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Pulmonate gastropod species composition inside and outside eucalyptus forests

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In coastal San Luis Obispo County, California, USA, forests of introduced eucalyptus occupy 61 ha of Montana de Oro State Park in an area of high endemism of plants and animals, including the federally listed Morro shoulderband snail (*Helminthoglypta walkeriana*; MSS). We used mapping layers of soil types, occupied snail habitat, and current and predicted historic vegetation composition, to locate eucalyptus within historic suitable MSS habitat. We then tested the hypothesis that eucalyptus excludes MSS while also noting the occurrences of three other terrestrial pulmonate gastropods. Thirty-seven MSS or their shells were found outside the eucalyptus canopy and one was found inside a *Eucalyptus cephalocarpa* stand. When comparing forested areas to areas of native vegetation we found the assemblages of the four snail species differed significantly. Study results show that MSS are excluded from eucalyptus forests for unknown reasons. Three other snail species, including two predatory species, increased in number within the eucalyptus forests.

Key words: Baywood fine sands, California, eucalyptus, exotic species, *Helminthoglypta walkeriana*, Montana de Oro State Park, Morro shoulderband snail

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Casual observations at Montana de Oro State Park in coastal San Luis Obispo County, California, USA, revealed an absence of a native, federally listed, snail species within forests of introduced eucalyptus (*Eucalyptus* spp). Given that previous research has shown species composition of various animal taxa were different between native (*Quercus agrifolia* and *Umbellularia californica*) and non-native (*Eucalyptus globulus*) woodlands (Sax 2002), we investigated the composition of mollusk communities in eucalyptus forests and adjacent native vegetation.

The Morro shoulderband snail (*Helminthoglypta walkeriana;* MSS) is a terrestrial mollusk listed as endangered under the U.S. Endangered Species Act. This snail is restricted to 3,100 ha surrounding the Morro Bay estuary in predominantly Baywood fine sands, a local ancient dune soil with high organic content (USFWS 1998). The range of the MSS encompasses a eucalyptus forest, the community of Los Osos, portions of the City of Morro Bay, and approximately 2,125 ha of open space. Habitat use by these snails includes coastal scrub and dune scrub (Roth and Tupin 2004) and, to a lesser extent, other mesic exposed habitats such as grasslands (Walgren 2003). Little is known about the biology or ecology of MSS; however, the diet is expected to be focused on vegetable detritus (Roth 1985). The snail is active during wet periods, aestivates during the remainder of the year, and is thought to have a lifespan of <10 years (Roth 1985).

The eucalyptus forest within the roughly 4,195 ha Montana de Oro State Park consists of 61 ha (Figure 1) of contiguous stands of mixed eucalyptus species and monoculture stands of *E. globulus, E. cladocalyx*, *E. camaldulensis*, *E. cephalocarpa*, and *E. viminalis.* These forests also occur on Baywood fine sands and are surrounded by native

