Regulating Invasive Species in Aquaculture:
Common State Approaches and Best Management Practices

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I. Pathways for non-native species in aquaculture

In August 2017, more than 160,000 Atlantic salmon escaped from a net-pen aquaculture facility in Washington into the Salish Sea. Although the farm was legally permitted to operate in the state, failure to properly maintain the facility led to equipment failure, thus resulting in the release of thousands of non-native fish into state waters. While many of the escaped salmon either died on their own or were eventually recovered through efforts of people in surrounding areas, the unprecedented nature of the disaster drew the nation's attention to the challenges associated with culturing non-native aquatic species. Many of the most popular species cultivated on aquaculture farms throughout the United States are non-native to most, if not all states, including such staples as tilapia, Atlantic salmon, and Pacific oysters. As exemplified by the Washington escape, aquaculture can easily become a pathway for the introduction of non-native species to new environments. If the released animals flourish in their new environment, an invasive[1] population can become established, thus imposing devastating effects on native ecosystems.

Non-native aquatic species can enter new environments in a variety of ways, although they are most often moved around by humans. Non-native aquatic species are imported from out of state and outside the country for sale at pet, aquarium, and garden stores. They are sold for live bait and food. They hitchhike in the compartments of boats and ships. Specifically, the most favorable pathways for the introduction of aquatic invasive species are created through the following activities: 1) stocking for food, sport, or forage; 2) aquarium release or escape; 3); bait release; 4) miscellaneous escape (including escape from aquaculture facilities); 5) stocking for conservation; 6) ballast release; and 7) stocking for biocontrol.[2]

Whether a release or escape will lead to the establishment of an invasive population depends upon: 1) the number of individuals introduced; 2) the frequency of the introductions from that pathway; and 3) the likelihood that the pathway will deliver healthy individuals.[3] Pathways that deliver large numbers of individuals are more likely to result in the establishment of a species than those that deliver only single individuals. Similarly, frequently introduced species are more likely to become established, as repeated releases of even single individuals in a localized area can grow a population of potential mates. Furthermore, pathways that deliver healthy individuals (such as well-fed fish grown in a hatchery) are more likely to lead to the establishment of a species, as those individuals are better equipped to survive and reproduce than those that are sick or dying.

While each of the aforementioned pathways is significant and presents its own challenges in limiting the introduction of invasive species, this report primarily focuses on escapes from land-based and marine aquaculture facilities. Land-based aquaculture facilities utilize ponds, recirculating systems, or flow-

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1 It is important to understand the difference between "invasive" and "non-native" species. Non-native species are simply species that are not native to the environment under consideration. Not all non-native species are invasive. Although alien to the environment, they are unable to survive or sustain populations that cause environmental harm. Invasive species, on the other hand, are non-native species that thrive in foreign environments, and are likely to cause harm to native ecosystems, human health, and/or the economy as a result.

2 Pam L. Fuller, *Freshwater Aquatic Vertebrate Introductions in the United States: Patterns and Pathways, in Invasive Species: Vectors and Management Strategies* 123, 134 (2003).

3 *Id.* at 144.

through systems to grow their yield. Animals can escape from these facilities due to of a number of factors, such as: 1) a lack of suitable screening over pond outflow pipes; 2) pond overflow during flood events; and 3) the transportation and dropping of non-native animals into nearby water bodies by predatory birds.[4] Mariculture, in contrast, refers to aquaculture practiced in marine environments and in underwater habitats instead of on land. In mariculture facilities, escapes can occur because of similar, yet distinct, circumstances, such as: 1) poor facility maintenance; 2) strong storms and adverse weather events; and 3) the destruction of nets or cages by other marine life.

One well-known example of the impact aquaculture facility failures can have on native ecosystems involves the Asian carp. These fish were originally imported into the southern United States from Southeast Asia to help aquaculture and wastewater treatment facilities keep their retention ponds clean. However, flooding events led to accidental releases of the fish into the Mississippi River system, where the fast-growing species now regularly out-competes native fish for food and space.

States play an important role in preventing the introduction and spread of aquatic invasive species through the regulation of key pathways. With respect to aquaculture, three general strategies are promoted to reduce the likelihood that exotic species will be introduced into new environments: 1) discouraging the culture of non-native species; 2) reducing the potential for escapes; and 3) reducing the potential for population establishment in the event of an escape. The following sections examine how state governments across the country are implementing these strategies to prevent the introduction of aquatic invasive species.

