Invasive Crayfish Assessment

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14. ABSTRACT
Research supports that crayfish behavior puts Reclamation infrastructure at risk. From the literature review best management practices support a strong trapping regime, release of sterilized male crayfish, and increase in predatory fish populations. There is a need for more research and imaging to describe the burrowing habits or crayfish especially when there are more than one crayfish species present.

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Threat Assessment and Evaluation of Burrowing Crayfish in Reclamation Canals

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Threat Assessment and Evaluation of Burrowing Crayfish in Reclamation Canals

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Acronyms and Abbreviations

Reclamation	Bureau of Reclamation
eDNA	Environmental DNA
LiDAR	Light detecting and ranging

Measurements

F	Degree Fahrenheit
cm	centimeter
km	kilometer

Contents

Executive Summary

Crayfish species are invasive in many areas within the United States. Some species have expanded their native ranges while others have been brought to new areas through human activity. The burrowing behavior of these species may be detrimental to infrastructure within the Bureau of Reclamation. There is a potential for extensive burrowing to cause embankment stability concerns, seepage, or even collapse.

Reclamation began with a literature review for pertinent information on the topic of invasive crayfish. Areas of information gathered included diet and behavior, water quality and substrate preferences, burrowing behaviors, and integrated pest management options. Preliminary trapping techniques were attempted in Washington state and Colorado. Samples of species were taken to work towards an eDNA assay for crayfish.

There are limits to the current literature available for management of invasive crayfish. The burrowing habits of crayfish have been summarized by species but there is not much information on behaviors when more than one species has become invasive to a waterbody. There is a need to summarize behaviors of the most common invasive crayfish species so that an overarching best management practice can be authored for use within the United States. There is a need to take actual imaging to assess the burrowing habits of crayfish using LiDAR and ground penetrating radar. The current best management practice for crayfish would include a trapping program with a release of males after sterilization is performed, removal and culling of females, and a catch and release program for predatory fish. The National Park Service at Lake Roosevelt National Recreation Area and Colorado Parks and Wildlife at Lake Granby are willing to partner on a multi-year project to implement the previously mentioned management practices.

1.Biology

Distribution

Red Swamp Crayfish, *Procambarus clarkia*, is the most widely introduced crayfish in the world. Native to the South-Central United States, it is frequently harvested for human consumption and has been cultivated outside its native range (Lodge, 2012). This species has replaced native species for domestic consumption in Europe (Lodge, 2012). Red Swamp Crayfish have been introduced as food for fishes in areas like Europe and Kenya (Lodge, 2012). Generally, this species as with other invasive crayfish, has a wide tolerance to environmental conditions, a high growth and reproductive rate, and flexible feeding strategies which make it a prime species to become invasive in introduced areas (Loureiro et al., 2015). Other species of interest include the devil crayfish *Cambarus diogenes*, calico crayfish *Orconectes immunis*, northern clearwater crayfish *Orconectes propinquus*, virile crayfish *Procambarus acutus*, and the prairie crayfish *Procambarus gracilis*.

Reproduction

Crayfish reproduce by sexual reproduction. Sexual maturity is often reached within three to six months depending on climate, species, and individuals may produces two to three generations per year (Loureiro et al., 2015). Mating periods and recruitment dependent on environmental and hydrographic conditions (Loureiro et al., 2015). Breeding seasons tend to peak in early spring but can extend throughout summer and into fall (Gherardi et al. 2000).

Behavior

Crayfish can move up to 4 km per day and have a land speed closely related to their size (Loureiro et al., 2015). Crayfish form social hierarchies in both adults and juveniles and are mostly nocturnal (Lourerio et al., 2015). Despite creating burrows crayfish do not hide exclusively in burrows and will use natural refuges (Ilhue, et al., 2003). Red swamp crayfish reduce the abundance of submersed macrophytes by 50% to 100% from herbivory and stalk-cutting (Lodge et al., 2012). This can reduce refuge for other species and increase phytoplankton and cyanobacteria blooms (Lodge et al., 2012). Crayfish will also cause declines in invertebrate taxa and can eliminate snails and other slow-moving species (Lodge et al., 2012). Crayfish also increase abundance of benthic algae mats from decreasing herbivorous macroinvertebrates (Lodge et al., 2012).

