

**Factors determining invasiveness in woody, ornamental species:
the roles of abiotic factors and bird dispersal (awarded 2006)**

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Proposal:

Prediction of future biological invasions in order to prevent ecological and economic damage relies on identification of traits associated with noninvasiveness (Rejmánek 2000, Jefferson et al. 2004, McDowall 2004). Woody, fleshy-fruited plants enable exploration of invasiveness and noninvasiveness because a) they are generally introduced purposefully for ornamental or agricultural purposes; b) their relatively long generation time (compared with many other invasive species) prolongs the early stages of introduction; and c) their ability to establish dispersal mutualisms with vertebrates makes them “high-risk” for becoming invasive (Jefferson et al. 2004). We have initiated a three-year study of bird dispersal of fleshy-fruited trees that have been introduced to central California without strong invasiveness, although they are problematic invasives in similar climates. Our objective is to assess the relative contributions of bird behavior and summer drought to regional noninvasiveness of our three study species.

The plants selected for this work are: Chinese tallow tree (*Sapium sebiferum*), glossy privet (*Ligustrum lucidum*), and European olive (*Olea europaea*). Chinese tallow has invaded the southeastern United States, taking over wetland areas (Renne et al. 2002, Siemann and Rogers 2003). We examine bird visitation and abiotic factors affecting *S. sebiferum*'s establishment in riparian settings. European olive is a problematic invasive in mediterranean Australia, and birds, including European starlings (abundant in California), are blamed for its spread there (Bass et al. 2006). Furthermore, Spennemann and Allen (2000) and others record strong reduction in fruit size as stands become feral. Such fruit size reduction may enlarge the suite of avian frugivores capable of dispersal of this species within California. Glossy privet, meanwhile, is invasive in Australia and mediterranean South America (Montaldo 1993, Panetta 2000). Managers of some Californian parks report invasive tendencies of *L. lucidum* in riparian areas (e.g., S. Mason, pers. comm.), so we examine riparian abiotic factors in our exploration of invasiveness of this species.

We have completed a pilot season of the following methods: To examine bird dispersal of these species, we selected mature stands in three urban sites (Chico, Davis, and Sacramento, CA) and two preserves adjacent to urban areas (Big Chico Creek Ecological Preserve; Putah Creek Riparian Reserve). We census birds to provide baseline comparisons of frugivore densities, and quantify bird feeding using focal individual observations. We also suspend fruit traps in trees to examine the percentage of fruits taken by frugivores. To assess bird feeding preferences, we will capture American robins and European starlings and house them in open-air aviaries, where they will be offered native (toyon, *Heteromeles arbutifolia*) and nonnative fruits. To examine abiotic factors influencing germination and early growth, we have chosen one strategy for Chinese

tallow and glossy privet (as potential invaders of riparian areas) and another strategy for olive (as a potential invader of upland areas). We buried Chinese tallow seeds after varying pretreatments at five elevations above water level in the Putah Creek Riparian Reserve. After retrieving seeds to evaluate germination, we planted seedlings to evaluate growth and survival through the summer drought period. We will repeat these steps with glossy privet next year, using the same sites. For olive, we constructed an upland garden with permanent shade structures to evaluate olive growth under Californian and Australian water regimes. We planted a first round of olives in April, mimicking the natural month of fruit fall from trees. However, rodent digging disturbed most emerged plants. We have since rodent-proofed the garden with a hardware cloth fence surmounted by aluminum flashing and intend to plant new olive crops in February and April.

Because olive has particularly large fruits and the frugivores capable of dispersing it may be dictated by gape size, we generated a list of potential dispersers for olive as follows: first, we measured fruit widths from three stands differing visibly in fruit size. We then created throat probes matching fruit sizes for each stand and inserted them into the esophagi of whole frugivore carcasses obtained from the wildlife museum of the University of California, Davis. If a probe could pass through the esophagus and into the body cavity, we considered the species capable of dispersing olives of that size. This method yielded lists of potential olive dispersers.

