

## Theme Session Q

### Interactions between aquaculture and wild stocks: comparative experiences for Atlantic cod and Atlantic salmon

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#### ICES CM 2009/Q:01

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##### **A set of single nucleotide polymorphism (SNP) loci for generic distinction of Norwegian farm and wild Atlantic salmon**

Sten Karlsson, Thomas Moen, and Kjetil Hindar

Breeding programmes for Atlantic salmon were established in Norway around 1970. Since then, production of farm salmon has steadily increased, and farm fish now outnumber fish of wild origin. Unfortunately, a large number of farm salmon escape and enter Norwegian rivers to interact with wild salmon. Experimental evidence suggests that genetic interactions between farm and wild salmon may weaken the viability of wild salmon, but the size of the effective gene flow and its consequences remain elusive. This has been difficult to study, partly because of the limited number of suitable genetic markers available. In the present study, a total of 1063 samples, including 12 different farm strains and 14 wild populations, were analysed for genetic variation at 4596 single nucleotide polymorphism (SNP) loci. A small set (~30) of SNPs were identified as being highly diagnostic in identifying individual fish as of farm or wild origin, regardless of their original population or strain. The set of SNPs presented here comprises a much needed tool for the study of genetic interaction between farmed and wild Atlantic salmon.

Keywords: SNP, genetic assignment, genetic interaction, Atlantic salmon.

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#### ICES CM 2009/Q:02

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##### **Movements and spatio-temporal distribution of escaped farmed and local wild Atlantic cod (*Gadus morhua*)**

Pål Arne Bjørn, Ingebrigt Uglem, Trine Dale, Sven Kerwath, Finn Økland, Rune Nilsen, Kåre Aas, Ian Fleming, and Robert Scott McKinley

The ecological consequences of cod culture are still poorly understood, but recent research suggests that Atlantic cod are more prone to escape than salmon. In the current study we examined the spatio-temporal distribution of farmed cod after simulated escape incidents relative to wild cod, both during and outside the natural spawning season. We also looked at whether the three-dimensional dispersal pattern of escaped farmed cod originating in Norwegian coastal (NCC) and northeast Arctic cod (NEAC) broodstock differs. Furthermore, we have investigated whether escaped cod are attracted to fish farms by releasing tagged cod both at a cod farm and near a mussel farm. The dispersal of escaped farmed and wild cod equipped with acoustic tags was monitored using an array of automatic listening stations. The farmed cod dispersed rapidly after escape, they randomly distributed over large areas and their distribution overlapped with that of wild cod. Escaped farmed fish were found at local spawning areas during the spawning season. Even though escaped cod dispersed rapidly from the farm they still seemed to be attracted to the farm if released at a location away from the farm. There was no variation in dispersal pattern between NCC and NEAC. Our results also indicated that the recapture rate of escaped cod was high compared with that of escaped salmon. Thus, although our results demonstrated that there is a considerable potential for ecosystem effects caused by escaped farmed cod, mitigating actions such as an efficient recapture fishery for escapees may be possible.

Keywords: Atlantic cod, *Gadus morhua*, aquaculture, fish escape, spatio-temporal distribution, telemetry.

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**ICES CM 2009/Q:03**

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**High connectivity of salmon farms revealed by aggregation, residence, and repeated movements of wild fish among farms**

Ingebrigt Uglem, Tim Dempster, Pål-Arne Bjørn, Pablo Sanchez-Jerez, and Finn Økland

