

Observations on the lichen colonisation of young reforestation areas in south-eastern Costa Rica

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Abstract: The lichen colonisation of four very young reforestation areas in south-eastern Costa Rica is documented. In addition, lichens were randomly collected in adjacent primary rainforests. Altogether, 40 foliicolous and 23 corticolous lichen species in 30 genera were found. Five species (*Coenogonium subdentatum*, *Graphis chlorotica*, *G. flavominiata*, *G. tenella*, and *Porina americana*) are additions to the known lichen flora of the Golfo Dulce region.

Zusammenfassung: In vier jungen Wiederbewaldungsgebieten im Südosten Costas Ricas wird die Besiedelung durch Flechten dokumentiert. Zusätzlich wurden stichprobenartige Aufsammlungen in angrenzenden Primärwäldern vorgenommen. Insgesamt wurden 40 foliicole und 23 corticole Flechten aus 30 Gattungen gefunden. Fünf Arten (*Coenogonium subdentatum*, *Graphis chlorotica*, *G. flavominiata*, *G. tenella* und *Porina americana*) sind Erstdnachweise für die Golfo-Dulce-Region.

Resumen: Se documenta la colonización de líquenes en cuatro áreas recientemente reforestadas en el sureste de Costa Rica. Además, se recolectaron aleatoriamente líquenes en bosques lluviosos primarios adyacentes. En total, se encontraron 40 especies de líquenes foliícolas y 23 corticícolas en 30 géneros. Cinco especies (*Coenogonium subdentatum*, *Graphis chlorotica*, *G. flavominiata*, *G. tenella* y *Porina americana*) son adiciones a la flora conocida de líquenes de la región del Golfo Dulce.

Although Costa Rica is well-known for its impressive conservation efforts (with about 25% of its territory under protection), its natural vegetation has been severely fragmented by human activities. This is also true for the rainforests in south-eastern Costa Rica (Golfo Dulce region), which are among the most species-rich regions in Central America (WEISSENHOFER & al. 2016). Efforts are made to establish biological corridors to connect remnants of natural vegetation. Ten years after the start of reforesting agricultural areas in the course of the COBIGA project (see below) the reforestation areas were investigated lichenologically for the first time.

