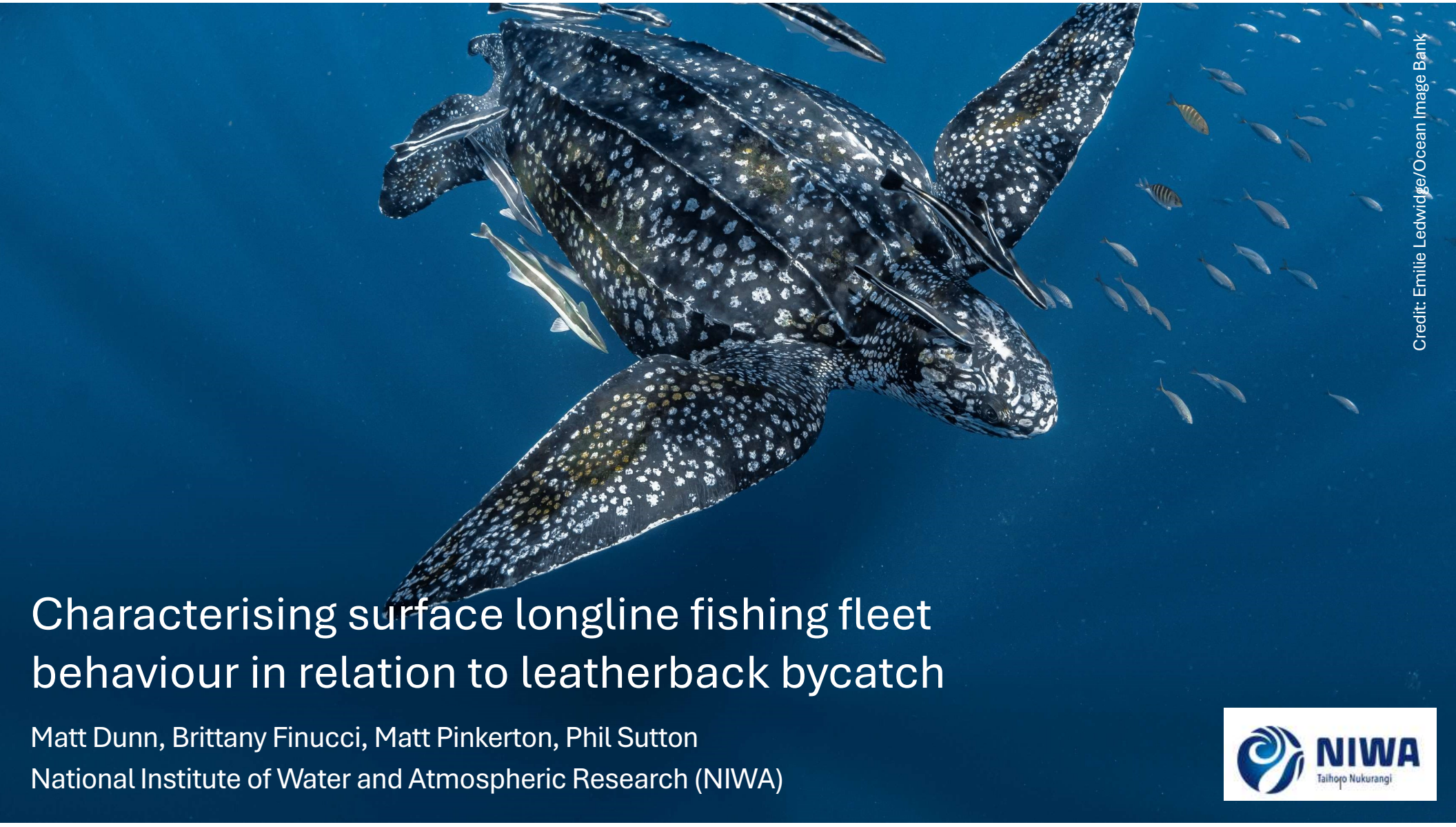

Credit: Emilie Ledwidge/Ocean Image Bank

Characterising surface longline fishing fleet behaviour in relation to leatherback bycatch

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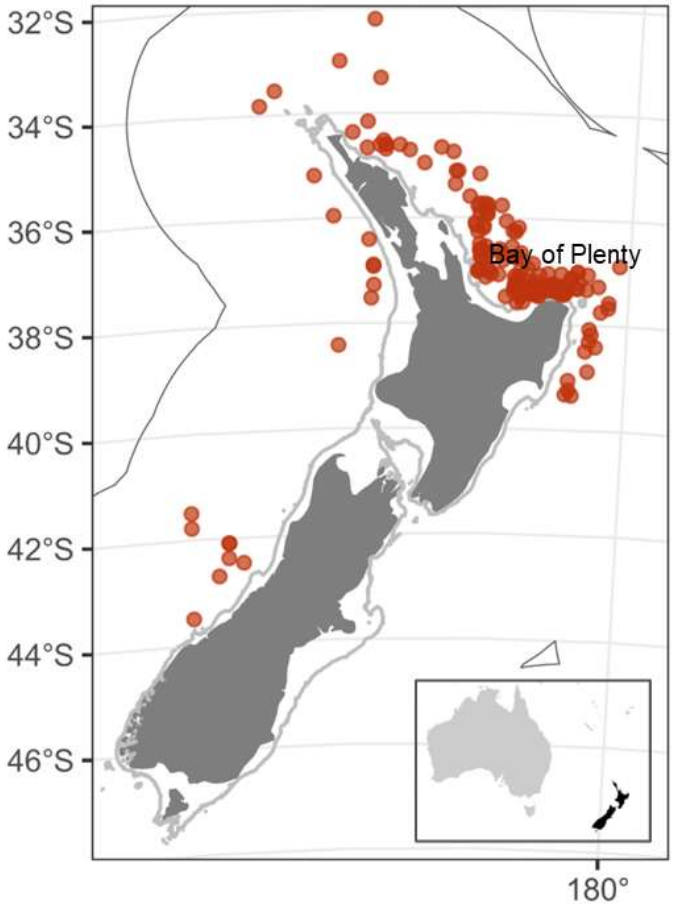
Background: Leatherbacks in NZ waters

- NZ is a foraging ground for Critically Endangered western Pacific population leatherbacks.
- Western Pacific leatherbacks forage as far south as NZ, and between Indonesia and the west coast USA.
- Protected species in NZ waters.

- In 2020–21 fishing year, **50 leatherback** interactions were reported in the surface longline fleet.
- The majority were fisher-reported interactions.
- The 2021 increase was associated with SST, and relatively more effort in the Bay of Plenty bycatch 'hotspot' area.
- Unclear if increased interactions in 2021 were an anomaly or emerging bycatch trend.
- Fate of released leatherbacks unknown.



Project objective

- Builds on **CSP project INT2021-03** (Review of commercial fishing interactions with marine reptiles) and subsequent research by NIWA (Dunn et al. 2023).
- Consider the relationship between leatherbacks, fisher behaviour, and fish species caught in the surface longline (SLL) fisheries.

Specific objectives:

1) Describe the temporal patterns in the distribution of SLL fishing effort by target species and leatherback bycatch off the North Island east coast (FMA1, FMA2).

2) Evaluate the spatial and temporal patterns of SLL fishing effort by target species relative to biological and environmental predictors of leatherback bycatch.

3) Evaluate the SLL catch in the region by species and weight for vessels reporting interactions with leatherbacks and those not reporting any leatherback interactions.

4) Identify any temporal changes in fishing practices and/or catch composition associated with changes in leatherback bycatch.

Data sources

- Add two years to the data compiled under **INT2021-03**.
- Data include *COD* database (observed data; NA for last two years), Non-Fish Protected Species Catch Returns (NFPS) via *Enterprise Data/Warehouse* database (reported data), commercial catch and effort data (event forms).
- We did not update the data in INT2021-03 covering citizen science, strandings, zoo hospital records, etc, nor those for species other than leatherbacks.
- Duplicate records removed: compare vessel key, date, location, time, and species.
- Earliest record to 30 September 2023, all of New Zealand EEZ.

Brief analytical approach

1) Describe the temporal patterns in the distribution of SLL fishing effort by target species and leatherback bycatch off the North Island east coast (FMA1, FMA2).

- Two versions, (a) a tabulation of fisheries data based on location and target species, (b) an analysis identifying fleet units from catch composition data (event-based, 40 fish species, LBT not included in clustering).

