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BUTTERFLIES AND VEGETATION IN RESTORED GULLIES OF DIFFERENT AGES AT THE COLOMBIAN WESTERN ANDES*

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Abstract

Erosion control structures made with green bamboo *Guadua angustifolia* and high density plantings have been combined efficiently for restoring gullies in the Andean hillsides of Colombia. However, the effects of these practices on the native fauna have not been evaluated. Richness and abundance of diurnal lepidopterans were studied between 2006-2007 in five 10 m^2 transects within each of eight gullies. Four gullies restored using the method mentioned above (6, 9, 12 and 23 months following intervention), each with its corresponding control (unrestored gully) were sampled four times with a standardized method. A vegetation inventory was done at each gully. More individuals and species (971, 84 respectively) were found in the restored gullies than in the control ones (501, 66). The number of butterfly species tended to increase with rehabilitation time. Ten plant species, out of 59, were important sources of nectar for lepidopterans. Larval parasitoids were also found indicating the presence of trophic chains in the study area. This paper describes the rapid and positive response of diurnal adult butterflies to habitat changes associated with ecological rehabilitation of gullies through erosion control structures and high density planting. Introducing and maintaining a high biomass and diversity of plants may help to reestablish the food chain and ecological processes in degraded Andean landscapes.

Key words: ecological restoration, erosion control, *Guadua angustifolia*, Lepidoptera, nectar.

MARIPOSAS Y VEGETACIÓN EN CÁRCAVAS RESTAURADAS DE DIFERENTES EDADES EN LOS ANDES OCCIDENTALES DE COLOMBIA

Resumen

Las estructuras biomecánicas para el control de la erosión hechas con guadua y la siembra de plantas en alta densidad han sido aplicadas eficientemente para restaurar cárcavas en las laderas de los Andes colombianos. Sin embargo, los efectos de estas prácticas sobre la fauna nativa no se han evaluado hasta ahora. Se estudiaron la riqueza y la abundancia de lepidópteros diurnos entre 2006 y 2007 en cinco transectos de 10 m^2 dentro de cada una de ocho cárcavas. Se muestrearon cárcavas que habían sido restauradas usando el método mencionado anteriormente (6, 9, 12 y 23 meses después de la intervención), cada una con su control correspondiente (cárcava sin restaurar) cuatro veces con un método estandarizado. Se realizó un inventario de la vegetación en cada cárcava. Se encontraron más individuos y más especies (971, 84 respectivamente) en las cárcavas restauradas que en las control (501, 66). El número de especies de mariposas tendió a incrementar con el tiempo de rehabilitación. Diez especies de plantas de un total de 59 fueron fuentes importantes de néctar para lepidópteros.

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Se encontraron parasitoides de larvas indicando la presencia de cadenas tróficas en el área de estudio. Este trabajo evidencia la rápida y positiva respuesta de las mariposas diurnas a los cambios de hábitat asociados con la rehabilitación de cárcavas a través de estructuras de control de la erosión con una alta densidad de siembra. El aumento en la biomasa y la diversidad de plantas puede ayudar a reestablecer cadenas tróficas y procesos ecológicos (i.e. polinización) en las laderas Andinas degradadas.

Palabras clave: restauración ecológica, control de la erosión, *Guadua angustifolia*, lepidóptera, néctar.

Landslides and the formation of headward-migrating gullies are two common problems linked to land degradation in the Andean region, where most of the Colombian population is concentrated (ETTER & VAN WYNGAARDEN, 2000). Gullies are open erosion channels formed when fast-flowing water converges on a small surface depression and the energy of water scours away the soil. Once the topsoil and vegetation are removed, gullies spread rapidly up or down the drainage lines (RIVERA & SINISTERRA, 2006). Natural factors such as geologic instability, deep slopes and heavy rainfall act together with anthropogenic disturbances related to overgrazing, road construction and poor soil conservation practices (RIVERA, 1998), causing human deaths, economic losses and ecosystem degradation.

One method for restoring severely degraded areas (i.e. gullies) combines erosion control structures made with giant bamboo *Guadua angustifolia* (Kunth) and high density planting of native plants that exhibit quick growth and sprouting (RIVERA & SINISTERRA, 2006). The interlocking roots of trees and shrubs provide deep and lateral anchorage in the soil profile. This vegetation restores slope stability by enhancing soil resistance to breaking (RIVERA, 1998). In turn, both, soil stabilization and vegetation growth promote the recovery of ecological processes, and contribute to support the local flora and fauna (BURYLO et al., 2007). Therefore, this method enhances hillside stability and recovers ecosystem structure and function (WALTZ & CONVINGTON, 2004).

Evaluating the results of any type of ecosystem intervention (natural or human induced) is vital in order to understand which characteristics have affected the recovery of its ecological components (RUIZ-JAÉN & AIDE, 2005). For this purpose, the diversity and abundance of arthropods, have been recognized as efficient indicators of certain functional aspects of ecosystems (i.e. pollination, decomposition of organic matter, trophic webs), all of which have applications to conservation planning (ROSENBERG et al., 1986; KREMEN et al., 1993; FAGUA, 1996). Arthropods also contribute to the maintenance of ecosystem processes such as energy transfer and nutrient cycling (HOLL, 1996; WALTZ & COVINGTON, 2004).

Butterflies are sensitive to changes in temperature, humidity and solar radiation associated to habitat disturbance. The inventory and comparison of butterfly communities might be useful for monitoring the effects of ecologically sound practices and for evaluating the success of restoration and rehabilitation projects (KREMEN et al., 1993; FAGUA et al., 1999). However, there are different ways in which butterfly assemblages respond to ecosystem disturbance. Their richness decreases after logging events (HAMER et al., 2003; WALTZ & COVINGTON, 2004) and also throughout the transition from natural to urban areas (BLAIR & LAUNER,

1997; BLAIR, 1999; HARDY & DENNIS, 1999), albeit their diversity usually increases in forest canopy openings (WALTZ & COVINGTON, 2004). Our understanding of the factors that explain ecological patterns of lepidopteran communities such as the spatial and temporal distribution of species is still limited in relatively undisturbed ecosystems (DEVRIES et al,, 2009) and almost inexistent in restored areas (HOLL, 1996; RIES et al., 2001; LOMOV et al., 2006).

