The Importance of Biosecurity in Intensive Culture

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Introduction

The explosive growth of worldwide aquaculture has resulted from culture intensification and from an increased number of species being cultured in an increased number of locations. As culture intensification has proceeded, catastrophic loss from infectious disease outbreaks has been repeatedly identified as a major cost to industry productivity. Major causes of disease-related financial loss are direct losses, market losses and costs resulting from lost opportunity. Direct losses include mortality, facility closure orders, restriction of movement orders, and the inability to replace stock. Market losses include reduced quality of survivors (e.g., from reduced growth rates and lower yields or reduced product quality), a restricted market for healthy stock because of damage to a facility's reputation, and missed markets. Examples of opportunity costs are diversion of management and labor and underutilization of the fish production facility (Paterson et al., 1991).

The purpose of this paper is to describe, 1) how increased intensification results in an increased risk of infectious disease outbreaks, 2) summarize the major risk factors for infectious disease outbreaks in finfish culture, and 3) describe ways to use the principles of biosecurity to decrease the risk that outbreaks of infectious disease will occur at facilities where intensive culture of finfish is an economic necessity.

Increased intensification results in an increased risk of infectious disease outbreaks

Crowding increases the vulnerability of a population of animals to disease and death from opportunistic and obligate pathogens. The theory behind why this increased vulnerability occurs has been well-established since the early 1900's. As described in the review by Anderson (1982), Hamer (1906) suggested that the course of an epidemic depends on the contact rate between susceptible and infectious individuals. This "mass action principle" states that the rate of disease spread is assumed to be proportional to the product of the density of susceptibles times the density of infectious individuals. In addition to Hamer's mass action principle, Kermack & McKendrick (1927) established the threshold theorem. According to the threshold theorem, the introduction of infectious individuals into a community of susceptibles will not lead to an epidemic outbreak unless the density of susceptibles is above a certain critical threshold density. Therefore, culture intensification creates ideal conditions because not only does the density of susceptible animals increase, but the introduction of even one infectious individual will result in proportionately more contacts with susceptible animals, thereby increasing the risk of an outbreak.

Many fish culturists reason that if they start a cohort with more fish, they will be able to "make up for" losses if an infectious disease outbreak does occur. Unfortunately, the disease dynamics are such that this strategy does not result in the ability to culture more fish. Results from infectious pancreatic necrosis (IPN) experiments (Fig. 1) where one infectious fish was added to each of 12 tanks of various densities of susceptible rainbow trout fry, demonstrate that at the end of 60 days there were no more fish remaining in the high density tanks than in the low density tanks (Bebak, 1996).

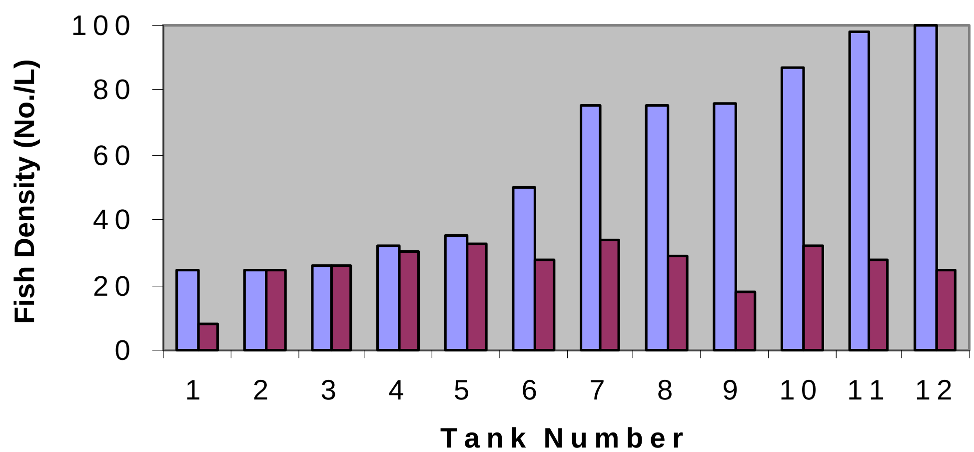

Figure 1. Rainbow trout fry densities at the beginning and end of epidemics of IPN

When fish culture density is not strongly influenced by economic factors, the fish culturist naturally, through experience, keeps cultured fish populations below their critical threshold density. An example of this tendency toward the threshold number of susceptibles can be seen in Piper et al. (1982), which recommends that a "rule of thumb that can be used to avoid undue crowding is to hold trout at densities in pounds per cubic foot no greater than 0.5 their length in inches". In laboratory experiments on the effect of density on IPN epidemics in rainbow trout, Piper's cutoff turned out to be the cutoff above which an IPN epidemic was more likely to occur (Bebak, 1996). An additional example of threshold densities can be seen in Wedemeyer and Wood (1974), who published a table of hatchery pond loading rates for chinook and coho salmon. Above these loading rates they found that infectious disease outbreaks were more likely to occur.

