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ESTIMATES OF MARINE MAMMAL, SEA TURTLE, AND SEABIRD BYCATCH IN THE CALIFORNIA LARGE-MESH DRIFT GILLNET FISHERY: 1990-2021

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**ESTIMATES OF MARINE MAMMAL, SEA TURTLE, AND SEABIRD
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FISHERY: 1990-2021.**

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Abstract

Bycatch of marine mammals, sea turtles, and seabirds in the California thresher shark / swordfish drift gillnet fishery from 1990 to 2021 is estimated with random forest classification and regression trees. Tree estimates are compared with annual ratio estimates using the same observer data. Biases associated with ratio estimators (systematic under- and overestimation of bycatch) are notable when observed bycatch is rare, when each annual bycatch estimate is informed only by data from the same year, and observer coverage is low. Tree methods provide more stable annual bycatch estimates with better precision, because estimates are informed by all available data. Even in years without observed bycatch, expected values from regression trees may be positive and include estimates of error, whereas corresponding ratio estimates are zero and lack error estimates. Regression tree bycatch models include oceanographic, location, and gear variables used as predictors to estimate bycatch at the fishing set level. Model variables were identified using 'balanced random forest' classification trees that deliberately oversample sets with observed bycatch to address zero-inflated data signal-to-noise challenges. This method was previously validated with a simulated rare bycatch dataset where significant predictor variables were correctly identified in most cases, even when simulated bycatch events represented <1% of all data (Carretta *et al.* 2017).

Introduction

The California thresher shark and swordfish drift gillnet fishery (hereafter, 'the fishery') began in the 1970s as an experimental fishery targeting pelagic sharks. By the mid-1980s, the fishery included over 200 vessels and annual effort was approximately 10,000 fishing sets (Hanan *et al.* 1993, Holts *et al.* 1998). Fishing effort has declined since, with mean annual effort of 365.2 sets during 2017 - 2021. From 1990 to 2021, trained fishery observers aboard vessels observed 9246 sets from an estimated 57586 sets fished, or 16% observer coverage (Figures 1-2). Prior estimates of marine mammal, sea turtle, and seabird bycatch, based on ratio estimates, are published in Julian and Beeson (1998), Carretta *et al.* (2004), and in a comparison of ratio and regression tree estimates from 1990-2020 (Carretta 2022). In this report, updated estimates of bycatch are summarized for the period 1990 - 2021. For commonly-entangled species with large sample sizes (e.g., short-beaked common dolphin, *Delphinus delphis* and California sea lion, *Zalophus californianus*), ratio estimates of bycatch are generally unbiased. However, there are many species that are rarely-entangled, including sperm whales (*Physeter macrocephalus*) and short-finned pilot whales (*Globicephala macrorhynchus*) that are subject to a mandatory drift gillnet Take Reduction Plan (Federal Register 1997) and for which ratio estimates suffer from low-observer coverage biases (Carretta and Moore 2014). Amandè *et al.* (2012) and Carretta and Moore (2014) showed via simulations that annual bycatch estimates derived from ratio estimates are biased, volatile, and imprecise, especially when events are rare and observer coverage is low. Strategies to provide mean annual estimates of bycatch in U.S. marine mammal stock assessments by pooling 5 years of estimates is insufficient to overcome such biases when estimates are based on annual data only and when these conditions exist (Carretta and Moore 2014). McCracken (2004) noted challenges in identifying predictor variables in the context of rare event bycatch, while Curtis and Carretta (2020) developed a tool for use in

assessing observer coverage levels necessary to detect rare events and estimate bycatch with varying precision goals. Estimation problems associated with low observer coverage and rare events in the drift gillnet fishery were highlighted by Martin *et al.* (2015), who presented a Bayesian model-based alternative to annual ratio estimates, resulting in more stable interannual estimates with better precision for two test cases; humpback whales (*Megaptera novaeangliae*) and leatherback sea turtles (*Dermochelys coriacea*). Random forest (RF) classification and regression trees (Breiman *et al.* 1984, 2001a, 2001b) are used for variable selection and bycatch estimation (respectively) for all species observed entangled in this fishery, with a secondary emphasis on comparing tree estimates to annual ratio estimates derived from within-year data.

Methods

Modeling approach

Bycatch models are constructed in a two-step process, first, using RF classification trees for variable selection with bycatch presence / absence data (see Variable Selection). Although variable importance can be assessed with either classification or regression trees, the rarity of bycatch events in the fishery necessitates oversampling fishing sets with observed bycatch to address signal-to-noise ratio issues common to zero-inflated data (Xie *et al.* 2009, Lin and Chen 2013). This strategy is implemented in RF by treating the response (bycatch or no bycatch) as a factor (or class) to be predicted, rather than a numeric response to be estimated. Variables selected for inclusion are then used in a regression tree RF to estimate the bycatch rate in unobserved fishing sets (see Bycatch Estimation).

Variable selection (classification trees)

Variable selection was implemented with RF classification trees (Breiman *et al.* 1984, Breiman 2001a, 2001b, Liaw and Wiener 2002) in the R-package *rfPermute* (Archer 2021), which implements the R-package *randomForest* (Liaw and Wiener 2002), but *rfPermute* additionally provides statistical significance measures for each variable. Variables evaluated for bycatch models included a suite of fishing gear, oceanographic, and location variables described in Table 1.

Classification trees are recursive partitioning algorithms. Subsets of variables (default = \sqrt{n} where n equals the number of variables) are randomly-selected at each tree node and the variable resulting in the greatest homogenization of the response variable in the subsequent daughter nodes is selected to split the data. Variable splits continue until all observations in terminal nodes contain the same response variable or the terminal nodes contain a single observation. Each classification tree is constructed from a bootstrap sample of data. Those data omitted from tree construction are referred to as 'out-of-bag' (OOB) data. The OOB data are introduced to constructed RF trees and classifications are made for all OOB data, based on variable characteristics of the OOB data, which determine the terminal node that the OOB data are assigned to. In addition, each tree provides a unique expected value of the known response variable in the OOB data, providing a direct measure of model error and uncertainty. The diversity of tree structures in random forests prevents overfitting of data that can occur with single trees and yields robust generalized predictive models where

variables are informative (Breiman 2001a, 2001b). The RF variable selection model consists of classification trees, where the response to be classified is the presence or absence of bycatch in an observed fishing set. Evaluation of the RF model is based on cross-validated classification accuracy: how often is the presence and absence of observed bycatch in OOB data correctly classified? The number of RF trees ($n = 1000$) is based on the approximate number required to return an asymptotic OOB error rate. Cross-validated bycatch presence/absence classifications for OOB data are summarized as a confusion matrix that includes the number of correctly and incorrectly classified presence/absence fishing sets. All RF analyses in this analysis were implemented in the programming language R, version 4.1 (R Core Team 2021).

Observed bycatch in the fishery is a rare event. The species that is most frequently observed entangled (short-beaked common dolphin) occurs in only 3.8% of all observed fishing sets, while some species such as sperm whales have been observed in 0.065% of all observed sets. Given so few entanglement events, determining which (or if) variables have explanatory power is challenging. Faced with high noise-to-signal ratios in bycatch data, the analyst must determine if node-splitting variables used in RF trees are reliable predictors of bycatch.

The variable selection strategy for zero-inflated data is to boost the signal-to-noise ratio by oversampling fishing sets with bycatch. The strategy is analogous to approaches that purposefully alter data class distributions to maximize the predictive accuracy of the minority data class of interest (Xie *et al.* 2009, Lin and Chen 2013), in this case, fishing sets with observed bycatch. RF models included 1000 individual classification trees, each constructed from equal numbers of sets ($n=1/2$ of smaller class size) with and without bycatch. Fishing sets used in construction of each classification tree are sampled without replacement. The relative importance of predictors in classifications of the RF model is assessed by permuting each predictor, and the resulting decreases in classification accuracy are measured. Important variables will result in the largest decreases in classification accuracy, while unimportant variables result in negligible decreases. For each predictor, an importance ‘score’ is defined as the mean decrease in classification accuracy (number of additional cases misclassified) across all trees when it was permuted. Statistical p-values for each variable are obtained by permuting the *response variable* (observed bycatch presence or absence in a set) 200 times, which yields a null distribution of variable importance scores, which is compared to the importance score from the unpermuted responses to calculate a p-value. Variables with p-values less than a 0.05 alpha-level threshold are selected for inclusion in estimation models, based on the feature ‘Mean Decrease in Gini Index’, a measure of how each variable contributes to the homogeneity of the nodes and leaves in the random forest. This is the method applied to simulated rare-event bycatch data by Carretta *et al.* (2017). In cases where no variables are identified as ‘significant’, a default set of variables are used (*days + lat + lon + sst*). RF models require at least 2 variables to be implemented, and where only one significant variable is identified, it was pooled with the set of default variables.

In a bycatch presence / absence context (was bycatch observed?), a RF model’s ability to correctly predict presence is known as ‘sensitivity’ and the ability to correctly predict absence is ‘specificity’ (Allouche *et al.* 2006). The overall accuracy of a RF model can be

expressed as a metric called the ‘true skill statistic’ (TSS, Allouche *et al.* 2006). The TSS is calculated as follows, given the following confusion matrix:

Cross-Validated OOB data		
RF Model	Presence	Absence
Presence	<i>a</i>	<i>c</i>
Absence	<i>b</i>	<i>d</i>

where

$$\text{Overall Accuracy} = (a + d) / (a + b + c + d);$$

$$\text{Sensitivity} = a / (a + c);$$

$$\text{Specificity} = d / (b + d);$$

and

$$\text{TSS} = \text{Sensitivity} + \text{Specificity} - 1$$

The TSS ranges from +1 (perfect prediction) to -1 (always inaccurate), with scores less than zero indicating prediction accuracy no better than chance (Allouche *et al.* 2006). We focus on ‘sensitivity’, because we are interested in correctly predicting bycatch occurrence. For all species, the expected value for sensitivity if all variables lack predictive power = 0.50 because classification trees are built using equal numbers of sets with and without bycatch events. Use of the TSS metric as an assessment tool is consistent with approaches used to estimate the strength of presence / absence models (Allouche *et al.* 2006).

Bycatch Estimation (regression trees)

Variables for each species / taxon bycatch model were identified using the balanced RF classification tree procedure described above and bycatch models were generated with RF regression trees, because the response (bycatch per fishing set) is a rate to be estimated (Watters and Deriso 2000, Walsh and Kleiber 2001, Jiménez *et al.* 2009). For regression trees, sample splits occur along lines of ‘least variance’, where the variable that minimizes the sample variance in daughter nodes of the tree is chosen for a given split. Splits continue until the sample variance is minimized or all observations have the same value. The mean of the observations in each terminal node of a regression tree represents the fitted value (estimate) for each observation in that node. For all species where the number of observed bycatch events ≤ 5 , we used a default set of variables (*lat* + *lon* + *days* + *sst*) in regression tree models, in recognition that most species in the California Current show seasonal and spatial movements within the region in response to prevailing oceanographic conditions (Forney and Barlow 1998, Becker *et al.* 2014). An exception was made for beaked whales

(*Berardius*, *Mesoplodon*, *Ziphius*) and other deep-divers (*Kogia*), where variables were selected based on a pooled multispecies category: ‘all beaked whales’. This is done in recognition that these species are known to be sensitive to anthropogenic sound (Barlow and Gisiner 2006, Tyack *et al.* 2011) and whose bycatch has apparently been absent in this fishery since the introduction of acoustic pingers (Carretta *et al.* 2008, Carretta and Barlow 2011). Variables used in regression tree models for species with observed sample sizes ≥ 6 are shown in Table 2. RF regression trees ($n=1000$) were fully-grown for all species models, where the number of tree nodes is generally greater for species with larger sample sizes. Predicted bycatch per set is obtained by building an RF model with all data, except one fishing trip is omitted for cross-validation. Individual vessel trips averaged 5.75 sets fished (range = 1 – 19). The resulting RF of 1000 trees was used to predict bycatch for each fishing set in the omitted fishing trip. Each tree provides a unique estimate of bycatch for omitted fishing sets, which yields a distribution of 1000 summed bycatch predictions for all 9246 observed sets.

For species s in year y , mean annual predicted bycatch per set $\bar{b}_{s,y}$, is the mean predicted bycatch for all observed sets in year y , where RF trees are constructed using all years of data. Mean annual estimates of bycatch from regression trees $\bar{T}_{s,y}$, are calculated as the product of $\bar{b}_{s,y}$ and the number of unobserved sets in year y (u_y), plus the sum of observed bycatch $o_{s,y}$ that year:

$$(1) \quad \bar{T}_{s,y} = \bar{b}_{s,y} * u_y + o_{s,y}$$

The approach of extrapolating predicted bycatch rates to unobserved fishing effort u_y reflects an assumption that observer data are representative of the fishery. The variance of each bycatch estimate is calculated as:

$$(2) \quad var(\bar{T}_{s,y}) = var(\bar{b}_{s,y} * u_{s,y}) * d_s * fpc^2$$

where

$var(\bar{b}_{s,y} * u_{s,y})$ = the variance of 1000 individual bycatch predictions (one for each tree) summed across observed sets in year y and d_s = the dispersion index of observed bycatch per fishing trip for species s , calculated as the ratio of the variance to mean of the number of observed bycatch events (o), per fishing trip (t), across all 1608 observed fishing trips from 1990-2021:

$$(3) \quad d_s = \sum_{t=1}^n N \frac{var(o_{s,t})}{\bar{o}_{s,t}}$$

The dispersion index is required to reflect uncertainty in the bycatch process (Curtis and Carretta 2020), because $var(\bar{b}_{s,y})$ alone reflects only the uncertainty in estimating mean bycatch rates. For many species, the bycatch process is not Poisson (variance to mean ratio $>> 1$, see Table 2) and without a dispersion factor term, the overall variance of the bycatch estimate may be underestimated. Finally, the variance also includes a finite population correction (fpc) (Snedecor and Cochran 1967) to account for incomplete observer coverage:

$$(4) \quad fpc = \sqrt{\frac{\text{total effort} - \text{observed effort}}{\text{total effort} - 1}}$$

For all bycatch estimates, the value of $fpc = 0.916$ (total effort = 57586 sets, observed effort = 9246 sets). Coefficients of variation (CV) for all estimates were calculated as

$$(5) \quad CV(T_{s,y}) = \frac{\sqrt{var(\bar{T}_{s,y})}}{\bar{T}_{s,y}}$$

In addition to total entanglements, estimated mortality and serious injury (MSI) levels are estimated for all species, using the fraction of observed entanglements recorded as dead, injured, or 'unknown' (f), to prorate estimates of unobserved bycatch. For example, of the 25 observed leatherback sea turtle entanglements in the fishery, 11 were released alive, 13 were released dead, and one was released in 'unknown' condition. Turtles released in unknown condition were conservatively treated as deaths. Of the 11 turtles released alive, 3 were injured to the point where survival was unlikely (NMFS 2013). In this case, the observed fraction (f) of deaths and injuries = 13 known deaths + 4 probable deaths = 17/25 = 0.68 (NMFS 2013). Total MSI was calculated as the product of unobserved bycatch $\bar{b}_{s,y} * u_y$ and f , plus observed MSI. Uncertainty in MSI estimates was estimated by treating f as a random binomial deviate, based on observed entanglement and injury/death sample sizes

for each species. Estimates of unobserved bycatch (one for each of 1000 forest trees) were multiplied by a randomly drawn (with replacement) value of f , yielding a distribution of unobserved MSI estimates of size = 1000, to which observed MSI totals were added. Precision of MSI estimates were calculated as CVs as in Equation 5. Small species such as dolphins, porpoises, and pinnipeds are rarely released alive because they drown quickly in gillnets, thus, they have f values equal to 1, and therefore MSI estimates are simply equal to $\bar{T}_{s,y}$, with the associated CV of $\bar{T}_{s,y}$. In this report, MSI for all species is calculated with $f=1$, except for olive ridley sea turtle (0), Northern fulmar (0.138), humpback whale (0.20), loggerhead sea turtle (0.25), minke whale (0.50), leatherback sea turtle (0.68), sperm whale (0.70), Cuvier's beaked whale (0.952), all beaked whales (0.969), and California sea lion (0.982). The value of f used for humpback whales (0.20) is similar to that used by Martin *et al.* (2015), or 0.25

Estimates from regression trees were compared to annual ratio estimates for all years. Ratio estimates were calculated as the product of observed bycatch in year y , and the inverse of observer coverage for that year. Ratio estimate CVs were calculated via bootstrap, where sets in year y were resampled 999 times with replacement to generate a distribution of bycatch rates, from which the mean and variance were obtained.

Results

Variables identified as important predictors for each species / taxonomic group are summarized in Table 2. Model performance measures (variables selected, sensitivity, selectivity, TSS metrics) for selected species with sample size $>=6$ are given in Table 2. Estimates of total bycatch and mortality and serious injury are summarized in Tables 3-33. Bycatch estimates from regression trees were more stable across years and had better precision (lower CVs) than corresponding ratio estimates. Precision gains from regression trees primarily resulted from the use of all 32 years of observer data in tree construction and estimation of mean bycatch rates based on variables. This contrasts with the use of ratio estimates that rely on one year of data for estimating mean bycatch rates. In sum, the information contained in the full dataset provides a better estimate of true bycatch rates and variable effects, which translates into better annual and multi-year estimates. Some annual regression tree bycatch estimates have large CVs (>1), which occurs when estimated bycatch is near zero even though the standard error (absolute rather than relative error measure) might be small. This is apparent for rarely-entangled species such as striped dolphin and fin whale. In years with few observed sets, the precision of regression tree estimates can also be poor, a consequence of fewer observations from which to predict the mean annual bycatch per set $\bar{b}_{s,y}$. Regression tree estimate CVs also reflect the diversity of predictions from the RF, which depends upon the variability in fishing set characteristics in year y used to extrapolate bycatch to unobserved fishing activity. In the extreme, if all observed sets in year y had identical set characteristics (location, date, depth, etc.), then a RF would predict the same mean bycatch rate for these sets, resulting in zero variance.

Discussion

Some large differences between annual bycatch estimates using regression trees and ratio estimators are due to the combination of rarely-observed events and low observer coverage. For example, in 2010, two sperm whales were observed entangled in one fishing set, out of only 59 observed sets that year and total estimated fishing effort of 492 sets. The observed bycatch rate of 2 whales in 59 sets, combined with 12% annual observer coverage, yielded a ratio estimate of 16.7 whales (Table 18). In contrast, the regression tree estimate of bycatch for 2010 is approximately 2.1 whales (2 observed + 0.1 whales estimated in 433 unobserved sets). Given observed sperm whale bycatch rates in this fishery over 32 years (\sim 1 animal for every 1,000 sets), it is highly unlikely that total bycatch in 2010 was \sim 17 whales. It is more likely that there were only two entanglements, both of which happened to be observed. Another problem with annual ratio estimates is when observed bycatch is zero, the resulting bycatch estimate is zero, even if undetected bycatch occurs. No sperm whale entanglements were observed in 648 sets in the first two years (1990-1991) of the observer program (Table 18), and resulting ratio estimates of bycatch were zero when total fishing effort exceeded 9,000 sets (Julian and Beeson 1998). The zero estimate is unrealistic, given observed long-term bycatch rates of 1 sperm whale in every 1,000 sets (a rate that could not be known after the first two years of the observer program). In contrast, summed 1990-1991 regression tree bycatch estimates are approximately 9 sperm whales, which is more realistic, given the level of fishing effort. One feature of using regression trees for bycatch estimation is that trees predict some amount of bycatch in most years, even in the absence of observations. This is more in the spirit of a probabilistic estimation that moderates inter-annual volatility in estimates resulting from applying ratio estimates to rare bycatch events with low observer coverage.

Bycatch reduction measures adopted by the fishery in 1996 included acoustic pingers, which resulted in significant reductions of short-beaked common dolphin bycatch (Barlow and Cameron 2003, Carretta and Barlow 2011) and the apparent elimination of beaked whale bycatch (Carretta *et al.* 2008). The efficacy of acoustic pingers in reducing bycatch for many other cetacean species in this fishery is unknown, because most species lack enough observations for reliable statistical inference (Carretta and Barlow 2011). However, Carretta and Barlow (2011) identified beaked whales and northern elephant seals as having more statistically significant bycatch reductions attributed to pingers than short-beaked common dolphin. In the present study, all three species bycatch presence / absence models include pingers as a ‘significant’ variable (Table 2). Current evidence still identifies pingers as the most likely factor in reducing beaked whale bycatch in the fishery, which makes sense, given their sensitivity to anthropogenic sound (Cox *et al.* 2006). Although no beaked whale bycatch has been observed in the fishery since 1995 (Carretta *et al.* 2008), bycatch estimates are slightly positive in subsequent years, which reflects that in addition to pingers, the variable *lon* (a proxy for depth in this region) also influences current estimates (Figure 3-5 and Table 7).