2) Evaluate the spatial and temporal patterns of SLL fishing effort by target species relative to biological and environmental predictors of leatherback bycatch.

- Update the 2021 GAM but for FMA 1 and 2 only, and compare models applied for fishery target and important bycatch species. We don't have data on leatherback prey.

3) Evaluate the SLL catch in the region by species and weight for vessels reporting interactions with leatherbacks and those not reporting any leatherback interactions.

- Tabulation and plotting of comparative data.

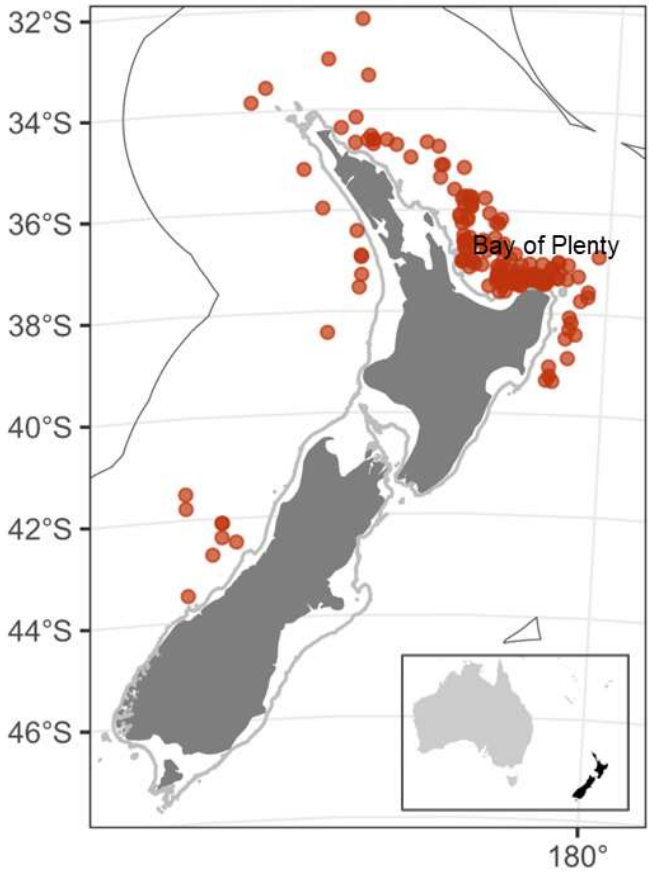
4) Identify any temporal changes in fishing practices and/or catch composition associated with changes in leatherback bycatch.

- Done through the cluster analyses under Obj. 1. Also, industry consultation including skipper interviews available from FNZ project PRO2023-15.

Fishery characterization (Obj 1 & 4)

Where is the LBT “Hotspot”?

- Tabulation by degree and month cells is coarse (36–38°S and Jan-Apr).
- Split by season (split at day of year 117.5), giving 1 January to 28 April.
- Split by latitude and longitude.



Where is the LBT “Hotspot”?

- Highest probability of capture in summer in coastal waters:
  - East Great Barrier Island (GBIsl) and Coromandel (0.170/1000 hooks).
  - Southern Bay of Plenty (0.095/1000 hooks).
  - Central Bay of Plenty (0.040/1000 hooks).

- Although north of East Cape may be the bycatch “hotspot”, a LBT occurrence hotspot may be in the western Bay of Plenty to GBIsl.

- The LBT aerial survey (POP2023-01) scheduled for summer 2025 will be (1) in the area north of East Cape, and (2) east of Coromandel.

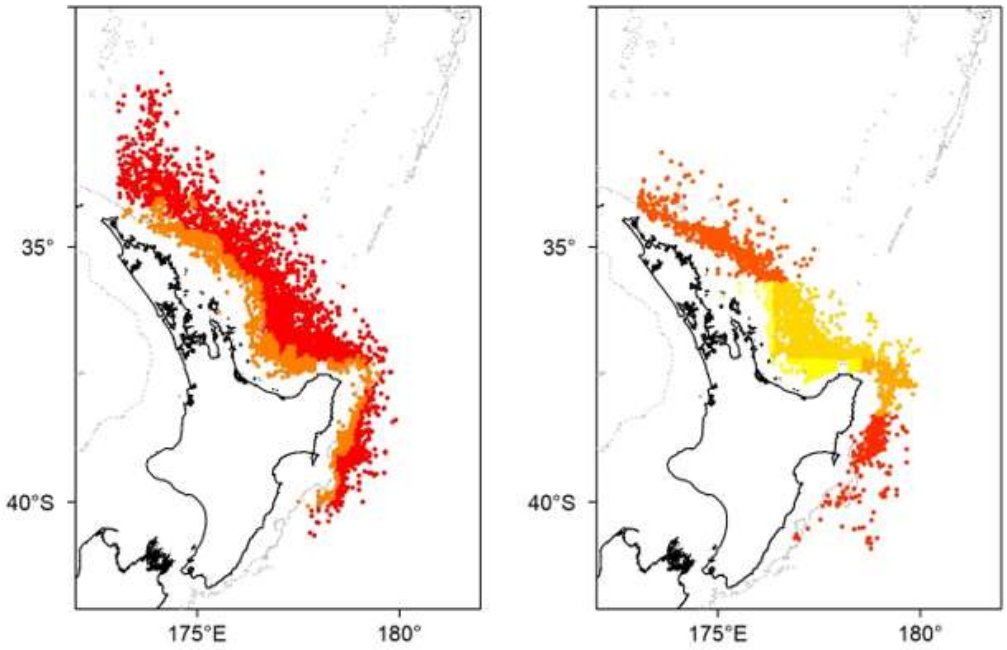


Figure 3-4: Leatherback capture in 0.1° latitude and longitude cells from cluster analyses. Left panel, 29 April to 31 December. Right panel, 1 January to 28 April. Cells are shaded using heat colours to show the probability of leatherback captures (lowest is dark red, highest is bright yellow).

In general, SLL effort has been decreasing

Table 3-1: Fishing effort, as number of events, for surface longline fisheries around New Zealand by fishing year and reported target species. Fishing year shown as year ending.

Fishing year	Albacore	Bigeye	Southern	Swordfish	Pacific	Yellowfin	Other
2008	2	1 050	725	131	25	7	19
2009	11	1 634	922	45	14	1	5
2010	25	1 362	1 279	147	22	1	4
2011	15	1 692	1 001	185	9	0	10
2012	0	1 346	1 229	195	13	0	0
2013	8	1 027	1 259	319	33	0	4
2014	4	852	1 239	212	15	0	0
2015	0	467	1 214	540	12	0	0
2016	23	759	1 376	520	25	0	3
2017	4	587	1 362	447	21	0	0
2018	0	706	1 405	474	23	3	0
2019	4	500	1 542	197	29	1	0
2020	7	465	1 535	198	43	0	1
2021	5	409	1 085	339	9	4	1
2022	41	233	1 007	143	0	0	1
2023	0	474	1 087	211	10	2	5

- Effort moves south as the season progresses (Oct to ~Apr).
- Returns north later in the year (~May to Sep).

Table 3-2: Number of surface longline fishing events 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.

	Latitude (°S)																			
Month	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
10												3	15	21	100	164	35	33	16	9
11	3	12		3	2		1					43	68	177	513	133	21	7	1	
12	1	10	33	7	2		3		2	3	17	332	396	264	219	48	14	1		
1		22	11	19	NA	1	4	8	55	121	142	745	385	258	322	41	15			
2	11	64	151	58	1	10	38	22	170	245	360	617	341	303	375	100	15			
3	2	100	202	193	16	75	311	254	182	385	776	632	366	331	450	251				
4		9	142	412	70	209	517	193	155	392	461	542	354	345	397	281	9			
5			3	466	475	364	738	271	333	875	696	509	201	216	246	205	49	3	1	
6				9	102	232	930	370	111	777	903	1 017	534	104	186	163	35	4		
7						6	554	384	57	55	270	888	1 330	474	301	379	135	14	1	3
8						4	178	327	26	5	18	324	737	524	662	518	265	106	3	
9							2	11	3	7	7	31	95	118	363	280	144	70	11	5

- LBT bycatch largely Jan-Apr, and at latitude 36–38°S (includes BoP "hotspot").

Table 3-3: Number of leatherback turtles reported 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 and includes 63.4% of all reports.

