Updated analysis of spine-tailed devil ray post-release survival

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Executive summary

Spine-tailed devil rays (*Mobula mobular*) are frequently taken as bycatch in purse-seine fisheries targeting skipjack tuna (*Katsuwonus pelamis*) around the northern North Island. Devil rays are a protected species, and they are returned to the water following capture. In previous research projects carried out for the Department of Conservation, we estimated the survival of devil rays returned to the sea, determined the factors that influence the capture and post-release survival of devil rays, and made recommendations on ways to reduce and mitigate devil ray captures. In this report, we update some of our previous analyses using observer and tagging data to the end of the 2018–19 fishing year, and also update the recommendations.

Ten purse seine trips aboard five different vessels were observed in 2013–2019. On these trips, 36 sets caught 71 devil rays, an average of 2.0 rays per set. Handling information was provided for 58 of those 71 rays: 22 came from skunked sets, and 36 from successful or partially successful sets. Devil rays caught in skunked sets were released while in the water (36%) or after lifting aboard in the net (64%). Devil rays caught in successful sets were mainly (81%) brought aboard in the brail net. Since 2013, vessels may have avoided setting on ray-associated tuna schools, and this may have reduced the number of devil rays caught. When devil rays have been caught, there is evidence of improved handling. Data from before and since 2013 show that there were similar proportions of skunked and successful sets in the two periods, but there has been a recent increase in the frequency of vessels opening the net on skunked sets to let devil rays go in the water. By reducing the handling and physical and physiological trauma caused by lifting devil rays onboard, their chances of survival have probably increased. Where rays were brought onboard in either the brail or net itself, there was evidence of improved release handling in the later time period, e.g. cutting the net to drop the ray directly back into the water and use of a cargo-net to lift rays over the side on one vessel.

Sixteen devil rays were tagged with ‘pop-up’ tags during 2013 to 2018, and 14 of the tags transmitted data, allowing a determination of whether the devil rays had survived 30 days following tag and release. Four of the first seven devil rays tagged in 2013−2015 (57%) died. However, only one of seven devil rays tagged in 2016−2018 (14%) died. The overall mortality rate for tagged rays in 2013–2018 was 36%. All mortalities of tagged rays resulted from skunked sets followed by lifting of devil rays aboard in the net. In contrast, all devil rays that were tagged from successful sets were brailed aboard, and all of them survived. The number of devil rays tagged is too small to draw strong conclusions, but a reduction in the mortality rate of released devil rays is consistent with observed improvements in handling and releasing methods used by purse seine crews.

Recommendations are made for avoiding devil ray captures, reducing mortality of rays that are caught, and improving data collection and analyses.

1 Introduction

Spine-tailed devil rays (*Mobula mobular*, formerly known as *M. japanica*; species code MJA) are frequently taken as bycatch in purse-seine fisheries targeting skipjack tuna (*Katsuwonus pelamis*) around the northern North Island (Paulin et al. 1982; Jones & Francis 2012). Spinetail devil rays (hereafter called 'rays') are not utilised by fishers, and are returned to the water following capture. The species was protected in New Zealand waters in 2010, and this has led to an increased awareness of the need to handle them carefully, and return them to the water quickly. It has also led to the funding of research projects by the Department of Conservation to estimate the survival of rays returned to the sea, determine the factors that influence the capture and post-release survival of rays, and make recommendations on ways to reduce and mitigate ray captures. In previous Department of Conservation studies, we reported on these features up to the end of the 2015 fishing year (October 2014 to September 2015) following analyses of data collected from commercial fishers, fisheries observers, and a satellite tagging study (Jones & Francis 2012; Francis 2014; Francis & Jones 2017). In this report, we update some of our previous analyses using observer and tagging data to the end of the 2018–19 fishing year (hereafter called the 2019 year).

The objectives of this study were:

Objective 1. To provide updated estimates of post release survival of *Mobula japanica* [= *Mobula mobular*] bycatch in purse seine fisheries

Objective 2. To identify operational, biological and environmental factors which affect the likelihood of post-release mortality

Objective 3. To provide recommendations on the most effective methods to reduce post-release mortality

2 Methods

In this study, we followed the same methods used for the analysis of observer and tagging data as used previously (Jones & Francis 2012; Francis 2014; Francis & Jones 2017). A summary of the relevant methods follows.

Data forms were provided to observers from 2012 onwards to document ray captures. The format of the forms and the information requested has varied since 2012. A questionnaire style form was supplied to observers in 2012 and 2013. These were subsequently replaced with an 'Observer Devilray Bycatch Form (DOC12307)', with pre-defined codes for ray status, handling codes to indicate which parts of the fishing operations the rays passed through (e.g., encircled in net, sacking [reducing the amount of net in the water to a 'sack' in which the catch is concentrated], in first brail [the small net used to hoist the catch out of the sack on to the deck]), time in the sack, time on deck and release method (e.g., released from net in the water, released from brail, released from deck), and release status. These forms were replaced with a 'Protected Ray Interaction Form' from 2016 onwards. This most recent format incorporates slightly modified codes with more space to provide descriptive information. The form records size and sex if collected, and a condition status table to score for activity on capture, wounds/injuries, and activity on release. In addition to these forms, the Non-fish Bycatch and Protected Species Form also records life status, injury status, size and sex and whether a fish is tagged or samples collected. Where a ray is tagged, a tagging sheet is also completed with information on the tag, the status of the ray, where the tag was attached, release location, etc.

