Characterising surface longline fishing fleet behaviour in relation to leatherback bycatch

Prepared for Department of Conservation, CSP project INT2023-03

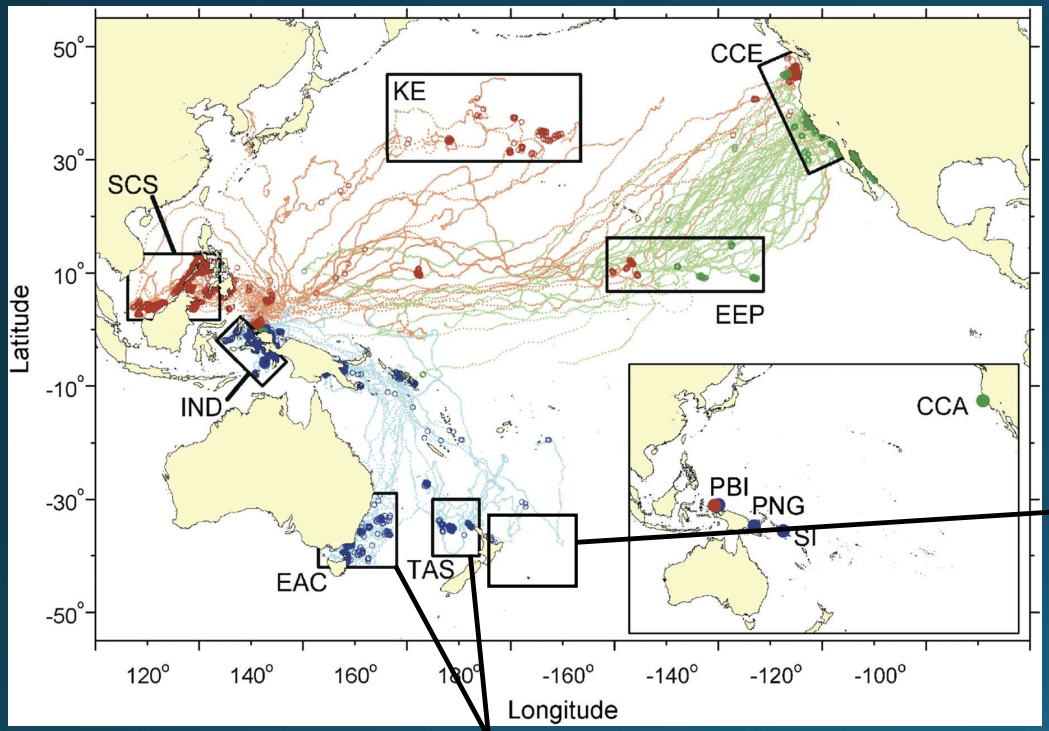
August 2024

Credit: Emilie Ledwidge/Ocean Image Bank

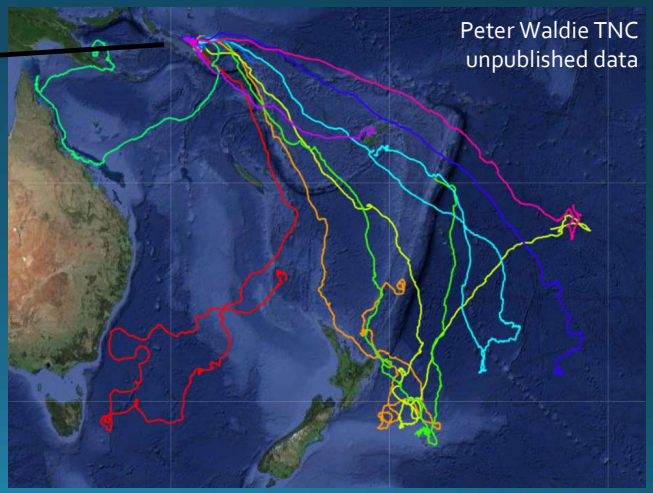
Dunn, M.R., Finucci, B., Sutton, P., Pinkerton, M.H. (2024). Characterising surface longline fishing fleet behaviour in relation to leatherback bycatch. NIWA Client Report 2024214WN. 80 p.

Where do leatherbacks in New Zealand waters come from?

