Update to NOAA Technical Memorandum NMFS-PIFSC-101: Incorporating Uncertainty in Maturation and Recent Fishery Takes into the Population-Level Impacts of Western Pacific Leatherback Sea Turtles

Zachary A. Siders[1], Summer L. Martin[2], Robert N.M. Ahrens[2], T. Todd Jones[2]

[1] Fisheries and Aquatic Sciences Program, School of Forest, Fisheries, and Geomatic Sciences, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL, USA 32611

[2] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, HI 96818

NOAA Technical Memorandum TM-PIFSC-184

December 2025

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Pacific Islands Fisheries Science Center

Acknowledgements

Mention throughout this document to trade names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

Edited by Revere Wood.

Recommended citation

Siders, Z. A., Martin, S. L., Ahrens, R. N. M., Jones, T. T. (2025). *Update to NOAA Technical Memorandum NMFS-PIFSC-101: Incorporating Uncertainty in Maturation and Recent Fishery Takes into the Population-Level Impacts of Western Pacific Leatherback Sea Turtles* (PIFSC Technical Memorandum Series, TM-PIFSC-184). Pacific Islands Fisheries Science Center.

Copies of this report are available from

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawai‘i 96818

Or online at

https://repository.library.noaa.gov/

Executive Summary

This technical memorandum update revisits, updates, and modifies the population viability analysis (PVA) of Martin et al. (2020a), the results of Martin et al. (2020b) and Siders et al. (2023) for the Hawai‘i deep-set pelagic longline fishery (DSLL) interactions with western Pacific leatherback sea turtles. The net result of the changes implemented is a small change between the last assessment, which included data through 2021, and the current assessment.

The latest application results in the population declining to below 50% of current annual nesters 0.47 years faster with take than without take (Table 1) with the difference between no take and take scenarios increasing over time in both deterministic and stochastic model runs (Figure 1). This is based on converting fishery interactions of leatherbacks to annual nester equivalents (ANE) based on their size and likelihood of survival (largely driven by the post-release mortality).

Incorporating the 2022–2024 years of data on interactions altered the shape of the distribution used to predict the anticipated take level (ATL); it also altered the relationship used to predict post-release fishery mortality. The Conway-Maxwell-Poisson distribution (Figure 2) for the ATL included a lower median and mean value (median 13, mean 16.3 leatherbacks per year) as compared to Siders et al. (2023; median 14, mean 16.5 leatherbacks per year), indicating an overall slightly lower anticipated level of leatherback interactions in the fishery (Table 2 indicates the parameters changes).

Updated data also changed the mean size and post-release mortality of the individuals with which the fishery interacted. The recorded size of turtles has increased (121.4 cm SCL from 2004–2021 to 128.2 cm SCL from 2004–2024). The assigned mean post-release fishery mortality following the Ryder et al. (2006) memo has changed (52.6% from 2004–2016, 50.4% from 2004–2021, 49.8% from 2004–2024). Compared to zero leatherback deaths observed in 2017–2021, there were 4 assigned deaths out of 93 interactions (4.1%) between 2022–2024.

In totality, the changes in lengths and assigned post-release mortality resulted in a change to the multivariate normal model (Figure 3, Table 3) used to predict the *unmeasured* interactions lengths and post-release mortalities. The expected interaction length has decreased slightly (113.4 cm SCL from 2004–2016, to 117.5 cm SCL from 2004–2021, to 115.1 cm SCL from 2004–2024) while the median model-based baseline (SCL = 0 cm, intercept of length mortality model) post-release mortality has increased 2.2% (64.3% from 2004–2017, to 53.5% from 2004–2021, to 55.7% from 2004–2024). The intercept of the interaction length linear relationship of SCL and annual total interactions increased, reflecting the observed SCL increase, while the slope was

roughly 2/3^{rds} of the 2004-2021 relationship. The latter indicates a weakening of the effect of the magnitude of annual interactions on the SCL.

Perhaps most importantly, the correlation (and covariance) between SCL and post-release mortality increased in strength from ρ=-0.51 in 2004–2021 to ρ=-0.61. Note that the proportion of unmeasured interactions has decreased relative to the previous 2017–2021 data addition, 58.3% in 2017–2021 versus 31.7% in 2022–2024, resulting in the model being used to estimate length and mortalities for a lower proportion of the *observed* interactions in the updated years. However, the proportion of the historical total interactions that have received imputed lengths and post-release mortalities has marginally increased (80.5% for 2004-2016, 81.7% for 2004–2021, and 82.2% for 2004–2024). This largely reflects declining observer coverage in recent years.

