Plaice survivability in the Irish seine net fishery

Fisheries Conservation Report

BIM Ireland's Seafood Development Agency

April 2020

Plaice survivability in the Irish seine net fishery

Martin Oliver, Matthew McHugh, Daragh Browne, Ronán Cosgrove
BIM, New Docks, Galway, Ireland. Email: Martin.Oliver@bim.ie

Key Findings

An 87% plaice survival rate was estimated in the Irish seine net fishery.

1

Water temperatures were close to their highest in Ireland which bodes well for survival rates at other times of year and in other areas.

2

High survival rates are likely to occur using 100 mm T90 and 120 mm diamond-mesh codends in the Irish seine net fishery.

3

Ireland's EU Structural and Investment Funds Programmes 2014 - 2020
Co-funded by the Irish Government and the European Union

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

EUROPEAN UNION
This measure is part-financed by the European Maritime and Fisheries Fund

Introduction

Plaice *(Pleuronectes platessa)* landings in the North East Atlantic predominantly occur in the North Sea and to a lesser extent the eastern Celtic Sea (Figure 1a). Approximately 574 t of plaice were caught and landed annually in mixed demersal fisheries by Irish vessels between 2016 and 2018, 75% of which was caught in ICES division 7.a (MI, 2019). Plaice is primarily taken as bycatch predominantly in coastal shallow sandy areas where they generally constitute less than 2% of landings (Figure 1b). With a 30 t bycatch allowance in 2020, Irish plaice quotas are particularly restrictive off the south west coast in 7.h-k making plaice a key high-risk choke species under the landing obligation in this area. Quotas are also tight in 7.b,c with 63 t allocated to Irish vessels in 2020 (EU, 2020).

Several high survivability exemptions have been implemented for plaice in the Celtic and North Seas. These include: otter trawls in 7.d,e,f,g, and otter trawls with a mesh size of at least 120 mm in 3.a and subarea 4; Danish anchor seines (SDN) in 7.d, 3.a and 4 (EU, 2019a; EU, 2019b). A previous application for an exemption for otter trawls in 7.h,j,k based on Oliver et al. (2018) was rejected on the basis that ~ 40% survival would not lead to a sufficient reduction in fishing mortality in a depleted stock (STECF, 2019a) (pg. 108).

Most plaice catches in 7.h,j,k are taken with otter trawls. However, plaice are also caught off Ireland's south-west and west coasts in the commercially important seine net fishery using the Scottish Seine (SSC) method. Given the specialised nature of the fishery, SSC vessels are extremely limited in their options to avoid unwanted plaice capture. They are generally restricted to targeting mixed demersal fish species, and incapable of switching to *Nephrops* and benefitting from a suite of selective gears available to *Nephrops* trawlers to reduce unwanted fish catches (EU, 2019a). Also, fishing grounds suitable for SSC operations are mainly off the south west and west coast so relocation is not an option.

A survival exemption would greatly assist the Irish SSC fleet in dealing with low plaice quotas. Fish survivability in bottom seines is likely superior to bottom trawls. Underwater camera observations have shown that the majority of fish herded by seine ropes enter the belly and codend sections in the closing phase of the seining operation. Hence, the actual fishing time may be as short as 15 minutes (Herrmann et al., 2016) with fish subject to physical stressors in the codend for much shorter periods compared with trawling. This is corroborated by Noack et al. (2020) who observed a substantially higher plaice survival rate of 78% in a seine net fishery compared with 44% in a bottom trawl fishery in the same area and time of year off the Danish coast.

Directly observed survival rates should ideally be obtained to ensure robust evaluation of proposed exemptions. This was not possible in the current study due to logistical and budget constraints. A 78% survival rate was obtained from the SDN fishery in the Skagerrak in 3.a (Noack et al., 2020) which bodes well for survival rates for this species in bottom seines. However, an application for a survival exemption for an SSC fishery in 7.d based on the work in 3.a was unsuccessful due differences in operational and catch characteristics between the two fisheries. The Scientific Technical and Economic Committee for Fisheries (STECF) did however recommend that data on vitality of discarded plaice could be sufficient to infer likelihood of survival in the SSC fishery from the SDN fishery (STECF, 2019b) (pg. 109). This is supported by a variety of studies which have shown fish vitality to be an excellent proxy for fish survival (e.g. Davis and Ottmar., 2006, Van Der Reijden et al., 2017 and Morfin et al., 2017). This study aimed to assess the vitality and infer likely survival rates of plaice caught in a SSC fishery in 7.j,k off the south west coast of Ireland, by applying survival estimates from the SDN fishery in 3.a.

