GREAT LAKES FISHERY COMMISSION

1992 Project Completion Report[1]

Current Pest Control Techniques – Potential Adaptations for Sea Lamprey Control
(Summary and Workshop Report)

by:

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[1]Project completion reports of Commission-sponsored research are made available to the Commission's Cooperators in the interest of rapid dissemination of information that may be useful in Great Lakes fishery management, research, or administration. The reader should be aware that project completion reports have not been through a peer review process and that sponsorship of the project by the Commission does not necessarily imply that the findings or conclusions are endorsed by the Commission.

Summary

CURRENT PEST CONTROL TECHNIQUES--
POTENTIAL ADAPTATIONS FOR SEA LAMPREY CONTROL

(Workshop sponsored by Great Lakes Fishery Commission)

Chateau Lodge
Cheboygan, Michigan
July 9-10, 1992

(Report to Great Lakes Fishery Commission)

By

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ABSTRACT

The second of a series of workshops designed to find new ways to control sea lamprey, Petromyzon marinus, populations in the Great Lakes took place at the Chateau Lodge, Cheboygan, Michigan on July 9-10, 1992. Pest control experts from the U.S. Department of Agriculture and the Ontario Ministry of Natural Resources met with personnel from the Great Lakes Fishery Commission and the sea lamprey control program to discuss and evaluate the current sea lamprey control program and to examine other potential control options.

Prior to the workshop the attendees provided written descriptions of their impression of the sea lamprey control program, how it compares with other pest control programs, and made recommendations for improving it. At the workshop, sea lamprey control personnel described the chemical control program and its history. Sea lamprey researchers discussed the use of barriers and traps, and the sterile-male-release technique in the control program as well as other control techniques that have been considered in the past. The pest control experts give their impressions of the program, made recommendations for future activities, and submitted additional written opinions after the workshop.

Generally, the pest control experts felt that the current sea lamprey control and research program was a good one. They were all concerned about the almost total reliance on chemicals to control sea lampreys and encouraged continued development and increased support for barriers and traps, and the sterile-male-release technique. They also felt that there are numerous other areas of research that may produce new control methods that should be examined more closely if funds are available.

The following recommendations (in order of priority) were made at the end of the workshop: 1. Support the re-registration of TFM (without it we have nothing). 2. Continue to develop and increase the support for the existing supplemental control techniques (barriers and traps, and the sterile-male-release technique). 3. Continue to develop and improve assessment methods for sea lamprey populations. 4. Continue to conduct high risk research for new control techniques.

RECOMMENDATIONS

Seelye presented the following list of research categories in order of priority.

1. Support the registration of and maintain the use of lampricides.

2. Develop existing supplemental techniques--maintain sterile-male-release technique, and work hard on barriers and traps, attractants and repellents, and fish passage around barriers.

3. Develop and improve assessment of sea lamprey populations.

4. Conduct high risk research for new control techniques.

A discussion on the level of funding for each of these aspects of sea lamprey control followed. It was agreed that all portions should be funded to some extent if at all possible, but under low budget periods the emphasis should be on the first

three categories. When this list was presented, there seemed to be a strong consensus concerning the ranking among the pest control experts and the rest of the attendees. There was also agreement that setting priorities under category four would be difficult and perhaps not very useful. Proposals in this category would have to be considered on their individual merit.

ALTERNATIVE CONTROL RESEARCH

WORKSHOP REPORT

Current Pest Control Techniques -

Potential Adaptations for Sea Lamprey Control

Great Lakes Fishery Commission

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INTRODUCTION

For over 30 years the sea lamprey, *Petromyzon marinus*, control program in the Great Lakes has relied almost entirely on selective toxicants to control populations of the pest. Although the Great Lakes Fishery Commission (GLFC) and its control agents have been committed to a program of integrated control since 1970 (Smith and Tibbles 1980), the development of new methods has been slow primarily because sufficient funding for research has not been available. Recently however, barrier dams and the sterile-male-release technique have been added to the control arsenal.

The GLFC is still very much concerned about the near total reliance on chemicals in the control program and continues to search for other control methods that will be useful in an integrated pest management (IPM) program. Scientists in other disciplines are currently being encouraged to participate in a series of workshops designed to develop fresh approaches and ideas. In the first workshop, experts on sex determination and differentiation in mammals, amphibians, birds and fishes met with sea lamprey personnel to discuss the latest information and techniques available in their fields and research needs were identified that may be useful in reducing dependency on selective toxicants (Sower and Hanson 1992). Experts involved in other pest management programs were invited to participate in the present workshop. The participants are listed in Appendix A. Sea lamprey personnel described the current control program as well as other control techniques that have been considered for sea lamprey control. The experts gave their impression of the program and made recommendations, both oral and written.

PRE-WORKSHOP OPINIONS

Prior to the workshop the attendees were asked to provide a written description of their background in pest management, their impression of the current sea lamprey control program and how it compares with other pest control programs, and to make recommendations for improving the sea lamprey control program. Their opinions are as follows:

ROGER A. BERGSTEDT

I. Introduction--I am currently employed by the USFWS as a fishery research biologist at the Hammond Bay Biological Station. Most of my time is spent on topics related to sea lamprey control or assessment and I consider myself familiar with most aspects of the control program. I am also a member of the Alternative Methods Task Group under the Sea Lamprey Integration Committee. Before coming to Hammond Bay, I worked on the USFWS's fish stock assessment project on Lake Ontario. There, I participated in assessments of the effects of sea lampreys on the fishery and on lake trout restoration.

II. Impression of Current Program--I have not been associated with pest control programs other than sea lamprey control. My initial impression of sea lamprey control was of a program that controlled lampreys in the Great Lakes Basin, while causing relatively little environmental damage and achieving some notable results. I am one who believes that sea lamprey control does in fact provide a necessary base for most of the fishery successes in the Great Lakes.

Compared to other pest control programs, I see our program being good in some respects and poorer in others. Our use of TFM seems safe and well regulated. It is applied only by a small group of well-trained professionals. It is also only applied where larvae of a size capable of entering the parasitic phase have been found by survey crews. Therefore, only a subset of the Great Lakes tributaries are treated, and usually only at intervals of three or more years. Use of TFM probably compares favorably with other limited-use pesticides used to treat specific infestations. Movement toward the concept of an integrated pest management approach in sea lamprey control promises some refinement in the current use of lampricide, and (if other alternative and supplemental control techniques continue to be developed) an overall reduction in lampricide use. An area where the comparison might be less favorable is in our knowledge of exactly what each specific treatment gains. Integrated management requires good information on what the treatment of a specific infestation buys in terms of population reduction and damage avoided. Our current knowledge in those areas seems primitive (at least compared to my perception of some other programs), but it is improving. In defense of the sea lamprey control program, assessment of aquatic organisms is difficult and costly, and the failure to do more has generally not been a matter of choice.

III. Recommendations--I was not sure how to handle this very open-ended question. The following are a few thoughts that I think bear on some of our current problems.

A. Increase the support for development of alternative methods of control. To have a truly integrated approach to sea lamprey control will require an array of fully operational methods. Achievement of two of the Commission's milestones for the 90's will require real progress in this area.

1. Support research to test and improve existing methods or to make them fully operational. I have a perception that there is a certain lack of enthusiasm for advancing the supplemental or alternative methods we have (sterile male and barriers). Once they are implemented (even experimentally), they seem to either lack the

excitement or prestige of new initiatives or are seen at that point as something routine to be accommodated operationally.

2. Support basic research on sea lampreys to promote development of new approaches. It will be critical in the long run to have a broader arsenal of techniques. Any truly new ideas will probably have to come from new basic research.

B. Although I remain skeptical about some aspects of the activities we group under IMSL, a number of good things have emerged from the concept. At the same time that we continue to evaluate which aspects are providing real benefits to the program, I would like to see a continued commitment to integrating fisheries and sea lamprey control programs and control methods within the control program. The increased awareness of sea lamprey control by the fish managers and the increased awareness of the needs of the fish managers by control personnel is making the program more accepted, more rational, and more responsive. We need to continue working toward setting realistic goals for lamprey control on each of the lakes. In the short run, we need to focus more on determining the levels of lamprey-induced morality acceptable for restoration of lake trout and for successful management of other fisheries.

C. Assessment of the different life stages of sea lampreys is central to improving the allocation of resources and techniques and determining the effectiveness of control. I would like to see progress in techniques for assessing residual ammocetes following treatments and for assessing escapement of parasites to the lake. Both would permit better determination of the source of the parasitic-phase animals entering the lake. Knowing the sources of those animals is the key to improving control.

D. Registration of a bottom-release formulation of a lampricide should be pursued. We suspect that lentic populations may be important in some situations. This is clearly the case in the St. Marys River (large portions of that system are more lake-like than river-like). We need a tool for treating those areas.

<u>DAVID A. CARLSON</u>

I. <u>Introduction</u>--I am a Research Chemist at the USDA-ARS-Medical and Veterinary Insects Research Laboratory, charged with discovery and development of novel (the 4th generation) insect control methods. I have worked with chemosterilant treatments of mosquitoes, stableflies, houseflies, and tsetse flies. This involved vapor treatment of insects, monitoring of larval baths, determining residues in insect tissues correlated with sterility and chromatographic analysis of chemicals used. An interesting finding was the appreciable vaporization of Bisazir chemosterilant from aqueous solutions to the air during actual use while sterilizing large numbers of reared mosquito larvae in field trials.