Marine fish farms are widespread in coastal waters throughout the world, yet how they modify the movement patterns of wild fish species is largely unknown. We determined the spatio-temporal distribution of saithe (*Pollachius virens*) in a fjord system with intensive salmon cage aquaculture in Norway. Abundances of 8000–18 000 saithe were estimated around two salmon farms in the fjord using an underwater video system. Residence of saithe around fish farms, movements among farms and throughout the fjord were studied using implanted acoustic transmitters and an array of automatic receivers. It was found that 63% of the saithe equipped with acoustic tags were observed daily at any of the three farms in the fjord over a three-month period. When resident at a farm, saithe spent 8–10 h per day close to the sea cages. Periods of residence at specific farms were interspersed with rapid and frequent movements to adjacent farms 1.6–4.7 km away. Out of 24 tagged saithe, 15 moved among farms 2–21 times during the three-month period. If the movement patterns of the tagged fish are representative of the movements of untagged saithe, we estimate that fish from two different farms made a total of  $167\,112 \pm 41\,764$  and  $7768 \pm 1831$  inter-farm movements, respectively, over the three-month period. Thus, fish farms should be considered as connected not only through ocean currents, but also through wild fish movements. If saithe share pathogens with farmed salmonids, their behaviours imply that they have the potential to act as vectors of diseases and parasites among salmon farms.

Keywords: aquaculture, sea cage, aggregation, movement, *Pollachius virens*, tagging, tracking.

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**ICES CM 2009/Q:04**

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**Adaptive phenotypic plasticity in Atlantic cod and its relevance to risk assessments of aquaculture**

Jeffrey A. Hutchings

Risks to wild populations resulting from interbreeding with farmed escapees depend primarily on the probability of spawning between groups, the level of genetic differentiation between farmed and wild individuals, and the abundance of wild populations relative to conservation targets. The present work pertains to the second of these factors. In addition to the divergence that breeding designs and domestication selection can generate, genetic dissimilarities will also depend on the magnitude and type of genetic differentiation that exists among populations in the wild. Here, using a common-or-garden experimental protocol, I describe experiments that document how larval growth, survival, and their norms of reaction differ genetically among four populations of Atlantic cod (*Gadus morhua*) in the Northwest Atlantic. These traits, and their plastic responses to changes in food supply and temperature, differed across spatial scales at which microsatellite DNA failed to detect population structure. The results are consistent with the hypotheses that (i) cod populations differ significantly in how they respond to environmental change and that (ii) these differences in plasticity are genetically based and may be a product of local adaptation. Disruption to reaction norms and adaptive phenotypic plasticity, resulting from interbreeding between wild individuals and farmed escapees, merits attention in risk assessments of the aquaculture of Atlantic cod.

Keywords: phenotypic plasticity, reaction norms, farmed–wild interbreeding, common-or-garden experiment.

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**ICES CM 2009/Q:05**

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**Assessment of the direct genetic impacts of escaped farm salmon: a retrospective study of a wild Scottish stock**

E. Verspoor, D. Knox, and S. Marshall

The potential exists for negative impacts on wild Atlantic salmon populations (*Salmo salar*) from interbreeding with escaped farm fish. However, its actual extent remains uncertain and controversial. Unfortunately, information on numbers of escapes and gene introgression is generally lacking, in part as a result of a lack of historical baseline information. A molecular genetic study was carried out to assess the direct genetic impacts in the Loch na Thull catchment, a small river system in northwest Scotland containing a small wild stock and used for freshwater cage rearing of farm smolts from 1997 to 2004 with a documented presence of escapes. The study was retrospective and based on an eclectic set of DNA sources and genetic data that precluded a simple before and after comparison. The study found significant genetic differences between wild and farm salmon and that farm escapes appeared to contribute little to the genetic character of the current wild stock through interbreeding and introgression. What cannot be ruled out is that ecological interactions with farm escapes, such as competition for food and space or increased pathogen transfers, may have had indirect genetic impacts as a result of increased mortality and smaller numbers of returning spawners (e.g. loss of genetic variability).

Keywords: Atlantic salmon, farm–wild interaction, direct genetic impacts.

