# 2nd International Workshop on the Swimming Physiology of Fish

**October 10th, 2014**

**Institut d'Estudis Catalans**

**Barcelona**



# Index

## BENVINGUDA / WELCOME

Benvolgut col·lega,

Us donem la benvinguda al **2nd FitFish Workshop on the Physiology of Swimming in Fish**. Aquesta jornada és la continuació del 1st FitFish Workshop que vam organitzar en aquest mateix lloc els dies 2 i 3 de juliol amb gran èxit. L'objectiu d'aquesta segona jornada és consolidar la tremenda quantitat d'experiències i coneixements sobre la fisiologia de la natació en peixos que s'han acumulat al llarg dels últims quatre anys i proporcionar als estudiants i investigadors en aquest camp, igual que altres científics, participants industrials i també polítics, amb una visió actualitzada d'aquest excitant camp de la recerca.

En aquesta segona jornada gaudirem de conferències d'investigadors punters en el camp que cobreixen tres aspectes principals relacionats amb la Fisiologia de la Natació en Peixos: 1) **Mecanismes funcionals implicats en les respostes adaptatives a la natació en peixos**, 2) **Migració de Peixos** i 3) **Nadant en Aqüicultura**. Donem les gràcies als conferenciants i als participants pel seu interès a participar en aquest esdeveniment.

El 2nd FitFish Workshop on the Physiology of Swimming in Fish està finançat en gran part per la **COST Action FA1304 "Swimming of fish and implications for migration and aquaculture (FITFISH)"**. Podeu trobar més informació a: http://www.cost.eu/domains_actions/fa/Actions/FA1304. Agraïm també el suport de la Societat Catalana de Biologia.

Estem segurs que aquest serà un esdeveniment científic interessant i estimulant.

Josep V. Planas
Organitzador Local

Dear Colleague,

We would like you to welcome you to the **2nd FitFish Workshop on the Physiology of Swimming in Fish**. This workshop is the continuation of the successful 1st FitFish Workshop that was held in this same venue in July 2-3, 2010. The purpose of this second workshop is to consolidate the tremendous amount of expertise and knowledge on the physiology of swimming in fish that has accummulated over the last four years and to be able to provide students and researchers in the field, as well as other scientists, industry participants and even policy makers, with an up-to-date vision of this exciting field of research.

In this second workshop we have invited talks by leading researchers in the field covering three major aspects related to the Swimming Physiology of Fish: 1) **Functional mechanisms involved in the adaptive responses to swimming in fish**; 2) **Fish migration** and 3) **Swimming in Aquaculture.** We thank the speakers, presenters and participants for their interest in participating in this event.

The 2nd FitFish Workshop on the Physiology of Swimming in Fish is supported by **COST Action FA1304 "Swimming of fish and implications for migration and aquaculture (FITFISH").** More info can be found at: http://www.cost.eu/domains_actions/fa/Actions/FA1304. We also thank the support of the Societat Catalana de Biologia.

We are confident that this will be an interesting and stimulating scientific event.

Josep V. Planas
Local Organizer

**COST - European Cooperation in Science and Technology** is an intergovernmental framework aimed at facilitating the collaboration and networking of scientists and researchers at European level. It was established in 1971 by 19 member countries and currently includes 35 member countries across Europe, and Israel as a cooperating state.

COST funds pan-European, bottom-up networks of scientists and researchers across all science and technology fields. These networks, called 'COST Actions', promote international coordination of nationally-funded research. By fostering the networking of researchers at an international level, COST enables break-through scientific developments leading to new concepts and products, thereby contributing to strengthening Europe's research and innovation capacities.

COST's mission focuses in particular on:

 Building capacity by connecting high quality scientific communities throughout Europe and worldwide;

 Providing networking opportunities for early career investigators;

 Increasing the impact of research on policy makers, regulatory bodies and national decision makers as well as the private sector.

Through its inclusiveness, COST supports the integration of research communities, leverages national research investments and addresses issues of global relevance.

Every year thousands of European scientists benefit from being involved in COST Actions, allowing the pooling of national research funding to achieve common goals.

As a precursor of advanced multidisciplinary research, COST anticipates and complements the activities of EU Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries. In particular, COST Actions are also open to participation by non-European scientists coming from neighbour countries (for example Albania, Algeria, Armenia, Azerbaijan, Belarus, Egypt, Georgia, Jordan, Lebanon, Libya, Moldova, Montenegro, Morocco, the Palestinian Authority, Russia, Syria, Tunisia and Ukraine) and from a number of international partner countries.

COST's budget for networking activities has traditionally been provided by successive EU RTD Framework Programmes. COST is currently executed by the European Science Foundation (ESF) through the COST Office on a mandate by the European Commission, and the framework is governed by a Committee of Senior Officials (CSO) representing all its 35 member countries.

More information about COST is available at www.cost.eu.

## VENUE

The **2nd FitFish Workshop on the Swimming Physiology of Fish** is being held at the historical building (XVII century) of the **Institut d'Estudis Catalans** (Institute for Catalan Studies) located in the center of Barcelona. Formerly a hospital for the convalescent, the building is an extraordinary example of catalan renaissance, arranged around a courtyard. The conference room (named **Sala Prat de la Riba**), located in the first floor of the building, is a beautiful state-of-the-art facility (including WiFi free of charge to participants) that can confortably accommodate up to 150 participants.

The coffee breaks, lunch and poster session will take place in the courtyard area, right outside the meeting room.

