Aquaculture 436 (2015) 21–26

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

A pan-European valuation of the extent, causes and cost of escape events from sea cage fish farming

Dave Jackson [a,*], Alan Drumm [a], Sarah McEvoy [a], Østen Jensen [b], Diego Mendiola [c], Gorka Gabiña [c], Joseph A. Borg [d], Nafsika Papageorgiou [e], Yannis Karakassis [e], Kenneth D. Black [f]

[a] The Marine Institute, Ireland
[b] SINTEF Fisheries and Aquaculture, Norway
[c] AZTI Tecnalia, Spain
[d] University of Malta, Malta
[e] University of Crete, Greece
[f] The Scottish Association for Marine Science, UK

ARTICLE INFO

Article history:
Received 10 May 2013
Received in revised form 3 October 2014
Accepted 15 October 2014
Available online 3 November 2014

Keywords:
Aquaculture
Escapes
Cage farming
Prevent escape

ABSTRACT

As part of an EU funded 7th Framework project, *Prevent Escape*, a programme of research was undertaken to document the extent, size and knowledge of the causes of escapes from marine fin fish farms in Europe over a three year period. Escape incidents were identified and assessed through questionnaires across the 6 countries (Ireland, UK, Norway, Spain, Greece, and Malta), and other data supplied by the Norwegian Fisheries Directorate and the Scottish Aquaculture Research Forum. A total of 8,922,863 fish were reported to have escaped from 242 incidents. Of these over 5 million occurred in two catastrophic escape incidents. Sea bream accounted for the highest number of escapes at 76.7% followed by Atlantic salmon at 9.2%. Of the 113 Atlantic salmon escape events, almost 75% were due to structure failure or operational error. Almost 50% of cod escape incidents were due to biological causes e.g. biting of nets. The nominal costs of escapes as calculated by value at point of first sale were very substantial, estimated at approximately €47.5 million per annum on average over the study period. Of this €42.8 million was for annual cost of losses of sea bass and sea bream in the Mediterranean and €4.7 million for losses of salmon in northern Europe.

1. Introduction

Knowledge of the extent and causes of escape incidents from sea-cage fish farms varies greatly from country to country across Europe. Several countries, such as Norway, Scotland and Ireland, have legislated reporting requirements whereby farmers are obligated to report escape incidents, their size and cause and when they occur. In contrast, Mediterranean countries have no such requirements; thus no statistics are available on the number of escapes or the underlying causes of escapes (Dempster et al., 2007).

Norway has the most comprehensive record of escapes, dating back approximately 15 years for salmonids and 5 years for Atlantic cod. A total of 722,000 and 963,000 salmon and rainbow trout were reported to have escaped from Norwegian farms in 2005 and 2006, respectively (Norwegian Fisheries Directorate, 2007). The real number of escapes has by some been estimated to be considerably greater (Torrissen, 2007) because not all escape incidents are believed to be reported.

Substantial escape events of salmon have also occurred in other major salmonid producing countries, such as Scotland, Chile and Canada (Naylor et al., 2005; Soto et al., 2001). Over one million salmon were reported to have escaped from Scottish farms during the period from 2002 to 2006 (Thorstad et al., 2008). The proportion of Atlantic cod that escape is high in comparison to salmon (Moe et al., 2007). In 2005 and 2006, 213,000 and 288,000 cod, respectively, escaped from Norwegian farms.

While no official statistics on the extent of escapes exist for Mediterranean countries, data available from companies that insure fish farm businesses indicate that escapes are a significant component of economic losses claimed by farmers (EU FP-6 ECASA project; www.ecasa.org.uk). From 2001 to 2005, 76 claims accounting for 36% of the total value of all insurance claims made by fish farmers in Greece were due to stock losses from storms, while damage to farm equipment due to storms accounted for 19%. A further, 39 registered 'predator attacks' resulted in claims of 10.4% of the total value of all insurance claims, although the proportion of this which relates to stock loss or cage damage is unknown. The existing evidence suggests that escapes are a relatively frequent occurrence on a pan-European scale.

* Corresponding author at: Marine Institute, Rinville, Oranmore, County Galway, Ireland. Tel.: +353 91 387200; fax: +353 91 387201.
E-mail address: dave.jackson@marine.ie (D. Jackson).

http://dx.doi.org/10.1016/j.aquaculture.2014.10.040

Escapes are caused by a variety of incidents related to farming equipment and their operation. Reports by fish farming companies to the Norwegian Fisheries Directorate following escape events during the period from 2001 to 2006 indicate that escapes can be categorised broadly into structural failure (52%), operational related failure (31%) and biological and/or other causes (17%). Structural failures may be generated by severe environmental forcing in strong winds, waves and currents, which may occur in combination with component fatigue or human error in the way farm installations have been installed or operated (Jensen, 2006). Operational related failures leading to escapes include collisions with boats, incorrect handling of nets or damage to nets by boat propellers. The risks to farm installations from the marine environment largely come from exposure to waves and currents (Lader and Fredheim, 2007; Lader et al., 2008) and from collisions with seagoing vessels. The further offshore a farm is located, generally the more exposed it is to the elements, thus increasing the risk of escapes.

