

The ecology, distribution and conservation status of *Myrcianthes coquimbensis*: a globally endangered endemic shrub of the Chilean Coastal Desert

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Background: *Myrcianthes coquimbensis* is an endangered shrub endemic to Chile. No published account is known about its biology, ecology or threats to its continued existence.

Aims: To document the current state of knowledge of *M. coquimbensis* regarding its geographic distribution, and population and reproductive parameters, and to evaluate threats in its distribution range.

Methods: Historical records and recent survey data of 110 localities were used to characterise its known distribution. Plots were established in seven localities to determine the proportion of flowering individuals, recruitment and estimate population size and structure. Finally, levels of post-dispersal seed predation were determined in one locality.

Results: The current distribution of *M. coquimbensis* extends along 82.8 km of the Chilean coast, where the species is mainly threatened by habitat loss. Only 13% of the individuals flowered during 2010, and 66% of these plants lost their entire flower crop due to desiccation. Few seeds (7.5%) were lost to post-dispersal seed predation. The populations are composed mainly of adult plants (70% of the individuals), and little to no recruitment was observed.

Conclusions: *M. coquimbensis* populations are threatened by habitat loss and are not naturally recruiting through sexual reproduction. This exemplifies a case where studies on the ecology of a species are urgently needed to be able to design effective conservation and management plans.

Keywords: Atacama Desert; Chile; conservation biology; habitat loss; Myrtaceae; restricted-range species

Introduction

The flora of Chile is known for its high levels of endemism. Approximately 46% of its 5708-strong flora is endemic (Marticorena 1990), making Chile the country with the largest percentage of endemic plants in South America. Within mainland Chile, the highest concentration of endemic plants occurs in the coastal fringe of the Atacama Desert (Squeo et al. 2001; Arroyo et al. 2004). One such plant is *Myrcianthes coquimbensis* (Barnéoud) Landrum and Grifo, a globally endangered shrub unique to the Coquimbo Region of Chile (Landrum and Grifo 1988).

A member of the Myrtaceae, *Myrcianthes* is a New World genus distributed in Florida and the Caribbean, and from southern Mexico to Chile, Argentina and Uruguay (Grifo 1992). *M. coquimbensis* is the only member of the genus *Myrcianthes* in Chile. In South America, its closest relatives are found in the province of Tucumán, Argentina (*M. pungens* and *M. callicoma*).

Myrcianthes coquimbensis was originally described in 1840 as *Myrtus coquimbensis* by François Marius Barnéoud; a century later in 1940, Eberhard Max Leopold Kausel placed it in his new, monotypic genus *Reichea* as *R. coquimbensis*. In 1968, Rogers McVaugh suggested a close relationship between *Reichea* and *Myrcianthes*, and

finally in 1988 Landrum and Grifo formally made the new combination of *Myrcianthes coquimbensis*.

This species is a low, dense, rounded shrub characterised by perennial glabrous aromatic leaves with oil glands, white flowers with five calyx lobes and abundant stamens, and a fruit consisting of a fleshy berry (Figure 1). A detailed description of the family and morphology of the species can be found in Landrum (1988) and Landrum and Grifo (1988), respectively.

In Chile, *M. coquimbensis* has an extremely narrow distribution along a coastal strip, 60 km long and ca. 2 km wide (Landrum and Grifo 1988; Hechenleitner et al. 2005). It grows along coastal slopes, and is almost exclusively restricted to large rock formations that constantly receive a moist breeze from the Pacific Ocean (Landrum and Grifo 1988; Hechenleitner et al. 2005). There are, however, some individuals that grow in open areas. This species also grows associated with other plant species, which commonly include *Bridgesia incisifolia* Bertero ex Cambess, *Oxalis gigantea* Barnéoud, *Heliotropium stenophyllum* Hook. & Arn., *Bahia ambrosioides* Lag. and *Polyachyrus poeppigii* Kuntze ex Less (Squeo et al. 2001; Hechenleitner et al. 2005; Zuloaga et al. 2008).

