



## The Post-Release Survival of Two Skate Species Discarded by Bottom Trawl Fisheries in Antalya Bay, Eastern Mediterranean

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### Abstract

Knowing post-release survival rates of fish escaping or being thrown back into the sea as discards is important for effective stock assessment. The aim of this study was to estimate the short-term discard survival rates of the two most abundant by-catch skate species (thornback skate: *Raja clavata* and brown skate: *Raja miraletus*) in the bottom trawl fisheries in Antalya Bay and to determine the factors affecting discard survival of skates. For the thornback skate the mean health score, the percentage with a health score  $\geq 2$  and percentage dead at time zero were 2.3, 91% and 2%, respectively. For brown skate, these values were 1.2, 43% and 26.5%, respectively. Considering the health score of these species, the fish length ( $P=0.001$ ) and the tow duration ( $P=0.006$ ) were significant parameters for the thornback skate, and the tow duration ( $P=0.046$ ), the total length ( $P=0.044$ ) and the catch amount ( $P=0.008$ ) were found to be significant for brown skate. The mean survival time and the survival rate after 48 hours in tanks were 41 hours and 81% for thornback skate, and 15 hours and 21% for brown skate. The health condition of the individuals transferred to the tanks is an important reference point for their survival rates. Thornback and brown skates entering the tanks with a health score of 1 had a 44% and 9% chance of survival, respectively. On the other hand, skates entering the tanks with a health score of 2 or 3 had a 92% chance of survival for thornback skate and 49% for brown skate.

**Keywords:** Skate, discards, survival, *Raja clavata*, *Raja miraletus*.

### Antalya Körfezi (Doğu Akdeniz) Dip Trol Balıkçılığında Iskarta Olarak Avlanan İki Vatoz Türünün Serbestlik Sonrası Sağ Kalma Oranı

#### Özet

Iskarta olarak tekrar denize atılan veya donanımdan kaçan balığın serbestlik sonrası sağ kalım oranının bilinmesi etkin bir stok değerlendirme için çok önemlidir. Bu çalışmanın amacı, Antalya Körfezi dip trol balıkçılığında en bol yakalanan iki vatoz türünün (*Raja clavata* ve *Raja miraletus*) serbestlik sonrası sağ kalım oranlarının tahmini ve bu sağ kalımı etkileyen faktörlerin belirlenmesidir. *R. clavata* için, ortalama sağlık değeri, sağlık değeri  $\geq 2$  olanların ve sıfır zamanda ölü olanların yüzdeleri sırasıyla 2,3, %91 ve %2 olarak hesaplandı. *R. miraletus* için ise bu değerler sırasıyla, 1,2, %43 ve %26.5'dir. Bu türlerin sağlık skorlarının oluşmasında, total uzunluk ( $P=0.001$ ) ve trol çekim süresi ( $P=0.006$ ) *R. clavata*; çekim süresi ( $P=0.046$ ), total uzunluk ( $P=0.044$ ) ve torbadaki av miktarı ( $P=0.008$ ) ise *R. miraletus* için istatistiksel olarak anlamlı faktörler olarak belirlenmiştir. Ortalama sağ kalım süresi ve tanklara konulduktan 48 saat sonraki ortalama sağ kalım oranı *R. clavata* için 41 saat ve %81 iken, *R. miraletus* için bu değerler sırasıyla 15 saat ve %21 olarak hesaplandı. Tankta konan bireylerin sağlık durumu, sağ kalma oranları için çok önemli referans noktasıdır. Sağlık skorları 1 olan *R. clavata* ve *R. miraletus* bireyleri, 48 saat sonra sırasıyla %44 ve %9 yaşam şansına sahiptirler. Diğer yandan, yaşam skorları  $\geq 2$  olan bireylerin sağ kalma şansı *R. clavata* için %92, *R. miraletus* içinse %49'a yükselmiştir.