Satellite tracks of post-nesting adult females, returning to their feeding grounds




Credit: Upwell Turtles


Peter Waldie TNC unpublished data

ECOSPHERE
AN ESA OPEN ACCESS JOURNAL

Article | Open Access

Large-scale movements and high-use areas of western Pacific leatherback turtles, *Dermochelys coriacea*

Scott R. Benson, Tomoharu Eguchi, Dave G. Foley, Karin A. Forney, Helen Bailey, Creusa Hitipeuw, Betuel P. Samber, Ricardo F. Tapilatu, Vagi Rei ... See all authors

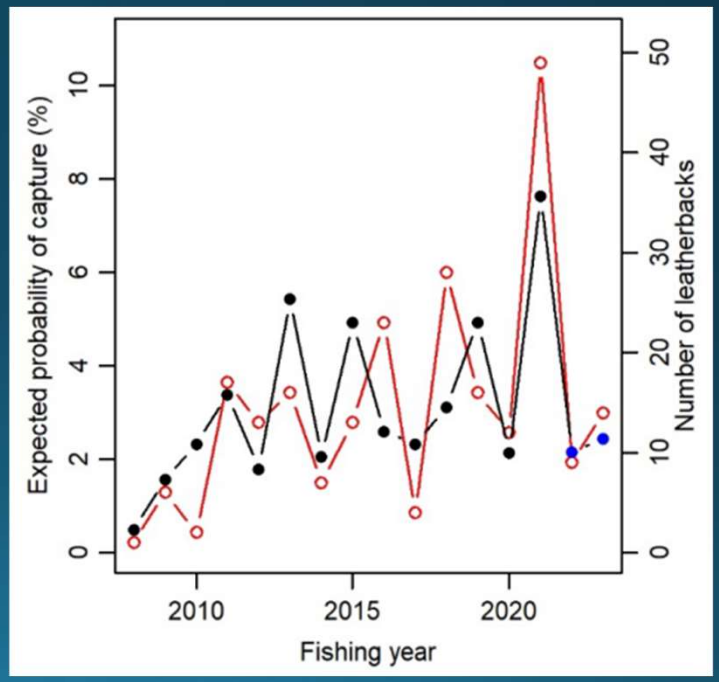
First published: 27 July 2011 | https://doi.org/10.1890/ES11-00053.1 | VIEW METRICS

The dark blue/red spots indicate foraging grounds

New Zealand turtle bycatch

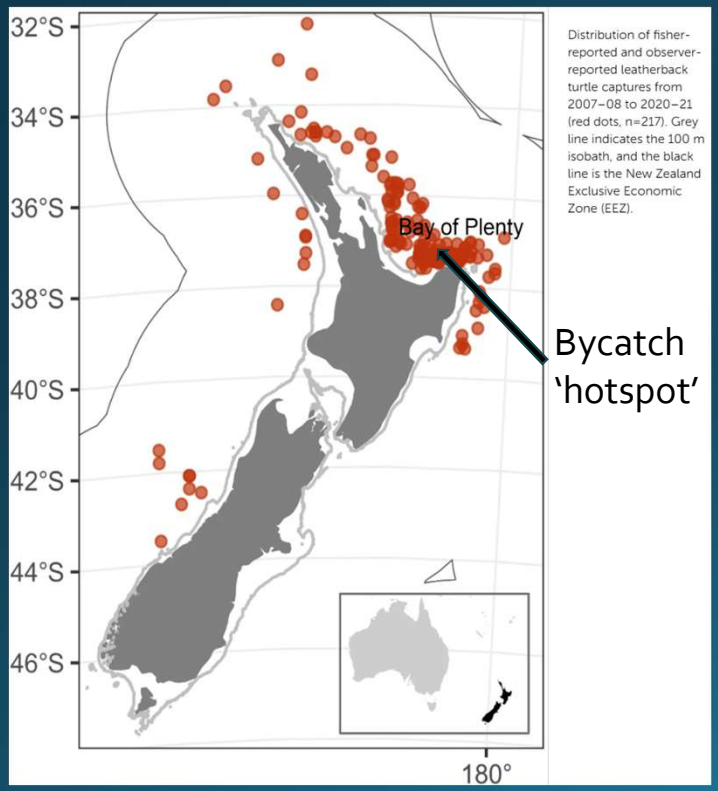
- Leatherback bycatch almost entirely from swordfish and tuna target shallow-set surface longline
- Also get a few green turtles in inshore fisheries, occasional hawksbill, olive ridley, & loggerhead
- Fisher turtle bycatch self-reporting forms used since 2008
- Used to have (limited) observer coverage, but all longline vessels are now monitored with cameras