Currently, *M. coquimbensis* is catalogued as endangered due mainly to its extremely restricted distribution

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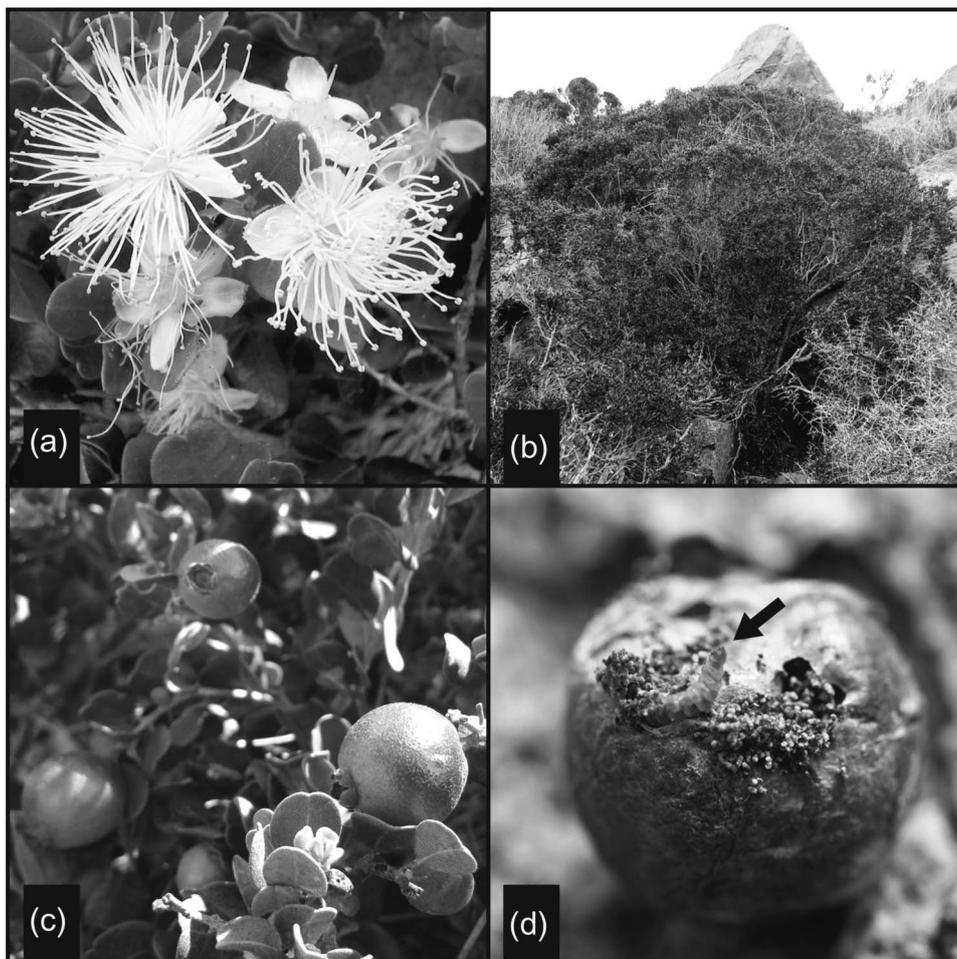


Figure 1. *Myrcianthes coquimbensis* (a) flowers; (b) growth form; (c) fruits and (d) one of its lepidopteran predispersal seed predators.

where it is affected by habitat loss (Riedermann et al. 2006). There have been very few studies made on the species; consequently there is very little known about its biology or ecology. The objective of this paper is to document the current state of knowledge on *M. coquimbensis*, the threats to it and its conservation status. To do so, we reviewed all accessible information from published and unpublished sources, and compiled information on the distribution of the species. In addition, we present preliminary empirical data on population and reproductive parameters. We use our findings to highlight knowledge gaps and conservation strategies for this endangered species.