Knowledge regarding the way resource availability and habitat quality in restored habitats interact to determine species diversity of consumers (SUMMERVILLE et al., 2005) is still incomplete. This study compares the composition and diversity of the diurnal adult butterfly assemblages in areas previously affected by severe erosion and later subjected to a rehabilitation treatment based on erosion control structures made with bamboo *G. angustilfolia* and high density planting in Colombian hillsides. The purpose was to characterize the community (abundance and richness) of diurnal lepidopterans that transit or settle in restored and unrestored gullies of the municipality of Cali in the Western Andes of Colombia. The study was also intended to identify nectariferous plants that provide energetic resources for adult butterflies in treated gullies and to discuss the efficiency of diurnal Lepidopterans as a bioindicator of habitat restoration.

MATERIALS AND METHODS

Study area

This study was carried out at three localities of the eastern slope of the western Andes or Cordillera Occidental of Colombia, near to the city of Cali: (1) Los Andes (N 03º26´33.4´´ W 076º35´51.8´´) at 1.628 m a.s.l., (2) El Saladito (N 03º29´07.9´´ W 076º36´29.8´´) at 1755-1796 m a.s.l., and (3) Felidia (N 03º28´28.1´´ W 076º37´09.2´´) at 1719 m a.s.l. The average annual rainfall at the three localities varies between 1365 and 2500 mm, with occasional heavy rains (> 70 mm in a single event); mean annual temperature ranges between 17 and 18 ºC. The region is classified as a lower humid montane forest in the Holdridge system (ESPINAL, 1968). The three localities show severe erosion, associated with deforestation, inadequate location of rural housing, water leaks caused by deficient plumbing, and inadequate road drainage structures, all of them factors which exacerbate the local problems related to leaching and run-off water management.

Four Restored Gullies (RG) with different recovery times following the restoration intervention were sampled at the three localities: El Cabuyal - 23 months (RG_{23}), El Saladito - 12 months (RG_{12}), Felidia - 9 months (RG_{9}) and El Saladito - 6 months (RG_{6}). The rehabilitation treatment applied in the gullies included (1) building bamboo terraces at regular intervals to control runoff and underground bamboo filters to drain internal water (RIVERA & SINISTERRA, 2006) and (2) planting fast growing shrubs, herbs and grasses such as *Trichanthera gigantea* H&B Nees (Acanthaceae), *Arachis pintoi* Krapov & WC Gregory (Leguminoseae - Papilionoideae), *Tithonia diversifolia* Hemsl Gray (Asteraceae), *Bambusa vulgaris* var. Vittata A&C Riviére (Poaceae), *Gynerium sagittatum* (Aubl) Beauv (Poaceae), *Tripogandra* sp. (Commelinaceae), *Cynodon plectostachyus* K. Schum (Poaceae) and *Canavalia ensiformis* L. DC (Leguminoseae - Papilionoideae) (GIRALDO et al., 2008). The four gullies were restored at different time periods (although close, in terms of months).

For each restored gully, there was a very close unrestored gully, i.e. without any human intervention; each of these unrestored gullies hereinafter will be called "Control Gullies" (CG_{23}, CG_{12}, CG_9, CG_6,). Even though all of the gullies were formed by the same human-induced factors, their location varied within the landscape (Table 1). Each gully was sampled four times. Five 5 m x 2 m horizontal transects (i.e. perpendicular to the slope) were established within each gully. These transects, which will be considered sub-samples, were separated at least 1 m from one another.

Table 1. Study sites: restored and control gullies in three localities of the western Andes.

Gullies	Área (m^2)	Height (m a.s.l.)	Slope	Restoration time (months)	Surrounded by
RG_{23}	2000	1621	72º	23	Agricultural matrix
CG_{23}	600	1631	52º	0 (control)	Agricultural matrix
RG_{12}	550	1755	48º	12	Urban matrix
CG_{12}	154	1755	63º	0 (control)	Urban matrix
RG_9	198	1721	48º	9	Wooded path
CG_9	210	1718	51º	0 (control)	Semi-forested area disturbed during the construction of a rural aqueduct
RG_6	630	1796	53º	6	Urban matrix
CG_6	510	1790	71º	0 (control)	Urban matrix

Butterfly sampling

Butterflies were sampled between November-December 2006 (wet period) and January-February 2007 (dry period). All butterfly censuses and captures were carried out by the same person (OAO) and in standardized time through direct visual search and entomological net catch. In order to enhance independence, only those individual butterflies flying below 10 m height and perched on the vegetation were recorded in each transect.

The complete field work included a total of 32 sampling events in the three localities (8 gullies x 4 samplings). All censuses and captures were done between 9:30 a.m. and 12:30 p.m. along the five transects (36 minutes/transect), for a total sampling effort of 96 hours (3 h x 8 gullies x 4 samplings). Butterfly behavior was also registered (sucking, flying, perching). A reference collection (one individual of each species) was mounted from the specimens collected during the first samplings. Further captures were done only for specimens with doubtful *in situ* identification. Samplings were carried out only in the absence of rain, preferably on sunny days. Voucher specimens are deposited at the Entomology Museum of the Universidad del Valle (MUSENUV) in Cali.

Richness and abundance data were totalized for each sampling and gully, and were further compared using the Shannon-Wiener (*H*) diversity index and Pielou´s (*J*) equitability index. Butterfly abundance and species richness were plotted against the recovery time following restoration intervention and a linear regression was used to relate them (ZAR, 1996). The composition of butterfly assemblages was assessed through cluster analyses. Butterfly assemblages were qualitatively analyzed in terms of the existing vegetation at the gullies.

