PROJECT N^{O}: FP6 32690

ESCAPEPROOFNET

Project title

Escapes in European Aquaculture – Development of an Escape-Proof Net especially for Cod, Bass and Bream fish farming

Cooperative Research

Horizontal Research Activities Involving SMEs

Final Publishable Activity Report
Date of issue of this report: 27th August 2009

Period covered: from 1st September 2006 to 31st May 2009

Start date of project: 1st September 2006 Duration: 33 Months

Project Coordinator: Refa Frøystad Group AS Version 1

CONTENTS

PROJECT INFORMATION

PROJECT NO:	FP6-32690
CONTRACT NO:	COOP-CT-2006-32690
TITLE OF PROJECT:	**EscapeProofNet** – Escapes in European Aquaculture – Development of an Escape-proof Net especially for Cod, Bass and Bream fish farming
COORDINATOR:	Kjetil Olsen
EXPLOITATION MANAGER:	Kjetil Olsen

SME CONTRACTORS:

~~4~~1 Refa Frøystad Group AS
~~5~~2 Burashi BSM Trading s.r.l
~~6~~3 Steen-Hansen
~~7~~4 IQAP
~~8~~5 Ocean Nets Ltd.
~~6 Helgelandstorsk AS~~
~~7 Marina 2000~~
11 Atlantic Cod Farms

Formaterade: Punkter och numrering

RTD PERFORMER CONTRACTORS:

~~9~~8 Teknologisk Institutt as (TI)
~~10~~9 Pera
~~11~~10 AIMPLAS

Formaterade: Punkter och numrering

PUBLISHABLE EXECUTIVE SUMMARY

This report covers the work carried out from September 1st 2006 to May 31st 2009. The main body of this report is a précised overview. However more detailed appendices are attached to cover the technical work programme performed in the 1 to 33 month period.

Intensive farming of species such as Seabass, Seabream and Cod, uses to a large extent technology that traditionally was developed and specialized for salmon farming purposes. This has been shown not to be optimal, among other things with respect to net design, materials used, and resistance against gnaws and chip-ups. The reason for these problems is differences in species behaviour. Seabass, seabream and cod are aggressive towards the net itself, more than other species, and biting, sucking and snatching on loose rope ends, knots etc.,is often seen. As a result, holes in the net may occur, leading to escapees and loss of fish stock. Due to this, there is considerable concern with respect to aquaculture representing a threat to ecology and biodiversity representing risk of disease transfer from aquaculture to wild fish populations and potential "genetic" pollution of wild fish. In addition, escapees represent a considerable decrease in competitiveness for the large community of European aquaculture SMEs.

The COOPERATIVE research project, ESCAPEPROOFNET, aims to **develop a sea cage net system especially suitable for farming of typical net aggressive fish species** like European seabass, Gilthead seabream and Atlantic cod, currently and in the near future important in the European fish farming industry.

To achieve this, we must develop a cost-effective net filament with exact physical characteristics and antibite as well as antifouling properties for the prevention of fouling, biting & snatching behaviour. An adaptation of existing net manufacturing techniques for optimal exploitation of material characteristics will be developed and used to produce a net with improved design regarding configuration, strength & durability that will also fulfil the requirements to embrace low operational costs.

The official project start was September 1st 2006 and the kick-off of the project was on September 20th.

Project innovation work over the project period is covered by work packages 1,2, 3 and 4.

Work Package 1 Scientific understanding of requirements for nets used in fish farming
Work Package 2 Creation of filaments for minimal fouling and biting
Work Package 3 Net design and manufacturing
Work package 4 System integration and Industrial Validation

During the second half of the project the DoW was altered to account for the comments received by the EC external evaluator to the year 1 reporting. The use of copper initially suggested was discarded as there were uncertainties on possible future legislation against it. This will be described in more detail when discussing the work package tasks. The project experienced an unforeseen delay in extrusion of filaments as the workshop hosting the extrusion machinery was flooded during a period of heavy rain. This caused failure of the extrusion equipment and a period of inactivity as the machinery was under maintenance. Also, the project experienced problems in processing of the newly developed compound. Pressure was built up in the extruder die where an unknown substance was precipitated; this also delayed work as a new compound was manufactured using a different PET grade to remedy the processing problem.

As a natural consequence, Work Package 3 requiring the material produced in Work Package 2 was also delayed. Work Package 4, System Integration and Industrial Validation, was delayed in terms of testing net samples but work was performed using single filament threads at the third party contributor Swansea University.

During the second half of the project, the consortium went through a few changes. The partners Marina 2000 and Helgelandstorsk that were not contributing sufficiently were replaced by Atlantic Cod Farms. In general, the Consortium has been cooperating well and has been working hard in order to catch up with work and solve upcoming issues. All project meetings have been well attended.

The project has created a web site for the combined use of an on-line administrative tool for the partners (password protected) and web presence. The address of the web site is www.escapeproofnet.com . Links to the partners' web sites is available on the public site.

SECTION 1 – PROJECT OBJECTIVES AND MAJOR ACHIEVEMENTS DURING THE REPORTING PERIOD

1.1 Overview of General Project Objectives

The overall objective of this work is to develop a sea cage net system especially suitable for farming of typical net aggressive fish species like European seabass, Gilthead seabream and Atlantic cod.

Scientific Objectives

- enhanced understanding of specific requirements with regards to specific species behaviour in order to achieve the basis for optimization of design and development of a fish net system to increase strength and resistance characteristics that would prevent farmed fish species showing aggressive behaviour towards net structures from escaping.
- enhanced understanding of specific requirements concerning fish repulsive and anti-fouling issues in habitats for fish farming in order to achieve the basis for selection of optimal technology for achieving antibite and antifouling properties of the resulting net structure..
- enhanced understanding of specific requirements and options with regard to weaving technology for the developed filament material in order to optimize the manufacturing procedure to avoid abrasive and biting promoting structures that could weaken the total strength of the net.

- Enhanced understanding of specific operational requirements including change of net, mending of net, harvesting of fish, handling of dead fish, water flow-through etc. in order to achieve the basis for design optimization of net configuration.

Technological Objectives

Develop a polyolefin filament with:

- Antifouling and antibite effect by use of fiber surface properties and/or natural antifoulants/antibite agents.

Establish a method for successful implementation of these fibers:

- in such a way that they contribute as effective impregnation and repulsive agents for the whole life-time of the net
- UV-resistance to provide a life-time of 3-4 years without reduced amount of strength that makes it unfit according to the Norwegian Standard NS 9415
- Withstand a water current speed of 1 m/sec with less temporary deformity than 10 % of the total production volume
- Scalable up to a size of 70-meter circumference and a depth of 15 meters with a production volume of approximately 4.700 m^3.

Total system with a single net that by empiricism reduces escapees to less than 0.5 % on a numerical basis

1.2 Summary of Recommendations from Periodic Reviews

In the evaluation report received by the EC, the expert evaluator has indicated that the cupric compound (Cu_2O) finally selected by the consortium to be used as the anti-fouling will probably be banned in the EU and EEA (Biocidal Products Directive, EC 98/8/EC). Therefore, the project objectives may not be as relevant anymore as at the start of the project. The expert proposed:

It is advisable to switch to another, non-chemical antifoulant. Generally, chemicals do not resolve anything, they only add to the problem, especially in the long term. There is no use in achieving higher production numbers if the cod are contaminated and hence unfit for consumption. This applies to both antifoulants and fish repulsive agents. Although it is acknowledged that non-toxic antifoulants and repulsive agents are still in a preliminary phase, various ecological methods have been explored and should be further investigated (D1 Task 1.3 sections 13.2.3 to 13.3; www.crabproject.com). One option could be to keep biofoul-grazing organisms between the internal sea-cage where the cod are kept and the external (second) net if a double sea-cage is employed (refer to D1 section 3.4 Figure 3-4). In the case of sea-cages, probably but not necessarily, a fish species should be used. This way no chemicals are involved, the biofouling problem can (partially) be resolved and the grazers may be sold for consumption and/or used as feed for cod. Obviously it cannot be excluded that the cod will try to catch the grazers and hence stimulate snatching at the net even more but aggressive cod behaviour may be reduced by adopting more efficient feeding methods or by cultivating triploid cod instead (refer to section 9b of this evaluation report).

Budget-wise, there are several options as well. For example, participant Marina 2000 dropped out since the start of the project and is projected to be replaced. The budget foreseen for this partner could be subdivided under the remaining partners to make up for the funds required for an eventual change of course regarding the antifoulant (and repulsive agent for that matter). Obviously in this case partner Marina 2000 would not be replaced.

According to the expert's comments, the Commission will approve the reports and deliverables subject to re-negotiation of the work to be performed during the next period and a revision of the Description of Work. The Commission may impose a suspension of the project of several months in accordance with Art. II.5. You will receive a formal notification in due time, and from the day of reception of this notification the suspension will take effect.