**Anahtar Kelimeler:** Vatoz, iskarta, sağ kalma, *Raja clavata*, *Raja miraletus*.

#### Introduction

Chondrichthyans are generally slow growing and late to mature with low fecundity and productivity, long gestation periods, high natural survivorship in all age classes and long life (Cailliet

*et al.*, 2005; Camhi *et al.*, 1998). These biological traits result in low reproductive potential and low capacity for population increase for many species (Cailliet *et al.*, 2005; Camhi *et al.*, 1998; Cavanagh and Gibson, 2007). Although directed fisheries have been the cause of stock collapse for many species of

elasmobranchs, a more important threat to long-lived sharks and rays is mortality in mixed-species fisheries and by-catch in fisheries targeted at other species (Bonfil, 1994; Musick, 1999). Bonfil (1994) reported that global catches of sharks and skates may represent half of what is actually being caught, and that large quantities are subsequently discarded (Stevens *et al.*, 2000).

On the Turkish Mediterranean coast, more than 210 commercial bottom trawlers are operating (Anonymous, 2011) and a high number of elasmobranch species are caught as by-catch in the bottom trawl fisheries. A pilot survey carried out to determine the by-catch species in bottom trawl fishing in the area revealed that 10 shark species (Güven *et al.*, 2012) and 12 skate species were caught between 20 m and 800 m depth. The effect of the catch-release process on the mortality of these species is unclear. Therefore, it is crucial to know the amount and the survival rate of discarded skates in bottom trawl fisheries for an effective management. Understanding discard survival alongside other sources of mortality and mortality patterns will contribute to a better understanding of population dynamics (Bonfil, 1994; Stevens *et al.*, 2000).

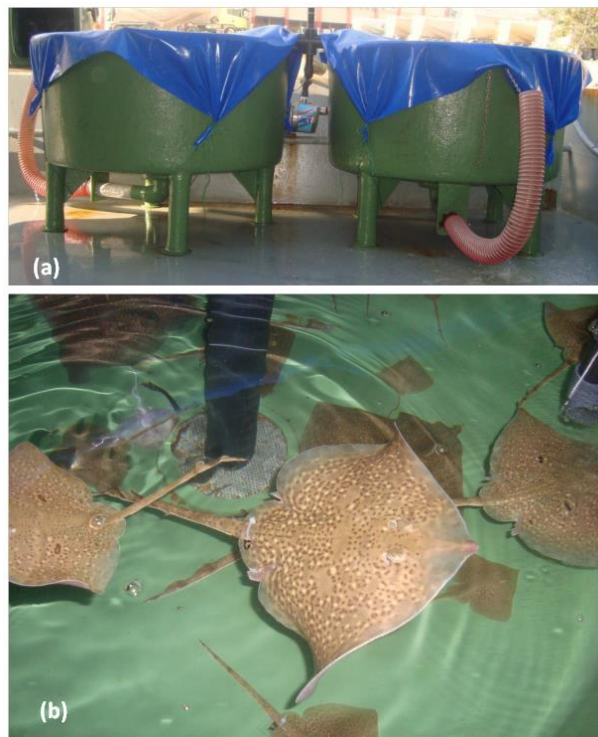
The aims of this study were to; *i*) estimate the short-term discard survival rates of the most abundant skate species caught as by-catch (thornback skate: *Raja clavata* and brown skate: *Raja miraletus*) onboard trawlers in Antalya Bay (eastern Mediterranean) and *ii*) to investigate the factors that affect skate survival. This study is the first of its kind in the Mediterranean basin.

## Materials and Methods

Experiments were carried out on the research trawler “*R/V Akdeniz Su*” (overall length 26.5 m, 160 GRT, engine power 670 kW) in December 2010 and February 2011 in Antalya Bay, eastern Mediterranean. The vessel used a traditional bottom trawl of polyethylene with a 17 m ground rope and cod end mesh size of 44 mm. Tows were conducted in a manner reflecting normal commercial practice. Trawling speed varied from 2.3 to 2.7 knots. Throughout the three surveys, 11 hauls were conducted, 6 of which were commercial (ca. 3 hours) and 5 of which were short (ca. 1 hour), during the daylight period at a depth stratum between 150 and 200 m.

