Fossil Creek Crayfish Removal Project

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Introduction:

Crayfish are not native to Arizona (Lodge *et. al.* 2000). The introduced species of crayfish, *Orconectes virilis* and *Procambarus clarkii*, now exist in most of the streams, lakes, and reservoirs of Arizona (Childs 1999). The problems of introduced crayfish are well documented. Crayfish consume fish eggs (Dorn & Wojdakl 2004 and Bryan et. al 2002), and also prey on frogs, and snakes (Rosen & Fernandez 1996). Crayfish decrease growth of native fish (Carpenter, 2004) and alter the food chain because of their broad diets and simultaneous effects on multiple trophic levels (Dorn & Wojdakl 2004). Crayfish also have the ability to physically alter instream and pond habitat by reducing emergent vegetation (Creed 1994, Dean, 1964; Lodge *et. al.* 1994) as well as having significant impacts on algal production (Weber and Lodge 1998, Luttenton *et. al.* 1998).

Yet despite crayfish prevalence and rapid spread across the southwestern landscape, few options currently exist to control and minimize their progression (Hyatt 2004 and references therein). Manual trapping efforts have been the most common method of control to date, but questions still remain as to how trapping regulates crayfish populations. Momot (1998) reports that populations increased after being exploited by trapping and attributed the increase partially to removal of adult males who regulate the growth and mortality rates in unexploited populations. Momot also reports traps select for larger males "which if abundant, agnostically exclude smaller males and females." In a study using modified Gee traps, Stuecheli (1991) reports Male:Female ratios of 62:38, 80:20, and 89:11. Somers and Green (1993) report catches of *O. virilis* to be correlated with water temperature for lakes in south-central Ontario. They report the highest catch rate from trapping occurs when the water temperature is the highest.

The objective of this study was to investigate different types of traps and capture devices. In addition, removal goals included determining if physical removal methods could reduce crayfish populations until the CPUE dropped to below 0.1 crayfish per trap night and to below 1 crayfish per hour of dipnetting. This study attempts to identify the effort needed to significantly reduce crayfish populations in a lotic system using manual removal techniques. This report fulfills the contract obligation under Order No 22410-2-M508A.

Project History and Site Description:

Fossil Creek is a small tributary to the Verde River in central Arizona (Figure 1). It is perennial along it's 14 mile length, it's flow sustained by a series of springs that have consistently provided 43 cfs of flow for nearly 100 years. Another unique aspect of Fossil Creek is an unusual geologic phenomenon called travertine formation. When spring water travels through limestone deposits and finally reaches the surface, it is highly charged with calcium carbonate and high levels of dissolved CO2. As the water progresses downstream, the CO_2 degasses and calcium carbonate precipitates out and forms a series of dams and formations. The result is a cascading step pool habitat that provides extensive surface area for macroinvertebrate colonization and rearing areas for small fish. In the upper areas of Fossil Creek, a native fish community still proliferates consisting of headwater chub (*Gila nigra*), desert sucker (*Pantosteus clarki*), Sonoran sucker (Catastomus insignis) and speckled dace (*Rhinichthys osculus*)