Predation

Common predators for crayfish include fish, birds and aquatic mammals (Lourerio et al., 2015). North American crayfish are a vector for multiple parasites and pathogens including the crayfish plague which can infect native crayfish species of Europe (Lodge et al., 2012).

Species Identification

Distinguishing between species can be difficult but using morphological features to differentiate between species is possible. Common features used are presence or absence of setae on the claws, presence or absence of spines or tubercles on the carapace, narrow or more robust carapaces, presence or absence of tubercles on the postorbital ridge, and different coloration can be use on adult individuals (Larson and Olden, 2011). See Figures 3-6 for crayfish anatomy.

2.Diet

Crayfish will feed on decaying plant and animal matter as well as live mollusks, insects, annelids, nematodes, tadpoles, fry, and macrophytes (Loureiro et al., 2015).

3.Water Quality

Crayfish can increase suspended solids from the destruction of macrophytes and can cause a switch to a turbid state and an increase in cyanobacteria blooms (Lodge et al., 2012). Along with an increase in cyanobacteria there can be increases in heavy metals which can cause a decrease in the health or increase in mortality of other aquatic life (Lodge et al., 2012). Crayfish can change nutrient cycling within sediment by reducing organic matter and increasing phosphorus and nitrogen sediments (Lodge et al., 2012).

4.Burrowing Behavior

Crayfish are considered ecosystem engineers due to their capacity to change water quality, vegetation abundance, bank integrity, and water turbidity (Pearl et al., 2011). Honeycombing of banks causes structural damage, increases bank erosion, and increases costs in areas with canal irrigation systems and water control structures. In northern Italy, crayfish burrowing damages 30% of the irrigation canals, costing 8% of the annual income of the management authority (Lodge et al., 2012). The bioturbating activities of some species can be extensive and cause complete riverbank collapse (Albertson and Daniels, 2016).

Helfrich et al. 2009, describes burrowing behaviors as follows “Tunnels dug below the water level provide channels through which water can escape. Tunnels dug above the water level can decrease structural support of the embankment and increase the risk of washout during flood conditions. These hazards are multiplied in waters where burrowing animals are abundant and where water levels fluctuate. Rising and falling water levels often stimulate these animals to dig new burrows, thereby increasing the potential for structural damage and water leaks."

Red swamp crayfish are efficient excavators using a combination of both tactile and visual information to orient their burrows. Burrows are used primarily for refuge from predation, dehydration, and nesting (Loureiro et al., 2015). Despite the time and energy needed to create burrows, burrows are abandoned often (Loureiro et al., 2015). Crayfish were found to excavate and occupy a burrow for around 6 hours on average and once abandoned were rarely reoccupied and often collapse (Barbaresi et al., 2004). New burrows may be favorable for time and energy than the amounts it would take to restore old burrows (Barbaresi et al., 2004). Females will create deeper burrows used frequently for egg incubation which are usually not submerged in ground water to allow for better oxygen diffusion. Females will fan eggs with swimmeret movements and deeper burrows may suggest the importance of having better access to water (Kouba et al., 2016). Females may stay in their burrow for several weeks with young remaining on their abdomen for 3 to 4 months (Loureiro et al., 2015).

Burrowing frequency and density may be related to sediment size. Burrows are mostly occupied during daylight hours. Larger environmental temperature fluctuations were correlated to multiple individuals using shelters (Ilheu et al., 2003). Moist sediment and composition may create burrows that are more prone to collapse. In turn this may increase the frequency of burrow creation (Barbaresi et al., 2004).

Burrowing intensity may change seasonally. There may be a preference for a ratio of fine particles over those of larger coarser particles (Correia and Ferreira, 1995). Juveniles occupied burrows in late fall winter and early spring while mature individuals were found in late spring, summer and early fall (Correia and Ferreira, 1995). Most burrows are located at water level or above, and a decrease in water level induced more burrowing activities (Correia and Ferreira, 1995). Large substrate, such as rocks or boulders may reduce burrowing frequency as this creates natural refuge. Sediment composition, vegetation and water availability likely affect the structure and burrowing behavior (Haubrock et al., 2019).

