Assessment Of Protocols And Development Of Best Practice Contingency Guidance To Improve Stock Containment At Cage And Land-Based Sites Volume 1: Report

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AND PREPARED BY

Thistle Environmental Partnership

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Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites

Volume 1: Report

Scottish Aquaculture Research Forum

Final Report
July 2010

Thistle Environmental Partnership
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The project steering group included SARF as well as representatives of the Scottish Salmon Producers’ Organisation (SSPO), the British Trout Association (BTA) and Marine Scotland (the Scottish Government). The steering group performed a valuable and supportive role and their participation is much appreciated.

Consultations and discussions were undertaken with a range of organisations and individuals throughout the supply chain including suppliers to the industry, fish farmers and supermarkets as well as wider stakeholders such as non-governmental organisations (NGOs) and academics. Regulators and industry bodies from various salmonid producing nations also provided information for the project. They all engaged with interest and their contributions were essential to the successful conclusion of this project.

Valuable assistance was provided by Robin Turner of Seawork (Scotland) Ltd in respect of the engineering aspects of moorings, cages and closed containment systems.

It should be noted that this is an independent report which is presented in good faith and represents the views of the authors.
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Executive Summary

1. This study aimed to investigate and assess escape incidents in respect of Scottish finfish farming, using existing information and research undertaken specifically for this project. The study included a literature review, desk based research, detailed consultations with fish farmers and suppliers. Key findings are summarised below.

Magnitude and Causes of Escape Incidents

2. Between May 2002 and October 2009 (inclusive) there were 136 reported escape incidents, resulting in 2.18 million reported escaped fish. Figures peaked in 2005 due to a particularly severe storm which was responsible for 12 escape events and 821 thousand (k) escaped fish. Whilst 2008 saw the lowest losses to date, 2009 surpassed this figure (with 14 escape incidents and the loss of 141k farmed finfish as of the end of October) and hence there is no indication that the trend is towards zero or minimal escapes. Escapes range from between 0.5 fish per tonne of farmed fish produced (2003 and 2008) to 6.6 fish per tonne in 2005, although if 2005 is excluded the average is between 0.5 and 2.6 fish per tonne of production.

3. Containment requirements in Scotland are primarily delivered through voluntary adherence to the Code of Good Practice for Scottish Finfish Farming (CoGP) introduced in 2006. Within the trout farming sector, the CoGP was benchmarked against an existing farm management scheme (Quality Trout UK (QTUK)) to ensure parity of the standards and trout farms are thus inspected and audited against the QTUK standard, itself containing the same containment requirements as the CoGP and subject to similar independent audit and reporting. Both documents seek to address all industry husbandry standards and are not specifically containment standards. Whilst there has been a reduction in the number of escape incidents since 2006 and some indication of a reduction in the number of escaped fish (although trends in the latter are less well developed), there is no indication that the trend is towards complete containment.

4. Sixty per cent of all escape incidents during the reporting period were from seawater cages. Seventy five per cent of all escape incidents were Atlantic salmon, with rainbow trout the second most important species by far. Therefore, to improve containment, it is necessary to address both sea water and freshwater operations and to focus on salmon and rainbow trout.

5. Other salmon and trout producing countries also experience escapes. Whilst comparisons of statistics should be treated with caution due to differences in the size and nature of industries (i.e. husbandry methods) and in the way data are collected, it is apparent that there are some differences between countries and provinces. Fish farmers in British Columbia and Newfoundland and Labrador have experienced some years without an escape incident. Considering the number of escapes per tonne of production, Newfoundland and Labrador and British Columbia have typically had the lowest in recent years, with Chile the highest and Norway and Scotland in between.
6. One main objective of this study has been to characterise Scottish escape incidents in order to obtain a greater understanding of the causes of escapes based on detailed discussions with fish farmers. Where possible, each incident has been characterised in terms of the immediate cause(s) (e.g. hole in the net), the underlying causes (e.g. chafe/snag) and contributory factors (e.g. use of equipment, weather etc). A total of 134 incidents have been characterised for this project meaning that just two remained uncharacterised.

7. The body of the report and accompanying annexes provide detailed breakdowns of escape incidents since statutory reporting was introduced in Scotland – between May 2002 and October 2009 – according to immediate and underlying causes as well as identifying contributory factors. The box below highlights the most important immediate (IC) and underlying causes (UC).

<table>
<thead>
<tr>
<th>Cause (IC)</th>
<th>Percentage of Incidents</th>
<th>Percentage of Escaped Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holes in the net</td>
<td>26%</td>
<td>12%</td>
</tr>
<tr>
<td>Predation</td>
<td>3%</td>
<td>12%</td>
</tr>
<tr>
<td>Chafe/snag</td>
<td>17%</td>
<td>9%</td>
</tr>
<tr>
<td>Cage/mooring failure</td>
<td>7%</td>
<td>23%</td>
</tr>
<tr>
<td>Inappropriate cages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate moorings</td>
<td>4%</td>
<td>16%</td>
</tr>
</tbody>
</table>

8. The insight into escape incidents provided by the above information suggests that more detailed and more accurate information on escape incidents should be supplied by industry. This should include the immediate investigation of significant incidents by persons with appropriate technical knowledge and industry experience.

**Observations and Recommendations**

9. There has been an increasing use of plastic circular cages and mooring grids which were considered more appropriate than their steel counterparts for use in more exposed locations, as well as a general increase in the specification of

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1 More information on the storm event is provided in Volume 2.
equipment at cage sites. This has led many farmers to be confident that their sites would withstand a storm of the severity of the January 2005 event.

10. Whilst many cage sites are designed and specified by professionals, some have been and continue to be developed on the basis of a farmer’s experience. This is of concern since it does not necessarily ensure a robust design. Further, environmental monitoring was not always sufficient to provide a satisfactory basis for installation design.

11. It is recommended that a technical standard be developed which sets out the minimum requirements for new and modified cage sites in both sea water and freshwater. Compliance should be mandatory. This should be based on appropriate environmental monitoring data and designs (based on worst case conditions) undertaken or verified by professionals. An appropriate vehicle would be the proposed ISO aquaculture standard or a Scottish technical standard and it is recommended that the Scottish aquaculture industry should commit to a technical standard suited to Scottish circumstances as well as fully engaging in the development of an ISO standard.

12. This technical standard should address site layout, moorings, cages, nets and maintenance. It should be based on a locality classification such that more exposed sites require more robust equipment. It should also specify a return period\(^2\) and engineering standards to be used for the basis of designs and require that installations can suffer the failure of at least one key component without a breakdown of the overall system.

13. The integrity of existing cage sites should also be assessed. A staged approach is recommended, with an initial screening so as to focus on those which may not have been designed by a mooring professional or where the original specification may now be out of date. Any sites where installations may be of concern should be required to upgrade.

14. A standard protocol for net testing is required. Whilst concerns about the efficacy of net testing are noted, this is the only mechanism available to help the industry assess net condition and its use should be enforced forthwith across all sectors of the industry.

15. A number of operational and training issues were identified which could help reduce the likelihood of escape incidents at cage sites from predators and chafe/snag. These should be included in a revised CoGP and QTUK which should apply across the entire industry\(^3\). One key measure is the visual inspection of nets on a regular basis. A risk assessment approach is recommended to ensure that the measures taken are appropriate to the site; guidance and examples of assessment methodology and mitigation measures should be provided.

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\(^2\) Such as a one in fifty year storm, one in a hundred or other as appropriate confirmed after discussion with meteorologists and engineers.

\(^3\) Whilst the majority of farmed finfish in Scotland is currently produced in accordance with these standards, a small proportion is not.
16. Industry standards such as the CoGP / QTUK should be used to address more minor causes of escapes, including those from freshwater tank sites and during fish transfer operations. This should include the use of mortality tanks or similar to prevent escapes from freshwater tanks reaching the external environment and the specification of screen materials for land-based sites.

17. Compliance with the new and revised protocols should be enforced through widening the scope of the Government’s containment inspections undertaken by Marine Scotland.

18. Training is a key issue. Consideration should be given to including containment and aquaculture engineering within a national qualification scheme for aquaculture. However, staff who are unlikely to become involved on such schemes should also receive training on the importance of containment and on the measures required to ensure effective containment on the equipment they are using prior to starting work. The lack of opportunity for staff to train on unstocked sites where they can appreciate the consequences of different actions is of concern and consideration should be given to a national training centre (which could also be used as a research centre). Containment should also be included in the syllabus of training courses for operators of boats, forklifts and cranes.

19. Whilst net tensioning is a key defence against predator attack, no information on the required tension is available to farmers. Similarly, farmers did not have information on the ability of different weighting systems and approaches to net design to help address both predator attack and chafe/snag issues. Nor do farmers have technical information on the ability of different cages and related equipment to withstand different environments. Therefore, research in these areas is recommended.

20. Farmers reported that one acoustic deterrent device (ADD) had delivered consistent results in preventing seal attack at sea water sites over recent months. These findings should be monitored over the medium term since if this continues to be successful it could be very beneficial to the industry and consideration should then be given to making its use mandatory.

21. There is no indication that net innovation or closed containment technology will provide practical or cost-effective solutions in the near future, although international research projects on these issues should be monitored.

22. The recently established Scottish Government Improved Containment Working Group, along with industry representatives, should play a pivotal role in the establishment of a new approach to containment. This should include input into setting up any new technical standard and promoting any new standard to the management boards of existing standards – e.g. CoGP / QTUK reviewing the existing CoGP and QTUK. They should also direct and review escape investigations and have the powers to recommend protocol changes accordingly.

23. Most farmers take the issue of containment seriously, as is evident in the high level of investment in new equipment and in experimentation with the use of
ADD, predator nets and trials of new net materials and also its positive engagement in the Improved Containment Working Group. However, more should be done to produce a culture of containment across all sectors of the industry and it is recommended that an aspirational target of 100% containment be promoted within industry and by the Scottish Government.

24. From the salmon perspective, it is evident that the Scottish salmon sector has more onerous protocol requirements for containment than some of the other producing countries and provinces/states, but less than others. Whilst, for freshwater trout, it is understood that containment requirements are in advance of most other countries.
1.0 Introduction

1.1 Introduction to the Project

Thistle Environmental was commissioned by the Scottish Aquaculture Research Forum (SARF) in March 2009 to investigate and assess escape incidents in respect of Scottish finfish farming using existing information and the findings of research undertaken specifically for this project.

The overall aim of the project was to provide robust information on protocols and practices from a containment perspective which may be used to inform the forthcoming review of the Scottish Finfish Code of Good Practice (CoGP, 2006), and to inform industry and regulatory reporting procedures and protocols.

The main objectives were as follows:

Objective 1: To identify and assess the contributory causes of a representative number of previously reported escape incidents in Scotland.

Objective 2: To identify the pros and cons of finfish protocols (industry and generic codes of practice, management systems, standards and regulation) in use in Scotland and worldwide in regard to their effectiveness in generating secure containment and preventing escapes.

Objective 3: To identify the pros and cons of the operational practices of Scottish and selected Norwegian finfish farmers from the perspective of their effectiveness in regard to generating secure containment and preventing escapes.

Objective 4: To assess whether there are existing or emerging aquaculture technologies and practices from Scotland and elsewhere in the world which, if adopted in Scotland, may help reduce escapes.

Project Scope:

1. The project focused on Atlantic salmon and, to a lesser although still important extent, rainbow trout, since these are the key farmed species in Scotland. Other species are considered and mentioned where relevant to the Scottish industry (e.g. halibut and cod).

2. The project included both freshwater (lochs and rivers) and sea water, although with more emphasis on the latter to reflect the greater number of breaches of containment from this environment.

3. The project included a desk study, informal consultations (remote and face to face) and site visits throughout Scotland as well as a consultation visit to Norway.

1.2 Rationale for the Project

Although numbers have varied year to year, breaches of containment have continued to be a persistent problem in the Scottish finfish aquaculture industry (Thistle Environmental, 2008; Thorstad, E. B. et al, 2008; Scottish Executive, 2008, 2002; Genimpact, 2007) – and one which appears to be replicated to a greater or lesser extent.

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4 This was timed to coincide with Aquanor 2009, the international aquaculture exhibition and conference at Trondheim in August 2009.
extent worldwide. This is recognised by both industry and the Scottish Government as identified through containment being a key theme of the renewed Strategic Framework for Scottish Aquaculture (Marine Scotland 2009).

In framing the debate, it is important to recognise that containment is a complex issue with many inter-related factors and disciplines. Therefore, solutions to the problem need to take account of a wide range of factors and be specific to equipment type and site conditions.

The recording of escape causes of over recent years by the Government, whilst useful as an indicator, is too generalised to give understanding of the real reasons behind different escape incidents and what should be done to prevent them (Thistle Environmental, 2008).

In regard to containment, debate in Scotland has focused on two questions: 1) is the current containment guidance followed by industry sufficient and 2) whether the industry should follow the Norwegian model, or other models (e.g. British Columbia), and adopt a binding technical standard. It has been difficult to answer these questions in Scotland from an informed perspective due to a lack of data and information. Therefore, one key purpose of this project was to provide information that may help inform this debate.
2.0 Methodology

2.1 Research

Literature Review
A brief review of relevant literature on containment, including grey and published sources was conducted (see Annex 1).

Collation and Review of Protocols
Finfish protocols\(^5\) from Scotland and worldwide, including those specific to finfish aquaculture as well as generic instruments were reviewed (see Annex 2). This information included the following types of protocols:

- Regulation
- Codes of practice
- Industry standards
- Generic standards
- Retailer’s codes
- Suppliers\(^1\) instructions/advice
- Advisors\(^2\) instructions/advice
- Current and forthcoming research
- Certification bodies’ materials

Review of CoGP Compliance
The Code of Good Practice for Scottish Finfish Aquaculture (CoGP, 2006) is one of the chief means through which containment guidance is offered and inspected in Scotland. A brief review of fish farmer’s compliance with the CoGP was undertaken to assess how well fish farmers are meeting the clauses of the standard\(^6\). This was undertaken through consultation with Food Certification International Ltd which is responsible for assessing compliance with the CoGP. The results are included in Annex 2.

Finfish Escape Incidents: Desk Based Collation and Review
This review focused on the Scottish industry, with additional information sourced from abroad where available. The review was based on publicly available information, augmented where necessary with information from consultees (see below). The results are presented in Annexes 3 and 4.

Review of Emerging Technologies
A brief review of emerging technologies and practices was undertaken, both within the UK and overseas, to assess whether they might be useful to improve containment within the Scottish finfish industry. This was based on desk research, consultations

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\(^5\) Note that the word protocols is used in this report to include all instruments which producers may conform to – either voluntary or statutory requirements – which are relevant to finfish containment. This includes regulations, codes of practice, national or international standards, retailer specifications, product certification schemes and standards produced by Non-Governmental Organisations (NGOs), related to containment within the finfish farming industry. Whilst some may relate to all forms of aquaculture, some to finfish farming and some concentrate on containment, others may be generic.

\(^6\) Since the CoGP is essentially only used by [the majority of the] salmon farmers in Scotland, this review does not include consideration of other species, particularly trout. More information on the use of the CoGP is provided in Volume 2.
(see below) and a visit to Aquanor 2009; the principal industry trade event. The results are included in Annex 1.

**Characterisation of Scottish Finfish Escape Incidents**

This project sought to characterise a representative number of Scottish finfish incidents since records began in May 2002. Copies of the completed initial and final notification forms used by fish farmers to report escape incidents and near misses were provided to this project by the Scottish Government. The information provided on the notification forms was augmented by consultations with fish farmers to identify the immediate and underlying causes of escape incidents and near misses and any additional contributory factors. Informal consultations were held with a wide range of Scottish freshwater and sea water salmon farmers and trout farmers. Where possible face to face meetings were conducted, backed up with telephone conference calls.

The results of this task are reported in Annex 4.