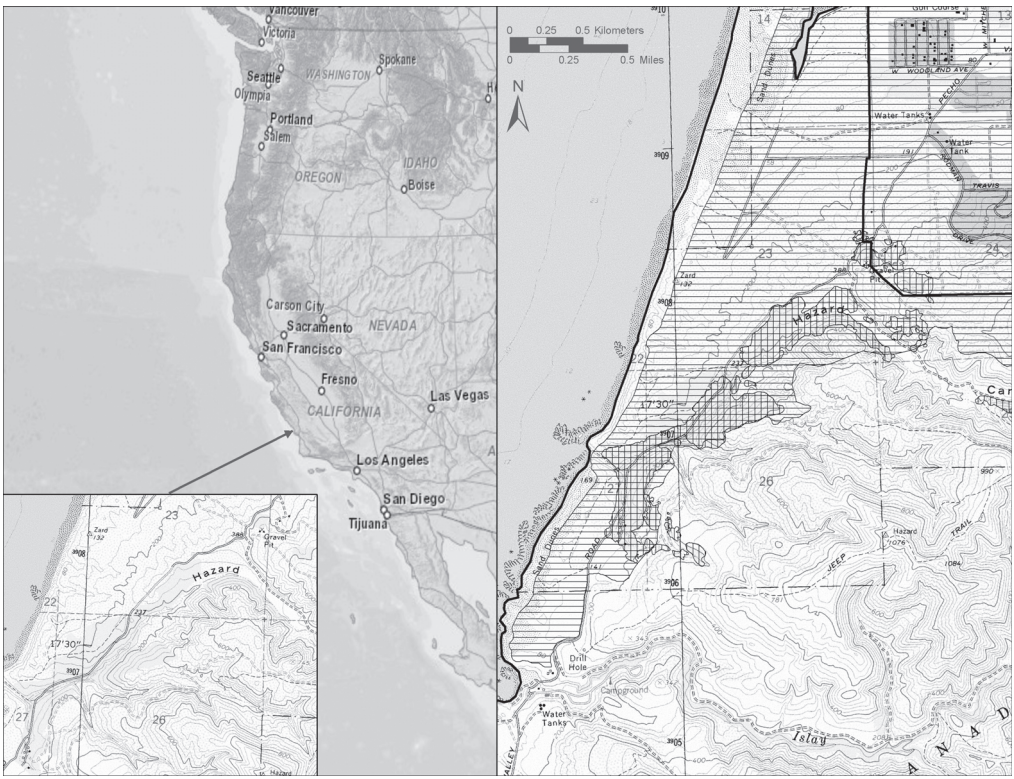

Figure 1.—Distribution of eucalyptus forests (vertical shading) and MSS habitat (horizontal shading) within Montana de Oro State Park and the neighboring community of Los Osos, San Luis Obispo County, California, USA.

maritime chaparral, coastal scrub, and dune scrub habitats. The stands were introduced in experimental plantation rows for commercial purposes in 1907 in an effort to determine the most appropriate species for the area. The plantations of each species of eucalyptus are planted in dense rows with a continuous canopy that creates a forest floor barren of vegetation and that is covered in dense litter and branches.

In addition to MSS, three other terrestrial pulmonate gastropods occur in the study area (*Helminthoglypta umbilicata*, *Oxychilus cellarius*, and *Haplotrema minimum*). *O. cellarius* was introduced from Western Europe and is closely associated with human habitation (Pilsbry 1939), feeding on plant material and the eggs of other snails, slugs, and earthworms (Mason 1970, White-Mclean 2011). *H. minimum* is a native predator of other snails, including *Helminthoglypta* spp. (Pilsbry 1939). *H. umbilicata* is a sympatric native species found over a wider range of habitats than are associated with MSS (Pilsbry 1939).

We tested the hypothesis that eucalyptus stands do not provide suitable habitat for MSS by examining encounter rates of MSS in eucalyptus forests and native habitat. We also recorded occurrences of all other terrestrial pulmonate gastropods encountered.

Materials and Methods

The study area in Montana de Oro State Park includes native vegetation and the adjacent eucalyptus forest that occurs on 61 ha of otherwise suitable habitat for MSS. Stands totaling approximately 3.2 ha were excluded if they were in proximity of roads, non-snail habitat, prescribed burn sites, or developed areas. Stands were also excluded if the area of the stand or adjacent native habitat could not accommodate the length of the transects. We were unable to sample stands of *E. cladocalyx* due to its limited occurrence and proximity to maritime chaparral, a plant community not associated with MSS.

We utilized ArcMap 9 software (ESRI 2010) to map suitable snail habitat using known snail occurrences (Walgren 2003, USFWS 2006, CDFG 2010), plant communities (CDPR 1986), and soil types (NRCS 2010). We then predicted historic plant community types within the eucalyptus forests based on soil and existing local conditions adjacent to those areas. Using these criteria, we identified eucalyptus stands located within the boundaries of areas known to be occupied by snails, where the soil type was Baywood fine sands, and coastal scrub or dune scrub was expected to have occurred historically. Two transects were then randomly selected for each eucalyptus species.

