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Quantifying effects of reporting changes for pāua (*Haliotis iris*) catch-per-unit-effort

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EXECUTIVE SUMMARY

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Pāua (*Haliotis iris*) fisheries in New Zealand are largely managed based on the outcome of regular stock assessments that determine the stock status of a particular quota management area (QMA). These stock assessments are largely dependent on catch-per-unit-effort (CPUE) from commercial fisheries as indices of relative abundance. The CPUE is also used to determine harvest control rules that support management procedures for pāua in an increasing number of QMAs. Although these management procedures are largely used internally by the fishing industry to manage catch levels between stock assessments, they are important tools to control removals.

Given the importance of CPUE for the assessment and management of pāua fisheries, the recent change from Pāua Catch Effort Landing Return (PCELR) forms to an electronic reporting system (ERS) via applications on handheld devices led to concerns about the continuity of CPUE data. The concerns were largely centred on two aspects of electronic reporting: spatial information and the duration of fishing effort (time). To address these concerns, the present study compared reporting patterns between PCELR forms and data reported via ERS over a comparable time period of three years of pre-and post-reporting change. To understand and omit records with poor effort reporting, a model was used to examine changes in reported effort time. This examination aimed to identify changes in client-effort reporting in relation to expected changes from inter-annual variation in PCELR data. To estimate spatial reporting fidelity, inferred statistical areas from catch records were compared with reported locations of catch bags recorded during dive fishing events. These analyses suggested that i) a limited number of clients changed their reporting, and ii) spatial reporting was accurate overall, although some clients tended to submit catch reports for areas other than areas where fishing had occurred.

Subsequent CPUE analyses, omitting different subsets of reported CPUE data, suggested that both spatial- and effort-derived subsets did not change CPUE trends for most areas that are currently monitored based on CPUE. Although changes in reported CPUE may have introduced changes in reporting for some clients, this finding highlights that inclusion or omission of these data has limited effects on estimated CPUE trends. For this reason, any effect on stock assessments and management procedures would be minimal. In contrast, other changes, such as selectivity changes from changes in targeting in most fisheries, will likely have a more substantial effect on CPUE.

[1]Dragonfly Data Science, New Zealand.

1. INTRODUCTION

With the exception of a few areas, pāua (*Haliotis iris*) fisheries in New Zealand are managed with regular stock assessments that determine the stock status within quota management areas (QMAs) or subareas. Stock assessments are greatly dependent on catch-per-unit-effort (CPUE) from commercial fisheries. In New Zealand and internationally, CPUE has been questioned as a suitable indicator for relative abundance (Prince & Hilborn 1998, Prince 2005, Neubauer 2017); however, it is routinely used as an index of relative abundance for pāua, supported by empirical studies that suggest that, despite potential non-linearities between CPUE and abundance, observed relationships are largely linear (Abraham & Neubauer 2015, McCowan & Neubauer 2018).

In addition, CPUE is also used as an assessment tool that determines harvest control rules that support management procedures for pāua in an increasing number of QMAs. These management procedures have been largely used by industry since 2016 to manage catch levels between stock assessments, and are important tools to control removals (Neubauer 2019, 2021).

Due to the importance of CPUE for assessment and management of pāua fisheries, recent changes in the fisheries have led to concerns about the reliability of CPUE as an indicator of changes in abundance. Changes in pāua fisheries in recent years include changes in selectivity as divers increasingly target large-sized pāua for live export; changes in markets and associated fishing patterns caused by COVID-19; and changes in reporting from Pāua Catch Effort Landing Return (PCELR) forms to an electronic reporting system (ERS). The latter data are reported via forms embedded in applications on handheld devices. These forms may be pre-populated to provide suggested effort metrics, such as dive time and other relevant parameters.

The concerns about the shift from paper-based reporting and potential impacts on the continuity of CPUE data were largely focused on the reporting of spatial information and of fishing effort duration. Spatial reporting changed from diver-reported statistical areas to automatically reported Global Positioning System (GPS) coordinates at the time when the fishery report is closed on the application. Some of these positions suggested that the closing of fishing events occurred at a distance from the actual fishing locations, leading to erroneous inferred statistical areas. In addition, effort reporting in the ERS is based on pre-populated fields, limiting the interpretation of fishing duration, and may differ systematically from effort reported on PCELR forms.

In this study, reporting patterns were compared between data reported on PCELR forms and by ERS. The comparison was over a comparable time period of three years of pre-and post-reporting change. It aimed to determine the degree to which PCELR and ERS may be used as a continuous time series to index relative abundance of pāua.

2. METHODS

2.1 Assessing changes in effort reporting

Changes in effort reporting were initially assessed by visual comparison of cumulative distribution plots of PCELR- and ERS-reported fishing duration. To address whether observed changes were due to reporting changes across the fleet or individual operators, the model of fishing duration was constricted for fishing reported by individual clients (generally holders of Annual Catch Entitlement, ACE). The model aimed to estimate changes in fishing duration based on differences between PCELR- and ERS-reported fishing effort (time). Estimates from this model were then compared with the standard deviation of inter-annual changes from PCELR data to calculate a probability that the reporting change was greater than differences among years in fishing duration.

The model for reporting change was written as:

$$Y_{i,r,q}^{[L,U]}\ SN^{[0,]}(\mu_{i,r,q}, \sigma, \eta), \tag{1}$$

$$\mu_{i,r,q} = \nu_q + \zeta_r + \epsilon_{i,r}, \tag{2}$$

where the superscript $[L, U]$ shows interval-censored duration data (Y) for reporting at time intervals of full, half, or quarter hours. For these records, it was assumed that the true fishing duration was unknown, but was likely to be between L and U, where L and U are dependent on the reporting: for hourly reporting, it was assumed that the true duration may have been between half an hour before and half an hour after the hour.

The variability in the fishing duration response was found to be adequately represented by a skew-normal distribution with standard deviation σ, skew η, with a lower truncation at zero. The regression formulation accounts for base differences in reported effort by QMA (ν_q), reporting type (ζ_r), and reporting changes by client i ($\epsilon_{i,r}$). The latter was modelled as a random deviation from the main effects. Priors were set to wide priors that carry minimal information about the change terms: fixed effect parameters had a normal prior with mean zero and $sd = 0$. Student-t distributions were used for standard deviation priors on random effects, with $sd = 100$ and three degrees of freedom.

The model for inter-annual changes in fishing duration for PCELR reporting was formulated as:

$$Y_{i,r,q}^{[L,U]}\ SN^{[0,]}(\mu_{i,y}, \sigma, \eta), \tag{3}$$

$$\mu_{i,y} = \nu_i + \epsilon_{i,y}, \tag{4}$$

where ν_i is the average client fishing duration for client i, and $\epsilon_{i,y}$ is the client effect for year y. Priors were the same as for the reporting effects model.

Changes in reporting were estimated on a per-diver basis by calculating the posterior inter-annual variability per client, and taking the 95th percentile as the threshold above which reporting is deemed to be certain to have changed. As the effect of fishing duration change carries uncertainty, the probability of change was calculated as the probability that the reporting change was greater than the 95th quantile of inter-annual changes.

