ECOLOGICAL ASSESSMENT OF *HOWELLIA AQUATILIS* HABITAT AT THE HARVARD–PALOUSE RIVER FLOOD PLAIN SITE, IDAHO

by

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ABSTRACT

Howellia aquatilis (water howellia) is an aquatic macrophyte that is Federally listed as threatened by the U.S. Fish and Wildlife Service. It occurs in internally drained ponds that dry out each year. The single known location of the species in Idaho differs from the typical habitat in that the ponds were formed by fluvial rather than glacial or other processes. The ponds occur on a rare, undeveloped parcel of land on the flood plain of the Palouse River in northern Idaho. This report documents the first work done at the site to characterize macro- and micro-scale characteristics related to its habitat and potential viability at the site. Flood plain dynamics were characterized by mapping flood plain vegetation and relief, examining historical photos, and examining historic discharge data for the river. Vegetation, substrate, and configuration of ponds containing *H. aquatilis* were described and water-level gages were installed to monitor pond depth. Surveying instruments were used to determine the relationship of the pond bottoms to the river channel bottom and other features of the flood plain. In spite of their contrasting orogeny, ponds are similar vegetationally to those occupying glacial potholes. Ponds are the low points of larger depressions which appear to represent abandoned river channels. Each pond consists of small shallow area with no outlet, that holds water into mid summer when plants are producing open flowers above water. Although the flood plain is marked by an intricate microtopography of troughs related to channel abandonment and alluvial deposition, only two other depressions held water into July of 1999 and only three contained plant species indicative of *Howellia* habitat. Monitoring of pond and river water levels over winter and spring, and characterization of bottom sediments will allow us to develop working hypotheses to describe pond hydrology, and provide a basis for possible future management of the site.

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INTRODUCTION

Howellia aquatilis (water howellia) is an annual aquatic plant representing a monotypic genus in the family Campanulaceae. *Howellia* has very specific habitat requirements and has been rare throughout the period of botanical record. It is currently known from 13 sites in western Montana, northern Idaho, and eastern and western Washington (Shelly and Moseley 1988). It is extremely limited throughout its range, occurring in ephemeral ponds and at the margins of permanent ponds, which in most cases are glacial potholes (Shapley and Lesica 1997). *Howellia* is listed as Threatened by the U.S. Fish and Wildlife Service.

The life cycle of *Howellia* is intimately tied to the hydrology of the ephemeral ponds that comprise its habitat. As an annual plant, viability in the short term depends on hydrologic conditions necessary for seed production and germination. Long-term survival of metapopulations may depend on the density and diversity of ponds available (Lesica 1992). Habitat management for *Howellia* requires better understanding of pond hydrology and geometry (Shapley and Lesica 1997) and the effect of exotic colonization of ponds and wetlands (Lesica 1997).

In Idaho, the sole *Howellia* site occurs on the flood plain of the Palouse River, in ponds created by fluvial processes. This project was undertaken to characterize the fluvial processes of the flood plain through the site and relate these to the long-term dynamics of flood plain vegetation in general, and the habitat of *Howellia* in particular. Our specific objectives were to describe the habitat occupied by *Howellia*, use historical records to characterize flood plain dynamics at the site, and to establish monitoring of water depth in *Howellia* ponds. Specific 1999 activities included 1) characterization of the flood plain vegetation, 2) description of general and localized habitat, 3) examination of historical photos and flow data, and 4) installation of water depth gages.

This characterization of ecological processes and habitats will facilitate two recovery actions outlined in the draft Recovery Plan (Shelly and Gamon 1996): 1) development of a management plan for the flood plain ecosystem on the property that will focus on the long-term maintenance of *Howellia* habitat, and 2) establishment of a habitat and population monitoring program.

HABITAT AND ECOLOGY OF *HOWELLIA AQUATILIS*

Range

Howellia is known historically from six widely disjunct areas in five western states– Montana (Lake and Missoula Counties), northern Idaho (Latah and Kootenai Counties), eastern Washington (Spokane Co.), western Washington (Clark Co.), northwestern Oregon (Clackamas, Marion, and Multnomah Cos.), and northern California (Mendocino Co.). All of the Oregon occurrences (at least 4) and the one in Kootenai County, Idaho are considered extirpated (Shelly and Gamon 1996).

Habitat

Although most of the ponds in which *Howellia* is found are of glacial origin, the Idaho site, one Washington site, and the Swan River Oxbow in Montana are located in fluvial environments. A critical feature of *Howellia* habitat is that the ponds dependably dry out, at least in part, by the end of the growing season. Most have no outlet and thus depend on inputs from precipitation, overbank flooding and groundwater, although the relative importance of each is not clear. *Howellia* populations are found almost exclusively in ponds with a bottom surface of firm, consolidated clay and organic sediments (Shelly and Moseley 1988).

