Great Lakes Fishery Commission

# FORUM

FOR STEWARDSHIP AND SUSTAINED BENEFITS

Fall 2000

# Using Migratory and Sex Pheromones to Manipulate Sea Lamprey

Photo: Weiming Li


Dr. Li's two-choice maze used to examine the behavioral responses of adult sea lamprey to pheromones (top). The above figure illustrates the design of the device.

**Dr. Peter Sorensen and Dr. Weiming Li have embarked on a course of study that could one day change the way sea lampreys are controlled in the Great Lakes.**

**by Heather Glock**

OVER A DECADE AGO, as a young assistant professor, Dr. Peter Sorensen opened a journal article and noted that the nose of a sea lamprey is bigger than its brain. To most people, that fact would be merely curious. To Dr. Sorensen and his former Ph.D. student, Weiming Li—two scientists devoted to studying the sense of smell in fish—that observation suggested that lamprey heavily rely on water-borne odors for such things as finding host fish, spawning streams, and ultimately mates. Drs. Sorensen and Li found that olfactory cues, or odors, can be powerful in determining sea lamprey behavior and thus can be exploited for use in lamprey control. They reasoned that if this species utilized pheromones (specific and potent chemical signals that pass between members of the same species), these cues might be identified, synthesized, and released into rivers to manipulate lamprey behavior.

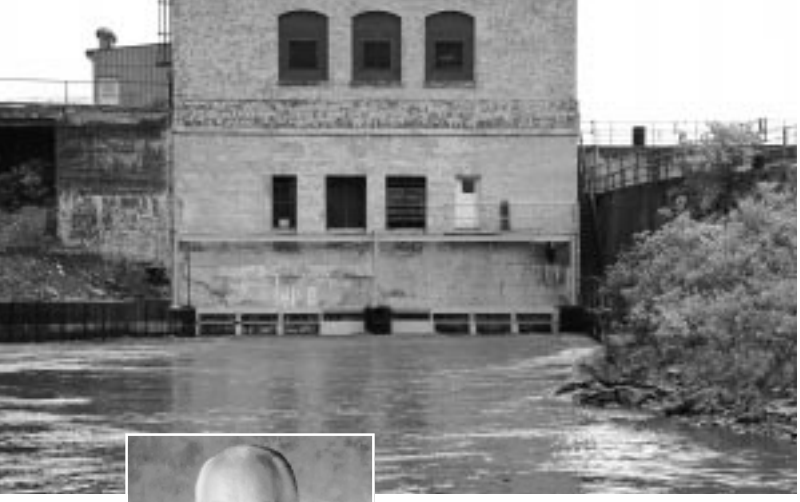
Dr. Sorensen, who is with the University of Minnesota, and Dr. Weiming Li, who is now with Michigan State University, have embarked on a course of study that could one day change the way sea lampreys are controlled in the Great Lakes. Their work could provide the Great Lakes Fishery Commission and its agents with the tools to move away from lampricides and toward an alternative control technique that uses pheromones to redirect lamprey movement and behavior to both increase captures and prevent successful sea lamprey spawning.

## Reducing Lampricides

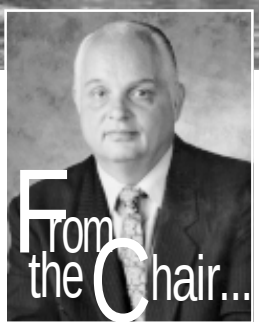
Any person who has fished the Great Lakes knows that the exotic sea lamprey is more than just a pest, it is devastating to a fishery valued at billions of dollars and it has dramatically changed the nature of the fish community. Fortunately, biologists have been successful in driving down sea lamprey populations in the Great Lakes. Primarily through the use of the lampricide TFM, and with the help of other techniques such as traps, barriers, and the sterile-male-release-technique, lamprey populations have been reduced by 90%.

Despite the success of TFM, the commission is reducing its use by half, largely because TFM

**PHEROMONES,** CONTINUED ON PAGE 6



The U.S. Army Corps of Engineers houses a major sea lamprey trap at the Soo Locks in Sault Ste. Marie, MI.




## GLFC and Corps of Engineers Collaborate on Fisheries

**Bernie Hansen**

When you think of the Army Corps of Engineers, the Soo Locks, dredging, or shipping canals usually come to mind. Indeed, the Corps has a long and successful history of aiding navigation in the Great Lakes region. What is perhaps less known is the Corps' involvement in protecting the Great Lakes fishery, an activity that has been strengthened through a partnership with the Great Lakes Fishery Commission. It is the Corps' expertise in such areas as barrier construction and trap design that the commission finds most valuable, as it strives to realize its goal to reduce the use of lampricides.

