

Russian olive invasion into cottonwood forests along a regulated river in north-central Montana

Peter Lesica and Scott Miles

Abstract: Russian olive (*Elaeagnus angustifolia* L.) is an exotic tree that is invasive in western North America where it may replace native riparian cottonwood forests. We mapped the occurrence of Russian olive and measured the size, density, and age of it and cottonwood in sandbar, low-terrace, and high-terrace habitats along the lower Marias River below Tiber Dam in Montana. Russian olive occurs along the entire study reach but is more abundant near domesticated plantings. It establishes in moist lower terrace habitat as well as under mature cottonwood on high terraces. Seventy-seven percent of cottonwood trees in all size classes were damaged by beavers in low terrace sites, while only 22% of Russian olives showed damage. Since construction of Tiber Dam, cottonwood establishment has been restricted to lower terrace sites. Beaver prevent cottonwood from developing a mature canopy close to the river while having little effect on the continued invasion of Russian olive. Riparian cottonwood forests will eventually be replaced by Russian olive as old cottonwoods die on upper terraces and young plants on low terraces are removed by beaver or shaded by the less palatable species.

Key words: Russian olive, cottonwood, riparian, beaver, exotic, dam.

Résumé : L'olivier de Russie (*Elaeagnus angustifolia* L.) est un arbre exotique envahissant dans le nord-ouest de l'Amérique où il peut remplacer les forêts ripariennes indigènes de peupliers. Les auteurs ont cartographié la présence de l'olivier de Russie et du peuplier et en ont mesuré la densité et l'âge sur des habitats de bancs de sable, de terrasses basses et de terrasses élevées, le long de la région inférieure de la rivière Marias, en aval du barrage Tiber, au Montana. L'olivier de Russie se retrouve sur toute l'étendue couverte par l'étude, mais il est plus abondant près des plantations domestiquées. Il s'établit dans les habitats humides de terrasses basses aussi bien que sous des peupliers matures sur les terrasses élevées. Sur les sites des terrasses basses, 77% des peupliers de toutes les classes de dimension sont endommagés par les castors, alors que seulement 22% des oliviers de Russie montrent de tels dommages. Depuis la construction du barrage Tiber, l'établissement du peuplier s'est limité aux sites de terrasses basses. Le castor empêche le peuplier d'établir une canopée fermée près de la rivière alors qu'il a peu d'effets sur l'invasion continue par l'olivier de Russie. Les forêts ripariennes de peupliers seront éventuellement remplacées par l'olivier de Russie, à mesure que les vieux peupliers mourront sur les terrasses élevées et que les jeunes plants sur les terrasses basses seront éliminés par le castor ou ombragés par les espèces moins prisées par le castor.

Mots clés : olivier de Russie, peuplier, riparien, castor, exotique, barrage.

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Introduction

Riparian ecosystems are threatened by impoundments that degrade functional values and exotic species that alter processes and species composition (deWaal et al. 1994; Ligon et al. 1995; Rood and Mahoney 1990). Invasions by exotic plants are occurring at an increasing rate and are considered a serious threat to the biological diversity of wildlands and natural areas (Drake et al. 1989). Exotic invasions in riparian areas are often positively associated with degree of disturbance (DeFerrari and Naiman 1994; Planty-Tabacchi et al.

1996). This is not surprising because most weedy exotics are early seral species adapted to the low competition environments created by disturbance (Bazzaz 1986). However, in the natural, frequent-disturbance regime of many riparian systems, the common dominant riparian plants often require disturbance to persist (Johnson et al. 1976; Scott et al. 1997). Lowering the rate or intensity of disturbance in such systems could open the way for invasion by late-seral species. Although the importance of disturbance to ecosystem health is now widely appreciated, exotic plant invasions resulting from lowered disturbance regimes in dynamic systems have rarely been demonstrated.

