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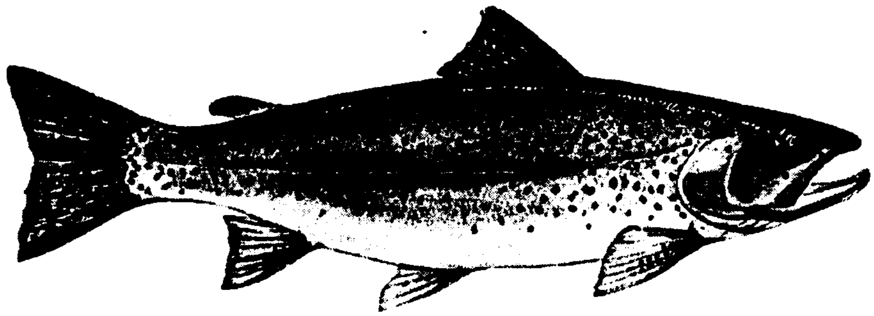

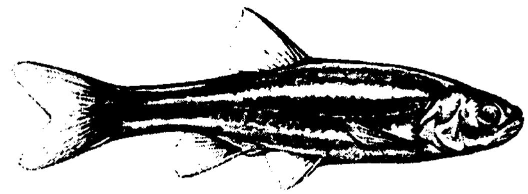

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INTERACTIONS AMONG TROUT AND LITTLE COLORADO SPINEDACE, *LEPIDOMEDA VITTATA*

Federal Aid in Sportfish Restoration
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INTRODUCTION

Introduced fish species can have negative effects on native fish species (Moyle 1986, Fausch 1988, Minckley and Deacon 1991). In Arizona, various nonnative salmonids (rainbow trout, *Oncorhynchus mykiss*, brook trout, *Salvelinus fontinalis*, brown trout, *Salmo trutta*, and cutthroat trout *O. clarki*) have been stocked since the early 1900s (Rinne and Janisch 1995), and trout angling remains an important component of the sportfishing industry. These nonnative salmonids may have contributed to the demise of native fishes in the Little Colorado River Basin through competition and predation (Miller 1961). Rainbow trout have been the primary trout species stocked, and are currently the only nonnative salmonid still stocked into high elevation waters (Rinne and Janisch 1995). This is of special concern, since rainbow trout may have contributed to the decline of Little Colorado spinedace (*Lepidomeda vittata*), a federally threatened cyprinid endemic to the Little Colorado River Basin. For example, Blinn et al. (1993) demonstrated that, in field enclosures, large rainbow trout prey on Little Colorado spinedace, and cause them to shift their habitat use.

Little Colorado spinedace are believed to be in decline (Miller 1963, Minckley 1973) and were listed as federally threatened with critical habitat designated in 1987 (USDI 1987). Probable causes for the decline of the species include habitat degradation and loss, pollution, poisoning, and negative interactions with introduced nonnative fishes (Miller 1961, 1963; Minckley and Carufel 1967). Spinedace are reported to be 'trout-like' in behavior, with similar habitat requirements and diet (Miller 1963, Minckley and Carufel 1967, Runck and Blinn 1993), therefore, rainbow trout may compete with spinedace in addition to preying on them. Distributions of the 2 species overlap to some extent, but spinedace distributions extend into lower elevations and rainbow trout extend into higher elevations (Arizona Game and Fish Department, unpublished data). Therefore, the species have the opportunity to interact where they are sympatric.

U. S. Fish and Wildlife Service (USFWS), in Section 7 (Endangered Species Act) consultation with Arizona Game and Fish Department (AGFD), determined that stockings of rainbow trout in habitats occupied by spinedace may affect spinedace populations through predation and competition. Adjustments to AGFD sportfish management practices regarding trout were proposed as a result of this consultation. Proposed actions included adjustments to timing of stockings at specific locations or species to be stocked, and a reduction in the numbers and types of nonnative salmonids stocked. In the final Biological Opinion relating to nonnative fish stockings in Nelson Reservoir, Blue Ridge Reservoir, and Knoll Lake (USDI 1995), USFWS recommended studies to determine trout dispersal out of the reservoirs and predation by these trout on spinedace. They further requested: (1) a list of actions necessary to maintain or enhance recreational fishing opportunity while proceeding with spinedace recovery, (2) a list of necessary actions to recover spinedace, and (3) evaluation of utilizing Apache trout in lieu of rainbow trout for recreational fishing opportunities. The research reported here was an attempt to provide information critical to address these recommendations and requests. The overall purpose of the research was to define trout interactions with spinedace, so that impacts to both trout management and spinedace populations can be minimized. Our objectives covered 5 broad areas of potential interaction: habitat use, diet, predation, health, and distribution. Our objectives were to 1) determine habitat use and diet overlap between Little Colorado spinedace and rainbow trout, 2) evaluate if spinedace shift their habitat use and diet in response to the presence of rainbow trout, 3) determine the incidence of predation by trout species on Little Colorado spinedace, 4) determine if rainbow trout affect the health of Little Colorado spinedace, 5) determine if rainbow trout stocked into Nelson Reservoir move out of the reservoir and into Nutrioso Creek, 6) document the distributions of Little Colorado spinedace and rainbow trout in the Nutrioso Creek critical habitat area and adjacent streams, 7) document movements by Little Colorado spinedace. Our approach was both observational and experimental.

STUDY AREAS

Field portions of the study were conducted in Nutrioso Creek, Rudd Creek, and the Little Colorado River (LCR) in east-central Arizona (Fig. 1); all sampling was conducted on U.S. Forest Service (USFS) and AGFD lands. Nutrioso Creek originates in spruce-fir forest and flows through both forested and meadow bound portions for 40 km until it empties into the Little Colorado River, in Springerville, Arizona. Approximately 20 km

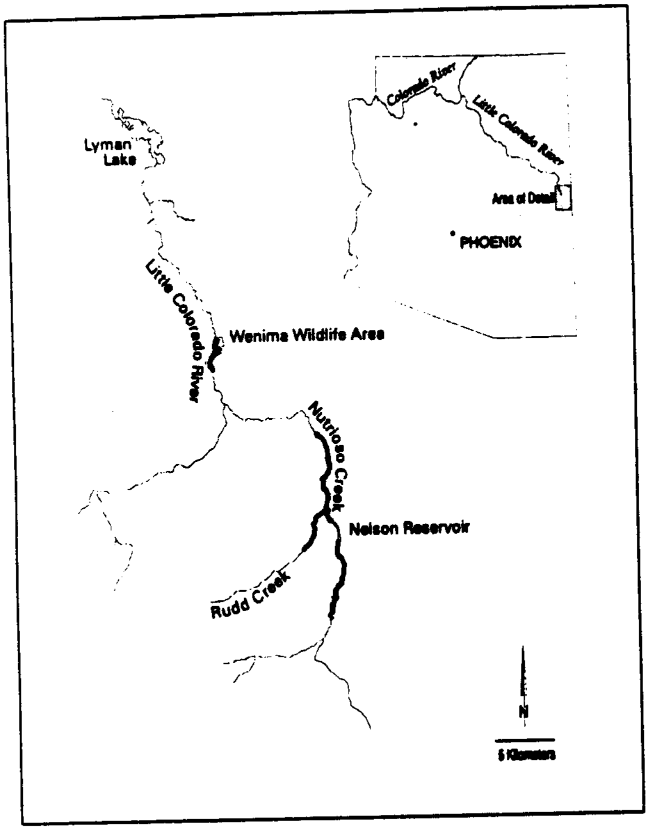

Figure 1. Map of the study area. Portions of the 3 study streams that were surveyed are highlighted.

downstream from its headwaters, Nutrioso Creek is impounded by Nelson Reservoir, which is managed as a recreational fishery by AGFD. We sampled both below and above Nelson Reservoir for the diet and predation portions of the study. The portion sampled below the reservoir was approximately 11.5 km from the dam of Nelson Reservoir downstream to the USFS land property boundary. Upstream from the reservoir, we sampled within the 8.3-km portion immediately above Nelson Reservoir; about 1.6 km of private land, between 3.0 and 4.6 km, was not sampled. The upper coniferous forest portion of Nutrioso Creek above Nelson Reservoir is dominated by rainbow trout, brook trout, and speckled dace (*Rhinichthys osculus*), whereas the fish assemblage in the downstream portions, above and below Nelson Reservoir, is comprised of Little Colorado spinedace, bluehead sucker (*Pantosteus discobolus*), rainbow trout, brown trout, fathead minnow (*Pimephales promelas*), and green sunfish (*Lepomis cyanellus*).

