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# Report of the Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (JFATB)

18 May 2009

Ancona, Italy

ICES
International Council for the Exploration of the Sea

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## Contents

## Executive summary

The 2009 Joint Workshop provided a forum for presentation of studies with an emphasis on interpretation of animal behaviour. Presentations were invited concerning natural, vessel or fishing-gear induced animal behaviour with the aim to explore "*why fish do what they do*". It responded to the challenge arising from the second ICES Symposium on fish behaviour, entitled "*Fish Behaviour in Exploited Ecosystems*" held in Bergen, June 2003, namely, to challenge the traditional approaches to the study of fish behaviour. A total of 10 presentations and 1 poster were delivered across topics of fish hearing and sound (n=3), fish behaviour at the individual level and in relation to catchability (n=4), and fish behaviour at the larger group level (n=4).

The presentations highlighted the complexity of the environment in which fish live and how multiple sensory inputs are filtered and choices are made about whether to respond to a particular stimuli or not. The stochastic nature of behavioural reactions combined with different environmental conditions (e.g. background noise, light levels, water temperature) or different "internal states" (e.g. fish condition, competing activity such as spawning or feeding) makes understanding and prediction of animal behaviour a tough challenge. However, the importance of striving to understand these behavioural choices was illustrated with the topics studied. At a population level the possible impact of increasing background noise on reproductive success, e.g. the herring spawning aggregations in a busy shipping area and the impact of noise produced by wind farms on distributions local fish populations. On a more direct level, understanding behavioural responses under different conditions, to sampling methods and also to changing environmental conditions that influence distributions and interactions with prey and predators and how these impact on the ability to accurately assess populations and fish commercially in a responsible way is vital. Quantitative description of behavioural responses and correlation with environmental and other explanatory variables, both natural and human-induced are still necessary. The applicability and value of behavioural ecology theories such as optimal foraging theory and optimal escape theory was demonstrated for fitting descriptive observations into a theoretic framework which can aid understanding and the direction of future questions.

# 1 Terms of Reference

In response to the ICES Resolution of the 94th Meeting, A Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] – [JFATB] (Co-Chairs: Paul Winger (Marine Institute, Canada), Julia Parrish (University of Washington, USA) and Emma Jones (NIWA, New Zealand) was held in Ancona, Italy on 18 May 2009 to:

a ) explore the decisions (i.e. behavioural trade-off's) made by fish and crustaceans during natural behaviour, vessel avoidance, and in response to fishing gear and other platforms.

# 2 Opening the Meeting

## 2.1 Opening and Welcome

The meeting was opened by our host Antonello Sala with welcoming messages from the President of Ancona's Fishing Fair, Dante Merlonghi, the Regional Authorities representative, Uriano Meconi and the Head of the CNR-ISMAR (National Research Council's Institute of Marine Sciences) Enrico Arneri.

## 2.2 Participants

A list of participants appears in Annex 1.

# 3 Introduction

The second ICES Symposium on fish behaviour, entitled "*Fish Behaviour in Exploited Ecosystems*" was held in Bergen, June 2003. Scientific research was presented across 5 key theme sessions, culminating in 27 peer-reviewed papers (Fernö *et al*. 2004) with *Discussion Sessions* recorded by Bjordal and Gerlotto (2004), Huse (2004), Glass and Gunn (2004), Walsh *et al*. (2004), and Thiele and Fernö (2004).

One of the dominant conclusions from several of the theme sessions was the need to challenge our traditional approaches to the study of fish behaviour. Technical limitations are becoming less of an issue but it was suggested that this science community needed to move beyond description of behaviour and become less risk adverse in terms of proposing and testing hypotheses (Bjordal and Gerlotto, 2004; Glass and Gunn 2004 ). It was recommended that the community strive for better integration of disciplines and coordination of field and laboratory experiments through a behavioural ecology framework that would allow a systematic approach to problem-solving issues as well as management requests (Walsh, Godø and Michalsen, 2004).