After being hauled in, the catches were emptied directly onto the deck and the crew sorted the catch in the usual manner, selecting for the landed species. After 10–20 minutes of sorting, skates were removed from the catch and transferred to one of four circular holding tanks (100 cm in depth, 120 cm diameter and 500 l capacity). Water exchange was achieved at 3-4 l/min with the aid of two electric pumps drawing from the surface of the sea.

Following transfer to a holding tank (Figure 1a), the health status of each skate was controlled (within 2–3 minutes: time zero) and removed from the tank when dead (health score 0). Live skates were left in the tanks, recorded by species and health condition (score of 1–3), and individually coded with a nylon cable tie (marker type) on the tail at the end of the



**Figure 1.** a) Survival tanks, b) Tagged thornback skates in tank.

pelvic fin (Figure 1b). Individuals exhibiting a disc width  $\geq 40$  cm were held 6 individuals to a tank, and those exhibiting a disc width  $< 40$  cm were held 10 individuals to a tank. During the observation period, dark ambience was created with a plastic material and fish were not fed.

The health condition of individual skates was checked from the moment they were placed in the tanks (time zero) and every two hours during the first six hours (Chiaramonte *et al.*, 2006) and at 12, 24 and 48 hours (Enever *et al.*, 2009). Dead individuals were removed from the tanks and coding, sex and total length (TL, cm) were recorded.

### Assessment of Health Condition

At the beginning of the tank experiment (at time zero), during the observation intervals (2, 4, 6, 12 and 24 hours) and at the end of the tank experiment (48 hours) the health condition of the skates was described using four different stages (Laptikhovsky, 2004; Enever *et al.*, 2009; 2010). These were: 0 (dead), there is no movement in the body; 1 (poor health), moribund, there is little movement in the spiracle, the body might be contracted; 2 (moderate health), the body is loose, the fin and spiracle movements are weak; 3 (good health), fin and body movements are observed, the spiracle movement is rapid and the individual reacts against stimuli.

Overall, 120 individuals of thornback skate and 68 individuals of brown skate were taken into the tanks for the short-term survival assessment.

### Analysis of the Factors Affecting Survival Rate

Similar to Enever *et al.* (2009; 2010) and Mandelman *et al.* (2013), logistic regression models (SPSS, 17.0) were used for the analysis of probable

biological and physical factors (Table 1) that can affect the health condition and the short-term survival of the skates.

We coded health status into an ordinal model and used it as a dependent variable. For the 48 hour survival model we used a binary variable model (dead = 1, survive = 2) as the dependent variable.

### Results

The ranges for surface seawater temperatures (SST) and air temperatures between tows were 18.1–20.1°C and 8.0–17.0°C, respectively. Because SST varied only two degrees between trials, SST was not included as a factor in the logistic regression models.

In the commercial tows, the total catch amounts obtained from the cod end were a minimum of 70.9 kg, a maximum of 171.1 kg and an average of 138.7 $\pm$ 13.5 kg. Values for the short tows were 22.0–28.8 kg (mean 25.2 $\pm$ 0.8 kg). The weight of the skates among the total catch varied approximately 7.1–16.0 kg (Table 2).

During the 11 hauls with ~23 h of total trawling time, a total of 189 skates belonging to three species were captured. These were: thornback skate (n=120), brown skate (n=68) and common guitarfish *Rhinobatos rhinobatos* (n=1). Catch per unit effort (CPUE: fish/h) for the combined species was 8.2 fish/h. These values were 5.2 for the thornback skate and 3.0 for the brown skate.

### Thornback Skate

The total length (TL) of male thornback skates ranged from 23 to 60 cm with a mean of 42.5 $\pm$ 1.1 cm, and females ranged from 27 to 66 cm with a mean of 48.6 $\pm$ 1.6 cm. A significant difference was found in mean total length ( $t = 3.175$ ,  $P < 0.01$ ) between sexes.