Rudd Creek is a second order stream with a length of approximately 13 km. It joins Nutrioso Creek approximately 2 km downstream of Nelson Reservoir. A fish barrier, located 4.5 km above the confluence with Nutrioso Creek, divides Rudd Creek into upper and lower reaches. The fish assemblage is comprised of rainbow trout and brook trout in the upper reach, whereas the lower reach contains Little Colorado spinedace, speckled dace, bluehead sucker, rainbow trout, and brook trout. Our sampling (for habitat use) was conducted on the lower 4.5-km reach.

The portion of the LCR we sampled is approximately 3.3 km of river, which flows through Wenima Wildlife Area (owned by AGFD), just northwest of Springerville, Arizona. The fish assemblage within this 3.3-km stretch includes Little Colorado spinedace, speckled dace, bluehead sucker, Little Colorado sucker (*Catostomus* spp.), fathead minnow, rainbow trout, brown trout, and green sunfish.

METHODS

For the sake of brevity and ease of reading, we do not report *P* values for statistical tests within the text; all tests mentioned were considered significant at $P < 0.05$. Instead, when significant, we indicate in the text that differences or dependencies were found, and when insignificant we indicate that no differences were found or relationships were independent.

Habitat Use and Overlap

Natural Settings

During 1996 - 1997, we sampled 80 fixed 5-m sites (randomly selected) in the lower 4.5-km section of Rudd Creek to document species co-occurrence and habitat use. These 80 sites were sampled prior to (April-May), during (June), and following (September) Little Colorado spinedace spawning activity. We established 5, equally spaced, perpendicular-to-flow transects in each site. Depth (cm), current velocity (cm/s), substrate type, and cover type were recorded along each transect at points 0.2, 0.4, 0.6, and 0.8 the width of the stream. Conductivity (μS), dissolved oxygen (DO; mg/L), pH, temperature (°C), alkalinity (mg/L $CaCO_3$), and turbidity (NTU) were measured at the approximate center of each site. Gradient (%) was measured for the entire site.

We captured fish via electroshocking. We placed block nets at the upstream and downstream end of each site and then electroshocked 3 times using a Smith-Root model 15-C backpack electrofisher. All fish captured were measured for total length (TL; mm) and weight (g). Fish were returned to the stream immediately after examination.

Based on examination of length frequencies, we recognized 2 size classes of spinedace; small (29 - 60 mm TL) and large (61 - 128 mm TL). For rainbow trout, we only had sufficient sample size to evaluate habitat use of 1 size class (84 - 177 mm TL); only 5 of 72 fish were < 84 mm TL (all < 36 mm). Throughout this paper we refer to the 84 – 177 mm TL size class simply as rainbow trout. Comparisons between species were restricted to the 1996 data set, since only 1 rainbow trout was captured in 1997.

We used chi-square analysis and the phi₂ (ϕ_2) coefficient (Zar 1984) to assess the association (co-occurrence) between rainbow trout and Little Colorado spinedace. The ϕ_2 coefficient ranges from -1 (species never occur together) to 1 (species always occur together), with the sign indicating either a negative or positive association. To evaluate density effects, we further evaluated associations by comparing the numbers of individuals captured at sites between species-size-classes with correlation analysis (Spearman's rho). We compared length of spinedace between rainbow trout present sites and rainbow trout absent sites with two-way analysis of variance (ANOVA); month was the second factor.

Habitat variables were aggregated by site and month so that each site-month had 1 value for each variable, and these aggregated data (means and percents) were used in subsequent analysis. Physico-chemical variables (i.e., alkalinity, oxygen, pH, conductivity, and temperature) were relatively constant, and were not included in comparisons between species or size-classes. To account for seasonal changes in habitat, we assessed habitat selection with a two-way MANOVA. For each species-size-class we compared habitat between sites with individuals present or absent and among months. Univariate comparisons were evaluated if the MANOVA (Wilk's Lambda) had a $P < 0.05$. We were not interested and do not present seasonal changes in habitat, but only the effects that those changes had on habitat use. We also used MANOVA and subsequent univariate tests to compare habitat use between species-size-classes and among months. We evaluated the magnitude of overlap between species-size-classes with Schoener's (1970) resource overlap index, which ranges from 0 to 100%.

Stream Enclosures

We observed habitat use by rainbow or Apache trout and Little Colorado spinedace in experimental stream enclosures on Rudd Creek to evaluate small scale overlap in habitat use (microhabitat use) and effects of large rainbow or Apache trout (potential predators) on habitat use by large Little Colorado spinedace. We conducted 2 sets of experiments, the first with rainbow trout and the second with Apache trout. In June 1998 we selected and enclosed 4 similar (approximately equal in proportions of pool and riffle habitat) 5-m long sites in Rudd Creek unoccupied by fishes. We placed 4 spinedace (81 - 103 mm TL; 0.3 - 0.6 fish/m^2) in each enclosure. We observed fish for 10 consecutive days at 5 fixed time periods which began at 1200 h and were separated by 40-min intervals. On the sixth day 1 wild-caught rainbow trout (200 - 300 mm TL) was added to each of 2 enclosures (densities of 0.1/m^2), the other 2 received no rainbow trout. Rainbow trout used in these experiments were approximately 2 times larger than spinedace and thus were considered potential predators as well as competitors.

Observations were made from behind a burlap blind on the bank. An individual spinedace was randomly selected, its location noted, and habitat measurements recorded. We also noted simultaneous locations of trout and recorded the same habitat information for the trout. Data recorded at fish locations were: (1) water column depth (cm), (2) focal depth zone (lower third, middle third, or upper third of water column) the fish was located in, (3) current velocity (cm/s) within the focal depth zone, (4) current velocity at 0.6 depth (mean water column velocity), (5) temperature (°C) in the focal depth zone, (6) primary substrate type (clay, silt, sand, gravel, etc.) below fish, (7) horizontal distance (cm) to nearest cover, (8) type of cover, (9) estimated length of fish, and (10) mapped location of fish. The second set of experiments was designed the same as the first set but utilized Apache trout (250 mm TL) instead of rainbow trout and was conducted in June 1999.

We calculated microhabitat use overlap (Schoener 1970) between Little Colorado spinedace and rainbow trout or Apache trout in treatment enclosures. We calculated overlap between spinedace in the post-treatment period with trout, between spinedace in the pre-treatment period with trout, and between spinedace in the pre-treatment period with spinedace in the post-treatment period. We also calculated overlap between spinedace in the pre-treatment period with spinedace in the post-treatment period in the control enclosures.

We assessed differences in habitat use between species by examining only data from post-treatment enclosures that contained both species. We compared total depth, current velocity at 0.6 depth, current velocity at focal-zone depth, distance to nearest cover, and ranked substrate size between the 2 species with Wilcoxon's signed rank tests; observations of species were paired within an observational period. Frequencies of categorical variables (focal-zone depth, substrate and cover type) were compared between species with Chi-square goodness of fit analysis.

To assess if spinedace shifted their habitat use due to the presence of rainbow trout or Apache trout, we compared habitat used by spinedace (continuous variables) between the pre- to post-treatment periods with Mann Whitney U test. We used chi-square goodness of fit tests to compare use of depth zones, substrate types, and cover types between pre- and post-treatment periods. Water temperature was constant within experimental periods and was therefore not analyzed.

Trout Density Laboratory Experiments

We evaluated the effects of density of rainbow or Apache trout on habitat use of different size-classes of Little Colorado spinedace in 2 530-L (213 x 61 x 56 cm) living streams (LSW-700 Living Stream, Frigid Units Inc., Toledo, OH). Gravel was placed on the bottom for substrate. Lines were drawn on the observation glass of each tank to create 6 imaginary zones (upper, middle, and lower depth zones for both upstream and downstream ends). Cover (simulated undercut bank) was created with a translucent dark gray plexiglass plate (43 x 30 cm), set with 1 end on the gravel at the downstream end of the tank and the other end propped up by 2 15 cm long PVC pipes. Lighting in the laboratory was held at a photoperiod of 14:10 h (light:dark).