Russian olive (*Elaeagnus angustifolia* L.), is a small tree planted for windbreak and wildlife enhancement purposes. Since about 1900 it has become extensively naturalized throughout the western United States, especially in riparian areas (Christiansen 1963; Little 1961) and is still being planted today. Russian olive can enhance habitat for some wildlife species and may, in some cases, increase the size of riparian forests by establishing in adjacent shrub steppe

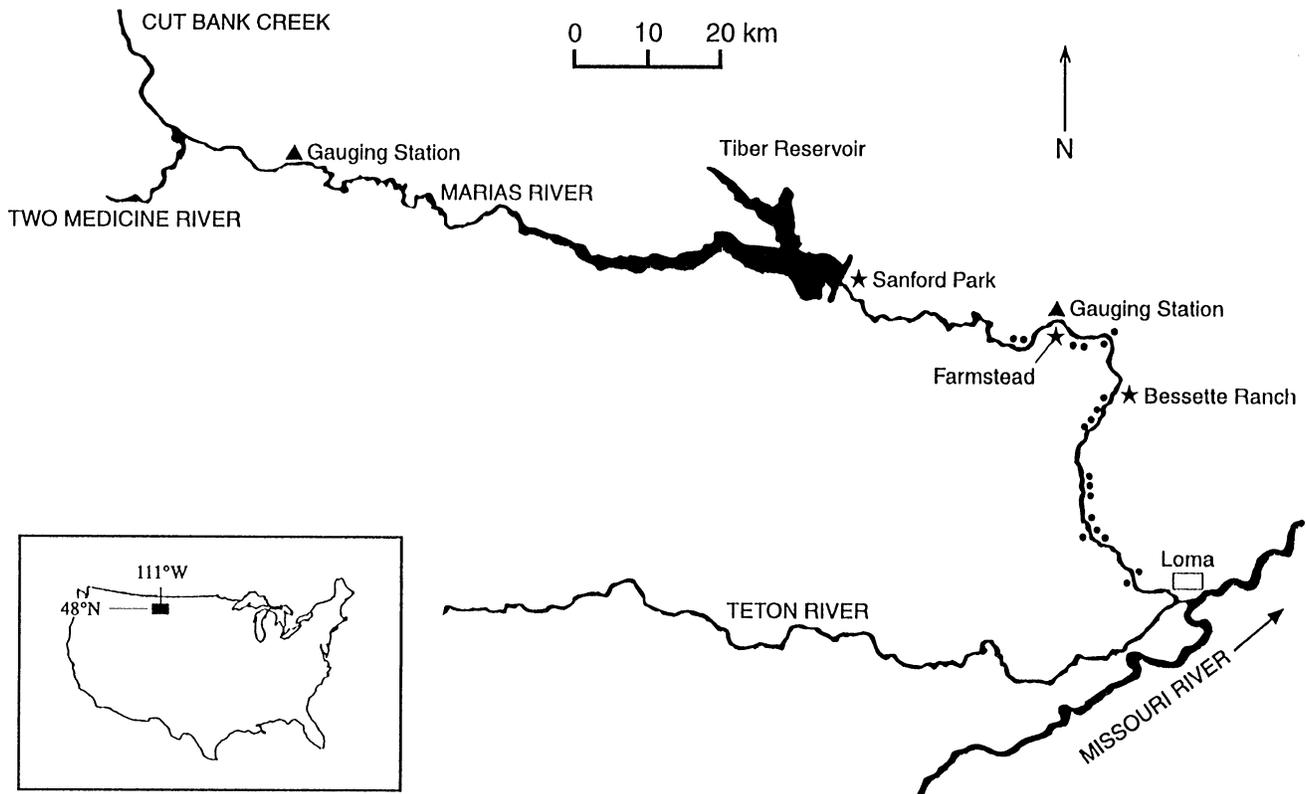
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Fig. 1. Map of the study area showing sample sites (●), gauging stations (▲), and Russian olive plantings adjacent to the river (★).



(Knopf and Olson 1984). On the other hand, Russian olive may also replace native vegetation and cause the loss of habitat for species such as cavity nesting and insectivorous birds (Knopf and Olson 1984; Olson and Knopf 1986a). Furthermore, Russian olive may hinder recruitment of cottonwood and willow, commonly the dominant native riparian woody plants (Currier 1982) and may be better adapted to establish under regulated stream flows (Shafroth et al. 1995).

