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Revised Stock Boundaries for False Killer Whales (*Pseudorca crassidens*) in Hawaiian Waters

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National Oceanic and Atmospheric Administration
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ABSTRACT

Three populations of false killer whales (*Pseudorca crassidens*) have been identified in the U.S. Exclusive Economic Zone of the Hawaiian Archipelago (Hawaiian EEZ): 1) a main Hawaiian Islands (MHI) insular population, 2) a pelagic population, and 3) a Northwestern Hawaiian Islands (NWHI) population. Spatially-explicit stock boundaries are needed to assess and manage each population. New data, primarily satellite telemetry data, were collected that indicate the existing stock boundaries should be refined. These data were used by the False Killer Whale Stock Boundary Revision Working Group to establish revised, scientifically-defensible stock boundaries that appropriately reflect uncertainty and are robust to routine inputs from ongoing data collection. For each stock, several stock boundary options were identified by the Working Group and reviewed by the Pacific Scientific Review Group before the revised stock boundaries were finalized. The MHI insular stock boundary was changed from a uniform 140-km radius around the MHI to a minimum convex polygon bounded around a 72-km radius of the MHI, resulting in a boundary shape that reflects greater offshore use in the leeward portion of the MHI. While the wide-ranging pelagic stock continues to be assessed within the Hawaiian EEZ, the inner stock boundary was reduced from a 40-km to an 11-km radius around the MHI, a result of individuals occurring closer to shore than previously observed. The NWHI stock boundary largely remained the area of the Papahānaumokuākea Marine National Monument extended to include a 50-nmi radius around Kaua‘i, although 2 vertices were removed to widen the eastern portion, accounting for movement outside of the existing boundary. The following report summarizes the stock boundary revision process for the 3 false killer populations. Additionally, because the stock boundary placement affects the line-transect abundance estimates of the pelagic and NWHI stocks and the proration of false killer whale bycatch, the report also provides updated abundance estimates for pelagic and NWHI false killer whales and outlines a revised approach for bycatch proration.

CONTENTS

INTRODUCTION AND BACKGROUND

Three populations of false killer whales (*Pseudorca crassidens*) have been identified in the U.S. Exclusive Economic Zone of the Hawaiian Archipelago (Hawaiian EEZ) based on genetic, photo-identification, and movement data (Chivers et al., 2007, 2010; Baird et al., 2008, 2010, 2013; Martien et al., 2014). The main Hawaiian Islands (MHI) insular and pelagic populations have been recognized by the National Marine Fisheries Service (NMFS) as management stocks since 2008 (Carretta et al., 2009), while the island-associated Northwestern Hawaiian Islands (NWHI) population was established as a management stock in 2012 (Carretta et al., 2013). Spatially-explicit stock boundaries are needed for each of the populations for various reasons related to NMFS stock assessment and management. The current boundaries of each of the three stocks (Fig. 1) were based on the locations of available sighting, biopsy sample, and satellite telemetry data (Forney et al., 2010, Carretta et al., 2013). The MHI insular stock was considered to occur no more than 140 km from the MHI, with waters 40-140 km from shore defined as an overlap zone with the pelagic stock. Although assessment of the pelagic stock is focused within the Hawaiian EEZ, the population is known to occur outside this boundary (Chivers et al., 2010). The NWHI stock boundary was defined as the area of the Papahānaumokuākea Marine National Monument (PMNM) extended to include a 50-nmi radius (the radius of the PMNM) around Kaua‘i.

Since the existing false killer whale stock boundaries were established, additional data have become available that indicate the boundaries should be refined. These data are predominantly satellite telemetry data collected by the Cascadia Research Collective (CRC) and the Pacific Islands Fisheries Science Center (PIFSC) (Table 1), although recent CRC sighting data and photo-identification analyses are also relevant. At a general level, the full set of available telemetry data suggest that the MHI stock boundary could be contracted along the windward sides of the MHI, the pelagic stock inner boundary could be moved closer to shore, and the eastern portion of the NWHI stock boundary could be widened latitudinally (Fig. 2). However, considerable uncertainty exists in aspects of these data for each of the stocks, and potential stock boundary revisions should be made in light of this uncertainty. Although NMFS has initiated a process for systematically examining a wide range of data types that may inform stock delineation (Martien et al. 2015), there are not currently guidelines for establishing associated spatially-explicit stock boundaries.

In the absence of formalized guidelines for defining marine mammal stock boundaries, a working group comprising the authors of this report was formed to revise the existing boundaries of the MHI insular, pelagic, and NWHI false killer whale stocks. The objective of the False Killer Whale Stock Boundary Revision Working Group (hereafter referred to as the Working Group) was to establish scientifically-defensible stock boundaries that appropriately reflect uncertainty, such that the revised boundaries are robust to routine inputs from ongoing data collection and would require revision less frequently. The Working Group convened on several occasions between April and October 2014. Stock boundary options identified by the Working Group were presented to members of the Pacific Scientific Review Group (PSRG) via webinar on 27 October 2014, and a final Working Group webinar was subsequently held to consider PSRG input and finalize the revised stock boundaries. The purpose of this report is to summarize the outcome of the stock boundary revision process for the MHI insular, pelagic, and NWHI false killer whale stocks. Additionally, because the line-transect abundance estimates used to assess and manage the pelagic and NWHI stocks depend on the location and area of the stock boundaries (Bradford et al., 2014), updated abundance estimates based on the revised stock boundaries are also included in this report. Finally, because the revised stock boundary placement affects the proration of false killer whale bycatch, the report will summarize a revised approach for bycatch proration.

DATA PROCESSING AND PRESENTATION

As indicated, most of the data used by the Working Group for the false killer whale stock boundary revision effort were satellite telemetry data collected primarily by CRC and secondarily by PIFSC. To a lesser degree, CRC sighting data and photo-identification analysis results also contributed to the revision process. The methods used to collect these sighting, photo-identification, and telemetry data have previously been detailed by Baird et al. (2008, 2010, 2012, 2013) and will not be covered here. Consistent with Baird et al. (2010, 2012), all newly-collected telemetry data made available to the Working Group were filtered using the Douglas Argos Filter (DAF) version 8.50 (Douglas et al., 2012). For many of the spatial analyses and representations prepared by the Working Group, all locations that passed the DAF were used. However, some of the satellite tracks from each stock represent individuals that were tagged in the same group. As individual false killer whales often remain affiliated for extended periods of time, there is pseudoreplication in the telemetry data sets (Baird et al., 2012). Further, some of the telemetry locations that remain after applying the DAF are not associated with an estimate of accuracy. As specified below, some of the data analyses considered by the Working Group required further filtering of the locations to minimize pseudoreplication and remove locations without an estimate of accuracy. Bathymetry sources for the telemetry data and spatial summaries by depth were the 50-m resolution multibeam synthesis model from the Hawaii Mapping Research Group[1] and, when 50-m resolution data were not available, either the 90-m resolution coastal[2] or coarser-scale global[3] relief models from the National Centers for Environmental Information. All spatial summaries and visualizations used by the Working Group were made in ArcGIS version 10.1 (ESRI, Redlands, CA) unless otherwise noted. Finally, a consistent color scheme is maintained on figures in this report, with locations and boundaries associated with the MHI insular, pelagic, and NWHI stocks shown in shades of red, blue, and green, respectively.

[1] Available at: **http://www.soest.hawaii.edu/HMRG/Multibeam/index.php**
[2] Available at: **http://www.ngdc.noaa.gov/mgg/coastal/coastal.html**
[3] Available at: **http://www.ngdc.noaa.gov/mgg/global/**

MHI INSULAR STOCK BOUNDARY

MHI insular false killer whales are known to associate preferentially in 3 social groups (or clusters) referred to as Clusters 1, 2, and 3 (Baird et al., 2012). Of the 31 MHI insular individuals satellite-tagged through 2013 (with some tags still transmitting in 2014; Table 1), 23 (74.2%) were assigned to Cluster 1 and 8 (25.8%) were assigned to Cluster 3. To date, no individuals in Cluster 2 have been satellite-tagged. All telemetry locations from Clusters 1 and 3 are within the existing MHI insular false killer whale stock boundary (Fig. 3). However, there is less offshore movement on the windward (northeast) sides of the islands than on the leeward (southwest) sides. Specifically, the maximum distance from shore of a windward location is 51.4 km, while the maximum distance from shore of a leeward location is 114.9 km. The telemetry data through 2010 were previously analyzed to determine high-use areas by cluster and revealed that Clusters 1 and 3 differ in their spatial use, although both clusters share a common high-use area (or "hotspot") off the northern coasts of Moloka'i and Maui (Baird et al., 2012). Given the lack of telemetry data, the high-use areas of Cluster 2 are unknown. However, a comparison of the observed vs. expected number of sightings by cluster for each island revealed that Cluster 2 individuals are seen more often than expected off Hawai'i Island and less often than expected off O'ahu and Maui (Baird et al., 2012). The observed sighting frequencies of Clusters 1 and 3 did not differ from expected values. The differences in sighting frequencies by island between Cluster 2 and Clusters 1 and 3 suggest that the spatial use of Cluster 2 may also differ from the other clusters.

The Working Group first considered whether the available MHI insular false killer whale telemetry data could be used to quantitatively derive a stock boundary. Common home-range metrics (e.g., Börger et al., 2006) that represent the spatial extent (minimum convex polygon; MCP) and density (kernel density estimator; KDE) of available locations were used to create potential MHI stock boundaries (Fig. 4). The KDE was based on independent tracks and was established using the 'adehabitatHR' package (Calenge, 2006) within the program R (R Development Core Team, 2014). The Working Group agreed that neither metric produced satisfactory results. The MCP was too close to shore in some areas (e.g., the east side of Hawai'i Island; Fig. 4A), while the KDE produced a complex shape and required choosing an appropriate probability contour (Fig. 4B). More importantly, in addition to the lack of telemetry data from Cluster 2 and the limited data from Cluster 3, there is also a seasonal bias in the available locations. Of the 11,280 locations, 9,989 (88.6%) are from August through January, while 1,291 (11.4%) are from February through July. Thus, the Working Group agreed that an empirically-defined boundary is premature, as it would presumably change with the addition of data from under-represented clusters and seasons.

