Draft working paper for predissemination peer review only

Working Paper #3

October 19, 2016

Cumulative discard methodology review for butterfish (*Peprilus triacanthus*) discards in the longfin squid (*Doryteuthis (Amerigo) pealeii*) fishery

Jerome M. Hermsen, Ph.D.
Greater Atlantic Regional Fisheries Office
National Marine Fisheries Service
55 Great Republic Drive
Gloucester, MA 01982
jerome.hermsen@noaa.gov

A working paper in support of the Cumulative Discard Methodology Peer Review

Introduction

In-season monitoring of the Butterfish (*Peprilus triacanthus*) Discard Cap in the Longfin Squid (*Doryteuthis (Amerigo) pealeii*) fishery was implemented in 2010 through Amendment 10 of the Atlantic Mackerel, Squid and Butterfish (MSB) Fishery Management Plan (FMP). The program was initially implemented as weekly monitoring of a butterfish catch (landings and discard) cap on *Loligo pealei* squid trips (the scientific name of Longfin inshore squid was changed from *Loligo pealei* to *Doryteuthis (Amerigo) pealeii*). A 'directed longfin squid trip' for this monitoring program is operationally-defined as a trip that landed greater than or equal to 2501 lb. of longfin squid. In 2013, the butterfish catch cap was modified to monitor butterfish discards only against a butterfish discard cap in the directed longfin squid fishery in Framework 7.

Reports of butterfish discards in the longfin squid fishery are generated by the Analysis and Program Support Division (APSD) of the Greater Atlantic Regional Fisheries Office (GARFO) on a weekly basis. The annual butterfish discard cap is currently divided into three 'trimesters' (January-April, May-August, and September-December). Trimester 1 and 2 butterfish discard allocations are monitored independently of one another. During Trimester 3, butterfish discards are monitored from the beginning of the year against the annual butterfish discard allocation. Although discards in trimesters 1 and 2 are monitored with individual period-based caps, the ratio of pounds of butterfish discarded to the pounds of all species kept, i.e. the 'discard rate', which is used to estimate discards in this fishery, is cumulative from the beginning of the fishing year for all trimesters, a cumulative ratio estimator (also referred to as a separate ratio estimator) (Wigley et al., 2007).

At the beginning of the fishing year, a transition discard rate is employed to generate an estimate of butterfish discards until five longfin squid trips have been observed. This transition discard rate integrates current year observed trips as they occur. If, during any of the three trimesters, estimated butterfish discards were to exceed the allocated trimester (or annual) threshold, the directed longfin squid fishery would be closed and an 'incidental' trip limit of 2500 lb. of longfin squid would be imposed. Of note is that vessels targeting *Illex* squid (*Illex illecebrosus*) during a directed longfin squid fishery closure are allowed a trip limit of up to 15,000 lb. of longfin squid. The directed longfin squid fishery has been closed one time as a result of attaining the butterfish catch or discard cap, during trimester 1 of 2012, from 2011 through 2015.

This working paper describes the data and methodology used to respond to the Terms of Reference of the 2016 Cumulative Discard Methodology Peer Review (Appendix 1).

Methods

Data sources

In-season monitoring of the butterfish discard cap on longfin squid trips relies upon two main sources of data:

1) Northeast Fisheries Observer Program Fisheries Observer Program (NEFOP) Reports: The NEFOP deploys fisheries observers on commercial fishing trips in New England and Mid-Atlantic waters. At the outset of the butterfish catch cap monitoring program, vessel operators intending to land more than 2501 lb. of longfin squid were required to alert the Observer Program of their intent, although this requirement is no longer in place. For the monitoring program, partially-audited observer data from longfin squid trips are made available to the Analysis and Program Support Division within 7 days of the end of an observed trip. For this analysis, data were drawn from both Observer Database System and At-Sea Monitoring databases. Information from trips that were reported by observers and at-sea monitors to have landed equal to or greater than 2501 lbs of longfin squid were included in this analysis. It is important to note that only hauls that were observed for discards were used to calculate a ratio of butterfish discarded to observed kept all species.

2) Data for total pounds of all species kept on longfin squid trips were sourced from the Data Matching and Imputation System (DMIS). DMIS data are dealer-reported landings reports matched to trip or subtrip-based information from Vessel Trip Reports (VTR) and Vessel Monitoring System (VMS) activity code declarations. VTRs are the source for area fished, landing date, fishing gear used and vessel length.

Estimation of butterfish discards and precision

The cumulative discard method in the directed longfin squid fishery is currently based on a ratio estimate pooled over all longfin squid trips for an entire fishing year. Total estimated pounds of discarded butterfish are defined as:

(1) $$\widehat{D}_{bt} = K_t r_b$$

(2) $$r_b = \frac{\sum_{i=1}^{n} d_{ib}}{\sum_{i=1}^{n} k_i}$$

where $\widehat{D}_{bt}$ are the total estimated discards of butterfish on longfin squid trips in time period *t*;

K_{bt} is the total kept pounds of all species on longfin squid trips;

r_b is the observed discard rate of butterfish on longfin squid trips;

d_{ib} is the observed discards of butterfish on observed trip *i*;

k_i is the observed kept pounds of all species on observed trip *i*;

The variance of $\widehat{D}_{bt}$ is defined as:

(3) $$V(\widehat{D}_{bt}) = \sum_{t=1}^{L} K_t{}^2 \left(\frac{N_t - n_t}{n_t N_t}\right) \frac{1}{\left(\frac{\sum_{i=1}^{n} k_i}{n}\right)^2} \left[\frac{\sum_{i=1}^{n}(d_i^2) + (r_b)^2 k_i^2 - 2 r_b d_{ib} k_i}{n_t - 1}\right]$$

And the coefficient of variation (CV) of $\widehat{D}_{bt}$ is defined as:

(4) $$CV(\widehat{D}_{bt}) = \frac{\sqrt{V(\widehat{D}_{bt})}}{\widehat{D}_{bt}}$$

where $\widehat{V(D}_{bt})$ is the variance of estimated discards of butterfish on longfin squid trips in time period (year or trimester) *t*;

K_t is the total kept pounds of all species on longfin squid trips for time period *t*;

r_b is the observed discard rate of butterfish on longfin squid trips;

d_i is the observed discards of butterfish on observed trip *i*;

k_i is the observed kept pounds of all species on observed trip *i*;

L is the number of strata

For Terms of Reference 1 and 2: '…summarize the variability in discard rate by measurable strata' of butterfish in the directed longfin squid fishery, boxplots of observed discard rates were generated by measurable strata: by year 2011-2015 (baseline); by trimester 2011-2015; by trimester and year 2011-2015; by gear 2011-2015; by gear and year 2011-2015, by volume of landings 2011-2015, by vessel length category 2011-2015, and by proportion of longfin squid kept 2011-2015. Additionally, frequency distributions of discard rates by number of observed trips, cumulative distribution functions of discard rates by proportion of trips, and violin plots of the discard rates were generated: by year 2011-2015 (baseline); by trimester 2011-2015; by trimester and year 2011-2015. Of note is that, for the sake of clarity, axes in relevant plots have been trimmed to facilitate visual comparisons of the variability in discard rates between and among strata.

The number of observed trips, observed butterfish discards, observed kept pounds of all species, observed discard rates, the total number of all commercial fishing trips, the total kept pounds of all species on commercial trips, observer coverage rates (trips and pounds estimated butterfish discards and their accompanying coefficients of variation were calculated by year under the baseline stratification (cumulative annual discard rates) and by trimester and year (trimester-based discard rates).

To address Term of Reference 3, coefficient of variation curves were generated on the observer data set to assess the precision of the discard ratio for a given level of observer coverage by trip by year. To assess the consistency of discard estimates calculated over the course of the fishing year (TOR 3b), discard rates by day, 'instantaneous' discard rates, and 'instantaneous' discard estimates in this fishery were calculated for 2013 through 2015 by fishing day.

For Terms of Reference 4 and 5, simulations as described in Linden, Galuardi and McAfee (2016) were run on 2014 and 2015 data for different stratifications: by year (baseline) and by trimester, for four different transition rates: 1) no transition rate; 2) with a transition rate comprised of observed trips from the year or trimester in the year prior until 5 trips had been observed (baseline); 3) until the number of trips required to achieve a coefficient of variation of 0.3 had been observed; 4) and with a 'moving window' transition rate (Table 1). The moving window transition rate uses observed trips from the year or year and trimester prior to generate a discard rate estimate for that year or trimester-year (e.g. when the halfway point of a time period has been reached, the discard rate will be derived from observed trips in the first half of the current time period and the second half of the prior time period.

Table 1. Matrix of potential simulation runs for butterfish discard estimation in the directed longfin squid fishery for 2014 and 2015.

Transition rate	No stratification	By trimester
None	S_0T_0	S_1T_0
5 trips	S_0T_1	S_1T_1
CV trips	S_0T_2	S_1T_2
Moving average	S_0T_3	S_1T_3

Results and Discussion

The range and distribution of discard rates appear similar between and among years (Figures 1a-d, Table 2). Observed discard rates by trimester (Figures 2a-d), however, were consistently lower in Trimester 2 from 2011-2015 (Figures 3a-d). Estimated discards of butterfish tended to be consistently lower in Trimester 2 when the discard rate was stratified by trimester rather than using a cumulative annual discard rate (Table 2). Estimates for trimester 2 butterfish discards ranged from 1.63 to 4 times higher when calculated with the cumulative annual discard rate over those estimates calculated with a trimester-based discard rate. Estimated butterfish discards in trimesters 1 and 3 were consistently lower when calculated with the cumulative annual discard rate over those estimates calculated with a trimester-based discard rate, save for two trimesters, with trimester 3 in 2012 as a notable exception.

No discernible differences in discard rates appeared evident between gear types by year (Figure 4a). Landings and discards in the directed longfin squid fishery mostly occurred on trips employing bottom fish trawls with a small proportion (~3%) of trips employing twin otter trawls over the time period. As most activity in this fishery was accounted for by bottom trawls, lower discard rates are seen in trimester 2 (Figure 4b) on bottom trawl trips. Stratification by gear type appears infeasible for in-season monitoring of butterfish discards the directed longfin squid fishery.

Three additional stratification variables were examined: vessel length category, volume of catch and proportion of total landings that were longfin squid. As with gear, vessel length category did not appear to relate to butterfish discard rates over the five-year period or in any given year (Figure 5a-b). Lower discard rates were seen in both vessel length categories in trimester 2 (Figure 5c). Discard rates tended to be lower on trips by vessels greater than 75 ft. over the five-year period (Figure 6a). However, the pattern was not consistent between years or trimesters (Figure 6b-c). Observed trips were divided into two categories: greater than or equal to OR less than 50% of total landings on a trip were longfin squid. These two categories of trips did not appear to differ considerably over the time period or between years (Figure 7a-b). Again, discard rates appeared lower in Trimester 2 regardless of the proportion of longfin squid landed (Figure 7c-d).

As mentioned, current monitoring on the butterfish discard cap uses the cumulative or separate ratio method to estimate discards on a trimester and annual basis (Wigley et al., 2007). This method currently uses a discard rate calculated from the beginning of the year and applies it to the ‘kept all pounds’ (total landings) of the fishery during and after each trimester. The separate ratio method under a number of temporal stratifications has been thoroughly reviewed and well tested in the northeast US in a number of fisheries, including the groundfish fishery (Wigley et al., 2007; Palmer, 2010; Nitschke, 2010). The difference in estimates seen for this fishery and time period for total estimated butterfish discards between the annual and trimester-based stratification methods is likely due to differences in sampling (observer coverage) rates between trimesters (Tables 2 and 3, Figure 8).

Discard estimates calculated with the temporally-based stratification by trimester and annual cumulative rates had a large influence on the trimester-level discard estimates (Tables 2 and 3, Figure 8). Using the annual discard method, relatively lower discard rates in trimester 2 biased discard estimates lower in trimesters 1 and 3 over the time period. The trimester-based temporally-stratified estimator appeared to reflect a more realistic distribution of discards by trimester, given the patterns in discard rates over the five year period. The total coefficients of variation for the annual discard estimates were lower in four of the five years using trimester-based temporally-stratified method (Table 3). Palmer (2010) found that finer temporally-stratified separate ratio estimates yielded lower CVs in some strata within the northeast US groundfish fishery, which was an expected result of temporal stratification. Indeed, the purpose of stratification is to increase estimation precision by separating a heterogeneous population into more homogeneous sub-sets (Cochran, 1977).

Coefficient of variation curves were generated to assess the precision of the discard metric by year and the observer coverage necessary to achieve a CV of 30%. Percentage of observer coverage required for a 30% CV ranged from 4% to 12 % over the five-year period (Table 2). Coefficient of variation curves by sampling coverage appeared to vary little between years (Figure 9).

Discard rates, estimated discards, and ‘instantaneous’ cumulative discard rates by day were examined for 2013-2015 (Figures 10-12). The discard rates at the beginning of the year do not include any transition rates in the instantaneous discard rate plot (Figure 10). High variability in discard rates and estimated discards occurred at the beginning of the year, with a decrease in the overall rates and their variability as well as discards in the second trimester (Figures 10-12). As expected, in the absence of a robust transition discard rate, the variability in the beginning of the year could potentially increase the probability of over or underestimating discards with a concomitant increase in the probability of a premature closure with trimester-based discard cap allocations if the cap is set low enough.

Simulations were run for the annual (baseline) stratification for fishing years 2014 and 2015 for different transition rate options for a total of 16 simulation runs (Linden, et al., 2016). Estimated butterfish discards and their respective confidence intervals did not approach the 8.56 million pound butterfish discard cap for 2014 and 2015 in any simulation (Figures 13-16). Stratification by trimester appeared to improve discard estimates, particularly in trimester 2 of 2015, when estimated discards began low and remained relatively static rather than decreasing through the period. The largest differences in simulation outputs were seen between the two stratification schemes. Changes to the trip-based transition rate calculations did not appear to have a noticeable effect on discard estimations or their variability over the course of the fishing year under the different stratification schemes except in the moving window transition scenario. The lack of a notable difference between the 5-trip and CV-based discard rate transition windows is likely related to an abrupt (and potentially unintended) phasing out of the influence of prior period trips, which can be remedied in future simulation runs. In 2014, the moving window transition appeared to have had a smoothing effect on the trimester 2 discard estimate (Figure 16d).

A current limitation in the simulations for this particular fishery is the lack of trimester-based discards beginning from zero under the temporally-based trimester stratification scheme and monitoring regimen. Improvements to the simulations in future might allow for the specification of temporally-based quotas to be incorporated, i.e. if a new monitoring period begins, discard estimates would re-start at zero. This particular fishery is akin to a hybrid of temporal monitoring as trimesters 1 and 2 are monitored separately. However, when trimester 3 is reached, discards are monitored from the beginning of the year against an annual cap with a ratio estimator calculated using trips from the beginning of the year.

For this particular fishery and current monitoring regimen, the trimester-based ratio estimation method with a moving window transition rate seemed to perform better than the annual-based ratio estimator by decreasing within-trimester estimation bias, particularly for 2014. If trimester-based estimates are indeed relevant to the monitoring because of trimester-based discard caps, then a compelling case can be made for stratification by trimester. That said, consistency with stock assessment and SBRM methodologies that utilize different stratification schemes and estimation methodology should be weighed against any management decision that invests further in the cumlative ratio temporally-stratified trimester method (Wigley, et al., 2007). Management has an important role to play in the monitoring and function of this fishery discard cap because, if potential estimation bias is known and predictable, discard caps could be set appropriately to compensate for known bias in the planning stages of management.

Acknowledgments

I would like to extend my sincere appreciation to my colleagues in the Monitoring and Analysis Section of the Analysis and Program Support Division in the Greater Atlantic Regional Fisheries Office for helpful comments and discussion during this review. Special thanks to Benjamin Galuardi and Brant McAfee for their collaboration and for their extensive and able assistance with programming in R, as well as helpful comments on the manuscript. I would also like to extend my appreciation to Susan Wigley of the Northeast Fisheries Science Center for her leadership of the Standardized Bycatch Review Methodology and for her very thorough and clear documentation on discard methodology, estimation, precision and sample size analysis; and to Michael Palmer and Paul Nitschke of the Northeast Fisheries Science Center for their very thorough reviews and testing to develop discard methodology in the Northeast Region of NOAA Fisheries.

References

Cochran, W.G. 1977. Sampling techniques (3rd edition). John Wiley and Sons, New York.

Linden, D.W., Galuardi, B., McAfee, B.M. 2016. Methods for examining in-season behavior of the cumulative discard estimation in the Greater Atlantic Region. Working Paper #1, Discard Estimation Methodology Peer Review.

Palmer, M.C. 2010. Estimating in-season discards from the Northeast United States groundfish fishery: an investigation of the separate ratio method (Part II). Working Paper #3. Discard Estimation Methodology Peer Review. Retrieved from http://nefsc.noaa.gov/groundfish/discard/WorkingPapers/

Nitschke, P.C. 2010. Estimating in-season discards from the Northeast United States groundfish fishery: Discard Estimation Performance Simulation Study (Part I). Working Paper #2. Discard Estimation Methodology Peer Review. Retrieved from http://nefsc.noaa.gov/groundfish/discard/WorkingPapers/

Wigley, S.E., Rago, P.J., Sosebee, K.A., Palka, D.L. 2007. The Analytic Component to the Standardized Bycatch Reporting Methodology Omnibus Amendment: Sampling Design and Estimation of Precision and Accuracy (2nd edition). U.S. Department of Commerce, Northeast Fisheries Science Center Reference Document 07-09.

Table 2. Summary data for butterfish discard estimates in the directed longfin squid fishery from 2011-2015.

Year	Number of observed trips	Observed butterfish discarded (lb.)	Total observed kept (lb.)	Butterfish discard rate	Number of trips	Total kept of all species (lb.)	Observer coverage rate (trips)	Observer coverage rate (lb.)	Estimated butterfish discards	Coefficient of Variation (CV) of butterfish discard estimate	Required number of trips for CV = 0.3	Required coverage rate of trips for CV = 0.3
2011	146	277,279	5,191,410	0.05	1,285	33,722,313	0.11	0.15	1,801,147	0.172	53	0.04
2012	75	175,411	2,339,574	0.07	1,670	40,751,943	0.04	0.06	3,055,400	0.508	202	0.12
2013	82	66,030	3,384,967	0.02	1,185	36,004,973	0.07	0.09	702,342	0.326	96	0.08
2014	131	208,492	5,256,743	0.04	1,539	38,258,581	0.09	0.14	1,517,407	0.276	114	0.07
2015	79	126,929	4,233,119	0.03	1,282	40,792,277	0.06	0.10	1,223,146	0.330	97	0.07
Total	513	854,141	20,405,813	0.04	6,961	189,530,087	0.07	0.11	8,299,442		561	

Table 3. Summary data for butterfish discard estimates in the directed longfin squid fishery from 2011-2015 stratified temporally by trimester.

Year	Trimester	Number of observed trips	Observed butterfish discarded (lb.)	Total observed kept (lb.)	Butterfish discard rate	Number of trips	Total kept all species (lb.)	Observer coverage rate (trips)	Observer coverage rate (lb.)
2011	1	49	181,102	2,938,011	0.06	292	13,595,807	0.17	0.22
2011	2	54	14,663	1,099,084	0.01	781	11,443,207	0.07	0.10
2011	3	43	81,515	1,154,315	0.07	212	8,683,299	0.20	0.13
2012	1	26	157,379	1,074,374	0.15	184	9,210,694	0.14	0.12
2012	2	24	12,480	271,756	0.05	1,197	18,540,494	0.02	0.01
2012	3	25	5,552	993,444	0.01	289	13,000,755	0.09	0.08
2013	1	7	11,814	191,721	0.06	97	4,727,555	0.07	0.04
2013	2	28	8,432	1,028,480	0.01	505	10,004,233	0.06	0.10
2013	3	47	45,783	2,164,766	0.02	583	21,273,185	0.08	0.10
2014	1	18	30,533	583,738	0.05	337	13,345,494	0.05	0.04
2014	2	67	35,643	2,446,726	0.01	857	14,107,627	0.08	0.17
2014	3	46	142,316	2,226,278	0.06	345	10,805,460	0.13	0.21
2015	1	26	44,998	1,137,277	0.04	219	12,799,453	0.12	0.09
2015	2	11	10,148	610,521	0.02	702	15,036,597	0.02	0.04
2015	3	44	71,783	2,485,321	0.03	361	12,956,227	0.12	0.19
Total		515	854,141	20,405,813	0.04	6,961	189,530,087	0.07	0.11

Table 3 (cont.). Summary data for butterfish discard estimates in the directed longfin squid fishery from 2011-2015 stratified temporally by trimester. Cells in yellow are from trimester 2 for each year.

