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PRIMARY RESEARCH PAPER

Archaeological data suggest broader early historic distribution for blue sucker (*Cycleptus elongatus*, Actinopterygii, Catostomidae) in New Mexico

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Abstract Zooarchaeological data are increasingly important for establishing late Holocene conservation baselines for species of concern. The blue sucker (*Cycleptus elongatus*) is experiencing range reduction and is endangered in the State of New Mexico. The early historic (ca. AD 1540) distribution of blue sucker is poorly understood, and the extent of habitat loss is unclear. In 1961, two blue sucker skeletal elements were recovered from a late prehistoric/early historic archaeological site in northern New Mexico called Rainbow House (LA 217). Those remains suggest that the past range of blue sucker was larger; however, since that publication, little consideration has been given to the past presence of this species in the Upper Rio Grande. New zooarchaeological data from a site in northern New Mexico called Ponsipa (LA 297) have revealed the presence of multiple blue sucker skeletal elements. Additionally, a review of site reports and regional archaeological journal publications increased the abundance of blue sucker elements found at Rainbow House and added three archaeological sites where blue sucker has been reported in the region. Collectively, this information suggests a broader pre-impoundment distribution for blue sucker than previously recognized and can help establish a new baseline for their conservation or restoration in New Mexico.

Keywords Applied zooarchaeology · Applied biogeography · Blue sucker (*Cycleptus elongatus*) · New Mexico · Upper Rio Grande

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Introduction

In recent decades, conservation biologists have turned to datasets and expertise from paleontology and archaeology to provide baselines for environmental management (Frazier, 2007; Humphries & Winemiller, 2009). Often, such research focuses on skeletal or exoskeletal remains recovered from paleontological or archaeological contexts of known age that date prior to contemporary human impacts, such as urbanism, industrial agriculture, and modification of rivers. Such research has been termed "applied zooarchaeology" (Lyman, 1996) or "applied paleozoology" (Wolverton & Lyman, 2012; see also Dietl et al., 2015); we use the term applied zooarchaeology in this paper. Applied zooarchaeological data are particularly valuable for understanding biogeographic shifts in species' ranges over time (Peacock et al., 2012). Like many rivers in

the US, the ecosystems associated with waterways in New Mexico have been highly modified over the last century due to impoundment for power, irrigation for agriculture, and provisioning of water for municipalities. As a result, the distribution of aquatic species is likely to have been altered as connectivity along rivers has been interrupted. If modern human impacts on the rivers of New Mexico have caused range constrictions for native fish species, the extent of such changes is unclear. One such species that exhibits ambiguous range constriction is the blue sucker (*Cycleptus elongatus* Lesueur, 1817 Catostomidae).

The blue sucker was listed as endangered in the state of New Mexico in 1976. Not much is known about the historic range of this species because of how difficult it is to find during surveys. Its current distribution in the state is in the Pecos River drainage basin, and the most stable populations are found in the Lower Pecos between the Brantley and Avalon dams (Propst, 1999). However, in 1961, Gehlbach & Miller reported the presence of two archaeological blue sucker skeletal specimens from Rainbow House (site number: LA 217), which is located in Bandelier National Monument and was occupied from approximately A.D. 1400 to 1600. The authors suggested that in the past the blue sucker occurred farther north than was previously thought when temperature and flow in the Rio Grande were more stable. At best, the zooarchaeological data reported by Gehlbach & Miller (1961) are treated as an ancillary piece of conservation evidence concerning the past distribution of blue sucker, and at worst they are rejected in terms of their meaning for biogeography and conservation. For instance, (Propst, 1999, p. 52) states that "[a]lthough archaeological evidence from Native American ruins indicates the blue sucker inhabited the Rio Grande in New Mexico… no specimens exist to confirm its historic occurrence there."

In this paper, we report new data on blue sucker remains from the archaeological site of Ponsipa'akeri (LA 297; hereafter Ponsipa). Further, we provide evidence from additional archaeological sites that indicate the historic range of blue sucker included the Upper Rio Grande. If the blue sucker occurred farther north than previously recognized, then the extent of habitat loss for this species is dramatically larger than currently accepted. If so, the identification of relict populations in the Rio Grande may be worthwhile and restoration of this species might be defensible.