Ponds are generally shallow and occupied by emergent and aquatic plants, typically including *Carex vesicaria* (inflated sedge), *Sium suave* (water-parsnip), and *Equisetum fluviatile* (horsetail). Other common associates are listed in Shelly and Moseley (1988). Ponds are ringed by shrubs on the immediate margin, and large deciduous tree species are usually present as well (Shelly and Moseley 1988). Zonal vegetation surrounding *Howellia* habitat ranges from grassland to coniferous forest.

Life history

The interesting reproductive biology of *Howellia* has been documented by Lesica et al. (1988) and is also described in Shapley and Lesica (1997), and Shelly and Moseley (1988). Several features of its life history are responsible for its narrow habitat restrictions. A dry pond bed is required for seed germination, which begins shortly after the bottom is uncovered and continues until seeds are once again submerged (Lesica 1992). Most of the current year's seed crop germinates during that interval. Plants begin to grow by early May, producing closed (cleistogamous) flowers below water and open (chasmogomous) flowers when they reach the surface. The fact that both types of flowers are adapted for self-pollination is responsible for the species' very low level of genetic variation (Lesica et al. 1988). If a pond does not fill with water in spring, no seed will be produced. If the portion of the pond supporting *Howellia* does not dry out at some point, that year's seed crop will not germinate. Seed viability is diminished by the next fall, indicating a lack of a dependable seed bank (Lesica 1992). Seeds are relatively large (2-4 mm long) and do not possess any wings or appendages to provide buoyancy. It is likely that seeds sink to bottom soon after release (Shelly and Moseley 1988).

SITE DESCRIPTION

In Idaho, *Howellia* is known from a single site on the flood plain of the Palouse River, where it has been observed in three different ponds. The site is located 13 miles east of Potlatch, Idaho at the intersection of highways 6 and 9 near the small town of Harvard (Appendix 1, Map 1). It is part of a 226-ac parcel of land owned by Ruth Ownbey, wife of the late Marion Ownbey, a botanist and long-time curator of the WSU herbarium. The property has been used for cattle grazing in the past, but is not currently grazed.

Examples of riparian and wetland communities in good condition occur at the site which has been documented in the CDC's conservation site database as the "Harvard-Palouse River Flood Plain." This is one of only three known sites in which *Howellia* occurs in ponds created by fluvial processes.

The Harvard-Palouse River Flood Plain site is an approximately one-mile section the Palouse River, the adjoining flood plain, and forested slopes bordering the plain to the south (Appendix 1, Map 2). The site is bounded to the north and east by highways, and on all sides by farmland.

At the site, the Palouse River is a fourth-order, clear running stream. It is a type C stream (Rosgen 1996) with a single channel and moderate sinuosity. The bottom is made up of cobble at riffles and sand at pools with outcroppings of bedrock in places. The natural flood plain is over 0.5 mi (0.8 km) wide at this point but is confined to the north by a railway/highway corridor. Records from a USGS river gage 15 miles downstream indicate average peak flows of 4129 cfs. Extremes of 619 and 14,600 cfs have been recorded over the 37-yr record (Figure 1). The record high discharge of 14,600 cfs was recorded in

Figure 1—Discharge

February, 1996, coinciding with a stage of 22 ft; the record low occurred only 2 years earlier. Minor impoundments upstream have little effect on the flow regime.

Deep alluvial soils of the flood plain are comprised of alluvial sand, silt and clay, forming fine-grained stratified deposits 6.5-16 ft (2-5 m) thick (Othberg 1982). Elevation at the site, near the transition from foothills to mountains, is 2560 ft. It lies about 50 miles south of the limit of continental glaciation.

Climate

From fall through spring, the climate of northern Idaho is dominated by Pacific-coastal air masses which carry abundant moisture, produce cloudy weather, and have a moderating effect on temperatures. Summers are dry due to the influence of a subtropical high pressure system and summer precipitation comes primarily in the form of convectional storms (Cooper et al. 1991). Precipitation at the site is well-characterized by the weather station at Potlatch, Idaho, 8 miles to the west, which indicates normal precipitation of 25.31 inches annually, of which 73% falls from November through May.

Vegetation

Vegetation of the flood plain is a mosaic of riparian shrubland and meadows with inclusions of mature conifers. A variety of conifers are represented, with *Pinus contorta* (lodgepole pine) and *Picea engelmannii* (Engelmann spruce) the most abundant and probably the most indicative of the environment. Slopes adjoining the flood plain to the south support mixed mid-seral conifer stands mostly in the *Abies grandis* (grand fir) series.