	Latitude (°S)																			
Month	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
10												0	0	0	1	0	0	0	0	0
11	0	0		0	0		0					1	0	0	5	1	0	0	0	
12	0	0	0	0	0		0		0	0	0	3	2	2	1	0	0	0		
1		0	0	0		0	0	0	0	1	0	31	9	1	3	0	0			
2	0	0	0	0	0	0	1	0	0	1	1	21	14	4	1	0	0			
3	0	0	0	0	0	1	1	0	0	0	5	34	9	7	0	0				
4		0	0	0	0	0	1	2	0	1	2	20	11	2	2	1	0			
5			0	0	0	0	1	0	0	2	3	4	2	4	1	2	1	0	0	
6				0	0	0	1	0	0	0	0	5	0	1	0	0	0	0		
7						0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
8						0	0	0	0	0	0	1	0	0	1	0	1	0	0	
9							0	0	0	0	0	0	0	0	0	0	0	0	0	0

- Bigeye (BIG)-tuna target fishery, similar to LBT bycatch, does not go much further south than East Cape, and includes a focus around the LBT “hotspot” region.

- Swordfish (SWO) target fishery extends further south.

Table 3-4: Estimated catch (t) of bigeye tuna 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 24.4% of all bigeye 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	1.1	1.5	12.2	17.1	5.2	4.9	2.0	1.2
11	0	0		0	0		0					6.1	3.7	20.8	76.5	13.2	1.4	0.1	0	
12	0	0	0	0	0		0		0	0	0.4	45.2	34.7	24.1	22.6	4.1	0.1	0.1		
1		0	0	0		0	0	0	17.2	15.8	15.1	70.3	33.0	25.8	32.7	2.4	0.2			
2	0	0	0	0	0	0	0	0.3	6.2	9.9	18.1	63.6	39.7	36.5	47.3	15.0	0.4			
3	0	0	0	0	0	0	0	0.1	2.9	22.4	43.2	76.6	33.9	44.7	69.6	34.2				
4		0	0	0.1	0	0	0	0	2.3	19.1	30.9	57.7	26.0	25.7	50.6	35.1	0.1			
5			0	0	0	0	0.3	0.1	2.1	12.7	13.2	24.6	7.2	10.2	14.8	14.5	0.8	0.1	0	
6				0	0	0	0	0	0.2	1.8	2.0	16.5	9.6	4.5	15.3	25.6	6.6	0		
7						0	0	0	0	0	0.7	5.1	9.5	11.4	19.1	47.4	17.8	0.9	0.3	0.2
8						0	0	0	0	0	0	1.7	13.4	18.3	40.1	35.6	27.6	12.4	0.5	
9							0	0	0	0	0	0.3	5.8	13.9	39.9	17.7	11.7	9.3	2.8	1.8

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

- Southern bluefin (STN) is almost all further south than LBT target fishing.

- Sunfish are thought to be associated with LBT, but (rather like SWO) catches extend further south.

Table 3-8: Estimated catch (t) of southern bluefin tuna 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 0.1% of all southern bluefin tuna 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	0.5	0.1	1.2	2.4	0.2	1.4	0	0.1
11	0.3	0.5		0.1	0		0					0.3	0.3	1.8	3.1	0.5	0	0	0	
12	0	0.4	1.5	0	0		0		0	0	0	0.5	1.4	0.6	0.5	0	0	0		
1		1.8	0.2	1.8		0	0.2	0.3	0.1	0.5	0.1	2.4	0.8	0.3	0.7	0	0			
2	2.8	33.4	52.4	13.6	0.1	1.7	3.1	1.3	0.6	2.2	0.1	0.5	0.2	0.1	0.6	0	0			
3	1.5	89.7	142	94.8	12.8	28.0	74.6	54.1	12.4	0.3	0.8	1.7	1.2	1.8	0.5	0.6				
4		7.9	70.7	273	58.9	137.0	242.0	59.2	16.1	11.8	8.3	5.9	1.1	1.0	1.4	0.2	0			
5			1.4	444	470.0	303.0	321.0	62.8	66.5	201.0	134.0	32.0	10.6	3.5	1.8	0.5	0	0	1.1	
6				2.4	86.4	189.0	601.0	210.0	83.2	381.0	372.0	449.0	174.0	10.6	10.4	7.2	0.4	0		
7						3.7	487.0	349.0	53.4	18.5	153.0	602.0	777.0	200.0	111.0	96.0	23.0	0.6	0	0
8						0.8	104.0	205.0	6.9	0.3	2.3	202.0	382.0	160.0	110.0	106.0	56.4	17.0	0	
9							0.5	3.4	0.3	1.9	1.3	9.0	18.0	23.5	32.3	21.4	9.2	1.3	0.1	0.2

Table 3-10: Estimated catch (t) of sunfish as a bycatch in 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 12.3% of all sunfish 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	1.3	1.2	14	13.5	2.5	2.8	1.3	1.3
11	0	0		0	0		0					0.2	1.2	15.7	80.2	17.4	1.4	0.1	0	
12	0	0	0	0	0		0		0	0	0.2	18.1	26.5	30.0	18.4	1.7	0.7	0		
1		0	0	0		0	0	0	0.3	3.6	6.2	44.0	31.1	17.2	21.5	0.9	0.3			
2	0	0	0	0	0	0.1	2.3	3.4	7.3	22.9	32.5	32.8	21.3	17.0	27.5	5.8	0.2			
3	0	0	0	0	0.3	3.4	18.2	20.2	18.8	64.6	98.2	49.0	27.4	17.2	26.3	9.2				
4		0	0	0	0.6	6.6	16.2	13.5	10.0	74.3	54.8	32.5	29.2	36.9	24.2	10.7	0			
5			0	1.0	2.7	2.4	6.7	3.7	13.9	67.4	43.9	33.1	14.6	34.1	23.2	10.7	1.4	0	0	
6				0	0.3	0.8	4.4	1.5	2.0	20.8	22.4	51.1	25.5	4.5	30.3	16.9	6.0	0		
7						0	0.8	1.2	0.7	0.6	2.1	17.7	43.1	30.1	30.1	53.9	18.7	1.6	0	0
8						0	0.3	0.7	0	0.1	0.4	3.8	26.0	15.2	55.2	72.4	33.2	13.3	0	
9							0	0	0	0	0	0.7	6.3	7.7	27.6	39.1	13.3	7.2	0.2	0

- Effort has recently become more focused on the BoP and East Cape latitudes.

Table 3-11: Number of surface longline fishing events by latitude and fishing year for 2008–2023. Fishing years labelled by year ending. Latitudes are floored, so a latitude of 38° S means >37° S to 38° S. Darker shading of cells indicates higher values.

	Latitude																				
Fishing year	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	Total
2008				69	93	28	33	39	10	105	243	368	226	106	326	242	47	21			1 956
2009				30	87	65	110	78	55	122	315	382	320	260	357	358	57	23	8	4	2 631
2010				49	91	10	165	67	120	304	504	281	395	302	298	192	45	11	4	2	2 840
2011				40	80	29	95	38	101	269	352	343	258	389	472	164	210	65	7		2 912
2012				16	53	78	310	188	96	299	160	227	339	224	320	293	128	46	5	1	2 783
2013			2	13	42	115	332	86	55	223	328	280	286	399	246	190	36	16			2 649
2014				6	21	92	324	188	74	223	170	203	304	308	137	234	29	9			2 322
2015				17	7	66	213	225	141	129	105	298	490	196	205	105	30	6			2 233
2016					5	60	283	198	73	218	280	423	527	189	287	145	13		1		2 702
2017					11	151	287	84	40	242	141	367	324	186	409	135	40	3	1		2 421
2018				48	22	56	162	148	65	194	228	495	368	213	381	185	33	2	4	7	2 611
2019		16	88	154	17	102	207	110	95	144	190	469	290	76	193	76	35	3			2 265
2020	4	62	167	141	26	25	306	92	32	159	228	434	157	79	216	86	17	17	1		2 249
2021	3	3	67	199	1	8	135	104	32	85	178	433	242	86	159	82	5	10			1 832
2022		63	72	175	27	1	224	79	27	76	117	275	136	46	63	40	1	1	1		1 424
2023	10	73	146	210	85	15	90	116	78	73	111	405	160	76	65	36	11	5	1	3	1 769

WCSI

- The closest correspondence between LBT bycatch hotspot and fishery catches is BIG-targeted fisheries. 24.4% of BIG catch taken in LBT hotspot region and season.
- SWO fishery follows a similar pattern to BIG but extended further south and later into the year. There was less overlap with LBT. 17.9% of SWO catch taken in LBT hotspot region and season.
- Few STN were caught (0.1% of catch) in LBT hotspot area and season.
- Sunfish are thought to often co-occur with LBT. Only 12.3% of the sunfish bycatch was taken in LBT hotspot area and season.