Year	Trimester	Estimated butterfish discards - trimester-based discard rates	Estimated annual butterfish discards - trimester-based discard rates	Coefficient of Variation of Butterfish Discard Estimate	Total CV for Year	Estimated butterfish discards-annual discard rate	Estimated annual butterfish discards - trimester-based discard rates	Ratio of the annual and trimester-based discard estimates	Required number of trips for CV = 0.3	Required coverage rate of trips for CV = 0.3
2011	1	838,057		0.25		726,168		0.87	35	0.12
2011	2	152,660	1,603,912	0.34	0.16	611,195	1,801,147	4.00	68	0.09
2011	3	613,195		0.22		463,785		0.76	26	0.12
2012	1	1,349,226		0.52		690,577		0.51	61	0.33
2012	2	851,431	2,273,309	0.32	0.33	1,390,084	3,055,400	1.63	28	0.02
2012	3	72,653		0.65		974,739		13.42	92	0.32
2013	1	291,321		0.52		92,220		0.32	19	0.19
2013	2	82,023	823,258	0.65	0.29	195,151	702,342	2.38	109	0.21
2013	3	449,914		0.40		414,972		0.92	77	0.13
2014	1	698,059		0.28		529,307		0.76	16	0.05
2014	2	205,513	1,594,317	0.57	0.21	559,535	1,517,407	2.72	202	0.22
2014	3	690,746		0.34		428,565		0.62	61	0.18
2015	1	506,430		0.38		383,788		0.76	39	0.18
2015	2	249,939	1,130,580	1.18	0.35	450,869	1,223,146	1.80	140	0.20
2015	3	374,211		0.47		388,489		1.04	91	0.25
Total		7,425,375				8,299,442				

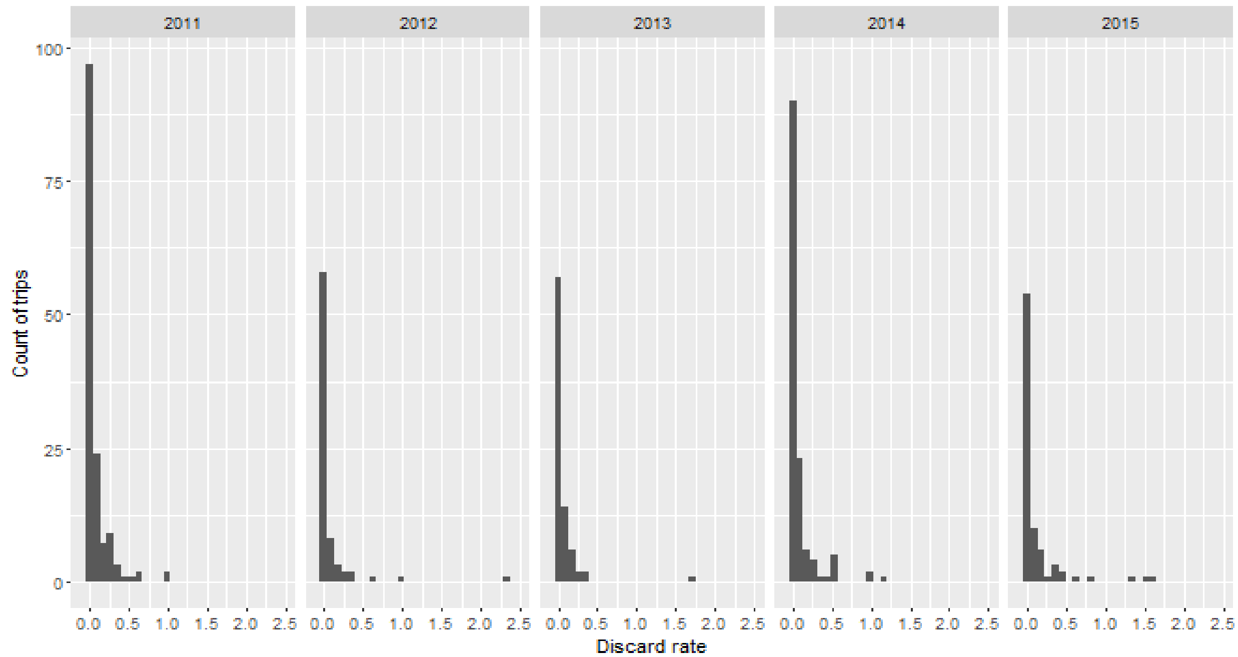

Figure 1a. Frequency distributions of the number of trips by butterfish discard rate in the longfin squid fishery, 2011-2015. Note that the horizontal axis was truncated to highlight the lower end of the distribution.

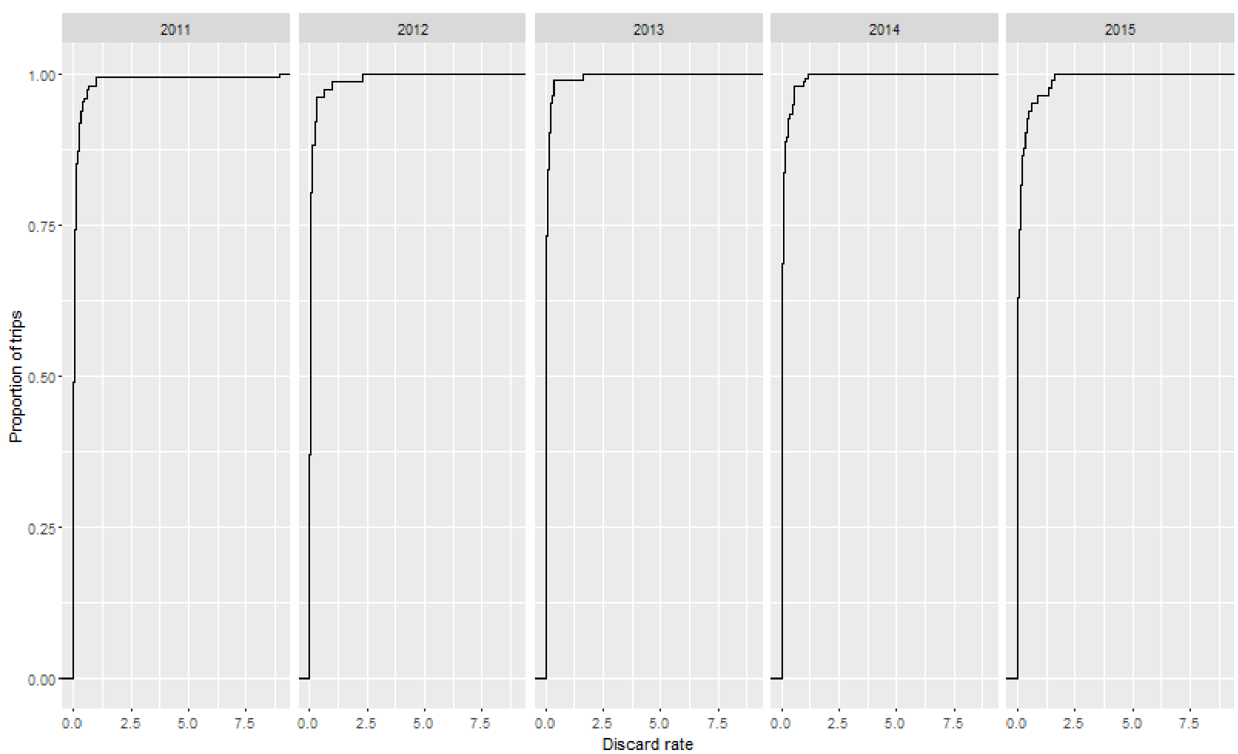

Figure 1b. Cumulative distribution functions of the proportion of trips by butterfish discard rate in the longfin squid fishery, 2011-2015.

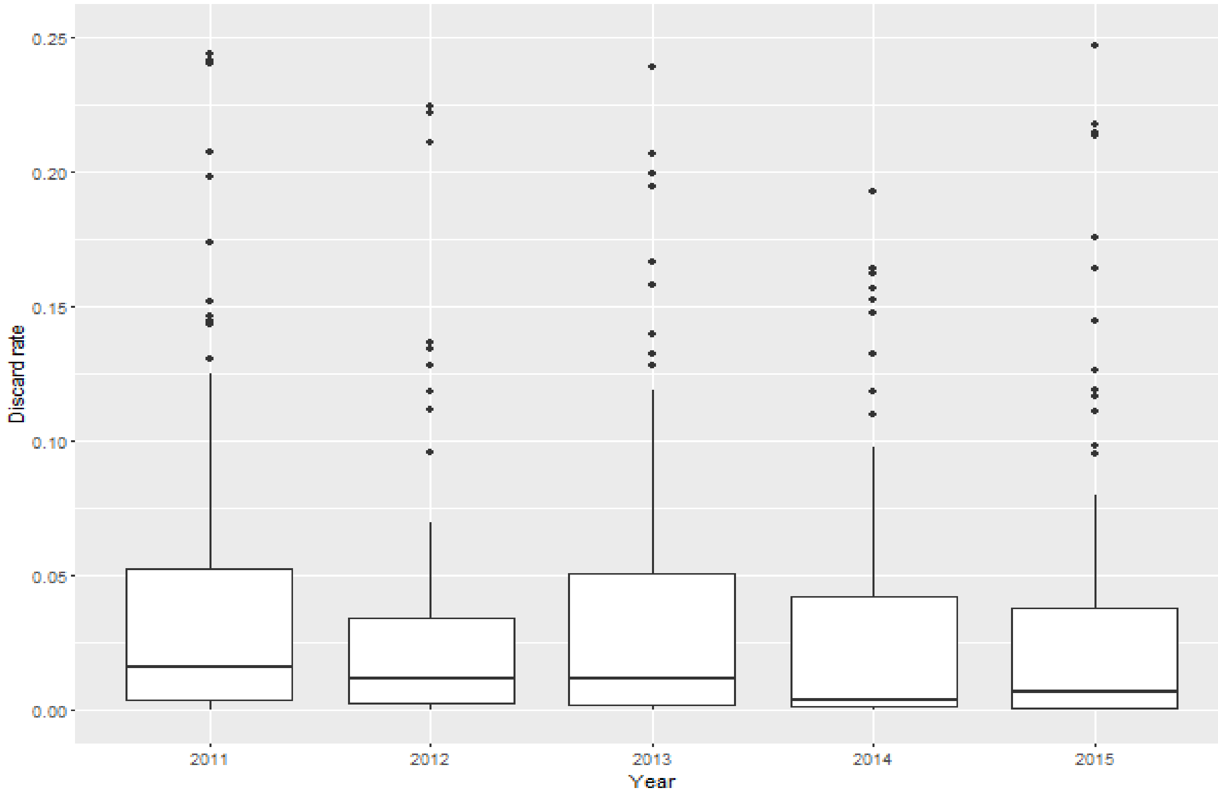

Figure 1c. Boxplots comparing the distribution of butterfish discard rates in the longfin squid fishery by year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

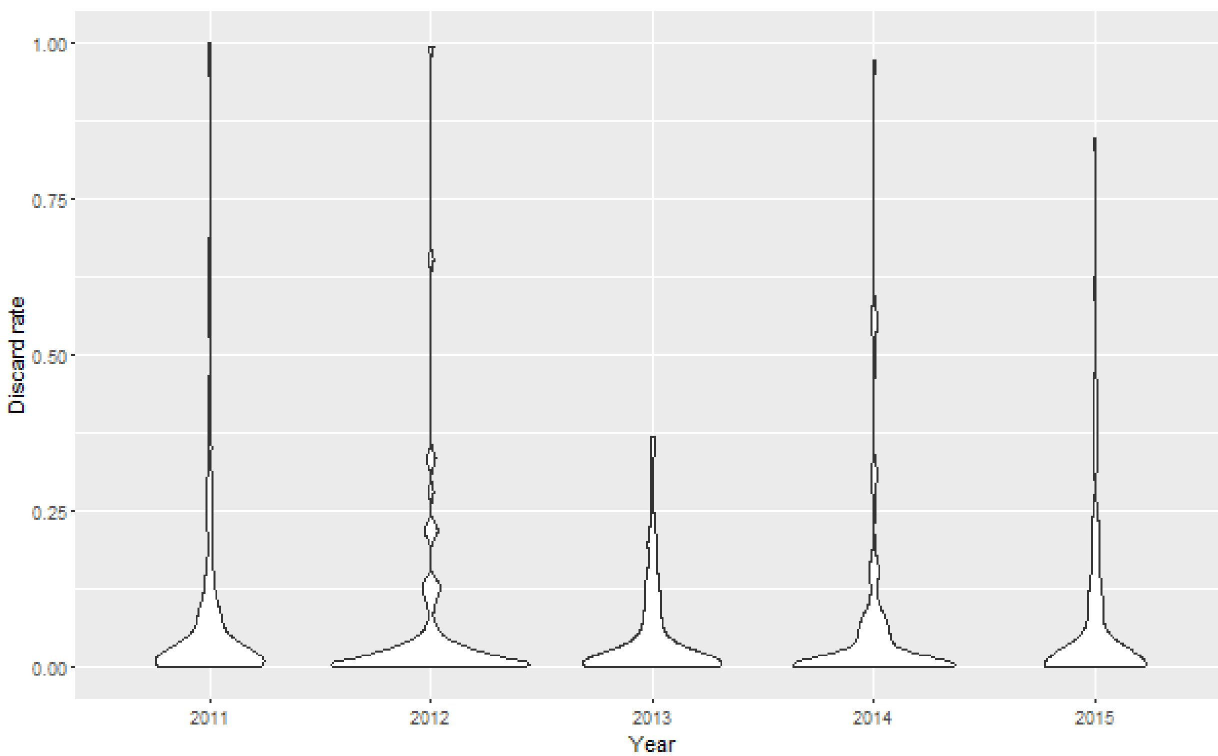

Figure 1d. Violin plots comparing the distribution of butterfish discard rates in the longfin squid fishery by year, 2011-2015. Note that the vertical axis was truncated to highlight the lower range of the distribution.

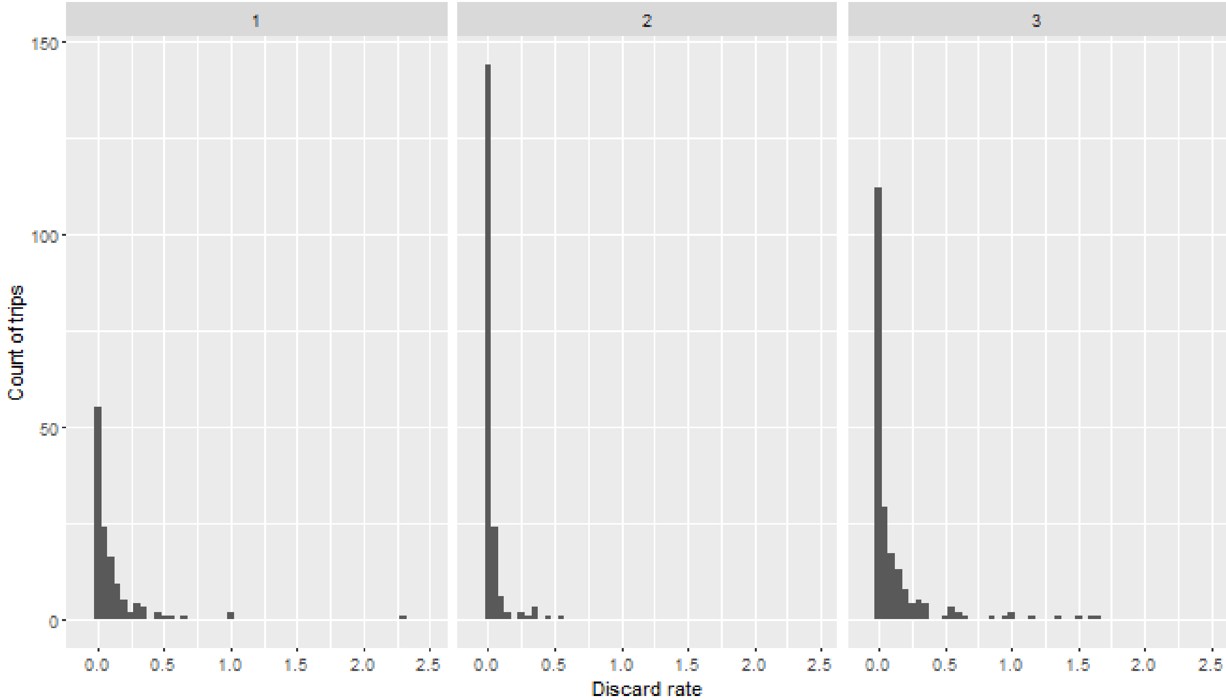

Figure 2a. Frequency distributions of the number of trips by butterfish discard rate in the longfin squid fishery by trimester, 2011-2015. Note that the horizontal axis was truncated to highlight the lower end of the distribution.

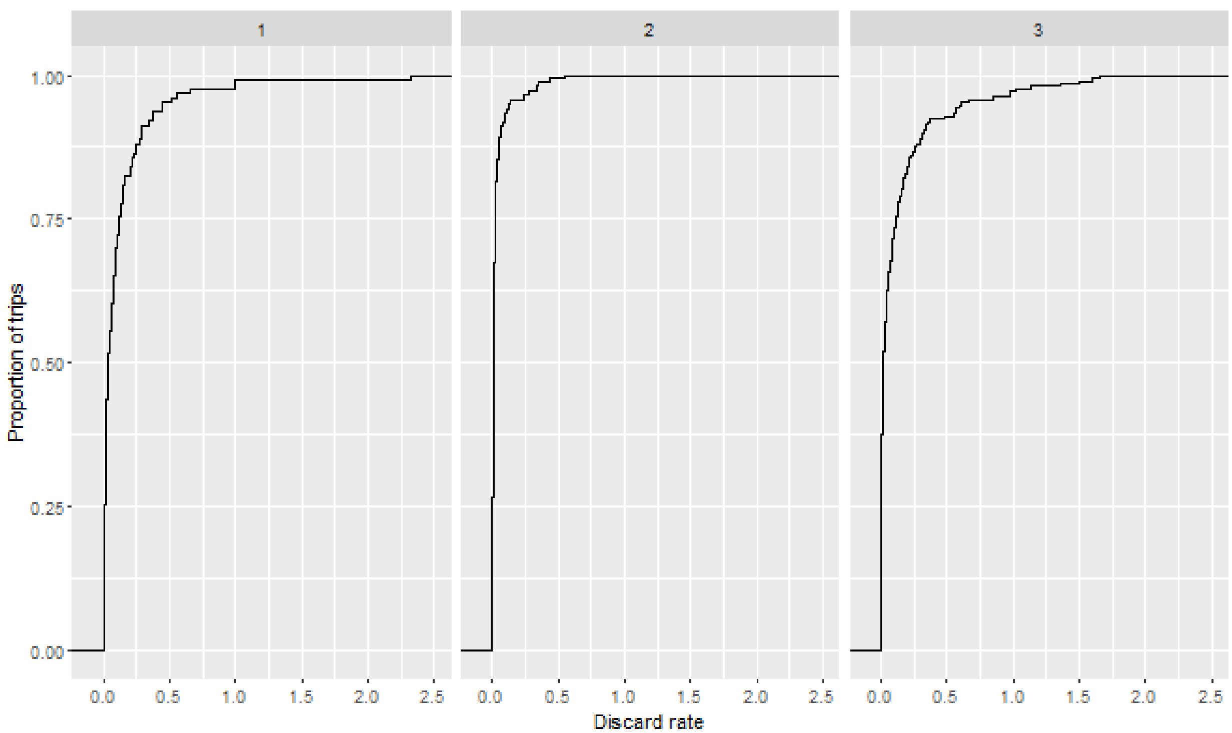

Figure 2b. Cumulative distribution functions (CDF) of the proportion of trips by butterfish discard rate in the longfin squid fishery by trimester, 2011-2015. Note that the horizontal axis was truncated to highlight the lower end of the CDF.