**Identification of Operational Practices in Scottish Finfish Farming**

Informal consultations were held with a wide range of Scottish finfish farmers to identify how equipment is specified, installed, inspected and maintained and operations conducted from a containment perspective. Companies were chosen so as to provide a representation of the Scottish finfish industry in terms of type of company (size and ownership), type of production (sea water, freshwater cage sites, freshwater tank sites and freshwater earth pond sites), species (Atlantic salmon, rainbow trout and limited focus on halibut and cod) and location (mainland west coast, Western Isles, Orkney, Shetland, Highlands, central and southern Scotland). Companies were also chosen on the basis of their escape history; therefore, most companies who had reported escape incidents were approached.

The results of these consultations are included in Annex 5.

**Consultations with Suppliers of Products and Services to the Scottish Fish Farming Industry**

Informal consultations were also held with equipment manufactures/suppliers (including cages, nets, moorings, tanks and valves etc.) and service providers (insurers/loss adjusters, engineers etc). Face to face meetings were held, backed up with telephone calls. The purpose of this consultation was to discuss how equipment is designed, specified, installed, inspected and maintained as well as to obtain views on the current CoGP and other protocols. This process was augmented by discussions with suppliers at Aquanor 2009. The results of these consultations are included in Annex 6.

**Other Consultees**

Informal consultations were also held with a range of other consultees including Government, regulators, research institutions, producer organisations and companies in Scotland and abroad. These consultations are not reported as a stand alone annex, but the results were used to inform specific elements of the project and are referenced in this report as appropriate. A list of consultees is appended.
2.2 Report Layout

A large amount of information was obtained for this project through desk based research and consultations. Volume 1 provides key analysis and interpretation of the results to address the project objectives. Volume 2 (bound separately) provides detailed information on which Volume 1 is based. Conclusions and recommendations are identified and numbered in the body of the text with emboldened text in square brackets (C for conclusion and R for recommendation) and are then prioritised in Chapter 9.
3.0 Escape Incidents: Magnitude, Trends and Causes

3.1 Introduction

This chapter presents summaries of information on the magnitude, trends and causes of escape incidents for finfish farming and discusses issues around counting the numbers of fish that escape. It is based on the collation of existing data on finfish escapes worldwide and primary research undertaken for this project on the causes of escape incidents in Scotland. The detailed results are included as Annexes 3 and 4, to which reference should be made for further information.

3.2 Magnitude and Trends

Scottish Finfish Farming

Escapes have been a persistent issue for the Scottish finfish farming industry since records began in 2002. Between May 2002 and October 2009 (inclusive) there have been a total of 136 reported escape incidents resulting in 2.18 million (m) escaped fish. Figures peaked in 2005 due to a particularly severe storm on the 11th and 12th January\(^7\) which was responsible for 12 escape events and 821 thousand (k) escaped fish. Whilst 2008 saw the lowest losses to date, 2009 surpassed this figure (with 14 escape incidents and the loss of 141k farmed finfish as of the end of October), and hence there is no indication that the trend is towards zero or minimal escapes.

It is evident that some escape incidents give rise to a greater number of escaped fish than others. There has been some conjecture that the magnitude of incidents will increase due to the use of larger cages, but this study has not identified any trend in this regard.

The annual numbers of escapes range from between 0.5 fish per tonne of farmed fish produced (2003 and 2008) to 6.6 fish per tonne in 2005. Excluding 2005, escapes have averaged between 0.5 and 2.6 fish per tonne of production which again shows the dominance of the January 2005 storm. There is no evidence that escape events have been linked to production levels as there does not appear to be a correlation between the changes in production levels and the numbers of escape incidents or escaped fish.

Over the eight years of data, the number of escaped finfish from seawater have been 69% of the total reported with freshwater being 31%. There was one year (2004) when there were no reported escapes from freshwater farms, whilst for the other years, the number of escaped freshwater fish ranged between 10% (2008) and 415(2005). In regard of seawater, the proportion of escapes ranged from 59% (2005) to 100% (2004). Therefore, to improve containment it is necessary to address both seawater and freshwater operations.

Atlantic salmon has dominated escapes of Scottish farmed finfish, accounting for around 75% or more of the total number (i.e. seawater and freshwater) of escaped fish each year during the reporting period – and averaging 89% over the period as a whole. Given that salmon has accounted for 95% of the total farmed fish production of all species in Scotland, this is not surprising (see Annex 3 for production statistics).

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\(^7\) Henceforth referred to as the January 2005 storm.
Whilst rainbow trout only accounted for 5% of total production over the period escapes have been 9%, although there was one year when there were no reported escapes and 2003 when escapes were minimal (2k). Volume 2 of this report presents details about escapes of species other than salmon and rainbow trout which have generally been a very small proportion of the total. However, there have been intermittent escapes of the other species which over the reporting period has included 8k brown/sea trout, 16k cod and 19k halibut. The recent demise of production of species other than salmon and trout suggests that consideration of other species at this time is of secondary importance.

**Worldwide**

Other salmon and trout producing countries also experience escapes. However, any comparisons of statistics should be treated with caution due to differences in the industries and in the way data are collected. Nevertheless, it is apparent that there are some differences between those countries for which information on escapes are available.

Production in Newfoundland and Labrador and, to a lesser extent, British Columbia have been characterised by several years without a reported escape incident (five years and two years respectively) although both provinces have also had years with higher levels of escapes. Escapes in Norway have ranged between 351k (2000) and 1,241k (2006) and, like Scotland, there have been no years without incident. Statistics for Chile are unavailable for several recent years, so it is not possible to determine whether there have been any years without an escape incident; however, there have been years with very high numbers of escapes including 2004, 2007 and 2008 when annual escapes exceeded 1.5m fish and 2004 when escapes totalled 3m.

The annual production of farmed fish in Scotland is about 3.5 times higher than in Newfoundland and Labrador and about double that of British Columbia, whilst Scottish production is less than a quarter of Chilean production and one fifth of Norwegian. Therefore, to some extent, it is not surprising that there are differences in escape levels between the countries. Taking the figures on the basis of the number of escapes per tonne of production, as tabulated in Volume 2, Newfoundland and Labrador and British Columbia have typically been the lowest in recent years, with Chile the highest and Norway and Scotland in between.

### 3.3 Inventory and Reconciliation

Fish farmers have a number of different methods and technologies available for counting their fish. However, it is difficult to count fish with complete accuracy due to the large numbers of fish involved, their fast movements and the small size of juveniles, especially at the earlier life stages. Farmers may expect up to ±3% inaccuracies or operating tolerances in stock numbers, although figures much lower than this are often quoted. After an escape or suspected escape event, farmers will typically count the remaining stock to ascertain the magnitude of the event, therefore

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8 Percentages have been calculated for the period 2002-2008 since production data for 2009 was not available at the time of writing.
it is possible that an escape incident might not be identified should the count be within the operating tolerance. Alternatively, the reported numbers may be inaccurate [C].

Improved technology is required to more accurately monitor incidents and further research and international collaboration is recommended in this area. The Norwegian Ministry is currently involved with research into a portable biomass counter for use by Government inspectors; it is recommended that contact is maintained in this regard as such a tool could be useful in the Scottish industry [R3.1].

Stock inventory reconciliation can be affected by inaccurate counting (e.g. when fry are counted by weight) and estimated or inaccurate mortality counts (e.g. following a large fish kill, or small fish or mortalities escaping through the net mesh). The Scottish authorities should consider including unexplained losses and fish mortalities in the annual production data published by Marine Scotland9 as well as escape information (such information is published by the Norwegian authorities) [R3.2].

No information was gained during this project on the extent to which any escape incidents may go unreported. It is possible that the reporting of events may have increased over the later years of the project period (2002-2009) due to the impact of the reporting legislation and so records in the latter years may be more accurate, although this cannot be verified.

3.4 Causes of Escapes

Approach to Classifying Causes

Escape causes have often been categorised by the use of a single descriptor e.g. ‘hole in net’ or ‘weather’ 10. This is insufficient to adequately characterise the event or to provide sufficient insight in order to discuss how to improve the situation.

One main objective of this study has been to characterise a large and representative proportion of Scottish escape incidents to allow a greater understanding of the causes of escapes. Where possible, each incident has been characterised in terms of the immediate cause (e.g. hole in the net), the underlying causes(s) (e.g. chafe/snag) and contributory factors (e.g. use of equipment, weather etc). Weather (and environmental conditions) has not been used as an immediate or underlying cause since equipment and operations are capable of being designed and planned to address weather conditions. Human error has also not been used as a cause because it appears to have contributed to such a large number of incidents that the use of this term is not necessarily helpful. Further, more detailed study would be required to confirm whether human error was a contributor.

A total of 118 (87%) of the 136 incidents have been characterised during this project on the basis of consultations with fish farmers. Information on existing records was used to partially characterise a further 16 incidents meaning that just two incidents

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9 Formerly, the Fisheries Research Services (FRS).
10 For example, the Scottish Government have allocated a cause against all incidents in this way on their internal records since escapes started to be reported in May 2002 and have also included this on their web-site since 2009. Authorities in Norway and British Columbia also use a single descriptor for the causes of escapes. See Annex 3 for more details.
remained uncharacterised. Further information on the project methodology is provided in Chapter 2.

**Results**

Analysis of the immediate causes of incidents (Table 1), suggest that 57% (78 incidents) were caused by a hole in the net, 18% (22 incidents) by cage and mooring failures (16%), 5% (7 incidents) by fish handling incidents with net under water and screen failure both accounting for 4%. Despite being second in terms of the number of incidents, cage and mooring failures accounted for by far the highest number of escaped fish at 1m (46%), which was followed by hole in the net at 700k (32%). In terms of escaped fish, net under water was the third highest cause (252k, 12%) and then flooding (108k, 5%) with vandalism in fifth place (29k, 1%).

**Table 1: Immediate Cause of Scottish Finfish Farming Escape Incidents (May 2002 - October 2009)**

<table>
<thead>
<tr>
<th>Immediate Cause</th>
<th>Escape Incidents</th>
<th>Escaped Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Hole in net</td>
<td>78</td>
<td>57</td>
</tr>
<tr>
<td>Cage/mooring failure</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Fish handling</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Net under water</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Screen failure</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Vandalism</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Helicopter bucket incident</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Transfer pipe failure</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Flooding</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Well boat collision</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>136</td>
<td>100</td>
</tr>
</tbody>
</table>

Base: 136 incidents.

Underlying causes and contributory factors were determined wherever possible for each incident. The detailed results are presented in Table A4.16 in 4 and Table 2 below provides a summary of the immediate and underlying causes.
Table 2: Summary of the Causes of Scottish Finfish Escape Incidents (May 2002 – October 2009)

<table>
<thead>
<tr>
<th>Immediate cause</th>
<th>Underlying cause</th>
<th>No. of incidents</th>
<th>No. of Escaped Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Hole in net</td>
<td>Predator</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Chafe/ snag</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Poor net servicing</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other underlying causes</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>78</td>
<td>57</td>
</tr>
<tr>
<td>Cage and mooring failure:</td>
<td>Inappropriate cages</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Inappropriate moorings</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Net under water</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Flotation tube failure</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other underlying causes</td>
<td>2</td>
<td>2</td>
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<tr>
<td></td>
<td>Unknown</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Fish handing</td>
<td>Sub-Total</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Net under water</td>
<td>Chafe / snag</td>
<td>1</td>
<td>&lt;1</td>
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<td></td>
<td>Other underlying causes and unknown</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Screen failure</td>
<td>All underlying causes</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Vandalism</td>
<td>All underlying causes</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Helicopter bucket</td>
<td>All underlying causes</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Transfer pipe failure</td>
<td>All underlying causes</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Flooding</td>
<td>All underlying causes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Well boat collision</td>
<td></td>
<td>1</td>
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<tr>
<td>Unknown</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>136</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
- Base: 136 incidents
- Figures have been provided against individual underlying causes where they constitute greater than 1% of escaped fish and are otherwise summarised as all or other underlying causes. An underlying cause was not provided for well boat collision so as to maintain confidentiality.
- Percentages are given against the total number of escape incidents or the total number of escaped fish. They are rounded to the nearest whole number or are identified as <1 where relevant. Percentages may, therefore, not total 100.
At 26%, predation resulting in a hole in the net is the highest single cause of escape incidents although it only accounts for the third highest number of escaped fish (12%). The second highest number of incidents (17%) was caused by chafe/snag which resulted in the fourth highest amount of escaped fish (9%). The third highest immediate cause (7%) was the use of inappropriate cages, which actually caused by far the highest number of escaped fish (23%) and was very much influenced by the January 2005 storm. Inappropriate moorings was the fourth highest cause of incidents (4%) yet was responsible for the second highest number of escaped fish (16%) which, again, was largely related to the January 2005 storm.

It is evident from Tables 1 and 2 that there are a wide range of causes and factors behind escape incidents, with multiple factors often coming together to create the incident. Therefore, there is no single remedy that will immediately reduce escape incidents in Scottish finfish farming; instead it is necessary to consider a range of issues across the sea water and freshwater environments, focusing on salmon and rainbow trout with consideration of issues as diverse as cage and mooring specification, net design, equipment installation and maintenance, operational issues, fish transfer operations (typically involving third parties), predator protection, flooding and vandalism – the majority of which have a human error and/or training element to them.

Nevertheless, four underlying causes accounted for 54% of incidents and 60% of escaped fish, whilst all the other causes each accounted for two per cent or less. Therefore, attention should be prioritised on hole in net incidents caused by predation and chafe/snag as well as cage and mooring failures due to the use of inappropriate cages and moorings. Given that cage and mooring failure has been less evident in recent years than holes in the net, greater attention should be given to the latter, although it is important to ensure that future severe storm events do not lead to cage and mooring failure.

Whilst it would be interesting to compare the results of this project with existing information on causes of escapes in Scotland, direct comparison is difficult because this project has been undertaken over a different timescale and used different categories. Table 3 below shows the causes assigned for 2009 incidents (up to the end of October 2009) by the Scottish Government compared to the classification used in this project.

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11 Of the nine incidents caused by the use of inappropriate cages, seven occurred during the January 2005 storm which resulting in 451,384 escaped fish.
12 Of the five incidents caused by the use of inappropriate moorings, three occurred during the January 2005 storm which resulting in 296,435 escaped fish.
### Table 3: Comparison of classification used to describe escape incidents for January to October 2009 by the Scottish Government and Thistle Environmental

<table>
<thead>
<tr>
<th>Scottish Government Classification</th>
<th>Thistle Environmental Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hole in net</td>
</tr>
<tr>
<td>Cause</td>
<td>No. of incidents</td>
</tr>
<tr>
<td>Hole in net - unknown</td>
<td>4</td>
</tr>
<tr>
<td>Hole in net - predator</td>
<td>3</td>
</tr>
<tr>
<td>Human error</td>
<td>4</td>
</tr>
<tr>
<td>Equipment failure</td>
<td>3</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>14</strong></td>
</tr>
</tbody>
</table>

**Notes:**
- The Scottish Government classification relates to the information provided on their web-site: [http://www.scotland.gov.uk/Topics/marine/Fisheries/Fish-Shellfish/18692/escapeStatistics](http://www.scotland.gov.uk/Topics/marine/Fisheries/Fish-Shellfish/18692/escapeStatistics)
- The upper line under Thistle Environmental Classification is the immediate cause and the lower line is the underlying cause.

Table 3 shows that the inclusion of underlying causes provides very much more insight into the nature of an incident. It also shows that, by asking for more detailed information and discussing the incident with relevant persons, it is usually possible to identify the underlying causes rather than reverting to a category of ‘unknown.’

It is considered essential that more accurate and detailed information on the reporting of escapes in Scottish finfish farming is obtained to allow a greater understanding of the causes of escape incidents. It is recommended that greater information is required on the Notification Forms used to report farmed fish escapes to the Government and that any incomplete or inadequately completed Notification Forms should be followed up by the Government to ensure that full information is provided in a timely manner [R3.3]. Consideration should also be given to the reassignment of escape information on Government records to allow trends to be identified to include identification of immediate and underlying causes and contributory factors. The Government should collaborate with other key finfish producing countries when determining the classifications to be used to facilitate benchmarking, although caution is required when comparing data due to the differences in production systems [R3.4].

