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Mexican native trouts: a review of their history and current systematic and conservation status

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Abstract

While biologists have been aware of the existence of native Mexican trouts for over a century, they have received little study. The few early studies that did much more than mention their existence began in the 1930s and continued into the early 1960s, focusing primarily on distributional surveys and taxonomic analyses. Starting in the 1980s the Baja California rainbow trout became the subject of more detailed studies, but very little remains known of mainland trouts of the Sierra Madre Occidental. We review earlier studies and report on our own collections and

observations made between 1975 and 2000. We present newly discovered historical evidence that leads us to conclude that a "lost" cutthroat trout, a lineage not previously known from Mexico, was collected more than a century ago from headwaters of the Río Conchos (a major tributary of the Rio Grande (= Río Bravo)), a basin not previously considered to harbor a native trout. We review the last century of regional natural resource management and discuss our own observations of trout habitats. Impacts of logging, road building and overgrazing are widespread and expanding. Many streams suffer from heavy erosion, siltation and contamination, and though long-term hydrologic data are generally not available, there is evidence of decreased discharge in many streams. These problems appear related to region-wide land management practices as well as recent regional drought. Trout culture operations using exotic rainbow trout have rapidly proliferated throughout the region, threatening genetic introgression and/or competition with native forms and predation on them. Knowledge of distribution, abundance, relationships and taxonomy, not to mention ecology and population biology, of native trouts of the Sierra Madre Occidental remains inadequate. Vast areas of most mainland drainages are still unexplored by fish collectors, and even rudimentary information regarding basic biology, ecology and population structure of stocks remains lacking. Concentrated exploration, research and management of this long overlooked and undervalued resource are all urgently needed. The history of natural resources exploitation that placed so many native trouts of the western United States on threatened and endangered species lists is repeating itself in the Sierra Madre Occidental. Without concerted action and development of region-wide socio-economic solutions for current, largely non-sustainable resource management practices, native Mexican trout gene pools will soon be in grave danger of extinction.

Introduction

Unambiguously native Mexican trouts range from near the U.S. border in Baja California and headwaters of mainland Pacific drainages of the Sierra Madre Occidental from the Río Yaqui southward to at least the Río Culiacán (Needham and Gard, 1959), and disputably native or introduced populations (Lindsey, 1960; Miller, 1960; Miller and Smith, 1986; Minckley et al., 1986) extend further southward in mainland Pacific drainages to at least the Presidio and perhaps Baluarte and Acaponeta river drainages (Figure 1). Other possibly native populations occur in endorheic basins that are part of the Casas Grandes or Guzmán system on the east side of the continental divide in Chihuahua (Behnke, 1992; Needham and Gard, 1959) and, though voucher specimens are lacking, a trout may be native to the upper Río Conchos, a major tributary of the Rio Grande (Río Bravo), which drains eastward to the Gulf of Mexico. Nearly half a century has passed since these interesting fishes were comprehensively studied. In the interim, relatively few collections have been made and habitats have been altered in many ways. Logging has expanded considerably and continues to do so, with sawdust and other waste products often contaminating streams as well as contributing to increased erosion, siltation, flow variability and decreased stream shading. Non-native fishes have been widely introduced, including rainbow trout (*Oncorhynchus mykiss*) native to the western United States, which many studies on other native trouts of the southwestern U.S. tell us will likely interbreed with native forms (Behnke, 1992; Behnke and Tomelleri, 2002; Carmichael et al., 1993; Carmichael et al., 1996; Dowling and Childs, 1992; Leopold, 1918; Propst et al., 1992; U.S. Fish and Wildlife Service, 1987), have been widely introduced. The construction of small hatcheries and growout facilities for this non-native continues to expand rapidly throughout the region. In general, many lines of evidence indicate that trout habitats in the Sierra Madre Occidental are more geographically restricted than they were when Needham and Gard and their colleagues sampled and there is no indication that habitat conditions will improve in the near future. Much of the historic range of Mexican native trouts remains unsampled and several taxa remain undescribed. Knowledge of these fascinating, little-studied, and potentially valuable fishes remains inadequate to allow managers to make sound management decisions, or even to simply assess conservation status of the various taxa and populations. These relatively unstudied trouts should probably all be considered threatened or endangered, yet, surely as a result of lack of information and formal taxonomic description, only two of them, the Mexican golden trout (*Oncorhynchus chrysogaster*) and Baja California rainbow trout (*O. mykiss nelsoni* – also sometimes called Nelson's trout), have been included in major lists of government or international agencies. Mexican golden trout has been listed by the Mexican Government as threatened ("amenazada") (Secretaría de Desar-

rollo Social, 1994; Secretaría del Medio Ambiente y Recursos Naturales, 2002), by CITES (Conference on International Trade in Endangered Species) as vulnerable (International Union for Conservation of Nature – IUCN, 2002), and was also included in the list of the American Fisheries Society (AFS) (Williams et al., 1989) as was Baja California rainbow trout (Nielsen, 1998). This last species is also afforded "special protection" under the Mexican endangered species legislation (Secretaría del Medio Ambiente y Recursos Naturales, 2002).

To help ameliorate the paucity of current information on native Mexican trouts, we recently renewed collecting efforts throughout the range of native and potentially native trouts. While in the field, we took notes on general habitat conditions and collected new specimens for morphological and genetic studies. One of us (JRT) did color illustrations of at least one trout specimen from most major river basins (as available), basing them on photographs, our field notes on live colors, and frozen and preserved specimes for anatomical and coloration accuracy (Figure 2).

This contribution attempts to set the stage for continuing studies by reviewing the literature on Mexican trouts within the range of confirmed or probably native trouts as described above. Based on our research and field work, we qualitatively assess the conservation status of all native Mexican trouts and recommend future research needed for management purposes. We hope our efforts stimulate and facilitate additional research and management efforts. Our own research continues, utilizing specimens we have collected and older material in genetic and morphological studies to be reported upon elsewhere.

Materials and methods

We limited our study area to include all hydrographic basins with prior collections of potentially native trouts or adjacent drainages: the Sierra San Pedro Mártir streams of the Baja California Peninsula, the Sierra Madre Occidental Pacific drainages of the ríos Yaqui, Mayo, Fuerte, Sinaloa, Culiacán, San Lorenzo, Piaxtla, Presidio and Baluarte, and streams of the endorheic Guzmán (Casas Grandes) system (Figure 1). We also address the possibility that a native trout lived (or still lives) in headwaters of the Río Conchos, a tributary of the Rio Grande (Río Bravo), which flows eastward to the Gulf of Mexico (Figure 1). Our study area thus includes parts of the states of Baja California, Sonora, Chihuahua, Sinaloa and Durango. We exclude as non-native, or presumably so, the many records of trout in Mexico outside of the area defined above. Such records now range from southernmost Mexico to the mountains of the northeastern state of Nuevo León (specimens at Universidad Autónoma de Nuevo León), with introduced trout now recorded from (at least) the states of Chiapas, Chihuahua, Coahuila, Distrito Federal, Guanajuato, Guerrero, Hidalgo, Jalisco, Mexico, Michoacán, Morelos, Nuevo León, Oaxaca, Puebla, Queretaro, Tlaxcala, and Veracruz (McCrimmon, 1971; Solorzano Preciado, 1981). We find it surprising that McCrimmon and Solorzano Preciado did not include Durango, Sonora and Sinaloa in their lists, since our collections and observations include rainbows from long-established hatcheries and streams of both Sonora and Durango, and we strongly suspect that rainbow trout have by now been introduced into Sinaloa as well.

We compiled and reviewed literature, reports and government documents pertaining to native and non-native Mexican trouts and their habitats in the study area. We also searched unpublished archives of persons involved, or potentially involved, in specimen collections or knowledgeable regarding habitat histories. Our archival research extended from formal archives to historical newspaper accounts and other materials as necessary to gain insights into early collections and habitat conditions, and we interviewed local residents and other persons involved in collections, or with knowledge of trout and their habitats in the study region.

We conducted fieldwork to collect new specimens of both native and non-native (hatchery) trouts from both previously unsampled and known trout localities, and to assess general habitat quality. Fish collections were made with a diversity of gears, ranging from bare hands through fly-fishing and small seines to electrofishing, with the last predominating. Occasionally, specimens were purchased directly from hatcheries. In the field we photographed live specimens extensively, and took notes on details of live coloration. Specimens were preserved in 10% formalin or 95% ethanol (or frozen on dry ice or in liquid nitrogen), and generally fin clips were taken prior to preservation and either dried, frozen or preserved separately in 95% ethanol. Habitats were also photographed and collection locality coordinates recorded using GPS (Global Positioning System) receivers, or (rarely) interpolated from maps. During all travels we were assisted by local residents who both directed us to trout local-

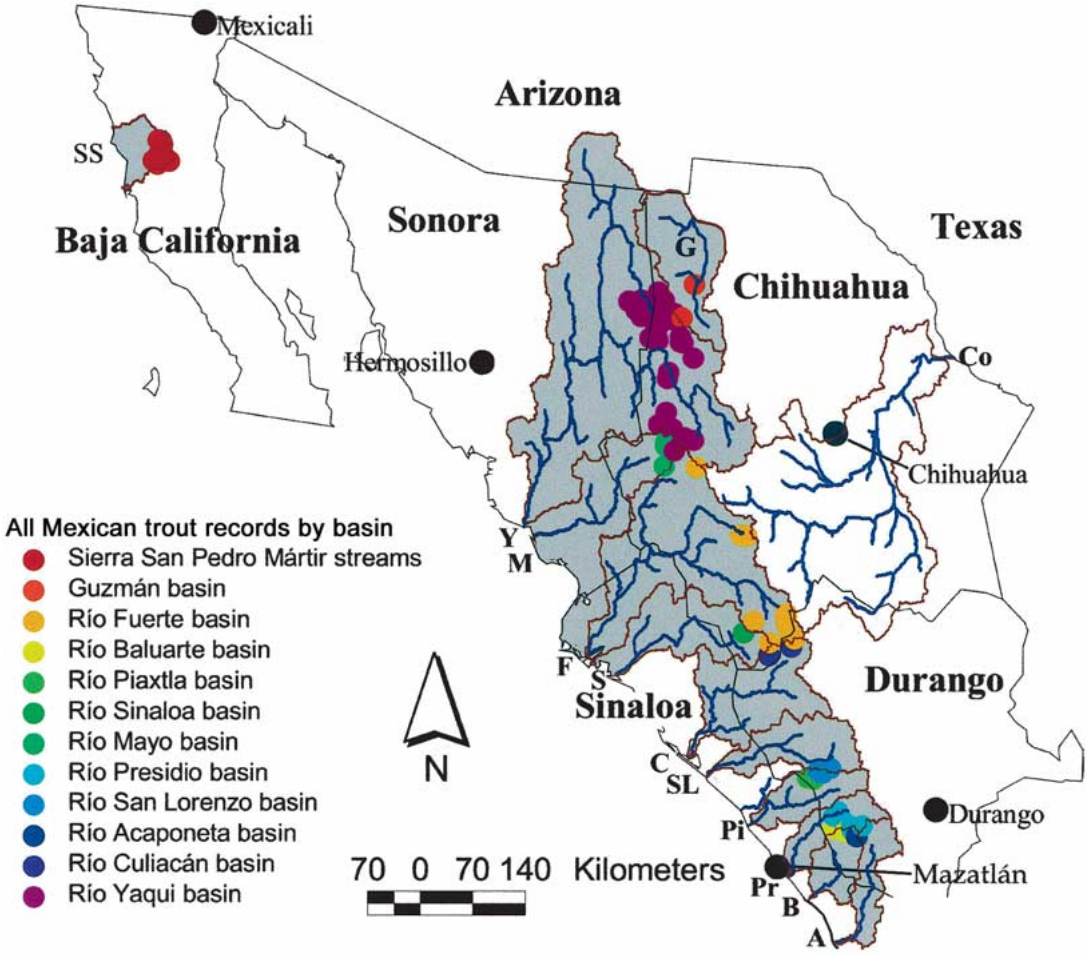

Figure 1. Distribution of native or potentially native trouts in northwestern Mexico. All drainages from which trout collections are known are shaded gray. Hydrographic divides are indicated by brown lines; state boundaries by black lines. Circles, color-coded by drainage as indicated, correspond to localities of all collections that have latitude/longitude coordinates listed in Table 1. Drainages are labeled at their mouths as follows: SS – Santo Domingo & San Rafael, Y – Yaqui, M – Mayo, F – Fuerte, S – Sinaloa, C – Culiacán, SL – San Lorenzo, Pi – Piaxtla, Pr – Presidio, B – Baluarte, A – Acaponeta, Co – Conchos, G – Guzmán (only Casas Grandes portion illustrated).

ities and discussed habitat and fish population histories with us. Additionally, several sport fishermen who have angled for native Mexican trouts shared their observations, sometimes providing data for localities previously (and sometimes still) unsampled by biologists, including ourselves.

Voucher specimens from our collections have been, or will be, deposited in at least the following collections (Collection codes follow Leviton and Gibbs (1985, 1988) except as otherwise noted): CIAD (Centro de Investigación en Alimentación y Desarrollo – Unidad Mazatlán), IB-UNAM-P, TNHC, UABC, UAIC, UAZ, UMMZ and USON (Universidad de Sonora, DICTUS – Departamento de Investigaciones Científicas y Tecnológicas, Hermosillo, Sonora).

Taxonomy and common names used throughout follow our conventions listed in Figure 2. Place names ending in "chic" are common on maps throughout our study area (e.g. Papigochic, Panalachic, Basaseachic), but are a corruption of indigenous names (of the Tarahumara language). We agree with an opinion recently reiterated in the popular press in Chihuahua (Anonymous, 2002) and express all place names in the indigenous form, dropping the terminal "c."

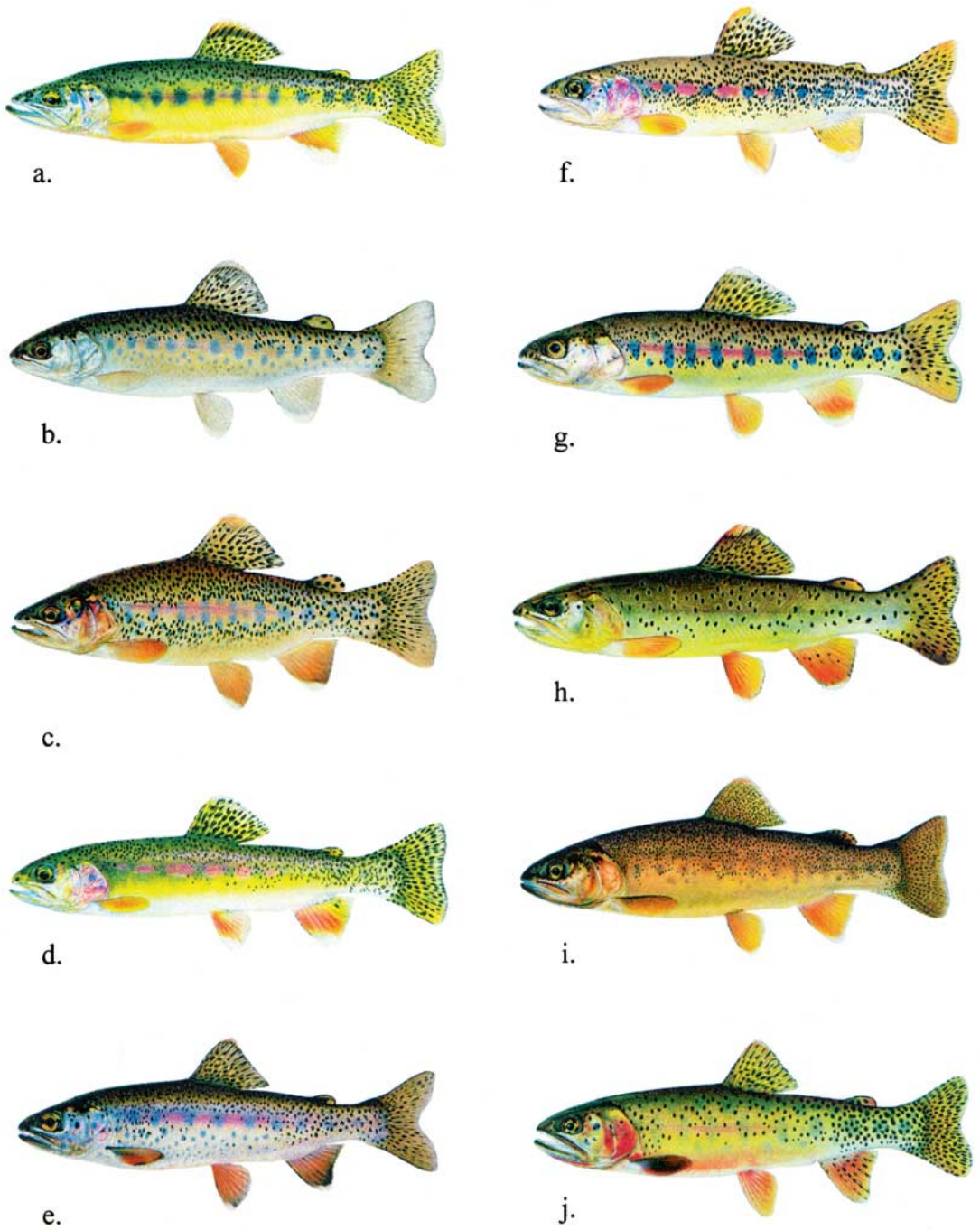

Figure 2. Mexican and geographically nearby trouts as illustrated by JRT (from specimens collected by the authors if museum catalog number included): (a) Mexican golden trout, trucha dorada mexicana – *Oncorhynchus chrysogaster* (UAIC 11620.01); (b) Río San Lorenzo trout, trucha del San Lorenzo – *Oncorhynchus* sp. (IB-UNAM-P 9548); (c) Arroyo La Sidra trout, trucha del Arroyo La Sidra – *Oncorhynchus* sp. (IB-UNAM-P 9547); (d) Río Mayo trout, trucha del Mayo – *Oncorhynchus* sp. (UAIC 11618.01); (e) Río Presidio trout, trucha del Presidio – *Oncorhynchus* sp. (IB-UNAM-P 9540); (f) Guzmán/Bavispe trout, trucha del Río Bavispe/Cuenca Guzmán – *Oncorhynchus* sp. (UAIC 11614.01); (g) Río Yaqui trout, trucha del Yaqui– *Oncorhynchus* sp. (UAIC 11615.01); (h) Apache trout, trucha Apache – *Oncorhynchus gilae apache* (from Soldier Creek, Arizona in May, 2000 – Glen McFaul collector); (i) Gila trout, trucha del Gila – *Oncorhynchus gilae gilae* (UNM specimen from South Diamond Creek, NM, collected 1955); (j) Rio Grande cutthroat trout, trucha degollada del Bravo – *Oncorhynchus clarkii virginalis* (from Jack Creek, NE of Santa Fe, NM – collected by JRT). Baja California rainbow trout, trucha arcoiris de Baja California – *Oncorhynchus mykiss nelsoni* is not illustrated.

Findings

Mexican trouts past and present

The Mexican fossil record

The marine anadromous fauna, including salmonids, that now characterizes North American Pacific drainages of the United States, extended during Pleistocene at least as far south as the Mexican Mesa (Plateau) Central to about 21° N latitude (Miller and Smith, 1986). Though Mexican salmonid fossils are fragmentary, and thus difficult to relate to modern forms, they have been referred to two species in the modern genus *Oncorhynchus* (Cavender, 1986; Cavender and Miller, 1982) (or the extinct *Rhabdofarío* (Smith, 1980; Smith, 1981). Though salmonids did not persist on the Mesa Central to modern times, other components of this same ancestral fauna apparently did; two lampreys of the genus *Lampetra* (subgenus *Tetrapleurodon*) are landlocked on the Mesa Central (Cochran et al., 1996; Lyons et al., 1994; Lyons et al., 1996), far south of their nearest relatives in Baja California (Ruiz-Campos and Gonzalez-Guzman, 1996).

