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Tini a Tangaroa

Pāua management procedure: review of current state and prospects for wider application

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Management procedures (MPs) are increasingly being used in fisheries management to link resource assessments to a set of rules that formalise the setting of allowable catches. In a New Zealand context, MPs have been considered for New Zealand abalone (pāua, *Haliotis iris*) fisheries, which are managed across different quota management areas (QMAs). For example, in all QMAs of PAU 5 (southern South Island), stakeholders agreed to a set of voluntary (non-mandatory) MPs since 2016, to manage the fisheries within the current Total Allowable Commercial Catch set by Fisheries New Zealand. The MPs have been used to set shelving levels at annual general meetings based on offset-year catch-per-unit-effort (CPUE), with discussion about trends supplementing model estimates. Corresponding decisions have been based on informal synthesis of stakeholder views and trends from data. For example, in 2018, the control rule suggested that catches be increased from 35% shelving levels due to an increase in CPUE in PAU 5D. The increase was not applied after deliberations, during which divers attributed the increased CPUE to unprecedented dive conditions that could not be standardised appropriately by the CPUE model. The overall process, therefore, retained a level of empiricism despite the introduction of the formal management framework.

Current changes in the fishery in the form of increased landing of live pāua with limited or no length-frequency data (or labelling of landings as live or whole frozen), together with concurrent changes from paper-based reporting to electronic reporting, present a difficult challenge for the continuation of MPs in their current form. Fishing for the live and whole-frozen market led to changes in selectivity, which likely affect both CPUE and the size of fished pāua. These changes disrupted initial plans to disregard reported CPUE and use predicted CPUE from the assessment, determined by length-frequency data, to apply the MPs and counter the anticipated disruptions to the CPUE time series from the change to electronic reporting. Given the lack of data on the live-trade pāua, this fishery cannot currently be incorporated in the assessment model. The average size of fished pāua is likely to be underestimated, because only pāua not destined for the live and whole-frozen trade are measured as part of the commercial catch-sampling length-frequency programme. Current changes led to MPs being shelved for decisions regarding the 2020–21 fishing year.

Further work is required to understand changes from electronic reporting, particularly regarding reported effort, to ensure reliable standardisation. In addition, robust data collection systems need to be established to capture data for pāua destined for the live and whole-frozen trade. This data collection is necessary to avoid that this fishery component biases information of the overall pāua catch, and to determine its effects on pāua populations. Combined with this improved data collection, it is also suggested that scales of assessment and management procedures are united with fine-scale management initiatives, such as catch-spreading and local fishing limits. This latter approach will ensure that controls are internally consistent across spatial scales of management.

1. INTRODUCTION

Fisheries management increasingly uses management procedures (MPs) for both well-informed and information-deficient stocks (Butterworth 2007, Dowling et al. 2015). The MPs are generally aimed at balancing conflicting objectives of high yield, stable yield, and low probabilities of resource collapse in a formal way (Butterworth 2007). To identify a suitable MP, a set of candidate MPs are usually simulation-tested to identify a set of rules (collectively called a control rule) that produces the "best" possible outcomes under a range of uncertainties (Butterworth 2007). Once identified, a suitable MP is agreed on by stakeholders prior to its implementation and application.

For New Zealand pāua (*Haliotis iris*), MPs have been developed based on harvest control rules determined by catch-per-unit-effort (CPUE) since 2015; they have been applied since 2016 (Neubauer 2019). The process was a first attempt at introducing formal MPs based on control rules in pāua fisheries in New Zealand. It was also meant to function as a test case for the application of control rules in other quota management areas (QMAs) throughout New Zealand.

At their annual general meeting (AGM) in 2016, stakeholders of all PAU 5 QMAs agreed to a set of voluntary (non-mandatory) control rules (Table 1, Figure 1) that specify voluntary shelving levels, within the current Total Allowable Commercial Catch (TACC) (Neubauer 2019). The control rules were generally the same for all PAU 5 QMAs, with identical CPUE reference points but different catch levels. This approach reflected the notion that all PAU 5 fisheries ought to be able to operate at similar catch rates. The catch-rate reference points correspond to three levels with QMA-specific settings for total commercial catch within each QMA.

Table 1: Control rule settings derived from consultation with stakeholders for management procedures for pāua fisheries in quota management areas (QMAs) of PAU 5. Parameters correspond with catch-per-unit-effort (CPUE) limits (C1 to C5), catch limits (L1 to L3), and Total Allowable Commercial Catch increase (P1), when CPUE is estimated to be above the highest catch plateau (defined between C4 and C5).

QMA	Parameter setting								
	C1	C2	C3	C4	C5	L1 (t)	L2 (t)	L3 (t)	P1
5A South	16	25	32	42	48	36	48	61	90
5A North	16	25	32	42	48	46	58	70	90
5B	16	25	32	42	48	80	90	100	90
5D	16	27	32	42	48	62	72	89	90

Over the course of two successive projects (PAU2015-05 and PAU2018-04, initially funded by Ministry for Primary Industries, then Fisheries New Zealand), these management procedures were simulation-tested using the stock assessment models as operating models, before subsequently applying them for a period of four years (see details in Neubauer 2019). Each year, reports were prepared for the AGM of the pāua industry group PauaMAC5, including offset-year standardised CPUE indices for each area and the corresponding catch (see example of this decision graph in Figure 2). Decisions about shelving levels were agreed at each AGM for all areas based on the MPs and also on diver interpretation of standardised CPUE. Nevertheless, the application of the MPs based on CPUE as a performance measure became increasingly difficult over time, due to a number of changes in the fishery that decouple CPUE from abundance trends. These changes are also considered to make assessment and statutory management of the fishery increasingly difficult.

The present report provides a brief review of the application of the MPs in PAU 5 over the past four years, and of the factors that are impeding the application of the control rules in their current form. The review includes suggestions about data collection and other approaches that may address some of the current challenges for the assessment and management framework.

