Working Group on Methods for Estimating Discard Survival (WGMEDS; outputs from 2019 meeting)

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Contents

i Executive summary

The potential for exemption from the European Union (EU) Common Fisheries Policy's (CFP) landing obligation (discard ban), where high discard survival can be demonstrated, has identified the need for scientific guidelines to conduct discard survival assessments. Robust estimates of discard survival can be used to justify exemptions from the landing obligation and inform on levels of post-release fishing mortality, which can then be accounted for in stock assessments.

The Working Group on Methods for Estimating Discard Survival (WGMEDS) set out to review and update ICES guidance on Methods to Estimate Discard Survival and complete meta-analyses of discard survival evidence to investigate variables influencing survival, with a view to influencing survival through modified fishing practices. We also explored the demand for ongoing monitoring requirements to inform on discard survival and took a proactive approach to sharing discard survival estimates with those working in stock assessment so that new evidence could be applied more widely.

In the past three years, the considerable investment in research in to discard survival, specifically from EU countries, has continued. The main outputs from WGMEDS include enhancements to the ICES guidance on how to quantify discard survival. This has supported the work of group members to estimate discard survival in a variety species-fishery combinations, including Nephrops, mackerel, plaice, common sole, eels, rays, much of which has been put forward as evidence to support exemptions from the EU discard ban. A critical review framework developed by WGMEDS has been used by the EU Scientific, Technical and Economic Committee for Fisheries (STECF) to assess the quality of discard survival evidence for proposed exemptions. There has been a high impact of work produced by the members of the group – specifically in multiple new EU regulated exemptions from the landing obligation. This has permitted fishers to continue discarding defined species and so assisting the implementation of the EU discard ban.

Future work is expected to focus on applying discard survival estimates in stock assessments. This would include developing guidance to assist assessment expert groups to determine whether available survival studies can be applied. It would require reviewing and assessing the quality and confidence in available discard survival estimates and exploring the potential to combine the results of survival studies so the effect of different variables could be accounted for in estimating an overall best survival estimate. Ultimately, we would aim to include estimates of discard survival in catch scenarios in the ICES advice sheets.

ii Expert group information

Expert group name	Working Group on Methods for Estimating Discard Survival (WGMEDS)
Expert group cycle	multiannual
Year cycle started	2017
Reporting year in cycle	3/3
Chair(s)	Tom Catchpole, UK
	Sebastian Uhlmann, Belgium
Meeting venue(s) and dates	27 November - 1 December 2017, Olhão, Portugal (22 participants)
	29 October - 2 November 2018, Mundaka, Spain (20 participants)
	4–8 November 2019, Dublin, Ireland (16 participants)

1 Main outcomes and achievements

WGMEDS main outcomes and achievements:

- There has been high impact of work of the members of the group – specifically in multiple new EU regulated exemptions from the landing obligation. This has a permitted fishers to continue discarding defined species, and assisted in the implementation of the EU discard ban.
- At the WG meetings, presentations were given on recent and ongoing discard survival assessments and agreed enhancements to the guidance were captured. There were additional presentations on the approaches for introducing discard survival estimates into stock assessments. Each presentation was supported by a brief written summary of the work (Annex 3; ToR a).
- Presentation summaries from all three WGMEDS meetings were considered in the context of the latest version of the 'Methods to Estimate Discard Survival' guidance document (draft Cooperative Research Report). A review was drafted on the methods applied in presented discard survival research, including any issues identified and enhancements developed (ToR a).
- The critical review method developed in the Workshop on Methods for Estimating Discard Survival (WKMEDS) was applied to the latest publications on discard survival. This enabled a detailed reviewed and assessed the quality of the methods applied in the context of the method guidance document (ToR a).
- A review of the progress made in the *Nephrops* meta-analysis work was produced. This was supplemented with a review of reports and publications from national research programmes on exploring factors effecting the survival of discarded catches. Examples of how these analyses could be used to develop methods of fishing to increase discard survival were identified (ToR b).
- A framework was provided to highlight policy relevance and relevant, practical considerations when proposing to integrate vitality/survival data collection within existing, routine sampling programmes (ToR c).
- Following the template developed in WGMEDS 2 for the North Sea plaice stock, discard survival evidence was mapped onto catch and discard estimates for plaice stocks in the Celtic Sea. This exercise illustrated the discard estimates in the context of the stock, and its management, particularly in the context of survivability exemptions from the Landing Obligation (ToR d).
- Application of discard survival evidence in fisheries management. Case studies were developed to illustrate the implications of introducing discard survival estimates into stock assessments. The outputs from these show the effect on stock descriptors and highlight important considerations for stock assessments when introducing discard survival estimates (ToR d).
- Revisions to the final ICES review of the Cooperative Research report (CRR) on Methods to Estimate Discard Survival were ongoing.
- A revised version of the manuscript on critical review of discard survival studies was submitted to the ICES *Journal of Marine Science*.

2 Report on Terms of Reference

2.1 ToR a) Review and update guidance on 'Methods to Estimate Discard Survival'

Response to this ToR includes three tasks:

1. Meeting participants presented methods and results from recent and ongoing projects. Each presentation was supported by a brief written summary (Annex 3).
2. The presentation summaries were considered in the context of the 'Methods to Estimate Discard Survival' guidance document (draft Cooperative Research Report, ICES, 2020), and any identified issues and agreed enhancements to the guidance were captured to be included as an amendment.
3. Recent papers and reports on discard survival estimates for selected species were critically reviewed using methods developed within WKMEDS. This task required an in-depth review of the applied methods of each identified study. Its limitations and new developments were discussed in the context of the methods guidance document (ICES, 2020).

2.1.1 Presenting ongoing research

Meeting participants presented methods and results from recent and ongoing projects (Annex 3). Observations and discussions based on these presentations informed further developments of the guidelines on how to conduct discard survival studies.

One specific area of discussion was in the strength of the relationship between (semi-quantitative) vitality scores and their indices with the probability of survival. This relationship was explored by Kraak *et al.* 2018 to compare model predictions with observed values. Logistic regression was used, and the variance simulated, although available distributions of parameters were known. In the study by Kraak *et al.* (2018) fish were kept in cages on the seafloor for a period of 5 to 7 days, which meant that the resolution in survival monitoring over time was considered to be low, because fish were only assessed after a period of 5-7 days, and as a consequence, the time of death of each fish was unknown. This, in combination with the fact that controls were used in a separate pilot-study, and thus not reflecting identical experimental conditions, resulted in a lower overall score compared to the other reviewed studies during the WGMEDS meeting in 2018. Another study using vitality indices to predict post-capture survival has been recently peer-reviewed and is going to be prepared for resubmission this year (S. Uhlmann, pers. comm.).

2.1.2 Summarising ongoing method development

Throughout the fixed, three-years term of the working group, any new developments with respect to the methodology of vitality assessments, captive observations and tagging were collected and the guidance updated accordingly. During the WGMEDS 2019 meeting, a reviewing exercise was conducted for three different topics:

1) Vitality assessments
2) Captive observation
3) Tagging

A draft of the forthcoming Cooperative Research Report (CRR, ICES, 2020) was used as a background document for this exercise. Methodological updates presented during the recent WGMEDS meetings (2017, 2018, 2019) were summarized under each of the three topics below. For each method, some advantages & potential disadvantages were listed.

2.1.2.1 Vitality assessments

Novel approaches have been emerging to test on-board condition of pelagic species and quantify the effects of crowding stress on vitality and survival (Anders *et al.*, 2019a & b; Handegard *et al.*, 2017; Marçalo *et al.*, 2018). For example, Marçalo *et al.* (2018) showed how to assess scale loss from dead and live fish. Anders *et al.* (2019a) used changes in schooling behaviour (specifically polarity and cohesion) in herring and mackerel released (or "slipped") from purse seines to infer welfare status in the released fish and how these vary with catch size and between fishing vessels. Furthermore, Anders *et al.* (2019b) and Handegard *et al.* (2017) by studying behavioural responses in stressed mackerel under controlled crowded and hypoxic experimental conditions defined "safe" crowding densities and dissolved oxygen concentrations for mackerel caught in purse-seines. Some of the vitality metrics studied among pelagic species (herring & mackerel) caught by pelagic fisheries in Norway are listed in Table 2.1 (Tenningen *et al.*, 2019).

Table. 2.1. Types and description of individual vitality metrics developed for species caught in pelagic fisheries (from Tenningen *et al*. 2019).

	Test	Positive Response	Negative implications (i.e. response absent or weak)
Free Swimming Observations			
Evasion 1	Fish transfered from net into observation tank	A "startle" response, or swims around tank seeking "escape".	Fish lacks awareness of substantial change in environment. Or is unable to respond due to exhaustion, or physical injury.
Orientation / Self-righting	Fish transfered from net into observation tank	Can self-orientate dorsal side up within 5 seconds of transfer.	Fish has lost a basic reflex - balance. Therefore, swimming and avoidance of potential threats will be severely compromised.
Head Complex	Fish transfered from net into observation tank	A coordinated and regular use of mouth and operaculae - indicative of normal respiration (> 1 per 10 sec).	Absence - respiratory failure, fish is dead or close to death. Very strong - fish may be hypoxic or fatigued.
Evasion 2	Observer's hand, in water, approaches fish from side; in preparation for "caudal reflex test (see below).	A "startle" response, or swims around tank seeking "escape".	Fish lacks awareness of potential visible threat. Or is unable to respond due to exhaustion, or physical injury.
Caudal Reflex	Observer touches, or attempts to hold, caudal fin.	Fish immediately (<1 sec) attempts to swim away from physical contact.	Fish lacks awareness of potential physical threat. Or is unable to respond due to exhaustion, or physical injury.
Observations While Handling			
Body Flex 1 - Restrained	Observer hold fish firmly in clenched hand, with thumb and fore-finger just posterior of operculae.	Fish should flex its tail musculatur in an attempt to escape (< 3 sec). [NB - test starts in water, as observer attempts to remove fish from tank].	Fish lacks awareness of strong physical threat (i.e. restraining). Or is unable to respond due to exhaustion, or physical injury.
Vestibulo-ocular response	Observer - while holding fish as above - rotates fish on the longitudinal axis.	Fish should attempt to hold eye steady, with respect to horizonal. 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 brain stem.
Mouth Closure	Observer - while holding fish as above - uses finger to open open fish's mouth.	Fish should attempt to resist opening action. May also respond with a "head-complex motion" and/or "body flex" (< 3 sec).	Fish lacks awareness of an intrusive physical threat. Or is unable to respond due to exhaustion, or physical injury.
Body Flex 2 - Flat surface	Fish is laid, unrestrained, on a flat surface.	Fish should flex its tail musculatur (< 3 sec).	Fish lacks awareness of substantial change in physical status - i.e. released but emersed. Or is unable to respond due to exhaustion, or physical injury.

Semi-quantitative vigour assessments using a three- or four-point categorical scale in demersal fisheries follow a similar protocol developed by Benoît *et al.* (2010). Such rapid assessments remain an important descriptor to describe an animal's condition immediately after capture. Semi-quantitative assessments are useful to describe both impaired movements and scale and severity of injury even though a spectrum of possible responses and injuries is being categorized into abstract categories. Quantitative reflex assessments follow a basic protocol, but can differ between species, and potentially assessors (Uhlmann *et al.*, 2016; Meeremans *et al.*, 2017; Uhlmann *et al.*, 2020a). The relevant suite of species-specific reflexes should always be established as part of a scoping study on unstressed fish. While some reflexes may show consistent responses across taxa and fishing gears, others may be really specific for the tested circumstances. For example, in pelagic fisheries, a rehotaxis assessment was suggested in contrast to demersal fisheries. Video footage can be useful when assessing reflex responses and recovery among some (pelagic) species (Barragán-Méndez *et al.*, 2019) and also for training purposes (Meeremans *et al.*, 2017; Van Bogaert and Uhlmann, 2018). For pelagic species, it proved best that reflex assessments were done by taking a sample of fish out of the catch. In their presentation at the 2019 WGMEDS meeting Onandia *et al.*, 2019 asked whether RAMP can be used to improve tagging methods of bluefin tuna (*Thunnus thynnus*). It was concluded that vitality assessments can be challenging with large specimens. In July 2019, the RAMP methodology was introduced to the tagging community at an ICAT meeting. Some species-specific reflexes that were established for bluefin tuna included:

- Strong coloration (brownish)
- Fins erected
- Finlets movement
- Operculum/mouth movement
- Body flex / Tail beat
- Oriented swimming when release

Injuries; bleeding

- Hook position
- Injuries in the skin
- Fin damage
- On-board tagging – air exposure

Video recordings of tagging procedures is likely to improve efficiency of on-board vitality testing in the future, and can be useful to illustrate to seagoing crew on how to (not) do it. Uhlmann *et al.*, 2020a used video recordings to train unexperienced assessors and to demonstrate whether an expectation about a treatment has the potential to influence the scoring. Post-release recovery can be aided by towing moribund fish alongside the vessel to get water flow through the gills. In the future, it is planned to use holding cages to aid the development of a complete RAMP curve using various capture methods. Video recordings of vitality assessments of skates were made at the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) within the SUMARiS project. As part of this project, existing protocols and candidate reflexes for testing vitality of discarded skates were harmonized and confirmed by testing aquarium-held individuals for their consistent and unambiguous responses to various stimuli (Van Bogaert *et al.*, 2020). The following, additional parameters were non-invasively and visually scored during captive observations assessments to derive another type of condition index (Lemey and Hensgens, 2019): spiracle count, (un)provoked swimming, cover, feeding, additional bleeding. It was noted that rays show protracted mortality in captivity and were therefore monitored for up to 21 days, with daily controls.

2.1.2.2 Captive observation

We summarized new or updated approaches to captive observation from the WGMEDS meetings 2017–2019 in Table 2.2 below. In general, there seem to be two new trends in recent captive observation studies:

- Increased interest into the post-capture, physiological and behavioural aspects of the recovery of fish species (Koeck *et al.*, 2017, Methling *et al.*, 2017; Ruiz-Jarabo *et al.*, 2018, Onandia and Arregi 2018; Eskelund *et al.*, 2019). In recent discard survival studies, species-specific stress biomarkers, heart rate function & respirometry have been used to investigate short- and longer-term recovery in different fish species (Koeck *et al.*, 2017, Ruiz-Jarabo *et al.*, 2018, Onandia and Arregi, 2018, Table 2.2).
- Increased attention for environmental enrichment of containment facilities during captive observation.

Animal welfare considerations associated with seeking and granting ethics approval to hold organisms in captivity has resulted in the notion that fish should be able to express their full range of normal behaviours in containment facilities (laboratory holdings). As part of recent captive observation studies researchers included various “environmental enrichment” options in the closed systems where fish were monitored on a daily basis. This seems to be partially incentivized by national animal welfare and control authorities (e.g., veterinary inspectors). For example, as requirement for holding artificial plants had to be added to the monitoring units to provide “refuge spots” for sole (M. Oliver, pers. comm.) and providing sand to tank bottoms to allow burying behaviour of rays (ILVO, Belgium). In a presentation by Noëlle Yochum (ICES, 2017) some “lessons learnt” for laboratory holdings were summarized:

- Consider the biology of the animal (tank requirements, ‘burping’, death enzymes, etc.).
- Test tag types in advance.
- Test tank set up in advance.
- Monitor more frequently for the first 1-3 days.
- Check the water quality
- Be aware of captivity effects, variables not included

2.1.2.3 Tagging

We summarized new or updated approaches to tagging from WGMEDS meeting 2017–2019 in Table 2.2 below. The main updates are some combinations of techniques to improve the efficiency of the tagging process to infer a survival rate (e.g. mark-recapture tags combined to electronic tags (Benoît and Morfin, 2018), or active and passive tracking of fish equipped with electronic tags (Morfin *et al.*, 2018). Although combining techniques gives more accuracy on survival rate estimations, it adds challenges to find financial and human resources to perform the experiments.

Table 2.2. Overview of recent updates on vitality assessments, captive observation and tagging approaches (2017–2019).

Type	Year	Reference (Authors, Title)	Update	Advantages	Disadvantages
Vitality Assessments	2017	Barbara Koeck, Jack Hollins, Shaun Killen (2017). "What is driving vulnerability of fish to fishing gear? The physiological basis of individual differences of vulnerability to fishing".	Vitality indicator (modified from Hasbrouck *et al.*, 2012) and the reflexes for the RAMP (modified from Davis and Ottmar, 2006; Davis, 2007; and Barkley *et al.*, 2012) used on Baltic flatfish. Indicator Description: "Vitality" Subjective semi-quantitative score: 1 ¼ excellent, 2 ¼ good, 3 ¼ poor, 4 ¼ moribund. "Evasion" Attempts to actively swim away when placed on the palm of the hand. "Undulating fins" Attempts to actively bury with rhythmical fin movements. "Tail handle" Attempts upward flexing of the tail when held between thumb and index finger "Head handle" Attempts upward flexing of the head when held between thumb and index finger. "Natural righting" Attempts to dorsoventrally right itself within 5 sec.	Findings show very little correlation between RAMP or vitality score and survival	Study did not assess fish until asymptote
		C. Lewin, "Estimating post-release mortality of European sea bass based on experimental angling"	Three reflexes (VOR, tail grab, righting) and two injury scores (deep hooking, heavy bleeding)	Quick and easy assessments, perhaps not representative of the fishery – potential effects of the use of cultured fish	
	2018	Ignacio Ruiz-Jarabo, C. Barragán-Méndez, J. M. Mancera and I. Sobrino (2018). "Physiological recovery of captured teleosts, elasmobranchs, cephalopods and crustaceans as a useful tool to evaluate discard survival", see full abstract in WGMEDS report 2018.	Interesting research on physiological recovery of fish may be a good indicator of post discard survival. Stress levels can be split into stages: Primary (hormone release), Secondary (actions of the secreted hormones), Tertiary (chronic stress situations). Cortisol levels may indicate post discard survival. Blood and tissue sampling for species-dependent stress biomarkers took place in ground facilities.	This approach is new and interesting, because it provides detailed insights into species-dependent recovery and details physiological and behavioural responses shortly after catch, which can be linked to immediate and delayed mortality	
		Iñigo Onandia and Luis Arregi (2018). "Survival and physiological recovery of the anchovy in the purse seine fishery in the Bay of Biscay", see full abstract in WGMEDS report 2018.	Reflexes observed: Orientation, Schooling, Rehotaxis, Startle response light /sound, Escaping behaviour. Reflexes tested when fish are being pumped onto the vessel.	/	

	2019	Van Bogaert, N., Uhlmann, S. S.., Torreele, E. (2019). Update on the SUMARIS WP2 survival rate tests. See abstract, Annex 3.	RAMP and injuries based off CEFAS, IFREMER and Wageningen Marine Research. Reflexes for skate and ray: startle touch, tail grab, body flex and spiracles. Injuries: bleeding head, body, tail, open wounds and fin damage.	Size limitations with ray in most studies	
Captive observation	2017	Barbara Koeck, Jack Hollins, Shaun Killen (2017). “What is driving vulnerability of fish to fishing gear? The physiological basis of individual differences of vulnerability to fishing”.	Short term recovery response using respirometry; Long-term recovery response using heart-rate loggers; Enzymatic profiles, blood chemistry & circulating hormones to investigate stress responses	Higher resolution into physiological recovery after catch	Time-consuming, expensive
	2018	Ignacio Ruiz-Jarabo, C. Barragán-Méndez, J. M. Mancera and I. Sobrino (2018). “Physiological recovery of captured teleosts, elasmobranchs, cephalopods and crustaceans as a useful tool to evaluate discard survival”, see full abstract in WGMEDS report 2018.	Fish were sampled on-board of a Spanish scientific survey vessel. After catch, fish were kept on-board in monitoring units with recirculating seawater. Within 48h after catching, blood and tissue sampling for species-dependent stress biomarkers took place in ground facilities. Additionally, behavioural responses were monitored by using cameras.	This approach is new and interesting because it provides detailed insights into species-dependent recovery and details physiological and behavioural responses shortly after catch, which can be linked to immediate and delayed mortality	
		Iñigo Onandia and Luis Arregi (2018). “Survival and physiological recovery of the anchovy in the purse seine fishery in the Bay of Biscay”, see full abstract in WGMEDS report 2018.	High resolution mortality using time-lapse photo techniques and physiological recovery of anchovies are analyzed in pumped fish from purse seine fishery in the Bay of Biscay. Delayed mortality is measured every 3 hours, arriving to the asymptote between 21 and 27 hours. Secondary stress responses are measured (glucose and lactate) from blood and mucus samples taken after 1, 2, 3, 6, 24 and 31 hours.	Same as above	
	2019	Lemey, L, Hensgens, R. 2019. Long-term health monitoring and survival rates of skates (Rajidae) caught as bycatch. MSc thesis.	During seatrips on-board of Belgian commercial beam-and ottertrawlers, skates were randomly selected from the catch and evaluated for vitality, reflexes and injuries using the RAMP method. A selection of these sampled rays was monitored ex situ for a 3 week (21 days) period. During captive observation additional biological & behavioural parameters (weight loss, burying, spiracle rate and feeding behaviour) as well as environmental parameters (e.g. dissolved oxygen, salinity, temperature) were followed up on a daily basis. The length of this monitoring period was based on a pilot-study & available literature for rays.	Extra resolution in health evolution of monitored fish in captivity and long monitoring period that was based on a pilot-study	Time-consuming, interrater variability when scoring health parameters of individuals
		Elor Sepp “Overview of a simple survival study of commercial species caught from the Estonian lake	Cages for captive experiment were covering all water column. Released fish (mostly benthic) were able to cope with the pressure shock at their own pace. Forcing the shocked fish back to the original pressure with small cage may have a positive effect (bias) on survival.	More similar to actual recovering process for discards.	Only possible in relatively shallow water,

