyzed the distributions of dung beetles in Costa Rica. They analyzed areas with high species richness and endemism based on Holdridge’s life zones map and altitudinal distribution. The species richness and endemism maps obtained were used for defining four different levels of priority for conservation areas, based on GAP analysis. Information was taken from the INBio’s database that represents approximately 90 000 Costa Rican dung beetle specimens, mostly from protected areas.

Results

Greatest species richness of dung beetles in Costa Rica was found in areas of elevation between 0-1000 m (84-110 species). Between 1000 and 2000 m diversity was moderate (65-71 species) but very low above 2000m (5-10 species). Endemism was major at middle (61 species) and lower altitude (54 species), but minor at highest altitude (6 species). Majority of strictly endemic Costa Rican species are located along the Guanacaste, Tilarán and Central mountain ranges, and in the rainforests of the Pacific and Caribbean lowlands.

In correlation with the life zone system of classification (see Figure 3), highest species richness occurs in the premontane wet forest (750-1500 m) in the Pacific versant (89 species), followed by the tropical wet forest (800-1500m), on the Caribbean versant (70 species), the tropical wet forests on the Pacific (62 species) and Caribbean versants (57 species), and the premontane wet forest on the Pacific versant (57 species). Kohlmann and collaborators mapped eight areas of endemism of dung beetles in Costa Rica based on the presence of at least nine species in each area. Mid-elevation wet forests have the majority of endemic species of dung beetles.

Prioritization

Based on maps of species richness, endemism and protected areas, Kohlmann et al. (2007) developed a map of four zones of priority (see Costa Rica in Figure 8). In priority zone 1 the highest species richness and greatest endemism coincide (from Guanacaste to the Central Cordillera along the Pacific versant at mid-altitudes); priority zone 2 represents an area of only the highest species richness (mid-altitude Caribbean versant of the Guanacaste Cordillera); priority zone 3 represents areas where the second highest ranks of species richness and endemism coincide (areas along both versants from low to mid-altitudes); priority zone 4 represents an area of only the second highest rank of endemism (both versants of the Talamanca Cordillera at mid-elevations).

Prioritization of Kohlmann et al. (2007) shows that:

1) Many protected areas in Costa Rica do not coincide with regions of high species
richness and endemism of dung beetles.

2) The zones with highest priorities (1 and 2), are under-protected in the National System of Protected Areas of Costa Rica.

6. Conclusions... What Lacks To Do?

Objective procedures for prioritization and selection of areas for establishment of biological reserves must replace the old opportunistic method based on availability of forests, supplemented with general botanical studies and scarce data on vertebrates (frequently, birds and big mammals) with a wide range of ecological requirements. Biodiversity inventories are scarce in Central America but often are considered as a tool for guiding conservation planning at a local scale. Beetles have been shown to be efficient, cost-effective indicators for prioritization of conservation areas. The only other organisms used for this kind of work have been birds, reptiles and amphibians in El Salvador (Komar 2002, Greenbaum and Komar 2005); the results also indicated, as with beetles (passalids, curculionids and staphylinids), that Cerro Montecristo is of highest priority for conservation for three countries, Guatemala, Honduras and El Salvador.

In the case of Costa Rica, data from endemism of dung beetles is similar to those of vertebrates and plants, supporting areas of endemism in the Talamanca mountain range, Central Cordillera, Golfo Dulce, Turrubares mountain, and the Herradura mountain range. Nevertheless, Kohlmann and collaborators, based on dung beetles analysis, also proposed the Guanacaste mountain range, the Tilaran mountain range and the Caribbean northern plains as new areas of endemism for Costa Rica.

In the case of Guatemala, Scarabaeoid beetles (particularly Passalidae) are the best known group of insects; in fact, more well-known than most organisms.

In Central America, biologists must supply useful data to policy makers so that they can make well-informed decisions concerning reserve establishment. In order to obtain this data biologists must receive adequate support for basic research into taxonomy of potential indicator taxa, especially in tropical countries where technical capacity is often limited. Various taxa could be useful as indicators, but little is known concerning their distributions and/or taxonomy. Some which may prove useful include: certain Tenebrionidae in rotting wood and fungi, certain Cerambycidae in leaf-litter and foliage, millipedes, Carabidae, ants, Fulgoridae, fleas, wingless Phoridae and other wingless flies and wasps.

Economical support to established scientific collections may guarantee the access to specimens and digitized databases in order to accelerate the knowledge and conservation of the rich Central American biodiversity.

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areas of Central America. Also thank Universidad del Valle de Guatemala and Escuela de Biologia de la Universidad de San Carlos de Guatemala for support. Ivonne Oviedo and Wilson Zúñiga provided data of protected areas in Honduras; Fernando Castro provide data of protected areas in Guatemala and Central America. The digitized maps were prepared by Jorge O. Aguilar. Scarab of Figure 12 was illustrated by Ariel Castillo.

Glossary

**Berlese Funnel:** A device used to collect insects from leaf litter using the heat from a lamp. The insects try to move downward away from the heat and end up falling into a collecting jar.

**Endemic species:** Species with a range of distribution natural restricted to a unique place or region of the world.

**Geniculate antenna:** Antenna with the first segment elongated and the remaining segments coming of the first segment at an angle.

**Morphospecies:** A morphologically recognizable species used for taxa that are difficult to name or that have not been described.

**Procoxae:** The basal segment of the first (anterior) pair of legs.

**Speciose:** Rich in number of species.

**Taxa:** Plural of taxon.

**Taxon:** A group of organisms classified together.

**Taxonomy:** The description, naming and classification of life forms.

**Terrane:** A crustal block or fragment that preserves a distinctive geologic history that is different from the surrounding areas and that is usually bounded by faults.

**Replica:** Number of experimental units receiving each treatment.

**Sample:** A portion of a biological community or assemblage chosen to represent the whole.

**Sifter:** A device used to collect, or strain, insects shaken out of the forest floor debris.

**Species richness:** A measure of biodiversity that represents the number of different species in a given area.

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Costa Rica


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