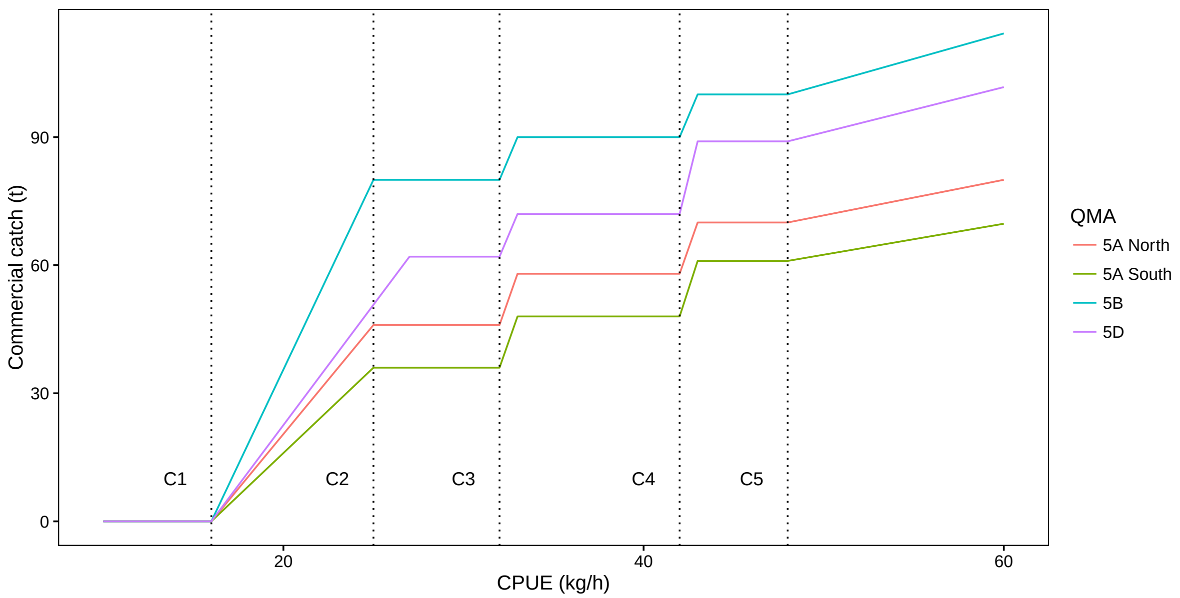


Figure 1: Illustration of control rules proposed for PAU 5, as agreed on by stakeholders of Quota Management Areas (QMAs) of PAU 5. Control rules have three catch levels, delimited by agreed catch-per-unit-effort (CPUE) limit reference points (C1 to C5). For PAU 5A and PAU 5B, the middle level is near commercial take at inception (2016); for PAU 5D, catch and catch-rates corresponded with the lower plateau.

2. APPLICATION OF MANAGEMENT PROCEDURES IN PAU 5

2.1 Stakeholder engagement and participation

To initially establish the control rules of the MPs, a series of meetings was held with fishers and quota owners in PAU 5. One of the aims of the meetings was to quantify objectives and identify control rules that are acceptable to stakeholders. These meetings involved illustrating potential control rules and their effects using a R-shiny web application (Chang et al. 2015). Management objectives were stated qualitatively as low risk and high biomass objectives. Rules were initially devised largely empirically by stakeholders with input from Fisheries New Zealand and project scientists on the basis of experience of CPUE and catch levels. The devised rules were hypothesised to lead to desirable outcomes (i.e., high biomass and low risk in the context of the management objectives). Subsequent simulation-testing confirmed these empirical rules as containing low risk (in the interpretation of the Fisheries New Zealand Harvest Strategy Standard; Ministry of Fisheries 2008).

Stakeholder input was critical to interpret CPUE trends and reach decisions when applying rules at AGMs, especially in view of a number of changes in the fishery. An example is the application of the MP in PAU 5D in 2019: standardised (offset-year) CPUE had increased markedly, to levels near the highest observed CPUE for the period of Paua Catch Effort Landing Return (PCELR) forms (from 2002 to 2019) (Figure 3). The CPUE had previously been relatively low, and a 35% shelving had been agreed on the basis of the first application of the control rule in 2016, for which CPUE had declined below the lowest CPUE plateau. The unexpected increase in CPUE in 2019 would have meant a decrease in the shelving to 20% of the quota. Diver feedback at the AGM, however, suggested that there had been little change, and that the high CPUE was due to unprecedented dive conditions along the PAU 5D coastline. It appeared that the CPUE standardisation model, which standardises on the basis of conditions observed over the entire time series, could not adequately control for the unprecedented dive conditions. Combined with the importance of empirical feedback for control rules, this event also suggested that CPUE alone may be too volatile and affected by externalities to be a long-term performance measure.

