Aquaculture Best Management Practices for Minnesota

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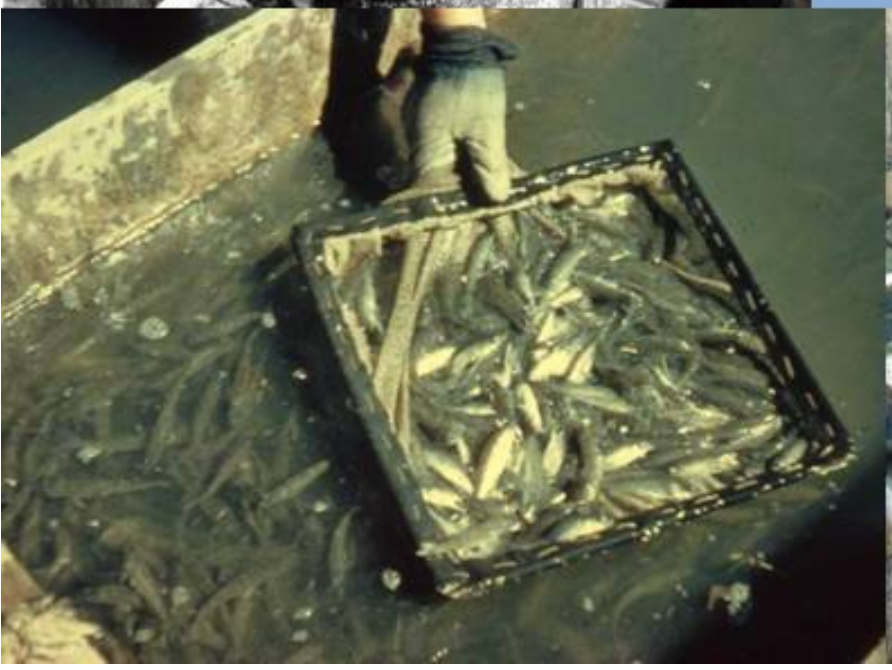

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Best Management Practices for Aquaculture in Minnesota

Introduction

In 2008, Session Law, Chapter 368, Sections 2 and 81 mandated that the Minnesota Department of Natural Resources (DNR) develop best management practices (BMPs) for aquaculture in Minnesota to ensure the long-term sustainability of both aquaculture and wetland function within the state. The DNR selected Deborah Brister from the University of Minnesota and Kyle Zimmer from the University of Saint Thomas as Project Managers. The document produced by the project managers was *Proposed Best Management Practices for Aquaculture in Minnesota* (Brister and Zimmer 2010a). The document produced by Deborah Brister and Kyle Zimmer was used as a framework for this document. *History of Aquaculture Practices and the Development of BMPs for Aquaculture in Minnesota* (Brister and Zimmer 2010b) describes management history leading up to the development of BMPs.

The following BMPs are recommended for aquaculture in Minnesota. Aquaculturists should be sure to consult and follow all state and federal regulations applicable to aquaculture activities in the state. This document supplements but does not supersede state and federal regulations. These BMPs address:

(1) preventing the spread of aquatic invasive species (AIS), disease, and escaped cultured aquatic animals,

(2) working in water bodies infected with AIS,

(3) minimizing disturbance and impacts on natural habitats and other organisms,

(4) preserving good water quality and conserving water,

(5) maintaining health of cultured animals and minimizing predation,

(6) keeping good relations with neighboring property owners,

(7) transporting cultured aquatic animals securely and humanely, and

(8) ensuring continuing education and safe treatment of employees.

1. Preventing the spread of aquatic invasive species (AIS), disease, and escaped cultured aquatic animals

Aquaculturists should ensure that all personnel are trained in techniques that prevent the spread of aquatic invasive species (AIS), transfer of disease pathogens, and escape of cultured aquatic animals. These can be considered biosecurity measures and include species identification, contamination prevention practices, and correct handling and maintenance procedures.