The Working Group concurred that the revised MHI insular false killer whale stock boundary needs to: 1) reflect the absence of telemetry locations throughout much of the windward extent of the existing stock boundary and the greater offshore use of the leeward portion, 2) account for the false killer whale "hotspot" off northern Moloka'i and Maui, and 3) incorporate uncertainty in the spatial use of Clusters 2 and 3 and in the seasonality of use by all clusters throughout the MHI. The Working Group initially considered establishing a windward-leeward axis along the MHI and then bounding the MHI by an appropriate windward and leeward radial distance.

However, the Working Group determined that defining a singular windward-leeward axis would be imprecise and subjective. The Working Group then explored bounding a radius around the MHI by an MCP and found that, in combination with an added buffer for uncertainty, the approach produces a desirable shape meeting the established boundary criteria. The resulting shape is an outcome of MCP geometry and the concavity of the leeward curve of the MHI, and matches the spatial use of MHI insular false killer whales without requiring an exact specification of windward and leeward waters. The radius should be at least 52 km (rounded upward from the 51.4 km maximum recorded windward distance from shore), but the Working Group agreed that the shape could be adjusted to appropriately account for uncertainty with one of two options (Fig. 5). The first option focuses the uncertainty buffer in the false killer whale "hotspot" by creating a 30-km point buffer around the maximum windward location and joining this buffer to the 52-km radius around the MHI for inclusion in the MCP (Fig. 5A). The second option distributes the uncertainty buffer more uniformly by adding a 20-km buffer to the initial 52-km radius around the MHI and then bounding the MCP around this 72-km radius (Fig. 5B).

The Working Group was unable to determine an empirical metric for establishing the distances of the uncertainty buffers in the two options. The Working Group considered using differences in the available telemetry data between Clusters 1 and 3 to inform appropriate uncertainty buffer distances, but found that while the cluster-specific data differ in their east-west extent, they overlap in distances from shore (Fig. 3). Likewise, the sighting data were examined to see if Cluster 2 has been sighted offshore of the other clusters by some definable distance, but this was found not to be the case (RWB, unpublished data). Ultimately, the Working Group chose 30 and 20 km for the point and radial buffers, respectively, because these distances were deemed sufficient by all members. Finally, the Working Group agreed that given the lack of Cluster 2 telemetry data, and the possibility that Cluster 2 individuals may not preferentially use the "hotspot" like the other clusters, the 72-km MHI radius MCP was the most suitable revised MHI insular stock boundary option (Fig. 6).

PELAGIC STOCK BOUNDARY

Pelagic false killer whales were previously thought not to occur within 40 km of the MHI (Fig. 1), but a group was encountered 22.8 km offshore of Hawaiʻi Island in October 2013, and three individuals were satellite tagged (RWB, unpublished data). The closest distance from shore of a received location with an estimate of accuracy was 11.4 km (with an estimated error of 250–500 m). Thus, pelagic false killer whales can occur in waters closer to shore than previously considered. However, of the 46 false killer whale sightings made within 50 km of the MHI, only 2 (4.3%) are known to be of the pelagic stock (with 39 of the remaining sightings being of MHI insular, 2 of NWHI, and 2 of unknown stocks; RWB, unpublished data), suggesting such nearshore occurrence is infrequent. The deliberation of the Working Group with regards to the pelagic stock centered on if or where there should be an inner stock boundary.

To address this question, the frequency of nearshore use was evaluated, with nearshore defined for this purpose as waters less than 2,000 m in depth or within 100 km of shore. Only locations of known accuracy (n = 1,147) from independent tracks (n = 4) were used. The resulting histograms revealed that pelagic false killer whales select more strongly for depth than distance from shore (Fig. 7), with only 64 (5.7%) of the 1,114 locations with available depths occurring in waters less than 2,000 m (Figs. 7A–B), while 278 (24.2%) of the 1,147 locations were within 100 km of shore (Figs. 7C–D). If the data from individuals tagged off Hawaiʻi Island (n = 2) are separated from the data associated with individuals tagged in the NWHI (n = 2), the depth signal is even stronger around the MHI, with only 1 (0.3%) of the 341 MHI locations within 2,000-m depth (Figs. 8A–B), while 63 (8.2%) of the 773 NWHI locations were within 2,000-m depth (Figs. 8C–D).

The Working Group agreed that the satellite telemetry data do not support establishing a pelagic inner stock boundary around the NWHI, as pelagic false killer whales clearly span and pass through the NWHI (Fig. 2A) and do not avoid nearshore NWHI waters (Fig. 8B). However, the telemetry data do indicate that an inner stock boundary around the MHI is appropriate. Although pelagic false killer whales appear to select more strongly for depth when using MHI waters (Fig. 8A), the Working Group concurred that an inner boundary based solely on a depth contour was not ideal because of the complexity of the resulting shape. The Working Group considered the possibility of using a depth-based distance from shore inner boundary that would be associated with some low probability of occurrence inshore of that boundary. For example, only 5 (1.5%) of the 341 MHI locations are within 25 km from shore, where 70.8% of the waters are less than 2,000 m and thus unlikely to be used by pelagic false killer whales (Fig. 9). Specifying such a boundary would require quantifying the spatial overlap in depth and distance from shore and then calculating an associated probability of false killer whale occurrence in that area, which was deemed problematic given the small telemetry dataset around a limited portion of the MHI. Further, the Working Group agreed that the inner stock boundary should not exclude any telemetry locations, as would result from a probabilistic definition of the inner boundary, and should instead include the full extent of the observed range. Therefore, factoring in the accuracy of the most nearshore received location (11.4 km), a pelagic inner stock boundary of 11 km was selected (Fig. 10).

NWHI STOCK BOUNDARY

Little is known about the more recently identified NWHI false killer whale stock. The convenient PMNM-based shape of the existing stock boundary (Fig. 1) reflects the uncertainty in the use and extent of the stock range in the NWHI. The Working Group evaluated new information about NWHI false killer whales and considered refining the radius (width) of the boundary, as well as the eastern and western extents. In terms of widening the boundary, the satellite telemetry data are too sparse to inform a robust new boundary shape. However, the data do indicate that NWHI false killer whales occur on the border and outside of the existing boundary (Fig. 2B). The Working Group first considered expanding the boundary to the maximum distance from the PMNM of a received location (12.2 km) plus a radial buffer to reflect uncertainty. However, because the telemetry data are concentrated in one area of the existing boundary, the Working Group was hesitant to expand the entire boundary uniformly. The Working Group thus agreed that removing two vertices from the existing stock boundary was a sufficient means to accommodate the available satellite locations and incorporate additional uncertainty (Fig. 11).

For the eastern extent, a photo-identification based sighting of NWHI false killer whales was made in April 2013 off Barber's Point, O‘ahu (RWB and T. Cullins, unpublished data), which suggested the stock could range as far east as O‘ahu. The Working Group considered two options for accounting for this sighting in the revised stock boundary (Fig. 12). First, a 20-km point buffer around the sighting location was joined to the existing boundary by an MCP (Fig. 12A). However, buffering the sighting location by this distance produced the undesirable result of including only part of an island in the putative stock boundary. Thus, for the second option, a 21-km radius around O‘ahu (half the distance between O‘ahu and Moloka‘i) was joined to the existing boundary by an MCP (Fig. 12B). Ultimately, the Working Group decided against an eastward extension of the existing NWHI stock boundary. Sighting effort in the nearshore waters of southwest O‘ahu is relatively high because regular trips are made in this area by eco-tour operators. Of the 67 false killer whale sightings made in this region through 2014, only 1 (1.5%) is known to be of the NWHI stock (with 65 and 1 of the remaining sightings of the MHI insular and unknown stocks, respectively; RWB, unpublished data). Therefore, the 2013 sighting of NWHI false killer whales near O‘ahu was regarded as a rare event that did not need to be reflected in their stock range (Quinn and Brodeur, 1991).

There are no satellite telemetry data or sightings to inform refining the western extent of the NWHI false killer whale stock boundary. Given the different oceanographic regime and isolation of the northern portion of the NWHI (Polovina et al., 2008), the Working Group considered the possibility that this region may not be used by NWHI false killer whales. For this purpose, the depth distribution of available satellite locations was compared to the bathymetry of the western portion of the NWHI stock boundary. Only locations of known accuracy (n = 844) from independent tracks (n = 4) were included. The resulting histogram revealed that there is a peak in the depth distribution below 1,200 m and that NWHI false killer whales essentially do not use waters deeper than 5,000 m (Fig. 13). An evaluation of the NWHI bathymetry in light of these findings indicated that there is a wide channel of deep (> 5,000 m) water west of Lisianski Island (Fig. 14). The Working Group contemplated truncating the western extent of the existing NWHI stock boundary to reflect that the deep water channel and reduced expanse of shallow (< 1,200 m) water may be unfavorable conditions for NWHI false killer whales. However, there are available acoustic data that could be used to determine if NWHI false killer whales are present in the western portion of the existing stock boundary. Specifically, an acoustic classifier for differentiating Hawai‘i false killer whale stocks is currently being developed and tested (Y. Barkley, unpublished data) so that archived and future acoustic false killer whale detections can be identified to stock. Of the 21 towed-array detections of false killer whales made during 2010 and 2013 PIFSC research cruises, five are in a region of interest for NWHI stock boundary evaluation as are 42 detections from the Pearl and Hermes bottom-mounted, high-frequency acoustic recording package (PIFSC, unpublished data) (Fig. 14). Given the substantial uncertainty regarding NWHI false killer whale use of the northern NWHI and the pending acoustic analyses that could clarify this issue, the Working Group agreed that the western extent of the existing NWHI stock boundary should remain unchanged. Overall, the widening of the existing boundary around the available telemetry data (Fig. 11) is the only change reflected in the revised NWHI stock boundary (Fig. 15).

PELAGIC AND NWHI STOCK ABUNDANCE

The 2010 abundance of the pelagic and NWHI stocks (Bradford et al., 2014) was estimated using line-transect methodology (Buckland et al., 2001). Thus, a spatially-explicit stock boundary was required for two purposes: 1) determining the distance of survey effort in that area, which is needed to compute the stock encounter rate, and 2) determining the area of the stock range, which is needed to compute abundance from density. The existing 2010 pelagic and NWHI false killer whale abundance estimates were recalculated based on the revised stock boundaries presented here using the same methods described in Bradford et al. (2014). For the pelagic stock, the stock boundary area increased to 2,430,381 km^2, which included 469 km of additional survey effort. For the NWHI stock, the stock boundary area increased to 449,801 km^2, which did not include any additional survey effort. Using the revised stock boundaries, the 2010 abundance of pelagic stock false killer whales was estimated to be 1,540 (CV = 0.67; 95% CI = 470–5,047, where CV is the coefficient of variation and 95% CI is the lognormal 95% confidence interval). The 2010 abundance of NWHI stock false killer whales was estimated to be 617 (CV = 1.11; 95% CI = 107–3,554). A summary of the stock-specific estimates of the line-transect parameters, density, and abundance is shown in Table 2. The pelagic stock encounter rate estimate decreased proportionally more than the stock area increased such that there was a slight net decrease in the estimate of abundance. However, the estimate of NWHI stock abundance increased because of the influence of the increase in stock area. Note that the abundance of the MHI stock was estimated using mark-recapture methods (Oleson et al., 2010) and is therefore unaffected by the by the revised MHI stock boundary.