To our knowledge, the only fossil fishes known from within or near the present range of Mexican native trouts include those from the Pliocene fauna of Yepómera, Chihuahua (southern Río Yaqui – Papigochi sub-basin). Though mammals, birds and other components of that fauna have been well studied (Lindsay and Jacobs, 1985, Smith, 1981), to our knowledge the fossil fishes have yet to be described beyond M.L. Smith's (1981) very brief mention only of a cyprinid and an unidentified, possible cyprinodontoid. The site appears, however, to be the only fossil fish locality within the present range of native trouts, being in the southern Río Yaqui (Papigochi) basin. Slightly outside of the currently known range of native trouts, but perhaps within prehistoric range, are two fossil fish localities. A Holocene cave deposit in Durango (Brooks et al., 1962) in the Río Nazas basin contains three families of fishes still found in the area, but typical of lower elevations than trout. The La Brean fauna from Rancho La Brisca (Van Devender et al., 1985) in the Río Sonora basin (the next major basin west of the Río Yaqui), had few fish remains typical of species found today very near the fossil locality at elevations well below those typical for trout.

Recent native trouts

Living Mexican native trouts currently consist of two described forms, the Mexican golden trout, *O. chrysogaster* (Needham and Gard, 1964) of the ríos Fuerte, Sinaloa and Culiacán, and the Baja California rainbow trout, *O. mykiss nelsoni* (Evermann, 1908) of the Sierra San Pedro Mártir in northern Baja California. Native trouts known from the mainland north of the Mexican golden trout in the ríos Yaqui, Mayo and Guzmán systems remain undescribed, but specimens of these forms are relatively abundant in museum collections compared to those from further south from the ríos San Lorenzo, Piaxtla, Presidio, Baluarte and Acaponeta. Whether these forms from south of Mexican golden trout are native or introduced or hybrids of native and introduced forms remains contested as mentioned above. We recently collected additional specimens from most of these basins and discuss them below.

Early explorations, observations and collections

The history of observations of trout in Mexico goes back further than previously reported. We report below a number of formerly overlooked early observations in a chronological review of collections and observations of specimens from the study area. Other similar, but site-specific and more habitat-oriented observations and selected extracts from interviews, archives and personal communications are reported later in our reviews of habitat and fish faunal histories.

James Woodhouse Audubon. More than 150 years ago, James Woodhouse Audubon (son of John James Audubon) traveled across Chihuahua enroute to northwestern Sonora as second in command of a group of about 100 men. Crossing the ríos Florido, Conchos, and Yaqui, he mentioned in his journal (Audubon, 1906) that on July 3rd, 1849, near the town of "Tomochi," he and his crew

> . . . looked in vain for fish in the most tempting of eddies and holes, but saw very few; little trout about five inches long were all that rewarded our search. We crossed and recrossed this stream twenty-two times in about seven miles, and encamped on a sandy bottom covered with fine pines.

Though overlooked by earlier researchers, this appears to be the first written report of trout in Mexico and it is not difficult to place the locality

fairly accurately with Audubon's detailed notes. He had crossed the Río Conchos (or its major tributary the Río Balleza) on the previous day (some four days out of the major regional city of Hidalgo de Parral) and place names (notably the mine of La Gabilana) and geography mentioned place him unambiguously in the Río Conchos basin on July 3, somewhere to the north of the modern-day *ejido* (small cooperative community) of Nonoava (about 27°29′ N; 106°44′ W), probably in either the ríos/arroyos Tecubichi, Guacareachi, or the Agua Caliente (Instituto Nacional de Estadistica Geografía e Informática (INEGI), 1979; Instituto Nacional de Estadistica Geografía e Informática (INEGI), 1998). He had passed a small stream and town by the name of "Tomochic" on the day he reported the trout. We are confident that this was not the present and more widely recognized mountain town of Tomochi (28°20′ N; 107°50′ W) in the Río Yaqui watershed, as he did not reach that area until at least the 12th of July, crossing at Concepción to the famous mining town of Jesus María in the nearby Río Mayo watershed on 19 July, but we do not find any "Tomochic" (or "Tomochi") on any historical or current maps of the uppermost Río Conchos basin that we consulted. The "San Juanito" map (Instituto Nacional de Estadistica Geografía e Informática (INEGI), 1998), however, shows a "Mesa Temochi" between the Río Tecubichi and Arroyo Agua Caliente, in the general area where we feel Audubon must have been when he reported seeing trout. Because Audubon did not collect specimens, it is impossible to ascertain that he was not referring to specimens of the cyprinid genus *Gila*, which in some areas at the time were also often called trout ("truchas") (Hendrickson and Minckley, 1984; Minckley, 1973). The genus *Gila* is known from the Río Conchos (Smith and Miller, 1986), including the general area where Audubon reported catching his trout specimens.

Fernando Ferrari-Pérez. Two trout specimens from Durango (with no additional locality detail), were exhibited at the World's Fair in Chicago in 1893, arriving there via Fernando Ferrari-Pérez, who may or may not have been the collector. The specimens subsequently found their way to the Smithsonian Institution's U.S. National Museum (Table 1). We have been unable to find additional documentation regarding these specimens or the exact locality from which they came, but have examined them. The larger specimen (320 mm SL) has small body spots; all fins except caudal are unspotted; lateral line scale count at 2 scales above the lateral line is 150; vertebrae number 64; dorsal rays 12; anal rays 12, possibly 11. This specimen well matches specimens we have collected in the Río Presidio of Durango. The second specimen differs somewhat, and is not in good condition. It is about 275 mm SL, and has 130 lateral line scales. Body spots seem larger than in the larger specimen, but are no longer clearly visible. The dorsal and caudal fins have been completely destroyed and the anal fin is partial. If the locality datum is correct, these likely represent the controversial trout populations from the southernmost rivers (e.g., San Lorenzo, Piaxtla, Presidio, etc.) that harbor extant populations. As discussed below, these populations, which strongly resemble coastal California populations of *O. mykiss*, have been suggested to represent early introductions from the U.S. (Lindsey, 1960; Miller, 1960; Miller and Smith, 1986) but at least these two specimens might pre-date the documented arrival of introduced rainbows to this part of Mexico (see below), since many of the natural history collections by Ferrari-Pérez were made in the mid 1880s (Ferrari-Pérez, 1886 and catalog of the Fish Collection, USNM).

Edward Drinker Cope. The first published description of preserved specimens of trout from Mexico was provided by the famous naturalist Edward Drinker Cope (1886), who stated that he had received two small specimens of "blackspotted trout" from his friend Professor Lupton

> . . . from streams of the Sierra Madre, of Mexico, at an elevation of between 7000 and 8000 feet, in the southern part of the State of Chihuahua, near the boundaries of Durango and Sinaloa. The specimens are young, and have teeth on the basihyal bones, as in *Salmo purpuratus*, which they otherwise resemble.

Cope did not formally describe the species, and provided only the few sentences quoted above (Cope, 1886), yet this relatively uninformative record was subsequently widely cited (Alvarez del Villar, 1949; Alvarez del Villar, 1950; De Buen, 1940; De Buen, 1947; Evermann, 1908; Jordan and Evermann, 1902; Meek, 1904; Miller, 1959; Needham and Gard, 1959). Unfortunately, Cope's specimens were lost, and to our knowledge were never examined by others. No authors subsequently citing Cope significantly questioned his cutthroat trout-like characterization of the specimens (e.g., presence of basihyal [=basibranchial] teeth),

Table 1. List of all known Mexican trout localities from the study area (i.e. excluding non-native populations outside the probable range of native Mexican trout) compiled from literature, museum databases, authors' collections, personal communications and personal observations. Locality descriptions and species unaltered from collections catalogs or literature (or as "sp." if voucher specimens not available and record not published). Latitude/Longitude from original source (if available), GPS, or taken from maps by authors. Missing coordinates indicate sites that we could not locate with reasonable (3–5 km radius) accuracy. Records sorted by major river basins from N to S and chronologically within basins. Dates in format yyyymmdd. Institutional codes follow Leviton et al. (1985) and Leviton and Gibbs (1988) except as noted in text

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss nelsoni	19450601	B.C.	San Rafael	Just west of San Pedro Martyr Mts.	C.I. Johnson	n/a	CAS 19573
Salmo gairdneri	19730420	B.C.	San Rafael	Rio San Rafael, Baja California at ca. 3800 ft elevation	R. & T. Croker	−115.67/31.11	UMMZ 199705
Oncorhynchus mykiss gairdnerii	19870103	B.C.	San Rafael	Northern third of San Pedro Martir Mts.; at Mike's Sky Ranch.	F. Talbot	−115.63/31.11	CAS 59782
Oncorhynchus mykiss nelsoni	19870127	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, G. Rubio, V. Roman y H. Cirilo	−115.63/31.11	UABC 851
Oncorhynchus mykiss nelsoni	19870322	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, V. Román y J.R. Gómez	−115.63/31.11	UABC 854
Oncorhynchus mykiss nelsoni	19870609	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	J. Gómez y V. Román	−115.63/31.11	UABC 103
Oncorhynchus mykiss nelsoni	19870917	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y col.	−115.63/31.11	UABC 102
Oncorhynchus mykiss nelsoni	19870917	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, V. Román, G. Rubio y J.R. Gómez	−115.63/31.11	UABC 858
Oncorhynchus mykiss nelsoni	19871206	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, V. Román, J.C. Bonino y J.R. Gómez	−115.63/31.11	UABC 861
Oncorhynchus mykiss nelsoni	19880212	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos y M. Villalobos	−115.63/31.11	UABC 848
Oncorhynchus mykiss nelsoni	19880327	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, J.R. Gómez y M. Villalobos	−115.63/31.11	UABC 849
Oncorhynchus mykiss nelsoni	19880508	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky (estación 2 y 3), en Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos y grupo F.C.	−115.63/31.11	UABC 842
Oncorhynchus mykiss nelsoni	19880629	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, aprox. 4,000 pies, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y grupo F.C.	−115.63/31.11	UABC 843
Oncorhynchus mykiss nelsoni	19880820	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, E. Lopez, I. Montes y D.L.G. León	−115.63/31.11	UABC 850
Oncorhynchus mykiss nelsoni	19881005	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos, M. Villalobos, L. García y I.P. Montes	−115.63/31.11	UABC 844
Oncorhynchus mykiss nelsoni	19881105	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos, M. Villalobos, L. García y I.P. Montes	−115.63/31.11	UABC 845
Oncorhynchus mykiss nelsoni	19881106	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, M. Villalobos, L. García y I.P. Montes	−115.63/31.11	UABC 846
Oncorhynchus mykiss nelsoni	19881111	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos y grupo F.C.	−115.63/31.07	UABC 847
Oncorhynchus mykiss nelsoni	19881211	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, en Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y grupo F.C.	−115.63/31.07	UABC 841

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss nelsoni	19890122	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, J. Delgadillo, J. Casteñon y Faustino Camarena	−115.63/31.11	UABC 852
Oncorhynchus mykiss nelsoni	19890218	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos	−115.63/31.11	UABC 99
Oncorhynchus mykiss nelsoni	19890219	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos	−115.63/31.07	UABC 853
Oncorhynchus mykiss nelsoni	19890521	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos, R.P. Arvizu, M. Villalobos y Jorge Alaníz García	−115.63/31.07	UABC 855
Oncorhynchus mykiss nelsoni	19890820	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos	−115.63/31.07	UABC 856
Oncorhynchus mykiss nelsoni	19900720	B.C.	San Rafael	Arroyo San Rafael en Rancho Mike's Sky, Sierra San Pedro Mártir, B.C.	Gorgonio Ruiz-Campos y M. Villalobos	−115.63/31.07	UABC 857
Oncorhynchus mykiss nelsoni	19920126	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Garet (1,650 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos, Arcadio Valdez y J.C. Garduño F.	−115.6/31.07	UABC 149
Oncorhynchus mykiss nelsoni	19930131	B.C.	San Rafael	Arroyo San Rafael, en Rancho Garet (= Las Truchas), 1,650 m elevation. Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y col.	−115.6/31.07	UABC 151
Oncorhynchus mykiss nelsoni	19930307	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y J.C. Garduño	−115.63/31.11	UABC 150
Oncorhynchus mykiss nelsoni	19930425	B.C.	San Rafael	Arroyo San Rafael, ca. Rancho Mike's Sky (1,219 m elevation), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y J. Ramírez	−115.63/31.11	UABC 98
Oncorhynchus mykiss nelsoni	19930729	B.C.	San Rafael	Arroyo San Rafael, Rancho Las Truchas (= Garet), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos	−115.6/31.07	UABC 148
Oncorhynchus mykiss nelsoni	19930729	B.C.	San Rafael	Arroyo San Rafael, en Rancho Garet (= Las Truchas, 1,650 m elevation). Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y J. Ramírez	−115.6/31.07	UABC 152
Oncorhynchus mykiss nelsoni	19990307	B.C.	San Rafael	Arroyo San Rafael en Rancho Las Truchas (=Garet), Sierra San Pedro Mártir	Jorge Alaníz García y Jesus Bernardino Ortiz Barrón	−115.6/31.07	UABC 952
Oncorhynchus mykiss nelsoni	19991009	B.C.	San Rafael	Arroyo San Rafael (cascada aprox. 1 km arriba del Rancho Garet), Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y Germán Ruiz Cota	−115.6/31.07	UABC 953
Salmo nelsoni	19050730	B.C.	Santo Domingo	San Antonio R. L. Calif.	E.W. Nelson	−115.63/30.82	USNM 00061056
Salmo nelsoni	19050730	B.C.	Santo Domingo	San Antonio R. L. Calif.	E.W. Nelson	−115.63/30.82	USNM 00061057
Salmo nelsoni	19050730	B.C.	Santo Domingo	Rio San Ramon L. Calif.	E.W. Nelson	−115.63/30.82	USNM 00076406
Salmo nelsoni	19050730	B.C.	Santo Domingo	Rio San Ramon L. Calif.	E.W. Nelson	−115.63/30.82	USNM 00076407
Salmo gairdneri	19050730	B.C.	Santo Domingo	San Ramón River at Rancho San Antonio (altitude 2000 feet) in San Pedro Martir Mountains, 35 miles northest of Port San Quintin	E.W. Nelson	−115.58/30.92	UMMZ 157681
Salmo gairdneri	19250424	B.C.	Santo Domingo	(Lower California) San Antonio Creek, trib Santo Domingo River, above Rancho San Antonio Orig. #4232, 2097	Chester C. Lamb & A.E. Borrell	−115.5/30.92	UMMZ 81307
Salmo gairdneri	19250424	B.C.	Santo Domingo	Lower California: San Antonio Creek, trib Santo Domingo River, above Rancho San Antonio Orig. #1497, 2108	Chester C. Lamb & A.E. Borrell	−115.58/30.92	UMMZ 81308

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss nelsoni	19250424	B.C.	Santo Domingo	Rancho San Antonio.	A.E. Brell & C.C. Lamb	n/a	CAS 20700
Oncorhynchus mykiss nelsoni	19250424	B.C.	Santo Domingo		C.C. Lamb	n/a	CAS 123938
Oncorhynchus mykiss gairdnerii	19250424	B.C.	Santo Domingo	San Antonio Ranch; 2100 ft elevation	C.C. Lamb & A.E. Borell	n/a	CAS 21222
Salmo nelsoni	19250425	B.C.	Santo Domingo	San Antonio Ranch, Santo Domingo River; 2100 ft elevation	C.C. Lamb	−115.58/30.92	ANSP 104592
Salmo gairdneri	19250427	B.C.	Santo Domingo	Lower California: San Antonio Creek, trib Santo Domingo River, above Rancho San Antonio Orig. #1535, 1539, 2109	Chester C. Lamb & A.E. Borrell	−115.58/30.92	UMMZ 81309
Salmo gairdneri	19250427	B.C.	Santo Domingo	Lower California: San Antonio Creek, trib Santa Domingo River, above Rancho San Antonio Orig. #4245, 4249, 4250, 2096, 2113	Chester C. Lamb & A.E. Borrell	−115.58/30.92	UMMZ 81310
Salmo gairdneri	19360517	B.C.	Santo Domingo	Rancho San Antonio. Seven-mile pack trip from end of road at Valladares near the Rancho San Jose	P.R. Needham & F.W. Johnson	−115.58/30.92	Not vouchered
Oncorhynchus mykiss nelsoni	19360517	B.C.	Santo Domingo	Rancho San Antonio.	P.R. Needham & F.W. Johnson	n/a	CAS 21223
Oncorhynchus mykiss gairdnerii	19370522	B.C.	Santo Domingo	Rancho San Antonio.	E. Horn, Johnson, Hugo, Needham & Rayner	−115.58/30.92	CAS 21224
Oncorhynchus mykiss nelsoni	19370522	B.C.	Santo Domingo	Rancho San Antonio.	E. Horn, Johnson, Hugo, Needham & Rayner	−115.58/30.92	CAS 137981
Oncorhynchus mykiss nelsoni	19370522	B.C.	Santo Domingo		Horn, Johnson, Hugo, Needham & Rayner	−115.58/30.92	CAS 85277
Salmo gairdneri	19370522	B.C.	Santo Domingo	From Needham and Gard 1959 Table 2 "Same locality as in 1925 and 1936. None preserved. All brought out alive and placed at Forest Home State Fish Hatchery near Redlands, California"	P.R. Needham & party	−115.58/30.92	Not vouchered
Oncorhynchus mykiss nelsoni	19390500	B.C.	Santo Domingo		P.R. Needham	−115.58/30.92	CAS 85273
Oncorhynchus mykiss nelsoni	19390500	B.C.	Santo Domingo		P.R. Needham	−115.58/30.92	CAS 85274
Oncorhynchus mykiss nelsoni	19390500	B.C.	Santo Domingo		P.R. Needham	−115.58/30.92	CAS 85275
Oncorhynchus mykiss nelsoni	19390500	B.C.	Santo Domingo		P.R. Needham	−115.58/30.92	CAS 85276
Salmo gairdneri	19390514	B.C.	Santo Domingo	From Needham and Gard 1959 Table 2 "Same as above localities. A total of 325 fingerlings two to four inches in length. All removed alive to the U.S. Fisheries Station at Clackamas, Oregon."	P.R. Needham & party	−115.58/30.92	Not vouchered
Oncorhynchus mykiss nelsoni	19821015	B.C.	Santo Domingo	Arroyo La Grulla en la Grulla, Sierra San Pedro Mártir, B.C.	C. Yruretagoyena y Katsuo Nishikawa	−115.63/31.11	UABC 859
Oncorhynchus mykiss nelsoni	19831028	B.C.	Santo Domingo	Arroyo San Antonio de Murillos ca. Rancho San Antonio, Sierra San Pedro Mártir	E.P. Pister, C. Yruretagoyena, V. Camacho y Diógenes Herrera	−115.63/30.82	UABC 862
Oncorhynchus mykiss nelsoni	19840618	B.C.	Santo Domingo	Arroyo La Grulla en la Grulla, Sierra San Pedro Mártir, B.C.	E.P. Pister y Gorgonio Ruiz-Campos	−115.48/30.89	UABC 860
Oncorhynchus mykiss nelsoni	19840618	B.C.	Santo Domingo	Arroyo La Grulla en la Grulla, Sierra San Pedro Mártir	E.P. Pister, C. Yruretagoyena, Gorgonio Ruiz-Campos et al.	−115.48/30.89	UABC 835
Oncorhynchus mykiss nelsoni	19851101	B.C.	Santo Domingo	Arroyo San Antonio de Murillos en Rancho San Antonio, Sierra San Pedro Mártir	A. Gerardo y Navarro Ayala S.	−115.63/30.82	UABC 736