Aquaculturists must prevent the transfer of unwanted organisms between basins and between aquatic animals. This includes unwanted organisms themselves, parasites on aquatic animals from other farms, parasites on aquatic animals from natural waters, and unwanted organisms transferred on equipment or in water. Certain life stages of aquatic organisms could survive for extended periods of time if they are accidentally trapped in damp nets, small puddles in fish egg-sorting machines, standing water in buckets, gloves or boots of workers attending to the cultured organisms, or other equipment. Therefore, all equipment must be properly cleaned and drained after each use. To ensure against accidental transport of organisms to other sites, equipment should be either used and stored on a single site or disinfected using a treatment lethal to all potentially present organisms and all of their life stages. A record of equipment maintenance should be kept and regularly updated.

Aquaculturists should use AIS-free broodstock/seedstock with documented disease-free histories based on fish health inspections. Both certifiable and emergency diseases, as well as AIS, are a concern. A “certifiable disease” means a fish disease that requires testing as prescribed in Minnesota State Statute 17.4982 Subdivision 12 and includes bacterial kidney disease, largemouth bass virus, koi herpes virus, heterosporis, and any emergency fish disease

(Minnesota State Statute 17.4982 Subdivision 6). An “emergency fish disease” means a fish disease not already present in this state that could impact populations of aquatic life if inadvertently released by infected aquatic life, including channel catfish virus, viral hemorrhagic septicemia virus, infectious hematopoietic necrosis virus, infectious pancreatic necrosis virus, whirling disease, creatomyxosis, proliferative kidney disease, epizootic epitheliotropic virus disease, and enteric septicemia of catfish, spring viremia of carp, white sturgeon herpes virus, white sturgeon iridovirus, pallid sturgeon iridovirus, and Asian tapeworm infection (Minnesota State Statute 17.4982 Subdivision 9). A health certificate indicating disease-free verification may be required for an aquaculture permit.

Additionally, all personnel should carry out complete disinfection procedures upon arrival and before going to other fish farms, lakes, or streams. Equipment should be dedicated to specific sites or completely cleaned and disinfected if moved between sites. A permit which specifies requirements to allow movement of equipment between sites when operating in designated infested waters is required(see BMP 2 below). Dead or moribund fish should not be released into water, and all surfaces that have contact with tissues and fluids of dead or moribund fish should be subject to strict disinfection.

Some nonindigenous species and strains of fish are not allowed in basins in the state. Aquaculturists must consult with the DNR to determine whether the species or strain is allowable in the selected basin. A nonindigenous species is defined as “a species of fish or other aquatic life that is (1) not known to have been historically present in the state; (2) not known to be naturally occurring in a particular part of the state; or (3) designated by rule as a prohibited or regulated invasive species” (Minnesota State Statute 17.4982 Subdivision 18a). A nonindigenous strain is defined as “a species of fish or other aquatic life that (1) has an original source outside of this state and contiguous states; (2) is an unnaturally occurring hybrid or genetically engineered species; or (3) in areas north of marked State Highway 210, is a walleye,

the original source of which is from south of marked State Highway 210 or from outside the state" (Minnesota State Statute 17.4982 Subdivision 18b).

Aquaculturists should also choose sites carefully to prevent escape of cultured fish. Only indigenous species can be cultured in basins connected to other water bodies or on 25-year flood plains with other water bodies. Waters continually connected by a permanent watercourse to other waters will not be approved for aquatic farm use, except that connected waters that are isolated from other waters may be licensed as a single water body. Waters that are intermittently connected or may become connected with other waters may be denied permits, or screening or other measures may be required to prevent passage of aquatic life (Minnesota State Statute 17.4981). Moreover, flow rates above 1 cubic foot per second are likely high enough to allow extensive escape of cultured fish downstream, especially in periods of high flow (e.g. in spring or following rain events). Furthermore, wetlands with high flow rates are also more likely to be colonized by unwanted fish from upstream and downstream habitats, potentially reducing yield of cultured fish in the basin due to competition or predation.

