

COST 827 ACTION ON VOLUNTARY FOOD INTAKE IN FISH

In April 1996, a new European Network was formed as a concerted action (COST 827), with the aim of increasing the contact among researchers interested in different aspects of “*Voluntary Food Intake in Fish*”. This subject is divided into five sub-topics (working groups): (1) Feeding management and engineering, (2) Environmental factors affecting feed intake, (3) Behavioural (including chronobiological) factors affecting feed intake, (4) Physiological control of feed intake, and (5) Dietary factors affecting feed intake. The action has three main objectives: (i) to promote, co-ordinate and harmonize pre-competitive research on the factors affecting voluntary feed intake in fish; (ii) to provide the necessary know-how for increasing the competitiveness of European research at a crucial moment for the development of new management techniques in fish feeding; and (iii) to promote new feeding strategies in fish farms. To achieve this, working group meetings and workshops are held and organized by the COST action.

For more information about the COST action see our home page:

<http://www.st-pee.inra.fr/ici/stpee/collab/cost/cost.htm>

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LOCAL ORGANIZERS

Puríður E. Pétursdóttir, Agricultural Research Institute, RALA, Iceland.

Logi Jónsson, University of Iceland.

Helgi Thorarensen, Hólar Agricultural College, Iceland.

Programme

AUGUST

15th:

16:00-20:00 **Arrival of participants
Registration and poster positioning at Oddi,
University of Iceland**

AUGUST

16th:

9:00 **Opening remarks: Árni M. Mathiesen, Minister of Fisheries**

Session I: Methods, models and techniques

Chairperson: Eva Brännäs

9:15 **Invited speaker: Discovering complex repeated patterns in
behavior and effects of experimental factors.**

Magnús. S. Magnússon

Human Behavior Laboratory, University of Iceland.

10:00 **Measuring feed intake with chemical markers and X-ray methods.**

O. Gudmundsson

Feed, Seed and Fertilizer Inspectorate, Iceland.

10:20 **Monitoring the triggering activity of individual fish with a self-
feeding system. Preliminary results in European sea bass,
*Dicentrarchus labrax.***

D. Covès

IFREMER, France.

10:40 **Coffee Break**

Chairperson: Skúli Skúlason

11:00 **The pulse dose marker method in fish nutrition research.**

H.R. Kristiansen

Aqualife, Denmark.

11:20 **In vitro digestibility based on trypsin activity of fish crude enzyme
extract could predict feed quality in growth trial.**

K. Rungruangsak-Torrissen,

Aquaculture Research Station, Matredal, Norway.

Session II **Environmental quality, requirements and influences**

11:40 **Invited speaker: How feed intake in fish is modulated by water
quality.**

Jeannine Person,

IFREMER, Centre de Brest,

Laboratoire de Physiologie des Poissons, France.

12:25 **Genetic and environmental effects on the growth of three stocks of
Arctic charr, *Salvelinu alpinus.***

H. Thorarensen,
Holar Agricultural College, Iceland.

12:45 Lunch

Chairperson: Emma Eythórsdóttir

14:00 Genetics and environmental effects on the size of the cardio-respiratory organs in Arctic charr, (*Salvelinus alpinus*).

M.Á.M. Ruiz,
Holar Agricultural College, Iceland.

14:20 Parallel sympatric segregation in arctic charr and threespined stickleback in Lake Galtarból, Iceland.

B. Jónsson
Institute of Freshwater Fisheries at Hólar, Iceland.

14:40 Dietary and morphological divergence of Icelandic threespine stickleback, *Gasterosteus aculeatus* L., towards mud and lava substrate in lakes.

B.K. Kristjánsson,
Holar Agricultural College, Iceland.

15:00 Coffee Break

Chairperson: Malcolm Jobling

15:20 Feed delivery rate in rainbow trout, *Oncorhynchus mykiss*, production.

J. Bailey
Swedish University of Agricultural Sciences, Umeå, Sweden.

15:40 Feed intake in relation to workload and diet composition.

J. Pickova,
Swedish University of Agricultural Sciences, Umeå, Sweden.

16:00 Culture conditions and spatial distribution: swimming patterns under high density in recirculating tanks around self-feeding events.

M.L. Bégout Anras,
Centre de Recherche en Ecologie Marine et Aquaculture,
IFREMER, L'Hommeau, France.

16:20 *Solea senegalensis* production in mono and policulture fish ponds of Sado Estuary.

M. A. Ramos
IPIMAR, Lisboa Portugal.

18:00 Reception by courtesy of the Mayor of Reykjavik in Reykjavík City Hall.

AUGUST

17th:

Session III Competition and cannibalism

Chairperson: Marilyn Beauchaud

- 9:00 **Invited speaker: Cannibalism in cultured fishes: Why eating conspecifics, what can we learn from it and how can we mitigate it?**
Etienne Baras,
University of Liège, Dept Ethology and Animal Psychology,
Tihange Aquaculture Station, Belgium.
- 9:45 **Influence of feeding frequency on feed intake and size distribution in groups of Arctic charr, *Salvelinus alpinus*.**
T. E. Pétursdóttir,
Agricultural Research Institute, RALA, Iceland.
- 10:05 **The effect of feeding on aggressive behaviour and growth in juvenile rainbow trout, *Oncorhynchus mykiss*.**
D.L.G. Noakes,
Department of Zoology, and Aquaculture Research Centre,
University of Guelph, Ontario, Canada.

10:25 Coffee Break

Chairperson: Kari Ruohonen

- 10:45 **Intracohort cannibalism: a time lagged lifeboat mechanism.**
P. Byström,
Swedish University of Agricultural Science, Sweden.
- 11:05 **Behavioural deficits in farmed brown trout, *Salmo trutta*.**
A. Alanärrä,
Swedish University of Agricultural Sciences, Umeå Sweden.
- 11:25 **Patterns of feeding and social interactions in cages of Gilthead Sea Bream, *Sparus aurata*, European Sea Bass, *Dicentrarchus labrax*, and Atlantic Salmon, *Salmo salar*.**
S. Kadri,
Institute of Biomedical & Life Sciences,
University of Glasgow, Scotland.
- 11:45 **Effects of dietary L-tryptophan on agonistic behaviour and stress responses in juvenile rainbow trout.**
S. Winberg,
Dept. Comparative Physiology, Uppsala University, Sweden.

12:05 Lunch

13:00-14:00: Poster session with authors present

Session IV Physiological signalling and intergration

Chairperson: Marie-Laure Bégout-Anras

**14:00 Invited speaker: Stressful environments and food assimilation:
Gut blood flow and gut feelings.**

Anthony P. Farrell,
Department of Biological Sciences,
Simon Fraser University Burnaby, Canada.

**14:45 Growth hormone, growth, behaviour and ecological consequences
in salmonids.**

B.T. Björnsson,
Göteborg University, Sweden.

15:05 Coffee Break

Chairperson: Thórarinn Sveinsson

**15:25 Food intake and the neuropeptide Y system of juvenile rainbow
trout.**

E.T. Larson,
Uppsala University, Sweden.

15:45 Adiposity and growth of post-smolt Atlantic salmon, *Salmo salar*.

M. Jobling,
University of Tromsø Norway.

16:05 Lipostatic regulation of voluntary feed intake in fish.

S.J.S. Johansen,
University of Tromsø Norway.

16:30 Bush trip to the Blue Lagoon (ca. 3 hours).

**20:00 Reception by courtesy of the Minister of Fisheries
Light meal and refreshments**

**AUGUST
18th:**

Chairperson: Dimitra Maragoudaki

9:00 **Macronutrient self-selection in European sea bass using macroencapsulated nutrients.**

V.C. Rubio,
University of Murcia, Spain.

9:20 **Regulation of food and nutrient intake in rainbow trout, *Oncorhynchus mykiss*, fed dry pelleted diets.**

D.J. Grove,
University of Wales Bangor, Wales, U.K.

9:40 **Effect of energy density and source on voluntary food intake in rainbow trout.**

I. Geurden,
Unité mixte INRA-IFREMER de Nutrition des Poissons,
St Pée-sur-Nivelle, France.

10:00 **Feed intake in relation to temperature and diet composition in Atlantic salmon parr.**

E.Å. Bendiksen,
BioMar AS, Norway.

10:20 **Coffee Break**

Session V Feeding strategies and tactics

V

Chairperson: Henrik Rosendahl Kristiansen

10:40 **Invited speaker: Strategical and tactical analyses of the feeding behaviour of fish (and Icelanders).**

Lawrence M. Dill,
Behavioural Ecology Research Group, Dept. of Biological Sciences,
Simon Fraser University Burnaby, Canada.

11:25 **Dynamics of appetite in teleosts experiencing cycles of feed deprivation.**

R.J. Wootton,
University of Wales, Aberystwyth, Wales, U.K.

11:45 **Contrasting results from efforts to elicit growth over-compensation in two fishes.**

R.S. Hayward,
University of Missouri-Columbia, USA.

12:05 **Lunch**

13:00-14:00 **Poster session, cont.**

Session V Feeding strategies and tactics

V Continued

Chairperson: Soffía Vala Tryggvadóttir

14:00 **Enhanced feeding activity: a correlated response to selection for growth in brown trout, *Salmo trutta*.**

M. Mambrini,

Laboratoire de Génétique des Poissons, INRA, France.

14:20 **Triggering activity rhythm of individual fish versus food intake activity of a population.**

M. Beauchaud,

Université J. Monnet. Faculté des Sciences. Saint – Etienne, France.

14:40 **Comparison of demand-feeding rhythms in individual and grouping rainbow trout: with emphasis on inter-individual social interactions.**

W.M. Chen,

Teikyo University of Science and Technology, Japan.

15:00 **Coffee Break**

Chairperson: Ólafur Gudmundsson

15:20 **Feeding rythms and macronutrient self-selection in a plantivorous marine species: sharpsnout sea bream, *Diplodus puntazzo*.**

J.A. Madrid,

Dep. Physiology. Murcia University, Spain.

15:40 **Food anticipatory activity in greenback flounder.**

J. Purser,

University of Tasmania, Launceston, Tasmania, Australia.

16:00 **Closing remarks from the chairman of the management committee:**

Thierry Bouchard

19:30 **Banquet at Viðeyjarstofa on Viðey in the Harbor of Reykjavík. The ferry leaves from Klettagarðar, Sundahöfn at 19:30.**

Coctail by courtesy of the Minister of Agriculture.

AUGUST 19-20th

Field trip to the aquaculture research stations in the north.
(Halibut, Seabass and Arctic charr research farms)

Posters

- 1. Comparing weaning techniques and formulated diets in fingerlings of *Stizostedion lucioperca* and *Perca fluviatilis***

L. Ljunggren and F. Staffan.

2. **Measuring digestibility with chemical markers mixed in the feed and sprayed on the pellets.**
T. E. Pétursdóttir and Ó. Guðmundsson.
3. **Early life history of the Atlantic eels *Anguilla rostrata* and *A. anguilla* recruiting to Iceland, as revealed by otolith microstructure**
M. Kawai, B. Jónsson, J. Aoyama, D. L.G Noakes
and K. Tsukamoto.

4. **Vertical distribution of caged Atlantic salmon during the first period after sea transfer.**
F. Oppedal and T. Hansen.
5. **Feeding rhythms of juvenile red porgy (*Pagrus pagrus*) in ambient environmental conditions**
D. Maragoudaki, M. Paspatis and M. Kentouri.
6. **Phenotypic and genetic basis of segregation in shape and life history among Atlantic salmon in River Viðidalsá, Iceland**
G. I. Gudbrandsson and B. Jónsson
7. **Agonistic pattern analysis of black-bass (*Micropterus salmoides*) during the establishment of social structure.**
G. Petit, M. Beauchaud, C. Bouchut and J. Attia .
8. **Individual growth and food intake in northern and southern populations of Eurasian perch (*Perca fluviatilis*)**
S.N.M. Mandiki, G. Blanchard, C. Mélard, M. Gielen,
J. Koskela and P. Kestemont.
9. **Effect of a soy-protein diet supplemented or not with methionine on the voluntary feed intake of sea bream (*Sparus aurata*).**
M.J. Sánchez-Muros, M.D. Suárez, G. Cardenete,
E Milán y M. de la Higuera.
10. **Seasonal variation in growth and feed conversion in Atlantic salmon (*Salmo salar* L.) postsmolts**
U. Nordgarden, G.L. Taranger, F. Oppedal,
G.-I. Hemre, and T. Hansen.
11. **The effect of social stress on the production of dividing red blood cells in triploid brook trout**
R.A. O'Keefe and T.J. Benfey
12. **Melatonin modifies food intake and macronutrient self-selection in European sea bass feeding on gelatine capsules**
V.C. Rubio, F.J. Sánchez-Vázquez and J.A. Madrid.
13. **Feed intake in Yellowtail (*Seriola quinqueradiata*) and Kampachi (*Seriola dumerili*) in relation to dietary protein and energy.**
Clive Talbot, S. Corneillie, and A. García Gomez.
14. **The effect of the degree of insaturation of dietary lipids on feed intake of European seabass juveniles (*Dicentrarchus labrax*).**
L.M.P. Valente, P. Rema, E. Gomes, and J. Dias.

15. **Perch feed efficiently on floating pellets**
J-E. Juell, Ø. Nilsen, N. Soleng and E. Austreng.
16. **Time learning and pre-feeding aggression in groups of Arctic charr**
E. Brännäs, U. Berglund and L. O. Eriksson.

17. **Daily feeding behaviour of Gilthead sea bream (*Sparus aurata*); effect of feeding method on growth and diet utilisation.**
M.J. Sánchez-Muros, M.D. Suárez, E. Milán and G. Cardenete.
 18. **Response of European sea bass in a 3-choice feeding**
M. Paspatis, D. Maragoudaki, M. Kentouri.
 19. **Influence of season and reward level on daily self-feeding patterns of European sea bass held in sea cages.**
J.L. Patiño, A. Sánchez-Mut, M. Azzaydi, M.C. Marín,
F.J. Sánchez-Vázquez and J.A. Madrid.
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Abstracts of oral communications

"Discovering complex repeated patterns in behavior and effects of experimental factors."

Magnus S. Magnusson

Human Behavior Laboratory
University of Iceland

This paper describes time structure models and corresponding pattern detection methods for the analysis of human and animal behavior. These models and computer methods have been developed over more than two decades in the context of human interaction research within ethology, psychology, psychiatry, and psychopharmacology. They have also been used in animal research including rodents and birds (notably, Feron, 1992; Filiatre, 1986; Martaresche et al., 2000). Analysis of fish behavior has not yet been attempted. As the models have been developed for human behavior, they have their roots in theoretical and empirical work with humans where it is implicitly and explicitly recognized that behavior holds a multitude of regularities such as regular repeated patterns that in practice may be hard or impossible to detect by unaided observers. This is, for example, witnessed by modern linguistics since people surely talked in much the same way long before any notion of grammar was invented while talk of such hidden structure would have been found absurd in early times.