Absolute California sea lion bycatch levels declined from 1990-2021, which largely reflects declining fishing effort (Table 4, Figure 2). However, observed and estimated sea lion bycatch per fishing set *increased* during a large portion of this time frame (Fig. 3-2),

coincident with a long-term increase of the sea lion population (Laake *et al.* 2018) and implementation of the Pacific Leatherback Closure Area (PLCA) (Figure 1), which shifted fishery effort to southern waters closer to sea lion breeding rookeries where at-sea abundance is highest. Observed and predicted bycatch per set has been highly-variable in recent years, as the size of the sea lion population has declined and fewer vessels participate in the fishery.

Martin *et al.* (2015) estimated leatherback sea turtle bycatch in this fishery for the 20-year period 1990-2009, with a total bycatch range of 104 - 242 leatherbacks (52 - 153 estimated deaths). Our estimates of total leatherback bycatch for the same 20-year period (~170 entanglements, ~123 estimated deaths, Table 10) are similar. In both studies, estimated leatherback entanglements decline each year, reaching low levels after PLCA implementation in 2001 (Fig. 1, Figure 3-8), which Martin *et al.* (2015) reported as the driving factor in reducing leatherback bycatch. The PLCA closure shifted fishing effort south of preferred summer / autumn leatherback habitat, resulting in declines in observed bycatch (Eguchi *et al.* 2016). After 2001, estimated leatherback bycatch is between 0 and 3.2 turtles annually, which reflects both PLCA effectiveness, declining fishing effort (Table 10), and a decline in North Pacific leatherback abundance (Tapilatu *et al.* 2013, Benson *et al.* 2020). Prior to the PLCA (1990-2000), the observed leatherback bycatch rate was 23 turtles in 5,973 fishing sets (0.0038 per set). Beginning with the closure (2001-2021), the observed bycatch rate was 2 turtles in 3,273 fishing sets (0.0006 per set). Individual leatherback entanglements in 2009 and 2012 give a false impression of a high bycatch rate in those years, because they are artifacts of the small number of sets observed (Fig. 3-8). Our leatherback bycatch model included the variables *lat + lon + depth*. Latitude and longitude collectively are proxy variables for the PLCA (Fig. 1), where fishing effort is now rare since the seasonal closure began. Based on study of satellite-tagged leatherback turtles in the California Current, Eguchi *et al.* (2016) noted that the seasonal restrictions of the PLCA (15-Aug to 15-Nov) are nearly optimal for reducing leatherback bycatch in this fishery.

The bycatch dataset includes 9246 observed fishing sets spanning 32 years, and while it might be considered ‘data rich’ by some standards, bycatch for many species is represented by fewer than 5 observed entanglements. For rarely-entangled species, it was necessary to assign a set of default variables (*days + lat + lon + sst*) for use in regression trees. The uncertainty in bycatch estimates for rarely-entangled species will always be large, but compared to intra-annual ratio estimates, the precision of model-based estimates is typically superior. The estimation variance associated with variability in true annual bycatch rates is unknown due to incomplete observer coverage, but is partially addressed here by including a dispersion index term reflecting individual fishing trip variance in observed bycatch. However, calculated CVs reported for bycatch estimates may still be underestimated relative to intra-annual variability in true bycatch rates.

Management advantages of model-based bycatch estimation methods that utilize all available data are that annual bycatch estimates are less volatile, less biased, and more precise, especially where observer data are characterized by rare bycatch and low observer coverage. Reducing the annual estimation volatility is important in protected species management, where decisions involving fishery regulation require accurate and timely assessment of bycatch. This is especially true for rare event bycatch, where an absence of

bycatch observations may result in the failure to detect impacts due to low observer coverage (Curtis and Carretta 2020). Conversely, the observation of a rare bycatch event in a low observer coverage situation can result in unrealistically high estimates and contribute to short-term management responses that overestimate the risk to populations. Pooling of data (where appropriate) to improve estimates of mean bycatch rates is the first step towards such bias reduction, but as fishery conditions change over time, it is also necessary to identify and use fishery and environmental variables that may influence bycatch rates over time. For species where observed bycatch is so rare that explanatory variables cannot be reliably identified, use of RF or other models with a default set of variables can provide a ‘null model’ that mirrors the mean observed bycatch rate, which can then be scaled up to total fishing effort. Such null models still represent a large improvement over calculating within-year bycatch rates previously used with ratio estimators in this fishery (Julian and Beeson 1998, Carretta *et al.* 2004).

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References

- Allouche, O., Tsoar, A. and Kadmon, R., 2006. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*, 43(6):1223-1232.
- Amandè, M.J., Chassot, E., Chavance, P., Murua, H., de Molina, A.D. and Bez, N., 2012. Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean. *ICES Journal of Marine Science: Journal du Conseil*, p.fss106.
- Archer, E. (2021). GitHub - EricArcher/rfPermute: Estimate Permutation p-Values for Random Forest Importance Metrics Version 2.5. <https://github.com/EricArcher/rfPermute>
- Barlow, J. and Gisiner, R., 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. *Journal of Cetacean Research and Management*, 7(3), pp.239-249.
- Barlow, J., and G.A. Cameron. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gillnet fishery. *Marine Mammal Science* 19:265–283.
- Barlow, J. 2016. Cetacean abundance in the California current estimated from ship-based line-transect surveys in 1991-2014. Southwest Fisheries Science Center, Administrative Report, LJ-2016-01. 63 p.
- Becker, E.A., K.A. Forney, D.G. Foley, R.C. Smith, T.J. Moore, and J. Barlow. 2014. Predicting seasonal density of California cetaceans based on habitat models. *Endangered Species Research* 23:1-22.

- Benson, S.R., Forney, K.A., Moore, J.E., LaCasella, E.L., Harvey, J.T., and Carretta, J.V. 2020. A long-term decline in the abundance of endangered leatherback turtles, *Dermochelys coriacea*, at a foraging ground in the California Current Ecosystem. *Global Ecology and Conservation*, e01371. <https://doi.org/10.1016/j.gecco.2020.e01371>
- Breiman, L., J. Friedman, C.J. Stone, and R.A. Olshen. 1984. Classification and regression trees. CRC press.
- Breiman, L. 2001a. Random forests. *Machine learning*, 45(1), 5-32.
- Breiman, L. 2001b. Statistical modeling: the two cultures. *Statistical Science* Vol. 16, No. 3, 199–231.
- Carretta, J.V. 2022. Estimates of marine mammal, sea turtle, and seabird bycatch in the California large-mesh drift gillnet fishery: 1990-2020. NOAA Technical Memorandum NMFS-SWFSC-666. <https://doi.org/10.25923/9z2t-4829>
- Carretta, J.V., J.E. Moore, and K.A. Forney. 2017. Regression tree and ratio estimates of marine mammal, sea turtle, and seabird bycatch in the California drift gillnet fishery: 1990-2015. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-568. 83 p. [doi:10.7289/V5/TM-SWFSC-568](https://doi.org/10.7289/V5/TM-SWFSC-568)
- Carretta, J.V. and J.E. Moore. 2014. Recommendations for pooling annual bycatch estimates when events are rare. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-528. 11 p.
- Carretta, J.V. and J. Barlow. 2011. Long-term effectiveness, failure rates, and “dinner bell” effects of acoustic pingers in a gillnet fishery. *Marine Technology Society Journal* 45(5):7-19.
- Carretta, J.V., J. Barlow, and L. Enriquez. 2008. Acoustic pingers eliminate beaked whale bycatch in a gill net fishery. *Marine Mammal Science* 24(4):956-961.
- Carretta, J.V., T. Price, D. Petersen, and R. Read. 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. *Marine Fisheries Review* 66(2):21-30.
- Cox, T., Ragen, T., Read, A., Vos, E., Baird, R., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L. And D'amico, A., 2006. Understanding The Impacts Of Anthropogenic Sound On Beaked Whales1. *J. Cetacean Res. Manage*, 7(3), pp.177-187.
- Curtis, K. A and J. V. Carretta. 2020. ObsCovgTools: Assessing observer coverage needed to document and estimate rare event bycatch. *Fisheries Research*. <https://doi.org/10.1016/j.fishres.2020.105493>
- Efron, B. and R. Tibshirani 1997. Improvements on Cross-Validation: The .632+ Bootstrap Method *Journal of the American Statistical Association* Vol. 92, No. 438. pp. 548-560.

- Eguchi, T., S.R. Benson, D.G. Foley, and K.A. Forney. 2016. Predicting overlap between drift gillnet fishing and leatherback turtle habitat in the California Current Ecosystem. *Fisheries Oceanography*, 26(1), pp.17-33.
- Federal Register. 1997. Taking of marine mammals incidental to commercial fishing operations; Pacific offshore cetacean take reduction plan regulations. Final Rule. 62(192):51805-14.
- Forney, K.A. and Barlow, J. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–1992. *Marine Mammal Science*, 14(3), pp.460-489.
- Hanan, D.A., D.B. Holts, and A.L. Coan, Jr. 1993. The California drift gillnet fishery for sharks and swordfish, 1981–82 through 1990–91. *Calif. Dep. Fish Game, Fish Bull.* 175, 95 p.
- Holts, D.B., A. Julian, O. Sosa-Nishizaki, and N. Bartoo. 1998. Pelagic shark fisheries along the west coast of the United States and Baja California, Mexico. *Fish. Res.* 39:115–125.
- Jiménez, S., Domingo, A. and Brazeiro, A. 2009. Seabird bycatch in the Southwest Atlantic: interaction with the Uruguayan pelagic longline fishery. *Polar Biology*, 32(2), pp.187-196.
- Julian, F., and Beeson, M. 1998. Estimates of marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990-1995. *Fishery Bulletin*, 96 (2), 271-284.
- Laake, J.L., Lowry, M.S., DeLong, R.L., Melin, S.R. and Carretta, J.V., 2018. Population growth and status of California sea lions. *The Journal of Wildlife Management*, 82(3), pp.583-595.
- Liaw, A., and M. Wiener. 2002. Classification and Regression by randomForest. *R news* 2, no. 3: 18-22.
- Lin, Wei-Jiun and J.J. Chen. 2013. Class-imbalanced classifiers for high-dimensional data. *Briefings in Bioinformatics* 14:13-26.
- Martin, S.L., S.M. Stohs, and J.E. Moore. 2015. Bayesian inference and assessment for rare-event bycatch in marine fisheries: a drift gillnet fishery case study. *Ecological Applications* 25(2):416–429
- McCracken, M. 2004. Modeling a Very Rare Event to Estimate Sea Turtle Bycatch: Lessons Learned. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS PIFSC-3, 25 p.
- Moore J.E. and Barlow J.P. 2013. Declining Abundance of Beaked Whales (Family Ziphidae) in the California Current Large Marine Ecosystem. *PLoS ONE* 8(1):e52770.
- NMFS. 2013. Endangered Species Act Section 7 Consultation Biological Opinion. Biological Opinion on the continued management of the drift gillnet fishery under the Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species. 158 p.
- NOAA. 2016. Guidelines for preparing stock assessment reports pursuant to the 1994 amendments to the MMPA.

R Core Team 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. The Iowa State University Press. 593 p.

Tapilatu, R.F., Dutton, P.H., Tiwari, M., Wibbels, T., Ferdinandus, H.V., Iwanggin, W.G. and Nugroho, B.H. 2013. Long-term decline of the western Pacific leatherback, *Dermochelys coriacea*: a globally important sea turtle population. *Ecosphere*, 4(2), pp.1-15. 2013.

Tyack, P.L., Zimmer, W.M., Moretti, D., Southall, B.L., Claridge, D.E., Durban, J.W., Clark, C.W., D'Amico, A., DiMarzio, N., Jarvis, S. and McCarthy, E., 2011. Beaked whales respond to simulated and actual navy sonar. *PloS one*, 6(3), p.e17009.

Watters, G., and Deriso, R.B. 2000. Catches per unit of effort of bigeye tuna: a new analysis with regression trees and simulated annealing. *Inter-American Tropical Tuna Commission Bulletin*, 21(8), 527-571.

Walsh, W.A. and Kleiber, P., 2001. Generalized additive model and regression tree analyses of blue shark (*Prionace glauca*) catch rates by the Hawaii-based commercial longline fishery. *Fisheries Research*, 53(2), pp.115-131.

Xie, Y., Li X., Ngai E.W.T. and Ying, W. 2009. Customer churn prediction using improved balanced random forests. *Expert Systems with Applications*, 36(3), pp.5445-5449.

Figure 1. Locations of observed fishing sets during 1990 to 2021 (n=9246) and the Pacific Leatherback Conservation Area (shaded). Observed sets (n=37) for the most-recent calendar year are shown in red.

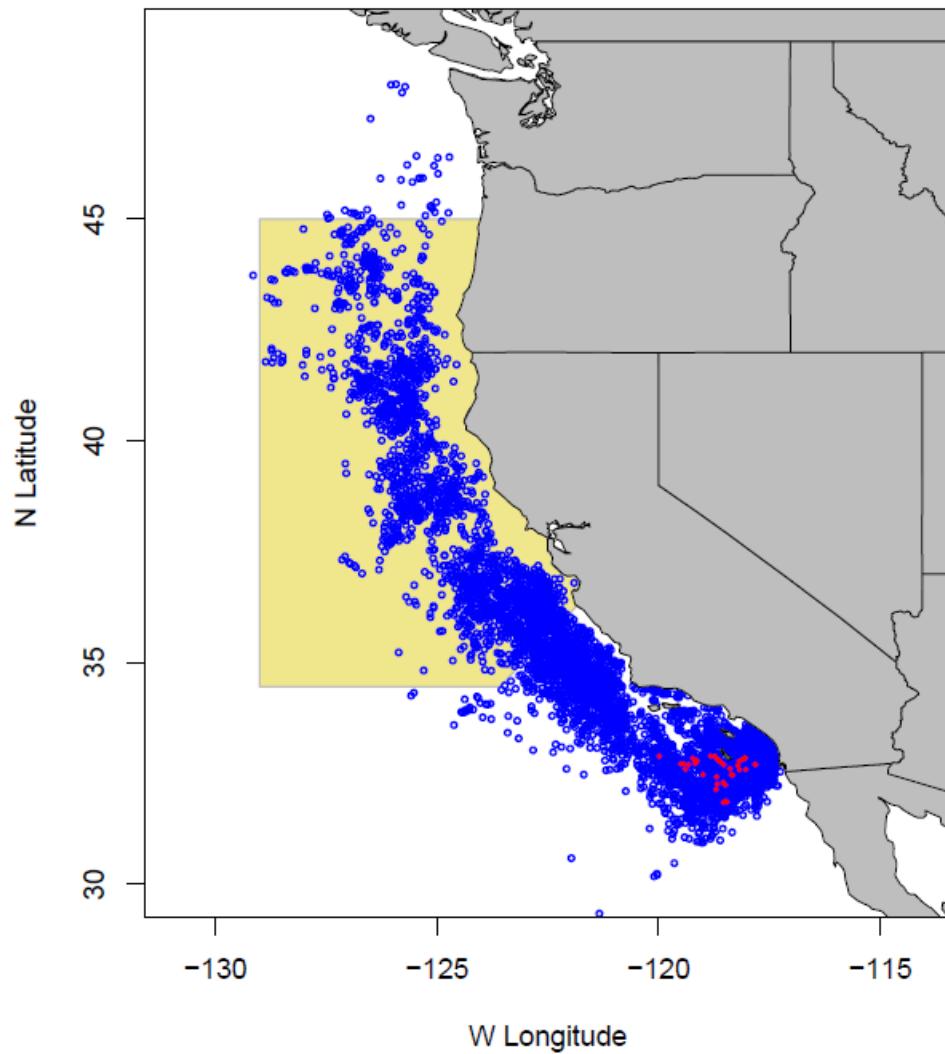


Figure 2. Observed and estimated number of fishing sets in the California large-mesh drift gillnet fishery, 1990 to 2021. Values in bars represent approximate fraction of annual observer coverage.

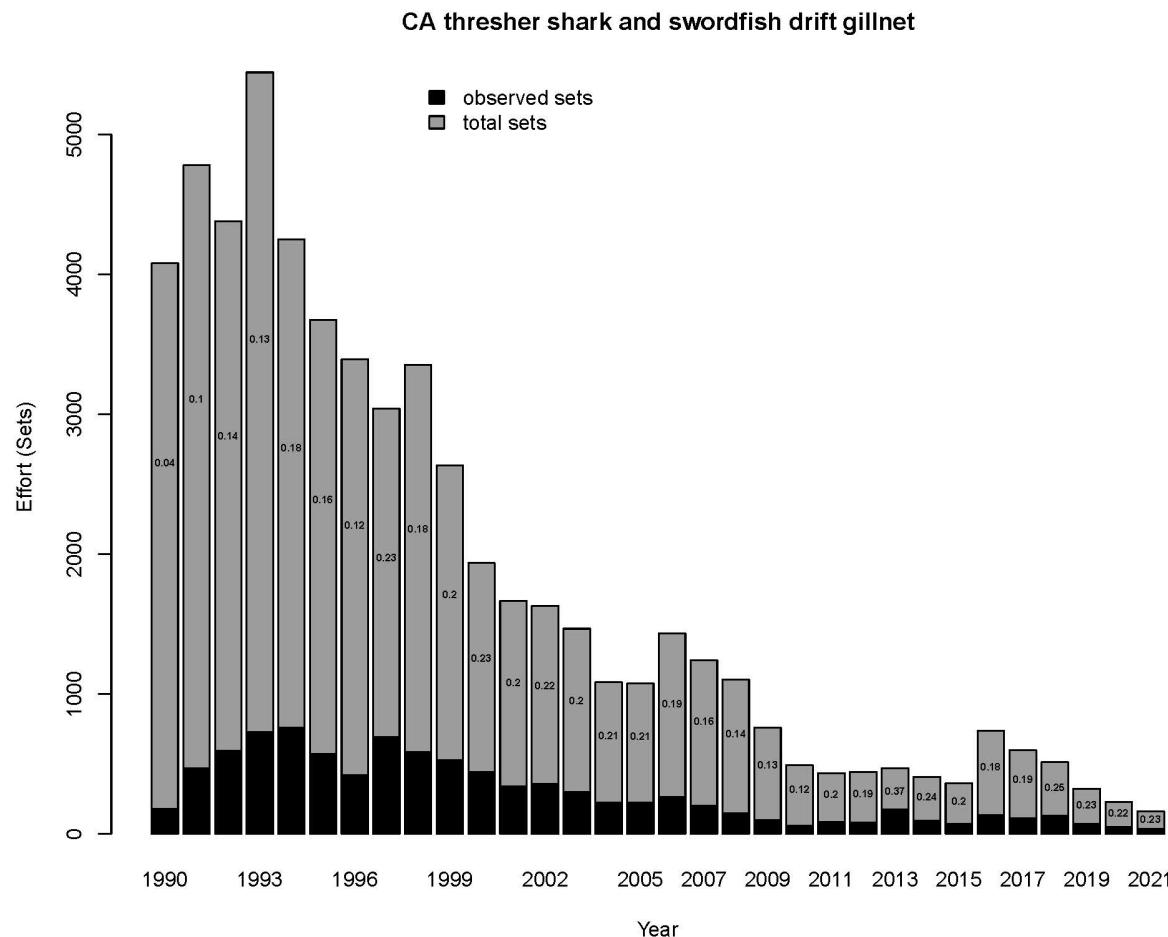


Figure 3-1. Observed and estimated bycatch of short-beaked common dolphin. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

