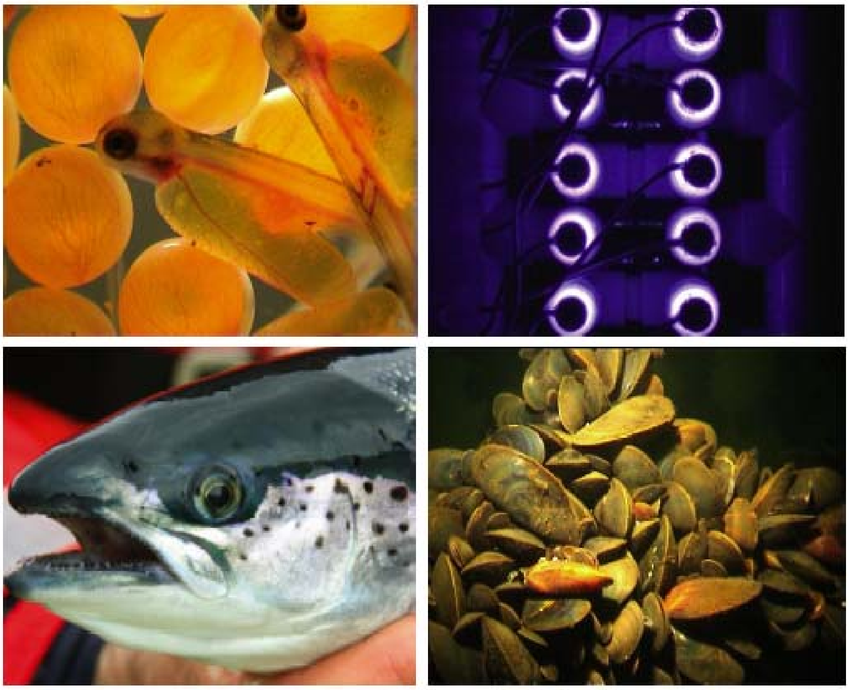
Scottish Aquaculture Research Forum

A Report Presenting Proposals for a Scottish Technical Standard for Containment at Marine and Freshwater Finfish Farms

SARF073



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Scottish Technical Standard for Containment at Marine and Freshwater Finfish Farms

Scottish Aquaculture Research Forum

Final Report

February 2012

Thistle Environmental Partnership

Introductory note to this draft version of the Scottish Technical Standard

This report presents the findings of a research project into the development of a Scottish Technical Standard to help prevent escapes. With the exception of this Introductory Note and the Appendices, this document has been written as if it is the Standard, although this is of course not the case. It is not envisaged that this introductory note would appear in the actual Standard.

This report has been informed by considerable consultation within and outwith the Scottish finfish farming industry, including informal discussions and formal workshops.

The overall intention of the Standard would be to help prevent escapes from technical failure and related issues at Scottish finfish farms. Whilst there is some consideration of operational issues where these are considered directly relevant to a technical issue, these were not the focus of this document.

This Standard aims to be:

1. Justifiable in reducing escapes;
2. Proportionate to the risk;
3. Appropriate to the Scottish environment;
4. Appropriate to the Scottish industry;
5. Enforceable and auditable; and,
6. ‘Future proofed.’

This document includes some additional notes to highlight knowledge gaps identified during the project which are considered essential or highly desirable to be addressed prior to the finalisation of the Standard. The notes are presented in shaded boxes and summarised at the end of the document; knowledge gaps are denoted ✘ (*KG)* in the text. It is not envisaged that the actual Standard would include references to knowledge gaps.

This is an independent paper which is presented in good faith and represents the views of the authors.

Contents

** Note: It is not intended that Appendices 1, 2 and 3 would be included in a final Standard.*

Foreword

This Standard was developed by Thistle Environmental Partnership in association with SINTEF Fisheries and Aquaculture and then reviewed by Bruce L. Smith & Associates. A Steering Group was formed by the Scottish Aquaculture Research Forum (SARF) in conjunction with the Scottish Government and the Equipment Sub-Group of the Improved Containment Working Group to direct and review the process. The Standard was further revised by the Scottish Government following an internal review and an external consultation process prior to being published.

Note 1, regarding the above paragraph on guidance to accompany this Standard
It is recommended that this Standard is accompanied by industry guidance to provide commentary and interpretation. This would also help reduce the need for future revisions. It is recommended that a committee be established or an existing committee authorised to develop and administer such guidance as well as administering the Standard and any revisions thereof. This should include appropriate and independent technical expertise as well as industry knowledge.

Acknowledgements

This project was commissioned by the Scottish Aquaculture Research Forum (SARF) and funded by the Scottish Government.

The project steering group included representatives of SARF, the Scottish Salmon Producers' Organisation (SSPO), the British Trout Association (BTA), Marine Scotland (the Scottish Government) and the Chair of the Improved Containment Working Group. The steering group performed a valuable and supportive role and its participation was much appreciated.

Consultations and discussions were undertaken with a range of organisations and individuals throughout the supply chain, including suppliers to the industry and fish farmers as well as wider stakeholders (see Appendix 3). They all engaged with interest and their contributions were essential to the successful completion of this project.

1. Introduction

1.1 Purpose

The purpose of this Standard is to help prevent escapes of aquaculture animals from technical failure and related issues at Scottish finfish farms.

1.2 Scope

The standard focuses on technical issues; consideration is only given to operational issues should they be directly relevant to technical issues.

The Standard applies to the farming of all species of finfish in Scotland:

- At all sea water pen sites (stocked and unstocked sites);
- At all freshwater pen sites (stocked and unstocked sites);
- When towing and storing pens and nets;
- At all land based farms (including tanks, ponds and raceways) regarding screens, flood risk and power failure and,
- When using fish transfer pipes and helicopter bins for transferring fish.

This standard applies to a wide range of persons involved with the above operations in Scottish finfish faming including (but not limited to):

- Equipment suppliers including the provision of pens, nets, mooring systems and components, weighting systems and ancillary equipment;
- Service providers including site surveyors, mooring designers, transport companies, boat suppliers (including work boats, well boats and feed boats) and mooring installers; and,
- Finfish company owners, directors and managers, purchasing managers, health and safety managers, environmental managers, boat skippers and operatives, maintenance personnel and certain operational staff.

1.3 Requirements and supporting information

The standard includes requirements and supporting information, the latter being differentiated by the use of italics[1]. To comply with this Standard, all relevant requirements shall be adhered to.

Note 2, regarding the inclusion of supporting information in the Standard
The amount of supporting information and explanatory text has been minimised to help keep the Standard concise and to acknowledge that this is a Standard rather than a guidance or good practice document.

1.4 Adherence to other protocols

Compliance with, or cognisance of this Standard does not absolve responsibility and/or obligation to comply with any legislative or other requirements.

[1] This excludes sub-headings, formulas and symbols in italics.

2. Normative references

The following normative documents are referred to in this document and, by so doing, constitute provisions of this Standard. For dated references only the edition referred to applies. For undated references, the last edition of the reference (including erratum) applies.

BS EN 13889:2003+A1:2008. Forged steel shackles for general lifting purposes. Dee shackles and bow shackles. Grade 6. Safety.

BS ISO 1704:2008. Ships and marine technology. Stud-link anchor chains.

BS EN 1677-4:2000+A1:2008. Components for slings. Safety. Links, Grade 8.

BS EN 10204:2004. Metallic materials. Types of inspection documents.

BS EN 1993-1-1:2005. Eurocode 3. Design of steel structures. General rules and rules for buildings.

NA to BS EN 1993-1-1:2005. UK National Annex to Eurocode 3. Design of steel structures. General rules and rules for buildings.

NA to BS EN 1990:2002+A1:2005. UK National Annex for Eurocode. Basis of structural design.

BS EN 1990:2002+A1:2005. Eurocode. Basis of structural design.

BS EN 12201-2:2003. Plastic piping systems for water supply. Polyethylene (PE). Pipes.

BS EN 3490:2007. Aerospace series. Steel FE-PM3901 (X15CrNi17-3). Air melted. Hardened and tempered. Bar for machining. De ≤ 200 mm. 900 MPa ≤ Rm ≤ 1100 Mpa.

BS EN ISO 1346:2004. Fibre ropes. Polypropylene split film, monofilament and multifilament (PP2) and polypropylene high tenacity (PP3). 3-, 4- & 8- strand ropes.

BS EN ISO 1140:2004. Fibre ropes. Polyamide. 3-, 4- and 8-strand ropes.

BS EN ISO 1141:2004. Fibre ropes. Polyester. 3-, 4- and 8-strand ropes.

BS EN 1991-1-4:2005+A1:2010. Eurocode 1. Actions on structures. General actions. Wind actions.

3. Definitions

Accessory: a piece of plant and/or equipment other than primary and/or secondary equipment.

All conceivable operations: see conceivable operations.

Anchor: includes drag anchor, dead weight moorings and any other system/component to attach the moorings to the loch bed with the exception of rock bolts.

Anchoring point: the point at which the mooring system is connected to the loch bed and/or the loch side. This includes, but is not limited to, drag anchors, dead weight moorings and rock bolts.

Authoritative source: the quoted material parameters should be based upon tests, measures or other verifiable and repeatable means undertaken, where relevant, in accordance with appropriate standards by reputable organisation(s).

Barge specification sheet: see product specification sheet.

Boats: includes all boats that may be used at the site when considering all conceivable operations, including feed delivery boats; well boats; boats used for transporting equipment, consumables, harvested fish, fish mortalities (including mass mortality situations); boats used for handling nets, pens, moorings, other equipment; boats used for undertaking fish farm operations including net installation, net handling, mooring installation, maintenance; boats used for harvesting fish; personnel boats; tow boats; and, any other type of work boat.

Bridle: the connector (of whatever material type or combinations thereof) from pen(s) to the mooring grid system.

Buoy line:

- For pens situated in a mooring grid: the rope and/or chain which connects the grid line to the cushion float in a mooring grid system; or,
- For pens not situated in a mooring grid: the rope and/or chain which connects pen(s) to the cushion float or which connects the pen(s) to the connector underneath the cushion float.

Characteristic value: maximum values of structural properties in respect of specific loads and defined probabilities (i.e. return periods) which should not be exceeded.

Competent / competency: demonstrated ability to apply knowledge and skills on the basis of education, training and/or experience.

Component: see individual component.

Conceivable operations: all planned and unplanned operations that may be undertaken at the site during the foreseeable future and/or the next production cycle in respect of the envisaged environmental conditions.

Contract/sub-contract personnel: persons working for or on behalf of an organisation who are employed by a different organisation and/or who are self-employed.

Current direction: the direction from which the current comes from.

Current velocity: the mean velocity of current averaged over a ten minute measurement period.

Cushion float: the buoy or float that supports the mooring grid, connector(s) and/or mooring line(s).

Depth of net: see net depth.

Diffraction and refraction analysis: the calculation of wave characteristics at a site from consideration of how ocean swells are affected by the local topography.

Dimensioning: the process of designing and specifying primary equipment so they are able to withstand the envisaged environmental conditions and all conceivable operations based on the use of calculations, experiments/tests and/or empirical data. The term implies design, specification and analysis.

Down ropes: ropes designed to be vertical or near vertical (including the down ropes on cone shaped nets) on a net and which support the weight of the net.

Dynamic analysis: analysis where a calculation is done of loads from wind, current and waves as well as acceleration as a result of wave movements in addition to mass, damping and rigidity of the construction.

Envisaged environmental conditions: the dimensioning current, dimensioning waves and dimensioning wind speed determined in the site survey.

Feed barge: a standalone fully integrated buoyant structure that includes the storage for feed and the related equipment to transport the feed directly to the pens along with all relevant equipment and facilities. These are usually either steel or concrete structures and may be purpose built or converted. A feed barge is different to a raft or other floating structure onto which feed storage and transportation equipment have been attached.

Fetch: the distance from the site or location of the pens to the nearest land.

Fish washout: the process by which fish may be lost through relatively high waves which could transport fish over the jump net and the handrail. This would usually only be expected in unfavourable weather conditions at more exposed sites and may be prevented by securely attaching an appropriately sized top net to the pen (usually by lacing to the handrail or taking it over the hand rail and down to be laced to the pen).

Flood/flooding/flood conditions: the situation occurring at a land based site when any plant, equipment, stock holding facilities, fish transfer equipment, inflow, effluent treatment and outflow facilities are immersed in water above the volume for which they have been designed, including that arising from unplanned natural and operational events.

Generic connection point: this refers to the notion on certain types of pens, notably plastic circles, that certain attachments may be made at any point on the pen providing that they occur to specific localities on the pen and at specified separation distances. This may include, but is not limited to, the means of attaching i) the net to the bridles, ii) the net to the pen, iii) the net to the handrail and iv) the weighting system to the pen.

Grid line: the rope and/or chain to which pens are attached via bridles in a mooring grid system and to which the mooring lines are attached.

Half mesh: a measurement of net mesh size pertaining to the length of one side of a square mesh – note that this is a different measurement to the net mesh aperture. The methodology for determining the half mesh measurement to comply with this Standard is given in Annex 8.

Individual component: a single element of primary and/or secondary equipment.

In-house personnel: staff directly employed by an organisation.

Irregular sea state: heterogeneous wave characteristics.

JONSWAP wave spectrum: the 'JOint North Sea WAve Project' spectrum can be used to describe wave conditions in coastal waters with a limited fetch.

Jump net: the upper portion of the net which is above the design water line; the area of the net between the water line and the handrail.

Lead line: a weighted line or other length of weighted material permanently attached to the net at the join of the side wall and base.

Lifting rope: a down rope on a net which can be used to lift the net in accordance with the manufacturer's instructions without damage to the net. A lifting rope shall cross the bottom of the net and proceed up the opposite side as a single entity or be securely joined to other down rope(s) or a central grommet in the base of the net dimensioned such that the rope can be used as a lifting rope.

Load factor: a factor to take account of the load variation from limit state design. Load factor times calculated load gives design load.

Material factor: a factor to take account of the variability of materials strength from limit state design. Material factor times yield strength gives design strength.

Manufacturer: the organisation that designs, manufactures and/or supplies primary and/or secondary equipment and/or boats.

Manufacturer's instructions: this refers to a set of instructions provided by the manufacturer and/or supplier of primary and or certain secondary equipment designed to help prevent escapes from the use of the relevant equipment in the envisaged environmental conditions and during all conceivable operations. Users are required by this Standard to comply with the manufacturer's instructions unless documented permission has been obtained from the manufacturer to deviate from those instructions in defined circumstances. The responsibility to provide the manufacturer's instructions shall rest with the following organisations unless otherwise agreed and documented:

- The mooring designer in regard of the mooring system;
- The pen designer in regard of the pen;
- The net designer in regard of the net;
- The feed barge designer in regard of the feed barge;
- For complete installations, the principal contractor; and,
- The designer in regard of the provision of any secondary equipment.

Mesh aperture: a measurement of open distance of a single net mesh pertaining to the size that a fish could pass through – note that this is a different measurement to the half mesh measurement.

Mooring grid system: a system whereby one or more pens are secured to a grid which is usually made of rope which is held in position through mooring lines.

Mooring line:

- For pens situated in a mooring grid: the rope and/or chain that connects the mooring grid to the anchoring point.
- For pens not situated in a mooring grid: the rope and/or chain that connects the pen to the anchoring point. This would typically be the line from the cushion float to the anchoring point or from the connecting point beneath the cushion float to the anchoring point.

Mooring specification sheet: see product specification sheet.

Mooring system: a complete installation of all the elements required to hold a pen or pens (and associated nets and secondary equipment and boats as required) in their planned position. Depending upon the type of installation, this may include the anchors (or rock bolts or other means to secure the mooring system), mooring lines, connectors, cushion floats, buoys, bridles, grid ropes and any other required components.

Mousing: the repeated passing of a small line or similar across the end of a shackle or other device to prevent accidental opening.

Net depth:

- For non-cone shaped nets: the vertical depth of the net from the designed waterline (which does not necessarily have to be at the exact location of the waist rope) to the bottom of the side wall, measured with the down ropes held taught.
- For cone shaped nets: the vertical depth of the net from the designed waterline (which does not necessarily have to be at the exact location of the waist rope) to the bottom of the net, measured with the down ropes held taught.

Net mesh aperture: see mesh aperture.

Net porosity: the total area of the net voids (i.e. aperture spaces) divided by the total area of the net.

Net specification sheet: see product specification sheet.

Ocean swell(s): waves which can affect the site which have been formed in the open sea.

Partial coefficient method: an approach which provides satisfactory margins of safety through the use of safety and/or material factors along with consideration of specific loads and the structure's resistance.

Peak period/peak wave period: the wave period associated with the greatest energy.

Pen specification sheet: see product specification sheet.

Pens: any floating installation that provides the support for a net used to contain fish. It includes all related elements, including: the walkways used to access nets, flotation elements to provide buoyancy, stanchions and handrails. It does not include rafts or barges, such as those used purely for storage or for undertaking ancillary operations. The term pen applies to the circular plastic installations and square steel/wooden/rubber installations that are in common use in Scottish aquaculture and other less common structures such as semi-submersible or closed containment units. Note that the term 'pen' is considered to have the same meaning in this Standard as 'cage,' 'floater' and 'floating collar'.

Plastic pen: a generic term relating to flexible fish farm pens made from polyethylene.

Porosity: see net porosity.

Principal contractor: the organisation with primary responsibility for the installation of primary equipment.

Primary equipment: a pen, net, mooring system and/or feed barge. This does not include boats and/or secondary equipment.

Product specification sheet: the document detailing the key design and parameters of primary equipment.

Quasi static analysis: simplified analysis where only constant loads are considered. Contribution from time dependent loads are included as constant loads.

Redundancy: the duplication of critical components or functions of a system to protect against the failure of a critical component.

Regular sea: homogenous wave characteristics.

ROV: remotely operated vehicle.

Responsible person: the person within an organisation responsible for the activity in question. This will typically, but not necessarily, be a site manager, area manager, senior manager or director. Whilst the activity may be designated, responsibility rests with the responsible person. The relevant responsibilities shall be included in a job description and/or company organisation chart.

Return periods: an estimate of the period of time between events of a defined magnitude.

Sacrificial panels: pieces of netting representative of the netting itself which are attached to the net and yet which can be easily removed for strength testing without making a hole in the net.

Safety shackle: a shackle with a closure that has a secondary means to ensure that the primary closure can not become undone. This may include, but is not limited to, the use of a clevis pin and/or mousing to hold the shackle bolt in place.

Secondary component: these relate to specific plant and equipment used on pen sites including a weighting system (including individual weights, sinker tubes and other weighting systems), feed system, mortality collection system, cameras and/or fish observation/counting devices, rafts (including, but not limited to, rafts used for feed systems, the storage of feed or other consumables/materials, the storage and/or use of plant and/or equipment, harvesting, grading, treatment systems etc.), pen lighting, fish treatment systems and mobile pens used to transport fish.

Significant wave height: the mean wave height for the highest third of the waves in a defined period of time.

Sinker tube: the use of a weighted ring suspended from the pen to which the net can be tensioned through the use of ropes (or perhaps chains) attached either directly to the ring or led through blocks attached to the rink for adjustment at the surface. Also known as a Frøya ring and weight ring.

Site:

- The area defined by the Local Authority planning permission in which a pen based fish farm can be installed;
- A set of pens and nets in a defined mooring system.

Specification sheet/relevant specification sheet: see product specification sheet.

Square pen: square or rectangular pen. This may also be used to refer to other shapes of pens based on a polygon design.

Stanchion: a vertical support for carrying the handrail and which, in fish farming applications, may be the point on some design of pens at which the net down ropes are attached.

Static analysis: simplified analysis where only constant loads are considered. All time dependent loads and load responses are neglected.

Swivel mooring(s): a mooring system whereby the pen(s) and/or secondary equipment and/or a boat or boats is connected to the sea bed through the use of a single line (or, possibly multiple lines) around which it is free to swing due to effects of the current and wind. Also known as a swing mooring.

Ultimate limit state: the condition associated with structural failure of primary or secondary equipment, or individual components, which is usually the maximum load carrying capacity.

Velocity of wind: see wind velocity.

Verifiable method of calculation: a method that can be verified either against experiments or method that utilizes internationally acknowledged methods of calculation.

Velocity of current: see current velocity.

Waist rope: a horizontal rope on a net within ± 0.2m of the designed waterline of the net.

Washout: see fish washout.

Wave direction: the direction from which the waves come.

Wave height: the vertical difference an adjacent wave trough and crest.

Wave length: the horizontal distance between successive wave crests.

Wave period: the time taken for successive wave crests to pass a given point.

