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NOTES

CORBICULA FLUMINEA (BIVALVIA: SPHAERIACEA: CORBICULIDAE) IN COLORADO

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ABSTRACT—We documented range expansion of the Asiatic clam, *Corbicula fluminea*, in Colorado since its first occurrence in 1993 in the South Platte River drainage. Using recent surveys and literature records, we compiled known occurrences of the Asiatic clam over the past 12 y and determined that it has expanded beyond the initial confines of the Platte River and Arkansas River drainages into the Colorado River and San Juan River drainages. All previously reported occurrences are still extant and the species continues to spread to new localities, especially in the Arkansas River drainage. We speculate on potential negative impacts to native freshwater mussels in Colorado, but have not conducted any definitive studies.

RESUMEN—Deseamos documentar la extensión de la gama de la almeja Asiática, *Corbicula fluminea*, en Colorado desde el primera ocurrencia en 1993 en el drenaje del Río South Platte. Usando exámenes y expedientes recientes de la literatura, compilamos ocurrencias sabidas de la almeja Asiática a partir de los docena años pasados y determinada que las poblaciones se han ampliado más allá de los límites iniciales de los drenajes del Río Platte y del Río Arkansas en los drenajes del Río Colorado y del Río San Juan. Todas las poblaciones previamente divulgadas siguen siendo extant y muchas continúan a aumento a nuevos lugares, especialmente en el drenaje del Río Arkansas.

Studies of freshwater mollusks in the Rocky Mountain region are rare compared to other regions of the United States, such as the Southeast and Northeast. Surveys include those by Cockerell (1889, 1927), Ellis (1916), Ellis and Keim (1918), and Henderson (1907a, 1907b, 1912, 1924). More recent surveys include Brandauer and Wu (1978), Herrmann and Fajt (1985), Wu (1989), Liu et al. (1996a, 1996b), Cordeiro (1999), Cordeiro and MacWilliams (1999) and A. H. Clarke et al. (2003, unpublished report). The invasive Asiatic clam, *Corbicula fluminea* (Müller, 1774) (family Corbiculidae), is native to temperate and tropical southern Asia west to the far eastern Mediterranean, as well as northern Africa, the southeastern Asian islands, and eastern Australia (Morton, 1986). It was first reported in the United States in 1938 in the Columbia River in Pacific County, Washington (Burch, 1944). Since that time it has been documented in 42 states (Counts, 1986; A. M. Foster et al., http://nas.er.usgs.gov/queries/SpFactSheet.asp?speciesID=92; A. J. Benson et al., 2004, unpublished report, United States Fish and Wildlife Service, Arlington, Virginiana). The first documented occurrence in Colorado was in June 1993 in Cherry Creek Reservoir, Arapahoe County (Nelson and McNabb, 1994). Subsequent occurrences in the state also have been documented in Highline Lake, Mesa County, in 1995 (Kreiser and Mitton, 1995). It has become established in Queen's (=Nee Skah) Reservoir, Kiowa County; in pools of the Arkansas River below the dam to John Martin Reservoir, Bent County; and in Pueblo Reservoir, Pueblo County (Cordeiro, 1999; Cordeiro and MacWilliams, 1999).

Based on targeted surveys of freshwater mollusks across Colorado in 2001–2004, we here