Vegetation structure and nectariferous plants

Because plants represent the food resources and refuge of diurnal butterflies, all individuals were counted and identified once within three 10 m^2 plots (2 x 5 m) in each gully. An Importance Value Index (IVI) was calculated for each species by adding its relative abundance, frequency and a cover class estimation value (based on DAUBENMIRE, 1959). Additionally, the vegetation height was measured five times. For this purpose, each vegetation plot was divided in five sub-subplots, 1 m x 2 m each. Plants were labeled and identified whenever a feeding behavior by butterflies occurred during the sampling periods.

RESULTS

Butterfly inventory. A total of 1476 individuals sorted in 102 species of butterflies were found in the gullies (Table 2). Nymphalidae was the richest family with 39 species, followed by Hesperiidae (23), Pieridae (16), Lycaenidae (13), Riodinidae and Papilionidae (six and five respectively). Nymphalidae, was represented by eight subfamilies, from which Heliconiinae was the richest (10 species), followed Satyrinae (9) and Nymphalinae (7). Subfamilies such as Danainae (2), Biblidinae (1) and Morphinae (1) were represented by a few species.

Butterfly assemblages: richness and abundance

The accumulated richness for the four restored gullies was 84 species (average of 19.15 ± 5.7 per transect), while a total of 66 species were found in the four controls (average of 13.5 ± 6.6 per transect). Shannon-Wiener index was H' = 1.8 for restored gullies and H' = 1.73 for the controls, and the Hutcheson test revealed statistical differences between the two means ($t_{[253]} = 3.03$; $P = 0.005$).

From the total lepidopteran fauna, 36 species were exclusively found in the restored gullies, while 18 were detected only in the controls. Hesperiidae (36%) and Lycaenidae (19.4%) most contributed to the exclusive species in the restored gullies, while Heliconiinae contributed the most to the controls with 16.66%. In terms of butterfly abundance, 66% and 34% of the registered events occurred in restored and control gullies, respectively. The most common species in the restored gullies was *Yphthimoides renata* (Nym.: Satyrinae) while *Siproeta epaphus* (Nym.: Nymphalinae) was the most abundant one in the control gullies.

Table 2. Butterfly species in restored (RG) and unrestored or control gullies (CG) at three localities of the Colombian Andes. The taxonomic classification followed LAMAS (2004).

	Restored Gullies (RG) and Control Gullies(CG)							
TAXON	**CG_{23}**	**RG_{23}**	**CG_{13}**	**RG_{13}**	**CG_{9}**	**RG_{9}**	**CG_{6}**	**RG_{6}**
HESPERIIDAE								
Hesperiinae								
Anthoptus epictetus (Fabricius, 1793)				X				
Cymaenes tripunctus (Herrich-Schäffer, 1865)			X					X
Quasimellana sp. Burns, 1994		X						
Morys valerius (H.B Möschler)		X			X			X
Nyctelius sp. (Hayward, 1948)								X
Psoralis degener (Plötz, 1882)		X						
Vacerra caniola (Herrich-Schäffer, 1869)				X		X		
Pyrginae								
Achlyodes pallida (Felder, 1869)	X							
Astraptes chiriquensis (Staudinger, 1876)		X						
Chioides catillus (Cramer, 1779)	X	X	X	X	X			
Cogia calchas (Herrich-Schäffer, 1869)		X						X
Eracon paulinus (Stoll, 1782)		X						
Heliopetes arsalte (Linnaeus, 1758)	X	X		X	X			X
Mylon lassia (Hewiston, 1868)				X			X	X
Noctuana noctua (C. & R. Felder, 1867)				X				
Pyrgus oileus (Linneaus, 1767)	X	X		X	X	X	X	X
Staphylus sp. Godman & Salvin, 1896		X						
Theagenes albiplaga (C. & R. Felder, 1867)					X			X
Urbanus proteus (Linnaeus, 1758)			X			X		

	Restored Gullies (RG) and Control Gullies(CG)							
TAXON	CG_{23}	RG_{23}	CG_{13}	RG_{13}	CG_{9}	RG_{9}	CG_{6}	RG_{6}
Urbanus simplicius (Stoll, 1790)								X
Urbanus teleus (Hübner, 182)		X			X			X
Xenophanes tryxus (Godman & Salvin, 1895)				X				
PAPILIONIDAE								
Papilioninae								
Heraclides paeon thrason (C. & R. Felder, 1865)				X	X	X	X	
Papilio polixenes americus (Kollar, 1850)		X		X		X		
Papilio thoas nealces (Rothschield & Jordan, 1905)	X	X						
Parides sp. Hübner, 1819				X				
Protesiliaus sp. Swainson, 1832		X						
PIERIDAE								
Coliadinae								
Anteos clorinde (Godart, 1824)			X	X				
Eurema albula (Cramer, 1776)	X	X		X	X	X	X	X
Eurema daira (Godart, 1819)	X	X	X	X	X	X	X	X
Eurema mexicana (Boisduval, 1836)					X			
Eurema salome (C. & R. Felder, 186)			X		X	X	X	X
Eurema sp. Hübner, 1819					X		X	X
Eurema xantochlora (Doubleday, 1847)	X			X	X		X	X
Phoebis neocypris rurina (C. & R. Felder, 1861)	X	X		X	X	X	X	X
Phoebis philea philea (Winhard, 2000)		X			X	X	X	X
Phoebis sennae (Linnaeus, 1758)	X	X	X	X	X	X	X	X
Pirysitia proterpia (Fabricius, 1775)	X							
Pirysitia venusta (Boisduval, 1836)	X	X			X	X	X	X
Dismorphiinae								
Dismorphia crisia foedora (Lucas, 1852)						X		