		Peipsi". See abstract, Appendix 2019			can be expensive. Danger of avian predation
	2018	Hugues P. Benoît, and Marie Morfin "Improved estimation of discard mortality within situ experiments involving electronic and traditional tagging". see full abstract in WGMEDS report 2018	Mark-recapture + telemetry The studied species is haddock based on Capizzano *et al.* 2019 in the New England recreational hook & line fishery. 154 electronic tags and ~2000 conventional tags were deployed. The authors describe a modelling procedure that combines both tagging approaches to better infer the haddock survival rate.	Optimise the cost of the experiment since it lowered the number of acoustic tags needed and increase the cheaper conventional tags. It makes the telemetry results more robust by reducing the confidence interval. Combining both approaches is beneficial when considering two or more groups (e.g. vitality classes).	Conventional tagging requires a tagging platform (e.g. observer program) to ensure enough tag recovery. When minimizing the number of electronic tags, the probability to detect the fish inside the detection area is reduced.
		Morfin, Julien Simon, Fabien Morandeau, Loïc Baulier, Sonia Méhault, and Dorothée Kopp Using acoustic telemetry to estimate post-release survival of undulate ray. see full abstract in WGMEDS report 2018	Active + passive tracking The study was performed in a semi-enclosed bay from the Bay of Biscay. Undulate rays were tagged using telemetry tags externally attached. The animals were monitored for a 3 months period. Survival was assessed based on detections from 15 acoustic receivers deployed in the area and a mobile reception antenna.	High-resolution movement data can be obtained with the active tracking and combining both approaches improves the ability to detect fish, even outside the area covered by the fixed receivers.	Expensive. Needs to buy a mobile directional hydrophone besides the fixed receptors. Time consuming. The active tracking needs researchers to spend a long time at sea following the fish
Tagging	2019	Iñigo Onandia Tagging big boys in Sweden – can RAMP be used to improve tagging	RAMP + electronic tagging	RAMP gives a fast-visual information on fish vitality and injuries.	Not really to estimate a discard survival

		methods of Bluefin tuna? See abstract, Annex 3.	The study was performed in Skagerrak on 6 big bluefins tunas. Reflexes and injuries were assessed as well as recovery techniques to enhance fish ability to bear the air exposure and the tagging process.		but to determine which individuals are the more susceptible to recover from the tagging process.
		Tom Catchpole Skates and rays discard survival evidence. See abstract, Annex 3.	Vitality + DST tags Cefas has performed several studies using DST tags since 2015 on undulate, blonde, cuckoo, small-eyed and thornback ray for otter trawl, longline and trammel nets. Several classes of vitality are considered. A total of 356 DST has been deployed. A decision tree is used to decide whether information obtained from the tag is valid.	High-resolution movement data can be obtained from temperature and depth information. A large geographical area could be covered compared to fixed receptors + acoustic tags. Pop up maximise the chance to find the tag even if the ray is not fished.	Expensive. A quite low percentage of tag recovery.

2.1.2.4 Critically review recent publications

During WGMEDS the critical review method was applied to four recent papers/reports on discard survival of plaice:

1. Kraak, S. B. M., Velasco, A., Fröse, U., & 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*.
2. Schram, E., & Molenaar, P. (2018). Discards survival probabilities of flatfish and rays in North Sea pulse-trawl fisheries (No. C037/18). *Wageningen Marine Research*.
3. Oliver, M., & McHugh, M. (2018). Draft report: plaice survivability in the Irish otter trawl fishery targeting fish species. *BIM.*
4. Randall, P., Santos, A. R., Firmin, C., O'Sullivan, H., White, E., & Catchpole, T. (2017). Assessing the survival of discarded sole (*Solea solea*) in an English inshore trawl fishery. *Annexes to Joint Recommendation of the Scheveningen Group*, 47.

To estimate survival rates, Schram and Molenaar (2018), Oliver and McHugh (2018) and Randall *et al.* (2017) used a combination of vitality assessments and daily monitoring during a period of captive observation. The study of Kraak *et al.* (2018) used a different approach: after testing vitality, fish were kept in cages on the seafloor for a period of 5 to 7 days.

Each of these publications was critically reviewed using the methods developed by WKMEDS (ICES 2015, 2016 a, b & c; Catchpole *et al.*, in review). In summary, each was scored (yes = 1, no = 0) in relation to questions related to the four main components of a typical discard survival study: vitality assessments, captive observation, controls and (statistical) analyses. Some questions (e.g. were controls used?) are scored at a higher rank (yes = 10, no = 0) to account for their importance. Based on this list of scores, a general score was attributed to each study, reflecting its overall quality.

While the four reviewed studies have clearly considered the WKMEDS guidelines, some issues were not always addressed in the manuscript (e.g. was observer bias discussed? Is there a suitable definition of dead?).

These reviews were added to a database of critical reviews created by WKMEDS which was then administered and updated by WGMEDS. The database now includes also studies from recreational fisheries and discard/post-release survival of cod which were searched for as described below.

Identify Relevant Studies & Original Data

This process is now complete. All relevant studies, conducted to date, that have generated discard survival estimates in relevant cod studies have been identified in a literature search.

Stage 1 – literature search

The first stage was a literature search using the scientific citation search engine 'Web of Science'. Web of Science (WoS, previously known as Web of Knowledge). The precise search terms applied are provided in earlier WKMEDS meeting reports. Search terms:

bycatch_mortality_cod

bycatch_mortality_gadus

bycatch_surviv_cod

bycatch_surviv_gadus

discard_mortality_cod

discard_mortality_gadus

discard_surviv_cod

discard_surviv_gadus

discard_vitality_cod

post-release_mortality_cod

post-release_mortality_gadus

post-release_surv_cod

post-release_surv_gadus

All references meeting the search criteria were recorded and those that contained original discard survival estimates were selected and acquired.

A total of ten references were selected with original data on survival of discarded cod. From these, nine are presented below. A full text was requested to the authors in Research Gate. A reference was added that was not found in this search.

Capizzano, CW ; Mandelman, JW ; Hoffman, WS Dean, MJ ; Zemeckis, DR ; Benoit, HP; Kneebone, J ; Jones, E ; Stettner, MJ ; Buchan, NJ ; Langan, JA ; Sulikowski, JA. (2016) Estimating and mitigating the discard mortality of Atlantic cod (Gadus morhua) in the Gulf of Maine recreational rodandreel fishery. ICES Journal of Marine Science, 73(9): 23422355. doi 10.1093/icesjms/

Depestele, J ; Desender, M ; Benoit, HP ; Polet, H ; Vincx, M. Shortterm survival of discarded target fish and nontarget invertebrate species in the "eurocutter" beam trawl fishery of the southern North Sea. Fisheries Research, 154: 8292. doi: 10.1016/j.fishres.2014.01.018

Evans, S. M., Hunter, J. E. and Elizal Wahju, R. 1994. Composition and Fate of the Catch and Bycatch in The FarneDeep (NorthSea) Nephrops Fishery. ICES Journal of Marine Science, 51(2): 155168. Doi: 10.1006/Jmsc.1994.1017

Farrington, M.; Carr, A.; Pol, M. and Szymanski, M. 2002. Selectivity and Survival of Atlantic Cod (Gadus morhua) [and Haddock (Melangrammus aeglefinus)] in the Northwest Atlantic Longline Fishery: Final Report. (2002)

Ferter, K., Hartmann, K., Kleiven, A. R., Moland, E., and Olsen, E. M. 2014. Catch-and-release of Atlantic cod (Gadus morhua): post-release behaviour of acoustically pretagged fish in a natural marine environment. Canadian Journal of Fisheries and Aquatic Sciences, 72(2): 252-261.

Ferter, K., Weltersbach, M. S., Humborstad, O. B., Fjelldal, P. G., Sambraus, F., Strehlow, H. V., and Vølstad, J. H. 2015. Dive to survive effects of capture depth on barotrauma and post-release survival of Atlantic cod (Gadus morhua) in recreational fisheries. ICES Journal of Marine Science, 72(8): 2467-2481.

Palsson, OK ; Einarsson, HA ; Bjornsson, H. 2003. Survival experiments of undersized cod in a handline fishery at Iceland. Fisheries Research 61(13): 7386.

Weltersbach, M.S., and Strehlow, H. 2013. Dead or alive - estimating postrelease mortality of Atlantic cod in the recreational fishery. ICES Journal of Marine Science, 70(4): 864872. Doi: 10.1093/icesms/fst038

Mandelman, J.; Capizzano, C.; Hoffman W.; Dean, M; Zemeckis, D.; Stettner, Marc; Sulikowski, J. (2014). Elucidating post-release mortality and "best capture and handling" methods in sublegal Atlantic cod discarded in Gulf of Maine recreational hook-and-line fisheries. BREP 1 (2014), pp. 43-51.

Further references added by Keno Ferter:

Benoît, H. P., Hurlbut, T., Chassé, J. & Jonsen, I. D. 2012. Estimating fishery-scale rates of discard mortality using conditional reasoning. Fisheries Research, 125-126, 318-330.-

Humborstad, O., Davis, M. & Løkkeborg, S. 2009. Reflex impairment as a measure of vitality and survival potential of Atlantic cod (Gadus morhua). Fishery Bulletin, 107, 395-402.

Milliken, H. O., Carr, H. A., Farrington, M. and Lent, E. 1999. Survival of Atlantic cod (Gadus morhua) in the Northwest Atlantic longline fishery. Marine Technology Society Journal, 33, 19-24.

Milliken, H. O., Farrington, M., Rudolph, T. and Sanderson, M. 2009. Survival of discarded sublegal Atlantic cod in the Northwest Atlantic demersal longline fishery. North American Journal of Fisheries Management, 29, 985-995.

Neat, F., Breen, M., Cook, R., Gibb, I. and Wright, P. 2009. Electronic tags reveal behaviour of captured and discarded fish. Journal of Fish Biology, 74: 715-721.

2.2 ToR b) Meta-analysis of discard survival data to identify variables influencing and potentially increasing survival

Response to this ToR includes three tasks:

1) Principally during the WGMEDS meetings, the development and application of a statistical approach to assess factors effecting the discard survival of Nephrops.
2) Reviewing reports from national research programmes which identified factors influencing survival and exploring analytical methods that were used to do so.
3) Identifying examples of studies experimenting with adapted fishing operations designed to increase survival.

2.2.1 Meta-analysis of Nephrops survival projects

Meta-analysis is a statistical technique to summarize the numerical results of a range of different studies and produce a summary statistic (with confidence intervals), which can be used as a means to compare the effect of discarding compared with a baseline (or control). Continuing the work of WKMEDS (ICES 2015, 2016a, b & c), WGMEDS has attempted to use this approach to address key research questions for the three case-studies Norway lobster (*Nephrops norvegicus*), plaice (*Pleuronectes platessa*) and sole (*Solea solea*) in European trawl fisheries. These cases were considered by WKMEDS to be informative examples with respect to the Landing Obligation, as well as having sufficient data (historic and emerging) to be viable examples for meta-analysis (ICES, 2015).

Primary research questions were:

- What is the discard survival (and variability) of *Nephrops norvegicus* in European trawl fisheries?
- What is the discard survival (and variability) of plaice (*Pleuronectes platessa*) and sole (*Solea solea*) in European trawl fisheries?

Secondary research questions that has been added (ICES, 2020):

- Is the survival 'high' enough for a particular species in a particular scenario?
- What is the effect of covariate X (e.g. species/taxa, gear type, season, handling processes...) on survival?

- What is the effect size (and variability) of experimental factors (e.g. cage study vs. tagging study, monitoring period) on survival?
- How consistent is an effect on survival across the studies applicable to a particular scenario?

Prior to the actual meta-analysis, a methodology outlining the criteria for including available discard survival estimates as well as for how to conduct the meta-analysis needed to be established. A critical review of survival assessment methods as described in the Cooperative Research Report developed in WKMEDS has been conducted to assign each survival estimate an overall quality score, which can be included in further meta-analysis of the data and enable comparisons across studies (T. Catchpole et al; unpubl. data). The data associated with each study has been extracted, for example, information on the fishery, the scale of the work, the design of the experiments, and the data from which the survival estimates have been derived. For studies that cannot demonstrate asymptotic survival estimates, this has been estimated.

Nine studies were included in the meta-analysis (Table 2.3). To ensure that a fair comparison was being made between different studies using an appropriate model, a four-step approach has been adopted by WGMEDS to conduct the meta-analysis (see ICES, 2018 for more details):

4) Data from longitudinal studies were modelled collectively to provide a generalized survival function for the species/fishery-specific data.
5) Asymptotic survival estimates were then projected for all studies using the model parameters estimated in step 1.
6) Preliminary analysis was conducted to validate the input data and identify potential explanatory variables. Where there was sufficient data for inclusion in a meta-analysis, input data included a description of each treatment that was included in the meta-analysis regarding area, gear characteristics, operational and environmental factors, and number of observations:

    - treatment identification (new study reference) as 'Treatment',
    - gear type (OTT or TBN) as 'Type',
    - gear rigging (single or twin trawl) as 'Rig.',
    - mesh size in mm (mesh shape, with D for diamond and S for square) as 'Mesh',
    - modified gear if present (SELTRA trawl, GRID, chute or standard) as 'Modif.',
    - mean air exposure in hour,
    - mean individual carapace length in cm,
    - mean tow duration in hour,
    - depth in meters,
    - catch weight in kg,
    - season,
    - air temperature in °C as 'Tair',
    - surface water temperature in °C as 'Tsurface',
    - bottom water temperature in °C as 'Tbottom',
    - number of observations (N).

Operational and environmental factors were given as mean (min-max) when appropriate.

Table 2.3. List of documents on *Nephrops* survival studies analysing the effect of explanatory variables and included in the meta-analysis during WGMEDS 2018.

Reference type	Reference	Species	Gear	Explanatory variables
Report	Willeman et al., 1999	*Nephrops norvegicus*	Bottom trawl	Mesh size
Paper	Castro et al., 2003	*Nephrops norvegicus*	Bottom trawl	Season
Paper	Ridgway et al., 2006	*Nephrops norvegicus*	Bottom trawl	Haul duration, season
Report	Nielsen, 2015	*Nephrops norvegicus*	Bottom trawl	NA
Working document	Valentinsson and Nilsson, 2015	*Nephrops norvegicus*	Bottom trawl	Type of gear, mesh size, season
Paper	Albalat et al., 2016	*Nephrops norvegicus*	Bottom trawl	Season
Report	Amstrong et al., 2016	*Nephrops norvegicus*	Bottom trawl	NA
Report	Oliver et al., 2017	*Nephrops norvegicus*	Bottom trawl	NA
Paper	Merillet et al, 2018	*Nephrops norvegicus*	Bottom trawl	Discarding system, season

The scientific community agrees that the variability observed in discard estimates is driven by the variability in both external stressors and individual characteristics and sensitivities, and especially (ICES, 2014; ICES, 2020):

- Operational factors: gear type and configuration, haul duration, and catch handling including air exposure durations;
- Environmental factors: water temperature and depth;
- Biological factors: body size and physical injury.

The operational, biological and environmental conditions will depend on the fishery investigated and the purpose of the experiment in the individual research projects. The chosen explanatory variables were those identified as relevant, by this working group, and that best describe the different conditions of each experimental treatment to avoid confounding factors and for which there was information across all studies:

- haul duration
- catch weight
- air exposure
- sea surface temperature (SST)
- depth and carapace length (CL)

For this analysis, it was considered realistic that differences in fishing practices (i.e., gear characteristics and handling techniques) are reflected by the catch weight and air exposure duration, respectively – and also by using treatment as a random effect, see below. So far, it has not been possible to find information on catch weight for one of the studies (Castro *et al.*, 2003). Thus, the analysis includes all chosen explanatory variables, but omits data from Castro *et al.* (2003).

Conduct a final meta-analysis by fitting a weighted Beta Generalised Linear Mixed Model (Beta GLMM) to the validated data, and the choice of random effects was made a priori based on the structure of the data, at both the study and treatment levels (ICES, 2020).

Table 2.4. Description of the different treatments included in the meta-analysis by area and study: gear and rigging (OTB for Otter Bottom Trawls with single rig and OTT for Otter Twin Trawls), codend mesh size in mm and shape with D for diamond and S for square, practice type e.g. the presence of selective devices, presence or absence of a sorting system ('Sort. syst.'), season, and the total number of hauls observed *n*.

Treatment	Gear	Mesh	Practice	Sort. syst.	Season	*n*
North Sea region						
Armstrong et al., 2016						
North_Sea_Grid_Winter	OTB	80-85	Netgrid	Yes	Winter	12
Nielsen, 2015						
Skagerrak_Panel_Summer	OTB	-	Large mesh in top panel	Yes	Summer	7
Valentinsson and Nilsson, 2015						
Skagerrak_SELTRA_Summer	OTT	90D	SELTRA	Yes	Summer	3
Skagerrak_SELTRA_Winter	OTT	90D	SELTRA	Yes	Winter	3
Skagerrak_Grid_Summer	OTT	70S	Swedish grid	Yes	Summer	3
Skagerrak_Grid_Winter	OTT	70S	Swedish grid	Yes	Winter	3
North Western Waters						
Oliver et al., 2017						
Aran_SELTRA_Summer	OTB	80	SELTRA	Yes	Summer	6
Albalat et al., 2016						
Clyde_Short_Spring_(Albalat)	OTB	85D	Short haul duration	Yes	Spring	3
Clyde_Short_Summer_(Albalat)	OTB	85D	Short haul duration	Yes	Summer	3
Clyde_Short_Winter_(Albalat)	OTB	85D	Short haul duration	Yes	Winter	2
Ridgway et al., 2006						
Clyde_Long_Autumn_(Ridgway)	OTB	-	Long haul (standard)	Yes	Autumn	2
Clyde_Short_Autumn_(Ridgway)	OTB	-	Short haul duration	Yes	Autumn	2
Clyde_Long_Spring_(Ridgway)	OTB	-	Long haul (standard)	Yes	Spring	2
Clyde_Short_Spring_(Ridgway)	OTB	-	Short haul duration	Yes	Spring	2
Wileman et al., 1999						
Minch_100Diamond_Summer	OTB	100D	Standard	Yes	Summer	3
Minch_60Square_Summer	OTB	60S	Standard	Yes	Summer	3
Minch_70Diamond_Summer	OTB	70D	Standard	Yes	Summer	3
South Western Waters						
Castro et al., 2003						
Algarve_Standard_Autumn	OTB	-	Standard	Yes	Autumn	3
Algarve_Standard_Spring	OTB	-	Standard	Yes	Spring	3
Algarve_Standard_Summer	OTB	-	Standard	Yes	Summer	3
Algarve_Standard_Winter	OTB	-	Standard	Yes	Winter	3
Merillet et al., 2018						
Biscay_Chute_Autumn	OTT*	80 D	Discarding chute system	Yes	Autumn	6
Biscay_Chute_Spring	OTT*	80 D	Discarding chute system	Yes	Spring	3
Biscay_Chute_Summer	OTT*	80 D	Discarding chute system	Yes	Summer	6
Biscay_Standard_Autumn	OTT*	80 D	Standard	No	Autumn	5
Biscay_Standard_Spring	OTT*	80 D	Standard	No	Spring	3
Biscay_Standard_Summer	OTT*	80 D	Standard	No	Summer	6

*With mandatory 100mm top square mesh panel

Data for the meta-analysis were collected at the haul level when possible. However, the original data were collected in the specific context of each case study, and therefore based on different sampling schemes. When information on the explanatory variables was not available in the original research article or report at the haul level specified procedures were followed (ICES, 2020). To conduct a weighted Beta GLMM, members of WGMEDS have collaborated with the developers of the R package *glmmTMB*, to further develop the package to incorporate a weighting factor that utilised the SA standard errors and quality scores from the systematic review of the data. This adapted package was successfully tested using some sample data (ICES, 2018a). *glmmTMB* can incorporate beta distributions and fixed and random effects models can be specified, as well as fixed effects for the dispersion parameter. Several challenges were identified and addressed before the application of the Beta GLMM (ICES, 2020):

- Both inclusion and exclusion of random effects could lead to biased results. As departure from some of the assumptions when including the random effects cannot be easily tested for, it was decided to keep the mixed structure of the model, but to keep the limitation in mind when interpreting the results.
- Even though explanatory variables were carefully chosen to limit confounding factors, some covariates are nevertheless confounded with study/area/season (Figure 2.1). The inclusion of the treatment and study random effects, to account for the hierarchical structure of the data, should account for any variance associated with these confounded effects. The model residuals (i.e. quantile residuals) was checked to ensure there was no unexplained structure.
- To account for differences in standard error (precision) of the asymptotic survival estimate for each observation in the GLMM, it was chosen to use the precision parameter in Beta glmmTMB algorithm. This is inversely proportional to the response variance and can be modelled using a log linear predictor composed of fixed effects.

