Comparison of Rockfish and Lingcod Catch Estimates from Internet Recreational Effort and Catch (iREC) and Creel Surveys

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by

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Stock assessments for inshore rockfish (*Sebastes* spp.) and Lingcod (*Ophiodon elongatus*) depend on having quality fishery data, such as those generated from creel surveys. Despite their usefulness, the cost of creel surveys has limited their deployment to certain areas and temporal periods. Another assessment tool, the Internet Recreational Effort and Catch (iREC) survey, has complete spatiotemporal coverage for Tidal Waters, but can be biased (relative to creel survey results) for a variety of reasons. To measure the effect of potential biases, a calibration procedure was developed to relate iREC estimates to those from creel surveys, using data from temporal and geographic strata for which both types of surveys were conducted. Data from the North Coast, Strait of Georgia, and West Coast of Vancouver Island dating from 2012 to 2021 were included in Bayesian Type II regression analyses, run separately for each of twelve taxa and for two disposition types (i.e., kept vs. released). Most of the analyses produced unimodal parameter estimates with little to no autocorrelation. In almost every case, the trendlines indicated that iREC catch estimates are larger than corresponding creel values. The magnitude of the slopes should be reliable estimators of the degree of bias in the iREC estimates, and their use as naïve ‘conversion factors’ should successfully minimize such bias.

RÉSUMÉ

Robichaud, D. and Haggarty, D.R. 2022. Comparison of Rockfish and Lingcod Catch Estimates from Internet Recreational Effort and Catch (iREC) and Creel Surveys. Can. Tech. Rep. Fish. Aquat. Sci. 3500: v + 46 p.

Les évaluations des stocks de sébastes (*Sebastes* spp.) et de morues-lingues (*Ophiodon elongatus*) dépendent de la qualité des données pour les secteurs de la pêche, comme celles qui sont générées par les enquêtes par interrogation des pêcheurs. Malgré leur utilité, le coût de ces enquêtes a limité leur déploiement à certaines zones et périodes seulement. Un autre outil d’évaluation, soit le programme de déclaration électronique de l’effort et des prises de la pêche récréative (iREC), offre une couverture spatio-temporelle complète pour les eaux de marée, mais peut être biaisé pour diverses raisons. Pour mesurer l’effet des biais possibles, une procédure d’étalonnage a été mise au point afin de relier les estimations de l’iREC à celles des enquêtes par interrogation des pêcheurs, en utilisant des données provenant de strates temporelles et géographiques pour lesquelles les deux types d’enquêtes ont été menées. Les données de la côte nord, du détroit de Géorgie et de la côte ouest de l’île de Vancouver pour la période allant de 2012 à 2021 ont été incluses dans des analyses de régression bayésiennes de type II, effectuées séparément pour chacun des douze taxons et pour deux types de disposition (c.-à-d. conservé ou remis à l’eau). La pluspart des analyses ont produit des estimations de paramètres unimodales avec peu ou pas d’autocorrélation. Dans presque tous les cas, les lignes de tendance indiquent que les estimations de prises de l’iREC sont supérieures aux valeurs correspondantes des enquêtes par interrogation des pêcheurs. L’ampleur des pentes devrait être une estimation fiable du degré de biais dans les estimations de l’iREC, et leur utilisation comme facteurs de conversion naïfs devrait réussir à réduire ce biais au minimum.

INTRODUCTION

Creel surveys are key tools used by managers to monitor recreational fishing activity. Due to their cost and to difficulties in accessing remote areas, temporal or spatial coverage of creel surveys in the tidal waters of Canada's Pacific region can be limited. The gaps in coverage create challenges for Fisheries and Oceans Canada (DFO) to use creel data to estimate total recreational catch and effort, or to conduct stock assessments and other analyses that are required by international agreements. In response, another assessment tool, the Internet Recreational Effort and Catch (iREC) survey, was developed to provide catch and effort estimates with complete coverage for Tidal Water areas (for all management areas, months, fishing methods, and species caught by the recreational sector). Whereas creel surveys involve trained technicians observing catch in the field, the iREC survey depends on participants filling out a catch and effort questionnaire after the fact. Like other similar tools, the iREC results can be biased for a variety of reasons, including recall bias, nonresponse bias, or due to species identification errors (Cane 1980, Tarrant et al. 1993, DFO 2015).

To measure the effect of potential biases in iREC estimates, a calibration procedure was developed to relate iREC estimates to those from creel surveys when both types of surveys are conducted in the same temporal and geographic strata (DFO 2015). Such calibration methods could then be used to adjust iREC results in management areas and times that are not covered by creel surveys. This calibration method was successfully applied to South Coast salmon (*Oncorhynchus* spp.) and Pacific Halibut (*Hippoglossus stenolepis*) fisheries in 2019 and 2020 (R. Houtman, pers. Comm.), but other fisheries could also benefit from the method.

Stock assessments for inshore rockfish (*Sebastes* spp.) and Lingcod (*Ophiodon elongatus*) depend on using the best available data from all sectors across the different fisheries. Quillback Rockfish (*Sebastes maliger*) and Lingcod will soon be assessed, for which an understanding of potential biases in iREC data will be required, so they can be reduced or accounted for. Hence, the objective of this work is to compare iREC-derived estimates of recreational catch for inshore rockfishes and Lingcod to those derived for anglers from creel surveys. Calibration relationships between the two datasets were built for each of these taxa from the Strait of Georgia, North Coast, and West Coast of Vancouver Island subregions.

MATERIALS AND METHODS

iREC Data

iREC data for Haida Gwaii (Pacific Fishery Management Areas 1-2, 101-102, and 142), North and Central Coast (Management Areas 3-10, 103-110, and 130), Strait of Georgia (Management Areas 13-19, and 28-29), West Coast of Vancouver Island (Management Areas 20, 23-27, 121, and 123-127), and Northern Vancouver Island and Johnstone Strait (Management Areas 11-12, and 111) were provided by DFO. These data included monthly estimates of kept and released catch ('disposition type'), by taxon (Table 1), management area, fishing method (boat, shore, dive), and year. Variances associated with each of the estimates were also provided. The methods used to derive the iREC estimates are described in DFO (2015). In order to be comparable to the creel survey data, which are limited to fishing from boats, we only used iREC boat fishing data, and, since most rockfish species and Lingcod are caught while fishing from boats, few data were omitted (see Appendix B).

Table 1. Thinning rates and posterior sampling steps for the JAGS models, by taxon and disposition type (kept vs. released). Shaded values show model configurations that failed to converge on a single solution for Beta, or that were highly autocorrelated. Regression sample size (n) is the number of unique combinations of year, month, and management area for which creel and iREC data were both available.

Taxon			Kept		Released	
Common Name	**Scientific Name**	**n**	**Thinning**	**Samples**	**Thinning**	**Samples**
Black Rockfish	*Sebastes melanops*	1,202	45	20,000	50,000	10,000,000
Bocaccio	*Sebastes paucispinis*	1,028	2	10,000	300,000	50,000,000
Canary Rockfish	*Sebastes pinniger*	1,202	70	20,000	10,000	3,000,000
China Rockfish	*Sebastes nebulosus*	1,202	3,500	1,000,000	70,000	10,000,000
Copper Rockfish	*Sebastes caurinus*	1,202	60	20,000	200	50,000
Quillback Rockfish	*Sebastes maliger*	1,202	24	10,000	35	10,000
Tiger Rockfish	*Sebastes nigrocinctus*	1,202	50,000	10,000,000	2	10,000
Vermilion Rockfish	*Sebastes miniatus*	1,154	35,000	10,000,000	200	50,000
Yelloweye Rockfish	*Sebastes ruberrimus*	1,202	140	40,000	22	10,000
Yellowtail Rockfish	*Sebastes flavidus*	1,202	3,000	800,000	50,000	10,000,000
Misc. Rockfish	*Sebastes* spp.	1,202	18	10,000	50	15,000
Lingcod	*Ophiodon elongatus*	1,202	14	10,000	14	10,000

In general, the iREC data were complete for the period from July 2012 to Dec 2021. However, there were no Bocaccio (*Sebastes paucispinis*) estimates before April 2014. Also, some of the management areas were split up into subparts midway through the timeseries, requiring some of the data to be pooled prior to analysis. Specifically, Management Areas 2, 19, 23, and 29 were split starting April 2014, and Management Area 20 was split starting April 2020. Where catch estimates were missing from the dataset for a given taxon in a given stratum (i.e., a specific combination of management area, month, year, fishing method, and disposition type) for which effort was provided and catches of other species were included, the missing values were assumed to be zero (with zero variance).

Some of the provided iREC records (n = 10) included non-zero catch values but no variance. Although details were not provided as to what scenario would produce catch estimates without variances, it was nevertheless desired to include these estimates in the subsequent analyses. To do so, a 'work around' was necessary: a variance equal to the estimate was assigned to these records. This assignment was based on the theory that for count data, which tends to follow a Poisson distribution, variance scales with the mean (Sokal and Rohlf 1995).

To derive annual estimates, data were pooled over month (years were excluded if data were missing for any of the 12 months). The annual and monthly iREC estimates of catch (kept and released) by fishing method are presented for each taxa in Appendix B and C, respectively. For regression analyses, iREC data without corresponding creel survey data were excluded (see Appendix Table A1), which largely limited the temporal scope of the comparisons to the months of May through September. However, most fishing for rockfishes and Lingcod occurs during these months (see Appendix C), and inshore rockfish and Lingcod recreational fisheries are closed October through May in Strait of Georgia or Salish Sea waters and October through April on the west coast of Vancouver Island..

Creel Data

Creel data from the South Coast and from West Coast Vancouver Island were accessed from the DFO CREST database by Kristopher Hein (in 2021) and Aswea Porter (in 2022). These data included information from Management Areas 11-21, 23-29, 111, 121, and 123-127. Temporal coverage ranged from 1981 to 2021, but not all months were included for all years (Appendix Table A1). Details on the creel survey design are in English et al. (2002). Creel surveys over this time period are typically only available for the main recreational fishing season for the months of May to September (see Appendix Table A1).

Creel data from the North Coast were provided by the North Coast Skeena First Nations Stewardship Society (NCSFNSS). These data included information from Management Areas 3 and 4. The North Coast data included estimates from June, July, and August for all years from 2015-2021, and also for May from 2019 to 2021 (Appendix Table A1). Whereas the North Coast data presented lodge and non-lodge estimates separately, for our purposes data were pooled to generate 'whole-fishery' estimates. The North Coast creel survey did not collect data on Bocaccio in 2015, or Vermilion Rockfish (*Sebastes miniatus*) in any year. Details on the North Coast creel survey design are in Robichaud and Addison (2021).

All creel data were manipulated to ensure that the species names and management area names matched those in the iREC data, where appropriate. As in the iREC data, creel estimates that had no associated variance were assigned a variance value that was equal to the catch estimate. Catch data were ignored if the area-year-month in question had no estimates of effort (this applied only to May and September data from 2014 in PFMA 18). Where catch estimates were missing from the creel dataset for a given taxon in a given stratum for which effort was provided and catches of other species were included, the missing values were assumed to be zero (with zero variance).

Creel data from the Haida Gwaii or Central Coast management areas were not available.

Bias Assessment

To measure the effect of potential biases in iREC estimates, a calibration procedure was developed to relate iREC estimates to those from creel surveys. This method was based on regression analysis. The independent variables (X axis) were the iREC estimates (only boat-based catch was included), and the dependent variables (Y axis) were the creel estimates. Replicates were the individual strata (combinations of month, year, and management areas). Separate analyses were run for each of the taxa and for each disposition type (i.e., kept vs. released). The only data points that could be included were from the strata for which both types of surveys were conducted (Appendix Table A1). The sample size for each regression analysis was n = 1,202 for all taxa except for Bocaccio (n = 1,028) and Vermilion Rockfish (n = 1,154; Table 1).

While an intuitive approach would be to regress the creel estimates against the iREC estimates using Gaussian linear regression, this model type does not account for the error associated with the X-axis observations (it assumes the X axis values are known without error; Sokal and Rohlf 1995), and only incorporates errors associated with model fit (i.e., not errors associated with the Y-axis estimates themselves) when outputting confidence bounds around the regression lines. Hence a more complex approach was required (DFO 2016). A Bayesian approach was used to estimate the slope, β (and the standard error of the slope, σ), of the relationships between creel and iREC values for each taxon and disposition type. Analysis was done in JAGS (a tool for analysis of Bayesian hierarchical models using Markov Chain Monte Carlo simulation) using the rjags package (Plummer 2019) in R (R Core Team 2021). The analyses were run over three chains with 10,000 'burn-in' iterations (discarded), followed by at least 10,000 posterior sampling steps (Table 1). Thinning rates (Table 1) were determined by examining trace plots, and were selected to maximize the number of utilized steps, while ensuring that autocorrelation among steps was <= 0.1.

Models were built to include uncertainty in both the X axis and Y axis values. Four data vectors of length *n* (see Table 1), with individual values, *i*, labelled 1 to *n*, were fed into each model:

- iREC estimates, ${R_{[est]}}_i$
- Variance of iREC estimates, $V\left(R_{[est]}\right)_i$
- Creel estimates, ${C_{[est]}}_i$
- Variance of creel estimates, $V\left(C_{[est]}\right)_i$

A very small amount of variance (SE = 0.00001) was added to any $V\left(R_{[est]}\right)_i$ or $V\left(C_{[est]}\right)_i$ values that were otherwise equal to zero to avoid a 'divide by zero' error in the model runs (since JAGS expects measures of precision to be inputted as the reciprocal of variance).

Two stochastic relationships were defined, for 'true' iREC observations (${R_{[true]}}_i$), and observed creel estimates:

- ${R_{[true]}}_i$ ~ normal distribution (mean = ${R_{[est]}}_i$; variance = $V\left(R_{[est]}\right)_i$)
- ${C_{[est]}}_i$ ~ normal distribution (mean = μ_i ; variance = $1/\tau_i$)

along with two deterministic ones:

- $\mu_i \leftarrow \beta \cdot {R_{[true]}}_i$
- $1/\tau_i \leftarrow V\left(C_{[est]}\right)_i + \sigma^2$

The prior for beta (β) was a normal distribution (mean of zero, variance of 10,000), and that for sigma (σ) was a uniform distribution (values ranging from 0 to 100).

Uncertainty of Species Identification

Since uncertainty of species identification is an issue that may affect rockfish data in both iREC and the creel surveys, the catch (harvest + release) proportion attributed to each of the taxa was plotted by region and year for each of the survey types (i.e., for creel and iREC surveys). If species identification was unimportant, we would expect that the species-specific iREC and creel time series would be in sync within each of the regions. We would also expect the Misc. Rockfish category to be relatively consistent and relatively low each year. Lingcod catch were excluded from this analysis, since there were no assumed identification issues between Lingcod and any of the rockfishes.

Additionally, logistic regressions were run for each taxon in each region and for both survey types, which showed the relationship between the proportion of rockfish catch identified to taxon vs. that identified as 'Misc.' rockfish. Each year was considered a replicate for these regressions. The Type I error was not controlled.

RESULTS

Bias Assessment

JAGS models were initially run once in order to examine the trace plots. If required, the number of iterations or the thinning rates were adjusted, and then the models were re-run (Table 1). With three exceptions (Black Rockfish [*Sebastes melanops*] released; Tiger Rockfish [*S. nigrocinctus*] kept, and Yellowtail Rockfish [*S. flavidus*] released), final models produced unimodal parameter estimates (trace plots showed good agreement among the chains), and little to no autocorrelation among steps. Models produced estimates of Beta (Figure 1) and Sigma that are shown in Table 2.

Estimated Betas looked believable when plotted over the raw iREC and creel estimates of harvest (Figure 2) or of released fish (Figure 3). In almost every case, Betas appeared closer to the 1:1 line than did the slopes of uninformed ("Type I") Gaussian linear regression lines.

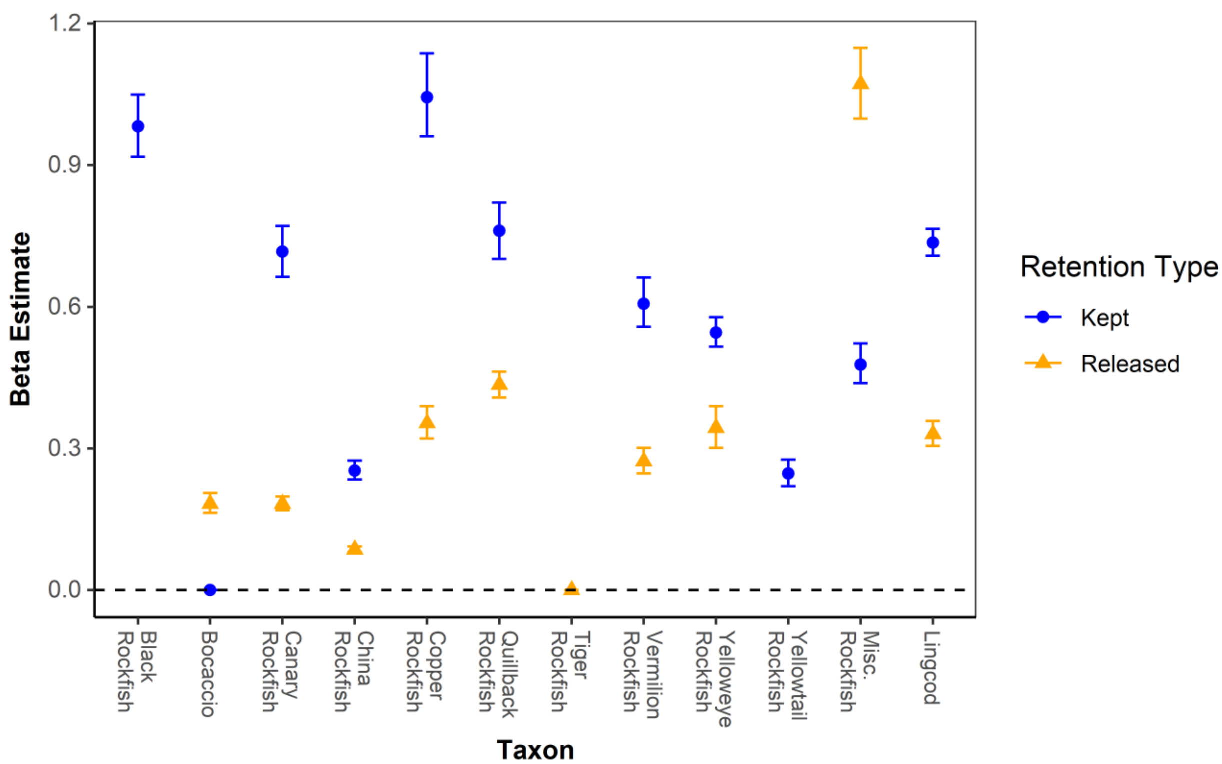

Figure 1. Beta (slope) estimates from Bayesian models, by taxon and retention (i.e., "disposition") type. Error bars show the 95% confidence intervals around the estimates of Beta. Note that some models failed to converge on a single solution for Beta, or were always highly autocorrelated, and have been removed from the plots. The horizontal dotted line at Y=0 indicates where Betas would lie if there were no relationship (zero slope).