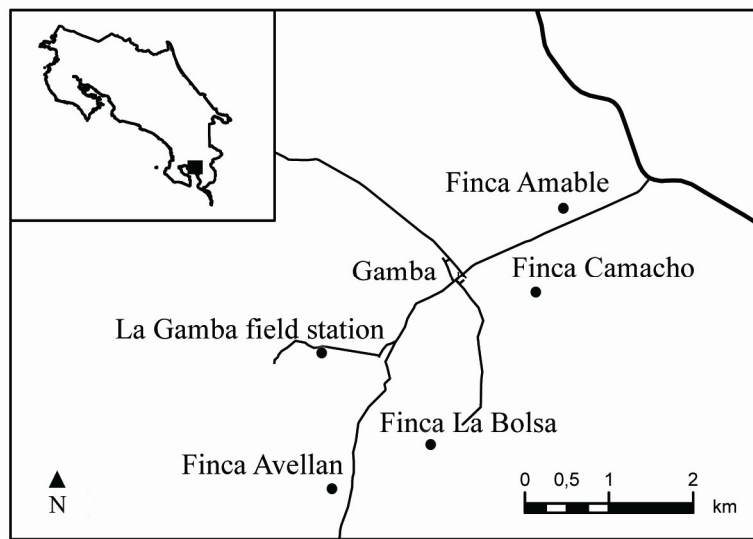
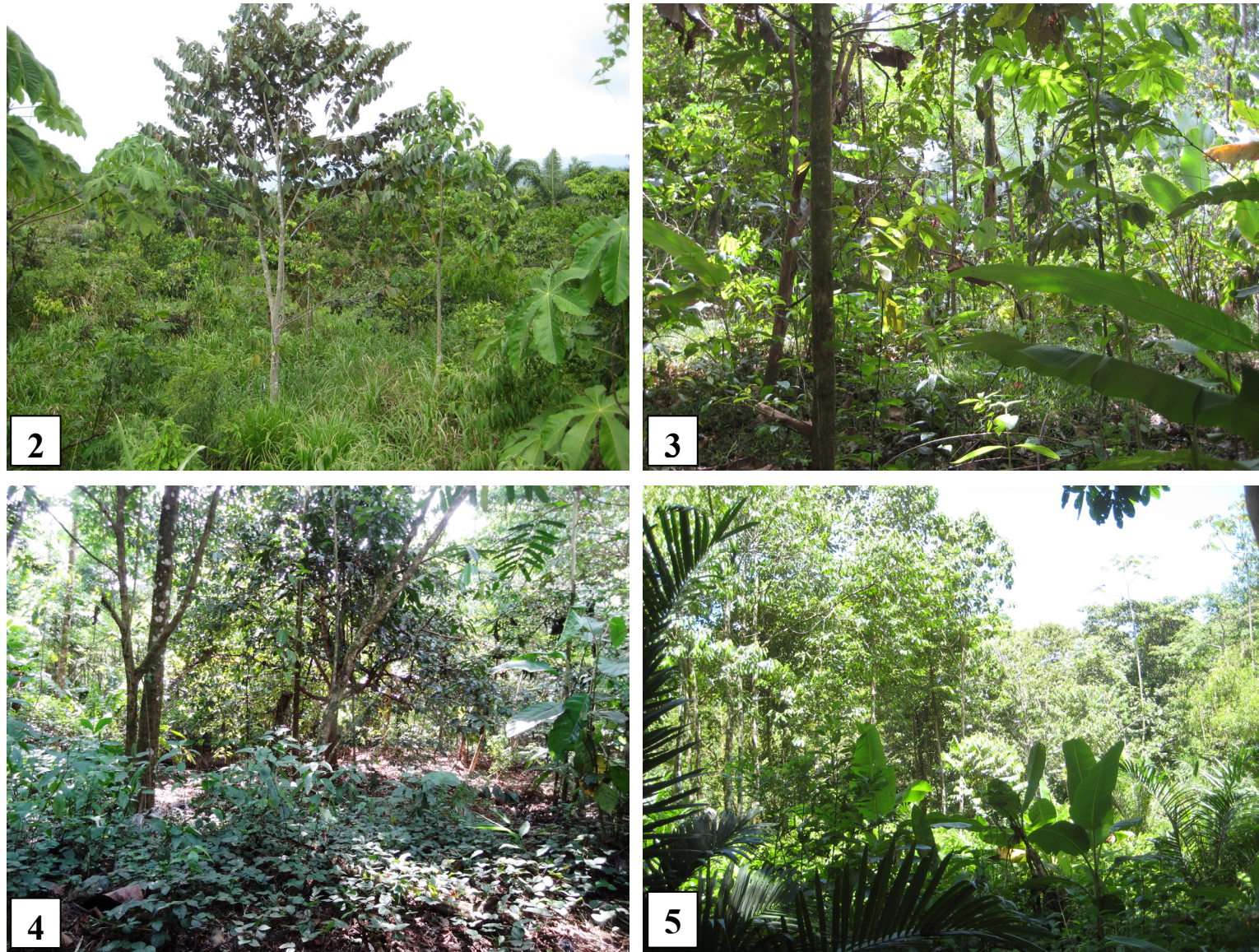


Fig. 1. Study area and sampling locations. Map sources: GADM database (www.gadm.org), version 2.8, November 2015; Geotecnologias S. A., 3. 6. 2016.

Tab. 1. List of phorophytes sampled with number of lichen species recorded.