The flood plain is dissected by seasonally inundated channel-like depressions lined with *Crataegus douglasii* (Douglas hawthorn) and other shrubs. These features are the result of alluvial deposition and channel migration. In most cases the bottoms are completely over-shaded by shrub canopy, but some that retain water longer contain open ponds and communities of obligate wetland plants, typically including *Carex vesicaria* (inflated sedge) and *Eleocharis palustris* (common spikesedge). Some are choked with *Phalaris arundinacea* (reed canarygrass). Low lying areas of riparian shrub thicket are separated by patches of upland mesic grass meadow.

METHODS

In 1999, six steps were taken toward our objective of characterizing the fluvial processes related to flood plain vegetation and *Howellia* habitat: 1) a survey of the site for *Howellia* populations and habitat, 2) description of *Howellia* habitat, 3) mapping and cataloging of flood plain vegetation, 4) surveying of a cross-section of the flood plain through the *Howellia* ponds, 5) examination of historical photos, and 6) installation of water-level gages. The site was thoroughly surveyed for *Howellia* and any potential habitat, on July 2 and 3, 1999. The sizes and shapes of three ponds containing *Howellia* were determined by measuring their various dimensions, and a scale diagram was made of each (Appendix 2). Vegetation associated with the ponds was recorded.

Vegetation of the flood plain was easily mapped at the Formation level from aerial photos, after a ground survey of the area. Wetland inclusions were mapped if they were considered possible habitat for *Howellia*. Vascular species observed were listed by vegetation type (Appendix 3). To describe the *Crataegus douglasii* and *Alnus incana* communities we collected ocular plant species and environmental data using the methods of Bourgeron et al. (1992; Appendix 4).

Using a surveyor's transit we surveyed a cross-section of the flood plain at the point where the *Howellia* ponds occur, establishing the relationship of the pond bottoms to the river bottom and the upland separating them. To determine how dynamic the channel has been in the recent past, we examined photos dating back to the 1930s.

To monitor water level in the three *Howellia* ponds, gages were installed on July 13 and 14. Gages consist of 2-inch PVC pipe marked in decimeters and pounded into the approximate deepest point of each pond with zero at the pond bottom (Appendix 5). At the time the gages were installed, only pond 2 still held water.

RESULTS

Flood plain dynamics

The extensive migration of the Palouse River across its flood plain is evident from the numerous cutoff channels and abandoned oxbows clearly visible on aerial photos. These also show that this segment of the river the channel was once much more sinuous than at present. The once highly sinuous channel formed oxbows which were eventually cut off, becoming wetlands or ponds.

The flood plain is thoroughly dissected by arcuate depressions many of which have the form of channels, but are not as deep as those that stand out on aerial photos (Figure 2b). Only the large meadow south of the river lacks this microtopographic relief, possibly as a result of being plowed in the past. These "channel scars", which appear to be old channels or portions of abandoned oxbows, control the pattern of vegetation on the flood plain. Some hold standing water in spring and contain wetland communities, but most dry out soon after the river begins to recede. Although the shapes of these features suggest abandoned channel courses, their density is difficult to explain for a single-channel river such as the Palouse.

Some of the flood plain relief may be the result of episodic point bar deposition. Migration of the channel occurs through incremental deposition of alluvium on point bars, concurrent with erosion of the inside bank. Successive point bar deposits of coarse alluvium take the form of a series of alternating, arcuate ridges and sloughs referred to as "meander scrolls" (Thornbury 1954). While abandoned channels stand out clearly on aerial photos, meander scrolls may be evident only as subtle vegetation patterns. Although the channel scar that borders the flood plain to the south and holds two *Howellia* ponds appears to be an abandoned channel, it dead-ends at the forested slope and may in fact be an overflow or back-channel.

An indication of the current stability of the channel, and of the great age of the abandoned meanders, is evident in a time series of photos showing the course of the Palouse River through the site (Figure 3). A slight migration of the channel can be seen over the last 37 years, as the broad point bar (a) grows, shifting the channel north. During the same time period, the mid-section of this river segment (b) straightened considerably. In 1996 the largest flood event on record probably contributed to this shift. A poor-quality aerial photo of the site from as far back as the 1930s showed a channel very similar to that seen in 1966.