It is worth discussing that the multivariate normal model is very sensitive to the data included in the estimation of its parameters (Table 4). This is largely due to the limited sample size (limited by the total observations of leatherback interactions with the DSLL). In Martin et al. (2020b), there were only 31 observations, in Siders et al. (2023) there were 41, and in this report, there were 57 (Table 4).

This change in the multivariate model is most noticeable between the last two reported years, 2024 and 2023. The addition of 7 observed leatherback interactions caused μ_D to jump considerably in 2024 (120% increase), the cohort effect to drop by almost half (55% of 2021's effect), and the correlation between interaction length and post-release mortality to increase 1.4-fold (Table 4). Thus, the timing of the assessment can drastically impact the expected interaction lengths and mortalities. As these parameters are used to set the ANE from each ATL draw in the population viability analysis, it should be expected that there will be variability assessment to assessment on the expected ANE, as well as the differences in threshold probabilities and timing in the fished and unfished scenarios.

Population Viability Analysis

The probabilistic maturity approach results in the probabilities of the projected 2024 nester population reaching the 12.5% threshold are 0%, 0.05%, 44.4%, 98.5% and 100% at the 5, 10-, 25-, 50- and 100-year benchmarks without the fishery (Table 5). Adding in the fishery interactions results in, for the same benchmarks, 0%, 0.09%, 71.7%, 99.9%, and 100% probabilities of reaching the 12.5% threshold (Table 5).

It should be noted that the trend originally produced in Martin et al. (2020b) was extended further in this current assessment, now seven years in the future. While this is the best available data at the time of the current report, it is possible that the observed population trend (-6% per annum) no longer holds. Using the updated anticipated take level (ATL), the median yearly annual nester equivalents (ANE) in the case-wise maturity population viability analysis (PVA) was 0.7 ANE/year while the probability of maturity PVA was 0.32 ANE/year. These values are lower than what was found in the Siders et al. (2023) ATL where the case-wise maturity PVA produced 0.9 ANE/year and the probability of maturity PVA produced 0.37 ANE/year.

Updating ATL to reflect the most recent 3 years of DSLL leatherback interaction data was an important part of this analysis. Differences between the Siders et al. (2023) results and those presented here result from the updated mortality estimates and sizes from the Hawai‘i deep-set pelagic longline fishery (DSLL) leatherback interaction dataset. These changes resulted in slight differences between this most recent approach and the approach taken in 2020. Together, adding three more years of DSLL interaction data, updating the anticipated take distribution, using the probability of maturity approach, projecting the declining leatherback population five more years, and adjusting the population benchmarks to reflect the 2024 population status produced an expected mortality of 0.32 annual nesters per year into the future assuming the anticipated take level is realized each year.

Table 1. The DSLL fishery—for western Pacific leatherbacks, using the **probability of maturity ANE calculation** with a 99% L_∞ fully mature cutoff on the **median population status** the probability of the population being above or below (p > θ or p < θ, respectively) abundance thresholds (θ = 50%, 25%, 12.5% of current Annual Nesters) within the 100-year simulation time frame, and the number of years (mean, median, & 95% credible interval [CI]) to reach each threshold for all runs that fall below them. Results are from the stochastic take model, both with and without take, and with historical ANEs added back into the population; results from the deterministic model were not notably different. ∆(*NT*–*T*) shows the difference between the take and no take projection scenarios. Note the 100-year simulation is based on the years where only the projected anticipated take is included.

Threshold	Scenario	$p > \theta$	$p < \theta$	Mean year	Median year	L95% year	U95% year
50%	No Take	0	1	5.74	4	1	18
	Take	0	1	5.26	4	1	15
	∆(NT-T)	0	0	0.47	0	0	3
25%	No Take	0	1	16.28	15	5	32
	Take	0	1	14.37	14	5	28
	∆(NT-T)	0	0	1.91	1	0	4
12.5%	No Take	0	1	27.41	26	13	48
	Take	0	1	22.54	22	12	37
	∆(NT-T)	0	0	4.88	4	1	11

Table 2. Comparison of the location (μ), scale (ν), and expectation ($E[x]$) of the Conway-Maxwell-Poisson distribution between Martin et al. (2020b), the Siders et al. (2023), and the updated parameter values used in this report. Note that the Martin et al. (2020b) and the Siders et al. (2023) parameter estimates were produced by M. McCracken outside of the analysis while this report's parameter estimates were produced internally using the direct estimates of total leatherback interactions in the DSLL.

