AQUA TIPS

Large-scale transport of fingerlings—specifically moi, the Pacific threadfin (*Polydactylus sexfilis*)

Kenneth K. M. Liu and Charles W. Laidley

Finfish Department, Oceanic Institute

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Introduction

Open-ocean cage culture has become a viable system for growing marine fish fingerlings to market size at commercial operations in the United States. Hukilau Foods of Oahu, Kona Blue Water Farms of Kailua-Kona, Hawaii, and Snapper Farms of Puerto Rico, use hatchery-based technologies to generate, respectively, large numbers of moi (*Polydactylus sexfilis*), kahala (*Seriola rivoliana*) and cobia (*Rachycentron canadum*) fingerlings for stocking large, submerged growout cages. Advantages of cage systems include large capacity (stocking rates currently are up to 200,000 fish per cage, each of which have a volume of 2,400 m^3) and unlimited supply of high-quality water, facilitating substantial increases in operational scale. Yet, scale-up has brought a need to transfer extremely large numbers of fingerlings from onshore hatcheries to open-ocean growout cages. Thus, CTSA sponsored a two-year study of fingerling transport to identify current limits for the safe transport of moi, also known as the Pacific threadfin, and the critical transport factors affecting fingerling survival. This report reveals our findings from that project.

Figure 1. *The experimental fingerling transport system (above) used in our study was composed of 24 insulated coolers, each with a 25-L working volume and supplemented with individually metered oxygen supplies.*

Methodology and Results

Transport Test System. After experimentation with several test systems, our project team began using a relatively simple, small-scale system, using 24 insulated plastic coolers (25-L working volume) for simulated transport trials (Figure 1). Each cooler was provided with an individually metered oxygen supply via in-tank airstones. Dissolved oxygen (DO), pH, temperature, and salinity were monitored using a hand-held, water-quality meter, and total ammonia nitrogen (TAN) was determined on 1.2µm-filtered water samples stored frozen at -5ºC and later analyzed using a Hach DR-69 colorimeter. Tanks were agitated every 15 minutes to simulate movement associated during actual transport. In the first trial, mortalities were placed into cotton mesh bags within each cooler, but, in later trials, plastic containers with ¼-inch holes were used to reduce fish entanglement in the netting.

The use of a small-scale system was necessary to facilitate replicated scientific study and to reduce the number of fish required for experimentation. This system provided an effective approach for determining optimal transport conditions for juvenile fingerlings, a technology that should be useful for companies working on other marine species, including kahala, also known as the longfin amberjack, and cobia. However, even at this small scale, individual trials required more than 5,000 fingerlings to examine multiple treatments with adequate replication.

Effect of Transport Density. A series of transport trials were conducted to establish the density-survival relationship for the Pacific threadfin under conditions currently used for moving moi fingerlings from hatchery to offshore cages in Hawaii. The objective of this research was to (1) determine the highest density at which moi fingerlings can be transported safely for periods up to 6 hours and (2) establish the LD_{50} density (the density at which half of the fish succumb to transport stressors) for use in optimizing transport conditions.

Early in a test trial, we experienced high levels of mortality due to rapid depletion of dissolved oxygen associated with the stress of fish handling. This highlighted the importance of ensuring oxygen levels are monitored carefully throughout all stages of a transport process, including during transfer from fish tank to transport containers. We also noticed a rapid deterioration of water quality with a buildup of mucous and scales released from handled fish. In response, fish handling protocols for transport studies were modified to include an additional period of oxygen supplementation and freshwater flushing of fish transfer buckets during the movement of fish from culture tank to transport tanks and before stocking in the transport system to ensure optimal water quality at the start of the experiment.

Moi fingerlings were then tested at transport densities of 10, 20, 30, 40, 50 g/L, using approximately 4 g fish, with four replicates per density. Dissolved oxygen was maintained above 6.5 mg/L throughout these trials. As was expected, data from these trials demonstrated a strong density-dependent effect of fish handling and transport on short-term fingerling survival. When moved under "standard" procedures typical of the trade, researchers began seeing significant fingerling mortality at densities greater than 10 g/L (Figure 2). Associated with increased mortality was a rapid reduction in transport water pH (to 6.8 at 10 g/L and to 6.6 at 50 g/L) and an increase in total ammonia nitrogen (to 2 mg/L at low density and 9 mg/L at high density).