Meanwhile and in order to reduce the period of suspension, the consortium should start to revise the Description of Work (DoW) following the expert's comments outlined in the attached review report. Once this revision is finished, please send it to me as a WORD document with track changes. Then the contract will be amended with the new DoW and the suspension will be lifted. Please be aware that the consortium can also ask for an extension of the duration of the project to compensate the period of suspension".

Based on the EU comments in the Review Report from the EU for the 1st reporting period and in the E-mail from EU Scientific Officer, a report was prepared in order to recommend revisions in the EscapeProofNet project addressing the key issues in the Review report.

Accordingly, the report presented an evaluation of potential problems related to fouling and use of especially copper based anti-foulings in the aquaculture sector. In addition, the report presented relevant legislation and especially the requirements due to the EU Biocide Directive (98/8/EC). Further, recommondations for future work and revisions in the work plan were presented. This report is included in the Final Reporting.

1.3 Project Objectives and Achievements for the project period

The specific objectives for the twelve-month period of 1st September 2007 to the 31st May 2009 of the project are summarised in the table below.

Deliverable No	Tasks	Objective	Achievements During Reporting Period	Update
D1	1.1 1.2 1.3	Report detailing requirements of the EscapeProofNet cage, including choice of material compound, additives, selection of materials and possible environmental impact of their use.	• Extensive report on requirements of the EscapeProofNet cage has been written. Materials and additives have been evaluated	100% Complete

D2	1.4	Report on requirements of net design to improve handling possibilities, durability and suitability.	• A report on requirements of net design has been written	100% Complete
D3	2.1 2.2 2.3	Report on specified polyolefin compound for net material and suitable impregnating and repulsive agents. Investigation of natural antifoulants.	• A polymer compound based on HDPE/PET has been produced. Natural antifoulants and substances to provide antibite properties have been evaluated	100% Complete
D4	2.4	Net samples for field test	• A HDPE/PET filament has been produced and made into net	100% Complete
D6		Report on required design criteria	• A report based on farmer questionnaires has been completed	100% complete
D7		Reference document specifying net characteristics, best practice for mending, net colour, mesh size etc. Properties, suitability and projected net costs.	• A report covering these aspects has been finalised	100% complete
D8		Integrated prototype	• The project has not completed an entire net cage prototype. Instead, the validation has been based on net samples placed inside a full scale net cage	100% complete
D9		Validation of the commercial viability of the technology application including feature benefits and cost implications	• The EscapeProofNet technology has been validated through trials with net samples inside of a full-scale net cage in addition to trials performed at Swansea University and material testing performed at TI	100% complete
D10		Report on competitive patents and a plan for patent application. Standards, ethical	• A report on competitive patents has been written also adressing ethical and regulatory aspects.	100% complete

		and regulatory aspects of result exploitation		
D11		Project presented at relevant conferences and exhibitions. Publications in the form of editorials, technical papers and trade press.	• The project has had good coverage at conferences and also in the press.	100% complete
D13	6.1	Dissemination and Use plan (DUP)	The Final Dissemination and Use plan has been written	100% Complete
D16		Publishable final report	Submitted with the final reporting	100% complete
D17		Review report on economic and societal issues	Submitted with the final reporting	100% complete

As described above, the project has experienced delay due to flooding of the workshop causing downtime for extrusion machinery. In addition, the compound showed processing difficulties making production of a new compound necessary. Also, the fact that extrusion cannot be made on full-size equipment as very large volumes of resin are then required, resulted in slow production of filaments for the net. The consortium worked intensively to get trial-frames ready for the placement in full-size net cages and meanwhile, trials with algae settlement on fiber were performed at Swansea University, where tests on effect of biting was also performed. The net samples were tested in regard to material properties at TI. The EscapeProofNet material has been compared to nylon and HDPE.

1.4 Issues during the Project Period

The main items to address here are the changes made to the DoW to account for the comments received after the first reporting period.

In the project plan, the issues raised in the review report for RP1 have been addressed. Special focus should be made on development of biocide free solutions instead of development of solutions with incorporation of copper additives in the filaments. Special focus should be on material development and more specifically the surface properties in order to minimise fouling on the new filaments for cage nets to be developed in the project. Hence, the following revisions in the project plan were made:

1. Major revisions in Work Package 2; creation of additive incorporated filaments
    a. Focus on development of new filaments with surface properties to minimise fouling.
    b. Development of surface treatment in order to use copper based or other anti-fouling/antibite coatings on new cage filaments
    c. Feasibility study with regards to use of natural anti-foulants identified in point 3.4 in this report.
2. Minor changes in Work Package 3: Design and Manufacturing Technology to Optimize Strength, Durability and Sustainability.
    a. No changes required with regards to design

b. Adjustments with regards to manufacturing technology addressing the changes in Work Package 2 with regards to new filaments developed.
3. Minor adjustments in Work Package 4 – industrial validations;
    a. Adjustments in order to address changes in Work Package 2 with regards to test procedure
4. No major revisions required in Work Packages 5, 6 and 7, i.e. Innovation Related Activities, Consortium Management and Project Management respectively.

These changes properly address the environmental focus and regulatory issues with regards to copper as biocide in the aquaculture sector. The revisions made to the workplan are consistent with the project idea and that the activity covered by project budget and allocated EU funding.

Swansea University was introduced as Third Party under Teknologisk Institutt as in order to perform the testing of fouling on new materials developed as tests performed in Work Package 2 as well as part of Work Package 4. Swansea University has the required infrastructure to perform testing of fouling on materials in a fully controlled environment (land based fish tanks) independent of seasonal variations experienced in the sea. Biting tests has also been performed at their facilities.

The above mentioned alterations where made to the project and the development work was continued without antifouling/antibite agents integrated into the base polymer compound. The project experienced a delay when the workshop hosting the extrusion equipment was flooded, causing complete failure of machinery. When the extrusion was started there were difficulties in processing the compound and very high temperatures where necessary to get the material out. Also, a substance was separated out at the extruder die. To remedy this problem a new compound was produced using a different PET grade. This resolved the problems and good quality filament was achieved. However, using lab scale equipment, the production of filaments in larger quantities is slow. The use of full-size equipment is not possible as too large volumes of resin are necessary to be able to use the machinery.

These things in all have rendered it impossible to produce a full-scale net cage prototype within the project time-frame. Instead, validation has been performed using framed net samples.

SECTION 2 – WORK PACKAGE PROGRESS REVIEW FOR THE PROJECT PERIOD

2.1 Work package objectives

The specific work package objectives for the 33-month period of 1st September 2006 – 31st May 2009 of the project are summarised in the table below.

Work-package No	Workpackage title	Lead contractor Short Name	Person-months	Start month	End month
WP 1	Scientific understanding of requirements for nets used in fish farming	TI	24,5	1	6
WP 2	Creation of additive incorporated filaments	AIMPLAS	26,0	4	12
WP 3.	Design and manufacturing technology to optimize strength, durability and suitability	Refa	20,0	6	33
WP 4	System Integration and industrial Validation	TII	22,0	12	33
WP 5	Innovation Related Activities	Ocean Nets	14,5	6	33
WP 6	Consortium Management	Refa	3,35	1	33
WP 7	Project Management	Refa	7,0	1	33

2.2 Overview of work package technical progress

Work package 1 Scientific understanding of specific requirements for nets used in fish farming

Task 1.1 Enhanced understanding of specific requirements with regard to specific species behaviour and fouling issues

Objectives
Detailed overview on specific species behaviour and requirements, in addition to fouling issues.

Progress
A study on fish species behaviour and biofouling has been made by TI based on literature and experience. TI has great knowledge in aquaculture which has been very valuable for this task. Task 1.1 has been completed and a task report has been written including facts about cod escapees, economical impact of escapees as well as cuases of escape. The species European Seabass and Gilthead Seabream have also been included as have behaviour and biology. The report also contains an overview of biofouling in European Aquaculture, describing the biofouling problem as well as attachment mechanisms and properties on non-living surfaces. Current antifouling strategies in aquaculture are described in addition to other potential strategies.

Fish Behaviour
Intensive farming of Seabass, Seabream and Cod, is largely based on technology that was traditionally developed and specialized for salmon farming purposes. This has been shown not to be optimal, among other things with respect to net design, materials used, and resistance against gnaws and chip-ups. The reason for these problems is differences in species behaviour. Seabass, seabream and cod are aggressive towards the net itself,

more than other species, and biting, sucking and snatching on loose rope ends, knots etc. is often seen. As a result, holes in the net may occur, leading to escapees and loss of fish stock. Due to this, there is considerable concern with respect to aquaculture representing a threat towards ecology and biodiversity; transfer of disease from aquaculture to wild fish populations; and potential “genetic” pollution of wild fish populations. In addition, escapees represent a considerable economic loss to the fish farmers which may reduce competitiveness for the large community of European aquaculture SMEs.

