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THE "VIRTUAL-CAGE CULTURE": CONTROLLING AND HARVESTING FISH USING BEHAVIOURAL CONDITIONING

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ABSTRACT World-wide stock enhancement and marine ranching of invertebrates and fishes includes more than 100 species in over twenty countries. While stock enhancement represents the effort to improve annual recruitment of depleted stocks, ranching represents in addition, an effort to increase the annual yield of a species. Present sea ranching technology mainly involves raising juveniles in hatcheries and releasing them into the water to rely entirely on natural food. With fish stocking the control over the released fish is terminated. The released fish are captured with the same fishing technology applied to wild stock. A "Virtual-Cage Culture" technology for sea ranching and harvesting stocked fish is suggested. Juvenile fish are trained to associate acoustic signals with food. Trained fish are released to the sea or lake to grow on natural food and finally "called" back to a collection spot, trapped and harvested when they reach a market size. Control over the fish location and behaviour is maintained by periodic signalling the associated signals from anchored floating platforms or moving fishing boats and rewarding the fish which gather close to the sound source with a very little amount of food, thus maintaining their response. This technology could possibly increase the capture rate and the overall profitability of sea ranching. It offers new possibilities for aquaculture, using the open sea for high quality food production. The technology may be beneficial for the environment, fisherman and consumers. There are many issues to be dealt with for this technology to become economically and ecologically viable. Of these issues, the behaviour of the species of interest and the fish capture technology are of major importance. Using tilapia (Sarotherodon galilaeus) as a model species, we have studied the ability of this fish to be trained to associate acoustic signals with food (and approach a feeder when called), to maintain this trained behaviour for long periods and their ability to identify a conditioned signal among other acoustic signals in their environment. Tilapia have readily learnt to approach a feeder when an acoustic signal was transmitted in the water. However, once training was terminated, their response to the signal decayed with time (Figure 1) and was completely lost after 6 months.

Keywords: Virtual-Cage Culture, capture rate, sea ranching, acoustic signals, capture technology

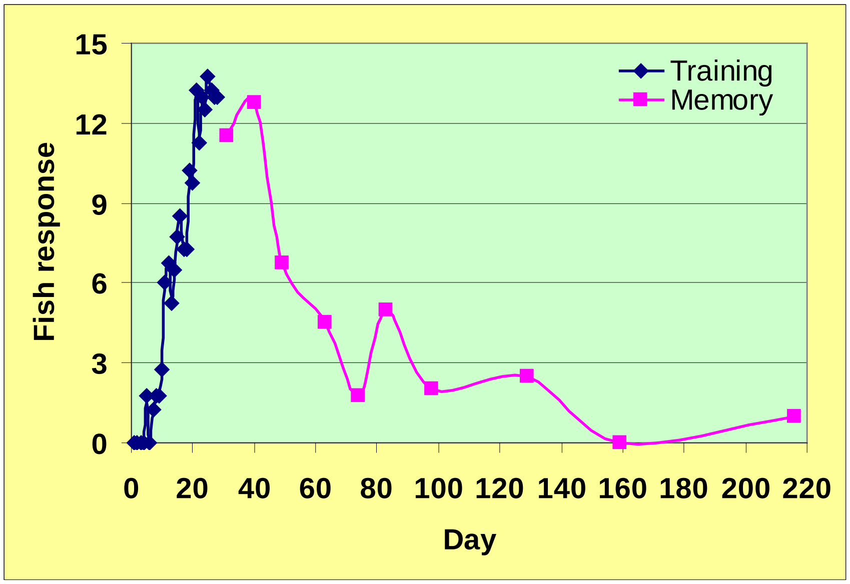

Figure 1. Acoustic memory of Tilapia fish. Fish were classically conditioned for 28 days until their response was fully established. They were then tested for their memory capability up to 188 days from the end of the training session.

For a sea ranching technology which relies mostly on natural feeding a longer period of acoustic memory is required. In a following study we found that by periodic transmission of the acoustic signal, the fish response to the signal could be maintained at a very high level for a long period, beyond their memory capability (Figure 2).