To assess the overall importance on nonnative plants in U.S. bird habitat, we mailed surveys to members of the Ornithological Societies of North America, asking them to report observed interactions between birds and nonnative plants. In all, 1020 surveys were sent and 175 responses received. We have coded responses and completed preliminary examination of data.

Pilot Season Results:

The observational portions of our fieldwork include bird population census and bird visitation and fruit use at selected stands. We collected pilot population information for frugivorous birds at our study sites. We performed sample size calculations after Buckland et al. (1993) and determined that distance sampling at 90 points per site during each field season will provide frugivore population estimates. We will use these estimates to compare between study sites, enabling us to assess bird visitation to study plants in consideration of available dispersers.

Quantification of bird visitation and fruit use at stands was much more difficult than anticipated and required us to revise our observation protocols several times. Because we are examining trees in urban sites, human presence in study areas is a constant factor and leads to disruption of observations. Furthermore, in our study sites, birds move between urban parks and private property where we are unable to follow. We therefore developed a sampling scheme that merges facets of published techniques (e.g., Tello 2003, Farwig et al. 2006) and is tailored to our particular circumstances and the challenges of urban ecology. Our method combines scan sampling and focal individual observations to calculate the average number of fruits utilized per unit time per species and also the relative visitation by species to the stand. During the pilot season, we observed the following frugivores consuming Chinese tallow: European starlings, American robins, yellow-rumped warblers, western scrub-jays, Northern flickers. We observed the following birds consuming olives: American robins, northern mockingbirds, European starlings. We observed the following species consuming glossy privet: house finches, yellow-rumped warblers, northern mockingbirds, European starlings. Because we altered methods several times, quantitative assessment of use by these species will require another field season.

Throat probes showed that the following species can disperse at least small olives: cedar waxwing, American robin, mourning dove, western scrub-jay, western bluebird, Stellar's jay,

Brewer’s blackbird, Swainson’s thrush, hermit thrush, house sparrow, varied thrush, European starling, northern flicker, and yellow-billed magpie. The list of species that can disperse larger olives is a subset of the above, indicating that smaller fruit have greater dispersal potential.

Our pilot aviary work was prevented by a state collection permit backlog, resulting from an office move at the California Department of Fish and Game. Although we submitted our permit request four months prior to our field season, approval took ten months. Therefore, we could not capture birds this year. We have obtained permits and prepared the aviaries to capture birds beginning in November and plan to conduct this experiment with 20 individuals between November and December. Our original plan was to complete aviary work in the first two years of the project; we will now conduct this experiment in years 2 and 3, without sacrificing power.

We examined germination of Chinese tallow, contrasting seeds that had been acid-treated, soaked in water, collected directly from the ground, and picked from parent trees with no further treatment. Percent germination was measured and the results are presented in Table A.

Elevation (cm. above stream)	Acid	Water	Tree	Ground
0	68.33	46.08	16.49	60.80
114.25	66.24	37.36	11.95	61.17
228.5	67.50	36.78	29.69	57.59
342.75	37.88	36.65	21.42	24.57
457	30.31	31.62	17.88	6.10
Germination over all treatments and elevations: 38.24				

Table A: Percent germination (averaged over 5 replications) of Chinese tallow (*Sapium sebiferum*) seeds under four treatment regimes and buried at five elevations above stream level.

After arcsine transformation, we performed an ANOVA and found significant effects of seed treatment, elevation, and the interaction between elevation and treatment ($p < 0.05$). Elevation and germination were inversely related ($p = 0.0008$; $R^2 = 0.11$). Seeds collected from the tree germinated significantly less than acid-treated or ground-collected seeds, although they did not differ significantly from water-soaked seeds (Tukey HSD Means Comparison, $p < 0.05$).

Overall, survey respondents reported interactions involving 158 introduced plant species and 173 bird species. Of these, 719 unique reports involved birds eating fruits, representing potential dispersal. Additionally, 452 interactions involved birds perching, roosting, or nesting in introduced plants, demonstrating birds’ integration of nonnative plants in their habitat.

