11-2011

# The Ringed Crayfish, *Orconectes neglectus neglectus*, in Nebraska with a Revision of Its Distributional Range

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Collections of crayfishes in Nebraska have yielded much new information on the distribution of the ringed crayfish, *Orconectes neglectus neglectus*. The distributional range of this species had been described as southwestern Missouri and northwestern Arkansas with extensions into Kansas and Oklahoma. Isolated, disjunct populations in northeastern Colorado, southwestern Nebraska, and northwestern and east-central Kansas were thought to be relict populations. Between 1995 and 2009, collections of crayfishes were made throughout Nebraska using various techniques including seining, trapping, dip-netting, and handgrabbing. To date, the ringed crayfish has been found in 56 streams in eight of Nebraska's 13 river basins. In the majority of Nebraska streams, they are found in clear, low-gradient, sand-bed streams where they utilize dense vegetative cover. In the Big Blue River basin, the streams are quite turbid and here they use rock riffles. The information collected during this work show that the previously known disjunct populations represent the edges of a much larger distribution centered in Nebraska. The data presented represents a significant revision of the range of distribution of this species.

## Introduction

The crayfishes of Nebraska have not been a well-studied fauna. While a common component of our aquatic biota, they are often dismissed as "crawdads" or "crabs." Children roll rocks or catch them with worms, fishermen collect them for bait, and biologists pick them out of their nets and discard them. In 1926, Engle stated, "Personal inquiry at the office of the game and fish department of Nebraska, at Lincoln, brought the information that crayfishes were worth nothing and could not be considered among the resources of the State." Perhaps because of attitudes like this, a comprehensive statewide survey has never been done.

According to the literature, the primary range of the ringed crayfish (*Orconectes neglectus neglectus*) is limited to an area centered on southwest Missouri and northwest Arkansas and extending into northeast Oklahoma and southeast Kansas (Creaser and Ortenburger 1933, Williams 1954a, Durbian *et al.* 1994, Bergey *et al.* 2004). Williams and Leonard (1952) illustrate a second small population center in Riley and Wabaunsee counties in east-central Kansas as well as isolated records for the Republican River and Sappa Creek in northwest Kansas and Black Wolf Creek in the Republican River drainage of Colorado. Engle (1926) and Unger (1978) reported *Cambarus (Orconectes) neglectus neglectus* in the Republican and South Platte River drainages of northeastern Colorado. In Iowa, Phillips (1980) mentioned an early collection of a ringed crayfish which may be the specimen in the Field Museum of Natural History (FMNH 1401) labeled as collected from Bear Creek near Edgood, Iowa by S.E. Meek. Phillips (1980) did not find the species in Iowa and did not discuss this museum specimen which suggests that this record may be in error. It should be noted that S.E. Meek was collecting elsewhere at this time, including the Big Blue River in Nebraska (Meek 1894). Williams and Leonard (1952) mention a collection from the Red River drainage in Texas; however I could find no museum vouchers or other documentation to support this.

### Historical Collections and Recent Introductions

Nebraska has five native and one non-native species of crayfish (Table 1). In addition to the ringed crayfish, native species include the northern crayfish (*O.virilis*), the papershell crayfish (*O.immunis*), the devil crayfish (*Cambarus diogenes*) and the grassland crayfish (*Procambarus gracilis*). The non-native rusty crayfish (*O.rusticus*) has recently been found in two Omaha city lakes.

The earliest known collections of Nebraska crayfish were made in the early 1890's (Meek 1894, Evermann and Cox 1896). While these published reports are on fishes and do not mention crayfish, the National Museum of Natural History has five voucher specimens which correspond to dates and locations where they collected. These do not include any specimens of the ringed crayfish.

In the first published work on Nebraska's crayfish, Engle (1926) reported on collections from locations in southeast and north-central Nebraska and northeastern Colorado. He stated that the ringed crayfish should be found in the Republican and South

**Table 1. Species of Crayfish That Have Been Collected From Nebraska**

| Common Name | Scientific Name |
|---|---|
| Ringed crayfish | *Orconectes neglectus neglectus* |
| Northern or virile crayfish | *Orconectes virilis* |
| Papershell or calico crayfish | *Orconectes immunis* |
| Devil crayfish | *Cambarus diogenes* |
| Grassland or prairie crayfish | *Procambarus gracilis* |
| Rusty crayfish (non-native) | *Orconectes rusticus* |

Platte Rivers of Nebraska but, as he did not collect in either basin, there is a large gap in his distribution map. While he did not report this species from his Nebraska collections, he did report collecting the northern clearwater crayfish (*Cambarus* (*Orconectes) propinquus*) from Coon Creek, a Big Blue River tributary near Milford, Nebraska. However, the current range of the northern clearwater crayfish is far to the east of Nebraska, which calls this identification into question. Faxon (1890) in his original description of *Cambarus (Orconectes) neglectus*, noted that "In general appearance, this species nearly resembles *C. propinquus*." In discussing the ringed crayfish, he noted "the sexual appendages of the male are quite different (from that of *C.propinquus*), resembling those of *C. rusticus placidus."* While Engle's specimens have apparently been lost (Unger 1978), he did provide a detailed description in which he stated that the rostrum was carinated and the first pair of abdominal appendages had free tips that were "long and slender, not recurved." This is consistent with the reported morphology of the ringed crayfish (Hobbs, 1974).

Between 1939 and 1941, R.E. Johnson (1942) conducted the first comprehensive statewide fishery survey. Queries to museums and an extensive search of museum databases found only a single record of crayfish that he had collected and saved. This was *O. causeyi* (no common name) collected from Looking Glass Creek in the Loup basin (NMNH 131120). I consider *O. causeyi* to be synonymous with the northern crayfish (*O. virilis*) (Schainost, submitted).

The National Museum of Natural History has nine lots of the ringed crayfish collected from the Republican River basin of Nebraska. These include two lots (NMNH 133096 and 133133) collected from a tributary to the Republican River in Dundy County in 1952 which may have been those mentioned by Williams (1954b). Two lots (NMNH 310564 and 310565) were collected from the Republican River in Furnas and Chase Counties in 1959. The remaining five (NMNH 133117, 133114, 133095, 133116, 133115) were collected by Metcalf and Distler (1961) from five streams in four river basins. These five streams were Cottonwood and Elm Creeks in the Republican River basin, Squaw Creek in the Big Blue River basin, the Little Blue River at Ayr, and the Dismal River south of Thedford in the Loup River basin.