II. Discouraging culture of non-native species

The most straightforward and effective method of discouraging the culture of non-native species is to promulgate regulations prohibiting such activity. However, complete prohibitions are oftentimes undesirable from a policy perspective, as many of the most popular species of cultured fish are not native to the United States. Instead, most states prohibit the import, possession, transport, sale, or release of non-native species without a permit from the responsible state agency.

State agencies responsible for preventing and controlling the spread of aquatic invasive species usually promulgate regulations that designate which species may be brought into the state and under what conditions. States generally will divide listed species into three general categories: 1) permitted or approved species; 2) prohibited species; and 3) conditional or regulated species. The exact terminology varies from state-to-state, but permitted species are those that states have determined to pose a minimal risk, and are cleared for import, possession, and use within the state. Prohibited and conditional species pose some sort of risk to the environment that has caused the state to place special limitations on their importation, possession, or use. Specifically, prohibited species are those that pose such a great risk to human or environmental health that state governments have banned their possession except in limited circumstances. For example, a state may generally designate certain invasive carp species as "prohibited," but allow their possession when used for scientific research.

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[4] *Id.* at 141.

The possession of conditional species, in contrast, is permitted subject to certain requirements that are imposed to mitigate risk. For example, a state may require that aquaculture facilities growing certain non-native species such as non-native minnows screen their outflow pipes in order to prevent eggs and/or fry from unintentionally entering native waterways.

Florida's regulations provide an illustrative example. In Florida, it is unlawful to import into the state any freshwater fish of any species without first obtaining a permit from the Fish and Wildlife Conservation Commission (FWCC).[5] It is also unlawful to possess freshwater fish that are not native to the state without a permit from the FWCC.[6] The FWCC classifies non-native species into two categories: prohibited and conditional. Prohibited species may not be personally possessed or used for commercial activities, but limited exceptions may be made by permit for research or public exhibition by facilities meeting biosecurity criteria.[7] No exceptions, however, are made for piranhas. They may not be possessed by anyone at any time. Eighty-six species of tilapia, a popular farmed fish, are listed as prohibited and may not be cultured in the state. Conditional species may not be personally possessed either, but commercial uses such as aquaculture may be allowed by permit provided certain security measures are utilized to prevent unintentional escape or release.[8] Four species of tilapia, including the Blue and Nile, are listed as conditional species and could be cultured within the state if the proper permits were obtained for the aquaculture facility. Four species of Asian carp – grass, silver, bighead, and black – are also listed as conditional species.

States also use import permits to limit the introduction of aquaculture-related pathogens into state waters. For example, Wyoming requires that a fish health inspection report accompany each shipment of live salmonid fish, fertilized eggs, or gametes scheduled for importation and also be on file with the state prior to entry.[9] The same is required for shipments of northern pike and carp originating from outside North America.[10] The health report must be signed by an aquatic animal health inspector or fish pathologist and must also include information regarding the occurrence of several listed pathogens of concern.[11] If the inspecting official finds evidence of certain pathogens, such as viral hemorrhagic septicemia, the state will prohibit infected shipments of fish from crossing state lines, thus eliminating the possibility that the pathogen enters state waters and harms the fish that dwell within. Many states have implemented similar health requirements that must be complied with prior to importation, yet the exact language and rigor of such rules varies from state-to-state.

Import permits only mitigate risks at the border. To manage risks once species are brought within a state, states often require individuals desiring to move invasive species around to obtain transport permits. For example, Idaho's invasive species rules designate three non-native species—the New Zealand Mud Snail,

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5 Fla. Stat. § 379.28.

6 Fla. Stat. § 379.231.

7 *Prohibited Species List*, Florida Fish and Wildlife Conservation Commission, http://myfwc.com/wildlifehabitats/nonnatives/regulations/prohibited.

8 *Conditional Species List*, Florida Fish and Wildlife Conservation Commission, http://myfwc.com/wildlifehabitats/nonnatives/regulations/conditional.

9 040-0001-10 Wyo. Code R. app. I § 2.

