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Surface-dwelling and Subterranean Invertebrate Fauna Associated with Giant Reed (*Arundo donax* Poaceae) in Southern California

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Abstract.—In the southwestern United States giant reed, *Arundo donax*, is a non-native invasive plant that has become widely established in moist places and forms its largest stands along riparian corridors. The most widely reported negative effects include competition with native species, increased rate of transpiration, increased potential for wildfires, and stream channel and bank alteration. However, little is known about the faunal communities associated with this plant and the potential effects on native fauna. In this study, we focused our efforts on determining the faunal composition specifically from rhizome clumps of *A. donax* from a site located along the Santa Margarita River in San Diego County, California. A total of 2590 individual macro-invertebrates were collected and identified, and represented 64 species from 7 classes. No sensitive species and few vertebrates were found to be in association with *A. donax* rhizome clumps. Four non-native invertebrate species made up 43% of the total number of captured invertebrates, and 31% of the sampled invertebrates were confirmed as native species. This study demonstrates that *A. donax* rhizome clumps, and the soils associated with them, provide habitat for several native macro-invertebrate species, but can be dominated by a greater abundance of non-native species.

Giant reed, *Arundo donax*, is a non-native invasive species from the Old World that has become widely established throughout riparian habitats in southern California (Dudley 2000). Previous studies have shown that *A. donax* competitively displaces native vegetation (Rieger and Kreager 1989), transpires greater quantities of water than native vegetation (Iverson 1994), increases the potential for wildfires (Bell, 1994), creates biological pollution by contributing vast amounts of detritus (Douce 1994), and alters channel and bank morphology (The Nature Conservancy 1996). However, given the dramatic changes in vegetation diversity and structure, hydrology, channel morphology, and fire regime that results from the invasion and establishment of *A. donax*, relatively little has been reported on the fauna associated with large clusters of *A. donax* thickets (Herrera 1997; Herrera and Dudley 2004).

Critical to the management of *Arundo donax* is a thorough understanding of the ecological relationships between this invasive plant and other species. This is especially important in southern California where critical populations of at-risk species are reliant

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Table 1. Physical characteristics of 41 rhizome clumps.

	Length (m)	Width (m)	Depth (m)	Volume	Percent rhizome clumps	Percent dirt	# of Species per rhizome clumps	# of Indiv. per rhizome clumps
AVERAGE	3.49	2.28	0.54	1.06	19.13	80.32	16.4	63.0
STANDARD DEVIATION	0.71	0.2	0.9	0.37	12.67	12.72	5.8	40.7

on the small and sometimes isolated remaining riparian and wetland ecosystems that still exist (Dudley and Collins 1995). The primary objective of this study is to determine the subterranean and surface-dwelling fauna that occur in *Arundo donax*.

Materials and Methods

The study site was located along the Santa Margarita River at Marine Corps Base Camp Pendleton (hereafter, MCBCP). The site was located in the interior of a several hectare infestation of *A. donax*. Sampling was accomplished by first snapping off the vertical stalks of the *A. donax* at their base by mechanically sweeping a grappler extension close to the ground. Following the clearing of an area, the grappler would grab and stack clipped plants into large piles. The grappler would periodically transfer these piles to large dump trucks for removal. Within the study area, specific locations for the mechanical grab of each *A. donax* rhizome clump was opportunistically selected by biologists trying to sample multiple sites to capture minor variations in habitat conditions (e.g. depth of leaf litter, % canopy cover) of the dense monotypic stand. Each grab by mechanical grappler extracted a single *A. donax* rhizome clump. Each rhizome clump was immediately placed upon a tarp following extrication and was immediately broken apart and carefully inspected for fauna. Clumps of *A. donax* were manually broken apart by hand or with the aid of hand tools (i.e., pickaxe, shovel, steel rake, sledge hammer and claw hammer). All macro-invertebrate taxa were collected, sorted, and immediately stored in 70% ethanol. In addition to manually sorting through the clump, random samples of associated sediment were sieved and stored in 70% ethanol to collect any specimens not previously located by the initial visual search. The inspected rhizome clumps were then set aside into a pile adjacent to the soil from the same clump; the relative volumes of rhizome clumps and soil piles for each clump were then visually estimated. Physical characteristics including length, width, and maximum depth of the hole created by the mechanical removal of each clump are provided in Table 1. A total of 41 clumps were surveyed between 28 Sept. 2000 and 24 Oct. 2000. All specimens collected during the field portion of the study were keyed out to morphospecies.