We have synthesized sex pheromones of pest insects, including the housefly, several species of tsetse fly, and the fruit fly *Drosophila melanogaster*, and studied the biosynthesis of several of these. Later work included microanalytical chemistry of insect hormones, juvenile hormones, and steroid hormones.

Most recently, we have completed the genetic engineering in *E. coli* of a synthetic gene that codes for a small peptide hormone that sterilizes female mosquitoes. This followed our identification of the natural peptide: cloning and sequencing of the natural gene in genomic DNA from *Aedes aegypti* mosquitoes is nearly complete.

I saw my first attached freshwater sea lamprey in 1952 while fishing and will never forget it. I was contacted by the program during chemosterilant testing some time ago, and was invited to review the sterilization program in 1991 as a published chemosterilant user. I am quite familiar with the sterilizing procedures employed, treatment of injected adult males, and the care and maintenance of the protective systems in use.

II. <u>Impression of Current Program</u>--The sea lamprey control program is remarkably similar to several (sterile-male) insect control programs familiar to me. I visited several tsetse projects in Africa, and have observed numerous integrated pest management (IPM) efforts in insects. The E. F. Knipling sterile male methodology has often been integrated with population reduction, appropriate cultural practices, modern methods of trapping (trapping out, or survey using attractants or pheromones), use of toxic or sterilizing species-specific baits, and use of sterile males or females. The sterile male sea lamprey approach seems to be working in limited effort. The failure to achieve 10/1 numerical superiority problem of sterilized/natural males is yet unresolved, mostly from unavailability of suitable caught/trapped/reared males.

Unfortunately, the sea lamprey program has only been able to use two of the IPM tools: 1. ammocoete population reduction with very expensive chemical treatment and 2. sterile male release. Other IPM tools are not available. Sex pheromones are known for about 800 species of insects, and are chemically identified and synthesized for about 300. Of these about 50 are in actual use in the field, but this took 25 years and thousands of scientist man-years. No sex pheromones are available for sea lampreys, and sea lamprey endocrinology appears to be in its infancy.

III. Recommendations--The problem of population reduction and, concomitantly, overwhelming native males with released sterilized males is of immediate concern. The present activity seems to be progressing well, and is limited by known factors.

The following is concerned more with long range than short range application, and is dependent upon research.

A. Endocrinology--Thorough understanding of metamorphosis would be invaluable:

1. Can biochemistry and physiology determine how larval forms are maintained? Answers may provide a point of attack.

2. How is metamorphosis triggered, and how is it ended?

3. Does metamorphosing/adult tissue provoke metamorphosis in bioassays of injected larvae? Extraction and injection of steroid hormones is possible from changing forms. Are the gonadotropin-releasing hormone (GnRH) and its analogs available for such a bioassay? Other peptide hormones are also likely involved: Complex modern chemistry/biochemistry/molecular biology is necessary to achieve success in this field. Eventually, dosage or overdosage of larval forms with peptide hormones could cause premature or (permanently?) delayed metamorphosis: Either would help population management.

4. Is cell culture necessary to answer some of the above questions? It may not be possible to use lab animals in vivo.

5. Is it possible to find sympatric bacteria, nematodes or other microorganisms that could be genetically engineered for release into the environment? Genetic engineering could utilize microorganisms containing genes that produce peptides deleterious to ammocoetes.

B. Behavioral modification using pheromones:

1. Alarm responses are common in insects, and can be quite potent in insects such as the African honey bee. Knowledge of the presence of alarm substances in sea lampreys would be useful. The primitiveness of sea lampreys does not necessarily rule out the existence of such materials. Use of any irritant chemical might function as a repellent/flushing agent which might work like tear gas, exposing animals to the environment at the "wrong" time.

2. Secreted/excreted sex pheromones might be useful in trapping or selecting males. However, identification of such materials in vertebrates has been unsuccessful. In any case, the animals cannot be made to do something in the presence of a sex pheromone that they would ordinarily not do anyway. They are not likely to be a magic bullet, meaning that a surrogate female (female decoy) is likely necessary to release responsive behavior(s) in male sea lampreys. Sorting out one behavioral element as a function of some chemical or blend of chemical is difficult. Aquatic animals are likely worse than terrestrials for this kind of effort. Various amino acids and proteins have been implicated as mating stimulants in crustaceans: these are released primarily at molting. None are identified.

3. Food or feeding response to chemicals in aquatic animals is again problematic. Bill Carr at the Whitney Marine Lab, Marineland, FL has been most successful at identification and formulation of bioactive materials for marine organisms. Do sea lampreys detect/tract fish by odors in secreted protein combined with electrical signals? Can fish be genetically engineered to be repellent? To eat lampreys? To possess better defensive behavior? (Mice catch and eat test mosquitoes).

4. Repellents, such as self-generated repellents, overcrowding factors, or fecal factors seem unlikely to be of any use: If slightly diluted the effects are likely lost. Vertebrates (rabbits, deer) will be selectively repelled until hungry, then eat anyway, despite noxious flavors. Emetics (polyphenolics), or cardiac glycosides that cause vomiting in birds are effective especially in avoidance training of these predators. These could be interesting if they

worked on sea lampreys and could be introduced into sea lampreys via fish blood. These may be accumulated by insects (monarch butterflies) through consumption of milkweed leaves. How can you make a selective emetic that can be removed by cooking? What do the seagulls and raccoons do?

However, some new synthetic cockroach repellents will keep cockroaches from feeding and they starve rather than entering treated harborages containing food. Mode of action is of course unknown, but may possibly be active against sea lampreys.

Gavin Christie

I. Introduction--I am a member of the Secretariat of the Great Lakes Fishery Commission. My position is formally titled Integrated Management of Sea Lamprey Specialist. The position was established, four years ago, to help refine and implement the Commission's Strategic Plan for Integrated Management of Sea Lamprey. My comments focus on the general issues of development and deployment of alternative control methods, rather than to specifics of different techniques or research areas.

II. Impression of the Current Program--Having only worked with the sea lamprey control program, my direct knowledge of other pest management programs is limited. I would offer the following general observations of the nature of the lamprey control program in the Great Lakes which should be considered when comparing the program to others.

A. The objectives for the program are tied to the objectives established by the fishery management agencies for the fish community. Defining the benefits of a given control action may not be as straightforward as simply estimating the increased fish production, like an agricultural situation. Rather, the population requirements for rehabilitation of the stock and its sustained reproduction need to be considered.

B. The systems to which we apply control are natural river and lake systems which have a wide range of social values of which fishing is one. Environmental impact of control efforts are of critical importance.

C. Our ability to measure abundances of lampreys, and our ability to measure the abundances of the fish upon which they feed, while improving all the time, are limited.

III. Recommendations:

A. Maintain a clear strategic vision:

The Commission has established its strategy of Integrated Management of Sea Lamprey (IMSL). The foundation of this strategy is the theory of Integrated Pest Management. This strategy defines quantitative objectives for the whole program. The theory behind the strategy defines methods for reducing its dependency on lampricides and using an array of methods while meeting these objectives.

The Commission's Strategic Vision for sea lamprey management reiterates the original strategy. The development of alternatives and deployment of an optimal mix of techniques is elemental to this Vision. But, the development of alternatives and the reduction in the dependency on lampricides must be done in the context of the overall Vision:

> ....provide an integrated sea lamprey management program that supports the Fish Community Objectives for each of the Great Lakes and that is ecologically and economically sound and socially acceptable.

The establishment of target levels of suppression for the program and the deployment of all control options must be integrated in one planning process.

B. Follow a protocol for incorporation of alternative methods:

The Commission is developing a protocol for planning all elements of the program. Key to this protocol are the methods for selecting what streams should be treated, when they should be treated, and by which method. This protocol and the control options selection tools to support it are necessary to plan for the best mix of techniques possible. It is critical that this protocol be in place so that we can deploy new methods of control and the ones we currently have.

Deployment "rules" must be developed for any and all control techniques. The factors which determine the effectiveness of any technique must be determined. From this understanding of how and how well a control technique can work, "rules" are established which will guide its deployment. These "rules" then must be combined with the "rules" governing the deployment of the other alternative measures. The optimum mix of control comes from the combined application of the "rules" for all available techniques.

C. Predictive models of the ecology of lampreys and salmonids:

To plan how to implement any new control methods or the methods we have at hand, we need to be able to make predictions about how these techniques will work. We need to be able to predict how lampricide treatments, barriers, and new techniques will affect the lamprey populations. We need to be able to predict the benefits of these reductions in lamprey populations to decide if they are cost effective. To make these predictions we need systems models of the dynamics of lampreys and their prey. Much work has gone into such models but there is a need for more ecological research and assessment to improve their predictive capabilities.

D. Basic ecology must be a part of the research program:

Our ability to predict the effect of a given control option is based on our level of understanding of the processes which determine the production of lamprey populations. The response characteristics of lamprey populations and their ability to compensate for the effects of various control actions are critical to understanding how to best advance the program.

E. Direct research and development toward a wide array of methods:

Our institutional structure of specific units, groups, and individuals is bound to focus on individual methods one at a time. Through the protocol we can ensure that the development and deployment of the individual methods are coordinated.

F. Coordination of research to meet priority needs:

We need to clearly define the full list of research needs and set priorities for meeting these needs. We need to ensure that the research to meet these needs is coordinated and collaborative to the fullest extent possible. We must carefully examine the research and analyses from the past to make sure we are not going down any paths which have already been visited. We must use as much of the experience of other fields of pest management as possible in approaching research, design and development, and planning deployment studies. We need to involve as wide a range of experts as possible while maintaining continuity and institutional memory.