We conducted 8 experiments; 3 sets of 2 with rainbow trout and 1 set of 2 with Apache trout. For each experiment, 10 spinedace were placed into each stream at 1700 h. Observations began the next day at 0700 and were conducted every 20 min thereafter until 1640 h. At 0630 h on the following day, rainbow trout were added to each tank (2 into 1 tank and 5 into the second tank). Observations began at 0700 h and were conducted every 20 min thereafter until 1640 h. In the first set of experiments, we placed large adult spinedace (93 - 124 mm TL, mean = 103 mm) in the tanks and then added either 2 or 5 rainbow trout (135 - 172 mm TL, mean = 148 mm). In the second set of experiments, we added rainbow trout (124 – 230, mean = 184) in with slightly smaller adult spinedace (68-112 mm TL, mean 86 mm), and in the third set we added rainbow trout (115 – 182 mm TL, mean = 154 mm) in with 50 – 80 mm TL spinedace (mean = 61 mm). For the Apache trout experiments, spinedace were 69-98 mm TL (mean 82 mm) and Apache trout were 188-233 mm TL (mean 210 mm).

Each observation was a 'snapshot' of the locations of fish in the stream. For each species, we recorded the number of fish in each zone and the number of fish under cover.

To evaluate if presence of rainbow trout or Apache trout caused spinedace to change their habitat use, we used chi-square goodness of fit tests to compare spinedace use of depth zones and cover between pre- and post-treatment periods. In addition, we assessed displacement by assessing species co-occurrence (during the post-treatment period) in zones or under cover with Spearman's correlation analysis. We also used chi-square analysis to compare zone and cover use between species in the post-treatment period. For all chi-square tests, data were pooled across experiments within trout species and densities if heterogeneity chi-square tests (Zar 1984) were rejected ($P > 0.05$).

Multiple Predator Laboratory Experiments

To determine if crayfish and trout species mutually influence spinedace behavior and habitat use through competition and predation, we compared cover use, movement, and survival of Little Colorado spinedace exposed to 1 of 4 treatments: 1) no predator (control), 2) crayfish present, 3) trout present, and 4) both crayfish and trout present. Separate experiments were run using rainbow trout and Apache trout.

Experiments were conducted in 3 living streams (see trout density experiments). Small diameter gravel was placed on the bottom of each stream and sloped to the surface of the water, creating variable depth. For refuge (cover), 6 12 x 12 cm dark-gray plexiglass plates were randomly placed within each living stream, and propped up 2.5 cm at 1 end with 2 fiberglass poles (Rahel and Stein 1988). In addition, an undercut bank was simulated with a 12 x 61 cm plexiglass plate attached to the shoreline. Lighting was set at a photoperiod of 14:10 h (light:dark). During dark hours, infrared lamps were used to facilitate nocturnal observations. A black plastic sheet with observation holes cut into it was draped in front of each living stream to minimize disturbances to the animals during observation.

Prior to each experiment, we placed 4 spinedace (50 - 108 mm TL) into each living stream and allowed them to acclimate for 24 h. Experiments began with the addition of 6 subadult crayfish (28 - 49 mm carapace length) and/or 1 rainbow trout (149 - 214 mm total length) or Apache trout (175 - 252 mm total length), depending on the treatment. The control stream received no predators. No fish or crayfish were used in more than 1 experiment to avoid pseudoreplication (Hurlbert 1984). Each treatment was replicated 3 times.

After experiments began, animals were observed every 2 h for 16 h (4 day and 4 night observations). At the beginning of each observation, the number of spinedace and crayfish in and out of refuges was recorded (initial refuge use). Within the next 5 min, we counted the number of times that spinedace and crayfish entered and exited refuges. Exits were classified as displacements when an individual exited immediately after another individual entered a refuge. Also, we randomly selected and observed 2 spinedace and 1 trout (if present) for 2 min, recording, as a measure of activity, the number of movements between vertical depth zones (bottom, mid-water, surface). Crayfish remained on the bottom and so were not included in these observations. In the next 5 min, we documented use of vertical zones by spinedace and trout by recording the number of fish in each depth zone every 30 seconds. To determine predation rates, we counted the number of individuals surviving after 24 h.

For Little Colorado spinedace, we compared initial refuge use, entrance rate (number entering refuge/5 min), exit rate (number exiting refuge/5 min), displacement rate (number displaced/5 min), and activity rate (number of movements between vertical zones/2 min) among the 4 treatments. For crayfish we compared refuge use, entrance rate, and exit rate between the 2 treatments that utilized crayfish; treatment 2 was considered the control and treatment 4 the trout-treatment.

Repeated measures ANOVA was used to assess differences in between-subject factors (treatment and temporal (day/night) effects) and within-subject factors (time) as well as interaction effects. If treatment effects were significant, we made pair-wise comparisons (Least Significant Difference test) between treatments. Proportions (refuge use) were arcsine transformed and rates (entrance, exit, and activity) were log transformed ($\log_{10} + 1$) prior to analysis to better meet assumptions of ANOVA. We used chi square analyses to compare vertical zone use between treatments for both day and night periods.

Diet Overlap

Field Collections

To determine diets and health of rainbow trout and Little Colorado spinedace, we collected fish from Nutrioso Creek during morning (0600 – 1000 h) and evening hours (1700 – 2000 h) in July (summer) and October (fall), 1996. We sampled the 11.6-km reach from Nelson Reservoir dam downstream to the Forest Service Boundary using a Smith-Root backpack electroshocker.

We collected spinedace from sites where trout were absent (allopatric sites) and from sites where trout were present (sympatric sites). We categorized sites as sympatric when we collected the 2 species within 5 m of each other, within the same macrohabitat. At sympatric sites, we collected all trout and up to 4 spinedace. We also collected rainbow trout from sites absent of spinedace (allopatric sites). We measured (TL, mm) and weighed (g) fish, and removed and froze the gastrointestinal tract.

We also sampled availability of food resources within each fish collection site. We used an Ekman dredge to collect benthos samples from 3 random locations, and we collected water column samples with a single 5-m tow of an invertebrate net (46 by 31 cm opening, 99 cm long, 750 µm mesh bag, and a bucket with 750 µm mesh) across each site.

In the laboratory, contents were removed from fish stomachs. We identified invertebrate,

vertebrate, and plant items to the lowest taxon practical, and counted and weighed (wet weight to the nearest 0.001 g) them by taxonomic grouping. Organisms from the benthos and water column samples were also identified, counted, and weighed (wet weight to the nearest 0.001 g). Insect taxa were identified as either larvae or adult. Terrestrial insects were lumped and considered 1 category; for some taxa (e.g., Chironomidae), adults were classified as terrestrial and larvae as aquatic.

We calculated frequency of occurrence and percent-composition-by-weight for each diet category, and percent-composition-by-weight for each available food resource category. Mean percent for each category was then computed for spinedace and rainbow trout. We assessed diet overlap between spinedace and trout, and within each species between allopatric and sympatric sites with Schoener's (1970) resource overlap index. We assessed differences in diets between the 2 species (sympatric situations only) and within each species between allopatric and sympatric sites using Mann-Whitney tests to compare mean percent-composition-by-weight of major diet items (frequency of occurrence > 10%) between groups, and Fisher's exact tests to compare frequency of occurrence of diet items between groups.

At sites where spinedace were captured, available food resources (mean percent-composition-by-weight) were compared between rainbow trout-present and rainbow trout-absent sites with Wilcoxon's Signed Rank test. Data from tow and dredge samples were combined prior to calculating mean percent-composition-by-weights.

Field Experiment

We further investigated effects of rainbow trout on diets of Little Colorado spinedace in an experimental stream enclosure. We limited our experiment to 1 enclosure in an effort to control for available food resources. We blocked off the upstream and downstream ends of a pool in Rudd Creek with 3.2-mm mesh seines. All fish were removed from the enclosed area via electrofishing and minnow traps.

We conducted 2 treatments within this enclosure. Ten adult Little Colorado spinedace (103 mm mean TL) and 10 rainbow trout (150 mm mean TL) were placed into the enclosure at 1800 h on July 22, 1999. At 1800 h on the following day, fish were removed from the pool, sacrificed, and frozen until laboratory analysis of the stomach contents could be made. Another 10 adult spinedace (104 mm mean TL) were added to the enclosure at 1800 h on July 24, 1999 and were removed and sacrificed the following day at 1800 h. Stomach contents were examined and statistically analyzed as mentioned for field collections.

Predation

Field Collections

We sampled Nutrioso Creek and the Little Colorado River at Wenima Wildlife Area during late spring, mid-summer, and early autumn, from spring 1996 through spring 2000. Predation information for 1996 was obtained from collections for diet, described above. Predation information for 1997 - 2000 was obtained from trout captured during distribution sampling (described below).

All trout captured were sacrificed and their stomach contents examined (in the laboratory) for fish remains. Length (mm), weight (g), and location of each salmonid sacrificed was recorded. We calculated percent incidence of piscivory (number of trout with fish in their guts / total trout examined X 100) on Little Colorado spinedace and on fish in general.