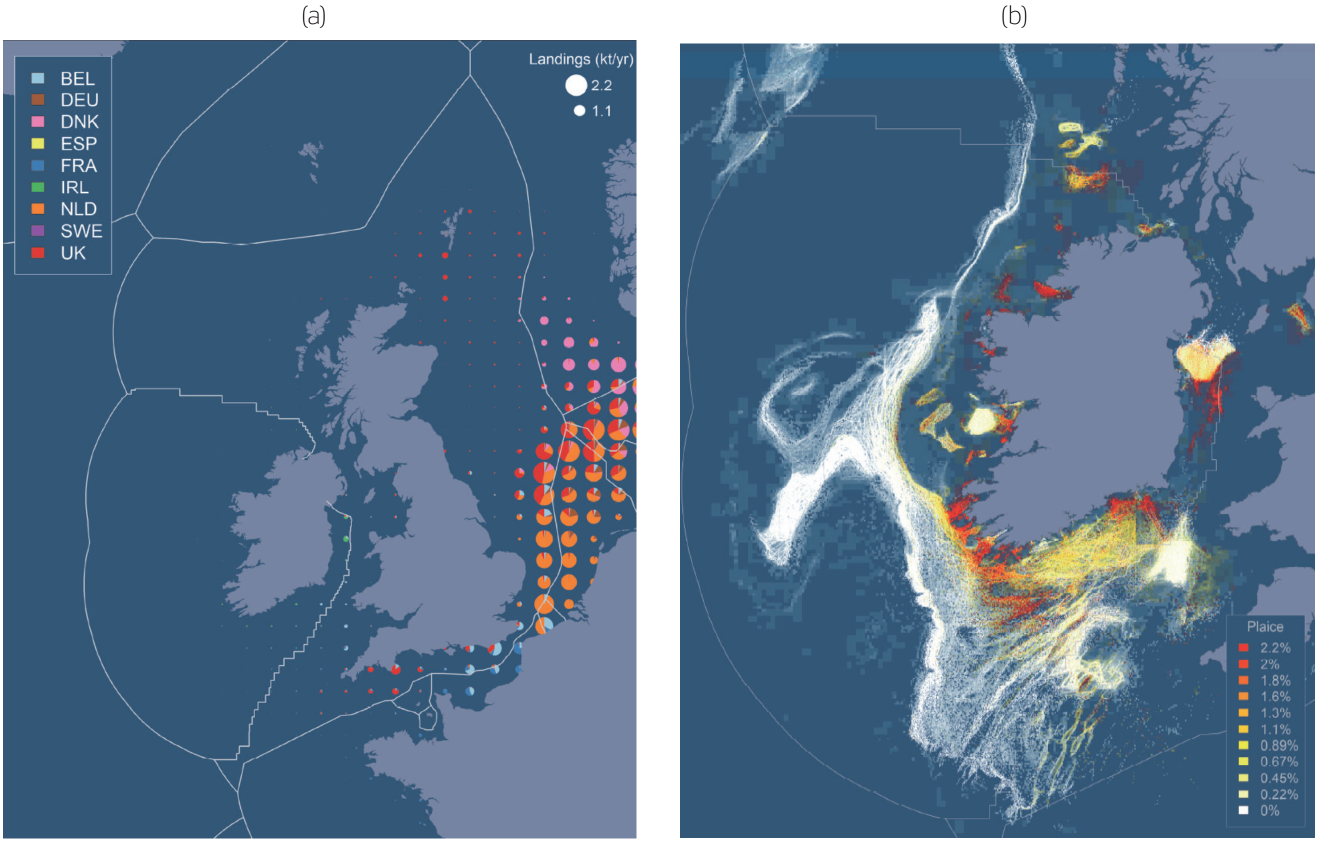

Figure 1. (a) Average distribution of the plaice landings in the Northeast Atlantic in the period 2011-16 (MI, 2019) and (b) Proportion of plaice in Irish bottom trawl landings (VMS/logbook data 2006-17). The highest proportions of plaice occur on shallow sandy grounds. Plaice does not consistently make up more than 2% of the landings in any area (MI, 2018).

Methods

The trial was conducted from the 22nd to 25th October 2019 onboard a 24 m steel SSC vessel, the MFV Róise Catríona (T100), on fishing grounds approximately five hours steaming south of Castletownbere off Ireland's south-west coast in ICES divisions 7.j,g (Figure 2).