Russian olive has been planted for windbreaks in Montana since at least 1953 (Montana Department of Natural Resources and Conservation nursery data), and naturalized trees occur along most major rivers in the Great Plains portion of the state (Olson and Knopf 1986a). The purpose of our study is to document the process of Russian olive invasion along the Marias River in north-central Montana. In particular we ask (i) what habitats does Russian olive occur in; (ii) how is river impoundment affecting the course of invasion; (iii) how do beaver (*Castor canadensis*) affect riparian succession; and (iv) how will Russian olive, beaver, and altered stream flows affect riparian vegetation along the Marias River in the future? Answers to these questions will allow managers to develop strategies for protecting the ecological integrity of riparian forests in the region and enhance our understanding of how altering disturbance regimes can affect riparian succession.

Species description

Russian olive is a small tree native to western Asia (Little 1961) that grows to 8 m tall in north-central Montana. Russian olive has deep vertical, as well as shallow nearly horizontal, roots and is capable of sprouting from the base when damaged. Trees become reproductively mature at about 10

years in north-central Montana (P. Lesica and S. Miles, unpublished data) and bear numerous clusters of small, edible, berrylike fruits in late summer that are consumed by birds and small mammals (Olson and Knopf 1986a, 1986b). Seeds germinate under a wide variety of moisture conditions at different times of the growing season (Shafroth et al. 1995).

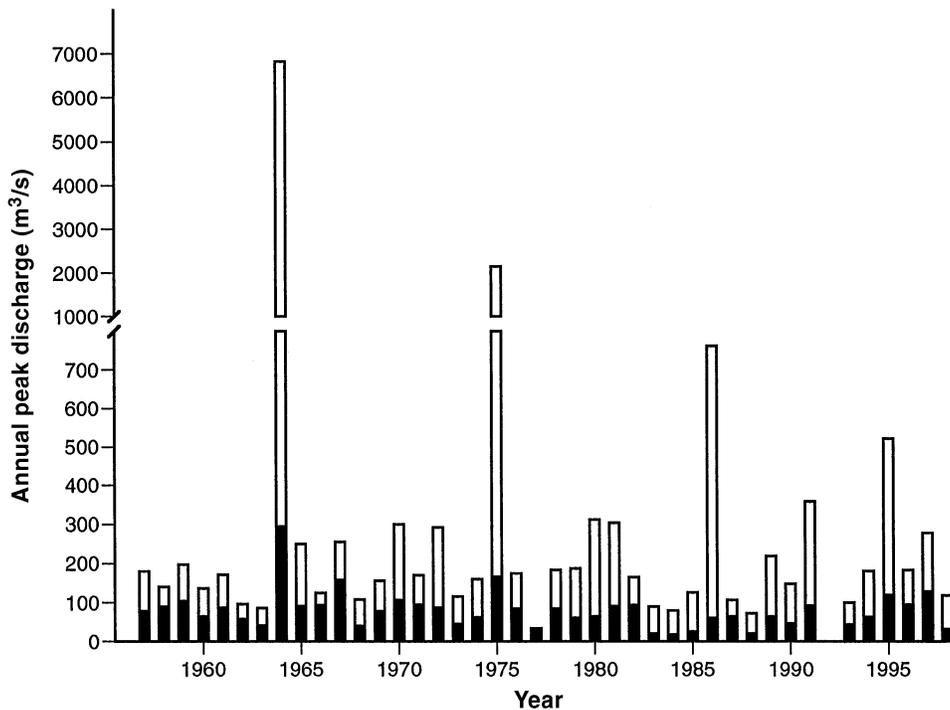
Plains cottonwood (*Populus deltoides* Bartr.) grows to 30 m tall and 1–2 m in diameter. Female trees produce millions of wind-dispersed seeds in most years after reaching maturity. Seeds germinate almost immediately, and seedlings require moist, mineral soil for establishment (Johnson et al. 1976). Plants grow quickly and are intolerant of shade (Braatne et al. 1996). Juvenile trees sprout from the base when damaged, but this ability is lost as the trees mature (Braatne et al. 1996).