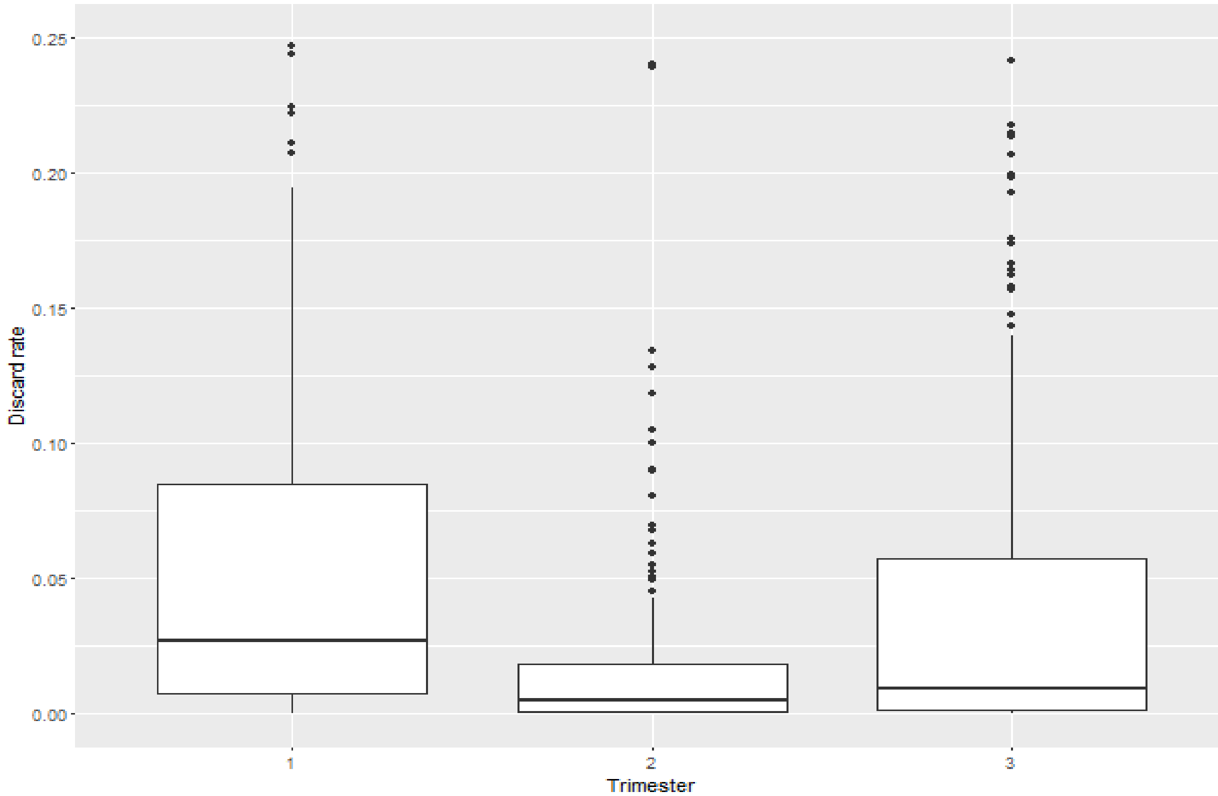

Figure 2c. Boxplots comparing the distribution of butterfish discard rates in the longfin squid fishery by trimester, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

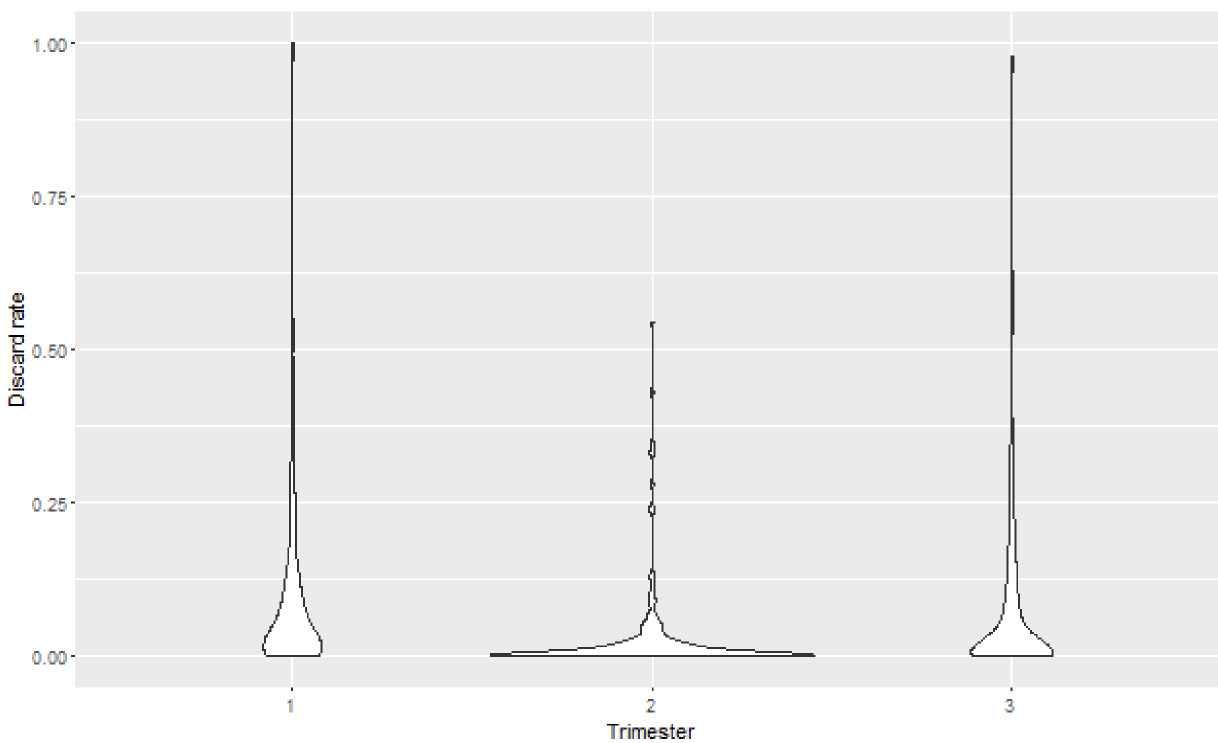

Figure 2d. Violin plots comparing the distribution of butterfish discard rates in the longfin squid fishery by trimester, 2011-2015. Note that the vertical axis was truncated to highlight the lower range of the distribution.

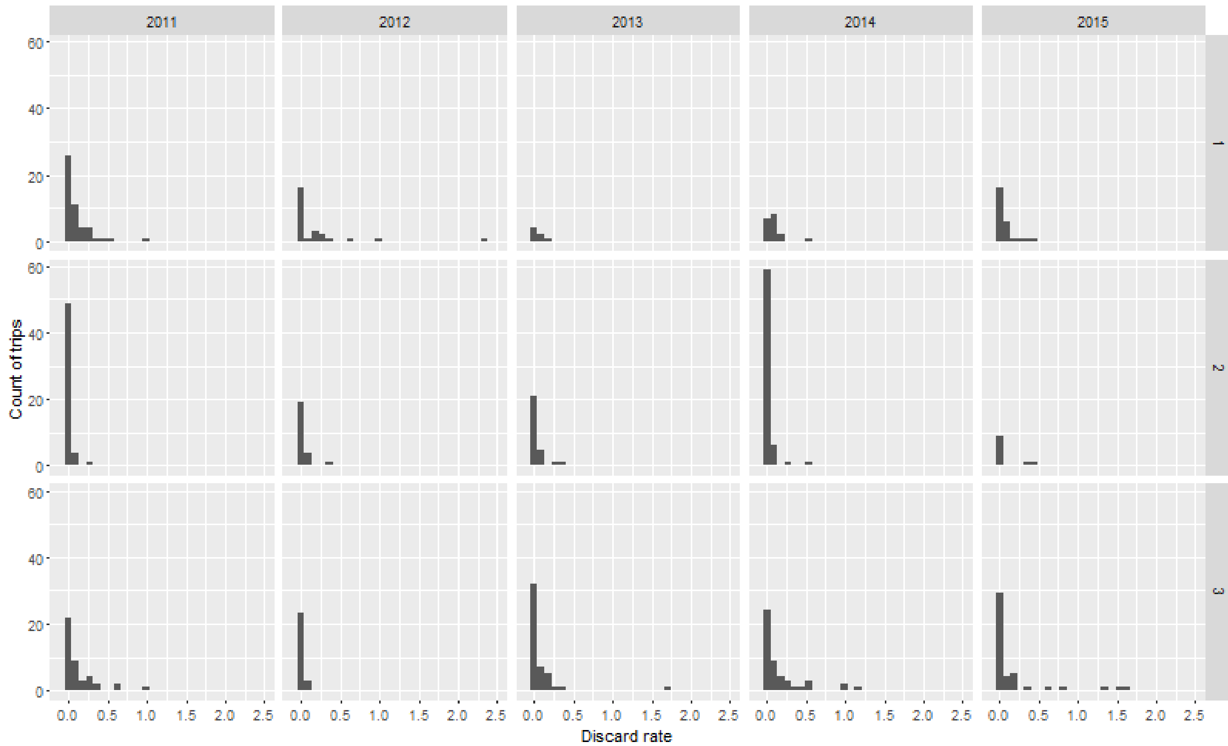

Figure 3a. Frequency distributions of the number of trips by butterfish discard rate in the longfin squid fishery by trimester and year, 2011-2015. Note that the horizontal axis was truncated to highlight the lower end of the distribution.

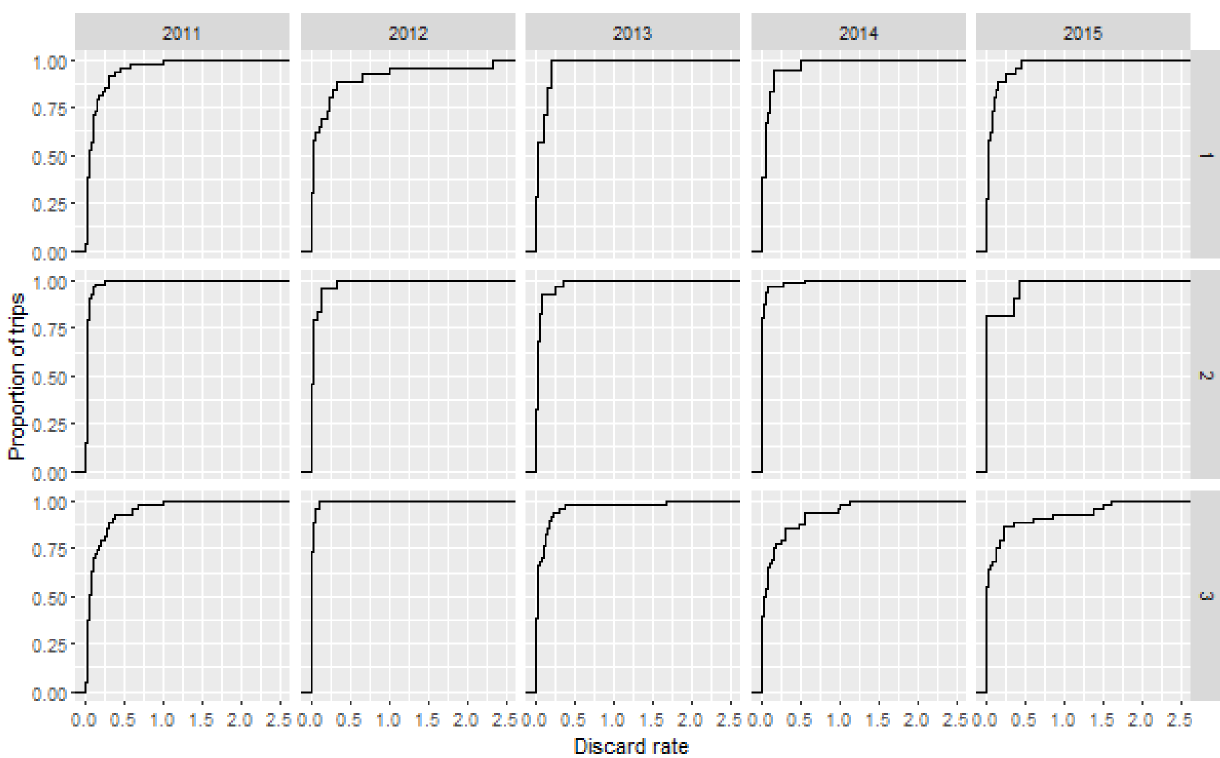

Figure 3b. Cumulative distribution functions (CDF) of the proportion of trips by butterfish discard rate in the longfin squid fishery by trimester and year, 2011-2015. Note that the horizontal axis was truncated to highlight the lower end of the CDF.

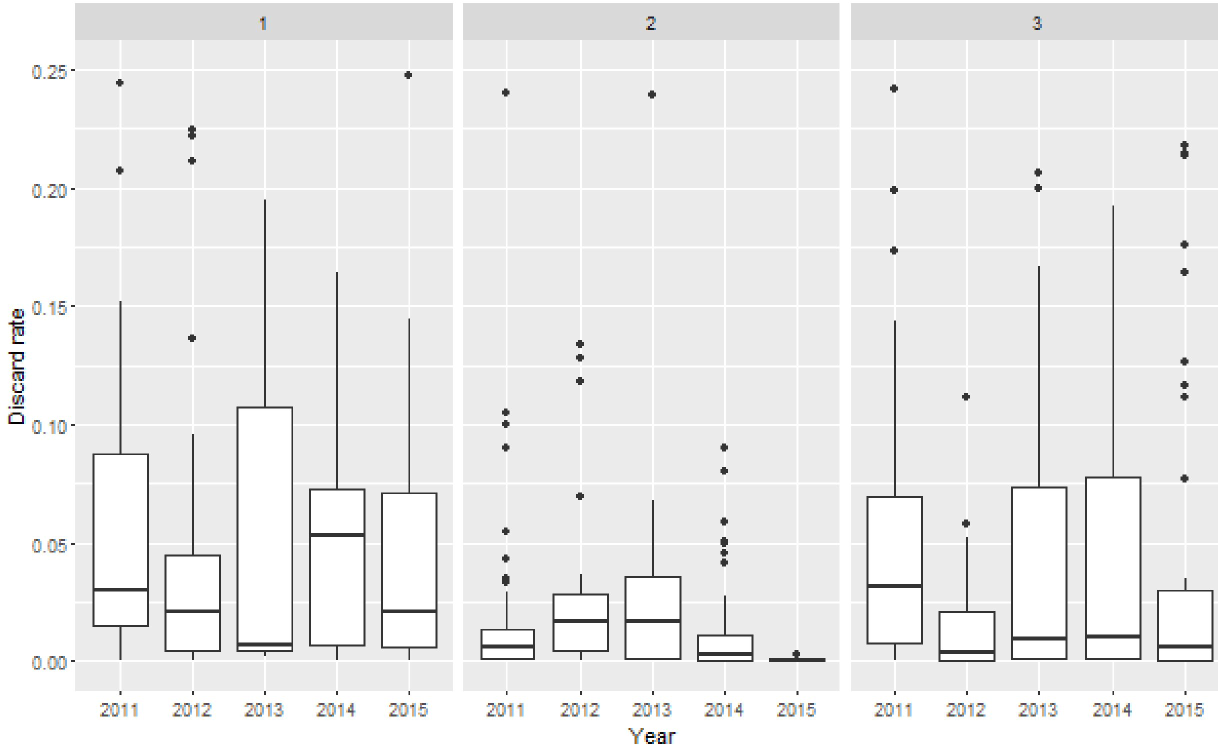

Figure 3c. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by trimester and year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

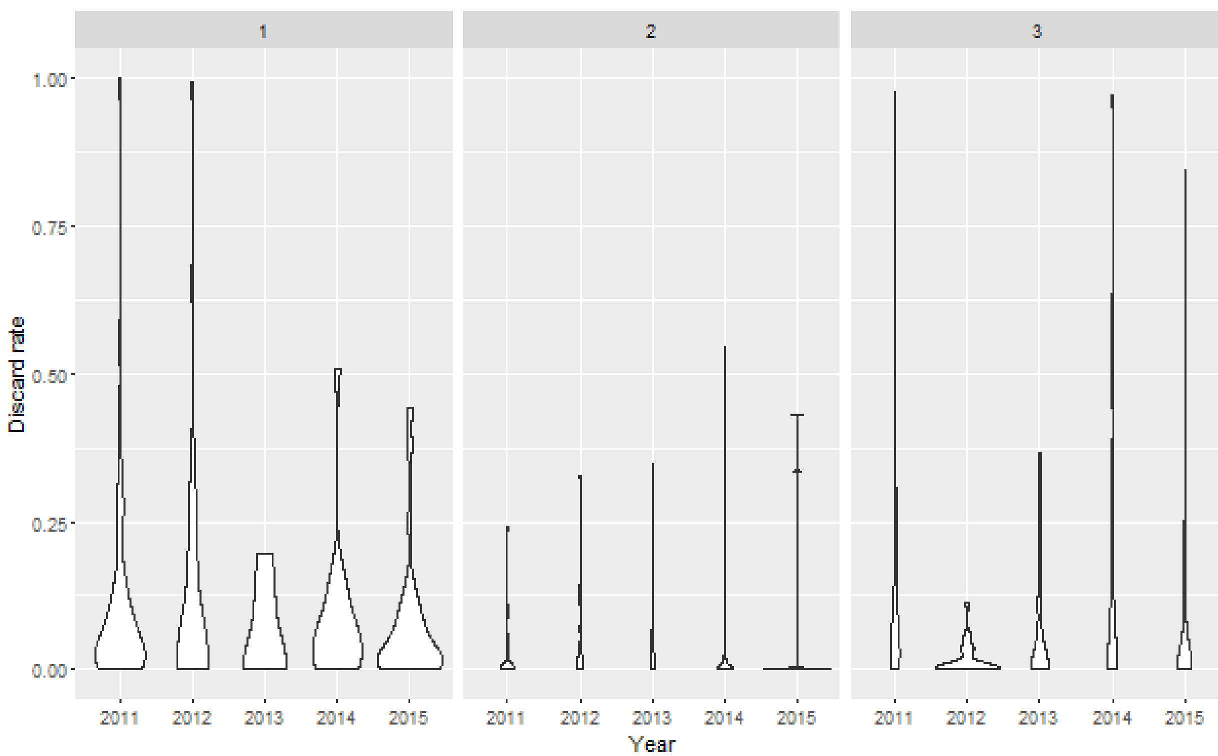

Figure 3d. Violin plots of the distribution of butterfish discard rates in the longfin squid fishery by trimester and year, 2011-2015. Note that the vertical axis was truncated to highlight the lower range of the distribution.

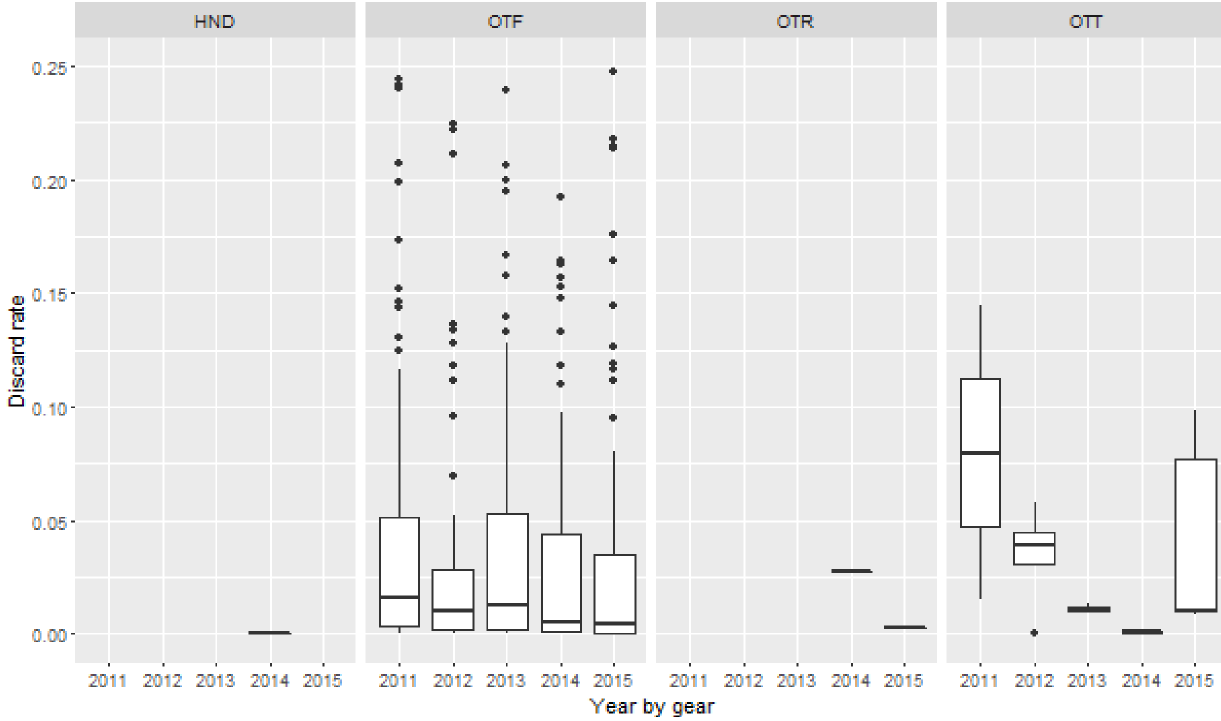

Figure 4a. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by gear and year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution. HND = handgear,; OTF = Otter trawl, fish; OTR = Otter trawl, Ruhle; OTT = Otter trawl, twin.

