Survival of sole (*Solea solea*), turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*), thornback ray (*Raya clavata*) and spotted ray (*Raya montagui*) discards in North Sea pulse-trawl fisheries

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This is a DRAFT report that presents preliminary and incomplete results that may be subject to change in the final version of this report. This DRAFT report has not been subjected to internal review nor has it been checked and approved by the management of Wageningen Marine Research.

Publication date: date

Wageningen Marine Research
place, month year

CONFIDENTIAL No

Wageningen Marine Research report reportnumber

WAGENINGEN
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Click here to add one or more authors, year. *Click here to add a title; Click here to add a subtitle*. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report *reportnumber*. 20 pp.; number of tables tab.; number of ref. ref.

Keywords: XXXXX, YYYYY, ZZZZ.

Client: client
Attn.: name
address
zipcode, place

A_4_3_2 V27

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Summary

1 Introduction

Demersal pulse-trawl fisheries in the North Sea is a mixed fisheries that mainly targets Dover sole (*Solea solea*) and plaice (*pleuronectes platessa*). In addition to these main target species, various bycatch species such as turbot, brill and rays are of economic importance to the fishermen. Undersized fish and species with no market value are discarded. By 2019 this practise of discarding will be restricted for all quota regulated species by the implementation of a discards ban by the European Commission. Fishermen will only be allowed to discard quota regulated fish species when the discarded fish have high chances to survive.

Accurate estimates of discards survival are required to include the impact of the discard ban, which leads to 100% mortality among discards, in fish stock assessments. Accurate and fisheries specific discards survival estimates are also required if fishermen want to apply for high survival exemptions on the discard ban.

Only one study previously assessed the survival of discards from pulse-trawl fisheries, resulting in survival rate estimates of 15% (95%CI: 11-19%) for plaice, 29% (95%CI:24-35%) for Dover sole and 16% (95%CI: 10-26%) for dab (Van der Reijden et al., 2017). For other species that are commonly discarded by pulse-trawl fisheries such as turbot, brill, thornback ray and spotted ray, discard survival has never been assessed. Reliable estimates of discards survival for these species are thus non-existent for pulse-trawl fisheries. As a result the impact of the implementation of the discard ban on the stocks of these species cannot be assessed nor can fishermen apply for 'high survival' exemptions on the discard ban.

This study therefore aimed to provide the first estimates of discards survival in 80 mm pulse-trawl fisheries for turbot, brill, thornback ray and spotted ray. The survival of sole discards was assessed to sharpen the first estimate made by Van der Reijden et al. (2017). We collected these fish at sea during nine trips with commercial pulse-trawlers and monitored survival for 15 to 18 days .

2 Materials and Methods

2.1 Ethics statement

The treatment of the fish was in accordance with the Dutch animal experimentation act, as approved by ethical committees (Experiment 2017 D0012.002)

2.2 Experimental design

All fish were collected during nine sea trips with three commercial pulse-trawlers and three trips per pulse-trawler. The numbers of fish collected per species and trips are presented in Table 1. Sea trips were spread out over the year (Table 1) to account for the potential effect of varying fishing conditions throughout the year on discards survival (Van der Reijden et al., 2017). Within each sea trip, fish were collected from multiple hauls to account potential for variation in discards survival among hauls. The typical number of hauls was 40 to 50 per sea trip and for each species the test fish were collected from three to five hauls. We aimed to collect equal numbers of fish per haul but in practice this was not always possible as for the unpredictable availability of species within hauls. During some trips mortalities among test fish resulted in empty tanks in the monitoring units which were then utilized to collect additional test fish. Survival monitoring started during the sea trip and was continued for 14 days after the fish had been transferred to the laboratory. Total survival monitoring time ranged from 15 to 18 days after collecting depending on the day of test fish collection at sea.