- About 32% of the fishing effort (by number of events) in 2023 took place between 36° and 38° S and of this effort, about 39% took place in January to April.
- This meant about an average of 12% of the overall effort took place in LBT hotspot area. This ranged from 7–15% over the period 2008–2023.

Clustering by catch composition

- Predict whether LBT was caught from potential spatial (lat, long, depth) and temporal predictors (day of year, month).

- The clustering was done using CLARA (Clustering LARge Applications).
- This is an extension of PAM (Partition Around Medioids) specifically designed for large datasets.
- Clustering uses predictors to split the data set into groups that have similar composition.

- CLARA works by selecting a random sample of the data, applying PAM to the sample, and repeating this process multiple times retaining the sub-set for which the mean (or sum) is minimal.
- The optimal number of clusters k is selected based the minimum dissimilarity measure, using the average silhouette method over a range of possible values for k.
- We clustered catch weights for 40 species and 37 657 events. Leatherback captures were not included in the catch weights, so they did not influence the identification of fisheries.

- Three clusters was the optimum, but also looked at six.

	Cluster1	Cluster2	Cluster3
Target	BIG, STN, SWO	STN, BIG, SWO	STN
Catch	**SWO**, BWS, STN	BWS, STN, SWO	STN, BWS
Peak season	March-May	May-June	June-July
Relative effort	High	Low (near absent 2023)	Intermediate, and increasing (peak in 2023)
Main location	BoP & East Cape; WCSI; SE SI	ECNI; WCSI more recently	ECNI; WCFI
Leatherback captures	**212** **0.82 per 100 events** **0.90 per 100 000 hooks**	**22** **0.37 per 100 events** **0.34 per 100 000 hooks**	**1** **0.02 per 100 events** **0.01 per 100 000 hooks**
Mean depth (m)	526	510	532
Mean SST	**18.7° C**	17.1° C	15.4° C

Cluster 1

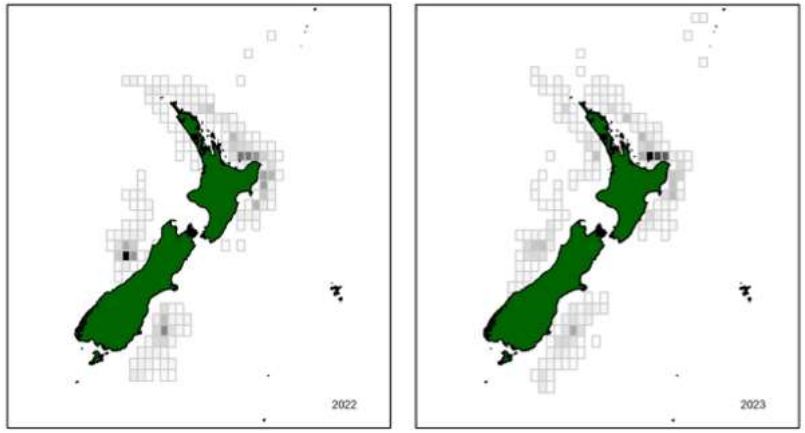


Figure 3-7: Cluster 1; spatial relative distribution of fishing events by 0.5° longitude and latitude cells, by fishing year (labelled year ending) for the last three fishing years (2023, 2022, 2021, and summarised for the years before that, 2008-2020). Darker shading indicates greater fishing effort.

Cluster 2

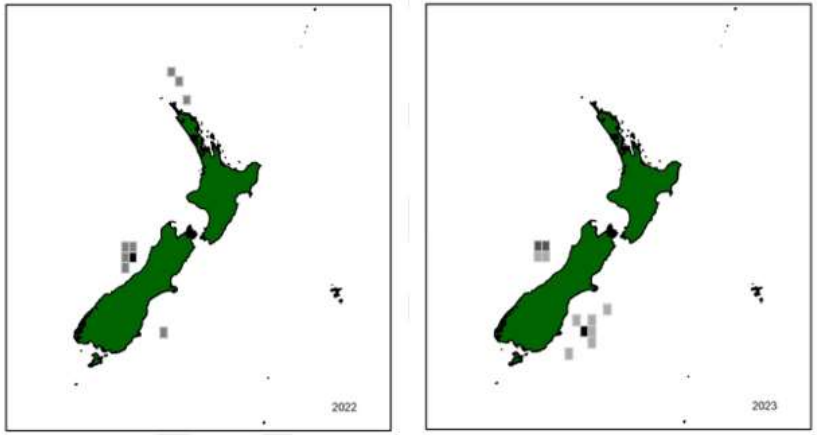


Figure 3-8: Cluster 2; spatial relative distribution of fishing events by 0.5° longitude and latitude cells, by fishing year (labelled year ending), for the last three fishing years (2023, 2022, 2021, and summarised for the years before that, 2008-2020). Darker shading indicates greater fishing effort.

Cluster 3

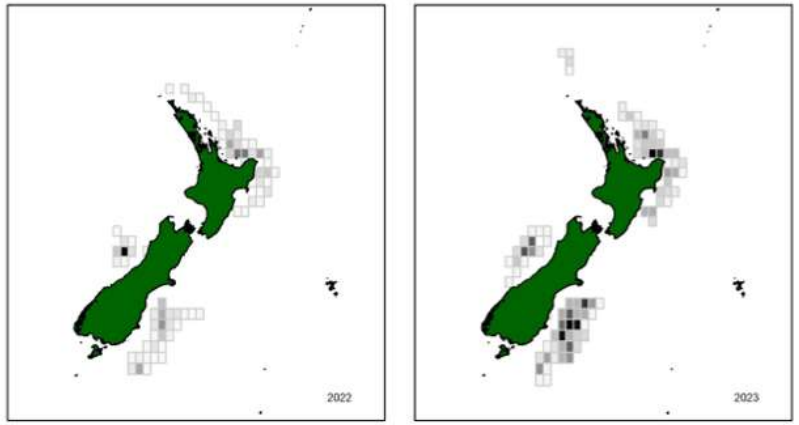


Figure 3-9: Cluster 3; spatial relative distribution of fishing events by 0.5° longitude and latitude cells, by fishing year (labelled year ending), for the last three fishing years (2023, 2022, 2021, and summarised for the years before that, 2008-2020). Darker shading indicates greater fishing effort.

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	Custer6
Target	BIG, STN	BIG, SWO, STN	STN, BIG	STN	STN	STN
Catch	BWS, SWO, ALB, BIG, SUN	**SWO**, BWS, ALB	BWS, STN	STN	STN, BWS	BWS
Peak season	March-June	**March-April**	May-June	July	June	May
Relative effort	Declined & moderate	Declined & low	Low (near absent)	Low but increasing	Moderate	Declining & gone
Main location	BoP; WCSI; SE SI	BoP & East Cape; WCSI	ECNI; WCSI	WCNI, EC SI, EC NI	WCNI, EC SI, EC NI	WCNI, EC NI
Leatherback captures	**138** **0.76 per 100 events** **0.85 per 100 000 hooks**	**76** **1.35 per 100 events** **1.27 per 100 000 hooks**	**17** **0.38 per 100 events** **0.38 per 100 000 hooks**	**0**	**3** **0.05 per 100 events** **0.04 per 100 000 hooks**	**1** **0.13 per 100 events** **0.10 per 100 000 hooks**
Mean depth (m)	520	536	512	520	534	487
Mean SST	18.6° C	**19.8° C**	17.2° C	15.0° C	15.7° C	16.3° C

Spatial distribution (Obj 2)

Reapplying the 2021 GAM

Leatherback occurrence ~ ST4-climatology + log(chl-a) + log(EKE) + latitude
from Dunn et al. (2023)