Table 2. Beta and Sigma estimates for JAGS models, by taxon and disposition type (SD in parentheses)

	Beta		Sigma	
Taxon	**Kept**	**Released**	**Kept**	**Released**
Black Rockfish	0.98 (0.03)	-	44.22 (2.47)	-
Bocaccio	0.00 (0.00)	0.18 (0.01)	0.03 (0.00)	0.07 (0.00)
Canary Rockfish	0.72 (0.03)	0.18 (0.01)	6.50 (0.21)	0.47 (0.01)
China Rockfish	0.25 (0.01)	0.09 (0.00)	0.29 (0.01)	0.09 (0.00)
Copper Rockfish	1.04 (0.05)	0.35 (0.02)	43.69 (1.76)	41.52 (1.22)
Quillback Rockfish	0.76 (0.03)	0.43 (0.01)	52.90 (1.98)	38.25 (1.26)
Tiger Rockfish	-	0.00 (0.00)	-	0.03 (0.00)
Vermilion Rockfish	0.61 (0.03)	0.27 (0.01)	0.27 (0.01)	1.95 (0.05)
Yelloweye Rockfish	0.55 (0.02)	0.34 (0.02)	6.06 (0.28)	44.68 (1.25)
Yellowtail Rockfish	0.25 (0.01)	-	0.16 (0.00)	-
Misc. Rockfish	0.48 (0.02)	1.07 (0.04)	63.96 (2.14)	84.75 (3.74)
Lingcod	0.74 (0.01)	0.33 (0.01)	97.10 (2.38)	73.25 (2.97)

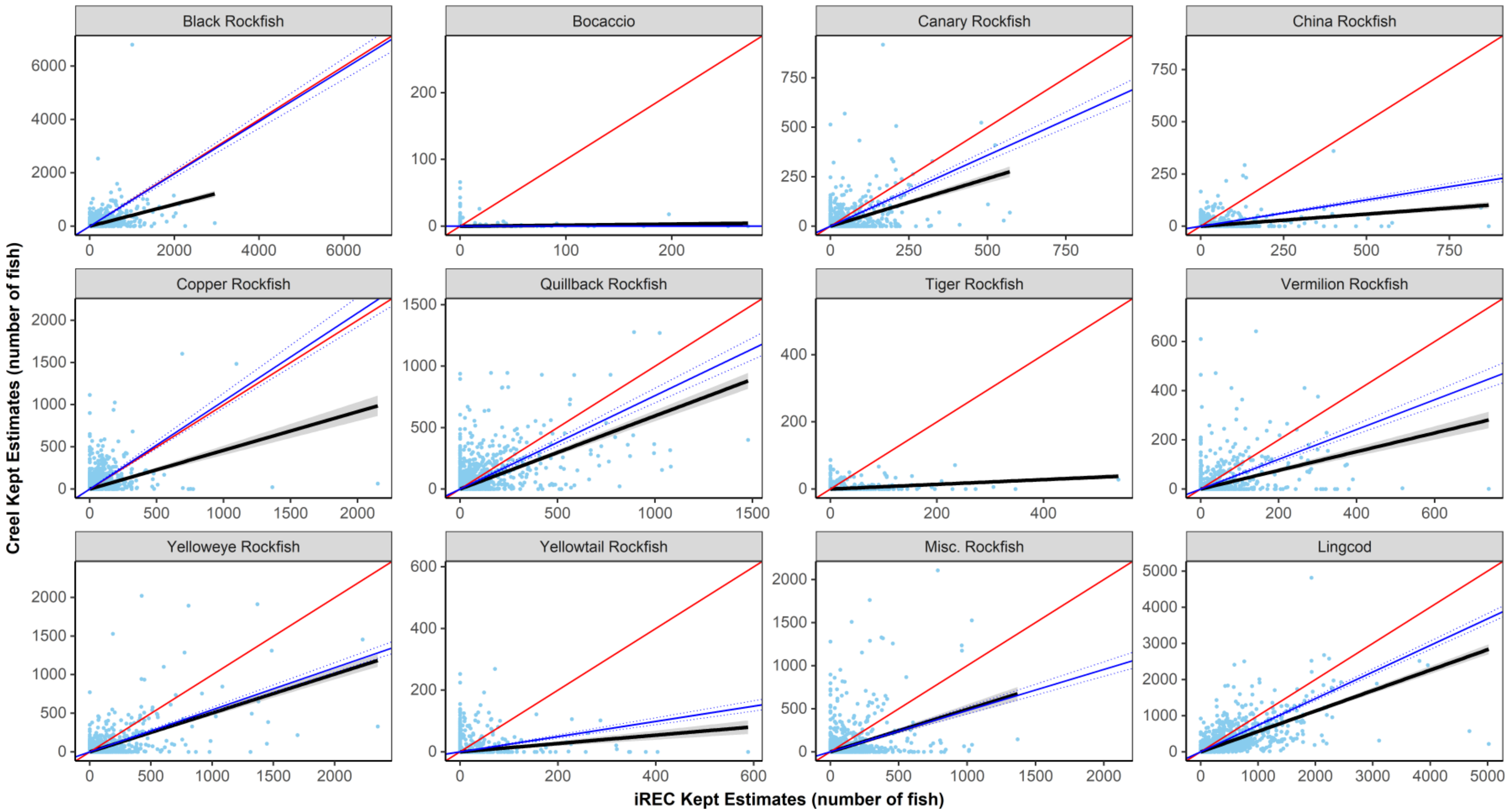

Figure 2. **Relationships between creel and iREC estimates of harvest (kept fish), by taxon. Raw data (i.e., estimates from the iREC and creel surveys) are shown as dots (variances of the estimates are not plotted). The 1:1 line (null hypothesis) is shown in red. Slopes (i.e., Betas), as estimated using the Bayesian model are shown in solid blue, with dotted blue lines indicating the extent of the 95% confidence interval around the slope. Simple linear regression lines are shown in black (with confidence bounds shaded gray) for reference. Note that model fitting failed for Tiger Rockfish, so no blue lines are drawn.**

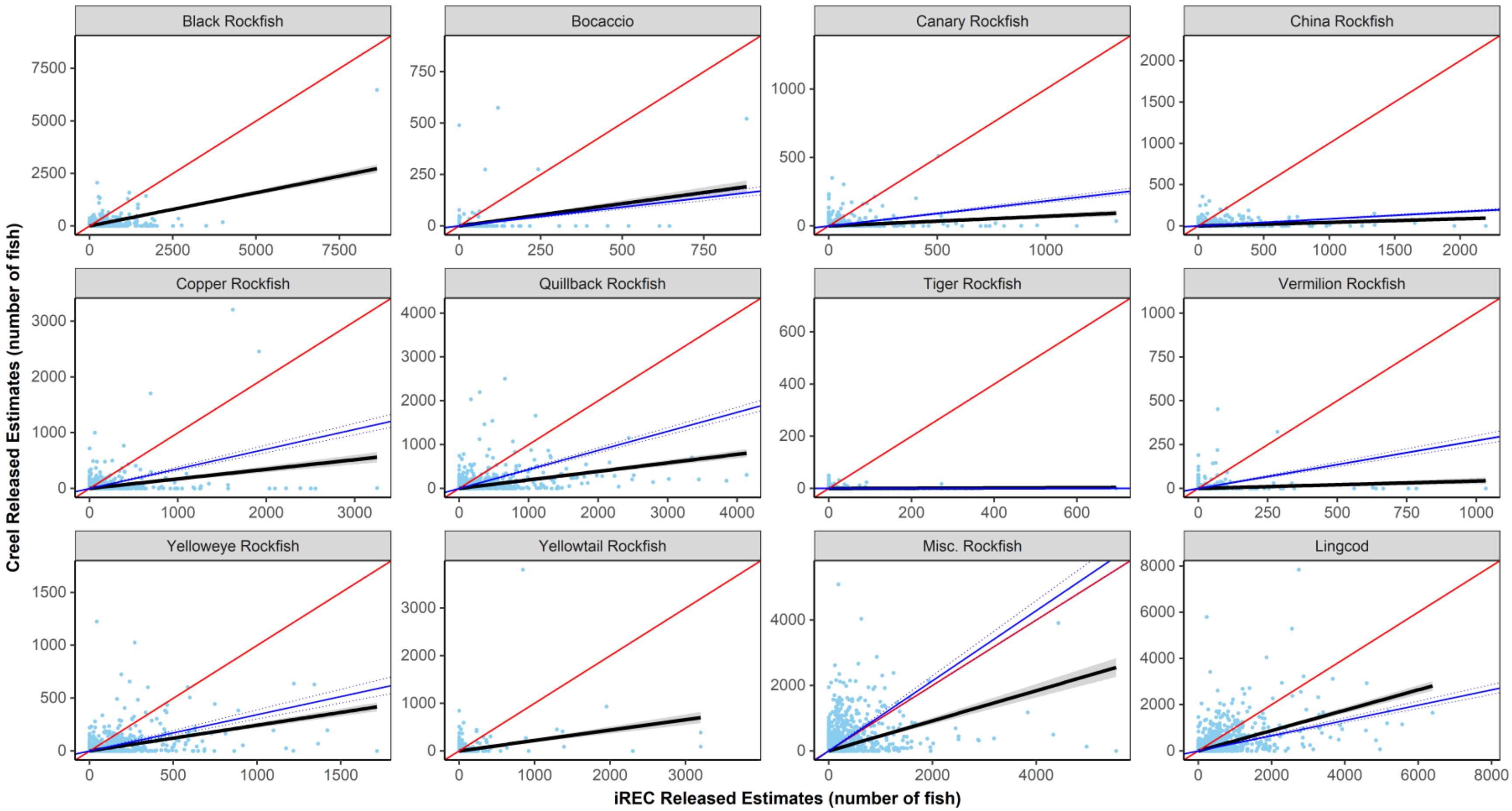

Figure 3. **Relationships between creel and iREC estimated of released fish, by taxon. Raw data (i.e., estimates from the iREC and creel surveys) are shown as dots (variances of the estimates are not plotted). The 1:1 line (null hypothesis) is shown in red. Slopes (i.e., Betas), as estimated using the Bayesian model are shown in solid blue, with dotted blue lines indicating the extent of the 95% confidence interval around the slope. Simple linear regression lines are shown in black (with confidence bounds shaded gray) for reference. Note that model fitting failed for Black and Yellowtail rockfish, so no blue lines are drawn.**

Uncertainty of Species Identification

Plots of the proportional catch by taxa (Figures 4 and 5) indicated general agreement between iREC and creel datasets, though discrepancies were apparent in each of the three regions as described below.

In the North Coast data, in all years except 2017, the creel survey was more likely to record rockfish as "Misc." as compared to the iREC survey (Figure 4). In 2017 the North Coast creel survey showed a relative decrease in the reports of Misc. Rockfish, possibly indicating that the observers that year were more skilled at ID or paid more attention to rockfish catch – and there was a concomitant increase in 2017 in the reports of Quillback and Yelloweye (*Sebastes ruberrimus*) rockfish relative to other years, possibly indicating that these species were the most likely to have been subsumed in the "Misc." category in other years. Quillback Rockfish proportions in the North Coast creel data showed a statistically significant negative relationship with Misc. Rockfish proportions overall (Figure 6). No such strong relationships were observed in the North Coast iREC data (Figure 7, Table 3).

In the Strait of Georgia, comparison of the time series (Figure 4) showed a marked decline in the proportions of fish recorded in the Strait of Georgia creel data as "Misc." in 2017, and a concomitant increase in Copper (*S. caurinus*) and Quillback rockfish proportions. Overall, there were statistically significant inverse trends between the proportion of "Misc. Rockfish" and Quillback Rockfish in both the creel (Figure 6) and iREC (Figure 7) data from Strait of Georgia (also see Table 3).

In the West Coast Vancouver Island data, creel surveys were more likely to record a fish as "Misc" in the earlier years, but the level decreased to match that in the iREC data by 2016 (Figure 4). In the West Coast creel data, Black and Copper rockfish proportions both showed statistically significant inverse trends with the proportion of "Misc. Rockfish" (Figure 6, Table 3). In the West Coast iREC data, the proportions of Quillback Rockfish were negatively related to the proportion of "Misc. Rockfish" overall (Figure 7, Table 3).

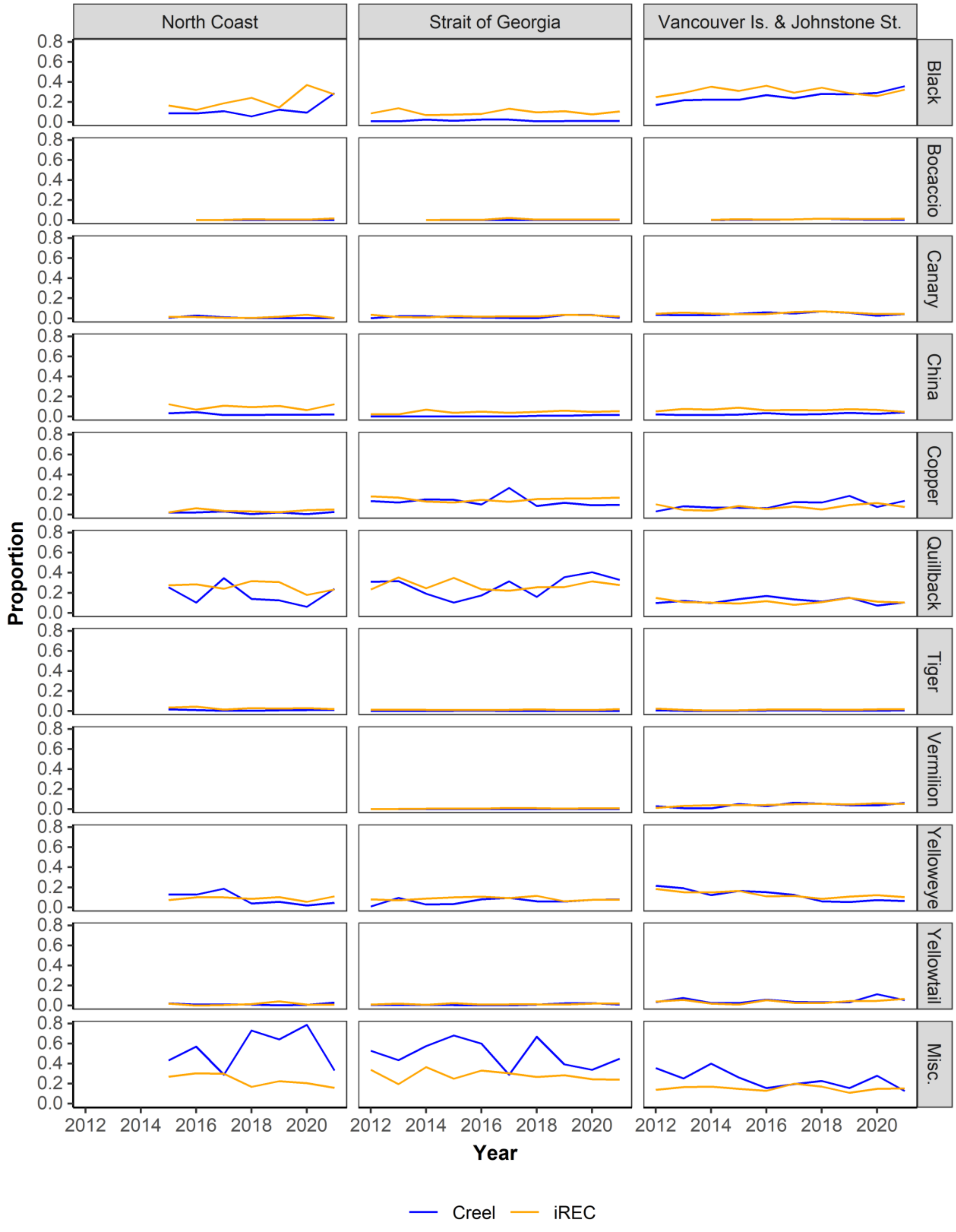

Figure 4. **Rockfish species proportions, by year, region, and survey type (iREC vs creel). Raw estimates were pooled over month, disposition type, and management area. Variances of the raw estimates were ignored.**

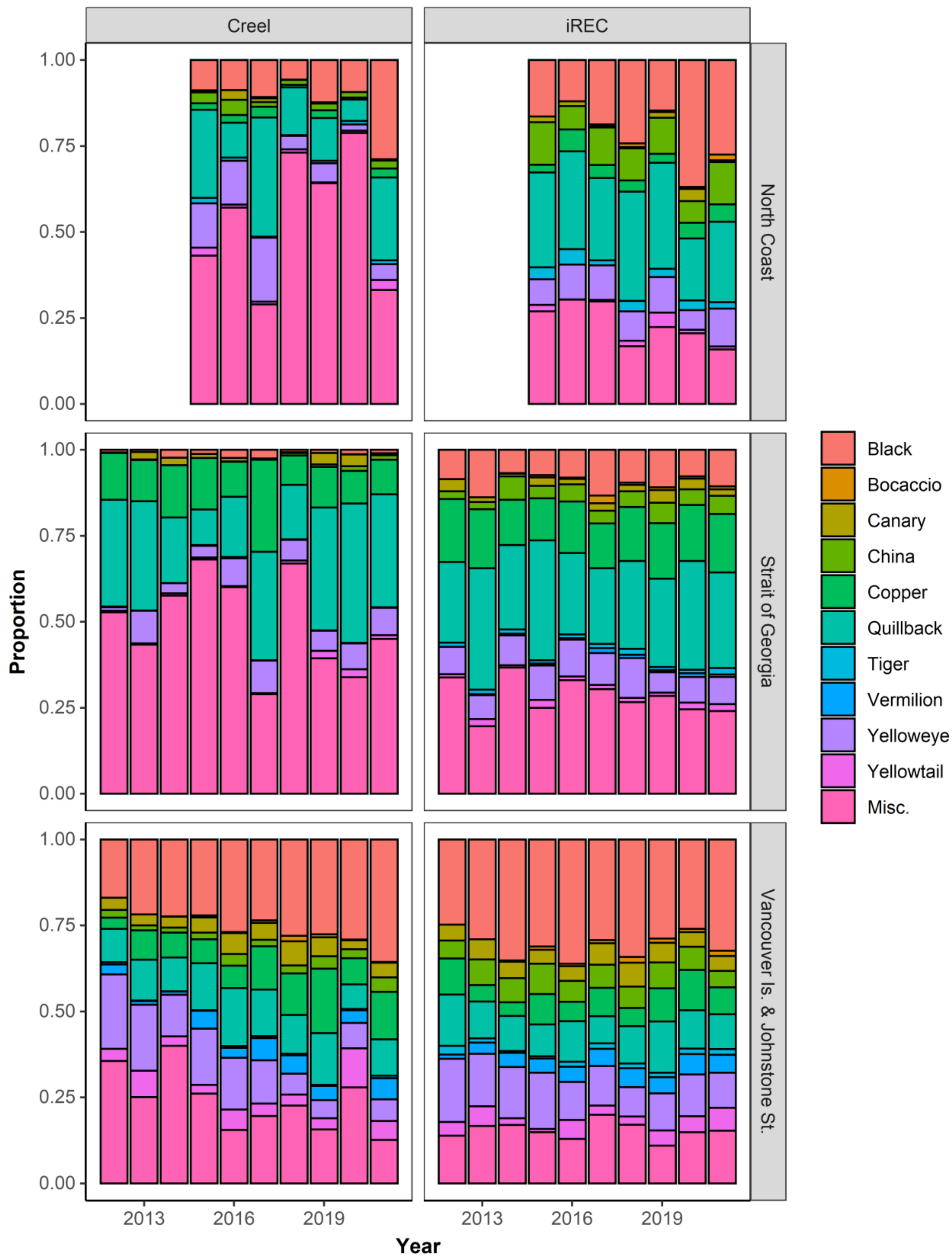

Figure 5. **Stacked rockfish species proportions, by year, region, and survey type (iREC vs creel). Raw estimates were pooled over month, disposition type, and management area. Variances of the raw estimates were ignored.**

Table 3. Logistic regression coefficients (in log space) and their statistical test results, for the relationships between the proportion of rockfish catch identified to taxon vs. that identified as ‘Misc.’ rockfish, for iREC and creel data in three regions. Regressions that were statistically significant at the 0.05 level are highlighted. No Type I error control methods were used, so results should be treated as liberal.