The EscapeProofNet focuses on developing a cost-effective net filament with exact physical characteristics and incorporated impregnation and repulsive agents for the prevention of fouling, biting & snatching onto the net by marine fish species in subject – i.e. the Atlantic Cod (*Gadus morhua*) and the “Mediterranean species” Seabass (*Dicentrarchus labrax*) and Seabream (*Sparus aurata*). Based on this, it is the objective of this report to give an introduction and overview of factors adhering to the netting which may (or are known to –) affect the behaviour of the fish species already mentioned under aquaculture conditions.

The likelihood that farmed Atlantic cod may escape from aquaculture installations is estimated at 10 times higher than with Atlantic salmon (S. salar) (pers.comm. Kåre Aas, Fiskeriforskning). Table 3-1 gives an overview of cod escapees in Norwegian aquaculture regarding incidents, amounts and causes in the period from 2001 to May 2005. In this period, escapees of 220.000 farmed cod have been registered, and the majority of these escapees is caused by damage of the cage nets.

Number of registered cod escapees from Norwegian fish farms, 2001 - May 2005 (Source: Directorate of Fisheries).

Reported	Cod escapees (No. of fish)	Cause
May 2001	*40000*	*Unknown*
Total 2001	**40000**	
Total 2002	**0**	
March 2003	*5000*	*Net damage, bad weather*
May 2003	*6700*	*Net damage, predator (seal)*
June 2003	*5000*	*Failure during net change*
August 2003	*2000*	*Net damage, predator*
September 2003	*4000*	*Net damage, installation of weights*
September 2003	*21181*	
September 2003	*6087*	
December 2003	*24293*	*Net damage, drift-goods during bad weather*
Total 2003*	**75000**	
March 2004	*2000*	
June 2004	*1900*	*Predator*

September 2004	*0*	*Net damage*
October 2004	*200*	*Hole in net caused by biting/snatching by cod*
November 2004	*14210*	*Hole in net*
November 2004	*572*	*Hole in net. Predator or biting damage*
December 2004	*100*	*Hole in net. Probably by fishing tackle/jig*
Total 2004*	**20000**	
January 2005	*72628*	*Storm damage on net-rope connected to floater*
January 2005	*3000*	*Hole in net. Biting / production failure??*
February 2005	*8000*	*Hole in net. Tear and wear*
Total Jan-May 2005*	**85000**	
Total 2001-May 2005*	**220000**	

Cod represents one of our most important marine resources in fisheries in the North Atlantic and thus – in the North-western parts of Europe. There is probably no doubt that farming of cod represents a potential opportunity to value creation in many coastal areas in these parts of the Union. “The crucial challenge lies in development of the sector in such a way that cod fish farming does not represent any threats towards the natural resources and fish populations” (Jørstad, 2005). €125 Million are invested in the Norwegian cod farming sector alone, and the value for money will not be considered acceptable unless the problem of escapees are solved in due time.

Biofouling

The diversity and intensity of biofouling in aquaculture is site specific, depending on season, geographic location and local environmental conditions. There are many problems associated with fouling in aquaculture[1]. Problem areas include fouling on infrastructure (immersed structures such as cages, netting and pontoons) and stock species (farmed species, particularly shellfish such as mussels, scallops and oysters). Examples are shown in Figure 1. Biofouling greatly reduces the efficiency of materials and equipment: it physically damages equipment (abrasion/brittleness/increased load) and flow can be significantly reduced directly reducing foods supply. Biofouling communities can directly compete for resources with cultured organisms and can include predators and harbour diseases. The selling of biofouled produce (shellfish) is affected on aesthetic grounds or because the fouling is not compatible with product processing or packaging methods. In addition biofouling can have direct toxic affects: a number of benthic marine organisms within biofouling communities produce secondary metabolites that act as antipredation strategies or natural antifoulants. These chemicals can be toxic to other marine organisms, including cultured organisms. Significant losses of cultures are

[1] Lane A. and P.R. Willemsen. 2004. Collaborative effort looks into biofouling. Fish Farming International September 2004: 34-35.

also attributable to deoxygenation and degradation products when biofouling communities die or simply swamp the cultures/cages preventing oxygen and waster product exchange.

Fig. 1. Biofouling in aquaculture. Top: Oyster with barnacle fouling. Bottom: Hydroid fouling on nylon netting.

The costs associated with biofouling can be very significant[2]. The replacement of nets is expensive, annual costs to replace nets and reapply antifouling for a medium-sized UK salmon farm are estimated to be ± € 120.000. Cleaning oyster cultures is estimated to be 20% of the market value and biofouling can reduce growth rates by over 40%. The estimated cost of fouling on cultured mussels in Scotland is ± € 450-750.000 per year for farmers, and the problem is worsening[3]. For many small (often family-run) businesses this can be the difference between profit and loss in a sector under extreme economic pressure.

Unlike other industries where biofouling is a problem, such as shipping, few studies have examined the impact and sought cost-effective solutions for the aquaculture industry. The most common methods to control the problem are mechanical cleaning or using antifouling coatings. Mechanical cleaning, involving brushing, scraping (Figure 2) or

---

[2] Beaz D., V. Beaz , S. Dürr, J. Icely, A. Lane, J. Thomason, D. Watson and P.R. Willemsen. Sustainable Solutions for Mariculture Biofouling in Europe. ASLO Meeting, Santiago da Compostela, Spain, 19th June 2005.

[3] Campbell D.A. and M.S. Kelly. 2002. Settlement of Pomatoceros triqueter (L.) in two Scottish lochs, and factors determining its abundance on mussels grown in suspended culture. J. Shellfish Res. 21:519-527.

cleaning using water jets (Figure 3), is labour intensive and tedious[4]. Air/sun drying when nets or oysters are hoisted out of the water and desiccation or heat kills but does not remove fouling. Cleaning of shellfish can be combined with immersing the biofouled shellfish in either hot or fresh-water, chlorine, salt solution or lime[5]. The stress of the immersion medium kills the fouling.

Fig. 2. Manual cleaning of oysters.

Fig. 3. Manual cleaning of cage nets using water jet device.

Applying a biocidal coating on the surface is still widely used in aquaculture. Net coatings are usually low-tech versions of coatings for vessels. Small amounts of the active substance are released to deter or kill the fouling. The lifetime of such coatings, mostly based on copper oxide (Cu_2O), is limited to one season, while the costs for treating nets are high. Antifoulants are known sources of pollution from aquaculture and are responsible for elevated levels of copper close to fish-farms. In addition to Cu_2O, organic biocides with improved environmental profiles (e.g. biodegradable) are available[6], but these are generally not targeted at the aquaculture industry. Environmental problems associated with commonly used biocides have lead to increasingly restrictive legislation and the banning of some compounds for use on vessels and in aquaculture, most notably TBT[7] and in some member states copper, Irgarol and Diuron. In the next years the choice

[4] Hodson S.L., T.E. Lewis and C.M. Burke. 1997. Biofouling of fish-cage netting: Efficacy and problems of in situ cleaning. Aquaculture 152:77-90.
[5] Arakawa K. 1980. Prevention and removal of fouling on cultured oysters: a handbook for growers. Maine Sea Grant Technical Report No. 56.
[6] Costello M.J., A. Grant, I.M. Davies, S. Cecchini, S. Papoutsoglou, D. Quigley and M. Saroglia. 2001. The control of chemicals used in aquaculture in Europe. J Appl Ichthyol 17:173-180.
[7] IMO. 2002. International Maritime Organization, Antifouling Systems, http://www.imo.org.

and availability of biocides for use as antifoulants will become much more restrictive within Europe with the application of Biocides Directive EC 98/8/EC[8]. When fish net cages impregnated with toxic coatings do become fouled they need to be removed and cleaned. This costly process causes stress to the fish resulting in mortality (estimated at 2%). Net washing plants have problems dealing with the copper containing waste and sludge. The waste must be specially disposed of and such safeguards evidently increase costs.

Some other antifouling methods certainly exist, examples of which are biological control using grazers[9]; avoidance when cultures are removed or repositioned during periods of heavy fouling settlement[10]; new materials (coatings) such as silicone based fouling-release coatings[11], generally in combination with mechanical cleaning[12] or coatings for netting and shellfish based on natural antifoulants[13]; new cage designs to limit fouling on shellfish or fish net cages[14]; and spraying with an antifouling solution such as acetic acid[15]. These methods are only being used locally or are under development. Biofouling persists as a significant practical and economic barrier to the development of competitive aquaculture and there is a need for cost effective, sustainable solutions to the fouling problem.

Task 1.2 Enhanced understanding of materials for fish net cages

Objectives

To create a detailed overview of issues regarding material options for use in fish farming nets.

