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Biological Status of Leatherside Chub: A Framework for Conservation of Western Freshwater Fishes

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Biological Status of Leatherside Chub: A Framework for Conservation of Western Freshwater Fishes

Mark C. Belk and Jerald B. Johnson

ABSTRACT   Outside of anadromous salmonids and a few endangered species, biology of native freshwater fishes of western North America is poorly known. What do we need to know to effectively manage native species and avoid decline and extinction? A recent analysis of the role of science in the Pacific salmon controversy outlines a clear framework for biological evaluation and management of native species. This framework has three components: (1) determine status of populations based on genetic and ecological variation, (2) identify and quantify threats to populations, and (3) determine actions to alleviate threats and promote conservation of populations. We use our studies of leatherside chub *Snyderichthys copei* (formerly *Gila copei*), a small cyprinid native to the Bonneville basin and upper Snake River drainage, as a case study to illustrate the application of this research and management framework. Recent surveys have revealed dramatic reductions in range of leatherside chub over the last 50 years. Genetic, morphometric, and ecological studies all indicate that leatherside chub comprise two distinct species. Leatherside chub is threatened by both habitat degradation and introduced brown trout *Salmo trutta*, and the interaction between these two threats exacerbates negative effects. We conclude by showing how studies of leatherside chub can inform and influence management, conservation, and habitat restoration activities.

Outside of anadromous salmonids and a few endangered species, biology of native freshwater fishes of western America is poorly known (Bruton 1995; Ruckelshaus et al. 2002). Studies on habitat, range of tolerance to environmental variables, species interactions, life history patterns, and other species level inquiries are conspicuously lacking for nonendangered native species. Even rarer are studies that characterize variation in morphology (McElroy and Douglas 1995), behavior, genetics, and life history (Baltz and Moyle 1982; Baker et al. 1998) among populations within a species— variation that determines evolutionary substructure within the species.

This dearth of information is the single greatest barrier to effective conservation of the unique western fish fauna (Bruton 1995). Although legislation designed to conserve species has been in place for several years (Williams and Deacon 1991), lack of information about the status and biology of species makes it difficult to apply legislative protections in a defensible and effective way. Even for species that do not require legislative protection, lack of biological information makes it difficult to determine appropriate management activities. As such, management activities are usually based on anecdotal information or overgeneralizations of broad ecological theories. Similarly, because of the lack of information about variation among populations within a species, few conservation efforts are implemented at a scale larger than the local population.

The antidote to this state of affairs is to focus efforts on understanding native species biology before crises of rarity or resource conflicts arise. What do we need to know to create effective management plans for native species? This question is faced by all those charged with managing or con-

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serving a species about which little is known. On the one hand, almost any type of information may prove useful in some way; however, managers must decide how best to allocate limited funds and guard against paying for studies that provide little useful information for management planning. A recent analysis of the role of science in the Pacific salmon controversy outlines a clear framework for biological evaluation and management of native species (Ruckelshaus et al. 2002). This framework has three components: (1) determine status of populations based on genetic and ecological variation, (2) identify and quantify threats to populations, and (3) determine actions to alleviate threats and promote conservation of populations. Typically, components 1 and 2 are viewed as research projects to obtain information necessary to implement component 3. However, component 3 can also involve research, for example, to assess the effectiveness of different management actions.

Leatherside chub *Snyderichthys copei* (formerly *Gila copei*) is typical of many nongame fish species in western North America in that until recently, little was known of the status or biology of the species. It was originally described from specimens obtained from the Bear River near Evanston, Wyoming by Jordan and Gilbert (1881). Leatherside chub is a small cyprinid native to streams of the Bonneville basin and upper Snake River drainage. General sources noted that they were found in cool flowing waters and that they were regarded as " excellent bait minnows" (Sigler and Miller 1963; Baxter and Simon 1970). They were reported as abundant in many locations, and large collections of specimens are available at the Smithsonian National Museum of Natural History and the University of Michigan's Museum of Zoology. Beyond these few general observations, nothing was known. Clearly, a better understanding of the biology of the species is required to make informed decisions about management actions.

