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Post capture fish condition within several pelagic fisheries

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Contents

Summary

Pelagic fisheries in European waters target small pelagic fish such as herring, mackerel, horse mackerel, blue whiting and silver smelt. The Dutch pelagic fishery is performed with pelagic freezer trawlers. Catches are pumped from the cod-end on board into the Refrigerated Seawater (RSW) tanks. From the RSW tanks fish are fed into the on-board fish processing factory where fish are sorted, frozen and packed. To gain insight in at what point fish die in catch-processing of pelagic freezer trawlers, the condition of fish sampled from the catch-processing directly after the fish-water separators was assessed during five research trips on four different vessels in the period December 2018 – December 2020. Condition of individual fish was assessed by scoring the impairment of a set of nine reflexes. Fish condition was expressed as RAMP score, calculated from the reflex scores (lower RAMP score represents better condition). Per haul the counts of living fish were expressed as percentage of the total number of fish sampled to determine the percentage of fish that was alive at the sampling point (the fish-water separator just before entering the RSW tanks). For all tested species the %Alive ranged widely among trips and hauls. Weighted mean %Alive and mean RAMP scores of fish that were alive when scored, were 81.2% and 0.28 for horse mackerel (799 fish, 3 trips, 34 hauls), 22.6% and 0.47 for mackerel (450 fish, 2 trips, 10 hauls), 56.0% and 0.41 for summer herring (113 fish, 1 trip, 11 hauls), 82.6% and 0.42 for winter herring (1150 fish, 2 trips, 14 hauls) and 68.7% and 0.40 for Atlanto-Scandian herring (385 fish, 1 trip, 14 hauls). Variation in %Alive and fish condition may be caused by haul duration, catch weight and the time the cod-end is behind the vessel before the pumping of fish on board starts. Dissolved oxygen concentration, pH and temperature were measured in the water in RSW tanks during one trip for horse mackerel (7 hauls) and herring (2 hauls). Oxygen levels in RSW tanks quickly decline upon introduction of the fish, probably due to oxygen consumption by fish.

1 Introduction

Pelagic fisheries in European waters target small pelagic fish such as herring, mackerel, horse mackerel, blue whiting and silver smelt. The Dutch pelagic fishery is performed with pelagic freezer trawlers using a single trawl with trawl doors or using pelagic pair trawling technique (Figure 1). Shoals of fish are located using echo-sounding equipment and the echogram is used to estimate the size and depth of the shoals. Once a shoal of a target species has been located, the crew shoot the trawls to catch the fish. Catches are pumped from the cod-end on board into the Refrigerated Seawater (RSW) tanks (Figure 2). From the RSW tanks fish are fed into the on-board fish processing factory where fish are sorted, frozen and packed.

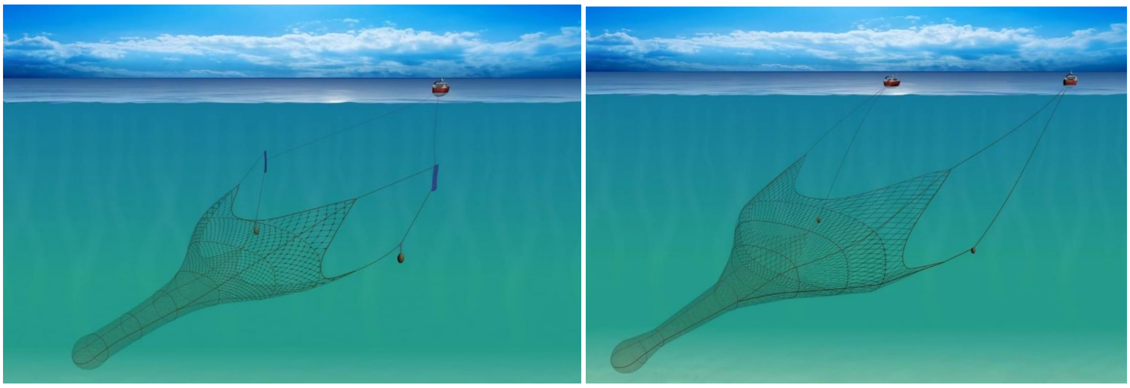

Figure 1. Schematic impression of a pelagic trawl. Left a pelagic trawl operated from a single vessel, the trawl spread is created by two pelagic trawl doors and the vertical opening is created by two clumb weights. Right an impression of the pelagic pair trawl. This trawl is operated and spread by two vessels, two clumb weights are used for vertical trawl opening. (source: Seafish)

Figure 2 Left a filled cod-end behind the vessel after hauling the trawl and prior to connecting the fish pump. Right a fish pump used for transporting the fish from the cod-end to the RSW tanks under the aft deck of the trawler.

Fisheries expose fish to multiple stressors during capture and handling (Cook et al., 2019). As a result, fisheries always involves some degree of stress and internal or external injury of fish due to interactions between fish and fishing gear (Davis, 2002) and thus infringement of fish welfare (reviewed by Veldhuizen et al., 2018). According to the Dutch Council on Animal Affairs attention to fish welfare has gradually increased in recent decades in policy, research and society (RDA, 2018). Despite this increasing attention to fish welfare, there is generally little information on fish welfare in the context of fisheries (Veldhuizen et al., 2018). As a first step towards more insight in welfare of fishes caught by pelagic freezer trawlers, the current study aimed to establish the condition these fishes. To this end, fish were sampled from the catch processing of pelagic freezer-trawlers directly after the fish-water separators and their condition was assessed.

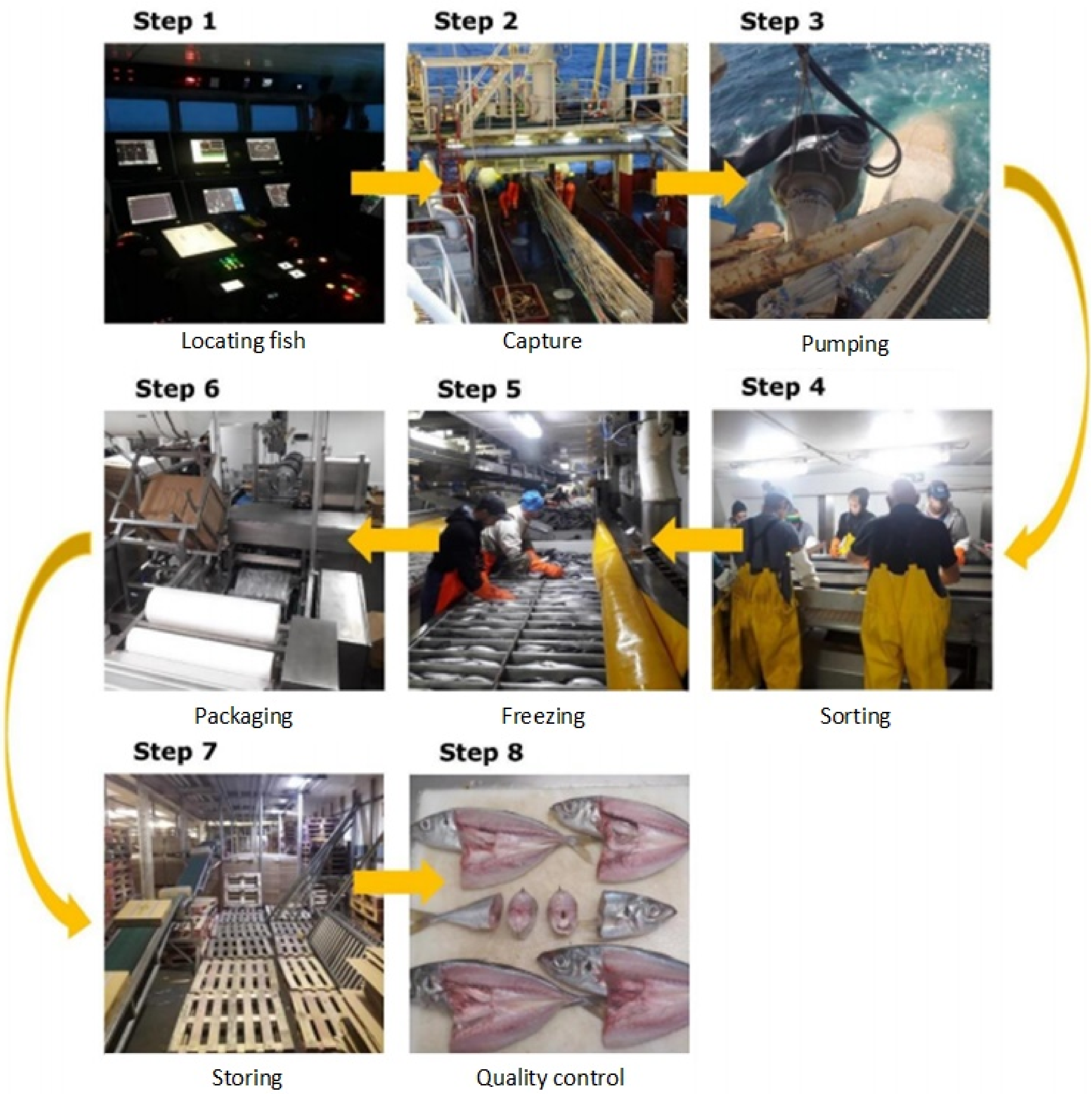

Figure 3. Pelagic freezer trawler capture and processing steps.

2 Materials and Methods

2.1 Research trips

Prior to the data collection trips an exploratory trip was undertaken in December 2018 by a WMR researcher to assess the possibilities for condition assessments and protocol development (trip 0). Data were collected during 5 research trips on pelagic freezer-trawlers in the period from January 2019 to December 2020 (Table 1). In total 4 pelagic freezer trawlers participated in the project. Trip 0 to 4 have been executed on conventional pelagic freezer trawlers, the fifth trip has been on a pelagic pair trawler. The fishing areas per trip, haul and species are shown in Figure 4.

