Review

Fish welfare in capture fisheries: A review of injuries and mortality

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ABSTRACT

Concerns about the welfare of production animals have extended from farm animals to fish, but an overview of the impact of especially capture fisheries on fish welfare is lacking. This review provides a synthesis of 85 articles, which demonstrates that research interest in fish welfare in capture fisheries has increased over time and that research has focused more on trawls and hooks than on purse seines, gillnets, traps and seines. We found that various gear characteristics, fish characteristics and context variables affect external injuries and mortality. Although the influence of gear characteristics on injuries and mortality can by nature not be compared across gear types, synthesis of the articles reviewed shows that fish characteristics and context variables influence injuries and mortality across gear types. In terms of fish characteristics, decreasing fish length and certain fish species were associated with higher mortality. In terms of context variables, greater capture depth and a longer fishing duration were associated with more injuries and higher mortality, whereas a large change in water temperature, a longer duration of air exposure and a high density in the net were associated with higher mortality. These relations provide options to reduce injuries and mortality from commercial capture fisheries. Implementation of such options, however, would require analysis of potential trade-offs between welfare benefits, and ecological and economic consequences.

1. Introduction

Concerns about the welfare of production animals have extended from farm animals to fish in aquaculture and capture fisheries (Diggles et al., 2011; Huntingford et al., 2006; OIE, 2016). Huntingford et al. (2006) reviewed the scientific literature on fish welfare and identified welfare issues that arise in aquaculture, recreational fisheries and ornamental fish keeping, but they did not identify the welfare issues that arise in capture fisheries other than pointing out that "there is very little information on the welfare of fish in the context of commercial fisheries" (Huntingford et al., 2006: 362).

This limited information on fish welfare in commercial capture fisheries is likely due to three causes. First, the experience of pain in fish is debated (for insightful but contrasting reviews on this topic, please see Huntingford et al. (2006) and Rose et al. (2014) or special issues on this topic in the journals *Diseases of Aquatic Organisms* (2007, volume 72, issue 2) and Animal Sentience (2016, no. 3)). Despite the debate whether or not fish can feel pain, fish welfare is increasingly acknowledged to be an important societal issue (Arlinghaus et al., 2007; Braithwaite and Boulcott, 2008; Branson, 2008; OIE, 2016).

Second, information on fish welfare in capture fisheries might be limited because, contrary to fish in aquaculture, the welfare of fish in capture fisheries is directly affected by humans only during the fishes' final life stage. In capture fisheries, various fishing gear types are used, such as trawls, purse seines and traps. Each of these gear types has its own modus operandi, for example in terms of the depths at which the gear type is deployed and the species that it targets. Consequently, the impact on fish welfare differs among gear types; e.g. compare a fish being caught by hook and line with a fish being caught by a trawl net (Metcalfe, 2009). Hence, an investigation into the impact of the capture process on fish welfare should acknowledge these differences in gear types.

Third, information on fish welfare in capture fisheries might be limited because of a (perceived) lack of economically viable, welfare-friendly alternatives to current practices (Jennings et al., 2016). However, by considering the effects of the capture process on fish welfare, improvement options and research gaps pertaining to fish welfare can be identified. Such improvement options may also benefit fishers, e.g., when a change in current practices results in improved societal and consumer acceptance or in less external damages of the captured fish, which increases product quality (Rotabakk et al., 2011; Savina et al., 2016).

Although animal welfare can be defined in various ways (Broom, 2011; Hagen et al., 2011; Korte et al., 2007; Ohl and van der Staay, 2012), key to all definitions is that poor welfare is associated with exceeding the coping capacity of animals, which may result in chronic stress-related physiology and behaviour, pathology and increased mortality. Fish welfare can focus on the measurable, objective condition of the fish (function-based), on the subjective experience of the fish (feelings-based), and on whether the fish can lead a natural life (nature-based) (Fraser, 2008; Fraser et al., 1997). For the purpose of this study, we selected indicators for fish welfare that are relatively easy measured in both field and laboratory settings: external injuries and mortality. External injuries are the visible effects of the capture process on the fish and mortality is the ultimate consequence resulting from the capture process exceeding the fish's coping capacity. Incidences of injuries or mortality thus indicate that welfare issues occurred during the capture process, which can be the result of a combination of various gear characteristics, fish characteristics and context variables.

The objective of this study was to conduct a review to determine what is known about the effects of the capture process in capture fisheries on fish welfare. This review focuses on external injuries and mortality in teleost (ray-finned) fish species caught in commercial fisheries. Results from this review are derived from and relevant for both discarded fish and landed fish. Although every fish species has its own species-specific characteristics, external injuries and mortality can be assessed across species.