Table 1 *Overview of sea trips and fish sampling: total number of test fish sampled and control fish deployed per species and sea trip.*

Trip	Vessel	Year	Month	Week	Sole		Turbot		Brill		Thornback ray		Spotted ray	
					# Test	#Control	# Test	#Control	# Test	#Control	# Test	#Control	# Test	#Control
1	UK33	2017	May	18	31	10	9	3	9	2	10	2	-	-
2	GO23	2017	May	21	30	10	11	3	12	3	11	2	-	-
3	TX3	2017	June	24	30	8	15	3	15	3	9	2	-	-
4	TX3	2017	July	28	30	10	8	3	9	3	9	2	-	-
5	UK33	2017	Sept	36	30	10	31	3	9	3	14	2	-	-
6	TX3	2017	Oct	44	30	15	12	3	9	3	14	2	-	-
7	GO23	2017	Dec	49	30	15	9	3	8	3	9	2	-	-
8	UK33	2018	Jan	4	30	10	9	3	10	3	10	2	14	2
9	GO23	2018	Feb	8										
Total					241	88	104	24	81	80	86	16	14	2

2.3 Sea trips

All fishery operations were conducted in the Southern North Sea according to the regular commercial practices of the pulse-trawlers. Sea trips typically started on Mondays around 0:00 and ended on Fridays around 4:00. For each haul during a sea trip the operational and environmental conditions were recorded by the skipper.

2.4 Experimental facilities

Fish sampled during sea trips were housed in four custom-built monitoring units installed on-board of the vessels. Each unit consisted of a stainless steel framework in which holds 16 24 L tanks (60 cm L x 40 cm W x 12 cm H), resulting in a total capacity of 64 tanks on a vessel. Each tank was equipped with an individual water supply. A central pump installed on the vessel continuously supplied surface seawater to the tanks. Water flow rates to the tanks were installed at approximately one tank volume per hour to maintain proper water quality. Tanks were covered with transparent lids to limit water losses by sloshing while allowing for visual inspection of the fish. Upon return of the vessels in their home ports, the entire units were off-loaded and transported to the laboratory by road in a temperature controlled truck. Transport time ranged from one to three hours depending on the home port of the vessel. During transport each unit was placed inside a pumping tank partly filled with seawater and equipped with a submerged pump to supply water to each fish tank in the unit. Fish tank discharged their effluents in the pumping tank allowing for recirculation of the water. Upon arrival at the laboratory the fish tanks containing sole were manually stacked in racks. Turbot, brill and rays were, grouped by species, stocked in x m2 tanks. All tanks were connected to a single water recirculation system consisting of a X L pumping tank and a X m3 trickling filter. Total system volume was approximately x m3 and continuously renewed with filtered water from the Oosterschelde at a rate of X m3/d. All tanks were placed in a temperature controlled room with its temperature set at the actual North Sea surface water temperature at the time of test fish collection. In the laboratory, all tanks were supplied with coarse sand as bottom substrate and the fish were fed daily to visually observed satiation with polychaete worms (*Nereis spp*) and uncooked brown shrimps (*Crangon crangon*). On-board, bottom substrate was not applied and the fish were not fed.

2.5 Collection and assessment of test fish

Test fish were randomly collected from the end of the sorting belt. To account for potential effects of processing time on discards survival (Benoit et al., 2013), fish were collected as much as possible in equal numbers at both the start and the end of the catch-sorting process of each haul. Collected fish were temporarily stored in 105L holding containers filled with seawater. During storage the seawater in the holding containers was regularly renewed to maintain sufficient dissolved oxygen levels.
Upon completion of fish collection, fish were sequentially taken from the holding containers to measure total length (TL: in cm below) and for vitality assessment and tagging. Fish were taken randomly from the holding containers in case more than the required number of fish had been collected. Vitality status of each individual fish was assessed by scoring vitality class, external damage and reflex impairment as described by Van der Reijden et al. (2017) and summarized in Table 2. For thornback and spotted ray the protocols for external damage and reflex impairment scores and were adapted (Table 2). Individual fish were tagged with Trovan Unique glass transponders (type ID100) to allow for identification of individuals throughout the experiments. Transponders were injected subcutaneously just behind the head using the injector IID100E. Upon completion of the vitality assessment and tagging, live fish were placed in 24 L tanks (see *Experimental facilities*) with a maximum of five (sole), three (turbot and brill), one or two (spotted rays) or one (thornback ray) fish per tank. Fish that were found dead (defined as the absence of Head-complex, Table 2) at the moment of vitality status assessment were recorded as dead at time zero. Dead fish were discarded and not replaced by live individuals.

2.6 Control fish

In each of the nine sea trips and for each species tested, control fish of the same species were deployed to separate potential effects of the experimental procedures on mortality from fisheries induced mortality.
Control fish were obtained from commercial beam trawlers which had been requested to collect least damaged and undersized fish from short hauls. Control fish were also collected during the sea trips

with the pulse-trawlers for use in subsequent sea trips. In both cases collected fish were stored on-board in 600L containers filled with surface seawater which was aerated and regularly exchanged to maintain proper water quality. Prior to their use as control fish were kept in tanks in the laboratory for at least three weeks. During this period, fisheries induced mortality levelled out while surviving fish could recover from injuries and regain good condition. Fish were fed daily with live polychaete worms (*Nereis spp)* and dead, uncooked brown shrimps (*Crangon crangon*) to visually observed satiation. Tanks with candidate control fish were inspected daily for mortalities which were removed upon detection.