G. Incorporate background research in program:

Background research is necessary for progress in many areas such as physiology and genetics. This research will be difficult to justify because its benefits will be long term. We must be careful not to exclude this background in our list of priority needs.

H. Complete experimental evaluation of all control methods:

Research has to be a critical part of all stages in the research, development, and deployment of any new method. Our understanding of how lampreys and fish work in the Great Lakes ecosystem is incomplete. We will be dependent on predictive models and on large scale experiments to test any new methods. We must use an adaptive experimental approach to the first application of any new method.

Field scale deployment and research will be very expensive. There will be pressure to rush to fully deploy a new control method without sufficient experimental results. These pressures will come from the public, interest groups, fishery and environmental managers, and the governments which are paying for the research. The careful design of evaluation studies will be compromised by trying to make a method operational too quickly. We must avoid "demonstration" applications and full scale "operational implementations" when "experimental evaluation" is needed.

I. Complete an integrated assessment program:

Without statistically designed assessment programs to evaluate the effects of new control methods it will be impossible to integrate these methods effectively. New methods could be thought to be more effective than they actually are and the switch from lampricides could be made with dire long term consequences. We will not be able to separate the effects of different methods and will therefore not be able to decide on the appropriate mix of techniques.

J. Need to meet all environmental impact assessment and registration requirements:

We will need to meet an increasing number of environmental impact assessment requirements and registration requirements for any new control method. The registration costs associated with any new agent we might want to introduce into the environment will be extremely high. This is a major impediment to developing new chemical control methods. We need to maintain registration of current techniques as a priority and work toward improving their efficacy and reducing their impact on the environment.

K. Need to manage for change:

To change a program the size of the sea lamprey control program toward using a new variety of methods will take creative management. We need to keep everyone involved in the Commission's program appraised of our goals, objectives, and strategic direction. We will all need to participate in education and re-training. We will need to have funding to support these efforts.

L. Need for full consistent funding:

We need to have funding to ensure that we are able to maintain a fully integrated program of research, development, and deployment of new alternative methods. Without continuity over time, we will be forced to take short cuts in the experimental development process. Without the full process and the information it will yield, we will not be able to define the optimal program, nor attain the long term savings that an optimal program will provide.

<u>GERALD T. KLAR</u>

I. <u>Introduction</u>--I am currently the Assistant Field Supervisor for U.S. sea lamprey control operations. I have been in this position for five years. My previous experience was in fish hatchery management and fish cultural research (physiology, genetics, nutrition and cultural methods). My graduate work was in fish physiology and genetics.

Invasion of the Great Lakes by the sea lamprey resulted in the elimination of lake trout from Lake Michigan and the reduction of lake trout populations to small remnants in lakes Superior and Huron. This perturbation of the Great Lakes ecosystem resulted in fluctuations in other species to the extent that dead alewives littered the beaches in the early 1960's. A once thriving commercial and sport fishery on the Great Lakes was eliminated.

Early efforts at sea lamprey control were aimed at blocking and trapping adult spawning runs. These methods were too limited to have any great impact on total lamprey populations. The discovery and use of the lampricide TFM brought lamprey populations under control and allowed the fishery to begin recovery. The Great Lakes sport and commercial fishery has been restored to provide an economic benefit of about 4 billion dollars.

Continued lamprey control is necessary because the few remaining lampreys recolonize the best streams annually. Application of lampricides to about 74 streams annually provide the bulk of the remedial lamprey control. A limited number of mechanical barriers, trapping and experimental electrical barriers and sterile male release provide some supplementary control.

II. Current Program--With the exception of Lake Huron, the current level of lamprey control is necessary on the Great Lakes to support the recovery of the fishery resources. Additional control is needed for the St. Marys River to support recovery of the Lake Huron fishery. With the exception of the St. Marys River, there is no technique immediately available that will replace lampricides and maintain the current level of control. The St. Marys River is too large for a conventional lampricide treatment. Partial treatments, trapping, and sterile-male-releases may be the only feasible techniques for control of lampreys in the St. Marys River.

III. Recommendations:

A. Lampricides:

1. Meet all regulatory requirements for maintenance of lampricide labels and registrations.

2. Label the liquid formulation of Bayer 73 for treatment. (This will save TFM and reduce nontarget mortality in some systems).

3. Label the new bottom formulation for treatment.

4. Continue work to improve application efficiency and reduce amounts of lampricides required.

B. Assessment:

Continue assessment program of sea lamprey populations to assist in evaluation of effectiveness of new and integrated methodologies.

C. Barriers:

1. Increase deployment of cost effective low-head barriers.

2. Continue development and deployment of electrical barriers.

3. Improve trapping at barriers.

D. Sterile-Male-Release Technique:

1. Continue evaluation of sterile-male-release technique.

2. Meet all regulatory and safety requirements of sterilization methods.

3. Identify and develop alternate sources of males for sterilization.

4. Investigate the possibility of biological sterilization (i.e. genetic, hormonal).

E. New Methods:

1. Investigate application of attractants and repellents.

2. Investigate use of genetic engineering or hormonal intervention to interfere with metamorphosis.

Integration of all available control methods in a most cost effective manner should reduce the dependency on chemicals. However, there needs to be a commitment to carry potential new methods through to implementation.

GEOFF MUNRO

I. Introduction--My history in pest management has been one of dealing with forest pests. In this area, pests are classified into insects, diseases and competing vegetation. In all three cases, we have some pesticide options but are constantly working towards biological control techniques including both biological pesticides and non-pesticide alternatives.

I was in private business for approximately 10 years working with property management where I was dealing with pests of trees on a case by case basis. This included a great deal of attention to Dutch Elm Disease which involves an insect vector and a fungal pathogen, both of which react differently depending on the condition of the host tree.

In 1982, I joined the Provincial Government in the Province of Manitoba (Natural Resources). My title was Chief, Forest Protection and Dutch Elm Disease. In this role I was responsible for setting up and implementing forest pest control programs for primarily insect pests such as spruce budworm. I was also in a position to effectively implement a truly integrated pest management program for Dutch Elm Disease, that when I left Manitoba in 1989, was being used in 43 communities across the province.

I joined the Ministry of Natural Resources in Ontario in 1989 as Manager of Forest Health and Protection. This is a similar position to the one described above with a few notable exceptions. Unlike Manitoba, Ontario has one of the largest forest vegetation management programs in the country. Again, we have a pesticide alternative but are working diligently to develop viable alternatives. My current position involves managing policy development for the whole forest policy agenda in Ontario and this includes policies associated with forest pest management.

During the time from 1982 to the present I have represented Manitoba and more recently Ontario at The National Forest Pest Control Forum, The National Forestry Pesticides Caucus and have chaired the Spray Efficacy Research Group. All three of these organizations are dedicated to improving the knowledge and subsequent skill of forest pest managers across Canada. Much of what I hope to offer at the workshop is drawn from a combination of experience and working with colleagues from the discipline through these organizations.

My familiarity with the sea lamprey program is based on local news media reports (I live in Sault Ste. Marie) and the material that was forwarded to us prior to the workshop.

II. Impressions of Current Program--The success of forest pest control has come primarily from a combination of techniques used in combination, usually described as "Integrated Pest Management". With my current knowledge of the sea lamprey program, I don't have an understanding of the degree to which operational control strategies are used in combination. It is my expectation, based on experience in the forest, that success may be enhanced by combining existing and new techniques.

The goal of the program and how the strategies might contribute to that goal is another question I look forward to discussing. In Forest Pest Management, the goal often varies. With Dutch Elm Disease for instance, the goal is to keep the fungal pathogen out of the tree, for once infected, little can be done. The treatment for an individual tree is also potentially different than for a population of trees and similarly for urban (street) populations or open grown stands of elms. With a pest like spruce budworm or gypsy moth, the goal is to keep the tree green enough to stay alive during the infestation. Strategies are planned with the specific goal in mind. Are we after lamprey eradication, population control below a certain level, or the protection of certain species of fish for a given period in their life cycle? What are the costs of each strategy and what constitutes an effective and efficient control program?

III. Recommendations--The paper "Current and Proposed Alternative Methods for the Control of Sea Lampreys" explores a number of possible control techniques but does not indicate which are currently used operationally and with what success. The categories outlined in the paper all have equivalents in the world of forest pest management, each with a history of research and operational testing with quantifiable results. Rarely do we use a single technique as we have learned that it is usually a combination of strategies, focused on a specific goal, that proves successful.

I prefer to withhold making recommendations until I have the opportunity to discuss the various options at the workshop.

ALAN J. SAWYER

I. Introduction--I did my graduate work in entomology at Michigan State University (M.S., 1976; Ph.D., 1979), where I emphasized insect population ecology and integrated pest management (IPM). From 1979 to 1986 I served on the faculty of entomology at Cornell University, where I did research in insect pest ecology and management, taught undergraduate and graduate courses in IPM, and had cooperative extension duties. Since 1987 I have been an Ecologist with the USDA's Agricultural Research Service. I conduct research on the ecology of fungal pathogens of insects, the dynamics of fungal epizootics in agricultural environments, and the use of fungal pathogens for biological control of insect pests.

In 1980 I presented an invited paper, "Prospects for Integrated Management of the Sea Lamprey," at the Sea Lamprey International Symposium in Marquette, MI. In 1982 I took part in a GLFC-sponsored workshop concerning application of IPM to control of the sea lamprey. Over the years I have been asked to review grant proposals and research programs on behalf of the Commission. Since November, 1989 I have served on the Commission's Sea Lamprey Integration Committee (SLIC) as a specialist in IPM. I am a member of SLIC's Research Task Group. I consider myself to be quite familiar with the sea lamprey control program.