Barriers should be used that prevent escape of cultured fish from hatcheries. Consequences of escaped fish are completely species dependent, making it difficult to know how much impact, if any, escapees will have. The accidental escape of cultured organisms might occur through any of the following components of the water system: influent water and makeup water (applicable in water reuse systems); effluent and drawdown water; and waste slurries collected when filters are backwashed, screens are scrubbed, or rearing units are cleaned by siphoning. Therefore, each water system component should have a sufficient combination and number of mechanical, physical, and/or chemical barriers to prevent escape.

2. Working in designated infested water bodies

Minnesota prohibits the collection of organisms from infested waters (e.g. Minnesota State Statute 84D.11 Subdivision 2a) but there are exceptions that would require additional permits. Determine first if the DNR considers the water body to be infested. Infested waters, or waters that have been found to contain AIS, may be unsuitable for collection or harvesting of organisms. Aquatic invasive species may occur in the waters or substrate from which the target organism is collected, or located on the collected target organism (e.g. parasite). These AIS can be inadvertently collected and sold with the desired fish.

When AIS are present in collecting waters, special measures must be taken to reduce the risk of transferring these AIS to other bodies of water that may not contain them. Hazard Analysis Critical Control Point (HACCP) plans and critical control points should be used in waters with AIS. The HACCP plan requires that the aquaculture operator identify significant environmental hazards associated with their operation. This includes considering the likelihood of occurrence and severity of each potential hazard that could lead to the spread of AIS. Where significant potential hazards occur, a list of steps to prevent or control hazards is then described. Critical control points are measures by which control is best achieved to reduce or prevent hazards from occurring. Details on HACCP and critical control points can be found in *AIS-HACCP: Aquatic Invasive Species-Hazard Analysis and Critical Control Point Training Curriculum,* Minnesota Sea Grant, Publications Number MN SG-F11 (Gunderson and Kinnunen 2004). Note: this manual does not yet include critical control points for pathogens.

3. Minimizing disturbance and impacts on natural habitats and other organisms

Aquaculture activities may influence features of aquatic ecosystems and native organisms via interactions between the introduced fish and native organisms, disturbing the physical environment via stocking and harvesting activities, and disturbing normal animal

behavior due to increased human activity on the water body. Growers should use techniques and strategies described in this section (or that may be developed at a later date) that minimize effects on ecosystems used for culturing.

Fishless Basins

Fishless basins are rare in Minnesota, yet they represent a critical habitat for numerous wetland-dependent species of invertebrates, amphibians, and birds. Thus, fishless basins (defined as a basin where a routine 24-hour fisheries survey fails to detect fish) should not be used for aquaculture. Beyond reducing habitat suitability for other species, fishless basins may not be good sites for aquaculture because physical (e.g. water depth and hydroperiod) and chemical features (e.g. salinity) are not conducive to fish propagation. Growers may use basins made fishless via rotenone application, commercial harvest, use of drawdown to induce winter kill, or stocking of predatory fish.

Other options to minimize impacts to natural water bodies are to: 1) restore drained wetlands specifically for aquaculture purposes and maintain them as a fishless basin by periodic drawdown or other methods, or 2) use man made ponds where water levels and other aspects of the pond can be controlled. There are issues with using man made ponds or drainable restored wetlands including availability of land, cost, available water sources, and where to drain the water. Use of drainable restored wetlands and drainable man made ponds could be a win-win situation for wildlife and aquaculturist, but more information is needed to determine the most cost effective strategies that have a least impact on natural systems.

Physical Disturbance

Growers should also try to minimize impacts of aquaculture activities on the physical characteristics of basins. Access points for boats should be chosen carefully to minimize the potential for shoreline erosion as well as impacts on riparian, emergent, and submergent

vegetation. Boat speed should also be minimized with “no wake” speeds used near shore to prevent sediment resuspension and shoreline erosion. Sediment resuspension and erosion both degrade water quality and promote excessive algal blooms. Nets used for harvesting fish also have potential to disturb wetland sediments and uproot submerged vegetation. Thus, growers should choose harvest areas to minimize impacts on aquatic vegetation and sediments.

