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# Loss and waste in fish value chains: A review of the evidence from low and middle-income countries

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ABSTRACT

This paper reviews the literature assessing fish waste and loss in low- and middle-income countries. We find significant variation in estimates of loss in different parts of the value chain, due in part to the diversity in approaches used to measure it. Studies of physical and nutritional loss are more common than those of quality or market force loss although nutritional loss has largely been studied with experimental rather than field-based approaches. Research gaps include the need for robust impact assessments of interventions to reduce fish loss and waste for consumers and actors and studies assessing the extent of loss affecting men and women differently. Standardized approaches are needed to accurately quantify loss in its various forms.

## 1. Introduction

Globally, around 14 percent of food produced is lost from the post-harvest stage up to, but excluding, the retail stage. Highly nutritious material is lost or nutritionally compromised, affecting the diets of millions of people, including in regions where undernutrition and micronutrient deficiencies are endemic (FAO, 2011). The magnitude of the issue led the authors of the Sustainable Development Goals to recommend to "*by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses (*Target 12.3*)*" and a number of new initiatives have been launched in response (United Nations, 2014; FAO, 2015).

Fish is a perishable food that has a high potential for waste and loss, but robust assessments from low- and middle-income countries are limited. All geographical regions are affected, from primary production to final consumption (Akande and Diei-Ouadi, 2010). In 2018, capture fisheries and aquaculture together produced 178.5 million tonnes of fish, of which 88% was intended for human consumption (FAO, 2020). Fish is considered of key importance for human nutrition, providing about 17% of the global intake of animal protein (FAO, 2020). Fish is also an important provider of key micronutrients, vitamins, and essential fatty acids that are deficient in the diets of poor populations (Gibson et al., 2003; Roos et al., 2003, 2007a, b, c; Kawarazuka and Béné, 2010, Kawarazuka and Béné, 2011; Thilsted et al., 2016), but fish consumption in many parts of the world is far below recommended levels (Michaelsen et al., 2011). These low levels of fish consumption are largely related to affordability and availability of fish, and to a lesser extent, cultural acceptability of fish in some specific contexts (Kawarazuka and Béné, 2010).

Estimates of fish loss and waste from different sources are sometimes contradictory (Akande and Diei-Ouadi, 2010). Measuring the extent of loss that occurs is challenged by a lack of uniformity in assessment methods, combined with a scanty evidence base that consists of case studies scattered across locations and time (Poulter et al., 1988; Rosegrant et al., 2013). The lack of information often leads to the generalization of findings from a single study or context to a whole region or country. The lack of accurate information is directly linked to the challenges of developing a methodology that accurately measures fish loss. Fish loss assessment methodologies need to account for a large

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diversity in fish species, types and sizes of fisheries, a lack of uniformity in weight units of catch, variability of spoilage rates between fish species, and variability of post-harvest cold chains within fish value chains (Akande and Diei-Ouadi, 2010). In addition, many fish value chains engage multiple actors along the chain, which increases the nodes where fish may be lost and complicates efforts to accurately measure loss (Morrissey, 1988).

This paper presents a review and synthesis of the evidence presently available on the nature, magnitude, and causes of fish loss and waste along the value chain, focusing on developing countries. By value chain, we refer to a sequence of integrated economic activities and actors that bring a good or service to the market, adding incremental value to the product at each node of the chain (Porter, 1985; Sturgeon, 2001). Value can be added, for example, through processing or grading products based on different quality attributes (Bjorndal et al., 2014). While supply chains focus on streamlining the process of supplying a final product to the market, value chain analyses are broader and incorporate aspects of 'value addition,' which is affected by quality deterioration, and market processes that bring a product to a consumer. We therefore use the value chain concept to categorize losses, starting from the time fish are lifted on the vessel for fisheries or harvested for aquaculture up to when they are eaten by consumers.

A multitude of value chain actor combinations, harvesting techniques, fish products, and geographical contexts create a wide range of possibilities for fish to be supplied to consumers (Vallejo et al., 2009). Value chain analysis has only recently become popular, hence, many studies have not been systematic in measuring losses at all value chain nodes. In addition, loss assessments are costly and time-consuming so few examples of full chain assessments exist. We therefore categorize losses by stage of the value chain, rather than pull out single chains, since studies most often collect and present information in this fashion. Losses are reported for the 'entire chain' for studies that do not separate loss estimates by value chain stage, recognizing that these different estimates may not reflect value chains with a similar number of nodes depending on if fish are sold directly to consumers or undergo numerous processing or marketing steps.

The review is based on secondary data from peer-reviewed and grey literature, providing an overview of studies so far conducted on the topic. The literature search was based on a narrative review and was conducted in Science Direct and Google Scholar and covers studies from low- and middle-income countries conducted from 1996 to 2018. Additional references reviewed were provided by authors and personal contacts.

## 2. Fish loss and waste: key concepts

Definitions of food loss and waste vary, and different terms are used by researchers from different backgrounds (HLPE, 2014a). For example, from a food security perspective, biofuels, feed and other non-food uses of resources intended for human consumption may be considered a "loss," while from a perspective of economics and value added, they are not (Rutten, 2013). In this paper, we use the "food-focused approach" proposed by FAO, which considers a food or part of a food "lost" only if they were originally intended for human consumption and were lost or discarded at some point in the food chain (HLPE, 2014a). It should be noted that what is considered "edible" may vary across contexts and time and therefore it is important to consider intended use with a commodity like fish, whose preparation can vary considerably due to context (Rutten, 2013).

Definitions of waste and loss are used inconsistently in the literature to reflect the social, economic, or nutritional lens being applied by the authors (FAO, 2019). Recognizing the importance of a consistent definition, the FAO has moved towards a uniform definition of food loss as a decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers, and consumers (FAO, 2019). Food waste is the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services, and consumers. Conceptually, this distinction separates actions taken along the food supply chain from those taken by consumers or on behalf of consumers. This is useful from a policy perspective as it distinguishes decisions and circumstances that affect the supply of food from those that are driven by demand for food.

This paper examines four categories of loss: physical, quality, nutritional, and market loss as they are incurred at all stages of the value chain (Fig. 1). Although subsequent authors have highlighted the flaws in measurement methodologies (Delgado et al., 2017), these categories are still widely used and thus there is value in discussing the merits of these loss categories for fish (Cheke and Ward, 1998; Ward and Jeffries, 2000; Kumolu-Johnson and Ndimele, 2011). Definitions of loss are presented in Table 1.

Fish loss occurs throughout the value chain from catch or production to final consumption. Loss is influenced by several factors including the species of fish, the associated physical characteristics (i.e., composition, weight, and shape), the perceived value of the fish, volumes handled, the level of seasonality present, and geographical location. Furthermore, fish enterprises in developing countries are likely to experience more losses than enterprises in developed countries during loading and unloading, processing, storage, transportation, and marketing of fish due to technical, financial, infrastructural, and managerial constraints (De Silva, 2011). Spoilage and quality downgrading of the product is more likely to occur in lower-income economies due to high ambient temperatures, lack of access to services, infrastructure, basic technology, a reliance on more traditional smoking and drying techniques for preservation, and lack of cooling (cold chain) facilities (HLPE, 2014a). Fig. 1 summarises a number of key causes of fish losses at different stages of the value chain.