In this paper, we use studies of leatherside chub conducted in the last 10 years to assess the current biological status of the species and to illustrate the utility of the framework outlined above. Recent surveys have revealed dramatic range reductions over the last 50 years, especially in the northern species. We show that genetic, ecological, and morphometric studies all indicate that leatherside chub comprise two distinct species. We show that leatherside chub is threatened by both habitat degradation and introduced brown trout *Salmo trutta* and that the interaction between these two threats exacerbates negative effects. We highlight an ongoing study to evaluate the threat of range fragmentation on population persistence and genetic variability of leatherside chub. We conclude by showing how studies of leatherside chub have informed and influenced management, conservation, and habitat restoration activities, and we provide recommendations for future management actions.

Status of Populations, Genetic and Ecological Variation

Determining the status of populations involves two distinct types of information. The first is to determine the current distributional status of the species. The second is to determine the pattern of variation in genetic, ecological, and environmental relationships among populations within the species.

Distributional status

Determining current distribution involves exhaustive surveys and comparison to historic surveys and records. Such surveys can be done in combination with surveys for other species. However, unless those doing the surveying are carefully instructed as to the importance of documenting all species, small, rare, or inconspicuous species are often missed or not recorded. For example, introduced, piscivorous sport fishes may induce habitat shifts in vulnerable native species, such that typical survey methods would fail to detect all species (e.g., Chapman et al. 1996). Understanding the number and distribution of extant populations, and the relative abundance of the species in each location, provides the basis for assessing threats and formulating management plans for the species as a whole (Ruckelshaus et al. 2002).

Surveys of distribution of leatherside chub over the last decade have revealed some surprising patterns of local extirpation and population fragmentation. Leatherside chub have disappeared from several entire drainages (e.g., Beaver River, central

Utah, Little Wood River, south-central Idaho, etc.), and within drainages where they still exist, their distribution has declined and become highly fragmented (e.g., Sevier River, central Utah, Bear River, Utah, Wyoming, Idaho, etc.). For example, comparison with historic distributions has resulted in an estimate of 42% range reduction in the Sevier River drainage (central Utah) over the last 100 years (Wilson and Belk 2001), and this drainage is considered to have the most extensive and abundant populations of leatherside chub anywhere. In contrast to the trend of declining distribution, several populations, once thought to be eliminated, have been rediscovered (e.g., lower Sevier River, Juab County, Utah; tributaries of the upper Bear River, Summit County, Utah; Pacific Creek, Teton County, Wyoming). Overall, leatherside chub probably occupy less than half of their historic range, and many populations are isolated remnants of a previously highly connected distribution.

Variation among populations

Understanding genetic, ecological, and environmental relationships among populations within the species involves assessment of genetic variation and ecological similarity within and among populations at various spatial and temporal scales (Crandall et al. 2000; Rader et al. 2005). Tools for obtaining such information include phylogenetic analysis using mitochondrial and nuclear gene sequence data and microsatellites. In addition to the use of molecular genetic data, it is important to use common-environment or reciprocal transplant experiments to assess ecological variability and the genetic basis of phenotypic variation among populations (Rader et al. 2005). Some species may be composed of a relatively homogeneous collection of populations; however, given the naturally fragmented nature of aquatic systems and the highly variable geologic history of western North America, genetic and ecological relationships among populations of native fish species are likely to be highly heterogeneous and complex.

Information about genetic, ecological, and environmental relationships among populations within the species will allow determination of the extent and boundaries of subdivisions within the species. Clusters of populations that have experienced different evolutionary histories from other populations have been referred to as evolutionary significant units (ESUs; Crandall et al. 2000). Evaluation of ESUs, can help guide the designation of biologically relevant subunits of the species referred to as management units (MUs; Vrijenhoek 1998; Crandall et al. 2000). In addition, such information might suggest selectively important environmental or biological conditions (e.g., temperature regimes, predator–prey relationships, etc.) that might influence future population growth or management actions.

