GREAT LAKES FISHERY COMMISSION

2000 Project Completion Report[1]

Determining the Next Steps in the Research and Development of the Migratory Pheromone for use in Sea Lamprey Control

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Appendix to the Completion Report for the Great Lakes Fishery Commission

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Summary

Understanding the lamprey migratory pheromone has progressed to a point where it is now appropriate to plan field tests. Careful planning and increased cooperation with control agents is necessary to increase the likelihood for success and focus efforts on answering the most important questions in the most appropriate and effective way. To begin planning for future field experiments, the authors have: 1) developed a long-term plan for research and implementation of pheromone control; 2) defined priority research questions; 3) defined the criteria of an experimental field site to test those questions; 4) begun the process of locating an appropriate field site; and 5) investigated the registration and permitting requirements for using pheromones in the field. Progress was guided by a survey which is described below.

Early in the process of conducting this study, the authors decided that management-based decision-making should be used to direct the research towards implementation of specific control strategies. To help identify the most promising strategies, the authors wrote and distributed a carefully structured survey that asked for specific opinions and ideas on how pheromones might best be employed. The survey was distributed to 19 control agents and scientists involved with lamprey control. All surveys were completed and returned. There was unanimous enthusiasm for developing pheromones for sue in lamprey control with the option of attracting animals from the Great Lakes to specific tributaries being considered the most promising strategy. Responses to survey also suggested that it would be worthwhile to investigate using larvae as a pheromone source for initial applications but that development of the synthetic pheromone should continue for would have advantages over a larval source once available.

The research questions identified in the survey as needing answers before pheromone control could be implemented were: 1) How do adult lamprey locate and orient into odor plumes (how might we design a plume)?; 2) What other cues might supplement pheromones (what type

of stream system is best used for pheromone tests)?; 3) How effective is a pheromone likely to be if added in an optimal manner? 4) What will be the effect of pheromonally-enhanced trapping on larval abundance, males available for sterilization, lampricide treatments, etc? A well controlled and small-scale field study could answer all questions except the last which could be cursorily addressed using population models. We have started to outline an experimental design for an initial field test and determined the criteria for a field site. It might have two components, the first using a lamprey river to describe adult lamprey migratory behavior, the second to address pheromone potency in stream which lacks lamprey but to which larval odor could be added. Control agents are assisting us with the task of identifying potential sites from a list of several dozen which we have now collected. Sites in Lake Champlain have also been described.

We find that although using pheromones for control purposes will require their registration as pesticides by the U.S. EPA and Health Canada, both governments recognize the benefits of pheromones and their inherent differences from traditional pesticides, and have set up special regulations for their registration. The data required to obtain an experimental use permit and to register the product is greatly reduced, with the potential for even greater reduction by applying for waivers when scientifically justified. However, no vertebrate or aquatic pheromone has ever been registered, so there is no precedent to indicate how our case will be handled. We have been assigned to pre-submission screening officers in both countries who will help guide us through registration. The use of native larval lamprey as a pheromone source will require the support and permission of state and provincial authorities. Conversations have begun with the natural resource agencies of Wisconsin, Michigan, and Ontario. All have expressed a desire to work with us, but they also have raised concerns and reservations about moving large numbers of native lamprey or moving them outside their historic range.

Preface.

This report is the product of a six-month project conducted by Lance Vrieze and under the direction of Peter Sorensen. The project proceeded in five steps: 1) identifying a working plan and research strategies; 2) writing and distributing a survey to ask those working with sea lamprey ('the experts') what the most promising strategy might be; 3) analyzing completed surveys; 4) identifying possible field test sites and visiting some of them; and 5) writing this report. We have had less than a month to write the final report because of delays in getting surveys back and commence this season's field research. Accordingly, we apologize if it is not comprehensive or as clearly written as we would have liked. Nevertheless, this report does describe all data collected as part of our survey and succeeds in providing several clear insights into where the majority of lamprey managers and biologists feel that pheromone research should be heading. It is notable that the authors agreed with almost all of the survey results which they attempt to report in an objective manner, identifying their personal opinions the few times deemed necessary. All completed surveys and correspondence remain in Dr. Sorensen's care and he would be very pleased to make these results available in greater detail if asked. Dr. Sorensen also expects to develop many of the ideas expressed in this survey in his next contract proposal.

1. Background and Objectives

The Great Lakes Fishery Commission has made the development and implementation of non-lampricide control techniques a priority of its management program. As part of this effort, the Commission has funded research into the lamprey migratory pheromone to determine if and how the pheromone might be used in an integrated control program. Research was initiated in the early 1980s under the direction of Dr. John Teeter, Monell Chemical Senses Center, and has been continued by Dr. Peter Sorensen, University of Minnesota. Research has lead to a basic understanding of the lamprey migratory pheromone, the identity of its principal components, and knowledge of its behavioral effects in the laboratory (Appendix A summarizes our current knowledge of the pheromone). Results to date affirm that the pheromone may have potential for application in the lamprey management program, although many questions, of both a basic and applied nature, remain to be investigated before full-scale implementation can be attempted.

Our knowledge of the migratory pheromone has reached a point where future research will require greater integration within the control program. A long-term research plan is needed to ensure that research proceeds towards the goal of implementing pheromone control in the lamprey management program. A planning meeting was held in May of 1999 and attended by representatives of the Commission Secretariat, scientists from the Hammond Bay Biological Station, lamprey managers from the U.S. Fish and Wildlife Service and Canada Department of Fisheries and Oceans, and us. Issues needing to be addressed in order to move towards the goal of pheromonal control were discussed and prioritized. It was decided that the needs that were able to be addressed at that time were: 1) elucidating a tentative long-term plan for developing migratory pheromones for control; 2) defining priority research areas which must be addressed to meet this goal; 3) defining the criteria for an experimental field site; 4) locating a proper field site; and 5) investigating the permitting procedure for the use of pheromones. Work on these areas was supported by a six month supplement to Dr. Sorensen's GLFC contract. The progress made in addressing each of these areas is the objective of this report.

2. The long term plan for developing migratory pheromones for control

The authors came to the immediate realization after the may meeting that a long-term "roadmap" was needed to guide the process of conducting research directed towards the goal of implementing migratory pheromones in the control program. According, the following plan has been developed:

1) Identify the 'key' basic biological attributes of the pheromone
2) Identify the most promising strategies for applying pheromones in lamprey control
3) Identify the key questions that need to be addressed before the identified control strategies might be implemented with a reasonable chance of success
4) Conduct basic and applied research to answer the aforementioned questions in the best manner
5) Design and test a full-scale application to evaluate the utility of the strategy for lamprey control

The defining features of this plan employ management-based decision-making to guide the research early in the process (step two) and careful identification and testing of questions (steps three and four) before attempting a full-scale management application. An alternative approach would be to move immediately from the identification of promising control strategies to testing their utility in a full-scale application. However, we believe that there are still too many questions about the migratory pheromone to be answered, and moving too quickly to a full-scale application may eliminate a chance of to learn anything from less than totally-successful results.

It should be noted that these steps need not be made in a linear fashion, but rather they can be implemented concurrently, and with feedback. For example, research into the basic biological aspects of the pheromone will most likely need to be continued throughout development as new questions arise. Further, investigations into issues for implementation (step four) show find that the control strategy identified (step two) is impractical and a new strategy must be identified.

3. Defining priority research areas

Our basic biological understanding of the pheromone has reached a point where it is now appropriate to move to step two and identify the most promising strategies for application in lamprey control. We decided that the best way to do this was to define the scientific facts and pose the question to those who know the most about lamprey control – the agents of the G.L.F.C. Accordingly, a survey was developed and distributed to lamprey research scientists (n=6), top level control agents (n=7), and lower level control agents (n=6). A list of participants is found in Appendix B. This survey sought to determine potential strategies that might be most feasible and valuable as well as identify priority areas of research relating to these strategies. It specifically asked respondees not to consider the question of compensatory mechanisms because this issue potentially plagues all lamprey control measures to an equivalent extent and is beyond the scope of our expertise.