Methods

Distribution and threats

Locality records for *M. coquimbensis* were obtained from scientific publications and herbarium specimens at the University of La Serena (ULS), University of Concepción (CONC) and the Chilean Museum of Natural History (SGO). In addition, we sought personal accounts from researchers and experienced botanists, and referred to conservation reports, technical studies and environmental

impact studies (Squeo et al. 2010). In order to update the known distribution of *M. coquimbensis*, during September and October 2010 localities with recorded occurrences of the species, as well as several sites beyond the known area of distribution (10 and 30 km to the south and north of the reported distribution, respectively), were visited and geo-referenced. At each of the sites the potential threats for this species were also identified.

Population estimates and age structure

To estimate population size of *M. coquimbensis*, we selected seven localities within its distribution range (Table 1). In each locality we established four 25 m × 25 m plots in which all *M. coquimbensis* individuals were marked and counted. Population size was calculated by extrapolating the mean value obtained for the four plots (i.e. mean number of individuals/625 m²) to the area of occupation (AOO) at each site (Gaston and Fuller 2009), which was estimated based on field observations guided by ASTER satellite images of the year 2007. For this analysis ArcMap 9.3 software was used. Note that, in almost all cases, population numbers are certain to be overestimates of the true number of individuals present because shrubs that

Table 1. Estimated population size in seven localities surveyed along the distribution range of *Myrcianthes coquimbensis*. The table shows coordinates for each locality, area of occupation (AOO), mean density within the 625 m² plots and the estimated population (see methods for further details).

Locality	Coordinates	Estimated AOO (km ²)	Density (Mean \pm SD)	Estimated population size
Barrancones	29°25' S – 71°79' W	0.87	18.0 \pm 6.2	6,239
Temblador	29°28' S – 71°18' W	0.45	60.5 \pm 44.6	11,011
Caleta Hornos	29°34' S – 71°18' W	0.09	50.3 \pm 30.4	1,857
Conchillas	29°34' S – 71°19' W	0.51	50.3 \pm 30.6	10,217
Punta Teatinos	29°49' S – 71°17' W	0.50	31.8 \pm 17.9	6,378
El Panul	29°59' S – 71°22' W	0.44	40.5 \pm 9.6	7,129
Totalillo	30°04' S – 71°22' W	0.23	43.5 \pm 20.0	4,062
TOTAL		3.10		46,892

are relatively close to each other are frequently clones of one individual connected by a common root system. Without digging deep in the rocky substrate, however, it is impossible to tell clones apart, thus each shrub was individually marked and is referred to as an individual hereafter. To determine population age structure, all marked plants within the plots ($n = 1205$) were classified into six relatively discrete stage classes: seedlings, saplings, trunk sprouts, root sprouts, small shrubs and adult shrubs. All stages, except the adult shrubs, are non-reproductive.

Flower and fruit production

We collected data on flowering patterns and fruit production of *M. coquimbensis*. To determine what proportion of the population flowered in the 2010–2011 season, in each of the seven localities mentioned above, all individuals that were in bloom within each 25 m \times 25 m plot were recorded. An interesting phenomenon observed along the distributional range of this species, is the almost simultaneous death of all flowers within plants due to desiccation, which is probably caused by summer droughts. Because dry flowers and flower buds remain on the shrubs for a few months, it was possible to record all individuals that experienced flower desiccation (dried flowers syndrome hereafter) in the plots.

Finally, the transition probability from flower bud to developing fruit (i.e. flower ovaries slightly swollen) was quantified at the Conchillas site (Table 1). To calculate this probability, two large branches of 23 individuals were individually marked, and in November of 2010 (at the beginning of the flowering season at the site), the total number of flower buds on each branch was counted. After 42 days, marked branches were re-surveyed and the number of developing fruits on each plant was recorded. The transition probability was calculated as the mean ratio of developing fruits to flower buds.

