00:00:00 Introductions. Q: What positions have you held in GCDAMP (Glen Canyon Adaptive Management Program) during the years you participated? A: In 1989, Valdez worked under contract with USBR (U.S. Bureau of Reclamation), studying humpback chub in Grand Canyon for GCES (Glen Canyon Environmental Studies). The study surveyed fish populations along 280 miles of river.

00:01:00 In 1999 Valdez convened a scientific panel on strategies to increase humpback chub populations, and in 2000 he participated in the LSSF (Low Steady Summer Flow) experiment. In 2003 he worked on a team assessing the need for a TCD (Temperature Control Device) for Glen Canyon Dam.

00:02:00 In 2004 Valdez worked with Steve Carothers on a fisheries survey of the Colorado River and its tributaries in Grand Canyon. He worked in 2010 on a razorback sucker reintroduction team. The Colorado River Basin states asked Valdez to convene a panel in 2012 to evaluate alternatives for the 2016 LTEMP (Long-Term Experimental and Management Plan) EIS (Environmental Impact Statement).

00:03:00 Valdez recently joined the brown trout management team with Mike Runge and Charles Yackulic. Q: How much of your work was contract research work with SWCA [SWCA Environmental Consultants] versus work directly as a participant with AMWG (Adaptive Management Work Group) or TWG (Technical Work Group)?

00:04:00 A: It was mostly contract work through BIO-WEST or SWCA. Valdez attended numerous AMWG and TWG meetings while working with those companies. Q: Let's drill down on the role of humpback chub in GCDAMP. You're probably going to be the most knowledgeable expert we interview on life history and recovery efforts for humpback chub. How did that get started and develop over time?

00:05:00 A: The humpback chub is probably the keystone species in GCDAMP. He has served as recovery team leader since 2015. Valdez is very familiar with humpback chub populations in Grand Canyon. He started studying fish populations in the Upper Colorado River Basin in 1968.

00:06:00 Before the Endangered Species Act (ESA) was passed in 1973, humpback chub were included in the Endangered Species Preservation Act (1966) and the Endangered Species Conservation Act (1969). The ESA mandated better protections, but nobody knew exactly how to protect endangered fish in Grand Canyon.

00:07:00 Valdez was involved in early Environmental Assessment (EA) and EIS processes concerning endangered native fish, especially in the Upper Colorado River Basin. He started

with U.S. Fish and Wildlife Service (USFWS) in 1979 to evaluate native fish populations above Lake Powell, which were declared to be in jeopardy on passage of the ESA.

00:08:00 Amendments to the ESA in 1980 introduced the concept of reasonable and prudent alternatives, "which really opened the door and allowed agencies, now, to start doing good things for the species to offset or mitigate those potential bad things." The alternatives developed for native fish affected by Glen Canyon Dam operations became the heart of the 1995 EIS.

00:09:00 In 2008, USFWS changed to a non-jeopardy determination for humpback chub. New conservation measures were finalized in 2010. Now USBR and NPS are working "not just to mitigate the potential jeopardy effects, but also to benefit the species." Because Grand Canyon has the largest population of humpback chub in the Basin, it was the stage for determining how the ESA would apply to the species.

00:10:00 The humpback chub was the main driver of management actions in the area. Q: In terms of modifying dam operations, improving habitat, or reducing predation? A: All of those things. Glen Canyon Dam put about 200 miles of what used to be native fish habitat under a lake. Razorback suckers can survive in a reservoir, but pikeminnow and humpback chub do not. The dam also changed downstream habitat by releasing cold water drawn from the depths of the reservoir.

00:11:00 Because native fish in Grand Canyon are adapted to warm water, biologists speculated that cold-water releases through the turbine penstocks may need to be offset with a Temperature Control Device (TCD). Proposed around 2002, the controversial TCD would have modified the dam to mix warmer surface water with the deeper cold water going into the penstocks.

00:12:00 In retrospect, biologists may not have adequately understood the situation. Cold-water releases may benefit native species by inhibiting the incursion of non-native warm-water fish into the system. Humpback chub still have access to the Little Colorado River (LCR), where the seasonally warm water is good for spawning.

00:13:00 Managers could target a water temperature using a selective withdrawal TCD, which would employ elevators to withdraw water from any level of the reservoir and release it through the penstocks.