Recent research on genetic and ecological variation among populations of leatherside chub has led to interesting taxonomic results. Analysis of mtDNA sequence data (Johnson and Jordan 2000; Dowling et al. 2002), and more recently nuclear DNA sequence data (Johnson et al. 2004), indicates that leatherside chub comprise two species rather than one as previously assumed. Furthermore, leatherside chub do not belong in the genus *Gila*, but rather they fit nicely within the genus *Lepidomeda*, and the two species appear to be nonsister taxa (Johnson and Jordan 2000; Dowling et al. 2002; Johnson et al. 2004).

The two species occupy distinct geographic regions. Leatherside chub found in the Bear River, and a variety of upper Snake River drainages, comprise one species (hereafter referred to as northern leatherside chub *Lepidomeda copei* [Johnson et al. 2004]), whereas leatherside chub found in the Utah Lake drainage (Provo River, Spanish Fork River, and some minor streams) and the Sevier River drainage comprise another species (hereafter referred to as the southern leatherside chub *Lepidomeda aliciae* [Johnson et al. 2004]). The boundary between the northern and southern leatherside species is formed by the Weber River drainage located in north-central Utah. Although it is mentioned as being native to the Weber River drainage (Sigler and Miller 1963), curiously, there are no museum, historical survey, or current records of leatherside chub occurrence in the Weber River drainage, suggesting that this gap in the distribution may represent a real and ancient condition.

In addition, morphometric variation in head shape between northern and southern leatherside chub corresponds to the phylogenetic separation

observed in molecular genetic data. Northern and southern leatherside chub exhibit distinct head shapes. The northern leatherside chub has a shorter, more rounded rostrum and is somewhat distinct compared to the other species of *Lepidomeda.* The southern leatherside chub has a more pointed rostrum, similar to the other species of *Lepidomeda* (Johnson et al. 2004).

Ecological variation among populations also supports designation of two species of leatherside chub. Common-environment experiments including representatives of both species show significant, apparently genetically based differences in temperature-specific growth (Belk et al. 2005). Southern leatherside chub experience higher growth rates at temperatures above about 19°C compared to northern leatherside chub. However, at temperatures below 19°C, northern leatherside chub grow significantly faster than southern leatherside chub. A corresponding analysis of time of hatching in northern versus southern leatherside chub suggests that the northern species may be spawning at lower temperatures, but at roughly the same time of year, as the southern species. Taken together, these data suggest local adaptation to differing environmental temperature regimes in northern versus southern leatherside chub (Johnson et al. 2004; Belk et al. 2005).

Obviously, northern and southern leatherside chub must be managed separately. The next question is whether there is evolutionarily significant variation among populations within the two species that might affect management or restoration activities. The short answer is we do not know yet. Currently, we are conducting a range-wide study of genetic variation in the southern leatherside chub aimed at detecting ESUs within the species. An added question that will be addressed by this study is what is the effect of recent fragmentation on patterns of genetic variation among populations. In 2 to 3 years, we will have sufficient data to recommend appropriate units for management that would correspond to ESUs, and we will also be able to determine the effect of recent barriers on genetic variation within and among populations. Given the current rarity of the northern species, a similar study for populations of the northern leatherside chub is imperative.

Identification of Population Threats

Immediate threats to populations will, in most cases, be ecological in nature and will consist of (1) habitat loss and degradation, (2) effects of introduced species, and possibly (3) overexploitation (see Bruton 1995). Populations that have been reduced to small size by the above-named ecological threats may become susceptible to genetic threats such as inbreeding or hybridization.

Habitat loss
Given the large-scale development of water in western North America, there are few, if any, aquatic habitats that have not undergone significant change over the last century (Minckley and Douglas 1991). Thus, almost by definition, all aquatic species have experienced habitat loss or degradation to some degree. How do we determine the significance of the threat to species persistence of this change in habitat? First, we must determine habitat requirements or preferences for the species. This can be done by measuring habitat use relative to availability in representative locations. Second, we must assess the degree of loss or degradation across the species range and the population level consequences. Habitat loss leads to an overall loss or decrease in abundance of populations; however, and maybe more importantly, it can lead to disruption of among population dynamics and other fragmentation phenomena (e.g., source-sink dynamics, metapopulations, and gene flow; Meffe 1986; Fagan et al. 2002). Knowledge of extent and effects of fragmentation is essential for effective species-wide conservation efforts.