3.1. The survey

Recipients were given a background document describing several potential applications for using migratory pheromones in lamprey control (see Appendix C). Applications were defined by three attributes: 1) The biochemical source of the pheromone (larvae or synthetic chemicals); 2) The source of the lamprey which are being attracted (geographic scale), and 3) Their management goal (why attract). Each of these attributes was described including their perceived advantages, disadvantages and research questions.

The survey (Appendix D) asked participants to respond to the various possible applications with numeric rankings and written comments. In so doing, we hoped to establish consensus on which strategy or strategies future research should focus on. Our questions primarily addressed the source of pheromone and the geographic scale of attraction, since we did not believe the larger issue of management goals should influence immediate research questions. However, results showed that the choice of different potential management goals influenced geographic scale and pheromone source considered most desirable by those most familiar with lamprey control.

3.2. Results of survey

Responses were received from 5/ 6 scientists, 6/ 7 higher level managers, and 5/ 6 lower level managers. In addition, three individuals involved with lamprey control on Lake Champlain provided input from the perspective of control on that lake, although their responses are not included in this summary. The overall response using migratory pheromones in control was highly favorable amongst all groups, with an average response of 4.3 (out 5) when asked to rank both the feasibility and value of using migratory pheromones in control. In addition, ten individuals stated specific ways they would be willing to assist with the planning and running of field trials, and three others expressed a desire to help with investigations into other areas associated with pheromone research. A summary of the results to the numeric ranking questions is included in Table 1. Note that not all participants responded to every question, which could potentially skew the simple numeric average. Often when individuals left questions blank, they indicated that not enough was known at present to provide an educated answer.

3.2.a. Results involving question of pheromone source

When given the option of developing a synthetic source or using a larval source of pheromone, there was a slight preference for using larvae. Nine individuals chose the larval source and six chose the synthetic source when asked which was the most important to develop. When participants were asked what proportion of development efforts should go towards each source, the effort was split evenly, with an average of 51% given to synthetic and 49% given to larval. This was the one area in the survey where there was a difference between the responses of scientists and control agents, with scientists favor a larval source (78% development effort to larval and 22% to synthetic) and managers favoring the synthetic source (36% effort to larval and 64% effort to synthetic). Examining written comments, this discrepancy can partly be explained by the fact that most individuals felt that the synthetic pheromone has many advantages and would eventually be the best way to proceed, but managers were immediately attracted to idea of a larval source because it is immediately available. Different individuals expressed interests in developing both sources (with larvae for the immediate future and synthetic for the distant future) in different ways in the numeric rankings. This feeling is clearly indicated when they were asked if experiments should begin with a larval source if the synthetic were not yet available--13 said yes, and 1 said no. However, three control agents felt strongly that a larval source should not be considered for control, citing the difficulty in manipulating larval populations and giving examples of places where native larvae do not appear to have an effect on spawning runs.

The survey asked for concerns about the use of a particular source and for questions that would need to be answered before the source could be used in control. The most frequent concern and area of research that participants identified for either a larval source (cited 9 times) or synthetic one (cited 11 times) was the minimum and maximum effective concentration of pheromone that would be required. Another commonly-raised category of questions for both sources was "Will it work?" or "How well will it work?" (cited by 10 and 5 individuals for synthetic and larval, respectively). For the larval source, five individuals were concerned about the difficulty of maintaining, moving, or establishing larval populations, and three individuals suggested that it would be difficult to manipulate larval populations for experiments and hard to assess their effects experimentally. Some stated that it would not be wise to release larvae directly into a system, and they thought only holding larvae in tanks or cages should be considered. The concern with registration of the synthetic pheromone or its possible effects on non-target species was raised in the comment section in five surveys, but when asked to rank the level of concern with registration from 0 to 5, the 16 responses averaged a moderate 3.3.

3.2.b Results involving question of geographical scale

The survey asked about attracting animals on three geographical scales: from a Great Lake to a river, to a tributary once within a river system, or to a trap in a river. Attracting animals from the Great Lakes to certain tributaries was clearly the favored application, ranked first by 12 individuals, with only two top rankings going to each of the smaller-scale strategies. When asked to divide the development effort among the strategies three ways, an average of 50% went for attraction from a Great Lake to river, 29% to a trap, and 21% to a tributary within a river.

When asked for concerns or questions that need to be answered before attracting animals to certain rivers from the Great Lakes for control purposes, most individuals (12) pointed out that it would not be 100% effective and wanted to know how large of an effect we could have on adult lamprey distribution and what that would mean for larval distribution when considering stock-recruitment relationships and compensatory mechanisms. Seven respondents had questions that could be categorized as dealing with the behavior of the pheromone plume in the lake (degradation, currents) or the migratory behavior of lamprey and their response to the plume (time of year attracted and ability to orient to a gradient). Five individuals were concerned about the effects of natural pheromones competing from neighboring rivers, and four wondered how attraction to the pheromone interacted with other possible migratory cues (temperature, flow, discharge). Some respondents (4) again raised the issue of needing to know the optimum pheromone concentration, reiterating what was expressed in the pheromone source section.

The biggest question about attracting animals to a tributary within a river was how effective this strategy might be for diverting animals, increasing captures, or reducing recruitment or lampricide treatments on the main branch (stated on 12 surveys). This again related to less than 100% effectiveness and the effects of compensatory mechanisms. Eight individuals thought research should focus on whether lamprey actually make use of pheromones to select tributaries in a river system, while five raised the related issue of the interaction of pheromones with other sensory cues associated with river flow. Finally, five responders raised the question of how far above the background concentration of the main river the tributary pheromone concentration would need to be to preferentially attract.

When asked for questions and concerns about using pheromones to attract animals to traps, nine respondants questioned whether lamprey were able to follow a concentration gradient to a point source within a river. Six respondents wanted to know how much above the natural background concentration the added pheromone would need to be to preferentially attract to a trap. The problems and costs associated with establishing and maintaining traps was given as a concern on three surveys.

3.2.c. Results involving the question of management goals.

Although not a focus of the survey, participants were asked in what ways application of migratory pheromones could be valuable for lamprey management. Increasing the number of males available for sterilization was determined to have the greatest potential value (average value of 4.4 on a scale of 0 to 5), with the remaining three possibilities ranked fairly equally below that (between 3.1 and 3.2). Increasing the number of animals trapped for sterilization provides an immediate benefit to the control program (assuming the efficacy of the sterile male program) and does not involve diverting animals from other areas and the issue of compensatory mechanisms.

However, judging from comments, many people favored using pheromones as a means to reduce larval recruitment or lampricide use. Those that looked at attraction at the two smaller geographic scales as a way of increasing the number of males to sterilize tended to look more favorably on the possibility of attraction at those scales. For example, on the questions of attracting animals to a trap, one person stated, "If sterile male program is proven effective, then this has much more application." Another simply stated, "Only useful to increase supply of males for sterilization program." Thus, the surveys may reflect a conflict between what was judged as the most valuable goal (increasing available males) and the most valuable geographical scale (from Great Lakes to river). If it is decided that migratory pheromones should primarily be developed for the sole purpose of increasing the capture of males, then the prioritization of research directions in this survey would most likely not accurately reflect that. It should be determined if development of the migratory pheromone should be viewed only as a tool of the sterile male program, or if its potential value and use in other areas (reducing recruitment or TFM use) should also be considered and researched.

3.3 Summary of survey results and corresponding research priorities

The survey proved effective for soliciting comments on using migratory pheromones for lamprey control and for gauging the relative potential of different control strategies. Although opinions varied, there was a fairly clear consensus that the synthetic pheromone should be developed for use in the future, while the possibility of using a larval source should be investigated for the time until a synthetic source becomes available. Respondents also generally felt that attraction from the Great Lakes to certain tributaries was the most promising strategy to explore for using pheromones in lamprey control.