	Restored Gullies (RG) and Control Gullies(CG)							
TAXON	**CG_{23}**	**RG_{23}**	**CG_{13}**	**RG_{13}**	**CG_9**	**RG_9**	**CG_6**	**RG_6**
Pseudopieris viridula (C. & R. Felder, 1861)	X		X	X	X	X	X	X
Pierinae								
Catastica flisa (Herrich & Schäffer, 1854)						X		
Leptophobia aripa (Boisduval, 1836)	X	X	X	X	X		X	X
NYMPHALIDAE								
Danainae								
Danaus gilippus (Cramer, 1775)	X				X			X
Danaus plexippus (Linnaeus, 1758)			X					
Heliconiinae								
Actinote anteas (Doubleday, 1847)	X	X	X	X	X	X	X	X
Altinote ozomene (Godart, 1819)	X	X	X	X	X			X
Dione juno (Cramer, 1779)	X	X			X			
Dryas iulia (Fabricius, 1775)	X	X	X		X			
Heliconius charitonia (Linnaeus, 1767)						X		X
Heliconius clysonimus (Latreille, 1817)			X		X			X
Heliconius cydno weymeri f. gustavi					X			
Heliconius erato chestertoni (Hewitson, 1872)		X	X	X	X			
Heliconius cydno (E. Doubleday,1847)					X			
Heliconius sara (Staudinger, 1896)	X							
Ithomiinae								
Dirccena dero (Hübner, 1823)								X
Greta andromica (Hewitson, 1855)	X		X		X	X	X	X
Hypothyris lycaste (Fabricius, 1793)		X						
Mechanitis polymnia (Linnaeus, 1758)			X		X			

	Restored Gullies (RG) and Control Gullies(CG)							
TAXON	CG_{23}	RG_{23}	CG_{13}	RG_{13}	CG_{9}	RG_{9}	CG_{6}	RG_{6}
Melitaeinae								
Anthanassa drusilla drusilla (Higgins, 1981)				X				
Castillia eranites (Hewitson, 1854)						X		
Chlosyne sp. Butler1870				X				
Tegosa anieta (Hewitson, 1864)	X	X		X	X	X	X	
Morphinae								
Morpho peleides peleides (Kollar, 1850)					X		X	
Nymphalinae								
Adelpha alala (Hewitson, 1847)						X		
Adelpha serpa celerio (Bates, 1864)	X	X			X			
Anartia amathea (Linnaeus, 1758)		X			X	X		
Catonephele numilia (Cramer, 1779)					X	X		X
Epiphile epimenes Hewitson, 1857	X							
Siproeta epaphus (Latreille, 1819)	X	X	X	X	X	X	X	X
Vanessa myrinna (Doubleday, 1849)	X			X				
Biblidinae								
Marpesia zerynthia (Hübner, 1823)			X					
Satyrinae								
Corades enyo Hewitson, 1849					X			
Euptychia hesione (Sulzer, 1776)	X	X						
Euptychoides saturnus (Butler, 1867)	X	X			X			
Euptychoides griphe (C. & R. Felder, 1867)			X					
Hermeuptychia hermes (Fabricius, 1775)		X		X			X	
Oressinoma typhla Doubleday, 1849	X	X	X	X	X	X	X	X
Pronophila cf. *unifasciata brennus* Thieme, 1907	X	X	X	X	X	X	X	X
Pronophila sp. Doubleday 1864	X	X	X		X	X	X	X

	Restored Gullies (RG) and Control Gullies(CG)							
TAXON	**CG_{23}**	**RG_{23}**	**CG_{13}**	**RG_{13}**	**CG_{9}**	**RG_{9}**	**CG_{6}**	**RG_{6}**
Yphthimoides renata (Stoll 1780)	X	X	X	X	X	X		X
RIODINIDAE								
Riodininae								
Adelotypa elpinice (Godman, 1903)			X					
Calephelis laverna (Godman & Salvin, 1880)						X		
Calephelis sp. Grote & Robinson, 1869						X		
Detritivora barnesi (Hall & Harvey, 2001)		X						
Emesis mandana (Cramer, 1780)			X					
Euselasiinae								
Euselasia mys (Herrich & Schäffer, 1853)						X		
LYCAENIDAE								
Polyommatinae								
Cupido (Everes) comyntas (Godart, 1824)							X	
Hemiargus hanno (Stoll, 1790)				X				
Leptotes cassius (Cramer, 1775)		X	X			X	X	
Zizula cyna (Edwards, 1881)		X		X	X	X		
Theclinae								
Contrafacia ahola (Hewiston, 1867)								X
Contrafacia imma (Prittwitz, 1865)		X		X				
Electrostrymosn sp. Clench, 1961				X				
Erora carla (Schaus, 1902)					X			
Panthiades bathildis (C. & R. Felder, 1865)						X		
Psudolycaena marsyas (Linnaeus, 1758)				X	X			
Rekoa palegon (Cramer, 1779)	X		X	X	X			
Strymon bazochii (Godart, 1824)				X				
Tmolus echion (Linnaeus, 1767)				X				

Changes in butterfly composition with recovery after restoration

The highest species richness was observed in one control gully CG_9, followed by the four restored gullies RG_{23}, RG_{12}, RG_9 and RG_6. The remaining three controls, CG_{23}, CG_{12} and CG_6 showed the lowest richness values (Table 3). A significant positive correlation was found between recovery time after restoration and butterfly species richness ($r^2 = 0.953$; d.f. 3; P = 0.004) (Fig. 1a) and a nearly significant relation was observed between restoration time and butterfly abundance ($r^2 = 0.766$; d.f. 3; P = 0.052) (Fig. 1b). A cluster analysis based on the Bray-Curtis similarity index showed that no gullies were very similar to each other (result not shown) regarding their butterfly composition. These results must be interpreted with caution because they might be influenced by the surrounding matrix and other landscape attributes.

Table 3. Diurnal butterfly richness, abundance, diversity (Shannon H´) and equitability (J´) in four restored (RG) and unrestored (CG) gullies of the Colombian Andes.