00:14:00 The cost to install a selective withdrawal TCD would have been about $100 million. While making careful evaluations in the face of concerns about the cost, scientists were reminded that despite our efforts at control, nature usually drives the system.

00:15:00 Elevations in Lake Powell and Lake Mead were dropping due to long-term drought since 2000. Water releases from Glen Canyon Dam that had been 8-10 degrees centigrade increased to up to 16 degrees centigrade. The warmest water came through in the fall due to "reservoir overturn."

00:16:00 The warmer water in the fall was of little benefit to humpback chub, which are spring spawners. Ironically, it could now be argued that a TCD may be needed cool the releases. Q: Have humpback chub always spawned in the LCR, or did that develop after the dam was built?

00:17:00 A: It has always occurred, at least in recent history. The Kolb brothers [historic Grand Canyon photographers] observed numerous fish in the LCR at spawning time early in the 20th century, and 1970s studies documented spawning in the system. Scientists suspect humpback chub also spawned in the mainstem before the closure of Glen Canyon Dam.

00:18:00 Post-dam spawning in just the LCR provides enough young to sustain the population. The other surprise from nature was the lowering elevation of Lake Mead, similar to that occurring at Lake Powell. This increased the length of the Colorado River into the Lake Mead basin.

00:19:00 The area that was once underwater in the upper reaches of Lake Mead has a layer of thick accumulated sediment brought down by the Colorado River that is now exposed. The river is re-carving out its original channel through those sediment layers and riparian habitat is regenerating. Humpback chub in that area have become the most productive of the monitored populations.

00:20:00 Native fish are thriving in the area between Diamond Creek and Pearce Ferry. Sometimes nature provides a twist that defies plans and expectations. Q: Science is a practice of developing a hypothesis, doing research, and developing a limited knowledge base of understanding. In adaptive management, we do a management action, try to monitor the effects, and find out if the response is what we expected. So it's constant learning.

00:21:00 A: Adaptive management also provides an opportunity to assess past hypotheses, analyses, and management actions from the vantage of many years later, "to see how right or wrong we were."

00:22:00 Carl Walters emphasized that adaptive management is a learning process. "If one were to believe that you could structure something in a way that's definitive, with predictable results and responses, that of course is not true at all. You learn as you do. You learn as you go." Nature always throws in unanticipated variables.

00:23:00 The benefit of being involved with GCDAMP over a long time period is realizing how much its participants have learned, whether or not they got things right. Q: Some of our other interviewees talked about how early hypotheses about predation evolved over time as we learned more. Can you talk a little bit about that?

00:24:00 A: The Colorado River has been isolated from nearby river basins for at least 3 to 4 million years. The river in the Upper Basin has not changed much through that time. In Grand Canyon, the river captured streams as the plateau rose.

00:25:00 Fish diversity is low in the river due to its historical isolation. Not counting marine fish in the estuary, only about 14 species are native to the entire Colorado River Basin, compared to other rivers with hundreds of species. The Colorado River has historically supported a "unique evolutionary scheme." Native species evolved with limited native predators and have few adaptive traits to cope with predators introduced into the system.

00:26:00 Valdez says of native species in the Colorado River, "all you have to do is look at them and you can tell, these are special. Very, very special fish. They're very uniquely adapted." The humpback chub's torpedo-shaped body and large falcate fins help it "soar," rather than swim, in high-velocity currents. A poor swimmer in laboratory experiments, it knows how to find eddies or pockets of low water velocity.

00:27:00 Valdez has worked with humpback chub throughout the Colorado River Basin. He enjoys watching the fish maneuver in the clear water of Grand Canyon. He equates them with raptors that ride thermals, making minor adjustments to maintain position with little energy expenditure. "Well, humpback chub do the same thing, except that they're in a water environment." The river delivers food to them as they stay in one place.

00:28:00 They have deeply embedded scales and thick skins to withstand the scouring of sand-laden water. The top of the humpback chub's head is flattened to allow water to pass by, and it has its namesake hump. Q: What is the purpose of that hump? A: Robert Rush Miller, who provided the fish's first taxonomic description in 1946, thought the fleshy structure of the hump was a hydrodynamic feature.

