Discussion on the use of geometric mean in comparison to other measures of catch to trigger accountability measures

During the discussion of Dolphin Wahoo 10 (DW 10), the Council asked for additional clarification on the use of the geometric mean for triggering post-season accountability measures. Specifically, the Council requested comparing the geometric mean of the prior three years of landings to other approaches now in use, such as single year landings estimates or total landings over three years.

Recreational data are used in fisheries management in multiple ways: estimating landings, monitoring landings relative to limits, and developing management measures. Although these are similar, there are important differences among each use. Estimated landings from prior years are typically used in stock assessments. Here, a single year of landings is just one part of the story used to evaluate population dynamics and ultimately develop harvest level recommendations. Stock assessments use landings data from multiple years, typically combine landings information with other indicators of stock condition including indices of abundance and age or size composition, and use information from multiple fishery sectors to evaluate the population. This is done through complex models that allow some lack of fit to any individual data point as well as statistical estimation and evaluation of uncertainty. Additionally, the landings used in stock assessments are based on finalized datasets that have been reviewed and checked for errors.

Landings are monitored to evaluate a fishery relative to its annual targets and limits. This is different from estimating landings for prior years because there is a need to estimate catch for the current time period using preliminary data, as well as to predict catch in future time periods that are not yet observed. The data used are not final, and therefore landings used for monitoring in this way may not match final landings used for things like stock assessments as described above. Moreover, since limits are evaluated on a set time frame such as a year, and there is a need to predict whether the limit will be met before the time period ends, landings for monitoring purposes are often predicted based on trends in prior years. As such, predicted landings used to evaluate progress toward a limit will often differ from the final landings estimated once all the data are reported. Additionally, the predicted landings may inadvertently incorporate errors because the preliminary data stream on which they are based has not been through a complete review process. Reviewing the underlying data and projection methods applied to preliminary information from a single, incomplete data source is critical to avoid triggering an accountability measure unnecessarily.

Management measures are developed to prevent landings from consistently exceeding sustainable harvest targets and limits while attempting to minimize negative social and economic consequences. Different management measures, such as changes to bag limits or changes to seasons, are analyzed by applying proposed alternative management measures to observed fishery conditions (such as a catch or effort time series) and determining how each measure likely affects fishery performance. For this type of analysis, it is usually most appropriate to use a recent time series to represent current fishery conditions, but not usually necessary to use incomplete and preliminary data. Therefore, data used to evaluate management measures usually fall between the incomplete but immediately available information used for catch level monitoring and the final, reviewed, long-time series of information used for stock assessments.

The effects of different management measures are compared to a no action alternative that represents the status quo, therefore the time series selected for management evaluations should ideally be representative of current fishery conditions from both a regulatory and stock status perspective.

This discussion will focus on monitoring landings and developing management measures because estimating landings is handled through the SouthEast Data, Assessment, and Review (SEDAR) process for a stock assessment in the South Atlantic region or developed using approved estimation methods developed by the Marine Recreational Information Program (MRIP) based on the survey design.

Dolphin Wahoo 10 is proposing different alternatives for fishery monitoring to determine the need for implementing post-season accountability measures for the recreational sector. There are two Magnuson–Stevens Fishery Conservation and Management Act (MSA) requirements that should be considered when developing a method to monitor the fishery: preventing overfishing and minimizing negative social and economic impacts. For DW 10, the Council has stated a general preference to keep the recreational fishery open throughout the year. Further, after considering the time series of catch estimates and their uncertainty, the Council is concerned that unnecessary bag or vessel limit reductions and shortened seasons may be triggered by random deviations in estimated recreational catch levels. It is important to acknowledge that the Council supports imposing accountability measures when necessary but wants to avoid such negative impacts to the fishery when not necessary and when not supported by sound scientific evidence.

