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Native freshwater mussel surveys of the North and South Platte river drainages, Wyoming.

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Abstract

North America hosts the world's highest diversity of freshwater mussels where more than 70% of the species have an imperiled conservation status. Wyoming has seven known native mussel species within two families: *Unionidae* and *Margaritiferidae*. Prior to 2011, little was known about the status and distribution of native mussels in Wyoming. The southeastern drainages of Wyoming host two species of native freshwater mussels: cylindrical papershell (CPM, *Unionidae:Anodontoides ferussacianus*) and plain pocketbook (PPM, *Unionidae:Lampsilis cardium*). A total of 37 sites in the North and South Platte river drainages in Wyoming were surveyed for native mussels from 2011-2014. Timed surveys were performed to look for native mussels, and live mussels were found at five sites (n=17 CPM; n=0 PPM). Live and shell forms of CPM and only shell PPM were found during our surveys. Total shell length (TL, mm) was recorded for live mussels. Empty shells of preferred specimens (both halves present, unweathered, pearlescent nacre, and periostracum intact) were added to the Wyoming Game and Fish Department's collection at the University of Colorado Museum of Natural History. Stream channel parameters such as bankfull depth (cm), bankfull width (m), wetted width (m), and substrate were measured. Mussel presence-absence was compared to habitat parameters using binary logistic regressions and no significant ($p>0.05$) relationships were found. Many factors limit the presence of native freshwater mussels including droughts, floods, substrate, and availability of host fish. Based on the findings in this report, ranks of NSS2 for CPM and NSS1 for PPM are recommended.

Introduction

North America hosts the world's highest diversity of freshwater mussels (over 300 species) and more than 70% of the species in North America are imperiled (Williams et al. 1993). In the Midwestern United States, half of the freshwater mussel species are listed as threatened or endangered (Cummings and Mayer 1992). Unregulated exploitation, loss of obligate host fishes, habitat degradation, and lack of management during the last century took a considerable toll on mussel populations (Bogan 1993, Watters 2000). The headwater nature of Wyoming drainages limits suitable habitat (low gradient streams with a mixture of sand and gravel substrate) and increases the risk of native mussel extirpation in the state. Development of water diversions, changes in habitat quality and land use, and host fish availability have all impacted Wyoming's native mussels over the last century and a half. Wyoming has seven known native mussel species within the families *Unionidae* and *Margaritiferidae* (Cvancara 2005). The North and South Platte river drainages of Wyoming host two species of native freshwater mussels: cylindrical papershell (CPM, *Unionidae:Anodontoides ferussacianus*) and plain pocketbook (PPM, *Unionidae:Lampsilis cardium*). The conservation status of these species varies widely throughout their ranges (Table 1). Prior to 2011, little was known about native mussels in Wyoming. The few studies carried out were limited in scope and produced sparse information on mussels (Henderson 1924, Hoke 1979, Beetle 1989, Hovingh 2004; Figure 1; Appendix A).

TABLE 1. Conservation status ranks for CPM and PPM at various scales (NatureServe 2014). The ranking key is as follows: (G) global, (N) national, and (S) statewide; (SX) possibly extirpated in that state, (NR) unranked and/or not assessed, (U) unrankable, and (Q) questionable taxonomy that may reduce conservation priority; (1) critically imperiled, (2) imperiled, (3) vulnerable, (4) apparently secure, and (5) secure. Instances with multiple ranks (G#G#, N#N# or S#S#) indicate a range of ranks due to uncertainty as to the exact rank. Statuses with a ? (S#?) denote an inexact numeric ranking.

United States		
Rank	CPM by State	PPM by State
S1	MO	LA, SD
S1?	KS	
S1S2	VT	
S2	CO, IA, WV	NE, WV
S2S3	PA	
S3	WY	IA, KS, WY
S3S4	WI	MS
S4	IL, NY, SD	AR, NY, OK, PA, WI
S4?	OK	
S4S5	KY	KY, MO, TN
S5	IN, OH	IN, OH
SNR	MI, MN, NE, ND	IL, MI, MN, ND
SU	AR	
SX	TN	
Canada		
Rank	CPM by Province	PPM Province
S3	Quebec	
S3S4		Quebec
S4	Manitoba, Ontario	
SNR	Alberta	Manitoba, Ontario
SU	Saskatchewan	Saskatchewan
Global, National, & Other Ranking		
Scale	CPM-Rank	PPM-Rank
Global Status	G5	G5
United States	N5	N5
Canada	N5	N5
IUCN Red List Category		Not Threatened
AFS Status	Currently Stable	Special Concern

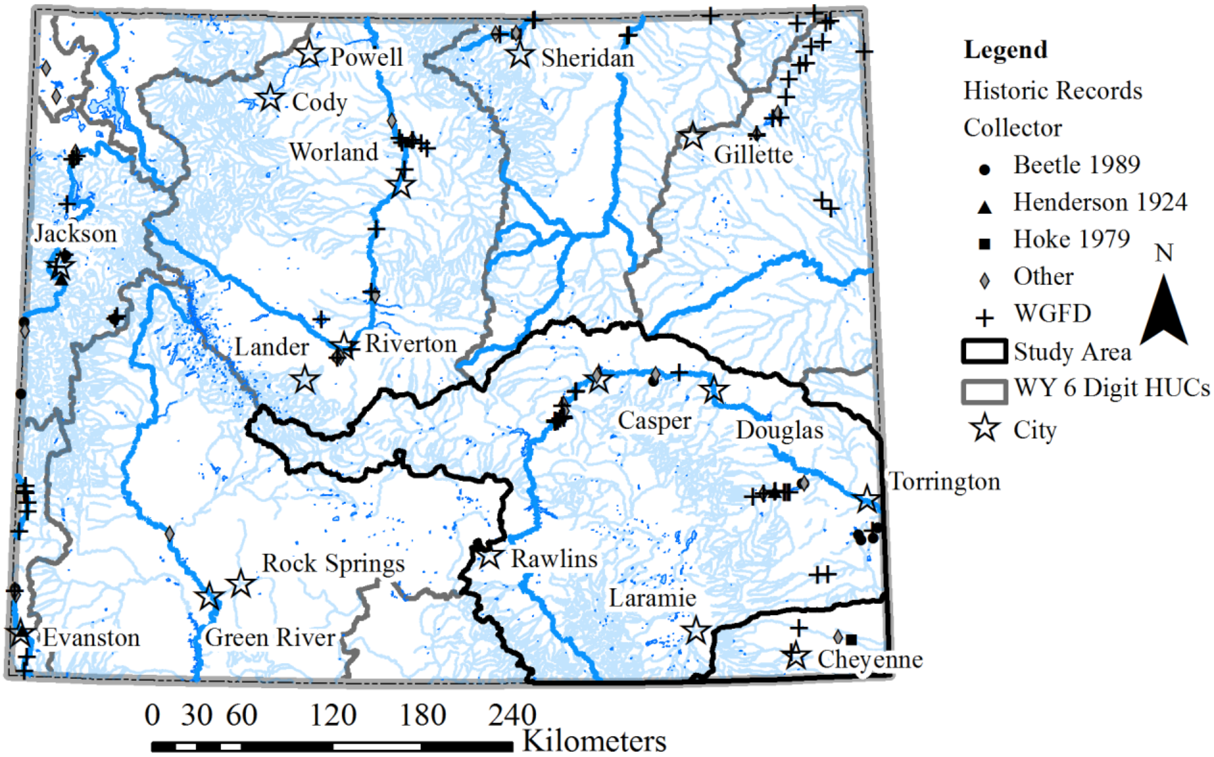

FIGURE 1. Map of Wyoming showing mussel observations from various studies (Beetle 1989, Henderson 1924, Hoke 1979) and incidental observations from WGFD personnel and various other sources.