Study area

The Marias River has its headwaters along the east front of the Rocky Mountains from Glacier National Park to near the town of Dupuyer. The river flows unregulated east from Cutbank to Lake Elwell which was formed in 1956 by construction of Tiber Dam. From Tiber Dam the lower Marias River flows east and then south to its confluence with the Missouri River just below the town of Loma (Fig. 1). The lower river valley is a few hundred metres to over 1 km wide and frequently bounded by steep breaks eroded from the soft sedimentary formations. The lower Marias is about 135 river kilometres long with 82 m of fall and no perennial tributaries above Loma.

Vegetation of uppermost river terraces is dominated by silver sagebrush (*Artemisia cana* Pursh), western wheatgrass (*Agropyron smithii* Rydb.), and green needlegrass (*Stipa viri-*

Fig. 2. Annual peak flows above (open bar; Shelby gauging station 06099500) and below (solid bar; Chester station 06101500) the Tiber Dam from 1957 (1 year after the dam was completed) to 1994. Peak flows were not recorded in 1992.



dula Trin.). Terraces closer to the river channel support riparian vegetation dominated by cottonwood, willow (*Salix* spp.), buffaloberry (*Shepherdia argentea* (Pursh) Nutt.), and hydrophytic grasses, sedges, and bulrushes. Cottonwood forests may be up to 300 m wide in meandering reaches of the river.

Mean annual flow on the Marias River is 26.6 m³/s. (U.S. Geological Survey, Water Resources of Montana data), with large annual fluctuations. Mean monthly discharge is five times greater for May and June than for other months of the year (Rood and Mahoney 1995). Since construction of Tiber Dam, average peak spring flows in the lower Marias River have been reduced by 70%, and extreme peak flows of 1964 and 1975 were attenuated by more than 90% (Rood and Mahoney 1995; Fig. 2).

Methods

Field methods

We used a canoe to travel the lower Marias River (Fig. 1) in mid-August 1997 and used binoculars to map all visible Russian olive plants on lower terraces onto aerial photographs. We classified the Russian olive into one of three size classes: sapling, pole, and mature (see below). Plants in the seedling size class were not tallied.

We located sites with Russian olive density of at least about 100 plants/ha during a canoe trip in May 1997 and randomly selected 19 of these 36 sites for sampling during mid-August and early September. At each site we sampled the stand of Russian olive nearest the river channel, the one farthest from the channel, and the recent alluvial sandbar habitat when they were present. Additional stands were sampled at two sites where terraces were especially wide. Sample plots were 500 m² and circular or rectangular, depending on the shape of the stands being sampled.

Following reconnaissance we subjectively located a sample plot to represent each stand at that site. For each sample plot we estimated the mean distance to the edge of the river channel and measured the elevation above the September 1997 river level to the nearest decimetre with a hand-held level and gauging pole. We estimated canopy cover (Daubenmire 1959) of all common (>1% cover) vascular plant species in the plot to the nearest 5% and estimated tall-tree canopy cover with a spherical densiometer at the center of circular plots and at two equidistant points in rectangular plots.