**Address:**

Sala Prat de la Riba
Institut d'Estudis Catalans
Carrer del Carme 47
08001 Barcelona
Spain

**FRIDAY, OCTOBER 10TH, 2014**

Room: Prat de la Riba

**8.00** **Registration IEC**

**8.30** **Welcome and Opening Remarks**

**8.45** ***A novel mechanism for enhanced oxygen delivery to the muscle and heart in fish during stress and exercise***

Colin Brauner (University of British Columbia, Canada )

**9.15** ***Hemodynamic changes in exercising fish***

Michael Axelsson (University of Gothenburg, Sweden)

**9.45** **Design and setup of an intermittent-flow respirometry system for aquatic organisms**

John Steffensen (University of Copenhaguen, Denmark)

**10.15** **Swimbladder function and the spawning migration of the European eel, Anguilla anguilla**

Bernd Pelster (University of Innsbruck, Austria)

**10.45** **Coffee-break**

**11.15** ***The current propagation system and physiological studies of imprinting and homing migration of Japanese chum salmon***

Hiroshi Ueda (Hokkaido University, Japan)

**11.45** **Insights into fish behaviour from large-scale electronic tagging programmes: Atlantic cod, European eels and Atlantic salmon**

David Righton (CEFAS, UK)

**12.15** **Track'n field...the challenge of following migrating fishes**

Kim Aarestrup (Technical University of Denmark, Denmark)

**12.45** ***Changes in abundance of anguillid leptocephali in the Sargasso Sea***

Reinhold Hanel (Thünen Institute of Fisheries Ecology, Germany)

**13.30** **Lunch (Provided in courtyard IEC)**

**15.00** **Wild versus cultured fish – could swim training reduce the physiological differences?**

Katja Anttila (University of Turku, Finland)

**15.30** **Swimming behaviour as an indicator of fish environmental adaptation**

Marie Laure Begout (IFREMER, France)

**16.00** **Applications for aerobic swimming in aquaculture: training and selection**

David McKenzie (University of Montpellier, France)

**16.30** **Coffee-break**

**17.00** **Bio-inspired hydrodynamic propulsion based on flapping**

Francisco Huera (Universitat Rovira i Virgili, Spain)

**17.30** **Robot fishes' escape from flatland**

Claudio Rossi (Universidad Politécnica de Madrid, Spain)

**18.00** **Beer, Wine & Posters**

**FRIDAY, OCTOBER 10TH, 2014**

18.00

**Location: First Floor**

## P1 - COST action FA1304: Swimming of fish and implications for migration and aquaculture (FITFISH)

Arjan P. Palstra[1], Josep V. Planas[2]

[1]Institute for Marine Resources and Ecosystem Studies (IMARES), Wageningen University and Research Centre, Korringaweg 5, 4401 NT Yerseke, The Netherlands

[2] Departament de Fisiologia i Immunologia, Facultat de Biologia, Universitat de Barcelona and Institut de Biomedicina de la Universitat de Barcelona (IBUB), Barcelona, Spain

## P2 - Simulated migration under mimicked photothermal conditions enhances sexual maturation of European eel (*Anguilla anguilla*)

Daan Mes[1], Ron P. Dirks[2], Arjan P. Palstra[1]

[1]Institute for Marine Resources and Ecosystem Studies (IMARES), Wageningen University and Research Centre, Korringaweg 5, 4401 NT Yerseke, The Netherlands

[2] NewCatch BV, J.H. Oortweg 19, 2333 CH Leiden, The Netherlands

## P3 - Muscle growth markers in response to sustained and moderate exercise in gilthead sea bream

Vélez E.J., Azizi Sh., Millán-Cubillo A.F., Moya, A., Lutfi E., Ibarz A., Navarro I., Fernández-Borràs J., Blasco J., Capilla E., Gutiérrez J.

Department de Fisiologia i Immunologia, Facultat de Biologia, Universitat de Barcelona.

## P4 - Application of swimming in juvenile male sea bass (*Dicentrarchus labrax*) to prevent precocious sexual maturation

Raúl Benito[1], Josep V. Planas[1] and Arjan P. Palstra[2]

[1]Departament de Fisiologia i Immunologia, Facultat de Biologia, Universitat de Barcelona, Barcelona (Spain).

[2]IMARES Wageningen UR, Korringaweg 5, 4401 NT Yerseke (The Netherlands).

## P5 - Evaluation of growth parameters and plasma metabolite levels in brown trout (*Salmo trutta*) subjected to sustained swimming under culture conditions

Hugo Soria and Josep V. Planas

Department of Physiology and Immunology, School of Biology, University of Barcelona, Av. Diagonal 643, 08028 Barcelona (Spain)

## P6 - Insights into the cellular and molecular mechanisms potentiating growth in response to exercise-swimming conditions in the skeletal muscle of zebrafish (*Danio rerio*)

Mireia Rovira[1], Arjan P.Palstra[2] , Josep V.Planas[1]

[1]Departament de Fisiologia i Immunologia, Facultat de Biologia, Universitat de Barcelona and Institut de Biomedicina de la Universitat de Barcelona (IBUB), Barcelona, Spain, [2]The Institute for Marine Resources and Ecosystem Studies, Yerseke, Netherlands

## P7 - Transcriptome profiling of the adult zebrafish heart under exercise

Mireia Rovira[1], Arjan P.Palstra[2] , Josep V.Planas[1]

[1]Departament de Fisiologia i Immunologia, Facultat de Biologia, Universitat de Barcelona and Institut de Biomedicina de la Universitat de Barcelona (IBUB), Barcelona, Spain, [2]The Institute for Marine Resources and Ecosystem Studies, Yerseke, Netherlands

## P8 -Patterns in diel habitat use of fish covering the littoral and pelagic zones in a reservoir

Milan Říha[1,2], Daniel Ricard[1], Mojmír Vašek[1], Marie Prchalová[1], Tomáš Mrkvička[1,3], Tomáš Jůza[1], Martin Čech[1], Vladislav Draštík[1], Milan Muška[1], Michal Kratochvíl[1], Jiří Peterka[1], Michal Tušer[1], Jaromír Seďa[1], Petr Blabolil[1,2], Martin Bláha[4], Josef Wanzenböck[5], Jan Kubečka[1]

[1]Biology Centre AS CR v.v.i., Institute of Hydrobiology, České Budějovice, Czech Republic, [2]University of South Bohemia, Faculty of Science, České Budějovice, Czech Republic, [3]University of South Bohemia, Faculty of Economy, České Budějovice, Czech Republic, [4]University of South Bohemia, Faculty of Fisheries & Protection of Waters, České Budějovice, Czech Republic, [5]University of Innsbruck, Research Institute for Limnology, Mondsee, Austria

## TECHNICAL SECRETARIAT

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**IMPORTANT**
Is prohibited the introduction food or drinks into the rooms

# ABSTRACTS:
# ORAL COMUNICATIONS

**O.1**

## A novel mechanism for enhanced oxygen delivery to the muscle and heart in fish during stress and exercise

Colin J. Brauner

Department of Zoology, University of British Columbia, 6270 University Boulevard, Vancouver, B.C., Canada.