report new occurrences of *Corbicula fluminea* from 18 additional sites, 6 well away from those previous reported (Table 1). Unlike Cordeiro (1999), who comprehensively surveyed 115 sites (80 different water bodies) across the eastern half of the state for freshwater bivalves, occurrences reported here are the result of both a comprehensive survey of 350 sites in eastern Colorado in 2001–2002 (A. H. Clarke et al., 2003, unpublished report, Colorado Division of Wildlife) and 453 sites in western Colorado in 2003–2004 (J. R. Sovell et al., 2005, unpublished report, Colorado Division of Wildlife) specifically targeting freshwater mollusks across the state. Also included are periodic non-targeted surveys at various new sites in eastern Colorado as documented by the Colorado Natural Heritage Program. Copies of these reports can be obtained by contacting co-author J. R. Sovell at the Colorado Natural Heritage Program . For purposes of this project, eastern Colorado is defined as all areas east of the Continental Divide and western Colorado includes all areas west of the Continental Divide plus areas >200 m elevation east of the Continental Divide. Also included are periodic non-targeted surveys at various new sites in eastern Colorado as documented by the Colorado Natural Heritage Program. In June 1999, S.-K. Wu collected 15 specimens from Bonny Reservoir in Yuma County close to Kansas. A second site was discovered in September of the same year in Totten Lake in Montezuma County in the extreme southwestern corner of the state (Colorado Natural Heritage Program , pers. comm.). In 2001–2002, 12 additional sites were discovered, all in the Arkansas River drainage: 3 in the Purgatoire River; 3 in John Martin Reservoir; 2 new sites in the Arkansas River (1.2 km north and 6 km west of Lamar); and 1 each in Hasty Lake, Lake Meredith (=Meredith Reservoir), Nee Gronda Reservoir, and Nee Noshe Reservoir (A. H. Clarke et al., 2003, unpublished report; Fig. 1). Surveys of western Colorado in 2003–2004 uncovered 4 additional sites in the Colorado River drainage: Beaver Pond in Delta Co., House Creek in Montezuma Co., and Spring and Whitewater creeks in Mesa Co. (J. R. Sovell et al., 2005, unpublished report). In addition, occurrences in Bonny Reservoir, Cherry Creek Reservoir, and the Arkansas River (below John Martin Reservoir) have been confirmed to be extant. Additional surveys by the Colorado Natural Heritage Program of Totten Lake in 2004, 5 y after the initial discovery, revealed that the species also is extant at this site. In particular, the occurrence of 12 additional sites on the Arkansas River drainage indicate *C. fluminea* is expanding in this region.

Corbicula fluminea has been documented in 4 of 6 major drainage basins (Arkansas, Colorado, Platte, San Juan; not documented in Rio Grande or White-Yampa) in Colorado (or 5 of the 12 subbasins) as of 2004 (Fig. 1). Historical introductions in North America can be initially traced to passive dispersal on water currents, anthropogenic transport in boat ballast and bait buckets, or through the aquarium pet trade (Counts, 1986; Isom, 1986). Range expansion of occurrences on the Arkansas River drainage has occurred rapidly since initial discovery of *C. fluminea* there in 1996 (Cordeiro, 1999; Cordeiro and MacWilliams, 1999) with 12 additional sites discovered. A similar rapid invasion pattern from recent initial introductions also has been documented in Texas where the species occurs in 180 of 257 counties (Karatayev et al., 1995). New invasions are not limited to the eastern plains as new occurrences have been uncovered in different regions of the Colorado River drainage as well. The widely disjunct distribution in Colorado of the remaining occurrences supports a theory of human-influenced transport. At least 2 instances of aquarium dealers in Colorado selling the species have been documented (Cordeiro and MacWilliams, 1999; University of Colorado Museum specimen lot UCM 41599).

Although previously reported to be limited in dispersal capability by intolerance of cold temperature (Mattice and Dye, 1976; Graney et al., 1980; McMahon, 1983; Sickel, 1986; French and Schloesser, 1991, 1996), *C. fluminea* has been shown to survive cold temperatures (<4°C) in areas without thermal refuge (Kreiser and Mitton, 1995; Cordeiro and MacWilliams, 1999). Totten Lake is situated at about 2,050 m elevation, Queen's, Nee Gronda and Nee Noshe Reservoirs at about 1,700 m, Cherry Creek Reservoir at about 1,850 m, Pueblo Reservoir at about 1,600 m, Highline Lake at about 1,550 m, Lake Meredith at about 1,350 m, John Martin Reservoir at about 1,280 m, Hasty Lake at about 1,200 m, and Bonny Reservoir at about 1,200 m elevation (http://parks.state.co.us/Boating/BoatableWaters/). New localities in western Colorado range from about 1,550 to 3,200 m elevation (Beaver Pond about 3,200 m, House

TABLE 1—Locality information for *Corbicula fluminea* (Müller) in Colorado (see Fig. 1 for distribution map).