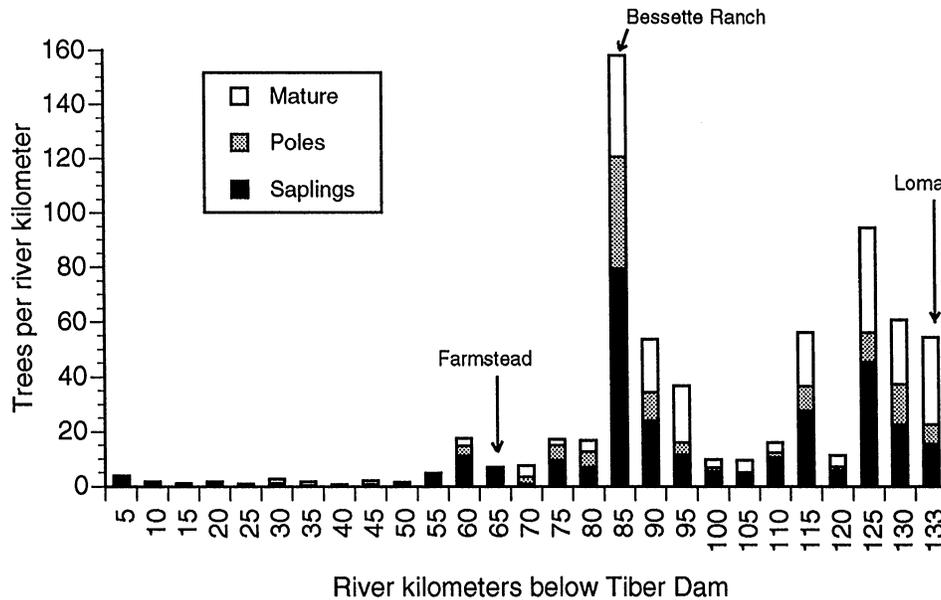
We classified each cottonwood and Russian olive tree in each plot into one of four size classes:

	Cottonwood		Russian olive	
	Height (m)	Basal diameter (cm)	Height (m)	Basal diameter (cm)
Seedling	<1.3	<2.5	<0.90	
Sapling	≥1.3	2.5–13	>0.90	<8
Pole		13–23	>1.8	8–13
Mature		>23		>13

We sampled cottonwood seedling density of sandbars with ten 1-m² evenly spaced circular microplots, or 2-m² microplots when seedlings were sparse. We obtained age estimates for three plants in the dominant size classes for both tree species from cross sections or increment cores taken at ground level. Age estimates of cottonwood taken from increment cores were likely to be smaller than the actual age because annual rings can be faint, and ground level is not always the level of the establishment surface (Bradley and Smith 1986; Scott et al. 1997). Additionally, many cottonwood trees, especially those previously felled by beavers, had rotten centers, making age determination inaccurate if not impossible.

Vascular plant nomenclature follows the Great Plains Flora Association (1986).

Fig. 3. Density of naturalized Russian olive in three size classes in low-terrace habitats along the lower Marias River.



Data analysis

We classified the sample plots into three habitats, (i) sandbar, (ii) low terrace, and (iii) high terrace, using a combination of three criteria: dominance of wetland plants, distance from the river channel, and elevation above September 1997 water level.

We compared the density and establishment age of cottonwood and Russian olive between high and low terrace habitats with paired-sample *t* tests using only sites with both species in both habitats. The nonparametric Mann-Whitney test was used to assess the difference in mean number of beaver-damaged trees per plot between Russian olive and cottonwood in the same habitat. We used chi-square goodness of fit tests to compare the proportion of beaver-damaged trees between the two tree species. Fisher's exact test was used when expected cell frequencies were <5.

Results

Habitats

Sandbars (*n* = 6)

Recent alluvial deposits adjacent to the river channel supported sparse stands of colonizing species such as cottonwood and sandbar willow (*Salix exigua*). If alluvium was deposited on existing vegetation, rhizomatous herbs such as *Scirpus pungens*, *Scirpus validus*, and *Eleocharis palustris* were present as well. Cottonwoods were 1–5 years old and occurred at densities of 0.01–5.54/m². Sample plots averaged 0.3 m above the September 1997 water level.

Low terraces (*n* = 19)

Low-terrace plots were dominated by the rhizomatous species, *Agrostis stolonifera* and *Glycyrrhiza lepidota* and the exotics, *Bromus inermis* Leyss. and *Melilotus alba* Desr. Tall-tree canopy cover was low or lacking in all plots. Cottonwood occurred in 11 plots, and stands were 3–26 years old. Low-terrace plots averaged 25 m from and 0.9 m above the September 1997 water level.

High terraces (*n* = 13)

All but one high-terrace plot were dominated by cottonwood about 40–110 years old with average tall-tree canopy cover of 33%. The understories of high terrace plots were dominated by snowberry (*Symphoricarpos occidentalis* Hook.) and western wheatgrass (*Agropyron smithii*) with the exotics, *Poa pratensis* L., *B. inermis* and *Cirsium arvense* (L.) Scop. High terrace plots averaged 160 m from and 2.0 m above the September 1997 water level.