Systematics, distribution, and life-history

Until recently, it was believed that the blue sucker was monotypic at the genus level within the family Catostomidae (subfamily Cycleptinae). Burr & Mayden (1999), however, formally described the southeastern blue sucker (*Cycleptus meridionalis* Burr & Mayden, 1999 Catostomidae) based on scale counts, lip morphology, body measurements, and head morphology. *C. meridionalis* is only found in the gulf slope drainages of the Mississippi River Basin, and *C. elongatus* is distributed throughout the interior of North America (Fig. 1). It occurs in the Mississippi River Basin with smaller populations in the Rio Grande Basin, mainly around Big Bend National Park. Even more recently, Bessert (2006) provided phylogenetic information that suggests the blue suckers present in the Rio Grande Basin are a distinct species. It is unclear how past populations entered into the Rio Grande, but researchers posit that either lateral or coastal migration occurred during the Miocene (Bessert, 2006). Within the Rio Grande Basin, during the historic period, blue suckers were recorded in the Pecos River from the Carlsbad area to the Texas/New Mexico border (Propst, 1999). Blue suckers also inhabit lower portions of the Black River (Cowley & Sublette, 1987; Zymonas & Propst, 2007). Zymonas & Propst (2007) found that the range of blue sucker decreased dramatically in the Pecos from 2001 to 2006 due to massive fish kills caused by golden algae blooms. Although some biologists argue that range-wide declines, especially in the Rio Grande, are an artifact of sampling effort (Burr & Mayden, 1999), the consensus is that the blue sucker is experiencing significant range reduction (see Williams et al., 1989; Bessert & Ortí, 2008). This seems to relate to two factors: first, the presence of dams that inhibit spawning migration and gene flow, and second, an increase in stream contaminants related to runoff.

The blue sucker has a periodic life-history strategy, which is characterized by long generation times, older ages at sexual maturity, large body size, high fecundity, and low juvenile survivorship (Winemiller & Rose, 1992). It is a large-bodied benthopelagic fish with a total length of approximately 66 cm, and it is a relatively long-lived fish with a maximum age around 22–37 years (Bednarski & Scarnecchia, 2006; Labay et al., 2011). Common foods of blue sucker include midge and caddisfly larvae as well as algae (Sublette

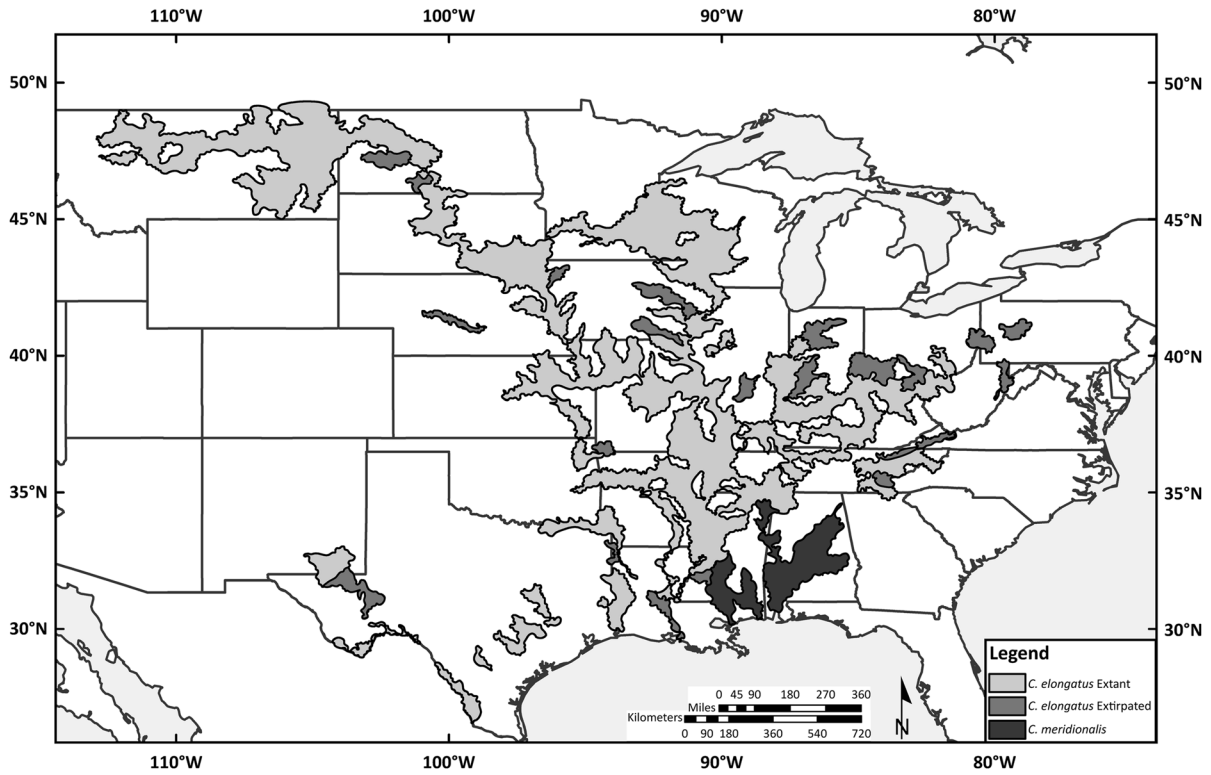

Fig. 1 North American distribution of blue sucker (*Cycleptus elongatus*) and southeastern blue sucker (*Cycleptus meridionalis*) based on its presence in watershed. Areas of likely extirpation for *C. elongatus* are also mapped. Distribution data provided by *NatureServe*