Toxicants

Copper sulfate is sometimes used to increase capture rates of walleye in culture ponds. However, this chemical is potentially toxic to aquatic plants and animals, and has the potential to accumulate in wetland sediments. Recent work has indicated that copper sulfate is likely safe in “hard water” lakes of western Minnesota, but its impacts are poorly known in other areas. Given the uncertainty associated with its use in basins in different areas of Minnesota, aquaculturists should avoid using copper sulfate except when absolutely necessary and in situations where it can be legally applied. If copper sulfate is used, aquaculturists must follow all applicable state and federal laws. Industrial or other activities that include the application of copper (e.g., copper sulfate) to waters of the state should be done in such way that ensures that standards are not exceeded. Aquaculturists should consult with Minnesota Pollution Control Agency (MPCA) Effluent Limits staff to determine how much copper sulfate (if any) can be safely applied. Aquaculturists planning to use copper sulfate or any other potential toxicant should work with the MPCA to determine if the chemical can be used in such a way that does not result in acute toxicity. In efforts to eliminate undesirable fish in basins, growers should use only techniques approved at the state and federal level for the purpose of eliminating fish (e.g. rotenone), and should follow all state and federal rules governing approved techniques.

Aeration

Winter aeration is commonly used by aquaculturists to maintain high wintertime dissolved oxygen levels for species that need to be cultured for multiple years. However, winter aeration influences aquatic organisms and chemical characteristics of natural water bodies and should be avoided where possible. Aeration may sustain high abundance of undesirable fish normally vulnerable to low oxygen conditions, delay migrations of waterfowl due to open water conditions associated with aeration, and alter nutrient cycling of wetland sediments. Thus, aeration should be used only when necessary to overwinter brood stock or oxygen sensitive fish species, and only when aquaculturists have exclusive control of riparian access (Minnesota State Statute 17.4984 Subdivision 4(3)). Ideally, aquaculturists should monitor winter dissolved oxygen levels in basins containing these fish, and begin aeration only when levels become dangerously low.

Human Disturbance

Sensitivity to human presence on water bodies is highly variable among waterfowl species. Growers should recognize more sensitive species such as canvasbacks, scaup, and redheads, and attempt to minimize disturbance by using slow boat speeds and routes on the water that give the birds as much “space” as possible. Aquaculturists should also design stocking and harvesting schedules that minimize the number of times a water body must be visited in a single year, and that minimize time spent on the water in a given year. Thought should also be given to the proportion of basins used for aquaculture within a given area. Keeping some basins aquaculture-free will provide refuge for more sensitive species of waterfowl and water birds, and also provide habitat for wetland dependent species that may not coexist well with cultured fish (e.g. amphibians).

Infrastructure

Aquaculturists should ensure that aquaculture construction, facility structures, and infrastructure (e.g. roads) minimally alter the ecological function of terrestrial landscapes. Additional structures or roads may be necessary for the aquaculture facility as it operates and if the facility expands in the future. Even if the rearing facility is located in a remote area, land access will still be necessary for a multitude of services.

Statutory requirements include a permit to construct, operate, and maintain a cold water aquaculture facility that harvests more than 9,090 kg/yr (approximately 20,000 lbs/yr), or a warm and cool water facility that harvests more than 45,454 kg/yr (approximately 100,000 lbs/yr). Additionally, Minnesota Rule 7053.0405 allows for the MPCA to require a permit on a case-by-case basis for any warm, cool, or cold water operation upon determining that it may cause a violation of applicable state or federal water quality rules.

4. Preserving good water quality and conserving water

All inputs must be compliant with state and federal regulations. Federal and State rules may apply when introducing feed, fertilizer, copper sulfate, or forage fish in natural water bodies. The use of natural basins and wetlands for aquaculture is subject to the nondegradation requirements in Minnesota Rules. These requirements allow for a lowering of water quality only after an exhaustive analysis of the impacts and alternatives has been completed.

