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Aquacultural Safety and Health

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1. Introduction

Worldwide, 11,289,000 people worked in aquaculture in 2004—up nearly three-fold from 3,832,000 workers in 1990 (Watterson et al., 2008). Aquaculture, including mariculture, is a fast growing sector of worldwide agriculture but has unaddressed occupational safety and health issues. Many fish farming tasks are dangerous; working around water poses a particular danger, and Working at night and alone compounds the danger. A safety or health hazard is any work design or property (physiological, physical, chemical, biological, or psychological) that may cause harm to workers or bystanders.

As the cultivation of aquatic organisms, aquaculture may include the complete value chain of production including feed production and fish processing, but for our purposes, we delimit the scope of our writing to aquatic organism production that includes the hatchery, nursery, and grow-out phases of production. Feeding, controlling predators, applying chemicals, harvesting, and refurbishing or constructing structures or ponds are examples of typical fish farm operations. While onshore aquaculture is associated with many of the same hazards that are present in agriculture generally, offshore aquaculture is more closely akin to a combination of hazards associated with shallow water commercial fishing and offshore drilling.

Mariculture has many hazards. SINTEF, an independent research organization headquartered in Norway, has presented data for Norwegian aquaculture showing that the fatality rate (9.13 deaths/100,000 work yearsIs "work years" the correct unit here?) is 17 times the average rate for other industries (0.53 deaths/100,000 work years) and equivalent to that of its fishing fleet (Clausen, 2000). In another study with more detail, 16 fatalities occurred in the Norwegian salmon farming sector between 1980 and 1999. Ten of the deaths were associated with using a boat: five in small boats, three occurring: in one type of incident, boats capsized with overloading and shifting loads along with bad weather. Three deaths occurred in workboats when two workers were either stuck by a crane or loads from a crane, and another incident on a well boat, a worker was struck by an anchor that was propelled into his face from a hang-up under the boat by the recoil of the anchor line. Three additional workers died while diving, all of whom lacked a professional diving certificate (Norwegian Labor Inspection Authority, 2001).

Figure 1 shows the percentage and type of non-fatal mariculture-related injuries. Most of these injuries were associated with machinery followed by slips trips. Knife cuts and fish

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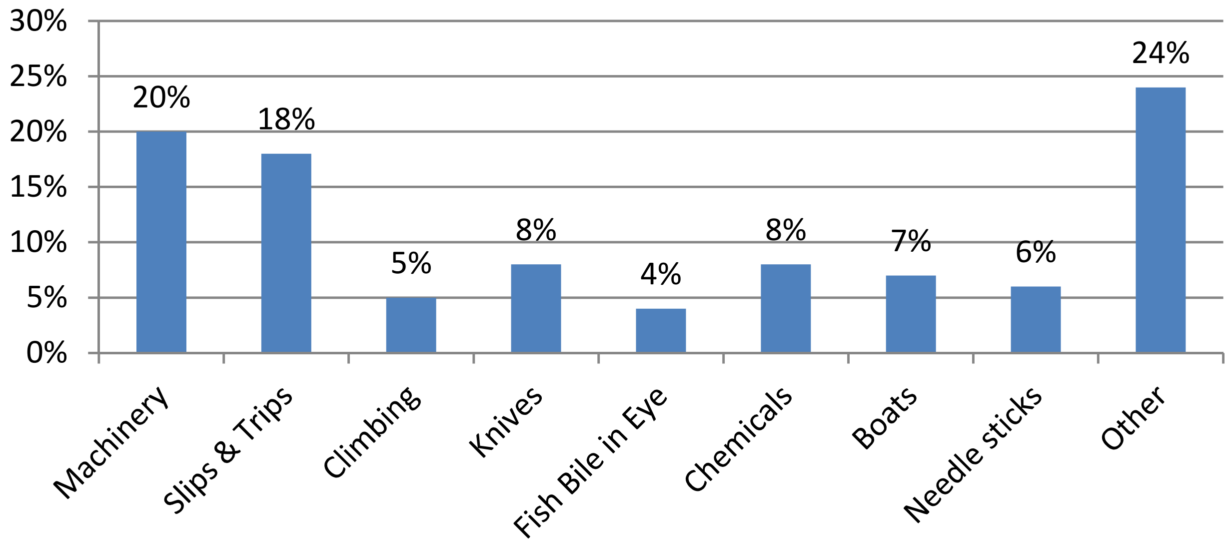

Fig. 1. Percentage of nonfatal occupational injuries associated with aquaculture in Norway, 1980-1999. Source: Norwegian Labor Inspection Authority, 2001

bile in the eye were likely processing-related injuries, but boat-related injuries and needle sticks were associated with fish production, as most probably were the climbing-related injuries.