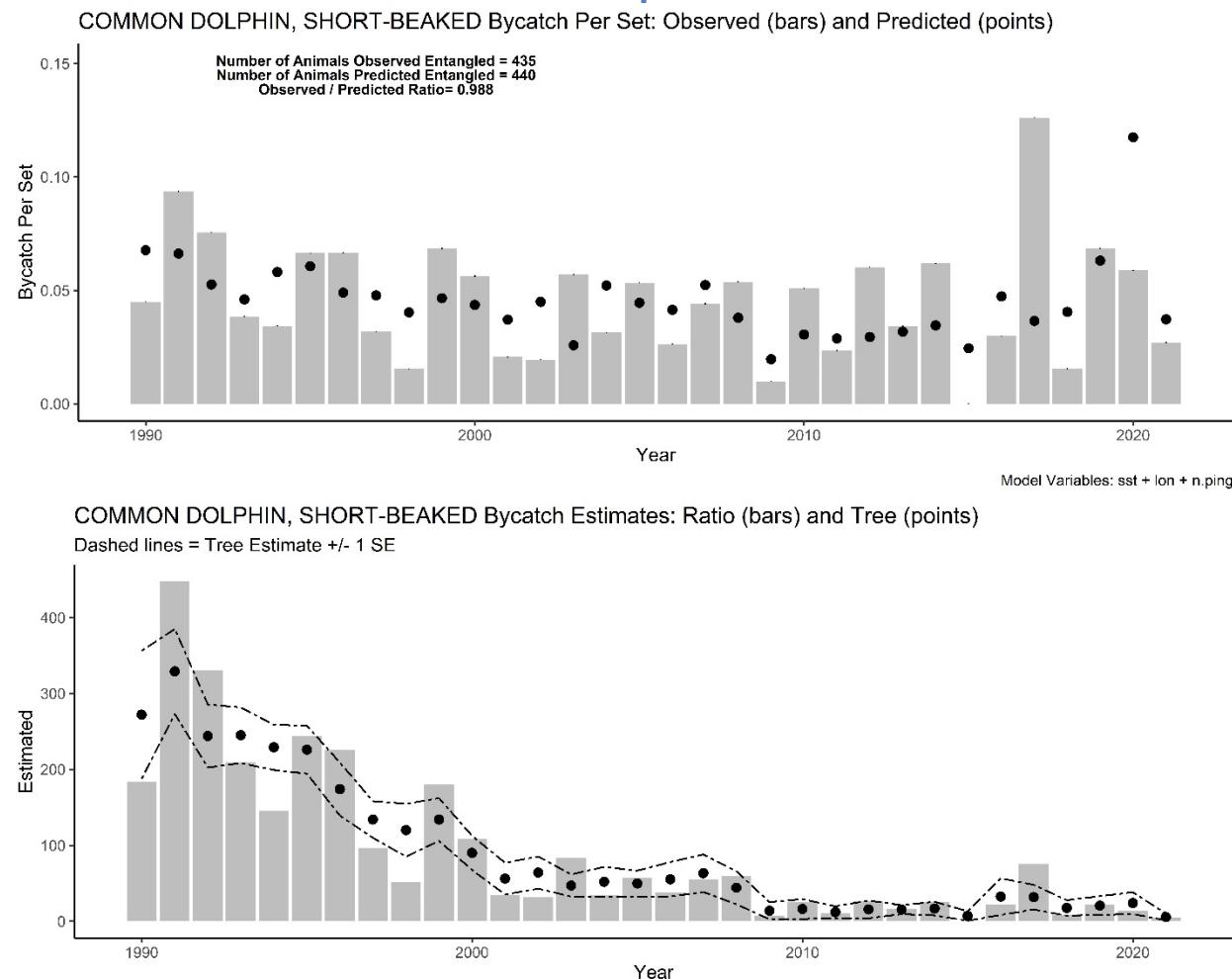


Figure 3-2. Observed and estimated bycatch of California sea lion. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

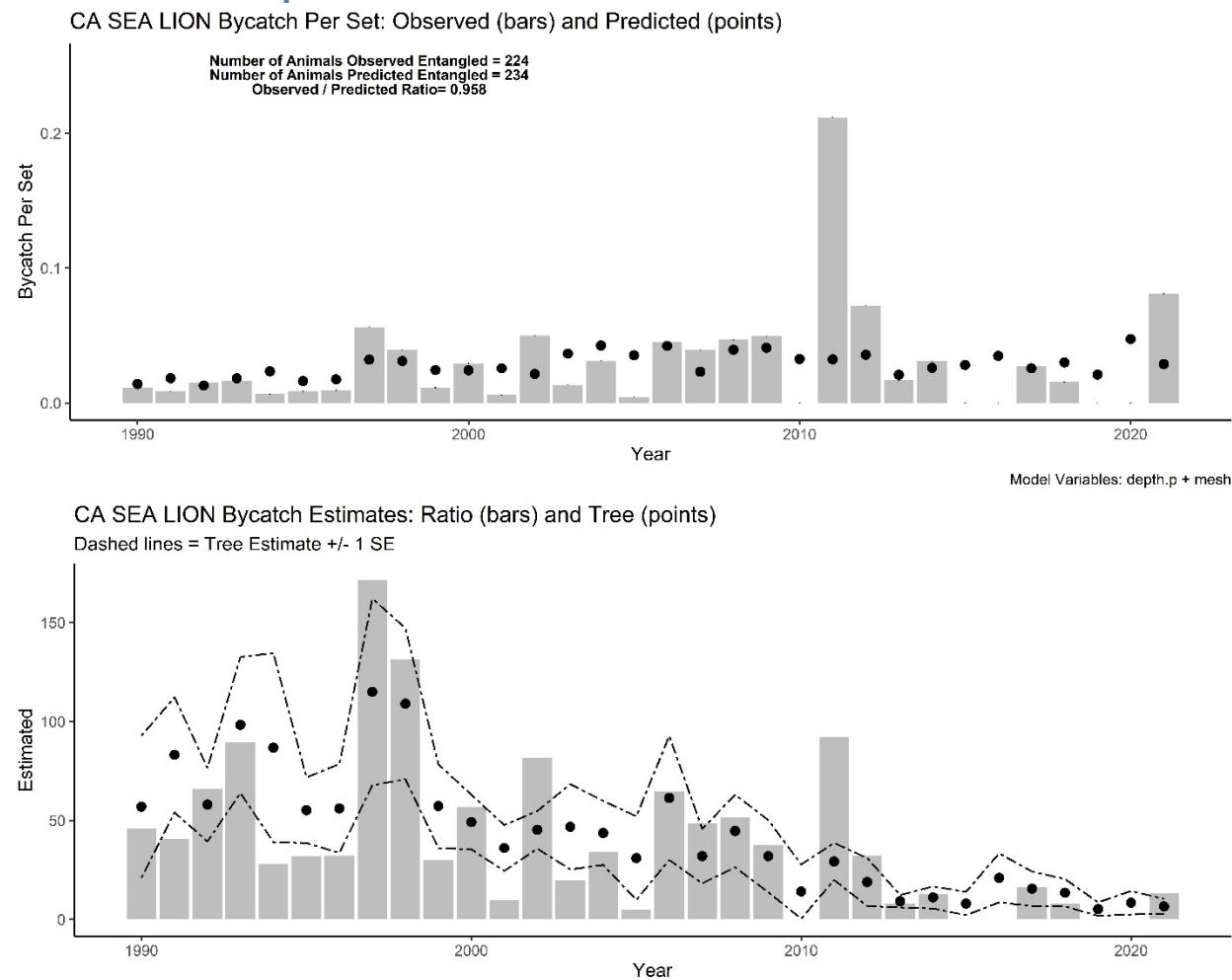


Figure 3-3. Observed and estimated bycatch of Northern elephant seal. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

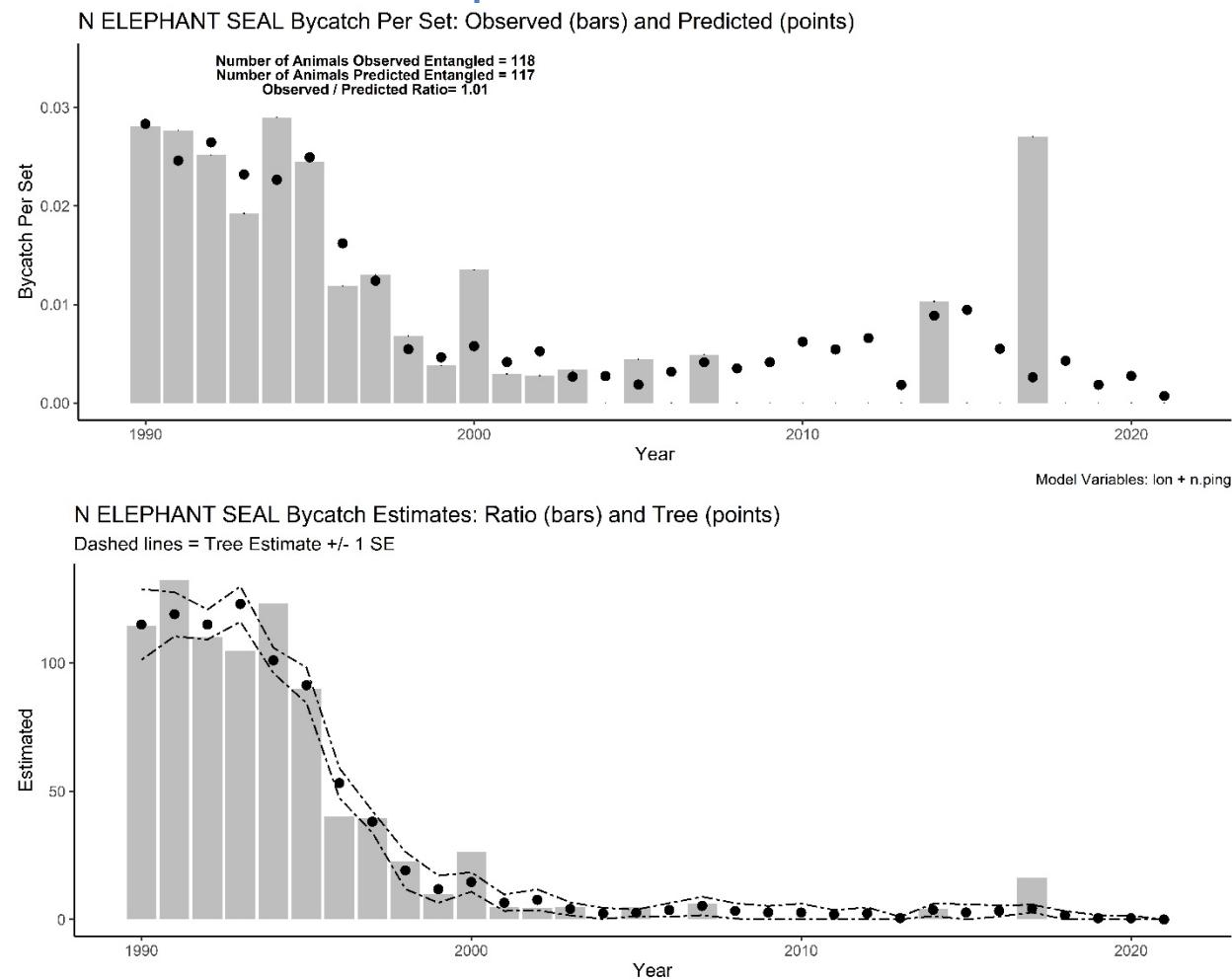


Figure 3-4. Observed and estimated bycatch of northern right whale dolphin. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

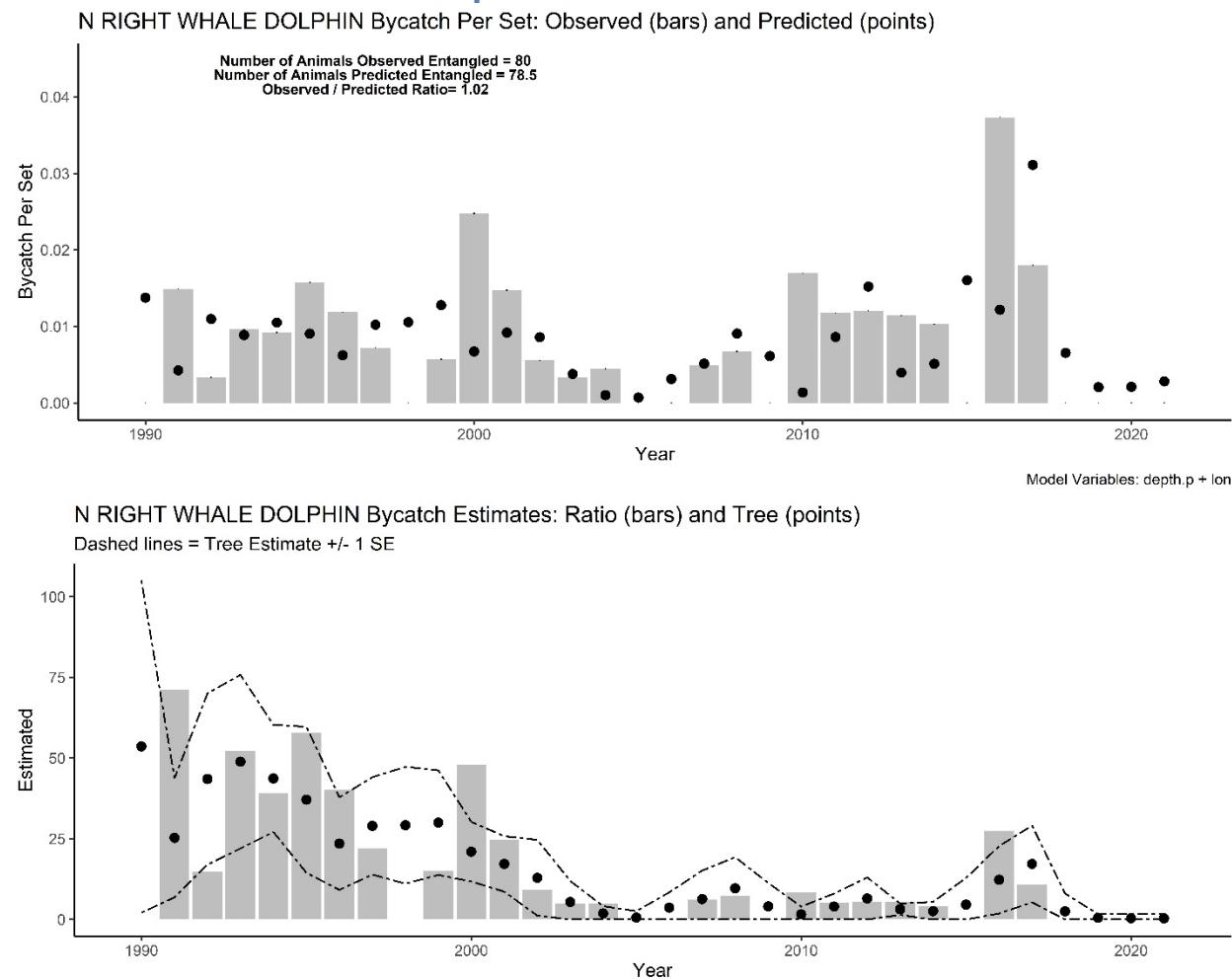


Figure 3-5. Observed and estimated bycatch of all beaked whales + *Kogia*. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

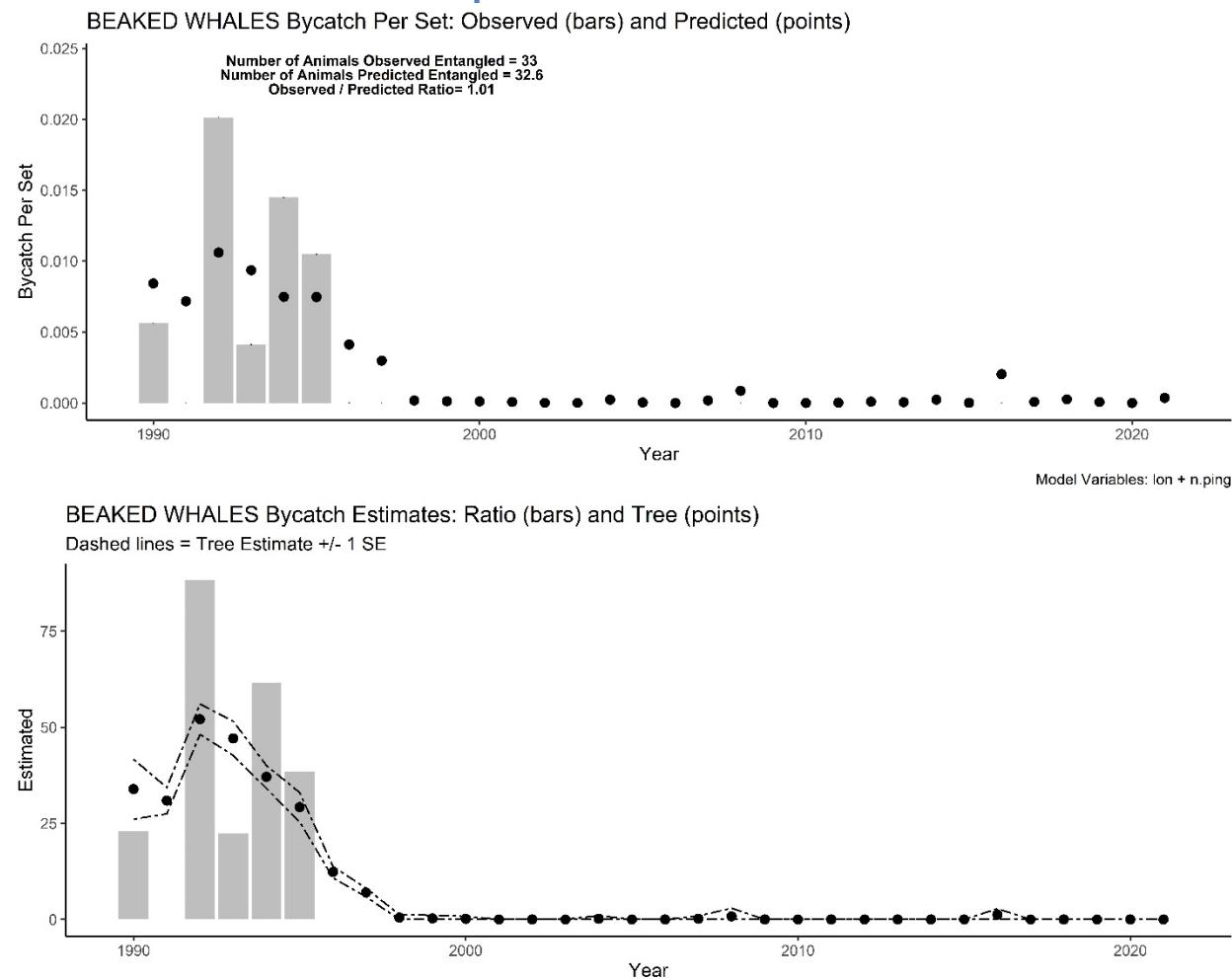


Figure 3-6. Observed and estimated bycatch of Risso's dolphin. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

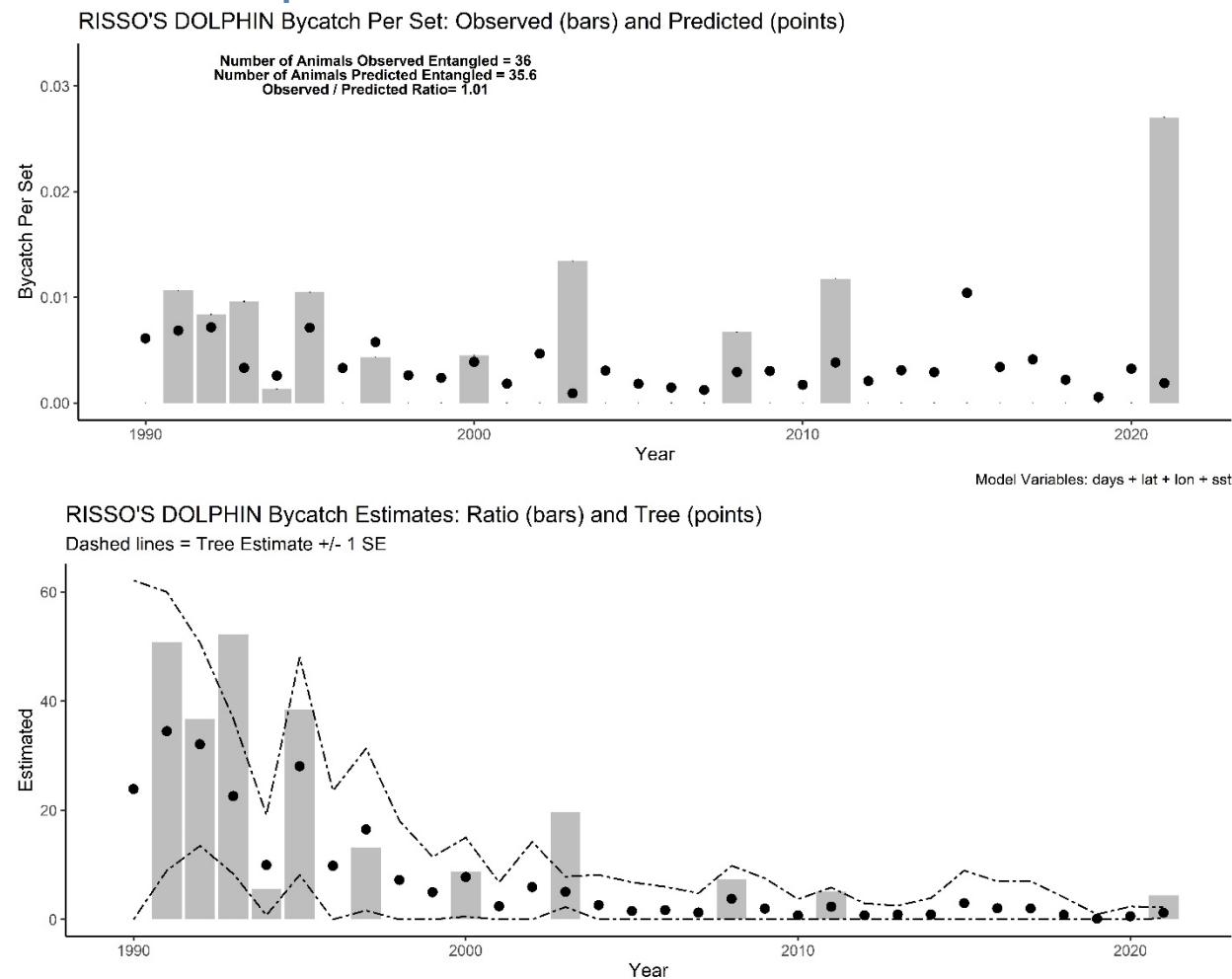


Figure 3-7. Observed and estimated bycatch of Pacific white-sided dolphin. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