Red circles & line (with second y-axis) is the reported number of leatherbacks bycaught in NZ commercial fisheries (black line is a fitted model)



- The New Zealand domestic surface longline fishery is spatially and temporally extensive; overlap with leatherbacks is largely off the northeast coast

Red spots are location of historical leatherback bycatch



Shaded squares are places fished by surface longline

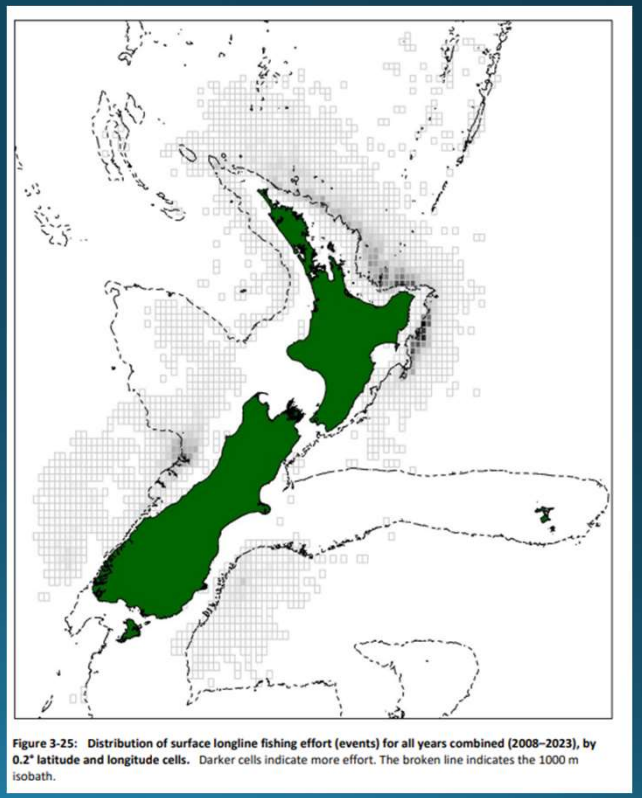


Figure 3-25: Distribution of surface longline fishing effort (events) for all years combined (2008–2023), by 0.2° latitude and longitude cells. Darker cells indicate more effort. The broken line indicates the 1000 m isobath.

- Seasonal fishery and bycatch (bycatch largely Jan-Apr)
- Fishery more extensive in time and space than the bycatch
- Most bycatch in lines reported as targeting bigeye tuna (*T. obesus*), but catch composition suggests it is really the swordfish fishery (*X. gladius*)
- There was nothing apparently unique about the fishing in and around the leatherback hotspot

Red shaded squares are places fished; the blue square marks the area where most leatherback bycatch takes place

Table 3-6: Estimated catch (t) of swordfish by surface longline by latitude and month for 2008–2023. Latitudes are floored, so a latitude of 38° S means >37° S to 38° S. Darker shading of cells indicates higher values. The blue box indicates an area and time of high leatherback reports (see Table 3-3) and includes 17.9% of all swordfish catches.

	Latitude																			
Month	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
10												0	0.3	0.2	6.0	11.3	3.4	3.9	3.8	2.1
11	0	0		0	0		0					1.7	2.0	11.7	25.8	9.6	2.0	1.5	0.5	
12	0	0	0	0	0		0		0	0	0.5	31.6	45.6	33.4	14.4	8.3	7.3	0.8		
1		0	0	0		0.3	0.2	0.3	7.5	12	14.0	193.0	97.7	77.4	71.8	7.5	8.6			
2	0	0	0	0	0	0.8	10.6	5.9	50.2	89.9	86.5	182.0	104.0	111.0	105.0	24.0	5.1			
3	0	0	0	0	1.0	14.2	113.0	130.0	76.5	122.0	262.0	214.0	137.0	109.0	102.0	95.3				
4		0	0	0.4	4.3	33.0	115.0	56.7	45.7	109.0	144.0	159.0	93.9	135.0	94.1	94.8	8.2			
5			0	2.1	7.3	29.2	117.0	83.6	42.3	137.0	191.0	155.0	69.7	83.2	62.4	63.3	30.9	4.4	0.2	
6				0	0.4	13.3	63.0	41.2	13.3	114.0	166.0	122.0	59.1	33.1	63.7	27.5	6.9	0.6		
7						0.3	17.7	19.6	1.4	5.7	36.8	58.9	84.6	61.0	63.0	58.7	26.3	1.8	0.5	1.2
8						0	2.8	7.4	1.1	0.4	1.7	13	23.9	55.2	84.8	54.9	32.2	18.7	1.3	
9							0	0	0	0	0	2	2.9	3.0	19.8	20.7	17.5	10.0	4.1	1.0