Figure 2 shows the frequency of mariculture-related illnesses in Norway during the 1980-1999 period. The highest number of reported cases was for musculoskeletal disorders followed by skin allergies and hearing loss.

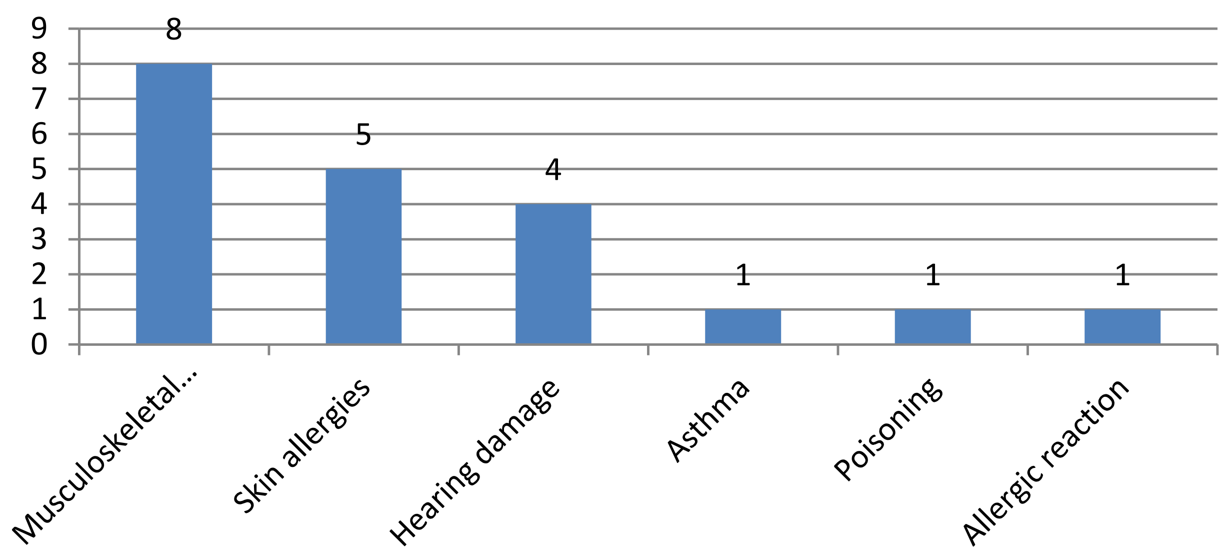

Fig. 2. Number and type of aquaculture-related occupational illness cases reported in Norway, 1980-1999. Source: Norwegian Labor Inspection Authority, 2001

In the United States, the non-fatal occupational injury rate in 2006 for onshore aquaculture was 6.8 injuries per 100 full-time employees according to the U.S. Bureau of Labor Statistics.

In comparison, rates were 5.3 and 7.8 injuries per 100 full-time employees for terrestrial crop and animal production, respectively, and 4.6 injuries per 100 full-time employees across all occupational sectors (Myers & Durborow, 2011; Cole et al., 2009).

Potential occupational hazards in aquaculture have been associated with fatalities that include drownings, electrocutions, crushing-related injuries, hydrogen sulfide poisonings, and fatal head injuries. Non-fatal injuries have been associated with slips, trips, falls, machine operation and repair, strains and sprains, chemicals, and fires. Risk factors include cranes (tip over and power line contact), aerators (entanglement and trauma), tractors and sprayer-equipped all-terrain vehicles (overturn), heavy loads (lifting), boat propellers, high pressure sprayers, slippery surfaces, rotting waste (hydrogen sulfide production), eroding levees (overturn hazard), storm-related rushing water, diving conditions (bends and drowning), night-time conditions, working alone, lack of training, no personal flotation devices (PFD), and all-terrain vehicle use (ATV, also known as a quad-bike). Other hazards include punctures or cuts from fish teeth or spines, needle-sticks, exposure to low temperatures, and bacterial and parasitic infections (Myers, 2010).A fatality of an aquaculture farm manager occurred in Kentucky when he was entangled in a tractor power-take-off during fence post installation, and a diver drowned offshore in Hawaii while working with submerged fish cages (Shikina, 2011).