For the period 2013–2019, the information on these forms, along with any available photos or video and information from the Central Observer Database (*COD*), were used to quantify the frequency of different interaction scenarios as a two-step process: first, how the ray was brought onboard, and second, the onboard handling and release method. We were able to use the 'Result' code from the COD database extract to classify sets as either successful or skunked (sets with no or minimal catch of the target tuna). Sets classed as 'partial' were re-classified as successful because they involved a similar operational process as successful sets. These set outcome data were also used to update the results from the previous study that covered fishing years 2005–2012, for which the status of sets was not always indicated in the information available to us at the time. From 2013 onwards, the handling of the tagged rays was also summarised separately.

Rays were tagged by MPI observers aboard commercial skipjack purse-seine vessels using pop-up archival transmitting (PAT) tags produced by Wildlife Computers Ltd (models miniPAT and sPAT; Table 1). The intention was to assess whether these rays survived after being caught by purse seine, subjected to normal handling practices, and then released. Consequently, observers were instructed not to make any special effort to treat the rays better than the crew would normally have done. Only rays that were lifted on to the deck were tagged, because rays that were released from the purse seine net while still in the water were expected to be in excellent condition and survive (Hutchinson et al. 2015). Observers were instructed not to tag rays that were dead or obviously moribund. All tagged rays appeared healthy and lively and had only minimal superficial injuries. Tags were anchored in the central, thick part of the wing musculature using a PIER umbrella anchor with eight plastic barbs, some of which were covered with a dacron sleeve to promote tissue healing around the anchor (Domeier et al. 2005). Anchors were attached to tags by 10–11 cm long monofilament nylon or stainless steel tethers. A plastic, serially numbered, conventional tag was looped around the tether of the PAT tag and its nylon anchor was inserted 50 mm into the wing to provide a secondary attachment point, and to restrict movement of the PAT tag. PAT tags were fitted with a release device designed to sever the tether and release the tags if they sank below 1700−1800 m, to avoid them being crushed. A similar attachment method has been used successfully to track *Mobula mobular* for up to 188 days in the Gulf of California (Croll et al. 2012).

Tagged rays were sexed (only possible if the pelvic fins were visible), and their disk width (DW), disk length (DL) and weight were measured or estimated. The entire tagging procedure took only a few minutes. The behaviour of the ray following release was recorded, as were the location, sea surface temperature (SST) and sea bed depth at the point of release.

MiniPAT tags are designed to monitor approximate geographic location, vertical movements and water temperature. The tags were programmed to record light intensity, depth and temperature at 5 s or 15 s intervals, and archive the data in memory until the tag released itself either on a programmed date, or detached prematurely. Tags also stored time series of depth and temperature measurements. MiniPAT tags 'detect' death by monitoring vertical movements from measurements of depth recorded by its pressure sensor. If no vertical movement is detected by the tag within a pre-programmed period (3 days in the present study), the tag releases itself by sending a current though the metal pin that connects the tag to its tether, and an electrolytic reaction with seawater dissolves the pin in a few hours. This allows the tag to float to the surface where it begins transmitting data to a satellite. Dead rays are expected to sink to the sea bed, thus producing a period of constant depth. If a ray dies over deep water, the tag's depth-activated safety mechanism will release it at about 1800 m depth. Live rays are expected to swim continuously and at various depths, so the constant-depth auto-release will not activate on living rays, and the tag will not pop up until the prescribed end-date for the experiment (or the tag anchor pulls free from the ray prematurely). Depth data from the days before tag pop-up were used to determine whether the ray survived until that time.

sPAT tags are designed to determine whether an animal survives being caught and released. They are similar to miniPAT tags, but they record and transmit a reduced set of data. These data are analysed by Wildlife Computers who then provide reports giving tag popup date and location, daily minimum and maximum depth and temperature, a daily assessment of whether light levels are varying, and a 'reason for release'. The last item is classified into four categories: (1) completed deployment (the animal is assumed to have survived based on daily variation in depth, temperature and light); (2) sinker (the tag sank deeper than 1700 m, presumably attached to a dead animal); (3) floater (the tag was floating at the sea surface, either through animal mortality or premature tag detachment); and (4) sitter (the tag was sitting stationary on the sea bed, presumably attached to a dead animal). sPAT tags were programmed by the manufacturer to pop up and transmit data if the ray died, or after 30 days, whichever happened first. Rays with tags in category 1 were interpreted as having survived the 30-day deployment, rays in categories 2 and 4 were interpreted as mortalities, and rays in category 3 were classified as alive or dead at tag detachment by inspecting the associated depth data.

3 Results

3.1 Tagging

Sixteen rays were tagged off northeastern North Island, New Zealand, during summer (January–April) 2013–2018 (Table 1). All rays were caught and released near the edge of the continental shelf (approximately defined by the 200 m isobath) (Figure 1). The rays were measured or estimated to be 110−200 cm DL and 191–270 cm DW. Eleven of the rays were sexed, and they comprised seven males and four females. Male *M. mobular* mature at about 200−210 cm DW, with females maturing at perhaps a slightly larger size (Notarbartolo-di-Sciara 1988; White et al. 2006), so all the tagged rays except one were probably mature.