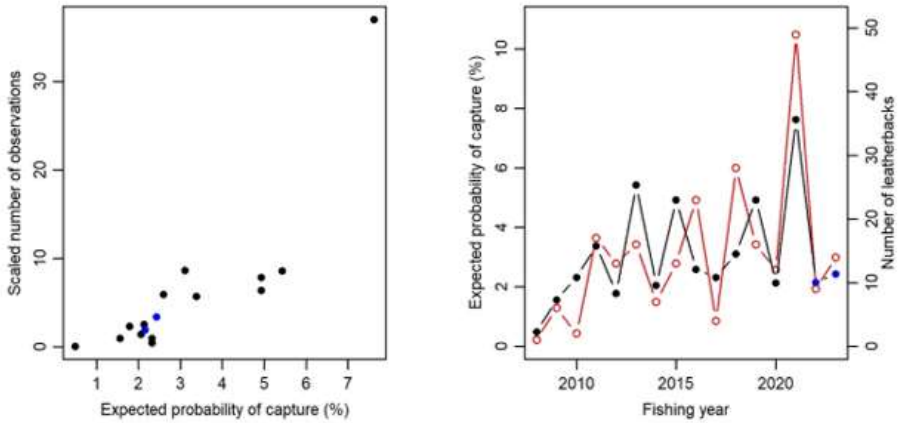


Figure 3-18: Left panel, the observed number of leatherback turtle reported captures versus the generalised additive model (GAM) predicted probability of leatherback turtle capture by fishing year using data to 2021; Right panel, the GAM expected median probability of capture (black line and points) and the observed reported number of captures (red line and points) by fishing year (scaled to have the same mean). Projected years 2022 and 2023 are shown as blue points.

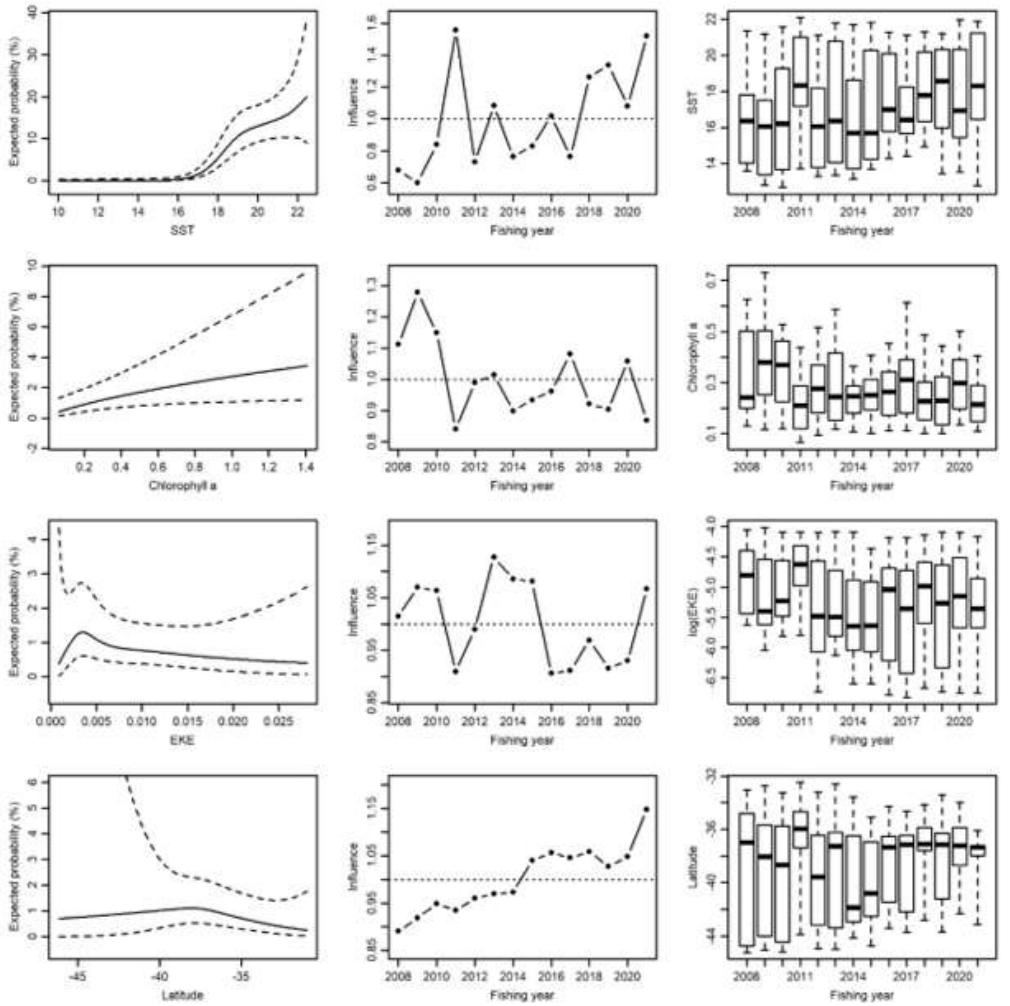


Figure 3-17: Leatherback turtle predicted probability of capture from the generalised additive model (GAM) predictors: Left panels, the predicted coefficient effect (with 95% confidence interval) estimated with other coefficients fixed at their median values; Middle panels, the influence of each term 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 2024 GAM

- Restricted to FMA 1 and 2.
- Wider variety of environmental predictors tested.
- Fisheries predictors also included (not *vessel* or *target species*).

Final model:

Leatherback occurrence (binomial) ~ sqrt(mld0p125_MO) + bathymetry + par_MO + Ugeo + log(MaggradOISST)

- Base model explained 14.2% deviance. The inclusion of SST variables to this base model increased the deviance explained to no more than 14.4%.
- Individually, mld0p125_MO (mixed layer depth) explained the most deviance (6.8%), followed by bathymetry (4.5%), par_MO (daily total irradiance, 3.5%), Ugeo_mean (zonal currents, 3.5%), and MaggradOISST (SST gradient, 0.8%).

- The 2021 model explained 10.2% of the deviance.

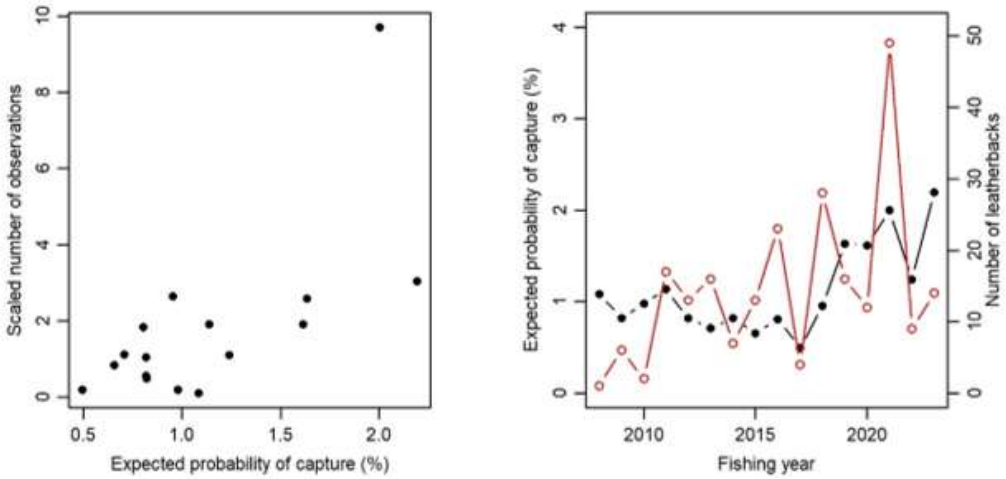


Figure 3-19: Left panel, observed number of leatherback turtle reported captures in FMA 1 and 2 vs the GAM predicted probability of leatherback turtle capture by fishing year; and right panel, GAM expected median probability of capture (black line) and the observed reported number of captures (red line) by fishing year (scaled to have the same mean).