The recently adopted practice of reporting the causes of escapes on the Scottish Government website should be continued. This should include the underlying as well as immediate causes of the incident. An annual report on Scottish finfish escapes is

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13 It might be possible to use the research undertaken for this report if confidentiality issues can be addressed.
also recommended which should provide a summary of the causes and compare data with previous years and other countries [R3.5]
4.0 Addressing Mooring and Cage Failure

4.1 Introduction

Whilst mooring and cage failure is the second most important cause of escape incidents, it accounted for the highest number of escaped fish between May 2002 and October 2009. The purpose of this chapter is to discuss the reasons for mooring and cage failure and to suggest ways in which these may be addressed.

Mooring and cage failure is strongly associated with gales, storms and, in this period, one particularly severe storm on the 11th and 12th January 2005\(^\text{14}\). Nevertheless, it is predictable that severe weather will occur on occasion in Scotland and consultees confirm that it is possible to design installations to withstand such severe conditions; a fact evident from the large number of cages and moorings that have not failed over the years, including during the January 2005 storm.

4.2 Changes in Moorings and Cages over Time

Cages

Aquaculture cages in Scotland include plastic circular cages, square plastic cages, square steel cages and square wooden cages. In the marine environment, plastic circles and square steels are by far the most common design used today, with only the occasional use of wooden or square plastic cages. In freshwater lochs, all types may be found.

Over recent years, there has been an increasing use of plastic circular cages. These were considered by consultees to be more appropriate for more exposed sites than steel cages because they can flex with the waves. The general move towards circular cages, particularly for more exposed sites, was considered by all consultees (farmers and suppliers) to have significantly reduced the potential for cage and mooring failure due to storm events. A number of companies which suffered cage failure in the January 2005 storms stated that such losses are now considered extremely unlikely if such an event recurred due to a change to plastic circular cages [C].

Moorings

The specification of moorings has also increased considerably over the years, including anchors, chains and ropes. Although the size of cages and other floating installations has also increased considerably over this time, consultees were of the opinion that mooring specifications had nevertheless increased in real terms [C]. A mixture of reasons were given for this increase, including that farmers and suppliers have learnt from mooring incidents over the years, that suppliers have increased the integrity of their products over time, and that farmers have invested heavily in new cages and refurbishing existing ones.

The other major change in moorings over the years has been the move to the use of a grid system at many Scottish sites. A grid system is applicable to sites with plastic circular cages and is not used for square steel cages. The grid is an inter-connected

\(^{14}\) As highlighted in Chapter 3, this storm was a contributory factor to a large number of escape incidents. It is one of the most severe storm events recorded in Scotland, with hurricane force winds and record breaking gusts in the far north and west (Wiseweather, undated).
system of anchors, chains, rope and buoys to which the cages are moored, compared to the older approach where each cage was moored individually. One advantage provided by the mooring grid approach is that different elements of the system may be able to compensate should an individual component fail. In engineering terms, this is known as ‘redundancy’.

With one exception, all consultees stated that they now use grid systems for plastic circular cages, a move which largely happened in the mid to late 1990s. The exception is a small independent company which considered that individual cage moorings provided greater flexibility (and had not experienced an escape event).

Square cages (steel and plastic) are generally moored by attaching mooring legs at individual points around the cage group. Moorings legs will typically consist of an anchor, chain, warp and buoy.

The other form of mooring used by farmers (for any cage type) is directly into rock using a large screw called a rock pin. This is used at freshwater and sea water sites in situations where cages are close to the shore and there is suitable substrate for receiving the pins. It may also be used under water on occasion in areas with a rocky sea/loch bed. Whilst many farmers prefer the use of mooring pins where possible, as they are considered to be more reliable than anchors, one event was identified where a line of rock pins failed in bad weather indicating that rock pins also carry the risk of failure. A new product allowing the remote installation of rock pins under water in one operation was noted at the international aquaculture exhibition Aquanor 2009 which may make the use of rock pins easier in the future.

4.3 Design and Specification of Installations including Moorings and Cages

Use of Mooring Professionals

Consultations with fish farmers indicate that mooring design and equipment specification in Scotland has been based on two different approaches or a combination thereof:

1. By independent mooring professional (e.g. mooring and/or cage supplier or engineer) [C]; or,

2. On the basis of the farmer’s experience and local knowledge [C].

In general, sites operated by larger companies are more likely to use the former approach whilst smaller companies more typically use the latter. However, there may be a combination of approaches within individual companies, where the moorings at some of the older sites may have been based on the farmer’s experience whilst those at newer sites may have been designed by a supplier. In most, though not all, cases, the moorings and cages at new sites will nowadays be specified by an independent professional.

15 Whilst grids may vary in detail, the following provides a general description. A grid, consisting of regular squares formed by rope, sits beneath the surface. Individual cages are moored within each square with briddles which connect the cage to each corner of the square. The external corners of each grid square are moored to the loch bed through a mooring leg which consists of an anchor, chain and warp. Each corner of every square is also connected to a buoy at the surface to maintain the grid at the required depth.
The practice of an installation being designed on the basis of experience and local knowledge is of concern, since it provides no guarantee that the correct environmental information has been used in the design. Nor does it ensure that appropriate calculations of forces have been undertaken and that components are manufactured to the quality standards required to meet those forces. Therefore, it is recommended that moorings and cages should be designed by suitably qualified and experienced persons. Alternatively, the farmer’s design should be approved by a suitably qualified third party. This is particularly relevant given the trend towards the use of more exposed and larger sites, for which farmers may not have relevant experience to draw upon [R4.1].

There may be advantages in requiring that persons involved in installation design should be appropriately qualified and/or in making this an accredited process; this is currently being considered in Norway. This project has not researched appropriate qualifications or accreditation for mooring and cage design nor has it consulted on whether it would be beneficial for the industry. It is recommended that the Improved Containment Working Group 16 gives due regard to this area, which should include consultations with engineers and practitioners working in this field [R4.2].

**Environmental Monitoring**

Moorings and cage specifications should be designed with full cognisance of environmental conditions, including wind speeds, wave data, fetch, tidal range, current, nature of the seabed as well as fish husbandry and welfare etc. It is understood that mooring professionals and cage suppliers will ask the farmer for such information and whilst some will provide all that is requested, others provide less. The most commonly omitted information appears to be wave data.

In some cases, information on environmental conditions has been for the determination of the farmer’s discharge licence application 17 or for an environmental impact assessment (EIA) rather than specifically for mooring design. Such information is usually based on a two week hydrographic monitoring period undertaken when desired. This is considered an insufficient basis for mooring design since it is too short a timescale and may not include poor weather conditions. This may result in certain variables being underestimated including:

- The strength of the tide (the strongest tides are at the equinoxes, although tide strength can also increase through low pressure and storms);
- The strength of any freshwater current (particularly where sites are located near to rivers which can be subject to significant spate, melt-water and/or storm surges);
- Wind generated currents, including directional changes with depth; and,
- Wave and wind data in storm conditions.

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16 Five working groups were established in 2009 to drive forward the Scottish Government’s Strategic Framework for Scottish Aquaculture (Marine Scotland, 2009), one of which focuses on containment. Further information on the establishment of these working groups is available from the Scottish Government website: http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/18692

17 In respect of The Water Environment (Controlled Activities) (Scotland) Regulations 2005.
The failure to give sufficient cognisance to freshwater water flows in particular has been noted by the independent Norwegian research organisation SINTEF (2009, SINTEF, pers. comm.). There have been incidents in Scotland over recent years, including escape incidents and near misses, where it is apparent that the underestimation of freshwater flow was a contributory factor if not the main cause of the event.

It is recommended that environmental data appropriate for designing moorings and specifying cages should be collected for establishing a new cage site or modifying an existing one. This should include a specified range of variables and time period; the latter should include occasions when conditions would be expected to be at their worst [R4.3].

As an alternative, a series of specifications could be provided to which a site could be designed should a farmer not wish to collect detailed environmental data; this would represent a worst case design and as such may be over-specified. This approach may be appropriate where the timescale for a new development does not allow a farmer to monitor at the time(s) of year when conditions would be expected to be at their worst [R4.4].

Consideration could also be given to a national (or regional) categorisation of aquaculture locations based on the collection of environmental monitoring data through an independent third party [R4.5]. This could be achieved through third party research, funded by government or industry or a combination thereof. The environmental data could be made available to prospective site operators, thereby reducing the burden of undertaking primary research for site development.

**Clarity of the Basis of Installation Design**

With one exception, farmers were not aware of the environmental conditions their mooring and cage installations had been designed to withstand. Discussions with suppliers also did not identify this facet in some cases, although one confirmed that they worked to a one in fifty year return period. It is recommended that a specific return period\(^ {18} \) should be specified for the Scottish industry, based upon advice from meteorologists and engineers and taking due regard of severe weather events over the past two or three decades as well as climate change. All installations should be comfortably able to withstand weather conditions such as the January 2005 storm as a minimum, with an additional safety factor [R4.6]. Installations should be designed on the basis of the predicted worst case rather than just the prevailing conditions (for example, should the prevailing wind be north west, but the site be most exposed to the south east, then storms from the south east should be included in the design rather than focusing just the north west) [R4.7].

A number of mooring failures – in both sea water and freshwater – appear to have started with the failure of a single component, such as a mooring line. Installations should be designed to allow for the failure of at least one such component (known as building in ‘redundancy’) which should include the most strategic components – without a breakdown in the overall system [R4.8].

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\(^ {18} \) Examples of such periods may include a one in fifty year storm event or one in a hundred, although this should be the subject of further research and consultation.
Farmers were also not aware of whether their installations had been designed to any specific engineering standards and whilst this was discussed with suppliers, it was not apparent whether there was a universal standard for floating aquaculture installations [C]. It is recommended that those standards to be used as a basis for installation design should be specified for the Scottish aquaculture industry; should these be considered inappropriate or outdated, industry representatives should engage with the relevant professional institutions to help ensure that standards are appropriate for use [R4.9].

**Locality Classification**

Although the specification of installations in Scottish aquaculture has, in general, increased over time, there are no minimum requirements. Given that cage and mooring failure has accounted for the highest proportion of escaped fish since records began in 2002, a standard which sets out the minimum requirements for all elements of the establishment of a new cage site or the modification of an existing one is recommended [R4.10]. This would help prevent the recurrence of escapes in major storm events.

Such a standard should be location specific, meaning that installations at more exposed sites would be required to have higher specifications suited to that locality. This would require aquaculture sites to be classified on the basis of exposure and that equipment is specified according to the site classification. This should apply to cages, barges, moorings and related components [R4.11].

Annex 2, provides some detail on the technical standard NS 9415 (Norsk Standard NS 9415, 2003) which is the mandatory basis for the design of aquaculture installations in Norway. It is recommended that the Improved Containment Working Group considers whether some or all of NS 9415 should be adopted for the Scottish industry, or whether an alternative standard should be developed in Scotland. Whilst considering the applicability of NS 9415, thought should be given to whether the locality classes are appropriate to the Scottish industry as sites are often thought to be more sheltered in Norway [R4.12].

Although most fish farming companies and those in their supply chain have considerable experience and expertise in the specification of individual components, a number of escape incidents have been caused by component failure (including failure of moorings, cages, nets, lifting equipment and shackles). It is therefore recommended that the minimum requirements for individual components related, where appropriate, to the classification of sites proposed above should be provided [R4.13].

There have been instances where the scope of the mooring leg has been reduced below a ratio of 3:1 to fit within the extent of the licensed area (specified by planning authorities and the Crown Estate) or because the farmer wishes to moor cages in a specific location. A ratio of 3:1 is typically considered the minimum required to absorb shock loadings on the cages through the catenary action of the mooring. In

19 The curve described by a flexible chain or a rope if it is supported at each end and is acted upon only by no other forces than a uniform gravitational force due to its own weight.
normal circumstances, a reduced ratio is unfavourable, although consultees confirmed that it could be adequately addressed by increasing the specification of anchors and chains. It is recommended that a reduced scope should be avoided wherever possible, and the industry should engage with the Crown Estate and planners to ensure that they are aware of the potential effects of a reduced scope on the security of installations [R4.14].

A small number of consultees raised concerns that the depth of the mooring grid may not be maintained at its design depth due to movement in the grid system. This gives the potential for the grid to snag on well boats or other vessels should it be significantly higher than envisaged. Companies should ensure that the grid is at the required depth before bringing in well boats or other larger vessels, such as feed delivery boats [R4.15].

4.4 Existing Installations

As discussed earlier, there is concern that installations which have not been designed by a mooring professional may be inappropriate for the location. This may also apply to existing installations designed by a professional but which are now out of date, either because the industry now tends to use higher specifications or because the installation may have been significantly modified. Therefore, it is recommended that the integrity of all existing cage sites throughout Scotland should be verified [R4.16]. A full engineering assessment of each site would be time consuming, expensive, and not warranted in many cases due to the level of the existing specification and hence a staged approach is suggested as follows:

1. Initial screening: desk based review of site survey information, and cage and mooring specifications;

2. Then, for any sites identified as of concern, mooring calculations should be undertaken based on existing information, augmented if required by additional desk based information, using current mooring standards.

3. For any sites of concern after Step Two, there are several actions which could be appropriate, including a site visit to ascertain local knowledge and sourcing additional survey information.

The above should be undertaken by appropriately qualified and experienced independent engineering professionals. All companies would be required to provide mooring and cage specifications for each site and site survey information. The source information and the findings could be retained in a database by the Scottish Government. Any sites where the installation integrity may be of concern should be required to upgrade to an appropriate level [R4.17]. The timescale for so doing should take into account the maturity of existing stock and the onset of winter conditions.

4.5 Provision of Documentation

The person designing the moorings should also be required to provide a specification which should include details of materials, components, dimensions and maintenance requirements. The basis on which the installation is designed should be included as should the return period and the identification of elements of redundancy [R4.18].
Cage manufacturers should be required to provide instructions on the installation, maintenance and operation of their cage [R4.19]. This should include details on such issues as tolerances in regard to setting out the grid, mooring vessels alongside and other issues in regard to the installation. Note that whilst the Code of Good Practice for Scottish Finfish Aquaculture (CoGP, 2006) requires that information is obtained on the installation (Clause 4.9.1.1.2), this is rarely provided and when it is, it tends to be general literature rather than technical information. Further, the CoGP places the emphasis on the farmer to obtain information rather than the one on the manufacturer to supply it.

4.6 Mooring Installation

Farmers should be required to ensure that moorings are installed by appropriately experienced and/or qualified personnel and inspected prior to use. Companies should have a documented method to verify that mooring grids are laid in accordance with the instructions provided by manufacturers and the mooring specification [R4.20].

There may be advantages in requiring that persons laying moorings should be appropriately qualified. This project has not researched appropriate qualifications for this nor consulted on whether it would be beneficial for the industry. It is recommended that the Improved Containment Working Group gives due regard to this area which should include consultations with farmers and practitioners working in this field [R4.21].

After an installation has been completed, the site should be subjected to a full inspection which should include a visual inspection (by diving or camera) of all elements of the mooring system including anchor siting. Consideration should be given to whether this inspection should be undertaken by an independent third party with expertise in mooring systems [R4.22].

4.7 Changes in Cage and Mooring Provision

There are occasions where farmers may change the facilities at a given site. This could include situations where:

- Additional cages are added to an existing group of cages, or cage size is increased;
- Different nets are used, perhaps deeper, or with a smaller mesh which could increase resistance to water flow;
- Well boats are used for the first time, or larger well boats are used;
- Feed delivery vessels are used for the first time, or larger feed vessels are used;
- Significantly larger work boats are used;
- There is a change in grid depth;
- There is a reduction in the scope of mooring legs;
- The site orientation or cage arrangement is changed;
- Key grid components are changed to ones of a different design, material or size;
- There is a change in barge configuration; and,
• There are significant changes in marine (or freshwater) traffic (including changes in routing or size of vessels).