Hubert (1988, 2010) reported collection of this species from two reservoirs in the South Platte River drainage in Laramie County, Wyoming. More recently, Sovell and Guralnick (2003) reported the species from one lake in the headwaters of the South Platte basin and five locations in northern and northwestern Colorado on the west slope of the Continental Divide.

## Methods

A formal survey of Nebraska crayfishes was not done but, beginning in 1995, samples were collected at randomly selected sites. Capture methods included trapping, electrofishing, dip-netting, hoop-netting and hand-grabbing. Agency fisheries personnel would occasionally provide crayfishes that had been collected in fishery surveys. Several samples were provided through a recent statewide stream fishery (Peters *et al.* 2004). As of the end of 2009, a total of 603 collections have been made throughout the state of Nebraska.

In many cases, basic water quality and habitat information were also recorded along with the collection. Turbidity was measured with an electronic meter (nephelometric turbidity units or ntu), a 60 cm turbidity tube or both. Conductivity and temperature were collected with a YSI Model 30 meter. Habitat data evaluations included riparian conditions (percent coverage by trees, woody shrubs and saplings, grasses and forbs, and bare dirt), instream fish cover (percent coverage of filamentous algae, macrophytes, woody debris, overhanging vegetation, undercut banks, boulders, and artificial structures) and substrate (bedrock, boulder, cobble, coarse gravel, fine gravel, coarse sand, sand, fines, and wood). Common and scientific names used here follow Williams *et al.* (1989) or Pflieger (1996).

## Results

### Distribution

To date, the ringed crayfish has been collected 148 times (Appendix) from 56 waterbodies in eight of Nebraska's 13 river basins. Collection locations are illustrated in Figure 1 and listed in the Appendix. These data and the information from museum collections were compiled into a revised distribution map for the ringed crayfish that is presented in Figure 2. Summaries of the current collection results follow.

*Niobrara River Basin* In the Niobrara River basin, the species has been found in the Niobrara River proper but not in any tributaries to the river. Within the Niobrara River, there are two segments of the river where they may be found. They are very common in the headwaters of the Niobrara from the Wyoming border to Hi-Way 29 at Agate. They are also found in the segment from the Highway 16f bridge south of Nenzel to the Fort Niobrara Refuge near Valentine.