BYCATCH STOCK PRORATION

Estimation of false killer whale bycatch in the Hawai‘i-based longline fisheries requires prorating estimated false killer whale takes to stock, as observer data input into the bycatch estimation are generally of unknown stock identity. When the stock identity of take is unknown, the Guidelines for Assessing Marine Mammal Stocks advise to either: 1) apply the take to all affected stocks, or 2) prorate the take based on the relative abundance of affected stocks (NMFS, 2005). The formalized method for prorating takes of Hawaiian false killer whales to stock only accounts for the existing overlap zone between the MHI insular and pelagic stocks (Fig. 1) (McCracken, 2010). In that approach, stock density in the overlap zone is modeled using a logistic decay function in which MHI insular and pelagic stock densities change inversely with distance from shore. The estimation framework uses the locations of observed takes (and the associated relative densities) to determine the proportion of total take by stock. For the draft 2014 Stock Assessment Report of the Hawaiian Islands false killer whale stock complex, which incorporated take estimates of the NWHI stock, a modified proration method was used (Carretta et al., 2015). That is, total MHI insular and pelagic stock takes were initially determined using the McCracken (2010) approach. In order to account for takes of the NWHI stock, the initial total two-stock take estimates were apportioned to all stock areas within the Hawaiian EEZ, including the two- and three-way overlap zones (Fig. 1), based on relative fishing effort (number of hooks). The take in each area was then prorated to stock based on the relative density of each stock within that area. Total false killer whale density was considered additive in each area, with the exception of areas of MHI insular and pelagic stock overlap, where the effective relative densities of those stocks were based on the McCracken (2010) density relationship.

The revised bycatch proration method simplifies the approach implemented in 2014. Specifically, total estimated false killer whale takes within the Hawaiian EEZ will be apportioned to each stock and stock overlap area outside of the Longline Exclusion Zone (Fig. 16) based on the relative fishing effort (number of sets) within that area. These takes will then be prorated to stock according to the ratio of stock densities in those areas. The approach will assume that the total density of false killer whales in overlap zones is additive, even between the MHI insular and pelagic stocks (i.e., there is no complex density relationship). The revised density estimates of the pelagic and NWHI false killer whale stocks were previously summarized (Table 2). A revised estimate of MHI insular stock density is 0.09 individuals 100 km^{-2}, which was determined by dividing the best available mark-recapture abundance estimate (151 individuals; Oleson et al., 2010) by the area of the revised stock boundary (172,268 km^2; Fig. 6).

CONCLUSIONS

The Working Group acknowledges that the stock boundaries presented herein were not empirically derived, but they were determined using the best available scientific information in the absence of guidelines for establishing stock boundaries. There is still considerable uncertainty associated with the boundaries of each of the stocks. Thus, the primary objective of the Working Group was to establish revised stock boundaries that are robust to the modest addition of new data, so that annual stock boundary revisions are not needed. However, it is expected that the future collection or analysis of substantial amounts of data will necessitate further stock boundary revision (particularly for the NWHI stock) or could allow stock boundaries to be quantitatively determined (in the case of the MHI insular stock).

The revised false killer whale stock boundaries established here are intended to reflect the full range of each stock and are associated with an average density estimate. Data are currently too limited to pursue stock boundaries that reflect areas of probabilistic occurrence and density. The outlined framework is manageable and appropriate in the context of bycatch estimation for the Hawai‘i-based longline fisheries. However, if false killer whale bycatch from nearshore Hawai‘i state fisheries is eventually estimated, a more complex stock boundary and proration approach may be needed. Hopefully, there will be more false killer whale data available to inform such a process.

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Table 1.--Summary of satellite telemetry data for the MHI insular, pelagic, and NWHI false killer whale stocks collected by either the Cascadia Research Collective (CRC) or the Pacific Islands Fisheries Science Center (PIFSC). Previous tracks are the telemetry data that were used to inform the existing stock boundaries, while current tracks are the telemetry data that were available to the False Killer Whale Stock Boundary Revision Working Group.

Stock	No. (years) of previous tracks	No. (years) of current tracks	No. of current CRC tracks	No. of current PIFSC tracks
MHI	11 (2007-2009)	31 (2007-2014)	31	0
Pelagic	1 (2008)	6 (2008-2014)	4	2
NWHI	2 (2010)	6 (2010-2013)	4	2

Table 2.--Estimates of line-transect parameters, density (individuals 100 km^{-2}), and abundance for false killer whales of the pelagic and the NWHI stocks in 2010 based on the revised stock boundaries. $f(0)$ = the probability density function of the perpendicular detection distances evaluated at zero distance; ESW = the inverse of $f(0)$ and the distance (in km) from the trackline for which as many individuals were detected beyond as were missed within; $E(s)$ = the expected size of false killer whale subgroups; n/L = the subgroup encounter rate (presented in subgroups 100 km^{-1}); and $g(0)$ = the probability of detection on the trackline. The coefficient of variation (CV) is shown for all parameters, and the lognormal 95% confidence interval (CI) is included for the abundance estimates.

Stock	$f(0)$	ESW	CV	$E(s)$	CV	n/L	CV	$g(0)$	CV	Density	Abundance	CV	95% CI
Pelagic	0.43	2.31	0.11	3.11	0.12	0.07	0.60	0.76	0.14	0.06	1,540	0.67	470–5,047
NWHI	0.43	2.31	0.11	3.11	0.12	0.16	1.04	0.76	0.14	0.14	617	1.11	107–3,554

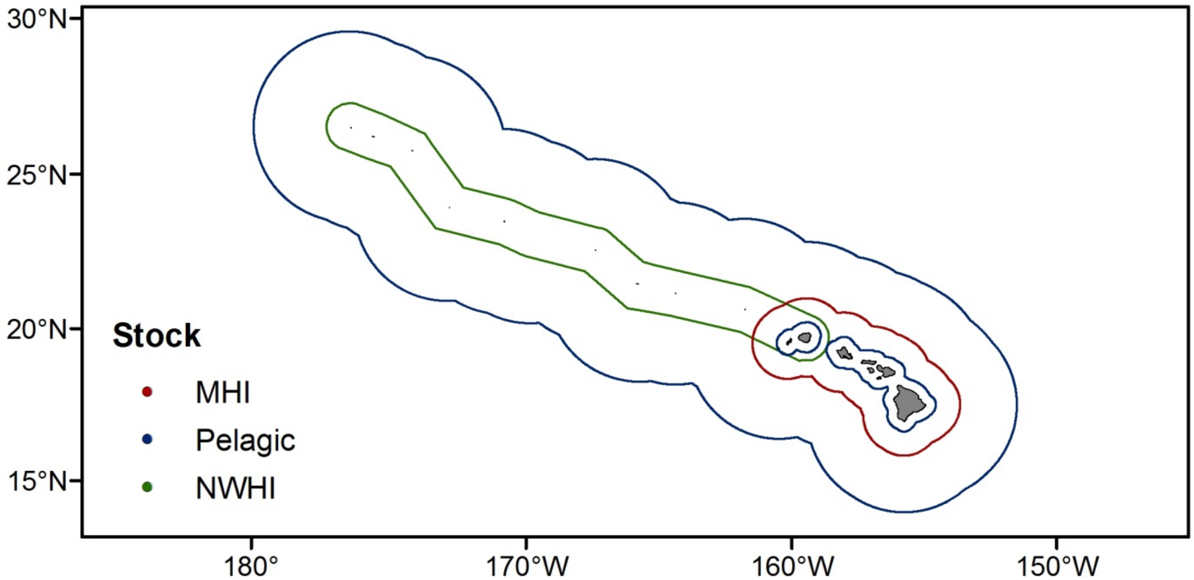

Figure 1.--Existing stock boundaries for the MHI insular, pelagic, and NWHI false killer whale stocks. The pelagic stock is assessed within the Hawaiian EEZ (outer blue line), but does range outside of this boundary. The inner blue line denotes the inner boundary of the pelagic stock near the MHI, such that the area between the inner blue line and red line is an overlap zone between the MHI insular and pelagic stocks. The pelagic and NWHI stocks overlap throughout most of the NWHI stock boundary, except for inside the inner pelagic stock boundary around Kaua‘i and Ni‘ihau. Note that the area within the intersection of the MHI insular and NWHI stock boundaries and outside of the inner pelagic boundary around Kaua‘i and Ni‘ihau is a three-stock overlap zone.