- Using a GAM to predict bycatch
- Variables offered to explain catch rates included both environmental and fishery operation
- Selected variables (from top to bottom in the figure)
  - proximity to steep sea surface temperature (SST) gradients (fronts)
  - mixed-layer depth
  - strength of the west-to-east current
  - water depth
  - moon phase
  - number of hooks between floats (an alias for fishing depth)
  - number of light sticks used between floats

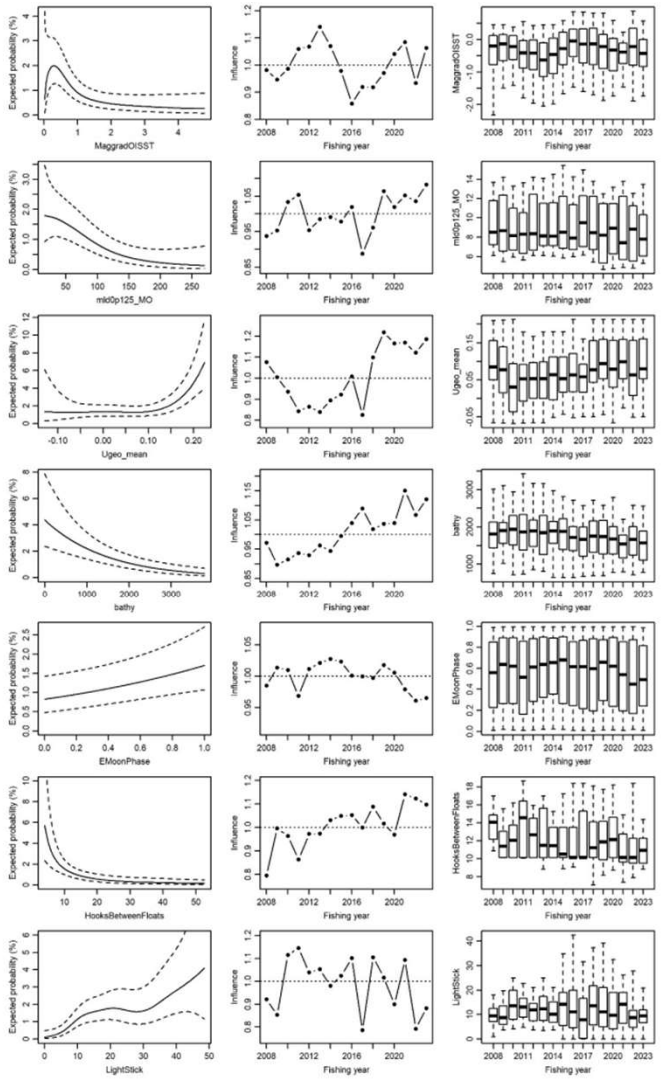


Figure 3-20: Leatherback turtle predicted probability of capture in FMA 1 and 2 from the GAM predictors: left panels, the predicted coefficient effect (with 95% confidence interval) estimated with other coefficients fixed at their median values; centre panels, the influence of each term on the estimate by fishing year; right panels, the distribution of each variable by fishing year (box plot showing median as the solid bar, interquartile range as the box, with whiskers extending to the 5% and 95% intervals).

- The GAM broadly described the observed bycatch, and suggested a broader 'hotspot' distribution

Where leatherback bycatch took place (darker squares = more)