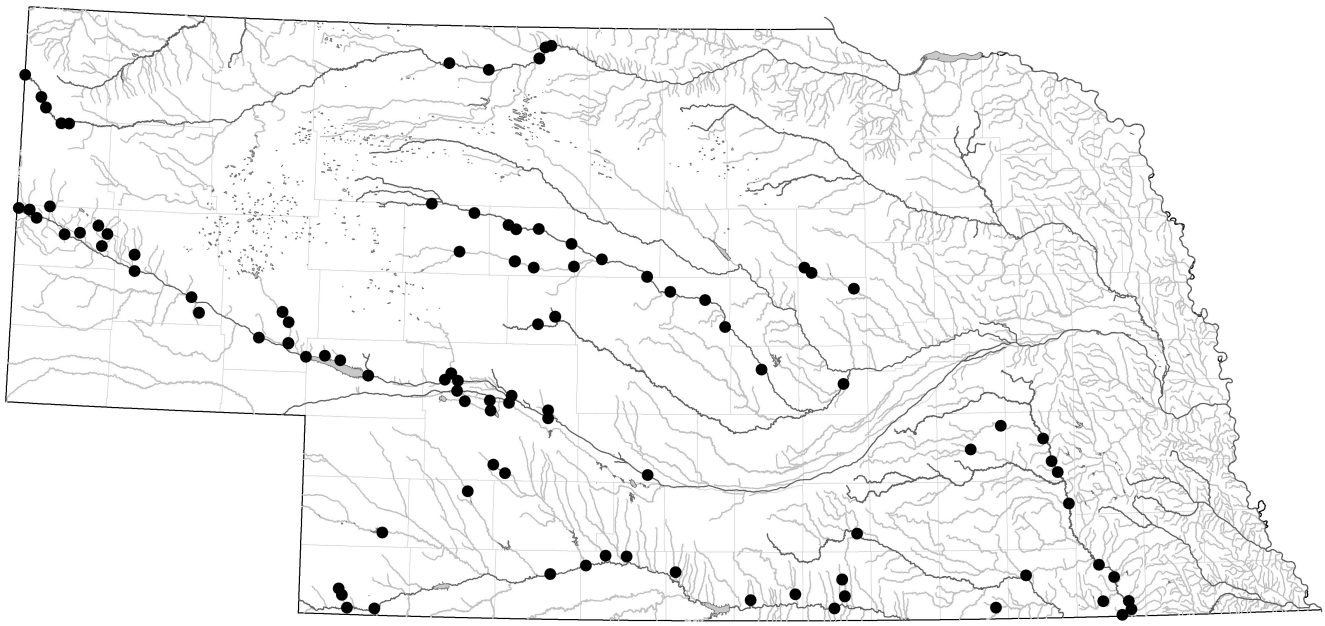

**Figure 1. Collection locations.**

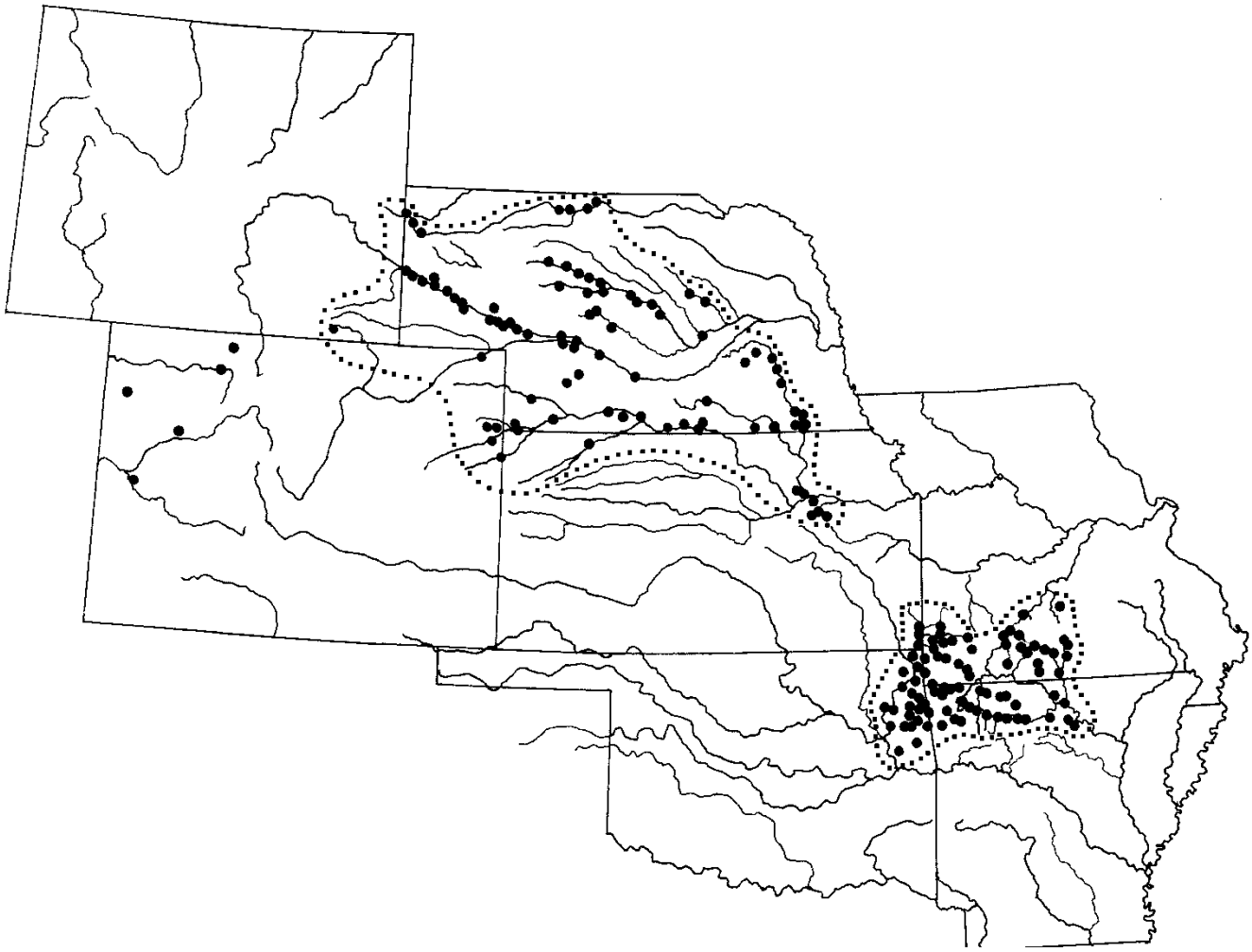

**Figure 2. Revised Distribution Map for the Ringed Crayfish.**

*Loup River Basin* The Loup River basin consists of six main tributaries contributing their flow to form the Loup River proper. From east to west these include: Beaver Creek, the Cedar River, the North Loup River, the Middle Loup River, Mud Creek, and the South Loup River. The ringed crayfish has been collected from the Loup River, the upper Cedar River, the entire Middle Loup River and it's main tributary, the Dismal River, and the headwaters of the South Loup River.

*North Platte River Basin* The ringed crayfish has been found in the entire North Platte River from it's confluence with the South Platte River almost to the Wyoming border. Tributaries from which the species has been collected include Alliance Drain, Sheep Creek, Winters and Ninemile Creeks in Scottsbluff County; Cedar, Red Willow, and Indian Creeks in Morrill County; Blue Creek in Garden County; Whitetail, Otter and Lonergan Creeks in Keith County; Birdwood and Whitehorse Creeks in Lincoln County; as well as the Sutherland Canal and Lake Maloney in Lincoln County. Lake Maloney may be the only instance where the species was collected from a lake in Nebraska, though technically, the collection was from the inlet channel and not the lake proper.

*South Platte River Basin* The ringed crayfish has been collected from the South Platte River and Fremont Slough, both in Lincoln County.

*Middle Platte River Basin* The ringed crayfish has been collected from the mainstem of the Platte River and the South Channel Platte River in Dawson and Lincoln counties and from Pawnee Creek in Lincoln County.

*Republican River Basin* The ringed crayfish has been collected from the Republican River proper in Webster, Red Willow and Dundy Counties. It has been found in several tributaries including Elm Creek in Webster County, Thompson Creek in Franklin County, Elk Creek in Furnas County, Spring Creek in Harlan County, Deer Creek in Red Willow County, Rock Creek in Dundy County as well as Red Willow Creek, Medicine Creek, and Frenchman Creek.

*Little Blue River Basin* The ringed crayfish has been collected from Spring Branch in Thayer County and Rock Creek in Jefferson County.

*Big Blue River Basin* This species has been collected from the Big Blue River proper at Seward, Milford, Beatrice, and Holmesville. Collections have been made from numerous tributaries including Bloody Run, Mud Creek, Wildcat Creek, Spring Creek, Plum Creek, and Big Indian Creek in Gage County, Lincoln and Beaver Creeks in York County; and Coon Creek in Seward County.

**Habitat and Cover Use**

Streams in seven of the eight river basins where the ringed crayfish is found (Niobrara, North Platte, South Platte, Middle Platte, Loup, Little Blue, and Republican) have predominately sand-beds with occasional admixtures of gravels or silt. Turbidity in these streams is low, ranging from 1 to 292 ntu with an average of 37 ntu. The ringed crayfish most commonly uses the cover provided by overhanging grasses, especially exposed grass root mats, and vegetation along the banks. Aquatic macrophytes or algae may be found along shorelines or forming mid-channel beds, particularly in the Niobrara River, but are less common than shoreline grasses. Woody debris may be present in theses streams but is not commonly used by the ringed crayfish. "Rock", usually concrete riprap placed to protect bridge abutments, diversion dams and canal banks, is used when present.

Habitat conditions in the Big Blue River basin differ from those in the more western basins. Streams in this basin tend to be deeply entrenched with silt being the dominant substrate. Sands and gravels are present as well as rock and cobble riffles. Measured turbidities were higher, ranging from 9 to 662 ntu with an average of 99 ntu. Shoreline vegetation and aquatic macrophytes are rare and here the ringed crayfish is usually found in rock and cobble riffles. This characterization extends to tributaries where even the smallest riffles will harbor juveniles. On one occasion, adult ringed crayfish were collected from a silt/sand-bed pool that had no cover whatsoever except that provided by depth and turbidity.

The ringed crayfish has not been found to burrow in Nebraska. However, in several instances, in drying streams, dewatered canals, or periods of no flow, they were found in small cavities excavated beneath rocks or logs. The cavity is the exact size and shape of the crayfish with no room to turn or move around.