During the 2011-2014 field seasons, much knowledge was gained about native mussels in southeastern Wyoming. Incidental observations from field personnel in the Laramie and Casper Fisheries Management regions were critical in determining potential survey locations. Many incidental records were acquired after 2000, due to efforts and encouragement by Gordon P. Edwards, Jr. and Roy Whaley.

Native mussels co-evolved with their fish hosts, and in the case of the PPM, a salamander, which increases the chance of upstream dispersal. Native mussel reproduction includes an encysted larval stage (glochidia) attached to a host fish's gills and fins. These fish can travel extensively within rivers and among watersheds, and assist with dispersal of mussels. The CPM can use a multitude of hosts in Wyoming, including White Sucker, Mottled Sculpin, Iowa Darter, Bluegill, Common Shiner, Largemouth Bass, Fathead Minnow, and Black Crappie (Watters et al. 2009). The PPM mostly uses centrarchids, but has many potential hosts in Wyoming, such as Tiger Salamander, Pumpkinseed, Green Sunfish, Bluegill, Largemouth and Smallmouth Bass, Black and White Crappie, Yellow Perch, Sauger, and Walleye (Watters et al. 2009). Sauger and Tiger Salamander are the only hosts native to Wyoming, but there may also be undocumented hosts native to Wyoming that PPM can use.

The CPM is a relatively short-lived mussel species, rarely exceeding seven years of age, with a maximum length of 100 mm (3.94 in; Watters et al. 2009). Its native range includes the Great Lakes drainages, upper Mississippi River (Missouri, Ohio, and upper Cumberland rivers, but not the Tennessee River), and east to New York and Pennsylvania in the United States (Watters et al. 2009). In Canada, its native range includes the James and Hudson Bay drainages (Watters et al. 2009). The CPM is generally a headwaters species and can tolerate intermittent streams (Watters et al. 2009). It can live in various substrate types from the crevices of bedrock to packed cobble to fine silts, mud, and clay (Watters et al. 2009).

The PPM grows quickly for three to four years before reaching sexual maturity (Watters et al. 2009). An individual that is 90 mm (3.54 in) can be from 5-15 years of age and individuals rarely exceed 30 years of age (Watters et al. 2009). The PPM is Wyoming's largest native freshwater mussel; their maximum shell length is around 140 mm to 150 mm (5.51 in to 5.90 in; Parmalee and Bogan 1998). Its native range includes Great Lakes drainages and the Red River of the North system. In the Mississippi River systems, it extends south to northern Louisiana; west to Missouri, Arkansas, and Wyoming; and east to Pennsylvania (Watters et al. 2009). The PPM may be extirpated in Wyoming. The PPM tolerates a wide assortment of water flows and substrate types (Watters et al 2009). It typically occurs in moderate to strong current with a substrate of coarse gravel and sand, but also thrives in stable substrate rich in mud and silt (Parmalee and Bogan 1998). It can be found in small to large streams, lakes, and ponds (Watters et al. 2009; Parmalee and Bogan 1998).

Wyoming native Species of Greatest Conservation Need (SGCN) are those with a native species status (NSS) rank of U or 1-4 (Table 2). Both CPM and PPM were ranked NSSU in the 2010 State Wildlife Action Plan (SWAP) due to the lack of information on their distribution and abundance at that time (WGFD 2010). Recommendations from this report will be used to make a more informed decision on the NSS of these species for the 2017 SWAP revision.

TABLE 2. Native Species Status (NSS) rankings and definitions for Species of Greatest Conservation Need (SGCN) (NSS1-NSS5; WGFD 2010).

NSS Rank	Definition
U	Distribution and general abundance is unknown.
1 (Aa)	Population size or distribution is restricted or declining and extirpation is possible. Limiting factors are severe and continue to increase in severity.
2 (Ab)	Population size or distribution is restricted or declining and extirpation is possible. Limiting factors are severe and not increasing significantly.
2 (Ba)	Population size or distribution is restricted or declining but extirpation is not imminent. Limiting factors are severe and continue to increase in severity.
3 (Bb)	Population size or distribution is restricted or declining but extirpation is not imminent. Limiting factors are severe and not increasing significantly.
4 (Bc)	Population size or distribution is restricted or declining but extirpation is not imminent. Limiting factors are moderate and appear likely to increase in severity.
4 (Cb)	Population size and distribution is stable and the species is widely distributed. Limiting factors are severe and not increasing significantly.
5 (Cc)	Population size and distribution is stable and the species is widely distributed. Limiting factors are moderate and appear likely to increase in severity.

The objectives of this study were to (1) identify species distributions, habitat associations, and core populations of native mussels in the North and South Platte river drainages of southeastern Wyoming, initially focusing on top aquatic priority areas listed in the Department's Strategic Habitat Plan; (2) propose Native Species Status rankings, identify potential limiting factors, and suggest potential management actions for native mussels in Wyoming; and (3) complete a comprehensive collection of native mussel voucher specimens at the University of Colorado Museum of Natural History.

Study Area

The North and South Platte rivers, major drainages east of the continental divide in Wyoming, were studied (Figure 2). We sampled 31 sites in the North Platte River drainage and six sites in the South Platte River drainage. Streams sampled in the North Platte River drainage were grouped for ease of display into three units: Horse Creek (near Torrington, WY), Laramie River, and North Platte River (main stem and smaller tributaries; Figure 2). In the Horse Creek drainage, we sampled the main stem Horse Creek, Bear Creek, and Fox Creek. In the Laramie River drainage, we focused on the main stem Laramie River above and below Grayrocks Reservoir and Chugwater Creek. In the North Platte River unit, we surveyed the main stem North Platte River, Rawhide Creek (near Lingle, WY), Wagon Hound Creek (near Douglas, WY), Boxelder Creek (near Glenrock, WY), Deer Creek (near Glenrock, WY), Horse Creek (near Pathfinder Reservoir), and the Sweetwater River (near Independence Rock). Our South Platte River drainage sites were in Lodgepole Creek and Crow Creek.