Weighting system: the system used which helps maintain the desired shape and tension of the net. This includes, but is not limited to, the use of i) individual weights, ii) sinker tubes and iii) systems where a net is tensioned through the use of a rope led through a block attached to a sub-surface weight which can be adjusted at the surface.

Wind direction: the direction from which the wind is blowing.

Wind velocity: the ten minute wind velocity measured at 10m above ground [or sea] level.

4. Site surveys

The purpose of this section is to determine the dimensioning currents, basic wave parameters and pertinent geographical features which will be used as a basis for dimensioning and specifying the primary equipment at a fish farming pen site. Such information is obtained from a combination of site monitoring and desk based research and, where required, is further processed to determine wind, wave, and current conditions with a return period of 50 years that might be expected at the site.

The importance of obtaining representative and robust information from site surveys is crucial to ensuring that aquaculture equipment is appropriate for use in the intended environment because it is used as a basis for calculating the forces to which the equipment will be subjected. Consideration of current, particularly tidal and wind generated, is of central importance since it usually generates the greatest forces on the equipment.

4.1 Determination of current at sea water pen sites

4.1.1 Approach to current monitoring

Current monitoring shall be undertaken in accordance with certain requirements of Attachment VIII (SEPA, 2008) as outlined in Annex 1.

4.1.2 Determining the dimensioning currents

The dimensioning currents shall be determined by following the approach in either 4.1.2.1 or 4.1.2.2 below. In each approach, dimensioning currents shall be obtained in at least eight concurrent directions aligned to include the direction(s) in which the highest velocity current(s) may be expected.

4.1.2.1 Measurement of current for at least 15 days

Knowledge gap 1: current adjustment factors for sea water pen sites

Section 4.2.1: measurement of current for at least 15 days

Rationale for developing a dimensioning current

Equipment designers need to work to a current velocity representative of the maximum that might be expected at the site; this is termed the 'dimensioning current'.

Should the dimensioning current be underestimated this could lead to the use of insufficient equipment, whilst an overly conservative figure could lead to unnecessarily high costs.

Background

Unless the site survey was undertaken during the strongest tide of the year and coincided with a major storm in an additive direction, the monitored current would most likely underestimate the velocity that could be encountered at the site. To address this, the monitoring results could be adjusted by applying an appropriate factor(s).

The crucial factors that should be considered are highlighted below.

- Adjusting for the equinox. The strongest tides occur at the equinoxes (usually 20th or 21st March and 22nd or 23rd September). If the monitoring has taken place at an alternative time, the results should be increased by a specified factor to give velocities representative of those which would have been obtained at the equinox.
- Adjusting for wind induced current. Total current velocities at sea water pen sites are primarily comprised of two elements: tidal generated and wind induced. Whilst the 15 day monitoring period, adjusted for the equinox as above, should address the tidal element, it is likely to underestimate the wind induced current unless it took place during a storm of suitable strength, direction and duration.

  Therefore, unless monitoring was during a storm, the results should be increased by a specified factor to give current velocities representative of those which would have been obtained had the monitoring been during a defined event (such as a 1 in 50 year wind).

Ideally, the wind induced factor should be applicable in an incremental manner to account for any moderate or strong winds before or during the monitoring period.

Wind induced current also depends upon the fetch length; ideally, a threshold would apply for sites with a very short fetch, below which a reduced factor would apply.

- Adjusting for storm surge. A severe storm may give rise to a particularly high tide with an increased tidal velocity. Ideally, the monitoring results should be adjusted by a specified factor to take account of this. The practicalities of producing a single factor for Scotland should be determined during a research project.

Whilst there are other elements which can contribute to the total current, including residual currents, research carried out during the project suggests that the above are the most important for consideration in this Standard.

Requirement for a 15 day period of monitoring

Although a 30 day period was preferred, most consultees considered that a 15 day period would be entirely adequate. This timescale was selected since this may enable fish farmers to use historical current records (a 15 day period is required for SEPA monitoring). Should SEPA change the 15 day requirement, this may need further consideration.

Review of applicable approaches

Several factors for adjusting the monitored current to provide a dimensioning current were evaluated for possible inclusion in this Standard. However, none were considered appropriate for the reasons below.

a) Factors contained in the Norwegian Standard NS9415 - these were considered inappropriate without further verification due to differences between the Scottish and Norwegian environment.

b) Existing factors used by aquaculture equipment suppliers in Scotland – no single approach was identified throughout the Scottish industry and it could not be verified that one approach was appropriate for inclusion in a national standard.

c) Existing factors used by Scottish fish farmers – whilst at least one company applies its own factor, it could not be verified that such an approach was appropriate for inclusion in a national standard.

d) Factors developed for this project. There was considerable discussion about the use of a factor that could be added to the current monitoring results – specifically 0.5 m/s – to give a dimensioning current. The main concerns with this approach were that it may give rise to an overestimate of the dimensioning current (and hence over-specification of equipment) at sites with relatively low tidal flows and an underestimate (and hence under-specification of equipment) for sites with a relatively fast tidal current.

Further, none of the above approaches took account of i) whether monitoring was carried out at the equinox, ii) the wind strength during and before monitoring or iii) storm surges. The consideration of these issues should, ideally, be included in this Standard.

Knowledge gaps

The development of factors to adjust the monitored current for the parameters identified above, or a similar approach, is an essential knowledge gap which requires to be addressed before this Standard can be finalised and opened to industry consultation.

Addressing this knowledge gap would require the analysis of data on currents and related issues for (or that are applicable to) existing sea water fish farming areas across Scotland, as well as areas which may be used in the foreseeable future. The data may need to be collected specifically for this project, which would require considerable resource utilising the deployment of current monitors over many months, most likely requiring a complete year of monitoring. However, it may be possible to analyse existing data set(s) which may be available from academia, government or industry sources, or a combination thereof. The latter approach would not only be very considerably cheaper, it would be much faster and more easily achievable within the timeframe for developing a Scottish Technical Standard.

Informal discussions were undertaken with a number of organisations that may be able to undertake the above research. One of the organisations – an academic institution with a strong track record in marine and aquaculture issues – was confident that it could address this knowledge gap through the analysis of existing data. In so doing, this could be undertaken in a relatively fast timescale and in a cost-effective manner. It is recommended that in the first instance an approach is made to this institution to discuss its proposals in detail. It is also recommended that discussions are held with SINTEF which undertook similar research for the Norwegian NS 9415 Standard and which may be able to help provide greater context for this Scottish work by detailing its research methodology and findings.

As this knowledge gap is considered the key issue to be addressed before the Scottish Standard can be finalised, it is recommended that this process should be initiated as soon as possible. The research organisation should report to a Steering Group which can consider the findings in the light of this report.

The maximum recorded current velocity obtained from the current monitoring in Section 4.1.1. will be adjusted as follows to provide a dimensioning current in each of the required eight directions:

a) Adjustment for equinox: unless the monitoring period has included the equinox period, increase the current in each direction by **x** (*KG*).

b) Adjustment for wind induced current: increase the current velocity in each direction determined from i) above by applying **x** (*KG*) and **x** (*KG*) respectively for the site's 10 year and 50 year speeds (see Section 4.4). In the case of a monitoring period which included moderate or high winds, the current can be adjusted by the following factor: **x** (*KG*).

c) Adjustment for storm surge: increase the current velocity determined from ii) above by **x** (*KG*) in each direction.

The original current data, the results of the application of each of the above factors and the resulting dimensioning current for each of the eight required directions shall be documented.

4.1.2.2 Measurement of current for one year

Current shall be measured for at least 12 months in accordance with Section 4.1.1 above (except that the 15 day requirement be changed to 365 days), either continuously or through the aggregation of two or more periods of a minimum of 15 days duration. The recorded data shall be processed using harmonic analysis with subsequent harmonisation of long-term statistics to give a dimensioning current velocity in each direction relating to 10 and 50 year return periods.

4.2 Determination of current at freshwater pen sites

Knowledge gap 2: current adjustment factors for freshwater pen sites

Section 4.2: measurement of current for at least 15 days

Purpose of developing a dimensioning current and background

Reference should be made to the discussion in Knowledge Gap 1, except that the only adjustment required is for wind induced current which, again, should be in respect of a defined return period.

Since the wind induced element can be affected by the length of fetch, sites on freshwater pen sites with relatively small fetches may not require current monitoring. Alternatively, it may be possible to develop a simple current model based on fetch distance which avoids the need for current monitoring altogether. Both of these approaches should be researched to address this knowledge gap.

Knowledge gaps

Reference should be made to the discussion in Knowledge Gap 1.

The development of factors to adjust the monitored current for the following is required as an essential requirement for this Standard:

a) One or more distance thresholds that could be applied in respect of the fetch that would negate the need for current monitoring at smaller freshwater sites; and,

b) A factor to be applied to the monitoring results for sites other than those with a smaller fetch to account for wind induced current resulting from a defined storm event; and,

c) A factor to take account of wind induced current resulting from a defined event (e.g. a 50 year return period), preferably with an incremental approach to take account of winds during or just before the monitoring period; or,

d) One or more factors that could be applied to the identified wind speed that would negate the need for current monitoring altogether.

e) Any additional safety margin that should be included; and,

f) Whether the above could be aggregated in to a single factor to provide a more straightforward approach.

When developing the above, consideration should be given to:

g) Ensuring that the factors developed are suitable for the range of environments in which freshwater fish farming is practised (and may be practised) in Scotland; and,

h) Assessing data to ascertain any temporal anomalies which could affect the results should monitoring have been undertaken at different times of the year.

The development of factors to adjust the monitored current for the parameters identified above, or a similar approach, is an essential knowledge gap which requires to be addressed before this Standard can be finalised and opened to industry consultation.

Addressing this knowledge gap would require the analysis of data on currents and related issues for (or that are applicable to) existing freshwater fish farming areas across Scotland, as well as areas which may be used in the foreseeable future. The data may need to be collected specifically for this project, which would require considerable resource utilising the deployment of current monitors over many months, most likely requiring a complete year of monitoring. However, it may be possible to analyse existing data set(s) which may be available from academia, government or industry sources, or a combination thereof. The latter approach would not only be very considerably cheaper, it would be much faster and more easily achievable within the timeframe for developing a Scottish Technical Standard.

Informal discussions were undertaken with a number of organisations that may be able to undertake the above research. One of the organisations – an academic institution with a strong track record in marine and aquaculture issues – was confident that it could address this knowledge gap through the analysis of existing data. In so doing, this could be undertaken in a relatively fast timescale and in a cost-effective manner. It is recommended that in the first instance an approach is made to this institution to discuss its proposals in detail. It is also recommended that discussions are held with SINTEF, which undertook similar research, albeit in regard of sea water pen sites, for the Norwegian NS 9415 Standard, and which may be able to help provide greater context for this Scottish work by detailing its research methodology and findings.

As this knowledge gap is considered the key issue to be addressed before the Scottish Standard can be finalised, it is recommended that this process should be initiated as soon as possible. The research organisation should report to a Steering Group which can consider the findings in the light of this report.

Current monitoring is required on freshwater loch sites where the minimum fetch measured in accordance with Section 4.5.1.2 is **x** (*KG*) or above.

The maximum recorded current velocity obtained from current monitoring in Section 4.1.1 will be adjusted as follows to provide a dimensioning current in each of the required eight directions:

a) Adjustment for wind induced current: increase the current velocity in each direction determined from i) above by applying **x** (*KG*) and **x** (*KG*) respectively for the site's 10 year and 50 year speeds (see Section 3.4). In the case of a monitoring period which included moderate or high winds, the current can be adjusted by the following factor: **x** (*KG*).

b) The original current data, the results of the application of each of the above factors and the resulting dimensioning current for each of the eight required directions shall be documented.

4.3 Additional current monitoring considerations for sea water and freshwater pen sites

4.3.1 Consideration of currents with a temporal element

Should it be possible that the site may be affected by currents other than tidal or wind-induced (such as, but not limited to, river flows and discharge from hydroelectric schemes) then either:

a) The 15 day monitoring period should be timed to coincide with peak currents and/or,

b) The additional contribution to the current velocity should be calculated.

In either of the above cases, the rationale for the approach to current monitoring along with all data and relevant calculations shall be documented.

4.3.2 Using existing current monitoring results

Existing current monitoring results may be used as a basis to determine the dimensioning currents providing they meet the requirements in 4.1.1 above. Should the monitoring have been at alternative depths, these can be interpolated (but not extrapolated) to obtain the results for the required depth(s). Any such interpolation shall be documented.

4.4 Determination of wind velocity

The wind velocity is used in the determination of the dimensioning currents and wave parameters. The wind velocity for the site shall be determined by either of the following two approaches.

4.4.1 Approach based on BS EN 6399

Reference shall be made to BS EN 1991-1-4:2005+A1:2010 for identifying the 10 and 50 year wind speed for sea water and freshwater pen sites.

4.4.2 Approach based on data from meteorological stations

Data from the nearest or most appropriate meteorological stations can be used providing that an assessment is undertaken to show that the data is representative of the site in question. This assessment shall be documented. The data shall be used to derive the long-term statistical mean wind velocity for return periods of 10 years and 50 years.

4.5 Determination of Waves

4.5.1 Determination of wind induced waves for sea water and freshwater pen sites

4.5.1.1 General

Wind induced waves shall either be determined by in situ wave measurements or by calculation – the chosen approach shall be documented.

4.5.1.2 Determination of wind induced wave parameters by calculation

The following process shall be followed:

a) Determine the effective fetch length.

  i) The effective fetch length shall be determined for eight concurrent directions, aligned to include the longest fetch for the site. This will be based on measurements taken from an appropriate marine chart; for freshwater sites, a navigational chart should be used if available or, if not, an Ordnance Survey map.

  ii) The fetch length will be measured at each of the eight directions at 1°intervals across an opening of ±12°. The effective fetch shall be taken as the median value of each set of 25 measurements for each of the eight directions.

b) Calculate the adjusted wind velocity using the following equation:

$$U_A = 0.71 \times U_{10}^{1.23}$$

Where U_A is the adjusted wind velocity and U_{10} the wind velocity

c) Determine the significant wave heights and equivalent peak periods for each of the eight effective fetch lengths for both the 10 and 50 year return periods using the 10 year and 50 year wind velocities and the following equations:

$$H_S = 5.112 \times 10^{-4} \times U_A \times F_e^{1/2}$$

$$T_P = 6.238 \times 10^{-2} \times (U_A \times F_e)^{1/3}$$

Where H_S is significant wave height, T_P is the equivalent peak period, U_A is the adjusted wind velocity and F_e is the effective fetch length.

d) The significant wave heights and equivalent peak periods determined in 4.5.1.2 above will be further processed using either the irregular or regular sea approach as below; the rationale for deciding which approach to use shall be documented.

  i) For an irregular sea, the JONSWAP spectrum shall be used (using γ = 2.5 for wind sea and γ = 6.0 for swells). In lochs or partly sheltered sites, however, a 2-paramater Pierson Moskowitz spectrum can be used instead. In both approaches, a fully developed sea state shall be assumed.

  ii) For a regular sea, a regular wave height shall be assumed, which is equal to:

$$H = H_{max} = (1.9)H\mathrm{s}$$

The regular wave period shall be defined as the peak period (see Section 4.5.1.2).

4.5.2 Consideration of ocean swells

Whether the site is subject to ocean swells should be determined through observation and/or desk study. This decision, and the accompanying rationale, will be documented. In the case of doubt, it will be assumed that ocean swells do affect the site.

Should ocean swells be considered likely to occur at the site:

a) The significant wave height and peak period shall be calculated by recognised and validated methods for return periods of 10 and 50 years;

b) The combined sea state shall be determined by combining the parameters determined for ocean swells with those calculated for wind-induced waves; and,

c) All relevant data, observations and calculations shall be documented.

4.5.3 Other wave conditions at the site

An assessment shall be made as to whether the site could be significantly affected by wave conditions other than wind induced and ocean swells. This could include, but is not limited to, ship-generated waves, wave reflection, the effect of several wave trains and those generated from wave/current interaction. Should such conditions be possible, the installation of a fish farm at the site should only proceed if it can be demonstrated that these will not adversely affect the integrity of the fish farm. This assessment shall be documented.

4.6 Icing – freshwater pen sites only

An assessment of the likelihood of icing at freshwater pen sites shall be made based on local knowledge and/or desk based research. This shall be documented and a summary included in the product specification sheet and manufacturer’s instructions.

4.7 Loch bed description

4.7.1 At the site

The bottom depth and type shall be charted across an area extending 100m beyond the consented site boundary on a grid of 10m squares or less. Any large irregularities shall be recorded.

4.7.2 Pen movement routes

The depth of water shall be available along paths in which pens with deployed nets are towed. In cases where the water depth may be less than 5m between the lowest point of the net and the loch bed, the towing route and a sufficient margin on each side to allow for unexpected course deviation shall be:

a) Sounded on a grid of 10m squares or less; and,

b) Swept by wire or similar to check for obstructions.

These water depths, along with identities and positions of obstructions, shall be available to the site manager and any personnel involved in moving pens.

4.8 Reporting

The information required to be documented in this section shall be presented in a Site Survey Report. This, or the relevant information thereof, shall be available to:

a) The suppliers of primary equipment during any design and dimensioning process;

b) Senior personnel and the site manager at the aquaculture production business operating the site; and,

c) Persons involved in the installation, maintenance, and operation of the site;

d) Persons involved in towing equipment; and,

e) The operators of well boats, feed boats and work boats servicing the site.

5. Operational planning and liaison

5.1 Operational planning

Prior to i) installing any primary and/or secondary equipment and/or ii) towing any pens, the fish farmer shall undertake the following at an appropriate level of seniority with respect to the envisaged environmental conditions and all conceivable operations at the site:

a) Identify any potential scenarios which could lead to a risk of a breach of containment and address these through operational procedures; and,

b) Assess the availability of resources, including human and mechanical, to satisfactorily implement the above procedures at the site and develop a plan to address any outstanding requirements in a timely fashion.

c) The above shall be documented.

5.2 Net damage assessment

An assessment of the potential for net damage from abrasion during transport, installation, use and recovery shall be undertaken prior to stocking in respect of the equipment to be used at the site. This shall include i) the identification of hazards, ii) associated control measures, iii) applicable monitoring, iv) corrective actions and v) records and responsibilities for planned and unplanned operations.

With reference to the net damage assessment:

a) Control measures shall be considered through a hierarchical approach, as follows: i) elimination of the risk, ii) substitution of materials, iii) protection of materials and iv) changes in operational procedures.

b) Monitoring/preventative maintenance shall reflect the level of certainty about the potential for damage and any reliance on net protection measures; an increased likelihood of damage and/or reliance on protective measures shall require a more regular and robust monitoring and maintenance programme

c) The assessment shall be documented.

5.3 Net depth requirements

The fish farmer shall ensure that all nets used at pen sites are sized such that they cannot come in to contact with the bed of the loch and/or basal obstructions when fully deployed at the location in which they are to be used in all conceivable environmental conditions. An appropriate margin of safety shall be included[2]. This shall be documented.

5.4 Project control and liaison

A project manager shall be appointed for projects involving the design and/or installation of primary and secondary equipment; this appointment shall be documented. The project manager shall be responsible for ensuring that:

a) All work is undertaken in accordance with this Standard;

b) There is appropriate liaison with and between suppliers as required to address the requirements of this Standard, including the provision of information and documentation;

c) That the manufacturers of primary equipment have provided documentation that the equipment is appropriate for use in the envisaged environmental conditions at the site at which it is to be deployed;

d) That primary and secondary equipment is compatible for use with each other and for all conceivable operations;

[2] Nets shall not meet this requirement by being partially deployed.

The project manager shall be i) sufficiently experienced and competent and ii) suitably resourced and supported to undertake this role satisfactorily.

6. Requirements for mooring of pens

Note that this section relates to moorings for pens. The mooring of feed barges is addressed in Section 9 and Section 10 includes mooring of boats and secondary equipment.

6.1 The mooring design process

Prior to finalising a specification for a new or refurbished mooring system, the mooring supplier shall be provided with:

a) A copy of the site survey report, or the relevant information thereof, undertaken in accordance with this Standard;

b) Details of the pen(s),for which the mooring system is to be designed, including size, shape and main construction materials;

c) Details of the net (including overall dimensions and net porosity) and weighting system for which the mooring system is to be designed;

d) Details of any secondary equipment and boats for which the mooring system will be designed including well boats, work boats and feed boats.

e) Alternatively, a set of generic parameters addressing the points a) to d) above may be provided to enable a mooring system to be designed for use with a range of primary and secondary equipment.

The mooring design shall be shown on a mooring specification sheet as detailed in Annex 2.