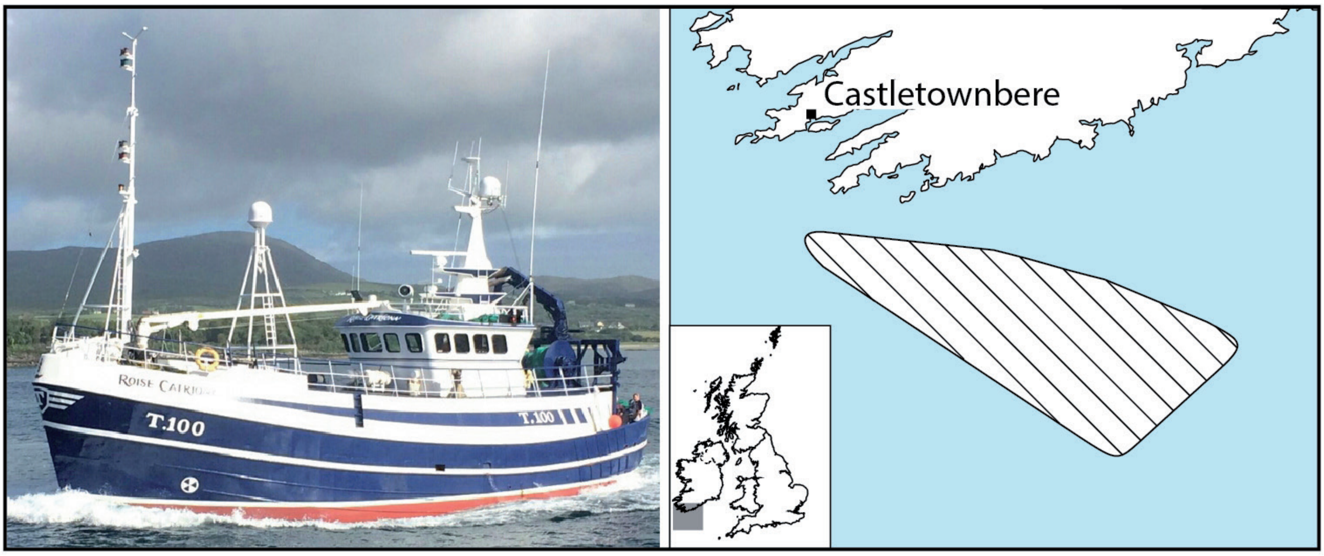

Figure 2. MFV Róise Catríona T100 and trial location (hatched area)

The vessel targeted mixed demersal fish using a bottom seine constructed from polyethylene twine with rope ground gear and a 100 mm T90 cod end. The SSC operation encircles fish by deploying port seine ropes which are attached to flotation buoys and payed out until the seine net is set. The starboard seine ropes are then payed out until the port rope is picked up and hauling can commence. Once hauling commences, the seine ropes gradually come together as the vessel moves slowly forward into the tide (Figure 3). Further details on the gear used are provided in Table 1. Fishery characteristics observed in the current study and Noack et al. (2020) were compared to better understand differences in observed vitalities and inferred survival.

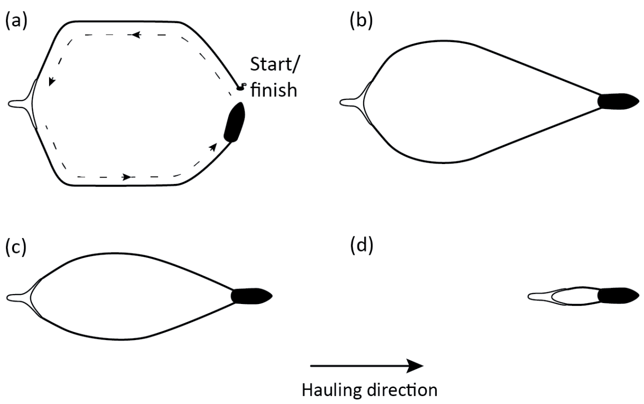

Figure 3. Seining operation: (a) setting the ring (b–d) hauling and closing the ropes.

Table 1. Gear characteristics

Characteristic	Detail
Gear type	Seine
Manufacturer	Jackson Trawls
Sweep length (m)	55
Headline (m)	60
Footrope (m)	68
Fishing circle (No., mm)	480 x 120
Seine rope length (m)	2860 × 2
Seine rope diameter (mm)	32
T90	100
Nominal mesh (mm)	100
Length (no. meshes)	49.5
Circumference (no. meshes)	80

The study followed protocols developed by the ICES workshop on methods for estimating discard survival (ICES, 2016). Plaice were caught under normal commercial SSC operations. In order to minimise observer bias, all plaice caught during the study were assessed for vitality and injuries by the same observer who had lead this work in a number of previous fish survival studies (Oliver et al., 2017; 2018; 2019). Catches were landed directly into a holding hopper, and once the seine was redeployed, they were placed on a conveyor belt, sorted by species and sampled. Plaice were put in 50 litre tubs of seawater prior to assessment. Vitality assessments were based on an approach from Benoît et al. (2010) (Table 2) while injury assessments were conducted using approaches developed by Depestele et al. (2014) and Smith et al. (2015). Injuries were scored as present (1) or absent (0) in each fish. The total score for each injury type was then divided by the overall injury score to derive proportional occurrence for each injury type.

