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Science FINDINGS

INSIDE

"Science affects the way we think together."
Lewis Thomas

The Carp Conundrum: Science-Based Insights to Control an Invasive Fish

Crews remove carp from the Blitzen River, a tributary to Malheur Lake in eastern Oregon, and a key summer refugia for this nonnative, invasive fish that's detrimental to native species in and around the lake. Researchers developed a model to explore the efficacy of various carp control measures. Photo by James Pearson.

IN SUMMARY

Nonnative carp were spotted nearly 75 years ago in eastern Oregon's Malheur Lake and have subsequently fully colonized the lake and surrounding wetlands, compromising water quality and the growth of native aquatic vegetation eaten by resident and migratory waterfowl. Eradication efforts have proven challenging; only a few carp are needed for the population to rebound. Managers at Malheur Lake are not alone in dealing with this invasive fish; aquatic managers elsewhere in the country face similar issues.

Following a Carp Control Workshop in 2010, Jason Dunham, a researcher with the U.S. Geological Survey, assembled a team consisting of J. Ryan Bellmore, a researcher with the U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, and James Pearson, then a Ph.D. student at Oregon State University, to develop management options for controlling the carp.

Collectively they developed CarpMOD, a model that examines potential responses to alternative control measures (commercially harvesting adults, trapping juveniles, and electroshocking embryos) and passive carp removal via avian predation, to determine which measures might work best at depleting carp populations. Lower summer water levels resulting from less snowmelt may naturally cause the carp population to decline but not completely eradicate it. The modeling results indicate a combination of all methods are needed to reduce the carp population and maintain the health of the native ecosystem.

"Fish say, they have their stream and pond; but is there anything beyond."

—Rupert Brooke, English poet

When standing along the edge of Malheur Lake in eastern Oregon, visitors can see bur-reed and hardstem bulrush. Cattails also line the edge and are beginning to extend their reach into the lake's interior. Coyote willow, previously not seen in the lake for decades, now grows in the southeast corner within Briggs Bay. And more waterfowl are present than in years past. Recent visitors might think that Malheur Lake has always looked like this. And it once did—before the carp arrived more than 70 years ago.

Introduced in the early 1950s, this nonnative fish species has compromised the wildlife habitat and water quality of Malheur Lake. When searching for food, carp root along the lake floor using a suction feeding technique that captures macroinvertebrates while simultaneously expelling excess sediment into the water column. This feeding method


Carp were introduced to North America from Europe in the 1800s. This one was caught in Malheur Lake. Photo by James Pearson.


A monitoring station in Malheur Lake used for monitoring water quality and tracking carp via radio telemetry. Photo by James Pearson.

disrupts aquatic vegetation by physically uprooting it from the lake floor and significantly alters the aquatic food web. In the shallow lake (with an average depth of 2 feet), the disturbed sediment remains suspended, resulting in a perpetual state of cloudiness, or turbidity. Wind exacerbates the turbidity by creating waves that disturb the sediment, resuspending particles, and further inhibiting vegetation establishment and growth.

Sago pondweed, a submerged aquatic plant with thread-like leaves, disappeared a few years after the carp appeared; the canvasback duck population that fed on this plant subsequently declined.

"People who both lived and worked here in the '50s and '60s remembered the lake being clear and have shared their photos with me," says Dominic Bachman, an aquatic biologist with the Malheur National Wildlife Refuge. "From an airplane, you could see the bottom of the lake."

Carp have been so destructive at this vital stopover for migratory waterfowl in the Pacific Flyway that the refuge has conducted repeated eradication measures, but their efforts have only been successful in the short term.

"For decades, they have tried different approaches to control carp populations and, ultimately, all of them had been unsuccessful," says J. Ryan Bellmore, a research fish biologist with the U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. "Carp are really resilient organisms."