Aquaculturists should use feed ingredients that are consistent with species' natural diets and nutritionally complete. Feed that is species-specific, high quality, and nutritionally complete reduces metabolic waste and uneaten feed due to high nutrient retention. Aquaculturists should base feeding regimes on the capacity of the pond to assimilate waste nutrients and organic matter. The assimilation capacity of ponds depends on factors such as pond size and depth, amount of supplemental aeration, and water exchange rate. Pond assimilation capacity can, however, be loosely determined by monitoring fish feeding response, with a reduced response

indicating assimilative capacity has possibly been reached or exceeded, provided reduced feeding response is not attributed to disease. For more discussion, see Tucker and Hargreaves (2008).

Aquaculturists should use only nontoxic, nonpolluting cleaning and sterilizing agents, and nontoxic products in production area structures (including paints, chemicals, and treated lumber). Using nontoxic agents for hatcheries, production, and processing reduces the potential for contamination of water that may affect biodiversity, employees, cultured animals, and the local community.

A baseline report of ambient water quality should be created for all basins used for aquaculture. Before an aquaculture facility begins operation, baseline measurements of the site's relevant biological, chemical, and physical variables should be taken to allow valid comparison of changes against pre-operation conditions. Before starting any baseline measurements, aquaculturists and the responsible government agencies should deliberate to reach agreement upon the appropriate and case-specific set of baseline measurements, duration of measurements, and appropriate methods. Threshold limits should also be identified and agreed upon before the start of production, thereby reducing the need for emergency measures. The operator should know what specific actions to take if monitoring suggests conditions are approaching threshold limits.

Aquaculturists must be compliant with federal and state water quality regulations. Growers should ensure minimal percentage water quality change in downstream effluents and provide water treatment if effluent water quality is less than ambient water by a percentage agreed upon by the regulating body and the aquaculturist. The amount and frequency of water leaving an aquaculture operation depends on the type of production system used. Pond systems, for instance, have a high evaporation rate and thus may require water addition even if water is seldom or never released. Because of low stocking levels in ponds, necessary water

exchange is reduced. Periodic draining of ponds during harvest, however, may result in temporarily high levels of effluent in receiving waters.

Aquaculturists using containment facilities must also disinfect effluent prior to discharge to public waters. Aquaculturists should ensure that personnel document monitoring of aquaculture operations. Protocols should be established for rearing water quality and treatment; ambient and downstream water quality and treatment of effluents, contaminants and pathogens; feed quality, feed allowances and waste; mortalities; and equipment and structural maintenance, monitoring and documentation. In some instances monitoring and documentation may be required. See Minnesota State Statute 17.4991 Subdivision 2(d, e). The effluent disinfection process must be sited, designed, and operated in a manner that allows inspection at all times to determine whether adequate effluent disinfection is maintained. The Commissioner of Natural Resources may request documentation of daily monitoring of treatment system performance as part of the licensee's annual report. The records must be available for daily inspection during normal business hours and maintained for three years.

Growers should extract surface and ground water at a sustainable rate. Excessive water withdrawal for aquaculture operations, just as for terrestrial farming operations, can adversely affect hydrology, geomorphology, biology, water quality, or connectivity of landscapes. Altered hydrology can create impassable areas during dry seasons, decrease hydrologic peaks and timing so that riparian areas are disconnected from main channels, and decrease ground water/stream bed interactions. Aquaculturists should use water-conserving technology (such as recirculating systems). In water-resource-poor areas, water use may compete with demand for drinking water, with crop and livestock production, and with demand for terrestrial and aquatic biodiversity and ecosystem services. Minnesota is a water-rich state, but some areas may not be suitable for outdoor aquaculture, due to lack of adequate water resources, limited space, or proximity to urban areas. In these cases, recirculating systems may be the appropriate systems

to use. Recirculating systems require considerably less water per pound of fish produced. Though they are more energy-intensive, recirculating systems require 5-50 gallons of water per pound of fish versus 200-800 gallons for pond systems. With few exceptions, water withdrawal from surface or ground sources of 10,000 gallons per day or more, or 1 million gallons per year or more requires a water appropriation permit (MR 6115.0620).

