Evaluation of Potential Fishing Location Bias When an Observer is Aboard a Hawaii Deep-set Longline Trip

Marti L. McCracken

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

National Marine Fisheries Service
Pacific Islands Fisheries Science Center

NOAA Technical Memorandum NMFS-PIFSC-84
https://doi.org/10.25923/e7qn-6x46

July 2019

Evaluation of Potential Fishing Location Bias When an Observer is Aboard a Hawaii Deep-set Longline Trip

Marti L. McCracken

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

NOAA Technical Memorandum NMFS-PIFSC-84

July 2019

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
RDML Tim Gallaudet, Ph.D., USN Ret., Acting NOAA Administrator

National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

Recommended citation:

McCracken ML. 2019. Evaluation of potential fishing location bias when an observer is aboard a Hawaii deep-set longline trip. U.S. Dept of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-84, 17 p. doi: https://doi.org/10.25923/e7qn-6x46

Copies of this report are available from:

Science Operations Division
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

Or online at:

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

Table of Contents

Introduction

The objective of the study discussed in this report was to evaluate if there is evidence that crews on deep-set longline vessels are less likely to fish within the U.S. Exclusive Economic Zone (EEZ) around Hawaii when a National Oceanic and Atmospheric Administration (NOAA) observer is aboard. There is particular concern about this behavior since the False Killer Whale Take Reduction Plan (FKWTRP) Final Rule went into effect on December 31, 2012 (77 FR 71260). This technical memorandum and the results presented were completed in March 2018.

Under the FKWTRP, NOAA Fisheries will close the Southern Exclusion Zone (SEZ) to deep-setting after the deep-set fishery reaches a “trigger” based on the false killer whale’s potential biological removal level. The FKWTRP defines the SEZ as bounded by 165°00′W longitude on the west, 154°30′W longitude on the east, the Papahānaumokuākea Marine National Monument and the main Hawaiian Islands Longline Fishing Prohibited Area on the north, and the U.S. Exclusive Economic Zone boundary on the south. The trigger is currently defined as two observed false killer whale interactions in the deep-set fishery that occurred within the EEZ around Hawaii and which NOAA Fisheries has determined are deaths or serious injuries. If the trigger is met, the SEZ will be closed to deep-setting for the rest of the calendar year and will be reopened at the beginning of the next calendar year. In the next calendar year, one of two things can happen: (1) if the trigger is not reached, the SEZ will remain open all year, or (2) if the trigger is reached, NOAA Fisheries will close the SEZ to deep-setting until certain bycatch reduction criteria have been met. This may mean the area is closed for longer than the calendar year.

As this Final Rule may have created an incentive to avoid having false killer whale interactions observed inside Hawaii’s EEZ, there is concern that the crew is less apt to fish inside this EEZ when an observer is aboard. If this fishing location bias exists, it would violate the trigger’s underlying assumption that there is no location bias between observed and unobserved deep-set trips.

To investigate the possibility of location bias, observer data recorded in the Longline Observer Data System (Pacific Islands Regional Office 2017), denoted as LODS, was used to estimate the deep-set longline (DSLL) fleet’s total number of operations inside and outside Hawaii’s EEZ for each calendar year from 2008 through 2016, where 2008–2012 were included to provide similar information for the 5-year period prior to the FKWTRP. These estimates are then compared to the total number of operations recorded in the Hawaii Longline Logbook Database (Pacific Islands Fisheries Science Center 2017), denoted as HLLD, that are inside and outside Hawaii’s EEZ. A statistical significant difference detected when comparing expanded observer with logbook values may indicate location bias.

This comparison assumes that the definition of a fishing operation (set) and its recorded locations are equivalent between LODS and HLLD; that is, the instructions for recording the set’s locations are equivalent and recorded without error. A comparison of recorded locations from each dataset is provided in the next section. Additionally, this comparison considers HLLD as our finite population, and the two finite population parameters derived from HLLD that are being estimated are the (1) total number of operations inside Hawaii’s EEZ and (2) total number of operations outside Hawaii’s EEZ. LODS is viewed as a probability sample of HLLD; that is, the values in LODS are used to estimate the totals, instead of HLLD sample values. If the values of the recorded locations between LODS and HLLD are not equivalent, then we have measurement error, one form of nonsampling error. Location bias is another form of nonsampling error that could be referred to as behavioral bias. Examining the validity of HLLD was not part of this analysis.