00:29:00 The razorback sucker also has a hump, formed around a bony structure, along with thick skin and large fins. It and the humpback chub are highly adapted to the Colorado River environment.

00:30:00 Starting in the 1930s with Lake Mead, the Colorado River Basin states looked at dams and reservoirs as opportunities to develop recreational fisheries. Up to now, more than 35

non-native fish have been introduced to the system. Humpback chub are ill-adapted to cope with alien species who prey on or compete with them.

00:31:00 Non-native fish are vectors for diseases and parasites. Now scientists understand that cold-water releases from the dam may be discouraging movement of warm-water adapted predatory fish into Grand Canyon. The fish currently preying on humpback chub in Grand Canyon are cold-water brown and rainbow trout.

00:32:00 Q: And they were introduced for fisheries recreation, right? A: Yes. NPS introduced them in the 1920s, starting in Bright Angel Creek. Grand Canyon National Park had just been established, and while the muddy, turbid Colorado River mainstem was not appealing for sport fishing, the side streams were.

00:33:00 Trout did well, and a hatchery was set up on Bright Angel Creek. Q: We have native trout in Arizona, like the Apache trout. Were there any native trout in the side streams, or were they all imported? A: The Apache and Gila trout are more closely related to salmon species than to mountain cutthroat trout.

00:34:00 They are native to Gila River tributaries, upstream of where it meets the Colorado River. Arizona native trout do not occur in waterways that flow into Grand Canyon.

00:35:00 The introduced rainbow trout came from California hatcheries, and the brown trout, a European species, from hatcheries in Michigan. Q: You were talking about their role in predation on the humpback chub. Where does that come in? A: Rainbow trout are concentrated between Glen Canyon Dam and Lees Ferry, forming a blue-ribbon sport fishery.

00:36:00 That area is usually too cold for brown trout, which were concentrated in the area of Bright Angel Creek and sometimes in the mainstem near the LCR. Warmer releases from Glen Canyon Dam seem to have enabled brown trout to spend more time in the mainstem.

00:37:00 Now, a sizeable number of brown trout are found at Lees Ferry, where it is feared they will compete with rainbow trout. In 2017, GCDAMP formed a science panel to explore alternatives for managing brown trout impacts on rainbow trout and humpback chub.

00:38:00 Q: A previous interviewee mentioned that early on, the thinking was that both species of trout were probably eating humpback chub and depressing the population. After further research, it was determined that the rainbow weren't, and the brown trout were. Is that correct in your mind? A: Yes.

00:39:00 Mike Yard found that both trout species prey on humpback chub, but brown trout eat 3 to 4 times the number of fish that rainbow trout eat. The smallmouth bass, which can tolerate cool water, is another potential predator.

00:40:00 Smallmouth bass have recently migrated into Grand Canyon, but there is no evidence that they have reproduced there. Q: And you expect them to be predators on humpback chub? A: They are intensive predators. The Upper Colorado River Endangered Fish Recovery Program spends about 40% of its budget removing smallmouth bass and northern pike. Q: There are northern pike in the Colorado River? A: Yes. The state of Colorado introduced them into Elkhead Reservoir some years back, and they escaped, along with smallmouth bass.

00:41:00 There are guided fishing tours in the Yampa River for northern pike, which prefer cold water and seldom leave the area. Smallmouth bass can tolerate a range of temperatures and may prove problematic in Grand Canyon. "It fills that intermediate niche between the cold-water species and the warm-water species, and could probably do quite well." Q: Where are we at today with the recovery of the humpback chub? I heard recently that there was talk about downlisting it from "endangered" to "threatened." What's the status now and where do you think we're going in the near future?

00:42:00 A: The humpback chub is currently listed as endangered. It was included in the original list of endangered species in 1966 and grandfathered into the Endangered Species Act in 1973. Today, the species is doing well in all parts of Grand Canyon.

00:43:00 There are six or seven aggregations, or small groups of humpback chub populations, outside the LCR area in warm-water areas. Humpback chub readily interact with boaters and are one of the fish most commonly sighted on river trips.

00:44:00 Humpback chub are very social and travel in groups. There are five populations outside Grand Canyon, in the Upper Colorado River Basin. A population in Yampa Canyon was recently declared functionally extirpated. The humpback chub recovery team is exploring the prospect of translocating humpback chub back into the Yampa River.