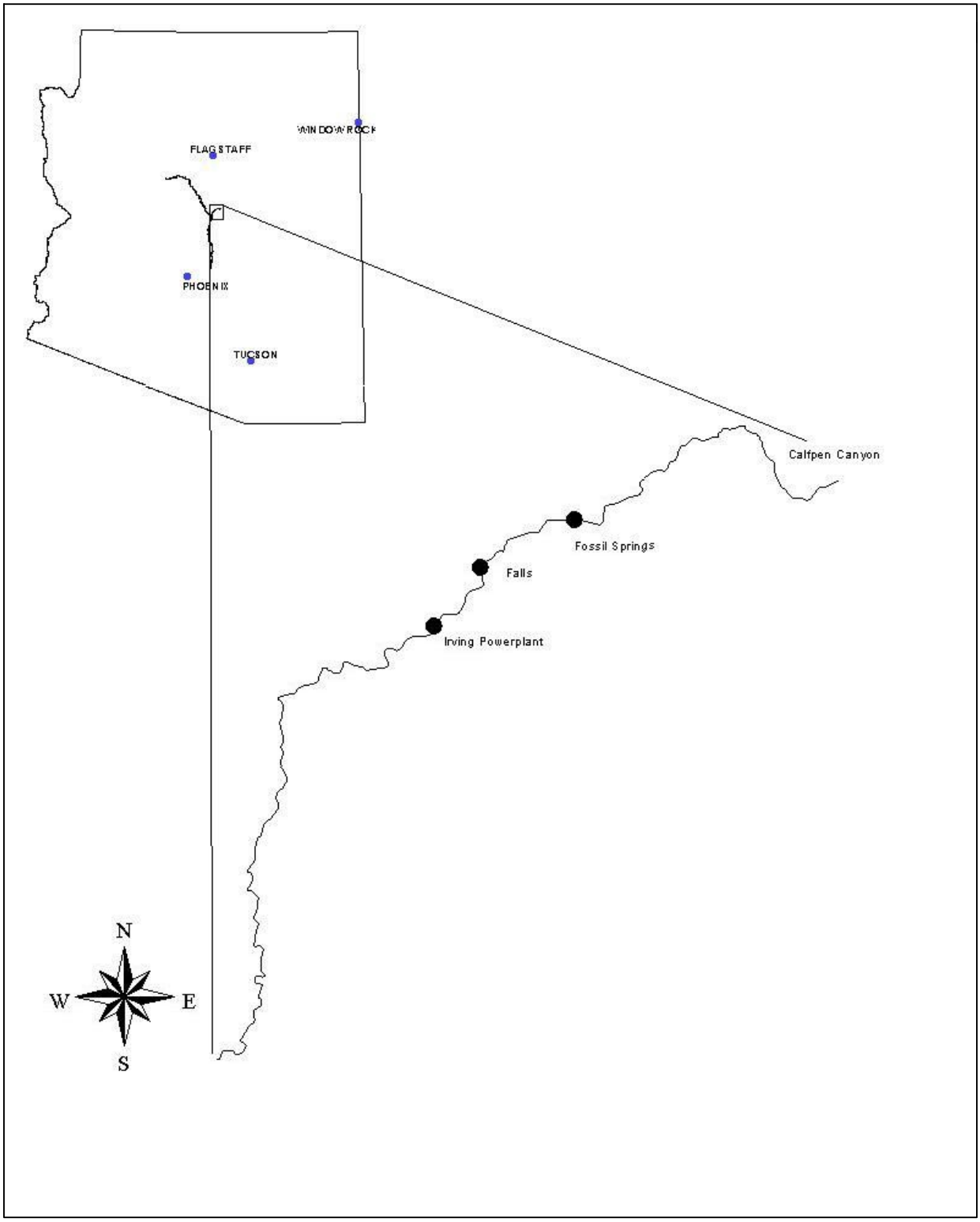


Figure 1. Map of Fossil Creek, Yavapai County, Arizona. Black circles indicate location of Fossil Springs where perennial flow begins as well as the Falls and Irving Powerplant sampling areas.

Early settlers recognized the opportunity to harness the consistent flows in Fossil Creek and in early 1900 erected a dam that effectively diverts nearly 98% of the flow just below the spring source. The Childs and Irving hydroelectric generating stations, located in the Fossil Creek drainage near the Verde River between Camp Verde and Strawberry, have been producing 4.2 megawatts of electric power since early in the century. The Arizona Power Company built the two plants to meet the industrial mining needs of the Jerome/Crown King/Prescott areas. Built in 1909, Childs has three 1800 kilowatt generators. Irving, located seven miles upstream of Fossil Creek Canyon, has a single generator rated at 1600 kilowatts and was build in 1916. Fossil Springs drives both these generators with a steady flow of 43cfs and is channeled into a steel and concrete flume. The water travels five miles before reaching the Irving plant, where it drives the single turbine. After five more miles through the winding flume, the water flows into Stehr Lake, then drops 1100 ft through a vertical penstock to the Childs plant before being released into the Verde River.

On November 12, 1999, Arizona Public Service (APS) committed to ceasing power production at Childs/Irving and restoring full flows to Fossil Creek no later than March 2005. In addition, APS committed to restoration of the Childs/Irving site, including removal of some or the entire project works, stabilization and rehabilitation of disturbed areas and restoration of affected riparian communities by December 2009. Decommissioning the facility and returning the creek's flow to the streambed will restore critical habitat for threatened and endangered fish and wildlife as well as re-establish travertine formation.