5.Integrated Pest Management

5.1 Trapping Techniques:

Most trapping techniques use wired mesh traps that are similar to minnow traps. These can be baited with almost any food source, but many times canned pet food is used. Other bait examples are fresh fish, meat scraps, fish heads, soybean cakes, or any high protein substance (Hein et al., 2007).

One-month long study found that crayfish with a carapace length of 2-6 cm frequented 5.1cm diameter traps while crayfish with a carapace length of 1-4 cm frequented 2.5cm diameter traps (Curti et al., 2021). Another study tested 12 trap designs with the most successful version being the Promar mesh 503 trap (De Palma-Dow, et al., 2020). During a 6-week trapping regime one population declined from 6,500 to 206 individuals during continuous trapping. In another instance 900 days of trapping were needed to reduce a population from 4,000 to 1,500 (Gherardi et al., 2011). Sparkling Lake in Wisconsin attempted an intensive trapping regime along with restrictions on harvesting predatory fish for a 5-year period which led to a substantial population reduction. Overall, 88,602 crayfish were removed (Gherardi et al., 2011).

Traditional traps catch mostly large adult males, in one study baited funnel traps were placed on artificial refuges which culminated in capturing a greater number of smaller males and female individuals (Green et al., 2018). Traps where crayfish were removed frequently from traps were far more successful than when crayfish were allowed to stay in the traps (Ogle and Kret, 2008). In high density areas traps with restricted openings were more successful with up to 155 crayfish per trap, whereas unrestricted opening traps plateaued at 50 crayfish per trap (Smith, 2020). Trapping techniques alone are not effective as crayfish will migrate considerable distances (Hein et al., 2007).

Trapping alone has failed in every case to control crayfish populations when used as the only method of management (Hyatt, 2003). One study found that escapement from traps was high for all trap designs and that retention rates was a persistent problem for monitoring and management (Kvistad et al., 2021).

Reclamation staff conducted trapping trials in March at Lake Roosevelt National Recreation Area in Washington and in May at Lake Granby in Colorado. Promar mesh traps were baited with canned cat food and dropped on the shoreline at a depth of 10 feet. These traps were tied to buoys for ease of relocating the traps. The traps were dropped for three 24-hour periods and crayfish were removed from the traps at each interval. Despite water temperatures below 50 degrees, 6 virile crayfish were caught in the traps at Lake Roosevelt. These included 2 females and 4 males. (See Figures 1 and 2) Samples were collected and taken back to the Technical Service Center to be used for eDNA assays. At Lake Granby traps were also dropped for three 24-hour periods but was unsuccessful in catching crayfish. This may have been due to a late spring storm that caused significant wave action.

5.2 Chemical Control:

Biocides like Pyblast have been used to eradicate populations but was only useful in waterbodies where there were no non-target species that would be affected by the lethal dose and is not appropriate for large waterbodies or canals (Ballantyne et al., 2018). Another study confirmed Pyblast to be the most effective methodologically versus other pyrethrins. Pyretrins have low toxicity to mammals and birds with a rapid breakdown in sunlight, are harmless to plants, but toxic to crustaceans, insects, and fishes (Gherardi et al., 2011). The use of Pyblast in a canal system was investigated with burrows sprayed, isolated stretches treated, and it was found that only the direct treatment of burrows reduced crayfish densities (Gherardi et al., 2011).

Altered CO2 concentrations caused avoidance behaviors, altered emergence behaviors, and loss of equilibrium (Frericks et al., 2020). Rotenone will also kill crayfish however dosages sufficient to kill crayfish will also cause the death of all other living organisms in the waterbody (Hyatt, 2003).

5.3 Biological control:

Disease causing organisms and microbes that produce toxins have been studied however the only method that was successful for biocontrol was the use of predaceous fish (Loureiro et al., 2015). Crayfish are susceptible to pathogens, but these pathogens lack host-specificity. Crayfish Plague, *Aphanomyces astaci*, is the most devastating disease that can infect European crayfish. This pathogen does not affect north American species in a similar method, but some genetically modified strains may one day be available to use within the US (Gherardi et al., 2011). Sterile male release techniques have been used to produce non-viable eggs in females. Although time consuming and expensive this method does not cause any other environmental contamination or non-target impacts (Gherardi et al., 2011). Increasing predatory fish populations over a 3-year period along with trapping removed a substantial portion of the crayfish population in an isolated northern Wisconsin lake (Hein et al., 2006). No physical control methods have been effective in open systems with abundant crayfish populations. Sex pheromones may be useful for species specificity in areas where non-target native crayfish are present (Kvistad et al., 2021).

