578. The possibilities of using electronic sensors in aquaculture breeding

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Abstract

The use of electronic sensors can greatly enhance our understanding of fish behaviour and physiology, and sensor data are emerging as key sources of information for improving aquaculture management practices. An integrated and interdisciplinary approach to monitor the activity pattern and physiological status of farmed fish, as well as environmental parameters, will enhance the sustainability and profitability of European aquaculture. For tailor made breeding programs, sensor technology offers the possibility to monitor traits in individual fish or families related to key factors that influence animal health and behaviour, such as hypoxia or sub-optimal water current. The better performing fish under these challenging environmental conditions can be selected for breeding.

Electronic sensors in aquaculture

Studying fish behaviour, physiology, health and welfare in aquaculture settings, as well as the farming environment, presents challenges because of the physical characteristics of water and the dimensions of the water bodies where the fish are cultured in. However, in recent years, the use of electronic sensors in aquaculture research is increasing, and is significantly improving our understanding of fish performance in aquaculture, as sensor data emerge as important sources of information for improving aquaculture management practices.

Collecting information of individual fish in aquaculture was difficult before sensor technology became available and often included catching, sedating and handling of the fish. Fish in aquaculture systems are grown in large water bodies in a high density, where the fish can't be distinguished individually for observation by the human eye or camera systems. Group observations during resting and feeding, monitoring fish growth and mortality, and monitoring the water quality, were, and often still are, management strategies to safeguard the fish in aquaculture systems.

Although sensors are widely used in terrestrial applications (Ellen *et al.*, 2019), their use in the marine environment and aquaculture was limited up to recent years because of the special attributes of water, the high cost of underwater sensors and malfunctions due to the harsh environment. Underwater sensors should be cost- and power-efficient, but also be robust and waterproof, non-metallic, and should have no effects on surrounding organisms (Parra *et al.*, 2018).

The various types of sensor technology that are nowadays available can be used to study the farming environment and to assess biomass and fish performance. Hence, depending on the purpose of the sensor and its physical appearance, sensors can be operated either inside the fish, attached to the fish, or placed in the water.

Biomass, environment, and fish tracking

Biomass estimators that can be installed on the feeding stations or on the cages or tanks, can provide information to monitor or expand the production. In addition, sensor- and camera systems may provide information for estimating the biomass in the cages and developing reliable fish feeding strategies.

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Sensors that monitor the environment in aquaculture settings record parameters such as oxygen, temperature, salinity, sea current, pH, wind and CO_2. Whereas in open sea cages this information can be used for management practices, such as feeding strategy, in Recirculation Aquaculture Systems this information can give full adaptive control over water quality parameters.

When monitoring individual fish, electronic sensor tags can track and identify individual fish (Lembo *et al.,* 2002). This provides information on the swimming behaviour of the fish in the aquaculture setting. Depending on the type of sensor, these tags have to be recovered from the fish to obtain the data, or the sensor sends the data to an external receiver. Placed in or on fish, more advanced tags incorporate sensors that measure and record multiple environmental and/or biological parameters of the fish during production (Cooke *et al.,* 2016).

A combination of sensor technologies can form a wireless communication system to monitor large scale aquaculture activities, and increases the accuracy of data, processing and interpretation (Kessel *et al.,* 2014). These data provide the industry with information needed to facilitate performance, health and welfare and to optimise management practices.

Fish breeding

For breeding purposes, the availability of sensor technologies allows to track and monitor individual fish. A large amount of data can be obtained from individual fish for specific traits related to environmental factors that influence animal health and behaviour, such as hypoxia or water current, and this information can be linked to the genotype of the individual fish. Better performing fish on desired traits can then be selected for tailor made breeding programs.

Sensor types and possibilities

Accelerometer tags can transmit a 3D acceleration of the tagged fish when they are within the receiver array, or logged on the sensor. The fish acceleration is the result of measuring acceleration on three axes. Accelerometer tags can be used as measure of animal activity, such as swimming speed via tail beat acceleration, detecting mortality, feeding, spawning activity, nocturnal/diurnal activity, and activity responses to changing oxygen, salinity and temperature (https://www.vemco.com/products/v9ap-v13ap-accelerometer/; https://www.thelmabiotel.com/).

Other sensor types measure heart rate, activity and body temperature simultaneously. These are ideal for monitoring behaviour and stress response, animal welfare and fish physiology (https://www.cefastechnology.co.uk/products/data-storage-tags/g7/).

Sensors that can record physiological data from free-swimming fish can be placed either externally or internally on the fish. The sensors measure muscle activity using probes inserted into the musculature of the fish and can provide an estimate of the energetic costs associated with physical activity via electromyograms (EMGs). These are records of bioelectric potentials that are strongly correlated with the strength and duration of muscle contractions, and as indicators of the intensity of fish activity (http://www.lotek.com/cemg2-series-emg-transmitters.htm).

Limitations

Sensor technology that is used to obtain information on individual fish poses constraints in the form of time and money, and physical limitations. When the sensors are be placed on, and particularly in the fish, this requires surgery by qualified staff, and recovery time is needed. In addition, the sensors are expensive, with thousands or tens of thousands of euro's needed for the sensors alone. These two factors can form a limitation to the number of fish equipped with a sensor. In addition, the environmental conditions for the sensors are challenging, especially in salt water. In addition, getting data from the sensors requires either retrieving the sensor physically from the fish, or having the fish swim in reach of receivers, which can also be challenging in (salt) water.