We accept and agree with the survey findings, and we propose the following research strategy to move towards the goal of implementing pheromonal control. This strategy is based upon the questions and concerns raised by the survey participants as well as our current level of understanding of different areas of pheromone and lamprey biology.

A) Questions which need be answered how to use pheromones to attract lamprey from a Lake to a river (these questions might need to be answered with Questions in B or C below)

1) How and when do adult find river odor plumes? We need to know this to both know when and how to introduce lamprey into odor plumes to test their potency and design an effective river plume. *This set of descriptive questions should be answered first. It can be answered by tracking adult sea lamprey released at the mouth of lamprey river at different times of the day and at different positons in and from riverine plumes whose distribution would be tracked.*
2) What sensory cues compliment odor in stream recognition? If odor-driven behavior is strongly influenced by other sensory cues (ex. temperature, flow, turbidity), then we would need to know this to design an effective plume and conduct a good full scale field test. *This question could be answered in the laboratory (Hammond Bay) fairly easily.*
3) How potent are pheromones at attracting adult lamprey from lakes? *This is a key question and once we know how to best create an odor plume (questions 1 and 2 above) we can easily answer it at field site by releasing tagged animals at increasing (but relevant)*

distances from river mouths contain known amounts of pheromones which could be varied. Knowing what time of day and year to release adults would make this a much more powerful experiment.

4) If pheromones can enhance adult capture rates, will it be at a rate that benefits sea lamprey control (either by providing males for sterilization, simply removing adults, or reducing TFM demand). *Once the potency of pheromone is well established (this may require additional field tests at a few sites), population models should be constructed to see if it is adequate.*
5) How many sites can be used for pheromone control? *Sites will have categorized according to relevant environmental characteristics (pheromone concentration, plume structure; A2, A3,and A4 above.*

B) Questions which need to be answered to determine if larval odor itself can be used an effective pheromone source.

1) Are adult sea lamprey attracted to larval odor as they are in the lab, and if so what population densities are best? *Once we understand how to design pheromone plumes (see above), we can conduct field tests in small streams using planted larvae held in cages or perhaps released. Adults would be tracked and trapped to provide both fine scale and large-scale information. This experiment is the same as A3. Correlation analysis of pheromone concentrations at rivers which are being trapped can add to this data set.*
2) Do native larval lamprey attract adult sea lamprey? *A field study similar to that described in B1 above would work.*
3) Can larval odor be extracted and used instead of larvae themselves? *This option would save moving larvae around. It might involve simple laboratory study and confirmation in the field as described above.*
4) Will the odor of native lamprey larvae in non-trapped stream interfere with a pheromone control program? *Once we know the answer of question 4 above, we can correlate pheromone concentration (measured by EIA) with potency and plume distribution and either conduct simple field test or build a model to answer this question.*

C) Questions which need be answered to determine if a synthetic pheromone can be usedin lamprey control.

1) What is the complete chemical composition of the larval sea lamprey pheromone? *Physiological, biochemical, and behavioral studies in the laboratory (current and ongoing)*
2) Can adult sea lamprey be attracted to the synthetic pheromone in the field? *This may be answered in a field study similar to the situation described above for the larval odor in B1, B2, and B3. An understanding of when and how adult lamprey migrate relative to a pheromone plume (A1,A2) would be very helpful.*
3) What concentrations of pheromone are maximally efficient (potent and affordable). This question is essentially the same as A3. A big advantage of synthetic pheromone is that it can be precisely metered and might be super-active at high concentrations. *This can be answered using a field experiment based on the design employed in C2.*
4) Can we synthesize the pheromone in adequate quantities at affordable costs? Contract with chemists and investigate analogues.

4. Defining the criteria for an experimental field site

The type of site that would be most useful for using pheromones for control purposes is most likely not the same site that would be appropriate for initial field tests of the pheromone. In initial experiments, we would wish to have control over as many variables as possible and would like to test clear, simple hypothesis and have a good chance of receiving clear results. Testing in a smaller system would improve our chance of obtaining interpretable results and also increase the chance of learning the reason behind possible failures. We have outlined initial field experiments and field site criteria for each of the three proposed geographical scales, but here only focus on the most favored scale--attracting to a river from a Great Lake.

As an initial experiment to test the possibility of attracting adults to rivers from a lake, we imagine starting with two tributaries in close proximity with low background levels of natural pheromone. Pheromone would be applied to one tributary and the other would serve as a control. Marked adults would be released multiple times at various locations in the lake and the relative proportion locating the two tributaries would be monitored with traps. Ideally, we would track some animals as well to get fine-scale resolution. The treatments of the two tributaries would be switched. After the initial simple test, more complicated questions could be addressed such as minimal and maximal effective concentrations, attractiveness of native larvae, etc. Additional nearby tributaries could also be brought into the experiment as research questions became more complex.

We have developed the following criteria for an idealized location to perform this initial experiment:

1) Small rivers to require less pheromone to activate, but substantial enough for lamprey to locate (annual mean discharge of approximately 0.2 to 3 m^3/s). If synthetic pheromone is used, size should be on the lower end of the range. Rivers that are not flashy and are not prone to flooding would be positive.

2) A grouping of rivers. Two ideal rivers should be used for the initial test, but additional nearby rivers to add in expanded experiments would not have to meet all criteria. Rivers should be in close proximity--how close will be dependent on the size of the rivers. Especially for the initial test with two tributaries, it would be best if they were within 5 km of each other. Other tributaries in a grouping beyond the initial two could be at greater distances. If rivers were grouped in a restricted area, such as a bay or inland lake, that would be ideal.

3) Rivers must be able to be effectively trapped. Monitoring the number of adults that enter a river is required. Established traps, net traps, or portable-assessment traps could be used. As a corollary, the rivers should be easily accessible.

4) A low background of natural pheromone from resident larvae should be present. This could be achieved by TFM treatment or by using streams with few or no larvae. A slightly altered experimental design could get around this requirement for one of the rivers.

5) A reliable supply of trapped lamprey should be available near the study site. These will be required for marking and releasing at various locations. As a corollary, to facilitate the releases, boat access should be nearby.

5. Location of a field site

The potential success of a field trial will be highly dependent on the selection of an appropriate site and experimental design. This process is still actively ongoing. Control agents with intimate knowledge of specific regions of the Great Lakes basin have expressed their willingness to help in the selection process. With their help, an initial list of candidate rivers has been obtained for all Canadian waters and the United States tributaries to Lake Superior and Ontario. A list of streams that may be useful for testing the attraction to a river from the Great Lakes is included in Appendix E. In addition, we have visited several sites on Lake Champlain and have had two meetings discussing the potential for collaborating with the local office of the Fish and Wildlife Service and the Lake Champlain Technical Committee. We have also talked with a fisheries manager on Lake Cayuga about the potential for performing experiments in that basin.

6. The permitting procedure for the use of pheromones

The application of synthetic pheromone to the environment for experimental or eventual management applications will require registration with the United States and Canadian governments, while the possible use of native lamprey species as a pheromone source will require the cooperation and permission of state and provincial authorities. We have started to determine what requirements will have to be met before either of the pheromone sources could be used in the field.

6.1. State and provincial openness to manipulation of native lamprey populations

If native larval lamprey are to be utilized as a source of pheromone, animals may need to be moved to previously unused watersheds in order to create a pheromone source. Individuals could be contained in in-stream cages, held in stream-side tanks, or released into the river. Conversations have begun with representatives of the natural resource agencies of Wisconsin (Bill Horns, Coordinator of Great Lakes Fisheries), Michigan (John Schrouder, Coordinator of Field Operations of Fisheries), and Ontario (Alan Dextrase, Introductions Biologist) to determine if they would allow such actions, and if so, what procedures would need to be followed. Representatives of all three agencies did not rule out the idea and have agreed to cooperate, but all also expressed concerns and reservations. They expressed the need to approve any final locations and numbers and also wished to be involved in the planning.