In this chapter we follow an order that has been developed in industrial hygiene for protection against hazards: identify, evaluate, and control the hazards. In the following sections, we describe approaches for recognizing hazards, including descriptions of the known occupational hazards involved with aquacultural work, and for evaluation, a job hazard analysis approach is described. A risk matrix is used for priority setting so as to deal with the "worst" hazards "first" and risk assessment is described. We describe precedence models—a safety hierarchy—for valuing the effectiveness of hazard controls, and finally, we provide an outline that can be used for developing a safety manual for the individual enterprise.

2. Identifying occupational hazards in aquaculture

This section describes the known hazards of aquacultural work and identifies and discusses the hazards associated with different species and rearing technologies. This information will aid fish farmers in recognizing hazards associated with their operations. Recognized hazards involves employees and includes observed close calls and occupational injury or illness history. The endpoint for the recognition of hazards is an inventory that lists the hazards associated with all tasks, equipment, and substances:

- Injury and illness information and data regarding the industry and related industries, e.g., farming or fishing.
- Information from past incidents and workplace injuries.
- Information from your workers as well as family members and neighbors.
- Product literature and information from suppliers.
- Best industry practices.
- Examine areas or activities where children or visitors may be present.

To identify and better understand hazards before product use, employers need to obtain and read the manuals and safety sheets that are provided by equipment, machinery, and chemical manufacturers. Employers should also develop and implement communication and emergency plans to allow for a timely response in the event of an incident.

Five categories of hazards are 1) physiological (work design), 2) physical, 3) chemical, 4) biological, and 5) psychological (Moreau & Neis, 2009). These categories are described in Table 1. Onshore and offshore exposures to hazards differ greatly, and most species raised offshore involve onshore tasks for the hatchery and nursery phases.

Categories	Exposures	Potential Consequences
Physiological (work design)	Heavy lifting, prolonged standing, awkward postures, repetitive motion, overexertion, lack of visibility	Low back pain, neck and shoulder pain, bursitis, tendonitis, tenosynovitis, carpal tunnel syndrome
Physical	Slips and trips, falls from height, falls overboard, transport and trucking, machinery, electricity, fire, heat and cold, diving, noise, vibration, confined spaces, entanglement, underwater entrapment, solar radiation	Injuries, cuts, burns, broken bones, amputation, hypothermia, hyperthermia, drowning, electrocution, injury-related death, asphyxiation, decompression illness, sprains and strains
Chemical (toxic, flammable, corrosive, explosive)	Disinfectants, parasiticides, piscicides, fungicides, antifoulants, anesthetics, antibiotics, radon gas from water sources, hydrogen sulfide, carbon monoxide, sulfites, dusts, fumes, styrene, needlesticks, flammabilities, battery explosion	Respiratory illness, burns, cancer, central nervous system effects, birth defects, reproductive effects, poisoning, hematopoietic effects, and lung, eye, or skin irritations
Biological	Sharp teeth, spines, aerosolized proteins, bacteria, parasites, skin contact with shellfish and finfish tissues and fluids, enzymes, airborne proteins and endotoxins, fish feed dust	Bites, cuts, punctures and related infections; allergy, asthma, eczema, urticaria (hives), chapped skin, itching.
Psychological	High demand and low control situations, remote locations away from family, potential for large fish kills, abusive social environment	Work-related stress

Sources: Moreau & Neis, 2009; Myers, 2010; Durborow 1997; Erondu & Anyanwu, 2005.

Table 1. Occupational Hazards Associated with Aquaculture

Table 2 provides a summary of common occupational hazards and associated consequences that have been related with work in aquaculture, focusing on the hazards particular to rearing different fish and plant species. Hazards by species vary, but occupational hazards also vary by the phase of production. While hazards associated with the nursery and grow-