The fishery could exceed the ACL if the recreational effort for dolphin or wahoo increases (**Figure 1**) or the number of fish retained by anglers per trip increases (**Figure 2**). This would represent a true increase in the harvest that justifies accountability measures and increased catch restrictions. However, there is inherent uncertainty in the recreational data collection survey that could result in estimates of increased landings that are not actually true increases, yet the same accountability measures could be triggered. The error could result from coverage, sampling, nonresponse, or measurement errors. An increase in estimated landings due to one of these sources of error could result in a premature implementation of an accountability measure such as a harvest closure, an outcome the Council wants to avoid. If the last year of data deviates appreciably from prior years, until several more years pass there is no way to know if the deviation represents the start of a future trend in the fishery, a true increase in catch, or is simply the result of expected error in the survey estimate. Implementing an accountability measure based on an error in the survey estimate is a management risk the Council should consider when proposing accountability measures for the Dolphin Wahoo Fishery Management Plan (FMP).

There are two ways the Council may want to consider developing triggers for accountability measures due to the uncertainty associated with recreational data: have a thorough review of a method that will be used to trigger an accountability measure or establish a process to review the data before the data are used to implement an accountability measure. The recreational landings estimate was assumed to be a true value without error when accountability measures were implemented for some recreational species since annual catch limit (ACLs) have been established. This caused some concern for the Council in the past when harvest for the recreational sector was closed and there seemed to be abnormalities in the data. The Council may wish to provide recommendations on the methods or data review when the Regional Administrator (RA) is considering implementing accountability measures since a stipulation is added in many accountability measures for the RA to consider if an accountability measure is needed. The current version of DW 10 has three generic methods that would be used to trigger a post-season accountability measure in the dolphin and wahoo fisheries: a single catch estimate value, the sum of three prior years, and the three-year geometric mean. No method is perfect and the method to monitor the fishery may vary based on data, species, or the Council's risk tolerance.

The risk of overfishing and risk of implementing accountability measures unnecessarily are mentioned in the following discussion. Both types of risk are classified into three general categories qualitatively: low, intermediate, and high. The actual difference between the risk categories is unknown and changes from one category to another should not be assumed to be equally different. Additionally, the true risk of overfishing is unknown since neither dolphin nor wahoo have an overfishing limit (OFL) defined. Using the third highest landings from 1994 to 2007 is the current preferred method to define the acceptable biological catch (ABC) for both species.

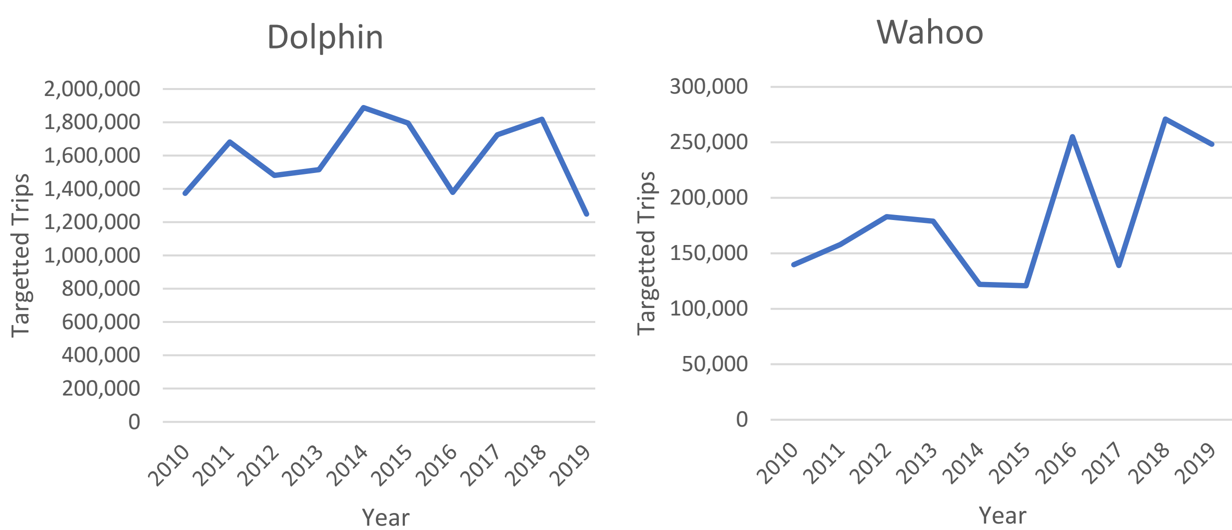


Figure 1. Number of trips targeting dolphin and wahoo along the Atlantic Coast including Monroe County based on MRIP directed effort. Targeted trips are based on primary target species. Source: Personal communication from NMFS, Fisheries Statistics Division, January 11, 2021.