10 *Id.*

11 *Id.*

Bullfrog, and Asian Clam—as "exempt," meaning that they were present in portions of the state before its adoption of any rules governing invasives.[12] Those wishing to use and/or possess an exempt species within the state are excused from state permitting requirements created to regulate other invasive species. However, because exempt species are not currently present throughout the entirety of the state, Idaho requires that those seeking to transport the species outside of their known established distribution area first obtain a transport permit in order to prevent the spread of the species to the greatest extent possible.[13] Idaho's transport permits are valid for five years, and require that applicants first submit personal information, information about the facilities involved in the transport, and a biological description of the invasive species being transported, among other things, to the state's satisfaction.[14] Furthermore, Idaho's aquaculture-specific regulations note that transport of exempt species is assumed when biological organisms and associated water from aquaculture facilities and hatcheries is moved from known infested areas within the state.[15] Aquaculture operators must therefore obtain transport permits before moving stock.

III. Reducing potential for escapes

Escapes from an aquaculture facility can occur for a variety of reasons, including the overflow of ponds during flood events, equipment failures, or improper facility design. Reducing the potential for escape events is extremely important in preventing unintentional introductions of invasive species into state waters. States generally focus on regulating the location and design of aquaculture facilities to mitigate the risk of escapes.

The first type of regulations states have utilized to help reduce the potential for escapes relates to location restrictions—those regarding floodplains, in particular. Floodplains are typically dry or semi-dry areas around rivers, lakes, and coasts where water can overflow or pool for extended periods of time as a result of seasonal rainfalls. They are created when the amount of water flowing into an area exceeds the land's ability to store and convey the water, and are a natural occurrence. However, floodplains can pose problems for land-based aquaculture, as facilities not prepared for severe flooding events can lose their yield to rising floodwaters if the crest rises over the highest point of a farm's ponds, tanks, or raceways. Fish can escape during periods of high water and enter surrounding waters as the flood recedes.

A common method for addressing this risk is to prevent the siting of aquaculture facilities in certain floodplains. For example, Minnesota requires that those wishing to conduct aquacultural activities first obtain an aquatic farm license from the state.[16] If the waters listed on the license application are located within a 25-year floodplain and are not enclosed within a building, the state can prohibit certain aquatic species from being farmed there on a case-by-case basis.[17]

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12 Idaho Admin. Code r. 02.06.09.104.
13 *Id.*
14 *Id.* at r. 02.06.09.104.04.
15 *Id.* at r. 02.06.09.104.03.
16 Minn. Stat. Ann. § 17.4984 (West).
17 *Id.*

This rule grants the state the discretion to mitigate harm when and where it sees fit. In another example, Florida has noted in its Aquaculture Best Management Practices (BMP) Manual, that "restricted nonnative species cultured outdoors may only be held in a water body which has the lowest point of its levee, dike, bank, or tank at an elevation at least one foot above the 100-year flood elevation."[18] Facilities culturing restricted nonnative species *must* adhere to this BMP,[19] and, in fact, all those who hold an Aquaculture Certificate of Registration in the state must comply with the entirety of the Aquaculture BMPs, or risk criminal or administrative penalties.[20]

Design requirements are another way in which states can help prevent unintentional escapes. Many states' requirements are fairly broad and vague. For example, Maryland's aquaculture BMP manual notes that, "all holding, culture or transport systems must be designed and operated to prevent the liberation of non-native, hybrid or transgenetic aquatic species, pathogens, or gametic products to the waters of the state."[21] However, some states may choose to enact and enforce more specific requirements. Mississippi's regulations note that the state will not issue the cultivation and marketing permit required for culturing non-native species until it approves a proposed aquaculture facility's design.[22] Similarly, Massachusetts requires that those wishing to culture non-native species first submit an operating plan to the state that details measures designed to prevent the escape or release of organisms or the discharge of biological effluents, including eggs, larva, parasites, and diseases into the marine environment.[23] In an even more specific example, Arkansas requires that those farms culturing restricted species construct a barrier that prevents the escape of juvenile and adult fishes from culture ponds.[24]

Many states have put forth requirements that aquaculture facilities be designed to guard against predation from other animals. If non-native fish are allowed to be taken from an aquaculture site, states risk those specimens entering state waters if predators lose control of their prey before consumption. Those species may then become invasive if released in numbers adequate to establish a viable population. Florida has taken steps to curb this outcome by requiring that bird nets be used to cover net pens where appropriate in order to reduce the risk of predation.[25] However, anti-predation measures, while effective, can cause adverse environmental effects that states may also need to address. For example, a report on net-pen aquaculture in the Great Lakes noted that net-pen covers built in a cage style, while effective at preventing predation, may serve to entangle other fish-eating species, including diving birds. Therefore, the Science Advisory Panel recommends that net pens instead be covered with netting, which minimizes bird mortalities.[26]

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18 Florida Department of Agriculture and Consumer Services, Aquaculture Best Management Practices Manual 27 (2016) [hereinafter Florida BMP Manual].