Species	Potential Fatal Incident	Potential Non-fatal Incident
Catfish	Injuries from traffic collision, unused seatbelt, or tractor overturns and electrocution from electrical contact.	Disease or illness from chemical exposure: formalin, potassium permanganate, hydrogen peroxide, fertilizers, lime, oxidants, disinfectants, algaecides, herbicides; burns from exposure to sulfuric acid or fires; injury related to fatigue or slips and falls; as well as hand infections, back injury, spine envenomation, and venomous injuries.
Trout	Injury related to falls from raceways or live tank trucks, roadway collisions or, crane overturn; drowning in raceways.	Injury related to high pressure water jet penetration, no guard rails, falls, and slips and trips; hearing loss from noise exposure; leptospirosis infection; toxic exposure to formaldehyde.
Shellfish	Drowning when scuba diving.	Electrical shock from broken electrical conduits; injuries related to loose hand rails, missing safety latches on electric hoists, and working on dredges; shrimp meal allergy; crab scrape-related infections.
Crawfish, snail (rice field flooding)	Crushing injury from tractor overturns.	Injury from boat propeller entanglement; wrist/hand and back strains.
Tilapia		Electrical shock from extension cords in water; injury related to poor flooring, missing hand rails, working alone, forklift, algae growing on walking surfaces, trip hazards, or no fall protection; toxic effects or burns related to chlorine, hydrogen peroxide, or hydrochloric acid exposure; musculoskeletal disorders; and spine prick infection (finger amputation).
Ornamental fish		Salt and coral dermatitis, fish tank granuloma, skin infection, cercarial dermatitis, skin granulomas after abrasions, *Mycobacterium marinum* infection.
Salmon	Respiratory failure from H2S exposure; drowning related to fall overboard, boat capsizing, or diving; injury when struck by crane or crane loads or gear entanglement	Decompression illness; toxic effects from styrene and acetone exposure during fiberglass tank construction; anaphylactic shock or infection from self-injection of vaccine; and pesticide poisonings.
Tuna	Diving-related drowning.	Decompression illness.
Sturgeon		Toxic effects or burns from exposure to hydrogen peroxide, lime, or muriatic acid; fork lift-related injuries; fire danger from oxygen.
Plant production (taro, cress, water spinach, mimosa, dropwort, water lilies)	Drowning related to fall overboard or no PFD.	Dermatitis, wastewater-related dermatitis, leptospirosis.

Source: Myers 2010.

Table 2. Recognized Hazards Associated with Specific Species or Phases of Production

out phases may differ between species and rearing technology, hatchery operations have much in common between species production. Deaths have occurred in hatcheries associated with hydrogen sulfide exposure and slips and falls. Other hazards associated with hatcheries include exposures to aerators, pumps, heaters, and other types of machinery; fuels, solvents, hypochlorite, formaldehyde, formalin, confined spaces, water jets, unguarded saws, ozone, and hair entanglement in hatching trough paddles.

Erondu & Anyanwu (2005) identified hazards in African aquaculture including noise, cuts, sprains, fractures, asthma, rhinitis, snake and fish bites, bronchitis, chemical burns, pesticides and disinfectant poisoning, parasites, and pathogens. In another review, Conway and RaLonde (1998) identified hazards associated with worldwide aquaculture including machine entanglements, hearing loss, slips and falls, drowning, lacerations, infections, electric shock, hypothermia, repetitive strains, sleep deprivation, decompression illness, organophosphate poisoning, respiratory illness, sunburn, keratotic injury, leptospirosis, and dermatitis. In another two reviews, Durborow (1997; 1999) identified several hazards associated with aquaculture including exposures to bacterial infection, hydrogen sulfide, sodium metasulfide, sodium bisulfite, anesthetics, antibiotics, vaccines, tractor overturns, electricity, overhead power lines, power-take-off or aerator entanglements, falls, muscle strains, drowning, hypothermia, and decompression illness.

Tables 1 and 2 can be helpful in listing known or potential hazards into a hazard inventory. This inventory should include the following (Myers, 2011):

- Process descriptions,
- Controls related to the hazards,
- Location organizationally and physically of each process,
- Supervisor name and contact information,
- Number of employees who work in the process,
- Medical information related to the hazards, and
- Historical information about the process and related hazards

3. Job hazard analysis

The evaluation step aids in decision-making about the nature and control of hazards given the circumstances of the work and exposure to the hazards (Myers, 2011). Priorities for focusing on the "worst first" are effected by using a risk matrix. The matrix maps the likelihood of an incident occurring versus the severity of the consequence, which informs the decision maker of the risk and the urgency for taking preventive action. A risk assessment tool summarizes and evaluates the workers' exposure, job redesign, and actual or potential control measures by the processes of the enterprise.

The job hazard analysis, which is currently used at some fish farms, identifies a job such as climbing a ladder and lists the steps involved in the job and the associated hazards with possible countermeasures to reduce exposure to the hazard. The job hazard analysis tool is presented in a table format in Table 3.