## 3. Fish loss and waste assessment methods: strengths and weaknesses

Methods to estimate fish loss and waste follow either a macro or a micro approach depending on the objective and scope of the assessment. Macro approaches provide an estimate of physical loss for the whole fishery sector at the country, regional or global level, using mostly secondary data from government authorities and large companies, coefficients from the literature and quantitative models. Micro approaches estimate fish loss for single value chains, usually located in limited geographical areas, based on direct physical measurements, observations, and/or questionnaires to acquire information from value chain actors directly (FAO, 2016).

The macro approach provides an opportunity to compare loss across different geographical areas and may assist in developing interventions and regulations at a higher level. Limitations of macro approaches used to date include (1) the aggregation of data from different fish species, which ignores the complexity of fisheries (2) estimates usually only capture physical loss, not quality or nutritional loss (3) estimates often lack accurate data (Schuster and Torero, 2016). Due to their aggregate nature, macro approaches often fail to provide guidance for interventions at the local level.

Use of the micro approach can address some of these limitations as it is based on primary data directly collected from value chain actors, usually along a single fish supply chain (Schuster and Torero, 2016). This helps to design targeted interventions and policies for local action. Disadvantages to this approach are: (1) micro loss assessments can be expensive and time-consuming (2) information provided by respondents may be partial and inaccurate due to a lack of data recording and difficulties in recall (Ward and Jeffries, 2000) (3) Seasonality introduces challenges to estimation as supply of fish and levels of loss will differ naturally due to temporal weather conditions, for example, when drying becomes more difficult during the rainy season and loss increases. (Hodges et al., 2011).

Guides developed by FAO and NRI outline the most prominently

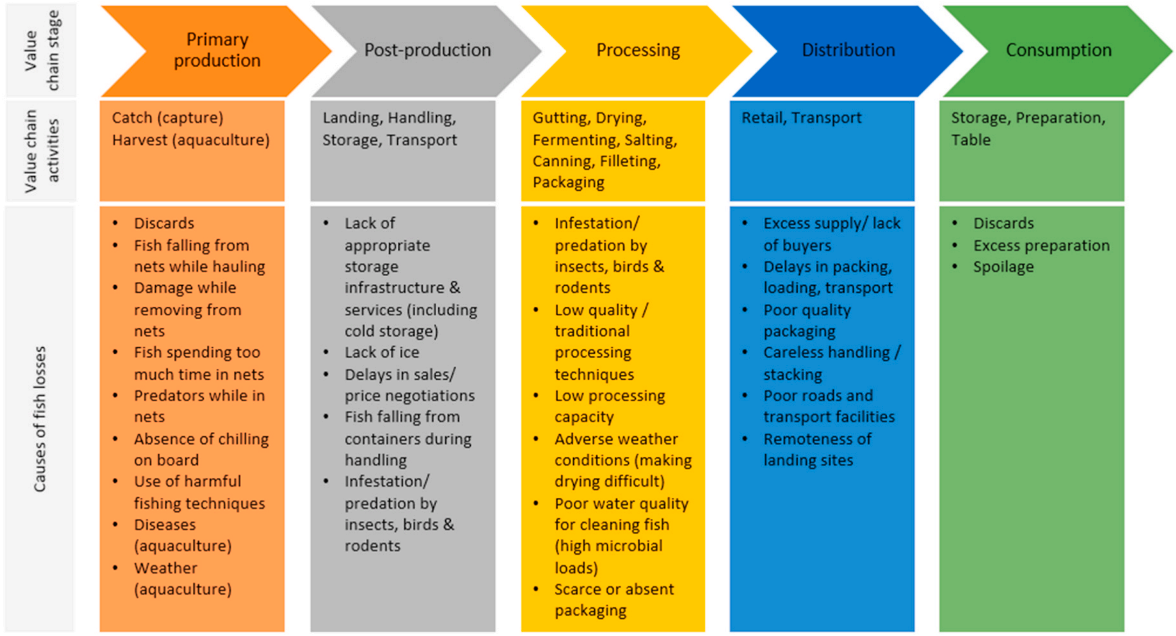


**Fig. 1.** Fish loss and waste along the value chain: stages and causes.
Source: Adapted from Schuster and Torero (2016), with information from Akande and Diei-Ouadi (2010); Ames et al., 1991; HLPE 2014a; Kumolu-Johnson and Ndimele (2011); Ward and Jeffries (2000); Kelleher (2005).

**Table 1**
Definitions of different types of loss.

| | |
|---|---|
| **Physical loss** | Physical loss can be expressed in terms of losses in weight and/or monetary value and occurs when fish are entirely removed from the value chain due to spoilage or consumption by insects or animals. In practice, it is often difficult to differentiate between physical loss due to poor postharvest practices and weight loss that is expected moisture loss (Affognon et al., 2015). |
| **Quality loss** | Quality loss estimates capture decreases in fish quality by quantifying the difference in the potential value of fish at best quality and its value after quality degradation. This type of loss is therefore usually expressed in monetary terms. Quality-deteriorated fish are sometimes sold as a downgraded product, such as fishmeal for animal feeds. While this type of loss is sometimes included in quality loss estimates, it does not fit into FAO's "food-focused approach" since this constitutes a complete exit from the chain for direct human consumption. This leads to substantial underreporting of fish loss. |
| **Nutritional loss** | Nutritional loss refers to specific changes in the nutritional content or properties of fish as a result of spoilage or processing. This includes loss of micronutrients, fatty acids, and protein during processing, including cooking/smoking as well as the removal of certain parts of the fish (such as head, bones, and part of the viscera, which often have a high content of certain nutrients). This loss is expressed in terms of nutrients, such as lipids, protein, fibre, carbohydrate, minerals, vitamins, and fatty acids. Sometimes nutritional loss is equivalent to quality loss if industry standards must be maintained. |
| **Market force loss** | Market force loss refers to different types of loss attributable to market behaviour or management. The product in itself does not change in terms of quality attributes, but market forces lead to a decrease in the price below the optimum, for example, as a result of oversupply. Market force loss is expressed in monetary terms. |

used micro approaches to assessing fish loss (Ward and Jeffries, 2000; Ward, 2000; Diei-Ouadi, and Mgawe, 2011). These approaches have been applied independently or in combination to assess physical and/or quality loss. Many of the micro-methods described across our literature review can be classified under these three approaches, even if they do not refer to these methods specifically. These include:

- **Informal Fish Loss Assessment Method (IFLAM), also known as the Exploratory Loss Assessment Method (EFLAM):** a rapid method for assessment of loss and waste based on a Rapid and Participatory Rural Appraisal approach involving checklists and group discussions used to roughly appraise the share and value of fish lost to identify hotspots (FAO, 2014b).
- **Load tracking**: an experimental method that produces statistically valid results for the calculation of loss between two stages in a distribution chain involving the direct measurement of a 'load' at different stages and the assessment of quality losses based on consultations with fish value chain operators. Because of its experimental and replicable nature, load tracking is the most robust and accurate procedure, but it is demanding in terms of financial and other resources and cooperation with local communities.
- **Questionnaire Loss Assessment Method (QLAM)**: a formal survey that provides quantitative data on issues such as types of loss, reasons for loss, frequency of loss, and variables that affect loss, such as fishing gear type, seasonality, livelihood activities and profile of those affected by fish loss. The analysis of survey data provides quantifiable information that can be used to validate the findings of IFLAM and load tracking.