Comparing Recorded Locations

As continual locations of a complete longline fishing operation are unavailable, the locations of the begin set, end set, begin haul, and end haul are used to classify if a fishing operation was inside or outside Hawaii's EEZ, where points on the EEZ boundary are classified as inside. These four locations are recorded by the observer and the recorder of the vessel's logbook and are available in LODS and HLLD. Herein, a fishing operation is classified as inside or outside Hawaii's EEZ if at least one of these four locations is within the region. Thus, a fishing operation can be classified both inside and outside of Hawaii's EEZ.

The current observer manual (Pacific Islands Regional Observer Program 2017) specifies that (1) the begin set location is the latitude and longitude of the vessel when the first piece of gear is put in the water, (2) the end set location is the vessel's location when the last piece of gear is put in the water, (3) the begin haul location is the vessel's location when the first piece of gear is pulled from the water, and (4) the end haul location is the vessel's location when the last piece of gear is pulled from the water. Latitude and longitude can be obtained from the vessel's GPS unit or the observer's handheld unit and are recorded down to the tenths of minutes. Instructions to the recorder of the vessel's logbook are less specific as they only request the positions at the beginning and ending of setting and hauling the gear without defining the begin and end of the set and haul; furthermore, the positions are only recorded down to the minutes.

Given the preceding instructions, we do not expect these four positions to be identically recorded in LODS and HLLD; however, they are expected to be similar. To investigate how similar the positions are between these two databases, observed sets were matched to logbook entries using the logbook page serial number (each set should have a unique logbook page serial number) and the vessel permit number. The permit number was used because there were situations where the logbook serial number matched sets by different vessels. Table 1 provides the number of sets recorded in LODS and HLLD and summaries concerning the results of matching the sets between LODS and HLLD. On a yearly basis, 0.1% to 3.1% of LODS sets could not be matched. The discrepancy between instructions and requested accuracy will introduce unwanted bias if they result in different classifications into the two regions: inside and outside Hawaii's EEZ. Therefore, the number of matched sets in these regions is compared in Table 1, and there seems to be little bias introduced by these discrepancies. For matched sets inside Hawaii's EEZ, the largest discrepancy was 5 sets, less than 0.5%: HLLD had 5 more sets than LODS in 2011 and LODS had 5 more sets than HLLD in 2016. With a similar comparison for outside Hawaii's EEZ, the largest discrepancy was 4 sets, less than 0.2%, in 2013, with HLLD having the larger number.

For each matched set, the 4 recorded latitudes and 4 recorded longitudes in HLLD were subtracted from their counterparts in LODS, minutes were converted to decimals. Figures 1 and

2 are box-whisker plots of these eight differences for years 2008–2012, before the FKWTRP, and 2013–2016, after the FKWTRP. The whiskers show either the maximum value or 1.5 times the interquartile range of the data, whichever is the smaller. For all the plots, the thick horizontal line centered at 0 encompasses the box and whiskers of the box-whisker plots, confirming that almost all the differences are small. These plots also show that there are a few large differences, the outliers, between LODS and HLLD; however, these large differences appear to be incorrect matches, recorder errors, or data entry errors. For example, some matched sets would have very different departure and arrival dates and some recorded locations would be off by one digit. Because of time constraints, it was not feasible to evaluate all suspected incorrect matches and make the necessary corrections. Although the incorrect matches do not affect the estimates of the totals, latitude and longitude recording errors can introduce some unwanted bias in our comparison of the estimated and HLLD totals. However, these outliers (most likely incorrect matches) were included in the dataset used to compile Table 1 where only a slight bias was indicated.

Next, let us examine these differences for patterns over time (year to year) or space. Table 2 provides the percentage of differences whose absolute values are less than or equal to the specified upper bound expressed in minutes. Slightly more than a half of the absolute values of the differences are less than 0.5 minutes and over 90% of the differences are less than a minute. This pattern is consistent throughout all nine years. To examine if there was an association between a set's location and the differences in the recorded locations between LODS and HLLD, spatial plots were created of a set's LODS location on a map of Hawaii and its EEZ, with size of a plot marker scaled in size to the distance between the two recorded locations. These plots are not provided as the specific locations are confidential information. There does not appear to be any spatial or temporal patterns between the recorded locations in LODS and the distance between the LODS and HLLD recorded locations, including with regards to Hawaii's EEZ boundary.

