Survival rates for rays discarded by the bottom trawl squid fishery off the Falkland Islands

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Waters off the Falkland Islands are subject to a specialized multispecies ray fishery and were first fished by a Korean fleet in 1989. More than twenty different rajid species have been recorded from catches around the islands, and five species accounted for 87.04% of the total catch during 1993–2002. Catches peaked in 1993 at 8523 metric tons, and specific fishing licenses—R (second season) and F (first season)—were first introduced in 1994 and in 1995, respectively (Agnew et al. 2000; Falkland Islands Government, 2002; Wakeford et al., in press).

In addition to the licensed ray fishery, rays are taken as bycatch in the bottom trawl fishery that targets the squid *Loligo gahi* and, to a lesser extent, by the trawl fishery that targets finfish. A 10% bycatch of nontarget species is allowed in both these fisheries. In 2000–2002, the reported ray bycatch of trawlers not licensed to catch rays represented between 20.2% and 31.9% of the total ray catch. However, under-reporting of elasmobranch bycatch is a common practice for trawl fisheries where sharks and rays are discarded (Stevens et al., 2000), and the reported chondrichthyan catch is only about half of the estimated actual global catch (Bonfil, 1994). The actual ray bycatch in Falkland waters may be much higher than reported because only large rays are processed (and therefore, reported) onboard trawlers. This situation makes ray fishery management in the Falkland Islands, which is already difficult because of the nature of the multispecies target, even more complicated. However, good management is of primary importance because sharks and rays appear to be particularly vulnerable to over-exploitation because of their late attainment of sexual maturity, long life span, both low fecundity and natural mortality, and close relationship between recruitment and parental stock (Stevens et al., 2000). In the Falkland trawl fisheries (which includes most trawlers licensed to catch rays), rays smaller than approximately 30 cm disk width are discarded after spending between 5 min and 4 hours in the fish bin and passing through the factory sorting line together with other catch. Some rays that have been caught, stored, and then discarded still show signs of life. In contrast to other marine organisms whose survival after being discarded has been investigated, ray survival has been studied only in Australian waters (Stobutzki et al., 2002). The aim of this study was to investigate the survival rates of discarded rays onboard trawlers in the Falkland waters.

Materials and methods

The research was conducted onboard the Falkland Islands registered trawler *Sil* (length of 78.5 m, gross tons (GRT) of 2156 t, net tons (NT) of 647 t). The vessel used a bottom trawl with a vertical opening of 5 m, horizontal opening of 30 m, and a codend mesh size of 110 mm. Trawling speed varied between 3.8 and and 4.2 kn. Fishing occurred at a depth of 80–190 m during the day and the early part of the night. The surface temperature was 8.7–9.2°C; the near bottom temperature was 6.8–7.6°C. Up to four hauls occurred daily. Each catch was released from the codend into the fish bin, which had a continuous supply of sea water, and the catch immediately began to be sorted on a conveyor belt. Squids and commercial fish were separated from the noncommercial discarded bycatch and were frozen. Of a total of 4306.2 kg of rays caught during the observed period, 67.0% were discarded and only the large rays were processed. The time taken to sort the catch was between 1 and 3 hours.

A total of 66 rays that had been discarded by fishermen were sampled randomly from the conveyor belt and put into a 40-liter (44×35×26 cm) or a 60-liter (31×76×26 cm) fish box that contained running seawater. For each animal, the species and sex was identified and total length (TL) and disk width (DW) were measured within 1 cm. Their "stamina index" was assigned according to four major categories:

- A alive, flapping wings.
- I immobile, but alive, reacting to irritation, spiracles beginning to work actively after being placed in seawater.
- D dead; immobile, but spiracles begin to move slowly and irregularly after being placed in seawater.
- DD dead; paralyzed, body stiffened and wings curved but may resume breathing after being placed in seawater.

Each ray (including those evidently dead) was kept in these boxes either until its death was evident (no breathing) or it fully recovered and began to try to swim actively. In some rays the rate of spiracle contractions was episodically recorded.

Manuscript submitted 5 June 2003 to the Scientific Editor's Office.

Manuscript approved for publication 30 June 2004 by the Scientific Editor.

Fish. Bull. 102:757–759 (2004).

Table 1

Species composition and survival of sampled rays. DW= disk width.

Species	*n*	TL, cm	DW, cm	Time spent in fish bin (min.)	Survival rate (%)
Bathyraja albomaculata	14	36–61	26–44	20–110 (mean 45)	71.4
B. brachiurops	11	15–67	9–49	31–145 (mean 72)	54.6
B. griseocauda	3	62–83	47–60	30–75 (mean 60)	0.0
B. macloviana	2	36–42	24–29	70–135	0.0
B. magellanica	5	30–44	20–30	50–125 (mean 90)	60.0
Bathyraja sp.	16	24–104	21–74	5–120 (mean 52)	75.0
Psammobatis sp.	15	29–47	18–33	30–200 (mean 98)	60.0

Table 2

Ray survival (S%), mean recovery time (RT, min.), and occurrence of the four "stamina index" categories after different periods of time (T, min.) spent in the fish bin. T=time (minutes). A=alive; I=immobile; D=presumed dead; DD=dead.