The literature also references two other methods, which have not been as fully developed. These are sensory quality assessments and a modelling approach (Table 2). Sensory assessments are subjective methods to determine quality loss that use ranking systems to evaluate organoleptic characteristics of fish, such as general body appearance, consistency of flesh, odour, colour, and eye and gill condition. While more efficient than assessing fish quality through laboratory methods, sensory assessments cannot detect many forms of microbial contamination that lead to quality loss (Nowsad et al., 2010). Nutrient loss assessments usually use a lab-based approach that may vary depending on the types of nutrients assessed.

## 4. Existing evidence on magnitude of fish loss and waste

The existing evidence on different forms of fish loss and waste by macro and micro approaches is presented in Tables 3–7.

**Table 2**
**Overview of methodologies used for fish loss and waste assessments.**

| Assessment method | Quant/Qual | Type of loss | Source(s) |
|---|---|---|---|
| *Macro approach* | | | |
| Estimations based on FAO FishStat database, FAO Food Balance Sheets, and loss and waste ratios derived from literature | Quantitative | Physical | Kelleher (2005); FAO, 2011. |
| *Micro approaches* | | | |
| IFLAM and other similar qualitative assessments | Qualitative | Physical Quality Market | Ward and Jeffries (2000); Akande et al., (2000); Mgawe (2008); Nowsad (2010); Akande and Diei-Ouadi (2010); FAO 2014b; Diei-Ouadi et al., (2015). |
| Load tracking | Quantitative | Physical Quality Market | Ward and Jeffries (2000); Akande et al., (2000); Mgawe (2008); Akande and Diei-Ouadi (2010); FAO 2014b. |
| QLAM and other questionnaires | Quantitative | Physical | Ward (1996); Ward and Jeffries (2000); Dey et al. (2011); Eyo and Mdaihli (2005); Mgawe (2008); Akande and Diei-Ouadi (2010); Gordon et al., (2011); Kasprzyk (2012); Kasprzyk et al. (2015); FAO 2014b; Diei-Ouadi et al., (2015); Adelaja et al. (2018) |
| Qualitative fish freshness assessment tool and other sensory quality assessment methods | Qualitative | Quality | Eyo and Mdaihli (2005); Nowsad (2010); Nowsad et al. (2015). |
| Compartmentalised model | Quantitative | Physical and quality | Cheke and Ward (1998). |

**Table 3**
Estimates of physical loss and waste in fish value chains, macro approach.

| Value chain stage | Loss estimate (% of catch) | Species | Location | Reference |
|---|---|---|---|---|
| Production | 8 | Marine fish | World | Kelleher (2005) |
| | 31 | All fish and seafood | Europe, incl. Russia | FAO (2011) |
| Entire chain | 29 | All fish and seafood | Latin America | FAO (2011) |
| | 30 | All fish and seafood | North Africa and West/Central Asia | FAO (2011) |
| | 32 | All fish and seafood | Sub-Saharan Africa | FAO (2011) |
| | 34 | All fish and seafood | South/Southeast Asia | FAO (2011) |
| | 36 | All fish and seafood | Industrial Asia | FAO (2011) |
| | 50 | All fish and seafood | North America and Oceania | FAO (2011) |

### 4.1. Physical loss

Table 3 presents the estimates derived using a macro approach. Loss estimates dated before 1996, the beginning of our reference period for this paper suggest higher prevalence of loss (e.g. Alverson et al., 1994). The decrease in loss has been mainly attributed to reductions of discards at sea (FAO, 2011). In Table 3, estimates are categorized according to their value chain stage. As the estimates from FAO (2011) are based on literature and refer to Kelleher (2005) as the source for the estimation of discards at production level, the two sources are consistent in their estimates.

Table 4 presents the estimates of physical loss in fish value chains estimated according to a micro approach. Most of the estimates are for African capture fisheries, except for Wibowo et al. (2017) in Indonesia and Daluwatte and Sivakumar (2018) in Sri Lanka. Physical loss is expressed in a percentage of weight lost; studies have inconsistently converted this into a monetary value. There is little consistency in the value chain nodes that are included and species and countries covered, although (caught) tilapia and silver cyprinid (*R. argentea*) seem to be more commonly studied than other species. Because the other estimates cover different countries, species, value chain nodes, and time frames, a comparison of the estimates is difficult.

While there is quite some evidence on physical loss, there is very little consistency and comparability between the different estimates. Only four studies compute physical loss across the entire value chain, suggesting a need for further research to create robust data to inform policy interventions. It is clear that all parts of the value chain are subject to physical loss; however, in most cases this is less than 5%. Physical loss appears to be higher for lower value fish consumed by the poor. Silver cyprinid in Tanzania and Uganda both recorded physical losses of 20–40% across the entire value chain (Akande and Diei-Ouadi, 2010). These low-value fish are often sun-dried and transported and sold in places with minimal infrastructure, which leads to high levels of loss. Watsa (purse seine) fisheries in Ghana recorded losses of roughly 20% during production. On the other hand, tilapia, a highly commercialized species, had low levels of loss along the value chain.

We identified one source that measured loss and waste of Nile perch (Lates niloticus) from Lake Victoria in Tanzania along multiple value chains, e.g. fresh, smoked, salted, and fried. The details provided in this study make it possible to compare loss estimates of fish caught at the same origin but then subjected to different value chains. Fish experienced the same degree of loss during fishing (~2%), but processed fish suffered additional losses during processing (smoked: 2.5%, salted: 2.2%, fried: 7.1%). Fresh fish had a larger loss estimate during transport (1%) and retail (1.5%) than processed fish (smoked: 0.01% and 0.8%, salted: 0.1% and 0.1%, fried: 0.3% and 0.8%). By the time fish reached consumers, fresh fish experienced 4.5% loss, smoked fish 5.3%, salted fish 4.4%, and fried fish 10.2%. This detailed accounting of fish loss demonstrates how loss levels can vary depending on a multitude of factors, e.g. what type of processing method is used and if fish is processed or fresh when it is transported. Unfortunately, it was not common for studies to measure fish loss at such a granular level.

Although our review identified studies from 1996 to 2018, there does not appear to be a reduced trend in loss levels during this time frame. In fact, high levels of loss can be seen in recent studies, such as *Labeobarbus* in the Amhara region of Ethiopia, where loss of over 50% was recorded. Variation in the way that results are presented, as well as in the amount of detail provided (for example reporting physical loss as the proportion downgraded but still sold versus entire removal from the chain) and lack of details in the methods used to determine loss, were also identified as challenges in our review of the literature.