Carp are resilient for several reasons. They are capable of surviving in a range of environments—cold or high temperatures; high or low salinity; and murky, turbid water. A single carp can lay more than a million eggs per year, so the population quickly rebounds even if only a few individuals survive the eradication efforts. Once a carp reaches a weight of around 10 pounds, "very little can kill them at that point because they have no predators," explains James Pearson, a now supervisory fisheries biologist with the East Bay Municipal Utility District.

Malheur National Wildlife Refuge is not alone in trying to eradicate this fish. The Mississippi Interstate Cooperative Resource Association has an Invasive Carp Advisory Committee, and in the Great Lakes region, the Invasive Carp Regional Coordinating Committee focuses on control and eradication efforts. In 1962, the government of Victoria, Australia, began efforts to eradicate carp from that state, and in 2022, Australia released a National Carp Control Plan.

Tagging and modeling

In 2010, Malheur National Wildlife Refuge organized a Carp Control Workshop in Burns, Oregon. Attendees included fisheries biologists, managers, and ecologists from throughout the region. Jason Dunham, a supervisory research ecologist with the U.S. Geological Survey (USGS), Forest and Rangeland Ecosystem Science Center attended. During the discussions, he noted that only tactical solutions were proposed for controlling carp. "There was no overall strategy for looking at the consequences of different tactics," he explains. "There was little understanding about how [the tactics] interact with the dynamics of the ecosystem, especially climate change and drought."

The U.S. Fish and Wildlife Service approached Dunham to study direct control of carp, specifically, capturing carp during the winter, which is when they congregate or "school up." This control approach is used successfully in the Midwest: "They basically scoop them all up with a net. Problem solved," he says.

Dunham agreed to undertake the study and Pearson came aboard; at that time, he was a graduate student at Oregon State University, where he also worked as a student trainee biologist with USGS.

To determine where the carp schooled up, they first had to find the groups. The team first used acoustic and radio telemetry methods, which are standard approaches for tracking fish. However, complications arose. Because Malheur Lake is so shallow and large, the receivers didn't work that well and would require placing a lot of them in the lake to detect the carp as they swam by. The researchers then tried tracking the carp with radio telemetry via a low-flying aircraft, but the persistent turbidity interfered with the tracking.

Another complication unrelated to the environmental conditions of Malheur Lake

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KEY FINDINGS

- The model CarpMOD can be used to forecast the effectiveness of alternative carp control measures such as commercially harvesting adults, trapping juveniles, electroshocking embryos, and passive carp removal via avian predation.
- Controlling the carp population solely through commercial fishing for adult carp, the most common approach to controlling carp in Malheur Lake, is unlikely to achieve management objectives. However, combinations of two or all three active removal methods, and sustaining those efforts for the long term, could substantially reduce populations.
- Malheur Lake experiences cyclical fluctuations in lake size, but the lake is anticipated to shrink in the future. A smaller lake would make control measures more effective; however, drier conditions may negatively affect the native aquatic ecosystem more than the carp themselves.

arose in January 2016 when an armed militia invaded and occupied the refuge. All the refuge staff, which included Pearson, now had to work from home. With their physical access to the lake cut off, the pair pivoted to another approach to study control methods: modeling. For this, Dunham reached out to Bellmore, with whom he had worked on earlier studies, to join the project because Bellmore had previous experience building ecological models.

"With a model we have the ability to evaluate different alternatives for carp control before we invest resources in trying them on the ground," Dunham explains. "Which ones do we think are the most likely to be successful?"

"And once we identify those successful control methods," adds Bellmore, managers can "prioritize those control methods."

Pearson recalls the Harney Basin Wetlands Collaborative, whose members include the High Desert Partnership, the Burns Paiute Tribe, and Bird Alliance of Oregon, being hesitant because such an approach hadn't been attempted before in the United States. "Our partners were afraid that the model outputs would be abstract and not useful to the managers and practitioners on the ground," he explained, but eventually they gave the go-ahead, so the team moved forward.