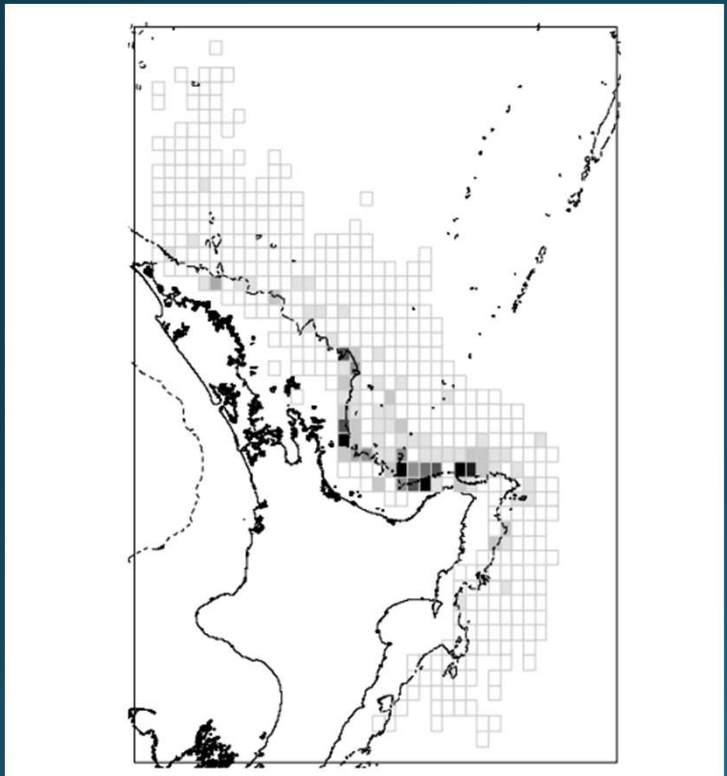
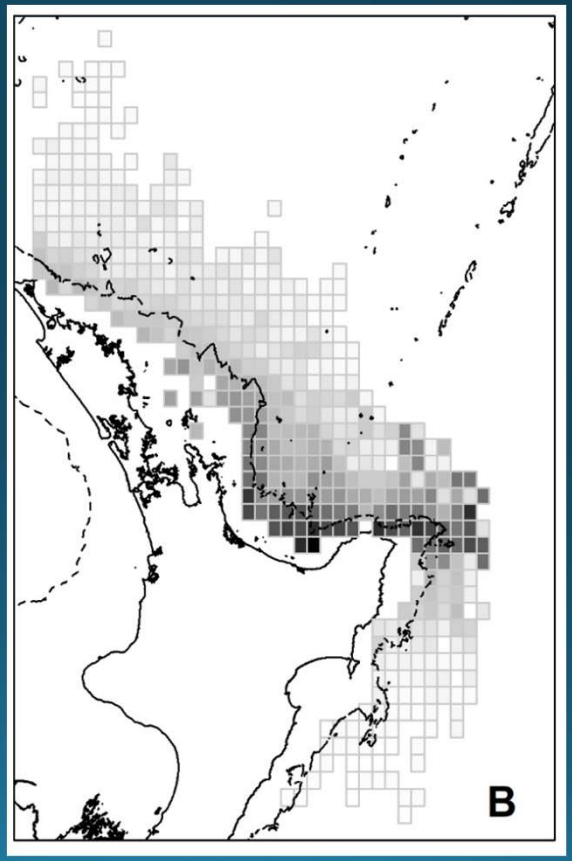


Figure 3-22: Distribution of fisher and observer-reported leatherback turtle captures from 2008 to 2021 in FMA 1 and FMA 2 (n=183). Broken line indicates the 1000 m isobath. Darker shading indicates greater probability.

Where the GAM predicted leatherback bycatch



- Further GAMs predicting leatherback occurrence and fish catch rates from environmental conditions
- Swordfish were most similar, in five of the seven variables. Southern bluefin tuna, big-eye tuna, and mako were similar in four of the seven variables.
- The species least similar to leatherbacks were porbeagle, blue shark, and albacore and moonfish
- Avoiding leatherbacks is going to be hardest when fishing for swordfish