00:45:00 The Upper Basin populations are not doing quite as well as those in Grand Canyon, but they are currently self-sustaining. USFWS initiated a downlist proposal in February 2020.

00:46:00 If the proposal is deemed appropriate, it could be implemented within the next year. Valdez thinks it will be, as the Grand Canyon populations are doing well and the Upper Basin groups are mostly stable.

00:47:00 The endangered Colorado pikeminnow is being evaluated for reintroduction into Grand Canyon. It had been extirpated there since 1975. Q: As a result of the changes in the river due to the construction of Glen Canyon Dam, or something else? A: Probably several factors.

00:48:00 The Colorado pikeminnow is highly migratory within a given river system. In the pre-dam Colorado River it probably migrated from as far as Yuma, perhaps even feeding in the estuary. Evidence shows this fish could reach 6 feet long and 100 pounds. Now restricted to the Upper Basin by Glen Canyon Dam, Colorado pikeminnow weigh no more than 30 pounds.

00:49:00 Some Colorado pikeminnow were introduced into the Salt and Verde rivers but are not part of a recovery program. USFWS, NPS and Arizona Game and Fish Department (AZGFD) are looking at reintroducing the species in Grand Canyon. Such a population would likely not be self-sustaining.

00:50:00 The life history requirements for Colorado pikeminnow are not present in Grand Canyon due to the current state of the dammed river.

00:51:00 A downlisting for humpback chub would not significantly change Glen Canyon Dam operations. The difference between an endangered species and a threatened species is small relative to Section 7 of the ESA. The states would have a more active part in conservation measures, providing some flexibility in management.

00:52:00 Q: To what extent is the improved health of the humpback chub population in Grand Canyon traceable to GCDAMP and changes in dam operations? How much of it is just serendipity, and how much of it is the results of our efforts to recover the species? A: It is a "scientist's nightmare" to look back on the management decisions made in a program and realize that many of them did not make much of a difference.

00:53:00 The humpback chub's recovery is partly attributable to GCDAMP management decisions, but part of it is serendipitous, stemming from the results of lowering elevations in Lake Powell and Lake Mead [due to the long-term drought].

00:54:00 One helpful management action, implemented in 1995, was reducing the large flow fluctuations created when maximizing hydropower generation. The daily 20-foot river elevation increase at the foot of Glen Canyon Dam generated a wave "that was almost a daily flushing of the Grand Canyon."

00:55:00 The daily fluctuations not only disrupted boat trips, they were detrimental to young humpback chub that used the shoreline for nursery areas.

00:56:00 The fluctuating flows displaced young fish from protected areas and exposed them to predation. The Modified Low Fluctuating Flow (MLFF) alternative resulted from studies conducted prior to 1995. Valdez argued at the time that flows needed to be even more stable, since the historic river was low and fluctuated very little in the summer.

00:57:00 The Low Steady Summer Flow (LSSF) concept was implemented in 2000 to test the low flow hypothesis. Scientists discovered that humpback chub adapt to modified fluctuating flows quite well by staying near talus slopes.

00:58:00 While high flow fluctuations were not good for humpback chub, moderate fluctuations may actually benefit them. Another highly beneficial management tactic was mechanical removal of trout, carp and channel catfish.

00:59:00 Q: Are catfish also predators on humpback chub? A: Absolutely. Q: But not carp? A: Carp are voracious predators of fish eggs. Valdez remembers watching red shiners spawn in Spencer Creek, and a few minutes later an "entire herd" of carp "vacuumed" the area of eggs. The effect of predation on native fish eggs and larvae may not get the attention it deserves.

01:00:00 High Flow Experiments (HFEs) also benefit native fish.

01:01:00 HFEs build beaches and deposit sediment into large recirculating eddy complexes, creating backwater habitat for fish. Native flannelmouth and bluehead suckers and speckled dace use the backwaters more than humpback chub do.

01:02:00 Q: How has the science of HFEs and our understanding of their impacts evolved over time? A: The first HFE was in 1996. "We called it the controlled flood through Grand Canyon."