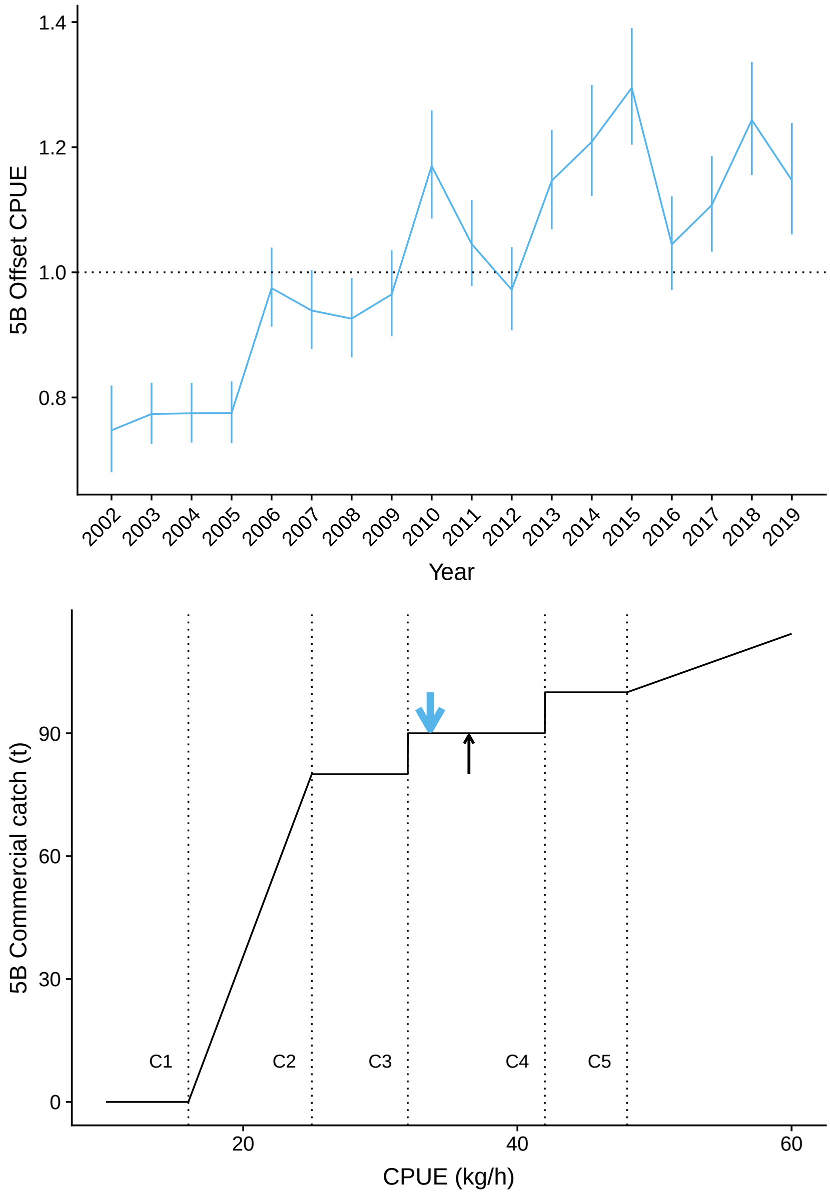


Figure 2: Update (2019) of the offset-year catch-per-unit-effort (CPUE) and management procedure for pāua quota management area PAU 5B. Top panel: Mean trend of offset-year CPUE and statistical uncertainty (vertical bars), with long-term average (geometric mean, dotted line at 1.0). Bottom panel: Control rule for PAU 5B, with offset-year CPUE for 2019 (blue bold arrow) and for 2018 (narrow black arrow).

2.2 Applying the control rules

Overall, there was strong support from stakeholders to develop and apply the control rules as a tool to guide shelving decisions and replace anecdotal discussion and empirical decisions that can be easily disputed with a rule-based procedure. Control rules were also welcomed as an external control process that ensures the sustainability of the fishery with a high probability. Given these potential benefits, decisions about shelving levels based on the control rules were generally reached without disagreements and on a consensus basis.

For example, for PAU 5D, simulation testing for the proposed control rule suggested steady rebuilding as the most likely outcome; however, there was only a small chance that biomass levels would reach 40% of spawning stock biomass SSB_0 in the medium term, despite shelving of 30% of the TACC at that time (Figure 4). Under the proposed control rule, shelving levels would likely be reduced relatively quickly,

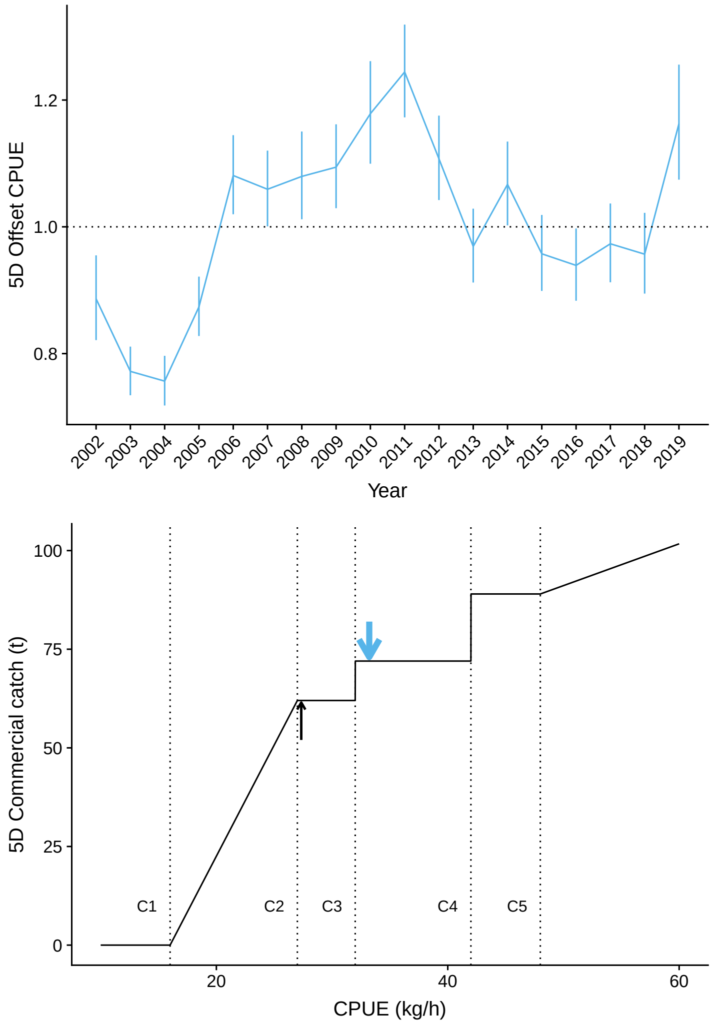


Figure 3: Update (2019) of the offset-year catch-per-unit-effort (CPUE) and management procedure for pāua quota management area PAU 5D. Top panel: Mean trend of offset-year CPUE and statistical uncertainty (vertical bars), with long-term average (geometric mean, dotted line at 1.0). Bottom panel: Control rule for PAU 5D, with offset-year CPUE for 2019 (blue bold arrow) and for 2018 (narrow black arrow).

and agreement to maintain current shelving levels would support faster rebuilding. For these reasons, the evaluation of the MPs suggested a difficult trade-off in PAU 5D between continued catch and rapid rebuilding to target levels.