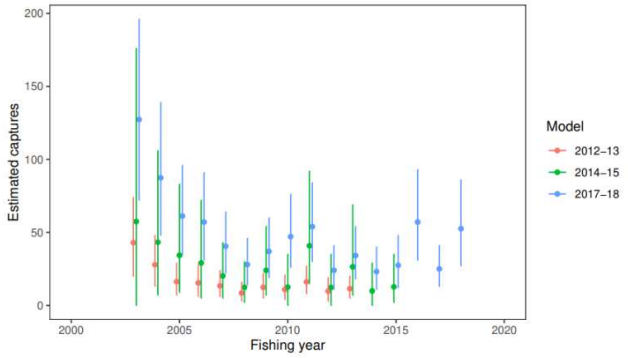
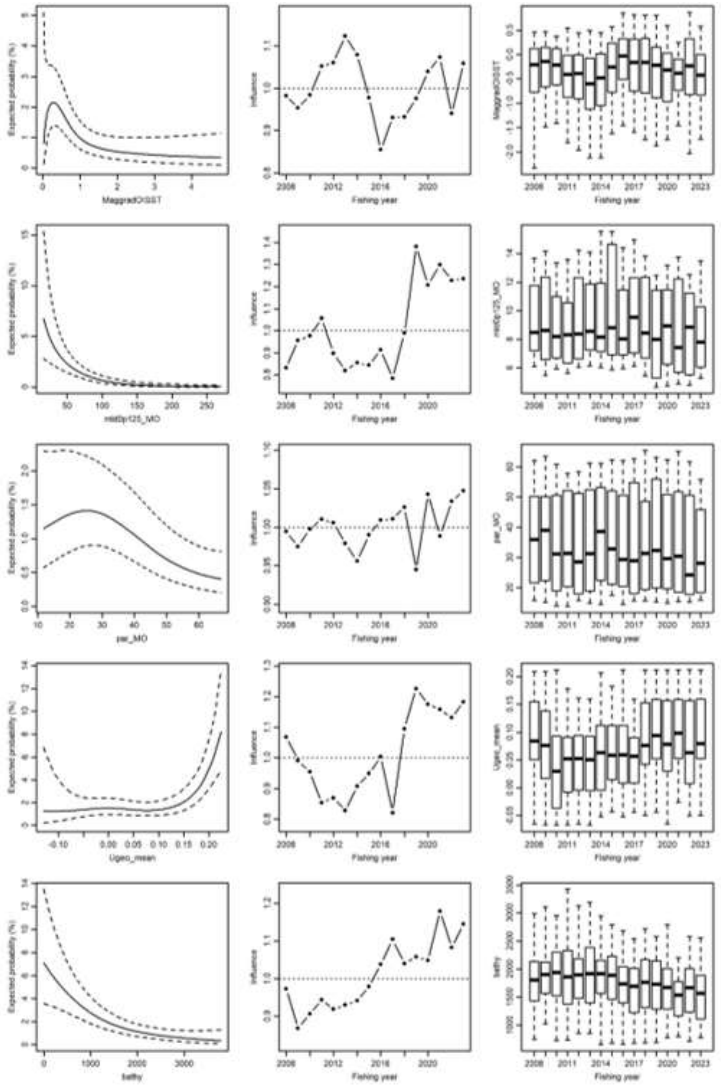


Figure 25: Comparison between models of turtle captures in surface-longline fisheries, for models fitted on data to 2012–13 (Abraham et al. 2016), 2014–15 (Abraham & Berkenbusch 2017) and 2017–18 (current report). Shown for each model are the mean (dot) and 95% credible interval (line) of the annual estimated captures of turtles in surface-longline fisheries.



gure 3-20: Leatherback turtle predicted probability of capture in FMA 1 and 2 from the GAM predictors: t panels, the predicted coefficient effect (with 95% confidence interval) estimated with other coefficients ed at their median values; centre panels, the influence of each term on the estimate by fishing year; right nels, the distribution of each variable by fishing year (box plot showing median as the solid bar,

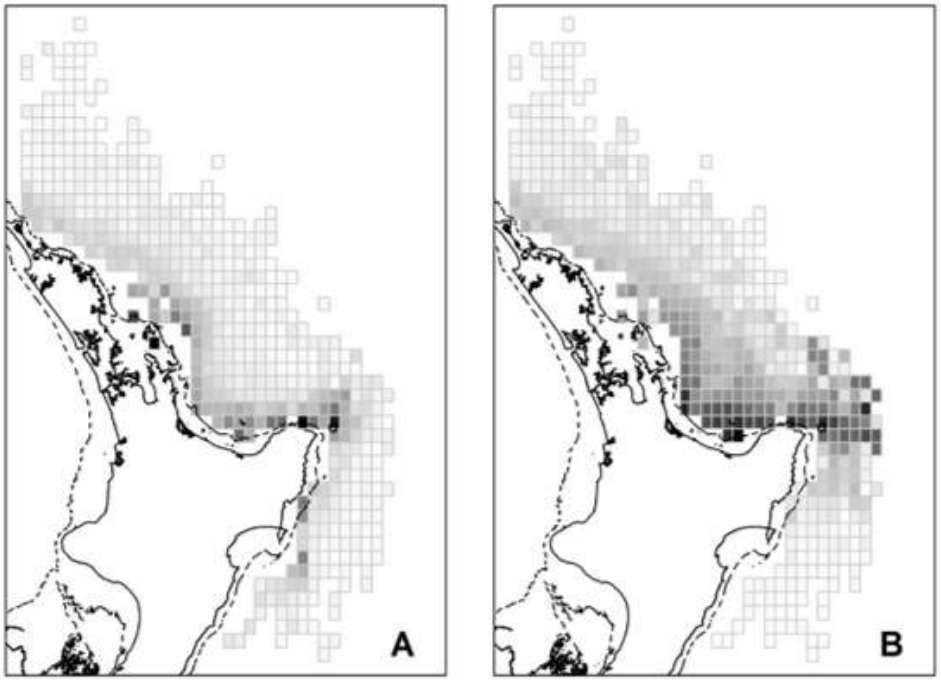


Figure 3-21: Probability of leatherback capture in surface longlines for commercial fishing records 2008 to 2023 in FMAs 1 and 2, using A, the GAM developed in 2024 (Section 3.4.1), and B, the GAM developed in 2021 (Section 3.3).Sdarker shading indicates greater probability.

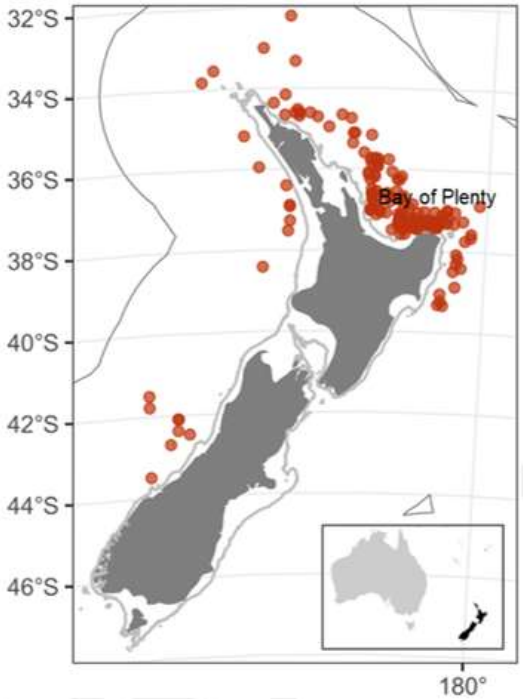


Figure 3-22: Distribution of fisher and observer-reported leatherback turtle captures from 2008 to 2021 (red dots, n=217). Grey line indicates the 100 m isobath, and the black line is the New Zealand Exclusive Economic Zone (EEZ). From Dunn et al. (2023).

- Not clear which model is “better” (the 2024 model does explain more deviance).
- In the 2021 GAM, latitude might be seen as a spatial “alias”.
- Skippers reported catches (and depth fished) will vary with water clarity and current (2024 model has mixed layer depth and current).

The 2024 GAM applied to other species

- Same predictors as LBT (red line) (i.e., not “best” models). Delta-lognormal rather than binomial. GAMs explained a similar level of deviance to the leatherback GAM (~5–15%).
- LBT and SWO (blue line) had similar predicted probability of capture for 4/5 variables:

  Higher bycatch/target catch rates when SST gradient (MaggradOISST) low (<0.5)

  Higher bycatch/catch rates at lower daily total irradiance (20–30, par_MO)

  Predicted probably of capture decreasing with increasing depth
- LBT had the strongest positive relationship with shallow (<50 m) mixed layer depths (mld0p125_MO), with SWO and bigeye (BIG) also showing the same relationship but less pronounced.
- Zonal current (Ugeo_mean) was the only variable where LBT and SWO differed; LBT relationship different to fish species.

- In 2021, models predicted the move towards fishing in waters with shallower mixed layer depth which increased BIG catch rate (and SWO, to a point), and more LBT bycatch.
- Fishing where the zonal current was weaker (westerly) increased BIG catch rate. Fishing in shallower waters reduced BIG catch rate, increased SWO catch rate and LBT bycatch.

