Alien plants and invasion patterns in different habitats of the Golfo Dulce area, Costa Rica

Plantas exóticas y patrones de invasión en diferentes hábitat del área de Golfo Dulce, Costa Rica

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Abstract: We recorded the invasion patterns of vascular plants across habitat types in a wet tropical lowland region of southern Costa Rica. We analysed vascular plant species composition in 29 plots with plot sizes ranging from 50 to 1.000 m^2; the habitats considered range from primary forest to strongly modified agricultural habitats. Of a total of 877 vascular plant species, 21 (2.4%) are alien and 29 (3.3%) are endemic. In most natural habitat types (e.g. primary forest), no or very few aliens have been recorded. However, habitats with a pronounced natural disturbance regime (e.g. coastal vegetation, riverine gravel banks) are affected by plant invasions. In man-made disturbed habitats (e.g. plantations, pastures) a relatively high number of aliens, some of them in high abundance, have been recorded. Hence, in concordance with other tropical continental lowlands, invasion patterns across habitats in southern Costa Rica show a strong correlation to human disturbance and habitat transformation.

Key words: Costa Rica, Golfo Dulce, tropical lowlands, alien species, invasive plants, invasion patterns.

Resumen: Se registraron los patrones de invasión de plantas vasculares en diferentes tipos de hábitat en una región de tierras bajas tropicales húmedas del sur de Costa Rica. Se analizó la composición de especies de plantas vasculares en 29 parcelas, con un rango de tamaño desde 50 a 1,000 m^2; el rango de hábitat considerado incluye desde bosques primarios hasta hábitat fuertemente modificados por la agricultura. De un total de 877 especies de plantas vasculares, 21 (2,4%) son exóticas y 29 (3,3%) son endémicas. En la mayoría de los hábitat naturales (por ejemplo bosques primarios), ninguna o pocas especies exóticas fueron encontradas. Sin embargo, hábitat con un marcado régimen de disturbios naturales (por ejemplo la vegetación costera, bancos ribereños de grava) son afectados por invasiones de plantas. En los hábitat con perturbación antrópica (plantaciones, pastizales), se encontró un número relativamente alto de especies exóticas, algunas de ellas en alta abundancia. Por lo tanto, en concordancia con otras tierras bajas tropicales continentales, los patrones de invasión en los diferentes tipos de hábitat en el sur de Costa Rica, muestran una fuerte correlación con la perturbación humana y la transformación del hábitat.

Palabras clave: Costa Rica, Golfo Dulce, Especies exóticas, invasiones biológicas, patrón de invasión, plantas invasoras.

Introduction

Alien species are considered a major threat to the conservation of global biodiversity (e.g. SALA et al. 2000, MCNEELY et al. 2001). Human activities such as agriculture, aquaculture, forestry, transportation, recreation and building activities promote the intentional and accidental spread of species across their natural boundaries.

Understanding the factors that determine the invasibility of habitats and plant communities is one of the key questions in invasion biology (DAVIES et al. 2005, REJMÁNEK et al. 2005). Previous studies have shown that invasibility of habitats is influenced by several variables, e.g. species diversity of the recipient habitats (which affects the utilisation of resources; PYŠEK et al. 2002, CASTRO et al. 2005), attributes of the native biota which interact with the alien species (GILBERT & LECHOWICZ 2005, HASTINGS et al. 2005), disturbance regime (PAUCHARD & ALABACK 2004), and the numbers of propagules introduced (COLAUTTI et al. 2006, PYŠEK & RICHARDSON 2006). Most studies on habitat invasion patterns have been performed in extra-tropical regions, so little is known about the validity of the observed patterns in moist tropical lowlands. It is, however, known that invasions are a major conservation problem in some rainforest regions, especially on isolated tropical islands (MEYER & FLORENCE 1996, TURNER 1996).

By using plot data across a wide range of habitats from southern Costa Rica, we address the following re-

Stapfia **88**, zugleich Kataloge der oberösterreichischen Landesmuseen Neue Serie **80** (2008): 105-110

search questions: (1) What is the pattern of invasions in different habitats and how is invasion success correlated to human impact on ecosystems? (2) What are the consequences for nature conservation caused by the invasion of alien plant species? For more detailed discussions see HUBER et al. (in prep.).

Material and methods

The study area is a wet tropical lowland region of south-western Costa Rica (Golfo Dulce region, La Gamba village; near tropical research station La Gamba – www.lagamba.at). With about 2.700 species of vascular plants, the region of the Golfo Dulce has an extraordinarily high diversity of plant species.

The average annual precipitation of 5.836 mm, the annual mean temperature of about 28°C and the absence of a pronounced dry season (WEISSENHOFER & HUBER 2008) have resulted in the establishment of a "perhumid tropical lowland wet forest". Land clearance and cultivation of the area occurred mainly in the 20th century, triggered by the establishment of large-scale banana plantations of the United Fruit Company. Today, agricultural land consisting of plantations of various fruit trees, oil palms, rice fields and pastures is now wide spread and primary forest is largely restricted to the national parks (Corcovado and Piedras Blancas National Parks).