II. Current Status of Agricultural IPM--Integrated pest management in agriculture arose from the need to integrate the use of chemical pesticides with more ecologically-based control methods. The cornerstones of IPM in agriculture have always been, and continue to be: (1) an ecological orientation, (2) an economic foundation, and (3) an arsenal of techniques consisting of judicious use of pesticides combined primarily with biological controls, pest-resistant host plants, and cultural controls. The concepts, history, and techniques of agricultural IPM, as well as the application of IPM to the sea lamprey problem, were outlined by Sawyer (1980). Most of what I wrote then applies today. Here I provide an update on the current status of agricultural IPM, draw some contrasts with the current sea lamprey control program, and offer some recommendations.

A. Pesticides: The place of pesticides in current IPM programs in agriculture varies with the type of pest being considered. In insect pest management, where IPM got its start, insecticides are waning in importance although they are still an essential element in the control of many important pests. Insecticide resistance continues to increase, with hundreds of examples extant. The public has a largely negative impression of pesticides, with their attendant problems of residues, nontarget impact, and environmental contamination. Registrations are increasingly costly and difficult to obtain, and chemical companies are less interested in product development and re-registration, particularly for products with limited markets. Unfortunately, this works against the desire to develop highly specific pesticides with toxicity limited to particular pest species. Insecticide research and development has entered a mature phase, in which current topics include: nontarget impact; environmental fate; resistance management strategies; selection for pesticide-tolerance in crops and beneficial organisms; the identification of naturally-occurring bioactive compounds; the development of formulations, delivery systems and application strategies that are safer for applicators and more selective in their impact; and the gathering of data to support re-registration.

In the control of weeds and plant pathogens, the use of herbicides and fungicides is holding steady or increasing, depending on the crop. The search for new compounds, particularly those representing new classes of compounds or those with novel modes of action, continues. However, the incidence of pesticide resistance is increasing among weeds and plant pathogens, and we may expect the pattern of herbicide and fungicide development and use to eventually follow that which was seen for insecticides.

B. <u>Biological control</u>: IPM began almost 50 years ago with the desire to find ways of using pesticides that would not interfere with natural control of insect pests by predators and parasites. During the pesticide era, research on biological control languished, but in the last 20 years it has staged a major comeback. Today, far more research is conducted on biological controls than on insecticides. Biological control of insects can now be considered a mainstream technique with a growing number of successes to its credit, particularly when used in conjunction with other methods in IPM programs. Current research topics include foreign exploration for natural enemies; the development of methods for rearing natural enemies for mass releases; conservation and management of existing natural enemies; the ecology of biological control, including multiple-species interactions and nontarget impacts; deployment theories and strategies; biotechnology of microbial pesticides; and regulatory issues. By comparison, biological control of weeds and plant pathogens is in its infancy, but is being pursued with increasing vigor.

C. <u>Pest-resistant host plants</u>: The use of host plants that resist or tolerate the attack of insect pests and disease organisms is as old as agriculture itself, and continues to be one of the foundations of IPM programs. Current research still emphasizes classical plant breeding, but also includes the study of natural variation in susceptibility of plants to pests; identification of defense mechanisms in plants; coevoluntionary responses of pests; collection and conservation of pest-resistant germplasm; strategies for effectively deploying host-plant resistance; and increasingly, the application of biotechnology to incorporate desirable traits into crop plants, including genes conferring resistance to pests. In some cases, "transgenic" plants are being developed which incorporate genetic material from other species, not necessarily plants.

D. <u>Cultural controls</u>: This is a catch-all category for a wide range of ancient and modern pest control techniques. Many old standbys, such as sanitation and cultivation, continue to be widely used. Others, such as burning and summer fallowing, are being abandoned for environmental reasons. A topic of great interest is the influence of reduced tillage systems on weeds, plant diseases and soil-inhabiting insects. Some techniques, such as adjustment of irrigation and fertilization regimes so as not to favor pest populations, can be viewed as forms of environmental management on a microhabitat scale. In ecological terms, many cultural controls affect temporal relations among crops, pests and natural enemies by altering plant and pest phenologies, by adjusting the timing of planting, harvesting and other agronomic operations, or by employing crop rotations or host-free periods. Other cultural controls alter spatial aspects of the environment, by adjusting plant spacing or by manipulating the mix of crop varieties or species on various spatial scales.

E. Semiochemicals. There has been considerable interest in pest control methods based on semiochemicals--natural chemical signals released by one organism which influenced the behavior of other organisms. Pheromones, conveying information to members of the same species, have received the most attention. They may be used as attractants for detection, surveillance and mass-trapping of insects, as repellents (marking and alarm pheromones), or in mating disruption schemes (sex pheromones). Kairomones, chemical cues used by insects to locate food or prey, may be used as attractants or, when broadcast, to disrupt host location. Allomones, largely defensive chemicals produced by plants and animals, may serve as repellents or feeding deterrents. Unfortunately, the early expectation that semiochemicals would usher in a new era of "biorational" pest control has not been borne out. To date, the primary application has been in pheromone traps used to monitor pest populations. There are a few examples of other uses in pest management programs, particularly in conjunction with other methods such as pesticides. Research on the use of semiochemicals continues. One interesting experimental technique is called "autodissemination," in which moths are attracted by a pheromone to a dispenser of a host-specific virus. The virus is transmitted to the offspring of contaminated females when they lay their eggs.

F. Physiological controls: Following initial discoveries years ago, there has been little recent work on insect growth regulators: specific hormones that interfere with normal growth and development when fed or applied to insects (e.g.

ecdysone, juvenile hormone analogues, chitin synthesis inhibitors). To date, only a few commercial products have been developed. On the other hand, plant growth regulators have been developed successfully as herbicides.

G. Genetic controls: Considerable effort has gone into developing the sterile-insect-release-method, or sterile-male technique. The method is usually dependent on insect rearing programs that operate on a massive scale. Aside from experimental trials and demonstrations, the technique has largely been used in eradication efforts aimed at isolated infestations of invading pests, such as fruit flies, or against insular populations. A notable exception is the screwworm eradication effort, whose goals has been to eliminate that pest from the United States and drive it south to Central America, where it may be more easily confined. The sterile-male technique has also played a central role in several area-wide boll weevil eradication demonstrations. Reestablishment of the target pest from residual populations or by new invaders is a problem with this method when the eradication zone is not well isolated.

Other genetics-based approaches to pest control have been considered. Hybrid sterility delays, but amplifies, the impact of sterile insects on a target population. Multiple translocations, cytoplasmic incompatibility, and other mechanisms have been investigated as means of achieving hybrid sterility or of moving conditional lethals or other deleterious genes into populations. Few of these methods have seen practical application in pest control programs.

H. Regulatory controls: Regulatory measures remain a first line of defense against invasions by exotic pests. Thousands of potentially harmful insects, weeds and plant disease organisms are intercepted by inspectors at international ports of entry each year. Eradication programs, involving cultural and physical controls, pesticides, semiochemicals, and sterile-insect releases, are undertaken to eliminate incipient invasions. Quarantines restrict the movement of plants, animals, soil, machinery and materials across county and state lines from infested to noninfested areas. These programs are dependent on detection and monitoring methods, a subject of continued research.

I. General Topics: A subject of great interest in IPM research is the integration of methods: how do various pest control techniques interact, and how can they be used in combination? There is a great need for basic research on such questions as how cultural practices affect biological control agents, how pesticides can be made compatible with biological control, how resistant host plants affect natural enemies, and how various biological control agents, such as parasites and insect pathogens, interfere with or enhance each other. Simulation models are used to evaluate these interactions and design integrated programs of pest management techniques.

Another subject of continuing interest is the economics of pest management, including cost/benefit analyses of various methods; the use of models to evaluate the economics of different integrated strategies; the development of simple economic injury levels or more complex, dynamic, multidimensional economic thresholds; and the use of models and expert systems as decision aids.

The environmental impact of pest control measures continues to be of concern. Increasingly, this includes the impact of nonchemical methods, such as the effect of exotic natural enemies on nontarget hosts, and the environmental effect of cultural controls. Guidelines and laws regulating the importation and release of biocontrol agents are currently in a state of confusion; they are likely to become more restrictive.

A lack of incentive to commercialize novel pest control methods remains an impediment to implementation. Major seed and pesticide companies are involved in research and development of some products, such as pest-resistant and transgenic plants, and novel pesticides. Smaller biotechnology firms are working on some high-risk ventures, such as microbial pesticides and microbial products. Unless a major market can be identified for a new pest management technique, it is unlikely to be developed by commercial interests. For this reason, government and university laboratories carry out almost all research on biological and cultural controls.

III. Impression of Current Sea Lamprey Program--I am extremely impressed with how the sea lamprey control community has adopted the IPM concept over the past 10-15 years. This change has been very rapid, and seems to have been accepted by most of the parties involved. There has been great progress in developing the decision-making tools and procedures that will permit the eventual implementation of an operational IMSL program.

I am impressed, too, with the ambitious goal of halving current levels of lampricide use by the year 2000. I agree that this is desirable, but wonder whether it will be possible. Until substitute control measures can be implemented, the present level of lamprey control absolutely depends on maintenance of current lampricide applications. This program, in turn, is completely dependent on TFM. I am very concerned that only one compound (plus the synergist Bayer 73) is available; this chemical could be lost at any time, due to loss of registration, termination of production by the supplier, public pressure to cease applications, or the development of resistance. This is a very unstable situation, comparable to some of the worst cases in the history of insect control.