Fourteen of the 16 tags transmitted data, allowing a determination of whether devil rays had survived 30 days following tag and release. The rest of this report analyses data for the 14 successfully tagged rays. At the time of our previous study, tags from seven of the nine rays tagged in 2013–2015 had reported data, and four of those seven rays (57%) died within 1−4 days of release, as indicated by their rapid descents to ~1800 m (Francis & Jones 2017). Since then, data have been received from seven further rays tagged in 2016–2018, of which one (14%) died. Photographs show that the position of the tag for the ray that died was over the body cavity, which could have caused damage to body organs and compromised chances of survival. The overall mortality rate for tagged rays in 2013–2018 was 36% (5 rays out of 14 for which data were received).

Table 2 summarises the onboard and release handling for each of the 14 tags that transmitted data. All of the tagged rays that were caught in skunked sets, and one of the rays that were caught in successful sets, were lifted aboard in the net, either because they were tangled in netting or were enclosed in the bunt of the net after it was pulled onboard. The remaining six rays from successful sets were brailed aboard.

All six rays that were brailed aboard survived, regardless of how they were released back into the water (Table 2). Five out of eight rays that were brought onboard in the net died; four came from skunked sets and one from a successful set that did not have enough fish to brail onboard. Rays that died were released by lifting by the crew (3), brailer (1) or cargo net (1). Rays that survived were released directly from the net (2) or by cargo net (1).

Rays lifted onboard in the brailer, returned to the sea swiftly, and handled in a way that minimised injury, were most likely to survive. Rays from skunked tows had a lower survival rate, probably because they were lifted aboard in the net rather than brailed out. However, the recent tagging results indicate that rays brought onboard in the net can survive when improved handling methods are used.

Table 1: Tagging details for 16 rays released from purse seine vessels off northeastern New Zealand. End status indicates whether the ray was alive or dead at the end of the track. Blanks indicate no data were available.

Tag date	Tag number	Tag type	Tagging location	Tag latitude	Tag longitude	Disk length (cm)	Disk width (cm)	Sex	Weight (kg)	Depth (m)	Days tracked	End status
10 January 2013	115490	MiniPAT	E Poor Knights Is	35.39	174.99	140	260		130	300	82	Alive
11 January 2013	115491	MiniPAT	N Poor Knights Is	35.29	174.62	130	260	F	140	141		
12 January 2013	115492	MiniPAT	NE Great Barrier Is	35.83	175.62	130	265		130	240		
10 February 2013	115487	MiniPAT	NE Great Barrier Is	35.75	175.50	110	215	M	90	179	186	Dead
11 February 2013	115488	MiniPAT	NE Great Barrier Is	35.74	175.49	140	240	M	100	187	4	Dead
11 February 2013	115489	MiniPAT	NE Great Barrier Is	35.78	175.56	130	260		110	215	190	Dead
7 March 2014	115490_2	MiniPAT	Gt Exhibition Bay	34.67	173.19	120	260	M	130	83	1	Dead
6 April 2015	142682	sPAT	Gt Exhibition Bay	34.72	173.49	115	245	M	150	145	30	Alive
9 April 2015	142681	sPAT	Gt Exhibition Bay	34.67	173.36	135	250	F	150	133	30	Alive
13 March 2016	142678	sPAT	Hokianga Harbour	35.54	173.08	120	240		80	164	4	Dead
14 January 2017	142683	sPAT	E Great Barrier Is	36.06	176.08	200	250				31	Alive
15 February 2017	142677	sPAT	N Mokohinau Is	35.65	175.23	120	240	M		204	12	Alive
19 February 2017	142679	sPAT	Doubtless Bay	34.83	173.86	135	270	M		155	14	Alive
25 January 2018	142680	sPAT	E Poor Knights Is	35.54	175.10	113	191	F	80	331	30	Alive
25 January 2018	152519	sPAT	E Poor Knights Is	35.54	175.10	115	240	M	100	331	10	Alive
18 February 2018	152518	sPAT	E Cape Karikari	34.79	173.83	150	250	F	160	157	3	Alive

Table 2: Onboard and release handling matrix, showing the fate of tagged rays. Tags that did not report data are not included. A, alive; D, dead.