Application of the control rule started with a decline in CPUE in 2016 compared with levels in 2015 (Figure 5). This decline led to an immediate decision to increase shelving to 35%. A direct application of the rule, with CPUE only just below the plateau level, would have led to a 1% increase in shelving; however, alternative scenarios that were tested for PAU 5D suggested faster rebuilding with higher shelving levels (Neubauer 2019). On this basis, stakeholders decided to increase the shelving to 35%, which has subsequently stayed in place, despite increased CPUE. In other areas (PAU 5B, PAU 5A North and South; Figure 5), rules were discussed in view of changes in minimum harvest size (for example in PAU 5B) and in spatial fishing patterns (such as in PAU 5A). The rules were applied without adjustments until 2020, at which time it was considered that CPUE by itself was not useful to determine the control rule.

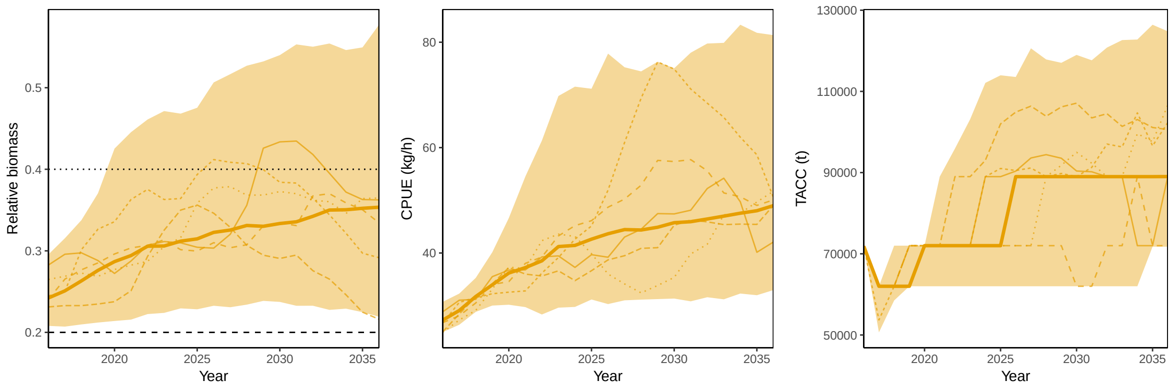


Figure 4: Time series of simulated relative biomass (in proportion of virgin spawning stock biomass SSB_0), observed catch-per-unit-effort (CPUE; kg/h) and total allowable commercial catch (TACC; t) for base-case simulations in pāua quota management sub-area PAU 5D.

2.3 Use of CPUE as performance measure

Concerns about using only CPUE as a performance indicator were initially raised by meetings of the Fisheries New Zealand Shellfish Working Group, which discussed initial research for management procedures and their evaluation. Although the relationship between CPUE and abundance is globally regarded as tenuous for abalone (see Neubauer 2017, and citations therein), the present setup was selected because i) it was consistent with CPUE determining pāua stock assessments, and ii) it was efficient to implement and evaluate, based on experience with New Zealand rock lobster (*Jasus edwardsii*) fisheries (e.g., Starr et al. 1997).

Change in minimum harvest size and internal controls In PAU 5B, there was evidence that successive increases in minimum harvest size (MHS) impacted CPUE. Discussions about applying control rules in this QMA highlighted the limit of using only CPUE for a fishery that is dynamic in terms of management controls (for example, there was a decrease in CPUE in PAU 5B in 2016, Figure 5). Changes in the MHS are likely to impact the proportion of biomass that is available to the fishery; because these changes are heterogeneous in space, impacts on CPUE will depend on spatial fishing patterns. In addition, in PAU 5A, fishing limits for sub-regions are agreed annually and would be expected to impact CPUE if divers fish areas that they would otherwise avoid. Although these types of impacts on CPUE may be minor, they make the application of MPs less direct and can potentially undermine their value over time.

Change to electronic reporting Electronic reporting introduced an expected change in reporting patterns, namely by reducing the average reported effort (time-in-water). This change affected all QMAs to some extent and led to markedly increased CPUE in 2020, both for the fishing year (Figures 6, 7, and 8) and for offset-year indices used to determine the control rules (Figure 5). Converting to catch-per-day removed this pattern in the CPUE for fishing year (Figures 6, 7, and 8). Similarly, by assuming a three-year average time-in-water for 2020, reduced CPUE indices were obtained for the 2020 offset-year (Figure 9). Nevertheless, this adjustment led to a marked decrease in CPUE for PAU 5A South, which exceeded any change that had been observed since 2002. The current changes to observed CPUE were considered dubious, so that the control rules for 2020 were abandoned in favour of *status quo* management for the subsequent 2020–21 season. Further investigation into the effect of electronic reporting on fishery reporting and resultant CPUE is required.