Gullies	Total number of species	Number of species/Plot, average ± standard deviation	Abun.	H´	J´
RG_{23}	43	25 ± 4.24	393	1.572	0.962
CG_{23}	33	13.4 ± 6.61	119	1.474	0.971
RG_{12}	39	17.4 ± 5.89	159	1.538	0.967
CG_{12}	28	9.80 ± 3.27	78	1.4	0.968
RG_9	35	17.4 ± 4.44	264	1.483	0.96
CG_9	46	20.6 ± 6.42	224	1.604	0.964
RG_6	35	16.8 ± 4.86	84	1.495	0.968
CG_6	26	10 ± 3.80	155	1.377	0.973

Vegetation structure and nectariferous plants

A total of 59 plant species were present in the complete set of gully vegetation plots (RG + CG). The richest families were Asteraceae and Poaceae with nine and six species, respectively. The total number of plant species in the restored gullies was 34 (11.5 ± 1.13 per transect) while the controls had 25 plant species (9 ± 1.89 per transect). Plant richness was neither related to restoration time nor with butterfly richness. Poaceae had a strong presence in the gullies, especially in the controls, and showed high Importance Value Indices (IVI%) at the initial restoration stages. The gullies with the longest recovery periods showed different dominant plants, belonging to the Asteraceae and Acanthaceae families. These were the same species planted at high densities in the restored gullies (Table 3). The restored gullies showed taller vegetation in average than the controls, with values exceeding 150 cm in the gully with the longest recovery time. Two events affected the vegetation during the study: first, the vegetation RG_{12} was pruned several times and second, CG_9 was surrounded by vegetation more than 150 cm high.

Plant species with abundant inflorescences such as *Althernantera* sp., *Vernonia* sp. (Asteraceae) and *Hyptis pectinata* L. Poit (Lamiaceae) offered flower resources permanently and attracted a variety of butterflies. Important energetic sources for the lepidopterans in the area include Asteraceae such as *Acmella* sp., Asteraceae sp2., *Calea glomerata* Klatt, *Pseudoelephantopus spiralis* Less and *Tithonia diversifolia* (Asteraceae); *Verbena* sp. (Verbenaceae), *Cordia* sp. (Boraginaceae) and *Kohleria* sp. (Gesneriaceae) along with Malvaceae such as *Gaya* cf. *mutiriana* Krapov and *Sida* sp. The butterflies most frequently observed sucking nectar were hesperiids such as *Chioides catillus, Heliopetes arsalte*, *Pyrgus oileus orcus*, *Cymaenes tripunctus*, the heliconid *Heliconius erato*, the lycenids *Leptotes cassius*, *Rekoa palegon*, the nymphalids *Anartia amathea*, *S. epaphus*, *Actinote anteas*, and the pierids *Eurema salome* and *Phoebis sennae*. Hesperiidae and Lycenidae were frequent visitors of the plants growing in the studied gullies, and rare butterflies, e.g. *Panthiades bathildis* (Lyc.: Theclinae) visited these areas whenever floral resources were available.

Opportunistic observations of butterfly larvae feeding on gully plants were done throughout the study. A total of 23 lepidopteran larvae were found, most of them moths (19 larvae). One Saturnidae species was reared to adult (16 larvae), feeding on *Mimosa albida* Humb. & Bonpl. ex Willd (Mimosaceae) and another moth belonging to the *Josia* genus (2 larvae) (Lepidoptera: Dioptidae), whose host plant is an unidentified Asteraceae. Five immature diurnal butterflies were also found: a pupa was found on a stem of *T. gigantea* (Acanthaceae), from which an adult of *Papilio polixenes americus* (Pap.: Papilioninae) emerged. Four additional collected larvae were reared, all of them parasited by Tachinidae flies. All of these were found only in the restored gullies. Host plants for these larvae were *T. gigantea* and Mexican sunflower (*T. diversifolia*).

DISCUSSION

One of the main objectives of some restoration projects is to promote the recovery, maintenance and development of biodiversity. The results of this study suggest that butterflies are a sensitive group that effectively responds to the restoration technique described above, which involves high density planting intended to rehabilitate severely eroded areas.

However, it is important to consider that butterflies were censused in small areas, which means that probably not all of the individuals were using resources within the transects. Even though we tried to overcome this inconvenient by setting a height limit above which butterflies were not considered (10 m) complete independence of each observation was not 100% guaranteed, and the same individual could have been counted twice. The error was though minimized since the same person made all samplings and was aware of this potential pitfall.

This study did not find a correlation between butterfly diversity and vegetation richness at a small spatial scale, an aspect that coincides with the studies done by HOLL (1996) and WALTZ & COVINGTON (2004). However, different butterfly species dominated the different gullies and the cluster analysis showed low similarities between them. This result suggests that the studied gullies supported visitors from the surroundings and that species turnover is high, which is quite reasonable considering that the sampling was made on flying and foraging diurnal butterflies.

Table 4. Plant species with highest importance values IVI in restored (RG) and unrestored or control (CG) gullies. CG_{12} had no vegetation.