Figure 2

Figure 3

Flood plain vegetation

Four vegetation formations are represented on the flood plain and were mapped as follows: 1) herbaceous grass meadow, 2) *Crataegus douglasii* shrub thicket, 3) *Alnus incana* riparian forest, and 4) coniferous forest (Figure 2a). Each of these units includes 1-3 plant associations. Coniferous forest occurs mainly as a stringer along the north boundary of the
site adjoining the railroad bed. Shrub thicket is comprised primarily of *Crataegus* along with *Philadelphus lewisii* and other shrubs, and is associated with abandoned channels, depressions, and low-lying areas. A *Crataegus douglasii/Heracleum lanatum* (Black hawthorn/cow parsnip) association (Jankovsky-Jones et al. 1999; Appendix 6) occupies broader, low areas. Large *C. douglasii* form a nearly complete canopy, with a subcanopy of *H. lanatum* and scattered *Physocarpus capitatus*. *Carex deweyana* dominates the groundcover layer. Good examples of this community can be found in places. Degradation is primarily evidenced in the abundance of *Glecoma hederacea* (ground ivy), an exotic species.

Stringers of *Alnus incana* line the river, and a wider zone occupies a low-lying area on the south side of the river that is cut by numerous high water channels. Most of the alder community has been significantly altered by extensive colonization by *Phalaris arundinacea*, but we were able to locate three plots in areas approximating natural understory conditions. In these the understory is a nearly continuous cover of tall forbs, dominated by *H. lanatum* and *Urtica dioica* with a groundcover layer of *C. deweyana* and *G. hederacea*.

Meadow areas are dominated by pasture grasses. *Pteridium aquilinum* (bracken fern) glades are included in this unit. There are large infestations of *Centaurea maculosa* (spotted knapweed) mostly in the large meadow south of the river. The only native graminoids observed were *Bromus carinatus* (mountain brome), *Danthonia californica* (California oatgrass), and *Carex pachystachya* (thick-headed sedge), all scarce. Shrubs and conifer saplings are absent except on the margins.

Howellia ponds

During a thorough survey of the site in early July, 1999, *Howellia* was found in three ponds. Two lie adjacent to one another within what appears to be a large abandoned meander at the south edge of the flood plain (Figure 2b). The other (pond 3) is the low point of a narrow, arcing depression on the north side of the river. The feature particularly stands out on a 1966 photo, when the woody vegetation was less dense, and appears to be an abandoned oxbow (Figure 3). The pond occupies a wider area within the trough. *Howellia* had been observed in each of these locations in previous years. Several other depressions still held water at this time, but most were dry or nearly dry.

Ponds with *Howellia* are shallow and have firm bottoms. The substrate of ponds 1 and 2 appears fine-textured, while that of pond 3 is a coarse-textured peat, apparently composed of decaying *Eleocharis* stems. Two fairly distinct communities are associated with the ponds, one of emergents and aquatics within the free-water area of the pond itself, and a tall-shrub community on the immediate margin of the pond. *Eleocharis palustris* (common spikerush) and *Carex stipata* (sawbeak sedge) occupy submerged areas after the water recedes. Pond 3 eventually develops a complete cover of *E. palustris*; in early July, the pond was filled with dead *Eleocharis* stems from the previous year.

Table 1. Plants associated with *Howellia aquatilis* ponds at the Harvard- Palouse River Flood Plain site.

	Pond 1	Pond 2	Pond 3
Aquatics and emergents			
Acorus calamus		x	
Alisma plantago-aquatica	x	x	x
Alopecurus aequalis	x	x	x
Carex retrorsa	x		
Carex vesicaria	x	x	x
Eleocharis palustris			x
Glyceria occidentalis	x	x	
Lemna minor	x	x	x
Ranunculus flabellaris		x	
Ricciocarpus natans	x	x	
Sium suave	x		
Sparganium emersum	x	x	x
Utricularia vulgaris		x	
Veronica anagallis-aquatica		x	
Graminoids and forbs of the pond margins			
Bidens cernua		x	
Carex stipata		x	x
Cicuta douglasii	x	x	
Equisetum hyemale			x
Heracleum lanatum	x	x	
Lycopus uniflorus			x
Myosotis scorpioides		x	
Phalaris arundinacea	x	x	x
Polemonium occidentalis	x		
Ranunculus orthorhynchus		x	
Rumex occidentalis	x		
Rumex salicifolius			x
Solanum dulcamara		x	x
Shrubs of the pond margins			
Acer glabrum	x		
Alnus incana	x	x	x
Cornus sericea	x	x	x
Crataegus douglasii	x	x	x
Lonicera involucrata		x	

Philadelphus lewisii	x		
Physocarpus capitatus	x	x	
Rosa woodsii			x
Salix bebbiana			x
Salix drummondiana	x	x	
Salix geyeriana	x		
Symphoricarpos albus	x		