Increasing water-use efficiency will be essential in the future, and can be increased in aquaculture via use of integrated systems (e.g., agriculture-aquaculture, hydroponic-aquaculture, multiple species or polyculture systems), restored (drainable) wetlands, and man-made (drainable) ponds. Agriculture-aquaculture systems are excellent examples of recycling and using otherwise unusable by-products of one system and incorporating them as inputs in another system. For example, nutrient-rich aquaculture effluent can be applied to crop production. In hydroponic-aquaculture systems the same principle applies, but the output of hydroponic plants includes water that is recycled back to the aquaculture component for reuse. Multiple species, or polyculture, systems make efficient use of water and nutrients available within the culture area. Polyculture systems require extensive knowledge of resource use by specific species and interactions between differing species, but many polyculture systems have been successfully used for centuries. New combinations of species are now actively being researched to mitigate effluent problems.

Manure should be tested for nitrogen and phosphorus content prior to removal from the manure-storage structure for land application. The nutrient analysis must be conducted using a laboratory certified by the Minnesota Department of Agriculture or commissioner-approved on-site sampling and analysis. Manure should be applied so as not to exceed appropriate agronomic rates.

Manure hauled on federal, state, or local highways, roads, or streets must be hauled in such a way as to prevent manure from leaking, spilling, or otherwise being deposited in the

right-of-way. Manure deposited on a public roadway must be removed and properly disposed. In accordance with Minnesota Rules 7053.0405 Subpart 6(B), permitted facilities shall transport aquatic animal mortalities for rendering or disposal at a land-based facility approved by the Commissioner of the Minnesota Pollution Control Agency. Aquatic animal mortalities shall not be disposed of in waters of the state.

5. Maintaining health of cultured animals and minimizing predation

Aquaculturists should ensure minimal contamination of inflow water by adequately distancing aquaculture operations from other aquatic and terrestrial farms, residential homes, or industrial pollutants. Fresh water used as inputs for aquaculture operations must not be contaminated with biocides or disease-causing agents, or have water-quality parameters that are beyond the necessary physiological requirements of cultured species (including oxygen levels, temperature, nitrates, pollution, and heavy metals). When parameters exceed the limits of the species cultured, the productivity of the species is greatly reduced. Additional treatment of the water prior to use in the aquaculture system will be required and this may include added energy expenses. While the risk of contamination from ground water resources is possible due to agricultural pesticide and fertilizer percolation, the risk of contamination from surface water is considerably greater, especially when multiple users of the surface water are upstream.

Aquaculturists should use only approved therapeutic agents and use them only for their approved purposes. Aquaculture therapeutic agents have the potential to adversely affect the environment and non-target organisms due to the way many therapeutic agents are applied and dispersed. For more information, aquaculturists should refer to the Joint Subcommittee on Aquaculture Guide to Drug, Vaccine and Pesticide Use in Aquaculture (2007) http://www.aquanic.org/jsa/wgqaap/drugguide/drugguide.htm) and the United Nations Food and Agriculture Organization Responsible Use of Antibiotics in Aquaculture (2006) (http://*www.fao.org/fi*).

Aquaculturists should use vaccines to prevent diseases when necessary. Preventative use of vaccines prior to an outbreak may be more economical than treatment once an outbreak has occurred. The alternatives include treating fish with antibiotics or destroying all fish and starting over with disease-free stock.

Aquaculturists should ensure that rearing environmental conditions, including dissolved oxygen, temperature, flow rates, and photoperiod, simulate the species' natural environment. If a fish's ability to maintain homeostasis is compromised by conditions that are not optimal for the specific species, stress responses will result as the fish expends energy to compensate for the condition. Long term stress responses include decreased immune function and can result in the fish succumbing to disease.

A protocol for removal and disposal of dead aquatic organisms should be established. Removal of mortalities in some types of aquaculture operations may be difficult (e.g. in large ponds) and costly. However, to reduce the discharge of dead and decomposing aquatic organisms and infectious agents into receiving waters, prompt removal of mortalities is recommended where feasible. Appropriate disposal is site specific and will depend on local and state regulations. Composting and nutrient recycling may be options in some locations.