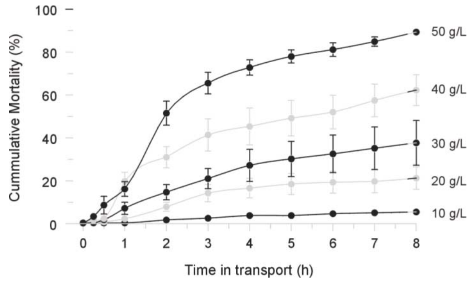

Figure 2. *Time-course of transport survival and changes in water quality (pH and ammonia) during simulated transport of moi fingerlings at transport densities ranging from 10 to 50 g/L.*

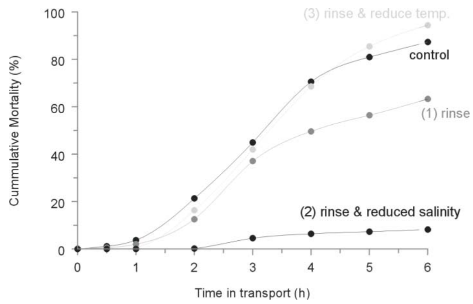

Figure 3. *Improvements in fingerling survival during high density (60 g/L) transport achieved by (1) adding a rinse step to remove mucous and scales prior to stocking in transport tanks and (2) rinsing and lowering salinity to 22 ppt during simulated 6-hour transport. Note that lowering transport temperature (3) reversed the beneficial effects of rinsing procedures and repeatedly was shown to reduce transport survival at high density levels.*

Methods for IncreasingTransport Density. In an effort to improve transport survival rates or increase maximum safe transport density, our next series of trials tested factors with potential for improving overall transport success. Tested parameters included (1) addition of a rinse step after handling but before stocking fingerlings, (2) light anesthesia using 20 ppm MS222 to sedate fish prior to handling, (3) reduction of water temperature 6–8ºC to slow metabolism, (4) lreduction of salinity to 25 ppt to reduce osmotic gradients across gills, (5) use of the ammonia chelator (Chloram-X®) to remove toxic ammonia; and (6) use of buffer (10 mM Trizma) to reduce pH shifts. Trials were conducted essentially as described earlier, with all transport tanks stocked at a single, relatively high test density and run for 6 hours. Density tolerance seemed to vary significantly between trials and/or batches of fingerlings, requiring the need to repeat some tests using fingerling densities higher than those densities used in our initial trials.

Overall, a combination of (1) using a rinse step after initial fingerling handling to prevent transfer of poor quality water to the transit system and (2) lowering transport water salinity to reduce osmotic gradients proved to be highly effective at improving transport performance (Figure 3).

Although sedating fingerlings with MS222 prior to handling and using a buffer to reduce pH shifts had beneficial effects for the first few hours, these effects disappeared for periods over 4 hours. Chemical ammonia chelation appeared to have no effect. Unlike with other fish species under culture, lowering water temperature during transport of moi fingerlings not only proved ineffective but also significantly increased mortality rates during transport, and, therefore, it should be strictly avoided (Figures 3 and 4).

Optimal Fish Size for Transport. The movement of fingerlings from hatchery to offshore cages is generally timed to facilitate the use of the smallest possible fingerlings that are large enough (> 2 g) to be retained by cage netting materials. However, rapid growth rates, along with between-run and in-run size variation, lead to significant variation in actual fingerling size at the time of transport. Further, external factors such as weather and staff availability may also affect transport timing. Therefore, we conducted a series of trials to determine the effects of fingerling size on transport durability.

