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**Note for the Ministry of Foreign affairs of Denmark**

# Discard survival in Danish set-net fisheries

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## *Abstract*
*A discard ban in the reformed European Common Fisheries Policy include the possibility of exempting species with proven high discard survival from landing obligation. European plaice (Pleuronectes platessa) is a key species for commercial and recreational fishing in the North Sea, Skagerrak, Kattegat and* Baltic Sea*. Discard survival in P. platessa from beam and otter trawls range from 68% to 0%, but survival data on trammel fished plaice is absent from the literature. To address this issue we estimated discard survival in 118 plaice from 13 different net chains, conducted by two fishing vessels over seven fishing days in three different periods in November 2017, January and February 2018. Individuals were caught using trammel nets having sea bed temperatures at 2–7°C; salinity, 11-14 ppt; depth, 7–18m; soaking time, 24–48h, and kept 4-10 days in livewells within local harbours for observation of post-capture survival rate. Fish were individually tagged and the vitality assessed via* catch-related injuries and reflex impairment, *was determined after capture and at the end of the predetermined observation periods. All individuals were alive at the end of the observation periods. Reflexes were limited affected by the capturing process, and retained at the end of the observation periods. In conclusion, our study show the vitality of trammel net fished P. platessa is limited affected after capture, and document a high short term discard survival.*

## Background
Discards refer to captured fish that is returned to the sea during commercial fishing and may exceed 50% of the total catch for some fisheries (Uhlmann *et al*., 2014). During netting and handling, captured fish are exposed to a range of physical (abrasion, crushing, scale loss), physiological (exhaustion, air exposure), and environmental (light, pressure, salinity and temperature changes) stressors (Davis, 2002**;** Tenningen *et al.*, 2012; Uhlmann and Broadhurst, 2015**;** Benoît *et al.*, 2010, 2013**;** Davis and Olla, 2002**;** Giomi *et a*l., 2008). Consequently, many discarded fish dies within days of being returned to the sea; either directly because of catch-related trauma, or indirectly because reduced vitality increase their susceptibility to predation (Broadhurst *et al*., 2006; Wood, 1991; Wood *et al*., 1983; Wilson *et al*., 2014**;** Benoît *et al.*, 2013**;** Davis and Olla, 2002; Depestele *et al*., 2014). These fish represent a waste both commercially and environmentally (Depestele *et al*., 2016**;** Diamond and Beukers-Stewart, 2011**;** Heath *et al*., 2014; Jensen and Vestergaard, 2002).

The Common Fisheries Policy (CFP) of the European Union and has enacted a landing obligation, prohibiting the discard of quota regulated fish species (Official Journal of the European Union, December 28th, 2013).

Discard survival may be substantial for some species or fishing methods, making the landing obligating a burden on both the fishers and the environment (Condie *et al*., 2014a, 2014b; Guillen *et al*., 2014). Consequently, the regulation includes the possibility of exemption from landing obligations for "*species for which scientific evidence demonstrates high survival rates, taking into account the characteristics of the gear, of the fishing practices and of the ecosystem*" (Article 15, paragraph 4b). The regulation does not provide an exact definition of "*high survival rate*", stating that exceptions must be based on scientific evidence, and may be allowed if "*survival levels are assessed to be sufficiently high*".

Discard mortality is typically assessed via tagging or captivity experiments. Tagging experiments allow survival to be assessed after the fish have been discarded back into the ocean, thereby providing a more 'realistic' estimate of survival rate. However, for many researchers, the high cost of tagging equipment limits the number of fish that can be assessed using this method (Capizzano et al., 2016). In captivity experiments, the fish are transferred to livewells and monitored for predetermined periods of time, or until mortality has subsided. This approach allows a relatively large number of individual fish to be monitored closely on a regular basis (several times a day), thereby providing a more 'exact' estimate of the survival rate. Furthermore, the ability of fish to recover from sub lethal trauma can be assessed by determining the vitality of the fish after capture and at the end of the monitoring period. Vitality is assessed based on the degree of injury sustained by an individual and impairment to its reflexes, which individually and jointly have been found to be good predictors of survival (Benoît et al., 2010, 2012; Davis, 2010; Davis and Ottmar, 2006). Injuries are scored of using a catch damage index (Benoît et al., 2010, 2012) and impairment of reflexes is determined via the reflex action mortality predictor (RAMP) method, (Davis and Ottmar, 2006; Davis, 2007, 2010). The RAMP method consists of a suite of species-specific observations of the voluntary behaviour, stimuli response, and clinical reflexes of the fish (Kestin et al., 2002; Uhlmann et al., 2016), and has been used on a wide number of teleost species, including several species of flatfish (Davis, 2010; Humborstad et al., 2016; Uhlmann et al., 2016).