**Table 1.** Factors evaluated as predictors of health score and 48 h survival in individual logistic regression models

Covariates	Levels	Health model	48 h survival model
Catch amount	$\leq 100$ kg=1; 100-200 kg=2	X	X
Total length (cm)	$< 40$ cm=1; $\geq 40$ cm=2	X	X
Tow duration (h)	short= 1; commercial= 2	X	X
Sex	male=1; female=2	X	X
Health score	dead=0; poor=1; moderate=2; good =3		X
Air temperature (C°)	$< 14^\circ\text{C}$ =1; $\geq 14^\circ\text{C}$ =2	X	X
Species*	Thornback/ brown	X	X

\*The factor was used only in accounting for both species together.

**Table 2.** Summary of trials and tows sampled, and the mean tow durations and cod end weights for short and commercial tows, standard errors (in brackets)

Tow	Date	No of hauls	Mean tow duration (h), ( $\pm$ se)	Mean haul weight (kg), ( $\pm$ se)	Mean skates weight (kg), ( $\pm$ se)
Commercial	24.12.2010	3	2.97 (0.1)	134.5 (23.1)	14.0 (2.6)
	28.12.2010	3	3.00 (-)	142.9 (13.8)	16.0 (2.8)
Short	09.02.2011	5	1.00 (-)	25.2 (0.0)	15.4 (3.4)

Of the 120 thornback skates captured, only two were dead at time zero and 109 skates were recorded with a health score  $\geq 2$  (Table 3). Ordinary logistic regression showed that the total length ( $P=0.001$ ) and the tow duration ( $P=0.006$ ) were significant parameters of health score at time zero (Table 4). The mean health score of 52 thornback skates captured in the short tows was 2.5 with no dead specimens recorded, and 98% had a health score  $\geq 2$ . The mean health score of 68 individuals captured in the commercial tows was 2.1, and 85% had a health score  $\geq 2$ .

The mean survival time in the tanks was 41 hours and the percentage surviving after 48 hours was 81% (Table 3). Binary logistic regression of the factors affecting skate survival in the holding tanks showed that only the health score at time zero ( $P=0.047$ ) was significant (Table 4). Skates entering the tanks with a health score of 1 had a 44% chance of survival. In contrast, skates entering the tanks with a health score of 2 or 3 had a 92% chance of survival.

### Brown Skate

The majority of brown skate captured were male (67.5%). The TL of males ranged from 14 to 43 cm with a mean of  $35.3 \pm 0.8$  cm, and females ranged from 27 to 59 cm, with a mean of  $39.4 \pm 1.2$  cm. A significant difference was found in mean total length ( $t = 2.823$ ,  $P < 0.01$ ) between sexes.

Individuals of brown skate that were assessed for health at time zero, exhibited a mean health score of 1.2, with 43% exhibiting a score  $\geq 2$ , and 26% (18 individuals) were dead (Table 3). Tow duration ( $P=0.046$ ), total length ( $P=0.044$ ) and catch amount ( $P=0.008$ ) were found to be significant parameters of the health score at time zero (Table 4).

The mean survival time of brown skate specimens in the tanks was 15 hours, and after 48 hours in the tanks their survival rate was only 21%. Binary logistic regression of the factors affecting brown skate survival in the holding tanks showed that only the health score at time zero ( $P=0.038$ ) was significant. Brown skates entering the tanks with a

**Table 3.** The health score at zero time, mean survival time in tanks and survival rate of two skate species caught

	Health score	Fish placed in survival tanks (n)		Mean time in tank, $h (\pm se)$	Survival rate (%)
		N	%		
<i>Raja clavata</i>	0	2	1.7	-	-
	1	9	7.5	26.7 (7.6)	44.4
	2	60	50	41.7 (1.7)	80.0
	3	49	40.8	45.8 (1.1)	91.8
		120	100	41.5 (1.3)	80.8
<i>Raja miraletus</i>	0	18	26.5	-	-
	1	21	30.9	9.2 (4.6)	9.5
	2	24	35.3	29.2 (3.9)	45.8
	3	5	7.4	26.0 (5.9)	20.0
		68	100	15.1 (2.3)	20.6
Both species	0	20	10.6	-	-
	1	30	15.9	14.5 (3.4)	20.0
	2	84	44.7	38.1 (1.8)	70.0
	3	54	28.7	44.0 (1.3)	85.1
		188	100	35.8 (1.3)	59.0