Pearson found an existing carp population model, CarpSIM, and through his customizations, it became CarpMOD; conversations with researchers from Australia, New Zealand, and other regions of the United States helped inform the modeling approach. Additionally, a 3-day workshop organized by the High Desert Partnership, a Harney County-based multidisciplinary collaborative, brought all the collaborators and partners together to discuss their long-term visions and desired management approaches for Malheur Lake.

"People had a lot of great ideas, one of which was carp control, and another was developing windbreaks or putting gravel on the lake bottom, so the sediment doesn't resuspend so easily," Dunham explains.

Pearson took these ideas back to the lab to build the model. The model eventually incorporated data on both the physical characteristics of Malheur Lake and the carp population dynamics, such as the fluctuations in food availability that affect the numbers of juveniles and how adult carp self-suppress the density of juveniles, whether by outcompeting them for food resources or reduction in spawning efficiency via spawning superimposition (multiple females laying eggs in the same location).

The four control methods he added to the model spanned the life cycle of the carp. Years earlier, the refuge explored the feasibility of harvesting adult carp for use in commercial products, such as dog food, fertilizer, or fresh fish for human consumption, which is done in the Midwest. A crew from the Midwest was invited to harvest the carp, but their catch was limited because their watercraft had difficulty navigating the shallow lake. When the carp were turned into a liquid fertilizer that was sprayed onto nearby agricultural fields, their scales clogged sprayers so that avenue was abandoned.

Although this trial wasn't successful, the refuge still wanted to model the effects of a commercial harvest of adults. After observing staff catching juveniles in nets with some success, Pearson added this method to the model. Egg and embryo electroshocking had also been recently tested via a small research project on the refuge with some success, and staff wondered if it would be successful when scaled up. While on-the-ground research was being conducted, Pearson added that option to the model.

A fourth control method, avian predation, was added to the model because collaborators had shared observations of pelicans, terns, and cormorants eating the carp.

A threshold of 50 kilograms per hectare of carp (or roughly 9 carp per acre if the adults weigh 5 pounds) was set as the target. Based on previous studies, this would allow the lake ecosystem to recover and return to a clear water state.

"There was an understanding from the beginning that we're never going to get rid of these things entirely," Bellmore explains. "However, can we keep them at a level we think could facilitate ecological recovery of the system?"

The simulations showed that no single control method would suppress and maintain the carp population to the target threshold, but a combination of all three active control methods might. "Just removing the adults is not enough," says Bellmore. "You also need to target multiple life stages. Potentially, if managers can hit the eggs, the juveniles, and


Malheur National Wildlife Refuge. Photo by Mary - stock.adobe.com.

LAND MANAGEMENT IMPLICATIONS

- CarpMOD is applicable to other shallow lakes across the globe for anticipating long-term carp-population responses to removal efforts and changing environmental conditions.
- The timing of removal efforts is important. Taking advantage of low lake levels when carp are more concentrated and easier to remove is likely to be the most effective time to reduce the population.
- A clear water state may not be achieved solely by removing carp. Other means of restoring Malheur Lake, such as installing artificial levees to negate the wind's deleterious effects, may be warranted.

the adults all at the same time, that's where you might be able to get the population down."

One of the results that Pearson found interesting (or counterintuitive) is that "removing the adults can increase the juvenile population's growth potential, creating an ecological ticking time bomb," he says. "If you don't maintain that suppression year after year, that juvenile population just explodes because they now have available habitat to grow."

The results also suggested that it's not feasible to implement these active control measures in perpetuity. "That's why we had to start thinking outside the box," Pearson adds. And that was the impetus for another modeling exercise.

Lower water levels may help

Malheur Lake is actually a wetland—one of the largest in North America. Its size has fluctuated throughout the decades, in part, mirroring snow melt from the neighboring Steens and Blue Mountains that is conveyed by the Silvies River and the Donner und Blitzen River. For instance, in 1984, the lake reached 129,535 acres, whereas in 1993, it shrank to less than 1,359 acres. This leaves two options for the carp: either remain in the lake where they will eventually become stranded and die or seek refuge in one of the rivers.