Leatherside chub are threatened by habitat loss (almost all following observations on threats to leatherside chub refer to the southern species). Factors leading to habitat loss include complete dewatering over extended periods, channelization, and construction of barriers (e.g., dams, diversions, etc.). Leatherside chub appear to have broad tolerance of rather extreme environmental conditions (Wilson and Belk 2001; M. C. Belk, personal observation). They can persist in remnant pools in the streambed for several weeks after the water flow has been completely eliminated. We have found thin, but living leatherside chub in such pools after all

other species have died (Belk, personal observation). As such, leatherside chub appear to be adapted to periodic, short-term (a few days to weeks) low water conditions such as during seasonal droughts. However, where dewatering has occurred over a prolonged period, leatherside chub have become locally extirpated (e.g., Panguitch River below Panguitch Reservoir, Garfield County, Utah).

Channelization affects leatherside chub populations by decreasing the complexity of habitat available. In the absence of introduced species, leatherside chub prefer pools and pockets of relatively low-velocity water in the midst of higher velocity habitats (Wilson and Belk 2001). Diet analysis suggests they consume both terrestrial and aquatic invertebrate prey from the drift, much like small salmonids (Bell and Belk 2004). Channelization tends to homogenize habitats into run and deep riffle segments of larger than natural extent. Runs and riffles do not provide the habitat necessary for leatherside chub, resulting in local extirpation or reduced population size in channelized areas (Ellsworth 2003).

In areas where introduced salmonids are abundant, channelization may be even more disturbing to leatherside chub populations because of the relationship between habitat use and the presence of predators. In the presence of predatory salmonids, leatherside chub shift their habitat use away from main channel pools to off-channel habitats such as backwaters and cutoff pools (Walser et al. 1999; Olsen and Belk 2005). Off-channel habitats provide refuge for leatherside chub because salmonids do not preferentially occupy such habitats. Channelization results in the loss of off-channel habitats; thus, leatherside chub have no refuge habitat available, and populations disappear (Ellsworth 2003).

Barriers in flowing water systems affect leatherside chub in two ways. First, leatherside chub do not appear to persist in lakes, ponds, or reservoirs. We are aware of no populations in nonflowing water. Thus, the creation of reservoirs replaces appropriate habitat with poor habitat for leatherside chub. Second, barriers such as dams and diversions impede movements and fragment once continuous populations (e.g., Schaefer et al. 2003). We are currently studying the effect of recent barriers

on genetic structure among populations of leatherside chub. In addition, we are conducting a mark–recapture study in several locations to determine the rate of movement and variation in demography among populations.

Introduced species

The second threat to native species is the widespread introduction of exotic species. The fish fauna of western North America is depauperate compared to other regions of the continent, especially if we consider large-bodied food or sport fishes (once again, excepting anadromous salmonids of the Pacific northwest; Minckley and Douglas 1991). In the latter part of the 19th and first half of the 20th century, the typical response to such depauperate conditions was to introduce species from other regions to provide food, recreational opportunities, or other resource management activities (e.g., control of other fish or mosquitoes). This common management response led to the introduction (both intentional and unintentional) of hundreds of species of fish throughout western North America for everything from food (e.g., carp, catfish) to sport (e.g., bass, walleye) to mosquito control (western mosquitofish *Gambusia affinis*) (Miller et al. 1991). Many introduced species have become the dominant species in the new system to the detriment of native species.

Introductions of exotic species were done with little understanding or concern about the potential effects on native fauna. We still understand little about the actual mechanisms by which introduced species impact native species. Interactions and mechanisms of impact of introduced and native species can be assessed by an experimental ecology approach. Both competition and predation can be assessed with replicated enclosures or tanks following a factorial approach (e.g., Mittelbach 1988; Belk 1993; Mills et al. 2004). Such experiments will yield information on the strength of various ecological interactions and thus allow determination of specific components of the threat of introduced species. Some species or life stages may not lend themselves to controlled factorial experiments (e.g., long-lived or large-bodied species). Inferences about such species must be made from correla-

tive and comparative observational studies (e.g., Levin et al. 2002).