Tree species	Family	Site	Forest type	No. of Lichen species
<i>Aiouea costaricensis</i> (MEZ) KOSTERM.	<i>Lauraceae</i>	Finca La Bolsa	Reforestation	5
<i>Anacardium excelsum</i> (KUNTH) SKEELS	<i>Anacardiaceae</i>	Finca Avellan	Species enrichment	1
<i>Astronium graveolens</i> JACQ.	<i>Anacardiaceae</i>	Finca Avellan	Species enrichment	1
<i>Calophyllum brasiliense</i> CAMBESS.	<i>Calophyllaceae</i>	Finca Avellan	Species enrichment	9
<i>Carapa nicaraguensis</i> C. DC.	<i>Meliaceae</i>	Finca Amable	Reforestation	4
<i>Carapa nicaraguensis</i> C. DC.	<i>Meliaceae</i>	Finca Avellan	Species enrichment	1
<i>Croton tenuicaudatus</i> LUNDELL	<i>Euphorbiaceae</i>	Finca Amable	Reforestation	0
<i>Cyclanthus bipartitus</i> POIT. ex A. RICH.	<i>Cyclanthaceae</i>	Finca La Bolsa	Reforestation	4
<i>Hieronyma alchorneoides</i> ALLEMÃO	<i>Phyllanthaceae</i>	Finca Amable	Reforestation	3
<i>Inga sapindoides</i> WILLD.	<i>Fabaceae</i>	Finca La Bolsa	Reforestation	3
<i>Luehea seemannii</i> TRIANA & PLANCH.	<i>Malvaceae</i>	Finca Amable	Reforestation	2
<i>Musa ×paradisiaca</i> L.	<i>Musaceae</i>	Finca La Bolsa	Reforestation	9
<i>Nectandra purpurea</i> (RUIZ & PAV.) MEZ	<i>Lauraceae</i>	Finca La Bolsa	Reforestation	1
<i>Platymiscium curuense</i> N. ZAMORA & KLITG.	<i>Fabaceae</i>	Finca Amable	Reforestation	3
<i>Schizolobium parahyba</i> (VELL.) S. F. BLAKE	<i>Fabaceae</i>	Finca Camacho	River revegetation	2
<i>Terminalia amazonia</i> (J. F. GMEL.) EXELL	<i>Combretaceae</i>	Finca Camacho	River revegetation	2
<i>Virola surinamensis</i> (ROL. ex ROTTB.) WARB.	<i>Myristicaceae</i>	Finca La Bolsa	Reforestation	21
? (dead branches)	?	Finca Avellan	Species enrichment	1
? (dead branches)	?	Finca Amable	Reforestation	8



Figs. 2–5. Vegetation of reforestation areas visited. 2 Finca Amable. 3 Finca La Bolsa, phot. KERSTIN RADA KOVITZ. 4 Finca Avellan. 5 Finca Camacho.

An overview on the lichenological exploration of the Golfo Dulce area was presented by BREUSS (2008); and an updated checklist of lichens yet known to occur in this region was compiled by NEUWIRTH & BREUSS (2011). Until now, inventories of lichens have been focused mainly on primary and secondary rainforests and to a lesser degree on anthropogenic or synanthropic plant communities. As far as we know, reforestation areas have not been studied in detail in terms of lichens. In the present paper we report on early stages of lichen colonisations observed in four newly planted reforestation areas (3, 6 and 9 years of age) in the vicinity of the Piedras Blancas National Park in south-eastern Costa Rica. Sampling was done by the first author; identifications were contributed by the second author.

Material and methods

The fieldwork was carried out during a one-week stay in the Tropical Research Station La Gamba, Costa Rica, in February 2016. Foliicolous and corticolous lichens in four reforestation areas near La Gamba were collected (Fig.1). At each site four to six trees or treelike monocotyledons of different species were selected for sampling. Corticolous lichens were collected from the base and trunk of stems approximately up to 1.5 meters above ground. For study of epiphyllous lichens several leaves from two twigs up to 6 meters above ground of every selected tree were gathered. The leaves were examined under a dissecting microscope; identifiable lichen thalli (specimens with at least three mature fruiting bodies) were examined with standard microscopic procedures; sterile thalli were eventually determined to genus level. Supplementary lichen collecting was undertaken in the primary forests adjacent to the reforestation areas. The lichen samples are preserved in WU. Taxonomy follows LÜCKING (2008), LÜCKING & al. (2008) and other modern treatments. Determination of phorophytes was conducted using GENTRY (1996), HAMMEL & al. (2003–2015) and QUESADA (1997).

Areas investigated

The reforestation areas visited are part of the ongoing COBIGA project (The Biological Corridor La Gamba), the aim of which is to link the lowland forests of the Piedras Blancas National Park with the Fila Costeña, a largely unprotected area covered with mountain rainforests, to promote species exchange between these ecosystems. Further biological corridors in the Golfo Dulce region are being established to link patches of natural vegetation within this area (WEISSENHOFER & al. 2012, 2016). For the COBIGA project selected agricultural land has been purchased from owners; or reforestation is conducted in cooperation with private farmers in order to establish a sustainable forest management. Thousands of native trees belonging to many different species were planted within recent years.