Previously, such changes may have taken place without professional advice. It is recommended that any significant changes to an existing site should be undertaken with the advice of a suitably qualified and experienced mooring professional who should advise on whether a change to the cage and/or mooring specification is required. Any required alterations should be implemented by the farmer before the site is stocked or the new elements of the installations are used [R4.23].

4.8 Interaction with Other Marine Users

Collision with non-aquaculture marine traffic has not been identified as a cause of an escape in Scotland since records began in May 2002, although there was at least one incident prior to this. Nevertheless, this issue has been of concern in the Mediterranean where it has led to at least one major escape incident. In Scotland, there is the distinct possibility of such an incident occurring.

An industry level discussion should be held with the Maritime and Coastguard Agency (MCA) and other organisations in regard to collision prevention approaches for fish farm installations and any recommendations should be taken forward [R4.24].

4.9 Cage and Component Design Testing and Provision of Information to Farmers

It appears that there is little information available to aid farmers in their choice of equipment, other than manufacturers’ brochures and sales literature. This particularly relates to empirical data on cage performance and mooring design in different environmental conditions. It is recommended that research into the stresses and design limitations of different types of cages and mooring configurations is undertaken to help address this issue20 [R4.25]. This could be undertaken by an independent organisation, perhaps with international collaboration. It is noted that the Norwegian research institute SINTEF were planning to set up a field based research station to consider issues such as these and so consultation with SINTEF is recommended [R4.26].

Although there has been one Scottish conference on aquaculture engineering, this was almost twenty years ago and there have been a number of papers on this topic in recent years (see Annex 1). Therefore, it is recommended that a symposium be held to bring fish farmers and stakeholders up to date on aquaculture engineering which should become a regular event, perhaps every two years [R4.27].

20 Or, should this information already exist, that it is made available to fish farmers.
5.0 Maintaining Net Integrity

5.1 Introduction

The second highest immediate cause of escaped farmed fish in Scotland between May 2002 and October 2009 was hole(s) in the net. There were a number of underlying causes, of which predators and chafing or snagging were by far the highest. This chapter presents discussion on possible means of reducing the likelihood of a breached net.

5.2 Preventing Predator Attack

Attacks on cage nets from predators can lead to escape incidents from the resulting hole(s) in the net. Addressing predation is a particularly difficult issue due to the unpredictability of otter and mink freshwater incidents and the persistent nature of seal attacks in sea water. Whilst some farmers think that the predation threat is remaining constant others consider that it has greatly increased, particularly from sea water seal attacks. Predation also varies on a site by site basis, with some locations having virtually no issues where others have significant losses. It also varies with time, with some sites which have previously been unaffected bearing significant losses. Nevertheless, some companies have not reported an escape incident caused by predators, including some with sites in areas of considerable predator activity, which suggests that there are approaches that may help to reduce the likelihood of an incident.

Net Materials

Nylon has been the traditional material used for cage nets and can be supplied across a range of breaking strengths and using different construction techniques. However, there appears to be little information available about whether it is possible to reduce the likelihood of successful predator attacks on nylon nets through increasing the net specification and, therefore, farmers have little on which to base their procurement decisions in this regard [C]. It is recommended that research is undertaken to help ascertain the role that the strength and construction of nylon cage nets may have in deterring attack from common fish farm predators in both freshwater and sea water environments [R5.1].

In recent years there has been some interest in nets made from materials other than nylon, specifically plastic. This includes high modulus polyethylene (HMPE) and in particular from Dyneema® – an HMPE material made by DSM Dyneema (FFI, 2006). Such nets are, according to manufacturers, much more resistant to predators. However, whilst manufacturers point to the use of such nets in aquaculture worldwide, no significant uptake in salmon or trout farming was identified in Scotland.

A small number of Scottish companies have trialled HMPE nets and encountered difficulties with handling which made them impractical for use. The trend towards larger cages and more exposed locations is likely to compound such concerns. There are some interesting developments in the use of industrial zip fasteners to join net panels in-situ which may help to address handling issues, although no Scottish farmers were identified that were considering their use.
The use of Dyneema® nets has been tested in industry based research trials in Scotland. Whilst the research has not yet reached its conclusions and no official reports have been released, consultations suggest that various issues need to be addressed (including an assessment of costs versus benefits) which makes widespread adoption unlikely in the near future. However, there appears to be a limited uptake of Dyneema® based nets abroad for commercial use (see Annex 1).

Therefore, whilst there is ongoing research and innovation in net materials, it does not appear that there will be a widespread uptake of new materials in the short term by Scottish farmers due to the difficulties experienced in handling plastic nets or concerns about the properties of Dyneema® based nets [C]. However, innovation through the European funded project entitled ‘EscapeProofNet’ which is looking into new net materials remains a possibility and recent research in Norway indicates that there may also be ways of improving net integrity through consideration of design and handling. It is recommended that the Improved Containment Working Group and industry representatives put in place mechanisms to keep themselves and the industry abreast of research developments in the UK and abroad [R5.2].

Net Tensioning

Net tensioning is primarily used to help maintain net volume in higher energy sites. However, there is strong agreement that net tensioning is also an essential instrument in deterring seal attacks and many farmers consider it their primary defence against predation. It is thought that it is very much harder for a seal to sufficiently deflect a taut cage net to access the stock and, in so doing, causing damage to the net. It is also more difficult for a seal to grip a taut net and bite, chew or shake it which can also lead to holes.

Net tension has traditionally been provided by suspending individual weights from the net and there has been a history of increasing weights to improve net tension. Over recent years, many companies have turned to the use of sinker tubes as an alternative to individual weights on plastic circular cages and some companies use large weights suspended beneath walkways to achieve a similar effect on square steel cages. These approaches allow nets to be tensioned without directly weighting the net, which reduces the strain on the net as well as providing a more effective means of generating net tension (Annex 5 provides further information on the use of sinker tubes).

Detractors consider sinker tubes harder to operate and highlight that larger equipment is required. Some also question their effectiveness in sites with higher currents, suggesting that use in such environments puts increased strain on the net. However, others are very much of the opposite opinion and consider sinker tubes as the preferred choice in high tide sites.

No company had any knowledge about the level of tension required to prevent predator attacks or any guidance on the optimum weight to be used. Instead these issues were approached on an experimental basis with some companies using much heavier weights than others, both for sinker tubes and individual weights.

21 http://www.escapeproofnet.com/wip4/
The difference in opinion on the use of sinker tubes in different environments is of concern since it suggests that there is insufficient information available for farmers to make informed decisions about how to optimise their net weighting systems. Similarly, the lack of information on the optimum level of tension and on the weight required to obtain that tension in different current regimes, for both individual weights and sinker tubes, is also of concern. It is recommended that research is undertaken into the ways that nets behave in different current regimes with different weighting systems so that advice can be given to farmers on the optimum tension required and how this may be achieved through the use of different types of equipment [R5.3].

Whilst sinker tubes do allow much of the cage net to be efficiently tensioned, they are limited in their ability to tension the base of a standard (i.e. conical) shaped cage net because the apex of the net hangs beneath the tube. So, the base is tensioned through hanging a single weight from the centre perhaps augmented by the weight of mortality collection equipment in the base of the net. Unless very heavy central weights are used, seals may still be able to deflect this area of the net which could leave it vulnerable to predator attack. The fact that some successful predator attacks on cage nets with sinker tubes were identified in the research suggests that use of sinker tubes may not provide a consistent defence to predators or that perhaps they are not always used effectively [C]. Therefore, it is recommended that research be carried out into systems which could tension the base as well as the sides of cage nets [R5.4].

There appeared to be little if any use of net tensioning systems at freshwater sites and no knowledge about whether this would be a useful approach to deterring mink and otter attack. Therefore, it is recommended that research be carried out into the potential for increased net tension to help prevent mink and otter attacks in freshwater sites [R5.5].

**Acoustic Deterrent Devices**

Farmers have used acoustic deterrent devices (ADD) over many years as a means to deter seals at sea water sites although, until recently, they have delivered inconsistent results\(^{22}\). Many consultees commented that ADD appeared effective to start with and then seals became used to them. However, consultations suggest that one product has recently been found to be more successful and has delivered consistent results, and that there has been significant investment by farmers in the recent past [C].

If this brief period of successful ADD use continues it could prove very beneficial to the industry, although a longer time period is required to allow full evaluation. Up to date information on the effectiveness of ADD is essential for policy makers and industry; it is recommended that the Improved Containment Working Group and industry representatives, put in place mechanisms to keep abreast of developments in the use of ADD which should include an ongoing quantitative assessment of ADD effectiveness. It is noted that there is an existing SARF funded project assessing the potential impact of ADDs on cetaceans and their efficacy in deterring seals (http://www.sarf.org.uk/SARF044.htm). It is recommended that the Improved Containment Working Group takes account of the results [R5.6]. Should ADD be a proven success in the medium term, the mandatory use of ADD should be considered by the Improved Containment Working Group on sea water sites [R5.7].

\(^{22}\) There are also stakeholder concerns regarding their use which are outwith the scope of this report.
Acoustic measures have been in use at freshwater sites through the occasional use of ultrasonic products (developed for the private householder to deter cats rather than for the fish farmer) to deter otter and mink. Of the farmers who used such products, there appeared to be little knowledge about their effectiveness on otter and mink. It is recommended that research be undertaken into the use of ultrasonic and other devices for deterring otters and mink from freshwater fish farms [R5.8].

Net Inspection

Many companies inspect cage nets at seawater sites by the regular use of divers (typically monthly) and prior to specific operations such as stocking or grading. Some also remove mortalities by diving which gives an additional opportunity to inspect the cage net. These companies highlighted that visual net inspections by divers gave the opportunity to identify net damage from predation (and chafe and snag) before it became problematic. It also allowed net tension to be monitored and adjusted accordingly. One freshwater company also undertook dive inspections, at larger sites.

Whilst other companies inspect nets at the surface when they are lifted or lowered, they did not typically use divers to inspect nets when they are in situ. It is harder to identify damage from surface inspections, especially on larger nets, as staff have to work their way through large amounts of material as well as trying to assess the condition of the centre of the net which will be many metres away from where they are standing.

Some escape incidents may have been avoided, or the magnitude reduced, by the use of dive inspections. This particularly applies to crowding operations where fish have on occasion been inadvertently crowded into an area of the net with a hole which has led to a much greater number of escaped fish than may have otherwise been the case.

Although the Code of Good Practice for Scottish Finfish Aquaculture (CoGP, 2006) states that nets should be ‘inspected regularly for damage’ (Clause 4.9.1.6.4), there is no stipulation of the method or frequency. It is recommended that nets be visually inspected in situ (i.e. in their fully deployed position) prior to being stocked and after every time a net is changed or installed and at least monthly thereafter. Visual inspection requires the use of divers or cameras and whilst the latter may be appropriate on very small cages in good visibility, divers would be required in most cases. This inspection should be given a high priority by management; it should be carried out by person(s) dedicated to the task with sufficient time to do so, properly supervised and recorded [R5.9]. Given the difficulties with using cameras to fulfil this task, it is also recommended that research be undertaken into devices that could detect holes in nets [R5.10].

Visual inspections should really also be undertaken after each net lifting and dropping operation, such as swim throughs, grading, treatments and harvests. However, the use of divers on such an intensive scale would be a major financial burden on the industry and particularly on those companies operating swim through systems. Therefore, it is recommended that a cost-benefit analysis be undertaken with the results to be considered by the Improved Containment Working Group [R5.11].
Waterline protection

Double thickness netting is used by many farmers above and below the waterline (typically 0.5m or 1.0m above and below) to make it harder for predators to attack the cage net, as well as to provide additional protection against chafe and snags in this area of the net. This is particularly relevant to freshwater sites as otters and mink are typically thought to attack this area of the net. Whilst traditional net materials are usually used, at least one company has trialed the use of more innovative net materials to provide waterline protection with positive results.

One recent freshwater escape incident was caused by mink attacking the base of the net, indicating that waterline protection by itself is not sufficient protection should predators attack elsewhere. It has been typically thought that mink only attack at or near to the surface, and so this incident suggests that there is insufficient knowledge of predator behaviour and research into freshwater predators is recommended [R5.12].

It is recommended that all freshwater cage nets have additional protection through the use of double netting or similar 1.0m above and below the waterline to help reduce the likelihood of a successful predator attack [R5.13]. Whilst waterline protection may also be used to protect sea water sites against seal attacks in this area of the net, most seal attacks are on the net base or lower down the side.

Predator Nets

It is possible to surround the cage net by a second net to help keep predators at bay. Whilst such predator nets are fairly rare in Scotland, they are being used or trialled by several companies, including one that has been using them on an ongoing basis. The nets being used are either full box nets which completely surround the cage net underwater or a curtain net which does not go under the net but would usually be used in shallower sites where it can reach to the seabed. Predator nets are only in use at sites where seals are a known concern and during the autumn and winter when seal attacks are most likely.

It is understood that predator nets were in more common use in the early days of Scottish salmon farming. However, they cause additional complexities for operators, require considerable additional work and can lead to significant by-catch (i.e. the inadvertent catching of fish and other animals) and hence are no longer favoured by Scottish companies.

Predator nets in Scotland are hung on the outside of the cage and are weighted independently to the cage net; however, this does not always give sufficient separation to ensure that a seal cannot push up against the cage net. This may be one reason why the use of predator nets does not seem to be a proven success as there have been several successful predator attacks when they have been deployed.

Predator nets are in widespread use in Canada and Chile where there is the added risk of sea lion attacks. Such nets may well be positioned at a greater distance to the cage net and surround the entire site rather than individual cages. They may also extend above sea level to help prevent sea lion access over the top. Limited consultations

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23 Some sea water sites are also prone to otter attack where this measure may also be useful.
suggest that whilst predator nets in Canada and Chile do generate significant additional work and expense they are workable. Consideration could be given to a delegation visiting Chile and Canada to assess how predator nets are used and to identify any measures which may be useful for the Scottish context [R5.14].

For predator nets to be more effective, means to ensure that the level of separation between the cage net and the predator net remains effective throughout the depth of deployment is required. This does not yet appear to have been achieved through the current approach of hanging nets on the outside of the flotation tube or walkway and using individual weights to help maintain separation. It is recommended that research be carried out to try and identify more effective approaches to maintaining the separation of predator nets from cage nets, as well as making them easier to use [R5.15].

Cage nets can also be made to incorporate a false bottom, which is effectively an in-built predator net across the base of the net. Whilst this study has shown that seals do attack the sides of the net as well, which not all farmers realise, it appears that some if not most successful seal attacks are on the base of the net and hence false bottom nets could help provide secure containment.

False bottom nets, however, do bring disadvantages in terms of handling, cleaning and reduced oxygen flow, although they are not as difficult to work with as predator nets. They are not in common use in Scotland, only being used by one farming company to a limited extent at its sea water sites.

The use of predator or false bottom nets was not identified in Scotland for species other than salmon. Nor was any use identified in the freshwater environment.

**Fish Mortality Control**

Efficient removal of mortalities from cage nets is important to prevent seals becoming attracted to their presence. Whilst farmers recognise the importance of effective mortality removal in reducing predator attacks, there were differences in the timescale and approach. Many would not be meeting the CoGP requirement that, weather permitting, fish mortalities should be removed daily (Clause 5.3.5.1), since the policy of some companies is for twice weekly or weekly removal under normal operating circumstances.

A few companies use seal blinds in the area of the cage net designed to collect fish mortalities (i.e. in the central area of the base of the net). These are additional panels of thick material which is thought to help reduce seal attacks as seal blinds should keep mortalities out of the sight of seals pending removal.

It is recommended that research is undertaken into the extent to which mortalities attract predation. Should this be considered significant, then the mandatory use of seal blinds or the daily recovery or fish mortalities should be required [R5.16].

**Risk Assessment**

The CoGP requires a predator risk assessment for each site (Clause 4.9.1.7.1). This has been a constant source of non-conformance since the introduction of the CoGP at both sea water and freshwater sites, although this may have reduced during 2009 (see
Annex 2). However, these risk assessments are clearly being undertaken by many companies otherwise the number of non-conformances would be higher. That predator attacks persist suggests that the risk assessments are not being undertaken properly or that they are ineffective in reducing the risk of an attack. It is recommended that the usefulness of these risk assessments is improved by additional guidance to farmers on the measures that could be implemented and on the approach to risk assessments. This should include the use of measures highlighted in this section of the report [R5.17].

