Research Status and Strategies
Fish Culture and Fish Health Theme Analysis

October 2007

1. Introduction

The Research Section began an analysis of research activities with respect to Division needs during its 2003 annual meeting in Alpena. A number of Research Themes were identified at that "Alpena 2003" meeting. "Fish Culture and Fish Health", although not specifically identified at the Alpena meeting, has since been selected as one of eight Research Themes. Research needs are revisited at each annual meeting of the Research Section. In addition to the annual Research Section meetings, the Fish Production Strategic Plan lists a number of research needs for the Division's Fish Culture and Fish Health program.

The purpose of this document is to gather and update in one place the priority needs identified by the Division for the Fish Culture research theme, inventory current and past studies that address the theme, and look for priority questions in this theme that require further research attention.

The term "research", for the purpose of this analysis, is loosely defined to be studies that were published in the Fisheries Division Technical or Research Report series or were otherwise publishable. That is, we consider research to be studies or development projects that were subject to study design protocols, peer review of results, and editorial review of final reports. This definition includes long-term monitoring and assessment provided they are subjected to design and publication review.

In 2006 and 2007, the Fish Culture and Fish Health Theme Task Group was composed of Jim Johnson, Martha Wolgamood, and Jan VanAmberg. The group was assisted by Gary Whelan.

2. Identification of research areas for fish culture/fish health:

The breakout-group at the MSU meeting identified criteria for selection of highest priority research areas for Fish Culture and Fish Health. They were:

1. Projects that help Fish Culture remain relevant with respect to the Fishery Division's strategic plan and to the Wildlife Conservation Strategy;
2. Project ideas that would have application to a wide range of waters rather than a strictly narrow focus;
3. Projects that could improve cost effectiveness of Fish Culture;
4. Projects that build on, but do not duplicate, current knowledge and current or past studies;
5. Projects that enhance our knowledge of linkages and ecosystem effects of stocking.

Many Fish Culture and Fish Health research areas were identified at the Alpena 2003 and 2006 and MSU 2005 meetings and in other documents. Some suggested research areas

were closely related and the Task Group tried to optimize the number of Fish-Production-related research areas such that they were not overly redundant. The 2007 Research Meeting focused on issues presented by aquatic invasive species. Fish culture, in both the private (including the live bait industry) and public sector, is a potential vector for invasive species, including pathogens such as VHS. Research areas that have been identified during these annual meetings include:

1. Standardization and improvement in data collection and management. This theme area of course laps over all other theme areas, but was identified separately because there are several specific data-collection and data-management tasks that are prerequisite to other task areas being accomplished satisfactorily.
    a. Develop standardized, and where possible, automated methods for sampling hatchery fish on-station. Provide the data in standard format for use in analyses that integrate hatchery history with on-station and post-release performance evaluations. This applies to the following types of data
        i. Fish health
        ii. Fish quality control
        iii. Fish size at release
        iv. Fish rearing history, densities, growth, and conversion efficiency
        v. Fish distribution method (boat, conventional shore-based, acclimation pen) as variables
    b. Make the stocking data base more GIS compatible. Assure that fields for latitude and longitude use spatial data formats compatible with other Department GIS projects and base maps and with those of the lake committees. Provide query tools for linking stocking locations with other data sets.
    c. Develop standard gear and methods for measuring post-release performance of hatchery fish so that performance can be compared between water bodies and studies.
        i. Gear types
        ii. Define units of effort for each gear type
        iii. Statistics (say, catch per unit of fishing effort per number stocked)
        iv. Creel census methods and analysis
    d. Provide metadata, explaining format and content of each field, for all data sets.
2. Evaluation of post-release performance. This is where most research has been directed to date and there are a number of current studies in this area.
    a. Comparisons of strains (matching broodstocks to receiving environment)
    b. Evaluate post-stocking effects of rearing operations, including diets, rearing densities, and other rearing conditions.
    c. Effect of distribution method on post-release performance
        i. Boat, conventional, imprinting/acclimation facilities
        ii. Evaluation of stocking windows (tailoring stocking to site-specific environmental conditions)
        iii. Time of day (night vs day, evening, etc.)