				Occurrence of categories (%)			
T	*n*	S	RT	A	I	D	DD
5–30	16	87.5	38.2	18.75	25	18.75	37.5
31–60	20	75.0	55.5	10.0	30.0	40.0	20.0
65–120	24	41.7	102.2	0	20.8	50.0	29.2
125–200	6	16.7	20[1]	0	16.7	83.3	0

[1] Only one individual (*Psammobathis* sp.).

Results

The sampled rays belonged to eight species (Table 1). Of the 66 sampled rays, a total of 21 were dead at sampling, four recovered breathing but then died, and 39 survived. Two rays recorded as category DD in the "stamina index" were released before full recovery after being held for 4 to 9 hours in running water. Even though these individuals were still breathing, both were considered dead because they still had stiffened bodies and curved wings. If they had been in such a state for a long time in their natural habitat, they almost certainly would have been consumed by scavengers or caught again by another trawler. The overall survival rate was 59.1%, female survival rate was 66.7%, and male survival rate was 56.4%.

All five rays assigned to the "stamina index" category A were sampled between 5 and 30 min (mean 20 min) after the catch was poured into the fish bin. All five individuals began immediately to breathe normally and recovered within 5 to 20 minutes.

Of a total of 18 rays assigned to the "stamina index" category I, which were sampled between 15 and 145 min (mean 55.7 min) after haul, 88.9% (n=16) survived. The breathing of these specimens at the time of sampling was usually slow, although occasionally normal. Spiracle contraction rates gradually increased from an initial rate of 5–15 bit/min to 25–28 bit/min for *B.brachiurops* specimens and to 35–38 bit/min for individuals of *B. albomaculata* and *Bathyraja* sp. Upon attaining normal breathing, they remained immobile, but fully recovered between 15 minutes and 3 hours.

The survival rate of 28 rays that were assigned to the "stamina index" category D was 39.3% (n=11). Of the remaining individuals, two rays died after 15 and 45 minutes after being placed in running seawater and 15 rays were dead at the time of sampling. The skates were sampled between 30 and 200 min (mean 84.2 min) after the haul. Those that survived took 5–80 minutes to recover normal breathing and between 15 and 315 minutes to attain full recovery.

A total of 15 rays were assigned the "stamina index" category DD. However seven of them (46.7%) survived. These individuals were sampled between 20 and 115 minutes (mean 63.9 min.) after the haul and fully recovered within 40 to 150 minutes.

Survival rate varied substantially among the eight species sampled (Table 1). In general, ray survival drastically decreased and recovery time increased with the time spent in the fish bin (Table 2). The critical duration in the fish bin appeared to be between one and two hours; only one *Psammobathis* sp. survived more than two hours in the fish bin and exhibited a surprisingly fast recovery.

Discussion

The survival of discarded rays during trawling operations in the Falkland waters is quite important. Although 65.2% of the individuals were initially assigned as dead, the actual mortality was 40.9%, although it took some rays up to six hours to recover. Survival of shallow-water shelf species such as *Psammobatis* sp., in particular, but also *B. brachiurops* and *B. magellanica,* was somewhat higher than relatively deep-water species such as *B. albomaculata*, *B. griseocauda,* and *Bathyraja* sp., which inhabit the shelf edge and upper part of the slope. This survival rate was most likely related to the greater resilience to environmental changes for shallow-water species, whose habitat is more changeable both seasonally and spatially. Male survival was lower, which is in accordance with data for rays and skates obtained in northern Australian waters (Stobutzky et al., 2002).

Recent data from a tropical prawn fishery off northern Australia showed that on average 44% of individuals of a number of ray and shark species survived a trawling event (Stobutzky et al., 2002). The Falkland ray survival rate was higher. This difference may be due either to the higher metabolic rates of tropical ray species (and therefore a higher vulnerability to asphyxia), or to an overestimation of their mortality, which was assessed immediately after individuals where landed on deck (unlike the recovery time allowed in the present study). The latter factor is more probable because in the present study 41.9% of rays initially recorded as dead (D and DD) eventually recovered.

Despite the demonstrated ability of skates to survive after being caught and stored in fish bins, their continued survival is not guaranteed once they are discarded. They may fall prey to the hundreds of albatrosses and other scavenging birds that are associated with trawlers (author's pers. obs.). The consumption of different discarded fish species and squids from trawlers in Falkland waters by seabirds, primarily by black-browed albatrosses, has been studied (Thompson, 1992), but it is not known whether rays are also taken by sea birds and to what extent. Despite the great abundance of seabirds around vessels in the Southwest Atlantic, it is likely that they consume a minor part of discards as found in Australia (Hill and Wassenberg, 2000). Most of the discarded fish probably fall to the sea floor and attract and are consumed by bottom scavengers and bottom dwellers (Laptikhovsky and Fetisov, 1999; Laptikhovsky and Arkhipkin, 2003). Consequently, even after recovering and successfully avoiding the seabirds, the discarded skates may be consumed or mortally injured by these bottom scavengers during the recovery time, which appears to be about 0.5–1.5 hours.

Acknowledgments

I would like to thank the crew of FV *Sil* for their valuable help during sampling procedures and their hospitality onboard; the Director of Fisheries, John Barton, for supporting this work; A. I. Arkhipkin and an anonimous reviewer for valuable comments; and Helen Otley (FIFD) for language editing.

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