Aquaculturists should use appropriate barriers for prevention of predator interactions. Aquaculture facilities located close to breeding or nesting areas for piscivorous birds and mammals can result in substantial losses to growers, because cultured fish are vulnerable to predation. When possible, preventative and nonlethal measures should be used, such as exclusion fencing, netting, propane cannons, and live trapping. When lethal measures are necessary, a federal and/or state depredation permit is required.

6. Keeping good relations with neighboring property owners

To use a water body for aquaculture purposes, legal access must be obtained to the water body. The laws governing access are found in Minnesota State Statute 103A.201 Subdivision 2 (3). On waters without a public access, legal access is usually gained by entering into a lease agreement with a person who owns land on the shoreline. Once legal access is obtained, a person may apply to the DNR for a license to use the water body for aquaculture. Minnesota State Statute 17.4984 provides direction to the DNR for inspection and licensing of a water body for aquatic farm or private hatchery use. State Statute 17.4984 subd. 1(g) requires that before a new aquatic farm license is issued for a natural water body, the applicant must notify all owners of property with direct access. Notifying landowners adjacent to a water body that is to be used for aquaculture will help to avoid conflicts. For water bodies that have never been licensed, the DNR will conduct an inspection of the waters, which may include test netting. If the licensee loses legal access, Minnesota State Statute 17.4984 Subdivision 2 (b) allows the DNR to approve the transfer of the water body to another licensee. Based on statutory criteria and results of an inspection, the DNR may approve or deny the use of the water body for aquaculture.

7. Transporting cultured aquatic animals

Aquaculturists should establish a monitoring program when live aquatic animals are transported by vehicles. This should include monitoring for dissolved oxygen and ammonia levels, and a visual assessment of stock transported. Tanks should not be overloaded, using a density that is appropriate for the species transported. Planned water changes should be included if transporting live aquatic animals long distances. If necessary, aquaculturists may add salt to water containing stock if stress in aquatic animals becomes apparent. When transporting aquatic animals, aquaculturists should prevent escape, especially during water changes. Transportation equipment should be routinely cleaned, inspected, and maintained.

8. Record keeping, continuing education, and employee safety

Employees should be provided opportunities for continuing education regarding changing regulations, safety practices, and other precautionary measures to ensure environmental and human health protection. Employees should have safe working conditions and equipment; safety and handling training; and access to safety and emergency manuals that are located on site. Employees have the right to know the proper procedures for handling chemicals and know the risks involved when handling these substances. Employees should have adequate protection from noise, dust, light, and exposure to hazardous chemicals.

An annual aquaculture operation record should be maintained and include the following elements:

a. a general description of the operations conducted for the operational year;

b. a summary of the monitoring data for the year;

c. the mass of aquatic animals currently at the facility;

d. aquatic animal production at the facility for the year;

e. amount of fish food used in the year;

f. methods, amounts, and locations of the removal and disposal of manure for the year;

g. proposed changes in operation and/or production for the next year; and

h. records required by Minnesota Statute 17.4984 Subdivision 7.

BMP 1: Preventing the spread of aquatic invasive species (AIS), disease, and escaped cultured aquatic animals

Applicable To:		Action	Outcome
Minnow Dealers	**Aquaculture Facilities and Fish Farms**		
✓	✓	train personnel	species identification contamination prevention practices correct handling and maintenance procedures understand current laws
✓	✓	disinfect equipement	prevent accidental transport of organisms
	✓	choose sites carefully	impacts of connectivity, flooding, and flow rates minimized
	✓	use mechanical, physical, or chemical barriers	prevent escapes
	✓	use AIS-free, disease-free broodstock/ seedstock	prevent certifiable and emergency fish disease

BMP 2: Working in water bodies infected with AIS

Applicable To:		Action	Outcome
Minnow Dealers	**Aquaculture Facilities and Fish Farms**		
✓	✓	develop Hazardous Analysis and Critical Control Point (HACCP) plans	reduce risk of transferring AIS

BMP 3: Minimizing disturbance and impacts on natural habitats and other organisms