   d. Post-release mortality:
      i. Immediate post-stocking losses from predation, physical stress induced by transport and release conditions
      ii. Natural mortality
         1. Survival after recruited to receiving water (subadult)
         2. Disease in wild
      iii. Return to creel and escapement
   e. Growth in receiving environments, effects of strain, and trophic conditions.
   f. Movement and dispersal after stocking.
   g. Statistical catch-at-age models (for example lakes Huron and Michigan for Chinook and coho salmon that integrate fish of both wild-born and hatchery origins).
3. Marking and tagging of hatchery products. Marking of hatchery products is fundamental to identifying hatchery products in the wild and to comparing effects on field performance of different treatments or products from hatcheries.
   a. Provide for coordination and programming of requests for marked lots of study fish
   b. Provide for mass-marking of all stocked fish for rapid differentiation of cultured from wild-born fish in the field
   c. Provide for holding facilities for various sized lots of study fish after marking, including small study groups. .
   d. Provide an array of marking and detection technologies to encompass a variety of study objectives.
4. Identification and evaluation of broodstocks
   a. Identify origin of existing broodstocks and inventory their genetic composition.
   b. Identify origin of feral broodstocks and inventory their genetic composition.
   c. Inventory and investigate potentially valuable wild stocks with respect to availability, origin, and genetic composition.
   d. Develop cost-effective methods for genetic monitoring and management to protect broodstock integrity.
5. Research and development into new or improved hatchery practices and tools. Statistically reliable tests are needed in order to evaluate cost effectiveness and efficacy of new and improved methods of fish culture.
   a. Evaluate fish rearing methods on cost effectiveness and post-stocking performance.
      i. Abiotic conditions: raceway configurations, pump and reuse operations, etc.
      ii. Biotic conditions: water temperatures, diets, feeding methods, etc.
      iii. Evaluate cost effectiveness of centralized walleye fingerling culture
   b. Develop more cost-effective and statistically valid methods for fish sampling and inventory on station.
   c. Investigate culture methods for “difficult” and nontraditional species

i. Threatened and endangered fish (sturgeon), herps, and mussels
ii. Fish for rehabilitation – native coregonids, rare strains of char
iii. Improvements in musky culture
iv. As called for in Wildlife Conservation Plan

d. Unfortunately, many of Michigan's aquatic ecosystems have been destabilized by aquatic nuisance species (ANS). Stocking practices must be adapted to new conditions wrought ANS. Fish production staff must work with managers and researchers to identify potential fish genetic stocks and stocking practices for use in biomanipulation or enhancement of ecosystems perturbed by such invasive species as:
   i. Rusty crayfish
   ii. Round gobies
   iii. Dreissenid mussels

e. Alternative methods of fish distribution and release, cost effectiveness, and effects on post-stocking performance.
   i. Time of day fish are released
   ii. Effect of trip length, duration
   iii. Effect of acclimation facilities at stocking site, why they work or don't work

f. Develop more cost effective effluent management tools that meet or exceed water quality criteria for each station

6. Fish health management and assessment. Design fish health assessment methods, sample sizes, sampling frequencies, and staffing to meet the following needs:
   a. Continuously monitor health of production lots on station
   b. Continuously monitor health of broodstock and eggs
      i. from both feral (weirs) and captive sources.
      ii. of wild stocks under consideration for use by hatcheries.
      iii. of wild stocks
      iv. Develop rapid field methods for assessing status of fish stocks with respect to certain pathogens, particularly BKD and VHS
      v. Develop methods to assure the Fish Production Section and its delivery systems do not become vectors for ANS, particularly fish diseases such as VHS
7. Public attitude, behavior, and opinion surveys. Determine preferences and responses of public to Fish Production activities and alternative programs. What fish culture products would stimulate the most angling activity?
   a. Regular surveys to monitor changes in angler opinion, preferences, and behavior.
   b. Measurement of angler behavior as function of specific Fish Production activities
   c. Evaluation of non-consumptive and non-fishing stakeholders opinions.

3. Inventory of research in fish culture/fish health area:

We used the Institute for Fisheries Research library listing of past research and technical reports and an inventory of current projects to measure how much emphasis has been placed on the seven Fish Culture/Fish Health research areas listed above.

From 1970 through 1989 there were a total of 90 projects directed at one of these research areas. For the period 1990 through present, there were 103 research or health oriented projects. The breakdown by research area for the period 1970-2005 is presented in Figure 1.