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss nelsoni	19890302	B.C.	Santo Domingo	Arroyo El Potrero, ca. Rancho El Potrero, Sierra San Pedro Mártir	Faustino Camarena Rosales y M. Villalobos	−115.65/30.92	UABC 735
Oncorhynchus mykiss nelsoni	19890517	B.C.	Santo Domingo	Arroyo El Potrero en Rancho El Potrero, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y Jorge Alaníz García	−115.65/30.92	UABC 834
Oncorhynchus mykiss nelsoni	19900323	B.C.	Santo Domingo	Arroyo La Grulla, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos	−115.48/30.89	UABC 69
Oncorhynchus mykiss nelsoni	19900810	B.C.	Santo Domingo	Arroyo La Grulla, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos	−115.48/30.89	UABC 157
Oncorhynchus mykiss nelsoni	19900930	B.C.	Santo Domingo	Arroyo La Grulla, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y col.	−115.48/30.89	UABC 672
Oncorhynchus mykiss nelsoni	19940629	B.C.	Santo Domingo	Arroyo San Antonio en la confluencia Arroyo La Zanja y Arroyo San Antonio Murillo, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos et al.	−115.63/30.82	UABC 97
Oncorhynchus mykiss nelsoni	19950930	B.C.	Santo Domingo	Arroyo El Potrero, Rancho El Potrero, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y A. Gerardo	−115.65/30.92	UABC 145
Oncorhynchus mykiss nelsoni	19951001	B.C.	Santo Domingo	Arroyo San Antonio de Murillos, ca. Rancho San Antonio, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos y A. Gerardo	−115.63/30.82	UABC 144
Oncorhynchus mykiss nelsoni	19951001	B.C.	Santo Domingo	Arroyo La Zanja, ca. 100 m antes de confluencia con Arroyo San Antonio, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos, W. Zuñiga C. y A. Gerardo	−115.63/30.82	UABC 143
Oncorhynchus mykiss nelsoni	20010401	B.C.	Santo Domingo	Arroyo Valladares at Rancho [Nuevo] Valladares, Sierra San Pedro Mártir	Gorgonio Ruiz-Campos	−115.7/30.86	UABC 1055
Oncorhynchus mykiss gairdneri	19550501	Chih.	Guzmán	Drove back to Chuhuichupa from Black Canyon and thence to Largo. Approximately 11 miles north of Largo we turned northeast for 9 to 10 miles, and then turned east and went down to village of Las Playas on Tres Treinte (sic) Creek. Five miles down this stream we branched off to the right up Arroyo Seco. Collections were made between 3 and 4 miles up Arroyo Seco from its mouth.	P.R. Needham & R.S. Rupp	−108.17/29.83	CAS 20701
Oncorhynchus sp.	19960921	Chih.	Guzmán	El Escalariado	Buddy Jensen & J. Hatch	−108.03 30.25	Not vouchered
Oncorhynchus sp.	19960927	Chih.	Guzmán	Arroyo La Playa (tributary of El Alamo) below Rancho Bella Vista	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.17/29.83	Not vouchered
Oncorhynchus sp.	19970216	Chih.	Guzmán	Arroyo Escalariado, Municipio Casas Grandes	D.A. Hendrickson, R.L. Mayden, J.R. Tomelleri, B. Kuhajda, Guy Ernsting & Thorpe Halloran	−108.03/30.25	UAIC 11614.01 & IB-UNAM-P 13164
Salmo gairdneri	19480821	Chih.	Yaqui	Rio Gavilan, trib Rio Yaqui, 7 miles SW of Pacheco, 5700 ft elevation, Orig. #811, 820	A.S. Leopold	−108.5/30	UMMZ 167081
Oncorhynchus sp.	19480821	Chih.	Yaqui	Rio Gavilan tributary Rio Yaqui 7 miles SW Pacheco	A.S. Leopold	−108.5/30.03	Not vouchered
Oncorhynchus sp.	19550429	Chih.	Yaqui	Chihuahua Black Canyon at head of Rio Bavispe near Chuhuichupa near border of Sonora and Chihuahua (Rio Negro Canyones Chihuahua)	P.R. Needham & R.S. Rupp	−108.47/29.53	Not vouchered
Oncorhynchus mykiss gairdneri	19550429	Chih.	Yaqui	Near eastern boundary of Sonora. Black Canyon (Río Negro Canyones [sic]) 9 miles southwest of Chuhuichupa at road crossing. Drove to latter place via Colonia Juarez, García, and Largo. Elevation approximately 6,700 feet.	P.R. Needham & R.S. Rupp	−108.47/29.53	CAS 20702
Oncorhynchus sp.	19751115	Chih.	Yaqui	Chihuahua Rio Tomochic at Ojo de Agua Caliente between Tomochic and Basaseachic	L.J. Findley, C.H. Lowe, D.W. Owens, C. Constant & Cal Lowe	n/a	UAZ 75-101

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss	19751227	Chih.	Yaqui	Chihuahua near La Mesa about 50 miles due west of Gomez Farias (6000–7000 ft elevation)	B. Stonoff	−108.29/29.15	ASU 6744
Oncorhynchus sp.	19751227	Chih.	Yaqui	La Mesa approximately 50 miles due W Gomez Farias	B. Stonoff	−108.29/29.15	Not vouchered
Salmo gairdneri	19780520	Son.	Yaqui	Rio de Bavispe at Rancho Tres Rios, 17.9 km E of Colonia Mesa Tres Rios by rd to Nuevo Casa Grandes, Orig. #RY28-78.	D. Hendrickson & D. Siebert	−108.63/29.88	UMMZ 211443
Oncorhynchus sp.	19780521	Son.	Yaqui	Arroyo Cuartel (tributary of Arroyo San Antonio) approximately 29°52′ N, 108°48′ W	D.A. Hendrickson	−108.8/29.87	ASU 13246
Oncorhynchus sp.	19780521	Son.	Yaqui	Arroyo Cuartel tributary to Arroyo San Antonio approximately 13.1 km (road to Cebadilla and Huachinera) from Colonia Mesa Tres Rios 29°52′ N, 108°48′ W (1900 m elevation)	D.A. Hendrickson & D.J. Siebert	−108.8/29.87	UMMZ 211440
Oncorhynchus sp.	19780521	Son.	Yaqui	Arroyo San Antonio at Rancho San Antonio 29°52′ N, 108°44′ W (1600 m elevation)	D.A. Hendrickson & D.J. Siebert	−108.73/29.87	UMMZ 211441
Oncorhynchus sp.	19780521	Son.	Yaqui	Rio de Bavispe at Rancho Tres Rios 17.9 km E Colonia Mesa Tres Rios by road to Nuevo Casa Grandes (1390 m elevation)	D.A. Hendrickson & D.J. Siebert	−108.63/29.88	Not vouchered
Salmo sp.	19780521	Son.	Yaqui	Arroyo Cuartel, trib to Arroyo San Antonio, ca 13.1 km (on road to Cebadilla & Huachinera) from Colonia Mesa Tres Rios	D Hendrickson & D Siebert	−108.92/29.97	UMMZ 211440
Salmo sp.	19780521	Son.	Yaqui	Arroyo San Antonio at Rancho San Antonio, 1,600 m elevation; Rio Yaqui drainage Orig. #RY27-78	D. Hendrickson & D. Siebert	−108.75/30	UMMZ 211441
Oncorhynchus sp.	19780522	Chih.	Yaqui	Rio Gavilan at Rancho El Gavilan 30°05′ N, 108°30′ W (1700 m elevation)	D.A. Hendrickson et al.	−108.5/30.08	ASU 9944
Oncorhynchus sp.	19780525	Chih.	Yaqui	Arroyo Calandria on Rancho Huapoca approximately 50 km W Madera 29°06′ N, 108°16′ W (1500 m elevation)	D.A. Hendrickson et al.	−108.3/29.08	ASU 13243
Salmo sp.	19780525	Chih.	Yaqui	Arroyo Calandria on Rancho Huapoca, ca 50 km W of Madera; 1500 m elevation; Rio Yaqui drainage Orig. #RY78-33	D. Hendrickson & D. Siebert	−108.3/29.08	UMMZ 211460
Oncorhynchus sp.	19780616	Chih.	Yaqui	Tributary of Rio Tomochic at crossing on new highway to La Junta from Basaseachic	D.A. Hendrickson	−107.88/28.35	ASU 13244
Salmo sp.	19780616	Chih.	Yaqui	Trib to Rio Tomochic (locally Arroyo Ahumado), 21.8 km from Tomochic along rd to Basaseachic, Orig. #RY54-78 = M78-34	Hendrickson et al.	−108/28.37	UMMZ 211522
Salmo sp.	19780616	Chih.	Yaqui	Arroyo Vallecillos, trib to Rio Tutuaca, ca 2 km upstream from Tutuaca, 1900 m elevation; Orig. #RY56-78.	D. Hendrickson, J. Johnson & D. Siebert	−108.37/28.5	UMMZ 211532
Oncorhynchus sp.	19780617	Chih.	Yaqui	Rio Tutuaca approximately 1 mile downstream from Tutuaca 28°28′ N, 108°11′ W	D.A. Hendrickson	−108.18/28.47	ASU 13245
Salmo sp.	19780620	Chih.	Yaqui	Rio Chico at Rancho Rio Chico, 2000 m elevation; Rio Yaqui drainage Orig. #RY74-78	Minckley, Siebert, Johnson, Ogan & Haddock	−108.13/29.53	UMMZ 211600
Oncorhynchus sp.	19780620	Chih.	Yaqui	Rio Chico at Rancho Rio Chico 29°36′ N, 108°10′ W (2000 m elevation)	D.A. Hendrickson et al.	−108.17/29.6	Not vouchered
Oncorhynchus mykiss	19780621	Chih.	Yaqui	Presa de Moctezuma on arroyo Moctezuma at Rancho Moctezuma 29°53′ N, 108°16′ W	D.A. Hendrickson, W.L. Minckley, D. Siebert & company	−108.27/29.88	ASU 12631

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Salmo sp.	19780723	Chih.	Yaqui	Rio Negro, ca 1 km above bridge on road from Chuhuichupa to Molino de Aserrar Huaynopa, 1990 m elevation; Orig. #RY89-78.	Hendrickson, Minckley, Collins & Clarkson	−108.47/29.53	UMMZ 211651
Oncorhynchus sp.	19780723	Chih.	Yaqui	Rio Negro approximately 1 km above bridge on road from Chuhuichupa to Molino de Aserrar Huaynopa 29°33′ N, 108°35′ W (1990 m elevation)	D.A. Hendrickson et al.	−108.58/29.55	ASU 9599
Salmo sp.	19790507	Chih.	Yaqui	Rio Chico, ca 300 m below Rancho Rio Chico; Rio Yaqui – Pacific drainage Orig. #M79-5	Miller, Uyeno & Chernoff	−108.13/29.53	UMMZ 208173
Salmo sp.	19790510	Chih.	Yaqui	Trib to Rio Tomochic, ca 80 km W of La Junta (on N side of Hwy 23) = 17 miles (27.4 km) W of Tomochic; Orig. #M79-7	R. Miller, T. Uyeno, B. Chernoff & M. Hatch	−108.03/28.33	UMMZ 208180
Oncorhynchus sp.	19860625	Chih.	Yaqui	Arroyo Ahumado (tributary of Rio Tomochic) 25 km west of Tomochic	J.N. Rinne & S.C. Belfit	−108.13/28.2	Not vouchered
Oncorhynchus mykiss	19860626	Chih.	Yaqui	Rio Negro ± 12 km west of La Nortena	J.N. Rinne & S.C. Belfit	−108.5/29.67	Not vouchered
Oncorhynchus sp.	19880515	Chih.	Yaqui	Arroyo La Laguna above confluence with A. Bisaldachic, 15 km SSE Chachamori (=10 km N by 13 km W Yahuirachic), 2400 m elevation. (tributary of A. Bichachiqui in A. El Riito fork of Rio Sirupa)	George M. Ferguson, P. Martin & R. Duncan	−108.28/28.66	Not vouchered
Oncorhynchus sp.	19890602	Son.	Yaqui	Arroyo La Cueva antes de subir al Ejido Mesa Tres Ríos, pasando la unión de los arroyos Palmillosos y La Presita.	Alejandro Varela-Romero, Jose Campoy-Favela y Martin Almeida-Paz	−108.72/29.82	USON 0687
Oncorhynchus sp.	19891014	Son.	Yaqui	Arroyo San Juan ca. 1 km al Noroeste del poblado San Juan por el camino Mesa del Huracan-El Colorado.	Alejandro Varela-Romero, Jose Campoy-Favela y Martin Alemida-Paz	−108.3/29.8	USON 0707
Oncorhynchus sp.	19951000	Son.	Yaqui	Arroyo La Presita (tributary of Rio La Cueva)	Buddy Jensen, Kevin Cobble, Bob David & Manuel Ulibarri	−108.73/29.8	Not vouchered
Oncorhynchus sp.	19960924	Chih.	Yaqui	Tributary of Río Tutuaca known locally as Arroyo Nayahuachic or Arroyo el Cinco	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch, EBM	−108.2/28.46	Not vouchered
Oncorhynchus sp.	19960924	Son.	Yaqui	Arroyo El Arco, tributary of Río Negro	Miles Romney, Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.63/29.82	Not vouchered
Oncorhynchus sp.	19960925	Chih.	Yaqui	Arroyo El Salto below El Vallecillo (tributary of Río Chico)	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.16/29.53	Not vouchered
Oncorhynchus sp.	19960926	Son.	Yaqui	Arroyo La Presita (tributary of Rio La Cueva)	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.73/29.8	Not vouchered
Oncorhynchus sp.	19960926	Son.	Yaqui	Arroyo Los Quarteles (tributary of Rio San Antonio)	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.75/29.87	Not vouchered
Oncorhynchus sp.	19960927	Chih.	Yaqui	Arroyo Las Guacamayas at cascada (tributary of Rio Gavilán)	Buddy Jensen, Kevin Cobble, José Campoy & J. Hatch	−108.5/30.03	Not vouchered
Oncorhynchus sp.	19970217	Chih.	Yaqui	Cañon Vallecillos, just W of Madera-La Mesa del Huracán highway at km 40 marker, 15 km WNW of Las Varas, near Cuarenta Casas	D.A. Hendrickson, R.L. Mayden, J.R. Tomelleri, B. Kuhajda, Guy Ernsting & Thorpe Halloran	−108.16/29.53	UAIC 11615.01 & IB-UNAM-P 13107
Oncorhynchus sp.	19970218	Chih.	Yaqui	Unnamed tributary of Río Negro, ca. 0.5 to 1 miles upstream of gravel road, 6 km W of La Norteña	D.A. Hendrickson, R.L. Mayden, J.R. Tomelleri, B. Kuhajda, Guy Ernsting & Thorpe Halloran	−108.52/29.65	UAIC 11616.01 & IB-UNAM-P 13108
Oncorhynchus sp.	19990000	Chih.	Yaqui	Arroyo Estribus	R. Johnson, 1999	−108.53/30	Not vouchered
Oncorhynchus sp.	19991017	Chih.	Yaqui	Río Chuhuichupa	M.V.Z. Gerardo Zamora Balbuena et al.	−108.44/29.76	IB-UNAM-P 13165
Oncorhynchus sp.	20010423	Son.	Yaqui	Arroyo La Presita, a tributary of Arroyo La Cueva, Mesa de Tres Ríos, Nacorichico	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.72/29.81	UABC 1098

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus sp.	20010423	Son.	Yaqui	Arroyo La Cueva, Ejido Mesa de Tres Ríos, Nacori Chico	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.73/29.82	UABC 1097
Oncorhynchus sp.	20010425	Son.	Yaqui	Arroyo El Palmilloso. Mesa de Tres Ríos, Nacorichico, Sonora	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.73/29.82	UABC 1112
Oncorhynchus sp.	1999?	Chih.	Yaqui	Arroyo en Rancho Gavilán (dueño Alvino Whetten)	R. Johnson, 1999	n/a	Not vouchered
Oncorhynchus sp.	199xxxxx	Chih.	Yaqui	Arroyo Yenquin (Jenkins) and its tributaries, Las Truchas	John Hatch (pers. comm.)	−108.55/29.9	Not vouchered
Oncorhynchus sp.	199xxxxx	Chih.	Yaqui	Arroyo La Nutria	Arny Stonkus, pers. comm.	−108.77/29.92	Not vouchered
Oncorhynchus sp.	199xxxxx	Chih.	Yaqui	Río El Gavilán and its tribuaries Horsecamp Creek and El Diablo	John Hatch (pers. comm.)	−108.43/30.02	Not vouchered
Oncorhynchus sp.	199xxxxx	Chih.	Yaqui	Arroyo Las Guerras, near Los Chales	John Hatch (pers. comm.)	−108.52/30.03	Not vouchered
Oncorhynchus sp.	199xxxxx	Chih.	Yaqui	Arroyo Bonito	John Hatch (pers. comm.)	−108.52 30.12	not vouchered
Oncorhynchus sp.	19750330	Chih.	Mayo	Basaseachic falls, at foot of falls (ca 3 miles from Rancho Basaseachic; ca 100 m. SW of Ciudad Guerrero	Peter Warren	−108.25/28	UAZ 75-28
Oncorhynchus sp.	19751116	Chih.	Mayo	Rio Candameña, 1–2 km above Cascada de Basaseachic (from near edge of waterfall upstream to just above where road from town of Basaseachic ends at the river)	L.T. Findley, C.H. Lowe, D.W. Owens, C. Constant & Cal Lowe	−108.25/28.3	UAZ 75-102 & UMMZ 209829
Oncorhynchus sp.	19751117	Chih.	Mayo	Rio Candameña in stream directly below Cascada de Basaseachic	D.W. Owens & Cal Lowe	−108.25/28	UAZ 75-103
Salmo sp.	19780515	Chih.	Mayo	Trib of Rio Candameña (Mayo), 0.25 miles above Cascada Basaseachic; Rio Mayo drainage Orig. #DH-066-78 (=M78-33)	D. Hendrickson & R.R. Miller	−108.25/28.25	UMMZ 211657
Salmo sp.	19780616	Chih.	Mayo	Trib of Rio Candameña above Basaseachic falls, 5.3 miles from parking lot at falls along hwy to La Junta (Orig. #DH-067-78)	Hendrickson, Siebert	−108.17/28.25	UMMZ 211658
Salmo sp.	19790509	Chih.	Mayo	Rio Candameña, ca 1.5 km below hwy 23 at turnoff to San Juanito, ca 120 km W of La Junta; Rio Mayo (Orig No: M79-6)	R. Miller, T. Uyeno, B. Chernoff & M. Hatch	−108.25/28.25	UMMZ 208176
Salmo sp.	19790714	Chih.	Mayo	Rio Candameña & arroyo known locally as 'de la Casita' trib of Rio Candameña; coll from 1–2 km upstr (Orig. #DH79−11). *bridge ca 0.1 miles E of fork of roads to Basaseachic & San Juan	D. & S. Hendrickson	−108.15/28.22	UMMZ 211659
Oncorhynchus sp.	19860625	Chih.	Mayo	Rio Casita in the vicinity of Riito and ±6 km east of Basaseachic	J.N. Rinne & S.C. Belfit	−108.15/28.2	Not vouchered
Oncorhynchus sp.	19970219	Chih.	Mayo	Unnamed tributary of Rio Candameña (Las Presitas?), 5.5 km N of Basaseachic, near Rancho El Potrero	D.A. Hendrickson, R.L. Mayden, J.R. Tomelleri, B. Kuhajda, Guy Ernsting & Thorpe Halloran	−108.21/28.26	UAIC 11618.01 & IB-UNAM-P 13109
Oncorhynchus sp.	20010427	Chih.	Mayo	Arroyo El Potrero de Gil at rancho of the same name, Basaseachic	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.2/28.24	UABC 1364
Oncorhynchus sp.	20010428	Chih.	Mayo	Arroyo La Estrella, Basaseachic, Chihuahua	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.18/28.21	UABC 1120
Oncorhynchus sp.	20010429	Chih.	Mayo	Arroyo El Concheño ca. El Concheño (an old mining village)	Gorgonio Ruiz-Campos, Alejandro Varela Romero & Faustino Camarena Rosales	−108.22/28.32	UABC 1363
Salmo chrysogaster	19520810	Chih.	Fuerte	Arroyo de la Rana, a tributary of the Arroyo Caeva (sic) Lobitas which in turn, is a tributary of the Rio Verde	Stanley H. Weitzman & Jack D. Lattin	−106.48/26.3	CAS 20703