Wisconsin has described their position in a letter from Michael Staggs, Director of the Bureau of Fisheries Management, which states that they would not want species moved outside their historic range and would want to monitor the numbers of animals removed from different locations (see attached letter). Michigan has raised similar concerns, and agency staff are currently discussing the issue for a second time after receiving additional information from us. Ontario is also currently discussing the idea within the Ministry of Natural Resources. They have mentioned that the northern brook lamprey (*Ichthyomyzon fossor*) is listed as a vulnerable species in Canada, and it would therefore not be desirable to remove animals from an established population of that species.

6.2. Registration of pheromone

If a synthetic pheromone were to be applied to streams for the purposes of lamprey control, it would require registration as a pesticide with both the United States Environmental Protection Agency (EPA) and Health Canada. It would also require an experimental use permit (or a specific waiver from such) for initial field studies. We have been assigned to pre-submission advisors in both countries

(Brian Steinwand, Biopesticides and Pollution Prevention Division of EPA, and Sean Muir, Pest Management Regulatory Agency, Health Canada) and have begun to determine what will be required for registration.

Pesticides are defined by their intended use, and not their chemical nature or source. This means that even naturally occurring chemicals, such as pheromones, are classified as pesticides by the government when they are used to mitigate pest populations. This also means that if the lamprey migratory pheromone were to be tested for purposes of population remediation (such as with Pacific lamprey or Atlantic-run lamprey) that it would then fall out of the jurisdiction of the pesticide regulations and would not need any registration at that time (Steinwand, personal communication). Even though pheromones used for pest control are classified as pesticides, the agencies recognize the inherent differences between pheromones and "traditional" pesticides. Their non-toxic mode of action, general species-specificity, and general lower level of application mean that there are fewer risks involved with these chemicals. They also realize that pheromones can reduce the use of other more adversive pesticides, and so they have created special regulations to reduce the data requirements and speed the registration process. The United States has created a special Biopesticides and Pollution Prevention Division to handle only this type of chemical, while Canada handles pheromones under Regulatory Directive 97-02, "Guidelines for the research and registration of pest control products containing pheromones and other semiochemicals." The time from first submission to full registration of pheromones typically takes less than a year. Registration can be accelerated further in both countries through concurrent and shared review of submissions under the NAFTA biopesticide review committee.

Each new proposed registrant is handled on a case-by-case basis. Many required tests are routinely waved when scientifically justified. This is especially true for insect pheromones that are closely related and have repeatedly been registered. However, no aquatic or vertebrate pheromone has undergone the registration process, so it is not known exactly how our case will be handled. We were informed that demonstrating that we would use small quantities of chemical at concentrations that close to those found in nature could greatly reduce the data requirements, but its aquatic application might cause still limit the data waivers (Steinwand, personal communication). Nevertheless, an experimental use permit likely would be required simply because Canada requires such permit for all aquatic applications and the United States requires it for all instances when greater than 1 acre of surface water will be exposed or there is potential for humans to come in contact with pheromone-containing water. Requirements for a permit are: 1) information on chemical character (formula, molecular weight, etc.)

and 2) data on acute toxicity to freshwater invertebrates or fish (a pheromone would not have any). Limited information on environmental fate and toxicology may also be requested after review.

Registration requirements for pheromones involve data on chemistry, acute tests of human health and safety (acute oral, acute dermal, acute inhalation, primary eye irritation, primary dermal irritation, and dermal sensitization), and acute tests of environmental fate and toxicology (acute invertebrate toxicity; acute fish toxicity; avian acute oral toxicity, and avian dietary toxicity). Biopesticides use a "tiered" approach for toxicology tests, with only acute tests required unless results of the acute tests raise some concern. In addition waivers are routinely granted when scientifically justified. Even though the toxicity tests required are fairly limited, purchasing the amount of pheromone required to perform these tests may prove to be the largest expense.

In summary, pheromones used for lamprey control will require registration, although the requirements for pheromones are greatly reduced and the registration review is accelerated. Since no vertebrate or aquatic pheromone has ever been registered, neither registration advisor could say exactly how our case would be handled. They suggested that a conference call or in-person meeting was appropriate at this point to determine how to move forward. It should be determined whose responsibility it will be to move forward with registration if it is decided desirable.

Table 1. Summary of survey results. See Appendix D for full text of questions

	scale	mean	SD	median	n	mean biologist	mean higher manager	mean lower manager	range	
How?										
larvae feasible?	(0-5)	4.0	0.9	4	15	4.2	3.8	4.0	2	5
larvae valuable?	(0-5)	3.7	1.4	4	13	4.3	4.0	3.1	0	5
registration concern?	(0-5)	3.3	1.9	4	16	3.2	3.8	2.6	0	5
which develop? (l or s)		l=9	s=6							
percent to larval	(0-100)	49.1	29.7	60	16	78.0	34.2	38.0	0	100
percent to synthetic	(0-100)	50.9	29.7	40	16	22.0	65.8	62.0	0	100
Where?										
from lake valuable?	(0-5)	4.3	0.8	4	16	4.6	3.8	4.4	2	5
how many locations?	(0-5)	3.4	1.2	4	13	3.0	3.2	3.9	2	5
to tribs valuable?	(0-5)	3.6	0.9	4	16	3.4	3.7	3.6	2	5
how many locations?	(0-5)	2.8	1.2	3	13	2.3	3.3	2.3	1	5
to traps valuable?	(0-5)	4.0	0.7	4	15	4.0	4.0	4.0	3	5
how many locations?	(0-5)	3.2	0.8	3	12	2.7	3.6	3.0	2	5
from lake rank	(1,2,3)	1.5	0.9	1	16	1.4	1.7	1.4	1	3
(l or s)		l=4	s=6							
to tribs rank	(1,2,3)	2.3	0.7	2	16	2.2	2.2	2.4	1	3
(l or s)		l=3	s=6							
to traps rank	(1,2,3)	2.3	0.7	2	16	2.4	2.2	2.2	1	3
(l or s)		l=1	s=9							
from lake percentage	(0-100)	50.0	23.8	50	13	57.5	44.0	50.0	10	90
to tribs percentage	(0-100)	21.2	15.6	20	13	25.0	21.0	17.5	0	50
to traps percentage	(0-100)	28.8	15.6	30	13	17.5	35.0	32.5	5	50
Overall program										
feasible?	(0-5)	4.3	0.7	4	16	4.0	4.2	4.6	3	5
valuable?	(0-5)	4.3	0.9	5	15	4.0	4.3	4.8	2	5
improve assessment?	(0-5)	3.2	1.4	3	16	2.6	3.7	3.2	0	5
increase sterilization?	(0-5)	4.4	1.0	5	16	4.2	4.8	4.2	1	5
decrease TFM?	(0-5)	3.2	1.3	3	15	3.0	3.7	2.8	2	5
decrease recruitment?	(0-5)	3.1	1.3	3	15	3.0	3.3	3.0	1	5

Appendix A: Our current understanding of the lamprey migratory pheromone

1) Lamprey use their sense of smell to locate spawning rivers. After being released in Lake Huron, migratory animals with plugged noses returned to the rivers at about 1/10th the rate of control animals. This has been repeated four times at three different rivers (Sorensen et al., unpublished). Furthermore, lamprey exhibit a strong attraction to river water in the laboratory, but this response is eliminated in nose plugged animals (Vrieze 1999). This suggests that if we could enhance the attractive odor of a river that we could have a pronounced impact on adult lamprey distribution.

2) Removal of larvae reduces the number of migratory lamprey that enter a river and appears to increase the number that enter proximate rivers. Years of trapping records show that in many cases there is a significant drop in the number of migrants that choose a stream for spawning the year after treatment with TFM (Moore and Schleen 1980). The strength of this effect appears related to the effectiveness of the particular TFM treatment in removing the larvae from the system. Although less extensively documented, the number of lamprey entering rivers neighboring the TFM treated stream increases, suggesting that animals are being diverted to rivers with higher larval populations (Vrieze, analysis of historical data).