	Bringing onboard handling	
Release handling	Brailed onboard	Lifted onboard in the net
Skunked sets		
Released directly from net into water (lowered or rolled)		A, A
Released from deck - lifted by crew		D, D
Released from deck - by brailer		D
Released from deck - cargo net & winch		A, D
Successful sets		
Released from deck - by brailer	A	
Released from deck – lifted by crew	A, A	D
Released from deck - rope sling & winch	A, A	
Released from deck - cargo net & winch	A	

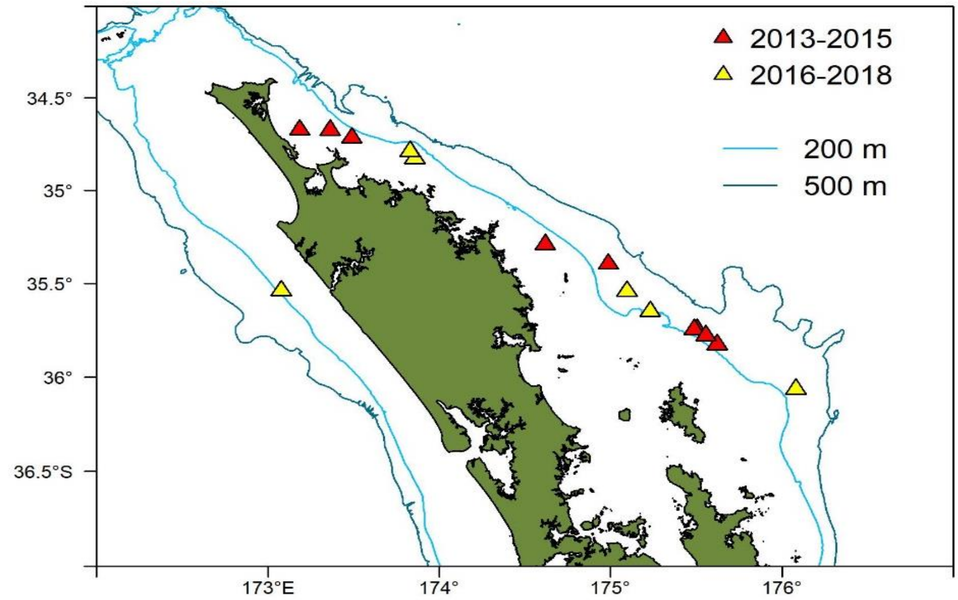

Figure 1: Tag release locations for rays in two time periods.

Most of the surviving tagged rays showed strong northward movements after release, with three tags popping off in Fiji and Vanuatu waters (Figure 2). The maximum distances travelled (via the shortest direct routes between tagging and popup locations) were 1404, 1867 and 1878 km respectively in 30 days.

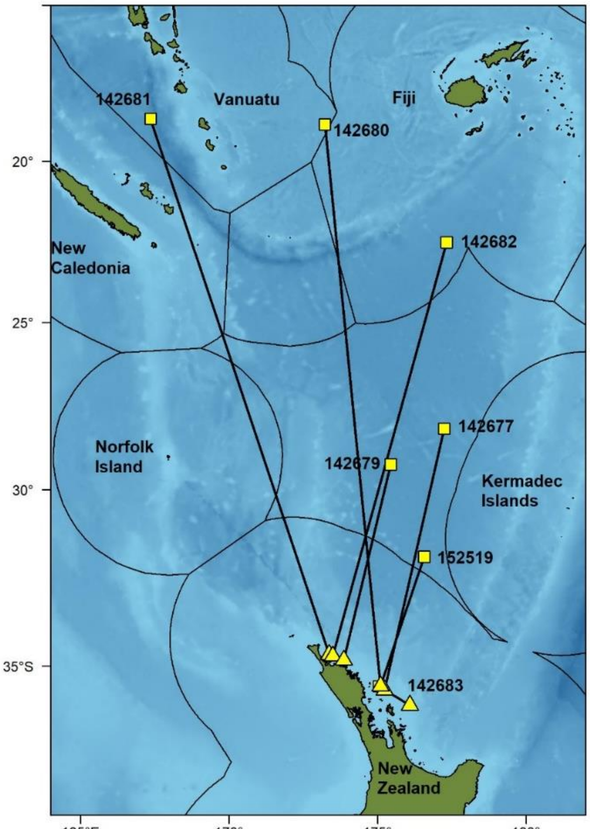

Figure 2: Start (triangles) and end (squares) locations of sPAT tag deployments on rays.

3.2 Observer data

3.2.1 Location and frequency of occurrence of rays in the purse seine fishery

Our previous studies summarised information on number of sets, location, and frequency of occurrence of rays from the observer database between 2005 and 2015 (Jones & Francis 2012; Francis & Jones 2017). From 2016 to 2019, observers reported 15 purse seine sets that caught 28 rays (Figure 3). Most ray sets occurred in the region between Great Barrier Island and North Cape This hotspot has been extended northwards from that identified by Francis & Jones (2017). For the recent period 2016–2019, 6.0% of all observed sets caught rays; however, in the hotspot region off northeast North Island, 23.3% of sets caught rays. These values are similar to the values calculated for the period 2005–2014, which were 8.2% of all sets and 24.3% for sets in the (smaller) hotspot (Francis & Jones 2017).