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Salmo chrysogaster	19520810	Chih.	Fuerte	Arroyo de la Rana, a tributary of the Rio Verde	Stanley H. Weitzman & Jack D. Lattin	−106.48/26.3	CAS 41652
Salmo chrysogaster	19520810	Chih.	Fuerte	Arroyo de la Rana, a tributary of the Rio Verde	Stanley H. Weitzman & Jack D. Lattin	−106.48/26.3	CAS 41653
Salmo chrysogaster	19530717	Chih.	Fuerte	Rio Verde 3 miles downstream from arroyo at kilometer 24 on the Vergel-to-Guadalupe y Calvo road. This stream is a tributary of the Río Verde, and the general area in which the trout were collected is known as "Agua Caliente"	A.O. Flechsig & C. Moller	−106.48/26.33	CAS 20704
Oncorhynchus chrysogaster	19530717	Chih.	Fuerte	Rio Verde 3 miles downstream from arroyo at kilometer 24 on the Vergel-to-Guadalupe y Calvo road. This stream is a tributary of the Río Verde, and the general area in which the trout were collected is known as "Agua Caliente"	A.O. Flechsig & C. Moller	−106.48/26.33	CAS 41654
Salmo chrysogaster	19530806	Chih.	Fuerte	Arroyo Tecolote, which flows southeast into the headwaters of Río Loeros (Río Verde)	Arthur O. Flechsig & Charles Moller	−106.91/26.21	CAS 20706
Salmo chrysogaster	19530811	Dur.	Fuerte	Arroyo Los Padres at elevation of approximately 8,000 ft. Said by guides [and confirmed from map by DAH] to be in the drainage of the Río Chinatú, a tributary of Río Verde	Arthur O. Flechsig & Charles Moller	−106.43/26.03	CAS 20705
Salmo chrysogaster	19530812	Dur.	Fuerte	Arroyo Pedernales, headwaters of the Río Verde. About 25 miles south of the town of Río Verde. About 6 hours by horseback generally south from kilometer 24 on the Bergel-Guadalupe y Calvo road	A.O. Flechsig & C. Moller	−106.36/26.03	CAS 20707
Oncorhynchus chrysogaster	19530812	Dur.	Fuerte	Arroyo Pedernales, headwaters of the Río Verde. About 25 miles south of the town of Río Verde. About 6 hours by horseback generally south from kilometer 24 on the Bergel-Guadalupe y Calvo road	A.O. Flechsig & C. Moller	−106.36/26.03	CAS 41655
Salmo chrysogaster	19790516	Chih.	Fuerte	Rio Verde at and to 0.5 mi above hwy 24 bridge; Rio del Fuerte to Pacific drainage Orig No: M79−10	R.R. Miller, T. Uyeno & B. Chernoff	−106.47/26.2	UMMZ 208199
Oncorhynchus chrysogaster	19970221	Chih.	Fuerte	Arroyo La Pijuela, just upstream of mouth at Rio Verde, outside of El Vergel, Chihuahua upstream from the bridge on the El Vergel – Guadalupe y Calvo road.	D.A. Hendrickson, R.L. Mayden, J.R. Tomelleri, B. Kuhajda, Guy Ernsting & Thorpe Halloran	−106.49/26.28	UAIC 11620.01 & IB-UNAM-P 13110
Oncorhynchus chrysogaster	19970223	Chih.	Fuerte	Arroyo La Onza, tributary of Arroyo Coloradas, Rio Fuerte drainage	D.A. Hendrickson, L.T. Findley, H. Espinosa-Perez & J. Nielsen	−106.68/25.95	IB-UNAM-P 13162
Oncorhynchus sp.	20001103	Chih.	Fuerte	Estacion de Piscicultura "El Aparique" del Ejido El Ranchito	Dean Hendrickson, Rick Mayden, Guy Ernsting, Azael Salazar, Buddy Jensen, Leslie Ruiz & Kelly Meyer	−107.81/28.02	IB-UNAM-P 9559
Oncorhynchus sp.	20001103	Chih.	Fuerte	Arroyo above Estacion de Piscicultura "El Aparique" del Ejido El Ranchito. Upstream of hatchery	Dean Hendrickson, Rick Mayden, Guy Ernsting, Azael Salazar, Buddy Jensen, Leslie Ruiz & Kelly Meyer	−107.81/28.02	IB-UNAM-P 9560
Oncorhynchus sp.	20010624	Dur.	Fuerte	Rio Verde ca. 0.3 km upstream of the bridge (El Vergel-Guadalupe y Calvo)	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106.49/26.27	UABC 1190

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus chrysogaster	20010624	Chih.	Fuerte	Rio Verde ca. 0.3 km upstream of the bridge (El Vergel-Guadalupe y Calvo)	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106.49/26.28	UABC 1185
Oncorhynchus chrysogaster	20010725	Chih.	Fuerte	Arroyo La Onza at Rancho La Onza, a tributary of Rio Turuachi, Guadalupe y Calvo	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106.68/25.96	UABC 1183
Oncorhynchus chrysogaster	20020313	Chih.	Fuerte	Río Urique, Piedra Pinto	Héctor P. Espinosa, D.A. Hendrickson, Javier Leti	−107.15/27.25	IB-UNAM-P 13005
Oncorhynchus chrysogaster	20020313	Chih.	Fuerte	Río Urique, Piedra Pinto	Héctor P. Espinosa, D.A. Hendrickson, Javier Leti	−107.15/27.25	IB-UNAM-P 13010
Oncorhynchus chrysogaster	20020313	Chih.	Fuerte	Río Urique, adelante de Piedra Pinto	Héctor P. Espinosa, D.A. Hendrickson, Javier Leti	−107.08 27.25	IB-UNAM-P 13016
Oncorhynchus chrysogaster	19530722	Dur.	Sinaloa		A.O. Flechsig, C. Moller & party	n/a	CAS 81102
Salmo chrysogaster	19530729	Chih.	Sinaloa	Arroyo Casa Quemada. Three hours by horseback generally southwest of Guadalupe y Calvo.	Arthur O. Flechsig & Charles Moller	−107.03/26.06	CAS 20708
Oncorhynchus chrysogaster	20010625	Chih.	Sinaloa	Arroyo Casa Quemada (=Macheros), a tributary of Río Muinora, Guadalupe y Calvo	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−107.03/26.06	UABC 1188
Salmo chrysogaster	19530811	Dur.	Culiacán	Arroyo Dulces Nombres	A.O. Flechsig & C. Moller	−106.39/25.93	CAS 20709
Oncorhynchus chrysogaster	19530811	Dur.	Culiacán	Arroyo Dulces Nombres	A.O. Flechsig & C. Moller	−106.39/25.93	CAS 41656
Oncorhynchus chrysogaster	19970224	Chih.	Culiacán	Arroyo Agua Blanca in community of same name (also known as Soledad de Agua Blanca – near Ejido La Trinidad)	D.A. Hendrickson, L.T. Findley, H. Espinosa-Perez & J. Nielsen	−106.68/25.81	IB-UNAM-P 13163
Oncorhynchus chrysogaster	20010626	Chih.	Culiacán	Arroyo La Mesa, a tributary of Arroyo Agua Blanca, at Soledad de Agua Blanca	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106.68/25.8	UABC 1175
Oncorhynchus chrysogaster	20010626	Chih.	Culiacán	Arroyo La Mesa, a tributary of Arroyo Agua Blanca, at Soledad de Agua Blanca	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106.68/25.8	UABC 1187
Oncorhynchus chrysogaster	19520701	Dur.	San Lorenzo	Rio Los Arroyos, a tributary of the Río Truchas above power dam that drains into Río Remedios	F. Nuñez	−105.95/24.43	CAS 85225
Oncorhynchus chrysogaster	19520711	Dur.	San Lorenzo	Rio San Ignacio, a tributary of Río Truchas. Located close to the Río los Arroyos as described above [referring to Table 2 of Needham and Gard 1959].	Three sons of F. Nuñez	−105.95/24.43	CAS 20710
Oncorhynchus mykiss gairdneri	19561102	Dur.	San Lorenzo	"Rio Truchas, near San Miguel. Same tributaries as are listed above [in Needham and Gard 1959 Table 2) for July 1, July 17, and August 11, 1952 collections in the Río San Lorenzo. These specimens were brought out alive by tank truck except for 17 that died en route to the Hot Springs State [actually National] Fish Hatchery in New Mexico. The latter are now a part of the fish collections at the University of California."	USFWS (C.L. Fuqua, Tom French, Raymond Johnson, Lynn Hutchens) & New Mexico Fish & Game Dept (Joe Gallegas, Alfred Miller)	−105.95/24.43	CAS 81104
Oncorhynchus sp.	20001029	Dur.	San Lorenzo	Arroyo La Sidra immediately above Granja Truticola del Ejido de Vencedores	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer & Miguel Angel Molina (local guide)	−105.79/24.47	IB-UNAM-P 9544
Oncorhynchus sp.	20001030	Dur.	San Lorenzo	Arroyo La Sidra for 100 m above diversion/waterfall that is about 200 m above the Granja Truticola del Ejido Vencedores	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer & Miguel Angel Molina (local guide)	−105.89/24.4	IB-UNAM-P 9545

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus sp.	20001030	Dur.	San Lorenzo	Arroyo La Sidra from 100–200 m above diversion/waterfall that is about 200 m above the hatchery Granja Truticola del Ejido Vencedores	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer & Miguel Angel Molina (local guide)	−105.89/24.4	IB-UNAM-P 9546
Oncorhynchus sp.	20001030	Dur.	San Lorenzo	Arroyo La Sidra from 400–500 m above diversion/waterfall that is about 200 m above the hatchery Granja Truticola del Ejido Vencedores	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer & Miguel Angel Molina (local guide)	−105.89/24.4	IB-UNAM-P 9547
Oncorhynchus sp.	20001030	Dur.	San Lorenzo	Granja Truticola del Ejido Vencedores (purchased direct from raceway)	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer & Miguel Angel Molina (local guide)	−105.89/24.4	IB-UNAM-P 9563
Oncorhynchus sp.	20001030	Dur.	San Lorenzo	Arroyo La Sidra below first large falls below Granja Truticola de Vencedores (just below confluence of two tribs)	Azael Salazar, Buddy Jensen, Leslie Ruiz & Kelly Meyer	−105.79/24.47	IB-UNAM-P 13106
Oncorhynchus sp.	20001031	Dur.	San Lorenzo	Arroyo San Ignacio (San Lorenzo basin) from 20–200 m above road crossing at San Ignacio, ca. 4 km SW of San Miguel de Cruces	Dean Hendrickson, Rick Mayden, Guy Ernsting, Azael Salazar, Buddy Jensen, Leslie Ruiz & Kelly Meyer	−105.89/24.4	IB-UNAM-P 9548
Oncorhynchus sp.	20001031	Dur.	San Lorenzo	Arroyo San Ignacio (San Lorenzo basin) from 200–500 m above road crossing at San Ignacio, ca. 4 km SW of San Miguel de Cruces. At road crossing	Dean Hendrickson, Rick Mayden, Guy Ernsting, Azael Salazar, Buddy Jensen, Leslie Ruiz & Kelly Meyer	−105.89/24.4	IB-UNAM-P 9549
Oncorhynchus sp.	20010630	Dur.	San Lorenzo	Arroyo La Sidra, upstream of the trout hatchery, Ejido Vencedores, San Dimas	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−105.79/24.47	UABC 1164
Oncorhynchus chrysogaster	20010701	Dur.	Piaxtla	Arroyo La Quebrada (= El Pinto), ca. La Traspana, Dimas	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106/24.32	UABC 1161
Oncorhynchus chrysogaster	20010701	Dur.	Piaxtla	Arroyo La Quebrada (= El Pinto), ca. La Traspana, Dimas	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−106/24.32	UABC 1162
Oncorhynchus sp.	2000?	Chih.	Piaxtla	Río Verde in Area Protegida La Bufa	Rogelio Otto	−106.08/24.33	UANL
Salmo gairdneri	19460505	Dur.	Presidio	City El Salto – 1.2 miles above mill pond of Durango Lumber Co.	Ralph G. Miller	n/a	USNM 00132433
Oncorhynchus mykiss gairdneri	19460506	Dur.	Presidio	Rio Hondo	Ralph G. Miller	−105.48/23.77	UMMZ?
Salmo gairdneri	19460506	Dur.	Presidio	15–18 miles W. of El Salto at Río Hondo	Ralph G. Miller	n/a	USNM 00132434
Salmo gairdneri	19460506	Dur.	Presidio	15–18 miles W. of El Salto at Río Hondo	Ralph G. Miller	n/a	USNM 00132435
Salmo gairdneri	19460508	Dur.	Presidio	Nr. El Salto, El Salto Creek from falls 4–5 miles above mill pond to meadows	Ralph G. Miller	n/a	USNM 00132440
Oncorhynchus mykiss gairdneri	19520630	Dur.	Presidio	Rio Hondo, 20 miles northwest of the town of El Salto; 2 miles northeast of the town of Las Adjuntas. Assumed to be the same locality as R.G. Miller's 1946 collections.	J. Jaromille (Weitzman & Needham)	−105.48/23.77	CAS 210184

Table 1. Continued

Species	Collection date	State	River basin	Locality	Collectors	Longitude/ latitude	Institution and catalog #
Oncorhynchus mykiss gairdneri	19520701	Dur.	Presidio	Near Los Adjuntas.	P.R. Needham & S.H. Weitzman	n/a	CAS 210208
Oncorhynchus mykiss gairdneri	19520703	Dur.	Presidio	Rio Tabacatiado, six miles northwest of Las Campañas; ten miles from Las Adjuntas and 22 miles northwest of El Salto. Truck left at edge of barranca; we then took trail to stream 1.5 miles	P.R. Needham & S. Weitzman	−105.6/23.83	CAS 210148
Oncorhynchus mykiss gairdneri	19520704	Dur.	Presidio	10 miles nw. of Los Adjuntas, in deep barranca, 1.5 miles from end of logging road, about 1000 ft. down into barranca.	A. Solorzano	−105.6/23.83	CAS 81110
Oncorhynchus mykiss gairdneri	19550630	Dur.	Presidio	About 10 km from El Salto; taken in lagunitas "which is 2 deep pools only in a stream muddy with summer rains."	J. Jaromille (Weitzman & Needham)	n/a	CAS 20712
Oncorhynchus mykiss	19850315	Dur.	Presidio	Arroyo El Salto, ca 102 km W of Durango City	E. Uribe	−105.35 23.78	UMMZ 213313
Oncorhynchus sp.	20001026	Dur.	Presidio	Arroyo El Rincón (tributary of Arroyo Nogales [= El Salto]) 1–2 km below road crossing at El Rincón	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer, Lloyd Findley, Albert van der Heiden, Alwin van der Heiden, Héctor Plascencia, Héctor Espinosa, José Luis Villalobos, Angélica Daza & Miguel Angel Molina (local guide)	−105.6/23.9	IB-UNAM-P 9539
Oncorhynchus sp.	20001026	Dur.	Presidio	Arroyo known locally as Arroyo Nogales, but probably what shows as Arroyo El Salto or Los Fierros on the F13A18 El Salto 1:50,000 map	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, Azael Salazar, George Scott, Charles Nix, Buddy Jensen, Leslie Ruiz, Kelly Meyer, Lloyd Findley, Albert van der Heiden, Alwin van der Heiden, Héctor Plascencia, Héctor Espinosa, José Luis Villalobos, Angélica Daza & Miguel Angel Molina (local guide)	−105.55/23.96	IB-UNAM-P 9540
Oncorhynchus sp.	20001028	Dur.	Presidio	Centro Truticola of the Comisariado Ejidal la Victoria, Carratera Durango-Mazatlan, 108 km (about 5 km W of El Salto)	Dean Hendrickson, Rick Mayden, Joe Tomelleri, Guy Ernsting, George Scott, Charles Nix & Lloyd Findley	−105.47/23.73	IB-UNAM-P 9541
Oncorhynchus sp.	20001030	Dur.	Baluarte	Municipio La Ciudad, just above town of La Ciudad, Arroyo La Angostura (La Pompa), Tributario del Río Baluarte	Albert van der Heiden, Alwin van der Heiden, Héctor Plascencia & Lloyd Findley	−105.71/23.73	CIAD-Mazatlán 2000-3
Oncorhynchus sp.	20010628	Dur.	Baluarte	Arroyo Coscomate-Chavarría, between Coscomate and Chavarría towns	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−105.56/23.7	UABC 1189
Oncorhynchus sp.	20010629	Dur.	Acaponeta	Arroyo Los Metates (= Los Laureles) at Rancho Los Estanques, Ejido El Brillante, El Salto	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−105.41/23.65	UABC 1193
Oncorhynchus sp.	20010629	Dur.	Acaponeta	Arroyo Los Metates (= Los Laureles) at Rancho Los Estanques, Ejido El Brillante, El Salto	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−105.41/23.65	UABC 1163
Oncorhynchus sp.	20010629	Dur.	Acaponeta	Arroyo Los Metates (= Los Laureles) at Rancho Los Estanques, Ejido El Brillante, El Salto	Gorgonio Ruiz-Campos, Alejandro Varela Romero, Faustino Camarena Rosales & Sergio Sánchez Gonzáles	−105.41/23.65	UABC 1160
Salmo	18920000	?	?	Mexico: Durango	Mexican Commission through Fernando Ferrari-Perez	n/a	USNM 00130899
Salmo sp.	19520000	?	?	No other data.	P.R. Needham & party	n/a	CAS 210020
Oncorhynchus chrysogaster	19530722	?	?	Either 1) headwater of R. Verde (FM-15), Durango, or 2) Rio Sinaloa (FM-17), Chihuahua	A.O. Flechsig & C. Moller	n/a	CAS 85226
Salmo chrysogaster	19530722	Chih.	?	Either 1) headwater of R. Verde (FM-15), Durango, or 2) Rio Sinaloa (FM-17), Chihuahua	A.O. Flechsig & C. Moller	n/a	UMMZ 18846

despite many years of no additional collections of cutthroat-like specimens being forthcoming from Mexico.

Carl Lumholtz. Norwegian explorer and naturalist Carl Lumholtz conducted three of the better-known explorations of the Sierra Madre Occidental between 1890 and 1897 and mentioned native trout in descriptions of his first west-to-east traverse of that range. After climbing to a mid-watershed, mainstem pool of the Yaqui's Río Gavilán in January 1891, he remarked (Lumholtz, 1902):

> We soon found out that in the river Gabilan, some four miles south of our camp, there were immense quantities of fish, which had come up to spawn. No one ever interfered with them, and their number was simply overwhelming. As the task of feeding thirty men in these wild regions was by no means a trifling one, we used a stick of dynamite. In two hours three of us gathered 195 fish from a single pool. Most of them were big suckers; but we had also thirty-five large Gila trout. All were fat and of delicate flavour, and lasted us quite a long time.

Lumholtz' account, although anecdotal, has some value in estimating historic change of trout habitat. It is often assumed that Mexican trouts had much broader historical distributions, especially at lower elevations, but there are essentially no written documents or specimens to support this assumption. Unfortunately, since Lumholtz, like Audubon before him, did not collect specimens, it is impossible to ascertain that he was not referring to specimens of the cyprinid genus *Gila*. Populations of species in this genus, as mentioned above, were often called "trout" ("truchas") and still occur throughout the Río Yaqui basin at lower elevations than do true trout, including in the exact area of Lumholtz's report of "Gila trout" (Hendrickson et al., 1981).

Walter C. Bishop. We have been in contact with Walter C. Bishop, whose grandfather established residence in Durango in 1887, and who collected trout in the area for E.W. Nelson in 1907 (Evermann, 1908). Trout specimens reported by Evermann (1908) to have been collected by Nelson west of Durango in 1898 have apparently been lost, as were those the same author reports were collected by Mr. Bishop in 1907 (Needham and Gard, 1959). Members of the Bishop family still live in the area, however, and have long fished for trout in many local streams. Walter Bishop queried his father about his trout fishing and collecting activities, and responded (pers. comm., 2001):

> . . . regarding the rainbow trout we have in our mountains, west of Durango. My father came here to stay in 1897: He installed the first telephone lines in Durango, and as you know, was appointed American Vice Consul in 1902, a position he held until 1919. He was a fishing enthusiast and he made several trips on mule back over the mountains to Mazatlán [on the Pacific coast of southern Sinaloa – Figure 1]. He told me about fishing there for deep water fish, surf casting, as well as for trout in the streams along the way, which according to the trail he followed were tributaries to the Presidio and Baluarte rivers. I doubt seriously that he followed the Acaponeta River trail as he never mentioned it. If I am not mistaken, I remember him telling me he thought the trout were native and do not recall him mentioning anything about anyone planting eggs or fry. At that time, and it was during the first years of the 1900s, the country was very sparsely populated, the main activity being mining, no lumber and very little agriculture, which, due to the topography, was done on hillsides by hand. I also recall him saying that the trout were small but very tasty, as I confirmed in later years. He not only fished for trout when he went on these over the mountains trips, but he and a good friend and partner of his, Ed Hartman, made special fishing and hunting trips. One of the ranches Dad had in the mountains, near a town called Empalme Purísima had trout in a stream which ran through it.