6.2 Suitability of the mooring system for use

The mooring system shall be designed to:

a) Be suitable for the envisaged environmental conditions and all conceivable operations at the site(s) at which it is to be deployed;

b) Be suitable for all primary and secondary equipment and boats which the mooring designer has been informed will be used at the site;

c) Prevent chafing of any primary or secondary equipment.

6.3 Key design issues

The mooring system shall be dimensioned in respect of all envisaged environmental conditions and during all conceivable operations:

a) To consider the fatigue and accidental limit states as well as the ultimate limit state.

b) To tolerate all expected loads and deformations with satisfactory safeguarding against failure – *such safeguarding is applied through the use of various load, material and environmental factors contained within this Standard;*

c) To maintain all primary and secondary equipment, as planned;

d) To prevent a significant deterioration of an initial incident – particularly ensuring the failure of a mooring component would not lead to the failure of any other component;

e) To protect against those mechanical, chemical, physical or biological processes that could have a significant negative impact on the equipment taking into account planned maintenance and expected operational life.

f) Such that for steel pens mooring lines in the same direction will be of approximately the same stiffness.

g) Such that unless the anchor is designed to carry vertical loads, the mooring lines shall be designed to avoid vertical loads; this shall be documented.

h) Such that all elements of the mooring system shall not be subject to chafing or snagging.

i) To prevent the unplanned wear and/or damage of all primary and secondary equipment.

The following shall be included in the manufacturer's instructions:

j) The maximum adjustment that can be made to any element of the mooring system; and,

k) The maximum draught for boats in respect of grid ropes (and any other relevant components of the mooring system) shall be given.

6.4 Dimensioning the mooring system

6.4.1 Documentation

All dimensioning activities, including calculations, assumptions and analysis shall be documented and be available to the fish farmer throughout the life of the mooring system.

6.4.2 Determining the loads

The loads acting on the mooring system shall be determined as follows:

a) The types of loads that may affect the mooring system shall be identified with reference to Annex 3.

b) The magnitude of the loads identified in a) above shall be determined using static, quasi-static or dynamic analysis. This shall be as follows

   i) It will be based upon the load factors in Annex 4;

   ii) It will use a verifiable method of calculation – this shall either follow the example in Annex 5 or shall follow a similar premise;

   iii) A fouling factor of 100% of aperture shall be used for sea water pen sites;

   iv) Net aperture shall be reduced by 10% to take account of fouling at freshwater pen sites unless site evidence indicates this should be increased; and,

   v) All other factors shall be identified and justified.

Knowledge gap 3: extent of net fouling at sea water and freshwater pen sites Section 6.4.2: Determining the loads
Fouling increases the resistance of the net to current; increased fouling requires higher specification moorings to account for the increased loads. It is in the interests of fish farmers to keep their nets clean as reductions in water flow can be detrimental to fish health, as well as increasing the loadings on the net and the mooring system. Sea water nets are typically allowed to foul to a certain extent before being cleaned or changed to prevent fouling being a major problem; however, some heavily fouled nets have been witnessed. Fouling is much less of an issue at freshwater pen sites. Ideally, this Standard would specify a minimum level of fouling which is used when calculating the load on the moorings. Given that farmers work to prevent a net becoming completely fouled, this would be lower than a fully occluded net. To enable this approach, there needs to be sufficient confidence that every net at every site meets this requirement, and robust information on net occlusion is not available to support this assertion. A project should be established to monitor the occlusion of nets from fouling in Scotland to determine whether a lower level of fouling could be included in the Standard for sea water pen sites. Should this be positive, it should be introduced with requirements for net cleaning and monitoring to ensure that the nets remain sufficiently clean to enable this to be introduced. Addressing this knowledge gap is not essential as a 100% factor for sea water pen sites can be retained. However, the opportunity to reduce this factor should robust research accompanied by effective monitoring and inspection suggest this is appropriate would be welcome if research indicated that assuming total occlusion was an overly cautious approach.

A nominal factor of 10% fouling has been included for freshwater pen sites, based on discussions with consultees. Since this has not been verified, it also represents a knowledge gap which, in this case, is essential to be addressed prior to the implementation of the Standard.

It is recommended that this project includes the following elements for both sea water and freshwater nets:

- Monitoring of nets returned to net manufacturers/suppliers for testing and servicing;
- Monitoring of nets at a sample of fish farming sites;
- Obtaining existing records in this regard from any fish farmers that collect net fouling information;
- Discussing net fouling with dive companies which undertake net inspection services for fish farmers and, if relevant, companies that supply remotely operated vehicles (ROVs) to fish farmers; and,
- Discussions with Marine Scotland and, perhaps, Food Certification International Ltd to consider whether a protocol to monitor net fouling could be included as part of its existing inspection remit.

The project should require the establishment of a robust methodology that does not rely on subjective observations. Appropriate approaches could include the use of digital imaging of nets with software or other means to enable fouling to be accurately assessed. Issues that should be considered in the project include:

- The expected changes in fouling across the depth of the net such that it can be related to changes in current with depth;
- The extent of fouling with respect to different net treatments, including but not limited to anti-fouling;
- The extent of fouling at different operational stages, particularly at the time of net changes and swim throughs and just in advance of net cleaning when nets would be expected to be at their most fouled;
- The ability to assess nets which may have not been changed or cleaned in accordance with company policy; and,
- The extent of fouling in different geographical areas of Scotland.

The project should be undertaken for a significant period of time, at least one year and preferably two (with a focus on the warmer months when the rate of fouling is greatest), and be timed so that the findings could feed in to the development of the final version of the Scottish Technical Standard. Given this timescale, it is recommended that the project be established as soon as possible.

Should waves be calculated, different combinations of environmental parameters shall be considered and the most unfavourable combination used for dimensioning each ultimate limit state for:

c) The 50 year current and 10 year wave; and,

d) The 10 year current and the 50 year wave.

Alternatively, should waves not be considered when dimensioning the moorings, the 50 year current shall be used.

6.4.3 Determining the resistance to the loads

The mooring system, and all component parts thereof, shall be dimensioned so as to be able to resist the loads acting upon at as identified in Section 6.4.2. This analysis shall be based upon the material factors in Annex 4 and shall be documented; note that material factor shall be applied to the certified strength of the materials as identified by the manufacturer.

6.4.4 Confirming satisfactory capacity

The mooring system shall be dimensioned such that the structure is able to resist the loads acting upon it in response to the ultimate limit state. This shall be assessed through partial co-efficient analysis as detailed in Annex 6 and shall be documented.

6.4.5 Characteristic values

The mooring designer shall determine all relevant characteristic values for all elements of the mooring system which the mooring system will not exceed with respect to the envisaged environmental conditions and during all conceivable operations.

6.5 Damage or failure of the mooring system

The mooring system will be dimensioned such that the loss, failure or damage of any component of or associated with the mooring system will not lead to a) failure of any other component(s) of the mooring system, b) damage that could compromise the integrity of pen(s) and/or c) damage that could compromise the integrity of net(s). Dimensioning shall be undertaken with respect to the envisaged environmental conditions, all conceivable operations, and the loads identified for the ultimate state conditions, and will be documented.

6.6 Requirements for mooring boats and secondary equipment

The mooring designer shall identify any requirements for the provision of mooring facilities by:

a) Confirming with the fish farmer the requirements for mooring boats and secondary equipment for which the site should be designed[3];

b) Identifying and dimensioning the mooring positions; and,

c) Confirming any restrictions on the use of mooring positions including, but not limited to, environmental conditions and boat characteristics.

With regard to the above:

d) Specific boat moorings shall be provided for all boats which are in excess of the capacity of the pens and/or the pen mooring system;

e) Any limitations in mooring well boats and other larger vessels shall be specified, including the maximum environmental conditions in which boats of specified characteristics *(such as length, tonnage, draught, windage etc.)* can be moored to boat moorings or to the pen mooring system.

f) Moorings (whether specific or as part of the pen mooring system) shall be provided for all relevant secondary equipment so that there is no requirement to moor directly to the pens when not in use.

g) Any mooring points provided for boats and secondary equipment within the vicinity of the pens shall be dimensioned, constructed and installed in accordance with this Standard.

The above shall be documented. All relevant information shall be included in the mooring specification sheet and manufacturer's instructions as appropriate.

6.7 Temporary removal of mooring component(s)

Should the partial or complete removal of any component of the mooring system be required for operational reasons, the operational scenarios and environmental conditions in which this can take place shall be identified; the rationale and accompanying calculations shall be documented. All relevant information shall be included in the manufacturer's instructions.

[3] The fish farmer shall consider all conceivable operations and the range of environmental conditions in which specific operations may be conducted, including the most unfavourable combinations

6.8 Requirements for components and materials

6.8.1 Connector testing

All connectors require a certificate where the strength has been documented either through testing or through calculations. Certificates shall be provided to and checked by the supplier, and included in the site documentation. This shall include, but is not limited to:

a) Coupling discs, plates and rope rings;

b) Pen couplings;

c) Slings;

d) Shackles;

e) Chains;

f) Ropes; and,

g) Buoys if they are connecting components of the mooring system.

Documentation should be available stating that knots and splices in the type of rope and adjoining hardware are of appropriate strength for use in the given application. The mooring designer shall ensure that the material factors used in this Standard are appropriate on the basis of this documentation and shall, if required, increase these appropriately; such factors, however, shall not be decreased.

6.8.2 Chains

Chain used in mooring lines shall meet ISO 1704 unless this is proved and documented to not be required.

The maximum inner link length shall be 6.58 times the chain diameter.

Chains other than those used in mooring lines shall be:

a) Protected against corrosion and tempered if appropriate; and,

b) A maximum of Grade 7.

All chain shall be tested post galvanisation to 62.5% of the break load.

All chain shall be accompanied with Test Certificate 3.1 in accordance with BS EN 10204.

When chain is re-used:

c) Reference shall be made to the material factors in Annex 4; and,

d) The actual diameter should be used rather than the new diameter.

6.8.3 Shackles

Shackles used in the mooring system shall meet the requirements:

a) In BS-EN 13889; or,

b) In ISO 1704 if they are used to connect anchor chain to other parts of the mooring system.

All shackles shall:

c) Be dimensioned in accordance with the relevant load and material factors in Annex 4;

d) Have a documented minimum breaking load (MBL);

e) Be a safety shackle; and,

f) Have corrosion resistant parts and shall not give the potential for increased corrosion in other elements of the shackle.

6.8.4 Grid connectors

All steel connectors including chain plates and rope rings should have sufficient three-dimensional strength for the intended use and attachment points which have been dimensioned as lifting equipment in accordance with BS-EN 1677.

Yield stress should be calculated in all possible break locations and must not exceed 270 MPa using a material factor of 1.5.

Should connectors other than steel be used, they shall be proven to be suitable for its intended use with an appropriate margin of safety. This shall be documented.

6.8.5 Rope

Rope manufactured from polypropylene, nylon and polyester shall meet the requirements of the appropriate Standard as follows:

a) BS EN ISO 1346 for polypropylene

b) BS EN ISO 1140 for nylon

c) BS EN ISO 1141 for polyester

Should any other types of rope be used, it shall be documented that they meet i) the principles of the above Standards and ii) the requirements of this Standard.

All rope shall be accompanied with a material certificate.

As well as meeting the material factors in Annex 4, ropes that pass around a curved shape shall be curved at a minimum of three times the rope diameter.

Knowledge gap 4: material factors for rope strengths

Section 6.8.5: rope

There appears to be a lack of scientific research on the reduction in the strength of ropes from the use of knots (and possibly splices too) and when being passed around a curved object (specifically a rope ring) in regard to the types of ropes and applications used in fish farm mooring in Scotland.

The lack of robust and directly applicable research is considered a knowledge gap which is highly desirable to address. Whilst this is not considered essential to the introduction of this Standard – because there are material factors which are available – it should be addressed since these material factors may not be completely satisfactory for use in this Standard.

Consultations highlighted that one research institute has undertaken research in regard to the reduction in strength when rope is passed around a curved object. Although this project was confidential the findings were briefly discussed in general terms and were used to inform this report. It is also noted that at least two net manufacturers have undertaken a certain amount of strength testing of ropes although this is confidential. Since the aforementioned research was confidential and since it is not thought to relate specifically to rope rings (which are the main area of interest from the perspective of Scottish aquaculture), it is recommended that a study be configured as follows to research rope strength regarding:

- The sizes and types of rope used in Scottish fish farming, with particular regard to grid ropes used in conjunction with rope rings;
- The reduction in rope strength from passing ropes around curved objects, with particular regard to rope rings; and,
- The reduction in rope strength from knots, with particular regard to a) the knots used in Scottish fish farming and b) from knotting rope to rope rings.

The methodology for this study should be robust, transparent and repeatable. It should take account of other strength testing studies and be undertaken on good quality reliable machines with a low tolerance and which are calibrated appropriately. Reference should be made to any relevant Standards for rope testing and any published research as appropriate.

Whilst this study would be primarily undertaken in a workshop/laboratory setting, it is recommended that industry and supplier consultations and site visits are undertaken in advance of the testing stage to ensure that the materials tested and methodology are appropriate for the Scottish industry at the present time and taking in to account future requirements.

6.8.6 Buoys

Buoys shall be dimensioned so as to be able to satisfactorily withstand forces from moorings.

Cushion floats shall demonstrate balanced buoyancy in regard to the vertical loads generated.

All steel elements of buoys shall be resistant to corrosion.

The connection point shall be dimensioned as lifting equipment in BS-EN 1677.

6.8.7 Anchors and mooring attachment points

6.8.7.1 Anchors

Dimensioning of anchors, including consideration of the anchor type and, for drag anchors blade angles and geometry where relevant, shall be undertaken with regard to the topography and type of bottom at the site and on the basis of test loads and/or demonstrable performance in similar conditions.

The rationale for the anchor specification, including reference to performance information, shall be documented.

6.8.7.2 Rock bolts

Rock bolts shall be:

a) Dimensioned to withstand the loads in the mooring lines using the relevant material factors in Annex 4;

b) Marked with the minimum breaking load;

c) Tempered if required, and of appropriate resistance to corrosion; and,

d) Installed in accordance with the manufacturer’s instructions, with specific reference to the penetration angle and the application of epoxy grout if used.

6.8.7.3 Dead weight moorings

Should dead weight moorings be used, their resistance to sliding and rising should be calculated and documented. The holding power is required to be at least 1.5 times the calculated load in the mooring line.

All calculations shall be documented.

6.8.8 Materials

A material certificate shall be available throughout the life of the mooring system for all components.

Materials shall be dimensioned in accordance with the material factors in Annex 4

6.9 Swivel moorings

The design of a swing mooring system, whether for mooring pens and/or boats or other ancillary equipment in the vicinity of the pens, shall:

a) Have a redundancy and/or ability to survive the loss of key components which gives at least the same security as other mooring systems designed and dimensioned in accordance with this standard;

b) Be able to withstand the forces from the envisaged environmental conditions; and,

c) Be able to withstand the forces from all conceivable operations.

The above shall be documented.

7. Pen design and construction

7.1 The pen design process

The pen manufacturer shall specify on the pen specification sheet:

a) The range of environmental parameters, including current and wave characteristics, for which the pen has been designed; and,

b) Any other restrictions/limitations on use.

7.2 Suitability of the pen for use

The pen and associated connectors shall be designed and constructed:

a) To be suitable for the environmental conditions stated on the pen specification sheet;

b) To be able to withstand the forces imposed from all loads acting upon them;

c) So as not to chafe and/or snag the net or mooring system in the environmental conditions for which it has been designed (assuming the net and weighting systems are handled and installed in accordance with the manufacturer's instructions);

d) So that it is capable of being towed to and from the site in the environmental conditions that may be encountered without damage – any restrictions in this regard shall be documented in the manufacturer's instructions;

e) So that the net, top net and weighting system is easily installed;

f) So that it is easy to keep clean and remove marine growth; and,

g) To minimise the retention of water and debris.

7.3 Dimensioning the pen(s)

7.3.1 Determining the loads

The loads acting on the pen(s) system shall be determined as follows:

a) The types of loads that may affect the pen shall be identified with reference to the list in Annex 4.

b) The magnitude of the loads identified in a) above shall be determined using static, quasi-static or dynamic analysis based upon the load factors in Annex 4. A verifiable method of calculation shall be used.

7.3.2 Determining the resistance to the loads

The pen(s) shall be dimensioned so as to be able to resist the loads acting upon it/them as identified in 7.3.1 above. This analysis shall be based upon the material factors in Annex 4 and shall be documented; note that material factor shall be applied to the certified strength of the materials as identified by the manufacturer.

7.3.3 Confirming satisfactory capacity

The pen(s) shall be dimensioned such that the structure is able to resist the loads acting upon it in response to the ultimate limit state. This shall be assessed through partial co-efficient analysis as detailed in Annex 6. This shall be documented.

7.3.4 Characteristic values

The manufacturer shall determine all relevant characteristic values for the primary equipment and/or components thereof which the pen will not exceed with respect to the envisaged environmental conditions and during all conceivable operations

7.4 Specific requirements for steel pens

7.4.1 Strength calculations

Strength calculations shall be undertaken and documented regarding global strength analysis and local strength analysis, including:

a) Maximum shear stress at mid spans of sections;

b) Maximum shear and torsional stresses at hinge positions; and,

c) Maximum tensile stress at mooring positions.

7.4.2 Materials and fastenings

Material factors shall be in accordance with BS EN 1993-1-1 and Annex 4. Safety factors shall be in accordance with BS EN 1990. The yield strength shall be used to describe the capacity of the steel.

Fastenings using bolts, screws and similar shall be undertaken as follows:

a) Bolts and screws shall be compatible with the materials being joined;

b) The materials in which bolts and screws are located shall be able to satisfactorily resist wear from their use in the envisaged environmental conditions and during all conceivable operations;

c) Bolts and screws shall be pre-stressed;

d) Locking nuts shall be used;

e) Bolts shall be of sufficient length that at least one thread pitch is visible when the nut is secured;

f) Appropriate washers shall be used to distribute the load and also to prevent galvanic corrosion if relevant;

g) Appropriate grades of bolts and nuts shall be used to prevent thread stripping; and,

h) All fastening devices and secondary equipment shall be used in accordance with the manufacturer's instructions, unless documented agreement has been made to deviate in defined circumstances.

An assessment of screw, bolt and hinge connections shall be performed and documented to confirm that with reference to the envisaged environmental conditions and during all conceivable operations that the connections:

i) Are of sufficient strength;

j) Will perform satisfactorily for the intended use; and,

k) Will not chafe the net.

7.4.3 Steel fatigue

Fatigue calculations shall be undertaken for all critical parts in accordance with BS EN 1993-1-1. Dynamic loads with oscillation periods within the expected wave period range shall be taken in to consideration.

7.5 Specific requirements for plastic pens

Note that Section 7.5 applies to both square and circular plastic pens.

7.5.1 General

Dimensioning shall be undertaken in regard of the ultimate limit state in accordance with the load combinations detailed in Annex 3. The calculations, as well as the following, shall be documented:

a) The loads and load combinations used;

b) The load factors used; and,

c) The material factors used.

When dimensioning:

d) The capacity of the cross section of plastic pipes shall not be exceeded; and,

e) Creep and temperature dependency should be taken into account when calculating the capacity of the cross section.

7.5.2 Strength calculations for plastic pens

When designing plastic pens, the pen's geometry, situation and external forces should be taken into account using either:

a) Standard mechanical engineering formulae in situations with small displacement, unchanged geometry and linear visco-elasticity, or

b) Non-linear finite element analysis in cases of non-linear material deformation or large geometrical changes.

Producers of plastic used in pens should provide data on stretch and shear strength of the materials they produce and these should be used in design calculations. Materials should also be tested independently by pen manufacturers taking account of stress time, type, static or dynamic situation, temperature and environmental conditions. The strength characteristics of the pen, especially in relation to long-term loads, should be documented.

The following material factors for plastic should be used:

c) Accident limit state: 1.0.

d) Ultimate limit state: 1.25.

7.5.3 Localised buckling

The buckling stress shall be calculated in areas where plastic pipes are exposed to significant bending forces, including areas with locally concentrated loads, using the following formula:

$$F_e = (0.5t)D^{-1})(E)$$

Where: F_e = buckling stress; D = pipe diameter; T = pipe wall thickness; E = elasticity module

7.5.4 Assessment of fatigue

A documented assessment of the probability of fatigue shall be undertaken for materials which may be subject to high and varying stress.

7.5.5 Production of polyethylene pipes

The production of all plastic pipes shall be in accordance with BS-EN 12201-2.

7.6 Additional requirements for timber pens

7.6.1 Strength calculation

Strength calculations shall be undertaken and documented to include:

a) Global strength analysis, including the forces from mooring; and,

b) Local strength analysis.