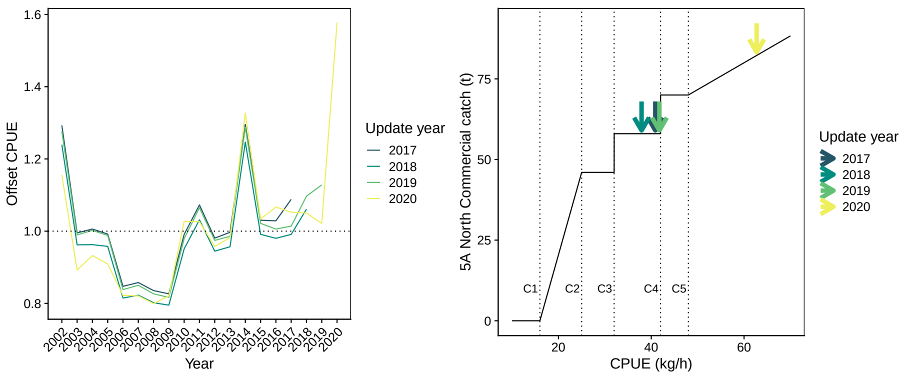
Increasing harvest sizes for live and whole-frozen markets In addition to documented changes in MHS, the increasing but undocumented change in harvest sizes led to additional difficulties in using

CPUE for control rules. In an attempt to anticipate these changes, it was proposed to replace standardised CPUE with predicted CPUE from the stock assessment: MPs could still be applied even if changes in CPUE from electronic reporting were too substantial to use CPUE on its own. This approach would rely on the assessment model to smooth the trends (and potentially, to operate without CPUE for one or two years). Nevertheless, there are currently considerable numbers of pāua exported for live or whole-frozen (LWF) trade, especially from PAU 5 QMAs. Some of the fishing activity for this trade is targeted towards large-sized pāua, effectively constituting a novel type of fishery, with its own selectivity and CPUE. The lack of data collection for this fishery up to 2020, however, means that there is currently no information about the amount of pāua for the LWF trade by QMA. Notable reductions in average size of shell measurements of pāua intended for the canning market (J. Cooper, unpublished data) suggest that a marked proportion of large-sized pāua has become part of the LWF trade.

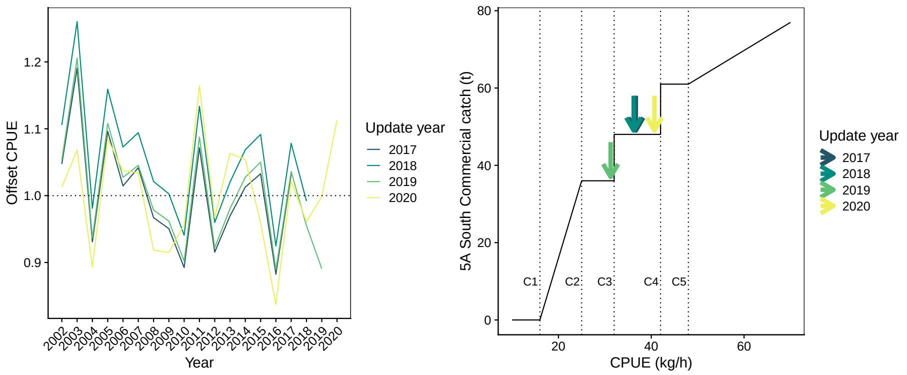
To account for these changes in target fisheries, the assessment model will need to be adjusted. These adjustments are needed for the LWF fishery and also for its impact on the canned fishery, which formed the basis of the assessment model. This adjustment would require adequate data collection from the LWF fishery:

- An indicator of what type of diving was performed on catch effort returns. This information could be indicated on the electronic reported form, especially if only large-sized pāua were targeted (e.g., using categories such as ”large LWF only”, ”mixed canned and LWF”, and ”no live targeting”).
- Some form of length or weight measurements for adequately sampled (or censused) catch from the LWF landings.

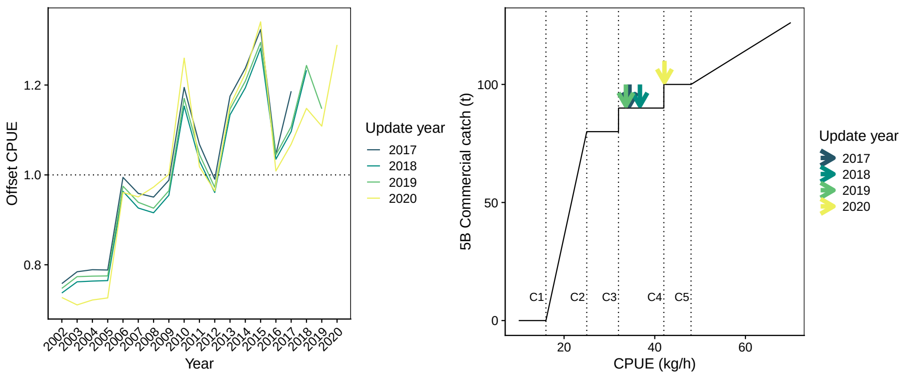
(a) PAU5 A North



(b) PAU5 A South



(c) PAU 5B



(d) PAU 5D

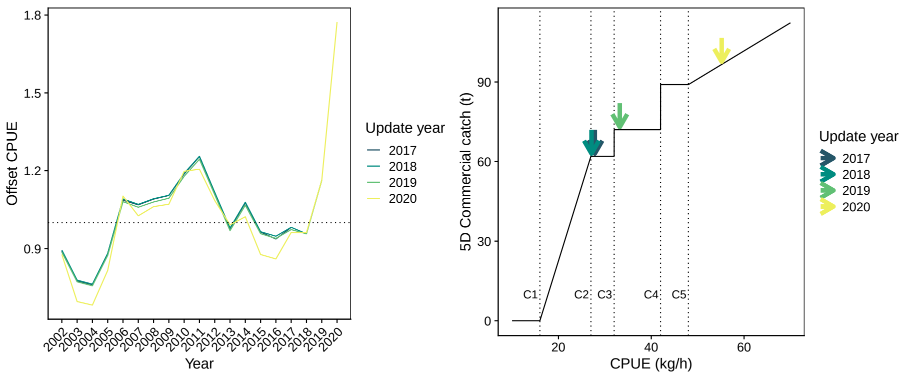


Figure 5: Updates (since 2016) of the offset-year catch-per-unit-effort (CPUE) and management procedure for pāua quota management area (a) PAU 5A North, (b) PAU 5A South, (c) PAU 5B, and (d) PAU 5D. Mean trend of offset-year CPUE, with long-term average (geometric mean, dotted line at 1.0) (left panels), and control rules for all updates since 2016 (right panels).

