Observer coverage levels and the precision of take estimates

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Introduction

In 1994, NOAA Fisheries required all Hawaiʻi longline vessels to, when requested, carry onboard an observer to gather information to better characterize and understand the effects of the fishery on incidental take of sea turtles, seabirds, marine mammals and other species. Initially, observers were placed onboard according to the Statistical Guidelines for a Pilot Observer Program to Estimate Turtle Takes in the Hawaiʻi Longline Fishery (DiNardo, 1993). Overall, observer coverage between 1994 and 1996 was between 4.5% and 5.3% of trips.

A previous analysis by Skillman et al. (1996) recommended an increase in coverage to a 20% observer coverage rate in order to more reliably estimate turtle take in the fishery. This recommendation was based on a bootstrap analysis of data from February 1994 through December 1995 that evaluated the coefficient of variation (CV) around average take rates of 0.0875 turtles per 1,000 hooks. The 95% quantile of hooks per set during this time period was observed to be 560 to 1850 hooks per set with a mean of 1080, which translates into odds of 1 turtle in 11 sets (1:11) with lower and upper odds of 1:20 to 1:6 per set. Given the average rate of turtle interactions and its variability, the recommended coverage levels of Skillman et al. (1996) were intended to provide estimates of turtle take that could have a CV of 30% with a risk tolerance of achieving this level of precision 90% of the time.

Since the previous analysis, the fishery has undergone significant changes in operations and data reporting. Operational changes have altered interaction rates with a number of protected species. Refinement in the categorization of the data has resulted in different interaction rates between sectors and altered how the fishery is monitored and regulated. In particular, the shallow-set trips of the Hawaiʻi longline have 100% observer coverage while 20% coverage is still the target for the deep-set component. A 100% coverage rate for the shallow-set longline has facilitated the monitoring of hard caps for loggerhead and leatherback sea turtle interactions in the past and is still in place to monitor vessel trip limits on loggerhead and leatherback interactions and a hard cap on leatherbacks.

Decades more information on protected species interaction rates and refinements in data collection shows that the interaction rate used in the original calculations of coverage may not be suitable. In the deep-set fishery, olive ridley turtles are encountered at a rate of about 1 per 300 sets, false killer whales at a rate of 1 per 600 sets, and leatherback sea turtles at 1 per 1500 sets. With interaction rates this small, these interaction rate estimates may no longer achieve desired levels of precision based on the current 20% observer coverage.

The suitability of observer coverage rates depends on precision objectives for interaction estimates across species. A CV of 30% has been recommended as the minimum standard for the precision of protected species bycatch estimates (NMFS, 2004). The establishment of potential biological removal (PBR) uses a value of 30% to set the highest recovery factor (RF=0.5) when establishing take levels for recovering marine mammal populations (Bettridge, 2023). A precision target of a 30% CV was used in the analysis presented here. There is no clear precedent for a certainty level of 90% with respect to achieving a CV precision target and results are presented for 50% to 90% certainty levels.

Data

We simulated set level interactions using odds of interaction ranging from 1:10 to 1:1000 for 20,000 sets. The number of sets and the interaction rates are based off values for the Hawaiʻi deep-set longline. These sets were then randomly selected without replacement with equal probability of selection to simulate levels of observer coverage from 4% to 80%. One thousand realizations were run for each combination of odds of interaction and observer coverage and the coefficient of variation of the estimate was assessed.

McCracken (2019) uses a Horvitz-Thompson estimator (Horvitz & Thompson, 1952) to estimate total take levels for the deep-set longline fishery and the associated variance. In reality, this estimation is a complicated process since the inclusion probabilities (the probability that a sampling unit was included in the sampling set) for a given set are unequal across the year. In this simulation, estimation is simplified by having each set have the same inclusion probability. As a result of this simplification, the CVs are likely optimistic compared to reality and this should be taken into consideration when interpreting the results. How different the results are compared to reality depends on the temporal distribution of inclusion probabilities in any given year and the temporal distribution of interactions making it difficult to generalize.

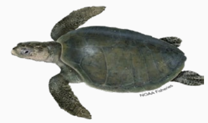
These simulations provide two patterns that are helpful when assessing desired observer coverage levels. The first pattern that emerges is, given a desired level of precision and a specified certainty level, higher species encounter rates and lower levels of certainty require lower observer coverage (Table 1). The desired level of certainty is the percentage of simulations that had a CV at or below the specified reference level. Having a higher percentage of simulations producing results below a specified level provides more confidence that estimates in any given year will be at the desired level of precision.

