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Assessing the Impact of Invasive Species Management Strategies on the Population Dynamics of Castor Bean (Ricinus communis L., euphorbiaceae) at Two Southern California Coastal Habitats

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Assessing the Impact of Invasive Species Management Strategies on the Population Dynamics of Castor bean (*Ricinus communis* L., Euphorbiaceae) at Two Southern California Coastal Habitats

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ABSTRACT: The diverse uses of *Ricinus communis* L. (Castor bean) in herbalism, agriculture, and horticulture have facilitated the worldwide dispersal of this invasive r-selected species. A common element in ruderal areas and transitional habitats, the invasive species management of *R. communis* in southern California has largely relied on manual removal strategies. This study evaluates how the survivorship and fecundity of naturalized *R. communis* populations is impacted by the invasive species management strategies at two sites: Ballona Wetlands and Temescal Canyon Gateway Park. Our findings suggest that documenting patterns of survival and reproduction serve as a tool for the adaptive management of invasive species control strategies.

Index terms: fecundity, invasive species management, life table, population biology, survivorship

INTRODUCTION

The Castor bean plant, *Ricinus communis* L. (Euphorbiaceae), is a woody shrub species that is native to India, East Africa, and Southern Europe ca. 1200 m (Linnaeus 1753). However, the wide use of *R. communis* in ethnobotanical treatments (Scarpa and Guerci 1982), agroecosystem biocontrol (Zaki and Bhatti 1990), chemical feedstock (Sommerville and Bonetta 2001), and landscape horticulture (Wu et al. 1995) has facilitated the escape, naturalization, and dispersal of this species throughout the world (Crooks 1948; Balls 1962). As a pioneer species of habitats in early secondary-succession (El-Sheikh 2005), *R. communis* is successful at invading non-native habitats with frequent and/or intense disturbance regimes (Aschman 1991; Hood and Naiman 2000; Sobrino et al. 2009) and is common in ruderal areas and transitional habitats such as habitat edges (e.g., ecotones, buffer zones, roadsides, etc.), fallows (e.g., agricultural, rural, urban, etc.), embankments (e.g., canals, channels, seasonal riverbeds, etc.), and bluffs (e.g., canyon, bajada, etc.). Dispersed primarily by autochory and secondarily by myrmecochory (Martins et al. 2009), there is some evidence that *R. communis* does not form long-term seed banks in non-native habitats (Martins et al. 2009). A generalist germination strategy also allows *R. communis* to germinate under a wide range of environmental conditions (Martins et al. 2011) where it exploits a superior competitive ability over native plant communities (Vavra et. al. 2007; Funk and Zachary 2010).

In southern California, *R. communis* invades a diverse array of habitats, ranging from the remaining estuaries and coastal wetlands to the riparian communities along the canyons and foothills of both *trans*- and *cis*-mountain ranges. Strategies to control invasive plant species in southern California primarily rely on mechanical and/or chemical eradication (Rejmanek et al. 1991), which suggests that the intensity and frequency by which invasive species like *R. communis* are removed may be impacted by budget resources (Westman 1990). For example, the budget available to the Ballona Wetlands, the last remaining major coastal wetland on the western edge of Los Angeles County (West 2001), allows for intense and frequent campaigns to remove invasive plants (Friends of Ballona, pers. comm.). In contrast, the limited budget at Temescal Canyon Gateway Park, a riparian habitat located in the foothills of the Santa Monica Mountains in Pacific Palisades, restricts the scope of campaigns to remove invasive plants (Santa Monica Mountains Conservancy, pers. comm.). However, while the early identification and eradication of invasive species are fundamental to environmental management (Garcia-de-Lomas et al. 2010), it is also important to monitor and evaluate the effectiveness of invasive species control strategies. We propose that field-studies on population dynamics (which document patterns of survival and reproduction) can serve as a tool to characterize the impact of invasive species management strategies (Meekins and McCarthy 2002; Hinton-Hardin, unpubl. data).

The objective of this study was to assess how the invasive species management strategies at Ballona and Temescal are respectively impacting the survivorship and fecundity of naturalized populations of *R. communis*. The pattern of survivorship in a population can be expressed in three types of curves: Type I, Type II, and Type III (Pinder et al. 1978). Populations that follow a Type I curve have a high survivorship as juveniles and low survivorship in older cohorts; Type II populations have equal survivorship rates regardless of cohort age; and Type III populations have low survivorship as juveniles and high survivorship in older cohorts. In general, plant populations follow the exponential decay pattern of a Type III survivorship curve (Miller 1923). We hypothesized that the aggressive invasive species eradication strategy at Ballona (in contrast to Temescal) would result in a lower survivorship and fecundity for *R. communis* populations.