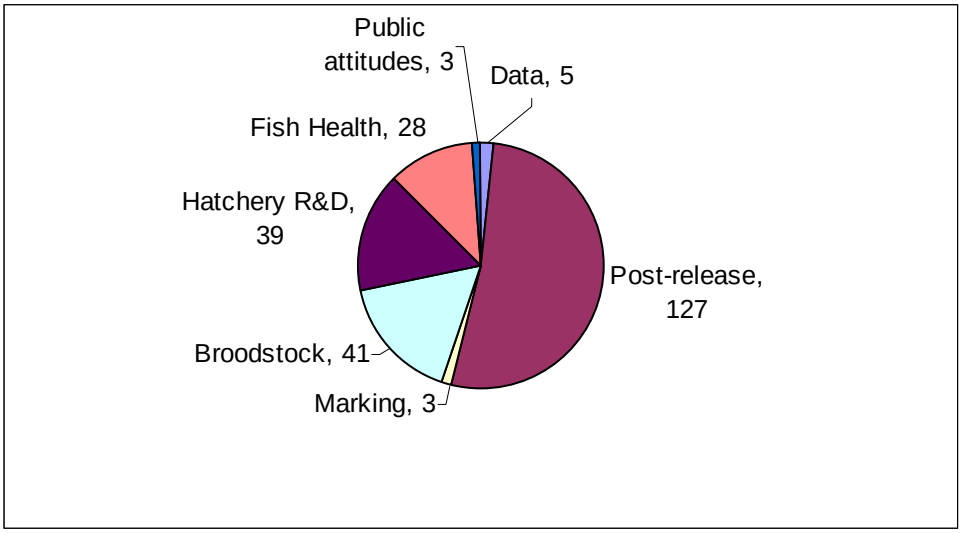

Figure 1. Number of research and technical reports and current studies addressing seven fish production/fish health key research areas since 1970, representing a total of 193 studies.

Some studies addressed more than one research area, thus the number of research areas addressed exceeds the number of studies. Fifty two percent of the studies looked at post-release performance (growth, harvest, movement, etc.) of stocked fish. The second most commonly studied research area was broodstock (17%). Most broodstock-oriented work took the form of weir returns of feral trout and salmon spawners; there were only a few studies into genetic monitoring or management of broodstocks. Hatchery Research and Development composed 16% of the studies; most having to do with developing culture techniques for nontraditional species (walleyes and tiger muskies in the 1970s, lake sturgeon, Atlantic salmon). Fish health was a topic for 11% of studies, however, nearly a third of these were weir reports, which presented incidence of bacterial kidney disease in the runs, leaving 9% that dealt with diagnostics and other on-station fish health considerations. Marking technologies, human dimensions, and data management each composed 5% or less of the remaining research.

4. Data gaps and research needs in fish culture/fish health

One way to assess whether data gaps or deficiencies exist in the Fish Culture/Fish Health Theme is to compare the orientation of past research to research needs identified in the Fish Production Strategic Plan and at the “Alpena 2003” and “MSU 2005” Research Meetings.

4.1 Post-stocking performance

Post-stocking performance evaluations are well represented in the research/technical report series. Much work has been done assessing effect of strain and stocking method

on return to creel and growth of stocked fish. Coded-wire tags have been used in numerous studies to assess movement, harvest, and survival. Fish population assessments have also been used to measure relative abundance, survival, and growth and results of these studies have been used in statistical catch at age models, principally for lake trout. Other studies have addressed prey consumption, predator/prey linkages and bioenergetics of stocked predator fish.

