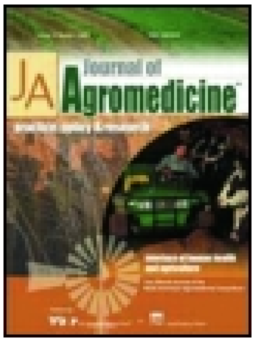

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HOW WE WORK

Simple Solutions for Reduced Fish Farm Hazards

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ABSTRACT. Aquaculture poses emerging challenges for agricultural safety and health. Fish farming has many of the same hazards as other types of farming, but it also poses additional hazards associated with water impoundments and night-time work. In a multidisciplinary approach, researchers from four universities are identifying occupational hazards in fish farming and identifying no-cost or low-cost "simple solutions" to reduce or eliminate them. Simple solutions are discovered through farm visits so as to understand the countermeasures that individual stakeholders have taken to protect their workforce, and these countermeasures are documented and photographed to inform other farmers of these solutions. Equipping tractors with rollover protective structures is a standard practice to protect operators from serious injury in the event of an overturn. Other solutions identified include eliminating the need to climb feed bins to open and close the hatch for feed delivery by using a pull-cable at ground level. This simple technology eliminates the exposure to falling from an elevation, a risk that accounts for at least one reported death of a worker on a fish farm. Another solution is to replace metal paddles on a hatchery trough with plastic paddles that if and when entangled in a worker's hair or clothing slip on the rotating drive shaft and thus reduce laceration and entanglement injuries. Another simple solution to prevent entanglements in large pond aerators, used to mechanically dissolve oxygen into the water, that are operated by farm tractor power take-off shafts is to use electrically powered aerators. Bubble-type aerators are safer than electrically powered paddle aerators because workers are shielded from moving parts. Many additional simple solutions have been identified for a range of tasks in this environment.

KEYWORDS. Aquaculture, fish, fish farm, hazards, safety

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INTRODUCTION

Aquaculture became widely practiced in North America in the late 1900s, and as of 1997, the United States produced 3% of farmed fish worldwide and has been a growth industry in U.S. agriculture.[1] According to the 2005 Census of Aquaculture, there were 4309 fish farms in the United States, up from 4028 in 1998.[2] These data represent farms that produced more than $1000 of aquaculture product in 1 year, totaling $1.1 billion in 2005. Aquaculture is defined as the farming of fish, crustaceans, mollusks, and other aquaculture products, implying some form of intervention in the rearing process, such as seeding, stocking, feeding, protection from predators, etc. The U.S. Department of Agriculture started collecting information every 5 years on aquaculture in 1974 through its Census of Agriculture. According to the 2005 Census, the major method of U.S. fish farm production was ponds (n = 2347); followed by mollusks on the bottom of water bodies, e.g., estuaries (n = 774), and flow-through raceways (concrete water channels) and recirculation systems that recycle at least 90% of their water through tanks (both n = 415). Remaining methods included nonrecirculation systems, cages, pens such as net systems floated in natural water bodies, mollusks off the bottom such as submerged ropes on which animals such as oysters are reared, and cropland used for crawfish production. Principle species of fish raised on U.S. farms in 2005 included catfish (n = 1060), mollusks, e.g., clams (n = 960), crustaceans, e.g., crawfish (n = 925), and trout (n = 410).

Fish farming has the hazards typical of farm operations, as well as those associated with water impoundments and work at night.[3,4] For example, fish ponds pose potential hazards such as drowning, electrocutions, equipment overturns, and slips and falls. Other possible hazards include punctures or lacerations from fish teeth or spines, exposure to low temperatures, and acquisition of bacterial and parasitic infections,[5,6] as well as exposure to chemicals[7] (Table 1). Aquaculture is an emerging sector of U.S. agriculture, but this industry has unaddressed occupational safety and health problems for its workers.

TABLE 1. Recognized Hazards on Catfish Farms

Electrical safety	Boom truck safety, tractors
Loading fish and other jobs	Battery service
Operating on slopes	Harvesting with a boat
Mowing levees	Handling catfish
Hitching to the tractor	Working around seine reels
PTO safety and setting aerators	Using lifts, jacks, and hoists
On public roads	

Sources: Minchew CD. Safety for Fish Farm Workers: Booklet. Fish Farm Safety Group, Catfish Farmers of America, Indianola, MS, FFS-Booklet No. 1. 2000. 16 pp. Available at http://www.cdc.gov/nasd/docs/d001701-d001800/d001756/d001756.html [accessed 24 January 2008].
Steeby JA, Minchew CD, Killian HS. Safety for Fish Farm Workers: Brochure. Fish Farm Safety Group, Catfish Farmers of America, Indianola, MS, FFS-Brochure No. 1, 2000. 4 pp. Available at http://www.cdc.gov/nasd/docs/d001701-d001800/d001757/d001757.html [accessed 24 January 2008].