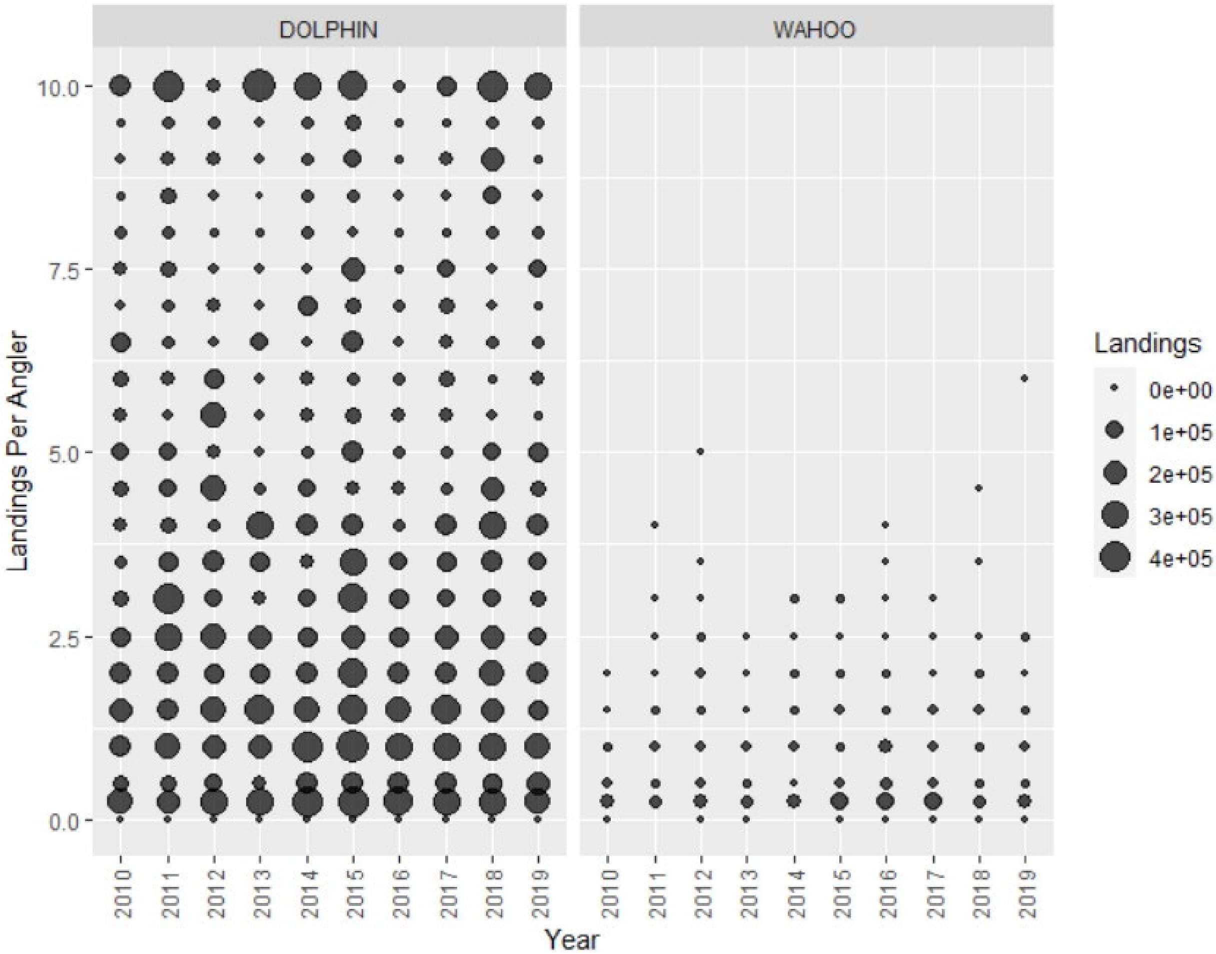


Figure 2. Landings per angler for Dolphin and Wahoo in the South Atlantic region including Monroe County from 2010 to 2019. The size of the circle is scaled to the total landing reported through MRIP. Source: Personal communication from NMFS, Fisheries Statistics Division, January 11, 2021.