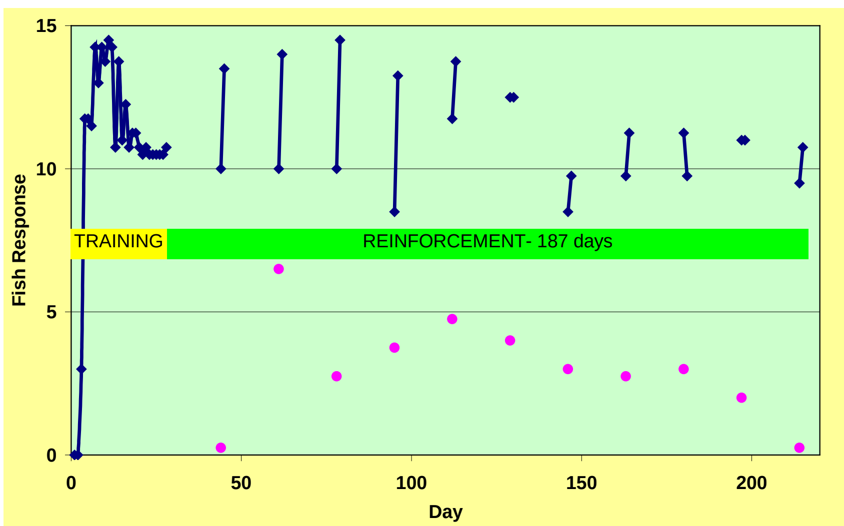

Figure 2. Memory reinforcement. The response of fish initially trained for 28 days and then re-trained for 2 days every 17 days.

It was further shown that fish can be trained to behaviorally discriminate between two different acoustic signals, responding to the food-associated signal and ignoring the food non-relevant signal (Figure 3).

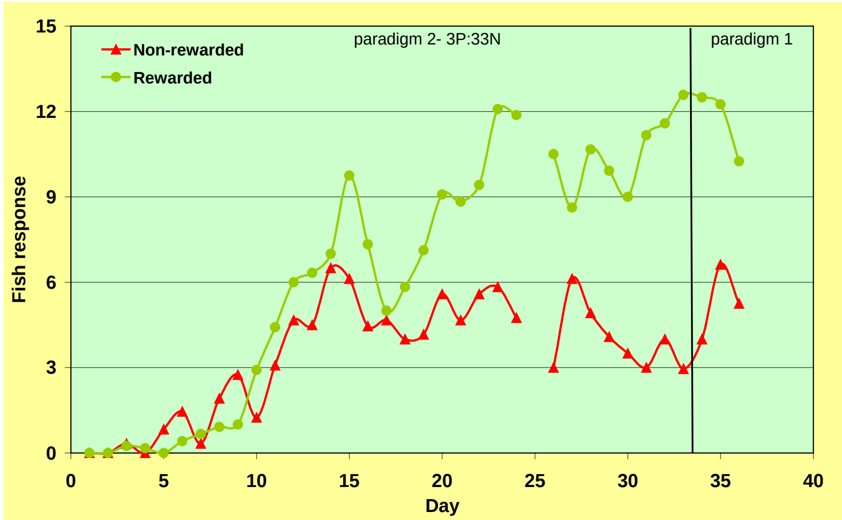

Figure 3. Behavioural discrimination. Common carps were trained to approach a feeder when a rewarding signal was transmitted and to avoid it when a non-rewarding signal was transmitted.

A large-scale experiment has been conducted in a fresh water reservoir into which acoustically trained tilapia (*Sarotherodon galilaeus*) were introduced. The fish were trained in our laboratory, transferred to the reservoir and kept in a net pen for 10 days during which training continued. The cage was a part of the floating fishing machine (Figure 4) designed to periodically and automatically retrain the fish according to a programmed schedule, to open the cage and let the fish free, call them back by transmitting the acoustic signal in the water and trap them by closing the cage while they feed on the pellets provided to them by the machine. The fishing machine is powered by solar panels and communicated with through cellular communication. Fish behaviour was monitored through underwater cameras and the functionality of the fishing machine was assessed by catching fish at various events.

Figure 4. The fishing machine used as a part of the "Virtual-Cage culture". It enables scheduled fish training and periodic re-training. It traps fish by 'calling' them to feed and automatically closing a net which hangs underneath it by lifting its fringes above water level.

In this presentation acoustic training and memory tests will be presented, as well as the results of the tests conducted in the reservoir. The prospects of the technology will be discussed.