European plaice (*Pleuronectes platessa*) is a key species for commercial fisheries in the North Sea, Skagerrak, and Kattegat area (Feekings *et al*., 2012; Madsen *et al*., 2013). Discard survival in P. platessa from beam and otter trawls range from 89% to 0% (Depestele et al. 2014**,** Methling et al., 2017; Van Beek et al., 1990; Kaiser and Spencer, 1995), but data on discard survival from set-net fisheries is absent from the literature. In general, a lower discard mortality could be likely in fish caught with set-net, because mortality inducing stressors such as crushing and exhaustion are minor relative to fisheries using trawls (Depestele et al., 2014**;** Mehault et al., 2016; Uhlmann et al., 2016). Furthermore, fish caught with set-net experience only short periods of air exposure, because unwanted fish are released from the net and subsequently discarded, almost immediately when the netting is hauled back on the vessel. This lack of prolonged air exposure would also be expected to reduce discard mortality, because the duration of air exposure prior to discard is identified as a principal factor contributing to discard mortality (Neilson et al., 1989, Parker et al., 2003**;** Benoît et al., 2010, 2013**;** Castro et al., 2003**;** Macbeth et al., 2006). On the other hand fish might be gilled in the net for several hours and subjected to stress and injuries. To test this hypothesis, we assess discard survival and vitality in *P. platessa* commercially caught with set-nets in the autumn 2017 and winter 2018.

## Materials and Methods

**Fish capture and housing**

Experimental trials were conducted in the Western Baltic Sea in ICES subsquare 23 (The Sound) and 22 (Belt Sea) from commercial gill-netters fishing with commercial trammel nets targeting plaice and cod (Table 1).

**Table 1 Gillnet information**

| Abbreviation Code | Standard Abbreviations | ISSCFG |
|---|---|---|
| Set gillnets (anchored) | GNS | 07.1.0 |
| Trammel nets | GTR | 07.5.0 |

| | | |
|---|---|---|
| Combined gillnets-trammel nets | GTN | 07.6.0 |
| Gillnets and entangling nets | GEN | 07.9.0 |

A total of 118 fish from 13 chains were assessed for discard survival. Chains were collected over 7 fishing days between 25 November 2017 and 10 February 2018, using two different vessels (Table 2).

**Table 2** Vessel information

| Name | H 32 - Fuglen | NF 76 - Duddi Krog |
|---|---|---|
| Captain/Owner | Jacob Pind | Jonny Krog |
| Harbour | Sletten, Denmark | Langø, Denmark |
| Crew | 1 | 2 |
| Overall length | 9,79 m | 12,6 m |
| Width / draft | 3,60 m / 1,60 m | 4.60 m / 2.10 m |
| Motor | 145 HP | 175 HP |
| Gross register tonnage | 9,6 t | 11,5 t |

Trammel net consists of three layers of net: an inner wall of fine-meshed net, with an outer wall of large meshed net on each side. The outer walls traps fish when they encounter the inner wall and attempts to escape. Consequently, the mesh size of the inner walls determines the size of fish trapped in the Trammel net. In general, a larger mesh size traps larger fish, while allowing smaller fish to escape. For the experimental trials, the nominal full mesh sizes for the inner walls was 150 mm for chain 1-10, and 170 mm for chain 11-13. The measured inner mesh sizes was 148±0.4 mm for chain 1-10, and 168.4±0.5 mm for chain 11-13. Measured mesh sizes were determined based on 10 randomly chosen meshes, using a ruler and light hand force to stretch the mesh. All other technical parameters of the nets also corresponded to commercial practice.