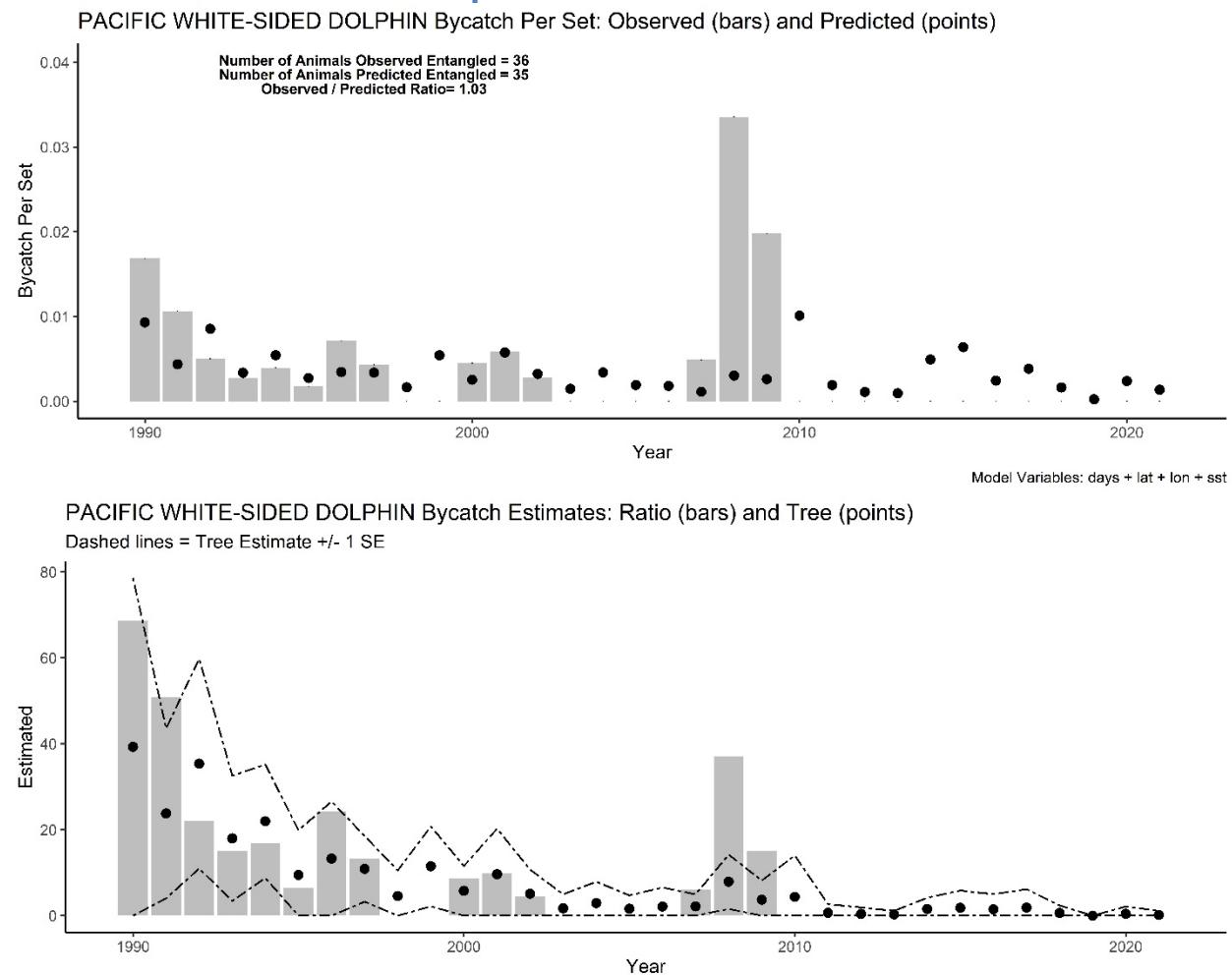


Figure 3-8. Observed and estimated bycatch of leatherback sea turtle. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

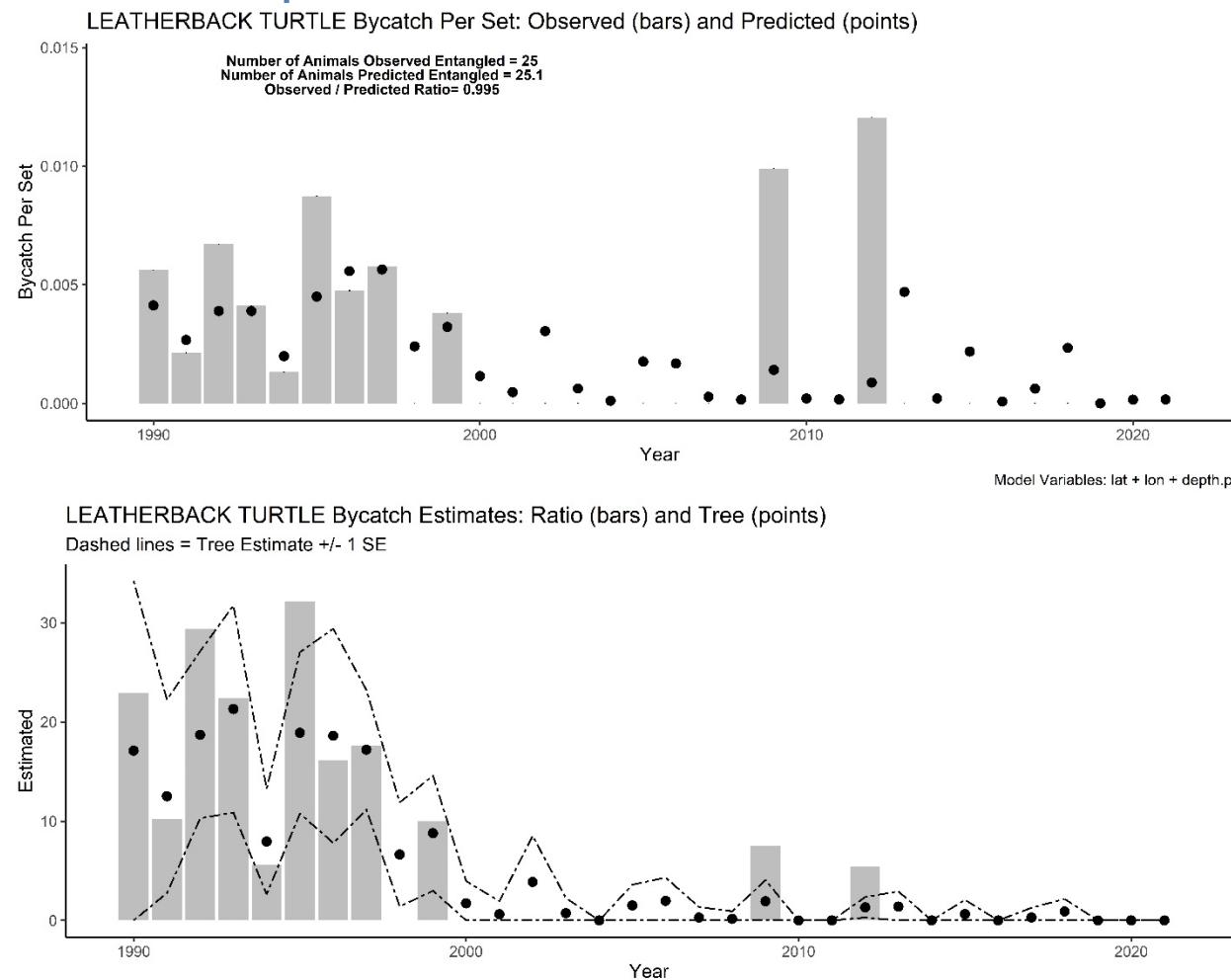


Figure 3-9. Observed and estimated bycatch of Cuvier's beaked whale. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

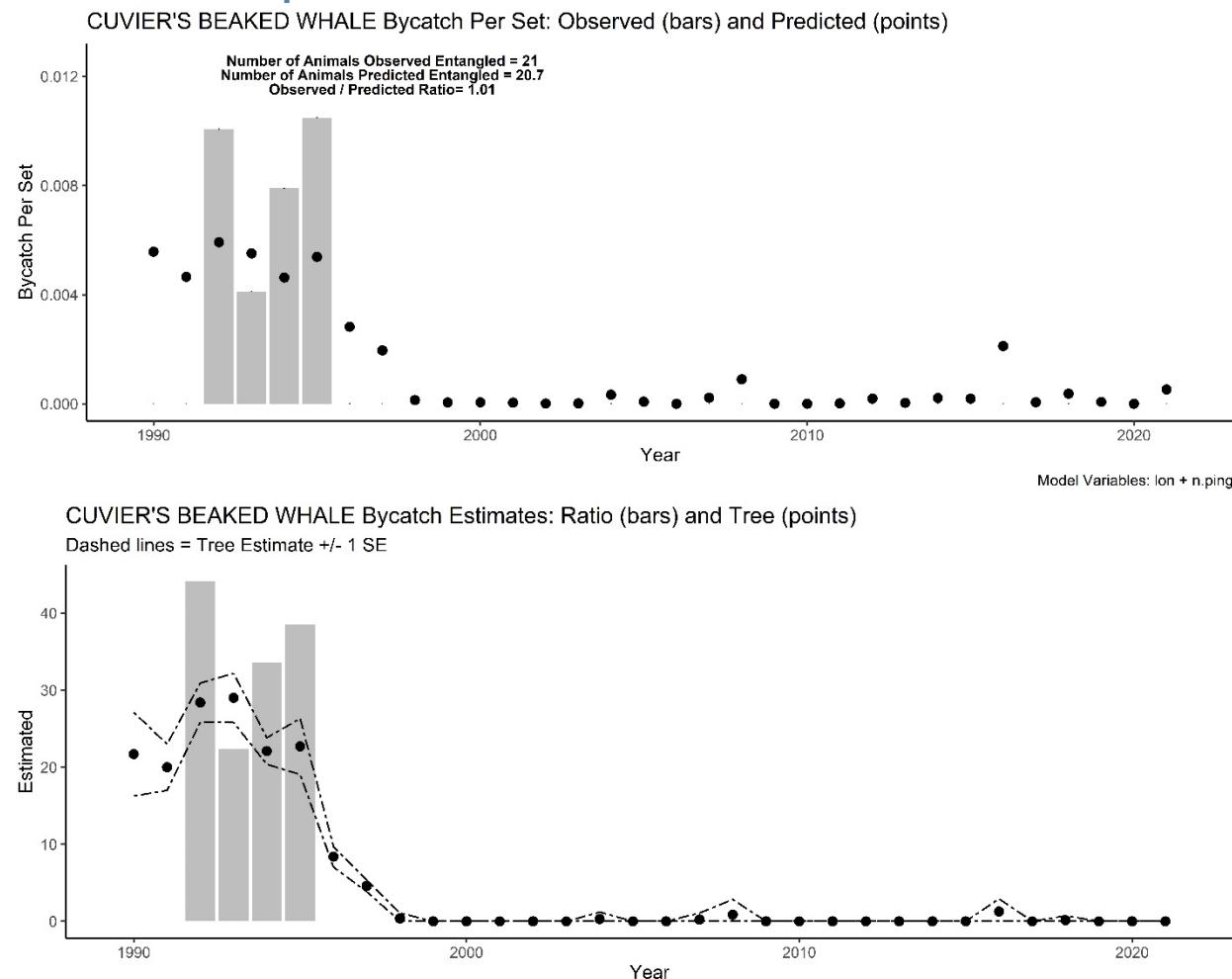


Figure 3-10. Observed and estimated bycatch of Dall's porpoise. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

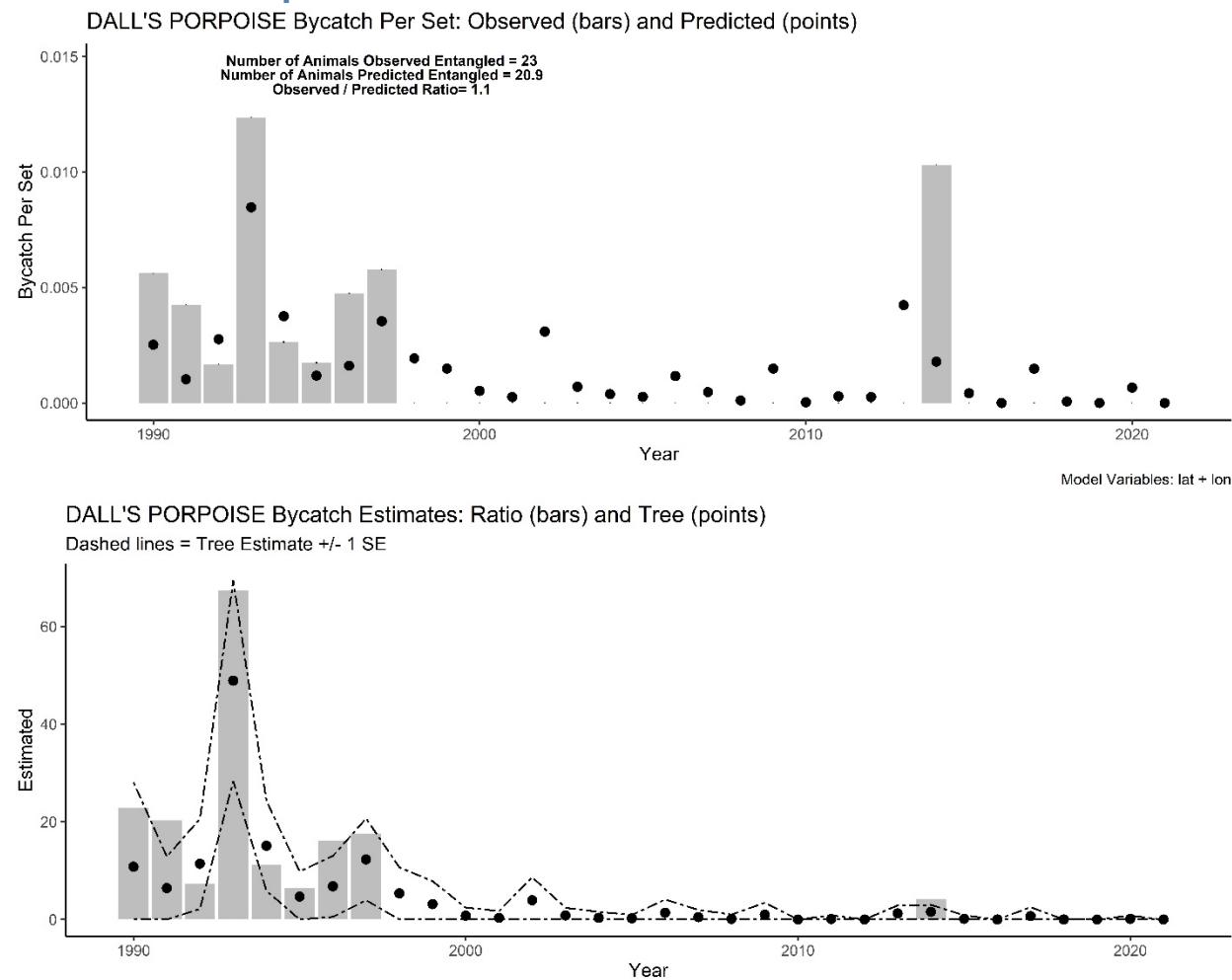


Figure 3-11. Observed and estimated bycatch of Northern Fulmar. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

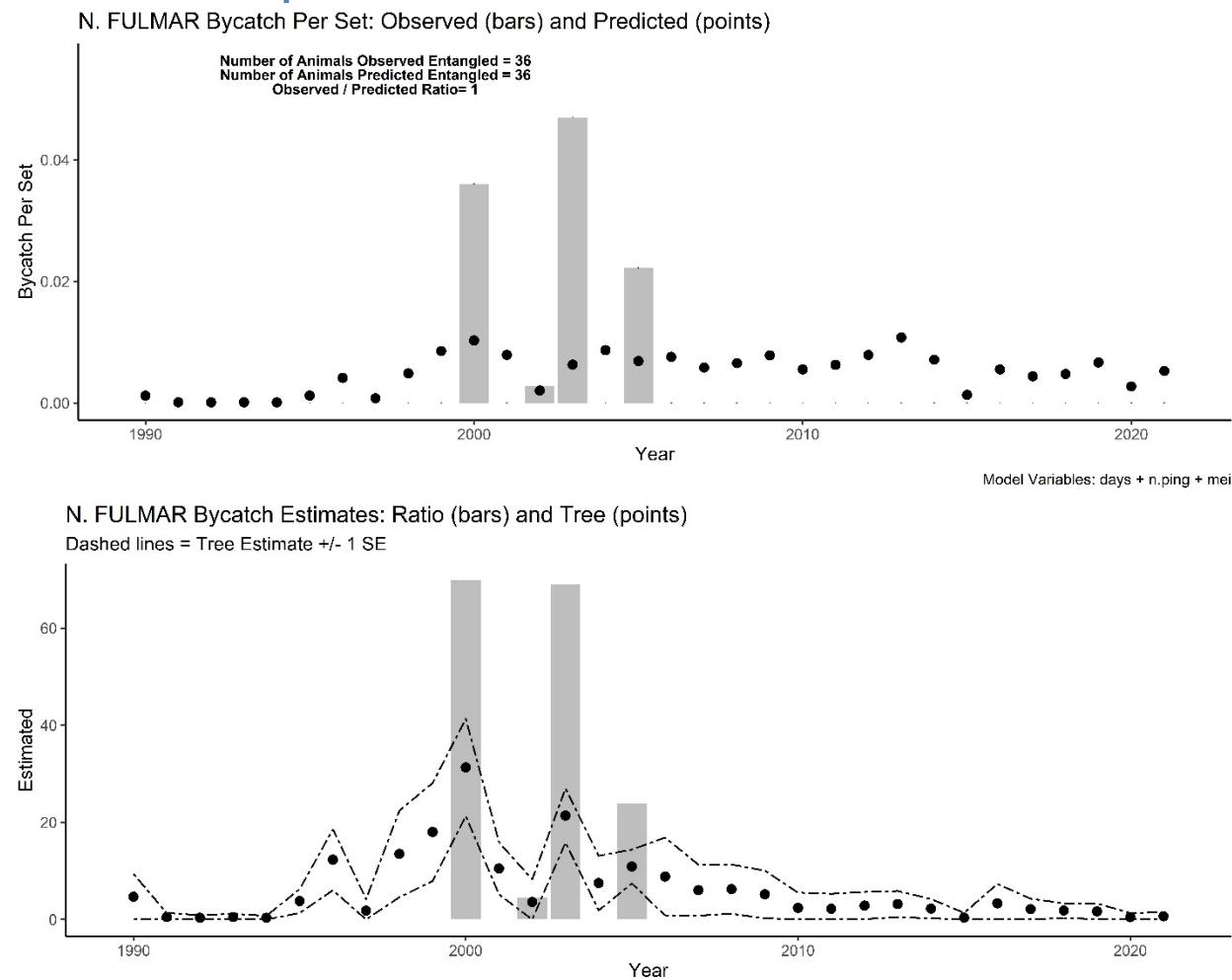


Figure 3-12. Observed and estimated bycatch of long-beaked common dolphin. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

