Effect of *Phalaris aquatica* on the abundance and diversity of vertebrate animals in Mediterranean coastal grasslands in California

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Context

Grasslands in California are important for ecosystems that support and sustain wildlife (Guisti *et al*., 1996). Invasion of non-native plant species have been shown to degrade the productivity and biological diversity of native plant communities through domination of resources within an ecosystem (Lambrinos, 2000; Stromberg *et al*., 2007). Harding grass (*Phalaris aquatica*), an invasive non-native species of bunchgrass, has been introduced to many grassland habitats in California, particularly regions that have had some form of disturbance, such as grazing and tilling (Stromberg *et al.,* 2007). This study examines the management history of two coastal grasslands, Rancho Marino Reserve (RM) and Fiscalini Ranch Preserve (FR) in California, and how previous and current usage of land (tilled or untilled) affects animal species. Specifically, this study investigates the effects of *P. aquatica* on animal abundance and diversity. A recent meta-analysis study discovered that invasive plant species have overall reducing or neutral effects on animal abundance and diversity, particularly in riparian and coastal grasslands (Shirmel, 2016). It has been shown that invasive species have different effects on different animals (Pysek and Richardson, 2010), with the highest effect on herbivores due to their dependence on plants for food (Schoonhoven *et al*., 2012). Although there has not been concrete research on factors that cause these negative effects, habitat modification is thought to play a key role (Wolkovich *et al*., 2009). Many of the previous literature focuses on one region invaded by Harding grass, with little focus on two coastal grassland systems that are geographically in proximity to one another. Although these systems have the same climate, weather and surrounding neighbourhood, each has a different management history (tilling, planting). This provided a novel situation to test the effects of management history, ie addition of *P. aquatica*, on the vertebrate species abundance and diversity. Due to the difference in vegetation diversity and coverage, it is hypothesized that *P. aquatica* has a negative impact on vertebrate animals in the coastal grass systems in Rancho Marino compared to Fiscalini Ranch (Poopatanapong, 1999). Thus, if there is no Harding grass cover, there should be an increased prevalence of animals. Conversely, when there is increasing cover, there should be a decrease in animal abundance and diversity. Based on previous research, Harding grass is predicted to have a negative effect on an animal's ability to maneuver in Harding grass, resulting in a decreased animal abundance (Spyreas *et al.,* 2010).

Materials & Methods

Management history of Rancho Marino and Fiscalini Ranch were investigated by observing tilled/planted and untilled/unplanted grasslands. Two 100 m transects at each site were utilized. The coordinates of the transects are as follows: Fiscalini Ranch (transect 1 start: [N35.54944, E121.10043], stop: [N35.55009, E121.10102]), (transect 2 start [N35.55046, E121.10166], stop [N35.5517, E121.10227]) and Rancho Marino (transect 1 start [N35.53966, E121.09032], stop [N35.53896, E121.08968]), (transect 2 start [N35.52933, E121.07793], stop [N35.52862, E121.07728]). Each transect consisted of eight plots where animal cameras were deployed over the course of three nights. The plots on each transect were chosen by randomization of 25 numbers ranging from 1 to 100. Eight of these numbers were again randomly selected for each of the three nights. No two plots were repeated. From the transect line, the 0.5 m x 0.5 m quadrat was placed down at a distance of 3 m to avoid interference with other sampling plots. Percent coverage of Phalaris aquatica, invasive grasses, and bare ground were measured by estimation. A motion triggered animal camera was placed on the bottom right corner of the quadrat facing

North. Plants obstructing the camera's field of view were subsequently removed. The bait, consisting of peanut butter and oats, was placed 1 m away from the camera on a white paper plate and weighed down with a stone. Cameras were deployed at 4:00 PM and footage was collected from 5:00 PM to 9:00 AM. The following day, the SD cards were taken from each camera and were analyzed for the presence of animal activity. The pictures were organized based on site, transect, day, and camera. A positive hit was defined as animal presence in the capture frame. Two or more animals of the same species were considered independent positive hits if they were seen an hour apart. Total abundance and diversity of animals were counted and recorded for each location. All data was collected and recorded for further analysis of results.