Understanding interactions and mechanisms of impact of introduced species can be further complicated by the fact that fish populations are size-structured. As such, size-structure of both the introduced and native species must be considered in determining effects of introduced species. Different size-classes may have different diets, habitat-use patterns, vulnerability to predation, and competitive abilities (Werner and Gilliam 1984; Polis and Holt 1992). Thus, the number of potential interactions between a native and introduced species is actually the product of the types of interaction (e.g., competition, and predation) and the number of size-classes or ontogenetic stages. For example, two similar-sized species of fish can interact as competitors in each of two size-classes (juveniles and adults). Adults may also compete with or prey on juveniles of the other species. Thus, rather than one potential interactive pathway (competition), there may be as many as six interactive pathways (four competitive pathways and two predation pathways; e.g., Olson et al. 1995). Such complexity of ecological interactions must be explored and understood to determine effective efforts aimed at reducing the negative effect of introduced species (Belk et al. 2001).

The most widely distributed and abundant introduced species in streams and rivers of the Bonneville basin and upper Snake River drainage is brown trout (Sigler and Sigler 1987). Brown trout are resilient and a favorite sport fish. They are comparatively more piscivorous than trout native to western North America, and when introduced to new regions, they can have detrimental impacts on native species (Garman and Nielsen 1982; Townsend 1996; Penczak 1999; Museth et al. 2003).

Several lines of evidence suggest that brown trout have strong negative effects on leatherside chub. Current distribution of leatherside chub is weakly negatively correlated with abundance of brown trout (Wilson and Belk 2001). In the presence of brown trout, leatherside chub occupy refuge habitats almost exclusively (Walser et al. 1999; Olsen and Belk 2005). In short-term survival experiments, leatherside chub experienced high mortality rates from brown trout (Nannini 2001).

The ongoing mark–recapture project mentioned above is being conducted in populations with and without brown trout. Mortality and growth estimates from this project will provide information on both the direct predatory effect of brown trout and the nonlethal effect resulting from forced use of refuge habitats and restricted movement.

It appears that in areas with complex natural habitats, leatherside chub may be able to coexist with brown trout, albeit at relatively low densities (Olsen and Belk 2005). It is not clear whether this coexistence is stable or transitory. The ongoing mark–recapture experiment will provide data to determine whether coexistence of leatherside chub and brown trout is a long-term possibility.

Overexploitation

Finally, in some species, overexploitation by humans may be an important threat to long-term persistence of the population (Bruton 1995). Typically, we think overexploitation will be manifest as a reduction in population abundance or, more often, as a decline in catch. However, in long-lived species, such indicators appear to have a long lag time potentially leading to catastrophic declines (Hutchings and Myers 1994; Shelton and Lilly 2000). A better indicator of population abundance and effects of exploitation is population age structure (Doak and Morris 1999; Holmes and York 2003). Age-growth studies provide a good index of a species life history and provide a baseline to assess effects of exploitation. For exploited populations, information about individual fecundity, age (and size) at maturity, and longevity are critical for development of predictive models to inform harvest regulations and other management activities (Holmes and York 2003).

Commercial exploitation is not currently a threat to leatherside chub populations. Some populations have been harvested for use as bait, but current laws prohibit the take of the species for such use. However, most people would not be able to distinguish between leatherside chub and other similar cooccurring species (e.g., redside shiner *Richardsonius balteatus*, small Utah chub *Gila atraria*, and speckled dace *Rhinichthys osculus*). Thus, inadvertent overexploitation for use as bait may still be a threat especially for small popula-

tions. Leatherside chub are relatively long-lived (up to 8 years of age), and they mature at age 2 (Johnson et al. 1995). In addition, leatherside chub are highly vulnerable to seining and electroshocking gears, especially in the fall when they seem to aggregate in deeper pools (Belk, personal observation). For these reasons, leatherside chub may be vulnerable to local overexploitation if baitfish harvests are not carefully monitored.