Digestion Rate of Fish Larvae Experiments

We conducted 7 laboratory experiments to determine if rainbow trout (124 – 190 mm TL) would consume larval fish and at what rate the larvae are digested. These experiments were done in order to design an effective experiment to detect predation on larvae in natural settings. In our first 2 experiments, 10 larval fathead minnows (surrogates for Little Colorado spinedace larvae) were placed into a 340 L aquarium with 1 rainbow trout that had been starved for 24 h. Every 0.5 h we counted the number of larval fish. If larval fish were missing the trout was removed, eviscerated and the time elapsed was recorded. The stomach contents were identified, enumerated, and the digestive condition of the prey was noted.

For the remaining trials, we modified the aquarium setup by placing black cardboard on 3 sides of the aquaria and an observation blind in front of the aquaria. In the last 2 trials trout were starved for 2 d prior to placement in the tank. In 2 trials, 10 corixids or 10 ephemeropterans were added to the tank in addition to the 10 larval fish. We counted prey at 1-h intervals and removed and processed the trout as mentioned above if larval fish were missing.

Health and Growth

Field Collections

We assessed health of all fish collected for diet following methods of Goede and Barton (1990). The condition of external (fins, skin, body deformities, eyes, opercula, gills, thymus, and pseudobranchs) and internal (spleen, kidney, liver, hindgut, gall bladder, and mesenteric fat) anatomy of fishes was qualitatively rated. Fulton's condition factor (Ricker 1975) was calculated for each fish.

We also compared condition (Fulton's condition factor) of spinedace (>60 mm TL) in Rudd Creek between 1996 (trout present) and 1997 (trout largely absent).

Laboratory Experiments

We conducted 2 laboratory experiments to evaluate the indirect effects of predatory rainbow trout (200 - 300 mm TL hatchery fish) on growth and feeding rates of Little Colorado spinedace. We conducted experiments in 2 (experiment 1) or 3 (experiment 2) 90 gallon aquaria; 1 control tank and 1 or 2 treatment tanks. Each aquarium was partitioned widthwise with 1-mm mesh screen into 2 equal-sized compartments to restrict movement of fishes.

In the first experiment we placed 9 spinedace (38 - 66 mm TL) into 1 compartment of each tank and 1 rainbow trout (238 mm TL) into the empty compartment of the treatment tank; no trout were put in the empty compartment of the control tank. Fish were held for 30 d, after which all spinedace were weighed (g) and measured (TL, mm). Health of spinedace at the end of experiments was not assessed (as originally planned), since fish in the control tank became infected with *Ichthyophthirius multifilis*, confounding comparison of health between trout and control treatments.

Our second experiment was similar in design to the first except that we individually marked all spinedace with fluorescent elastomeres. Sixteen spinedace (28 - 49 mm TL) were placed into 1 compartment of each of 3 tanks. We placed 2 rainbow trout (205 and 246 mm TL) into the empty compartment of 1 tank, into the empty compartment of another tank we placed 2 Apache trout (206 and 248 mm TL) and we placed no fish into the empty compartment of the third tank (control). Fish were held for 40 d after which they were removed and measured for length (mm TL) and weight (g).

We observed Little Colorado spinedace in the first growth experiment to evaluate if rainbow trout presence effects spinedace feeding rates. Immediately after dropping food into the tank (twice a day, once in the morning and once in the evening), a fish was randomly selected and observed for 2 min and the total number of feeding attempts recorded. The same procedure was then applied to the other tank. Observations were made for 10 d for a total of 20 observations per tank.

Movements and Distributions

Rainbow Trout Escapement

Rainbow trout stocked into Nelson Reservoir were marked with coded-wire tags (injected into the nose or just below the adipose fin). Tetracycline was also introduced into the feed of rainbow trout in the hatchery to mark bony structures. Each year, rainbow trout were stocked in Nelson Reservoir (typically in May) immediately subsequent to the end of reservoir overflow.

Roving creel surveys were conducted during 1996 - 1999 on Nelson Reservoir and Nutrioso Creek below Nelson Reservoir. Boat and shore anglers were checked between 7 and 10 days per month. All anglers observed fishing in Nutrioso Creek were surveyed. Creel data were used to determine estimates of salmonids removed by angling from Nelson Reservoir and Nutrioso Creek.

Nutrioso Creek was surveyed during 1996 - 2000 for marked trout upstream and downstream from Nelson Reservoir. Surveys were made prior to stocking (typically May) and then post-stocking during low flow periods (late summer to early autumn). During 1997 - 1998 we restricted our sampling in Nutrioso Creek to 18 50-m sites to reduce possible impact to the spinedace population. We sampled 9 of the sites in May and the other 9 in late summer. In 1999 - 2000, the entire Forest Service bound section of Nutrioso Creek below Nelson Reservoir was sampled using a backpack electrofisher in May and September. We also conducted pre- and post-stocking surveys in Nutrioso Creek above Nelson Reservoir; 6 50-m sites in September 1997 and 12 50-m sites during

May 1998 - 2000. To survey the 50-m sites, block nets were placed at the upstream and downstream boundaries, and fish were sampled using a backpack electroshocker and the 3-pass fish removal method.

On the Little Colorado River, we sampled the entire 3.3-km reach within Wenima Wildlife Area during 1997 (June, July, and October), 1998 (April, June, and September), and 1999 (May and September) and 2000 (May). Fish were captured via backpack electrofishing (single pass) during June and July 1997, and May 1999 and 2000. We sampled the river with backpack and canoe electrofishing (in portions where backpack electrofishing was inefficient) in October 1997, April 1998, and September 1999.

Spinedace Movements

To assess downstream and upstream movements of spinedace, we marked spinedace prior to spring runoff in selected reaches of Rudd and Nutrioso creeks and the LCR and later surveyed the reaches where fish were marked as well as upstream and downstream portions of the streams. In spring 1998, we captured spinedace in a 500-m reach of Rudd Creek, 3.5 km above the Nutrioso Creek confluence, and injected coded wire tags into the caudal peduncle of each fish. In Nutrioso Creek, we captured and marked (coded wire tags injected into the snout) spinedace in a 500-m reach approximately 7.1 km above Nelson Reservoir.

In March - April 1999, spinedace were marked with fluorescent elastomeres (unique mark for each fish) in the 2 creeks and in the LCR. In Rudd Creek, we marked the fish in 3 reaches (1.0 – 1.5, 2.0 – 2.5, and 3.0 – 3.5 km above the mouth). In Nutrioso Creek, we marked fish in 2 500-m reaches (6.3 – 6.8 and 7.3 – 7.8 km above Nelson Reservoir). In the LCR, we marked spinedace within 4 50-m sites (4 of the 6 50-m sites that were established).

We attempted to mark a minimum of 40 and a maximum of 200 spinedace during each marking period for each year. We recorded total length (mm), weight (g), sexual maturity, mark location and type, and location for each fish captured. All fish were captured using a backpack electrofishing unit.

We surveyed for marked fish after spring-runoff during May, during summer monsoons in July (in 1999 our sampling on all 3 waters was cancelled due to high flows) and again in September after summer monsoons. We surveyed for marked fish using a backpack electroshocker (single pass), except in September 1999 when we used a canoe electroshocker in the LCR. In Rudd Creek, the entire 4.5 km of lower Rudd Creek from the fish barrier to the Nutrioso Creek confluence was electrofished. In addition, we surveyed Nutrioso Creek, above and below the confluence with Rudd Creek. In 1998, we surveyed the 500 m above and below the confluence, and in 1999 we surveyed the entire reach of Nutrioso Creek between the dam and the USFS property boundary (during the September sampling, 2 backpack shockers were used simultaneously). In Nutrioso Creek above Nelson Reservoir we electrofished the marking reaches and 500 m above and below the marking reaches. In the LCR, we surveyed the entire 3.3 km, on Wenima Wildlife area. We recorded TL (mm), weight (g), sexual maturity, mark location and type (if there was a mark), and capture location for each fish.

RESULTS AND DISCUSSION

Habitat Use and Overlap

High overlap in habitat use between species indicates a high potential for interaction. Our data, (Table 1 and 2) both observational and experimental, indicate extensive overlap in habitat use between rainbow trout (84 - 177 mm TL) and Little Colorado spinedace. In Rudd Creek, small spinedace occurrence was independent of rainbow trout (Table 3), and yet these 2 species-size-classes overlapped extensively in habitat use. It may be that predation or displacement (either competitive displacement or predator avoidance) by rainbow trout led to the independent distributions of these 2 species-size-classes. In contrast, large spinedace and rainbow trout used similar habitat (Tables 1 and 2) and had a positive co-occurrence (Table 3). Similar habitat use and co-occurrence likely increases the probability for competition.