The purpose of this article is to identify occupational hazards on fish farms and to suggest simple and inexpensive ways to make aquaculture tasks safer. This investigation is important because many fish farming tasks are dangerous and prior studies have not addressed fish farming hazards.

METHOD

The study method involves the identification and enumeration of simple solutions to eliminate or mitigate potential work-related hazards beyond musculoskeletal disorders as addressed in agriculture[8] and construction.[9] With this approach, low-cost and even no-cost changes in the work environment can make a significant difference in the prevention of occupational injuries and illnesses. The information collected does not produce new obligations or establish any specific standards or guidelines. Voluntary implementation of the identified solutions by fish farm operators can reduce the potential for occupational illness and injury and in many cases yield a return on the investment.

Detailed information was collected from interviews of the farm operators and other key personnel and on-site surveys of fish farms. Each operator reported the injury and close call history for the operation and was asked what he or she thought were major fish farming hazards. For each injury, close call, or illness case identified, the operators were asked what they did or could do to eliminate or reduce the risk of injury or illness in the future. After completion of the interview, a walk-through site inspection was completed with the fish farm operator. During the walk-through, an investigator documented and photographed examples of hazards and simple solutions. A total of 22 interviews and inspections were conducted in 2008; because this is a small number, the study was descriptive yet is helpful in the identification of problems worthy of further investigation and implementation of solutions that can be adopted on other fish farms. The interviews and inspections were distributed across the various types of fish farming operations as listed below.

- Mississippi: catfish in ponds (*n* = 3)
- South Carolina: clams in estuaries and bays (submerged nets) (*n* = 3)
- North Carolina: trout in raceways (*n* = 6)
- Kentucky: trout, bass, and catfish in ponds and raceways (*n* = 7)
- British Columbia: salmon in ponds and net pens (*n* = 3)

RESULTS

To date, this study has identified seven fish farm hazards. These include electrical shock, drowning, slips, trips, and falls, sprains and strains, machines, chemicals, and fires and explosions. In Table 2, four examples for each hazard were selected to illustrate their scope. These describe the agent of the potential injury or illness and a countermeasure (simple solution) as described by the subject or the investigator's observation for each of these examples.

Electrical Shock

Fatal contact of crane and augur booms with overhead power lines were reported. The absence of ground-fault-interrupter circuits was prevalent, and extension cords often were used instead of permanent wiring. One catfish farm worker always carried a padlock with him to lock out service panel switches when he repaired an electric aerator (machines that deliver oxygen into the water through agitation by paddles or through air bubbles). However, on another farm, the investigators found that such a procedure could be compromised when the emergency electrical back-up power system would activate 20 seconds after the main power was shut off. The solutions to the hazards identified were to bury the power lines, install permanent power lines where extension cords were permanently used, install ground-fault-interrupters, implement lock-out and tag-out procedures, and gang together the manual off-on switches to the main electrical power and the emergency backup system.

Drowning

One catfish farmer drowned when he swam underwater to clean a screen over the drain line in a pond; he was sucked into the drain pipe after the screen was cleared. Another farmer fell into his vinyl-lined reservoir and had difficulty climbing out of the pond because of the slick surface of the liner. A youth was drowned when his all-terrain vehicle (ATV), used for herbicide application, overturned into a pond and pinned him underwater. A diver entangled his respirator regulators in a net in a coastal region and drowned. These hazards could be reduced by closing the drain line valves when working underwater near drain pipes, installing floating lifelines or other devices for exiting plastic lined ponds, and equipping vehicles (including ATVs) with rollover protective structures (ROPS) so operators can escape after an overturn. Divers should ensure that protective shrouds are mounted around their respirator regulators when diving near nets.