01:03:00 Valdez and others edited a book on the flood, archiving many of the studies done on the first HFE. [Webb, Robert H., John C. Schmidt, G. Richard Marzolf, and Richard A. Valdez, eds. The Controlled Flood in Grand Canyon. Vol. 110, Geophysical Monograph Series. Washington, DC: American Geophysical Union, January 1, 1999. https://agupubs.onlinelibrary.wiley.com/doi/book/10.1029/GM110.] HFEs were formerly called Beach Habitat Building Flows (BHBFs). Dave Wegner asked the National Academy of Sciences to do a review of GCES in the mid-1980s, soon after the emergency dam releases during the flood years of 1983-1984.

01:04:00 The National Academy of Sciences concluded high flows were bad for the river ecosystem through Grand Canyon because they transport large amounts of sediment out of the system.

01:05:00 A subsequent review a few years later was more nuanced, proposing high flows could be used to build beaches by suspending sediment and entraining it in recirculating eddies.

01:06:00 The Secretary of the Interior approved the first HFE. It was notable because the 30,000 cfs (cubic feet per second) release involved the bypass tubes, which did not generate electricity. The 1996 HFE lasted for almost 2 weeks.

01:07:00 Most of the sediment influenced by the HFE moved in the first 2 or 3 days, so 48-96 hours is enough time to get the desired effect. Managers later developed a protocol for doing HFEs when sediment was available in spring or fall. Because sediment from the Upper Basin is trapped in Lake Powell, the LCR and the Paria River provide most of the sediment downstream of the dam.

01:08:00 The Paria contributes sediment in late summer, and the LCR contributes in spring. HFEs were initially done in spring because that better simulated the natural hydrograph.

01:09:00 Because the Paria contributes the majority of sediment and is closer to the dam, and many of the large recirculating complexes are upstream of the LCR, the HFE protocol changed to fall releases.

01:10:00 A recent decline in production of insects and algae–the Grand Canyon food base–may be tied to fall HFEs. Production is inhibited by the scouring effect of 40,000 cfs releases in the Lees Ferry reach and a low sun angle in fall that limits photosynthesis, followed by winter weather that does not allow for recovery.

01:11:00 Fall HFEs may be a net negative for the system. Q: We've been hearing about low Bug Flows lately. Can you explain that? A: Releases from Glen Canyon Dam are a uniform temperature rather than fluctuating with the seasons, and although recent releases are warmer, the river still does not reach pre-dam temperatures.

01:12:00 Cold and unvarying water temperatures, along with fluctuating flows, have a negative effect on certain invertebrate species that fish rely on as food. Species that require both a warm and a cold period to complete their life cycles cannot currently exist in Grand Canyon.

01:13:00 Ted Kennedy of Grand Canyon Monitoring and Research Center (GCMRC) proposed the Bug Flow concept. Bugs crawl onto rocks to lay their eggs, and a steady release can keep the rocks wet long enough for the eggs to hatch before drying out. Q: Is that working? A: It appears to be, in that certain insects that fish feed on are doing better. The scouring effects of HFEs are still an issue under consideration.

01:14:00 Q: As I understand it, they won't even do an HFE if they haven't determined that a certain amount of sediment has come down one of those two tributaries and is available to push down the Colorado. A: Yes. Two factors determine if an HFE will take place: availability of a volume of water aside from that needed for normal dam operations, and availability of sediment.

01:15:00 There are years when an HFE is not authorized. Q: How about if we take a short break now, and then come back in about five minutes? (Recording paused.) Q: One of the topics we touched on earlier was mechanical removal of predatory fish that impact the chub population. What role has mechanical removal of brown and rainbow trout played in fish management, and what happened when it was adopted for GCDAMP?

01:16:00 A: Predation on humpback chub, especially the young, was a concern across the Colorado River Basin. The most direct management solution was mechanical removal of as many non-native predatory fish as possible.

01:17:00 Going back to the 1996 Record of Decision (ROD), predation was identified as a major threat to native fish in Grand Canyon.

01:18:00 Although brown trout had been identified as the biggest threat to humpback chub, they were outnumbered by rainbow trout.

01:19:00 Water in the Colorado River mainstem was too cold for rainbow trout to self-sustain, so AZGFD introduced them annually to sustain the fishery. They were able to reproduce after implementation of the MLLF alternative. Younger trout began to move downstream, closer to prime humpback chub territory near the LCR.

