Final Report on Initial Visit (May 16-19, 2017)
Caddisfly Problem on the Colorado River

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May 24, 2017

Introduction

The Colorado River is a vast river system that flows nearly 4,000 miles from Colorado to the Gulf of California covering approximately 242,000 square miles of diverse eco-regions with unique environmental profiles (Mission 2012; Triedman 2012). The fragile nature of this ecosystem is compromised two fold by the complex and diverse pressures exerted by human overuse and poor river management and magnified by a changing climate (Triedman 2012; Mission 2012). Historically, human needs, such as the harnessing of hydroelectric power have taken priority over environmental concerns when managing large river systems, especially, the Colorado River with a significant percentage of our total energy production directly attributed to hydroelectric power (USGS 2000; Triedman 2012). There are approximately six dams located along the river and its tributaries with the Davis Dam backing water upstream 67 miles creating Lake Mohave (Mission 2012). The Davis Dam is used for regulating water releases from the Hoover Dam but also generates power at the Davis Power Plant just north of Laughlin, Nevada (Mission 2012). This multipurpose exploitation of the river via hydroelectric power, agricultural irrigation, flood control and basic river management efforts has resulted in a conflict of beneficial uses with maintaining ecological integrity and functioning of the river (CRGCESWS & TBCGER 1990). Such conflicts are sometimes reflected in positive or negative organismal population changes e.g., blackflies in West Africa (Goldsmith and Hildyard 1984; Jobin 1999), nuisance midges in Lake Sanford, Florida (Ali and Fowler 1983), midge infestations in Maui (Berg et al 2002; Merritt and Ali 2002), and caddisflies in the Mississippi (Fremling 1960), Uji River in Japan (Kobayashi and Takemon 2014) and most relevant to this issue - nuisance caddisflies in the CAP canal near Phoenix, AZ (Claudi and Dewey 2011) .

In 2015, I was contacted by Mr. Chris Bramley to discuss the nuisance caddisfly problem in and around Laughlin, NV and Bullhead City, AZ. After several email conversations with Mr. Bramley and a brief visit with Dr. Iburg in Pennsylvania, I scheduled a visit to Laughlin, NV and Bullhead City, AZ to gain a first hand perspective as to the severity of the problem and to provide input and an action plan to reduce caddisfly populations in an environmentally safe manner. From May 16-19, 2017, I was able to spend two days on the river, informally sampling rock substrate for larvae, riparian vegetation and other resting locals for adult caddisflies, interact with watertaxi personnel as well as local residents to formulate an action plan for Dr. Iburg and Mr. Bramley.

Problem Statement and Initial Impression

While the tri-state area and specifically, the Laughlin/Bullhead City area has dealt with aquatic insect pests since 1984 when the pest abatement program was first established to control black flies, the latest in insect infestations to this area involves the caddisfly, *Smicridea fasciatella*, a net-spinning aquatic insect that has reached nuisance

status in the last seven years. Noteworthy to mention is that the Central Arizona Project (CAP) has noticed this problem since 2004 and has conducted some preliminary research to understand the population dynamics of both larvae and adult *S. fasciatella* in the region covered by the CAP (Nelson et al 2009). From my perspective this issue is a nuisance to three entities, casino and other business operations, private residences, public and tribal lands and watercrafts (Figure 1).

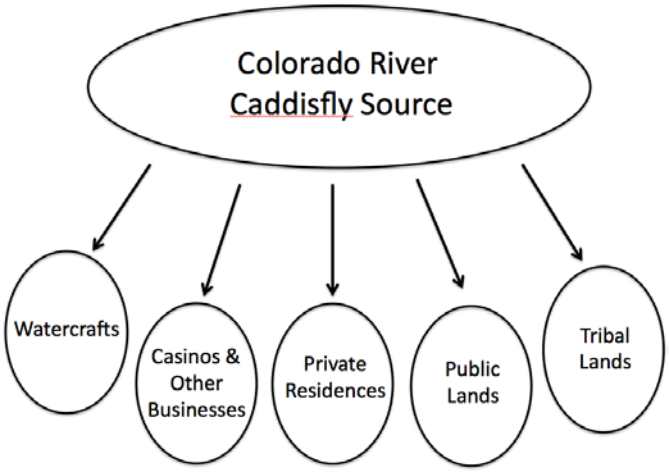

Figure 1. Schematic depicting groups of concern relative to the caddisfly nuisance issue in the greater Laughlin/Bullhead City region.