Slips, Trips, and Falls

Slips, trips, and falls can result in broken bones and potential drowning to an injured, unconscious victim. Workers have tripped over tools left on walkways, have slipped on slimy or icy surfaces, and have fallen fatally from the top of feed bins while opening the hatch to deliver feed. In order to service aerators, workers have risked potential falls while balancing

TABLE 2. Examples of Occupational Hazards, Their Circumstances, and Simple Solutions for Eliminating or Reducing Risk on Fish Farms Based Upon Interviews and Observation

Hazard	Agent	Countermeasure
Electrical shock	Crane contact with overhead power line	Bury the power line
	Extension cords used as permanent wire	Install permanent wiring
	Shock possibility in a wet environment	Install ground-fault-interrupters
	Backup power activates when power turned off for equipment maintenance	Gang together the back-up and service panel switches for lock-out, tag-out
Drowning	Pulled into drains when cleaning screens	Shut drain valve when cleaning screens
	Ponds with slippery plastic liners	Install float-to-land lines in pond
	Vehicle overturn into ponds, i.e., ATV	Maintain levees, install roll bar or cage
	Air-supplied respirator entangled in net	Install shroud over regulators
Slips, trips, and falls	Tools, etc., on walking surface	Keep walkways free of obstacles
	Slipped and fell on slimy surfaces	Replace with non-slip material
	Climbing ladder to open feed bin hatches	Install pull-cable at ground to open hatches
	Angle-iron struts for access to paddles	Install catwalk to aerator paddles
Sprains and strains	Manual filling of live tanks with water	Use water boom to fill tanks
	Unload fish from tubs or nets	Use chute to reduce lifting
	Netting and lifting fish loads	Reduce weight of fish loads
	Netting, weighing, and transferring fish	Install overhead beam and pulley system to carry load
Machines	Live tank lids can fall onto fingers	Install lock hinges or arrestors on lid
	Tractors can overturn	Install ROPS or cab with egress
	Entanglement in power take-offs	Install guards
	Hatchery metal paddles can scratch or lacerate	Plastic paddles can be stopped by hand
Chemicals	Backpack sprayers can leak	Wear protective clothing
	Manual application of pesticide	Wear protective clothing
	Manual spreading of hydrated lime	Use mechanical spreader
	Needle sticks when vaccinating fish	Use corrugated table to hold fish
Fires and explosions	Natural gas leak	Detect and repair leaks
	Building fires	Install sprinkler suppression systems
	Exposed battery positive terminal in boats	Cover the terminal to prevent sparks
	Spark source, e.g., smoking, and clothing used around oxygen	Keep spark sources away from oxygen tanks and impregnated clothing

themselves with a pole as they walked on one of two angle-iron struts leading out over the water. One additional hazard not listed in Table 1 is the problem of working at night where lighting may be missing or inoperable. Such a hazard exists on trout and other types of operations, especially for workers who need to clean the screens of storm-related debris on the head box (see Figure 1), which provides inflow of water from streams into raceways. Solutions to these problems include keeping walkways free of obstructions, providing nonslip walking surfaces, providing ground-level controls for opening and closing elevated hatches, installing catwalks on aerators, and ensuring that adequate lighting and backup lighting are available to conduct night work. An unlit head box on a trout farm is shown in Figure 1.

Sprains and Strains

Most musculoskeletal issues relate to fish handling during the harvesting process, although twisting motions while working on raceways also have resulted in knee disorders and falls. One safety practice has been to partially fill live tanks with water from ponds before emptying fish from dip nets into the tank. Filling the live tanks traditionally involved man-handling 4-inch flexible pipes to direct pressurized water into the tanks. Recoil from the water can cause strain injuries or

FIGURE 1. A photograph of a head box above trout raceways that lacks lighting and poses nighttime trip hazards when cleaning the intake screens of debris.

knock a worker off a truck, resulting in a serious injury. A simple solution was to use a water-supply boom positioned over the tank hatch that prevents the recoil. The primary solutions to other musculoskeletal stresses and injuries related to lifting were to (1) provide mechanical assists, (2) reduce the weight of lifted loads (such as dip nets filled with fish), and (3) lower the heights of live tanks. All three simple solutions reduce the physical burden on the workers.

Machines

Hazards include the lids on the top of live tanks have fallen from an upright position and amputated fingers, tractors have overturned on levees, missing machine guards on power take-offs (PTOs) and drivelines create the potential for entanglements, and small metal paddles used as aerators in hatchery tanks pose scratch, laceration, and clothing and hair entanglement hazards to workers.[8] Solutions to these hazards include installing lock hinges or arrestors on live tank lids, retrofitting tractors with ROPS, installing PTO guards where they are missing, and replacing metal paddles on hatchery tanks with plastic paddles that will slip on the drive rod, thus giving way when a contact occurs, instead of injuring a human hand or causing an entanglement.

Chemicals

Backpack sprayers have leaked pesticides onto the backs of applicators, farmers have mixed their pesticides into water solution with their hands, workers have distributed dusty hydrated lime powder into water manually, and workers have experienced serious toxic reactions when they stuck needles into their hands while vaccinating fish. Simple solutions include wearing protective clothing, spreading lime mechanically, and using a corrugated table to secure fish while vaccinating.