The manufacturer's instructions shall include the frequency and methodology of inspection and the qualifications and experience required of the inspector.

All elements shall be in accordance with the relevant parts of BS-EN 1995-1-1 Part 1-1.

7.6.2 Materials

Material factors shall be in accordance with BS-EN 1995-1-1 Part 1-1.

7.7 Requirements for other types of pens

For any types of pens not covered by this Standard, the above principles for pen design and construction shall apply. Full documentation is required to support the dimensioning process.

7.8 Requirements for integrated feed barges and pens

Where a feed barge is directly attached to the pen to form a single unit, the principles of this Section shall be applied to the integrated installation. In addition, the movement, or potential for movement, between the barge and the pen(s) shall be assessed and any specific measures required to protect against breach of containment specified; this assessment shall be documented.

7.9 Statement of conformity

The manufacturer shall confirm that each completed pen has been manufactured:

a) In full accordance with the pen specification sheet, or with any deviations clearly indicated;

b) In full accordance with this Standard; and,

c) Provide the date of completion and unique identifier.

8. Net design and construction

It should be noted that nylon nets are considered in Section 8.3 and non-nylon nets in Section 8.5. The other sections of this apply to nets of all materials.

8.1 The net design process

The net manufacturer shall specify on the net specification sheet any restrictions/limitations on use of the net.

8.2 Suitability of the net for use

The net shall be designed and constructed:

a) To be suitable for the pen(s) in which it is to be deployed;

b) To be suitable for the weighting system(s) with which it will be deployed;

c) To prevent chafing on the pen, weighting system and mooring system through consideration of sizing, design, choice of materials and construction; and,

d) To properly fit the pen.

All nets shall be provided with manufacturer's instructions in accordance with Annex 7.

8.3 Nylon nets

8.3.1 Netting size

Netting size shall be described by the half-mesh measurement undertaken as detailed in Annex 8. *It should be noted that this measurement is not a measurement of the net aperture.*

8.3.2 Key design issues

The net shall be designed, manufactured and assembled so that:

a) Forces are transferred through ropes rather than the twine throughout all operations when the net is used in accordance with the manufacturer's instructions.

b) All ropes have less elasticity than the netting when manufactured and when the net is in use.

c) Lifting ropes shall tolerate the load when the net is lifted as detailed in the manufacturer's instructions.

d) The net shall be inspected following manufacture for all quality issues, including the absence of holes. This shall be documented.

e) The potential for the reduction in rope strength from splices shall be taken into account in the design process.

8.3.3 Down ropes

The net will be designed such that the weight of the net, the weighting system and any other equipment attached to the net is taken by the down ropes and not by the netting.

Down ropes shall be:

a) Consistently spaced around the circumference of the net;

b) With maximum intervals of 5.1m; and,

c) On nets for use on circular pens, the total number shall be divisible by four.

With the exception of i) down ropes on freshwater nets with a circumference of ≤ 60m and ii) the down ropes nearest to each corner on nets with offset corner ropes for use in square pens with a perimeter of ≤ 60m, down ropes shall either:

d) Cross the base of the net and proceed up the opposite side in a continuous length; or,

e) Be otherwise constructed such that they can be used as a lifting rope.

f) Such down ropes will be capable of being used as lifting ropes when used in accordance with the manufacturer's instructions.

8.3.4 Horizontal ropes

All nets with i) a circumference of ≥ 49m for use with circular pens and ii) all nets for use on square pens shall be constructed with a horizontal rope within ± 0.2m of the designed waterline of the net – this rope is known as the 'waist rope'.

8.3.5 Attachment points

On nets deployed from circular pens, the attachment points for transmitting the main vertical loads of the net to the pen shall be:

a) Taken from attachment points connected to the down ropes of the net at a depth of between 0.4m and 0.75m below the waterline; or,

b) Taken from the point where the down rope crosses the waist rope; and,

c) Designed such that their weight is taken by the flotation tube(s).

On nets deployed from square pens, the location of the attachment points for transmitting the main vertical loads of the net to the pen shall be identified by the manufacturer and documented on the product specification sheet and in the manufacturer's instructions.

All attachment points shall be designed and constructed so that the net integrity is maintained when design loads are applied. This will include, but is not limited to, situations where two attachment points are located close together on the same down rope (for connection to a lifting rope and the weighting system) which may result in loads applied from different directions thereby creating additional strain on the net.

Nets to be used with sinker tubes shall have the attachment points from the net to the sinker tube spaced equally around the net at a maximum distance of 5m.

8.3.6 Net protection and reinforcing

Nets used with mortality baskets or similar systems, shall be fitted with double netting of the same mesh size as used in the net in the vicinity of the basket to protect against chafing from the mortality system. This double netting shall extend as appropriate to give sufficient protection in all operational situations and shall be on the inside of the net.

Nets used with air lift mortality collection systems shall have netting of sufficient mesh strength so as to be able to satisfactorily support the lift up system to prevent damage to the net; this netting shall extend for an appropriate area to give sufficient support. Alternatively, other means of strengthening or reinforcing the net shall be used for this purpose.

Where appropriate, the net manufacturer shall confirm what mortality systems the net is and is not suitable for use with in the product specification sheet and manufacturer's instructions and any associated limitations for use in this regard.

Knowledge gap 5: research on how predators 'attack' the net Section 8.3.6: Net protection and reinforcing
Knowledge gaps It is not proposed to include specific net measures from a design and construction perspective to protect against predation, since there is considered to be insufficient objective evidence on which to base such measures. Additional research is required on the way in which different freshwater and sea water predators breach net integrity and how effective

possible defence measures might be. Whilst not essential to publishing a STS, it is highly desirable to include predation at the earliest opportunity as it is such an important issue in Scottish finfish farming.

Although there is knowledge on seal 'attacks' at sea water sites most, if not all, appears to be anecdotal. Whilst all farmers consider that net tensioning is effective, there appears to be no information on how tight such tensioning should be and whether higher net strengths (or indeed net materials) may provide greater resistance. Questions of particular interest include:

- How do seals actually breach nets – is this from a single bite, or are repeated bites required over a period of time?
- Are higher net strengths more resistant to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Do different net materials offer greater resistance to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Are different net treatments more resistant to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Depending upon the findings to the above, are nets more vulnerable to attack during the life of the net?
- Do seals attack nets in a coordinated action involving more than one seal (there is anecdotal reports of such approaches)?

The above research should include the following:

- Phase 1:
    - Desk based assessment of any existing literature;
    - Discussions with fish farmers to collect and collate anecdotal evidence (which should be used to inform the detailed research requirements; and,
    - Discussions with marine scientists who may be able to provide information on seal behaviour.
- Phase 2:
    - Research on the resistance of nets to simulated seal attacks; and,
    - If feasible, consideration of actual seal attacks on nets.

Similar research to the above is also required for freshwater predators, particularly mink and otter (the latter can also be problematic at some sea sites and should also be considered in the sea water research above).

Knowledge gap 6: net protection measures regarding predation

Section 8.3.6: Net protection and reinforcing

There are a range of net protection measures that can be undertaken to reduce the likelihood of net abrasion and/or predator attacks. These include, but are not limited to, seal blinds, waterline abrasion resistance and gussets between the inside of the net side wall and base.

Requiring such measures within this standard has been rejected at the present time because a) the stipulation for 5m apart down ropes and that all down ropes could be used for lifting make the likelihood of a tear at the join of the side wall and base less likely, b) there was insufficient evidence that waterline abrasion was a significant problem on sites where the pens had been kept in a clean condition, and, c) it was felt that there was insufficient evidence that the use of these necessarily reduced the likelihood of a successful predator attack.

However, it is recommended that an ongoing research project into a) net abrasion and b) predator attacks on nets is established so as to provide further information in this regard. Should the evidence gained indicate that the use of additional net protection would be effective to help reduce the likelihood of escapes, it should then be included in further revisions of this Standard. This should take account of work to address knowledge gap 6.

Whilst addressing this knowledge gap is not considered essential to the introduction of this Standard, due to the reasons above, it is highly desirable that this knowledge gap is addressed to help inform farmers about the effectiveness of different net protection measures. The analysis such knowledge may also provide essential information for future editions of this Standard.

This research should follow on from, or be part of that recommended to address knowledge gap 5 above. In particular, it should include consideration of whether the use of additional (or different) materials would reduce the likelihood of successful predator attacks and, if so, whether it is possible to quantify this.

This research should also include consideration of measures that might be employed in other countries which may be worthy of consideration for use in Scotland.

Knowledge gap 7: net protection measures regarding species aggressive to nets

Section 8.3.6: Net protection and reinforcing

Cod, and other farmed fish species, are known to be aggressive towards nets, which can be problematic from a containment perspective. There appears to have been little research in to this area (Thistle Environmental Partnership, 2010a, b). Whilst cod production is understood to be minimal at the present time in Scotland, it is possible that production may increase in the future. Therefore, research should be undertaken in to the use of nets that may provide a more robust barrier. This should take account of work to address knowledge gap 4.

Whilst this is not considered essential to the introduction, due to the current levels of cod production and the relatively small amount of historic cod escapes, it is considered highly desirable to research this issue such that measures can be in place should cod production increase in the future.

Again, this should include desk based and practical research methods. This project may usefully be combined as an extension of the research requirements for knowledge gaps 5 and 6.

References:

Taylor, M., Kelly, R. (2010a) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0

Taylor, M., Kelly, R. (2010b) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 2: Supporting Information. pp 177. ISBN: 978-1-907266-31-7

8.3.7 Net strength and rope strength

The minimum mesh strength shall be as detailed in Table 1 for freshwater pen sites and Table 2 for sea water pen sites.

Table 1: Net mesh and rope strength for freshwater nets

Net class	FW1	FW2	FW3	FW4
Net depth (m)	**Net perimeter (m)**			
≤ 15.0	**<49**	**50 - 69**	**70 - 89**	**90 – 109**
> 15.1	**-**	**< 69**	**50 - 89**	**90 – 109**
Mesh size (mm)	**Minimum mesh strength for new nets (kg)**			
6.0 - 8.5	39	47	55	55
8.6 - 13.0	47	55	63	71
	Minimum breaking load for all ropes (kg)			
	1400	1900	2800	3400

Notes:

a) Mesh strength is not specified for mesh size smaller than 6mm.

b) In all cases, the mesh strength for a net shall be the lowest test result. Each test result shall be the mean of three mesh strength tests undertaken on the same panel of the net. The number of strength tests required per net is detailed in Section 12.1.6.1.

c) Nets tested on-shore with a mesh strength result of ≤60% of their new mesh strength shall be retired immediately.

d) Nets in use with a mesh strength result of ≤60% of their new mesh strength tested in accordance with this Standard shall be retired from use within a maximum of forty days.

e) Nets in use with a mesh strength result of ≤50% of their new mesh strength tested in accordance with this Standard shall be retired from use within a maximum of five days.

f) Mesh size refers to the half mesh measurement (see Annex 8).

Table 2: Net mesh and rope strength for sea water nets

Net class	SW1	SW2	SW3	SW4	SW5	SW6
Net depth (m)	**Net perimeter (m)**					
0 – 15	**<49**	**50 - 69**	**70 – 89**	**90 - 109**	**110 - 149**	**150 - 169**
15.1 – 30	**-**	**<69**	**-**	**70 - 109**	**110 - 129**	**130 - 149**
Mesh size (mm)	**Minimum strength for mesh of new nets (kg)** (NB: for more exposed sites, advance one category – see Note d))					
13.1 - 17.0	39	47	55	63	71	71 (79)
17.1 - 22.0	47	63	79	79	79	95 (95)
22.1 - 29.0	63	71	95	95	117	136 (136)
29.1 - 35.0	95	95	117	117	136	136 (151)
	Minimum breaking load for all ropes (kg)					
	1400	1900	2800	3400	4100	4100

Note: the notes b) to e) from Table 1 apply also to Table 2.

Note 3 regarding Tables 1 and 2
It may be appropriate to seek permission from Standards Norway in regard of the use of

Tables 1 and 2 since there are some similarities with those in Norsk Standard NS 9415. Since some of the information contained in these tables is based on experience throughout the industry, it is thought that permission should be forthcoming. Legal advice is recommended prior to approaching Standards Norway.

8.3.8 Specification of net ropes

The minimum strength of ropes used in the construction of the net shall meet the requirements of Tables 1 and 2. When determining the load that can be applied at the attachment point, a material factor of 3.0 shall be used for ropes without knots and 5.0 for ropes with knots.

8.3.9 Net construction

Net panels shall be joined prior to being attached to the ropes.

When fixing netting to rope, the netting shall be sufficiently slack and evenly distributed so that the rope takes the loads when the net is in use.

The start and end of a seam shall be properly secured to ensure integrity.

Lacing twine shall be joined using a reliable knot.

All fixings shall be on the outside of the net unless there are specific design requirements that require attaching on the inside; in such cases, the reasons for this shall be documented on the net specification sheet.

The breaking strength of all seams shall be equal to or greater than the breaking strain of the net mesh.

When fixing rope to net pens, the threads shall be wound over the rope and twine through i) at least every second mesh and ii) every mesh for nets with a half mesh size of 15.5mm or above). There shall be a maximum of 12cm between each attachment point (knot). There shall be at least three hitches or other reliable knots per attachment point.

The use of net treatments and other chemical applications shall be in full accordance with the manufacturer's instructions unless documented permission has been obtained to deviate from these in accordance with the manufacturer's approach.

8.3.10 Sacrificial panels

Note 4 regarding section entitled 'sacrificial panels'
Depending upon research to address Knowledge Gaps 8 and 9, it may be necessary to amend this section. This should be undertaken prior to the finalisation of the Standard.

Where sacrificial panels are required for subsequent net testing they shall be:

a) Constructed from the same batch of netting that the net itself was made from;

b) Of the same specification of the netting that the net itself was made from;

c) Subject to the same treatments applied in the same manner as the netting that the net itself was made from, including pre-shrunk, UV treatments and any antifoulants and/or any other treatments including those designed to inhibit the ingress of foreign materials and/or to enhance the net strength;

d) Large enough to allow three strength tests to be carried out on each panel;

e) Individually marked with permanent markers such that each is referenced to the net on which it will be attached and each having its own unique identifier;

f) Firmly attached to the netting so that it will remain attached throughout the operational use through the lifetime of the net, but can also be easily removed; and,

g) Attached to the netting at approximately 0.5m above and below the design waterline in two areas on approximately the opposite sides of the net.

h) Sufficient panels should be fitted to enable testing in accordance with this standard during the life of the net, subject to the requirements of the fish farmer.

Knowledge gap 8: research in to the use of 'sacrificial panels' for testing nylon netting Section 8.3.10: Sacrificial panels
The use of sacrificial panels to assess general net deterioration is a relatively recent approach utilised by a proportion of Scottish finfish farmers. Whilst its use is understood to be well established in regard of testing safety nets, there is discussion about how representative such tests may be for aquaculture nets. Nevertheless, proponents of this approach point to several advantages, including: a) That there is no need to make a hole in the net to undertake net testing, which requires subsequent repair if the net is to continue in use; b) The net can remain in situ but the test can be carried out in controlled conditions. Given that such strength testing is focused on assessing general deterioration from exposure to ultraviolet light, the use of sacrificial panels may well be appropriate. However, before this can be confirmed, research is required to ensure that such panels do indeed give representative results. Whilst addressing this knowledge gap is not considered essential to the introduction of this Standard, because other approaches to net testing are available, it is highly desirable that this knowledge gap is addressed in order to: c) Help improve net testing in the industry; and, d) Not disadvantage those farmers who are keen to implement this approach. This research should consider whether the expected deterioration in sacrificial panels from exposure to ultraviolet light and the marine environment mirrors that of fish farm nets in both the freshwater and sea water environments and whether it is sufficiently representative that strength tests undertaken on a sacrificial panel would be representative of those undertaken on the netting itself. This research should include: a. Research over several production cycles so as to be representative of nets throughout their operational life; b. Research at different locations on the net (i.e. north/south/east/west facing and on the inside and outside of the nets); c. Research at different depths of the net; d. Research from different areas of Scotland to reflect possible differences in exposure to ultraviolet and the marine environment; and, e. Research on different types of netting (both material type and material strength) and different net treatments and colours.

8.3.11 Quality assurance of incoming materials

The net manufacturer shall confirm and document that all incoming materials meet its requirements.

Incoming bales of netting shall be tested in terms of half-mesh size and mesh strength by the net manufacturer to ensure that it meets the required specification as follows:

a) Bales of netting of a specification that is regularly and frequently used and supplied by the same supplier shall be tested periodically;

b) Each bale of netting that is of an infrequently used specification shall be tested;

c) When using a new supplier, the first three bales of each type of netting shall be tested;

d) Additional testing is required when the results of testing of materials from a given supplier indicates issues of concern;

e) Three areas of netting shall be tested on each occasion, taken from approximately the start, middle and end of a bale, and each is to be tested three times with the result averaged;

f) Should the results be less than the quoted specification, with a 5% tolerance level, additional tests shall be undertaken. Unless the additional tests confirm otherwise, the bale should be considered out of specification;

g) The above tests shall be undertaken as specified in Annexes 8 and 9. The results shall be documented. There shall be full traceability to enable each manufactured net to be traced back to individual bales and hence to individual mesh testing.

8.3.12 Yarn

Yarn shall be:

a) From a certified producer;

b) Appropriate to meet the requirements of the net specification sheet;

c) Protected against ultraviolet light; and,

d) Stable.

8.3.13 Netting

Netting shall be pre-shrunk prior to use in construction.

The net and rope shall be designed and constructed such that it will not shrink in use so that it a) either transfers forces from the rope to the net or b) does not properly fit the pen.

8.3.14 Rope

Rope shall be:

a) From a certified supplier.

b) Tested in accordance with BS EN ISO 2307.

c) Labelled as ‘yarn construction’ rope.

d) Mixed polyolefine rope shall also satisfy the requirements in BS-EN 14687 here.

8.4 Net repair

The materials used in net repair should:

a) Be of at least the strength required for the relevant specification of new net;

b) And otherwise meet the requirements of this Standard.

8.5 Nets manufactured from material other than nylon

Other netting and rope materials can be used providing it is documented that as a minimum they satisfy the functional requirements in this Standard.

The minimum mesh strength for Dyneema nets shall be as detailed in Table 3 for freshwater pen sites and Table 4 for sea water pen sites.

Tables 3 & 4: x (*KG*) Net mesh strength for freshwater and sea water Dyneema nets and Dyneema/nylon combinations.

Knowledge gap 9: mesh strength for Dyneema nets Section 8.5: Nets manufactured from material other than nylon
A net strength table should be included in the Standard for nets constructed from Dyneema and Dyneema mixed with other materials. Whilst the existing tables for nylon nets may

suffice, there is concern that the reduced elasticity of Dyneema may require higher mesh strengths than for nylon nets to account for shock loadings, and that a higher portion of the loads will be carried by the net material and not by the ropes, although it may be possible to address this by building in a certain amount of slack in to the netting to ensure that the mesh does not take the forces.

It is recommended that a research project be undertaken to identify what level of mesh strength is required for Dyneema for different mesh sizes with the objective of either developing a specific mesh strength table or advising on how the existing table for nylon nets may be used. This project should take the elasticity of both materials into account and should address both freshwater and sea water nets. Whilst we acknowledge that some research has been done on this subject by at least one net manufacturer, this is understood to have been based more on experience than strength tests and it has not been published or otherwise made available. This project should include a literature review and consultations with manufacturers in Scotland and abroad.

There has been considerable interest in Dyneema nets in the recent past in Scotland and there are signs that this may continue in the future, with several companies apparently looking to increase the use of Dyneema nets. Therefore, addressing this knowledge gap is considered essential for the future of the Scottish industry.

8.6 Net identification tag

Each net shall be permanently marked with two tags:

a) Permanently attached to two different areas of the top rope of the net;

b) That will remain clearly readable when the net is in use; and,

c) Which indicate the manufacturer and the unique identifier.

8.7 Statement of conformity

The manufacturer shall confirm that each completed net has been manufactured:

a) In full accordance with the net specification sheet, or with any deviations clearly indicated;

b) In full accordance with this Standard; and,

c) Provide the date of completion and the serial number and unique identifier.

8.8 Manufacturer’s Instructions

Each net shall be accompanied by manufacturer’s instructions designed as a reference for fish farmers on-site in accordance with Annex 7.

9. Feed barges

A stand-alone feed barge shall not be moored directly to a pen.

Feed barges moored in a stand-alone mooring system shall be moored by adhering to the requirements of Section 6, amended as follows:

a) Consideration of waves is required as appropriate for the site; and,

b) Consideration of the direct wind loads on the structure is required.