Parameter	Martin et al. (2020b)	Siders et al. (2023)	This report
μ	7.38694	8.284754	4.727993
ν	0.04967579	0.05725318	0.04148856
$E[x]$*	16.95221	16.51789	16.27951

$$^{*}E[x] = \mu + \frac{1}{2\nu} - \frac{1}{2}$$

Table 3. Summary of the median parameter estimates for the multivariate normal model of lengths and interaction mortalities of leatherback sea turtles interacting with the DSLL fishery. Parameters are baseline post-release mortality (μ_D, SCL=0 cm), imputed mean interaction length (μ_L) from observed lengths, back-transformed interaction length intercept (β_0), slope of the interaction length relationship with annual total interactions (β_1), standard deviation of in the logistic-transformed post-release mortality (σ_D), standard deviation of the log-transformed interaction length (σ_L), and the correlation between interaction length and the post-release mortality (ρ).

Parameter	2004-2016 Median	2004-2021 Median	2004-2024 Median	Description
μ_D	0.643	0.535	0.557	mean interaction mortality
μ_L	113.4	117.5	115.1 cm SCL	mean interaction length
β_0	106.4	108.8	107.9 cm SCL	interaction length intercept
β_1	0.00519	0.00618	0.00428	interaction length slope
σ_D	4.231	3.783	3.77	std. dev. In logit(D)
σ_L	0.372	0.338	0.362	std. dev. in log(SCL)
ρ	-0.57	-0.51	-0.61	correlation coefficient

Table 4. Summary of the median parameter estimates for the multivariate normal model of lengths and interaction mortalities of leatherback sea turtles interacting with the DSLL fishery as a function of included years (ranging from 2004 to the maximum included year). Note data included is based on 2025 pull of observer lengths and assigned mortality dataset so slight differences will occur between previous estimates (see Table 3).

Max. Year	n	μ_D	β_0	β_1	σ_L	σ_D	ρ
2024	57	0.557	108	0.00428	0.362	3.77	-0.612
2023	50	0.462	104	0.00775	0.352	3.49	-0.447
2022	46	0.5	103	0.00777	0.366	3.6	-0.475
2021	41	0.536	103	0.0063	0.345	3.78	-0.519
2020	40	0.54	102	0.00646	0.349	3.83	-0.528
2019	46	0.587	103	0.00487	0.357	3.97	-0.535
2018	33	0.619	103	0.00478	0.372	4.13	-0.577
2017	31	0.645	100	0.00532	0.379	4.22	-0.577
2016	31	0.644	100	0.00524	0.38	4.22	-0.575

Table 5. The DSLL fishery—for western Pacific leatherbacks, using the **probability of maturity ANE calculation** on the **median population status** from Martin et al. (2020a, 2020b), the probability (median with 95% credible intervals [CI]) of the population reaching abundance thresholds at 5, 10, 25, 50, and 100 years from final data year (2021). Results are from the

stochastic version of the take model with historical takes accounted for by adding the ANEs back into the population. Scenarios with and without take are provided, with $\Delta(NT–T)$ showing the difference between the two scenarios.