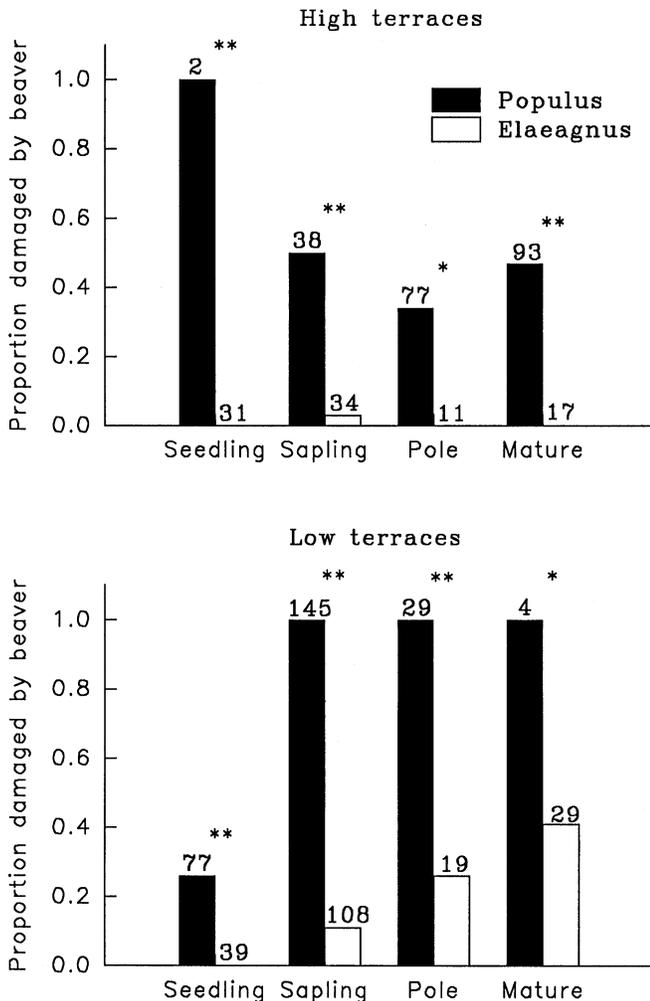
Distribution of Russian olive

Large, mature windbreak plantings of Russian olive near the river are found at Sanford Park just below Tiber Dam, at the Bessette Ranch, about 80 river kilometres below the dam, and near the town of Loma just above the confluence of the Marias and Missouri rivers (Figs. 1 and 2). There is a planting of four trees near the river on a farmstead about 65 river kilometres below the dam. The Bessette Ranch windbreak was planted in 1962. Our mapping of the entire lower river from the canoe revealed that naturalized Russian olive are scattered from the dam to about 50 river kilometres downstream. They become more common just above the farmstead planting and reach greatest densities around the Bessette Ranch. A second peak in Russian olive density occurs near the town of Loma (Fig. 3). All size classes are distributed throughout the study area (Fig. 3).

Russian olive was not observed on sandbars, but it did occur in 89% of low-terrace plots and 47% of high-terrace plots. It was observed only once on an upper terrace without an overstory of cottonwood. Density of Russian olive averaged 200 and 152 plants/ha in low- and high-terrace plots, respectively, and was not different between the two habitats at sites where it occurred in both (paired *t* test, *t* = 1.02, *n* = 7, *P* = 0.35).

All low-terrace and most high-terrace plots had Russian olive in one or both of the two smaller size classes. Establishment age of Russian olive stands varied between 5 and 27 years on low terraces and between 5 and 36 years on high

Fig. 4. Proportion of beaver use of cottonwood (*Populus*) and Russian olive (*Elaeagnus*) trees in four size classes in high- and low-terrace habitats at all study sites. Number of plants in each size class presented above the bar. Differences in proportions determined by chi-square or Fisher exact tests (*, $P < 0.05$; **, $P < 0.001$).



terraces, and there was no consistent difference in establishment age between the two habitats (paired t test, $t = 0.14$, $n = 7$, $P = 0.89$).