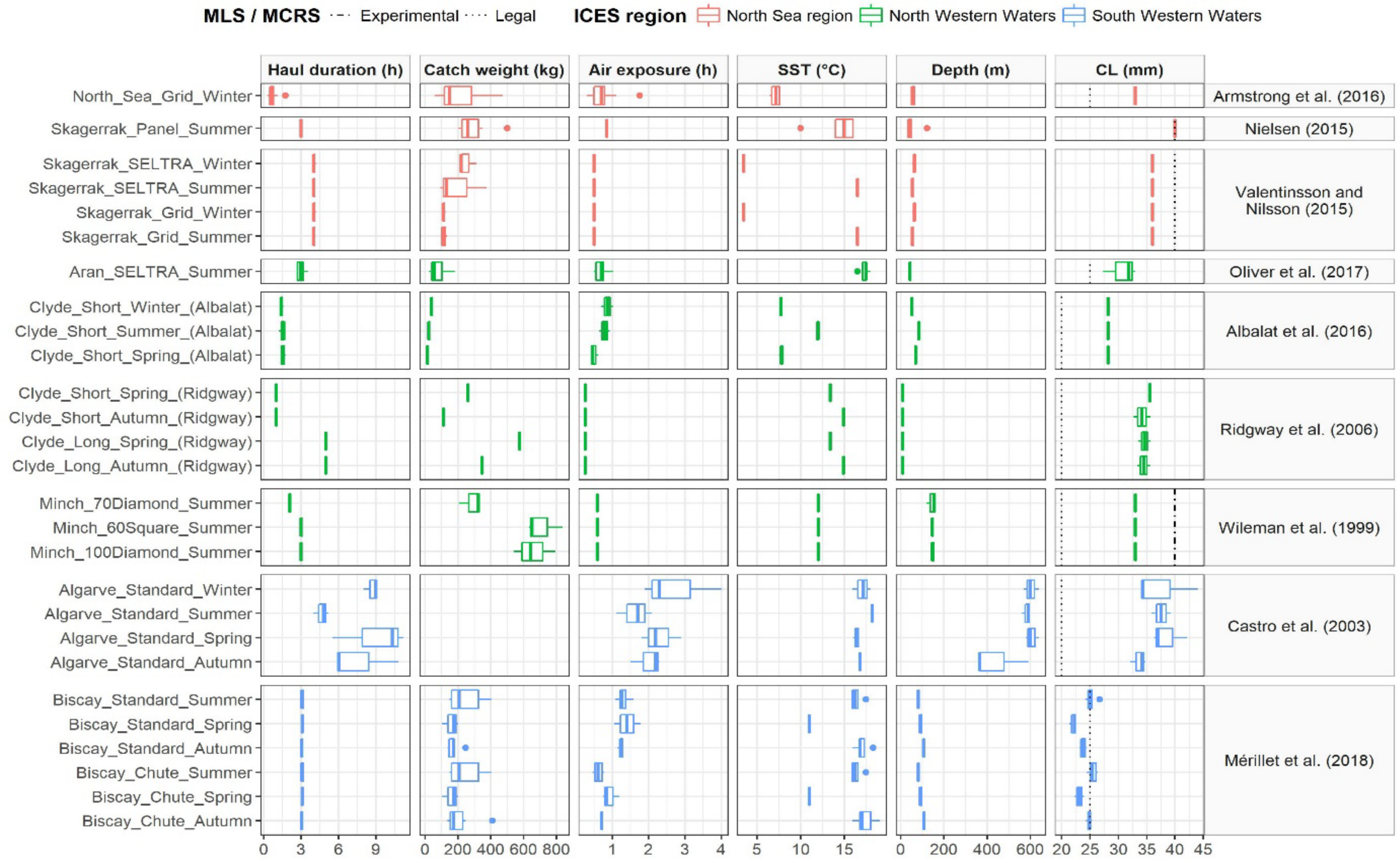


Figure 2.1. Boxplots of the included covariates by study (right) and treatment (left).

Inclusion of other measures of uncertainty and/or data quality in the meta-analysis was evaluated. Q-scores are generated as part of the critical review and is a quantified summary of the "quality" of a particular study, with respect to several qualifying criteria as judged by two or more reviewers (ICES 2017 & 2018; Catchpole *et al.*, in preparation). It was decided to exclude Q-score as a weighting factor, because it had strongly influenced the selection of the studies to be included in the meta-analysis, and the criteria related to the projection at asymptote of survival estimates, were already partly included as a precision parameter (i.e., the standard error of the asymptotic survival estimate).

The control mortality/survival is a potentially informative measure of the uncertainty associated with survival estimates from respective studies. That is, the higher the control mortality within a particular study the greater the uncertainty in the accuracy of the observed treatment survival, with respect to being representative of "true" discard related mortality. Indeed, examination of the relationship of the control survival and treatment survival estimates for *Nephrops* revealed that captivity/control related mortality can potentially cap the observable scope of survival within the treatments (Figure 2.2).

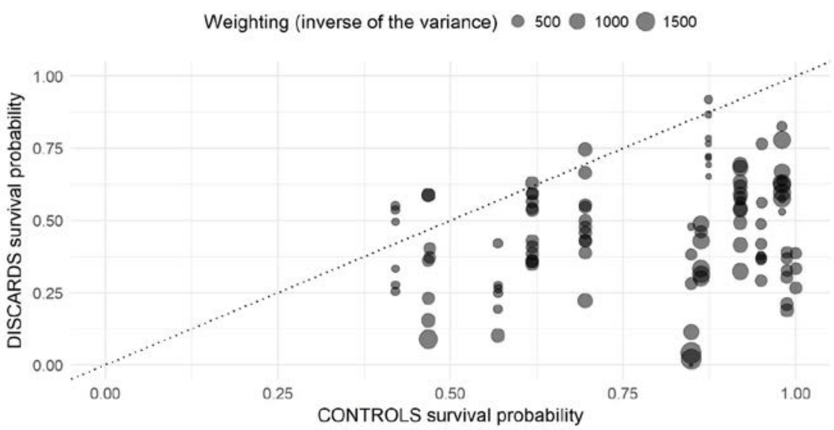


Figure 2.2. Relationship between the asymptotic discard survival estimates (experimental treatments) and the control survival probabilities. The dotted line with intercept 0 is showing how captivity/control related mortality can potentially cap the observable scope of survival in the treatments.

For utilizing the control survival estimates in the meta-analysis (Figure 2.3), the response variable (asymptotic survival) was transformed with respect to control survival. Taking the ratio to the asymptotic survival (S^) and control survival (C) (and limiting values to < 1) will directly account for the bias and capping observed in the *Nephrops* data. This assumes that experimental mortality can be no higher than control mortality, if the control is properly representative of experimental/captivity induced mortality (i.e., the stressors imposed on the controls are a complete subset of the stressors experienced by the treatments cases). It also assumes that the relationship between S^ and C is directly proportional.

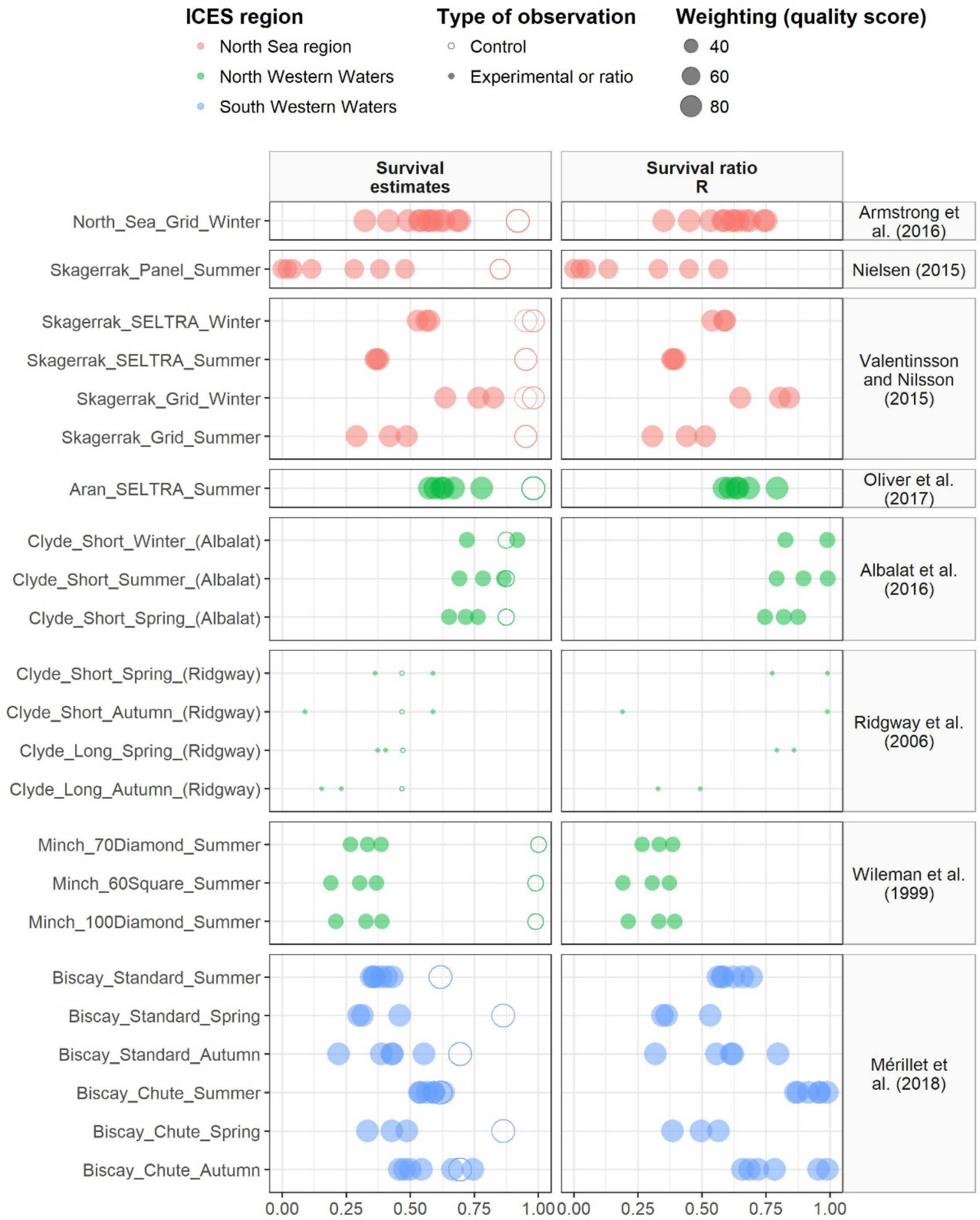


Figure 2.3. Experimental discard and control survival estimates (predicted at asymptote), and survival ratio R (between discard and control survival estimates), by area, study and treatment, weighted by the critical review quality score (one score per study).

Plan for *Nephrops* meta-analysis completion:

- For the random effect, a constant study and treatment will be tested, as well as an interaction between the study and the CL to handle a potential confounding effect of the sorting practices between studies.
- For the fixed regression part, all the combinations of potential covariates (Catch weight, Depth, CL, Air exposure and SST) will be tested, as well as the interactions: Catch weight*Depth, CL*Depth and STT*Air exposure.
- To avoid the problem of the determination of the degrees of freedom for the AIC for mixed models, we will use a leave-one-out cross-validation procedure to select a best model.
- The predictive performance of the model will also be assessed without accounting for the nested structure of the data (i.e. only based on the explanatory factors) to evaluate to what extent it is possible to predict survival for an independent study.

COPE-project

The work with the meta-analysis, including the methodology, was partly funded by the Ministry of Environment and Food of Denmark and the European Union through the European Maritime and Fisheries Fund (EMFF) under the project COPE (grant no. 33113-B-16-086). The project includes the investigation of whether a meta-analysis of flatfish discard survival from different studies applicable to the fishing conditions in Danish waters would be realistic to conduct (i.e. if there is enough good quality data available) and relevant in terms of management. To do so, the methodological considerations as to how to conduct a meta-analysis with discard survival data at a large scale is highly relevant. Thus, the collaboration between WGMEDS and the COPE-project has been mutually beneficial.

Flatfish dataset

New information about flatfish discard survival estimates, have been obtained by an overall search in google scholar and research gate to identify recently published articles (ICES 2018b). Search terms used included flatfish, sole, plaice, discard, discards, survival, trawling, fishery, fisheries; and combinations of these. Also, background documents that support the Joint Recommendations of STECF regarding the Landing Obligation have been reviewed.

Four out of 14 new documents were critically reviewed using the methods developed by WKMEDS (ICES 2015, 2016 a, b & c; Catchpole *et al.*, in review):

1. Kraak, S. B. M., Velasco, A., Fröse, U., & 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.
2. Schram, E., & Molenaar, P. (2018). Discards survival probabilities of flatfish and rays in North Sea pulse-trawl fisheries (No. C037/18). Wageningen Marine Research.
3. Oliver, M., & McHugh, M. (2018). Draft report: plaice survivability in the Irish otter trawl fishery targeting fish species. BIM.
4. Randall, P., Santos, A. R., Firmin, C., O'Sullivan, H., White, E., & Catchpole, T. (2017). Assessing the survival of discarded sole (*Solea solea*) in an English in-shore trawl fishery. Annexes to Joint Recommendation of the Scheveningen Group, 47.

The flatfish data have been comprehensively checked and formatted according to the protocol described in ICES, 2016.

2.2.2 Review reports identifying variables influencing discard survival

During the first term of WGMEDS and preceding WKMEDS, due to the likely variability in precision and accuracy of published discard survival estimates, a critical review of survival assessment methods has been conducted to determine the quality of the estimates and to assign a quality score (see more details in section for ToR a)). Following, the group conducted a literature review focused on those studies that could potentially be used for a meta-analysis, and one of the key issues was to evaluate what are the explanatory variables influencing survival probabilities. During the previous meetings, studies to be incorporated in the meta-analysis were listed for *Nephrops* (Table 2.1) and flatfish (Table 2.5). During 2019 meeting, an update of flatfish studies was conducted along with a new review of the survival studies on skates and rays (Table 2.6).

Although a meta-analysis was not yet conducted for skates and rays by WGMEDS, the description of the potential effects of explanatory variables on the survival of that group of species was conducted and summarized in this report. Additionally, during this meeting and under this ToR a review of the studies aiming to increase discard survival trough modified fishing practices. Both findings on the effects affecting survival using skates and rays as an example and on modified fishing practices can help to inform fisheries managers of the appropriateness of proposals to gain exemption from the Landing Obligation under the high survivability provision in European Regional Discard Plans (Alves *et al.*, 2019). These features also have wider application in developing best practice for fishing operations and therefore increase the survival chances of discarded fish.

To note that not all documents considered in the critical review will be included in the meta-analysis (i.e. different fisheries, other study species) but most can be used as sources of additional information about similar species and methodologies. The meta-analysis on *Nephrops* was already conducted in previous meetings (ICES, 2018b) and the main findings will be described below in this chapter. The meta-analysis for the remaining two groups of species is still to be done, which could be one the aims of future WGMEDS meetings.

Based on the listed studies, several factors were identified as influencing discard survival, which could be classified into three groups:

a) **Operational factors**: gear type and configuration, haul duration, total catch weight, and catch handling/sort time, including air exposure durations.
b) **Environmental factors**: air and water temperature, season, depth, wave features (height and period), wind (speed and direction) and avian predation.
c) **Biological factors**: body size and physical injury.

2.2.3 Examples of studies investigating variables influencing survival probabilities of skate and ray species

During WGMEDS 2019, a compilation of recent studies investigating variables influencing survival probabilities of skate and ray species were compiled (Table 2.6). Morfin *et al.* (2017) investigated the variables affecting the time-to-mortality (TTM) of a set of species, including for skates and rays (not discriminated by species) in the Bay of Biscay and in the Eastern Channel. TTM studies are good to identify candidate species for further discard survival studies but also provides some guidelines to the preferred maximum time that fishermen have to sort the fish and to release the ones to be discarded in good health conditions. Two studies on analysing the effects of explanatory variables (abiotic, operational and biological) on the survival of discarded skates by-caught in North Sea pulse- trawl fisheries were also considered for this Tor (Schram and Molenaar. 2018; Schram *et al.*, 2019). Cefas analysed the information collated under the ASSIST project (Bird *et al.*, 2018) to investigate 11 Cefas projects conducted between 2007 and 2018 from fisheries around England and Wales and try to link the health condition of discarded skates and rays with associated technical conditions and biological characteristics (Alves *et al.*, 2019). The results obtained inform on measures to improve the survival chances of discarded ray and assess the appropriateness of extrapolating survival estimates across different fisheries. The analysed projects covered a total of 13 skate and ray species, 3 fishing gears from 6 fishing areas (Table 2.6). A Portuguese report (Serra-Pereira *et al.*, 2019) summarized the results obtained from two projects during which vitality status of five different species of skates and rays caught by trammel net were analysed according to different factors.

In summary, and from the analysis of the abovementioned studies, for skates and rays the main factors influencing the health status or immediate mortality and therefore their survival were: a) operational factors, such as gear type, haul duration, air exposure, b) environmental factors, such as fishing depth and c) biological factors, such as fish length, species. Following the effects of such variables are summarized in more detail:

a) Operational factors
    1. The **type of gear** is correlated with the size of the fish caught, where survival may be higher in static and longline gears: otter trawls catch more smaller fish that are generally in poor health conditions, while static gears and longline gears catch larger fish and in better condition (Alves *et al.*, 2019);
    2. Gear characteristics, like **mesh size** of set nets, may also affect the health status in some species (e.g. spotted ray), being the fish in better condition when captured by small mesh sizes (Serra-Pereira *et al.*, 2019).
    3. **Haul duration** had different effects on fish vigour depending on the type of fishing gear used (Alves *et al.*, 2019):
        i. Decreasing survival with increasing fishing time in otter trawls (e.g. thornback ray) (Alves *et al.*, 2019).
        ii. Better health condition with increasing fishing time for longline and static net gears. This may be related to the fishing process of static gears, in which the time skates are subject to the stressors may not relate to the total fishing time, and therefore haul duration is a less relevant variable for these gears (Alves *et al.*, 2019). This can also be concluded based on the fact that depending on the species, and for the same type of set nets, the haul duration may have a negative effect, as in longer haul durations the health condition seems to decrease, while in others to increase (Serra-Pereira *et al.*, 2019).
    4. Longer **air exposure** causes a decreased survival, but a higher variability in TTM is observed among skates than in other fish species, generally having a stronger capacity to resist hypoxia (Morfin *et al.*, 2017).

b) Environmental factors:
    1. Increasing **depth** is associated with an increase in health condition and in TTM but may be linked to the presence of larger fish in deeper waters and juveniles in shallower waters (Morfin *et al.*, 2017; Alves *et al.*, 2019).
    2. **Air temperature** showed a significant negative effect on the TTM of skates caught by trawl fisheries but not in all regions analysed (Morfin *et al.* 2017).

c) Biological factors
    1. **Fish length** has a strongest relationship with health status (Alves *et al.* 2019): higher proportion of fish assessed to be in good health condition for larger skates. Hence, introducing more selective fishing methods that avoid the capture of smaller skates will likely allow for a higher survival of the subsequent unwanted catch.
    2. As different skate **species** can have differing maximum sizes, the larger bodied species (e.g. undulate ray, blonde ray and thornback ray) are related with higher survival, than smaller bodied species (e.g. spotted ray and cuckoo ray) (Alves *et al.* 2019).