However, we detected some difference in habitat use between the species (Tables 4 and 5). Rainbow trout tended to use undercut banks (both in the wild, stream enclosures, and in laboratory settings) more than small or large spinedace. In addition, spinedace occupied locations in enclosures that were deeper and had faster current velocities than those occupied by rainbow trout (Table 5), and as mentioned above, occurrence of small spinedace was independent of rainbow trout in Rudd Creek. These spatial differences, although seemingly slight,

Table 1. Percent overlap [Schoener's (1970) index] in habitat at 5-m sites used by small (30 - 60 mm TL) and large (61 - 120 mm TL) Little Colorado spinedace and 84 - 177 mm TL rainbow trout, Rudd Creek, 1996.

Habitat Variable	Small spinedace X rainbow trout	Large spinedace X rainbow trout	Small spinedace X large spinedace
Area	71.4	61.1	72.2
Depth	65.5	65.1	63.5
Current velocity	79.8	60.3	78.6
Turbidity	72.6	82.1	70.6
Substrate	89.6	84.0	78.5
Cover	94.2	88.3	84.6
Mean	78.8	73.5	74.7

Table 2. Percent overlap [Schoener's (1970) index] in habitat used by species in stream enclosures during pre- (trout absent) and post-treatment (after trout added) periods, Rudd Creek 1998 (rainbow trout) and 1999 (Apache trout).

	Post-treatment spinedace versus	Pre-treatment spinedace versus	
Habitat variable	Rainbow trout	Post-treatment rainbow trout	Post-treatment spinedace
Depth	85.7	37.9	45.7
Focal zone depth	96.4	89.0	85.4
Current velocity at 0.6 depth	82.9	76.6	83.8
Focal zone current velocity	80.0	64.4	81.6
Substrate	82.9	71.4	85.7
Cover	38.6	43.7	73.0
	Apache trout	Post-treatment Apache trout	Post-treatment spinedace
Depth	80.0	75.1	72.6
Focal zone depth	85.0	94.7	79.7
Current velocity at 0.6 depth	72.5	54.7	82.2
Focal zone current velocity	85.0	78.2	70.7
Substrate	87.5	87.5	75.0
Cover	85.0	74.7	69.7

Table 3. Co-occurrence of Little Colorado spinedace and rainbow trout at 5-m sites in Rudd Creek during 1996. Spinedace ≤ 60 mm TL were categorized as small, and those > 60 mm TL as large.

Sites with Little Colorado spinedace		Sites with rainbow trout (total) Absent	Present	Statistics and P
Total	Absent	162	23	
	Present	42	13	$\chi^2 = 4.17$, $\phi_2 = 0.13$, $P = 0.04$
		84 - 177 mm TL rainbow trout Absent	Present	
Small	Absent	176	22	
	Present	36	6	$\chi^2 = 0.34$, $\phi_2 = 0.04$, $P = 0.56$
		84 - 177 mm TL rainbow trout Absent	Present	
Large	Absent	200	22	
	Present	12	6	$\chi^2 = 8.86$, $\phi_2 = 0.19$, $P = 0.003$
		Large Little Colorado spinedace Absent	Present	
Small	Absent	185	37	
	Present	13	5	$\chi^2 = 1.42$, $\phi_2 = 0.08$, $P = 0.23$

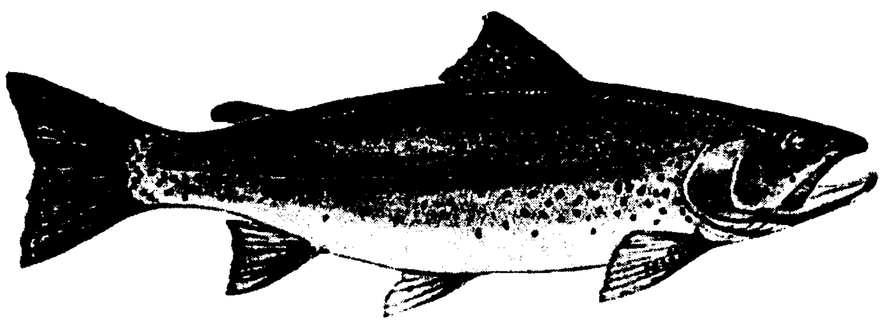

Table 4. Means (SE in parentheses) of habitat characteristics at 5-m sites in Rudd Creek, 1996 and 1997, with species-size-classes absent (unused) and present (used). Results are for significant univariate comparisons; comparisons with $P > 0.05$ are not shown. Multivariate habitat differed (MANOVA) among used and unused sites and months (see text) for all 3 species-size-classes. Habitat used by small spinedace or rainbow trout in 1997 was not analyzed and is not presented because sample size was too small.

	Habitat	
Species-size-class and habitat variable	Unused	Used
1996, Small spinedace		
Gradient (%)	1.4 (0.10)	0.7 (0.18)
Turbidity (NTU)	52.0 (3.32)	31.8 (2.97)
Area (m^2)	4.9 (0.30)	7.67 (7.56)
Depth (cm)	10.4 (0.56)	17.0 (1.20)
Current velocity (cm/s)	5.0 (0.30)	2.6 (0.40)
Substrate size (rank)	2.6 (0.06)	2.3 (0.10)
Cover (proportion)	0.50 (0.02)	0.38 (0.05)
Large spinedace		
Area (m^2)	4.8 (0.22)	12.0 (2.05)
Depth (cm)	10.4 (0.46)	25.2 (2.53)
Current velocity (cm/s)	4.9 (0.27)	1.8 (0.59)
Substrate size (rank)	2.6 (0.05)	2.1 (0.15)
Cover (proportion)	0.50 (0.02)	0.17 (0.04)
84-177 mm TL rainbow trout		
Area (m^2)	4.9 (0.25)	8.4 (1.4)
Depth (cm)	10.7 (0.49)	17.9 (2.34)
Current velocity (cm/s)	4.9 (0.28)	3.0 (0.59)
Cover (proportion)	0.50 (0.20)	0.34 (0.05)
Undercut bank	0.03 (0.00)	0.05 (0.02)
1997, large spinedace		
Area (m^2)	5.5 (0.31)	8.1 (0.96)
Depth (cm)	13.0 (0.49)	20.7 (1.54)
Cover-Undercut bank	0.03 (0.01)	0.09 (0.17)

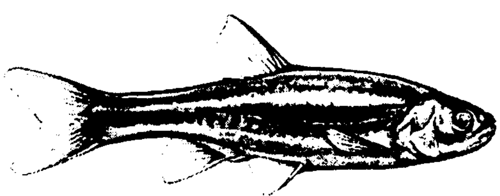

Table 5—Comparison of habitat use by Little Colorado spinedace held in stream enclosures in Rudd Creek, 1998, before and after rainbow trout were added, and comparisons between species in trout-treatment enclosures. Means (continuous variables; ±SE), or percentages (categorical variables) of habitat variables measured are presented. For between species comparisons, means were calculated from paired samples (28 cases with both species observed during the same period). Significance levels (*P*) were derived from Mann-Whitney U tests (before versus after; continuous variables), Wilcoxon's signed rank tests (between species comparisons; continuos variables) or G tests (categorical variables).

Habitat Variable	Before trout (N = 40)	After trout (N = 40)	*P*	Spinedace	Rainbow trout	*P*
Depth (cm)	34.0	27.0	<0.001	25.6	23.3	0.018
	(1.1)	(1.1)		(1.3)	(1.1)	
Current velocity at 0.6 depth (cm/s)	0.8	0.5	0.035	0.5	0.3	0.206
	(0.1)	(0.1)		(0.1)	(0.1)	
Focal zone current velocity (cm/s)	0.5	0.3	0.025	0.3	0.0	0.034
	(0.1)	(0.1)		(0.2)	(0.0)	
Distance to cover (cm)	6.8	0.0	<0.001	0.0	0.0	1.000
	(1.7)	(0.0)		(0.0)	(0.0)	
Focal zone depth (%)			0.030			0.542
Lower	67.5	87.5		87.5	82.1	
Middle	32.5	12.5		12.5	19.9	
Substrate (%)			0.026			0.093
Gravel		2.5		2.5		
Sand		10.0		10.0	28.6	
Silt	100.0	87.5		87.5	71.4	
Cover type (%)			<0.001			<0.001
Debris		2.5		2.5		
Instream vegetation	13.0	15.0		15.0		
Overhanging vegetation	43.5	47.5		47.5	21.4	
Net	30.4	7.5		7.5	78.6	
Undercut bank	13.0	27.5		27.5		

may reduce the probability of interactions between species (Ross 1986).