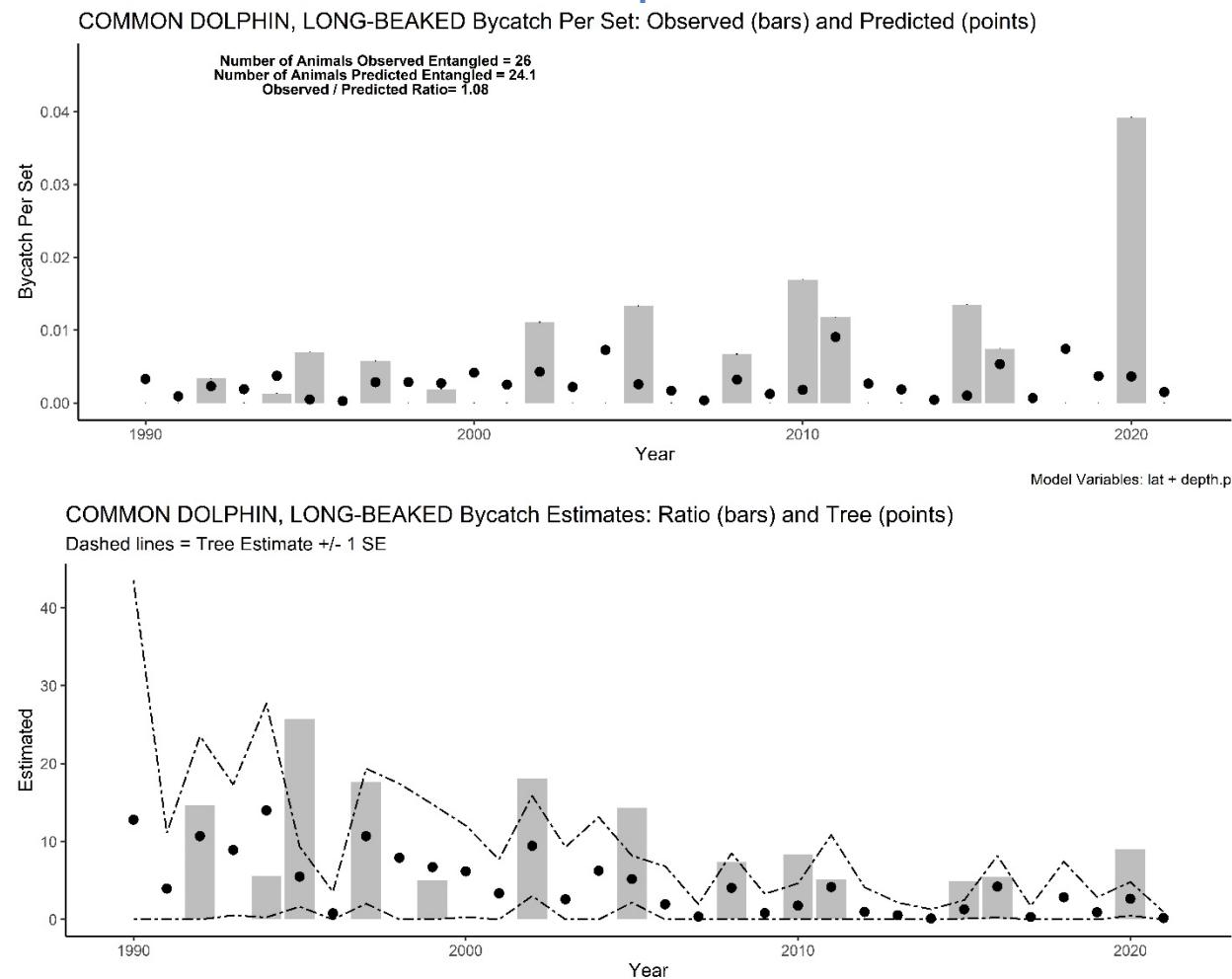


Figure 3-13. Observed and estimated bycatch of loggerhead sea turtle. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

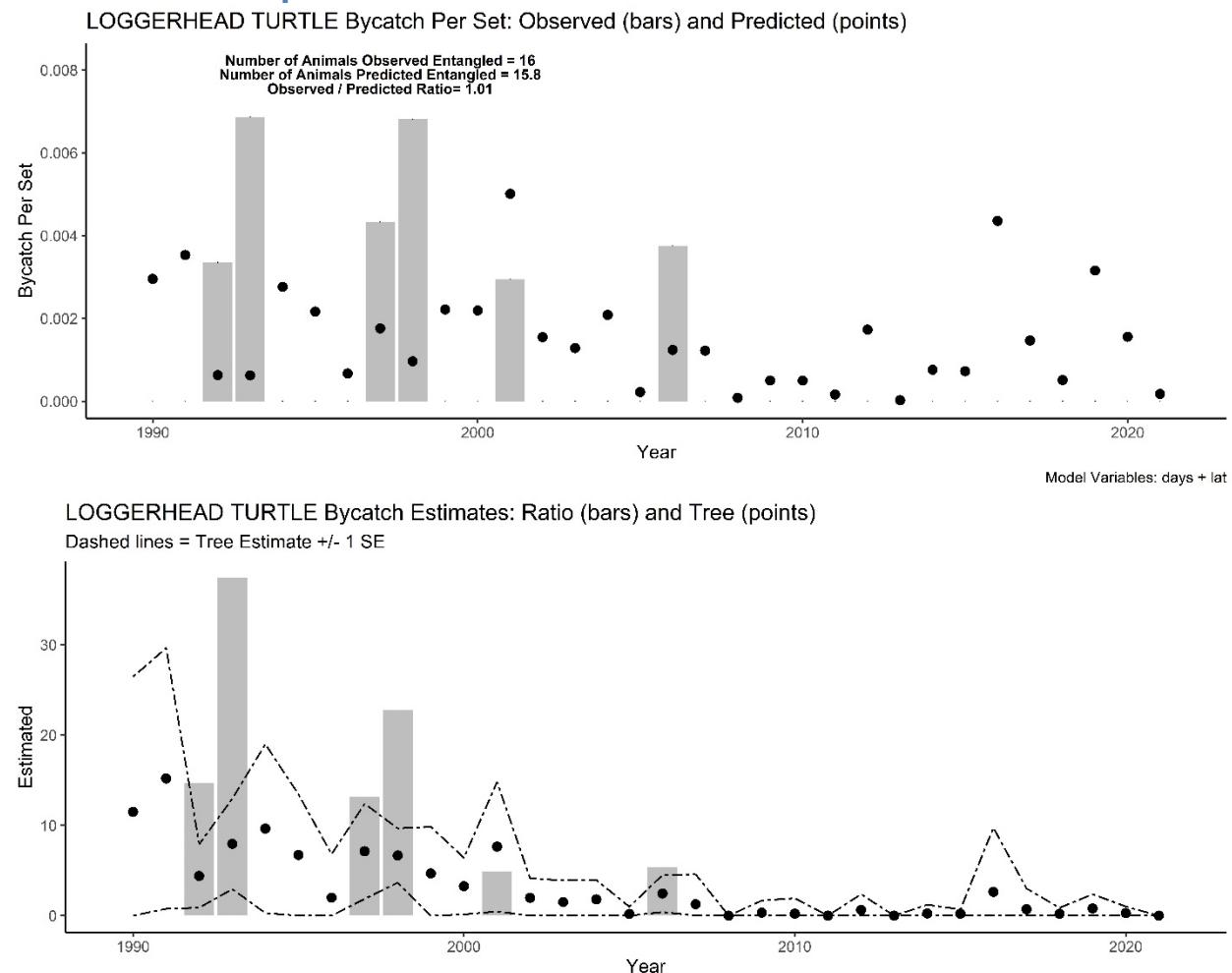


Figure 3-14. Observed and estimated bycatch of short-finned pilot whale. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

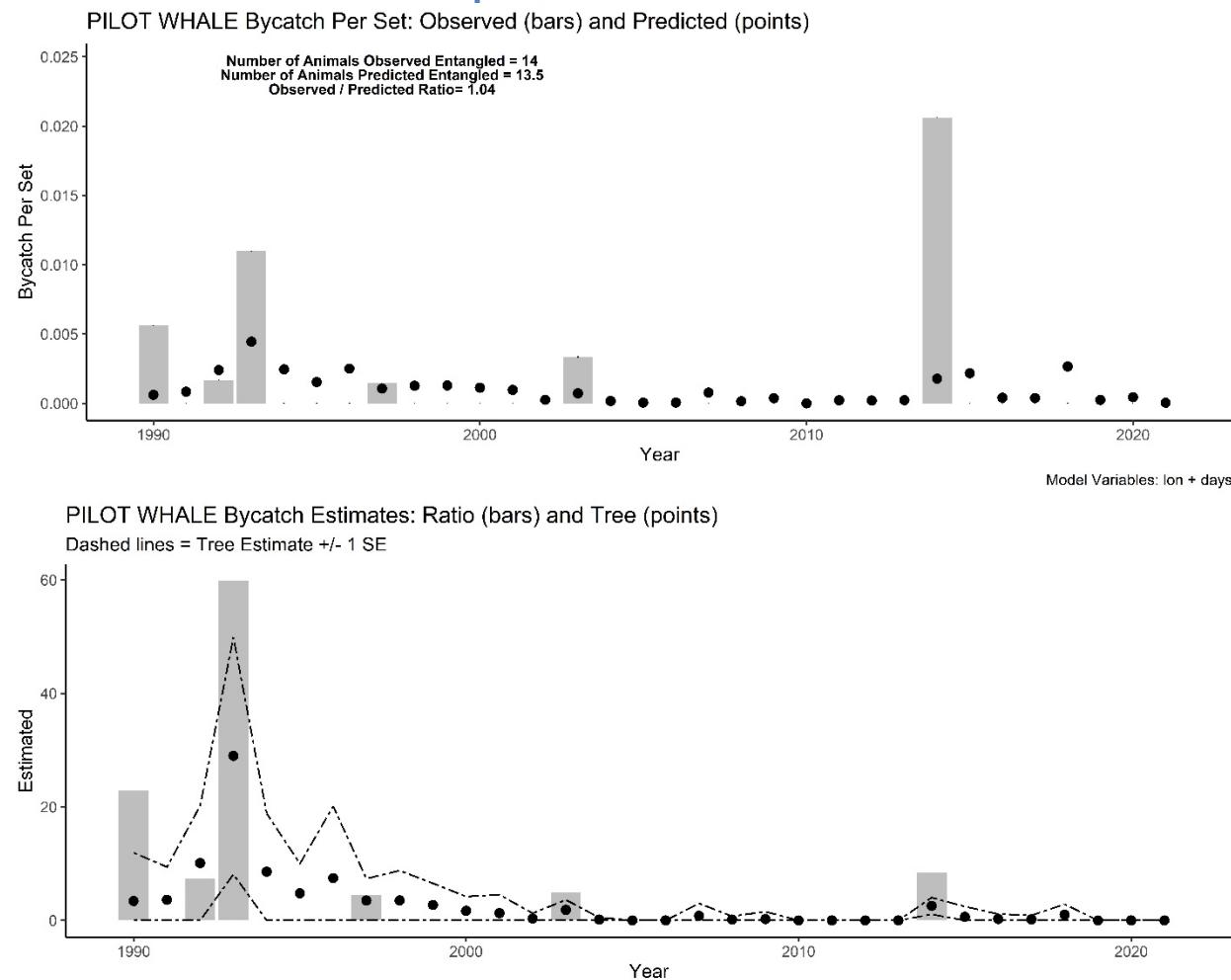


Figure 3-15. Observed and estimated bycatch of all *Mesoplodon* species. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

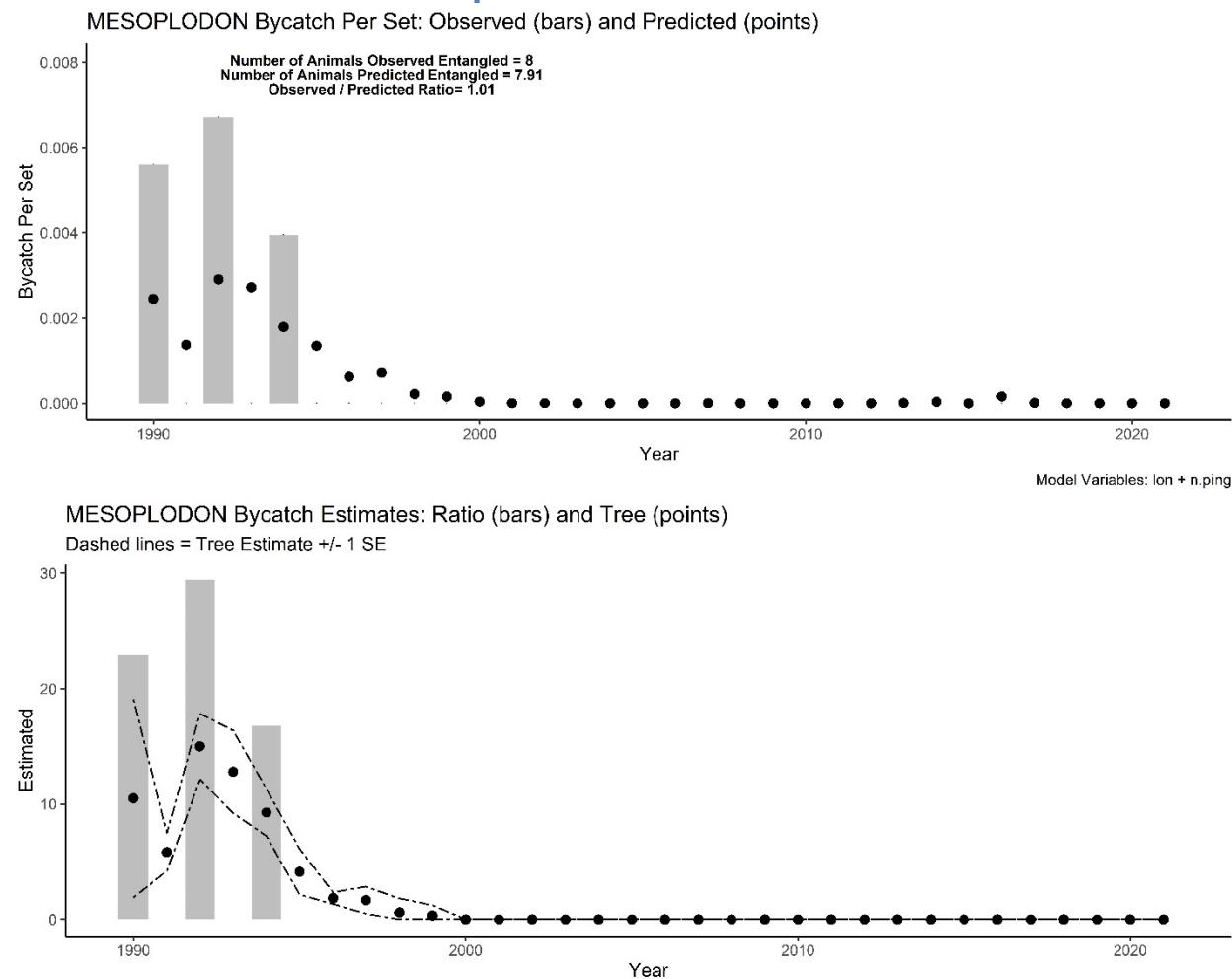


Figure 3-16. Observed and estimated bycatch of sperm whale. The top panel shows annual observed and predicted bycatch per fishing set. The ratio of observed to predicted bycatch is also shown for the cross-validated dataset of 9246 fishing sets. Bottom panel shows observed annual bycatch and estimated total bycatch from both random forest regression trees and ratio estimates. Dashed lines represent +/- 1 standard error of the random forest estimates.

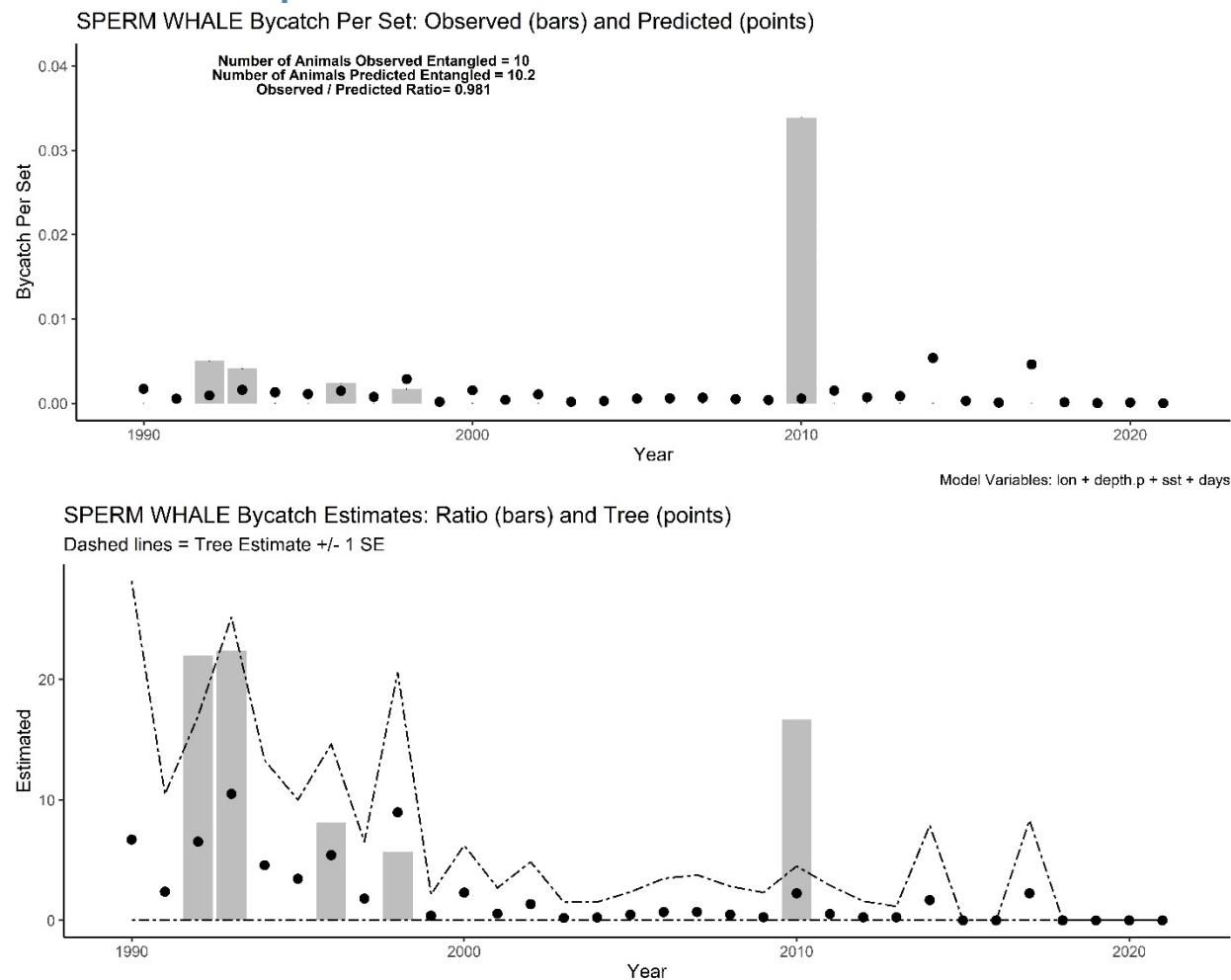


Figure 4. Selected random forest variables (*depth.p*, *sst*, *lat*, *days*) by year. Variables are shown to demonstrate variability of some commonly-used variables through the time series. Median values are shown by large black dots.

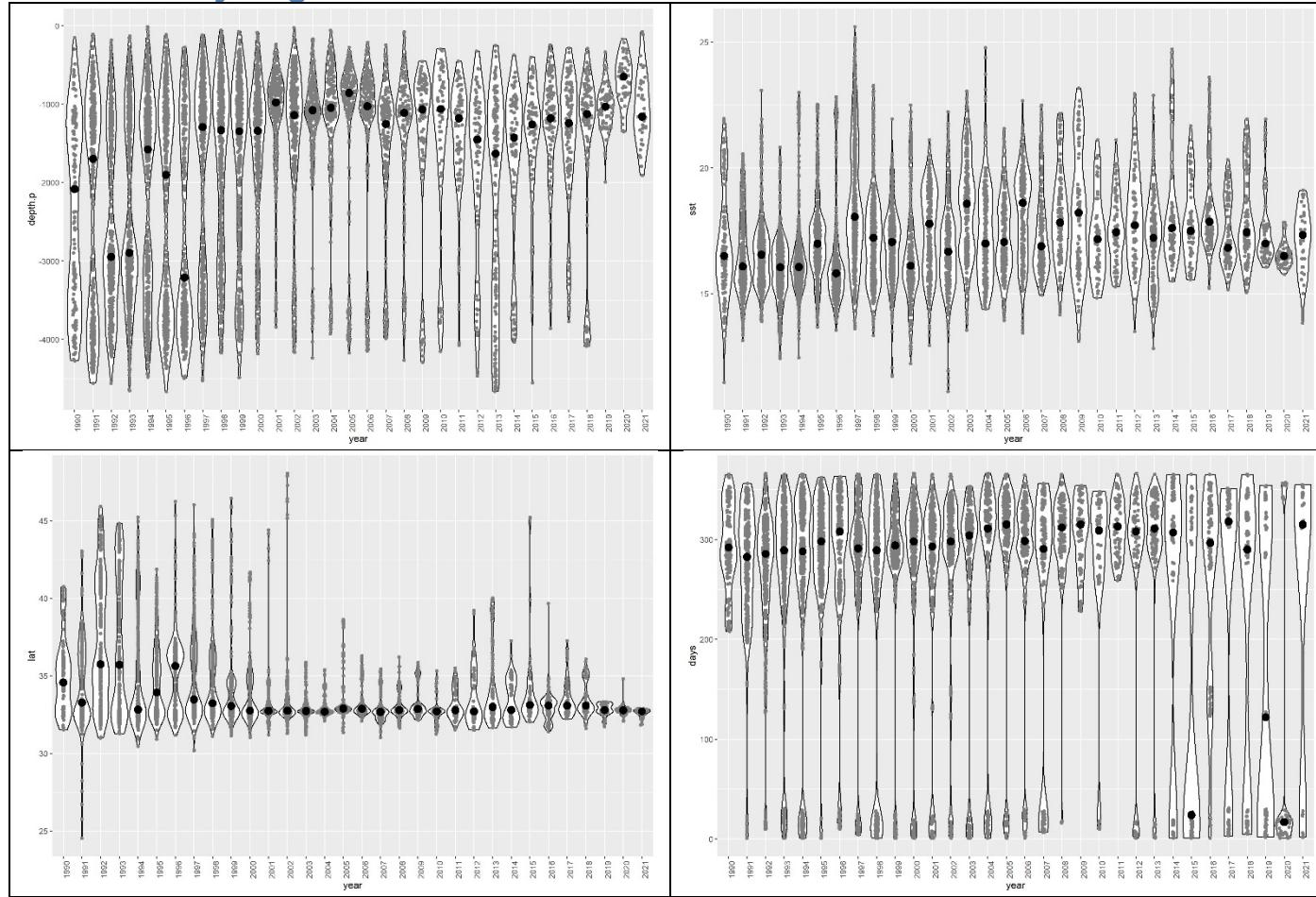


Table 1. Variables evaluated in random forest classification tree bycatch presence / absence models. Variables with p-values less than a 0.05 alpha-level threshold are selected for inclusion in species-specific estimation models, based on the feature ‘Mean Decrease in Gini Index’, a measure of how each variable contributes to the homogeneity of the nodes and leaves in the random forest. In cases where no variables are identified as ‘significant’, a default set of variables are used (*days + lat + lon + sst*). RF models require at least 2 variables to be implemented, and where only one significant variable is identified, it was pooled with the set of default variables.