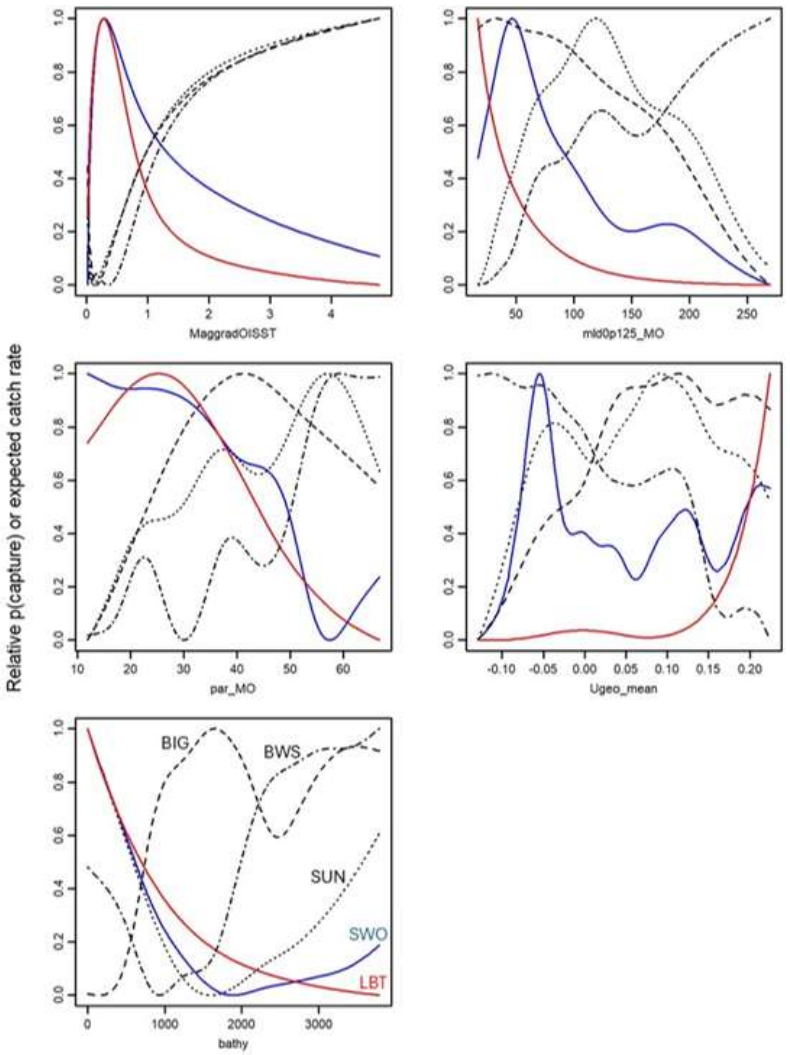


Figure 3-23: Leatherback turtle (LBT), swordfish (SWO), bigeye tuna (BIG), sunfish (SUN), and blue shark (BWS) predicted probability of capture (leatherbacks) or catch rates (fishes) in FMA 1 and 2 from a binomial GAM for leatherbacks, and delta-lognormal GAM for fishes, for the same variables as selected for the leatherback GAM. The predicted effect is estimated with other coefficients fixed at their median values.

Differences between vessels with reported leatherback captures and those without (Obj 3)

- Five SLL vessels (6% NZ fleet) reported >10 LBT each between 2008 and 2023 and accounted for 91% (n=192/211) of the total LBT records.
- There were 76 vessels between 2008 and 2023 which reported surface longline fishing but never reported a LBT capture.
- SLL fleet includes 19 vessels currently.
- Vessels that did report LBT bycatch had a focus of fishing effort around 37°S, a location that includes the Bay of Plenty, relatively more fishing effort over summer and in warmer waters. Fishing effort decreased slightly after about 2017.

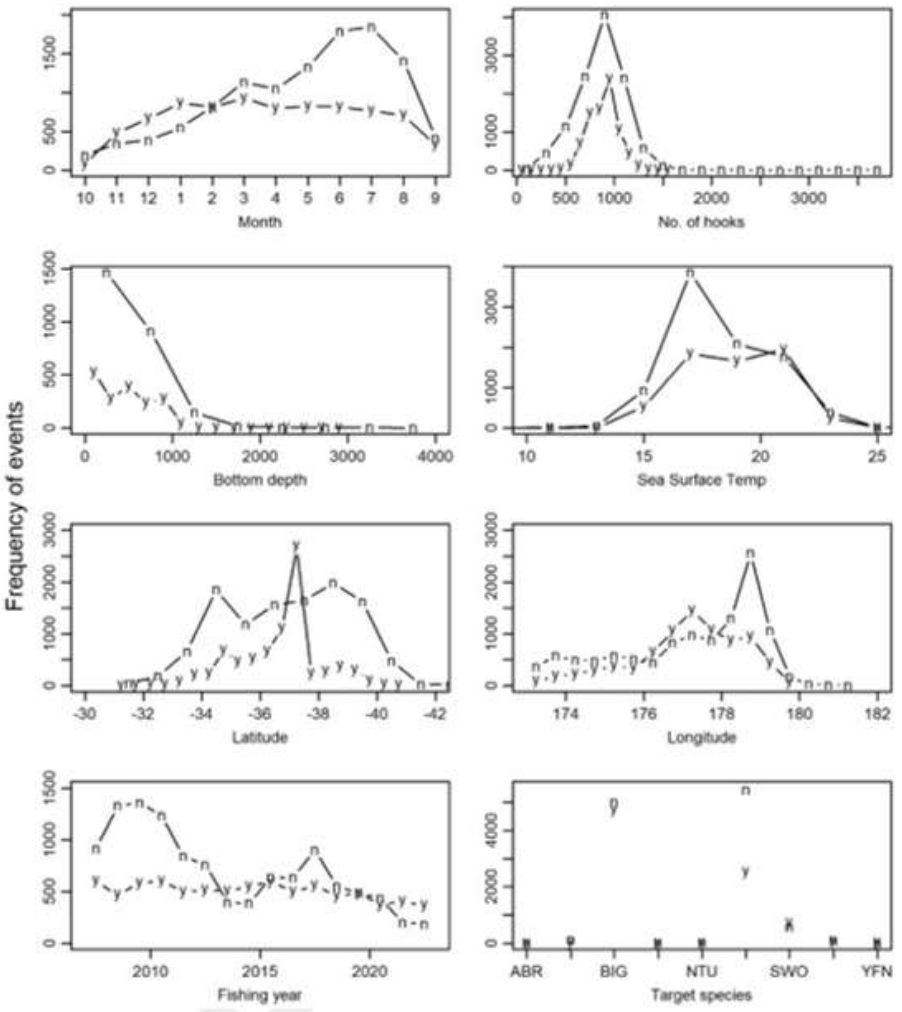


Figure 3-24: Frequency of surface longline fishing events in FMAs 1 and 2 by reported fishing effort variables for all years combined (2008–2023). y, reported at least 10 leatherback captures; n, never reported a leatherback capture.

- The absence of leatherback captures on Chatham Rise is consistent with a lack of SLL fishing effort in that region.