The Root effect is a pH-dependent reduction in haemoglobin-$O_2$ carrying capacity. Unique to ray-finned fishes, the Root effect has been ascribed specialised roles in retinal oxygenation and swimbladder inflation; however, our recent work indicates it may be associated with greatly enhanced $O_2$ delivery to other tissues, specifically red muscle (RM) and the heart. During a generalized acidosis or stress, catecholamines are released into the blood, activating red blood cell (RBC) $Na^+/H^+$ exchange (NHE), thus protecting RBC pH and subsequent $O_2$ binding at the gill. However, plasma-accessible carbonic anhydrase (CA) at the tissues (and absence at the gills) may result in selective short-circuiting of RBC NHE pH regulation within the circulation. When rainbow trout are exposed to elevated water $CO_2$, (1.5%) red muscle $PO_2$ increases by 65%, which we estimate could double $O_2$ delivery with no change in perfusion. Inhibiting plasma accessible CA abolished this effect illustrating its importance to this process. The atrium of the heart also possesses plasma accessible CA which could greatly enhanced $O_2$ delivery to this metabolically active tissue during stress. Based upon measured and predicted changes in blood pH, we estimated that tissue $O_2$ delivery in the presence of plasma accessible CA may be more than doubled during exercise and tripled during some levels of hypoxia with no change in blood flow. Unparalleled among vertebrates, this remarkable enhancement in $O_2$ delivery may be central to the athletic performance of salmonids specifically, but may also represent the incipient function of the Root effect in fish, a trait strongly associated with the adaptive radiation of teleosts.

**NOTES**

## O.2

## Hemodynamic changes in exercising fish

Michael Axelsson

*Department of Biological and Environmental Sciences, University of Gothenburg, Sweden*

The hemodynamic changes during exercise in fish are complex and are affected by both biotic and abiotic factors. Looking at the whole animal level, the Fick equation is a starting point for the discussion of the necessary adjustments that need to be made during exercise. Cardiac output, affected by both heart rate and stroke volume, and the arterio-venous oxygen content levels are both factors in this equation describing the metabolism of the animal. It is clear that in order to support the increase in oxygen demand during increased activity, adjustments of both cardiac output, oxygen pulse needs to meet the increased demand or the animal will have to rely on an anaerobic component that will have to be paid back when the activity level drops below the anaerobic threshold. The adjustments of overall blood flow also include reallocation of blood within the animal to optimize the delivery of oxygen to the working muscle groups. The concept (i.e. aerobic scope), defines the possibility of an individual to increase its metabolism in order to be able to meet various challenges. A broad range of factors such as acutely changed environmental temperatures, oxygen availability, feeding status and health status affects the scope. Most fish species are fully ectothermic animals and are thus affected by the environmental temperature that sets the overall metabolism and may affect the scope; however, it has also been shown that acclimation can restore the scope under elevated environmental temperatures. Another important factor setting the scope for activity is feeding status. In unfed animals the gastrointestinal canal receives a rather large proportion of the cardiac output that is reallocated to the active muscles during exercise, but after feeding there will be a conflict between the increased demand for oxygen for digestion and absorption and the exercising muscles. The postprandial increase in oxygen consumption, SDA (specific dynamic action) consumption taps into the overall scope for activity and can affect the exercise capacity. Large species differences exist in the response to exercise and it is hard to draw any general conclusions from individual studies because there is also a large phenotypic plasticity that is important and sometimes neglected.

**NOTES**

**O.3**

## Design and setup of an intermittent-flow respirometry system for aquatic organisms

Svendsen, M.B.S., Bushnell, P.G. and Steffensen, J. F.

University of Copenhaguen, Denmark
and Indiana University South Bend, USA

One hundred years after Ege and Krogh (1914) investigated the effect of temperature on gas exchange in goldfish, the basic technique of measuring metabolism in aquatic organisms still remains an important tool for estimating energy expenditure in a variety of circumstances. For instance standard metabolic rate (SMR), the minimum aerobic metabolic rate of a poikilothermic animal at a specific temperature (Beamish, 1964; Beamish and Mookherjii, 1964) is often a widely reported value in the literature of many fields (Ultsch and Duke, 1990; Ultsch et al., 1981). It is therefore important that it is measured in a reliable and repeatable fashion (Clark et al., 2013). This presentation will describe how to design an intermittent-flow respirometry system, but is not intended to take up issues related to fish physiology or the use of metabolic rate measurements in theoretical modelling constructs. Instead, we intend to focus on some of the underlying assumptions, possible technical pitfalls, and limitations that will impact the design and function of an aquatic stop flow respirometer.

**NOTES**

**O.4**

## Swimbladder function and the spawning migration of the European eel, *Anguilla anguilla*

Bernd Pelster

Institute for Zoology, University of Innsbruck, Austria

The spawning migration of the European eel is an extensive journey over 5000 to 7000 km from the European coast to the Sargasso Sea. Eels do not feed during this journey and the alimentary canal regresses. Therefore on-board fuels must be sufficient to support the journey of 3.5 to 6 month, as well as sexual maturation and the spawning activity. Swimming of eels appears to be quite energy efficient compared to other fish species, and elevated hydrostatic pressure has been shown to even reduce the costs of transport. Recent studies revealed, however, that during travelling eels perform extensive diurnal migrations and swim at a depth of about 100-300 m at night time, but go down to 600-1000 m at day time. Accordingly, without any compensation at a depth of 800 m swimbladder volume will be reduced to about 25% of the volume established with neutral buoyancy at 200 m. Consequently, these diurnal changes in depth must be taken into consideration for a calculation of the energy requirements of the spawning migration. Without compensation a compression of the swimbladder will result in a status of negative buoyancy, which makes swimming more costly. Trying to keep the status of neutral buoyancy during descent by gas secretion into the swimbladder in turn requires metabolic activity to enhance swimbladder perfusion and for acid production of the gas gland cells to stimulate gas secretion. During ascent gas is passively removed from the swimbladder in the resorbing section and in the blood transported to the gills, where it is lost into the water. Therefore the investment into gas secretion during descent is not recovered by gas removal from the swimbladder during ascent. Accordingly, the swimbladder appears to be a crucial organ for the spawning migration. It can be assumed that an impairment of swimbladder function for example due to an infection with the nematode *Anguillicoloides crassus* significantly threatens the success of the spawning migration.