3) In laboratory, migrant lamprey are attracted to stream water in which sea lamprey or native lamprey larval odor has been added. If water from a tank of larval sea lamprey is added to stream water in one arm of a two-choice maze, migratory lamprey are consistently and strongly attracted to that arm. In fact, just one liter of larval holding water can make 100,000 liters of river water more attractive. Waters from streams containing larval lamprey are consistently preferred to waters lacking larvae when placed side-by-side in the same maze. However, this preference can be reversed by adding larval holding water to the stream that originally lacked larvae. (Bjerselius et al., 2000; Vrieze 1999). Holding water from tanks of American brook lamprey (*Lampetra appendix*) and *Ichthyomyzon sp.* also makes stream water more attractive when tested in a two-choice maze (Sorensen et al., unpublished).

4) Sea and native lamprey larvae release the bile acid petromyzonol sulfate in large quantities. This bile acid is detected at very low levels by the adult lamprey nose. Larval sea lamprey and other native larval lamprey release large quantities of the unique bile acid petromyzonol sulfate (PS) into the water (Polkinghorne 1997). Adult lamprey have a narrowly tuned sense of smell, and one of the compounds they can smell with the most acuity is PS, which they detect at concentrations of 1 gram in 40 billion liters of water (Li et al. 1995). PS has been measured in river waters at concentrations that adults can detect (Sorensen et al., unpublished).

5) In laboratory, petromyzonol sulfate will attract lamprey to stream water, but it does not appear to be as strong as larval odor. When PS is added to stream water and tested in the same two-choice maze as in the above experiments with larval water, the PS enhanced water is made more attractive to migrant sea lamprey. This has been repeated three times (Vrieze 1999). However, the attraction does not appear to be as strong or consistent as what is seen with larval water. We believe that PS is a primary component of the attractive odor of larvae, but other larval compounds may make a contribution. This issue is currently being investigated.

Bjerselius, R., W. Li, J.H. Teeter, J.G. Seelye, P.B. Johnsen, P.J. Maniak, G.C. Grant, C.N. Polkinghorne, and P.W. Sorensen. 2000. Direct behavioral evidence that unique bile acids released by larval sea lamprey function as a migratory pheromone. Can. J. Fish. Aquat. Sci. **57**: 557-569.

Li, W., P.W. Sorensen, and D.D. Gallaher. 1995. The olfactory system of migratory adult sea lamprey (*Petromyzon marinus*) is specifically and acutely sensitive to unique bile acids released by conspecific larvae. J. Gen. Physiol. **105**: 569-587.

Moore, H.H., and L.P. Schleen. 1980. Changes in spawning runs of sea lamprey (*Petromyzon marinus*) in selected streams of Lake Superior after chemical control. Can. J. Fish. Aquat. Sci. **37:** 1851-1860.

Polkinghorne, C.N. 1997. Determining whether bile acids released by larval sea lamprey and other fishes may be functioning as species-specific migratory cues. M.S. Thesis. University of Minnesota, Minneapolis, Minnesota.

Teeter, J. 1980. Pheromone communication in sea lampreys (*Petromyzon marinus*): implications for population management. Can. J. Fish. Aquat. Sci. **37**: 2123-2132.

Vrieze, L.A. 1999. Determining the importance of the larval sea lamprey pheromone in adult migration. M.S. Thesis. University of Minnesota, Minneapolis, Minnesota.

Appendix B: List of recipients of survey

Top level control agents	Lower level control agents	Research scientists
Terry Morse	Mike Fodale	Roger Bergstedt
John Heinrich	Kasia Mullett	Bill Swink
Gerald Klar	Mike Twohey	Bill Beamish
Dennis Lavis	Jeff Slade	Weiming Li
Larry Schleen	Rod McDonald	Mike Jones
Rob Young	Paul Sullivan	John Kelso
Doug Cuddy		

Appendix C: Summary of potential lamprey management scenarios using the migrational pheromone

Selective application of migrational pheromones may become a valuable and environmentally friendly tool in the integrated management of lamprey. Extremely small quantities (grams/year) could manipulate the distribution of migratory lamprey to our advantage. Although other pheromone-based control methods can be imagined (antagonists to block migration etc.), all strategies that are conceivable for the immediate future involve attracting migratory anima to certain areas for our benefit. All potential strategies have three components:

I. Why we are attracting--to increase capture of males for sterilization, to reduce recruitment, etc.

II. How we are attracting--with synthetic pheromone or larval populations

III. Where we are attracting from--to rivers from lake, to tributaries within rivers, or to traps within rivers

Different combinations of these component parts could prove useful in different situations. For example, in one case we may want to increase the males available for sterilization by using larval populations to attract animals to a tra in a tributary of a river. In another location, we could possibly reduce recruitment by using a synthetic pheromone to attract animals from the lake to certain rivers lacking larval habitat. However, some of these possibilities are probably more feasible and/or are more potentially useful than others. Also, there may be strategies that we have not identified. In order to focus our research efforts in the most effective way, we hope you will help us identify those strategies that you feel are best pursued. This document discusses these different components and will help guide you and provide background information as you complete the survey.

I) Why we attract. Identifying the goal.

Although determining the reasons pheromones are used in particular locations will eventually be a very important decision, at this point in pheromone development it is actually of only minor consequence. This is because future research would progress very similarly no matter which goals were identified as worthy of pursuit. In fact, it should be possible to fully develop the pheromone 'tool' and have it available for use in control for whatever reason that is seen fi for a particular situation. Nevertheless, it is important to keep the various potential reasons for using pheromones in mind as you progress through the remainder of the document. Therefore, a few possible benefits of pheromone control are briefly discussed here.

Attracting animals to relatively effective control locations (efficient traps or barriers, little or no larval habitat, TFM treatment is especially effective or inexpensive, TFM treatment scheduled in the next two years) would reduce the number of animals available to spawn in proximate areas that are more problematic for control. This diversion could benefit the control program in several ways:

- Less TFM could be required to suppress lamprey populations
- Lamprey populations could be suppressed to a lower level than could be achieved by alternatives
    - Lamprey populations could be suppressed at a lower cost than could be achieved by alternatives

The level of control stemming from such diversion will be directly related to the effects of compensatory mechanisms. Since so much is still unknown about the potency of pheromones and the strength of compensatory mechanisms, pheromone research should continue to proceed forward as we learn about these issues. Once more data is obtained on the potency of pheromones in the field and the strength of compensatory mechanisms, the level of population suppression using pheromonal control can be modeled.

If the goal of pheromone application is to attract more animals to traps in order to increase the number of males available for sterilization, then it would not matter if the animals were being diverted from other locations. Similarly, i pheromones were used to improve the accuracy of adult assessment at traps, diversion would not matter and compensatory mechanisms would not come into play.

II) How we attract. Two possible sources of pheromone--larval and synthetic

A synthetic pheromone could be produced and metered into streams. Several groups are looking into ways to produce significant quantities at a reasonable cost. Alternatively, larval lamprey could be employed to release the pheromone naturally as a low technology solution. Both sources have advantages and disadvantages. We seek advice on which source efforts should focus on in future research. Please note that when referring to the synthetic source for this survey, we are assuming that the 'complete' pheromone is already identified (i.e. please don't let the fact that the complete pheromone may not be currently identified influence your decision).

	Larvae	**Synthetic**
Advantages	*Source already exists *Cheap, effective production *Once population is established, little maintenance required *Promote and conserve native lamprey populations	*Larval habitat not necessary *Greater flexibility and control of concentrations *More potential uses and locations *Could produce 'super attractive' rivers
Disadvantages	*Habitat needs to be available. Fewer potential applications. *Little control over concentration, application, and distribution (unless caged) *Upper limit to concentration that could be created *Established at site for long term--can't quickly change among rivers *Need to address issues of species (re)introduction	*Unknown cost, but may be high *Will need to undergo abbreviated form of pesticide registration

Synthetic: Could be used in more places and ways than a larval source of pheromone, with potential of being more effective. Is preferable in experimental tests because of precise control of concentrations and alternation of treatment and control sites. Due to cost, optimization of application would be priority for initial tests.