01:20:00 Managers proposed intensive removal between Lees Ferry and Badger Creek at key times of the year, when they suspected rainbow trout would be moving downstream. They did removal experiments and coordinated an Environmental Assessment.

01:21:00 Q: Was the research on that before the 1995 EIS, or at the time it was being developed? A: Immediately after. In the early 2000s, the idea of removing trout when they got to the LCR area, rather than trying to intercept them on their way, was proposed. The multi-year experiment involved several removal trips.

01:22:00 Mass trout removal led to some complicating issues. The first was what to do with the dead fish. NPS would not allow them to be ground up and returned to the water or buried alongside the river. Instead, the ground fish remains were put in barrels and used as fertilizer.

01:23:00 The second issue was that Native American tribes had concerns about the taking of life in Grand Canyon. Removal was effective in reducing trout numbers as long as it was ongoing.

01:24:00 It only took a year or two for rainbow trout to repopulate a designated area, leading to doubts about mechanical removal as a sustainable management action. Managers considered how many adult humpback chub there needed to be for a population to sustain a certain amount of predation by rainbow trout, and developed triggers for mechanical removal based on numbers of both species.

01:25:00 The research was incorporated into the 2016 LTEMP EIS. Predation by brown trout, which primarily spawn in Bright Angel Creek, continued to be a problem.

01:26:00 In about 2012, NPS put a fish weir at the mouth of Bright Angel Creek to remove brown and rainbow trout.

01:27:00 Q: So rainbow trout were spawning also in Bright Angel Creek. A: Yes. In the last 5 years, NPS has removed trout directly from Bright Angel Creek. Valdez cites a paper reporting a decline in these non-native trout of 75%-80% following removal actions. [Healy, Brian D., Robert C. Schelly, Charles B. Yackulic, Emily C. Omana Smith, and Phaedra Budy. "Remarkable Response of Native Fishes to Invasive Trout Suppression Varies with Trout Density, Temperature, and Annual Hydrology." Canadian Journal of Fisheries and Aquatic Sciences. Ottawa: NRC Research Press e-First Article, June 3, 2020. https://www.nrcresearchpress.com/doi/10.1139/cjfas-2020-0028#.Xz8YHDV7mUn.] Q: Let's pause. (Recording paused.)

01:28:00 The NPS interception of large, spawning adult trout was also controversial. People made annual hikes down Bright Angel trail to catch the big fish in the fall.

01:29:00 The paper reporting the sharp decline in trout after removal efforts in Bright Angel Creek (see Minute 87) also cited a 400% increase in that area of native flannelmouth and bluehead suckers.

01:30:00 The costs of maintaining management actions for as long as needed has to be considered at the outset. Another option is to do them periodically.

01:31:00 GCMRC and AZGFD monitor the river through Grand Canyon, so any sudden increase of a given species should be detectable before it becomes a big problem. Smallmouth bass may be the next problematic species. Q: So as far as you know, there isn't an active mechanical removal program today, but it's still a possibility and may become necessary in the future?

01:32:00 A: The mechanical removal program in Bright Angel Creek is ongoing. There is also some removal in Havasu Creek. Humpback chub were translocated there, as well as to Shinumo Creek. In light of Native American concerns, the approach is to improve humpback chub population so that it can sustain a certain level of predation.

01:33:00 The brown trout management team has developed an incentivized removal program at Lees Ferry that pays "bounties" on brown trout brought in by anglers.

01:34:00 The incentivized removal program has the potential to be cheaper overall than mechanical removal.

01:35:00 Q: Are you aware of any objections by the Havasupai Tribe of mechanical removal of trout in Havasu Creek? A: Valdez is aware of concerns, but has no recent involvement in the issue. Q: Who do you think have been the most important researchers and participants in GCDAMP over time? A: Valdez says he knows more scientists than administrators or managers.

01:36:00 Dave Wegner was instrumental in bringing together scientists under GCES. The GCMRC facilitated Carl Walters' participation in GCDAMP. Walters "shook up the scientific community in Grand Canyon. Because we thought we were pretty darn good at what we were doing. Carl made us realize that we could do more, much more."

01:37:00 Walters urged GCDAMP participants to understand how adaptive management really works, and to be alert to "natural experiments that were taking place right in front of our eyes."