## Discussion

Williams (1954b) and Pflieger (1996) described the preferred habitat of the ringed crayfish as clear, rocky or gravelly, streams where they live in riffles or pools that are free of silt. Gore and Bryant (1990) found that while young-of-the-year preferred "high velocity, cobbled" areas, adults were usually found in low velocity areas with sand substrate and beds of macrophytes. My collections have found that the habitats used by the ringed crayfish in Nebraska are more consistent with those described by Gore and Bryant (1990). Habitats in Nebraska were primarily beds of aquatic macrophytes and shoreline terrestrial

vegetation, secondary habitats were rock (either as rip-rap or rock riffles), while woody debris was used rarely. Juveniles were often collected from very small, shallow gravel riffles, if this habitat was present. From these results, the "typical" ringed crayfish stream in Nebraska would be a perennial, low-gradient groundwater-fed sand-bed stream with abundant aquatic and shoreline terrestrial vegetation where they inhabit the vegetated stream margins. Coarse substrates, where available, are utilized, especially at times of low flow or where vegetative cover is rare or absent.

There are two main population centers for the ringed crayfish (Figue 2), one in the Ozark Interior Highlands and the second in the central Great Plains. Crandall and Templeton (1999) in a genetic study of the group to which the ringed crayfish belongs (*Procericambarus*), placed the group's center of origin in the Ozark Highlands, a population center that has been known since the work of Williams and Leonard (1952). Williams (1954b) thought that the isolated populations in north-central and northwestern Kansas, northeastern Colorado, and southwestern Nebraska represented relict populations. He felt that these were the remnants of a much larger range that extended through a large drainage system that flowed east and south through central Kansas during the Pleistocene glaciations as described by Frye and Leonard (1952). Following glacial retreat, the two population centers were disconnected. Williams (1954b) hypothesis was that European settlement in the 1800's brought the Great Plains under cultivation which increased the siltation of it's streams, making them unsuitable for the ringed crayfish. As a result, most of the Great Plains populations were presumably lost (Williams 1954b).

The plowing of the prairies had a negative impact on many species, including the ringed crayfish, but my Big Blue River collections (where turbidities often exceed 500 ntu) is evidence that this species can tolerate turbid, silty waters. It is possible that this tolerance may represent an adaptation as the Big Blue River has not always been as turbid as we now know it. John Charles Fremont camped on the Big Blue on 20 May 1842 (Fremont 1845) and he wrote: "This is a clear and handsome stream. …" Dobbs (1918, p.52), in his history of Gage County noted: "…before the wash from cultivated lands had changed their character its waters were clear, sparkling, beautiful as a mountain stream—in deep places as blue as the overhanging sky."

There are a number of fishes in central North America with disjunct distributions (Metcalf 1966; Cross 1970; Cross *et al.* 1986). One of these, the plains topminnow (*Fundulus sciadicus*) (Lee *et al.* 1980; Cross 1970; Fig. 4), has a distribution that is strikingly similar to the current distribution of the ringed crayfish. Metcalf (1966) postulated the existence of an Ancestral Plains Stream that formed when the Illinoian and Kansan glaciations diverted eastward-flowing rivers to flow southward through the central Great Plains. Cross *et al.* (1986) also discussed this drainage stating "..the modern distribution of *Fundulus sciadicus* suggests southeastward displacement of that species from a place of origin in the central plains into the northern and western parts of the Interior Highlands, where relict populations persist. The Ozarkian populations might have been established as early as the Kansan glaciation via the newly integrated Missouri River Basin or the Ancestral Plains Stream." Support for this hypothesis is presented by Li *et al.* (2009) who, in a genetic study of the plains topminnow, found two distinct but related clades suggesting that the populations of the plains topminnow in Nebraska and in the Lamine River of Missouri were once connected. Li *et al.* (2009) further stated that the "estimated divergence time between the two primary clades of 0.622 MYA is consistent with a late Pleistocene fragmentation". Given this information, it would seem that, if it was possible for the plains topminnow to disperse southeast through this hypothesized Ancestral Plains Stream, then it would seem to be equally possible that the ringed crayfish could disperse northwest through the same system.

Fish distributional data have been used to describe the hydrographic history of drainage basins (e.g. Miller 1946, Waters *et al.* 2001). In the same way, the distribution of the ringed crayfish may show us the nature of the Pleistocene and post-Pleistocene drainages in Nebraska. The ringed crayfish has been collected from the Republican, Big and Little Blue, Platte, Loup, and Niobrara River basins in Nebraska. Souders, *et al.* (1990) show the Republican River flowing east and southeasterly approximately where it is today during Illinoian times (~200,000 years ago). They also show that the North and South Platte Rivers merged into a southeasterly flowing stream in the early Pleistocene to Illinoian times (about where the Little Blue River is now). At that time, the Loup River and the Big Blue River appear to have been connected (Lueninghoener 1947, Conlon, 2005; Figure 17). The location of the upper Niobrara River is not as clear but there was a southeasterly trending paleovalley in that area in the Pliocene (Swinehart *et al.* 1985, Swinehart and Diffendal 1989) which may have connected to the Loup system. Taken together, during the Pleistocene, we have the Niobrara, Loup/Big Blue, Platte and Republican basins all trending southeasterly feeding into the Ancestral

Plains Stream that could have been the route by which the ringed crayfish could migrate from the central Ozarks to colonize these same drainages. These drainages began to separate during the post-Pleistocene formation of the Missouri River. At that time a tributary began to form (the current lower Platte River) and moved west where it captured the Loup tributaries, separating them from the Big Blue (Lueninghoener 1947) as well as capturing the pre-Pleistocene Platte River. At the same time, another tributary that was to become the Niobrara River began eroding it's way westward, capturing several of the southeast-trending drainages (Skinner *et al.* 1972) as well as the upper Niobrara River.

## Conclusions

This paper is a significant revision of the known distribution of the ringed crayfish. The revised distribution map (Figure 2) shows two main population centers with one in the cental Ozarks and a second in the Great Plains, as postulated by Williams (1954b). However, contrary to Williams (1954b) conclusions, the Great Plains population center was not totally decimated after European settlement, but has persisted to the present day as has been seen in this study.

It had been assumed that the small isolated populations of the ringed crayfish in northern Kansas, northeastern Colorado, and southwest Nebraska were relicts of a much larger distribution. Data from this study finally make sense of those isolated populations, showing that they represent the edges of a much larger range centered to the north in Nebraska. As a result, I suggest that if the Kansas portion of the Big and Little Blue River drainages were examined, the Riley and Waubaunsee County populations would connect with the Nebraska range (Figure 2).