We studied vegetation composition in 29 different habitats, using plots with sizes ranging from 50 to 1.000 m^2. In each habitat type, one plot was established. The habitats investigated ranged from primary forest to cultivated land. We included different types of primary and secondary forests, fern fields (dominated by *Dicranopteris* and *Nephrolepis*), various kinds of agricultural land, gravel banks of rivers, and coastal vegetation (Table 3). Plots were selected by the first two authors and Eva Schembera. In forest plots, only woody species with a stem diameter at breast height (dbh) > 5 cm have been recorded, whereas in the other plots, all plants have been recorded. For a more detailed description of the vegetation, see the chapter "Vegetation" in this volume.

To identify whether invasion of alien plants matches local hot spots of range-restricted species, 29 endemic species – that is species restricted to Southern Costa Rica and nearby Panama – have been counted separately. Systematic treatment follows APG II (2003).

Table 1: List of the alien plant species recorded in the plots.

Species	Family
Allamanda cathartica	Apocynaceae
Arachis pintoi	Fabaceae-Faboideae
Citrus aurantifolia	Rutaceae
Cocos nucifera	Arecaceae
Costus speciosus	Costaceae
Desmodium adscendens	Fabaceae-Faboideae
Eichhornia crassipes	Pontederiaceae
Emilia fosbergii	Asteraceae
Hedychium coronarium	Zingiberaceae
Ipomoea batatas	Convolvulaceae
Kyllinga odorata	Cyperaceae
Lagerstroemia speciosa	Lythraceae
Ludwigia hyssopifolia	Onagraceae
Ludwigia octovalvis	Onagraceae
Mimosa pudica	Fabaceae-Mimosoideae
Nephrolepis multiflora	Oleandraceae
Psidium guajava	Myrtaceae
Quararibea cordata	Bombacaceae (now Malvaceae)
Senna alata	Fabaceae-Caesalpinioideae
Syzygium jambos	Myrtaceae
Terminalia catappa	Combretaceae

Results

We recorded a total of 877 species of vascular plant species, of which 29 (3.3%) are endemic. The most species-rich habitat was the primary forest on ridge (285 species), whereas the *Nephrolepis* fern field (12 species) was the least diverse.

In total, we recorded 21 (2.4%) alien plant species (Table 1) and another eight non-indigenous cultivated plant species (Table 2). No alien plant species were found in primary forests, in the clearing dominated by the fern *Dicranopteris*, on the rock in the surge and in the steep coastal forest of the Golfo Dulce (Table 3). In the two coastal plots, three alien plant species were identified, the alien *Cocos nucifera* and *Terminalia catappa* being the dominant arboreal species. The alien fern *Nephrolepis multiflora* is dominant in wet, unwooded areas, and in total five alien plants have been recorded in this plot. Four alien species were counted in the *Gmelina arborea* plantation, six species in the teak (*Tectona grandis*) plantation. In three habitats associated with pastures, we found a total of nine alien plant species.

Table 2: List of cultivated non-indigenous plants recorded in the plots.

Species	Family
Bactris gasipaes	Arecaceae
Elaeis guineensis	Arecaceae
Ficus benjamina	Moraceae
Gmelina arborea	Verbenaceae
Oryza sativa	Poaceae
Persea americana	Lauraceae
Tectona grandis	Verbenaceae
Theobroma cacao	Sterculiaceae (now Malvaceae)

Table 3: Native and alien plant species diversity across habitats. The columns show habitat type, plot size (m^2), primary or anthropogenic habitat, total species number, alien species diversity, and number of endemics and percentage of endemic and vascular plant species in the overall species count, respectively.

habitat type	plot size (m^2)	primary / anthropo-genic habitat	total species no	alien species no	endemic species no	% alien species	% endemics
Pasture	325	anthrop.	51	9	0	17.6	0.0
Primary ridge forest	1000	primary	285	0	10	0.0	3.5
Secondary forest	1000	anthrop.	54	0	3	0.0	5.6
Primary coastal forest	1000	primary	121	0	4	0.0	3.3
Primary gorge forest	1000	primary	207	0	13	0.0	6.3
Fern field – *Dicranopteris*	350	anthrop.	22	0	1	0.0	4.5
Fern field – *Nephrolepis*	200	anthrop.	12	5	0	41.7	0.0
Plantation – *Tectona*	1500	anthrop.	24	6	0	25.0	0.0
Plantation – *Gmelina*	1000	anthrop.	58	4	0	6.9	0.0
Plantation – African oil palm	500	anthrop.	16	0	0	0.0	0.0
Plantation – rice	1000	anthrop.	16	2	0	12.5	0.0
Gap in ridge forest	250	primary	91	0	2	0.0	2.2
Gap in gorge forest	150	primary	78	2	2	2.6	2.6
Secondary ridge forest	1000	anthrop.	164	1	6	0.6	3.7
Secondary young forest	1000	anthrop.	191	1	12	0.5	6.3
Secondary forest with *Vochysia*	1000	anthrop.	196	0	10	0.0	5.1
Secondary forest old	1200	anthrop.	55	0	3	0.0	5.5
Vochysia forest	1000	anthrop.	132	0	5	0.0	3.8
Gravel bank with *Gynerium*	1000	primary	38	4	1	10.5	2.6
Gallery forest – Quebrada Negra	1000	anthrop.	138	3	4	2.2	2.9
Gallery forest I – Rio Bonito	1000	primary	135	2	8	1.5	5.9
Swampy forest – Rio Oro	1000	primary	28	0	1	0.0	3.6
Gallery forest II – Rio Esquinas	1000	primary	69	4	1	5.8	1.4
Edge of primary forest	1000	primary	243	0	10	0.0	4.1
Wayside	—	anthrop.	40	5	0	12.5	0.0
Vegetations on rocks on the coast	10	primary	13	0	1	0.0	7.7
Rocky coastal forest	100	primary	23	0	0	0.0	0.0
Beach forest – *Hibiscus*	50	primary	10	4	0	40.0	0.0
Beach forest – *Cocos*	50	primary	7	2	0	28.6	0.0
Total			**877**	**21**	**29**	**2.4**	**3.3**

