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Grand Canyon Near Shore Ecology Study

Figure 1. A juvenile humpback chub displaying two visible implant elastomer tags (orange and green slashes). Placement of these markings in particular places on the fish indicates when and where the fish was originally tagged (Photo: Bill Pine).

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On July 25, Dr. William Pine from the University of Florida presented the results of the Grand Canyon Near-shore Ecology study (NSE) for the Upper Colorado Regional Office and invited guests. The study, which consisted of four years of intensive fishery field investigations and data analysis, was funded by Reclamation in cooperation with the Grand Canyon Research and Monitoring Center (GCMRC) as a conservation measure of the 2008 Biological Opinion on Glen Canyon Dam operations. The goal of the study was to relate dam operations to ecological attributes of near-shoreline fish habitats and to determine the relative importance of various habitat types to critical life stages of native and nonnative fishes under contrasting flow regimes. This study was designed to increase our understanding of juvenile native fish habitat requirements and identify how habitat selection, preference, and availability affect native vital rates such as growth and survival. To facilitate the study, operators at Glen Canyon Dam delivered an experimental steady discharge during the months of September and October from 2008 through 2012, which provided the opportunity to examine fish use of various near-shore habitat types during steady and fluctuating flow operations. While reports and publications from the study are forthcoming, Dr. Pine summarized the key results and highlights in his presentation to the UC Region.

The 2008 pilot study worked out fundamental logistic details and specific techniques such as gear types for catching juvenile fish in the mainstem river and sampling methodologies to determine density, growth, and survival during the two flow regimes. The pilot study was followed by intensive field sampling from 2009 to 2011 below the confluence of the Little Colorado River (LCR) and the mainstem Colorado River (figures 2, 3). Field sampling trips were conducted once per month during July and August under fluctuating flows and during the steady flow period of September and October. Sampling occurred at three sites measuring 1,500 meters on each side of the river. For three weeks during each sampling occasion, crews collected fish and other habitat data almost continuously, day and night. Their home away from home was a rocky crag just big enough to fit the crew of up to 15 people, their kitchen, laboratory, and beds, but not much more (Figure 4). Weather conditions ranged from hot to hotter, with torrential rain thrown in during the monsoon months.

Biologists used a variety of fish capture gear types to collect fish, including hoop nets, seines and electrofishing (Figure 5), which stuns fish through the use of an electric current passed through the water. Some fish were marked with elastomer pigments (Figure 1), a temporary mark which allows researchers to identify fish captured during previous trips. A small subset of the total catch was implanted with radio transmitters, also, to follow fish movement among habitat types in real time. Still others were sacrificed for collection of their otolith, or “ear stones” to determine their natal origins (see below).

The study site has historically supported the highest density of humpback chub in Grand Canyon due to its proximity to the LCR where humpback chub spawning is known to occur. Fish collection methods devised during the pilot study proved to be highly successful. For example, during the span of a single sampling trip, investigators captured more endangered humpback chub than had ever been encountered in all the previous decades combined. The success of sampling during NSE showed that these habitats were “swamped” with juvenile HBC and all available habitat types were being utilized. Juvenile HBC abundance estimates derived during NSE were the first ever achieved in the mainstem Colorado River.

Dr. Pine highlighted key findings of the three years of research. Juvenile HBC did not show strong nearshore habitat relationships and they had similar daily movements and habitat use, regardless of the flow events. All shoreline habitats were being used by chub within the sampling area but highest abundance occurred in talus slopes, which are made up of large angular chunks of the eroding canyon walls. There was no obvious change in their HBC abundance related to the steady flow experiment. An unexpected finding was that juvenile HBC growth actually declined during steady flows in the mainstem. This may have been due to cooler water temperatures associated with the fall months, when the sun is much lower in the sky and river warming rates are lower than during the summer months. Predation was highest when the turbidity of the water was intermediate (between clear and opaque). This degree of water clarity exposes juvenile fish to multiple species of predators, both those that locate their prey by sight and those that use olfactory and other senses to locate prey.

Water quality differences between the mainstem Colorado and the LCR are distinct and provide chemical markers in the rings of HBC otoliths. Otoliths or ear stones are tiny calcified structures associated with a fish’s sense of hearing that have growth rings much like the rings of a tree. These rings or annuli are used for determining the age of fish and other aspects of its life history (Figure 6). Otoliths also accumulate isotopic elemental signatures that occur in the water around them. These signatures usually contrast sharply from one water body to the next; those contrasts can be seen in the fish's otoliths. For example, a fish born in the LCR will have an LCR signature at the core of its otolith, signifying its birth place, but a Colorado River signature near the edge of the otolith indicates where it has spent the more recent years of its life.