Fishing procedures were conducted commercially and not influenced by the experimental sampling. When the netting was hauled back onto the vessel, netting and fish passed through a 2x10 kg net hauler (NET-OP 125). Through the net hauler, the netting and fish were placed on a steel table while the fish are untangled manually by the fishermen. Untangled fish can be released back into the ocean over the railing (*i.e.,* discarded) or placed in a number of plastic containers specifically assigned to individual species. The duration of time from netted fish exited the sea until they were untangled was very short (often less than 1 min). All of the captured fish were cleaned manually within 30 min of the last fish being untangled. Because a limited number of plaice were captured by the fishing vessels, all captured fish with a total length (TL) ≤40 cm were used for experimentation. Although previous experiments on plaice captured using otter trawl did not find any statistically significant sized related mortality (Methling et al., 2017), it was deemed important to collect over a size span to detect any possibly size related mortality in plaice captured using trammel net.

During experimentation, fish marked for potential discard was placed in 45L plastic tanks with oxygenated seawater. Here, reflex impairment (described below and in Table 3) was assessed and the total length (TL) measured, after which the individual fish were tagged in the dorsal fin with a 1cm plastic tag and transferred to 90L lidded boxes, submerged in a 300L lidded holding tank with oxygenated seawater. A fifth of the water in the holding tank was exchanged with fresh seawater every 15 min, ensuring the temperature did not rise above sea surface temperature. For individual fish, the duration of time from the fish exited the ocean until it was placed in the holding tank did not exceed 5 min. For chain 1-4, the experiments were performed from a smaller motorboat following the fishing vessel, rather than on the vessel. In these experiments, the untangled fish were collected into a knotless net and moved to a 45L plastic tank on the motorboat.

All fish was brought to shore with 3 hours of being placed in the holding tank. Within an hour of arriving at the dock, catch-related injuries (described below and in Table 3) were assessed and the individual fish randomly assigned and transferred to 360L livewells within the harbour. The livewells (W120 x D80 x H38 cm) were constructed of wood, and the sides equipped with holes to facilitate continues exchange of water between the harbour and the inside of the livewells. The top was equipped with a lid to shield the fish from birds, and the bottom was covered by a 1-cm layer of sand to simulate the fish's natural environment. A maximum of 10 fish was assigned to each livewell.

**Post-capture survival rate**

Following transfer to the livewells, the post-capture survival rate was monitored every 6 hour for a period of 4-10 days (Table 4). Individual fish were identified as dead if they exhibited a lack of visible operculum movement, loss of equilibrium, or were unresponsive to a gentle nudge on the caudal peduncle. Fish identified as dead were removed from the livewell, euthanized in an overdose of 2-phenoxyethanol, and sacrificed by spinal transection. Once a day, water temperature, dissolved oxygen, and salinity was measured in each livewell, and in the surrounding water. Salinity was measured using an EC300 Conductivity Meter (VWR, 1, 100 Matsonford Rd #200, Radnor, PA 19087, USA). Temperature and dissolved oxygen was measured using a MULTI 3420 D.O. Meter (WTW, Dr.-Karl-Slevogt-Straße 1, 82362 Weilheim, Germany). At the end of the monitoring periods, surviving fish were transferred from the livewells to 45L tanks with oxygenated seawater, for a second assessment of reflex impairment and injuries (Table 4). After this assessment, the fish were *sacrificed* via an overdose of 2-phenoxyethanol and spinal transection.

**Reflex action mortality predictor (RAMP) and catch damage index**

Assessment of reflex impairment for RAMP (see Table 3 for description of reflexes) was performed in 45L tanks with oxygenated sea water. Reflexes were selected from 12 candidate reflexes tested on 20 healthy plaice, caught by seine (Depestele et al., 2014; Methling et al., 2017). Assessment of catch damage index was performed on wet towels (see Table 3 for description of injuries). Injuries were selected from Methling et al. (2017). All assessments were completed within 10 min. For RAMP and catch damage index, a score of 1 was given if a reflex or injury was present and a score of 0 if it was absent.

