SHORT NOTE

THE SURVIVORSHIP OF RAYS DISCARDED FROM THE SOUTH GEORGIA LONGLINE FISHERY

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Abstract

Post-haulage survival experiments were conducted on 95 *Raja* sp. anon. cut off longlines at the sea surface by the Chilean fishing vessel *Isla Sofía* in May and June 2003 during the toothfish fishing season in Subarea 48.3. Capture depth had a consistently significant influence on the mortality of skates. There were some suggestions (not statistically significant) that wind speed (i.e. weather conditions) and the sex of rays also had some small influence on survivorship. Discard survivorship was 75% in waters shallower than 1 300 m (i.e. 1 200–1 300 m), 46% in waters 1 300–1 500 m, and 24% in waters between 1 500 and 2 000 m. These findings support CCAMLR's recommendation that skates and rays be cut from the line at the sea surface, so as to maximise their chances of survival. Results from this experiment can also be used to calculate the expected skate mortality within the fishery, based on depth of capture. Further survival experiments should be conducted, particularly in shallow waters, where sampling in this study was restricted.

Résumé

Des expériences de survie à la remontée ont été menées sur 95 spécimens de *Raja* sp. anon. coupés des palangres à la surface de la mer par le navire de pêche chilien *Isla Sofía* en mai et juin 2003 pendant la saison de pêche à la légine dans la sous-zone 48.3. Il s'est révélé que la profondeur de la capture avait toujours une influence marquée sur la mortalité des raies. Il a de plus été suggéré, sans pourtant que cela soit d'importance sur le plan statistique, que la vitesse du vent (les conditions météorologiques) et le sexe des raies avaient une légère influence sur leur survie. La survie au rejet était de 75% dans les eaux de moins de 1 300 m de profondeur (1 200–1 300 m), 46% dans les eaux de 1 300–1 500 m et 24% dans les eaux de 1 500 à 2 000 m. Ces constatations confortent la recommandation de la CCAMLR selon laquelle, pour avoir le maximum de chance de survie, c'est à la surface de la mer que les raies devraient être coupées de la palangre. Les résultats de cette expérience peuvent aussi être utilisés pour prévoir la mortalité des raies dans cette pêcherie, en fonction de la profondeur de la capture. Il conviendrait d'effectuer d'autres expériences sur la survie, notamment en eaux peu profondes où, dans cette étude, l'échantillonnage était trop limité.

Резюме

Эксперименты по выживаемости скатов после подъема были проведены с 95 особями неидентифицированного вида *Raja*, срезанными с яруса у поверхности моря на чилийском промысловом судне *Isla Sofía* в мае и июне 2003 г. во время сезона промысла клыкача в Подрайоне 48.3. Глубина поимки имела постоянно значительное влияние на смертность скатов. Имелись свидетельства (статистически незначимые) того, что скорость ветра (т. е. погодные условия) и пол скатов также оказывали незначительное влияние на выживаемость. Выживаемость выброшенных особей составила 75% в водах глубиной менее 1300 м (т. е. 1200–1300 м), 46% при глубине 1300–1500 м и 24% при глубине 1500–2000 м. Полученные результаты подтверждают рекомендацию АНТКОМа о том, чтобы скаты срезались с яруса у поверхности моря в целях максимального повышения их шансов на выживание. Результаты этого эксперимента могут также использоваться для расчета ожидаемой смертности скатов при промысле, исходя из глубины поимки. Необходимо провести дальнейшие эксперименты по выживаемости, особенно на малых глубинах, где выборка в данном исследовании была ограниченной.