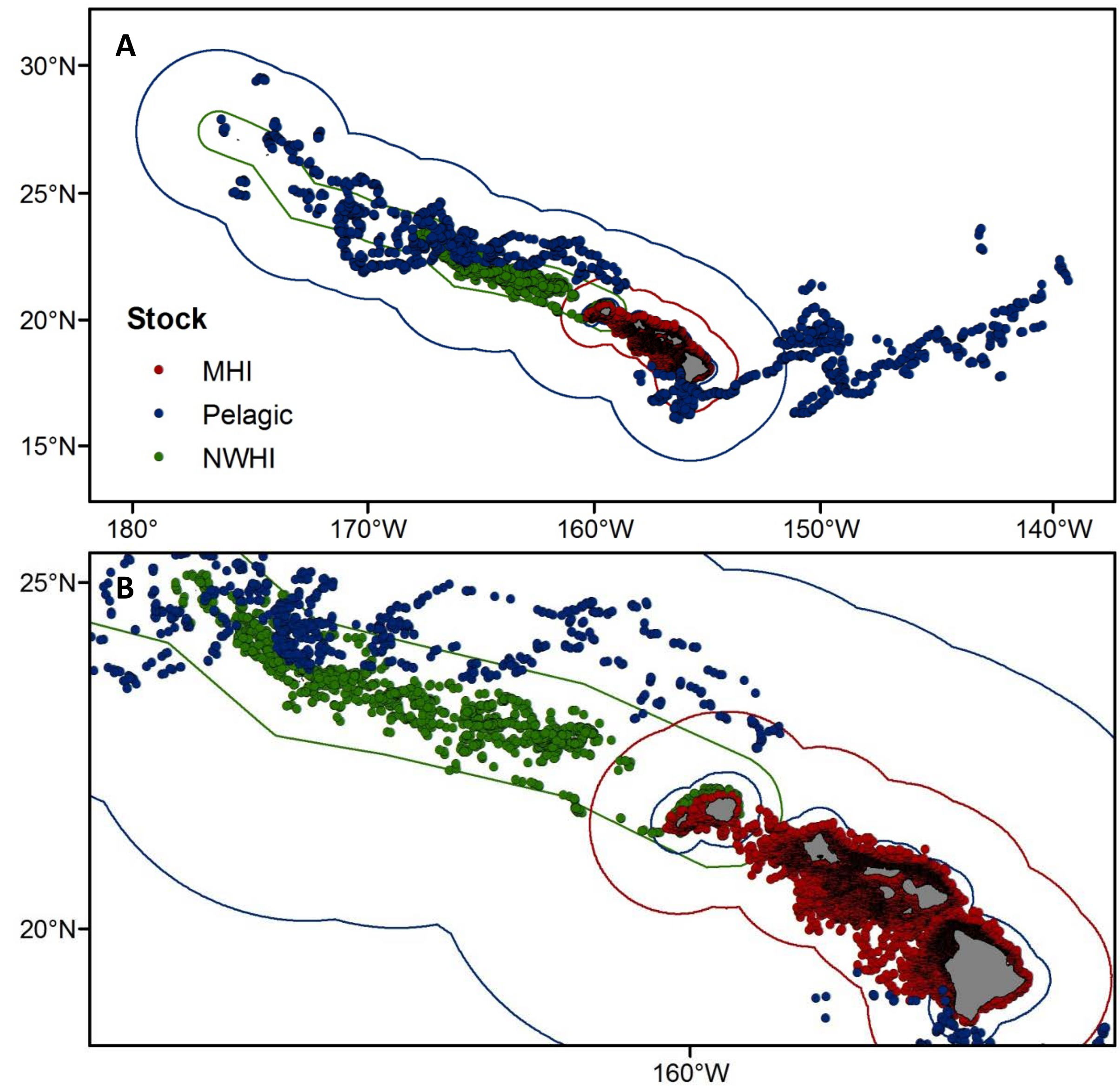

Figure 2.--Existing stock boundaries for the MHI insular, pelagic, and NWHI false killer whale stocks and satellite telemetry data (colored points) available to the False Killer Whale Stock Boundary Revision Working Group. Views of the full extent of the telemetry data (A) and zoomed to the MHI insular and NWHI locations (B) are shown.

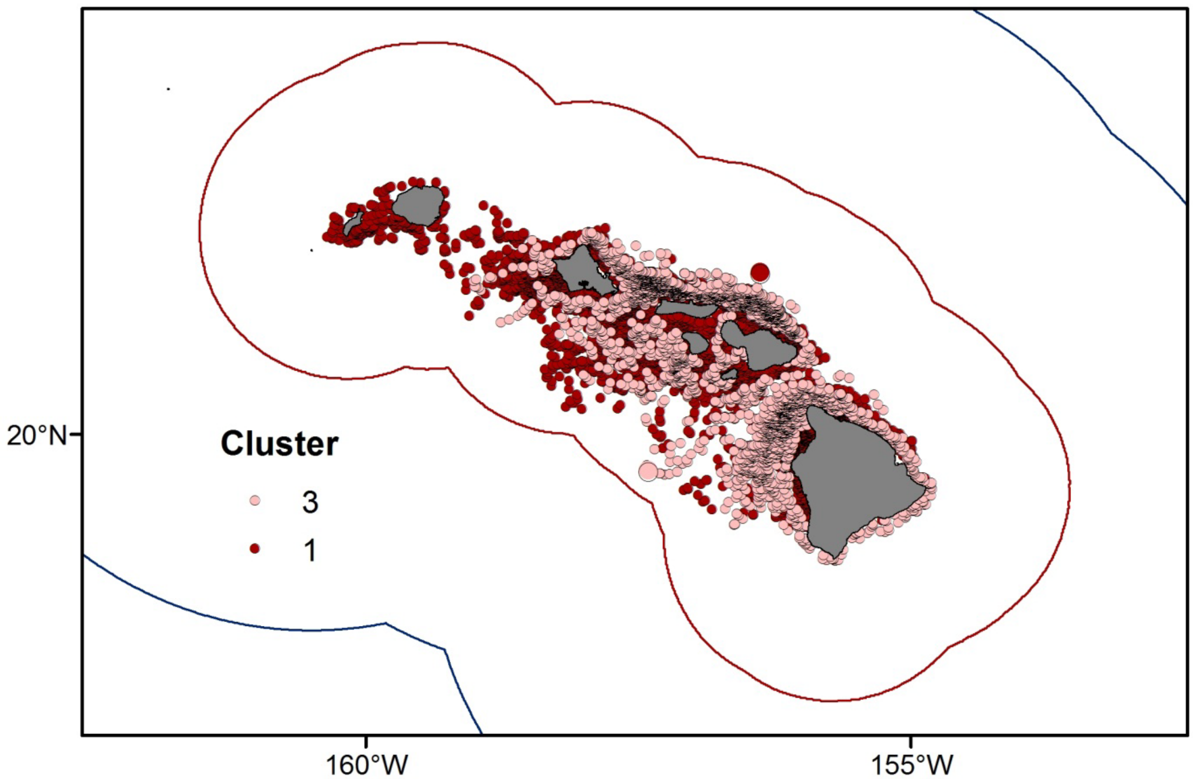

Figure 3.--Satellite telemetry data (red and pink points) for two of the three MHI insular false killer whale social clusters shown relative to the existing MHI insular stock boundary (red line). Enlarged points represent the windward and leeward locations with the maximum distance from shore. The blue line denotes the Hawaiian EEZ.

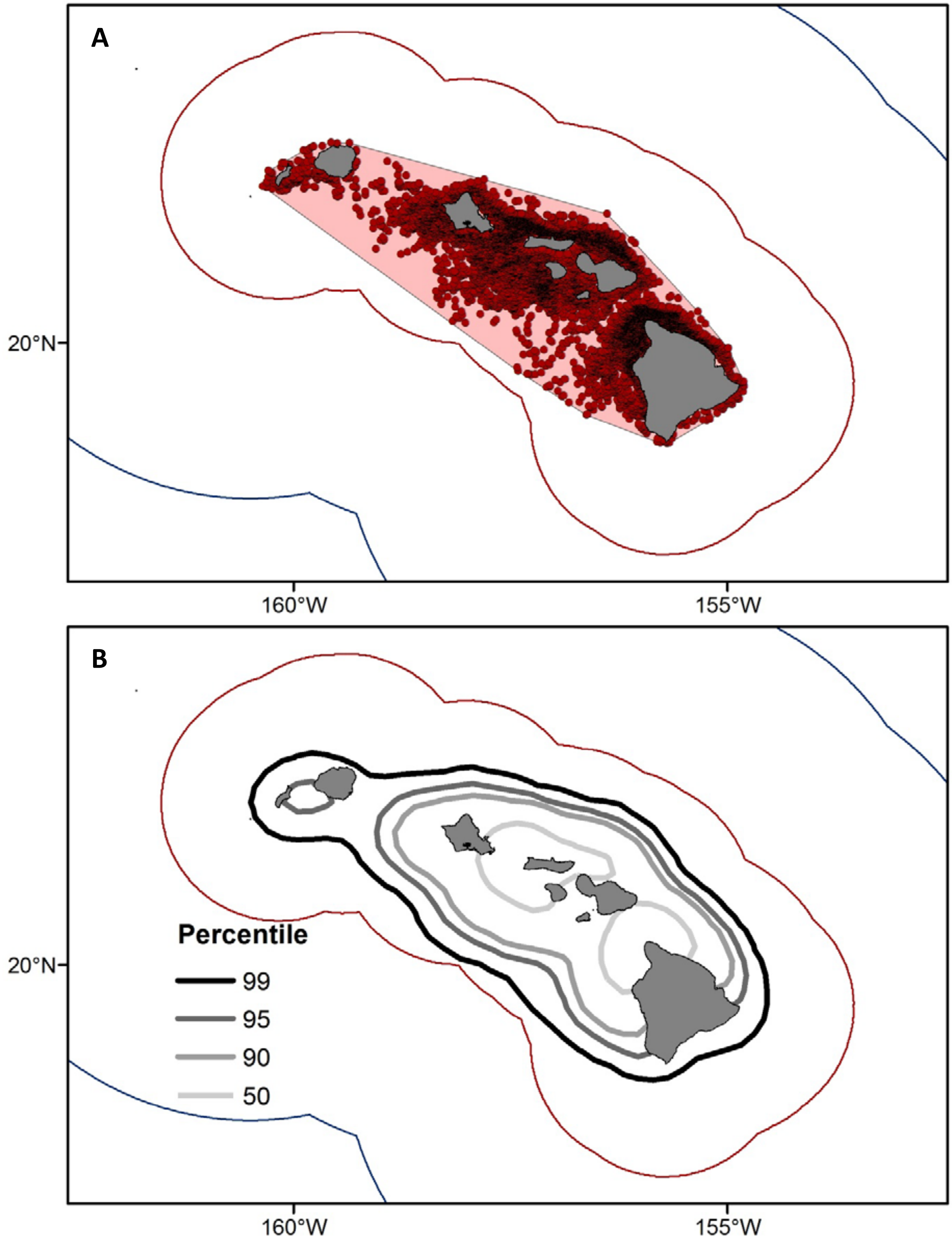

Figure 4.—The MHI insular false killer whale satellite telemetry data (red points) as represented by a minimum convex polygon (pink polygon) (A) and kernel density estimator, with the percentages representing probabilities of spatial use (B), shown relative to the existing MHI insular stock boundary (red line). The blue line denotes the Hawaiian EEZ.

