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Post-release survival for leatherback turtles caught in New Zealand surface longline fisheries

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Post-release survival for leatherback turtles caught in New Zealand surface longline fisheries

New Zealand Aquatic Environment and Biodiversity Report No. 345.

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The Critically Endangered and declining population status of the Western Pacific leatherback turtle population makes it important to quantify the post-release survival for leatherback turtles caught in surface longline fisheries in New Zealand.

This report summarises information on at-vessel and post-release survival for leatherbacks globally.

Two workshops were conducted during this project, to better understand the New Zealand surface longline fishery and to agree to a scoring scheme for estimating leatherback post-release mortality.

Post-release survival for leatherbacks caught in the New Zealand surface longline fishing fleet was estimated to be about 78%. This estimate was based upon 23 interactions.

EXECUTIVE SUMMARY

Finucci, B.[1]; Dunn, M. R.[1] (2024). Post-release survival for leatherback turtles caught in New Zealand surface longline fisheries.

***New Zealand Aquatic Environment and Biodiversity Report No. 345.* 36 p.**

A review commissioned by the Department of Conservation of commercial fishing interactions with marine reptiles in New Zealand waters identified an increase in reported leatherback turtle (*Dermochelys coriacea*) bycatch in surface longline fisheries in the 2020–21 fishing year. It was not known whether this increase was anomalous or if it represented an emerging bycatch trend. The Critically Endangered and declining population status of the Western Pacific leatherback population makes it important to quantify the post-release survival for leatherback turtles caught in surface longline fisheries in New Zealand.

This report summarises information on at-vessel and post-release survival for leatherbacks globally. At-vessel survival for leatherbacks has been relatively well-documented, but there are very few studies on post-release survival, and limited information from the West Pacific Ocean.

Two workshops were conducted during this project, to: (1) better understand the New Zealand surface longline fishery; and (2) agree to a scoring scheme for quantifying leatherback post-release mortality.

This report estimates post-release survival for leatherbacks caught by the New Zealand surface longline fishing fleet using the agreed scoring system, information from validated observer-reported interactions from 2008 to 2022, and data collected on the Liaison Officer Turtle Capture Forms implemented since summer 2023.

Post-release survival for leatherbacks caught in the New Zealand surface longline fishing fleet was estimated to be about 78%. This estimate was based upon 23 interactions. The Liaison Officer reports indicated that some observed leatherbacks in New Zealand were less than 1.5 m in length and therefore possibly juveniles.

Recommendations to improve knowledge and conservation outcomes for leatherbacks are made including: 1) turtle handling and release training for skippers and crew; 2) any leatherbacks released with trailing gear should be recorded as “Alive and Injured”; 3) continue collection of data on turtle interactions via the Liaison Officer Turtle Capture Forms to refine expected mortality estimates and 4) New Zealand should explore options to satellite tag bycaught leatherbacks when released at sea to provide data specific to the New Zealand region.

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1. INTRODUCTION

A review commissioned by the Department of Conservation of commercial fishing interactions (bycatch events) with marine reptiles in New Zealand waters identified a peak in reported leatherback turtle (*Dermochelys coriacea*, herein referred to as leatherbacks) bycatch in surface longline (SLL) fisheries in the 2020–21 fishing year (n = 50; Dunn et al. 2022). It is not known whether this increase was anomalous, or if it represented an emerging bycatch trend for this species. However, an increased focus of fishing in areas preferred by leatherbacks in 2021, particularly the Bay of Plenty region, may have contributed to the increase in bycatch (Dunn et al. 2023).

Leatherbacks in New Zealand waters are likely to originate from Western Pacific nesting beaches (Benson et al. 2011) and migrate to foraging grounds in New Zealand. The Western Pacific leatherback population is in decline and is listed as Critically Endangered under the IUCN Red List of Threatened Species (IUCN 2024). In New Zealand, leatherbacks are protected under the Wildlife Act 1953. Bycatch of leatherbacks in New Zealand commercial fisheries is most common in SLL fisheries off the east coast of the North Island (Fisheries Management Areas FMA 1 and FMA 2), with lower numbers off the west coast North Island (FMA 9) and west coast South Island (FMA 7). Probability of capture is higher between January and May and includes a mixture of hooked and entangled individuals (Dunn et al. 2022). It is not known how the interactions in New Zealand affect turtle survival after release, making it difficult to assess the potential impact on the population. Most New Zealand leatherback captures have been self-reported by fishers due to low Ministry observer coverage in the SLL fishery. When observer-reported turtle captures are scaled to estimate total turtle capture rates in New Zealand SLL fisheries, the estimates accordingly have very high uncertainty (Abraham et al. 2021).

Post-release survival (PRS) is the proportion of animals released alive after capture in fisheries that are expected to survive. In the United States of America (USA), expert workshops were conducted to produce criteria by which PRS for turtles caught in fisheries could be estimated (Ryder et al. 2006). Criteria were based on a combination of hooking location, gear attached on release, and turtle species. Estimates of PRS for leatherbacks in the Hawaiian longline fishery are routinely updated using the Ryder et al. (2006) criteria, while other USA fisheries have used modified versions with more detailed criteria on hooking location and release condition, or assessment tailored to other fishing methods (SESFC 2012, NMFS 2022).

The concept of PRS here does not include non-lethal forms of impairment, such as possible behavioural responses after release that induce changes to foraging and migratory behaviour, which might reduce growth rate or future reproductive output.

This research for Fisheries New Zealand research project PRO2023-15 aims to better understand and estimate post-release survival for leatherbacks caught in SLL fisheries in New Zealand.

Overall Objective:
To estimate post-release survival for leatherback turtles in New Zealand surface longline fisheries.

Specific Objectives:
1. Conduct a workshop in conjunction with Fisheries New Zealand to collate information on the specific nature of both surface longline fishing and turtle captures in New Zealand.
2. Conduct a second workshop in conjunction with Fisheries New Zealand to review methods and refine inputs for post-release survival estimation of leatherback turtles caught in New Zealand surface longline fisheries.
3. Estimate post-release survival of leatherback turtles caught in New Zealand surface longline fisheries.

2. METHODS

2.1 Literature review

A literature review was undertaken to document current knowledge on at-vessel survival (i.e., the status of an individual when brought to the vessel) and post-release survival (i.e., the long-term survival following release) of leatherbacks to identify influencing factors. There are few studies that have documented at-vessel survival for leatherbacks in detail, and even fewer studies that have measured post-release survival; thus studies from all regions and all time periods were considered. Information collected here was used to guide the scope of workshop discussions as described in Section 2.2.

2.2 Expert workshops

Workshop 1: State of New Zealand surface longline fisheries

The first workshop was held on 2 May 2024 to elicit input from a range of experts who had operational/observational knowledge of the New Zealand SLL fishing fleet, and/or turtle interactions. This included commercial fishers, fishery observers, industry representatives, and fisheries liaison officers (LOs). Additional phone conversations were had with two fishers who could not attend the workshop. The purpose of Workshop 1 was to discuss and collate information on: (1) the specific nature of surface longline fishing in New Zealand; and (2) the specific nature of turtle interactions in SLL fisheries in New Zealand, including any knowledge of historical interactions and anecdotal information. The knowledge gained here was used to inform estimates of post-release survival and integrated into results presented at Workshop 2.

Workshop 2: Review applicability of methods used to estimate post-release survival

A second workshop was held on 24 July 2024 to review and discuss the material derived from Workshop 1. Participants, including fisheries managers, scientists, and international turtle experts are listed in Appendix 1. The purpose of Workshop 2 was to summarise the material derived from Workshop 1 and determine the applicability of the methods of Ryder et al. (2006) and/or SEFSC (2012) to estimate post-release survival for leatherbacks in the New Zealand SLL fisheries (see Appendix 2). The workshop included discussion about the equivalent scoring methodology for trawl, net, and pot/trap caught turtles developed in 2022 (NMFS 2022). The priority of the workshop was to determine whether the methods of Ryder et al. (2006) and/or SEFSC (2012) were appropriate for New Zealand and still represented international best practice, or whether a revised or alternative method was warranted. The workshop also discussed recommendations for future data collection that would improve assessments of post-release survival.

2.3 Estimating post-release survival of leatherbacks caught in New Zealand surface longline fisheries

Using the recommended method from Workshop 2, two sources of data were used to estimate survival rates for leatherbacks in the New Zealand SLL fisheries: 1) Liaison Officer (LO) Turtle Capture Forms, and 2) validated reported interactions from Ministry observers.