Humpback chub otoliths were analyzed at Cornell University, using scanning X-ray fluorescence and a high energy Synchrotron source. This very "high tech" analysis revealed previously undetected movements of young juvenile HBC in and out of the mainstem and the LCR. It also, indicated that more HBC spawning may be taking place outside of the LCR than was previously thought, perhaps in areas upstream of the LCR that are associated with warm springs. By combining these otolith markers with age and growth information the habitat use and success of HBC in different habitats can also be assessed. Whatever the ultimate outcome, use of otolith isotopic analysis is clearly a powerful tool in evaluating origins of fishes; such a technique has also been utilized successfully in the Upper Colorado River Basin to determine origins of invasive non-native fish.

Fundamentally, the study demonstrated that juvenile HBC within the study area are not significantly affected by the fluctuating versus steady flow treatments that were used in this experiment. There was considerable evidence to suggest, however, that the limited spatial and temporal design of the experiment may have restricted a full evaluation of hypotheses about river fluctuations, warming rates, and humpback chub growth and survival parameters. Dr. Pine recommended that nearshore monitoring continue as part of GCMRCs' annual sampling regime but additional downstream locations should be included to provide a contrast with findings from the LCR reach. Habitat use patterns of juvenile fish farther away from the LCR where they are not likely to be so abundant may provide an opportunity to more completely evaluate habitat preference and the "crowding" effect (i.e., fish occurring in all habitat types) would not be so pronounced. Varying shorelines types should be sampled, particularly those that are influenced more by discharge and stage of the river such as shallow backwaters and other gently sloping habitat types. Dr. Pine also recommended that fish otolith work be continued because it provides otherwise unattainable patterns of fish movement and an indication of the location of their origins.

In addition to the findings regarding fish behavior, survival and growth during steady versus fluctuating flows, a widely held assumption about humpback chub survival in the Colorado River took a sound beating from the results of the NSE study. For decades, the common assumption among many workers in Grand Canyon was that fish migrating from the LCR –particularly extremely young fish less than a year old—had a near-zero chance for surviving to adulthood in the harsh, cold environment of the Colorado River. By marking individual fish with elastomer tags and recapturing them at later dates, Dr. Pine's study demonstrated that not only can such fish survive in this environment at such a young age, but that they can do so for several years without unprecedented declines in abundance. They also demonstrate the ability to grow in size, which is also important to the fish from a survival standpoint. This finding will fundamentally change how the population dynamics of this endangered fish are evaluated in the Colorado River in Grand Canyon.

The NSE project has provided new and valuable information on the influence of dam operations on downstream resources and has expanded our knowledge on the life history of juvenile HBC and other native species. The study adds pieces to the puzzle that advance the adaptive approach of managing resources in the Grand Canyon and guides future scientific endeavors and management actions. In addition to these contributions, the NSE study provided three graduate students with Masters Degrees, and twelve papers are in various stages of peer review for publication in scientific journals. Reclamation should feel proud to be a key player in this study. We are encouraged by these finding and hope to see such innovative methods and rigorous analytical procedures continue in years to come as we continue to operate Glen Canyon Dam while minimizing impacts to the iconic national treasure that is Grand Canyon and its inhabitants.