Let us now consider if there is a difference in the recording of fishing operations. There were cases where a HLLD set would be recorded as multiple sets in LODS. For example, one trip in 2008 has 19 recorded sets in LODS and 11 recorded sets in HLLD. This trip had 8 days where 2 sets were recorded in LODS, but for each of these 8 days, the 2 sets in LODS were recorded as 1 set in HLLD. A longline vessel will occasionally deploy the longline gear in portions (the line will not be continuous) or the vessel will make multiple sets in a day. In the current observer manual, the instructions specify that each individual portion of deployed gear will get its own Set and Haul form and set number. If this happens, the observer is instructed to inform the captain to use a separate log sheet for each portion of the gear fished; i.e., each portion of gear fished will receive a unique logbook page serial number. However, instructions to the recorder of the vessel's logbook provide no guidance in this situation; i.e., what is considered a fishing operation is not clearly defined. For matched sets, the problem of a LODS set being recorded as two sets in HLLD was rare: 8 LODS sets in 2008; 1 LODS set in 2012; 5 LODS sets in 2014; and 1 LODS set in 2016. There were no cases of a matched LODS set being recorded as more than 2 sets in HLLD. For trips without an observer, we do not know how often fishing operations that occurred in portions were recorded as one set. It is possible that it occurs more frequently since there is no observer aboard to convey the instructions. Problems with portions of fishing operations not consistently being recorded as separate sets can introduce unwanted bias in our comparison of the estimated and HLLD totals.

In summary, our assumption that the locations recorded in LODS and HLLD are equivalent does not entirely hold but only makes a difference in region classification for less than 1% of matched sets (Table 1). If we assume that the observer and the vessel's recorder on an observed trip are not intentionally falsifying records, the comparison of the recorded locations for the matched sets should provide a measure of the level of differences we would expect. Because of these differences, we expect some unwanted bias in our comparison; however, these biases seem to be small. It is unclear how to determine the possible level of bias introduced as a consequence of reporting an operation that is set in segments (line is not continuous or multiple sets in a day) as a single operation. We did not explore this bias beyond that described in the previous paragraph, because of insufficient time.

Sampling Design for the DSLL Fishery

As our estimator for the annual total number of sets inside and outside Hawaii's EEZ is based on the sample design used to select trips for observer placement, it is important to understand the complex adaptive sample design that was developed to select DSLL trips for observer placement and why an adaptive design is necessary. An adaptive design is used to adapt to the availability of observers. Because a selected trip can only be sampled if an observer is available for deployment, observer availability must be taken into account. Observer availability and coverage levels vary throughout the year because of (1) fluctuation in the fleet's activity level, (2) demands of 100% coverage in the Hawaii longline shallow set fishery for swordfish, (3) an influx of observers after completion of NMFS observer training, (4) the departure of observers from the observer program, and (5) observers leaving and returning from leave. Because observers are not paid while waiting to be deployed, they must be assigned with minimal delay when available. The alternative of paying them while they are waiting to be deployed would increase the cost of the observer program. To adapt to the variability in observer availability and reach a balance between obtaining a probability sample and being cost effective, an adaptive sampling protocol that is based on two sampling schemes was developed

Before departing on a fishing trip, longline vessels are required to notify the NOAA Fisheries Pacific Islands Regional Office (PIRO) observer program contractor at least 72 hours prior to their intended departure date. To enable sample selection, the PIRO contractor numbers notifications sequentially in the order in which they are received. Herein, this assigned number is referred to as the notification number. It is these notification numbers that are selected and the trips associated with them designated to be sampled.

The first stage of the sampling protocol is a systematic sample. The systematic sample is drawn at approximately 5% lower coverage than the targeted coverage level, which is typically 20% of the DSLL fishery. Drawing the systematic sample at this level seems to provide the maximal percent coverage by the systematic sample in which few selected trips are missed. A systematic sample is a special case of a cluster sample with k clusters in the population. For example, suppose there are a total of 100 trips and a systematic sample at 20% coverage with 5 starting points is to be drawn. Using sets of notification numbers, the 25 clusters that define the population are {1,26,51,76}, {2,27,52,77}, …, {25,50,75,100}. To draw a sample of 5 clusters, only 5 starting points between 1 and 25 need to be drawn to define the selected clusters. If only 1 starting point is drawn, then the sample contains 1 cluster; consequently, it is not possible to obtain an unbiased estimate of the variance of the estimated bycatch. When drawing a systematic sample for sampling the DSLL fishery, 5 starting points are selected from the integers 1 to k using simple random sampling without replacement (SRSWOR), where k is the value of 100(5)/(percent coverage) rounded up to the nearest integer. Using 5 starting points provides the benefits of multiple starting points while preventing too many randomly selected trips being clumped together by random chance. The decision to use 5 starting points was based on practical considerations and not on any statistical inference regarding the number of starting points for maximal precision.