Mr. Bishop's son has also fished extensively for trout in Durango's mountains for many years, telling us (pers. comm., 2001):

> I went to work at El Salto (8500 feet and higher), with the Durango Lumber Co., a British company, in the year of 1937, when I was17 years old. At that time, El Salto was accessible only by railroad. Our main diversion was hunting and fishing and we did plenty of both. There were several streams and all had trout in great numbers and on some occasions I caught as many as 200. They were an average of about 9-inches long and quite a delicacy, the smaller ones could be eaten bones and all. On one occasion, I believe around 1942–1943, an American gentleman by the name of Frank Miller (if I am not mistaken) [authors' comment – this was probably Ralph G. Miller, though dates

mentioned here are 3–4 years prior to those on his specimens at USNM – Table 1], from San Francisco, came from some scientific institution to study these trout. My boss, Mr. C.H. Cooper, the company manager, told me to accompany Mr. Miller to the different places where trout were more plentiful. We camped out several days and Miller, who must have been about 70 years old, collected hundreds of specimens, from tiny half inch fry up to 8–9 inches. I think we had about 8 or 10 gallon jugs filled with formaldehyde in which he put all he caught. He used seines, and he stirred up the fish by hand in the cavities alongside the streams, and when he had had enough we came back to the lumber camp. These jugs were well packed in lumber crates for protection and taken back to the States by Miller. I was called to the Army in 1943 and do not know what the outcome of this trip was.

On several occasions when fishing on a stream south of El Salto called La Rosilla creek, I caught several trout which were entirely different. Larger (11-13-inches long), and the meat was of different color, rather salmon colored; the meat on the others was cream colored. I am listing the names of the main streams where we used to fish: La Rosilla, Arroyo del Agua, Las Adjuntas, San Juan, Bajio Seco, Arroyo Hondo (I fished this last one about a couple of years ago and only caught three over a period of five hours, the longest one was about 8-inches long), Paso de las Mulas, San Esteban, etc. People say that the streams are pretty well fished out, and there are other factors which do not make camping out as safe as it used to be. It makes me feel pretty good that Dad sent those five specimens that you mentioned. I am surprised to hear that trout have been planted up in those streams, I've never heard about it from any other source. I worked for the lumber company from 1937 to 1950, and have been going back very often, but I never heard of the practice.

We interpret the information from the Bishop family as supporting the hypothesis that trout are native to the Río Presidio and other nearby drainages. Despite Stilwell's (Stilwell, 1948) suggestion to the contrary, it seems highly unlikely that rainbow trout could have been stocked and established over such an extensive and remote area as Mr. Bishop describes so quickly after the initial 1888 arrival of rainbow trout eggs to the Mexico City area for cultivation. The government's trout culture guide published in 1892 (Secretaría de Fomento, 1892) stated (in its title) that rainbow trout would first be available for distribution (from the Chimaleápam station near Mexico City) in 1893, thus leaving only about 10 years for distant and very remote parts of mountainous Durango to be widely stocked and large populations to become established for the far-flung fishing adventures of the Bishop family (and others) by shortly after the turn of the century. Additionally, if rainbow trout stocking was so prevalent early-on, and particularly, as Stilwell (Stilwell, 1948), Miller (1960) and Miller and Smith (1986) argued, promoted by American workers in the area, it seems unlikely that the Bishops, who obviously spent much time fishing and were obviously leaders of the American ex-patriot and local communities, would not have known of the practice. Furthermore, simply getting hatchery rainbow stock into the area at all was not nearly as easy as Miller surmised. For example, the railroad did not arrive to El Salto until the 1920s, prior to which it was accessible only by a two or three-day ride on mules from the capital city of Durango.

Seth Eugene Meek. Needham and Gard (1959) correctly summarized Meek's (1904) mention of trout west of Ciudad Durango as well as E. W. Nelson's visit to El Salto and his obtaining a series of specimens from there in the fall of 1907 (Evermann, 1908). Unfortunately, as seems to be the case with other early collections of Mexican trouts, the 1907 specimens (and apparently any that Nelson may have collected to the same area on his visit in 1898 (Evermann, 1908)) disappeared and were never described.

Aldo Leopold. Two visits to the Sierra Madre Occidental between 1936 and 1938 had a profound effect on Aldo Leopold, one of the most influential thinkers in conservation history (Forbes and Haas, 2000). Leopold's unusually perceptive field skills led him to question the impact of modern man on the pine-oak ecosystem of the southwestern United States, and sound a surprisingly early warning against genetic contamination of native trouts by introduced stocks (Leopold, 1918). He also warned against overgrazing that was already leading to brush encroachment, erosion, and altered fire and hydrological regimes in the southwestern U.S. (Leopold, 1924). Upon becoming the nation's first professor of wildlife management in the 1930s, Leopold tried to resolve widespread deer population explosions, and visited

biologically impoverished, highly managed German forests just before his Sierra Madre visits.

Leopold's mental model of historic land health was brought to life through his visits to the Río Gavilán, a Río Yaqui tributary with headwaters approximately 80 km west of Nuevo Casas Grandes, Chihuahua. There, frequent fires mixed with historical predator-prey relationships (wolf/puma-deer) in a pine-oak setting with streams that supported native trout.

Leopold remarked that all his life he "had seen only sick land, whereas here was a biota still in perfect aboriginal health." Much of the northern Sierra Madre Occidental had been kept from modern timbering and grazing until the 1940s through Apache raiding parties and sporadic occupations (1700s–1800s), the Mexican Revolution (1910–1920), and subsequent delays in land reform.

Leopold was inspired so much by the workings of the entire ecosystem that he mentioned it in numerous essays, and proposed the area as a control in a wide-ranging scientific study of land health (Forbes and Haas, 2000). He did not often specifically note trout in his essays and trip journal, but we do find passing mentions of them, such as the comment that his Mormon guide, Clarence Lunt, at the end of an unsuccessful day of hunting, caught seventeen native trout ranging from seven to eleven inches in length (Leopold, 1936). Leopold's prosaic focus on aspects of a healthy watershed is important to Mexican trout conservation (Leopold, 1937):

> To my mind these live-oak dotted hills fat with side oats grama, these pine-clad mesas spangled with flowers, these lazy trout streams burbling along under great sycamores and cottonwoods, come near to being the cream of creation. But on our side of the line the grama is mostly gone, the mesas are spangled with snakeweed, the trout streams are now cobble-bars.

Starker Leopold. Aldo Leopold's son Starker is well known to Mexican wildlife and conservation biologists for his major text on Mexican wildlife (Leopold, 1959). He accompanied his father to the Río Gavilán in 1938, and noted changes upon returning there shortly after his father's passing in 1948 (Leopold, 1949):

> At once it was evident that great change had come to the Sierra Madre. Around almost every bend we met a lumber truck groaning down the grade under a staggering load of pine planks. One of the mills was at Pacheco; a dozen others were operating in the high country around García and Chuhuichupa – the headwaters of our Gavilán. We knew then that instead of initiating an era of renewed acquaintance with the wilderness, we had come to witness its passing. Elsewhere in Mexico I had learned that sawmills and logging roads are followed inevitably by settlers and livestock.

Upon returning to the 1938 campsite, Starker noted:

> What had been a narrow channel winding through grassy banks was now a wide, scoured trough of cobblestones left by summer floods. The banks were undercut and piles of debris marked the high water of recent years. Sand bars in sheltered coves of the channel were mixed with coarse pine sawdust from the mills upstream. Apparently the logging in the headwaters, followed by hot slash fires, had destroyed in part the "watershed sponge," and the Gavilán was experiencing flash floods – the inevitable result of watershed abuse.

A photo taken during the Leopold's visit to the Gavilán in the late 1930s is reproduced in Figure 3a, together with a recent photo (b) that depicts the Río Gavilán very near the same site probably much as Starker Leopold saw it in 1948.

Two trout specimens collected from headwaters of the Río Gavilán in 1948 by Starker Leopold (Table 1) were examined by R.R. Miller (1950), who considered them to represent a native rainbow-like lineage.

Stanley Weitzman and Jack Lattin. Stan Weitzman made the first extant collections of Mexican golden trout in 1952 with Jack Lattin. Weitzman (pers. comm., 2002) recalled their journey, made at the request of Paul Needham, telling us:

> Essentially, our instructions were to head for the Río Verde, and we were headed towards that river when we met a young Mexican man returning from Parral who was looking for a ride to his home . . . that turned out to be near the crest of the ridges more or less east of the Arroyo Caeca Lobitas to which the Arroyo de la Rana is a tributary. Actually the natives there called it the 'Arroyo a la Rana' but Needham insisted on changing it to the name he published. We (Jack Lattin and myself) asked this man if he knew of any trout in the region. He responded in the positive and offered to have members of his family take us to the 'Arroyo

Figure 3. (a) The Río Gavilán, a tributary of the upper Río Bavispe of the Río Yaqui basin, as photographed by Leopold in January 1938 (photo from New Mexico Journals, Aldo Leopold Papers, University of Wisconsin-Madison Archives); (b) The Río Gavilán within 1 to 1.5 km downstream of the site photographed by Leopold, as photographed in April 1999 by WF. Some riparian vegetation has been removed by severe scouring floods, and the river bed severely aggraded and cobbled with high sediment content. The river has downcut 0.3 to 1.3 meters to a stable base since 1938, with remaining riverside sycamores important to bank stability. Riparian regeneration is hindered by cattle grazing throughout the growing season. Native trout are typically no longer found here, but persist in nearby tributaries. The conditions evident in 1999 (b) are unfortunately pervasive throughout much of the study area.

a la Rana' where he knew trout existed. We drove in as far as we could, then hiked in with him to what was actually his father's small ranch in the Cerro Agua Caliente. We were greeted warmly and given a 'room' to stay in for a few days. They took us by horse back to the 'Arroyo a la Rana' (yes, there were frogs there) and that is where I took the color photos of the live trout. These were the photos from which Plate 1 in Needham and Gard (1959) was made. Part of the trail to 'Arroyo a la Rana' was on a pack trail headed to Guadalupe y Calvo, and we were passed by more than one mule pack train carrying mostly bottles of soft drinks.

As I recall it, areas where Jack Lattin and I collected in the Conchos drainage (after Needham had left) were at lower elevations, as Jack wanted to collect aquatic insects there. We found no trout and expected none in these localities.

Arthur Flechsig and Charles Moller. In 1953, University of California Los Angeles ichthyology graduate students Arthur Flechsig and Charles Moller traveled to western Chihuahua in search of trout and spent several days in the Río Conchos watershed. Flechsig's field notes state that residents of the mountain village of Panalachi told him that fish matching his description of trout could be found in the Conchos basin within a days ride on horseback. Although lack of accurate topographic maps and being in unfamiliar and rugged territory hampered Flechsig in knowing his exact location, he rode to an aforementioned site (possibly the mainstem of the upper Río Conchos) but found it largely dewatered by drought conditions (Flechsig, unpublished field notes, 1953; Flechsig, pers. comm., 2002). A collection by Flechsig west of Panalachi included Rio Grande sucker, *Catostomus plebeius*, and longnose dace, *Rhinichthys cataractae*, two species frequently associated with Rio Grande cutthroat trout in New Mexico.

Paul R. Needham and Richard Gard. Needham and Gard (Needham, 1955; Needham and Gard, 1959), were the first to comprehensively synthesize information about Mexican native trouts after securing large series of specimens from numerous collecting expeditions to Baja California and diverse locations in the Sierra Madre Occidental from 1936–1956. Their work was driven in part by hopes of discovering species or races with high temperature tolerances that might be introduced to establish fisheries in the United States in habitats otherwise too warm for the trout stocks then known to fisheries managers (Needham, 1938; Needham, 1955; Needham, 1959). They first collected *Oncorhynchus mykiss nelsoni* in the Sierra San Pedro Mártir of northern Baja California, then explored mainland Pacific drainages to seek out the trout mentioned long before by Cope (1886). They later collected still-undescribed forms in Chihuahua, that had been reported earlier by Meek (1904) and R.R. Miller (1950).

Needham's and Gard's extensive sampling allowed them to compile significant morphometric and meristic data sets, analyses of which resulted in a massive overview paper on their work, published in 1959, and later description of the Mexican golden trout (Needham and Gard, 1964). This distinctive species from headwaters of the ríos Fuerte, Sinaloa and Culiacán (Figure 2a), was easily differentiated by Needham and Gard from specimens they had collected from headwaters of rivers further south, the San Lorenzo and Presidio (Figure 2b, e) as well as those to the north in the Río Bavispe (northern Yaqui) and Gúzman drainages (Figure 2f). Such specimens from north and south of the Mexican golden trout distributional area, however, were found by Needham and Gard to be variable and not easily classified, and remain undescribed today. Though Needham and Gard considered trout of the Río Presidio drainage, which strongly resembled rainbow trout from California, to be possibly native, their reviewers did not (Lindsey, 1960; Miller, 1960). Twenty-six years; later, Miller still held that opinion (Miller and Smith, 1986), and Minckley et al. (1986) did not counter it, but Behnke and Tomelleri more recently (Behnke and Tomelleri, 2002) did not concur, considering the San Lorenzo and Río Presidio trouts to be native.

Post Needham and Gard literature and unpublished collections

Since Needham's and Gard's collections, additional specimens of Mexican trouts were added to museum collections and several other populations were sampled or observed, including some in drainages not previously sampled. Though much of this new collection information went unpublished, as discussed in the systematics section of this contribution, publications began to appear that used modern genetic techniques to address complex issues of relationships of these trouts. We discuss these more recent collections and publications in a geographic context.

Baja California. Almost 45 years after the first collections of the Baja California rainbow trout by P.R. Needham and collaborators in the Sierra San Pedro Mártir (SSPM), collections in Baja California were renewed by Edwin P. Pister, Carlos Yruretagoyena and the late Katsuo Nishikawa. Their 1984–1986 collections produced samples for allozyme studies by Berg (1987) and Berg and Gall (1988), while their 1987–1994 work explored new localities and expanded knowledge of the distribution, habitat and conservation status of this subspecies (Ruiz-Campos, 1993; Ruiz-Campos et al., 1997; Ruiz-Campos and Pister, 1995). Most of their specimens were deposited in the Fish Collection of the Universidad Autónoma de Baja California (UABC) at Ensenada, Mexico. Samples taken in 1995 by Ruiz-Campos and collaborators from four populations (San Rafael, El Potrero, La Zanja and Santo Domingo) were used in mtDNA and microsatellite DNA studies by Nielsen and collaborators (Nielsen et al., 1997, Nielsen et al., 1998).

Yaqui, Mayo, and Guzmán basins. The proximity of the Yaqui, Mayo and Guzmán systems to the international border and, at least in the case of the Yaqui and Guzmán systems, the facts that their hydrographic boundaries cross the border and that they harbor endangered species shared by both countries, have resulted in more attention by biologists than has been paid to other basins of the northwestern mainland that are wholly in Mexico.

Needham and Gard did not report existence of native trout in either the Río Mayo basin or the southern (Papigochi) Río Yaqui basin. It appears that the first specimens of these were obtained in late March 1975 (Table 1) by Peter Warren, then a graduate student at the University of Arizona (UAZ) in Tucson. While on an ecology course field trip transect of the northern Sierra Madre Occidental with faculty and other students, Warren purchased four small specimens of trout from a local fisherman encountered ascending the rough trail from the headwaters of the Río Candameña at the base of the waterfall of Cascada de Basaseachi where they had been caught. Although erring in the specific identification ("*Salmo chrysogaster*") and number of trout purchased ("one"), the collection was mentioned in print much later by Paul Martin (one of the faculty members on the trip) in his introduction to a book on the region by Charles Bowden (Martin, 1993). Warren preserved the specimens and took them to the Fish Collection at UAZ, where one of us (LTF), then curating the collection, and Charles H. Lowe, Jr., faculty member at UAZ, recognized their importance as a native species different from the Mexican golden trout. Warren's discovery thus prompted organization of a return trip to the Sierra Madre Occidental of Chihuahua in November 1975. Several specimens of the trout, as well as other fishes, were collected from the Arroyo Basaseachi stream above the falls, as well as a few more specimens from the Río Candameña below the falls, and were cataloged into the UAZ Fish Collection (Table 1). Although subsequent loan of the specimens and their partial study by R.R. Miller at the University of Michigan resulted in some specimens remaining there (Table 1), all are presently under morphological study and description and comparison with other Mexican native trouts by some of us (DAH, LTF, HEP) and colleagues. In addition to collections from the headwaters of the Río Mayo, the 1975 UAZ party also collected fishes in the Río Tomochi headwater stream of the upper Río Yaqui system which produced a single small trout (Table 1). This specimen appears to be the first one collected from that part of the Río Yaqui and made available for scientific study until Hendrickson and collaborators (Hendrickson et al., 1981) reported on extensive fish collections, including trouts, that were made throughout the Río Yaqui basin in 1978. During the same survey, they also made collections from headwaters of the closely adjacent Río Mayo basin and later collected elsewhere in the Sierra Madre Occidental. Though not all previously published, all of these collections resulted in specimens deposited at ASU and UMMZ, and somewhat later a few trout specimens were collected from the Río Yaqui by another of us (AVR) and colleagues (Table 1).

Two attempts by DAH to collect trout from Needham and Gard localities in the Guzmán basin near the Yaqui divide in the 1980s and early 1990s failed to produce trout, as had a survey of part of the Guzmán system in the late 1980s, though it primarily targeted other species (Propst and Stefferud, 1994). During the 1990s, however, one of us (BJ) and collaborators collected tissues (but not voucher specimens) of trout from numerous localities in both the Yaqui and Guzmán basins (Table 1) and genetic analyses of these have since been published (Nielsen, 1997; Nielsen et al., 1997).

Fly-fishermen from the U.S. have discovered, sampled and reported on native trouts in northwestern Mexico by personal communications with us and via occasional magazine articles and books, adding

valuable anecdotal observations to our database (M. Graybrook, 2002; Johnson, Jr., 1997; Johnson, Jr., 2000; Prosek, 1997; Smith, 1983; A. Stonkus, 1998; A. Stonkus, 2002). What are reported to be some of the best habitats and largest populations of native trout in the Río Yaqui basin remain to be sampled by biologists for voucher specimens. Notable among these are tributaries of the Río Gavilán and uppermost Río Bavispe, such as the Arroyos Arco, Estribu, Nutria, Yunque, Guacamayas, Los Chales and Yenquins (Table 1).

Fuerte, Sinaloa, and Culiacán basins. Trout collections in these basins subsequent to those reported by Needham and Gard (1959, 1964) are from expeditions made by several of us in 1997 and 2001 (Table 1, Figures 1, 2). Results of genetic analyses of these samples was recently published (Nielsen, 1997; Nielsen and Sage, 2001), however, the sample from Arroyo La Onza was erroneously reported in those papers as being from the Sinaloa basin. Arroyo La Onza is a Río Fuerte tributary (Table 1). The Agua Blanca sample reported in the same papers is correctly placed in the Culiacán basin (Table 1).

San Lorenzo, Piaxtla, Presidio, Baluarte and Acaponeta basins. Some of us explored this region in late October, early November, 2000 and in 2001, obtaining samples from the San Lorenzo, Piaxtla, Presidio, Baluarte and Acaponeta basins (Table 1, Figures 1, 2). Additionally, a small sample of small specimens from La Bufa on the Río Verde, a northern tributary of the Río Piaxtla, has been deposited at Universidad Autónoma de Nuevo León (UANL – Roger Otto, pers. comm., 2000, Table 1). We have not examined these specimens, but long-time residents of the area report that there have always been trout in this stream, and the collector, Roger Otto, based on such testimony and long familiarity with the region, feels quite certain that no introductions of trout have occurred in the area and that these specimens represent a native population.