2.2 Assessing accuracy in spatial reporting

Accuracy in spatial reporting was assessed by comparing statistical areas inferred from GPS positions at closing of fishing events with reported locations of catch bags. The latter are recorded on a voluntary basis by the majority of divers. By comparing the position records from catch bag locations, it is possible to obtain accurate information of fishing locations that can provide an indication of the spatial accuracy of inferred statistical areas. Thereby, the comparison provides an indication of whether misreporting could influence CPUE indices, particularly over small spatial scales.

The reporting was split by version 1 (v1) and version 2 (v2) dive events. The latter reporting represents an update to circulars specifying reporting requirements for pāua dive fishing events. The update has been in place since October 2021; however, reporting to the new standard has only been compulsory since December 2021. The v2 dive events allow manual entry of statistical areas by pāua diver in addition to the reporting of target size. They, therefore, differ from initial ERS-reported pāua catch-effort data, which imputed dive locations from GPS coordinates of catch-effort reports, and did not allow for entry of target size.

2.3 Importance of potential reporting changes

To assess the importance of potential reporting changes on CPUE indices, the initial analyses (described above) were used to provide subsets of CPUE datasets that can be used to understand the impact of potential reporting changes on CPUE indices. For both effort and spatial reporting analyses, this assessment used increasingly restrictive definitions of change, which included progressively more data. At a minimum, no data were excluded from the models, whereas the most restrictive setting omitted substantial proportions of CPUE datasets from the analyses, and results were inspected for consistency.

Spatial subsetting proceeded by the following steps:

1. including all data,
2. including only data retained for spatial accuracy analysis (i.e., clients who reported spatial information using ERS)
3. including only dive events for which any catch bag location matched the inferred statistical areas and,
4. including only dive events if all reported catch-bag locations matched the inferred statistical area.

These subsets were designed to provide increasing certainty that inferred statistical areas were correct and represented the statistical area in which fishing occurred.

Effort subsets were constructed from the effort-reporting analysis by excluding progressively more clients from the CPUE datasets as a function of the probability that these clients changed their reporting. All subsets were applied in a grid of CPUE analysis across all QMAs of subdivisions thereof (if QMAs have spatial assessment models). These analyses followed methods used for individual assessments, but all used generalised linear mixed models. For all areas or subareas, eight models were run based on spatial and effort subsets. In addition, models were run with and without effects for fine-scale statistical area. These latter models were used to assess the potential impact of excluding fine-scale statistical areas from the analysis on CPUE indices, if spatial reporting is considered to be insufficiently accurate in the future.

3. RESULTS

3.1 Assessing changes in effort reporting

Initial visual assessments suggested considerable differences in fishing duration between PCELR and ERS data, particularly for PAU 5 QMAs (PAU 5A, 5B, and 5D; Figure 1). In these QMAs, fishing duration was significantly shorter for ERS-reported effort relative to PCELR reporting. In PAU 7, however, changes appeared to be small and in the opposite direction, with slightly longer duration reported under ERS.

The model of fishing duration fitted the data reasonably well and showed no undue influence of priors on the outcome (Figure 2). The model confirmed trends of change in QMA PAU 5, but suggested little change in other areas (Figure 3). Furthermore, model estimates of the interaction effects of client-form-type suggested that this change was variable among different clients; some clients showed marked differences between paper forms and ERS reporting, whereas others showed little to no change (Figure 4).

The current assessment calculated the probability that the difference in reporting change (ΔFD_{form}) is greater than the 95th percentile of year-on-year change in PCELR data (ΔFD_{PCELR}). This calculation showed that some clients had a high probability of reporting differently between reporting systems

(Figure 5). At the same time, for many other clients, the change was within the expected year-on-year changes from PCELR data. When excluding clients from CPUE datasets based on these probabilities, only three clients were excluded with a threshold of 95% (Figure 6). Nevertheless, a markedly higher number of clients was excluded when this threshold was moved towards requiring more certainty that the reporting was the same (i.e., requiring less certainty of change, Figure 6; and see Appendix A, Figure A-1).

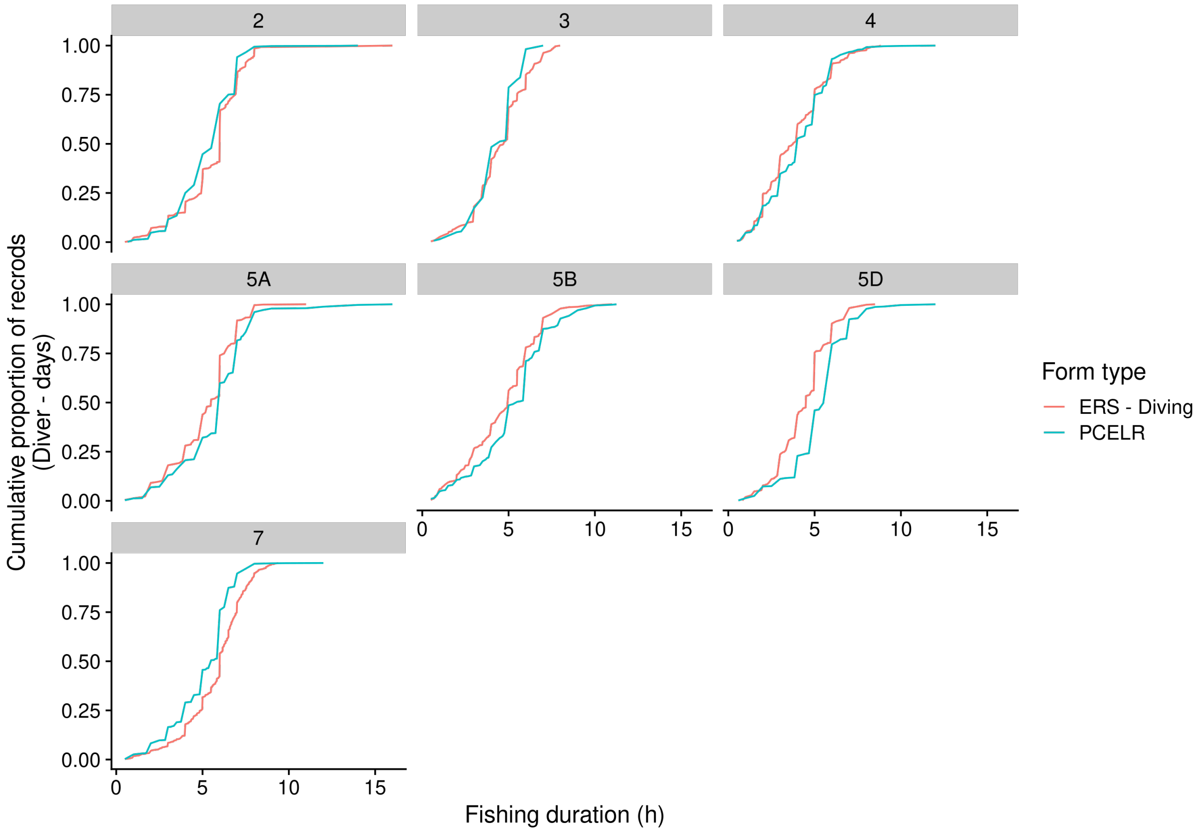

Figure 1: Cumulative distribution of reported fishing effort (duration) across pāua quota management areas (numbers at the top). Data are from the electronic reporting system (ERS) and Pāua Catch Effort Landing Return (PCELR) forms, for three years of data for each reporting system.