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**ICES CM 2009/Q:06**

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**Estimating salmon louse (*Lepeophtheirus salmonis*)-associated mortality among juvenile pink salmon (*Oncorhynchus gorbuscha*) in western Canada**

Simon R.M. Jones and N. Brent Hargreaves

A threshold of lethal infection was estimated from controlled laboratory exposures to be 7.5 *L. salmonis* per gramme for pink salmon averaging less than 0.7 g. This threshold was used to assess the risk of mortality caused by *L. salmonis* among pink salmon of the same size class in the Broughton Archipelago, Canada from 2005 to 2008. Virtually all ( $\geq 98.9\%$ ) pink salmon collected in late March belonged to the small size class and this proportion declined to  $\leq 1\%$  by early July. The proportion of small pink salmon with infections at or above the threshold declined from 4.5% in 2005 to 0% in 2008, coincident with an overall decline in parasite prevalence and intensity during this period. In 2005 and 2006, this proportion was greatest in March (7.8% and 1.1%, respectively) whereas in 2007, the proportion exceeding the threshold was greatest in May (2.9%). In 2008, no infections exceeded the threshold. Most new infections were acquired in early spring and there was no evidence of the acquisition of new infections in July. Parasite development coincided with fish migration through the study area. The declining risk to the smallest pink salmon between 2005 and 2008 was possibly related to changes in ocean conditions such as temperature, to changing treatment practices for this parasite on salmon farms or to changes in the abundance or distribution of non-farmed hosts. Results are discussed in the context of disease interactions between wild and farmed salmon.

Keywords: sea lice, interaction, farmed salmon, wild salmon, surveillance.

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**ICES CM 2009/Q:07**

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**Spawning success of farmed Atlantic cod (*Gadus morhua*): effects of photoperiod on gonad development in sea-cages in eastern Canada**

Edward A. Trippel and Steven R. Neil

The use of extended daylength to suppress sexual maturation of Atlantic salmon (*Salmo salar*) in sea cages has been successfully adopted by fish farmers. However, the same methods when applied to Atlantic cod (*Gadus morhua*) have been disappointing as gonad development of cod in sea cages exposed to extended daylength is seasonally delayed but not arrested. Results of a set of photoperiod trials using 20 h and 24 h light in sea cages indicated that ~90% of fish achieved sexual maturation despite using threefold greater light intensity than for salmon cages. The use of lights did, however, delay sexual maturation such that females were gravid for several months through summer. Spawning success was suppressed, with large numbers of females resorbing ovaries and exhibiting abnormally high gonadosomatic indices. Grower diets currently used in Atlantic Canada have led to enlarged livers and presumably played a role in disrupting gonad development and affecting gamete quality. Hepatosomatic indices were also well above those of wild cod. Sperm motility of farmed Atlantic cod was lower than that of wild cod. The use of lights has delayed potential spawning to periods of warmer water where, if embryos are released, they will be less likely to survive than those of cod reared in ambient light conditions. In Canada, the fate of drifting eggs from sea cages has not been evaluated. The extent of Atlantic cod farming in Canada is in a preliminary phase with limited concentration in the Bay of Fundy and coastal Newfoundland. No escaped juvenile or mature cod have been reported to date.

Keywords: maturation, photoperiod, light intensity, diet, liver, farmed cod, sea cages.

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**ICES CM 2009/Q:09**

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**The risk of genetic introgression from farmed escapees to wild cod populations**

J. E. Skjæraasen, J. J. Meager, and A. Fernö

Global declines of commercially exploited fish have resulted in new aquaculture targets. One such species is the Atlantic cod (*Gadus morhua*) which is already being cultured in Norway, with farming also underway in Iceland, Scotland, and several other countries in the North Atlantic. It is necessary to assess the potential impact of this aquaculture on the already severely depleted wild stocks. As farming inevitably leads to genetic divergence from wild stocks, one potential adverse effect of fish farming is fitness depression in wild populations because of interbreeding between escaped farmed fish and wild fish. To assess this risk, we used a combined laboratory and field approach. We first examined morphological and physiological traits known to affect reproductive success of farmed and wild cod. We then examined the behaviour and reproductive success of farmed and wild cod breeding naturally in large mesocosm experiments. Finally, we used telemetry to investigate movements of wild and farmed cod on a natural field spawning ground. We found that hybridization between farmed and wild cod is likely, but that farmed females are the main vector for genetic introgression.

Keywords: cod, farming, escapees, mating, genetic introgression.