It is important to highlight that the observed effect of the selected variables in skate and ray health condition may be confounded with covariates that were not recorded and analysed in the presented studies. Also, additional unrecorded explanatory factors such as environmental variables, including weather and sea conditions, and also catch composition and sorting method, are likely also to have effect on the health status and consequently on the survivability of the discarded specimens (Alves *et al.* 2019). WGMEDS encourages the analysis for the effect of as many explanatory variables as possible when studying the survival of a species, in order to allow for a better understanding of those affecting the condition of discarded fish and the chances of survival.

Table 2.5. List of documents on flatfish survival analysing the effect of explanatory variables and reviewed in WGMEDS 2018 and updated with new studies in 2019.

Reference type	Reference	Species	Gear	Survival	Explanatory variables
Article	Sparrevohn and Stottrup. 2007	Turbot (*Psetta maxima*)	Flatfish-trawl	34 – 66%	Fish length
Report	Hasbrouck et al. 2012	Summer flounder (*Paralichthys dentatus*)	Bottom trawl	6 – 35%	Sorting time, haul duration, total catch weight, air temperature
Article	Viva et al. 2015	Four-spot megrim (*Lepidorhombus boscii*), Sole (*Solea solea*)	Otter trawl	Proxy (vitality)	
Article	Morfin et al. 2017	European plaice (*Pleuronectes platessa*)	Otter trawl	Proxy (TM)	Air temperature, fish length, tow depth, two duration
Communication/Note	DTU Aqua. 2017	European plaice (*Pleuronectes platessa*)	Danish seine	67 – 87%	Air exposure, fish length, bottom temperature, sorting time
Report	Randall et al. 2017	Sole (*Solea solea*)	Trawl	79 – 89%	Trial seasons, fish length, avian predation, RAMP, injuries
Communication/Note	SLU-Aqua. 2017.	Dab (*Limanda limanda*)	Creel	33%	Avian predation
Communication/Note	Ern. et al. 2018	European plaice (*Pleuronectes platessa*)	Set net (trammel net)	100%	Fish length, RAMP, injuries
Communication/Note	Noack et al. 2018	European plaice (*Pleuronectes platessa*)	Otter bottom trawl	41 – 75%	Fish length, haul duration, catch weight, bottom temperature
Article	Tsagarakis et al. 2018	Spotted flounder (*Citharus linguatula*), Scaldfish (*Arnoglossus* sp.), Four-spot megrim (*Lepidorhombus boscii*)	Bottom trawl	0%	Fishing depth, haul duration, total catch, water temperature
Report	Schram and Molenaar. 2018	Plaice (*Pleuronectes platessa*), Sole (*Solea solea*), Turbot (*Scophthalmus maximus*), Brill (*Scophthalmus rhombus*)	Pulse-trawl	13 – 30%	Species, Catch-processing time
Report	Molenaar and Schram. 2018	Plaice (Pleuronectes platessa), Sole (Solea solea)	Pulse-trawl	5-20%	Improvements catch handing and fishing practices
Report	Oliver et al. 2018	European plaice (*Pleuronectes platessa*)	Otter trawl	39%	
Article	Adão et al. 2018	Four-spot megrim (*Lepidorhombus boscii*)	Bottom trawl	Proxy (TM)	Injuries
Article	Kraak et al. 2018	Plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*), dab (*Limanda limanda*)	Demersal trawl	0 - 100%	Air and water temperature, total catch
Report	Schram et al. 2019	Plaice (*Pleuronectes platessa*), Sole (*Solea solea*), Turbot (*Scophthalmus maximus*), Brill (*Scophthalmus rhombus*)	Pulse-trawl	expl. variables	Temperature, bottom type, total catch, wave hight, wind speed, catch processing time, water in hopper & interactions

Table 2.6. List of new documents compiled in WGMEDS 2019 on skate and ray survival studies analysing explanatory variables.

Reference type	Reference	Species/Family	Gear	Method(s)	Explanatory variables
Paper	Morfin et al. 2017	Rajidae	Bottom trawl	Time to mortality	Air temperature, fish length, depth, haul duration
Report	Schram and Molenaar. 2018	*Raja clavata, Raja montagui*	Pulse-trawl		Species, Catch-processing time
Report	Schram et al. 2019	*Raja clavata*	Pulse-trawl		Temperature, bottom type
Project/Report	By-watch 1 (Alves et al. 2019)	*Raja brachyura, Raja montagui, Raja clavata*	Longline, Otter Trawl, Static Net	vitality assessment	Gear, haul duration, species, fish length
Project/Report	By-watch 2 (Alves et al. 2019)	*Raja clavata*	Longline, Otter Trawl, Static Net	vitality assessment	Gear, depth, haul duration, fish length
Project/Report	C18270 (Alves et al. 2019)	*Raja brachyura, Raja microcellata, Raja montagui, Raja clavata*	Otter Trawl	vitality assessment	Depth, haul duration, fish length
Project/Report	C5979A (Alves et al. 2019)	*Raja clavata*	Static Net	vitality assessment	Depth, haul duration, fish length
Project/Report	C5979Y (Alves et al. 2019)	*Raja clavata*	Otter Trawl	vitality assessment	Depth, haul duration, fish length
Project/Report	C5979Z (Alves et al. 2019)	*Raja undulata*	Otter Trawl	vitality assessment	Depth, haul duration
Project/Report	Enever 2010 (Alves et al. 2019)	*Raja brachyura, Leucoraja naevus, Raja microcellata, Raja montagui, Raja clavata*	Otter Trawl	vitality assessment	Depth, haul duration, species, fish length
Project/Report	MB5202 (Alves et al. 2019)	*Raja brachyura, Raja microcellata, Raja montagui, Dasyatis pastinaca, Raja clavata, Raja undulata*	Longline, Otter Trawl, Static Net	vitality assessment	Gear, depth, haul duration, species, fish length
Project/Report	MF052 (Alves et al. 2019)	*Raja brachyura, Raja montagui, Raja clavata*	Longline	vitality assessment	Depth, haul duration, species, fish length
Project/Report	MF1234 (Alves et al. 2019)	*Raja clavata*	Static Net	vitality assessment	Haul duration, fish length
Project/Report	Thames FSP (Alves et al. 2019)	*Raja brachyura, Raja montagui, Raja clavata*	Longline, Otter Trawl, Static Net	vitality assessment	Gear, depth, haul duration, species, fish length
Report	Serra-Pereira et al., 2019	*Raja clavata, Raja brachyura, Raja microcellata, Raja montagui, Raja undulata, Leucoraja naevus*	Static Net (trammel nets)	vitality assessment	Mesh size, haul duration, fish length

2.2.4 Identify examples fishing adaptations to increase discard survival

Relative to the number of studies on estimating discard survival there is limited reported research on trialling adapted fishing methods to increase discard survival. There are several examples of discard survival studies using short-tow hauls to capture samples that can be used as controls in captive observation studies. These are monitored alongside treatment samples collected from representative fishing operations and generally show high levels of survival, indicating that tow duration is an important factor. There are also examples of improvements to selectivity associated with better health condition of discarded fish and other modifications to the catch and sorting practices on-board vessels increasing survival changes of discards. Here we described selected examples, of selectivity measures and catch and sorting modifications that have tested to increase survival of discards.

The work of Pieke Molenaar, and Edward Schram was presented at WGMEDS on discard survival for of undersized plaice (*Pleuronectus platessa*), sole (*Solea solea*), turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*), thornback ray (*Raya clavata*) and spotted ray (*Raya montagui*) caught with commercial 80 mm pulse trawl operating in the southern North Sea flatfish fishery. The captive observation method was applied with a monitoring period of 15–18 days. In all species tested, discard survival was strongly correlated with fish condition, with large differences in survival probability between fish in best and worst condition. Therefore, adaptations to the fishing operation were explored aimed at improving the health condition of discarded fish. Catch-processing time was assessed to have no effect on fish condition nor discards survival, so measures focussed on the capture process rather than catch processing. Measures to increase discard survival in the 80 mm pulse-trawl fisheries were assessed under commercial fishing conditions for plaice (*Pleuronectes platessa*).

The measures tested were a water filled hopper (8 sea trips), short hauls (90 instead of 120 min, 4 sea trips) and a knotless cod-end (1 sea trip) with undersized plaice. For all sea trips combined, no effect of short (90 instead of 120 min) hauls on discards survival probability could be detected: survival probabilities for plaice discards were equal at 11% (95% CI 8–15%) for both short and conventional hauls. No effect of a knotless cod-end on plaice and sole discards survival probability could be detected. Deployment of a water filled hopper does not result in higher survival probability for plaice discards than a conventional dry hopper in year-round pulse-trawl fisheries. However, it is clear that for individual trips the deployment of a water filled hopper can result in an increase of survival chances of discarded plaice, but as it seems only under certain specific, yet to be established, conditions.

The next phase of experiments to increase the survival of discards was to test an innovative cod-end concept, the Kiwi cod-end was tested in this fishery. In this concept the netting of the cod-end is replaced by a canvas tube shaped cod-end with specialized openings in the front aft and no openings in the section where the catch aggregate. This concept reduces the waterflow and turbulence in the cod-end and reduces injuries of both marketable catch and discards. First trials show reduced injury rates for discards from in the innovative cod-end, indicating better survival (Molenaar *et al.*, 2019). Further improvements are essential to achieve equal catch efficiencies as conventional cod-ends.

Enever *et al.* (2010) showed the survival of fish discarded after being caught can be improved by simple gear-based technical measures aimed at reducing discards. The effects of three different cod ends on the initial health and short-term survival of trawl-caught skate (Rajidae), using a control cod end (80mm diamond mesh used as standard in the fishery) and two experimental cod ends (100mm diamond mesh and 100mm diamond mesh turned on the square) were explored. Both experimental nets reduced discarded numbers of fish by ~70%, with no commercial loss. This reduction in discards had an effect in reducing the total weight of the experimental cod ends by as much as 80%. 278 rays were placed in on-board holding tanks for 48h and evaluated the survival rates of fish caught in the different cod ends. Visual inspection of "health" at time zero was a good indicator of survival, because 86% of skate with a good health score survived. From a further 1539 skate assessed for health, it was shown that fish caught in the control cod end have the lowest proportional good health score (25%), followed by the 100 mm diamond mesh cod end (34%) and the 100 mm square mesh cod end (47%). The health of the fish caught is related to cod end weight. It was concluded that technical measures aimed at reducing discards can indirectly increase discard survival.

Mérillet *et al.* (2018) conducted a study to obtain a reliable value for survival rate (after a 14-day monitoring period in onshore tanks). The study also tested the effect on the survival rate of using a discarding chute system, a sorting device that was made mandatory on the 1st of January 2017 for *Nephrops* trawlers in the Bay of Biscay. This device is joined to the sorting table and makes it possible to discard individuals back to the sea throughout the on-board sorting process. This minimises the duration of air exposure as well as the possibility of being injured during the time spent on the deck, compared with the standard sorting practice that consisted in discarding *Nephrops* back to the sea at the end of the sorting process. This device led to an increased average survival rate (51.2%) compared with the standard sorting practice (36.9%). The impact of biological, environmental and fishing operation related variables on survival from the first day of captivity to the end of the monitoring period was examined. The results indicated that injuries, season and duration of the air exposure, significantly influence the survival from the 1st day of captivity to the end of the monitoring period. The survival rate was higher for non-injured *Nephrops* as well as for *Nephrops* that have undergone short air exposure, in summer and autumn.

The release of unwanted fish from purse seines whilst still in the water is termed slipping and may lead to significant mortality following release. Anders *et al.* (2019a) conducted a study to determine the fish welfare implications of a new slipping methodology in which fish are released via a discharge opening formed in the bunt end of the purse seine net. Video analyses of collective (schooling structure) and individual level (activity; i.e. tail beat frequency) fish behaviour were undertaken in the Norwegian mackerel (*Scomber scombrus*) and herring (*Clupea harengus*) purse seine fisheries, to quantitatively describe slipping behaviour and to determine its driving factors. The majority of fish escaped the purse seine with the schooling structure intact as part of large groups towards the end of slipping process, increasing their swimming speed following escape. However, there was also a tendency (24% of all escapes) to escape in a manner likely to impact negatively upon their welfare, with a breakdown in schooling structure and physical contact with the fishing gear and conspecifics. The tendency to express such welfare compromising behaviour was higher for mackerel than for herring, but was also influenced by the vessel releasing the fish, the amount of fish being slipped, how long the discharge opening had been open and the particular slipping event. Further to this, Marçalo *et al.* (2018) used captive observation to demonstrate the benefits of modified slipping practices on the survival of sardines (*Sardina pilchardus*) released from purse seines. Using a method suggested by local fishers, they added weights to the floatline of the seine and showed a significantly improved survival during modified slipping (44.7%, 95% confidence interval 39.3, 50.1) compared to the standard slipping technique (11.7%; 95% CI: 8.9, 15.2). Furthermore, much of the observed mortality in the modified slipping was thought to be due to captivity related handling stress because it was not significantly different from the control survival (43.6%; 95% CI: 38.0, 49.3). These results provide important information for future science-based development of welfare friendly slipping practises.

Other measures of improving catch handling include the gentle lifting of the codend when hauling on board. In most fishing operations full cod-ends are dragged over the vessels side before discharging in a hopper or on deck. This process may impact discard survival as the catch is mechanically impacted. To reduce this impact cod-ends can be horizontally lifted next to the vessel, gently moved to the hopper without impacting the vessels side. Explorative trials have been performed but the effects in discard vitality were limited and this procedure appeared impossible in commercial operations with wind gusts exceeding 5 bft. Several fisheries discharge the catch on the vessels deck and select first all marketable fish from the catch while leaving the discard on the deck until sorting is finished. With this catch practices air expo-sure for discarded individuals is extended till all fish are sorted, and therefore this practice may have a negative influence on discard survival.

Quantifying post-release survival of European plaice has become relevant for the discard-intensive Belgian beam-trawl fishery considering the phasing in of the European Landing Obligation. In this project, eight Belgian beam trawlers were involved representing the i) coastal; ii) <221 kW Eurocutter; and iii) >221 kW fleet segments. The objective was to quantify the effect of a flip-up rope which avoids the entry of stones into the codend. This work is still ongoing to produce evidence in support of a high survival exemption to the Landing Obligation.

2.3 ToR c) Ongoing monitoring to inform on discard survival levels

2.3.1 Policy requirements

With this terms of reference (ToR c), a possibility was explored whether there is a need from a policy perspective for routine discard survival data collection given the exemptions to the Landing Obligation and the annual evaluation of proposals by the European Scientific, Technical and Economic Committee for Fisheries (STECF). There may be a requirement for a member state to demonstrate that an exemption is still relevant to a fishery of interest, when delegated acts are not indefinitely valid and a regular review and re-evaluation of their validity is established by the European Commission for example. Annually, the European Commission decides whether or not to grant proposals for an exemption for a given species and fishery (STECF, 2014). But not without challenges. One is the need for guiding frameworks on what should be included in exemption proposals and how their quality can be evaluated and ranked against a prescribed set of criteria. Without it, decisions may lack rigour. Some stakeholders often criticize the arbitrariness of decision-making without a rigid and robust framework of criteria. The other challenge is, that the number of prioritized species-fishery combinations often exceeds available monetary resources for conducting dedicated studies to collect direct survival observations from either captive monitoring or tagging (ICES, 2020). A more cost-effective approach which at the same time increases overall sampling coverage within representative fishing conditions can include the collection of survival proxies (so called on-board vitality assessments, see ICES, 2014; ICES, 2020) and infer/predict survival based on an established and existing survival-vitality relationship (see section 2.1.1, above).

To maintain or extend an existing exemption from the Landing Obligation, vessel operators are required to report the amount of fish discarded under exemptions (ICES, 2018b; STECF, 2017, 2019). STECF experts repeatedly voiced concerns as follows that "*in line with STECF 17-01, 18-01, 18-02, EWG 18-06, 19-08, STECF highlights the "lack of [required] reporting by vessel operators of fish discarded under exemptions…*". Describing how healthy and vital fish look when landed on deck may be of interest as well, not just to demonstrate sustainable harvesting practices that meet concerns about catch welfare, but also to maintain or extend an existing exemption to the Landing Obligation.

Considering the above, such needs for on-going vitality data collection could have implications on how to integrate it within existing, long-term monitoring programmes which has, so far, not been attempted in Europe. An earlier study is known from Canada (Benoît *et al.*, 2010). Previously, WKMEDS had recommended the following: "*It is recommended that, where vitality data provide an effective indicator for survival rates, the potential for ongoing monitoring of vitality as part of the EU Data Collection Framework is explored. Particularly in fisheries where species exemptions have been awarded on the basis of high survival*" (ICES, 2015).

We identified the following (policy) needs for routine collection of vitality/survival parameters:

- To support (ongoing) exemptions;
- To support transferability and extrapolation of estimates across areas/gears/species, together with an inventory of fishing activity of fishing vessels beyond what is currently collected as descriptors during DCF trips with respect to fishing locality, season, and other parameters such as gear deployment duration and sorting times, and marine environmental conditions (weather and temperatures) using suitable sensor systems;
- To support the integration of survival data into stock assessments;
- To support (proposed or an existing) seafood certification scheme/label;
- To facilitate data collection in relation to animal welfare and catch quality (i.e., providing relevant input for seafood certification programmes);
- To describe suitable analytical techniques to establish and test whether vitality is linked to survival.

2.3.2 Implications for data collection programmes

To meet the (possible) evaluation and reporting needs (as mentioned above) and to assist with establishing a robust framework to support the process of evaluation of exemptions, we explore here, what it would take to meet such needs. Can some of the need be addressed by complementing routine discard data collection programmes? This can be achieved by collecting additional variables to better describe representativeness of discard survival monitoring studies and better describe fishing and handling procedures within the context of discard survival.

Most parameters that influence discard survival are recorded routinely as part of existing DCF protocols (e.g., gear type, gear configuration, deployment duration, depth change and body size). Variables that need to be included are air exposure/sorting time; catch handling procedure; water temperature; and physical injury; the latter most likely integrated within vitality assessments.

To gauge what it takes to collect vitality observations routinely, depending on the associated objective of the study (Table 2.7), the following is suggested:

- Review of available (current) sampling procedures and its effective sampling sizes. Can time be freed up or not? (see ICES, 2012 for example descriptions of sampling protocols).
- To reduce the burden of additional tasks by seagoing observers, a review may be required to see, if time can be freed up to allow dedicated sampling for vitality on additional hauls.
- Implications for data collection programmes:
    - Strengths/Limitations of the method and its implications for data collection; how to accommodate within existing working routine (less hauls, extra sampling effort, times, finances);

- Strength: quick and cheap approach to assess a fish's condition on-board a vessel in remote, and at times adverse environments. Concept on the rise: used for recreational fisheries (Brownscombe *et al.*, 2016), various taxa;
- Limitations: species-specific; requires knowledge about underlying physiological processes;
- Best practice protocol, what to consider, either semi-quantitative vs quantitative methods? Immediate vs post-release monitoring or both?
- Describe fishing operations in more detail relevant to survival (implications to transferability of observations to other gears/areas/species).

Another argument looking into the future: an observer's sampling time may be freed up, because scanners and digital image analyses techniques may automate species identification work and length measurements (Uhlmann *et al.*, 2020b; Van Helmond *et al.*, 2020).

Table 2.7. Requirements, advantages and disadvantages for routine vitality/survival parameter collection in relation to the management or research objective to estimate discard survival (see ICES, 2014, Table 3.1, p. 16).