Data gaps – The Fish Production plan calls for field performance evaluations of the progeny of its broodstocks so as to match genetic sources with receiving water habitat conditions. The Fish Production Section is also continuously improving the definition of a "quality fish" at stock-out. In pursuit of this objective, there is a need to identify "quality criteria" that measurably influence field performance. Performance field studies could be linked to selected "quality criteria" measured at stocking to better define what a "quality fish" is at stocking and, ultimately, to improve the effectiveness of hatchery operations in meeting resource management goals. At the 2005 MSU meeting, it was recognized that there has generally been adequate attention to ecosystem effects of stocked fish, that ecosystem effects are very important to know, and that emphasis on ecosystem effects/contributions of stocked fish needs to continue. The emphasis of the 2006 meeting was "Status and Trends", which constitutes the long-term monitoring program of the Fisheries Division. The contribution of hatchery fish to fish communities can be assessed using long-term monitoring, but only if the stocked fish are recognizably marked. Furthermore, it was recognized that stocking has established naturalized, reproducing populations in many waters, particularly the Great Lakes. Failure to account for reproduction can lead managers to overstock systems. Lake Superior's fish community in particular is composed mostly of wild-born fish. The efficacy of stocking over wild populations with hatchery fish is questionable because post-stocking survival and interactions of hatchery fish with wild stocks are unpredictable. *Greater emphasis needs to be given to defining what constitutes a "quality" hatchery product and to data standardization between production and field so that test variables both from the hatchery and the field can be readily shared. Future research needs to continue to emphasize the ecosystem effects of stocked fish, both in local waters and with regional and statewide perspectives. All species of fish stocked in waters where wild stocks of that species exist, should be marked. Methods for mass marking fish stocked in the Great Lakes and other waters where wild-born fish contribute prominently to recruitment are needed so that stock assessments (Status and Trends program) can evaluate such stockings.*

4.2 Broodstock evaluations

Broodstocks are also subjects of many studies, most taking the form of weir operation reports. The Strategic Plan calls for inventory and monitoring of the histories and genetic profiles of captive and feral broodstocks. Few past studies were directed at genetics and genetic monitoring. The strategic plan also calls for identifying potentially valuable wild broodstock sources and few if any studies have been devoted to his area. At the "MSU 2005" meeting, the following needs were identified as potential research areas: 1) better information on how to maintain genetic integrity of feral breeding stocks and how to identify potentially useful wild broodstocks; 2) genetic inventory of wild T&E species

with potential for use in hatchery supplementation of wild populations; and 3) the effect of hatchery procedures on genetic integrity of captive broodstocks. In 2006, the Division began collecting Sturgeon River brown trout to replace the Seeforellen strain, which was suffering from lack of genetic diversity. *Thus, systematic genetic monitoring and genetic assessment of domestic and important wild brood sources is an area needing greater emphasis. The health status of the new Sturgeon River brown trout strain is currently being assessed, but a gene management plan and post-stocking performance evaluations of the strain in various waters (lakes, streams) are needed.*

4.3 Research and development of improved methods and tools for fish production

The strategic plan calls for fish culture experiments to improve rearing efficiency and performance of stocked fish, including rearing methods, diets, distribution methods, and standardization and automation of data collections. Most research cataloged as "fish culture research and development" was directed at methods for culturing nontraditional species and very few studies were on-station. Certainly, there have been a multitude of innovations in Michigan's hatchery operations, but they are seldom published or tested with scientific peer review. At the MSU 2005 meeting, it was suggested that the hatcheries take advantage of the experimental units (raceways) offered by standard hatchery design to investigate effects of rearing variables such as feed formulations, feeding methods, food storage methods, rearing densities, water quality, etc. on the cost effectiveness of hatchery operations and quality of products. Cost effective improvements of inflow water, hatchery effluent treatment, and securing hatcheries from pathogens were also suggested as worthy research areas. While demands for traditional species may diminish as reproduction in the wild increases, there is growing demand for species that have not traditionally been cultured in large numbers by the hatchery system. Development of methods for rearing T & E species of fish (lake herring and lake sturgeon) and other aquatic species (mussels) could assist the Department in pursuit of the Wildlife Conservation Strategy. A better understanding of elements of the early life history of candidate species for culture is needed so that culture methods are consistent with rehabilitation needs of the species. For example, culturists need to know when and how imprinting of lake sturgeon occurs so that rearing methods employed lead to imprinting of the stocked fish at rehabilitation sites and minimize straying to tributaries inhabited by other genetic strains. *Thus, recognizing that many studies of this sort have been conducted on DNR hatcheries, there is a particular need to subject on-station studies to more rigorous peer review of study design and peer-reviewed reporting. There is a further need to extend on-station studies to nontraditional species, particularly lake herring and lake sturgeon, not only with respect to culture methods, but also early life history attributes important to rehabilitation strategies. There is a continuing need to investigate better methods for securing hatcheries from pathogens, and to improve the quality and cost effectiveness of traditional hatchery products. There is a need to review existing biomanipulation strategies and design new ones as the ANS species mix changes, as has been occurring in the Great Lakes. Stocking strategies, including genetic stocks employed, and stocking windows, numbers, and sizes need to be tailored to the new conditions. Experimental stockings should be designed and evaluated.*