The 2007 Joint Workshop showcased advances in the use of optical and acoustic technologies applicable to fisheries science. Techniques that combined optics with either acoustics and / or physical capture methods enhanced the ability to estimate fish and invertebrate abundance as well as improving the understanding of their spatial relationships with seabed structure, gear catchability and the impact of trawling on the seabed. Whilst no direct behavioural studies were presented, the importance of behaviour for almost all aspects of this work was highlighted. However, it was pointed out that we need to differentiate between studies that quantify "fish reaction" and those that elucidate "fish behaviour" and that the stochastic nature of the latter should not be underestimated (ICES, 2007). The 2009 Joint Workshop was proposed as a forum for presentation of studies with an emphasis on interpretation of animal behaviour, even if it meant speculation. Presentations were invited concerning natural, vessel or fishing-gear- induced animal behaviour with the aim being to explore "why fish do what they do".

# 4 Presentations

## 4.1 Fish and Sound

**AD Hawkins, Loughine Ltd.**

### 4.1.1 Abstract

Sound has played an important part in the evolution of aquatic animals. Fish have been around for a very long time and sound is an important source of information about the environment. In contrast, the generation of sound in the sea by humans has been relatively recent. Sounds from ships, sonar systems, seismic surveys, and coastal construction have developed only over the last century.

Sound transmits well through water and the detection of sounds - hearing - is one of the basic senses of fish. Fish live in a 'soundscape' where sounds from many different sources impinge upon them. Some, like the sounds from prey, the calls of conspecifics and the sounds from larger predators are of vital importance to them. Those sounds will determine whether fish eat and grow, hold territories, secure mates and survive attacks from others.

Through the application of behavioural and electrophysiological techniques it has been possible to compare the hearing abilities of different fish. Experiments have been carried out to determine the limits to sound detection; the masking of one sound by another; the ability to discriminate between different sounds and the ability of fish to determine the direction from which a sound is coming. However, there are around 28 000 species of fishes. For most of them there are no empirical data on their hearing characteristics. Even where data are available they are often poor in quality. We have to divide these very diverse animals into functional classes. In some, the otolith organs of the ear are directly stimulated by sound (flatfish, mackerel, sharks & rays). In other the organs are linked indirectly to the gas-filled swim bladder (codfishes). Others have intimate connections between the ear, the swim-bladder & other gas-filled spaces (carps, croakers, & squirrel-fish). Some, like the plaice detect and respond only to the particle acceleration component of low frequency sounds; others can detect higher frequency sound pressures, and a few respond to high level sounds at ultrasonic frequencies (shads).

Knowing how well fish can hear does not tell us how they will respond to particular sounds, or how they use sound in their everyday lives. Examining behaviour and investigating the behavioural responses of fish to sounds is inherently difficult. While physiological experiments can be performed in a specially designed tank, in a corner of the laboratory, behaviour has to be observed in a natural context. Not only is the behaviour of fish in the wild difficult to observe; it is also difficult to monitor the levels and characteristics of the sounds and other stimuli received by the fish. The responses may be variable from one place or time to another. It is also necessary to relate the behaviour to its function and significance in the life of the animal. We observe an overt action by the fish; a startle response, directional movement, changes in spacing or orientation within a school, or cessation in vocalisation. What is important is the functional significance of that expressed behaviour. Is a change in behaviour

significant for feeding, growth or maturation; does it impair survival; does it influence migrations; what will the impact be on mating and reproduction? And ultimately we have to consider the effects on populations. Does a response to human generated sounds have any significance in terms of reducing numbers, narrowing spatial distribution or reducing genetic diversity? What are the risks to fish populations and to the wider ecosystem from exposure to human generated sounds?

If human-generated sound is harming fish populations then it is important to regulate, eliminate or reduce that damage, with minimal disruption to commercial activities. Under what circumstances does sound pose a threat to fish populations? Can the effects be mitigated? How do these impacts compare with those imposed by other activities like fishing, water pollution and dredging for aggregates?