5.3 Preparing Escapes from Net Chafing and Snagging

Net chafing and snagging has continued to be an important cause of escape incidents, and one which appears to have become more prevalent with time.

Contributory Factors

A number of contributory factors have been identified which have been instrumental in chafing and snagging incidents. These are identified below and discussed in regard to potential solutions in the following sub-sections.

- A failure of prevention measures (e.g. protection on a shackle);
- Inadequate design (e.g. insufficient separation between a net and a mooring line);
- Poor equipment (e.g. cage with protruding bolts, weights with rough edges or equipment with sharp or abrasive edges);
- Poor maintenance (e.g. marine growth on a flotation tube which can chafe nets);
- Poor inspection and monitoring, thereby failing to identify issues which could be addressed by maintenance or replacement before they become problematic;
- Inappropriate facilities for operating a site (e.g. inadequate crane or winch facilities for the size of cage);
- Lack of knowledge about how to operate a specific net and cage system (including the weighting system); and,
- Poor management, supervision and training of staff.

Although, management, supervision and training are mentioned as a separate point in the above list, these are also factors in many of the preceding points. These contributory factors suggest that some staff involved in escape incidents either have insufficient awareness of the equipment they are using or that their knowledge is inadequately applied. Further, failure to operate systems correctly suggests poor supervision and management in some cases [C].

Several difficulties with regard to training, supervision and management particular to the aquaculture industry were identified during consultations with fish farmers 24. These are listed below:

- The range of different equipment that may be in use at installations within the same company;

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24 This is also an issue that has been repeatedly picked up by the government inspectors during containment audits (see Annex 2).
• Different operating systems between sites require different knowledge and skills to operate;
• Keeping staff up to date on new equipment and operating systems;
• The lack of opportunity to train on unstocked cages or simulators prior to working on stocked sites;
• Reluctance to train staff in their induction period in case they leave and hence the training costs are wasted;
• Difficulties in training staff who may speak limited English;
• Difficulties in motivating relatively low paid staff undertaking largely routine work in inclement weather conditions;
• The lack of structured training programmes in many companies, particularly in regard to operational issues;
• The large number of sites operated by many companies requires a higher proportion of supervisory staff than may be the case in many other industries; and,
• The remote nature of many sites means that communication and training is often difficult.

A number of the larger companies have been standardising their equipment across their Scottish sites to help address some of the above points. In particular this has included standardisation of weighting systems and net types. However, escapes in respect of such issues have continued, suggesting that more is required.

It is recommended that companies have specific operational procedures in place which address containment and particularly protecting against chafe and snag issues [R5.18]. Companies should be required to train staff in the type of equipment in use at the installation they will work at prior to undertaking work at any given site25. This should include details of the operating systems and procedures employed by the company, the role of different staff members in specific operations and the consequences of not following company procedures [R5.19]. Whilst it is recognised that initial training carries a risk that staff may leave before the company has reaped the benefits of this training, it is considered that initial awareness training on the type of installation they will be working on will reduce the likelihood of an escape incident.

The initial awareness training should include a classroom session where the workings of cage nets and weighting systems can be explained by the use of models or graphical representations [R5.20]. However, staff should also be given the opportunity to practise operations on unstocked sites where the consequences of different actions can be easily understood without the risk of escape incidents. It is recommended that consideration is given to the development of a national training centre where staff can be trained on unstocked sites; this could double as a research station to address some of the recommendations in Section 6.2 above. Alternatively,

25 This could be staged so that it only applies to the operations to which the trainee will be working; for example, there may be no need to immediately train staff in harvesting for a site where harvests are not planned in the near future.
companies should be encouraged to provide their own unstocked training facilities representative of the types of installations that they are operating. Staff should be required to undertake such training within their induction period prior to working on new types of equipment [R5.21]. Consideration should be given to including containment and aquaculture engineering within a national qualification scheme for aquaculture. However, staff who are unlikely to become involved on such schemes should also receive training on the importance of containment and on the measures required to ensure effective containment on the equipment they are using prior to starting work. Containment should also be included in the syllabus of training courses for operators of boats, forklifts and cranes [R5.22].

‘Tool box talks’ or other mechanisms to focus staff on containment issues and to gain suggestions prior to specific operations are recommended [R5.23].

The recent programme of SSPO containment workshops offered an appropriate method of disseminating best practice. This, or a similar programme, should be continued on an industry wide basis for freshwater and sea water, trout and salmon farming staff. Accompanying documentation should be made available to the industry [R5.24].

Training material should be translated as necessary for foreign staff and, if required, translators should be used for training [R5.25].

Net Design

The potential for chafe and snags should be identified and assessed for which a risk assessment approach could be utilised [R5.26]. This should include the requirement for fish farmers to prevent chafe and snags through a hierarchical approach, with prevention by design above protection. Whilst protection can reduce the likelihood of chafe on exposed parts, there have been incidents where such protection became eroded over time thereby leading to chafe and an escape incident and hence avoidance of the problem through design should be the preferred approach [R5.27]. The following issues should be addressed:

- The preferred type of material for cage weights should be specified and those to be avoided due to concerns about chafe (e.g. concrete) identified;
- Marine growth should be regularly removed from all equipment which could potentially (including under severe weather conditions) come into contact with the net (for example, cage collar for plastic circular cages and floats for steel cages, weights, bridles and perhaps some of the mooring grid);
- Farmers should be required to protect against net chafe from sinker tubes and their supporting chains/lines, preferably by design rather than mitigation; and,
- Protection, preferably by design rather than mitigation, against net chafe from all other cage and mooring equipment;

There have been recent incidents in Norway where chafe from sinker tubes or supporting chains has caused wear on cage nets. Therefore, farmers should be vigilant regarding the use of sinker tube systems at sites with high currents, unless appropriate measures have been taken to prevent chafe; this should particularly
include the design of nets such that they cannot come into contact with components of the sinker tube system as well as other elements of the mooring system. Farmers should be required to demonstrate that appropriate measures have been taken [R5.28].

A number of measures can be built into cage nets to reduce the likelihood of chafe leading to an escape incident. This particularly includes the following measures which are standard on the majority if not all nets, and others which may currently be specified by some but not all farmers:

- Ensuring that forces are taken by the net roping rather than the net mesh. This particularly includes the need for down ropes to be continuous (i.e. fully extend across the base of the net and up each side);
- Attachment at or from below the waterline;
- The use of a floatline (i.e. buoying the net all around the perimeter at the surface) to provide the net attachment point which may reduce the strain on the cage and net and prevent chafe at this point and/or protection at the waterline (e.g. 1.0m above and below the waterline);
- A gusset at the join of the side walls and base of the net to protect against a tear in the net at this point;
- Increased thickness/reinforcement or other protection in the vicinity of mortality removal systems, feed pipes, camera systems and other ancillary equipment;
- Increased thickness/reinforcement around areas taking additional strain, such as net attachment points.

It is recommended that all of the above measures be required within aquaculture nets in Scotland in both freshwater and sea water cages [R5.29].

Net Use

There appears to be limited information available to farmers about the potential amount of net deflection at specific sites for given conditions. The lack of such information means that it may be difficult for farmers to adequately assess the risk of chafe and snags on moorings and cages, and also the risk of entanglement on boats including on under water appendages as well as the propeller.

Ideally, farmers should hold information about the expected amount of net deflection in different environmental conditions for their sites. However, this may be a difficult and expensive undertaking and the practicality and accuracy of determining this information is not known. The practicality of providing such information should be discussed with the net manufacturers and installation designers by the Improved Containment Working Group and industry representatives [R5.30].

A protocol for well boat and other large vessel access for each site is recommended, as well as for the use of work boats; this should be provided by the farmer [R5.31]. A specification should be provided for the minimum operating distance between propellers and critical elements of the cage systems, including nets and mooring grids; vessels should be assessed prior to visiting the site. Consideration should be given to
There appears to be no information on the potential for well boat thrusters to distort the net, cause entanglement or affect net longevity. Whilst there have been few incidents due to well boats in Scotland, this is an increasing area of activity and therefore research into this area is recommended [R5.33].

Farmers send those staff involved in operating boats on training courses, specifically the powerboat courses to the RYA (Royal Yachting Association) Powerboat syllabus for those operating open boats and for those operating larger work boats to the Maritime and Coastguard Agency (MCA) Boatmaster’s syllabus. It is recommended that all such training, as well as that related to crane use includes elements in respect of containment, particularly in regard of manoeuvring boats and handling cranes to avoid net damage. It is recommended that the Improved Containment Working Group and industry representatives liase with the relevant agencies to ensure that such issues are included on the relevant syllabus, either as a standard requirement or as additional modules [R5.34].

Another area of concern in regard to net longevity is the use of net washers – both off-site and in situ. Again, there appears to be little apparent information in this regard. Nets are getting larger and there is an increased interest in moving away from the use of antifoulants, making the use of net washers more likely. Whilst one consultee had evidence of damage from high pressure washing, empirical research into this area is recommended [R5.35].

A number of farmers identified net shrinkage as an issue which has caused operational difficulties and perhaps gives an increased likelihood of net failure. From a containment perspective, it is of particular concern if it results in the net not being effectively supported at the cage collar, which may lead to greater strain on the net and stanchions. Farmers should ensure that only nets appropriately dimensioned are used for the cage in question. Consideration should be given to specifying the minimum (and maximum) net dimensions for specific cage sizes [R5.36].

Net handling operations are of particular concern since a net which snags on equipment under water can then be easily holed. This is of increasing concern since the increasing size of nets means that cranes are now used and it is very much harder for a crane operator to know when a net has snagged compared to when personnel are used. Following discussion with one crane manufacturer, research should be carried out into the use of limiters or other mechanisms to help prevent damage to nets which have become snagged on cage components when being lifting by crane or hauler [R5.37].

The issues identified in the section under predators in regard to net longevity apply equally in regard to addressing chafing and snagging and similar research and specifications are required (see section above for further details).

5.4 Net Specification and Strength Testing

Whilst the CoGP includes a clause on net strength testing (4.9.1.6.3), this was widely considered by consultees to not have aided improved containment since values were
below those being used. Also, there is no standard protocol for net strength testing, specifying the instruments and methodology to be used. There appeared to be less knowledge of net strengths in the trout industry. Whilst strength testing is included within the CoGP, and is widely undertaken by the majority of salmon farmers, there are some who do not undertake this which is also the case at many trout sites. Quality Trout UK (QTUK, 2008) does require nets to be tested based on manufacturer’s advice but no net strengths (or testing protocols) are specified beyond this requirement. Whilst the limitations of strength testing are recognised, it is the only quantitative tool open to the industry to assess net condition and hence it should be ensured that all farms undertake net testing on an ongoing basis. A standard protocol specifying the instruments and methodology of net testing should be developed under the auspices of the Improved Containment Working Group and included in a new technical standard.

It should be required that nets of appropriate strength, design and construction are used in respect of the level of exposure of the site. Therefore, there needs to be a classification according to locality in a similar vein to that being done in some other countries.

Whilst the CoGP (4.9.1.5.2) refers to mesh sizes being capable of containing the smallest fish there is no specification in this regard. Maximum mesh sizes relative to minimum fish weights should be prescribed.

5.5 Closed Containment Systems

As described in Annex 1, there has been much interest in the development of closed containment systems which could greatly reduce the risk of escapes due to the use of a physical barrier between the fish and the surrounding environment instead of cage based systems. However, closed containment is not considered economically viable for Scottish finfish farming and hence does not represent a viable alternative to cages in the foreseeable future.

There is an international research project which is looking into the development of closed containment and it is recommended that the Improved Containment Working Group and industry representatives take note of any relevant outputs.

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26 Note that there is a written protocol for net testing in British Columbia – see Annex 2 for further details.
6.0 Land-based Farms and Stock Transfers

6.1 Introduction

This chapter focuses on land-based finfish farming in Scotland, specifically in tanks, earth ponds, raceways and hatcheries. The former includes both salmon and trout, whilst earth ponds and raceways relates largely to trout farming. Juveniles are also reared in freshwater lochs which have been considered in Chapter 4 in regard to moorings and cages, and in Chapter 5 for nets.

6.2 Freshwater Tank Sites

Whilst escapes from screen failure are relatively small, they continue and should be easily addressed. Although some commentators speculate that there may be an additional 'leakage' of small numbers of escaping fish over long periods of time from tank-based facilities above reported incidents, this project did not identify any quantitative information of such incidents.

Tank screens are commonly fabricated from aluminium and can be easily damaged during routine operations creating opportunities for, usually minor, escape incidents. Such escapes should be mitigated by the use of a ‘mortality tank’, outwith the main fish tank, which can catch escaping fish as well as being used to collect fish mortalities or by similar means [R6.1]. The Code of Good Practice for Scottish Finfish Aquaculture (CoGP, 2006) requires the outflow from a settlement pond to be screened (clause 4.9.5.3). The design of the screen should be such that fish cannot pass through the screen apertures or around the frame sides. Aluminium and plastic should not be used as a material for final screens discharging directly to a watercourse. Consideration should be given to specifying the design of final outflow screens such that any 'leakage' escapees are retained by them [R6.2].

The use of a secondary system to contain escapes in the event of catastrophic tank failure is a current concern in Norway (Norwegian Ministry of Fisheries and Coastal Affairs, 2009, pers. comm.). Consideration should be given to such facilities in Scotland although it should be recognised that such failure is perhaps less likely in Scotland as tanks are understood to be typically much smaller. Consideration should be given to a secondary containment system on new tank sites or the redevelopment of existing ones, whilst for existing sites farmers should assess the risk and provide such facilities where it may be considered significant [R6.3]. Protection against tank failure caused by site operations, such as forklift movements, is required on sites where this could be a potential issue [R6.4].

6.3 Transfer Pipe Failure

Transfer pipes are used to move fish to and from well boats and lorries. Although escapes from transfer pipe failure are not large, they continue and should be easily addressed. Transfer pipes should be inspected prior to use and during use, particularly just after starting the operation when any issues may become evident. Pipes with visible damage, including leaks should be prohibited from use [R6.5].
There has been concern with the older type of ‘mucon’ valve which led to one incident. The types of valves appropriate for use should be researched and specified [R6.6].

Secure methods of attachment from the pipe to the tanks and at each join of lengths of pipe should be provided. They should be inspected prior to and during use. Consideration should be given to measures to ensure they remain secure during use and, perhaps, to a secondary coupling [R6.7].

A means of immediately alerting operators in the case of problems should be provided, and operators should be trained on their use [R6.8].

### 6.4 Helicopter Bucket Incidents

There have been four helicopter bucket incidents since May 2002, resulting in a reported loss of nearly 14k escaped fish. Three of these were caused by the failure of the bucket locking mechanism. Whilst these are relatively small incidents, they should be preventable by, for example, the use of a second locking device. Alternatively, the lock needs to be made failsafe such that it cannot inadvertently open if it becomes caught on an obstacle or receives a hard blow such as during a harsh landing. It is recommended that the industry consults with helicopter companies in order to improve the design of the bucket locking mechanism [R6.9].

The fourth helicopter bucket incident was caused by the failure of lifting apparatus on a well boat crane. There was also an escape incident caused by the failure of lifting equipment on a work boat crane. All lifting gear is subject to statutory health and safety requirements and therefore such failures are of concern. The need for companies to regularly inspect lifting equipment and to consider how to address this with contractors should be part of all farmers’ health and safety systems; it is recommended that reference to such requirements are made within Scottish finfish farming protocols in regard to containment [R6.10].

### 6.5 Flooding

There were just two flooding incidents that led to escapes, although this represented 5% of the total number of escapes during this period, which is quite high. There were also two near misses in regard to flooding. A major flooding event leading to large fish loss (either through escape or fish mortalities) could have a catastrophic impact upon the viability of land-based sites, particularly the smaller trout operators.