### 4.2. Quality loss

Several studies used IFLAM or an IFLAM-style tool combined with Load Tracking to assess quality loss. Only Nowsad et al. (2015) in

**Table 4**
Estimates of physical loss in fish value chains, micro approach.

| Value chain stage | Estimation of loss | | Species | Location | Reference |
|---|---|---|---|---|---|
| | Weight loss (%[e]) | Value loss (USD or %)[a] | | | |
| Production | 0–7.5 | – | Silver cyprinid | Kenya | Akande and Diei-Ouadi (2010) |
| | 1–5 | – | Jarife (gillnet fisheries) | idem | idem |
| | 1.50 | 266,000 USD/yr | Nile perch | Lake Victoria | Ward (1996) |
| | 2.03 | | Multi-species fisheries | Barotse Floodplain, Zambia | Kefi et al. (2017) |
| | 2.30 | 24,000 USD/yr | Multi-species fisheries | Mafia Island, Tanzania | Ward (1996) |
| | 7.57 | | Shrimp | Ondo State, Nigeria | Adelaja et al. (2018) |
| | 7.76 | | Catfish | idem | idem |
| | 8.15 | | Croaker | idem | idem |
| | 16.67 (theft) | | Gillnet fishery | Gunung Kidul, Indonesia | Wibowo et al. (2017) |
| | 16–20 | – | Watsa (purse seine) fisheries | Ghana | Akande and Diei-Ouadi (2010) |
| | 22 | 1.4 M USD/yr | Mud crab | Madagascar | Kasprzyk et al. (2015) |
| Landing | 2–6 | 10–50% | Katsuwonan Pelamis | Sri Lanka | Daluwatte and Sivakumar (2018) |
| | 7.60 | 4.6 M USD/yr | Kainji Lake fishery: tilapia, Nile perch, moon fish e.a. | Nigeria | Eyo and Mdaihli (2005) |
| | 8–18 | 13%–45% | Decapterus russeli | Sri Lanka | Daluwatte and Sivakumar (2018) |
| | 13–23 | 39%–51% | Auxis Thazard | Idem | idem |
| | Some form of loss: 29.3% of the consignment Totally discarded: 6% of the consignment | | Multi-species fisheries | Barotse Floodplain, Zambia | Kaminski and Cole (2017) |
| | | | | Sri Lanka | Daluwatte and Sivakumar (2018) |
| Landing to wholesale | 5 | 6.4 M USD/yr | Silver cyprinid | Tanzania | Mgawe (2008) |
| After landing | 0.1615 | | Multi-species fisheries | Port Sudan, Sudan | Hamza et al. (2017) |
| | 1.04 kg/day [b] | 500 USD/yr | Multi-species fisheries (including Bagrus documak, Catfish, Labeobarbus, Tilapia) | Lake Hayd, Amhara region, Ethiopia | Assefa et al. (2018) |
| | 15,55 ton/year[c] | | Multi-species fisheries | Lake Tekere, Amhara region, Ethiopia | idem |
| | 6.08 kg/day[b] | 3672 USD/yr | Multi-species fisheries (including Bagrus documak, Catfish, Labeobarbus, Tilapia) | Lake Tekere, Amhara region, Ethiopia | idem |
| | 7.92 ton/year[c] | | Multi-species fisheries | Lake Hayd, Amhara region, Ethiopia | idem |
| Processing | 1.8 (IFLAM), 4.73 (load tracking) | | Small pelagics | Tegal, Indonesia | Wibowo et al. (2017) |
| | 2.7 | 1300 USD/yr | Multi-species fisheries | Mafia Island, Tanzania | Ward (1996) |
| | 3.8 | 75,000 USD/yr | Silver cyprinids | Lake Victoria | idem |
| | 7.4 | | Multi-species fisheries | Barotse Floodplain, Zambia | Kefi et al. (2017) |
| | Frying: 7.1<br>Scorching: 6.5<br>Smoking: 2.5<br>Salting: 2.2 | 98,000 USD/yr | Nile perch | Lake Victoria | Ward (1996) |
| | Breakage: 61.5 of the consignment<br>Over-processing: 23.1 of the consignment | | Multi-species fisheries | Barotse Floodplain, Zambia | Kaminski and Cole (2017) |
| | 42.9 | | idem | Idem | idem |
| | 10.8 | | idem | Idem | idem |
| Processing and Transport | 3.9–10 | – | Processed fish | Nigeria | Akande et al. (2000) |
| Transport | 0 | 0 | Multi-species fisheries | Mafia Island, Tanzania | Ward (1996) |
| | 0.30 | 725 USD/yr | Silver cyprinids | Lake Victoria | idem |
| | Fresh: 1<br>Salted: 0.1<br>Smoked: ~0 | 9200 USD/yr | Nile perch | Lake Victoria | idem |
| | 6.01 | | Mini trawl fishery | Brondong, Indonesia | Wibowo et al. (2017) |
| Trading | Minimal | – | Tilapia | Uganda | Akande and Diei-Ouadi (2010) |
| | 2.90 | | Multi-species fisheries | Barotse Floodplain, Zambia | Kefi et al. (2017) |

(continued on next page)

**Table 4** (*continued*)

| Value chain stage | Estimation of loss | | Species | Location | Reference |
|---|---|---|---|---|---|
| | Weight loss (%[e]) | Value loss (USD or %)[a] | | | |
| | 10 | | Lobster | Gunung Kidul, Indonesia | Wibowo et al. (2017) |
| Marketing | Minimal | – | Tilapia | Kenya | Akande and Diei-Ouadi (2010) |
| | 6.40 | – | Kainji Lake fishery: tilapia, Nile perch, moon fish e.a. | Nigeria | Eyo and Mdaihli (2005) |
| Physical loss | 10 | 25,420 USD | Multi-species fisheries | Tekeze Dam and Lake Hashenge, Ethiopia | Tesfay and Teferi (2017) |
| Retail | 0.1 | 450 USD/yr | Multi-species fisheries | Mafia Island, Tanzania | Ward (1996) |
| | 0.8 | 9000 USD/yr | Silver cyprinids | Lake Victoria | idem |
| | Fresh: 1.5<br>Smoked: 0.8<br>Salted: 0.1 | 23,000 USD/yr | Nile perch | Idem | idem |
| | 57.1 | | Catfish | Amhara region, Ethiopia | Assefa et al. (2018) |
| | 38.5 | | Bagrus documak | Idem | idem |
| | 42.3 | | Labeobarbus | Idem | idem |
| | 71[d] | | Tilapia | Idem | idem |
| Entire chain | Negligible | | Squid | Muara Angke, Indonesia | Wibowo et al. (2017) |
| | 1–3 | – | Smoked clarias | Mali | Akande and Diei-Ouadi (2010) |
| | 2 | – | Tilapia (caught) | Togo | Diei-Ouadi et al. (2015) |
| | 2–3 | – | Fresh fish | Mali | Akande and Diei-Ouadi (2010) |
| | 3–17 | | Smoked fish | Ghana | Idem |
| | 4 | – | Multiple species | Ghana | Diei-Ouadi et al. (2015) |
| | 6 | – | Tilapia (caught) | Burkina Faso | Idem |
| | 12.32 | ~USD 6 million | Multi-species fisheries | Barotse Floodplain, Zambia | Kefi et al. (2017) |
| | 20–40 | – | Silver cyprinid | Tanzania | Akande and Diei-Ouadi (2010) |
| | 26–40 | – | Silver cyprinid | Uganda | idem |

[a] Nominal prices based on the average exchange rate of reference currency for USD for the year the data was collected.
[b] Estimation from questionnaires (GLM estimators).
[c] Calculation from secondary data.
[d] Load tracking method.
[e] Except if indicated otherwise

Bangladesh conducted a sensory assessment combined with laboratory analyses. Quality assessments were often conducted in conjunction with physical loss assessments, as can be seen from the repetition of studies from Table 4 to Table 5, but are conducted less frequently than physical loss assessments overall. We found fewer estimates of quality loss in the existing literature than those of physical loss (Table 5). Quality loss is more commonly estimated across entire value chains.