Four emergent macrophytes–*Alisma plantago-aquatica* (American waterplantain), *Alopecurus aequalis* (short-awn foxtail), *Sparganium emersum* (small bur-reed), and *Carex vesicaria* (inflated sedge)– and three shrubs–*Crataegus douglasii, Alnus incana*, and *Cornus sericea* (red-osier dogwood)–were common to all three ponds (Table 1). *Phalaris arundinacea* also occurs at all three, but is less abundant at pond 3. Ponds 1 and 2 are adjacent and separated only by a low divide a few meters wide. They share many species in common, however pond 2 is largely dominated by a dense colony of the exotic *Acorus calamus* (sweet flag) which does not occur in pond 1.

The total area occupied by *Howellia* at the time of our survey was about 0.5 m^2 at pond 1, 50 m^2 at pond 2, and 0.5 m^2 at pond 3 (Appendix 2). *Howellia* was found growing in shallow water among *Phalaris* stems and aquatics including *Ranunculus flabellaris* (yellow water-buttercup) and *Alopecurus aequalis*. Plants were first observed blooming on July 2 and were still blooming on July 13. Plants were blooming close to the pond edges in ponds 1 and 3. Some stems with open flowers were left decumbent on the mud bank as the water receded. All ponds held water on July 3 but only pond 2 still held water by July 13 when water-level gages were installed (Table 2). On September 1 the bottom of pond 2 was still saturated and soft; footprints became filled with water.

Table 2. Depth of water in *Howellia* ponds with concurrent river discharge rate and stage (at Potlatch), 1999.

Date	Water depth (m)			Discharge	Stage
		Pond			
	1	2	3	(cfs)	(ft)
July 1	.20*			50	5.5
July 13**	.00	.24	.00	28	5.3
July 16		.21		25	5.2
Aug 3		.00		14	5.1

*estimated
**gages installed

In our cross-sectional diagram of the flood plain (Figure 4) the vertical distance is exaggerated by the use of different horizontal and vertical scales, but it illustrates the relationship of the pond bottoms, the river channel and another concavity of the flood plain occupied simply by *Phalaris*. The ponds are set well back from the river, with bottoms well above the level of the river bottom, but below bank-full stage (Table 3). Only ponds 2 and 3 are illustrated in the cross-section. The situation of pond 1 is the same as 2 except that its bottom is 1 ft higher. A plan view of the transect is inset in Figure 4.

The hydrology of the ponds is a function of their depth, shape, and relationship to groundwater–possibly also to the nature of their bottom sediments. In both cases (north and south ponds) the ponds are set into a wider trough (Figure 4). This wider, shallower area does not hold water, except possibly for a short time after a flood, and is vegetated with *Phalaris* and riparian shrubs.

Figure 4: x-section

Table 3. Height of flood plain features relative to the channel bottom.

	Height (m)
Channel bottom	0.0
South transect (#1):	
Top of river bank	2.1
Middle of meadow	2.7
High water mark in pond 1	2.4
Gage, Pond 1	1.8
Gage, Pond 2	1.5
North transect (#2):	
Top of river bank	2.0
Bottom of meander scar	1.3
Flood debris	3.0
Middle of meadow	3.4
High water mark in pond 3	2.2
Gage, Pond 3	1.7

Potential habitat

This section of the Palouse River is a single-channel stream; the numerous channel scars that dissect the flood plain are not connected to the river or to each other and probably only flow during over-bank flood events. None of those within the site hold permanent water, most do not contain wetland vegetation, and some appear to never hold water. Their capacity to hold water depends on the texture of underlying sediments. By July 1999, most were dry or nearly dry.

Three other ponds were found that might provide habitat for *Howellia* based on the amount of water and type of vegetation present (Figure 2b). Two of them differ from the occupied ponds in the amount of shade, one being more deeply shaded (C) and another completely open (A). Between pond 3 and the river there is a meander scar that holds a large, relatively deep pond that is easily seen from the road (A). In July it still contained a significant amount of water, but no *Howellia*. In addition to being open, the pond has no *Carex vesicaria*–an indicator species for *Howellia* habitat. Like pond 3, it develops a complete cover of *Eleocharis palustris* after the water draws down.

DISCUSSION

Over the short-term, the viability of *Howellia* populations in the Harvard ponds is related to the dependability of the filling and drying cycle. For the time being we are assuming that inputs to the ponds are from precipitation and shallow groundwater tied to the river. Given the amount of interannual variability in precipitation, a significant relationship to ground-water seems necessary to achieve a dependable level of water in the ponds.