Table 1 Research trips

Trip no.	Year	Week	Vessel	Sampled species	N sampled hauls	Main research objective
0	2018	51	1	Herring	2	Exploratory trip
1	2019	49-50	2	Herring	11	Collect data
2	2020	3-5	2	Horse mackerel	10	Collect data
				Mackerel	4	Collect data
3	2020	30-32	1	Herring	22	Collect data
4	2020	38-43	3	A. S. herring	14	Collect data
				Horse mackerel	16	Collect data
				Mackerel	6	Collect data
5	2020	50-51	4	Horse mackerel	8	Collect data & extended protocol
				Herring	2	Collect data & extended protocol

2.2 Characteristics sampled fisheries

Herring is targeted by the pelagic trawlers in several seasons and area's with each a different strategy. Within the herring fisheries three main types can be distinguished. i) Summer herring fishery is performed in the northern north sea on dense schools of herring. As a result of the dense schools, haul duration is limited (30 minutes to 2.5 hours) and catches vary from 3 to 180 tonnes. During day and night herring is caught on depths ranging between 20 and 140m. ii) Another summer fishery targets the Atlanto-Scandian herring in Norwegian Sea. During the day Atlanto-Scandian herring is caught on depths from 300 to 450m while during the night the fish can be caught at a depth between 30 and 70m. This capture characteristic is related to the vertical diurnal migration of the fish. Haul duration is generally long (1 up to 9.5 hours) and catches vary between 20 and 190 tonnes. The Atlanto-Scandian herring is generally larger than North Sea herring (~36 cm A.S. herring and ~30 cm for North Sea) and therefore they might be more resilient to the capture process. iii) The third herring fishery is performed in the winter in the English Channel at depths up to 60m. This fishery targets the herring spawning aggregations in this area. The trawlers preferably only target the parts of the school in the proximity of the seabed as those herring contain roe. To achieve undamaged high quality roe a different fishing strategy is applied. Short hauls (~20 minutes) and small catches (10-50 tonnes) are preferred for optimal quality. After capture fish are stored in the RSW tanks with relatively large sea water fish ratio compared to the other pelagic fisheries.

The fishery for mackerel is performed both in the North sea and Atlantic. This fishery is performed on large dense schools of mackerel. Tow duration may be short (~30 minutes up to 2.5 hours) to realize large catches (~150 up to 420 tonnes), therefore only a few hauls per trip may be sufficient to achieve the required volume. Those catches result in prolonged cod-end retention of the catch behind the vessel as it takes longer to pump those volumes to the RSW tanks.

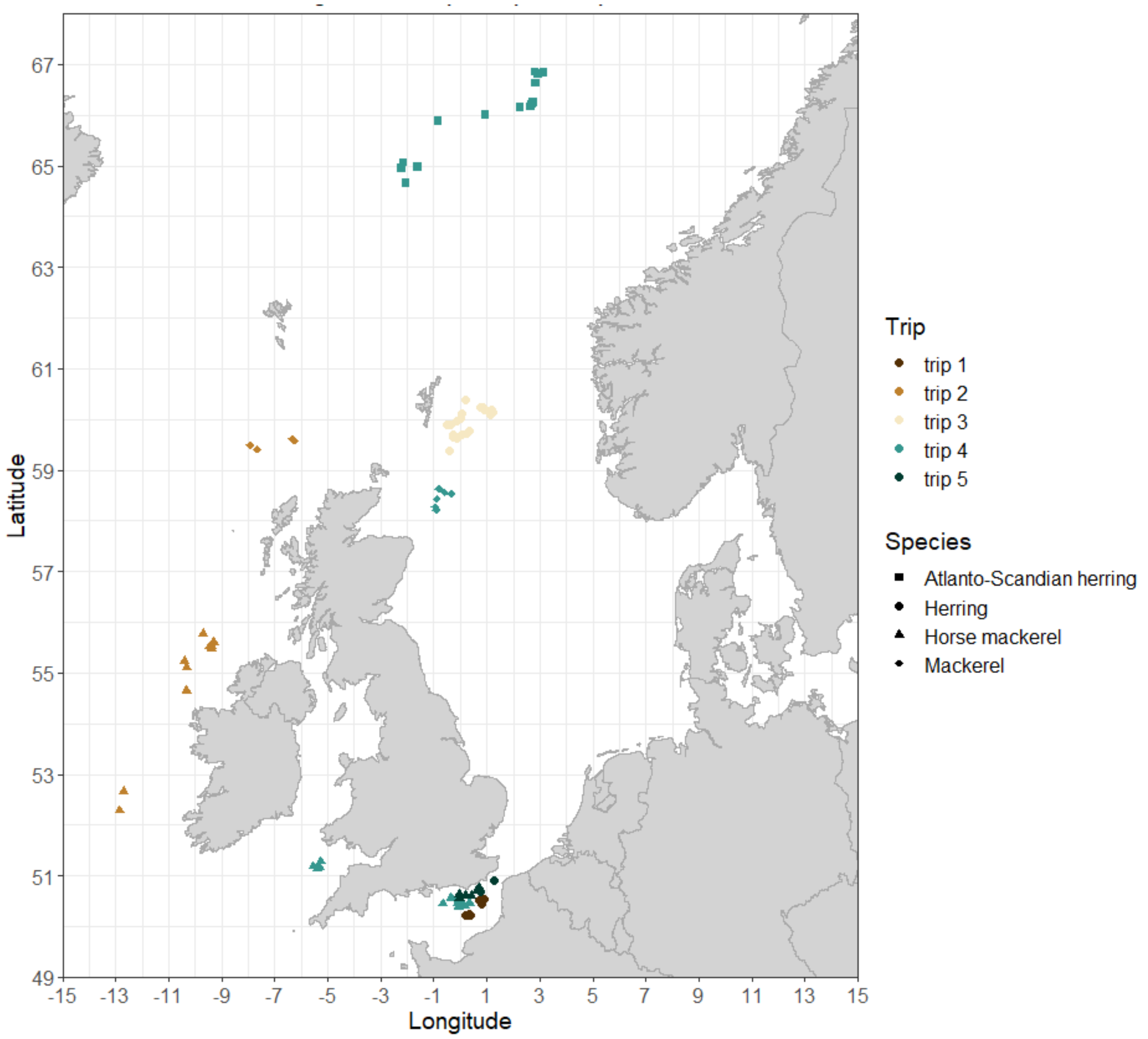

Figure 4 Haul locations per trip (colour of points) and species (shape of points).

Horse Mackerel is targeted in the North Sea, English Channel en Atlantic. This fishery may be performed on dense schools if available. In some area's dense horse mackerel schools might disperse during night, therefore longer hauls are performed in the scatted school of horse mackerel to obtain sufficient catches. Haul duration varies between 1 up to 7 hours with catches ranging from 14 to 220 tonnes. Horse mackerel has spiny scutes on the caudal peduncle and could damage each other in the RSW tank. To minimize catch damage resulting from sloshing fish, the RSW tank is supplied with a minimum of additional water to have the horse mackerel densely packed in the tank.

2.3 Exploratory trip

At the start of the project a two day exploratory trip was done in week 51 of 2018 by a WMR researcher. The aim of the trip was to explore the possibilities to measure fish condition on a pelagic trawler and perform preliminary reflex and behaviour observations. The capture and fish processing was monitored closely to identify indicators and measurements that are relevant for developing a protocol for structured fish condition assessments. Additionally camera observations in a RSW tank were done to gain insights in the possible condition of fish after being pumped and stored in a RSW tank. The observations of this exploratory trip were used to develop the protocol for fish condition assessments and data collection.

2.4 Protocol condition assessment

2.4.1 Basic protocol

For this study two protocols have been applied to collect data. The basic protocol was designed to collect specifics on trawling, hauling, and catch handing and processing before the fish-water separator in combination with fish condition assessment. An additional extended protocol was applied that include RSW tank measurements and video observations after the fish-water separator.

2.4.1.1 Trawl list

During the trips, the observer recorded for each haul general information (date, time, latitude, longitude, wind speed, wind direction and wave height) and fishing information (trawling speed, fishing depth, haul duration, first fish on the net sonar, time cod-end behind the vessel, pumping time, species composition and total catch weight) on a trawl list.

2.4.1.2 Assessment set-up

Condition assessment set up required a sample collection bucket, a temporary sample storage container and an assessment container (Figure 5). For sample collection, a white plastic 15 litre bucket was used. The temporary sample storage system was designed to maintain sampled fish condition while the first fish in the sample are assessed. This system was equipped with a continuous flow of surface sea water. The water supply was positioned horizontally on the side to create a solid circular flow in the black round container. The round design combined with a circular flow enables pelagic species to maintain their swimming and ventilation behaviour in a limited volume. In the centre of the tank an overflow stand pipe was placed to maintain the water level and support the circular flow. The top of the standing pipe was provided with a grid to prevent floating fish clogging the pipe. Condition assessments were performed in a white round container filled with 30cm surface sea water.

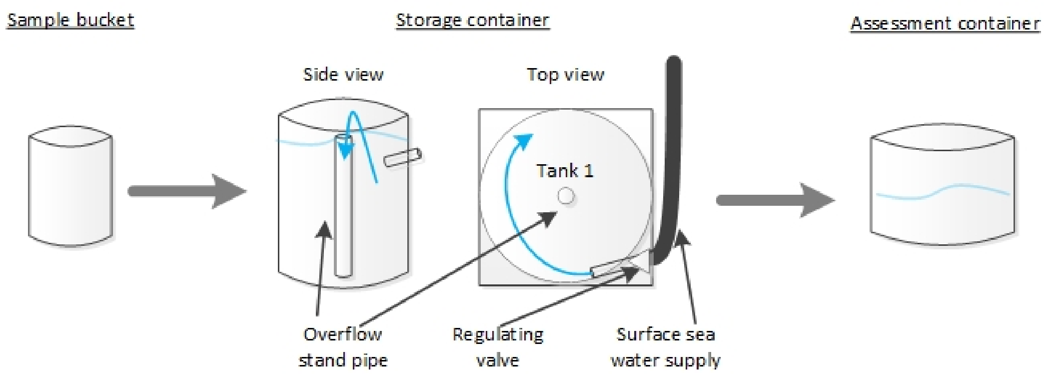

Figure 5. Schematic impression of sample collection and storage for fish condition assessment

2.4.1.3 Fish collection

Fish samples for condition assessment were collected after the fish-water separator just before fish entered the RSW tank (Figure 5 & Figure 6). Exact sample time was noted for each sample to allocate the sample within the pumping process. The sample was taken by holding a 15 litre bucket under the constant flow of fish behind the fish-water separator. When the bucket was half full, it was taken to the storage container. From the bucket 5 fish were randomly selected and placed in the temporary storage container. Directly after placing the sample in the container the observer started the fish condition assessment. The duration of sample collection and subsequent condition assessment was approximately 10 minutes. When the condition assessment of the five fish in the sample was completed the observer proceeded by collecting the next sample at the fish-water separator. This collecting and assessment process continued as long the as fish was pumped from the cod-end to the storage tanks of the vessel. With this procedure the observer was able to collect 2 or 3 samples for hauls with a small catches, while multiple samples were collected for very large catches as the pumping process could exceeded ~60 minutes. In case most fish in the catch and sample appeared dead, the required time for the assessment procedures would decrease. The observer then delayed the next sample collection at least 10 minutes after collection of the previous sample.