Although very few references reported quality loss, many of those that did, reported larger volume and monetary loss as a result of deteriorating quality rather than due to physical loss. In several fish value chains, physical loss was reported as almost negligible, yet quality loss was significant. For example, in Kenya fresh tilapia traders suffered minimal physical loss, but 27% of total volume was lost to deteriorating quality (Akande and Diei-Ouadi, 2010). Diei-Ouadi et al. (2015) noted that quality loss was the predominant type of loss they observed in the fish value chains they studied in Burkina Faso, Ghana, and Togo. They linked quality loss to a lack of improved technology, infrastructure, and good manufacturing practices, but also stressed the influence of social and cultural dimensions. Women were more vulnerable to postharvest loss than men, and the lack of responsible governance, regulations, and enforcement allowed quality loss to proliferate (Diei-Ouadi et al., 2015). Again, low-value small fish suffer large losses, particularly in the rainy season, when sun drying is extremely difficult. Akande and Diei-Ouadi (2010) estimated that for low-value small fish in the African countries studied, only 5% was discarded as physical loss while another 80% was sold at less than 20% of the best price for good quality product. This resulted in a loss valued at US $30 million annually.

### 4.3. Market force losses

We only encountered three studies that attempted to estimate market force loss (Table 6). These studies already appeared in Tables 3 and 4 The lack of studies on market force loss may be related to the difficulty to assign a loss to market forces only, rather than reductions in quality. This would require more in-depth research.

### 4.4. Nutritional loss

Most studies of nutritional loss in fish have examined the effects of processing, storage, and cooking methods on the nutritional value of the product and have focused on developed country settings, commonly consumed species in those settings, and preservation methods used in those settings. Lipid oxidation, which causes the loss of polyunsaturated fatty acids is a common concern (Aubourg, 2001). Apart from mincing and grinding, lipid oxidation is also affected by storage temperature, as well as the length of storage (Secci and Parisi, 2016). The literature often focuses on microbial decomposition, including histamine formation and enzyme activity (Aubourg, 2001), which affect the sensory quality of fish and lower prices, but rarely examines the nutritional consequences of degradation.

**Table 5**
Estimates of quality losses in fish value chains, micro approach.

| Value chain stage | Estimation of loss | | | | |
|---|---|---|---|---|---|
| | Loss (%) | Unit | Species | Location | Reference |
| Production | 0.1 | Volume | Gillnet fishery | Gunung Kidul, Indonesia | Wibowo et al. (2017) |
| | 0.1 | Value | Mini trawl fishery | Brondong, Indonesia | idem |
| | 0.2 | Volume | Mini trawl fishery | Idem | Wibowo et al. (2017) |
| | 0.3 | Volume | Jarife (gillnet fishery) | Kenya | Akande and Diei-Ouadi (2010) |
| | 0.3 | Value | Small pelagics | Tegal, Indonesia | Wibowo et al. (2017) |
| | <0.1 | Volume | Squid | Muara Angke, Indonesia | Idem |
| | 1.5–18.9 | Volume | Silver cyprinid | Kenya | Akande and Diei-Ouadi (2010) |
| Production up to marketing | 0.1 | Cases | Catfish (P. sutchii) | Bangladesh | Nowsad et al. (2015) |
| | 0.1 | idem | Grass carp | idem | idem |
| | 0.2 | idem | Silver carp | idem | idem |
| | 0.2 | idem | Mrigel | idem | idem |
| | 0.2 | idem | Catla | idem | idem |
| | 0.2 | idem | Ilish (T. ilisha) fresh | idem | idem |
| | 0.2 | idem | Rohu (L. rohita) | Idem | idem |
| | 0.2 | idem | Ribbon fish (dried) | Idem | idem |
| | 0 | idem | Ilish (T. ilisha) salted | Idem | idem |
| Landing to wholesale | 0 | Volume | Silver cyprinid | Tanzania | Mgawe (2008) |
| Processing | 0.1 | Volume | Squid | Muara Angke, Indonesia | Wibowo et al. (2017) |
| Marketing | 0.3 | Volume | Tilapia (fresh) | Kenya | Akande and Diei-Ouadi (2010) |
| | 2.5–5.2 | Volume | Tilapia | Uganda | idem |
| Trading | 4.8 | Value | Small pelagics | Tegal, Indonesia | Wibowo et al. (2017) |
| | 4–6 | Volume | Gillnet fishery | Gunung Kidul, Indonesia | Idem |
| Transport | 10–15 | Value | Catfish | Nigeria | Gorman and Webber (2010) |
| Entire chain | <0.1 | Volume | Tilapia (caught) | Togo | Diei-Ouadi et al. (2015) |
| | <0.1 | idem | Multiple species | Ghana | idem |
| | 0.1 | idem | Smoked clarias | Mali | Akande and Diei-Ouadi (2010) |
| | 0.1 | idem | Tilapia (caught) | Burkina Faso | Diei-Ouadi et al. (2015) |
| | 0.2 | idem | Silver cyprinid | Tanzania | Akande and Diei-Ouadi (2010) |
| | 0.3 | idem | Watsa (purse seine) fishery | Ghana | idem |
| | 0.4 | idem | Smoked fish | Idem | idem |
| | 2–5 | idem | Silver cyprinid | Uganda | idem |
| | 7.5–25 | idem | Fresh fish | Mali | idem |

**Table 6**
Estimates of market force losses, micro approach.

| Value chain stage | Estimation of loss (%) | Unit | Species | Location | Reference |
|---|---|---|---|---|---|
| Production | 1–2 | value | Mini trawl fishery | Brondong, Indonesia | Wibowo et al., (2017) |
| Landing to wholesale | 11 | weight | Silver cyprinid | Tanzania | Mgawe (2008) |
| Entire chain | 8 | volume | Tilapia (caught) | Togo | Diei-Ouadi et al. (2015) |
| | 20 | volume | Multiple species | Ghana | idem |
| | 40 | volume | Tilapia (caught) | Burkina Faso | idem |

The literature concerned with microbial loads and other food quality measures does not link these measures to the marketability of fish, and we have therefore excluded this literature for this review as we would be unable to draw any conclusions about the effect on supply. Table 7 does not provide a complete overview of the studies that have examined changes in nutritional composition; however, we provide examples of the types of nutritional values that are being examined in the literature on processing. While there are a large number of studies available on specific processing methods, there are, to our knowledge, much fewer studies on nutritional loss along entire value chains. Another major gap in this literature concerns studies in low-income countries, and of common preservation methods in those countries, such as drying. Canning as a processing method is not as relevant for consumers in low-income countries.