Progress

The work done in the task has focussed on selection of the most suitable materials achieving the desired final properties. The selected materials must fulfil the aquaculture requirements and the manufacturing process with melt flow index being the key parameter. Nylon, which is the most frequently used material for fish cage nets, has been used as a reference. In the material evaluation, two types of HDPE with different melt flow indexes were chosen and in addition blends of recycled PET/HDPE have been

---

[8] European Commission. 1998. Directive 98/8/EC of the European Partiament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market. Official J. of the EC, L 123/1. <http://europa.eu.int/comm/environment/biocides>

[9] Hidu H., C. Conary and S.R. Chapman. 1981. Suspended culture of oysters: biological fouling control. Aquaculture 22:189-192.

Lodeiros C and Garcia N (2004) The use of sea urchins to control fouling during suspended culture of bivalves. Aquaculture 231:293-298

[10] Rikard F.S., R.K. Wallace and C.L. Nelson. 1996. Management strategies for fouling control in Alabama oyster culture. J Shellf Res 15:529

[11] Baum C., W. Meyer, L.G. Fleischer and D. Siebers. 2002. Biozidfreie Anti-fouling Beschichtung, EU Patent EP1249476A2.

[12] Hodson SL, C.M. Burke and A.P. Bissett. 2000. Biofouling of fish-cage netting: the efficacy of a silicone coating and the effect of netting colour. Aquaculture 184:277-290.

[13] McCloy S and R. De Nys. 2000. Novel Technologies for the reduction of biofouling in shellfish aquaculture. In: Fisheries N (ed) Flat Oyster Workshop, Sydney, p 19-23.

De Nys R.C., P. Steinberg, T.S. Charlton and V. Christov. 2004 Antifouling of shellfish and aquaculture apparatus. Unisearch Limited, US, p 32.

[14] Menton DJ and J.H. Allen. 1991. Spherical (Kiel) and square steel cages: First year of comparative evaluations at St. Andrews, NB. Bull Aquacult Assoc Canada 91:111-113.

[15] Carver C.E., A. Chisholm and A.L. Mallet. 2003 Strategies to mitigate the impact of Ciona intestinalis (L.) biofouling on shellfish production. J Shellf Res 22:621-631.

investigated. This blend combines the dimensional stability of PET with the good impact strength of HDPE. The main reason for using recycled PET is to reduce the material cost and achieve a more environmentally friendly material while maintaining the mechanical properties. The incompatibility of polyesthers and polyolefins causes a need for compatibilizer. Compatibility is usually promoted by use of copolymers with segments capable of specific interactions and/or chemical reactions with the components of the blend.

Several different compatibilizers for the HDPE/PET blend have been investigated and EGMA (ethylene-glycidyl methacrylate copolymer) was chosen for the EscapeProofNet material. Trials with tensile testing of different mixtures of HDPE/PET/EGMA show that the optimal concentration was 10 % by weight. Tensile tests also show that the PET/HDPE blend outperforms the HDPE. The PET/HDPE blend shows higher melt strenght than HDPE, slightly lower drawability and draw resonance and good elongation properties while the extensional performance was very similar for all compounds. The initial material selection was the following:

- Alcudia HDPE M5305
- HDPE/PET/EGMA blend 80/20/10
- Nylon 6 SUNYLON

For the antifouling additive the active ingredient Cu_2O (5 and 10% addition by weight) has been chosen, due to explosion risk the migrating agent initially suggested had to be excluded since it was impossible to use it at the required processing temperatures. The resulting material is now under test for release of Cu_2O. Initial tests show that the addition of Cu_2O does not significantly affect the mechanical properties.

Task 1.3 Enhanced understanding of impregnating and repulsive agents

Objectives
Create an overview of antibite agents for possible integration into the filament yarn.

Progress
A report with an overview on antifouling nets in use today, regulations on antifouling agents,present-day antifouling agents, non-toxic antifouling agentsother antifouling strategy and repulsive agents has been written.

In summary, there are a number of antifouling agents on the market. Most of these are copper-based. Metals and organometallic compounds are still common antibacterial agents but are prone to bioaccumulation and alternatives are therefore sought. Marine microbes as a potential source of non-toxic antifouling agents is looked into and an example is cyanobacterial metabolites that show antibacterial, antialgal and antimacrofouling properties. Other possibilities discussed are poly-APS, tannin and tannate and enzymes , which are classified into direct and indirect enzymes in regard to mode of antifouling action. The main challenge for enzyme based antifouling systems is how to retain functional activity for a period that is long enough to ensure commercial viability.

Antifouling by limitation of attachment points is also discussed. Low surface energy coatings, commonly known as fouling release coatings, reduce the strength of adhesion of attaching bio-fouling organisms so that fouling is released or more easily washed off.

The report also describes that studies show that the colour of the net has an effect on the extent of biofouling. This is under the hypothesis that differences in colour may impact the short-term development of a biofouling community and therefore bias the results.

In regard to repulsive agents, any substance in either the net itself or a coating that discourages or repels the fish from biting by emitting a smell or having a certain taste can be termed a repulsive agent. Fish are good at smelling and tasting, a scent for a fishis a dissolved compound, usually an amino acid or a pheromone. The following are possible repulsive agents for fish:

- Insect repellent
- Various sunscreens
- Nicotine and tobacco
- Some types of liquid detergents
- Diesel
- Creosote
- Sweat

Smells that repel bass are the smell of predators like pike and muskie. L-serene present in mammal sweatis another possible repellant.

Other possibilities are:

- Marine arthropods-phenolics more efficient than carbonylic or acidic
- Capasaicin
- Denatonium Capsaicinate – interesting since it combines antifouling and repellant properties
- Manipulating the fish rather than the net – PVCR modulator

Task 1.4 Enhanced understanding and requirements for improvement of net weaving technology

Objectives
Take into consideration developments in net design to increase strength and reduce biting.

Progress
Aquaculture cage designs can be classified in a number of ways for instance by their performance characteristics, or materials of construction. For the purpose of this report they have been classified into three categories, the first two of which are not relevant to the project and hence will only be briefly resumed. Aquaculture cages may be classified as rigid structures, semi-rigid and flexible. All consist of some form of mesh to retain fish and allow for the circulation of naturally oxygenated water, and easy removal of waste. All require ancillary systems such as flotation systems, anchorage, auto-feeders, predator protection and much more. Cages are designed to meet individual field requirements such

submergibility, tidal flows, anchorage, etc. Consideration may also be made for the means of maintenance of the cages in the field. Harvesting the fish must also be considered in line with the type of service vessel used for this work.

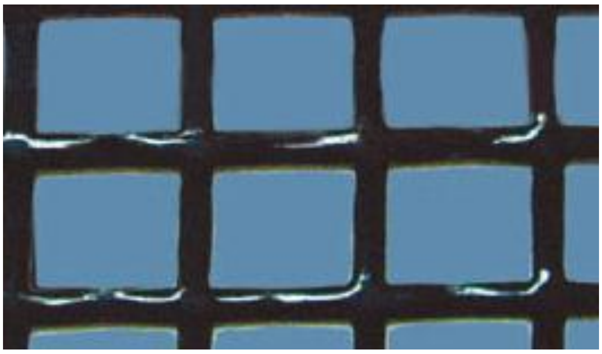
Rigid cage structures

Rigid cage structures are fabricated from sections consisting of a triangular hollow steel section with a wire mesh permanently fixed to it. The sections are designed to be buoyant in sea water and are designed using computer aided techniques to be able to be built into complex polyhedral structures. Claimed benefits include optimised volume to surface area, ease of transportation, ease of submergibility and anchorage. Ease of cleaning by method such as brushing and jetting is also claimed. Resistance to damage by predators is seen as a major problem in areas where these structures are used and they are claimed to be predator proof. Cages consist of triangular sections that can be bolted together to form a hollow sphere. These are constructed onshore, then lowered into the sea and towed into position at the offshore site where they may be used as floating units or submerged and anchored in position.

Schematic of a polyhedral steel fish cage

Semi-rigid Netting

Aquaculture cages can be made from semi-rigid materials that fall into three classes. The first of these is a normal warp knitted (Raschel net), twisted or knotted net that has been coated making it less flexible than a normal net structure. When the coating is applied to the yarn of the net, it penetrates the fibres preventing their relative movement and producing a stiffer net. The coating has the added advantages that it can be impregnated with anti-foulants to prevent build up of a bio-layer. The coating will also have a relatively smooth surface that will prevent initial colonisation by bacteria and it will prevent the pilling of the net yarn by browsing fish such as sea bream.



Coated Net

The second type of product under the classification of semi-rigid netting is an extruded net material. This product is produced by extrusion of the molten polymer using extrusion tool with counter-rotating mandrel and die , the extruded product is drawn (stretched) under controlled conditions to give high molecular alignment in the polymer and produce a final monofilament net with good strength. The product can be manufactured in square, diamond, and hexagonal form.

Next, semi-rigid netting can also be produced from an extruded polymer sheet. After extrusion the sheet is cooled to a controlled temperature, circular holes are then cut into the sheet in either a straight pattern (to form square holes) or in an offset pattern (to form triangular holes). The sheet is the stretched in both length and width under carefully controlled conditions to produce the final netting which has very high strength, and toughness.