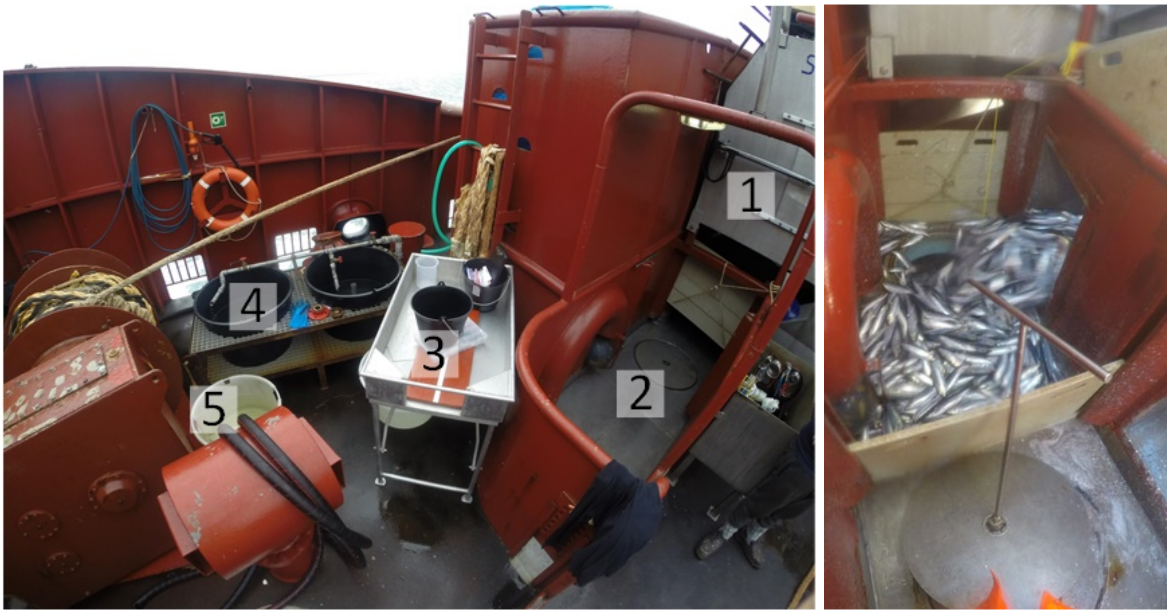

Figure 6. Right picture with fish condition assessment set-up on the aft deck of a pelagic trawler. 1) fish-water separator, 2) entrance to one of the fish storage tanks, 3) sample bucket, 4) temporary sample storage container, 5) assessment container. Fish condition samples were taken from the fish flow (left picture) between the fish-water separator (1) just before they entered the RSW tank (2).

2.4.1.4 Fish condition assessment

Before sampling and condition assessment, the assessment container was filled with 30cm surface seawater. Sampled fish were carefully netted with a rubber coated net from the temporary storage container and placed in the assessment container. Subsequently behaviour and reflex responses were assessed in the order as presented in Table 2. Responses were recorded with an 0 for presence and 1 for absence. A present response was observed within 1, 3, 5 or 10 seconds, depending on the specific response (Table 2). After the assessment, total length was measured (to the cm below) and based on the behaviour and reflex responses the observer determined whether the fish was alive. For each individually assessed fish, species, behaviour-, reflex scores, total length, visibly alive, sampling time and assessment time were recorded.
Reflex Action Mortality Prediction (RAMP) scores were calculated for each assessed fish as the sum of presence/absence scores divided by the total number of scored responses (9) (Davis, 2010). The resulting RAMP score lies between 0 and 1, where a score of 0 represent fish in the best possible condition without any impairment of reflexes and behavioral responses. The higher the RAMP score, the poorer the condition of the fish.
Variables, time and scores during the condition assessment were recorded with a headset and mobile phone. After the assessment all recorded data were digitalized in Excel. Data on trip level were compiled to a large dataset containing all collected data.

2.4.2 Extended protocol including RSW tank measurements

Trip 5 (Table 1) was performed on a pelagic pair trawler. On this trawler the basic protocol was extended with additional measurements to gain insight on oxygen, pH, temperature and fish movement and behavior in the RSW tanks. The basic and extended protocol were applied simultaneously on the same hauls. During this trip two observers participated, one observer applied the basic protocol with condition assessments while the second observer focused on the additional RSW tank measurements.
For the RSW tank water parameter measurements a system was designed to extract water from the RSW tank before, during and after filling the tank with the catch. A tube with a non-return valve and a mesh cone was placed at approximately 1 meter above the RSW tank bottom. The system consisted of several tubes, a suction pump and a reversed funnel at the end of the tube (Figure 7). This funnel was used to hold the probes for continuous dissolved oxygen concentration, pH and temperature measurements with a 10 second interval. Measurements were performed and stored using a WTW

Multi meter (3430). Measurements were started prior to filling the tank and continued for 60 up to 100 minutes to record the changes in oxygen, pH and temperature.

Water quality parameter measurements combined with fish movement observations could potentially indicate water quality thresholds where fish stop moving in a RSW tank. For camera observation in the RSW tank a camera dome was constructed derived form a circular rooflight dome. This dome was used to prevent fish in the RSW tank from obstructing visibility while pressed against the GoPro Hero 4 lens. Prior to filling the RSW tank the dome was filled with clear seawater, this prevented reduced visibility while fish mucus accumulates in the RSW tank water. Additional light was provided with a Lindgren Pitman Electralume Swordfish Deep Drop Fishing Light White placed inside the dome under the camera. Prior to filling the RSW tank the camera dome was placed approximately one meter above the tank bottom (Figure 7), at the same height as the intake tube for water parameter measurements.

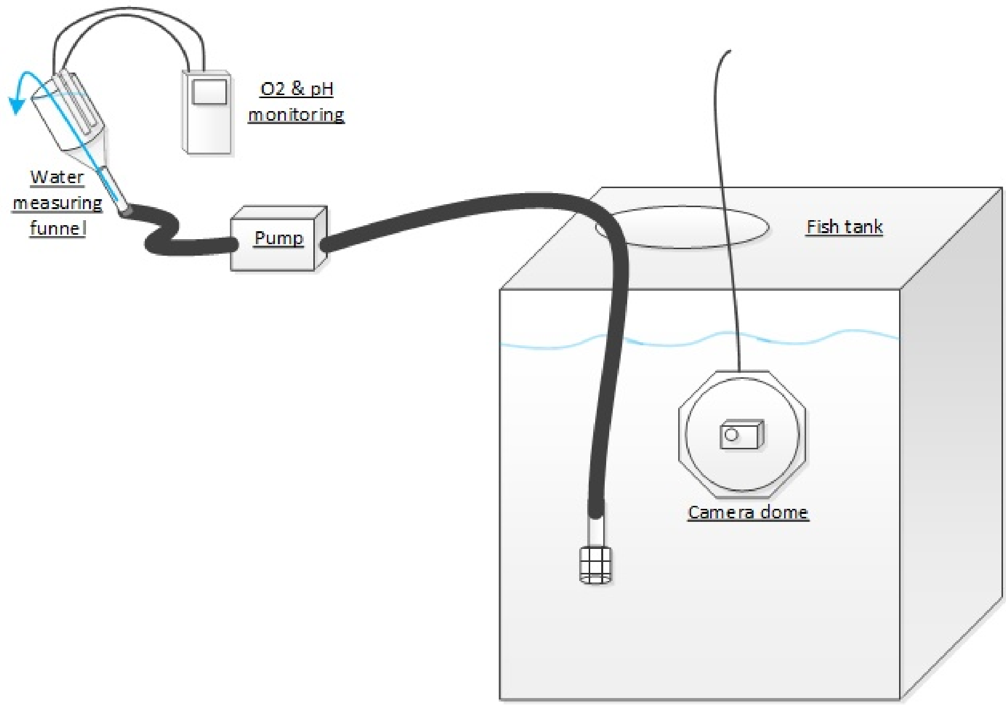

Figure 7. Schematic drawing set-up for RSW tank measurements. A pump was applied to collect water for continuous oxygen and pH measurement in RSW tank water. For fish movement observations a GoPro camera combined with a camera dome and light were submerged in the RSW tank prior to filling up.

As pelagic pair trawlers both have a pelagic trawl on board they alternate between hauls which vessels shoots its trawl. After the trawl is shot, one fishing line is handed over to the other trawler and together they tow and manoeuvre the trawl. The trawler who shot the trawl takes the first half of the catch on board. After handing over the fish pump hose, the other trawler receiver the second half. With this procedure the condition of the catch can only be assessed for the first half or the second half of the catch. The observed condition may not be representative for the whole catch. Therefore the data of this trip are presented separately in Annex 2.

2.5 Definition of dead fish

Fish can be considered dead when either rigor mortis is observed or brain activity is absent. Brain activity can only be measured by recording an electroencephalogram (EEG). For practical reasons EEG measurements were beyond the scope of this project while assessment of rigor mortis could not be used to establish death because of the time it takes for full rigor mortis to occur. Therefore instead of quantifying numbers of dead fish, numbers of fish that were alive upon condition assessment were quantified. Fish were considered alive in case at least some movement of the operculum (Dutch: "kieuwdeksel") was observed during condition assessment. Fish that did not shown movement of the operculum, where considered to be dead, even though it may still have brain activity and thus, strictly speaking, still be alive. Despite this limitation, the definition of 'dead' is adequate because recovery of 'dead' fish is highly unlikely.

Table 2. behaviour and reflex responses performed on individual fish for condition assessment.