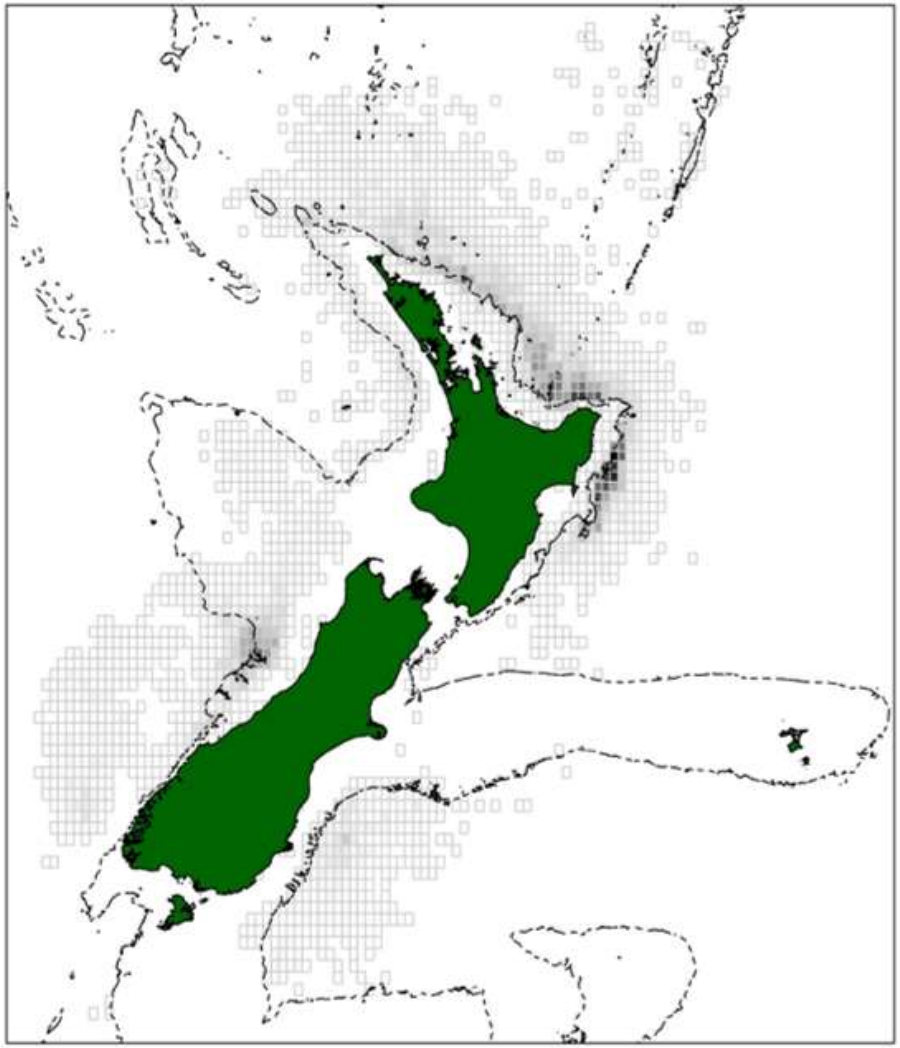


Figure 3-25: Distribution of surface longline fishing effort (events) for all years combined (2008–2023), by 0.2° latitude and longitude cells. Darker cells indicate more effort. The broken line indicates the 1000 m isobath.

- When compared within the fishery cluster that reported most LBT captures (Cluster 1 of the 3-cluster analysis) the difference between vessels that did and did not have reported LBT bycatch was reduced.

- The difference was still apparent in latitude and longitude (the peak being roughly just north of East Cape), with vessels reporting LBT also fishing in areas with slightly higher SST and less frequently targeting STN.

- Observer coverage was lowest in Cluster 1 (7.1%), higher in Cluster 2 (14.7%), and highest in Cluster 3 (21.7%).

- Only two vessels completed both observed and unobserved trips within the LBT hotspot area and season.

- The first completed 40 observed fishing events and 159 unobserved events, with no LBT encountered in the observed events, and 12 in the unobserved events.

- The second vessel completed 55 observed fishing events and 173 unobserved events, with 4 LBT encountered in the observed events (0.073 LBT per event) and 13 LBT in the unobserved events (0.075 LBT per event).

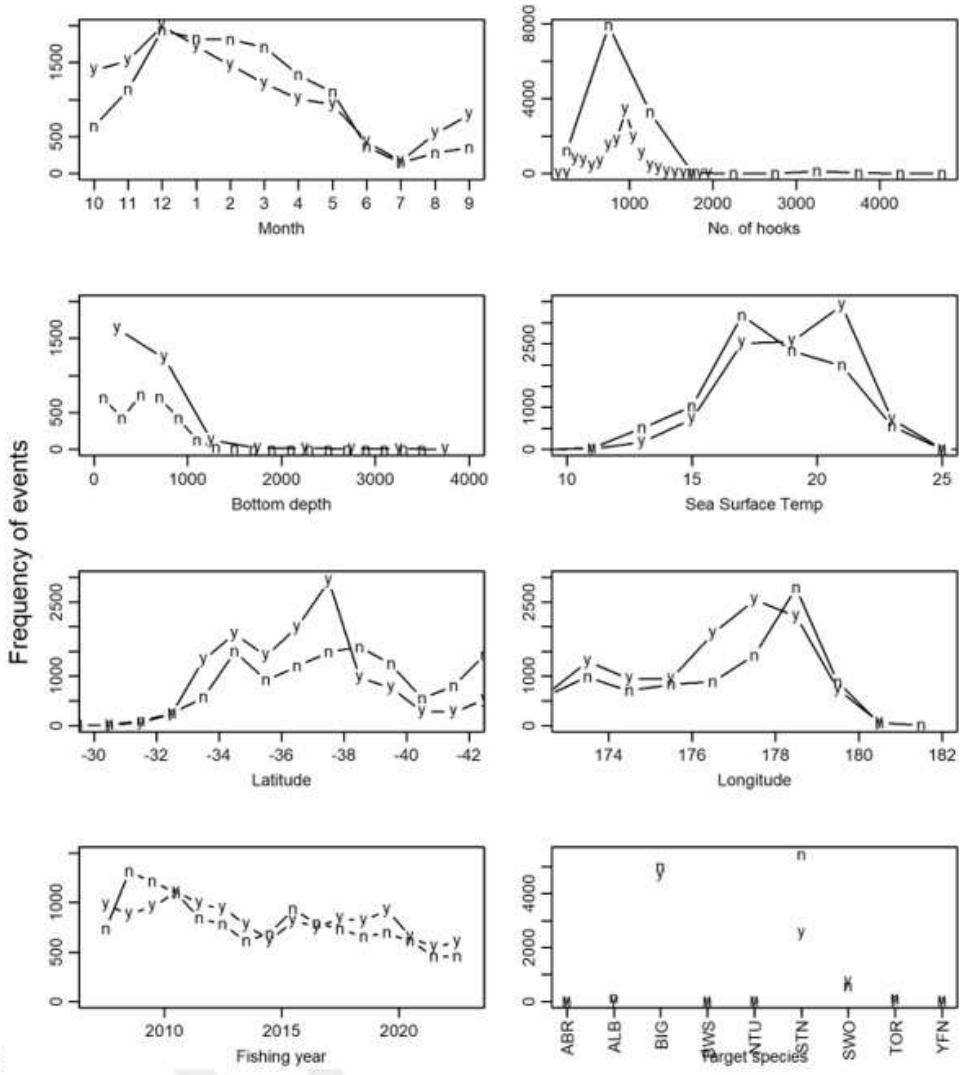


Figure 3-26: Frequency of surface longline fishing events in FMAs 1 and 2 for Cluster 1 (see Section 3.2.1) by reported fishing effort variables for all years combined (2008–2023). y, reported at least 10 leatherback captures; n, never reported a leatherback capture.

Conclusions & Recommendations

A few checks and tests still need to be run so these are preliminary/draft.

- The leatherback bycatch hotspot (broadly defined by latitude and month), included overall 24.4% of the BIG catch, 17.9% of SWO catch, and 0.1% of STN catch.
- Substantial fishing grounds occur outside of the leatherback bycatch hotspot (especially if that areas was more spatially and temporally refined).
- Fishery characterisation indicated leatherback bycatch was greatest in the BIG-target fishery
- Analyses based on clustering of catch compositions showed the strongest association between leatherbacks and vessels catching SWO. Leatherback catch rates were highest when catching SWO, in late summer, in warmer water.

- The leatherback predicted environmental variable effects were closest to those for SWO.
- Although sunfish have been associated with leatherbacks elsewhere (Mosnier et al. 2019), in New Zealand their environmental effect was similar to leatherbacks only for depth.
- A predictive model might best choose predictors known to have meaningful and interpretable effects. There are likely multiple model configurations giving similar explanatory performance.

- Leatherback bycatch seems to have more to do with where and when the vessel fished, rather than reporting behaviour.
- With very limited data, leatherback bycatch of vessels with/without observers were the same.
- Electronic Monitoring (i.e., cameras on vessels) was introduced to the fleet from 16 January 2024

- Anecdotal information from fishers was that the leatherback bycatch rate was relatively high in 2023, but overall bycatch was reduced because fishing effort was lower.
- Skippers report leatherback bycatch is not easily predictable but associated with warmer waters in summer (late-summer especially), and ocean currents are more important than target species.

- Currently it is not known whether the Bay of Plenty is a key foraging site for leatherbacks, or whether SLL fishery effort in the area is capturing migrating turtles.

- The aerial leatherback habitat survey scheduled for summer 2025 should help to provide more information on the habitat.

Acknowledgments

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Climate, Freshwater & Marine Science

NIWA
Taihoro Nukurangi