Feed barges that share moorings with pens shall meet the above requirements for a standalone mooring system and, in addition, shall be designed and constructed to meet safety, construction, maintenance, installation and other relevant requirements in accordance with other appropriate Standards, *such as those produced by Lloyds and DNV, or by following NS9415*. This shall be documented.

10. Design and construction of secondary equipment

10.1 Weighting Systems

Weights and weighting systems at sea water pen sites shall:

a) Not be placed within the net at sea water pen sites (this does not preclude the use of a lead line);

b) Have a smooth surface;

c) Be designed to not cause significant net abrasion in the envisaged environmental conditions and during all conceivable operations.

Weights and weighting systems at all pen sites shall:

d) Use connectors that will not cause significant net abrasion;

e) Be of sufficient strength;

f) Be designed to avoid trapping or snagging the net.

g) Not exert loads beyond the design loads of pens and nets.

Sinker tubes shall be hung from the outer edge of the outer buoyancy tube. The pen manufacturer should verify that this will not adversely affect the buoyancy and/or stability of the pen in all envisaged environmental conditions and during all conceivable operations.

Weighting systems shall not have parts in which the net can become trapped underwater. This prohibition includes, but is not limited to, systems utilising a component that slides underwater on a chain or rope.

Weighting Systems purchased as complete entities shall be provided with manufacturer's instructions in accordance with Annex 7.

All individual components used to attach sinker tubes to the net and/or pen shall be in accordance with this Standard.

10.2 Mortality collection systems

Mortality collection systems shall be designed to not significantly chafe on the net in the envisaged environmental conditions.

Systems purchased as complete entities should be provided with manufacturer's instructions in accordance with Annex 7.

10.3 Barges, rafts, pontoons and floating support structures

This section excludes feed barges which are considered in Section 9. However, this section does include a raft or similar structure used to accommodate a feeding system.

The requirement to moor any barges, rafts, pontoons and other floating support structures shall be brought to the attention of the mooring designer and, for equipment that may be moored directly to pens, to the pen manufacturer who will:

a) Identify and/or provide specific moorings or mooring locations on a pen for such equipment for when they are in use;

b) Identify and/or provide specific moorings or mooring locations away from the pen for such equipment so that they do not need to be moored to the pens when not in use;

c) Ensure that the loads are taken into account for such moorings by following the mooring requirement in Section 6;

d) Specify the maximum characteristics of equipment that can be moored to the designated locations and any environmental restrictions; and;

e) Highlight any specific requirements in the product specification sheet and/or manufacturer's instructions as appropriate.

10.4 Other secondary equipment

All other secondary equipment that may be used within or in the vicinity of nets and which has the potential to cause chafe or damage shall be:

a) Designed and constructed to avoid chafing the net; and,

b) Provided with manufacturer's instructions in accordance with Annex 7 should poor installation, handling, operation, or maintenance have the potential to cause an escape incident.

11. Site installation

11.1 Planning

The person and/or position with overall responsibility for the installation of primary equipment shall be identified and documented.

11.2 Availability and use of documentation

The relevant manufacturer's instructions and specification sheets shall be available to all appropriate personnel prior to the handling and assembly of primary equipment and for secondary equipment when required.

11.3 Transport of primary equipment

The transport of all primary equipment, including towing, shall be undertaken in accordance with the manufacturer's instructions.

11.4 Post delivery assessment

All main primary equipment shall be inspected post delivery and prior to assembly and/or installation as appropriate to ensure that they are i) in accordance with the relevant specification sheet and ii) undamaged

11.5 Handling and assembly of primary equipment

All main primary equipment shall be handled and assembled in accordance with the manufacturer's instructions and product specification sheet in such a manner as to avoid damage.

11.6 Installation of primary equipment

All primary and, where relevant, secondary equipment shall be installed at the site as below.

a) The primary equipment is located at the site as planned;

b) All individual components are as specified;

c) All primary and secondary equipment and individual components (including anchors of all designs, such as drag anchors and dead weight anchors, and rock bolts) are correctly installed in accordance with the manufacturer's instructions and the product specification sheets.

d) All drag anchors installed in sea water pen sites shall be embedded to 100% of the design load as specified in the manufacturer's instructions through a gradual and sustained application of force. A means to easily monitor the load shall be provided.

Knowledge gap 10: research in the methodology for embedding drag anchors Section 11.6: Installation of primary equipment
Opinion on the most appropriate level of force required to securely embed anchors differed amongst consultees from 30% to 100%, as well as the approach to ensuring secure deployment. It is recommended that a research project is undertaken to address this using a range of anchors representative of those used in Scottish fish farming at both sea water and freshwater pen sites and at representative locations. Addressing this knowledge gap is highly desirable to help inform the specification and installation of anchors. Whilst there are published anchor tests available, none were identified which were specifically related to the types of anchors and environments applicable to Scottish fish farming or in respect of the approach to embedding anchors. It is recommended that several test sites are identified representative of the different types of sea water loch bed conditions encountered in Scottish fish farming and that tests are undertaken with a range of anchor sizes with a boat of sufficient size and power to apply a range of powers

representative of the forces expected on anchor lines at Scottish fish farming sites. The boat should be fitted with equipment so that the magnitude and duration of the force can be recorded.

This research would require that each anchor was tested on a number of occasions at each location to ensure that the results were representative. The anchor behaviour should be visually observed and recorded – ideally filmed by a diver (or at least filmed through the use of an ROV). The research should assess both the magnitude of the force applied as well as the timescale for each size of anchor at each location. Input when designing the methodology is required from a mooring designer working in Scottish aquaculture installations to ensure that the anchors and associated equipment (i.e. chain lengths and sizes) were representative of those in use at the current time and forecast for the foreseeable future – this should be checked with a number of fish farming companies.

Research is also required to identify (if possible) a minimum settling period required for dead weight anchors to achieve their holding power in the types of loch beds representative of where such anchors are used in freshwater and sea water sites in Scotland.

e) All drag anchors installed in freshwater pen sites shall be embedded using a gradual, substantial and prolonged application of force.

f) The position(s) of all anchors (this excludes rock bolts) shall be assessed for dragging following installation using electronic instrumentation; should this be identified in excess of the tolerance specified in the manufacturer's instructions, the anchor shall be re-laid.

g) That no element of the mooring system or nets can be chafed by or snagged upon any other equipment, components, sub sea structures or anomalies of whatever origin;

h) Mooring lines within a pen group shall not cross one another. Should mooring lines from barge moorings cross pen moorings, sufficient separation shall be provided to prevent chafe.

i) All mooring lines, components of the mooring grid and bridles are adjusted in accordance with the techniques and tolerances in the manufacturer's instructions;

j) Any required knots are correct for the required use and type of rope and tied securely;

k) Any materials used to protect individual components are positioned correctly, undamaged and protected against chafe;

l) The likelihood of galvanic corrosion is reduced to an insignificant level through the use of appropriate protective materials and/or the positioning of individual components;

m) The final length of all mooring lines following final adjustments is i) recorded and ii) verified as being within the tolerances in the manufacturer's instructions; and

n) The actual positions of all anchor points (including rock bolts) and pens are recorded using electronic instrumentation.

11.7 Post installation inspection

The installation of any primary equipment shall be inspected prior to stocking as follows:

a) The inspection shall be by person(s) independent to those who undertook the installation;

b) The inspection shall assess whether the primary equipment has been satisfactorily undertaken by addressing each point in Section 11.6;

c) The inspection of mooring and/or weighting systems shall include a visual assessment of all mooring lines and connectors and weighting systems;

d) The inspection shall be documented; this shall include the retention of photographic and/or video images of anchor emplacement and the routing of mooring lines;

e) The inspection shall include access to manufacturer's instructions;

f) The inspection shall include an assessment of whether the primary and secondary equipment have been satisfactorily installed and detail any anomalies.

g) Any such anomalies will either be satisfactorily addressed and re-inspected in accordance with this Standard prior to stocking, or confirmation shall be obtained from the relevant manufacturer/supplier that stocking can commence with this anomaly outstanding; and,

h) The documented records shall be retained by the aquaculture production business, with appropriate back-up held separately, for the life of the relevant primary equipment – or until further installation and/or inspections render these records obsolete.

12. Site operation

12.1 Nets

12.1.1. Selecting the net mesh aperture

Nets shall be of sufficient size to prevent the smallest fish escaping. As a minimum, the following sizes shall apply: **×** *(KG).*

Knowledge gap 11: research in to the minimum net mesh aperture Section 12.1.1: Selecting the net mesh aperture
Whilst there is information on net mesh apertures held by various parties in the industry, it could not be confirmed that this related to the minimum weight rather than the average weight of fish. It is recommended that the following be researched: a) Determination of the minimum number of fish in a population which should be weighed and measured in order to ensure a statistically valid sample for characterising the minimum size of fish in a population; and, b) The recommended mesh sizes required to contain all of a population of fish. The lack of robust and directly applicable research is considered a knowledge gap which is considered essential to address. This research should include: • Physical trials to assess mesh size which should include the use of nets containing populations within tanks or nets such that the ability of fish of different sizes to pass through different sized nets can be evaluated. • Consideration of different species, with a focus on salmon and trout, but also including other species that may be commercially grown in Scotland in the future.

12.1.2 Reducing escapes from predation

Nets on sea water pen sites should be tensioned. *This can be achieved through a variety of methods including, but not limited to, the attachment of weights to the net or by the use of weighting systems such as sinker tubes or weighted blocks).*

Knowledge gap 12: net tensioning to reduce escapes by predation Section 12.1.2: Reducing escapes from predation
Whilst most fish farmers and stakeholders consider that nets should be tensioned to reduce the likelihood of predation and consequent escapes, there appears to be little information a) how effective tensioning actually is in this regard, and b) the level of tensioning required. Whilst addressing this knowledge gap is not considered essential for this Standard, it is highly desirable. This is because such research may provide information to farmers which may help to reduce the likelihood of future predation attacks. Such research should also be analysed from the perspective of whether to include specific measures in future versions of this Standard. This research should be linked to knowledge gaps 5, 6 and 7. It should include the use of nets at different (and verifiable) levels of tension in controlled experiments to assess whether such variations lead to a reduction in the ability of seals to breach nets. It should include nets of different strengths, ages, materials and coatings. The analysis should include an assessment as to how the levels of tension applied correspond to the actual tensions achieved on fish farming sites through the use of direct weights and other types of tensioning systems (including sinker tubes).

Knowledge gap 13: use of predator nets Section 12.1.2: Reducing escapes from predation
Research undertaken previously identified a range of practices in Scotland in regard to the use of predator nets, with varying levels of success (Thistle Environmental Partnership, 2010a, b). It is recommended that research into the use of different types of predator nets is undertaken for both freshwater and sea water pen sites. Whilst this is not considered essential to the introduction this Standard it is considered highly desirable to address so as to help inform farmers about the usefulness of different approaches to the use of such nets. This should include consideration of the use of predator nets abroad, particularly Canada and Chile, where protection from more hostile predators is required. This research should be linked to knowledge gaps 5, 6, 7 and 8. Where appropriate and practical, this should include the evaluation of the effectiveness of predator nets that are in use at fish farming sites in Scotland and abroad – specific trials should be set up to consider this. References: Taylor, M., Kelly, R. (2010a) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0 Taylor, M., Kelly, R. (2010b) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 2: Supporting Information. pp 177. ISBN: 978-1-907266-31-7

12.1.3 Suitability of the net for use

At all times when the net is deployed, the net shall:

a) Be suitable for the pen;

b) Properly fit the pen;

c) Be hung in accordance with the manufacturer's instructions.

Any holes or tears in the net when it is stocked (including the jump net) shall be repaired immediately. It is acceptable to use a temporary repair providing that a more permanent repair is affected as required – a more permanent repair is required when:

d) The nature of a temporary repair may be of insufficient strength to last until the net is available for a long-term repair or when it is retired;

e) When the temporary repair may give rise to forces on the netting for which it was not designed; or,

f) Should the temporary repair in itself give rise to other containment concerns including, but not limited to, increasing the potential for net chafing.

Equipment shall not be attached to any element of the net unless specified in the user manual or following the documented agreement of a net manufacturer or net service company.

12.1.4 Top nets

Sites where washout is possible should be identified on the basis of experience and/or the site survey and documented by the fish farmer. The potential for escapes from washout should be addressed by the use of top nets which are:

- Of the same aperture size as the pen net; and,
- Securely attached to the pen so as to prevent escapes by methods (this may include lacing to the pen net).

12.1.5 Net inspection: on-site

Nets shall be visually inspected for wear and tear and damage as a minimum:

a) Prior to stocking;

b) Every six weeks when stocked;

c) During/after each operation when the net is lifted[4]; and,

d) Should an escape incident be suspected.

Net inspections shall include inspecting the following elements of the net for a) damage, b) correct alignment, and c) any issues that may increase the risk of future escapes:

e) All attachment points;

f) All ropes; and,

g) Each net panel.

Any required repairs shall be identified and undertaken as required. An assessment shall be made of the suitability of the net for continued use.

Inspection findings shall be documented along with the name and company of the person(s) undertaking the inspection, the name and company of the person in charge of the inspection and the method and date of inspection.

12.1.6 Annual net testing and inspection

12.1.6.1 Net strength testing

Note 5 regarding section entitled 'net strength testing'
Reference should be made to Knowledge Gap 8 in regard of the use of sacrificial panels for net testing throughout this section.

Knowledge gap 14: net strength testing
Section 12.1.6.1: net strength testing

The strength of nets can essentially be tested through the use of larger factory based equipment or smaller hand held testers. Due to concerns about the reliability of the latter amongst several consultees, the more accurate approach is to require that nets (or sacrificial panels) are returned to the manufacturer or a net servicing centre for testing using factory based equipment. However, concerns were expressed by several industry representatives about the practicality and costs of transporting nets or sacrificial panels for such testing and so no such requirements have been included in this Standard at the present time.

Instead it is considered that the use of hand meters should be subject to a research project to assess their capabilities and ability to obtain reliable, accurate and repeatable results in a range of representative conditions in the field. This research should include:

- A range of environmental conditions and net mesh strengths;
- The use of commonly available hand held net strength testing equipment;
- The use of parallel tests by factory based equipment to assess the reliability of the hand held meters; and,
- The development of a net testing protocol and method to take account of the location in which the testing is undertaken and the type of meter(s) used – cognisance should be taken of 'BS EN ISO 1806:2002 Fishing nets – Determination of mesh breaking force of netting' which should, ideally, be the basis for such testing. The method should be included in this Standard, probably as an additional annex.

It is understood that some tests of hand based equipment has been undertaken at one of the

[4] The inspection can be undertaken as the net is being lifted and/or lowered. In the case of net changes and swim throughs, the inspection shall be undertaken as soon as is reasonably practical to the time the net is stocked.

net testing companies and so the research should take account of its findings. SINTEF has also undertaken research in to net strength testing and cognisance should be given to its findings.

Depending upon the results of the above project, it may be useful to consider an academic research project to design an appropriate hand held net mesh strength testing machine.

Obtaining reliable, repeatable and accurate results is essential to the implementation of an effective and useful net strength testing regime; failure to do so very much devalues the value of the exercise. This is an essential area that should be addressed prior to the finalisation and implementation of a Scottish Technical Standard.

Results shall be expressed as a) a numerical value in kg and b) as a percentage of the net's dimensioned class and shall include the net's unique identifier and manufactured class, date of manufacture, date of first use, date of the test, name and company of the person undertaking the test and details of the equipment used to undertake the test. The tester shall sign to confirm that the testing equipment was appropriately calibrated.

See notes accompanying Tables 1 and 2 for information about how nets shall be withdrawn from use following a failed net mesh strength test.

12.1.6.2 Net inspection

Nets shall be visually inspected 12 months after manufacture and annually thereafter to assess general wear and tear and identify any specific damage. Inspections shall:

a) Be undertaken by person(s) independent to those with responsibility for the management of the site from which the net will be tested;

b) Be undertaken within two weeks of the annual net strength testing (see knowledge gap 13);

c) Include the detailed examination of all areas of the net mesh, all ropes, all connecting points and any areas of net reinforcement;

d) Include an assessment as to whether the net is a) suitable for use at the present time, b) suitable for use following specific repair work, or c) unsuitable for further use; and,

e) Be fully documented.

Any nets which are deemed unsuitable for further use shall not be used. Those requiring specific additional work shall not be returned to use until such work is undertaken. Any repair work shall be documented.

12.2 Operating in accordance with the manufacturer's instructions and product specification sheets

The use of all primary equipment and, where relevant, secondary equipment and individual components shall be in complete accordance with the relevant manufacturer's instructions and product specification sheets at all times – with the following exception:

a) Should the farmer have obtained documented approval from the relevant manufacturer to deviate from the manufacturer's instructions in a specified manner.

12.3 Changes in operations, activities, equipment and consumables

Should the fish farmer wish to change the use of a given site installation and/or the use of primary and secondary equipment[5] such that this may be result in equipment being used i) outwith its design parameters or ii) outwith the manufacturer's instructions, the supplier or an independent engineer shall confirm that:

[5] This shall include a) the use of boats for which the existing moorings and/or pens were not designed, b) the introduction of additional pens into a mooring system, c) a change in the type/dimensions of pens and/or nets in a mooring system, d) a significant change in the weighting system or e) a change in orientation of a mooring system.

a) The proposed changes are acceptable; or,

b) The proposed changes are acceptable with specific modifications and/or restrictions.

In the case of the latter, the change(s) shall only commence once the modifications have been made and/or the restrictions are in place.

The above shall be documented.

The fish farmer shall also require verification as above that any primary equipment may continue to be used in the event of:

c) Damage of a level which could reduce the integrity of the installation; and/or,

d) Concern that the actual environmental conditions experienced at the site are significantly different to the envisaged environmental conditions; and/or,

e) The possibility that the actual operations that are, or could conceivably be, undertaken at the site are different, or may be undertaken differently, to those originally considered.

12.4 Mooring of boats and secondary equipment

Boats and secondary equipment shall not be moored to pens (including on mooring points specified by the manufacturer) when:

a) Not in use (excluding short work breaks); and,

b) When environmental conditions exceed those stated in the manufacturer's instructions as appropriate for the specific equipment.

12.5 Installation of unstocked primary equipment

This Standard shall apply to all installations whether stocked or unstocked unless the components will not be used at stocked fish farms again. This will be documented.

Should primary or secondary equipment have been installed in a situation which was not in accordance with this Standard, including the situation when a decision to retire them has been reversed, an independent damage assessment is required prior to use.

12.6 Lack of historical information on equipment use

Should there be i) a lack of information about the history of primary or secondary equipment, or ii) doubts about the accuracy of such information, an independent assessment by a suitably competent person shall be undertaken before:

a) The site is stocked; or,

b) For sites which are already stocked, at the earliest opportunity and within four weeks of the first input of fish.

The independent assessor shall verify that the equipment is i) acceptable for use, ii) acceptable for use providing that specific modifications/actions are undertaken, or iii) unacceptable for use;

c) The equipment shall not be used in the new situation unless the independent assessment has confirmed it is i) acceptable or ii) that the work specified in the independent assessment has been satisfactorily undertaken.

d) Should the equipment be stocked, any required work shall be undertaken as specified in the independent assessment or, for unacceptable equipment, the net/site shall be emptied as soon as possible as specified by the assessment; and,

e) The above shall be documented.

12.7 Maintenance and inspections

Note that net inspections are detailed in 12.1.6.

12.7.1 Inspection regime and preventative maintenance plan

An inspection regime and a preventative maintenance plan shall be developed to include:

a) Requirements in the relevant manufacturer's instructions;

b) Frequent and regular checks by site staff;

c) Actions required to prepare a site for the arrival of poor environmental conditions;

d) A preventative maintenance programme for engineers.

e) Issues that could lead to a breach of containment, including mooring integrity, connector wear and net abrasion;

The a) requirements, b) compliance with, c) reporting of and d) actions arising from the inspection and preventative maintenance plans shall be documented.

12.7.2 Responding to maintenance requirements

The fish farmer shall have sufficient resources, whether in-house or contracted, to undertake planned and corrective and reactive maintenance in accordance with this Standard so as to maintain effective containment.

The fish farmer shall identify a list of spare parts, consumables and associated materials which may be required for maintenance, including unplanned situations, to maintain effective containment and shall ensure these are available as may be required. This list and associated stock shall be documented.

12.7.3 Post acquisition inspection

Following the acquisition of an existing site, or equipment thereof, a full installation inspection shall be undertaken in accordance with Section 11.7.

12.8 Freshwater pen sites – protection against icing

Fish farmers at freshwater pen sites that have been identified as at risk from icing (see Section 4.6) shall develop an action plan to reduce the likelihood of a containment incident from icing. This plan shall be displayed on-site and implemented in the event of icing. All equipment identified in the plan shall be available at the required time of year.