Map key	Water body	Specific locality	County	Drainage: subbasin	Latitude, longitude
A	Arkansas River	About 1 m N of Lamar	Prowers	Arkansas: Upper Arkansas	38°06′27″N, 102°37′16″W
B	Arkansas River	At first bridge below Lamar, 5.4 m E of Lamar center	Prowers	Arkansas: Upper Arkansas	38°05′76″N, 102°31′14″W
C	Arkansas River	At pools below John Martin Reservoir, south of Hasty Lake near Caddoa	Bent	Arkansas: Upper Arkansas	38°04′16″N, 102°55′73″W
D	Beaver Pond	12 m N of Cedaredge at highway 65	Delta	Colorado: Gunnison	39°00′29″N, 107°59′43″W
E	Bonny Reservoir	[North and] south shores, 1.2 to 2.0 m E-SE of dam	Yuma	Platte: Republican	39°36′43″N, 102°11′75″W
F	Cherry Creek Reservoir	All shores, SE of Denver	Arapahoe	Platte: South Platte	39°39′05″N, 104°51′17″W
G	Hasty Lake	On Arkansas River, just below John Martin dam, near Caddoa	Bent	Arkansas: Upper Arkansas	38°04′31″N, 102°55′75″W
H	Highline Lake	Ute Base Line, NW of Loma	Mesa	Colorado: Colorado Headwaters	39°16′07″N, 108°50′30″W
I	House Creek	7.0 m N of Dolores on County Road 31 (Forest Service Road 526)	Montezuma	Colorado: Upper Colorado-Dolores	37°33′52″N, 108°27′25″W
J	John Martin Reservoir	North side, 1 m W of Lookout Point, just south of Hasty	Bent	Arkansas: Upper Arkansas	38°04′86″N, 102°59′30″W
K	John Martin Reservoir	South side, east end from near dam to ¾ mile west, 1.0 m SW of Caddoa, 4.6 m SSE of Hasty	Bent	Arkansas: Upper Arkansas	38°03′14″N, 102°56′53″W
L	John Martin Reservoir	Northeast corner, near N end of dam, 2 m S of Hasty	Bent	Arkansas: Upper Arkansas	38°03′60″N, 102°58′43″W
M	Lake Meredith (=Meredith Reservoir)	Northeast side	Crowley	Arkansas: Upper Arkansas	38°13′42″N, 103°39′90″W
N	Nee Gronda Reservoir	Southeast side, 2 m N of tri-county line	Kiowa	Arkansas: Upper Arkansas	38°17′70″N, 102°44′43″W
O	Nee Noshe Reservoir	South side	Kiowa	Arkansas: Upper Arkansas	38°19′99″N, 102°41′65″W
P	Pueblo Reservoir	Lake Pueblo State Park	Pueblo	Arkansas: Upper Arkansas	38°16′06″N, 104°43′28″W
Q	Purgatoire River	Route 101 crossing, 2 m S and 1 m E of Las Animas	Bent	Arkansas: Upper Arkansas	38°02′47″N, 103°12′21″W

Table 1—Continued.

Map key	Water body	Specific locality	County	Drainage: subbasin	Latitude, longitude
R	Purgatoire River	USGS station, above Highway 106, 1.9 m S and 1 m E of center of La Junta	Otero	Arkansas: Upper Arkansas	37°45′73″N, 103°30′50″W
S	Purgatoire River	At Highway 109, about 1.7 m SSE of La Junta, 2 m SE of Higbee	Otero	Arkansas: Upper Arkansas	37°45′73″N, 103°25′85″W
T	Queen's (=Nee Skah) Reservoir	5.5 m N and 5.25 m E of Big Bend	Kiowa	Arkansas: Upper Arkansas	38°16′17″N, 102°38′05″W
U	Spring Creek	8.0 m SW of Collbran on County Road KE.00	Mesa	Colorado: Colorado Headwaters	39°10′23″N, 108°05′42″W
V	Totten Lake	3.5 m E and 1 m N of Cortez	Montezuma	San Juan: San Juan	37°22′06″N, 108°31′18″W
W	Whitewater Creek	7.0 m SE of Grand Junction at Highway 50 bridge	Mesa	Colorado: Gunnison	38°58′39″N, 108°26′13″W