et al., 1990; Walburg et al., 1971). The age at sexual maturity for blue suckers is approximately 3-years old; females mature faster than males and exhibit larger sizes (Moss et al., 1983). Generation times are roughly 10 years (Bessert & Ortí, 2008). *C. elongatus* is a non-guarding annual spring spawner (April–June) that can migrate hundreds of kilometers upstream to deposit young in deep riffles that have coarse substrate (Moss et al., 1983; Mettee & Shepard, 1997). In the middle Missouri River, blue suckers rely heavily on different habitat types between spring and summer (Neely et al., 2010). Particularly preceding spawning, blue suckers choose to occupy habitats with reduced water velocity as a way to reduce the energetic costs of reproduction. Post spawning, blue sucker prefer habitats with an increased amount of food sources. Juvenile blue suckers are more commonly affiliated with off-channel habitats than with main channel habitats in the Mississippi River, and they frequently feed on invertebrates associated with vegetated islands (Adams et al., 2006).

The biogeography and life-history ecology of blues suckers indicate that river connectivity, flow rate, and primary and secondary production are crucial for their reproduction and for the survival of juveniles. Further, as a large-bodied fish with a long reproductive cycle that travels long distances to spawn, the blue sucker is vulnerable to population reduction in the face of declining habitat availability and connectivity.

Materials and methods

Study site

Ponsipa is located about 53 km northeast of Rainbow House on the east bank of the Rio Ojo Caliente—nearly 435 km away from where blue suckers are currently found on the Pecos River (Zymonas & Propst, 2007). The site is approximately 15 km upstream from the confluence of the Rio Ojo Caliente and Rio Chama, and from there the Rio Chama joins with the Rio Grande about 9 km downstream. Ponsipa included three cultural occupations, and the peak population at the site was around 1350 people (Duwe,

2011). The site was excavated in 1910 by Sylvanus Morley and from 1979 to 1981 by David Bugé. Blue sucker remains were recovered during Bugé's excavation, most of which derive from sedimentary deposits late in the site's occupational sequence.

Blue sucker identification at Ponsipa

Comparative collections, which are libraries of skeletal specimens of known taxonomy, are imperative for precise zooarchaeological identifications (Lyman, 2010). The Ponsipa ichthyofauna was identified using three comparative collections—at the University of North Texas, Laboratory of Zooarchaeology; the Vertebrate Paleontology Laboratory located at the University of Texas; and at the Museum of Southwestern Biology housed at the University of New Mexico. Each bone and bone fragment from Ponsipa received individual attention to avoid taxonomic designation based on what had previously been identified in the assemblage, which is a problem known as identification by association (see Driver, 1992; Wolverton, 2013). Positive identifications to blue sucker were made through morphological comparison to multiple sucker skeletal specimens. In addition to comparative specimens, guides and keys can also be useful in aiding faunal identification. The main key used for identification of skeletal elements in this study comes from Branson (1962), though other sources were used (Nelson 1948, 1949; Gehlbach & Miller, 1966; Eastman, 1977, 1980; Olsen, 1968).

When identifying faunal remains from archaeological sites, it is important to recognize taxa that potentially overlap in skeletal morphology, and thus their remains can be difficult to distinguish (Wolverton, 2013). There are four sucker species that are anticipated to occur in the Upper Rio Grande: the blue sucker, the Rio Grande sucker (*Catostomus plebeius* Baird & Girard, 1854 Catostomidae), the white sucker (*Catostomus commersonii* Lacepède, 1803 Catostomidae), and the river carpsucker (*Carpiodes carpio* Rafinesque, 1820 Catostomidae) (Sublette et al., 1990). Unlike the blue sucker, which is in the subfamily Cycleptinae, the Rio Grande sucker is in the subfamily Catostominae and is a small-bodied fish with a maximum total length at 20 cm. The common total length of blue sucker is approximately three times as great as the maximum total length of Rio Grande sucker. Therefore, we assume that blue sucker skeletal remains can be distinguished from Rio Grande sucker based on this difference in body size. The white sucker, also in the subfamily Catostominae, is a large-bodied sucker and might be difficult to separate from the blue sucker, but this species was introduced to the Rio Grande in the mid to late nineteenth century and was not present in the Upper Rio Grande during the late prehistoric/early historic periods. The river carpsucker is, however, a relatively large-bodied catostomid belonging to the subfamily Ictiobinae that is native to the Upper Rio Grande and might be difficult to separate from the blue sucker. Therefore, it is important to describe osteological criteria for distinguishing blue sucker skeletal remains from those of river carpsucker.