Gullies	Family	Species	IV%
RG_{23}	Acanthaceae	*Trichanthera gigantea*	22.06
	Asteraceae	*Tithonia diversifolia*	22.06
		Morphotype 11	14.12
RG_{12}	Papilionaceae	*Arachis pintoi*	26.09
		Morfotype 6	12.47
	Poaceae	*Cynodon plectostachyus*	10.54
RG_9	Poaceae	*Cynodon plectostachyus*	40.18
	Acanthaceae	*Trichanthera gigantea*	24.67
	Boraginaceae	*Cordia* sp.	22.84
RG_6	Poaceae	*Cynodon plectostachyus.*	31.01
	Gesneriaceae	*Kohleria* sp.	13.37
	Fabaceae	*Mimosa albida*	12.6
CG_{23}	Fabaceae	*Rynchosia schomburgkii*	31.78
	Poaceae	*Schyzachyrium* sp.	19.28
	Poaceae	*Melinis minutiflora*	16.56
CG_9	Convolvulaceae	sp. 2	28.52
	Poaceae	*Paspalum sacharoides*	11.71
	Boraginaceae	*Cordia* sp.	7.4
CG_6	Asteraceae	sp. 2	24.63
	Boraginaceae	*Cordia* sp.	12.98
		Morphotype 4	8.98

Other studies have demonstrated that butterfly assemblages positively respond to vegetation type, quality (BLAIR & LAUNER, 1997; COLLINGE et al., 2003; MACCHERINI et al., 2009) and complexity (HOLL, 1996), which in turn determine microhabitat physical conditions such as temperature and humidity (DIDHAM & LAWTON, 1999; MESQUITA et al., 1999; WEATHERS et al., 2001). These subtle changes were not directly measured in this study but qualitatively observed and described (Ascuntar-Osnas, pers. obs.). The oldest restored gullies, where the vegetation was taller, provided more microhabitat choices than the young gullies and the controls (except for CG9, where the complex surrounding vegetation might have influenced butterfly presence). Therefore vegetation development may have also determined different "environmental qualities" within the gullies. Large butterflies, such as *S. epaphus*, *Pronophila* cf. *unifasciata brennus* (Nym.: Satyrinae) and *Phoebis neocypris rutina* (Pie.: Coliadinae) which are good and rapid fliers were frequently found in the controls, while smaller butterflies such as *Y. renata*, *Eurema daria* (Pie.: Coliadinae), *P. oileus orcus* (Hes.: Pryrginae), *Eurema albula* (Pie.: Coliadinae), were frequently found in the restored gullies. This result is reasonable because butterflies with a vigorous flight are more likely to cross open and hostile environments than species with flight limitations. In this way, Satyrinae, which are sensitive to humidity changes and changes in canopy cover (HAMER et al., 2003), were best represented (76% of the observations) in gullies with taller vegetation and higher plant density (which did not prevent them from visiting control gullies). Hesperiidae and Lycaenidae include many species displaying hilltopping behavior; they fly to mountain tops in search of mates (PRIETO & DAHNERS, 2006). This behavior might be contributing to the high diversity of these families in this study, given that the gullies are close to hill tops (obs. pers. O.A.O.). PRIETO & DAHNERS (2006) reported hilltopping events at the nearby Cerro de San Antonio area. However, this must be studied in more detail.

Even though this study provides evidence of a positive response of butterflies to gully restoration, it is remarkable that two of controls, CG_9 and CG_6, were very rich in butterflies and plants. In control gully CG_9 the high butterfly diversity is probably related to the dense surrounding vegetation, taller than 1.5 m; in CG_6 the roots of a large tree remained at the base of the gully after the landslide and facilitated rapid plant regeneration. Plant assemblages in the studied gullies, particularly in the restored ones, were composed of herbaceous species, characteristic of early succession stages, 10 of which are important nectar sources for butterflies. Given that either a few or a wide variety of these plant species can by used by specialist or generalist butterflies respectively (BAZ, 2002), the presence of a particular group of butterflies in the studied gullies confirms the recovery of a variety of food resources following the restoration treatment. Specialist butterflies include *Dismorphia crissia foedora* (Pie.: Dismorphiinae), *Phoebis neocypris rurina*, *Altinote ozomene* (Nym.: Heliconiinae) and *Catasticta flisa* (Pie.: Pierinae); some generalists were *Heliconius clysonimus* (Nym.: Heliconiinae), *Danaus plexippus* (Nym.: Danainae), *Eurema xantochlora* (Pie.: Coliadinae) and *Dione juno* (Nym.: Heliconiinae).

This result confirms that the process of gully restoration is dynamic and facilitates succession through the sowing of pioneer plant species. These results are consistent with those obtained by BURYLO et al. (2007) who found increased herbaceous plants at the initial stages of restoration in the French Alps, followed by the emergence of woody species three years later. Although the herbaceous plants showed the same trend in this study, it is not clear to what degree butterfly abundance is positively influenced by nectar offer, because our method was not explicitly designed to answer this question. HOLL (1996) found a positive correlation between plant and moth (Lepidoptera) diversity in rehabilitated mines, while WALTZ & COVINGTON (2004) did not observe any trend. Other elements of a trophic structure, such as parasitism by tachinid dipterans were observed in the restored gullies, showing that a food web structure is present. The reestablishment of biological interactions is another way of evaluating the success of restoration activities and the presence of complex interactions might be interpreted as a sign of increased ecosystem resilience (RUIZ-JAÉN & AIDE, 2005).

Even though this study did not strictly involve butterfly monitoring (repeated observations over a long period of time), our results suggest that butterflies might be useful for long term biodiversity studies of restored areas as has been done in Europe and North America (HOLL, 1996; KLEINTJES et al., 2004; POYRY et al., 2004; WALTZ & COVINGTON, 2004; DUMBRELL & HILL 2005; LOMOV et al., 2006). The use of diurnal butterflies as bioindicators is advantageous because they are an attractive group for people, and field guides are available for non-specialists, who may start working with local communities after receiving some technical training, as compared to other groups such as moths, more difficult to sample and identify.

However, gullies represent a special challenge for biodiversity studies given their relatively small size and contrasting matrices. It is very difficult, perhaps impossible, to come up with a perfectly designed experiment with replicated restored and control gullies of the same size, age and landscape context. The richness and composition of flying insects will obviously be affected not only by vegetation within the gullies but also by their surroundings. Our study took advantage of a set of paired restored and unrestored gullies of different ages in a mountainous degraded area, and tried to provide insight into the effects of gully restoration on the lepidopteran fauna. Complementary studies are required in order to understand the separate effects of gully size, age, restoration treatment and landscape context on the recovery of butterfly assemblages.