From discussion with a number of farmers, it is evident that some sites are at far more risk than others. It is recommended that a flood risk survey of all land-based sites is undertaken so as to identify the number that may be at risk from flooding [R6.11].

Certain measures can be undertaken to help prevent floods causing escapes. Although many would be site specific, they may include the following:

- Secure restraint of tanks to prevent them being washed away;

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27 The immediate cause of this incident was identified as ‘net under water’ and this is discussed in Chapter 8.
• Protection against tank foundations being eroded or undercut;
• Netting or covers to the top of tanks to prevent fish escaping;
• Netting the top of earth ponds and raceways to prevent fish escaping;
• Siting of mechanical, electrical and electronic equipment (as well as fuel, oils, consumables and wastes) so as to be above the height of flood waters;
• Ensuring that flood waters would not result in screens being bypassed;
• The raising of outflow screens and frames;
• The raising of inflow screens and frames;
• Ensuring that inflow screens are sufficiently robust and appropriately sized to keep the inflow clear of flood debris;
• Ensuring that inflow screens can be safely accessed in flood conditions for maintenance purposes;
• Ensuring that oxygen systems and pumping equipment is suitable for use in flood events;
• Engineering works to prevent flood water affecting the site in the first place; and,
• Engineering works to protect the outflow from backing up which may include flood barriers and pumping systems.

A flood risk assessment should be undertaken of all land-based farms and appropriate mitigation measures identified, which may include those listed above. Consideration should be given to these assessments being undertaken by an independent organisation. These assessments should be reviewed and a strategic assessment of flood risk should be made by the Improved Containment Working Group [R6.12]. Good practice guidance on flood risk assessments and associated mitigation measures should be provided [R6.13].
7.0 Addressing Other Causes of Escape Incidents

7.1 Fish Handling

Fish handling has accounted for a relatively small number of incidents (7) and escaped fish (713) although there does appear to be an increased amount of very small incidents, or the increased reporting thereof.

Five of the seven handling incidents were caused by errors when handling fish for inspection, presumably using a hand net, and one was caused by a fish jumping off a harvest table. All these incidents should be easily preventable and companies should have in place measures to prevent them.

One of these incidents was interesting because it was caused by a Government inspector and yet is reported against the fish farming company. It is recommended that only fish farm staff should be involved in handling fish, for example by taking the required samples under the direction of the inspector, so as to prevent such occurrences in the future and ensure that responsibility lies with the farmer. Alternatively, such incidents should be reported against the Government or against a ‘third party’ [R7.1].

The largest handling incident was caused by the introduction of fish into a net where the mesh was the wrong size. Whilst any experienced member of staff should have been sufficiently knowledgeable to prevent this incident, the company or site supervisor should ensure that there are working methods in place which ensure that nets and stock are checked prior to transfer [R7.2].

7.2 Net Under Water

There were six incidents caused by the net being under the water. Five of these accounted for relatively small escape incidents, but one was particularly large. The small ones included issues connected with the net not being properly secured, failure of a crane lift, and the weight of fish mortalities on the net. The large one was caused by chafe/snag.

A number of contributory factors were identified, including equipment specification, bad weather, training and supervision. Some of these elements could be addressed through the specification of equipment, others by risk assessment and others by training as mentioned elsewhere in this report.

7.3 Vandalism

There were four vandalism events which have led to escapes totalling just below 29k – a little over 1% of the total escapes during the period. Whilst this figure is relatively low, it is of concern since aquaculture equipment is quite vulnerable to determined attacks and is hard to protect. Although many sites are remote and often require boat access, some are more easily accessible.

Industry representatives should initiate a dialogue with the police and, possibly, private security experts to look into security arrangements for fish farming. Should there be cost-effective issues which could be implemented, these should be publicised.
to the industry. Given the relatively low incidence of these attacks, this should not currently be accorded a high priority [R7.3].

7.4 Well Boat Collision

There was one incident of well boat collision which, due to confidentiality, is not discussed in detail. Reference should also be made to collision as an underlying cause in cage and mooring failure, which is discussed in Chapter 5. In addition to the recommendation made in Chapter 5, full communication between company representatives on the appropriate cages and an approaching sub-contracted vessel is recommended [R7.4].
8.0 Protocols

8.1 Introduction
The preceding chapters have identified areas where actions are considered necessary to reduce escapes. In many cases this has included a suggestion that an action ‘should’ be undertaken; i.e. that it should become a requirement. In this chapter attention is given to how protocols could be revised to provide the mechanisms for delivering these requirements.

Finfish farming is a global industry which is essentially controlled, from a legislative perspective, at the national or state level. In addition, there are a range of non-legislative protocols which producers may agree to conform to – either voluntarily or through regulatory endorsement of the protocol. Some of these protocols apply nationally or at the state level, and some are international.

Information on relevant protocols in regard to Scotland and finfish farming worldwide was obtained from a number of sources, as described in Chapter 2. Whilst this included a range of countries and states, the focus was on those considered of most interest to Scottish aquaculture, specifically those used in Norway, Canada, Chile, the USA and Ireland as well as Scotland. This information was collated and is included in Annex 2.

8.2 Scope of Requirements
From the salmon perspective, it is evident that the Scottish salmon sector has more onerous protocol requirements for containment than some of the other producing countries and provinces/states, but less than others. Whilst, for freshwater trout, it is understood that containment requirements are in advance of most other countries.

Aquaculture Installations
Chapter 4 recommended that aquaculture equipment for cage sites should be subject to specific requirements in regard to environmental monitoring, the design process, specification of components, site exposure, maintenance and installation. It is considered that such requirements would be too detailed to be included within the existing Code of Good Practice for Scottish Finfish Aquaculture (CoGP, 2006) and that a detailed aquaculture technical standard should be developed instead. This would cover salmon and trout production as well as other species in both sea water and freshwater cage environments [R8.1].

Cognisance should be taken of the Norsk Standard NS 9415 in regard to a Scottish technical standard. Whilst NS 9415 does not include all issues recommended in this report, it would provide a useful basis for the development of a Scottish technical standard. However, particular note should be taken of the fact that the standard, including the location classifications, was developed for the Norwegian operating environment, which is typically considered to be less exposed than Scotland and hence the suitability of this standard for use in Scotland should be reviewed [R8.2]. It should also be noted that NYTEK does not cover freshwater. A Scottish standard will need to cover freshwater.
It should also be noted that Standards Norway is working on the internationalisation of NS 9415 through the International Organization for Standardization (ISO). Given that NS 9415 would most likely require adaptation for use in Scotland, it is recommended that Scotland commits to the mandatory adoption of a future aquaculture standard, possibly ISO if it is suitable for Scottish specific circumstances. To ensure that such a standard is appropriate to the Scottish industry, active involvement by relevant persons on the ISO Committee is recommended [R8.3].

Given that an ISO aquaculture standard is unlikely to be developed in the short term, it is recommended that interim requirements in regard to establishing new cage sites or modifying existing ones are implemented. These could form a stand alone document addressing the recommendations made in Chapter 4 of this report on cages and moorings [R8.4].

Operating Practices
The current version of the CoGP and Quality Trout UK (QTUK, 2008) includes a section on containment. It is considered appropriate that CoGP and QTUK are used as the vehicle for delivering containment issues in regard to the operation of fish farms and on training requirements. This is because both the CoGP and QTUK are existing and well known codes with an established audit structure. Their use, rather than the development of another standard, would also help to reduce the proliferation of standards which has become a burden in the industry over recent years [R8.5].

An alternative model would be to make more use of ISO 14001 which could also help deliver new requirements in terms of operations and training. ISO 14001 is already used by many Scottish salmon farmers (although not by the trout industry) and also operates within an existing audit structure.

8.3 Legal Status
There are no legal requirements relating to containment, such as equipment specification or fish farm operation, in respect of Scottish finfish farming, although there are requirements to report escapes28 and to keep certain records pertaining to containment29. This contrasts with Norway where there are legal requirements in regard to the design and specification of equipment for floating installations and in regard to the operation of a fish farm. In regard to design and specification, this is through a technical standard, NS 9415 (Norsk Standard NS 9415, 2003), which is implemented in law through the NYTEK regulation (Norwegian Ministry of Fisheries and Coastal affairs, 2005)30.

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28 The Registration of Fish Farming and Shellfish Farming Businesses Amendment (Scotland) Order 2002. Note that the forms were subsequently revised in the following legislation: The Registration of Fish Farming and Shellfish Farming Businesses Amendment (Scotland) Order 2008.
29 The Fish Farming Businesses (Record Keeping) (Scotland) Order 2008.
30 Whilst the 2003 version of NS 9415 has been reviewed for this report, it is understood that a second version has recently been published which includes some changes; however, since a translation was not available at the time of reporting, the reviewed version has not been considered in this report. It is recommended that the Improved Containment Working Group and industry representatives review the most recent version of NS 9415 when a translation is available [R8.6].
Instead, a voluntary approach to containment has been implemented in Scotland which is centred on the CoGP and QTUK. Whilst the CoGP is voluntary, it has been adopted as a condition of membership by the Scottish Salmon Producers’ Organisation (SSPO). Further, the containment clauses of the CoGP have largely been incorporated into the trout farming standard, QTUK. Although QTUK is not a condition of membership of the British Trout Association (BTA), BTA strongly recommended its adoption by its members.

Since some 95% of farmed fish tonnage in Scotland is produced by companies working in accordance either the CoGP or QTUK, most is produced in accordance with the containment requirements of the CoGP. However, it is considered inappropriate that five per cent of the industry is working outwith the CoGP – especially as there are no other protocols with detailed and specific containment requirements which are adopted by Scottish farmers. Although five per cent is a small amount of tonnage, this represents a number of companies and the potential remains that one or more could have (or continue to have) escape incidents. It is, therefore, recommended that a framework is put into place by which containment, including specification, operation, training and managerial issues – is a requirement for all finfish farming in Scotland [R8.7].

The mandatory adoption of containment requirements could be delivered through the adoption of relevant codes of practice, or parts thereof, under the Aquaculture and Fisheries (Scotland) Act 2007 or by the development of new legislation. Given that the 2007 Act has provision for such adoption, it is recommended that this approach be used [R8.8].

8.4 Process and Outcomes

That the current CoGP does not appear to have been completely effective in ensuring secure containment suggests it could be improved in terms of specification, coverage, structure, implementation and/or inspection.

As highlighted elsewhere, it is considered that fish farmers operating in Scotland should be subject to specific technical (including moorings, cages, components and nets) and operating requirements. It is considered that the technical issues should be specified in a detailed document including the design process and specification of environmental monitoring, moorings, cages, components, nets and related equipment.

In terms of operating issues, it is considered that a risk assessment approach should be applied to address chafe/snag so that individual issues are addressed on a site specific basis (see R5.26). This would also ensure that containment considerations keep up with innovation. However, the minimum requirements and guidance on both the risk assessment process and the issues to be considered should be included within a revised CoGP. Examples of risk assessment protocols are the current CoGP (Annex 2) approach with regard to fish health and HACCP (Hazard Analysis Critical Control Point) familiar to farmers in respect of food safety and used in the Maine Aquaculture Association Generic Containment Management System (see Annex 2). Cognisance

31 As highlighted in Annexes 2 and 3, there has been a marked reduction in escape incidents since 2006, although still not approaching complete containment. Whilst there has also been a reduction in the number of escaped fish since 2006, there is not such an obvious downward trend in this regard.
could also be given to the health and safety approach, whereby examples of risk assessment are provided on the Health and Safety Executive’s (HSE) website whilst specific issues are addressed within approved codes of practice.

8.5 Inspection and Enforcement

CoGP and QTUK Audits

Companies working in accordance with the CoGP and QTUK are audited against their respective requirements. The CoGP audits have been undertaken by Food Certification International Ltd (FCI) since the implementation of the Code in 2006. FCI provided information on compliance which is presented in Annex 2.

QTUK is accredited under EN 45011 and audited by SAI Global. It is a standard which covers the operational procedures and practices for the production of farmed rainbow trout which incorporates containment sections of the CoGP relevant to trout farming.

Farmers have adjusted to the CoGP by formalising and documenting husbandry practices. In freshwater, for example, fish transfers, handling and grading are increasingly being risk assessed, and operational procedures followed and documented. In so far as such management system processes improve efficiency, containment will have improved also.

There are still, albeit fewer, operational and managerial issues with regard to conformance with CoGP cage net clauses. Net information, specification and net records non-conformances are generally declining, but non-compliances in freshwater and, to a lesser extent sea water, persist.

Certain clauses incur a consistent level of non-conformances, specifically fish handling and transfer contingency planning (in sea water more than in freshwater), and predator risk assessment on a site by site basis. The latter is a controversial and important clause in relation to containment which featured in the SSPO workshops, indicating a level of concern, and perhaps also confusion, by the industry.

Nevertheless, it is important to note that there was 100% conformance to many clauses throughout the period. However, the continued number of non-conformances indicates that there is opportunity for improvement.

Scottish Government Containment Inspections

As is evident from Annex 2, the Scottish industry is widely audited against a variety of protocols, many of which involve the inspection of similar records and activities. Given this backdrop of existing audits, it is considered that the recently commenced containment inspections and audits undertaken by Marine Scotland under the Aquaculture and Fisheries (Scotland) Act 2007 add little to aid the improvement of containment standards. This is emphasised by a review of their findings undertaken for this project (see Annex 2) which highlighted that most were record keeping issues rather than related to measures that would be expected to tangibly improve
Nevertheless, a significant number of operational issues of concern were noted, including:

- Holes in nets;
- Protecting nets from ultra violet light during storage, which can cause degradation;
- Lack of a net testing regime;
- Damage to cage hand rails; and,
- An improperly weighted net.

It is recommended that the scope of the containment Government inspections is increased so as to be more effective. This should include means of assessing the issues that are key in the cause of escape incidents, including the specification and condition of moorings, cages and nets, as well as operational practices and training [R8.9].

A number of containment audits should be undertaken by Marine Scotland at short notice (e.g. two days) across a proportion of the industry each year. Whilst this should take account of corporate performance on containment and prioritise areas of greatest concern, it should include a variety of companies, operating conditions and equipment [R8.10].

Several incidents have been caused by the use of poor equipment or lack of maintenance at companies experiencing financial difficulty, quite often after a new company has acquired the site in question. Therefore the due diligence process for acquisitions should also include a containment audit [R8.11]. The mechanism for delivering this could, perhaps, be through planning consent conditions. Consideration should be given to mechanisms that require companies to act on the findings of such a containment audit in the acquisition process; this could again be through the planning process [R8.12].

Not all the current CoGP clauses regarding containment are easily auditable. It is therefore recommended that advice from auditors is sought in order to ensure that revisions to the CoGP and QTUK as well as the proposed new technical standard can be effectively audited [R8.13].

### 8.6 Incident Investigation

A mechanism to investigate the causes of escapes and to deliver high level recommendations to both industry and Government is recommended. It is considered that all significant escape incidents and near misses should be investigated in detail on-site immediately after the event. This could be undertaken by independent companies, government officials or universities with appropriate technical knowledge and industry experience under the auspices of the Scottish Government Improved Containment Working Group [R8.14].

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32 This issue was discussed with a small number of fish farmers, none of whom thought that the audits undertaken by Marine Scotland have or would help to improve containment. However, it is noted that some stakeholders consider that the process of implementing and maintaining records as required by the relevant legislation is bringing focus to the suitability and maintenance of equipment.
Recommendations from an incident investigation should be considered by the Improved Containment Working Group as well as the company concerned and any general feedback should be made available to the industry and its supply chain. The Working Group should, on the basis of such investigations, have the authority to make recommendations for a change in practice to be implemented within the relevant protocol [R8.15].

Cognisance should be given to the Norwegian Escapes Committee and the role played by SINTEF in the investigation of escape incidents in Norway which has been a very useful way of providing feedback to the industry on escape events. The Committee has also been instrumental in the revision of NS 9415 [R8.16].