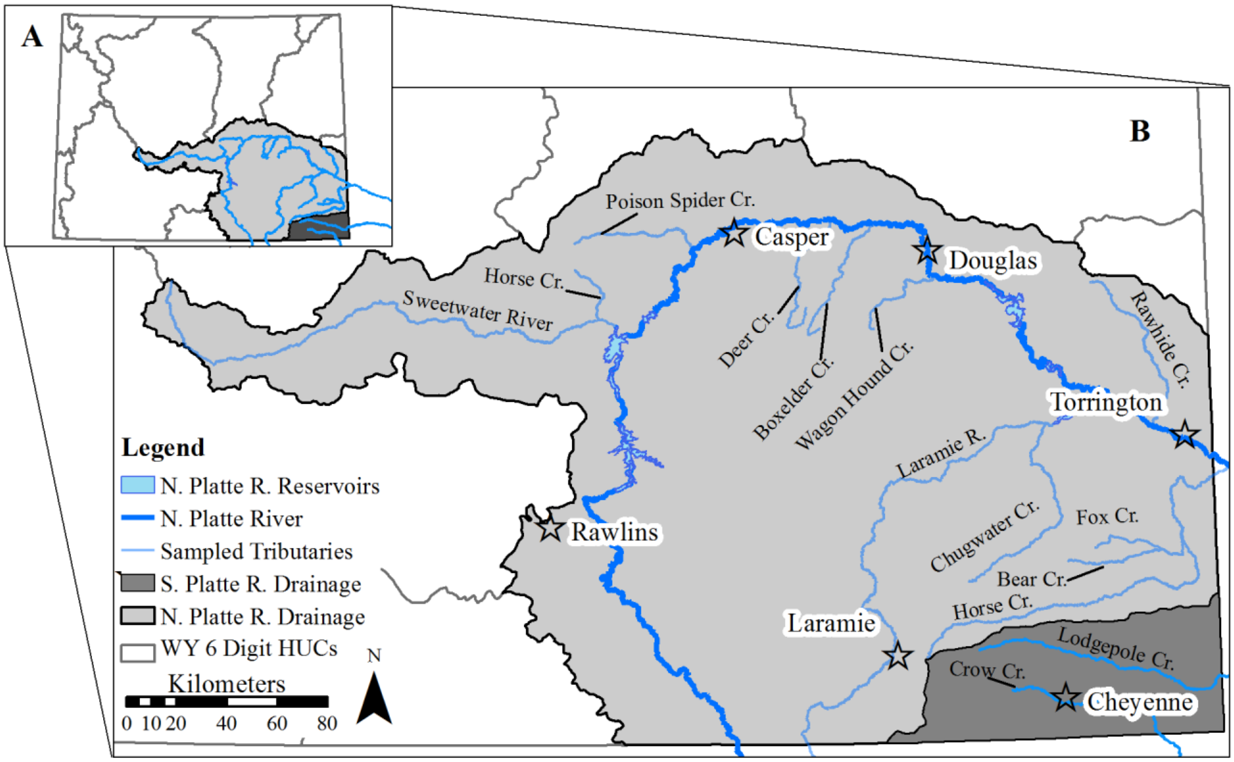

FIGURE 2. (A) Map of the study area in Wyoming. (B) Map of the North Platte River and South Platte River drainages in Wyoming with sampled tributaries included.

Methods

Site Selection

We selected sampling sites with perennial flow on public land or private land where access was allowed. Surveys are best performed at low flows in the summer and autumn after the runoff has occurred. Many of our sites were based on historical records, incidental reports from fisheries biologists, and recommendations from regional fisheries biologists. We then focused our sampling efforts on portions of streams where major habitat changes occur (i.e., diversions, dams, confluence of major perennial tributaries). We attempted to sample a site upstream and downstream of each major habitat change, if possible and attempted to sample major tributaries within each drainage.

Surveying for Native Mussels

Once a site was chosen, we determined the best sampling method for that site. We began by walking the banks looking for hazards in and out of the water and evidence of shells along the banks. Native mussel shells are often deposited on the banks by high flows and/or predators (e.g., muskrats or raccoons; Grabarkiewicz and Davis 2008). Deposited shells were collected as evidence that the species inhabited that section of stream. Based on our observation of the site (i.e., water clarity, depth, etc.), we used the most appropriate sampling technique: snorkeling, glass bottomed viewbuckets, and/or polarized sunglasses. Each method was performed as a timed search, meaning that we recorded the total time sampled and the number of surveyors to calculate the overall person-hours and catch per unit effort (CPUE, number of live mussels per person-hour).

Wetted width was the first variable measured. The average wetted width was multiplied by 40 and rounded up to the nearest 50 m (164 ft) to determine the site length, up to 600 m (1969 ft). Our protocol was based on the U.S. EPA Environmental Monitoring and Assessment Program (Lazorchak et al. 2006). Surveys began at the downstream end of the site to reduce turbidity issues. Substrates were not excavated to find buried mussels, giving a bias to less cryptic and larger, and thus older, individuals and species (Hornbach and Deneka 1996, Metcalfe-Smith et al. 2000, Obermeyer 1998). We measured the total length (TL, mm) of live mussels observed at each site. Measuring live mussels' TL gave a relative population age structure. If there was a large diversity of sizes, especially with small individuals present, it confirmed that recruitment was occurring as TL increases with age. After live mussels were measured and photographed, they were returned to their approximate original locations and placed in the substrate in the correct orientation (anterior portion of the shell in the substrate). We collected empty shells for our voucher collection at the University of Colorado Museum of Natural History.

Habitat Measurements

After we surveyed for mussels, streams were measured for basic habitat parameters. The site was divided into 11 equispaced transects. We then measured wetted width (m), bankfull width (m), and approximate bankfull depth (cm). Bankfull depth was approximated by locating the stream elevation at the greenline (first line of perennial vegetation), suspending the measuring tape across the stream at the greenline, and measuring the vertical distance downward to the bottom of the wetted-channel at five positions across the stream (left bank, left-center, center, right-center, and right bank; left is to the surveyor's left as he faces downstream). Bankfull width and bankfull depth were used in our analysis because we assumed these measurements to be the maximum hydrologic pressure a site would regularly experience (Gangloff and Feminella 2006). Substrate was also categorized at each position where bankfull depth was measured. Substrate was categorized as fines (silt, clay, muck, not gritty), sand (< 2 mm, gritty to ladybug size), fine gravel (2-16 mm, ladybug to marble size), coarse gravel (16-64 mm, marble to tennis ball size), cobble (64-250 mm, tennis ball to basketball), boulder (250-4,000 mm, greater than basketball), hardpan, bedrock (> 4,000 mm, larger than car), wood, and other (Lazorchak et al. 2006). Between transects, we identified the dominant habitat type as pool, riffle, or run. We also recorded basic site information, including location (UTM, NAD27) at upstream and downstream extent of each site (downstream was used as the UTM for the site), elevation, property owner, nearest town, county, date, time start/stop, site name, site code, river, drainage, management region, surveyors, and data recorder.

Species-Habitat Associations

Binary logistic regressions were used to assess the relationship between habitat and the occurrence of live CPM in the North and South Platte river drainages (R 3.0.2, R Commander; R Core Team 2013, Fox 2005; Appendix B). Only CPM were analyzed because it was the only live native mussel species found in the study area. Pearson correlation analyses were first conducted to identify redundant habitat variables, which were removed before logistic regressions were analyzed.

Drainage area was calculated using mosaiced 10 m (32.8 ft) resolution National Elevation Dataset (NED) files to create 10 m (32.8 ft) contour lines in ArcMap 10.1 (ESRI). The closest contour line to each site was used to split the HUC12 polygon that each site was located in. The drainage area was then calculated for the split polygon. The area of the split polygon was added to the additional HUC12 polygons upstream of the split polygon to get the total drainage area (km^2) upstream of each site.

Sites NPR.07, NPR.08, and NPR.09 were shorter in length (<40 times the wetted width) due to high flows and turbidity, but the area surveyed was included in the statistical analysis. Site NPR.12 was not included in the statistical analysis because no habitat data were measured.

Results

We sampled 37 sites across the two drainages, yielding 17 live CPM from five sites: two sites in the Horse Creek drainage and three sites in the Laramie River drainage (Tables 3 & 4, Figure 3). Two sites in the Horse Creek drainage and five sites in the Laramie River drainage had shell-only evidence of CPM. Most of the shells had their periostracum and hinge intact and several still had tissue. No live PPM were found, but relic shells were found at eight sites in the Laramie River and three sites in the North Platte River drainage. None of the PPM shells had intact tissue, and their periostracums were mostly worn off indicating they had been dead for well over a year. The 2013 field season ended earlier than planned because of precipitation that resulted in high discharges and turbidity at several sites.

TABLE 3. Survey locations and dates for 37 sites in southeastern Wyoming surveyed from 2011 to 2014. The site code, HUC5 code, and WGFD WaterID (WaterID) are listed for each site. All sites are in UTM Zone 13 (NAD27). Landownership category (Owner) is also included.