Resumen

En mayo y junio de 2003, durante la temporada de pesca de austromerluza en la Subárea 48.3, el pesquero chileno *Isla Sofía* realizó un experimento para estudiar la supervivencia de 95 rayas de especies no identificadas luego de ser capturadas. Un factor significativo de la mortalidad de rayas fue la profundidad de captura. Asimismo, se observó cierta relación entre la supervivencia y velocidad del viento (condiciones meteorológicas) y el sexo de las rayas, si bien estos factores no fueron significativos. El porcentaje de supervivencia de las rayas liberadas por intervalo de profundidad fue de: un 75% a una profundidad menor de 1 300 m (i.e. de 1 200 a 1 300 m), 46% en el intervalo de 1 300 a 1 500 m, y 24% entre 1 500 y 2 000 m. Estos resultados corroboran la recomendación de la CCRVMA de soltar las rayas cortando la línea en la superficie del mar, para aumentar al máximo su probabilidad de supervivencia. También se pueden utilizar los resultados de este experimento para pronosticar la mortalidad de las rayas causada por la pesquería, sobre la base de la profundidad de captura. Se recomienda seguir realizando experimentos de este tipo, y en particular en aguas menos profundas, donde fue difícil realizar experimentos durante este estudio.

Keywords: survival, rajid, skate, rays, by-catch, longline, South Georgia, CCAMLR

Introduction

Knowledge of the post-haulage survival of Rajidae from the longline fishery around South Georgia is currently limited. The only information available relates to the preliminary findings of a survival experiment reported by Endicott et al. (2000). The findings of Endicott et al. (2000) suggested that skates hauled from depths of <500 m have a higher chance of survival than those hauled from greater depths. Endicott et al. (2000) also noted, through direct observation, that numerous injuries, such as damaged jaws, ripped musculature and externally prolapsed intestines, were thought to be attributable to capture and subsequent handling. These injuries were expected to significantly affect the ability of the skate to survive after haulage.

Findings by Francis and Smith (2002) from tagged skate recaptures in the Ross Sea indicated that skates can survive being captured and released by longline fisheries. Nevertheless preliminary findings by Endicott et al. (2000) suggested this is not the case for the majority of skate by-catch in the longline fishery around South Georgia. Although Francis and Smith (2002) found that skates can survive capture and release, the methodology used during tagging needs to be taken into consideration. Normally only skates that are alive and undamaged are selected, with animals not being deemed fit for tagging being discarded. This means that a potentially large and injured proportion of the population is not included in the study and would therefore have an unknown survival rate after hauling and release.

As part of the continuing commitment by CCAMLR to safeguarding the habitat and ecology of Antarctic and sub-Antarctic waters, conservation measures are continually being revised. During the meeting of CCAMLR's Working Group on Fish Stock Assessment (WG-FSA) in October 2002, methods of reducing skate by-catch were debated (SC-CAMLR, 2002). It was decided that whenever possible during longlining operations, live skates and rays should be cut from the line while still in the water. It was also recommended that scientific observers monitor the numbers of rays being caught, cut off the line as proposed, and brought on board the vessel.

The following experiment was conducted to determine what the discard survivorship might be under this new discard regime (i.e. cutting rays off at water surface level), making use of the presence of scientific observers on board commercial vessels fishing at South Georgia in the 2003 season. The experiment was undertaken during May and June 2003 with the support of the South Georgia Government and Pesca Suriberica and Gairloch Fishing, whose vessel, the *Isla Sofía*, was used for the work.

Materials and methods

The survivorship of Rajidae caught in the fishery was examined over a 2-month period in May and June 2003. Individual skates were selected from a variety of locations and depth ranges (between 746 and 1 913 m). Survivorship was determined by removing skates from the hauled longline and monitoring them in experimental tanks on the vessel for a period of up to 12 hours.

Eight insulated experimental tanks were installed on the foredeck of the fishing vessel *Isla Sofía*, with each tank having the capacity to hold an estimated 672 litres. It was considered necessary to use insulated tanks due to the extremely cold conditions that would be experienced during the course of the experiment. These tanks were fitted with a constant water supply fed by the ship's fire hydrant system, allowing a continuous circulation of fresh seawater to be pumped through the tanks (851 litres per tank per hour). The water intake for the fire hydrant was situated approximately 4 m below the sea surface. Monitoring of the water temperatures in the tank confirmed that there was no significant difference between water temperatures in tanks in which skates from the same haul had been placed. The overall mean water temperature throughout the series of experiments was 1.5°C.