19 Fla. Admin. Code Ann. r. 5L-3.005.

20 Fla. Stat. § 597.0041.

21 Maryland Aquaculture Coordinating Council, Best Management Practices: A Manual for Maryland Aquaculture 31 (2007) [hereinafter Maryland BMP Manual].

22 Miss. Code Ann. § 79-22-9(3) (West).

23 322 Mass. Code Regs. 15.10.

24 002.00.1 Ark. Code R. § J1.01.

25 Florida BMP Manual, *supra* note 18, at 38.

26 Michigan Science Advisory Panel, Great Lakes Net-Pen Commercial Aquaculture: A Short Summary of the Science 7 (2015).

Alaska's regulations permit the state to condition an aquatic farm or hatchery operation permit so any predator exclusion methods used do not adversely affect the environment and/or incidental species.[27]

Oftentimes, states will also choose to regulate the design of outflow pipes used in semiclosed circulation systems.[28] Unaltered outflow pipes run the risk of introducing non-native eggs or fry into surrounding waters, depending on the species being cultured and the discharge point. Screening requirements help to mitigate this phenomenon by filtering out non-native organisms before they can be unintentionally discharged. Utah, for example, has promulgated a requirement that screens or other devices designed to prevent the movement of aquatic animals into or out of an aquaculture facility be placed at all inflow and outflow points.[29] Aquaculturists who fail to meet the requirement cannot receive a new or reissued Certificate of Registration, without which a facility may not legally operate in the state.[30] Arkansas has also promulgated a similar requirement, noting that, when culturing restricted species, pond drainpipes should be double screened prior to any pond drainage with at least one screen being of a mesh size small enough to prevent the passage of any permitted fish present in the pond.[31]

Even in states that have not explicitly regulated aquaculture facility outfall pipes, such discharges may be otherwise regulated under the Clean Water Act's (CWA) National Pollutant Discharge Elimination System (NPDES) permit program. The federal NPDES program aims to prohibit unpermitted discharges of pollutants from "point sources"[32] into the nation's navigable waters. NPDES permits contain limits on what facilities can discharge, monitoring and reporting requirements, as well as other provisions to ensure discharges do not harm water quality or human health. Most states have also gained some level of authorization from the federal government to administer their own programs, which can include additional restrictions that may directly impact aquaculture. For example, Illinois' state program contains several aquaculture-related provisions, and explicitly notes that NPDES permits are required for the construction, modification, or operation of most aquaculture facilities.[33] The state further notes that NPDES permits are required for facilities that contain, grow, or hold any non-native species of fish or aquatic animal life when such a facility discharges into a navigable water at any time.[34] Therefore, in Illinois, the state must first verify that a facility's discharges are compliant before it can issue a NPDES permit and, thus, authorization to operate. A facility discharging effluent that

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27 Alaska Admin. Code tit. 5 § 41.250(a)(7).

28 In semiclosed systems, culture water makes one pass through the system and is discharged. These systems are also referred to as "flow-through" or "once-through." In contrast, closed systems are those where water is reconditioned and recirculated into culture units. Open systems also exist, and refer to aquaculture conducted in natural bodies of water, such as oceans, bays, or rivers. Due to the nature of these systems, only ponds employing the semiclosed method utilize outflow pipes.

29 Utah Admin. Code r. R58-17-7(A).

30 *Id.*

31 002.00.1 Ark. Code R. § J1.01.

32 "Point sources" are any discernible, confined and discrete conveyances, such as pipes, ditch, channels, or tunnels. In the context of aquaculture facilities using semiclosed circulation systems, discharge pipes are considered to be point sources.

33 Ill. Adm. Code tit. 35, § 503.101(a).

34 *Id.* at § 503.101(b).

carries evidence of non-native eggs or fry is highly unlikely to pass a NPDES inspection to the state's satisfaction. This is due to the fact that non-native species are considered to be biological materials under the CWA, and pollutants when they are discharged from point sources.[35] A point source discharging an unacceptable amount of pollutants will not pass NPDES muster.