Results

Blue sucker remains from Ponsipa

Blue sucker remains from Ponsipa provide an additional point of reference, along with those reported by Gehlbach & Miller (1961) who document the extent of this fishes' distribution in the Rio Grande basin. Fish specimens are common at Ponsipa, and 10 blue sucker specimens were identified. The blue sucker specimens are represented by eight skeletal elements: the urohyal, pharyngeal, opercle, maxilla, cleithrum, parasphenoid, hyomandibular, and basipterygium. Only one of each skeletal element is represented at the site except for the cleithrum and basipterygium, each of which are represented by two elements. General osteological characteristics and terminology utilized below derive from Rojo (1991).

Smith (1992) utilized the urohyal to construct phylogenies of members of the family Catostomidae, and from his analysis it is clear that the cycleptine urohyal is morphologically distinct at the subfamily level. As Gehlbach & Miller (1961) noted, the backward oriented wings of the urohyal are diagnostic in *C. elongatus*. The process on the urohyal of the carpsucker is split (Fig. 2a). The pharyngeal arch and teeth of *C. elongatus* are robust, and compared to the river carpsucker the pharyngeal arch is slender and the teeth are fine (Fig. 2b). The opercle of the blue sucker has a rounded posterior angle and dorsal edge, while the carpsucker has a sharp posterior angle and a flat to concave dorsal edge (Fig. 2c). The caudal process of the maxilla is dorsoventrally oriented in *C. elongatus*,