- **Questions that need to be answered before using synthetic chemical in management applications:**
  1) Can lamprey be attracted to synthetic chemical in the field?
  2) What is the maximal and minimal effective concentration of pheromone?
  3) What time of day and year do lamprey migrate? There is sufficient data on the timing of migration within a stream, but we do no know about migration within the lake as lamprey search for streams. Limiting pheromone application to the most effective time of day and year would drastically reduce costs.
  4) How do different pheromonal components affect the attractiveness? Some components may make the pheromone slightly more attractive but greatly increase the cost of application. The blend should be optimized for cost and potency.

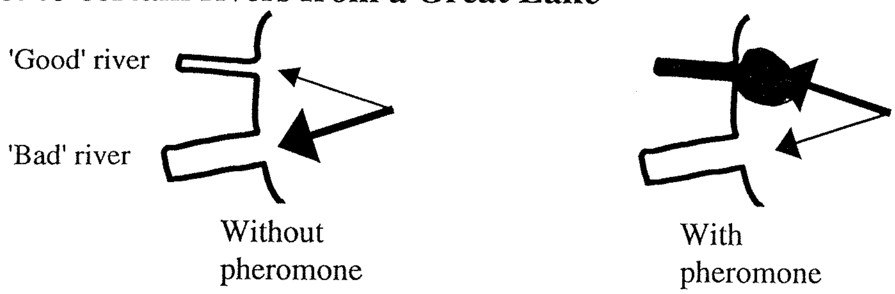
Larval: Potential applications and locations would be more limited than with synthetic pheromone, but may be very effective in certain locations. Laboratory tests indicate that native lamprey species could provide an effective source. "Seed populations" could be introduced and allowed to reproduce, limiting need for movement of large numbers. Alternatively, larvae could be maintained in cages, but this would be more labor-intensive.

- **Larvae in early field trials:** Currently, synthetic pheromone is too expensive and we do not know if we have identified all component parts. This prohibits immediate use of synthetics in field trials. While these issues are being resolved, we could begin field tests using sea lamprey or native larvae. Stream-side tanks may be able to be maintained for experiments, but would most likely not be feasible for control situations.
- **Questions that need to be answered before using larvae in management applications:**
  1) How does the pheromone degrade in the river and lake? Needs to be established to determine how close to the n larvae need to be to be effective.
  2) What are the minimal and maximal effective number of ammocoetes in a stream? If very few larvae produce a l attractive effect, then there are many more possibilities for control.
  3) Are native lamprey larvae attractive in the field? Are they as attractive as sea lamprey larvae?

III) Where we attract from. A question of scale.

It may be possible to manipulate lamprey distribution at a wide-range of geographical scales. Each scale would require different types of research to determine its utility in lamprey management. We would like to know the scale at which you would most like to have control over lamprey distribution.

III.a) Attract to certain rivers from a Great Lake



Positives:

- We know larvae (pheromones) exert a strong influence on distribution at this scale from years of trapping data
- Could influence lamprey distribution over a large area

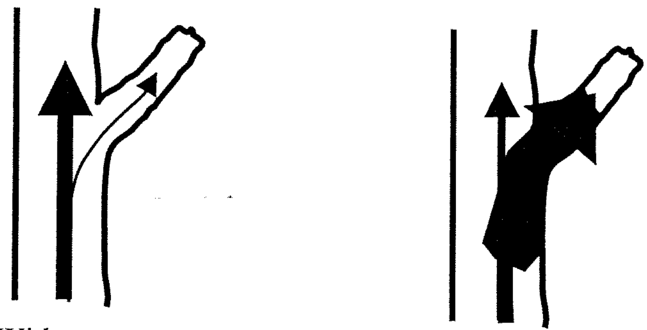
Negatives:

- On average, higher discharges would require greater quantities of pheromone
- Do not yet understand how pheromone concentrations in neighboring rivers affect the distribution of animals among rivers (what magnitude difference of concentration would be required to exert an appreciable effect in distribution).
- Because of large scale, effects may be difficult to assess

Example of Brule River. The Brule River on Lake Superior has a highly effective trap and barrier. However, after TFM treatment, the natural pheromone concentration in the river is reduced, and very few animals migrate into it. These animals presumably enter other nearby rivers (historical trapping data supports this), and the control (and assessment and males for sterilization) potential of the Brule barrier and trap is effectively wasted. By increasing the pheromone concentration of the Brule, either by establishing native lamprey above the barrier or adding synthetic pheromone, we could draw more animals into the river and take better advantage of the control structure already in place. This could reduce the recruitment or increase the interval between TFM treatments in nearby rivers. Once the Brule is within two years of a scheduled treatment, it would be advantageous to attract as many lamprey as possible so as to kill the greatest number of larvae with the single treatment.

- **Questions that need to be answered before we can implement control at this scale for management purposes:**
  1) Can we attract animals to rivers with pheromone?
  2) From what distance can animals be attracted from?
  3) Does attracting more animals to a river reduce the number that enter other rivers?
  4) How many can be diverted from other rivers in relation to the distance between rivers?
  5) How many can be diverted from other rivers in relation to the natural pheromone concentration in the other rivers?
  6) How would attracting to a river affect the size of the lamprey population? Would it reduce TFM use? Would it increase males available for sterilization? Would it improve assessment?
  7) How much would it cost to apply, and do the benefits outweigh the costs?

III.b) Attract animals to certain tributaries once within a river system



Advantages:

- Could attract to tributaries that can be trapped more easily than the main stem
- Could attract to tributaries that are easier and cheaper to treat with TFM
- On average, would be dealing with lower discharges than in (III.a), so less pheromone required
- Experiments would be easier to perform and effects easier to assess than at a larger scale

Disadvantages:

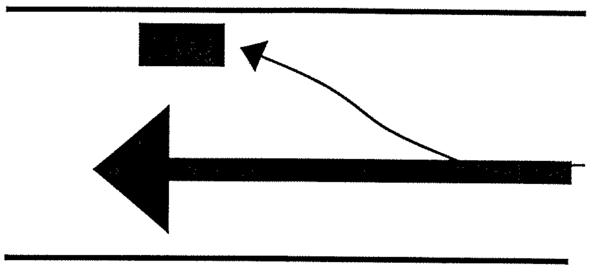
- Would be manipulating the distribution of animals that already have entered a certain river system so would not exert an effect over as large of a geographical area
- Due to downstream larval drift, the potential for reducing TFM use by attracting to more easily treated tributaries woul probably only be realized in more extensive tributaries that larvae wouldn't drift out of
- There is not extensive historical data on the effects of larvae influencing migration once within a river system

Example of St. Mary's River tributaries: Every animal that enters a tributary to the St. Mary's is one less anima available to spawn on the rapids. This diversion has the same effect on the rapids population as trapping on the river proper. The tributaries could be trapped and/or treated with TFM relatively cheaply. This diversion is already occurring into rivers such as the Echo, but could be greatly enhanced and expanded with pheromone application.

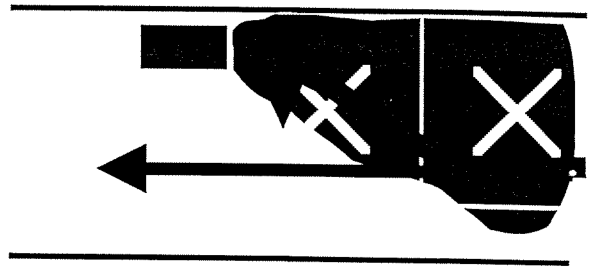
- **Questions that need to be answered before attracting at this scale could be utilized for managemen purposes:**

1) Do lamprey use pheromones once in a river in order to select tributaries?
2) Can lamprey follow a concentration gradient? How much above the background pheromone concentration does the supplemental pheromone need to be to preferentially attract to a tributary?
3) How many lamprey could be diverted from other portions of the river?
4) How would diverting animals to tributaries affect the lamprey population? How would it reduce use of TFM? Would it provide more animals for the sterile male program? Would it improve assessment?
5) What is the cost of applying the pheromone, and do the benefits outweigh the costs?