IV. Reducing potential for establishment

Recognizing that unintentional releases may occur despite the existence of preventative regulations and measures, many states have taken additional steps to reduce the potential that invasive populations become established after escape events. Perhaps the most common way states attempt to reduce the potential that invasive populations become established is through biological restrictions. While states generally have promulgated lists of species that are either prohibited, permitted, or conditionally approved for culture, many have narrowed the lens of their rules to address factors such as gender and genetic modification. For example, the New Mexico Department of Fish and Game has put forth restrictions related to the gender of both Nile and Mozambique varieties of cultured tilapia. By encouraging that farmed fish be single-gendered, the state decreases the chance that any escaped tilapia can live to reproduce and, thus, become invasive. In New Mexico, if a population of tilapia is first certified as either all male or otherwise sterile by a qualified independent laboratory or other state-approved means, the state will permit their stocking.[36] However, tilapia certified as capable of reproduction and/or propagation must undergo a *much* stricter process before the state will consider permitting their culture.[37] Specifically, those fish must be examined by a "qualified expert," who is an official designated by the state to import a specific non-domesticated animal (in this case, tilapia).[38] If the qualified expert decides to approve a population of tilapia for import, farms are then required to take additional security measures, such as creating a comprehensive biosecurity plan and submitting that plan to the state.[39] Only after the creation and approval of such a plan will reproductive tilapia be permitted for culture by the state.[40]

States can also choose to impose biological restrictions based on a fish's genetic modification. In particular, many states require that invasive fish be genetically altered to be "triploid." While fertile fish have two sets of chromosomes and are classified as "diploid," triploids have been modified to have three sets of chromosomes, making them sterile. Escaped triploids should not be able to reproduce with other triploid members of their species, and, thus, cannot become established as an invasive population past the generation that was initially released. One example of a state that has promulgated regulations making use of triploidy is Utah. Utah, along with

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35 *See generally Northwest Environmental Advocates v. U.S. EPA 537* F.3d 1006 (9th Cir. 2008) (ruling invasive species are biological material and, thus, potentially pollutants that can only be discharged from a point source into navigable waters pursuant to a NPDES permit).

36 New Mexico Department of Game & Fish, Aquaculture Permit Information 1 (2015), available at http://www.wildlife.state.nm.us/download/enforcement/special-permits/aquaculture/Aquaculture-Permit-Information.pdf.

37 *Id.*

38 *Id.*

39 *Id.*

40 *Id.*

other states such as Pennsylvania,[41] requires that all grass carp meant for importation or sale first be verified as triploid by the National Grass Carp Inspection and Certification Program (NGCICP)—a nationally administered, federal inspection service headed by the U.S. Fish and Wildlife Service.[42] Failure to obtain NGCICP certification means that the state will refuse to permit culture of the grass carp at issue, as any unknown diploids could spell disaster if unintentionally released. The veracity of a state's chosen inspection method is extremely important in this regard, as there have been scientific studies that indicate methods of both induction and detection of triploidy may not be 100% effective.[43] However, even when utilizing the most thorough of inspection protocols, some triploid organisms have been found to produce viable gametes and offspring which may allow triploid fishes to establish reproductively sustainable populations in some circumstances.[44]

Another method of risk management is the imposition of financial requirements. Some states may choose to implement financial requirements to help ensure invasive populations do not become established in the event of an escape. One way several states have done this is by requiring those who wish to culture non-native species to first pay a bond to the state. Bonds are used to compel those importing non-native species to financially contribute to any control and eradication efforts the state must make if the species is unintentionally released. For example, Louisiana's rules governing tilapia aquaculture note that aquaculturists may, at the option of the Department of Wildlife and Fisheries, be required to post a $25,000 performance bond, or present a letter of credit from a financial institution stating that the $25,000 is available to the department on a certificate of deposit.[45] The regulation also requires that tilapia live holder permittees post a $10,000 performance bond or guarantee the same through a letter of credit.[46] In a more general sense, the state requires that permittees reimburse the department for all costs deemed necessary to contain, kill, or recapture fish, even if that cost rises above the initial bond amount.[47] While Louisiana's regulations are strong with regards to tilapia, the state does not currently require bonds for the culture of any other aquatic species. This intermediate approach differs from comprehensive frameworks in that the latter would require payment of a bond in order to possess *any* particularly harmful invasive species. However, research failed to reveal any state policies currently in effect that would meet the standards of a comprehensive framework.