The collection of the ringed crayfish from the Niobrara and the North Platte Rivers at the Nebraska/Wyoming border suggests that they may also be found in the Wyoming portions of these watersheds, especially the Niobrara. The collection from Crystal Lake and Granite Reservoirs in Wyoming (Hubert 1988, 2010) and from Bellaire and Parvin Lakes in Colorado (Sovell and Guralnick 2003), all in the South Platte River basin, implies that a larger portion of that watershed could be included in the range, though the possibility of bait bucket introductions at these sites cannot be ruled out. Collections by Sovell and Guralnick (2003), west of the Continental Divide in Colorado, would seem to be introductions though one wonders about their source. It is also of interest that these Wyoming and Colorado collections were from lakes, a habitat that is seldom used in Nebraska. Taken together, it appears that additional sampling in the South Platte, North Platte, and Niobrara River basins of Colorado and Wyoming is needed to refine the western limits of the distribution of the ringed crayfish.

## Literature Cited


Bergey, E. A., S. N. Jones, and D. B. Fenolio. 2004. Surveys and studies of Oklahoma crayfish and the grotto salamander. *Oklahoma Biological Survey, The University of Oklahoma. State Wildlife Grant Performance Report*. Grant No. T-11-P-1.

Conlon, S. M. 2005. Geologic studies of the Platte River, south-central Nebraska and adjacent areas-geologic maps, subsurface study, and geologic history. *United States Geological Survey Professional Paper 1706*. 63 pp.

Cranall, K. A. and A. R. Templeton. 1999. The zoogeography and centers of origin of the crayfish subgenus Procericambarus (Decapoda: Cambaridae). *Evolution* 53(1): 123-134.

Creaser, E. P. and A. I. Ortenburger. 1933. The decapod crustaceans of Oklahoma. *Publications of the University of Oklahoma Biological Survey* 5: 14-47.

Cross, F. B. 1970. Fishes as indicators of Pleistocene and recent environments in the central Plains. Pp. 241-257 *In* W. Dort, Jr. and J.K. June Jr. eds. *Pleistocene and recent environments of the Central Great Plains*. University of Kansas Press, Lawrence, KS.

Cross, F. B., R. L. Mayden, and J. D. Stewart. 1986. Fishes in the western Mississippi Basin (Missouri, Arkansas, and Red Rivers). *In* Hocutt, C.H. and E.O. Wiley, eds. *The zoogeography of North American freshwater fishes*. Wiley, New York.

Dobbs, H. J. 1918. *History of Gage County, Nebraska.* Western Publishing and Engraving Company, Lincoln, Nebraska. 1,100 pp.

Durbian, F. E., B. J. Frey, and D. W. Moore. 1994. Crayfish species from creeks and rivers of Cherokee County, Kansas. *Transactions of the Kansas Academy of Science* 97(1-2): 13-17.

Engle, E. T. 1926. Crayfishes of the Genus *Cambarus* in Nebraska and eastern Colorado. *Bulletin of the U.S. Bureau of Fisheries* 42: 87-104.

Everman, B. W. and U. O. Cox. 1896. A report upon the fishes of the Missouri River basin. *United States Commission of Fish and Fisheries, Report of the Commissioner for the year ending June 30, 1894*, Part XX: 325-429.

Faxon, W. F. 1890. Notes on the North American crayfishes-Family Astacidae. *Proceedings of the United States National Museum* 12: 619-634.

Fremont, Brevet Captain J. C., 1845. *Report Of The Exploring Expedition To The Rocky Mountains In The Year 1842, And To Oregon And North California In The Years 1843-44. Printed By Order Of The Senate Of The United States*.

(Senate Doc. 174; 28th Congress, 2nd session) Gales and Seaton, Washington, DC. 1845. 693 p.

Frye, J. C. and A. B. Leonard. 1952. Pleistocene geology of Kansas. *University of Kansas Publications, State Geological Survey of Kansas. Bulletin* 99: 1-230.

Gore, J. A. and R. M. Bryant, Jr. 1990. Temporal shifts in physical habitat of the crayfish, *Orconectes neglectus* (Faxon). *Hydrobiologia* 199: 131-142.

Hobbs, H. H., Jr. 1974. A checklist of the North and Middle American crayfishes (Decapoda: Astacidae and Cambaridae). *Smithsonian Contributions to Zoology, No. 166*, Smithsonian Institution Press, Washington, D.C. 161 pages.

Hubert, W. A. 1988. Survey of Wyoming crayfishes. *Great Basin Naturalist* 48 (3): 370-372.

Hubert, W. A. 2010. *Survey of Wyoming crayfishes.* Report prepared for the Fish Division, Wyoming Game and Fish Department, Cheyenne, Wyoming. 14 pages.

Johnson, R. E. 1942. *The Distribution of Nebraska Fishes*. M.S. Thesis, University of Michigan.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980 *et seq. Atlas of North American Freshwater Fishes*. North Carolina State Museum of Natural History, Raleigh. 854 pp.

Lueninghoener, G. C. 1947. The post-Kansan geologic history of the lower Platte Valley area. *University of Nebraska Studies, New Series, no. 2.* 82 pp.

Li, C., M. L. Bessert, J. Macrander, and G. Orti. 2009. Low variation but strong population structure in mitochondrial control region of the plains topminnow, *Fundulus sciadicus*. *Journal of Fish Biology* 74: 1037-1048.

Meek, S. E. 1894. Notes on the fishes of western Iowa and eastern Nebraska. *Bulletin of the United States Fish Commission*. Vol. XIV: 133-138.

Metcalf, A. L. and D. A. Distler. 1961. New distributional records for two species of crayfish. *Transactions of the Kansas Academy of Science* 64(4): 353-356.

Metcalf, A. L. 1966. Fishes of the Kansas River system in relation to zoogeography of the Great Plains. *University of Kansas Publications, Museum of Natural History* 17(3): 23-189.

Miller, R. R. 1946. Correlation between fish distribution and Pleistocene hydrography in eastern California and southwestern Nevada, with a map of the Pleistocene waters. *The Journal of Geology* 54(1): 43-53.

Peters. E. J., T. Barada, W. Garvey, S. C. Schainost, and R. S. Holland. 2006. *Nebraska statewide stream fishery inventory.* F-164-R Final Report, Nebraska Game and Parks Commission, Lincoln, Nebraska. 184 pp.