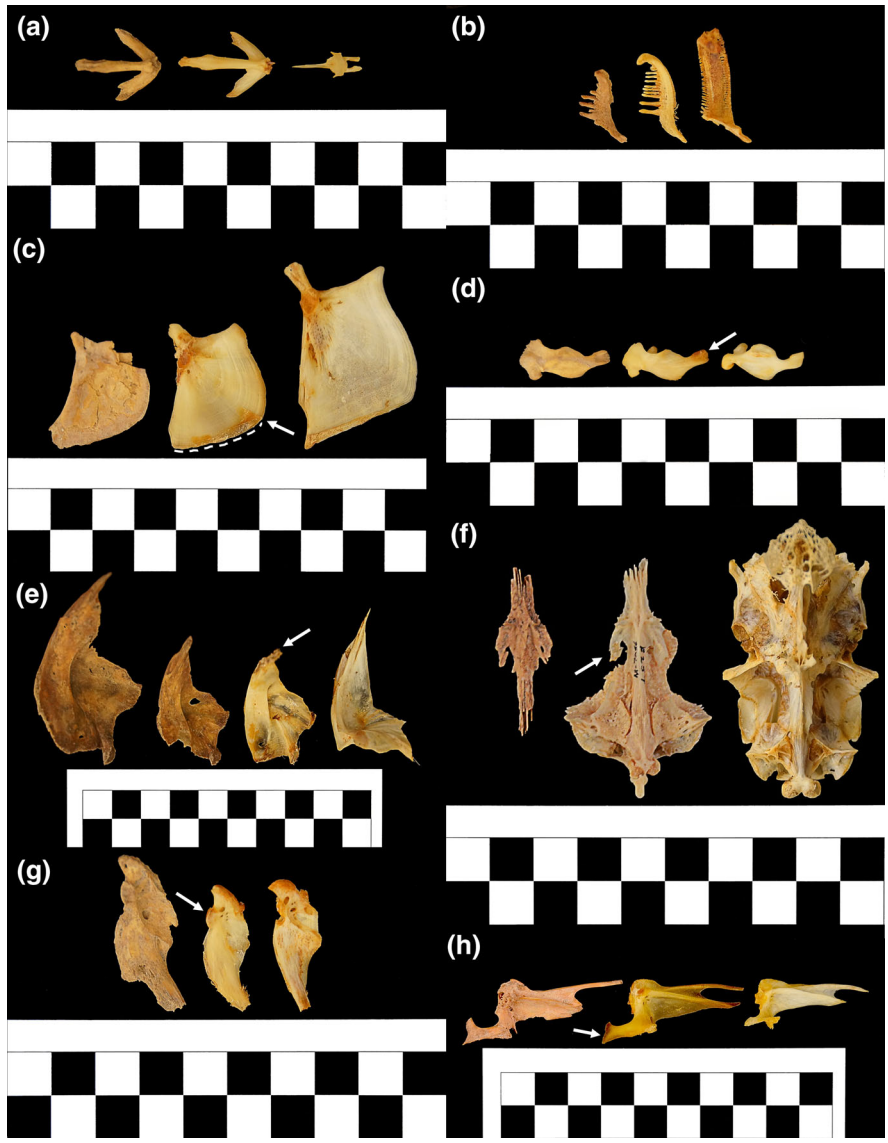

Fig. 2 Archaeological blue sucker (*Cycleptus elongatus*) specimens from Ponsipa compared to modern blue sucker comparative specimens and modern river carpsucker specimens (*Carpiodes carpio*). **A** urohyal, **B** left pharyngeal arch, **C** right opercle with *arrow* pointing to posterior angle and the *dotted line* showing the shape of the dorsal edge, **D** right maxilla with *arrow* pointing to caudal process, **E** cleithra with *arrow* pointing to dorsal narrow strut, **F** parasphenoids with *arrow* pointing to alar process, **G** left hyomandibular with *arrow* pointing to the pterotic facet, and **H** left basipterygium with *arrow* pointing to posterior process

while it is twisted in the *C. carpio* (Fig. 2d). The cleithra of blue sucker have a pinched dorsal narrow strut and a more robust body, the cleithra of the carpsucker is narrow and has a dorsal narrow strut that gradually tapers to a point (Fig. 2e). The alar process of the parasphenoid in the blue sucker is oriented downwards and the midpart of the parasphenoid body has prongs, while these features are absent in the river carpsucker (Fig. 2f). The hyomandibular exhibits an accentuated S-shape in *C. elongatus* with a projected pterotic facet, and is straighter in shape with a less pronounced pterotic facet in the river carpsucker (Fig. 2g). Finally, the posterior process of the basipterygium in *C. elongatus*, as evidenced by Branson (1962), is less pointed with a more laterally oriented external process, and the posterior process is more pointed in the river carpsucker with an external process that points directly forward (Fig. 2h). Based on these characteristics, the remains from Ponsipa can be identified to blue sucker.

The early historic distribution of blue sucker in northern New Mexico

In addition to the remains from Ponsipa, Gehlbach & Miller (1961) reported the presence of a blue sucker

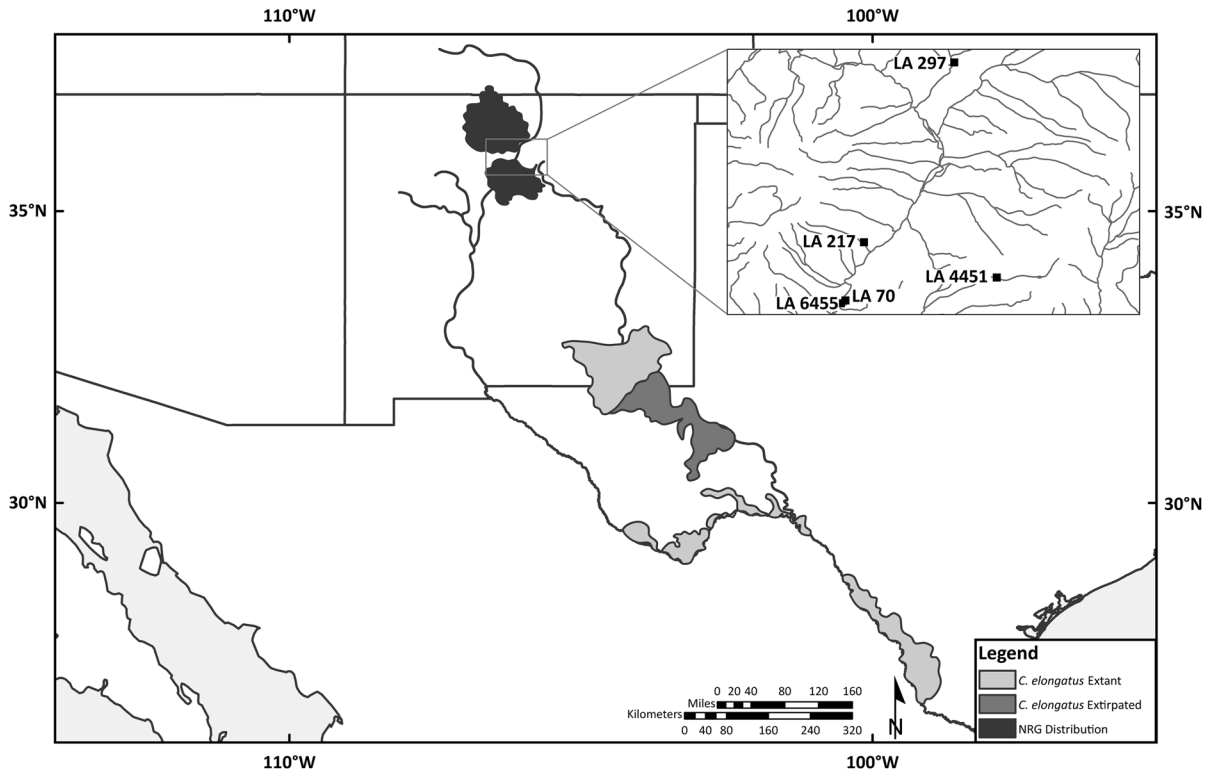

Fig. 3 Distribution of blue sucker (*Cycleptus elongatus*) in the Rio Grande Basin based on its presence in watershed. Five archaeological sites where blue sucker (*Cycleptus elongatus*) has been identified in the Northern Rio Grande (NRG) region are highlighted. Areas of likely extirpation for *C. elongatus* are also mapped. Distribution data provided by *NatureServe*