2.4 Liaison Officer Turtle Capture Forms

An initiative to collect additional information from fishers regarding turtle interactions was initiated in March/April 2023 by Fisheries New Zealand, in collaboration with the Department of Conservation (DOC). The LO Turtle Capture Form (Appendix 3) was developed for two primary reasons: 1) a low level of observer coverage on the SLL fleet due to watchkeeping issues (health and safety concerns); and (2) a requirement for more detailed information to assess post-release survival of bycaught turtles. The forms were not intended to replace the Non-Fish Protected Species (NFPS) forms used by fishers to report protected species interactions, but to collect additional information not specified on the NFPS form. The LO Turtle Capture Form was designed to record information regarding the fishery interaction,

the turtles' life status, and how the turtle was released, using a set of standardised descriptors based on Ryder et al. (2006) and NMFS (2022). Completed forms could then be used to help assess the turtles' likelihood of post-release survival.

LOs deployed by DOC's Liaison Programme contact fishers upon return to port after receiving notification ('trigger event') of a turtle interaction. Trigger events can be a combination of fisher self-reports via Ministry for Primary Industries, observer notifications via Observer Services, or fishers directly contacting a LO. Questions included on the form are prioritised into "high", "medium", and "additional", where the high priority questions are considered the minimum amount of information needed to assess post-release survival. Where possible, fisheries observers also take the form out to sea in the event of an observed turtle interaction. The first completed questionnaire was returned in May 2023 (for an interaction in April).

2.5 Validated observed interactions

Details on fisheries interactions with protected species have been captured in trip report forms and diaries carried by Ministry observers. Observers may also include photographs and videos of the interaction, including release of the animal. Information on observer-reported leatherback interactions with surface longline fisheries were collated, and where sufficient details on leatherback capture and release were available to score the interaction using the Ryder et al. (2006) criteria, and where those details could be validated with photographs or video, then the interactions were included in the post-release survival estimate. Interactions where insufficient information was available, or where photographs of video were not available, are summarised in Appendix 4.

3. RESULTS

3.1 Literature review

Estimates of post-release survival from satellite telemetry

Studies using satellite telemetry to assess leatherback post-release survival are limited, with seven studies found in the published literature, and most being opportunistic rather than directed studies where the primary purpose of the research was to assess survival (Hays et al. 2003, Doyle et al. 2008, López-Mendilaharsu et al. 2009, Almeida et al. 2011, Bond & James 2021, Dodge et al. 2014, 2022, Mangel et al. 2024, see Table 1). Most studies (n = 5) occurred in the Atlantic Ocean; one study each off Canada, the USA, Brazil, Uruguay, and Ireland. One study included leatherbacks captured off South Africa (Atlantic) and Indonesia (Pacific Ocean), and one study took place in the East Pacific off Peru.

The number of leatherbacks in four of the studies were low (1–6 individuals) and three of these studies were opportunistic tagging events. One study, occurring from 2005–2019, used a combination of satellite (n = 9) and acoustic (n = 1) tags, as well as Passive Integrated Transponder (PIT) tags/photo identification from entanglements (n = 6) and strandings (n = 2) to monitor post-release outcomes for 16 individuals (with two turtles having a second entanglement event). Three of the studies deployed tags on leatherbacks entangled in pot and trap fisheries, two from a drift net fishery, one from a combination of longline and gillnet fisheries, and one study did not define what fishery the leatherbacks interacted with. Leatherbacks were tracked for up to 2972 days, but also for as little as two days (when the leatherback was entangled again). Post-release survival was assessed to be high, with four of the studies estimating 100% survival (n = 11 leatherbacks), one study estimating 81% survival (n = 16 leatherbacks), and two studies estimating 75% survival (n = 8 and n = 16 leatherbacks). Here, three of the leatherbacks died within weeks of their first interaction, with two leatherbacks reported to be entangled in the pot and trap fishery again. The second study reported one observed and one inferred mortality based on irregular tagging behaviour.

Of particular relevance to New Zealand, the longline fishery study reported tagging three leatherbacks after becoming entangled in the main and branch line in fisheries operating off Uruguay. All leatherbacks were assessed to survive the interaction and were tracked for 237–631 days post-release.

At-vessel survival studies

The review included 26 studies that reported at-vessel survival of leatherbacks (Table 2). These studies largely assessed the status (alive or dead) at hauling based on information collected at sea during normal fishing operations. Of these, 17 included data from longline fisheries, three trawl, three gillnet, three from pot/trap fisheries, two drift net, one purse seine, and one vertical fishing line. Most studies took place in the Atlantic, and mostly from the West Atlantic (Canada or USA, $n = 11$), and several studies assessing high-seas fleets operating throughout the Atlantic (via International Commission for the Conservation of Atlantic Tunas, ICCAT, collected data). In the Pacific, there have been studies completed off Hawaii ($n = 2$), Marshall Islands ($n = 1$), and six in the East Pacific (Peru, Ecuador, Panama, Costa Rica, or generally in the Inter-American Tropical Tuna Commission, IATTC, region). No specific study has been conducted in the Southwest Pacific, however, observer-reported and fisher-reported (via NFPS form) interactions in the New Zealand SLL fleet indicate that approximately 5% of leatherbacks are dead at hauling based on their status at release (i.e., released dead).

Most studies were not leatherback-specific but reported on general sea turtle bycatch. The number of leatherbacks available for many studies was low ($n < 20$), but nine studies had over 100 observations, and as many as 468 (reported from 2006–2017). The at-vessel survival rate was reported to be relatively high for most studies, with estimates between 83 and 100% (for studies where sample size was greater than 20) and was particularly high for interactions with longline fisheries (85–100% estimated survival). At-vessel survival was lower in trawl, trap, and gillnet fisheries. These studies also reported that leatherbacks were more likely to be entangled or foul hooked (flipper hooked) when caught in longline fisheries.

Additional relevant studies

An additional 12 studies identified leatherback interactions with fisheries but did not report survival estimates (Table 3). Seven of these studies focused on industrial longline fishery interactions, and one study reported on artisanal longline fishery interactions. Of the longline fleet studies, most leatherbacks were flipper hooked or entangled (73–90%), and few were internally hooked (hook ingested; up to 5%). Sea surface temperature (SST) was found to be an important influence on bycatch rates in some studies. One study assessed the effectiveness of tag attachment in free-swimming individuals, as well as one individual entangled in a trap. A study assessing injuries of leatherbacks at nesting beaches and foraging areas found that 62% of assessed leatherbacks had at least one injury, which were largely on the shoulder (39% of injuries) and on the left side (57% of shoulder injuries), on the carapace (27%), and flippers (17%), but very few injuries were found on the jaw (<0.01%). Approximately 17% of injuries appeared to be from hooks and 19% from gear entanglement. Ten studies occurred in the Atlantic, one in the Caribbean (Barbados), and two studies took place in the Pacific, one in the Philippines, and one using combined-turtle data held at the Pacific Community (SPC). In this latter Pacific study, leatherbacks accounted for about 20% of the approximate 350 turtle records.

Table 1: Post-release survival of leatherback turtles (LBT) estimated with satellite telemetry.

Fishing method	Year of Study	Region	*n* (survival estimate)	Factors examined/affecting survival	Comments	Reference
Unknown	2003 (but review of other studies)	Indian, Pacific (Indonesia, South Africa)	8 (75%)	Observed, inferred mortalities during tagging exercises	Fishery capture of tagged turtles inferred from "unusual telemetry" hence lower confidence; Used previously published data; 1 mortality in Indonesia (observed), 1 in South Africa (inferred)	Hays et al. (2003)
Fish trap entanglements	2003–2012	Northwest Atlantic (Canada)	4 (100%)	Post-release survival after disentanglement	LBT tagged with harness (2) and direct attachment (2); LBT tracked for 212–537 d	Bond & James (2021)
Longline, industrial; gillnet, artisanal	2005–2006	Southwest Atlantic (Uruguay)	4 (100%)	Opportunistic tagging event	3 entangled on mainline/branchline; 1 caught in bottomset gillnet; harness tagged; LBT tracked for 237–631 d	López-Mendilaharsu et al. (2009)
Lobster pot, industrial; drift net, industrial	2005–2006	Northeast Atlantic (Ireland)	2 (100%)	Opportunistic tagging event	Both turtles entangled; One in lobster pot, one in salmon drift net; Harness tagged and direct tag; LBT tracked for 233, 375 d	Doyle et al. (2008)
Drift net, industrial	2006	Southwest Atlantic (Brazil)	1 (100%)	Opportunistic tagging event	3 additional nesting females tagged; LBT tracked for 97 d	Almeida et al. (2011)
Entanglement (most pot/trap)	2007–2020	West Atlantic (USA)	16 (75%)	Post-release survival after disentanglement	LBT tagged with satellite and acoustic tags and PIT tag/photo ID from entanglements/strandings; 3 died within weeks (two entangled again); 6 alive turtles entangled again 2–11 d after first release; LBT tracked for 2–2972 d	Dodge et al. (2014, 2022)
Driftnet, artisanal	2014–2018	East Pacific (Peru)	16 (81%)	Post-release survival after disentanglement	One tag found four days later, not clear if died in tagging interaction or another fishing interaction; 2 more tags showed similar tracks to dead individual, assume injured/died; LBT tracked for 3–297 d	Mangel et al. (2024)

Table 2: At-vessel survival of leatherback turtles (LBT) estimated with life status assessment.