Drainage/ Water body	Site	HUC5	WaterID	Date	UTM Easting	UTM Northing	Owner
North Platte River Drainage							
Horse Creek Drainage							
Horse Cr.	HOR.01	1018001206	LE8N1035GN	06/12/2013	571926	4636278	Private
Horse Cr.	HOR.02	1018001206	LE8N1035GN	06/12/2013	570025	4636558	Private
Fox Cr.	HOR.03	1018001205	LE8N1050GN	06/11/2013	548881	4615930	Private
Bear Cr.	HOR.04	1018001203	LE8N1045GN	06/13/2013	546197	4609571	Private
Bear Cr.	HOR.05	1018001203	LE8N1045GN	06/13/2013	543460	4609238	Private
Laramie River Drainage							
Laramie R.	LLE.01	1018001105	LE8N1200GN	Multiple Dates*	538878	4671841	Public
Laramie R.	LLE.02	1018001105	LE8N1200GN	07/23/2013	529444	4670857	Private
Laramie R.	LLE.03	1018001105	LE8N1200PE	07/09/2013	526964	4671449	Private
Laramie R.	LLE.04	1018001105	LE8N1200PE	07/10/2013	525886	4668793	Private
Laramie R.	LLE.05	1018001105	LE8N1204PE	05/30/2013	516071	4662965	Private
Laramie R.	LLE.06	1018001105	LE8N1204PE	09/04/2013	513860	4662624	Private
Laramie R.	LLE.07	1018001105	LE8N1204PE	07/24/2013	512155	4663261	Private
Laramie R.	LLE.08	1018001105	LE8N1204PE	09/06/2013	510503	4663524	Private
Chugwater Cr.	LLE.09	1018001109	LE8N1225PE	07/25/2013	512687	4663203	Private
Chugwater Cr.	LLE.10	1018001109	LE8N1225PE	09/04/2013	511850	4662095	Private
Chugwater Cr.	LLE.11	1018001108	LE8N1225PE	06/18/2013	517282	4627570	Public
Chugwater Cr.	LLE.12	1018001108	LE8N1225PE	06/18/2013	517654	4625707	Public
North Platte River & Smaller Tributaries							
Rawhide Creek	NPR.01	1018000903	CR8N1145GN	05/31/2013	556182	4660751	Public
Wagon Hound Cr.	NPR.02	1018000802	CR8N3950CE	07/11/2011	470256	4722824	Public
Boxelder Cr.	NPR.03	1018000711	CR8N3390CE	07/24/2014	445903	4744035	Private
Boxelder Cr.	NPR.04	1018000711	CR8N3415CE	07/18/2013	431950	4722833	Public
Deer Creek	NPR.05	1018000710	CR8N4660CE	Multiple Dates†	428634	4743103	Public
North Platte R.	NPR.06	1018000709	CR8N1012CE	09/10/2013	425793	4745798	Public
North Platte R.	NPR.07	1018000709	CR8N1012CE	09/10/2013	420454	4744723	Public
North Platte R.	NPR.08	1018000703	CR8N1012CE	09/12/2013	415009	4746739	Public
North Platte R.	NPR.09	1018000703	CR8N1012NA	09/09/2013	403738	4745516	Public
Poison Spider Cr.	NPR.10	1018000704	CR8N6130NA	09/01/2011	372184	4741938	Public
North Platte R.	NPR.11	1018000701	CR8N1014NA	10/20/2011	367239	4725877	Public
North Platte R.	NPR.12	1018000701	CR8N1014NA	10/07/2014	368055	4721189	Public
Horse Cr.	NPR.13	1018000611	CR8N6350NA	06/29/2011	338791	4718241	Public
Sweetwater R.	NPR.14	1018000609	CR8N4390NA	07/17/2013	324371	4706298	Public

*Data collected 08/12/2013-08/14/2013 and 10/08/2014-10/09/2014.
†Data collected 06/28/2011, 08/30/2013, and 06/17/2014.

TABLE 3. *Continued.*

Drainage/ Water body	Site	HUC5	WaterID	Date	UTM Easting	UTM Northing	Owner
South Platte River Drainage							
Crow Creek Drainage							
Crow Cr.	LOC.01	1019000902	LE8O8440LE	07/09/2014	526469	4552769	Private
Crow Cr.	LOC.02	1019000901	LE8O8440LE	07/08/2014	524285	4552045	Private
Crow Cr.	LOC.03	1019000901	LE8O8440LE	07/09/2014	514574	4552876	Public
Lodgepole Creek Drainage							
Lodgepole Cr.	ULP.01	1019001502	LE8O8080LE	07/16/2014	549867	4563987	Private
Lodgepole Cr.	ULP.02	1019001501	LE8O8080LE	07/16/2014	522812	4570977	Private
Lodgepole Cr.	ULP.03	1019001501	LE8O8120LE	07/15/2014	512014	4574710	Private

TABLE 4. Survey results and techniques listed by site in the North Platte River and South Platte River drainages. Length is site length in meters (m). Techniques are visual (V), view bucket (B), and snorkel (S). The number (*n*) of live occurrences is listed (Live) and whether there was shell evidence present (Dead). Only CPM was found live; all PPM occurrences were in shell form only. Total length (TL) was measured in millimeters (mm). Catch per unit effort (CPUE) is the number of live mussels found per person-hour.

Drainage/				Occurrences		Live (TL)		
Site	Length	Technique	Species	Live	Dead	Min	Max	CPUE
North Platte River Drainage								
Horse Creek Drainage								
HOR.01	600	B/V	CPM	2	Y	86	93	1.000
HOR.02	250	B/V	CPM		Y			
HOR.03	200	B/V	CPM		Y			
HOR.04	200	B/V	CPM	1	Y	53		0.461
HOR.05	150	B/V						
Laramie River Drainage								
LLE.01	4100	S/B/V	CPM+PPM	12	Y	87	54	1.596
LLE.02	600	B/V	CPM+PPM		Y			
LLE.03	600	B/V	CPM+PPM		Y			
LLE.04	600	B/V	PPM		Y			
LLE.05	600	B/V	CPM+PPM		Y			
LLE.06	600	B/V	CPM+PPM	1	Y	76		0.444
LLE.07	600	B/V	CPM+PPM		Y			
LLE.08	600	B/V	CPM+PPM	1	Y	68		0.667
LLE.09	300	B/V	CPM		Y			
LLE.10	200	B/V						
LLE.11	200	B/V						
LLE.12	200	B/V						
North Platte River & Smaller Tributaries								
NPR.01	200	B/V						
NPR.02	200	B/V						
NPR.03	600	B/V						
NPR.04	350	B/V						
NPR.05	600	B/V	PPM		Y			
NPR.06	600	B/V						
NPR.07‡	480	B/V						
NPR.08‡	240	B/V						
NPR.09‡	240	B/V						
NPR.10	250	B/V						
NPR.11	600	B/S	PPM		Y			
NPR.12*	300	B/V	PPM		Y			
NPR.13	100	B/V						
NPR.14	600	B/V						

‡Sites were <40 times the wetted width because high flows and turbidity compromised researcher's safety.
*No habitat data were collected; a targeted mussel survey was performed and resulted in a PPM shell.

TABLE 4. *Continued.*

Drainage/ Site	Length	Technique	Species	Occurrences Live	Occurrences Dead	Live (TL) Min	Live (TL) Max	CPUE
South Platte River Drainage								
Crow Creek Drainage								
LOC.01	250	B/V						
LOC.02	250	B/V						
LOC.03	200	B/V						
Lodgepole Creek Drainage								
ULP.01	150	B/V						
ULP.02	250	B/V						
ULP.03	200	B/V						