However, as negotiations progressed on the decommissioning aspects, fishery biologists recognized the opportunity to also address restoration of the native fish community. Over time, nonnative fishes such as smallmouth bass and green sunfish had been progressively invading upstream areas and negatively impacting the remaining native species. Fossil Creek remains one of the last strongholds for roundtail chub in the entire Gila drainage, yet upstream migration of nonnative species from the Verde River was contributing to a chronic life history failure in most of the native, aquatic species, including ranid frogs. As a conservation action to offset some of their water diversion projects, the Bureau of Reclamation committed to funding a fish barrier near the confluence of the Verde River and the associated environmental compliance. In a collaborative effort between four federal agencies, including two national forests, 3 state agencies, two Universities, one private company (APS) and many volunteers, commenced a restoration effort that included a salvage operation for native fish species that covered 10 miles of creek using helicopter transport and icthyocide application that involved more than 90 individuals and volunteers.

While fishery biologists could address the restoration of the fish community, it was uncertain how nonnative fish removal would impact crayfish populations. Some evidence exists that suggests native chub species will prey upon small life stages of crayfish in a laboratory setting however it is uncertain if this phenomena is widespread in the wild (Jeanette Carpenter, USGS, personal communication). Since few options exist to permanently remove invasive crayfish, evaluation of manual removal techniques is a critical need as return of full flows will predictably increase wetted perimeter and available habitat for crayfish.

Methods:

For this study, areas of focus were broken into two reaches separated by natural barriers in Fossil Creek. These barriers were between 18-25ft high and were assumed to preclude significant upstream migration by crayfish. The two study reaches were 5.5 Km long and broken down into two sections including a 3 Km section above and another 2.5 Km reach below the natural falls into the Irving Power plant outlet pool (Figure 1).

Traps used for this study included commercial pillow traps constructed of ¾" plastic coated chicken wire, commercial Gee traps that were modified to a 2" funnel, homemade pillow traps made of ¾" chicken wire, commercial collapsible minnow traps with a 2" funnel opening, and LiNi traps imported from Sweden (Table 1). The pillow traps and Gee traps were baited by suspending a bait bag in the approximate center of the trap. The LiNi traps have a stainless steel safety pin in the center where meat scraps can be skewered or a bait bag suspended. The collapsible minnow traps have a zipper pocket to hold bait. For this study a a trap night is defined as a 12 hour set. Evaluation of different trap types included ease of use, ability to transport over difficult terrain as well as capture efficiency and bias of captured crayfish.

Table 1. Summary and dimensions of traps used for crayfish removal efforts in Fossil Creek, Yavapai County, Arizona from May 2001- September 2004.

Trap	Collapsed Dimensions	Open Dimensions	Mesh size (mm)	Weight (Kg)
Collapsible Minnow	10"X10"X1"	10"X10"X17"	1	.4
LiNi (From Sweden)	12" Round X 1.2"	12" round X 18"	12	.95
Commercial Pillow	Not Collapsible	12"X10"X17"	18	.9
Modified Gee minnow trap	10" Round X 10"	10" Round X 18"	6	1.2

All traps were baited before being deployed. Bait consisted of approximately 25 gm of dry dog food. Other baits used included dry cat food, canned cat food, meat scraps (trimmings consisting primarily of chicken and beef fat), green sunfish, and smashed crayfish. Trapping was accomplished by baiting a trap and positioning it in favorable crayfish habitat, including pools, runs and near overhanging bank structure. All traps were checked every morning and evening, emptied, and fresh bait was added every evening. Dipnetting was done at night, visually spotting crayfish with a headlamp and ensnaring them using a dipnet.

Data collected includes dates, and weather conditions. Trap data includes date and time the trap was set, date and time it was checked, and location. All crayfish captured were recorded including sex, carapace length, and weight. Carapace length was measured with calipers and was recorded to the nearest mm. Crayfish were weighed on an Acculab GSI-200 scale that was calibrated each month. Weight was recorded to the tenth of a gram. All captured crayfish were sacrificed. Native fish caught were recorded by species and were measured for total length and released near the point of capture.

Most of the removal was done from the large falls, about a mile above the trailhead parking area to the pool below the bridge on the road between Strawberry and Camp Verde. Since much of the work was done at night alone, access to the road was desirable. The falls into the pool at the outlet of the Irving Power plant is used as a point separating the "above Irving" and the "below Irving" data. For this study, CPUE for trapping is defined as the number of crayfish caught per trap per overnight set. CPUE for dipnetting is defined as the number of crayfish caught per hour of dipnetting.