Mechanical Control:

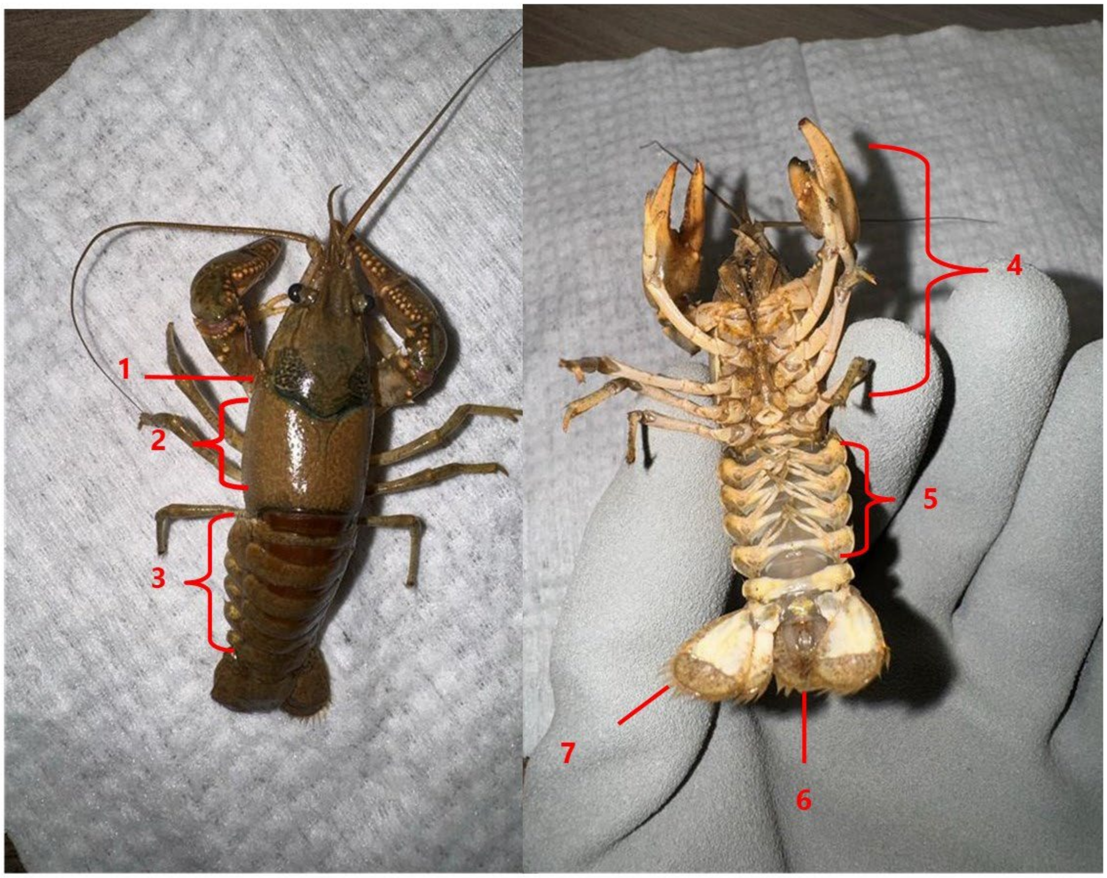
Drainage of waterbodies has been attempted however these methods did not confirm control as crayfish are resistant to drought and can burrow to find refuge (Loureiro et al., 2015).