The systematic sample requires having an observer available to be deployed whenever a selected trip is ready to depart. Achieving this requirement under full targeted coverage, typically 20% coverage, throughout the year requires having enough observers on contract to accommodate higher levels of fleet activity and paying them when they are not deployed on a vessel. These requirements frequently cannot be met under the current level of funding; therefore, the sample selected under the systematic design is slightly smaller than the targeted coverage, typically 5% less. For example, for the most commonly targeted level of coverage by the systematic sample, 15% coverage, $k = 33$.

Now let us consider drawing the additional samples required to achieve the targeted coverage level. Only after all upcoming notifications selected by the systematic sample are assigned an observer and there are still observers ready to be deployed should additional samples be drawn. The method for drawing these samples needs to be straightforward as they are needed quickly and with little forewarning. Drawing the additional notifications using SRSWOR from the list of notifications still eligible for observer placement is straightforward and the method that the observer program is instructed to use. Hereafter, this complex adaptive sample design is called a “systematic-plus”" (SYSPLUS) design.

Because the occasions when secondary samples are drawn are not randomly selected but determined by the need to deploy observers, the probability a notification is selected by the secondary sample is unknown and needs to be approximated. To approximate these probabilities, the contractor's list of notifications is used. Examination of these records reveal time periods when coverage appears to have been greater or less than the full targeted coverage. Specifically, time periods for which the number of secondary samples is greater than expected represents higher coverage and those for which the number of secondary samples are fewer than expected represents lower coverage. Before computing the inclusion probabilities (the probability a unit is included in the sample), periods of comparable coverage are identified. The inclusion probabilities are computed by enumerating the number of notifications during consecutive time periods of comparable coverage and assuming that the secondary samples were selected with equal probability from those trips that had not been selected as part of the systematic sample. An outcome of the secondary sample is that notifications are selected with unequal probability. For example, notifications that are included in the sampling frame of the secondary sample will have a greater probability of being selected than those excluded.

Comparing the HLLD Total to the Estimated Total

In this analysis, we expanded the LODS data on number of locations inside and outside the EEZ using a sample-based estimator based on the SYSPLUS design and compared the confidence interval boundaries to the total numbers from the HLLD. Based on the inclusion probabilities of the SYSPLUS design and using the classifications into regions based on the recorded locations in LODS, the generalized ratio estimator (Thompson, 1992) was used to estimate the total number of fishing operations and locations (begin set, end set, begin haul, and end haul) inside and outside Hawaii's EEZ based on LODS data. The generalized ratio estimator is a generalized form of the ratio estimator that takes into account unequal sampling probabilities. Because the inclusion probabilities are related to observer availability, a proportional relationship between the number of sets inside and outside Hawaii's EEZ and the inclusion probabilities is not expected. In this circumstance, the variance of the Horvitz-Thompson estimator (a commonly used estimator for unequal probability designs) can be very large and using the generalized ratio estimator with the auxiliary variable equaling one for each primary sampling unit is recommended (Thompson, 1992). Hence, the auxiliary variable for the generalize ratio estimator equaled 1 for all DSLL trips and the DSLL fleet total number of trips was that recorded in HLLD.

Sets were assigned to the year that the trip landed. Therefore, a year's total may include sets that were completed in the previous year. Similarly, the SYSPLUS sample based on notifications received in one year will include trips that are assigned to the following year. For example, a trip may have provided its notification in 2013 but landed in 2014. In this case, the trip was assigned to 2014 despite it being part of the 2013 SYSPLUS sample.

Although we are primarily interested in comparing the estimated (from LODS data) and HLLD totals for the number of sets, the number of locations (begin set, end set, begin haul, end haul) in each region is also estimated. This is because each of the four locations can only be classified into a single region, whereas, it is possible for a set to be classified into both regions as it is classified into a region if at least one of its 4 locations fall into that region.

The approximate 95% confidence intervals (CI) are the commonly used normal-based CI. These CI assume only sampling error is present. Sampling error is the error that results from taking one sample instead of examining the whole population, and we expect approximately 95% of the CI derived from repeated sampling of the finite population to contain the true value (HLLD value in this study) of the parameter being estimated. The coverage of the CI is expected to be less than 95% when there are nonsampling errors. Therefore, if the 95% CI does not overlap the corresponding HLLD total, then there is evidence of nonsampling errors. No other potential sources of nonsampling error besides location bias indicate evidence of location bias. However, the reporting errors and differences in instructions and required accuracy can bias our results (i.e., we would expect the coverage of the CI to be less than 95% based on these measurement errors).