Results and Discussion:
Between March of 2001 and September 2004, 67 nights were spent in Fossil Creek resulting in 2432 trap nights (Table 2.) and 53 hours of dipnetting (Table 3.) resulting in removal of 3406 crayfish (*O. virilis*) weighing at total of 82.112 Kg. Additionally, 232 native fish were captured in traps. This included 61 desert suckers(*Pantosteus clarki*), 143 roundtail chubs (*Gila robusta*), 26 Sonoran suckers (Catastomus insignis), and 2 longfin dace (*Agosia chyrsogaster*).

Table 2. Summary of trapping effort for crayfish above and below the Irving.Powerplant, in Fossil Creek, Yavapai County, Arizona from March 2001-September 2004.

Location	# of days	# of traps	# of crayfish	# Male	# Female	Tot Gm	Av Gm	CPUE
Above Irving	51	1750	1289	560	729	37993.0	29.47	0.737
Below Irving	24	682	1030	496	534	32930.4	31.97	1.510

Table 3. Summary of dipnetting effort for crayfish above below the Irving Powerplant in Fossil Creek, Yavapai County, Arizona from March 2001-September 2004

Location	Time (hrs)	# crayfish	# Male	# Female	Tot Gm	Av Gm	CPUE
Above Irving	49.33	1042	528	514	10183.7	9.77	21.12
Below Irving	3.5	45	19	26	1005.9	22.35	12.86

The commercial pillow traps and modified Gee minnow traps were too bulky to carry far in the terrain around Fossil Creek. The commercial pillow trap also allowed smaller crayfish to escape, a design that is good for commercial crayfish harvesting, but not appropriate for trying to remove all crayfish. The LiNi traps imported from Sweden where they are the most used in commercial crayfish fisheries were heavier than the collapsible minnow traps and so were primarily used in areas easily accessible by road. The collapsible minnow traps became the trap of choice because it was easy to collapse and lighter to carry, had a convenient, built-in bait bag, and had a mesh size that keeps even the smallest crayfish from exiting. Up to 50 collapsible minnow traps could be carried in a standard backpack into areas not accessible by road.

Although different baits were used, dry dog food proved to be the most practical. It was easy to pack and appeared to attract as many crayfish as canned cat food, meat scraps, or dry cat food. Since it is readily available at a low cost, it was the primary bait used. Green sunfish and crayfish parts were frequently used when available to freshen up the bait for another night of trapping.

Diel differences in crayfish activity were clear in Fossil Creek. Crayfish were primarily nocturnal and daytime trap sets yielded only 43 crayfish, 2.2% of the total trapped. Ovigerous females were observed only in March and April, and were observed each spring. *O. virilis* has a maximum lifespan of 3 years and reproduction occurs once per year in the spring (Page 1986, Dorn 2004).

Any trapping program needs to address bycatch of nontarget species. Due to the sensitive and declining nature of southwestern fish fauna, concern existed over the potential adverse effects of trapping on native fishes. Despite having crayfish in the trap along with native fish, there was no fish mortality or observed damage to any of the 232 native fish captured during this study.

Trapping results and effort varied widely by year ranged from a total of 79 crayfish in 121 trap nights in 2001 to 1019 crayfish in 1100 trap nights in 2003 (Table 4). The CPUE for 2001 is lower than subsequent years possibly explained by an unskilled trapper and a variety of traps used, many of which allowed easy escape of smaller crayfish. From 2002 to 2004, the CPUE declined, yet the average weight of crayfish increased in 2004. The decrease in average weight from 2001 to 2003 may be due to the increased trapping pressure. As the trapping pressure decreased in 2004, the average weight increased. This increase in average weight may be a function of less competition for food and a more rapid growth rate at lower densities. Brown *et. al.* (1995) report weight gain decreases as densities of *O. virilis* increase. Momot (1990) reports that *O. virilis* "are well regulated with both excellent responses to harvest and short biomass turnover times."

Table 4. Summary of yearly trapping results of crayfish in Fossil Creek, Yavapai County, AZ from May 2001-September 2004.