8.7 Culture

Although the use of protocols is an essential part of driving forward containment performance, consultees (particularly in Norway) emphasised the importance of developing a culture of minimising escapes. It is noted that the Scottish Government have heightened containment through the renewed Strategic Framework for Scottish Aquaculture (Marine Scotland 2009) and the associated establishment of the Improved Containment Working Group and that large portions of the Scottish industry have given containment a high priority over recent years, as is evident by the considerable expenditure on capital equipment.

Nevertheless, it is considered that more could be done by the Government and the industry to raise awareness of containment and to develop an enhanced focus in this regard. It is recommended that an aspirational target of 100% containment be established, promoted by the Scottish Government and industry representatives, backed up by a national awareness campaign throughout industry [R8.17].

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33 It should be noted that the Government through the Fresh Start Initiative and the associated Improved Containment Working Group, along with the SSPO, equipment suppliers and individual farmers have put in place measures to increase the focus on containment.
9.0 Conclusions and Recommendations

9.1 Introduction

The recommendations developed in the text\(^{34}\) are collated below. They are prioritised according to those considered likely to have a greater impact on improving containment, with higher priority recommendations in bold. Each set of recommendations is preceded by commentary to present the relevant conclusions and context.

There are a wide range of causes and factors behind escape incidents in Scotland. Therefore, there is no single remedy that will reduce escape incidents and instead attention should be given to all the recommendations across sea water and freshwater sites and Atlantic salmon and rainbow trout production. Nevertheless, priority should be given to hole in the net incidents caused by predation and chafe/snag as well as cage and mooring failure due to the use of inappropriate cages and moorings as these accounted for 54% of incidents and 60% of escaped fish between May 2002 and October 2009.

9.2 Establishing a Mechanism for Improving Containment

Escapes have been a persistent issue for the Scottish fish farming industry since records began in May 2002 and there is no indication that the trend is towards zero or minimal escapes. This suggests that the current Code of Good Practice for Scottish Finfish Aquaculture (CoGP) (CoGP, 2006) and Quality Trout UK (QTUK, 2008), which are the key protocols for containment requirements have delivered total containment to date\(^{35}\). Recommendations are presented to change the mechanism of addressing containment as well as addressing the detailed requirements to which the industry should work.

New Technical Standard and Revised CoGP and QTUK

The issues raised in the report regarding new and modified cage sites are considered too onerous and detailed to sit within existing protocols and hence a new mandatory technical standard is recommended. Given that fish farm sites are located in sites with widely differing levels of exposure, this standard should be based around the classification of sites according to their level of exposure with the specification of minimum standards of equipment for each level of site. This would help prevent the occurrence of escapes, particularly in major storm events.

Regarding the operation of fish farms and staff training, revised CoGP and QTUK are considered appropriate to contain the recommendations included in this report providing that they are mandatory. These schemes are well known to farmers, have an existing audit system and their use avoids the establishment of another standard.

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\(^{34}\) Recommendations are identified in the body of the report in square brackets with the prefix ‘R’ and are numbered on a chapter by chapter basis. Reference should be made to the relevant chapter and annex for further information on each recommendation.

\(^{35}\) Although the number of incidents has reduced since their introduction which suggests they may have had a positive effect.
To ensure compliance, it is inappropriate that the containment requirements apply to 95% of the industry (by tonnage) rather than all fish farmers. Therefore, a new technical standard and the revised CoGP and QTUK should be mandatory.

Whilst the Government has recently started to undertake containment inspections, these are considered of limited use in identifying the causes of escape incidents. There is also no mechanism to inform the industry of findings and subsequently change protocols from such inspections.

Some escape incidents have been caused through poor equipment and lack of maintenance at companies suffering financial difficulties. Whilst this is a difficult issue to address, the heightened risk of an escape incident when a company is in financial difficulty or when sites have been recently acquired needs to be considered.

**R4.10**

A technical standard which sets out the minimum requirements for moorings, cages, barges and individual components when establishing a new cage site or modifying an existing one is recommended. This should be location specific, meaning that installations at more exposed sites would be required to have higher specifications. Aquaculture sites would, therefore, be classified on the basis of exposure and equipment specified accordingly.

**R4.11**

In order to deliver this technical standard, Scotland should commit to the mandatory adoption of an aquaculture standard which suits Scottish circumstances. The Scottish industry and Government should be proactively involved with proposed development of an ISO aquaculture standard to ensure that it is appropriate to the Scottish industry.

**R4.12**

In the interim, specific requirements in regard to establishing a new cage site or modifying an existing one should be implemented in Scotland, perhaps in the form of a stand alone document, which should address the above issues. (Cognisance should be taken of the Norsk Standard NS 9415 as it would provide a useful basis for a Scottish technical standard, although it should be reviewed to assess its suitability for the Scottish industry giving particular regard to the location classifications. An updated version of NS 9415 has recently been published; this should be reviewed by the Improved Containment Working Group when an English translation is available.)

**R4.13**

Revised CoGP and QTUK should be used as vehicles for delivering containment issues in regard to the operation of fish farms and training requirements.

**R8.13**

Revisions to the CoGP and QTUK as well as a new technical standard should be undertaken with advice from auditors to ensure that it can be effectively audited.

**R8.7**

All fish farmers in Scotland should address containment issues rather than just those currently working to the CoGP and the QTUK. These codes should be revised as required and then made mandatory using powers under
the Aquaculture and Fisheries (Scotland) Act 2007.

**R8.9**  The scope of Government containment inspections should be increased so as to be more effective. This should include issues that are key in the cause of escape incidents, including the specification and condition of moorings, cages and nets as well as operational practices and training.

**R8.10**  Some containment audits should be undertaken by Marine Scotland at short notice across a representative range of fish farming companies.

**R8.11**  Marine Scotland should undertake containment audits of each site and the associated equipment of any company that is known, or thought to be, entering financial difficulties.

**R8.12**  The due diligence process for acquisitions should include a containment audit of each site and the associated equipment and any key issues should be addressed. The mechanism for delivering this could, perhaps, be through the planning process.

**Consideration of Existing Cage Sites**

As well as new or modified installations (considered above), attention should be focused on existing installations as some of these have not been designed or specified by mooring professionals. However, since a full engineering assessment of every existing site would be time consuming, expensive, and not warranted in many cases due to the level of the existing specification, a staged approach is suggested.

**R4.16**  The integrity of all existing floating installations in Scotland should be verified. A staged approach is suggested including an initial screening with new mooring calculations undertaken if required. Should the installation integrity be of concern an upgrade would be required.

**Obtaining Information to Improve Containment Performance**

This report has demonstrated that the collection of detailed information on escape incidents and near misses, including classification according to the immediate and underlying causes and the identification of contributory factors, provides greater insight into the nature of an incident. This is considered an essential basis to improve the containment performance of the industry.

**R3.3**  Greater information is required on the Notification Forms used to report farmed fish escapes to the Government. Any incomplete or inadequately completed Notification Forms should be followed up by the Government to ensure that full information is provided in a timely manner.

**R8.14**  All significant escape incidents and near misses should be investigated on site, in detail, immediately after the event, by persons with appropriate technical knowledge and industry experience, under the auspices of the ImprovedContainment Working Group.
| R8.15 | Recommendations from an incident investigation should be considered by the Improved Containment Working Group as well as the company concerned, and findings made available to the industry and supply chain. The Working Group should make recommendations to the relevant protocol and inform development/improvements to CoGP operational procedures. |
| R8.16 | Cognisance should be given to the Norwegian Escapes Committee and the role played by SINTEF in the investigation of escape incidents in Norway. |
| R3.4  | Escape information on Government records should be classified by immediate and underlying causes to allow trends to be identified. This should include international collaboration when determining classifications. |
| R3.5  | The recently adopted practice of reporting the causes of escapes on the Scottish Government website should be continued. This should include the underlying as well as immediate causes of the incident. An annual report on Scottish finfish escapes is also recommended which should provide a summary of the causes and compare data with previous years and other countries. |
| R3.2  | The Scottish authorities should consider including unexplained losses and fish mortalities as well as escape information in the annual production data published by Marine Scotland. |
| R4.27 | A symposium should be held to bring fish farmers and stakeholders up to date on aquaculture engineering; this should become a regular event, perhaps held every two years. |

Prioritising Containment

Discussions with consultees in Norway highlighted that whilst the technical standard NS 9415 Norsk Standard (NS 9415.E, 2003) had been instrumental in addressing the integrity of floating installations, of equal importance was work undertaken to promote a containment focused culture. The facts that a number of Scottish companies have operated without a reported escape incident (including some in areas with high levels of seal activity) and both British Columbia and Newfoundland have had some years without any escape incidents suggest that performance at or close to 100% containment should be possible.

| R8.17 | An aspirational target of 100% containment for the Scottish industry promoted by both the Scottish Government and industry representatives is recommended, backed up by a national awareness campaign throughout industry. |
9.3 Detailed Content of a New Technical Standard on Establishing a Cage Site and Modifying an Existing One

Cage and mooring failures accounted for the highest number of escape incidents between May 2002 and October 2009 (1m fish, 46% of total escapes). Many of these losses were related to the January 2005 storm (700k fish and 10 of the 14 incidents). It is considered that floating installations should be able to withstand storms of such magnitude and many farmers that suffered losses in this storm are confident that their sites would now withstand the same event due to changes to plastic circular cages and a general increase in the specification of mooring equipment.

A number of issues were identified which are of concern, since these do not give confidence that future severe storm events or other incidents would not lead to further escape incidents, including:

- Some mooring design and equipment specification is not undertaken by a professional who could ensure that key issues are satisfactorily addressed;
- It was not apparent which standards are used as a basis for installation design;
- The environmental monitoring information used as the basis for the design of new installations does not always include the full range of variables required, nor is it necessarily undertaken for a sufficient period at a time of year when conditions may be expected to be at their worst;
- There have been occasions when farmers have significantly modified their sites, or the operation thereof (including the use of well boats and feed boats), without recourse to a mooring professional to assess whether the existing specification is satisfactory;
- Mooring failures – in both sea water and freshwater – have started with the failure of a single component;
- On occasion, the scope of a mooring has been reduced below the preferred ratio to fit within the licensed area; and,
- A collision between a ship and a fish farm in the Mediterranean suggests that the risk of collision in Scotland should be considered.

General Principles

| R4.9 | The engineering and meteorological standards to be used as a basis for installation design should be specified; if existing standards are inappropriate or outdated, industry representatives should engage with the relevant professional institutions to help ensure they are appropriate. |
| R4.6 | A specific return period\(^{36}\) should be specified based on advice from meteorologists and engineers. All installations should be comfortably able to withstand weather conditions such as the January 2005 storm as a minimum, with an additional safety factor. |

\(^{36}\) For example, a one in fifty year storm or one in a hundred.
| R4.3 | Environmental data appropriate for designing moorings and specifying equipment for new sites and modifying existing ones should be obtained for a specified range of variables and time period (including when conditions would be expected to be at their worst). |
| R4.4 | R4.5 | Alternatively, a series of specifications could be provided to which a site could be designed which would represent a worst case situation or consideration could be given to a national (or regional) categorisation of aquaculture locations based on the collection of environmental monitoring data through an independent third party. |
| R4.7 | R4.8 | Installations should be designed on the basis of the predicted worst case conditions and to allow for the failure of key components\(^{37}\). |
| R4.1 | Moorings and cages should be designed by suitably qualified and experienced persons. Alternatively, the farmer’s design should be approved by a suitably qualified third party. |
| R4.2 | The Improved Containment Working Group should consider whether qualifications for mooring and cage design should be specified or whether to make this an accredited activity. |
| R4.23 | Any significant changes to an existing site should be undertaken with the advice of a suitably qualified and experienced mooring professional who should advise on whether a change to the cage and/or mooring specification is required. Any required alterations should be implemented by the farmer before the site is stocked or the new elements of the installations are used. |
| R4.21 | The Improved Containment Working Group should consider whether minimum qualifications should be specified for persons laying moorings and, if so, what these should be. |
| R5.29 | Nets in both freshwater and sea water should include the following measures: |
|       | • Ensuring forces are taken by the net roping rather than the mesh; |
|       | • Ensuring that down ropes are continuous; |
|       | • Attachment at or from below the waterline; |
|       | • A gusset at the join of the side walls and base of the net; |
|       | • Increased thickness or other protection in the vicinity of mortality removal systems and around areas taking additional strain; |
| R5.28 | Designed to ensure that they cannot come into contact with components of the sinker tube system as well as other elements of the mooring system; and, |
| R5.13 | The use of a float line and/or waterline protection by additional |

\(^{37}\) Known as building in ‘redundancy.’
### Conclusions and Recommendations

| R5.17 | Additional guidance to farmers should be provided on the approach to, and measures to be considered in, risk assessments.\(^{39}\) |
| R4.14 | A mooring scope of less than a 3:1 ratio should be avoided wherever possible, and industry should engage with the Crown Estate and planners to ensure that they are aware of the potential effects of a reduced scope on the security of installations. |
| R4.24 | A discussion should be held with the appropriate parties, led by the industry, in regard to collision prevention approaches for fish farm installations and any recommendations should be taken forward. |
| R4.18 | The mooring designer should provide a specification which details materials, components, dimensions and maintenance requirements and includes the standard to which the installation is designed, the return period and elements of redundancy. |
| R4.19 | Cage manufacturers should provide instructions on the installation, maintenance and operation of their cages, including details on tolerances in regard to setting out the mooring grid, the size of vessels that can be moored alongside and other issues in regard to the installation. |
| R5.39 | A standard protocol for net strength testing should be developed under the auspices of the Improved Containment Working Group and included in the new technical standard. |
| R5.40 | To ensure that cage nets of appropriate strength, design and construction are used in respect of the level of exposure of the site, a locality classification system is required for nets which could be based on that for cages. |
| R5.41 | Maximum mesh sizes relative to minimum fish weights should be prescribed. |

#### Requirements for Farmers

| R4.20 | Moorings should be installed by appropriately experienced and/or qualified personnel and be inspected prior to use. Companies should have a documented method to verify that mooring grids are laid in accordance with the mooring specification and instructions provided by manufacturers. |
| R4.22 | After an installation has been completed, it should be subjected to a full visual inspection by an independent third party with appropriate expertise. |
| R4.15 | Companies should ensure that the grid is at the required depth before |

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\(^{38}\) Which should be mandatory for freshwater nets. 
\(^{39}\) This should include the predator risk assessments currently required in Clause 4.9.1.71 of the CoGP.
Thistle Environmental

9.4 Detailed Content of Recommended Changes to the Scottish Finfish Code of Good Practice regarding the Operation of Fish Farms and the Training of Staff

The cause of the greatest number of escape incidents (57%, 78 incidents) and the second highest number of escaped fish (700k, 32%) between May 2002 and October 2009 was hole in the net. Of these, the most important underlying causes were predators and chafe/snag. Some net specification issues can be addressed by the aforementioned technical standard, but there are also important issues in regard to the operation of the fish farm and the training of staff which are addressed below in terms of both industry wide issues and specific requirements for fish farmers.

There are also important considerations for land-based sites. Of particular interest are flooding events which, whilst infrequent, have caused high losses and could be financially devastating to smaller operators.

General Principles and Industry Wide Issues

A number of contributory factors were identified which have been instrumental in chafing and snagging incidents, including:

- Staff do not always appear to have sufficient awareness of the equipment they are using, or that knowledge is inadequately applied;
- Staff should be given the opportunity to practice operations on unstocked sites where the consequences of different actions can be easily understood;
- Whilst the Scottish vocational qualification (SVQ) in aquaculture is recognised, uptake has been poor and there is little specific training on containment;
- Farmers are not necessarily aware of the maximum net deflection under different conditions, which could lead to entanglement with a boat or chafe/snag; and,
- Training courses for boat, forklift and crane operators do not include containment.

In terms of operating issues, a risk assessment approach\(^40\) should be used, with a revised CoGP and QTUK detailing the minimum requirements and presenting guidance on the risk assessment process and the issues to be considered.