Creek about 2,450 m, Spring Creek about 1,850 m, Whitewater Creek about 1,550 m–J. R. Sovell et al., 2005, unpublished report). All experience periods of freezing during winter with potentially no areas of thermal refuge. Morgan et al. (2003) detected positive correlation of survival in winter with average water temperature in winter and negative correlation with frequency of daily mean water temperatures ≤1°C in a *C. fluminea* in the lower Connecticut River. Despite high mortality in winter from cold water temperatures and in early spring from high water flow, Morgan et al. (2003) noted that clams were over-wintering under ambient river temperatures and surviving in the lower Connecticut River for ≥10 y. Other drainages in Connecticut also now support over-wintering populations, as well (J. R. Cordeiro, pers. observ.). *Corbicula fluminea* apparently also is over-wintering successfully throughout Colorado, although we have not documented relative abundance or winter mortality rates.

The impact of the spread of Asiatic clams in Colorado on native freshwater mussels is not known, although preliminary studies indicate the species competes for space and food (Fuller and Imlay, 1976; Clarke, 1986; Devick, 1991; Bogan, 1993; Strayer, 1999). Filter-feeding activity of *C. fluminea* causes significant decline in phytoplankton levels (Cohen et al., 1984; Leff et al., 1990), which in turn, may lead to a trickle-down effect in other filter-feeding organisms, including freshwater mussels. Cooper et al. (2005*a*, 2005*b*) linked potential negative effects of *C. fluminea* die-offs on native freshwater mussels due to increase in ammonia levels. Bio-fouling impacts of *C. fluminea,* particularly on power plants, industrial water systems, and irrigation canals and pipes, have been well documented (Prokopovich and Hebert, 1965; Isom, 1986; Isom et al., 1986; Williams and McMahon, 1986; Devick, 1991; Morgan et al., 2003, 2004). Only 3 native species of freshwater mussels are considered extant in Colorado and of these, *Pyganodon grandis* (Say, 1829) and *Uniomerus tetralasmus* (Say, 1831) co-occur with *C. fluminea* (Cordeiro, 1999; A. H. Clarke et al., 2003, unpublished report). *P. grandis* is considered imperiled (rank S2- Imperiled because of rarity or because of some factor(s) making it vulnerable to extirpation or extinction) and *U. tetralasmus* is considered critically imperiled (rank S1- Critically Imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable