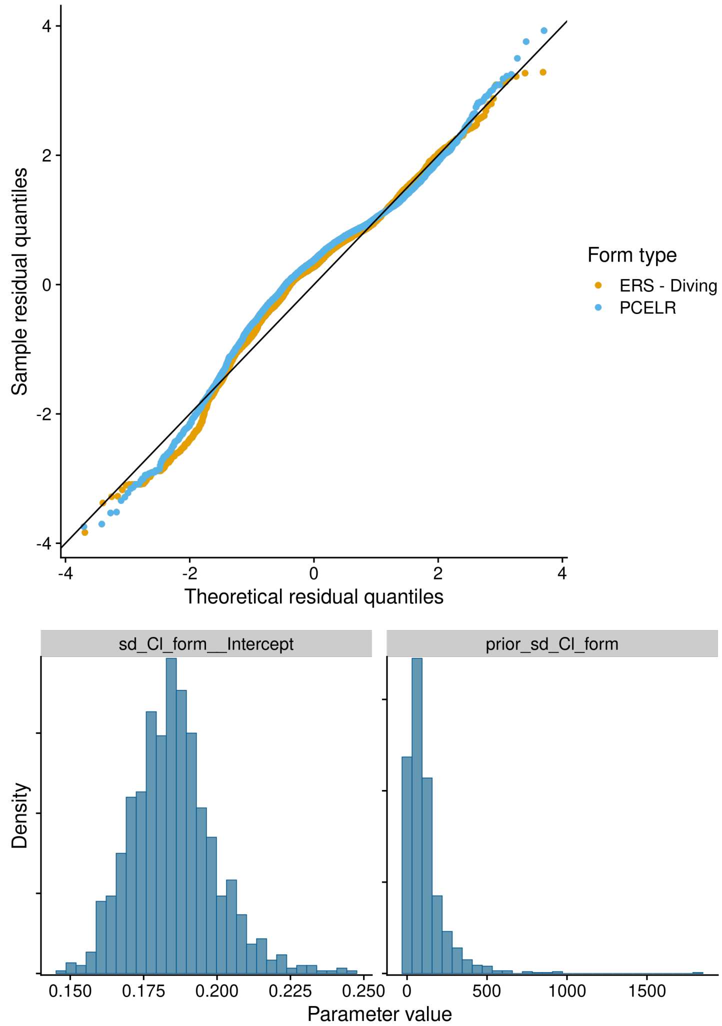

Figure 2: Model of fishing duration reported via electronic reporting system (ERS) and on Pāua Catch Effort Landing Return (PCELR) forms. Top: Diagnostics of model fit, showing quantile residuals by reporting type. Bottom, Priors impacts, showing the posterior (top row) and corresponding prior (bottom row) for model parameters.

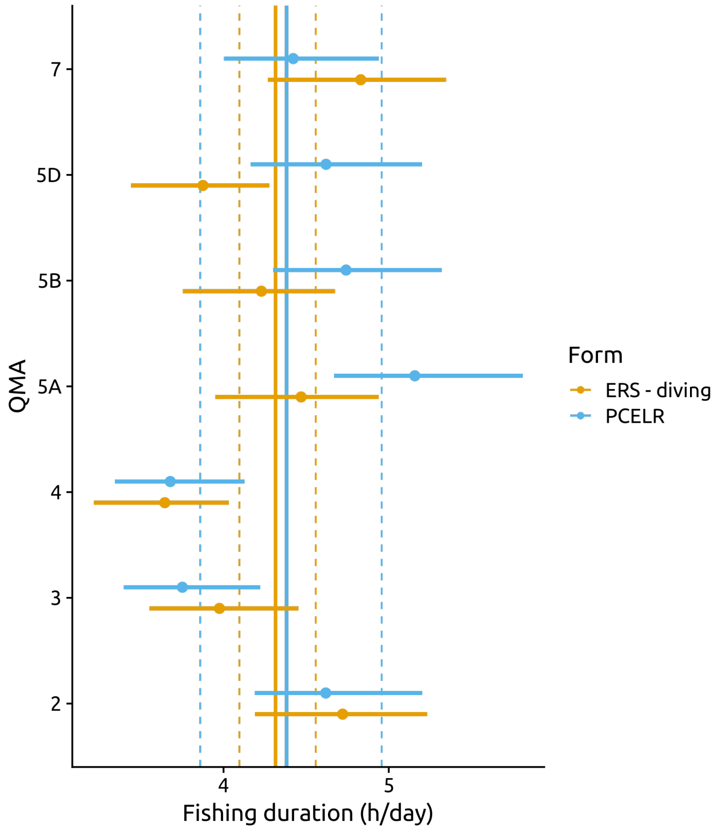

Figure 3: Estimated mean fishing duration by day per quota management area (QMA) reported via electronic reporting system (ERS) and on paper-based Pāua Catch Effort Landing Return (PCELR) forms. Vertical solid lines show estimates of the global mean duration under ERS and PCELR reporting, with their uncertainty (95% confidence interval) indicated with dashed vertical lines.

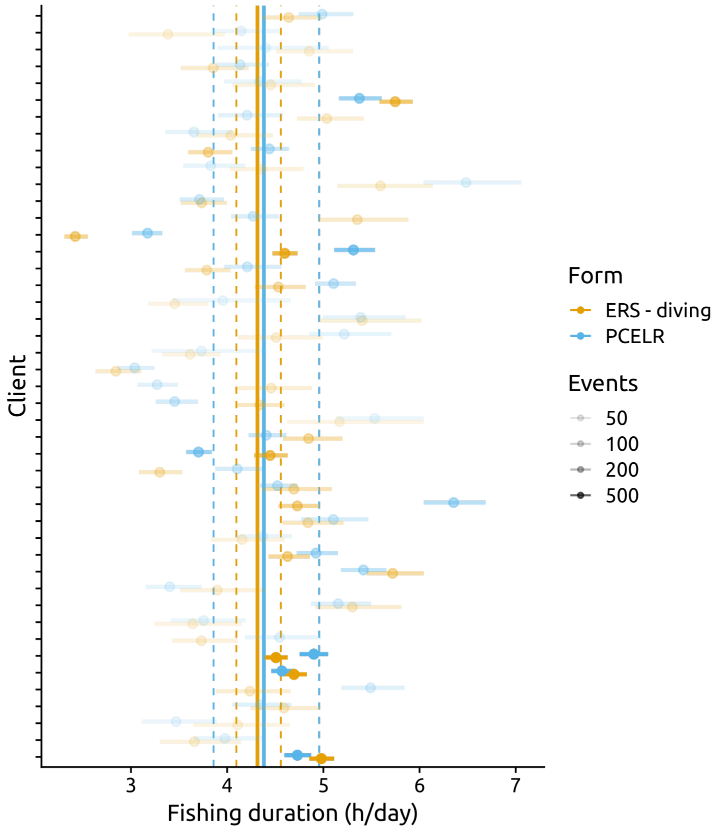

Figure 4: Estimated mean fishing duration by day per client reported via electronic reporting system (ERS) and on paper-based Pāua Catch Effort Landing Return (PCELR) forms. Estimates are for clients with sufficient data for the period pre- and post the reporting system change. Vertical solid lines show estimates of the global mean duration under ERS and PCELR reporting, with their uncertainty (95% confidence interval) indicated with dashed vertical lines.