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**ICES CM 2009/Q:10**

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**Possible genetic interactions between reared strains and wild populations of cod (*Gadus morhua*): relevance of findings from salmon (*Salmo salar*) common-or-garden field experiments**

P. McGinnity J. Carlsson, J. Coughlan, E. Dillane, E. deEyto, Andy Ferguson, P. Prodöhl, and T. F. Cross

With the rapid increase in production from cod farming and ranching around the North Atlantic concern has been raised about detrimental effects of accidental or deliberate introductions of reared strains into the wild. Here we concentrate on the possible genetic effects of interactions of captive bred fish with wild conspecifics by comparing with the major findings of Irish field experiments with reared and wild salmon and discussing the likelihood of similar effects being observed in cod. In the case of *S. salar* in a “common-or-garden” scenario in a natural freshwater stream, native wild populations were found in many situations, simulating both farm escapes and stocking, to have significantly higher lifetime reproductive success (LRS) than their reared counterparts. Where wild × reared hybrids were produced LRS was lower depending on the extent of reared involvement (e.g. wild backcrosses more fit than F2 hybrids). The role of MHC in determining the fitness of introduced individuals was also demonstrated and suggested a high degree of local adaptation in salmon populations. There is also evidence that adaptation to thermal stress is constrained within captive bred fish and these can affect fitness of wild populations when they breed in the wild. Cod differ from salmon in many aspects of their biology (e.g. there is considerably less observed genetic population structure), so the applicability of salmon results to cod is questionable, although genes associated with adaptation have been identified. However, some extrapolation should be possible and should be attempted using a combination of inference and modelling, because field experiments are time-consuming and expensive to conduct, and are likely to be more difficult in cod than salmon.

Keywords: cod, salmon, interactions, adaptation.

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**ICES CM 2009/Q:11**

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**Triploid Atlantic salmon: current status and future prospects**

Tillmann J. Benfey

The concept of using induced triploidy as a means of providing sterile fish for aquaculture and fishery management is not new, having been first suggested over 30 years ago. Triploid Atlantic salmon were first produced almost 25 years ago, and they have been evaluated in the European, North American, and Australian aquaculture industries. Through this work it was been demonstrated that it is easy to mass produce triploid salmon and that, when combined with simple and proven methods for producing all-female populations, triploidy is highly effective at suppressing gonadal development in Atlantic salmon. However, aside from Tasmania, there is currently no use of triploid Atlantic salmon in commercial aquaculture. This paper will review the development of triploidy as a management tool and outline some of the limitations of triploid performance that have influenced the decisions of industry not to adopt this technology. Finally, suggestions will be made for how to approach genetic and husbandry improvements to enhance the potential of triploid Atlantic salmon in commercial culture.

Keywords: aquaculture, Atlantic salmon, sterility, triploidy.

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**ICES CM 2009/Q:12**

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**The use of genetic tagging to study interactions between farmed and wild cod stocks**

K. E. Jørstad, T. van der Meeren, G. Dahle, O. I. Paulsen, T. Svåsand, and H. Otterå

Escape of farmed fish from aquaculture is considered to pose a risk of negative genetic impacts on native gene pools. In order to investigate potential interbreeding between cultured and wild Atlantic cod (*Gadus morhua*) a genetically marked cod strain was developed. The strain was homozygous for a rare allele (GPI-1\*30), expressed in white muscle tissue. Offspring from this strain were first used in large-scale enhancement experiments at three locations in western Norway (1990–1994). As expected, the releases were followed by a significant increase in the overall frequencies of the marker allele in all locations, but the frequency declined rapidly thereafter. After about 10 years, however, significant higher frequency was only detected in one region, suggesting survival to maturation and some reproductive success of the released cod. Mature cod possessing the marker allele were collected from this region as the basis for establishing a farmed genetic tagged strain of cod. This strain was allowed to spawn in net-pens in 2006 and 2007, and successful spawning was documented as well as leakage of fertilized farmed eggs and larvae into the natural environment. The survival and geographical spread of the farmed offspring are now being investigated. In addition, a new industrial-scale study has been initiated based on the same cod strain. Two year classes (2007 and 2008), each consisting of 500 000 juveniles, are being farmed in a commercial cod facility, and a comprehensive monitoring programme has been established to detect escapees during the farming period and leakage of eggs as a result of net-pen spawning.