Due to the unpredictability of skate capture in longlining, selection of skates was based on when and where they arose on a hauled line. This was effectively a random selection procedure. Upon selection, the skates were removed from the line by cutting the snood, and immediately placed in a tank where they remained for the duration of the experiment. During each experiment only one skate at a time would be placed in a tank, with a maximum of eight skates being tanked at any one time.

At the time of placement of each skate into the experimental tank, the following data was collected: haul number, depth of capture, time of tanking, species, sex and general condition. No other data were collected at this time, but further data were collected on completion of each experiment. Each skate was kept in the tank for a period of up to 12 hours, with observations being made at 6 and 12 hours to establish the condition of each animal.

During the initial stages of the experiment, it became apparent that there were difficulties in establishing whether a skate was alive or not. To overcome this, a set of criteria was developed to establish mortality. A combination of the following criteria was used:

(i) no movement of the spiracles;

(ii) no response to external stimuli;

(iii) no eye response to touch;

(iv) gill colouration: a ruby red colour in live animals and a pale pink or white in dead animals;

(v) when removed from the tank, live animals will arch back and may curl into a ball. Normally, muscle movement will also be seen in the spiracle and gill area in live animals. Common reactions observed in live skates: pectorals and tail curl under the body in a protective poise, or the tail may be arched upwards similar to that of a scorpion.

Skates that survived the 12-hour tanking period were released after taking measurements of total length and disc width, and were weighed using spring scales. When weather permitted, skates were tagged, and marked with oxytetracycline (OTC) for future growth validation on recapture. These animals were released back into the open water with the use of a dip net.

Skates that did not survive for the duration of the experiment were removed from the tank for post-mortem examination, noting the time at which they were observed to be dead. Morphometric measurements were taken as for live skates, with the addition of disc length, tail length, clasper length, noting stomach contents and stage of sexual maturity for both males and females.

Observations of injuries during the initial period of the experiment suggested that even skates which survived to the end of the experiment might not survive long term if they were seriously damaged by injuries sustained during the hauling process. Therefore all skates were examined at the completion of each experiment, and categorised by the seriousness of their injuries and their observed state of recovery in the light of its likely effect on their survival when released (Table 1).

Results

A total of 102 skates was tanked over the experimental period (Table 2). All three previously recorded skate species from this fishery were caught during this experiment: *Raja georgiana*, *Raja* sp. anon. and *Bathyraja meridionalis*. *Raja* sp. anon. was the most abundant skate species caught with a total of 95 individuals. Due to the low number

Table 1: Post-release survival categorisation of skates caught during the experimental period.

1. 100% expected death after release:
   - The skate is found to be dead within the 12-hour period after hauling.
   - The skate is alive after the twelfth hour of observation. However, injuries are observed which are considered life-threatening.
   - Examples of injuries: damaged mouthparts, prolapsed intestines, severely ripped muscle in the oesophagus and mouthparts.
   - Skate appears to be barely alive on completion of experiment. Either there has been no change in the skate since tanking or there has been an obvious deterioration observed in the skate throughout the experiment.
2. 50% expected mortality after release:
   - The skate is found to be alive at the twelfth hour of observation, but with limited activity. On examination it appears to have serious injuries, which are not deemed to be immediately life-threatening. Nevertheless, injuries are serious enough to possibly reduce post-release survival. Examples of injuries include large areas of ripped soft tissue in the oesophagus and mouthparts (observed whilst removing the hook) and small areas of ripped muscle.
   - A significant increase in activity has been observed since initial tanking, suggesting some recovery from the shock of hauling, and a decreased chance of mortality.
3. 100% expected survivorship after release:
   - The skate is alive and active after the twelfth hour of observation, and is found to have some small injury that is not deemed to be life-threatening. Examples: small areas of observed ripped tissue and muscles of the pectoral fins; hook puncture wounds in the soft tissue of the mouthparts.
   - The skate is found to be actively swimming around the tank at the end of the twelfth hour of observation with no obvious injuries seen.

Table 2: Descriptive statistics by sex of *Raja* sp. anon. retained for survival experiments during May and June 2003.