### 4.1.2 Discussion

There was some discussion around the challenge from the speaker that the question of why fish do what they do was less important than whether particular behavioural patterns and changes caused by anthropogenic activity had an impact at a population level, e.g. male haddock in mating areas produce individually identifiable mating sounds; noise pollution may impact on the ability of females to detect and distinguish between males. Knowing why fish, at an individual level, respond in a certain way could allow mitigation of anthropogenic impacts at a population level. It was acknowledged that the huge variability in response represents a challenge in terms of categorizing and understanding the behaviour, a simple "Dose – Response" relationship is unlikely. The relative importance of hearing in fish compared to other senses was discussed and the value of understanding how fish use sound themselves and how they process sound was highlighted. As with vision and the importance of detection of objects against a "background space light", a key aspect of hearing is the detection and discrimination of important stimuli from background noises, the fish version of the "cocktail party effect" or auditory scene analysis" (Bregman, 1990).

## 4.2 Herring in pens – observations of behaviour induced by various stimuli

**Lise Doksæter, Nils Olav Handegard*, Olav Rune Godø, Institute of Marine Research, Bergen Norway**

***speaker**

### 4.2.1 Abstract

Herring (*Clupea harengus*) were exposed to various sound stimuli with the objective of studying herring reaction to low frequency military sonars. We held herring in a pen equipped with both horizontal and vertical looking echosounders, a steerable camera and hydrophones. The pen was towed into the open water fjord basin and the herring exposed to low frequency military sonar emissions (1–2kHz) using the new Frigates of the Royal Norwegian Navy. In addition, an underwater loudspeaker was used to stimulate the herring at different output levels, using killer whale vocalization playback. Controlled experiments with an outboard engine in the vicinity of the pen, as the source of stimulus, and associated reaction patterns were also logged. Very little reaction was observed, both to the sonar emissions and to the playback. When the herring were exposed to lower frequency emissions from the outboard engines, strong reactions were observed.

#### 4.2.2 Discussion

The possible impact of the fish being held in the experimental pen for a year was discussed. Whilst these could not be described as truly wild fish, they were certainly feeding, and as such, deemed to be "happy, unstressed fish". Whether the gradient of noise increase and habituation were potential explanations for the lack of response to the sonar and killer whale playback sounds was mentioned.

### 4.3 *Electrona carlsbergi*, probably the reason King Penguins (Aptenodytes patagonicus) forage at the Polar Front

**Sophie Fielding, Martin A. Collins, Ian Staniland and Hugh Venables, British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET.**

#### 4.3.1 Abstract

In January and February of 2007 five breeding king penguins were tracked on foraging trips from South Georgia (South Atlantic Ocean). At the same time the RRS James Clark Ross undertook at sea observations around the Polar Front (PF), north of South Georgia, in the location where the penguins were tracked to. Acoustic observations were collected using a calibrated three frequency (38 120 and 200 kHz) EK60 echosounder, and RMT25 net samples were undertaken to determine the targets observed.

We observed significantly greater acoustic biomass (NASC) of swim-bladdered fish, identified by a negative dB difference (Sv120–38), at the PF, compared with waters near South Georgia. This acoustic fish biomass was 100 m shallower at the PF with maximum amounts occurring at 200 m depth. The increased biomass at a shallower depth was associated with waters of sea surface temperatures (SST) between 5 and 5.5 ˚C, linearly increasing from 100 to 650 $m^2$ $nm^{-2}$ from 4 to 5.5˚C SST during daytime observations on transit to the PF. Stratified net samples indicated that these layers were comprised of myctophid fish, primarily the schooling species Electrona carlsbergi.

Time depth recorder data from the tracked penguins indicated that they changed their foraging behaviour in waters of 5 to 5.5 ˚C, diving more frequently to depths of 80–200m, coinciding with the shallow layer of myctophids. The finescale meandering patterns of penguins in waters of 5 to 5.5 ˚C is well known, for the first time we show increases in "prey" distribution.

#### 4.3.2 Discussion

The reasons for the daytime only foraging of the penguins was discussed; they are visual rather than tactile foragers, resting on the surface at night. The seasonality of this foraging behaviour was also discussed; recent surveys have shown an absence of the prey in this area during winter months. Whether the study observed evidence of a halo-effect (i.e., Ashmole 1963) in prey density distribution was discussed. The largest differences appear to be the result of seasonality

## 4.4 Testing Ydenberg and Dill's (1986) economic cost-benefit model of anti-predator behaviour for its application to vessel/trawl avoidance.