Sea lamprey barriers are a tested and true method to control sea lampreys in the Great Lakes. Low-head barriers prevent sea lampreys from reaching their spawning grounds while still allowing other fish to migrate upstream. Once a barrier is built in a sea lamprey-producing stream, it is no longer necessary to treat upstream of the barrier with lampricides. Traditionally, the commission has designed the barriers and contracted the construction to others. Now, thanks to new legislation passed in 1999 (The *Water Resources Development Act*), the Corps will partner with the commission to design *and* construct those barriers. The advantages of this partnership are enormous. Not only does this legislation help the commission leverage funds, but it also allows us to draw upon the Corps' considerable expertise in barrier construction.

The Corps' partnership with the commission has also been pivotal to the control of sea lampreys in the St. Marys River, a major challenge for the commission. Until very recently, the St. Marys River produced more sea lampreys than all of the Great Lakes combined. Two major elements of control on the St. Marys River are traps and the sterile-male-release-technique. Sea lamprey traps can remove spawning sea lampreys from the system and serve as a source of males for the sterile-male-release-technique. Permanent traps constructed by the Corps and located at the Corps' facility at the locks provide the commission with thousands of sea lampreys for use in the successful sterile-male-release-technique.

The Great Lakes Fishery Commission is pleased to partner with the Corps on critical fisheries protection projects in the Great Lakes region. With the Corps' help, we can improve sea lamprey control, reduce lampricides, and facilitate the passage of desirable spawning fish in our tributaries, all with the goal of protecting our resources long into the future. ≈

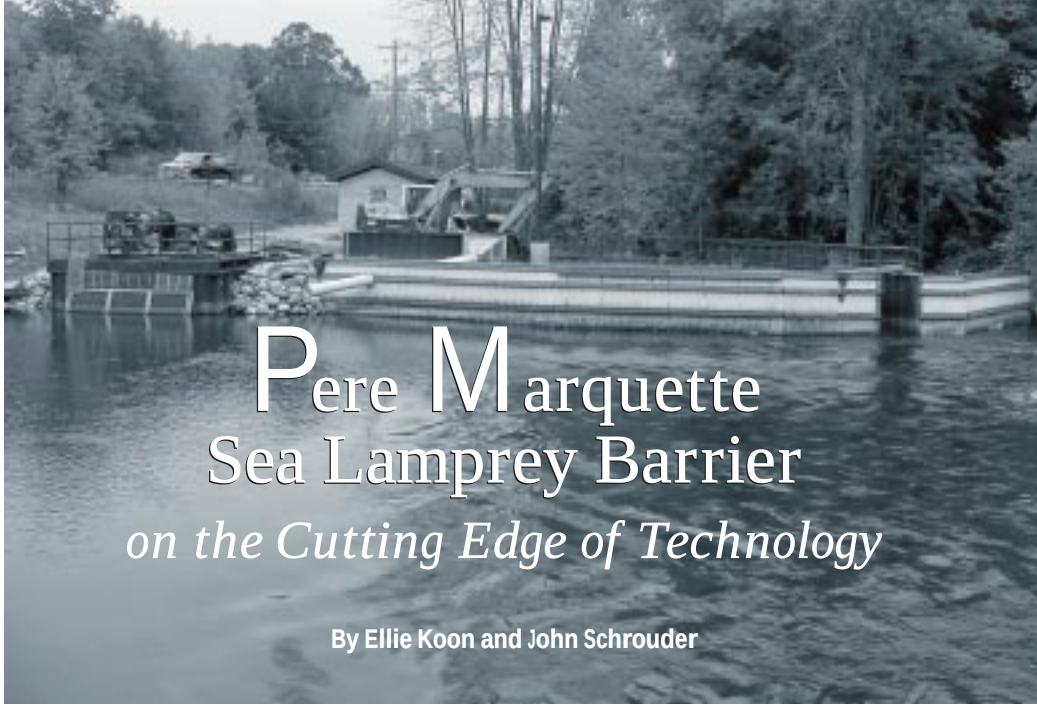
## Krueger Joins GLFC Secretariat

The GLFC welcomed Dr. Charles Krueger to the secretariat in September, 2000. Dr. Krueger, former GLFC chairman and professor of fisheries at Cornell University, became the new senior scientist, replacing Randy Eshenroder, who retired earlier this year. As senior scientist, Dr. Krueger will be responsible for coordinating Great Lakes fisheries research, in accordance with the *Convention on Great Lakes Fisheries*. Dr. Krueger will retain an adjunct appointment at Cornell University and a term appointment at Michigan State University. "Dr. Krueger is a world-class research scientist," said GLFC chairman Bernie Hansen. "Krueger has a long history of dedicated work to the Great Lakes fishery and to the commission. We are fortunate to have him on board." ≈

Doug Dodge (left) receives a certificate of recognition from commissioner Burton Ayles.