The single issue is the adult stage of the insect and the timing of adult emergence, flight periods and distributions of adults during these periods that create nuisance and at times health issues for private citizens and business owners. Based on their susceptibility to pollution, the order of caddisflies, Trichoptera, is part of a group of three orders of aquatic insects (Ephemeroptera - mayflies, Plectoptera - stoneflies and Trichoptera – caddisflies) that are indicators of good to excellent water quality or in other words, a barometer to river health (Rosenberg et al 2010). However, an overabundance of some may indicate problems in the river ecosystem. This particular species of caddisfly, *S. fasciatella* experiences two generations in this river system which would explain the two primary adult flight periods of April - June and September – November. As larvae, this species builds sand/small stone cases on the undersides and sometimes lateral edges of rocks and vegetation where larvae make silken nets to collect or catch particles. This family of caddisflies can be abundant in streams that are heavily impacted by agriculture and so they are not reliable indicators of a healthy system.

Through conversations with Chris Bramley and Joe Iburg, there were a number of actions that have been performed to understand the basic biology of the insect. Informal larval surveys have been conducted along shallow regions of the river as well as on aquatic vegetation and anthropogenic debris (plastics, buoys, and dock pilings). A number of adult surveys using sticky traps have been performed along both sides of the river and in a downstream direction from the dam to understand spatial densities in this impacted region. The purpose of my visit was to evaluate the efforts currently being conducted to understand the biology of this caddisfly as well control strategies either suggested for

implementation or actually being performed to remediate the adult caddisfly nuisance in the impacted region. The objectives of this visit included 1) provide consultation on how to improve basic research efforts to understand the biology of the system and the caddisfly; 2) outline additional control strategies via an integrated approach to minimize harmful effects on the ecological integrity of the river and the residents/visitors to the regions and; 3) develop a citizen science monitoring network to help involve the community in this effort.

Initial Impressions

On May 17, Chris, Joe and Captain Doug guided me with the abatement research vessel up to Davis Dam and then back down river past the unfinished casino/hotel on river right going downstream. During this trip, I observed many plumes of adult caddisflies hovering in and amongst the riparian vegetation. We stopped in several areas to informally sample the substrate for black fly and caddisfly presence. I observed no trout on this run and several large carp scattered throughout the river. Of note, there were no small fish classes observed throughout the river, this observation is of concern with regards to fish replacement and whether the aquatic community is diverse enough to support fish of all size classes.

Chris pointed out that he had halted the black fly abatement for some time prior to this visit but was about to restart the program. The purpose behind this change was to observe if caddisfly numbers were influenced by increased numbers of black flies. Anecdotally, Chris noted that adult numbers during this spring (2017) appeared lower than previous years. Joe described how populations of an invasive mussel, the quagga mussel (*Dreissena bugensis*) were rapidly increasing amongst the rocks and cobbles in the river. This mussel, like its close relative, the zebra mussel (*D. polymorpha*) both come from Europe, similarly, *D. polymorpha* has occupied similar niches in the eastern United States, We noticed where black flies were accumulating dorsally on rocks; mussels and caddisfly larvae were occupying the underside of the same rocks. Caddisfly cases were observed on floating plastic, buoys, ropes, and dock pilings. Of special note was the collection of a single dragonfly (Family: Libellulidae) larva was obtained from a snagged piece of plastic. It is unique because Chris mentioned that it was the first dragonfly larva he has seen in the river. After that statement, I noticed that I rarely saw any adult odonates skimming or flying near the water surface, docks, or the islands we stopped near.

We docked at a private residence to examine the adult populations along a stretch that has been inundated with caddisflies. We observed many adults on the undersides of porch roofs, in stairwells, in the vegetation along the docks, in spider webs and generally anywhere there was shade for cover from the heat. The resident noted that the numbers were not as high as previous springs but underscored the need to reduce them further. Captain Doug of the research vessel explained how the caddisflies affect patrons that use the watertaxis and provided interesting natural history notes of where he sees adults flying around and when.