**Table 3** Stimulus and responses of the reflex action mortality predictor (RAMP) test, and description of injuries assessed with the catch damage index. For RAMP, individuals was scored 1 if the response was completed as described within 5 seconds of the stimulus, or 0 if the response was absent (*i.e.,* not completed within 5 seconds). For catch damage index, individuals was scored 1 if the damage was present, or 0 if the damage was absent.

| **Reflex** | **Stimulus and responses** |
|---|---|
| Evade | Swims toward the bottom when released at the surface. |
| Righting | Righting itself when turned upside down under water. |
| Tail grab | Struggle or tries to escape when tail is held between two fingers. |

| **Injury** | **Description** |
|---|---|
| Abrasion (<10% / 10-50% / >50%): | Bruises and discoloration (both sides). |
| Fin fraying: | Shredding of the thin skin between the fins. |
| Blood dot: | Red dots (r ≈ 1 mm) on the downwards facing side. |
| Blood clot: | Blood clots visible through the skin. |
| Wounding (head / body): | Shallow cuts or punctured skin. |
| Deep wounding (head / body): | Deep cuts or punctured skin, often with Bleeding. |
| Protruding intestine: | Intestines visible through the anus. |
| Net-mark: | String cuts from net contact. |

## Results

All plaice were alive at the end of the observation periods (Table 4). The assessments of reflex impairment for RAMP showed that >90% of the 118 fish completed all three responses (Evade, Righting, Tail grab) when stimulated, both after capture and at the end of the observation periods (Figure 1). After capture, approximately 2/3 of the fish had <10% abrasion and 1/3 of the fish had 10-50% abrasion. At the end of the observation periods, approximately 1/10 of the fish had recovered sufficiently to have their score downgraded from 10-50% to <10% abrasion. Only a few percent of the fish had >50% abrasion after capture, and at the end of the observation periods. Approximately 1/2 of the fish displayed 'Fin fraying, Blood dots and Net marks after capture. For most fishes, these injures were unchanged at the end of the observation periods. The number of fish with Blood clots declined from 13% after capture to 5% at the end of the observation period. Less than five percent of the fish suffered Deep Head or Body wounding, or Head Wounding. A few fish appeared to have sustained Body Wounding during the observation periods (Figure 1).