In this analysis, we expanded the LODS data on number of locations inside and outside the EEZ using a sample-based estimator based on the SYSPLUS design and compared the confidence interval boundaries to the total numbers from the HLLD. Alternative methods are possible. Instead of evaluating if the HLLD total is within the boundaries of the CI from expanding LODS data, the sampling distribution of the estimator could have been generated from HLLD data by applying a SYSPLUS sampling design and the location of the value of the estimated total derived using LODS identified within this distribution to see if it fell outside a predetermined percentile such as 2.5% and 97.5%. From the practical standpoint, it is not clear how to proceed generating all possible samples for the SYSPLUS sample since it is an adaptive sample. Furthermore, since the sample is drawn from the notifications logs, the notifications would need to be matched to their HLLD records and this would have likely taken considerable time. One would not expect the statistical conclusions drawn from generating the sampling distribution to be very different from the method used here, unless the normal distribution is a poor approximation of the sampling distribution. In our situation, we expect the normal distribution to be a good approximation of our sampling distribution based on the Finite Population Central Limit Theorem (see Thompson 1992 for a discussion).

The strength of the approach taken in this paper is that it uses known sampling probabilities based on the SYSPLUS sampling design. Any analysis that does not take into account how the data was collected can result in misleading results. The greatest effort within Hawaii's EEZ typically occurs between October and February, but even during these months, the amount of effort within the EEZ will fluctuate. As sampling inclusion probabilities also fluctuate over time (i.e., observer availability and the number of trips in a given time period fluctuate over time), they must be taken into account. For example, in 2008 there were 7,426 HLLD sets inside the EEZ. If one assumes an equal probability sample in 2008, the realized estimate is 5,985 sets; whereas, using the generalized ratio estimator as done here, the realized estimate is 6,973 sets.

Results

Table 3 presents the estimated total number of locations (total number of begin set, end set, begin haul, and end haul locations that are in the region) and estimated total number of sets inside and outside Hawaii's EEZ, as well as corresponding approximate 95 % CI using LODS. Also presented for comparison are the actual HLLD totals, the percent difference between LODS estimated total and HLLD total, and whether the HLLD total falls within the LODS estimated 95% CI. If the HLLD total falls within the estimated 95% CI, then there is no significant evidence of location bias occurring at the ≈ 0.05 significance level. The HLLD totals for Hawaii EEZ in 2013 are the only totals not within their corresponding 95% CI: there are more HLLD sets and locations than there are LODS estimated sets and locations reported inside Hawaii's EEZ. This result could be a consequence of fishing location bias where crew are choosing to fish less often inside the EEZ when an observer is onboard, given that 2013 was the first year the TRT final rule went into effect, but it may also be a consequence of recording errors or different instructions (measurement error), drawing a random sample whose CI does not include the total (we expect approximately 5% of samples to result in 95% CI that do not include the HLLD total), or a combination of the above. In fact, where 2013 underestimated the total by about 19%, the 2014 estimate overestimated the total by about 11%. It could be that the SYSLUS sample at the end of 2013 selected a random sample by chance whose CI does not include the total. If we compare the sum of 2013 and 2014 LODS set estimates to the comparable sum from HLLD, we have a sum of 9,576 LODS estimated sets compared to an estimate of 10,162 HLLD sets, or approximately –5.7% error. The LODS estimated locations and sets outside the EEZ in 2013 and 2014 show the opposite pattern: the LODS estimates overestimate in 2013 and underestimate in 2014. The fact that the HLLD totals outside the EEZ are within the CI is not too surprising. Typically, a large percentage of effort is inside the EEZ at the end of the year; whereas, outside the EEZ is fished more heavily between March and September. Thus, we would expect the estimates inside the EEZ to be more sensitive during this period, and the effect on the estimates outside the EEZ to be muted.

Despite any potential bias introduced by reporting errors and differences in instructions or any other sources, the LODS estimates appear to be close to the HLLD total. For inside Hawaii's EEZ, the average percent difference for the estimated number of locations and number of sets is –1.0% and 0.7%, respectively. For outside Hawaii's EEZ, the average percent difference for the estimated number of locations and number of sets is –1.9% and 1.8%, respectively.