Our collections from Arroyo La Sidra (Table 1) in the San Lorenzo drainage proved interesting. We collected from the stream alongside a rainbow trout growout facility and from upstream, above a 15-m waterfall that would presumably prevent any escapees from the hatchery from ascending. Specimens from above the falls are unusual for their tall, thin parr marks, as sometimes seen in cutthroats and redband trouts, and they are sparsely spotted when young and generally stout and stubby in body form (Figure 2c). Lateral-line scale counts range from about 145 to 160; higher than might be expected from any known hatchery rainbows. Vertebral counts from seven specimens are 62, 63, 64, 65, 65, 65, and 66. Río Truchas trout (also San Lorenzo drainage) averaged 61 vertebrae (Needham and Gard, 1959), whereas McCloud rainbows (introduced into Mexico in 1888 – see above) average 63 or fewer vertebrae (Behnke and Tomelleri, 2002). We also collected Arroyo La Sidra further downstream, well below the hatchery and below another series of large waterfalls, again finding specimens (including individuals up to 304 mm SL) that expressed broad variation in coloration and spotting patterns. The hatchery proprietor stated that he and his father formerly caught trout with orange bellies in Arroyo La Sidra prior to establishment of the hatchery in 1990, but that the orange-bellied fish had since become increasingly rare. We collected several small specimens above the falls immediately above the hatchery that had orange bellies, and many of the larger specimens showed a faint orange blush. About five of our specimens showed a classic cutthroat trout-like pattern of spots clustered on the caudal peduncle, with very few spots anterior to the dorsal fin. Most of our adult males showed coloration similar to rainbow trout, but had higher scale counts characteristic of native Mexican trouts. Such a "rainbow appearance" may be expected from this part of Mexico, as any native trouts are thought to derive from ancient invasions of coastal rainbows (Miller, 1960; Needham and Gard, 1959). The Arroyo La Sidra fish appear to differ significantly in many ways from historical populations of San Lorenzo trout from the Truchas watershed (Needham and Gard, 1959), and from others we collected in the San Lorenzo drainage (Table 1). These latter specimens average 65 vertebrae but otherwise bear little resemblance to the Arroyo La Sidra trout. We hope that our ongoing analysis of DNA from fin clips of these specimens will help shed light on their origins, but we provisionally suggest that throughout Arroyo La Sidra, highly variable body proportions, counts and coloration suggest hybridization of native and non-native stocks.

Is there a native trout in the Río Conchos basin?

Though Needham and Gard (1959) and others mentioned the somewhat surprising lack of records of trout from the upper Río Conchos, and Miller (1950, 1960) stated "the possibility that cutthroat trout still exist somewhere in northwestern Mexico

merits careful investigation," such investigations have yet to occur; the Río Conchos headwaters remain very poorly sampled for fishes. We hypothesize that the Rio Grande cutthroat trout, *Oncorhynchus clarkii virginalis*, currently found in the Pecos and Rio Grande headwaters in New Mexico (Sublette et al., 1990), potentially had access to the Conchos drainage, where surely adequate habitat existed and perhaps still exists.

Historical evidence from the late 1800s place Rio Grande cutthroat trout populations in the Guadalupe and Davis Mountains in southwestern Texas (Garrett and Matlock, 1991), near the mouth of the Río Conchos, at elevations far below those found in much of the Conchos basin. Trout scales were reported by archeologists analyzing 1,100-year-old human coprolites from shelter caves along the lowermost Pecos River in Texas (Sobolik, 1991), about 200 km below the mouth of the Río Conchos. Expanding on these studies indicating that trout were once present in Texas near the mouth of the Río Conchos, we here report on published and recently found archival materials that support existence of a cutthroat trout in the headwaters of the Río Conchos.

Were Cope's specimens true cutthroats? The term "blackspotted trout" used by Cope in his three-sentence communication (Cope, 1886) was the synonym at the time for "cutthroat trout," and *Salmo purpuratus* (with which he briefly compared his specimens) is now considered a synonym of cutthroat trout, *Oncorhynchus clarkii*. Cope's mention of basihyal (basibranchial) teeth supports identifying the trout as a cutthroat (Behnke, 1992; Behnke and Tomelleri, 2002), since rainbows and all other known Mexican trouts lack them. Furthermore, we are confident that if Cope's specimens represented any of the currently known Mexican trouts (which were unknown in 1886), he would have surely noticed their prominent, broadly white-tipped anal and pelvic fins, a character not seen in any form of "southern" cutthroat trout (the Rio Grande, greenback, Colorado River, Bonneville, Yellowstone, and/or Lahontan subspecies). Cope was familiar with several forms of cutthroat trout, having collected them in the southwestern U.S., and he described *Salmo spilurus* (Cope, 1872), which was later synonymized with the Rio Grande cutthroat. The only other trout known to be native to southwestern Chihuahua (as Lupton, who provided the specimens to Cope, described his collection locality) is the Mexican golden trout (Needham and Gard, 1964), found in Pacific drainage headwaters of the ríos Fuerte, Sinaloa and Culiacán, but unknown to science at the time Cope was examining Lupton's specimens. Like other known Mexican trouts, the Mexican golden is a close relative of the rainbow trout, *Oncorhynchus mykiss*), with many small dark spots on the body, typically confined to the dorsal region (above the lateral line). The southern cutthroat trouts (including the Rio Grande cutthroat) have less profuse spotting on the dorsum, have spots on the side of the body below the lateral line, and have a longer maxillary (upper jaw) than rainbow trout. Additionally, the Rio Grande cutthroat, unlike the Mexican golden, typically has a concentration of larger spots on the posterior trunk and tail region, and has basibranchial teeth. Cope clearly seems to have been looking at cutthroat specimens, not Mexican golden trout.

Where were Cope's specimens collected? The standing belief, expressed in the literature, that Cope's specimens attained from Lupton were from a Pacific drainage appears erroneous, and we believe we have traced the source of the error through archived personal correspondence. The report by Jordan and Evermann (1902) that cutthroat trout occurred in the Sierra Madre of Chihuahua, Mexico was undoubtedly based on Cope's 1886 note in *American Naturalist*. Archived correspondence clearly indicates that Evermann (*in litt*., 1906, to Nelson, Archive of Edward William Nelson) believed it likely that the trout mentioned by Cope (collected by Lupton) came from the Río Conchos watershed. Evermann wrote to Nelson at the Smithsonian Institution, querying about any trout the latter might have seen during his travels in the Sierra Madre Occidental, and quoting the vague locality of Lupton's trout specimens almost verbatim from Cope's published note (Archive of E.W. Nelson). Nelson replied that he had been in that "exact place," where he saw trout in a stream on the Pacific slope of Mt. Mohinora (he was near El Tule in the Río Sinaloa drainage) (Barton W. Evermann Archive, 1906; Field journal of E.O. Goldman, 1898). Headwaters of each of the ríos Fuerte, Conchos, Culiacán and Sinaloa all interdigitate closely on and near Cerro Mohinora. The correspondence between Evermann and Nelson clearly shows that neither knew any more of Lupton or his travels and collections in Mexico than what was described so vaguely by Cope (1886), and Nelson's "exact place" can only be a reference to the general geography of the area as described in Evermann's

letter (and Cope's note) "between 7000 and 8000 feet, in the southern part of the State of Chihuahua, near the boundaries of Durango and Sinaloa." Evermann (1908), however, mistakenly published Nelson's "exact place" as the locality where Lupton's trout were collected, an error later repeated by Needham and Gard (1959).

The "Professor Lupton" whom Cope indicated collected the specimens that he examined and declared to be "blackspotted trout," was undoubtedly Nathaniel Thomas Lupton, Chair of the Department of Chemistry at Vanderbilt University in the 1870s and early 1880s. Lupton was an associate of William Henry Morgan, President of the Santa Gertrudis Mining Company in Mexico (W.H. Morgan Papers, 1836–1893), who traveled with Lupton in 1879 to Chihuahua and Coahuila via El Paso, Texas (Anonymous, 1879). Their exact destination(s) in Chihuahua remains unknown, but Lupton did donate silver ore samples from Chihuahua to the Vanderbilt University Museum during the 1878–1879 school term (Vanderbilt Register, 1879). We have found no firm evidence that Lupton's trout specimens were collected during this trip, but subsequent trips clearly took him through what might have been trout habitats.

A letter from Dr. Wm. T. Arrington (of Memphis, Tennessee) to W. H. Morgan shows that Lupton was again in Mexico in 1883 (W.H. Morgan Papers, 1836–1893). Arrington states that Lupton reported on the "San Francisco" mine in "Old Mexico" and was procuring technologically advanced machinery for it. Exactly which "San Francisco" mine Arrington was referring to is unknown (the place name occurs repeatedly all over Mexico), but the mine likely was the San Francisco del Oro, at the time a large and affluent mine west of the city of Hidalgo del Parral, Chihuahua. Lupton also visited the then relatively isolated mountain mining town of Guadalupe y Calvo in southwestern Chihuahua (Flippin, 1889). In 1883, common routes to the mines and town of Guadalupe y Calvo of southwest Chihuahua and northwest Durango were negotiated by mule or horseback from Hidalgo del Parral, which was reached via stagecoach from the railroad depot at the eastern city of Jimenez (Flippin, 1889; Griggs, 1907; Hamilton, 1883; Ober, 1884). These routes passed near San Francisco del Oro, near Hidalgo del Parral, and crossed headwaters of two major tributaries of the Río Conchos, the ríos Florido and Balleza (Anonymous, 1883; Goldman, 1898; Griggs, 1907) and, on the other (Pacific) side of the continental divide, crossed the westward-flowing Río Verde and its tributary, the Turuachi, tributaries of the Río Fuerte.

Lupton was also in the same region in the summer of 1884, having traveled to the Refugio Gold and Silver Mines just west of Copalquin in northwest Durango (Killebrew, 1898). According to Killebrew (1883, 1898), Lupton met with a Major Warren in Hidalgo del Parral and subsequently rode to Copalquin. Copalquin was at least two days ride south of Guadalupe y Calvo. Lupton may have kept a more southwesterly course (hence a more direct route to Copalquin) than that required to reach Guadalupe y Calvo, and presumably would have crossed tributaries of the Sinaloa watershed, as well as those of the upper Río Balleza (Conchos basin). We strongly suspect that Lupton's trout specimens came from the Río Balleza or its tributaries, such as the Rancho Viejo or El Maiz, or possibly even from the more easterly Río Florido (also Conchos basin) watershed, rather than the Pacific drainage as assumed by subsequent authors. Modern maps of northern Mexico show the major headwaters of the Río Balleza to be within the state of Durango, reaching within a few kilometers of the Pacific slope Río Verde watershed. However, in the 1880s, the Chihuahua/Durango border in that vicinity was as much as 60 kilometers south of its current location, thus placing all headwaters of the Balleza entirely within Chihuahua (Rand McNally Co., 1880). Additionally, maps of Chihuahua in use during the late nineteenth century (Mexican Central Railway Co., 1898; Moore, 1894; Ober, 1884; Rand McNally Co., 1880) consistently placed Hidalgo del Parral and the Río Balleza about 20 to 80 kilometers west of their actual location, hence apparently much closer to the Durango/Sinaloa borders that figure so prominently in Cope's description of Lupton's collection site. In summary, a locality in the upper Río Balleza drainage at the time Lupton collected the specimens he gave to Cope would have very nicely fit the description that Cope (1886) published: "between 7000 and 8000 feet, in the southern part of the State of Chihuahua, near the boundaries of Durango and Sinaloa."

Another earlier report of trout in the Río Conchos basin. As mentioned above, Audubon (1906) was the first to mention trout in Mexico, and a careful reading reveals that he must have been in the Río Conchos basin on July 3, 1849 when he reported trout (above). His itinerary, map, place names, direction of travel as he moved upstream, and other details regarding

the journey leading to and beyond this point, allow us to place him unambiguously on this date in the Río Conchos basin, to the north of modern-day Nonoava, and probably in the Tecubichi, Guacareachi, or Agua Caliente sub-drainage. Furthermore, his mention of groves of pine trees along the stream corroborate that he was potentially in trout habitat, probably at or above 2000 meters elevation, and argue against the possibility that his reference was to cyprinids of the genus *Gila*, that were sometimes called "trout" in the southwestern U.S. (Minckley, 1973), instead of to true trout. Though species of *Gila* in the region do range into high-elevation streams in pine forests, they are more commonly found at lower elevations (DAH unpubl.).

Why have there been no subsequent collections of trout from the Río Conchos? Our review of literature and museum fish collection catalogs reveal that though lower reaches of the Río Conchos basin have been moderately sampled, collections in that basin's extensive headwater areas have been very rare since Flechsig's and Moller's brief excursion (above). The basin remains almost completely unsampled above 1700 m elevation, which our experience in adjacent drainages indicates to be below the lower limit for trout in the region. Sydney Anderson collected at two sites near the town of Bocoyna in 1958, taking Rio Grande sucker (*Catostomus plebeius*) and longnose dace (*Rhinichthys cataractae*) at about 2400 m elevation, and one of us (RLM) collected the same species from a tiny tributary of the Arroyo Bocoyna in 1987. We found no scientific collections of fishes from the more than 2000 km^2 of the Río Nonoava watershed, which reaches 2850 m elevation. Similarly, the Río Balleza and Río Florido are apparently unsampled for fishes above 1700 m, although they reach more than 3300 m.

Did trout have access to the Río Conchos? Evidence from other fishes. Throughout the Rio Grande basin in the United States, presence of longnose dace is considered an indicator that trout formerly had access to, or might inhabit higher reaches of, the same streams (Mike Hatch, pers. comm., 2002; Robert Behnke, pers. comm., 2002). Our survey of museum collections found at least 14 collections from the Río Conchos basin that include longnose dace, a species also ranging to lower elevations (below typical trout habitat) in New Mexico and Texas. Longnose dace is thought to have entered the Rio Grande drainage via stream capture by the Pecos River between 12,000 and 20,000 years ago during the last major pluvial (Hatch, 1985) and since dispersed throughout the drainage into headwaters of both the Rio Grande/Río Bravo and Río Conchos. The climate was much cooler during this pluvial and "life zones" for flora and fauna were some 1300 meters lower than present day. Consequently, we believe the Rio Grande cutthroat trout could have accessed the Conchos through the same dispersal corridor. Alternatively, trout could have arrived to the Conchos via other hydrographic connections to Pacific drainages. During mid-Pleistocene or more recently, the Río Papigochi (now the major far southeastern tributary to the upper Río Yaqui system – Figure 1) may have been confluent with the Río Conchos. Many species and groups of fishes share a Conchos – Yaqui (and beyond) distribution, and structural geology also supports the likelihood of past connections between these basins (Brand, 1937; Miller, 1959; Miller, 1976; Hatch, 1985; Minckley et al., 1986; Echelle and Echelle, 1998, Minckley et al., 2002; Mayden, in press; Norris et al., in press). Among the fishes involved are species of the genus *Gila* (some still undescribed), the former *Catostomus conchos* (of the Río Conchos) that was synonymized by R.R. Miller with *Catostomus bernardini* of the Río Yaqui and Pacific drainages to its south (Hendrickson, 1984; Hendrickson and Varela-Romero, 2002), *Codoma ornata*, *Campostoma ornatum*, and the genus *Cyprinodon*.

Trout phylogenetic relationships and biogeography

The taxonomy, systematics, and biogeography of western North American trout species and subtaxa in general are relatively poorly known or in a state of flux and debate. Especially little understood are diversity and phylogenetic relationships of native Mexican trouts. While many historical and recent studies of variation (genetic and non-genetic data) have been conducted within and between trout species of the western United States and Canada, very few comparative analyses exist at a geographic and taxonomic scale providing meaningful genealogical information with respect to the biodiversity of these taxa and the Mexican trout species and relatives. Without a doubt, most systematic and evolutionary studies of western North American trouts have not been done within a comparative phylogenetic perspective and have focused on single species, subspecies or populations within a species, and many of these studies have

only evaluated questions regarding possible hybridization. Without comparative data for related populations or species these studies are difficult to interpret and provide no predictive power as to interpreting patterns of diversification, possession of particular morphological and molecular traits, and the evolution of life history strategies. Further hindering our understanding of the evolution of Mexican trouts is the fact that few studies of other trouts have included them. However, a few important studies have employed morphological and molecular data and phylogenetic methods that provide insight into the evolution of Mexican trouts.

From a historical perspective, many have argued that the Mexican trout species are part of a larger polytypic "rainbow-trout" lineage, presumed to be monophyletic and closely related to a "cutthroat-trout" lineage (Behnke, 1992; Utter and Allendorf, 1994). The "rainbow-trout" lineage also includes forms referred to as redband trout, the various subspecies of rainbow trout (*Oncorhynchus mykiss*), the Mexican golden trout, the California golden trout (*O. mykiss aguabonita*), as well as the anadromous rainbows known as steelheads. In some perspectives this group has also included the Gila (*O. gilae*) and Apache (*O. gilae apache*) trouts of New Mexico and Arizona. For example, Behnke (1992) argued that the "coastal rainbows of the ríos Presidio and San Lorenzo, the Mexican golden trout, trouts from the ríos Mayo and Yaqui, and both the Apache and Gila trouts were derived from a common ancestral lineage inhabiting rivers draining to the Gulf of California. However, many of these studies lack critical phylogenetic arguments and supporting data to corroborate the monophyly of groups. As an example, Utter and Allendorf (1994) provide a general overview of phylogenetic relationships in *Oncorhynchus* that clearly identifies gross problems in the current state of trout taxonomy, systematics, and evolutionary studies.

Phylogenetic relationships of trout from Mexico and southwestern U.S. have generally been poorly understood. As previously mentioned, Apache and Gila trouts, and trouts from rivers of Mexico, have traditionally been considered to be part of a group related in some way to cutthroat (*O. clarkii*) and rainbow (*O. mykiss*) trouts. These early studies (Behnke, 1979; Gold, 1977; Legrendre et al., 1972; Miller, 1972; Needham and Gard, 1959) left many questions regarding relationships among these trouts unanswered. It was not until the phylogenetic analysis by Stearley and Smith (Stearley, 1992; Stearley and Smith, 1993), using morphological and other data, that support for evolutionary hypotheses among these species became available. Their findings diverged from previous ideas on relationships of Pacific salmon and trout, demonstrating that at least two independent lineages of trout occur in Mexico, the Mexican golden trout and a rainbow lineage, of which the Baja California rainbow trout and possibly the various forms in other mainland Pacific drainages are thought to be members. Their evaluation of relationships clearly refutes the previous hypothesis of a sister- group relationship between a "cutthroat-trout lineage" and a "rainbow-trout lineage," and no evidence was found to support monophyly of a rainbow-trout lineage consisting of *O. mykiss irideus*, *O. m. gairdneri*, and *O. m. aguabonita*. Rather, these taxa were found to be more closely related to a monophyletic Pacific salmon clade than to other *Oncorhynchus*. Mexican golden trout is hypothesized to be the basal sister group to a clade involving a lineage inclusive of Gila and Apache trouts and sister to the "rainbow" and Pacific salmon clade, agreeing with the earlier suggestion of Miller (1972). In direct conflict to relationships presented by Stearley and Smith, however, a more recent phylogenetic analysis of molecular data on a reduced number of taxa of western trout species (including *O. mykiss* and *O. clarkii*) and Pacific salmon species (Oakley and Phillips, 1999) supported the hypothesis that *O. mykiss* is more closely related to *O. clarkii* than it is to Pacific salmon species.