## Commission Honors Doug Dodge Upon His Retirement

During the GLFC's 2000 annual meeting in Duluth, Dr. Doug Dodge was honored for 30 years of exemplary service to the Great Lakes. His outstanding contributions on behalf of Great Lakes fish and fish habitat are commendable. During his career in government service at the Ontario Ministry of Natural Resources, he was a longtime member of the IJC's Water Quality Board where he ensured the quality of water for Great Lakes' species. Dr. Dodge was also a member and chairman of the Habitat Advisory Board for the commission. His earnest interest in fish and their habitat, combined with his dedication, has left a lasting legacy that will be valued by future generations. The commission wishes him the best in his retirement. ≈



# Pere Marquette Sea Lamprey Barrier

## *on the Cutting Edge of Technology*

**By Ellie Koon and John Schrouder**

Over forty years ago, on Michigan's Pere Marquette River, biologists experimented with their first attempts to control the sea lamprey. Back then, sea lamprey experts had few tools to control the destructive pest, relying mostly on crude AC electrical barriers to prevent lampreys from reaching their spawning grounds. Although the old AC electrical barriers blocked sea lampreys, they also blocked the upstream migration of desirable fish, zapped wildlife, and shorted-out frequently. It did not take long for biologists to abandon the Pere Marquette's first electrical barrier and opt instead for a control effort that used the lampricide TFM.

Today, the U.S. Fish and Wildlife Service and the State of Michigan are testing a new and improved DC electrical sea lamprey barrier on the Pere Marquette River (PM). The new barrier uses state-of-the-art technology to block upstream migration of sea lampreys while attracting desirable fish into a fishway, while not impounding water or blocking the flow of the river. The new barrier went into operation in early 2000 and has worked successfully throughout the year. All indications are that this new barrier design will represent the future of sea lamprey barriers in the Great Lakes.

### The Pere Marquette: A Very Productive Sea Lamprey Stream

The PM is one of the Great Lakes' most productive sea lamprey streams, and without sea lamprey control, it would produce tens of thousands of sea lampreys annually. Clearly, sea lamprey control on the PM is a top priority if we want to protect our fishery. The PM is also one of Michigan's most popular streams for anglers and recreational users, so a primary goal for biologists is to make sea lamprey control as unobtrusive as possible.

Barriers in use today prevent sea lampreys from accessing reproductive habitat in Great Lakes tributaries at a fraction of the cost of a typical lampricide treatment. A top priority is to stop lampreys while not blocking the passage of other fish. To reduce the impacts on fish passage, sea lamprey control agents have invested in the design and operation of a new DC electrical barrier on the PM that operates only during the spring lamprey migration.

A new high-tech sea lamprey barrier on the Pere Marquette uses electricity to repel sea lampreys and a fish passage device to pass desirable fish while trapping lampreys. The barrier does not block the flow of the stream.

Photos: USFWS

### Learning From the Past to Improve Our Future

The first electrical barrier method used to control sea lampreys on the PM was costly and ineffective because of inadequate design. The new electrical barrier design applies lessons learned from the past by allowing fish to get around the barrier, while blocking the destructive sea lamprey.

The new barrier on the PM is built into the streambed of the river and as a result does not block the natural flow of the stream or impound water. The barrier has a grid on the stream bottom with an increasing electrical field that works by repelling lampreys and fish, not zapping them as with the old AC electrical barrier. It is augmented with a state-of-the-art fish passage device that contains a pump to create an attractant stream. The fish remain blocked by the electrical current until they find the fish passageway to get around the electrical current. The passageway is designed to allow desirable fish to leap over a series of false weirs to get upstream while capturing sea lamprey.

The revised design of the PM barrier is the first time that the U.S. Fish and Wildlife Service has used a combination of an electrical barrier and a pumped passageway in the Great Lakes to get fish around the barrier. Observations confirmed that the new barrier design is successful. The barrier denied lampreys upstream migration while allowing steelhead and other desirable fish to enter the fishway and successfully pass to spawning grounds upstream. Researchers at Michigan State University are conducting further evaluations of the effectiveness of the barrier. Their evaluation will serve as a means to formulate modifications to the barrier to make it even more effective in passing sport fish upstream.