Objective (for the selected species, variables & management unit)	Suggested approach	Resource Implications	Advantage	Disadvantage
To estimate discard survival potential for particular conditions	Vitality assessment on-board commercial vessel(s), with targeted observations of the factors that affect mortality	Personnel: Trained observers & fishers, Specialist equipment: None. Time frame: hours to days for field trials	Quick Economical Few resource implications	Limited applicability to estimate survival
To estimate discard survival potential that is representative of the management unit	Vitality assessments on-board commercial vessels during representative range of conditions	Personnel: Trained observers & fishers, Specialist equipment: None. Time frame: hours to days for field trials	Quick Economical	Limited applicability to estimate survival
To estimate discard survival rate, excluding predation, for particular conditions	Captive observation of individuals under particular conditions	Personnel: Experienced researchers & fishers Specialist equipment: Containment facilities (e.g. aquaria & sea cages) Time frame: days to weeks for monitoring period	Quick and economical, if combined with existing survival observations derived from comparable conditions;	Requires captive observations: Long durations Expensive Multiple assessments
To estimate discard survival rate, excluding preda-	Vitality assessments on-board commercial ves-	Personnel: Trained observers, Experienced re-	To complement a proposed/ongoing captive observation and/or tagging study	Requires captive observations: Long durations Expensive

tion, representative of the management unit	sel(s) during a representative range of conditions combined with captive observation of individuals representing the various vitality levels to generate an overall weighted mean survival estimate	searchers & fishers. Specialist equipment: Containment facilities Time frame: days to weeks for monitoring period		Multiple assessments
To estimate discard survival rate, including predation effects, for particular conditions	Tagging/biotelemetry on-board commercial vessel(s) under particular conditions	Personnel: Experienced researchers & fishers. Specialist equipment: Tags Time frame: days to months/years for monitoring	Engages directly with the sector by encouraging tag recovery and retrieval	Long duration (very) expensive Unlikely to establish a routine programme
To estimate discard survival rate, including predation effects, representative of the management unit	Option 1: Vitality assessment on-board commercial vessel(s) during representative range of conditions combined with tagging/biotelemetry of individuals representing the various vitality levels on-board commercial vessel(s) to generate an indirect survival estimate	Personnel: Trained observers, Experienced researchers & fishers. Specialist equipment: Tags Time frame: days - months/years for monitoring	Engages directly with the sector by encouraging tag recovery and retrieval	Long duration (very) expensive Approval process involved

	Option 2: Vitality assessment on-board commercial vessel(s) during representative range of conditions combined with captive observation (to estimate short term mortality) and tagging/biotelemetry (to estimate conditional long-term mortality) of individuals representing the various vitality levels on-board commercial vessel(s) to generate an indirect survival estimate	Personnel: Trained observers, Experienced researchers & fishers. Specialist equipment: Tags, Containment facilities (e.g. aquaria & sea cages) Time frame: days to months/years for monitoring	Creates an opportunity to integrate data from tagging with data from captive observations	Long duration (very) expensive

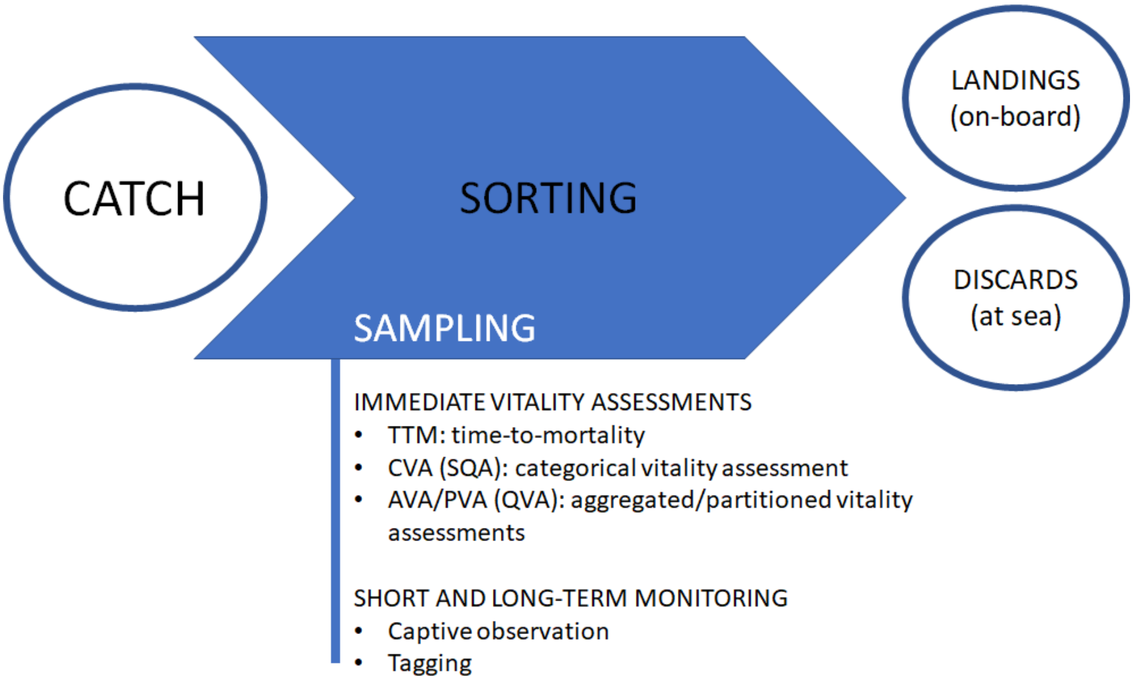


Figure 2.5. Flow chart illustrating the available sampling parameters to quantify either immediate, on-board survival/mortality/vitality and/or delayed survival/mortality via monitoring in captivity or by tagging.

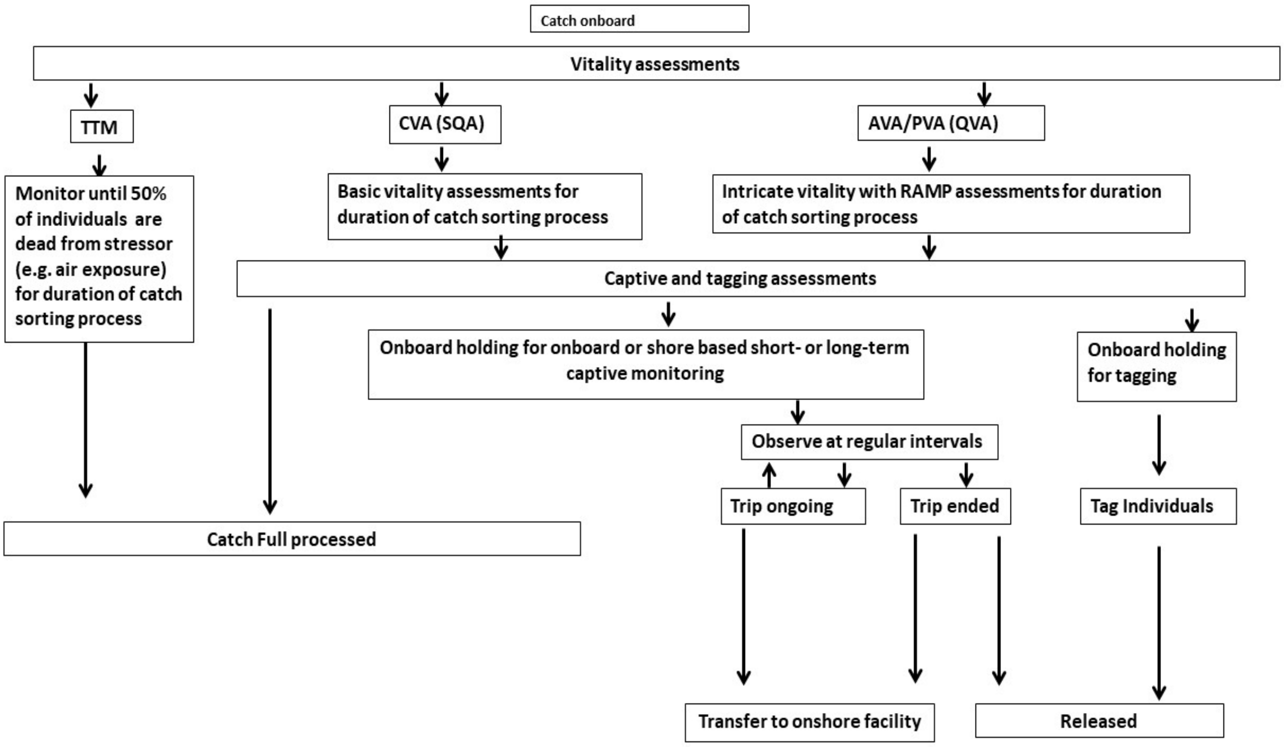


Figure 2.6. Decision tree to facilitate the choice of vitality parameter to be collected routinely.

2.4 ToR d) Applying of discard survival estimates in fisheries management

Fishing commonly leads to capture of individuals that are unwanted. These individuals are often 'discarded'. Not all discarded animals are dead or dying, however, and some may survive the process. In cases where the capture of unwanted fish cannot be avoided, and in the absence of exemptions from the recently introduced Landing Obligation (discard ban), this may translate into an increase in fishing mortality for some EU stocks.

The recent increase in opportunities to research discard survival has been catalysed by introduction of the EU landing obligation. The main aim of recent discard survival assessments for commercial species in European fisheries has been to provide fishery managers with survival estimates that could support exempting the species caught in a defined fishery from the landing obligation based on high survival (article 15(2b) of the Landing Obligation). If a species is granted an exemption, it can still be discarded and potentially survive when returned to the sea.

There are other uses for new evidence on discard survival. Except for a limited number of European stocks, discard survival estimates are not included in the analytical stock assessments. Where estimates of discard survival are robust these could be included to enhance the assessments. Concern over discard mortality levels at a population level can generate interest for including of discard survival estimates in stock assessments, for example with Tanner crab bycatch in Alaska Pollack fishery. Similarly, assuming 100% mortality of yellowtail flounder (*Limanda ferruginea*), a commonly discarded species in large volumes which are considered resilient to the stress of the capture-and-discarding process, are considered to possibly overestimate the population impact of multi-species trawl fishing in the Southern New England Mid-Atlantic region (Barkley and Cadrin, 2012).

Among assessed European stocks, there is one example of discard survival estimates being used in fish stock assessments (ICES sub-Division VIIa, Irish Sea). That stock was benchmarked in 2017 and the following issue was mentioned: "There is considerable uncertainty about the survival rate of discarded fish. The conclusion of WKIrish2 was that a survival rate of around 40% may be suitable, but that sensitivities over the whole range 0–100% should be investigated". The discard survival estimate selected was informed by a range of estimates from different fisheries and areas, but not from Irish Sea fisheries.

For Norway lobster (*Nephrops norvegicus*), discard survival is accounted for in several ICES assessments, for example, sub-Division VIIIa, b. A discard survival rate of 30% is used, however, this does not reflect the most recent estimates of discard survival for this fishery. The stock assessors stated that: "a discard survival rate of 30% [was applied] based on historical experiments (Charuau *et al.*, 1982). However, Méhault *et al.* (2016) found that the discard survival rate (55%) is higher than the historical reference. Based on further experiments, it was estimated by Mérillet *et al.*, 2018 a discard survival rate at 51% when using the quick chute system for discarding Norway lobster, which is mandatory since 1 January 2017. This updated estimate was considered reliable enough to confirm the existing exemption [from the Landing Obligation] (STECF, 2017). The updated discard survival rate will be considered by the ICES assessment group "both when the revision of the reference points is carried out and in future assessments."

During the 2017 ICES WGCHAIRS meeting, it was suggested that if sufficient evidence has been gathered to justify the inclusion of discard rates to improve a stock assessment, that stock assessment working group chairs and stock coordinators shall consider their inclusion in the assessment. WGMEDS was able to explore the implications of including discard survival evidence into stock assessment within the following cases studies:

1. Mapping discard survival onto plaice catches by fleet for EU stocks
2. Inclusion of discard survival in the stock assessment process
    a. Case study 1: North Sea and Celtic Sea plaice stocks
    b. Case study 1 – NE Atlantic mackerel and herring stocks
    c. Case study 3 – Thornback ray in the North Sea

2.4.1 Mapping discard survival onto plaice catches by fleet for EU stocks

The case study to explore the implications of introducing discard survival estimates into the stock assessment for selected European plaice stocks includes three steps. Firstly, using the example of the North Sea plaice stock, a proposed template was created detailing all of the relevant information. Secondly, a condensed version of the template was used to collate the equivalent evidence for plaice stocks in the Celtic Sea (an output from STECF PLEN 19-01 (EU, 2019). Thirdly, the implications for introducing discard survival evidence into the assessment was explored. The output from these three steps are given below.

2.4.1.1 North Sea plaice stock

1. The stock
2. Fleet catches
3. High survival exemptions awarded for stock
4. Discard survival evidence
5. Mapping discard survival onto catches in the context of exemptions for the stock

1. The stock

North Sea plaice stock code: 27.420; stock key: 169189

ICES advice (at the time of the exercise): North Sea Plaice: Plaice (*Pleuronectes platessa*) in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak):

http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/ple.27.420.pdf

2. Fleet catches

In this case, fleet contributions to total catch was derived from the STECF database using the criteria in Table 2.8.

Table 2.8. Data extraction criteria for North Sea plaice from STECF FDI: https://stecf.jrc.ec.europa.eu/dd/effort

Species	Years	Annex	Regulated area	Fishing area	Regulated gears
Plaice	2014-2016	IIA	3B1 3B2	ICES area IIIaN (Skagerrak) ICES area IV	all

Table 2.9. Catch and discard data from STECF FDI (gear codes as per https://stecf.jrc.ec.europa.eu/dd/effort).

	2014			2015			2016			Mean 2014-16		
Gear	L	D	DR%	L	D	DR%	L	D	DR%	L	D	DR%
BT2	30655	25364	45	33825	56235	62	34455	30098	47	32978	37232	51
TR2	5115	15383	75	4429	13260	75	3877	7925	67	4474	12189	72
BEAM	39	177	82	78	1389	95	39	2632	99	52	1399	92
TR1	26629	2313	8	32291	2022	6	33034	1207	4	30651	1847	6
BT1	10070		0	6615	302	4	11255	1135	9	9313	719	5
GT1	2446	20	1	2390	217	8	2570	74	3	2469	104	4
DREDGE	15		0	0		0	0	24	99	5	24	33
GN1	1366	3	0	1043	4	0	1183	5	0	1197	4	0
OTTER	16	1	3	68	0	1	20	4	17	34	2	7
PEL_TRAWL	26		0	22		0	108	0	0	52	0	0
POTS	0	0	7	23	0	0	0	0	8	8	0	5
TR3	3	0	9	12	0	0	56	0	0	24	0	3
LL1	0		0	0		0	0		0	0		0
Total	76378	43260	36	80797	73430	48	86599	43105	33	81258	53265	39

The largest contribution to catches comes from the BT2 fleet, average of 52% (Table 2.9, Figure 2.7) and then the TR1 fleet (average 24%). Most discards are generated by the BT2 fleet (70%), and then the TR2 fleet (23%).

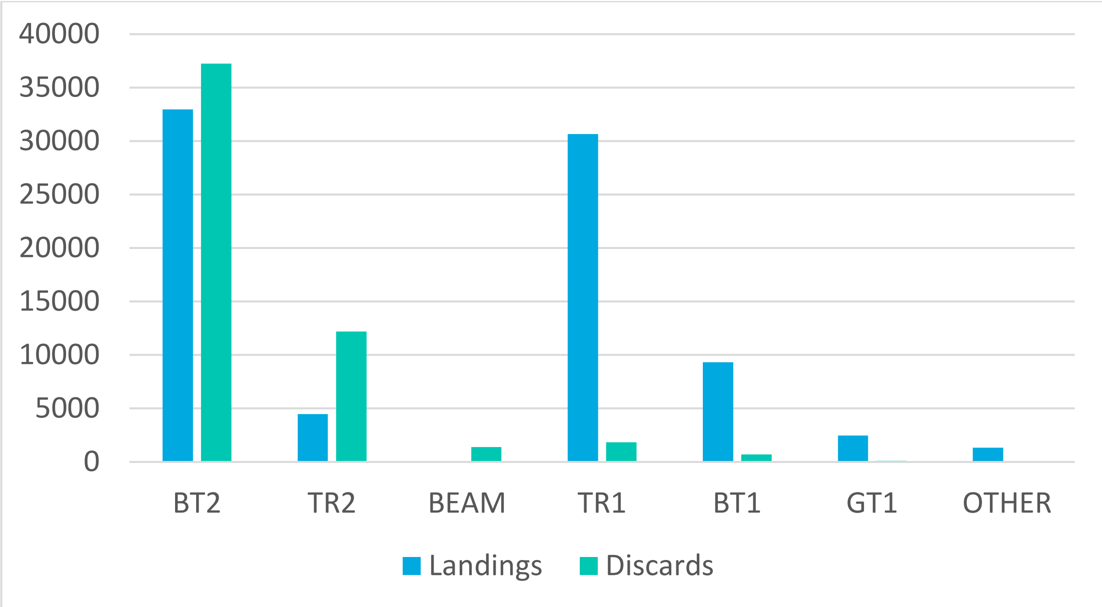


Figure 2.7. Contributions to North Sea plaice landing and discards (mean 2014-16) by fleet; source STECF FDI).

3. High survival exemptions awarded for stock

The relevant Delegated Act for North Sea plaice[1] specifies the details of implementation of the Landing Obligation for certain demersal fisheries in the North Sea including for North Sea plaice (correct at the time of writing):

Survivability exemption for catch and bycatch of plaice

1. The survivability exemption referred to in Article 15(4)(b) of Regulation (EU) No 1380/2013 shall apply in Union waters of ICES division 3a and subarea 4 to:

(a) plaice caught with nets (GNS, GTR, GTN, GEN).

(b) plaice caught with Danish seines.

(c) plaice caught with bottom trawls (OTB, PTB) with a mesh size of at least 120 mm when targeting flatfish or roundfish in winter months (from November 1 to April 30).

2. When discarding plaice caught in cases referred to in paragraph 1, the plaice shall be released immediately and below the sea surface.

Article 7 Survivability exemption for plaice below the minimum conservation reference size

1. The survivability exemption referred to in Article 15(4)(b) of Regulation (EU) No 1380/2013 shall apply in Union waters of ICES subarea 4 and division 2a to catches of plaice below the minimum conservation reference size made with 80-119 mm beam trawls (BT2).

2. The exemption referred to in paragraph 1 shall only apply to vessels with a maximum length of less than 24 metres or a maximum engine power of not more than 221 kW constructed to fish within the twelve nautical miles of the coast and operating with tow durations of no more than 1.30 hours.

3. The exemption referred to in paragraph 1 shall be provisionally applicable until 31 December 2019. Member States having a direct management interest shall submit as soon as possible before 31 May 2019

[1] COMMISSION DELEGATED REGULATION (EU) 2018/2035 of 18 October 2018 specifying details of implementation of the landing obligation for certain demersal fisheries in the North Sea for the period 2019-2021

additional scientific information supporting that exemption. The Scientific, Technical and Economic Committee for Fisheries (STECF) shall assess the provided scientific information before 1 August 2019.

4. When discarding plaice caught in cases referred to in paragraph 1, the plaice shall be released immediately and below the sea surface.

Article 5 Survivability exemption for bycatch of species subject to catch limits in pots and fyke nets

1. The survivability exemption referred to in Article 15(4)(b) of Regulation (EU) No 1380/2013 shall apply in Union waters of ICES division 3a and subarea 4 to catches of cod, haddock, whiting, plaice, sole, hake and saithe made with pots and fyke nets (FPO, FYK).

2. When discarding fish caught in cases referred to in paragraph 1, the fish shall be released immediately and below the sea surface.

4. Discard survival evidence

Details of discard survival evidence for North Sea plaice in the context of authorised exemptions from the Landing Obligation are shown in Table 2.10.

Table 2.10. Details of known discard survival evidence for North Sea plaice by fleet.