Fishing method	Year of Study	Region	*n* (survival estimate)	Factors examined/affecting survival	Comments	Reference
Longline, industrial	Not reported	Southwest Atlantic (Brazil)	28 (95%, one unknown)	Life status (Alive vs Dead); hook type	65% decline in capture with circle hook; 22 entangled, 4 mouth hooked	Sales et al. (2010)
Longline, experimental	1991	Central Pacific (Hawaii)	1 (100%)	Life status (Alive vs Dead)	Hook and bait ingested; Hook timer used but was lost	Skillman & Balazs (1992)
Purse seine, industrial	1993–2019	East Pacific (IATTC)	112 (99%)	Life status (Alive vs Dead)	Post-release mortality likely to be high because safe handling/release rarely implemented, estimated at 25%	Griffiths et al. (2020)
Longline, industrial	1994–2002, 2004–2006	Central Pacific (Hawaii)	46 (100%)	Life status (Alive vs Dead); Hook type; Bait type	Comparison of pre- and post-regulation implementation; 100% observer coverage; LBT mostly caught foul hooked (84%) on body or entangled (6%); 10% deeply hooked but after regulations implemented, 100% lightly hooked; 83% decline in catch with circle hook and fish bait	Gilman et al. (2007)
Longline, industrial	1997–2012	North and South Atlantic (ICCAT)	244 (92%)	Life status (Alive vs Dead)	56% of total turtle records were LBT	García-Cortes et al. (2015)
Entanglement (mostly pot fisheries, 44%, and trap net, 26%)	1998–2014	Northwest Atlantic (Canada)	205 (85%)	Life status (Alive vs Dead)	Where identified, most line wrapped around front flipper (n=59/119); Most (74%) entanglements reported by fishers; Death by drowning or asphyxiation, considered "gross underestimate of actual entanglement-associated mortality"	Hamelin et al. (2017)
Drift net, artisanal	2000–2007	East Pacific (Peru)	5 (100%)	Life status (Alive vs Dead)	All alive at capture but one retained	Alfaro-Shigueto et al. (2011)
Longline, artisanal	2000–2007	East Pacific (Peru)	12 (100%)	Life status (Alive vs Dead)	Longline targeting dolphinfish and shark	Alfaro-Shigueto et al. (2011)

Fishing method	Year of Study	Region	*n* (survival estimate)	Factors examined/affecting survival	Comments	Reference
Longline, industrial	2001–2005	Southeast Pacific (Chile)	284 (99%)	Life status (Alive vs Dead)	Longline targeting swordfish with J-hooks and squid bait; Only two LBT reported dead	Donoso & Dutton (2010)
Longline, industrial	2002	Southwest Atlantic (Brazil)	1 (100%)	Opportunistic tagging event	Initially tagged at nesting beach in Gabon; captured by longline vessel off Brazil; retagged and released with no gear attached	Billes et al. (2006)
Driftnet, industrial	2002–2008	Southwest Atlantic (Brazil)	252 (69%)	Life status (Alive vs Dead)	LBT comprised most of sea turtle bycatch; most fishing sets (71%) had no LBT captures; 46% sets had one LBT, two had 10, one had 18 LBT; Capture highest in austral spring/summer/autumn; vessel effect in captures	Fiedler et al. (2012)
Driftnet	2003–2007	Northeast Atlantic (Morocco)	9 (100%)	Life status (Alive vs Dead)	Estimated captures 101 LBT per year, scaled up to fishing effort – driftnet phased out by 2012; LBT not hauled on board; No LBT reported in SLL or BLL	Benhardouze et al. (2012)
Longline, artisanal	2004–2010	East Pacific (Ecuador, Panama, Costa Rica)	3 (not specified, assumed alive)	Life status (Alive vs Dead); Hook type	1208 turtles observed overall; Most ORT and 99% released alive	Andraka et al. (2013)
Entanglement (most pot/trap)	2005–2019	West Atlantic (USA)	272 (83%)	Life status (Alive vs Dead); At release survival after disentanglement	97% turtle entanglements were LBT; Most (62%) in recreational gear, 12% commercial; 92% from pot/trap gear and on buoy line	Dodge et al. (2014, 2022)
Longline, industrial	2006–2007	Southwest Atlantic (Brazil)	16 (94%)	Life status (Alive vs Dead); Hook type	Lower catch on circle hook but not significant; One LBT dead at hauling	Pacheco et al. (2011)
Longline, industrial	2007, 2009	Central Pacific (Marshall Islands)	14 (0%)	Life status (Alive vs Dead)	Onboard observer-reported interactions in tuna fishery (9 LBT in 2007, 5 in 2009)	Gilman et al. (2014)

Fishing method	Year of Study	Region	*n* (survival estimate)	Factors examined/affecting survival	Comments	Reference
Longline, industrial	2006–2017	Northwest Atlantic (Canada)	468 (>99%)	Life status (Alive vs Dead); Commercial vs observer-reported interactions	Considerable underreporting by commercial vessels	Hurtubise et al. (2020)
Longline, industrial	2008–2011	West Atlantic (Portuguese fleet, ICCAT)	183 (~90%)	Life status (Alive vs Dead); Hook type; Bait type	LBT accounted for 81% of total turtle records; Most (~75%) hooked on flipper or entangled (~25%); Mortality higher (~12%) when entangled; Catch rate reduced (55%) when changed to circle hook	Coelho et al. (2015)
Longline, industrial	2008–2012	South Atlantic (Portuguese fleet, ICCAT)	26 (85%)	Life status (Alive vs Dead); Hook type; Bait type	LBT mostly caught in flipper (73%) or entangled (19%); Circle hooks with mackerel bait reduced catch up to 100%	Santos et al. (2013)
Longline, industrial	2009–2010	Southwest Atlantic (Brazil)	1 (100%)	Life status (Alive vs Dead)	On the line for six hours before being released alive; 12 LBT in total, fate unknown for 11 but survival likely to be high	Nunes et al. (2019)
Longline, industrial	2009–2011	Central Atlantic (Portuguese fleet, ICCAT)	58 (97%)	Life status (Alive vs Dead); Hook type; Bait type	LBT accounted for 25% of total turtle records; Most (~64%) hooked on flipper or entangled (~33%); Only entangled turtles dead; Catch rates reduced (91%) when changed to circle hook with mackerel bait	Santos et al. (2012)
Trawl, industrial	2011–2015	West Atlantic (USA)	2 (50%)	Life status (Alive vs Dead)	Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 50%	Upite et al. (2018)
Gillnet, industrial	2011–2015	West Atlantic (USA)	2 (0%)	Life status (Alive vs Dead)	Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 79%	Upite et al. (2018)
Gillnet, artisanal	2014–2018	East Pacific (Ecuador)	1 (90%)	Life status (Alive vs Dead); Net illumination	8% of turtle records were LBT; Captures reduced by 86% with lights	Mangel et al. (2019); Darquea et al. (2020)

Fishing method	Year of Study	Region	*n* (survival estimate)	Factors examined/affecting survival	Comments	Reference
Trawl (bottom otter trawl), industrial	2014–2018	West Atlantic (USA)	26 est., 3 obs. (50%)	Life status (Alive vs Dead)	At-vessel survival rates scaled to total estimated observed interactions	Murray (2020)
Longline, industrial	2007–2021	South Pacific (New Zealand)	233 (~95%)	Life status at release (Alive vs Dead)	Observer reported captures 3/33 dead status at release; Fisher reported captures 8/200 dead status at release	Dunn et al. (2023)
Longline, industrial	2015–2020	East Atlantic (Portugal, Azores)	38 (100%)	Life status (Alive vs Dead)	21% of turtle records were LBT; Most (81%) flipper hooked, 16% in mouth, one deep hooked; Most captures at 19–20°C	Parra et al. (2023)
Trawl, industrial	2017–2021 (2012–2021)	West Atlantic (USA)	2 (~50%); 4 (~25%)	Life status (Alive vs Dead)	Update of Upite 2018 for 5- and 10-year periods; Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 46% (47%)	Upite et al. (2023)
Gillnet, industrial	2017–2021 (2012–2021)	West Atlantic (USA)	2 (~50%); 4 (~25%)	Life status (Alive vs Dead)	Update of Upite 2018 for 5- and 10-year periods; Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 62% (74%)	Upite et al. (2023)
Vertical fishing line, industrial	2017–2021 (2012–2021)	West Atlantic (USA)	80 (~25%); 215 (~28%)	Life status (Alive vs Dead)	Update of Upite 2018 for 5- and 10-year periods; Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 55% (54%)	Upite et al. (2023)
Fish trap, industrial	2017–2021 (2012–2021)	West Atlantic (USA)	8 (~40%)	Life status (Alive vs Dead)	Update of Upite 2018 for 5- and 10-year periods; Post-release survival also estimated based on expert opinion using at-vessel condition (see Upite 2011); Overall mortality of 40% (56%)	Upite et al. (2023)

Table 3: Additional studies where survival estimates not reported.