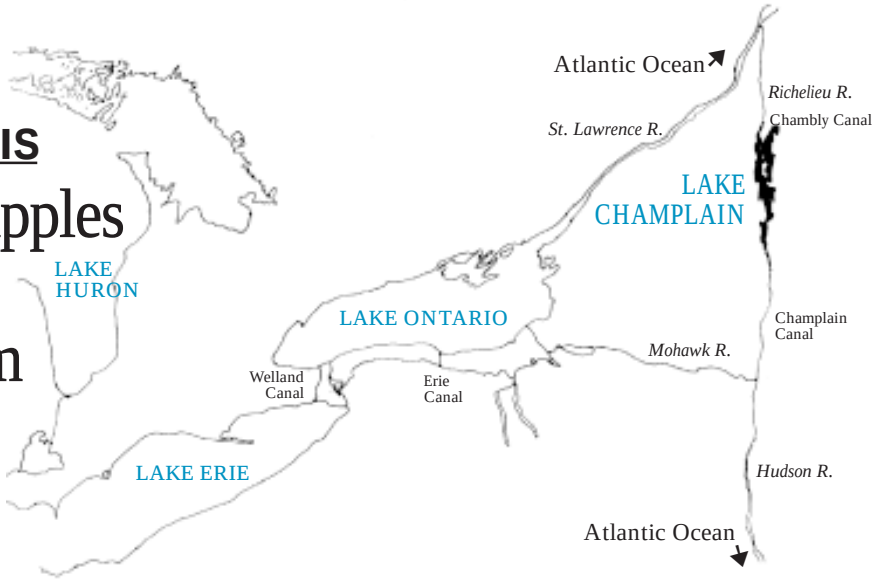
Sea lamprey experts have been battling the pest for more than forty years and will continue to pursue alternative control techniques. Barriers, such as the one on the PM, are a step in the right direction. Some sea lampreys may spawn below the barrier, but the reduced numbers of lamprey makes it easier and far less expensive to deal with the PM's lamprey problem. ≈

Ellie Koon is the barrier coordinator for the U.S. Fish & Wildlife Service. John Schrouder is the fisheries field coordinator for the Michigan Dept. of Natural Resources.

## OUR COMMON NEMESIS

# Lake Champlain Grapples with Its Own Sea Lamprey Problem

**Abstracted from a forthcoming article entitled "Sea Lamprey Control in Lake Champlain" by J. E. Marsden, J. K. Anderson, W. Bouffard, B. D. Chipman, L. E. Durfey, J. E. Gersmehl, L. J. Nashett, W. F. Schoch, N. R. Staats, and A. Zerrenner**




**Today, Lake Champlain is at a crossroads: after an experimental effort to control sea lampreys, and through a close relationship with lamprey control specialists in the Great Lakes region, biologists in Lake Champlain now have the opportunity to formulate an integrated pest management program that suppresses sea lampreys while protecting the fishery now and for the future.**

BENEATH THE PICTURESQUE WATERS of Lake Champlain lurks the sea lamprey, a notorious predator the people of the Great Lakes know all too well. The sea lamprey, the Great Lakes' most noxious pest, has a lengthy and equally horrendous reputation in Lake Champlain as the exotic nuisance limiting the health of an otherwise vibrant fishery.

Wayne Bouffard, a biological technician with the U.S. Fish and Wildlife Service, measures sea lampreys in Lake Champlain to assess the status of the spawning population.

Photo: USFWS

### Sea Lampreys in Lake Champlain

Lake Champlain is a long, narrow lake that lies between New York and Vermont, extending northward into Quebec. The lake has a surface area of 1,127 km$^2$, about the same as Lake St. Clair. Lake Champlain contains a diverse fish community, similar to that of the Great Lakes, which includes lake trout, Atlantic salmon, rainbow trout, brown trout, lake whitefish, yellow perch, walleye, bass, and sturgeon. Like the Great Lakes, Lake Champlain supports a thriving sport fishery; unlike the Great Lakes, there is no traditional commercial fishery on the lake.

Unfortunately, Lake Champlain and the Great Lakes share another member of the fish community: the sea lamprey. As in the Great Lakes, sea lampreys and other problems have stressed the fish community and reduced sport-fishing benefits. In Lake Champlain, the presence of sea lampreys substantially inhibited efforts to rebuild salmonid populations and fisheries that had been extirpated by overfishing, the construction of mill dams on spawning tributaries, and environmental degredation in the 1800s. For example, in the worst hit areas, 87-100% of the fish surveyed exhibited sea lamprey wounds. To make matters worse, Lake Champlain, despite its small size, has an inordinately large number of tributaries (over 100 permanent streams), creating ample habitat for a constant barrage of sea lampreys into the lake. Because a high potential for sea lamprey production is concentrated in a small volume of water, sea lampreys can easily overwhelm the fish in Lake Champlain.

The origin of sea lampreys in Lake Champlain has long been a topic of debate. Some researchers suggest that sea lamprey are native to Lake Champlain, based largely on the absence of effective barriers to block their migration into the lake. Most conclude, however, that sea lampreys invaded the lake more recently either from the Hudson River via the Champlain Canal, opened in 1823, or from the Richelieu River via the Chambly Canal, opened in 1843. By 1929 there was no doubt—sea lampreys were reported to be moderately common.