01:38:00 Scientists and managers must remember that conditions in Grand Canyon varied from year to year. "It was basically conducting a huge outdoor experiment over which you have little control over environmental variables." Condition dependency allowed for conducting experiments only in years when the conditions were suitable.

01:39:00 Bill Pine initiated the Near Shore Ecology Studies that broadened understanding of young humpback chub survival.

01:40:00 Pine also introduced the use of laser ablation sampling of fish inner ear bones, which can reveal in detail the life events of individual fish.

01:41:00 Lew Coggins also introduced new analytical techniques. Coggins earned his PhD under Pine and Walters, who both have strong marine fish backgrounds.

01:42:00 The study of marine fisheries involves large scales and much uncertainty, so its analytical techniques are more advanced than those used in freshwater fisheries. Coggins

developed a mark-recapture model to better estimate the numbers of humpback chub in Grand Canyon

01:43:00 Josh Korman applied his research experience with trout in Canada and Alaska to better determine how brown and rainbow trout behave in Grand Canyon.

01:44:00 Korman and Mike Yard found out that rainbow trout in Grand Canyon are late winter spawners. After hatching in spring, the fry stay in shallow, sheltered areas around Lees Ferry. A fluctuating flow dam operations scenario strands the young because they are in shallow water.

01:45:00 Young trout seek out rocky, steeper shorelines as they get older. This knowledge inspired the concept of trout management flows for regulating their population.

01:46:00 Intentionally stranding fry before they have a chance to grow and migrate downstream is an alternative to mechanical removal. Q: Has anyone tried that option yet? 01:00:00 A: Experimental trout management flows have worked to a certain degree.

01:47:00 Part of the trout population in the Lees Ferry reach was spawning not in shallow areas, but more toward the middle of the channel. Warmer releases from the dam expanded the spawning window, so there are young of different ages in the area over a longer time.

01:48:00 There may be competition for spawning areas between rainbow and brown trout. Browns spawn from October into January, and rainbows from late December to February. “I think the important message here is that, if you understand the life history of the species, it may not be a direct sledgehammer that’s the solution.”

01:49:00 That understanding illustrates the value of Walters’ and Pine’s influence. Jack Schmidt pioneered understanding of sediment distribution and the HFE concept. Schmidt has mentored many graduate students in studying Grand Canyon, including Paul Grams of GCMRC.

01:50:00 Most recently, Charles Yackulic joined GCMRC around 2010. He has an extensive ecosystem modeling background.

01:51:00 Yackulic has especially advanced understanding of the relationship between the Colorado River mainstem and the LCR for humpback chub. He coordinated work across the different Grand Canyon science disciplines for evaluating the 2016 EIS alternatives. Larry Stevens is knowledgeable in almost every aspect of Grand Canyon science.

01:52:00 Stevens has an “almost insurmountable” understanding of Grand Canyon. Steve Carothers conducted one of the first fish surveys through Grand Canyon.

01:53:00 Carothers started environmental consulting company SWCA in the 1970s. Valdez joined SWCA in the late 1980s, when Carothers got tired of competing against him for research contracts. Q: What key reports or studies would you highlight as particularly important, that have retained their value over time?

01:54:00 A: The 1996 EIS is pivotal. Glen Canyon Dam was built before NEPA (National Environmental Policy Act) compliance was a factor. The 2016 LTEMP EIS is a good archival document for GCDAMP research and management. The four reviews from the National Academy of Sciences show "evolution of thinking by scientists in the Grand Canyon."

01:55:00 The first review was done right after the natural high flows of 1983-1984. Flows through Grand Canyon peaked at almost 90,000 cfs. The National Academy of Sciences cautioned that an HFE would flush all the sediment into Lake Mead, a contention subsequent NAS reviews revised.

01:56:00 Jack Schmidt was a proponent of common-sense management policy. There are many reports and manuscripts detailing Grand Canyon Science. In his own work, Valdez is most proud of an article he co-authored in BioScience. [Schmidt, John C., Robert H. Webb, Richard A. Valdez, G. Richard Marzolf, and Lawrence E. Stevens. "Science and Values in River Restoration in the Grand Canyon: There is No Restoration or Rehabilitation Strategy That Will Improve the Status of Every Riverine Resource." BioScience 48, no. 9 (1998): 735–747. https://doi.org/10.2307/1313336.]