Research on the sterile-male-release technique (SMRT) has been very successful, and implementation appears to be going smoothly on Lake Superior. Whether the method can be extended to additional lakes, and the eventual outcome of this effort remain to be seen. Total eradication of the sea lamprey from the Great Lakes is unlikely ever to be achieved, and should not be seen as a goal. SMRT may play a vital role in maintaining low levels of sea lampreys with the use of far less lampricide, or in treating problem areas such as the St. Marys River. Obtaining a continuous supply of males for sterilization will certainly become a problem if the method is widely used. Rearing, so important in applications of SMRT against insects, does not appear to be a possibility with lampreys. Other options must be explored.

Barrier dams represent the third major element of a very limited arsenal of methods currently available for sea lamprey control. The barrier dam program should be protected and expanded. At the same time, a strong research program should be pursued to develop efficient barriers having minimal impact on fish and invertebrate populations, water quality, and recreational and aesthetic values. The combination of barriers with other methods, particularly those exploiting the behavior of lampreys, should be investigated vigorously. The proposed ORBITF facility will play an essential role in this research. The facility should be completed as soon as possible, and visiting scientists should be encouraged to conduct research there.

I am encouraged by the institution of an external grant program for funding research into alternative control methods. The amount of money available is low, however, and lobbying efforts should be continued to obtain additional funds. At least some portion of these funds should be reserved for speculative or "high risk" proposals, in the hopes that something entirely new and unanticipated will be discovered. There is a great need for additional management options.

Along these lines, I am somewhat puzzled that two of the main types of control techniques used in agricultural IPM, biological control and the use of pest-resistant hosts, seem to have no counterpart in the current integrated sea lamprey program. Although these approaches have apparently been considered and dismissed, I believe there may be great potential here.

Few organisms are without natural enemies, particularly pathogens. Most insects are subject to disease caused by viruses, bacteria, protozoa, fungi and nematodes. The great majority of these pathogens are highly specific, or at least restricted to closely related hosts (while some pathogen species have a wide host range, highly specific strains usually exist). Because the sea lamprey is so remotely related to most other fish, it would appear to be an ideal candidate for biological control. A successful technique in classical biological control is to go to the geographic origin of a pest to search for natural enemies that have coevolved with the pest or its relatives. Strict quarantine procedures and host-range tests ensure that imported natural enemies will not become established in non-target hosts following release.

It is known that the sea lamprey is selective in its choice of prey. Furthermore, the tolerance of different species of fish to lamprey attack varies. The behavioral, physiological or other basis for host preference and the tolerance of prey should be examined for possible application in selective breeding or genetic engineering efforts. The existing institutional structure of the hatchery system, and the associated background knowledge of aquaculture, would seem to make breeding for lamprey-resistant or tolerant fish a feasible enterprise. What is needed is a concerted scientific effort to find and exploit heritable variations among fish populations.

IV. Recommendations in Order of Priority

A. A vigorous program of research into alternative control methods should be pursued to supplement methods currently available. Funding levels should be increased, and protected against being used to maintain or refine existing methods.

   1. The population ecology of sea lampreys and related parasitic lampreys should be studied in their native habitats, to discover the natural

regulatory factors acting on those populations. Features of the habitat, characteristics of prey, and natural enemies should be investigated at the site of origin of the sea lamprey.

2. A search for biological control agents, particularly lamprey-specific pathogens, should be undertaken.

3. Genetic variation among fish populations in their susceptibility to lamprey attack and injury should be investigated.

4. Lamprey-specific physical and behavioral controls, to be used in conjunction with barriers, should be pursued at the ORBITF facility.

5. Physiological controls interfering with the growth, development, metamorphosis or reproduction of lampreys should be investigated.

B. The SMRT technique should be refined to the point where it can be routinely implemented on selected streams as part of an overall, integrated management program to suppress lamprey populations to target levels. Sources of males for sterilization must be secured.

C. The barrier dam program should be maintained or expanded, and improved designs should be investigated at the proposed ORBITF facility.

D. The use of TFM should be fine-tuned to minimize environmental and social concerns. Improvements in formulation, dose-determination, stream selection and scheduling, and application methods should be made, if possible, to prolong the lifetime of this vital control method, while minimizing its cost and impact.

<u>LARRY SCHLEEN</u>

I. <u>Introduction</u>--I have been involved with the sea lamprey control program in the Great Lakes since 1969, with field and supervisory experience in larval and adult assessment, lampricide control and alternate control techniques while employed at the Sea Lamprey Control Centre. Since 1989 I have been responsible for coordination of all field projects of the Centre.

II. <u>Impression of Current Program</u>--With 23 years of experience in the sea lamprey control program, I have witnessed (for the most part) the continual, and still ongoing, improvements to the program, including refinements to the lampricide treatment program and the initiation and development of alternate techniques such as barriers and the sterile-male program.

Despite some recent budget restrictions, which have limited progress, the program has been highly successful and has allowed for rehabilitation of valuable fish stocks.

The essentially uncontrolled St. Marys River larval population, and its effect on the Lake Huron fishery, continues to be the largest single impediment to effective control. The lack of an effective and registered bottom toxicant prevents control of lentic larval populations, which are probably most significant in certain bays of Lake Superior.

The threats of high re-registration costs, formulation changes, and actual supply and cost of present lampricides have been continual.

The barrier dam program, which has been very successful in reducing treatment costs, etc., on the Canadian side of the lakes, has not been matched in the United States.

The recent budget restrictions have limited the progress of the IMSL process. Better and more quantitative assessments of larval and adult populations are required to further this process and to fuel current and future prediction models. More quantitative larval assessment would also provide better cost vs. kill analyses for lampricide treatments and the sterile male program. I feel the Canadian Agent has fallen behind the U.S. Agent in larval assessment efforts, particularly regarding the quantitative aspects, which are so crucial for furthering the IMSL approach.

III. <u>Recommendations for Improvement (in order of priority)</u>

A. Investigate and develop attractants/better trapping techniques for spawners to:

1. Remove potential spawners before spawning.

2. Provide captures for use in the sterile-male program.

This area would seem to be the least costly and most environmentally friendly (does not utilize pesticides). A method to attract parasitic-phase lampreys would seem to be valuable, but is harder to envision.

B. Assessment techniques and tools have shown continual improvements but this needs to be continued. Significantly more assessment effort is a requirement to further the IMSL approach.

C. Lampricide toxicology:

1. Re-registration of present lampricide is of high priority,

2. Development and registration of an effective and licensed bottom formulation should be pursued. Lentic populations are still significant in some bays, in-stream lakes, and within large rivers such as the St. Marys.

D. Control technique efficiency:

1. There is a need to better define or arrive at cost vs. kill of larval lamprey by conventional treatments.

2. The % of total (lentic vs. lotic) population--more quantitative estimates of lentic populations and transformation rates are required.

JAMES G. SEELYE

I. Introduction--My experience in pest control is limited to the last ten years working as a research-manager on the sea lamprey control program. Contacts with other pest control programs have been through talking to individuals about specific projects we were involved in or by reading scientific literature.

My formal training through the PhD level was in biogeochemical cycling. My career started with the Corps of Engineers where I studied the effects of the open water disposal of dredged material, then I went to the USFWS and studied the effects of contaminants on reproduction of lake trout, and finally to this position conducting studies in support of the control program for sea lampreys.

Because I have generally been on the environmental protection side of the contaminant issue, I can easily understand those who take a strong stance against the use of pesticides. This is a popular view, but not necessarily a practical view, and not the one that prevails among the pest control research community. Once the costs, dependability, and availability factors are considered, the use of pesticides seems even more appropriate as a principle pest control technique. Examining the methods of application, the reasons for use, the chemical formulation, the scheduling of use, the effects on non target organisms, and the amount of pest control necessary, the controlled use of lampricides might make more sense than suggesting that pesticides are to be avoided.

I strongly support the use of barriers and weirs combined with traps as a good alternative way of controlling the reproduction of sea lampreys. With a reasonably small amount of systematic research, the application of this technology will become an important part of the overall program.

The use of the sterile-male-release technique seems to be a potentially important method for controlling sea lampreys. If the current experiments start to show promise after one or more generations, I would suggest that we expand the program as far as possible to supplement the use of lampricides and barriers.

II. Impressions of Current Program--The current program is perhaps the most successful aquatic pest control program ever carried out. Sea lamprey control is the foundation on which the rest of the fishery restoration program rests in the Great Lakes. This fishery is worth in excess of four billion dollars annually and the results of the lamprey control combined with other efforts has allowed the ecosystem to make major strides toward returning to a healthy self-sustaining system.

The program's nearly total dependency on lampricides as it's principle control device is unfortunate. However, the reasons for this are easily understood. This program like many other pest control programs was very successful with the simple application of pesticides. The way the pesticide was used, the direct ties to the rehabilitation of salmonids, and our understanding of the safety of the lampricide have all contributed to the complacency that developed over about the first 30 years of the program. Researchers and leaders in the sea lamprey control program were always concerned about the total dependency on lampricides as evidenced by the lists of alternative and supplemental methods they developed. Barriers were popular before the lampricide program and research on the sterile-male-release technique for lampreys began more than 20 years ago. The level of effort the program put into studying these other methods, measured in dollars, has been minor when compared to other pest control programs.