During each of the nine sea trips, control fish were taken on-board of the pulse trawler where they were stored in 600L tanks with aerated and regularly renewed surface seawater. Only fish in visually observed good condition, well fed and without visible injuries, were selected for use as control fish. Control fish were exposed to the exact same experimental procedures as the test fish, including vitality assessment, tagging and housing in the monitoring units throughout the experiments. The number of control fish deployed was approximately 30% of the number of test fish per species (Table 1).

2.7 Monitoring of survival and experimental conditions

Monitoring of survival and experimental conditions started after the first fish had been placed in the monitoring units. All tanks containing fish were inspected twice daily on-board and once daily after transfer to the laboratory. Tanks were inspected for mortalities through the transparent lid of the tanks by visual observation of fish movement. In case any mortalities were suspected to be present, these individuals were gently touched with a blunt plastic probe to provoke a behavioural response. Fish that showed no response were manually removed from the tank and dead was confirmed by visual observation of the absence of the 'head complex' reflex (Table 2). Lethargic fish were not removed. Dissolved oxygen concentration and saturation and water temperature were measured (Hach Lange Multimeter XX). Water flows to the tanks were increased if oxygen saturation was below 60%.

2.8 Data analysis

The overall survival of test fish and control fish was estimated using the non-parametric Kaplan-Meier estimator (Kaplan and Meier, 1958). PM.

Table 2

Description of criteria to score vitality status.

Vitality class – All species	
Class	**Description**
A	Fish lively, no visible signs of loss of scale or mucus layer.
B	Fish less lively, minor lesions and some scales missing, mucus layer affected up to 20% of skin surface area, some point haemorrhaging on the blind side.
C	Fish lethargic, intermediate lesions and some patches without scales, mucus layer affected up to 50% of skin surface area, several point haemorrhaging on the blind side.
D	Fish lethargic or dead, clear head haemorrhaging, major lesions and patches without scales, mucus layer affected for more than 50% of the skin surface area, significant point haemorrhaging on the blind side.
External damage scores – All species (Damages marked with * were not scored for	

Thornback an Spotted ray)	
Damage	**Description (1 = present; 0 = absent)**
Fin or wings	Fins are damaged or split (including tail fin). Wings in case of rays.
>50%*	Damage to skin surface, scale or mucus layer at more than 50% of the dorsal body surface.
Head haemorrhages*	Presence of a haemorrhage in the head of the fish
Hypodermic haemorrhages	Presence of a hypodermic haemorrhage
Intestines	Intestines are protruding or are visible through damaged body tissue of the fish.
Wound	Presence of a wound such that flesh is visible.
Reflex impairment scores – Sole, turbot and Brill	
Reflex	**Description (1 = impaired; no (clear) response within 5 s of observation; 0 = unimpaired; obvious response within 5 s).**
Body flex	Fish is held on the palm of the hand with its ventral side up in the air. Fish actively tries to move head and tail towards each other or wriggle out of the hand.
Righting	Fish is held on the fingers of two hands with the dorsal side touching the water surface. When released the fish actively rights itself under water.
Evasion	Fish is held underwater in an upright position by supporting its ventral side with the fingers and its dorsal side with the thumbs. When the thumbs are lifted the fish actively swims away.
Stabilize	Untouched fish tries to find a stable position flat on the bottom by rhythmic and swift movement of the fins and/or body.
Tail grab	Fish is gently held by the tailfin between the thumb and index finger. Fish actively struggles free and swims away.
Head complex	Fish moves its operculum or mouth during 5 s of observation while laying undisturbed under water.
Reflex impairment scores – Thornback ray and Spotted ray	
Reflex	**Description (1 = impaired; no (clear) response within 5 s of observation; 0 = unimpaired; obvious response within 5 s).**
Wings	Ray is held out of the water, dorsal side up with one hand supporting the body at the head of the ray and the other hand supporting the body at the start of the tail. The ray actively flaps its pectoral fins (wings).
Eye retraction	While in the water the ray is gently tapped on the head just behind the eyes with a blunt probe. The ray actively closes and retracts its eyes.
Stabilize	While resting on the bottom, the ray is gently held by the tail. When the tail is lifted, the observer notices more resistance than caused by the weight of the ray; as if the ray sucks its body to the bottom of the tank.
Tail grab	While resting on the bottom the ray is gently held by the tail. When the tail is gently pulled backwards, the ray struggles free and swims away.