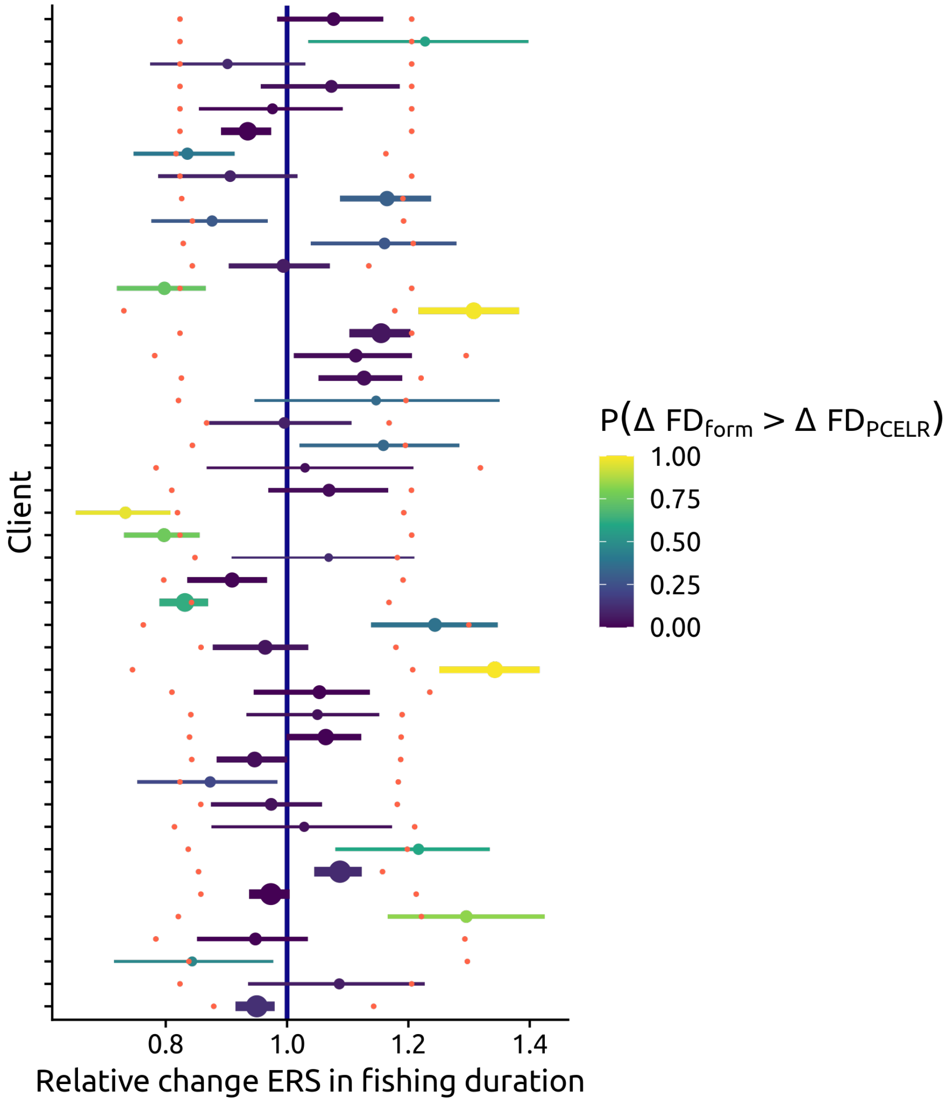

Figure 5: Estimated relative change in mean fishing duration by day per client reported via electronic reporting system (ERS) and on paper-based Pāua Catch Effort Landing Return (PCELR) forms. Estimates are for clients with sufficient data for the period pre- and post the reporting system change. Change was calculated as a probability that the difference in reporting change (ΔFD_{form}) is greater than the 95th percentile of year-on-year change in PCELR data (red points; ΔFD_{PCELR}).

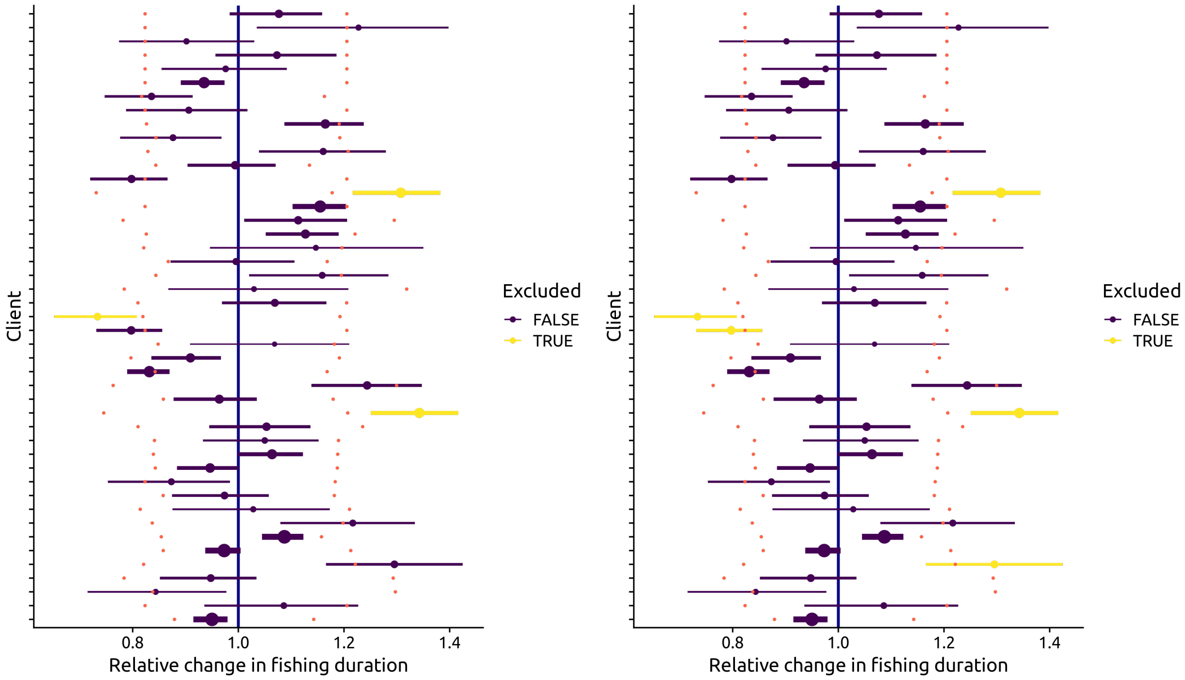

Figure 6: Exclusion of clients from pāua catch-per-unit-effort datasets based on a probability of ≥95% (left) and ≥75% (right) that the estimated relative change in mean fishing duration by day is greater than expected from year-on-year changes in data reported on Pāua Catch Effort Landing Return forms.