	North Coast			Strait of Georgia			Vancouver Is. & Johnstone St.		
Taxon	**F**	***P***	**Coeff**	**F**	***P***	**Coeff**	**F**	***P***	**Coeff**
iREC Data									
Black Rockfish	5.07	0.07	-5.43	3.22	0.11	-2.86	0.08	0.78	0.71
Bocaccio	32.48	0.005	-18.18	0.25	0.64	-3.86	0.04	0.84	-1.39
Canary Rockfish	0.33	0.59	3.60	0.19	0.68	-1.25	2.14	0.18	3.82
China Rockfish	0.26	0.63	-0.95	4.03	0.08	3.83	0.00	0.99	0.05
Copper Rockfish	0.04	0.86	0.51	1.68	0.23	-1.14	1.17	0.31	-5.41
Quillback Rockfish	0.00	0.99	0.03	17.53	0.003	-3.73	15.68	0.004	-7.03
Tiger Rockfish	0.87	0.39	2.22	0.22	0.65	-0.68	0.29	0.61	-3.19
Vermilion Rockfish				0.04	0.85	-0.78	0.35	0.57	2.49
Yelloweye Rockfish	0.01	0.93	-0.13	1.03	0.34	1.31	0.01	0.91	-0.47
Yellowtail Rockfish	0.24	0.64	-3.26	27.76	0.0008	-6.72	1.42	0.27	-8.01
Creel Data									
Black Rockfish	4.64	0.08	-2.47	0.29	0.61	-0.71	6.50	0.03	-1.96
Bocaccio	35.33	0.004	-9.59	0.91	0.38	-3.89	0.49	0.51	-2.89
Canary Rockfish	0.56	0.49	-2.71	1.69	0.23	-2.49	4.07	0.08	-2.31
China Rockfish	0.34	0.59	-0.51	1.06	0.33	-2.81	12.59	0.008	-3.39
Copper Rockfish	12.59	0.02	-2.61	1.49	0.26	-1.26	7.92	0.02	-4.28
Quillback Rockfish	25.82	0.004	-2.94	32.91	0.0004	-3.67	5.17	0.05	-1.94
Tiger Rockfish	0.23	0.65	-0.63	2.33	0.17	2.74	1.89	0.21	-3.04
Vermilion Rockfish				0.02	0.89	-0.77	4.83	0.06	-3.89
Yelloweye Rockfish	4.76	0.08	-2.84	4.06	0.08	-1.78	1.86	0.21	2.68
Yellowtail Rockfish	4.68	0.08	-2.58	1.53	0.25	-2.09	0.04	0.84	-0.52

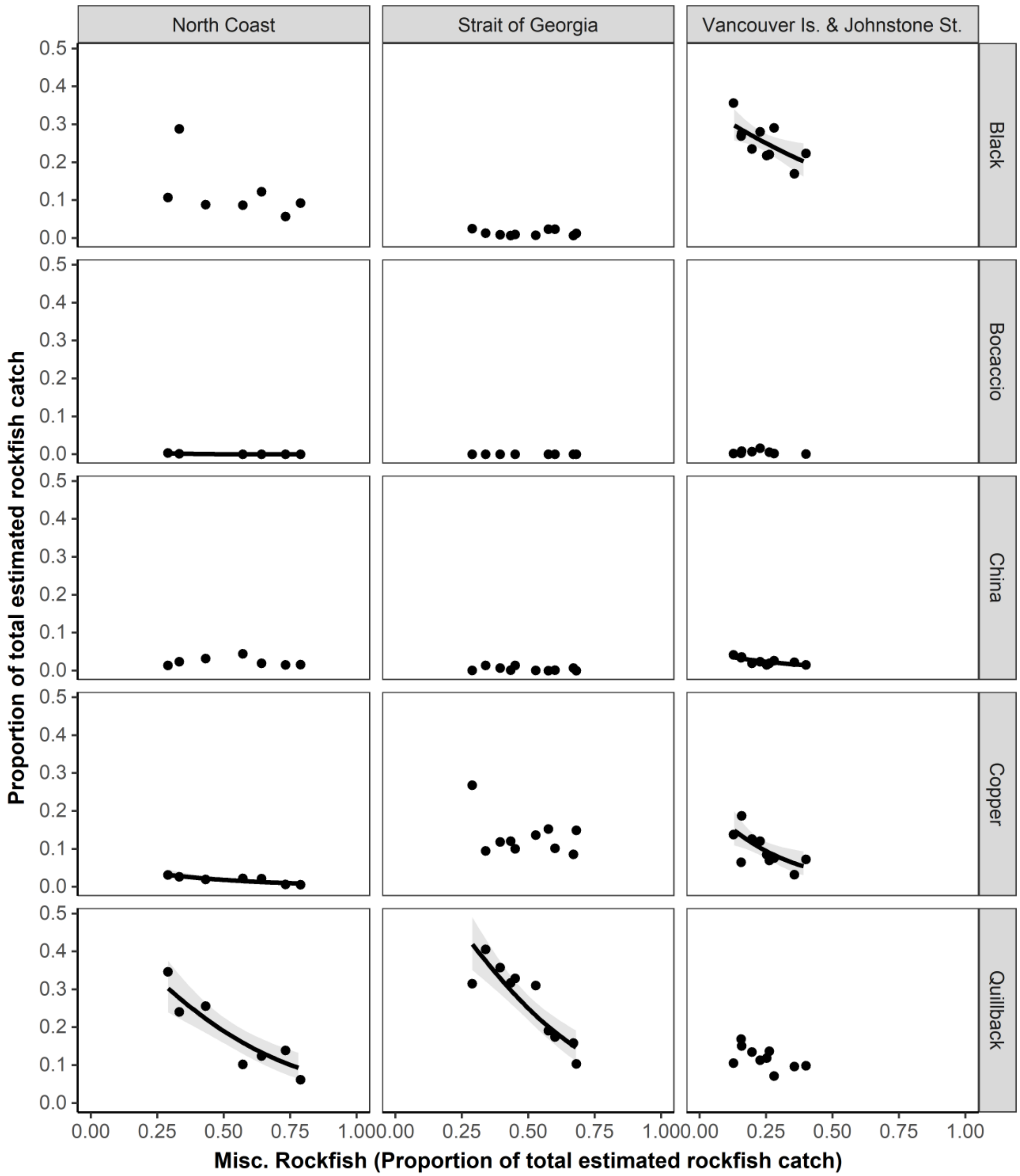

Figure 6. Relationships between Black, Bocaccio, China, Copper, and Quillback rockfish proportions versus "Misc." rockfish proportions in the creel survey data. Observations (one per year) are plotted in all panels, but trendlines are drawn only where statistically significant at the 0.05 level.

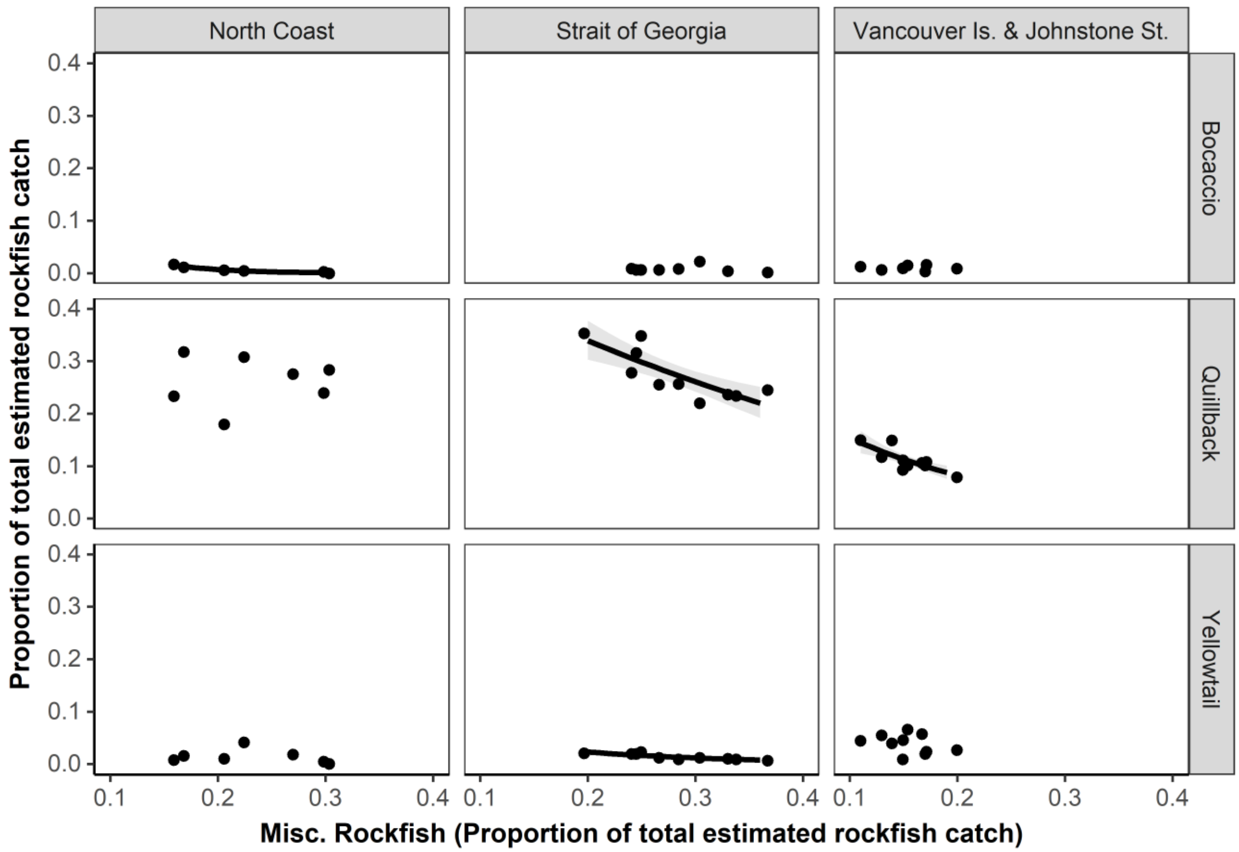

Figure 7. Relationship between Bocaccio, Quillback and Yellowtail rockfish proportions versus "Misc." rockfish proportions in the iREC survey data. Observations (one per year) are plotted in all panels, but trendlines are drawn only where statistically significant at the 0.05 level.

DISCUSSION

The objective of this work was to compare iREC-derived estimates of recreational catch for inshore rockfishes and Lingcod to those derived from creel surveys. While creel surveys are themselves not perfect, their estimates can have negligible bias (Rasmussen et al. 1989), especially since they were carried out using trained technicians who monitored effort independently, and interviewed recreational fishers during or immediately after their fishing trips. For the iREC survey, recreational fishers entered their effort and catch values into online questionnaire forms, filled out after (sometimes considerably after) their trip was complete. The creel surveys in this study only collected data from boat-based anglers, so we limited the iREC dataset in the same way. Otherwise, these surveys, although carried out in different ways, were both designed to collect data to generate effort and species-specific catch estimates by month, and management area. Thus, when all else is equal and there are no biases in either dataset, the two surveys should produce identical estimates of catch, and regression lines should approach the 1:1 line (i.e., a slope of 1). For the datasets available to us, Bayesian-derived regression slopes (or 'Betas') were successfully estimated for most taxa and dispositions. In almost every case, Betas were closer to the 1:1 line than were the slopes of uninformed (“Type I”) Gaussian linear regression lines. Type II regression methods (including the Bayesian model used here) effectively weight points based on their reliability, which would reduce the overall influence of imprecise estimates (e.g., where large values have large variances). Gaussian linear regressions do not account for uncertainty in that way, and can therefore allow extreme values to have too much influence. Despite being closer to the 1:1 line than the Gaussian slopes, the Betas were nevertheless usually less than 1, indicating a general trend for the iREC estimates to be larger than the corresponding creel values.

The Betas can be used as calibration tools so that managers can adjust iREC results in management areas and at times that are not covered by creel surveys. Unfortunately, the use of a Bayesian model does not make for a simplistic tool for computing ‘predicted creel catch values’ from estimated iREC catch values. One might naively expect that the Betas could be used as ‘conversion factors’ (e.g., if iREC estimate is 100 and Beta is 0.5, then ‘predicted’ creel would be 50), but the reality is more complex since there is uncertainty associated with both the ‘average slope’ parameter (i.e., the model term Beta) and with the ‘variance in slope’ parameter (i.e., the model term Sigma). In the example above, we might conclude that the ‘predicted’ creel is between 40 and 60 if Sigma is small, or we might calculate the ‘predicted’ creel to be between 10 and 90 if the Sigma was larger. In reality, the value that is selected to be used as a ‘conversion factor’ should be thought as of coming from a distribution of possible values where neither the mean of the distribution nor the variance of the distribution are known with certainty. Rather, the mean of the distribution is itself a value drawn from a distribution with a mean of Beta, and SD as shown in Table 2. Furthermore, the variance of the distribution is also itself another distribution, with a mean of Sigma, and SD as shown in Table 2. Thus, simulation runs would be required to fully determine the expected values and confidence intervals of each predicted ‘creel-equivalent’ value. To complicate matters, the distributions of Beta and Sigma are not fully independent, so they should really be drawn as a pair from the model posteriors (which can be saved during the model runs). Although doable with present day computer power, it is beyond the scope of this study to run such simulations. Nevertheless, the simulations could be packaged behind a graphic user interface (e.g., a Shiny app) such that they would be straightforward for a manager to run if predicted ‘creel equivalent catch’ estimates are needed with confidence bounds.

Despite the complexity involved in predicting ‘creel-equivalent’ values from iREC estimates, the Betas presented in this report are nevertheless useful. The goals of this analysis were to assess the degree of bias and estimate adjustment factors to minimize it. The Bayesian method successfully produced Betas for most of the taxa and disposition types. The magnitude of the Betas should be reliable estimators of the degree of bias in the iREC estimates, and their use as naïve ‘conversion factors’ should therefore successfully minimize such bias (i.e., even if the full variance of the predicted ‘creel-equivalent’ estimate is not determined via simulation). The Bayesian regression analyses should be periodically updated since additional future data may further improve the regressions, and updated results may warrant different adjustment factors being used for management.

For these analyses, omnibus Betas have been estimated for each species and disposition type. By contrast, previous work by DFO (R. Houtman, Pers. comm.) has used a method that generated licence-year-specific Betas. In these studies, a different Beta was calculated for each species in each year, using the management areas as the replicate data points in the regressions. Each of the annual Beta estimates were generated using much more restricted datasets, but the resulting estimates were free to vary among licence-years. According to the authors, survey designs have evolved over time (more so in the early years), and iREC data accuracy is thought to have improved (licence-holders have become more experienced with the survey, and have learned what information they need to retain for reporting). These factors, coupled with ever-changing licence-holder attitudes towards DFO, and random economic influences (e.g., currency exchange affecting nonresident fishing), means that the true relationship between the surveys may vary annually. This approach can be useful in situations where there are always plenty of creel data available to generate year-specific Betas, which are then used to 'convert' the few remaining iREC estimates from strata for which no creel survey was conducted. Here, however, omnibus Betas were estimated for each taxa, using all years of data pooled. The result is the Betas are more general, and can be applied even in years where no creel data are available. Regardless, future work could assess the influence of year on the regressions – if the quality of the iREC data improve over time (e.g., with angler familiarity and participation rates), regression slopes may eventually approach the 1:1 line.

One of the main shortcomings of the available datasets is the ambiguity surrounding the use of the taxon "Misc. Rockfish". It is unclear whether this term is used for fish of unknown species, or whether it is a catch-all category for a collection of rare species. In reality, it is probably used for both, and is probably used differently from year to year or among regions, and it may be used differently in the creel surveys vs. the iREC survey. An analysis of the relative among-taxa estimated catches showed that some species were indeed probably being lumped into the Misc. Rockfish category by creel survey observers, most notably Black, Copper, and Quillback rockfish. There were statistically significant negative relationships between the relative catch of these species and that of Misc Rockfish – in years with higher Black, Copper, or Quillback catches, the Misc. Rockfish catches were lower – with specific relationships depending on the survey region. Rockfish species ID can indeed be challenging (e.g., Kramer and O'Connell 1995), and there is no way to judge the correctness of the identifications of the observers, of anglers reporting released fish, or, for that matter, of the anglers in their iREC data submissions.

ACKNOWLEDGMENTS

I mainly thank the recreational anglers who submit their effort and catch data to iREC, and who submit to interviews during creel surveys. Thanks to DFO and NCSFSS for supplying the data used in these analyses. Thanks to Wendell Challenger (LGL Limited) for discussions about analytical methods, and to John Holmes, Rob Houtman, Nicholas Komick, and Matthew Siegle who reviewed the manuscript. Funding of this research was provided by DFO.

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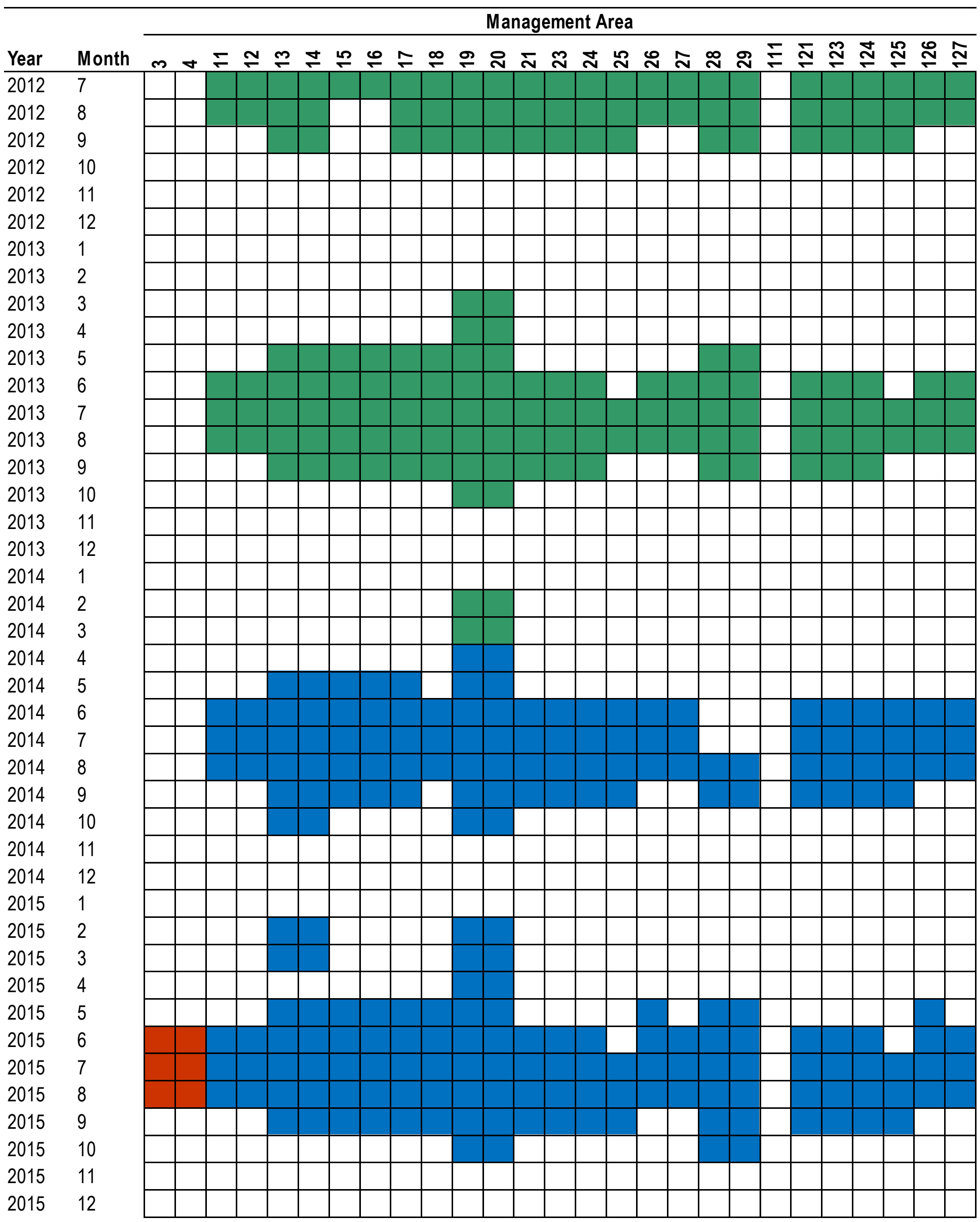
APPENDICES

Appendix A. Temporal and spatial strata for Bayesian regression analysis.