Discoveries

Initially, two transects were set up at both sites being examined, for a duration of three days. Over this period, FR consistently displayed greater animal abundance and diversity. At both transects, FR had 0% *P. aquatica* cover, with an average of 81.6% other exotic plant species. Conversely, RM had an average 37.3% *P. aquatica* cover, with an estimated 66% of other exotic species. When comparing the average abundance of animals found in FR and RM, FR had greater average abundances on days one and three with averages of 17 and 46 compared to 9.5 and 25 in RM (ANOVA, P=0.1). However on day two, RM had a greater average abundance of animals by 2.5. The overall average animal abundance for the three consecutive days in FR was 26.8 versus 18.2 in RM (ANOVA, P=0.1). The rate of captures was measured and averaged to 1.1 captures per hour in RM and 1.7 captures per hour in FR (ANOVA, P=0.006). There was little difference in average abundance of tilled/planted and untilled/unplanted transects in RM (18.6 tilled/planted; 17.6 untilled/unplanted) and average diversity (1.6 tilled/planted; 1 untilled/unplanted). In regards to animal diversity, RM had a maximum diversity of 2 animals, whereas FR had a maximum of 4 animal species (Figure 1). This indicates a two-fold increase in diversity at FR. However, in both cases the results are not statistically significant when plotted as a trend. There is considerable overlapping in the error bars (Figure 1). Animal camera captures included small rodents such as mice and ground squirrels as well as larger mammals such as skunks, deer, and foxes. Ground squirrels and foxes were only observed in FR. As hypothesized, animal abundance and diversity decreased as Harding Grass coverage increased, thus resulting in a reduced rate of animal visits (ANOVA, P = 0.005) (Figure 2). This was confirmed as the untilled/unplanted areas had more animal abundance and diversity compared to tilled/planted due to the lack of Harding Grass.

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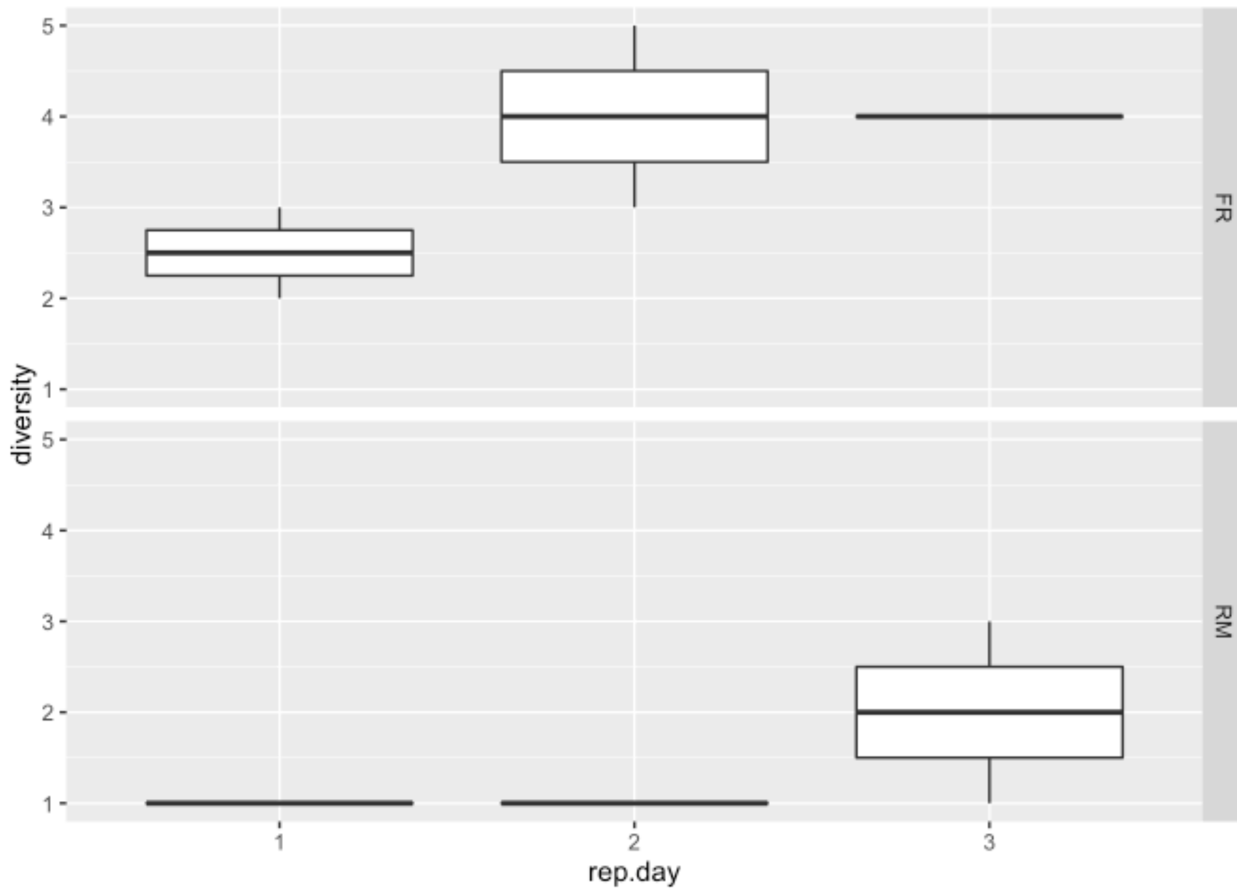