We must remind ourselves that the sea lamprey problem is a regional situation in the U.S. and Canada. Funding for this program has always been difficult to obtain--especially when we thought sea lampreys were under control to a degree that would allow achievement of the fish community goals in all the Lakes except Lake Huron. About ten years ago we were shocked at the estimates of the numbers of dead lake trout on the bottom of Lake Ontario due to sea lamprey attacks. The management agencies had trouble believing that sea lampreys were killing as many large lake trout as the fishermen were. Realizing that sea lampreys might still be a factor in our efforts to rehabilitate the fishery combined with the adoption of an integrated pest management perspective have changed the priorities and needs of our program dramatically.

We now must know what effects the sea lampreys are having on the fishery to a level of precision far greater than in the past. To do this we must estimate the numbers of lampreys present, the relative effects of the lampreys on the fishery, the species of fish the lampreys are preying on, their resistance to lamprey attacks, the influence of environmental factors on the effects of lampreys on the fishery, and ways of keeping track of all of this information that is conducive to making predictions. With this huge increase in the amount and type of information needed, the program should see a proportional increase in the budget. Research must be substantially better funded but monies must also be readily available to implement the programs as they are developed.

III. Recommendations--My highest research priority has been and will be to maintain the integrity of the lampricide program for the control of sea lampreys. Huge improvements in the efficiency and safety of the lampricide program have been made over the past 35 years, and additional improvements are feasible.

Secondly we should do what needs to be done to support the sterile-male-release technique experiments to see that the method is thoroughly tested and supported with data on the safety of the material we are using.

Next, we should systematically develop weirs, barriers, and traps that can be used effectively against sea lampreys while doing minimal damage to the environment. This includes testing and developing a number of physical and chemical cues that might enhance our ability to trap sea lampreys.

We should also put a substantial effort into assessment techniques that will allow a systematic semi-quantitative evaluation of the program. This activity could easily overwhelm the rest of the program if we are not careful. The level of assessment necessary is a difficult judgement and must be more carefully examined. The disparity between the U.S. and Canadian programs in this area is a major deterrent to implementation of lake wide or watershed wide management program.

Although we have maintained some contact between the principals of this program and other pest control experts, the level of contact should be increased to a point that if a new method of control begins to work well in another field, we will already be on the way to testing it on the sea lamprey.

Lastly, we need to spend a reasonable amount of money on high risk research (I think the tendency would be to spend too much rather than too little money on long shots). A small percentage of the budget should be spent on a variety of topics at the cutting edge of pest control. Genetic and other biochemical techniques might prove to be valuable to the program by resulting in the development of a control method. This type of research might also provide basic biological information about the sea lamprey and ways that sea lampreys could be manipulated to conduct research that might lead to a control strategy.

The research budget should be large enough to support research in all of the areas identified above at the same time. Some of these studies can be accomplished most efficiently and effectively at the line-funded research facilities and by the control units themselves. Others would best be accomplished through collaborative efforts between university and GLFC line-funded researchers. The most specialized research might be best accomplished by researchers independent of the current programs.

JAMES W. SMITH

I. Introduction--I have a B.S., M.S., and Ph.D. in Entomology and have been involved in pest management research for 30 years. From 1971 until 1982, I was a research entomologist working with cotton insect control at the Bioenvironmental Insect Control Laboratory at Stoneville, Mississippi. My major interest was in population dynamics of cotton field arthropods. I studied and developed sampling techniques. During this period, I conceived the idea and developed techniques to study interspecific hybridization as an autocidal method for controlling the two-spotted spider mite, *Tetranychus urticae*. I was also a member of a team researching the potential for hybrid sterility in tobacco budworm management.

From 1982 until 1987, I was Research Leader of the Insect Control Systems Research Unit at the Southern Field Crop Insect Management Laboratory at Stoneville, Mississippi. During this period I led a team that established estimates of the population density of overwintered tobacco budworms in the Delta Area of Mississippi. The studies were conducted with releases of known numbers of reared marked moths over a 200-square-mile area. I also was leader of a team that investigated chemical control of early season insect pests of cotton during this period. This research led to the recommendations on control of early season pests that are now widely used and have led to substantial cotton yield increases.

In January of 1987, I became Research Leader of the Boll Weevil Research Unit, ARS-USDA, at Mississippi State University. In this position, I have led a team that has developed and field tested two major suppression techniques available for boll weevil eradication efforts.

First, we conducted a large-scale area test of released sterile boll weevils that resulted in reasonably accurate measurements of the effectiveness of sterile boll weevils against a naturally occurring population in commercially grown cotton. Second, I was part of a team that developed a unique formulation of a plastic bait that attracts and kills boll weevils. This formulation incorporates a pheromone, color attractant, and feeding stimulant along with a toxicant. This suppression device is an economical and environmentally-sound approach to pest management that can be applied over large areas to aid in an eradication effort. In addition, I have worked closely with the Boll Weevil Eradication Program in the Southeastern United States, and I am now involved in a pre-eradication program that is essentially a mapping and trapping effort in Mississippi. We are now developing a Geographical Information System (GIS) for the state and studying populations with pheromone traps.

Internationally, I have directed research in Egypt and helped set up a research program on cotton in China. Recently I was invited to Argentina to aid that country in preparation for the boll weevil's invading their cotton growing areas.

During the last year I have attended two meetings on sea lamprey control and feel that I'm fairly familiar with the program.

II. Impression of Current Program--The sea lamprey control program has many similarities to the boll weevil control program. The types of programs available for control of the boll weevil over a large area can be grouped into three broad program alternatives: 1) no action (that is, no control by the Federal Government), 2) area-wide eradication of the boll weevil, and 3) area-wide suppression of the boll weevil.

Eradication or suppression of the boll weevil throughout its U. S. range is not presently considered technically feasible without some use of chemical insecticides. Chemical control is considered the only active control method that is consistently efficacious in rapidly suppressing or eliminating high-density populations of boll weevils. High and damaging populations can generally be reduced within hours and thus provide immediate protection of the crop.

The benefits of nonchemical controls are varied and unpredictable, and for this reason, many growers are reluctant to depend entirely on these practices. In addition, the uncertainties associated with commodity prices and weather may force a grower to choose to abandon cotton before the benefits of nonchemical controls are realized.

Most nonchemical methods are limited in effectiveness to low population densities, and they cannot be used alone to suppress or eliminate the boll weevil from heavily infested fields. These methods include mass-trapping, bait sticks, and the release of sterile insects. In addition, the sterile insect technique is not available for large-scale use at this time. The use of this technique on an area-wide basis would require the construction and operation of a large-scale sterile insect production facility. An estimated 7 years and approximately $10 million would be required before adequate supplies of sterile insects would be available for release. Certainly, the sea lamprey program has a more favorable situation concerning the use of sterile-male releases.

Cultural control methods for the boll weevil provide some degree of population reduction, but they cannot be used alone to effectively suppress or eliminate a population. These methods are preventive and do not provide direct or immediate crop protection. In many cases, the suppression provided by cultural techniques is inadequate, and chemical insecticides are still required.

Many current insect management schemes do not seek to eliminate chemical treatment but rather seek to reduce the number of required treatments by implementing nonchemical control methods whenever possible. Elimination of chemically controlled methods would not accomplish the goals of area-wide eradication or even suppression.

III. Recommendations

A. Improve methods of population density measurement and couple sampling programs to Geographic Information Systems.

B. Develop the use of stream barriers as an effective nonchemical control technique.

C. Continue to improve the sterile-male-release program and develop methods to evaluate its effectiveness.

D. Investigate the use of chemical attractants and repellents for sea lamprey control.

E. Minimize the environmental impacts of chemical treatments now used for control.

WORKSHOP PRESENTATIONS AND DISCUSSIONS

Description of Current Sea Lamprey Control Program (Gary Klar and Larry Schleen).

The chemical control program and its history was described by Klar. He pointed out that although there are 5,233 tributaries to the Great Lakes, only 208 of these are chemically treated on a regular cycle, and that during a typical day during the field season, TFM is most likely to be completely absent from or present in only 1 of the 5,233 tributaries of the Great Lakes.

The organizational and operational aspects of the program was described by Schleen. In U. S. waters, 50% of budget is used for assessment and 50% for control. In Canada most of the budget is spent on control. Assessment activities and chemical control methods were described. Some of the problems (fish kills, notification of public prior to treatments, etc.) and limitations (St. Marys River) were discussed.

Klar discussed the re-registration of TFM (EPA has requested that additional studies be conducted). Klar stated that because of the long history of use without significant problems and because studies to support registration in the past did not reflect adversely on the use of TFM, that it is unlikely that we will lose the TFM registration. A discussion about registration ensued and it was agreed that it is likely that any chemical added to streams in the future (pheromones, chemical attractants and repellents, etc) will likely face strict registration requirements.

Seelye pointed out that an increase in the use of lampricides may be necessary on a short term basis to make other techniques work. Klar stated that occasionally it may be cost effective to re-treat a stream if the original stream treatment was only 97% (or less) effective. More frequent treatments will increase the effectiveness of the control program. Seelye discussed the St. Marys River lamprey problem and its effect on the Lake Huron fishery.

Seelye stated that while the control program has been successful, most fishery managers on the Great Lakes want better lamprey control in their areas. Bergstedt explained how dead lake trout were found in Lake Ontario and how estimates of lamprey induced mortality were made. Seelye stated that in laboratory studies, 50-60% of lake trout attacked once by a sea lamprey died.

Klar responded to a question by Smith concerning optimization of the lampricide program by stating that if we had sufficient funds available for chemical control we could reduce the lamprey populations in Lake Superior and Lake Ontario by an additional 50% and do it cost effectively and environmentally effectively as well. We probably could do the same in Lake Michigan but not in Lake Huron because of the St. Marys River problem. Hanson stated that it would be useful and may be necessary to do that on Lake Superior (or any other lake where the sterile-male-release technique is used) in order to make the sterile-male release program successful since the technique is most useful when lamprey populations are low. The cost of an intensification program would not be high since only a few streams would have to be re-treated for residuals or treated annually to prevent re-establishment of lentic populations.