	Number	Minimum Length (cm)	Maximum Length (cm)	Average Length (cm)	Average Weight (kg)	% 12-hr Survival
Males	63	69	116.5	98.1	8.7	68
Females	32	69	117	97.4	9.3	34
Total skates tanked	95					

of *R. georgiana* and *B. meridionalis* caught in this study, a comparison of survivorship between species was not possible (Table 2). For the purposes of this paper, only data for *Raja* sp. anon. has been analysed.

Of a total of 95 *Raja* sp. anon. caught in the experiment, 53 (56%) were still alive after the 12-hour monitoring period. However, of these only 24 were judged to be in category 3 of Table 1 (100% survival after release), 16 were in category 2 (50% survival) and 13 were in category 1 (post-release survival unlikely). Adjusting the number of survivors to take account of this yields an expected total survivorship of 32 animals (all those animals in category 3 plus half those in category 2) (34% survivorship).

Two datasets were constructed taking into account the above adjustment to expected long-term post-release survivorship, based on the survival categorisation of skates in Table 1. Dataset 1 was used to examine the proportional survival rate of skates on a haul-by-haul basis (29 hauls in total), with the average reading of each environmental variable being determined for each haul. Variables examined for causal significance regarding proportional survival were depth of capture, air temperature and wind speed (Beaufort scale). Dataset 2 was used to examine the post-haulage survival of individual skates (95 individuals). Variables examined in this dataset were sex, maturity, total length, method of removal, position on the line, air temperature, depth and wind speed.

Dataset 1

Initial examination of the data established that depth was clearly an important determinant of survivorship. Unfortunately, because vessel operations were mainly directed at deep-water fishing

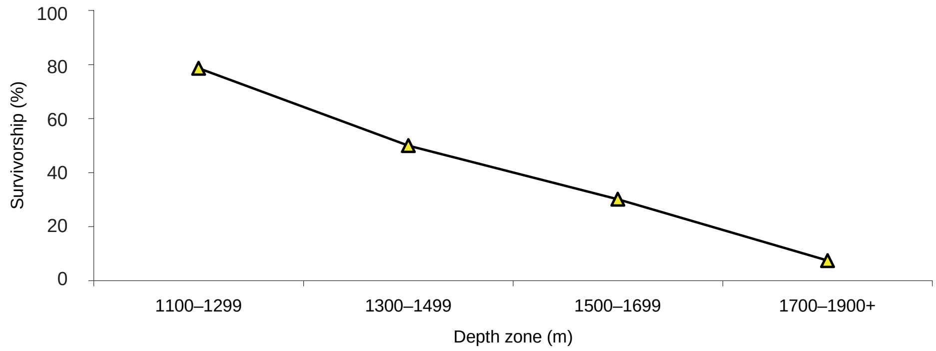

Figure 1: Results of survivorship experiments. Percentage of rays surviving 12 hours, adjusted for the '50% survivorship' category of Table 1.

for toothfish, 27 of the hauls were deeper than 1 100 m and one was at 746 m. This shallow haul caught only one ray that could be used in survivorship experiments. Because of the difficulty of interpreting the results of this single haul in terms of the general survival of rays caught in shallow water, the analysis was restricted to hauls deeper than 1 100 m (94 animals, Figure 1).

The importance of various factors was investigated with generalised additive models (GAMs) and generalised linear models (GLMs). Initial investigation of the data using a GAM with a spline on depth established that a three-order polynomial was a good approximation for the depth function. Weighting in the GAM/GLM was by number of skates in the haul experiment. A good fit was obtained with a binomial model and proportional survivorship as the dependent variable, resulting in a very linear normal quantile plot.

In both this and a GLM with the same structure, depth was the only significant parameter (Table 3). There was no difference in the fit, whether wind speed and air temperature were considered as continuous variables or factors. However, even though it was not significant there was a decrease in survivorship with increasing wind speed.

Figure 2 presents all the findings from the prediction model of dataset 1, clearly showing the strong relationship between survivorship and depth and predicting that skates caught at depths down to 1 200 m will have an 85% chance of recovery if released at the sea surface. Skates caught in waters deeper than 1 200 m are predicted to have a sharp decline in survivorship: between 1 400 and 1 700 m there is an expected 35% survivorship, and in deeper waters, survivorship declines further to 0% survival at 2 000 m.