	Procedure	**Present – not impaired Score = 0**	**Absent – impaired Score = 1**
Free swimming observations			
Evasion 1	Fish transferred from net into observation tank	A "startle" response, or swims around in tank seeking "escape".	Fish lacks awareness of substantial change in environment or is unable to respond due to exhaustion or injury.
Orientation/ Self-righting	Fish transferred from net into observation tank	Can self-orientate dorsal side up within 5 s of transfer.	Fish has lost basic reflex-balance. Therefore, swimming and avoidance of potential threats will be severely compromised
Head complex	Fish transferred from net into observation tank	A regular and coordinated use of mouth and operaculae – indicative of normal respiration (>1 per 10 s)	Absence – respiratory failure, fish is dead or close to death. Very strong – fish may be hypoxic or fatigued.
Evasion 2	Observers hand, in water, approaches fish from the side	A "startle" response, or swims around in tank seeking "escape".	Fish lacks awareness of potential visible threat or is unable to respond due to exhaustion or injury.
Caudal reflex	Observer touches or attempts to hold the caudal fin	Fish immediately (<1 s) attempts to swim away from physical contact	Fish lacks awareness of strong physical threat or is unable to respond due to exhaustion or injury.
Observations while handling			
Body flex 1 – restrained	Observer holds fish firmly in clenched hand, with thumb and fore-finger just posterior from operaculae.	Fish should flex its tail musculature in an attempt to escape (< 3s) (NB test starts in water as observer attempts to remove fish from tank)	Fish lacks awareness of strong physical threat or is unable to respond due to exhaustion or injury.
Vestibulo-ocular response	Observer – while holding the fish as above- rotates fish along its longitudinal axis.	Fish attempts to hold its eye steady, with respect to horizontal. That is, looking from the posterior, the eye should appear to look down, as the head is rotated clockwise, and vice versa.	Fish has lost a basic reflex – balance. May indicate loss of functionality in the brain stem.
Mouth closure	Observer – while holding the fish as above- uses finger to open the fish' mouth	Fish should attempt to resist opening action. May also respond with a "head complex motion" and/or "body flex" (< 3s)	Fish lacks awareness of intrusive physical threat or is unable to respond due to exhaustion or injury.
Body flex 2 – Flat surface	Fish is laid, unrestrained, on a flat surface.	Fish should flex its tail musculature (< 3s)	Fish lacks awareness of substantial change in physical status, i.e., released but out of the water or is unable to respond due to exhaustion or injury.

2.6 Data analysis

All collected data were entered in MS Excel and further processed in R version 4.0.3. There were two types of datafiles: 1) trawl list, and 2) fish scoring data. The data in both datafiles were checked for possible input errors and adjusted if necessary. Data from four fish was excluded from further analysis as the sample size was insufficient.

The number of fish samples, percentage of live fish and total catch (in tonnes) was calculated for each trip and species. The overall mean percentage of live fish was calculated with the mean percentage alive (%Alive) per haul and species and averaged over all hauls. The range of %Alive are the minimum and maximum of all the hauls. The unweighted mean RAMP score was calculated as the mean RAMP score per haul and species. The weighted mean RAMP score was calculated using the mean RAMP score per haul and a ranking score for each haul based on the total catch.

3 Results and Discussion

3.1 Percentage fish alive

The observed average overall percentages of fish that are alive (%Alive) in the catch-sorting process just after the water-fish separator range from 23 to 83% depending on the species (Table 3). For the five fishing trips considered, the overall unweighted average percentage alive is 62%. For all species the range of %Alive as observed for individual hauls varies widely (Table 3, Figure 8), suggesting an effect of fishing conditions. Hauls for which all (100%) or nearly all (>90%) sampled fish were alive, occurred in all sampled species except mackerel. Hauls with low (<10%) or no (0%) counts of alive fish were only observed for mackerel (Figure 8).

Table 3 Percentage of fish alive after the fish-water separator per species.

Species	Season	n trips	n hauls	n fish	% Alive		Catch weight (ton)	
					Overall	Range	Range	Total
Horse mackerel		3	34	799	81.2	5.7-100	14-221	3426
Mackerel		2	10	450	22.6	0-80	44-421	2215
Herring	Summer	1	11	113	56.0	46.7-100	25-115	610
Herring	Winter	2	24	1150	82.6	16.9-100	3-180	1793
Atlanto-Scandian herring		1	14	385	68.7	29.2-100	23-188	1360

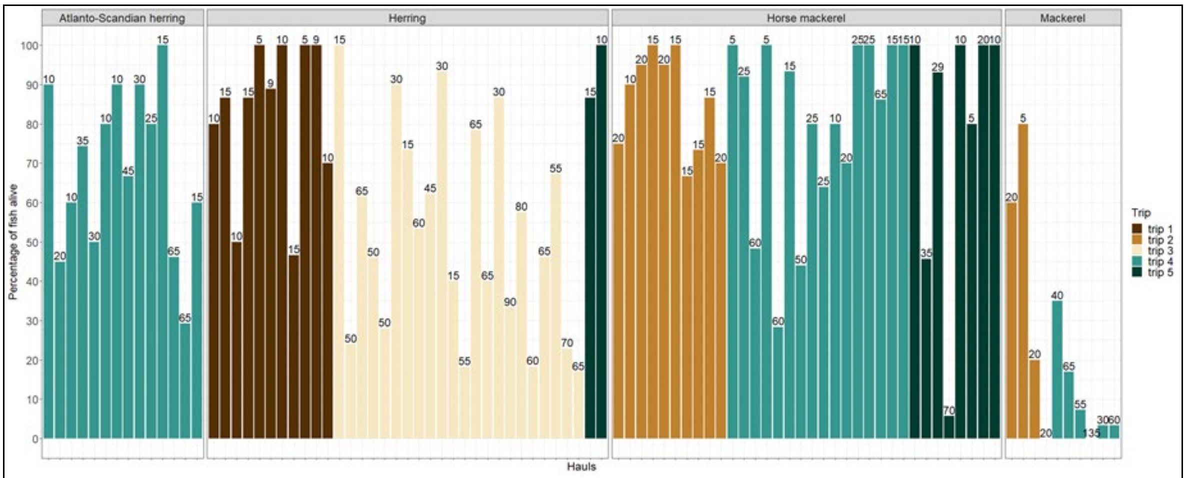

Figure 8 Percentage of fish alive after the fish-water separator per sampled haul for Atlanto-Scandian herring (top-left), herring (top-right), horse mackerel (bottom-left) and mackerel (bottom-right). In all panels identical coloured columns refer to observations during the same trips. Numbers above the columns indicate the number of fish sampled for that haul.

3.2 Fish condition

Fish condition was assessed by scoring the presence of behavioural responses and responses to stimuli in individual fish. The scoring results are summarized in a RAMP score with a value between 0 and 1. The lower the RAMP score, the better the condition of the fish. To be able to assess the condition of the fish that are alive after the fish water separator, weighted mean RAMP scores are presented for all sampled fish and the for the subset of fish that was alive when sampled (Table 4).

The weighted mean RAMP score was calculated using the mean RAMP score per haul and a ranking score of each haul based on the total catch to correct for possible variation between hauls. There is a difference in total catch between the hauls which may influence the RAMP scores of individuals fish from these hauls. Hauls with a higher total catch will have a higher ranking and contribute more to the total weighted mean RAMP score.

Table 4. Mean RAMP scores for sampled fish species.

Species	**Season**	***n* fish**	**Weighted mean RAMP**	***n* fish alive**	**%Alive**	**Weighted mean RAMP alive**
Horse mackerel		799	0.631	550	81.2	0.279
Mackerel		450	0.920	52	22.6	0.466
Herring	Summer	113	0.553	90	56.0	0.408
Herring	Winter	1150	0.753	553	82.6	0.421
Atlanto-Scandian herring		385	0.631	232	68.7	0.398

3.3 Effects of fishing conditions

General
A preliminary exploration was carried out on the effects of catch weight, haul duration and duration that the cod-end was behind the vessel before the pumping started, on the condition of fish. Note that this exploration does not include testing for statistical significance of effects; statistical analyses were beyond the scope of this project. The alleged effects described below thus remain to be confirmed by statistical analyses.
Effects of haul duration may be difficult to detect because individual fish enter the trawl at an unknown moment during the haul. Haul duration may thus not reflect the actual time fish have spent in the trawl.

The effects of fishing conditions are explored on both the %Alive and the mean RAMP score of life fish only. Fish that were considered dead (see section 2.5) were excluded from this section as they will always have a RAMP score of 1. The use of life fish only, gives more insight into the possible factors affecting the condition of fish.

Horse mackerel

For horse mackerel, %Alive is generally higher than 60%. Catch weight does not have a clear effect on %Alive (Figure 9, top panels). Increasing haul duration appears to lead to lower %Alive (Figure 9, top right panel). The variables catch weight, duration of cod end behind the vessel and haul duration do not provide clear explanations for the observed variation among hauls in %Alive, suggesting that other aspects of the fisheries need to be considered.

Smaller catch weights appear to lead to lower RAMP scores of horse mackerel that are alive in the catch sorting process:. All hauls with small catches (50 tons) had RAMP-scores <0.3 (Figure 9, bottom panels). However, small catches do not seem to be a prerequisite for low RAMP score as we also observed a RAMP score as low as 0.2 for a 200 ton catch (Figure 9, bottom panels). The duration that the cod-end was behind the vessel before the pumping of fish on board was started nor the haul duration seem to have an effect on condition of alive horse mackerel (Figure 9, bottom panels). Given the generally high %Alive and average RAMP score that are always < 0.6, it appears that horse mackerel is the most robust species tested in this study.

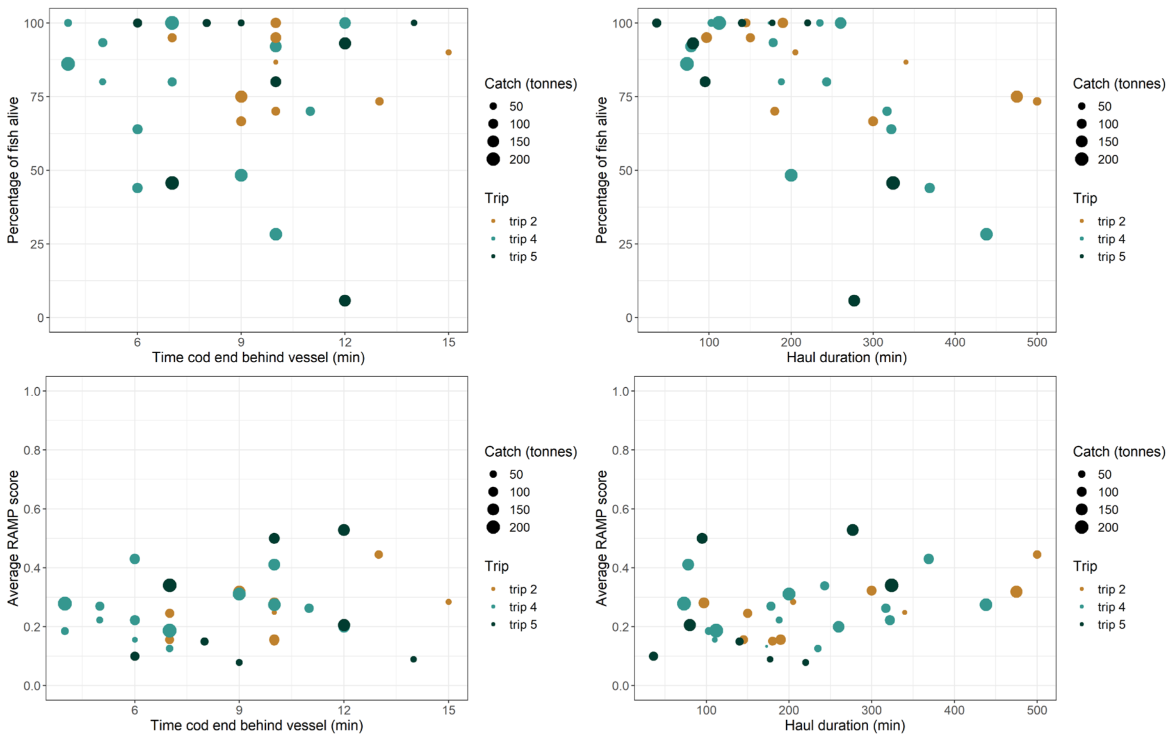

Figure 9. **Horse mackerel**. Percentage of fish alive (%Alive, top panels) and average RAMP score alive fish (bottom panels) observed per haul in fish sampled after the fish-water separator in relation to the time the cod-end was behind the vessel prior to fish pumping (left column) and in relation to haul duration (right panels). Same sized markers size represent hauls with equal catch weights. Same coloured markers represent hauls from the same trip.