Flexible Netting

By far the majority of netting used in aquaculture is flexible netting similar to that used in trawl and seine nets. It can be made from a wide variety of yarns including monofilament, twisted multiple bundles, or braided yarns made from monofilament or continuous yarn bundles. As the materials used for netting tend to be polymers and are processed by melt extrusion (or gel in the case of Dyneema ultra high molecular weight polyethylene) spinning it is normal for them to be made from continuous filaments and not from staple or chopped filaments. The netting may be manufactured by a number of processes including knotting, warp knitting (Raschel net) or twisting to form square, diamond or hexagonal meshes. The precise gauge and shape of holes in the net is governed by knot spacing, stitch number or number of twists. Materials of manufacture include polyamides such as nylon-6, polypropylene, polyethylene and polyesters such as polyethyleneterephthalate. Specific grades of materials with properties suited to the process of melt spinning are used. These materials can also be tailored to give high resistance to ultraviolet light, good abrasion resistance and high tenacity.

Knotted nets

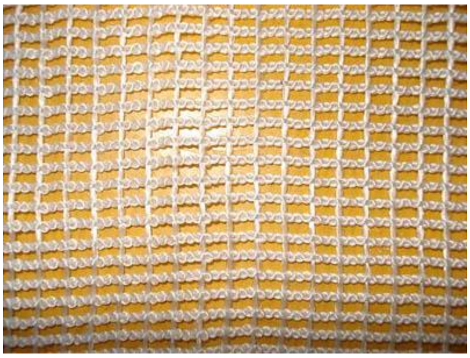
Knotted net may be made from monofilament or yarn in any of the above materials. There are two basic knots in use to make them with the standard single knot being the most common for net manufacture with the double knot being used almost exclusively for gill nets where the knot's resistance to slipping is essential to retain the catch.

Knotted nets have a number of technical shortcomings compared to warp knitted or twisted nets. The knots are more likely to cause damage to fish by increased chance of removing their protective slime; this in turn can lead to an increased chance of disease especially in the more concentrated environment farmed fish experience with respect to numbers per unit volume of water.

Warp knitted netting (Raschel)

The problems with knotted net cages mentioned above, particularly loss of filament strength and potential damage to fish have lead to the development of knotless mesh nets, one way of making these is by warp knitting.

Briefly, there are two distinct way of knitting fabrics and or nets, the first is weft knitting where a single yarn is used to produce rows of loop across the direction of the fabric i.e. the weft direction in weaving. There are three basic stitches plain, purl and rib.
Raschel type nets can take a number of different forms, but for the purposes of aquaculture cages the ones used are square, diamond, or hexagonal which is simply a diamond form with a longer joint section between the vertically knitted rows.



Work package 2 Creation of additive incorporated filaments

Task 2.1 Characterisation of material for optimal physical properties and additive incorporation

Objectives
Choice of base material with best properties.

Progress
Blends with PET have been evaluated for EscapeProofNet as they offer an attractive balance of mechanical properties and processability. These blends can combine the

stiffness of PET with the good impact strenght of HDPE. Several compounds have been evaluated using EGMA as compatibilizer. The results have shown that the integration of PET improves the strength of the material, 10% EGMA is optimal and shear stress and production are not critical factors.

The compounds prepared have:

- Higher melt strength than HDPE
- Slightly lower drawability and draw resonance than HDPE
- Extensional performance very similar for all the compounds
- HDPE/PET/EGMA (80/20/10), low shear, 6 kg/h (optimum material considering mechanical properties), good elongational properties

The blends selected for further evaluation were HDPE/PET/EGMA (80/20/10) and HDPE/PET/EGMA (60/40/10). In the first trials recycled PET was used in the compound, this turned out to be difficult to process depending on the melt viscosity, as the recycled PET is mainly from bottle grade material. To remedy this problem, a new compound was produced using virgin, fiber grade PET. This new compound showed much better results in processing and a good quality fiber was produced. This new material is described in more detail in an additional report under task 2.1.

Task 2.2 Testing and selection of environmentally friendly impregnating agent

Objectives
Selection of agents for anti-biofouling.

Progress
A considerable quantity of antifouling was introduced into the different polymers to see how this affects the properties of the compound.

Once having introduced the additive, the release of the active ingredient must be evaluated.

The basic requirements of the antimicrobials are:

- Effective antimicrobial activity
- Low toxicity to humans, animals and environment
- Easy application
- Compatibility with processing aids and other additives
- No negative impact on plastic
- Storage stability and long-lasting efficiency

During production of compound and processing, the goal of all additives handling processes is to ensure accurate dosing and dispersion of additives in the resin.

The EscapeProofNet project has made a thorough investigation of natural antifoulants. This report is submitted as an addition to D3.

As the comments on the Year 1 reporting was received, stating that integration of chemicals should, if possible, be avoided, the EscapeProofNet project has instead focussed on investigating the inherent surface properties of the material and to compare the behaviour of the HDPE/PET blend to the standard nylon nets and the newer HDPE-nets in addition to a literature study of natural antifoulants. Investigations have also been made in regard to using surface modification technologies to enable coating of HDPE containing compounds. Plasma treatment with oxygen as well as nitrogen has been investigated.

Work package 3 Design and manufacturing technology to optimize strength, durability and suitability

Task 3.1 Adjustment of manufacturing technique
Task 3.2 Cage net design development

Objectives

Improve production technique and Design new net system based on WP 1 and 2

Progress

The dynamic wave loads on the net may be expressed by means of the wave height as other relevant parameters (frequency, distribution and energy) may be related to the wave height.

The ocean currents will vary with depth and may be described by means of a climatological flow at the location (average pressure driven currents) plus the flow generated by means of wind, waves and tides. The vertical shear in the ocean current may influence the shape of the net.

All marine fish farm installations should be constructed in a way that will minimise the risk of break down and the subsequent loss of fish. The main dimensioning factors for such installations are current velocity and wave height. It is not possible to come up with specific descriptions of oceanographic characteristics related to any given location in European waters based only on large scale oceanographic evaluation. This as the characteristics at any given location will depend on both large and small scale effects. Large scale effects include the general circulation patterns enforced by wind, sun intensity stratification and tides. The small scale effects are mainly governed by bathymetry, topography, river run off and ice/melting processes. Ocean currents and density characteristics may change significantly over just a few kilometres laterally and 50-100 metres vertically (even smaller length scales in fjords and estuaries). Because of this, location specific studies with regards to these parameters are necessary in order to get a precise description of a farming locality. The resulting data of wave and current characteristics for that locality will then form the basis for an appropriate dimensioning of the marine fish farming installations to be used at that locality.

Norway is one of the countries with the longest history in marine fish farming on a commercial scale, and is also the worlds leading salmon producer. Due to the scale of the farming activities and the sometimes extreme weather conditions along the Norwegian coast the government has introduced laws and standards to govern this industry. All new species to marine aquaculture in this country, such as cod, are currently under the same legislation. This includes requirements for the physical design of the marine fish farming installations, and how that is to be documented. The requirements for physical design include all main components the installation consists of, cage net, moorings, floater, barges and any auxiliary equipment, as described by the Standard: NS 9415.E ("Marine fish farms. Requirements for design, dimensioning, production and operation"), together

with FOR 2004-12-22 nr 1785 ("Forskrift om krav til teknisk standard for installasjoner som nyttes til akvakultur"). The main purpose of this standard and this law is to minimise the risk of fish escaping from aquaculture installations as a result of technical failure and/or wrong use of the installations, as well as ensuring that the installation is dimensioned correctly to withstand the loads at the locality it is to be used. There is currently a strong focus on the problems relating to escapees, from both the government and the aquaculture industry in Norway, and as a result of this both NS 9415.E and FOR -12-22 nr 1785 are currently under revision, and the revised version will take effect the 01.01.2009.
As cod is one of the target species in the EscapeProofNet project, and as Norway is one of the main producers of farmed cod, the above mentioned standard (NS 9415.E) will determine the general minimum requirements regarding the design, dimensioning and materials for the cage net in this project. Furthermore there is currently a committee working with a mandate to make this an international standard, with implementation scope of 3-4 years. As the design, following this standard, is dependant on what degree of natural exposure a locality has, it also includes a way of classifying localities in relation to their degree of natural exposure to elements, such as wave height and current velocity. This has resulted in 4 Locality categories (NS 9415.E 5. Annex A & C), where 1 is the lowest degree of exposure and 4 the highest. These Locality categories in combination with the size and depth of the cage net dictates the minimum requirements for dimensioning, material choice and design of the cage net (NS 9415 8. Annex E).

Flexible Netting

By far the majority of netting used in aquaculture is flexible netting similar to that used in trawl and seine nets.