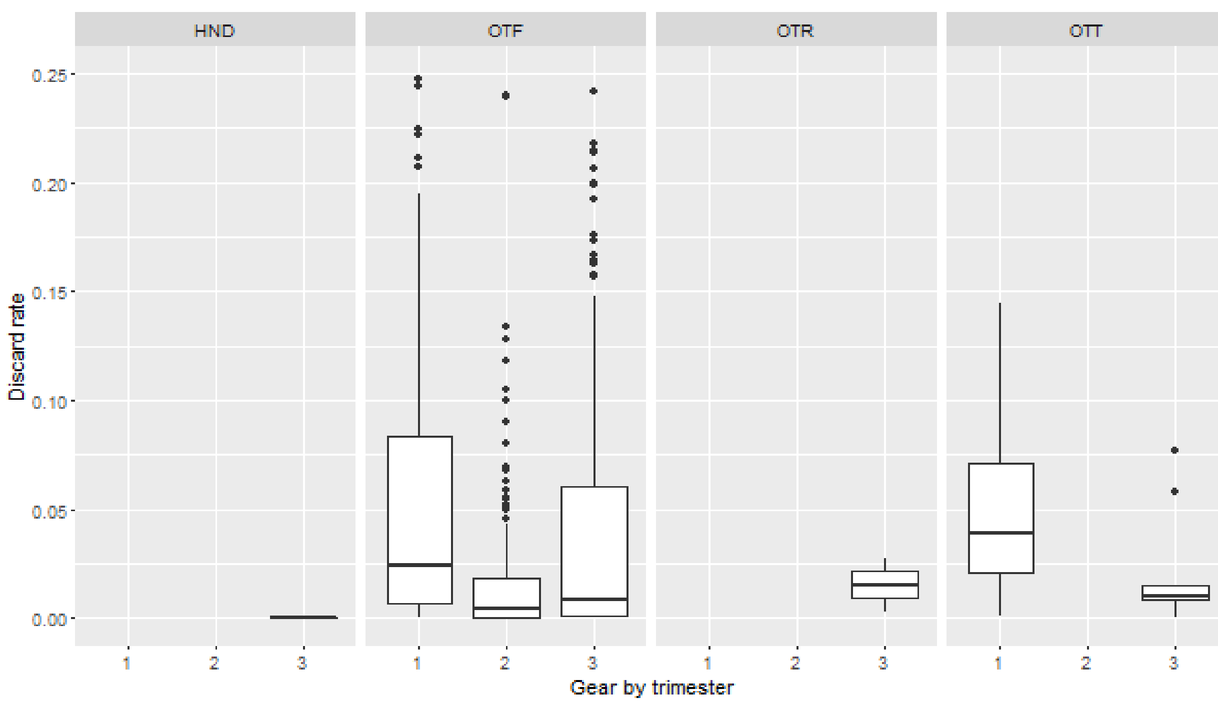

Figure 4b. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by gear and trimester, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

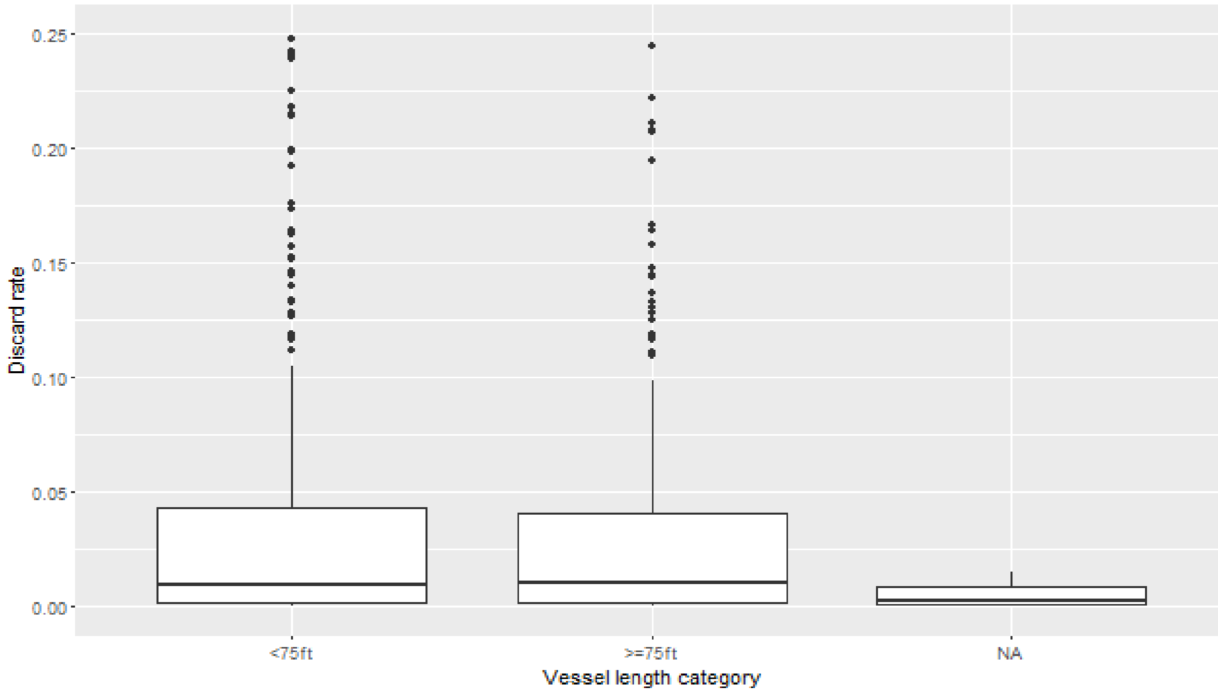

Figure 5a. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by vessel length category (greater than or equal to 75 ft, less than 75 ft.), 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

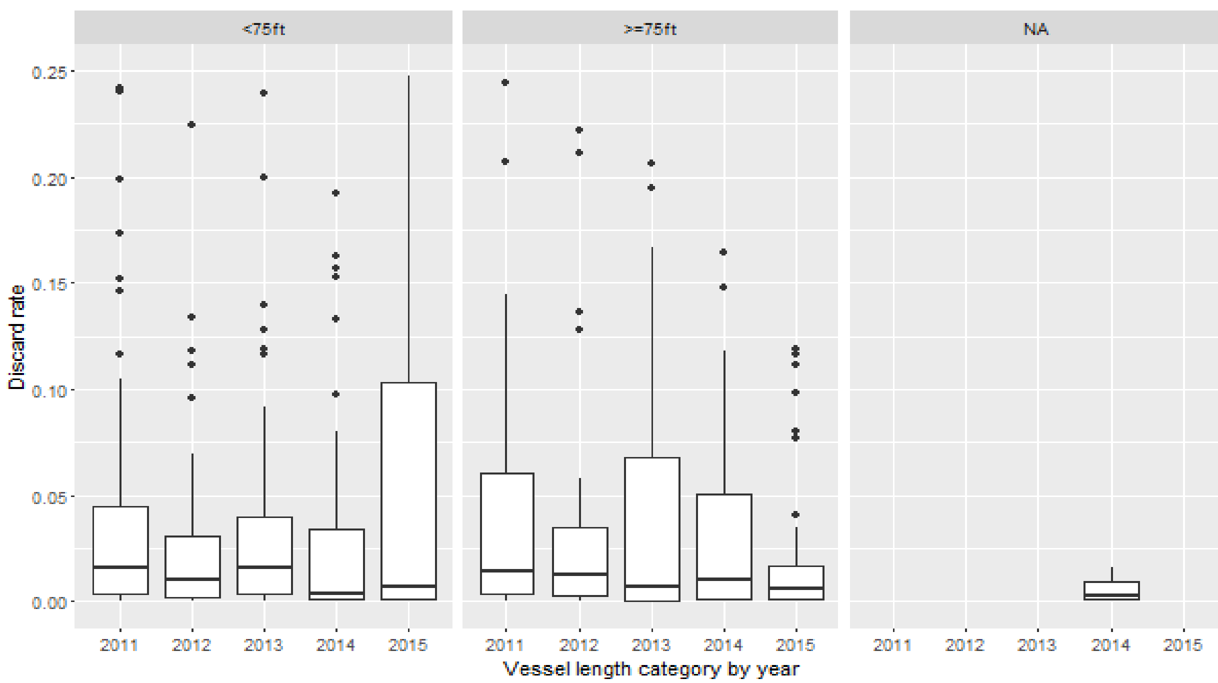

Figure 5b. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by vessel length category (greater than or equal to 75 ft, less than 75 ft.) and year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

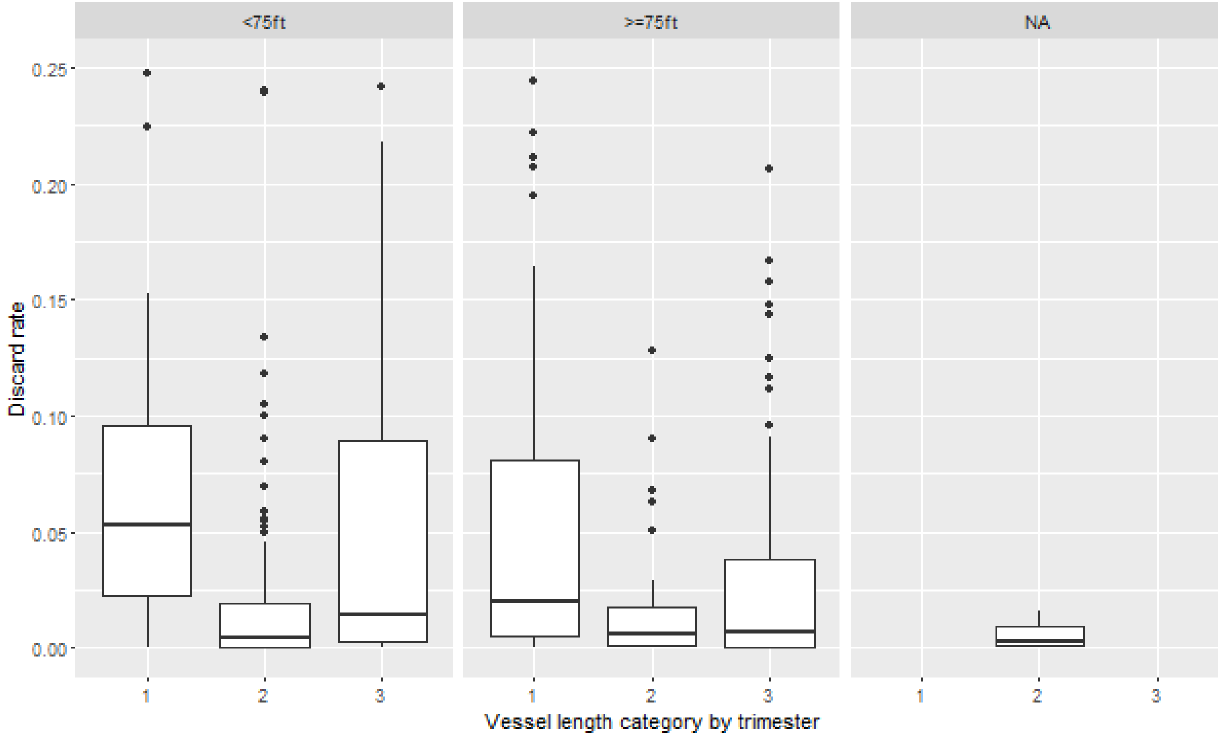

Figure 5c. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by vessel length category (greater than or equal to 75 ft, less than 75 ft.) and trimester, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

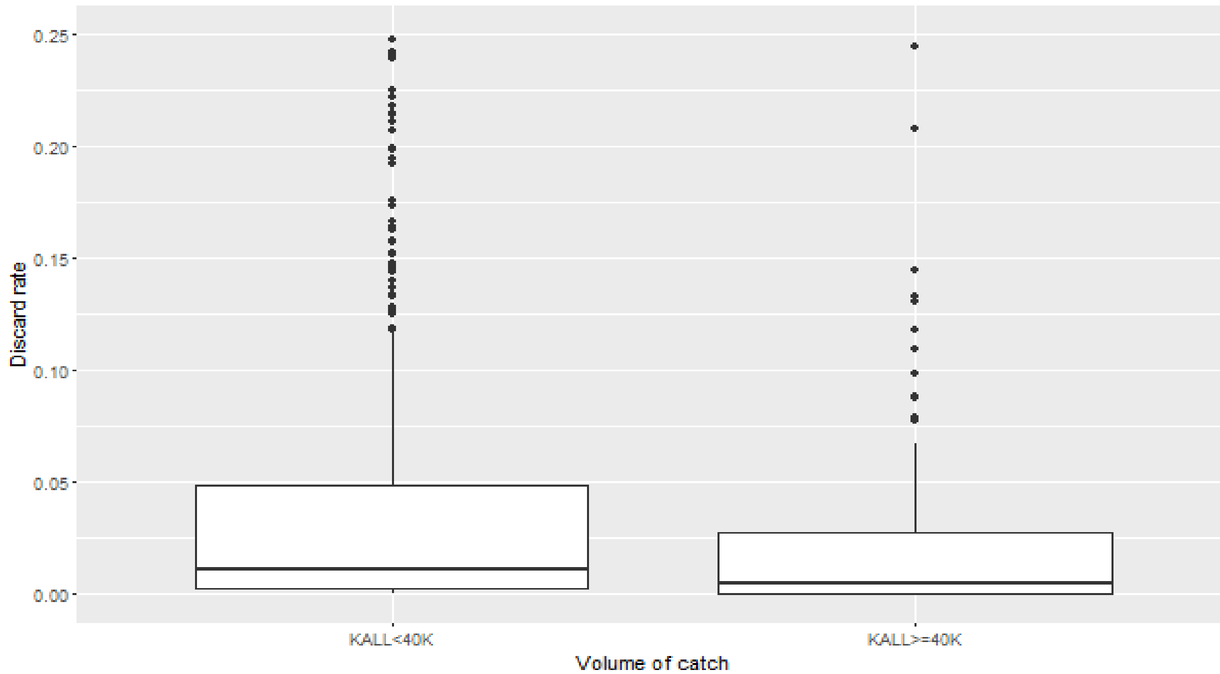

Figure 6a. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by volume of catch category (greater than or equal to 40,000 lb, less than to 40,000 lb), 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

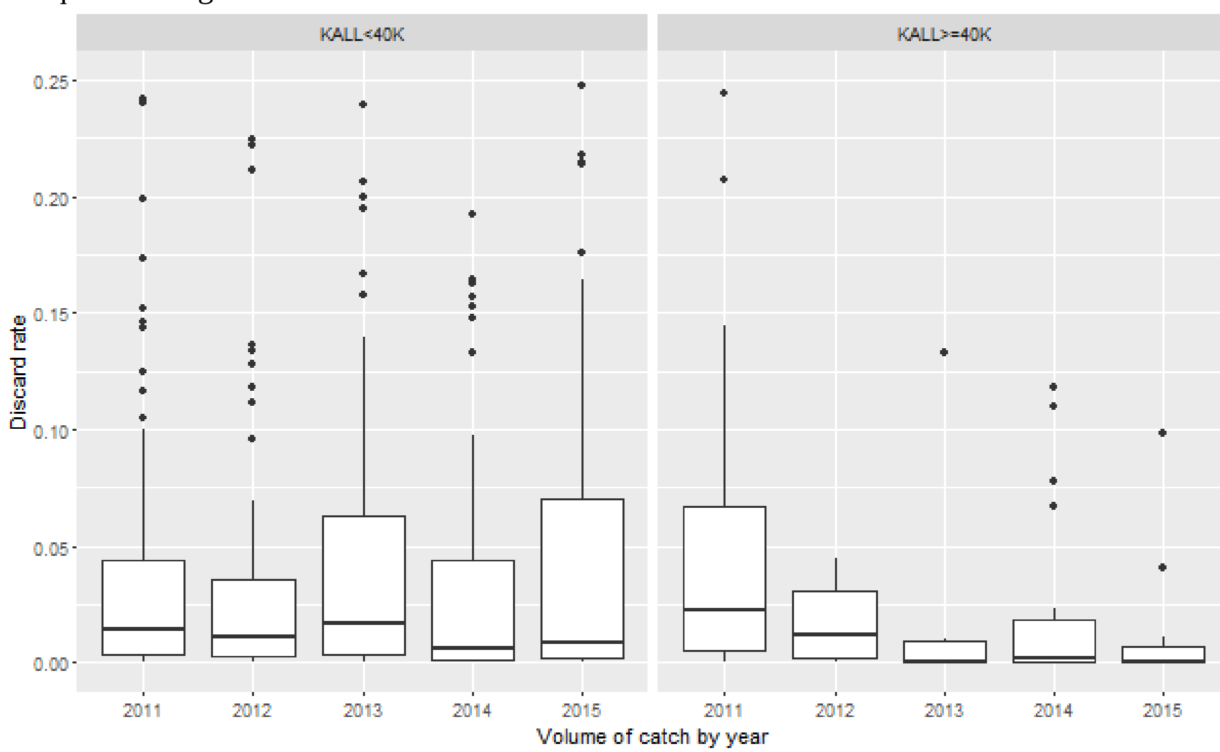

Figure 6b. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by volume of catch category (greater than or equal to 40,000 lb, less than to 40,000 lb) by year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

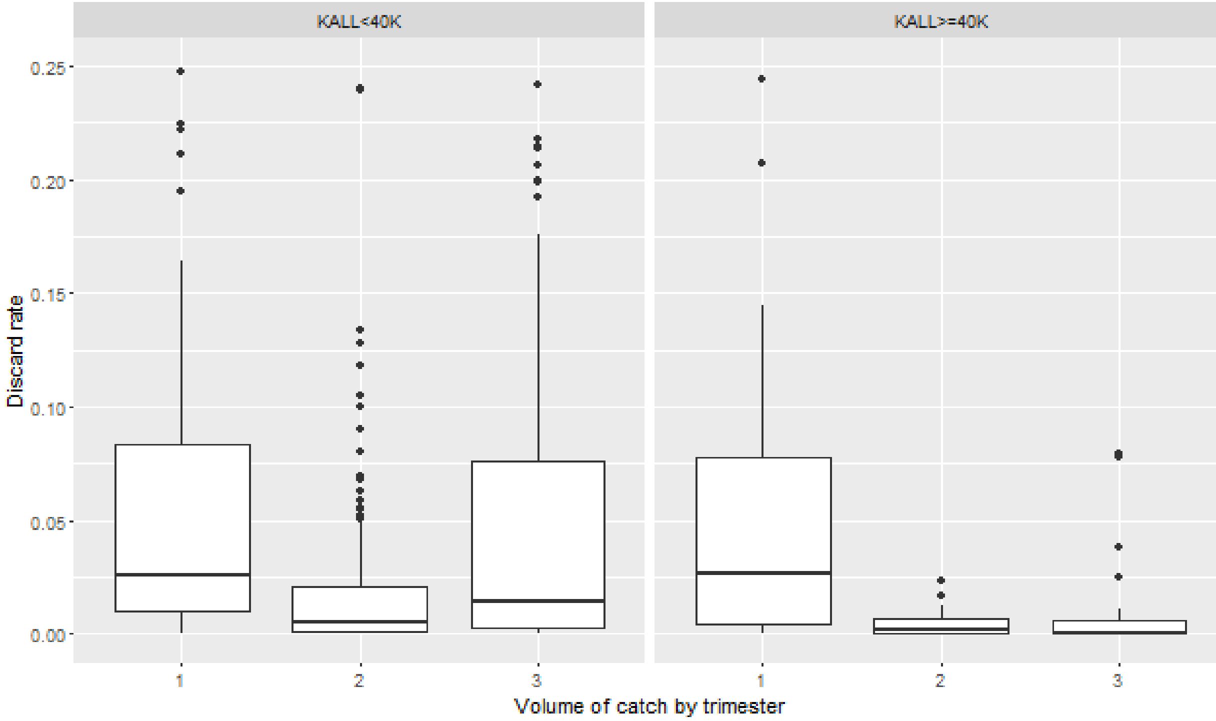

Figure 6c. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by volume of catch category (greater than or equal to 40,000 lb, less than to 40,000 lb) by trimester, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

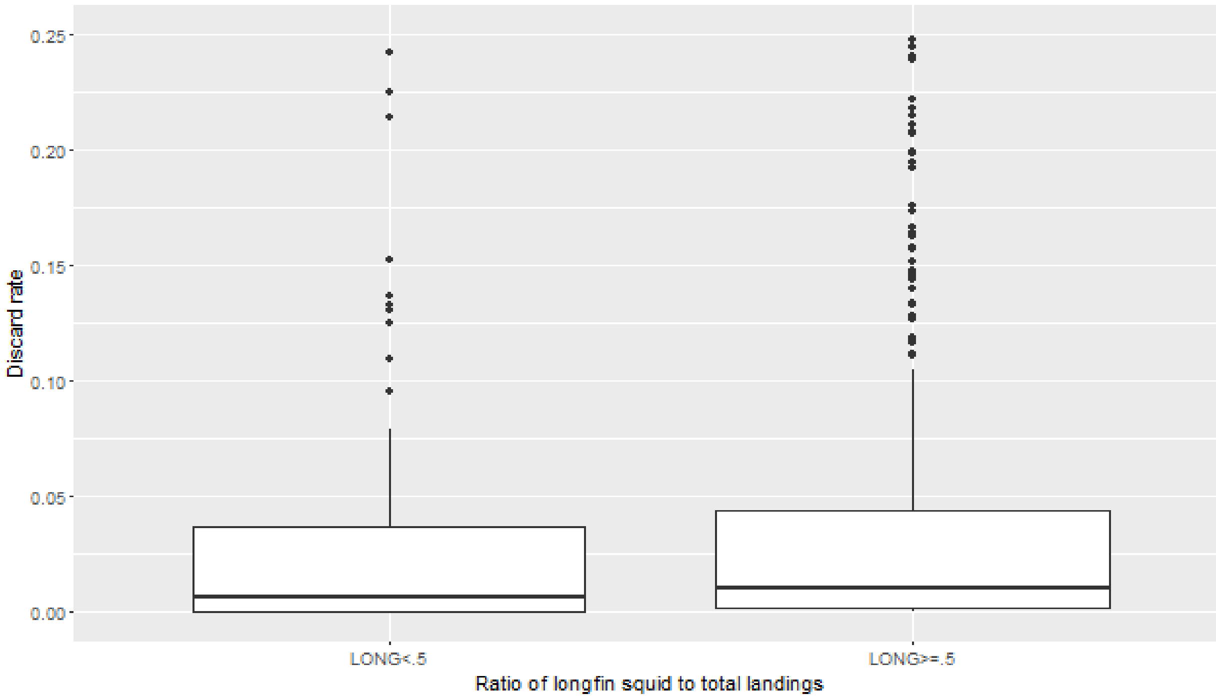

Figure 7a. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by proportion of longfin squid landed (greater than or equal to 50%, less than 50%), 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