Table A1 **Data (i.e., combinations of year-month-area for which both creel and iREC estimates were available) for Bayesian regression analysis. Blue: data available for all 12 taxa; Green: all but Bocaccio; Gold: all but Vermilion Rockfish; Red: all but Bocaccio and Vermilion Rockfish. Management Areas 3-4 correspond to North Coast, 11-12 and 111 to North Vancouver Island and Johnstone Strait, 13-19 and 28-29 to Strait of Georgia, and 20-27 and 121-127 to West Coast Vancouver Island.**



		Management Area																										
Year	Month	3	4	11	12	13	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	111	121	123	124	125	126	127
2016	1																											
2016	2																											
2016	3																											
2016	4																											
2016	5																											
2016	6																											
2016	7																											
2016	8																											
2016	9																											
2016	10																											
2016	11																											
2016	12																											
2017	1																											
2017	2																											
2017	3																											
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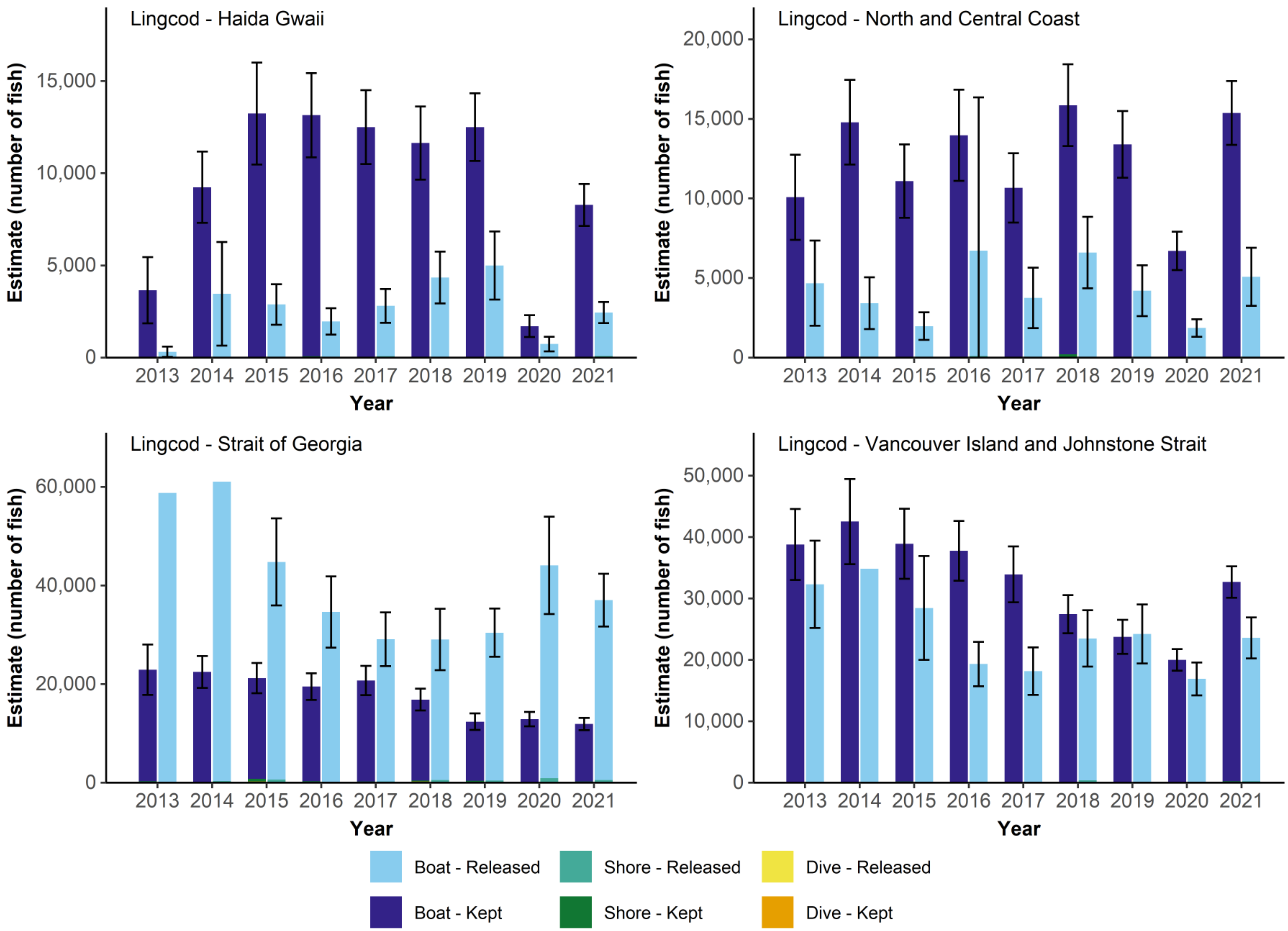
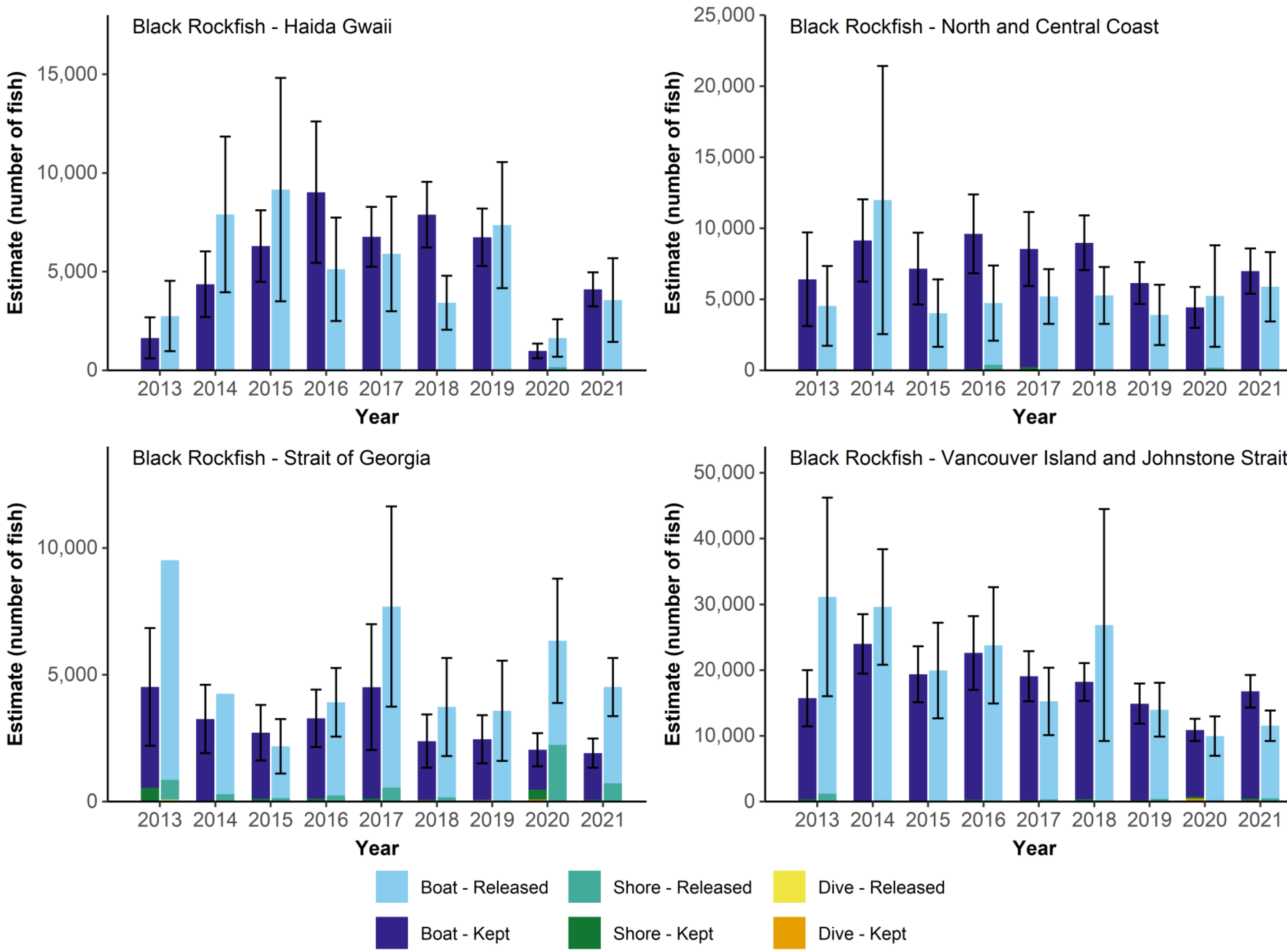
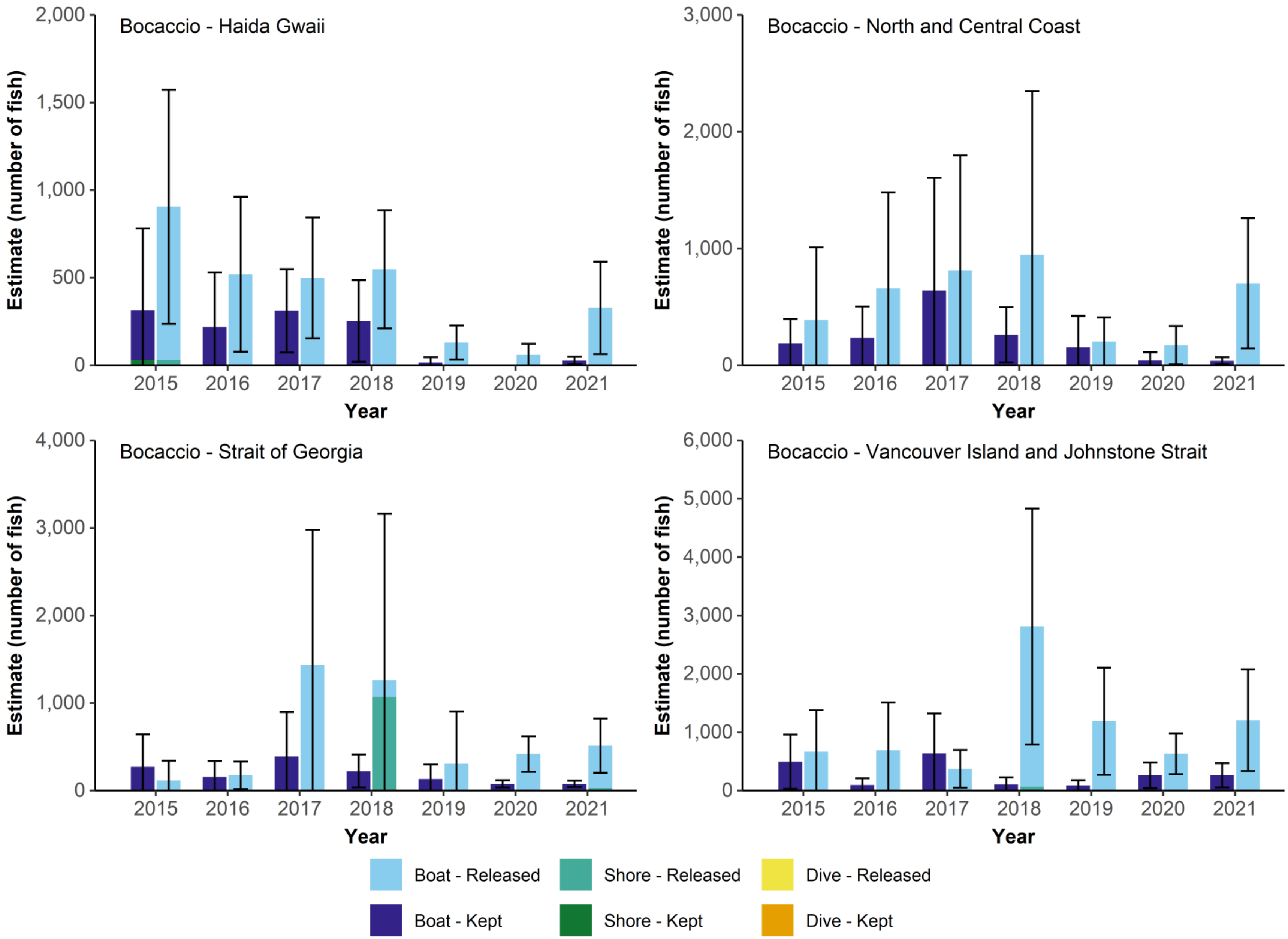
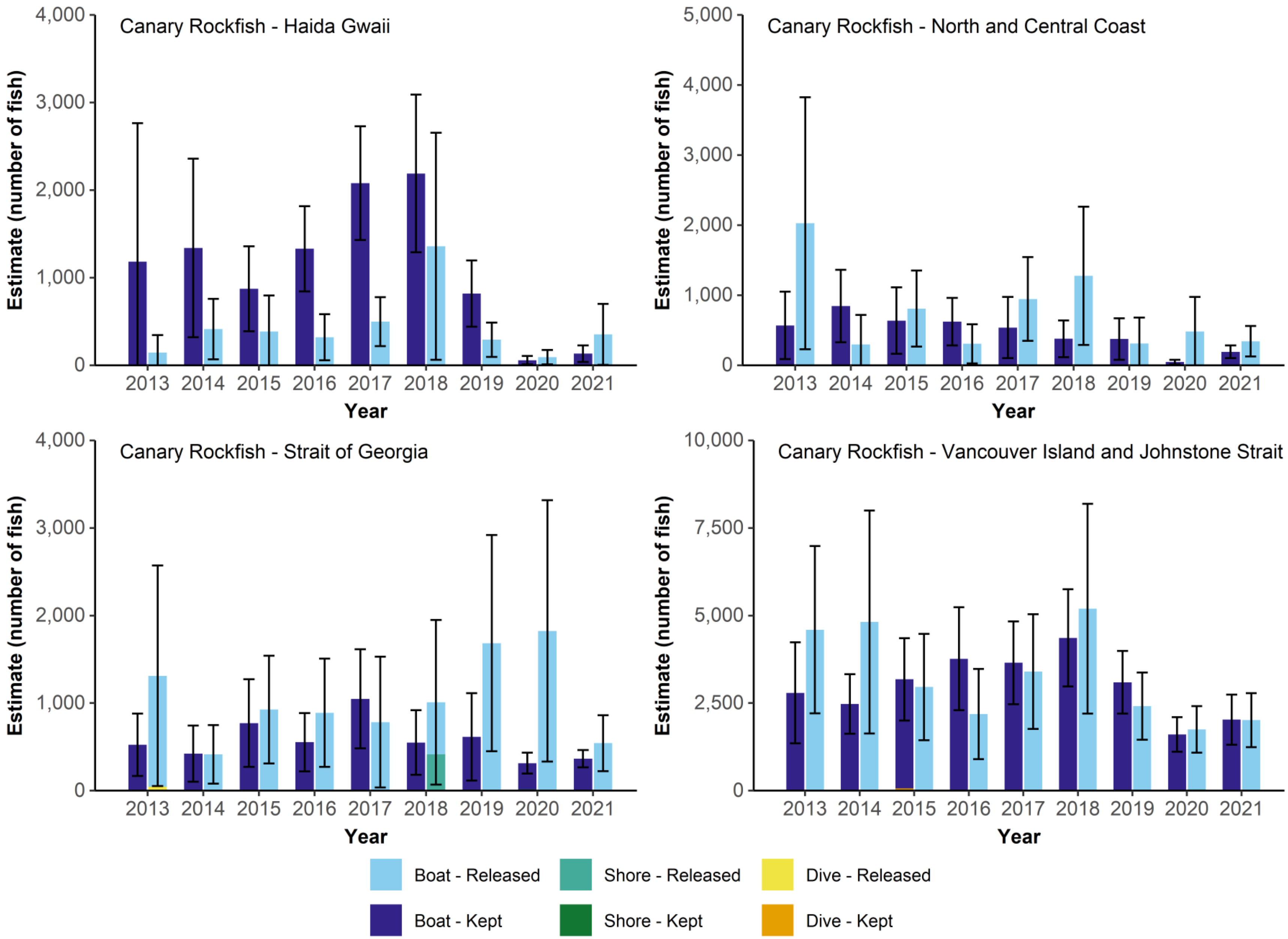
2017	7																											
2017	8																											
2017	9																											
2017	10																											
2017	11																											
2017	12																											
2018	1																											
2018	2																											
2018	3																											
2018	4																											
2018	5																											
2018	6																											
2018	7																											
2018	8																											
2018	9																											
2018	10																											
2018	11																											
2018	12																											
2019	1																											
2019	2																											
2019	3																											
2019	4																											
2019	5																											
2019	6																											
2019	7																											
2019	8																											
2019	9																											
2019	10																											
2019	11																											
2019	12																											

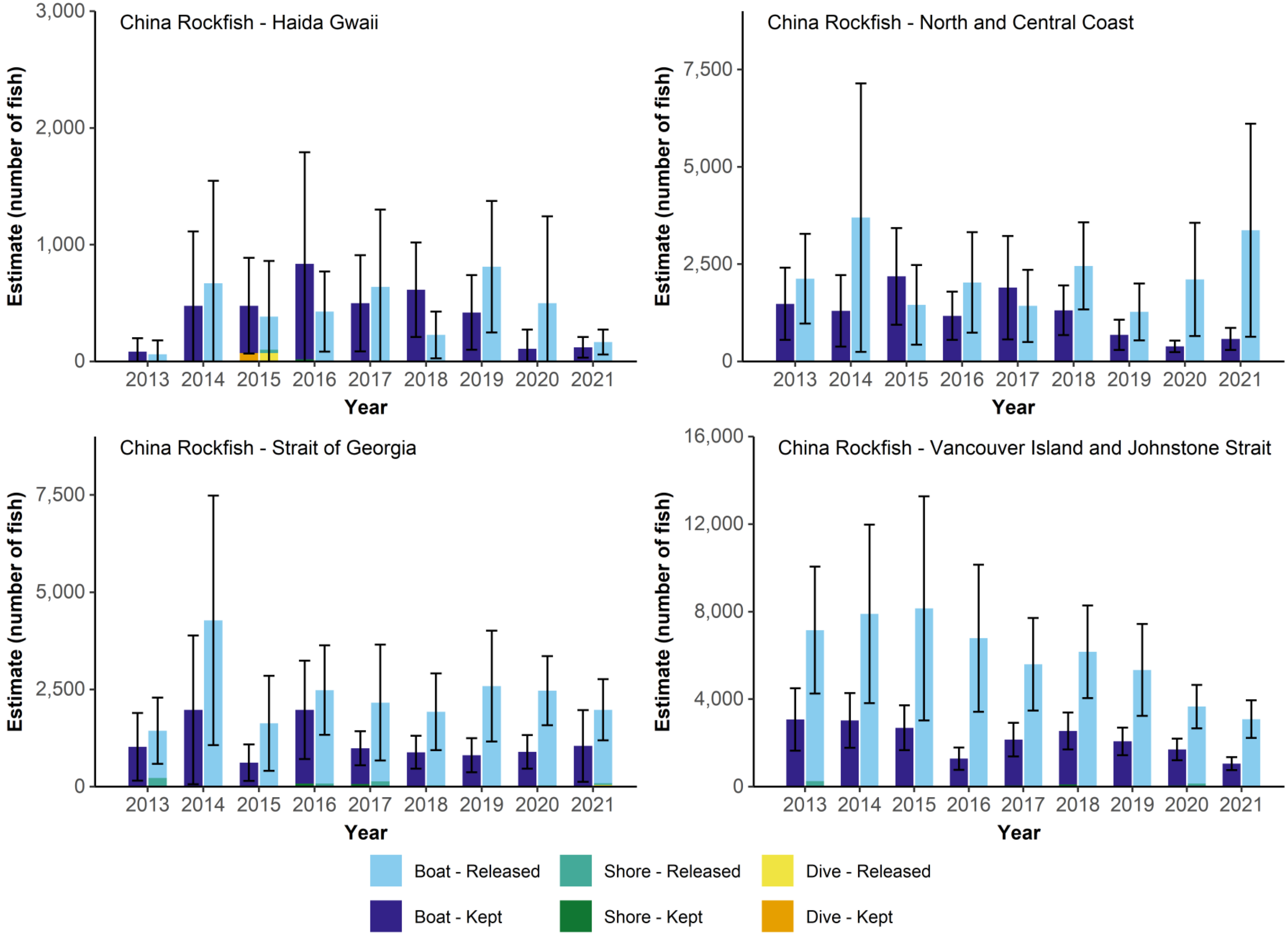
Appendix B. **iREC estimates of annual catch by taxon, management subregion, disposition type (kept, released), and fishing method (shore, boat, dive). To derive annual estimates, data were pooled over month (years were excluded if data were missing for any of the 12 months). Management subregions are defined as: Haida Gwaii (Management Areas 1-2, 101-102, and 142); North and Central Coast (Areas 3-10, 103-110, and 130); Strait of Georgia (Areas 13-19, and 28-29); and Vancouver Island and Johnstone Strait (Areas 11-12, 20-27, 111, 121, 123, and 125-127).**