It can be made from a wide variety of yarns including monofilament, twisted multiple bundles, or braided yarns made from monofilament or continuous yarn bundles. As the materials used for netting tend to be polymers and are processed by melt extrusion (or gel in the case of Dyneema (ultra high molecular weight polyethylene)) spinning it is normal for them to be made from continuous filaments and not from staple or chopped filaments.

The netting may be manufactured by a number of processes including knitting, warp knitting (Raschel net) or twisting to form square, diamond or hexagonal meshes. The precise gauge and shape of holes in the net is governed by knot spacing, stitch number or number of twists

Materials of manufacture include polyamides such as nylon-6, polypropylene, polyethylene and polyesters such as polyethyleneterephthalate. Specific grades of materials with properties suited to the process of melt spinning are used. These materials can also be tailored to give high resistance to ultraviolet light, good abrasion resistance and high tenacity.

Some of the problems with these materials include resistance to ultraviolet light which requires the addition of stabilisers, organic chemicals that react to ultraviolet in preference to the polymer. The low density of the materials (particularly when compared to saltwater) requiring weighting of the net to keep its shape. The reduced strength of nylon when immersed in water, though this is balanced to a certain extent by improved toughness and flexibility.

Knotted nets

Knotted net may be made from monofilament or yarn in any of the above materials. There are two basic knots in use. To make them with the standard single knot being the most common for net manufacture with the double knot being used almost exclusively for gill nets where the knot's resistance to slipping is essential to retain the catch. The basic knots are:

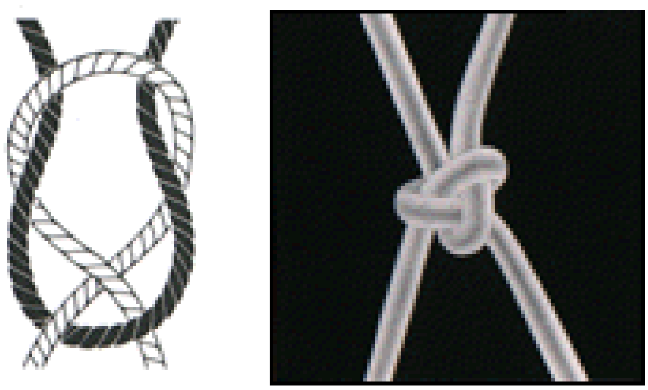


Figure 9. Single knot

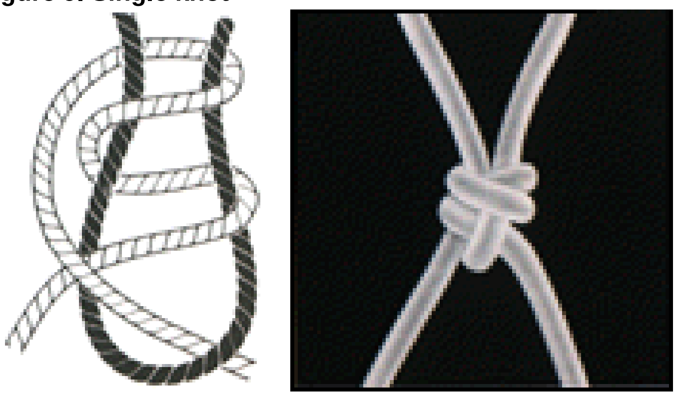


Figure 10 Double knot

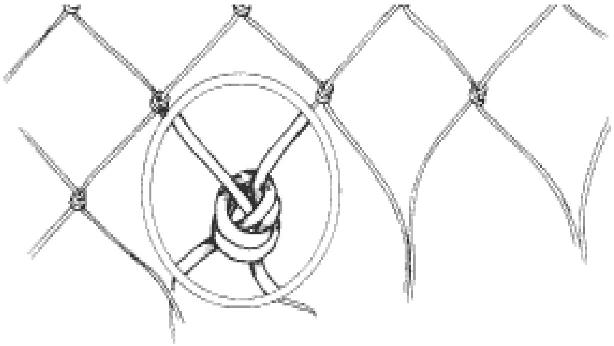


Figure 11. Double overhand knot

A number of other more obscure knots may also be used, but these are of little practical value in practice and rarely if ever found, two examples are:

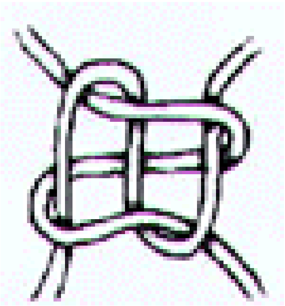


Figure 12. Square bend

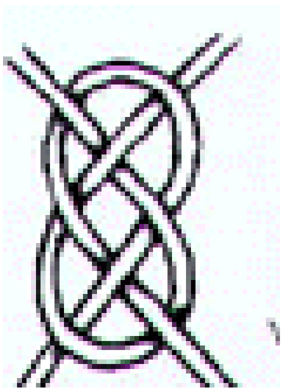


Figure 13. Carrick bend

Knotted nets have a number of technical shortcomings compared to warp knitted or twisted nets. The knots are more likely to cause damage to fish by increased chance of removing their protective slime; this in turn can lead to an increased chance of disease especially in the more concentrated environment farmed fish experience with respect to numbers per unit volume of water.

Knots also reduce the apparent strength of spun or braided yarns, but this is most significant with monofilament where breakage of a single filament is catastrophic to the net structure at that point. This reduction in strength is caused by strangulation of the filament as the knot is tightened. In a multi-filament yarn, this can be accommodated to a certain extent by the individual fibres moving relative to each other, but in a monofilament, the problem can seriously reduce the strength.

It is also noticeable that the knots draw the filament or yarn into particular angles as in the picture above; there is a definite tendency for the knot to draw the loose ends together, and this means the cage structure and behaviour in use will be governed by the orientation of the net with respect to the cage, i.e. whether the net is built into the cage vertically or horizontally.

Warp knitted netting (Raschel)

The problems with knotted net cages mentioned above, particularly loss of filament strength and potential damage to fish have lead to the development of knotless mesh nets, one way of making these is by warp knitting.

Briefly, there are two distinct ways of knitting fabrics and or nets, the first is weft knitting where a single yarn is used to produce rows of loop across the direction of the fabric i.e. the weft direction in weaving. There are three basic stitches plain, purl and rib

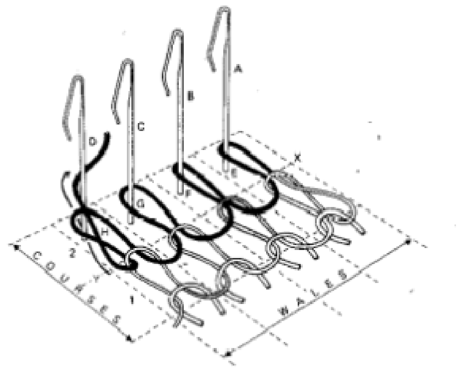


Figure 14. Weft Knitting

Warp knitting represents the fastest method of producing fabric from yarns. Warp knitting differs from weft knitting in that each needle loops its own thread. The needles produce parallel rows of loops simultaneously that are interlocked in a zigzag pattern. Fabric is produced in sheet or flat form using one or more sets of warp yarns. The yarns are fed from warp beams to a row of needles extending across the width of the machine.

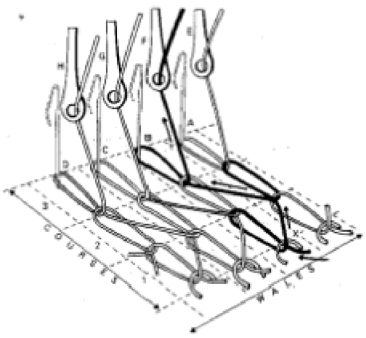


Figure 15, Warp Knitting

The term Raschel derives from the textile industry and refers to the actual type of warp knit of which there are several varieties including Tricot and Milanese. The major characteristic of the Raschel type of knitting is that it is a coarser knit with lower stretch than other types this makes it more suitable to producing a net structure than other types. It is much better suited to applications such as netting as hole formation is much simpler and the hole does not stretch due to the properties of the Raschel knitting..

Raschel type nets can take a number of different forms, but for the purposes of aquaculture cages the ones used are square, diamond, or hexagonal which is simply a diamond form with a longer joint section between the vertically knitted rows.

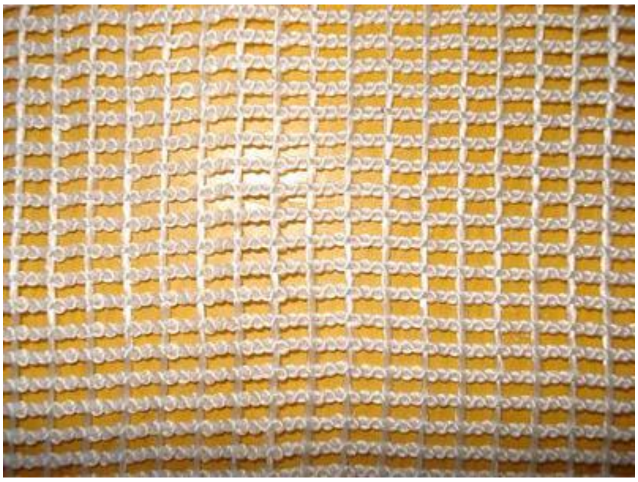


Figure 16. Square Raschel knitted mesh

Figure 17 Diamond Raschel knitted mesh

Figure 18. Hexagonal Raschel knitted mesh.