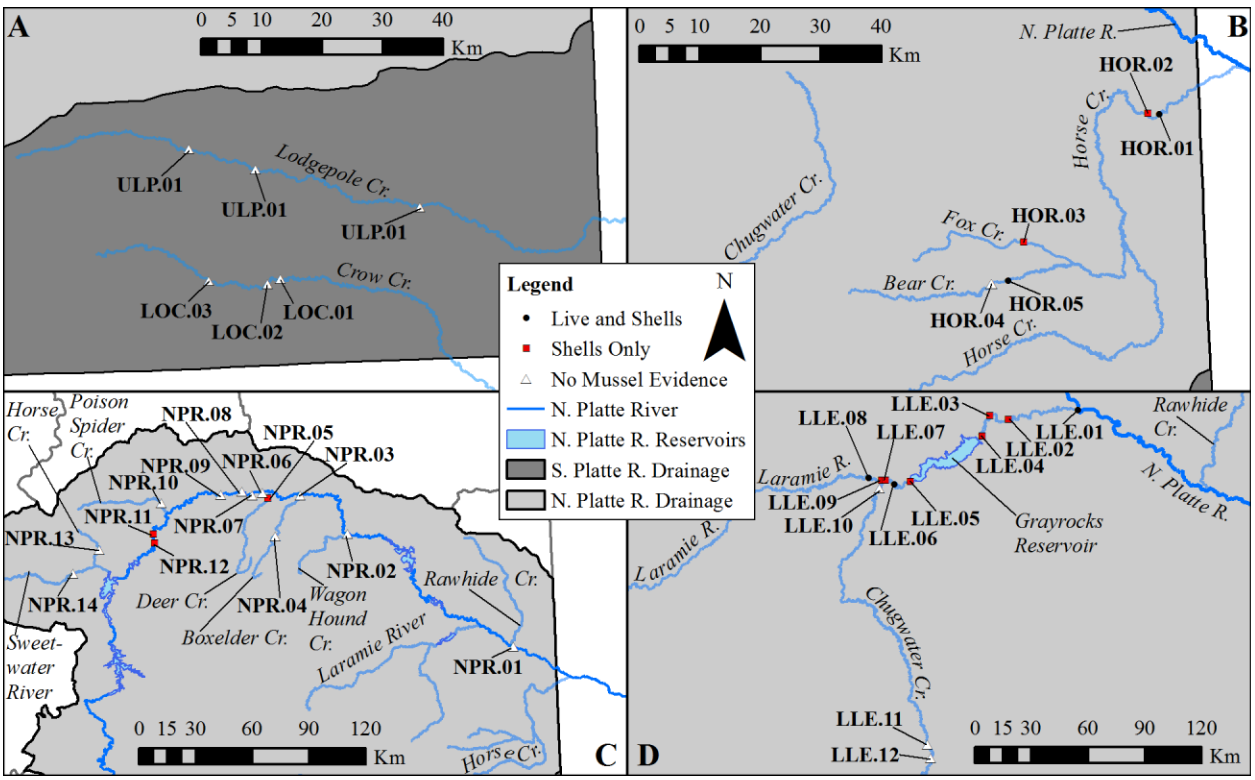

FIGURE 3. (A) South Platte River drainage in Wyoming showing survey sites and results. (B) Horse Creek drainage in southeastern Wyoming showing survey sites and results. (C) North Platte River and tributaries in Wyoming showing survey sites and results. (D) Laramie River drainage in Wyoming showing survey sites and results. All live mussels were CPM.

South Platte River Drainage (HUC 1019)

No live or shell evidence of native mussels was found during six systematic surveys (LOC.01-LOC.03 and ULP.01-ULP.03; Figure 3). Shells of CPM have been found in both Lodgepole Creek (HUC 10190015) and Crow Creek (HUC 10190009) drainages as recently as 2014, and one live CPM was found in Lodgepole Creek in 1978 (Appendix A).

North Platte River Drainage (HUC 1018)

We found live CPM (*n*=17) in the North Platte River drainage (Table 4). No live PPM were found in this area during extensive systematic surveys. Shells of PPM were found from as early as 1917 until 2014 (Appendix A). The most recent live PPM observation (2008) was found in the Laramie River near the confluence with Chugwater Creek.

Horse Creek Drainage (HUC 10180012)

Three live CPM were found in the Horse Creek drainage at HOR.01 (*n*=2) and HOR.04 (*n*=1; Table 4). Shells of CPM were found at all sites except HOR.05. Plain pocketbook has not been recorded in the Horse Creek drainage.

Laramie River Drainage (HUC 10180011)

Live CPM (*n*=14) were found at three sites in the Laramie River drainage (Table 4): LLE.01 (*n*=12), LLE.06 (*n*=1), and LLE.08 (*n*=1). No live PPM were found during systematic surveys in the Laramie River drainage, though shells of PPM were found at eight of 12 sites (LLE.01-LLE.08).

North Platte River and Smaller Tributaries (HUCs 10180006, 10180007, 10180008, and 10180009)

No live native mussels were found in the North Platter River or the smaller tributaries sampled. Shells of PPM were found at three sites during our systematic surveys (NPR.05, NPR.11, and NPR.12; Table 4). Shells of PPM have been found in the North Platte River from Alcova Dam downstream to the Wyoming-Nebraska border (Appendix A).

Species-Habitat Associations

Dominant substrate was the only variable not correlated ($p \geq 0.05$) with any other variable (mean bankfull width, mean bankfull depth, Stahler's stream order, or drainage area upstream of each site; Appendix C). Uncorrelated variables were analyzed using binary logistic regressions to predict the presence of live CPM. No significant ($p \geq 0.05$) predictors or models of presence-absence of CPM were found using uncorrelated habitat data (Table 5). Further analyses were unnecessary because of a lack of statistically significant results.

TABLE 5. Results from binary logistic regressions for survey sites to predict the presence of CPM using habitat measurements. Models included dominant substrate (DS), mean bankfull width (W; m), mean bankfull depth (D; cm), Stahler's stream order (O), and drainage area (A; km^2).

Model	SE	*p*-value
DS+W	2.00	0.646
DS+D	1.93	0.403
DS+O	2.84	0.276
DS+A	1.88	0.333

Discussion

During the 2011-2014 field seasons, much knowledge was gained about native mussels in southeastern Wyoming. Systematic survey methods were developed that can be used in the future for qualitative native mussel surveys. Live CPM were found in the Horse Creek and Laramie River drainages, but live PPM were not found in any of the drainages surveyed. Shells of CPM found in Fox Creek (HOR.03) were unexpected, because this site is very high in the Horse Creek Drainage and CPM had not been documented in this tributary.

Habitat and Water Quality

Many factors limit the presence and abundance of native freshwater mussels. Viable populations may be extirpated by stochastic events (e.g., floods, droughts, etc.). These sites may never be recolonized naturally despite a return to previous habitat conditions. Wyoming is susceptible to detrimental anthropogenic influences, such as human enhanced rapid and drastic fluvial changes, can have severe impacts on mussel abundance. Loss or decline of host fish populations can also have major effects on the viability of native mussel populations (Haag and Warren 2008, Hastie et al. 2001, Nicklin and Balas 2007).

Prolonged drought and cessation of flow can cause major declines in native mussel communities, especially in smaller streams (Haag and Warren 2008). Diversions for irrigation and municipal drinking water can cause desiccation of portions of streams that host fish could use to transport glochidia. The secondary effects of drought (i.e., lower dissolved oxygen, warmer water temperatures, etc.) likely cause of declines in native mussel communities, can homogenize native mussel communities, and greatly impact already rare native mussels (Haag and Warren 2008), such as PPM in Wyoming. When barriers to host fish movement exist, native mussels may never recolonize an area affected by drought (Haag and Warren 2008). In these instances, if fish passage structures around barriers are not available, translocation of native mussels by humans may be the only way to reestablish a population.

Hydrological conditions and stream geomorphology can affect presence of native mussels on both a reach and drainage scale (Gangloff and Feminella 2006). Little work has been done to predict mussel presence-absence on a large-scale, but many studies have focused on microhabitats. Native freshwater mussels use unique microhabitats that are both species-specific and population-specific (Nicklin and Balas 2007). Due to these microhabitats, detecting a relationship between habitat and presence of native mussels proved to be impossible at the scale we measured. Future surveys should include quadrat sampling with a substrate component to evaluate microhabitat correlations to the presence of native mussels.

Though both CPM and PPM have habitat preferences, the scale at which we took our habitat variables (equispaced, not where individual mussels were found), did not allow us to detect a relationship between substrate type and the presence of mussels. An individual mussel's location in a mussel bed is not simply influenced by a particular substrate type, but rather a combination of stream velocity and the stream's ability to sort the substrate, water depth, the number of types of substrate available, and recent alterations of fluvial dynamics (Huehner 1987). With limited time available for native mussel surveys, these parameters could not be measured more than once.