3.2 Assessing spatial accuracy

The accuracy of spatial reporting was assessed with GPS data recorded for catch bag locations. These data were reported for 58.5% to over 90% of events, depending on the QMA and year/ERS report type (v1 or v2; Table 1). When assessing the match between catch bag locations and event locations in statutory data, between 60% and 95% of records were matching (Table 2, Figure 7).

Considerable variation in the reporting of catch bag locations and spatial accuracy was due to a number of clients who tended to report a relatively small percentage of catch bag locations, and clients who did not achieve high spatial accuracy (Table 3, Figure 8). Clients with a high number of fishing events tended to show relatively accurate reporting. The improvements from v2 dive events for position reporting were small, with a relatively high number of clients showing less accurate reporting. This aspect may be related to uncertainty about fine-scale statistical areas. Nevertheless, records from other clients had improved accuracy.

Table 1: Number of fishing events and proportion with reported catch bag locations by pāua quota management area (QMA) and reporting event type (v1, dive location ascertained from catch-effort data; v2, catch location (statistical area) and target size recorded by pāua divers).

QMA	v1/diving		v2/diving	
	No. of events	Proportion	No. of events	Proportion
2	988	0.72	351	0.66
3	360	0.81	141	0.88
4	512	0.70	125	0.59
5A	763	0.92	126	0.91
5B	733	0.90	115	0.83
5D	522	0.86	121	0.71
7	1653	0.85	392	0.91

Table 2: Total number of fishing events used for comparison, and proportion of correctly-reported statistical areas by pāua quota management area (QMA), fishing year, and reporting event type ((v1, dive location ascertained from catch-effort data; v2, catch location (statistical area) and target size recorded by pāua divers).

QMA	Event type	2019–2020		2020–2021		2021–2022	
		No. of events	Proportion	No. of events	Proportion	No. of events	Proportion
2	v1/diving	360	0.83	577	0.75	19	0.70
2	v2/diving					340	0.76
3	v1/diving	157	0.87	192	0.84	6	0.64
3	v2/diving					131	0.79
4	v1/diving	297	0.87	184	0.87	2	0.60
4	v2/diving					110	0.81
5A	v1/diving	368	0.83	327	0.86	52	0.85
5A	v2/diving					126	0.93
5B	v1/diving	322	0.85	356	0.81	28	0.80
5B	v2/diving					115	0.68
5D	v1/diving	209	0.87	272	0.88	18	0.90
5D	v2/diving					118	0.72
7	v1/diving	909	0.91	695	0.94	22	0.95
7	v2/diving					383	0.90

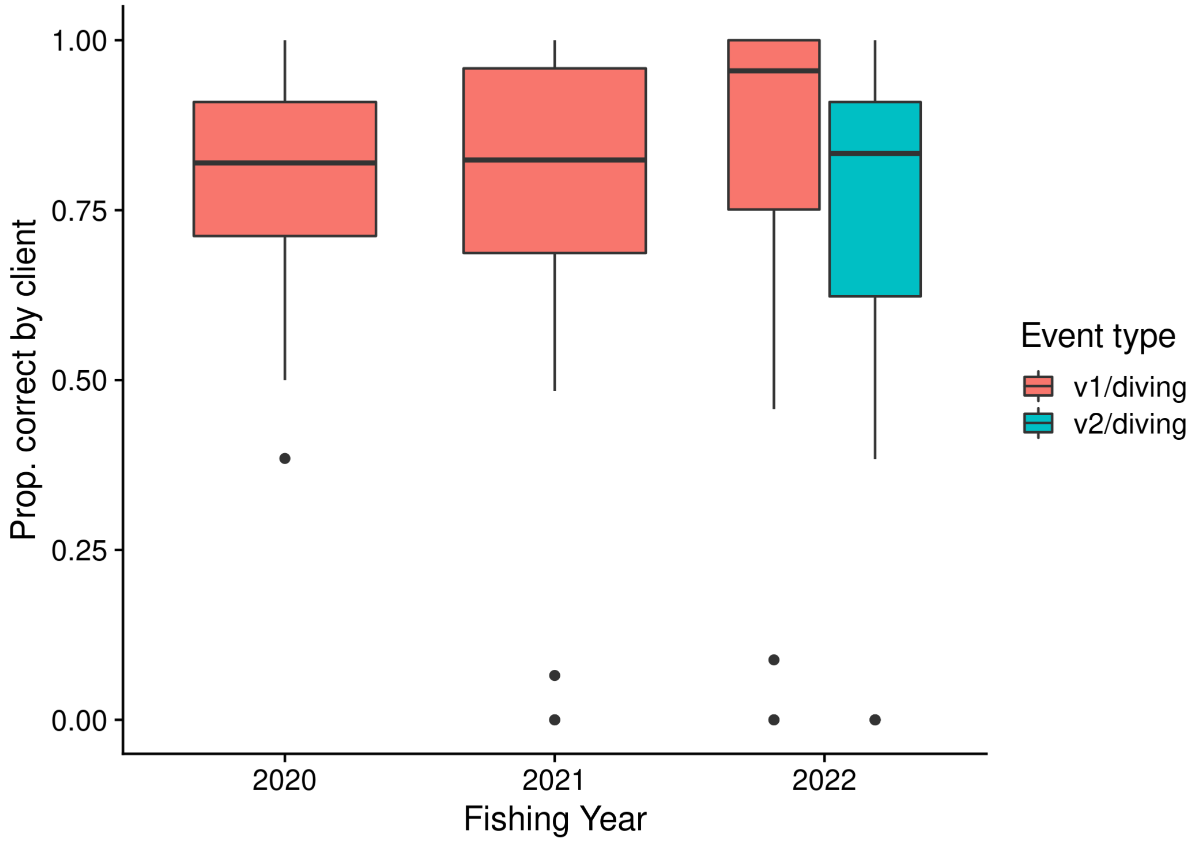

Figure 7: Proportion of correctly-reported statistical area for pāua fishing events by client. Data are provided by fishing year for fishing events in the year the catch bag locations were reported for v1 and v2 dive events (v1, dive location ascertained from catch-effort data; v2, catch location (statistical area) and target size recorded by pāua divers).