We detected shifts in spinedace habitat use in response to the presence of rainbow trout both in natural (Table 4) and experimental settings (Tables 5 - 7). In Rudd Creek during 1996, spinedace did not select for sites with undercut banks, but rainbow trout did. Then in 1997, when trout were nearly absent, large adult spinedace selected for sites with undercut banks. In stream enclosures, spinedace increased their use of cover (from 57.5% to 100%), undercut banks (cover type), the bottom depth zone, and used more substrate types and deeper and slower water after rainbow trout were added to enclosures (Table 5). In our multiple predator experiments, spinedace increased movements between depth zones and increased use of the bottom depth zone when rainbow trout were present (Tables 6 and 7). We also found evidence for a shift in habitat use in our artificial stream experiments (Figs. 2 and 3), and the changes in habitat use appeared to be dependent upon density of trout added. When a low density of rainbow trout were added to the artificial streams, spinedace use of cover (undercut bank) increased (Fig. 2). When a high density of rainbow trout were added to the artificial stream, spinedace use of cover decreased, a similar response was reported by Blinn et al. (1993) in stream enclosures. As in other predator-prey and competitive relationships (Tonn et al. 1989, Tonn et al. 1992, Post et al. 1999), negative effects of rainbow trout on Little Colorado spinedace are likely dependent upon densities of both species where they co-occur. As rainbow trout densities increase, spinedace risk more predation and use more sub-optimal habitat (less undercut banks; Blinn et al. 1993).

Our experimental evidence also indicates high overlap in habitat use between spinedace and Apache trout (Table 2). In addition, we did not detect any significant effects of Apache trout on habitat use by spinedace in stream enclosures. However, in laboratory density experiments spinedace increased their use of cover (Fig. 2) and decreased their use of the lower depth zone (Fig. 3) when Apache trout were present. However, rather than avoiding each other, the two species tended to co-occur both under cover and in zones. In laboratory multiple predator experiments, spinedace increased their movements into and out of cover (Table 6) and changed their depth zone use when Apache trout were present (Table 7). However, results from our multiple predator experiments (Tables 6 and 7) indicate spinedace respond more to crayfish than to either trout species.

Diet Overlap

We are limited to what we can conclude about diet interactions between rainbow trout and Little Colorado spinedace to the size classes we examined. Lengths of individuals of the 2 species did not overlap, but were adjacent; all spinedace were smaller than all trout.

Diet overlap (Table 8) between rainbow trout and Little Colorado spinedace was low both in experimental and natural settings, indicating a low potential for competition for food resources in general. However, the 2 species could potentially compete for corixids and terrestrial insects, since these 2 categories comprised a large portion of the diets of both species (Tables 9 and 10). Although our sample sizes for both wild and experimental fish were generally low, a common pattern was evident in both data sets; frequency of occurrence of terrestrial insects and corixids in spinedace diets tended to decrease when rainbow trout were present. Dietary overlap may be greater between similar-sized (Werner and Gilliam 1984) rainbow trout and Little Colorado spinedace and a shift in spinedace diet in response to rainbow trout may be more likely if fishes of the 2 species were similar in size.

Predation

Based on examination of gastrointestinal tracts (Table 11), rainbow, brook, and brown trout all consume cyprinid fishes, so all 3 may affect spinedace populations and distributions. Brown trout were the most piscivorous (7 of 24 individuals consumed fish, 1 of which was a spinedace), followed by brook trout (1 of 4 individuals consumed fish), and rainbow trout (3 of 54 individuals consumed fish). During artificial stream habitat use experiments, we observed only 2 incidences of predation by rainbow trout on spinedace. We did not detect any predation on larval fish in the wild, but larval fish are digested rapidly (typically not detectable in gut 30 min after consumption in our laboratory experiments), so we cannot dismiss the possibility that rainbow trout consume larvae in the wild. In aquaria, rainbow trout consumed larval fish in 4 of 7 trials, even when alternate prey were available, indicating that they may consume larval fish in the wild. Predation on

Table 6. Effects of crayfish, Apache trout, and rainbow trout on Little Colorado spinedace activity and refuge use. Mean differences (standard error) in the control (spinedace alone) vs. each treatment are presented along with *P* values for repeated measures ANOVA. Analyses were performed on log transformed entry, exit, and activity rates, and on arcsine transformed proportions of refuge use. Values are significant (*) when $P < 0.05$.

Variable	Crayfish		Apache Trout		Crayfish x Apache Trout		Rainbow Trout		Crayfish x Rainbow Trout	
	Mean Diff.	*P*	Mean Diff.	*P*	Mean Diff.	*P*	Mean Diff.	*P*	Mean Diff.	*P*
Refuge Use	0.05 (0.06)	0.432	-0.06 (0.05)	0.274	-0.04 (0.05)	0.463	0.31 (0.10)	0.613	-0.00 (0.11)	0.986
Entrance Rate	-0.75 (0.14)	0.000*	-0.60 (0.13)	0.002*	-0.65 (0.13)	0.001*	0.12 (0.27)	0.939	-0.67 (0.30)	0.026*
Exit Rate	-0.70 (0.14)	0.001*	-0.61 (0.12)	0.001*	-0.68 (0.12)	0.000*	0.11 (0.28)	0.976	-0.68 (0.31)	0.023*
Activity Rate	-5.20 (1.63)	0.011*	-1.48 (1.45)	0.629	-3.13 (1.45)	0.074	-5.54 (1.14)	0.001*	-4.83 (1.27)	0.002*

Table 7. Spinedace temporal use of vertical zones (bottom, mid-column, and surface) in the presence of crayfish, Apache trout, rainbow trout, and combinations of crayfish and trout. All treatments are significantly different than the control (chi-square, $P < 0.05$). All treatments differ significantly between day and night (chi-square, $P < 0.05$), except spinedace x crayfish x rainbow trout ($P = 0.841$).

		Control		Crayfish		Apache trout		Crayfish x Apache trout		Rainbow trout		Crayfish x Rainbow trout	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*N*	%
Day	Bot	221	46.0	318	66.3	210	43.8	309	64.4	348	72.5	350	72.9
	Mid	229	47.7	160	33.3	139	29.0	167	34.8	123	25.6	129	26.9
	Sur	30	6.3	2	0.4	131	27.3	4	0.8	9	1.9	1	0.2
Night	Bot	116	24.2	209	43.5	239	49.8	260	42.9	260	54.2	358	74.6
	Mid	318	66.3	250	52.1	184	38.3	185	48.8	141	29.4	121	25.2
	Sur	46	9.6	21	4.4	57	11.9	35	8.3	79	16.5	1	0.2

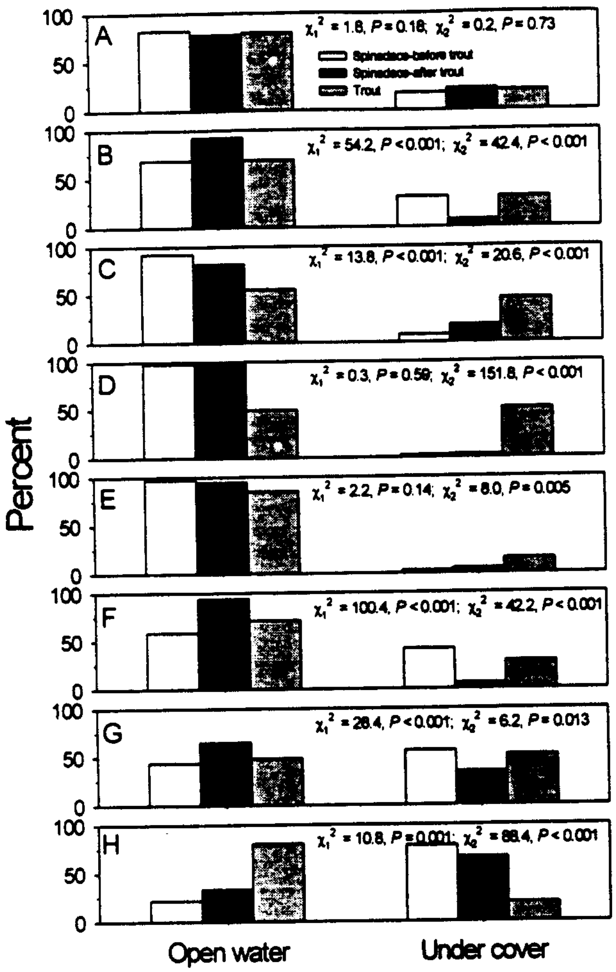

Figure 2. Use of cover in artificial streams by Little Colorado spinedace (before and after trout added) and rainbow trout (A – F) or Apache trout (G – H). Ten spinedace were used in each experiment and ranged in total length from 93 - 124 mm (A and B), 68 – 112 mm (C and D), 50-80 mm (E and F), and 69-98 mm (G and H). Either 2 (A, C, E, and G; N = 60 observations) or 5 (B, D, F, and H; N = 150 observations) trout (115 – 230 mm TL rainbow trout or 188 - 233 mm TL Apache trout) were added. For spinedace, 300 observations were recorded before and after trout were added, except in experiment E (N = 299 before), F (N = 292 after), and C (N = 279 after). Chi-squares with subscript 1 indicate comparisons between spinedace cover use before with after trout added, and those with subscript 2 indicate comparisons between species (when both were present).