Seed predation

To estimate the proportion of seeds that are lost to post-dispersal seed predation, the removal of *M. coquimbensis* seeds from experimental seed depots was quantified at the Totalillo site in September 2010. Seed depots consisted

of 10 seeds each. Depots were blocked by microhabitat, where each block consisted of a depot adjacent to, or in between, large rocks and a site on bare soil; these microhabitats were selected because they constitute the natural recruitment sites of *M. coquimbensis*. A total of 21 depots per microhabitat were used. Seed depots were left in place for 21 days; the number of seeds that showed signs of being predated (i.e. seed fragments, seeds with teeth marks) and the number of seeds removed was recorded. The assumption was made that seeds that had been removed from the depots were predated.

Recruitment

An assessment of the recruitment level of *M. coquimbensis* along its area of distribution was made by conducting thorough searches for seedlings in 110 localities. Each locality was searched exhaustively for seedlings between September 2010 and February 2011. This is the time period when one is most likely to find the current years' newly emerged seedlings, because September is the end of the fruiting season and the time of the winter rains, and thus it is the period when seedlings are most likely to emerge because soil water potentials are the highest of the year (Muñoz et al. 2008). In contrast, February is the end of the flowering season and it is unlikely that seedlings emerge during or after this time, as it is the peak of the summer droughts.

Results and discussion

Distribution and threats

The reported historical distribution of *M. coquimbensis* extended from Punta Calavera (40 km to the north of La Serena) to Totalillo (20 km to the south of La Serena) (Landrum and Grifo 1988, herbarium records [ULS, CONC and SGO]), giving a total latitudinal extent of 60 km along the coast. With our data, however, the occurrence range of *M. coquimbensis* was expanded by 20.8 km to the north (from Punta Calavera to Barrancones) and 2 km to the south (from Totalillo to Las Tacas), giving a new latitudinal extent of 82.8 km along the coast (Figure 2).