Recommendations to Alleviate Threats

Given a reasonable understanding of the status of populations and threats to a species' persistence, actions can be formulated to promote conservation. One clear advantage to following the above framework is that conservation efforts can be coordinated across the species as a whole rather than at the single population level. Conservation efforts focused on a single population may harm, or at least not help, the conservation and persistence of the species as a whole. For example, using inappropriate populations as source populations for augmentation or repatriation efforts may harm the source population and result in wasted time and effort (Stockwell 2003). Some may suggest that use of the "nearest neighbor" rule (use the population in closest geographic proximity) for determining source populations would be sufficient; however, this rule assumes that genetic and ecological variation follows a simple isolation by distance pattern. Given the complex geological history and current disturbed condition of aquatic habitats in western North America, departure from the simple isolation by distance pattern is likely common. Deciding where to focus conservation efforts and use limited funds to most benefit the species cannot be done without an understanding of the relationship among populations and the nature and extent of threats.

Recent studies on leatherside chub outlined above have already influenced management, conservation, and habitat restoration activities. In 1998, leatherside chub was listed as a state sensitive species in the state of Utah as a result of the survey work done in the early 1990s (e.g., Wilson and Belk 2001). This designation requires that proposed activities specifically consider effects on leatherside

chub. In addition, a leatherside chub working group within Utah has met several times to coordinate research and conservation activities. Two workshops (2004 and 2005) have been held with representatives from responsible agencies and organizations in Idaho, Wyoming, and Utah to discuss, plan, and coordinate conservation activities for leatherside chub. Recent habitat restoration efforts in the Provo River have explicitly included habitats designed to encourage persistence and expansion of populations of leatherside chub.

Additionally, previous and ongoing research provides clear recommendations for future conservation-related activities for leatherside chub. Genetic and ecological variation among populations suggests that many populations are not exchangeable (Crandall et al. 2000). Additional clarification of the variance among remnant populations is needed before population augmentation or repatriation efforts proceed, especially among populations of the northern species. Additional information about the genetic structure among populations in the southern species, as part of our ongoing study on effects of fragmentation, will be useful to determine appropriate source populations for future repatriation efforts.

Our studies of habitat use in leatherside chub and effects of introduced brown trout have revealed an important interaction between habitat and predation. In streams without brown trout (or other introduced predators), some guaranteed minimal water flow is apparently all that is required for leatherside chub to persist. However, in areas with brown trout, habitat restoration activities must include plans for construction of off-channel habitats such as backwaters that provide a refuge for leatherside chub. Simply adding meanders and pool-riffle sequences will not be sufficient to allow leatherside chub to coexist with an introduced predator. Recent restoration work on the Provo River in central Utah has provided an opportunity to assess the utility of off-channel habitats in promoting coexistence of leatherside chub with an abundant population of brown trout. Ongoing monitoring of the development of the fish community in restored sections of the Provo River is needed to assess the success of the project relative to leatherside chub and other native fishes.

Because of the aggressive nature and piscivorous habit of brown trout, it may be advisable to stock native cutthroat trout (e.g., *Oncorhynchus clarkii utah*) for recreational fishing purposes in streams occupied by leatherside chub. Stream-dwelling cutthroat trout are less piscivorous and less likely to pose a significant threat of predation compared to brown trout. Leatherside chub coevolved with native cutthroat trout in many locations, so it seems likely that they might be adapted to persist with native cutthroat trout. We encourage an experimental evaluation of the relationship between leatherside chub and cutthroat trout.

Finally, fragmentation among populations and population reduction due to brown trout might have long-term detrimental effects on populations of leatherside chub. Historic records indicate that leatherside chub were quite continuously distributed within major drainages in their range (e.g., Sevier River, Little Wood River, etc.), and they were often quite abundant. Species with such distributions may be adapted to high levels of gene flow and social interactions (Meffe 1986). Decreased levels of gene flow may lead to isolation and eventual loss of genetic variability within populations. Populations that are adapted to high population sizes and attendant social interactions may exhibit Allee effects (e.g., decreased individual fitness at low population sizes; Courchamp et al. 1999; Stephens 1999) further complicating conservation efforts. We suggest efforts be made to restore habitat and decrease brown trout numbers to facilitate reconnection of recently isolated populations of leatherside chub and to increase population sizes in areas where numbers have been reduced.

Acknowledgments

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