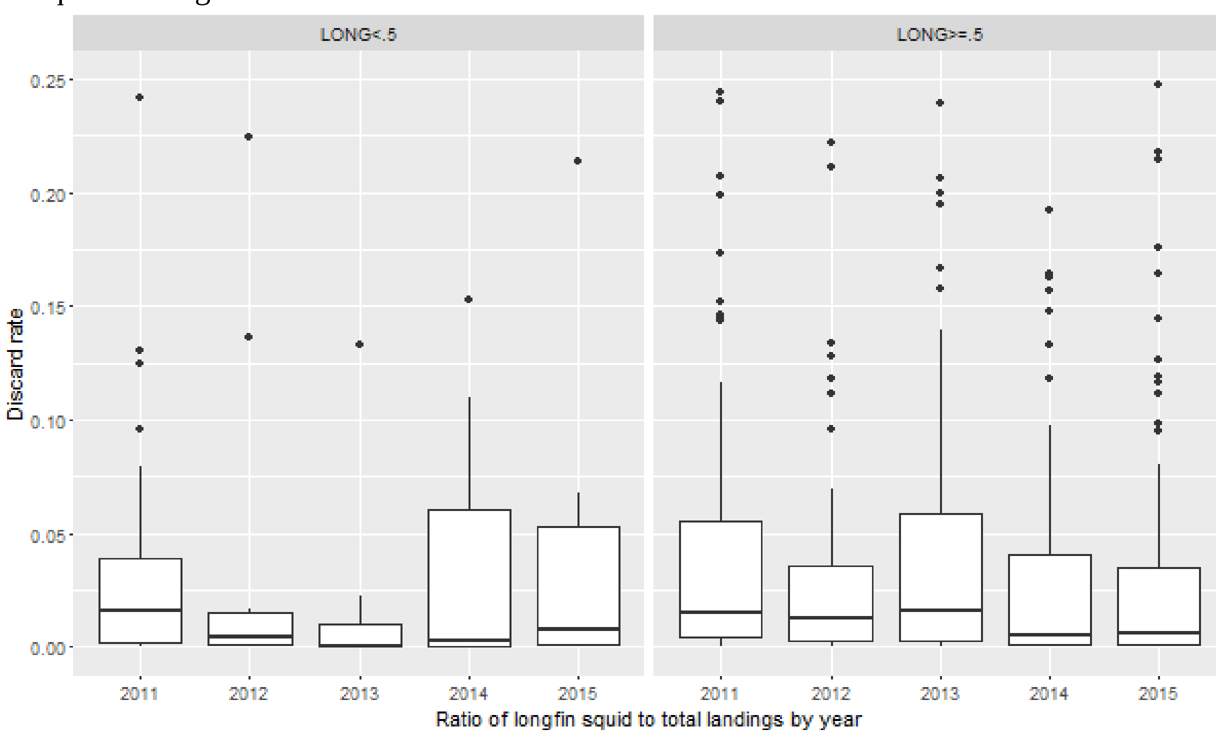

Figure 7b. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by proportion of longfin squid landed (greater than or equal to 50%, less than 50%) by year, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

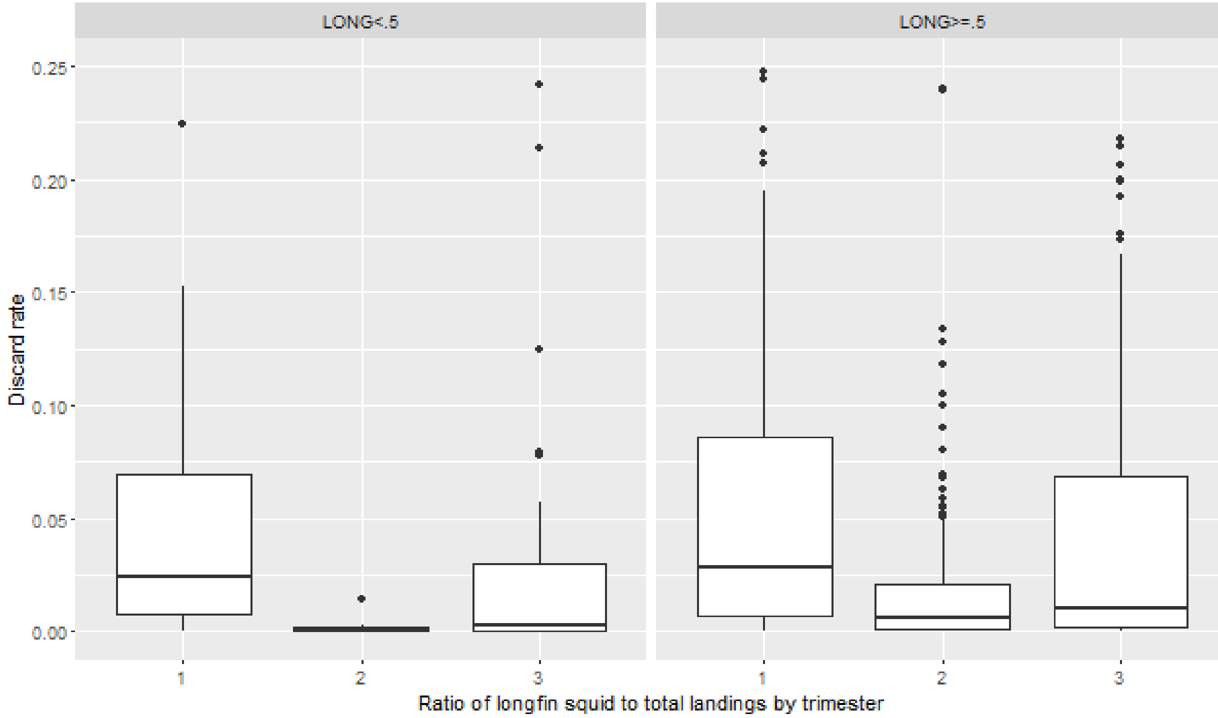

Figure 7c. Boxplots of the distribution of butterfish discard rates in the longfin squid fishery by proportion of longfin squid landed (greater than or equal to 50%, less than 50%) by trimester, 2011-2015. Boxes show the 25th, 50th and 75th percentile of the distribution, whiskers run to 1.5 times the interquartile range, points are outliers. Note that the vertical axis was truncated to highlight the interquartile range of the distribution.

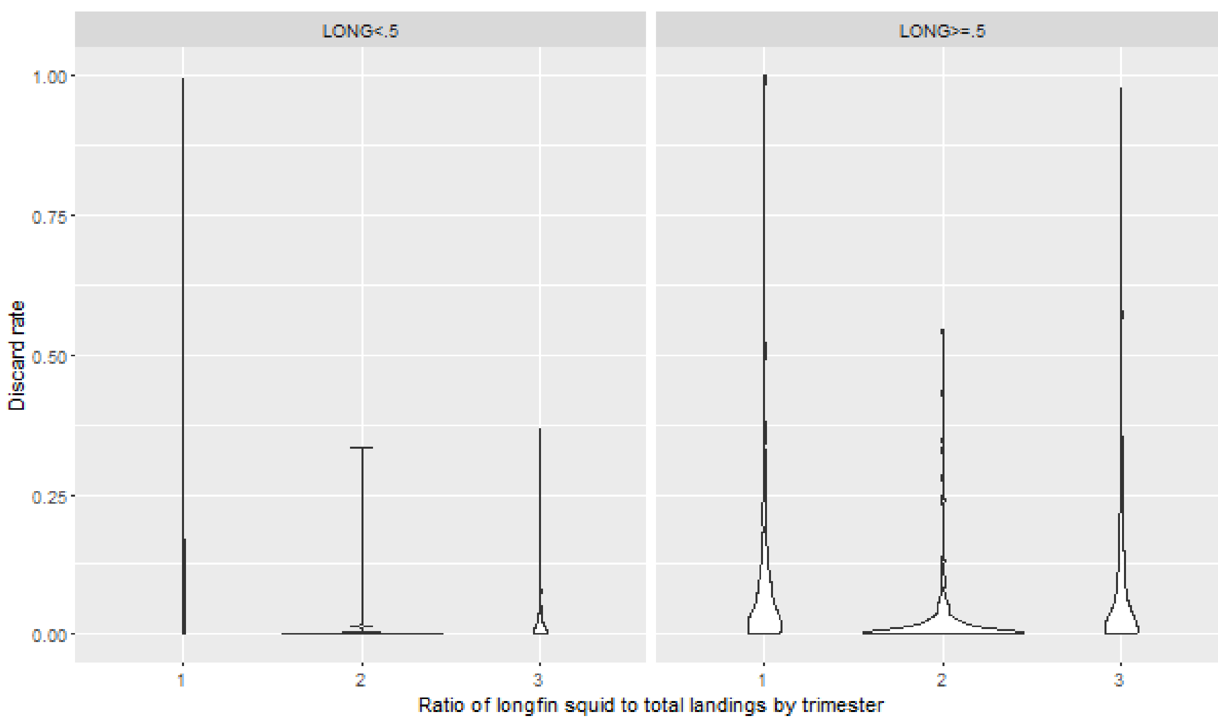

Figure 7d. Violin plots of the distribution of butterfish discard rates in the longfin squid fishery by proportion of longfin squid landed (greater than or equal to 50%, less than 50%) by trimester, 2011-2015. Note that the vertical axis was truncated to highlight the interquartile range of the distribution

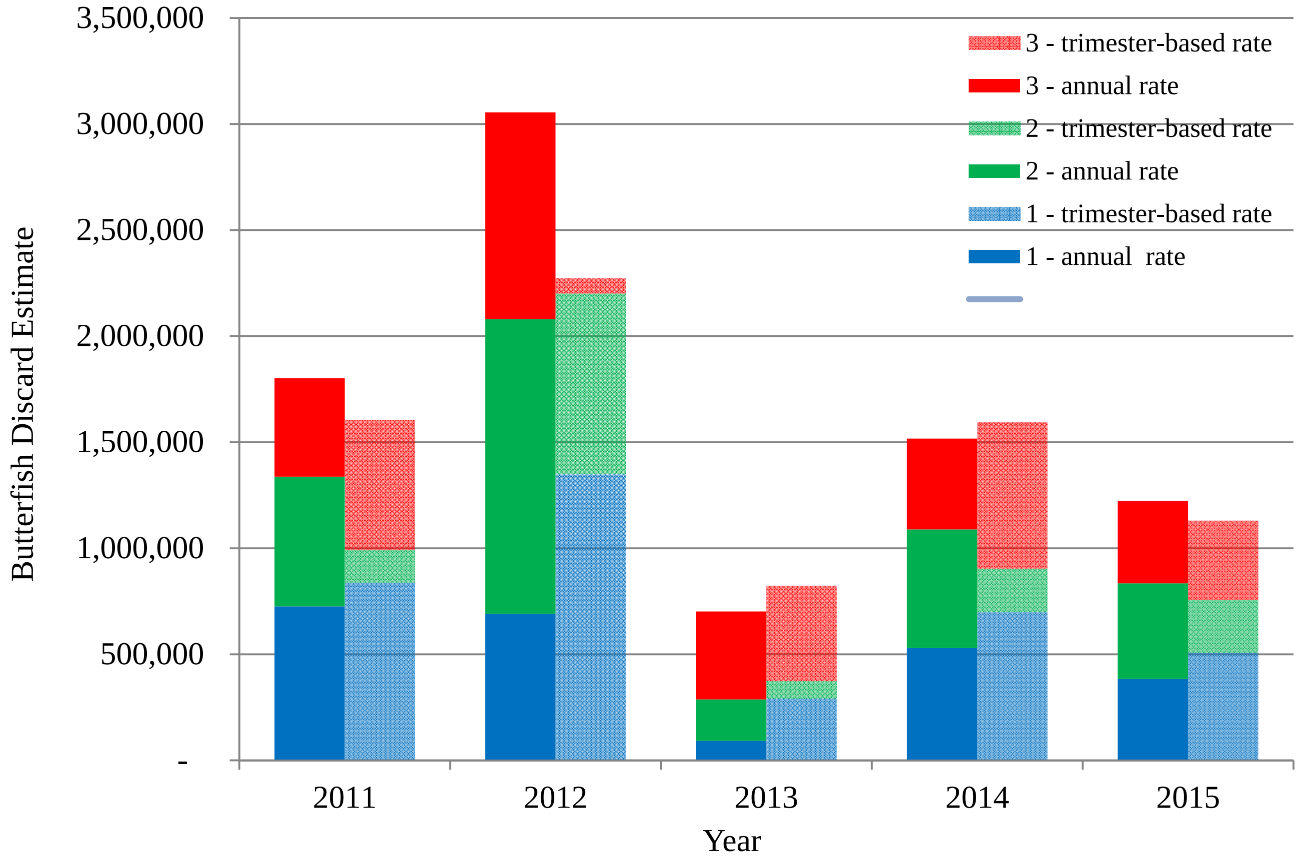

Figure 8. Estimated annual and trimester butterfish discards with an annual cumulative discard rate and trimester-based rates by year and trimester in the directed longfin squid fishery, 2011-2015.

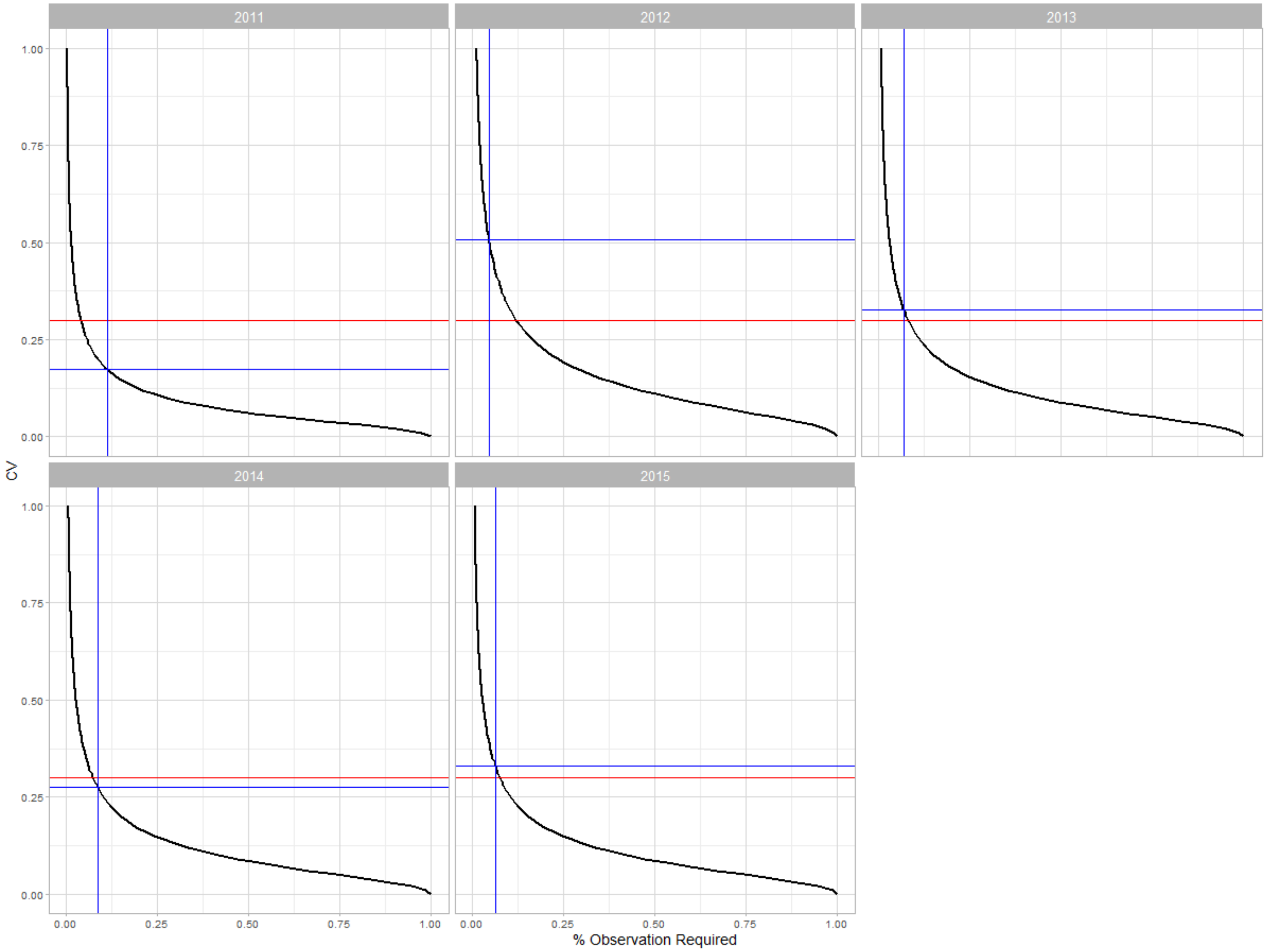

Figure 9. Coefficient of variation of butterfish discard estimates by the proportion of trips observed in the longfin squid fishery by year, 2011-2015. Red horizontal lines denote a CV of 0.3. Blue vertical lines represent the actual observed proportion of trips. Blue vertical lines represent the realized CV of the butterfish discard estimate in the longfin squid fishery for a given year.

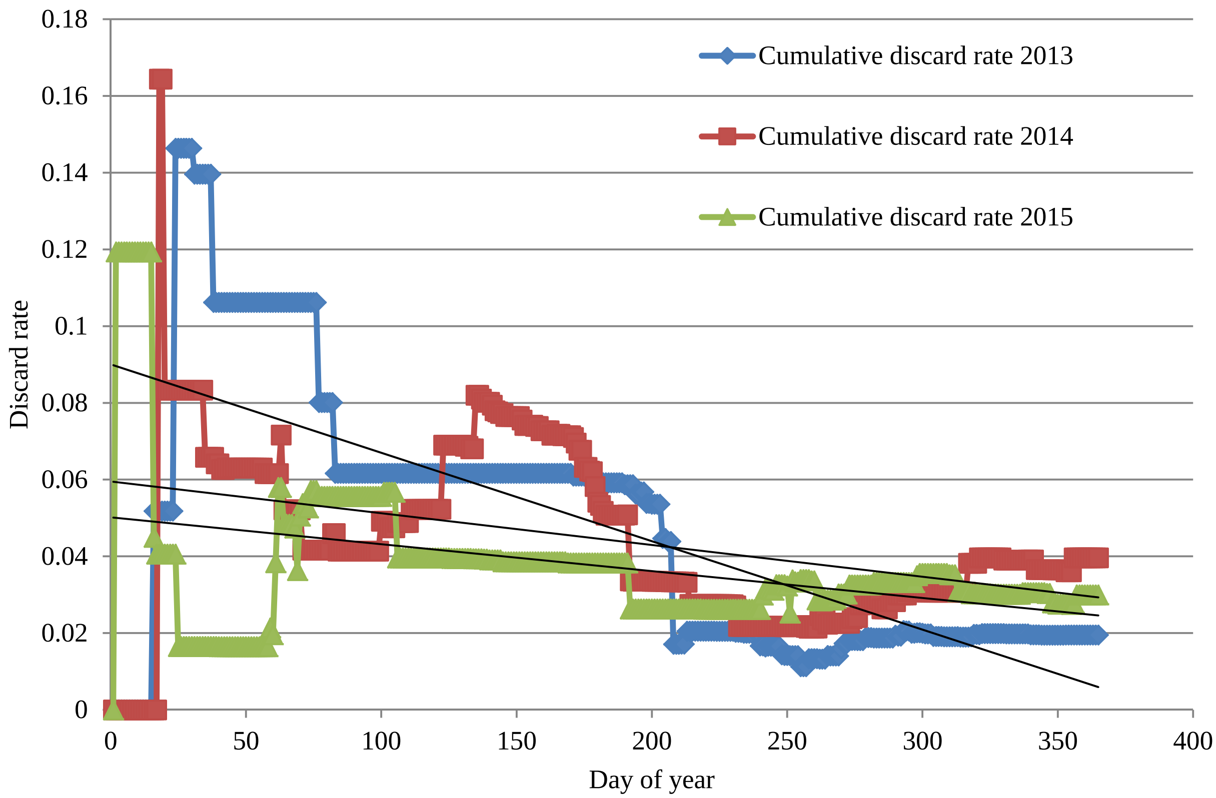

Figure 10. Cumulative discard butterfish rate over day of fishing year in the longfin squid fishery for 2013-2015.