Loudenslager and collaborators (Loudenslager et al., 1986) were the first to examine molecular variation in some populations of trouts in Mexico and presumed relatives within a phylogenetic context. Using samples of Río Mayo trout provided by one of us (DAH.), and samples of Apache (then *O. apache*), Gila (then *O. gilae*), rainbow trout (*O. mykiss*, then *O. gairdneri*), and cutthroat trout (*O. clarkii*), these authors employed starch-gel electrophoresis for 36 presumptive gene loci and distance Wagner analyses of Nei's (1972) similarity index to examine genetic distinctiveness of these taxa and evidence for hybridization between the latter four species. Historically, the classification of *Oncorhynchus* from the ríos Yaqui and Mayo have been uncertain; however, Behnke (1979) considered trout south of the range of Mexican golden trout in the ríos Presidio and San Lorenzo to be *O. mykiss*. Loudenslager and collaborators (Loudenslager et al., 1986), using midpoint rooted trees, identified a *O. clarkii* lineage "sister" to a lineage wherein Apache and Gila trout form a clade

sister to Río Mayo trout and hatchery-reared rainbow trout. While this can essentially be viewed as an unrooted network of relationships, it is clear that Apache and Gila trout are closely related to the *O. clarkii* and *O. mykiss* groups as well as to the Mexican trouts; unfortunately, these authors did not include Mexican golden trout in their analysis. Samples of Baja California rainbow were used as an outgroup by Berg (1987) and Berg and Gall (1988) to infer the evolutionary genetics of coastal rainbow trout (*O. m. irideus*). The Baja California rainbow is distinguished from other coastal rainbows by the presence of the Ck-2 (115) allele. In an unpublished work on Baja California rainbow trout, Pister and collaborators identified different frequencies of Ck-2 (115) allele, from 0 to 50%, in three populations sampled. These authors compare Baja California rainbow with the Río Mayo trout, where the Idh-1, 2 (100) and Palb-1, 2 (105) alleles were synapomorphic and delineated these taxa as discrete lineages. Their analyses supported a closer relationship between coastal rainbow trout and Baja California rainbow trout than between either of these and the Río Mayo trout. More recent molecular analyses of Baja California rainbow trout using mtDNA and DNA microsatellites confirmed this close genetic relationship between coastal rainbow trouts and Baja California rainbow, but also documented unique dominant alleles for three nuclear microsatellites in Baja California rainbow trout (Nielsen, 1997; Nielsen et al., 1997; Nielsen et al., 1998).

Collections of Mexican trouts from the early 1990s made by some of us (Table 1), while largely unvouchered in museums, included fin clips that were provided to one of us (JLN) for microsatellite DNA analysis and sequencing of the mitochondrial control region (Nielsen, 1996; Nielsen, 1997; Nielsen et al., 1998; Nielsen and Sage, 2001) and have provided the most extensive database for relationships of Mexican trout species. Nielsen and collaborators (Nielsen et al., 1997) examined both the Río Mayo trout and Baja California rainbow trout. In their unrooted neighbor-joining analysis of DNA sequence data, the latter taxon was linked with California steelhead and McCloud River rainbows, whereas the former taxon was very divergent from the remaining rainbows, steelheads, and California golden trout (*O. aguabonita* or *O. mykiss aguabonita*). Microsatellite data from the same specimens identified the former as most similar to either California golden trout or steelhead, while the latter was always most similar to Little Kern River golden trout and some California steelheads. Later work by the same group (Nielsen et al., 1998) included more taxa from the rainbow group, various cutthroat taxa, and some Pacific salmon species. In a neighbor-joining analysis of control region mitochondrial sequences, if rooted with Pacific salmon species, there is a monophyletic *O. clarkii* lineage sister to a monophyletic group inclusive of an Apache and Gila trout lineage that is sister to an essential *O. mykiss* lineage. Within the latter group, Baja California rainbow trout is a member of a well-corroborated group that also includes coastal rainbow and Sacramento redband (*O. mykiss stonei*). The trout from the Río Yaqui system were found to be part of a larger coastal rainbow clade. These relationships are inconsistent with those observed by Stearly (1992) and Stearley and Smith (1993) using morphological and chromosome data, wherein *O. clarkii* formed the sister group to a clade where the Apache + Gila trout clade was sister to a clade inclusive of Pacific salmon species and various forms of *O. mykiss*, including Río Yaqui trout and Baja California rainbow trout. Furthermore, in their analysis *O. mykiss* was never observed to be a monophyletic group. Finally, adding data on Mexican golden trout to the molecular data on Mexican trouts, Nielsen and Sage (2001) compared populations from the Mayo, Yaqui and Guzmán systems with the Mexican golden trout. They found that Mayo and Yaqui trouts are as different from coastal *O. mykiss*, as is Mexican golden trout. The Guzmán populations were shown in that analysis to be very closely related to the Río Bavispe trout.

Histories of habitats and threats

Prehistoric anthropogenic alterations. Habitats occupied by native Mexican trouts have a long history of human modifications. Obviously, prehistoric peoples long inhabited these areas (Lumholtz, 1902; Sauer, 1935). We do not here pursue details of their influences on aquatic systems, but remnants of 'trincheras' and check-dams hypothesized to be erosion control structures (Doolittle, 1985) remain evident today in many areas, including trout streams (Leopold, 1940), providing evidence of their former activities and purposeful stream habitat modifications. Canals were also in use in the general region (Doolittle, 2000), though primarily at lower elevations.

Climate changes. Whether anthropogenic or not, there are a number of indications that today's climate in the region is on average warmer and drier than it was

prehistorically, or even historically. Surprisingly, a Spanish manuscript from the 18th century indicates that Cerro Mohinora had a year-round snowcap (de Villagran 1777). Today, this peak, one of the highest in the Sierra Madre of Chihuahua, from which descend tributaries of the ríos Fuerte, Conchos, Sinaloa, and Culiacán, certainly has snow many months of the year, but it almost surely has not seen year-round snow in the lifetimes of anyone living in the area today. Similarly, pollen and packrat midden studies in the region indicate that today's vegetation zones were shifted downward hundreds of meters at times during Pleistocene and Holocene (Van Devender, 1977; Van Devender, 1990; Van Devender and Spaulding, 1979). Climatic variation was also apparently pronounced, with, for example, at least one extremely severe drought in the 16th century (Acuña-Soto et al., 2002). That drought was probably far more severe than recent droughts (Esquivel E., 2002) that may have been at least partially responsible for the 1999 drying of the famous waterfalls of Cascada de Basaseachi in the uppermost Río Mayo drainage (Guerrero et al., 2000) and apparently Cascada de Cusárare (local residents, pers. comm.) in the Urique/Fuerte watershed, though we suspect that this may have at least as much to do with local land management practices as regional long-term climate change.

Mining, logging and fire. The Sierra Madre Occidental has long seen intensive exploration and exploitation of its mineral deposits. Dating from the 17th century, but intensifying and expanding in the last half of the 19th century (Griggs, 1907), localized mining remains an important industry today, albeit mostly at lower elevations and outside of areas where mining might have direct impacts on trout populations. Also late in the 19th century and continuing and intensifying to present, logging became a major industry. For many years Chihuahua and Durango have consistently been the top-ranked Mexican states in terms of income from forestry resources (Guerrero et al., 2001), together producing about half of the total forestry production of the country. A major Sierra Madre Occidental forestry development project proposed by The World Bank in the late 1980s and early 1990s (Lowerre and English, 1994) generated considerable controversy and was subsequently not implemented (Guerrero et al., 2000), yet it is estimated (Lammertink et al., 1996) that over 98% of the old-growth forest of the Sierra Madre Occidental has now been logged. Improved access to remote areas for logging provides access for other human-based activities to follow. The dominance and importance of the logging industry in the Sierra Madre Occidental today is obvious throughout the higher, forested areas, and combined with grazing's effect on fire ecology and active fire control programs, the natural fire regime has clearly changed. Fule and Covington (1994, 1996, 1997) documented reference stands in Durango that represent historically more frequent fire regimes than characterize the area today. An elderly rancher who has worked in the Río Gavilán since the 1920s recounted the extent of small sawmills in the 1940s and 50s, and the resulting sawdust waste that choked its mainstem and many tributaries (Hendrickson et al., 1981; E. Whetten, 1997). Many trout populations have likely recovered, to varying degrees, from this once-serious impact, yet we and others (Guerrero et al., 2001) have noted a recent increase in local sawmills throughout the region, many dumping sawdust directly into or adjacent to streams.

In summary, it is clear that environmental impacts directly or indirectly associated with logging have had major impacts on trout habitats, yet no published studies on this subject exist, and it is beyond the scope of this contribution to examine the issue in detail. We refer interested readers to the comprehensive review of the complex, fascinating history of logging and analysis of social, economic and environmental issues surrounding this industry in the Sierra Tarahumara area of the Sierra Madre Occidental recently provided by the Texas Center for Policy Studies (http://www. texascenter. org) (Guerrero et al., 2001). Their findings for Chihuahua are generally applicable throughout pine forests of the greater Sierra Madre Occidental.

Grazing. Our travels in the Sierra Madre Occidental lead us to conclude that grazing has also impacted many trout habitats, though in most areas not to the same extent as logging. Increased grazing, which often followed road construction for logging, also contributed to altered hydrological (and fire) regimes. Stocking rates on mid-watershed private ranches are not particularly high (approximately one head per ten hectares), yet cattle left within the confines of fenced pastures do not let grasslands recover sufficiently to penetrate the soil with roots, increasing runoff and erosion rates and decreasing fuels for low-intensity fire (Forbes and Haas, 2000). Locally increased juniper cover due to fire suppression consumes both rangeland and water, and increases risk of high-intensity fire, as noted relatively early in the area by Marshall (1957).

The upper watersheds of the Mayo, Sinaloa and Culiacán drainages, and particularly the Fuerte and Conchos watersheds, unlike other drainages discussed here, are home to the Tarahumara (or Rarámuri) and the Tepehuanes. These indigenous peoples have populated the area for many centuries longer than have mestizo populations. Many Tarahumara still practice their ancestral lifestyle of extensive dry farming, primarily of corn and beans, and extensive grazing, primarily of goats (Bergtold, 1991; Fontana, 1979; Lumholtz, 1902; Pennington, 1963; Raat and Janecek, 1996; Sheridan and Nash, 1979). The Tepehuanes lived a similar existence until recently when most were integrated into the forestry industry (Molinari and Nolasco, 1992). As compared to mestizos, who graze mostly cattle, focus their more intensive agriculture in river bottoms along larger watercourses, and live in larger towns, the Tarahumara (and formerly Tepehuanes) are relatively evenly distributed over this very remote area, living in diffuse, small family groups and small multi-family communities. The impacts of these culturally diverse populations inhabiting much of the range of native trouts in the Sierra Madre Occidental are thus very different from one another, and any impacts associated with the traditional Tarahumara and Tepehuan cultures have been present for far longer than have those of mestizo populations. In our experience, Tarahumara-occupied high country is typically quite overgrazed, with highly eroded watersheds drained by streams flowing over bedrock or highly silted large-rock bottoms with little riparian vegetation or other cover. In much of the core Tarahumara area, peak logging activity occurred decades ago, and is not now as prominent as it is elsewhere, such as in the Durango highlands or in much of the Río Yaqui basin.

Human exploitation of fishes. While Lumholtz (1902) reported fishing with dynamite over a century ago, and we have heard of it still being used in the region, we believe it is not common within the probable range of trouts, and have not witnessed its impacts. In the uppermost Río Urique (Fuerte) and Conchos basins, however, our interviews with locals revealed that ichthyotoxic extracts of native plants have long been used to harvest fishes, and some of us (DAH, HEP) have seen first-hand evidence of their use. The impacts of fishing with toxins in flowing waters likely extend over greater distances than do impacts of dynamite, and this practice may therefore have significant impacts on fish populations.

Non-native fishes. Fish culture in Mexico, including rainbow trout, dates to the 19th century (Cházari, 1884; Secretaría de Fomento, 1892), but through very nearly the end of that century (and even then) it was focused in the Mexico City area until, just as logging opened new areas to grazing, it also improved access for introductions of non-native fishes into formerly remote areas. Promotion of non-native fisheries development projects in Mexico can be traced back to the late 1800s (Cházari, 1884; Secretaría de Fomento, 1892), but activity increased with projects initiated by the administration of President Lazaro Cardenas in the 1930s (Simonian, 1995). Numerous rustic rainbow trout grow-out facilities were being built on streams in formerly remote areas of our study area by the 1960s and 1970s, including considerable activity in the Sierra Tarahumara area (ríos Conchos, Mayo, Fuerte) (Rosas, 1976; Sevilla, 1960). Trout species listed as in use in Mexican fish culture in the 1970s were "*Salmo gairdneri* var. Kamloops ("trucha Kamloops"), *Salmo gairdneri* var. arco-iris ("trucha arcoiris"), *Salvelinus fontinalis* ("trucha de arroyo"), and, interestingly, the 'native trouts' "*Salmo clarkii* y *Salmo chrysogaster*" (Rosas, 1976). Of course, voucher specimens from the introduced stocks mentioned by Rosas were not taken, and we have no way to assess the accuracy of his identifications. We are, however, certain that fish culture activities will increase in the area in the near future, as state offices of the federal agency SEGARPA (formerly under SEMARNAT) and other development groups (Bosque Modelo Chihuahua A.C., 2001; Torres G. et al., 1997), promote it as a rural economic development tool. Obviously, presence of non-native fishes, and particularly non-native trouts, in streams of this area present risks of disease, competition, and hybridization to the native trouts. As this paper was in final revisions, M.V.Z. Gerardo Zamora, of SEGARPA's El Zarco hatchery near Mexico City, notified us that Infectious Pancreatic Necrosis had been recently documented in hatcheries in the country and that contaminated stocks had apparently already been sent to culture facilities within the ranges of native trouts.

Non-native trout introductions in Mexico

Origins of Mexican hatchery rainbows. Information on the origins of Mexican hatchery strains of rainbows may be useful to future genetic studies in which introgression of native and hatchery stocks may confound interpretations. The earliest documentation that we find of importation of rainbow trout to Mexico comes

from the U.S. Fish Commission Report for the period July 1, 1887–June 30, 1888 (McDonald, 1891), which indicates that 33,000 rainbow trout eggs were shipped to E. Cházari, commissioner of fisheries for Mexico, stating that the shipment was made at the request of "the Mexican Government through the U.S. Department of State." This agrees with a fish-culture guide published in 1892 by the Mexican agency that had requested the eggs (Secretaría de Fomento, 1892), as well as with Needham and Gard's (1964) citation of McDonald (1891) documenting apparently the same transfer. Arredondo-Figueroa (1983), however, states that the first importation of trout eggs to Mexico was in 1886. Nevertheless, all sources agree that the eggs came from Baird Station on the McCloud River, California, which opened operations in 1879 for "the propagation of the rainbow trout (*Salmo irideus*)." It is generally agreed that Baird Station utilized only locally derived stock (i.e. McCloud rainbow trout). It is interesting to note that Cházari, in his 1884 book on freshwater aquaculture, reviews a great many species cultured throughout the world at that time and discusses their relative merits for fish culture in Mexico. Though he clearly settled on McCloud rainbow trout as his salmonid of choice for Mexico's first forays into fish culture, he also stated that studies of the salmonids that already inhabit Mexico's rivers would be particularly interesting and useful, and he especially recommended that such studies be done. It is clear from several statements made in different parts of the book that at the time he was writing, no non-native trout had yet been imported to Mexico.

Other information provided by Arredondo-Figueroa (1983) indicates that in 1937 and shortly thereafter, eggs from the U. S. were arriving at two new trout production stations at Almoloya del Río and another close to the Río Lerma (both near Mexico City), so that by 1945, 118,597 trout from these facilities had been planted in seven Mexican states. The El Zarco station opened in 1943 in the Distrito Federal and by the early 1970s was producing large numbers of rainbow trout eggs domestically so there was no longer a need for importation (Arredondo-Figueroa, 1983).

We have not yet researched records apparently existing in Mexican government offices concerning releases of non-native fishes. Our observations and conversations with local managers of trout culture facilities lead us to conclude, however, that most fish aquaculture and releases in our study area involve hatchery strains (perhaps more than one) of rainbow trout, though we have verbal accounts of introductions of brown trout (*Salmo trutta*). Robert Behnke (pers. comm., 2002) mentioned a letter that he received from Robert Stone Smith in 1983 reporting that locals in the Río Bavispe (northern Yaqui) drainage had told him that they had obtained and released "brown trout" (presumably *Salmo trutta*) in that system. One of our occasional collaborators, a long time resident of Chihuahua, later confirmed that in 1982 or 1983 (before he was aware of the importance of native trouts and the possible impacts of such introductions) he and friends obtained 5,000 brown trout fingerlings from a private hatchery in Pagosa Springs, Colorado and stocked them in several localities including private ponds, streams and rivers. They released 1,000 in the Río Piedras Verdes (Guzmán/Casas Grandes system) above Colonia Juárez, 500 in a small tributary of that same stream above Corrales/Pacheco, and 2,500 in the Río Gavilán (Yaqui basin), half at the road crossing at Elvin Whetten's ranch and half downstream at the confluence of Los Chales and the Río Gavilán. He reports that they caught some of these fish later in the year of the releases, but had not since taken or seen any in any of the streams that were stocked despite many fishing trips to all of them.

Transplants of native trouts within Mexico

Transplants of native trouts have long been an integral part of endangered trout management in the western U.S. (Behnke and Tomelleri, 2002; Propst et al., 1992; U.S. Fish and Wildlife Service, 1978; U.S. Fish and Wildlife Service, 1979; U.S. Fish and Wildlife Service, 1987). If not carefully managed, however, transplants could have adverse impacts and, if not well documented, have the potential to confuse future workers. We thus attempt to document here those transplants of native stocks of which we are aware.

The Baja California rainbow trout has been introduced to a number of watercourses near the streams in which it was first found, but that history is well documented and has been recently summarized (Ruiz-Campos et al., 2000). In contrast, native trouts of mainland Mexico have also been moved, but with only minimal documentation. Hendrickson et al. (1981) reported that trout they collected in a small stream at Rancho Huápoca, near Madera, Chihuahua, had been introduced by the local rancher from a stream to the northeast in the Bavispe sub-basin of the northern Río Yaqui. The receiving stream is in the southern

Yaqui (Sirupa – Aros) sub-basin, which harbors its own, distinct, native trout (Hendrickson et al., 1981; Minckley et al., 1986; Nielsen, 1997), though collections of the southern Yaqui form from the immediate vicinity of the stream receiving the transplant are not known.

Our subsequent explorations revealed additional, but previously unpublished, evidence of inter- and intrabasin transplants. In 1998, reports of two earlier transplants of trout from the Río Yaqui basin eastward across the continental divide to the Guzmán system were related to one of us (BJ) by long-time area resident Elvin Whetten at his Rancho Gavilán on the Río Gavilán (Yaqui/Bavispe drainage). Mr. Whetten, in his 80s at the time of the interview, grew up in Colonia García, about 30 miles SSE of his Río Gavilán ranch. He related that trout from the Río Gavilán were transplanted to the "Hop Valley", now known as the "Jovales" or "Hernández Jovales", a tributary of the Río Piedras Verdes (tributary of the Río Casas Grandes of the Guzmán system) between 1905 and 1910. The mother and uncle of one of us (BJ) grew up with Mr. Whetten, and regularly fished the upper headwaters of the Piedras Verdes, several miles upstream from Jovales, during the late 1920s and early 1930s. They referred to the stream as "Pacheco Creek" since it continued down to Colonia Pacheco, and indicated that trout were very abundant; "if you didn't catch at least a hundred fish a day, you weren't much of a fisherman!" This successful transplant therefore was likely the source of specimens we collected from Arroyo Escalariado (Table 1), and, indeed, molecular analyses of specimens from that site determined them to be very close to specimens from the upper Río Bavispe (Nielsen, 1997), thus agreeing with close morphological similarities earlier noted by others (Needham and Gard, 1959; Smith and Miller, 1986) and the purported transplant.

The other transplant related by Mr. Whetten took place in the mid 1930s when BJ's maternal grandfather and his brothers were operating a sawmill at Rancho Bella Vista on the hill above Arroyo La Playa, a tributary of El Álamo, which flows to the Río Casas Grandes (Guzmán system). One of the men at the mill went to the Río Negro (Yaqui/Bavispe drainage) and brought back trout, releasing them in La Playa. Presumably, therefore, specimens that we collected from Arroyo La Playa on September 27, 1996, and those collected earlier near the same locality by Needham and Gard (Table 1), stemmed from this introduction.