Facilities that culture fish for conservation purposes are more likely to have the freedom to culture fish below the population's critical threshold density. Economics require that food fish production facilities must intensively culture finfish. Fortunately, the minimum threshold density of susceptible individuals for an infectious disease outbreak will change as the environmental conditions change. The principles of biosecurity can be used to increase that threshold density of susceptibles and decrease the risk that an infectious disease outbreak will occur.

Biosecurity

Intensive biosecurity practices have been more commonly employed in European and Japanese fish hatcheries than in North American fish hatcheries (Amend and Conte, 1982). Biosecurity, or "hazard reduction through environmental manipulation" (Plumb, 1992), is often defined as practices that reduce the number of pathogens that enter a facility. This paper will use an expanded definition for biosecurity, which consists of management practices and procedures that 1) reduce the risk that pathogens will be introduced to a facility, 2) reduce the risk that pathogens will spread throughout the facility and 3) reduce conditions that can enhance susceptibility to infection and disease. Often one would like to think that implementing biosecurity practices on the fish farm will prevent entry of even a single pathogen. Realistically, biosecurity for food fish production accomplishes pathogen reduction rather than pathogen elimination.

Reducing the risk that pathogens will be introduced to a facility

Entry of pathogens through the water supply (usually when fish are present) and through the introduction of fish to a facility have been identified by epidemiologic studies as major risk factors for outbreaks of infectious disease in cultured finfish (Thorburn, 1987; Jarp et al., 1993; Bebak et al., 1997). Any food fish production facility that plans to intensify culture in a given water supply, and 1) uses a water supply with a resident population of fish or 2) imports fish into the facility, can expect to experience infectious disease outbreaks if no changes in these two management practices are made.

Ideally, a farm would use a pathogen-free water supply that is protected from contamination and would purchase only certified eggs to restock the facility. Unfortunately, not all farms have access to a pathogen-free water supply, nor do all farms culture species that are readily available as eggs. If a pathogen-free water supply is at risk of contamination, or is unavailable, then incoming water should be disinfected. Ozonation and ultraviolet radiation are the most commonly used methods. If possible, the facility should only be restocked with fish hatched from certified eggs that have been disinfected upon arrival at the facility (Appendix 1). If fish must be imported into the facility, then strict quarantine procedures should be implemented (Appendix 2). In addition, fish should only be purchased from a reliable source with certified broodstock that has been kept in a pathogen-free and/or disinfected water supply. The risk of pathogen introduction can also be reduced by keeping the number of different suppliers to a minimum. Farms that culture species that are not available as certified eggs should actively support research on broodstock development and egg production.

As biosecurity practices are considered, begin with the areas where the population is most susceptible (e.g., egg and fry rearing areas). Management practices that may be implemented to further reduce the risk of introduction of pathogens include:

- Wash hands with anti-bacterial soap upon entering the facility.
- Disinfect footwear or change footwear to disposable, or disinfected non-disposable, boots before entering the facility.
- Access to egg incubation and fry facilities should be restricted to a minimum number of well-trained individuals.
- Reduce the number of visitors to a minimum and/or only people working on the farm should be allowed into the facility.
- Disinfect wheels of delivery vehicles when they come onto the facility and when they leave. Establish a visitor parking area on the periphery of the facility grounds.

Reducing the risk that pathogens will spread throughout the facility

Meticulous husbandry is an essential component of an effective biosecurity plan. Feces, uneaten feed, algae, aquatic plants and other decomposing debris provide a substrate for opportunistic pathogens to flourish. Tank surfaces should be kept free of uneaten feed, feces, algae and aquatic plants. Inflow and outflow pipes, aerators, spray bars and any other equipment inside the tanks should be cleaned frequently.

It is critically important that every part of the rearing system be constructed so that the system can be easily cleaned as necessary. All parts of recycle systems including the biofilters, low head oxygenators (LHOs) and CO_2 strippers should be accessible for cleaning. Clean-outs should be installed to access pipe interiors. Construction materials should be non-porous and easy to clean and disinfect. Avoid the use of wood. If wood is to be used, it should be considered disposable. Wood use should be limited to temporary structures and these structures should never be transferred to another site.

Culling dead and sick fish is a very important strategy that can reduce the spread of pathogens from fish to fish. How culling will be accomplished should be considered early on in facility design. Culling should be done at least once a day or, if possible, on a continuous basis. Culled live fish should be humanely killed and not allowed to die from suffocation.

Monitoring is an important part of early identification, isolation and treatment of a problem. How monitoring will be accomplished should be considered early on in facility development. Ideally, daily observation of the fish should be possible. Dim lighting and very large tanks with limiting viewing access limits the possibility of visual inspection of fish, one of the most valuable tools for detecting an incipient problem. Culled fish should be periodically assayed for pathogens. Records on growth and feed conversion ratios can be used to detect subclinical problems. Consider keeping a susceptible species as sentinel fish.

