Kilarc Research

A Discussion Document

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This working paper is made available for the purpose of generating discussion on how to best use the Kilarc facilities, and will be updated periodically.

Introduction

Davis Hydro's staff has had a long term interest in finding ways that hydropower and various fish species can coexist. We take a broad view, enquiring about the benefits to fish that we can derive from using existing facilities and hydropower.

We recognize that people doing research on Salmonids may have little interest in hydropower. Our objective is to enable them to conduct research with the hydropower operations providing field, lab, housing, and various types of financial support.

The proposed research station is an integral part of the Kilarc Hydroelectric facility. The old transformer building near the powerhouse will be converted into a modern field research station for the study of local anadromous fish. The old headrace continues to be in use but would also be used as a fish spawning and research facility. These facilities also will use various ponds in the area to hold stocks and individual fish for testing and breeding. This facility will have the additional purpose of producing an appropriate genetic mix of anadromous and of ancestral genotypes from the Cow Creek.

The primary mission of the station will be to enable the reestablishment of any indigenous anadromous fish in the area. Profit sharing from the hydropower station will be used to support the research and to improve fish habitat. These revenues will be under the direction of a Kilarc Trust whose mission will be to enhance fish resources in the area and to undertake research to support that objective. The Kilarc Trust will endeavor to have board members from the community, fish resource agencies, and others who have a connection to the range of issues that can be addressed by the facility.

We ask the reader to review this paper as an initial set of ideas about how best to use the facility. We are not fish scientists or geneticists. However, we are sufficiently knowledgeable to propose a physical structure that will address questions of interest to some fish scientists, and understand the major problems in taking steps toward the dual goals of anadromy and the restoration of the ancestral genotype. We are trained researchers committed to solving problems and providing resources for others to

contribute to this goal. The following sections describe the physical facilities, some of our initial research questions, the site operation, and the anticipated funding available.

Physical Facilities

The following project components are the principal facilities for use in research. All of them serve multiple functions, supporting hydropower, fish production, and research at the same time.

The Kilarc Field Station

The Kilarc Field Station will be the local office for the hydropower, and have a fish research mission. It will be built into the old transformer building next to the powerhouse. This is easily accessible year round. The only deficiency as a field station is that it is far from lodging and places to eat so it will need some internal lodging facilities.

The Kilarc Field station will contain:

- A small KC Hydro office and a research area with desks and a high speed Internet connection.
- A wet and dry lab with benches, storage and basic equipment e.g. sieves, microscopes, monitors, DSL Data telemetry to the web.
- Ethernet access to ports along the research beds on the canal and possibly, should cooperation with land owners be provided, along parts the Old Cow Creek.
- A small kitchen and bunk house which will be food and sleeping bag.

Funding for the building redesign will come from the hydropower profits. It will be built to suit those from the scientific, operations, and local community who will use it.

Spawning Canal

The primary function of the Kilarc headrace is to carry water to the forebay for recreation and power generation. This flow will be essentially continuous but subject to scheduled and unscheduled maintenance. The amount will be dictated primarily by rain on the catchment area upstream. The canal is long and often wide, and flows vary only a little with incoming rain. It is also easily accessible 9 months of the year and with difficulty for 1 or 2 months. The flow can be controlled so that operational plans could be considered, such as: Modulating the flow at different times to allow study upstream kinesiology of fish moving against the current. This will allow fish to enter various upstream spawning beds they may or may not reach, allowing studies on why this

happens. It will allow for selection of fish based on their mobility rather than only on their fecundity, and for competition for spawning beds.

The secondary integrated function of the headrace channel is to provide spawning as needed to restore and enhance anadromous salmonids indigenous to the Upper Sacramento River. Fish restoration and salmonid enhancement is part of the Davis Hydro mission for the Kilarc Hydropower Project. This mission will be carried out as part of day to day hydropower plant operations. The genetic content being restored is of special interest for the restoration of any ancestral genotypes, and a particular goal of some agents. Further definition of the word “restore”, and in particular what is being restored, will be the subject of a future discussion and work as the project progresses.