Initial sorting of collected macroinvertebrates utilized parataxonomists (personnel not formally trained in taxonomy). All collected specimens were initially sorted into one of 140 identified morphospecies classes. Morphospecies classes were determined by obvious visually identifiable differences. Following the sorting by non-specialists, samples were then transferred to invertebrate taxonomy specialists and keyed out. A determination of whether species were native or non-native was also made for as many of the sampled taxa as possible. All specimens are housed at the United States Geological Survey, San Diego Field Station, San Diego, California, USA.

Table 2. Number of species identified by class.

Annelida	1
Arachnida	23
Chilopoda	2
Crustacea	2
Diplopoda	2
Insecta	33
Molusca	1

Results

Forty-one rhizome clumps were examined between 28 September 2000 and 24 October 2000. Average size of each rhizome clumps was 1.06 m^3, as calculated from length, width, and depth of the hole created by removal of rhizome clumps, with physical characteristics summarized in Table 1. A total of 2590 individual macroinvertebrates were collected and identified, representing 64 species from 7 classes (Table 2). Four non-native species made up 43% of total captured arthropods *Armadillium vulgare* (pillbug), *Porcellio laevis* (sowbug), and *Dysdera crocata* (sowbug killer), and *Linepithema humile* (Argentine ant). Thirty one percent of all sampled invertebrates were confirmed as native, with spirobolid millipedes making up over 11% of total captures. Over 55 species were represented by 3 individuals or less. Relatively low densities of invertebrates were found under the clumps and living in and around the rhizome clumps that were examined. In 32 of the 41 rhizome clumps, less than 100 individual invertebrates were found. On average there were 16 species and 63 individuals found per rhizome clump (Table 1). Fifty six of sixty four species of invertebrates sampled were from two classes, Arachnida and Insecta (Table 2). None of the other five classes were represented by more than 2 species.

Diversity of all sampled invertebrates ($n=2590$), as measured by the Shannon Wiener index (Krebs 1989) was 1.28, or about 71% of maximum possible diversity or evenness (1.80) assuming an equitable distribution of all taxa across the sampling effort (Table 3). Those species that were confirmed as native ($n=901$, 29 species) had a diversity of 1.03, or 71% of maximum possible diversity (1.46), while confirmed non-native species ($n=1201$, 8 species) had a diversity measure of 0.62, or 68% of maximum possible diversity (0.90, Table 3). There were 488 specimens that could not be determined as native or introduced, because they could not be keyed out to species and/or so little is known about their distribution, and which composed at least 27 distinct taxa. The native and non-native Shannon Wiener diversity indices were tested for the null hypothesis that these two diversities are equal following the two-tailed t test of Hutcheson (1970), as outlined in Zar (1984). The null hypothesis was rejected ($t = 10.51$, $df = 996.0$, $p < 0.001$), and native species diversity is significantly greater than non-native species diversity.

Table 3. Diversity indices for all captures, confirmed native, and confirmed non-native species.

	Total Species (n=2590)	Native Species (n=901)	Non-native Species (n=1201)
SHANNON DIVERSITY (H′)	1.28	1.03	0.62
SHANNON EVENNESS MEASURE (J′)	0.71	0.71	0.68
MAXIMUM DIVERSITY (H′max)	1.81	1.46	0.90

Few vertebrates were observed, but the vole (*Microtus californicus*) (n=4, 2 live, 2 dead), woodrats (*Neotoma sp.*) (n=2, live), and the Pacific treefrog (*Pseudacris hypochondriaca*) were observed. Black-tailed deer (*Odocoileus hemionus*) and western fence lizards (*Sceloporus occidentalis*) were also sighted along the edge of the *A. donax* thickets being removed.