θ	Pop. Status	Scenario	5 year	10 year	25 year	50 year	100 year
50%	Median	No Take	0.596	0.864	0.997	1	1
		Take	0.628	0.888	0.999	1	1
		Δ(NT-T)	-0.032	-0.024	-0.002	0	0
	L95%	No Take	0.587	0.858	0.997	1	1
		Take	0.618	0.882	0.999	1	1
		Δ(NT-T)	-0.031	-0.024	-0.002	0	0
	U95%	No Take	0.607	0.871	0.998	1	1
		Take	0.638	0.894	1	1	1
		Δ(NT-T)	-0.031	-0.023	-0.002	0	0
25%	Median	No Take	0.029	0.205	0.894	0.999	1
		Take	0.037	0.263	0.955	1	1
		Δ(NT-T)	-0.008	-0.058	-0.061	-0.001	0
	L95%	No Take	0.026	0.197	0.888	0.999	1
		Take	0.033	0.253	0.951	1	1
		Δ(NT-T)	-0.008	-0.057	-0.063	-0.001	0
	U95%	No Take	0.032	0.213	0.9	1	1
		Take	0.04	0.272	0.96	1	1
		Δ(NT-T)	-0.008	-0.059	-0.06	0	0
12.5%	Median	No Take	0	0.005	0.444	0.985	1
		Take	0	0.009	0.717	0.999	1
		Δ(NT-T)	0	-0.004	-0.273	-0.014	0
	L95%	No Take	0	0.003	0.433	0.983	1
		Take	0	0.007	0.708	0.999	1
		Δ(NT-T)	0	-0.003	-0.274	-0.016	0
	U95%	No Take	0	0.006	0.454	0.988	1
		Take	0	0.01	0.727	1	1
		Δ(NT-T)	0	-0.004	-0.272	-0.012	0