Proportional plaice survival estimates and CIs in relation to vitality categories in the Danish seine net fishery (Noack et al., 2020) were applied to the proportions of plaice occurring in each vitality category in the current study. Eleven randomly sampled plaice were retained in an onboard holding tank (1500 mm × 1500 mm × 800 mm; L × W × H) with a continual flow through of seawater for 92 hours to provide additional qualitative information on survival.

Data on environmental parameters which could impact fish condition such as water and air temperature, wind direction, and swell height were collected during the trial. Bottom temperature was recorded at eight-minute intervals via star oddi data-storage tags (DSTs) mounted to the headline of the seine.

Table 2. Vitality assessments

Vitality	Code	Description
Excellent	V1	Vigorous body movement
Good	V2	Weak body movement
Poor	V3	No body movement but fish can move operculum
Moribund	V4	No body or operculum movement

Results

A total of 10 hauls containing plaice were completed with a mean haul duration and depth of 02:18 h and 100 m, respectively (Table 3). The main species caught during the trial were hake, haddock, boarfish, monkfish, whiting, plaice and a mixture of non-commercial species primarily consisting of lesser spotted dogfish and boarfish. Bulk catches ranging from 233 to 652 kg were observed during the trial (Table 4). A negative correlation between the proportion of plaice in excellent (V1) condition and bulk catch across hauls was observed (R^2 = 0.42).

Most plaice were in excellent condition (~ 59%) followed by good (~ 29%), poor (~ 12%) and moribund (~ 1%). Applying the survival rates obtained for seine caught plaice in Noack et al. (2020) inferred a survival estimate of ~ 87% in the current study (Table 5). Scale and mucus loss were the predominant injuries accounting for > 70 % of total injury scores (Table 6). Injury scores were generally correlated with vitality scores (Table 7).

Mean plaice length was 34.1 cm (± 0.22 SE) with just 4% of the plaice catch occurring below the minimum conservation reference size (MCRS) of 27 cm. Air exposure ranged from 15 – 26 min with a mean of 21 min. Nine out of the 11 (82%) plaice held onboard were still alive after 92 hours.

Observed mean sea surface temperature (SST) during the study of 13.8°C was slightly lower than the mean October temperature in the Celtic Sea of 14.38°C. Observed SST was 13% lower than the highest average monthly SST in the Celtic Sea of 15.83°C. Mean observed bottom water temperature of 10.9°C was lower than observed SST. Haul depths varied from 95 to 109 m with a mean of ~ 100 m. The weather was relatively calm during the trial with wind force and swell height averaging 12 kt and ~ 1 m respectively (Table 8).

Table 3. Summary trawl operation and catch data

Haul ID	Haul date	Haul duration (min)	Haul depth (m)	Total catch (kg)	Total Plaice (N)	Vitality code			
						V 1	V 2	V 3	V 4
1	22/10/2019	135	109	652	4	3	1		
2	22/10/2019	135	109	491	15	10	5		
3	23/10/2019	135	95	366	31	25	5	1	
4	23/10/2019	150	95	351	25	19	6		
5	23/10/2019	145	95	579	104	41	39	21	3
6	23/10/2019	140	95	652	104	50	40	14	
7	24/10/2019	145	95	607	80	57	15	7	1
8	24/10/2019	135	95	454	71	49	14	8	
9	24/10/2019	140	95	534	36	22	11	3	
10	24/10/2019	140	95	233	7	6		1	

Table 4. Species catch weights

Species	Total weight (kg)
Hake	870
Haddock	849
Megrim	385
Monk	245
Whiting	218
Plaice	214
Skates/ Ray	53
Red Gurnard	25
Lemon sole	20
Cod	4
Turbot	4
Black sole	3
Witch	2
Ling	2
Cuttlefish	1
John Dory	1
Other species	2023
Bulk catch (kg)	4919

Table 5. Vitality and survival estimates from bottom seine net fisheries in ICES divisions 3.a, 7.j,g

Vitality Code	Observed vitality				Observed survival			Inferred Survival		
	Seine 3.a		Seine 7.j,g		Seine 3.a			Seine 7.j,g		
	(N)	(%)	(N)	(%)	(%)	Lower CI (%)	Upper CI (%)	(%)	Lower CI (%)	Upper CI (%)
V1	39	13.9	282	59.1	89.7	80.7	99.8	53.0	47.7	59.0
V2	120	42.7	136	28.5	87.5	81.8	93.6	24.9	23.3	26.7
V3	96	34.2	55	11.5	79.2	71.4	87.7	9.1	8.2	10.1
V4	26	9.3	4	0.8	23.1	11.4	46.5	0.2	0.1	0.4
Totals	281		477		78.0	67.0	87.0	87.3	75.0	97.4