Gear	Exemption	Published discard survival rate %	Discard survival rate range %	Discard survival reference	Assumed fishery survival rate %	Comment on the fishery survival rate
BT2	Y (partial)	15% 14% 15%	43-57 (beam trawl, coastal) 10-26 (beam trawl, small vessels) 3-5 (beam trawl, large vessels) 12-35 (beam trawl, all fleet segments) 11-18 (pulse trawl) 11-19 (pulse trawl)	Uhlmann *et al.* (2018) Uhlmann *et al.* (2018) Uhlmann *et al.* (2018) Uhlmann *et al.* (2018) Schram and Molenaar (2018) van der Reijden *et al.* (2017)	15%	The description in the regulation is not clear. Assumed that 'plaice below MCRS made with beam trawl gears in ICES subarea 4 and ICES division 2a.' is the most likely exemption. Based on this, the survival estimate chosen reflects the whole fleet (and not only the coastal fleet).
TR2	N	35% (Nephrops fishery); 32% (fish fishery)	25-46 (Nephrops fishery); 13-42 (fish fishery)	Randall *et al.* (2016); +J15	33%	Assumed that the discard ratios when targeting fish and Nephrops are similar.
BEAM	N	unknown	-	-	unknown	

TR1	Y (partial)	78% (Danish seine); 75% (otter trawl winter) 44% (otter trawl summer) 100% otter trawl winter)	20-86 (Danish seine); 67-83 (otter trawl winter) 37-52 (otter trawl summer) 100-100 (otter trawl winter)	Karlsen *et al.* (2018a) Karlsen *et al.* (2018b) Karlsen *et al.* (2018b) Methling *et al.* (2017)	75%	Based on the representativeness of the fleet and assumed that the discard ratios of the trawl fishery are higher than the Danish seine.
BT1	N	unknown	-	-	unknown	
GT1	Y	64% 100%	47-75 100-100	Catchpole *et al.* (2015) Ern *et al.* (2018)	82%	
DREDGE	N	unknown	-	-	unknown	
GN1	Y	64% (GT1)	47-75 (GT1)	Catchpole *et al.* (2015)	64%	
OTTER	N	unknown	-	-	unknown	
PEL_TRAWL	N	unknown	-	-	unknown	
POTS	Y	unknown	-	-	unknown	
TR3	N	unknown	-	-	unknown	
LL1	N	unknown	-	-	unknown	

5. Mapping discard survival onto catches in the context of exemptions for the stock

Table 2.11, Figure 2.8 and 2.9 show the fleet catches, discards, levels of dead unwanted catch where survival evidence is available and the implications for the exemptions for the stock. The BT2 fleet generates the most unwanted catch and dead unwanted catch; 23% of the total catch is of unwanted dead plaice from the BT2 fleet. This fleet had exemption from the Landing Obligation in 2019; around 28% of the total catch of North Sea plaice will be of unwanted fish from the BT2 fleet; the unwanted dead plaice from the BT2 fleet contribute 23% to the total catch. The dead unwanted plaice caught by the TR2 fleet contributes around 13% to the total catch; this fleet will not be exempt from the landing obligation; therefore, all of the unwanted catches should come ashore, including those that could otherwise have survived (around 3% of the total catch, assuming no change in selectivity).

Table 2.11. Mean landings and discards data, survival proportions, and unwanted catch that is dead as a percentage of total catch.

Gear	Exemp-tion	Landings (mean 14-16)	Discards (mean 14-16)	Survival propor-tion	Estimated survivors (mean 14-16)	Unwanted dead (mean 14-16)	Unwanted dead as % total catch
BT2	Y	32978	37232	0.15	5585	31647	23%
TR2	N	4474	12189	0.33	4022	8167	13%
BEAM	N	52	1399	unknown	unknown	unknown	<1%
TR1	Y	30651	1847	0.75	1385	462	1%
BT1	N	9313	719	unknown	unknown	unknown	<1%
GT1	Y	2469	104	0.82	85	19	0%
DREDGE	N	5	24	unknown	unknown	unknown	<1%
GN1	Y	1197	4	0.64	3	1	<1%
OTTER	N	34	2	unknown	unknown	unknown	<1%
PEL_TRAWL	N	52	0	unknown	unknown	unknown	<1%
POTS	Y	8	0	unknown	unknown	unknown	<1%
TR3	N	24	0	unknown	unknown	unknown	<1%

Figure 2.8 shows the components of the North Sea plaice catch in absolute mean values. Discard survival estimates are available for the fisheries generating most discards. Figure 2.9 shows these data in percentage terms for each fleet. The figures show that most catches were exempt from the landing obligation in 2019 and most discards will not survive when returned to the sea. Of the total estimated discard amount, around 60% of the previously discarded plaice are likely to be discarded and will not have survived.

Figure 2.8. Components of the North Sea plaice catch in absolute mean values (2014-16) by metier with breakdown of discards and estimated survivors following the introduction of Landing Obligation.

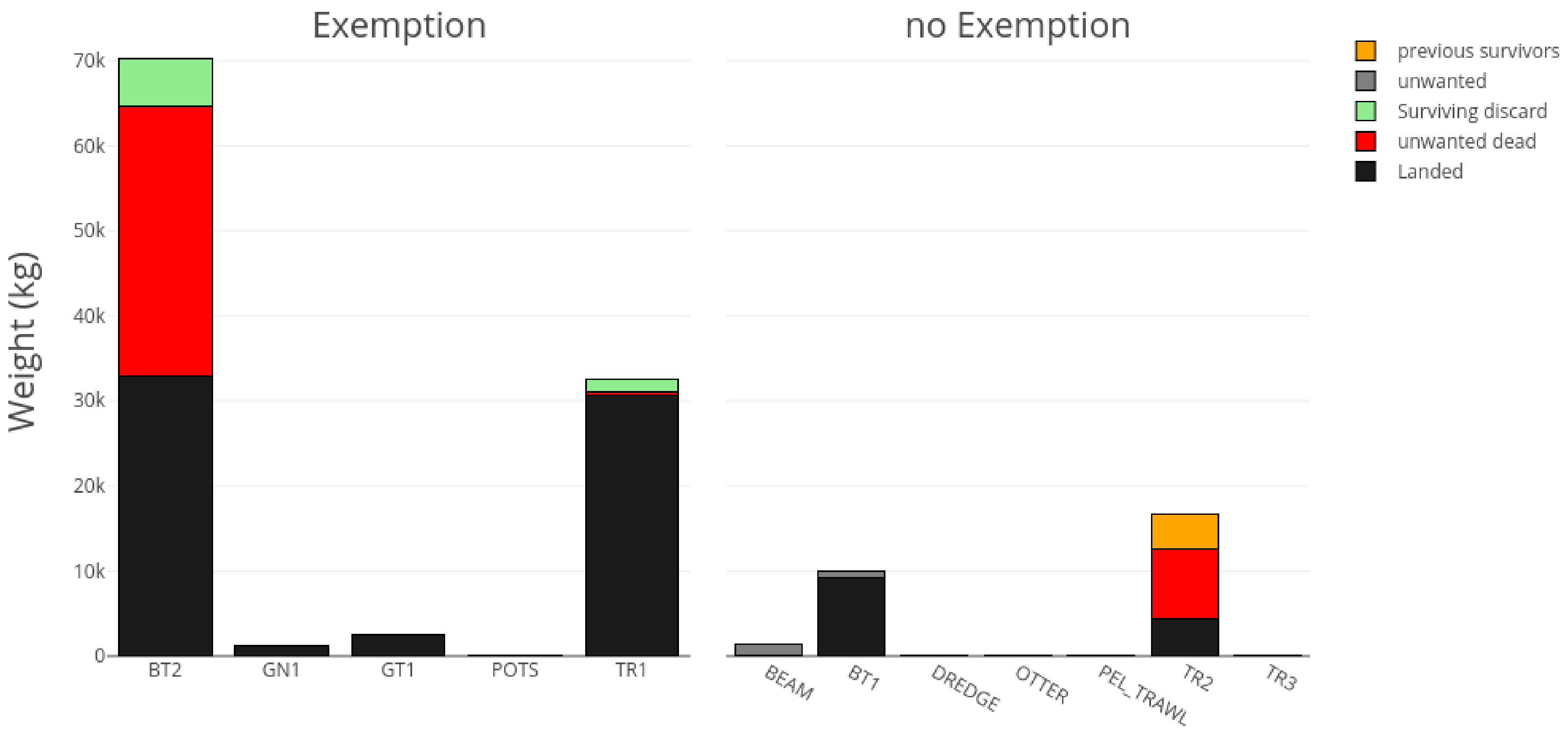
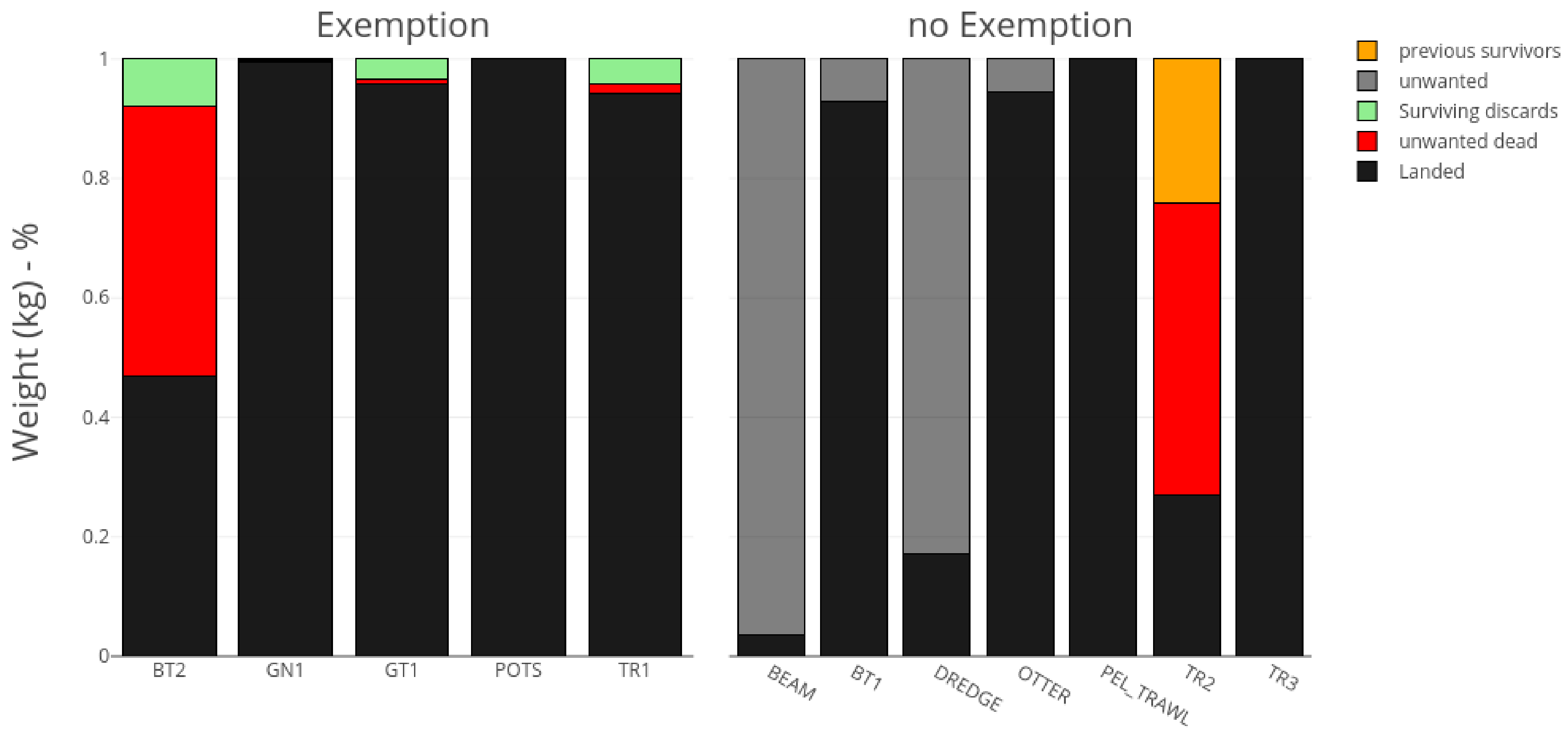


Figure 2.9. Components of the North Sea plaice catch with breakdown of discards and estimated survivors following the introduction of landing obligation by percentage for each metier.



2.4.1.2 Mapping discard survival against catches of Celtic Sea plaice stocks

The WGMEDS template created for North Sea plaice was used by STECF PLEN 19-01 to produce equivalent data for the six Celtic Sea plaice stocks. The output tables are reproduced here, full details are given in STECF PLEN 19-01 (EU, 2019). The information provided here are:

1. Fleet catches by stock
2. Relevant discard survival evidence
3. Mapping discard survival onto catches in the context of exemptions for the stocks

i) Celtic Sea plaice fleet catches by stock

To illustrate the context for discard survival exemptions for stock management and sustainable fishing, plaice catches by fleet for each assessed stock, were compiled from ICES advice (Table 2.12). Discard survival estimates were then applied to indicate the proportion of the total catch effected by the existing exemptions. The ICES fleet descriptions are at a lower resolution than the fleet descriptions to which existing exemptions apply. For example, ICES catch data refer to fixed nets and the exemptions apply only to trammel nets; and, exemptions apply to plaice caught by beam trawlers having a maximum engine greater than 221 kW fitted with a flip-up rope or benthic release panel, whereas ICES aggregate all beam trawl catches (details of the existing exemptions are described in the discard plan for the North Western Waters EU 2018/2034). Therefore, the data presented are only indicative of the context of the plaice survivability exemptions.

ii) Plaice discard survival evidence

Existing relevant plaice discard survival evidence from the North Sea and North Western Waters (Table 2.13) was collated, this evidence has been submitted to support exemptions (Rihan *et al.*, 2019). There are both survival estimates derived from direct observation, and those based on a proxy. using relationships from other studies between health condition at the point of discarding and survival probability. The most relevant discard survival estimate was mapped to each fleet for each area 7 plaice stock. A maximum and minimum survival estimate from the studies was used to show a range of effects of the survivability exemptions. The data used, assumptions and limitations of the outputs are given in Table 2.13. Directly observed survival estimates from the relevant sea area or the closest area were used preferably where available. Where estimates were derived from modelled health condition, these were supplemented with the geographically closest directly observed estimates.

Table 2.12. Catch distribution of Division 7 plaice stocks by fleet in 2017 as estimated by ICES.

Divi-sion	Wanted catch					Unwanted catch				
7.a.	Beam trawl	Ot-ter trawl	Other gears			Beam trawl	Ot-ter trawl	Other gears		
	58%	32%	10%			52%	40%	8%		
	586 tonnes					852 tonnes				
7.d	Beam trawl	Ot-ter trawl	Trammel nets	Other gears	x	Beam trawl	Ot-ter trawl	Trammel nets	Other gears	
	56%	27%	9%	8%						
	3689 tonnes					4075 tonnes				
7.e*	Beam trawl	Ot-ter trawl	Fixed nets	Other gears		Beam trawl	Ot-ter trawl	Fixed nets	Other gears	
	71%	24%	4.30%	0.97%		53%	47%	0.02%	0.02%	
	1915 tonnes					593 tonnes				
7.f, g	Ot-ter trawl	Beam trawl	Gill net	Seine	Other	Ot-ter trawl	Beam trawl	Gill net	Seine	Other
	42%	52%	0.80%	4%	2%	58%	37%	1%	2%	2%
	389 tonnes					895 tonnes				
7.h, j,k	Ot-ter trawl	Beam trawl	Other gears			Discards in Division 7.h are unknown. Discards in divisions 7.j–k are in the order of 30% of the catch for otter trawls (average 2007–2017).				
	75%	17%	8%							
	115 tonnes					unknown				

***Catch and the catch contribution by fleet correspond to the amount taken in Division 7.e and do not include the catch taken in Division 7.d.**

Table 2.13. Details of plaice discard survival evidence in the context of the Landing Obligation, adapted from Rihan *et al.*, (2019)
https://link.springer.com/chapter/10.1007/978-3-030-03308-8_3

ID	Fishing gear	Location / ICES	min%	max%	*N*	Comment	Reference
1	Beam trawls	English Channel (7.e)	4	15	275	Observed survival, adjusted to asymptote	Catchpole *et al.* 2015
2	Beam trawls	North Sea (4.c)	11	22	558	Observed, pulse trawl	Schram and Molenaar 2018a, b
3	Beam trawls	North Sea (4.c)	30	40	446	Observed survival for various beam trawl sectors (mean of hauls +/-sd; range 4-93%)	Uhlmann *et al.* 2018
4	Beam trawls	Eastern and Western English Channel (7.d, e, h, g)	30	32	1314	Inferred survival using vitality data from 4.c	Uhlmann et at., 2018
5	Otter trawls	Bideford Bay (7.f, 7.g)	75	88	572	Inferred survival using vitality data from 7. e	Smith *et al.* 2015
6	Otter trawls	Eastern and Western English Channel (7.d, e)	45	67	1040	Observed and inferred survival using vitality data from 7. e	Smith *et al.* 2015; Morfin *et al.* 2017
7	Trammel net	Swansea Bay (7.f, 7.g)	37	60	96	Observed survival, adjusted to asymptote	Smith *et al.* 2015
8	Otter trawls	North Sea (4.c)	28	37	385	Observed survival for Nephrops trawl, adjusted to asymptote	Randall *et al.* 2016
9	Otter trawls	Irish Sea (7.a)	37	43	88	Observed survival for demersal fish trawl	Oliver *et al.* 2018
10	Trammel net	English Channel (7.d)	71	72	168	Observed survival, adjusted to asymptote	Catchpole *et al.* 2015
11	Otter trawls	North Sea (4.c)	19	20	292	Observed survival, adjusted to asymptote	Catchpole *et al.* 2015
12	Otter trawls	English Channel (7.e)	47	63	348	Observed survival, adjusted to asymptote	Catchpole *et al.* 2015

Table 2.14. Indicative amounts of surviving and dead catches associated with survivability exemptions for plaice in area 7.

Stock	Gear	Wanted Catch	Unwanted catch	DR %	Min. survival rate %	Max. survival rate %	Data derived from	Ref ID	Max. survivors (exemption) tonnes	Max. dead (exemption) tonnes	Comment
7.a	Beam trawl	339.9	443.0	57%	4%	32%	7.d, e,f,h	1, 4	141.8	425.3	No survival observations from 7.a. Max. survival from model
7.a	Otter trawl	187.5	340.8	65%	37%	43%	7.a	9	146.5	214.7	No survival data on Nephrops trawls
7.a	Other gears	58.6	68.2	54%	unknown	unknown	7.f, g	-	-	-	
7.d	Beam trawl	2065.8	4075.0	52%	4%	32%	7.d, e,f,h	1, 4	?	?	Max. survival from model
7.d	Otter trawl	996.0			45%	67%	7.d, e	6	?	?	
7.d	Trammel nets	328.3			37%	72%	7.d, 7.f, g	7, 10	?	?	
7.d	Other gears	298.8			unknown	unknown			?	?	
7.e	Beam trawl	1359.7	314.3	19%	4%	32%	7.d, e,f,h	1, 4	100.6	301.7	Max. survival from model
7.e	Otter trawl	459.6	278.7	38%	45%	67%	7.d, e	6	186.7	153.3	Direct observation
7.e	Fixed nets	82.3	0.1	0.1%	37%	60%	7.d, 7.f, g	7	0.1	0.1	No survival data for gill nets, trammel net data from 7.f, g inshore fishery

7.e	Other gear	18.6	0.1	1%	unknown	unknown	-	-	-	-	No data
7.f, g	Otter trawl	164.9	522.7	76%	45%	88%	7.f, g	6, 5	460.0	287.5	Max. survival from model
7.f, g	Beam trawl	201.1	332.9	62%	4%	32%	7.d, e,f,h	1, 4	106.5	319.6	No survival data from 7.f, g. Max. survival from model
7.f, g	Gillnet	3.1	8.1	72%	37%	60%	7.d, e, 7.f,g	7	4.8	5.1	Based on trammel net data
7.f, g	Seine	14.0	17.0	55%	unknown	unknown	-	-	-	-	
7.f, g	Other	5.8	13.4	70%	unknown	unknown	-	-	-	-	
7.h, j,k	Otter trawl	86.3	37.0	30%	45%	67%	7.d, e	6	24.8	20.3	Max. survival based on model. No exemption requested
7.h, j,k	Beam trawl	19.6	?	Un-known	4%	32%	7.d, e,f,h	1, 4	?	?	No survival data from 7.h, j,k. Max. survival from model
7.h, j,k	Other gears	9.2	?	un-known	unknown	unknown	-	-	-	-	

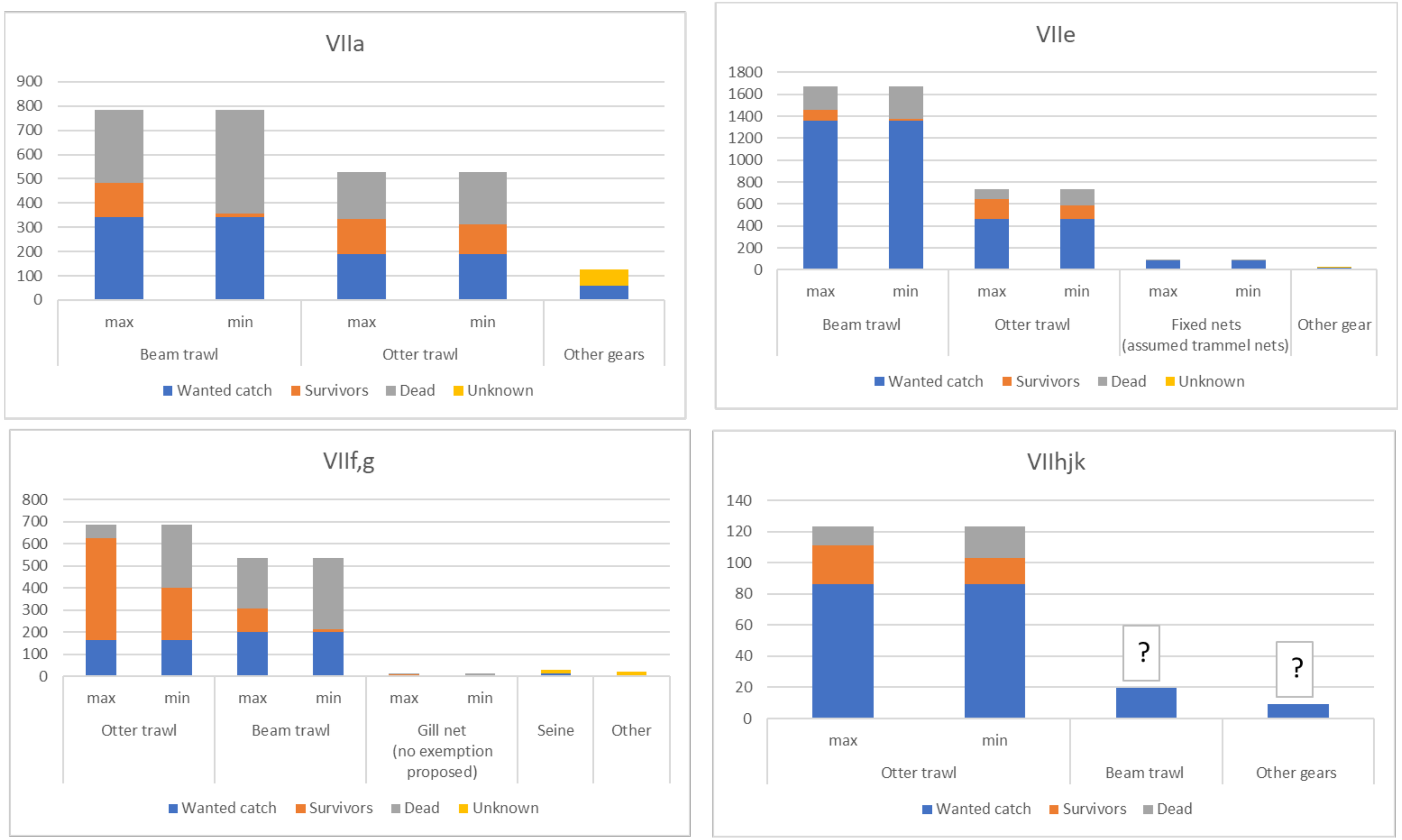


Figure 2.10. Estimated quantities of surviving and dead discards by fleet and stock for plaice in area 7.