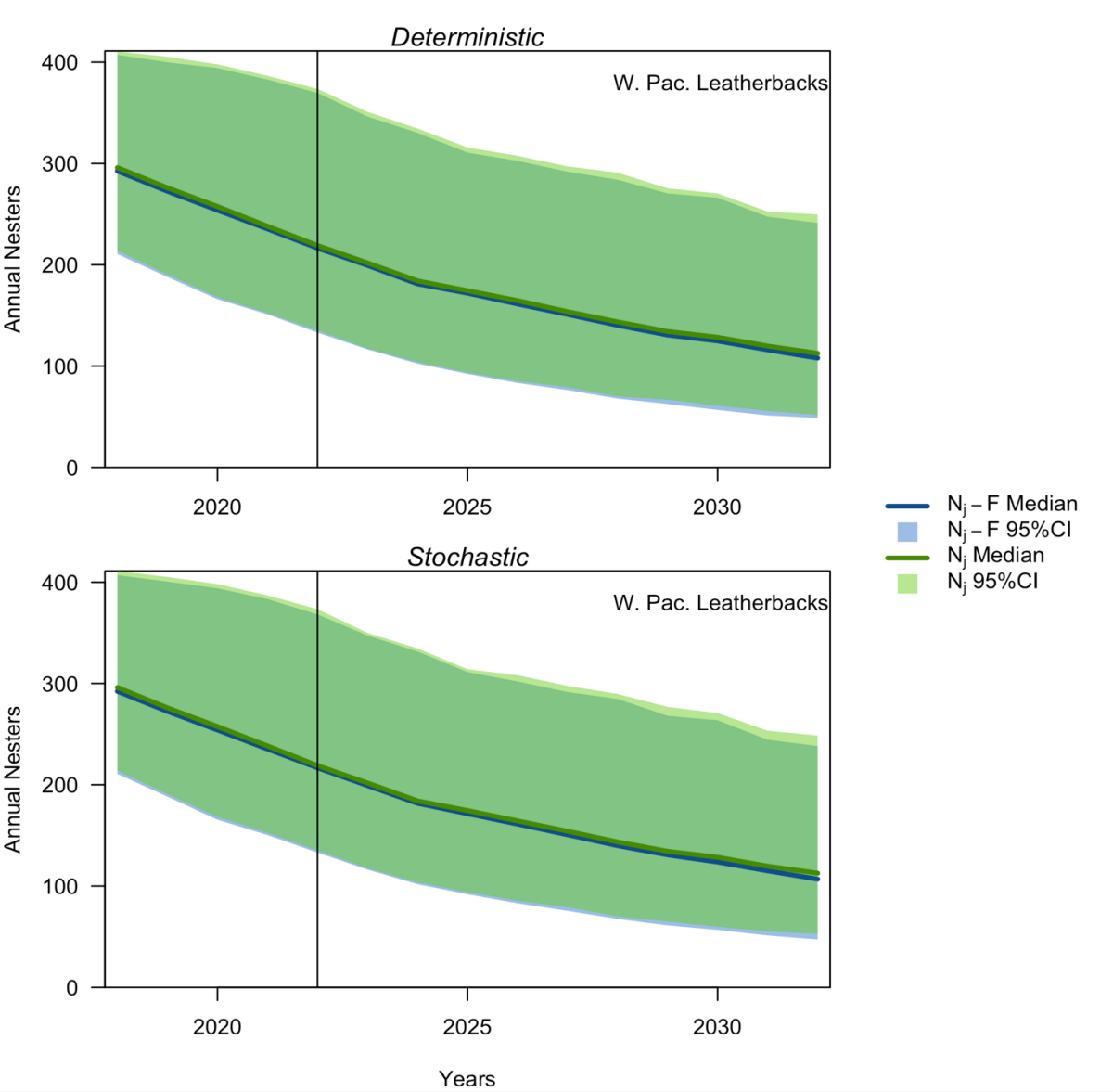


Figure 1. Projection of the western Pacific leatherback population without future fishery interactions (green) and with future fishery interactions (blue) over 10 projected years using the **probability of maturity ANE calculation** with a 99% L_∞ fully mature cutoff. Years to the left of the vertical black line indicate a forward projection of the leatherback population trend including the historic interactions, while years to the right indicate forward projection with projected anticipated take levels. The initial population size and trend parameters are from the **median population status** from the imputation conducted in Martin et al. (2020a).

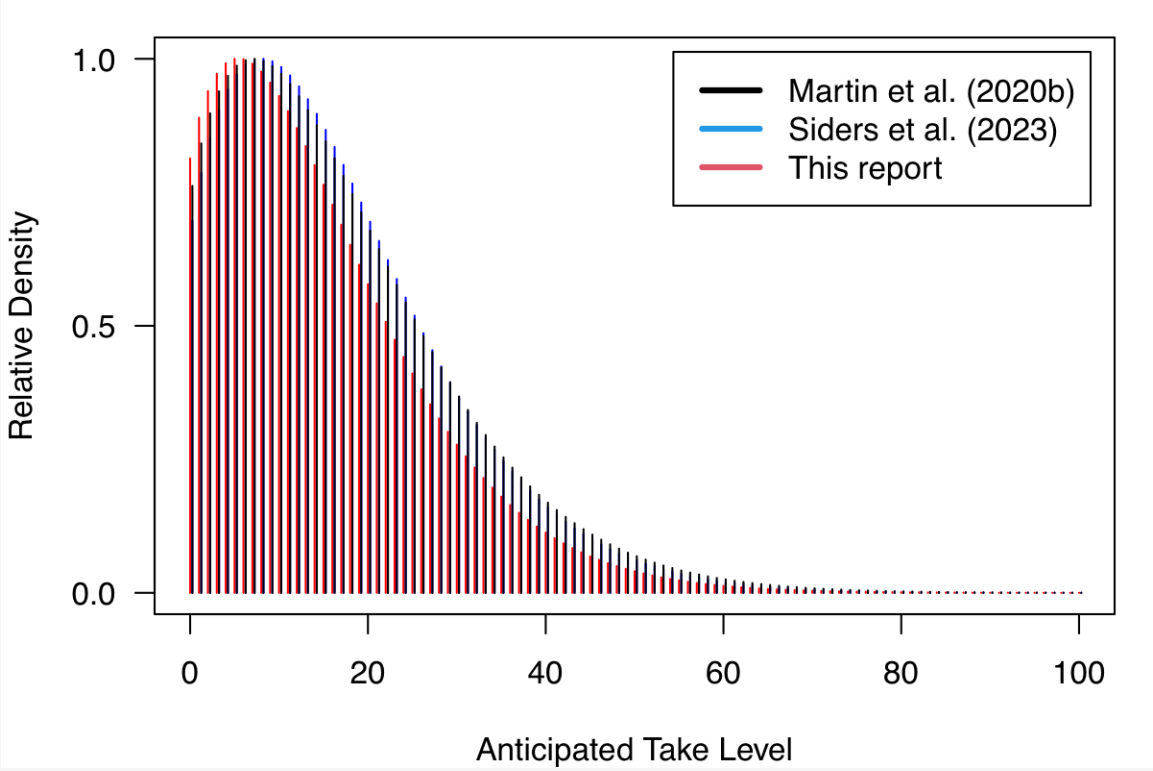


Figure 2. Relative density of anticipated take levels using the location and scale parameters of the Conway-Maxwell-Poisson distribution used in the Martin et al. (2020b) estimated impacts, the values used in the Siders et al. (2023), and the updated values used in this report's estimated impacts.