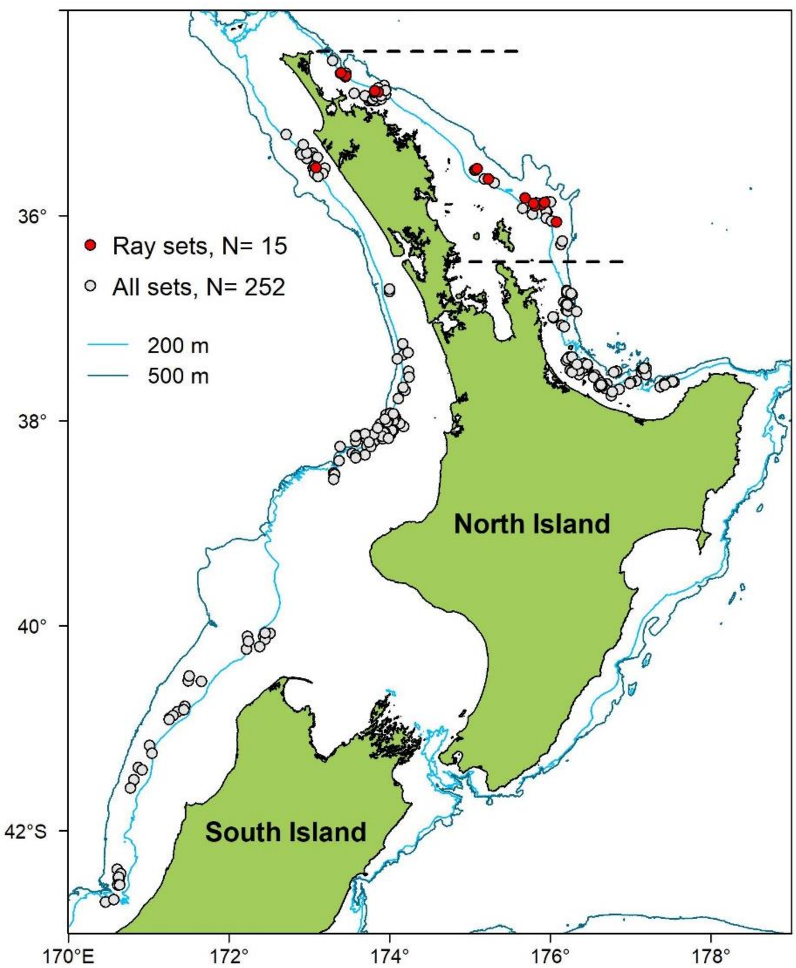

Figure 3: Locations of observed purse seine sets and ray captures in 2016–2019 fishing years. Dashed lines encompass the region identified here as a ray 'hotspot' area for purse seine captures.

3.2.2 Analysis of handling and release of rays

Update of data from 2004 to 2012

In our previous studies, information on handling was often only available in relation to how rays were brought onboard, and if this depended on whether the set was successful or skunked. With access to more information from the *COD* database, we have updated the previous table from Jones & Francis (2012) to include sets with previously unknown outcomes (Table 3). For the sets where rays were observed as a bycatch, 40% were classed as skunked. For half of the skunked sets, the ray handling method was unknown; where observations were made, the rays were usually brought on deck in the bunt of the net, with only three instances of them being released from the net while still in the water. In successful sets, where information was provided, the rays were mostly brailed onboard with the catch, apart from one instance where a ray was brought onboard in the bunt after brailing had occurred, and one instance of being released while still in the water. Although not usually described, photos and occasional comments indicated that a common method to release the rays overboard from the deck was to lift them using a large hook inserted into their gills or into an incision made in a wing.

Table 3: Frequency of different handling methods for ray bycatch as inferred from observer diaries and photographic evidence during 2004–2012. Successful sets include partially successful sets.

Handling method	Skunked	Successful	Total
Released in water, swam out of net	2	1	3
Tangled &/or caught in bunt, lifted out of water / brought on deck	10	1	11
Brailed onboard		21	21
Tangled but released while still submerged	1		1
Unknown handling	13	16	29
Total	26	39	65

Data from 2013 to 2019

The more detailed information collected by observers from 2013 allowed an in-depth description of handling and release methods (Table 4). A total of 10 trips aboard five different vessels were observed in 2013–2019. On these trips, 36 sets caught 71 rays, an average of 2.0 rays per set. Handling information was provided for 58 of those 71 rays: 22 came from skunked sets, and 36 from successful or partially successful sets.

From the skunked sets, 8 out of the 22 rays observed were released in the water by opening the net or sinking the corks. This represented three sets from two trips on different vessels. In one trip, the observer commented that the pursed net was submerged and opened to release trapped rays after two skunked sets. In another trip, five rays were 'seen during rolling, the Hautzer was released and all five swam free'. Because the rays remained in the water, none were tagged, but odds of survival were assumed to be good. In the remaining skunked sets, rays were generally brought onboard in the net as it was rolled (around two-thirds of the skunked total), usually in the bunt (Figure 4). Of these, most (n=8) were able to be rolled out of the net directly off the stern or dropped directly from the net back into the water (Figure 5). Two rays from this group from two different trips were tagged, and both survived (tags 142683 and 152518). These two categories represented around 70% of the rays caught in skunked sets, and it is assumed that in these instances, time out of the water and handling of the rays was limited and survival was high. Risk factors could include how long the net took to be rolled onboard, and whether the rays became entangled and injured in that process.

Table 4: Summary of handling methods of rays in skunked and successful purse seine sets, 2013–2019. Successful sets include partially successful sets.