Dataset 2

In an attempt to identify individual factors affecting survivorship, the analysis described above was repeated for individual skates. In this case survivorship was 0, 0.5 or 1 and weighting (sample size) was 1. The results were not as consistent as for Dataset 1, but the same patterns were apparent. The only additionally significant factor was sex, although there were suggestions that wind speed and animal size (length) were important (Table 4, Figure 3).

This GLM using individual data was not as robust as the GLM using data grouped by haul. For instance, if the 'intermediate survivorship' animals (group 2 in Table 1) were removed, sex ceased to be a significant factor.

Discussion

Although 102 skates in total were caught and tanked over the experimental period, only one species, *Raja* sp. anon., was found in sufficient numbers (95 individuals) to analyse at species level. The findings of this study have clearly shown that the depth of capture has a significant effect on post-haulage survival of *Raja* sp. anon., with post-haulage survivorship decreasing at depths >1 100 m (Figure 1). These results are similar to those first noted by Endicott et al. (2000).

There is some suggestion in the analysis of the second dataset that the sex of skates is important. However, this was not as consistent a result as the effect of depth and it remains to be investigated further. Findings by Francis and Smith (2002) have shown that for *R. georgiana* caught in the Ross Sea, female skates are much heavier and broader than males. *Raja* sp. anon. in all respects is a very close relative to *R. georgiana* and may have similar sexual dimorphism.

Table 3: Results of a binomial GLM in S-plus examining the individual significance of the effect of depth, air temperature and Beaufort scale on the proportion of skate post-haulage survival (response) within haul.

Variables	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)
Null			26	44.1	
Depth	3	16.5	23	27.6	0.0008
Wind speed (Beaufort scale)	1	2.9	22	24.6	0.085
Air temperature	1	0.17	21	24.4	0.679

Table 4: Results of a binomial GLM in S-plus examining the individual significance of the effect of depth, sex, total length, method of removal from line, position of capture on the line, air temperature and Beaufort ranking (variables) on the proportion of skate post-haulage survival (response).

Variable	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)
Null			93	97.0	
Depth	3	14.3	90	82.6	0.002
Wind speed	3	1.92	89	80.76	0.166
Sex	1	5.10	88	75.66	0.023
Total length	3	0.94	87	74.71	0.331
Placement on line	2	0.13	85	74.58	0.935
Method of removal from line	1	0.14	84	74.44	0.709
Air temperature	3	0.25	83	74.19	0.615