Discussion

Non-native species comprised at least 45% of all collected invertebrates in *A. donax*, while confirmed native species represented 31% of all collected invertebrates. 24% of the collected individuals could not be assigned as native or non-native due to lack in basic distribution data for these species. This indicates some variation in the use of *A. donax* by native versus non-native species, with non-native species being more abundant. Four species made up 97% of all confirmed non-natives from the samples. Shannon Wiener diversity measures of natives versus non-natives also differ significantly when tested ($t = 10.51$, $df = 996$, $p < 0.001$). Non-native species were more abundant, and diversity measures reflect this. Diversity indices for these two groups differ statistically, and indicate that native species have a significantly higher diversity than non-native species. Confirmed native species are also represented by 29 species, versus 8 non-native species. It is interesting that the diversity of native species is greater than that of non-native species in an entirely non-native stand of vegetation, but both have similarly high levels of evenness (71% for natives, and 68% for non-natives). This indicates that many native species are found in association with *A. donax*, but clearly, there are large numbers of only a few non-native species.

Figure 1 shows the number of individuals captured for each species, and highlights the three most abundant species. This finding is important to understanding the role and impacts of *A. donax* to native species in the riparian habitats it occupies. Species sampled in this study were largely ground dwelling invertebrates, which have been shown to differ less in diversity across non-native habitats than their aerial counterparts (Herrera and Dudley 2004). Other studies have shown that invertebrate abundance and diversity declined in non-native habitats when compared with those in adjacent native habitats (Slobodchikoff and Doyen 1977; and Beerling and Dawah 1993).

It is well known that non-native species pose a considerable threat to the biodiversity of California (Mooney et al. 1986). A previous study at Sonoma Creek California (Herrera 1997; Herrera and Dudley 2004) sampled both aerial and ground-dwelling invertebrates in *A. donax* dominated areas, mixed Arundo- native willow, and willow riparian habitats. Their results found that native insect abundance, biomass, and species richness were significantly higher in native riparian vegetation than in *A. donax* dominated riparian habitat. Biomass was not analyzed in this study, but confirmed native insects were less abundant than confirmed non-natives (Fig. 1). Herrera and Dudley (2004) found that abundance and diversity declined from spring to summer for invertebrates in *A. donax*, and Bolger et al. (2000) found that diversity and abundance of arthropods were lowest in the fall. Our study gathered results only during the fall, so seasonal comparisons cannot be made.

It is well known that large numbers of invertebrates have been introduced and naturalized to the Mediterranean climate of southern California (Dowell and Gill, 1989). One obvious aspect of controlling non-native species introductions is stopping their entry into California. Another important consideration is the maintenance of healthy and intact native ecosystems to combat the establishment of non-natives. It has been shown

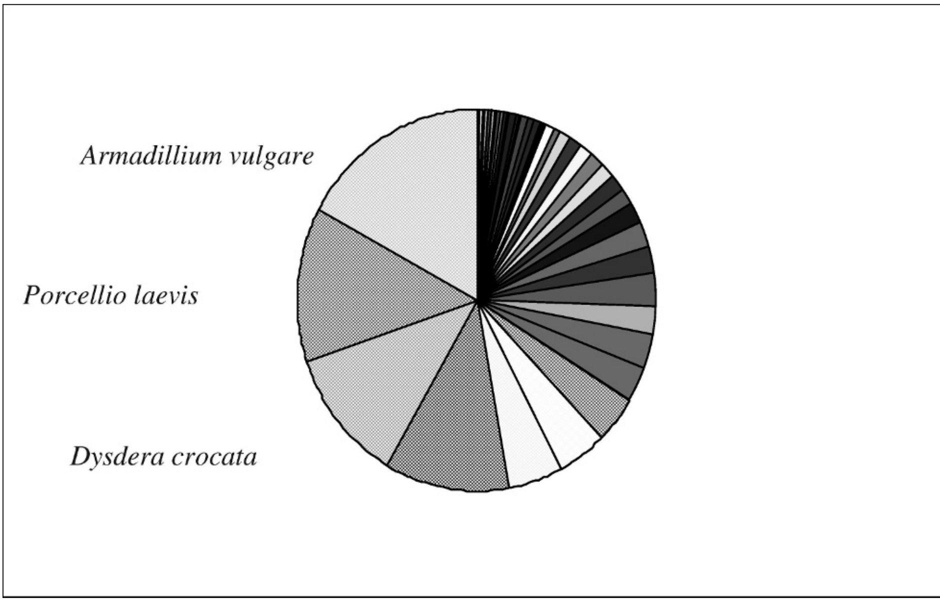

Fig. 1. Number of individuals (n=2590) per species. The three most commonly encountered species are indicated, all of which are non-native. *Armadilium vulgare* comprises 17.1%, *Porcelio laevis* 13.1%, and *Dysdera crocata* 11.4% of all species respectively.