4.4 Fish health

There are relatively few formal studies oriented to fish health. In recent years Fish Production staff have published important studies into early mortality syndrome. Other published studies reported frequency of bacterial kidney disease in weir harvests. Pathogen and fish quality monitoring are integral elements of hatchery operations, but they are usually not published and seldom are their findings integrated with performance evaluations of hatchery products. The Production Strategic Plan calls for continued monitoring of pathogens and fish quality on the stations. At the MSU 2005 meeting, the effects of hatchery practices and environments on fish health and quality were felt to be especially important topics for research in this area. At the 2006 meeting in Alpena, monitoring of pathogens in the wild was recognized as an important element of the Status and Trends program that currently was not receiving sufficient attention. Another concern raised in 2006 and 2007 was the role of the live minnow industry as a vector of pathogens and invasive/nuisance fish species. A *gap appears to be that the findings from on-station fish health monitoring are not published nor are they widely integrated with field performance and other studies of hatchery products and that fish health monitoring needs to include examination of roles of causative agents such as specific hatchery practices and environmental conditions. A plan is needed for integrating pathogen/fish health monitoring with the Status and Trends program. Upon completion of a fish-health assessment plan for wild populations, a long-term commitment will be needed to provide staff to implement the plan as a regular element of the Division's Status and Trends program. A plan for monitoring pathogens and invasive/nuisance fish species in the live bait industry and sufficient staffing to implement recommendations are also needed. Fish production stations need to know how hatchery practices, genetics of its brood stocks, water quality, and other attributes of the rearing cycle can be managed or manipulated to improve the health and fitness of hatchery products.*

4.5 Automation and standardization of data management and improved data collection methodologies.

There are very few reports of studies pertaining to improving data collection methods or addressing the standardization and design of Michigan's on-station monitoring. There have been many studies into improving methods for measuring performance of hatchery fish in the field (for example reviews of creel survey designs and efforts to optimize sample sizes). The Fish Production Strategic Plan calls for investigation of new methods to inventory fish, developing real-time estimates of costs to rear fish by species and size of fish, developing technologies that automate data collection for all aspects of fish rearing, implementing GPS technology, and the use of improved routing models in the transportation of hatchery fish. The Alpena 2003 meeting called for emphasis on standardizing spatial data, using formats compatible between disciplines. *A data gap is that, while innovations in data collections are ongoing in the Fish Production Section, linkages necessary to integrate these data with field performance studies are sometimes lacking. Spatial data (latitude and longitude) in fish stocking reports need to be expressed in standardized formats used by the lake committees and compatible with Division base maps and query tools are needed that tap into the spatial information.* Hand held GPS units are now available to all fish transport units to document coordinates of all stocking sites. *The stocking data base may need further improvements to assimilate this new method of recording stocking locations and to integrate the stocking data base*

with other data sets. As another example, field performance studies, especially those addressing growth, require individual measurements of fish at stocking so an estimate of variance can be assigned to size at stocking; *this can be accomplished by designing sampling methods on station to provide measures of individual lengths, weights, and other parameters at time of stocking, with adequate sample sizes, stored in a shared data bas*e.