Release handling	Bringing onboard handling			Total
	Remained in water	Brailed onboard	Lifted onboard	
Skunked sets				
Released while in water	8			8
Brailed over side - not brought on deck				0
Released directly from net into water (lowered or rolled)			8	8
Released from deck - lifted by crew			2	2
Released from deck - by brailer			2	2
Released from deck - rope sling & winch				0
Released from deck - cargo net & winch			2	2
Total from skunked sets				22
Successful sets				
Released while in water	3			3
Brailed over side - not brought on deck		5		5
Released from net lowered into water (lowered or rolled)			2	2
Released from deck – lifted by crew		4		4
Released from deck - by brailer		4	2	6
Released from deck - rope sling & winch		11		11
Released from deck - cargo net & winch		3		3
Released from deck - rope threaded through cut in wing		2		2
Total from successful sets				36
Total for onboard handling categories overall	11	29	18	58

Figure 4: Examples of ray handling: rays being brought onboard in different sized brailers (top row) and in the net during retrieval (second row). Devil ray on deck after being lifted onboard in the net (bottom left), and another being manhandled overboard after being tagged in the bunt (bottom right).

Of the six rays brought onboard in the net from skunked sets, two were released using the brailer, one of which was tagged and did not survive (tag 115490-2). This ray had been encouraged to exit the net when still in the water but became entangled in the bunt. Unsuccessful attempts were made to release the ray from the bunt directly. It was then lowered onto the deck, removed from the bunt, tagged, and rolled into the brailer to release. Another two rays from one trip were manhandled back over the side after the net had been opened. Photos and observer comments suggested the handling was sub-optimal, exacerbated by the rays being in an awkward position between the net and the side of the vessel. Both were tagged, and noted to have only minor or no external injuries, and both died within a few days of release (tags 115488 and 115489). Although the release time was recorded, it is not known when the rays came onboard and whether time on deck could have been a factor. One vessel was observed to be using the recommended large mesh cargo net, which was used to release two rays from skunked sets. These rays were brought onboard in the bunt, the cargo net was manoeuvred underneath the rays and they were lifted up by the crew and released over the side of the vessel (Figure 6). Both rays were tagged (tags 142678 and 142677), with one surviving and one dying. The latter result may not be a reliable reflection of the handling, as photographs show that the tag was placed over the body cavity, where there was a risk of puncturing organs.

Of the 36 rays caught in successful and partially successful sets, 81% (n=29) were brought onboard during the brailing process (Figure 4). For one trip, observers noted that three rays from two sets were brailed aboard in the first load. For the remainder, this detail was not recorded because of form changes, so all are reported in Table 3 in a single ‘brailed onboard’ category. A variety of different methods were used to release rays back into the water. For five rays from two sets, the observers recorded that they were released directly from the brailer without coming onboard. In one of these sets, the observer noted that the rays had spent a long time in the pursed net with fish, and that there were ‘no signs of life’, although the rays ‘swam away weakly’ with chaffing injuries noted. This suggests that the rays were left until last to be brailed out of the net and that although handling and time out of water were reduced, the chances of survival may have been impacted by the time spent in the sacked net with the tuna catch. Another four rays were returned to the sea from the deck by brail. Two from the same trip were brailed onboard ‘with the last of the catch’, tagged, and released out of the bottom of the brailer. The information provided indicated that the time from when sacking began to the ray being released was 50–60 minutes, with 5–10 minutes spent out of the water. Although no data were received from one tag, the other tag indicated that the ray survived (tags 115490, 115491). Eleven rays captured during one trip were removed from the deck using a rope sling and winch (Figure 5). Rays were in the sacked net for 30–110 minutes depending on the size of the tuna catch. Seven of the rays were judged to be in poor condition or moribund, with various injuries noted: deep cuts, missing tail, everted anus, and bleeding. However, one of these seven was tagged (tag 142682), along with another deemed to be in better condition (tag 152681), and both survived.