Pflieger, W. L. 1996. *The Crayfishes of Missouri.* Missouri Department of Conservation. 152 pp.

Phillips, G. S. 1980. The decapod crustaceans of Iowa. *Proceedings of the Iowa Academy of Science* 87(3): 81-95.

Skinner, M. F. and C.W. Hibbard. 1972. Early Pleistocene pre-glacial and glacial rocks and faunas of north-central Nebraska. *Bulletin of the American Museum of Natural History* 148(1): 14-54..

Souders, V. L., J. B. Swinehart, and V. H. Dreezen. 1990. Postulated evolution of the Platte River and related drainages. *University of Nebraska-Lincoln, Conservation and Survey Division, Map GIM*-14, 1 sheet.

Sovell, J. R. and R. Guralnick. 2003. Montane mollusk and crustacean survey of western Colorado. *2003 Annual Report to Colorado Division of Wildlife.* The Colorado Natural Heritage Program, Colorado State University. 16 pp.

Swinehart, J. B., V. L. Souders, H. M. McGrew, and R. F. Diffendal, Jr. 1985. Cenozoid paleogeography of western Nebraska. Pages 209-229 *in* Flores, R.M. and S.S. Kaplan (eds.), 1985. *Cenozoic paleogeography of west-central United States.* Rocky Mountain Section – S.E.P.M., Denver, Colorado.

Swinehart, J. B. and R. F. Diffendal, Jr. 1989. Geology of the pre-dune strata. Pages 42 *in* Bleed, A. and C. Flowerday (eds.), 1989. *An Atlas of the Sand Hills.* Resource Atlas No. 5a, Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln. 265 pages.

Unger, P. A. 1978. The crayfishes (Crustacea: Cambaridae) of Colorado. *Natural History Inventory of Colorado, No. 3. University of Colorado Museum, Boulder*. 20 pp.

Waters, J. M., D. Craw, J. H. Youngson, and G. P. Wallis. 2001. Genes meet geology: fish phylogeographic pattern reflects ancient, rather than modern, drainage connections. *Evolution* 55(9): 1844-1851.

Williams, A. B. 1954a. Speciation and distribution of the crayfishes of the Ozark plateaus and Ouachita provinces. *University of Kansas Science Bulletin* 36: 803-918.

Williams, A. B. 1954b. An explanation for the distribution of a North American crayfish. *Ecology* 35: 573-575.

Williams, A. B. and A. B. Leonard. 1952. The crayfishes of Kansas. *University of Kansas Science Bulletin,* Vol. XXXIV, Pt. II, No. 15: 962-1012.

Williams, A. B., L. G. Abele, D. L. Felder, H. H. Hobbs, Jr., R. B. Manning, P. A. McLaughlin, and I. P. Farfante. 1989. *Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans.* American Fisheries Society Special Publication 17.

## Appendix – Collection Records Sorted by River Basin and County

**Big Blue River Basin**

Gage County – Big Blue River, 31 Aug 2006, below Hiway 136 bridge in Beatrice (40.26500,-96.75491); Big Indian Creek, 9 Nov 2005, at Krider, (40.07572,-96.74618); Bloody Run, 30 Aug 2006, 2 miles south and 4 miles west of Virginia, (40.20892,-96.57679); Mud Creek, 30 Aug 2006, 1 mile south, 6 miles west of Virginia, (40.23256,-96.60997); Wildcat Creek, 31 Aug 2006, 2 miles north of Barneston (40.07304,-96.58023); Big Blue River, 6 Sept 2006, below Holmesville Dam, (40.19720,-96.6293); Plum Creek, 18 Oct 2006, 1 mile south of Barneston, (40.03573,-96.57664); Spring Creek, 18 Oct 2006, 1.5 miles south and 3 miles west of Barneston at Kansas line, (40.00106,-96.61057)

Saline County – Unnamed stream, 8 Sept 1961, 2.5 miles south of Crete (40.5732,-96.9604)

Seward County - Big Blue River, 22 Sept 1999, Blue Bluffs SWMA, (40.7406, -97.02533); Big Blue River, 4 March 2000, Blue Bluffs SWMA, (40.7401,-97.02422); Big Blue River, 6 Sept 2006, Blue Bluffs SWMA, (40.74056,-97.02503); Big Blue River, 2 March 2006, at Hiway 34 bridge, (40.9033,-97.1116); Big Blue River, 13 April 2005, Blue Bluffs SWMA, (40.74058,-97.0176); Coon Creek, 6 Sept 2006, south edge of Milford, (40.7762,-97.0479); Coon Creek, 1925, Milford, (40.7762,-97.0479); Unnamed spring, 22 June 2005, 1 mile north and 1 east of Milford, (40.79429,-97.05019); Big Blue River, 24 June 2009, Hiway 34 bridge at Seward (40.90301,-97.1-W158)

York County – Beaver Creek, 28 Sept 2000, in York City Park, (40.85908,-97.59320); Lincoln Creek, 13 Aug 2000, southeast of Gresham, (40.97483, -97.38733)

**Little Blue River Basin**

Adams County – Little Blue River, 9 Sept 1961, 4 miles east of Ayr on Hiway 74 (40.4376,-98.3566)

Jefferson County – Rock Creek, 18 Oct 2006, Hiway 8 at Endicott (40.07862,-97.09212)

Thayer County – Spring Creek, 9 Nov 2005, 6 miles west of Reynolds (40.05497,-97.44438)

**Loup River Basin**

Blaine County – Dismal River, 11 June 2003, Nebraska National Forest at Whitetail Campground (41.79657,-100.2629); Middle Loup River, 11 June 2003, at Halsey National Forest lower canoe access (41.90151,-100.29546); Middle Loup River, 22 Sept 2004, at Milburn Diversion Dam (41.75122, -99.77125); Middle Loup River, 17 Sept 2007, at Milburn Diversion (41.75072,-99.77327); Dismal River, 18 Sept 2007, at Dunning (41.32272,-100.10059); Middle Loup River, 4 Oct 2004, at Milburn Diversion (41.75122,-99.77125); Middle Loup River, 11 Aug 2008, at Dunning (41.83139,-100.10073)

Cherry County – Middle Loup River, 27 July 1993, Middle and South Branches in Cherry and Hooker Counties (42.09167,-101.238)

Custer County – Middle Loup River, 7 Nov 2003, canal off Arcadia Diversion (41.49117,-99.23867); Middle Loup River, 17 Sept 2007, at Sargent Diversion (41.62752,-99.37078); Middle Loup River, 25 May 2005, 2 miles north of Gates (41.66323,-99.64026)