The models presented assume that the behavior of an individual and/or of two or more interacting individuals consists of a real-time stream of events, many of which may occur in parallel (i.e., concurrently). Elementary behaviors (such as sniffing, licking, swimming, fanning, etc.) typically have some non-negligible duration, but the models are based on data concerning only their beginning (and possibly end) points where each individual may begin or end one or more behaviors at the same point in time. When two or more individuals are co-present at least some of the behaviors performed may be interrelated in a repetitive fashion. In some cases such relationships may be interactive and possibly causal. The behavior record or data thus consists of series of occurrence time points of event-types each of which is some actor's beginning or ending of some behavior (a point process). The data is thus a multivariate point process within an observation period.

The models are pattern types with some related terms. The recurrent rituals and routines of everyday human and animal lives inspired the basic pattern type, the t-pattern. Another inspiration is the hierarchical structure of speech patterns where phonemes combine to form words, which again are combined to form standard phrases, proverbs, poems, etc. The corresponding detection algorithms are aimed at the detection of hidden cases, i.e., the repeated occurrences of particular behaviors performed by one or more co-present individuals in a particular order (and/or concurrently). A further essential aspect of the basic pattern type is that the time distances between the involved behaviors are "significantly similar" over repeated pattern occurrences. Examples of such patterns are repeated "dances" or rituals, including greeting rituals, where causality may or may not be involved (see Magnusson, 1996, 2000). T-patterns have also been shown to be highly sensitive to external factors sometimes making t-pattern analysis a powerful means to detect effects of experimental variables (see Magnusson, 2000b).

If fairly complex patterns of this kind are present in data, they may be impossible to detect through the use of standard methods (see, for example, Keren, 1993 a and b) found in the major statistical packages or in specialized behavior analysis software such as, for example, The Observer (Noldus, 1991) or GSEQ (Bakeman & Quera, 1995) basically because these tools were not made to search for this kind of pattern. This is why special software, Theme has been developed together with the models to search for t-patterns and the derived types.

The specially developed fully automatic algorithms of Theme involve the search for "critical interval" relationships between all point series indicating their co-presence in repeated patterns. On the basis of such information, patterns are gradually detected bottom-up, level-by-level as all detected patterns are automatically added to the data. Combinatorial explosion problems are dealt with through competition between patterns where only the most complex patterns survive while many simpler ones are ignored when found to occur only as parts of more complex ones. More formal definitions of pattern types will be presented and illustrated with examples of hidden patterns detected in various types of behavior. Possibilities of use for the analysis of fish behavior will be discussed.

Bakeman, R. & Quera, V. (1995) Analyzing interaction: Sequential analysis with SIDS and GSEQ. New York: Cambridge University Press.

Feron, C. (1992) Les comportements socio-sexuels des souris stagers mâles: caractéristiques et effets de l'expérience sociale. Doctoral thesis, Université de Paris XIII, Villetaneuse, France.

Filiatre, J.-C. (1986) Contribution à l'étude des systèmes de communication chez un Canidé, *Canis familiaris*. Doctoral thesis, Université de Franche-Comté, Besançon.

Keren G. & C. Lewis, Ed. (1993a). A Handbook for Data Analysis in the Behavioral Sciences: Methodological Issues. Hillsdale, New Jersey, Lawrence Erlbaum Associates.

Keren G. & C. Lewis, Ed. (1993b). A Handbook for Data Analysis in the Behavioral Sciences: Statistical Issues. Hillsdale, New Jersey, Lawrence Erlbaum Associates.

Martaresche M., Le Fur C., Magnusson M., Faure J.M., Picard M. (2000) Time structure of behavioral patterns related to feed pecking in chicks. J. Physiology and Behavior, 70 (5): 443-451, 2000.

Magnusson, M. S. (1996) Hidden real-time patterns in intra- and inter-individual behavior: Description and detection. European Journal of Psychological Assessment, 12, 112-123.

Magnusson, M. S. (2000) "Discovering Hidden Time Patterns in Behavior: T-Patterns and their Detection." Behavior Research Methods, Instruments and Computers, 32(1): pp. 93-110.

Magnusson, M. S. (2000b) Diagnostic possibilities of behavioral time structure analysis: discovering group differences through statistical analysis of detected T-patterns. Poster at Measuring Behavior 2000, 3rd International Conference on Methods and Techniques in Behavioral Research, Nijmegen, Netherlands. Abstract retrieved March 28, 2001 from www.noldus.com/events/mb2000/program/abstracts/magnusson.html

Noldus, L. P. J. J. (1991) The Observer: a software system for the collection and analysis of observational data. Behavior Research Methods, Instruments & Computers, 23, 415-429.

Measuring feed intake with chemical markers and X-ray methods.

T. E. Pétursdóttir* and Ólafur Guðmundsson**.

*Agricultural Research Institute, RALA, Keldnaholti, 112 Reykjavík, ICELAND.

**Feed, Seed and Fertilizer Inspectorate, Keldnaholti, 112 Reykjavík, ICELAND.

Three methods of measuring feed intake were compared. Chemical marker method with internal marker a) n-alkanes (dotriacontane (C₃₂)) mixed into the pellets, b) n-alkanes (hexatriacontane (C₃₆) sprayed on the outside of the pellets and an X-ray method with glasbeads mixed in the feed. Four hundred Arctic charr, mean weight of 175 g, was fed in the morning, an exact weight (5 g) of the marked feed with a third n-alkane type (octacosane (C₂₈)), as an external marker inside the pellets. During the day the charr was then fed the internal markers both inside the pellets and sprayed on the outside of the pellets. This was continued for 14 days and faeces collected in the Guelph faecal collection system for the last 7 days. Feed and faeces were analysed for n-alkanes. Feed intake was calculated from the ratio of internal and external markers in feed and faeces. The fish was fed a days rations with glasbeads three times with two days interval. The fish was X-rayed at the end of each day and feed intake calculated from the number of glasbeads in the fish.

There was a loss in the marker, which was sprayed on the readymade pellets but feed intake did not differ statistically between the chemical marker methods. There was a significant difference between the chemical marker method a) and X-ray method but not between chemical marker method b) and X-ray method.

We conclude that spraying readymade pellets with n-alkanes as a chemical marker is a useful tool for measuring feed intake.

Monitoring the triggering activity of individual fish with a self-feeding system. Preliminary results in European sea bass, *Dicentrarchus labrax*.

Denis Covès & Gilbert Dutto

Station Expérimentale d'Aquaculture Ifremer. Laboratoire de Recherche Piscicole de Méditerranée. Chemin de Maguelone. F-34250 Palavas-les-Flots.

Two successive experiments were carried out with 2 groups of individually PIT-tagged seabass (initial average body weight and CV: 299 g, 15 % and 157 g, 13 %). Each groups of 50 fish were stocked in 1 m³ tanks and submitted to 21-22 °C temperature and 16h-L/8h-D photoperiod during respectively 55 and 57 days. A computerised on-demand feeding system coupled with a PIT-tag monitoring device was used to continuously record the triggering activity of individual fish among each group.

Respectively 95.7 % and 95.4 % of the whole rewarded demands were associated with a PIT-tag detection. Each individual has been detected while 67 % and 74 % of each group members have actuated the trigger at least once. Only two (males) individuals in the first group and one (female) in the second one accounted respectively for 82 % (42+39) and 77 % of the total delivered feed. These 3 individuals did not exhibit a specific growth nor an agonistic behaviour (demonstrated by video monitoring) and stayed at the same weight rank all along the experiments.

These preliminary results in sea bass differ from data previously published in Arctic charr and in rainbow trout (Brännäs and Alanärä, 1993; Alanärä and Brännäs, 1996) where the demand feeders were predominantly monopolised by the highest-ranked fish under low stocking densities.

Thursday the 16th of August 11:00

The pulse dose marker method in fish nutrition research

H. R. Kristiansen* & T. E. Petursdottir**

*Aqualife, Denmark, ** Agricultural Research Institute, RALA, Iceland

The main objective was to apply the pulse dose marker method (PDM) in experiments with fish, which to our knowledge has never been tried before. We will be able to quantify faeces production postprandially on an hourly basis in a Choubert faeces collector and quantify the variation in pulse dose marker concentration during 37 h. Based on the time lag, shape, peak(s) and duration of the marker excretion period it will be possible to recommend how future feed intake studies based on faeces output assessed by the pulse dose method should be conducted.

The PDM experiment is carried out in the period from 18-25 February 2000. Arctic charr *Salvelinus alpinus* (200 g) are used in a study design with eight flow-through tanks at 10-11 °C. Two types of feed is used: Non-marker feed and single marker feed (0.5 % chromic oxide). A sub sample of feed is frozen for quantification of the markers. The fish are adapted to the procedure by handfeeding non-marker feed at 3 hours interval from 8:30-15:00 for 5-7 days at the end of the acclimation period. Then a pulse dose of marker feed was given 10.00 AM the 19 February followed by regular feeding non-marker feed at daily intervals. Faeces was collected in the Choubert collector for 37 hours on an hourly basis in each of the eight tanks.

Marker analysis: Wet faeces is lyophilized in small plastic containers at ARI and transported to the laboratory facilities of Mobile Nutrients Ltd. at the Danish Institute of Agricultural Sciences (DIAS) in Foulum, Denmark. Wet weight of each faeces sample is obtained. A number of samples are selected and homogenized in a Retsch Mixer mill using a special procedure with small grinding balls for samples in the range of 30-250 mg. Homogenised samples are transferred to small plastic tubes with lid, vacuum dried at 50 °C for three hours and cooled in dessicator. Chromic oxide is analysed with the new bleach oxidation method, where 30 mg dry matter containing 0.5% chromic oxide is sufficient for a triplicate analysis. 10 mg samples were dry ashed in Duran test tubes at 500 °C and ignition loss was recorded. Then samples were wet oxidised with bleach simultaneously with triplicate standards in the concentration range from 0 to 5% chromic oxide. Chromic oxide in the samples was oxidised to potassium dichromate and after spectrophotometric determinations at 440 nm the standard curve was used to quantify chromic oxide in the samples.

The temporal variation in faeces excretion is shown for each of the eight tanks. The variation was between 0 and 250 mg dry matter per hour with few samples containing less than 30 mg dry matter. Thus the major number of samples contained sufficient dry matter for a triplicate chromic oxide analysis. Based on the dry wt. data cumulative faeces excretion curves were constructed. These were more or less linear and did not exhibit any pronounced diurnal or nocturnal patterns. The variation in pulse dose marker concentration showed some interesting trends. There was a lag phase of about 8-10 hours before the first marker was recorded. The duration of the marker excretion period was about 28 hours and there were two marker peaks with the maximum at about 23 mg chromic oxide per gram dry matter about 30 hours after the pulse dose meal.

***In vitro* digestibility based on trypsin activity of fish crude enzyme extract could predict feed quality in growth trial**

K. Rungruangsak-Torrissen^{1*}, A. Rustad^{1,2}, J. Sunde¹, S.A. Eiane^{1,2}, H.B. Jensen², J. Opstvedt³, E. Nygård³, T.A. Samuelsen³, H. Mundheim³, U. Luzzana^{4,5} and G. Venturini⁵

¹Matre Aquaculture Research Station, Department of Aquaculture, Institute of Marine Research, N-5984 Matredal, Norway (Phone: +47 56 366040; Fax: +47 56 366143; E-mail: Krisnart@imr.no); ²Department of Molecular Biology, University of Bergen, P.O. Box 7800, N-5020 Bergen, Norway; ³Norwegian Herring Oil and Meal Industry Research Institute, Kjerreidviken 16, N-5033 Fyllingsdalen, Norway; ⁴Istituto di Zootechnica, Facoltà di Medicina Veterinaria, Università degli Studi di Milano, via Trentacoste, 2, 20134 Milano, Italy. ⁵A.S.A. s.r.l.–Agridea, Viale del Lavoro 45, San Martino Buon Albergo, 37036 Verona, Italy.

In vitro digestion of different experimental feeds, based on trypsin activity of Atlantic salmon crude enzyme extracts, was studied in association with growth trials in order to investigate its value as a criterion for industrial strategy in predicting feed quality. Crude enzymes were extracted from the pyloric caeca before (day 0) and after 3 months (day 90) feeding. Significant differences in the *in vitro* digestibility between the experimental feeds should be observed if there would be potential growth differences within the next 3 months. In the growth experiment showing differences in feed conversion efficiency (FCE), a significant difference in the *in vitro* digestibility between the experimental feeds was observed by the enzyme extracts from day 0. On the other hand, in the experiment where differences in fish growth had not yet been observed, a significant difference in the *in vitro* digestibility between the experimental feeds was detected by the enzyme extracts from day 90. There were associations between the *in vitro* digestibility and other parameters for dietary quality, such as mink digestibility and biochemical structure of the dietary protein [reactive SH content, content ratios of SH/S–S and D-Asp as % of total (D+L)-Asp] due to different processing conditions.

Different fish species have different digestion ability to the same feed types, and effecting time for feed utilization and growth is dependent on fish sensitivity and the extent of difference in digestibility between the feeds consumed. For the species investigated, sensitivity ranking of the enzymes to feed quality under the condition studied was Atlantic salmon > rainbow trout > European seabass.

The results indicated that *in vitro* digestibility study of experimental feeds by using pyloric caecal (intestinal) crude enzymes extract from a specific species at an age of interest and based on trypsin activity could be a practical, quick and reliable method for testing feed quality in growth trials.

Financial support was from the European Commission through the project FAIR–CT96–1329: Effect of processing technology on the quality of aquaculture feeds (FISHFEED).

Thursday the 16th of August 11:40

How food intake in fish is modulated by water quality

Jeannine Person-Le Ruyet

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Fish growth is highly dependent on energy available for growth (= ingested energy-energy losses due to excretion and metabolic processes). Food intake (FI), defined as food consumption, is species specific and size dependent (it decreases as fish weight increases) and it may be affected by ecological factors, food availability, nutritional factors and any rearing conditions leading to the establishment of social interactions in a group. Captive fish cope with a deterioration of water quality using energy saving strategies at a behavioral, physiological and tissue level. Behavioral responses are a lowering of swimming activity and of FI related to the severity and the duration of the stress and, in practice, environmental manipulations are currently used by farmers to improve growth rate in order to produce economically fish of the best quality. This presentation in 3 points will be focused on the long-term effects of environmental factors on fish FI with reference to growth performances.

1-How FI changes versus water quality could be studied in fish ?

The different methods to estimate FI in a group of fish at a laboratory scale (controlled environmental conditions), in land-based systems (fluctuating environmental conditions) or under natural conditions (extensive rearing systems and coastal areas) are rapidly recalled. The experimental design used by the Ifremer group to study FI modulation versus water quality in seabass (*Dicentrarchus labrax*), turbot (*Scophthalmus maximus*), and to a less extent in rainbow trout (*Oncorhynchus mykiss*) is then after described. The main substance of the presentation is the long-term (1-3 month) feeding response of groups of 100-200 fish per experimental condition when access to food is not limited. All results referred exclusively to juvenile stages (first year class fish) without references to larvae or to maturing fish (FI is lowered during spawning season).