Photos below

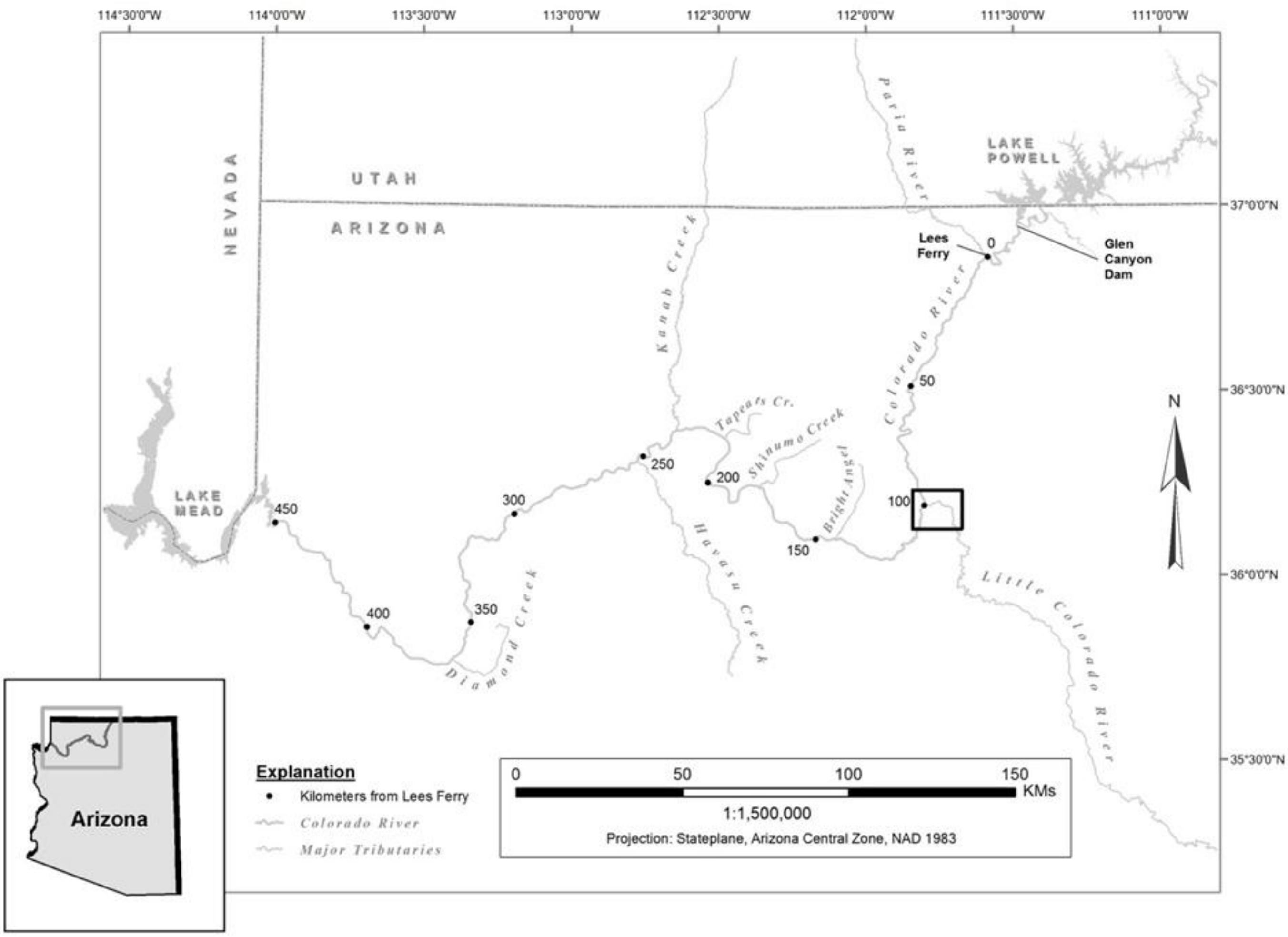

Figure 2. Map of Grand Canyon area showing nearshore ecology study site near the confluence of the Little Colorado River and the Colorado River (inset).

Figure 3. Confluence of the Little Colorado River (left) and the Colorado River (right). Calcium carbonate in the Little Colorado River gives it a turquoise coloration (Photo: Melissa Trammell, NPS).

Figure 4. The nearshore ecology science camp on the Colorado River, Grand Canyon. (Photo: Bill Pine)

Figure 5. Capturing fish using electrofishing gear, which temporarily stuns fish by passing an electric current through the water. Stunned fish are netted and placed in tanks where they quickly revive.

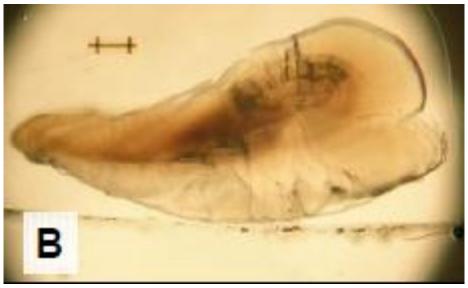

Figure 6. Photomicrographs of fish otoliths or “ear stones”. Concentric rings in the structures record the fish’s age as well as other life history attributes. Size: about 1-2 mm each.

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