Keywords: aquaculture, Atlantic salmon, sterility, triploidy.

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**ICES CM 2009/Q:13**

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**Competitive spawning of male triploid Atlantic cod (*Gadus morhua*) and the early life history performance of their offspring**

Nathaniel J. Feindel, Edward A. Trippel, and Tillmann J. Benfey

Farmed Atlantic cod escaping or spawning directly in sea cages poses a continuous risk to the natural environment similar to that recognized for the salmon aquaculture industry. Cod culture is in its infancy, providing the industry and scientific community with the opportunity to develop cod culture in an environmentally sound and profitable manner. Preliminary research has revealed that triploid females do not produce hydrated oocytes, whereas male triploids undergo spermatogenesis. Although this precludes the opportunity for within-cage mating of triploid females and males, it does pose a possible problem if male triploids were to escape. The purpose of this study was to examine whether male triploid Atlantic cod are capable of outcompeting male diploids for spawning access to female partners, and to evaluate the viability of their offspring. Fertilization rates, daily embryonic survival, hatch rates and daily, unfed larval survival were compared by manually fertilizing eggs with sperm from males of each ploidy. Data were collected from ten replicate trios, with each trio made up of a male of each ploidy and a diploid female. No significant difference was found between fertilization rates using milt stripped from triploids and diploids. A significant difference was found for hatch rates and larval survival, with offspring from diploid males being superior to those of triploids. Trios of fish were also placed in eight tanks and permitted to undergo spawning to determine whether a triploid male was able to gain access to a female in a competition setting. Egg batches were collected from tanks and microsatellite DNA makers used to determine proportion of embryos sired by each male.

Keywords: triploidy, male, mating competition, fertilization, offspring viability, Atlantic cod.

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**ICES CM 2009/Q:14**

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**Genetic assignment as a tool to identify the origin for Atlantic cod (*Gadus morhua*) escapees in Norwegian fjords**

Geir Dahle, Knut Jørstad, Torild Johansen, Jon-Ivar Westgård, Halvor Knutsen, and Kevin Glover

Although Atlantic cod farming is a small industry in Norway, it is widely recognized that cod is more prone to escaping from net-pens than Atlantic salmon, and therefore would represent a possible threat to the genetic integrity of natural populations. Not all escapement events are reported, and consequently, there is a need to develop an effective tool for the identification of escapees. This study investigates the potential to identify the farm of origin for escapees in a region with a number of cod farms. The approaches described here will be of relevance to a range of other marine species reared in culture where identification of escapees may be required. More than 400 cod were collected from nine cages located on four operational farms in western Norway, in addition to 30 escapees. These were all screened for nine microsatellite loci. In order to explore the possibilities for genetic assignment, tests were performed in the program Gene class V. 1.02.01 using the self-assignment, Bayesian option, leave-one-out sub-option. The power of each locus to contribute to self-assignment in the entire dataset was investigated by plotting cumulative number of alleles against cumulative relative assignment, while sequentially adding loci.

Keywords: farmed Atlantic cod, assignment.

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**ICES CM 2009/Q:15**

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**Cultural invasions: understanding the potential for, and implications of fish escapes from aquaculture**

Ian A. Fleming

Escapes are well known to accompany the open net-pen farming of fish in marine environments. This is exemplified by the farming of salmon, the most widely farmed marine finfish for commercial markets, with escapes reported in all salmon aquaculture regions. As such, salmon provide one of the best models for assessing biological risk associated with farmed fish escapes. Their escape into the wild can result in interbreeding and competition with wild salmon and can facilitate the spread of pathogens, thereby negatively impacting wild populations. Such impacts are exemplified by whole-river experiments that have documented evidence of an immediate depression in wild population productivity, as well as a longer term depression in fitness caused by interbreeding. Here, I explore how such risks vary across regions and what parallels there may or may not be for cod aquaculture. An understanding of such risk is critical in designing aquaculture policy and developing management options, not only for the farming of salmon, but also other marine finfish.