13. Land based sites

13.1 Site design and construction

Sites should be arranged or protective measures provided to prevent fish holding units being damaged by vehicles, including forklifts and delivery/fish transfer lorries.

Engineering advice shall be sought and followed in regard of the design and construction of tanks and production facilities, including foundations, from appropriately qualified and experienced professionals. This shall be documented.

13.2 Screens

Each fish holding unit shall be designed and/or protected so that fish cannot enter the inflow under any conceivable conditions.

Fish shall be retained in the holding unit by the provision of a screened overflow device should:

a) The primary screen become completely blocked and/or

b) The water level in the tank rise beyond the normal operational level and/or

c) Freezing temperatures be experienced (including protecting against the primary screen lifting out of position and/or becoming partially or fully blocked due to icing).

In addition to the primary screen, there shall be a second screen between the holding units outflow and the final site discharge. This, along with any other on-site containment structures, shall be capable of preventing any fish entering any water courses in the event of:

d) Fish escaping into the effluent or other internal channels or pipes at the site;

e) The total failure of any fish holding unit;

f) An escape incident occurring during a fish handling and/or transfer operation;

g) An escape incident occurring during a power failure; and/or,

h) Freezing temperatures (including protecting against the screen moving out of position and/or becoming partially or fully blocked due to icing).

All screens and any associated containment structures shall be:

i) Designed, constructed and installed so that during any conceivable operation and/or environmental condition:

    i) Fish cannot escape around the edges; and,

    ii) They cannot be inadvertently dislodged or otherwise removed;

j) Of an appropriate material such that they will not break or deform during any conceivable operation and/or any conceivable situation, including if they are completely blocked;

k) Such that complete containment will be maintained during inspection and maintenance – for secondary screens, this would normally require facilities for a replacement screen(s) to be installed in a manner which meets the requirements of this Standard prior to the removal of the first screen(s); and,

l) Sufficient to maintain effective containment in flood conditions.

Screens shall be of sufficient size to prevent the smallest fish escaping. As a minimum, the following sizes shall apply: ✗ *(KG).*

Knowledge gap 15: research in to the minimum screen aperture Section 13.2: Screens
Whilst there is information on net mesh apertures held by various parties in the industry, it could not be confirmed that this related to the minimum weight rather than the average weight of fish nor could it be confirmed whether this may also be applicable to screen sizes. It is recommended that the following be researched: a) The amount of sample weighing and/or the use of alternative methods to characterise the minimum size of fish in a population; and, b) The recommended screen apertures are appropriate to contain all of a population of fish. The lack of robust and directly applicable research is considered a knowledge gap which is considered essential to address. This research should include: • Physical trials to assess screen aperture size which should include the use of nets containing populations within tanks or nets such that the ability of fish of different sizes to pass through different sized nets can be evaluated. • Consideration of different species, with a focus on salmon and trout, but also including those that may be commercially grown in Scotland in the foreseeable future. The research for this knowledge gap should be linked to that undertaken for knowledge gap 10.

Screens shall be inspected regularly, and at least daily when the relevant units are stocked, in accordance with a documented maintenance regime.

Sufficient spare screens, and repair materials as appropriate, shall be available on-site to ensure effective containment in the case of damage or unexpected variations in the size of fish.

13.3 Flooding

Where sites are to be located in an area where the probability of flooding is equal or greater than 0.5% in any given year a documented flood risk assessment shall be undertaken.

Sites shall be designed to contain fish at the highest flood level determined by the flood risk assessment. This shall be documented.

13.4 Stock transfer: using fish transfer pipe

This sub-section relates to the transfer of fish in locations outwith areas which are protected by screens and/or containment structures such that an incident could lead to the escape of fish into a watercourse. Therefore, it does not include the transfer of fish within the areas of a land based site protected by screens and containment structures as detailed above.

Pipes used to transfer fish shall:

a) Be adequately supported to prevent undue stress on the pipe; and,

b) Be constructed from material that is sufficiently strong and suitable for the purpose.

When using transfer pipes:

c) Both the input and output shall be continuously observed when fish are being transferred;

d) Staff shall be stationed to allow the transfer to be instantaneously stopped;

e) Appropriate communications devices shall be provided to ensure instantaneous communication between those observing and operating the transfer;

f) The upstream and down stream ends shall be secured and/or positioned so as to prevent the opportunity for an escape incident;

g) Connectors shall be secured to the transfer pipe with a secondary device such as a clip or clamp and in accordance with manufacturer's instructions; and,

h) The pipe shall be protected against fish escape, should any intermediate join/connection fail, by the use of a tube of net of an appropriate mesh size being placed around the pipe at each join and extending at least one metre each side of the join. The pipe shall be well secured by two clamps or clips or other appropriate mechanical connecting devices each side of the join so as to prevent fish loss in the event of failure.

Maintenance requirements for transfer pipe connectors and valves shall be determined, documented and implemented.

13.5 Stock transfer: using helicopter bucket

A helicopter bucket overflow screen shall be securely attached to the top of the helicopter bucket when loading other than when fish are being loaded by hand net.

It shall be ensured that all areas where the helicopter bucket will be landed are sufficiently:

a) Large and free of obstructions so that the bucket cannot be damaged or the locking mechanism inadvertently opened; and,

b) Flat and horizontal to prevent any likelihood of the bucket toppling over.

The locking mechanism of a helicopter bucket containing fish shall be checked:

c) Following landing if it is to be subject to a further lift (whether by crane or helicopter) to ensure that it has not been damaged or inadvertently opened during landing; and,

d) Prior to loading fish.

Annex 1: Approach to current monitoring

The approach to current monitoring shall be carried out in accordance with Box 1 below.

Box 1: Current monitoring requirements with reference to Attachment VIII (SEPA 2008)

2.1, Position Fixing: the elements regarding the current meter apply in their entirety.

2.3, Data Reporting: the location of the current meter shall be identified in accordance with this section.

3.1, Duration and Resolution: applies in its entirety.

3.3, Equipment: applies in its entirety, except that SEPA should not be approached regarding equipment 'slightly outwith' the specifications - in these situations, the use of such equipment should be justified and documented.

3.4, Data Quality Assurance: applies in its entirety.

3.5, Deployment Position and 3.6 Depth of Data Retrieval: these apply in their entirety except that:

- Data is only required to meet the sub-surface and cage-bottom current requirements.
- SEPA should not be contacted to discuss uncertainties regarding current meter locations; instead, the use of an additional monitoring location(s) should be utilised – such a decision should be justified and documented.

In addition to the requirements in Section 3.5, the following apply:

- The monitor shall be positioned where the highest velocities of current from tidal and wind induced factors are expected.
- The monitoring point shall be representative of the location where the fish farm pens are to be located.
- One or more additional monitoring points are required where variations in tidal or wind induced current may be expected across the area where pens and, if appropriate, feed barges will be located which could affect the design and specification of equipment at the site.
- One or more additional monitoring points are required where a significant contribution to total current velocity from variables other than tidal or wind induced current may be expected across the area where pens and, if appropriate, feed barges will be located. This could include, but is not limited to, discharge from rivers / estuaries and hydroelectric schemes.

3.7, Meteorological Data: applies in its entirety except that there is no need to meet the requirements of the quoted maximum wind speeds during the monitoring period.

3.8, Numerical Data: data shall be stored in accordance with the requirements of this clause except that there is no requirement to submit data to any authority.

Notes:

a) Numbers refer to paragraph numbers in Attachment VIII (SEPA, 2008).

b) Clauses other than the above do not apply.

Annex 2: Product specification sheets

Product specification sheets shall be provided by the relevant manufacturer for primary equipment. They shall include the following.

a) Confirmation of the environmental parameters for which the equipment has been designed, including nature of environment (sea water or freshwater) maximum current, significant wave height and peak wave period.

b) A diagram of the equipment with all relevant dimensions and, where appropriate, showing the three dimensional manner in which it should be installed.

c) The specification of all materials (including material type and capacity).

d) Identification of the location, material, intended use of and maximum load (with any constraints on the direction of load application) for all attachment points.

e) Details of any redundancy built in to the design.

f) Confirmation as to whether or not the mooring system and/or pen has been designed to accommodate the mooring of boats, rafts, barges and/or any secondary equipment and, if so, the location of mooring points, the maximum sizes that can be accommodated and any restrictions that may apply (including environmental conditions and/or operations).

g) Any requirement for the tensioning/pre-tensioning of the pen.

h) Chemical treatments – specifically anti-fouling or other paints/surface treatments.

i) Confirmation of the maximum weights of plant, equipment and/or consumables that can be stored and used on the pen, or areas thereof.

j) Confirmation of any specific types of secondary equipment for which the net may have been designed to be used with (e.g. mortality collection systems).

k) Confirmation of whether any specific plant or equipment can (or cannot) be attached to the pen and net, if so, what, how and where.

l) Confirmation of the manufactured weight of the completed pen and net.

m) Details of any weighting system for which the pen and net have been designed, if relevant.

n) Details of any requirements for how the pen shall be positioned within the mooring system and associated tolerances.

o) For freshwater pen sites, a summary of the icing assessment undertaken in Section 4.6.

p) Details of any assumptions used in the design.

q) Confirmation that all equipment has been designed and will be manufactured in accordance with this Standard.

Knowledge gap 16 regarding the above requirement for net manufacturers to confirm that the net is suitable for use Annex 2: Product specification sheets
It is understood that net suppliers are not easily able to verify the design of their products for use in specific locations since they are not usually privy to historical performance data, particularly which nets are used at which sites. It is recommended that data on environmental conditions on existing sites should be correlated against net specifications and net use to provide a database which net manufacturers can refer to. This should include the analysis of net records (or net registers) held by fish farmers (or net manufacturers/suppliers), environmental site data held by the Scottish Environment Protection Agency (SEPA) and net specification information (held by the fish farmer and/or the net manufacturer/supplier).

Addressing this knowledge gap would enable net manufacturers to be able to specify nets on the basis of experience and past performance data. Addressing this knowledge gap is considered useful for providing data to support the use of the net tables within this Standard and also to provide information for farmers and net manufacturers.

Annex 3: Types of loads

The loads which should be considered during dimensioning shall include, but not be limited to, those listed in Table 2 below.

Table 2: Types of loads

Permanent loads: loads present throughout the working life of the equipment	
Including:	- The weight of the fish farm in air. - The weight of fixed equipment. - Static buoyancy forces.
Variable function loads: loads which can be moved on the site or removed from it.	
Including:	- Mechanical equipment. - Personnel. - Consumables. - Variable ballast. - Mutual load between primary equipment and, if relevant, secondary equipment. - Routine boat impact. - Fendering or mooring of boats, including feed boats, well boats, personnel boats, work boats and boats used to remove mortalities - Fendering and mooring of other floating equipment. - Any extra loads applied as a result of particular work operations.
Deformation loads	
Including	- Pre-tensioning. - Mooring. - Temperature.
Environmental loads	
Including	- Wind. - Waves* - Current
Accidental loads	
Including	- Breaks in mooring lines - Breaks in connectors - Puncturing or loss of floating parts

*Note: *the consideration of waves is not required in static analysis - although it is recommended*. Waves shall be considered for sites affected by ocean swells.

Annex 4: Material factors and load factors

Note 6 regarding Annex 4
It is recommended that permission is sought from Standards Norway in regard of the use of the tables in Annex 4 since the same or similar tables appear in Norsk Standard NS 9415. Since some of the information contained in these tables are common factors used in structural engineering and that other information is based on experience, it is thought that permission should be forthcoming. Legal advice is recommended prior to approaching Standards Norway.

Annex 4 presents the material factors and load factors to be used in the partial co-efficient analysis (see Annex 6).

Table A4.1: Material factors for mooring lines

Type	Material factor
Synthetic rope	3.0
Synthetic rope with knots	5.0
Chains and chain components	2.0
Used chains	5.0
Coupling discs and other connecting points of steel*	1.5
Shackles	2.0
Rock bolts and other bottom attachments	3.0

Notes:

* First yield

i) Should the relevant component not be included in the table above, the mooring supplier shall source and document the material factor.

ii) Material factors assume that the component is used as intended in the manufacturer's/supplier's instructions. This includes, but is not limited to, a mooring component used/attached at a different angle to that specified; in such cases, a different material factor shall be used in consultation with the manufacturer – the chosen factor and all associated correspondence shall be documented.

Table A4.2: Load factors for mooring lines

Type	Load factor
Static analysis	1.6
Quasi-static analysis	1.15 x DAF*
Dynamic analysis	1.15
Accident limit (break in mooring line)	1.0
Spring tide	1.0

Notes:

* DAF shall be set at ≥ 1.0 – the actual value used shall be documented and justified.

Table A4.3: Load factors for steel and plastic pens in different limit states

Dimensioning situation	Permanent load	Variable function load	Deformation load	Environmental load
Establishment of capacity	1.0	1.0	1.0	1.3
Accident situation – damaged condition* **	1.0	1.0	1.0	1.0

Notes:

* Favourable load (buoyancy) and unfavourable load (weight) shall be regarded as separate loads. The favourable part has a load factor of 0.9 and the unfavourable part has a factor of 1.0.

** Applies to loads from ice and show.

*** Applies to breaks in mooring lines, puncturing and ice and snow.

Table A4.4 Material factors for steel installations

Limit states	Parameters	Material factor
Breaking strength	Cross-section capacity	1.1
Breaking strength	Screw, bolt, friction and welding connections	1.25
Fatigue limit	All material factors	1.0
Accident limit	All material factors	1.0

Annex 5 (informational): Example force equation

The following equation may be used to determine the forces on a mooring system:

$F = 0.5\rho C_D A V^2$

Where:

- F is the force, ρ is the density of the fluid, C_D is the drag coefficient, A is the area upon which the force is acting and V is the current velocity.
- All factors shall be documented and justified.
- A shall meet the fouling requirements in Section 4.4.2.

Further information on the forces that mooring systems may be subject to are presented in a wide range of publications which include those listed below.

Aarsnes, J. V., Løland, G., and Rudi, H. (1990). “Current Forces on Cage, Net Deflection.” Engineering for offshore fish farming, Glasgow, United Kingdom.

Aquaculture International Volume 1, Number 1, 72-79. DOI : 1007/BF00692665by Geir Leland of MARINTEK

Berstad, A. J., H. Tronstad, S. A. Sivertsen and E. Leite. (2005) “Enhancement of Design Criteria for Fish Farm Facilities Including Operations” OMAE 2005, The 24th International Conference on Offshore Mechanics and Arctic Engineering Halkidiki, Greece, 12-17 June, 2005. Paper 67451. ISBN #: 0791837599.

Berstad, A. J., Tronstad, H., Ytterland, A. (2004)” Design Rules for Marine Fish Farms in Norway. Calculation of the Structural Response of such Flexible Structures to Verify Structural Integrity.” Proceedings of OMAE2004 23rd International Conference on Offshore Mechanics and Arctic Engineering June 2004, Vancouver, Canada. OMAE2004-51577

Blendermann, W. An analysis of the hydrodynamic forces on cables and nets. Applied Ocean Research 1997 Vol 9 No4.

Lader, P. F. and B. Enerhaug (2005). Experimental investigation of forces and geometry of a net cage in uniform flow. IEEE Journal of Ocean Engineering (30).

Lader, P. F., B. Enerhaug, A. Fredheim and J. Krokstad (2003). Modeling of 3D Net Structures Exposed to Waves and Current. 3rd International Conference on Hydroelasticity in Marine Technology, 15-17 September 2003, Oxford, UK

Milne, P. H. ‘Fish Farming: A guide to the Design and Construction of Net Enclosures’ University of Strathclyde April 1970

Morison, J. R.; O'Brien, M. P.; Johnson, J. W.; Schaaf, S. A. (1950), "The force exerted by surface waves on piles", Petroleum Transactions (American Institute of Mining Engineers) 189: 149–154

Sea loads on ships and offshore structures. O.M. Faltinsen. 1990. Cambridge University Press. ISBN 0 521 45870 6.

Sintef ‘Hydrodynamic loads on net structures’ 17th July 2006

Wikipedia references:

http://en.wikipedia.org/wiki/Morison_equation

http://en.wikipedia.org/wiki/Drag_force

Annex 6: Partial co-efficient analysis

Where partial coefficient analysis is required in this Standard, this shall be undertaken such that the following expression is fulfilled:

$$S_f \leq \frac{R}{\gamma_m}$$

Where: S_f is the design load multiplied by the load factor(s).

R is the capacity of the equipment.

γ_m is the material factor

Annex 7: Manufacturer's instructions

Introduction

All primary equipment and certain secondary equipment[6] shall be accompanied by manufacturer's[7] instructions designed as a reference for fish farmers on-site. It should provide key information about the use of the relevant equipment to help prevent escapes.

The manufacturer's instructions shall be followed for all aspects of the use of the equipment as detailed in Section 10.

The manufacturer's instructions shall include as a minimum the relevant requirements listed below.

Background information

a) Manufacturer's name and place of business;

b) Manufacturer's contact details;

c) For imported equipment, the contact details of a UK representative if appropriate; and,

d) Product reference number/descriptor if relevant.

Generic requirements

a) A copy of the final product specification sheet for primary equipment – and all key dimensions and characteristics for secondary equipment.

b) Any measures to prevent damage during handling and installation.

c) Any measures to ensure correct installation.

d) Preventative maintenance requirements, including an inspection regime with maximum intervals and indicators for replacement.

e) The maintenance regime shall include an inspection regime in regard to metal fatigue where appropriate.

f) Reactive maintenance regime to include how components subject to wear and tear should be replaced.

g) The specifications and any other useful info to facilitate traceability of individual components and parts.

h) Where required, any specific qualifications, experience, training and/or competencies for specific tasks shall be identified.

i) For freshwater pen sites, a summary of the icing assessment undertaken in Section 2.6.

Towing

a) The location of towing points.

b) The approach for attaching towing equipment.

c) Any measure required to prevent damage to the pen whilst being towed.

d) The maximum towing velocity (expressed as speed through the water) and any other restrictions on the environmental conditions that can be experienced during towing.

e) Requirements for inspection and maintenance during and after towing.

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[6] Manufacturer's instructions are required for secondary equipment where this relates to purchased systems, rather than those assembled by or on behalf of the fish farmer.

[7] In the case of systems such as mooring systems, weighting systems, the instructions shall be provided by the designer of the system – in the case that an aquaculture production business was the designer rather than the manufacturer, it shall provide instructions as if it were the manufacturer.

Mooring system

a) Instructions as to how to lay or install each type of anchor, rock point, dead weight mooring or other form of anchoring system being used.

b) Requirements for how to load each mooring line to ensure that each anchor is firmly embedded into the substrate, taking in to account the requirements of Section 11 of this Standard and a statement when an anchor shall be installed again.

c) The length of all mooring lines – and the associated scope of mooring lines for those attached to anchors/drag anchors.

d) The tolerances for the adjustment of all relevant elements of the mooring system, including mooring lines, grid ropes and bridles. This shall clearly state the maximum adjustments that can be made (i.e. corresponding to the minimum length of each element that is acceptable from the perspective of maintaining the integrity of the mooring system).

e) Any measures require to ensure that the geometry of the mooring system is maintained during installation.

Pens

a) Instructions as to how to connect pen(s) to the mooring system.

b) Any measures required to ensure that the location of the pen within the mooring system is maintained as required.

c) The approach to lifting pens, which shall include lifting circular pens afloat for cleaning purposes – this shall state the maximum height that one point of a circular pen can be lifted in relation to the rest of the pen;

Nets and weighting systems

a) Details of any net treatments used.

b) Mesh strength and rope strength.

c) The maximum weights that can be attached to down ropes.

d) The method for attaching the net to the pen and any stipulations about how the net should not be attached.

e) The method for attaching the net to the weighting system and any stipulations about how the net should not be attached and how the weighting system should be used, including the maximum distance that ropes supporting the weighting systems can be lifted/dropped in any one lift/drop where relevant.

f) Instructions as to how the net can be tensioned/weighted without risking chafing or other damage and the predicted net deflection.

g) Any key information about how the net shall be lifted/dropped, including the maximum distance that down ropes can be lifted/dropped in any one lift/drop.

h) How the net shall be hung when raised/partially raised and what parts of the net can be used for supporting the weight of the net during such operations.

i) Confirmation of any specific types of secondary equipment for which the net may have been designed to be used with (e.g. mortality collection systems).

j) A statement that the net should be suitable for the pen and properly fit the pen.

k) Whether the netting or ropes can be used to take the weight of any pieces of equipment and, if so, to specify how and what.

l) The number and location of pen attachment points.

m) The number and location of down ropes.

n) The height of the jump net.