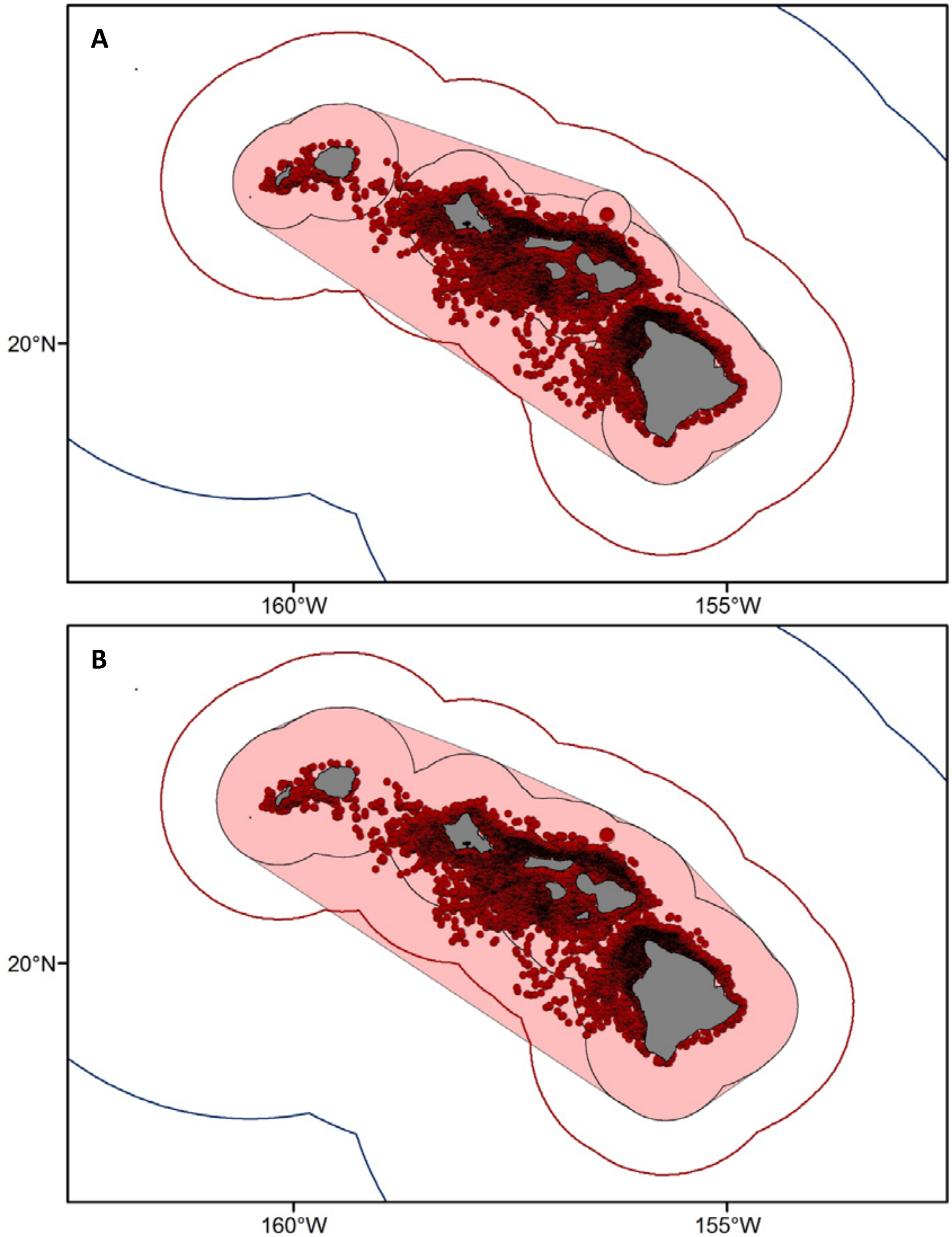

Figure 5.--Revised MHI insular false killer whale stock boundary options considered by the False Killer Whale Stock Boundary Revision Working Group: (A) a minimum convex polygon (MCP) of a 52-km radius around the MHI joined to a 30-km point buffer around the maximum windward location (enlarged point), and (B) an MCP of a 72-km radius (52-km radius plus a 20-km buffer) around the MHI. The buffers bounded by each MCP (pink polygons) are outlined in black. The MHI insular satellite telemetry data (red points) and existing stock boundary (red line) are shown. The blue line denotes the Hawaiian EEZ.

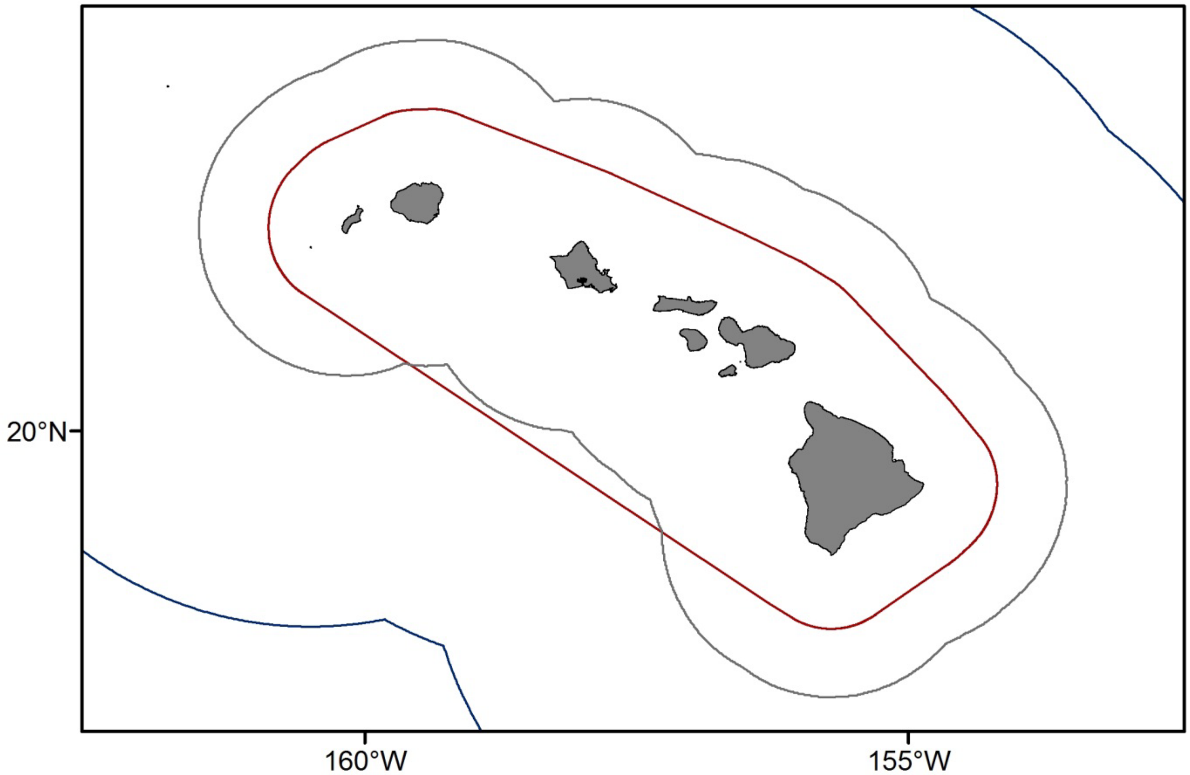

Figure 6.--Revised MHI insular false killer whale stock boundary (red line) with the previous stock boundary shown in gray. The blue line denotes the Hawaiian EEZ.

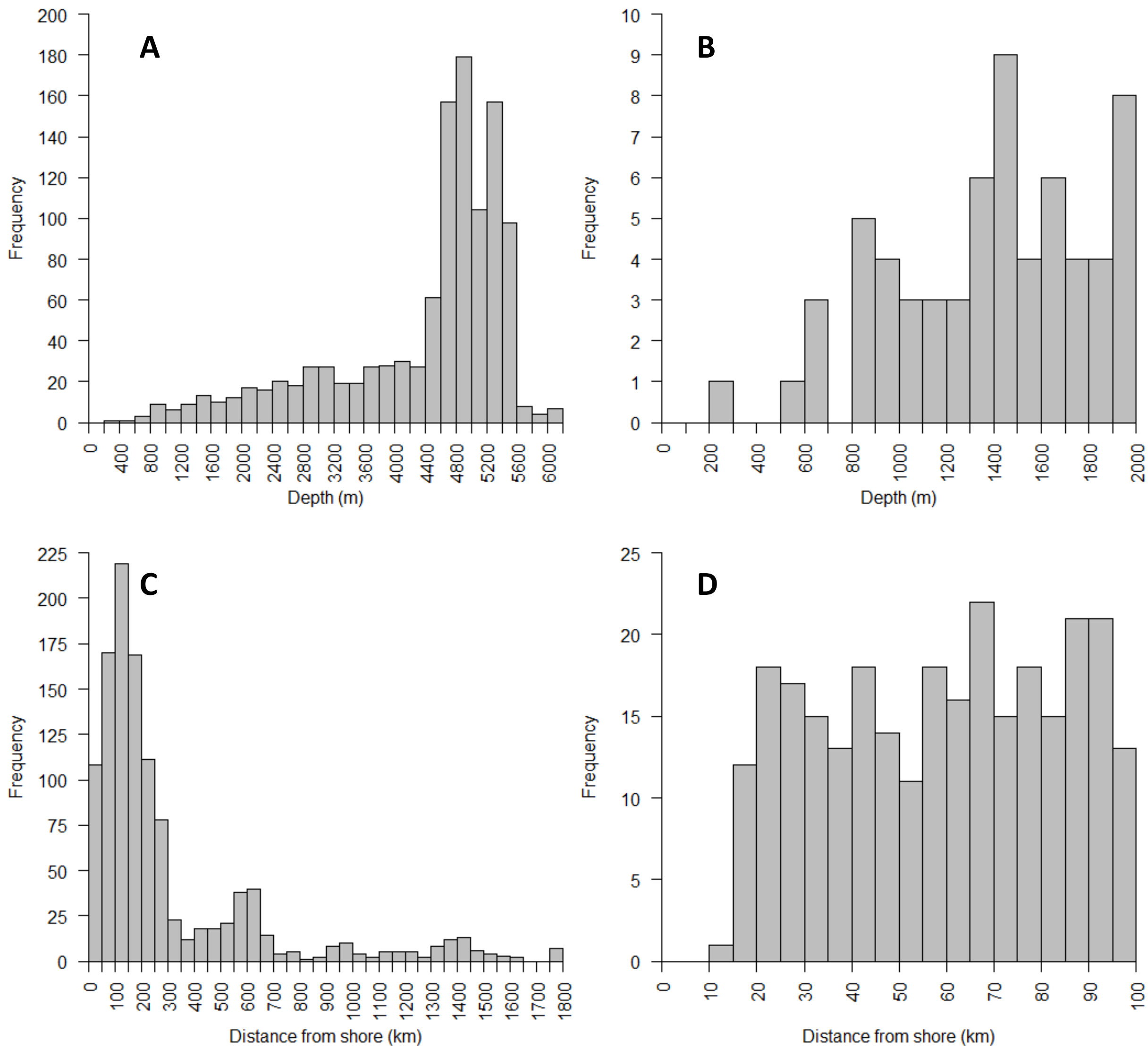

Figure 7.--Frequency of nearshore use of depth, showing all locations (A) and locations in waters less than 2,000 m (B), and distance from shore, showing all locations (C) and locations within 100 km of shore (D), by pelagic false killer whales around the Hawaiian Archipelago. Histograms are based on independent satellite tracks and locations of known accuracy.