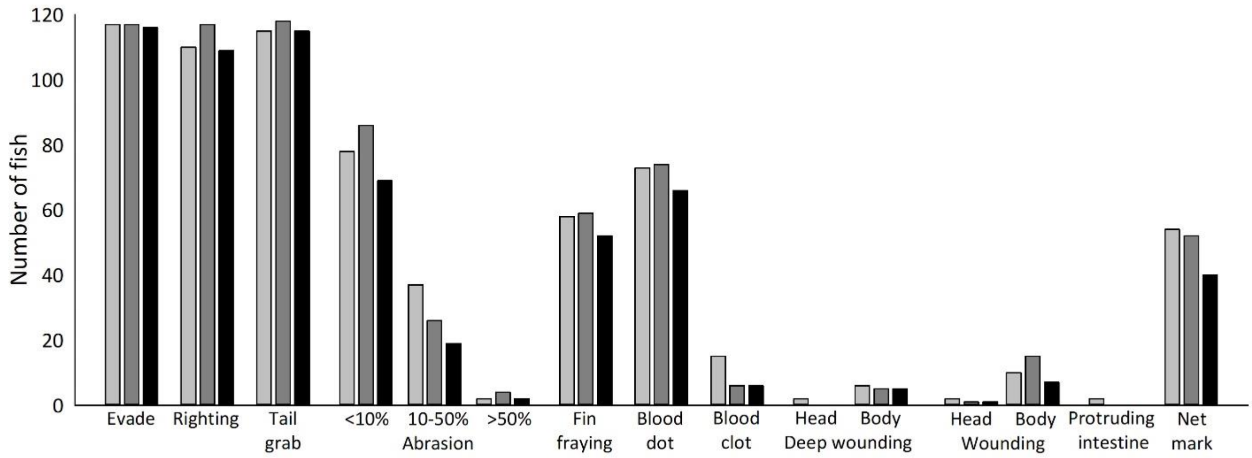


**Figure 1** Number of fish (out of a total of 118) scoring 1 on the reflex action mortality predictor (RAMP) test, and the catch damage index. Show are number of fish scoring 1 after capture (light grey), number of fish scoring 1 at the end of the observation periods (dark grey), and number of fish scoring 1 both after capture and at the end of the observation periods (black).

**Table 4** Summary of fishing conditions and fish survival.

| Chain number | Date | Depth (m) | Soaking time (hrs) | Deck temp (°C) | Bottom temp (°C) | Average length (cm) | Length range (cm) | Numbers | Observation period (days) | Survival (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25-11-17 | 7 | 23 | 4.0 | 7.1 | 32.8±1.9 | (30-40) | 5 | 10 | 100% |
| 2 | 25-11-17 | 9 | 26 | 4.0 | 7.0 | 31.6±0.6 | (28-35) | 10 | 10 | 100% |
| 3 | 26-11-17 | 7 | 24 | 5.0 | 7.0 | 33.8±0.6 | (31-37) | 8 | 10 | 100% |
| 4 | 26-11-17 | 7 | 25 | 5.0 | 7.0 | 32.6±3.6 | (22-39) | 4 | 10 | 100% |
| 5 | 18-01-18 | 11 | 24 | 6.0 | 3.8 | 35.0±0.0 | (35-35) | 3 | 7 | 100% |
| 6 | 18-01-18 | 11 | 25 | 6.0 | 4.1 | 33.0±1.4 | (25-37) | 10 | 7 | 100% |
| 7 | 19-01-18 | 9 | 23 | 4.0 | 3.7 | 34.5±1.3 | (25-40) | 11 | 6 | 100% |
| 8 | 19-01-18 | 11 | 24 | 4.0 | 4.0 | 31.8±1.1 | (26-35) | 9 | 6 | 100% |
| 9 | 20-01-18 | 8 | 24 | 4.7 | 3.4 | 33.5±1.1 | (28-36) | 6 | 5 | 100% |
| 10 | 20-01-18 | 10 | 24 | 4.7 | 3.6 | 33.0±2.0 | (27-39) | 5 | 5 | 100% |
| 11 | 09-02-18 | 16 | 46 | 0.0 | 2.3 | 33.1±0.5 | (30-38) | 16 | 5 | 100% |
| 12 | 09-02-18 | 17 | 47 | 0.0 | 2.1 | 33.9±0.5 | (31-37) | 13 | 5 | 100% |
| 13 | 10-02-18 | 18 | 19 | -0.1 | 2.3 | 35.4±0.8 | (30-40) | 18 | 4 | 100% |

On individual days, during the observation periods, the differences in water parameters (temperature, dissolved oxygen, and salinity) between the livewells and the harbour was negligible. The dissolved oxygen level was normoxic, the salinity around 10 ppt and the temperature decreased from ~6°C in November 2017 to ~1°C in February 2018 (Table 5).

**Table 5** Water parameters during the observation periods.

| Start | End | Temperature (°C) | Dissolved oxygen (%) | Salinity (ppt) |
|---|---|---|---|---|
| 26-11-17 | 05-12-17 | 6.1 ± 0.1 (5.4-7.0) | 91.8 ± 0.4 (87.0 - 97.0) | 10.7 ± 0.1 (9.8 - 11.9) |
| 18-01-18 | 26-01-18 | 3.1 ± 0.1 (3.0 - 3.2) | 93.9 ± 0.1 (92.0 - 94.0) | 12.2 ± 0.1 (12.0 - 12.4) |
| 09-02-18 | 14-01-18 | 1.0 ± 0.1 (0.5 - 1.5) | 96.5 ± 0.1 (95.2 - 97.4) | 10.5 ± 0.1 (9.7 - 11.1) |


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