Table 6. Injury type, description and percentage score across all plaice

Injuries	Description	Score (%)
Exophthalmia	Eyes distended outwards from the head	0.3
Corneal gas bubbles	Air bubbles visibly present in the eye or the membrane covering the eye	0.0
Subcutaneous gas bubbles	Air bubbles visibly present under skin	0.0
Bleeding	Visible bleeding from any part of the body	0.3
Abrasion	Haemorrhaging red area from abrasion	2.8
Mucus loss	Visible area of mucus loss	34.8
Scale loss	Visible area of scale loss	38.1
Wounding	Shallow cuts on the body	0.2
Deep wounding	Deep cuts or gashes on the body	0.0
Fin fraying	Fins damaged	0.2
Predatory damage	Bite marks or area of the body eaten or lice actively present	0.0
Prolapsed internal organs	Intestine protruding out of anus	0.1
Net marks	Visible line marks caused by the net	14.5
Bruises	Red/ purple bruising visible on the body	6.6
Scratches	Scratch marks visible on the body	2.2

Table 7. Plaice vitality and injury scores

Vitality Code	Plaice (N)	Plaice (%)	Mean injury score (± SE)
V1	282	59	2.09 (0.06)
V2	136	29	2.69 (0.07)
V3	55	12	3.71 (0.18)
V4	4	1	4.25 (0.75)

Table 8. Environmental data. Mean values are in brackets.

At sea parameters	Values
Air temperature range (°C)	8 - 12 (10.7)
Sea surface temperature range (°C)	13 - 14 (13.8)
Sea surface salinity (ppt)	35 - 36 (35.4)
Bottom water temperature range (°C)	10 - 12 (10.9)
Depth fished (m)	95 - 109 (99.6)
Swell height (m)	0.5 - 3 (1.04)
Wind force (kt)	5 - 19 (12.0)

Table 9. Average monthly sea surface temperatures (°C) in relevant areas around Ireland from 2015 – 2018.
Source: https://data.gov.ie/dataset/weather-buoy-network

Month	West of Ireland	Celtic Sea	Irish Sea	Galway Bay
January	11.17	10.50	10.43	7.83
February	10.84	9.21	9.10	7.40
March	10.55	8.79	8.44	8.19
April	10.99	9.84	8.74	10.02
May	11.43	11.74	10.01	12.04
June	13.20	14.47	12.46	14.57
July	14.61	15.83	13.48	15.90
August	14.85	15.75	14.06	16.32
September	13.93	15.34	14.25	15.44
October	13.93	14.38	13.98	13.15
November	12.71	13.07	13.09	10.86
December	11.55	11.52	11.41	9.47

Table 10. Comparison of observed fishery characteristics between the current study and Noack et al. (2020). Mean values are in brackets.

Characteristic	Current study	Noack et at. (2020)
Gear type	Scottish seine (SSC)	Danish seine (SDN)
ICES Division	7j,g	3a
Months	October	August to October
Vessel length (m)	24	16
Vessel power (kW)	413	142
Fishing circle (No. meshes x mesh size)	480 x 120	360 x 120
Bulk catch (kg)	234 - 652 (492)	150 - 700 (283)
Nominal codend mesh size (mm)	100 mm T90	120 mm T0
Haul duration (min)	135 - 150 (138)	153 - 480 (179)
Haul depth (m)	95 - 109 (100)	12 - 61 (33)
Plaice sample size (N)	477	281
Mean plaice size (cm)	21 - 59 (34)	13 - 28 (25)
Plaice air exposure (min)	15 - 26 (21)	0 - 45 (15)
Air temperature (°C)	8 - 12 (10.7)	5 - 19 (14)
Bottom temperature (°C)	10 - 12 (10.9)	10 - 17 (15)
Estimated plaice survival (%)	87	78

Discussion

The inferred 87% plaice survival rate corresponded well with the 82% survival observed in the small-scale on board plaice holding experiment, and compared well with the 78% estimate off the Danish coast (Noack et al., 2020). Relatively little difference in observed survival rates (~ 79 - 90%) in the V1 - V3 vitality categories in the Danish study meant that variable numbers of fish in those categories had minimal impact on survival estimates in either study. The difference in overall survival between the two studies was largely attributable to a lower proportion of 0.8% of plaice in the Irish study compared with 9.3% of plaice in the Danish study occurring in the V4 moribund category. Given ~ 77% mortality of plaice in this category, this accounted for ~ < 1% and ~ 7% of plaice mortalities in the Irish and Danish studies respectively. While the other three categories relate to various degrees of fish movement, moribund is categorised as no movement of the body or operculum and is likely the most objective vitality category. These findings suggest minimal impact of any differences in interpretation of vitality categories between the two studies on overall survival estimates.