A likely hazardous exposure to workers or bystanders must be corrected immediately. When a hazard has been identified, the risk can be assessed by examining the likelihood of the hazard resulting in injury to workers or other persons (is it likely or unlikely to

Job: Lifting and Carrying Feed Bags		Date: 02.11.2003
Title of Person doing the job:		Analysis by:
Organization:	Location:	Reviewed by:
Required or recommended personal protective equipment:		Approved by:

Sequence of job steps	Potential hazards	Recommended control
1. Planning ahead.	1. Holding the bag may cause strain, or it may be dropped.	1. Know where the bag is to go; Have a place to put the bag. Consider lighter loads with more trips.
2. Lifting bag.	2. Back injury.	2. Use arm and leg muscles, not your back; When in doubt make it a 2-person task.
3. Carrying the bag.	3. The bag may slip and fall resulting in strain from overexertion.	3. Grasp bag firmly and secure your footing; Keep your back straight and the bag close to your body. Avoid twisting your back while carrying the load; the back muscles may be strained or the foot could stick to a high traction surface while the rest of the body is twisting, causing knee sprain.
4. Seeing where you are walking.	4. Carrying the load in front of you can cause injury to you or another person.	4. Make sure the load does not block your view while walking; Use a hand truck or move bags stacked on pallets with a forklift.
5. Setting the load down or dumping the load.	5. Back injury.	5. Use your arm and leg muscles. Avoid bending back.

Table 3. Sample Job Hazard Analysis Form

occur) and if the incident occurs, what is its potential severity, i.e., death, serious injury, or minor injury?

Ask questions like: How many people come in contact with the hazard? How often? How seriously could someone be harmed? How quickly could a dangerous situation occur if something goes wrong (PEI, 2005)? Other factors to consider include abilities of the individual, the weather and terrain, and how equipment is used.

The UN Food and Agriculture Organization provides a typical risk matrix as shown in Table 4 that can be used to set priorities for controlling hazards. In this table "catastrophic" refers to death or a lethal disease, "critical" relates to severe injury or occupational disease, "serious" relates to injury or disease requiring medical care but is not critical or catastrophic, "minor"

Likelihood	Consequence				
	Insignificant	Minor	Serious	Critical	Catastrophic
Rare	N	L	L	M	M
Very low	N	L	M	H	H
Low	N	L	H	H	E
Moderate	N	M	H	E	E
High	N	M	E	E	E

Risk level denoted by: N = negligible, L = low, M = moderate, H = high, E = extreme
Source: Arthur et al. 2009.

Table 4. A Risk Matrix

refers to a minor injury or disease, and "insignificant" refers to property damage only (Myers, 2011).

In Norway, job hazard analyses are summarized by job location. This summary is a risk assessment that is made easy by asking three questions (Norwegian Labor Inspection Authority, 2001):

1. What can go wrong (hazard)?
2. What can we do to prevent this (recommended control)?
3. What can we do to reduce the consequences if something occurs (recommended control)?

The emphasis should be aimed at the greatest risk. The format for this assessment is to place answers to these questions as shown in Table 5. The examples developed in Norway suggest different tables for each location in salmon farming: (1) fish hatchery, (2) dock, (3) fish fry boat, (4) feed boat/work boat, (5) plant base, floating or on land, (6) plastic net pens, (7) steel installation, and (8) feeding station. One example is shown in Table 5, which is consistent with the Job Hazard Analysis and uses recommended control information from the US Occupational Safety and Health Administration and the US National Institute for Occupational Safety and Health.

4. Hierarchy of controls

This section introduces the reader to the hierarchy of controls as an extension of the identified countermeasures listed in the job hazard analysis. It distinguishes passive from active controls. Passive controls involve no human action for protection and include the elimination of the hazard at the top of the hierarchy, followed by substitution of a less hazardous technology or an engineered guard against the hazard. Active controls include awareness through warnings or training and the use of personal protective equipment. Farm operators are encouraged to adopt or develop inherently safety technologies by first (**eliminating**), then (**guarding against**), and finally (**warning about**) the hazard. Warnings are not always reliable in preventing contact with hazards. Examples of this hierarchy, which has evolved for safety engineering, are presented in Table 6 (Wogalter, 2006).

