







**Acknowledgements**

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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.

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

## CONTENTS

### VOLUME 1: REPORT

Executive summary	1
1. Introduction	6
2. Methodology	8
3. Escape incidents: magnitude, trends and causes	11
4. Addressing cage and mooring failure	19
5. Maintaining net integrity	27
6. Land-based farms and stock transfers	39
7. Addressing other causes of escape incidents	42
8. Protocols	44
9. Conclusions and recommendations	50
References	64
Appendices:	
A List of Consultees	65

### VOLUME 2: SUPPORTING INFORMATION (bound separately)

Annexes:	
1. Literature review	1
2. Aquaculture containment protocols (worldwide)	23
3. Finfish escape statistics: worldwide	98
4. Causes of escapes in Scottish finfish farming	115
5. Consultations with Scottish fish farmers	143
6. Consultations with suppliers to the Scottish aquaculture industry	163

## 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 sea water 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).

The highest number of incidents (26%) were due to holes in the net (IC) caused by predation (UC) although this only accounted for the third highest number of escaped fish (12%).

The second highest number of incidents (17%) were due to holes in the net (IC) caused by chafe/snag (UC) which resulted in the fourth highest amount of escaped fish (9%).

The third highest number of incidents (7%) were a result of cage/mooring failure (IC) caused by the use of inappropriate cages (UC). This accounted for by far the highest number of escaped fish (23%) and was very much influenced by the January 2005 storm<sup>1</sup>.

The fourth highest number of incidents (4%) were due to cage/mooring failure (IC) caused by the use of inappropriate moorings (UC). This was responsible for the second highest number of escaped fish (16%) and, again, was largely related to the January 2005 storm.

All other immediate causes each accounted for 5% or fewer of incidents and included fish handling, net under water, freshwater screen failure, vandalism, helicopter bucket incident, transfer pipe failure, flooding and well boat collision. Whilst most of these incidents accounted for a relatively small number of escaped fish, there was one particularly large net under water incident and flooding, although accounting for just 1% of incidents resulted in 5% of escaped fish.

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

<sup>1</sup> 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<sup>2</sup> 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<sup>3</sup>. 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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<sup>2</sup> Such as a one in fifty year storm, one in a hundred or other as appropriate confirmed after discussion with meteorologists and engineers.

<sup>3</sup> 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 / QUTK 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<sup>4</sup>.

### 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

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<sup>4</sup> 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<sup>5</sup> 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'<sup>1</sup> instructions/advice
- Advisors'<sup>2</sup> 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<sup>6</sup>. 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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<sup>5</sup> 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.

<sup>6</sup> 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 11<sup>th</sup> and 12<sup>th</sup> January<sup>7</sup> 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 sea water 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 sea water and freshwater operations.

Atlantic salmon has dominated escapes of Scottish farmed finfish, accounting for around 75% or more of the total number (i.e. sea water 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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<sup>7</sup> 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)<sup>8</sup>.

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  $\pm 3\%$  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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<sup>8</sup> 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 Scotland<sup>9</sup> 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'<sup>10</sup>. 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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<sup>9</sup> Formerly, the Fisheries Research Services (FRS).

<sup>10</sup> 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)**

Immediate Cause	Escape Incidents		Escaped Fish	
	No.	%	No.	%
Hole in net	78	57	700,359	32
Cage/mooring failure	22	16	1,005,195	46
Fish handling	7	5	713	<1
Net under water	6	4	252,294	12
Screen failure	6	4	3,427	<1
Vandalism	4	3	28,613	1
Helicopter bucket incident	4	3	13,793	1
Transfer pipe failure	4	3	8,821	0
Flooding	2	1	107,767	5
Well boat collision	1	1	10,534	0
Unknown	2	1	51,109	2
<b>Totals</b>	<b>136</b>	<b>100</b>	<b>2,182,625</b>	<b>100</b>

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)**

Immediate cause	Underlying cause	No. of incidents		No. of Escaped Fish	
		No.	%	No.	%
Hole in net	Predator	35	26	270,430	12
	Chafe/ snag	23	17	195,711	9
	Poor net servicing	2	2	45,976	2
	Other underlying causes	9	7	53,038	2
	Unknown	9	7	135,231	6
	<i>Sub-Total</i>	<b>78</b>	<b>57</b>	<b>700,359</b>	<b>32</b>
Cage and mooring failure:	Inappropriate cages	9	7	495,431	23
	Inappropriate moorings	5	4	357,611	16
	Net under water	2	2	45,200	2
	Flotation tube failure	2	2	30,000	1
	Other underlying causes	2	2	19,964	<1
	Unknown	2	2	56,953	3
	<i>Sub-Total</i>	<b>22</b>	<b>16</b>	<b>1,005,159</b>	<b>46</b>
Fish handling	<i>Sub-Total</i>	<b>7</b>	<b>5</b>	<b>713</b>	<b>&lt;1</b>
Net under water	Chafe / snag	1	<1	238,420	11
	Other underlying causes and unknown	5	4	13,874	<1
	<i>Sub-Total</i>	<b>6</b>	<b>4</b>	<b>252,294</b>	<b>12</b>
Screen failure	All underlying causes	<b>6</b>	<b>4</b>	<b>3,427</b>	<b>&lt;1</b>
Vandalism	All underlying causes	<b>4</b>	<b>3</b>	<b>28,613</b>	<b>1</b>
Helicopter bucket	All underlying causes	<b>4</b>	<b>3</b>	<b>13,793</b>	<b>1</b>
Transfer pipe failure	All underlying causes	<b>4</b>	<b>3</b>	<b>8,821</b>	<b>&lt;1</b>
Flooding	All underlying causes	<b>2</b>	<b>2</b>	<b>107,767</b>	<b>5</b>
Well boat collision	-	<b>1</b>	<b>&lt;1</b>	<b>10,534</b>	<b>&lt;1</b>
Unknown	-	<b>2</b>	<b>2</b>	<b>51,109</b>	<b>2</b>
<b>Totals</b>		<b>136</b>	<b>-</b>	<b>2,182,625</b>	<b>-</b>

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<sup>11</sup>. 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<sup>12</sup>.

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 [C]. Therefore, there is no single remedy that will immediately reduce escape incidents in Scottish finfish farming [C]; 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 [C]. 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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<sup>11</sup> 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.

<sup>12</sup> 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**

Scottish Government Classification		Thistle Environmental Classification						
		Hole in net		Fish Handling			Screen failure	Well boat collision
Cause	No. of incidents	Predator	Chafe / snag	Poor net design	Dropped fish	Wrong net used	-	-
Hole in net - unknown	4	3	1	-	-	-	-	-
Hole in net - predator	3	3	-	-	-	-	-	-
Human error	4	-	-	-	2	1	-	1
Equipment failure	3	-	1	1	-	-	1	-
<b>Totals</b>	<b>14</b>	<b>6</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>

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>
- 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<sup>13</sup>. 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

<sup>13</sup> 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 11<sup>th</sup> and 12<sup>th</sup> January 2005<sup>14</sup>. 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

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<sup>14</sup> 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).

















































































































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