**NOTES**

**O.5**

## The current propagation system and physiological studies of imprinting and homing migration of Japanese chum salmon

Hiroshi Ueda

Laboratory of Aquatic Bioresources and Ecosystems, Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Japan. hueda@fsc.hokudai.ac.jp

In northern Japan, chum salmon (*Oncorhynchus keta*) is mainly propagated via artificial insemination, the release of juveniles from their natal river to the ocean, and the recapture of homing adults along the coast and within the natal river. The biomass of Japanese chum salmon increased steadily from 1970 to 1996 because of the successful improvement of propagation systems and favorable oceanic environments. However, the recapture rate of homing adults has become unstable, likely due to the lack of methods for preventing fish disease in juveniles and the regime shift in the North Pacific ecosystem. Moreover, the aftermath of the 2011 Tohoku earthquake and tsunami caused a major decrease in the number of juveniles released in the Tohoku area. It is now widely accepted that some specific odor signature characterizing the natal stream is imprinted in the olfactory systems of juvenile salmon during downstream migration, and that adult salmon recall these factors to recognize the natal river during the homing migration. However, there are still many uncertainties regarding which hormones control imprinting migration and how olfactory systems discriminate among stream odors to identify the natal stream. Chum salmon imprinting and homing migration are closely related to downstream migration seaward and gonadal maturation in the natal stream, respectively. Although the onset of downstream migration, including smoltification, is under the complex regulation of several endocrine hormones, the brain-pituitary-thyroid (BPT) axis should have critical roles in imprinting during downstream migration. My research group is currently investigating the hormone profiles of thyrotropin-releasing hormone (TRH) in the brain, thyrotropin (TSH) in the pituitary gland, and thyroid hormones (thyroxine ($T_4$) and triiodothyronine ($T_3$)) in the thyroid gland of chum salmon during imprinting migration, in association with olfactory memory formation in the brain. The hormone profiles in the brain-pituitary-gonadal (BPG) axis were investigated in chum salmon during their homing migration from the Bering Sea to the spawning ground in the Chitose River, Hokkaido. We are now investigating gene expression levels of salmon gonadotropin-releasing hormone (sGnRH) in various brain regions, in association with olfactory memory recalling in the brain. The olfactory functions of chum salmon are studying using electrophysiological, behavioral, and molecular biological techniques. We found that dissolved free amino acid (DFAA) composition of the natal stream water likely determines the natal stream odor, and that the long-term stability of the DFAA composition of natal streams might be crucial for olfactory homing in chum salmon. We applied blood oxygenation level-dependent functional magnetic resonance imaging (fMRI) to investigate the odor information processing of natal stream odors in the brain of lacustrine sockeye salmon (*O. nerka*) and found that strong responses to the odors of the natal stream were mainly observed in the lateral area of dorsal telencephalon, which is homologous to the medial pallium (hippocampus) of terrestrial vertebrates. These newly elucidated physiological mechanisms of imprinting and homing migration in chum salmon are useful for developing new chum salmon propagation systems to enhance the survival rates of juveniles in coastal areas and stabilize the recapture rate of homing adults. New trials are being conducted to introduce a semi-closed recirculating aquaculture system to estimate the health condition and improve the olfactory imprinting capability of juvenile chum salmon. *Acknowledgements:* The present study was supported in part by Grant-in-Aid for Scientific Research from the Japan Society for the promotion of Science (JSPS) and Japan Science and Technology Agency (JST).

**NOTES**

**O.6**

## Insights into fish behaviour from large-scale electronic tagging programmes: Atlantic cod, European eels and Atlantic salmon

David Righton

Centre for Environment, Fisheries & Aquaculture Science (CEFAS), Lowestoft, UK

Tracking and observing free-living marine organisms is challenging, but there is much to be gained from knowing the 'what, how, when and why' of fish behaviour when they are in their natural environment. Telemetry, using electronic devices attached to, or implanted into, an animal offers the capability to record its movements and behaviour while simultaneously recording at least some of the environmental variables to which it is exposed. In this talk I shall review three recent large-scale field programmes that have increased our understanding of marine fish behaviour over seasonal and even multi-annual timescales. This new information can then be integrated with our understanding of fish physiology to improve our capacity to predict how individuals may respond to environmental challenges, both in captivity and in the wild.

**NOTES**

**O.7**

## Track'n field...the challenge of following migrating fishes

Kim Aarestrup

Technical University of Denmark, National Institute of Aquatic Resources, Vejlsoevej 39, DK-8600 Silkeborg, Denmark

Telemetry is the transmission of remotely obtained information. In animals it has particularly good merit in migration ecology studies, a fundamental aspect of life histories in fish. Additionally, telemetry combined with other methods has a particularly wide applicability in migration ecology. The wide applications and ability to address otherwise impossible challenges makes it one of the fastest growing method employed in fish science. Methods range from hand-operated systems that are used to identify the locations of a limited number of fish every few hours to automatic systems that monitor the position of many individuals in three dimensions in near real-time. In studies that extend over large areas, remote methods such as archival tags or pop-up satellite transmitters, and large networks of acoustic arrays are also used. On-board sensor technology is also rapidly expanding making remote measurement of a variation of environmental and physiological parameters possible. In my talk, I will go through the concepts and methods of telemetry and show examples from our recent research on brown trout showing how telemetry studies often reveal previously unknown behavioural characteristics as well as overturning dogmas within fisheries science.