Consideration should be given to specifying the minimum (and maximum)
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R5.32</strong></td>
<td>A specification should be provided for the minimum operating distance between propellers and critical elements of the cage systems, including nets and mooring grids; vessels should be assessed prior to visiting the site. Consideration should be given to physical measures to enhance separation between boats and critical elements of the cage system.</td>
</tr>
<tr>
<td><strong>R5.7</strong></td>
<td>Recent improvement with the consistency of acoustic deterrent devices (ADD) in regards to one product was identified. Should ADD continue to be a proven success in the medium term, the mandatory use of ADD should be considered by the Improved Containment Working Group. (See also R5.6.)</td>
</tr>
<tr>
<td><strong>R5.21</strong></td>
<td>Consideration should be given to the development of a national training centre where staff can be trained on unstocked sites (which could double as a research station); this should be undertaken within the induction period or prior to working on new types of equipment. Alternatively, staff should be encouraged to train staff on unstocked sites.</td>
</tr>
<tr>
<td><strong>R5.22</strong></td>
<td>Consideration should be given to including containment and aquaculture engineering within a national qualification scheme for aquaculture. However, staff who are unlikely to become involved on such schemes should also receive training on the importance of containment and on the measures required to ensure effective containment on the equipment they are using prior to starting work. Containment should also be included in the syllabus of training courses for operators of boats, forklifts and cranes.</td>
</tr>
<tr>
<td><strong>R5.24</strong></td>
<td>Containment workshops (such as those run by the SSPO) should be continued on an industry wide basis for freshwater and sea water, trout and salmon farming staff, with accompanying documentation made available to the industry.</td>
</tr>
<tr>
<td><strong>R6.11</strong></td>
<td>A flood risk assessment of all land-based farms should be undertaken and any required mitigation measures identified. Consideration should be given to these assessments being undertaking by an independent organisation.</td>
</tr>
<tr>
<td><strong>R6.12</strong></td>
<td>Flood risk assessments should be reviewed and a strategic assessment of the risk to the industry should be made by the Improved Containment Working Group.</td>
</tr>
<tr>
<td><strong>R6.13</strong></td>
<td>Good practice guidance on flood risk assessments and associated mitigation measures should be provided.</td>
</tr>
<tr>
<td><strong>R7.3</strong></td>
<td>In regard to vandalism, industry representatives should initiate dialogue with the police and, possibly, private security experts to look into security issues.</td>
</tr>
</tbody>
</table>
Containment Contingency Planning

Conclusions and Recommendations

arrangements for fish farming.

R6.10 The need for authorised persons to regularly check lifting equipment\(^{41}\) and to consider how to address this with contractors should be part of all farmers’ health and safety systems and should be included within Scottish finfish farming protocols.

R7.1 Only fish farm staff should be involved in handling fish; alternatively, any incidents caused by third parties, such as auditors and inspectors, should be reported against those persons.

Requirements for Farmers: Cage Sites

A number of contributory factors have been identified which have been instrumental in hole in the net incidents, including:

- Lack of visual (particularly dive) inspections;
- Failure of prevention measures;
- Inadequate installation design;
- Poor equipment, poor maintenance, and poor inspection and monitoring.

R5.26 The potential for chafe and snags should be identified and assessed through a risk assessment. Farmers should prevent chafe and snags through a hierarchical approach, with prevention by design above protection. This should include consideration of:

  - Type of material for cage weights;
  - Regular removal of marine growth from equipment; and,
  - Protection against net chafe from all cage and mooring equipment.

R5.18 Companies should have specific operational procedures in place from a containment perspective, particularly to protect against net chafe and snag.

R5.31 A protocol for well boat and other large vessel access, as well as work boat access, should be provided by the farmer for each site.

R7.2 Companies should have procedures to ensure that the net mesh is checked against the size of the fish to ensure the correct size is in place prior to stocking.

R5.9 Nets should be visually inspected in situ (i.e. in their fully deployed position) prior to being stocked and after each time a net is changed or installed and at least monthly thereafter by divers (or, on very small cages in good visibility, by the use of cameras). This inspection should be given a high priority, undertaken by a person or persons dedicated to the task with sufficient time to do so, properly supervised and recorded.

\(^{41}\) A requirement from a health and safety perspective.
R5.10  Given the difficulties with using cameras to fulfil this task, it is also recommended that research be undertaken into devices that could detect holes in nets.

R7.4  Full communication between company representatives on the appropriate cages and an approaching subcontracted vessel is recommended.

R5.19  Companies should be required to train staff in the type of equipment in use at the installation they will work at and on the relevant operational procedures prior to undertaking work at any given site.

R5.20  This should include a classroom session where the workings of cage nets and weighting systems can be explained prior to working on the sites followed up with practice on un-stocked sites.

R5.23  ‘Tool box talks’ or other mechanisms to focus staff on containment issues and to gain suggestions should be undertaken prior to specific operations.

R5.25  Training material should be translated as necessary for foreign staff and, if required, translators should be used for training.

Land-based Farms and Stock Transfers

Relevant issues identified in the report include:

- Aluminium screens can be easily damaged;
- Catastrophic tank failure is a current concern in Norway;
- Three helicopter bin incidents were caused by the failure of the bucket locking mechanism and one by the failure of lifting equipment; and,
- Escapes from transfer pipe failure are not large but continue to occur.

R6.1  A ‘mortality tank’ or other similar means should be used to collect any fish escaping from tanks.

R6.2  Aluminium and plastic should not be used as a material for final screens discharging directly to a watercourse. All screens should be specified so that fish cannot pass through the screen apertures or around the frame sides. Consideration should be given to specifying the design of final outflow screens.

R6.7  Secure methods of attachment from the pipe to the transfer tanks and at each join of lengths of pipe should be provided. Consideration should be given to measures to ensure that couplings remain secure during use and, perhaps, to a secondary coupling.

R6.5  Transfer pipes should be inspected prior to and during use particularly just after starting an operation. Pipes with visible damage should not be used.

R6.8  A means of immediately alerting operators in the case of problems during transfers should be provided, and operators trained in their use.
Protection against tank failure caused by site operations, such as forklift movements, is required on sites where this could be a potential issue.

Consideration should be given to secondary containment in the event of catastrophic tank failure on new tank sites or the redevelopment of existing ones. At existing tank sites farmers should assess the risk and provide such facilities where the risk may be considered significant.

9.5 Research Related Recommendations

High Priority Research

There appears to be little information available to fish farmers on the following issues which are crucial from a containment perspective:

- Design constraints of different cage and mooring systems;
- The ability of different net strengths or construction parameters to withstand predators;
- The level of tension required to help deter predators;
- The effectiveness of acoustic deterrent devices (ADD) in deterring seal attacks;
- The potential for ultrasonic devices to deter freshwater predators.
- Whether net tensioning may be useful to deter freshwater predators;
- A divergence of opinion about the usefulness of sinker tubes;
- The inability of weighting systems to effectively tension the base of a standard shaped net (i.e. one with a conical base); and,
- The lack of limited information about the potential amount of net deflection at specific sites for given conditions.

The body of the report also highlighted that predator nets cause additional complexities for operators, require considerable additional work, can lead to significant by-catch and that the way in which predator nets are deployed in Scotland does not always give sufficient separation to be effective. It was also noted that predator nets are widely used in Canada and Chile.

Research into the stresses and design limitations of different types of cages and mooring configurations in different environmental conditions should be undertaken or, should this information already exist, it should be made available to fish farmers. Consultation with SINTEF in regard to their proposed work in this area is recommended.

Research should be undertaken into the ways that nets behave in different current regimes with both individual weights and sinker tubes so that advice can be given to farmers on the optimum tension required and how this may be achieved through the use of different types of equipment for

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42 The Norwegian based independent research institution.
both sea water and freshwater sites.

| R5.4 | Research should also be carried out into tensioning systems which would help to tension the base of the cage net which is not as effectively tensioned as the sides by either sinker tubes or individual weights. |
| R5.8 | Research should be undertaken into the use of ultrasonic and other devices for deterring otters and mink from freshwater fish farms. |
| R5.1 | Research should be undertaken to help ascertain the role that the strength and construction of cage nets may have in deterring attack from seals, mink and otters in particular and also from birds. |
| R5.6 | The Improved Containment Working Group and industry representatives should put in place mechanisms to keep abreast of the effectiveness of acoustic deterrent devices (ADD), including an ongoing quantitative assessment of ADD effectiveness, and to be informed by the current SARF funded project into seal predation in aquaculture. |
| R5.11 | The Improved Containment Working Group and industry representatives should discuss whether the costs of undertaking visual inspections after each net lifting and dropping operation, such as swim-throughs, grading, treatments and harvests, would be financially prohibitive to certain sectors of the industry. Thought should then be given to whether such visual inspections should be mandatory43. |
| R5.34 | It is recommended that the Improved Containment Working Group and industry representatives liaise with the relevant agencies to ensure that containment issues are included on the relevant syllabus of training courses for operators of boats, forklifts and cranes, either as a standard requirement or as additional modules. |

Lower Priority Research

The body of the report noted that:

- Stock numbers may vary due to inaccuracies in counting technology and operating tolerances in stock numbers which may lead to inaccuracies in escape numbers;
- Whilst the importance of effective mortality removal in reducing predator attacks is recognised, there were differences in the timescale employed from daily to weekly removal;
- Lack of knowledge of, or changing patterns in, freshwater predator attack; and,
- Whilst closed containment is not considered economically viable for Scottish finfish farming at the current time, there is an international research project which may help to address this.

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43 This would be in addition to the requirement for monthly dive inspections in recommendation R5.9.
<table>
<thead>
<tr>
<th>R5.12</th>
<th>Research should be undertaken into the behaviour of freshwater predators.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5.15</td>
<td>Research is required to try and identify more effective approaches to maintaining the separation of predator nets from cage nets, as well as making them easier to use.</td>
</tr>
<tr>
<td>R5.16</td>
<td>Research should be undertaken into the extent to which mortalities attract predation. Should this be considered significant, then the mandatory use of seal blinds or the daily recovery or fish mortalities should be required.</td>
</tr>
<tr>
<td>R5.14</td>
<td>A delegation should visit Chile and Canada to assess how predator nets are used and to identify any measures which may be useful for the Scottish context.</td>
</tr>
<tr>
<td>R5.2</td>
<td>The Improved Containment Working Group and industry representatives should put in place mechanisms to keep themselves and the industry abreast of research developments in the UK and abroad.</td>
</tr>
<tr>
<td>R5.30</td>
<td>The practicality of providing information on net deflection to fish farmers in different environmental conditions should be discussed with the net manufacturers and installation designers by the Improved Containment Working Group and industry representatives.</td>
</tr>
<tr>
<td>R5.33</td>
<td>Research on the potential for well boat thrusters to distort the net, cause entanglement or affect net longevity should be undertaken.</td>
</tr>
<tr>
<td>R5.35</td>
<td>Research should be undertaken into the affects of off-site and in situ net washers on net longevity.</td>
</tr>
<tr>
<td>R5.37</td>
<td>Research should be carried out into the use of limiters or other mechanisms to help prevent damage to nets which have become snagged on cage components when being lifted by crane or hauler.</td>
</tr>
<tr>
<td>R6.9</td>
<td>Industry representatives should consult with helicopter companies in order to improve the design of the bucket locking mechanism.</td>
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<tr>
<td>R6.6</td>
<td>The types of valves appropriate for use on transfer pipes should be researched and specified.</td>
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<tr>
<td>R5.42</td>
<td>The Improved Containment Working Group and industry representatives should take note of any relevant outputs from the international research project on closed containment systems.</td>
</tr>
<tr>
<td>R3.1</td>
<td>Improved technology is required to more accurately monitor incidents and further research and international collaboration is recommended in this area including with regard to work in Norway on a portable biomass counter for use by Government inspectors.</td>
</tr>
</tbody>
</table>
References


Norwegian Ministry of Fisheries and Coastal affairs, 2005. NYTEK Technical requirements for fish farming installations.


Appendix A: List of Consultees

Fish Farmers

* Denotes a company which is no longer trading; information was obtained from a former director or employee.

** The companies in brackets have either been acquired by, or sold sites to, or is the former name of the main listing; hence, information on the bracketed companies has been obtained from the main listing.

Balta Island Seafare
Bressay Salmon Ltd*
Cro Lax Ltd*
David M Brien
Dawnfresh Farming Ltd
Fjord Seafood*
Hebridean Salmon Company
Hebridean Smolts Ltd
Hjaltland Seafarms Ltd
Hogansess Salmon Ltd
Howietoun Fishery
Invicta Trout Ltd
John Eccles Hatcheries
Kames Fish Farming Ltd
Lakeland Marine Farm Ltd
Lakeland Unst Ltd
Landcatch Ltd
Lewis Salmon Ltd
Lighthouse Caledonia (Scotland) Ltd (Panfish Scotland Ltd and Murray Seafoods Ltd) **
Loch Duart Ltd (Ardvar Salmon Ltd and The Salmon Management Company Ltd) **
Mainstream Scotland Ltd
Marine Harvest (Scotland) Ltd
Marine Harvest Norway AS
Migdale Smolt Ltd
North Uist Fisheries Ltd
Scottish Sea Farms Ltd
Shetland Halibut Company Ltd*
Stolt Sea Farm UK*
Uyeasound Salmon Company
Weddell Fish Farm*
West Minch Salmon Ltd
Wester Ross Fisheries Ltd

**Suppliers**
AKVA Group Scotland Ltd,
Aqua Systems (UK) Ltd,
Aquaculture Risk (Management) Ltd.,
Bennex Group
Boris Net Co. Ltd.,
Bruce L Smith & Associates
FPM Henderson Ltd,
Fusion Marine Ltd.,
Gael Force Marine Ltd.,
Hook Marine Ltd.,
McCluskie (Claims Negotiations) Ltd.,
Ocean Nets Ltd
SBJ Global Risks Ltd.
Seaworks (Scotland) Ltd
SIMCorp Marine Environmental Inc
Sweeney International
W & J Knox Ltd.

**Retailers**
Asda Stores Ltd
J Sainsburys Limited
Marks & Spencer Group PLC
Tesco Stores Limited
Waitrose Ltd

**Other Consultees**
Aquaculture Association of Novia Scotia (AANS)
Bord Iascaigh Mhara (BIM)
British Columbia Salmon Farmers Association (BCSFA)
British Trout Association (BTA)
Canadian Aquaculture Industry Alliance
Essentia AS
FHL (Norwegian Seafood Federation)
Fiskeridirektoratet (Norwegian Directorate of Fisheries and Aquaculture)
Food Certification International Ltd.
Government of Newfoundland and Labrador - Fisheries and Aquaculture
International Salmon Farmers Association
Irish Salmon Growers Association
Maine Aquaculture Association
Marine Conservation Society
Marine Scotland (Scottish Government)
National Aquaculture Council (Australia)
National Association of State Aquaculture Coordinators
New Brunswick Salmon Growers Association
New Zealand Salmon Farmer’s Association Inc
Newfoundland Aquaculture Industry Association
North Atlantic Salmon Conservation Organization
RKA (Rømmingskommisjonen for Akvakultur) (The Norwegian Aquaculture Escape Commission)
SAI Global Efsis
Scottish Environment Protection Agency (SEPA)
Scottish Salmon Producers’ Organisation (SSPO)
Sea Mammal Research Unit
SINTEF – Fisheries and Aquaculture
Tasmanian Salmonid Growers Association
The Faroese Fish Farmers Association
WWF

The organisations below were contacted but no response was obtained

* Denotes consultees approached on behalf of the authors by the British Trout Association (BTA).

Aquaculture Association of Canada
Association of Chilean Salmon and Trout Farmers
Association of Danish Trout Farmers
Associazione Piscicoltori Italiani (API)*
Australian Trout & Salmon Farmers Association
Catalunyan Trout Producers*
Danish Sea Farmers Association
Dansk Akvakultur (Danish Aquaculture Association)*
Federation of European Aquaculture Producers*
Fundacion Chile
Galician Trout Producers*
German Trout Producers*
Irish Farmers Association*
National Aquaculture Association (United States)
SalmonChile
United States Trout Farmers Association
Washington Fish Growers Association