Fishing method	Year of Study	Region	*n* (survival estimate)	Survival type and assessment	Factors examined/affecting survival	Comments	Reference
Longline, industrial	1989–2015	South Pacific (SPC holding data)	~350 (not reported)	Not reported	Combined sea turtle catch: Soak time; Time of day of set; Hooks between floats; Bait type; Hook type; SST; Hook size	LBT accounted for 20% of SPC records	Common Oceans (2017)
Free swimming, entanglement	1996–2016	Northwest Atlantic (Canada)	86 (not reported)	Not reported	Effectiveness of tag attachment	91% tags deployed on free-swimming turtles, 8% on entangled turtles; 1 LBT with trailing gear (lobster pot); No difference in attachment type; female tag loss may be attributed to mating; Tracked for median of 227 (harness), 235 (direct)	Hamelin & James (2018)
Longline, industrial	1997–2015	North and South Atlantic (Japanese fleet, ICCAT)	312 (not reported)	Not reported		LBT accounted for 46% of known turtle records(n=621); Higher catch rates at higher latitudes and at 23–25°C SST	Okamoto et al. (2018)
Longline, industrial	2000–2010	West Atlantic (USA)	328 (not reported)	Not reported	Hook type	LBT mostly (90%) externally hooked (90%) or entangled regardless of gear type; Very few swallowed hooks (1–4%)	Stokes et al. (2012)
Longline, industrial	2001–2002	Northwest Atlantic (Canada)	147 (not reported)	Not reported	Hook type; Bait type	Most (73%) hooked in shoulder/armpit/front flipper (n=107); 5% internally hooked; Catch rate reduced by 65–66% when mackerel bait used; SST important for catch rates	Watson et al. (2005)

Fishing method	Year of Study	Region	*n* (survival estimate)	Survival type and assessment	Factors examined/affecting survival	Comments	Reference
Gillnet, artisanal	2001–2011	Philippines	3 (not reported)	Not reported		Flipper tag of leatherbacks reported by fishers	Bagarinao (2011)
Longline, industrial	2002–2003	West Atlantic (USA)	228 (or 171?) (not reported)	Not reported	Hook type; Bait type	Catch rate reduced by 63–74% when circle hook and mackerel bait used; SST important for catch rates	Foster et al. (2012)
Longline, industrial	2004–2011	North and South Atlantic (Taiwan fleet, ICCAT)	375 (not reported	Not reported		LBT accounted for 60% of total turtle records; 41% hooked, 34% entangled, 25% status unknown; ~40% were released alive and 35.1% were dead (does not specify species)	Huang (2013)
Longline, industrial	2006	North and South Atlantic (Spanish fleet, ICCAT)	235 (not reported)	Not reported	Hook size; Hook type; Bait type; Location	Most interactions flipper hooked (82%) or entanglement (9%); Little to do with hook type or bait; Location of capture only important for catch rate	Mejuto et al. (2008)
Unknown	2008 (data from other studies)	West Atlantic (Canada, Caribbean)	42 (not reported)	Not reported	Study of effects of tagging, rather than survival after capture in fishing gear	Turtles tagged and released after entanglement in fishing gear were much more likely to immediately leave foraging grounds (17/42)	Sherrill-Mix & James (2008)

Fishing method	Year of Study	Region	*n* (survival estimate)	Survival type and assessment	Factors examined/affecting survival	Comments	Reference
Nesting beaches, foraging areas	2012–2015	West Atlantic (Canada, Trinidad)	228 (not reported)	Not reported	Injuries	62% had at least 1 injury; Most had multiple injuries and most healed (62%); Injuries on shoulder (39%) and on left side (57%), carapace (27%), flippers (17%); <1% injuries in jaw; 17% injuries assessed as hook interactions, 19% entanglement	Archibald & James (2018)
Longline, artisanal	2015	Caribbean Sea (Barbados)	~374 turtles estimated per year of which leatherbacks most common (not reported)	Anecdotal (skipper interviews)		Most (45%) entangled in mainline/branch lines, hooking around the mouth (45%), hook ingestion (10%); Dead reports uncommon; Prior injuries reported (hook damage most common, 75%); Fishing at 40–55 m depth	Blades et al. (2019)

3.2 Workshop 1: Summary of New Zealand surface longline (SLL) fisheries

An overview of the New Zealand SLL fisheries is presented here based on the input provided during Workshop 1. Overall, the fishery structure and dynamics reported during the workshop were consistent with characterisation studies on the SLL fleets (Finucci et al. 2021, Griggs et al. 2021).

Fishing season

The SLL fishing starts in the north and moves south as the water temperatures rise. There are fewer vessels early in the season (around November), and some vessels do not start fishing until summer (around February). Fishing in summer (February, March) may extend from Great Barrier Island and Coromandel through the Bay of Plenty and East Cape to Gisborne. Some vessels move further south to fish off the southeast South Island (roughly 100 nautical miles off Dunedin). Vessels fishing off the east coast South Island follow the late summer southern bluefin tuna (*Thunnus maccoyii*) migration northward, and by May–June are again fishing off East Cape and into the Bay of Plenty.

Primarily those vessels that remain fishing off the North Island encounter turtles (all species). Leatherback captures start around December as the water warms (to about 20° C), and the highest turtle capture rates are thought to be in late summer. Turtles are most often encountered from the eastern Bay of Plenty through East Cape to Hawke Bay, are rarely caught south of Gisborne, and are very rarely caught in winter. Time of year and currents were noted by fishers as influential on leatherback captures, but their captures were not seen as "predictable". Anecdotally, water current was noted as a more important predictor of turtle capture than target species. There were no reports of aggregations of turtles. Anecdotally, turtle encounter rates were high in 2023 but total captures were fewer than in previous years because there was less effort (fewer boats).

Gear

The target species in the SLL fleet are bigeye tuna (*Thunnus obesus*), swordfish (*Xiphias gladius*), southern bluefin tuna (*T. maccoyii*), and occasionally yellowfin tuna (*T. albacares*). Albacore tuna (*T. alalunga*) is caught as bycatch. If skippers decide to target bigeye, swordfish, or yellowfin tuna they remain off the east coast North Island; if they decide to target the bluefin tuna, they will move south to off the southeast South Island. The skipper, vessel design, market prices, and availability of Annual Catch Entitlement (ACE) were noted as influences on the choice of target species and fishing location.

For longliners working in the Bay of Plenty and east coast North Island, the preferred bait has been squid, but squid bait is now considered expensive. Fish bait, such as mackerel and saury/sanmar, may be used as an alternative, but was thought to increase shark bycatch. There is some use of artificial (plastic) lures and light sticks are common but not always used. Weighted lines are mandatory when setting during the day. However, east coast North Island longliners typically shoot after dark (about 20:00) and hauling begins about 12 hours later, so not all vessels use weights. It was noted that about 10–15 years ago there was very little weighted gear used in the fleet, but most vessels now use weights (uptake has been slower in the North Island fleet than in the South Island fleet). Hookpods are available, but their use is not favoured. For the primary longliner vessels in the Bay of Plenty region, the depth fished may vary with water clarity and current but is usually to about 50 m. Vessels targeting southern bluefin tuna fish at slightly deeper depths (50–100 m).