The following areas were investigated (age of reforestations in years in parentheses): Finca Amable (3), Finca La Bolsa (6), Finca Avellan (9), and Finca Camacho (9). They are at 72–130 m above sea level, have a perhumid climate with precipitation of c. 6000 mm/a, relative humidity of c. 75% and mean air temperature of 28.3°C (www.lagamba.at). Finca Amable is surrounded by plantations, the other fincas are bordered by primary forests (where supplementary lichen collecting was undertaken). Within several years the planted trees have grown up to 5–20 meters (Figs. 2–5). The species of the sampled trees are listed in Tab. 1.

Results and discussion

Altogether, c. 130 samples of identifiable lichens were collected (Tab. 2); 62 species (40 foliicolous and 23 corticolous) in 30 genera were found; 41 species assigned to 11 families (Tab. 3) were found in the young reforestation areas, 24 of them were foliicolous and 18 corticolous; one species (*Leptogium* cf. *azureum*) was found on both substrata.

Tab. 2. Lichens collected in the COBIGA project area. The list includes lichens randomly collected in primary forests (P) bordering the reforestation areas (R); *f* foliicolous, *c* corticolous, *Am* Finca Amable, *LB* Finca La Bolsa, *Av* Finca Avellan, *Ca* Finca Camacho, *1–5* number of samples of a certain species per site.

Species	Family	f/c	Am R	LB R	LB P	Av R	Av P	Ca R	Ca P
<i>Arthotheliopsis tricharioides</i> (KALB & VĚZDA) LÜCKING et al.	<i>Gomphillaceae</i>	f				1			
<i>Aspidothelium papillicarpum</i> LÜ- CKING	<i>Thelenellaceae</i>	f		1			1		
<i>Aulaxina quadrangula</i> (STIRT.) R.SANT.	<i>Gomphillaceae</i>	f		3					
<i>Badimia dimidiata</i> (C.BAB. ex LEIGHTON) VĚZDA	<i>Pilocarpaceae</i>	f		1					
<i>Byssoloma leucoblepharum</i> (NYL.) VAIN.	<i>Pilocarpaceae</i>	f		4					1
<i>Calenia graphidea</i> VAIN.	<i>Gomphillaceae</i>	f		1					
<i>C. lueckingii</i> HARTMANN	<i>Gomphillaceae</i>	f			1				
<i>C. phyllogena</i> (MÜLL.ARG.) R. SANT.	<i>Gomphillaceae</i>	f					1		
<i>C. subdepressa</i> LÜCKING	<i>Gomphillaceae</i>	f		1					
<i>Calenia</i> sp.	<i>Gomphillaceae</i>	f					1		
<i>Calopadia fusca</i> (MÜLL.ARG.) VĚZDA	<i>Pilocarpaceae</i>	f		1					
<i>Coccocarpia stellata</i> (NYL.) TUCK.	<i>Coccocarpiaceae</i>	f		1					
<i>Coenogonium dilucidum</i> (KREMP.) KALB & LÜCKING	<i>Coenogoniaceae</i>	f			1				
<i>Coe. linkii</i> EHRENB.	<i>Coenogoniaceae</i>	c		1					
<i>Coe. minimum</i> (MÜLL.ARG.) LÜ- CKING	<i>Coenogoniaceae</i>	f		1					
<i>Coe. subdentatum</i> (VĚZDA & G.THOR) RIVAS PLATA & al.	<i>Coenogoniaceae</i>	c		1					
<i>Coenogonium</i> sp.	<i>Coenogoniaceae</i>	f		3	2	2	1	1	1
<i>Cryptothecia filicina</i> (ELLIS & EVERH.) LÜCKING & al.	<i>Arthoniaceae</i>	f							2
<i>Diorygma poitaei</i> (FÉE) KALB, STAIGER & ELIX	<i>Graphidaceae</i>	c	1						
<i>Dyplolabia afzelii</i> (ACH.) A. MAS- SAL.	<i>Graphidaceae</i>	c	1						
<i>Echinoplaca pellicula</i> (MÜLL. ARG.) R.SANT.	<i>Gomphillaceae</i>	f		1	2				
<i>E. verrucifera</i> LÜCKING	<i>Gomphillaceae</i>	f	1	1					
<i>Echinoplaca</i> sp.	<i>Gomphillaceae</i>	f					1		
<i>Graphis chlorotica</i> A. MASSAL.	<i>Graphidaceae</i>	c	1						
<i>G. flavominiata</i> MONCADA & LÜ- CKING	<i>Graphidaceae</i>	c	2						
<i>G. longula</i> KREMP.	<i>Graphidaceae</i>	c				1			
<i>G. tenella</i> ACH.	<i>Graphidaceae</i>	c	5						
<i>G. vestitoides</i> (FINK) STAIGER	<i>Graphidaceae</i>	c	1						
<i>Graphis</i> sp.	<i>Graphidaceae</i>	c	2						
<i>Gyalideopsis rubescens</i> VĚZDA	<i>Gomphillaceae</i>	f			1				
<i>G. verruculosa</i> VĚZDA & HAFELL- NER	<i>Gomphillaceae</i>	f	1						
<i>Lasioloma arachnoideum</i> (KREMP.) R. SANT.	<i>Pilocarpaceae</i>	f		5					