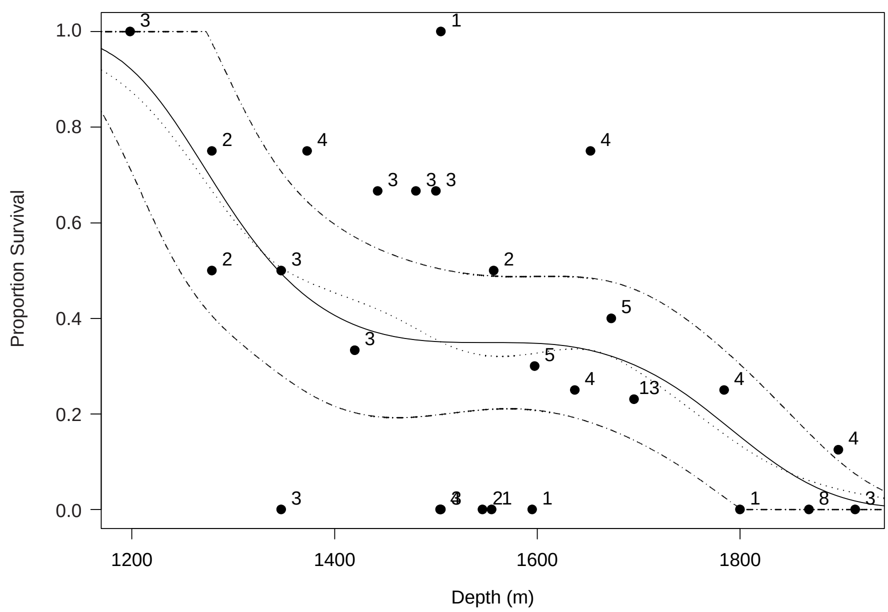

Figure 2: Predicted survival proportion and confidence levels, by haul, for *Raja* sp. anon. caught by the Chilean longliner *Isla Sofía* during May and June 2003 in the toothfish longline fishery in Subarea 48.3. The solid line and dashed 95% confidence intervals are from the GLM with the third-order polynomial function on depth. The dotted line is the GAM-fitted spline function on depth, plotted to show the close relationship between this and the polynomial approximation. Points are survivorship data for individual hauls, with sample sizes (number of skates) attached.

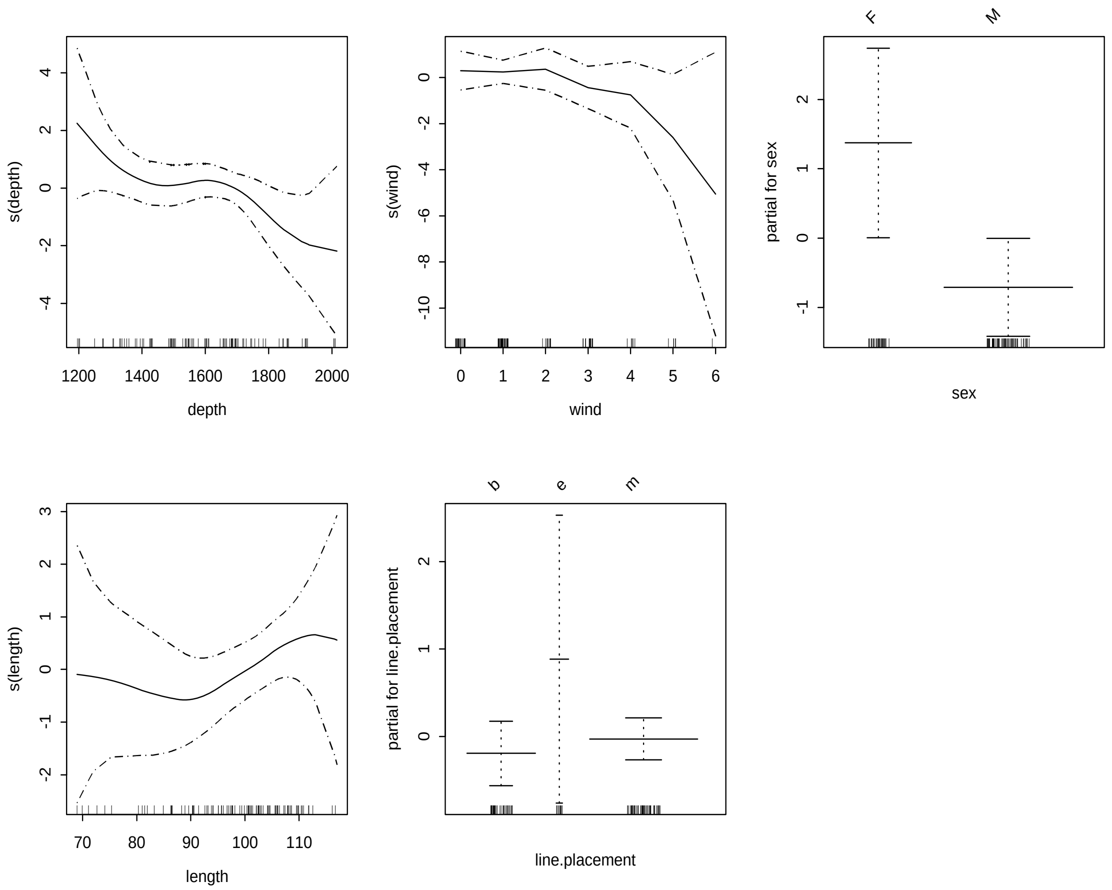

Figure 3: Results of GAM models in S-plus showing individual effects of depth, wind strength, sex, skate total length and position of capture on the line being hauled (b = beginning, m = middle, e = end) on skate survival.