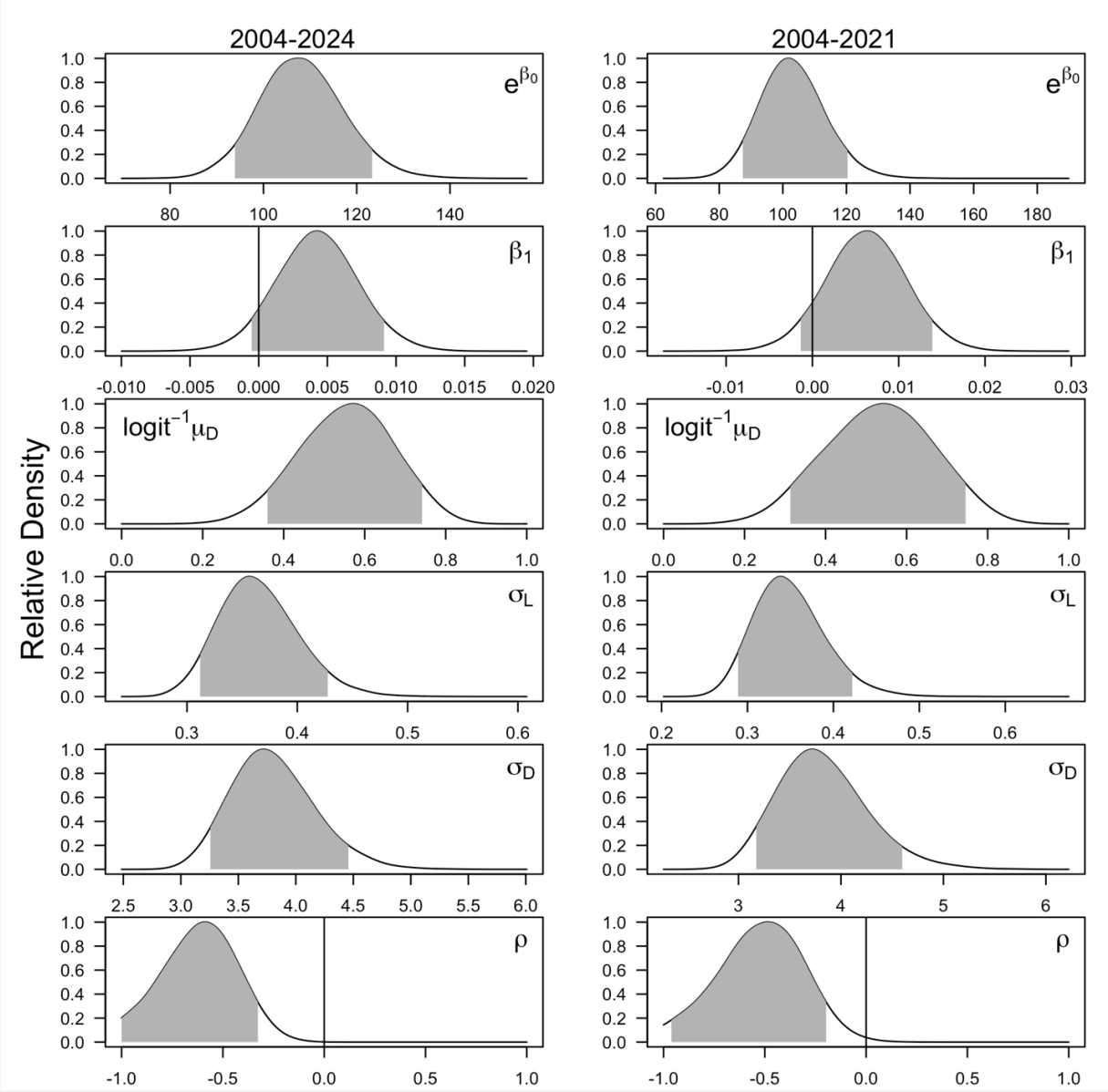


Figure 3. Distribution of the key parameters of the multivariate normal model describing the historical leatherback interactions length (in cm of SCL) and interaction mortalities. e^{β_0} describes the expected interaction length, β_1 describes the change in interaction length as a function of cohort strength, $\text{logit}^{-1}\mu_D$ describes the interaction mortality, σ_L is the standard deviation of the log-transformed lengths, σ_D is the standard deviation of the logistic-transformed interaction mortality, and ρ is correlation coefficient between the log-transformed lengths and logistic-transformed interaction mortality.