Using a catch estimate from a single year seems to be the simplest and easiest method to evaluate the need for accountability measures. However, to get management measures in place and let fishermen plan their trips for the following year, DW 10 includes a notification date of up to September 1 to announce the bag limits, trip limits, and season for dolphin (if needed). If restrictive measures are deemed necessary as part of the accountability measure after September 1, only a shortening of the season will be considered. This will require the National Marine Fisheries Service (NMFS) to use preliminary data for the earlier part of the year (Waves 1-3, 2010 to 2019 average: dolphin = 50%, wahoo = 38%) and potentially project catches from previous years for the later part of the year (Waves 4-6, 2010 to 2019 average: dolphin = 50%, wahoo = 62%). In this situation, NFMS will be relying on preliminary and prior years of data to evaluate the need for accountability measures and potentially implement temporary management measures. This approach could work well if the fishery and catch estimates are fairly stable from year to year and during the year. Due to the uncertainty in recreational catch estimates, it carries risk of implementing an accountability measure that is not necessary if the estimated catch exceeds the true catch, or of allowing overfishing if the estimated catch is below the true catch. Using a multi-year averaging approach may help address this risk as well as address the added uncertainty provided by preliminary data or the unusual wave estimates that happen far too often.

Additionally, unlike the commercial sector or headboat component of the recreational sector, whose landings are based on a census of trips, the private and charter components of the recreational sector are based on a surveyed subset of trips. Since surveys do not encompass all trips, there is potential for random deviations from the true value. The presence of random deviations was investigated by calculating the mean catch over a decade for 17 species managed by the SAFMC from 2010 to 2019 (sub-region 6 in MRIP) and identifying years with catch estimates two standard deviations above or below the mean, defined as a spike for above and dip for below. Species with a trend in the data were removed since the trend in the data could cause certain years to exceed the standard deviations. Seven of the 13 remaining species had one spike over the decade (blueline tilefish and yellowtail snapper were only 2,000 lbs away from having a spike in one year) and none were identified with a dip (**Table 1**). Since the spike is not combined or smoothed with other years like the two methods described in more detail below, using a single point estimate results in the highest risk of implementing an accountability measure due to error in the survey.

Table 1. Seventeen species managed by the SAFMC to determine if spikes or dips (two standard deviations above and below the mean) were presented compared to the mean catch from 2010 to 2019. Species with trends were not compared to the mean.

Species	Trend in Landings	Spike	Dip
BLUELINE TILEFISH		*	
DOLPHIN		1	
GRAY TRIGGERFISH		1	
GREATER AMBERJACK		1	
HOGFISH		1	
RED GROUPER			
RED PORGY		1	
SCAMP		1	
SNOWY GROUPER			
SPANISH MACKEREL			
WAHOO		1	
WHITE GRUNT			
YELLOWTAIL SNAPPER		*	
BLACK SEA BASS	Yes	N/A	N/A
GAG	Yes	N/A	N/A
KING MACKEREL	Yes	N/A	N/A
VERMILION SNAPPER	Yes	N/A	N/A

*Indicates a point in the landings stream did not exceed the threshold but were within 2,000 lbs of being classified as a spike.

The Council has recognized these spikes in the recreational data in the past and expressed concern over the validity of the estimates when such spikes occur. To avoid the spikes in the data causing accountability measures to be implemented, multi-year approaches such as the sum over three years or a geometric mean could be used to smooth out or average potential spikes over a series of years. It should also be added that dips would be affected as well. The sum of the most recent three years of catch compared to the annual catch limit for three years is essentially an average (arithmetic mean) if the ACL does not change. Because spikes would be combined with two other years of recent catch, the spike would be reduced. Therefore, an estimate using the sum of the three most recent years of landings may not trigger an accountability measure even if a single annual catch estimate exceeds the limit. The amount of the reduction will vary, but combining over three years of landings should theoretically get closer to the true average since there are more data points used to estimate the landings. Since it is unknown if the spike is a true estimate of catch, the sum of three years has an intermediate risk of overfishing among the alternatives. The risk of implementing an accountability measure when it is not needed is also moderate among the alternative approaches because the smoothed estimate reduces the influence of a single year. One issue with using the sum of three years is the assumption that the data have a normal distribution, meaning that it is just as likely that when a potential error occurs in the estimation of landings it occurs on both the low and high sides of the mean. Based on information described above, it is more likely that spikes occur and the data are not likely normally distributed. The geometric mean (the cubic root of the product of three landings estimates in the case being examined) is an averaging technique used to estimate the likely average when data are skewed on the high side of the mean. Because the geometric mean is designed to reduce the influence of high values, it reduces the spike more than the average and is lower than the average described above in all situations. This results in the geometric mean having the highest risk of overfishing among the alternatives if the spike in the data is a true observation but lowest risk of implementing accountability measures if the spike in the data is due to random error. It is worth noting that multi-year approaches could result in triggering an AM over multiple years if the spike is large enough to drive the sum or geometric mean over the trigger level during the entire three-year period it remains part of the calculation. This is one reason even multi-year approaches may not function as hard and fast rules to simply set and forget.