### Improving the Lake Champlain Fishery

Joint efforts to improve fisheries in Lake Champlain began in 1973 with the formation of the Lake Champlain Fish and Wildlife Management Cooperative, composed of the U.S. Fish and Wildlife Service, Vermont Department of Fish and Wildlife, and the New York State Department of Environmental Conservation. These agencies have worked diligently to sustain and rehabilitate the aquatic ecosystem in Lake Champlain. The long-term goals of this cooperative effort includes habitat restoration, stocking, and sea lamprey control.

Sea lamprey control on Lake Champlain —though critical to the success of the fishery—so far has been strictly experimental. In 1990, the Lake Champlain Management Cooperative initiated an eight-year program of sea lamprey control based on the use of the lampricides TFM and granular Bayluscide, though the effectiveness of alternative techniques—including barriers and traps—was also considered. This first round of sea lamprey control concluded in 1997 and future sea lamprey control efforts will depend on the results of a program evaluation and the preparation of an Environmental Impact Statement.

One thing is clear, the experimental program of sea lamprey control on Lake Champlain was successful. Spawning-phase sea lampreys declined by 80–90% from 1989–1997, estimated angler catch of lake trout increased by 76%, and returns of Atlantic salmon to tributaries increased significantly. All told, sea lamprey control facilitated a 3-fold increase in economic returns to the Lake Champlain sport fishery.

### The Future of Sea Lamprey Control

Biologists from the Great Lakes and Lake Champlain have a long history of cooperation on lamprey issues. Lessons from the successful sea lamprey control program on the Great Lakes suggest that Lake Champlain would benefit from an integrated effort that uses lampricides and non-chemical control techniques. Lampricides have proven effective in Lake Champlain with minimal impact on non-target species. Managers in Lake Champlain are also taking a look at the alternative techniques that have worked so well in the Great Lakes. Sea lamprey barriers that allow passage of migrating fish may be useful on some streams, and in a few small streams, trapping may provide adequate control. Research into the use of pheromones as attractors for spawning sea lamprey could be conducted on a number of small tributaries in the basin. Application of other techniques such as sterile-male-release will be considered if future research demonstrates their efficacy.

The Great Lakes sea lamprey control program benefits from the work in Lake Champlain as well. Many sea lamprey-laden streams in the Lake Champlain basin have never been treated to remove lamprey larvae. Research funded by the Great Lakes Fishery Commission is allowing biologists to acquire critical information about changes in sea lamprey growth and age at maturation in these streams before and after a first treatment. Very little such research was carried out prior to and after the first sea lamprey treatment in the Great Lakes region.

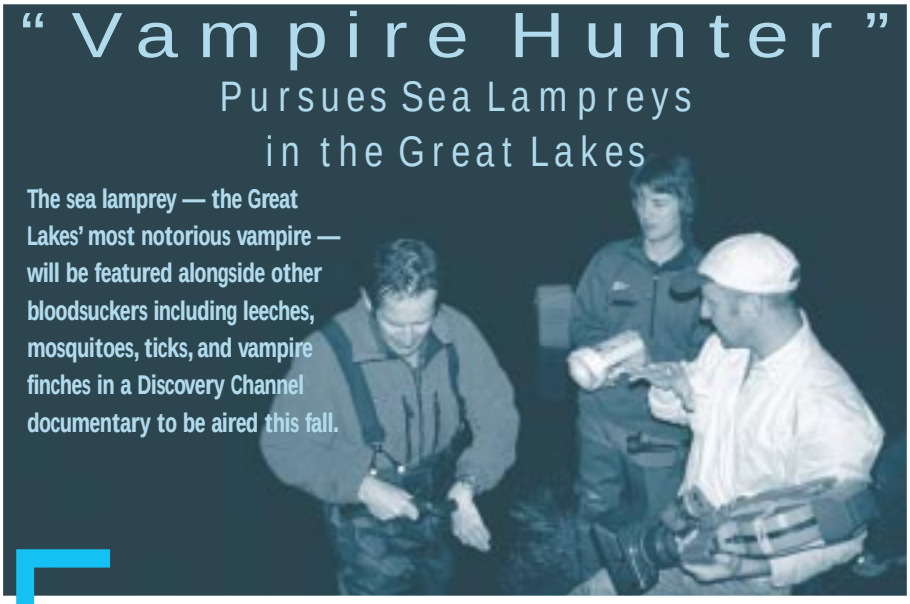
Lake Champlain and the Great Lakes have much in common. The high level of cooperation that exists between managers in both regions has been and will continue to be instrumental in the protection of valuable fish communities. ≈

The authors are affiliated with federal, state, and academic institutions interested in the health of the Lake Champlain fishery.

