



Fisheries New Zealand

Tini a Tangaroa

Monitoring of recreational harvest of red rock lobster *Jasus edwardsii* in CRA 2

New Zealand Fisheries Assessment Report 2024/52

J.Q. Maggs, O.E. Evans, R. Taylor, H. Armiger, C.
Marsh, B.W. Hartill

ISSN 1179-5352 (online)

ISBN 978-1-991308-41-2 (online)

August 2024



Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

This document is published by Fisheries New Zealand, a business unit of the Ministry for Primary Industries (MPI). The information in this publication is not government policy. While every effort has been made to ensure the information is accurate, the Ministry for Primary Industries does not accept any responsibility or liability for error of fact, omission, interpretation, or opinion that may be present, nor for the consequence of any decisions based on this information. Any view or opinion expressed does not necessarily represent the view of Fisheries New Zealand or the Ministry for Primary Industries.

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
<http://www.mpi.govt.nz/news-and-resources/publications>
<http://fs.fish.govt.nz> go to Document library/Research reports

© Crown Copyright – Fisheries New Zealand

Please cite this report as:

Maggs, J.Q.; Evans, O.E.; Taylor, R.; Armiger, H; Marsh, C; Hartill B.W. (2024). Monitoring of recreational harvest of red rock lobster *Jasus edwardsii* in CRA 2. *New Zealand Fisheries Assessment Report 2024/52*. 41 p.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1. INTRODUCTION	2
2. METHODS	3
2.1 Study area	3
2.2 Data collection	4
2.3 Data analysis	5
3. RESULTS	9
3.1 Sampling activity	9
3.2 Bag frequencies	12
3.3 Tail width frequencies	15
3.4 Tail width-weight conversion	17
3.5 Harvest estimation	17
4. DISCUSSION	23
5. POTENTIAL RESEARCH	25
6. ACKNOWLEDGEMENTS	25
7. REFERENCES	25
APPENDIX 1	27

PLAIN LANGUAGE SUMMARY

Red rock lobster support one of New Zealand's most valuable fisheries and the species is important in the commercial, recreational, and customary sectors. The National Panel Survey (NPS) estimates the recreational harvest but is only conducted every 5–6 years with little known about the harvest during intervening years. To track the harvest annually, a boat ramp creel monitoring programme was established in northeastern New Zealand (CRA 2) to operate complementarily with the NPS. The scaled harvest estimated from the creel monitoring programme was in close agreement with the NPS during 2017–18 and 2022–23, remaining well below the recreational allowance of 34 tonnes. There was an initial increase in the harvest from 2017–18 to 2019–20, followed by a 45% decline from 2021–22 to 2022–23. The mean weight of individual lobster fluctuated between 0.689 and 0.929 kg over the study period.

EXECUTIVE SUMMARY

Maggs, J.Q.¹; Evans, O.E.¹; Taylor, R.¹; Armiger, H.¹; Marsh, C.¹; Hartill, B.W.^{1,2} (2024).
Monitoring of recreational harvest of red rock lobster *Jasus edwardsii* in CRA 2.

New Zealand Fisheries Assessment Report 2024/52. 41 p.

Red rock lobster support one of New Zealand's most valuable fisheries and is important in the commercial, recreational, and customary sectors. An assessment of the CRA 2 stock in 2017 suggested that the stock was in an overfished state, leading to a substantial reduction of the Total Allowable Catch from April 2018. At the same time, the recreational allowance was reduced from 140 t to 34 t. The daily bag limit was later reduced from six to three lobster per fisher on 1 July 2020. A subsequent stock assessment in 2022 suggested that the stock had rebuilt. Setting a recreational allowance that accurately reflects current landings requires ongoing monitoring.

The National Panel Survey (NPS) estimates the recreational harvest from the CRA 2 stock, among many others, but is only conducted every 5–6 years with little known about the harvest during intervening years. Annual creel surveys provide ongoing monitoring of relative changes in the harvest. When creel surveys are conducted in tandem with the NPS, the relative estimates can be scaled up to provide annually up-to-date harvest monitoring.

This study reports on creel surveys conducted at boat ramps throughout the CRA 2 region in 2011–12, 2017–18, and 2019–20 to 2023–24 to monitor relative changes in levels of recreational harvesting from CRA 2, as well as changes in the length compositions of landed rock lobster. Sampling took place at boat ramps through the summer (October to February) in all years. Sampling intensity was relatively lower in 2011–12 and 2017–18 than for 2019–20 to 2023–24, which had more coverage of weekdays. Overall, we recorded 2322 survey days, 26 522 boat outings, 26 962 fisher interviews and 2054 lobster tail width measurements. An individual bag size of one lobster was more frequent than any other bag size in all survey years except 2020–21, which had more three-lobster bags. The mean weight of individual lobster fluctuated between 0.689 and 0.929 kg.

The relative harvest of lobster landings (kg per day) in CRA 2 showed a sharp decline from 2021–22. Using a variety of approaches, the relative index was scaled to absolute estimates provided by the NPS (2011–12, 2017–18, 2022–23) and a study by Blue Water Marine Research (2011–12). All approaches showed similar trends in scaled harvest with a sharp decline from 2021–22. The scaled harvest did not exceed 30 t and remained well below the recreational allowance of 34 t set in April 2018. Considering the statistical uncertainty in the estimates, the probability of the harvest exceeding 34 t was consistently low.

One of the scaling approaches implemented in this study, used an integrated model. This approach, proposed by the Marine Amateur Fisheries Working Group, integrates multiple data sources into a maximum likelihood estimation process, providing a robust scaling approach. Further development of this approach is needed, and the model should be generalised for future harvest estimation.