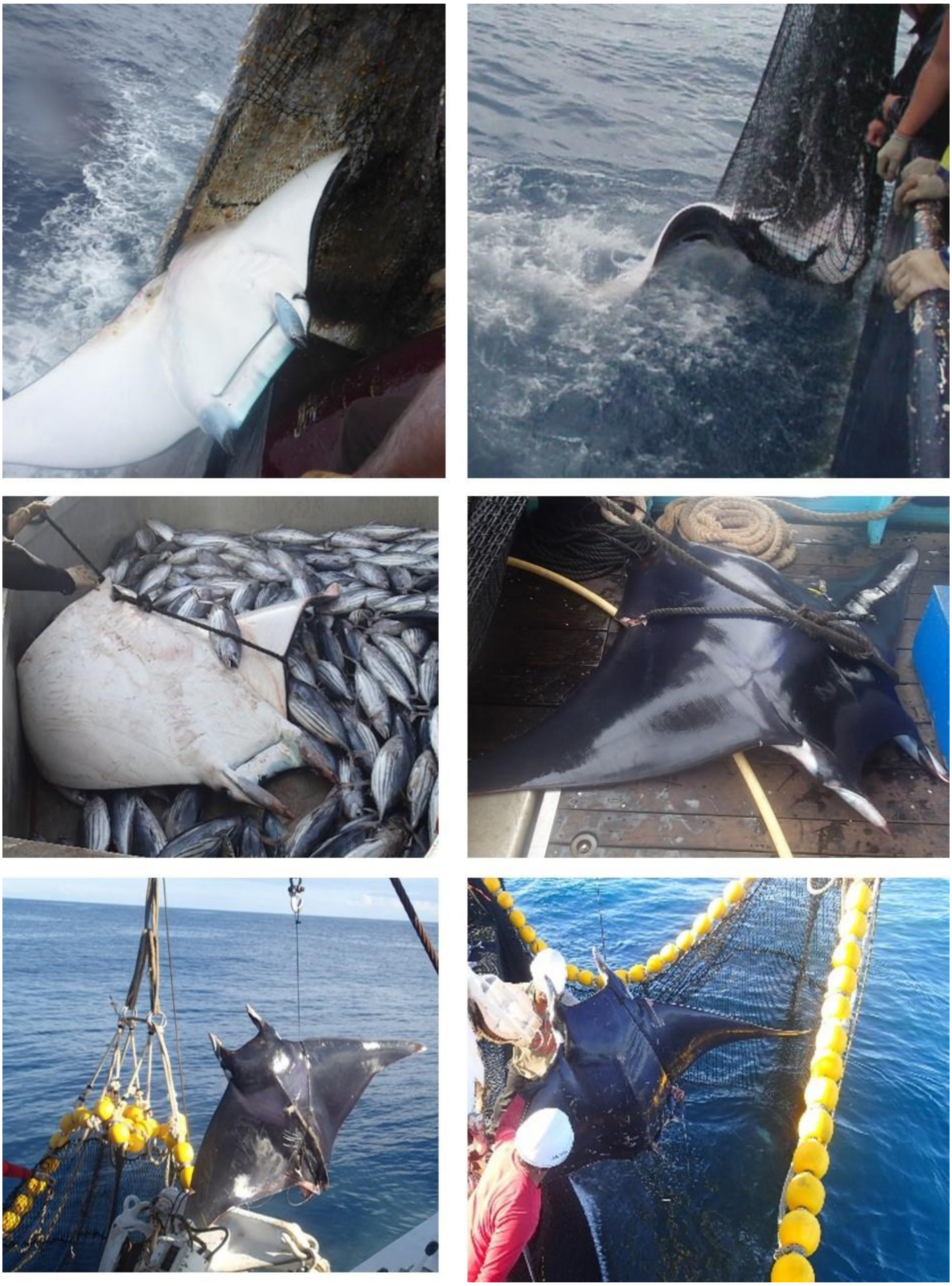

Figure 5: Rays being released directly from the net by cutting the net to drop them back into the water (top left and right). Rays being released from the hopper and the deck using a rope sling (middle and bottom rows).

The vessel that was using the rope sling developed a version of the recommended cargo net, which was in use on a later observer trip in 2017 (Figure 6). Three rays were released with this method on that trip, with one tagged and surviving (tag 152681). The remaining six rays in the 'brailed onboard' category were either lifted by hand to return them to the water, or lifted using a rope that was threaded through a cut made in the wing. The latter category was specifically noted for two rays in one set, which were described as being a long time unobserved in the net (around 3 hours) and classed as moribund on return to the water. It is not known if this method was used for more lively rays on this vessel. Another two rays from this trip were classed as 'released from deck – lifted by crew'. The other two rays in this category were from a more recent trip on the same vessel where the rays were carefully lifted by hand, and imagery shows the rays on the deck with the seawater hose running on the deck so that the ray was partially submerged (Figure 7). Both these rays were tagged and survived (tags 142680 and 152519).

Occasionally, rays caught in successful sets were retained in the net with the catch throughout the rolling, sacking and brailing process. In three sets, the rays were released while still in the water. Although two rays appeared lively, a third was seen 'in the bunt…trapped against the side of the net' and was released 'by dropping the corks, glided down, no visible swimming'. One of the livelier rays 'made contact with the brailer during brailing'. A further four rays were either entangled in the net or were lifted out of the water as the net was retrieved after brailing. Of these four rays, two were released by being lowered back into the water in the bunt. One was tagged and 'lowered back into the water and net opened so could swim away'. Although very lively, no data were received from this tag to confirm its survival or otherwise (tag 115492). Another was 'rolled out of bunt after brailing'. The final two rays were released by hand; one had become entangled in the net by its horns during the rolling process, was lifted onboard, cut out of the net and released at the stern. The other was tangled in the net during rolling, was cut out, tagged, and released shortly afterwards by being 'pushed overboard at the stern'. This ray died after four days.

Figure 6. Rays being released from the deck using a mesh cargo-style net.

Figure 7: Ray being tagged while partly submerged on deck.

4 Discussion

This report summarises observer data on the handling of rays taken as purse seine bycatch, and the results of a tagging study to assess the survival of rays released alive from purse seines. Although the amount of data is minimal in both cases, it is worthwhile examining the results for any evidence of changes through time in handling and ray survival. For this comparison, we define the 'early' period as 2004–2012, and the 'later' period as 2013–2019.