Case study

In a case study performed by researchers from Wageningen Livestock Research, electronic sensors were implanted in yellowtail kingfish (*Seriola lalandi*), a powerful and pelagic fish that lives in warmer waters worldwide. The STAR ODDI logger DST milli-HRT (Figure 1; https://www.star-oddi.com/products/data-loggers?sensors=heart-rate) monitors heart rate, body temperature and acceleration in the fish simultaneously and is ideal for monitoring behaviour and stress response of the fish. The logger takes a burst measurement of ECG at a programmed time interval and calculates the mean heart rate for each recording.

The fish were exposed to a series of increasing water flow speeds ranging from 0.2 to 1.0 m/s in a swim tunnel (van den Thillart *et al.*, 2004; Palstra *et al.*, 2015), forcing the fish to swim against the current. Preliminary results for heart rate and external acceleration at increasing swim speeds are shown in Figure 2. The heart rate remains at a (high) basal level at lower swim speeds, only to increase towards the highest speeds of 0.8 and 1.0 m/s. The external acceleration shows a similar pattern and appears, in this fish, to be correlated to the swim speed. However, preliminary data from other fish equipped with a sensor show that individual variation in heart rate and external acceleration at different swim speeds proves that electronic sensors indeed are a powerful tool to acquire in-dept physiological and performance information on individual fish that can be used for aquaculture management practices.

Concluding remarks

The use of electronic sensors offers great opportunities to study specific traits for breeding programs in individual fish in aquaculture settings. Enhanced environmental and biological sensor data collected by a network of electronic sensors can provide accurate measurements and predictive modelling of environmental conditions and desired traits on fish health, welfare and physiology, that can be linked to the genotype of the fish (Cooke *et al.*, 2016).

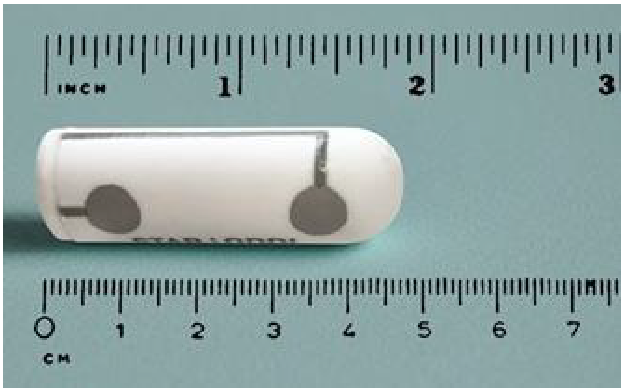

Figure 1. The STAR ODDI logger DST milli-HRT.

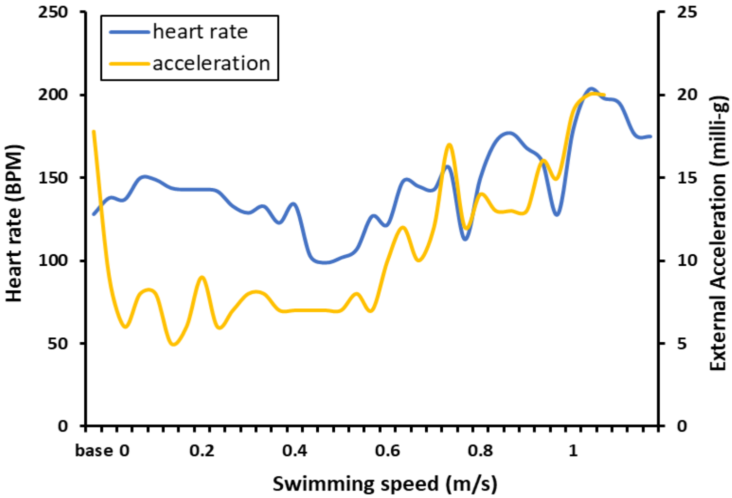

Figure 2. Heart rate and external acceleration of a yellowtail kingfish (*Seriola lalandi*) at increasing swimming speeds.

References

Cefas Technology. Available at: https://www.cefastechnology.co.uk/products/data-storage-tags/g7/

Cooke S.J., Brownscombe J.W., Raby G.D., Broell F., Hinch S.G. *et al.* (2016) Comp Biochem Physiol A 202: 23–37. http://doi.org/10.1016/j.cbpa.2016.03.022

Ellen E.D., van der Sluis M., Siegford J., Guzhva O., Toscano, M.J. *et al.* (2019) Animals 9(3), 108; https://doi.org/10.3390/ani9030108

Kessel S.T., Cooke S.J., Heupel M.R., Hussey N.E., Simpfendorfer C.A. *et al.* (2014). Rev Fish Biol Fisher 24: 199–218. https://doi.org/10.1007/s00227-018-3384-1

Lembo G., Spedicato M.T., Økland F. Carbonara P., Fleming, I.A. *et al.* (2002). Hydrobiol. 483 249-257. http://doi.org/10.1023/A:1021360419150

Lotek. Available at: http://www.lotek.com/cemg2-series-emg-transmitters.htm

Palstra A.P., Mes, D., Kusters K., Roques J.A.C., Flik G., *et al.* (2015) Front. Physiol. 5:506. https://doi.org/10.3389/fphys.2014.00506

Parra L., Lloret G., Lloret J. and Rodilla, M. (2018). IEEE Sens J 18(10), 3915-3923. http://doi.org/10.1109/JSEN.2018.2817158

STAR ODDI. Available at: https://www.star-oddi.com/products/data-loggers?sensors=heart-rate

Thelmabiotel. Available at: https://www.thelmabiotel.com/

Van den Thillart G., Van Ginneken V., Körner F., Heijmans R., Van Der Linden R., *et al.* (2004) J. Fish Biol. 65(2): 312-318. https://doi.org/10.1111/j.0022-1112.2004.00447.x

Vemco. Available at: https://www.vemco.com/products/v9ap-v13ap-accelerometer/