01:57:00 In a "wonderful conversation" that happened before the time of GCDAMP, Schmidt encouraged Valdez and his other co-authors to document what they had learned in studying Grand Canyon.

01:58:00 The paper introduced the "intractable dilemma" concept, the recognition that no single management action in Grand Canyon could simultaneously benefit all resources.

01:59:00 The idea that different conditions are available at different times of the year and management should be conducted accordingly "opened the door, beautifully, for adaptive management." Experiments are designed and continuously evaluated and adjusted over time.

02:00:00 Yackulic and others recently published a paper that nicely visualizes how humpback chub spend their lives in the Grand Canyon system. [Yackulic, Charles B., Michael D. Yard, Josh Korman, and David R. Haverbeke. "A Quantitative Life History of Endangered Humpback Chub That Spawn in the Little Colorado River: Variation in Movement, Growth, and Survival." Ecology and Evolution 4, no. 7 (2014): 1006-1018. doi:10.1002/ece3.990.]

02:01:00 Q: What do you think is the value of adaptive management in trying to manage complex resources in a environment that we can't predict or control? A: That is the most pressing question for many systems.

02:02:00 The system in Grand Canyon is similar to others in the western U.S. in that dams and diversions have fundamentally altered the ecosystem. The Colorado River ecosystem, while dynamic, had persisted over 3 to 4 million years. Evidence shows lava flows dammed the river in parts of Grand Canyon before slowly eroding.

02:03:00 It was a dynamic system long before it was subject to large-scale human influences.

02:04:00 It is unlikely that the system could be restored to its pre-human state. The components of the historical river cannot be replicated, and managers have to work with the system in its current form.

02:05:00 Ideas about how the current components might work can be expressed as hypotheses, making the system a good setting for adaptive management.

02:06:00 Surprises from nature and condition-dependent frameworks complicate experiments. "You're basically doing experimentation in a large open laboratory, with no control whatsoever, except for perhaps a large spigot called Glen Canyon Dam."

02:07:00 Now that Valdez is not as involved in GCDAMP, he finds value in the ability to look at it objectively. Mechanical removal of non-native fish was more complicated than first hypothesized. HFEs had unanticipated effects that had to be incorporated into subsequent experiments.

02:08:00 Carl Walters cautioned that experiments need to be conducted and evaluated before policy is implemented. Many GCDAMP participants have trouble understanding how long that experimentation and evaluation actually takes.

02:09:00 There are few definite answers for managers, even after over 30 years of experimentation. Ongoing involvement, and ongoing understanding of the system's dynamics, are critical.

02:10:00 Q: Will there be some point in the future when we've learned enough that we don't really need GCDAMP anymore? Or is the constant evolution and accretion of knowledge so valuable that it should be continued, at least for the foreseeable future?

02:11:00 A: Yes, it should be continued, but not simply for the sake of science. Society has decided that Grand Canyon is one of North America's most valuable resources. "It's important to maintain the Grand Canyon as well as we can, and maintain all the resources within the Grand Canyon. When it is a societal decision, and it is a societal value, I think it does rise to the level of justifying an ongoing funding of the program."

02:12:00 AMWG is a federal advisory committee under the authority of the Secretary of the Interior. This reduces complexity, especially in funding. Only the program managers can decide if paring down the budget is necessary.

02:13:00 The role of scientists in Grand Canyon is to gather information objectively, and the role of GCDAMP administrators is to facilitate science-based decision-making. Those roles are necessary to protect resources in Grand Canyon and downstream.

02:14:00 If GCDAMP were to go away, the situation might be similar to the "water wars" that happened before the Upper Colorado River Endangered Fish Recovery Program was implemented.

02:15:00 Q: What advice would you have for people coming newly into GCDAMP about how to be successful in advancing the program?

02:16:00 A: Patience and humility. New members have to realize that many people before them have been working toward the best balance of water management and protection of resources. Understanding of roles. Scientists, especially, need to understand their function in GCDAMP.

02:17:00 Humility is essential. No one person is going to be able to solve every problem.

02:18:00 Have patience with fellow stakeholders. Understand that the intent of adaptive management is to figure out how to do things better.

02:19:00 GCDAMP does well at coordinating the science. Having GCMRC under USGS means reports are easily accessible and kept current, which is not the case with all river basin programs.