Keywords: salmon, cod, aquaculture escapes, interbreeding, ecological impacts.

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**ICES CM 2009/Q:16**

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**Pacific salmon and farmed salmon on the Pacific coast of Canada**

Richard J. Beamish

The relationship between Pacific salmon and farmed Atlantic salmon on the Pacific coast of Canada remains as one of the most contentious issues in the history of the management of Pacific salmon. The scientific issue of impacts of salmon farming on Pacific salmon is fuelled by a decrease in the commercial catch of Pacific salmon in British Columbia at a time when the total catch by all countries is at historic high levels. The Canadian percentage of Pacific salmon in the total catch

declined from about 24% in the mid-1970s to less than 1% in 2008. At the same time, the production of farmed salmon increased to over 10 times the 2008 catch. There is no evidence that the declining catch results from the impacts of salmon farming, but there is evidence that salmon farming can contribute to the natural mortality of some populations. The impact of this mortality at the population level is debated by scientists, whose interpretations are promoted in the popular press by groups or individuals who find support for their views in the various studies. The declines in catch are not related to salmon farming, but to changing ocean conditions. There is evidence that farmed and wild salmon can coexist successively. However, the strong public concern will continue until a monitoring and reporting system for salmon farming is fully supported.

Keywords: Pacific salmon, Atlantic salmon, wild fishery, aquaculture, management, oceanography, natural mortality.

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### ICES CM 2009/Q:17

#### **Genomic signatures of local adaptation in natural populations of Atlantic cod: implications for interactions between aquaculture and wild cod populations**

Einar E. Nielsen, Jakob Hemmer-Hansen, Nina A. Poulsen, Volker Loeschcke, Thomas Moen, Torild Johansen, Christian Mittelholzer, Geir-Lasse Taranger, Rob Ogden, and Gary R Carvalho

Marine fish display low levels of genetic structuring and associated high levels of gene flow, suggesting limited or a lack of local adaptations among populations. We investigated 98 gene-associated single nucleotide polymorphisms (SNPs) in local populations of Atlantic cod (*Gadus morhua*) across the species distribution. Genome scan tests for selection revealed eight loci with very high support for a statistical model of local selection compared with a model of neutral population divergence. On a south/north transect of central and eastern Atlantic populations, seven loci displayed strongly elevated levels of genetic differentiation consistent with adaptive evolution at the studied or closely linked loci. In general, outlier loci were not only associated with one or a few particularly divergent local populations. Temporal stability of allele frequencies within populations was confirmed by assessing SNP variation in DNA retrieved from historical otoliths. Our study of wild cod populations found that adaptive population divergence may be prevalent in cod on various geographical scales. This finding may have a number of strong implications for future sustainable aquaculture management and conservation of adaptive genetic diversity within the species.

Keywords: adaptive evolution, genome scan approach, marine fish, local adaptation, landscape genomics.

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### ICES CM 2009/Q:18 Poster

#### **Culture of Atlantic cod (*Gadus morhua*) in the vicinity of major spawning sites for Northeast Arctic cod and Norwegian coastal cod populations— is it hazardous?**

Svein-Erik Fevolden, Jon-Ivar Westgaard, and Jørgen Schou Christiansen

Waters along and adjacent to the coast of northern Norway are unique in housing two major populations of Atlantic cod with very distinct behavioural patterns. The northeast Arctic cod (NEAC) has its nursery and feeding grounds in the Barents Sea but migrates down to the coast of northern Norway to spawn. Norwegian coastal cod (NCC) is more stationary, spawns mainly at local sites in individual fjords but to some degree also overlaps with the spawning sites of NEAC. These unique patterns in behaviour are reflected in a distinct genetic divergence between the two populations. Various molecular genetic markers (scnDNA, microsatellites, and single nucleotide polymorphisms) have displayed genetic differences between NEAC and NCC that are remarkable for marine fish with a comparable gene flow potential. These facts need to be taken into

consideration when designing a management regime for cod culture in northern Norway. In contrast to captive Atlantic salmon, the iteroparous and batch-spawning Atlantic cod may spawn over an extended period of time, allowing escapement of the pelagic eggs and larvae in addition to adults. Thus, strict criteria should be set on the choice of broodstocks, using preferably local populations, to avoid producing hybrids between NEAC and NCC despite potential production advantages they may have. The list of reservations against an impetuous development in cod culture is extensive and should be founded entirely on the unique characteristics of the natural cod populations of concern. A simulation study on the effects of escapees on small local stocks is outlined here.