Simulation results can be compared to observed odds of interaction from the deep-set longline. Recent odds ratios were calculated for protected species at the set level using set level data from 2016 to 2022. Using a 30% CV as the desired level of precision—similar to what was recommended as a minimum in the Skillman et al. (1996) report and assuming a 90% credibility level—the observer coverage level needed can be referenced from the simulation (see Table 1). For oceanic white tip sharks (1:10 odds), observer coverage levels can be quite low because the number of encounters is high.

For less frequently caught species, such as black footed albatross and olive ridley sea turtles (approximately 1:200 and 1:300 odds), observer coverage levels around 15-20% are required. For species that are rarely encountered, such as false killer whales and giant manta ray (1:600 and 1:1000 odds), much higher observer coverage (36-47%) is required. If the certainty level is reduced to where there is only a 50% chance of achieving the CV of 30% then observer coverage can be reduced to 10% for 1:200, 15% for 1:300 but still remains above 20% for 1:600 and 1:1000. The relationship between observer coverage, odds of interaction, and certainty levels is presented in greater detail in Figure 1.

The recommendation in Skillman et al. (1996) of an observer coverage level of 20% to meet a required 30% level of precision at a 90% certainty rate would be sufficient for olive ridley sea turtles. The coverage rate is not sufficient for species such as the false killer whale, giant manta ray, or leatherback sea turtle. The current 20% coverage rate is not sufficient for species with odds of interactions lower than 1:300.

Table 1. Percentage of observer coverage required (OCR) to achieve a CV of at least 30% given a set level odds of interaction (1:XX) and certainty level (90% to 50%). Species icons indicate the odd ratio that most closely reflects the encounter rate in the Hawai'i deep-set longline fishery for that species; blank cells indicate no significant species interaction for that odds of interaction.

	 Oceanic white tip shark	 Black-footed albatross	 Laysan albatross	 Olive ridley sea turtle	 False killer whale	 Giant manta ray	 Leatherback sea turtle
OCR	**Odds of interaction (1:XX)**						
	1:10	1:100	1:200	1:300	1:600	1:1000	1:1500
90%	1%	8%	15%	20%	36%	47%	59%
80%	1%	7%	13%	19%	31%	45%	55%
70%	1%	7%	12%	18%	28%	42%	54%
60%	1%	6%	11%	16%	28%	37%	47%
50%	1%	6%	10%	15%	27%	37%	46%