To help display the points above, accountability measure triggers were developed for recreational landings of dolphin and wahoo from 2010 to 2019 based on the different methods. In this example, the point value is that year's landings. The average and geometric means were calculated with the point value and two years prior to the year (e.g., 2010 would include 2008, 2009, and 2010). The recreational dolphin landings typically remained between 11,000,000 and 17,000,000 million pounds (**Figure 3**). The 2015 landings estimate was approximately 8,000,000 pounds higher or 52% to 127% greater than any other point in the time series. The increase in 2015 over the all the other years results in the data distribution being non-normal (Shapiro-Wilk normality test p=0.0291). In this dolphin example, catch returned to below the annual catch limit without management measures. Since the effort (targeted trips) in the fishery (**Figure 1**) and landings per angler in 2015 (**Figure 2**) did not shift substantially, it seems unlikely that estimated landings should have increased by 50% over the preceding and following years. Therefore, point estimate accountability measures, which would have been triggered due to the annual catch limit being exceeded by 11%, would have been unnecessary. Both the average and geometric mean would have prevented a need to implement an accountability measure.

The landings data for the wahoo fishery had three years in a row when the estimated catch exceeded the potential new annual catch limit (**Figure 4**). The second highest effort occurred in 2016 when the landings spiked and along with the 2015 landings estimate being higher than the annual catch limit; therefore, evidence would have indicated a potential need to consider management. Based on this scenario, a point estimate accountability measure would have been triggered for the fishing years 2016, 2017, and 2018 and the catch exceeded the potential annual catch limit by 5%, 79%, and 28%, respectively. An almost 100% increase in the landings over the previous year (2016 compared to 2015) is unlikely for this fishery because it is a highly specialized fishery and recreational fishermen are limited to 2 fish per person. The landings per angler did not show a noticeable change in the number of wahoo kept per angler, just an increase in number of targeted trips.

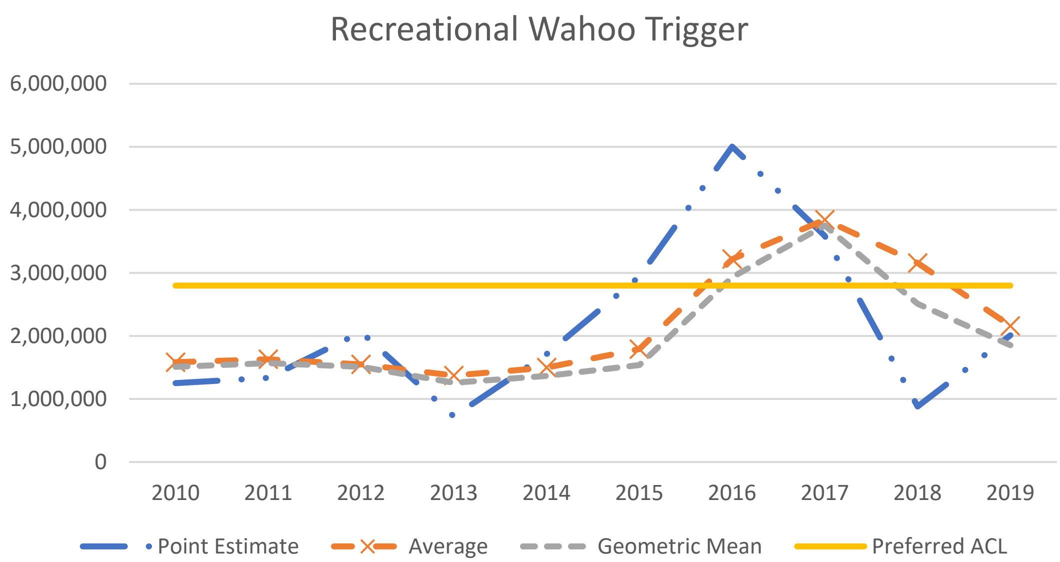
Both smoothing methods would have resulted in accountability measures beginning in 2017 after the spike in 2016. The average would have triggered accountability measures in 2017, 2018, and 2019, a year later than the point estimates, and the annual catch limit was exceeded by a smaller amount compared to the point estimate (15%, 37%, and 13%). The geometric mean would have resulted in the trigger being met in only two years (2017 and 2018, 5% and 34% over the annual catch limit).