Effects of beaver

Cottonwood trees in all size classes received significantly higher beaver damage than Russian olive in both low- and high-terrace habitats (Fig. 4). Recent beaver damage was evident on cottonwood and Russian olive in 91 and 36%, respectively, of low-terrace sample plots where both occurred ($n = 11$, Fisher exact test, $P = 0.02$). Beaver damage was apparent on a mean of 77% of cottonwood trees but only 22% of Russian olive trees in all low-terrace plots (Mann-Whitney $U = 35$, $P < 0.001$). Most beaver-damaged cottonwoods were cut off at the base, while damage to Russian olive was usually confined to one or two basal limbs. In low-terrace plots where beaver damage was evident, the age of oldest undamaged cottonwood shoots from beaver-damaged trees across all plots was 2.4 ± 0.94 (mean \pm SD; $N = 9$ with 1

outlier omitted), indicating that beavers returned to harvest cottonwood in low terrace habitats at least every 2–3 years on average.

Beaver damage was lower in high-terrace plots. Recent damage to cottonwood was observed in 50% of plots where both species occurred, but only 8% of these plots had beaver damage to Russian olive ($n = 12$, Fisher exact test, $P = 0.07$) with 41% of cottonwood trees but only 2% of Russian olive trees showing use ($U = 43$, $P = 0.016$). Dead beaver-caused cottonwood stumps occurred in 33% of low-terrace and 73% of high-terrace plots that supported cottonwood. The number of stumps per plot was 20 ± 21 ($n = 12$). Beaver-caused Russian olive stumps were not observed in either terrace habitat.

Discussion

Russian olive on the Marias River

Russian olive establishment along the lower Marias River is recent and ongoing but less common in the first 50 km below Tiber Dam with plants of juvenile and mature size classes occurring throughout (Fig. 3). All but one of the naturalized Russian olive sampled were under 30 years old, and only 18% of trees in sample plots were in the mature size class. High densities of Russian olive are correlated with plantings at human habitations in the river corridor (Fig. 3). The low density of Russian olive directly downstream from plantings just below Tiber Dam is puzzling.

Although Russian olive is capable of germinating with cottonwood on bare, moist alluvium of sandbar habitats (Shafroth et al. 1995), we found no evidence that this occurs along the lower Marias River. Russian olive does not appear to require a disturbance event to establish. It has large seeds that can germinate throughout the growing season and under a wide variety of conditions (Shafroth et al. 1995). Young plants were found on both high and low terraces in spite of river impoundment and flow regulation. Knopf and Olson (1984) predicted that Russian olive invasion would increase the width of riparian corridors in some areas by establishing adjacent to but outside of native woody riparian vegetation. We found little evidence for this occurring along the lower Marias River.

Russian olive seed is dispersed primarily by birds (Olson 1974). Frugivorous birds are more likely to defecate in forested habitats, which would result in the primary invasion foci being on high terraces (Currier 1982). However, we did not detect a difference in the age of Russian olive between high- and low-terrace habitats at the same site, suggesting that invasion of one habitat was not dependent on prior colonization of the other.

Effects of beaver

Beaver damage to Russian olive occurred in only one third of low-terrace stands, and less than 25% of trees were damaged overall. On the other hand, beavers cut down most cottonwood trees in nearly all sampled low-terrace sites on average every 2–3 years. Furthermore, severity of damage to Russian olive was lower than for cottonwood. Cottonwood and other members of the genus *Populus* are preferred foods for beaver throughout their range (Hall 1960; Jenkins 1985), and our results indicate that beaver herbivory of Russian olive is uncommon when cottonwood is available, although the

reason for this lack of use is not known. Cottonwood stands on high terraces received much lower levels of beaver herbivory than low terraces, probably because beaver are more vulnerable to predators farther from water, and transporting food material greater distances requires more energy (Belovsky 1984).