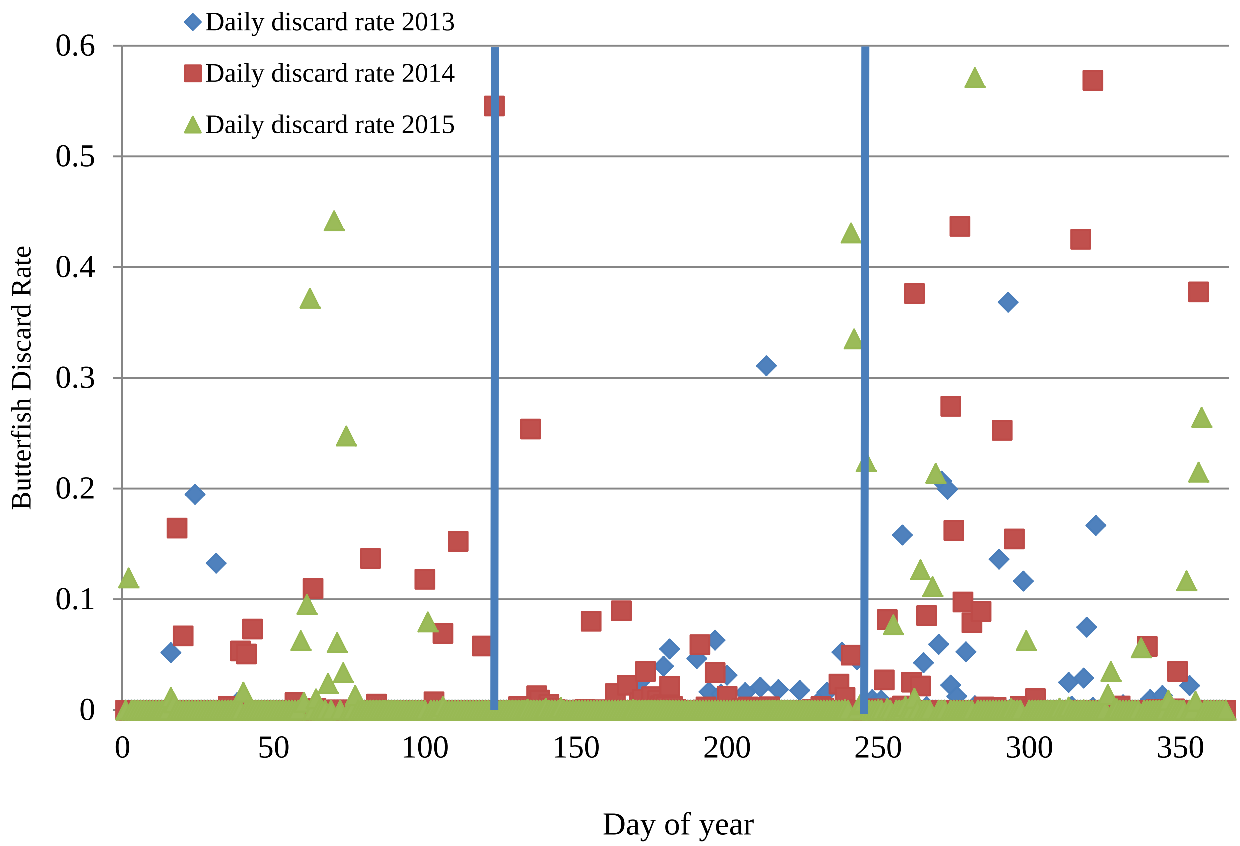

Figure 11. Daily butterfish discard rates by day of fishing year in the longfin squid fishery for 2013-2015. Blue vertical lines denote trimester boundaries.

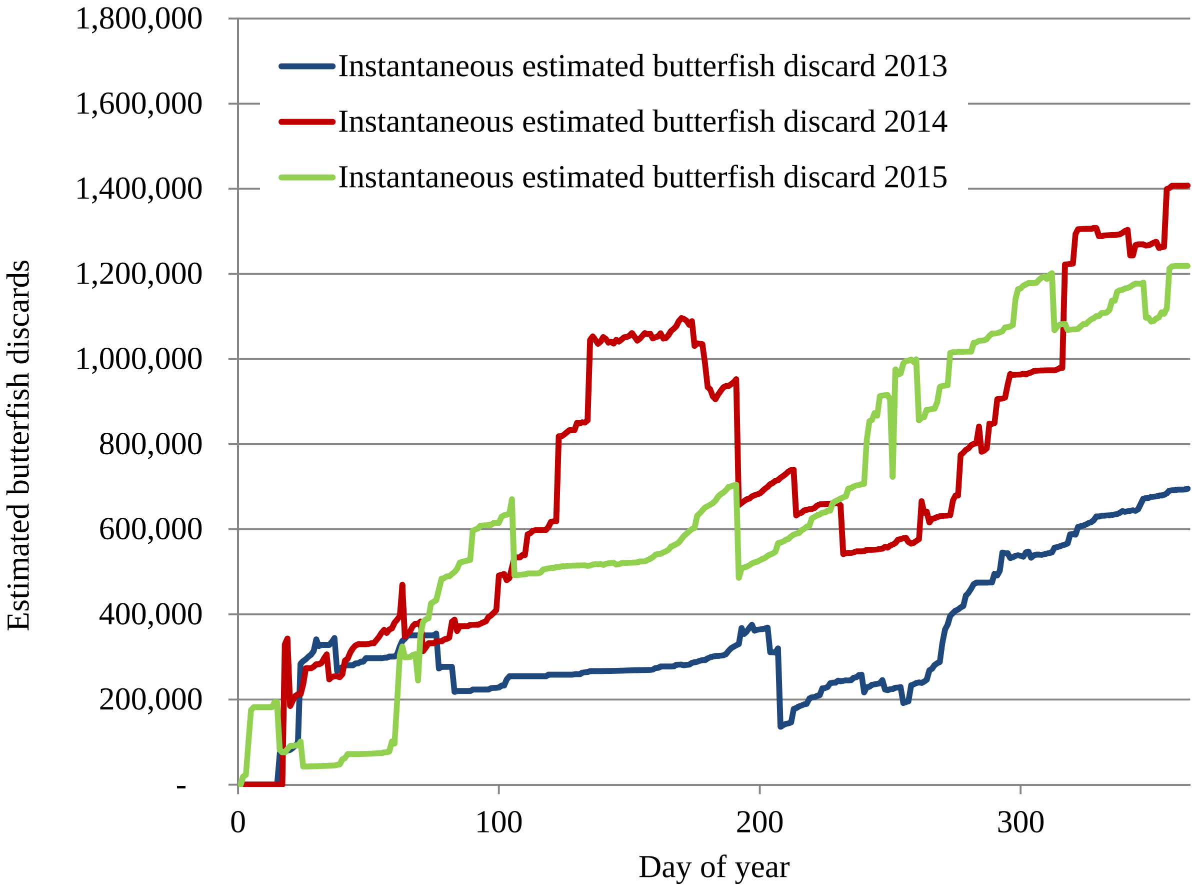

Figure 12. Instantaneous butterfish discard estimates by day of fishing year in the longfin squid fishery for 2013-2015.

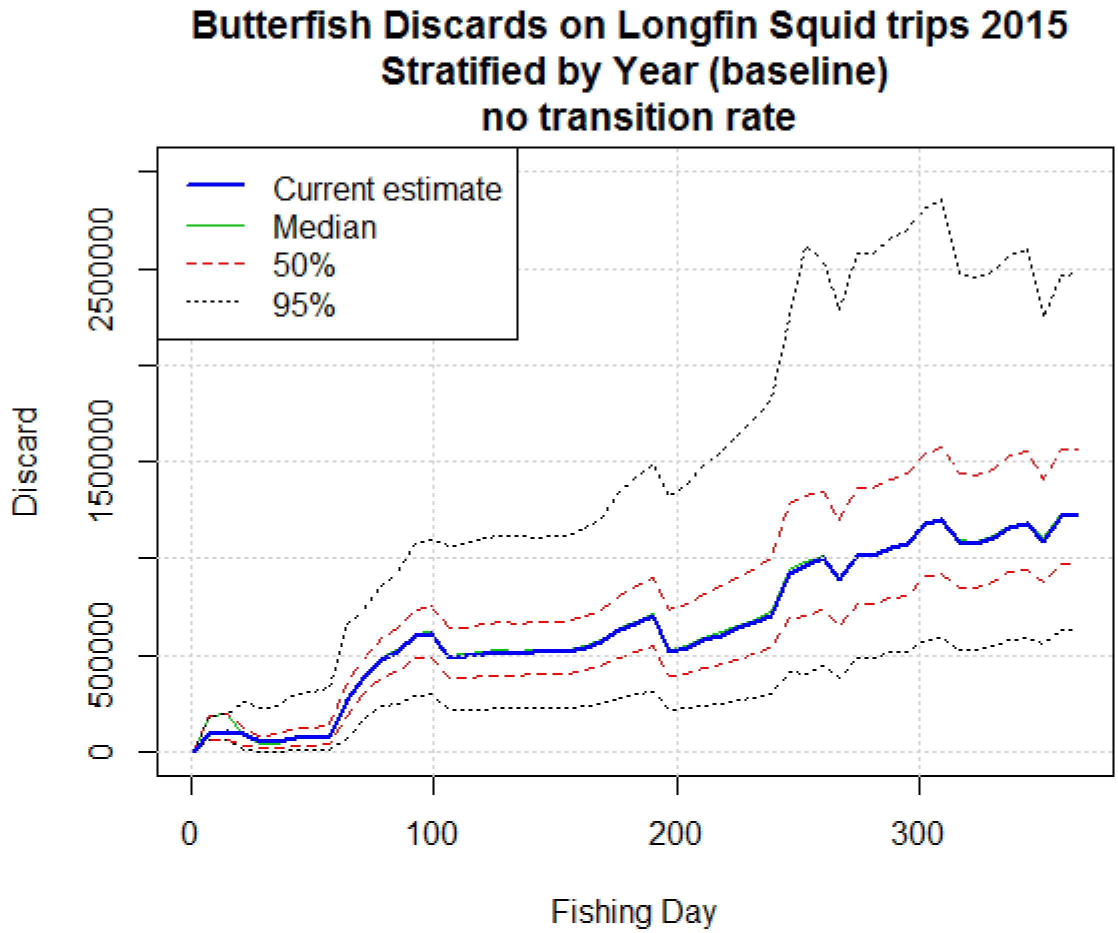

Figure 13a. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the combined ratio method with no transition discard rate.

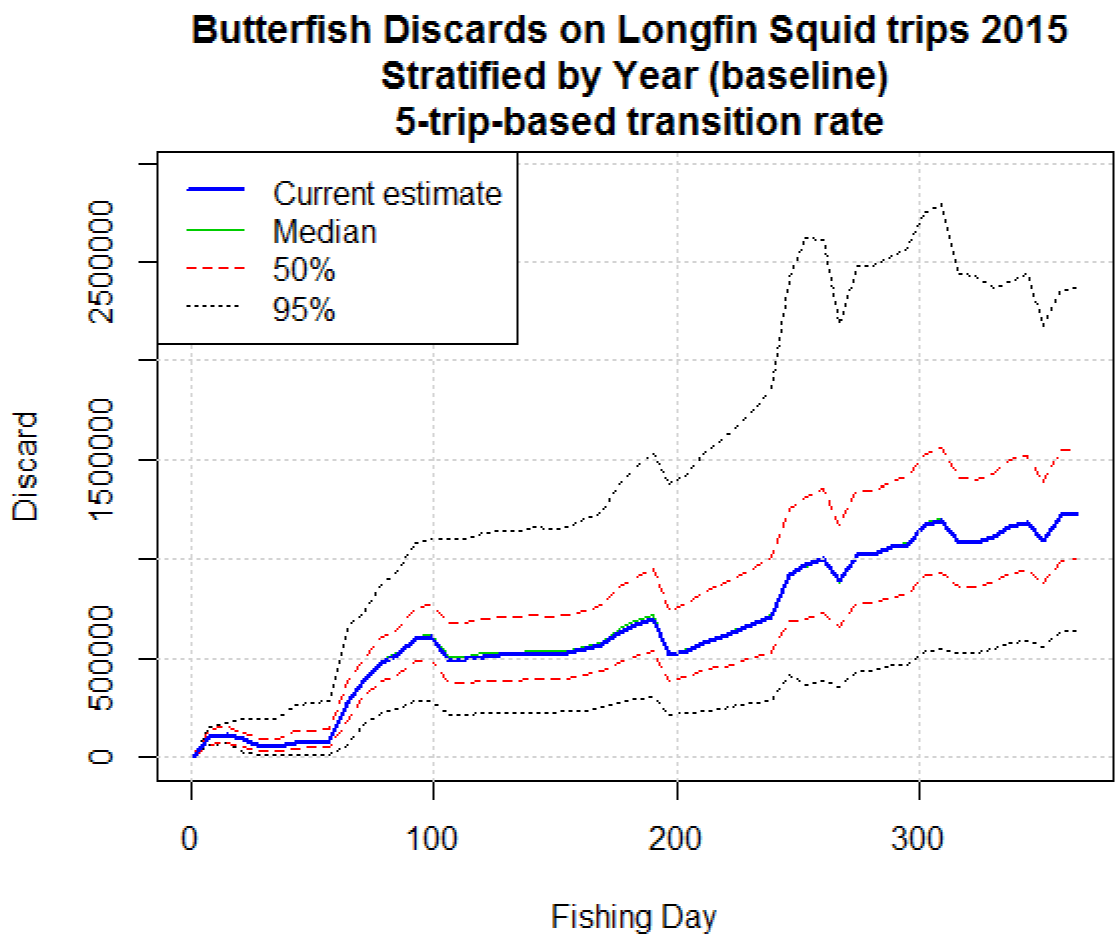

Figure 13b. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the combined ratio method with a 5-trip based transition discard rate (after 5 observed trips, the discard rate is derived only from observed trips in the current year).

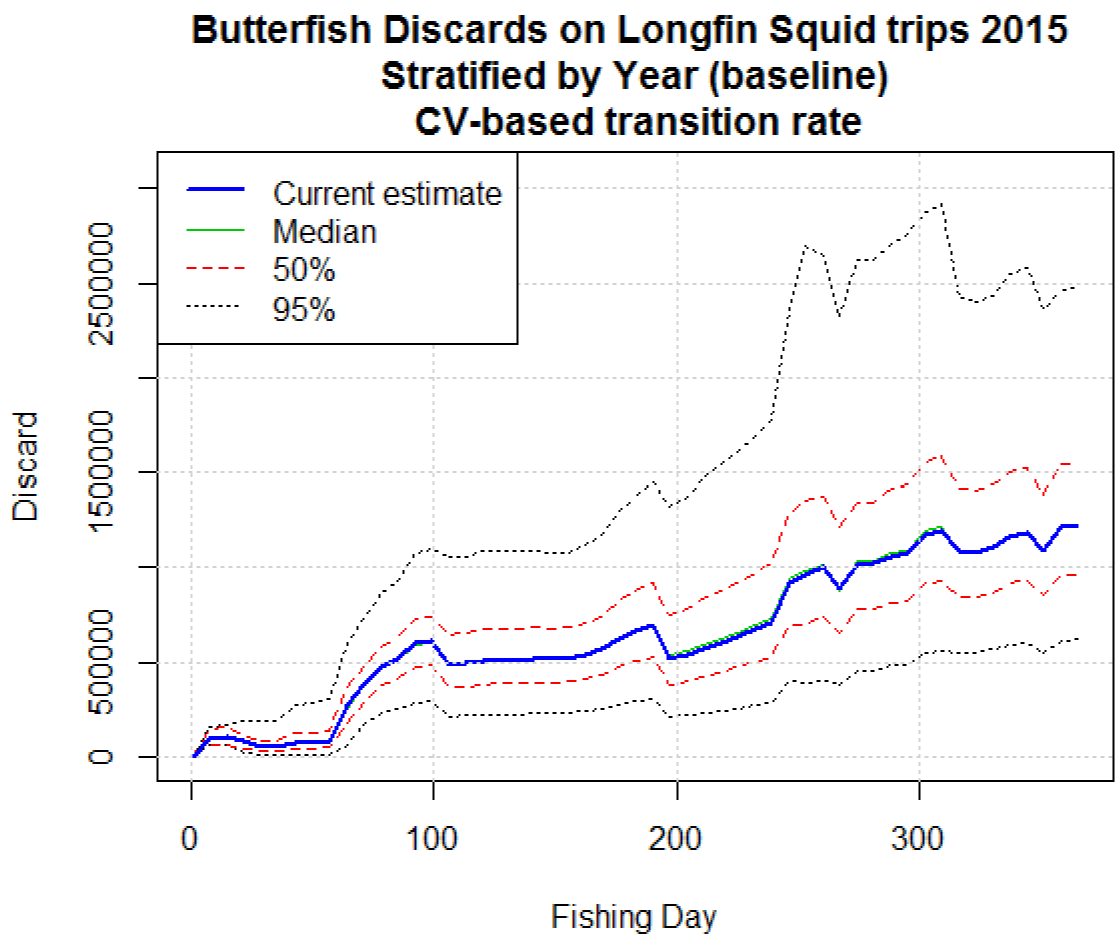

Figure 13c. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the combined ratio method with a CV-trip based transition rate (in-season discard rate in use after the number of observed trips reaches the required sampling rate for a CV of 0.3).

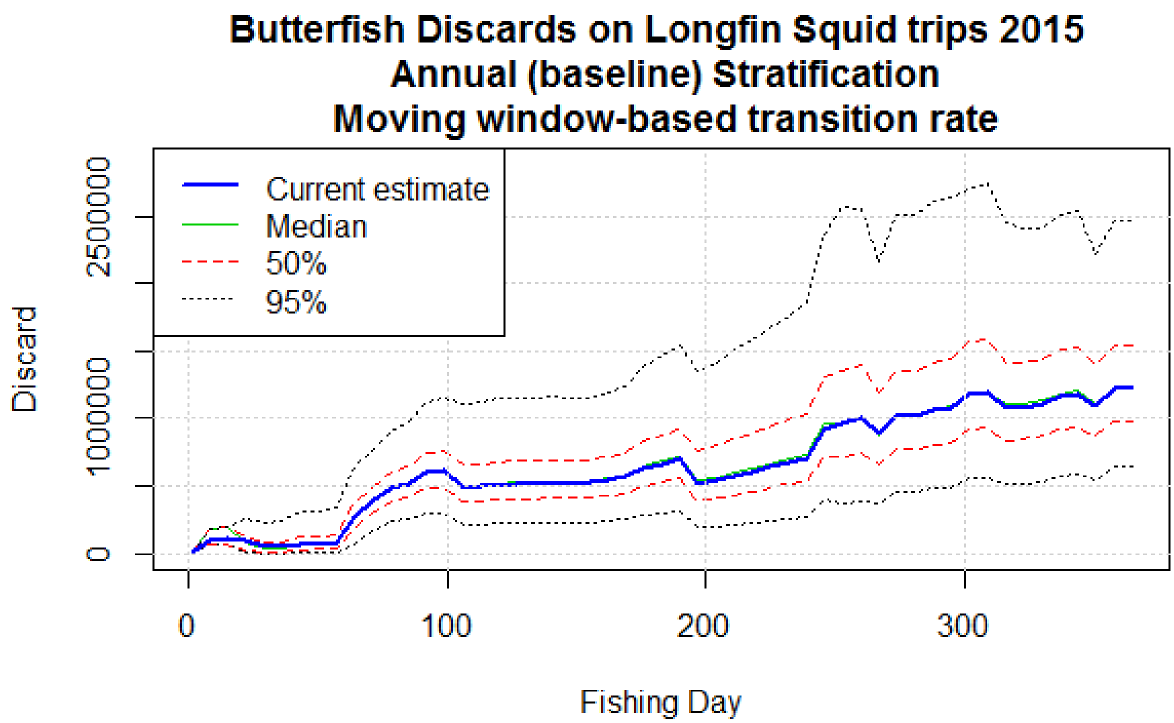

Figure 13d. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery with a moving window trip-based transition rate (fully in-season-based discard rate in use at the end of the year).