From 3 August 2023, commercial fishers were required to use circle hooks when surface longlining in New Zealand fisheries waters under the Fisheries (Commercial Fishing) Amendment Regulations 2023. Most vessels were already using only circle hooks, for many years, and only one vessel was reportedly still occasionally using J-hooks (for better swordfish catches) prior to the legislation change. The size of the circle hook used is most often 15/0 or 16/0.

Leatherback encounters

Leatherbacks were reported as most often caught in the "shoulder", occasionally in the flipper or carapace ("backbone"), and sometimes in the mouth or "cheek". Leatherbacks were almost always

released in the water. De-hooking was considered difficult and thought to cause the animal stress as it is pulled to the vessel. The use of de-hookers designed for J-hooks could "make things worse" (since fishers are using circle hooks), and turtles were therefore cut away with as little line as possible attached; it was noted that this was difficult to do because leatherbacks are powerful swimmers. Upon release, the snood may remain attached to the turtle, and additional gear such as weights, swivels, and Hookpods may also be attached. The length of snood remaining on the turtle was usually half the length of carapace (usually 1–2 m of snood line). When tangled, as much line as possible was cut away until the leatherback broke free. Fatalities were rare, and usually associated with full entanglement, often in the mainline. There were no reports of captured turtles being seen with injuries from previous captures. Leatherbacks were reported as "large", and the smallest size observed was estimated to be around 1.2 m length.

3.3 Workshop 2: Review applicability of methods used to estimate post-release survival

The workshop participants confirmed that the Ryder et al. (2006) scoring method was still considered best practice for assessing leatherback post-release survival at this time. The Ryder method was re-evaluated in a 2011 workshop and based on the available data, no changes were needed (SEFSC 2012). The workshop participants recognized the need to update the estimates, but highlighted that there were no substantive data available to do so. Workshop participants discussed some of the patterns in leatherback mortalities and injuries, and key uncertainties of Ryder et al. (2006) such as the mortality estimates being based upon hard shell turtle estimates adjusted for leatherbacks. Ongoing trials of direct at-sea satellite tagging in the Hawaiian SLL fishery by the National Oceanic and Atmospheric Administration (NOAA) hope to improve knowledge in coming years.

Workshop participants cautioned that handling and release methods may differ when interactions are observed. Survival estimates could not be determined for most historical New Zealand captures because of the lack of appropriate data. Previous experience confirmed that leatherbacks were often entangled and hooked in the shoulder. The workshop highlighted the importance of removing trailing gear from leatherbacks prior to release to improve survival outcomes. The distinction in Ryder et al. (2006) between more or less than half the carapace length was considered somewhat arbitrary, but the threat of trailing gear becoming re-entangled and causing injury to the turtle was considered accurate (flipper line entanglement was considered particularly damaging).

Juvenile leatherback mortality was reported to likely be higher than adult mortality, which may be attributed to increased probability of drowning and differences in physiology and response to capture stress (smaller leatherbacks have higher metabolic rates and become more stressed). Whilst leatherbacks were more often caught in surface-set longlines, and these fisheries had been a focus for leatherback bycatch mitigation, the mortality rate from deeper-set longlines was higher due to the increased chance of drowning. Experience from satellite tagging found that the tag attachment could be expelled, and the attachment site wound healed (tag anchor was drilled into a carapace ridge). It was suspected that hooks may similarly be expelled, but leatherbacks had also been seen with hooks embedded from previous encounters with longlines.

The Ryder et al. (2006) assessment made no account for sub-lethal effects, such as reduced growth or productivity, that might occur from the turtle changing behaviour or recovering from a bycatch encounter.

3.4 Liaison Officer Turtle Capture Forms

Between April 2023 and June 2024, 13 LO Turtle Capture Forms were returned, of which 11 were for leatherback interactions (Table 4). Two reports for green turtle (*Chelonia mydas*) interactions were also available but are not summarised here. Nearly all interactions occurred in summer and autumn months (January to May), and one interaction occurred in early winter (June). Most (n = 10) forms were completed within two weeks of the interaction being reported (median = 8 days), with one form completed 28 days after the interaction was reported. The estimated size of the leatherbacks varied from

0.75 to about 3 m in carapace length, with seven of the leatherbacks estimated to be between 1 and 1.5 m in carapace length. Based on estimates of size-at-maturity, these seven leatherbacks were likely to be juveniles. One leatherback did not have an estimated size.

Seven leatherbacks were hooked externally, two in the left front flipper, two in the shoulder, one on the underside, and one in the 'cheek'. For one leatherback, the hooking location was unclear, but reported to be in the shoulder/body. The remaining four leatherbacks were entangled either in the main line (n = 1), or both the main line and branch line (n = 3). One leatherback was also entangled in the float rope. All leatherbacks were reported as alive: eight were described as active; two had occasional voluntary movement of limbs; and one was described as lethargic. Seven leatherbacks were reported to have no injuries and three had superficial abrasions. No leatherback was identified as comatose/resuscitated, nor were any provided time to recover on deck before release.

More leatherbacks (n = 7) were released with some gear still attached than released with all gear removed (n = 4). Of the leatherbacks left with trailing gear, six were left with gear less than half the length of the carapace (estimates of 0.15 and 0.5 m snood provided), and one had trailing gear equal to, or greater than, half the length of the carapace (approximately 1 m snood). None of the leatherbacks were released still entangled in the gear. Five forms noted that leatherbacks appeared to be in good health and lively, with two fishers mentioning that it was hard to handle the animal and get it close enough to the boat so trailing gear could be cut. All leatherbacks were reported to swim/dive deliberately away from the vessel upon release. Additional details about the interaction were provided by some vessels. Five forms reported using 16/0 circle hooks and three forms reported using squid bait and one used a 3:1 ratio of squid to saury bait. Depth of fishing was reported for two vessels: 50–80 m and 11 m. Sea surface temperature was available for six interactions, occurring between 17° and 21°C. One form reported the presence of 'small/medium purple jellies' in the area, while another mentioned jellies were not present. Two fishers observed that leatherbacks were not carrying tags.

3.5 Validated observed interactions

Between May 2008 and April 2022, 36 observer-reported surface longline interactions with 41 leatherbacks were recorded. Of these, 12 interactions from 11 events (Table 5) had sufficient information validated with photographs and/or video to include in the Ryder et al. (2006) post-release survival estimate. These events were recent, occurring in summer and early autumn months (January to April) between 2020 and 2022. Three events included two leatherback interactions each, but only one of these events had sufficient details for both leatherbacks to be scored.

Half of the leatherbacks (n = 6) were reported to be hooked externally, three were hooked in or around the mouth, two were hooked and entangled, and one was entangled. Most leatherbacks were released with trailing gear, four with gear equal to or longer than half the length of the carapace, and five with trailing gear less than half the length of the carapace. Two leatherbacks had all gear removed before release (including the entangled leatherback) and one leatherback was released still entangled (initially hooked and entangled). Three leatherbacks were reported to swim away after release; details were unavailable for the remainder of interactions.

Table 4: Responses from the Liaison Officer Turtle Capture Forms collected by Fisheries New Zealand. Size is estimated carapace length; DoQ: date of questionnaire.

LBT	Capture date	Size (mm)	Capture location	Behaviour, injuries at capture	Release condition	Behaviour, injuries at release	Comments
LBT1	19/04/2023	1100	Hooked externally or on the hard beak (left front flipper)	Alive - active (rapid/strong swimming or movement on the deck); No injuries	With hook and trailing line < half the length of the carapace but not entangled (~15 cm snood)	Swam/dived deliberately away from vessel	**DoQ**: 2/05/2023 **Hook**: 16/0 circle **Bait**: squid **Depth**: 50–80 m **SST**: 19–20°C **Time**: -
LBT2	23/05/2023	900	Entangled in the main line, Other (entangled in float rope around carapace and main line around left front flipper)	Alive - active (rapid/strong swimming or movement on the deck); No injuries	With all gear removed; Turtle was partially lifted to cut free	Swam/dived deliberately away from vessel	**DoQ**: 6/06/2023 **Hook**: - **Bait**: - **Depth**: 11 m **SST**: 17°C **Time**: 1900h
LBT3	24/01/2024	-	Entangled in the main line, Entangled in the branch line	Alive - occasional voluntary movement of limbs; No injuries	With all gear removed	Swam/dived deliberately away from vessel	**DoQ**: 3/02/2024 **Hook**: - **Bait**: - **Depth**: - **SST**: - **Time**: -
LBT4	21/01/2024	1500	Hooked externally or on the hard beak (shoulder)	Alive - active (rapid/strong swimming or movement on the deck); No injuries	With hook and trailing line < half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	**DoQ**: 30/01/2024 **Hook**: 16/0 circle **Bait**: squid:SANMA (3:1 ratio) **Depth**: - **SST**: +20°C **Time**: -