4. Illustration of discard survival and exemptions for the stocks

The estimated quantities of surviving and dead discards by fleet and stock are given in Figure 2.10. Data were available to illustrate the indicative levels of survivors and dead discards under survivability exemptions for plaice stocks 7.a, 7.e, 7.f,g and 7.h,j,k. For all stocks, most catches and discards are taken by otter and beam trawl fleets.

For the Irish Sea plaice stock 7.a, the total amount of discards generated by beam trawlers equated to 31% of the total catch; discards generated from otter trawls equate to 24% of the total catch. The overall discard survival for the 7.a plaice stock is estimated at 18–37%, equating to 10-20% of the total catch (Table 2.15), however, this maybe an overestimate because survival is lower for otter trawlers catching Nephrops, and this is not accounted for in these calculations. This stock is the only plaice stock for which discard survival estimates are included in the assessment. A discard survival rate of 40% has been applied, this exercise suggests that this could be an over-estimate of survival (18–37%).

The 7.e plaice stock has directly observed discard survival estimates for the fleets generating most of the discards and therefore, the most certainty on the effect of survivability exemptions. Under existing exemptions, the overall discard survival rate for the stock is estimated at 23–48%, equating to 6–11% of the total catch (Table 2.15). The overall discard survival is relatively high, but because this stock has the lowest discard rate of the Celtic Sea plaice stocks, the effect of accounting for discard survival in the assessment is likely to be limited.

The 7.f,g stock displays the highest discard rates and there are no directly observed discard survival estimates. There is data on the health of discarded plaice from the otter trawl fleet in 7.f., which has been used as a proxy for survival. The overall stock discard survival rate is estimated at 29–66%, equating to 19–44% of the total catch (Table 2.15).

For the 7.h,j,k stock, discard estimates are available only for otter trawls. Discard estimates for the beam trawl fleet are needed to assess the implications of a survivability exemption for this fleet.

Table 2.15. The estimated survivors as % of total catch and of total discards each area 7 plaice stock.

ICES stack area	Max. Survivors as % total catch	Min. Survivors as % of total catch	Max. Survivors as % discarded catch	Min. Survivors as % of discarded catch	Gears for which survival estimates are available
7.a	20%	10%	37%	18%	Beam trawl, Otter trawl
7.e	11%	6%	48%	23%	Beam trawl, Otter trawl, Fixed nets (assumed trammel nets)
7.f,g	44%	19%	66%	29%	Otter trawl, Beam trawl, Gill net (no exemption)
7.h,j,k	16%	11%	67%	45%	Otter trawl, Beam trawl (no discard data)

In accordance with STECF, WGMEDs recognise that mapping discard survival evidence against discard levels by fleets enables an indicative assessment of the implications of survivability exemptions. Where discard rates are high, and survival rates are similar to the values presented here, substantial quantities of dead discards can be generated. To achieve agreed levels of fishing mortality, these dead discards should be accounted for in the stock assessment and the fishing opportunities advice derived from it.

2.4.2 Inclusion of discard survival in the stock assessment process

The WG considered three aspects of this ToR, looking at the effect of different assumptions regarding discard survival on the ability to estimate stock status, the consistency of application in catch forecasts across the ICES advice, and the effectiveness of management measures in light of existing and future issuance of exemptions to the landings obligation. Three specific case studies were examined at the meeting (mackerel and herring in the NE Atlantic, plaice in the Celtic and North Sea, and elasmobranchs in WGEF which are predominantly category 3 and 4 stocks).

The WG aimed to determine the impact of discard survival on the accuracy and precision of stock assessments used in the production of ICES advice. For most elasmobranchs and category 3 stocks the assessment process is based on trends in survey or fleet CPUE information. These do not rely on catch estimates to determine exploitation rates so the ability to estimate stock status is unaffected by all unknown mortality processes including discarding, so these are not considered further here.

For the NE Atlantic pelagic stocks there is considerable uncertainty regarding both the discard rate and the likely survival rate of those discards and the effect of including this uncertainty in the stock assessment process could be counter-productive (Dickey-Collas *et al.* 2007). Therefore, a more general approach to unaccounted mortality rate was applied using some priors in this case study.

Estimated range of unaccounted catches

Based on available literature and data a range of probable discard rates and mortality rates of the discarded fish were estimated. Due to the limited quantitative basis, the possible discard proportion was estimated to range between 1% to 50% and mortality rates between 10% to 50% for herring and 30% to 100% for mackerel. Combined, this resulted in a matrix of discarded proportion × discard mortality for each stock. Assuming that both discarded proportion and discard mortality are continuous vectors with 1% steps, the matrix consists of 2601 combinations for herring and 3621 for mackerel. This was used as the probability distribution of unaccounted catches to sample from in the subsequent runs of the assessment models.

Assessment model

The assessment model and configuration were used as reported in their 2018 assessments (ICES, 2018c). For both stocks, the current assessment is based on the state-space assessment model SAM (Nielsen and Berg, 2014), with some modifications in the case of herring (XSAM, Aanes *et al.*, 2016). To simplify assessment models and to avoid potentially strong effects of specific survey indices (ICES, 2019) the number of survey indices was reduced from four to one per stock, choosing the most consistent one. For herring, this was the International Ecosystem survey in the Nordic Seas in May, and for mackerel, the international coordinated ecosystem survey in the Norwegian Sea and adjacent areas during summer, both on the respective feeding grounds. The approach followed the method of Zimmermann and Enberg (2017).

Assessment runs

Each run, a value from the probability distribution of unaccounted catches was randomly selected and applied as multiplier to the reported annual catches at age according to four different scenarios:

1. All ages equally affected (equal multiplier for all ages)
2. Lower age-classes over-proportionally affected (multiplier decreases linearly with age)
3. The first four age classes affected (multiplier applied to first four ages used in assessment)
4. Increase depends on total catch (multiplier varies with total catch and is applied to all ages equally)

Each scenario was bootstrapped with 1000 individual runs of the assessment, and in each run a value from the probability distribution of possible catch increases was randomly selected and applied as catch multiplier. From the resulting stock estimates, we calculated the mean annual SSB and 95% confidence intervals of the estimates over all the assessment runs of each scenario.

The results suggest:

i. a wide range of unaccounted mortality values and a limited sensitivity analysis on how that mortality applies to different age components largely suggests that for these stocks and assessment models, the result is a rescaling of SSB, abundance at age and recruitment values. F was not affected.

ii. the observed rescaling suggests that for relative biomass reference points (SSB / Bmsy), little impact of unaccounted mortality can be expected. The ability to assess the trends in stock status is not affected. However, considerable potential for bias in estimation of stock size was found and, consequently, of absolute reference point and catch advice. This implies that if unaccounted mortality is ignored the stock productivity is potentially underestimated, resulting in inadequate harvest strategies and forgone yields.

iii. assuming the appropriateness of the prior uncertainty and the independence of the discard and discard survival processes the additional process uncertainty not formally included in the stock assessment is at least as large as the variance estimates used to describe the uncertainty in the current advisory process. This has significant impacts for management strategies where a precautionary buffer is applied to minimize the risk of a stock biomass below limit reference points. Less risk is associated with target reference points, though the ability of management to remain close to those reference points will be impaired so that the realised long-term yield is likely to be less than idealised long-term yield estimated in the assessment.

For the plaice assessments discard estimates, at least in the recent period are more certain than for the herring and mackerel stocks. Despite this, the inclusion of discard data more generally in assessments has taken quite different approaches and plaice are a good example of this. Plaice 7.e ignores discard rates in the assessment process (equivalent to assuming 100% survival). But other plaice stocks include some estimation of raised discard estimates. Methods of raising are still variable as sampling protocols are being refined under expert groups lead by WGCATCH and the Regional coordination groups under the DCF. The method of hindcasting discarding (estimation for years where no estimates exist) varies from independent assessments (plaice 7.fg), to independent process based estimation such as length based estimates from surveys (plaice 7.a) to integrated ones estimated within the assessment model through development of discard ogives (plaice 7.d & 4bc20).

Presumably, all these methods have impacts on uncertainty and bias in assessments but the objective in this case study was to specifically assess the uncertainty cause by discard survival in the assessment process so the objective was to see if general conclusions could be derived as to the likely type and magnitude of any impacts. The approach was therefor to take accept the information as used in assessments and to scale up or down the discard portion used in the assessment. Where possible the full range of discard survival rates (0–100%) were used unweighted by likelihoods. Therefore, the results are only indicative of the range of possible impacts, not the probability of any one specific scenario. The implementation methodology follows that of Verkempynck *et al.* (2018) up to and including the evaluation of the assessment. Unlike that study it does not estimate stock productivity quantitatively or carry it through to the management implementation through long-term forecasts for a lack of knowledge of the precise implementation process and the assessment history.

The NS plaice assessment demonstrated uncertainty in SSB F and Recruitment in response to different assumptions about scale of the discard survival rate (Figure 2.11). For the most part different discard survival rates rescaled the parameters more or less consistently over the time-series. Higher discard survival resulted in lower estimates of all parameters suggesting the assessment simply interprets this as smaller ‘effective’ catches from a smaller stock. The smaller “catches” are also interpreted as a lower F-rate suggests the parameters are not entirely independent in the model. The results of increased bias at times of strong changes in F due to inclusion of discard data (inverse of the effect of increasing discard survivorship) for NS plaice which had been observed by Dickey-Collas *et al.* 2007 using XSA was not consistently observed here because discard survival is more constant than discarding, a different stock assessment model was used, or simply F-trends have been more stable. We did observe in 7e plaice that when the biomass changed the uncertainty associate with discarding increased (Figure 2.11). In this stock the change was driven by recruitment variation in contrast to variation in F in Dickey-Colas *et al.* 2007.

In the EC assessment there was comparatively little effect of discard survival on the estimates of SSB and the estimates of recent recruitment and F indicated that the impact of different discard survival rates were greater in the recent years than in previous years (Figure 2.13). Despite the relatively small variation in SSB the estimates for the last 10 years provide evidence that inclusion of the discard rate can both increase and decrease the estimate of the stock estimates for different years in the assessment.

The plaice assessment for the WC stock had the greatest uncertainty of all the stocks in SSB and Recruitment associated with the uncertainty in discard mortality (Figure 2.12). It resulted in a largely parallel rescaling in for these parameters with lower discard survival rates. F trends were only minorly affected by the changes in assumed discard survivor ship and the direction of impact varied for different years. Uncertainty, in SSB did increase over the most recent years, likely a scaling issue with currently high SSB as recruitment and recruitment uncertainty decrease at the same time.

The Irish sea place assessment is unique in that it already includes an estimate of discard survival (60%), so that the current assessment sits in the middle of the range of uncertainties (Figure 2.13). Variation in recruitment SSB is largely unaffected by the scale of the discard survivorship. Most of the differences are in the Recruitment estimates which are largely rescaled consistently over the time period. F estimates are also rescaled, but the temporal variability with 1992–2012 showing greater variation than recent estimates. Historic estimates are likely not to vary due to an absence of discard data.

The results indicate:

- Routine assessment sensitivity to discard survival estimates is situation specific and few generalities are apparent. Sometimes estimates are rescaled, sometime there is no rescaling or temporally variable rescaling. The parameters that are rescaled are not consistent across the stocks (or the models used). Recruitment tends to be most consistently rescaled, but this is likely because in plaice discarding is predominantly of small / young individuals.
- The relatively small but systematic divergence in the responses (linear rescaling, proportionate rescaling and non-linear rescaling) in F, SSB and recruitment across different stocks are caused by different assessment attributing different data weightings to their respective data sources, i.e. the stock dynamics are interpreted differently.
- Methods of deriving historic discards are surprisingly influential and greater consideration of options used should be given to this at the benchmark process if consistency across assessments is considered important by ACOM

- Although not specifically tested here the impact on management seems relatively insensitive as the management metrics and reference points change either little (within the uncertainty of the assessment) or change proportionally as also indicated by Verkempynck *et al.* (2018). But do note that for WC plaice for example this could lead to different long-term productivity estimates since SSB rescales while F does not.
- Stock productivity estimates are likely to be biased which may impact both estimates of predicted long-term yield at intermediate stock sizes and recovery rates under poor stock condition. All place stocks examined are currently at high levels of SSB recovery rates where density dependent changes in mortality are likely to greatly reduce the impacts of reasonable levels of discard survival. In case of poor stock-condition the predicted recovery rate would be quicker if discard survival differed significantly from the values used in the assessment.

2.4.3 Consistency of application in catch forecasts across ICES advice

In addition to the differences in treatment of discard estimation in the assessment process as indicate in the previous section the use of discard mortality rates in the forecast procedures across ICES advice has been mentioned as an issue. This is particularly urgent to management as the Landings obligation reaches its full implementation in the near future.

While it may appear that treatment of discard survival is variable across advice, it is actually only a single study from the 1980s (Charuau *et al.*, 1982) that drives these estimates across all stocks and fisheries. This study ahead of its time as it was, is unlikely to pass the best practice criteria developed by WGMEDS and its implementation harps back to a methodologically simpler time when assessment methodology itself and the treatment of uncertainty were less relevant in fisheries management. The estimate used was not because it was a particularly sound or appropriate estimate, but rather the fact that it was the only estimate. Although more up to date estimates exist for nephrops (37%; Mérillet *et al.*, 2018) the fact that the uncertainty of these new estimates if formally considered leads to the conclusion that the old estimate falls within the uncertainty bounds of the new methods and therefore the old estimates are appropriate despite a lack of uncertainty estimates of the latter. In addition, at least in the French fishery the catch processing methodology has changed and according to latest survival estimates (51%, Mérillet *et al.*, 2018) is now substantially higher than the original estimate (30%).

It seems that the differences in discard survival treatments in advice is more to do with institutional inertia then differences in evidence or differences in perception of the importance of including such values in assessments. This highlights the importance of communication between WGMEDS and assessment and benchmark groups and a possible task for the future of WGMEDS or WGMEDS-like groups.

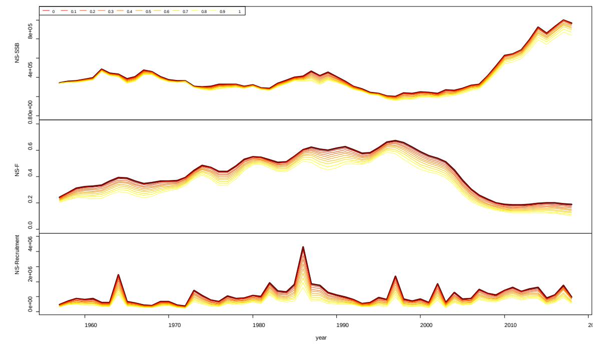


Figure 2.11. The uncertainty of the North Sea plaice assessment stock dynamic estimates based on different assumed discard survival rates. Increasing survival rates (0=red to 1= yellow), scale down SSB, F and recruitment more or less consistently over the time period.

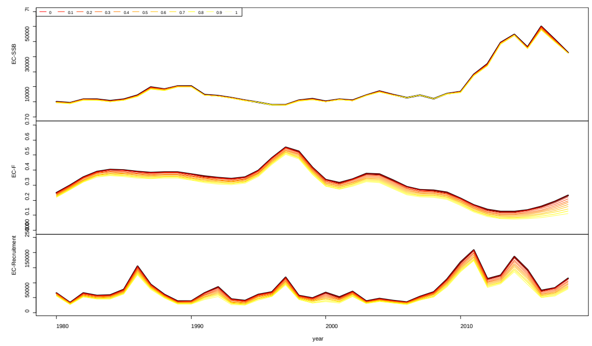


Figure 2.12. The uncertainty of the Eastern Channel plaice assessment stock dynamic estimates based on different assumed discard survival rates. Increasing survival rates (0=red to 1= yellow), scale down SSB, F and recruitment but F and recruitment estimates show increasing variability in recent years

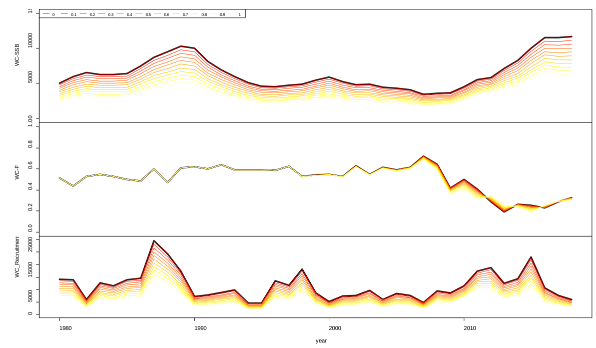


Figure 2.13. The uncertainty of the Western Channel plaice assessment stock dynamic estimates based on different assumed discard survival rates. Increasing survival rates (0=red to 1= yellow), scale down SSB, recruitment with SSB and Recruitment uncertainty scaled by the size of the estimate.

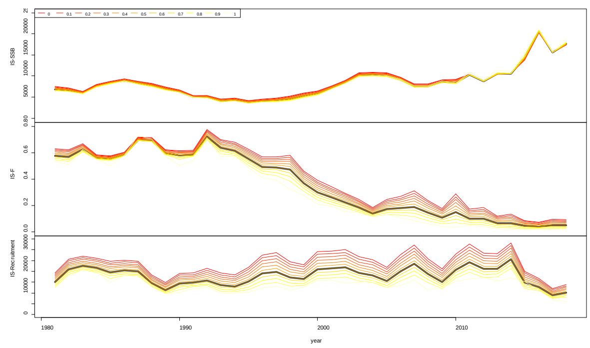


Figure 2.14. The uncertainty of the Irish Sea plaice assessment stock dynamic estimates based on different assumed discard survival rates. Increasing survival rates, scale down F and recruitment with Recruitment uncertainty scaled by the size of the estimate while F is most variable during the period of F-reductions.