Annex 8: Method to determine the half-mesh measurement on netting

Half mesh measurement for nylon and Dyneema® nets with a square mesh

The methodology for determining the half-mesh size for nylon and Dyneema nets with a square mesh shall be undertaken as described below.

a) Netting shall be pulled tight so as to distort the square mesh into a narrow diamond;

b) The measurement shall be made across the length of the diamonds (i.e. across the narrow aperture rather than along the twine);

c) The measurement shall be made between either a) the centres of the twine joins, b) the inside edge to the outside edge of the twine join or c) from the outside edge to the inside edge of the twine join.

d) The measurement shall be made across a minimum of ten meshes and divided by the number of meshes measured and the answer then further divided by two to give a single half mesh measurement.

e) A tolerance of ≤ 5% is acceptable.

Half mesh measurement for nylon nets with a hexagonal mesh

The half mesh size of net mesh for nylon nets with a hexagonal mesh shall be undertaken as described below:

a) Identify the corresponding square mesh side measurement by reference to Annex J in NS9415.

b) Use the square mesh side measurement by following the methodology above to identify the half-mesh measurement

Half mesh measurements for other products

This standard does not include a method of measurement for nets constructed of materials other than nylon and Dyneema. Should it be necessary to measure other such materials, a satisfactory approach shall be developed which addresses the following principles:

a) The measurement shall correspond to a half-mesh measurement;

b) The measurement shall be from two corresponding points on the netting;

c) The measurement shall not describe the net aperture;

d) The measurement shall be averaged over a minimum of ten meshes, and more if required to gain a representative result;

e) The measurement shall be undertaken in such a way as to ensure consistent results when repeated;

f) The measurement shall be documented; and,

g) The maximum tolerance shall be 5%.

Appendix 1: Summary of knowledge gaps

This appendix collates the knowledge gaps contained within this report. It is not intended that this appendix would be included in the final version of this Standard.

Knowledge gap 1: current adjustment factors for sea water pen sites

Section 4.2.1: measurement of current for at least 15 days

Rationale for developing a dimensioning current

Equipment designers need to work to a current velocity representative of the maximum that might be expected at the site; this is termed the 'dimensioning current'.

Should the dimensioning current be underestimated this could lead to the use of insufficient equipment, whilst an overly conservative figure could lead to unnecessarily high costs.

Background

Unless the site survey was undertaken during the strongest tide of the year and coincided with a major storm in an additive direction, the monitored current would most likely underestimate the velocity that could be encountered at the site. To address this, the monitoring results could be adjusted by applying an appropriate factor(s).

The crucial factors that should be considered are highlighted below.

- Adjusting for the equinox. The strongest tides occur at the equinoxes (usually 20th or 21st March and 22nd or 23rd September). If the monitoring has taken place at an alternative time, the results should be increased by a specified factor to give velocities representative of those which would have been obtained at the equinox.
- Adjusting for wind induced current. Total current velocities at sea water pen sites are primarily comprised of two elements: tidal generated and wind induced. Whilst the 15 day monitoring period, adjusted for the equinox as above, should address the tidal element, it is likely to underestimate the wind induced current unless it took place during a storm of suitable strength, direction and duration.

  Therefore, unless monitoring was during a storm, the results should be increased by a specified factor to give current velocities representative of those which would have been obtained had the monitoring been during a defined event (such as a 1 in 50 year wind).

  Ideally, the wind induced factor should be applicable in an incremental manner to account for any moderate or strong winds before or during the monitoring period.

  Wind induced current also depends upon the fetch length; ideally, a threshold would apply for sites with a very short fetch, below which a reduced factor would apply.
- Adjusting for storm surge. A severe storm may give rise to a particularly high tide with an increased tidal velocity. Ideally, the monitoring results should be adjusted by a specified factor to take account of this. The practicalities of producing a single factor for Scotland should be determined during a research project.

Whilst there are other elements which can contribute to the total current, including residual currents, research carried out during the project suggests that the above are the most important for consideration in this Standard.

Requirement for a 15 day period of monitoring

Although a 30 day period was preferred, most consultees considered that a 15 day period would be entirely adequate. This timescale was selected since this may enable fish farmers to use historical current records (a 15 day period is required for SEPA monitoring). Should SEPA change the 15 day requirement, this may need further consideration.

Review of applicable approaches

Several factors for adjusting the monitored current to provide a dimensioning current were evaluated for possible inclusion in this Standard. However, none were considered appropriate for the reasons below.

e) Factors contained in the Norwegian Standard NS9415 - these were considered inappropriate without further verification due to differences between the Scottish and Norwegian environment.

f) Existing factors used by aquaculture equipment suppliers in Scotland – no single approach was identified throughout the Scottish industry and it could not be verified that one approach was appropriate for inclusion in a national standard.

g) Existing factors used by Scottish fish farmers – whilst at least one company applies its own factor, it could not be verified that such an approach was appropriate for inclusion in a national standard.

h) Factors developed for this project. There was considerable discussion about the use of a factor that could be added to the current monitoring results – specifically 0.5 m/s – to give a dimensioning current. The main concerns with this approach were that it may give rise to an overestimate of the dimensioning current (and hence over-specification of equipment) at sites with relatively low tidal flows and an underestimate (and hence under-specification of equipment) for sites with a relatively fast tidal current.

Further, none of the above approaches took account of i) whether monitoring was carried out at the equinox, ii) the wind strength during and before monitoring or iii) storm surges. The consideration of these issues should, ideally, be included in this Standard.

Knowledge gaps

The development of factors to adjust the monitored current for the parameters identified above, or a similar approach, is an essential knowledge gap which requires to be addressed before this Standard can be finalised and opened to industry consultation.

Addressing this knowledge gap would require the analysis of data on currents and related issues for (or that are applicable to) existing sea water fish farming areas across Scotland, as well as areas which may be used in the foreseeable future. The data may need to be collected specifically for this project, which would require considerable resource utilising the deployment of current monitors over many months, most likely requiring a complete year of monitoring. However, it may be possible to analyse existing data set(s) which may be available from academia, government or industry sources, or a combination thereof. The latter approach would not only be very considerably cheaper, it would be much faster and more easily achievable within the timeframe for developing a Scottish Technical Standard.

Informal discussions were undertaken with a number of organisations that may be able to undertake the above research. One of the organisations – an academic institution with a strong track record in marine and aquaculture issues – was confident that it could address this knowledge gap through the analysis of existing data. In so doing, this could be undertaken in a relatively fast timescale and in a cost-effective manner. It is recommended that in the first instance an approach is made to this institution to discuss its proposals in detail. It is also recommended that discussions are held with SINTEF which undertook similar research for the Norwegian NS 9415 Standard and which may be able to help provide greater context for this Scottish work by detailing its research methodology and findings.

As this knowledge gap is considered the key issue to be addressed before the Scottish Standard can be finalised, it is recommended that this process should be initiated as soon as possible. The research organisation should report to a Steering Group which can consider the findings in the light of this report.

Knowledge gap 2: current adjustment factors for freshwater pen sites

Section 4.2: measurement of current for at least 15 days

Purpose of developing a dimensioning current and background

Reference should be made to the discussion in Knowledge Gap 1, except that the only adjustment required is for wind induced current which, again, should be in respect of a defined return period.

Since the wind induced element can be affected by the length of fetch, sites on freshwater pen sites with relatively small fetches may not require current monitoring. Alternatively, it may be possible to develop a simple current model based on fetch distance which avoids the need for current monitoring altogether. Both of these approaches should be researched to address this knowledge gap.

Knowledge gaps

Reference should be made to the discussion in Knowledge Gap 1.

The development of factors to adjust the monitored current for the following is required as an essential requirement for this Standard:

a) One or more distance thresholds that could be applied in respect of the fetch that would negate the need for current monitoring at smaller freshwater sites; and,

b) A factor to be applied to the monitoring results for sites other than those with a smaller fetch to account for wind induced current resulting from a defined storm event; and,

c) A factor to take account of wind induced current resulting from a defined event (e.g. a 50 year return period), preferably with an incremental approach to take account of winds during or just before the monitoring period; or,

d) One or more factors that could be applied to the identified wind speed that would negate the need for current monitoring altogether.

e) Any additional safety margin that should be included; and,

f) Whether the above could be aggregated in to a single factor to provide a more straightforward approach.

When developing the above, consideration should be given to:

g) Ensuring that the factors developed are suitable for the range of environments in which freshwater fish farming is practised (and may be practised) in Scotland; and,

h) Assessing data to ascertain any temporal anomalies which could affect the results should monitoring have been undertaken at different times of the year.

The development of factors to adjust the monitored current for the parameters identified above, or a similar approach, is an essential knowledge gap which requires to be addressed before this Standard can be finalised and opened to industry consultation.

Addressing this knowledge gap would require the analysis of data on currents and related issues for (or that are applicable to) existing freshwater fish farming areas across Scotland, as well as areas which may be used in the foreseeable future. The data may need to be collected specifically for this project, which would require considerable resource utilising the deployment of current monitors over many months, most likely requiring a complete year of monitoring. However, it may be possible to analyse existing data set(s) which may be available from academia, government or industry sources, or a combination thereof. The latter approach would not only be very considerably cheaper, it would be much faster and more easily achievable within the timeframe for developing a Scottish Technical Standard.

Informal discussions were undertaken with a number of organisations that may be able to undertake the above research. One of the organisations – an academic institution with a strong track record in marine and aquaculture issues – was confident that it could address this knowledge gap through the analysis of existing data. In so doing, this could be undertaken in a relatively fast timescale and in a cost-effective manner. It is recommended that in the first instance an approach is made to this institution to discuss its proposals in detail. It is also recommended that discussions are held with SINTEF which undertook similar research, albeit in regard of sea water pen sites, for the Norwegian NS 9415 Standard, and which may be able to help provide greater context for this Scottish work by detailing its research methodology and findings.

As this knowledge gap is considered the key issue to be addressed before the Scottish Standard can be finalised, it is recommended that this process should be initiated as soon as possible. The research organisation should report to a Steering Group which can consider the findings in the light of this report.

Knowledge gap 3: extent of net fouling at sea water and freshwater pen sites

Section 6.4.2: Determining the loads

Fouling increases the resistance of the net to current; increased fouling requires higher specification moorings to account for the increased loads.

It is in the interests of fish farmers to keep their nets clean as reductions in water flow can be detrimental to fish health, as well as increasing the loadings on the net and the mooring system. Sea water nets are typically allowed to foul to a certain extent before being cleaned or changed to prevent fouling being a major problem; however, some heavily fouled nets have been witnessed. Fouling is much less of an issue at freshwater pen sites.

Ideally, this Standard would specify a minimum level of fouling which is used when calculating the load on the moorings. Given that farmers work to prevent a net becoming completely fouled, this would be lower than a fully occluded net. To enable this approach, there needs to be sufficient confidence that every net at every site meets this requirement, and robust information on net occlusion is not available to support this assertion.

A project should be established to monitor the occlusion of nets from fouling in Scotland to determine whether a lower level of fouling could be included in the Standard for sea water pen sites. Should this be positive, it should be introduced with requirements for net cleaning and monitoring to ensure that the nets remain sufficiently clean to enable this to be introduced.

Addressing this knowledge gap is not essential as a 100% factor for sea water pen sites can be retained. However, the opportunity to reduce this factor should robust research accompanied by effective monitoring and inspection suggest this is appropriate would be welcome if research indicated that assuming total occlusion was an overly cautious approach.

A nominal factor of 10% fouling has been included for freshwater pen sites, based on discussions with consultees. Since this has not been verified, it also represents a knowledge gap which, in this case, is essential to be addressed prior to the implementation of the Standard.

It is recommended that this project includes the following elements for both sea water and freshwater nets:

- Monitoring of nets returned to net manufacturers/suppliers for testing and servicing;
- Monitoring of nets at a sample of fish farming sites;
- Obtaining existing records in this regard from any fish farmers that collect net fouling information;
- Discussing net fouling with dive companies which undertake net inspection services for fish farmers and, if relevant, companies that supply remotely operated vehicles (ROVs) to fish farmers; and,
- Discussions with Marine Scotland and, perhaps, Food Certification International Ltd to consider whether a protocol to monitor net fouling could be included as part of its existing

inspection remit.

The project should require the establishment of a robust methodology that does not rely on subjective observations. Appropriate approaches could include the use of digital imaging of nets with software or other means to enable fouling to be accurately assessed. Issues that should be considered in the project include:

- The expected changes in fouling across the depth of the net such that it can be related to changes in current with depth;
- The extent of fouling with respect to different net treatments, including but not limited to anti-fouling;
- The extent of fouling at different operational stages, particularly at the time of net changes and swim throughs and just in advance of net cleaning when nets would be expected to be at their most fouled;
- The ability to assess nets which may have not been changed or cleaned in accordance with company policy; and,
- The extent of fouling in different geographical areas of Scotland.

The project should be undertaken for a significant period of time, at least one year and preferably two (with a focus on the warmer months when the rate of fouling is greatest), and be timed so that the findings could feed in to the development of the final version of the Scottish Technical Standard. Given this timescale, it is recommended that the project be established as soon as possible.

Knowledge gap 4: material factors for rope strengths

Section 6.8.5: rope

There appears to be a lack of scientific research on the reduction in the strength of ropes from the use of knots (and possibly splices too) and when being passed around a curved object (specifically a rope ring) in regard to the types of ropes and applications used in fish farm mooring in Scotland.

The lack of robust and directly applicable research is considered a knowledge gap which is highly desirable to address. Whilst this is not considered essential to the introduction of this Standard – because there are material factors which are available – it should be addressed since these material factors may not be completely satisfactory for use in this Standard.

Consultations highlighted that one research institute has undertaken research in regard to the reduction in strength when rope is passed around a curved object. Although this project was confidential the findings were briefly discussed in general terms and were used to inform this report. It is also noted that at least two net manufacturers have undertaken a certain amount of strength testing of ropes although this is confidential. Since the aforementioned research was confidential and since it is not thought to relate specifically to rope rings (which are the main area of interest from the perspective of Scottish aquaculture), it is recommended that a study be configured as follows to research rope strength regarding:

- The sizes and types of rope used in Scottish fish farming, with particular regard to grid ropes used in conjunction with rope rings;
- The reduction in rope strength from passing ropes around curved objects, with particular regard to rope rings; and,
- The reduction in rope strength from knots, with particular regard to a) the knots used in Scottish fish farming and b) from knotting rope to rope rings.

The methodology for this study should be robust, transparent and repeatable. It should take account of other strength testing studies and be undertaken on good quality reliable machines with a low tolerance and which are calibrated appropriately. Reference should be made to any relevant Standards for rope testing and any published research as appropriate.

Whilst this study would primarily be undertaken in a workshop/laboratory setting, it is recommended that industry and supplier consultations and site visits are undertaken in advance of the testing stage to ensure that the materials tested and methodology are appropriate for the Scottish industry at the present time and taking in to account future requirements.

Knowledge gap 5: research on how predators 'attack' the net

Section 8.3.6: Net protection and reinforcing

Knowledge gaps

It is not proposed to include specific net measures from a design and construction perspective to protect against predation, since there is considered to be insufficient objective evidence on which to base such measures. Additional research is required on the way in which different freshwater and sea water predators breach net integrity and how effective possible defence measures might be. Whilst not essential to publishing a STS, it is highly desirable to include predation at the earliest opportunity as it is such an important issue in Scottish finfish farming.

Although there is knowledge on seal 'attacks' at sea water sites most, if not all, appears to be anecdotal. Whilst all farmers consider that net tensioning is effective, there appears to be no information on how tight such tensioning should be and whether higher net strengths (or indeed net materials) may provide greater resistance. Questions of particular interest include:

- How do seals actually breach nets – is this from a single bite, or are repeated bites required over a period of time?
- Are higher net strengths more resistant to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Do different net materials offer greater resistance to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Are different net treatments more resistant to seal attacks and, if so, which are most resistant and is it possible to quantify the reduced risk?
- Depending upon the findings to the above, are nets more vulnerable to attack during the life of the net?
- Do seals attack nets in a coordinated action involving more than one seal (there is anecdotal reports of such approaches)?

The above research should include the following:

- Phase 1:
    - Desk based assessment of any existing literature;
    - Discussions with fish farmers to collect and collate anecdotal evidence (which should be used to inform the detailed research requirements; and,
    - Discussions with marine scientists who may be able to provide information on seal behaviour.
- Phase 2:
    - Research on the resistance of nets to simulated seal attacks; and,
    - If feasible, consideration of actual seal attacks on nets.

Similar research to the above is also required for freshwater predators, particularly mink and otter (the latter can also be problematic at some sea sites and should also be considered in the sea water research above).

Knowledge gap 6: net protection measures regarding predation

Section 8.3.6: Net protection and reinforcing

There are a range of net protection measures that can be undertaken to reduce the likelihood of net abrasion and/or predator attacks. These include, but are not limited to, seal blinds, waterline abrasion resistance and gussets between the inside of the net side wall and base.

Requiring such measures within this standard has been rejected at the present time because a) the stipulation for 5m apart down ropes and that all down ropes could be used for lifting make the likelihood of a tear at the join of the side wall and base less likely, b) there was insufficient evidence that waterline abrasion was a significant problem on sites where the pens had been kept in a clean condition, and, c) it was felt that there was insufficient evidence that the use of these necessarily reduced the likelihood of a successful predator attack.

However, it is recommended that an ongoing research project into a) net abrasion and b) predator attacks on nets is established so as to provide further information in this regard. Should the evidence gained indicate that the use of additional net protection would be effective to help reduce the likelihood of escapes, it should then be included in further revisions of this Standard. This should take account of work to address knowledge gap 6.

Whilst addressing this knowledge gap is not considered essential to the introduction of this Standard, due to the reasons above, it is highly desirable that this knowledge gap is addressed to help inform farmers about the effectiveness of different net protection measures. The analysis such knowledge may also provide essential information for future editions of this Standard.

This research should follow on from, or be part of that recommended to address knowledge gap 5 above. In particular, it should include consideration of whether the use of additional (or different) materials would reduce the likelihood of successful predator attacks and, if so, whether it is possible to quantify this.

This research should also include consideration of measures that might be employed in other countries which may be worthy of consideration for use in Scotland.

Knowledge gap 7: net protection measures regarding species aggressive to nets

Section 8.3.6: Net protection and reinforcing

Cod, and other farmed fish species, are known to be aggressive towards nets, which can be problematic from a containment perspective. There appears to have been little research in to this area (Thistle Environmental Partnership, 2010a, b). Whilst cod production is understood to be minimal at the present time in Scotland, it is possible that production may increase in the future. Therefore, research should be undertaken in to the use of nets that may provide a more robust barrier. This should take account of work to address knowledge gap 4.

Whilst this is not considered essential to the introduction, due to the current levels of cod production and the relatively small amount of historic cod escapes, it is considered highly desirable to research this issue such that measures can be in place should cod production increase in the future.

Again, this should include desk based and practical research methods. This project may usefully be combined as an extension of the research requirements for knowledge gaps 5 and 6.

References:

Taylor, M., Kelly, R. (2010a) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0

Taylor, M., Kelly, R. (2010b) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 2: Supporting Information. pp 177. ISBN: 978-1-907266-31-7

Knowledge gap 8: research in to the use of 'sacrificial panels' for testing nylon netting

Section 8.3.10: Sacrificial panels

The use of sacrificial panels to assess general net deterioration is a relatively recent approach utilised by a proportion of Scottish finfish farmers. Whilst its use is understood to be well established in regard of testing safety nets, there is discussion about how representative such tests may be for aquaculture nets.

Nevertheless, proponents of this approach point to several advantages, including:

e) That there is no need to make a hole in the net to undertake net testing, which requires subsequent repair if the net is to continue in use;

f) The net can remain in situ but the test can be carried out in controlled conditions.

Given that such strength testing is focused on assessing general deterioration from exposure to ultraviolet light, the use of sacrificial panels may well be appropriate. However, before this can be confirmed, research is required to ensure that such panels do indeed give representative results.

Whilst addressing this knowledge gap is not considered essential to the introduction of this Standard, because other approaches to net testing are available, it is highly desirable that this knowledge gap is addressed in order to:

g) Help improve net testing in the industry; and,

h) Not disadvantage those farmers who are keen to implement this approach.

This research should consider whether the expected deterioration in sacrificial panels from exposure to ultraviolet light and the marine environment mirrors that of fish farm nets in both the freshwater and sea water environments and whether it is sufficiently representative that strength tests undertaken on a sacrificial panel would be representative of those undertaken on the netting itself. This research should include:

a. Research over several production cycles so as to be representative of nets throughout their operational life;

b. Research at different locations on the net (i.e. north/south/east/west facing and on the inside and outside of the nets);

c. Research at different depths of the net;

d. Research from different areas of Scotland to reflect possible differences in exposure to ultraviolet and the marine environment; and,

e. Research on different types of netting (both material type and material strength) and different net treatments and colours.