**Paul Winger, Centre for Sustainable Aquatic Resources, Fisheries and Marine Institute of Memorial University of Newfoundland, St John's, Canada.**

### 4.4.1 Abstract

This presentation discusses the avoidance of fish to vessels and trawls in the context of the widely popular "optimal escape theory" first established by Ydenberg and Dill (1986). The theory rests on the premise that animals, when in the presence of a threat, continually choose between two behavioural options (fleeing or remaining) as the distance between them and the threat increases or decreases. Balancing the economics between these two choices determines the optimal reaction distance. This approach deviates from the more common approach which tends to describe fish behaviour based on a series of environmental/physiological constraints. This presentation builds on the earlier thoughts of Fernö and Huse (2003) and Winger (2004). It takes data from an earlier vessel/trawl avoidance experiment and tests the model for its applicability

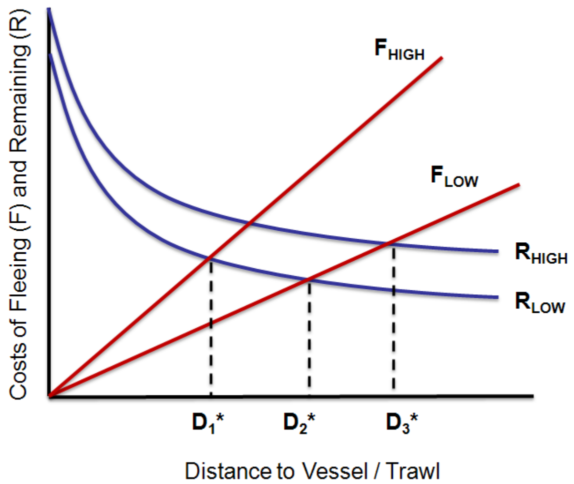


**Figure 1. Representation of the economic cost – benefit model applied to fish avoidance of a vessel or trawl.**

### 4.4.2 Discussion

How appropriate the linear and non-linear elements of the response theory was challenged and the effect of "patchiness" was discussed, such as the tendency for these cod to clump together in deeper water in winter and how a group effect might influence the decision to stay or flee. Clumping may also occur through patchy food resources and optimal exploitation of these.

## 4.5 Catchability of Pacific halibut – how behaviour contributes to hooking

**Stephen M. Kaimmer, International Pacific Halbut Commission, Seattle, WA, USA**

### 4.5.1 Abstract

The International Pacific Halibut Commission (IPHC) has studied halibut behavior from a number of platforms over the years. Recent studies designed to directly

observe hooking success have yielded far more in the way of behavior before, during, and after hooking. Various gear studies and analyses have also given inferential indications of apparent halibut behavior.

Direct camera observations have described approach direction relative to bottom currents, pre-biting behavior, social interaction with other halibut or other species, attack rates, and hooking success. Halibut approach along the supposed scent trail, most often singly or in pairs, and often lie downstream from bait prior to biting. Approaches of other fish or a struggling fish on a nearby hook attract more halibut, and often initiate a hook attack. Attack rate does not seem to be size dependent, and only seldom did a large fish seem to 'spook' a smaller fish from bait. Gear studies suggest that halibut may aggregate by size and sex on the seafloor, and there may be some feeding dominance by size.

While many factors contribute to attack rate, once an attack was initiated, hooking success appears to be determined by hook size, particularly the gap between the point and the shank, and the dimensions of the jaw.

#### 4.5.2 Discussion

The distance travelled to reach the bait and the influence of this on the motivation of the individual was discussed; fish that appeared from the direction of the scent plume appeared to be "drugged up' on the odour plume and were more likely to attack the bait. The soak time used was (2 h). The lack of influence of con-specifics on behaviour was attributed to the fact that halibut generally have few predators.