Most of the studies reviewed are experimental in nature (with the exception of Saliu (2008)), and therefore provide an impression of how food processing affects nutritional content under experimental conditions, rather than storage or preparation in a real-life environment. Our review mostly found experimental studies, which means that the usefulness of these studies for policy recommendations is limited.

## 5. Policies and other approaches to reduce fish loss and waste

The SDG mandate to reduce food loss and waste by 2030 has led many countries, agencies, institutions, and civil society groups to develop policies to combat food loss and waste (United Nations, 2014; FAO, 2015). This requires an integrated approach that includes a combination of the right policy, legislation, capacity building, services, infrastructure and technology, and a thorough understanding of the socio-cultural setting (Morrissey, 1988; FAO, 2016). Table 8 provides a summary of a few examples of how the problem of fish loss and waste has been addressed at different stages of the value chain.

### 5.1. Global level

At the global level, there are several notable initiatives including the

**Table 7**
Estimates of nutritional loss, micro approach.

| Nutritional component | Treatment | Value (%) | % change from fresh | Unit | Species | Location | Reference |
|---|---|---|---|---|---|---|---|
| Processing | | | | | | | |
| Crude protein | Fresh | 14.5 | NA | % loss | *O. niloticus* | Nigeria | Kumolu-Johnson et al. (2010) |
| | Smoking | 50.2 | 35.7 | idem | idem | idem | idem |
| Mono-unsaturated fatty acid | Marinated | 20.67 | −0.31 | % of total lipid | Anchovy (Engraulis encrasicholus) | Turkey | Özden (2005) |
| | Fresh | 20.98 | NA | idem | idem | idem | idem |
| | Fresh | 30.87 | NA | idem | idem | idem | idem |
| | Marinated | 31.35 | 0.48 | idem | idem | idem | idem |
| Phosphorus | Fresh | 0.00012 | NA | % loss | *O. niloticus* | Oman | Chukwe (2009) |
| | Smoking kiln at 70–85 °C for 20 h | 0.00042 | 0.0003 | idem | idem | idem | idem |
| | Electric oven at 110 °C for 45 min | 0.00042 | 0.0003 | idem | idem | idem | idem |
| Poly-unsaturated fatty acid | Marinated | 33.27 | −0.61 | % of total lipid | Rainbow trout (Salmo gairdneri) | Turkey | Özden (2005) |
| | Fresh | 33.88 | NA | idem | idem | idem | idem |
| | Marinated | 34.14 | −2.09 | idem | idem | idem | idem |
| | Fresh | 36.23 | NA | idem | idem | idem | idem |
| Protein | Fresh | 23.06 | NA | % loss | *O. niloticus* | Oman | Chukwe (2009) |
| | Smoking kiln at 70–85 °C for 20 h | 63.64 | 40.58 | idem | idem | idem | idem |
| | Electric oven at 110 °C for 45 min | 64.1 | 41.04 | idem | idem | idem | idem |
| | Smoking | 23.0–44.3 | | % loss | *Clarias gariepinus* | Nigeria | Saliu (2008) |
| | Smoking | 28.0–29.3 | | % loss | Sarotherodon melanotheron | idem | idem |
| Saturated fatty acid | Fresh | 24.29 | NA | % of total lipid | Rainbow trout (Salmo gairdneri) | Turkey | Özden (2005) |
| | Marinated | 24.92 | 0.63 | % of total lipid | Rainbow trout (Salmo gairdneri) | idem | idem |
| | Marinated | 30.44 | −0.76 | % of total lipid | Anchovy (Engraulis encrasicholus) | idem | idem |
| | Fresh | 31.2 | NA | % of total lipid | Anchovy (Engraulis encrasicholus) | idem | idem |
| Vitamin A | Fresh | 0.00025 | NA | % loss | *O. niloticus* | Oman | Chukwe (2009) |
| | Smoking kiln at 70–85 °C for 20 h | 0.00046 | 0.00021 | idem | idem | idem | idem |
| | Electric oven at 110 °C for 45 min | 0.00084% | 0.00059 | idem | idem | idem | idem |
| **Storage** | | | | | | | |
| Crude fat | Icing | 1.5 | −1.1 | % loss | Rohu (Labeo rohita) | Pakistan | Dar and Mateen (2018) |
| | Salting | 1.5 | −1.1 | idem | idem | idem | idem |
| | Fresh (no storage) | 2.6 | NA | idem | idem | idem | idem |
| | Sun drying | 10.83 | 8.23 | idem | idem | idem | idem |
| Crude protein | Icing | 16 | −2.2 | idem | idem | idem | idem |
| | Salting | 16.8 | −1.4 | idem | idem | idem | idem |
| | Fresh (no storage) | 18.2 | NA | idem | idem | idem | idem |
| | Sun drying | 59.3 | 41.1 | idem | idem | idem | idem |
| Moisture | Sun drying | 21.27 | −55.33 | idem | idem | idem | idem |
| | Salting | 56.23 | −20.37 | idem | idem | idem | idem |
| | Fresh (no storage) | 76.6 | NA | idem | idem | idem | idem |
| | Icing | 79.1 | 2.5 | idem | idem | idem | idem |
| Mono-unsaturated fatty acid | 120 days stored marinated fish | 23.92 | 2.94 | % of total lipid | Anchovy (Engraulis encrasicholus) | Turkey | Özden (2005) |
| | Idem | 30.58 | −0.29 | % of total lipid | Rainbow trout (Salmo gairdneri) | idem | idem |
| Poly-unsaturated fatty acid | Idem | 32.54 | −1.34 | % of total lipid | Rainbow trout (Salmo gairdneri) | idem | idem |
| | Idem | 33.74 | −2.49 | % of total lipid | Anchovy (Engraulis encrasicholus) | idem | idem |
| Protein | Frozen storage | 24.5–27.5 | | % loss | Chrysichthys nigrodigitatus | Nigeria | Saliu (2008) |
| | Idem | 28.5–44.4 | | % loss | *Clarias gariepinus* | idem | idem |
| Saturated fatty acid | 120 days stored marinated fish | 30.09 | 5.8 | % of total lipid | Rainbow trout (Salmo gairdneri) | Turkey | Özden (2005) |
| | Idem | 34.77 | 3.57 | % of total lipid | Anchovy (Engraulis encrasicholus) | idem | idem |