Keywords: Atlantic cod, population divergence, aquaculture, broodstocks.

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**ICES CM 2009/Q:19      Withdrawn**

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**ICES CM 2009/Q:20      Poster**

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**A comparative analysis of milt produced by triploid and diploid Atlantic cod (*Gadus morhua*)**

Stefano Peruzzi, Geir Rudolfsen, Raul Primicerio, Marianne Frantzen, and Goran Kaurić

Growing concern about possible genetic interactions between cultured and wild Atlantic cod following accidental fish escapes or release of fertilized eggs from natural spawning in net-pens has raised interest in the production of triploid sterile fish. Initial results reveal that gonadal maturation in triploid cod is impaired in females with rudimentary ovaries and that some triploid males may produce variable amounts of spermatozoa. In the present work, we compare the characteristics of the milt produced by triploid and diploid cod in terms of nuclear DNA content, sperm count, motility, seminal fluid composition, and egg fertilization capacity. We also assess the competence of triploid males to induce spawning in diploid females and the fate of their progeny following natural or artificial crossings. No major differences between ploidies were observed for the majority of sperm motility descriptors as for spermatozoa density, spermatocrit, or seminal fluid's variables. Triploid males produced aneuploid sperm cells and the larvae generated from crossings with diploid females were grossly abnormal and did not survive to exogenous feeding. Because they are at least gametically sterile, triploid cod may be of value in aquaculture to minimize the ecological impact of large-scale escapes and to avoid the establishment of feral populations.

Keywords: milt characteristics, diploid, triploid, Atlantic cod, *Gadus morhua*.

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**ICES CM 2009/Q:21      Poster**

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**Oogenesis and spermatogenesis of triploid Atlantic cod (*Gadus morhua*)**

Nathaniel J. Feindel, Edward A. Trippel, and Tillmann J. Benfey

Atlantic cod (*Gadus morhua*) is a prime candidate for aquaculture in view of the collapse of wild stocks, low supply, and large demand. Pre-harvest sexual maturation of Atlantic cod is a key constraint for profitable mariculture, as fillet quality and adult survival are compromised by maturation. Spawning within cages and the possibility of escaped cod interbreeding with wild stocks are also negative aspects of maturation of farmed cod. With the aim of generating sterile cod, we are exploring triploid populations to minimize these problems. Triploidy induction was achieved through hydrostatic pressure treatment of eggs shortly after fertilization. Based on preliminary results, at age 26 months, no sexually mature triploid females were observed, and only 12.5% of triploid males were mature. In November, approaching the winter/spring spawning

season, triploid females possessed oocytes in the preparatory and ripening stages. Ovaries were orange-red, with no vitellogenic oocytes. Triploid males in November were in the ripening stage with large, reddish-white lobules but with no mature spermatozoa extruded. In February, during the diploid spawning season, triploid females were in the preparatory and ripening stages (opaque oocytes present), but no developing vitellogenic or hydrated oocytes were present. Triploid males were in the spawning stage, with opaque creamy-white lobules with free-flowing viscous milt. During the spawning season, significant differences were found between female triploid and diploid gonadosomatic indices ( $3n = 0.92$ ,  $2n = 26.41$ ), but there was no significant difference between male gonadosomatic indices ( $3n = 2.97$ ,  $2n = 4.21$ ). Histological preparations of gonadal tissues are underway to more clearly delineate the differences in oogenesis and spermatogenesis of diploid and triploids.

Keywords: triploidy, oogenesis, spermatogenesis, gonadal stages, spermatozoa, oocytes, spawning, Atlantic cod.

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