Presence of native mussel communities may be better predicted by host fish communities and reproductive ability of the native mussels than by microhabitat variations at a site (Haag and Warren 1998). Haag and Warren (1998) found that mussel assemblages were similar among sites near mouths of rivers, while the headwater assemblages varied widely. Communities with host fish specific mussels are often dependent on host fish densities and stability in the number of host fish available (Haag and Warren 1998). However, sites with unstable host fish assemblages, such as headwaters, tend to have mussels that can use multiple fish species to disperse their offspring (Haag and Warren 1998). Barriers to host fish (i.e., dams, diversions, waterfalls, etc.) prevent upstream colonization or recolonization of native mussels within a drainage. The age structure of the host fish community also plays an important role. Young (age 0+) fish are the most important age group for mussel populations, because older fish may be less susceptible to glochidia infection, due to potential immunity developed from previous exposures (Hastie and Young 2001). Therefore, annual fish recruitment likely has a strong influence on reproductive success of many mussel species. Both CPM and PPM can use many host species (Watters et al. 2009). Their plasticity in host fishes should allow for higher recruitment in years when conditions are favorable for successful fish recruitment.

South Platte River Drainage

There are historic records of CPM in Lodgepole Creek and Crow Creek, but none were found during systematic surveys from 2011-2014. The sample sites may have been unfavorable habitat or previously intermittent, thus no mussel evidence was found. Lodgepole Creek goes dry near the Wyoming-Nebraska border and Crow Creek goes dry near the Wyoming-Colorado border due to anthropogenic causes such as irrigation diversions and municipal impoundments. The intermittent portions of these streams do not support native mussels, however more perennial portions may host live CPM, but more surveys are needed.

North Platte River Drainage

Horse Creek Drainage

Only CPM were found in the Horse Creek drainage. Presence of large numbers of recently dead (still had tissue in them) CPM shells was common. At many sites, evidence of predation by raccoons or muskrats was prominent (Figure 4; Grabarkiewicz and Davis 2008). During our survey season, many portions of Horse Creek run dry or subsurface, which limits suitable habitat for CPM and reduces connectivity between populations. Though few CPM were found, much more effort should be expended on this stream to find more populations.

FIGURE 4. Punctures and scratches inflicted by a predator on a CPM shell from site HOR.01in Horse Creek near Table Mountain Wildlife Habitat Management Area. Photo by Philip Mathias, WGFD.

Laramie River Drainage

Since native mussel surveys began in Wyoming, only two live PPM have been found in the State. One live PPM was found during historical surveys by Henderson (1917) and during fish surveys by WGFD personnel in 2008. Both were located in the Laramie River, and the most recent observation was located upstream of Grayrocks Reservoir and downstream of the Chugwater Creek confluence. A 2013 survey near this point produced no live PPM. The large number of PPM and CPM shells found throughout the Laramie River suggests that the species were recently common. Insight from landowners on the Laramie River may help explain what caused low numbers of CPM and possible extirpation of PPM. Almost every landowner mentioned the Laramie River going dry during some point in their life, and several mentioned large floods. While planning surveys at the Fort Laramie National Historic Site (LLE.01) in 2013, a large flash flood occurred that could have potentially washed native mussels out of their habitat. As the water receded, these native mussels would not have been able to move quickly enough back to the thalweg and would have died. At every site with shells in the Laramie River drainage, PPM shells were fairly eroded and found high on the banks, lending support to the possibility that the flooding destroyed mussel beds in this drainage. Some landowners mentioned that the Laramie River switched channels several decades ago below Grayrocks Reservoir after a large flood and others mentioned temporary dewatering. Both of these scenarios would be destructive to live native mussels.

The Arapaho Fire in the Laramie Range in 2012 caused heavy ash siltation, debris flows, and extensive fish kills in the Laramie River upstream of Grayrocks Reservoir (WGFD 2013). Both CPM and PPM were found in the affected area prior to the 2012 wildfire (Appendix A). One landowner described how the water turned opaque black after torrential downpours that succeeded the fire. Evidence of this was present just below the surface substrate. In some locations, there was more than a foot of ash below the surface substrate. Exhaustive literature review and interagency correspondence produced no published data and very little anecdotal information on the impacts of wildfire on native mussels. Heavy soot, which would alter water chemistry, may be detrimental to native mussels—as with fish (Minshall and Brock 1991, Propst et al. 1992, Bozek and Young 1994, Rinne 1996, Reiman and Clayton 1997)—although two live CPM were found in the area with heavy ash siltation. Localized extinctions of sensitive species are quite possible after forest fires (Rieman and Clayton 1997), and fire may have caused the extirpation of PPM from the Laramie River drainage. More research is needed on the effects of fire on native mussels.

North Platte River and Smaller Tributaries

The North Platte River system has several large dams and reservoirs that contributed to the loss of a native mussel community in the main stem North Platte because much of the host fish community was lost. No relic shells have been documented upstream of Alcova Reservoir in the North Platte River drainage, which is caused by a currently unknown reason. Shells of PPM found lower in the North Platte River and its smaller tributaries were very old. The periostracum had been worn off and many of the shells were fragments when found. Haag (2012) states that large bottom release dams severely impact native mussel communities, even though habitat may remain intact. Seasonally variable flow can wipe out the entire mussel fauna from a community (Haag 2012).

At least two oil spills in the North Platte River drainage had severe, deadly effects on native fish and aquatic invertebrates during the 1980's (Wichers 1992, Conder 1989, Mcknight et al. 1981). These spills killed fish from 63 km (39 mi) upstream of Casper to Glendo Reservoir. Another pollution source, toxic effluent from the Holly Sugar Refinery in Torrington, WY, was identified as the cause of death for fish in the North Platte River from the refinery downstream to Henry, NE (Bosley et al. 1963). Though native mussels were not mentioned in any of these reports, it is very likely they would have died in conjunction with the fish.

Peterson and Leik (1958) determined that the cessation of discharge from Alcova Reservoir into the North Platte River caused complete oxygen depletion from Casper downstream to Guernsey. The cessation of flow coupled with sewage decomposition and industrial pollution killed fish in this area. It was determined that a winter flow from Alcova Reservoir was necessary to maintain a fish population in the North Platte River from Casper to Guernsey. Gray Reef Dam was completed in 1961 and winter flows below Casper have been more stable since (Figure 5).