Herring

For herring, a small catch seems a prerequisite for a high %Alive: more than 75% alive was only observed for the smaller catches (Figure 10, top panels). Trip 1 and 5 were during winter, while trip was during summer, however no distinct differences seem in place for seasonality. Smaller catches generally result in lower RAMP scores (better condition) of the live fish (Figure 10, bottom panels). However, small catches do not always result in a high %Alive, indicating that other variables also play a role. Based on one incident in which the cod-end was behind the vessel exceptionally long (>15 min) before the pumping of fish on board was started and <25% of the fish sampled from that haul were alive (Figure 10, top left panel), it seems that this variable may lead to lower %Alive. The high RAMP scores of the living fish from that haul (Figure 10, bottom left panel) seem to confirm the deterioration effect of waiting time on herring. Increasing haul duration appears to lead to lower %Alive, especially for the larger catches (Figure 10, top right panel).

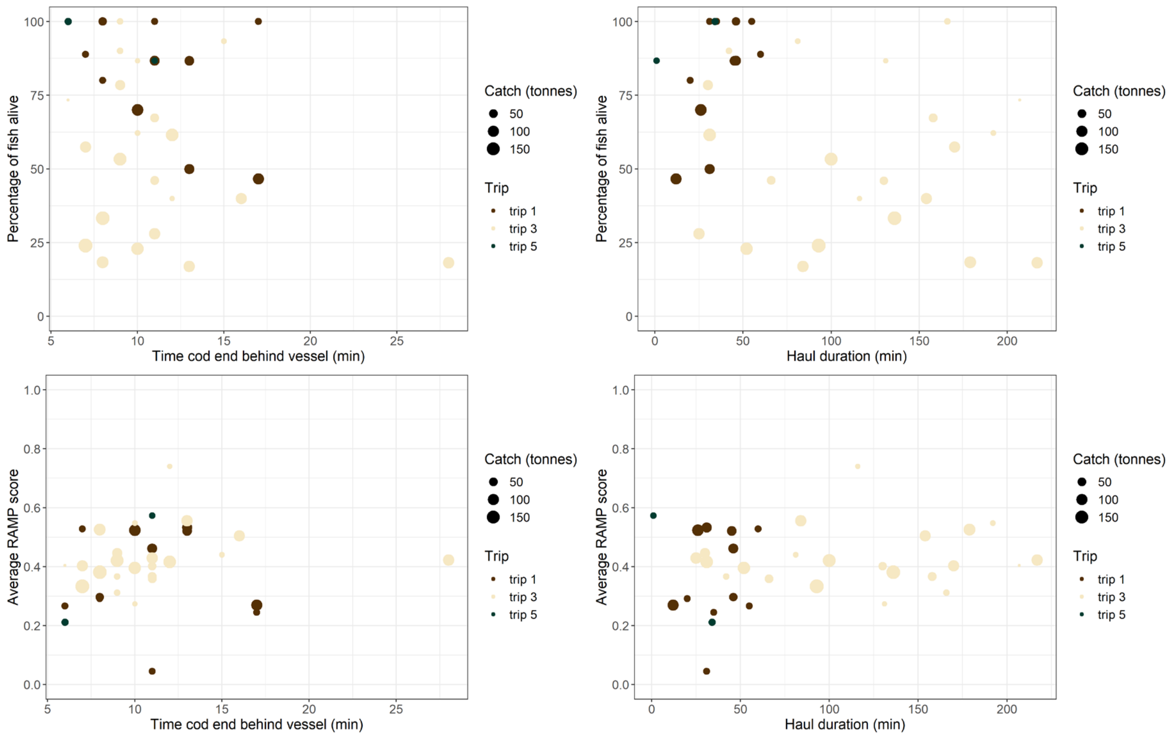

Figure 10. **Herring.** Percentage of fish alive (%Alive, top panels) and average RAMP score alive fish (bottom panels) observed per haul in fish sampled after the fish-water separator in relation to the time the cod-end was behind the vessel prior to fish pumping (left panels) and in relation to haul duration (right panels). Same sized markers size represent hauls with equal catch weights. Same coloured markers represent hauls from the same trip.

Atlanto-Scandian herring

Similar to North Sea herring a small catch seems a prerequisite for a high %Alive and low RAMP score in Atlanto-Scandian herring: more than 75% alive in the catch sorting process was only observed for the smaller catches (Figure 11, top panels) and RAMP scores were lower with declining catch weight (Figure 12, bottom panels). Compared to North Sea herring, %Alive generally seems somewhat higher in Atlanto-Scandian herring. A distinct difference between the two herring types is their size and this may affect robustness. Although the slightly higher overall RAMP scores of Atlanto-Scandian herring compared to North Sea herring may reflect this size effect (Table 5) it remains to be established whether their larger size explains their higher %Alive.

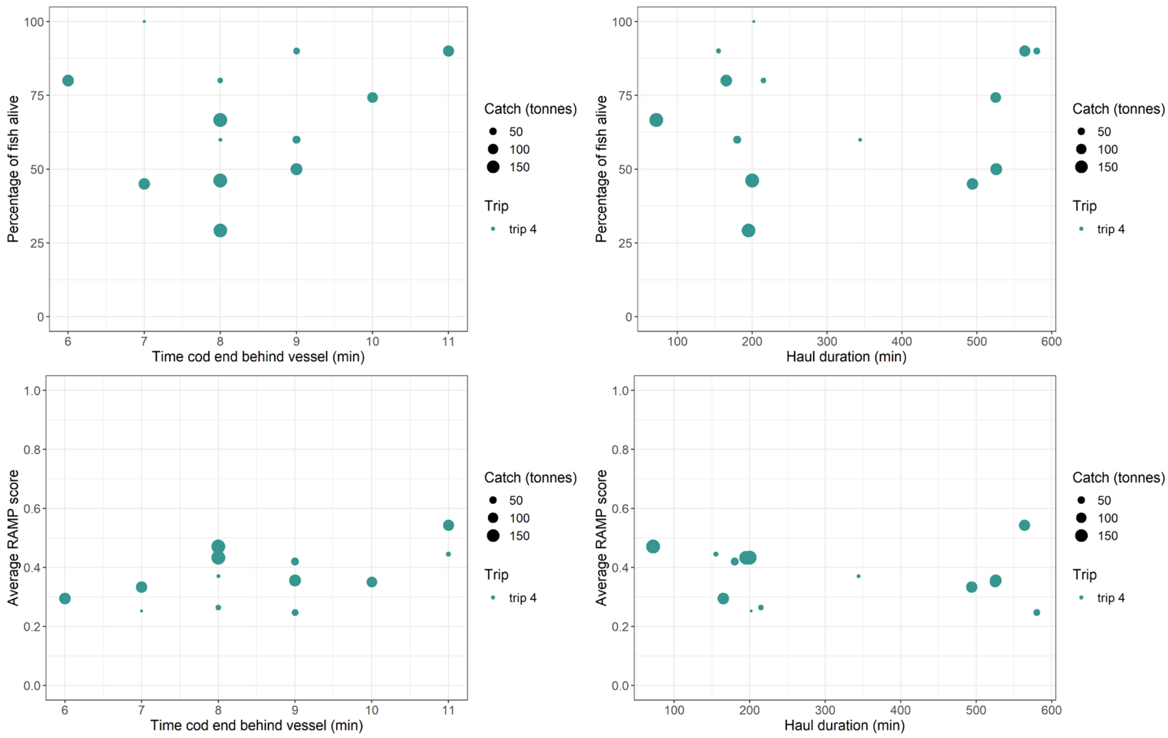

Figure 11 **Atlanto-Scandian herring.** Percentage of fish alive (%Alive, top panels) and average RAMP. score alive fish (bottom panels) observed per haul in fish sampled after the fish-water separator in relation to the time the cod-end was behind the vessel prior to fish pumping (left panels) and in relation to haul duration (right panels). Same sized markers size represent hauls with equal catch weights. Same coloured markers represent hauls from the same trip.

Mackerel

The number of observations for mackerel is rather low, limiting the possibilities to explore the effects of fishing conditions on %Alive and RAMP scores. For mackerel, %Alive was generally low (<35%) compared to other species we investigated, except for two hauls for which we observed that 60% and 80% of the fish were alive in the samples (Figure 8). These two hauls stand out from the other hauls for their small catch weight (<50 ton), short haul duration (<50 min) and a time of the cod-end being behind the vessel of 10 min or shorter (Figure 11, top panels). Effects of time behind the vessel are hard to detect because the observed range is narrow (5-18 min). However, none of the hauls that spend more than 10 min behind the vessel, yielded high %Alive, indicating that, similar to herring, longer waiting time may lead to lower %Alive (Figure 11, top left and bottom left panels). More fish condition observations are needed to establish such effect of longer waiting time on %Alive. Observation of fish behaviour and measurements of water quality parameters such as dissolved oxygen and carbon dioxide concentrations inside the cod end over (waiting) time could give insight in underlying mechanisms.

Small catches, short hauls or short waiting time behind the vessel do not always result in high %Alive. It seems that only in case all three variables are low, the majority of the mackerel is alive at the sampling point. All in all it appears that among the fish species tested in this study, mackerel is most sensitive to the factors that this study explored.