III.c) Attract to a specific locale (trap) in a river



Without pheromone



With pheromone

Advantages:

- Could improve efficiencies of traps not associated with barriers where only one section of the river is able to be trappe
- The St. Mary's River traps are obvious candidates for this scenario, although the volume of water may make it prohibitive
- Possibility of trapping in areas not now feasible, such as river mouths
- Only a small quantity of pheromone may be necessary to have an effect in small systems

Disadvantages:

- Do not know if lamprey are able to follow a pheromone concentration gradient within a river or how much above background concentrations pheromone needs to be in area of trap.
- For larvae to be used as a pheromone source, would probably have to be held in cages
- Due to lampreys' exploratory nature at barriers, would probably not have much effect at traps associated with barriers

- **Questions that need to be answered before this scenario could be utilized for management purposes:**
  1) Will lamprey spend more time on the side of a river with higher pheromone concentration?
  2) Can lamprey follow a pheromone concentration gradient within a river? How much above background concentration does the pheromone need to be to preferentially attract to a location?
  3) Would more animals be caught in traps baited with pheromone?
  4) Would increasing trap efficiency provide more animals for the sterile male program? Would it improve adult assessment? Would it reduce lamprey population?
  5) What is the cost of applying the pheromone, and do the benefits outweigh the costs?

Appendix D: Survey form

(Please return -- attach additional pages if necessary)

Document C. Survey: Where should we focus our efforts?

Your name (optional) ____________________

Please provide your opinions on the feasibility and potential value of different types of pheromonal control. Refer to the appropriate sections of Document B as you complete this document. In order to reduce the time required to take the survey, we have tried to keep the questions focused. However, please feel free to provide any additional comments, and use additional sheets, on any matter that you feel can't be appropriately addressed in the structured format provided.

From document B, part II: How we attract: larvae or synthetic?

How we attract--larvae:

1) What are the key strengths of using larvae as a source?	0-no value 5-great value
A) Already available	0 - 1 - 2 - 3 - 4 - 5
B) After establishment, little cost or maintenance	0 - 1 - 2 - 3 - 4 - 5
C) Promotes native lamprey populations	0 - 1 - 2 - 3 - 4 - 5

2) What are the key concerns with using larvae as a source?	0-no concern 5-very concerned
A) Larval habitat needs to be available--fewer potential applications	0 - 1 - 2 - 3 - 4 - 5
B) Little flexibility in changing concentrations or application sites (this would be a long-term application at select locations)	0 - 1 - 2 - 3 - 4 - 5
C) Difficulty in (re)establishing native larval populations	0 - 1 - 2 - 3 - 4 - 5

3) What additional strengths and concerns can you identify with using a larval source of pheromone? (rank on a scale of 0 to 5, as above)

A) Strengths:

B) Concerns:

4) Is using larvae for pheromone source in the control program feasible?	0--not 5--should be feasible
	0 - 1 - 2 - 3 - 4 - 5

5) Assuming it is found to be feasible, would using larvae in the control program be useful/valuable?

0--not 5--very valuable
0 - 1 - 2 - 3 - 4 - 5

6) What are the key questions that need to be answered before larvae could be used? (from Document B or additionally) Picture yourself actually having to go out and implement this. What would you need to know?

How we attract--synthetic:

1) What are the key strengths of using a synthetic source?	0-no value 5-great value
A) More potential applications--no larval habitat necessary	0 - 1 - 2 - 3 - 4 - 5
B) Potential to produce 'super attractive' locations	0 - 1 - 2 - 3 - 4 - 5
C) Greater temporal and spatial flexibility in application and concentrations	0 - 1 - 2 - 3 - 4 - 5

2) What are the key concerns with using a synthetic source?	0-no concern 5-very concerned
A) Will probably always have significant expense	0 - 1 - 2 - 3 - 4 - 5
B) Will need to undergo abbreviated form of pesticide registration	0 - 1 - 2 - 3 - 4 - 5

3) What additional strengths and concerns can you identify with using a synthetic source of pheromone? (rank on a scale of 0 to 5, as above)

A) Strengths:

B) Concerns:

4) If the synthetic source of pheromone were not yet available, would it be prudent to begin answering questions using a larval source for field trials?

(yes)
(no, wait until synthetic available)

5) What are the priority questions that need to be answered before synthetic pheromone could be used in lamprey control? (from Document B or additionally) Picture yourself actually having to go out and implement this. What would you need to know?

From document B, part II: How we attract--overall:

1) Given all considerations, which source is the most important to develop? (larval) (synthetic)

2) What proportion of development efforts should go towards each source? (2 numbers add to 100; this is gauging whether we should continue to investigate both, or should drop one from consideration)
larval______
synthetic_______

From document B, part III: Where we attract from

Part III.a) Attract to rivers from the lake

1) If found to be feasible, what is the potential value of this application to lamprey management?
0-- no value 5-- high value
0 - 1 - 2 - 3 - 4 - 5

2) At how many potential locations could this be applied?
0-- none 5-- many, widespread
0 - 1 - 2 - 3 - 4 - 5

3) Why might this strategy not work, or what might limit its effectiveness?

A) Issues involving lamprey biology

B) Management issues:

4) What are the primary questions that need to be answered before this application could be used in lamprey management? (From Document B or additional). Imagine yourself actually trying to attract lamprey to certain rivers for control. What would you need to know?

5) Do you know of any specific sites where it would be useful to attract animals to certain rivers from the lake?

From Document B, Part III.b) Attract to certain tributaries within a river system

1) If found to be feasible, what is the potential value of this application to lamprey management?

0-- no value   5-- high value
0 - 1 - 2 - 3 - 4 - 5

2) At how many potential locations could this be applied?

0-- none   5-- many, widespread
0 - 1 - 2 - 3 - 4 - 5

3) Why might this strategy not work, or what might limit its effectiveness?

A) Issues involving lamprey biology

B) Management issues:

4) What are the primary questions that need to be answered before this application could be used in lamprey management? (From Document B or additional). Imagine yourself actually trying to attract lamprey to a certain tributary within a river system. What would you need to know?

5) Do you know of any specific sites where it would be useful to attract animals to certain tributaries within a river system?

From Document B, Part III.c) Attract to certain area of river (to traps)

1) If found to be feasible, what is the potential value of this application to lamprey management?

0-- no value   5-- high value
0 - 1 - 2 - 3 - 4 - 5

2) At how many potential locations could this be applied? 0-- none 5-- many, widespread
0 - 1 - 2 - 3 - 4 - 5

3) Why might this strategy not work, or what might limit its effectiveness?
A) Issues involving lamprey biology

B) Management issues:

4) What are the primary questions that need to be answered before this application could be used in lamprey management? (From Document B or additional). Imagine yourself actually trying to use pheromones to attract lamprey to traps. What would you need to know?

5) Do you know of any specific sites where it would be useful to attract animals to certain locations (traps) within a river?

From document B, part III: Where to attract from--overall

1) Rank (1, 2, and 3) the strategies according to which would be most useful to control the distribution of lamprey. For each scale, indicate if a larval source or synthetic source would be most useful.