There is growing evidence that with cod the reasons for escape differ from salmon. This stems from behavioural variations in captivity. Firstly, cod bite the net and might thus increase wear and tear and contribute to the creation of holes (Moe et al., 2007). Secondly, cod show more pronounced exploratory behaviour than salmon and might thus have a higher probability of discovering small holes in the net (Damsgård et al., 2012; Hansen et al., 2009).

Official statistics and other sources of information which apportion causality to escape events provide little explicit detail to support technological development that will improve farming equipment and modify operations to avoid mistakes that cause escapes. Categorisation of causes may also be inaccurate, as causes are rarely investigated in detail (Valland, 2005). Such detail only comes through thorough investigation of the causes of escape incidents on a case by case basis (e.g. Rist et al., 2004).

This study documents the extent and costs of escapes and presents the biological, technical and operational causes giving rise to escapes of fish from sea-cage fish farms in marine waters in 6 European countries over a three year period.

2. Materials and methods

A specific methodology was applied across all 6 countries (Ireland, UK, Norway, Spain, Greece and Malta) in order to ensure comparability of results. The methodology was made up of the following components and actions:

1. Consult with industry and relevant agencies through a confidential questionnaire and follow-up interviews to gather information on methodologies and technologies currently used to on-grow finfish in the marine environment.
2. Gather available existing information on the extent, size and knowledge of the causes of escapes from national reports and other published data.
3. Conduct detailed assessments of the explicit technical or operational causes of escapes at sea-cage fish farms throughout Europe by direct assessment of known escape events at industrial fish farms, by way of site visits and interviews.
4. Establish the total economic cost of escape events through a cost evaluation using both available data and through direct gathering of data by way of interview.

The questionnaire was divided into 4 main sections:

Section 1, Infrastructure, was designed to gather data relating to materials used and design of floater types (i.e. cage structures), nets and mooring systems. Section 2, Maintenance, was aimed at establishing if the site employed maintenance management systems for the infrastructure and how these maintenance systems were carried out. Section 3, Escapes, was used to establish if there were escape incidents and if so, how many and if there was further information available on the events. This section also required the farmers to give an estimate of the cost of the stock loss and clean-up operations to the business. Section 4, Environment, was used to gather the environmental data available for the sites in question. The full methodology, including details of the questionnaire and interview processes used, has been published (Dempster et al., 2013) as part of a compendium of outputs from the Prevent Escape project.

National statistics were consulted where they were available (Anon., 2012; Browne et al., 2007; Jensen et al., 2010). In addition other sources of national data were accessed including government reports (www.scotland.gov.uk/Topics/Fisheries/Fish-Shellfish) and studies. Finally EU and FAO (Barazi-Yeroulanos, 2010; http://www.globefish.org/homepage.html) statistics were used where appropriate. The average size of fish at harvest was derived from a combination of national statistics, where available, and from information received *(pers. comm.)* from the relevant producers organisations. Results for nominal costs of losses are reported both as a cost per kilogramme and as an estimated total cost based on the average harvest weight of the relevant fish stocks.

In each of the participating countries a series of follow-up visits with industry were conducted. These considerably added to the detail and availability of data. Each partner identified 5 escape events in their region which were to be investigated in greater detail. In some countries it was necessary to focus on a few companies which had encountered several escape events.

The cost of escapes from marine fish farms can be evaluated in a number of different ways. Depending on the starting point, the parameters and paradigm used to quantify costs can be very different. Many of the concerns held over the impacts of escapees relate to potential negative impacts on the surrounding environment. If such impacts were well described they could be assigned a cost, but doing so would be fraught with multiple assumptions based on very scant data. There is however a very pragmatic and relevant basis for assigning a cost to aquaculture escapees; the measure of lost income at point of first sale due to loss of stock due to escape incidents. As part of the FP7 project *Prevent Escape* (FP7-KBBE-2008-2B-226885) an exercise to evaluate the cost of escapees in partner countries was undertaken. The basis of this exercise was to calculate the numbers of fish escaping and to assign them an appropriate value at point of first sale in order to arrive at a nominal cost of losses which would facilitate comparison across a number of different farmed species, a range of management regimes and across a wide geographic area encompassing both northern Europe and the Mediterranean region.

A specific methodology was developed and applied across all participating countries in order to facilitate comparability of results. In the development of this methodology cognisance had to be taken of the quality and extent of available data and information. Where possible, published figures, such as FAO fisheries and aquaculture statistics, together with nationally available official figures were relied on as a basis for calculations. This data was combined with the outputs from the *MAP Escape* component of the Prevent Escape project (Dempster et al., 2013) to derive a nominal cost of losses with a defined set of assumptions and limitations. The analysis was carried out for six countries; Ireland, Norway, Scotland (UK), Spain, Greece and Malta.

3. Results

A total of 242 escape incidents were identified through questionnaires, which were completed across the 6 countries, and using other data supplied by the Norwegian Fisheries Directorate and the Scottish Aquaculture Research Forum. The causes given for these events are shown below in Table 1. Some of the events were as a result of a combination of causes. The majority of escape incidents related to net damage due to predator attacks and abrasion. Storm damage or weather was also a common cause. However, it was not clear from the responses obtained whether the storm losses were due to net, mooring or floater damage.