Transects consisted of ten 1-m^2 quadrats, spaced at 5-m intervals, in both native plant habitats and eucalyptus forests. The canopy interface area, between the last tree trunk and the furthest reaching canopy branches, was excluded in order to simplify comparisons between forested and non-forested areas. Within each 1-m^2 quadrat, we thoroughly searched for snails (defined as live or shells) within the litter, vegetation, and soil to a depth of approximately 2.5 cm. Both live snails and shells were recorded and lumped together in this study since shells are indicative of habitat occupation and habitat suitability (Roth 1985, Adams et al. 2000, Reeves et al. 2000, Walgren 2003, Roth and Tupin 2004).

All terrestrial pulmonate gastropods encountered were recorded, as was the dominant plant community in which they were located. Data were collected only once on each transect, and only during dry conditions when live snails would be expected to be aestivating and inactive (Roth 1985, USFWS 1998).

Because the data from transects had a distribution with many low values and few high values, a two-sample Poisson rate comparison test (Ott and Longnecker 2001) was

conducted for the number of MSS individuals found inside and outside the stands of each eucalyptus species (α=0.05). The program Minitab 15 was used to conduct the Poisson rate comparison test, create a scatter plot of distance from eucalyptus vs. count of snails, and to calculate the associated coefficient of correlation. In addition, the numbers of occurrences for each of the four snail species were treated as a species assemblage inside and outside the stand and were tested in the program SAS/STAT using Fisher's exact test.

Results

The plant communities surrounding the selected eucalyptus stands were coastal scrub and dune scrub with varying levels of invasive veldt grass (*Ehrharta calycina*), whereas no native plant communities were observed within those stands; only occasional individual native shrubs or herbs and low density patches of introduced annual grasses and herbs were observed within the eucalyptus.

We found 37 MSS in native habitat and 1 MSS within a stand of *Eucalyptus cephalocarpa*. There was an overall difference between the number of MSS present within eucalyptus stands compared with that detected outside of those stands; differences were especially pronounced within stands of *E. camaldulensis* and *E. cephalocarpa* when compared to encounter rates in native habitat (Table 1). There was a positive, but insignificant ($F_{1,9}$=1.51, P=0.250, r^2=0.144), relationship between the number of MSS encountered in native habitat and distance from eucalyptus stands, but distance did not explain much of

Table 1.—Results of the two-sample Poisson rate test (Ott and Longnecker 2001) for differences in the number of *Helminthoglypta walkeriana* (MSS), by eucalyptus species, both inside and outside the eucalyptus forest. *N*=the number of quadrats per eucalyptus species. Montana de Oro State Park, San Luis Obispo County, California, USA.

Species of *Eucalyptus*	MSS Inside	MSS Outside	*P*-value
E. camaldulensis	0 (N=20)	13 (N=20)	<0.001
E. viminalis	0 (N=20)	1 (N=20)	1.000
E. cephalocarpa	1 (N=20)	23 (N=20)	<0.001
E. globulus	0 (N=20)	0 (N=20)	N/A
Combined	1 (N=80)	37 (N=80)	<0.001

the variation in the number of MSS encountered. While MSS decreased inside forests, three other species (*H. umbilicata*, *O. cellarius*, and *H. minimum*) were more abundant within. Indeed, the distribution of snail species numbers within assemblages from inside and outside forests differed substantially (P<0.001; Figure 2).