Great Lake to river ______.
(larval) (synthetic)
tributaries in river ______.
(larval) (synthetic)
location/trap in river ______.
(larval) (synthetic)

2) What proportion of development effort should go towards studying the potential of each scale? (3 numbers add to 100; this is gauging whether we should continue to investigate all, or should drop some from consideration)

Great Lake to river ______
tributaries in river ______
location/trap in river ______

Questions on the general program:

1) Do you think using pheromones to attract lamprey to favorable management locations is feasible?	0--not 5--should be feasible 0 - 1 - 2 - 3 - 4 - 5
2) Assuming it is feasible, what is the potential value of pheromone technology in an integrated lamprey management program?	0--not 5--very useful 0 - 1 - 2 - 3 - 4 - 5
3) How might pheromone control be valuable for management?	0--no value 5--very valuable
A) Improve assessment of adult population	0 - 1 - 2 - 3 - 4 - 5
B) Increase capture of males for sterilization	0 - 1 - 2 - 3 - 4 - 5
C) Decrease use of TFM	0 - 1 - 2 - 3 - 4 - 5
D) Decrease recruitment	0 - 1 - 2 - 3 - 4 - 5

4) In what ways would you be willing to assist in development of pheromonal control?

Please provide any additional thoughts, concerns, or potential uses for the migratory pheromone:

Appendix E: Partial list of Great Lakes tributaries with potential for testing attraction of lamprey from a lake to a river

Canada

Lake Superior

Old Woman River

Speckled Trout

Bostons

Baldhead

Coldwater

Barruts

Sand

Mink

Angler

Little Monroe

Nishin

Little Cypress

McVicars

Polly

Cash

Pine

Cloud

Jarvis

Firehill

Kaministiqua

Lake Huron

Silver

Bothwalls

Pretty

Sydenham

Neftels

Ninemile

Maitland

Bayfield

Whitefish River

Indian Brook

Hughson

Kabaoni

Shvigley

Grimsthorpe

West Bay

Lake Ontario

Carruthers

Smithfield

Gage

Grafton

Napanee

Highland

Petticoat

Ganaraska

United States

Lake Ontario

Eight mile
North Sandy
Sage
Blind
Stoney
Sodus
First
Third
Second
Northrup
Braddock
Wolcott

Lake Superior

Orianna Brook
Whetstone Brook
Copper Creek
Sand River
Mosquito Creek
Eagle River
Garden City Brook
Silver River
Jacobs Creek
Fannyhooe Outlet
Silver Creek
Winters Creek
Big Betsy River
Little Betsy River
Pilgrim River
Gooseneck Creek
McCullum Creek
Sawmill Creek
Montreal River
Union Creek
Cedar Creek
Eliza Creek
Gratiot River
Spring Creek
Swedetown Creek
Cole Creek
Graveraet River
Slate River
Linden Creek
Six-mile Creek
Little Carp River
Kelsey Creek
Lester River
Sucker River
French River
Knife River
Gooseberry River
Splitrock River
Manitou River
Caribou River
Poplar River
Arrowhead River

Inland Lakes

Lake Champlain
Lake Oneida
Lake Cayuga
Seneca Lake
Lake Charlevoix
Mullett Lake
Black Lake

New York State Department of Environmental Conservation
Division of Fish, Wildlife and Marine Resources, Region 5
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Environmental Conservation 30 YEARS
John P. Cahill
Commissioner

April 3, 2000

Peter Sorensen, Ph.D.
University of Minnesota
Department of Fisheries and Wildlife
College of Natural Resources
200 Hodson Hall
1980 Folwell Avenue
St. Paul, MN 55108-6124

Dear Dr. Sorensen:

The Fisheries Technical Committee of the Lake Champlain Fish and Wildlife Management Cooperative wishes to thank you for your remote presentation on sea lamprey migratory pheromones during its February 28, 2000 meeting. The presentation was well-received, and the Technical Committee views with interest advances in the use of pheromones in sea lamprey control.

Further, we would welcome the opportunity to review any research proposals you may generate for pheromone studies in the Lake Champlain Basin as a result of your presentation and the anticipated information exchange to follow. Dr. Ellen Marsden of the University of Vermont, suggested that if you should decide to conduct research in the Lake Champlain Basin, the University of Vermont's new water resources laboratory may temporarily accommodate your office or laboratory needs. In the interim since the meeting, Dave Nettles has distributed questionnaires regarding the potential uses and importance of pheromones in applied sea lamprey control. Hopefully these have been returned to you or Lance Vrieze by now.

A pheromone-related topic of great interest to me, would be the development of an effective repellent. We have a small stream (Beaver Brook, NY) in which a safe, effective TFM treatment is technically difficult to perform due to numerous beaver dams and impoundments that the sea lamprey successfully navigate during the spring spawning period. We are considering construction of a barrier dam on Beaver Brook. However, we recently verified that a critical landowner in a potentially good location will not allow construction of such a dam. We plan to continue to evaluate Beaver Brook barrier potential at locations further upstream under different ownership. We also have a larger, two-river system (the Poultney-Hubbardton drainage, NY & VT) that is simple to treat; but obtaining acceptable treatment permits for this system has been problematic due to its special resource designation, the presence of several state-listed endangered species and special interest group concerns. Any barrier that prevents walleye or minnow passage on the Poultney is out of the question since this is an important spawning stream for walleye and possibly for the minnows. However, if there were an effective, environmentally benign and reasonably priced alternative to repel sea lamprey from these systems, I feel the Fisheries Technical Committee would be greatly interested in its possible use here.

Thank you again for a most interesting, thought provoking presentation.

Sincerely,

Lawrence J. Nashett

Lawrence J. Nashett, Chairman
Fisheries Technical Committee

cc: Fisheries Technical Committee
File: 34-55, Sea Lamprey Attractants

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

WISCONSIN DEPT. OF NATURAL RESOURCES

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March 27, 2000

Lance Vrieze
Department of Fisheries and Wildlife
University of Minnesota
1980 Folwell Avenue
St. Paul, MN 55108-6124

Dear Mr. Vrieze:

Thank you for your letter and the information about your project proposal for evaluating native lamprey pheromones as a sea lamprey control option. The Bureau of Fisheries Management and Habitat Protection is interested in your work and the potential for working with you. I would suggest Bill Horns remain as your main contact within our Department. I believe that you have already talked to Bill about your proposal. There are a number of initial concerns that would have to be worked out in order for part of this project to take place in Wisconsin waters.

We would not approve of the stocking of a lamprey species outside of the native range of that species and we may not approve the stocking of a native parasitic lamprey. I have had John Lyons of our Bureau of Integrated Science Services review your letter and fact sheet. John recommends that those conditions would limit the options for Lake Superior waters to the northern brook lamprey. In that basin, some tributaries in the Bois Brule River system have suitable habitat and historically had northern brook lamprey populations present. Native populations have been nearly extirpated due to sea lamprey control treatments. In Lake Michigan waters, most of the streams that lack native lamprey do not have suitable habitat.

Our other concern would be the impacts on removing large number of lamprey from current populations. We would have to work out details of how many lamprey can be reasonably removed from specific sites (obviously removing a lower percentage of lamprey from a larger number of sites may be preferrable to removing a large percentage of adults from one site). The best collection sites for northern brook lamprey that are close to Minnesota would be the upper Chippewa River system (above Chippewa Falls). The Flambeau River lacks lampreys, the St. Croix, upper Black, and upper Wisconsin river systems have only southern brook lampreys, and the lower Chippewa (including the Red Cedar) and middle Wisconsin river systems have a mixture of northern brook, American brook, and chestnum (parasitic) lampreys.

Wisconsin DNR is willing to assist with this project and I think that our concerns are ones that can be incorporated in any field work that you do. The paperwork involved in performing part of the project in Wisconsin waters would involve a simple letter of support from our Madison office, a scientific collector's permit and a stocking permit and fish health certificate for the transfer of lamprey into a tributary. Please work with Bill Horns and he will help you make the appropriate contacts at the field and region level as needed. Please keep Bill informed as your project develops. Bill's phone number is (608)

266-8782 and his email is hornsw@dnr.state.wi.us. We look forward to working with you on this project, if you choose to work in Wisconsin waters.

Sincerely,

Michael Staggs, Director
Bureau of Fisheries Management and Habitat Protection

cc: George Meyer, AD/5
Susan Sylvester, AD/5
Bill Horns, FH/3
Bill Smith, Regional Director, Spooner