2. Methods

This review on fish welfare in capture fisheries started with the development of a search strategy that was subsequently applied to the literature. Next, the information that was extracted from each relevant article in the literature search was synthesized in relation to this review's objective (Brunton et al., 2012; European Food Safety Authority, 2010).

2.1. Development and application of a search strategy

The first step in developing a search strategy for this review was to determine relevant search terms based on key concepts in the research objective, i.e., capture fisheries and fish welfare. Potential search terms relating to capture fisheries were based on the different gear types used in capture fisheries (Nédélec and Prado, 1990). Since not all these gear types are used in the commercial capture of teleost fish, only trawl nets, hook and line (hereafter referred to as hooks), surrounding nets (hereafter referred to as purse seines), gillnets and entangling nets (hereafter referred to as gillnets), traps, and seine nets were included (see Appendix A in Supplementary material for a description of these gear types and their main subtypes). Potential search terms relating to fish welfare were identified based on two earlier reviews on fish welfare (Ashley, 2007; Huntingford et al., 2006). The efficacy of each potential search term was determined by comparing results based on all search terms with results based on all search terms except one. In case the exclusion of a search term resulted in the exclusion of a relevant article, the search term was retained because this meant that the search term resulted in an additionally relevant result. Searches to determine search terms were performed in October 2015, and the resulting search terms are shown in Appendix B in Supplementary material.

Next, exclusion criteria were defined that were used to determine relevant exclusion terms. These exclusion criteria were based on the objective of this review and subsequent delineations. An article was excluded when it did not focus on teleost fish, capture fisheries, fish welfare, relevant gear types, external injuries or mortality, or when it lacked empirical or experimental data. Such exclusion criteria could not be used directly to exclude irrelevant articles, but rather, were used to define specific exclusion terms. The efficacy of each exclusion term was assessed by adding the exclusion term to the confirmed search terms

and determining whether this exclusion term excluded (relevant) results or not. In case relevant or zero results were excluded, an exclusion term was not retained. In addition to these specific exclusion terms, additional exclusion terms were defined to ensure that only peer-reviewed scientific articles and reviews (thus excluding e.g. conference proceedings) in English would be included. Searches to determine exclusion terms were performed in October and November 2015, and the resulting exclusion terms are shown in Appendix B in Supplementary material.

Finally, a search with all final search and exclusion terms was performed on 7 January 2016 and resulted in 677 articles. This search was repeated right before article submission (30 June 2017), which resulted in 73 additional articles. The titles, abstracts and full text of the 750 articles were screened using the aforementioned exclusion criteria (Brunton et al., 2012), which resulted in a final list of 85 peer-reviewed scientific articles.

2.2. Synthesizing information

For each article, basic information on data collection, species, capture process and capture site was recorded in Excel. Moreover, relevant empirical results, experimental results, results from data analysis, conclusions, limitations and generalizability were recorded for each article. The synthesis of this information focused on the influence of explanatory variables on injuries and mortality.

Since terminology for external injuries was not used consistently across the articles reviewed, these injuries were classified into five broad categories, i.e., scale, skin, fin, pressure and hooking injuries. Scale injuries are injuries such as scale damage and scale loss, skin injuries are injuries such as cuts and tissue loss, fin injuries are injuries such as fin erosion and fin loss, pressure injuries are injuries that arise from large changes in depth and pressure such as stomach eversion and exophthalmia (i.e., bulging eyes), and hooking injuries are injuries from hooks specified by their location, i.e., hooking in the mouth, deep-hooking (hook is swallowed) and foul hooking (hooking outside the mouth).

Variables that were commonly used to explain injuries and mortality in the articles reviewed were classified into gear characteristics, fish characteristics and context variables. Gear characteristics that were considered are gear subtype, size and material, and selectivity device. Fish characteristics that were considered are fish length and species. Context variables that were considered are change in water temperature (due to higher temperatures of surface water), capture depth, fishing duration (from setting out to surfacing the gear), duration of air exposure after surfacing, density in the net, species composition in the net and boarding procedure.

Relations between explanatory variables, and injuries and mortality are presented in the Results and Discussion Section if findings on such relations were reported in the articles reviewed.

3. Results and discussion

In total, 85 relevant articles were identified that focused on the welfare of approximately 150 fish species, with cod, herring and sablefish among the main species (see Appendix C in Supplementary material for a complete overview including scientific names). Eight of these articles included results on injuries, 51 articles included results on mortality and 26 included results on injuries and mortality.

Table 1 shows that the number of articles on fish welfare in capture fisheries has increased over time and that fish welfare in the northeast Atlantic, the world's third most important fishing area in terms of volumes landed (FAO, 2014), received most research interest. Only eight articles investigated fish welfare in the four other most important fishing areas i.e., the northwest, western central and southeast Pacific, and the eastern Indian Ocean. No studies on fish welfare were found in other fishing areas, such as the eastern central and southwest Atlantic.