The amount of precipitation in the form of snow is expected to decline in the coming decades, which will result in less runoff to Malheur Lake.

"Drought can be your friend in terms of controlling carp," Dunham says. "Adding a realistic set of climate scenarios on top of an invasive species removal effort is [useful] because it's a long-term effort."

The team wanted to see if targeting removal methods at a given water level would be helpful for managers. Within CarpMod, Pearson built a hydrologic model using satellite imagery of the lake between 1938 and 2018, in combination with annual snow levels, to run scenarios of how carp populations responded to historical changes in lake size—which varied from completely dry to more than 127,250 acres. He then modeled the potential effects of carp removal efforts when the lake was large and small.

As expected, carp populations declined as the lake area shrank. Removing carp when the lake was less than 2,470 acres proved as effective as annually removing carp. However, a smaller lake may make it more difficult to navigate to remove the carp. It also means less habitat for the waterfowl, aquatic plants, and other organisms that depend on the lake.

Bellmore cautions that passively waiting for the lake to shrink is not a realistic control measure; "Overall, we're still in a situation where we're not getting below that 50 kilogram-per-hectare carp threshold as often as we would like."

Making peace with carp?

At the end of the study, Harney Basin Wetlands Collaborative accepted the modeling approach, and Dunham says that "they felt like those models were their models, as well as James's."

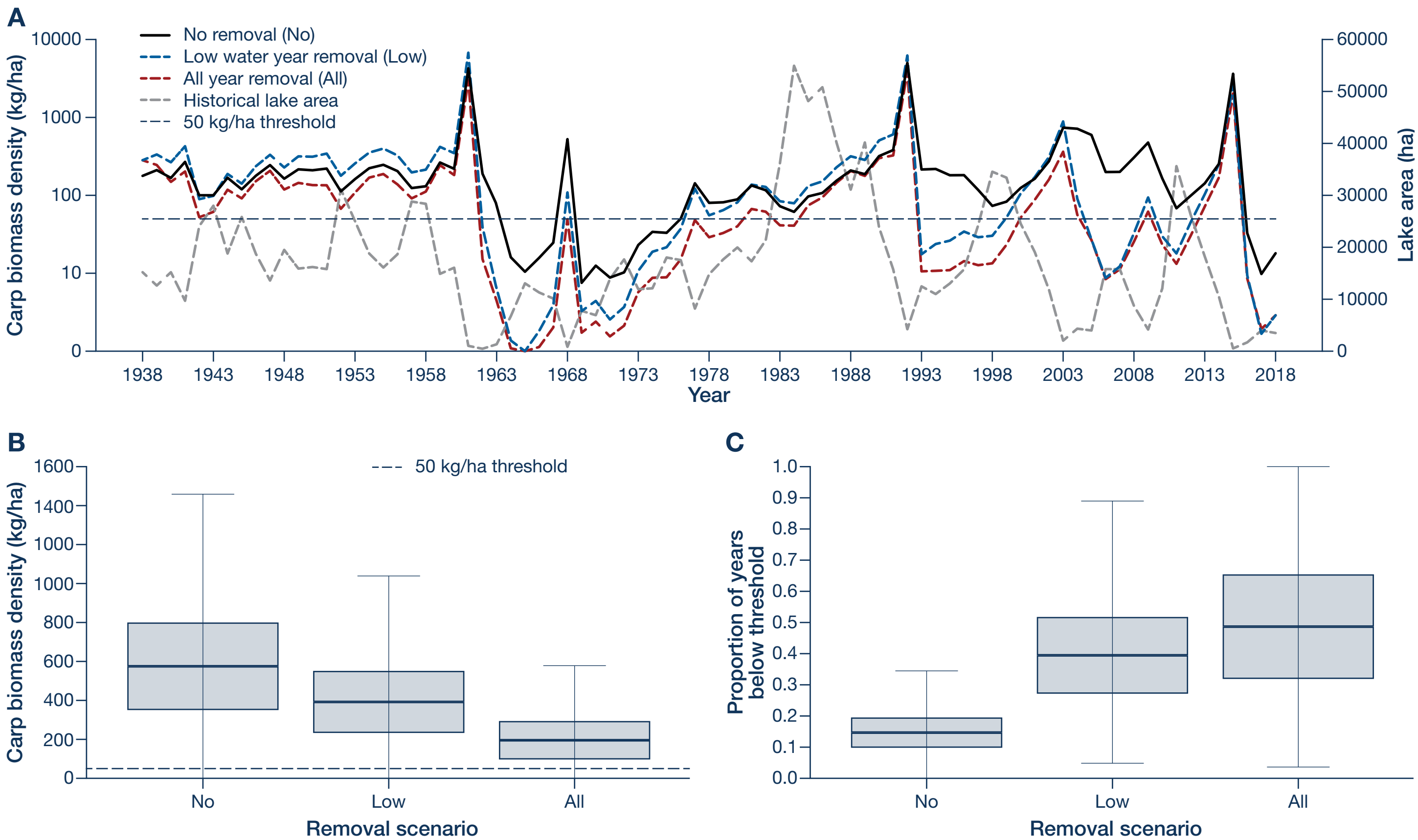
"People gained a durable appreciation of the full range of ecosystem processes that can contribute to a turbid water state in that system and they're more aware of a broader range of alternatives to meet their objectives," he says.