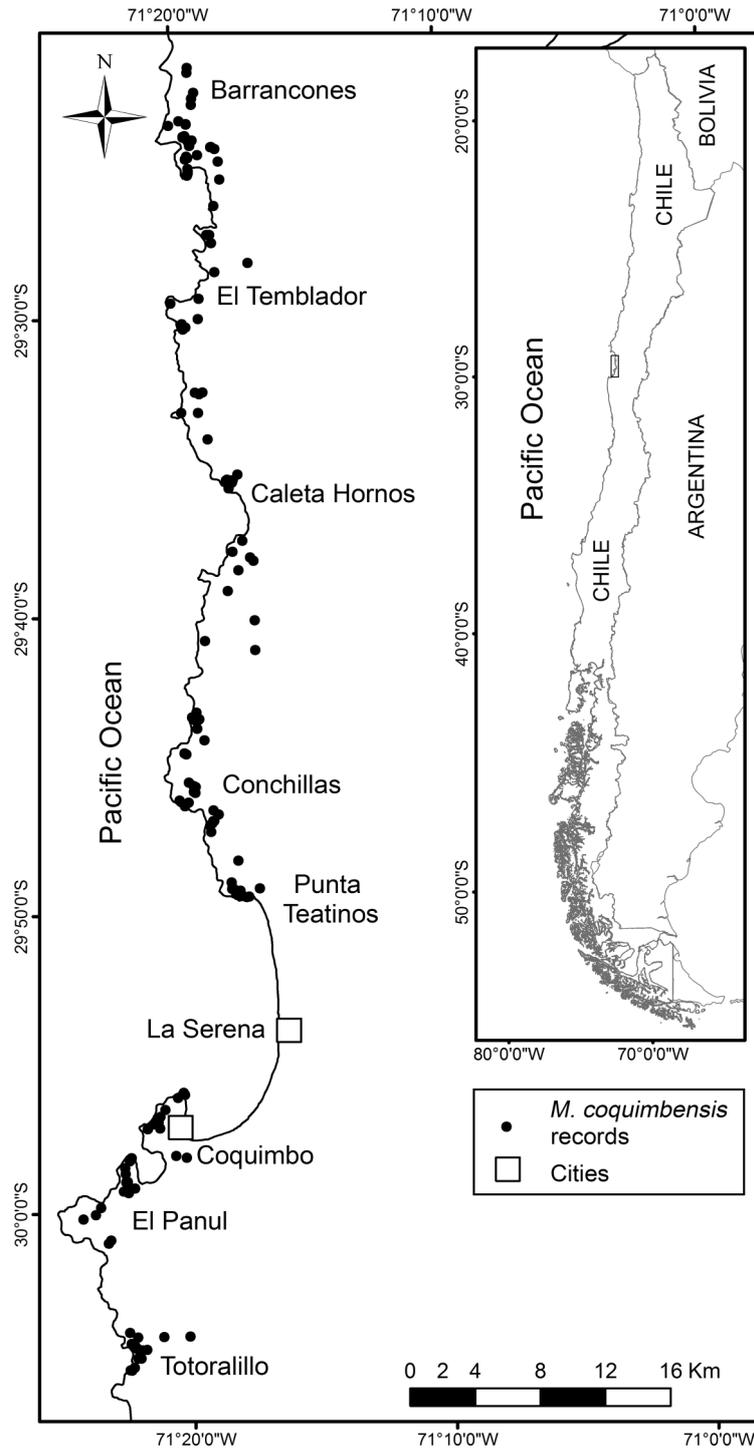


Figure 2. Current distributional range of *Myrcianthes coquimbensis*. Each point represents a current record of the species. The experimental sites described in Table 1 are labelled on the map.

The main threat that *M. coquimbensis* faces is habitat loss; most of its habitat is being destroyed by development projects for tourism, recreational areas and urban sprawl. The localities that are most affected by these projects are El Panul and El Arrayán (Table 1; Figure 3). The extraction of leaf litter from underneath shrubs, which is used as a natural soil fertilizer (Squeo et al. 2001), may also constitute an important threat to the species for at least

two reasons. Firstly, from an ecological perspective, leaf litter is likely to be important for seed germination and seedling establishment, because it provides nutrients to the nutrient-poor desert soils (Callaway 1995), hence removing leaf litter may reduce reproductive output. Secondly, to make removal of leaf litter easier, the shrubs are often cut from the base or at least large branches are removed, which also reduces reproductive output. Leaf litter removal

