Exercising Juvenile Marine Finfish to Enhance Growth and Lower Stress

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SUMMARY

It sounds crazy, exercising fish to make them gain weight. But that is exactly what happens with juvenile California yellowtail, a once common species off California and Mexico fished heavily by the Japanese. Not surprisingly, given parallels with human health, exercise also alleviates stress in fish, as measured by bloodstream levels of cortisol, the same stress hormone in humans. The findings have led a California Department of Fish and Game biologist to consider rearing juvenile endangered salmon in raceways, in the hopes of boosting their post-release survival.

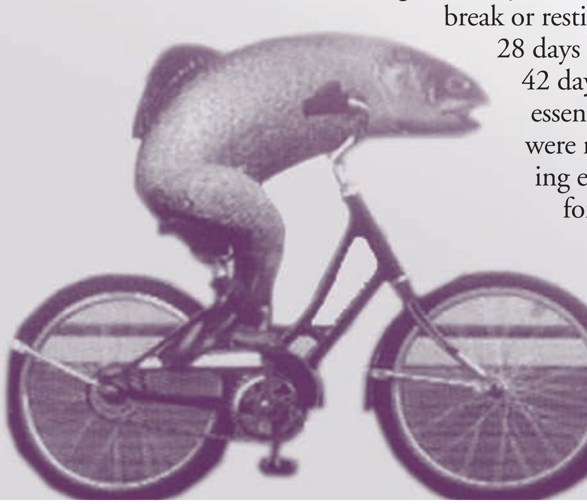
PROJECT

Scientists examined effects of continuous moderate exercise on growth, plasma cortisol and insulin-like growth factor (IGF-1, a marker of growth) on three species of juvenile finfish: California yellowtail (*Seriola lalandi*), white seabass (*Atractoscion nobilis*) and California sheephead (*Semicossyphus pulcher*). Each has a distinctive life history and swimming style. Markers of conditioning, including ventricle mass, ratio of red and white muscle fibers, and citrate synthase in red muscle, were measured. Of the three species, yellowtail responded most positively to exercise, in terms of growth, ventricle mass and lowered stress.

METHOD

To enable concurrent experiments on multiple fish, scientists built a tank with four fiberglass raceways (each with dimensions of 5.5 meters by 50.8 centimeters by 30.5 centimeters) through which water was pumped to create a sort of endless lap lane.

They then calculated each species' maximum aerobic capacity, using Ucrit, a widely recognized measure of aerobic fitness for human athletes. Once Ucrit was determined, fish were exercised at three speeds, corresponding to 20 percent, 40 percent and 60 percent of Ucrit. Fish then swam at the target velocity continuously (no break or resting) for between 28 days (sheephead) and 42 days (seabass). In essence, young fish were reared in a moving environment that forced them to exercise continuously even while feeding. This continuously moving environment is quite different from what juvenile sheephead and seabass, but not yellowtail, would experience in the wild.



Subsamples of fish were removed before and after transfer to the experimental tank and at intervals throughout the experiment to measure body mass and length. Blood samples were drawn to monitor cortisol and IGF-1. Fish were frozen at -80°C for later measurement of muscle enzyme activity and RNA extraction. At the experiment's end, muscle samples were fixed in formalin for histology and fiber diameter measurements.

Two trials with fish from different spawns were conducted for yellowtail (a high-speed, vigorous swimmer) and white seabass (a generalist). Only one was conducted for sheephead, a labriform swimmer that typically swims in and out of kelp forest cover, because in the project's second year, the Hubbs-SeaWorld Research Institute stopped rearing the species due to its slow growth. Labriform swimming is a mode of location in which fish row their pectoral fins to go forward.

RESULTS

All three species "got fit" when reared in raceways and demonstrated improved aerobic conditioning when subjected to faster currents. Each species, however, had its own biochemical and morphological means of meeting the aerobic demands of continuous exertion.