### 4.6 Size-dependent escapement of walleye pollock from midwater trawls

**Kresimir Williams [1,2], Andre, E. Punt [2], Christopher D. Wilson [1]*, and John Horne [2]. (1) NOAA Fisheries, Alaska Fisheries Science Centre, 7600 Sand Point Way NE Seattlw, WA. (2) School of Fisheries and Aquatic Sciences, University of Washington, Seattle, WA.**

*** presenter**

#### 4.6.1 Abstract

Midwater trawls are used as sampling tools in acoustic surveys to provide species and length composition of acoustically detected fish aggregations. Length distributions of target species are used to scale the acoustic echo energy into estimates of abundance. Non-representative trawl catches caused by selective retention of fish can bias estimates of population size composition and abundance. In midwater trawls, retention of fish in the trawl body is dependent on behavioural responses such as herding rather than on physical retention because mesh sizes are larger than the fish. Field experiments were conducted during 2007/2008 in the Bering Sea and Gulf of Alaska to estimate the extent of size-dependent escapement of walleye pollock, and to characterize fish behaviours within the net that may influence escapement. Escapement was measured by attaching twelve small recapture nets to randomly assigned locations on the outside of the trawl. A Bayesian hierarchical model of escapement was developed to estimate the parameters determining selectivity, their uncertainty, the extent of between-haul variation, and the distribution of escapement from different locations on the trawl. Escapement varied as a function of trawl location, ambient light level, and survey vessel. Greater escapement occurred through the bottom panels of the net and during the night. Ongoing work, using remote sensing devices attached to the trawl is providing smaller-scale fish behavioural information within the net to give insight into strategies that may reduce escapement. A better

understanding of the interaction between gear-induced behaviour and trawl selectivity will enable gear optimization and sampling strategies to minimize sample bias.

#### 4.6.2 Discussion

The discussion centred around other possible factors that may have influenced the escape behaviour of the fish such as whether towing speed and water temperature varied between the surveys and the condition of the fish caught. There were differences in water temperature between the surveys and interesting inter-haul variation in fish condition. The discussion highlighted the difficulty in avoiding potentially confounded data in field trials and teasing out the significant environmental and biological drivers that influenced escape behaviour and also distinguishing between active and passive escapes given the large size of the meshes in these kinds of pelagic trawls.

### 4.7 To eat or be eaten: why hake do what they do

**Cooke, K.[1*], Thomas, R.[2], Chu, D.[2], Hufnagle, L. [2], and Deblois, S. [2] (1) Fisheries and Oceans, Canada, Pacific Biological Station, Nanaimo, BC. (2) National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA.**

#### 4.7.1 Abstract

The US and Canada have jointly conducted acoustic-trawl surveys to estimate biomass and number of Pacific hake (*Merluccius productus*) since 1992. Surveys are conducted in the summer months after most of the migration from spawning areas to feeding grounds is complete. The stock can extend from central California to southeast Alaska but shows inter-annual variability in its distribution and aggregation patterns that we hypothesize are related to environmental factors, food availability, and predator interaction. Nominally, hake are found at about 100–300 m depth in a fairly contiguous band contained within or near the highly productive upwelling zone of the continental shelf edge. The northward extent of the distribution along the shelf edge shows that older and larger fish are generally found furthest north and younger fish are more south and inshore. However, we have observed a wide range in behaviour patterns independent of size and age that we hypothesis are in response to both large scale ocean circulation changes and small scale regional conditions that will impact on food availability and predator presence. We explore the influence these factors may have on hake aggregation behaviour and assess the impact that shifts in distribution have on recruitment success and overall stock abundance.