In summary, based on LODS and HLLD, there is no statistically significant evidence that a location bias exists inside or outside Hawaii's EEZ for observed vs. unobserved trips in the DSLL fishery, with the possible exception of 2013. In 2013, location bias may have occurred but it's possible that differences may also have occurred due to different instructions, recording/reporting errors, or by chance drawing an unrepresentative sample. Even if the results for 2013 were a consequence of fishing location bias, in recent years, there is no evidence of fishing location bias between observed and unobserved operations.

Acknowledgement

Thanks to Maia Kapur for generating confidential spatial plots of the differences in LODS vs. HLLD reported locations; Annie Yau for comments that helped with clarity and framing; and Erin Oleson, Amanda Bradford, Karin Forney, and Kevin Brindock for suggestions on additional analyses to strengthen the study.

References

Pacific Islands Regional Observer Program. 2017. Hawaii longline observer program field manual: LM.17.02, Pacific Islands Regional Office, National Marine Fisheries Service, Honolulu, Hawaii. URL: *www.st.nmfs.noaa.gov/observer-home*.

Pacific Islands Regional Office. 2017. Longline observer data system from 2013-01-01 to 2013-12-31. NOAA National Centers for Environmental Information, https://inport.nmfs.noaa.gov/inport/item/9027.

Pacific Islands Fisheries Science Center. 2017. Hawaii longline logbook from 2010-06-15 to 2010-08-15. NOAA National Centers for Environmental Information, https://inport.nmfs.noaa.gov/inport/item/2721.

Thompson SK. 1992. Sampling. New York (NY):Wiley.

Table 1. Summary statistics concerning the number of sets in LODS and HLLD. The number of DSSL fishing operations in LODS that could not be matched to a set in HLLD is given in the column labeled "LODS sets not matched." The number of matched sets within the regions of interest based on positions recorded in LODS and HLLD are in the last four columns.

	Number of deep-set fishing operations				Number of matched sets			
			Number of LODS sets in	LODS sets	Hawaii EEZ		Outside EEZ	
Year	LODS	HLLD	Hawaii EEZ	not matched	LODS	HLLD	LODS	HLLD
2008	3,917	17,875	1,293	26	1,292	1,293	2,735	2,734
2009	3,520	17,001	1,120	4	1,119	1,117	2,505	2,508
2010	3,580	16,051	910	82	904	908	2,662	2,664
2011	3,540	16,888	1,265	49	1,243	1,248	2,390	2,391
2012	3,659	18,151	1,245	63	1,213	1,216	2,509	2,512
2013	3,830	18,750	874	40	862	862	3,044	3,048
2014	3,831	17,873	990	54	961	963	2,921	2,919
2015	3,725	18,409	1167	72	1,144	1,148	2,688	2,690
2016	3,880	19,315	1076	118	1,054	1,049	2,873	2,874

Table 2. Percentage of differences whose absolute values are equal or below the upper bound where the upper bound is expressed in minutes.

		Upper bound in minutes				
Measurement	Year	0	0.25	0.50	0.75	1.00
Latitude	2008	0.6%	31.6%	58.5%	79.9%	95.0%
	2009	0.7%	31.1%	57.7%	78.8%	94.7%
	2010	0.6%	31.8%	57.8%	79.1%	94.8%
	2011	0.5%	31.1%	57.6%	78.2%	93.9%
	2012	0.7%	30.6%	57.5%	79.1%	94.0%
	2013	0.5%	31.1%	57.3%	78.4%	93.8%
	2014	0.6%	31.0%	56.9%	77.8%	93.8%
	2015	0.6%	31.1%	56.6%	77.7%	94.0%
	2016	0.6%	29.9%	56.2%	77.8%	93.9%
Longitude	2008	2.0%	30.7%	56.5%	78.5%	93.5%
	2009	2.0%	30.3%	56.2%	77.1%	92.3%
	2010	2.2%	30.2%	56.7%	77.7%	93.0%
	2011	2.1%	30.6%	56.3%	76.8%	92.0%
	2012	1.8%	30.2%	56.9%	78.0%	92.2%
	2013	1.9%	30.3%	55.6%	76.7%	91.7%
	2014	2.5%	30.3%	56.4%	76.6%	92.4%
	2015	2.7%	30.1%	55.3%	76.2%	91.7%
	2016	2.5%	29.1%	54.6%	75.9%	91.8%

Table 3. The HLLD total and LODS estimated total with 95% CI and if the HLLD total is within the 95% CI (Within) for the two regions is given for the two metrics, where "4 locations" demarks the sum of begin set, end set, begin haul, and end haul positions that were inside the region of interest. Also included is the percent difference comparing LODS estimated total to HLLD total.