that large and widespread stands of non-native vegetation, such as *A. donax*, displace native vegetation and allow for non-native species to dominate an area (Bell 1994). In this study, 43% of all captures by abundance were represented by four non-native species (Fig. 1). The two highest species captures in this study by abundance were Armadillium vulgare (17%), and Porcellio laevis (13%). Bolger et al. (2000) had abundances of 24.8% and 5.4% respectively for these same two taxa when sampling throughout the greater San Diego County region. Indeed, while canopies of *A. donax* and native riparian gallery trees differ greatly, the physical characteristics between habitat types are more similar on the ground. Herrera and Dudley (2004) found that captured arthropods in *A. donax* were larger and more generalized than those found in native riparian vegetation. Thus, opportunistic and generalized non-native arthropods may be more tolerant of degraded conditions and form an invasion complex (Dudley and Collins 1995).

Several new findings as a result of this study indicate the importance of continued studies on the invertebrates of southern California, and shed new light on those that are associated with dense stands of *A. donax*. These novel findings include a grub in the family Lygaeidae that was collected from Arundo and is known to be a non-native species detected in southern California only in the last 5 years (D. Faulkner, pers. comm.). Also, a grub that is commonly associated with oak and pine forests was also found in association with *A. donax*. Several members of the spider species Clubiona californica were found, and these represent a new county record for this California native.

The most significant abundance of native species found in association with *A. donax* was two species of Spirobolid millipedes that combined to make up over 11% of all captures by abundance. Millipedes as a group are generalized detritovores associated with damp or moist areas where they can feed on rotting plant material. While it has not been shown that these millipedes feed on *A. donax* , this is quite likely the case given their abundance in an entirely *A. donax* dominated habitat type such as that sampled in this study.

The non-native Argentine ants (Linepithema humile) were the only ants collected in this study, although other species of ants, both native and nonnative, were active nearby at this time of year (unpub. data). This finding along with other studies indicates that Argentine ants establish themselves readily in non-native dominated or disturbed habitats. Bolger et al. (2000) showed that argentine ants pose a considerable threat to the arthropod fauna of southern California. Suarez et al. (1998) showed that argentine ants are more abundant in areas dominated by non-native vegetation. Since these ants were commonly found in rhizome clumps, this species may be having a deleterious impact on native species at the study site, and indirectly maintain the abundance of non-native species encountered in this study.

The impacts of dense stands of *A. donax*, and large-scale vegetation removal projects on sensitive species are poorly known. There is some evidence that *A. donax* poses a threat to the endangered least bell's vireo (*Vireo bellii pusillus*; Kisner 2004), and three-spine stickleback (*Gasterosteus* aculeatus; Frandsen and Jackson, 1994). While the three-spine stickleback is now absent from the Santa Margarita River, the least Bell's vireo and endangered arroyo toad (*Anaxyrus californicus*) are still present. Recently, removal of *A. donax* from this area has been accomplished by means of heavy equipment and the use of a grappler. While there were no arroyo toads encountered during this project, that does not mean that there will be no impacts if this eradication method is used elsewhere or at a different time. The habitat in the study area is within an expansive stand of *A. donax*, which represents atypical habitat for the arroyo toad. Such dense non-native vegetation stands are likely to be prohibitive to overland movements of the arroyo toad, and may be the reason why none were encountered. Had this work been done closer to open riparian habitat or suitable upland habitat, it is likely that toads would have been encountered. Also, it must be emphasized that this study was conducted during the fall of a relatively dry year, and different climatic conditions or seasonality may produce different results. Further research is needed to effectively determine the impacts of mechanical *A. donax* eradication on the arroyo toad during different conditions, or in different locations.

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