Discussion:

Because we were determining or inventing appropriate field methods, the data we have collected thus far enable only sample size determination and method refinement. A new field season will initiate with fruit ripening in October, and we believe that our methods have been improved by the lessons of the first year and will yield useful data over the next two seasons.

Our exploration of Chinese tallow response yielded significant effects of both treatment and elevation, as well as their interaction ($p < 0.05$). Treatments were selected to mimic common routes of Chinese tallow dispersal: 1) Seeds fall directly from trees onto soil; 2) Seeds are eaten from trees and pass through bird guts; and 3) Seeds fall into water that disperses them to. Seeds picked from trees germinated at a lower rate than those treated with acid or collected from the ground beneath trees. Acid treatment resulted in the highest percent germination overall, indicating that bird dispersal should result in high germination rates. We buried seeds at five

elevations above streamside in the Putah Creek Riparian Reserve. These elevations were proxies for moisture level, since we expected the soil just above the stream to be wetter than that several meters away. As expected, elevation had a significant effect on seed germination and more seeds at lower elevations germinated than at higher elevations.

The high rate overall of germination of Chinese tallow (38%) in this study is cause for concern. This rate is comparable to studies of *S. sebiferum* germination in its region of invasion, the southeastern U.S., where researchers record germination ranging from 3% (Conway et al. 2000) to 80%, depending on pretreatment (Renne et al. 2001). Since our results show strong germination potential, we believe that abiotic conditions in riparian areas in central California permit germination by *S. sebiferum*. The seedlings we are currently tracking in the field will enable us to explore the effect of rainfall limitation on the early plant growth post-germination.

Questionnaire results provide evidence that introduced plants redefine native bird habitat, but the quantitative degree of such transformation is unknown. Further survey data analysis will examine the percentage of reported interactions that are known from the literature vs. unknown, and whether certain plant guilds are more likely to be utilized for so-called “habitat interactions” (nesting, roosting, and other benign uses by birds) than for so-called “dispersal opportunity interactions” (fruit feeding with potential for dispersal of nonnatives).

Publications:

Because we consider the year past to be pilot work and intend to collect rigorous data for two succeeding field seasons, we have not yet attempted to publish these results.

Long-Term Goals and Continued Progress of Research

As indicated above, we are approaching a new field season, in which we plan to employ the lessons and revised methods that emerged from the pilot work reported here. We will carry out the following research activities over the next two years: bird population assessments and stand visitation observations (2 seasons each), captive bird feeding trials (2 seasons each), germination and early growth under varying abiotic conditions for glossy privet and European olive (2 seasons each), germination and early growth under varying abiotic conditions for Chinese tallow (1 more season). We expect to complete all data collection in October, 2009.

Benefits of Seed Money:

The research year supported by CIPM seed money was essential for refinement of methods. Data collected enabled us to perform sample size calculations that will ensure that future work will have sufficient statistical power. Major expenditures included transportation to research sites for pilot season data collection, construction of outdoor aviaries, construction of upland garden plot, construction of seedling cages and fruit traps, and postage for questionnaires.

Another essential accomplishment of this pilot year was the creation of relationships. We have received permission to conduct research in the Big Chico Creek Ecological Reserve, the Putah Creek Riparian Reserve, Bidwell Park, the Davis Audubon Research Ranch, and numerous city parks. We have also delivered informal presentations to the staff of the Davis Audubon Society and members of Altacal Audubon in Chico, as well as meeting with leaders among the Friends of Bidwell Park and the Sacramento Weed Warriors.

Advancing This Research:

After the upcoming two field seasons are completed, we will have quantitative assessments of the rate of dispersal of these plant species by various bird species, as well as the effect of drought on early plant establishment. A natural next step would be to integrate modeling methods designed by Haddad and others (Levey et al. 2005) to evaluate bird movements and consequential seed rain across the central Californian landscape; this would enable us to predict the spread of these plant species. Modeling of this sort would require joint effort with ecological modelers and access to computer resources outside our own lab.

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