Table 3: Comparison of the reported location of pāua catch bags and spatial accuracy from statutory data by year. Total number of fishing events, the proportion of events with reported catch bag locations (Prop. CB), and the proportion of correctly-reported statistical areas (based on matching catch bag locations and event areas). Client numbers were anonymised, event type included v1 and v2 dive events (v1, dive location ascertained from catch-effort data; v2, catch location (statistical area) and target size recorded by pāua divers).

Client	Event	2019–20			2020–21			2021–22		
(anon.)	type	No. of events	Prop. CB	Prop.	No. of events	Prop. CB	Prop.	No. of events	Prop. CB	Prop.
1	v1/diving	464	0.97	0.99	434	0.96	1.00	2	1.00	1.00
1	v2/diving							254	0.89	1.00
4	v1/diving	152	0.65	1.00	107	0.69	1.00	11	0.58	1.00
4	v2/diving							92	0.56	1.00
5	v1/diving	260	0.80	1.00	298	0.80	1.00	10	0.83	0.91
5	v2/diving							131	0.74	1.00
6	v1/diving	26	0.91	1.00	54	0.98	1.00	6	0.92	1.00
6	v2/diving							35	0.81	1.00
9	v1/diving	49	0.70	1.00	54	0.80	1.00	15	0.46	1.00
10	v1/diving	85	0.78	0.98	58	0.86	1.00	11	0.74	1.00
10	v2/diving							16	0.74	1.00
11	v1/diving	36	0.89	0.92	29	1.00	0.91	4	1.00	1.00
11	v2/diving							35	0.96	1.00
12	v1/diving	49	0.72	0.89	68	0.81	0.96	32	0.77	1.00
12	v2/diving							22	0.91	1.00
15	v1/diving	106	0.98	1.00	59	0.98	1.00	3	1.00	1.00
15	v2/diving							2	1.00	1.00
16	v1/diving	49	0.80	1.00	163	0.72	1.00	1	1.00	1.00
16	v2/diving							81	0.85	0.95
18	v1/diving	45	0.90	1.00	36	0.96	1.00	1	1.00	1.00
18	v2/diving							31	0.86	1.00
21	v1/diving	33	0.91	1.00	45	1.00	1.00	14	1.00	1.00
21	v2/diving							25	0.88	1.00
25	v1/diving	39	0.93	1.00	54	0.97	1.00	1	1.00	1.00
25	v2/diving							20	0.80	1.00
28	v1/diving	58	0.87	1.00	34	0.94	1.00			
28	v2/diving							28	0.95	1.00
29	v1/diving	165	0.89	0.99	200	0.82	1.00	52	0.89	1.00
29	v2/diving							84	0.81	1.00
32	v1/diving	110	0.97	1.00	74	0.93	0.99	1	0.88	1.00
32	v2/diving							46	0.96	1.00
34	v1/diving	6	0.83	1.00	71	0.68	0.95	1	0	1.00
34	v2/diving							37	0.89	1.00
37	v1/diving	74	0.99	1.00	59	0.85	1.00	7	0.66	1.00
37	v2/diving							25	0.57	1.00
39	v1/diving	390	0.97	1.00	292	0.98	1.00	25	0.95	1.00
39	v2/diving							167	0.95	1.00
42	v1/diving	15	0.73	1.00	47	0.87	1.00	11	0.82	1.00
42	v2/diving							28	0.54	1.00
47	v1/diving	20	0.97	1.00	96	0.86	1.00			
47	v2/diving							31	0.75	1.00

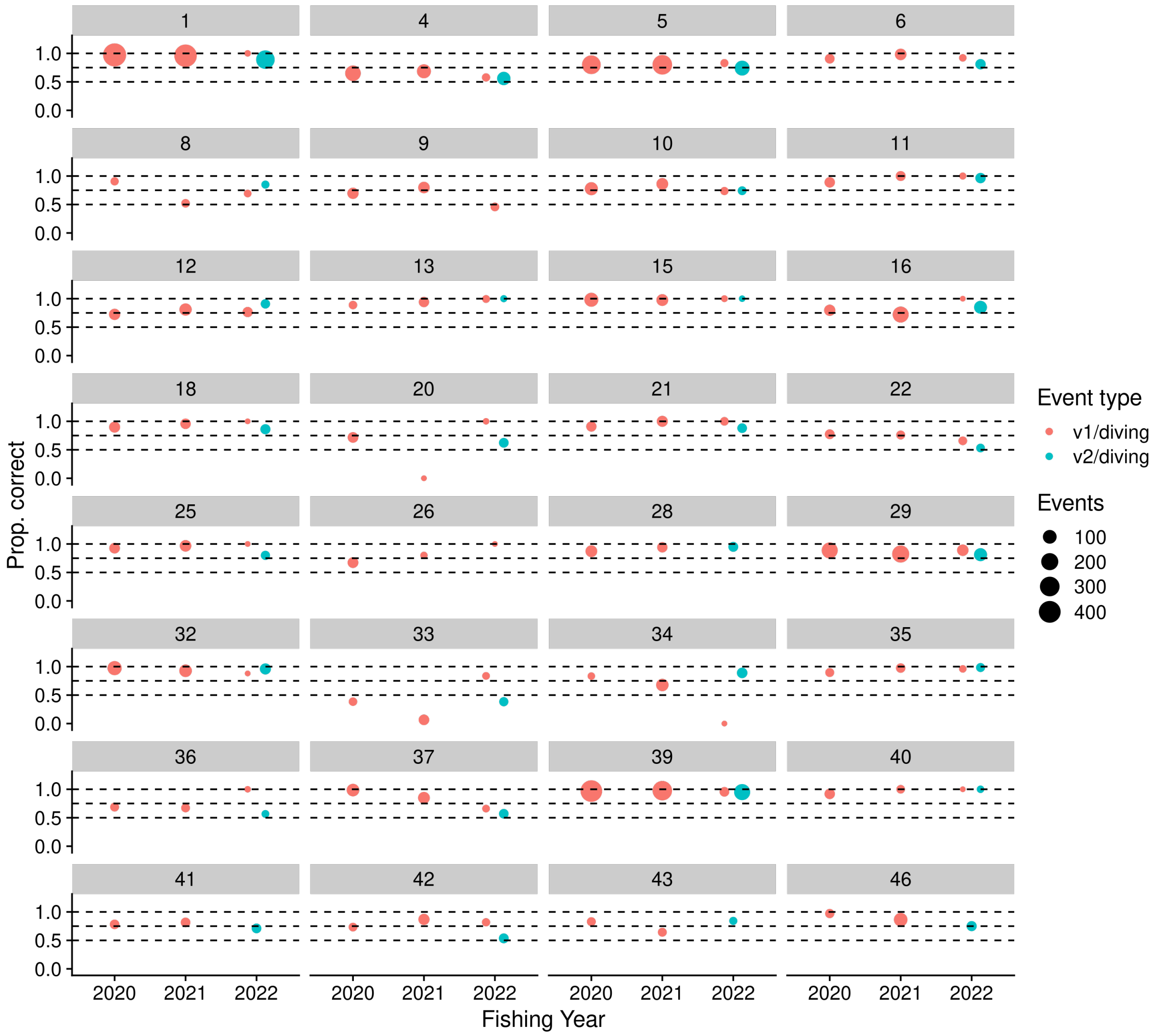

Figure 8: Proportion of correctly-reported statistical areas by client (anonymised, number at the top) and fishing year. Data are for fishing events in the fishing year when the catch bag locations were reported. Circle sizes indicate the relative number of fishing events that a client contributed to the overall dataset.