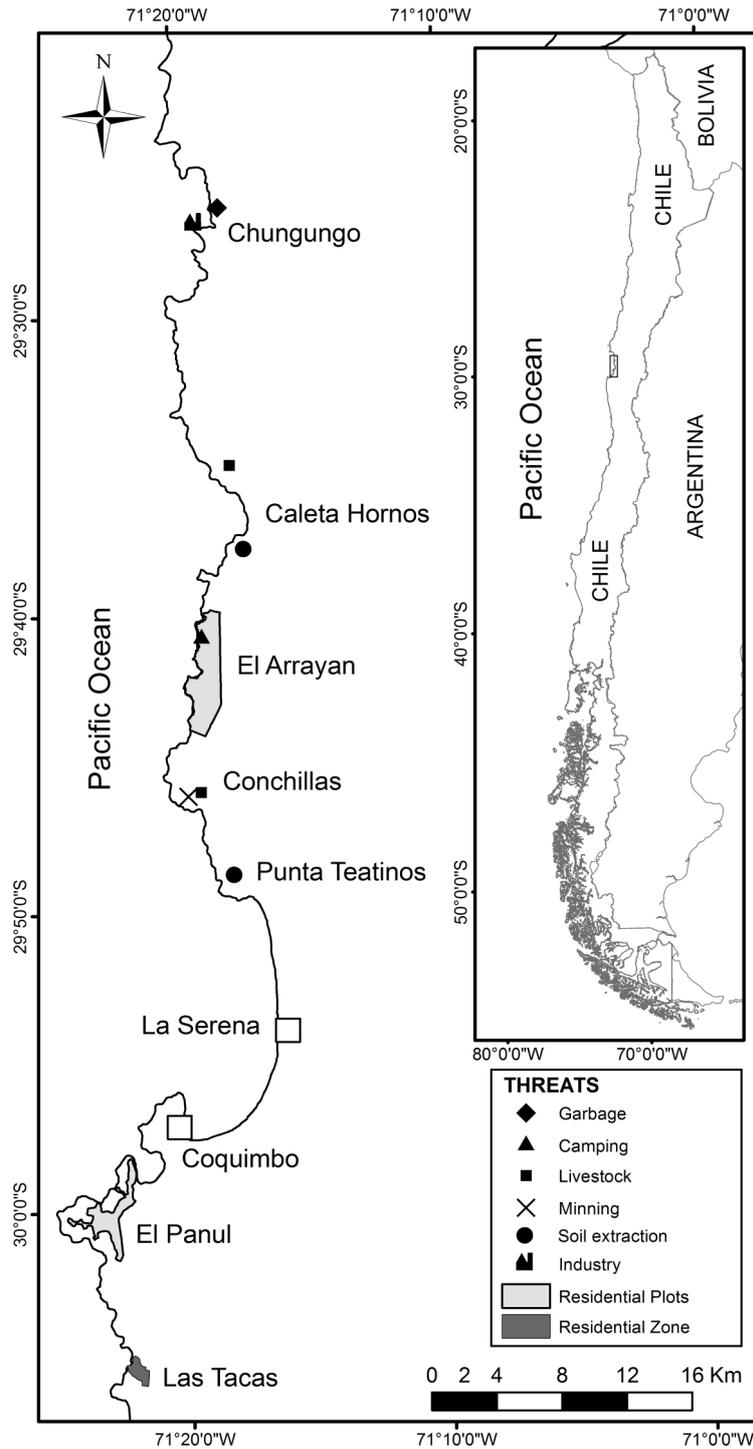


Figure 3. Identified potential threats to *Myrcianthes coquimbensis* along its distributional range.

was recorded in two localities: Punta Teatinos and Caleta Hornos (Figure 3). There are other threats that reduce the habitat of *M. coquimbensis*, but which currently impact only few localities, namely underground mining, charcoal kilns and illegal dumps in urbanised or semi-urbanised areas. Although localised now, these threats may become of more concern if they extend to more localities across the distribution of this species. Finally, there is a major project

for industrial energy (Cruz Grande) (Abastecimientos CAP S.A. 2008) that threatens the *M. coquimbensis* population located in Chungungo (Figure 3).

Estimates of population size

The minimum and maximum density of *M. coquimbensis* individuals per 625 m² plot (mean ± SD) ranged

between 18.0 ± 6.2 and 60.5 ± 44.6 , respectively (Table 1). Interestingly, the locality with the lowest density of plants (Barrancones) was also the site with the largest individuals, resembling small trees rather than shrubs. The total estimated population size was 46,892 individuals (Table 1), with the highest numbers in the two most northern sites. However, as mentioned previously, these numbers are certainly an overestimation of the real values, not only because of the inclusion of clones as separate individuals, but also because, given the very small-scale habitat patchiness of this species distribution, the AOO at each site was probably overestimated.

Across its area of distribution, the stage classes of *M. coquimbensis* were distributed as follows: seedlings (0.9%); saplings (2.6%); small shrubs (22.3%); root sprouts (2.1%); trunk sprouts (2.1%); and adult shrubs (70%). Within each site, population structure varied significantly (Table 2). However, populations in general were composed mainly of adult individuals with few to none individuals of younger stage classes (i.e. seedlings and saplings).

Flower and fruit production

The reported flowering season of *M. coquimbensis* is from October to December (Landrum 1988; Cortes 2010). In our field observations, flowering occurred from mid November until late December, with some individuals flowering until late February. Approximately 13% ($\pm 14\%$) of the individuals flowered during the 2010–2011 season.

The overall probability of a flower transitioning to a developing fruit at the Conchillas site was extremely low, ranging from 0 to 0.15 (median = 0). In fact, only four of the 23 marked shrubs showed such a transition; in all other cases flowers died before forming fruits. With respect to the dried flowers syndrome, on average 66% ($\pm 19\%$) of the individuals that flowered in the plots showed clear signs of having undergone widespread flower desiccation. Both the fact that a small fraction of the individuals produces flowers and that most plants lose their entire flower crop suggests that a recruitment bottleneck occurs at this stage in the plant's life.