2- How fish FI is affected by water quality under stabilized environmental conditions ? Examples are taken from experiments conducted at Ifremer to determine the long-term influence of « determining » factors (temperature, salinity and photoperiod) or « limiting » factors (oxygen depletion, ammonia and CO₂ accumulation) using a comprehensive approach (growth performances, O₂ and N metabolism, physiological status of fish). These ecological factors maintained at constant levels were tested one by one, under apparent unrestricted feeding conditions.

- Temperature is a major « determining » factor controlling FI and consequently fish growth, and in a general way, when approaching the upper thermal tolerance limit for growth, a progressive decline in FI is observed. In turbot fed to apparent satiety, an increase in temperature lead to an increase in FI up to a plateau reached in the 17-20°C range and specific growth rates are correlated strongly with food intake. As seabass and turbot tolerate a large range of salinity and photoperiod, these 2 « determining » factors have minor effects on FI. Regarding salinity, a decline in FI is observed below the lower salinity tolerance limit, i.e. 5 ‰ in seabass and 10‰ in turbot (local salinity, 35‰). In seabass, the lack of day light alternance lead to a

decrease in FI and growth performances which is more marked under full darkness conditions than continuous illumination.

- Among « limiting » factors, oxygen is the major one. In seabass and turbot, FI and consequently growth are depressed under moderate (6 mg l^{-1}) and severe (4 mg l^{-1}) hypoxic conditions and suppressed by $3 \text{ mg l}^{-1} \text{ O}_2$. Conversely, the use of O_2 -supersaturated water has no significant effect on turbot FI. Food ingestion of fish is also strongly affected by a natural pollutant, ammonia. In seabass and turbot, FI are depressed as ammonia accumulates in water, threshold concentration for FI and growth have been established in the range $5\text{-}10 \text{ mg l}^{-1} \text{ TA-N}$ (total ammonia nitrogen) and feeding is definitely suppressed by $20 \text{ mg l}^{-1} \text{ TA-N}$. Rainbow trout in fresh water, responds to water quality in the same way as marine fish. In poor water quality (O_2 depletion + ammonia accumulation), voluntary FI is 30% lower than in high quality water while it is not markedly affected by the stabilized stocking density tested ($25, 75$ and 120 kg m^{-3}) suggesting the lack of major dominance hierarchy under the rearing conditions of the experiment, even at the highest density used..

3- To what extent FI is regulated under fluctuating and natural environmental conditions ?

Experimental data on the influence of environmental factor interactions on fish FI are rather rare. Laboratory studies and farm observations indicate that fish are more sensitive to fluctuating environmental conditions than to constant conditions. An environmental stability, more easily obtained in land-based systems than in sea cages, is required for regular FI. Under natural environmental conditions of farming, fish have to cope with the variability of the environment (circadian & seasonal rhythms) by continuous complex adjustments, the resulting disturbances in FI and the adaptative energy cost explain largely the loss in growth compared to optimal rearing conditions.

In the last point of the presentation, comparisons of FI modulation under stabilized or fluctuating environmental conditions will be made with available data for other fish species. Fish feeding adjustments will be discussed with regards to the kinetic of feeding response (immediate response, short-term and long-term regulation of FI). The role of neuro-hormonal factors in the regulation of FI and the importance of physiological and metabolic mechanisms controlling fish appetite in fish are also recalled. To conclude, in a general way, fish responds to an environmental stress or deterioration in water quality by a lowering of FI (dose and time related) without most often any change in food utilization efficiency. 3 ecological factors have major effects on FI and consequently on somatic growth: temperature out-with the thermal optimal range, oxygen below a threshold of about 80% air saturation and ammonia above $5\text{-}10 \text{ mg l}^{-1} \text{ TA-N}$, while their interactions are not yet well understood.

Genetic and environmental effects on the growth of three stocks of Arctic charr (*Salvelinus alpinus*).

Helgi Thorarensen and Miguel Angel Montañez Ruiz
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The growth of Arctic charr from three Icelandic stocks was compared in several experiments. In its natural habitat, one of these stocks is migratory while the other two come from landlocked lakes. The initial mean body mass of the fish was 15-20g and they were grown for one year at three different temperatures - 5, 9 and 14 °C. The fish were individually tagged and came from full sib families. The best long-term growth of all stocks was at 9 °C. This is a lower optimum temperature than has been reported for this species in most previous studies. Although the stocks originated from different environmental conditions and employ different life history strategies, the growth of all stocks was similar. However, there were significant interactions between stocks and rearing temperature, suggesting that the action norms of the stocks are slightly different. Families, when used as a factor in an ANOVA, give an indication of the genetic effects on the growth of the fish. Families accounted for 15-30% of the total variance in body-mass at each temperature while stock differences usually accounted for less than 4% of the variance. In all stocks, there was a significant family and temperature interaction which suggest that some fish are genetically better suited for growth at high temperatures while other fish grow better at lower temperatures.

Genetic and environmental effects on the size of the cardio-respiratory organs in Arctic charr (*Salvelinus alpinus*)

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The relative heart size of many species of fish is plastic and depends on factors such as environmental temperature, sex, maturity, activity level and routine oxygen consumption. Less is know about the plasticity of gill size. The aim of this study was to evaluate the significance of environmental (temperature) and genetic factors on the size of hearts and gills in Arctic charr. Fish from two different stocks, one being anadromous and the other landlocked, were reared for one year at 5°, 9°and 14°C, and gills and heart sizes were measured at the end of the experiment. The fish were individually tagged and came from several full-sib families, thus allowing estimation of genetic effects on heart and gill mass.

Temperature had a significant effect on relative heart and gill mass. The hearts of fish reared at 14 °C were comparatively larger than the hearts of fish reared at 5 °C. This is different from what is observed in temperate species, such as rainbow trout, where relative heart size increases at lower temperatures. Genetic effects on heart and gill mass were also observed. There were significant differences in the relative gill and heart mass of the two stocks. Moreover, there were significant differences in the heart and gill mass of different families, suggesting that there exists a significant genetic variability in these traits within each stock.

Thursday the 16th of August 14:20

Parallel sympatric segregation in arctic charr and threespined stickleback in Lake Galtarból, Iceland

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Two sympatric forms of arctic charr, and threespined stickleback co-occur in Galtarból, an isolated lake in NW Iceland. Both species are found to have a larger fusiform limnetic/benthic form with generalised feeding habits and a more stocky bodied benthic form with more specialised feeding habits. It is suggested that this is an example of parallel sympatric segregation of arctic charr and threespined stickleback, and this has been made possible by habitat complexity and the absence of other fish species.

Dietary and morphological divergence of Icelandic threespine stickleback (*Gasterosteus aculeatus* L.) towards mud and lava substrate in lakes.

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In the past decades there has been increased interest among scientists on the evolution of diversity in ecology, morphology, physiology and behaviour within species. Freshwater fish are particularly interesting in this respect. Icelandic freshwater systems have highly diverse habitats with only six species of freshwater fish, offering unique opportunities to study the evolution of diversity and how it relates to speciation. Elsewhere, research has shown threespine sticklebacks to be highly variable in morphology, physiology and behaviour. In some cases this variability has lead to the formation of new species. Icelandic sticklebacks are highly diverse with indications that two different forms, adapted to two different habitats, occur in several lakes. This makes the sticklebacks a good candidate for a study on ecological and morphological adaptations.

This study focuses on dietary differences related to morphological divergence of threespine sticklebacks towards two distinct substrates types, lava and mud. We collected sticklebacks from four lakes to examine dietary and morphological divergence of sticklebacks and possible morph formation. We also examined parallel patterns in diet and morphology of stickleback from each habitat among lakes could be detected. Icelandic stickelbacks were found to be highly diverse in their diet and morphology, and in all the lakes studied some divergence in morphology and/or diet between the two substrate types was observed. These results provide further understanding on the adaptation of animals to distinct ecological factors. Such a process is important for revealing the origin of biological diversity.

Feed Delivery Rate in Rainbow Trout (*Oncorhynchus mykiss*) Production

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The number of feed portions per day, the time between portions, and the size of each portion all play important roles in the feeding schedule and should be considered when feeding fish at various temperatures. Groups of rainbow trout, *Oncorhynchus mykiss* (Walbaum), were fed at various intensities in terms of number of pellets per fish at 5°, 10°, and 15°C. In order to evaluate the performance of fish at various feeding intensities, growth rate (Thermal Unit Growth Coefficient, TGC), feed conversion ratio (FCR), and coefficient of variation of TGC (CV_{TGC}) were combined into a numerical index, where a high value corresponds to high TGC and low FCR and CV_{TGC} . Optimal feeding intensity was generally higher at higher temperatures. At 5°C the index was highest when fish were fed at an intensity of 0.52 pellets per fish·portion⁻¹. At 10°C a feeding intensity of 1.89 pellets per fish·portion⁻¹ gave significantly greater growth rates than all other groups while minimising FCR and CV_{TGC} . At 15°C good growth was achieved at a feeding intensity of 2.82 pellets per fish·portion⁻¹. In general, FCR increased with increasing feeding intensities while TGC tended to decrease. CV_{TGC} decreased with increasing temperatures. Recommendations are made with respect to practical application in aquaculture.

Feed intake in relation to workload and diet composition.

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By exposing individually PIT tagged chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*) to different water currents for either 70 or 240 days in 2.4 m diameter swimming channels equipped with feed waste collectors (detailed in Kiessling *et al.* 1994) effects of varying work loads on group feed intake was investigated. In addition dietary energy was manipulated by giving a reduced ration level (RL) to *O. tshawytscha* and varying dietary lipid and carbohydrate levels in iso-nitrogenous and iso-energetic diets to *O. mykiss* (caloric equivalents; protein, 5.65, lipid, 9.45 and carbohydrate, 4.1 kcal/g).

O. tshawytscha responded to an elevation in swim speed of 1.0 bl/sec with a 20% increase in feed intake. This increase in energy intake was sufficient to both hold position in the channel and maintain growth but led to an increased feed conversion. This effect was independent of ration level (Kiessling *et al.*, 1994). *O. mykiss* showed no significant increase in feed intake but instead a significant reduction in growth with elevated swim speed. An elevated feed conversion of *O. mykiss* indicates that a larger proportion of ingested food was used to support the increased workload. Replacing lipid in the diet with carbohydrate reduced growth even further.

We conclude:

- That physical workload is a strong modulator of feed intake in *O. tshawytscha* but not *O. mykiss*.
- That in spite resulting in negative energy balance (measured as reduced growth) lipid substitution with carbohydrate on an iso-energetic basis did not significantly stimulate feed intake in *O. mykiss*.

The biological rationale for this inter species difference is difficult to discern as *O. mykiss* has an inferior swimming capacity and therefore should have an even greater need to compensate an elevated workload by increasing its energy intake compared to *O. tshawytscha*. Amongst other things one can speculate that *O. mykiss* lacks the ability of *O. tshawytscha* to increase the oxygen carrying capacity of the blood in response to elevated workloads, allowing both a maintained intestinal and increased muscular blood flow (Thorarensen *et al.*, 1992) and thereby supporting a maintained or even increased digestion. An alternative interpretation could be that the domestication process aimed at improved growth and also most likely feed intake is more marked in *O. mykiss* which thereby could be close to the upper limit of its ingestion capacity already in the artificial farming situation of low workload and abundant supply of high energy feed.

Kiessling, A., Higgs, D.A., Eales, J.G. and Dosanjh, B.S. 1994. Can. J. Fish. Aquat. Sci. 51:1975-1984.

Thorarensen, H., Gallagher, P. E., Kiessling, A. K., and Farrell, A. P. 1993. J. exp. Biol. 179:115-129.

Culture conditions and spatial distribution : swimming patterns under high density in recirculating tanks around self-feeding events.

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Fish culture in recirculating tanks under high density still is an innovative method. Under the framework of EUREKA EU1 960 "Aqua-Maki 2" project, different aspects of this cultivation process were examined in order to improve the method. Among them, swimming activity of seabass was studied using acoustic telemetry to measure fish movements in the tank. A production recirculating hexagonal tank (5.4 x 5.4 m, 1.8 depth, 48 m³) was equipped with a high accuracy acoustic positioning system, a computerised demand-feeding system, oxygen and temperature probes. Initial density was 50 kg m³ in Mars (12 000 fish, mean weight 200 g) and rose to 90 kg m³ at the end of the experiment in May. A group of 9 fish was implanted with acoustic transmitters in the abdominal cavity. During this period, each single fish movements were continuously recorded for 24 hrs reaching a total of six 24 hrs-episode at 8 days interval. Swimming activity was analysed in terms of activity rhythms and space occupation specially around feeding events in order to assess fish behavioural plasticity under these particular culture conditions.

Thursday the 16th of August 16:20

***Solea senegalensis* production in mono and policulture fish ponds of Sado Estuary**

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The *Solea senegalensis* culture was developed in the Sado Estuary fish culture units in mono extensive and in policulture semi intensive conditions. The growth of this species and the importance of the bentic organisms in the litoral ecosystems are related in quantity and quality. Also the biochemical composition of Solea and *Polychaeta* its preferencial food is compared.

Friday 17th of August 9:00

Cannibalism in cultured fishes: Why eating conspecifics, what can we learn from it and how can we mitigate it ?

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Cannibalism is a frequent phenomenon in fishes, especially in culture environments where fish can't escape predation through size-dependent habitat segregation or migration. Not all cultured fish species start exerting cannibalism at the same age or size nor is cannibalism equally intense in different species or at different life stages of the same species. Predator to prey size ratios also vary substantially between species and life stages, chiefly as the allometric growth of mouth parts governs the logistics of cannibalism, and the development of sense organs, hard body parts, swimming and escape capacities in predator and prey determines further prey size selectivity. The dynamics of cannibalism is ruled by these factors, as well as by exogenous, biotic or abiotic factors that influence feed intake, growth depensation and facilitate or complicate the exercise of piscivory. The knowledge of cannibalistic behaviour, logistics of cannibalism, enhancing environmental factors and their variation during the fish's ontogeny is a pre-requisite to the mitigation of cannibalism in aquaculture. Also, within the context of strain selection, it is of importance to determine whether cannibals are natural-born killers or just lottery winners. Aside of these aspects, the study of predation in general, and cannibalism in particular provides an excellent means for precise investigations of feed intake in fish, as food is adequate, available 24-7, and easily numbered, and this applies particularly to early life stages where other feed intake measurement techniques are less accurate or can't be applied on a regular basis. Here, I present a mini-review of these factors, chiefly as they apply to intracohort cannibalism, as well as suggested guidelines for cannibalistic risk assessment and possible mitigation of cannibalism in new cultured fish species.