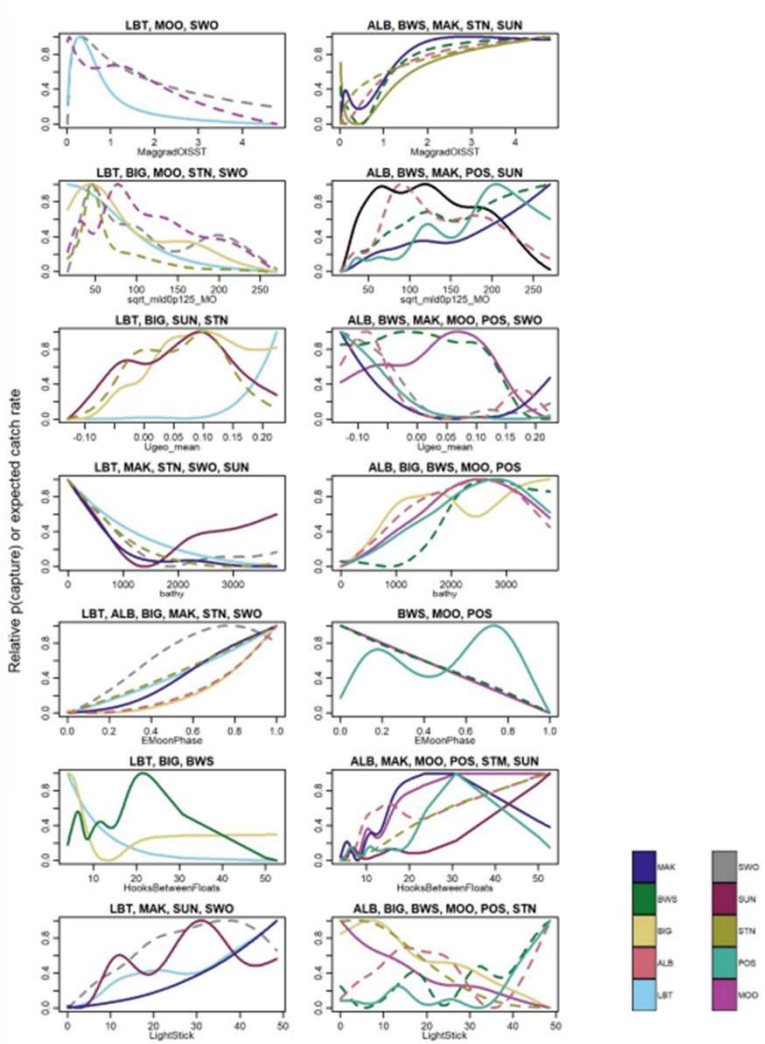
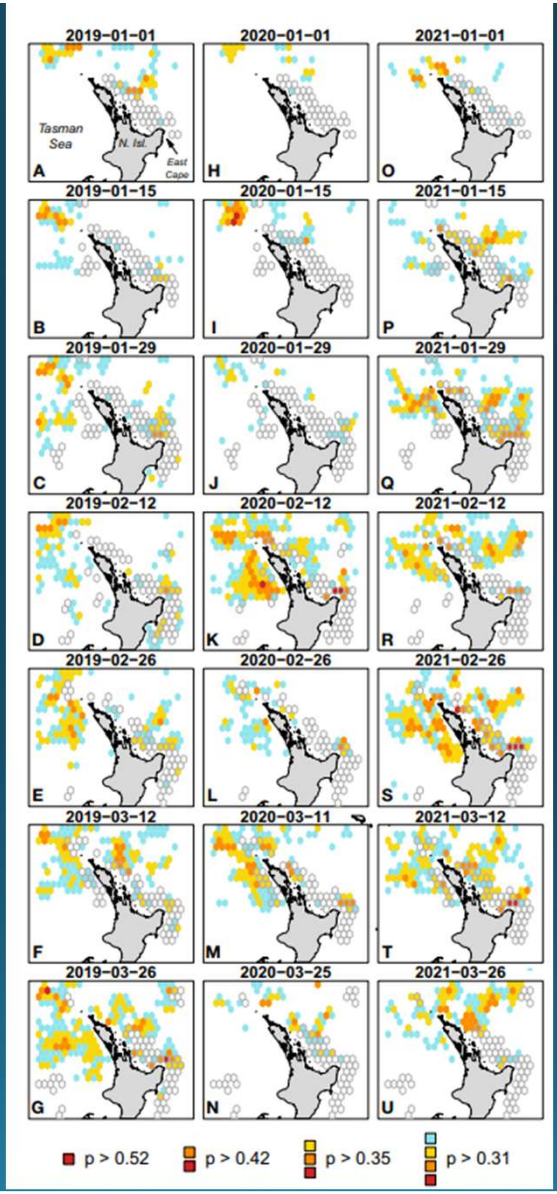


Figure 3-23: Leatherback turtle (LBT), mako (MAK), swordfish (SWO), bigeye tuna (BIG), sunfish (SUN), southern bluefin tuna (STN), albacore (ALB), porbeagle (POS), moonfish (MOO), and blue shark (BWS) predicted probability of capture (leatherbacks) or catch rates (fishes) in FMA 1 and 2 from a binomial GAM for leatherbacks, and delta-lognormal GAM for fishes, for the same variables as selected for the leatherback GAM. Effects are not plotted when both the binomial and lognormal were insignificant ($p<0.05$). The predicted effect is estimated with other coefficients fixed at their median values.