urohyal bone and an incomplete Weberian apparatus from Rainbow House, which was occupied ca. A.D. 1400 to 1600 (Kohler, 2004). In regards to the identifiability of the urohyal bone, Gehlbach & Miller (1961, p. 5) state that "[w]ith its broad, strongly developed wings directed obliquely backward and originating at the anteroventral end of the bone, the urohyal is unlike that of any other genus of North American sucker and this establishes without question its pertinence to the monotypic genus *Cycleptus*." Concerning the date blue sucker remains were deposited at the site, Gehlbach & Miller (1961) specify that the "bones were associated with Kidder's Glaze IV pottery, which dates them between approximately 1550 and 1600 A.D." The historic period in the northern Rio Grande region is generally regarded as starting at A.D. 1540 with Francisco Vázquez de Coronado's entrada (Barrett, 2009), suggesting that blue suckers were in the northern Rio Grande during the historic period.

Sixteen years after excavations ceased at Rainbow House, Caywood (1966) compiled a site report in which he mentioned the blue sucker remains identified by Gehlbach & Miller. Caywood described five additional blue sucker specimens from Rainbow House that were identified by Miller as four basipterygia and one lateral ethmoid. These specimens suggest that people were exploiting blue sucker from either the Rito de los Frijoles, the tributary that runs through Bandelier National Monument, or the Rio Grande less than 3 km away.

Blue suckers appear to have been more ubiquitous in the archaeological record of the Upper Rio Grande than once thought (Fig. 3). In addition to the specimens from Rainbow House and Ponsipa, blue sucker remains have been reported from three other archaeological sites. In addition, Sublette et al. (1990) noted the possibility that blue sucker remains were recovered farther downstream. Particularly, the authors mention sites related to the Cochiti Dam Archaeological Salvage Project. This assertion was corroborated by Snow (2002). In one of the few publications detailing how fishes may have been utilized in the

region during the late prehistoric and early historic periods, Snow (2002) reports three sites, two of which are from the Cochiti Dam project, from the Northern Rio Grande from which *C. elongatus* specimens were identified in 1983 by W. J. Koster, the former Curator of Fishes at the University of New Mexico. While the current study has gone to great lengths to ensure that specimens from Ponsipa represent blue sucker, the identifications given by Koster are assumed to be accurate because of his extensive experience in handling fish specimens from New Mexico. The three archaeological sites that have gone unmentioned in the conservation literature are Palace of the Governors (LA 4451) that was occupied from A.D. 1605 to 1692, Alfred Herrera (LA 6455) occupied around A.D. 600 to 1600, and Pueblo del Encierro (LA 70), which was occupied from A.D. 1300 to 1600. Both Alfred Herrera and Pueblo del Encierro were excavated as part of the Cochiti Dam project.

Discussion

It is clear that the pre-impoundment distribution of the blue sucker was more extensive in the state of New Mexico at the start of the historic period than it is today, which may relate to installation of impoundments on the Rio Grande. The extent of spawning migration is a key attribute of the blue sucker's periodic life-history strategy. Although this species is adapted to periods of discontinuity from intermittent flow that sometimes characterizes the Rio Grande, it is also adapted to rapidly take advantage of the re-establishment of continuity and increased flow in river systems. For the blue sucker, the fragmentation of its habitat caused by impoundments creates permanent discontinuity and severely disrupts migration and spawning. One way to promote increased habitat connectivity for this species, and potential re-establishment of past range is through the construction of fishways. Cooke et al. (2005) note that relatively little work has been done understanding how suckers utilize fishways. The construction and monitoring of fishways in the lower Pecos might be a good way to assess the feasibility of reconnecting past habitat and thus, possibly, restoring blue sucker in the Rio Grande.

In addition, it is possible that relict populations exist in the Rio Grande that have not been found during contemporary fish surveys. If relict populations are encountered, it is clear that they should be targeted for conservation based on applied zooarchaeological data indicating range curtailment during the historic period. The Comprehensive Wildlife Conservation Strategy for the state of New Mexico (New Mexico Department of Game and Fish, 2006) has no clear management plan for this species, and labels its monitoring as "periodic." For any new sampling and more effective management to be done, a clear conservation strategy is required.