States may also require that aquaculturists wishing to farm non-native species make a financial commitment in the form of liability insurance. While requiring proof of liability insurance does not involve a direct monetary contribution to the state, it similarly guarantees that aquaculturists have access to funds that can be used to help compensate the state for its efforts in mitigating any

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41 *See* 58 Pa. Stat. Ann. § 71.7 (West).

42 Utah Admin. Code r. R58-17-13(E).

43 Usgs, Invasive and Exotic Species: Reproductive Potential of Triploid Grass and Black Carp 1 (2003), *available at* https://www.cerc.usgs.gov/pubs/center/pdfDocs/black_carp.pdf.

44 *Id.*

45 La. Admin. Code tit. 76, § 903(H)(11).

46 *Id.*

47 *Id.*

unintentional releases. Georgia, for example, notes in its regulations that the possession of certain listed species may require liability insurance, regardless of how individuals are held.[48] The state's listed species include aquatic invasives such as snakeheads, piranha, and Grass, Silver, and Bighead carp.[49]

One final way states can help prevent the establishment of invasive populations is by instituting reporting frameworks that help coordinate an effective, quick response effort in the event of an escape. Even the simplest of reporting requirements can have a major impact on the long-term effects of an unintentional release. In fact, the USDA identifies early detection and rapid response as one of the most cost-effective and ecologically viable methods of controlling invasive species.[50] This is because quick reporting and responses to introductions of non-native species helps the proper authorities eradicate or contain invasive species while infestations are still localized.[51] The longer it takes to respond to an unintentional release, the more money and time must be spent restoring and protecting the ecosystem, and the less chance there will be for removing all escaped individuals from native waters.

Florida requires that aquaculture facility managers report, within 24 hours, any escape of a cultured species to the Florida Department of Agriculture and Consumer Services.[52] The report must include species identification, the location of the escape, and the approximate size and number of fish involved.[53] Maryland has implemented a fairly involved rapid response effort for aquatic invasive species incidents.[54] In the event of an unintentional release, those aware of the introduction must first contact the Maryland Department of Natural Resources (MDNR) Invasive Species Matrix Team. If the report is deemed credible and worthy of a response, the Matrix Team will then contact experts to identify the specimen(s) in question. If the introduced species is, in fact, non-native, the Matrix Team will then send biologists to the field to confirm the siting and its location. If confirmed, the team will utilize listed criteria to determine whether to act, and then brief the Secretary of MDNR and MDNR Communications as to the incident as well as the team's recommendation of a response. If a response is warranted, an Incident Management Team is then formed, which will conduct a risk assessment, analyze management options, and take action if needed. The state will then conduct monitoring to determine if the non-native species has been successfully eradicated from state waters or further action is necessary.

States may also require that aquaculturists take additional measures that increase escape preparedness on farms themselves. For example, Florida requires that aquaculturists develop and submit to the state a Loss-Control and Escape Recovery Plan that includes a site-specific analysis of the potential risks of escapes, their causes, and the specific procedures employed by the farm

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48 *Aquaculture Regulations & Licensing,* Georgia Department of Natural Resources, https://georgiawildlife.com/aquaculture.

49 *Wild Animals/Exotics,* Georgia Department of Natural Resources, https://georgiawildlife.com/exotics.

50 *Early Detection and Rapid Response,* USDA, https://www.invasivespeciesinfo.gov/subject/early-detection-and-rapid-response.

51 *2008 – 2012 National Invasive Species Management Plan,* The National Invasive Species Council (Aug. 2008), https://www.doi.gov/sites/doi.gov/files/migrated/invasivespecies/upload/2008-2012-National-Invasive-Species-Management-Plan.pdf.

52 Florida BMP Manual, *supra* note 18, at 36.

53 *Id.*

54 *Id.*

to reduce risk.[55] These plans must include: 1) minimum equipment and operating standards; 2) emergency repair procedures; 3) escape recovery procedures; 4) practices and equipment that reduce the need for predator reduction/destruction; and 5) preparations for severe weather.[56] Furthermore, the plan must include a notification procedure that informs FDACS when fish are not recovered following an escape.[57] Requiring detailed planning such as this forces aquaculturists to deeply consider their responses to potential escape events so that effective recovery can begin as soon as a release is discovered.

V. Additional considerations

Introductions of potentially invasive species do not stem exclusively from equipment failures, natural weather events, or predation. Introductions can also occur through the intentional or unintentional release of farmed fish as part of stocking operations or use as bait. It is therefore also important to consider the risk of invasive species introductions presented by the intended use of the aquaculture stock.