Christie presented a paper entitled "Strategic Vision of the Great Lakes Fishery Commission for the Decade of the 1990s" (Great Lakes Fishery Commission 1992). The milestones for sea lamprey management were discussed including how we have been reducing our reliance on lampricides in the past and how we hope to reduce it to 50% of current levels in the future.

<u>Use of Barriers and Traps and the Sterile-Male-Release Technique for the Control of Sea Lampreys</u> (Jim Seelye).

Seelye described the history of the use of barriers (mechanical, electrical, and low-head dams) with traps in the sea lamprey control program. The proposed ORBITF facility on the Ocqueoc River and the Smith-Root electrical barrier system were described. He stated that additional work on trapping (combined with the use of attractants or repellents) for control, assessment, and as a source of males for sterile-male releases is needed. Peter Sorenson's and Monell's work on attractants and repellents was described. He stated that a committee has been formed to evaluate the barrier program again and that there is renewed interest in the program but it will take additional money. The use of weirs and the removal of spawning-phase sea lampreys offers the most practical approach for decreasing the use of lampricides in the short term.

The development of the sterile-male-release program in sea lamprey control was described. Chemosterilants, radiation, and immunological methods of sterilization were investigated and the chemosterilant bisazir, was found to effectively sterilize lampreys without affecting behavior. The sterile-male-release program on Lake Superior and the St. Marys River was described. The program is long term and results will not be seen for several years because of the long larval period in the lamprey's life history.

The stock recruitment problem was discussed. Sawyer felt it should be solved because the success or failure of the sterile-male technique depends on the nature of the stock-recruitment curve. He felt there is an opportunity to study this in conjunction with the SMRT trial on Lake Superior. Others felt it would be extremely expensive and difficult to do. Bergstedt stated it would probably be different for each stream and also that the number of reliable stock recruitment curves for fish that have been developed could probably be counted on one hand.

Christie briefly described the experiments that are going on in four Lake Superior streams at this time. Seelye stated that we need to develop the technology to measure the production of parasitic-phase lampreys from streams.

Beamish described his work on brook lampreys in 70 streams and stated that sex ratios vary from 20-80% females and that where you have fast growing populations they are predominantly female with high fecundity. Hanson stated that the fact that sex ratios of spawning-run lampreys in Lake Superior has shifted from 70% male prior to chemical control to about 35% male after treatment may be an indication that the density of larvae in the streams is much less now. All agreed that assessment of various control methods is extremely important but that the lack of funding is a problem.

Seelye discussed prey species selection by lampreys. He described laboratory studies conducted at Hammond Bay and various lake studies. He suggested that we should not try to manage around sea lampreys by altering prey species but instead should directly attack the problem and conduct the control program to the best of our ability as we have for the past 35 years.

Other Control Techniques that Have Been Considered for Sea Lampreys (Roger Bergstedt).

Bergstedt summarized the report entitled "Current and Proposed Alternative Methods for the Control of Sea Lampreys" by Bergstedt and Seelye (1992). The use of barriers was described and Bergstedt stated that fish passage was the major problem that needs to be solved.

Regarding attractants and repellents, Beamish stated that C. Buttons (St. Johns, Newfoundland, Canada) suggested that lampreys may be attracted by means of electricity and that a study regarding this has been proposed to the GLFC. Bergstedt described the various ways attractants and repellents could be used in the lamprey control program.

Munro asked why lampreys spawn successfully in some streams and not in others. Christie stated that lampreys generally prefer high quality streams. Occasionally a year class may develop in poor quality streams if conditions temporarily improve.

Bait and kill techniques were discussed. Seelye suggested that a combination of sound and a bio-energetic field to attract parasitic-phase sea lampreys off the mouths of streams may be possible. Sawyer suggested using a controlled release chemical to attract them and then kill them. The pros and cons of this technique were discussed. The use of ORBITF for testing attractants and repellents was discussed by Seelye. Carlson stated that the discovery and use of pheromones in insect control has required millions of man hours and that it has been difficult and it will likely require considerable effort and basic research in the sea lamprey program too. Smith stated that the pheromone technique is very useful where pest populations are low. If populations are high, they have to reduce the population by some other means before the pheromones are useful in boll weevil control. Seelye stated that Peter Sorenson from the University of Minnesota has materials that could be tested in the ORBITF facility now and that the testing would not be expensive. Hanson stated that spawning-run lampreys appear to be attracted to the larger streams and that flow may be the critical factor. Synthetic sex attractants may not be useful until the lampreys begin to seek mates and spawn and they may only be useful when lamprey populations are low.

Bergstedt discussed the concept of competitive displacement. Beamish discussed the possibility of making streams cooler by planting trees as a means of prolonging larval life. However this approach would be difficult, expensive, and might not produce the desired level of control.

The use of predators (including man) was discussed. The consensus was that spawning-run sea lampreys in the Great Lakes are not fit to eat making it difficult to promote a commercial fishery. The potential of bounties on lampreys was also discussed and dismissed as not being feasible.

The use of parasites and pathogens in sea lamprey control was discussed. Sawyer stated that it might be useful to look for specific parasites or pathogens of the sea lamprey in its native habitat. Hanson warned that great care would have to be taken to be sure a parasite or pathogen is specific for sea lampreys before it is introduced into the Great Lakes watershed and that the testing of any new organism on nontarget species would be both time consuming and expensive. Christie and Seelye stated it may be possible to do research on parasites or pathogens in the lamprey sterilization facility.

The use of species of fish resistant to sea lampreys was discussed. Sawyer suggested looking at various strains of Lake Trout. Seelye suggested looking for behavioral differences. Laboratory studies with different strains of lake trout showed no differences in susceptibility to sea lamprey attack but differences observed in the wild may be due to behavior differences.

The disruption of the life cycle or the reproductive behavior of the sea lamprey by using hormones or genetic manipulation was considered a fertile field for investigation by Bergstedt. Carlson stated that EPA is encouraging this type of research. The concept of paired species (parasitic and non-parasitic forms) was discussed.

Impressions of the Program and Recommendations for Future Activities (Pest Control Experts).

Alan Sawyer--Sawyer described the status of alternate control techniques in agricultural IPM. There is little work being done to discover new chemical compounds. More work is being done on how to use pesticides selectively so they will not disrupt natural controls. Resistance to pesticides is becoming more of a problem all the time. More herbicides are being used than insecticides.

In comparing agricultural pest management to the sea lamprey program he stated that the sea lamprey program has done little work with biological control and the use of resistant hosts. He was concerned about the few techniques available in the sea lamprey program. His major recommendation was that semi-operational techniques such as barriers, traps, and the sterile-male-release technique, be protected and developed and that other new techniques be developed as well. He believes a portion of research funds should be used for "high risk" research for new approaches to lamprey control. As far as priorities go, he felt that it's difficult to predict where effective new control approaches will come from. Rather than constrain the free exploration of research ideas it's better to evaluate proposals as they come in, from people with interest in the problem and expertise in a particular area of research, whatever it may be. To set priorities beforehand may cause us to overlook something entirely new and unanticipated. He doesn't think it matters what research topics are being addressed, as long as something new is pursued.

Geoff Munro--Munro was concerned about our almost total dependency on only one tool--chemical control. Regardless, he stated that our number one priority was to maintain the registration of TFM. His second priority was to do good assessment of lamprey populations. This is critical for making management decisions. After that we must establish a base program and support all aspects of it.

Jim Smith--Smith stated that the sea lamprey program is a well-founded program. The research and control efforts are excellent. He supports eradication and feels strongly that IPM and eradication are compatible. If the pest can be gotten rid of economically and environmentally, that is the way to go.

He stated that resistance is not something that is necessarily going to happen. TFM is a very powerful suppression device and we should be thankful we have it.

He said one major problem is that we are not able to make life tables and see where the mortality factors are and to know that the actions we are taking are having an effect.

Other recommendations for improving the sea lamprey program were included in his pre-workshop report.

Dave Carlson--Carlson felt the sea lamprey control program is a good one. The sterile-male-release program is a good one and IPM is useful. Population modeling is useful. He stated that development of behavioral resistance is real in some insects. He felt that pheromones are not likely to be the silver bullet. He then summarized the recommendations he made in his pre-workshop report.

POST-WORKSHOP OPINIONS

Seelye recommended that the experts should examine the list of possible studies that have been developed by the Alternate Method Work Group and try to prioritize them. They should also either add, subtract, or modify the various research categories as they see fit. The following written opinions were received after the workshop:

Dave Carlson--Thank you for the opportunity to discuss the proposed program in sea lamprey research and control in the Expert Pest Control Workshop, July 9-10, 1992. I would like to reemphasize comments made several times during this very interesting meeting: the present program appears to have been well thought out, is well run, and appears to be operating at the full potential expected for the funds available.

Recent support for only three grant efforts is the minimum expected, and support should be expanded for Alternative Methods. The evaluation of proposals is problematic, especially since an unknown part of the budget will of necessity go to re-registration of the toxicants currently available. I believe that the outside reviewers appreciate the difficult position that program managers often face. Here again, rational thought cries out for scientific progress on new methods for control based on high-risk molecular or biological techniques, while budget constraints indicate that research cannot be financially supported.