Year	# trap nights	# Crayfish	Ave Wt	CPUE
2001	121	79	35.809	0.653
2002	812	939	33.049	1.156
2003	1100	1019	27.320	0.926
2004	399	282	32.706	0.707

Trapping by year above Irving				
Year	# trap nights	# Crayfish	Ave Wt	CPUE
2001	109	68	37.985	0.624
2002	508	295	34.000	0.581
2003	868	751	27.100	0.865
2004	265	175	28.740	0.660

Trapping by year below Irving				
Year	# trap nights	# Crayfish	Ave Wt	CPUE
2001	12	11	22.357	0.917
2002	304	644	32.613	2.118
2003	232	268	27.936	1.155
2004	134	107	39.192	0.799

When comparing the CPUE above and below Irving by year, the decreases in the overall CPUE appear to be driven by the catch rates below Irving. CPUE below Irving is significantly ($p>0.001$) higher than above Irving (Table 5). This difference can probably be attributed to differences in water quality, water temperature, and amount of water, since there is more flow below Irving (5 cfs was added below the Irving Powerplant) and the water is much closer in temperature and quality to the outflow of Fossil springs. Also, there is more and better habitat below Irving due to the increased flow, which could contribute to higher abundances of crayfish.

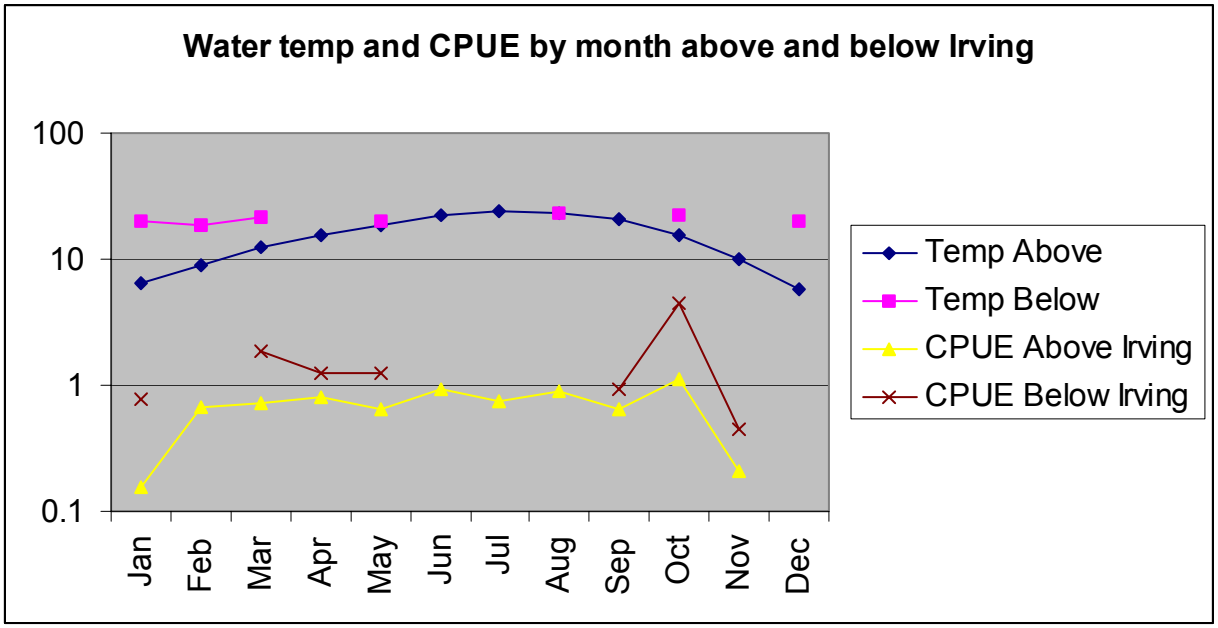
Table 5. Catch per unit effort for crayfish captured above and below Irving for dates when traps were deployed in both locations in Fossil Creek, Yavapai County, AZ from May 2001-September 2005. .

	CPUE	
Date	Above Irving	Below Irving
4/7/2002	2.143	3.241
5/18/2002	0.919	1.396
10/2/2002	1.556	4.463
11/10/2002	0.049	0.452
1/25/2003	0.154	0.786
4/26/2003	1.05	1.58
4/27/2003	1.224	1.455
4/28/2003	0.431	1.212
5/21/2003	0.453	1
5/25/2003	0.625	1.14
3/11/2004	0.875	1.071

However, CPUE in both locations decreased during winter months. The effect appeared to be greater in the area above Irving where the water temperature is much lower than in the area below Irving where the water temperature is much more constant (Figure 2). The CPUE below Irving where the water temperatures are relatively stable all year indicates a seasonal change in activity levels that is not dependent on water temperatures. This does not support the findings of Somers (1993) who showed a correlation of CPUE and water temperature for *O. virilis* in south-central Ontario (Canada) lakes. There appears to be a period of relative inactivity in the winter, even in the warmer water below Irving. The highest CPUE is seen in the spring and fall just after and before the lows of the winter months. It might be that *O. virilis* is feeding heavily in early spring after this period of relative inactivity and then foraging actively before winter.