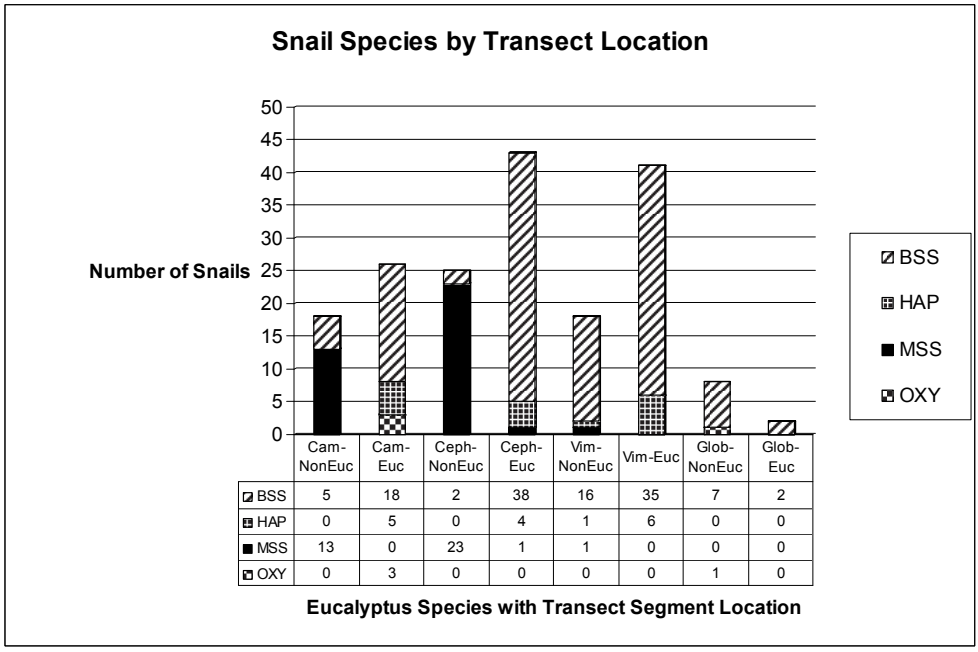

Figure 2.—Number of snails by species in each segment of transects. "NonEuc" indicates the transect outside the eucalyptus forest, while "Euc" indicates the transect within the forest. Eucalyptus species are abbreviated as follows: Cam=*E. camaldulensis*, Ceph=*E. cephalocarpa*, Glob=*E. globulus*, and Vim=*E. viminalis*. Snail species are abbreviated as follows: BSS=*Helminthoglypta umbilicata*, HAP=*Haplotrema minimum*, MSS=*Helminthoglypta walkeriana*, OXY=*Oxychilus cellarius.* Montano de Oro State Park, San Luis Obispo County, California, USA.

Discussion

The impacts of invasive plant and animal species are widely recognized by ecologists but seldom are formally defined (Parker et al. 1999), which often leads to a lack of prioritization of management actions. The impacts of introduced eucalyptus stands on native flora and fauna have been documented to change species compositions among invertebrates, birds, mammals, reptiles and amphibians (Sax 2002). Additional studies focusing on commercial crops indicate significant allelopathic effects of eucalyptus (Sasikumar et al. 2001, Khan 2008, Zhang 2010) and, as a result, the presence of eucalyptus forests on lands set aside to conserve native biodiversity would be expected to alter the species composition of native plants and animals.

The absence of MSS in otherwise suitable habitat within eucalyptus forests is an added threat to the long term survival of that listed species. The 3,100 ha range (USFWS 2006) of this endangered snail is already fragmented by the community of Los Osos, and has been altered by an invasion of veldt grass across the majority of occupied habitat (USFWS 1998, 2006). The reasons that MSS do not inhabit eucalyptus forests are not known, but likely include alterations in the availability of vegetable detritus and predation by, or competition with, other species of snails. Alterations of light, moisture, soil chemistry, and physical

attributes may also contribute to the absence of MSS within eucalyptus forests. Other species of snails occupying eucalyptus forests may have a wider dietary tolerance and also may benefit from increased moisture, which generally is associated with each of those mollusks.

The differential species composition and varied abundance of four gastropod species identified within and outside the eucalyptus forests demonstrates community-level effects of that non-native habitat. Impacts to gastropod communities include alterations to species composition, species abundance, and the balance of predatory and prey snail species. Land managers and regulatory agencies interested in conservation of native biodiversity should prevent the expansion or establishment of eucalyptus stands within conserved lands and consider habitat restoration of current stands, particularly, as in this case, when a rare endemic species is impacted.

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