Key words: cannibalism, ontogeny, behaviour, feed intake, growth, aquaculture

Influence of feeding frequency on feed intake and dominance in groups of Arctic charr (*Salvelinus alpinus*)

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When Arctic charr are reared in a group there will occur a considerable size distribution within each group after a while. It has been suggested that the reason for this size distribution is the development of dominant hierarchy in the groups. Larger fish will dominate and get the most of the feed and keep the smaller fish from eating and growing. This experiment was constructed to examine the influence of different feeding frequency on feed intake and the formation of hierarchy of individuals in rearing groups of Arctic charr. The fish was fed either 24 hours a day, twice a day, once a day or once every other day. The experiment lasted for 130 days. Growth was measured by individual weighing of fish and feed intake of each individual was measured by the X-ray method (Talbots and Higgins, 1983) four times during the rearing period. Size distribution within the rearing groups, mean share of individuals in the group meals and the relationship between the mean share of the group meal and the coefficient of variation of consumption was used to assess the development of hierarchy within the groups. The results show that the feeding frequency did not influence size distribution except for the groups fed for 24 hours a day. In those groups the coefficient of variation was higher than in other groups. Feeding frequency did not influence growth rate of the fish except in the group that was fed only once every other day. There the growth rate was lower than in the other groups. Feeding frequency did not affect the development of hierarchy. Few individuals in each group consumed the biggest share of each meal but in consecutive measurements there were never the same individuals that received the biggest share. Furthermore the relationship between the coefficient of variation of feed intake and the mean share of each meal was weak and as much positive as negative. Surprisingly the results did not show a positive relationship between growth rate and feed intake of the individuals in each group. The result showed also that many individuals had an empty stomach when feed intake was measured, especially in the groups that were fed for 24 hours a day. The results raise questions about the use of the X-ray method in feed intake measurements of a recently domesticated species as the Arctic charr. Wild animals eat when food is available. Which may not be every day. Thus they may eat big meals one day and small meals or nothing at all for one or two days afterwards. Measurement of feed intake of individuals for one day at long intervals will therefore not give an accurate picture of what is happening in the groups between measurements. The results showed a great difference between replicates within treatments. This implies high individual variation among the fish, even though they came from the same stock and were more or less related.

Friday 17th of August 10:05

The effect of feeding on aggressive behaviour and growth in juvenile rainbow trout, *Oncorhynchus mykiss*

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We investigated the relationship between aggressive behaviour and growth of juvenile rainbow trout. We compared groups of trout in two conditions. One condition had a defensible food source that allowed food monopolization. The other condition had a non-defensible food source that promoted scramble feeding. We gave the same amount of food to groups in both conditions. We recorded behavioural interactions of marked individuals in each group. We found higher, less variable fish weights in groups of trout with a non-defensible food source than in groups with a defensible food source. Aggressive behaviour decreased when we moved fish into different tanks. This disruption significantly altered size - ordered social aggressive interactions for fish receiving an non-defensible food source. Through their effects on social interactions, feeding regimes can have significant effects on growth, and hence production, in aquaculture systems.

Intracohort cannibalism: a time lagged lifeboat mechanism

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Cannibalism can have profound effects on population dynamics through the energy gain made by cannibals and through the mortality imposed on the victims. Fish populations with their inherent size-structure provide prerequisites for cannibalism as cannibalism generally acquires a size difference between cannibal and victim and cannibalism is commonly reported in fish. Intra-cohort cannibalism, the consumption of individuals born at the same year, has mainly been observed under cultivation conditions or in laboratory but have rarely been observed in natural systems. In this study we explore mechanism how intra-cohort cannibalism arise in field and its consequences on individual growth and survival. Diet, growth and survival of a newborn cohort of perch (*Perca fluviatilis*) was studied to the age of one year in a small low productive lake. Gape-limitation in perch larvae and a dominance early in the season of large bodied zooplankton (*Holopedium*) caused an increase in the size variation of young-of-the-year (YOY) perch as large perch larvae were able to feed on *Holopedium* and grew at their maximum rate. In contrast smaller perch larvae were unable to feed on large *Holopedium* due to gape limitation and showed a reduced growth. When zooplankton abundance decreased to very low levels in July intracohort cannibalism was observed where the largest YOY perch cannibalized on the smallest members of the cohort. Intracohort cannibalism was observed through out July as size difference between cannibals and victims was upheld as cannibals continue to grow at high rates whereas small YOY perch grew slowly due to lack of suitable prey (zooplankton). The zooplankton resource increased in abundance in August and cannibalism was not observed from August and onwards. At the end of the growth season cannibal weight was 2-4 times higher than that of non-cannibals. Due to strong size selective winter starvation mortality directed to smaller individuals only 7% of all YOY perch survived the winter. The corresponding estimated survival for cannibals was 30%. Our results suggest that strong size-dependent relationships between YOY fish and their resources may initialize large size variation within a cohort that promotes intracohort cannibalism. When resource levels decreases intracohort cannibalism may ensure high growth rates necessary to reach sizes large enough to survive later periods of resource limitation (e.g. winter conditions).

Friday 17th of August 11:05

Behavioural deficits in farmed brown trout (*Salmo trutta*)

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Brown trout (*Salmo trutta*) is a species that has a wide natural distribution and are important in the recreational fisheries in Europe and North America. To meet the increasing demand of fishing, huge numbers of trout are annually stocked in natural waters by managed fisheries. There are, however, many examples on poor survival rates of farmed fish in natural waters, and many studies indicates that these problems are related to behavioural deficits.

In this paper we present data from three different studies, where the territorial, feeding and anti-predatory behaviours are compared in wild and hatchery-reared brown trout. The territorial and aggressive behaviour differs dramatically between wild and farmed trout. Wild individuals were always dominant over farmed ones, and the strength of aggression differed considerably. The aggression by wild trout are characterised by few but very intense and powerful attacks, whereas the aggression in farmed fish are much more frequent in numbers and very light in strength (e.g. nips). A consequence of this is that the mortality rates is high when the dominant fish is of wild origin, whereas no mortality occurred among hatchery-reared fish.

Wild trout have a significantly higher feeding rate than hatchery-reared fish, when given natural prey items that drifts with the water current. The low feeding rate in hatchery-reared fish resulted in negative growth rates.

Hatchery-reared trout expose themselves significantly more and are more risk prone than wild trout. The ability to balance predation risk against foraging is of crucial importance for the long-term survival of juvenile fish, and farmed fish probably increase the risk for predation substantially by spending too much time outside shelter. Wild trout always responded to threats by different anti-predatory behaviours, where the two most common ones were freeze or refuging. On the contrary, hatchery-reared trout showed a very high degree of non-adaptive anti-predatory behaviour.

These experiment clearly shows that hatchery-reared trout have severe deficiencies in territorial, feeding and anti-predatory behaviours. This will decrease their ability to get established and survive in natural habitats. The possibility to adapt fish to natural environments by different measures within the hatchery environment will be discussed.

Patterns of Feeding and Social Interactions in cages of Gitlhead Sea Bream (*Sparus aurata*), European Sea Bass (*Dicentrarchus labrax*) and Atlantic Salmon (*Salmo salar*)

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Feeding patterns of fish in aquaculture production cages have proven difficult to monitor continuously over long periods, primarily due to technological limitations and the difficulties of carrying out behavioural data collection within a commercial aquaculture operation. Recent advances in feeding technology and in particular the introduction of demand feeding systems suited to large cages have meant that this 'gap' in the scientific literature is beginning to be filled, with long term data from Atlantic salmon cages having recently been reported. While Atlantic salmon production is concentrated in the cooler areas of Northern Europe however; sea bass and sea bream are the most important species for Southern European cage aquaculture. Information on feeding patterns and behaviour of these warm water species in cages is not available in the current scientific literature

In the present paper we describe studies of sea bream, sea bass and Atlantic salmon in cages, examining natural appetite rhythms as well as using video observation to assess variation in social and foraging behaviour of the fish when fed by demand vs. standard feeding regimes. The data was collected from 3 different fish farms in Spain (Sea bass), Greece (Sea Bream) & Scotland (Atlantic salmon). Findings will be presented and discussed in terms of feeding patterns, how these relate to other behavioural data and their implications for aquaculture.

Friday 17th of August 11:45

Effects of dietary L-tryptophan on agonistic behaviour and stress responses in juvenile rainbow trout

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In a recent series of experiments we have found that the addition of the amino acid L-tryptophan (TRP) to fish feed leads to a significant reduction of intraspecific aggressive behaviour in rainbow trout (*Oncorhynchus mykiss*). The amino acid L-tryptophan (TRP) is the precursor of the monoaminergic neurotransmitter, serotonin (5-HT), and the rate of 5-HT synthesis appears to be restricted by TRP availability. We observed elevated plasma and brain levels of TRP in fish given TRP supplemented feed as compare to controls. Moreover, brain levels of 5-hydroxyindoleacetic acid (5-HIAA, the major 5-HT metabolite), as well as 5-HIAA/5-HT ratio (an index of 5-HT activity), were increased in fish fed TRP supplemented feed. Behavioural effect of 5-HT are well documented in both teleost fish and mammals, and the consensus is that 5-HT mediates a general behavioural inhibition, including the reduction of aggressive behaviour. Brain 5-HT is also involved in the control of the hypothalamic-pituitary-interrenal (HPI) axis. In another experiment we found that feeding fish TRP supplemented feed for one week significantly lowered plasma levels of cortisol in fish subjected to a standardised stressor, lowering of the water level. In aquaculture, stress as a result of handling, transport and prophylactic treatment is unavoidable. Additionally, intraspecific aggressive behaviour, and the formation of social dominance hierarchies, may constitute a substantial problem for the rearing of fish at high densities in aquaculture systems, and raise a number of problems concerning both production and animal welfare. Providing feed with increased TRP could prove an interesting aquaculture management strategy, especially during periods of feed restriction. The effect of dietary TRP will be most pronounced in dominant individuals, who consume the larger part of the feed offered. Therefore the tendency to develop strong dominance hierarchies will be diminished. Consumers generally react negative to food additives like hormones and drugs used for the purpose of increasing growth and performance of animals kept for food production. However, modifying the amino acid composition is not expected to create such problems, since amino acids are natural constituents of feed, as well as of fish and all organisms.

Stressful environments and food assimilation: Gut blood flow and gut feelings

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In intense aquaculture, fish face many metabolic challenges beyond those of simply feeding and growing. Changes to the pattern of circulation are central responses to these metabolic challenges. For example, under controlled laboratory conditions fish display postprandial increases in gut blood flow (GBF) and oxygen uptake that service the processing and assimilation of food (e.g., gut motility, membrane transport and intracellular biochemical activity), as well as ensuring a timely transfer of absorbed substances from the intestine to the liver. However, in stressful environments fish may have to compromise food assimilation because there is a finite limit to what the circulatory system can do. Based on what we know of integrated cardiovascular control in mammals, the gut, unlike the brain and heart, is not a priority circulation. Thus, by being low on the circulatory totem pole, GBF could decrease when the fish are stressed or are forced to chase other fish for food in an aquaculture environment. This could result in sub-optimum food conversion and growth rates. In addition to my own gut feelings, this paper examines what is known about how stressful swimming and hypercapnic stress affect GBF in fish (see Farrell et al. 2001 for the full expose).

Blood flow to the gut circulation has been measured using both direct and indirect methods. However, indirect methods using colored or radiolabelled microspheres have yielded lower, as well as unreliable values for GBF than direct measurements. This paper therefore is based on direct measurements of GBF with Doppler, electromagnetic and Transonic flow probes that have been recorded in white sturgeon (*Acipenser transmontanus*), chinook salmon (*Oncorhynchus tshawytscha*), Atlantic cod (*Gadus morhua*), sea raven (*Hemitripterus americanus*) and red Irish lord (*Hemilepedotus hemilepedotus*) and dogfish (*Squalus acanthias*).

The gut circulation normally receives 30-40% of cardiac output in unfed fish and is under a tonic α -adrenergic vasoconstriction. The postprandial increase in GBF, which can range from as little as 42% to > 100% of cardiac output at 24-h, involves a release of this α -adrenergic tone and a possible involvement of tachykinins. The postprandial increase in GBF lasted four days with large meals in red Irish lord (10-15% body mass at 7-9°C), but had returned to pre-feeding levels by 36 h in chinook salmon fed 2% of body mass at 8-11°C. Meal size, water temperature and species-specific differences are all expected to influence the time course and extent of the postprandial increase in GBF.

Whenever fish struggle, GBF is reduced through an intensified α -adrenergic vasoconstriction. (In fact, avoiding such responses is a major problem in obtaining reliable records of routine GBF). Even minor struggles can cause an almost complete cessation of GBF and it may take 20 min for routine GBF to recover after prolonged struggling behaviours. Importantly, there is no compensatory increase in GBF following a struggle (reactive hyperemia). Thus, in aquaculture settings where fish struggle a lot, this may mean the food absorption is delayed with each struggling

event and growth is sub-optimum. However, although GBF has been observed to decrease with struggling in fed fish, this response has not been properly quantified.

Continuous aerobic swimming also decreases GBF in unfed fish by upto 60%. This decrease in GBF has been directly related to the locomotory increase in oxygen uptake. However, both rainbow trout and chinook salmon had a lower critical swimming speed postprandially compared with starved fish even though maximum oxygen uptake was the same for both the fed and fasted fish. This suggests indirectly that GBF is spared to some degree when fed fish swim continuously but at cost (10-15%) to their critical swimming speed. Also, exercise-trained chinook salmon were better able to spare GBF during swimming. Thus, a fish's athletic fitness apparently influences GBF control. This could be important information for rearing salmon in fish enhancement programs in that it may be possible to pre-train or habituate fish to certain environments.

Severe respiratory acidosis (hypercapnia) can be created by the new intensive aquaculture settings that use oxygen injection into re-circulated water. White sturgeon are cultured under such conditions in California, and though hypercapnic white sturgeon are stressed (they have high plasma cortisol and catecholamine levels), they apparently tolerate the hypercapnia because routine GBF and gut vascular resistance are no different compared with normocapnic fish. However, hypercapnic sturgeon become hyperactive, struggling three-times more frequently than normocapnic fish, and routine GBF takes more than twice as long to be restored after a struggle compared with normocapnic sturgeon. We predict that this hyperactivity and hypersensitivity of the gut circulation would have adversely affect food assimilation.

In summary, the stresses of swimming, struggling and hypercapnia can adversely affect GBF in unfed fish. While GBF may be spared to some degree in fed fish during swimming, hypercapnic stress may be more problematic. The implications of these sorts of changes in GBF to food assimilation have yet to be studied.

Acknowledgements

Thanks are extended to my collaborators (Helgi Thorarensen, Michael Axelsson, Carlos Crocker, Kurt Gamperl, Suzanne Holmgren, Stefan Nilsson and Joe Cech Jr.) without whom these studies of GBF in fish would not have been possible. My research is supported by grants from the Natural Sciences and Engineering Research Council of Canada.