Siders et al. (2024)

- Same observational data set, different statistical model (ensemble random forest)
- High bycatch areas were ephemeral (1-2 weeks) and localized
- The apparent presence of discrete spatial areas with elevated risk may be useful to inform future management in the area

- However, any close place and time would change from week to week. So a move on rule might be better?



Maps show model predicted bycatch, by fortnight, in three different years (years as columns)

Potential of dynamic ocean management strategies for western Pacific leatherback sea turtle bycatch mitigation in New Zealand

Zachary A. Siders[1*], Campbell Murray[2], Charity Puloka[2], Shelton Harley[2], Clinton Duffy[3], Christopher A. Long[1], Robert N. M. Ahrens[4] and T. Todd Jones[4]

Conclusions & recommendations

- There are spatial and temporal patterns in leatherback bycatch and longline fishing
- Nevertheless, it appears hard to identify small-scale places and times within the New Zealand EEZ that could be closed to surface longline fishing (particularly for swordfish, bigeye tuna) such that leatherback bycatch would be avoided

- We recommended the following:
  - If a Spatial Distribution Model (SDM) is required for risk assessment and/or informing potential areal closures, then we need to identify the most robust SDM approach and data set, and variables should be included only when they have plausible predicted effects. i.e., three different models gave different results – which is "right"?
  - Variables describing distance from land or particular isobaths might be tested as additional potential predictor variables. i.e., more "perceptive" models might do better?
  - Develop a tool to show areas outside leatherback bycatch hotspots where target catch could be maintained for swordfish and tuna, similar to the US West Coast fisheries EcoCast product. i.e., extra information, provided it is not misleading, may always be helpful?

Acknowledgements

- Co-authors Brit Finucci, Phil Sutton, Matt Pinkerton
- This project was funded by the Department of Conservation's Conservation Services Programme project INT2023-03

Fisheries New Zealand
Tini a Tangaroa

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

New Zealand Aquatic Environment and Biodiversity Report No. 345.

B. Finucci
M. R. Dunn

ISSN 1179-6480 (online)
ISBN 978-1-991330-15-4 (online)

October 2024

Credit: Emilie Ledwidge/Ocean Image Bank

Post-release survival/mortality

- Turtles may be hooked or tangled, and drown
- Turtles may be released, but die later because of the injuries (post-release mortality)
- Turtles may be released, but lose condition and reproductive potential because of the injuries (or disease)

Quite a lot of scientific literature; most on loggerhead and green turtles

This information review has just been published:

Unintended Victims: A Systematic Review of Global Marine Turtle By-Catch in Fisheries

by Breno Carvalho da Silva [1,*], Lucas Garcia Martins [2], João Hemerson de Sousa [1], Yedda Christina Bezerra Barbosa de Oliveira [3] and Rômulo Romeu Nóbrega Alves [1]

[1] Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Universidade Federal da Paraíba, João Pessoa 58051-900, Paraíba, Brazil
[2] Laboratório de Biogeografia da Conservação e Macroecologia, Instituto de Ciências Biológicas (ICB), Universidade Federal do Pará, Belém 66075-110, Pará, Brazil
[3] Programa de Pós-Graduação em Etnobiologia e Conservação da Natureza, Universidade Federal Rural de Pernambuco, Recife 52171-900, Pernambuco, Brazil
* Author to whom correspondence should be addressed.

Coasts **2026**, *6*(1), 2; https://doi.org/10.3390/coasts6010002

Submission received: 3 September 2025 / Revised: 16 October 2025 / Accepted: 24 December 2025 / Published: 8 January 2026

PART 1/4: Literature review of post-release survival studies


Photo: Upwell Turtles

Using satellite tags to track the outcome

Fishing method	Year of Study	Region	N (survival estimate)	Factors examined/affecting survival	Comments	
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; 1 mortality in Indonesia (observed), 1 in South Africa (inferred)	Hays (2003)
Fish trap entanglements	2003–2012	West 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 (2021)
Longline, industrial; gillnet, artisanal	**2005–2006**	**South 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**	**Lopez-Mendilaharsu (2009)**
Lobster pot, industrial; drift net, industrial	2005–2006	East 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 (2008)
Drift net, industrial	2006	South Atlantic (Brazil)	1 (100%)	Opportunistic tagging event	3 additional nesting females tagged; LBT tracked for 97 d	Almeida (2011)
Entanglement (most pot/trap)	2007–2020	West Atlantic (USA)	16 (75%)	Post release survival after disentanglement	LBT tagged with satellite tags (6), acoustic tag (3), PIT tag/photo ID (6); 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 (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 (2024)