Applicable To:		Action	Outcome
Minnow Dealers	Aquaculture Facilities and Fish Farms		
	✓	do not use fishless basins, excluding basins made fishless by management actions	preserve habitat for wetland-dependent species not tolerant of fish
✓	✓	choose access points carefully, minimize boat speed, and harvest in areas that minimize impact on aquatic vegetation	minimize impacts of aquaculture activities on the physical characteristics of basins
	✓	use copper sulfate only when necessary and where it is legal to apply, follow state and federal laws if used	prevent buildup in sediments and potential adverse effects on wildlife
	✓	eliminate undesirable fish, using techniques approved at the state and federal levels	increase production in individual basins
	✓	use winter aeration only when necessary based on winter dissolved oxygen levels	minimize potential effects on the physical, chemical, and biological features of the basin
✓	✓	recognize and give “space” to species sensitive to human disturbance	minimize impacts on sensitive species
✓	✓	design stocking and harvesting schedules that minimize the number of visits and time spent on the water	minimize impacts on species sensitive to human presence
	✓	consider design and location of facilities and structures and infrastructure	minimize altering the ecological functioning of terrestrial landscapes
	✓	obtain all relevant permits, including water quality permits	remain compliant with all applicable state and federal statutes
	✓	Emphasize use of drainable constructed ponds or wetlands specifically for aquaculture	reduce impacts on natural waterbodies

BMP 4: Preserving good water quality and conserving water

Applicable To:		Action	Outcome
Minnow Dealer	**Aquaculture Facilities and Fish Farms**		
	✓	inputs must be compliant with state and federal regulations	maintain high water quality in surface and subsurface water
	✓	extract surface and ground water at a substantial rate	minimize potential to adversely affect hydrology, geomorphology, biology, water quality, or connectivity of landscapes
	✓	use water-conserving technology	conserve water
	✓	apply percentage of effluent to crops or hydroponic systems, and use integrated systems when possible	maximize resources
	✓	handle manure correctly and test before land application	avoid contamination

BMP 5: Maintaining health of cultured animals and minimizing predation

Applicable To:		Action	Outcome
Minnow dealers	Aquaculture Facilities and Fish Farms		
	✓	adequately distance aquaculture operations from other aquatic and terrestrial farms, residential homes, or industrial pollutants	minimize contamination of inflow water
	✓	use only approved therapeutic agents and use them only for their approved purposes	prevent adversely affecting the environment and non-target organisms
	✓	use vaccines when necessary	prevent diseases
	✓	ensure optimal rearing conditions	minimize stress to aquatic animals
	✓	establish protocol for removal or mortalities	minimize disease and discharge of dead and decomposing animals into receiving waters
	✓	use appropriate predator barriers	minimize predator interactions

BMP 6: Keeping good relations with neighboring property owners

Applicable To:		Action	Outcome
Minnow Dealers	Aquaculture Facilities and Fish Farms		
✓	✓	notify each landowner adjacent to waterbody	avoid conflict with adjacent property owners
✓	✓	obtain legal access to waterbody	use water for aquaculture purposes

BMP 7: Transporting cultured aquatic animals securely and humanely

Applicable To:		Action	Outcome
Minnow Dealer	Aquaculture Facilities and Fish Farmers		
✓	✓	establish monitoring program when transporting aquatic animals	minimize stress and risk of escape of aquatic animals

BMP 8: Ensuring continuing education and safe treatment of employees

Applicable To:		Action	Outcome
Minnow Dealer	Aquaculture Facilities and Fish Farms		
✓	✓	provide continuing education opportunities for employees	understand changing regulations, safety practices, and other precautionary measures to ensure environmental and human health protection
✓	✓	provide safe working conditions and equipment	protect employees from harm
✓	✓	maintain an annual aquaculture operating record	have data for annual and long-term assessment of individual aquaculture programs

Appendix B. Additional Reading

General Reports on Aquaculture

Brister, D., and A. Kapuscinski. 2007. A life cycle framework to identify effects of aquaculture on environmental, economic and social sustainability goals: a tool for organic and other eco-labeling systems. Working paper for FAO Expert Workshop on Aquaculture Certification. Fortaleza, Brazil.

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