Reference

Farrell, A.P., M. Axelsson, H. Thorarensen, C.E. Crocker, A.K. Gamperl and J.J Cech Jr. 2000. Gut blood flow in fish during exercise and severe hypercapnia. *Comp. Biochem. Physiol. A.* 128, 551-563.

Growth hormone, growth, behaviour and ecological consequences in salmonids

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Growth hormone (GH) is the major growth-promoting hormone in vertebrates. It stimulates cell growth and proliferation, directly and/or indirectly through growth factors, increases protein accretion and mobilizes energy through lipolysis. Thus, GH-treatment normally results in leaner, fast-growing fish.

In a number of experimental studies, we've shown that GH has various behavioural effects in salmonids. Both GH-treated and GH-transgenic fish have increased ability to compete for food as well as increased appetite (Johnsson & Björnsson 1994, Devlin *et al* 1999). Laboratory experiments on GH-treated salmonids reveal that this is associated with increased aggression, swimming activity and decreased predator avoidance (Johnsson *et al* 1996a,b, Jönsson *et al* 1996, 1998). It is notable that GH-induced behavioural changes in wild brown trout mimic normal behaviour of domesticated conspecifics (Jönsson *et al* 1996), and domesticated Atlantic salmon may have higher pituitary GH content than wild salmon (Björnsson *et al* in prep).

As GH affects both growth and behaviour, ecological consequences could be expected, which are relevant to interactions between wild and domesticated (or GH-transgenic) fish in nature.

Sustained-release GH treatment of brown trout in both semi-natural (Johnsson *et al* 1999, 2000) and natural streams (Johnsson & Björnsson, in prep), shows that GH has clear growth promoting effects in nature, while survival is not adversely affected. This indicates that growth-enhanced fish can be competitive in nature.

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Johnsson & Björnsson 1994. *Animal Behav* 48:177-186

Johnsson, Jönsson & Björnsson 1996. *Horm Behav* 30: 13-21

Jönsson, Johnsson & Björnsson 1996. *Proc Royal Soc London B* 236: 647-651

Johnsson, Petersson, Jönsson, Björnsson & Järvi 1996. *Can J Fish Aquat Sci* 53: 1546-1554

Jönsson, Johnsson & Björnsson 1998. *Horm Behav* 33: 9-15

Devlin, Johnsson, Smailus, Biagi, Jönsson & Björnsson 1999. *Aquacult Res* 30: 479-482

Johnsson, Petersson, Jönsson, Järvi & Björnsson 1999. *Funct Ecol* 13: 514-522

Johnsson, Jönsson, Petersson, Järvi & Björnsson 2000. *J Fish Biol* 57: 326-336

Friday 17th of August 15:05

Food intake and the neuropeptide Y system of juvenile rainbow trout.

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The brain plays an important role in controlling food intake. Information about nutrient stores, satiety, and palatability of food can be conveyed to the brain via endocrine hormones, metabolic signals or neural pathways connecting the brain and periphery. Central mechanisms involved in appetite regulation have been well-studied in mammals, largely due to the search for potential pharmacological treatments aimed at weight control in humans. These studies also have been motivated by the need for controlling feed intake in livestock. Appetite regulation is also an important factor in the culture of fishes and is likely controlled by similar mechanisms as in other vertebrates. Neuropeptide Y (NPY) is expressed abundantly throughout the central and peripheral nervous system in all species investigated, and is important in terms of social and environmental cues triggering neuroendocrine events. This peptide is responsive to various types of stress, feeding, aging, steroids, and circadian rhythms. Neuropeptide Y is important in the central regulation of appetite, sexual behavior, reproductive function, and puberty. This peptide is also thought to be the link between feeding and reproduction in times of unfavorable metabolic conditions. The study of NPY as a tool in aquaculture is relatively new but could prove to be invaluable in improving feeding in cultured fishes. In order to investigate the role of NPY in feeding in an aquaculture species, we quantified NPY-receptor densities in various brain regions of fed and starved juvenile rainbow trout (*Oncorhynchus mykiss*). Visually isolated fish were either fed daily to satiation or starved for one month, after which they were sacrificed, blood samples and brains collected and frozen. Peptide YY (PYY), which binds cleanly to all NPY receptor subtypes, was labeled with ¹²⁵I and applied to *O. mykiss* brain sections to determine receptor distribution. Distribution of peptide as well as plasma levels of cortisol and NPY will also be measured. Autoradiography indicates upregulation of NPY receptors in starved fish. Starved fish show greater binding of PYY in the hypothalamus than do fed fish. This indicates that NPY receptors are upregulated in fish that are food deprived and suggests that NPY plays a role in feeding in fishes as it does in other vertebrates.

Adiposity and Growth of Post-smolt Atlantic Salmon, *Salmo salar*

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The adipose tissue houses the largest energy reserve of the body. Adipocytes maintain stores of fat that are replenished in times of plenty and mobilised in times of nutritional deficit. Moreover, under normal feeding conditions mammals (and possibly fish) seem to have the ability to maintain body adiposity within relatively narrow limits, resulting in a long-term adipose homeostasis. This represents a balance between energy intake, regulated by feeding, and energy expenditure, which may involve modulation of metabolic rate, growth and reproduction. Long-term adipose homeostasis, coupled to the control of fat mass, gives rise to a 'lipostatic' model in which signals produced in proportion to fat stores serve to regulate long-term energy intake. An extension of this model might also predict an impact of these signals on energy utilization and growth; either directly, or indirectly via the regulation of feeding. The prediction was tested via monitoring fat deposition and growth among groups of Atlantic salmon, *Salmo salar*, provided with feeds that differed in fat content.

Atlantic salmon parr (Mass *ca.* 20g) were fed either high- (HF: 34%) or low-fat (LF: 22%) feeds for several months to create groups of fish that differed in adiposity at the time of the parr-smolt transformation (Mass *ca.* 115g). This was confirmed by measurement of fat concentrations in three body compartments; fillet, viscera and remaining carcass. Fish were transferred to sea water (*ca.* 35‰, 8°C, 24L:0D), and growth was monitored over the following 14 weeks. During the on-growing, seawater phase different groups of fish were fed on either high- or low-fat feed, giving the following treatments: HF→HF, HF→LF, LF→LF, LF→HF. Samples of fish were taken at regular (*ca.* 3 week) intervals for analysis of fat depots in the three body compartments.

Fish that were fed the same feeds during on-growing converged towards similar levels of adiposity over time. Further, the results were in general agreement with predictions from the 'lipostatic' model, in that fish with the greatest fat reserves following the parr-smolt transformation tended to grow slower than fish that were 'leaner' at this time.

Friday 17th of August 16:05

Lipostatic regulation of voluntary feed intake in fish

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Work we have presented at previous COST 827 workshops suggest a role for accumulated energy reserves in appetite regulation in Atlantic salmon, and we have developed a model whereby feed intake may be regulated in response to changes in patterns of lipid deposition in an attempt to maintain the energy status of the fish.

A test of this lipostatic model was carried out on groups of fish in which lipid content had been manipulated by feeding feeds of different lipid concentration. Thereafter the fish were offered both lean and lipid rich diets simultaneously. Our hypothesis was that when given a choice of feeds the groups of fish that initially differed in lipid status would gradually converge with respect to body lipid content. In other words, feed intake and feed preferences should provide a reflection of the current state of energy storage.

Data are currently being processed. The results will be presented both as a talk at the final COST 827 workshop, and as a full paper in the proceedings in Aquaculture Research. A revised abstract for the book of abstracts will be submitted before the deadline of 01.05.01.

Saturday 18th of August 9:00

Macronutrient self-selection in European sea bass using macroencapsulated nutrients

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Macronutrient self-selection has been demonstrated in fish simultaneously presented with diets of different macronutrient composition. From these studies, we have learned that goldfish, rainbow trout and European sea bass exposed to incomplete food sources are able to combine them to put together a complete diet adapted to their particular physiological needs. However, the widely different oro-sensory features of the diets used in these experiments may have masked the real selection patterns. The aim of the present paper is to describe our experimental protocol and report preliminary results on macronutrient intake regulation, using pure macronutrient-loaded gelatine capsules of different colour, but otherwise entirely similar chemosensory and size properties. European sea bass, 39.86 ± 6.16 g in body weight, were kept in groups of 5 fish per tank and trained to ingest macrocapsules (n° 4, 0.2 ml) containing different nutrients. Depending on the experimental phase, the capsules were filled with powdered standard diet or a mixture of casein-gelatine (protein capsules), pollock visceral oil and soybean oil (fat capsules) or dextrin (carbohydrate capsules). All capsules were supplemented with vitamin and mineral complexes. A sufficient number of capsules of three different colours (red, orange and yellow) was provided daily, and those left uneaten were recovered and counted after 30 min. The independent variables were: initial capsule location within the tank, capsule colour and macronutrient associated to each colour. Sea bass were able to ingest enough capsules to account for their normal daily amount of feed. The position of the capsules in the tank, but not the colour, had an effect on capsule intake. Despite their similar chemosensory features, sea bass were able to select varying numbers of each capsule as to compose a nutritionally complete diet. The final composition (expressed in % of weight) was 42.3% of protein, 31.7% of carbohydrate and 26.0% of lipids. Upon changing the colours associated to each macronutrient, it took fish about a week to recover a stable level of macronutrient intake using the new colour code. A key issue of diet selection is how animals recognise food and distinguish between macronutrients. Our results show that once a food is consumed, fish learn to associate the colour of the food with its post-ingestion consequences.

In conclusion, our results prove the viability of this new experimental approach to investigate regulation of macronutrient intake and provided the first insights on the fish ability to selectively regulate macronutrient intake using their post-ingestive effects to develop colour preferences.

Acknowledgements: This research was supported by the CICYT (project MAR98-0446 to J.A. Madrid) and by the "Instituto de Fomento de la Region de Murcia, programa Séneca" providing financial aid to V.C. Rubio.

Regulation of Food and Nutrient intake in rainbow trout (*Oncorhynchus mykiss*) fed dry pelleted diets.

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We examined the time scales over which rainbow trout will (a) compensate for changes in nutrient composition when offered single diets (without choice) and (b) show hyperphagia after feeding with restricted rations.

50 rainbow trout (*Oncorhynchus mykiss* Walbaum) of *ca* 250g body weight were held in four groups at 12.6 ± 0.2 °C. Fish were acclimated and fed to satiation daily with Trouw High Performance 5mm trout pellets for two weeks prior to the experiment. This diet contained 18.55 MJ/kg and (by dry weight) 45% protein and 21% oil. Four diets were prepared from crushed trout pellets, added oil where appropriate, kaolin as filler and sprayed with gelatin to minimise texture and taste differences between diets. The four diets provided two levels of protein (38.5 and 20.5% of dry weight) and four energy levels (from 8 to 19 kJ g⁻¹). Each diet was fed to the four groups of fish for one week using a Latin Square design. A further 36 trout (400-450 g) were allocated into 6 groups and fed Trouw Amino Balance 50 (45% crude protein, 30% oil) once daily to satiation for 1 week (12°C). All fish were given a restricted number of opportunities to feed to satiation during the next 11 day period but the sequence of deprivation (2 days, 3 days, 6 days) prior to satiation feeding on day 11 varied between groups. Daily feeding to satiation was resumed followed by restricted feeding with the same protocol but with each meal restricted to 70% of the daily satiation amount. On day 11 they were fed to satiation.

The trout did not change food intake to regulate either protein or non-protein energy alone but attempted to optimise intake of both macronutrients. Short term food deprivation (up to 6 days) with restricted rations led to hyperphagia where maximum meal size increased by more than 50% compared with restricted but satiated controls. Similar results for voluntary nutrient intake and for hyperphagia will be shown for several marine species (turbot, sea bass and clown fish).

Effect of energy density and source on voluntary food intake in rainbow trout

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Two feeding trials of 9 weeks each were conducted to evaluate the capacity of rainbow trout (± 50 g initial body weight) to adjust their voluntary feed intake (VFI) as a function of the density (expt I) and the nature (expt II) of the dietary energy. In expt I, the energy density of the control diet was diluted by adding 10, 20 or 30 % of cellulose or zeolith. In expt II, diets had an identical content of digestible energy with a gradient in the ratio of non-protein / protein energy (EnP/EP). Diets were fed by hand twice a day to visual satiation and water temperature was constant at 16 °C.

Fish in expt I clearly increased their VFI when dietary energy was diluted, without any visible negative effect of the bulk addition on their well-being. The VFI adjustments were seen from the first week onwards, but were incomplete, with fish receiving the 30 % energy dilution increasing their VFI (g diet DW per ind per day, at equal theoretical body weight) by only c. 15%. The incomplete compensations resulted in comparable body weight losses, since food efficiencies, expressed as g body weight gain per g diet \times (100-%dilution) ingested, were identical between the groups. VFI data will be presented in relation to the final whole body composition of the fish and will be completed by results on the effect of both bulk additions on the apparent digestibility of the three macro-nutrients.

In expt II, fish offered the diet with the lowest EnP/EP ratio, ingested more food at equal theoretical body weights, and thus more energy than those fed the low protein diets. This implies a low satietogenic effect of dietary protein energy as compared to non-protein energy and/or an absence of VFI regulation based on total protein intake. Fish fed the diet with the low EnP/EP had the best growth. VFI data will be presented in relation to whole body compositions.

Feed intake in relation to temperature and diet composition in Atlantic salmon parr

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There is little information about feed intake of fish at low temperature even though water temperatures below 4°C are regularly encountered during the winter months at high latitudes. A feeding experiment was conducted with groups of juvenile Atlantic salmon (*Salmo salar* L.) held at 2 and 8°C to investigate the effect of temperature on feed intake and growth. Two feeds, differing in fat (340 or 220 g kg⁻¹) and protein content (400 g kg or 520 g kg⁻¹), were supplied in excess to triplicated groups of salmon parr over 6 months. Feed intake was estimated by registration of uneaten pellets, collected using a meshed nylon unit connected to the water outlet from each tank. Waste pellets were washed rapidly from the tanks, were trapped effectively by the collection units and they were registered the next day. Samples of feed waste were taken regularly, dry matter determined, and feed intake estimates were corrected for dry matter loss determined for each feed. Fish fed the high protein feed ate approx. 10% more (g fish⁻¹) than those fed the high fat feed at both temperatures, but no differences was found when feed intake was calculated in energy units (kJ fish⁻¹). Temperature had a major effect on feed intake and growth, the weight of the fish doubling over 6 months at 2°C and increasing 5-fold at 8°C. Daily, and cumulative, feed intake was compared for fish growing over the same weight interval (20 – 40 g) at the different temperatures: 2 months of growth in groups at 8°C, and 6 months at 2°C. The data will be discussed in relation to dietary and temperature influences on feeding and growth.