Beaver populations on the lower Marias River may have increased following construction of Tiber Dam because safe den sites are usually more abundant along banks that experience minimal water level fluctuations (Retzer et al. 1956). Flooding is thought to be an important cause of beaver mortality and den abandonment (Hill 1982). In addition, beaver prefer to build dens on well-vegetated banks adjacent to deep water (Dieter and McCabe 1989) because low water levels that expose den entrances are also an important cause of den abandonment. Prior to river damming, The Marias experienced large fluctuations in water level, and many reaches of the river probably had few favorable den sites. Operation of Tiber Dam has greatly attenuated large annual fluctuations in water level, resulting in inactive, densely vegetated point bars (Rood and Mahoney 1995) and increased shoreline with stable, deep water. These changes may have enhanced beaver denning habitat and caused an increase in population size. High beaver densities may also be due to decreased pressure from predators including man.

Effects of the Tiber Dam on Marias River fluvial processes

Older cottonwood forests along the lower Marias River established as a result of two processes: channel meandering and flood deposition (Bradley and Smith 1986; Rood and Mahoney 1995; Scott et al. 1996). Flow regulation by Tiber Dam has altered fluvial processes responsible for cottonwood establishment by changing seasonal flow patterns and attenuating flood flows (Rood and Mahoney 1995). Attenuated flood flows have apparently prevented alluvial deposition on all but the lowest terraces close to the river channel. Consequently, there will be a significant reduction in the area of cottonwood forest along the lower Marias River if current flow conditions persist (Rood and Mahoney 1995).

Conclusions

Russian olive invades cottonwood stands of all ages along the Marias River as well as low-terrace wet meadows without cottonwood. At this time the invasion is occurring slowly; only rarely does Russian olive stature and density approach that of cottonwood. On upper terraces, Russian olive forms an understory canopy beneath mature cottonwood. Unlike cottonwood it is able to reproduce in shade. As old cottonwood trees die, forests of Russian olive will be left in their place because native late-successional trees, such as green ash (*Fraxinus pennsylvanica* Marsh.) do not occur in the area.

Our study indicates that cottonwood recruitment will be restricted to a narrow zone along the Marias River channel if Tiber Dam continues to attenuate peak flows. Russian olive occurs in this low-terrace zone as well. In the absence of beavers, we believe that cottonwood would overtop Russian olive and form narrow riparian forests with a Russian olive and (or) willow understory. Unfortunately, beaver concen-

trate their feeding activity in this same near-channel zone. Beaver damage will suppress cottonwood maturation while allowing Russian olive to increase. Eventually the shade of the Russian olive canopy will preclude cottonwood recruitment. As in the upper terrace habitat, the Russian olive forest will be self-perpetuating. Russian olive is likely to become the dominant riparian tree along the Marias River under controlled flow regimes.

Green ash and box elder (*Acer negundo* L.), late-seral, riparian trees throughout much of the northern Great Plains, are absent or rare along the lower Marias River. Russian olive appears able to fill this late-seral niche in north-central Montana and is likely to persist in upper terrace habitats as cottonwood trees senesce. Large or frequent disturbance results in increased invasibility of many plant communities (reviewed in Hobbs and Huenneke 1992), because many invasive exotics are adapted to ruderal habitats (Bazzaz 1986). However, our study demonstrates that the reverse pattern also occurs; invasion of late-seral exotics may be facilitated when the disturbance regime of highly dynamic systems is damped. Managers should consider that lower disturbance regimes may promote exotic plant invasions, especially in highly dynamic systems.

Management implications

Loss of riparian cottonwood forests along the Marias River is in its early stages. Flooding has been attenuated for 40 years, about one third the life-span of a cottonwood stand. Periodic large spring releases from Tiber Dam followed by gradual decreases in flow may reinitiate channel migration, and allow cottonwood recruitment. Many of the cottonwood stands recruited following periodic flood flows would probably be lost without a concomitant lowering of beaver density. Trapping may be necessary to attain beaver populations compatible with management goals. Russian olive plantings near major stream courses should be curtailed. Strategies to increase cottonwood recruitment should include measures to limit livestock use during the critical first years of establishment and growth (Green and Kaufman 1995). Further studies of fluvial geomorphology and beaver populations would be required before an effective management strategy could be developed.

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