Shapley and Lesica (1997) developed two conceptual models to explain the hydrology of *Howellia* ponds in the Swan River Valley of Montana. Both models assume that ponds are continuous with the water table. One model assumes that input is from shallow ground-water alone, and the other allows for the possible input from regional groundwater flow as well. Anderson (1992) investigated the hydrology of the Swan River Oxbow, one of the few *Howellia* sites occurring in a fluvial environment like that at the Harvard ponds. He found that the oxbow pond was continuous with a shallow groundwater system underlying the flood plain and that water level fluctuations in the pond occurred simultaneously with those of the river. At the Harvard ponds, monitoring pond water depth and concurrent river stage will provide data to either support or refute this relationship.

The other input to consider is flow from overbank flood events. It is not known how often this occurs, but inferences might be made by examining the relationship of river stage at the site to that at the USGS gage. Much of the overbank flow would be carried by channel scars (Malanson 1993), which would then retain water after the river recedes. This process would be accompanied by the deposition of fine sediments on the bottoms of scars, increasing their capacity to retain water.

Since the ponds have no outlet, water loss occurs through evaporation, transpiration by pond vegetation, and possibly downward seepage. An examination of the sediments underlying the ponds may give us a better idea of the importance of water loss through seepage. The depth of the water table is related to river stage, so if pond bottoms are highly permeable, water loss to the groundwater would begin to occur as soon as the river begins to recede. At the same time, the substrate underlying most of the channel scar containing the pond must be more permeable than the pond bottom. Otherwise, in wet years or after overbank floods water would remain in the ponds too long.

Over the long-term these same ponds cannot continue to provide habitat for *Howellia* because processes of sedimentation and plant succession will lead to their eventual filling-in. These processes are being accelerated by the colonization of ponds by *Phalaris arundinacea* and *Acorus calamus*. Since we found only a small amount of marginally suitable habitat, the long-term viability of *Howellia* at the site depends on the development of new habitat. For this reason, the relationship of fluvial processes to pond development is of interest.

Wetland and lentic habitats are created by migration of the river channel and overbank floods. Although the flood plain is marked by numerous depressional features, few contain vegetation indicative of the hydrologic conditions required by *Howellia*. In fact, the evolution of a pond with hydrologic characteristics suitable for *Howellia* appears to be a very rare event. Overbank floods may play a role in the development of new habitat through scouring out and deepening of troughs, creation of meander scrolls, and the deposition of fine sediment in trough bottoms. Because the channel through the site is migrating relatively slowly, new habitat creation will involve a much longer timeframe than in a rapidly changing system. In comparison, Everitt (1968) estimated rates of channel migration of 1000-2000 ft over 100 years for the Little Missouri River. At the same time we cannot rule out the possibility that the stability of the system is responsible in part for the persistence of *Howelli*a at this site, especially as a stable system would be more comparable to glacial pothole sites.

The similarity of the Harvard ponds to those of the Swan Valley is reflected in their vegetation. While the Harvard ponds were formed by entirely different processes than glacial potholes, the vegetation characterizing the ponds is very similar. *Alisma plantago-aquatica*, *Alopecurus aequalis*, *Sparganium emersum*, and *Carex vesicaria* are considered habitat indicator species for *Howellia* (Shelly and Moseley 1988) and occur at all three of the Harvard ponds. Ponds are also partly shaded by deciduous shrubs and trees as at the Montana sites.

Because suitable pools are rare even in this relatively natural portion of flood plain, and their formation is unpredictable, viability of *Howellia* over the long term would seem to require many miles of flood plain. Both the existence and evolution of suitable habitat has been severely limited by the conversion of most of the flood plain to development and agriculture.

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MANY **APPENDICES NOT AVAILABLE ON WEB**

Appendix 1

Maps

Appendix 2

Diagrams of *Howellia* ponds

Appendix 3

Plant species list for the Harvard-Palouse River Floodplain

Appendix 3

Species list for the floodplain portion of the Harvard-Palouse River Flood Plain site

A/E = aquatic/emergent; SI = seasonally inundated; ST = shrub thicket; A = alder; HM = herbaceous meadow; F = forest.