In terms of control strategies suggested prior to members of the casinos, Bullhead City Abatement District and others, biological control options via trout stockings while halted have been recommended to start up again. Informal gut surveys revealed that trout were in fact feeding on larval caddisflies and were observed feeding on emerging and

ovipositing adult caddisflies. In addition, bats were considered but local populations have plummeted and suggest that bats may not be a worthy option. Because of the time of the adult flight plumes being around dawn and dusk periods, it was suggested that light bulbs of alternative (non-attractive wavelengths) be substituted, to date, it appears that no changes in light fixtures have been implemented. I am uncertain if chaining has been done to disturb larval attachment sites in the Laughlin/Bullhead City area. To my knowledge, no chemical or biocidal agents other than *Bti* have been applied to the river in an effort to control caddisflies.

On May 18, 2017, Captain Doug took us downriver several miles near the tribal casino. On this trip we were scouting possible locations for both larval and adult basic and applied research efforts. This river trip was critical to identify such sites so that Dr. Iburg could initiate the upcoming studies. In the afternoon that day, Joe and I were based in his lab detailing the protocols for these studies.

Basic Research Needed

Before targeted control options can be implemented, a more thorough understanding is required of both larval and adult populations of *S. fasciatella* caddisflies. The basic biology aspect of this model incorporates baseline studies on the river in general with more focused efforts on the larval and adult populations scattered throughout the Laughlin/Bullhead City area. Through several hours of conversation on the river and in the lab, I have provided Dr. Iburg and Mr. Chris Bramley outlines of study objectives to address these needs. In this report, I will provide the basic framework for these studies and rationales.

River Water Quality – There are a number of environmental impacts on this river exerted by the Davis Dam, stormwater/wastewater effluents from nearby communities, agriculture, etc. I have recommended that basic physical/chemical data be obtained for the reach of river beginning at Davis Dam and continuing south until the beginning of tribal lands. Perhaps the United States Geological Survey (USGS) has or collects such information from which the abatement program can mine these data. If not, I recommend that weekly flow rates, temperature, pH, dissolved oxygen and conductivity measurements be collected. This information can be useful to correlate with adult emergences that in turn can be used to model and potentially predict future population changes in adult caddisfly numbers.

While it is true that caddisflies can be an indication of a healthy aquatic system, a system with only a few taxa can be one that has been impacted by some sort of natural or anthropogenic source. Obtaining a better understanding of the ecological functioning of the river in terms of the trophic relationships may provide additional information useful towards the 'health' of the river system in this region. The functional feeding group classification of a river this size would indicate that the macroinvertebrates that inhabit the substrate of the river would be primarily characterized by filter feeding and predator invertebrates and vertebrates.

Caddisfly Larval Research – Two important aspects that influence larval biology are river flow and river substrate type. Adequate flow is required to keep larval nets expanded such

that larvae may be able to collect and filter food particles. River cobble and rocks are needed for larvae to attach their silken nets and sand/stone cases. Resource limitation in this river is most likely not food or particles, however, appropriate space in the required flows of the river may be. I have recommended both lab and field studies for Joe to undertake to better understand larval requirements with regards to space and how these requirements may influence larval and ultimately adult population densities both spatially and temporally along the river reach in this area.

In the lab, I have suggested using mesocosms, aquaria with circulating pumps and flow generators with substrate to mimic a flowing river system. The mesocosms can be used to examine competition for space between caddisfly and black fly larvae. These experiments would involve manipulating the density (e.g., low, medium, high) of both species and record how caddisfly larvae respond in terms of where they locate themselves. Understanding larval distribution in the presence/absence of a filter feeding competitor may elucidate valuable information to apply some sort of chemical or biocidal agent e.g., *Btk* or methoprene if such a control strategy were selected. This experiment should be paired with a field component with two objectives, 1) establish transects and sample rocks of similar sizes and enumerate blackflies and caddisflies and their distribution on the rocks and; 2) identify larval attachment substrate types and determine densities. Understanding where larvae are attached e.g., on rocks, dock pilings, submerged vegetation, ropes etc and which river areas influence greater densities can be of value in directing larval control efforts. For example, larval density in submerged and exposed portions of the river would be important to know with regards to manipulating river flow units. I have suggested examining exposed sand bars to determine which areas caddisfly larvae are able to survey being exposed v. those where they ca not over a period of time.