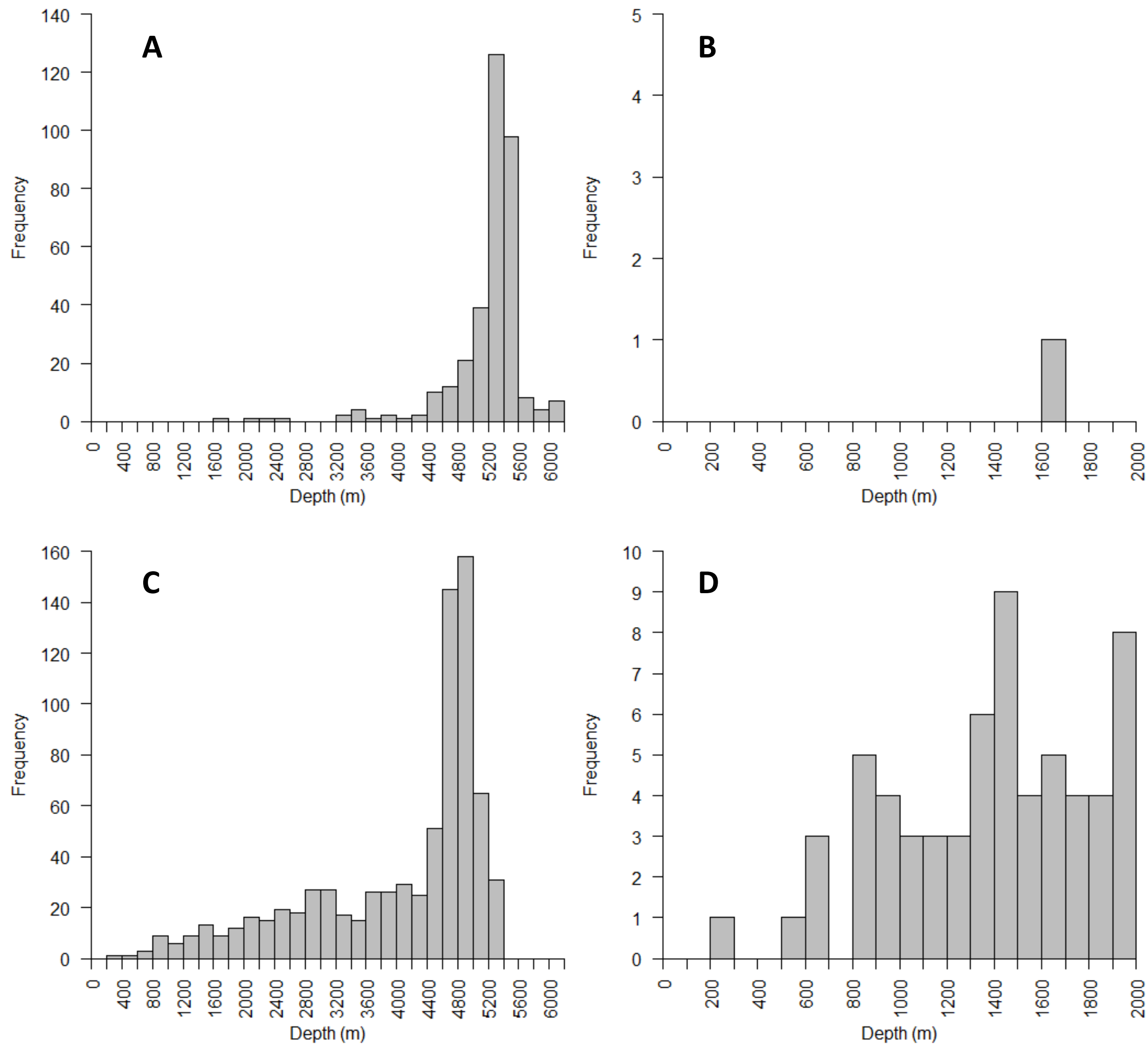

Figure 8.--Frequency of nearshore use of depth by pelagic false killer whales tagged off Hawai‘i Island, showing all locations (A) and locations in waters less than 2,000 m (B), and off the NWHI, showing all locations (C) and locations in waters less than 2,000 m (D). Histograms are based on independent satellite tracks and locations of known accuracy.

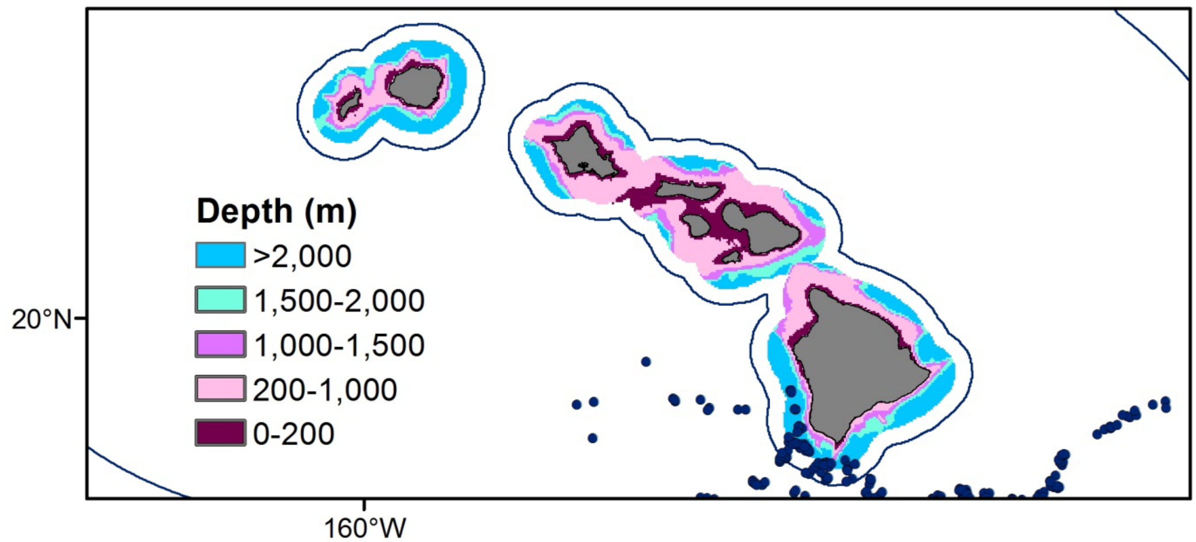

Figure 9.--Classifying depths within 25 km from shore of the MHI to quantify the spatial overlap in depth and distance from shore, which could serve as a basis for estimating the probability of pelagic false killer whale occurrence in that area. This graphic is an example of how a depth-based distance from shore inner stock boundary was considered for pelagic false killer whales. The inner blue line denotes the existing inner boundary of the pelagic stock. A portion of the pelagic satellite telemetry data (blue points) and Hawaiian EEZ (outer blue line) is shown.

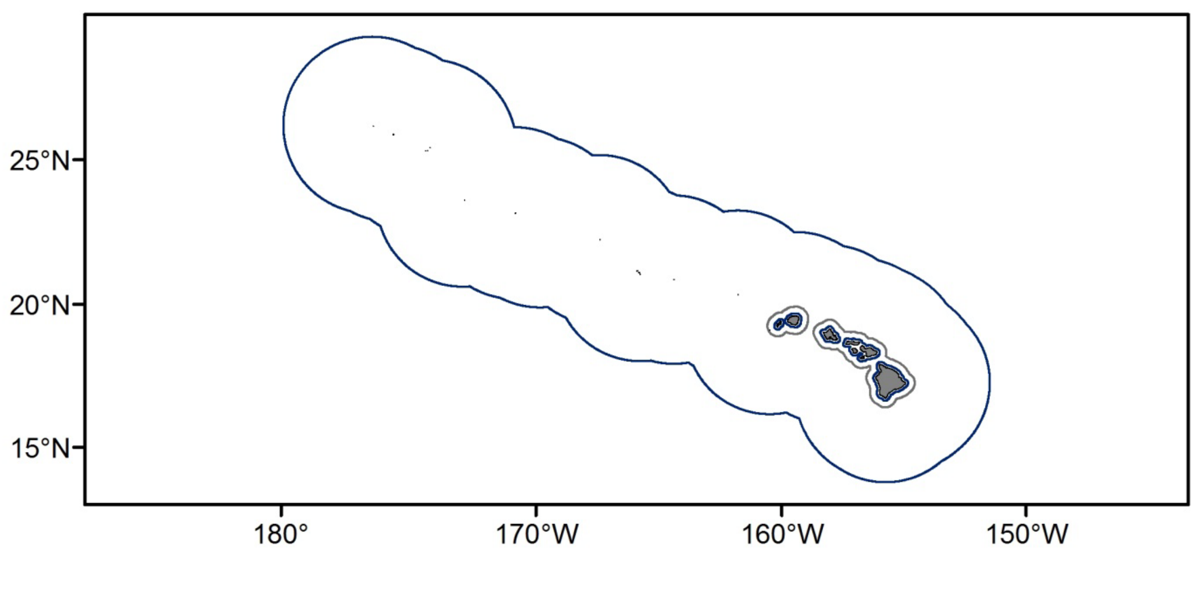

Figure 10.--Revised pelagic false killer whale inner stock boundary (inner blue line) with previous inner boundary shown in gray. The pelagic stock is managed within the Hawaiian EEZ (outer blue line), but does range outside of this boundary.