4.6. Fish marking

Of course, fish marking is essential for field evaluations so that hatchery products can be differentiated from wild-born fish. Lot-specific marks are required for comparing effects of two or more treatments. With increasing reproduction of steelhead, lake trout, and Chinook salmon, it has become increasingly important that all salmonids stocked in the Great Lakes bear recognizable marks so that stocking plans can be adapted to accommodate contributions from the wild. Virtually all field research studies have employed fish marking; however, only 1.2% of past studies were directed at improving or testing efficacy of fish marking. One study on floy tagging and another on oxytetracycline marking methods have been published in the technical series. The Fish Production Strategic Plan identifies the need to develop new marking techniques and methods, and calls for construction of smaller raceway units to hold various sized lots of marked fish. The Michigan DNR and other Great Lakes Fishery Commission affiliated agencies have called for Great-Lakes-wide mass marking of all stocked salmonids, which in turn will require retooling of all Great Lakes hatcheries to accommodate whatever mass marking technique is selected. An automated coded-wire tagging/fin clipping demonstration project was funded by the Great Lakes Fishery Commission and conducted by affiliated agencies in 2004. There has been interest expressed in thermal and Calcine marking, but we know of no studies or tests of these marking methods in the Great Lakes region. The MSU 2005 Fish Production Research group identified measuring ecosystem impacts and contributions of stocked fish as important research areas which can only be accomplished with effective marking of hatchery products. The 2005 MSU meeting also called for identifying and comparing methods for mass marking of both large and small lots of hatchery fish based on cost effectiveness, mark detectability, mark retention, and effects of the marks on performance in the wild. At the 2006 meeting attention was directed to the status of Lake Superior, where most fish are wild born, and whether it was prudent to continue stocking unmarked fish into that lake. *Research and development into marking methods will need to grow in order to meet the stated objectives for fish marking in the Fish Production Strategic Plan and the call for mass marking of Great Lakes salmonids. The need for continued stocking of Lake Superior with trout or salmon needs to be carefully evaluated. Because Lake Superior's fish community is predominantly supported by natural reproduction, all fish stocked into Lake Superior should be marked. Traditional marking methods (preferably fin clips so that hatchery fish can be recognized in the field) should be used for Lake Superior until new mass marking technology is delivered.*

4.7 Demographics and human dimensions

There have been almost no surveys of public attitudes and opinions with respect to fish culture activities. Recreational creel surveys measure human behavior in terms of what is

harvested, but seldom are angler opinions queried. Only 1.2% of the report series pertained to attitudes and opinions of anglers. Studies nearing completion at Michigan State University are beginning to address this deficiency. *While there are numerous assessment plans for fish communities, a long-term plan for assessment of human dimensions is lacking.* Thus, the Fisheries Division runs the risk of overweighting programs in favor of more vocal minorities at the expense of more pervasive public needs. For example, salmon, trout, bass, and walleye anglers are well organized and represented on advisory committees. Their opinions are frequently aired. *The majority of anglers, however, probably fish for perch, sunfish, or "anything". They are not organized and, lacking systematic opinion sampling, their voices are seldom heard. There is little information on the attitudes of those who do not fish but may care deeply about Michigan's aquatic resources. It would be useful to know the public's perceptions of what the role of fish production should be, both with respect to traditional game fish species and less traditional species that might be candidates for fish culture.* These perceptions may or may not be aligned with what is realistic and could be used to identify content for future public information efforts.

4.8 Infrastructure improvements needed to enhance research opportunities on production stations.

Although not a "research area" the MSU 2005 work group identified a need to improve the infrastructure and methods used in fish production to facilitate research on the production stations. Unlike the Research Section, there are no incentives or policies calling for peer review of study designs or study findings, and there are no reporting requirements or reporting standards prescribed for hatchery research. No research biologists serve in, or are designated as resources for, the Fish Culture Section. A permanent Fish Health Unit has not yet been formally established. *Research design and reporting protocols and providing for research biologist assistance to the Fish Production Section are needed to assure that research projects are implemented and successfully completed on Michigan's Fish Production stations.*

5.0 Three Recommended Priority Research Areas from the MSU 2005 meeting

The Fish Production Research breakout group listed and ranked various research areas listed above and others that were suggested by group members by research areas. The leading research areas from that exercise were further combined and winnowed to the point that three leading general research areas were identified based on the criteria of 1) relevance to the Fish Culture Theme Area; 2) aligning Fish Production to the Fisheries Strategic Plan and the State Wildlife Conservation Strategy; and 3) increasing the ecosystem orientation of the Fish Production system.