Strategical and tactical analyses of the feeding behaviour of fish (and Icelanders)

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Strategies and tactics are a fish's way of coping with an uncertain world. These concepts are central to the discipline of behavioural ecology, but not well understood (and frequently greatly misunderstood) outside it. Even within behavioural ecology, the distinction between these terms is not always clearly drawn, and different workers, even those studying fish foraging, have used the terms in somewhat different ways. What all do agree upon is the hierarchical nature of these concepts, strategies being at a higher level than tactics. Perhaps that is what is most important, i.e., the recognition that there are different levels of approach to any problem. Nevertheless, I will start with my own definition of strategies and tactics, and the relationship between them. This usage is consistent with that in the broad field of evolutionary ecology if not always consistent with usage by foraging theorists.

A *strategy* is a decision rule that tells an animal how to behave in any situation in which it may find itself. It is important to appreciate that the term "decision" does not imply any conscious cognitive ability on the fish's part, simply a choice among available behavioural options. A *tactic* is a behavioural option, employed in support of a strategy. An example will make the distinction clearer: the Western buffalo bream (*Kyphosus cornelii*), an endemic Australian herbivorous fish, has three foraging options, or tactics available to it: 1) defend a territory on the reef platform, and feed on attached algae; 2) invade another's territory (alone or in a group) and steal its algae; or 3) feed on drifting algae in the water column (Ian Hamilton, pers comm). The bream's strategy is the decision rule which allows it to choose among these tactics in an adaptive way, in response to changes in present conditions, including other fishes' behaviour, relative food availability, current speed, etc.

If the strategies and tactics of a foraging animal are genetically determined (and they are assumed to be), then natural selection will favour those utilized by the animals who contribute the most offspring (carrying more of the relevant alleles) to subsequent generations. In indeterminate growers like fish, more food energy generally means more potential investment in reproduction, and it is for this reason that foraging behaviour can be expected to be maximally efficient in some sense. This is often equated with maximizing net energy intake rate (NEIR), but it is important to realize that foraging can be a risky activity, exposing a fish to predators of its own, and that good strategies are those which take such conflicting selection pressures into account, and solve the trade-offs appropriately. Sometimes the optimal tactic may also depend on some characteristic of the forager, such as its size or past experience; we refer to such strategies as "conditional" or "state-dependent". In addition, the success of a tactic may depend on its frequency in the population (i.e., its success is frequency-dependent). In this case the strategy must also take into account of what other fish are doing and there may no longer be a single optimal tactic under a particular set of conditions, but rather a stable solution (referred to as an evolutionarily stable strategy, or ESS), or even a stable mixture of tactics (a mixed

ESS). Here the distinction between strategies and tactics becomes more than a little confusing.

Understanding what a foraging fish is attempting to achieve, the options available to it, and any constraints on their choice, allows behavioural ecologists to predict how that forager will behave in any given situation in which it may find itself. One of the great advantages of this approach is that it doesn't simply describe what fish do, but explains why they do it. This allows us to predict how the fish's foraging behaviour will change when exposed to novel situations, e.g. new food types or new environmental conditions.

There are several sorts of foraging problems faced by fish (or any forager) which have been viewed from this perspective, including: where to forage, when to forage, whether to forage alone or with others, whether to defend access to food in some way, what prey types to eat (the diet problem), and how to search for, attack and eat these prey. In aquaculture facilities, the where, when and with whom questions are largely irrelevant, as they are determined for the fish by an outside agent, the aquaculturist (but note that understanding fish behaviour may lead to the design of better feeding regimes), and defense of food is usually futile.

This talk will consider some examples of the other problems, illustrating them with examples, and showing how S&T thinking may lead to different ways of thinking about the problems, and perhaps novel insights for those who raise fish in farm facilities. As one example, consider the classical diet problem. The tactics may be considered to be: 1) feed selectively (eat only the best food type); 2) be partially selective (eat the x best types); or 3) be completely non-selective, and eat everything encountered (or offered). The strategy chooses among these options (which are continuous, in actuality) based on the profitability of different prey types, and how their inclusion would affect the overall diet value (NEIR). An interesting historical example deals with the question of whether it is strategically wise for Icelanders to eat dried cod heads!

Within a species, individuals may have a choice of different foraging modes; these modes are really tactics, whose use depends on environmental or prey characteristics. For example, perch (*Perca*) can be ambushers or searchers, depending on prey availability and habitat vegetation structure. Other sources of intra- and/or inter-individual tactical variability include individual state (as noted above), and developmental stage. All of this variation may be considered as examples of what is termed *phenotypic plasticity*.

The tactics of other fish species are genetically-fixed species characteristics, but these are still selected/chosen according to the same sorts of strategic rules, i.e., the foraging tactic characteristic of a species is that which maximizes its energy intake rate given its prey base, environment, and morphological and physiological constraints. Alternative tactics would either provide a lower NEIR, or have been impossible to achieve given the species' other characteristics and its evolutionary history.

Dynamics of appetite in teleosts experiencing cycles of feed deprivation.

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A previous study demonstrated species differences in the dynamics of appetite when *ad lib* feeding followed a single period of feed deprivation. In the present study, the consequences of cycles of one week of deprivation followed by two weeks of *ad lib* feeding on appetite were studied in four species, two that were primarily omnivorous and two that were primarily carnivorous. The species were the European minnow, the gibel carp (both omnivores), the long-snouted catfish and the three-spined stickleback (both carnivores). The results confirmed that the inter-specific differences persisted when cycles of feed deprivations were imposed. Two main patterns were observed. In the minnow, for example, appetite of deprived fish tended to decline over the two weeks of *ad lib* feeding, whereas the control minnows showed no consistent trend. In the stickleback, appetite declined over the first week of re-feeding, but then increased during the second week. Again the control sticklebacks showed no consistent trends in appetite. The possible factors underlying these inter-specific differences are discussed. The temporal trends in appetite of the control fish were examined for evidence of endogenous cycles of appetite as have been demonstrated for salmonid species. The capacity of the species to compensate for the periods of feed deprivation by catch-up growth was assessed.

1) Prof. Yibo Cui died 30 December 2000

Contrasting results from efforts to elicit growth over-compensation in two fishes.

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A previous study used a novel feeding approach that repeatedly elicited compensatory growth (CG) in juvenile, age 1 hybrid sunfish causing fish in some treatments to outgrow *ad libitum* fed controls by up to two-fold. The approach involved feeding schedules with repeating cycles of food deprivation followed by *ad libitum* feeding for as many days as hyperphagia continued. A similar feeding approach was subsequently applied to maturing, age 2 yellow perch in an effort to produce growth over-compensation (GOC) as in the juvenile hybrid sunfish. Unlike the hybrid sunfish responses, episodes of CG from feeding schedules involving food deprivation were generally insufficient to cause the yellow perch to even catch up to control weights. A similar repeating-cycle feeding schedule where less severe food restriction (maintenance feeding) was used in place of food deprivation to elicit CG, did produce rapid catch up growth in the yellow perch. However, upon reaching control weights, yellow perch consumption immediately declined, rapid CG slowed abruptly, and GOC did not occur. Clearly, internal growth regulation involving appetite control, precluded GOC from occurring in the yellow perch. This same internal regulation was either absent or was otherwise relaxed in the juvenile hybrid sunfish previously studied. Because substantial GOC had not been previously produced in fishes, we suspect that the novel feeding approach, believed to maximize CG responses, was key to producing GOC in the hybrid sunfish. However, the findings for yellow perch demonstrate that in addition to using a CG maximizing feeding schedule, internal regulation that precludes GOC must also be absent for GOC to occur. We suspect that the less resilient and less vigorous CG responses shown by the maturing yellow perch, in contrast to the juvenile hybrid sunfish, are indicative of lack of GOC capacity. Because previous studies have shown stronger CG responses in juvenile fish versus their later-stage conspecifics, we suspect that GOC capacity may be largely restricted to the juvenile stage. There is also indication from the literature that GOC capacity may be time-of-year dependent.

Enhanced feeding activity: a correlated response to selection for growth in brown trout (*Salmo trutta*)

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The genetic gain of brown trout selected for growth by an optimized individual process was mainly explained by enhanced intake (Sanchez *et al.*, 2000). The objective was to compare the feeding activities of these selected (S) and control (C) lines. Selected fish were reproduced 12 days after C, so that fish of both lines reached the same initial weight (4 g) at the same date. Three groups of 500 fish of each genotype were then constituted and fed for 126 days a commercial diet *ad libitum* using self-feeders with free access during the photophase. After a starving period of one month, they were refeed under the same conditions for 42 days. Growth and feed intake were measured every third week and uneaten feed was weighted daily. The trigger actuations during the photophase were recorded continuously, pooled per periods of half an hour over a 3-week period. The results were analyzed by ANOVAs. At the end of the feeding period, the mean body weight was 75% higher for S than for C (45 g). Because feed efficiency was not different between the two genotypes (1.23, $P > 0.21$), the differences in growth performance between the two lines were caused by differences in feed intake. Brown trout ate 16-20% of their daily intake at dawn and on average 6% per hour thereafter. This feeding activity profile was exacerbated for S, which ate relatively more than C at dawn ($P < 0.01$). At the end of the starving period the loss of weight was comparable for S (-13%) and for C (-15%). It was compensated during the refeeding period because of hyperphagia and the mean final body weight was 91% higher for S than for C (78.4 g). The two genotypes restored rapidly their own feeding profiles, S eating again more at dawn. Selected fish seem to recover more rapidly appetite after nocturnal or long starving periods. Whether selection has altered the feeding behavior or not deserves further studies at the individual level. Sanchez *et al.*, 2001, *Aquat. Living Resour.*, 14, to be published

Triggering activity rhythm of individual fish within a group versus food intake activity of the group.

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Since many years, food intake rhythms were studied as well on fundamental level, to put forward rhythms mechanisms, and also on applied research to optimise food intake in rearing conditions. Now, the self-feeder is more and more used as a tool to determine these food intake variations. Nevertheless, in most cases, animals are anonymous, and only fish population rhythm is assessed.

This work has been carried out on two groups of 50 sea bass (*Dicentrarchus labrax*) reared in tanks (1 m³) of IFREMER laboratory in Palavas under controlled photoperiod conditions (LD: 18-6) at constant temperature (21-22°C). All animals were tagged with PIT-tag. System used permits to monitor each fish actuating the triggering system. This device has been designed by IFREMER (for more details, see abstract of Covès and Dutto in this workshop).

First results show that only few animals within a population actuate self feeder. So rhythms of different “users” and rhythm of the population were studied and compared. The aim of this work is to answer this question : is the food intake rhythm observed within a population reflect the activity of a single fish or is a combination of several fish activity?

Comparison of demand-feeding rhythms in individual and grouping rainbow trout: with emphasis on inter-individual social interactions

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The effect of inter-individual social interactions on daily and circadian demand-feeding rhythms in rainbow trout (*Oncorhynchus mykiss*) was investigated.

The experiment was conducted in two consecutive stages in two adjacent insulated rooms. Water temperature was constantly maintained at 14.0 ± 0.2 °C. The initial fish size ranged from 120 to 170 g. In Stage 1, 40 fish were held individually in Room 1, and eight groups of 10 fish in Room 2. In Stage 2, four groups of 10 fish were relocated into 40 individual tanks in Room 1, those 40 fish from Room 1 were grouped 5 fish in each tank based on their free-running period length, and placed into eight tanks in Room 2. The reward level was 1 (0.013 g) and 12 (0.156 g) pellets per trigger activation for individual and grouping fish, respectively. In both stages, demand-feeding activity was automatically monitored under light:dark cycle of 16.5:7.5 h and constant light conditions, respectively. The dominant feeding hierarchy in groups was examined using video observation of trigger activation by tagged fish.

One to three fish in groups dominated trigger activation. However, the other fish were also able to capture pellets. Some of the non-dominant fish grew as well as the dominant fish. In both stages, trout kept in both individual and group was, in general, diurnal feeder, indicating inter-individual social interactions did not affect daily feeding pattern. Self-sustained circadian demand-feeding rhythms were observed in 60% (Stage 1) and 45% (Stage 2) of individual fish and 50% (Stage 1) and 75% (Stage 2) of groups. A group of five fish free-ran at a period of 25.8 h although those individual fish displayed period length shorter than 24 h. A significant circadian component was detected in a group consisting of five fish that did not display circadian rhythm when they were held individually. In contrast, no circadian rhythm was revealed in a group in which five fish previously exhibited circadian rhythm. Taken together, the expression of circadian demand-feeding rhythms seemed to be influenced by inter-individual social interactions.

Feeding rhythms and macronutrient self-selection in a plantivorous marine species: sharpsnout sea bream (*Diplodus puntazzo*).

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Fish usually do not feed continuously but show well defined rhythmic patterns: feeding periods followed by resting intervals. Similarly, in the wild, food resources are often scarce and so fish must actively look for different types of food which composition may differ remarkably. Since the development of self-feeders, which fish can operate directly to obtain any food at any time, researchers have investigated “when” and “what” fish feed. Feeding rhythms, for instance, have been described using self-feeders in many fish species, which may show pretty different behavioural patterns (i.e. diurnal, nocturnal or crepuscular). In addition to feeding behaviour, self-feeders have been proved most effective to investigate fish nutrition from a different view point: a geometrical framework which takes advantage of the nutritional wisdom of fish to self-select a complete diet from a wide variety of incomplete food sources. Using this new approach, previous investigations revealed the capacity to select a nutritionally balanced diet to meet the macronutrient requirements of several fish species with different feeding habits, carnivorous (trout and sea bass) or omnivorous (goldfish). This technique appears particularly useful to design diets for fish species which requirements are poorly understood. The aim of the present research was to investigate the feeding behaviour of a new marine fish species (*Diplodus puntazzo*), with increasing interest for Mediterranean aquaculture. Besides its commercial interest, sharpsnout sea bream has a special interest for nutritional studies since this is a plantivorous species that feed mostly on sea plants and so has a great potential to test alternative plant feed sources. In this communication we present the latest results on the daily and seasonal feeding patterns of five groups of fifteen sharpsnout sea bream held in tanks under natural environmental conditions and given free access to a single standard diet or three macronutrient diets containing pairs of macronutrients (protein-fat, protein-carbohydrate and fat-carbohydrate).

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Food anticipatory activity in greenback flounder

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This paper reports the findings of three experiments on food anticipatory activity (FAA) in groups of greenback flounder (*Rhombosolea tapirina*) exposed to restricted feeding regimes, with an emphasis on understanding the roles of the light:dark (LD) cycle, number of daily periodic meals, meal duration and meal size in regulating the development of FAA.

In the first experiment, a distinct FAA was observed in the groups of fish receiving a single daily meal either during the photophase or scotophase. FAA also developed before at least one of three daily meals but not before any meal in the regimes of six or more daily meals.