The hierarchy of controls is an approach for evaluating the inherently safer technologies with an emphasis on moving from active to passive controls. This simple two-step hierarchy was used in highway safety with the highest precedence based upon (1) passive control that

Work task	What can go wrong? (Potential hazards)	What can we do? (Recommended control)
Walking on the dock..	Slipping or tripping on dock.	Eliminate, to the extent possible, conditions causing slippery working and walking surfaces in immediate work areas, e.g., brush poured cement before it dries to provide traction to the walking surface. Active work areas shall be kept free of equipment and materials not in use, and clear of debris and other objects not necessary for the work in progress. Cargo and material shall not obstruct access to or egress from boats, cranes, vehicles, or buildings. PFDs must be available.
Climbing aboard and ashore from boats.	Falling into sea.	An adequate gangway must be provided. When a gangway is not practical, then a ladder or floating bridge must be used. The gangway must have clear access, have hand rails, and be properly trimmed and illuminated. When boarding, leaving, or working from small boats or floats, workers shall be protected by personal flotation devices.
Loading or unloading with cranes.	Crushed by load or crane contact.	Cranes are to be operated only by qualified and trained personnel. Inspect all rigging prior to use. Do not exceed the load chart capacity while making lifts. Suspended loads must not pass over the gangway or above workers. Shut down the operation during extreme wind or during storms.
Forklift loading or unloading.	Crushed by runover.	Do not operate a forklift unless you are trained and licensed. Do not handle loads that are heavier than the weight capacity of the forklift. Operate the forklift at a speed that will permit it to be stopped safely.

Source: Norwegian Labor Inspection Authority, 2001. Adapted to recommendations by US agencies: the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health.

Table 5. An Example of a Job Hazard Analysis Related to a Work Location: The Dock

requires no human intervention at the work interface, whereas the less safe approach was (2) the active control that depends upon human behavior at the work interface (Haddon, 1974). The passive control emphasized roadway and vehicle design features while active controls focused on the driver.

PASSIVE CONTROLS—protection does not depend upon the worker's actions (Haddon, 1974).

1. Eliminate hazards posed by equipment, animals, and the environment if at all possible or substitute something safer by using a different machine, material or work practice that poses less risk to perform the same task. For example, replace a faulty machine or use a safer chemical instead of a more dangerous chemical.
2. Guard against the hazard when it is not possible to eliminate hazards. Engineered controls include machinery guards and PTO shields. Design controls, such as locked fences, isolate the worker from the hazard.

ACTIVE CONTROLS—protection depends upon the worker's actions (Haddon, 1974).

3. Warn against the hazard if other controls are inadequate. Protect workers through training, supervision, and personal protective equipment (PPE). For example, supervise new workers until they are competent to deal with hazardous situations.Use and provide proper clothes and respirator protection for handling dangerous chemicals or biohazards.

With more than 50 fish farm visits, investigators were able to identify hazards on fish farms as well as different levels of hazard control on different farms (Durborow, et al., 2011; Ogunsanya et al.,2011). Farmers were generally aware of the hazards but were less aware of controls that different farmers had used to prevent injury from the hazards. Twelve hazards and a range of controls for each hazard are summarized below in Table 6, which classifies the interventions against the precedence hierarchy of controls (Myers & Durborow, 2011; Myers & Cole, 2009).

5. Model safety manual

The Global Aquaculture Alliance for Best Aquaculture Practices (BAP) is a standards-based certification system that combines site inspections and records review to help program participants meet the global demands for wholesome seafood produced in an environmentally and socially responsible manner. BAP has developed standards to certify shrimp hatcheries and shrimp, tilapia, channel catfish, pangasius, and salmon farms. One section of 13 sections in the certifications process includes Worker Safety and Employee Relations (BAPa, 2011). Other sections have an effect on worker safety and health: Storage and Disposal of Farm Supplies, Drug and Chemical Management, Microbial Sanitation, and Harvest and Transport.