Figure 1: Average number of different animal species captured per day from the sample footage collected between 7:00pm to 8:00 am for three consecutive days in Fiscalini Ranch (FR) and Rancho Marino Reserve (RM). Footage was collected from two transects with eight plots of cameras each from both FR and RM. Error bars representing standard deviation of uncertainty are plotted. ANOVA, P<0.05.

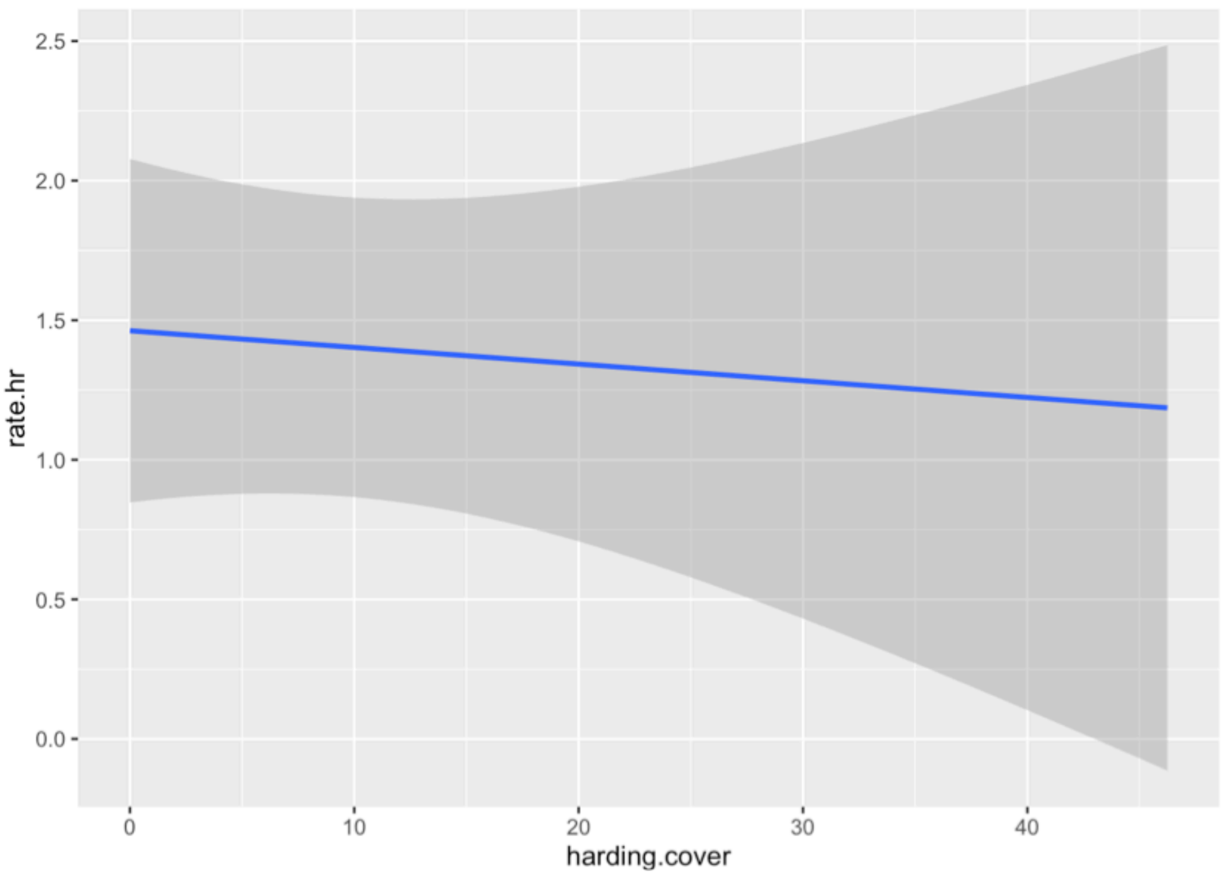

Figure 2: Effects of Harding Grass coverage on rate of animal visits in RM and FR. A negative effect is observed; as Harding Grass coverage increases, rate of animal visits decrease. Thus, untilled/unplanted grasslands that have no Harding Grass have higher animal visit rates. Fitted line is significant as $P<0.05$. High error curves due to low replication.

Implications

Understanding the relationship between plants and animals is important in conservation and sustainability. When fast spreading invasive species appear in an ecosystem, the fundamental nature of that ecosystem is disturbed. In line with the pre-experimental hypothesis, we confirmed that *P. aquatica* presence decreases both animal diversity and abundance. Rancho Marino is dominated by *P. aquatica* presence due to a history of tilling and planting at the site. Compared to Fiscalini Ranch, where there was no *P. aquatica* presence, there was both a decrease in animal abundance and diversity. With increasing cover there were less animal captures, which supported the second prediction. Previous research also found similar results whereby small mammal diversity was highest in regions with greater runways and channels in the ground compared to regions with tall grasses (Geier and Best, 1980).

Overall, Fiscalini Ranch had greater average abundance and diversity of animals compared to Rancho Marino. A plausible reason for this outcome is that invasive grass species cause a decline in native vegetative state, and thus vertebrates that were previously adapted to the region can no longer traverse effectively in persistent grass (Germano *et al*., 2012). Thus supporting the notion animals have difficulty in manoeuvring in the tall exotic grass.