We have no quantitative data on when ripe fruits become available along the distribution range of *M. coquimbensis*. Given that some plants have developing fruits in early February, we estimate that ripe fruits may

be available from April until August (winter). Moreover, during field observations in September and October, we observed only three individuals with fruit, whereas many others had already dropped fruits on to the ground, suggesting the end of the fruiting season.

Seed predation

The percent of seeds predated (mean \pm SD) at the end of the experiment (21 days) did not differ between bare ground ($6 \pm 9\%$, $n = 21$) and rocky surface ($9 \pm 10\%$, $n = 21$). On average, only 7.5% of seeds at the Totoralillo site were lost to post-dispersal seed predation, suggesting that this process may not limit recruitment. In most cases, seeds appeared to have been predated by small mammals (as indicated by tooth marks on seed remnants); however, more studies are needed to determine the contribution of different seeds predators to the total percentage of post-dispersal fruit loss.

Fruits also suffer from pre-dispersal predation, and infested fruits with at least two species of Lepidoptera larvae that consume the seed were often seen (Figure 1), but there are no data on the proportion of fruits that are lost due to this process. Finally, goats are also known to consume the fruits before they are dispersed, but there is no quantitative data on the proportion of the fruit crop they consume.

Recruitment

There were 42 seedlings and/or saplings found in the 110 localities visited; one seedling was located at the Coquimbo site growing on grass leaf litter and died relatively soon after emerging. Other seedlings and/or saplings were observed at the Totoralillo ($n = 1$), El Panul ($n = 3$), Conchillas ($n = 9$) and Punta Teatinos ($n = 28$) sites. In all of these sites, seedlings were growing in soil inter-spaces sheltered by large rock formations, which have microclimatic conditions different from those in open areas (e.g. higher soil moisture and lower daily air temperature; authors' pers. obs.). This suggests that rocks may be acting as nurse objects, facilitating early recruitment (Munguía-Rosas and Sosa 2008; Peters et al. 2008). In addition, at the Punta Teatinos site we also found seedlings emerging underneath an adult *M. coquimbensis* shrub.

Table 2. Population structure of *Myrcianthes coquimbensis* in seven localities surveyed along its distribution range. The table shows the percentage of individuals distributed in each stage class. BR, Barrancones; CL, Caleta Hornos; CN, Conchillas; PN, El Panul; PT, Purta Teatinos; TM, El Temblador and TT, Totoralillo.

Stage	Average	BR	TM	CL	CN	PT	PN	TT
Saplings	2.6	0.0	0.0	0.0	0.0	13.5	2.5	0.6
Seedlings	0.9	0.0	0.0	0.0	0.0	7.5	0.0	0.0
Adult shrub	70.0	88.2	59.1	76.4	67.9	68.4	62.3	89.1
Small shrub	22.3	7.4	38.4	16.1	24.1	9.8	29.6	8.0
Root sprout	2.1	4.4	0.8	3.5	4.8	0.0	2.5	1.1
Trunk sprout	2.1	0.0	1.7	4.0	3.2	0.8	3.1	1.1

In all localities visited vegetative growth was observed, especially in individuals with bare roots, from which sprouts often arise. Together, these observations suggest that *M. coquimbensis* is a species where recruitment by seed is strongly limited. Interestingly, however, field and laboratory observations of seed germination showed that a large percentage of seeds germinate within a few days after the fruits fall to the ground. Therefore, in addition to the loss of flower crops, another bottleneck to recruitment by seed may occur during the seedling establishment stage. In this sense, Holmgren et al. (2006) have suggested that seedling establishment in the Atacama Desert may be determined by climatic anomalies in the region, specifically climatic changes associated with El Niño Southern Oscillation (ENSO) events, although more studies over longer time periods are necessary to confirm this hypothesis.