In the certification process, the following standards regard worker safety: Living quarters provided by the employer shall be well ventilated and have an adequate shower and toilet and potable water; and wholesome meals should be available for workers. National labor laws or criteria in the International Labor Organization Conventions for minimum age and child labor shall be followed. Minimum standards for occupational safety and health include (1) medical care access, (2) an emergency response plan regarding serious illnesses or injuries, (3) workers trained in first aid and the emergency response plan, (4) available first aid kits, and (5) personal protective devices and clothing should be

Hazard	Warning	Guarding	Elimination
Falling lid on live tanks	Post sign urging caution when working near raised lid	Place wooden wedge under open lid	Install locking or pneumatic hinges
Impalement on electric fence rods (to deter otters)	Be careful and don't fall	Use top insulators as impalement caps	Place rods horizontally on raceway walls
Fall from feed bin roof	Hang on tight to ladder	Install a ladder guard or use a harness attached to a cable	Install hatch handles at ground level
Needle stick while vaccinating fish	Keep fingers away from injection site.	Use corrugated table top to immobilize the fish in the corrugated groove	Install automatic fish vaccination machine
Overhead electric power line contact	Flag areas under power lines	Raise power lines, e.g., 30′ to 45′	Bury power lines
Lifting fish with a dip net	Keep good posture while lifting	Lift smaller loads of fish making more frequent trips	Install a pulley to raise fish nets from tank and a track to slide loaded net to the weighing point
Tractor overturn	Stay off of slopes that could cause rollover	Install rollover protection and use the seatbelt	
Net entanglement & drowning while diving	Don't panic	Place regulator shrouds on O_2 tanks	
Traffic collision hazard	Don't drive sleepy	Maintain distance from other drivers	
Aerator PTO entanglement	Keep away from rotating PTO shafts	Place guards on power-take offs	Use electric-powered aerators
Hatchery paddle entanglement	Use panic wire to stop shaft when hair entangles	Replace bolted metal paddles with plastic paddles that slip upon contact	Mount motor that drives the paddles on a movable platform that completely disengages the drive belts if disturbed
Solar radiation	Don't expose bare skin	Wear sun block	Work in covered areas

Table 6. Examples of Prevention Effectiveness Related to the Hierarchy of Controls

provided as needed. Best Available Practices are established for the following categories of fish farms and hatcheries:

Tilapia Farms (BAPb, 2011):

- The above standards apply.

Shrimp Farms (BAPc, 2011):

- The above standards apply.

Shrimp Hatcheries (BAPd, 2011):

- The above standards apply, and
- Train and assure appropriate licensing of machinery operators, drivers, and repair personnel in machine safety.

Channel Catfish Farms (BAPe, 2011):

- The above standards apply.
- Electrical pumps and aerators must be wired according to standard and safe procedures.

Pangasius Farms (BAPf, 2011):

- The above standards apply, and
- Comply with laws that govern diving on fish farms.
- Dive safety plans that include diver training, maintenance of diving logs, and equipment maintenance.
- Written procedures and trained staff to handle diving emergencies, and regular audit of records and procedures.

Salmon Farms (BAPg, 2011):

- The above standards apply, and
- Initial training of workers for their assigned tasks and safety procedures and use of boats and related equipment.
- Familiarize workers with emergency response plans and train them in first aid, one of whom shall be present among untrained personnel.
- The employer and diving contractors shall comply with laws that govern diving on fish farms or implement a dive safety plan requiring diver training and certification.
    - Minimize the frequency of ascents during the diving day.
    - Maintain dive logs that document procedures and safety-related incidents.
    - Require records on equipment maintenance.
    - Dive safety equipment shall include the availability of bottled oxygen.
- Written safety policies for contractors.

A possible safety manual is provided by the Prince Edward Island Workers' Compensation Board in its Aquaculture Safety Code of Practice. It can be accessed online at http://www.wcb.pe.ca/DocumentManagement/Document/pub_aquaculturesafetycodeofpractice.pdf. An outline for this manual is shown in Table 7. It does not address confined spaces, but a US Occupational Safety and Health Administration publication can be used to develop policies regarding confined spaces (OSHA, 2004).

Responsibilities Under the Law	Hand & Power Tools
Aquaculture Safety Planning	Hoisting and Conveyor Systems
Boat, Deck & Navigational Safety	Hydraulic Safety
Chainsaw Safety	New & Young Workers
Chemical, Fuel & Lubricant Safety	Personal Protective Equipment
Diving Safety	Rescue Procedures
Electrical Safety	Sharp Objects Safety
Equipment & Machinery Safety	Slip, Trip and Fall Prevention
Ergonomics	Transportation Safety
Finfish Safety	Weather Hazards
Fire Prevention	Welding, Cutting or Soldering Safety
First Aid and Emergencies	Winter Harvesting Safety
Confined Spaces*	Workplace Housekeeping

Sources: PEI, 2005.
*OSHA 2004.