Differences in observed vitalities and estimated survival rates between the two studies could be attributable to differences in fishery characteristics outlined in Table 10:

Engine power in the Irish seine net vessel (413 kw) was higher than the Danish seine net vessel (142 kw). However, a review of the Irish fleet register shows that from a sample of nine known seine net vessels, engine power ranges from 250 to 500 kw (DAFM, 2020). Engine power in the Danish seine net fleet ranges from 67 – 901 kw (DTU Aqua, 2018) so it is not clear that the Irish seine net fleet is more powerful. In any case, power is less likely an issue in relation to fish survival in bottom seine net fisheries due to the relatively short periods fish spend in the codend (Herrmann et al., 2016).

The Irish seine net fishery uses a higher opening trawl (see information on fishing circle, Table 10) to target a range of flatfish and gadoid species whereas the Danish seine net fishery generally targets flatfish with a lower opening trawl. This likely contributed to a greater mean bulk catch of 492 kg haul^{-1} in the Irish study compared with 281 kg haul^{-1} in the Danish study. A significant negative correlation between bulk catch and V1 fish in the current study is likely due to greater physical stressors in the codend associated with greater bulk. Higher bulk catches likely negatively impacted fish vitality and survival in the Irish compared with the Danish seine net fishery. However, the vitality and injury assessments corresponded to a relatively large range of bulk catches (234 to 652 kg) in the Irish study and implicitly took into account all of the factors which affect fish condition. Hence, negative impacts from higher bulk catches were likely outweighed by some of the positive fishery characteristics outlined as follows.

A T90 mesh codend was used on board the Irish seiner and a diamond mesh codend was used on board the Danish vessel. T90 is known to improve the quality and condition of fish catches (Digre et al., 2010). Mean haul duration was shorter in the Irish study compared with the Danish study potentially resulting in lower stress associated with a shorter herding process in the Irish study. Mean haul depth was substantially higher in the Irish compared with the Danish study. Exophthalmia, corneal gas bubbles, subcutaneous gas bubbles and prolapsed internal organs can all be associated with barotrauma or other potential underlying issues (Hannah et al., 2008; Catchpole et al., 2015). Occurrence of these injuries was minimal (Table 6) suggesting that depth did not have a negative effect on plaice condition in the current study.

The entire plaice catch was sampled in the Irish study whereas plaice < 27 cm (MCRS) were sampled in the Danish study resulting in mean sizes of 34 and 25 cm respectively. Larger plaice have been shown to better survive the capture process (Revill et al., 2013) which could partially explain the superior plaice vitality during the Irish study.

Air exposure is known to be a key factor affecting plaice survival (Methling et al., 2017; Morfin et al., 2017). Mean air exposure was slightly higher (21 min) in the Irish study compared with the Danish study (15 min). However, an estimated survival rate of 86% was obtained for seine caught plaice with air exposure times < 30 min in the Danish study (Noack et al., 2020) so this factor is unlikely to have contributed to differences in vitalities between the two studies.

Air and water temperatures are known to be highly correlated with plaice mortality (Kraak et al., 2018). Superior fish condition in the Irish study may be partially attributable to slightly lower temperatures in the Irish study (Table 10).

Water temperatures during October are close to their highest in Ireland (Table 9) which bodes well for the survival of plaice in the Irish seine net fishery at other times of year. Also, temperatures in the Celtic sea are generally higher than the west coast of Ireland during summer months (Table 9) which supports extending a survival exemption to that area.

Depending on catch composition requirements, Irish seiners also use 120 mm diamond mesh codends (McHugh et al., 2019). Larger diamond mesh retains fewer small plaice (O'Neill et al., 2020) resulting in higher overall fish survival (Suuronen, 2005). Also, diamond mesh is generally more selective and retains fewer smaller flatfish compared with T90 mesh (e.g. Browne et al., 2017; Lomeli et al., 2017) again contributing to higher overall fish survival. A relatively high 78% plaice survival rate was observed with a 120 mm diamond-mesh codend in the Danish seine net study (Noack et al., 2020). These positive attributes of large diamond mesh in relation to plaice selectivity and survival suggest that a relatively high plaice survival rate would also likely occur with a 120 mm diamond-mesh codend in the Irish seine net fishery. An application for a survival exemption should be made for 120 mm diamond-mesh codend as well as 100 mm T90-mesh codend in the Irish seine net fishery.

Conclusion

The majority of plaice in the current study were in excellent condition with few plaice occurring in the moribund vitality category. This resulted in a relatively high inferred survival rate of 87%. Differences in the observed Irish SSC and Danish SDN fisheries were examined to better understand variable plaice vitalities and inferred survival rates. Use of T90 mesh in the codend, shorter haul durations, larger plaice size, and lower air and water temperatures likely benefited fish condition in the Irish study. Greater bulk catches negatively affected fish condition but there was no evidence to suggest that greater engine power nor water depth negatively impacted fish condition in the Irish seine net fishery. Ultimately, all of these factors were implicitly taken into account as part of the vitality assessment and inferred survival estimation.