Conservation status and avenues for future research

Following International Union for Conservation of Nature (IUCN) guidelines, *M. coquimbensis* was officially declared by the Chilean environmental agencies as 'endangered' (EN B1ab(iii) + 2ab(iii)) in 2008. As mentioned above, the species is currently threatened by habitat loss; most of its habitat is rapidly being destroyed to accommodate a variety of construction/development projects. In addition, little to no recruitment is observed in natural conditions. Currently, it is imperative to determine if the lack of observed recruitment is due to low fruit production because of pollen limitation, high rates of flower or fruit loss, low germination and establishment probabilities, or other underlying processes.

Virtually nothing is known about the ecology of this species, therefore there are several avenues for future research; here we cite a few critical ones that are important to strengthen any conservation planning for *M. coquimbensis*. Firstly, data on the breeding system are needed. Field observations suggest that it is an outcrossing species, but no data are available to confirm these observations. González-Varo et al. (2009) showed that a related species (*Myrtus communis*) has a self-compatible breeding system that benefits from pollinator services and cross-pollination (i.e. higher fruit set and brood size, respectively). Only recently, in a study located in Punta Teatinos, Cortes (2010) examined the structure of a pollination network, where *M. coquimbensis* was a member of the community. In this study, *M. coquimbensis* was visited by 17 insect species, with visit frequencies evenly distributed among them, suggesting that this species is not pollinator limited. However, more information is needed about the reproductive system and pollination biology of *M. coquimbensis* to confirm this hypothesis. Secondly, it is important to identify why such a large proportion of the flowers are lost to desiccation, including whether this is a common phenomenon, or something that was unique to the year of observation. Thirdly, quantitative data on pre- and post-dispersal seed loss across the distributional range are required to determine if this

seed loss limits recruitment. In long-lived plant species, the probability of escaping seed predation and arriving at a suitable microhabitat for germination and establishment is important for the viability of natural populations (García 2003). Further work should establish seedling emergence thresholds of *M. coquimbensis*. This is important, because *M. coquimbensis* has recalcitrant seeds (i.e. they are large and photosynthetically active) (Gold et al. 2004), and thus have a small window to germinate during the season in which seeds are produced. In addition, at the beginning of the twentieth century, rainfall in the distribution area of *M. coquimbensis* averaged 170 mm year⁻¹, while currently, the average is 80 mm year⁻¹ (Squeo et al. 1999), and climate change scenarios predict even drier conditions in the near future. Consequently, it is fundamental to determine how different rainfall regimes will affect seedling emergence, as it will enable us to predict recruitment capabilities of this species in different climate change scenarios. Finally, future studies should examine the degree of genetic diversity that is present in this taxon. This information can help determine the degree of genetic isolation among populations, as well as aid in making informed conservation decisions.

Conservation strategies for *M. coquimbensis* should be directed to reduce habitat loss due mainly to housing and development projects, which are the main threat identified for the species. A way to achieve this goal is by promoting in situ conservation activities, such as the creation of natural reserves that protect not only the target species, but also the habitat, non-target species and the set of biological interactions within the protected area (Possingham et al. 2006). In the Coquimbo region almost no public land is left, thus an alternative is to focus on the creation of private reserves (F. Squeo et al. unpublished data) at sites identified as priority areas for conservation (Squeo et al. 2001).

Conclusions

This paper highlighted ongoing concerns in understanding the current status and threats faced by *M. coquimbensis*, a globally endangered endemic plant of the Atacama Desert. Our data shows that most of the populations of this species along its distribution range are threatened by habitat loss and urban expansion. Further, *M. coquimbensis* is not recruiting naturally by sexual reproduction; however, there is no detailed information on which ecological process may be limiting recruitment. In order for this species to persist in the long term, we emphasise the need for studies on its ecology, particularly those that examine the relative importance of each vital stage to the overall fitness of the populations. With such information, it will be possible to design effective actions for the conservation and management of *M. coquimbensis*.

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