Finally, the taxonomic status of the blue sucker in the Rio Grande is in question. Bessert (2006) found that Rio Grande blue suckers form a unique clade among other populations of *C. elongatus* and *C. meridionalis*. This clade seems to have diverged almost ten million years ago. Such data may lead to the formal taxonomic description of a new species of cycleptine in the Rio Grande. If this does occur, Rio Grande blue sucker would be a prime candidate for federal listing as an endangered species, and its conservation in the state of New Mexico is warranted.

Conclusion

It has been 55 years, since Gehlbach & Miller published their novel paper on archaeological blue sucker remains at Rainbow House in the American Southwest, and, since then, little research has been reported on the pre-impoundment distribution of blue sucker in the state of New Mexico. With increased sample size from Rainbow House, reporting of remains from three additional archaeological sites, and new data from Ponsipa, it is clear that the extent of the blue sucker's pre-impoundment distribution included the Upper Rio Grande. This zooarchaeological evidence indicates that range decline in this species has been dramatic, and should the Rio Grande blue sucker be formally described as a species, it may meet criteria to be considered federally endangered. The Northern Rio Grande region has recently received renewed archaeological attention (see Ortman, 2012; Vierra, 2013 and references therein), and it is possible that with new zooarchaeological data, a clearer early historic distribution of the blue sucker will continue to be revealed.

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References

Adams, S. R., M. B. Flinn, B. M. Burr, M. R. Whiles & J. E. Garvey, 2006. Ecology of larval blue sucker (*Cycleptus elongatus*) in the Mississippi River. Ecology of Freshwater Fish 15: 291–300.

Barrett, E. M., 2009. Conquest and Catastrophe: Changing Rio Grande Pueblo Settlement Patterns in the Sixteenth and Seventeenth Centuries. University of New Mexico Press, Albuquerque.

Bednarski, J. & D. L. Scarnecchia, 2006. Age structure and reproductive activity of the blue sucker in the Milk River, Missouri River drainage, Montana. Prairie Naturalist 38: 167–182.

Bessert, M. L., 2006. Molecular systematics and population structure in the North American endemic fish genus *Cycleptus* (Teleostei: Catostomidae). Doctoral Dissertation. University of Nebraska - Lincoln.

Bessert, M. L. & G. Ortí, 2008. Genetic effects of habitat fragmentation on blue sucker populations in the upper Missouri River (*Cycleptus elongatus* Lesueur, 1918). Conservation Genetics 9: 821–832.

Branson, B. A., 1962. Comparative cephalic and appendicular osteology of the fish family Catostomidae. Part I, *Cycleptus elongatus* (Lesueur). The Southwestern Naturalist 7: 81–153.

Burr, B. M. & R. L. Mayden, 1999. A new species of *Cycleptus* (Cypriniformes: Catostomidae) from Gulf Slope drainages of Alabama, Mississippi, and Louisiana, with a review of the distribution, biology, and conservation status of the genus. Bulletin of the Alabama Museum of Natural History 20: 19–57.

Caywood, L. R., 1966. Excavations at Rainbow House, Bandelier National Monument, New Mexico. National Park Service, Southwest Archeological Center, Globe, Arizona.

Cooke, S. J., C. M. Bunt, S. J. Hamilton, C. A. Jennings, M. P. Pearson, M. S. Cooperman & D. F. Markle, 2005. Threats, conservation strategies, and prognosis for suckers (Catostomidae) in North America: Insights from regional case studies of a diverse family of non-game fishes. Biological Conservation 121: 317–331.

Cowley, D. E. & J. E. Sublette, 1987. Distribution of fishes in the Black River drainage, Eddy County, New Mexico. The Southwestern Naturalist 32: 213–221.

Dietl, G. P., S. M. Kidwell, M. Brenner, D. A. Burney, K. W. Flessa, S. T. Jackson, & P. L. Koch., 2015. Conservation Paleobiology: leveraging knowledge of the past to inform conservation and restoration. Annual Review of Earth and Planetary Sciences 43.

Driver, J. C., 1992. Identification, classification and zooarchaeology. Circaea 9: 35–47.

Duwe, G., 2011. The Prehispanic Tewa World: Space, Time, and Becoming in the Pueblo Southwest. Doctoral Dissertation. The University of Arizona.

Eastman, J. T., 1977. The pharyngeal bones and teeth of catostomid fishes. American Midland Naturalist 97: 68–88.

Eastman, J. T., 1980. The caudal skeletons of Catostomid fishes. American Midland Naturalist 103: 133–148.

Frazier, J., 2007. Sustainable use of wildlife: The view from archaeozoology. Journal for Nature Conservation 15: 163–173.

Gehlbach, F. R. & R. R. Miller, 1961. Fishes from archaeological sites in northern New Mexico. The Southwestern Naturalist 6: 2–8.