Tab. 2 (continued).

<i>Leptogium austroamericanum</i> (MALME) DODGE	<i>Collemataceae</i>	c					1	
<i>L. cf. azureum</i> (SW.) MONT.	<i>Collemataceae</i>	f		2	1			
<i>L. cf. azureum</i> (SW.) MONT.	<i>Collemataceae</i>	c		1				
<i>Malmidea psychotrioides</i> (KALB & LÜCKING) KALB & al.	<i>Malmideaceae</i>	c					1	
<i>Mazosia rotula</i> (MONT.) A. MAS- SAL.	<i>Roccellaceae</i>	f						2
<i>Phaeographis haematites</i> (FÉE) MÜLL. ARG.	<i>Graphidaceae</i>	c	1					
<i>Phyllobathelium leguminosae</i> (CAVALC. & A. A. SILVA) LÜCKING & SÉRUS.	<i>Strigulaceae</i>	f			1			
<i>Platygramme caesiopruinosa</i> (FÉE) FÉE	<i>Graphidaceae</i>	c	1					
<i>Porina alba</i> (R. SANT.) LÜCKING	<i>Porinaceae</i>	f		1	1	2	3	2
<i>P. americana</i> FÉE	<i>Porinaceae</i>	c						1
<i>P. distans</i> coll.	<i>Porinaceae</i>	c						1
<i>P. lucida</i> R. SANT.	<i>Porinaceae</i>	f		2				
<i>P. mastoidea</i> (ACH.) MÜLL. ARG.	<i>Porinaceae</i>	c						2
<i>P. rufula</i> (KREMP.) VAIN.	<i>Porinaceae</i>	f		1		1		1
<i>Porina</i> sp.	<i>Porinaceae</i>	f		1		1		
<i>Pyrenula acutispora</i> HAF. & KALB	<i>Pyrenulaceae</i>	c						1
<i>Py. aspistea</i> (ACH.) ACH.	<i>Pyrenulaceae</i>	c						1
<i>Rubrotricha subhelminthospora</i> LÜCKING	<i>Gomphillaceae</i>	f					1	
<i>Sarcographa cf. heteroclita</i> (MONT.) ZAHLBR.	<i>Graphidaceae</i>	c						1
<i>S. labyrinthica</i> (ACH.) MÜLL. ARG.	<i>Graphidaceae</i>	c	2					1
<i>Strigula phyllogena</i> (MÜLL. ARG.) R.C.HARRIS	<i>Strigulaceae</i>	f		1				
<i>St. smaragdula</i> FR.	<i>Strigulaceae</i>	f						1
<i>St. subtilissima</i> (FÉE) MÜLL. ARG.	<i>Strigulaceae</i>	f						2
<i>Strigula</i> sp.	<i>Strigulaceae</i>	f				1		1
<i>Thalloloma hypoleptum</i> (NYL.) STAIGER	<i>Graphidaceae</i>	c	1					
<i>Tricharia amazonum</i> VAIN.	<i>Gomphillaceae</i>	f					1	
<i>T. vainioi</i> R.SANT.	<i>Gomphillaceae</i>	f						1
<i>Tricharia</i> sp. 1	<i>Gomphillaceae</i>	f		4	1	2	1	1
<i>Tricharia</i> sp. 2	<i>Gomphillaceae</i>	f					1	
<i>Tricharia</i> sp. 3	<i>Gomphillaceae</i>	f					4	
<i>Dictyonema phyllogenum</i> (MÜLL. ARG.) ZAHLBR. f. <i>phyllogenum</i>	<i>Hygrophoraceae</i> (<i>Agaricales</i>)	f		4				