Other important management practices that will decrease the risk that pathogens will be spread around the facility include:

- Frequent hand-washing with anti-bacterial soap should be standard practice.
- Disinfectant and rinse areas should be readily accessible for disinfecting buckets, nets, dissolved oxygen meters, thermometers and other equipment.
- Tanks and equipment should be disinfected before using for a different group of fish.
- Even when tanks are on the same recycle loop, each tank should be regarded as a discrete rearing unit and the potential for cross-contamination should be minimized.
- Strategically schedule culture activities. Minimize the number of different personnel working with a particular group of fish. As soon as any suspicious mortality above baseline levels occurs, only one person should be allowed to work with affected fish. Alternatively, if personnel resources are limited, work should be done on the unaffected tanks first, leaving the affected tanks for last.
- Aerosol transmission of pathogens can occur. Consider placing barriers between tanks.
- Minimize transfer of fish between tanks.
- Whenever possible, employ the use of vaccination as a disease prevention management tool.

Reduce conditions that are stressful to the fish and that can enhance susceptibility to infection and disease

Stress associated with crowding, low water flow, poor nutrition, poor water quality and other husbandry related factors will render fish more susceptible to, and aggravate the consequences of, infection with opportunistic and obligate pathogens. There are many strategies that can be used to increase fish vigor and reduce stress. Some of these include:

- Use of gentle fish crowding and other methods of gentle fish handling
- Monitor water quality parameters to verify that they remain within recommended limits.
- Poorly nourished fish are more susceptible to disease. The fish feed schedule and feed characteristics should be such that the fish receive the best nutrition possible.
- Purchase eggs and fish only from optimum year class broodstock.

Summary

Intensive culture of finfish increases the risk of infectious disease outbreaks that can have catastrophic effects on a facility’s ability to meet production goals. Effective biosecurity can help decrease the risk that infectious disease outbreaks will occur. But, effective biosecurity if very difficult to implement after a problem begins. Biosecurity should be considered in the early stages of intensification of an existing facility and in the early design of a new facility. Biosecurity should not be considered to be a static, unchanging set of rules and procedures. Biosecurity is implemented in a dynamic biological system. Once they are in place, biosecurity plans and protocols should be constantly reevaluated and changed as necessary.

Appendix 1. Egg disinfection procedures

Very few disinfectants have properties that can be safely used around fish eggs and still have quick-acting, broad-spectrum activity. In addition, the disinfection of eggs for food fish falls under the regulatory jurisdiction of the FDA and only disinfectants that are included as FDA-Approved New Animal Drugs or Unapproved New Animal Drugs of Low Regulatory Priority (LRP) for FDA may be used (Federal Joint Subcommittee on Aquaculture, 1994). Iodophors (organic iodine complexes), are one commonly used option. Iodophors, which are LRP drugs, are generally used at 100 ppm for ten minutes after water hardening to disinfect fish eggs. One advantage of iodophors is the amber color which indicates the disinfectant is effective. Once the color turns yellow or colorless, it is no longer effective. With other disinfectants, it is more difficult to determine if the solution is effective (Amend and Conte, 1982).

Appendix 2. Quarantine

Quarantine is designed primarily to prevent introduction of pathogens into a facility from which eradication would be difficult or impossible. Isolation is the key to quarantine. Quarantine can be costly, and should be considered early in the facility design phase. There is no “recipe” quarantine protocol that covers all fish species cultured in all conditions. The following guidelines should be included when developing quarantine protocols for a facility. Many of these recommendations are included in (Harms, 1993).

- Quarantine protocol development should take into account the species, age and source of fish being quarantined.
- Length of quarantine should take into account information about incubation periods and development times for the pathogens that are known to present a risk. Although 30 days is often given as the “standard” quarantine period, it could be longer or shorter depending on pathogen life cycles and expression of clinical disease in warmwater vs. coldwater conditions.
- Quarantine should protect against foreign or exotic pathogens to avoid the introduction of a potentially serious, “new” problem.
- Do not use prophylactic antibiotics as part of a quarantine protocol. Prophylactic antibiotic use is illegal and can have serious consequences for the development of bacterial resistance to antibiotics.
- Quarantine must be closed. Any addition of fish to ongoing quarantine resets the quarantine clock to day zero.
- Fomites (e.g., nets, buckets and hands) and aerosols can breach even well-designed isolated quarantine systems. Minimize aerosols with tank covers

and by maintaining quarantine and exhibit tanks in separate rooms. Quarantine equipment should be used only in quarantine.
- Personnel should wash hands before going between areas and should save quarantine work for last.
- Consider keeping water temperatures at the upper end of the species optimum range to speed up pathogen life cycles.
- Introduce production system water before transfer so that fish can acclimate to it.
- Some authors recommend keeping fish densities as low as possible to minimize stress. Alternatively, consider exposing the fish to the same conditions they will encounter in the production system, so that a problem may be detected before the fish are moved out of quarantine.
- Consider transferring fish to a new tank within the quarantine system if dealing with the possibility of stages of organisms that can be left behind when the fish are moved from the tank.

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