Table 7. Possible Sections That Can be Chosen for an Aquacultural Safety Manual

6. Conclusion

This chapter aims to provide information for establishing programs for protecting aquaculturalists from occupational hazards. It presents many occupational hazards associated with aquaculture with some regarding specific species and rearing technologies. These recognized hazards can help the aquaculture production enterprise identify potential hazards in its operation. Next, approaches are described for evaluating these hazards including the job hazard analysis and risk assessment approaches with a description of the risk matrix that can aid in setting priorities for controlling hazards. Section 4 addresses the use of the hierarchy of controls to implement the most effective protection by emphasizing passive controls (protection independent of the worker) over active controls (protection dependent on the actions of the worker). Finally, a possible table of contents for developing a safety manual for an operation is presented (Section 5).

We began with the model developed by industrial hygienists to protect against occupational hazards: the identification, evaluation, and control of hazards. More recently, industrial hygienists have added another purpose for their profession, the anticipation of hazards (Myers, 2005). The anticipation of hazards is of high importance to aquaculture, which is developing rapidly worldwide. One approach is to use known hazards and controls from other sectors. Procedures in the fish processing sector can be expanded into the fish production sector, and the unique procedures of the fishing sector can be adapted to offshore aquaculture. In addition, the traditional regulatory sector regimes for onshore and offshore operations need to come together to protect aquacultural workers (Claussen, 2000), many of whom work both onshore and offshore.

Other sources may aid in more specific approaches. As an example, regarding channel catfish, the Catfish Farmers of America, USDA Southern Regional Aquaculture Center, and National Aquaculture Association developed Safety for Fish Farm Workers program guidelines, which can be accessed at http://www.cdc.gov/nasd/docs/d001701-d001800/d001756/d001756.html. A manual for aquaculture safety in cold waters *Spawn,* *Spat, and Sprains* is available at http://seagrant.uaf.edu/lib/an/17/AN-17.pdf, which deals not only with safety and ergonomics, but also with survival in the event of a vessel capsizing. A *Guide to Drug, Vaccine, and Pesticide Use in Aquaculture* produced by the Federal Joint Subcommittee on Aquaculture revised in 2007 can be accessed at http://www.aquanic.org/jsa/wgqaap/drugguide/drugguide.htm.

7. Acknowledgments

The project that informed this chapter was supported by the Centers for Disease Control and Prevention (NIOSH) Cooperative Agreement number 2 U50 OH007547-07, and human subjects review was provided by the University of Kentucky Office of Research Integrity under IRB protocol number 06-0564-P2G. We are grateful to Teresa Donovan of the University of Kentucky College of Public Health for her help in editing this paper.

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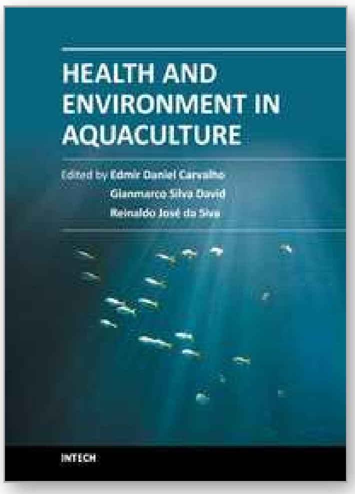

Health and Environment in Aquaculture

Edited by Dr. Edmir Carvalho

ISBN 978-953-51-0497-1
Hard cover, 414 pages
Publisher InTech
Published online 11, April, 2012
Published in print edition April, 2012

Aquaculture has been expanding in a fast rate, and further development should rely on the assimilation of scientific knowledge of diverse areas such as molecular and cellular biology, and ecology. Understanding the relation between farmed species and their pathogens and parasites, and this relation to environment is a great challenge. Scientific community is involved in building a model for aquaculture that does not harm ecosystems and provides a reliable source of healthy seafood. This book features contributions from renowned international authors, presenting high quality scientific chapters addressing key issues for effective health management of cultured aquatic animals. Available for open internet access, this book is an effort to reach the broadest diffusion of knowledge useful for both academic and productive sector.

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

Melvin L. Myers and Robert M. Durborow (2012). Aquacultural Safety and Health, Health and Environment in Aquaculture, Dr. Edmir Carvalho (Ed.), ISBN: 978-953-51-0497-1, InTech, Available from: http://www.intechopen.com/books/health-and-environment-in-aquaculture/aquacultural-safety-and-health

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