Irish seine net vessels mainly operate off Ireland's south-west coast in ICES divisions 7.h-k and west coast in 7.b,c. The current study was conducted off the south-west coast but similarities in fishing operations and environmental characteristics in the two areas suggest that a potential survival exemption could also be extended to 7.b,c. Irish seine net vessels use 120 mm diamond mesh codends as well as 100 mm T90 codends. Positive attributes of large diamond mesh outlined for plaice selectivity and survival suggest that a relatively high plaice survival rate would also likely occur with a 120 mm diamond-mesh codend in the Irish seine net fishery and a survival exemption should also apply to that gear.

STECF previously recommended that data on vitality of discarded plaice could be sufficient to infer likelihood of survival in a SSC fishery in the English Channel from a SDN in the Skagerrak (STECF, 2019b) (pg. 109). It is hoped that this recommendation is taken into consideration when the current study is reviewed.

Acknowledgements

BIM would like to thank Damien Turner and the crew of the Róise Catríona for a productive collaboration, and Shane Murphy for assistance with on board sampling. This work was funded by the Irish Government and part-financed by the European Union through the EMFF Operational Programme 2014-2020 under the BIM Sustainable Fisheries Scheme.

References

Benoît, H.P., Hurlbut, T., and Chasse, J. 2010. Assessing the factors influencing discard mortality of demersal fishes using a semi-quantitative indicator of survival potential. Fisheries Research, 106: 436–447.

Browne, D., Tyndall, P., Jackson, E., and Cosgrove, R. 2017. T90 mesh improves selectivity and addresses the landing obligation for Celtic Sea whiting. Poster presented at the XXlll Conference of the European Association Fisheries Economists, Dublin, April 2017.

Catchpole, T., Randall, P., Forster, R., Santos, A. R., Armstrong, F., Bendall, V., and Maxwell, D. 2015. Estimating the discard survival rates of selected commercial fish species (plaice - Pleuronectes platessa) in four English fisheries.108 pp.

DAFM 2020. www.agriculture.gov.ie/seafood/seafisheries administration/seafisheriesadministration/seafishingfleet register

Davis, M.W., and Ottmar, M.L. 2006. Wounding and reflex impairment may be predictors for mortality in discarded or escaped fish. Fisheries Research, 82: 1–6.

Depestele, J., Desender, M., Benoit, H.P., Polet, H., and Vincx, M. 2014. Short-term survival of discarded target fish and non-target invertebrate species in the "eurocutter" beam trawl fishery of the southern North Sea. Fisheries Research 154: 82-92.

Digre, H., Hansen, U.J., and Erikson, U. 2010. Effect of trawling with traditional and 'T90' trawl codends on fish size and on different quality parameters of cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*. Fisheries Science, 76: 549-559.

DT Aqua 2018. Discard survival and vitality of plaice *(Pleuronectes platessa)* caught in the Danish anchor seine (SDN) fisheries in Skagerrak during summer. 9 pp.

Enever, R., Revill, A., Caslake, R. and Grant, A. 2010. Discard mitigation increases skate survival in the Bristol Channel. Fisheries Research, 102: 9-15.

EU 2019a. Commission Delegated Regulation (EU) 2019/2238 of 1 October 2019 specifying details of implementation of the landing obligation for certain demersal fisheries in the North Sea for the period 2020-2021. 13 pp.

EU 2019b. Commission Delegated Regulation (EU) 2019/2239 of 1 October 2019 specifying details of the landing obligation for certain demersal fisheries in North-Western waters for the period 2020-2021. 12 pp

EU 2020. Council Regulation (EU) 2020/123 of 27 January 2020 fixing for 2020 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters. 156 pp.

Hannah R.W., Parker S.J. and Matteson K.M. 2008. Escaping the Surface: The Effect of Capture Depth on Submergence Success of Surface-Released Pacific Rockfish, North American Journal of Fisheries Management, 28:3, 694-700

Herrmann, B., Larsen, R.B., Sistiaga, M., Madsen, N.A.H., Aarsæther, K.G., Grimaldo, E. and Ingolfsson, O.A. 2016. Predicting size selection of cod *(Gadus morhua)* in square mesh codends for demersal seining: A simulation-based approach. Fisheries Research, 184: 36–46.

ICES 2016. Report of the Workshop on Methods for Estimating Discard Survival 5 (WKMEDS 5). ICES CM 2016/ ACOM: 56. 47 pp.