5.4 eDNA:

eDNA assays have been produced and one study was able to successfully detect eDNA concentrations up to 7km downstream of a source population throughout any season (Chucholl et al., 2021). Another study used eDNA to see if crayfish carcasses could be detected up to 28 days after release. This study suggested that when populations are small or have not been established long, carcasses may not produce detectable eDNA (Curtis and Larson, 2020). The presence of eggs increased the concentrations of available eDNA when studied in tanks, with female only tanks producing far higher concentrations (Dunn et al., 2017). Another study positively detected crayfish species via eDNA even with unsuccessful trapping techniques (Harper et al., 2018). eDNA alone has not proven to be adequate to identify population size (Dougherty et al., 2016).

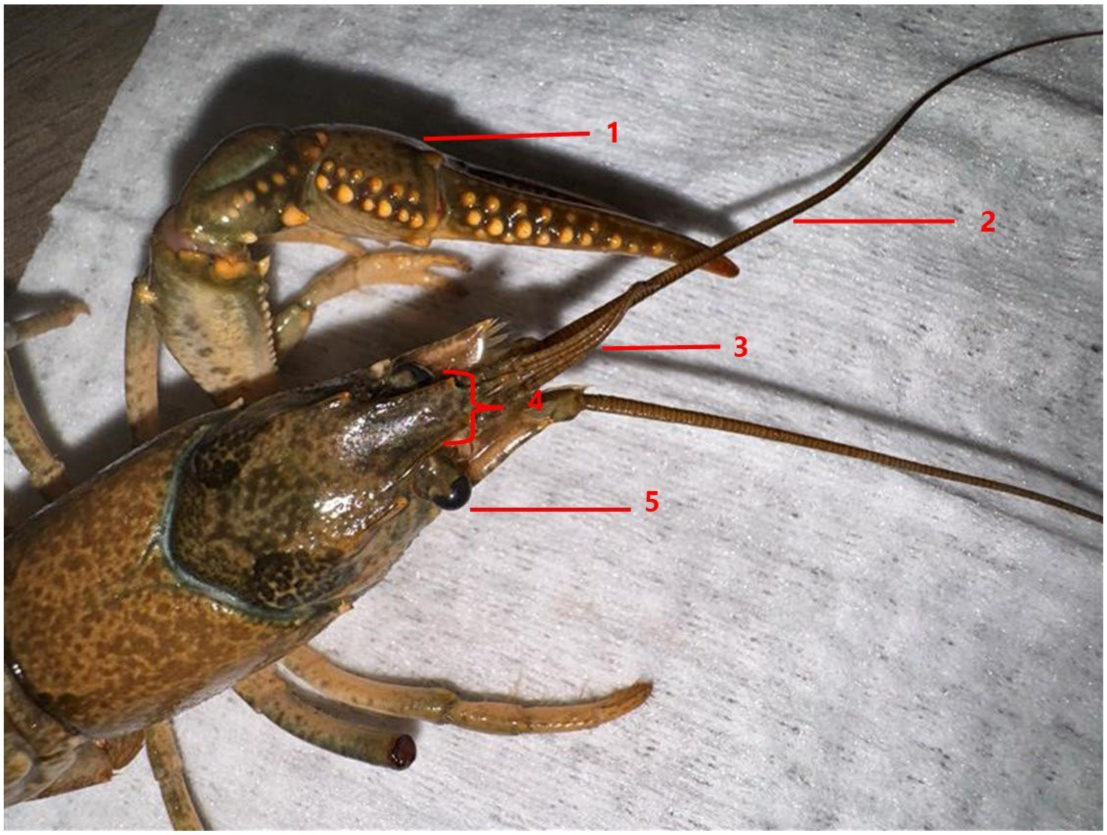
Figure 1 Crayfish traps on Lake Roosevelt, WA

Figure 2 Virile crayfish, *Faxonius virilis* captured on Lake Roosevelt, WA



1. **Cervical groove**
2. **Carapace**
3. **Abdomen**
4. **Pereiopods**
5. **Pleopods**
6. **Telson**
7. **Uropod**

Figure 3 Crayfish anatomy overview



1. **Cheliped**
2. **Antenna**
3. **Antennule**
4. **Rostrum**
5. **Compound eye**

Figure 4 Upper crayfish anatomy

1. **Hook**
2. **Gonopods**
3. **Gonopods**

Figure 5 Male crayfish anatomy

1. **Annulus ventralis**
2. **Swimmerets**
3. **Anus**

Figure 6 Female crayfish anatomy

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