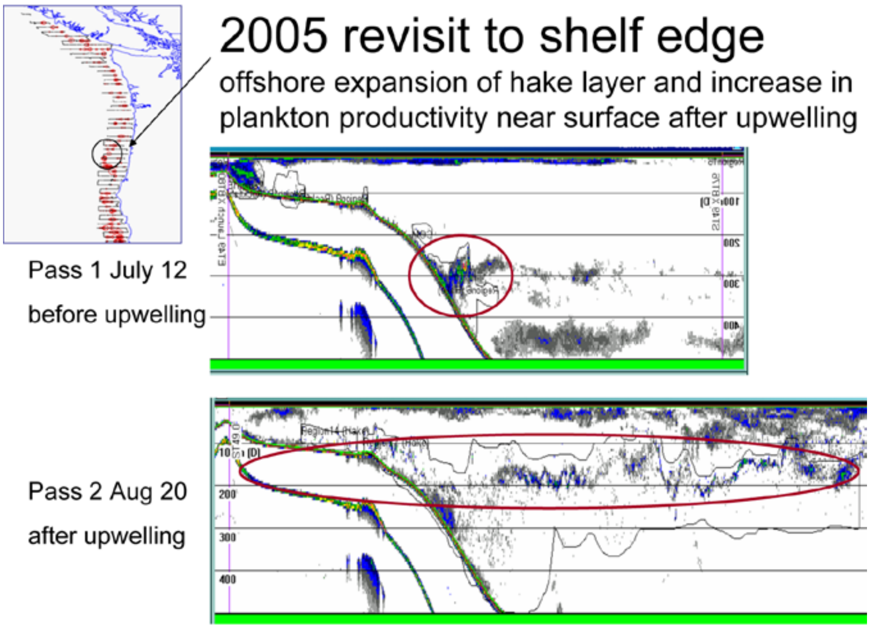


**Figure 2. Comparison of echograms illustrating the change in distribution of Pacific hake on the shelf edge before and after upwelling events.**

#### 4.7.2 Discussion

The importance of predator-prey relationships and how these may change and influence distribution during El Niño years was discussed. The occurrence of an invasive red crab off Chile and Peru which has become an important food source for several fish species was mentioned; it was not known (?) if the same species occurred within the range of Pacific hake in the northern hemisphere. In turn the possible influence of the northward extension of hake as prey for Humboldt squid was discussed.

### 4.8 Three dimensional characteristics of Young–of–Year fish schools in lake and fish species discrimination

**Patrice Brehmer[1], Jean Guillard[2], Michel Colon[3] and Yvon Guennégan[4] (1) INRA – UMR CARRTEL, BP 511, 74203 Thonon-les-bains, France; (2) IRD, CRHMT/UR109, 1 Avenue Jean Monnet, BP 171, 34203 Sète, France; (3) IFREMER, CRHMT, 1 Avenue Jean Monnet, BP 171, 34203 Sète, France**

#### 4.8.1 Abstract

Fish schools are aggregative structures encountered in all types of aquatic environments but have as yet been little studied in freshwaters except at small spatial scales. This study represents the three dimensional description of juvenile fish schools (*Perca fluviatilis* and *Rutilus rutilus*) in a lake environment using high resolution multibeam sonar system operating at a frequency of 455 kHz, composed of 60 beams of 1.5 allowing a 90 observation plane. The *in situ* diurnal schooling behaviour of young-of-the-year fish of both species is confirmed. The morphological, energetic and spatial variables of these schools are described and related to one another. The structures described are of the same order of magnitude as those described in the marine environment. The school shape is elliptical, they are shallow and they display a temporal and spatial stability over the course of a day but a highly variable morphology. The number of vacuoles, a descriptor of the internal morphology of the schools, was found to be significantly ($p < 0.01$) correlated with the volume of the school, and showed two distinct relationships, with proportions similar to the percentage occur-

rence of both species sampled by a pelagic trawl. The relation may be efficient for fish species discrimination by 3-D acoustics methods in this lake with two main aggregative fish species.

#### 4.8.2 Discussion

Questions focused on vacuoles (the empty spaces between groups of fish in large schools); how they are measured, how you determine the difference between true vacuoles and empty voxels, what their function is and whether the relationship between school size and number of vacuoles is influenced by physiological and/or ecological factors.

### 4.9 Exploring fish schools using 3D information from the ME70: a progress report

**Verena M. Trenkel, L. Berger, and G. Quemener. Ifremer, BP 21102, 44311 Nantes, France**

#### 4.9.1 Abstract

In this presentation we will provide an update of research and software developments using 3D acoustic data provided by the multibeam echosounder ME70 for studying fish schools. We first detail the algorithm for detecting (defining) fish schools and describe the descriptors for characterising school morphology and energetics. We present results from a sensitivity analysis of the values of detection parameters (energy threshold, maximum alongship, athwardship and vertical distance factors) using real data from the Bay of Biscay and simulated data. Some empirical results of observed school behaviour are then presented.