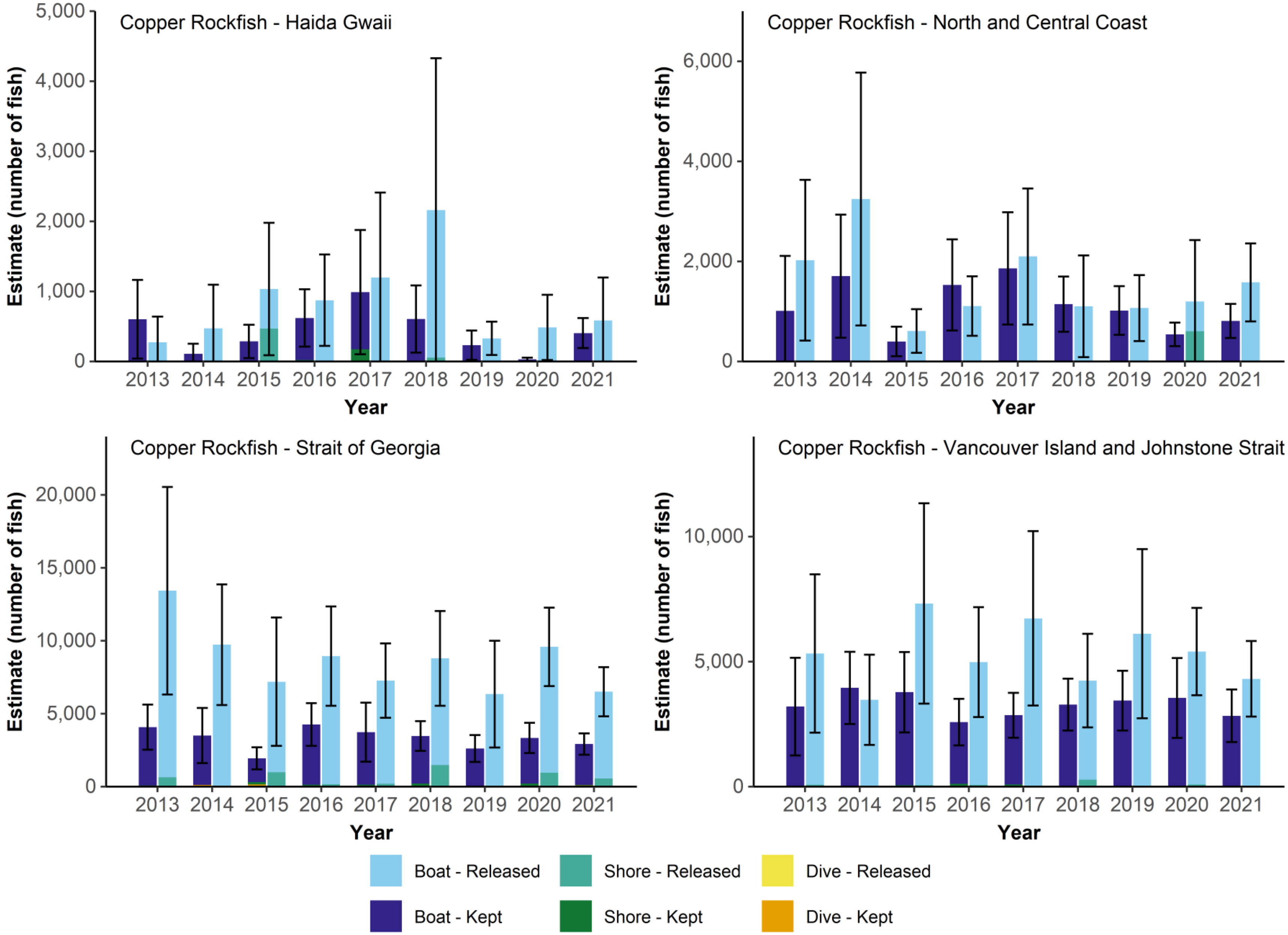

Lingcod - Haida Gwaii
Lingcod - North and Central Coast
Lingcod - Strait of Georgia
Lingcod - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013 2014 2015 2016 2017 2018 2019 2020 2021
0 5,000 10,000 15,000
0 5,000 10,000 15,000 20,000
0 20,000 40,000 60,000
0 10,000 20,000 30,000 40,000 50,000
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

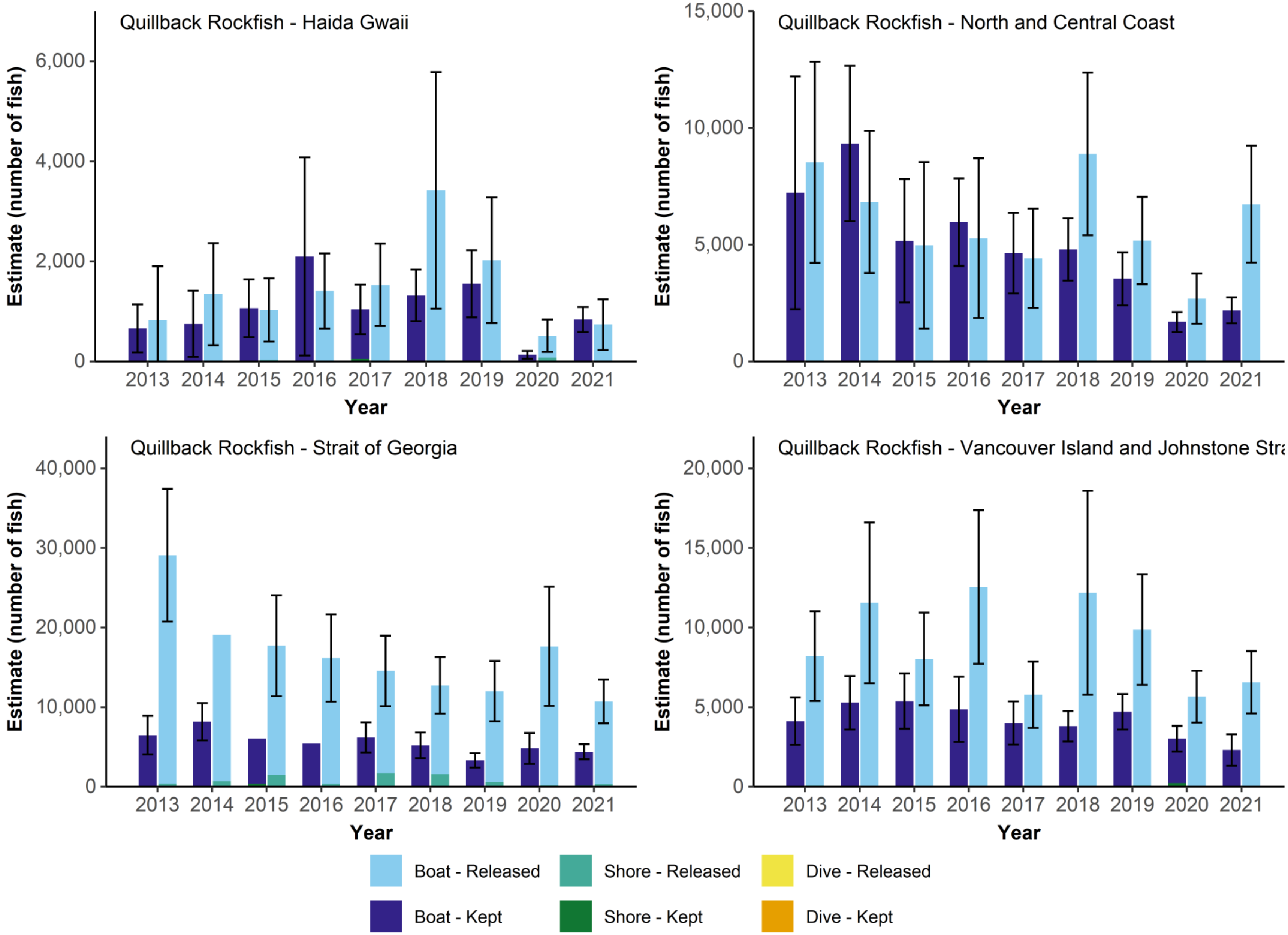

Black Rockfish - Haida Gwaii
Black Rockfish - North and Central Coast
Black Rockfish - Strait of Georgia
Black Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

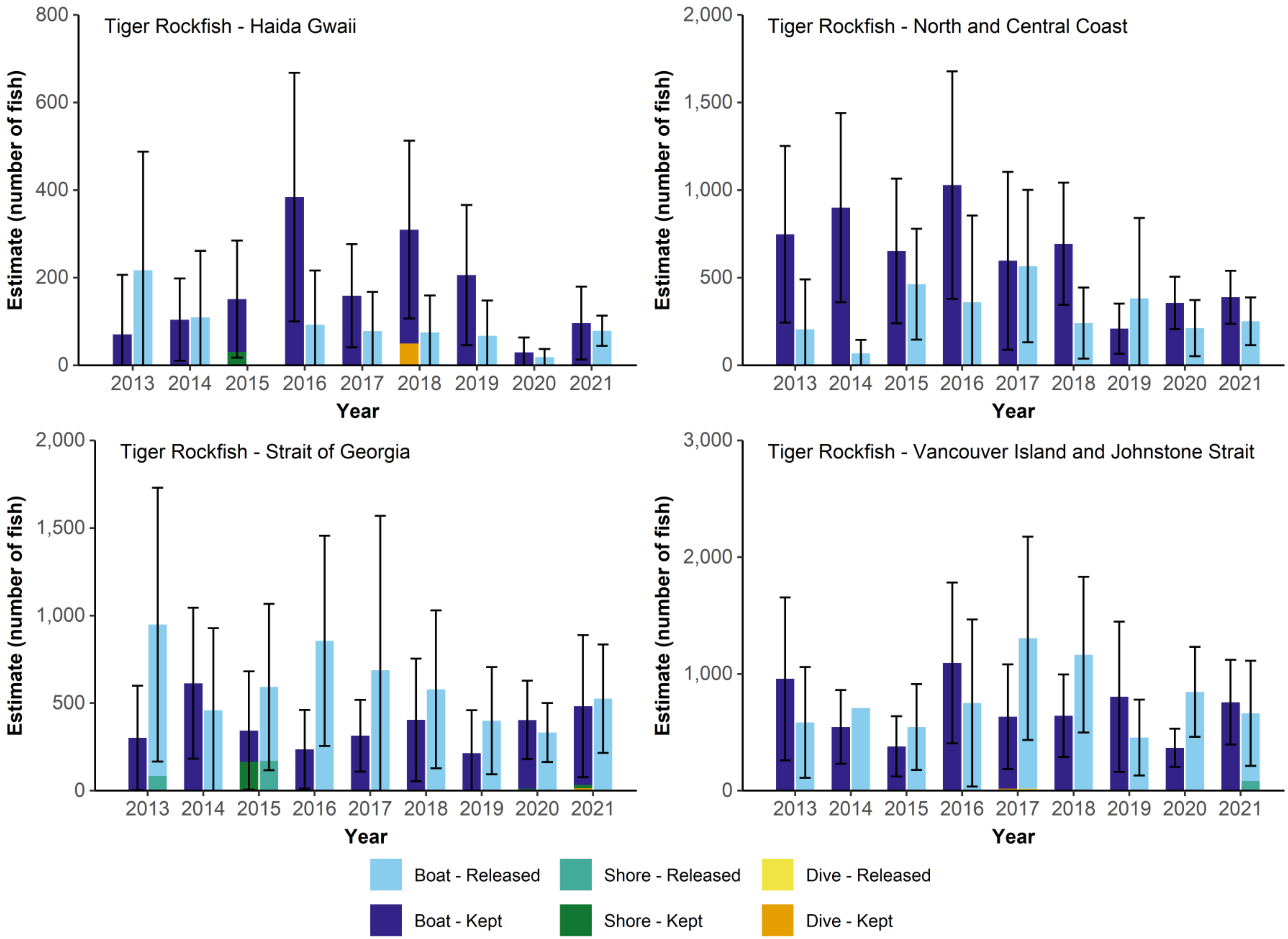

Bocaccio - Haida Gwaii
Bocaccio - North and Central Coast
Bocaccio - Strait of Georgia
Bocaccio - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2015
2016
2017
2018
2019
2020
2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

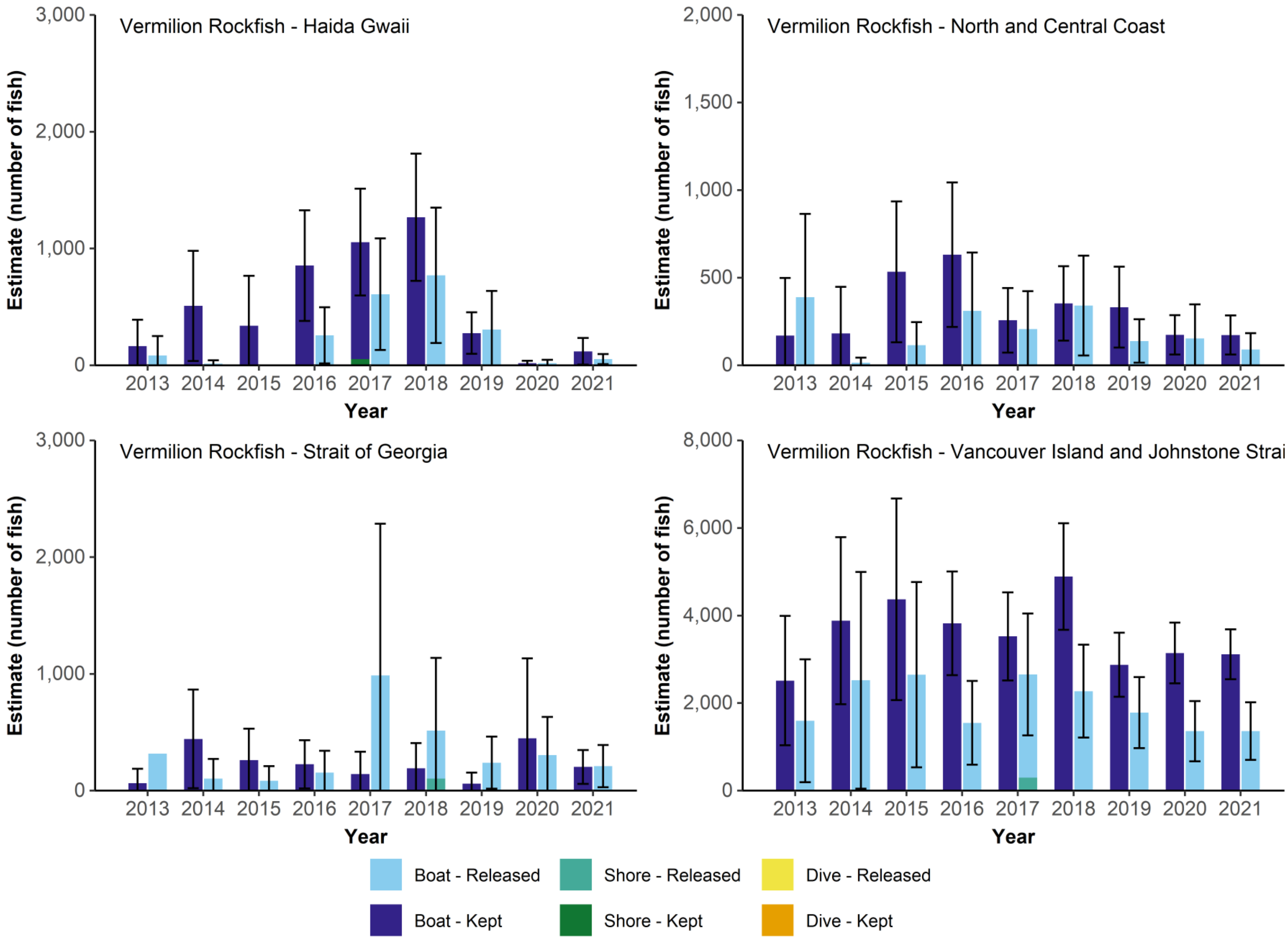

Canary Rockfish - Haida Gwaii
Canary Rockfish - North and Central Coast
Canary Rockfish - Strait of Georgia
Canary Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
0
1,000
2,000
3,000
4,000
5,000
2,500
7,500
10,000
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

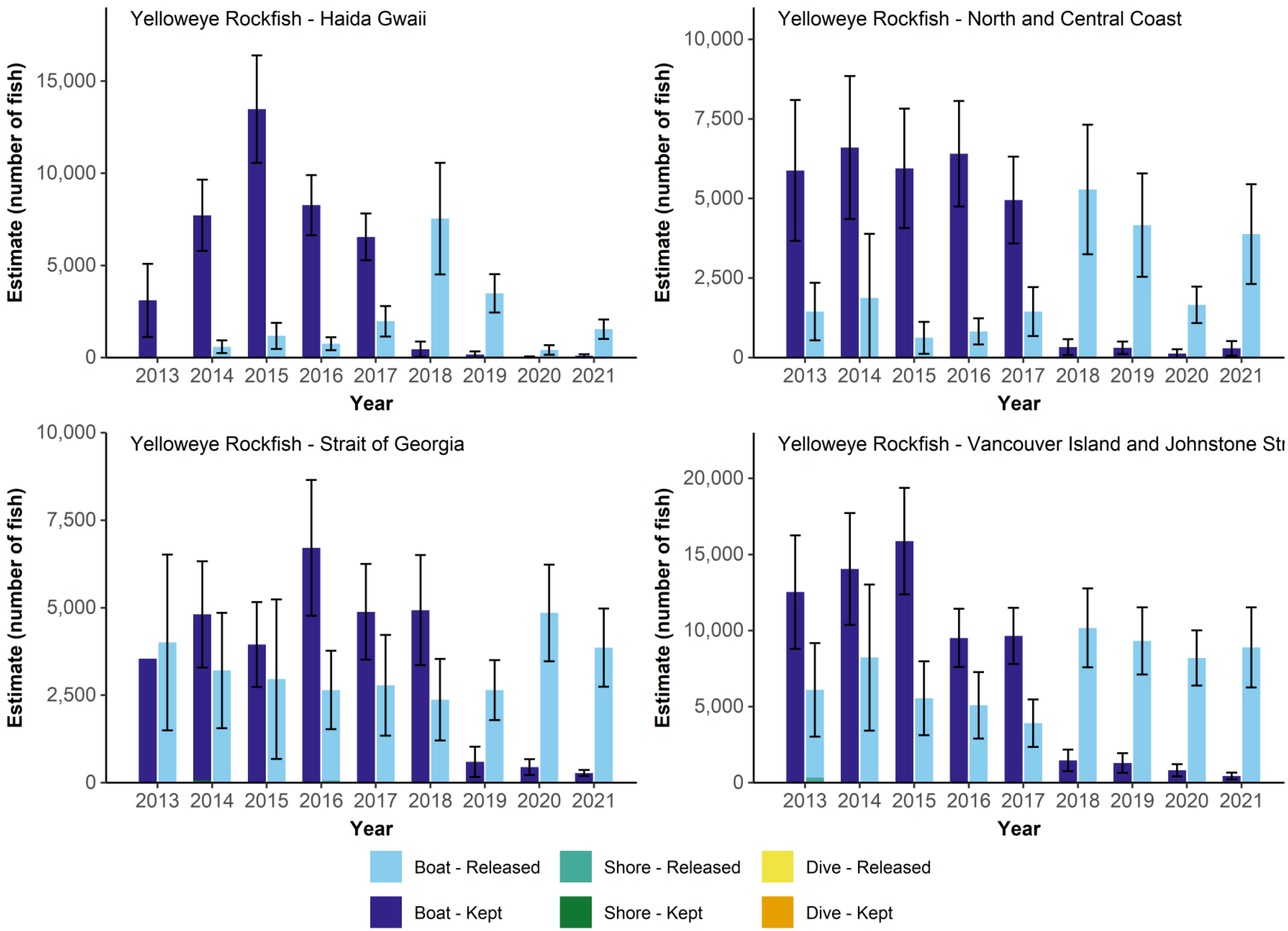

China Rockfish - Haida Gwaii
China Rockfish - North and Central Coast
China Rockfish - Strait of Georgia
China Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013 2014 2015 2016 2017 2018 2019 2020 2021
0 1,000 2,000 3,000
0 2,500 5,000 7,500
0 4,000 8,000 12,000 16,000
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