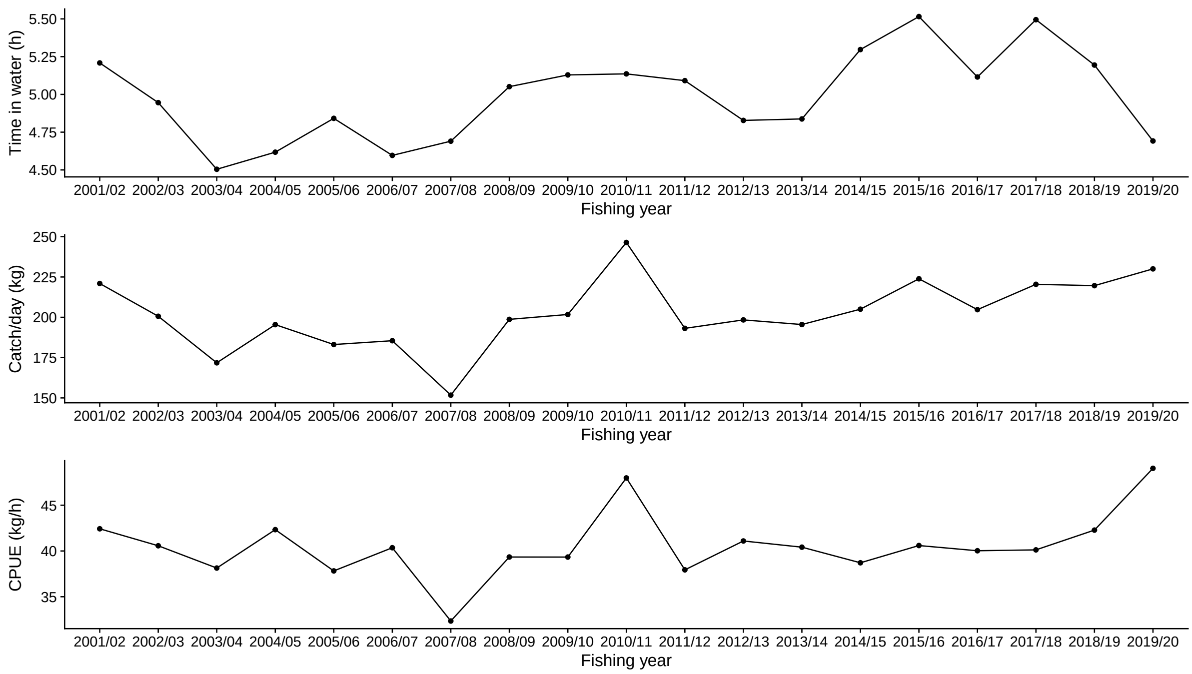


Figure 6: Mean estimated time in water, catch per day and catch per unit effort (CPUE) by fishing year for pāua fishing in quota management area PAU 5A.

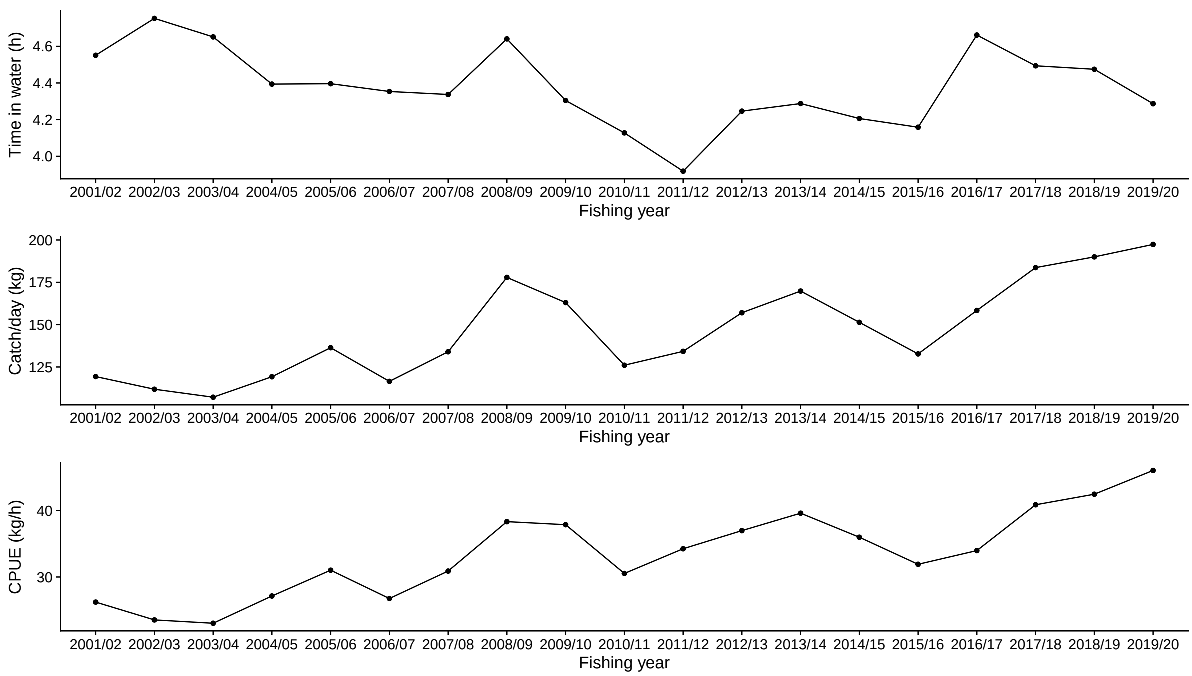


Figure 7: Mean estimated time in water, catch per day and catch per unit effort (CPUE) by fishing year for pāua fishing in quota management area PAU 5B.