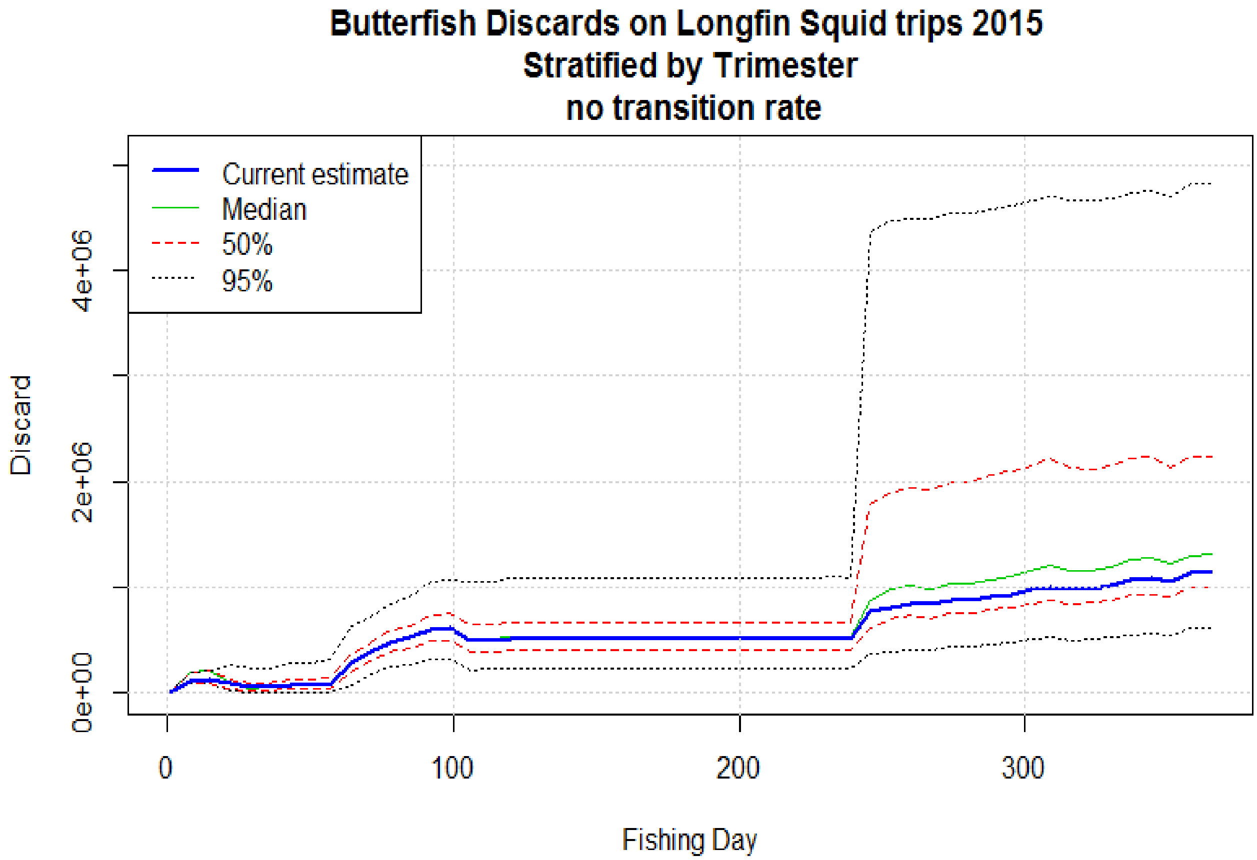

Figure 14a. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with no transition discard rate.

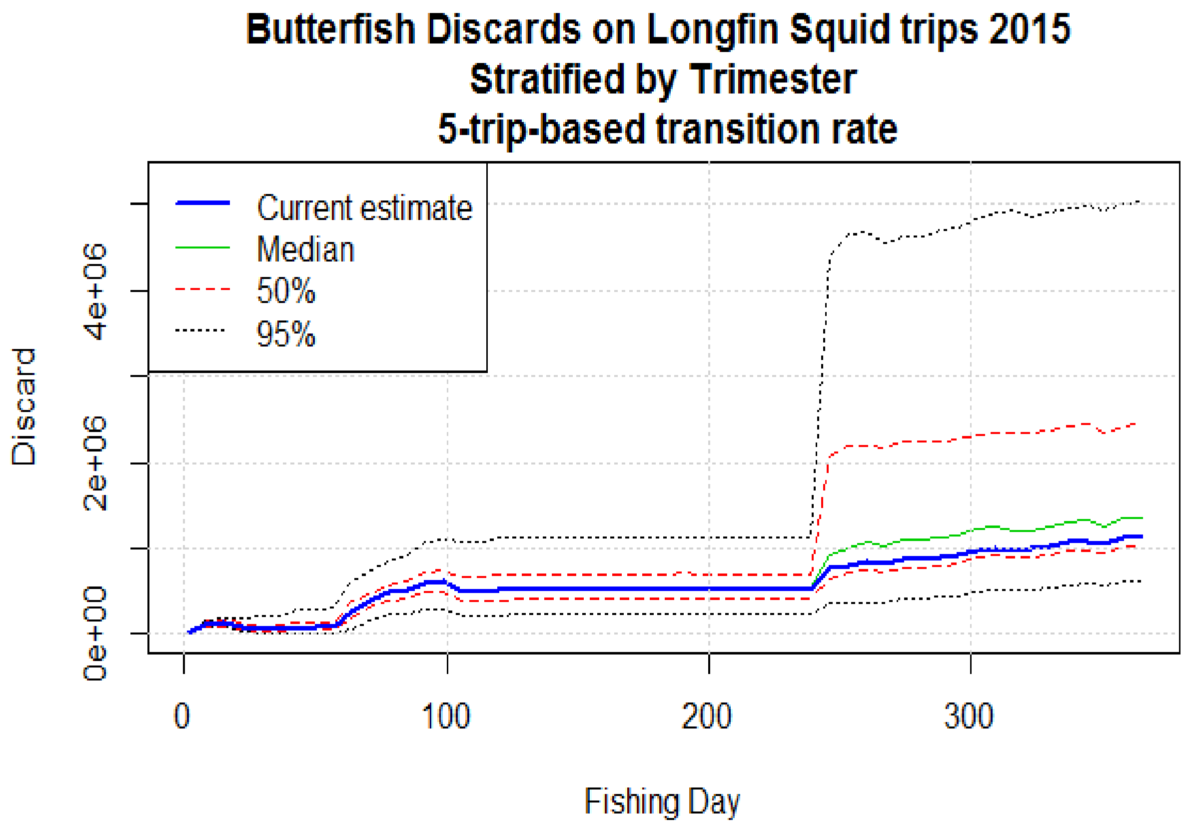

Figure 14b. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a 5-trip based transition discard rate (after 5 observed trips, the discard rate is derived only from observed trips in the current year and trimester).

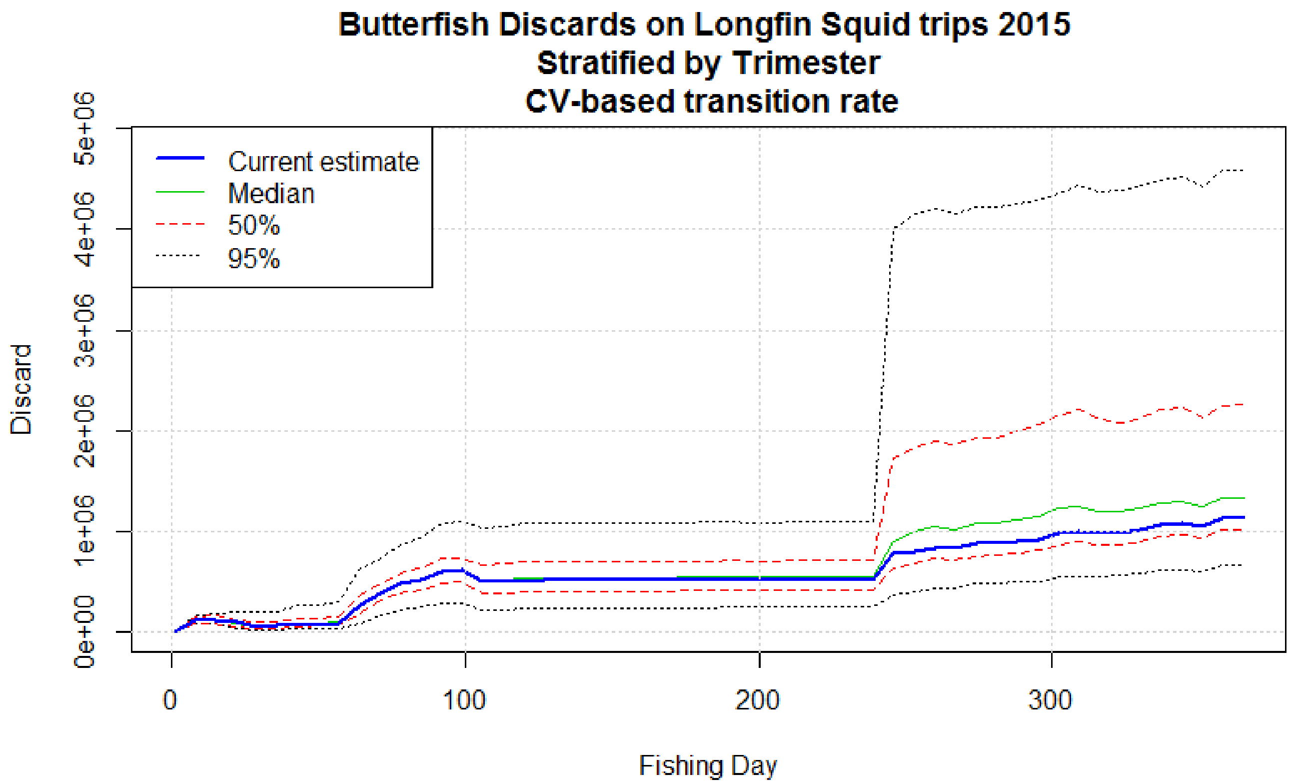

Figure 14c. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a CV-trip based transition rate (in-season discard rate in use after the number of observed trips reaches the required sampling rate for a CV of 0.3).

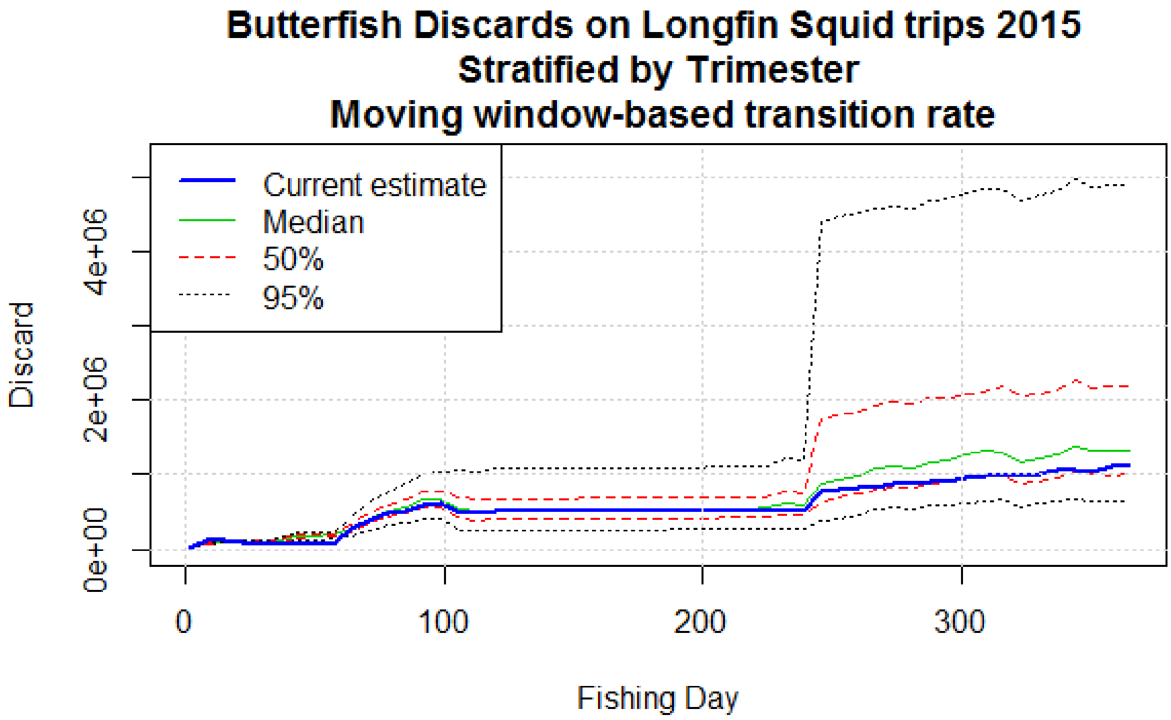

Figure 14d. Simulation output of 2015 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a moving window trip-based transition rate (fully in-season-based discard rate in use at the end of the trimester).

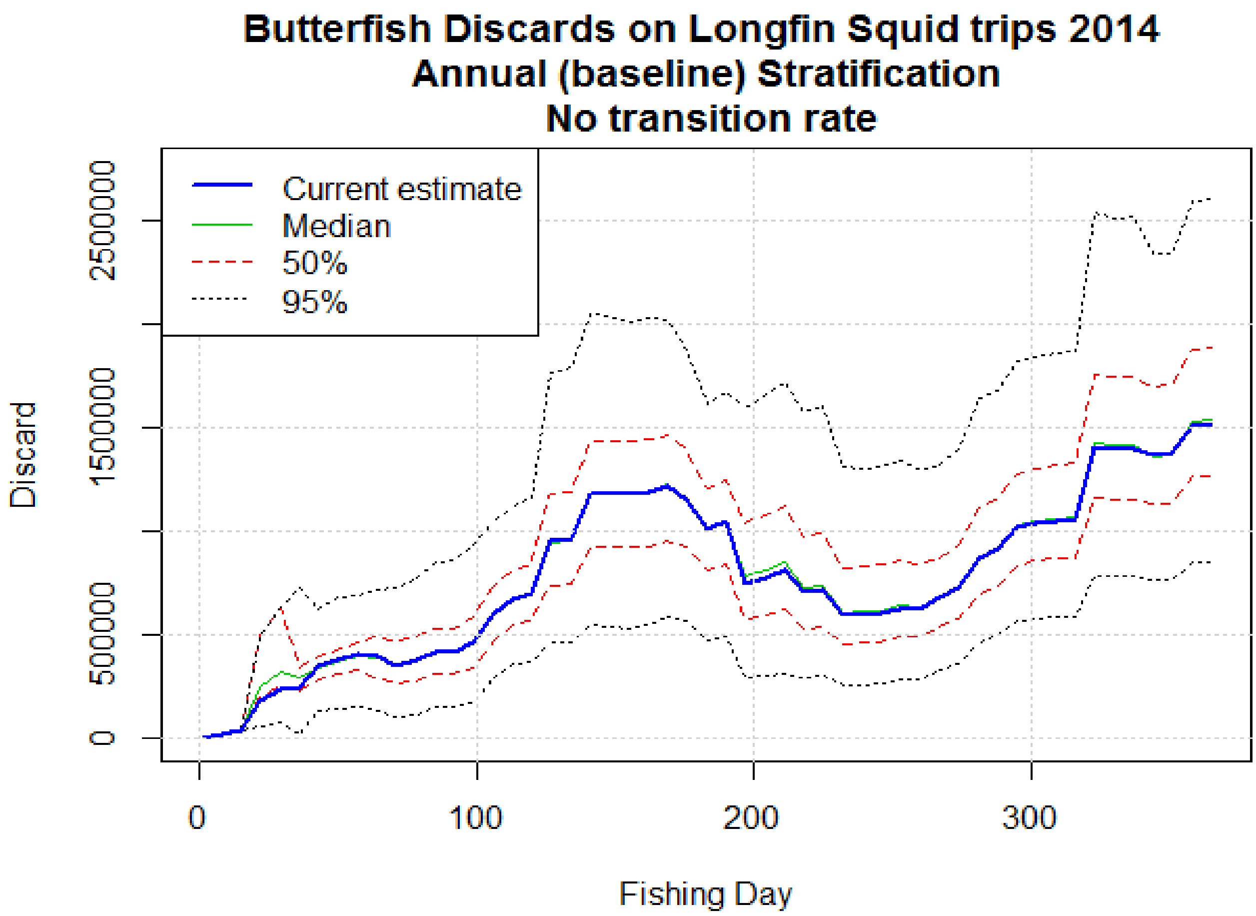

Figure 15a. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery with no transition discard rate.

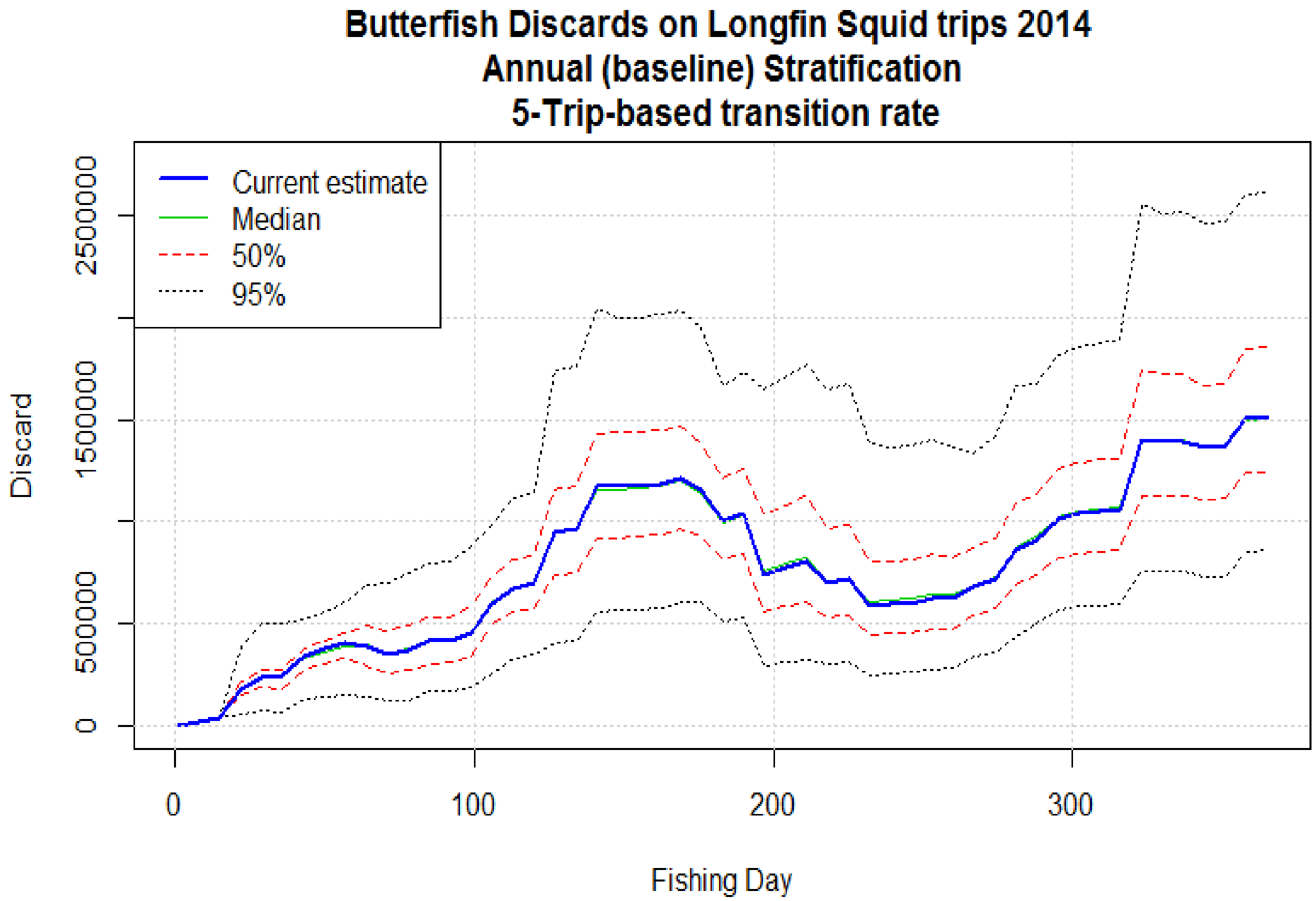

Figure 15b. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery with a 5-trip based transition discard rate (after 5 observed trips, the discard rate is derived only from observed trips in the current year).