**Table 4.** Significant factors of the health score (Model I) and 48 h survival (Model II) for two skate species according to logistic regression modeling

Species	Parameters	Model I				
		estimate	st.err.	Wald $X^2$	df	P
<i>Raja clavata</i>	Total length	1.231	0.447	7.603	1	0.006
	Tow duration	-2.426	0.751	10.444	1	0.001
<i>Raja miraletus</i>	Catch amount	-2.556	0.963	7.048	1	0.008
	Total length	1.294	0.643	4.047	1	0.044
	Tow duration	-2.969	1.491	3.967	1	0.046
Both species	Species	-1.412	0.421	11.258	1	0.001
	Total length	1.161	0.358	9.853	1	0.001
	Tow duration	-1.517	0.580	10.514	1	0.009
Model II						
<i>Raja clavata</i>	Health score	0.929	0.468	3.945	1	0.047
<i>Raja miraletus</i>	Health score	1.361	0.656	4.312	1	0.038
Both species	Species	-1.577	0.515	9.369	1	0.002
	Health score	0.983	0.343	8.212	1	0.004

health score of 1 had a 9% chance of survival. On the other hand, skates entering the tanks with a health score of 2 or 3 had a 49% chance of survival.

### Both Species

Data for these two species were pooled to calculate the percentage of skates in each health score that survived at least 48 hours after being captured.

When accounting for both species together, the significant factors on the health of the skates were the total length of the fish ( $P=0.001$ ), tow duration ( $P=0.009$ ) and species ( $P=0.001$ ). Significant covariates of 48 h survival were the health score at time zero and species, with thornback skate exhibiting a higher survival rate (81%) relative to brown skate (21%).

### Discussion

Previous studies (Revill *et al.*, 2005; Enever *et al.*, 2009) have suggested that most mortality occurs during the first 24 hours of holding and that survival to 48 hours is a very good predictor of survival over a longer period. The 48 hour period therefore represented a good compromise between describing the mortality rate of individual fish and the number of fish that could be studied (Mandelman *et al.*, 2013). Following these studies, our study accepted the 48 h observation period as adequate for estimating survival of discarded skates.

The two skate species we evaluated had an average survival rate of 59% for at least 48 h when the skates were returned to the sea in the bottom trawl fishery. The data from a tropical prawn fishery off northern Australia showed that on average 44% of individuals of elasmobranch species survived a trawling event (Stobutzki *et al.*, 2002). Laptikhovsky (2004) reported broad survival rates in 66 sampled rays belonging to eight species (average 59%, range 0–75%) caught by commercial bottom trawlers off the Falkland Islands. Enever *et al.* (2009) estimated 55% survival in four species by using a standard 80 mm diamond cod end. Changing the mesh shape from square to diamond increased the survival rate from 59% to 65% for 48 hours (Enever *et al.*, 2010). In previous studies evaluating the short-term survival of winter skate (*Leucoraja ocellata*) in a scallop dredge fishery in the western North Atlantic, the percentage of post-release survival (48 hour) ranged from 50% (Benoît, 2006) to 90% (Benoît *et al.*, 2010a). For the same region, Mandelman *et al.* (2013) estimated an overall survival rate of 81% (range 41–92%) for 72 hours in four trawled skate species. Due to the different tows, depth ranges, deck sorting times and evaluated species, it is difficult to make direct comparisons between studies.