Finally, the results of this study indicate that ecological restoration of highly degraded areas (i.e. migrating gullies) with erosion control structures (biologically originated), and high density planting had positive effects on the composition, abundance and richness of the associated lepidopteran fauna. Butterfly richness did not relate directly to plant richness, perhaps because the spatial and time scales of the study were not adequate to reveal such a pattern.

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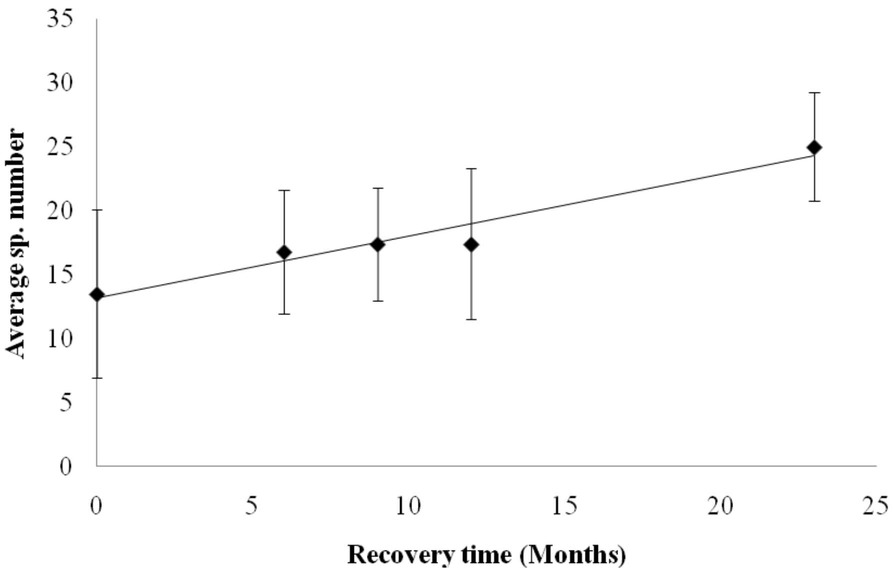

Figure 1a.

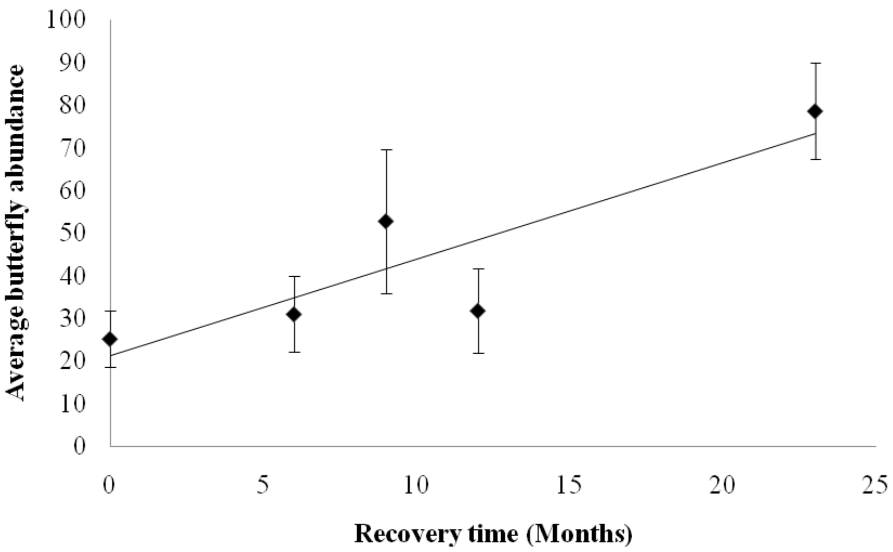

Figure 1b.

Figure 1. Linear regression between (a) the butterfly richness and (b) butterfly abundance, and gully recovery time following the restoration intervention. Points and vertical bars show average values and standard deviations.

BIBLIOGRAPHY

BAZ, A., 2002.- Nectar plant sources for the threatened apollo butterfly (*Parnassius apollo* l. 1758) in populations of central Spain. *Biol Conserv*., 103: 277-282.

BLAIR, R.B., 1999.- Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity. *Ecol. Appl*., 9: 194-170.

BLAIR, R.B. & LAUNER, A.E., 1997.- Butterfly diversity and human land use: species assemblages along an urban gradient. *Biol. Conserv*., 80: 113-125.

BURYLO, M.; REY, F. & DELCROS, P., 2007.- Abiotic and biotic factors influencing the early stages of vegetation colonization in restored marly gullies (Southern Alps, France). *Ecol. Engin*., 30: 231-239.

COLLINGE, S.K.; PRUDIC, K.L. & OLIVER, J.C., 2003.- Effects of local habitat characteristics and landscape context on grassland butterfly diversity. *Conserv. Biol*., 17: 178-187.

DAUBENMIRE, R., 1959.- A canopy coverage method of vegetation analysis. *Nort. Scie*., 33: 43-64.

DEVRIES, P.J.; WALLA, T.R. & GREENEY, H.F., 1999.- Species diversity in spatial and temporal dimensions of fruit-feeding butterflies from two Ecuadorian rainforests. *Biol. J. Linn. Soc*., 68: 333-353.

DIDHAM, R.K. & LAWTON, J.H., 1999.- Edge structure determines the magnitude of changes in microclimate and vegetation structure in tropical forest fragments. *Biotrópica*, 31: 17-30.

DUMBRELL, A.J. & HILL, J.K., 2005.- Impacts of selective logging on canopy and ground assemblages of tropical forest butterflies: Implications for sampling. *Biol. Conserv*., 125: 123-131.

ESPINAL, L. S., 1998.- Visión ecológica del departamento del Valle del Cauca. Universidad del Valle, Cali, Colombia.

ETTER, A. & VAN WYNGAARDEN, W., 2000.- Patterns of landscape transformation in Colombia, with emphasis in the Andean region. *Ambio*, 29: 432-439.