Foliicolous lichens are typical inhabitants of tropical rainforests. Because of the short-lived substratum – the life span of individual leaves of tropical trees rarely exceeds 2–3 years (LÜCKING 2001) – foliicolous lichens evolved rapid reproduction resulting in early development of fruiting bodies and thus having mature ascomata already on small thalli (or they produce specialised vegetative propagation structures). Besides rapid reproduction, foliicolous lichens have a vigorous ability to colonise new habitats (SÉRUSIAUX 1989). There are few studies on establishment and succession of foliicolous lichen communities on individual leaves (e.g. CONRAN & ROGERS 1983;

ROGERS 1989, 1995; ROGERS & al. 1994). The influence of drip tips, hairs, glands, and surface structure of leaves on lichen growth is shortly discussed by LÜCKING (2001, 2008, and references therein). Lichen growth on artificial leaves made of plastic tape was studied by MONGE-NÁJERA & BLANCO (1995) and LÜCKING & BERNECKER-LÜCKING (2002).

Tab. 3. Lichen families found in reforestation with their species numbers.

Family	Species no.
<i>Graphidaceae</i>	13
<i>Gomphillaceae</i>	8
<i>Coenogoniaceae</i>	4
<i>Pilocarpaceae</i>	4
<i>Porinaceae</i>	4
<i>Collemaaceae</i>	2
<i>Strigulaceae</i>	2
<i>Coccocarpiaceae</i>	1
<i>Malmideaceae</i>	1
<i>Thelenellaceae</i>	1
<i>Hygrophoraceae</i>	1

tation, often along forest edges; *Porina lucida*, *P. rufula* and *Strigula phyllogena* typically occur in the shady understory of closed forests (LÜCKING 1997).

Corticolous lichens have somewhat lower growth rates than foliicolous and reach maturity later. However, in the youngest reforestation area, Finca Amable, 11 species of bark inhabiting lichens could be recorded; all of them belong to the *Graphidaceae*, which is the largest family of corticolous tropical lichens. Interestingly, very few members of *Graphidaceae* were found in the older reforestation areas. Contrary, *Pyrenulaceae* were absent on young trees and only found in primary forest. Not surprisingly, most of the lichens found in the reforestation areas are crustose; only three species (*Coccocarpia stellata*, *Leptogium* cf. *azureum*, *L. austroamericanum*) are foliose. The highest numbers of lichen samples are from Finca Amable and Finca La Bolsa. The phorophytes with the most lichen records are *Virola surinamensis*, *Musa × paradisiaca*, and *Calophyllum brasiliense* (Tab. 1).

All recorded species are widely distributed in the Neotropics. *Coenogonium subdentatum*, *Graphis chlorotica*, *G. flavominiata*, *G. tenella*, and *Porina americana* are additions to the known lichen flora of the Golfo Dulce region.

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Taken the early stage of development of the reforestation the record of 24 epiphyllous lichen species is remarkable (and the number will undoubtedly rise with longer investigations). Only early successional stages of lichen cover could be found; most species were represented by single or few individuals. *Tricharia* thalli were found to be the earliest colonisers, with abundant occurrences on some leaves, but mostly sterile. Members of *Porinaceae* were rather rare, the most frequent species was *Porina alba*, apparently due to effective dispersal by isidia. Most of the recorded leaf-dwelling species have a broad ecological range, occurring in light gaps of rainforests or in semi-open to open vegeta-

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