The third function for this canal, and the subject of this paper, is to use the large area not needed for multiple spawning areas for research on all aspects of salmonid spawning, focusing to the extent practical on steelhead. This research is supported as part of the Davis Hydro mission, and a personal interest of Dr. Ely in consultation with others active in fish biology and genetics.

Communications

The canal will have multiple redundant data channels along its entire length via wireless networking. Networks will cover the area from the diversion down to the forebay. If we can work out permissions with other parties, one of them may also extend up the Old Cow from the Field Station to research areas along the bypass stream. These networks are part of the new Kilarc hydropower control system to be installed. For example, with this Ethernet bandwidth, underwater POS cameras could be used for slow scan TV monitoring of activity within the gravel. We may be able to supplement slow digital TV with CCTV network if more bandwidth is needed. TV monitoring can be used in fish-screen monitoring, predation control, human and bear security, and other activities. Gathering real time data under varying conditions is key to understanding fish behavior.

The data and video networks will connect as far up the Old Cow stream as possible, down the Kilarc Canal, and terminate at the field station near the powerhouse. Currently, we have cooperation of some lower bordering land owners and more may be obtained in the future. Upstream, Sierra Pacific currently is opposed to introduction of any anadromous fish into the Creeks, so obtaining permission to work on their land needs further discussion.

Ponds and new micro-spawning beds as adjunct facilities

Local landowners on the Cow Creek have offered their ponds for use and modification as facilities for maintaining breeding stock. The ponds may hold preferred phenotypes

(ancestral or anadromous) for releasing in the nature-like spawning areas such as those we are creating at Kilarc. They are designed to hold moderately small stocks of individuals of the correct genetic mix for the Cow Creek location. Other functions of the ponds may include facilities for juvenile counting, maturing and for capturing and handling any returning fish.

It might be optimal to have many small juvenile production facilities along the Sacramento - similar although smaller to what we rebuilding at Kilarc - each specializing as appropriate in the genotype best adapted to a very specific tributary or area. If the Trust so directs, one of the operational elements of the Kilarc facility may be to establish tens of small nature-like spawning beds in the Sacramento River system and to inseminate them with the local genotypes as discussed above. These small facilities may be very useful; this is to be explored.

Canal Bedding

Currently planned are two or three research areas within the canal that may or may not be in the same areas as the "production" spawning pads. Each area has access for trucks, bucket loaders, power rakes and other heavy equipment needed to install and maintain various types of gravel beds. In each area the flow is controlled over a known range and there are no flood events. This has both advantages and disadvantages. For research purposes, it means that the beds will be physically stable during any study period. If the beds are small, flow can be channeled using inflatable dams assuring nearly constant flow and stable micro-hydraulic structure. The down side is that the beds will have to be periodically maintained by heavy tilling to get the fines and unwanted organics out. The only known disadvantage of natural reproduction in the canal is that the canal width – about 10' - is not much larger than a large steelhead redd. Thus, there is the probability of crowding which will have to be considered in experimental and bed design.

Typical possible foci of this research area (bedding matrix) might be fungus and in-gravel predation. By studying different eggs as they develop within the gravel, and which gravels, it might be possible to develop a better understanding of the origins of the mortality and morbidity. The canal has uniform sections that allow for varying bedding with homogeneous cover. Elsewhere, possible bedding areas of the headrace are long enough to have heterogeneous cover over uniform spawning beds. Carrying this further, we can vary the types of cover, density, and water flow configuration to study many behaviors. The whole area is expected to be instrumented and communications provided as discussed below. Instrumentation development for monitoring is an important component of the research agenda.

Canal Research Mission

The headrace canal has a series of long, somewhat homogeneous gravel spawning bed areas that can be isolated from each other and modified independently. They differ in cover and light, although they are consistently facing North to Northwest precluding much direct sunlight. The channel can be used for any fish-related research that does not grossly conflict with the water delivery or fish production. Modifications for research purposes are simple and include gravel matrix, cover, hydraulics, light, and depth. What cannot be easily changed are temperature, weather, daylight cycles, season, and water quality. The following is a list of some of the issues that might be addressed at this site. These are our initial list, of interest to Dr. Ely, this can and will be modified by scientists far more involved in the science and biology.