Variable Name	Variable Description	Range of Values
<i>days</i>	Sequential Day of Year	1 to 366
<i>depth.p</i>	Depth (meters) net pull	-4666 to -13
<i>extnd</i>	Top of net depth below surface (in feet)	3.0 to 99.0
<i>height.net</i>	Height of net (number of meshes)	14.0 to 300.0
<i>lat</i>	Latitude	24.53 to 48.04
<i>length.net</i>	Length of net (meters)	50 to 2000
<i>lon</i>	Longitude	-117.08 to 129.15
<i>mei</i>	Multivariate El Niño index ('Cold', 'Normal', 'Warm'). Categorical variable based on mean of bimonthly ENSO anomalies for Jan + Aug – Dec of each calendar year, corresponding to fishing activity. 'Cold' <= -0.5; 'Normal' > -0.5 and < 0.5; 'Warm' = >0.5)	Cold-Normal-Warm
<i>mesh</i>	mesh size (in)	14.0 to 28.0
<i>n.ping</i>	number of acoustic pingers	0 to 76
<i>soak</i>	soak time of net (hours)	0 to 62
<i>sst</i>	sea surface temperature (C)	11.11 to 25.61

Table 2. Variable selection results. Species with ≤ 5 events (not shown in this table) utilize a default set of variables (*days + lat + lon + sst*), unless they belong to the pooled group consisting of all beaked whales + *Kogia* (e.g. *Berardius*, *Kogia*, *Mesoplodon*, *Ziphius* and unidentified ziphiids), shown here. The number of observed and correctly classified positive bycatch events are shown, along with True Skill Statistic (TSS) scores. Dispersion indices (variance divided by mean) for observed bycatch per fishing trip are also shown.

Species	Events	Animals	Var.1	Var.2	Var.3	Var.4	Dispersion.Trip	Correct.Events	Sensitivity	Specificity	Accuracy	TSS
COMMON DOLPHIN, SHORT-BEAKED	348	435	<i>sst</i>	<i>lon</i>	<i>n.ping</i>		2.040	224	0.644	0.623	0.624	0.267
CA SEA LION	183	224	<i>depth.p</i>	<i>mesh</i>			2.980	106	0.579	0.678	0.676	0.257
N ELEPHANT SEAL	114	118	<i>lon</i>	<i>n.ping</i>			1.200	90	0.789	0.650	0.652	0.439
N RIGHT WHALE DOLPHIN	58	80	<i>depth.p</i>	<i>lon</i>			1.900	45	0.776	0.727	0.727	0.503
BEAKED WHALES + <i>KOGIA</i>	33	33	<i>lon</i>	<i>n.ping</i>			1.100	31	0.939	0.680	0.681	0.619
RISSO'S DOLPHIN	28	36	<i>days</i>	<i>lat</i>	<i>lon</i>	<i>sst</i>	1.920	20	0.714	0.787	0.786	0.501
PACIFIC WHITE-SIDED DOLPHIN	27	36	<i>days</i>	<i>lat</i>	<i>lon</i>	<i>sst</i>	1.590	12	0.444	0.771	0.770	0.215
LEATHERBACK TURTLE	25	25	<i>lat</i>	<i>lon</i>	<i>depth.p</i>		1.150	19	0.760	0.699	0.699	0.459
CUVIER'S BEAKED WHALE	21	21	<i>lon</i>	<i>n.ping</i>			0.988	20	0.952	0.672	0.673	0.624
DALL'S PORPOISE	21	23	<i>lat</i>	<i>lon</i>			1.680	13	0.619	0.748	0.747	0.367
N. FULMAR	20	36	<i>days</i>	<i>n.ping</i>	<i>mei</i>		2.870	19	0.950	0.723	0.724	0.673
COMMON DOLPHIN, LONG-BEAKED	19	26	<i>lat</i>	<i>depth.p</i>			2.060	14	0.737	0.738	0.738	0.475
LOGGERHEAD TURTLE	14	16	<i>days</i>	<i>lat</i>			1.490	11	0.786	0.795	0.795	0.581
PILOT WHALE	10	14	<i>lon</i>	<i>days</i>			1.990	8	0.800	0.706	0.707	0.506
MESOPLODON	8	8	<i>lon</i>	<i>n.ping</i>			0.996	7	0.875	0.759	0.759	0.634
SPERM WHALE	6	10	<i>lon</i>	<i>depth.p</i>	<i>sst</i>	<i>days</i>	2.000	5	0.833	0.689	0.689	0.522

Table 3. COMMON DOLPHIN, SHORT-BEAKED. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	8	178	4078	0.044	183.3	0.44	272	0.31	272	0.31
1991	44	470	4778	0.098	447.3	0.21	329	0.17	329	0.17
1992	45	596	4379	0.136	330.6	0.2	244	0.17	244	0.17
1993	28	728	5442	0.134	209.3	0.29	245	0.15	245	0.15
1994	26	759	4248	0.179	145.5	0.2	229	0.13	229	0.13
1995	38	572	3673	0.156	244	0.31	226	0.14	226	0.14
1996	28	421	3392	0.124	225.6	0.24	174	0.2	174	0.2
1997	22	692	3039	0.228	96.6	0.31	134	0.18	134	0.18
1998	9	587	3353	0.175	51.4	0.35	120	0.29	120	0.29
1999	36	526	2634	0.2	180.3	0.26	134	0.21	134	0.21
2000	25	444	1936	0.229	109	0.27	90.1	0.25	90.1	0.25
2001	7	339	1665	0.204	34.4	0.39	56.2	0.37	56.2	0.37
2002	7	360	1630	0.221	31.7	0.45	64.1	0.33	64.1	0.33
2003	17	298	1467	0.203	83.7	0.28	47.1	0.31	47.1	0.31
2004	7	223	1084	0.206	34	0.49	51.9	0.38	51.9	0.38
2005	12	225	1075	0.209	57.3	0.3	49.8	0.34	49.8	0.34
2006	7	266	1433	0.186	37.7	0.49	55.3	0.41	55.3	0.41
2007	9	204	1241	0.164	54.8	0.4	63.3	0.39	63.3	0.39
2008	8	149	1103	0.135	59.2	0.43	44.2	0.49	44.2	0.49
2009	1	101	761	0.133	7.5	0.97	14	0.81	14	0.81
2010	3	59	492	0.12	25	0.66	16.2	0.81	16.2	0.81
2011	2	85	435	0.195	10.2	0.67	12.1	0.64	12.1	0.64
2012	5	83	445	0.187	26.8	0.68	15.7	0.74	15.7	0.74
2013	6	175	470	0.372	16.1	0.43	15.4	0.38	15.4	0.38
2014	6	97	409	0.237	25.3	0.4	16.8	0.53	16.8	0.53
2015	0	74	361	0.205	0	NA	7.02	0.89	7.02	0.89
2016	4	134	737	0.182	22	0.59	32.5	0.74	32.5	0.74
2017	14	111	598	0.186	75.4	0.36	31.8	0.51	31.8	0.51
2018	2	129	513	0.251	8	0.68	17.6	0.58	17.6	0.58
2019	5	73	323	0.226	22.1	0.46	20.8	0.59	20.8	0.59
2020	3	51	230	0.222	13.5	0.67	24	0.6	24	0.6
2021	1	37	162	0.228	4.4	0.93	5.65	0.79	5.65	0.79

Table 4. CA SEA LION. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	2	178	4078	0.044	45.8	0.99	56.9	0.63	55.9	0.63
1991	4	470	4778	0.098	40.7	0.61	83.2	0.35	81.7	0.35
1992	9	596	4379	0.136	66.1	0.35	58	0.32	57.1	0.32
1993	12	728	5442	0.134	89.7	0.43	98.3	0.35	96.8	0.35
1994	5	759	4248	0.179	28	0.44	86.8	0.55	85.3	0.55
1995	5	572	3673	0.156	32.1	0.42	55.2	0.3	54.3	0.3
1996	4	421	3392	0.124	32.2	0.5	56.1	0.4	55.2	0.4
1997	39	692	3039	0.228	171.3	0.3	115	0.41	113	0.41
1998	23	587	3353	0.175	131.4	0.25	109	0.35	107	0.35
1999	6	526	2634	0.2	30	0.38	57.3	0.37	56.4	0.37
2000	13	444	1936	0.229	56.7	0.38	49.2	0.28	48.5	0.28
2001	2	339	1665	0.204	9.8	0.69	36.1	0.32	35.4	0.32
2002	18	360	1630	0.221	81.5	0.26	45.3	0.21	44.8	0.21
2003	4	298	1467	0.203	19.7	0.5	46.8	0.46	46	0.46
2004	7	223	1084	0.206	34	0.39	43.7	0.37	43	0.37
2005	1	225	1075	0.209	4.8	1.05	31	0.68	30.5	0.68
2006	12	266	1433	0.186	64.6	0.43	61.4	0.51	60.5	0.51
2007	8	204	1241	0.164	48.7	0.64	32	0.43	31.6	0.43
2008	7	149	1103	0.135	51.8	0.51	44.7	0.41	44	0.41
2009	5	101	761	0.133	37.7	0.77	32	0.57	31.5	0.57
2010	0	59	492	0.12	0	NA	14.1	0.97	13.8	0.97
2011	18	85	435	0.195	92.1	0.84	29.3	0.32	29.1	0.31
2012	6	83	445	0.187	32.2	0.57	18.9	0.64	18.7	0.64
2013	3	175	470	0.372	8.1	0.74	9.17	0.34	9.06	0.34
2014	3	97	409	0.237	12.6	0.9	11.1	0.5	11	0.5
2015	0	74	361	0.205	0	NA	8.07	0.73	7.92	0.73
2016	0	134	737	0.182	0	NA	21	0.59	20.7	0.59
2017	3	111	598	0.186	16.2	0.69	15.5	0.56	15.3	0.55
2018	2	129	513	0.251	8	0.71	13.5	0.51	13.3	0.51
2019	0	73	323	0.226	0	NA	5.25	0.64	5.16	0.64
2020	0	51	230	0.222	0	NA	8.47	0.7	8.31	0.7
2021	3	37	162	0.228	13.1	0.68	6.6	0.57	6.53	0.57

Table 5. N ELEPHANT SEAL. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	5	178	4078	0.044	114.6	0.42	115	0.12	115	0.12
1991	13	470	4778	0.098	132.2	0.28	119	0.072	119	0.072
1992	15	596	4379	0.136	110.2	0.26	115	0.051	115	0.051
1993	14	728	5442	0.134	104.7	0.29	123	0.056	123	0.056
1994	22	759	4248	0.179	123.1	0.26	101	0.049	101	0.049
1995	14	572	3673	0.156	89.9	0.28	91.3	0.076	91.3	0.076
1996	5	421	3392	0.124	40.3	0.52	53.2	0.11	53.2	0.11
1997	9	692	3039	0.228	39.5	0.33	38.1	0.11	38.1	0.11
1998	4	587	3353	0.175	22.8	0.5	19.1	0.38	19.1	0.38
1999	2	526	2634	0.2	10	0.69	11.8	0.45	11.8	0.45
2000	6	444	1936	0.229	26.2	0.39	14.6	0.26	14.6	0.26
2001	1	339	1665	0.204	4.9	0.97	6.51	0.49	6.51	0.49
2002	1	360	1630	0.221	4.5	0.99	7.67	0.53	7.67	0.53
2003	1	298	1467	0.203	4.9	1	4.12	0.62	4.12	0.62
2004	0	223	1084	0.206	0	NA	2.36	0.92	2.36	0.92
2005	1	225	1075	0.209	4.8	0.98	2.59	0.5	2.59	0.5
2006	0	266	1433	0.186	0	NA	3.69	0.73	3.69	0.73
2007	1	204	1241	0.164	6.1	0.94	5.28	0.68	5.28	0.68
2008	0	149	1103	0.135	0	NA	3.34	0.9	3.34	0.9
2009	0	101	761	0.133	0	NA	2.73	0.93	2.73	0.93
2010	0	59	492	0.12	0	NA	2.69	1.3	2.69	1.3
2011	0	85	435	0.195	0	NA	1.9	0.94	1.9	0.94
2012	0	83	445	0.187	0	NA	2.38	0.99	2.38	0.99
2013	0	175	470	0.372	0	NA	0.54	0.94	0.54	0.94
2014	1	97	409	0.237	4.2	0.93	3.77	0.64	3.77	0.64
2015	0	74	361	0.205	0	NA	2.71	1.2	2.71	1.2
2016	0	134	737	0.182	0	NA	3.32	0.65	3.32	0.65
2017	3	111	598	0.186	16.2	0.67	4.27	0.35	4.27	0.35
2018	0	129	513	0.251	0	NA	1.64	1	1.64	1
2019	0	73	323	0.226	0	NA	0.462	2.6	0.462	2.6
2020	0	51	230	0.222	0	NA	0.492	2	0.492	2
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 6. N RIGHT WHALE DOLPHIN. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	53.6	0.96	53.6	0.96
1991	7	470	4778	0.098	71.2	0.42	25.3	0.73	25.3	0.73
1992	2	596	4379	0.136	14.7	0.68	43.5	0.61	43.5	0.61
1993	7	728	5442	0.134	52.3	0.41	48.9	0.55	48.9	0.55
1994	7	759	4248	0.179	39.2	0.47	43.7	0.38	43.7	0.38
1995	9	572	3673	0.156	57.8	0.67	37.1	0.61	37.1	0.61
1996	5	421	3392	0.124	40.3	0.64	23.5	0.61	23.5	0.61
1997	5	692	3039	0.228	22	0.44	29	0.52	29	0.52
1998	0	587	3353	0.175	0	NA	29.2	0.62	29.2	0.62
1999	3	526	2634	0.2	15	0.75	30	0.54	30	0.54
2000	11	444	1936	0.229	48	0.5	21	0.44	21	0.44
2001	5	339	1665	0.204	24.6	0.62	17.2	0.5	17.2	0.5
2002	2	360	1630	0.221	9.1	0.69	12.9	0.91	12.9	0.91
2003	1	298	1467	0.203	4.9	1.01	5.42	1.2	5.42	1.2
2004	1	223	1084	0.206	4.9	1.02	1.87	1.2	1.87	1.2
2005	0	225	1075	0.209	0	NA	0.601	3.3	0.601	3.3
2006	0	266	1433	0.186	0	NA	3.65	1.3	3.65	1.3
2007	1	204	1241	0.164	6.1	0.97	6.32	1.4	6.32	1.4
2008	1	149	1103	0.135	7.4	0.98	9.65	1	9.65	1
2009	0	101	761	0.133	0	NA	4.04	1.8	4.04	1.8
2010	1	59	492	0.12	8.3	0.94	1.59	1.5	1.59	1.5
2011	1	85	435	0.195	5.1	0.98	4.02	1	4.02	1
2012	1	83	445	0.187	5.4	0.93	6.51	1	6.51	1
2013	2	175	470	0.372	5.4	1	3.17	0.56	3.17	0.56
2014	1	97	409	0.237	4.2	0.97	2.59	1.1	2.59	1.1
2015	0	74	361	0.205	0	NA	4.6	1.8	4.6	1.8
2016	5	134	737	0.182	27.5	0.68	12.3	0.85	12.3	0.85
2017	2	111	598	0.186	10.8	0.68	17.2	0.69	17.2	0.69
2018	0	129	513	0.251	0	NA	2.51	2.2	2.51	2.2
2019	0	73	323	0.226	0	NA	0.517	2.2	0.517	2.2
2020	0	51	230	0.222	0	NA	0.378	3.8	0.378	3.8
2021	0	37	162	0.228	0	NA	0.352	3.9	0.352	3.9

Table 7. BEAKED WHALES + Kogia. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	1	178	4078	0.044	22.9	1.01	33.9	0.23	32.9	0.23
1991	0	470	4778	0.098	0	NA	30.9	0.11	30	0.11
1992	12	596	4379	0.136	88.2	0.34	52.1	0.076	50.9	0.08
1993	3	728	5442	0.134	22.4	0.59	47.1	0.094	45.8	0.097
1994	11	759	4248	0.179	61.6	0.29	37.1	0.08	36.3	0.083
1995	6	572	3673	0.156	38.5	0.37	29.2	0.13	28.5	0.13
1996	0	421	3392	0.124	0	NA	12.3	0.12	11.9	0.12
1997	0	692	3039	0.228	0	NA	7	0.16	6.78	0.16
1998	0	587	3353	0.175	0	NA	0.484	1.6	0.469	1.6
1999	0	526	2634	0.2	0	NA	0.252	3.2	0.244	3.2
2000	0	444	1936	0.229	0	NA	0.157	4.2	0.152	4.1
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0.198	4.1	0.192	4
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0.187	3.9	0.181	3.9
2008	0	149	1103	0.135	0	NA	0.813	2.6	0.789	2.6
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	1.22	1.3	1.19	1.3
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 8. RISSO'S DOLPHIN. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	23.9	1.6	23.9	1.6
1991	5	470	4778	0.098	50.8	0.51	34.5	0.74	34.5	0.74
1992	5	596	4379	0.136	36.7	0.54	32.1	0.58	32.1	0.58
1993	7	728	5442	0.134	52.3	0.55	22.6	0.63	22.6	0.63
1994	1	759	4248	0.179	5.6	1.02	9.99	0.92	9.99	0.92
1995	6	572	3673	0.156	38.5	0.63	28.1	0.71	28.1	0.71
1996	0	421	3392	0.124	0	NA	9.83	1.4	9.83	1.4
1997	3	692	3039	0.228	13.2	0.74	16.5	0.9	16.5	0.9
1998	0	587	3353	0.175	0	NA	7.24	1.5	7.24	1.5
1999	0	526	2634	0.2	0	NA	4.99	1.3	4.99	1.3
2000	2	444	1936	0.229	8.7	0.69	7.78	0.93	7.78	0.93
2001	0	339	1665	0.204	0	NA	2.43	1.8	2.43	1.8
2002	0	360	1630	0.221	0	NA	5.93	1.4	5.93	1.4
2003	4	298	1467	0.203	19.7	0.94	5.07	0.55	5.07	0.55
2004	0	223	1084	0.206	0	NA	2.64	2.1	2.64	2.1
2005	0	225	1075	0.209	0	NA	1.55	3.4	1.55	3.4
2006	0	266	1433	0.186	0	NA	1.71	2.5	1.71	2.5
2007	0	204	1241	0.164	0	NA	1.27	2.8	1.27	2.8
2008	1	149	1103	0.135	7.4	0.97	3.79	1.6	3.79	1.6
2009	0	101	761	0.133	0	NA	1.99	2.8	1.99	2.8
2010	0	59	492	0.12	0	NA	0.745	4	0.745	4
2011	1	85	435	0.195	5.1	0.99	2.34	1.5	2.34	1.5
2012	0	83	445	0.187	0	NA	0.755	2.9	0.755	2.9
2013	0	175	470	0.372	0	NA	0.911	1.8	0.911	1.8
2014	0	97	409	0.237	0	NA	0.91	3.3	0.91	3.3
2015	0	74	361	0.205	0	NA	2.99	2	2.99	2
2016	0	134	737	0.182	0	NA	2.05	2.4	2.05	2.4
2017	0	111	598	0.186	0	NA	2.01	2.5	2.01	2.5
2018	0	129	513	0.251	0	NA	0.846	3.8	0.846	3.8
2019	0	73	323	0.226	0	NA	0.139	5.8	0.139	5.8
2020	0	51	230	0.222	0	NA	0.58	3.1	0.58	3.1
2021	1	37	162	0.228	4.4	0.95	1.23	0.83	1.23	0.83