3 Results

DISCLAIMER

The results presented in this draft report are preliminary and subject to change because at the time of writing data collection nor data analyses has been fully completed. The overall survival per species presented here as preliminary results are subject to change because more data will be added (trip 9). The preliminary results presented below should therefore only be considered as indicative for the final, yet to be established final result.

3.1 Discards survival

Mean discards survival per species and discards survival per sea trip and species are presented in Table 3. Survival is presented as the number of fish alive after 15 to18 days of monitoring expressed as percentage of the total number of fish collected (test fish) or deployed (control fish).

The discards survival percentages reported for turbot, brill and thornback ray are based on a limited number of observations per species (Table 1). Therefore these discards survival percentages should be considered as indicative for the true discards survival percentages for these species in the 80 mm pulse-trawl fisheries.
The discards survival percentages reported for sole are based approximately three times more observations than the other species and therefore probably provides a more accurate estimation of the true discards survival in the 80 mm pulse-trawl fisheries. To what extend the current estimate for the sole discards survival represents the true discard survival percentages remains to be established.

The development over time of the survival of discards after collection at sea is presented per species in Figures 1 to 4. Mortality levelled out in all cases before survival monitoring was terminated showing that survival monitoring periods were of sufficient duration.

Clearly discards survival varies among species as well as sea trips. Environmental conditions such as sea state and water temperature and fishing conditions such as catch composition varied among sea trips (data not shown). The effect of these factors on discards survival is subject of further data analysis and will be reported in the final version of this report.

Survival among control fish was consistently high (mean survival over nine sea trips > 90%, Table 4) for all species tested. This shows that it is unlikely that the experimental procedures caused any additional mortality on top of the fisheries induced mortality.

Table 3 *Mean (n=8) discards survival (%) per species and the discards survival per species and sea trip for control fish and test fish. Survival is presented as the number of fish alive after 15 to18 days of monitoring expressed as percentage of the total number of fish collected (test fish) or deployed (control fish).*

Trip	Vessel	Year	Month	Week	Sole		Turbot		Brill		Thornback ray	
					# Test	#Control	# Test	#Control	# Test	#Control	# Test	#Control
1	UK33	2017	May	18	45%	100%	44%	100%	33%	100%	40%	100%
2	GO23	2017	May	21	50%	100%	55%	100%	25%	100%	82%	100%
3	TX3	2017	June	24	40%	100%	40%	100%	7%	100%	65%	100%
4	TX3	2017	July	28	23%	100%	63%	100%	0%	100%	56%	100%
5	UK33	2017	Sept	36	3%	90%	17%	100%	0%	100%	57%	100%
6	TX3	2017	Oct	44	10%	100%	33%	100%	33%	100%	79%	100%
7	GO23	2017	Dec	49	0%	100%	22%	100%	0%	100%	44%	100%
8	UK33	2018	Jan	4	0%	100%	0%	100%	10%	67%	0%	50%
9	GO23	2018	Feb	8								
Average of 8 trips					**21%**	**99%**	**34%**	**100%**	**14%**	**96%**	**53%**	**94%**