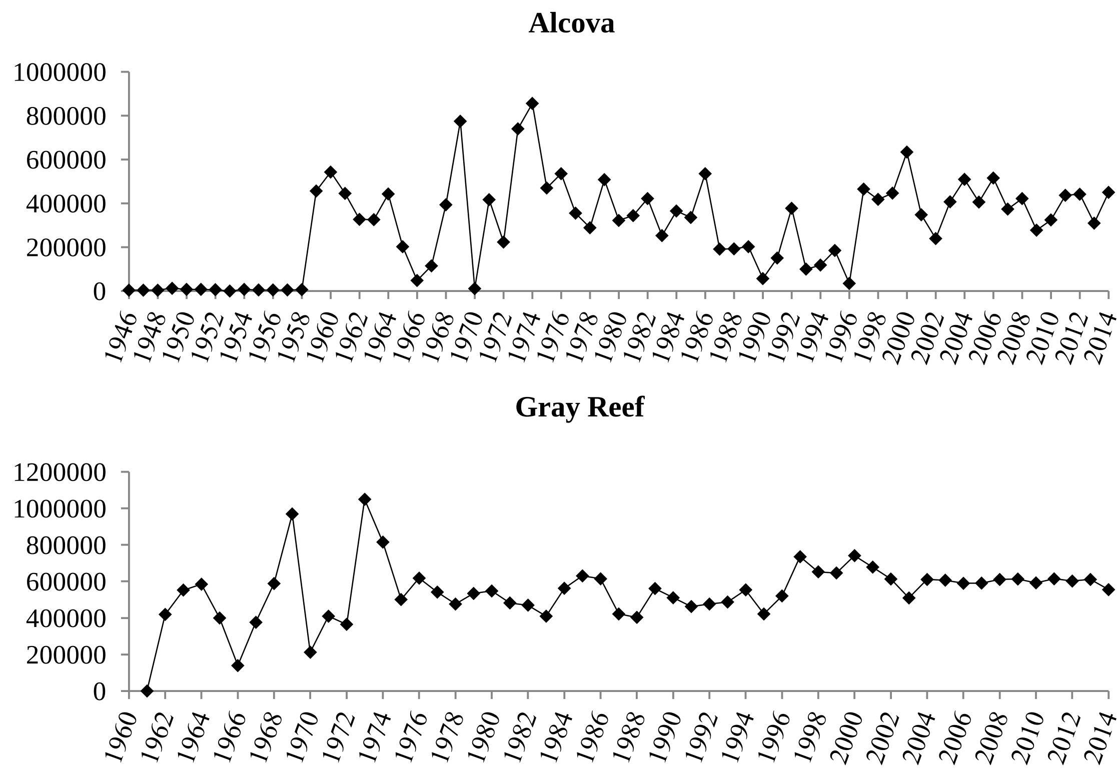

FIGURE 5. United States Bureau of Reclamation data for minimum daily discharge (m^3/day) from two North Platte River reservoirs: Alcova Reservoir and Gray Reef Reservoir). Data were available from 1946 to 2014 for Alcova Reservoir and from its establishment in 1961 to 2014 for Gray Reef Reservoir.

It is likely that mussels in the North Platte River were wiped out for similar reasons as the fish kills and because host fish may have been lost. No purposeful human stocking of mussels has occurred to reestablish the native mussels, but shells and live mussels found in tributaries do offer hope for natural reestablishment of native mussel populations in the North Platte River drainage. Deer Creek at the Glenrock Fairgrounds (site NPR.05) had shells of PPM present on two of three surveys, but no live individuals have been found in this stream. No shells have been found downstream of the fairgrounds during incidental surveys in the Glenrock city park. Shells present at NPR.05 may be coming from a living population upstream. If live mussels are present, they could be used for reestablishing PPM populations in Wyoming, assuming permission could be obtained to access that stream reach.

NSS Rankings

CPM

Impoundments and irrigation diversions throughout CPM's range present challenges for native mussels to complete their life history and maintain stable populations. Not only do these barriers prevent downstream populations of CPM from moving upstream with their host fish (Watters 1996), they can also cause streams to dry or stagnate by impounding or diverting water. In Wyoming, CPM are only native to the North and South Platte drainages. The conservation status of CPM in downstream states is either S2 (CO) or unranked (NE; NatureServe 2014). Source populations in downstream states and within Wyoming are limited making natural recolonization almost impossible. The short lifespan of CPM requires them to spawn successfully more frequently than longer-lived species (Haag and Warren 2008). Given the low numbers of CPM found, and considering the impacts of water development (e.g., stream dewatering and the presence of barriers to fish movement); CPM may be more imperiled in Wyoming than previously thought. Five of 37 sites yielded a total of 17 CPM. Using WGFD's 2010 SWAP NSS Matrix and the description of limiting factors, I recommend assigning CPM a rank of NSS2.

PPM

In Wyoming, PPM are only native to the North Platte River drainage. No live PPM have been found since 2008, even after extensive surveys near the site of the last known live individual. I assume that the PPM has been extirpated from the main stem North Platte River due to the installation of bottom release dams, historically unregulated flows that caused portions of the river to go completely dry, and numerous oil and gasoline spills. Populations may still exist in tributaries such as Deer Creek. The Laramie River has potential for a surviving population, but the Arapaho Fire may have caused PPM's extirpation above Grayrocks Reservoir in 2012. In addition, no recently dead PPM shells were found downstream of Grayrocks Reservoir and flash flooding and persistent drought may have negatively impacted these populations. Using WGFD's 2010 SWAP NSS Matrix and the description of limiting factors, I recommend assigning a rank of NSS1 for any remaining PPM, though extirpation is likely.

Recommendations

- Regional Fisheries crews are encouraged to continue to report incidental findings of mussels, especially live individuals. If possible, UTM coordinates and photos of live mussels should be sent to the Aquatic Assessment Crew (AAC). Collection of empty shells is also encouraged; empty shells and site information can also be sent to the AAC. Instructions and forms can be found on the Fish Division Intranet Homepage.
- Modifying necessary structures and removing unnecessary host-fish migration barriers would greatly help native mussels. Allowing native host fish to migrate throughout rivers would make it easier for CPM and PPM to colonize upstream portions of streams. At the very least, minimum flows from impoundments should be established to allow the persistence of CPM and PPM. More analysis of the diversions within these drainages is needed to determine which have the greatest impact on native mussels and base flows.
- Collection of chemical parameters (e.g., ammonia) over long periods of time and during different seasons, and comparison of those data to mussel absence in Wyoming is needed to determine if and/or what chemical parameters are influencing mussel absence.
- Spending more time at fewer sites to collect quantitative habitat and mussel data may improve our ability to predict mussel presence and absence, but will reduce the number of sites that can be visited in a single field season. With fewer survey sites, refined species distributions may not be achieved. Surveying microhabitats around individual mussels, collecting detailed stream channel and water quality data (e.g., chemicals, temperature, daylight, stream gradient, maximum and minimum flows etc.), and doing

square-meter or quarter-meter-square quadrat surveys at high abundance mussel sites would be options to explore if time and funding is available.
- Potential reintroductions with CPM and PPM from populations within Wyoming and/or neighboring states could augment existing populations and help establish new populations.

South Platte River Drainage

- Additional records of CPM from the South Platte River drainage would be extremely valuable. If time and resources are available, additional thorough systematic surveys should be performed where incidental CPM observations occurred. Surveying for CPM (average lifespan of seven years) is recommended every five years, especially at historic sites where only shell evidence was found (Appendix A). Any new sites in the North and South Platte river drainages with live CPM present would be critical to refine the NSS ranking. Reintroductions of CPM from populations in Wyoming (Horse Creek and Laramie River) and/or neighboring states could augment existing populations and help establish new populations.

North Platte River Drainage

- Additional records of both CPM and PPM from the North Platte River drainage would be extremely valuable. If time and resources are available, additional thorough systematic surveys should be performed, especially where incidental CPM and PPM observations occurred. Intensive mussel surveys should be done at least every five years with more intensive surveys for PPM should be done as often as possible to document its existence or possible extirpation. Sites with CPM present (HOR.01, HOR.04, LLE.01, LLE.06, and LLE.08) should be sampled every five years to determine if their populations are increasing, decreasing, or stable. Revisiting sites at a minimum of every five years where only shell evidence of CPM was found (HOR.02, HOR.03, LLE.02, LLE.03, LLE.05, LLE.07, and LLE.09) is also encouraged. Finding any live PPM in Wyoming would be extremely valuable. Efforts should be focused in the Laramie River drainage where live individuals have been recorded and in other North Platte River tributaries such as Deer Creek where shell evidence has been recorded. New sites in the North Platte River drainage with live CPM and PPM would be critical in refining the NSS rankings. Reintroductions of CPM and PPM from populations within Wyoming and/or neighboring states could augment existing populations and help establish new populations.

NSS Rankings

- CPM should be ranked as NSS2 in the 2015 SWAP revision.
- PPM should be ranked as NSS1 in the 2015 SWAP revision.

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APPENDIX A. Historic records of CPM and PPM in Wyoming from various studies (Beetle 1989, Henderson 1924, Hoke 1979) and incidental observations by WGFD personnel and others (mainly Alan Cvancara and Kerry Lippincott). All UTMs are in zone 13 (NAD27). Empty shells are recorded as fractions of the whole. A single valve (left or right) was recorded as 0.5. Fragments of shells are also indicated (*). Near fossil records are recorded as "fossil"; these are shells that were very old with no periostracum or tissue and the nacre was no longer pearlescent.