Table 9. PACIFIC WHITE-SIDED DOLPHIN. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	3	178	4078	0.044	68.7	0.58	39.3	1	39.3	1
1991	5	470	4778	0.098	50.8	0.66	23.8	0.83	23.8	0.83
1992	3	596	4379	0.136	22	0.73	35.4	0.69	35.4	0.69
1993	2	728	5442	0.134	15	0.66	18	0.81	18	0.81
1994	3	759	4248	0.179	16.8	0.74	22	0.6	22	0.6
1995	1	572	3673	0.156	6.4	1.02	9.48	1.1	9.48	1.1
1996	3	421	3392	0.124	24.2	0.76	13.3	1	13.3	1
1997	3	692	3039	0.228	13.2	0.56	10.9	0.7	10.9	0.7
1998	0	587	3353	0.175	0	NA	4.58	1.3	4.58	1.3
1999	0	526	2634	0.2	0	NA	11.5	0.81	11.5	0.81
2000	2	444	1936	0.229	8.7	0.66	5.79	1	5.79	1
2001	2	339	1665	0.204	9.8	0.71	9.64	1.1	9.64	1.1
2002	1	360	1630	0.221	4.5	0.99	5.11	1.1	5.11	1.1
2003	0	298	1467	0.203	0	NA	1.72	1.9	1.72	1.9
2004	0	223	1084	0.206	0	NA	2.93	1.7	2.93	1.7
2005	0	225	1075	0.209	0	NA	1.63	1.9	1.63	1.9
2006	0	266	1433	0.186	0	NA	2.12	2.1	2.12	2.1
2007	1	204	1241	0.164	6.1	1.01	2.16	1.3	2.16	1.3
2008	5	149	1103	0.135	37	0.71	7.9	0.8	7.9	0.8
2009	2	101	761	0.133	15.1	0.99	3.72	1.2	3.72	1.2
2010	0	59	492	0.12	0	NA	4.38	2.2	4.38	2.2
2011	0	85	435	0.195	0	NA	0.673	3	0.673	3
2012	0	83	445	0.187	0	NA	0.396	3.9	0.396	3.9
2013	0	175	470	0.372	0	NA	0.279	3	0.279	3
2014	0	97	409	0.237	0	NA	1.54	1.7	1.54	1.7
2015	0	74	361	0.205	0	NA	1.83	2.2	1.83	2.2
2016	0	134	737	0.182	0	NA	1.47	2.4	1.47	2.4
2017	0	111	598	0.186	0	NA	1.87	2.3	1.87	2.3
2018	0	129	513	0.251	0	NA	0.626	2.8	0.626	2.8
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0.427	4	0.427	4
2021	0	37	162	0.228	0	NA	0.171	5.5	0.171	5.5

Table 10. LEATHERBACK TURTLE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	1	178	4078	0.044	22.9	1	17.1	1	12	1
1991	1	470	4778	0.098	10.2	0.98	12.5	0.78	8.83	0.78
1992	4	596	4379	0.136	29.4	0.46	18.7	0.45	14	0.42
1993	3	728	5442	0.134	22.4	0.56	21.3	0.49	15.5	0.48
1994	1	759	4248	0.179	5.6	1.03	7.94	0.67	5.72	0.66
1995	5	572	3673	0.156	32.1	0.5	18.9	0.43	14.5	0.4
1996	2	421	3392	0.124	16.1	0.71	18.6	0.58	13.3	0.58
1997	4	692	3039	0.228	17.6	0.62	17.2	0.35	13	0.34
1998	0	587	3353	0.175	0	NA	6.64	0.79	4.52	0.8
1999	2	526	2634	0.2	10	0.72	8.79	0.66	6.62	0.61
2000	0	444	1936	0.229	0	NA	1.72	1.3	1.17	1.3
2001	0	339	1665	0.204	0	NA	0.626	2.1	0.425	2.1
2002	0	360	1630	0.221	0	NA	3.87	1.2	2.63	1.3
2003	0	298	1467	0.203	0	NA	0.727	2.1	0.495	2.2
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	1.5	1.4	1.02	1.4
2006	0	266	1433	0.186	0	NA	1.96	1.2	1.34	1.2
2007	0	204	1241	0.164	0	NA	0.286	3.7	0.194	3.7
2008	0	149	1103	0.135	0	NA	0.154	5	0.105	4.9
2009	1	101	761	0.133	7.5	0.98	1.93	1.1	1.63	0.92
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	1	83	445	0.187	5.4	1.02	1.32	0.78	1.22	0.58
2013	0	175	470	0.372	0	NA	1.39	1.1	0.942	1.2
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0.627	2.3	0.426	2.3
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0.303	3.2	0.206	3.2
2018	0	129	513	0.251	0	NA	0.899	1.4	0.611	1.4
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 11. CUVIER'S BEAKED WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	21.7	0.25	20.7	0.24
1991	0	470	4778	0.098	0	NA	20	0.15	19.1	0.16
1992	6	596	4379	0.136	44.1	0.38	28.4	0.089	27.3	0.094
1993	3	728	5442	0.134	22.4	0.56	29	0.11	27.8	0.12
1994	6	759	4248	0.179	33.6	0.4	22.1	0.078	21.4	0.085
1995	6	572	3673	0.156	38.5	0.4	22.7	0.16	21.9	0.16
1996	0	421	3392	0.124	0	NA	8.38	0.16	7.98	0.17
1997	0	692	3039	0.228	0	NA	4.59	0.16	4.37	0.17
1998	0	587	3353	0.175	0	NA	0.373	1.9	0.355	1.9
1999	0	526	2634	0.2	0	NA	0	0	0	0
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0.287	3.2	0.273	3.1
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0.23	3.7	0.219	3.7
2008	0	149	1103	0.135	0	NA	0.858	2.3	0.817	2.3
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	1.27	1.3	1.21	1.3
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0.142	4.1	0.135	4.1
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 12. DALL'S PORPOISE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	1	178	4078	0.044	22.9	0.96	10.8	1.6	10.8	1.6
1991	2	470	4778	0.098	20.3	0.72	6.43	1	6.43	1
1992	1	596	4379	0.136	7.3	0.98	11.4	0.81	11.4	0.81
1993	9	728	5442	0.134	67.3	0.49	48.9	0.42	48.9	0.42
1994	2	759	4248	0.179	11.2	0.7	15.1	0.61	15.1	0.61
1995	1	572	3673	0.156	6.4	0.97	4.68	1.1	4.68	1.1
1996	2	421	3392	0.124	16.1	0.7	6.79	0.92	6.79	0.92
1997	4	692	3039	0.228	17.6	0.78	12.3	0.68	12.3	0.68
1998	0	587	3353	0.175	0	NA	5.34	1	5.34	1
1999	0	526	2634	0.2	0	NA	3.13	1.5	3.13	1.5
2000	0	444	1936	0.229	0	NA	0.783	2.1	0.783	2.1
2001	0	339	1665	0.204	0	NA	0.344	4	0.344	4
2002	0	360	1630	0.221	0	NA	3.93	1.2	3.93	1.2
2003	0	298	1467	0.203	0	NA	0.823	1.9	0.823	1.9
2004	0	223	1084	0.206	0	NA	0.334	3.7	0.334	3.7
2005	0	225	1075	0.209	0	NA	0.228	3.1	0.228	3.1
2006	0	266	1433	0.186	0	NA	1.36	2	1.36	2
2007	0	204	1241	0.164	0	NA	0.488	3	0.488	3
2008	0	149	1103	0.135	0	NA	0.101	8.9	0.101	8.9
2009	0	101	761	0.133	0	NA	0.981	2.5	0.981	2.5
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0.1	7.4	0.1	7.4
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	1.25	1.3	1.25	1.3
2014	1	97	409	0.237	4.2	0.98	1.56	0.92	1.56	0.92
2015	0	74	361	0.205	0	NA	0.122	6.1	0.122	6.1
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0.721	2.5	0.721	2.5
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0.118	5.7	0.118	5.7
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 13. N. FULMAR. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	4.68	1	0.649	1.3
1991	0	470	4778	0.098	0	NA	0.514	1.6	0	0
1992	0	596	4379	0.136	0	NA	0.357	1.5	0	0
1993	0	728	5442	0.134	0	NA	0.507	1.3	0	0
1994	0	759	4248	0.179	0	NA	0.367	1.1	0	0
1995	0	572	3673	0.156	0	NA	3.78	0.65	0.525	0.96
1996	0	421	3392	0.124	0	NA	12.3	0.51	1.7	0.85
1997	0	692	3039	0.228	0	NA	1.81	1.3	0.252	1.5
1998	0	587	3353	0.175	0	NA	13.5	0.66	1.87	0.94
1999	0	526	2634	0.2	0	NA	18	0.56	2.5	0.85
2000	16	444	1936	0.229	69.8	0.33	31.3	0.32	18.1	0.12
2001	0	339	1665	0.204	0	NA	10.5	0.51	1.45	0.83
2002	1	360	1630	0.221	4.5	1.02	3.59	1.3	1.36	0.56
2003	14	298	1467	0.203	68.9	0.48	21.4	0.26	15	0.071
2004	0	223	1084	0.206	0	NA	7.49	0.75	1.04	1
2005	5	225	1075	0.209	23.9	0.99	10.9	0.32	5.81	0.13
2006	0	266	1433	0.186	0	NA	8.83	0.91	1.23	1.2
2007	0	204	1241	0.164	0	NA	6.03	0.87	0.838	1.1
2008	0	149	1103	0.135	0	NA	6.24	0.81	0.866	1.1
2009	0	101	761	0.133	0	NA	5.16	0.95	0.717	1.2
2010	0	59	492	0.12	0	NA	2.4	1.3	0.333	1.4
2011	0	85	435	0.195	0	NA	2.2	1.4	0.305	1.7
2012	0	83	445	0.187	0	NA	2.86	0.98	0.397	1.2
2013	0	175	470	0.372	0	NA	3.18	0.84	0.442	1.2
2014	0	97	409	0.237	0	NA	2.22	0.9	0.309	1.2
2015	0	74	361	0.205	0	NA	0.385	2.5	0	0
2016	0	134	737	0.182	0	NA	3.33	1.2	0.462	1.5
2017	0	111	598	0.186	0	NA	2.14	1	0.298	1.3
2018	0	129	513	0.251	0	NA	1.83	0.83	0.254	1.1
2019	0	73	323	0.226	0	NA	1.67	0.98	0.231	1.2
2020	0	51	230	0.222	0	NA	0.487	1.7	0	0
2021	0	37	162	0.228	0	NA	0.657	1.3	0	0

Table 14. COMMON DOLPHIN, LONG-BEAKED. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	12.8	2.4	12.8	2.4
1991	0	470	4778	0.098	0	NA	3.96	1.8	3.96	1.8
1992	2	596	4379	0.136	14.7	0.91	10.7	1.2	10.7	1.2
1993	0	728	5442	0.134	0	NA	8.92	0.94	8.92	0.94
1994	1	759	4248	0.179	5.6	0.99	14	0.98	14	0.98
1995	4	572	3673	0.156	25.7	0.99	5.5	0.7	5.5	0.7
1996	0	421	3392	0.124	0	NA	0.789	3.5	0.789	3.5
1997	4	692	3039	0.228	17.6	0.79	10.7	0.81	10.7	0.81
1998	0	587	3353	0.175	0	NA	7.92	1.2	7.92	1.2
1999	1	526	2634	0.2	5	1	6.72	1.2	6.72	1.2
2000	0	444	1936	0.229	0	NA	6.18	0.95	6.18	0.95
2001	0	339	1665	0.204	0	NA	3.35	1.3	3.35	1.3
2002	4	360	1630	0.221	18.1	0.79	9.45	0.68	9.45	0.68
2003	0	298	1467	0.203	0	NA	2.58	2.6	2.58	2.6
2004	0	223	1084	0.206	0	NA	6.26	1.1	6.26	1.1
2005	3	225	1075	0.209	14.3	0.52	5.18	0.58	5.18	0.58
2006	0	266	1433	0.186	0	NA	1.95	2.5	1.95	2.5
2007	0	204	1241	0.164	0	NA	0.371	4.3	0.371	4.3
2008	1	149	1103	0.135	7.4	0.98	4.05	1.1	4.05	1.1
2009	0	101	761	0.133	0	NA	0.817	3	0.817	3
2010	1	59	492	0.12	8.3	0.98	1.78	1.6	1.78	1.6
2011	1	85	435	0.195	5.1	1.02	4.17	1.6	4.17	1.6
2012	0	83	445	0.187	0	NA	0.959	3.3	0.959	3.3
2013	0	175	470	0.372	0	NA	0.544	3	0.544	3
2014	0	97	409	0.237	0	NA	0.136	8.6	0.136	8.6
2015	1	74	361	0.205	4.9	0.97	1.29	0.92	1.29	0.92
2016	1	134	737	0.182	5.5	0.99	4.22	0.94	4.22	0.94
2017	0	111	598	0.186	0	NA	0.331	4.2	0.331	4.2
2018	0	129	513	0.251	0	NA	2.85	1.6	2.85	1.6
2019	0	73	323	0.226	0	NA	0.921	2.1	0.921	2.1
2020	2	51	230	0.222	9	0.91	2.65	0.81	2.65	0.81
2021	0	37	162	0.228	0	NA	0.188	4.2	0.188	4.2

Table 15. LOGGERHEAD TURTLE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	11.5	1.3	2.88	1.6
1991	0	470	4778	0.098	0	NA	15.2	0.95	3.81	1.1
1992	2	596	4379	0.136	14.7	0.67	4.4	0.8	2.6	0.39
1993	5	728	5442	0.134	37.4	0.51	7.95	0.63	5.74	0.26
1994	0	759	4248	0.179	0	NA	9.64	0.97	2.41	1.2
1995	0	572	3673	0.156	0	NA	6.72	1	1.68	1.2
1996	0	421	3392	0.124	0	NA	2	2.4	0.499	2.6
1997	3	692	3039	0.228	13.2	0.58	7.13	0.74	4.03	0.37
1998	4	587	3353	0.175	22.8	0.76	6.67	0.45	4.67	0.2
1999	0	526	2634	0.2	0	NA	4.68	1.1	1.17	1.4
2000	0	444	1936	0.229	0	NA	3.27	0.96	0.818	1.2
2001	1	339	1665	0.204	4.9	0.99	7.64	0.94	2.66	0.81
2002	0	360	1630	0.221	0	NA	1.97	1.1	0.492	1.4
2003	0	298	1467	0.203	0	NA	1.5	1.6	0.376	1.9
2004	0	223	1084	0.206	0	NA	1.8	1.2	0.449	1.5
2005	0	225	1075	0.209	0	NA	0.189	4.2	0	0
2006	1	266	1433	0.186	5.4	1.03	2.45	0.84	1.36	0.42
2007	0	204	1241	0.164	0	NA	1.27	2.6	0.317	2.6
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0.33	4.1	0	0
2010	0	59	492	0.12	0	NA	0.216	7.9	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0.627	2.8	0.157	3.1
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0.238	4.1	0	0
2015	0	74	361	0.205	0	NA	0.209	2.3	0	0
2016	0	134	737	0.182	0	NA	2.63	2.7	0.657	2.8
2017	0	111	598	0.186	0	NA	0.715	3.2	0.179	3.5
2018	0	129	513	0.251	0	NA	0.198	3.4	0	0
2019	0	73	323	0.226	0	NA	0.789	2	0.197	2.2
2020	0	51	230	0.222	0	NA	0.279	2.6	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 16. PILOT WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	1	178	4078	0.044	22.9	0.99	3.41	2.5	3.41	2.5
1991	0	470	4778	0.098	0	NA	3.62	1.6	3.62	1.6
1992	1	596	4379	0.136	7.3	0.98	10.1	1	10.1	1
1993	8	728	5442	0.134	59.8	0.58	29	0.72	29	0.72
1994	0	759	4248	0.179	0	NA	8.58	1.2	8.58	1.2
1995	0	572	3673	0.156	0	NA	4.76	1.1	4.76	1.1
1996	0	421	3392	0.124	0	NA	7.45	1.7	7.45	1.7
1997	1	692	3039	0.228	4.4	1.05	3.5	1.1	3.5	1.1
1998	0	587	3353	0.175	0	NA	3.51	1.5	3.51	1.5
1999	0	526	2634	0.2	0	NA	2.72	1.4	2.72	1.4
2000	0	444	1936	0.229	0	NA	1.68	1.5	1.68	1.5
2001	0	339	1665	0.204	0	NA	1.29	2.5	1.29	2.5
2002	0	360	1630	0.221	0	NA	0.323	2.9	0.323	2.9
2003	1	298	1467	0.203	4.9	1.01	1.84	0.97	1.84	0.97
2004	0	223	1084	0.206	0	NA	0.148	2.4	0.148	2.4
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0.811	2.7	0.811	2.7
2008	0	149	1103	0.135	0	NA	0.146	3.9	0.146	3.9
2009	0	101	761	0.133	0	NA	0.243	5.3	0.243	5.3
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	2	97	409	0.237	8.4	0.66	2.55	0.58	2.55	0.58
2015	0	74	361	0.205	0	NA	0.625	2.9	0.625	2.9
2016	0	134	737	0.182	0	NA	0.245	3.6	0.245	3.6
2017	0	111	598	0.186	0	NA	0.187	3.7	0.187	3.7
2018	0	129	513	0.251	0	NA	1.02	1.8	1.02	1.8
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 17. MESOPLODON. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	1	178	4078	0.044	22.9	1	10.5	0.82	10.5	0.82
1991	0	470	4778	0.098	0	NA	5.84	0.28	5.84	0.28
1992	4	596	4379	0.136	29.4	0.48	15	0.19	15	0.19
1993	0	728	5442	0.134	0	NA	12.8	0.28	12.8	0.28
1994	3	759	4248	0.179	16.8	0.58	9.27	0.22	9.27	0.22
1995	0	572	3673	0.156	0	NA	4.13	0.48	4.13	0.48
1996	0	421	3392	0.124	0	NA	1.84	0.28	1.84	0.28
1997	0	692	3039	0.228	0	NA	1.67	0.7	1.67	0.7
1998	0	587	3353	0.175	0	NA	0.602	2	0.602	2
1999	0	526	2634	0.2	0	NA	0.332	2.7	0.332	2.7
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 18. SPERM WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	6.71	3.2	4.7	3.4
1991	0	470	4778	0.098	0	NA	2.38	3.4	1.67	3.3
1992	3	596	4379	0.136	22	1	6.54	1.6	5.48	1.4
1993	3	728	5442	0.134	22.4	0.75	10.5	1.4	8.25	1.3
1994	0	759	4248	0.179	0	NA	4.58	1.9	3.21	1.9
1995	0	572	3673	0.156	0	NA	3.45	1.9	2.41	2
1996	1	421	3392	0.124	8.1	0.98	5.42	1.7	4.09	1.7
1997	0	692	3039	0.228	0	NA	1.81	2.6	1.26	2.7
1998	1	587	3353	0.175	5.7	1.01	8.97	1.3	6.58	1.3
1999	0	526	2634	0.2	0	NA	0.386	4.6	0.27	4.7
2000	0	444	1936	0.229	0	NA	2.31	1.7	1.61	1.7
2001	0	339	1665	0.204	0	NA	0.551	3.9	0.386	3.9
2002	0	360	1630	0.221	0	NA	1.35	2.6	0.948	2.6
2003	0	298	1467	0.203	0	NA	0.215	6	0.15	6.4
2004	0	223	1084	0.206	0	NA	0.239	5.4	0.167	5.4
2005	0	225	1075	0.209	0	NA	0.473	4	0.331	4.2
2006	0	266	1433	0.186	0	NA	0.695	4	0.486	3.9
2007	0	204	1241	0.164	0	NA	0.699	4.4	0.489	4.4
2008	0	149	1103	0.135	0	NA	0.48	4.9	0.336	4.8
2009	0	101	761	0.133	0	NA	0.263	7.8	0.184	7.9
2010	2	59	492	0.12	16.7	1	2.25	1	2.18	0.7
2011	0	85	435	0.195	0	NA	0.528	4.5	0.369	4.4
2012	0	83	445	0.187	0	NA	0.258	5.2	0.181	5.3
2013	0	175	470	0.372	0	NA	0.253	3.6	0.177	3.5
2014	0	97	409	0.237	0	NA	1.68	3.7	1.17	4
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	2.25	2.7	1.58	2.8
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 19. HUBB'S BEAKED WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	8.02	1.2	8.02	1.2
1991	0	470	4778	0.098	0	NA	3.26	0.34	3.26	0.34
1992	3	596	4379	0.136	22	0.58	9.37	0.23	9.37	0.23
1993	0	728	5442	0.134	0	NA	7.77	0.39	7.77	0.39
1994	2	759	4248	0.179	11.2	0.71	6.42	0.32	6.42	0.32
1995	0	572	3673	0.156	0	NA	2.26	0.65	2.26	0.65
1996	0	421	3392	0.124	0	NA	1.03	0.55	1.03	0.55
1997	0	692	3039	0.228	0	NA	1.17	0.98	1.17	0.98
1998	0	587	3353	0.175	0	NA	0.311	2.9	0.311	2.9
1999	0	526	2634	0.2	0	NA	0.411	2.5	0.411	2.5
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 20. HUMPBACK WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.256	4.8	0	0
1991	0	470	4778	0.098	0	NA	2.99	1.5	0.598	2
1992	0	596	4379	0.136	0	NA	0.877	2.1	0.175	2.9
1993	0	728	5442	0.134	0	NA	0.91	2.3	0.182	3.5
1994	1	759	4248	0.179	5.6	1	4.78	1.2	1.76	0.87
1995	0	572	3673	0.156	0	NA	0.664	2.6	0.133	4
1996	0	421	3392	0.124	0	NA	0.477	3.3	0	0
1997	0	692	3039	0.228	0	NA	2.19	1.4	0.438	2.1
1998	0	587	3353	0.175	0	NA	1.07	1.6	0.215	2
1999	1	526	2634	0.2	5	0.97	1.79	0.84	1.16	0.35
2000	0	444	1936	0.229	0	NA	1.78	1.9	0.356	3
2001	0	339	1665	0.204	0	NA	0.815	1.8	0.163	2.3
2002	0	360	1630	0.221	0	NA	0.551	2.1	0.11	2.9
2003	0	298	1467	0.203	0	NA	0.708	2.3	0.142	2.7
2004	1	223	1084	0.206	4.9	1.02	1.22	0.55	1.04	0.21
2005	0	225	1075	0.209	0	NA	0.255	3.2	0	0
2006	0	266	1433	0.186	0	NA	0.63	2	0.126	2.6
2007	0	204	1241	0.164	0	NA	0.751	2.2	0.15	2.9
2008	0	149	1103	0.135	0	NA	0.373	3	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0.51	3.1	0.102	4.2
2011	0	85	435	0.195	0	NA	0.32	3	0	0
2012	0	83	445	0.187	0	NA	0.167	4	0	0
2013	0	175	470	0.372	0	NA	0.335	2.1	0	0
2014	0	97	409	0.237	0	NA	0.375	2.6	0	0
2015	0	74	361	0.205	0	NA	0.39	2.9	0	0
2016	0	134	737	0.182	0	NA	0.547	2.9	0.109	4.1
2017	0	111	598	0.186	0	NA	0.516	2.7	0.103	4.5
2018	0	129	513	0.251	0	NA	0.175	3	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	2	37	162	0.228	8.8	0.66	2.05	0.14	2.01	0.037