#### 4.9.2 Discussion

The observed behaviour of a large school of herring aggregating in the English Channel to spawn was presented and the relatively minimal vessel avoidance behaviour of fish in an area so heavily impacted by anthropogenic noise was discussed.

### 4.10 Do marine wind parks affect fish spatial distribution?

**Thomas Didrikas[1] and Thomas Axenrot[2], (1) Dept. of Systems Ecology, Stockholm University, Sweden; T.Axenrot - Institute of Freshwater research, Swedish Board of Fisheries (2) Institute of Freshwater Research, Swedish Board of Fisheries**

**(poster)**

#### 4.10.1 Abstract

Marine wind parks are being planned for and built in coastal and shallow offshore areas in response to increasing demand for renewable energy. Today's knowledge is limited about possible effects on fish and consequences for the fishery from habitat change and generated underwater sound. Studies on fish hearing have shown that many fishes hear low frequency sound like that produced by wind turbines. This study investigated pelagic fish abundance and their spatial distribution at one wind park and two reference areas at five different occasions from 2005 through 2007 in the Kalmar Sound of the Baltic Sea. The highest abundance was found in the most remote reference area where underwater sound generated by the wind turbines in the wind park was below the hearing threshold for fish. However, the variation between areas and seasons was substantial, and the lowest abundance was recorded at the reference area close to the wind park. The difference between areas was strongest for fish of the

size groups 30–80 and 140–250 mm, mainly representing three-spined stickleback and adult herring. GAM modelling for these size groups pointed out that "Area" is the most important parameter. For fish >250 mm, representing cod and salmon, no difference between areas was observed. However, other parameters than the ones examined in this study may still affect fish distribution within and between areas.

# 5 Synthesis and Discussion

The studies presented during the Session highlighted the complexity of the environment in which fish live and how multiple sensory inputs are filtered and choices are made about whether to respond or not;

- Which sounds are important and which should be ignored?
- How far is it worth travelling to reach your favourite food?
- How best to respond, either individually or as a group to a predatory threat, be it a Humboldt squid, an approaching vessel, or a trawl?

In most scenarios, a simple "dose – response" would not be appropriate as the same stimulus under different environmental conditions (e.g. background noise, light levels, water temperature) or different "internal states" (e.g. fish condition, competing activity such as spawning or feeding) will vary. The huge range of different scenarios possible, combined with the stochastic nature of behavioural responses can make understanding seem an impossible goal. The group was challenged as to whether this was really necessary, or realistic. However, the importance of striving to understand these behavioural choices was illustrated with the topics studied. At a population level the possible impact of increasing background noise on reproductive success, e.g. the herring spawning aggregations in a busy shipping area and the impact of noise produced by wind farms on distributions local fish populations. On a more direct level, understanding behavioural responses under different conditions, to sampling methods and also to changing environmental conditions that influence distributions and interactions with prey and predators and how these impact on our ability to accurately assess populations and fish commercially in a responsible way are vital. In order to fully understand human-induced behaviour, a fuller understanding of "natural" interactions with prey, predators and con-specifics is necessary and the applicability of behavioural ecology theories such as optimal foraging theory and optimal escape theory was demonstrated.

In response to the "do we care?" it is suggested that it depends on the level of requirement or expectation. Observation can potentially allow correction for the response / phenomenon on a case by case basis, e.g. vessel avoidance. Prediction doesn't even necessarily require a full understanding, *"Why does opium induce sleep? Because it has in it a sleeping quality" (Moliere),* but prediction without understanding the underlying causes can be dangerous outside the known range of a natural factor and where critical management decisions rely on this, and this can undermine the value of the science.

Behaviour is everywhere; why come, leave, stay, eat, follow your neighbours or not. But is behaviour too variable, messy and labour intensive to get to grips with? Is it enough just to describe and find correlations? This step should not be dismissed or under-estimated - it is the necessary starting point and the building blocks for models, which shouldn't be built on flimsy data. But it should not be the end point and we should strive to fit descriptive observations into a theoretic framework to aid understanding and the direction of future questions.