METHODS

We located two sites with *R. communis* at both Ballona and Temescal and measured stem diameter (mm) at the base of the plant stem using a dial caliper. The plants were then assigned to cohorts based on stem diameter size (Tables 1 and 2). For each of the four sites, survivorship (l_x) was calculated using the formula:

$$l_x = \frac{n_x}{n_0} \qquad (1)$$

where n_0 is the number of individuals in the first cohort group and n_x is the number of individuals in each of the successive cohort groups. We counted the number of seeds produced by each plant and calculated fecundity (seeds produced per surviving individual) and the total seeds produced per member of each cohort. The fit of the cohort survivorship was tested against an exponential curve:

$$y = \lambda e^x \qquad (2)$$

where λ=3, using a Kolmogorov-Smirnov (KS) one-sample test. The distribution of cohort survivorship for all four sites was compared using a KS two-sample test. The exponential term "x" in equation (2) was used as the survivorship rate for each of the four sites. Survivorship rate was tested for normality using a Shapiro-Wilks test, and mean differences of both survivorship rate and fecundity between Ballona and Temescal were determined using a parametric t-test. Differences in variance in both survivorship rate and fecundity between Ballona and Temescal were tested using an F-test.

RESULTS

We collected stem diameters from 561 plants at Ballona and 337 plants at Temescal sites, and used a static life table to calculate survivorship and fecundity among size-class based cohorts (Tables 1 and 2). The survivorship curves for *R. communis* cohorts at all sites did not differ significantly from an exponential decay pattern (Kolmolgorov-Smirnov one-sample test, $P > 0.05$ respectively, Figure 1). Additionally, the cohort survivorship distribution did not differ significantly among the four sites (Kolmolgorov-Smirnov two-sample test, $P > 0.05$, respectively, Table 3). Both mean survivorship rate and mean fecundity were normally distributed (Shapiro-Wilks, $P > 0.05$). Neither mean survivorship rate nor mean fecundity differed significantly between Ballona and Temescal (T-Test, $P > 0.05$, Figures 2 and 3). Additionally, the variance of the survivorship rates did not differ significantly between Ballona and Temescal (F-Test, $P > 0.05$, Figure 2). However, the variance of fecundity was significantly greater in Ballona than Temescal (F-Test, $P < 0.05$, Figure 3).

DISCUSSION

The cohort survivorship of *R. communis*

Table 1. The static life table of the *R. communis* populations sampled across two sites in Ballona.

Cohort (x)	Cohort Size (mm)	Number Alive (n_x)	Survivorship (l_x)	Seeds Produced	Fecundity	Seeds Produced per Member of Cohort
1	20	512	1.0000	60	0.1	0.12
2	40	23	0.0449	4,044	175.8	7.90
3	60	12	0.0234	5,752	479.3	11.23
4	80	2	0.0039	1,404	702.0	2.74
5	100	3	0.0059	2,500	833.3	4.88
6	120	5	0.0098	11,156	2,231.2	21.79
7	140	1	0.0020	536	536.0	1.05
8	160	1	0.0020	160	160.0	0.31
9	180	1	0.0020	256	256.0	0.50
10	200	1	0.0020	340	340.0	0.66
11	220	1	0.0020	400	400.0	0.78
TOTAL				26,608		51.97

Table 2. The static life table of the *R. communis* populations sampled across two sites in Temescal.

Cohort (x)	Cohort Size (mm)	Number Alive (n_x)	Survivorship (l_x)	Seeds Produced	Fecundity	Seeds Produced per Member of Cohort
1	20	304	1.0000	0	0.0	0.00
2	40	23	0.0757	128	5.6	0.42
3	60	6	0.0197	1,020	170.0	3.36
4	80	2	0.0066	2	1000.0	6.58
5	100	2	0.0066	200	100.0	0.66
TOTAL				1,556		11.01

was not significantly impacted at either Ballona or Temescal, despite the differences in frequency and intensity of invasive plant eradication. Instead, cohort survivorship of *R. communis* followed the expected exponential decay pattern of a Type III survivorship curve. Additionally, *R. communis* at Ballona and Temescal did not differ significantly in terms of either mean survivorship rate or mean fecundity. However, there was greater variability in the fecundity of *R. communis* at Ballona, where the invasive plant eradication is both more frequent and intensive. Our findings suggest that the population dynamics of *R. communis* are not negatively impacted by the invasive species eradication strategies at either Ballona Wetlands or Temescal Canyon. Our study further suggests that the control of invasive species in Ballona Wetlands, at best, only introduces variability in the fecundity of *R. communis*. We propose that cohort structure can be negatively impacted by management strategies at both sites if plants are cut down earlier in flowering (Gao 2009). We further propose that evaluation of the population dynamics of invasive plants can serve as an assessment tool in the management of exotic species across non-native habitats.