Furthermore, studies suggest that soil quality affects burrowing animals. Richer soil retains more moisture thus allowing burrowing species to create channels and burrows with greater ease (Braithwaite and Gullan, 1978). Additionally, moisture-retaining soil is able to sustain plants that provide a better food source for animals. Invasive species deplete the moisture from the soil as they compete with native plant species and other invasive species (Wetzel and van der Valk, 1998). Native plants, which are a vital resource to animals, would also be negatively affected due to the lack of sufficient amounts of nutrients and water for growth and reproduction (Stromberg *et al*., 2007). Furthermore, Fiscalini Ranch and Rancho Marino regions were in a drought and soils were drier than normal. Although previous evidence supports the hypothesis, results showed little differences between Rancho Marino and Fiscalini Ranch therefore further research is needed in order to identify other factors that may affect the abundance and diversity of animals. Several external factors such as fog, strong winds, and predators were encountered during the sampling days and may have affected data collection in this study. Predatory birds have been shown to be in greater numbers along shorelines (Sokolowski *et al.*, 2013).

Invasive plants have the ability to increase rapidly in space and lead to ecosystem degradation, which can cause many risks (Wilgen *et al*. 2013). Ecosystems face the risk of fragmentation and disturbance when engaged with invasive plants, which leads them away from areas of variability. It is usually unachievable to bring the ecosystem back to its original state, therefore understanding the relationship between mammal behaviour such as burrowing and habitat preference will help conservation biologists create conservation strategies that will ensure that mammalian populations remain stable (Hobbs, 2006).

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