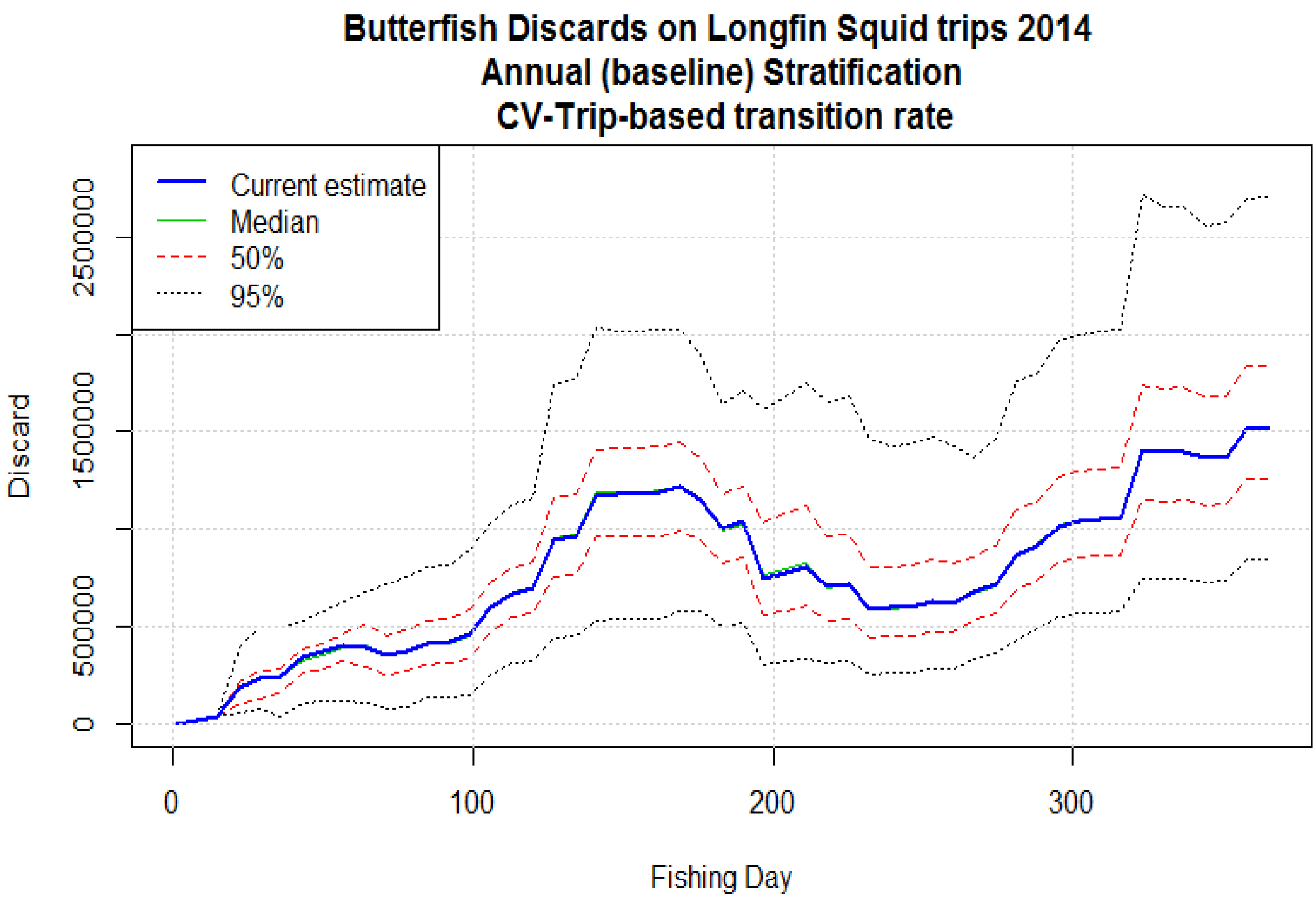

Figure 15c. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery with a CV-trip based transition rate (in-season discard rate in use after the number of observed trips reaches the required sampling rate for a CV of 0.3).

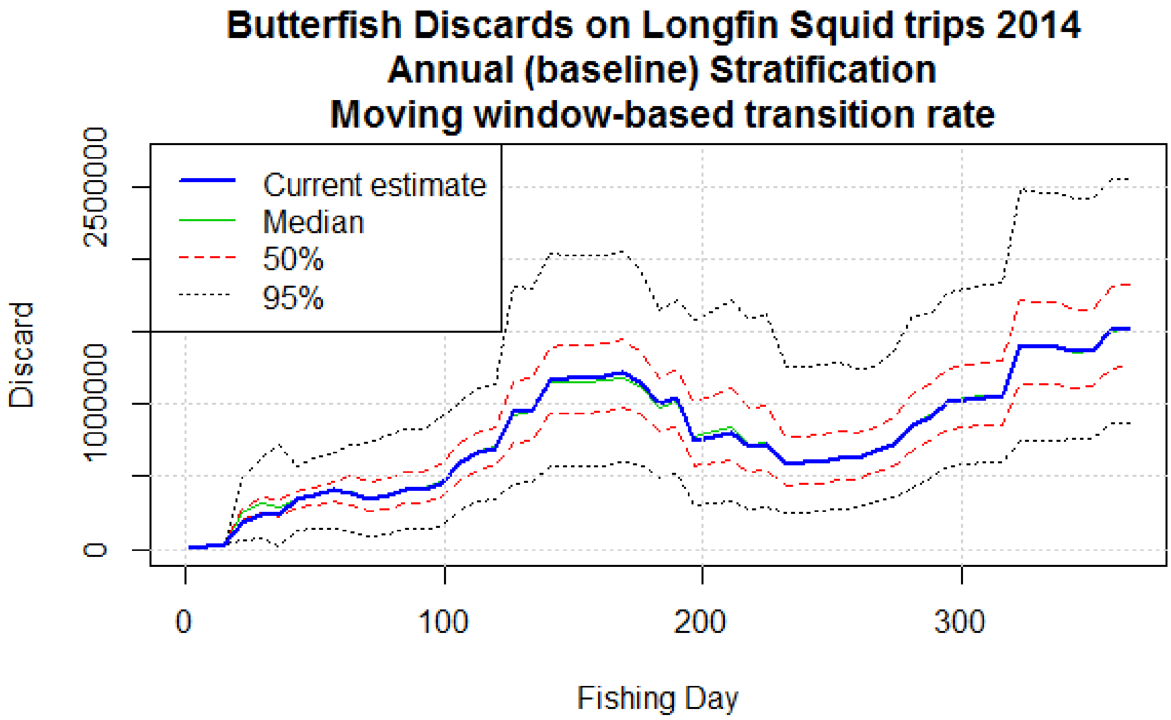

Figure 15d. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery with a moving window trip-based transition rate (fully in-season-based discard rate in use at the end of the year).

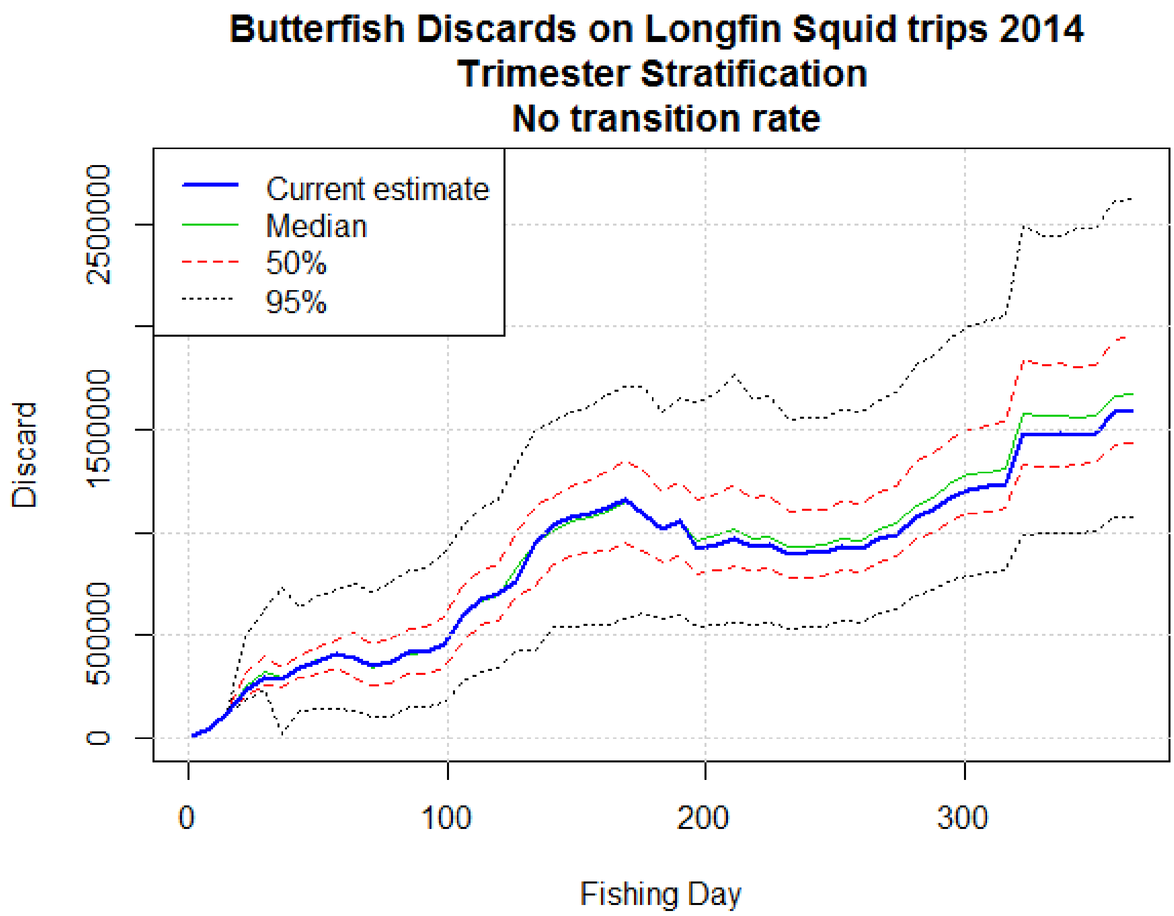

Figure 16a. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with no transition discard rate.

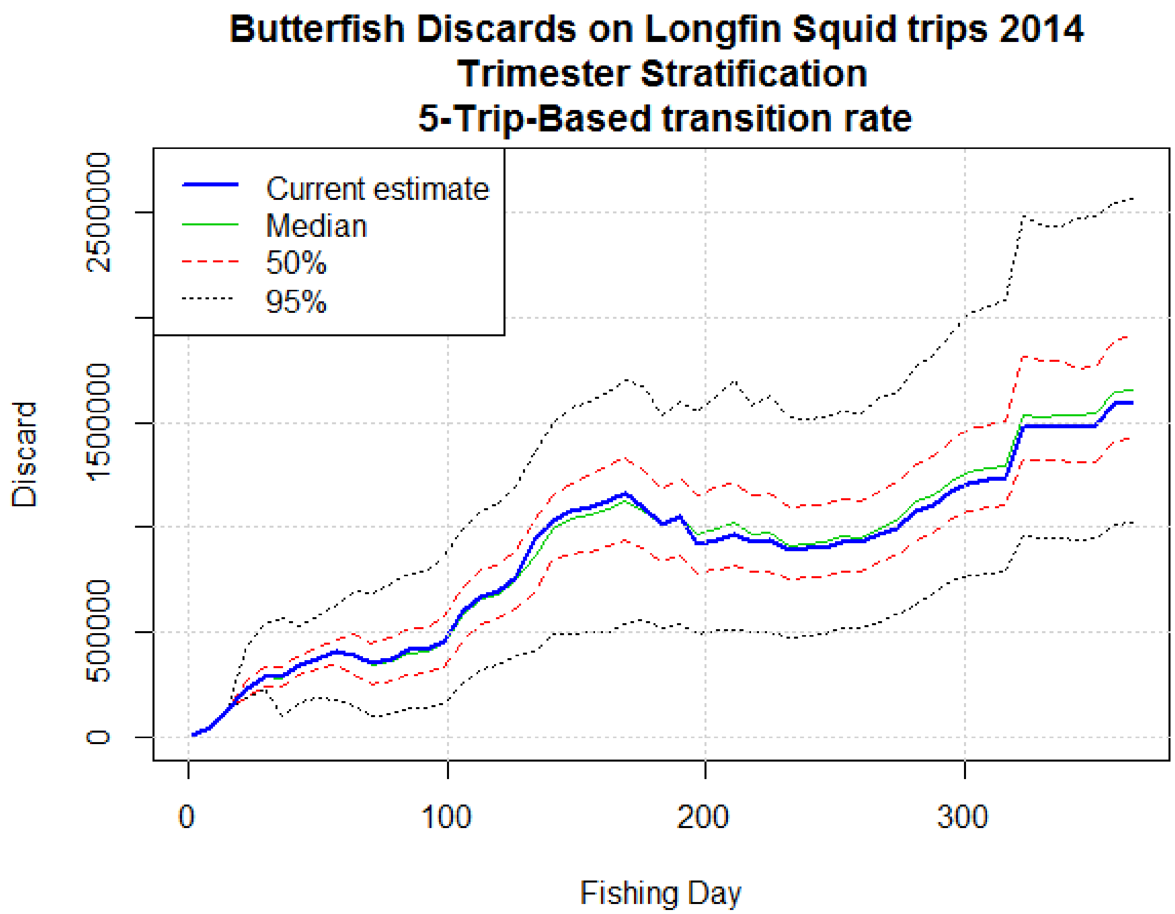

Figure 16b. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a 5-trip based transition discard rate (after 5 observed trips, the discard rate is derived only from observed trips in the current year and trimester).

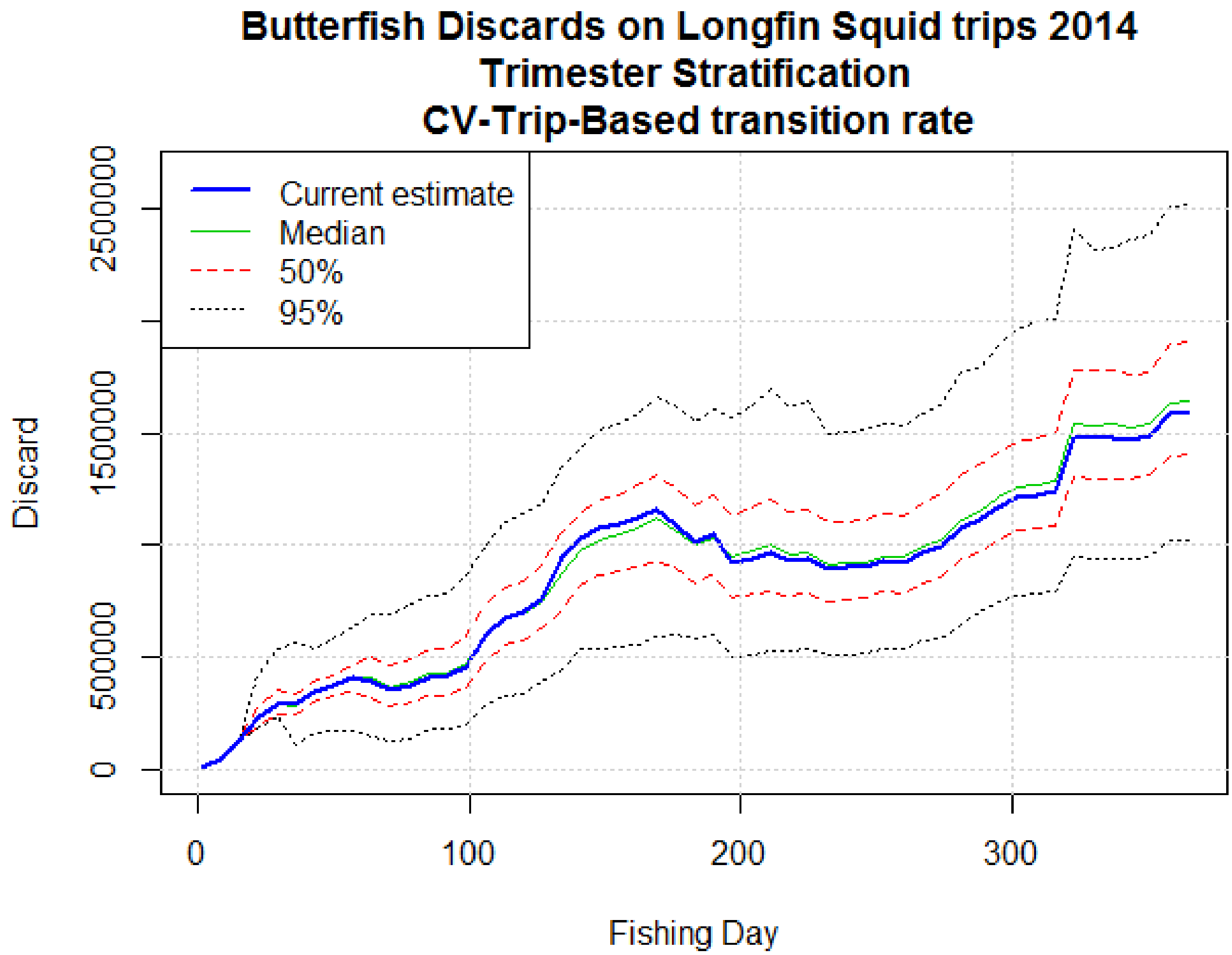

Figure 16c. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a CV-trip based transition discard rate (in-season discard rate in use after the number of observed trips reaches the required sampling rate for a CV of 0.3).

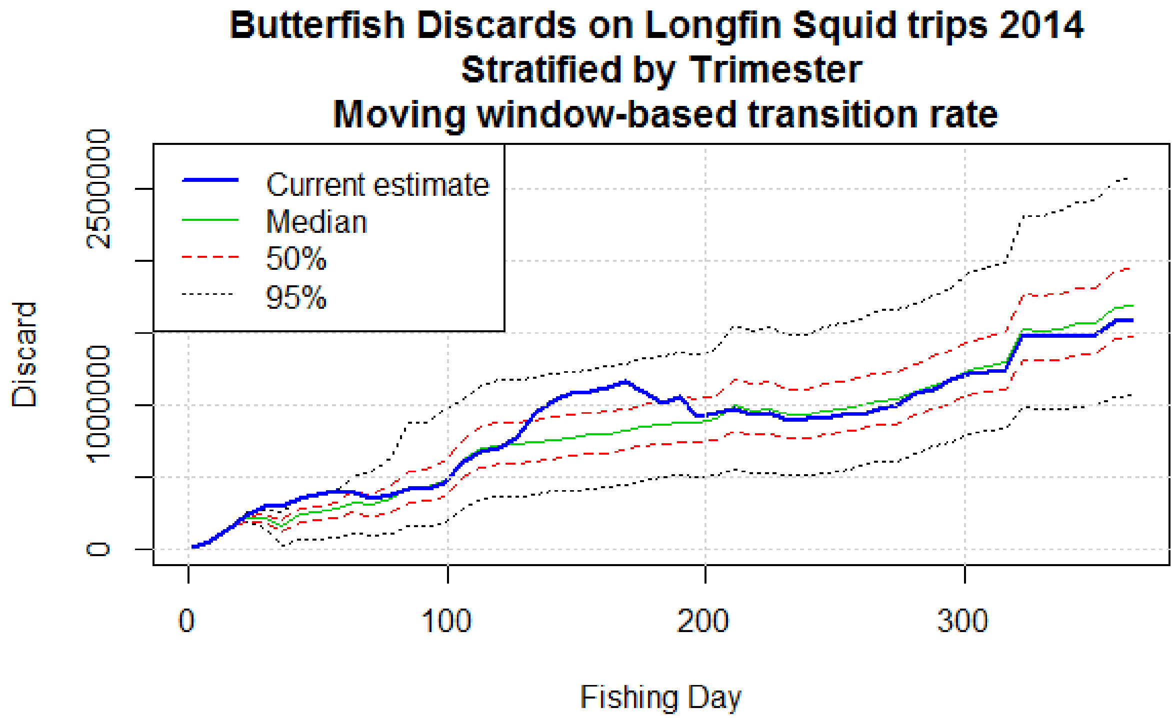

Figure 16d. Simulation output of 2014 estimated butterfish discards in the directed longfin squid fishery using the separate ratio method (temporally-stratified by trimester) with a moving window trip-based transition rate (fully in-season-based discard rate in use at the end of the trimester).

Appendix A. Terms of reference

Terms of Reference- In-Season Discard Methodology Peer Review

GARFO Analysis and Program Support Division – July 2016

1. For each fishery subject to in-season discard monitoring utilizing the cumulative discard method, summarize the variability in discard rate by measurable strata: fishery, gear, area, season, volume of catch, etc.

2. Identify more optimal applications of the current cumulative method for in-season estimation of discards in comparison to existing cumulative discard methodology and stratification schemes. Alternatives identified will include

    a. Existing cumulative discard methodology and stratification scheme as a baseline

    b. Pooling data across current stratifications to increase information and precision. As an example, pooling across sectors and gears.

    c. Including seasonality as a stratification

    d. Allocate/restrict sampling requirements to those strata which in aggregate constitute a target fraction of total stock-specific discards. (i.e, excluding or minimizing sampling for strata with negligible discard totals)

3. Methods identified in TOR 2 will be compared using the following metrics

    a. Precision of the discard estimates for a given level of observer coverage

    b. Consistency of discard estimates calculated over the course of the fishing year.

    c. Precision and consistency of the CV discard metric for a given level of observer coverage

    d. Sensitivity to missing or erroneous data.

4. Examine methods for including data from past years to improve predicting the in-season estimation of discards.

5. Use archived data to simulate in-season behavior (with various time steps and discarding patterns) and recommend a preferred method for each fishery with consideration of the following:

    a. Feasibility, particularly the implications of stratum size and within-year pattern of precision.

    b. The probability and timing of premature closure (i.e. false positive).

    c. The probability and magnitude of exceeding a cap (i.e. e. false negative).