Siblings from a single moi hatchery production run were tested for transport survival at densities of 40 and 80 g/L under optimized transport conditions (i.e., fish rinsed and transported at reduced salinity). Transport trials were conducted with fish at mean weights of 5, 10, 15, and 25 g, with no fish being reused in successive trials. In addition, we recorded fingerling survival post-transport to account for transport-related mortalities occurring over a 24-hour period after trials were completed. Trial results verified size/age-related changes in susceptibility to transport stressors, as fish demonstrated increased tolerance for high-density transport with increasing size (Figure 5). Large fingerlings exhibited greater survival than their small cohorts over the 6-hour transport procedure, with lower oxygen requirements, less scale loss, and less post-transport mortality. Also noted were declines,

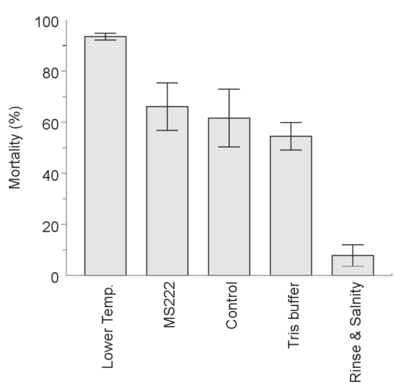

Figure 4. *Effects of lowering transport temperature, MS222 sedation, Tris buffer, rinse, and reduced salinity on fingerling mortality rates during 6-hour simulated transport at a 60 g/L density.*

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with fingerling size, in the benefits from the procedures of pre-transport rinsing and lowering the salinity of transport water. However, these age-related benefits of improved tolerance to high-density transport stressors are countered by the increased biomass needed to transport an equivalent number of animals. At the extremely high transport density of 80 g/L, peak survival rates were seen with large fish, but at lower densities (still extremely high) small, 5 and 10 g, fingerling sizes appeared preferable.

Discussion and Summary

The goal of this project was to develop a practical test system for a study of fingerling transport, identifying current limits to safe transport for the Pacific threadfin (moi) and the critical factors affecting fingerling transport survival. Our density research shows that under standard (starting) transport conditions, Pacific threadfin exhibit good survival up to densities around 10 g/L. Special attention should be given to maintaining adequate oxygen levels during stocking to counter stress-related increases in respiratory rates. At densities higher than 10 g/L, survival was effectively increased by exchanging transport water after handling fish to remove released scales and mucous and by lowering transport water salinity to 25 ppt.

A variety of treatments, including lowering water temperature, adding an ammonia chelator, buffering transport water, and tranquilizing fish with MS222 during handling, were shown to be relatively ineffective. In fact, efforts to lower temperature during fish transport, a standard method used with many other species, led to survival rates for the moi that were dramatically lower than in trials where temperatures were not lowered. Moi fingerlings also demonstrated a significant size-dependent sensitivity to transport stressors, with large fingerlings exhibiting much higher survival rates than the small sizes at which fingerlings are currently shipped to offshore cages. However, these benefits must be balanced by the need to move an increased fish biomass, which counteracts many of the benefits associated with improved survival rates. It remains unclear which factor(s) limit(s) increasing densities during fingerling transport, an important area for future research.

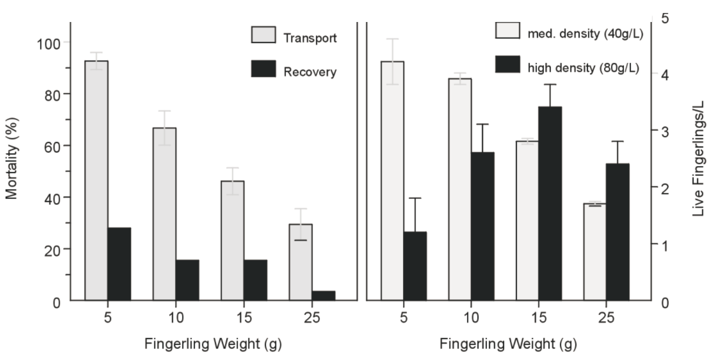

Figure 5. Effect of fish age/size on transport performance after 6 hours of simulated transport. As they age and increase in size, fingerlings clearly exhibit an improved ability to tolerate transport stressors with increases in survival during transport and in recovery from transport (left graph). However, the benefits of transporting large fingerlings are countered by increased biomass when the same data is presented on a basis of g/L (right graph).

This research should assist commercial hatchery operations in their efforts to move fingerlings from hatchery to offshore growout sites or to other islands. This period is a critical one, where mortalities can be very costly but where erring on the side of caution can cause major inefficiencies. This work, therefore, will allow industry to increase fingerling density and efficiency with greater confidence by lowering salinities and flushing tanks before moving fish.

Acknowledgements

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