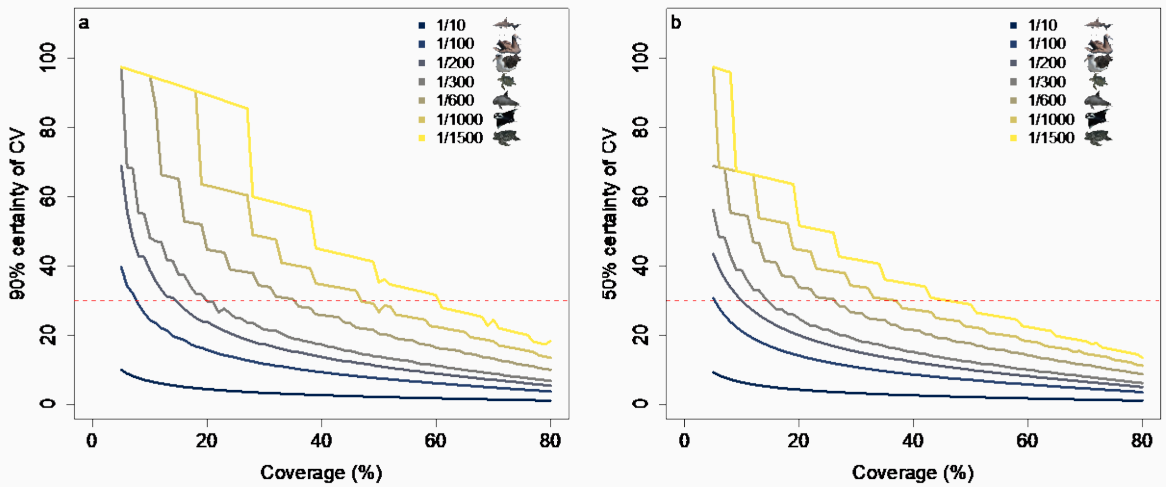


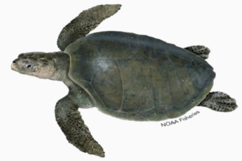
Figure 1. Plots lines indicate, given a specified certainty, a) 90% b) 50%, the expected CV that would be achieved given an observer coverage level under certain set level odds of interaction. The expected CV of 30% is indicated by the dotted red line. Dark lines are for high interaction rates blending to yellow for low interaction rates. The species images indicate the approximate line that corresponds to interaction rates in the Hawai‘i deep-set longline fishery (oceanic white tip shark, black-footed albatross, Laysan albatross, olive ridley sea turtle, false killer whale, giant manta ray, and leatherback sea turtle).

Sampling programs are designed to be unbiased on average, but the precision of the estimate in any given year can have consequences when specific interaction thresholds are used to mitigate impacts on protected species. Since the Hawaii shallow-set longline fishery 100% observer coverage, there is no question about the number of interactions, but as coverage levels decline, we are less precise about the estimated value. When the precision of estimates becomes low, there is the potential to have undetected large annual impacts on populations or unnecessary impacts to the fishery in any given year.

To illustrate this effect, the same simulations presented above were used to explore the relative absolute error (ARE) in annual estimates. Results are presented for observer coverage levels of 5% to 30% for a range of odds of interaction from 1:10 to 1:1500. In Table 2, the odds of achieving an estimate that is greater or less than 50% of the true estimate are presented along with the risk relative to an observer coverage of 20%. Decreasing observer coverage increases the odds that any year's estimate will be much lower or higher than the true value. This can have important consequences for annual population impacts not being detected or fisheries being impacted by closures when it was unnecessary.

It is evident in Figure 1 that this effect is not linear, as observer coverage declines the possibility of estimating these more extreme values accelerates (similar to the pattern seen for CV in Figure 1). The effect is further amplified in species with low odds of interaction. Since low odds species have lower overall total numbers interacted with, small changes in the observed number interacted with have large effects on the overall estimate.

Table 2. The effect of observer coverage levels (OCL) on the odds of obtaining an absolute relative error (ARE) that is higher (+) and lower (-) than 50% and the relative risk of this estimate compared to a 20% coverage level. Null entries (-) are indicative of no estimate occurring at 50% ARE. Odd ratios are representative of interaction rates in the Hawaiʻi deep-set longline fishery.

		 Oceanic white tip shark		 Black-footed albatross		 Olive ridley sea turtle		 False killer whale		 Leatherback sea turtle	
		Odds of interaction (1:XX)									
		1:10		1:100		1:300		1:600		1:1500	
OCL	**ARE**	**Odds**	**Risk**	**Odds**	**Risk**	**Odds**	**Risk**	**Odds**	**Risk**	**Odds**	**Risk**
30%	+	-	-	-	-	1:200	0.19x	1:28	0.46x	1:7.9	0.71x
	-	-	-	-	-	1:250	0.36x	1:45	0.3x	1:7.9	0.72x
25%	+	-	-	-	-	1:91	0.42x	1:22	0.59x	1:6.7	0.84x
	-	-	-	-	-	1:125	0.72x	1:20	0.7x	1:6.7	0.85x
20%	+	-	-	-	-	1:39	-	1:13	-	1:5.6	-
	-	-	-	1:1000	-	1:90	-	1:14	-	1:5.7	-
15%	+	-	-	1:500	-	1:17.5	2.2x	1:7.7	1.7x	1:4.7	1.2x
	-	-	-	1:600	1.7x	1:25	3.6x	1:9	1.6x	1:4.3	1.3x
10%	+	-	-	1:59	-	1:9.5	4x	1:5.5	2.3x	1:3.8	1.5x
	-	-	-	1:200	5x	1:12	7.5x	1:6	2.3x	1:3.6	1.6x
5%	+	-	-	1:19	-	1:6.8	5.7x	1:4.7	2.8x	1:3	1.9x
	-	-	-	1:20	50x	1:7	13x	1:5.3	2.6x	1:2	2.9x