Fires and Explosions

Natural gas or propane leaks, especially indoors, can lead to explosions and fires that have destroyed fish farm buildings. An uncovered positive battery terminal on a boat can produce a spark where gasoline fumes from fuel tanks may accumulate within a cabin or hull. Working with oxygen tanks and valves can produce an oxygen-rich environment that can infiltrate and be retained in clothing. A lit cigarette can lead to ignition of clothing. Solutions include detecting and repairing gas leaks, covering positive battery terminals, and not smoking or otherwise creating ignition sources near oxygen tanks and lines.

DISCUSSION

Many of the hazards identified in this study of a sample of aquaculture operations can be addressed by low-cost simple solutions. Nevertheless, aquaculture is a rapidly evolving industry, and as technology substitution is applied, new and different hazards emerge. For example, one simple solution to PTO entanglements related to paddle aerators in fish ponds was to replace them with electric-powered aerators and bubble-type aerators that are considered to be safer than paddle aerators because workers are shielded from moving parts. However, a barrier to the adoption of these technologies is the unproven effectiveness of mixing oxygen into the water by a safer aerator as compared to one with a potentially more hazardous design. In addition, the use of electric aerators, while reducing entanglement risks, may introduce a new major hazard: electrical shock. Noteworthy and relative to this particular hazard, walleye farmers in the North have started experimenting with safer, direct current (DC) solar-powered aerators in their ponds. Nascent hazards need to be recognized and abated as safer technologies replace more dangerous ones.

A unique problem identified in this study was the presence of safety cabs on tractors that may trap an operator inside in the event of an overturn into a pond with the door facing the bottom of the pond.[10] A second exit reduces the risk of entrapment and death.

In addition to regional and commodity-specific hazards, a broad range of hazards exist for the fishing industry worldwide.[11] Thus, the creation of standards for occupational safety and health for aquaculture has become an agenda item for the International Standards Organization (ISO). First on the ISO agenda is salmon farming, which has several potential safety and health hazards.[12],[13] Some research has begun on the prevention of musculoskeletal disorders among fish farmers.[14] Indeed, our study has found that such disorders are prevalent in the fish farming industry and emphasizes the need for a "best practices" approach for fish farming, similar to that which has emerged for environmental protection. Furthermore, night work in the fishing industry requires more attention to artificial lighting.[15] In addition, unprotected boat propellers can cause abrasions, fractures, and severed limbs.[16] This variety of hazards indicated a need for an extensive program of research to investigate these problems so as to eliminate or mitigate their affects on workers.

We describe initial findings from the study and continue to investigate the hazards on fish farms and simple solutions to abate them. It is important that these solutions be cost-effective from a business perspective in order to be acceptable to the farmer.

The fish farm industry has been challenged by drought, increasing fuel prices, and higher feed costs. As a result, many farms are shifting their production to commodities such as corn. Nonetheless, as the markets stabilize, we anticipate a return to fish farming. The simple solutions identified can be effective for controlling hazards within the reemerging industry.

Polyculture may be on the rise because of environmental and sustainability problems. For example, sea kelp and mussels may be an environmentally friendly way to dispose of salmon manure around net pens while also providing a marketable product.[17] Another emerging industry is deep sea or open ocean farming, an experimental form of fish farming. For example, off the coast of Puerto Rico, the carnivorous Cobia is being grown in "Aqua-Pods."[18] Such experiments portend a future with large-scale offshore fish farms in waters hundreds of feet deep, which is seen as necessary to meet the increasing demand for protein worldwide. Deep sea farms need to be designed to withstand the currents and large storms at sea and deep ocean anchorages. The process involves sinking giant cages or nets down well below the surface of the water and tying them to a series of anchors using high-strength polymer ropes with several large feed buoys floating on the water surface. Potential hazards are present while deploying the cages, transporting fish, filling the cages with fish, feeding and medicating the fish, harvesting the fish, and refurbishing or repairing the cage system. The potential hazards include drowning with falls overboard from boats or when tending to the cages while diving underwater; decompression sickness (the bends) from deep sea diving[13] as well as flammability hazards during decompression in high oxygen chambers; struck-by injuries from breakage of high tension ropes; stresses and strains related to manual handling of heavy or impulsive loads; punctures or bites from the farm-raised fish or from sea-borne predators, e.g., sharks; and exposures to chemicals used as pesticides, e.g., to control sea lice or as net impregnations, e.g., to deter jellyfish.

On many farms, fish processing is an integral part of the operation. Although this study does not address fish processing, this area may be important for future study, particularly where workers are exposed to both fish production and fish-processing operations. Moreover, occupational health problems that emerge in processing[19] may also be present in fish production.[5,20]

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