FAGUA, G., 1996.- Comunidad de mariposas y artropofauna asociada con el suelo de tres tipos de vegetación de la serranía de Taraira (Vaupés, Colombia), una prueba del uso de mariposas como bioindicadores. *Rev. Colom. Entomol*., 22: 143-151.

FAGUA, G.; AMARILLO, A. & ANDRADE, G., 1999.- Mariposas (lepidóptera) como bioindicadores del grado de intervención en la cuenca del río Pato (Caquetá): 284-315 (in) AMAT-ANDRADE G.; Fernández-F. (eds.) *Insectos de Colombia, volumen II.* Academia Colombiana de Ciencias Exactas, Físicas y Naturales. Colección Jorge Álvarez Lleras. Bogotá, Colombia.

GIRALDO, C.; DOMÍNGUEZ, Y.; RIVERA, L.; CALLE, Z.; PIEDRAHITA, L. & SINISTERRA, J.A., 2008.- Diversidad de insectos y plantas en cárcavas restauradas con bioingeniería: 137-147 (in) BARRERA-CATAÑO J.L., AGUILAR-GARAVITO M.; RONDÓN-CAMACHO D.C. (eds.) *Experiencias de restauración ecológica en Colombia.* Pontificia Universidad Javeriana, Bogotá, D.C. 274p.

HAMER, K.C.; HILL, J.K.; BENEDICK, S.; MUSTAFFA, N.; SHERRATT, T.N.; MARYATI, M. & CHEY, V.K., 2003.- Ecology of butterflies in natural and selectively logged forests of northern Borneo: the importance of habitat heterogeneity. *J. Appl. Ecol*., 40: 150-162.

HARDY, P.B. & DENNIS, R.L., 1999.- The impact of urban development on butterflies within a city region. *Biodiver. Conserv*., 8: 1261-1279.

HOLL, K.D., 1996.- The effect of coal surface mine reclamation on diurnal lepidopteran conservation. *J. Appl. Ecol*., 33: 225-236.

KLEINTJES, P.K.; JACOBS, B.F. & FETTIG, S.M., 2004.- Initial response of butterflies to an overstorey reduction and slash mulching treatment of a degraded pinon-juniper woodland. *Restor. Ecol*., 12: 231-238.

KREMEN, C.; COLWELL, R.K.; ERWIN, T.L.; MURPHY, D.D.; NOSS, R.F. & SANJAYAN, M.A., 1993.- Terrestrial arthropod assemblages: their use in conservation planning. *Conserv. Biol*., 7: 796-809.

LAMAS, G., 2004.- Atlas of Neotropical Lepidoptera, Check list: Part 4A, Hesperoidea-Papilionoidea. Association for Tropical Lepidoptera, Gainesville. 439p. In *Tropical Andean Butterfly Diversity Project (TABDP).* 2007. Darwin Database of Andean Butterflies. http://www.andeanbutterflies.org/database.html. Consulted on June 2008.

LOMOV, B.; KEITH, D.; BRITTON, D. & HOCHULI, D., 2006.- Are butterflies and moths useful indicators for Restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. *Ecol. Manag. Restor*., 7: 204-210.

MACCHERINI, S., BACARO, G., FAVILLI, L., PIAZZINIA, S., SANTI, E. & MARIGNANI, M., 2009.- Congruence among vascular plants and butterflies in the evaluation of grassland restoration success. *Acta. Oecol.* 35: 11-17.

MESQUITA, R.C.G.; DELAMONICA, P. & LAURANCE, W.F., 1999.- Effect of surrounding vegetation on edge-related tree mortality in Amazonian forest fragments. *Biol. Conserv*., 91: 129-134.

POYRY, J.; LINDGREN, S.; SALMINEN, J. & KUUSSAARI, M., 2004.- Restoration of butterfly and moth communities in semi-natural grasslands by cattle grazing. *Ecol. Appl*., 14: 1656-1670.

PRIETO, C. & DAHNERS, H., 2006.- Eumaeini (Lepidoptera: Lycaenidae) del cerro de San Antonio: Dinámica de la riqueza y comportamiento de "Hilltopping". *Rev. Colomb. Entomol*., 32: 179-190.

RIES, L.; DEBINSKY, D.M. & WIELAND, M., 2001.- Conservation value of roadside prairie restoration butterfly communities. *Conserv. Biol*., 15: 401-411.

RIVERA, H., 1998.- Control de cárcavas remontantes en zonas de ladera mediante tratamientos biológicos. *Avances técnicos Cenicafé*, 256: 8.

RIVERA, H. & SINISTERRA, J.A., 2006.- *Uso social de la bioingeniería, para el control de la erosión severa.* CIPAV, Cali, Colombia.

ROSENBERG, D.M.; DANKS, H.V. & LUHMKUHL, D.M., 1986.- Importance of insects in environmental impact assessment. *Enviro. Manag.*, 10: 773-783.

RUIZ-JAÉN, M.C. & AIDE, M., 2005.- Restoration success: how is it being measured? *Restor. Ecol.*, 13: 569-577.

SUMMERVILLE, K.S.; STEICHEN, R.M. & LEWIS, M.N., 2005.- Restoring lepidopteran communities to oak savannas: contrasting influences of habitat quantity and quality. *Restor. Ecol.*, 13: 120-128.

WALTZ, A. & COVINGTON, W., 2004.- Ecological restoration treatments increase butterfly richness and abundance: mechanisms of response. *Restor. Ecol.*, 12: 85-96.

WEATHERS, K.C.; CADENASSO, M.L. & PICKETT, T.A., 2001.- Forest edges as nutrient and pollutant concentrators: potential synergisms between fragmentation, forest canopies, and the atmosphere. *Conserv. Biol.*, 15: 1506-1514.

ZAR, J.H., 1996.- *Biostatistical analysis.* 3rd ed. Prentice Hall, New Jersey.