3.3 Importance of potential reporting changes

The subsets of the CPUE datasets were used to assess the influence of potential reporting changes on CPUE indices. These subsets for the CPUE datasets were increasingly restrictive in that the proportion of records retained became smaller (Tables 4 to 6). In spite of this increasing restrictiveness, the resulting CPUE analyses showed only minor differences across QMAs (Figure 9). There were some changes in CPUE in PAU 5B, but the only marked changes within any of the QMAs were from excluding statistical areas for PAU 7, the subareas D'Urville Island and Northern Faces.

Table 4: Percentage of dive events retained for pāua catch-per-unit-effort analysis for which any catch bag location matched the inferred statistical area. Data are shown by quota management area (QMA) and fishing year.

QMA	2019–2020	2020–2021	2020–2022
2	0.51	0.62	0.56
3	0.76	0.77	0.73
4	0.71	0.56	0.56
5A	0.85	0.84	0.91
5B	0.87	0.78	0.74
5D	0.80	0.82	0.63
7	0.80	0.83	0.84

Table 5: Percentage of dive events retained for pāua catch-per-unit-effort analysis for which all catch bag location matched the inferred statistical area. Data are shown by quota management area (QMA) and fishing year.

QMA	2019–20	2020–21	2021–22
2	0.46	0.57	0.49
3	0.61	0.61	0.63
4	0.62	0.47	0.50
5A	0.70	0.69	0.77
5B	0.71	0.62	0.52
5D	0.67	0.67	0.55
7	0.72	0.76	0.77

Table 6: Fishing effort subsets, constructed by progressively excluding an increasing number of clients from the pāua catch-per-unit-effort datasets. Clients were excluded as a function of the probability (%, column header) that they changed their reporting.

QMA	Original	95%		75%		50%		5%	
	no. of clients	Prop.	No. of clients	Prop.	No. of clients	Prop.	No. of clients	Prop.	No. of clients
2	10	0.96	9	0.83	8	0.77	7	0.53	5
3	10	1	10	1	10	0.87	9	0.33	4
4	11	0.68	10	0.68	10	0.65	9	0.35	4
5A	8	0.89	7	0.89	7	0.89	7	0.47	4
5B	12	0.91	11	0.91	11	0.85	10	0.47	5
5D	9	0.93	8	0.85	7	0.85	7	0.27	4
7	8	1	8	1	8	0.84	7	0.54	5

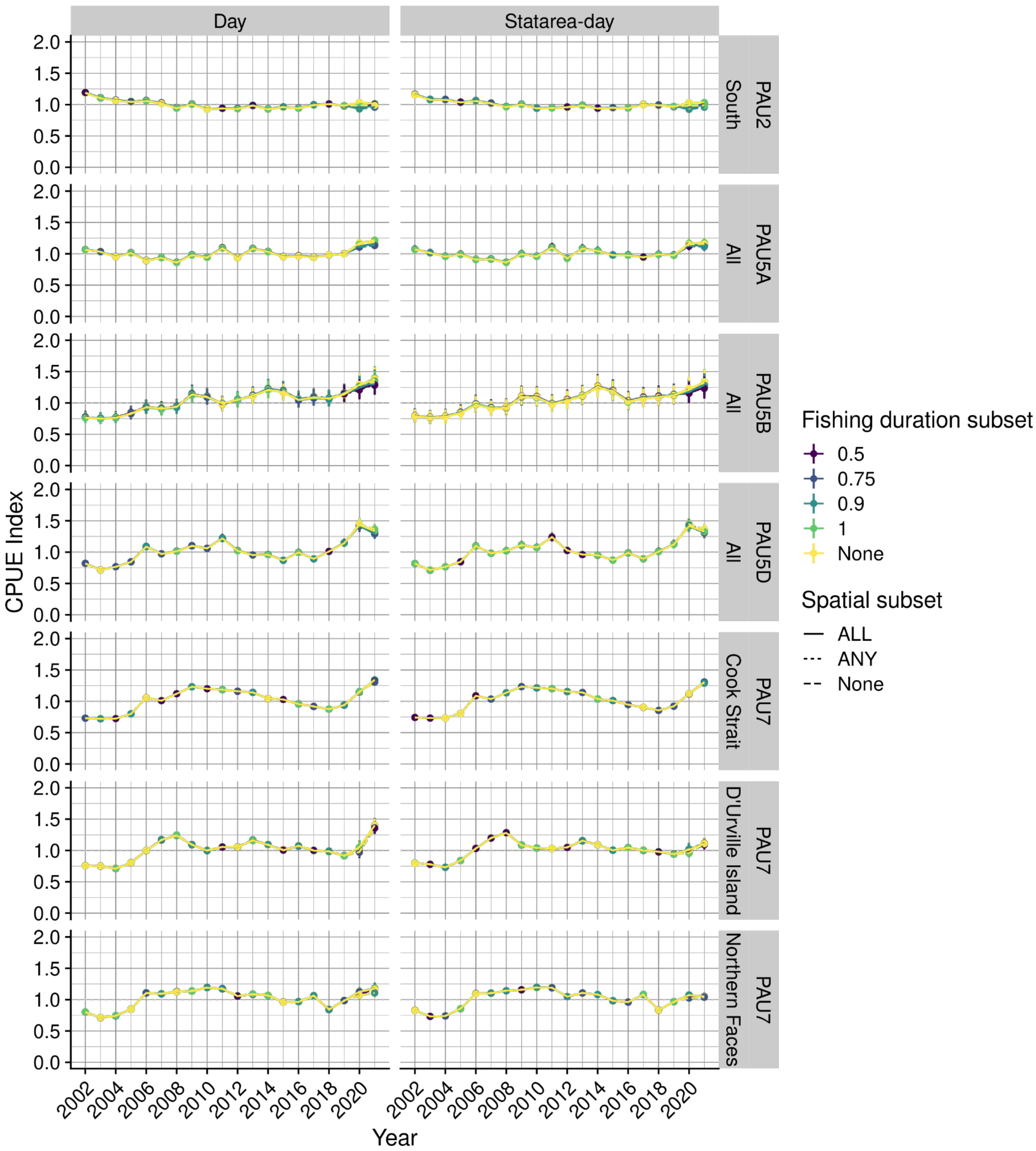

Figure 9: Estimated pāua catch-per-unit effort (CPUE) indices based on different fishing effort subsets by quota management area (QMA). Subsets for fishing duration were constructed by progressively excluding an increasing number of clients as a function of the probability P that they changed their reporting. Spatial subsets were constructed by retaining dive events for which any or all catch bag locations matched the inferred statistical areas from GPS (Global Positioning System) coordinates reported in statutory data. For each QMA, CPUE indices were estimated with generalised linear mixed models.