**NOTES**

**O.8**

## Changes in abundance of anguillid leptocephali in the Sargasso Sea

Reinhold Hanel

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The European eel *Anguilla anguilla* has shown decreased recruitment in recent decades. Despite increasing efforts to establish species recovery measures, it is unclear if the decline was caused by reduced numbers of reproductive-stage silver eels reaching the spawning area, low early larval survival, or increased larval mortality during migration to recruitment areas. To determine if larval abundances in the spawning area significantly changed over the past three decades, two plankton trawl sampling surveys for anguillid leptocephali were conducted in 2011 and 2014 in the spawning area of the European eel that were designed to directly compare to collections made in the same way in 1983 and 1985. While the composition of the assemblage of anguilliform leptocephalus larvae was the same than in previous years, the relative abundances of larvae of the two freshwater eel species *Anguilla anguilla* and *Anguilla rostrata* were significantly lower in 2011 and 2014 compared to 1983 and 1985. The fact that there are presently fewer European and American eel larvae in the Sargasso Sea than during previous time periods indicates that lower continental recruitment already begins within the spawning area.

**NOTES**

**O.9**

## Wild versus cultured fish – could swim training reduce the physiological differences?

Katja Anttila

*University of Turku, Finland*
*katja.anttila@utu.fi*

Stocking of cultures fish to nature is common practice worldwide. However, the efficiency of the releases is low and the cultured fish has significantly lower survival rate as compared to the wild ones. One reason for this could be the significantly lower swimming capacity of cultured fish than wild ones. This is because swimming capacity is related to the ecological competence of fish including ability to complete long migrations, catch pray and escape from predators. From physiological point of view there are indeed significant differences between wild and cultured fish in swimming muscles and in aerobic capacity which are related the differences in swimming performance. However, by training the cultured fish with proper program some of these differences can be diminished. Training increases e.g. swimming capacity and the capacity for aerobic metabolism. Would training effect on the survival rate of the fish at nature needs still more focused studies but there are evidences suggesting so as e.g. migration pattern of cultured fish changes due to training.

**NOTES**

**O.10**

## Swimming behaviour as an indicator of fish environmental adaptation

Marie Laure Begout and Sandie Millot

Ifremer, BP 7, 17137 L'Houmeau, France
Marie.Laure.Begout@ifremer.fr, Sandie.Millot@ifremer.fr

In natural ecosystems, swimming behavior of fish is very important for feeding, migrating or for escaping a predator. It is also essential in a captive environment where it allows access to food, adaptation to water flow rate and good positioning in the group. It is already established that chronic stress (e.g. change of water temperature, hypoxic conditions, photoperiod), or repeated acute stress (e.g. handling) modifies swimming components such as for example velocity and rhythmic expression. Swimming activity or pattern can also be used as a relevant indicator of fish environmental adaptation. In this presentation we will illustrate how swimming behavior can be used to evaluate fish responses to environmental challenges at early live stages, the altered responses after contaminants exposures, and other features such as learning and cognitive abilities, sociability and other personality traits. Results will be discussed in the light of consequences from the individual to the population level and how swimming behavior could be used to determine an appropriate rearing management and fish welfare in culture conditions.

**NOTES**

**O.11**

## Applications for aerobic swimming in aquaculture: training and selection

David McKenzie

University of Montpellier, France

There is much interest in the potential for using sustained aerobic exercise to increase growth rates and improve the welfare of certain species in aquaculture. There is, however, some contrasting evidence for beneficial effects, the reasons for which will be considered. This followed by consideration of evidence that exercise performance may have another potentially valuable application in aquaculture, as a tool to select 'fitter' animals or families.

**NOTES**

**O.12**

## Bio-inspired hydrodynamic propulsion based on flapping

Francisco Huera

Department of Mechanical Engineering, Universitat Rovira i Virgili, Spain

The talk will be focused on the analysis of the hydrodynamic propulsion performance of several bio-inspired simplified robotic systems, based on flapping. By using these simplified models, we have been able to describe optimal ways of flapping depending on if thrust or efficiency is desired.

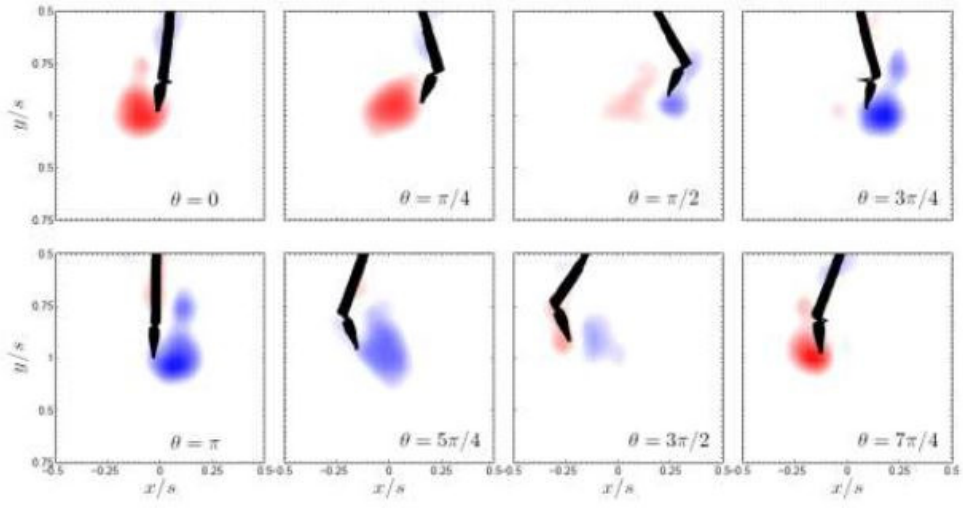
I will discuss by describing different sets of experiments, about the physics underlying propulsion based on flapping systems undergoing mainly pitch motions. Efficiency and thrust production for systems with different flexural stiffness and therefore different passive deformations will be described. Biologically speaking these systems are inspired in Thunniform or Ostraciiform swimmers in which most of the thrust is due to the caudal fin.

Another case I will be describing is related to the effect of flapping near a wall. The physics of ground effect have been very well described for fixed wing configurations; the need was imposed by the aeronautical and the motorsports industry. Rajiforms are known to swim near the ground, and their propulsive appendages are obviously not rigid. I will be showing what is the effect of a wall near a system based on undulatory propulsion.