Drainage/ Water Body	HUC	Date	UTM Easting	UTM Northing	Collector	Species	Live	Dead
North Platte River Drainages								
Horse Creek Drainages								
Horse Cr.	1018001202	06/27/2012	560852	4597067	WGFD	CPM		1.5
Bear Cr.	1018001203	09/13/2005	540236	4607556	WGFD	CPM		5
Bear Cr.	1018001203	06/17/2009	533263	4607404	WGFD	CPM	1	
Horse Cr.	1018001206	1988	561431	4633174	Beetle	CPM		1
Horse Cr.	1018001206	1988	563120	4629857	Beetle	CPM		1
Dry Cr.	1018001206	1988	571415	4631046	Beetle	CPM		1
Horse Cr.	1018001206	1988	574667	4637741	Beetle	CPM		1
Horse Cr.	1018001206	10/12/2005	570946	4635662	WGFD	CPM	1	0.5
Horse Cr.	1018001206	06/22/2009	570907	4635654	WGFD	CPM	2	5
Laramie River Drainages								
Laramie R.	1018001101	07/27/2005	491834	4660497	WGFD	CPM	1	
Laramie R.	1018001105	1917	506612	4664000	Henderson	PPM	1	
Laramie R.	1018001105	1953	525975	4668576	Beetle	PPM		1
Grayrocks Res.	1018001105	1988	524780	4668481	Beetle	CPM		1
Laramie R.	1018001105	06/17/2002	526101	4668708	Other	PPM		1
Laramie R.	1018001105	07/20/2002	498760	4662442	Other	CPM		1
Laramie R.	1018001105	06/29/2005	506638	4663962	WGFD	CPM		2
N. Laramie R.	1018001105	08/02/2005	506251	4663640	WGFD	CPM		4.5
Laramie R.	1018001105	09/04/2008	499220	4662375	WGFD	CPM	1	
Laramie R.	1018001105	09/05/2008	516027	4662953	WGFD	PPM		1
Laramie R.	1018001105	09/09/2008	513119	4662991	WGFD	PPM		1
Laramie R.	1018001105	10/16/2008	512900	4662892	WGFD	CPM	2	10
Laramie R.	1018001105	10/16/2008	512900	4662892	WGFD	PPM	1	*
Laramie R.	1018001105	10/16/2008	515497	4662781	WGFD	CPM		7
Laramie R.	1018001105	10/16/2008	515497	4662781	WGFD	PPM		1
Laramie R.	1018001105	06/29/2011	535993	4672069	WGFD	PPM		2
North Platte River & Smaller Tributaries								
North Platte R.	1018000701	09/04/1997	367268	4726338	Other	PPM		1
North Platte R.	1018000701	10/30/1997	367098	4717455	Other	PPM		1
North Platte R.	1018000701	03/16/2006	362991	4714902	WGFD	PPM		1
North Platte R.	1018000701	08/24/2006	367929	4721644	Other	PPM		Fossil
North Platte R.	1018000701	03/31/2007	366955	4717649	WGFD	PPM		1.5
North Platte R.	1018000701	05/25/2007	367280	4716950	WGFD	PPM		3
North Platte R.	1018000701	02/18/2008	361125	4715029	WGFD	PPM		1
North Platte R.	1018000701	03/25/2008	361158	4714768	WGFD	PPM		3
North Platte R.	1018000701	04/13/2008	364852	4716780	WGFD	PPM		1.5
North Platte R.	1018000701	05/03/2009	361423	4715296	WGFD	PPM		*
North Platte R.	1018000703	04/08/2004	375960	4734670	WGFD	PPM		0.5
North Platte R.	1018000703	10/12/2010	375586	4734124	WGFD	PPM		4.5*
North Platte R.	1018000709	10/20/2010	445041	4744893	WGFD	PPM		0.5
Deer Cr.	1018000710	08/13/1999	429482	4743971	Other	PPM		1

APPENDIX A. *Continued*.

Drainage/ Water Body	HUC	Date	UTM Easting	UTM Northing	Collector	Species	Live	Dead
South Platter River Drainages								
Sloan's Lake	1019000901	04/12/2006	514401	4555950	WGFD	CPM		1
Lodgepole Cr.	1019001501	05/28/2009	520059	4572219	WGFD	CPM		*
Lodgepole Cr.	1019001501	08/26/2014	503071	4577282	WGFD	CPM		0.5
Lodgepole Cr.	1019001502	1978	554902	4563507	Other	CPM	1	
Lodgepole Cr.	1019001502	08/25/2007	545642	4565044	WGFD	CPM		2.5

APPENDIX B. Data used in binary logistic regressions for all sites. Presence/Absence (P/A) had two categories: sites with live mussels present were coded as (P) and sites with no live mussels or only relic evidence of mussels were coded as absent (A). Width (m) and depth (cm) are mean bankfull width and depth at each site. Dominant substrate is the dominant substrate type within the wetted width [cobble (1), coarse gravel (2), fine gravel (3), sand (4), or fines: silt, clay, and/or muck (5)]. Stream order is Stahler's stream order. Drainage area is the calculated drainage area (km^2) upstream of the survey site.

Site Code	P/A	Width	Depth	Dominant Substrate	Stream Order	Drainage Area
HOR.01	P	11.5	145.9	4	5	3868.5
HOR.02	A	9.4	45.0	3	3	3648.2
HOR.03	A	2.3	16.8	4	2	391.7
HOR.04	P	2.1	30.5	4	4	871.4
HOR.05	A	3.0	29.3	5	4	867.5
LLE.01	P	15.5	31.7	2	5	10904.4
LLE.02	A	18.6	32.5	4	5	10772.4
LLE.03	A	24.2	45.5	4	5	10768.7
LLE.04	A	21.8	31.2	2	5	10765.0
LLE.05	A	14.0	64.7	4	5	10668.2
LLE.06	P	15.5	15.0	4	5	10856.9
LLE.07	A	10.9	14.1	4	5	8780.3
LLE.08	P	7.4	8.8	4	5	8778.7
LLE.09	A	4.2	18.9	4	4	1656.8
LLE.10	A	2.3	10.7	4	4	1656.3
LLE.11	A	4.4	40.6	5	4	994.2
LLE.12	A	3.4	18.6	4	4	982.1
LOC.01	A	5.9	24.5	4	4	1026.0
LOC.02	A	3.7	39.8	3	4	967.8
LOC.03	A	3.7	29.0	3	4	877.1
NPR.01	A	3.5	42.0	5	4	1234.2
NPR.02	A	4.4	50.0	4	4	470.2
NPR.03	A	9.9	29.0	5	4	635.0
NPR.04	A	6.9	32.2	1	3	265.3
NPR.05	A	8.6	18.7	2	4	1058.7
NPR.06	A	89.5	86.9	5	7	28917.8
NPR.07	A	68.3	96.0	2	7	28698.2
NPR.08	A	66.2	100.0	4	7	27828.3
NPR.09	A	55.0	122.7	2	7	27812.9
NPR.10	A	8.8	78.8	4	4	603.0
NPR.11	A	76.5	160.5	1	7	23008.9
NPR.13	A	12.5	136.3	4	3	153.3
NPR.14	A	14.5	54.3	4	5	5327.1
ULP.01	A	3.4	19.2	4	4	950.8
ULP.02	A	3.7	34.4	5	3	569.1
ULP.03	A	4.9	14.3	3	3	374.3

APPENDIX C. Pearson correlation analysis results (*p*-values) for survey sites.

	Width	Depth	Dominant Substrate	Stream Order	Drainage Area
Width		0.000	0.090*	0.000	0.000
Depth			0.180*	0.001	0.001
Dominant Substrate				0.182*	0.081*
Stream Order					0.000
Drainage Area					

*Uncorrelated variables ($p>0.05$)