# "Vampire Hunter"

## Pursues Sea Lampreys in the Great Lakes

**The sea lamprey — the Great Lakes' most notorious vampire — will be featured alongside other bloodsuckers including leeches, mosquitoes, ticks, and vampire finches in a Discovery Channel documentary to be aired this fall.**



Nigel Marven (left), cameraman Gavin Thurston, and producer Colin Collis film a nighttime scene on the Trout River.

**by Heather Glock and Marc Gaden**

FILM PRODUCER Nigel Marven is no stranger to the world's fierce creatures. As the star in wildlife television features around the globe, Marven has found himself face-to-face with grizzly bears, skulking with komodo dragons, wrapped in anacondas, and swimming (uncaged!) with sharks. And when he searched the world to produce a Discovery Channel program about blood sucking animals, the Great Lakes' sea lamprey was a natural.

In late May, Marven and his film crew traveled from the United Kingdom to Rogers City, MI and Sault Ste. Marie, Ontario to film the sea lamprey portion of this television feature. "I became interested in this story not only because lampreys have a 'face for television' but also because their impact on the environment and the people of the Great Lakes has been severe," said Marven. Lampreys have had a devastating impact on fish populations since they were accidentally introduced into the Great Lakes through shipping canals in the early 20th century.

Considering the film crew needed to shoot approximately 40 minutes of film for every minute used in the final production, they spent a significant amount of time filming the lampreys and learning about the sea lamprey control program.

The blood feeding sea lamprey will be included in a show on the Discovery Channel entitled "Bloodsuckers, with Nigel Marven." It will be broadcast this fall in the U.S. The date to air in Canada is yet to be announced. The show promises spectacular travel sequences and fascinating encounters with blood feeding creatures, so be sure to tune in. You don't want to miss it! ≈

Nigel Marven (right) and his crew film sea lamprey spawning nests in the Trout River near Rogers City, MI (below). The crew observes the impact that a parasitic sea lamprey has on lake trout and whitefish after the lamprey has fed on its blood (right).



Photos: GLFC

is expensive and because any sound pest management program uses several techniques together to achieve its goals. To add to the lampricide reduction challenge, a cut in TFM must not result in a reduction in sea lamprey control.

Today, Drs. Sorensen and Li are on the cutting edge of sea lamprey control and fish pheromone research. Through their respective research, they have zeroed in on a handful of naturally occurring pheromones which they believe are a key to the lamprey spawning cycle.

Studies of the sea lamprey sense of smell have clearly demonstrated that adult lampreys, like many migratory fish, rely on water-borne pheromones to locate spawning streams. Sorensen and Li have identified two types of cues: a migratory attractant released by larvae and a sex pheromone released by mature males. Sorensen and his colleagues have revealed that the larval pheromone is so important to the life of lamprey that if the nostrils of migratory adults are blocked, they fail to find spawning streams. Similarly, the sex pheromone appears to be quite potent in attracting mature females. Thus, these naturally occurring cues could be used to lure lamprey into traps or into streams that are not suitable for reproduction. This would supply more males for the sterile-male-release program and reduce the need to treat rivers with TFM.

"Pheromones could be the future for sea lamprey control," said Dr. Chris Goddard, Executive Secretary of the Great Lakes Fishery Commission. "We are so confident in the work of Drs. Sorensen and Li that the commission wholeheartedly supports their research."

### Dr. Sorensen: Identifying Larval-Emitted Pheromones

Through the support of the Great Lakes Fishery Commission, Dr. Sorensen and his students have made great advances during the past ten years in understanding how adult sea lampreys use migratory pheromones secreted by larval sea lampreys to locate rivers and streams for spawning. Their research has led to a fundamental understanding of the lamprey migratory pheromone, the identity of its principal components, and the knowledge of how the pheromone affects sea lamprey behavior.

Photo: GLFC

Dr. Peter Sorensen (middle) and student researchers Jared Fine (left) and Lance Vrieze of the University of Minnesota, explore the role of migratory pheromones on sea lamprey behavior.

**...it is not far-fetched to think about using these pheromones in spawning streams to disrupt the natural chemical communications among spawning individuals.**

Two key elements of the pheromone have been identified, synthesized, and measured in river waters. They are unique bile acids produced only by lamprey and are detected by the lamprey olfactory system at minute concentrations. The search is now on to identify an additional unknown component of this cue. Field trials are planned to explore how pheromone additions to streams might be instituted most effectively.