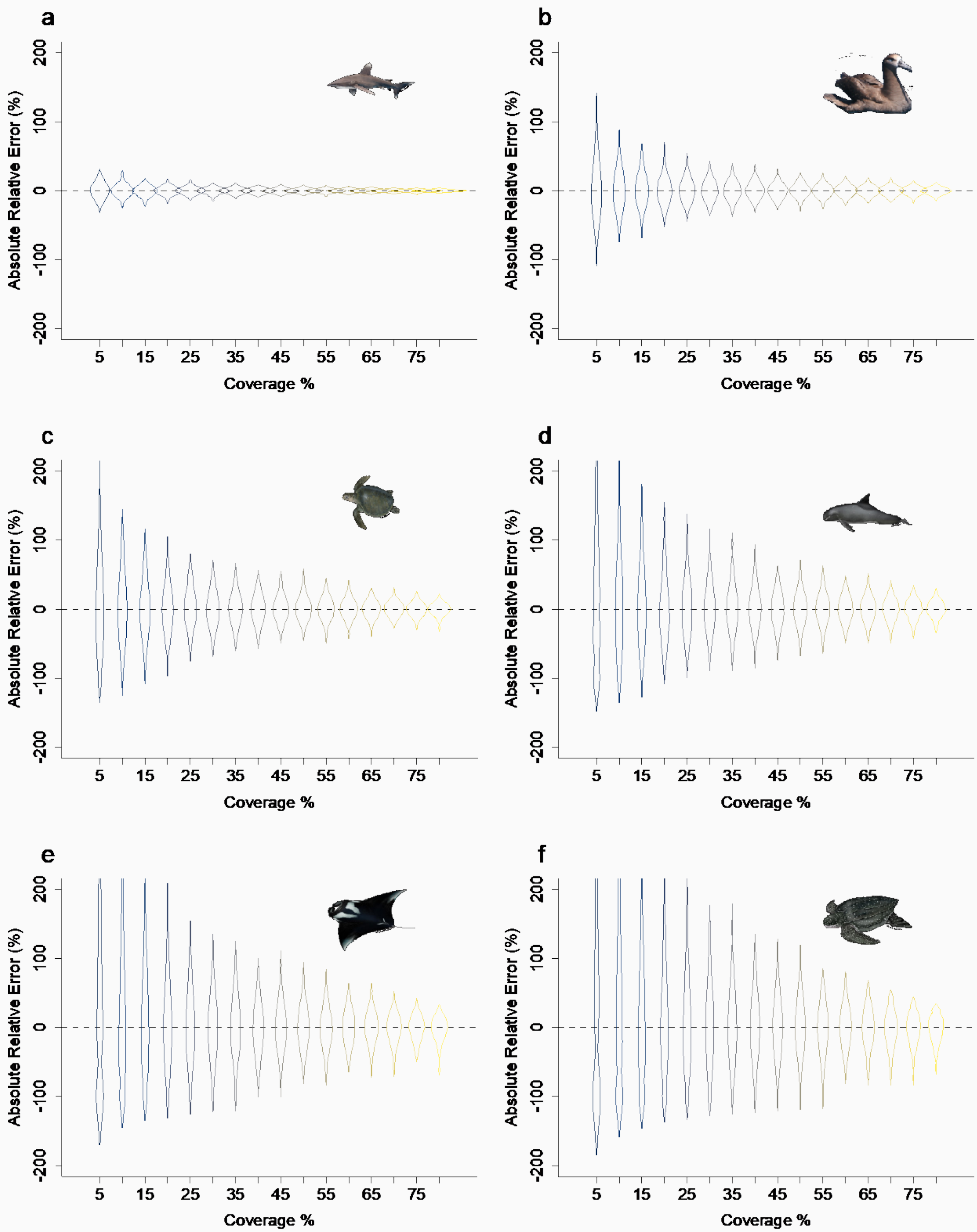


Figure 2. Six violin plots showing the distribution of relative absolute error in the number of interactions as a function of observer coverage. Each panel represents different odds of interaction based on observed interaction rates in the Hawaiʻi deep-set longline fishery a) 1:10—oceanic white tip shark, b) 1:100—black-footed albatross, c) 1:300—olive ridley sea turtle, d) 1:600—false killer whale, e) 1:1000—giant manta ray, and f) 1:1500—leatherback sea turtle.

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