One element of this work that Dunham raises is that despite targeted eradication measures, carp may never be totally removed from the system. The key is then determining the threshold where, despite the presence of carp, the lake can retain native ecosystem processes.

By happenstance, drought from 2021 to 2024 enhanced a concerted effort in 2022 by refuge

Malheur Lake's levels fluctuate depending on the amount of snowmelt conveyed by the Silvies River and the Donner und Blitzen River. The lake is a crucial stop along the Pacific Flyway for migratory birds. Adapted from Pearson et al. (2022).

Malheur Lake, Oregon. Photo by James Pearson.



Modeling suggests that pairing carp removal efforts when the lake level is low can make the control more effective and reduce the carp population to the target level (50 kilograms per hectare, or roughly 9 carp per acre if the adults weigh 5 pounds). Using at least two of three active methods of control (commercially harvesting adults, trapping juveniles, electroshocking embryos) is also key. Adapted from Pearson et al. (2022).

staff and volunteers to remove about 44 tons of carp by hand. This was most of the carp in the system, and it gave the ecosystem a chance to recover.

Cattails, hardstem bulrush, and bur-reed grew back so thick that Bachman, the aquatic biologist with the refuge, says the carp will have difficulty uprooting the plants. Submergent vegetation such as sago pondweed and widgeongrass also returned. Redband trout and redside shiners that reside upstream in the rivers have been spotted swimming in the wetlands surrounding Malheur Lake.

"A significant portion of the wetland has actually recovered," Bachman explains. "It's still not back to a clear water state, but it is a really massive recovery, which is also benefiting millions of birds."

As Malheur Lake recovers, CarpMod may need to be updated to include information on the current physical characteristics of Malheur Lake and the carp population dynamics. But because of the team's due diligence to include these variables at the onset, the model will remain useful to address shifting environmental conditions and future management questions.

"This research illustrates that ecological modeling, when done collaboratively and transparently with partners, can inform on-the-ground decision making in ways that lead to beneficial outcomes," says Bellmore. "Making sure that decision makers are part of the modeling process from the beginning is critical to success."

"Unless man has a natural bent in accordance with nature's, he has no chance of understanding nature at all."

—Charles Sanders Peirce, American scientist

Writer's Profile

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For Further Reading

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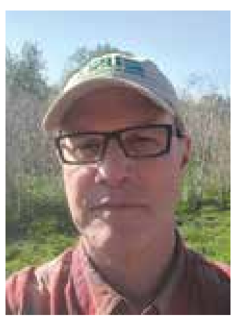

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