LBT	Capture date	Size (mm)	Capture location	Behaviour, injuries at capture	Release condition	Behaviour, injuries at release	Comments
LBT5	5/02/2024	<1500	Entangled in the main line	Alive - lethargic; No injuries	With all gear removed; Held at sea door while crew cut mainline/snood	Swam/dived deliberately away from vessel	**DoQ**: 12/02/2024 **Hook**: 16/0 circle **Bait**: squid **Depth**: - **SST**: 21°C **Time**: -
LBT6	14/03/2024	<1000	Hooked externally or on the hard beak (shoulder)	Alive - active (rapid/strong swimming or movement on the deck)	With hook and trailing line < half the length of the carapace but not entangled (<0.5 m snood, hook in shoulder*)	Swam/dived deliberately away from vessel	**DoQ**: 19/03/2024 **Hook**: 16/0 circle **Bait**: squid **Depth**: - **SST**: 19–20°C **Time**: - No sea jellies present
LBT7	4/04/2024	1000–1500	Hooked externally or on the hard beak (‘in cheek’, externally)	Alive - active (rapid/strong swimming or movement on the deck); Superficial abrasions	With hook and trailing line < half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	**DoQ**: 6/04/2024 **Hook**: - **Bait**: - **Depth**: - **SST**: - **Time**: -
LBT8	7/04/2024	~1000	Hooked externally or on the hard beak (hooked on the underside)	Alive - active (rapid/strong swimming or movement on the deck); No injuries	With hook and trailing line < half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	**DoQ**: 12/04/2024 **Hook**: 16/0 circle **Bait**: - **Depth**: - **SST**: 18°C **Time**: - Lots of small/medium purple jellies in the area; 9 hooks per basket, turtle caught in middle; snood ~14 m

LBT	Capture date	Size (mm)	Capture location	Behaviour, injuries at capture	Release condition	Behaviour, injuries at release	Comments
LBT9	30/04/2024	~3000	Entangled in the main line, Entangled in the branch line	Alive - occasional voluntary movement of limbs; No injuries	With all gear removed	Swam/dived deliberately away from vessel	**DoQ**: 30/04/2024 **Hook**: - **Bait**: - **Depth**: - **SST**: - **Time**: -
LBT10	19/04/2024	750	Hooked externally or on the hard beak (left front flipper)	Alive - active (rapid/strong swimming or movement on the deck); Superficial abrasions	With hook and trailing line ≥ half the length of the carapace but not entangled (~1 m snood)	Swam/dived deliberately away from vessel	**DoQ**: 17/05/2024 **Hook**: - **Bait**: - **Depth**: - **SST**: - **Time**: -
LBT11	17/06/2024	~1500	Hooked externally or on the hard beak (shoulder or body)	Alive - active (rapid/strong swimming or movement on the deck); Superficial abrasions	With hook and trailing line < half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	**DoQ**: 18/06/2024 **Hook**: - **Bait**: - **Depth**: - **SST**: - **Time**: -

*It was unclear if the hook was an old or new injury. For the purposes here, the hook was assumed to be a new injury (and was released with it).

Table 5: Details from validated observer-reported leatherback interactions.

LBT	Capture date	Size (mm)	Capture location	Behaviour, injuries at capture	Release condition	Behaviour, injuries at release	Comments
LBT1	18/02/2020	–	'Hooked through mouth'	–	With hook and trailing line ≥ half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	–
LBT2	13/03/2020	–	'Hook in mouth'	–	With hook and trailing line ≥ half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	–
LBT3	27/01/2021	–	Hooked externally	–	With hook and trailing line < half the length of the carapace but not entangled	–	–
LBT4, LBT5	3/02/2021	–	Hooked externally; Hooked and entangled	–	With hook and trailing line < half the length of the carapace but not entangled; Entangled in line	–	–
LBT6	20/02/2021	–	Hooked externally (right front flipper)	–	With hook and trailing line < half the length of the carapace but not entangled	–	–
LBT7	26/01/2021	–	Hooked externally (right flipper/pectoral region)	–	With hook and trailing line ≥ half the length of the carapace but not entangled	–	–
LBT8	31/01/2021	–	Hooked externally	Superficial abrasions; Bleeding	With hook and trailing line ≥ half the length of the carapace but not entangled	–	–

LBT	Capture date	Size (mm)	Capture location	Behaviour, injuries at capture	Release condition	Behaviour, injuries at release	Comments
LBT9	24/02/2021	–	Entangled	Superficial abrasions; Bruising	With all gear removed	–	Two LBT interactions, only one could be scored
LBT10	25/02/2021	–	Hooked and entangled	–	With all gear removed	–	Two LBT interactions, only one could be scored
LBT11	21/02/2021	–	Hooked externally (flipper)	–	With hook and trailing line < half the length of the carapace but not entangled	Swam/dived deliberately away from vessel	–
LBT12	20/04/2022	–	Hooked externally (in or near the mouth)	–	With hook and trailing line < half the length of the carapace but not entangled	–	–

3.6 Survival estimates

Using the Ryder et al. (2006) scoring method and the information provided by the LO Turtle Capture Forms and validated observer-reported interactions, a post-release survival estimate of 77.8% was calculated (Table 6).

Table 6: Number of leatherbacks released alive as recorded by the Liaison Officer Turtle Form (*n* = 11, see Table 4) and validated observer-reported interactions (*n* = 12, see Table 5) by their injury and release condition. Numbers in parentheses are the corresponding post-interaction mortality rates from Ryder et al. (2006) (see Appendix 2 for additional details).

	Release Condition					
Injury Category	Released with hook & line trailing ≥half the carapace length	Released with hook & line trailing <half the carapace length	Released with hook and entangled	Released with all gear removed	Total	Post-release mortality (PRM)
I. Hooked externally, no entanglements	3 (0.3)	9 (0.15)	1 (0.65)	1 (0.10)	14	3.00
II. Hooked in upper or lower jaw with or without entanglement	-	-	-	-	-	-
III. Hooked in cervical esophagus, glottis, jaw joint, soft palate, tongue, other jaw tissue, with or without entanglement	2 (0.55)	2 (0.45)	-	-	4	2.00
IV. Hooked in esophagus at or below the heart (hook cannot be seen from the mouth)	-	-	-	-	-	-
V. Entangled only, no hook involved	-	-	-	5 (0.02)	5	0.10
VI. Comatose/ resuscitated	-	-	-	-	-	-
				Total released alive	**23**	
					Total dead	**5.10**
					Total PRM%	**22.17**
					Total PRS%	**77.83**

4. DISCUSSION

This report summarises information on at-vessel and post-release survival for leatherbacks globally. At-vessel survival for leatherbacks was relatively well-documented in many parts of the world, but there were very few studies on post-release survival and limited information from the West Pacific Ocean. This report provides the first estimate of post-release survival for leatherbacks caught in the New Zealand SLL fishing fleet using the Ryder et al. (2006) criteria.

4.1 Ryder criteria

The Ryder et al. (2006) criteria were first developed by the National Marine Fisheries Service (NMFS) as an outcome of the Office of Protected Resources (OPR) Workshop on Marine Turtle Longline Post-Interaction Mortality (Workshop) in Bethesda, Maryland on 15–16 January 2004. The workshop reviewed the NMFS post-hooking mortality criteria (established February 2001) and refined the criteria based on a comprehensive review of all available information and inputs from seventeen experts in the areas of sea turtle biology, sea turtle anatomy/physiology, sea turtle veterinary medicine, sea turtle satellite telemetry, and longline gear deployment. Key outcomes of the refined criteria included expanded injury categories to capture the specific nature of a fishing interaction, an additional criterion recognising that the removal of all or some of the gear (except deeply ingested hooks) may improve survival probability, and that species differences played a role in survival (with higher rates of mortality for leatherbacks). The Ryder et al. (2006) criteria was reviewed and slightly modified to account for hooking location (only for hardshell turtles) in a follow-up workshop conducted by the Pacific Islands Fisheries Science Center (PIFSC) in November 2011. Here it was noted that limited new data were available to justify a revision of the method, and that post-release survival estimates must continue to rely on expert opinion (SEFSC 2012).

Workshop 2 in this project recognised that the Ryder et al. (2006) criteria and estimates would benefit from updating. However, like the 2011 PIFSC workshop, there was still insufficient data to do this. Specifically, post-release survival studies on leatherbacks are still sparse and more are required. With few studies available on post-release survival of leatherbacks, it is not possible to validate the scoring system.

