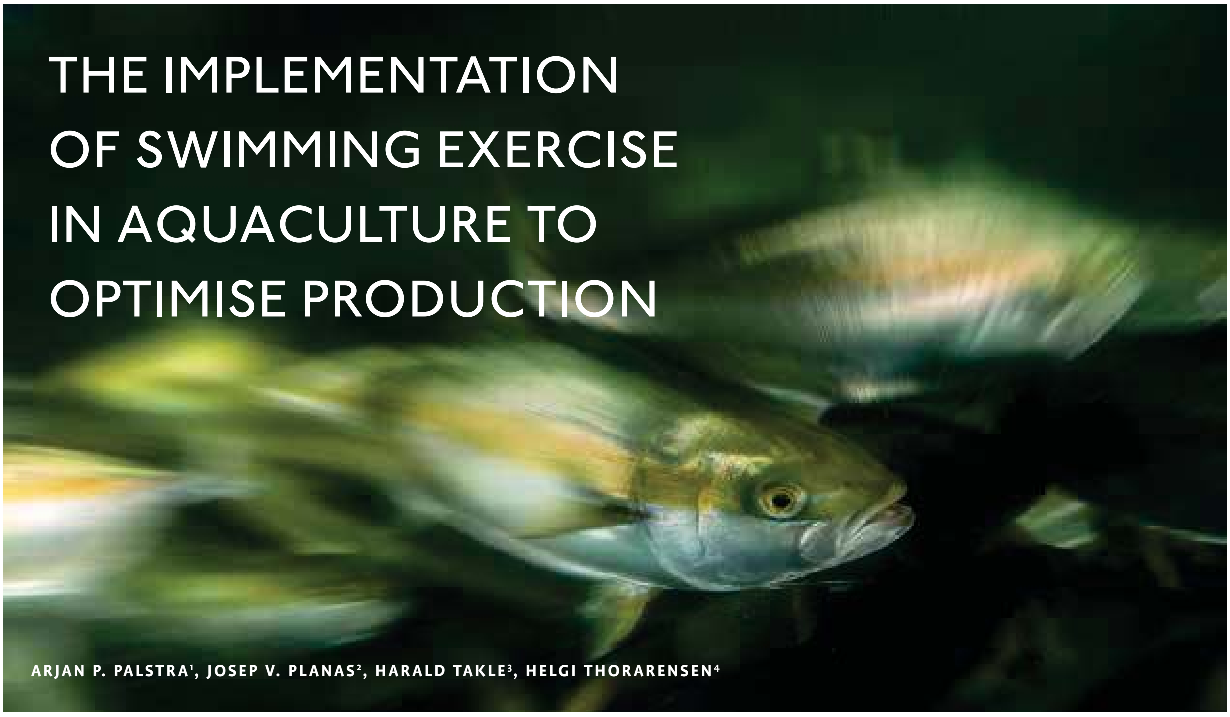
THE IMPLEMENTATION OF SWIMMING EXERCISE IN AQUACULTURE TO OPTIMISE PRODUCTION



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Swimming yellowtail kingfish. *(Photo by Y. van Es).*

Aquaculture plays an important role in securing our future by supplying the increasing demands for animal protein. Poor fish health and welfare are a challenge for the growth of aquaculture. Aquaculture should aim to produce fish that are physically fit and robust (i.e. having the ability to maintain homeostasis under changing conditions and the capacity to mount a strong disease resistance). For fish, swimming is an essential characteristic that is intimately linked to their ability to develop, survive, grow and reproduce successfully. Current farming conditions, however, often do not allow fish to fully display their normal swimming behaviour. Therefore, farmed fish cannot experience the physiological benefits that swimming gives their wild counterparts. Exercise represents a tool in aquaculture to improve growth, health, welfare and filet quality (Jobling et al., 1993; Davison, 1997; Palstra & Planas, 2011; 2013).

The level of exercise for aquaculture fish is optimal at swimming speeds where the fish reap the benefits of the exercise without wasting energy on aggressive behavior (at speeds which are too low) or using excessive energy for swimming (at speeds which are too high). This level of exercise depends on the species, life-stage and the physiological fitness of the fish; on environmental conditions (water quality, oxygen); on the system design (RAS or flow through, tanks or raceways) and on how exercise is induced which can be accomplished by creating a current or by using the optomotor response of the fish (Herbert, 2013). Optimal exercise may be beneficial not only for athletic fish but also for species that are less known for their swimming abilities in their natural habitat. Species-specific exercise protocols that vary in duration and intensity may, therefore, be developed. Effects of optimal exercise may include: 1) Improved feeding efficiency, growth rates and skeletal muscle mass; 2) Changes in muscle composition leading to higher flesh quality; 3) Increased survival by increased robustness or fitness; 4) Increased welfare by lowered stress; 5) Improved immune capacity, and 6) Control of reproduction. Furthermore, swimming exercise can be applied to select fish on the basis of their swimming performance e.g. to select out weak or abnormal fish.