The second experiment tested whether the ability of a single daily meal to act as a potent zeitgeber to synchronise daily locomotor activity pattern, was dependent upon the combination of meal size and meal duration. The fish fed at the meal sizes of 0.25 and 0.5% body weight (BW) day⁻¹ exhibited FAA under all the three meal durations (1, 3 and 7 h) investigated. FAA was also expressed by the fish fed at 1.5% BW day⁻¹ but only combined with the meal duration of 1 h. FAA was shorter and lower in magnitude, the longer the meal duration, while for each meal duration, FAA was shorter and lower, the higher the ration. The latency of FAA was about 21 days but was reduced to 8 days during a period of re-entrainment following food deprivation. FAA persisted for less than 3 days during food deprivation.

In the third experiment, it was shown that FAA was associated with each meal of the 1, 2, or 3 meal feeding regimes. A 7 h light phase advance of LD 12:12 produced a temporary shift in FAA coinciding with the same duration after lights on. The phase of FAA did not change after LD 12:12 was shifted to dim LL. FAA persisted for less than 2 days under constant feeding.

In conclusion, the results suggest that greenback flounder possessed functional feeding-entrainable oscillators, with the energetic (meal size) and temporal (meal duration) components of a periodic meal and the LD cycle being involved in the development of FAA.

Poster abstracts

Comparing weaning techniques and formulated diets in fingerlings of *Stizostedion lucioperca* and *Perca fluviatilis*

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Perca fluviatilis and *Stizostedion lucioperca* are currently not farmed for food markets in Europe but are receiving a growing interest. These species have very small and undeveloped larvae which complicates initial feeding. Weaning pikeperch to commercial trout feed has previously been reported as difficult, since it was hard to make all fish accept the feed. Perch larvae have previously been successfully weaned to formulated diets. It is however complicated and costly due to the fact that perch larvae demand live artemia when being weaned to a formulated diet. Mortality and costs could possibly be decreased if weaning was performed on larger and thereby less sensitive fish. We investigated whether pond cultured, zooplankton fed pikeperch and wild caught perch fingerlings could be weaned to feed on formulated diets. In both species we compared three weaning methods regarding growth rate, condition factor and stomach fullness of the fish. Thereafter, using the most effective weaning method, we compared the same parameters between groups of fingerlings fed four different formulated diets (A, T, N, P). Three weaning techniques were tested; no weaning eg formulated diet from the beginning, zooplankton flavoured with formulated diet or yolk flavoured with formulated diet for a couple of days before feeding the fish formulated diet only. The results were similar in both species. Feeding the fingerlings the formulated diet A without weaning was as effective as the weaning methods tested. Diet A gave a growth rate of approximately 0.08 (g/g*day) for pikeperch and 0.05 (g/g*day) for perch whereas the other diets gave growth rates of 0.005 - 0.054 (g/g*day) for pikeperch and -0.004 - 0.017(g/g*day) for perch. By the last day of the experiment 99% of the pikeperch (PP) and perch (P) offered diet A did not have empty stomachs. Corresponding figures for pikeperch and perch with the other diets were: diet T 37 % and 79 %, diet N 88 % and 86 %, diet P 48 % and 86%. Also, the condition factor for fish fed on diet A was higher than for fish fed the other diets. Thus, diet A was nearly twice as effective as the other diets for pikeperch and three times as effective for perch.

Measuring digestibility with chemical markers mixed in the feed and sprayed on the pellets.

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Chemical marker method with the marker a) n-alkanes (dotriacontane (C₃₂)) mixed into the pellets and b) n-alkanes (hexatriacontane (C₃₆) sprayed on the outside of the pellets was used to measure digestibility. Four hundred Arctic charr, mean weight of 175 g, were fed with feed with the markers both inside the pellets and sprayed on the outside of the pellets. Feeding was continued for 14 days and faeces collected in the Guelph faecal collection system for the last 7 days. Feed and faeces were analysed for n-alkanes. Feed intake was calculated from the ratio of the markers in feed and faeces. There was a loss in the marker, which was sprayed on the redymade pellets. A significant difference was detected between the two methods in digestibility of protein and ash. There was no difference in the measurement of fat with the two methods. We conclude that spraying redymade pellets with n-alkanes as a chemical marker can not be used for quantitative measurement of digestibility of feeds. It can however be used to compare digestibility of different feeds.

Early life history of Icelandic eels (*Anguilla rostrata* and *A. anguilla*) as revealed by otolith microstructure

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In the Atlantic Ocean, there are two species of eels, *Anguilla rostrata* and *A. anguilla*, both of which are known to spawn in the Sargasso sea. However they differ in having separate freshwater habitats, located along the east coast of the American continent and along the west coast of Europe respectively. Only in Iceland have these species been reported to co-exist. It is not known how these two species maintain separate freshwater habitats elsewhere. It has been suggested that these different habitats are the consequence of differences in the timing of metamorphosis in the two species, but this has been not verified. Study of early life histories of these species in Iceland, using otolith microstructure, will provide information on the recruitment mechanism of these two species.

The age and otolith microstructure of both species were examined in glass eels collected in southwest Iceland in 1999 and 2000.

Averaging 349 days, the total age of Icelandic *A. rostrata* was about 100 days older than reported previously. On the other hand, *A. anguilla* was found to average 365 days, about 100 days younger than reported before.

Otolith microstructures differed from that previously reported for *Anguillid* eels. The drastic increase in otolith increment width corresponding to the metamorphosis stage, which has been reported in *Anguillid* species, was found to be absent. This indicates that glass eels may experience low temperatures near the coast of Iceland during metamorphosis.

These results suggest that both species may follow the same migration route from the Sargasso Sea to Iceland and that the timing of metamorphosis could be an important factor in deciding the place to which glass eels recruit.

Vertical distribution of caged Atlantic salmon during the first period after sea transfer.

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Atlantic salmon in sea cages stocked under commercial densities have the opportunity to choose their swimming depth within the cage. The surface and the cage bottom physically limit the swimming depth. The distance from the surface depends upon many factors and trade-offs, where light conditions, time of year, time of day, hunger status, feeding motivation, food availability, environment and predators have been suggested to be of importance.

This study investigated the swimming depth of Atlantic salmon, held in 4 replicate sea cages during short term ambient variations in temperature and salinity during the first months after sea transfer. The cages were situated in a fjord where variable freshwater runoff create strong thermo- and haloclines.

The results revealed a surprising correspondence between the preferred swimming depth and the halocline, whereas earlier findings in elder fish have indicated a stronger preference for the highest temperature. Age and time after sea transfer may modify the trade-off between salinity and temperature preference in Atlantic salmon.

Feeding rhythms of juvenile red porgy (*Pagrus pagrus*) in ambient environmental conditions

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Feeding rhythms of red porgy in culture conditions were studied over the first year of life. Fifty or 100 fish (in duplicate) were reared in 500 l tanks in ambient environmental conditions, and fed by means of self-feeders. Feeding activity was recorded continuously and seasonal feeding rhythms were compared using the Principal Component Analysis.

Red porgy was mainly a diurnal forager throughout the year. In the summer (July to September), juvenile fish of 3 months in both densities fed mainly at dawn and kept active until dusk. During the night there was no feeding activity. In autumn (October to December) fish fed for fewer hours, as the duration of the day gradually decreased. In low density tanks (50 fish per tank) feeding activity was almost stable during the day while at night there were still some activations of the feeder. In high density tanks (100 fish per tank) feeding activity during the day showed high fluctuation, forming two peaks, at 10.00 and 16.00 h. There were no activations after 24.00 h till dawn.

In winter (January to March) the duration of feeding activity decreased even more. In the low density tanks, activity increased continuously after dawn, and it showed a peak at 17.00 h. In the high density tanks, activity was high and almost stable during the day, but did not cease completely at night.

In spring (April to June) fish were eating continuously day and night, but activity during the day was higher in both densities.

As fish grew bigger and their visual ability increased, their feeding activity expanded to night hours, most probably in order to cover increasing feeding needs. This could also be due to the formation of hierarchic relations among fish, that forced subordinates to utilise the hours of low interest for feeding for the leader fish.

Phenotypic and genetic basis of segregation in shape and life history among Atlantic salmon in River Víðidalsá, Iceland

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Two populations of Atlantic salmon coexist in River Víðidalsá, Iceland. They differ in various life history characteristics, and shape features related to feeding and swimming performance. This variation is developed early in life. The segregation between forms appears to have a genetic basis, with juvenile salmon maintaining their differences, when reared in captivity. We suggest that these differences between forms represent alternative adaptive strategies aimed at utilising local habitats in the river system. These results emphasise the need to incorporate within river multi-stock approach in conservation and management of Atlantic salmon.

Agonistic pattern analysis of black-bass (*Micropterus salmoides*) during the establishment of social structure.

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Laboratory study was realized with six pairs of black-bass placed in conflict situation in aquaria. The two fish of a pair, coming from two different tanks, were introduced simultaneously in aquarium and filmed during 24 hours. Video-registration were used to describe the behavioural acts of fish. In all the pairs of fish, we observed the setting up of agonistic behaviours which conducted to a social hierarchy with a dominant and a subordinated fish.

The different agonistic acts observed for each fish were noted every minute during a continuous period of eight hours. Then the sequence of agonistic acts were computed and analysed by Theme. Theme is a software developed by Magnusson that identifies and analyses time structure of elementary acts. The algorithm developed is described in details by Magnusson, 1996 & 2000.

We also compared space occupation of the dominant and the subordinated fish. So the aquaria have been divided in six parcels under the video-screaming to quantify the mean number of parcels filled by each fish per minute. At the end of each trial, we determined the size, the weight and the sex of fish and noted eventual damage on fish body.

Individual growth and food intake in northern and southern populations of Eurasian perch (*Perca fluviatilis*)

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This paper is a first report on a large study conducted in Belgium in order to evaluate the growth performances of different populations of Eurasian perch in recirculating system. Larvae were obtained from wild breeders held in captivity in their respective regions of origin (Finland and Belgium). Finnish fertilised eggs were transferred to Belgium and larvae reared under similar conditions until and during the experiments (recirculating system, T = 22-23°C, automatic feeding during the daylight period). Due to differences in the spawning season of Finnish (June) and Belgian (April) perch (FP and MP, respectively), comparisons of growth and food intake were performed with fish of similar size (initial body weight = 1.26 g) and age (86-90-day old), but at different periods. The experiment was conducted in triplicates with 150 fingerlings per 50-L tank. Survival and growth parameters were monitored fortnightly for each group during 4 months. A second experiment was conducted during 10 weeks at a larger size (34 g), when fish were 9 (FP) to 10 (MP) months old. Forty-five juveniles from each strain were individually tagged (PIT-tag) and allocated in triplicates to 100-L tanks. Fish were fed to satiation with commercial re-pelleted food and weighed fortnightly. One hour before the growth control, fish were fed the same commercial food containing 2.5% leaded glass beads to evaluate the individual feed intake by X-ray.

In experiment 1 (early juvenile stage), survival rate was lower ($P < 0.05$) in FP than in MP (85% and 94%), mainly due to a higher incidence of cannibalism ($P < 0.05$). Values for specific growth rate (SGR %d⁻¹), feed efficiency and condition factor were comparable between both populations, ranging between 2.1 vs 2.3, 0.76 vs 0.73, and 1.02 vs 1.09, respectively. In experiment 2 (late juvenile stage), survival rate was still lower in FP ($P < 0.05$) than in MP (85% vs 97%). On the other hand, individual growth was higher ($P < 0.05$) in FP than in MP (SGR = 1.20 vs 0.89) in relation to a higher ($P < 0.05$) individual feed intake ($r^2 = 0.38$ vs 0.17) but not a better feed efficiency.

Effect of a soy-protein diet supplemented or not with methionine on the voluntary feed intake of sea bream (*Sparus aurata*)

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Feed chemical properties including essential nutrient availability is one of the main factors affecting voluntary feed intake. Fish are able to select diets differing in dietary macro or micronutrients content. Furthermore, the time-course of the availability of essential nutrients and energy could affect feeding frequency. It is known that supplemented free amino acids are more rapidly absorbed from the gastrointestinal tract than protein-bound amino acids, thereby inducing their oxidation so that a relative deficiency may persist. Two possible alternatives may be considered: either coatin supplemented amino acids or to increase feeding frequency. The second alternative has been the aim of this work. To that purpose 3 groups of 15 fish (30g b.w.) were allocated 250 l tanks supplied with a continuous sea water flow and maintained at natural environmental conditions (T^a 15°C; L:D 11.15:12.45 h) for 6 days after adaptation to experimental conditions. Diets with a similar general composition (45% protein, 14% lipids, 20% carbohydrates) differed in the protein source (diet 1: fish meal, diet 2: soy protein concentrate, diet 3 : soy protein supplemented with free methionine). Self-feeders were adapted to the tanks and connected to a control unit (Aquarium MA32) governed by a computer where time and number of demands were registered. Results were subjected to spectral analysis based on Furriel series to determine whether circadian rhythms of voluntary feed intake exist or vary within the experimental conditions. Results showed that sea bream has a preference for feeding at the end of the day-light period with different feeding pattern in relation with diet composition. Fish showed maximum feeding activity between 18.30 and 19.30 decreasing slowly until 24h when fed on diet 1. Feeding activity for diet 2 (Met-deficient) was significantly reduced to 20-21 h period. Fish fed on diet 3 (Met-supplemented) showed a longer feeding period (14-23h). Deficiency of an essential nutrient (diet 2) is known to reduce feed intake in order to prevent or reduce metabolic disorders associated to an unbalanced diet. Consequently, methionine supplementation increased feed consumption. Furthermore, a higher feeding frequency on diet 3, during a longer period, would allow methionine to coincide with postprandial protein-bound amino acids to reach a more adequate amino acid pattern to cover fish requirements for protein synthesis and growth.

Seasonal variation in growth and feed conversion in Atlantic salmon (*Salmo salar* L.) postsmolts

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To map seasonal variation in growth and feed conversion, Atlantic salmon postsmolts (*Salmo salar* L.) were exposed to either simulated natural photoperiod for 12 months (SNP) or continuous light from January to June (LL) followed by SNP until December. The fish were held in indoor tanks (20 m³). Feed was given in surplus and waste feed was collected for estimation of feed intake and calculation of biological feed conversion ratio. Body weight increased from 1090±340g (mean±SD) of both groups in January to 4970±690g (SNP) and 5190±660g (LL) in December. Specific growth rate (SGR) displayed strong seasonal variation in both groups, independent of temperature and fish size. LL had highest SGR during spring (0.80±0.16), while SNP had highest SGR during late summer and autumn (0.77±0.18). Similarly, the seasonal pattern of the condition factor (K) varied, with the lowest levels of K in March for the LL group, advanced by 3 months compared to SNP, which had low levels until May. In both groups K peaked in November (1.42±0.12 (LL) and 1.40±0.14 (SNP)). Thus, the LL photoperiod advanced the natural seasonal pattern of SGR and K which Atlantic salmon follow. Seasonal variations in growth rate were inversely correlated with differences in feed conversion ratio of both groups, with low feed conversion ratio in periods with high specific growth rate.