Finally, the effect of active control of the trailing edge of a flapping system, on thrust production, will be analysed. Aquatic locomotion appendages in nature's in some species are passive, but in others are active and controllable by muscles and tendons. With this experiment we can produce a wide variety of control strategies in the appendage, in order to simulate different active or passive situations in nature's swimmers.

In all these cases, we have measured not only hydrodynamic loads, but also we have used advanced optical measurement techniques such as Particle Image Velocimetry (PIV), to study the fluid dynamics and the wakes of such systems. The figure below shows an example of the vorticity field generated by pitching flapping system in which the tip can be independently controlled.

All these topics should be of interest not only for the biology community for its implications in evolution or physiology, but also for the design of novel, more efficient and specialized propulsion systems for underwater vehicles.



**NOTES**

## O.13

# Robot fishes' escape from flatland

Claudio Rossi, William Coral

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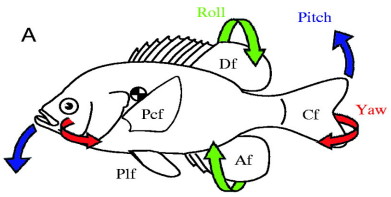
Underwater robot design based on the mechanism of fish locomotion is nowadays a relatively popular research field. Over the past few years, researches have been developing underwater robots based on underwater creatures swimming mechanism, mainly based on fish swimming, but also inspired on jellyfish, penguins and even bacteria. Terms as "carangiform", "thunniform" etc. are commonly found in bio-inspired underwater robotics.

Besides locomotion, fishes display an incredible maneuverability. Yet, most of the research on bio-inspired underwater robots focuses on locomotion. Few works address turning maneuvers in the horizontal plane, and vertical movement is given little or no consideration in the literature.



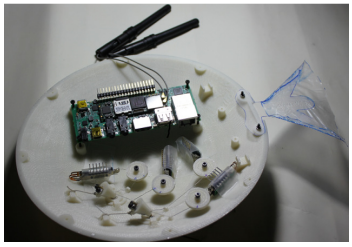

Thus, current robot fishes' movements are mainly constrained to the horizontal plane: they are living in flatland, and many of them even in a one-dimensional land.

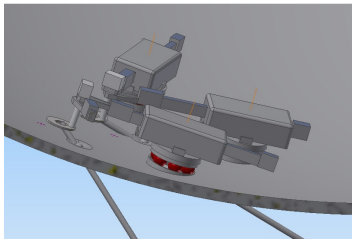
Starting form initial work also devoted to fish locomotion (our *iTuna* was in fact another inhabitant of robot fishes' flatland), we are currently addressing fin-based maneuvering in the three-dimensional space.

In order to leave the horizontal plane, we are looking at fishes' pectoral fins, which can be used to generate a vertical thrust whose displacement from the center of mass produces a torque, i.e. a rotation of the fish body w.r.t. the transversal axis (a change of the robot's *pitch* in aeronautical terms). We are also studying actuated flexible caudal fins in order to generate *roll* maneuvers (rotations along the longitudinal axis).

As an additional challenge, our purpose is to avoid classical mechanical actuation systems (servomotors, gearings, bearings etc.). Instead, we explore the use of alternative actuation technology based on *smart materials* in order to develop *motor-less and gear-less* robots.

We are aware that this a (perhaps over-) simplification of the complexity of the orchestrated fins motion that fishes adopt when they maneuver in the 3D space, but this reductionist approach is, at the moment, needed to approach such complexity.





*The first prototype of robot fish with SMA-actuated fin for pitch control (BSLab, 2012) and current design based on piezoelectric actuators.*

*SMA-actuated flexible tail fin for roll control (BSLab, 2014)*

**NOTES**

# ABSTRACTS:

# POSTERS

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## COST action FA1304: Swimming of fish and implications for migration and aquaculture (FITFISH)

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The study of swimming of fish is essential for our understanding of the interplay between migration, growth and reproduction in wild fish but also has considerable interest for fish in aquaculture. The main objective of the COST Action FITFISH is to develop a research network in which fish swimming in the wild and in aquaculture is studied for the first time under a multidisciplinary perspective. FITFISH will provide the ground 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. FITFISH will add value to independent, nationally funded research activities by providing the means to exchange information, promote industrial activities and influence policies at a European level in a new common forum. Activities in FITFISH also include the training and exchange of early stage researchers in the area. For more information: http://www.cost.eu/domains_actions/fa/Actions/FA1304.

P2

# Simulated migration under mimicked photothermal conditions enhances sexual maturation of European eel (*Anguilla anguilla*)

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Vitellogenesis and spermatogenesis in European eels (*Anguilla anguilla*) occur during and/or after the 6,000 km reproductive migration from their freshwater habitats to the spawning grounds in the Sargasso sea. This is the first study to simulate an anorexic, mixed-sex (119 females and 188 males), group-wise freshwater migration (2 weeks; 689 km) and subsequent seawater migration (9 weeks; 3,103 km) under mimicked photothermal conditions (as experienced during these migrations) using farmed silver eels. The aim of these two consecutive experiments was to determine the effects of these combined treatments on the progress of sexual maturation. The two-week freshwater migration significantly increased plasma testosterone levels in both migrating females (37.7 ± 7.2 *vs.* 15.1 ± 4.9 pg $ml^{-1}$) and males (38.9 ± 7.5 vs. 8.2 ± 2.1 pg $ml^{-1}$), but did not enhance sexual maturation further as no significant increases in gonad weight, gonadosomatic index (GSI) nor eye index (EI) were observed. The subsequent nine-week seawater migration significantly increased gonad weight and GSI (1.40 ± 0.06 *vs.* 1.00 ± 0.10 %) of migrant females as compared to control groups, indicating a stimulation of maturation. Eye index was significantly higher in migrant males (14.0 ± 0.6) as compared to their controls (12.3 ± 0.4). Plasma levels of the gonadotropins FSH and LH were not elevated in migrating eels. These results show that simulation of migration under mimicked photothermal conditions has significant effects on early maturation and can therefore be used to condition farmed eels for the use as broodstock eels for further hormonal stimulation of maturation protocols. In order to obtain insights about the progress of maturation during oceanic migration, a similar experiment should be repeated using migrating silver eels from the wild.