Anecdotal comments from an observer indicate that vessels have made a concerted effort in the later period to avoid setting on ray-associated tuna schools, and this may have reduced the number of rays caught. When rays have been caught, there is evidence of improved handling in the later period. Both periods had similar proportions of skunked and successful sets, and similar onboard handling, but there has been an increase in the frequency of vessels opening the net on skunked sets to let rays go in the water. By reducing the handling and physical and physiological trauma caused by lifting rays onboard, their chances of survival have probably increased. Although release handling wasn't well documented before 2013, the movement of rays by lifting them with hooks through the gill slits or by cuts made in the wings was clearly not conducive to ray survival. In the later period, there is more evidence of careful handling. Comments from observers suggest that two vessels are using cargo nets (with photographs confirming this for one vessel), and also following the suggestion to stretch the cargo net across the hopper to sieve the rays from the catch when the brail is emptied to minimise handling. This is encouraging, but other vessels in the fishery should be encouraged to adopt the use of a cargo net to lift rays into the water.

Four of the first seven rays tagged in 2013−2015 (57%) died. However, only one of seven rays tagged in 2016−2018 (14%) died. The number of rays tagged is too small to draw strong conclusions, but a reduction in the mortality rate of released rays is consistent with observed improvements in handling and releasing methods used by purse seine crews. The use of a cargo net, or even a rope sling, appears to improve survival of rays that are trapped in the bunt and lifted onboard. Five tagged rays from successful/partially successful sets all survived being brailed onboard or lifted in the bunt, and then lifted over the side by hand or in a cargo net or lowered in the bunt. The only recently tagged ray not to survive, despite the use of the cargo net, was potentially compromised by the location of the tag, which was attached over the body cavity.

5 Recommendations

Below we provide recommendations for reducing the numbers of rays caught by the skipjack purse seine fishery, and reducing ray mortality if they are caught. These recommendations are modified and updated from those made previously (Jones & Francis 2012; Francis & Jones 2017).

5.1 Avoiding ray captures

1. Vessels should not set on tuna schools that are associated with rays. Rays are frequently seen by the pilots of spotter planes before setting, enabling vessels to avoid such schools in favour of those with no associated rays. In addition to reducing mortality of rays, avoiding ray sets would reduce the chance of skunked sets (rays are thought to spook the tuna and cause them to exit the net before pursing is complete) and reduce the time spent handling rays following their capture.

2. Vessels should minimise fishing in the hotspot area identified on the north-east coast of North Island. If fishing does occur in the hotspot, effort should be restricted to over the continental shelf (seabed depth less than 200 m) because rays are more common in oceanic waters beyond the shelf edge.

5.2 Reducing ray mortality

3. Rays should be removed from the net while still in the water. The best way to reduce ray stress and mortality is to release them rapidly from the net, and to minimise the handling and physical trauma that results during sacking or brailing, or while on the deck. Options for releasing rays in the water include opening the net (especially for skunked sets with no tuna), sinking the corkline, and brailing the rays directly from the net into the sea.

4. If rays cannot be removed while in the water, they should be brailed out very early in the brailing process and returned rapidly to the sea. The probability of ray survival declines rapidly if they are left in the pursed net with the catch because of physical compression, stress, and deoxygenation of the water.

5. Rays should be brailed out of the net in preference to being dragged aboard in the sacked net. Although some tagged rays have survived after being lifted onboard in the net, ray survival is higher when brailed.

6. Physical handling of rays on deck should be minimised so that rays are returned to the sea rapidly and with minimal trauma.

7. Vessels should carry and use a cargo net to facilitate the return of rays to the sea. This net can be stretched over the fish hold or hopper to enable the ‘sieving’ of rays from a brail load of skipjack, and then used to lift the rays back over the side into the water. We suggest that net design recommendations be developed, and various materials tested for effectiveness and practicality. This should be done in consultation with those vessels already using cargo nets to better understand how the nets are used in practice and any design constraints. Ideally, cargo nets

should be constructed from soft straps or webbing, rather than thin twine or rope to protect the heavy, soft-bodied rays from being sliced by the net as they are lifted off the deck. Use of a cargo net also has strong benefits for the vessel, because it can substantially reduce the handling time for large bycatch species that are discarded, such as devilrays, sunfish and sharks.

8. Use of a rope sling to return rays to the sea should be discouraged. Although a sling probably reduces ray handling time, which is desirable, observers have noted that the sling ropes sometimes cut deeply into the wings of the rays.

5.3 Improved data collection and analysis

9. Data provided by spotter pilots flying in association with purse seiners should be analysed to determine (a) whether pilots are routinely recording ray sightings, and (b) to provide more information on the spatial and temporal distribution of rays, particularly in relation to defining the hotspot area in north-eastern North Island.

10. Observers record information on ray captures using the Protected Ray Interactions form. This form provides valuable data on things such as when and by whom a ray was first sighted, and crew handling techniques. However, no information is specifically collected on whether a cargo net is used, or other details of the ray handling approach. Such information is sometimes recorded by observers in comments fields, but it is important to collect this information for all ray sets. We recommend additional fields be added to the form for this purpose. Re-introduction of a data box to record whether a ray was brailed early or late in the brailing process would also be useful.

11. This study provides an updated analysis of tagging and observer data, but not commercial catch and effort data. An updated analysis of commercial data would provide a larger data set from which to determine whether there have been any changes in the distribution of fishing effort, or ray captures and capture rates, in relation to factors such as month, location, and seabed depth.

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