Yellowtail

Moderate exercise, corresponding to 40 percent and 60 percent Ucrit, increased yellowtail body mass to the extent that after 34 days of conditioning, juveniles weighed about 15 percent more than control fish. The fit juveniles also had higher Ucrit values and a greater proportion of red muscle in the caudal peduncle, reflecting an increase in slow-twitch endurance capacity, a sign of improved aerobic fitness. Strikingly, the ventricle mass of conditioned fish was about 50 percent greater than controls. Exercise did not dramatically affect citrate synthase in red muscle, however, possibly because the species' baseline mitochondrial content is already so high. In summary, yellowtail met the demands of exercise through improved cardiac function and oxygen delivery to muscles.

White Seabass

In the experiments under discussion, continuous exercise did not lead to weight gain in juvenile white seabass. An enhanced growth response was, however, observed in similar, previous experiments conducted in 2000. The cause of the discrepancy is unknown; but, it could be related to the different ages of the fish used in the 2000 vs. 2007 experiments. The juveniles in the 2007 trials were selected to be about the same length and weight as those in the earlier trials. These fish, however, turned out to be consistently older than the fish used in 2000. Differences in tank water

White seabass in flume.

temperatures or feed might explain their slower basal growth rates. More likely, though, it reflects higher stress levels in fish used in 2007. Tellingly, their cortisol levels did not spike after transfer to the raceways, presumably because their stress levels were already at a maximum. Their cortisol levels remained high and variable throughout the conditioning experiments.

Though seabass growth was not enhanced in the 2007 experiments, fish reared in higher velocity flows had higher Ucrit levels, more slow-twitch red muscle in the caudal peduncle and greater citrate synthase activity in muscle fiber than control fish. Notably, ventricle mass did not increase in any of the conditioned fish. Seabass seem to support exertion entirely though the conditioning of skeletal muscle.

Sheephead

California sheephead lost weight after transfer to the experimental raceway and their weight remained low for the first two weeks of conditioning. It was not until day 27 of the experiment that all groups of fish weighed more than controls, the heaviest being those reared in the strongest flows. As with the other two species, conditioned fish had higher Ucrit values but, notably, not higher levels of citrate synthase, likely because muscle enzyme activity was measured in the caudal peduncle, not in the pectoral muscles, which actually propel the fish during routine swimming.

ENDOCRINE RESPONSES

In yellowtail and sheephead, bloodstream levels of cortisol and IGF-1 were inversely correlated, and lower cortisol was associated with faster growth. This same pattern was observed with white seabass in 2000 but not 2007. It is believed the seabass used in the 2007 experiments were suffering from chronic stress of unknown cause. In parallel with human health, a chronically stressed organism may not be capable of responding positively to an otherwise health-enhancing activity.

CONCLUSION

The project demonstrates that rearing fish in a continuously moving environment enhances their aerobic capacity and improves aerobic performance. Growth can also be enhanced, and stress lowered, in fish that are not chronically stressed prior to exercising.

APPLICATION

Because of the high value of yellowtail flesh and concerns about the wild fishery's sustainability, collaborators on this project are investigating the possibility of culturing yellowtail regionally in open-ocean net pens. This project suggests that rearing juveniles for at least part of their life cycle in raceways might confer health and growth benefits outweighing any additional operating costs. Those involved with stock enhancement projects might also want to consider conditioning juveniles prior to their release to improve the animals' ability to forage and otherwise survive wild conditions. Paul Adelizi of the California Department of Fish and Game has expressed interested in rearing Central Valley Chinook salmon in raceways to improve health and survival of released fish.

CONFERENCE PROCEEDINGS

Peters, C.J.; M.S. Lowery; K.M. Kelley and M.A. Drawbridge. Effects of Continuous Exercise on Growth and Cortisol in Juvenile California Yellowtail (*Seriola lalandi*) and White Seabass (*Atractoscion nobilis*). 2007. World Aquaculture Society, San Antonio, Texas.

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This publication is sponsored by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA08OAR4170669, Project number C/P-1. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U.S. government is authorized to reproduce and distribute for governmental purposes. This document is available in PDF on the California Sea Grant website: www.csgc.ucsd.edu.

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