For that reason I think it is presumptuous for me to attempt a numerical prioritization of potential research directions, particularly without having seen any of the proposals expected soon from scientific groups as a result of your recent request for proposals. Your group can evaluate most of these proposals as well as anyone, especially since the expertise dealing with sea lampreys exists nowhere else. For example, could anyone else evaluate a barrier research program?

The list of Alternate Methods research topics is also somewhat problematic, since it did not distinguish between projects expected to be done in house and outside. Any prioritization would be remiss if it did not note that many proposed efforts are likely to be high-risk, long-range strategies unlikely to result in a useful control strategy anytime soon.

Amplified Topics (added to those submitted prior to the meeting): Biological control efforts in entomology with which I am familiar are based on successful searches for natural enemies (parasites and predators) in the native habitat. Classic biological control allows importation and establishment of such an organism: perhaps there are such organisms present in European sea lampreys that are exploitable. A ripe area for this might be in northeastern Europe, with a search of native sea lamprey populations in the Baltic Sea that holds nearly fresh water and is physically very similar to the Great Lakes. Since scientists from this region are highly anxious for funds, and they are inexpensive: enclosed is a fresh copy of application materials from USAID/PSTC. An overseas cooperator is necessary.

Originally, I had in mind that a nematode might be an appropriate organism, with reference to the excellent results recently achieved against mole crickets in Florida. It might be possible to create new pathogenic organisms from existing commensal bacteria that live in sea lampreys, or in sea lamprey nematodes, using molecular techniques. Searches of European populations of sea lampreys may provide such organisms. Otherwise, the research scientists who work with nematodes are a relevant source for ideas and material.

Without these organisms, molecular biologists might attempt to change the genome of sea lampreys by introducing deleterious traits into the population. Injection of females is possible today: is it possible to inject males or females with genetically-engineered bacteria such that they would produce non-transforming ammocetes?

The method of application of the recently discovered GnRH is not clear: again, the potential for use of such a material in genetically-modified commensal or sympatric bacteria is possible. The effort to employ this material in the field is long-range, although potentially biocompatible and species-specific.

Eliminate: Competitive displacement with native lampreys seems unlikely to be of use, since this did not occur originally. Also, habitat alteration seems unworkable, as does alteration of stream temperature and flow.

New sterilants and lampricides will be expected from endocrinology research, and may well be peptides or hormones. The synthetic organic compounds worked on years ago are well known to you, and most likely are the only candidates. As with pesticides, new chemical species are unlikely to be easily found, since industry does not do general screening/synthesis anymore. Fish resistance: I don't see how to make this practical, unless someone figures how to make lake trout grow teeth. Can you introduce tiger fish from Lake Kariba in Zimbabwe?

Amplify: Search for pathogens and parasites (in Europe?). Endocrinology, relating metamorphosis and development. Attractants and repellents: flushing agents. Sex pheromones: these have been very difficult in vertebrates, and worse in aquatic animals. There is so little known that success is likely a long way off, unless you can show spawning-age males to prefer female water.

Geoff Munro--First I would like to take this opportunity to thank you for inviting me to be part of this workshop. I found it very interesting and informative. I enjoyed meeting others with pest management backgrounds and pest problems to solve but more importantly I liked the workshop idea itself of trying to apply our respective pest management approaches to the sea lamprey situation.

As I indicated in my pre-workshop material I have always experienced the most success in any pest management situation when an integrated approach is used. I strongly recommend that a strategic plan for sea lamprey control be developed that takes into account all the current control techniques, their possible improvements through research and operational trials, and any new techniques that are being worked on and show promise.

Lampricide toxicology: This clearly should be the first or highest priority for the sea lamprey research and development budget, or possibly the whole program budget, particularly as it relates to the required re-registration of the current material (TFM). To this end, I would even recommend reduced applications to streams for selected periods of time to provide the funds necessary for this work if necessary.

Improving the efficacy of this or other materials, while useful is significantly less important as the public pressure against the use of chemical pesticides continues to mount and the effort could be better spent in the development of alternatives.

Lamprey ecology: Sea lamprey distribution, population dynamics and population assessment techniques are all relatively important for two specific reasons. First this information is needed for one other important component of the program, "Control Technique Efficiency". There is need to continually evaluate the effectiveness of the program as a whole and where possible, the individual treatments that make up the integrated program. Secondly, studies in this area may well lead to other possible control techniques that have not been thought of, or believed to be useful due to a lack of understanding about some aspect of the sea lamprey life cycle or their interaction with their ecosystem.

Development of alternative and supplemental control techniques: The effective use of barriers and traps in the current program makes this an obvious topic of future work as the opportunity to enhance the existing barriers/traps makes this an alternative that can be made operational quickly. This is true in both the current use pattern and possibly in an enhanced fashion with attractants and/or repellents, as long as funding is available. The study of attractants and/or repellents by themselves also rates consideration as this has proven to be a worthwhile technique with other pests.

Like the barriers, the sterile-male-release component of the program is a relatively high priority as it already contributes to the successful control of sea lamprey. This in turn makes it important for further work as variations on the simple model may well increase the efficacy of the treatment and you have a baseline of existing treatments to use a control.

Studies of the basic life history, I have rated on the low side of the scale as I believe that a basic understanding of the life cycle is known and the likelihood of finding an as yet unknown "weak link" is somewhat remote. I find the idea of trying to stimulate metamorphosis too early to produce a surviving adult or alternatively to stimulate the production of a non-parasitic variety of sea lamprey fascinating, but based on my experience in other pest management areas, must ask if this high risk and often expensive research is the most likely route to finding a new control technique.

Other alternatives that I recommend be part of the overall research agenda include a detailed screening of parasites and pathogens. This has proven to be a wealth of possible alternatives to chemical pesticides in both the insect and weed control disciplines in recent years. Some of the results have translated into biological pesticides like the NPV Virus "Gypcheck" that is used in the control of gypsy moth or Bt, the bacterium that is used in control of various lepadoptra pests like spruce budworm. Other results have led to the "release" of naturally occurring organisms that set up a natural population control over the pest infestation, like the parasitic wasp trichogramma.

Control technique efficiency-valuation: As I indicated above, I believe that this is one area of critical importance to any successful integrated pest management program. The various aspects of technique efficiency need to be repeatedly demonstrated for each control strategy and for the integrated program as a whole. Therefore the need for the supporting assessment techniques cannot be overstated.

In many ways, the fifth topic area "Valuation" is merely an extension of the efficiency question, but put in economic rather than biological terms. I have rated the economic analysis as less critical than the biological for two reasons. First and perhaps simplest, you cannot develop the economic valuation without the proven ability to do the biological assessments accurately. Secondly, there is a need to prove repeatedly that the damage to the fishery that is being prevented is significant. This is critical to maintaining public support for this program, particularly as sea lamprey control currently relies very heavily on the use of a chemical pesticide. The alternative would be to not exercise control and have public support regained only after devastation to the fishery.

Fish-lamprey interactions: I have suggested that this area of study is less of a priority as the control program is aimed at producing a natural fishery that meets the objectives of the fish community for each of the Great Lakes. Knowing that some individuals may survive attack and why, would only be a useful control technique if that objective included the introduction of a new fish specie(s) that have been bred to survive lamprey attack. In other words we would then have to advocate the development of an artificial fishery, rather than an attempt to manage the existing lamprey population, allowing the natural species of fish to survive and rebound.

Systems Research-modeling: Finally, I have rated this area of work in the higher category as my experience has shown this to be a very powerful tool in combining known habitat, water quality, and other variables including the use of various control techniques with predication models that become support tools in the business of making decisions. The only reason I have not given this the highest rating is that I have also learned how all consuming and expensive these systems can become. I recommend that they be reviewed and considered, but not allowed to overshadow the other agenda items discussed above.

General: One of the points that a number of us made at the workshop, and that I would like to repeat here is the need to try and have some activity going on in each of the major research categories. I believe we finally settled on three categories plus the area of assessment. Although the most expensive, high risk group seems like an easy thing to give up in times of fiscal restraint, I strongly recommend that no category be completely eliminated as you never really know where the next successful control strategy will come from.

James W. Smith--It's been two weeks since our meeting and I've been very busy in the meantime. My recommendations are as follows:

1. Do whatever is needed to re-register the lampricide TFM. This is the most important thing at this time.

2. Develop alternative control measures that have a high probability of being a key element in a suppression program: a) barriers and traps; b) sterile-male-release technique; and c) attractants and repellents.

3. At a lower level than above, but still important, are studies on lamprey ecology such as distribution studies and density assessments.

4. Important still are studies on control technique efficiency.

High risk methods of control (little chance of success) should be placed at a lower priority at the present level of funding. Modeling should only be supported if additional funding is obtained.

You have a good program, and I believe you are going in the right direction. Try not to be overly concerned about following some textbook definition of IPM as practiced by the entomological community. We have many more failures than we have successes.

RECOMMENDATIONS

Seelye presented the following list of research categories in order of priority.

1. Support the registration of and maintain the use of lampricides.

2. Develop existing supplemental techniques--maintain sterile-male-release technique, and work hard on barriers and traps, attractants and repellents, and fish passage around barriers.

3. Develop and improve assessment of sea lamprey populations.

4. Conduct high risk research for new control techniques.

A discussion on the level of funding for each of these aspects of sea lamprey control followed. It was agreed that all portions should be funded to some extent if at all possible, but under low budget periods the emphasis should be on the first three categories. When this list was presented, there seemed to be a strong consensus concerning the ranking among the pest control experts and the rest of the attendees. There was also agreement that setting priorities under category four would be difficult and perhaps not very useful. Proposals in this category would have to be considered on their individual merit.

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Appendix A

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