Fish Spawning Access and Contention

How do Steelhead access, contend for and defend spawning beds? This facility, with its ability to setup and operate a fully observable set of beds, will allow studies of these issues around the clock.

Micro Studies of Woody Debris

Stream restoration usually involves consideration of woody debris and all sizes and densities can be tested. Varying debris design, shape, size, complexity, and interaction with pad shapes and other stream features can be studied. Stream modifications are straightforward from the level banks. With controlled conditions, and real time data collection, observations can be made day and night to understand fish behavior relationships to various debris configurations.

Hydraulics

In the gravel matrix the hydraulics are critical for bringing oxygen, fungus control, and for waste removal. However there is still a large amount of egg and alevin loss that may be from physical and biological interaction within the gravel. Special in-gravel research is proposed that will be aimed at the causes of egg failure. With the data collection system, the canal is a perfect place to study in-matrix processes.

Screening and Diversions

After gravel matrix design, the facility will focus on informal screening design to see if economical screens, that can be field installed by untrained people, do a good job of protecting fish if they are maintained. There are many types of screening designed to lessen the entrainment of fish of various sizes. However, we have observed that very

few screens are in use because they are very expensive to install and maintain unless of an industrial scale. Smaller mechanical screens are not always well maintained, causing excessive approach velocities. This facility would be a good public place to develop smaller, rancher-friendly and timber-company-friendly screens. And get them into the field. Perhaps Kilarc Trust monies could be used for maintenance as necessary.

A different approach that we are suggesting for some sites is to put the screen in the diversion channel and return the screened fish directly back into the stream. The benefit is that the screen is out of the stream floods, and up where it can more easily be maintained. Since that is very similar to what we are going to do in the Kilarc canal, its fish screens and the fish return make a good facility for testing small informal screen designs.

Places to try this technology might be in the German and Abbott Ditch diversions on the South Cow, if appropriate folks are interested in helping the fish there.

Fish Guidance

Davis Hydro initially came to the Cow Creek area to test a fish guidance system that has the possibility to move fish in a preferred direction. This is hoped to be tested at various river bifurcations in the area and possibly in the canal if of interest at that scale. If the tests prove successful, it will assist fish past diversions and into spawning grounds. We still would like to do this project and the junction of the Old and South Cows may be a good test place if appropriate permission can be had.

Fry Survival

Below and out of the project boundaries, the spawning canal and the fish return facility will be a long section of the Old Cow that we currently have access to, and which will be an ideal place very near the field lab, to study fry mortality. This is generally very high, primarily through predation, and there is the possibility of studying what can be done to better prepare the fry for survival. Fry mortality in the first month can approach 95 %. With cooperation of our neighbors we may be able to research how to reduce this considerably thereby allowing for earlier release of fish increasing imprinting efficacy.

Which Steelhead?

Perhaps no issue is more contentious than the effects of hatcheries on the genetics of the fish in a geographic location. There are many questions that might be asked in a research facility that has near perfect genetic control over the fish released downstream. For example, which fish are anadromous? Can and should we build in a quick genetic field test to find out? Are all rainbow trout (*O. Mykiss*) potentially anadromous, or only some? If “some,” how can we tell which ones? The control over

the genetic mix at this site combined with the difficulty of upstream migration will allow for experiments in this area. If anadromy is one goal, and the reconstitution of historic or ancestral fish, if isolated ones can be found, is another, what is the best objective? If these objectives are separable, the research and production agendas of the Kilarc facilities will be quite different. What are the implications if a reconstituted ancestral gene pool contains no alleles for, or phenotypes willing under existing environmental pressure to express, anadromy?