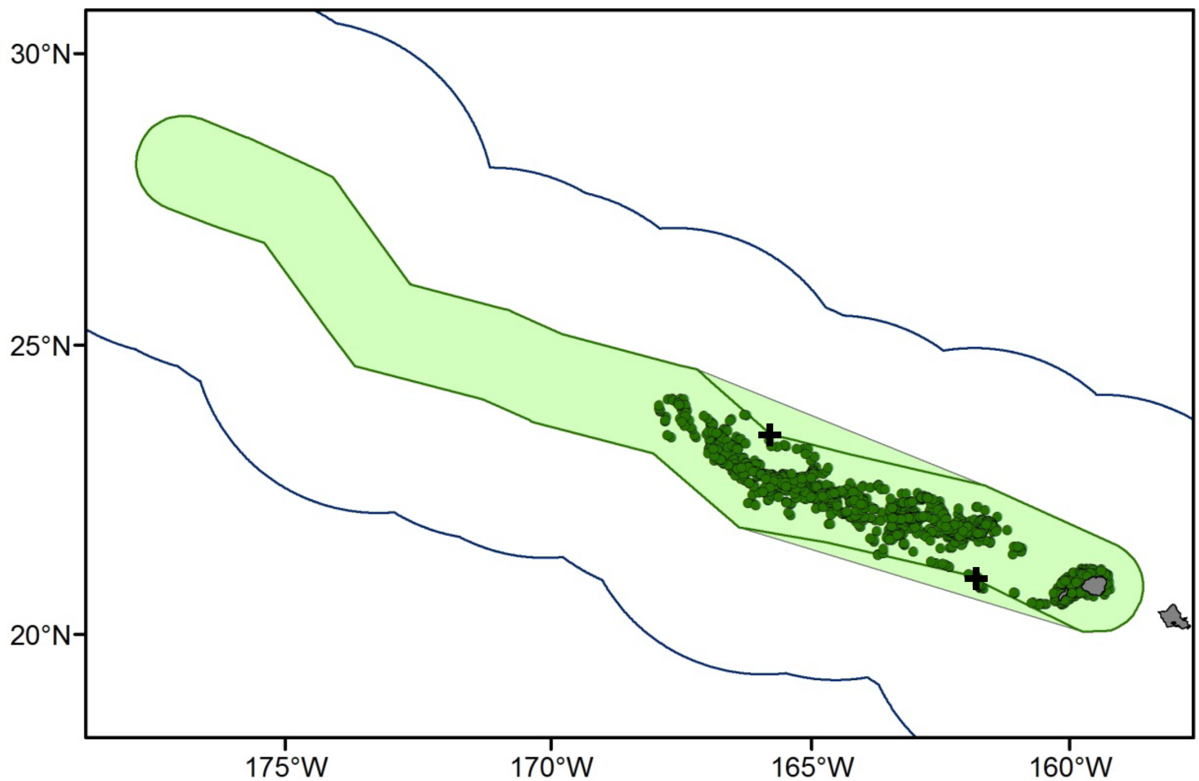

Figure 11.--Widening the NWHI false killer whale stock boundary (light green polygon) by removing two vertices (black crosses) of the existing stock boundary (green line). The green points are the NWHI satellite telemetry data, and the blue line denotes the Hawaiian EEZ.

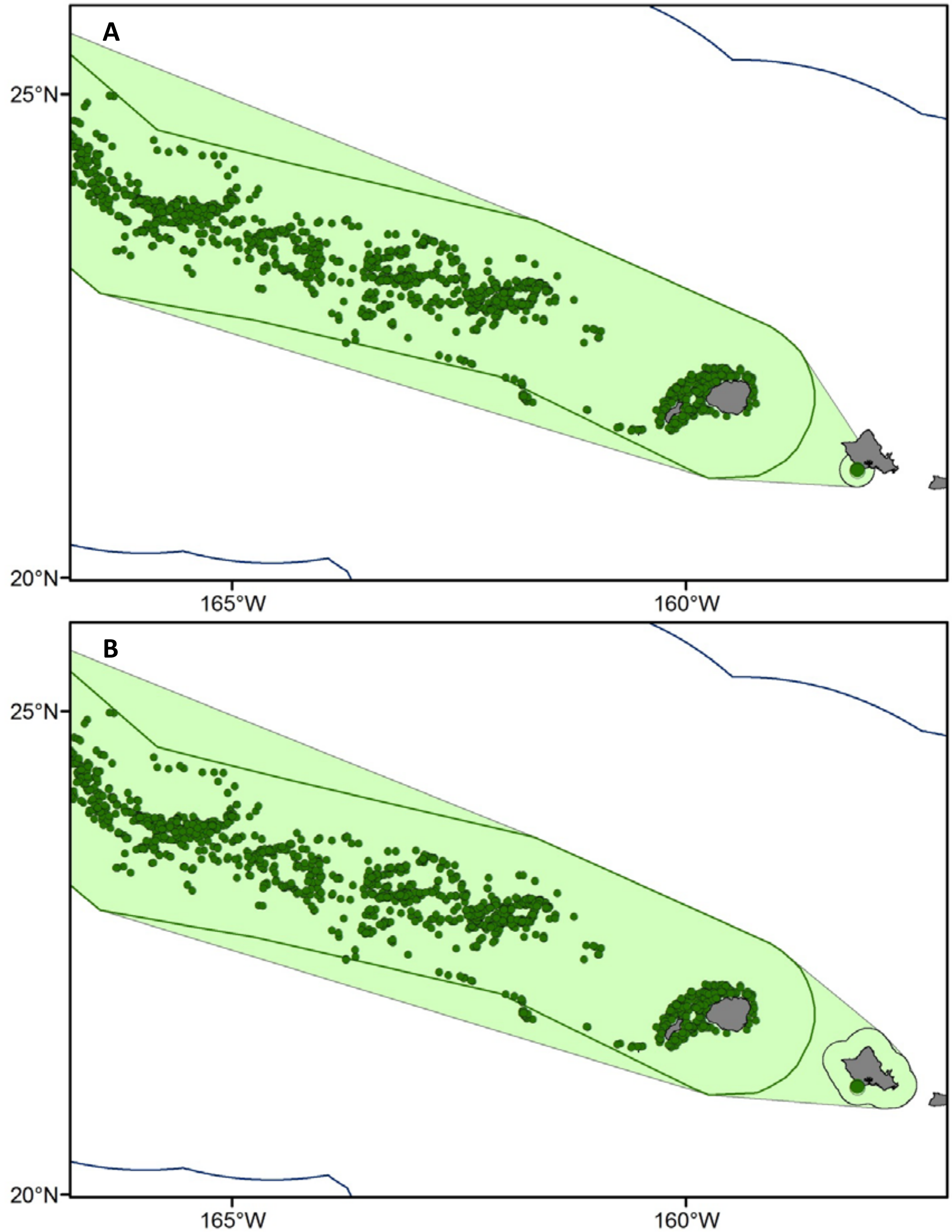

Figure 12.--Two options (light green polygons) for extending the eastward extent of the existing NWHI false killer whale stock boundary (green line) considered by the False Killer Whale Stock Boundary Revision Working Group: (A) a minimum convex polygon (MCP) of the newly widened boundary joined to a 20-km point buffer (black line) around the 2013 O‘ahu sighting (enlarged point), and (B) an MCP of the newly widened boundary joined to a 21-km radius (black line) around O‘ahu. A portion of the NWHI satellite telemetry data (green points) and the Hawaiian EEZ (blue line) are shown.

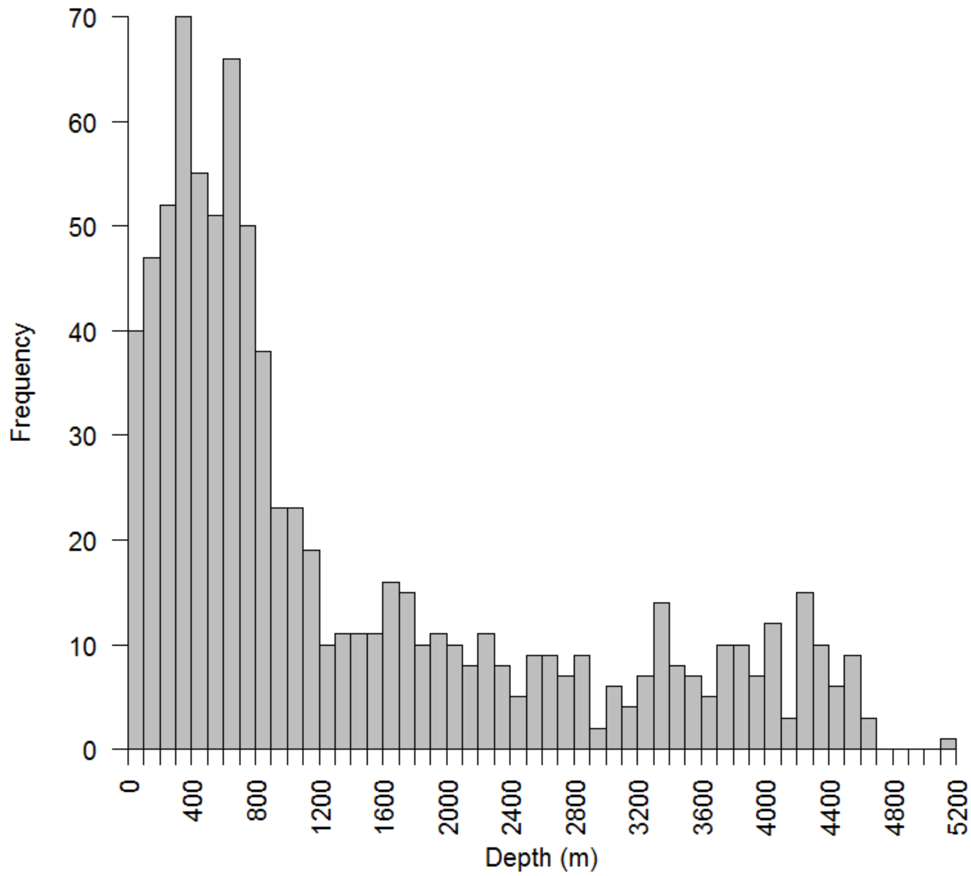

Figure 13.--Frequency of depth use by NWHI false killer whales. Histograms are based on independent satellite tracks and locations of known accuracy.