4.2 Survival estimates

Post-release survival for leatherbacks caught in the New Zealand SLL fishing fleet may be around 78%. We caution that this estimate is preliminary because of the small sample size for the LO Forms (n =11), and insufficient or unverifiable data for n = 29/41 of observer-reported interactions. The Turtle Capture Forms provide a large step forward in data collection, but (to our knowledge) have not been independently verified. All leatherbacks reported on the Turtle Capture Forms were reported to be released alive, but about 5% of leatherbacks reported by commercial fishers on NFPS forms (n = 233) were reported dead at hauling (Dunn et al. 2023).When estimating total survival (at-vessel and post-release survival) for leatherbacks caught in New Zealand SLL fisheries, the at-vessel component of that estimate should be informed by the larger commercial dataset while the post-release component should be informed by this study with appropriate consideration of sample size.

Some uncertainty in scoring remains around the hooking location; leatherbacks reported to be hooked in the jaw or in or around the mouth (n = 4) were scored here with a higher risk of mortality (Injury Category III being either 0.45 or 0.55, depending on the release condition) because it was unclear if the leatherback was hooked in a ‘hard’ (e.g., upper or lower beak) or ‘soft’ (e.g., jaw joint, soft palate, tongue) part of the mouth. If scoring had been assessed with a lower risk of mortality (Injury Category II), the post-release mortality estimate would increase slightly from 77.8% to 80.4%. We note that leatherbacks have minimal keratinous covering to their jaws (Wyneken 2015) and may suffer greater injury when jaw hooked compared to hard-shelled turtles, which have hard keratinised rhamphotheca.

An additional uncertainty in survival rates comes from the life history stage (size) of the leatherbacks. The size of leatherbacks reported on the LO Turtle Capture Forms included some animals that are likely to be juveniles, based on a size-at-maturity of 142.7 cm straight carapace length (Martin et al. 2020). Juvenile leatherbacks are suspected to have higher mortality rates than adults, which may be attributed to increased probability of drowning (less powerful swimming) and differences in physiology and response to capture stress. Of the observed leatherbacks captured and released alive in the Hawaiian deep-set longline fishery between 2004 and 2022, a total mortality rate for leatherbacks was calculated at 35% (95% CI = 23% to 50%). However, the mortality rates were 60% (95% CI = 34% to 81%) for juveniles and 24% (95% CI = 12% to 43%) for adults when leatherbacks were separated into life history stages (NMFS 2023).

4.3 The impact of trailing gear

The amount of trailing gear is likely to influence long-term post-release survival of leatherbacks. The NMFS criteria, which mostly account for interactions with trawl and pot fishing gear types, assume that any gear remaining on a leatherback at release presents a high risk (NMFS 2022). Leatherbacks are most often reported to be entangled in fishing gear and may be released with trailing gear. Trailing line can become snagged on a floating or fixed object, causing further entanglement which may constrict around a turtle's appendages. This entanglement can lead to infection or the loss of a flipper, which in turn reduces a turtle's ability to feed, evade predators, and reproduce (Parga 2012). Leatherbacks are also regularly captured by becoming hooked in the shoulder, and while a hook may be considered a minor injury upon release, minor injuries have been noted to become progressively worse over time. Serial entanglements (leatherbacks becoming entangled at least twice within days to weeks) off Massachusetts, USA, showed that minor leatherback entanglement wounds were reported to look more severe at the time of the second disentanglement (Dodge et al. 2022). The cause of increased injury was suspected to be pressure necrosis from constricting lines (Dodge et al. 2022). Delayed mortality (months after an interaction) resulting from chronic responses (e.g., secondary infections, slow organ failure) are suspected to occur following release (SEFSC 2012).

Based on the information collected by the LO Turtle Capture Forms to date, more leatherbacks were released with some gear still attached. While it was noted that leatherbacks were difficult to handle and release, and NOAA best-practice guidelines are to release large turtles in the water with trailing line minimised, removing all gear would likely increase leatherback long-term survival.

5. POTENTIAL RESEARCH

Handling and release training for skippers and crew
In order to limit stress and reduce the possibility of further injury or entanglement, gear removal needs to be completed as quickly as possible and efforts made to remove all gear from leatherbacks before release. To facilitate this, vessels could be provided and trained with the best available de-hookers.

Leatherbacks released with any trailing gear
For consistency in data collection to support future research, any leatherback that is captured and released with trailing gear should be reported as "Alive and Injured" on NFPS forms. Additional details about the interaction can be collected on the LO Turtle Capture Form.

Continue collecting information via LO Turtle Capture Forms
Information collected on the LO Turtle Capture Forms has provided valuable insight into the nature of turtle interactions, and their probability of survival, that has enabled the Ryder et al. (2006) method to be applied. Therefore, continued collection of information on turtle interactions on the LO Turtle Capture Forms is supported.

Explore options to satellite tag by-caught leatherbacks

Current attachment methods to satellite tag leatherbacks caught at-sea require decking the turtle. Novel tagging technology is being developed to potentially tag leatherbacks in the water. If successful, this technology could allow efficient and comprehensive tagging of bycaught leatherbacks, leading to greater information on survival and outcomes including non-lethal effects.

6. FULFILLMENT OF BROADER OUTCOMES

As required under Government Procurement rules[2], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project. The following broader outcomes were delivered:

Building capacity and capability in the research sector
The proposed research team and workshop participants included a combination of senior and early/mid-career scientists and collaboration with international experts.

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APPENDIX 1: Workshop Attendees

Name	Affiliation	Country	Workshop (WS) attended
Brit Finucci	NIWA	New Zealand	WS1, WS2
Matt Dunn	NIWA	New Zealand	WS1, WS2
Campbell Murray	FNZ	New Zealand	WS1, WS2
Tiffany Plencner	DOC	New Zealand	WS1, WS2
Karen Middlemiss	DOC	New Zealand	WS1, WS2
Rosa Edwards	Seafood NZ	New Zealand	WS1, WS2
Nigel Hollands	DOC	New Zealand	WS1
Ben Leslie	DOC	New Zealand	WS1
Samuel Darling	Fisheries observer	New Zealand	WS1
Dave Goad	Independent contractor	New Zealand	WS1
Charity Puloka	FNZ	New Zealand	WS2
Mark Hamann	James Cook University	Australia	WS2
Richard Reina	Monash University	Australia	WS2
Sean Williamson	Monash University	Australia	WS2
Richard Hamilton	The Nature Conservancy	Australia	WS2
Simon Vuto	The Nature Conservancy	Solomon Islands	WS2
Eric Gilman	Fisheries Research Group	United States	WS2
Scott Benson	NOAA	United States	WS2
Tina Fahy	NOAA	United States	WS2
Alexander Gaos	NOAA	United States	WS2
Summer Martin	NOAA	United States	WS2
Melissa Snover	NOAA	United States	WS2
Yonat Swimmer	NOAA	United States	WS2
John Wang	NOAA	United States	WS2

APPENDIX 2: Ryder et al. (2006) scoring criteria, with updates in SEFSC (2012)

Table 1: Criteria for assessing marine turtle post-interaction mortality after release from longline gear. Percentages are shown for hardshelled turtles (i.e., loggerhead, Kemp's ridley, olive ridley, hawksbill, and green turtle), followed by percentages for leatherbacks (in parentheses).

Injury Category		Release Condition			
		Released with hook and with trailing line greater than or equal to half the length of the carapace (line is trailing, turtle is not entangled)	**Released with hook and with trailing line less than half the length of the carapace (line is trailing, turtle is not entangled)**	**Released with hook and entangled (line is not trailing, turtle is entangled[1])**	**Released with all gear removed**
		Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)
I	Hooked externally with or without entanglement.	20 (30)	10 (15)	55 (65)	5 (10)
II	Hooked in upper or lower jaw with or without entanglement. Includes ramphotheca, but not any other jaw/mouth tissue parts (see Category III).	30 (40)	20 (30)	65 (75)	10 (15)
III	Hooked in cervical esophagus, glottis, jaw joint, soft palate, tongue, and/or other jaw/mouth tissue parts not categorized elsewhere, with or without entanglement. Includes all events where the insertion point of the hook is visible when viewed through the mouth.	45 (55)	35 (45)	75 (85)	25 (35)
IV	Hooked in esophagus at or below level of the heart with or without entanglement. Includes all events where the insertion point of the hook is not visible when viewed through the mouth.	60 (70)	50 (60)	85 (95)	n/a[2]
V	Entangled only, no hook involved.	Released Entangled 50 (60)			Fully Disentangled 1 (2)
VI	Comatose/resuscitated.	n/a[3]	70 (80)	n/a[3]	60 (70)

[1] Length of line is not relevant as turtle remains entangled at release.
[2] Per veterinary recommendation hooks would not be removed if the insertion point of the hook is not visible when viewed through the open mouth.
[3] Assumes that a resuscitated turtle will always have the line cut to a length less than half the length of the carapace, even if the hook remains.