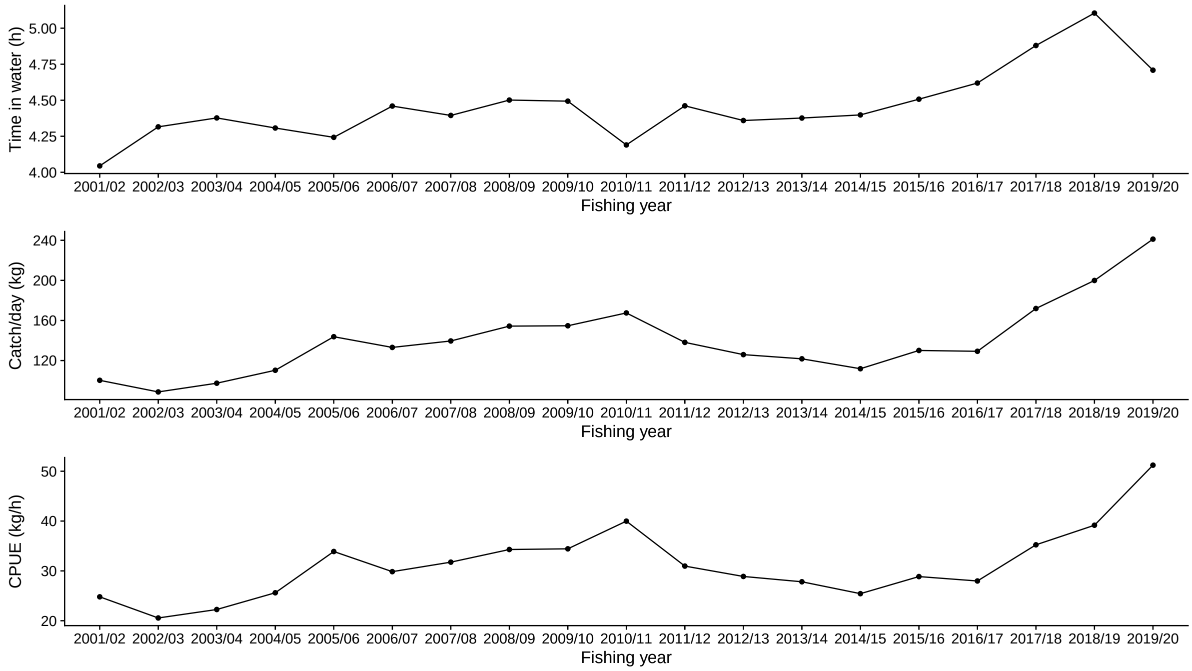
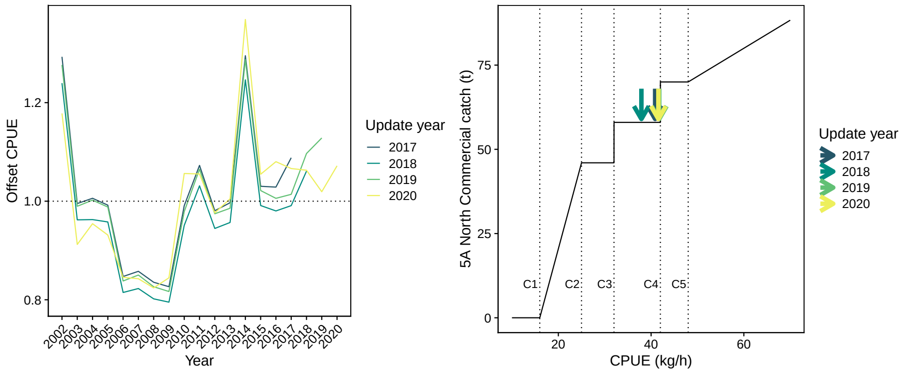
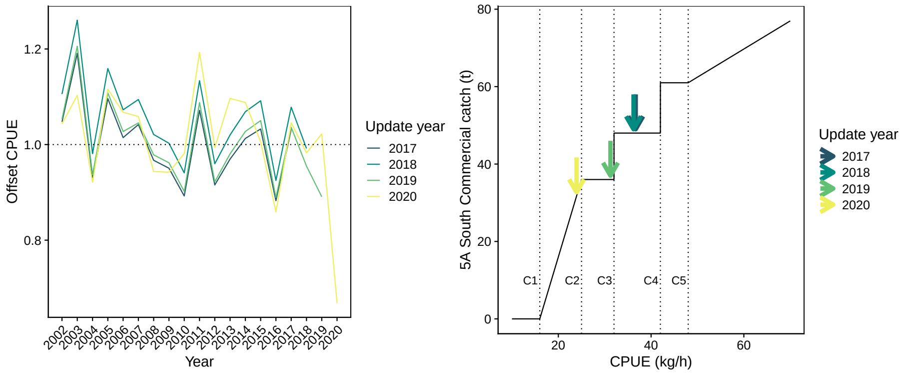


Figure 8: Mean estimated time in water, catch per day and catch per unit effort (CPUE) by fishing year for pāua fishing in quota management area PAU 5D.