At IMARES we have six swim-tunnels, 123 L each, to perform respirometry of individual fish or small groups of juveniles while swimming at speeds up to 1 m/s (Fig. 1). These tunnels were originally designed to study the migration performance of eels (van den Thillart et al., 2004). Now we mostly use them for determining the optimal swimming speed, where the cost of transport (energy spent on swimming over a certain distance) is lowest and the energetic efficiency is highest. Importantly, the optimal swimming speed reflects very well the swimming speed for optimal growth in a variety of salmonid species and *Seriola* sp (reviewed by Davison and Herbert, 2013). A recently built 3600 L oval flume, where currents that reach 1.2 m/s can be created by a propellor driven by an electric motor (Fig. 2), is used to swim groups of fish, either to select them on their swimming performance (good vs bad swimmers), to study effects of long-term swim-training or to simulate migration. A semi-industrial RAS set-up consisting of 6 systems with each 3 tanks has been modified to study the effects of increased flow on fish and system. Over the last four years, we had eight national and EU projects running together with the aquaculture industry to apply exercise in order to solve a range of biological bottlenecks for most major aquaculture spe-

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Pikeperch in the swim-tunnel during a swimming test. *(Photo by R. Blonk)*.

cies. We have applied exercise to stimulate uniform muscle growth in yellowtail kingfish (Palstra et al., 2015; Fig. 3), pikeperch (Fig. 4) and seabream; to relate exercise parameters with genetic selection in seabream and Atlantic salmon; to stimulate maturation in eel and trout; and to improve welfare of Claresse. Together with the University of Barcelona we have applied exercise to prevent precocious maturation in seabass. With the Universities of Barcelona and Leiden we study the underlying physiological mechanisms using our comparative exercise model zebrafish (Palstra et al., 2010, 2014).

The swim-flume at IMARES has been used for simulated migration of eels, long-term swim training of yellowtail kingfish, pikeperch, seabass and seabream, and selection trials with seabream and Atlantic salmon. *(Photo by Y. van Es)*.

Nofima has specialised in exercise systems for salmonids. Twenty-two fresh water rearing tanks were built for automatic and exact control of swimming speed in a wide range of water velocities and for direct measures of oxygen consumption and feed utilisation of salmon smolts. For the post-smolt stage of salmonids, up-graded industrial tanks for accurate swimming speed control are present at the Norwegian centre for recirculation in aquaculture. These tanks are also used to model the effects of exercise in closed containment system in combination with different water qualities. To study exercise in open net-pens, a system with large propellers was developed to create currents similar to those in the most exposed sea cages. In recent studies we have focussed on salmon cardiology and immunity using four large swimming flumes with respirometers which are combined with physiological measures of oxygen consumption capacities, heart rate and in-depth molecular studies of mechanisms underlying robustness and disease resistance (Castro et al., 2011, 2013, Ytteborg et al., 2013; Takle & Castro, 2013; Anttila & Jørgensen et al., 2014). The applied interest of the salmon aquaculture industry in utilising exercise to optimise production is high and Nofima is involved in a number of projects funded by farming, feeding and breeding companies as well as aquaculture research funds.

"FitFish" aims to promote research on the swimming physiology of fish and to increase fundamental knowledge on exercise mechanisms as well as applied knowledge that can be used for implementation of exercise for aquaculture purposes, e.g. swimming to optimise production. In 2010, Dr. Arjan Palstra and Dr. Josep Planas organised the first FitFish workshop in Barcelona and related symposia at the Int. Congress on the Biology of Fish (Barcelona 2010; Madison 2012; Edinburgh 2014). A special issue of the journal "Fish Physiology and Biochemistry" was edited as well as the book entitled "Swimming Physiology of Fish. Towards using exercise to farm fit fish in sustainable aquaculture" (Springer). Recently, a Frontiers special issue was edited on the "Physiological adaptations to swimming in fish". In April 2014, the COST Action FA1304 on the swimming of fish and implications for migration and aquaculture (www.fitfish.eu) was started. Already 23 countries are participating in this network action that has the objective to further develop the research network in which fish swimming in the wild and in aquaculture is studied for the first time under a multidisciplinary perspective. The Action will provide the basis for technological breakthroughs (e.g. more accurate monitoring of migrant fish; design of exercise-"friendly" fish farming facilities), for establishing swimming as an essential factor determining welfare and for demonstrating that swimming can benefit quality production. The Action will add value to independent, nationally funded research activities by providing the means to exchange information, promote industrial

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Seabream waiting in swim-tunnels at IMARES to be tested on their swimming performance. *(Photo by A. Palstra)*.

activities and influence policies at a European level. Activities in FITFISH also include the training and exchange of early stage researchers in the area.

At AE2015 in Rotterdam we will organise a session on swimming to optimise production as a part of the COST Action. This is a meeting of the Action's Working Group 3 "Exercise in Aquaculture" lead by Dr. Harald Takle and Dr. Helgi Thorarensen. The aim of this WG is to gather scientific information on swimming of aquaculture fish, to identify potential gaps in our knowledge for targeting future research efforts and to design optimal swimming protocols for specific species and conditions. Also appropriate for your potential interest, Working Group 1 lead by Dr. Paolo Domenici and Dr. Gudrun De Boeck studies the functional mechanisms behind the beneficial effects of swimming. A meeting is organised by Dr. David McKenzie during the Aquaculture conference in Montpellier.

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