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P3

## Muscle growth markers in response to sustained and moderate exercise in gilthead sea bream

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Fish growth is strongly influenced by environmental and nutritional factors. It is commonly known that muscle growth is the result of the balance between protein synthesis and protein degradation. In this context, growth is mainly regulated through the Target Of Rapamycin (TOR) signaling pathway, which acts as a key molecule conveying the nutritional and endocrine inputs controlling protein turnover. Swimming activity primarily accelerates growth by increasing protein synthesis and energy efficiency. The aim of this work was to characterize the effects of five weeks of moderate sustained activity in gene and protein expression of myogenic regulatory factors, proliferation markers, proteolytic enzymes, as well as AKT and TOR signalling pathways activation in muscle of gilthead sea bream juveniles. Western blot results showed an increase in proliferation markers expression and TOR phosphorylation with exercise. Moreover, real-time PCR data showed that exercise increased the gene expression of proteases in the epaxial anterior region, whereas enhanced proliferation markers expression in the epaxial caudal area compared with control fish; thus, suggesting a different response of both muscle regions during swimming adaptation. In summary, the present study contributes to improve knowledge on gilthead sea bream myogenesis and demonstrate the beneficial effects of exercise in order to optimize muscle growth and quality in this important aquaculture species. Supported by MICINN (AGL2012-39768); XRAq; 2009SGR-00402.

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## Application of swimming in juvenile male sea bass (Dicentrarchus labrax) to prevent precocious sexual maturation

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The European sea bass (*Dicentrarchus labrax*) is a species of considerable economical interest for European aquaculture. However, current culture conditions that promote rapid growth result in an advancement of the time of puberty in sea bass males. Precocious sexual maturation is an economically important problem in the European sea bass. Efforts to control the onset of puberty in sea bass have concentrated on manipulating the photoperiod. Exposing male juvenile sea bass to a constant light regime for the first 12 months after hatching resulted in a decrease in the incidence of precocious male maturation. In other species, such as the European eel (*Anguilla anguilla*), swimming has been shown to delay ovarian development by suppressing vitellogenesis. Also in female rainbow trout, ovarian development is delayed when fish are subjected to sustained swimming during early vitellogenesis. However, nothing is known regarding the possible modulatory effects of swimming on reproduction in the European sea bass. In order to attempt to reduce the incidence of precocious maturation in sea bass males we subjected fish to swimming-induced exercise. We used a 3,600 l oval swim flume as RAS with 100 sea bass per chamber, one chamber for the swimmers (N=100; swimming at their optimal speed or $U_{opt}$) and another one for the resting controls (N=100; minimal flow of 0.10 m/s to assure good water quality). Water temperature was set at 25 ºC, salinity at 30.1‰, pH at 7.7 and light intensity at 40-50 lux at the water surface. Initial sea bass body weight was 3.91±0.22 g (mean ± s.e.m.). $U_{opt}$ was measured every 4 weeks by respirometry in 123 l swim-tunnels (3 times in total; courtesy of Dr. G. van den Thillart, Leiden University). Fish in the flume swam for a total of 10 weeks and were sampled every 2 weeks (5 samplings; N=15 fish per chamber) to record weight (g), standard length (cm), GSI (%), 11-ketotestosterone levels in plasma and histology of the testes. Weight, length and GSI increased over time in both groups. However, we did not find differences in size between swimmers and resters at any of the sampling points. Interestingly, at week 10, male sea bass from the swimmers group had a significantly ($p<0.05$) lower GSI than the control group. Histological analyses of testes samples from sea bass at week 10 showed a predominance of spermatogonia A in the swimmers, in contrast to the presence of well-formed cysts containing spermatogonia A and a higher number of spermatogonia B in the resters indicating advanced spermatogenesis. 11-KT plasma levels were however similar between resters and swimmers (0.87 ± 0.17 and 1.04 ± 0.48 ng/ml, respectively). This is the first study that evaluates the potential effect of swimming-induced exercise on testicular development aiming to reduce the incidence of precocious sexual maturation in male sea bass. When forcing other species of fish (e.g. European eel and rainbow trout) to swim for weeks, sexual maturation can be delayed because their energy reserves are invested in the extra effort required by swimming instead of initiating the sexual maturation process (Palstra et al., 2010ab). For males at week 10, the GSI of the swimmers was significantly lower ($P<0.05$) than the GSI of the resters. Therefore, swimming -induced exercise at $U_{opt}$ may be effective in delaying the onset of the puberty. This result was supported by the reduced presence of type-B spermatogonia in testes from swimmers, when compared to resters. 11-KT can be considered as a firm candidate for the regulation of the onset of puberty in teleost (Rodríguez et al., 2005). However, no differences in 11-KT plasma levels were observed between swimmers and resters. It is possible that determination of 11-KT levels in whole testis could better show putative differences in testicular 11-KT production between resters and swimmers. Our results so far indicate that early stages of gonad development can be identified by GSI or histological analysis rather than by 11-KT levels. For the first time in this species, we provide evidence that swimming may delay testicular development in juvenile sea bass. These results are highly indicative of the promise of swimming induction for the control of reproductive development in sea bass and, specifically, to address the issue of precocious male maturation in this species. We would like to acknowledge the support by an AQUAEXCEL grant.