It is important to consider the distribution of the data when determining which method is more appropriate to describe the central tendency of the estimated landings. The wahoo data did not appear to depart from normality (Shapiro-Wilk normality test p=0.2042). However, the distribution was skewed (skewness = 1.17) and log-transformation resulted in a more normal distribution (**Figure 5**). This indicates that geometric mean is the more appropriate method to smooth the data to describe central tendency particularly when catches spike.

The above examples just look a short time period to consider when different methods would have been triggered in the past for the recreational sector of the dolphin and wahoo fisheries. In conclusion, the Council is considering alternative methods of evaluating landings against accountability measures due to concerns about the reliability of the recreational catch estimates. Such issues are not being evaluated for the commercial sector accountability measures because the mandatory, census-style reporting by dealers and harvesters results in a more accurate and reliable data series. When examining triggers for recreational accountability measures, the Council should consider balancing its risk tolerance for potentially allowing overfishing with its desire to avoid imposing unnecessary, temporary, restrictive management measures due to skewed, outlier, or uncertain estimates. There are stock consequences to overfishing, and social and economic consequences to restrictive management measures.

Multi-year approaches tend to have a higher risk of allowing overfishing if data are accurate and precise, but they can help mitigate anomalies in the data when they are imprecise and, particularly spiky. Of the alternatives the Council is considering in DW 10 to trigger the recreational accountability measure, a geometric mean has the highest risk of allowing overfishing when a high catch estimate is legitimate, while providing the greatest likelihood of mitigating outliers and addressing issues with distribution of the data. A multi-year sum or arithmetic mean is likely a less risky approach in regard to overfishing but riskier in terms of implementing accountability measures unnecessarily. Single year approaches could be more likely to reduce the risk of overfishing when data are accurate and reliable, but do not address anomalies in the recreational data and assume a normal distribution, which, as exhibited in the landings data examined, is not always the case. The Council may wish to consider past performance of the catch estimate for a particular species before deciding how to balance the risk of overfishing with the risk of unnecessary regulatory changes. This could include the PSE of the estimates, their distribution and trends over the time series, and the frequency of spiky estimates as illustrated here. In the end, the Council can examine each species on a case by case basis to determine the most appropriate approach for triggering recreational accountability measures or develop a protocol to review recreational data prior to implementing recreational accountability measures.

Figure 3. The recreational dolphin annual accountability measure trigger values for a point estimate,



three-year average (defined as arithmetic mean), three-year geometric mean, and the Preferred sector Annual Catch Limit (ACL).