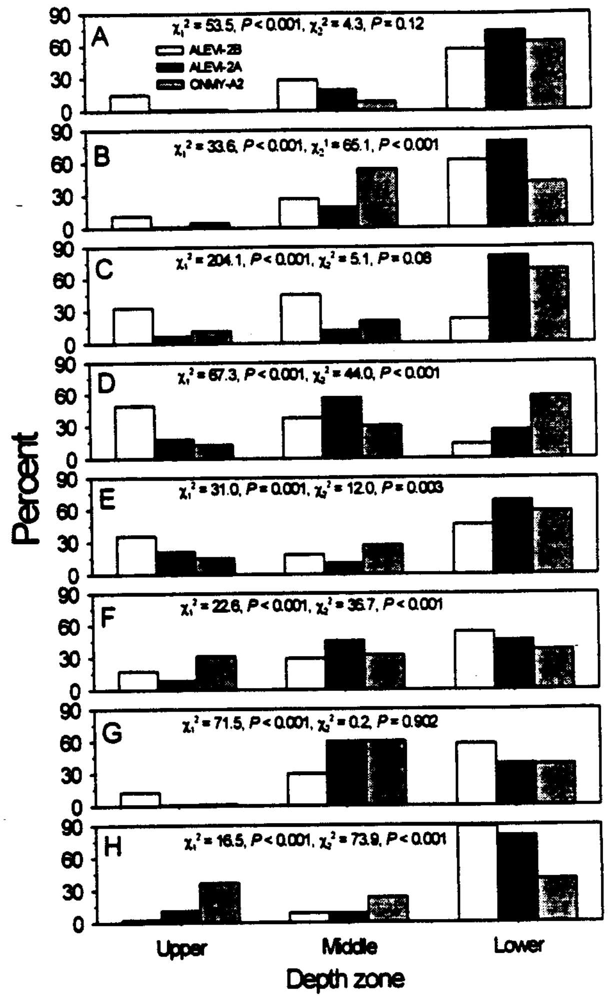

Figure 3. Use of depth zones in artificial streams by Little Colorado spinedace (before and after trout added) and rainbow trout (A – F) or Apache trout (G – H). Ten spinedace were used in each experiment and ranged in total length from 93 - 124 mm (A and B), 68 – 112 mm (C and D), 50-80 mm (E and F), and 69-98 mm (G and H). Either 2 (A, C, E, and G; N = 60 observations) or 5 (B, D, F, and H; N = 150 observations) trout (115 – 230 mm TL rainbow trout or 188 - 233 mm TL Apache trout) were added. For spinedace, 300 observations were recorded before and after trout were added, except in experiment E (N = 299 before), F (N = 292 after), and C (N = 279 after). Chi-squares with subscript 1 indicate comparisons between spinedace cover use before with after trout added, and those with subscript 2 indicate comparisons between species (when both were present).

Table 8. Overlap (Schoener's index) in diet between Little Colorado spinedace (LEVI) and rainbow trout (ONMY) collected from allopatric and sympatric sites in Nutrioso Creek, July 1996 and in an experimental enclosure in Rudd Creek, July 1999. Species absence (-) and presence (+) at sites are indicated.

	Spinedace with	Rainbow trout with	
	ONMY(+)	LEVI (+)	LEVI (-)
Nutrioso Creek			
Spinedace with ONMY (-)	90.7	46.9	30.7
Spinedace with ONMY (+)		44.4	28.2
Rainbow trout with LEVI (+)			80.0
Rudd Creek Experiment			
Spinedace with ONMY (-)	61.4	53.0	
Spinedace and ONMY (+)		44.1	

Table 9. Frequency of occurrence (% of fish with prey taxa in stomachs; numerator) and mean percent-composition-by-weight (denominator; only non-empty stomachs) of diet items of Little Colorado spinedace and rainbow trout collected from allopatric or sympatric sites on Nutrioso Creek during July 1996. Total number of fish examined (N) and the number with non-empty stomachs (in parentheses) is given. Spinedace examined were 51 - 96 mm TL (mean 67 mm) and rainbow trout were 105 - 168 mm TL (mean 139 mm).

	Spinedace with trout		Rainbow trout with spinedace	
Prey taxa	Absent	Present	Absent	Present
N	20 (19)	15 (13)	7 (7)	8 (8)
Aquatic				
Branchipoda	5.0/0.2			
Copepoda	5.0/5.1			
Decapoda			85.7/61.2	50.0/44.1
Insecta				
Ephemeroptera		6.7/4.4		
Coleoptera				
Hydrophilidae				12.5/3.7
Hemiptera				
Veliidae			14.3/0.1	
Corixidae	20.0/18.3	13.3/11.0	85.7/36.9	37.5/34.1
Terrestrial (insects)	55.0/55.3	46.7/53.9	14.3/1.8	50.0/18.1

Table 10. Frequency of occurrence (% of stomachs with prey taxa; numerator) and mean percent-composition-by-weight (denominator; calculated with non-empty stomachs) of diet items of Little Colorado spinedace and rainbow trout from the diet experiment, Rudd Creek, July 1999. Total number of fish examined (N) and number with non-empty stomachs (in parentheses) is given. Spinedace examined were 89 - 121 mm TL (mean 103 mm) and rainbow trout were 129 - 173 mm TL (mean 150 mm).

	Spinedace with trout		
	Absent	Present	
N	9 (6)	10 (10)	8 (8)
Aquatic			
Amphipoda	33.3/13.3	10.0/15.8	12.5/0.6
Insecta			
Coleoptera	16.7/3.4		
Haliplidae			
Hydrophilidae			37.5/8.7
Neuroptera	16.7/10.0	10.0/15.0	
Corydalidae			
Diptera	16.7/10.0		
Tipulidae			
Chironomidae	16.7/0.5	10.0/9.8	12.5/0.4
Hemiptera	66.6/33.41	30.0/11.2	87.5/54.8
Corixidae			
Gerridae			12.5/8.9
Eggs			12.5/2.4
Terrestrial insects	83.3/18.0	30.0/31.7	62.5/23.6
Vegetation (seeds)	33.3/11.3		12.5/0.5

Table 11. Incidence of piscivory by 3 salmonid species captured in Nutrioso Creek and the Little Colorado River, 1996-1999. Total number (N) of trout stomachs examined is presented as is frequency and percent (in parentheses) of trout captured with fish, with spinedace, and with other cyprinids, and number of sites with trout and the percent of those sites with spinedace.

	Rainbow trout (N = 54)	Brown trout (N = 24)	Brook trout (N = 4)
Trout with fish in stomachs	3 (6)	8 (33)	4 (25)
Number with spinedace	0	1 (4)	0
Number with other cyprinids	3 (6)	7 (29)	1 (25)
Number of sites with trout	37	18	4
% of trout sites with spinedace	48	33	25

Table 12. Rainbow trout stocked and harvested from Nelson Reservoir, 1996 - 1999.

	Year			
	1996	1997	1998	1999
# Rainbow trout stocked	16,042	19,897	20,000	19,546
Creel census period	April 1996 to April 1997	May 1997 to April 1998	May 1998 to April 1999	May 1999 to Dec. 1999
Estimated harvest	7,723	13,943	11,956	16,529
% Removed	48	70	60	85

early life-stages is hypothesized to be 1 of the greatest impacts that nonnative fishes have on some native fish populations (Marsh and Langhorst 1988, Johnson and Hines 1999). However, given the fact that rainbow trout and Apache trout are largely insectivorous, the impact of predation on larval stages on the overall population of spinedace is unknown.