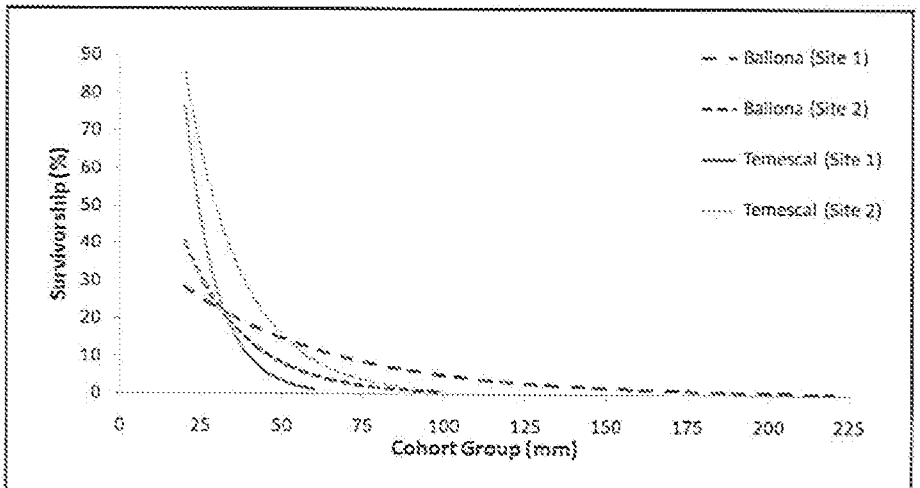

Figure 1. The survivorship curves of *R. communis* across size-classed cohorts encountered at Ballona and Temescal sites.

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Table 3. The α-values resulting from a Kolmolgorov-Smirnov two-sample test contrasting the *R. communis* survivorship curves among the Ballona and Temescal sites.

	Ballona Wetlands Site 1	Ballona Wetlands Site 2	Temescal Canyon Site 1	Temescal Canyon Site 2
Ballona Wetlands Site 1	-			
Ballona Wetlands Site 2	0.984	-		
Temescal Canyon Site 1	0.413	1	-	
Temescal Canyon Site 2	0.236	0.820	1	-

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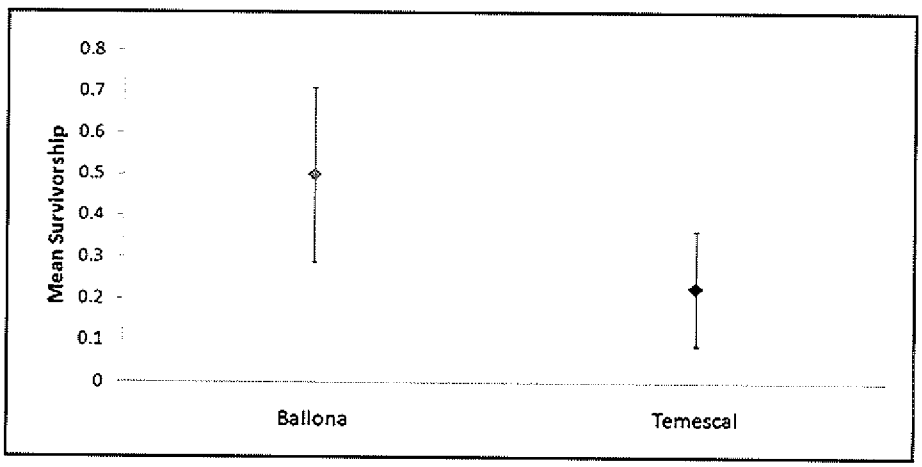

Figure 2. Mean survivorship rate of the *R. communis* populations encountered at Ballona and Temescal sites. Bars denote a standard deviation.

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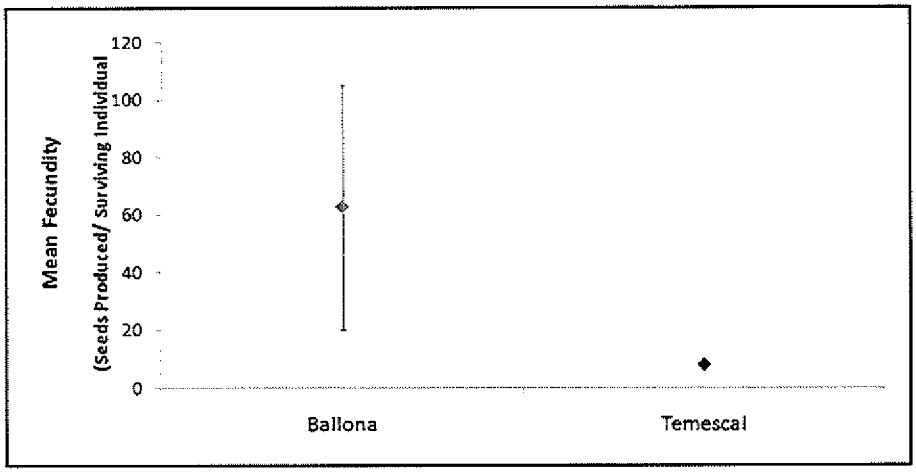

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