2.4.3.1 The effectiveness of management measures in light of existing and future issuance of exemptions to the landings obligation

The group has recently been looked to for guidance on threshold levels of discard survival rate above which the granting of an exemption to the landings obligation should be considered. This task applies to all fisheries including those considered above but is probably best exemplified by fisheries which target elasmobranchs and fisheries that have substantial by-catch of these species. Concerns over the slow reproductive rates of these species have placed them high on the list of conservation priorities for requiring significant improvements in management effectiveness. This is relevant for many fisheries as the suggested TACs are likely to act as ‘choke species’ for other species for which there is lower conservation concerns.

An example on the impacts of including discard survival estimates into the advisory process of an ICES Category 3 stock, i.e. for which advice is based on an indicative trend of fishery-independent surveys, a case-study was considered: thornback ray (*Raja clavata*) in the North Sea (ICES subarea 4 and divisions 3.a and 7.d) advised for 2018 and 2019 (ICES, 2017). The inclusion of discards in the advisory process of such stock was explored by WKSHARK5 (ICES, 2019) and the main finding on this subject are summarized below.

Due to the uncertainty of discard estimates in these by-catch species their inclusion in the advice process was not yet accepted by WGEF, mainly because of issues of data quality in terms of species identification, size range of the catch, coverage of sampling programmes and raising procedures (ICES, 2019).

The ICES framework for category 3 stocks (ICES, 2012) regular advice (based on previous landings) implies that the overall index of stock development (stock size indicator) is based on the biomass index of one or multiple surveys combined and the subsequent advice is derived by multiplying the previously advised landings with the ratio between the two latest index values and the five preceding index values. In the case of catch-based advice that ratio is multiplied by the average catches.

The thornback ray in the North Sea, the stock is in good condition as the stock size indicator has been consistently increasing over the recent years (Figure 2.15), and landings are mainly derived from bottom and beam trawls (72%), followed by trammel nets (18%); (ICES, 2017). The regular advice was compared to the corresponding catch-based advice (considering an average discard rate of 0.34 and the average catches for the period 2011–2016). The resultant landings based on the catch advice and assuming the historic discard rate is 1811 tonnes which is 35% lower than that estimated by the previous advice procedure (2574 tonnes). The new advice approach does not capture the uncertainty associated with the survival estimate. WGMEDS notes that although the survey estimate could potentially provide uncertainty this is not used in the assessment. Instead the management procedure itself has been tested to be robust to uncertainty if using the 'uncertainty cap' so that the uncertainty of the survival estimate should provide an appropriate measure of risk.

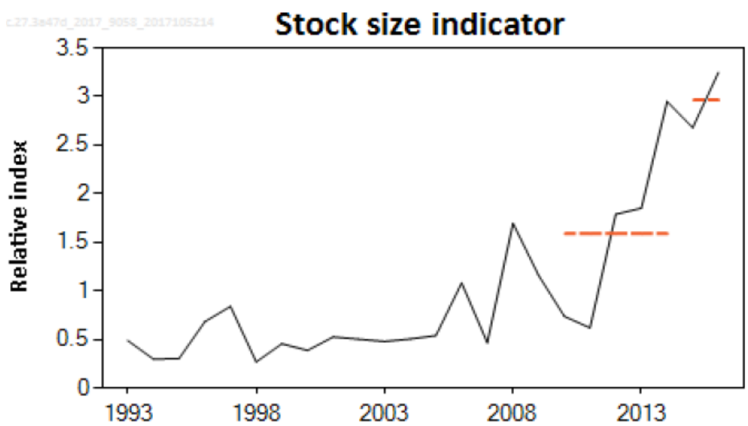


Figure 2.15. Case study: stock size indicator (relative biomass index, based on individuals of ≥ 50 cm total length) for thornback ray in Subarea 4 and in division 3.a and 7.d. The dotted horizontal lines show the mean stock indicators for 2015–2016 and 2010–2014 (Adapted from ICES, 2017).

Results suggest:

- the interpretation from WKSHARK suggests that using catch-based advice reduces the landings of the fishery in spite of an apparent substantial increase in the stock. However, the potential for landings is in fact an increase in the potential for landings by 6% if you can avoid discards all together.
- realistically, this will be difficult, but the problem is more to do with the precautionary approach used interacting with the mismatch between discard rates estimates based on an average including a smaller stock when discards were less. One would expect a reverse situation with a declining stock due to poor recruitment.
- The question is what is management really trying to achieve by managing to catches rather than landings and what are the associated risks and benefits to stock and productivity?

The final question of risks and benefits is the same trade-off is analogous to the question of when to issue an exemption. The landings obligation is not about correcting the 'waste' of natural resources because discard sized fish landed for no gain provide little or no benefit to the stock. Instead the objective is to gain closer control of F by eliminating the opportunity to exceed intended F. This has two benefits. First, F can be maintained closer to target levels ensuring that long-term yield for the stock are more optimal. Second, it incentivises the fishery to take measures to avoid discarding which will improve long-term productivity further. If discard survival is near 0 there are few risks to the implementation through the landings obligation, however with increasing rates of discard survival there is a trade-off in short-term productivity especially problematic for stocks thought to require rebuilding and a long-term reduction in yield assuming it is not possible to reduce discard rates through incentivisation. The effects are not through the management against catches rather than landings, but the requirement to 'land' discards as an enforcement measure. With realistic reporting of discarded catch quantities, the benefits could be realised without the risks. This is therefore an implementation / enforcement issue not a management issue. An exemption to the landings obligation is merely the reciprocal view, so when should one be granted?

Verkempynck *et al.* (2018) demonstrated how the differences between returning discarded and implementing the landings obligation can be quantified through simulations under the assumption that future discard rates are known and the uncertainty in discard survival estimates can be estimated accurately. WGMEDS would be in a position to provide the necessary information to complete such simulations.

The trade-off between the benefit of returning discarded fish / granting a dispensation and the risks of increasing the difference between the realised and targeted Fs expected by relinquishing at least partial control over the discard rate is a management implementation issue not estimable from existing data and will require socio economic expertise to predict fishermen's behaviour not in the current make up of WGMEDS. Without this work potential thresholds re unlikely to be any more objective than the value of 50% survival discards that has been suggested elsewhere.

Joint workshops or consideration of how such expertise could be brought into the group in conjunction with new ToRs for WGMEDS would present opportunities to make progress.

3 Conclusions

WGMEDs has successful met all ToRs set out at the beginning of the three-year term.

WGMEDS completed its 3-year term in November 2019. There have been discussions in the expert group whether there is a need for the expert group to continue since the original ToRs have been addressed. The expert group appears to be willing to consider new ToRs to address issues relating to discard survival that would benefit the ICES system.

The issue of the incorporation of discard survival in ICES advice has been a concern to some of the requesters of advice given the link between discard survival and the landings obligation regulations. Greater consistency in the use, description and treatment of discard survival in catch scenarios is therefore desired. Discard survival is routinely quantitatively considered in many Norway lobster (Nephrops) catch scenarios but seldom formally considered for other stocks with the exception of plaice in the Irish Sea where 40% of discards are assumed to survive. The rationale for not including discard survival for other plaice stocks is unclear. In addition, other species such as rays and skates can have high discard survival rates, but these are seldom quantitively included in catch scenarios.

ICES would benefit from the continuation of the expert group if future ToRs would address the issue of the incorporation of discard survival in ICES advice. Specifically, the expert group could:

1. Develop guidance to assist benchmark workshops and assessment expert groups determine whether the available survival studies for a given stock have been adequately conducted and are sufficiently robust and representative of the fishery to be used in catch scenarios.
2. Review specific discard survival studies that have not been peer-reviewed and provide comments on their suitability for inclusion in catch scenarios for ICES advice. For example, there are a number of recent studies on *Nephrops* (Bim, 2017; Albalat *et al.*, 2016) as well as on other stocks that are not used because it is unclear whether they are adequate.
3. Develop methodology to combine the results of survival studies on a given stock conducted with different gears, seasons, areas and handling methods to derive an overall best survival estimate of discards for the stock.
4. Propose standard approaches (preferably consistent across multiple stocks and species) to including discard survival in catch scenarios in the advice sheets depending on the ICES stock categories (1-6). The proposals would include the standard terminology to use, formatting of tables and details of the calculations depending on the stock category.

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Annex 1: List of participants

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Annex 2: WGMEDS resolution

2017/MA2/HAPISG03 A **Working Group on Methods for Estimating Discard Survival** (WGMEDS), chaired by Tom Catchpole, UK, and Sebastian Uhlmann, Belgium, will be established and will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	27 Nov-1 Dec	Olhão, Portugal	Interim report by 1 February 2018	
Year 2018	29 Oct-2 Nov	Mundaka, Spain	Interim report by 1 February 2019	
Year 2019	4–8 November (tbc)	Dublin, Ireland	Final report by 1 February 2020	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
a	Review and update guidance on 'Methods to Estimate Discard Survival' based on further theoretical and practical developments to assess discard survival levels.	a) Science Requirements b) The European Commission requested an EG develop Methods for Estimating Discard Survival to address the need for guidance on methods.	2.7; 3.1; 4.1; 6.4	3 years	Report on developments in methods and amendments or corrections required on the ICES CRR on Methods to Estimate Discard Survival, February 2020
b	Based on meta-analysis of discard survival data and practical studies, investigate variables influencing survival probabilities, with a view to increase survival through modified fishing practices.	a) Science requirements	2.1; 6.1; 6.4	2 years	Peer reviewed paper, February 2019
c	Review ongoing monitoring requirements and methods and recommend amendments that generate data which inform on the survival probabilities of released marine organisms	a) Science Requirements Promote i) the development of methods for assessing the vitality of animals released from commercial and recreational fisheries; including the validation of vitality assessment as proxy estimates of discard survival and assessing the utility of stakeholder self-sampling; and ii) advice on	1.6; 2.7; 3.1; 6.1	2 years	Report, February 2019

		effective sample sizes to estimate discard survival within confidence limits at fisheries scales.			
d	Application of discard survival estimates in fisheries management. Being proactive in engaging with other EGs to share new knowledge on discard survival.	a) Science Requirements b) Advisory Requirements The primary use for survival estimates has been in gaining exemption from the Landing Obligation. There are many other applications for this evidence relevant to stock assessments, ecosystem models, and fishing gear technology, and more broadly improving catch welfare.	2.7; 5.1; 5.4	2 years	Report describing and detailing new evidence on discard survival, February 2020

Summary of the Work Plan

Year 1	Working on all ToRs, but with special focus on ToR B, and identifying points of collaboration with other WGs (ToR D).
Year 2	Working on all ToRs, but with special focus on ToR C.
Year 3	Working on all ToRs, but with renewed focus on ToR A and ToR D.

Supporting information

Priority	The current activities of this Group will lead ICES into issues related to the ecosystem effects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities	SharePoint site.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	The work of this group will enable the collection of standardised discard survival data for a number of European fisheries, and therefore will provide supporting information for the advisory groups.
Linkages to other committees or groups	The activities of this group will be coordinated by SCICOM, through HAPISG. It will work closely with WGFTFB and WGRFS, and will develop links with other WGs and advisory groups utilising data from discard survival assessments.
Linkages to other organiza tions	The outputs from this group will be of interest to various Regional Advisory Councils, as well as institutes and organisations conducting discard survival assessments in support of the Landing Obligation of the new EU Common Fisheries Policy and relevant institutes in USA, Australia and elsewhere.

Annex 3: ToR a) Abstracts of presentations from recent discard survival assessments

***2019 only (for presentations for 2017 and 2018, please see WGMEDs reports 2017 and 2018)**

Survival of discarded invertebrates from bottom trawling fisheries in the Bay of Biscay

Germain Boussarie, Dorothée Kopp, Sonia Méhault, Marie Morfin

Studies on commercial fish survival are conducted everywhere in Europe to get exemptions from the landing obligation. Non-commercial species constitute a large part of the discarded fraction, but scientific knowledge associated with the survival of these untargeted but functionally important species remains to be filled. This is notably the case for a great proportion of discarded invertebrates, for which only a handful of studies have investigated their survival. In this study, 600 individuals from six different benthic invertebrate genera were collected in commercial conditions in the Bay of Biscay, aboard a 10.95 m-long bottom trawler rigged with a single otter trawl (20 m headline), and put in water tanks with continuous flow for survival experiments. Overall, the observed survival after 100–130 hours and the predicted survival via mixture models (SMMs) were very high (>93%) for *Asterias rubens*, *Aphrodita aculeata*, *Buccinum undatum* and *Pagurus pagurus*. Survival of *Maja brachydactyla* was lower though still high (>80% overall), and *Atelecyclus undecimdentatus* was more vulnerable to trawling and handling, with ~50% of survival. No biotic or abiotic parameters were found highly correlated to survival, except injury class for *M. brachydactyla* and *A. undecimdentatus*. This study shows an overall high survival but highlights the fact that otter trawl fisheries may differentially affect the discarded benthic invertebrates.

Plaice vitality assessments on-board an Irish Seiner (SSC)

Martin Oliver, Matthew McHugh, Daragh Browne, Shane Murphy, Ronán Cosgrove

In 2018 BIM conducted plaice survivability trials on an Irish otter trawler with a survivability result of 37–43% after 360 hours captive observation. With these results, an exemption to the landing obligation was applied for, however it was not granted for several reasons. Following this, BIM was approached by the seining fleet to consider a trial on seine caught plaice. The seining fleet consider their fish in good condition due to their softer fishing process – shorter tow duration and lighter ground gear. BIM decided to conduct vitality assessments on a commercial seiner operating in the Celtic sea. Plaice condition assessments were performed in the Celtic Sea ICES 7 j & g on request from the Irish seining fleet (SSC*). In total 477n plaice were assessed over a four-day period between 21– 25 October 2019. 11 fish were also retained in captivity on-board the vessel for a total of 92–96 hours. From a total of 477n assessed plaice, 282n were excellent, 136n were good, 55n poor vitality and 4 dead at the point of discard or gutting. Although a small sample size, captive observations showed 81% survival after 92–98 hours. Overall, preliminary results prove promising, with high percentages of plaice in excellent or good vitality and low injuries scores.

Survivability experiments on blackspot seabream (*Pagellus bogaraveo*) caught with longline in Portugal mainland (ICES Division 27.9.a)

Bárbara Serra-Pereira, Pedro Tomé, Tiago Bento, Inês Farias and Ivone Figueiredo

The Joint Recommendation of the South-Western Waters Regional Group (SWW) has requested for 2019 a high survivability exemption from the Landing Obligation for blackspot seabream (“red seabream“) *Pagellus bogaraveo* caught by “voracera” fishery in south of Spain (ICES Division 27.9.a) and for the hook-and-line fisheries in the Azores (ICES Subarea 27.10). The European Commission (EC) granted the exemption for those two fisheries and areas for the period

2019–2021, but which did not apply to catches of blackspot seabream by the demersal longline fisheries in Portuguese mainland waters (ICES Division 27.9.a). So, due to national interest on requesting an extension of that exemption, survivability experiments on-board the demersal longline fishery were done following the normal fishing activity by IPMA in 2019, under the project PPCENTRO. The main findings of those experiments were summarized to WGMDES, along with the main information on fisheries catching blackspot seabream in Portuguese mainland waters. From categorical, semi-quantitative vitality assessments after capture, the majority of the specimens of blackspot seabream were found to be in excellent (85–89%) or good (8–12%) condition, independent soak time. Body lesions assessed in this study did not seem to affect the observed vitality status after capture. The at-vessel-mortality observed in the sampled trips was 0.6–2.6%. From time-to-mortality experiments, the time at which 50% of individuals were expected to die after being exposed to air on deck, ranged from 45 minutes for specimens with an excellent vitality status to 23 minutes for specimens with a poor vitality status. No differences were found between different soaking times. From the captive observations the estimated survival rate after 36 hours was 86%.

Summary of scientific evidences available on discard survival of skates and rays (Rajidae) in Portuguese mainland waters (ICES division 27.9.a)

Bárbara Serra Pereira and Ivone Figueiredo

The available information on survival studies of skates and rays in Portuguese mainland waters (ICES Division 27.9.a), conducted by IPMA since 2011, was summarized, including evidences of survival of skates caught by setnets and trawl. Experiments were conducted on categorical vitality assessment (*R. clavata*, *L. naevus*, *R. montagui*, *R. brachyura* and *R. undulata* in net fisheries and R. clavata in trawl survey), mark-recapture (*R. undulata* in net fisheries) and short-term survival (preliminary captive experiments on *R. undulata* in trawl survey). The scientific results obtained so far during the different projects conducted by IPMA (DCF pilot study on skates and the UNDULATA project) support the fishermen perspective of high survivability of skates and rays to fishing. In particular, the vitality status after capture of *R. clavata*, *L. naevus*, *R. montagui, R. brachyura* and *R. undulata* caught by net fisheries is generally high, as the percentage of skates in Excellent and Good vitality status always represented more than 75% of the fish sampled, independently of the species, mesh size or soak time. The mark-recapture study (UNDULATA project) of *R. undulata* caught by trammel net obtained a return rate of 11% and the mean observed time-at-liberty was of 54 days and maximum of 313 days. These results are a good indication that the species has a potential high long-term survival. Vitality results *R. clavata* caught by otter-trawl in IPMA's surveys indicate that in overall most of the specimens are found in Excellent or Good conditions (60–72%), with an at-vessel-mortality of 6–7%. The preliminary estimated survival of *R. clavata* caught by otter- trawl in the Demersal survey was 64%.

Unaccounted mortality scenarios in Atlantic mackerel and herring fisheries and effect on stock assessment

Maija Tenningen and Fabian Zimmermann, IMR

The aim of this study is to review the literature on discard, slipping and net burst data for Atlantic herring and mackerel (rates and mortality), based on the available literature and data create likely scenarios with different quantities and age distributions of unaccounted mortality and run the assessment models including scenarios of unaccounted mortality. We estimated a proportion of possible unaccounted catches ranging from 1% to 50% and a mortality rate between 10% to 50% for herring or 30% to 100% for mackerel. A value from the probability distribution of unaccounted catches was randomly selected and applied as multiplier to the reported annual catches at age according to different scenarios. This process was repeated 1000 times and from the resulting stock estimates we calculated the mean annual SSB and 95% confidence intervals. The results show that current stock size is most likely an underestimation and the unknown discard/slipping proportion and mortality increases uncertainty substantially.

Discard survival estimates of commercially caught skates of the North Sea and English Channel

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Within the INTERREG 2-Seas SUMARiS (Sustainable Management of Rays and Skates) project, the goal of Work Package (WP2) was to quantify vitality, reflex impairment, injury and survival probability of skates discarded in the English Channel and the North Sea after being captured by commercial active (beam trawl - TBB, otter trawl - OTB) or passive (gillnets - GTN, trammelnets - GTR) fishing gears. This was achieved by combining on-board vitality assessments with monitoring observations of skates held in captivity (min. 21 days). The focus was on four commercially important skates of the North Sea (ICES-area 4c) and English Channel (ICES-area 7d), i.e. thornback ray (*Raja clavata*, L.), blonde ray (*Raja brachyura*, L.), spotted ray (*Raja montagui*, Fowler) and undulate ray (*Raja undulata*, Lacepède).Thirty-one trips were organized on-board of French, English and Belgian commercial vessels between July 2018 and January 2020. During these trips, biological parameters (e.g., length, sex, maturity, amongst others) were collected on-board and the condition of randomly selected individuals of skate species scored for their vitality, reflex responsiveness and visible bleeding injury (‘vitality assessments’). Vitality was determined by attributing a generic vitality score on a four-point ordinal scale (A = “excellent”, B = “good”, C = “poor” or D = “dead”) to the selected individuals from the catch and scoring quantitatively for four reflexes and six types of injuries. Using the proportion of “dead” (vitality score D) individual, the immediate survival was calculated. Skates were picked from the beginning, mid- and end part of the catch sorting process on deck. Trips were spread out over the year to incorporate potential seasonal effects on discard survival. For French and Belgian trips, a subset of the vitality-scored rays was kept on-board and transported to onshore holding facilities for further discard survival monitoring for at least 21 days. On-board of the vessel and during transport to the holding facility, rays were kept alive in custom-built monitoring units with recirculating seawater. During the monitoring period, dead rays were recorded and removed on a daily basis. During transport and monitoring, control rays were exposed to identical conditions as test rays to account for mortality caused by experimental procedures and holding conditions. Total survival estimates for all species tested were high for trammel netters at 99–100%. For active gears (OTB, TBB), average total mortalities varied among species and gears. For thornback ray caught by active gears (TBB and OTB), total survival ranged between 54% (TBB) and 72% (OTB). Blonde ray had a higher survival range of 67–86%. For spotted ray and undulate ray caught by beam trawlers, total survival was 27% and 58% respectively.