Fig. 1: The attractive fern *Nephrolepis multiflora* is the dominant fern in wet, unwooded areas. The species is native to India.

Fig. 2: *Lagerstroemia speciosa* (Lythraceae) – the Pride of India or queen's crape myrtle – is native to Southeast Asia and has very attractive large pink or purple flowers. This species was introduced as an ornamental tree and now invades open wet pasture land.

Fig. 3: *Eichhornia crassipes* (Pontederiaceae), the water hyacinth, whose origin is the Amazon Basin, has become the most serious invasive weed in many tropical freshwater habitats around the world.

Most alien plant species have been recorded in one habitat type; few have been recorded in several habitat types (e.g. *Desmodium adscendens*, *Mimosa pudica*, *Psidium guajava*). However, in agricultural habitats, in some coastal habitats and in fern fields, some of the alien species occur in high abundance (e.g. *Nephrolepis multiflora*, *Terminalia catappa*; Fig. 1 and 4). *Lantana camara*, which is native to parts of Central and South America and an alien in many tropical regions, was not classified as alien, as it might be native to Costa Rica. *Cocos nucifera* is native to the western Pacific and eastern Indian Ocean, but is now growing on tropical coasts world-wide; according to SAUER (1983), we classified this tree as alien for Costa Rica.

Discussion

Invasion patterns

The total number of aliens recorded is rather low (21 species) and several alien species per plot have been recorded only in few plots (agricultural land, coastal vegetation). However, other habitats with a pronounced natural disturbance regime (e.g. coastal vegetation, riverine gravel banks) are also affected by plant invasions.

In agreement with other studies from Central American tropical lowlands (e.g. HARTSHORN & HAMMEL 1994), invasion patterns across habitats in southern Costa Rica show a strong correlation to human disturbance and habitat transformation. As endemic species occur mostly in primary forests, habitat match between alien and endemic species is poor and range-restricted species are thus not threatened by biological invasions.

The absence of alien plant species in primary and secondary forests is conspicuous. Although we did not explore the causal factors for this phenomenon, we argue that this high invasion resistance can be attributed to the intense use of resources (light, nutrients) by the resident vegetation, which makes invasions less likely (DAVIS et al. 2000). However, other factors (e.g. time lag phenomena, low disturbance intensity, low introduction effort and hence low propagule pressure of shade-resistant planted non-native species) might also help to account for this invasion pattern.

The invasion of alien plants in the tropical lowlands of Southern Costa Rica is not as pronounced as in the country's highlands, which are mostly invaded by alien species originating from temperate regions (BERNHARD & KOCH 1994). This result is in contrast to invasion patterns in most other regions world-wide, where a strong negative correlation between the invasion success of alien species and the annual mean temperature (or altitude, as a surrogate for temperature) exists, e.g. Central Europe (CHYTRÝ et al. 2005) and North America (DARK 2004, PALMER 2006).

As we established only one plot per habitat type, a detailed quantitative analyses of invasion patterns across habitat types is currently not possible. However, based on a detailed knowledge of the vegetation and floristic composition of the Golfo Dulce region, we are convinced that the presented invasion patterns are robust and will not change substantially if new data were included.

Consequences for nature conservation

The impact of invasions on habitats and native species was not assessed in our study. However, alien

Fig. 4: In beach forest on the coast of the Golfo Dulce, the non-indigenous plants *Cocos nucifera* (Arecaceae) and *Terminalia catappa* (Combretaceae) are the dominant arboreal species.

plants are mostly restricted to human-disturbed habitats and invaded few natural habitats (e.g. coastal vegetation). Hence, we assume that problems for nature conservation are minor. However, the low total species number in the fern fields dominated by the alien *Nephrolepis multiflora* might result from competitive exclusion. As far as natural habitats are concerned, coastal habitats, riverine pioneer habitats, and open wetlands harbour some alien species which reach higher abundances.

However, the absence of alien plants in primary forests does not necessarily mean that future invasions into these habitats are impossible. Lag phenomena, the introduction of new alien species and changing climate might make these habitats more vulnerable.

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