Twisted Netting

The final manufacturing method for netting is to twist pairs (or more) of filaments or yarns together to form a rope, the net is then formed when the filaments are intertwined at the junctions of the diamond structure. After each junction in the net, the pairs of filament resume their twist together until they reach the next junction.

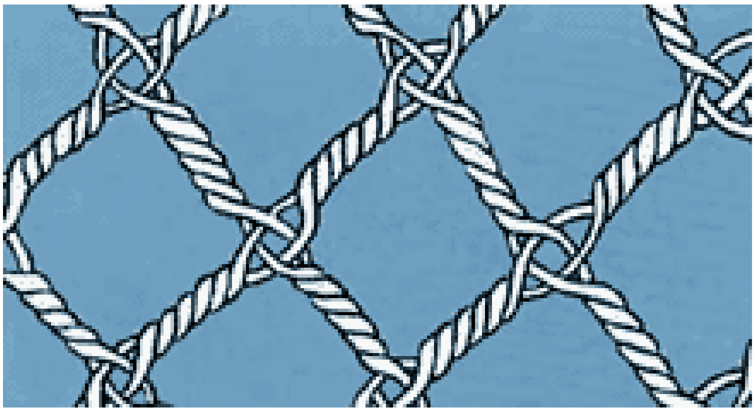


Figure 19. Twisted knotless netting diagram

Figure 20. Twisted knotless netting from yarn

The advantages of twisted nets over knotted are their greater strength and reduced damage to fish.

Advantages of twisted net over Raschel are also claimed and include reduced weight especially when wet, this has the added advantage of savings in fuel and other in use costs. Twisted net is also claimed to be superior in its hydrodynamic properties, this means that when used in commercial fishing, trawlers use less fuel, and when used in aquaculture, fish get more oxygenated water and cages suffer less distortion in a tidal flow.

Task 3.3 Cage Net prototype production

Objectives

Create the new net for testing

Progress

For reasons described earlier in this report, a cage net prototype has not been possible to produce within the scope of this project. By exchanging the recycled PET that caused processing problems with virgin fibre grade PET, enough fibre material was produced to enable production of handmade knotted HDPE/PET-net. This material was tested according to ISO 1806 and test frames for placement in the sea were produced. In addition, samples were sent to Swansea University for testing of biting resistance. The results of this testing has been thoroughly presented in a separate report.

Work package 4 System Integration and Industrial

As stated earlier, it has not been possible for the consortium to produce an entire net cage prototype within the scope of the EscapeProofNet project. This is due to the fact that the technological approach was altered after receiving the comments on the Year 1 reporting, meaning that the copper containing compound already produced was not to be taken further in the project. Instead, a new compound without integrated antifouling additives was produced. Processing difficulties at extrusion of this compound, in addition to flooding of the workshop causing downtime for machinery combined with extrusion being performed on laboratory equipment have all been contributing factors to not being able to produce the great quantity of filament needed to produce an entire net cage. Instead net samples mounted on frames were produced and tested.

Task 4.1 Functional tests

Objectives

Undertake tests on the complete system at two fish farming sites. Monitor fish behaviour and fouling.

Progress

Test frames, (ange storlek etc, specifikationer) were sent to Norsk Havbrukssenter in Brønnøysund, Norway for fouling tests in the sea. The frames were placed in……..

Task 4.2 Total System Industrial Validation

Objectives

Validation of technology impact

Progress

At this point in time it is not possible to make an evaluation of the total system as a fullscale net cage has not been produced. The evaluation of HDPE/PET for use in net cages for fish farming has therefore been done using tests performed on a smaller scale in the sea and in laboratory.

Work package 5 Innovation Related Activities

Throughout the project, the consortium has kept itself updated on possible competitive patents and also has good control on what goes on in the aquaculture sector through the network of the project partners and TI. The EscapeProofNet project was represented at AquaNor in August 2007 and at the Aquaculture Europe conference in September 2008. The project has used newswire for dissemination, resulting in 11 articles in the press.

Work package 5 Innovation Related Activities

Task 5.1 Protection of IPR

Objectives
Patent search to assess the viability of a patent application.

Progress
A patent search has been performed and have been reported in D10.

Task 5.2 Absorption of results by proposers

Objectives
To transfer specific knowledge from the RTD performers to the SME participants to enable them to rapidly apply and embed the technology onto specific products, including setting up basis for a design and operation guide and holding workshops on specific areas of the design and process.

Progress
The SME participants have been involved in all aspects of the development throughout the project and have good knowledge and insight into the work that has been done. The best practice for maintenance of a net will be very useful to the end-users.

Task 5.3 Dissemination of knowledge

Objectives
To broadcast the benefits of the developed technology and knowledge beyond the consortium to potential industrial user communities via press releases and presentations at major exhibitions and conferences.

Progress
The project has been disseminated via press releases using Newswire with 11 hits. The project has also been represented at the AquaNor Exhibition in Trondheim and the Aquaculture Europe Exhibition in Krakow, Poland.

Task 5.4 Socio-economic aspects

Objectives
To assess the socio-economic impact of the generated knowledge and technology, as well as analysis of the factors that would influence their exploitation, e.g. standardisation and regulatory aspects.

Progress
These issues have been covered in deliverable 17.

Task 5.5 Promotion of exploitation

Objectives
Identification of market areas and feasibility studies and web-based contact in the European countries.

Progress
A dissemination and use plan has been issued.

2.3 Deviation and correction of the activity plan

The table below summarises the deviations from the work programme, and the corrective actions taken.

Work package no.	Title	Deviations from plan	Corrective action
WP 1.	Sc. Understanding of requirements for nets used in fish farming	WP 1 was completed without deviations	None
WP 2.	Creation of additive incorporated filaments	The comments received after the Year 1 reporting caused a change in technology, moving away from additives incorporated into the fiber.	The project has instead been focussing on the inherent surface properties of HDPE containing compound and effects of using coating to cover up attachment sites for fouling and to make it more difficult for fish to find sites to bite on.
WP 3	Design and manufacturing technology to optimize strength, durability and suitability	The comments received after the Year 1 reporting caused a change in technology, moving away from additives incorporated into the fiber.	Adjustments with regards to manufacturing technology addressing the changes in Work Package 2 with regards to new filaments developed
WP 4	System Integration and industrial Validation	The initial plan was to have the system validation performed on a fullscale net cage. As it5 has not been possible to manufacture a fullscale net cage prototype within the lifetime of the project,	Adjustments in order to address changes in Work Package 2 with regards to test procedure

		evaluation of the new system has been made by test frames placed in the sea and by laboratory tests.	
WP5	Innovation Related Activities	None	None

2.4 Work package deliverables update

Deliverable No	Deliverable title	Work Package No	Delivery date	Task Leader	% Completed	Estimated indicative Person Month	Used indicative Person Month
D1	**Report detailing requirements of the net-cage, including choice of material compound, additives and selection of materials and possible environmental aspects of their use**	1	6	TI	100 % Complete	12,5	13,0
D2	**Report on requirements of net design to improve handling possiblities, durability and suitability**	1	6	TI	100 % Complete	13,0	12,6
D3	**Report on specified polyolefin compound for net material and suitable impregnating and repulsive agents**	2	12	AIMPLAS	100 % Complete	8,0	8,0
D4	**Polyolefin filament prototype**	2	12	AIMPLAS	100 % Complete	9,0	9,1
D5	**Report with assessment of risks, decision on contingency planning**	2	12	AIMPLAS	100 % Complete	8,0	7,0
D6	**Report on required design criteria**	3	33	Refa	100 % Complete	10,0	9,0
D7	**Reference document specifying net characteristics, best practice for mending, net colour, mesh size etc. Properties, suitability and projected net costs**		33	Refa	100 % Complete	10,0	8,0
D8	**Integrated prototype**	3	33	TI	100 % Complete	14,0	9,0
D9	**Validation of the commercial viability of the technology application, including feature benefits and cost implications**	4	33	TI	100 % Complete	8,0	6,0
D10	**Report on potentially competitive patents, plan for patent application with possible exploitation agreements. Standards, ethical and regulatory aspects of exploitation**	5	33	Ocean Nets	100 % Complete	6,0	5,0
D11	**Project represented at relevant conferences and exhibitions. Publications in the form of editorials, technical papers and trade press**	5	33	Ocean Nets	100 % Complete	8,5	6,5

D12	**Project web site including a publishable presentation**	6	4	Refa	100 % Complete	0,5	0,5
D13	**Dissemination and Use plan (DUP) final**	6	33	Refa	100 % Complete	0,85	0,25
D14	**Project Interim review report**	6	6	Refa	100 % Complete	0,5	0,5
D15	**Midterm review report**	6	12	Refa	100 % Complete	0,5	0,5
D16	**Publishable final report**	6	33	Refa	100 % Complete	1,0	0,9
D17	**Review Report on economic and societal issues**	7	33	Refa	100 % Complete	3,0	1,0

SECTION 3 – CONSORTIUM AND PROJECT MANAGEMENT

3.1 Consortium and Project management tasks and achievements

Work Package 6: Consortium management

Task 6.1 Coordination of knowledge management and Innovation Related Activities
Patent searches have been performed regarding HDPE/PET cages

Task 6.2 Collation of deliverables, reports and cost statements
This has been followed up regularly throughout the project period, all deliverables are finalized and cost statements collected.