Studies of the condition of the turtle when caught

- 25 studies reported on at-vessel survival of leatherbacks (largely general sea turtle bycatch studies)
- Assessed at-hauling status (alive or dead) from at-sea observations during normal fishing operations
- 11 studies from longline fisheries, most studies from West Atlantic or high seas fleets (ICCAT)
- In Pacific, studies off Hawaii (n=2), Marshall Islands (n=1), East Pacific (n=6, IATTC), **none from Southwest Pacific**
- Number of leatherbacks available for many studies was low (<20), but 9 studies had >100 (max 468 reported from 2006–2017)
- At-vessel survival rate was reported to be relatively high, 83–100% (n=20+), particularly high for longline fisheries (85–100% estimated survival)

PART 2/4: State of NZ surface longline fisheries

- An initial workshop was held to review information about the relevant New Zealand fisheries

PART 3/4: Review applicability of methods used to estimate post-release survival

- Given we have no actual data: Review the applicability of the methods of Ryder et al. (2006) and SEFSC (2012) to estimate post-release survival for leatherbacks
- 20 people in attendance, international experts (scientists, turtle experts) from 3 countries (Australia, Sols. Islands, US) and 4 institutes (NOAA, Monash University, JCU, The Nature Conservancy)
- Specific issues
  - Discussed whether the methods of Ryder et al. (2006) and SEFSC (2012) were appropriate
  - Made recommendations for future data collection that will improve assessments of post-release survival

Ryder et al. (2006) Criteria

- A way of estimating whether a turtle will survive given data on how it was caught & released
- Developed by National Marine Fisheries Services (NMFS, NOAA) after a post-interaction mortality workshop (2004)
- Revised for 2006 to better describe injury categories, specific nature of interactions

Ryder, C.E.; Conant, T.A.; Schroeder, B.A. (2006). Report of the Workshop on Marine Turtle Longline Post-Interaction Mortality. NOAA Technical Memorandum NMFS-F/OPR-29. Maryland: National Oceanic and Atmospheric Administration.

- Key changes:

  Separated external hooking (less damaging) from mouth hooking

  Recognised that removal of all or some of gear (except for ingested hooks) may improve survival

  Recognised species differences in survival; higher mortality rates for leatherbacks

- Reviewed and revised (very slightly) again in 2012 to account for hooking location (only relevant for hardshell turtles)

Southeast Fisheries Science Centre (SEFSC) (2012). Protocols for categorizing sea turtles for post-release mortality estimates. National Marine Fisheries Service. 2012, Southeast Fisheries Science Centre, Miami FL, August 2011, revised February 2012.

Revised & reordered Table of Ryder et al. 2006 (SESFC 2012)

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)	

PART 4/4: Estimate post-release survival for New Zealand leatherback bycatch

- Liaison Officer Turtle Capture Forms; active from May 2023. Questionnaire developed for two main reasons:

(1) the low level of observer coverage on the surface longline fleet

(2) the requirement for more detailed information to assess post release survival of bycaught turtles

- Followed components of Ryder et al. (2006) & NMFS Procedure 02-110-21 (n.b. table reordered)

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**

Workshop outcomes

- Confirmed Ryder et al. (2006) criteria still considered best practice for assessing leatherback post-release survival
- Recognized the criteria are imperfect, but no data are available to make the scoring more accurate
- Recognised that ongoing trials of direct at-sea satellite tagging in the Hawaiian surface longline fishery should improve knowledge in upcoming years

- Highlighted the importance of removing trailing gear prior to release to improve survival outcomes

- Recognised juvenile leatherback mortality is likely to be higher than adult mortality (seen in deep-set longline); may be attributed to increased probability of drowning, differences in physiology and response to capture stress (smaller leatherbacks have higher metabolic rates and become more stressed)

Report recommendations

- All efforts should be made to remove all gear before release
- Skippers need correct de-hookers to release turtles (and should receive training)
- Leatherbacks released with any trailing gear should be recorded as "Alive and Injured"

- Currently in New Zealand:
  - Skippers and crew have turtle training
  - All bycatch reports must include capture and release information
  - All vessels must have a line cutter and de-hooker
  - Move-on rules being implemented

Acknowledgements

- Co-author Dr Brit Finucci
- Thanks to all workshop attendees for sharing their experience, insight, and expertise
- This work was funded by Fisheries New Zealand project PRO2023-15