The effect of social stress on the production of dividing red blood cells in triploid brook trout

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Stressed triploid salmonids show an increased number of dividing red blood cells in the blood stream. Subordinate fish in a hierarchy may be more stressed than dominant fish. The objective of this experiment was to correlate the number dividing red blood cells in circulation with the fish's position in a hierarchy. Ten groups of six triploids were placed in troughs and hierarchies were established by feeding a limited diet over a five day period. The of number pellets eaten by each fish was counted and on this basis each fish was assigned a hierarchical rank. Fish were bled before and after the hierarchy was established. Blood smears were stained with Wright-Geimsa and the percentage of dividing cells was determined. Preliminary experiments suggest that there is a correlation between social stress and the production of dividing red blood cells.

Melatonin modifies food intake and macronutrient self-selection in European sea bass feeding on gelatine capsules

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Only in the last few years have researchers started to pay attention to the regulation of macronutrient intake in fish. To date, all studies have focused on the self-selection of granulated diets having different macronutrient composition, disregarding the fact that intake of a particular macronutrient can be influenced by the diet's organo-sensory features. Nutrient macroencapsulation into gelatine capsules has proved a powerful tool to investigate macronutrient intake regulation in fish, without the masking influence of the diet's flavour and texture. In wild fish, seasonal-dependent diet selection changes have been extensively reported. Since the pineal hormone melatonin is the final mediator of photoperiodical changes, the objective of this paper was to evaluate the role of melatonin on food intake regulation and macronutrient intake in European sea bass, using macroencapsulated nutrients. To this end, twelve sea bass individually held in 75 l tanks, and previously trained to feed on gelatine capsules, were daily supplied with capsules of three colours (red, orange and yellow), each one containing either protein, carbohydrate or lipids. Forty five minutes before this meal, a capsule containing standard diet (placebo) or standard diet plus melatonin at 0.1, 0.5 or 2.5 mg/kg b.wt. was supplied to each fish. Each experimental phase (placebo, 0.1, 0.5, 2.5, placebo) lasted a minimum of 10 days. Melatonin concentrations of 0.1, 0.5 and 2.5 mg/kg b.wt. induced total food intake dose-dependent inhibitions of 9.2, 26.1, 34.2%, respectively, with respect to placebo. Melatonin also affected carbohydrate (16.9, 32.7, 42.2% inhibition), and to a lesser extend, lipid intake (2.6, 21.7, 24.5%). Also, protein intake was affected in a similar way as total food intake. This results show that peripherally administered melatonin affects both food intake and macronutrient selection, and they constitute the first evidence of the existence of neurohumoral mediators affecting macronutrient selection in fish.

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FEED INTAKE IN YELLOWTAIL (*Seriola quinqueradiata*) AND KAMPACHI (*Seriola dumerili*) IN RELATION TO DIETARY PROTEIN AND ENERGY.

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This paper reports trials which investigated effects of dietary protein and energy levels on feed intake, growth, and body composition in two *Seriola* species.

In a trial with yellowtail (*S. quinqueradiata*), fish of c.a. 1kg initial weight were fed a dry extruded feed, a moist feed, or a 1:1 mix of both diets. Satiation meal size and the intake of macronutrients was determined. In a trial with kampachi (*S. dumerili*), fish of c.a. 100g initial weight were fed iso-nitrogenous extruded diets (400g.kg⁻¹ protein), containing either 180, 220, 260, or 300g.kg⁻¹ dietary lipid.

In the first trial, the fish fed the different diets appeared to adjust feed intake to maintain a constant protein intake. Growth rate and body energy stores increased with increasing energy intake per unit protein intake. In the trial with kampachi, feed intake appeared to be inversely related to energy intake, and muscle and visceral lipid stores increased with increasing dietary energy levels. The different dietary protein:energy ratios had no influence on growth rates.

These results are discussed in the context of the mechanisms by which the physiological consequences of macronutrient ingestion influence appetite, and hence growth rate and body composition.

The effect of the degree of insaturation of dietary lipids on feed intake of European seabass juveniles (*Dicentrarchus labrax*).

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Two trials were undertaken with European seabass (*Dicentrarchus labrax*) juveniles, to evaluate the effect of the degree of insaturation of dietary lipids on voluntary food intake. Four isonitrogenous diets (crude protein, 44% DM) were formulated to contain a constant (18%) fat levels. The dietary lipid source was varied by the incorporation of various lipid sources: 18% fish oil (diet 18F), 18% sunflower oil (diet 18S), 9% fish oil + 9% sunflower oil (diet 18FS) and 9% fish oil + 9% palm oil (diet 18FP). A fifth diet with an identical protein level was also formulated to contain 9% fish oil level (diet 9F). In the first trial, diets 18F, 18S and 18FS were fed in duplicate to homogenous groups of seabass juveniles (initial mean body weight: 25 g) reared in a seawater recirculated system (salinity: 35 ppt; temperature: 22°C) for 21 days. Under identical rearing conditions, in the second trial, fish had an initial mean body weight of 27 g and were fed diets 9F, 18F and 18FP for 21 days. In both experiences, fish were fed by hand to apparent satiety, three times a day. Food intake by individual fish within each treatment was measured twice using X-radiography. The feed intake of the tested fish was not significantly affected by the degree of insaturation of dietary lipids. Although fish fed diet 9F tend to consume more feed than fish fed diets 18F or 18FP, differences were not significant.

Perch feed efficiently on floating pellets

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Perch (*Perca fluviatilis*) is a temperate fish species and a candidate for culture in recirculation systems. In such systems it is particularly important to control the level of nutrients in the outflow in order to stabilise the performance of the bio-filter. Use of floating pellets may contribute to this by improved feed waste control. It was not known whether perch are able to adapt efficiently to surface feeding as under natural conditions perch is primarily considered as a demersal feeder.

In this study the growth, feed intake and feed conversion of perch fed floating and sinking pellets were compared. Triplicate groups of 12 individually marked perch (initial size = 88 ± 3 g) were held in circular tanks at 100 l with 24 h light and a water temperature of about 18 °C. They were handfed an experimental diet (fish meal 67.7%, wheat gluten 9.9%, wheat grits 21.7%, vitamin/mineral premix 7%) of either floating (97% after 10 min) or sinking 6-mm pellets to satiation two times per day for 39 days. The floating pellet was produced by extrusion and the sinking pellet was produced during subsequent compression of the floating feed with a pellet mill without use of steam. The only difference between the two experimental feeds was therefore the floating/sinking characteristic. Feed intake was estimated by retrieving and weighing uneaten pellets after each meal and growth performance was observed by sampling all fish at days 1, 16 and 39.

Rejection of floating pellets was frequently observed at the start of the experiment. This resulted in a lower mean daily feed intake (6.7 ± 0.28 g vs. 10.1 ± 0.17 g, $p < 0.001$) and a tendency of lower growth rate (0.67 ± 0.13 vs. 1.01 ± 0.07 % bwd^{-1} , $p = 0.09$) and poorer feed conversion ($\text{FCR} = 1.28 \pm 0.16$ g intake g^{-1} gain vs. 1.13 ± 0.19) for fish fed floating pellets in the 16-d adaptation period. When the fish had adapted to floating pellets they fed and grew at the same mean daily rate as fish fed sinking pellets (1.07 ± 0.09 vs. 1.10 ± 0.13 % bwd^{-1}) resulting in no significant difference in FCR (0.85 ± 0.04 vs. 1.07 ± 0.07 , $p = 0.09$).

The main conclusion of this study indicates that perch can adapt to feed efficiently on floating feed pellets.

Time learning and pre-feeding aggression in groups of Arctic charr

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Time learning and pre-feeding aggression was studied in five groups with 15-16 Arctic charr. Registration of the self-feeding activity during periods of unrestricted feeding followed by time-restricted access gave a pronounced effect on the diel self-feeding pattern. At unrestricted conditions the self-feeding activity was distributed throughout the light period from 08⁰⁰-20⁰⁰ whereas the activity during the restricted period was concentrated to the 2 hour with access to food. A profile of the proportion of trigger actuations before, during the time-restricted periods and the following unrestricted period gave an increase in proportion of trigger actuations from 0.15 to 0.7 during the two restricted hours within a week. The proportion of trigger actuations during the "restricted" two hours decreased the first day with unrestricted conditions. During the time restricted feeding, the food anticipatory activity, measured as aggressive interactions close to the trigger, was pronounced. Compared to the unrestricted period before and the following unrestricted period, the mean number of aggressive interaction was significantly higher during the hour before the food was available. In each group, there was one individual that dominated the actuation activity. Visual observations and id scanning confirmed that these fish were the ones that defended the area close to the trigger. These fish displayed a typical dominant behaviour and also had a high growth rate. There was no pattern of a changing proportion of actuations between dominant and subordinate individuals at restricted compared to unrestricted self-feeding conditions.

DAILY FEEDING BEHAVIOUR OF GILTHEAD SEA BREAM (*SPARUS AURATA*); EFFECT OF FEEDING METHOD ON GROWTH AND DIET UTILISATION.

M.J. Sánchez-Muros* , M.D. Suárez , E. Milán and G. Cardenete

Maximum performance of diet involves two important advantages: reduction of feeding costs and decreased waste production. The study of feeding behaviour in several species of fish has revealed that feeding times appropriate to their natural rhythm improve nutrition parameters. In this work, we studied the feeding behaviour of the gilthead sea bream for one month in order to establish its daily feeding rhythm. At the same time, the performance of the animals' diet was studied, both with free access to food and when well fed manually *ad lib*. In order to do this we used gilthead sea bream having an initial weight of approximately 30 gr. Distributed in 6 lots of 15 animals each and kept in 250-L tanks with a continuous flow of sea water and at natural temperature conditions and photoperiod, during an experimental period of 25 days. The feed supplied was fabricated in our facilities (45% protein, 14% lipids and 20% MELN) and supplied to 3 lots by hand twice a day, at 10:00 a.m. and 4:00 p.m. and to the other 3 with automatic dispensers connected to a feed control module (Aquarium MA32) which allows programming of feeding time, as well as registering the hour, tank and number of requests. In these 3 lots, the dispensers were programmed to release food when the fish asked for it by hitting a target. The results obtained from the feeding demand were subjected to spectral analysis, based on a Fourier series, in order to identify the existence of circadian rhythms in food demand.

As the dispensers were open 24 hours a day in the demand lots, dispensations appear all day long, however the greatest feeding activity was focussed during the evening, the spectral analysis revealing the existence of a 24-hour cycle ranging from 6:30 to 7:30 p.m. We have found a certain increase in activity coincidental with lunar cycle, which we cannot confirm since the experiment only lasted 25 days.

Demand feeding is clearly more beneficial than hand feeding. In spite of the low temperatures, which did not allow for very high feeding or growth rates, the use of automatic dispensers improved the diet conversion rate by 60% and the protein growth efficiency coefficient by 37%.

Response of European sea bass in a 3-choice feeding

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European sea bass (*Dicentrarchus labrax*) is widely cultured in the Mediterranean region. However, research on feeding of fish is still in progress, because there are interesting behavioural aspects, which could promote species rearing, but have not been studied adequately. The opportunistic tendency of sea bass, observed in the wild, could affect feed intake and efficiency in farming conditions. This study was conducted to investigate this hypothesis in fish with initial body weight 63 g kept indoors in 500-l circular tanks and subjected to 12L:12D photoperiod and ambient water temperature (18.4±1.6 °C). All fish groups fed by means of electronic self-feeders which were on-line with a computer. Four feeding protocols were applied in triplicate: (a) a 3-choice feeding, where fish had free access to three different commercial feeds (feed for carnivorous fish (B), for herbivorous fish(C), and for omnivorous fish (E)); (b) mono-feeding with feed B, (c) with feed C, and (d) with feed E. In fish group subjected to the 3-choice feeding, self-feeders with different kinds of feed were moved circularly above the tanks every week. All fish were weighed weekly. The experiment lasted for 9 weeks. The 3-choice feeding showed increased feed input, compared to mono feeding, except for feed C. Due to their opportunistic behaviour, fish were asking for more feed than they really needed. Fish fed only with feed C showed a higher feed demand, to compensate for the low dietary protein and lipid of feed. The 3-choice practice had no positive effect on growth and feed efficiency of fish. None of the feeding practices affected fish survival. Fish clearly preferred feed B in the 3-choice feeding, which proved to be the most efficient food for fish growth in relation to the other types of feed (C and E). Due to the weekly circulation of feeds in the 3-choice feeding, fish showed spatial preference for locations, which were far from the water inflow in the tanks. Recording of daily demands proved increased activity during photophase in mono-feeding independently of feed type, and in the 3-choice feeding for feed B. Conclusively, sea bass presented opportunistic behaviour in the 3-choice feeding, increasing their feed demands and choosing the feed most suitable for growth. The specific combination of tested feeds (low dietary value of feed C and E) did not cast enough light on the influence of the 3-choice feeding in terms of growth.

Influence of season and reward level on daily self-feeding patterns of European sea bass held in sea cages.

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In the last few years self-feeders has been used to demonstrate the existence of daily rhythms of feeding activity in European sea bass held in small groups under laboratory conditions. This daily rhythm of feeding activity was modified seasonally according to water temperature and photoperiod. Thus, sea bass show diurnal feeding behaviour under long photoperiods and high temperature, but shift to nocturnal behaviour under winter conditions. When considering the parameters influencing self-feeding, besides environmental conditions, the reward level (that is the amount of feed released after each actuation of fish on feeding sensor) deserves special consideration. Low reward levels may lead to low feed waste, but high competition and therefore low feed efficiency. On the contrary, high reward levels may lead to an increase in feed waste. To date no studies are available on the influence of seasonal changes and reward level on self-feeding patterns in European sea bass held in sea cages.

To this end, three experiments have been done. In experiment one, four sea cages containing 14.000 fish each, with an initial body weight of 110 g were fed by means of self-feeders. Feed demands, water temperature and light intensity were recorded and stored at 10 min intervals between February to May of 1999. In experiment 2, four sea cages with 1000 sea bass each were studied as in experiment 1, between June 2000 to February 2001. In experiment 3, four groups of 1000 fish each were provided additionally with uneaten pellets detectors (Aquasmart, U.K.) to detect in real time the feed waste associated to different reward levels. In two weeks periods, sea bass were fed at 0.02 to 0.4 g.kg⁻¹ of reward level. In all experiments the self-feeders were triggered by means of string sensor to avoid unintentional sensor activation.

The results obtained showed a clear seasonality in the daily patters of feeding activity in sea bass in sea cages, however, the precise moment in which fish inverted their behaviour from diurnal to nocturnal was group-dependent and year-dependent. Besides photoperiod, the variability in water temperature can be considered as the main environmental variable to explain such variability. Reward level influences both the rhythm of feeding activity and feed waste; however, sea bass show a wide range of self-regulation of this parameter. In summary, the wide variability in feeding patters of sea bass under commercial rearing conditions suggest the use of self-feeding systems to match daily fish nutritional needs to feed availability.

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