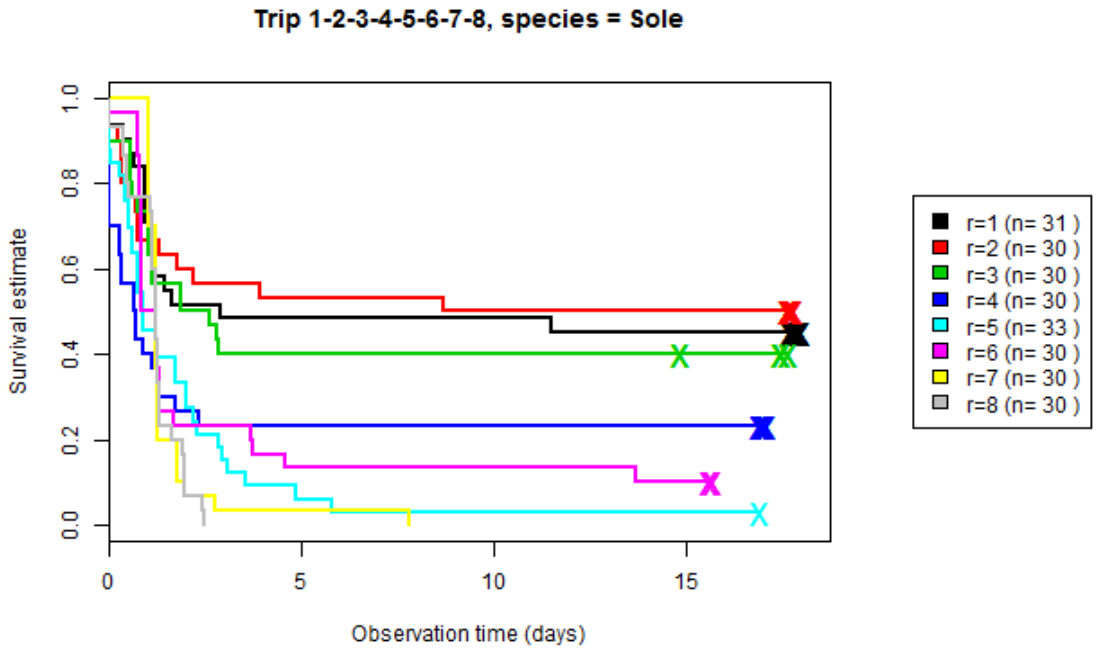

Fig. 1 Discards survival curves for sole per sea trip (r=1 to 8).

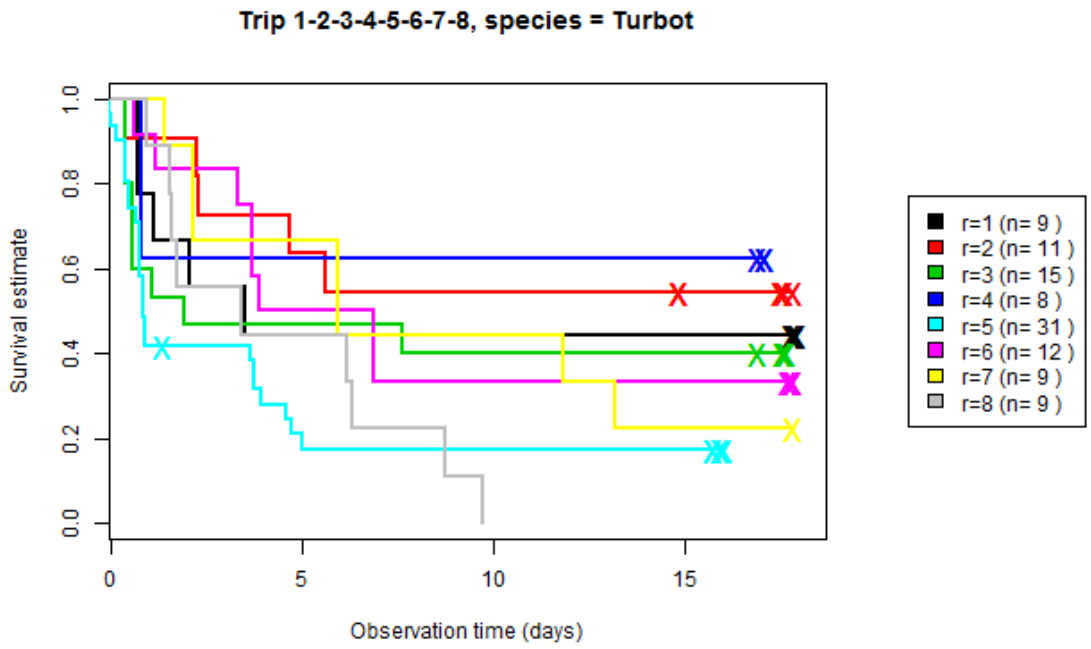

Fig. 2 Discards survival curves for turbot per sea trip (r=1 to 8).