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## Annex 2: Agenda

The Joint Workshop on Fishing Technology, Acoustics and Behaviour (JFATB) Meeting Agenda:

Meeting Place: ERF, Consiglio Nazionale delle Richerche (CNR), Instituto di Scienze Marine, Ancona, Italy.

| | |
|---|---|
| 08:00 | Registration / coffee |
| 09:00 | Opening Remarks |
| 09:30 | Opening of Joint Session |
| 09:40 | Anthony Hawkins; Fish and Sound. |
| 10:00 | Nils Olav Handegard; Herring in pens – observations of behaviour induced by various stimuli. |
| 10:20 | Morning break |
| 10:50 | Sophie Fielding; *Electrona carlsbergi*, probably the reason King Penguins (*Aptenodytes patagonicus*) forage at the Polar Front |
| 11:10 | Paul Winger; Testing Ydenberg and Dill's (1986) economic cost-benefit model of anti-predator behaviour for its application to vessel/trawl avoidance. |
| 11:30 | Stephen Kaimmer; Catchability of Pacific halibut - how behavior contributes to hooking |
| 12:10 | Discussion |
| 12:30 | Lunch |
| 14:00 | Chris Wilson; Size-dependent escapement of walleye pollock from midwater trawls |
| 14:20 | Ken Cooke; To eat or be eaten: why hake do what they do |
| 14:40 | Partrice Brehmer; Three dimensional characteristics of Young–of–Year fish schools in lake and fish species discrimination |
| 15:00 | Verena Trenkel; Exploring fish schools using 3D information from the ME70: a progress report |
| 15:20 | Discussion |
| 15:40 | Afternoon break |
| 16:00 | Summary |
| 16:20 | Update: New ICES Science Plan |
| 17:00 | Close |

## Annex 3: JFATB Terms of Reference for the next meeting

The **Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour** [WGFTFB] **and the Working Group on Fisheries Acoustics Science and Technology** [WGFAST] **(JFATB)** (Co-Chairs: to be confirmed) will meet in Iceland [to be confirmed] on DATE [to be confirmed] 2011 in conjunction with WGFTFB and WGFAST to:

a ) Progress the development of a behavioural ecology framework to allow a systematic approach to future fish behaviour studies within the context of by-catch mitigation, fisheries surveys (acoustic, trawl and other methods) and the ecosystem approach to fisheries management.

b ) Facilitate links between the WGFTFB and WGFAST Working Groups and academic / research organizations outside the field of direct fisheries research to build collaborations to address behavioural and physiological data gaps.

JFATB will report by DATE [to be confirmed] 2011 to the attention of SCICOM.

### Supporting Information

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|---|---|
| Priority: | The current activities of this group will lead ICES into issues relating to the effectivness of technical measures and size selectivity, and the efficiency of acoustic, trawl and other fisheries surveys. Consequently these activities are considered to have a very high priority. |
| Scientific justification and relation to action plan: | Understanding and predicting fish behaviour is a key component of the research activities of many ICES countries – in particular, in relation to the monitoring and measuring fish biomass, understanding the catchability of sampling/survey gears, and improving the selectivity of commercial fishing gears. Leaders within this arena of the scientific community recently recognized the need to challenge the traditional approaches to the study of fish behaviour (ICES Symposium, Bergen 2003) which has justified this new terms of reference. |
| Resource requirements: | The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible. |
| Participants: | The Joint Session is normally attended by some 50–100 participants from WGFTFB, WGFAST and invited experts. |
| Secretariat facilities: | None. |
| Financial: | No financial implications. |
| Linkages to advisory committees: | ACOM |
| Linkages to other committees or groups: | There is a very close working relationship with all the groups of the Fisheries Technology Committee. It is also very relevant to the Working Group on Ecosystem Effects of Fisheries. |
| Linkages to other organizations: | None |

# Annex 4: Recommendations

| Recommendation | For follow up by: |
|---|---|
| JFATB recommends that the WGFTFB and WGFAST meet jointly, in April/May 2011. The Terms of Reference are to be mutually decided by the Working Group Chairs and designated joint session chairs. | SSGESST, WGFTFB, WGFAST |