Further south, our local guide in the Río Presidio basin, Miguel-Ángel Molina-Rodríguez, reported that he and family members had transplanted trout between two headwaters of the Río Presidio, from Arroyo Nogales to Arroyo El Rincón. We obtained specimens from both streams in October 2000 (Table 1).

Even more recently, M.V.Z. Gerardo Zamora advised (pers. comm. to Hendrickson, 2001) that in October 1999, 50 mature native trout specimens were captured and transported alive from the "Río Chuhuichupa" and "Guaynopa" (Table 1) in Chihuahua, to his place of employment, the Centro Nacional de Investigación en Acuacultura "El Zarco" in the Distrito Federal (far outside of presumed native trout range). Specimens of these now captive stocks have been deposited in the Fish Collection of IB-UNAM (Table 1). According to M.V.Z. Zamora, reproduction in captivity has occurred, but both the brood stock and offspring are "nervous and aggressive" and refuse to take prepared foods. Evaluation of the adaptability of these stocks and their hybrids with hatchery rainbows continues at "El Zarco" (M.V.Z. Zamora, pers. comm.).

Discussion

Current status of knowledge of distribution and abundance

Current knowledge of distribution and abundance of native trouts in the study area remains inadequate. Only in the Yaqui basin, and perhaps in the Mayo, has sampling been anywhere near comprehensive, yet still inadequate. Other basins remain grossly undersurveyed, and now, with the threat of increasing rainbow trout introductions, documentation of the distribution of both natives and non-natives takes on new importance. We must now consider all trout streams throughout our study area to be imminently threatened by the introduction of rainbows. The numbers and distribution of rainbow trout growout and fry production facilities in northwestern Mexico are rapidly increasing, and they are appearing in more and more remote locations. In 2001 one of us (BJ) documented three new rainbow trout growout facilities in the upper Río Yaqui basin (Río Bavispe sub-basin); at El Colorado in the Río Gavilán headwaters, in the Río La Cueva, and in the Río San Antonio. About the same time a colleague, Arny Stonkus, who has many times traveled to remote areas

in the Sierra Madre Occidental to fly-fish for native trouts, reported that one of the most pristine streams in the Gavilán sub-basin of the Río Yaqui system, the "Yenquin" (local orthography for "Jenkins"), with a very healthy native trout population, now has a rainbow trout growout facility in its headwaters, and he observed that some of the captive stock had escaped to the stream. In the uppermost Río Mayo basin we recently saw several small rainbow trout growout ponds alongside, and in, headwater streams of the Río Candameña above Basaseachi. Some had clearly washed out during floods and released their contents to the stream. Similar rustic growout facilities, as well as large-scale rainbow trout hatchery operations, abound throughout much of the Río Fuerte system (at least in the Río Urique sub-basin, near the towns of Guachochi, Creel, and San Juanito), and have for many decades (Ramirez Granados and Sevilla-Hernandez, 1962; Sevilla, 1960). Further southward we found many rainbow trout hatcheries operating in the ríos Presidio and San Lorenzo basins. It will be important to team with Mexican government officials and others promoting rainbow trout culture to both document distributions and reconcile the conflict that rainbows pose for native trout conservation.

The threat of genetic introgression or other interactions with non-native trouts is relatively recent compared to the older, but continuing threats posed by logging, grazing and other human activities. These impacts, too, are largely controlled by large-scale economic issues. We have seen intensive logging come and go in some areas, and a very large regional lumber development project was almost begun in the 1990s that surely would have had extensive impacts on aquatic ecosystems. Invariably, as economic conditions vary, so will future threats to native trouts.

Systematics, phylogenetics and taxonomy

Despite some recent, rather limited localized advances in the systematics and population genetics of Mexican trouts resulting from application of molecular techniques, much work remains to be done before we can fully understand interrelationships among populations and taxa, not to mention the complicated issue of potential introgression of non-native genetic material into native stocks. Though we still lack data that unambiguously demonstrate such introgression, our preliminary work indicates that it probably is occurring, at least in the southernmost basins we have surveyed. Unfortunately, resolution of the problem is made even more difficult in this area since potentially native stocks have hardly been studied at all. More comprehensive sampling throughout the region (with deposition of voucher specimens to museum collections) for analyses of both morphological and genetic characters is urgently needed to give managers the tools needed to recognize pure native populations and so protect them. Although deciphering systematic relationships is far from easy with these highly variable and sometimes closely related populations, undescribed taxa need to be formally named since political systems that could provide some level of protection rely heavily on such formalized taxonomic units.

Agreeing with earlier researchers, more recent data support the conclusion that the Río Yaqui system appears to harbor two distinct trouts, one in the more northern Río Bavispe drainage, and another in its southern tributaries (the sub-basins of the ríos Papigochi, Tomochi, and Sirupa/Aros) (Figure 2). The southern Río Yaqui form may be identical or very closely related to the trout found in the nearby headwaters of the Río Candameña of the Río Mayo system (Nielsen, 1997; Nielsen and Sage, 2001). Further southward the Mexican golden trout (Figure 2) persists in all parts of the river basins (Fuerte, Sinaloa, and Culiacán) in which it was found by earlier workers (Needham and Gard, 1959), but apart from recent molecular data on two populations from two basins (Nielsen, 1997; Nielsen and Sage, 2001) we have little more data on distribution and intra-specific variation in this species than was presented by Needham and Gard in 1959. Yet further southward, our recent collections in the Presidio and San Lorenzo basins, still in analysis, have so far done little more than improve our own ability to comprehend the confusion of earlier researchers regarding the systematics of these populations. Preliminary analyses of our collections of highly variable specimens lend some support to the hypothesis that a native trout existed, and probably still exists, in these rivers, but additional samples from the region and molecular studies will surely be necessary before solid conclusions can be reached.

Conservation status and threats

Hybridization and competition threats

Hatchery strains of rainbow trout are now widely distributed throughout the range of all native Mexican trouts except those of Baja California, and almost everywhere have escaped from culture facilities to

wild habitats. We apparently have found areas where introgression of native and non-native gene pools is advanced, though substantiation of that requires additional analyses. In other areas, we have not yet detected indications of hybridization, but our sampling to date is likely inadequate for elucidation of this possibility. There is little doubt in our minds that future sampling will reveal more and more widely distributed occurrences of introgression of rainbow and native gene pools. The extent of the area involved, its general topographic complexity, and the (even now) remoteness of many of its headwater tributaries, should help assure that small, isolated native populations will remain unexposed to non-native stocks in the near future, but we feel it is important to quickly discover and protect those populations before they become contaminated.

In this contribution we have concentrated on real or potential problems created by introductions of non-native trouts, but other non-native fishes also have their potential impacts on the system. Our collections and those of others have documented the presence of several species of exotic centrarchids and ictalurids within the general range of native Mexican trouts. Largemouth bass surely will feed on trout if given the opportunity, as might large catfishes, and smaller centrarchids likely compete with trout for food, as well as prey on fry and juveniles. Nonetheless, all of these exotics are being increasingly introduced into a surprising number of high-elevation, man-made ponds and (eventually) natural waterways which could harbor native trouts. Ways need to be found to limit or, at least, rigorously manage the continued introduction of species now being promoted by government agencies and others.

Threats from logging, grazing and other agriculture

Logging will continue to expand in the region, although accelerated harvest has resulted in a shortfall of commercially-sized secondary growth. Pulpwood markets have recently promoted commercial exploitation of smaller material, including oak, and sawmills are still touted as value-added economic development. Supporting out anecdotal observations, Guerrero and colleagues (Guerrero et al., 2001) reported that the number of registered sawmills in Chihuahua increased from 108 in 1993 to 309 in 1998. As it was in the 1950s, sawdust waste entering watercourses is again a concern, along with leakage of associated oil-based pollutants into streams and groundwater.

Forestry policies have changed numerous times over the past century through efforts to make Mexico more competitive and sustainable in the global forest products market. Evolving policies often offer incentives that tend to increase pressure to cut more forest to make ends meet (Guerrero et al., 2001). A relatively new Agrarian Code now allows privatization of parcels within *ejidos* (a community-based land ownership system which has existed in one form or another for centuries, but instituted in its present format following the 1910 revolution) to attract capital and promote efficient management. However, the socio-economics of rural Mexico make changing forestry practices in the direction of habitat protection very difficult. Approximately seventy percent of forest land in Chihuahua is under ejido ownership (Association of Mexican Professional Foresters, 1996), and much of that includes native trout habitat. The complexity of negotiating conservation agreements with ejidos is illustrated by the experience of McDonnell and Vacariu (2000), who found it necessary to provide economic alternatives in order to reach an agreement protecting the most critical remaining nesting site of the endangered thick-billed parrot. Thoms and Betters (1998) outline four components favorable to implementing ecosystem management in ejidos: (1) communication and cooperation between numerous agencies; (2) diversifying the economy to reduce pressure to log; (3) environmental education and both short- and long-term planning; and (4) expanded administration capacity to address resources other than timber. García and collaborators (1994) surveyed residents of Ejido Largo Madera, one of the larger and more successful ejidos in Chihuahua, extending from Madera, Chihuahua to the headwaters of the Río Gavilán. Their study exemplifies the importance of providing economic alternatives. Those they interviewed were keenly interested in economic diversification and fearful of over-reliance on traditional forestry practices, but lacked capital to try new initiatives. In such settings, government-financed initiatives, such as rainbow trout culture, can be popular. Even if agreements are reached that appear sustainable, illegal practices can remain a concern despite proper changes in forestry laws and land management. Barry (1994) indicates that environmental laws in Mexico can often be more stringent than in the U.S., but enforcement is almost always problematic (Guerrero et al., 2001; Klooster, 1999). Regardless of such concerns, progress is being made in some areas. Aguirre-Bravo and Reich (1998) promoted an inte-

grated resource monitoring program for Ejido Largo Madera, which is slowly being implemented.

Domestic livestock grazing is extensive throughout the study area, and as in the western U.S., it is also a cultural institution. Many areas are heavily overgrazed, leading to removal of vegetation, increased erosion and siltation, with concomitant impacts on streams and their fishes and other organisms. Responses to economic stress, exacerbated during drought periods, are often to increase herd size to make ends meet.

Education and increased promotion of healthier rangeland practices is necessary to protect and restore trout habitat. Starker Leopold found that the wealthier ranchers were more receptive to conservation practices when he surveyed ranchers' perceptions of the last Mexican grizzly bears in Chihuahua's Sierra del Nido in the 1960s. Isolated examples of rotational grazing exist; presidents for 1999 of the cattlemen's associations for Casas Grandes and Nuevo Casas Grandes, Chihuahua both practice this type of grazing (pers. comm. to WF). Workshops on grassland or riparian management are occasionally held in the region, and riparian ecological successional practices promoted by the National Riparian Service Team (part of the Cooperative Riparian Management Program of the U.S. Bureau of Land Management and U.S. Forest Service (1997), have been translated into Spanish. Such practices can be beneficial to both ranchers and stream health.

Illegal drug production in the region is a complex socio-economic and political issue not mentioned here before and better discussed by professionals from other disciplines, but we cannot ignore it, and so provide brief comments because its impacts on local economies in and near the range of native Mexican trouts are pervasive. We have many times seen cultivated marijuana fields growing near trout streams in remote areas, and many mainland Mexico trout habitats are short distances upstream from areas infamous for high levels of illicit drug activities. Anti-narcotic drug military patrols are common in the region, and local residents relate many stories about local drug lords and related violence. Travel in these areas is not recommended without reliable local guides, who, in our experience, will sometimes advise against exploring promising-looking trout habitats, considering entry too dangerous. Illegal drug activity thus also directly impacts research. Although drug agriculture, as well as its countering official control activities, may have direct effects on habitats through pesticide and herbicide applications, water diversions, and other means, its most significant threat to native trouts may be indirect through economic processes. While this industry may discourage other development in lower elevations where crops are generally grown, it is clear to us that it widely "feeds" local economies, including those at adjacent higher elevations, and thus may indirectly fuel generally unsustainable development there and associated diverse impacts on trout habitats.

Impacts of tourism

Tourism is increasing in the Sierra Madre Occidental, particularly in the upper Río Fuerte basin in the vicinity of the Barranca del Cobre (Copper Canyon). Many tourists access the area via a special train that passes through scenic canyon areas between Los Mochis on the coast and Creel in the high sierra. More importantly, completion in the last decade of a paved road connecting the major lowland cities of Ciudad Chihuahua and Hidalgo de Parral via Creel and Guachochi in the sierra has improved access to larger, scenic mountainous areas, and many new hotels have recently appeared. We have heard that the Mexican federal government has plans for large-scale tourism development and promotion in the Barranca del Cobre area, but lack first-hand information. Certainly, some of the recently constructed hotels cater to wealthy foreign and domestic tourists. Future tourism developments could either benefit or adversely impact native trouts. The fact that we have seen many restaurants in the area with rainbow trout on their menus may indicate that tourism will at least indirectly support non-native fish culture, but potential also exists for tourism that may promote native trout conservation, such as "eco-tourism" and sport fishing for native trouts.

Protected areas and other conservation initiatives

The Baja California rainbow of the Sierra San Pedro Mártir of Baja California is at least partly protected within the Área Nacional Protegida (National Protected Area) de San Pedro Mártir, but important habitats for it lie outside the Protected Area, including the type locality of this taxon. Protection should be expanded to include all known populations of this highly geographically restricted species.

Elsewhere, few native Mexican trouts live in habitats that afford them demonstrable protection, though increased protection is proposed for some areas. The Nature Conservancy Parks in Peril Program

prepared a pre-investment analysis for the U.S. Agency for International Development (Dedina et al., 1998) that chronicled various conservation initiatives in the Sierra Madre Occidental. That report recommended the establishment of a ríos Ajos-Bavispe National Forest and Wildlife Refuge in the upper Río Yaqui basin in northeastern Sonora as an "anchor" site for their conservation activities. The 184,770 ha refuge encompasses several "sky island" habitats, including Sierra El Tigre and Sierra Huachinera, with at least the latter potentially including native trout habitats. The few existing protected areas in our study area include the small Cascada de Basaseachi National Park, northwest of Chihuahua City in the upper Río Mayo (Río Candameña) basin, established for its natural wonder of one of the highest waterfalls in the world. Proposed protected areas include Sierra San Luis, a "sky-island" site in northeastern Sonora; Mesa del Campanero-Arroyo el Reparo, an ecological transition zone in southeastern Sonora; Barrancas del Cobre-Sinforosa Canyon Biosphere Reserve, in the upper Río Fuerte drainage; and Las Bufas, a high-elevation old-growth forest in western Durango. Native trouts occur, or are likely to occur, in Basaseachi, Barrancas de Cobre-Sinoforosa and Las Bufas, and habitat for them may exist in the other reserves, but trout habitat was not among the reason for protected status proposals for any of these cases. Recently, however, Mexico's federal Commission for Biodiversity (CONABIO) published its list of priority hydrologic regions for biodiversity conservation (Arriaga Cabrera et al., 2000). Included here are a number of large regions that are clearly relevant for native trout conservation: 16 (Río Yaqui – Cascada Basaseachi), 17 (Río Mayo), 18 (Upper Río Fuerte), 20 (Upper ríos Culicán and Humaya), 21 (Upper ríos San Lorenzo-Piaxtla), 22 (Río Baluarte), 39 (Upper Río Conchos). Most of these regions with native trouts score high on many factors used to rank their priorities for conservation-related programs. This document is designed to serve as a management and conservation planning tool for government at all levels in México, and is definitely being used by at least CONABIO to determine the focus of funding for biodiversity inventories and research. Our own work was in part supported by CONABIO (see Acknowledgments) under this prioritization scheme. Similarly, at an international level, areas 61 and 62 of the World Wildlife Fund's recent publication on conservation priority for freshwater ecoregions of North America includes all mainland basins harboring native Mexican trouts in priority class 2 (of 5, with 1 highest priority) (Abell et al., 2000). So, although existing and proposed protected areas appear unlikely to contribute in significant ways to native trout conservation, the relevant high-level planning needed to prioritize conservation actions is now in place and being implemented.

Habitat alteration

Our observations lead us to conclude that primary causes of trout habitat decline are related to non-point alteration of hydrological regimes and water quality and quantity. Despite important improvements in road design and maintenance, this alteration continues despite important improvements in road design and maintenance, through proliferation of sawmills, deregulation, forestry law enforcement issues, and economic pressure to log small material and to exploit remote locations. Alteration also continues due to ranching practices through concentration of livestock in pastures for long periods, resulting in lack of proper fallowing and maintenance of stream vegetation in early successional stages. Risk of intense disturbance is increased by diminished water-holding capacity of soils, and increased brush cover that fuels high-intensity fires. The end result is the highly eroded, silt-laden and exposed streambeds that we find so prevalent in the region.

General recommendations

Some recommendations for future conservation and management of the Baja California rainbow trout have been previously published (Ruiz-Campos, 1993; Ruiz-Campos and Pister, 1995), and are largely applicable to other areas in the range of Mexican mainland native trouts. Protection of key habitats is important, together with prohibition or strict control of introductions of non-native species. Most importantly, however, and encompassing and affecting aspects of the first two themes, implementation of sustainable management and preservation of native Mexican trouts clearly requires holistic watershed-based conservation and management plans that are developed in close coordination with local residents, and tightly integrated into the local and global socio-economic contexts.

Priority habitats for conservation are found in the upper tributaries of all drainages in our study area. As obvious from Figure 1, all collections of Mexican trout have been in, or very near, extreme headwaters. These headwaters are critical refugia for

native trouts. Despite their relatively smaller extents, such tributaries often traverse multiple land tenancies, thus complicating conservation actions. Tributaries that cross single or few ownerships, held by parties economically stable and favorable to conservation, make good starting points for protection from further habitat alteration.

Management of large-scale processes, through integrated forestry management plans (Thoms and Betters, 1998) and rotational grazing that protects streams (National Riparian Service Team, 1999), is also important. Best management practices for forestry, similar to those successful in the U.S. under minimal regulation, should be encouraged. Economic diversification is important to both replace non-native fish farms and lessen pressure to log and graze (Lammertink and Otto, 1997; McDonnell and Vacariu, 2000). Ecotourism and catch-and-release sport fishing may present viable options to the current scenario, however have clear potential to be detrimental (King and Czech, 1995).

Northwestern Mexico provides an opportunity to apply knowledge learned from natural resource management mistakes made in similar habitats in the southwestern U.S. (List et al., 2000). Many species or natural processes have remained intact for longer here than they did in counterpart regions in the U.S. Examples are the thick-billed parrot, Mexican wolf, grizzly bear, jaguar (Brown, 1985; Brown and López Gonzáles, 2001; Lammertink and Otto, 1997; Shaw, 2002), prairie dogs, and frequent, low-intensity fire regimes, as well as pure populations of native trouts, but all are quickly disappearing. Experience in the U.S. shows the exorbitant costs of waiting to deal with such resource issues at a very late stage. Just one example is the current $1.6 billion-dollar proposal to thin forests in the western U.S. to "reduce" fire hazard. Critical, cooperative efforts are urgently needed to promote and effect aquatic conservation in northwestern Mexico in order to avoid, for example, the critical stage reached with the Gila trout in the southwestern U.S. (Propst et al., 1992; U.S. Fish and Wildlife Service, 1987).

Though some limited work toward conservation goals is now possible with the limited current state of knowledge of native Mexican trouts, the long-term management and effective integration of trout into broadly based eco-regional plans requires considerable additional basic biological research. It must be recognized that humans are an undeniable and likely most important single factor in native trout persistence in the region. With more research in concert with careful planning, the obvious potential values of native trouts long ago alluded to by the first Mexican scientific fish culturist (Cházari, 1884), and the same sorts of values believed to characterize Mexican trouts and sought so painstakingly over many years by dedicated U.S. researchers (Needham, 1955), as well as potential other values not yet perceived, will be revealed and provide new concrete economic incentives to greatly facilitate integration of this unique resource into eco-regional management plans. Hopefully, any short-sighted losses occurring prior to such planning integration and implementation will not be so extensive as to prevent long-term preservation of the genetic diversity of all of these unique trouts and the realization of its importance in the ecology of northwestern Mexico.

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