Year	Zone	Metric	HLLD Total	LODS Estimated Total	LODS Estimated 95% CI	Percent Difference	Within
2008	Outside EEZ	4 locations	43,006	45,886	[39,865;51,907]	6.7	Yes
		Sets	11,059	11,831	[10,299;13,362]	7.0	Yes
	Hawaii EEZ	4 locations	28,494	26,471	[22,035;30,907]	–7.1	Yes
		Sets	7,426	6,973	[5,824;8,123]	–6.1	Yes
2009	Outside EEZ	4 locations	44,811	45,267	[38,839;51,696]	1.0	Yes
		Sets	11,490	11,587	[9,960;13,213]	0.8	Yes
	Hawaii EEZ	4 locations	23,193	23,941	[19,240;28,641]	3.2	Yes
		Sets	6,089	6,257	[5,046;7,468]	2.8	Yes
2010	Outside EEZ	4 locations	50,015	50,447	[44,003;56,891]	0.9	Yes
		Sets	12,704	12,759	[11,135;14,383]	0.4	Yes
	Hawaii EEZ	4 locations	14,189	13,930	[10,978;16,882]	–1.8	Yes
		Sets	3,750	3,631	[2,873;4,388]	–3.2	Yes
2011	Outside EEZ	4 locations	44,753	46,586	[40,429;52,743]	4.1	Yes
		Sets	11,507	12,015	[10,450;13,580]	4.4	Yes
	Hawaii EEZ	4 locations	22,795	22,939	[18,909;26,969]	0.6	Yes
		Sets	6,016	6,088	[5,033;7,144]	1.2	Yes
2012	Outside EEZ	4 locations	49,408	49,039	[42,650;55,427]	–0.7	Yes
		Sets	12,661	12,608	[10,988;14,228]	–0.4	Yes
	Hawaii EEZ	4 locations	23,196	23,948	[19,704;28,193]	3.2	Yes
		Sets	6,119	6,299	[5,194;7,404]	2.9	Yes
2013	Outside EEZ	4 locations	53,815	57,618	[50,610;64,625]	7.1	Yes
		Sets	13,769	14,697	[12,939;16,472]	6.7	Yes
	Hawaii EEZ	4 locations	21,185	16,930	[13,593;20,268]	–20.1	**No**
		Sets	5,602	4,524	[3,657;5,391]	–19.2	**No**
2014	Outside EEZ	4 locations	54,233	53,251	[46,728;59,775]	–1.8	Yes
		Sets	13,805	13,587	[11,936;15,239]	–1.6	Yes
	Hawaii EEZ	4 locations	17,259	19,145	[15,471;22,820]	10.9	Yes
		Sets	4,560	5,052	[4,099;6,004]	10.8	Yes
2015	Outside EEZ	4 locations	51,059	50,520	[44,119;56,922]	–1.1	Yes
		Sets	13,170	13,101	[11,467;14,735]	–0.5	Yes
	Hawaii EEZ	4 locations	22,577	22,444	[18,406;26,482]	–0.6	Yes
		Sets	6,053	6,088	[5,015;7,160]	0.6	Yes
2016	Outside EEZ	4 locations	57,533	57,535	[50,661;64,409]	0.0	Yes
		Sets	14,785	14,859	[13,102;16,616]	0.5	Yes
	Hawaii EEZ	4 locations	19,727	20,273	[16,448;24,097]	2.8	Yes
		Sets	5,353	5,557	[4,540;6,575]	3.8	Yes