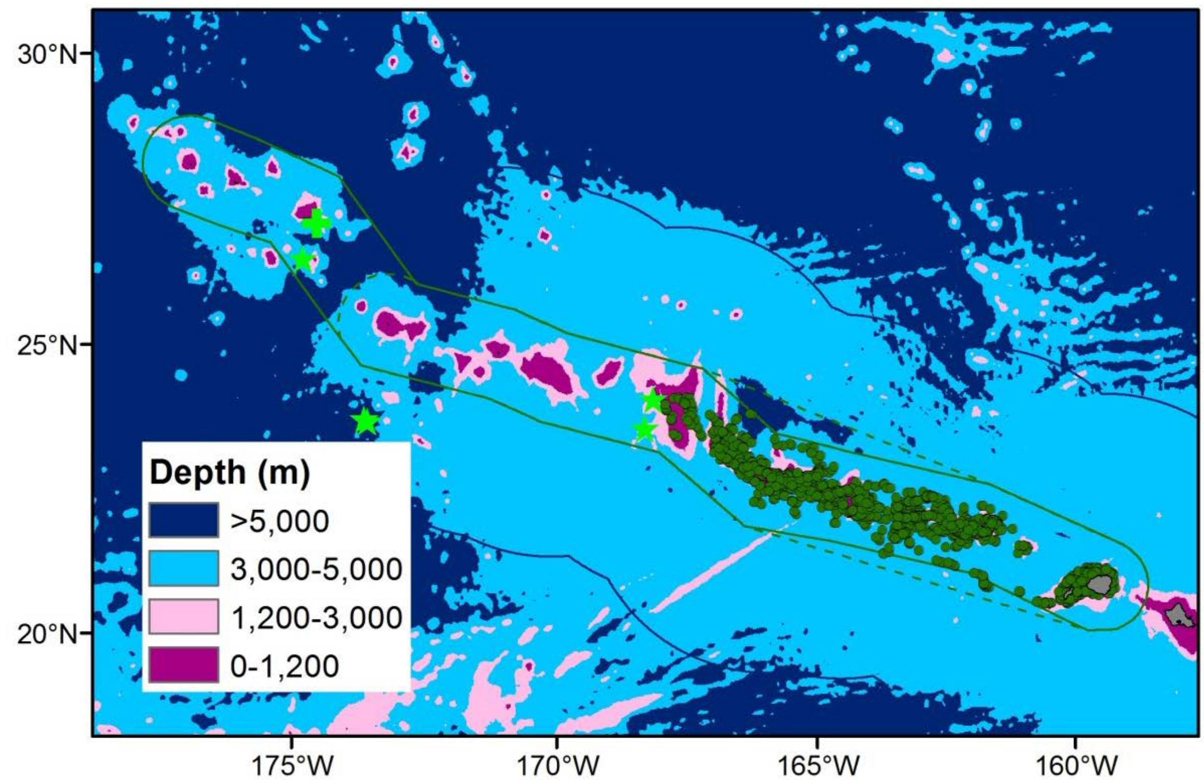

Figure 14.--Classified depths with respect to NWHI false killer whale satellite telemetry data (green points). Dashed green lines are modifications to the existing NWHI stock boundary (green line) considered by the False Killer Whale Stock Boundary Revision Working Group. Bright green stars and cross are towed array and fixed recorder acoustic detections, respectively, that could inform NWHI false killer whale use in the western extent of the stock boundary.

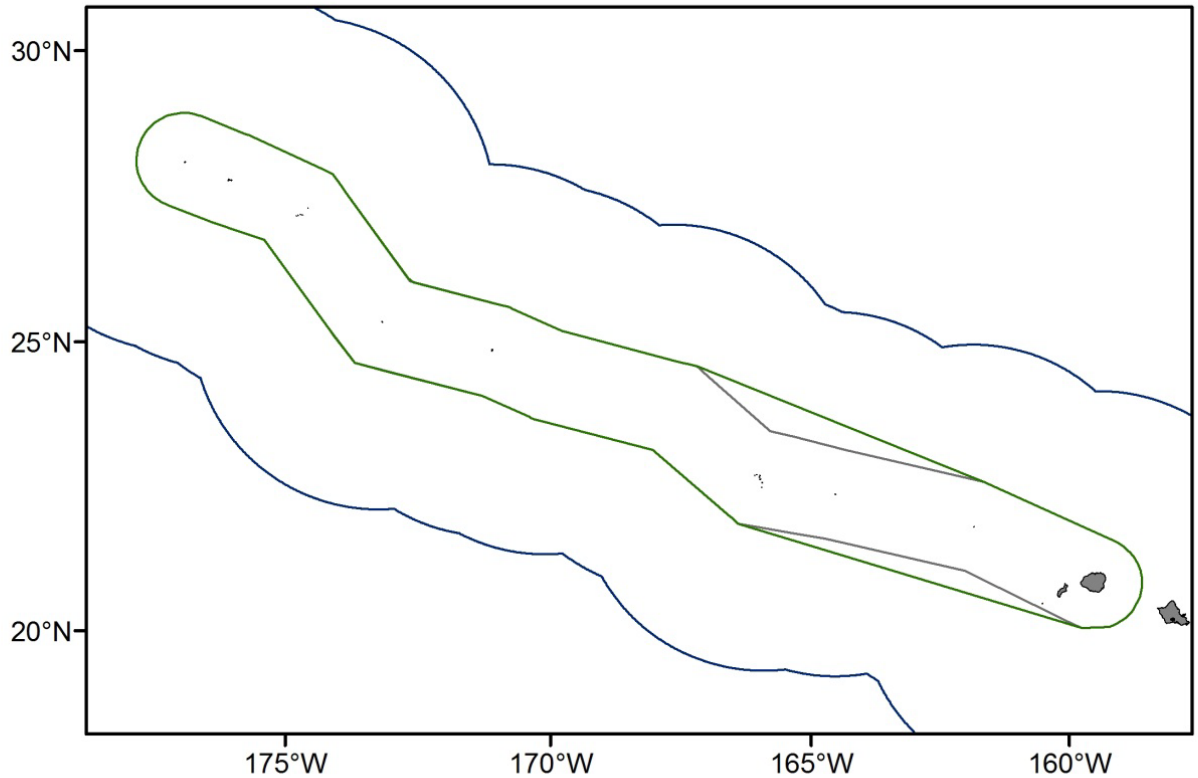

Figure 15.--Revised NWHI false killer whale stock boundary (green line) with previous stock boundary shown in gray. The blue line is the Hawaiian EEZ.

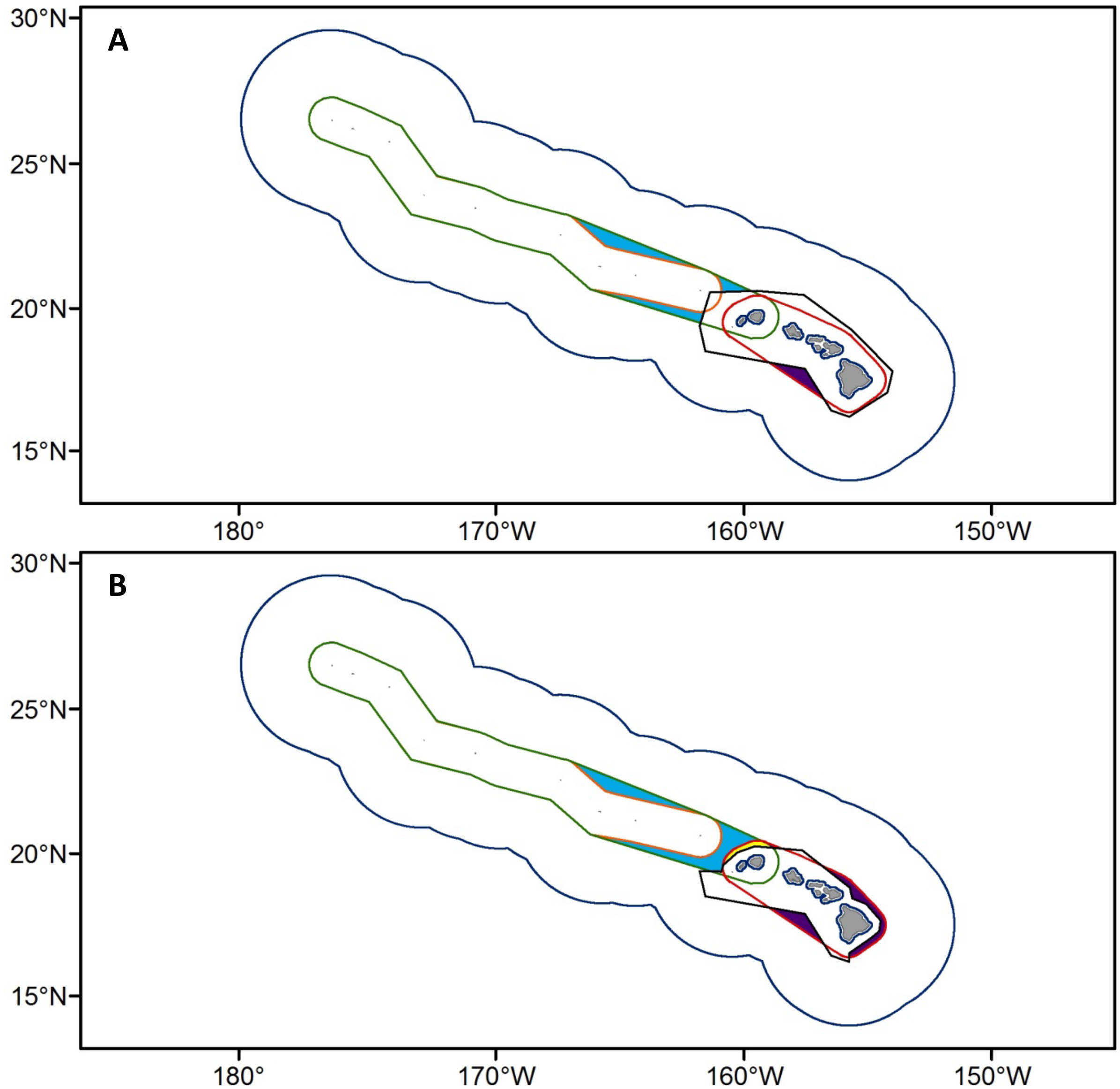

Figure 16.--Revised false killer whale stock boundaries and areas of stock overlap relative to the Longline Exclusion Zone (black outline) at its full extent, in place year-round as of 2013 (A), and as seasonally contracted in October through January of previous years (B). Revised MHI insular, pelagic, and NWHI stock boundaries are shown in red, blue, and green, respectively. Purple shading represents MHI insular-pelagic stock overlap zones where fishing occurs, light blue shading pelagic-NWHI stock overlap where fishing occurs, and yellow shading three-stock overlap where fishing occurs. The Papahānaumokuākea Marine National Monument (closed to fishing) is outlined in orange.

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