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## Evaluation of growth parameters and plasma metabolite levels in brown trout (Salmo trutta) subjected to sustained swimming under culture conditions

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Exercise, in the form of intermittent or even continuous long-term swimming, otherwise known as training, is emerging as an important factor in the rearing of fish in captivity. Importantly, cultured salmonid species are expected to improve their growth and health status under swimming conditions because these species swim actively in their natural environments. Therefore, there is interest in examining the potential application of swimming in aquaculture for growth-potentiating purposes. The objectives of the present study were to (1) test the biometric changes in weight, length and growth rates in brown trout subjected to sustained swimming for 2, 4, 6 and 8 weeks and raised under farming conditions, (2) study the changes in plasma metabolites levels in brown trout subjected to sustained swimming (3) measure the mRNA expression levels of the myokine IL-6 in white skeletal muscle of brown trout subjected to sustained exercise. Our results indicate that although fish showed a significant increase in growth during the progression of the experiment, there were no significant differences in weight, length, standard growth rates ($SGR_L$ and $SGR_W$) or condition factor (K-Fulton) between swimmers and resters at any of the sampling times during the 8 week-long swimming experiment. Interestingly, plasma glucose levels were significantly lower in swimmers at week 4 and triglyceride plasma levels were also significantly lower in swimmers at weeks 6 and 8. Examination of IL-6 mRNA expression in white muscle indicated that IL-6 is indeed expressed in this tissue but no differences in IL-6 mRNA expression were detected between swimmers and resters at week 2. In the present study, swimming did not improve growth of brown trout under culture conditions. It is possible that water speed may not have been high enough or that the swimming experiment may not have been long enough to cause an increase in body mass by hyperplasia or hypertrophy in white and red skeletal muscle. However, in the absence of changes in somatic growth, glucose and triglyceride plasma levels significantly decreased in swimmers over the course of the experiment. We propose that the decrease in plasma glucose levels in week 4 may have been the result of the increase in glucose uptake by white and red skeletal muscle in swimmers caused by sustained exercise. These results would agree with studies suggesting that sustainable swimming activity at 1-2 $BL \cdot s^{-1}$ is supported by contributions of carbohydrate and lipid oxidation in rainbow trout, and also by studies that indicated that swimming activity decreases plasma glucose levels and increases glucose utilization in skeletal muscle in rainbow trout. In addition, the decrease in triglyceride plasma levels in swimmers suggests that fatty acids from plasma may have been taken up by the skeletal muscle to provide energy for swimming. At this point, we cannot support the hypothesis that the myokine IL-6 may play a mediatory role in the metabolic effects of swimming in brown trout white muscle. Overall, our results suggest that swimming activity causes metabolic changes in brown trout related to the use of glucose and triglycerides as major sources of energy for red and white skeletal muscle, as it has been demonstrated in many studies, although it does not show significant changes in growth. Further studies are necessary to find the conditions to optimize growth in brown trout subjected to sustained swimming.

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## Insights into the cellular and molecular mechanisms potentiating growth in response to exercise-swimming conditions in the skeletal muscle of zebrafish (*Danio rerio*)

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Under exercise conditions, skeletal muscle plays an important role in the regulation of metabolic homeostasis and in the prevention and amelioration of chronic pathologic conditions in humans (muscle dystrophy, cardiopathologies or metabolic alterations). In a previous study, we reported on the potential of adult zebrafish as a tractable experimental model for exercise physiology and established the optimal swimming speed for this species and showed that swimming potentiated somatic growth. In the present study, we aimed at investigating the cellular and molecular adaptative mechanisms on white skeletal muscle in adult zebrafish in response to swimming exercise. By performing gene expression profiling by microarray analysis we have identified over four thousand significantly differentially expressed genes in skeletal muscle that are involved in different processes such as muscle growth and development, muscle contraction, angiogenesis, metabolism and immune-related genes. Moreover, we examined the cellular properties of white muscle fibres and a significant increase in fibre size and vascularization was found in response to swimming exercise. These results show that exercise produces meaningful changes in the white muscle transcriptome and suggest that fibre hypertrophy may be responsible for the growth-promoting effects of exercise accompained by a switch to a more oxidative capacity of white muscle fibres to fuel the energy demands imposed by swimming. These findings provide insight into the cellular and molecular adaptive mechanisms taking place in skeletal muscle in zebrafish that underlie the swimming-induced potentiation of growth and establish the zebrafish as a useful model species for exercise physiology in biomedicine.

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## Transcriptome profiling of the adult zebrafish heart under exercise

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In mammals, it is known that exercise or physical activity provides cardioprotective effects that are beneficial for the prevention and treatment of cardiovascular diseases such as myocardial infarction. Cardiomyocyte hypertrophy and renewal, vascular remodelling, improved calcium sensitivity and metabolic alterations have been described as the main physiological adaptations of the cardiac tissue in response to exercise. Over the last few years, cardiovascular research using the zebrafish (Danio rerio) as model species has made important contributions to cardiac cell specification, regeneration and function. However, the response of the adult zebrafish heart to exercise has not been evaluated to date. Our group is investigating the physiological effects of exercise in adult zebrafish and recently established a swim-training protocol under sustained exercise conditions (i.e. optimal swimming speed) (Palstra et al. PloS One, 5:e14483, 2010). In the present study we aimed to investigate the molecular mechanisms involved in cardiac remodelling under exercise-swimming conditions in the adult zebrafish heart. As a first approximation, we subjected adult zebrafish to 20 days of swim-training and analyzed the transcriptomic response in the zebrafish heart by microarray analysis. We identified more than seven hundred differentially expressed genes involved in processes such as cell cycle and proliferation, extracellular matrix and cytoskeleton, muscle contraction, growth factors/signalling pathways and metabolism. The results from the present study provide insights into the adaptative mechanisms taking place in the heart in response to exercise-induced activity and may contribute to improve our understanding of the mechanisms involved in the cardioprotective effects of exercise. Importantly, these studies may also set the basis for evaluating the potential effects of exercise on cardiac regeneration.

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## Patterns in diel habitat use of fish covering the littoral and pelagic zones in a reservoir

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We investigated diel habitat use of fish covering the littoral and pelagic zones of the Římov Reservoir (Czech Republic) and analyzed the influence of predator presence and of shifting feeding habitats in all dominant species and age groups. Our sampling revealed distinctive diel changes of fish distribution in the reservoir, which were age- and species-dependent. The overall abundance of subadult fish in all littoral habitats was significantly higher at night than during the daytime. Subadults were almost absent in pelagic habitat during the day and their presence increased during the night, although densities were smaller than in the littoral. Adults preferred the pelagic zone during the day and partly migrated to the littoral at night. Potential fish predators were most likely responsible for small fish avoidance of the littoral and pelagic zones during day. Higher availability of food in the littoral was the most important driver of the high occurrence of subadults at night. Day preference of pelagic zone by adults is most likely caused by higher profitability of this habitat in comparison with littoral. The reasons for night inshore migration of adults are not obvious, but the homogenization of their distribution or resting in the littoral could explain such behavior.