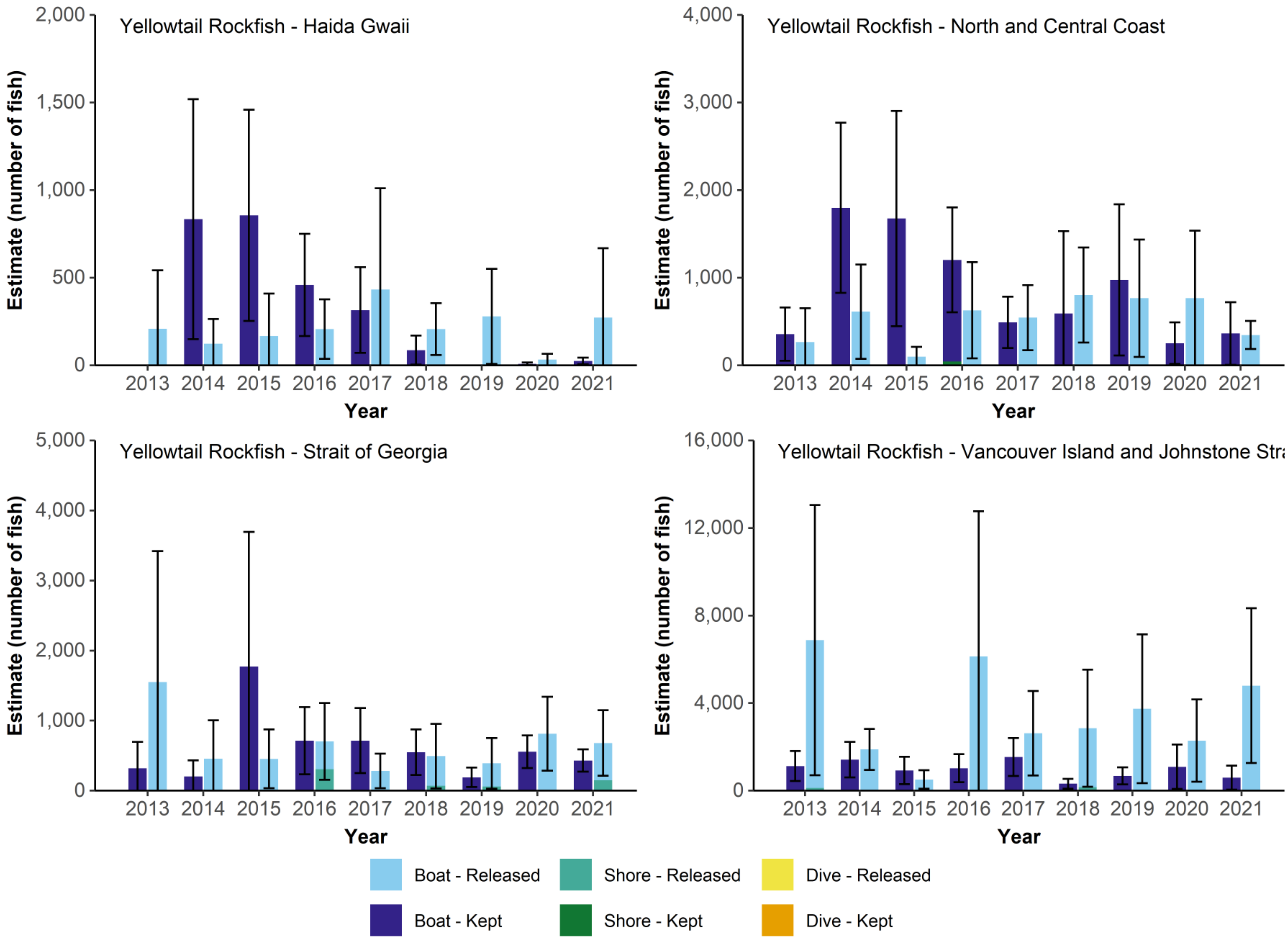

Copper Rockfish - Haida Gwaii
Copper Rockfish - North and Central Coast
Copper Rockfish - Strait of Georgia
Copper Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013 2014 2015 2016 2017 2018 2019 2020 2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

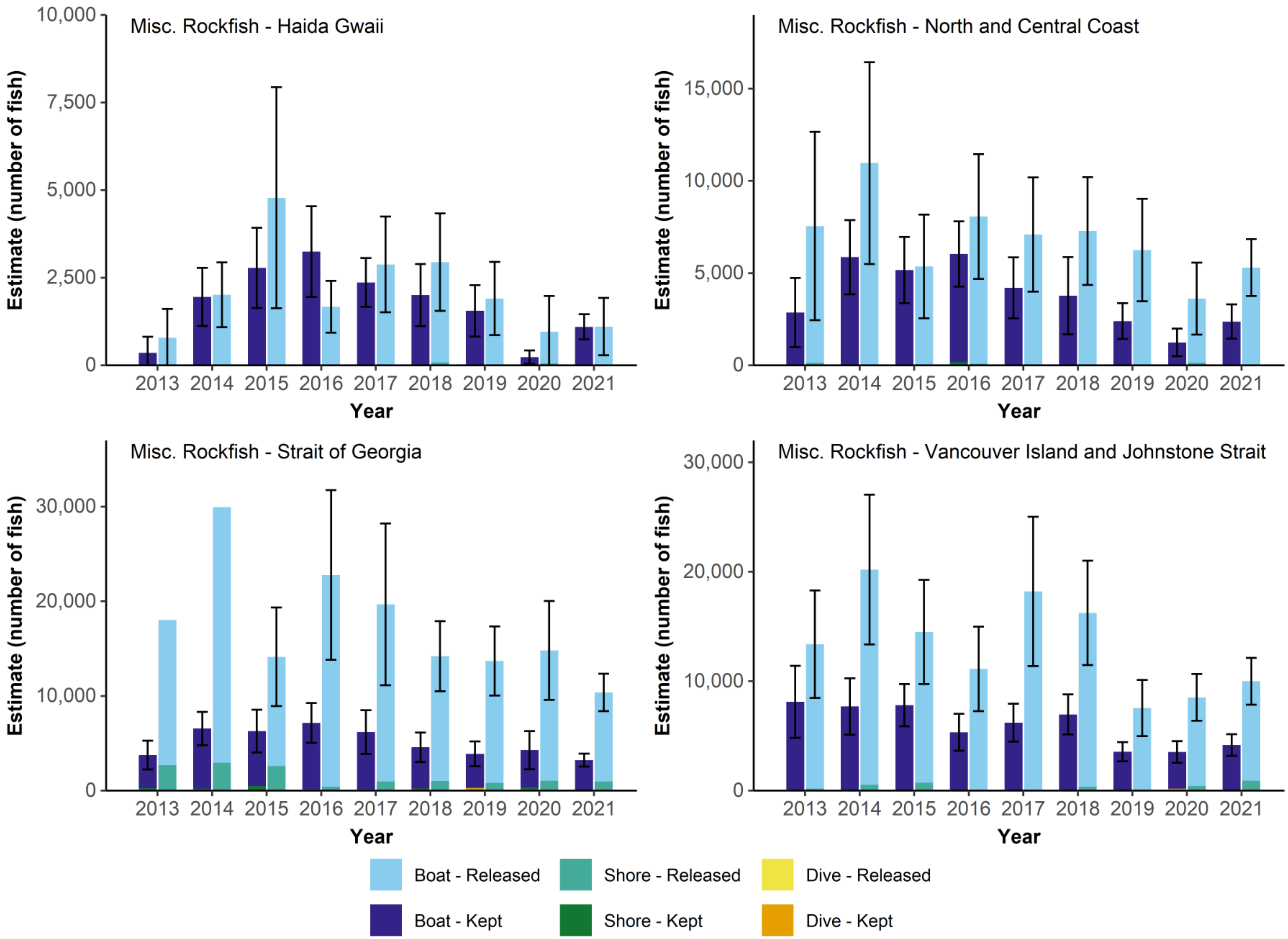

Quillback Rockfish - Haida Gwaii
Quillback Rockfish - North and Central Coast
Quillback Rockfish - Strait of Georgia
Quillback Rockfish - Vancouver Island and Johnstone Stra
Estimate (number of fish)
Year
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept


Tiger Rockfish - Haida Gwaii
Tiger Rockfish - North and Central Coast
Tiger Rockfish - Strait of Georgia
Tiger Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
0
200
400
600
800
500
1,000
1,500
2,000
3,000
2013
2014
2015
2016
2017
2018
2019
2020
2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

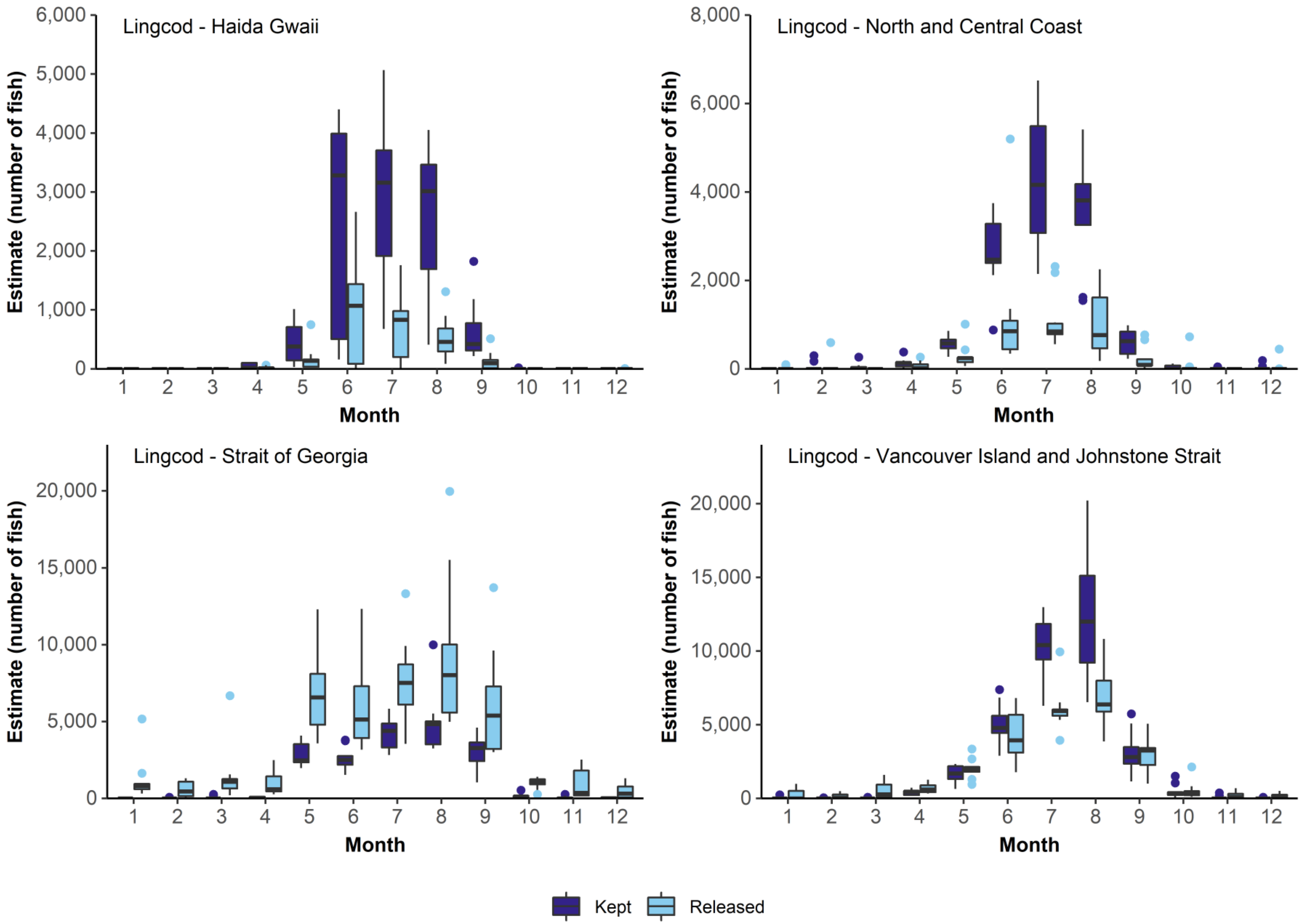

Vermilion Rockfish - Haida Gwaii
Vermilion Rockfish - North and Central Coast
Vermilion Rockfish - Strait of Georgia
Vermilion Rockfish - Vancouver Island and Johnstone Strai
Estimate (number of fish)
Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

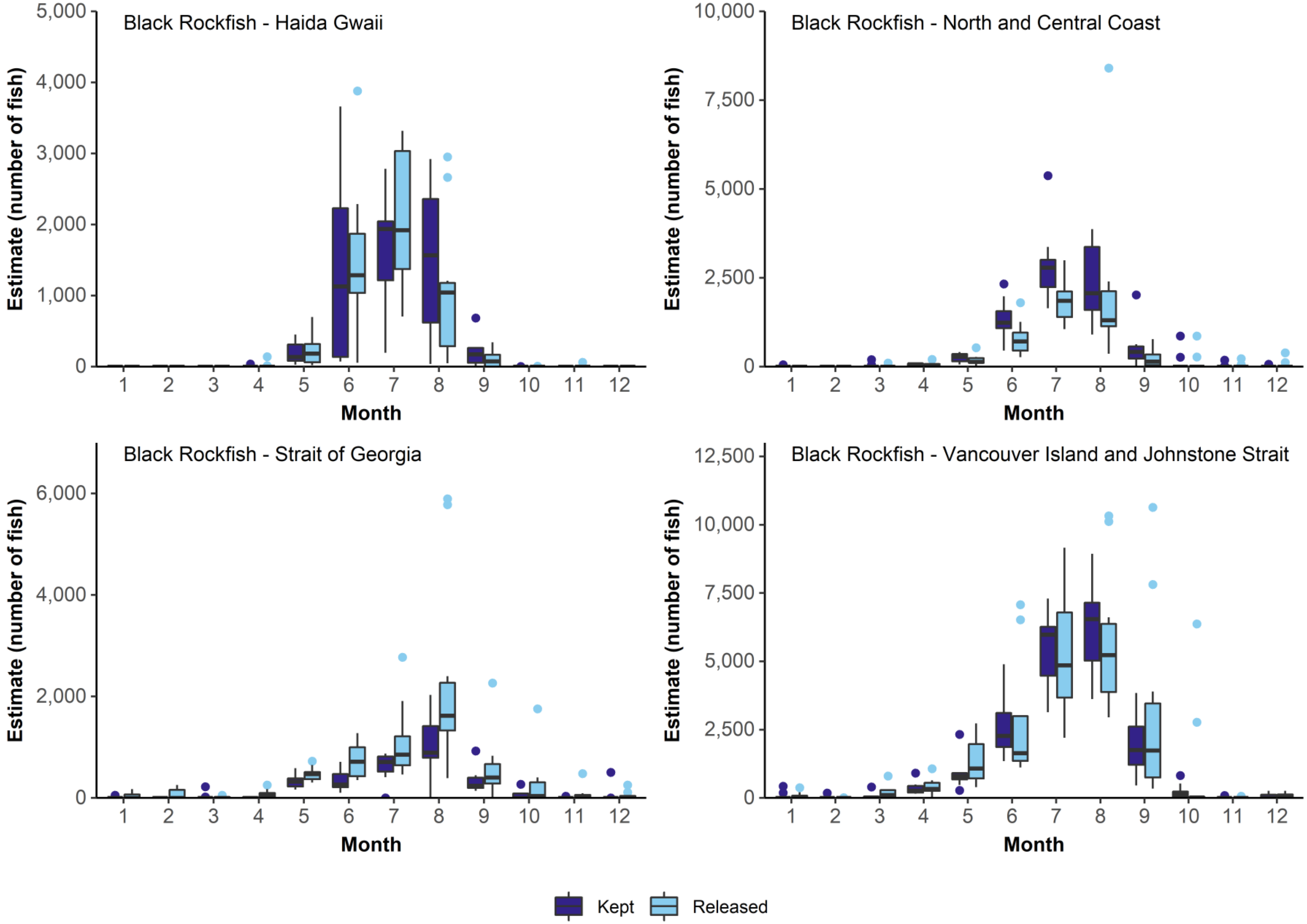

Yelloweye Rockfish - Haida Gwaii
Yelloweye Rockfish - North and Central Coast
Yelloweye Rockfish - Strait of Georgia
Yelloweye Rockfish - Vancouver Island and Johnstone Str
Estimate (number of fish)
Year
2013 2014 2015 2016 2017 2018 2019 2020 2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