Health

We did not detect rainbow trout related impacts on the health or condition of Little Colorado spinedace collected from Nutrioso Creek in 1996. Spinedace collected from sites with rainbow trout had a mean health index of 6.0 and a mean condition factor of 0.94 (SE = 0.02), whereas those from sites where rainbow trout were absent had a mean health index of 2.0 and a mean condition factor of 0.97 (SE = 0.02). In addition, condition of spinedace > 60 mm TL in Rudd Creek did not differ between trout absent (0.96, SE = 0.03) and trout present sites (1.0, SE = 0.04), nor between 1996 (0.96, SE = 0.02) when trout were present and 1997 (0.95, SE = 0.02) when trout were largely absent. We also did not detect indirect effects (trout and spinedace were held in different compartments within the same living stream) of rainbow or Apache trout on growth of spinedace in laboratory experiments, nor did we detect indirect effects of rainbow trout on spinedace feeding rates in living streams. It is likely that spinedace in these experiments became habituated to the trout since the trout posed no threat to the spinedace because they were held in separate compartments. Effects of trout on growth or feeding rates of spinedace may have been detected if they had been allowed to interact (held within the same compartment).

Distributions

Of the 16,000 – 20,000 rainbow trout stocked into Nelson Reservoir each year, 48 – 70 percent were removed by anglers (Table 12). Escapement of rainbow trout from Nelson Reservoir was minimal during our study. Only 1 tagged rainbow trout was captured in Nutrioso Creek (downstream from the reservoir) and except for 1996, few rainbow trout were captured in Nutrioso Creek in any year. We removed all salmonids we captured in Nutrioso Creek, which likely contributed to the low trout numbers in years subsequent to 1996 (Fig. 4).

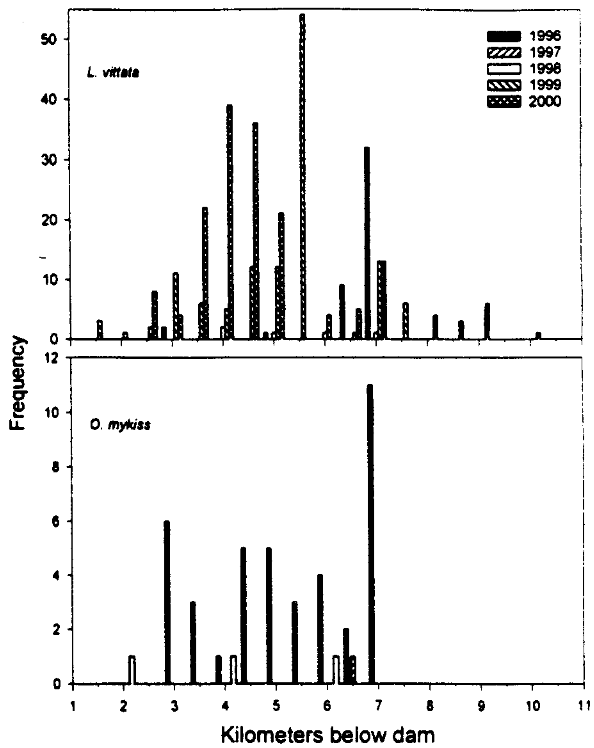

Figure 4. Number of Little Colorado spinedace and rainbow trout captured per 500 m in Nutrioso Creek below Nelson Reservoir (1996-2000).

However, trout numbers also decreased in Rudd Creek (where we did not remove any salmonids) subsequent to 1996. Annual precipitation was below average each year during our study (data from the Western Regional Climate Center, Reno NV), and during summer-autumn of 1996 - 1997, Rudd and Nutrioso creeks became intermittent. We estimate that 50 - 75% of Nutrioso Creek below Nelson Reservoir (intermittent from the dam to approximately 7.0 km downstream and completely dry below that), and more than 50% of lower Rudd Creek were dry in the summers of 1996 and 1997. Such large decreases in available habitat coupled with likely decreases in habitat quality (increased water temperatures and turbidity due to nonexistent flows) likely contributed to the decline of salmonid populations.

Based on mark-recaptures, Little Colorado spinedace exhibited high site fidelity (of 66 recaptures of 210 marked fish, 56 did not move), but some (15%) fish did move. We detected both upstream and downstream movements, with a maximum movement of > 1 km. Although precipitation and resultant discharge was higher than normal during the summer 1999, our recapture rates were relatively low in 1999 (11 of 107 marked were recaptured), and only 2 were recaptured subsequent to the high flows, so we can conclude little about effects of discharge on spinedace dispersal. Changes in spinedace distribution from 1996 to 1999 (Fig. 4) were likely related to drought and subsequent recolonization, but the removal of salmonids from the systems in 1996 also likely played a role. It is possible that spinedace may not have moved into previously vacant reaches if salmonids had not been removed. Based on experiments in stream enclosures, Blinn et al (1993) suggested that rainbow trout might limit the distribution of Little Colorado spinedace. However, in 1996 we often caught the 2 species within the same pools, lending little evidence to suggest that spinedace distributions were limited by rainbow trout.

MANAGEMENT OPTIONS

Introduced fishes often have negative effects on native fish species (Moyle 1986). However, nonnative species such as rainbow trout are valued sport fish, which is why they have been introduced world-wide. In Arizona, the challenge for managers is finding an approach that will conserve native fish species while maintaining or enhancing a trout fishery. The results of our study indicate that such an approach may be possible. In northeastern Arizona, a trout fishery (primarily rainbow trout) exists within the range of the federally threatened Little Colorado spinedace. Our results indicate that escapement of stocked rainbow trout out of Nelson Reservoir was minimal, even though opportunities (dam overflow) existed. Rainbow trout were only stocked into Nelson Reservoir during spring, following cessation of dam overflows, and it is believed that most were fished out or suffered mortality before spring of the following year. However, even during 1999, when precipitation resulted in summer-time dam overflows, no trout were captured in sampled reaches above or below the reservoir.

In stream settings, rainbow trout and Little Colorado spinedace likely compete at some level, since they overlap in habitat use, and rainbow trout will cause spinedace to shift their habitat use. In addition, spinedace likely experience some level of predation by rainbow trout since the 2 species overlap spatially and rainbow trout are opportunistic piscivores; we detected a low level of piscivory by rainbow trout, but none on Little Colorado spinedace. Dietary overlap between spinedace and larger rainbow trout was low, so food resource competition between these size classes may be minimal. However, overlap between species is more likely for equal sized fish, but this aspect needs to be studied to better assess competition for food resources between the species. Our results did not indicate a strong negative interaction between the species, but since Little Colorado spinedace is threatened, any negative impacts to their populations should be minimized. In other words, efforts should be made to reduce trout densities in streams occupied by Little Colorado spinedace.

When planning trout management or Little Colorado spinedace conservation actions, managers are encouraged to consider the following options; the first 2 options are being implemented and should be continued:

1. Within the range of Little Colorado spinedace, restrict nonnative (e.g., rainbow) trout stockings to reservoirs, and stock in the spring, subsequent to cessation of dam overflows. These stocking protocols will minimize rainbow trout escapement out of reservoirs.

2. Within the range of Little Colorado spinedace, increase bag limits on nonnative trout in streams and reservoirs. This will also help reduce escapement and will help reduce nonnative trout numbers in streams occupied by spinedace.

3. Avoid stocking fry or fingerlings, but stock catchable rainbow trout (> 8 inches). Stocking multiple sizes of rainbow trout (fry – catchables) would likely increase the probability of competition with and predation upon Little Colorado spinedace.

4. During periodic stream surveys for Little Colorado spinedace, remove captured nonnative trout. This will help reduce nonnative trout numbers in streams occupied by spinedace.

5. Within the range of Little Colorado spinedace, stock Apache trout into reservoirs in lieu of rainbow trout; a native fish assemblage is

preferable to 1 that has a mix of natives and nonnatives.

6. The introduction and spread of nonnative crayfish, fish, or other species should be avoided.

7. When considering streams for reintroduction of Little Colorado spinedace, priority should be given to segments that are low gradient and have pools containing undercut banks (habitat selected by spinedace) and that are unoccupied by nonnative trout and crayfish. Second priority should be given to segments containing the desired habitat characteristics and where nonnative trout and crayfish densities can be easily reduced and maintained at low numbers.

8. To improve or restore habitat and to minimize negative interactions, remove nonnative crayfish and fish from stream segments occupied by Little Colorado spinedace.

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For a more technical presentation of methods including statistical analyses, results and discussion for a specific section from this Technical Guidance Bulletin, the authors refer you to the following citations, which can be obtained by contacting:

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