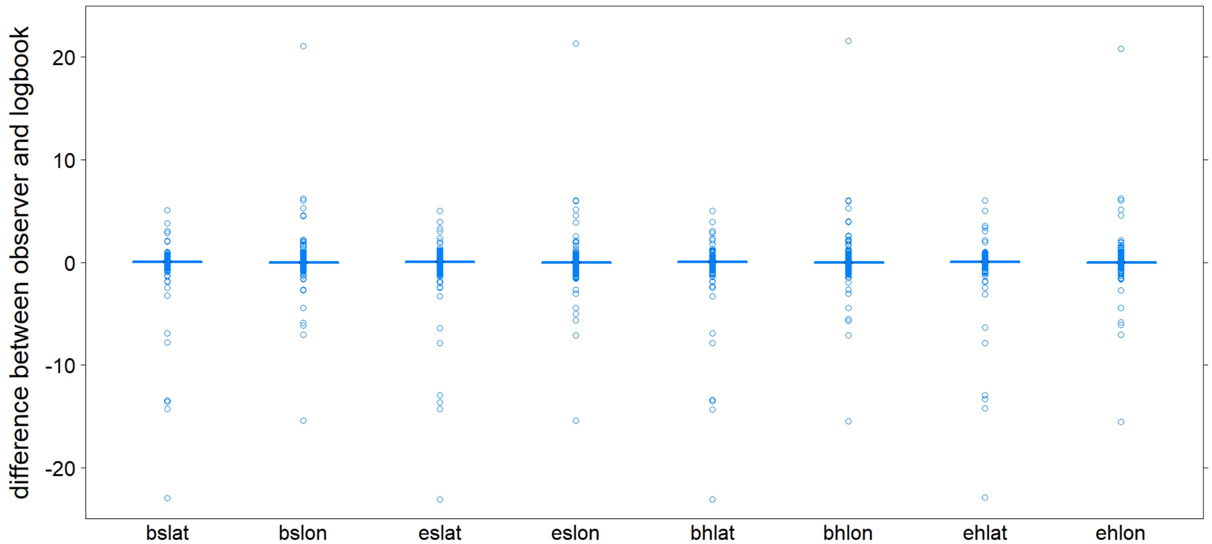

Figure 1. Box-whisker plots of the differences (degrees) between the recorded locations in the LODS and HLLD for 2008–2012. The locations are denoted as bslat (begin set latitude), bslon (begin set longitude), eslat (end set latitude), eslon (end set longitude), bhlat (begin haul latitude), bhlon (begin haul longitude), ehlat (end haul latitude), and ehlon (end haul longitude).

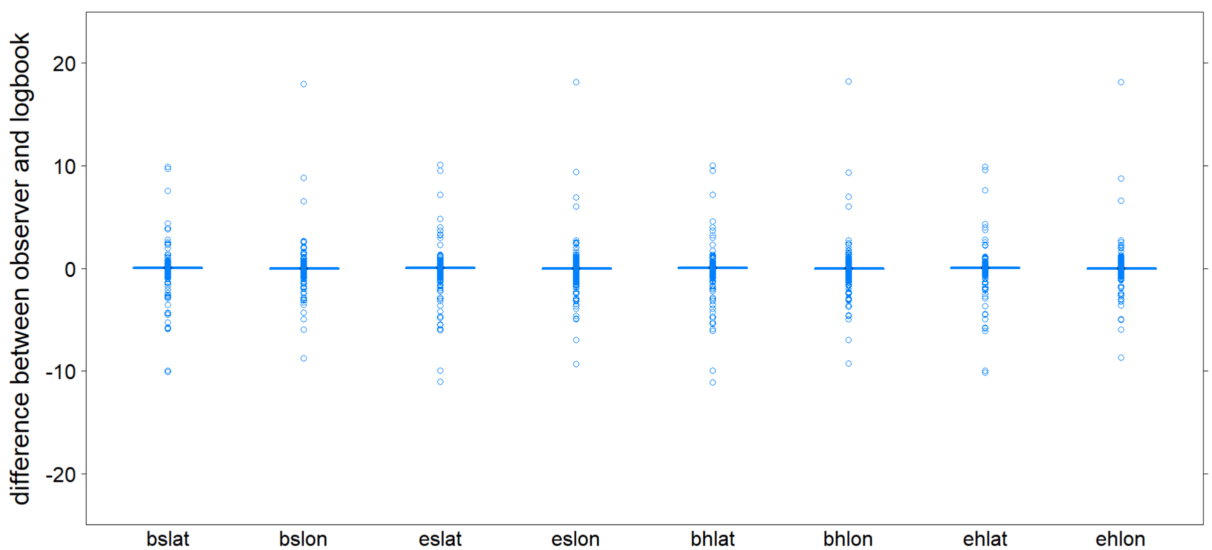

Figure 2. Box-whisker plots of the differences (degrees) between the recorded locations in the LODS and HLLD for 2013–2016. The locations are denoted as bslat (begin set latitude), bslon (begin set longitude), eslat (end set latitude), eslon (end set longitude), bhlat (begin haul latitude), bhlon (begin haul longitude), ehlat (end haul latitude), and ehlon (end haul longitude).