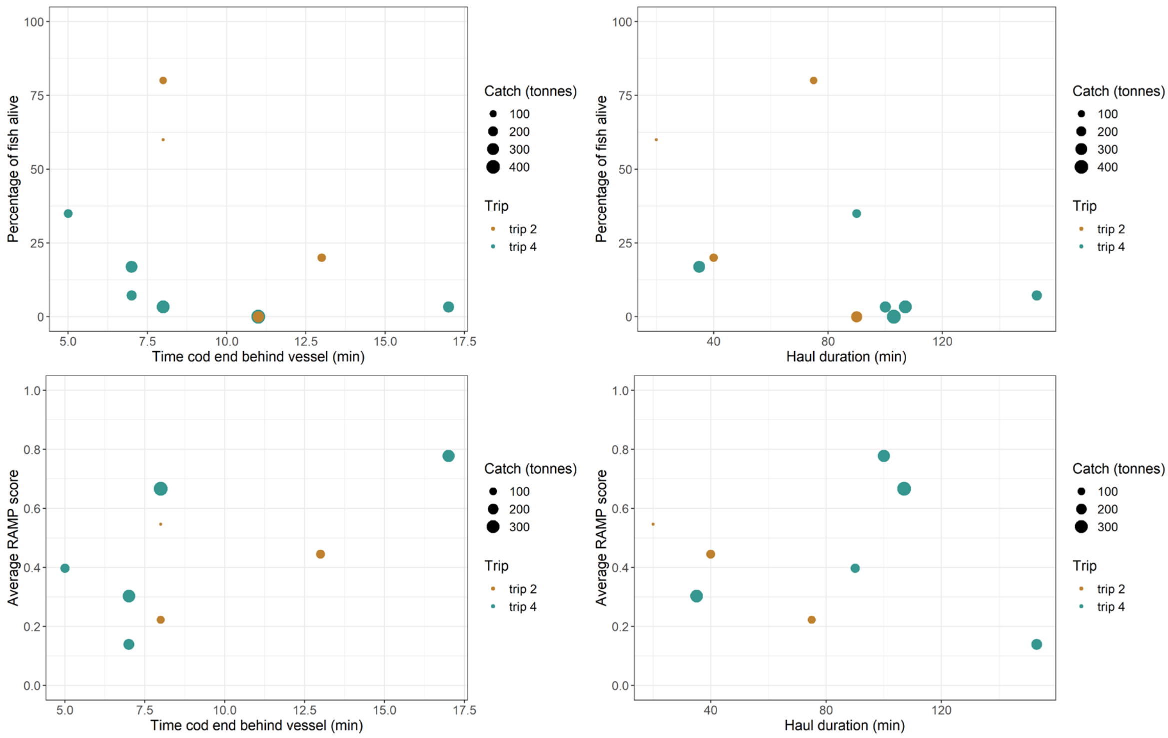

Figure 12. **Mackerel.** Percentage of fish alive (%Alive, top panels) and average RAMP score alive fish (bottom panels) observed per haul in fish sampled after the fish-water separator in relation to the time the cod-end was behind the vessel prior to fish pumping (left panels) and in relation to haul duration (right panels). Same sized markers size represent hauls with equal catch weights. Same coloured markers represent hauls from the same trip. Note that for both lower panels there is no data point for the >400 tonnes, this is due to the absence for life fish in this haul.

3.4 Abiotic conditions in RSW tanks

Dissolved oxygen concentration, temperature and pH of the water in RSW tanks were measured for nine hauls of Trip 5 (Figure 13). Characteristics of these hauls and RSW tanks are summarized in Table 5. Fish species were horse mackerel (7 hauls) and herring (2 hauls). Tank filling with fish was deliberately high (75-90% of the tank volume, Table 5) to avoid fish damaging each other. Upon the introduction of fish in the RSW tanks, dissolved oxygen concentrations and pH generally decline while temperature increases. The changes in these water quality parameters can all be explained by the metabolic activity of the fish. The decline of the oxygen concentration is explained by oxygen consumption by the fish. The decline of pH can be explained by the production of carbon dioxide by the fish. Carbon dioxide excreted to the water is taken up in the carbonate system where it results in an increased production of hydrogen ions and thus a decline of pH. The increased water temperature can be explained by warmth production of the fish as end product of its metabolic activity. Only living fish can have these effects on water quality through metabolic activity.

The effects on water quality thus depend on the absolute amount of living fish introduced in an RSW tank, their condition, size and species. Also ambient water temperature will have an effect as metabolic activity in fish increases with increasing temperature. However, we have no data that show such effect of ambient water temperature because all measurements were done during a single trip. The general trends in the quality of the water in RSW tanks following introduction of fish (decline in dissolved oxygen concentrations and pH, increase in temperature) are clearly shown by the measurements on hauls 1, 5, 6 and 12 (Figure 13). For haul 12 the measurements started approximately 12 min before fish were introduced in the tank, hence the delay in changing water quality.

Table 5 Characteristics of hauls and RSW tanks in which oxygen, temperature and pH were measured. Fish species was horse mackerel for all hauls except Haul 6 and 10 (herring).

Haul	RSW tank	RSW tank volume	Fish species	Fish condition[1]		Amount of fish	
Nr.	Nr.	(m^3)		%Alive	RAMP score all fish	(ton)	(% tank filling)
1	1	32	HOM	5.7	0.97	25	90
2	5	18	HOM	100	0.10	25	90
3	1	32	HOM	100	0.08	22	80
5	1	32	HOM	45.7	0.70	22	80
6	1	32	HER	86.7	0.63	20	75
7	5	18	HOM	93.1	0.26	14	90
8	1	32	HOM	80	0.60	25	90
10	1	32	HER	100	0.21	19	70
12	1	32	HOM	100	0.09	19	70

[1] As expressed by the mean RAMP score of all fish entered in the tank

The general trends in water quality change may be interrupted by operational management of the RSW tanks, including actions like adding water and fish and switching on water cooling. This results in variation in levels of water quality parameters over time. Water addition or renewal immediately results in an increase of the oxygen level and its decline thereafter, most likely due to consumption by the fish (haul 2 at ~ 23 min, haul 3 at ~ 20 min, haul 7 at ~10 and at ~60 min). The size and duration of the oxygen peaks are subject to the amount of new water, the amount of fish and the condition of the fish. The oxygen peaks coincide most of the time with a small increase in pH, probably due to the higher pH value of the incoming water. Temperature gradually increases until heat production by the fish is overruled by the switch on of water cooling (e.g. haul 2 at ~30 min and haul 7 at ~ 70 min).

The often steep decline of oxygen levels followed by stabilization at low levels suggest that the fish that enter the RSW tanks alive quickly consume the available oxygen and probably suffocate once oxygen is depleted. Oxygen levels then stabilize because its consumption stops. The rate at which fish deplete the available oxygen depends on %Alive, amount of fish, tank filling rate and fish condition. The effects of these factors seem to appear when combining data in Table 5 and Figure 13. For

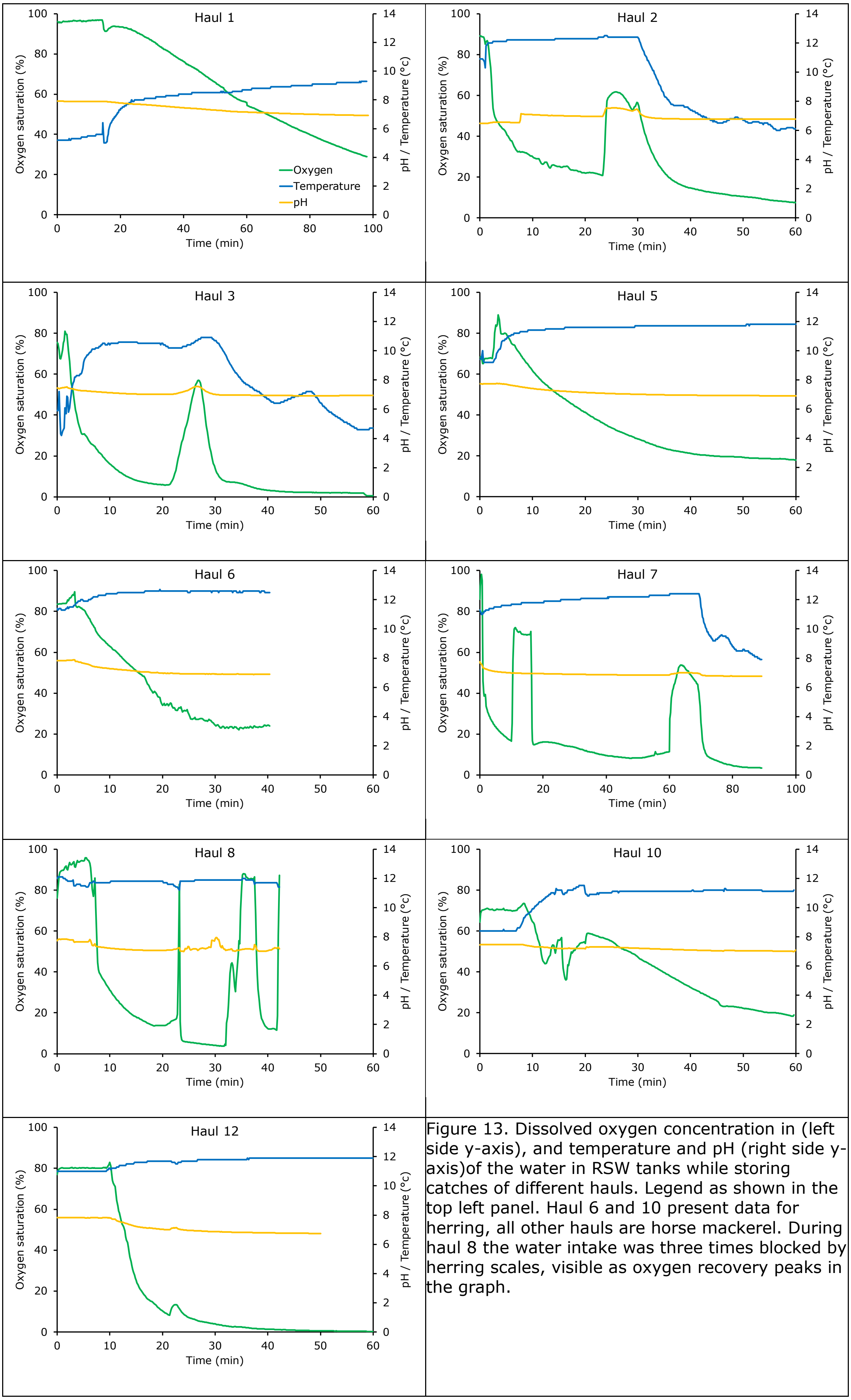

Figure 13. Dissolved oxygen concentration in (left side y-axis), and temperature and pH (right side y-axis)of the water in RSW tanks while storing catches of different hauls. Legend as shown in the top left panel. Haul 6 and 10 present data for herring, all other hauls are horse mackerel. During haul 8 the water intake was three times blocked by herring scales, visible as oxygen recovery peaks in the graph.

example hauls 1 and 5 that have lower %Alive indeed show a slower decline of the oxygen concentration than most other hauls. However, these patterns are not consistent. For example, based on the 100 %Alive in haul 10 we'd predict a fast decline of oxygen but this was not observed. Although this may be explained by a higher oxygen availability per fish for haul 10 due to a relatively low tank filling rate of 70%, it seems clear that our data cannot fully explain the observed patterns in oxygen concentrations.
Unfortunately, due to high water turbidity and poor visibility, our underwater video recordings could not be used to confirm that cessation of fish activity coincides with oxygen depletion. Assessment of fish condition and oxygen levels over time are needed to confirm that fish indeed suffocate and die when stored in the RSW tanks.