In the current study, when considering the species independently, thornback skate demonstrated higher health scores (at time zero) (91%  $\geq 2$ ) and a

smaller percentage (19%) died in the holding tanks. In contrast, brown skate showed lower health scores (43%  $\geq 2$ ) and a higher proportion (79%) died. Most thornback skate captured in the bottom trawl fishery are released alive and in very good condition, suggesting that post-release survival is high. This finding is supported by Enever *et al.* (2009). The thornback skate is more robust to the capture and discard process than other species (*R. microocellata*, *R. brachyuran*). Thornback skate have more accentuated spines, which offer it better physical protection than the much smoother skin of the other species, a possible factor for their high survival rates (Enever *et al.*, 2009).

Health scores have in turn been shown to reflect the diverse conditions experienced by fish during the capture and discard process (Benoit *et al.*, 2012). Discard mortality is known to increase with air exposure duration. Depth of capture and duration of the fishing set can also affect mortality (Benoit *et al.*, 2010b). In the current study, the logistic regression model showed that health score was positively affected by fish length while tow duration negatively affected the health score at time zero for both species (*R. clavata* and *R. miraletus*) ( $\beta=-2.426$  and  $\beta=-2.969$ ). Previous work has demonstrated that increasing the retention time may lead to a reduction in the number of surviving skates (Enever *et al.*, 2009; Enever *et al.*, 2010; Mandelman *et al.*, 2013).

The health score (at time zero) of skate species was also influenced by additional factors. The catch amount was determined to be another negative effect ( $\beta:-2.556$ ) on the health score at time zero in brown skate. The correlation between catch weight and survival of discarded skate is likely to be due to the skates being subjected to increased compression in the cod end leading to more injuries (Mandelman and Farrington, 2007; Revill *et al.*, 2005). The thornback skate (mean TL: 47 cm) exhibit no effect from the catch amount, which is likely due to the larger specimen size than brown skate, offering it better physical protection. The smaller total length of brown skate (TL mainly between 14–43 cm, with a mean of 37 cm) likely explains the lower health score as a function of the catch amount. Sex was not significant for either species. The species was a significant factor in both models (health score and 48 hour survival), confirming that for any given body length, *R. clavata* have a higher health score and survival rate than *R. miraletus*.

The health score at the beginning was the main significant factor on the survival of the skates in the tanks. Results of the previous studies (Enever *et al.*, 2009, 2010; Benoit *et al.*, 2010) are also parallel to our findings as the ray specimens released back to sea with a health condition above 2 had a better chance of survival. In this study, 88% of skates entering the holding tanks with a poor health score did not survive. In contrast, 76% of skates with a health score of 2 or 3 did survive.

There are few published studies on survival rates of by-catch species globally, and no other similar study exists in the Mediterranean basin.

The Turkish bottom trawl fishery in the eastern Mediterranean, as in the rest of the area, is based on a multi-species nature. In this fishery, when selectivity is achieved in only some species, sufficient selectivity is not possible for many other species due to differences in body shape, size and behaviors (Ateş *et al.*, 2010). Skates and rays of all sizes are widely caught in multi-species fisheries and because of their body morphology are not able to escape from the cod end (Enever *et al.*, 2009). A recent paper by Enever *et al.* (2010) suggests that two experimental cod ends (100 mm diamond mesh and 100 mm square mesh) reduced the mean cod end weight by 47% and 78%, respectively. It stated that greater survival rates of skates were obtained with experimental cod ends (59% and 65%) in comparison to standard cod ends (80 mm diamond mesh) (56%). Today bottom trawl fisheries carried out in the Aegean and Mediterranean coasts of Turkey enforce a minimum mesh size of 44 mm diamond shaped mesh.

In order to create an effective stock assessment on the ray species and to evaluate the data obtained more efficiently in bottom trawl fisheries in the eastern Mediterranean, we recommend that *i*) the amounts of by-catch and discarded skate species should be recorded in commercial fisheries, *ii*) for identification of the long-term survival rate, a tag-recapture study should be started, and *iii*) future research should also be directed towards applying the turtle excluder devices (TEDs) and by-catch reduction devices (BRDs) in bottom trawls.

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