Caddisfly Adult Research – Currently, the river is experiencing the end of the spring emergence period, while timing is unfortunate, preliminary data can be obtained to launch more large scale samplings in the fall and again next spring (2018). The objectives for these studies are directed to understand 1) temporal aspects of adult flight plumes, 2) adult densities in plumes, 3) sex ratios of adults in plumes and, 4) size and spatial distributions of swarms. Other data to collect with adult plume sampling would include time of day, area of swarm (e.g., on vegetation, over water, next to buildings, stairwells, docks, watertaxis, etc.

I have recommended that a standardized sampling approach be developed to sample plumes. With this approach, plumes would be sampled randomly from the time they initiate in the season until their cessation. Other data to obtain while sampling plumes would time of day, temperature and wind speed to be able to model what days plumes would be worse. There could be a caddisfly nuisance index (CNI) developed based on temperature and wind speed models if plume timing and density are known, such an index could be broadcast over the radio or communicated in casinos. Collecting sex ratio data will provide information on when males and females emerge. Like many other insects, based on growth rates and size at maturity, males tend to emerge first with females later. Understanding the density of each may allow targeted controls to skew sex ratios to reduce female mate pairing. Furthermore, obtaining sex ratio data now, will allow Joe to be able to target females for later pheromone studies for control.

Many studies have documented the use of female pheromones to trap male insects, this is especially true with caddisflies (Wood and Resh 1984; Resh et al 1987). The family Hydropsychidae, to which *S. fasciatella* belongs, is no exception. Joe has already begun a literature search to develop a pheromone approach to lure or attract males to traps. We discussed sampling strategies and methods to expedite this aspect of research. Since departing Laughlin, I have been in communication with Joe and have provided him with identification keys and illustrations to distinguish male and female *S. fasciatella* caddisflies.

Control Research Needed

It is clear from this case and many other examples in the literature that a single silver bullet is not going to be what solely reduces caddisfly numbers to a tolerant level. The CAP project has suggested a few mechanical and chemical approaches to the river system in that region e.g., from chaining to disturb river substrate and copper additions to brushing a large aquaduct to control larvae with mile do significant results. To date, some approaches using sticky traps, biological control methods and pheromones have been discussed. During my visit, I helped outline studies that would be conducted on the small scale to evaluate efficacy later on larger scales.

Small Scale BACI Studies – There are small, more localized studies that can be done in conjunction with adult swarm sampling as described above. For example, we discussed taking a stretch of the riverwalk where swarms appear around and on walk light posts. We discussed a BACI (Before/After/Control/Impact) approach to sample swarms prior to light bulb switches and post switches to determine adult plume density with such subtle changes. In addition, a sister study could be done in areas where people walk with substantial vegetation. Plumes would be sampled pre and post vegetation pruning. Both studies would provide immediate feedback to abatement officials on the impacts small measures such as light fixture and vegetation pruning can have on adult plumes. Adults are attracted to vegetation and lights, altering these in some fashion may reduce adult plumes or perhaps relocate them to other areas away from human use.

Large Scale Studies – On day one of my visit, we noticed an abandoned hotel or casino south of Laughlin/Bullhead City. I suggested that this structure would be an ideal place to initiate a large scale study on the use of light and sticky traps to perhaps lure and capture adult caddisflies away from populated areas. We discussed the use of different colors to paint abandoned spaces coupled with tanglefoot baited sticky traps and lights of varied wavelengths to lure caddisflies. The purpose of this study would be to identify the optimum color and light wavelength to maximize adult luring and capturing away from populated areas. Much of the Arizona side of the river and many islands within the river could be locations for such large scale and non-toxic trappings. This approach has been used in the past for similar large, nuisance insect emergences e.g., midges in Lake Sanford, Florida (Ali and Fowler 1983). We also discussed the possibility of using a known biocontrol method, methoprene, an insect growth regulator that has had some success in controlling caddisflies. However, the potential to use this approach may have negative impacts on non-target organisms. I suggested that lab studies could be initiated to test the efficacy of methoprene and toxicity to non-targets.