**Table 8**
Fish loss and waste reduction strategies.

| Value chain stage | Main types of loss addressed | Proposed fish loss reduction strategies |
|---|---|---|
| Fishing | Physical, Quality | ● Use of appropriate/authorised/modified fishing gear<br>● Use of (high quality) ice, refrigeration, evaporative cooling, freezing on board<br>● Avoid exposure of fish to direct sunlight and contamination<br>● Landing fish as fast as possible<br>● Handle fish with care<br>● Improving production planning to better respond to markets<br>● Enhancing education of producers on post-harvest loss<br>● Support to credit for collective marketing and better access to technologies |
| Landing | Physical, Quality | ● Proper infrastructure at and management of landing sites<br>● Use of ice/refrigeration<br>● Implementation of food safety legislation and practices |
| Processing | Physical, Quality, Nutritional | ● Use of improved processing techniques (e.g. raised racks, improved ovens, etc.)<br>● Use of screens to prevent insect infestation<br>● Controlled use of insecticides and fumigants<br>● Use of hygienic practices for processing, handling, and storage<br>● Use of clean water<br>● Use of good quality raw material (fresh fish)<br>● Use of appropriate packaging for processed fish |
| Transport & distribution | Physical, Quality | ● Use of ice/insulated boxed for fresh fish<br>● Use of appropriate packaging such as rigid containers<br>● Use of proper packing before transport<br>● improving transportation and logistics management |
| Storage | Physical, Quality, Nutritional | ● Use of properly designed storage facilities to avoid pests and spoilage<br>● Improving storage management and product rotation (first in first out)<br>● Use of hygienic practices<br>● Improving preservation and packing technologies |
| Marketing | Quality, Market force | ● Proper market infrastructure and management<br>● Implementation of food safety legislation at markets<br>● Use of ice/insulated boxes or other preservation techniques<br>● Promotion of value-added products from low-value fish species<br>● Raising public awareness on fish quality and food waste<br>● Improve access to market information on prices and demand<br>● Improve access to more rewarding markets |
| Consumers | Physical | ● Enhancing consciousness of purchasing and consumption habits<br>● Promotion of consumption towards less valued fish species (utilization of discards/bycatch) |

Sources: Author's compilation from Akande and Diei-Ouadi (2010); Ames et al., 1991; FAO 2014b; HLPE 2014b; Hodges et al., (2011); Kumolu-Johnson and Ndimele (2011); Mgawe and Diei-Ouadi (2011); Ward and Jeffries (2000).

voluntary international guidelines on bycatch management and discards reduction by the FAO Committee on Fisheries (FAO, 2014a), the EU fish discards ban (EU, 2015), the SAVE FOOD Initiative on Food Loss and Waste Reduction,[1] and the launch of a Technical Platform on the Measurement and Reduction of Food Loss and Waste[2] support processes to reduce food loss and waste, by promoting partnership with the private sector, creating a favourable business climate, and working with research organizations and civil society to raise awareness and advocacy on the matter (FAO, 2014b). Guidance for fish loss and waste reduction has also been provided by the FAO Code of Conduct for Responsible Fisheries (FAO, 1995) and regionally, guidance for fish loss and waste reduction has been offered, for example, by Africa, in particular by the Malabo Declaration (AU, 2014).

### 5.2. *Bycatch and discards*

There are a number of factors that appear to encourage (or discourage) the landing and utilization of fish that would otherwise be discarded at sea. The development of new technologies to make use of bycatch is one such factor: for example, in Indonesia, bycatch is now used as a raw material to manufacture peptone growth media for the probiotic bacteria *Lactobacillus johnsonii,* which has uses in the food, industrial, healthcare and pharmaceutical sectors. (Renhoran et al., 2011). However, use of bycatch is limited by lack of storage space inside vessels as well as by the distance between fishing and landing sites. Buy in and behaviour change is needed from crew and vessel owners who have incentives to align themselves with a specific processing industry that prioritizes a target species if bycatch is to be preserved on fished vessels (Irianto et al., 2014). Given the variation in how such factors influence what happens in a particular country, it is impractical to recommend a "one size fits all" approach to utilization of bycatch (FAO, 2019b).

Due to the past quota system, there were high levels of fish discards at sea in many EU fisheries as fishers selected the most profitable and legally allowed fish to be landed from catches. Partly due to a popular public campaign to change the system and avoid discards, and partly because it was seen as a serious waste of fish, the EU changed its policy and introduced a discard ban. In line with EU regulation 2015/812, from January 1, 2015 onwards, fishers in certain parts of the EU must land all the fish they catch, and by 2019 all fishers will have the same obligation. Under the landing obligation, all catches of species that are subject to minimum sizes or quotas must be kept on board, landed and counted against quotas, except when used for live bait (Marine Scotland, 2015). On a more macro level, the International Guidelines on Bycatch Management and Reduction of Discards, endorsed by the Committee on Fisheries (COFI) in 2011, are designed to assist state and regional fisheries management organizations and arrangements in formulating and implementing appropriate measures to manage and reduce discards (FAO, 2011b).

### 5.3. *Harvest and ice usage*

Encouraging the use of ice on board vessels helps reduce fish loss and waste. Many larger vessels capable of spending a day or more in fishing operations will benefit from the use of some form of on board preservation, such as ice or chilled seawater (CSW). This might include artisanal fishing vessels, such as larger dugout canoes, outboard-motor-powered launches and larger inboard-engine-powered vessels up to 20 m long. The use of ice for preserving fish and fishery products has proved to be an effective handling method on board fishing vessels.

Larger boats are able to carry more ice, which allows them to make longer fishing trips, generally with better economic returns for the vessel

[1] http://www.fao.org/save-food/background/en/.
[2] http://www.fao.org/platform-food-loss-waste/en/.

and crew (Shawyer and Pizzali, 2003).

With advances in refrigeration, in particular the advent of compact and relatively lightweight ice-making machines suitable for on board installation, it is now possible to install ice machines of various types on quite small vessels. This gives a certain measure of independence in fishing operations where trip length is no longer limited by the quantity of ice loaded in port or by how long it will last in the ice hold (Shawyer and Pizzali, 2003).

### 5.4. Investments in infrastructure

Large-scale investment in agricultural infrastructure, technological skills and knowledge, storage, transport, and distribution have occurred, for example, in the Nile perch fishery in East Africa where the international market for Nile perch stimulated infrastructure development, which in turn reduced post-harvest loss but also resulted in over-fishing and local conflict (Parfitt et al., 2010). Large-scale capital investment in infrastructure in low- and middle-income countries has often failed if it is not connected with international markets and a good fit with local policies (Parfitt et al., 2010; Shawyer and Pizzali, 2003).

In Sri Lanka, one of the lessons from the post-tsunami investment in fish landing centres (FLC), in part to reduce post-harvest loss and improve quality of fish products, was the importance of preparing business plans in consultation with the government and respective fishing communities. These same communities were then given training to help build their capacity to establish the FLC facilities as small business centres. While it is accepted that not all landing centres can or will be financially sustainable, the preparation of bespoke business plans for each FLC was seen as ultimately for the benefit of a wide range of fisheries-related microenterprises (Diffey, 2012).