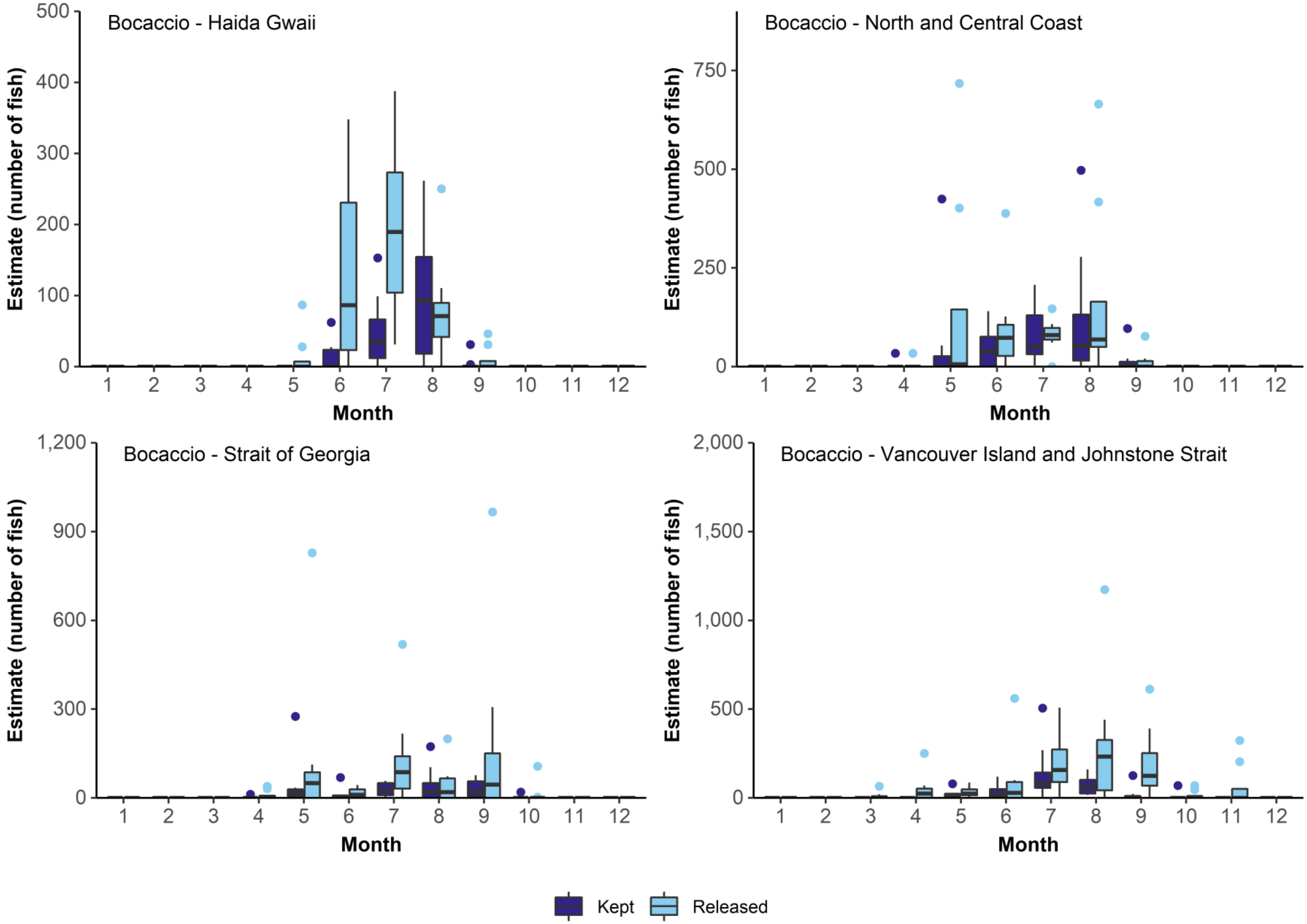

Yellowtail Rockfish - Haida Gwaii
Yellowtail Rockfish - North and Central Coast
Yellowtail Rockfish - Strait of Georgia
Yellowtail Rockfish - Vancouver Island and Johnstone Stra
Estimate (number of fish)
Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

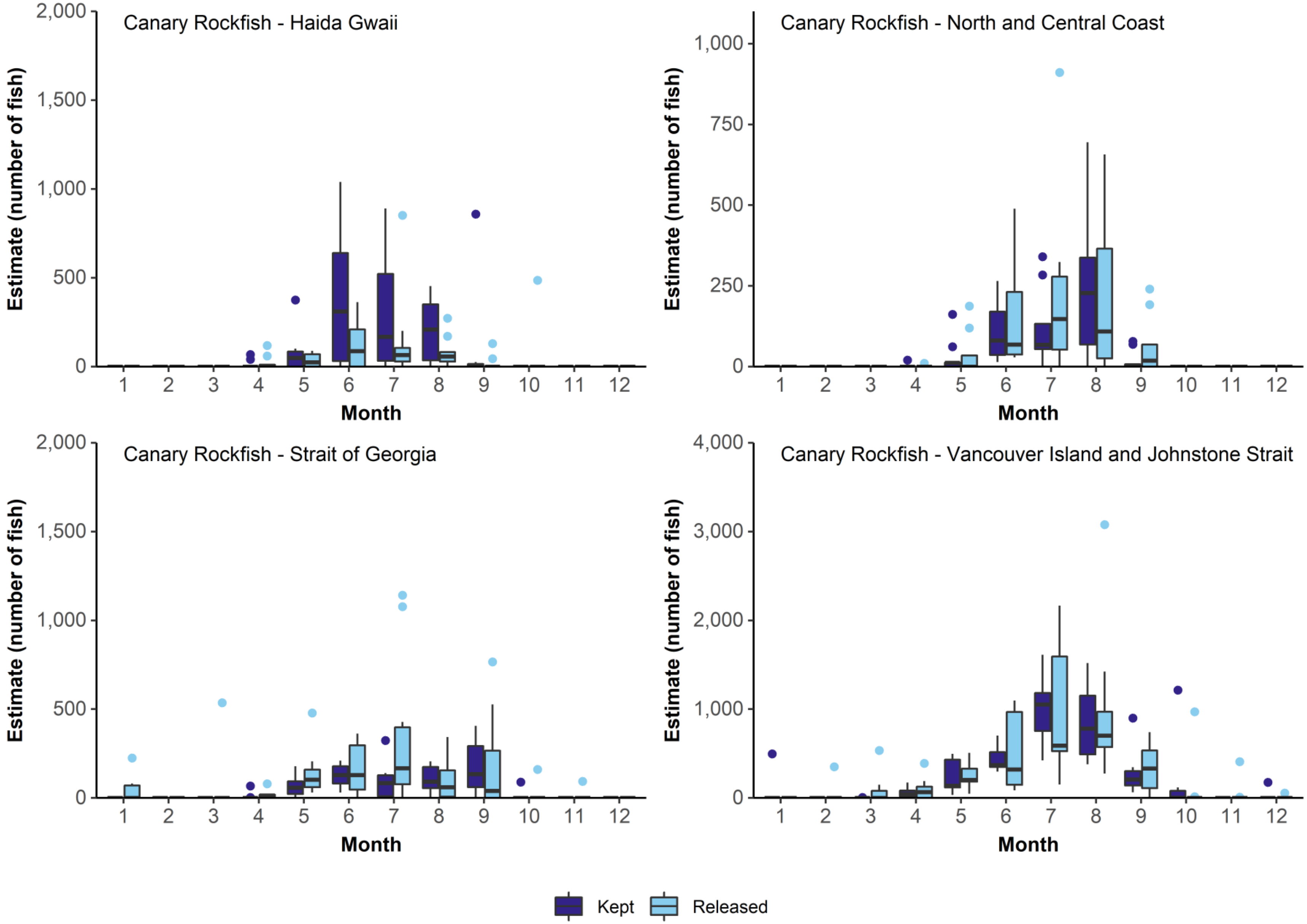

Misc. Rockfish - Haida Gwaii
Misc. Rockfish - North and Central Coast
Misc. Rockfish - Strait of Georgia
Misc. Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Year
2013 2014 2015 2016 2017 2018 2019 2020 2021
0 2,500 5,000 7,500 10,000
0 5,000 10,000 15,000
0 10,000 20,000 30,000
Boat - Released
Shore - Released
Dive - Released
Boat - Kept
Shore - Kept
Dive - Kept

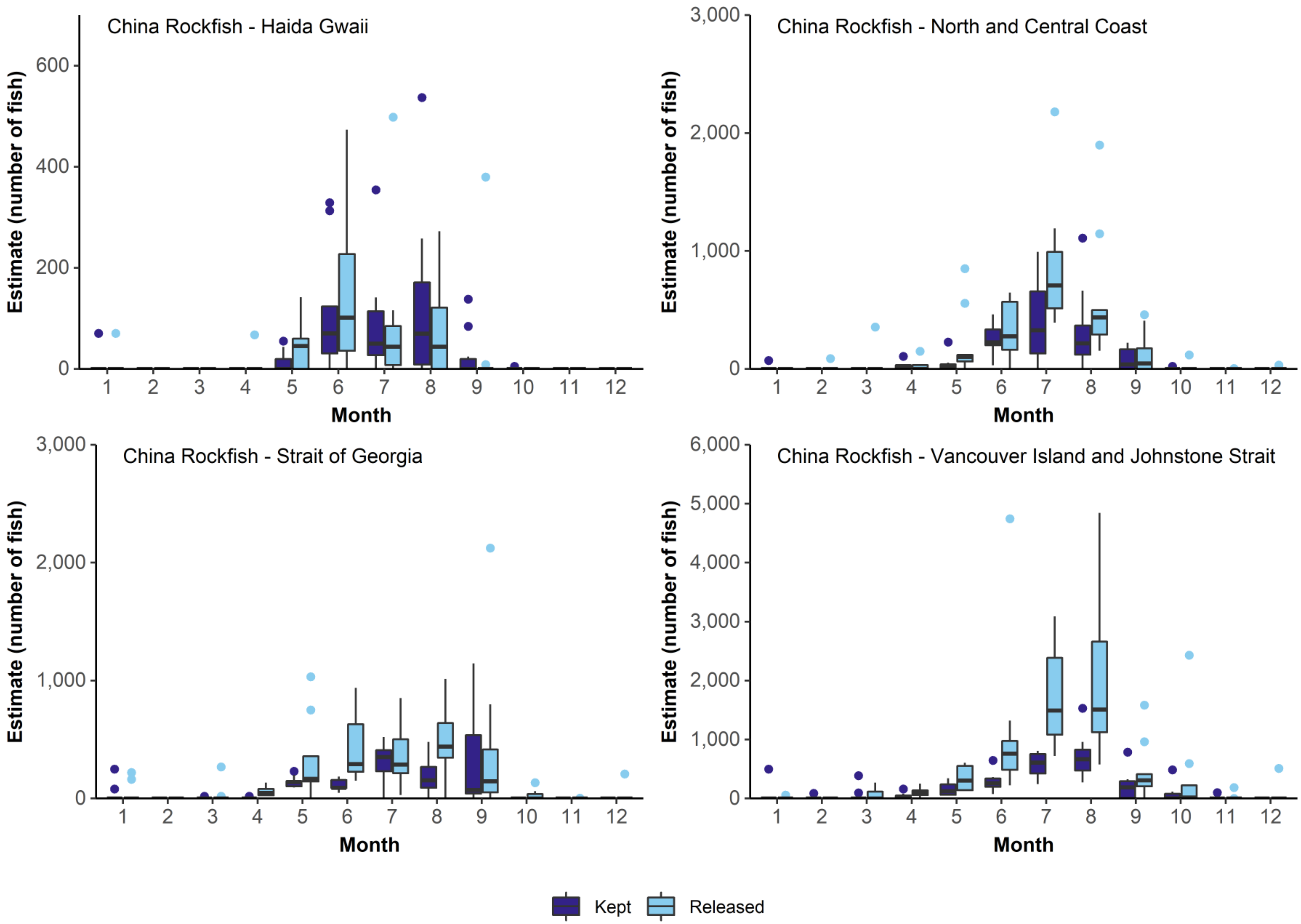
Appendix C. iREC estimates of monthly catch by taxon, management subregion, and disposition type (kept, released). Sample sizes for each month are determined by the number of months for which data were obtained. Data are presented using box-whisker plots. Boxes extend from the 25th to 75th percentiles, with a bold bar showing at the median value. Whiskers extend to largest estimates that are within 1.5 times the interquartile range. Estimates that were greater than the extent of the whiskers are shown as dots. Management subregions are defined as: Haida Gwaii (Management Areas 1-2, 101-102, and 142); North and Central Coast (Areas 3-10, 103-110, and 130); Strait of Georgia (Areas 13-19, and 28-29); and Vancouver Island and Johnstone Strait (Areas 11-12, 20-27, 111, 121, 123, and 125-127).

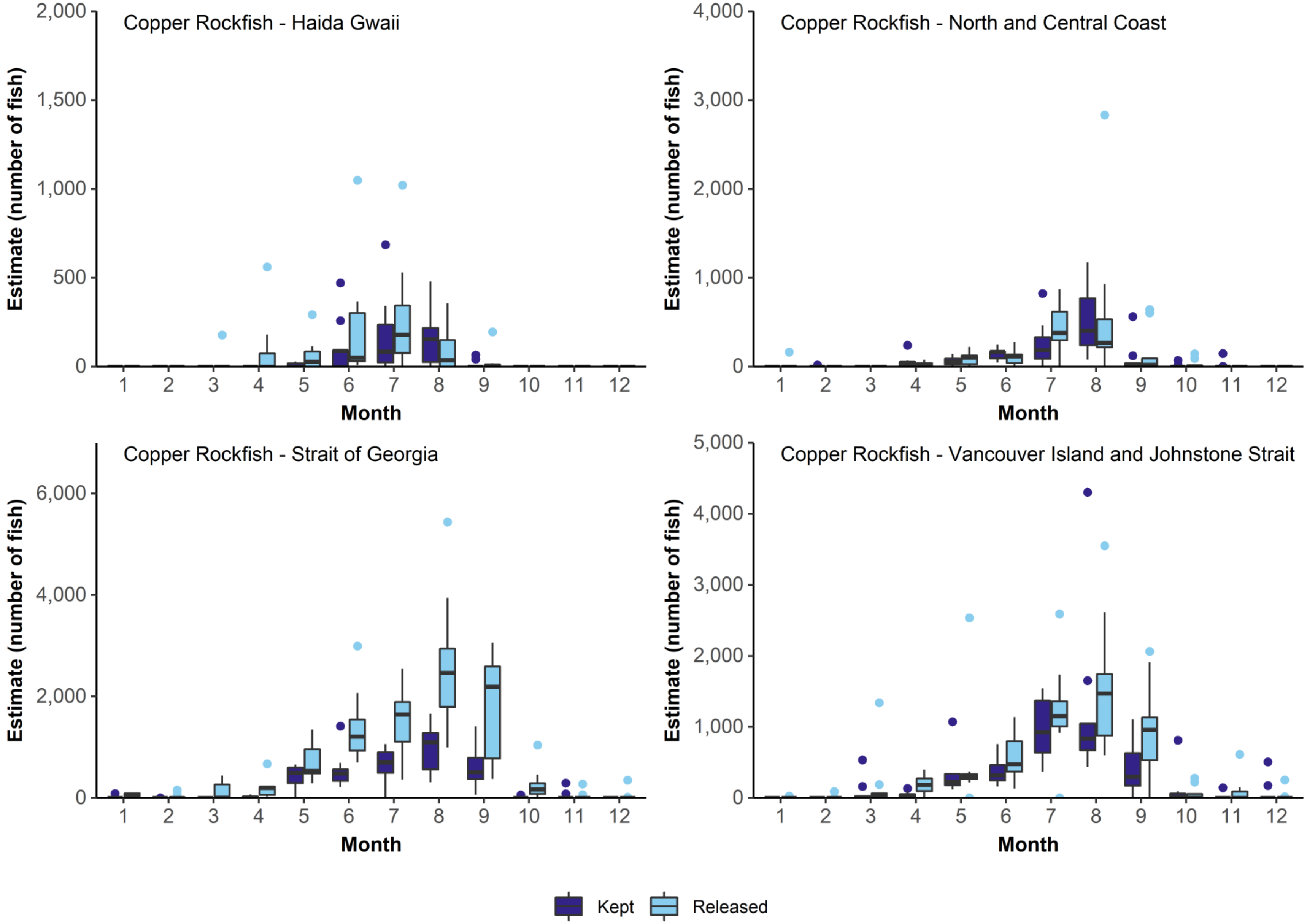

Lingcod - Haida Gwaii
Lingcod - North and Central Coast
Lingcod - Strait of Georgia
Lingcod - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released

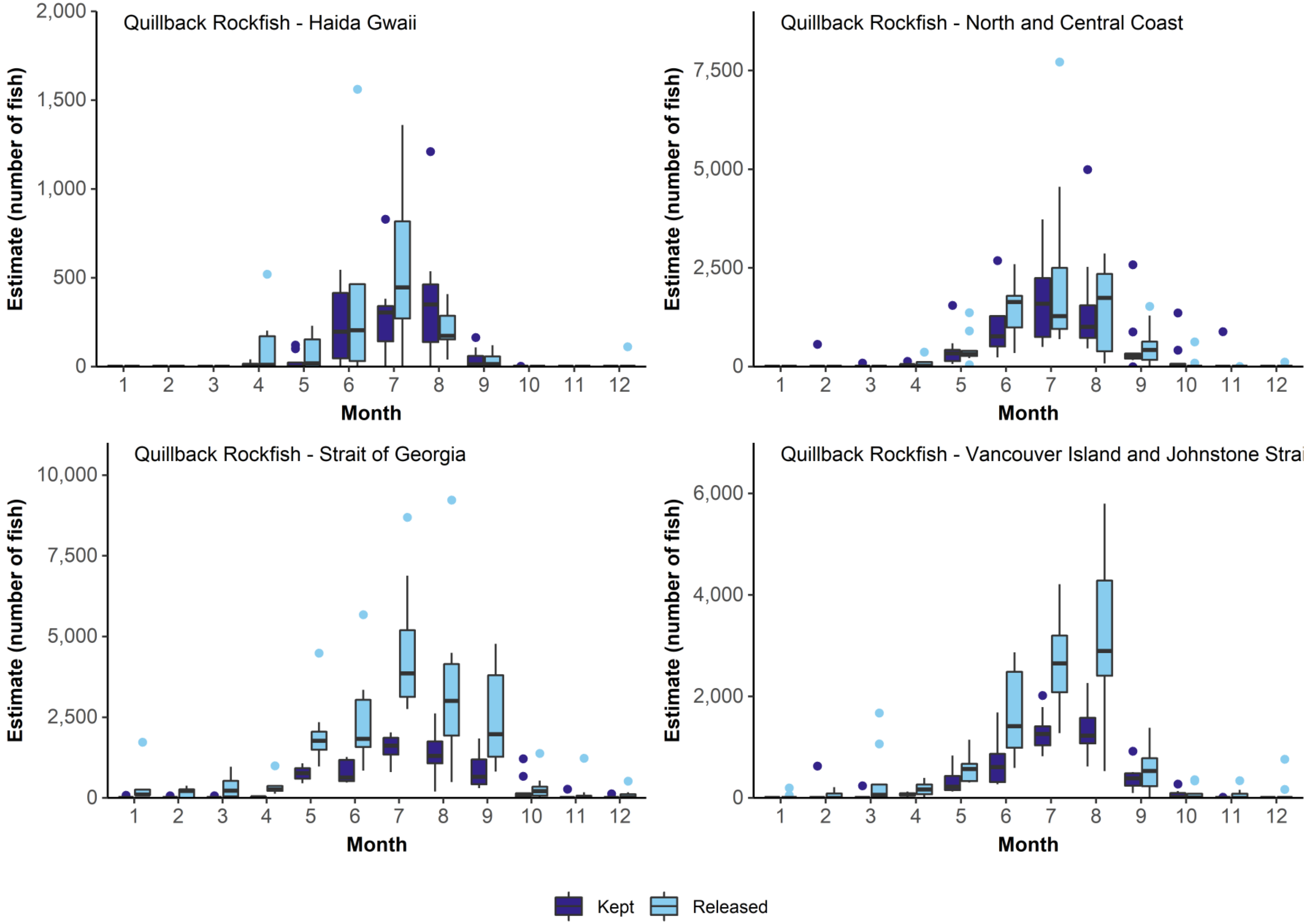

Black Rockfish - Haida Gwaii
Black Rockfish - North and Central Coast
Black Rockfish - Strait of Georgia
Black Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released