	A/E	SI	ST	A	HM	F
TREES						
Abies grandis				X		X
Alnus incana			X	X		
Betula papyrifera						X
Larix occidentalis						X
Malus pumila			X			
Picea engelmannii						X
Pinus contorta				X		X
Pinus ponderosa					X	X
Populus tremuloides						X
Populus trichocarpa				X		X
Pseudotsuga menziesii					X	X
Salix lasiandra			X			
SHRUBS						
Acer glabrum				X		
Amelanchier alnifolia			X	X		
Cornus sericea		X				
Crataegus douglasii			X	X		X
Holodiscus discolor				X		
Lonicera involucrata			X	X		
Philadelphus lewisii			X			
Physocarpus capitatus			X			
Rhamnus alnifolia		X		X		
Rosa nutkana			X			
Rosa woodsii			X			
Rubus parviflorus			X	X		X
Salix bebbiana		X				
Salix drummondiana		X				
Salix exigua		X				
Salix geyeriana		X				
Salix lutea		X				
Symphoricarpos albus			X	X		X
GRAMINOIDS						
Agropyron intermedium					X	
Agrostis exarata		X				

Agrostis interrupta					X	
Agrostis stolonifera					X	
Alopecurus aequalis	X					
Alopecurus pratensis					X	
Bromus carinatus					X	
Bromus inermis					X	
Bromus japonicus					X	
Carex aperta		X				
Carex arcta		X				
Carex athrostachya		X				
Carex bebbii		X				
Carex deweyana			X	X		
Carex lenticularis		X				
Carex lanuginosa		X				
Carex pachystachya					X	
Carex praticola					X	
Carex retrorsa		X				
Carex stipata		X				
Carex vesicaria	X					
Cinna latifolia				X		
Dactylis glomerata			X	X	X	
Danthonia californica					X	
Echinochloa crusgalli		X				
Eleocharis ovata	X	X				
Eleocharis palustris	X	X				
Elymus glaucus				X		
Festuca arundinacea					X	X
Festuca subulata				X		
Glyceria elata		X				
Glyceria grandis		X				
Glyceria occidentalis	X	X				
Juncus articulatus		X				
Juncus bufonis		X				
Juncus effusus		X				
Juncus ensifolius		X				
Juncus filiformis		X				
Juncus orthophyllus		X				
Juncus tenuis		X				
Luzula campestris					X	
Phalaris arundinacea		X				
Phleum pratense					X	
Poa bulbosa					X	
Poa compressa					X	
Poa palustris			X	X		
Poa pratensis			X	X	X	
Scirpus microcarpus		X				

FORBS AND FERNS						
Aconitum columbianum				X		
Acorus calamus	X					
Achillea millefolium					X	
Actaea rubra			X	X		X
Agastache urticifolia					X	
Alisma plantago-aquatica	X					
Anemone piperi			X			X
Angelica arguta				X		
Anthemis cotula					X	
Arctium minus					X	
Artemisia ludoviciana					X	
Asarum caudatum						X
Aster modestus					X	
Athyrium filix-femina			X	X		
Bidens cernua						
Callitriche sp.	X					
Camassia quamash					X	
Campanula rotundifolia					X	
Centaurea maculosa					X	
Chenopodium sp.		X				
Cicuta douglasii		X				
Circaea alpina						X
Cirsium arvense					X	
Cirsium vulgare					X	
Cryptantha (affinis?)					X	
Cystopteris fragilis			X			
Delphinium nuttallianum				X		
Disporum hookeri				X		X
Elodea canadensis	X					
Epilobium watsonii		X				
Equisetum arvense		X	X	X		
Equisetum hyemale		X	X			
Erigeron speciosus					X	
Gaillardia aristata					X	
Galium aparine			X	X		
Galium boreale					X	
Galium triflorum			X	X		
Geum macrophyllum					X	
Glecoma hederacea			X	X		
Gnaphalium palustre		X				
Gratiola neglecta		X				
Heracleum lanatum			X	X		
Howellia aquatilis	X					
Hypericum perforatum					X	

Lactuca biennis			X		
Lathyrus sp.					X
Lemna minor	X				
Linaria dalmatica		X			
Lupinus leucophyllus					X
Lycopus uniflorus		X			
Madia sp.					X
Mentha arvensis		X			
Mertensia oblongifolia			X	X	
Mimulus moschatus		X			
Monarda fistulosa					X
Montia linearis		X			
Montia siberica			X		
Myosotis scorpioides		X			
Osmorhiza chilensis			X		
Osmorhiza occidentalis				X	
Penstemon confertus					X
Perideridea gairdneri					X
Plagiobothrys tenellus		X			
Plantago lanceolata					X
Plantago major					
Polemonium occidentalis			X		
Polygonum amphibium		X			
Polystichum munitum				X	
Potamogeton epihydrus	X				
Potentilla gracilis					X
Potentilla recta					X
Prunella vulgaris					X
Pteridium aquilinum					X
Ranunculus flabellaris	X				
Ranunculus flammula		X			
Ranunculus orthorhynchus			X	X	
Ranunculus repens		X			
Rorippa nasturtium-aquaticum		X			
Rorippa curvisiliqua		X			
Rudbeckia occidentalis					X
Rumex acetosella					X
Rumex crispus		X			
Rumex occidentalis		X		X	
Rumex salicifolius		X			
Senecio foetidus					X
Sidalcea oregana					X
Silene menziesii		X			
Sium suave	X				
Solanum dulcamara		X	X		
Solidago missouriensis					X