The three research areas recommended for emphasis were:

1. Definition of a "Quality" hatchery product and achieving quality standards in fish production output. Stocking success is a function of the quality parameters of the hatchery product and attributes of the receiving water/ecosystem. There is a need to define more precisely what constitutes a "Quality" fish for each stocking situation, recognizing that each receiving water may have somewhat different quality requirements. For example, the requirement for stocking Chinook acclimation pens might be that the

fish be parr of no more than 200 per kg on May 10, while the best definition of quality for Chinooks to be directly stocked would be that they be pre-smolts of approximately 100 per kg on June 1. Studies are needed that identify how genetics, rearing history, disease status, and physiological condition contribute to return to creel, angler satisfaction, survival, growth, and effects on ecosystems (including genetics of the managed population and biodiversity). Fish production stations need to know how hatchery practices, genetics, water quality, and other attributes of the rearing cycle can be manipulated to improve the health, fitness, and other elements of quality of hatchery products. Methods of broodstock collection and maintenance, disease prevention and management, feeding, feed formulations, rearing density, inflow water quality management, and pre-stocking conditioning of the fish, among other possibilities, need to be evaluated with respect to meeting target quality criteria for hatchery products.

2. Post-stocking evaluations, with particular attention to efficacy of stocking in largely self-regulating systems such as Lake Superior. Status and Trends monitoring can only assess trends in performance and contributions of hatchery products to ecosystems if all fish stocked are marked. Field assessments of hatchery fish are furthered when the fish have external, field recognizable, marks such as fin clips. Research and development is needed in the area of mass marking so that all fish stocked in lakes and streams with reproduction can be marked. Until improved mass-marking tools are available, all fish stocked in Lake Superior should receive an externally recognizable mark (fin clips) so that effects and value of stocking Lake Superior can be assessed and a decision can be made regarding the need for further stocking in that self-regulating system. Aquatic invasive/nuisance species have significantly altered food webs of some receiving waters, particularly the Great Lakes. ANS have redefined stocking opportunities by altering stocking windows and potential predators of, and prey for, stocked fish. New roles for stocking are becoming apparent as old stocking opportunities fade. Evaluation of stocking practices and experimental stockings of these newly altered ecosystems is required to assure that existing stocking protocols are appropriate, to design new protocols more consistent with the altered conditions of receiving waters, and to prevent wasteful use of hatchery products in receiving waters where their use is no longer appropriate.

3. Improved cost effectiveness of fish culture. Fish production accounts for approximately one third of the Fisheries Division's budget and costs are rising with rising utility rates and costs of feed and personnel. Technically innovative ways to rear fish offer the most promise for containing fish production costs. Evaluation of automation, water quality management, feeding, feed storage and feed formulation, effluent management, inventory, performance monitoring, and management of production and broodstock lots of fish are all areas inviting investigation

6.0 Discussion

Most research conducted since the 1970s has been focused on performance of hatchery products after release. This is appropriate because, after all, the value of fish production rests on the contributions of stocked fish to fish communities and fisheries. And the environments of receiving waters continue to change as a consequence of ANS and other

environmental changes (climate change for example). The power to detect differences in field performance could be enhanced with better marking tools, more attention to data collection methods, and better means for storing and sharing data.

More attention to human dimensions research would help assure that the Fish Production Section's and the Division's areas of emphasis are in tune with stakeholder preferences.

Fish health, on-station hatchery research and development, and broodstock management research areas probably suffer more from lack of systematic reporting than from lack of attention. Much of the experimentation conducted in the hatcheries is designed in-house and either not reported or "casually" reported in annual reports or shared informally within the section. Most hatchery-based studies would benefit from the disciplines of peer review of study plans, peer review of findings, and a publication process for documentation of their results. There are research needs that Fish Production staff do not always have the technical expertise or experience in experimental design to address. In other words, a fundamental gap in hatchery-based research is the lack of a framework, with standards and protocols, for research. This may explain the paucity of technical and research reports authored by Production Section staff. This deficiency would be addressed by providing for research staff assistance to the hatcheries, more peer review of study needs and study designs, and regular publication of findings in the Division report series. Clearly, our heavy reliance on the Division's report series under represents the amount of research and development that Fish Production staff conducts on station. Much R&D done by Production Section staff has led to significant improvements in production methods and technology. By definition, however, research is peer reviewed and published, and this analysis is directed at research in the Fish Production theme area. Thus, it would be inappropriate to classify unpublished investigations as research. Conversely, with more attention to research protocols, much work conducted by Fish Production staff would and should measure up to our definition of research.

While Fish Production staff collaborate closely with the Research Section in field performance trials, there appears to be a need for the Research Section to collaborate more closely with Fish Production staff to assure that more on-station work led by the production staff is shared with the rest of the profession via the research and technical report series or other peer reviewed publications.