Greeley County – Cedar River, 15 Sept 2009, below Spalding powerhouse (41.68117,-98.36682)

Hooker County – Middle Loup River, 17 June 2003, 4 miles east of Mullen (42.0564,-100.95728); Dismal River, 15 July 2004, 14 miles south of Mullen (41.85227,-101.03595)]; Dismal River, 21 Oct 2005, at Hiway 97 south of Mullen at the forks (41.8512,-101.0376)

Howard County – Middle Loup River, 14 June 2005, 1 mile south of St. Paul (41.20408,-98.44362); Spring Creek, 8 July 2008, 1 mile south, 0.5 miles west of Cushing (41.28552,-95.37896)

Logan County – South Loup River, 3 Aug 2004, at Hiway 83 (41.49811,-100.50395); South Loup River, 28 Oct 2009, Hiway 83 bridge (41.49757,-100.50196)

Sherman County – Middle Loup River, 8 July 2008, 1.5 miles west of Loup City (41.27633,-98.99350)

Thomas County – Middle Loup River, 11 June 2003, Halsey National Forest west access (41.97688,-100.51075); Middle Loup River, 11 June 2003, at Hiway 83 bridge at Thedford (41.97615,-100.55878); Middle Loup River, 11 June 2003, private bridge 6 miles west of Thedford (41.98453,-100.69295); Middle Loup River, 11 June 2003, Halsey National Forest canoe launch (41.90547,-100.32625); Dismal River, 16 June 2003, Hiway 83 bridge 13 miles south of Thedford (41.77908,-100.52667); Middle Loup River, 17 June 2006, off Hiway 2, 5 miles west of Thedford (41.97493,-100.6913); Middle Loup River, 14 Aug 2003, Halsey National Forest west canoe access (41.90522, -100.31557); Middle Loup River, 15 Oct 2003, Nebraska National Forest at Halsey, east canoe access (41.9014, -100.29552); Dismal River, 3 Aug 2004, at Hiway 83 bridge (41.77825, -100.52495); Middle Loup River, 30 Sept 2008, 6 miles east and 3.5 miles south of Seneca at Hi-Way 2 (41.9906, -100.7089); Dismal River, 28 April 2009, Jameson Bridge, 13.5 miles south of Thedford (41.82257, -100.64470)

Wheeler County – Cedar River, 25 May 2005, 1 mile southeast of Ericson (41.76991, -98.66841); Cedar River, 28 June 2005, 1 mile east of Ericson (41.7835, -

98.6976); Cedar River, 4 Oct 2005, just above Ericson Lake (41.76925, -98.66687)

**Niobrara River Basin**

Cherry County – Niobrara River, 27 July 2004, Nebraska National Forest canoe access south of Nenzel (42.80518,-101.12568); Niobrara River, 5 Sept 2007, below Cornell Dam in Valentine (42.89959,-100.48303); Niobrara River, 5 Sept 2007, just downstream of Fort Falls on Fort Niobrara National Wildlife Refuge (42.90339,-100.46327); Niobrara River, 2 June 2009, Anderson Bridge SWMA south of Kilgore (42.78740,-100.93032); Niobrara River, 30 June 2009, Borman Bridge SWMA southeast of Valentine (42.7874,-100.93032)

Sioux county – Niobrara River, Oct 1993, 7.7 miles south and 2.2 miles west of Harrison (42.57593, -103.93488); Niobrara River, 7 April 2004, 0.25 miles east of Nebraska/Wyoming border (42.65254, -104.05160); Niobrara River, 7 April 2004, Hiway 29 bridge at Agate (42.4236,-103.79115); Niobrara River, 26 July 2004, Hiway 29 bridge at Agate (42.42129,-103.74635); Niobrara River, 2 June 2005, Hiway 29 bridge at Agate (42.4229,-103.79122); Niobrara River, 27 July 2005, 10 miles south, 2 miles west of Harrison (42.53267,-103.92777); Niobrara River, 27 July 2005, 7.7 miles south, 2.2 miles west of Harrison (42.57593,-103.93488); Niobrara River, 2 Aug 2005, 10.5 miles south, 2 miles west of Harrison (42.52837,-103.92837); Niobrara River, 23 July 2008, Hiway 29 bridge at Agate (42.42318,-103.79189); Niobrara River, 13 April 2009, at Hiway 29 at Agate (42.42318,-103.79111)

**North Platte River Basin**

Garden County – North Platte River, 2 July 2003, 3 miles east and 2 miles south of Lewellen (41.301,-102.0713); Blue Creek, 18 May 2004, 2 mile west of Lewellen at Hiway 92 (41.34485,-102.17657); Blue Creek, 22 June 2004, 13 mile north of Oshkosh (41.53053,-102.25005); North Platte River, 14 July 2004, 1 mile south of Oshkosh (41.38093,-102.34993); Blue Creek, 23 Feb 2005, 12 miles north and 1 mile east of Oshkosh (41.56262,-102.27942); Blue Creek, 23 Sept 2008, 8 miles north and 5 miles east of Oshkosh (41.495,-102.187)

Keith County – Otter Creek, 10 Jan 1996, 5 miles north of Lake McConaughy (41.33467,-101.94017); Otter Creek, 30 Jan 2003, north side of Hiway 92 (41.3068,-101.9285); Otter Creek, 5 Nov 2003, 0.5 mile north of Lake McConaughy (41.29788,-101.92528); North Platte River, 6 May 2004, 3 miles east and 2 miles south of Lewellen (41.29958,-102.07693); Lonergan Creek, 22 June 2004, 1.25 miles east of Lemoyne (41.27730,-101.81970); Lonergan Creek, 1 Sep 2004, between Hiwy 92 and Lake McConaughy (41.27187,-101.81807); North Platte River, 22 Sept 2004, below Keystone Diversion (41.21035,-101.63242); Otter Creek, 23 Feb 2005, 2 miles north of Lake McConaughy (41.33093,-101.9356); Whitetail Creek, 11 April 2007, 2 miles west of Keystone (41.22184,-101.61921); Birdwood Creek, 11 April 2007, 4 miles north and 3 miles west of Hershey (41.22149,-101.07041); Clear Creek, 23 Sept 2008, 5.5 miles east of Lewellen (41.32270,-102.04120)