Task 6.3 Legal, contractual, financial & administrative management of the consortium
Continuously managed throughout the project lifetime.

Task 6.4 Preparation, updating and management of the consortium agreement
Continuously throughout the project period.

Task 6.5 Organisation of project management
Continuously throughout the project period.

Task 6.6 Obtaining audit certificates
Audit certificates have been obtained.

Task 6.7 Coordinating payments
According to plan.

Task 6.8 Communication between consortium and the EC
Continuously throughout the project period.

Work Package 7: Project management

Task 7.1 Review and management of project progress
Continuously throughout the project period

Task 7.2 Review and management of impact on economic and societal issues
Continuously throughout the project period

Task 7.3 Workflow scheduling and work plan change control procedure
Continuously throughout the project lifetime.

Task 7.4 Communication between partners
Continuously throughout the project period

Task 7.5 Provision of minutes taken at technical meetings
Continuously throughout the project period

Task 7.6 Coordination of technical activities
Continuously throughout the project period

3.2 Consortium Status Overview

Throughout the project duration the consortium has been working well together, providing valuable input and direction for the research programme.

Project management Structure
The project is controlled by a Core Group, which in turn is headed by the Co-ordinator (RFG), who has the ultimate responsibility for the project. Each task has been allocated to the proposer or RTD performer with the most appropriate skills or requirements relating to that particular task and they will be responsible for delivery of that task to plan. The task leaders are detailed in the work programme and report to the Co-ordinator. A consortium agreement has been prepared and signed to cover any specific issues that are not covered in the EC contracts, this details voting and dispute issues.

Partnership voting was never needed in this project. IT based management and communication techniques are used within this research programme. Neither have there been any confidentiality issues. Prior to meetings, information was circulated to all partners in advance to enable maximum time usage.

3.3 Project timetable and status

The original plan is presented in the Gant chart below

#	TASK	PARTNERS		MONTHS																							
		Resp		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24-33
1.0	**Scientific Understanding of Requirements**		**DE**																								
1.1	Specific requirements on behaviour and fouling		6																								
1.2	Requirements to material for fish farming nets		6																								
1.3	Specific understanding regarding additives		6																								
1.4	Improvement on weaving technology and design		6																								
2.0	**Additive Incorporated Filaments**		**12**																								
2.1	Selection of material compound		12																								
2.2	Selection of antifouling and repulsive agents		12																								
2.3	Set up of net sample testing		12																								
2.4	Extrusion of new filament		12																								
			12																								
3.0	**Net Design and Manufacturing**		**18**																								
3.1	Fish farmer questionnaire		16																								
3.2	Development of net design		16																								
3.3	Net prototype		18																								
4.0	**System Integration and Industrial Validation**		**24**																								
4.1	Functional testing of net samples		24																								
4.2	Total system industrial validation		24																								
5.0	**Innovation Related Activities**		**24**																								
5.1	Protection of IPR		**24**																								
5.2	Absorption of results by proposers		24																								
5.3	Dissemination of knowledge		24																								
5.4	Socio-economic aspects		24																								
5.5	Promotion of exploitation		24																								

6.0	Consortium Management		**24**
6.1	Coordination of knowledge/IPR		24
6.2	*Deliverables, milestones, reports and* cost		24
6.3	Legal, contract, ethical, financial & adm. aspects		24
6.4	Prep. updating & management of consortium		24
6.5	Project Management and Exploitation Board		24
6.6	Audit certificates		24
6.7	Coordinated payments and distribution of money		24
6.8	Communication towards EC		24
7.0	Project Management		
7.1	**Project progress**		**24**
7.2	Impact on economical and societal issues		24
7.3	Scheduling and Work Plan change control		24
7.4	Communication between partners within WPs		24
7.5	Provision of minutes taken		24
7.6	Co-ord. of technical activities among partners		24

3.4 Co-ordination activities in the period

Changes to the work programme were made in the 13-33 month period. These have all been detailed in this activity report and will also be accounted for in the management report and reports submitted in the final reporting.

Meetings and Communication

The project partners have been actively involved in the research work through trials, working party meetings and have been working very well together

There have been 7 project meetings since the start of the project. These have all combined technical, management and exploitation issues.

No	Date	Purpose of meeting	Location
1	20.09.06	Kick-off meeting	TI, Oslo
2	11.01.06	3-month meeting	RFG, Tromsø
3	23.05.07	6-month meeting	Sant`Antioco, Italy
4	27.09.07	12-month meeting	Valencia, Spain
5	05.03.08	18-month meeting	Milan, Italy
6	26.06.08	21-month meeting	Melton Mowbray, UK
7	08.01.09	28-month meeting	Oslo, Norway

In addition to the formal meetings a number of working party meetings have been held to discuss the technical and management aspects of the project.

No	Date	Purpose of meeting	Location
1		Confidentiality agreement Steen-Hansen	TI, Oslo
2		Working party meeting Pera and TI	Pera, Melton Mowbray
3		Working party meeting TI and Steen Hansen	TI, Oslo
4		Telephone meeting TI and RFG	Telephone meeting
5		Telephone meeting TI, RFG and Pera	Telephone meeting
6		Telephone meeting TI, Pera and Aimplas	Telephone meeting

The venues for the formal project meetings have been rotating at different partners-sites to give the consortium an opportunity to learn more about the hosting company. A tour of the facilities has always followed the meetings.

The working party meetings have all been at Pera and TI. There has also been a presentation of the project at conferences and meetings/seminars.

3.5 Dissemination Activities

Protection and Licensing of Knowledge

The IPR generated in this project is owned by the SMEs. Patents will be applied for on a joint basis and exploitation rights will be assigned to each consortium member in such a way that no single company gains unfair benefit. The exploitation strategy is developed into an Exploitation Plan, which will also include an Exploitation Agreement between the partners.

Technology Transfer

Each partner has been involved in a continuous process of technology transfer and absorption through their role in the project. Appropriate companies have inputs in their areas of specialisation and knowledge is being continuously disseminated at project meetings.

Validation of the Technology

The technology has been validated through use of net frames mounted in full-scale net cages. Testing has also been performed at the Swansea University in Wales.

Dissemination Methods

All partners have played an active role in technology transfer and dissemination. The technology will be available for best practice demonstration through the use the test frames produced.

The RTD performers have presented the project at suitable conferences and seminars. The technology has also been outlined to visitors as part of a structured presentation of a wide range of leading edge process technologies.

Project dissemination h by a number of Newswire publications, see below.

Nordlys: http://www.nordlys.no/nord24/article2760935.ece
Trønder-Avisa: http://www.t-a.no/apps/pbcs.dll/article?AID=/20070509/NYHETER/70509010
Hegnar Online: http://www.hegnar.no/hegnar/newsdet.asp?id=252753
Harstad Tidende: http://www.ht.no/incoming/article88341.ece
Avisa Nordland: http://www.an.no/nyheter/article2760723.ece
iTromsø: http://www.itromso.no/nyheter/article88341.ece
Framtid i nord: http://www.framtidinord.no/nyheter/article88341.ece
Troms Folkeblad: http://www.folkebladet.no/nyheter/article88341.ece
Vesterålen Online: http://www.vol.no/aktuelt/index.asp?F=F&N=7927
Fremover: http://www.fremover.no/nord24/fisk/article2760935.ece
Radio City: http://www.radiocity.no/nyhetdetail.php?id=3851

In addition, the project was represented at AquaNor 2007 in Trondheim, one of the most important aquaculture events and the principal venue for everyone related to the fish farming industry. All major aquaculture nations are represented by exhibitors, delegations and visitors. The project was also represented at the Aquaculture Europe Conference in Krakow, Poland in September 2008.

A project web site has been created with a restricted and an open area with links to all the partners web sites. Results and scientific publications, trade journal articles, overview of seminars and demonstration will be uploaded on the website. The website address obtained by the consortium is www.escapeproofnet.com