Kraak, S.B.M., Velasco, A., Fröse, U., and Krumme, U. 2018. Prediction of delayed mortality using vitality scores and reflexes, as well as catch, processing, and post-release conditions: evidence from discarded flatfish in the Western Baltic trawl fishery. ICES Journal of Marine Science, 76: 330-341.

Lomeli, M.J.M., Hamel, O.S., Wakefield, W.W. and Erickson, D.L. 2017. Improving Catch Utilization in the U.S. West Coast Groundfish Bottom Trawl Fishery: an Evaluation of T90-Mesh and Diamond-Mesh Cod Ends. Marine and Coastal Fisheries, 9: 149-160.

McHugh, M., Oliver, M., Browne, D., Minto, C. and Cosgrove, R. 2019. Benefits of 120 mm diamond and 100 mm T90 codends in the Celtic and Irish Seas, Irish Sea Fisheries Board (BIM), Fisheries Conservation Report, February 2019. 6 pp

Methling, C., Skov, P.V. and Madsen, N. 2017. Reflex impairment, physiological stress, and discard mortality of European plaice *Pleuronectes platessa* in an otter trawl fishery. ICES Journal of Marine Science, 74: 1660-1671.

MI 2018. The Stock Book 2018: Annual Review of Fish Stocks in 2018 with Management Advice for 2018, Marine Institute. 521 pp.

MI 2019. The Stock Book 2019: Annual Review of Fish Stocks in 2019 with Management Advice for 2020, Marine Institute. 516 pp.

Morfin, M. Kopp, D., Benoît, H.P., Méhault, S., Randall, P., Foster, R. and Catchpole, T. 2017. Survival of European plaice discarded from coastal otter trawl fisheries in the English Channel, Journal of Environmental Management. 204: 404–412.

Noack, T., Savina, E. and Karlsen, J. D. 2020. Survival of undersized plaice *(Pleuronectes platessa)* discarded in the bottom otter trawl and Danish seine mixed fisheries in Skagerrak. Marine Policy. 115: 103852

Oliver, M., McHugh, M., Browne, D., Murphy, S. and, Cosgrove, R., 2017. Irish Sea Fisheries Board (BIM), *Nephrops* survivability in the Irish demersal trawl fishery. Fisheries Conservation Report, September 2017, 14 pp.

Oliver, M., McHugh, M., Murphy, S., Browne, D. and Cosgrove, R. 2018. Irish Sea Fisheries Board (BIM), Plaice survivability in the Irish otter trawl fishery. Fisheries Conservation Report, November 2018, 12 pp.

Oliver, M., McHugh, M., Murphy, S., Browne, D. and Cosgrove, R. 2019. Irish Sea Fisheries Board (BIM), Post-capture condition of cuckoo ray in an Irish otter trawl fishery. Fisheries Conservation Report, March 2019, 12 pp.

O'Neill, F. G., Fryer, R. J., Frandsen, R. P., Herrmann, B., Madsen, N., and Mieske, B. 2020. A meta-analysis of plaice size-selection data in otter trawl codends. Fisheries Research, 227: 105558.

Revill, A.S., Broadhurst, M.K. and Millar, R.B. 2013. Mortality of adult plaice, *Pleuronectes platessa* and sole, *Solea solea* discarded from English Channel beam trawlers. Fisheries Research, 147: 320-326.

Smith, S., Elliot, S. and Catchpole, T. 2015. Estimating the discard survival rates of Common sole (Solea solea) and plaice *(Pleuronectes platessa)* in the Bristol Channel trammel net fishery and of plaice in the Bristol Channel otter trawl fishery. Cefas report, 64 pp.

STECF 2019a. 61st Plenary Meeting Report (PLEN-19-02). Publications Office of the European Union, Luxembourg, ISBN 978-92-76-09515-6, doi:10.2760/31279. 141 pp.

STECF 2019b. Evaluation of Landing Obligation Joint Recommendations (STECF-19-08). Publications Office of the European Union, Luxembourg, 2019, 166 pp.

Suuronen, P. 2005. Mortality of fish escaping trawl gears, Food & Agriculture Org. 73 pp.

van der Reijden, K. J., Molenaar, P., Chen, C., Uhlmann, S. S., Goudswaard, P. C. and van Marlen, B. 2017. Survival of undersized plaice *(Pleuronectes platessa)*, sole *(Solea solea*), and dab (Limanda limanda) in North Sea pulse-trawl fisheries. ICES Journal of Marine Science, 74: 1672–1680.

Bord Iascaigh Mhara
An Cheannoifig,
Bóthar Crofton,
Dún Laoghaire,
Co. Bhaile Átha Cliath.
A96 E5A2

Irish Sea Fisheries Board
Head Office,
Crofton Road,
Dún Laoghaire,
Co. Dublin.
A96 E5A2

T +353 (0)1 214 4100
F +353 (0)1 284 1123
www.bim.ie