It is well known that insufficient oxygen is an important and potentially fatal stressor for all aerobic organisms, including fish (Hughes 1975; Domenici et al. 2012). The observed depletion of the available oxygen in the water in RSW tanks by horse mackerel and herring thus probably affected fish condition and caused suffocation, but we have no data to confirm this.
Considering that all living fish consume oxygen and produce carbon dioxide and heat, it is likely that water quality measurements in RSW tanks containing other species would lead to observations similar to what was observed for Horse mackerel and herring.

4 Conclusions and recommendations

The main objective of this study was to gain insight in at what point fish die in catch-processing of pelagic freezer trawlers. To address this question the condition of fish sampled from the catch-processing directly after the fish-water separators was assessed. This study leads to the following conclusions and recommendations.

1. Fish caught by pelagic freezer trawlers may enter the RSW tanks alive. Overall 62% (unweighted mean) of the sampled fish was alive directly after the fish-water separator (just before the RSW tanks).
2. Weighted mean %Alive and mean RAMP scores of fish that were alive when scored, were 81.2% and 0.28 for horse mackerel (799 fish, 3 trips, 34 hauls), 22.6% and 0.47 for mackerel (450 fish, 2 trips, 10 hauls), 56.0% and 0.41 for summer herring (113 fish, 1 trip, 11 hauls), 82.6% and 0.42 for winter herring (1150 fish, 2 trips, 14 hauls) and 68.7% and 0.40 for Atlanto-Scandian herring (385 fish, 1 trip, 14 hauls).
3. The part of the fish that is alive (percentage alive) directly after the fish-water separator ranges between 0 and 100%, depending on species and haul.
4. The within species variation in percentage alive is probably caused by fishing conditions. This study indicates that catch weight, haul duration and the time the cod end is behind the vessel before the fish is pumped on board may affect percentage alive.
5. Statistical analyses are required to establish and quantify effects of catch weight, haul duration and the time the cod end is behind the vessel as well as other variables.
6. Alive fish stored in RSW tanks appear to quickly consume the available oxygen in the water, probably causing the fish to suffocate.
7. It is recommended to further study the development over time of the water quality and the condition of fish in RSW tanks in relation to factors like species, amount of fish, residence time and water renewal rate to establish when and how fish die in RSW tanks.
8. It is recommended to study fish behaviour and water quality in cod-ends in the time period between hauling and pumping of fish.

5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

References

Cook, K.V., Reid, A.J., Patterson, D.A., Robinson, K.A., Chapman, J.M., Hinch, S.G., Cooke, S.J. 2019. A synthesis to understand responses to capture stressors among fish discarded from commercial fisheries and options for mitigating their severity. Fish and Fisheries 20, p 25-43.

Davis, M.W. 2002. Key principles for understanding fish bycatch discard mortality. Can. J. Fish. Aquat Sci. 59, p1834-1843.

Davis, M.W., 2010. Fish stress and mortality can be predicted using reflex impairment. Fish and Fisheries,11(1), pp.1-11.

Domenici P, Herbert NA, LeFrançois C, Steffensen JF, McKenzie DJ (2012) The effect of hypoxia on fish swimming performance and behaviour. In: Palstra AP, Planas JV (eds) Swimming physiology of fish. Springer, Berlin, pp 129–161.

Hughes GM (1975) Respiratory responses to hypoxia in fish. Am Zool 13:475–489

RDA (2018): Welzijn van vissen. Den Haag Raad voor Dierenaangelegenheden (Council on Animal Affaires), Nederland. 2018.038, 55 pp.

Veldhuizen, L.J.L., Berentsen, P.B.M., De Boer, I.J.M., Van de Vis, J.W., Bokkers, E.A.M. 2018. Fish welfare in capture fisheries: A review of injuries and mortality. Fisheries Research 204, p. 41-48.

Justification

Report C048/21
Project Number: 4316100173

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: M. Boonstra MSc.
Colleague scientist

Signature: 

Date: 13 July 2021

Approved: Dr. ir. T.P. Bult
Director

Signature: 

Date: 13 July 2021

Annex 1 Pelagic trawl data per haul

Herring

Trip nr.	Week	Year	Vessel	Haul nr.	Depth cod-end (m)	Water temp. cod-end (°C)	Water temp. surface (°C)	Wind direction & speed (bft)	Wave hight (m)	Haul duration (hour)	Cod-end behind vessel (min.)	Pumping time (min)	Species	Catch (tonnes)	Nr. of samples	Alive fish (%)	avg, RAMP all fish	Alive fish in samples (n)	avg, RAMP alive fish	SD RAMP alive fish
1	49	2019		15	25	13.3	12.1	W 3	0.5	0.3	8	22	HER	25	2	80	0,43	8	0,29	0,38
1	49	2019		16	25	13.2	12.2	W 3	0.5	0.8	11	30	HER	75	3	86.7	0,53	13	0,46	0,39
1	49	2019		17	25	13.3	12.1	W 3	0.5	0.5	13	28	HER	80	2	50	0,77	5	0,53	0,14
1	49	2019		19	25	13.3	12.1	W 7	-	0.8	13	25	HER	70	3	86.7	0,59	13	0,52	0,24
1	49	2019		20	25	13.3	12.1	W 7	-	0.6	17	8	HER	25	1	100	0,24	5	0,24	0,33
1	49	2019		21	25	13.2	12.1	WSW 8	3	1	7	18	HER	25	2	88.9	0,58	8	0,53	0,40
1	50	2019		26	25	12.7	11.7	NW 4	-	0.9	6	13	HER	25	2	100	0,27	10	0,27	0,24
1	50	2019		27	27.5	12.6	11.7	NW 4	-	0.2	17	31	HER	100	3	46.7	0,66	7	0,27	0,21
1	50	2019		22	25	12.5	11.7	NW 5	0.5	0.5	11	15	HER	25	1	100	0,04	5	0,04	0,10
1	50	2019		23	22.5	12.2	11.6	NW 5	0.5	0.8	8	16	HER	45	2	100	0,30	9	0,30	0,33
1	50	2019		24	25	11.8	11.6	NW 4	-	0.4	10	36	HER	115	2	70	0,67	7	0,52	0,39
3	30	2020		2	131	8	14.5	Z 4	1	2.8	9	9	HER	20	1	100	0,31	15	0,31	0,08
3	30	2020		6	140	8	15	WNW 3	1.8	1.6	7	31	HER	180	4	24	0,84	12	0,33	0,14
3	31	2020		8	70	11	14.5	Z 4	1	0.4	11	24	HER	110	4	28	0,84	14	0,43	0,24
3	31	2020		9	120	8	14.8	ZO 4	1.8	0.7	9	12	HER	20	2	90	0,43	27	0,37	0,18
3	31	2020		11	90	8.3	14.8	O 5	3.2	3.5	6	6	HER	3	1	73.3	0,56	11	0,40	0,27
3	31	2020		13	120	8.2	14.8	NW 3	1.8	1.7	9	31	HER	150	6	53.3	0,69	32	0,42	0,20
3	31	2020		15	120	8.6	14.4	NW 5	2.8	3.2	10	14	HER	15	3	62.2	0,72	28	0,55	0,24
3	31	2020		17	40	12	14.2	W 5	3	1.4	15	9	HER	15	2	93.3	0,48	28	0,44	0,22
3	31	2020		19	140	8.2	14	NW 3	1.5	1.9	12	6	HER	10	1	40	0,90	6	0,74	0,21
3	31	2020		20	40	11.9	14.2	ZO 3	1	3.6	28	24	HER	110	5	18.2	0,90	10	0,42	0,20
3	31	2020		22	98	9.3	14.1	ZO 6	3.8	0.5	9	30	HER	80	7	78.5	0,57	51	0,45	0,24
3	31	2020		25	120	8.3	14.5	W 4	2	0.5	12	32	HER	140	7	61.5	0,64	40	0,42	0,28
3	31	2020		26	140	7.8	14.6	WNW 2	0.5	2.2	11	16	HER	45	4	46	0,72	23	0,40	0,25
3	32	2020		28	25	12.8	14.5	ZW 4	0.8	2.6	16	31	HER	100	7	40	0,80	26	0,50	0,26
3	32	2020		30	110	8.1	14.2	ZW 4	1.9	2.2	10	6	HER	10	2	86.7	0,37	26	0,27	0,18
3	32	2020		33	70	9.1	14.3	Z 5	3.5	2.3	8	41	HER	170	12	33.3	0,79	30	0,38	0,21
3	32	2020		34	70	8.6	14.3	ZW 3	2	2.8	7	36	HER	100	10	57.5	0,66	46	0,40	0,24
3	32	2020		36	20	13.1	14.4	Z 2	1	3	8	28	HER	120	6	18.3	0,91	11	0,53	0,19
3	32	2020		37	100	8.4	14.2	O 2	0.5	1.1	11	19	HER	50	7	46.2	0,70	30	0,36	0,25
3	32	2020		40	100	8	15	ZO 4	1.3	2.6	11	20	HER	55	5	67.3	0,57	37	0,37	0,21
3	32	2020		42	20	13.6	14.7	W 4	1.5	0.9	10	33	HER	130	8	22.9	0,86	16	0,40	0,27
3	32	2020		43	70	8	15	W 3	0.5	1.4	13	28	HER	110	7	16.9	0,93	11	0,56	0,31