Stocking is the process of raising fish in a hatchery (an aquacultural activity) and releasing them to supplement existing populations or establish a population where none currently exists. Sometimes, non-native species are intentionally introduced, such as is the case with coho and Chinook salmon in the Great Lakes. However, non-natives species can be released by accident during stocking either because of stock contamination or misidentification. This can happen when an intended species and a potentially invasive species look similar to one another, or if other species were unintentionally gathered when collecting the target stock. For example, flathead catfish are sometimes unintentionally included in shipments of channel catfish. States may help prevent unintentional releases by either promulgating rules that require careful examination of cultured stock prior to release or encouraging such in a best practices manual. States may also require routine inspections of hatcheries where fish intended for stocking are grown, in order to better assess whether those facilities risk producing contaminated stock. For example, Maine currently requires that a facility intending to serve as a qualified source/hatchery that stocks fish into the coastal waters of the state successfully pass an inspection of all production lots at least annually.[58]

Somewhat similarly, introductions of non-native aquatic species can occur through baitfish shipments, sales, and release. Oftentimes, baitfish are raised in an aquaculture facility in another state, then shipped out-of-state where they are bought, sold, and utilized. Ensuring that such shipments and sales are all of one species, rather than a mixture including individuals of an unintended species, reduces the likelihood of introducing non-native species into native waters.

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55 Florida BMP Manual, *supra* note 18, at 36.

56 *Id.*

57 *Id.*

58 13-188-24 Me. Code R. § 21(E)(1).

Some areas in the Great Lakes, for example, train bait dealers to inspect and recognize problematic contaminants such as round goby and ruffe. Additionally, some states have restricted the states from which they will accept cultured baitfish depending on the rigor of an exporting state's invasive inspection regulations as well as the species, parasites, and pathogens that could potentially be introduced along with shipments.

Non-native bait releases can also prove extremely damaging. Anglers often release unused live bait without realizing that the species may be non-native to the area and can potentially become invasive. For example, species such as golden shiners and fathead minnows have been introduced in this way. Bait release can have consequences beyond the expected direct competition with, or predation on, native species. Some non-natives may be able to hybridize with native fish, thereby compromising their genetic makeup, and other species have served as pathways for the introduction of parasites that have proved devastating to fragile, native fish populations. States may engage in public education either directly or as a best management practice that serves to inform anglers of the consequences of dumping live bait, and discourages them from doing so. States may also permit only native species to be used as bait within state lines, as enforcing a prohibition on non-native baitfish further reduces the chance of invasive introductions. Some areas already experiencing problems with bait introductions have even found success in prohibiting the use of any live bait, though this is clearly an extreme measure.

VI. Conclusion

Preventing the influx of non-native, cultured species into new areas is a problem with many potential solutions, but no one "right" answer. The best methodologies vary from facility-to-facility depending on factors such as location, species, and the type of aquaculture being practiced. However, the following preventative strategies provide an important foundation for state management programs:

- **Species restrictions** – Restricting the type of species authorized for culture helps states mitigate the risk that specific non-natives are introduced.

- **Permitting requirements** – Permitting frameworks help states control the culture of non-natives at every stage, from import to harvest and eventual transport.

- **Location restrictions** – Restricting where facilities culturing non-native species can operate helps diminish the likelihood that natural events, such as floods, can facilitate unintentional escapes.

- **Design requirements** – Design standards add an extra layer of protection that can help prevent unintentional releases due to factors such as equipment failure or predation.

- **Biological restrictions** – Restricting permitted species by factors such as gender and genetic modification provides a layer of redundancy that helps ensure non-native populations cannot become established in the event of an escape.

- **Financial requirements** – Assuring that aquaculturists can contribute financially in the event of an escape—through tools such as bonds and liability insurance—adds to a state's ability to prevent non-native populations from becoming invasive.

- **Reporting requirements** – Establishing reporting frameworks helps ensure both facilities and state authorities can coordinate an effective, quick response effort in the event of an unintentional release.

By utilizing these strategies, states can help erect barriers to the spread of non-native species and mitigate the disastrous ecological outcomes that can result. To facilitate this, states should consider conducting a systemic review of other state laws and regulations that have successfully integrated some or all of the listed preventative strategies. State officials should then undertake a review of their own laws and regulations as currently written to identify potential areas for improvement.