Anadromy has been shown in Salmonids to not be independent of the river in which the fish have evolved. Moving anadromous stocks from one river system to another and thinking that they will imprint on the local river chemistry appears to be only part of the story, and only works in certain species. The dismal return rates of hatchery fish that have been moved between rivers testifies that this does not work well with steelhead. The research question then might be stated, “what is an efficient mixture of locally adapted stock, ancestral stock, and known anadromous exotics that is plausible, practical and desired?”

This is the subject of this research task. A breeding stock is needed for restoration of a locally adapted type so as to capture in so far as possible those traits that have helped the local fish to survive. In restoring the area from a depleted stock every effort could be made to correctly balance the indigenous genotypes of ancestral and current resident fish with genes of other local strong lines of observed anadromous phenotypes, so as to maximize survival in this area while engendering migration.

An Initial Restoration Protocol

The initial effort to repopulate this area of the Sacramento River will focus on exploiting the genotype resources available within the upper reaches of the Cow Creek – both upstream and along the lower river. Only if the effort to build up viable populations from local resources fails will DH then seek to introduce exotic anadromous genes.

The first step in the development of a breeding stock will be to obtain fry from fish which currently spawn upstream and have been isolated for 60 years from hatchery fish within the Cow Creek system. These genotypes have presumably survived in these streams and lakes for more than a hundred years subsequent to the construction of the dams, without being able to display whatever anadromous behavior their ancestors may have had. However, if the genes in rainbow trout which trigger anadromous behavior have simply remained dormant over this period, rather than being selected against, then the propensity for anadromy may well have remained latent in the revealed gene pool.

In parallel with the capture of isolated upstream specimens, the lower river should be monitored and a systematic effort made to capture any steelhead that are discovered

below Whitmore Falls. These fish would also be used for spawning as they are the most likely to contain both the anadromy allele and the genetic familiarity with the Cow Creek river. DNA samples will be collected and stored from all fish to be used in the spawning facility.

Adults will be carefully reared in the local ponds discussed in this paper (or other facilities) and bred in the spawning channel. This will release large numbers of fry from these two parentage populations down the Old Cow and will initiate a process of rigorous directed genetic drift. Some of the resulting juveniles will not migrate but may still constitute the best reconstruction of the ancestral population in the area. Some percentage of the fry will head to sea. After several years at sea, the returning steelhead (perhaps captured below Whitmore falls) will be comprised of some ratio of the upstream ancestral stock and the progeny of prior steelhead returnees. DNA marker technology will be used to isolate those fish originally from the Cow Creek area. These endogenous members would be subsequently used alone for spawning if the emphasis is on enhancing the genetic drift to increase the prevalence of the anadromy allele. Whatever percentage of fish released had retained the anadromous trait, it is obvious that all returnees would possess it. This method would address the anadromy objective.

If rather the emphasis is on accurately restoring the ancestral genotype in the area, then the local isolated fish would be raised and used to concentrate the local alleles – whether or not they are anadromous. There are dual objectives which may or may not overlap, and are unlikely to be congruent.

If the percentage return rate from these activities proves to be inadequate, and if anadromy is important relative to DPS purity, it may be worth attempting to cross-breed locally captured rainbow trout with exotic fish, transferred from nearby river systems. This should be envisaged as a last resort, perhaps after five years or more of attempts to revive the ancestral stock, provided that returning fish numbers are great enough, and reveal sufficient diversity, to ensure that it is worth persisting with efforts to rely entirely on locally-caught steelhead.

Subsequent selection of genotypes may be undertaken to meet one or more of several objectives. The question of priorities needs to be raised now so that the Kilarc facility can direct its attentions appropriately once the exercise is underway. When established, it will address the quandary of multiple, possibly non-overlapping and conflicting, objectives as suggested by others:

More fish - A CDFG objective
More geographically local fish - the DPS objective
More ancestral fish - a genotype preservation objective

More diverse ancestral genepool – a sustainability objective
More anadromy – a sport fishery objective

Clearly this jumble of goals is chaotic and conflicted as presented to us at this point and needs discussion – ongoing discussion as genetic research on the local populations reveals what is possible.