4. DISCUSSION

The present analysis aimed to assess whether recent changes in reporting of pāua catch and effort data notably influenced the ability to use CPUE as an index of abundance across pāua QMAs. The findings showed that there was evidence that the reported fishing duration had changed, particularly within reporting areas of PAU 5. Nevertheless, the resulting CPUE appeared not to be impacted, as evidenced by relatively unaffected trends in CPUE from a range of different data subsets.

Although there were changes in effort in PAU 5, it is likely that these changes are not related to reporting changes, but other factors. For example, they may be caused by the increasing proportion of pāua that are targeted for the live market in this QMA. This aspect means that fishers are fishing to order, targeting a fixed number of pāua above a certain size. The timing of this change pre-dates the change from PCELR forms to ERS; however, much of the shift from canned pāua to live pāua fishing occurred over the same period. For this reason, it is likely that this shift caused changes in the fishery.

Regardless of the underlying reasons, the changes in effort did not appear to affect the CPUE in aggregate. Nevertheless, it it recommended to omit these records in future CPUE analyses of the area to ensure that the live pāua and canned pāua fisheries can be separately represented in stock assessments, and CPUE trends can be constructed for each.

Spatial reporting appeared consistent between recent v2 records and earlier v1 records. This finding indicates that both types of records may have similar error rates for reporting fine-scale statistical areas. These errors were also detected when using data from pāua data loggers, suggesting that similar error rates may have been prevalent throughout PCELR reports (Neubauer et al. 2014). This findings suggests that initial concerns and exclusion of statistical areas from recent standardisations (P. Neubauer unpubl. data) may have been largely unfounded.

In contrast, the comparative CPUE analysis conducted here highlighted that the omission of fine-scale statistical areas may mask hyper-stability when the fishery shifts to remaining productive areas in declining fisheries. This aspect appeared to be the case in the D'Urville Island and Northern Faces subareas of PAU 7. In both of these subareas, the commercial fisheries have markedly declined, so that only few remaining areas are currently being fished. Although CPUE indices in these subareas indicate an upward trajectory, when accounting for statistical area in the standardisation, the CPUE trend shifts to a largely stationary index.

Overall, this analysis suggests that reporting changes have a limited impact on CPUE. Nevertheless, caution is warranted given other, possibly more substantial changes in pāua fisheries, which may affect CPUE in yet unknown ways.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Abraham, E.R.; Neubauer, P. (2015). Relationship between small-scale catch-per-unit-effort and abundance in New Zealand abalone (pāua, *Haliotis iris*) fisheries. *PeerJ Preprints 3*: e1733. https://doi.org/10.7287/peerj.preprints.1388v2

McCowan, T.A.; Neubauer, P. (2018). Paua biomass estimates and population monitoring in areas affected by the November 2016 Kaikoura earthquake. *New Zealand Fisheries Assessment Report 2018/54*. 24 p.

Neubauer, P. (2017). Spatial bias in pāua *Haliotis iris* catch-per-unit-effort. *New Zealand Fisheries Assessment Report 2017/57*. 33 p.

Neubauer, P. (2019). Development and evaluation of management procedures in pāua quota management areas 5A, 5B and 5D. *New Zealand Fisheries Assessment Report 2019/37*. 63 p.

Neubauer, P. (2021). Pāua management procedure: review of current state and prospects for wider application. *New Zealand Fisheries Assessment Report 2021/03*. 13 p.

Neubauer, P.; Abraham, E.; Knox, C.; Richard, Y. (2014). Assessing the performance of pāua (*Haliotis iris*) fisheries using GPS logger data. Final research report for Ministry for Primary Industries project PAU2011-03 (Unpublished report held by Fisheries New Zealand, Wellington). 49 p.

Prince, J. (2005). Combating the tyranny of scale for haliotids: Micro-management for microstocks. *Bulletin of Marine Science 76 (2)*: 557–578.

Prince, J.; Hilborn, R. (1998). Concentration profiles and invertebrate fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences 125*: 187–196.

APPENDIX A: SUPPLEMENT

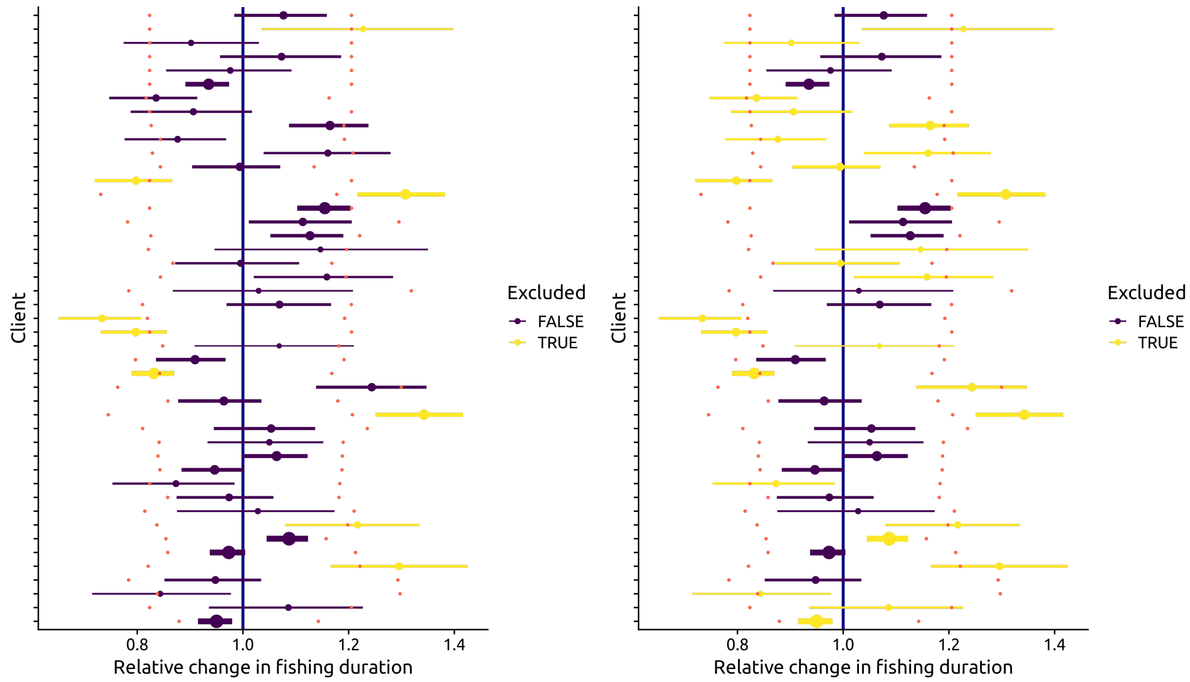

Figure A-1: Exclusion of clients from pāua catch-per-unit-effort datasets based on a probability of ≥50% (left) and ≥5% (right) that the estimated relative change in mean fishing duration by day is greater than expected from year-on-year changes in data reported on Pāua Catch Effort Landing Return forms.