Public Education Via Citizen Science

A key to controlling any pest insect is education. With the dedication of Chris and Joe on this effort and the skill sets they possess, we discussed how they are poised to initiate a public education program that is not only essential but critical to mounting an integrated control strategy that employs both the theoretical and applied research gathered in a concentrated, focused and non-toxic manner to reduce caddisfly populations (Figure 2).

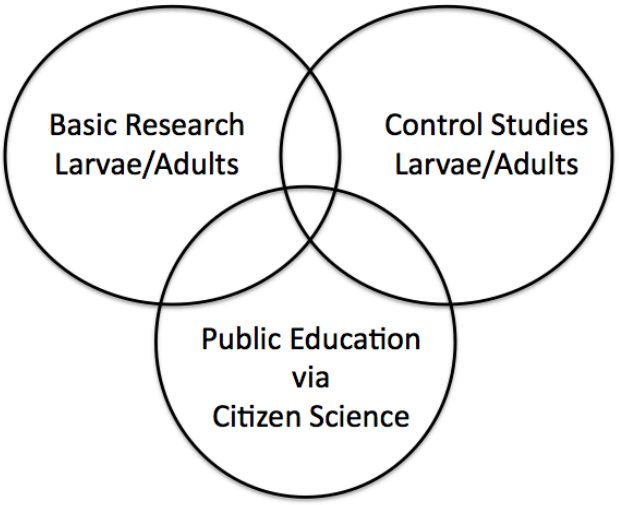

Figure 2. Schematic illustrating the integrated approach to successfully reduce caddisfly populations via a concerted effort by citizen volunteers.

Considering how Joe is a staff of one with his time split among three control paths for mosquitoes, black flies and caddisflies, he requires help to obtain some of the information described in the above experiments. Citizen science programs are idea for this purpose. The term “citizen science” typically refers to research partnerships between scientists and citizen volunteers with the goal of expanding the opportunities for scientific data collection and most importantly provides access of these data for the community at large (Citizen Science 2017). Essentially, citizen scientists are research armies that are trained and focused towards a common goal. The objective for this project is to answer the real world question on how best to reduce caddisfly numbers in an environmentally safe manner.

We discussed the idea of involving schools, creating ‘caddis crews’ of volunteers to collect adult swarm data, temperature and wind data as well. The citizen science program would create a database for volunteers to enter data. By involving schools, the abatement program trains future, science-minded adults with skill sets that can benefit the community and any environmental issue at hand. Many older citizens, e.g., retired folks want to be involved in such programs and are very reliable data gatherers. I suggested that local resident volunteers, some of whom I met and are deeply concerned and were eager to help us on my brief visit, could essentially be trained to collect adult plume data under the guidelines of the proposed study thus not only facilitating the collection of valuable scientific data but doing so in an economically and time efficient manner to

maximize Joe's efforts in these project goals. Volunteers would be trained to collect swarms, weather data and store them until Joe came by to collect them. We outlined how this program could be initiated, who could be involved, how they could assist this project and essentially allow them to be part of the team, with some proverbial "skin" in the game, they will want and be eager to contribute. For additional information on other types of programs, please click on this link: https://en.wikipedia.org/wiki/List_of_citizen_science_projects. Public relations is critical in this area, public events such as 5K run/walk events e.g., the Caddis Flutter Run with proceeds going to citizen science research will help immensely. Social media is very important, blogs could be created, semi-regular newspaper articles in the Mohave Daily News and other papers would be helpful.

As part of any applied research/control program, it is essential to share this information not just with the business and general public communites but also with the scientific communities to receive feedback on how best to improve such programs. Therefore, we discussed the opportunity to present various aspects of the data collection at a suite of local, regional and national scientific conferences. This sharing of data will allow the abatement program to gather feedback on how to proceed and improve the caddisfly abatement efforts.

Conclusion

This visit was very productive from my perspective. It allowed me to meet the people involved with this effort, the extent of this problem, the spatial and temporal aspects related to it and variety of people affected by the caddisfly nuisance. I have been in regular communication with Chris and Joe and hope that we can forge a continued effort towards controlling the caddisfly populations in the Laughlin/Bullhead City area.

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