### 5.5. Fish drying

Raised drying racks enable fish to be dried off the ground faster and in a cleaner environment, reducing loss and improving quality and price. Work in India under the ODA Bay of Bengal Programme examined the use of racks to reduce loss and waste in the anchovy processing sector. The project demonstrated that raised drying racks could improve quality and add value. The project also involved the development of regional market linkages (Bay of Bengal Programme, 1992). Similarly, drying racks introduced through projects along the shores of Lake Tanganyika have enabled local communities to double the value of dried fish compared with sand dried fish, increasing incomes and employment[3].

### 5.6. Insect infestation

A systems-based strategy to reduce fish loss and waste due to blowfly infestation was field tested in India. Field trial data showed real benefits associated with the adoption of the interventions selected by the processors, for example, salting tank lids, raised drying racks, and more hygienic fish handling practices led to lower infestation and loss levels compared with control processors. This translated into economic benefits once adopted more broadly (Esser et al., 2003).

### 5.7. Information technology

The integration of information technology (IT) systems offers comprehensive stock tracking along the supply chain. This adds value to the catch once it arrives at its final destination, the customer/supermarket and helps avoid loss in quality by accelerating the transaction or sale process. Such technologies can enable tracking of the catch from where it is landed as well as provide details such as when the fish was caught/landed or location. (European Foundation for the Improvement of Living and Working Conditions, 2003).

### 5.8. Transportation technology

In India, improved technology has been developed and introduced to improve the quality and workload of mobile fish vendors. Modified rickshaws with retail units on trolleys, fabricated using Fibre Reinforced Plastics (FRP), which reduces the weight, requires lesser draft for motion and enhances the ergonomics. The trolley consists of a fish storage chamber, insulated ice box, water tank, and fish dressing deck with washbasin, cutting tool, waste collection chamber, and toolbox and working space (ICAR undated). This type of simple technology helps improve hygiene and sanitation as well as improving handling and marketing.

### 5.9. Capacity building

Effective post-harvest fish loss reduction does not rely on a single factor or variable such as the introduction of a new technology. It requires a combination of the right policy, legislation, capacity building, services and infrastructure and, last but not least, technology. These are what we refer to here as the “building blocks” for effective loss reduction and waste minimization. There is a high likelihood of reducing loss if we can accomplish the following: provide fishers with knowledge and skills in good fish handling; provide fishers access to insulated holds and cold chain equipment; ensure fishers have access to the right services and infrastructure to land their fish well; put into place and enforce legislation that supports good handling, hygiene, and marketing. Understanding how these different factors interact in a given situation is important, but the interaction and priorities will vary according to location, species, climate, and culture FAO, 2016 . Tracking baseline levels of fisheries’ loss and waste and evaluating the effectiveness of interventions is also key and is something that requires more attention going forward.

### 5.10. Evaluating projects

A handful of projects mentioned in this paper have implemented loss and waste recommendations found in Table 8, although robust evidence of their effectiveness is limited and needs to be collected. Interventions to reduce food loss have been hypothesised to have benefits for poverty reduction, improved food security, and efficiency of natural resource use (FAO, 2014b; FAO, 2015; FAO, 2016; HLPE, 2014a). To date, however, there has been limited empirical research on these impacts (Rutten, 2013). It would be expected that reducing fish loss would increase available supplies of fish, and as a result lead to a reduction in prices. The size of the impacts will depend on the size of the loss relative to the size of the market (Rutten, 2013), which varies by fish species, location, and price elasticities of demand.

## 6. Discussion

We reviewed two macro-level and twenty micro-level studies that provide detailed assessments of physical, quality, and/or market force loss in fish. The literature includes a wide array of species, locations, value chain stages, and research methodologies. Several studies found significant variations within the same study setting, using different methods, such as load tracking compared to IFLAM (Assefa et al., 2018; Wibowo et al., 2017). Data generated through micro-approach methods also suffer from inconsistencies due to the difficulty of capturing seasonality. Nutritional loss is mainly covered in experimental research and not in real-life situations, making it less useful for the design of interventions.

Gaps in the literature include a defined methodology for tracking nutritional loss along the value chain and limited coverage of loss and waste in fish value chains that originate from aquaculture. Studies that

[3] http://www.fao.org/news/story/en/item/238308/icode/

covered aquaculture focused predominantly on yield gaps, which measure actual yields against a potential optimum yield obtained under ideal conditions rather than postharvest loss. Another important shortcoming of the available evidence is that fish loss and waste data are mostly not sex-disaggregated. Gender considerations are important for fish loss, as women are estimated to constitute half of the workforce in the capture fisheries sector globally (World Bank, 2012), and between 40 and 80% in aquaculture, depending on the country (Phillips, 2016). Fish losses lead to disparate effects on men and women, firstly because they perform different roles in the chain, and, as stated above, loss is not equal across different stages. Secondly, as shown in a recent study in Zambia, even within value chain nodes there are differences in the levels of loss incurred by men and women, with women losing between three and eight-fold more than men of the total volume handled in terms of physical loss, depending on the stage in the chain (Kaminski and Cole, 2017). The authors attribute these inequalities among others to differences in the levels of decision-making power about fishing, processing, and trading (Kaminski and Cole, 2017). Similarly, men in East and West Africa were found to be more affected by physical and quality loss while women incurred market force loss due to the gendered nature of fish value chains (Akande and Diei-Ouadi, 2010).

While many documents suggest ways to tackle loss and waste in fish value chains, there is little evaluation or assessment of the impact of these interventions. Potential positive and negative impacts need to be considered both for value chain actors and consumers. Efforts to reduce fish loss will incur costs for value chain actors, negating some of the reduction in price due to shifts in the supply curve. With this in mind, it is important to acknowledge that zero loss scenarios are unrealistic, even in technology-sophisticated value chains. It is important that value chain actors instead work from a paradigm of trying to achieve optimal losses, defined as those that are commercially viable and do not place an undue burden on the environment. The public and private sector will need to work together to ensure that measures taken to reduce loss and waste ultimately move the food system to a more sustainable place.

It is also important to consider, that while improved availability of fish may result in price reductions, upgrading of fish value chains in order to reduce loss may, in the short term, reduce access to low-priced fish by the poor. Finally, because impacts of fish loss are not evenly distributed along value chains nor between men and women, there will be winners and losers. These are important areas of research if food security and nutrition targets are to be achieved. This needs to be done in combination with developing consistent approaches and indicators that measure multiple aspects of fish loss and waste, which enable tracking of progress, capture seasonal losses, and provide sex-disaggregated data.

## 7. Conclusions

In this paper, we have presented a review of the literature assessing fish loss in low and middle-income countries over the period 1996–2018. Estimates of loss varied greatly between studies, with comparisons across studies challenged by diversity of approaches used, parts of the chain assessed, variation in product type, definitions of loss, seasonality, and interpretation of data. Physical and nutritional loss are more commonly covered than the more difficult to assess quality and market force loss. Although there is a dearth of studies, nutritional loss is commonly assessed in experimental designs rather than in real-life situations. Other important research gaps include the lack of sex-disaggregated data on the extent of different types of loss affecting men and women in the value chain and an almost complete absence of robust impact assessments of interventions to reduce fish loss and waste for both consumers and value chain actors. This together means that there is little information to inform policy making, and that more robust and harmonized evidence is needed.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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