Trapping did not demonstrate the predominance of males as reported by Momot (1998) and Stuecheli (1991). The M:F ratios in this study were 43:57 above Irving and 48:52 below Irving. Overall, trapping yielded 45.5% males and 54.5% females. This suggests a difference in the behavior of *O. virilis* in Fossil Creek from that in the lentic study sites of Momot and Stuecheli.

Figure 2. Water temperature readings below Irving provided by Alan Hayden (Northern Arizona University). Water temperatures averaged by month are collected from a temperature probe placed about 1/3 mile above Irving by AZGFD.



Dipnetting proved to be problematic and unreliable capture method in Fossil Creek. Turbidity was high during many of the trips to Fossil Creek. Following rains, runoff increased turbidity, decreasing the ability to see crayfish as they forage. In the fall, leaves covered some shallow pools and tannins colored the water also decreasing visibility. With relatively clear water, the maximum depth of water for effective dipnetting was about 1 meter. The best areas for effective dipnetting were shallow pools and runs with bedrock, sand or cobble substrate. Small mesh (1/4" or less) is necessary for dipnets, as crayfish escape through lager mesh nets. More durable nets prove worth the investment, as several $20 nets wore out after 6-8 hours of dipnetting, since the technique used requires scraping the dipnet across rocks and the bedrock bottom. No dipnet used was adequate for boulder substrate and it was impossible to capture some visible crayfish between large rocks. Most dipnetting was restricted to shallower pools and bedrock runs. Despite the challenges, dipnetting yielded 32% (1085 of 3406) of all crayfish caught in this study. Crayfish caught with dipnet were much smaller than ones caught in traps. Above Irving where most dipnetting was done, the average weight of dipnetted crayfish was 9.5 gm while the average weight of trapped crayfish was 29.4 gm. Dipnetting is the only way to remove the young of year (YoY) crayfish, as they primarily occupy in very shallow water and do not enter traps that are in deeper (a minimum of 10") water. Dorn (2004) states that young of year *O. virilis* are too small to be recruited into traps.

Young of year crayfish were observed in very shallow (<1cm) water along the stream bank. In July-August of 2001, large numbers of young of year crayfish were observed and caught by dipnet preceding a high flow event (HFE) where the water was about 1 M. higher than the normal flow for much of the area above Irving. Following the high flows, few YoY were

observed and the dipnet CPUE dropped from a pre-HFE of 28/hr to 8/hr while the average weight of dipnetted crayfish went up from 5.2 gm to 20.1 gm. suggesting that small crayfish may be swept downstream during high flow events.

Conclusions and Recommendations:
Much is yet to be learned about removal of invasive crayfish from streams. Physical removal techniques are very labor intensive and require the transport of manpower and equipment. The wilderness conditions surrounding many Arizona streams like Fossil Creek make physical removal almost impossible. The search for a chemical to remove crayfish needs to be intensified. However in the interim, intensive control efforts may work to reduce overall size of crayfish making them more vulnerable to fish predation. Monitoring densities and biomass of crayfish during control efforts would provide useful information on the effectiveness of these efforts.

With the closure of the Irving Power plant, the conditions that existed below Irving during this study now exist below the dam. The changes in the water temperature and flow in the reach above Irving to the dam make that prime for crayfish growth. Unless there is some intervention, it seems that there will be significant crayfish growth in that area. Another observation is the movement of crayfish back into the prime locations. When a pool was intensively trapped, the CPUE would go down to a relatively low level, just to go back up the following month. The crayfish appear to seek out the prime locations. Working in an open system, there seems to be significant movement of crayfish. This movement appears to be restricted to the water, as in all the time spent in Fossil Creek, no crayfish were observed out of the water (on the bank). More study of movement of crayfish and what kinds of barriers might be effective in stopping migration of crayfish in streams should be done.

High flow events may be the only natural event to limit crayfish population in Fossil Creek. Care should be taken to allow natural flows and flooding in Fossil Creek.

Specific Recommendations are as follows:

- Dedicate funding to develop and license a chemical solution for crayfish removal
- Removal efforts in lotic systems need to focus on discrete areas defined by barriers to crayfish movement
- Removal efforts need to be accompanied by density and biomass monitoring to assess effectiveness

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