Atlanto-Scandian Herring

Trip nr.	Week	Year	Vessel	Haul nr.	Depth cod-end (m)	Water temp. cod-end (°C)	Water temp. surface (°C)	Wind direction & speed (bft)	Wave hight (m)	Haul duration (hour)	Cod-end behind vessel (min.)	Pumping time (min)	Species	Catch (tonnes)	Nr. of samples	Alive fish (%)	avg, RAMP all fish	Alive fish in samples (n)	avg, RAMP alive fish	SD RAMP alive fish
4	41	2020		43	35	9.1	10	ZO 2	0.5	2.6	11	6	A.S. HER	28	2	90	0,50	9	0,44	0,25
4	41	2020		44	345	6	9.9	W 1	0.5	8.2	7	25	A.S. HER	118	4	45	0,70	9	0,33	0,14
4	41	2020		46	40	9.2	10.1	NW 4	1	5.7	8	5	A.S. HER	24	2	60	0,62	6	0,37	0,26
4	41	2020		47	330	6.3	10	NW 4	2	8.8	10	21	A.S. HER	105	7	74.3	0,52	26	0,35	0,19
4	41	2020		48	70	8.5	10.2	NO 3	1	8.8	9	21	A.S. HER	133	6	50	0,68	15	0,36	0,15
4	41	2020		33	330	1.4	9	ZO 4	3	3.6	8	8	A.S. HER	32	2	80	0,41	8	0,26	0,12
4	41	2020		35	410	0.5	9.1	NO 4	1.5	9.7	9	10	A.S. HER	43	2	90	0,32	9	0,25	0,24
4	41	2020		36	46	9.3	9	NO 5	1.5	1.2	8	36	A.S. HER	188	9	66.7	0,65	30	0,47	0,22
4	41	2020		38	330	1	10.2	NO 3	1	9.4	11	23	A.S. HER	117	6	90	0,59	27	0,54	0,25
4	41	2020		39	30	8.5	9.6	ZO 3	0.5	2.8	6	24	A.S. HER	128	5	80	0,44	20	0,29	0,19
4	41	2020		42	355	1.6	10.1	ZW 6	2	3.4	7	7	A.S. HER	23	3	100	0,25	15	0,25	0,13
4	42	2020		49	290	6.4	10	N 3	1	3.3	8	33	A.S. HER	185	13	46.2	0,74	30	0,43	0,25
4	42	2020		50	360	5.6	10	NO 4	1.5	3.2	8	40	A.S. HER	178	13	29.2	0,83	19	0,43	0,22
4	42	2020		52	43	8.7	10.2	N 4	1	3	9	15	A.S. HER	58	3	60	0,65	9	0,42	0,25

Horse mackerel

Trip nr.	Week	Year	Vessel	Haul nr.	Depth cod-end (m)	Water temp. cod-end (°C)	Water temp. surface (°C)	Wind direction & speed (bft)	Wave hight (m)	Haul duration (hour)	Cod-end behind vessel (min.)	Pumping time (min)	Species	Catch (tonnes)	Nr. of samples	Alive fish (%)	avg, RAMP all fish	Alive fish in samples (n)	avg, RAMP alive fish	SD RAMP alive fish
2	3	2020		16	80	10.1	10.5	NNW 4	3	7.9	9	43	HOM	160	4	75	0,49	15	0,32	0,31
2	3	2020		18	95	10.4	9.9	SSW 6	3	3.4	15	13	HOM	29	2	90	0,36	9	0,28	0,27
2	4	2020		20	70	10.2	10.3	WSW 7	2.5	1.6	10	33	HOM	125	4	95	0,32	19	0,28	0,23
2	4	2020		21	75	9.9	9.4	WSW 6	2	2.4	7	19	HOM	75	3	100	0,16	15	0,16	0,12
2	4	2020		22	15	9.9	9.4	SW 4	1.5	2.5	7	31	HOM	80	4	95	0,28	19	0,25	0,23
2	4	2020		23	75	10	10.7	SW 3	1.5	3.2	10	23	HOM	110	3	100	0,16	15	0,16	0,16
2	4	2020		24	85	10.5	11.1	WSW 3	1	5	9	21	HOM	100	3	66.7	0,55	10	0,32	0,24
2	4	2020		25	100	10.5	9.9	W 4	1.5	8.3	13	24	HOM	65	3	73.3	0,59	11	0,44	0,35
2	4	2020		28	100	10.5	10.3	SSW 5	2.5	5.7	10	25	HOM	21	3	86.7	0,35	13	0,25	0,24
2	4	2020		30	105	10.6	11.1	S 5	2.5	3	10	28	HOM	73	4	70	0,41	14	0,15	0,18
4	38	2020		2	45	18	19	NO 7	3	2.9	7	5	HOM	14	1	100	0,13	5	0,13	0,09
4	38	2020		3	55	18.2	19	NO 6	3	1.3	10	27	HOM	150	5	92	0,46	23	0,41	0,31
4	38	2020		5	30	18	19	NO 7	3.5	3.3	9	42	HOM	181	12	48.3	0,67	29	0,31	0,18
4	38	2020		7	32	17.8	18.8	NO 6	3	1.8	6	7	HOM	26	1	100	0,16	5	0,16	0,06
4	38	2020		8	30	17.8	19	NO 6	2	7.3	10	46	HOM	173	12	28.3	0,79	17	0,27	0,27
4	38	2020		9	43	17.9	18.9	NO 6	1.5	3	5	17	HOM	78	3	93.3	0,32	14	0,27	0,20
4	38	2020		10	52	18	19	NO 5	1.5	6.2	6	39	HOM	107	10	44	0,75	22	0,43	0,29
4	38	2020		11	33	18	18.8	NO 6	2	4	7	21	HOM	78	5	80	0,47	20	0,34	0,17
4	39	2020		14	48	17.9	19.1	NO 2	0.5	5.4	6	26	HOM	103	5	64	0,50	16	0,22	0,23
4	39	2020		15	48	17.9	19	ZW 2	0.5	3.1	5	12	HOM	43	2	80	0,38	8	0,22	0,19
4	39	2020		18	49	17.9	19	ZW 4	1	5.3	11	21	HOM	86	4	70	0,48	14	0,26	0,15
4	42	2020		57	60	13.9	15.2	ZO 3	0.5	1.9	7	25	HOM	221	5	100	0,19	25	0,19	0,21
4	42	2020		58	58	14.1	15.4	ZO 3	0.5	4.3	12	21	HOM	144	5	100	0,20	25	0,20	0,11
4	42	2020		59	48	14.1	15	ZO 5	1	1.2	4	67	HOM	219	13	86.2	0,38	56	0,28	0,21
4	43	2020		60	60	14	15.1	ZO 7	1.5	1.7	4	13	HOM	55	3	100	0,19	15	0,19	0,14
4	43	2020		61	55	14.2	15	ZO 6	2	3.9	7	12	HOM	50	3	100	0,13	15	0,13	0,11

Mackerel

Trip nr.	Week	Year	Vessel	Haul nr.	Depth cod-end (m)	Water temp. cod-end (°C)	Water temp. surface (°C)	Wind direction & speed (bft)	Wave hight (m)	Haul duration (hour)	Cod-end behind vessel (min.)	Pumping time (min)	Species	Catch (tonnes)	Nr. of samples	Alive fish (%)	avg, RAMP all fish	Alive fish in samples (n)	avg, RAMP alive fish	SD RAMP alive fish
2	5	2020		34	95	10	9.4	Var 3	1.5	0.3	8	37	MAC	44	4	60	0,73	12	0,55	0,37
2	5	2020		35	95	10	9.4	S 4	1	1.2	8	4	MAC	107	1	80	0,38	4	0,22	0,24
2	5	2020		37	110	10	9.6	W 3	1	0.7	13	29	MAC	135	4	20	0,89	4	0,44	0,41
2	5	2020		38	135	10.1	9.6	W 4	1	1.5	11	-	MAC	250	4	0	1	0	-	-
4	40	2020		27	70	11	12	NW 2	1	1.7	11	106	MAC	421	27	0	1,00	0	-	-
4	40	2020		28	84	10.2	11.7	ZO 7	3	1.7	17	47	MAC	258	12	3.3	0,99	2	0,78	0,16
4	40	2020		29	78	10.1	12	ZW 3	2	1.5	5	26	MAC	147	8	35	0,79	14	0,40	0,26
4	40	2020		30	78	10.1	11.6	ZW 5	1.5	0.6	7	54	MAC	289	13	16.9	0,88	11	0,30	0,23
4	40	2020		31	65	11.2	12.3	ZO 3	4	2.5	7	44	MAC	210	11	7.3	0,94	4	0,14	0,06
4	40	2020		32	38	11.5	11.8	ZO 5	3	1.8	8	62	MAC	354	6	3.3	0,99	1	0,67	NA

Annex 2 Pelagic pair trawl data per haul

Horse mackerel and herring

Trip nr.	Week	Year	Vessel	Haul nr.	Depth cod-end (m)	Water temp. cod-end (°C)	Water temp. surface (°C)	Wind direction & speed (bft)	Wave hight (m)	Haul duration (hour)	Cod-end behind vessel (min.)	Pumping time (min)	Species	Catch (tonnes)	Catch pump order	Nr. of samples	Alive fish (%)	avg, RAMP all fish	Alive fish in samples (n)	avg, RAMP alive fish	SD RAMP alive fish
5	50	2020		1	16	13.8	13.8	W 3	0.5	4.6	12	80	HOM	150	1st	14	5.7	0,97	4	0,53	0,45
5	50	2020		2	30	12.8	12.8	WSW 4	0.5	0.6	6	31	HOM	80	2nd	2	100	0,10	10	0,10	0,10
5	50	2020		3	27	12.7	12.7	W 4	1	3.7	9	22	HOM	40	1st	2	100	0,08	10	0,08	0,07
5	50	2020		5	25	12.7	12.7	W 4	0.5	5.4	7	83	HOM	210	2nd	7	45.7	0,70	16	0,34	0,24
5	50	2020		7	23	12.6	12.6	W 4	1	1.3	12	67	HOM	160	1st	6	93.1	0,26	27	0,21	0,25
5	51	2020		8	40	13.7	13.7	SW 4	1.5	1.6	10	57	HOM	125	2nd	1	80	0,60	4	0,50	0,33
5	51	2020		9	40	12	12	SW 3	1	2.3	8	18	HOM	60	All	4	100	0,15	20	0,15	0,15
5	51	2020		12	30	11.9	11.9	S 5	2.5	3	14	22	HOM	35	1st	2	100	0,09	10	0,09	0,16
5	50	2020		6	25	12.6	12.6	W 5	1	0	11	13	HER	20	All	3	86.7	0,63	13	0,57	0,27
5	51	2020		10	25	12.6	12.6	SW 4	1	0.6	6	10	HER	30	All	2	100	0,21	10	0,21	0,21

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