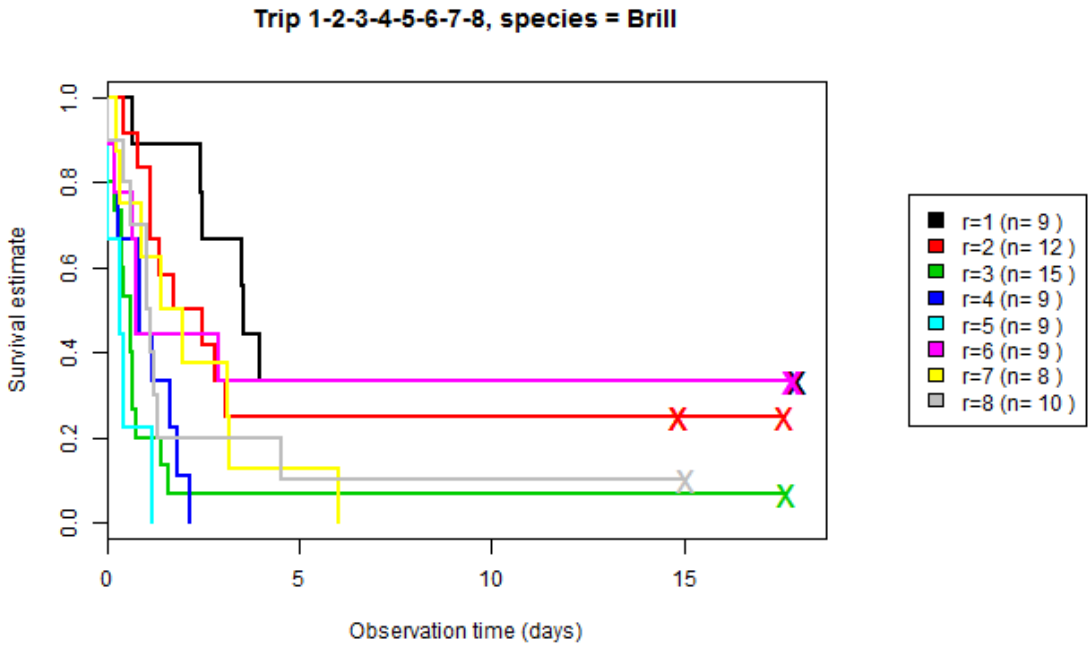

Fig. 3 Discards survival curves for brill per sea trip (r=1 to 8).

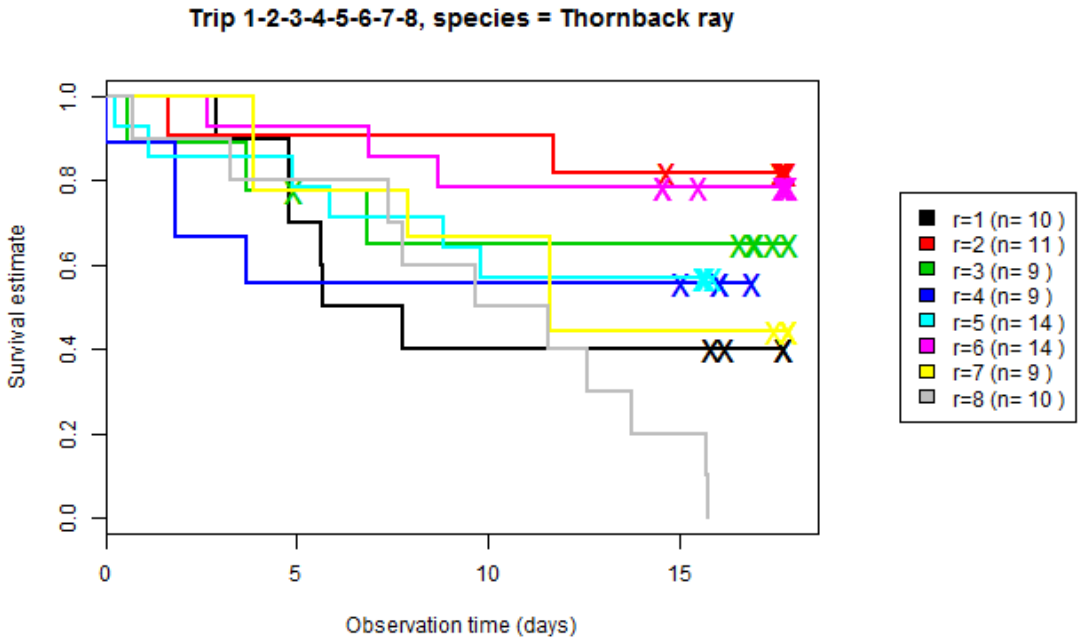

Fig. 4 Discards survival curves for thornback ray per sea trip (r=1 to 8).

4 Conclusions and recommendations

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5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2021 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

References

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Justification

Report reportnumber
Project Number: projectnumber

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

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Annex 1 Title annex

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