Table 21. GRAY WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.707	5.2	0.707	5.2
1991	0	470	4778	0.098	0	NA	1.12	2.2	1.12	2.2
1992	0	596	4379	0.136	0	NA	1.08	2.1	1.08	2.1
1993	0	728	5442	0.134	0	NA	0.821	2.1	0.821	2.1
1994	0	759	4248	0.179	0	NA	0.543	2	0.543	2
1995	0	572	3673	0.156	0	NA	0.344	2.8	0.344	2.8
1996	0	421	3392	0.124	0	NA	1.02	2.5	1.02	2.5
1997	0	692	3039	0.228	0	NA	0.924	1.6	0.924	1.6
1998	1	587	3353	0.175	5.7	0.99	4.95	0.68	4.95	0.68
1999	1	526	2634	0.2	5	1	2.53	0.74	2.53	0.74
2000	0	444	1936	0.229	0	NA	0.656	1.9	0.656	1.9
2001	0	339	1665	0.204	0	NA	0.833	1.8	0.833	1.8
2002	0	360	1630	0.221	0	NA	1.17	1.4	1.17	1.4
2003	0	298	1467	0.203	0	NA	1.03	1.8	1.03	1.8
2004	0	223	1084	0.206	0	NA	1.98	1.5	1.98	1.5
2005	1	225	1075	0.209	4.8	0.98	1.38	0.63	1.38	0.63
2006	0	266	1433	0.186	0	NA	0.367	2.3	0.367	2.3
2007	0	204	1241	0.164	0	NA	0.539	2.5	0.539	2.5
2008	0	149	1103	0.135	0	NA	0.305	3.8	0.305	3.8
2009	0	101	761	0.133	0	NA	0.122	4.9	0.122	4.9
2010	0	59	492	0.12	0	NA	0.582	2.6	0.582	2.6
2011	0	85	435	0.195	0	NA	0.35	2.7	0.35	2.7
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	1	175	470	0.372	2.7	0.98	1.03	0.12	1.03	0.12
2014	0	97	409	0.237	0	NA	0.12	4.1	0.12	4.1
2015	0	74	361	0.205	0	NA	0.238	3	0.238	3
2016	0	134	737	0.182	0	NA	0.343	2.3	0.343	2.3
2017	0	111	598	0.186	0	NA	0.505	2.6	0.505	2.6
2018	1	129	513	0.251	4	0.97	1.12	0.52	1.12	0.52
2019	0	73	323	0.226	0	NA	0.245	3	0.245	3
2020	0	51	230	0.222	0	NA	0.503	1.8	0.503	1.8
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 22. MINKE WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	1.06	4	0.528	4.9
1991	0	470	4778	0.098	0	NA	3.41	1.6	1.71	1.9
1992	0	596	4379	0.136	0	NA	2.65	1.6	1.32	1.7
1993	0	728	5442	0.134	0	NA	2.29	1.4	1.14	1.6
1994	1	759	4248	0.179	5.6	1	2.34	1.2	1.67	0.92
1995	0	572	3673	0.156	0	NA	1.51	1.6	0.754	1.8
1996	1	421	3392	0.124	8.1	0.97	3.31	1.2	2.16	0.94
1997	0	692	3039	0.228	0	NA	0.432	2.4	0.216	2.5
1998	0	587	3353	0.175	0	NA	0.306	2.9	0.153	3.3
1999	1	526	2634	0.2	5	0.98	1.62	0.8	1.31	0.55
2000	0	444	1936	0.229	0	NA	0.495	2.2	0.248	2.4
2001	0	339	1665	0.204	0	NA	0.532	2.3	0.266	2.4
2002	0	360	1630	0.221	0	NA	0.297	3.2	0.149	3.4
2003	0	298	1467	0.203	0	NA	0.291	4	0.146	4.7
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0.13	3.5	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	1.06	1.9	0.532	2.1
2008	0	149	1103	0.135	0	NA	0.719	2.4	0.359	2.6
2009	0	101	761	0.133	0	NA	0.497	2.6	0.249	2.8
2010	0	59	492	0.12	0	NA	0.238	4.4	0.119	3.9
2011	1	85	435	0.195	5.1	0.99	1.05	0.33	1.03	0.24
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0.12	3.6	0	0
2014	0	97	409	0.237	0	NA	0.436	2.7	0.218	2.8
2015	0	74	361	0.205	0	NA	0.156	4.1	0	0
2016	0	134	737	0.182	0	NA	0.294	3	0.147	3.6
2017	0	111	598	0.186	0	NA	0.189	3.6	0	0
2018	0	129	513	0.251	0	NA	0.226	3.7	0.113	3.9
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 23. UNID. ZIPHIID. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	1.98	1.5	1.98	1.5
1991	0	470	4778	0.098	0	NA	2.09	0.98	2.09	0.98
1992	2	596	4379	0.136	14.7	0.7	6.01	0.46	6.01	0.46
1993	0	728	5442	0.134	0	NA	3.39	0.3	3.39	0.3
1994	1	759	4248	0.179	5.6	0.98	2.28	0.23	2.28	0.23
1995	0	572	3673	0.156	0	NA	2.31	0.87	2.31	0.87
1996	0	421	3392	0.124	0	NA	0.611	0.19	0.611	0.19
1997	0	692	3039	0.228	0	NA	0.34	0.19	0.34	0.19
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	0	526	2634	0.2	0	NA	0.709	2	0.709	2
2000	0	444	1936	0.229	0	NA	0.962	1.7	0.962	1.7
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 24. STELLER'S SEA LION. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.131	12	0.131	12
1991	0	470	4778	0.098	0	NA	1.04	3.1	1.04	3.1
1992	1	596	4379	0.136	7.3	1.02	2.18	1.3	2.18	1.3
1993	0	728	5442	0.134	0	NA	2.06	2.1	2.06	2.1
1994	1	759	4248	0.179	5.6	0.96	1.55	0.98	1.55	0.98
1995	0	572	3673	0.156	0	NA	0.533	2.8	0.533	2.8
1996	0	421	3392	0.124	0	NA	1.12	2.8	1.12	2.8
1997	0	692	3039	0.228	0	NA	0.185	4.1	0.185	4.1
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	0	526	2634	0.2	0	NA	0.306	3.2	0.306	3.2
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0.103	5.4	0.103	5.4
2002	0	360	1630	0.221	0	NA	0.898	2.1	0.898	2.1
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0.162	4.5	0.162	4.5
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0.166	5.5	0.166	5.5
2009	0	101	761	0.133	0	NA	0.159	5.2	0.159	5.2
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0.16	2.8	0.16	2.8
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0.341	3.9	0.341	3.9
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0.126	4.8	0.126	4.8
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 25. PYGMY SPERM WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	1.36	0.31	1.36	0.31
1991	0	470	4778	0.098	0	NA	1.2	0.21	1.2	0.21
1992	1	596	4379	0.136	7.3	1.04	2.48	0.44	2.48	0.44
1993	1	728	5442	0.134	7.5	0.99	2.82	0.39	2.82	0.39
1994	0	759	4248	0.179	0	NA	1.01	0.48	1.01	0.48
1995	0	572	3673	0.156	0	NA	3.6	0.83	3.6	0.83
1996	0	421	3392	0.124	0	NA	0.598	0.23	0.598	0.23
1997	0	692	3039	0.228	0	NA	0.323	0.89	0.323	0.89
1998	0	587	3353	0.175	0	NA	0.42	2.9	0.42	2.9
1999	0	526	2634	0.2	0	NA	0	0	0	0
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 26. BOTTLENOSE DOLPHIN. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0	0	0	0
1991	0	470	4778	0.098	0	NA	0.832	4.5	0.832	4.5
1992	3	596	4379	0.136	22	0.97	15.5	1.7	15.5	1.7
1993	0	728	5442	0.134	0	NA	6.65	4.2	6.65	4.2
1994	0	759	4248	0.179	0	NA	0.391	6.1	0.391	6.1
1995	0	572	3673	0.156	0	NA	0.176	8.8	0.176	8.8
1996	0	421	3392	0.124	0	NA	0.218	6.7	0.218	6.7
1997	0	692	3039	0.228	0	NA	0.213	6.4	0.213	6.4
1998	0	587	3353	0.175	0	NA	0.64	6.9	0.64	6.9
1999	0	526	2634	0.2	0	NA	1.41	4.1	1.41	4.1
2000	0	444	1936	0.229	0	NA	0.324	8	0.324	8
2001	0	339	1665	0.204	0	NA	0.238	8.2	0.238	8.2
2002	0	360	1630	0.221	0	NA	0.255	5	0.255	5
2003	0	298	1467	0.203	0	NA	0.257	4.7	0.257	4.7
2004	0	223	1084	0.206	0	NA	0.265	4.6	0.265	4.6
2005	0	225	1075	0.209	0	NA	0.751	2.8	0.751	2.8
2006	0	266	1433	0.186	0	NA	0.409	4.4	0.409	4.4
2007	0	204	1241	0.164	0	NA	0.374	5.3	0.374	5.3
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	1	59	492	0.12	8.3	0.96	1	0	1	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0.101	10	0.101	10
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 27. OLIVE RIDELY TURTLE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0	0	0	0
1991	0	470	4778	0.098	0	NA	0	0	0	0
1992	0	596	4379	0.136	0	NA	0	0	0	0
1993	0	728	5442	0.134	0	NA	0.447	2.9	0	0
1994	0	759	4248	0.179	0	NA	0.805	1.8	0	0
1995	0	572	3673	0.156	0	NA	0	0	0	0
1996	0	421	3392	0.124	0	NA	0.219	4.3	0	0
1997	0	692	3039	0.228	0	NA	0	0	0	0
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	1	526	2634	0.2	5	0.97	1.48	0.66	1	0
2000	0	444	1936	0.229	0	NA	0.321	2.4	0	0
2001	0	339	1665	0.204	0	NA	0.216	3.2	0	0
2002	0	360	1630	0.221	0	NA	0.251	2.7	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0.216	2.7	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0.271	4.7	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0.13	5.5	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0.138	4.1	0	0
2016	0	134	737	0.182	0	NA	0.195	3.3	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 28. GREEN TURTLE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0	0	0	0
1991	0	470	4778	0.098	0	NA	0.411	3.7	0.411	3.7
1992	0	596	4379	0.136	0	NA	0.156	4.8	0.156	4.8
1993	0	728	5442	0.134	0	NA	0	0	0	0
1994	0	759	4248	0.179	0	NA	0.182	3.7	0.182	3.7
1995	0	572	3673	0.156	0	NA	0	0	0	0
1996	0	421	3392	0.124	0	NA	0	0	0	0
1997	0	692	3039	0.228	0	NA	0.355	2.3	0.355	2.3
1998	0	587	3353	0.175	0	NA	0.122	3.8	0.122	3.8
1999	1	526	2634	0.2	5	0.98	1.63	0.72	1.63	0.72
2000	0	444	1936	0.229	0	NA	0.36	2.8	0.36	2.8
2001	0	339	1665	0.204	0	NA	0.154	4.1	0.154	4.1
2002	0	360	1630	0.221	0	NA	0.253	2.7	0.253	2.7
2003	0	298	1467	0.203	0	NA	0.245	2.9	0.245	2.9
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0.26	3.4	0.26	3.4
2012	0	83	445	0.187	0	NA	0.235	3	0.235	3
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0.509	2	0.509	2
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0.371	2.9	0.371	2.9
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 29. STEJNEGER'S BEAKED WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.367	0.81	0.367	0.81
1991	0	470	4778	0.098	0	NA	0.678	1.8	0.678	1.8
1992	0	596	4379	0.136	0	NA	0.894	0.39	0.894	0.39
1993	0	728	5442	0.134	0	NA	2.23	0.94	2.23	0.94
1994	1	759	4248	0.179	5.6	0.99	1.33	0.094	1.33	0.094
1995	0	572	3673	0.156	0	NA	0.223	0.32	0.223	0.32
1996	0	421	3392	0.124	0	NA	0.123	0.39	0.123	0.39
1997	0	692	3039	0.228	0	NA	0	0	0	0
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	0	526	2634	0.2	0	NA	0	0	0	0
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 30. BAIRD'S BEAKED WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.322	0.65	0.322	0.65
1991	0	470	4778	0.098	0	NA	0.432	0.37	0.432	0.37
1992	0	596	4379	0.136	0	NA	0.922	0.69	0.922	0.69
1993	0	728	5442	0.134	0	NA	0.929	0.7	0.929	0.7
1994	1	759	4248	0.179	5.6	0.98	3.26	0.72	3.26	0.72
1995	0	572	3673	0.156	0	NA	0.284	1.6	0.284	1.6
1996	0	421	3392	0.124	0	NA	0.132	0.37	0.132	0.37
1997	0	692	3039	0.228	0	NA	0	0	0	0
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	0	526	2634	0.2	0	NA	0	0	0	0
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 31. STRIPED DOLPHIN. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021.

Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV).

Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0	0	0	0
1991	0	470	4778	0.098	0	NA	0.599	3.7	0.599	3.7
1992	0	596	4379	0.136	0	NA	0.491	2.4	0.491	2.4
1993	0	728	5442	0.134	0	NA	1.54	1.8	1.54	1.8
1994	1	759	4248	0.179	5.6	0.95	1.88	0.85	1.88	0.85
1995	0	572	3673	0.156	0	NA	0	0	0	0
1996	0	421	3392	0.124	0	NA	0.134	8.7	0.134	8.7
1997	0	692	3039	0.228	0	NA	0	0	0	0
1998	0	587	3353	0.175	0	NA	0	0	0	0
1999	0	526	2634	0.2	0	NA	0.124	4.9	0.124	4.9
2000	0	444	1936	0.229	0	NA	0	0	0	0
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 32. KILLER WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0.392	6.3	0.392	6.3
1991	0	470	4778	0.098	0	NA	0.683	3	0.683	3
1992	0	596	4379	0.136	0	NA	0.373	3.8	0.373	3.8
1993	0	728	5442	0.134	0	NA	0.247	3.7	0.247	3.7
1994	0	759	4248	0.179	0	NA	0.544	2.9	0.544	2.9
1995	1	572	3673	0.156	6.4	1	1.21	0.7	1.21	0.7
1996	0	421	3392	0.124	0	NA	2.84	2.1	2.84	2.1
1997	0	692	3039	0.228	0	NA	0.48	1.9	0.48	1.9
1998	0	587	3353	0.175	0	NA	0.232	3.4	0.232	3.4
1999	0	526	2634	0.2	0	NA	0	0	0	0
2000	0	444	1936	0.229	0	NA	0.259	3.5	0.259	3.5
2001	0	339	1665	0.204	0	NA	0	0	0	0
2002	0	360	1630	0.221	0	NA	0	0	0	0
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0	0	0	0
2007	0	204	1241	0.164	0	NA	0	0	0	0
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0.875	2.5	0.875	2.5
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0

Table 33. FIN WHALE. Observed entanglements, observed sets, estimated Sets, observer coverage, and estimated bycatch from 1990–2021. Estimated annual bycatch from ratio estimates (RatioAnn) and regression trees (TreeEstAnn) are shown, along with coefficients of variation (CV). Total mortality and serious injury (MSI) is based on prorating TreeEstAnn by the fraction of fishery observations resulting in death or serious injury (see text).

Year	ObsAnn	ObsEffortAnn	EstEffortAnn	ObsCovAnn	RatioAnn	CV.RatioAnn	TreeEstAnn	CV.TreeEstAnn	TreeEstAnn.MSI	CV.TreeEstAnn.MSI
1990	0	178	4078	0.044	0	NA	0	0	0	0
1991	0	470	4778	0.098	0	NA	0	0	0	0
1992	0	596	4379	0.136	0	NA	0	0	0	0
1993	0	728	5442	0.134	0	NA	0	0	0	0
1994	0	759	4248	0.179	0	NA	0.938	1.8	0.938	1.8
1995	0	572	3673	0.156	0	NA	0	0	0	0
1996	0	421	3392	0.124	0	NA	0	0	0	0
1997	0	692	3039	0.228	0	NA	0.333	2.9	0.333	2.9
1998	0	587	3353	0.175	0	NA	0.675	2.2	0.675	2.2
1999	1	526	2634	0.2	5	0.95	1.36	0.74	1.36	0.74
2000	0	444	1936	0.229	0	NA	0.562	2.5	0.562	2.5
2001	0	339	1665	0.204	0	NA	0.146	3.3	0.146	3.3
2002	0	360	1630	0.221	0	NA	0.273	3.9	0.273	3.9
2003	0	298	1467	0.203	0	NA	0	0	0	0
2004	0	223	1084	0.206	0	NA	0	0	0	0
2005	0	225	1075	0.209	0	NA	0	0	0	0
2006	0	266	1433	0.186	0	NA	0.195	3.5	0.195	3.5
2007	0	204	1241	0.164	0	NA	0.339	3.4	0.339	3.4
2008	0	149	1103	0.135	0	NA	0	0	0	0
2009	0	101	761	0.133	0	NA	0	0	0	0
2010	0	59	492	0.12	0	NA	0	0	0	0
2011	0	85	435	0.195	0	NA	0	0	0	0
2012	0	83	445	0.187	0	NA	0	0	0	0
2013	0	175	470	0.372	0	NA	0	0	0	0
2014	0	97	409	0.237	0	NA	0	0	0	0
2015	0	74	361	0.205	0	NA	0	0	0	0
2016	0	134	737	0.182	0	NA	0	0	0	0
2017	0	111	598	0.186	0	NA	0	0	0	0
2018	0	129	513	0.251	0	NA	0	0	0	0
2019	0	73	323	0.226	0	NA	0	0	0	0
2020	0	51	230	0.222	0	NA	0	0	0	0
2021	0	37	162	0.228	0	NA	0	0	0	0