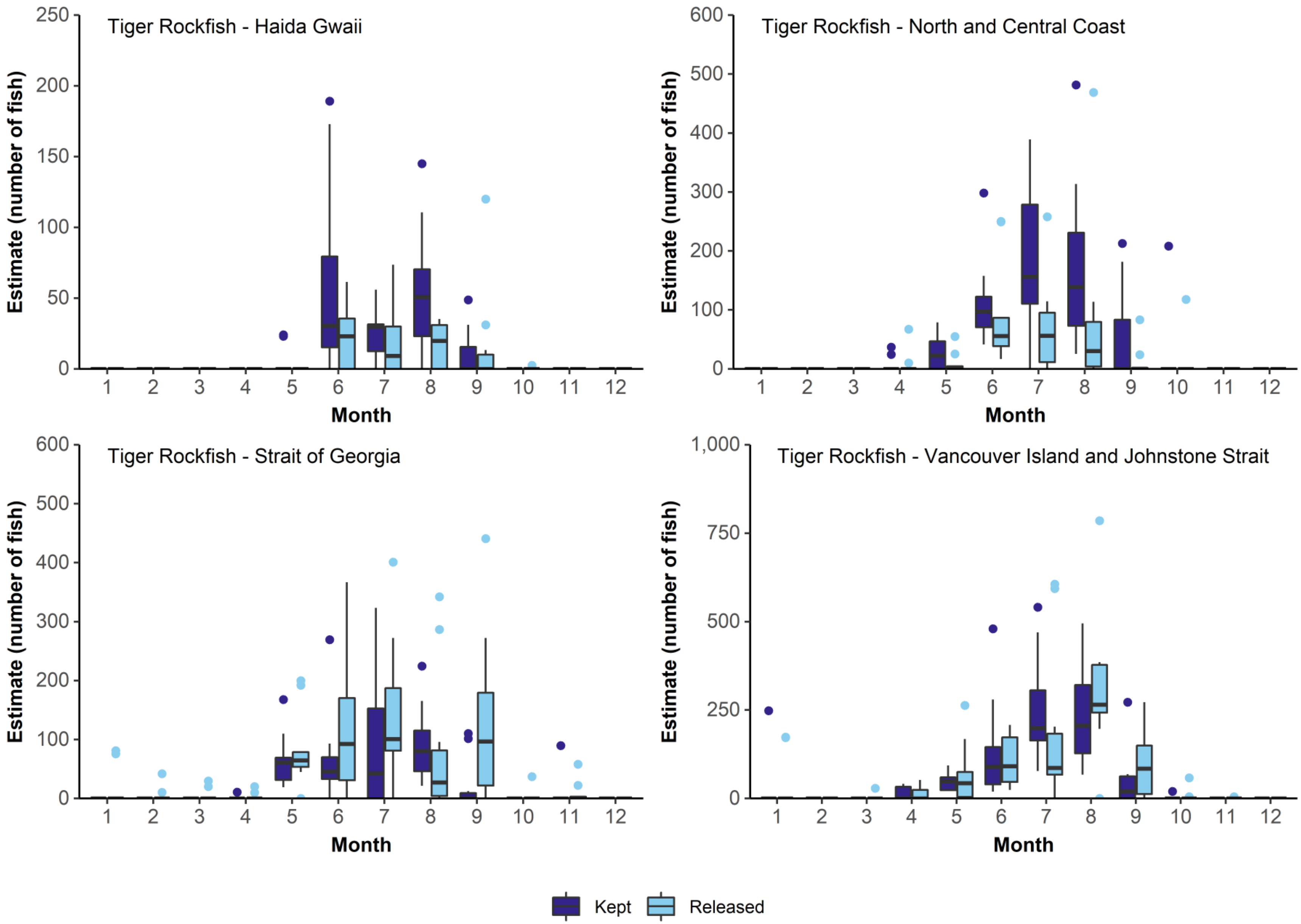

Bocaccio - Haida Gwaii
Bocaccio - North and Central Coast
Bocaccio - Strait of Georgia
Bocaccio - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
1 2 3 4 5 6 7 8 9 10 11 12
0 100 200 300 400 500
0 250 500 750
0 300 600 900 1,200
0 500 1,000 1,500 2,000
Kept
Released


Canary Rockfish - Haida Gwaii
Canary Rockfish - North and Central Coast
Canary Rockfish - Strait of Georgia
Canary Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released

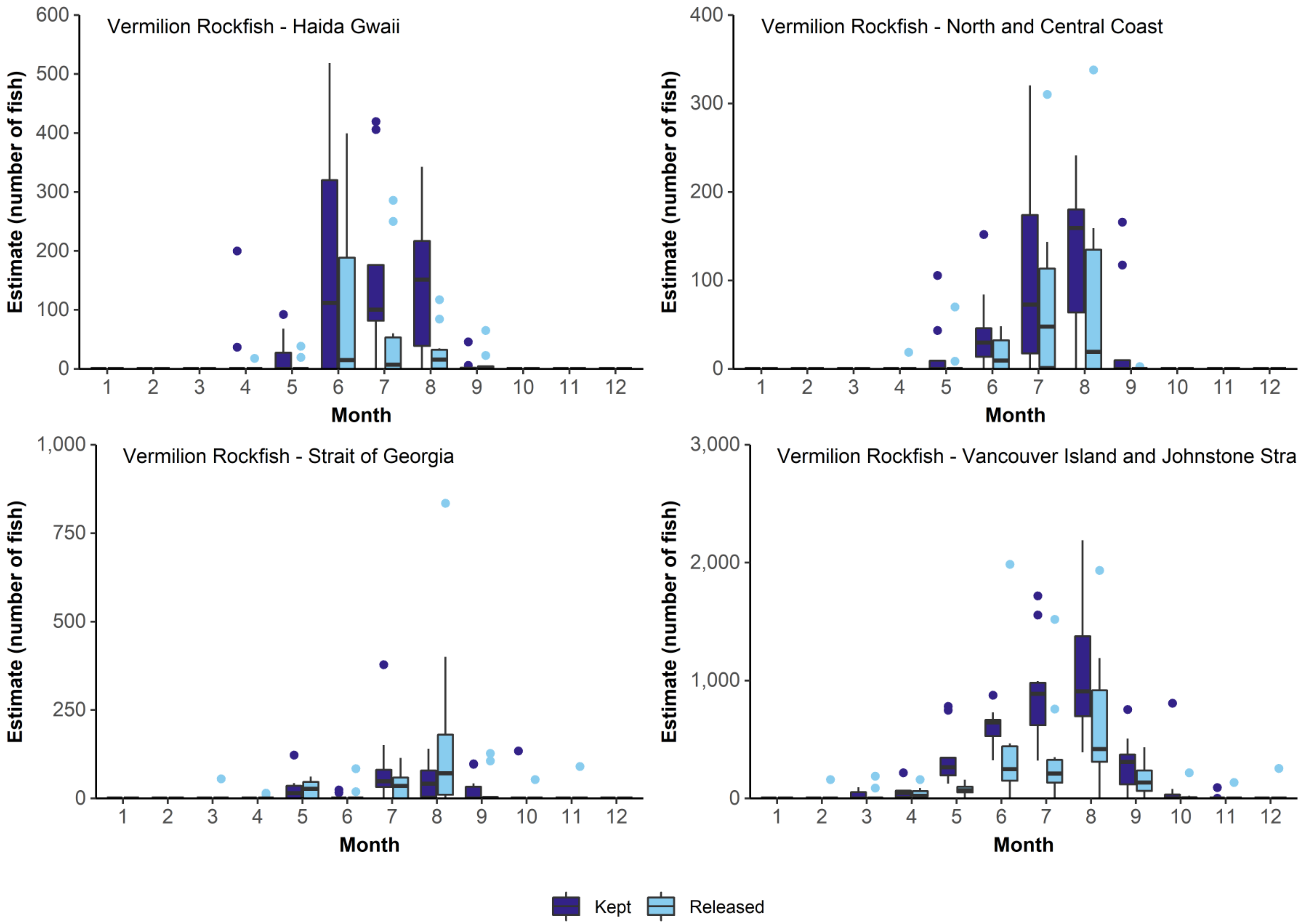

China Rockfish - Haida Gwaii
China Rockfish - North and Central Coast
China Rockfish - Strait of Georgia
China Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
0
200
400
600
1,000
2,000
3,000
4,000
5,000
6,000
1
2
3
4
5
6
7
8
9
10
11
12
Kept
Released

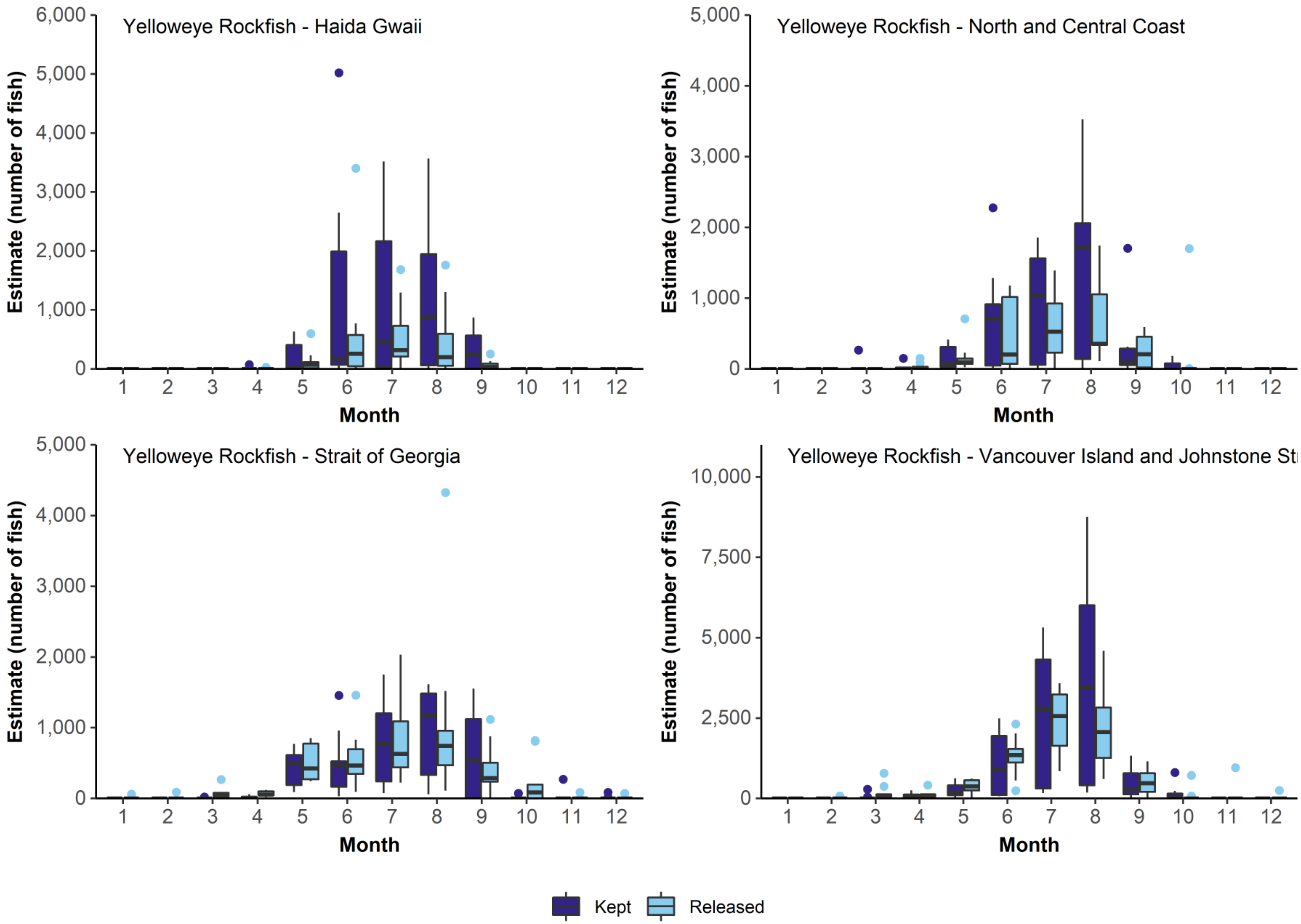

Copper Rockfish - Haida Gwaii
Copper Rockfish - North and Central Coast
Copper Rockfish - Strait of Georgia
Copper Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released

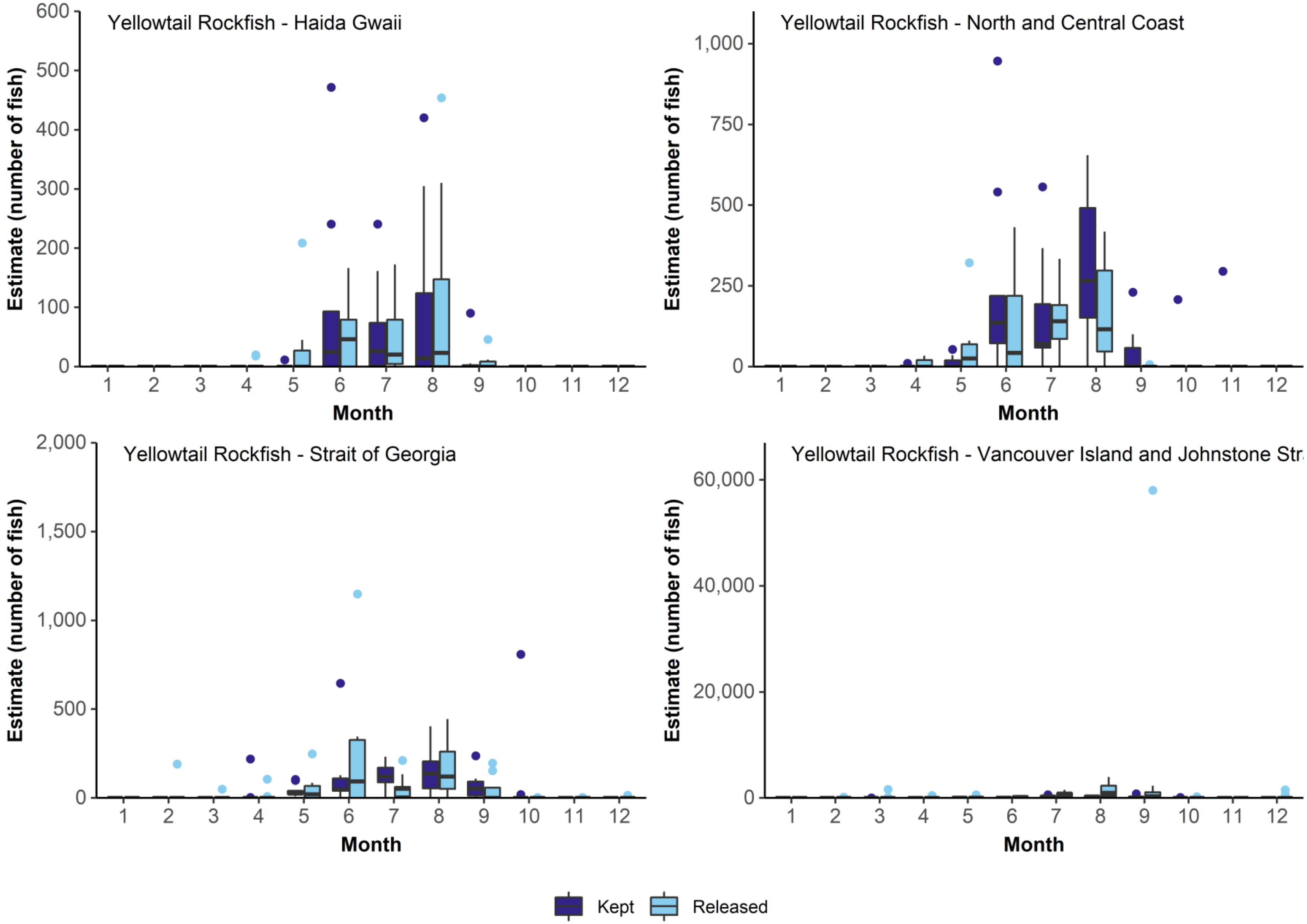

Quillback Rockfish - Haida Gwaii
Quillback Rockfish - North and Central Coast
Quillback Rockfish - Strait of Georgia
Quillback Rockfish - Vancouver Island and Johnstone Strai
Estimate (number of fish)
Month
Kept
Released

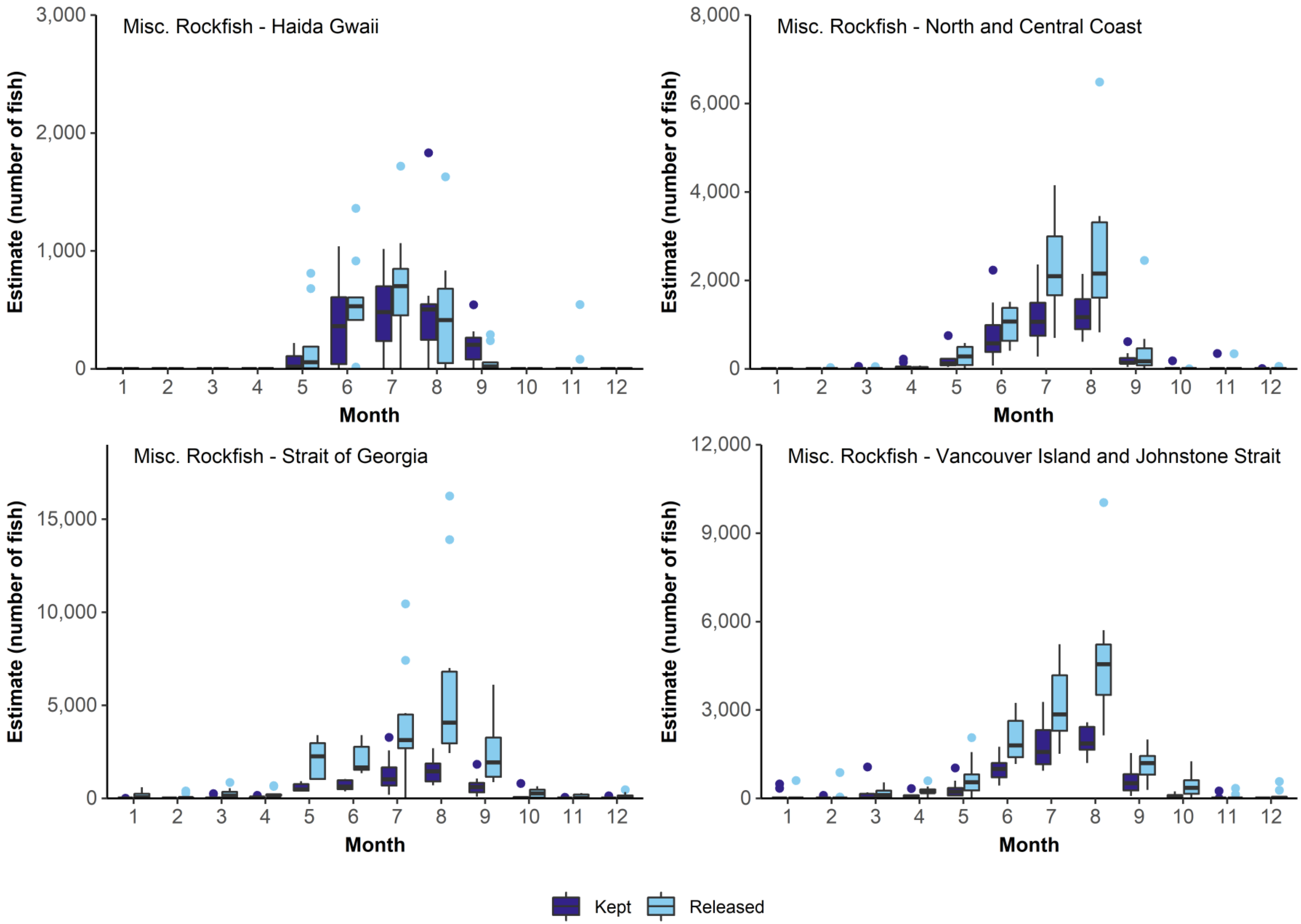


Tiger Rockfish - Haida Gwaii
Tiger Rockfish - North and Central Coast
Tiger Rockfish - Strait of Georgia
Tiger Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released


Vermilion Rockfish - Haida Gwaii
Vermilion Rockfish - North and Central Coast
Vermilion Rockfish - Strait of Georgia
Vermilion Rockfish - Vancouver Island and Johnstone Stra
Estimate (number of fish)
Month
Kept
Released


Yelloweye Rockfish - Haida Gwaii
Yelloweye Rockfish - North and Central Coast
Yelloweye Rockfish - Strait of Georgia
Yelloweye Rockfish - Vancouver Island and Johnstone St
Estimate (number of fish)
Month
Kept
Released


Yellowtail Rockfish - Haida Gwaii
Yellowtail Rockfish - North and Central Coast
Yellowtail Rockfish - Strait of Georgia
Yellowtail Rockfish - Vancouver Island and Johnstone Str
Estimate (number of fish)
Month
Kept
Released


Misc. Rockfish - Haida Gwaii
Misc. Rockfish - North and Central Coast
Misc. Rockfish - Strait of Georgia
Misc. Rockfish - Vancouver Island and Johnstone Strait
Estimate (number of fish)
Month
Kept
Released