Smilacina stellata			X	X		X
Sparganium emersum	X					
Spergula arvensis		X				
Spiraea betulifolia				X		
Tanacetum vulgare					X	
Thalictrum occidentalis						X
Thermopsis montana					X	
Thlaspi arvense					X	
Tragopogon dubius					X	
Trautvetteria caroliniensis			X			
Trillium ovatum			X			X
Trillium petiolatum			X			
Urtica dioica			X	X		
Utricularia vulgaris	X					
Veratrum californicum			X	X		
Verbascum thapsus					X	
Veronica americana						
Veronica anagallis-aquatica	X					
Veronica scutellata		X				
Veronica serpyllifolia		X				
Vicia americana					X	
Viola adunca					X	
Viola glabella			X	X		X
Viola palustris		X				
NONVASCULAR						
Ricciocarpus natans	X					

Appendix 4

Completed plot forms

Appendix 5

Photos of *Howellia aquatilis* and its habitat

Appendix 6

Canopy cover data for *Crataegus douglasii* and *Alnus incana* communities

Appendix 6

Canopy cover data for *Crataegus douglasii/Heracleum lanatum* (plots 1-3) and *Alnus incana/mesic forb* (plots 4-6) communities of the Harvard-Palouse Flood Plain site. Species are in order of decreasing constancy.

Plot:	1	2	3	4	5	6
Trees and Shrubs:						
Symphoricarpos albus	1	10	1	3	1	1
Crataegus douglasii	60	80	98	-	10	30
Rosa sp.	3	1	1	-	1	1
Physocarpus capitatus	20	1	-	20	30	3
Philadelphus lewisii	-	1	1	1	20	10
Alnus incana	-	3	-	90	30	70
Salix lutea	3	-	-	-	-	3
Amelanchier alnifolia	20	-	-	-	-	-
Rubus parviflorus	-	-	1	-	-	-
Abies grandis (saplings)	-	-	-	1	-	-
Graminoids:						
Carex deweyana	80	50	80	3	3	30
Elymus glaucus	1	1	20	10	3	3
Festuca subulata	1	1	1	1	3	1
Dactylis glomerata	20	20	1	-	1	3
Poa palustris	1	-	-	-	1	1
Phalaris arundinacea	-	-	-	3	3	3
Cinna latifolia	-	-	-	1	-	1
Glyceria grandis	-	1	-	-	-	-
Forbs and Ferns:						
Heracleum lanatum	30	10	30	10	3	3
Urtica dioica	1	3	30	3	20	3
Montia siberica	1	1	3	1	3	3
Glecoma hederacea	10	20	-	10	10	10
Mertensia oblongifolia	1	-	1	1	3	1
Aconitum columbianum	1	-	-	3	3	1
Smilacina stellata	-	-	1	3	10	1
Athyrium filix-femina	-	10	1	3	1	-
Disporum hookeri	-	1	1	1	-	-
Equisetum hyemale	-	-	-	1	1	1
Osmorhiza occidentalis	1	-	-	30	3	1
Cystopteris fragilis	1	-	1	-	1	-
Osmorhiza chilensis	-	1	1	-	-	-
Thalictrum occidentalis	-	-	1	-	3	-
Lactuca biennis		-	1	-	1	-
Solanum dulcamara	-	3	-	-	1	1
Cirsium vulgare	1	1	-	-	-	-
Rumex occidentalis	1	1	-	-	-	-
Equisetum arvense	-	1	1	-	-	-
Geum macrophyllum	-	1	-	-	-	1
Senecio foetidus	1	-	-	-	-	-

Veratrum californicum	1	-	-	-	-	-
Tanasetum vulgare	-	1	-	-	-	-
Arctium minus	-	1	-	-	-	-
Trillium ovatum	-	-	1	-	-	-
Viola glabella	-	-	-	3	-	-
Spiraea betulifolia	-	-	-	1	-	-

Cont.

Appendix 6 continued

Polystichum munitum	-	-	-	-	1	-
Prunella vulgaris	-	-	-	-	1	-
Pteridium aquilinum	-	-	-	-	3	-
Anemone piperi	-	-	-	-	-	1
Unknown forb	1	-	-	-	-	-
Unknown aster-like	-	1	-	-	-	-