Humphries, P. & K. O. Winemiller, 2009. Historical impacts on river fauna, shifting baselines, and challenges for restoration. BioScience 59: 673–684.

Kohler, T. A. (ed.), 2004. Archaeology of Bandelier National Monument: Village Formation on the Pajarito Plateau, New Mexico. University of New Mexico Press, Albuquerque.

Labay, S. R., J. G. Kral & S. M. Stukel, 2011. Precision of age estimates derived from scales and pectoral fin rays of blue sucker. Fisheries Management and Ecology 18: 424–430.

Lyman, R. L., 1996. Applied zooarchaeology: the relevance of faunal analysis to wildlife management. World Archaeology 28: 110–125.

Lyman, R. L., 2010. Paleozoology's dependence on natural history collections. Journal of Ethnobiology 30: 126–136.

Mettee, M. F. & T. E. Shepard, 1997. Status survey of a blue sucker (*Cycelptus elongatus*) population below Millers Ferry lock and dam, Wilcox County. Alabama Geological Survey of Alabama, Tuscaloosa.

Moss, R. E., J. W. Scanlan & C. S. Anderson, 1983. Observations on the natural history of the blue sucker (*Cycleptus elongatus* Le Sueur) in the Neosho River. American Midland Naturalist 109: 15–22.

Neely, B. C., M. A. Pegg & G. E. Mestl, 2010. Seasonal resource selection by blue suckers (*Cycleptus elongatus*). Journal of Fish Biology 76: 836–851.

Nelson, E. M., 1948. The comparative morphology of the Weberian apparatus of the Catostomidae and its significance in systematics. Journal of Morphology 83: 225–251.

Nelson, E. M., 1949. The opercular series of the Catostomidae. Journal of Morphology 85: 559–567.

New Mexico Department of Game and Fish, 2006. Comprehnsive Conservation Strategy for New Mexico. New Mexico Department of Game and Fish, Santa Fe.

Olsen, S. J., 1968. Fish Amphibian and Reptile Remains from Archaeological Sites. Peabody Museum, Cambridge.

Ortman, S. G., 2012. Winds from the North: Tewa Origins and Historical Anthropology. University of Utah Press, Salt Lake City.

Peacock, E., C. R. Randklev, S. Wolverton, R. A. Palmer & S. Zaleski, 2012. The "cultural filter," human transport of mussel shell, and the applied potential of zooarchaeological data. Ecological Applications 22: 1446–1459.

Propst, D. L., 1999. Threatened and endangered fishes of New Mexico. In Marsh, P. C. (ed), Technical Report No. 1, 1999, New Mexico Department of Game and Fish, Santa Fe

Rojo, A. L., 1991. Dictionary of Evolutionary Fish Osteology. CRC Press, Boca Raton.

Smith, G. R., 1992. Phylogeny and biogeography of the Catostomidae, freshwater fishes of North American and Asia. In Mayden, R. L. (ed.), Systematics, Historical Ecology, and North American Freshwater Fishes. Stanford University Press, Stanford: 778–826.

Snow, C. T., 2002. Fish tales: The use of freshwater fish in New Mexico from A.D. 1000 to 1900. In Wiseman, R., T. O'Laughlin & C. T. Snow (eds), Forward into the Past: Papers in Honor of Teddy Lou and Francis Stickney. Archaeological Society of New Mexico, Albuquerque: 119–131.

Sublette, J. E., M. D. Hatch & M. F. Sublette, 1990. The Fishes of New Mexico. University of New Mexico Press, Albuquerque.

Vierra, B. J. (ed.), 2013. From Mountaintop to Valley Bottom: Understanding Past Land Use in the Northern Rio Grande Valley, New Mexico. The University of Utah Press, Salt Lake City.

Walburg, C. H., G. L. Kaiser & P. L. Hudson, 1971. Lewis and Clark Lake tailwater biota and some relations of the tailwater and reservoir fish populations. In Hall, G. E. (ed.), Reservoir Fisheries and Limnology. American Fisheries Society, Bethesda: 449–467.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister & J. E. Deacon, 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14: 2–20.

Winemiller, K. O. & K. A. Rose, 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49: 2196–2218.

Wolverton, S., 2013. Data quality in zooarchaeological faunal identification. Journal of Archaeological Method and Theory 20: 381–396.

Wolverton, S. & R. L. Lyman, 2012. Conservation Biology and Applied Zooarchaeology. University of Arizona Press, Tucson.

Zymonas, N. D. & D. L. Propst, 2007. Ecology of Blue Sucker and Gray Redhorse in the Lower Pecos River, New Mexico, 2000–2006. Conservation Services Division, New Mexico Department of Game and Fish, Santa Fe.