"Odors appear to be almost everything to migrating sea lamprey," said Dr. Sorensen. "In fact, their reliance on this sensory system may be one of the greatest among the fishes and this can be exploited to our advantage." Adult sea lampreys depend on their keen sense of smell to locate and then migrate up spawning streams. "The lamprey is guided by trace amounts of unique, environmentally safe pheromones which we should be able to synthesize and add into streams. Pheromones are a new tool with which to exploit an important dimension of this species' biology," he added.

### Dr. Li: Discovering Adult Male Sex Attractants

Dr. Weiming Li has focused his research on another attractant: a pheromone secreted by adult male sea lampreys to attract spawning females. Sexually mature female sea lampreys are strongly attracted to the potent odor secreted by male sea lampreys. Dr. Li set out to identify that attractant so that it could one day be synthesized and used as another tool to manipulate sea lamprey behavior. Dr. Li serves as a Partnership for Ecosystem Research and Management (PERM) scientist at Michigan State University, a program partially funded by the Great Lakes Fishery Commission.

During Dr. Li's research trials—carried out using a two-choice maze design—sexually mature males emitted an odor that induced mature females to heighten their search for a mate. The searching activities ultimately led the females to the source of the odorant, the mature males.

"The odor emitted by the sexually mature male is indeed a pheromone that modifies the behavior of adult females," said Dr. Li. "These results indicate that the male sex pheromone could be used to influence the behavior of adult females in their natural habitat. We believe this knowledge could be a potent tool in the lamprey control arsenal."

### The Future

"The potential use of the current pheromone research is exciting," said Commissioner Roy Stein of Ohio State University. "The Great Lakes Fishery Commission sees tremendous opportunity to manipulate sea lampreys during their spawning phase. Right now, it is not far-fetched to think about using these pheromones in spawning streams to disrupt the natural chemical communications among spawning individuals. We could use lamprey attractants to trick them into spawning in areas that are not optimal for their reproduction. We could use these attractants to lure lampreys into traps."

Stein continued: "Above all, the work of Drs. Sorensen and Li may one day allow the commission to significantly reduce the use of lampricides while still maintaining effective sea lamprey control. More than a decade ago, we set out under our *Strategic Vision for the Decade of the 1990s* to reduce lampricide by 50%. Careful application of migratory and sex pheromones may become a valuable and environmentally friendly tool in the integrated management of sea lamprey. We are excited about what the future holds." ≈

Heather Glock is an intern at the GLFC.

# Protecting Mudpuppies, Protecting Stream Ecosystems

**By Gavin Christie**

THE HEALTH OF FISH COMMUNITIES in the Great Lakes depends on the success of sea lamprey control. But that success cannot come at the expense of the health of the streams and rivers entering the lakes. Therefore, sea lamprey control agents make every effort to protect even the most sensitive of creatures during sea lamprey treatments.

Among the most mysterious and fascinating creatures inhabiting the Great Lakes and their tributaries is the mudpuppy (*Necturus maculosus*). This primitive amphibian is the largest species of salamander living in the region, growing to about a foot (25-30 cm) long. During the day, they hide under rocks or in weeds. At night they feed on crayfish, worms, small fish, and insects. Unlike other amphibians, the mudpuppy spends its entire life in the water without metamorphosing to live on land.

In the Great Lakes region, studies are underway to monitor the status of amphibians, including the mudpuppy. While there is very little direct information about the status of the mudpuppy, they are widely observed around the Great Lakes. Mudpuppies are often found in streams where sea lamprey larvae are found, which puts them into contact with sea lamprey control efforts, particularly stream treatments and the lampricide TFM. While most species of fish and animals are not sensitive to TFM at the concentrations applied to streams, the primitive mudpuppy is more sensitive than most. This sensitivity means that sea lamprey control agents must take special precautions to ensure that TFM causes minimal impact on mudpuppies, while still killing the maximum number of sea lampreys in a stream. By protecting this sensitive animal, biologists protect the entire stream ecosystem.

### TFM: A Selective Lampricide

Sea lampreys live for many years in Great Lakes streams as larvae before they transform into parasitic adults and migrate to the open waters to prey on fish. It is during that larval stage that sea lampreys are vulnerable to the lampricide TFM. As larval sea lampreys take several years to mature in a stream, the stream only needs to be treated about once every 3-6 years.

The key to a successful TFM application is to apply the lampricide at exactly the concentration necessary to kill larval sea lampreys while not affecting other organisms. Prior to and during each TFM application, sea lamprey control agents conduct a thorough assessment of the water chemistry and flow in a river to determine just how much TFM should be used to maximize sea lamprey removal and minimize or eliminate non-target mortality. This work ensures that non-target mortality is very small, with only a few of the weakest individuals of any species being affected. This work is painstaking but critical to the success of the treatment and to the protection of non-target species in the river.