Some trend between length of skate and survivorship was found, but this was rather counterintuitive, as one would expect larger skates to suffer more damage and therefore to have lower survivorship.

Surprisingly, weather conditions did not have a significant effect on survivorship, despite the fact that observations in the field and the trends in the GAMs (e.g. Figure 2) suggest that such a relationship might exist. It is logical that skates hauled to the surface during rough weather conditions would suffer more life-threatening injuries than those hauled during calmer conditions. It is assumed that such injuries would occur due to the increased jerking of the longline caused by the fishing vessel being buffeted by bad weather.

Although this analysis suggests high survivorship in depths shallower than 1 100 m, the sample size at depths less than 1 200 m is low. This was a consequence of the toothfish fishing pattern of the vessel, as the average depth for all hauls set over the experimental period was 1 321 m. Nevertheless, most *Raja* sp. anon. are caught in waters deeper than 1 000 m (Endicott et al., 2002, reported that 94% of this species were caught below 1 000 m, with the greatest number of captures occurring between 1 200 and 1 600 m). Thus the results of this study probably quite accurately reflect the expected survivorship of this species, but do not accurately estimate survivorship of rays caught in water shallower than 1 200 m.

Summarising the results of these analyses, uing the GLM in Figure 2, the discard survivor ship of *Raja* sp. anon. is estimated to be 75% in waters shallower than 1 300 m (i.e. 1 200–1 300 m), 46% in waters 1 300–1 500 m, and 24% in waters 1 500 and 2 000 m. In 2003, WG-FSA used these reults (adjusted for slightly different depth bands: 78% survivorship in waters <1 200 m, 56% 1 200–1 500 m, 24% 1 500–2 000 m) and combined them with the methodology of Agnew et al.

(2003) to estimate that the total mortality from the 172 tonnes of rays caught in Subarea 48.3 in the 2003 fishing season, of which 142 tonnes of rays were cut off the line, was 85 tonnes of rays (SC-CAMLR, 2003, Table 5.26).

More experiments are needed to determine survivorship of skates from shallow water, although present experiments, observations on the UK trawl surveys and previous reports (Endicott et al., 2000) suggest that survivorship of these skates at South Georgia is likely to be higher than those in the present experiment. Most of these rays will also not be *Raja* sp. anon. – they are more likely to be *R. georgiana*.

What is causing the mortality of skates? Is it the changes in pressure that the skate endures as it is hauled to the surface or injuries from the hauling process itself? Evidence from some other studies would tend to suggest the latter. Using skates caught in trawls, Laptikhovsky (pers comm; unpublished data from the Falkland Islands) found that skates are able to recover from considerable periods lying out on deck before being replaced back into water. Endicott (2003) reported good survival rates of skates trawled from depths down to 700 m during the South Georgia 2003 survey, where 60% of the 50 skates tanked were found to make a good recovery. He also reported that the skates that did not recover tended to come from trawls where there had been large amounts of benthos or fish within the trawl and speculated that these skates had been crushed within the trawl.

Summary

In May and June 2003, 102 skates were opportunistically selected from toothfish lines hauled by the vessel *Isla Sofía* and placed in specially constructed tanks on the deck of the vessel. Rays were lifted from the sea surface to mimic the handling they would experience if they were cut off the snoods at that level. After 12 hours the condition of the skates was recorded as 'likely to survive', 'intermediate' or 'unlikely to survive'.

Most rays caught (95 individuals) were *Raja* sp. anon., and only these were analysed further. Survivorship was primarily dependent on depth. For skates caught at depths between 1 200 and 1 300 m there was a predicted 75% chance of survival post haulage. Although evidence from other studies conducted by the authors suggested that survival will be higher in waters shallower than 1 200 m, for operational reasons, sampling for the present experiment unfortunately did not extend into these shallower waters. For skates caught in water between 1 300 and 1 500 m, survivorship was approximately 46%, and 24% for skates caught between 1 500 and 2 000 m. There is some suggestion that males have a better survival rate than females.

It is recommended that similar experiments be conducted elsewhere, especially in shallow water where sampling in this study was restricted. The results support the suggestion that cutting rays off the line at the sea surface will ensure that a significant proportion of them survive.

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