Injury Category As Defined in Ryder et al. 2006 (with revisions noted in parentheses)	Release Condition[i]				Hooking locations as reported by SEFSC observers
	(A) Released entangled (line is trailing or not trailing, turtle is entangled[ii])	(B) Released with hook and with trailing line ≥ half the length of the carapace (line is trailing, turtle is not entangled)	(C) Released with hook or with hook and with trailing line < than half the length of the carapace (line is trailing, turtle is not entangled)	(D) Released with all gear removed	
	Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)	
I Hooked externally with or without entanglement. (note: this category now includes all rhamphotheca (beak) hooking locations)	55 (65)	20 (30)	10 (15)	5 (10)	rear flipper/groin/tail; flipper (front or back); carapace/plastron; carapace; plastron; beak (external)/head/neck; front flipper/shoulder/armpit; front flipper; rear flipper; armpit; groin; head external; beak external, unknown; beak external, lower jaw; beak external, upper jaw; tail; beak internal, unknown[iii]; beak internal, lower jaw[iii]; beak internal, upper jaw[iii]; neck; shoulder; unknown external
II Hooked in upper or lower jaw with or without entanglement. Includes rhamphotheca, but not any other jaw/mouth tissue parts (see Category III). (note: this category no longer includes rhamphotheca; it does include jaw/mouth tissue parts not categorized elsewhere)	65 (75)	30 (40)	20 (30)	10 (15)	mouth, lower jaw, other[iv]; mouth, side, other[iv]
III Hooked in cervical esophagus, glottis, jaw joint, soft palate, tongue, and/or other jaw/mouth tissue parts not categorized elsewhere, with or without entanglement. Includes all events where the insertion point of the hook is visible when viewed through the mouth. (note: no longer includes other jaw/mouth tissue parts not categorized elsewhere)	75 (85)	45 (55)	35 (45)	25 (35)	beak (internal)/mouth, unknown; beak (internal)/mouth, lower jaw; beak (internal)/mouth, upper jaw; side jaw joint; mouth, unknown; mouth, lower jaw, unknown; mouth, side, unknown; mouth, upper jaw, unknown; mouth, upper jaw, other; glottis; roof of mouth; tongue; swallowed, hook visible to insertion point; swallowed, cervical (all line removed); swallowed, hook partially visible[v]; not known if hooked (all gear removed) [vi]
IV Hooked in esophagus at or below level of the heart with or without entanglement. Includes all events where the insertion point of the hook is not visible when viewed through the mouth.	85 (95)	60 (70)	50 (60)	75 (85) [vii]	not known if hooked; unknown location; unknown internal [vi]; swallowed, hook not visible; swallowed, hook visibility unknown
V Entangled only, no hook involved.	Released Entangled 50 (60)	n/a[viii]		Fully Disentangled 1 (2)	not hooked
VI Comatose/resuscitated	n/a[ix]		70 (80)	60 (70)	

APPENDIX 3: Liaison Officer Turtle Capture Form

Questions for skippers related to turtle interactions

Vessel: **Trip/event number:** **Capture date:** **Questionnaire date:**

1. High priority questions

General

What species of turtle (leatherback or hard shell if species uncertain)?_____

How big was the turtle? Carapace (top shell) length?_____

How the turtle was caught (tick where applicable)

- ☐ Just holding the bait/hook in its mouth?
- ☐ Hooked
  - ☐ Externally or on the hard beak?
  - ☐ In the upper or lower jaw or corner of mouth?
  - ☐ Hook visible inside the mouth attached to soft tissue/jaw joint?
  - ☐ Suspected to be swallowed (hook not visible)?
- ☐ Entangled
  - ☐ in the main line
  - ☐ in a branch line
  - ☐ Other: _____

Was the animal comatose/resuscitated (Y/N)?_____

Release condition

If comatose or lethargic, was turtle allowed to recover on deck before being released (Y/N/NA)?_____

Was the turtle released (choose one):

- ☐ With all gear removed?
- ☐ With hook and trailing line ≥ half the length of the carapace but not entangled?
- ☐ With hook and trailing line < half the length of the carapace but not entangled?
- ☐ Entangled in line?

2. Medium priority questions

Animal behaviour when caught?

- ☐ Dead/unconscious
- ☐ Alive – occasional voluntary movement of limbs
- ☐ Alive - lethargic
- ☐ Alive – active (rapid/strong swimming or movement on the deck)

Injuries

- ☐ No injuries
- ☐ Superficial abrasions/scratches/ligature/line marks – what part of the body?_____
- ☐ Bruising – what part of the body?_____
- ☐ Deep cuts, fractures to shell, fractured limbs
- ☐ Damage to eyes
- ☐ Partial or complete amputation of limb
- ☐ Water or froth discharging from mouth or nose
- ☐ Bleeding – from where?_____

Animal behaviour upon release?

- ☐ Sunk without moving
- ☐ Remained at the surface without moving
- ☐ Did not deliberately swim away from the vessel for more than 1 minute
- ☐ Swam/dived deliberately away from the vessel

☐ Other, e.g., swam in circles, did not use both front flippers, could not right itself._____
_____

3. Any additional information/observations in comments box

- Other turtles in the vicinity?
- Were there sea jellies in the area (e.g., jellyfish)?
- What hook type and size (including offset angle of the barbs) was used?
- Bait type?
- Set or haul?
- Depth of fishing gear/number of hooks between floats?
- Number of hooks from sea turtle to the nearest float?
- Species caught either side of the turtle?
- The duration of the fishing event?
- Weather/sea conditions at the time?
- Sea surface temperature?
- Did the animal have a tag? Any information on the tag?

Comments

APPENDIX 4: Additional data from observer trip reports and diaries

These data were obtained from observer trip reports and personal diaries and were not included in the main report. The observer data cover the years 2008 to 2022, with 41 leatherback turtles from 37 observed surface longline fishing events. Of these, 12 had sufficient data and were verified, and the remaining 29 are summarised here. Judgements about the amount of trailing gear a turtle was released with were not made, after the verification process found comments similar to "hauled to the side of the vessel and cut as close as possible" could not be reliably interpreted as being less than half the carapace length. It is also not known if the detail of reporting might have been biased by the manner of capture and/or release, for example, when a turtle was brought close to the vessel and dehooked it is possible the event was more "memorable" and therefore better reported, compared to when a turtle was cut away some distance from the vessel. As in the main report, hooking reported in the "mouth" was scored as injury category III. Where the leatherback was released with hook and line trailing but the amount of trailing line was unknown (n = 13), the observation was given the average score of the two categories.

Table A4.1: Number of leatherbacks (total n = 29) reported in observer trip summary reports and personal diaries by their injury and release condition. Numbers in parentheses are the corresponding post-interaction mortality rates from Ryder et al. (2006). Injury and release categories are shortened; see Appendix 2 for full descriptions. Descriptions in italics are not part of the Ryder et al. (2006) table and are not included in the survival estimate. Numbers in parentheses are the corresponding post-interaction mortality rates from Ryder et al. (2006), averaged when two categories combined.

	Release Condition							
Injury Category	**Released with hook & line trailing ≥half CL**	**Released with hook & line trailing <half CL**	**Released with hook and entangled**	**Released with all gear removed**	*Unknown*	*Dead*	**Total**	**Post-release mortality (PRM)**
I. Hooked externally, no entanglements	11 (0.225)			4 (0.1)			15	2.875
II. Hooked in upper or lower jaw with or without entanglement							–	–
III. Hooked in cervical esophagus ..,	2 (0.5)						2	1.00
IV. Hooked in esophagus at or below the heart							–	–
Hooked, no location							–	–
V. Entangled only, no hook involved							–	–
VI. Comatose/ resuscitated							–	–
Hooked, unknown location	*4*				*3*		*7*	*N/A*

Injury Category	Released with hook & line trailing ≥half CL	Released with hook & line trailing <half CL	Released with hook and entangled	Released with all gear removed	*Unknown*	*Dead*	**Total**	**Post-release mortality (PRM)**
Unknown					*3*		*3*	*N/A*
Dead						*2*	*2*	*N/A*
							Total dead	**3.875**
							Total PRM%	**22.79**
							Total PRS%	**77.21**