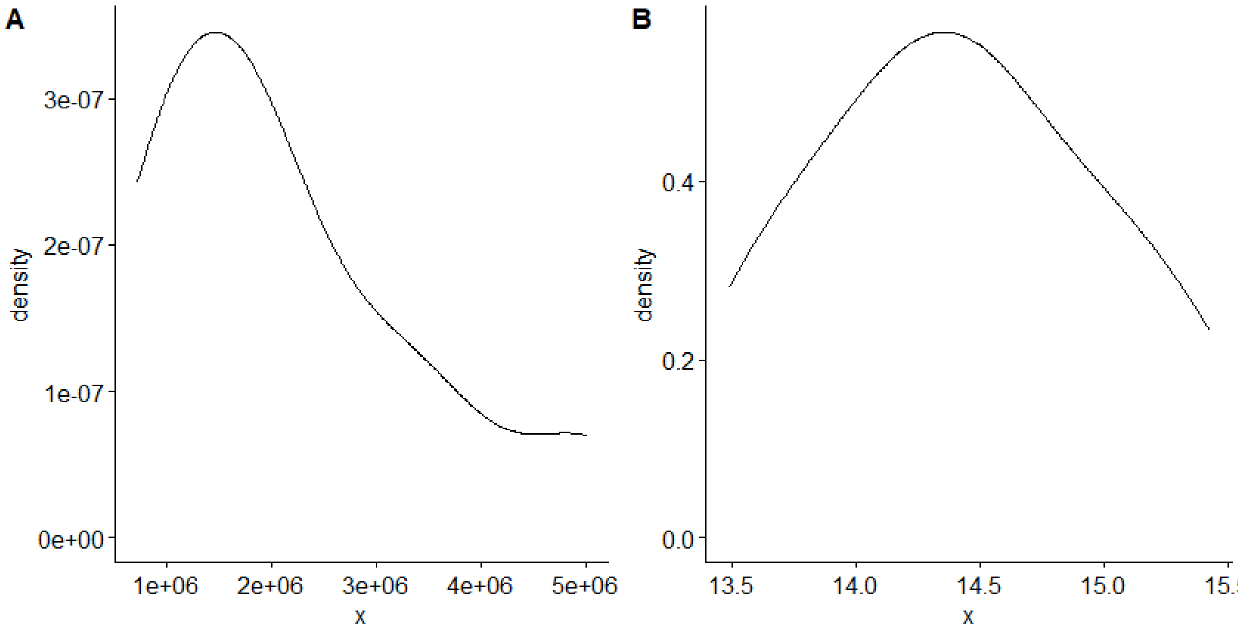


Figure 4. The recreational wahoo annual accountability measure trigger values for a point estimate, three-year average (defined as arithmetic mean), three-year geometric mean, and an average of Annual Catch Limits (ACL) (no preferred selected).

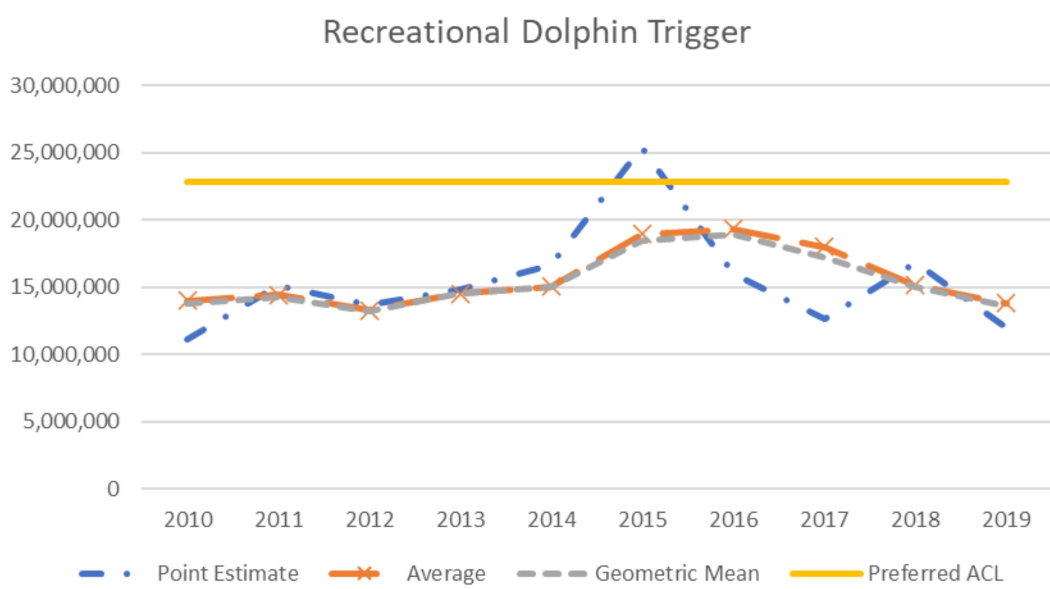


Figure 5. Wahoo landings density distribution (A) and log-transformed wahoo landings density distribution (B) for the South Atlantic region from 2010 to 2019.