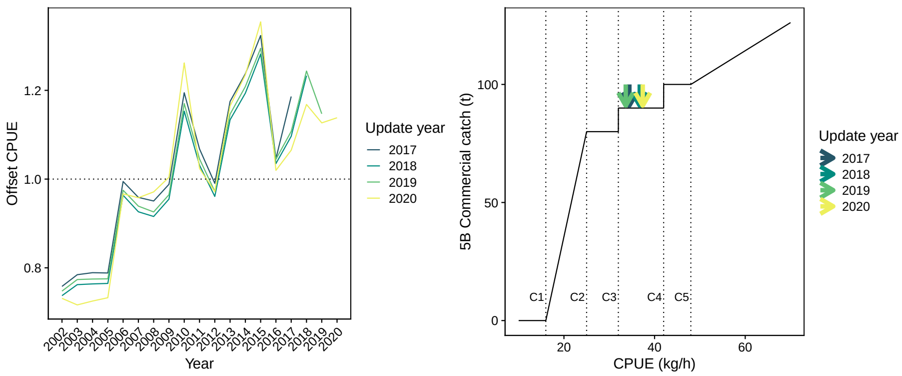
(a) PAU5 A North



(b) PAU5 A South



(c) PAU 5B



(d) PAU 5D

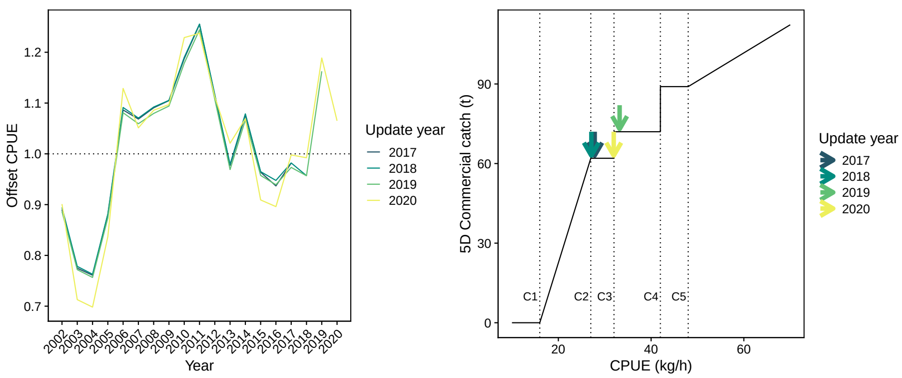


Figure 9: Updates (since 2016) of the offset-year catch-per-unit-effort (CPUE) and management procedure for pāua quota management area (a) PAU 5A North, (b) PAU 5A South, (c) PAU 5B, and (d) PAU 5D. Mean trend of offset-year CPUE, with long-term average (geometric mean, dotted line at 1.0) (left panels), and control rules for all updates since 2016 (right panels). The CPUE in 2020 is based on average effort from the period between 2016 to 2019.

3. DISCUSSION

3.1 Considerations for continuing management procedures in PAU 5

In view of the limitations of using CPUE as a sole indicator of abundance, and the difficulties associated with the use of existing assessment models for PAU 5 areas with considerable catch for LWF trade, the future use of MPs for this QMA is uncertain. The limitations of the MPs will also be evident in future stock assessments, impacting on the management of the fishery by industry via MPs, and also affect statutory management based on stock assessments.

For both MPs and statutory management to continue in their previous forms, the following requirements need to be addressed:

- Further investigation of changes resulting from electronic reporting. The investigation would focus on obtaining comparable CPUE for use in assessments and MPs. Alternatively, it may be necessary to delay assessments until sufficient data are available for a new CPUE time series.
- Urgent start of data collection for the LWF fishery, including CPUE and catch-composition (length-frequency) reporting.
- Inclusion of the LWF fishery in the stock assessment, including use of alternative methods of catch-composition reporting (e.g., total length over basal length).

3.2 Considerations for management procedures in other QMAs

Across all QMAs, a common theme has been the increase of fine-scale management within industry, such as the use of dashboards to monitor and restrict local catch and CPUE, as well as catch spreading at the pāua statistical area level. These measures can be viewed as management procedures that operate on smaller scales within the statutory management (with MPs in PAU 5 operating at an intermediate level, within TACC limits, but at a larger scale than catch-spreading limits in PAU 5A). Nevertheless, there is a risk that over time, low-level management procedures become inconsistent with high-level MPs. For example, small-scale measures have the potential to decouple CPUE from biomass at large scales, thereby affecting QMA-wide MPs, and potentially leading to conflicting signals.

Small-scale management initiatives, such as catch limits and catch spreading, can be considered as empirical control rules, similar to rules used for abalone across fishery authorities in Australia. Nevertheless, the process for establishing local catch in a given year in Australian fisheries is usually based on formalised indicators, such as small-scale CPUE and other indicators, including length frequencies or recruitment surveys. These indicators are then combined according to predefined formulae (i.e., the draft Victoria Abalone Harvest Strategy (unpublished); Victorian Fisheries Authority, Australia). Importantly, in these approaches, management is performed at small scales and integrated to a large-scale TACC, thereby assuring consistency across scales. In addition, by performing the assessment at small scales, there is less potential for bias in large-scale indicators from small-scale fishing trends (Neubauer 2017).

Formalised empirical control rules could be considered for areas where model-based assessments and management procedure evaluations are not an option: either because there are no (reliable) assessments or formal assessments are not feasible, such as for the earthquake-affected area in PAU 3. Although these models cannot be tested based on a stock assessment, simulation models such as spatial length-based simulations can be used to assess their general performance and trade-offs of proposed rules given assumed population characteristics. These operating models could in time be refined to include increasing amounts of data, yet provide a valuable starting point in the near term.

In areas with adequate data collection, it is recommended that assessments and MPs are developed at fine spatial scales. This approach reflects an effort to achieve data- and model-driven management at small scales, while ensuring an integration with large-scale statutory management. This type of development could be based on a spatial assessment model (Neubauer 2020), with refined spatial resolution to pāua statistical-area scale, and formalisation of small-scale control rules at the same scale to be tested with the assessment model. A potential disadvantage of this approach is that assessments would need to rely on fine-scale data, which have only been available since 2002.

4. ACKNOWLEDGMENTS

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