Knowledge gap 9: mesh strength for Dyneema nets

Section 8.5: Nets manufactured from material other than nylon

A net strength table should be included in the Standard for nets constructed from Dyneema and Dyneema mixed with other materials. Whilst the existing tables for nylon nets may suffice, there is concern that the reduced elasticity of Dyneema may require higher mesh strengths than for nylon nets to account for shock loadings, and that a higher portion of the loads will be carried by the net material and not by the ropes, although it may be possible to address this by building in a certain amount of slack in to the netting to ensure that the mesh does not take the forces.

It is recommended that a research project be undertaken to identify what level of mesh strength is required for Dyneema for different mesh sizes with the objective of either developing a specific mesh strength table or advising on how the existing table for nylon nets may be used. This project should take the elasticity of both materials into account and should address both freshwater and sea water nets. Whilst we acknowledge that some research has been done on this subject by at least one net manufacturer, this is understood to have been based more on experience than strength tests and it has not been published or otherwise made available. This project should include a literature review and consultations with manufacturers in Scotland and abroad.

There has been considerable interest in Dyneema nets in the recent past in Scotland and there are signs that this may continue in the future, with several companies apparently looking to increase the use of Dyneema nets. Therefore, addressing this knowledge gap is considered essential for the future of the Scottish industry.

Knowledge gap 10: research in the methodology for embedding drag anchors

Section 11.6: Installation of primary equipment

Opinion on the most appropriate level of force required to securely embed anchors differed amongst consultees from 30% to 100%, as well as the approach to ensuring secure deployment. It is recommended that a research project is undertaken to address this using a range of anchors representative of those used in Scottish fish farming at both sea water and freshwater pen sites and at representative locations. Addressing this knowledge gap is highly desirable to help inform the specification and installation of anchors.

Whilst there are published anchor tests available, none were identified which were specifically related to the types of anchors and environments applicable to Scottish fish farming or in respect of the approach to embedding anchors. It is recommended that several test sites are identified representative of the different types of sea water loch bed conditions encountered in Scottish fish farming and that tests are undertaken with a range of anchor sizes with a boat of sufficient size and power to apply a range of powers representative of the forces expected on anchor lines at Scottish fish farming sites. The boat should be fitted with equipment so that the magnitude and duration of the force can be recorded.

This research would require that each anchor was tested on a number of occasions at each location to ensure that the results were representative. The anchor behaviour should be visually observed and recorded – ideally filmed by a diver (or at least filmed through the use of an ROV). The research should assess both the magnitude of the force applied as well as the timescale for each size of anchor at each location. Input when designing the methodology is required from a mooring designer working in Scottish aquaculture installations to ensure that the anchors and associated equipment (i.e. chain lengths and sizes) were representative of those in use at the current time and forecast for the foreseeable future – this should be checked with a number of fish farming companies.

Research is also required to identify (if possible) a minimum settling period required for dead weight anchors to achieve their holding power in the types of loch beds representative of where such anchors are used in freshwater and sea water sites in Scotland.

Knowledge gap 11: research in to the minimum net mesh aperture

Section 12.1.1: Selecting the net mesh aperture

Whilst there is information on net mesh apertures held by various parties in the industry, it could not be confirmed that this related to the minimum weight rather than the average weight of fish. It is recommended that the following be researched:

a) Determination of the minimum number of fish in a population which should be weighed and measured in order to ensure a statistically valid sample for characterising the minimum size of fish in a population; and,

b) The recommended mesh sizes required to contain all of a population of fish.

The lack of robust and directly applicable research is considered a knowledge gap which is considered essential to address.

This research should include:

- Physical trials to assess mesh size which should include the use of nets containing populations within tanks or nets such that the ability of fish of different sizes to pass through different sized nets can be evaluated.
- Consideration of different species, with a focus on salmon and trout, but also including

other species that may be commercially grown in Scotland in the future.

Knowledge gap 12: net tensioning to reduce escapes by predation

Section 12.1.2: Reducing escapes from predation

Whilst most fish farmers and stakeholders consider that nets should be tensioned to reduce the likelihood of predation and consequent escapes, there appears to be little information a) how effective tensioning actually is in this regard, and b) the level of tensioning required.

Whilst addressing this knowledge gap is not considered essential for this Standard, it is highly desirable. This is because such research may provide information to farmers which may help to reduce the likelihood of future predation attacks. Such research should also be analysed from the perspective of whether to include specific measures in future versions of this Standard.

This research should be linked to knowledge gaps 5, 6 and 7. It should include the use of nets at different (and verifiable) levels of tension in controlled experiments to assess whether such variations lead to a reduction in the ability of seals to breach nets. It should include nets of different strengths, ages, materials and coatings. The analysis should include an assessment as to how the levels of tension applied correspond to the actual tensions achieved on fish farming sites through the use of direct weights and other types of tensioning systems (including sinker tubes).

Knowledge gap 13: use of predator nets

Section 12.1.2: Reducing escapes from predation

Research undertaken previously identified a range of practices in Scotland in regard to the use of predator nets, with varying levels of success (Thistle Environmental Partnership, 2010a, b). It is recommended that research into the use of different types of predator nets is undertaken for both freshwater and sea water pen sites.

Whilst this is not considered essential to the introduction this Standard it is considered highly desirable to address so as to help inform farmers about the usefulness of different approaches to the use of such nets. This should include consideration of the use of predator nets abroad, particularly Canada and Chile, where protection from more hostile predators is required.

This research should be linked to knowledge gaps 5, 6, 7 and 8. Where appropriate and practical, this should include the evaluation of the effectiveness of predator nets that are in use at fish farming sites in Scotland and abroad – specific trials should be set up to consider this.

References:

Taylor, M., Kelly, R. (2010a) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0

Taylor, M., Kelly, R. (2010b) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 2: Supporting Information. pp 177. ISBN: 978-1-907266-31-7

Knowledge gap 14: net strength testing

Section 12.1.6.1: net strength testing

The strength of nets can essentially be tested through the use of larger factory based equipment or smaller hand held testers. Due to concerns about the reliability of the latter amongst several consultees, the more accurate approach is to require that nets (or sacrificial panels) are returned to the manufacturer or a net servicing centre for testing using factory based equipment. However, concerns were expressed by several industry representatives about the practicality and costs of transporting nets or sacrificial panels for such testing and so no such requirements have been included in this Standard at the present time.

Instead it is considered that the use of hand meters should be subject to a research project to assess their capabilities and ability to obtain reliable, accurate and repeatable results in a range of representative conditions in the field. This research should include:

- A range of environmental conditions and net mesh strengths;
- The use of commonly available hand held net strength testing equipment;
- The use of parallel tests by factory based equipment to assess the reliability of the hand held meters; and,
- The development of a net testing protocol and method to take account of the location in which the testing is undertaken and the type of meter(s) used – cognisance should be taken of 'BS EN ISO 1806:2002 Fishing nets – Determination of mesh breaking force of netting' which should, ideally, be the basis for such testing. The method should be included in this Standard, probably as an additional annex.

It is understood that some tests of hand based equipment has been undertaken at one of the net testing companies and so the research should take account of its findings. SINTEF has also undertaken research in to net strength testing and cognisance should be given to its findings.

Depending upon the results of the above project, it may be useful to consider an academic research project to design an appropriate hand held net mesh strength testing machine.

Obtaining reliable, repeatable and accurate results is essential to the implementation of an effective and useful net strength testing regime; failure to do so very much devalues the value of the exercise. This is an essential area that should be addressed prior to the finalisation and implementation of a Scottish Technical Standard.

Knowledge gap 15: research in to the minimum screen aperture

Section 13.2: Screens

Whilst there is information on net mesh apertures held by various parties in the industry, it could not be confirmed that this related to the minimum weight rather than the average weight of fish nor could it be confirmed whether this may also be applicable to screen sizes. It is recommended that the following be researched:

a) The amount of sample weighing and/or the use of alternative methods to characterise the minimum size of fish in a population; and,

b) The recommended screen apertures are appropriate to contain all of a population of fish.

The lack of robust and directly applicable research is considered a knowledge gap which is considered essential to address.

This research should include:

- Physical trials to assess screen aperture size which should include the use of nets containing populations within tanks or nets such that the ability of fish of different sizes to pass through different sized nets can be evaluated.
- Consideration of different species, with a focus on salmon and trout, but also including those that may be commercially grown in Scotland in the foreseeable future.

The research for this knowledge gap should be linked to that undertaken for knowledge gap 10.

Knowledge gap 16 regarding the above requirement for net manufacturers to confirm that the net is suitable for use

Annex 2: Product specification sheets

It is understood that net suppliers are not easily able to verify the design of their products for use in specific locations since they are not usually privy to historical performance data, particularly which nets are used at which sites.

It is recommended that data on environmental conditions on existing sites should be correlated against net specifications and net use to provide a database which net manufacturers can refer to. This should include the analysis of net records (or net registers) held by fish farmers (or net manufacturers/suppliers), environmental site data held by the Scottish Environment Protection Agency (SEPA) and net specification information (held by the fish farmer and/or the net manufacturer/supplier).

Addressing this knowledge gap would enable net manufacturers to be able to specify nets on the basis of experience and past performance data. Addressing this knowledge gap is considered useful for providing data to support the use of the net tables within this Standard and also to provide information for farmers and net manufacturers.

Appendix 2: Notes on legislative, enforcement and inspection/ auditing regimes

Introduction

Whilst the introduction of a Scottish Technical Standard (the Standard) is an important step in preventing escape incidents, the associated regulatory, inspection and guidance regimes are of equal merit. As part of their remit to develop a draft Standard, the authors were also asked to make recommendations on this subject. These are the views of the authors and are presented as a basis for discussion. It is not envisaged that this appendix will be included in the final Scottish Technical Standard.

Finalising the Standard

This draft Standard should be subject to further consultation. It is recommended that consideration be given to a further series of industry workshops where discussions could be held on the detailed draft content in advance of a formal public consultation process.

Scope and status of the Standard.

The Scottish Technical Standard should apply to all fish farmers and suppliers and be enforced by either new legislation or through the use of existing powers.

Given that many escape incidents have been the result of human factors, we recommend:

a) That protocols for operational control, supervision, management and training from a containment perspective are developed;

b) That these should apply to all fish farmers (and suppliers where relevant); and,

c) That such protocols should also become a legal requirement.

The land based elements of the Standard should be expanded to include more detail on the design and construction of the site and its facilities. It may then be more appropriate for all the land based elements to be included as a standalone Standard.

The legislation accompanying the Standard should include appropriate implementation dates based upon consideration of the risk from delay versus the costs of conformance with the Standard. Staggered implementation dates should be proposed to avoid the unnecessary early redundancy of existing equipment and should take in to account the industry investment cycle. A regulatory impact assessment, required by the legislative process, can form the basis for this discussion.

The Standard, or the key principles thereof, should apply to existing sites – in particular to ensuring that sites have been designed on the basis of appropriate environmental information and that equipment is correctly installed and maintained.

Training

Statutory training courses, including forklift, crane, boat, diving and helicopters do not usually address containment. Since operations involving these skill areas (with the possible exception of forklift use) have been subject to escape incidents, it is considered that such courses should include a short containment module – this could be awarded as an aquaculture endorsement which should be an industry requirement.

It should be a requirement that fish farm staff are trained in the operation of pens, nets, weighting systems and other relevant secondary equipment, and in the installation and adjustment of the mooring system to help prevent escapes. This should be accompanied by a general module on the causes of escape incidents and the importance of prevention. Training should include operations on an unstocked pen prior to utilising new equipment or techniques - this may require additional facilities to be made available and could be addressed through the establishment of national or regional training centres and/or in-house facilities. However, the cost of establishing and servicing such facilities would be substantial.

Enforcement regime

There are several different regimes that could be considered, including government inspection, third party certification and third party audits. Different approaches, and combinations thereof, have different attractions – these are not explored in this Appendix as this would entail further consultations. Instead, consideration has been given to presenting key requirements.

It is considered that the enforcement regime should include the following:

a) Mooring designs, and significant alterations, to be independently verified against the Standard prior to being installed.

b) The site survey should also be verified – this could be undertaken as part of the mooring verification.

c) Pens, nets and secondary equipment where relevant should be certified or otherwise shown to meet the Standard;

d) The installation should be inspected prior to stocking (including landbased sites);

e) All verifiers, auditors and inspectors should be competent on the basis of appropriate qualifications, training and/or experience for the relevant task.

At this stage it is not considered that contractors such as site surveyors, boat operators (including well boats, feed boats and work boats) and divers should be certified to the Standard. However, inspections should include the activities of such operations and this area should be subject to future review.

The following should be considered when developing the enforcement regime for this Standard:

a) To minimise unnecessary additional burden on fish farmers (it has been commented that existing audit and inspection regimes are already too onerous);

b) To include follow-up detailed containment inspections/audits of all sites on a periodic basis – perhaps every three years;

c) To include additional unannounced (or short notice) containment inspections/audits – sites should be selected by a random element and also on the basis of risk;

d) To undertake an additional inspection/audit following the acquisition of new sites;

e) To undertake an additional inspection/audit following an escape or near miss; and,

f) To include the underwater components of the installation in inspections/audits.

It was not considered appropriate to develop a suggested enforcement regime during this project. However, when this is approached in the future, cognisance could be taken of the following approaches.

a) The Scottish industry is used to the concept of third party certification, with many companies working in accordance with the Code of Good Practice, BS EN 45011 accredited product certification schemes and ISO 14001.

b) In Norway, the Norsk Standard NS 9415 details specific requirements for the aquaculture industry, the focus of which is preventing escapes. NS9415 is a legal requirement through the NYTEK regulations (Regulation No. 1785 of 2004). A certification approach has been implemented whereby the mooring designer is certified against NS9415 and each type of pen and net are certified against NS9415. Forthcoming changes to NYTEK are expected to require that the site survey and site installation are certified activities.

c) In Norway, operational requirements are addressed through operational regulations (Regulation No. 1785). And, it is understood that land based aquaculture will shortly be the subject of a separate technical standard which will also be a legal requirement.

d) It would be useful to discuss the implementation of the NYTEK Regulations with the Norwegian authorities and industry so as to learn from any issues and therefore help ease the transition period in Scotland.

e) It may be useful to consider regimes in other legislative areas. One such example is the UK building control regulations which may, to a certain extent, be an appropriate model for an initial desk-based verification of mooring designs.

Monitoring, guidance, incident investigation and disseminating information

The establishment of the Containment Working Group is a welcome initiative to help prevent escapes in Scotland. It is considered that the good work of the Working Group could be built upon by implementing a number of measures outlined below.

Investigating incidents

The investigation of incidents, evaluation of findings and dissemination of information is essential to help circulate knowledge on containment and respond to events and changes in technology. The following are recommended.

a) Ensuring that near misses are reported as well as actual escape incidents.

b) Investigating all escapes and near misses (with the possible exception of very small fish handling incidents caused by human error) from both a technical and operational context. Such investigations should be robust and immediate, include on-site investigations and interviews with all relevant staff, require full industry cooperation and be undertaken by independent experts with appropriate competency.

c) Presenting the findings of investigations with recommendations for changes to industry protocols to the Improved Containment Sub-Group.

d) Issuing amendments to the Standard, associated guidance or industry circulars on the basis of the above investigations.

e) That all investigative reports should be published.

f) Liaising closely with those undertaking similar roles abroad, particularly in Norway where a similar system already exists, so that farmers and suppliers can learn from all incidents, whether in Scotland or abroad. This should include the translation of reports and dissemination of information to the industry.

The Government has already implemented measures to provide a more comprehensive monitoring of the causes of escape incidents. It is recommended this be aligned with the investigation of incidents (as proposed above) to provide a more robust process. More information on the equipment and operations at the time is required so that a database on incidents can be built up and scrutinised to monitor trends. Such activities could be undertaken by the Government, the industry or other parties.

Guidance

The workshops and consultations undertaken for this Standard suggest that:

a) There is considerable interest in this field by practitioners and suppliers alike;

b) There is support for the implementation of well researched and proven practical techniques on-site;

c) There may be more than one appropriate approach to addressing a situation – this should be reflected in the Standard and accompanying legislation; and

d) Other than the Improved Containment Working Group, there has been a lack of forums for the discussion of such topics over many years in Scotland, with the exception of the two series of road shows facilitated by the SSPO in recent years and the recent publication of a containment supplement in the Fish Farmer publication.

It is recommended that consideration be given to a regular forum/conference on aquaculture engineering and, perhaps, the development of best practice guidance in preventing escapes.

Aquaculture engineering

With notable exceptions, there appears to be a limited number of experienced and qualified practitioners in the field of aquaculture engineering in Scotland. The encouragement of appropriate education and training should be strongly encouraged through liaison with the appropriate academic institutions and training providers.

Culture

Although the use of legally binding protocols is necessary, the importance of establishing a culture focused on preventing escapes is also essential. There has been considerable work in this regard by the SSPO and a number of individual fish farming companies, which should be applauded; this is considered to be one reason for the improved containment performance over the recent past in Scotland and should be continued.

References

CoGP, 2010. Code of Good Practice for Scottish Finfish Aquaculture http://www.thecodeofgoodpractice.co.uk/publish

Norsk Standard NS 9415.E:2009. Marine fish farms – Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation. Standard Norge.

NYTEK Regulations. Regulation 1490 of 2003 (NYTEK) relative to technical standard requirements for plant and equipment to be used in aquaculture.

QTUK, 2008. Quality Trout UK. Combined Farm and Hatchery Certification Standards. Issue 01 Rev: combined vs 3.0. 2008

Regulation No. 1785 of 2004 (1785) relative to the operation of aquaculture facilities.

Taylor, M., Kelly, R. (2010) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0

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Appendix 3: List of consultees and workshop attendees

Informal consultations were undertaken with the following organisations during the course of the project:

AKVA Group Scotland Ltd

Anderson Marine Surveys Ltd

Aqua Systems (UK) Ltd

Aqualine AS

Aquastructures AS

Archibald, Campbell & Harley

Boris Net Co. Ltd

British Trout Association

Brow Well Fisheries Ltd

Dawnfresh Farming Ltd

Directorate of Fisheries (Norway)

EIVA Safex AS

FHL (Norwegian Seafood Federation)

Fish Vet Group

Fusion Marine Ltd

Gael Force Marine Ltd

GL Noble Denton

Health and Safety Executive

International Centre for Island Technology

Loch Duart Ltd

Marine Harvest (Scotland) Ltd

Marine Scotland

Marine Scotland Science

Meridian Salmon Group

Migdale Smolt Ltd

Mohn Aqua Group

National Oceanography Centre

Net Services (Shetland) Ltd

PDG Helicopters

Richard Austin Alloys (Scotland) Ltd

Scanbio (Scotland) Ltd

Scottish Association for Marine Sciences

Scottish Environment Protection Agency

Scottish Salmon Producers' Organisation (SSPO)

Seatronics Ltd

SINTEF Fisheries and Aquaculture

Solway Transport Ltd

Sterner Aquatech Ltd

The Aluminium Federation

The Crown Estate

The Highland Council (Planning Department)

The Hydrographic Society UK

The North Highland College

The Scottish Salmon Company

W & J Knox Ltd

Wester Ross Fisheries Ltd

Three workshops were held during the project to present and discuss our proposals with the industry. The following organisations attended:

AKVA Group Scotland Ltd

Aquatic Hygiene

Argyll and Bute Council

Boris Net Co. Ltd

Bruce L. Smith & Associates

Comhairle nan Eilean Siar

Dawnfresh Farming Ltd

Food Certification International

Freedom Food

Fusion Marine Ltd

Gael Force Marine Ltd

Highland Council

Highlands and Islands Enterprise

Hjaltland Seafarms UK Ltd

Kames Fish Farming Ltd

Lochs Diving Services

Marine Harvest (Scotland) Ltd

Marine Scotland

Migdale Smolt Ltd

Mohn Aqua (UK) Ltd

Northern Isles Salmon Ltd

Scottish Aquaculture Research Forum (SARF)

Scottish Environment Protection Agency (SEPA)

Scottish Salmon Producers' Organisation (SSPO)

Scottish Sea Farms Ltd

Seaworks (Scotland) Ltd

Delta Marine Ltd

Shetland Islands Council

SINTEF Fisheries and Aquaculture

The Crown Estate

The Scottish Salmon Company

Thistle Environmental Partnership

W & J Knox Ltd

Wester Ross Fisheries Ltd

Scottish Aquaculture Research Forum

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