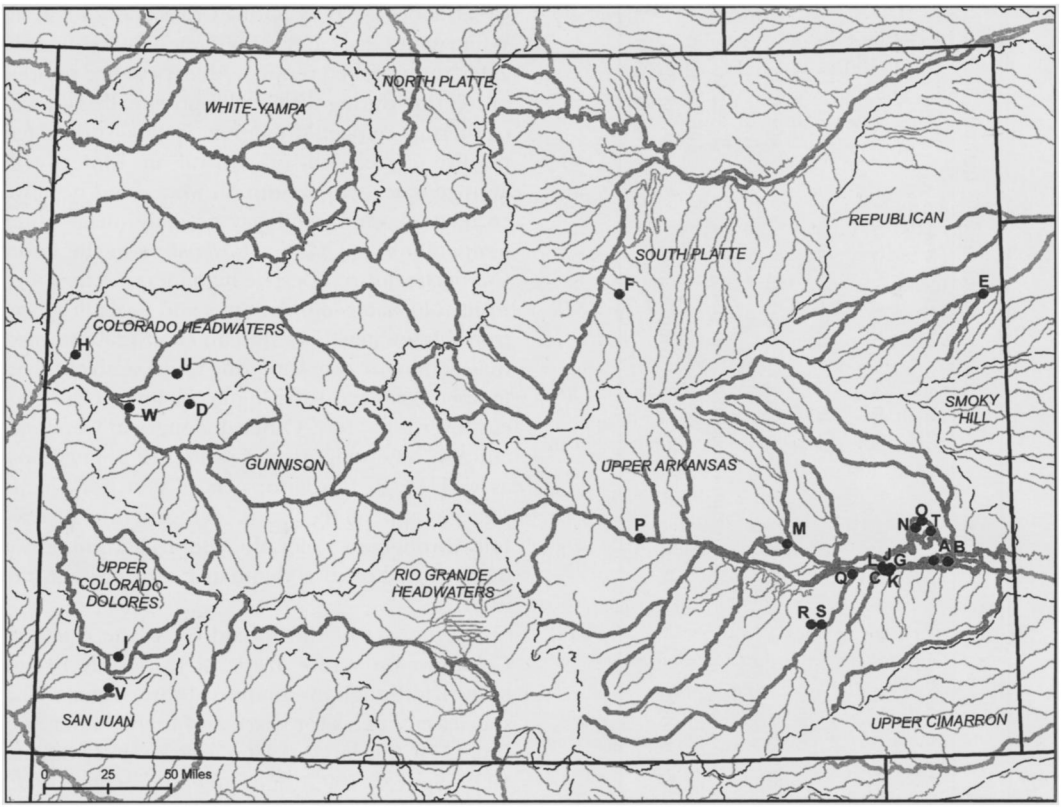

FIG. 1—Distribution map of *Corbicula fluminea* (Müller) in Colorado (see Table 1 for specific locality information).

to extirpation or extinction) in Colorado (NatureServe, http://www.natureserve.org/explorer). *P. grandis* has ≥6 water bodies documented with extant occurrences in the state (Cordeiro, 1999; A. H. Clarke et al., 2003, unpublished report). It co-occurs with *C. fluminea* in Cherry Creek Reservoir (site F), Hasty Lake (site G), John Martin Reservoir (sites J, K, L), and Pueblo Reservoir (site P; Table 1). *U. tetralasmus* may be extirpated from Colorado with the only recent specimens being a single adult dead shell collected by the first author on the southwestern shoreline of Queen's Reservoir in Kiowa County (site T) in 1999 (Cordeiro, 1999) and another dry shell collected in the Arkansas River just north of Lamar in Prowers County (site A) in 2001 (A. H. Clarke et al., 2003, unpublished report), co-occuring in both sites with *C. fluminea* (Cordeiro and MacWilliams, 1999). Historical occurrences of *U. tetralasmus* from the Cimarron River, Carrizo Creek, and Lake Henry are believed extirpated (Cordeiro, 1999) and potential negative effects of competitive interaction between the 2 species at the remaining sites have not been investigated.

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CHROMOSOMAL VARIATION IN NATURAL POPULATIONS OF *DROSOPHILA PSEUDOOBSCURA* INHABITING NORTHERN MEXICO

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ABSTRACT—Samples of 8 natural populations of *Drosophila pseudoobscura* inhabiting northern Mexico were cytogenetically analyzed. Twelve distinct chromosomal arrangements of the third chromosome were identified. Number of inversions at each locality varied from 6 to 8. A total of 468 third chromosomes were examined in the area of study, and relative frequencies of inversions in each population were calculated. The most common inversions in decreasing order of relative frequency were: TL, SC, OL, and CU; the other 8 inversions had frequencies <10%. Each locality had 3–4 inversions that accounted for ≤80% of the total. All populations were heterogeneous. Relative frequency of each inversion did not form a gradient along the transect studied. Unexpected was the presence of the ST inversion, as well as the incidence, in some populations, at a moderate frequency, of the inversion OL. Another exception was the increase in frequency of the EP inversion compared with previous collections in the area. More information from the region is needed.

RESUMEN—Muestras de 8 poblaciones naturales de *Drosophila pseudoobscura* que habitan en el norte de México fueron analizadas citogenéticamente. Doce diferentes arreglos génicos o inversiones en el tercer cromosoma fueron detectados. El número de inversiones en cada población varió entre 6 y 8. Un total de 468 terceros cromosomas fueron analizados en el área de estudio y la frecuencia relativa de las inversiones en cada población fue calculada. Las inversiones más comunes encontradas en orden decreciente a su frecuencia relativa fueron: TL, SC, OL y CU; las restantes 8 inversiones presentaron frecuencias menores al 10%. Cada localidad tuvo entre 3 y 4 inversiones representando hasta un 80% del total. Todas las poblaciones fueron heterogéneas. Las frecuencias relativas de cada inversión no formaron un gradiente en el transecto estudiado. Inesperada fue la presencia de la inversión ST así como la presencia en algunas poblaciones, en frecuencias moderadas, de la inversión OL. Otra excepción fue el incremento en frecuencia de la inversión EP cuando comparada con colectas previas en el área. Más información del área es requerida.