The results of sea lamprey control have been astounding. Agents have been able to reduce sea lamprey populations by 90% in the Great Lakes, facilitating healthy fish communities free from the terrible damage caused by sea lampreys. This success has allowed agencies to undertake fisheries rehabilitation and to stock fish with confidence knowing that fish will live to reproduce or to be harvested by humans. This success has happened with almost no impact on non-target organisms.

### Mudpuppies and TFM

The mudpuppy has a special relationship with the sea lamprey control effort, and its interaction with TFM illustrates the commitment to non-target-mortality reduction. Mudpuppies remain widely distributed and are not listed as endangered or threatened; they do not have special status in either Canada or the United States. Nevertheless, concern about this sensitive species has focussed the effort of sea lamprey control biologists and researchers.

Recent research by the GLFC, carried out at the USGS Upper Midwest Environmental Sciences Center, has shown that by carefully monitoring stream water chemistry, precise dosages of TFM can be applied to streams that can significantly reduce mortality of sensitive species. Scientists were able to carry out laboratory studies that defined new lower concentrations of TFM that would not harm mudpuppies, but would still kill sea lamprey larvae. This new application protocol has been used successfully during the treatment of the Conneaut River, a tributary to Lake Erie, this past summer where post-treatment surveys showed minimal impact on mudpuppies. Continuing research into the effects of lampricides will lead to even more improvements in how sea lamprey control is carried out.

**By protecting this sensitive animal, biologists protect the entire stream ecosystem.**

The GLFC is implementing methods to protect mudpuppies during sea lamprey control. Photo: Michael Oldham, OMNR

Sea lamprey control in the Great Lakes is one of our region's great success stories, reversing a major insult to Great Lakes ecosystems and the valuable fisheries they support. Steadfast respect for species like the mudpuppy and continued research into minimizing non-target mortality will ensure that the success of the sea lamprey control program is realized by everyone who values a healthy environment. ≈

Gavin Christie is the sea lamprey program manager for the GLFC.

Tom Todd of the USGS Great Lakes Science Center identifies ciscoes.

# Where have all the males gone?

**By Randy Eshenroder and Ann Krause**

Photos: GLFC

WHAT CAUSES a disproportionate number of females in some Great Lakes fishes and what are some of the consequences of unbalanced sex ratios? Femaleness, sex ratios tilted towards more females and fewer males, can be extreme in an important Great Lakes fish—the bloater. This species, one of three surviving deepwater ciscoes marketed as chubs, occurs in all three of the upper Great Lakes and is also being considered for reintroduction in Lake Ontario.

Femaleness as high as 90% has been observed in bloater populations from Lakes Michigan and Huron. Researchers have concluded that such bouts of femaleness are cyclical and are associated with two factors: reductions in the supply of recruits to the spawning population and shortened life spans of adult males. At the end of a cycle, weak recruitment means that few fish of either sex are available to replace those adults that are taken in fisheries, eaten by predators, or die of natural causes. The adult population is then dependent on fish with advanced ages, and females, living longer than males, then become the dominant sex. Recruitment improves eventually, sometimes markedly, and the cycle begins anew. This explanation is insightful but it does not account for why males do not live as long as females and why recruitment is suppressed in the first place. These questions remain to be answered.

The consequences of bloater femaleness are becoming better recognized. When recruitment slacks off, fewer juvenile bloaters are available to top predators like trout and salmon. If other forage species are not abundant enough to replace bloaters in top-predator diets, growth and survival of top predators may decline. This scenario played out in Lake Michigan in the early 1990s and may have aggravated an already shortened forage supply that occurred at that time.

The consequences of femaleness are different for commercial fisheries than for top predators because commercial fisheries unlike top predators target adult rather than juvenile bloaters. Commercial fishing may actually improve when bloater recruitment initially declines because the remaining adults grow faster making a larger proportion of the adult population marketable. Too much fishing at this time, however, can deplete the spawning population before recruitment has a chance to kick-in. Recent research suggests that this scenario—intensive fishing—played out in Lake Huron in the late 1950s causing a population collapse.

Femaleness in bloaters presents challenges for fishery managers. Changes in management such as in the number of top predators stocked or in the allowable catch can have big effects on fisheries. Yet, the life cycle of the bloater, and for other ciscoes as well, requires flexible, responsive management for sustained benefits. Biologists can now better predict cycles of femaleness. Whether they can get the needed changes implemented remains to be determined. ≈

Randy Eshenroder is the former senior scientist at the GLFC.
Ann Krause is a research associate.

GREAT LAKES FISHERY COMMISSION 2100 Commonwealth Blvd., Suite 209, Ann Arbor, MI 48105-1563
Phone: 734/662-3209 FTS: 734/741-2077 FAX: 734/741-2010
www.glfc.org

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