Lincoln County – Sutherland Canal, 23 Oct 2001, 1.5 miles downstream of Keystone Diversion Dam (41.206,-101.6052); North Platte River, 16 Oct 2002, North River SWMA (41.1985,-101.0013); Whitehorse Creek, 5 Nov 2003, 1 mile north of North Platte at Hiway 83 bridge (41.1733,-100.7547); Lake Maloney, 9 March 2006, at canal inlet (41.0473,-100.7952); Sutherland Canal, 9 March 2006, 4 miles south and 1 mile east of Hershey (41.0958,-100.9832); North Platte River, 29 May 2008, 4 miles north and 0.5 miles east of Sutherland (41.21086,-101.11745)

Morrill County – Red Willow Creek, March 1994, 1 mile north and 1 mile east of Bayard (41.7733,-103.2465); North Platte River, 20 May 2004, Hiway 26 bridge at Bridgeport (41.6763,-103.0968); Cedar Creek, 23 June 2004, 6 miles south and 1.5 miles east of Broadwater (41.52049,-102.82376); North Platte River, 22 May 2006, downstream of Broadwater bridge (41.5817,-102.8549); North Platte River, 25 July 2006, below Belmont Diversion Dam (41.70131,-103.24395)

Scottsbluff County – Ninemile Creek, 21 Feb 2003, Ninemile Creek SWMA (41.89438,-103.43377); Ninemile Creek, 7 Aug 2003, Ninemile Creek SWMA (41.88918,-103.43369); Winters Creek, 23 June 2004, 3.5 miles east of Scottsbluff (41.85796,-103.62643); North Platte River, 13 July 2004, 1 mile east and 1 mile south of Henry (41.98406,-104.03452); Alliance Drain, 20 Oct 2004, in canal below Lake Minatare (41.91768,-103.48917); Ninemile Creek, 1 June 2006, Ninemile Creek SWMA (41.88942,-103.43368); Ninemile Creek, 7 June 2006, Ninemile Creek SWMA (41.87844,-103.43517); Indian Creek, 25 July 2006, 2 miles northwest of Bridgeport at railroad crossing (41.6959,-103.1230); Minatare Drain, 20 March 2007, 1 mile east of Minatare (41.8150,-103.4759); North Platte River, 3 April 2007, at diversion dam south of Morrill (41.9383,-103.92603); Sheep Creek, 3 April 2007, 1 mile west of Morrill (41.96609,-103.95009); Ninemile Creek, 29 May 2007, 2 miles east and 2 miles north of Minatare (41.83759,-103.46125); Ninemile Creek, 31 Aug 2007, Ninemile Creek SWMA (41.88860,-103.46502); North Platte River, 19 Sept 2007, 1 mile west of Scottsbluff at Hiway 92 (41.86582,-103.72090); Dry Spotted Tail Creek, 15 July 2009, 3 miles north and 1 mile west of Mitchell (41.98619,-103.83214); Dry Spotted Tail Creek, 15 July 2009, 5 miles north and 1 mile west of Mitchell (42.01548,-103.82517); Dry

Spotted Tail Creek, 14 July 2009, 4 miles north and 1 mile west of Mitchell (42.00077,-103.82930)

**South Platte River Basin**

Lincoln County – Fremont Slough, 12 Oct 2005, Hiway 83 bridge at North Platte (41.09727,-100.76432); South Platte River, 17 May 2008, at Hershey (41.14633,-101.00262); Fremont Slough, 23 June 2008, 2.5 miles south and 3 miles west of North Platte (41.10795,-100.84886)

**Middle Platte River Basin**

Dawson County – Platte River, 19 May 2005, 3 miles south of Lexington (40.73558,-99.74544)

Lincoln County – Platte River, 17 May 2005, 0.25 mile south of Brady (41.01804,-100.36910); South Channel Platte River, 12 Oct 2005, 2 miles south and 0.5 mile west of Brady on Chester Island SWMA (40.9927,-100.3879); Pawnee Creek, 12 Oct 2005, 2 miles west of Brady at Hiway 30 (41.0363,-100.3892); South Channel Platte River, 16 March 2006, 2 miles south and 0.5 mile west of Brady on Chester Island SWMA 940.9930,-100.3908); Whitehorse Creek, 28 April 2009, 3 miles east of North Platte at Hiway 30 (41.12681,-100.67179)

**Republican River Basin**

Chase County – Frenchman Creek, 12 Oct 2005, below Enders Dam (40.42087,-101.51267)

Dundy County – Rock Creek, 31 Oct 1995, at Rock Creek State Fish Hatchery (40.11685,-101.78057); Rock Creek, 27 March 1996, Rock Creek State Fish Hatchery (40.1445,-101.1270); Rock Creek, 20 May 2003, 4 miles north and 3 miles west of Parks above Rock Creek Lake (40.10557,-101.76865); Rock Creek, 25 May 2004, at Rock Creek State Fish Hatchery (40.10547,-101.77452); Rock Creek, 26 May 2004, at Parks (40.04104,-101.72331); Rock Creek, 13 May 2009, just above Rock Creek State Lake (40.10022,-101.76659); Republican River, 13 May 2009, south of Benkelman (40.03445,-101.54311)

Franklin County – Thompson Creek, 8 June 2004, 6 miles north of Riverton (40.13660,-98.77198)

Frontier County – Medicine Creek, 2 June 2004, 1 mile east of Stockville (41.53399,-100.37364)

Furnas County – Elk Creek, 9 Sept 2005, 1 mile east of Arapahoe (40.22257,-99.88048); Deer Creek, 2 Sept 2009, at Holbrook (40.30695,-100.00587)

Harlan County – Spring Creek, 9 Sept 2005, 3 miles east of Oxford on Hiway 136 (40.22117,-99.57057)

Hayes County – Red Willow Creek, 27 July 2006, 8 miles north and 4.5 miles east of Hayes Center (40.62175,-100.94138)

Lincoln County – Medicine Creek, 1 June 2004, below Wellfleet Lake (40.74407,-100.72974); Medicine Creek, 1 June 2004, above Wellfleet Lake (40.76132,-100.75584)

Red Willow County – Republican River, 1 Sept 2009, 2 miles east and 0.5 mile south of Indianola at Bartley Diversion Dam (40.22477,-100.38667)

Webster County – Elm Creek, 9 June 2004, 4 miles north of Lester (40.17174,-98.44540); Republican River, 9 Sept 2004, 2 miles south of Red Cloud (40.06257,-98.51923); Elm Creek, 9 Sept 2004, 4 miles east and 2 miles north of Red Cloud on Elm Creek SWMA (40.1183,-98.44508).