For example, we bring up immediately the question of, “what if the ancestral genotype has no alleles that express anadromy?” If rather, all *O. Mykiss* is of a genotype that has anadromous alleles, then why bother with anadromy as an objective other than sport fishing? Davis Hydro is anxious to assist in reestablishing fish in the area, but immediately and hopefully not too far in advance is starting to ask, “What fish, local, ancestral, or anadromous – are all these different?” This is immediately important and set the framework for production and research at this facility.

Operation

The initial related tasks are expected to be as follows:

1. Start a long term measurement and monitoring program to look for any ancestral isolated stocks
2. Enable close monitoring for any anadromy below Whitmore falls.
3. Establish genetic markers for existing fish in isolated genetic populations
4. Develop initial stocks (local, ancestral, and anadromous)
5. Design target population(s) (local, ancestral, and anadromous)
6. Establish production baselines for comparison with the demolition Alternative.
7. Design a production facility in the headrace for spawning a target mix of steelhead.
8. Build initial spawning beds and a fish return facility, data links and other infrastructure.
9. Start work on the research agenda and facility. Design research beds, screens, and variations on screen cleaning mechanisms.
10. Start work on the research field station.
11. As budget allows under the direction of the Trust, start off-site projects and research projects.
12. Start measurement and evaluation protocols at the site and below Whitmore Falls and possibly at other Cow Creek monitoring sites.
13. Commence release of target fish.

The whole Kilarc site will be set up and maintained by Davis Hydro (or more likely a derived and dedicated operating company for this site). It may operate the site and fund it under License Articles of the FERC. The management of the economic resources

generated by the hydro will balance fish protection and fish research will be overseen by the Kilarc Trustees who are charged with that dual mission. Once the site is functioning and hopefully generating positive revenue, profits will be shared with the trust for distribution for fish resource enhancement and research. Beyond this plan, Davis Hydro is looking for ideas and collaborative partners who have an interest in the fish research.

Questions and Answers

Earlier drafts of this paper have generated some questions. Here are some answers.

Who will own the site? Most likely this will be a local LLC with a charter that will incorporate all the above issues on fish support.

Who will be responsible for disasters and liability? The site will carry significant liability and other insurance to protect the workers, researchers, surrounding neighbors, timber companies, and the public. All the hydro sites that Davis Hydro operates have this type of coverage.

Why are you doing the research? Dr. Ely, head of Davis Hydro, is interested in protecting fish and generating green sustainable power to help save this planet. He knows no better way to do his part. All members of Davis Hydro share this goal.

What is the Kilarc Trust and what does it own and control

Davis Hydro has a solid idea for the Trust as a permanent recipient of hydro profits. However DH is indifferent as to the exact role of the Trust other than it should have the ability to care for the fish production and research at this facility. It might own the whole complex and hire DH as an operator, or it might operate at arm's length taking funds from the hydro project and spending them for the benefit of the fish. We ask the reviewer to share opinions as to the best method for this to work. Several things are clear:

- Davis Hydro principals are mortal and will pass – the Trust needs to be immortal and independent.
- Davis Hydro can run the hydro – other people will in the future.
- Davis Hydro has a fairly good idea of how to build the facility, but the long term optimization will need to be guided by fisheries biologists.
- A working codified balance has to be set up between the Trust and the Hydro operation to maximize the production and research return from the site.

Who are the Davis Hydro Trustees

We would like to have Trustees from the resource agencies, community, and scientific community. DH may or may not be a trustee – or possibly will be an initial trustee of limited term to help get it established. We may use a professional environmentally oriented trust organization to provide structure if no other envelope makes sense. We are open to ideas.

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The reader of this paper might refer to the Davis Hydro www.Kilarc.info site for the latest version. Our understanding of the problem continues to evolve and this paper – originally written in 2008 - continues to evolve and change as we develop plans for using the site for the benefit of the local fish and the community.

We encourage additional ideas. For updated versions, see:
http://kilarc.info/Docs_Maps_Drawings/Documents/docs.htm