The results of this study provide annual estimates for the recreational harvest in CRA 2 using a range of scenarios and can be used to inform the recreational allowance. It is suggested that the harvest estimates predicted by the integrated model in this study be regarded as preliminary due to the model being in a developmental phase. The harvest estimates contained in this report do not include landings by the recreational charter fishery or section 111 recreational take by the commercial sector, which are reported through other systems.

¹ National Institute of Water and Atmospheric Research, Ltd (NIWA).

² Fisheries New Zealand, Auckland

1. INTRODUCTION

The red rock lobster *Jasus edwardsii* is caught throughout New Zealand, including the North Island, South Island, Stewart Island, and the Chatham Islands. Red rock lobster support one of New Zealand's most valuable fisheries and the species is important in the commercial, recreational and customary sectors (Fisheries New Zealand 2023). Red rock lobster was incorporated into the Quota Management System on 1 April 1990 under the species code CRA. The CRA 2 Quota Management Area (QMA) extends from Te Arai Point, just south of Whangarei, to East Cape at the eastern end of the Bay of Plenty (Fisheries New Zealand 2023). This QMA includes the Hauraki Gulf, both coasts of the Coromandel Peninsula, and the Bay of Plenty (Figure 1).

An assessment of the CRA 2 stock estimated that the spawning stock biomass was below the 20% B_0 soft limit in 2016–17 (Webber et al. 2018). This triggered management action in the form of significant catch reductions, which were implemented on 1 April 2018 (Fisheries New Zealand 2023). The Total Allowable Catch (TAC) was reduced by 58%, from 416.5 t to 173 t. The Total Allowable Commercial catch (TACC) was reduced from 200 t to 80 t. The recreational allowance was also reduced from 140 t to 34 t, which was based on exploitation rate projections (Webber et al. 2018). Later, in July 2020, the recreational daily bag limit was changed from six to three lobster per fisher. A subsequent stock assessment in 2022 reported that the CRA 2 stock had rebuilt, was very likely not overfished (not below the agreed management reference level), and not undergoing overfishing (Rudd et al. 2023).

Ongoing monitoring of the recreational harvest is required to assess whether the harvest is exceeding the allowance and so that removals by the recreational sector can be supplied as inputs for stock assessments. Levels of recreational harvesting from CRA 2 are hard to assess, given the spatially and temporally heterogeneous distribution of targeted fishing effort and the low incidence of rock lobster fishers in the general population. The only CRA 2 stock wide absolute estimates of recreational harvesting that are considered reasonably accurate are those provided by the National Panel Survey (NPS) and the Blue Water Marine Research (BWMR) access-point creel survey conducted in 2011–12. The NPS estimated a CRA 2 harvest of 40.9 t in 2011–12 (Wynne-Jones et al. 2014), 14.2 t in 2017–18 (Wynne-Jones et al. 2019) and 9.99 t in 2022–23 (Heinemann & Gray 2024). The BWMR creel survey estimated a CRA 2 harvest of 22.1 t in 2011–12 (Holdsworth 2016). These periodic surveys provide absolute estimates of the harvest and are essential to recreational fisheries monitoring, but little is known about the harvest during intervening years. Annual creel surveys provide ongoing monitoring of relative changes in the harvest. When creel surveys are conducted in tandem with the surveys of absolute harvest, the relative estimates can be scaled up to provide up-to-date harvest monitoring.

A creel survey was therefore conducted at 11 boat ramps throughout the CRA 2 region from 2019–20 to 2023–24 to monitor relative changes in levels of recreational harvesting from CRA 2, as well as changes in the length compositions of landed rock lobster. The creel survey provided only a relative index of harvest as the data collected during the survey cannot be used as the sole means to estimate all forms of recreational harvesting from the CRA 2 QMA. The creel survey was intentionally timed to overlap the 2022–23 NPS, so that the relative creel harvest index could be scaled up to an absolute harvest estimate and therefore estimate the annual tonnage landed from this stock over the five years.

This work was conducted for Fisheries New Zealand with the overall objective being to monitor the amateur harvest of red rock lobsters from the CRA 2 stock. The project had one specific objective, which was to monitor the amateur harvest of rock lobsters from the CRA 2 stock over the 2019–20 to 2023–24 April–March fishing years. Six of the 11 ramps selected for this study had comparable boat ramp creel data collected in 2011–12 and 2017–18. At the outset of the project, the Marine Amateur Fisheries Working Group (MAFWG) suggested that this data be explored and, if possible, used to extend the temporal coverage of the CRA 2 recreational fishery, albeit at the expense of some spatial coverage. That is, the five ramps with no 2011–12 or 2017–18 data could not be included in the longer time series. This report thus includes analyses that are based on a six-ramp network covering fishing years 2011–12, 2017–18, 2019–20 to 2023–24, and an 11-ramp network covering fishing years 2019–20 to 2023–24. The

harvest estimates contained in this report do not include landings by the recreational charter fishery or section 111 recreational take by the commercial sector.

This is the final report for Fisheries New Zealand research project MAF2019-05.

2. METHODS

The methods used were closely based on those described in Hartill (2019).

2.1 Study area

The 11 boat ramps surveyed in this study from 2019–20 to 2023–24 are distributed throughout the CRA 2 QMA (Figure 1). These 11 ramps were chosen based on the results of the 2011–12 and 2017–18 NPS, which provided catch by area. Although Mangawhai in the north occurs outside CRA 2, it is used frequently to access the northern extent of CRA 2 and was therefore included in the initial selection of 11 ramps.

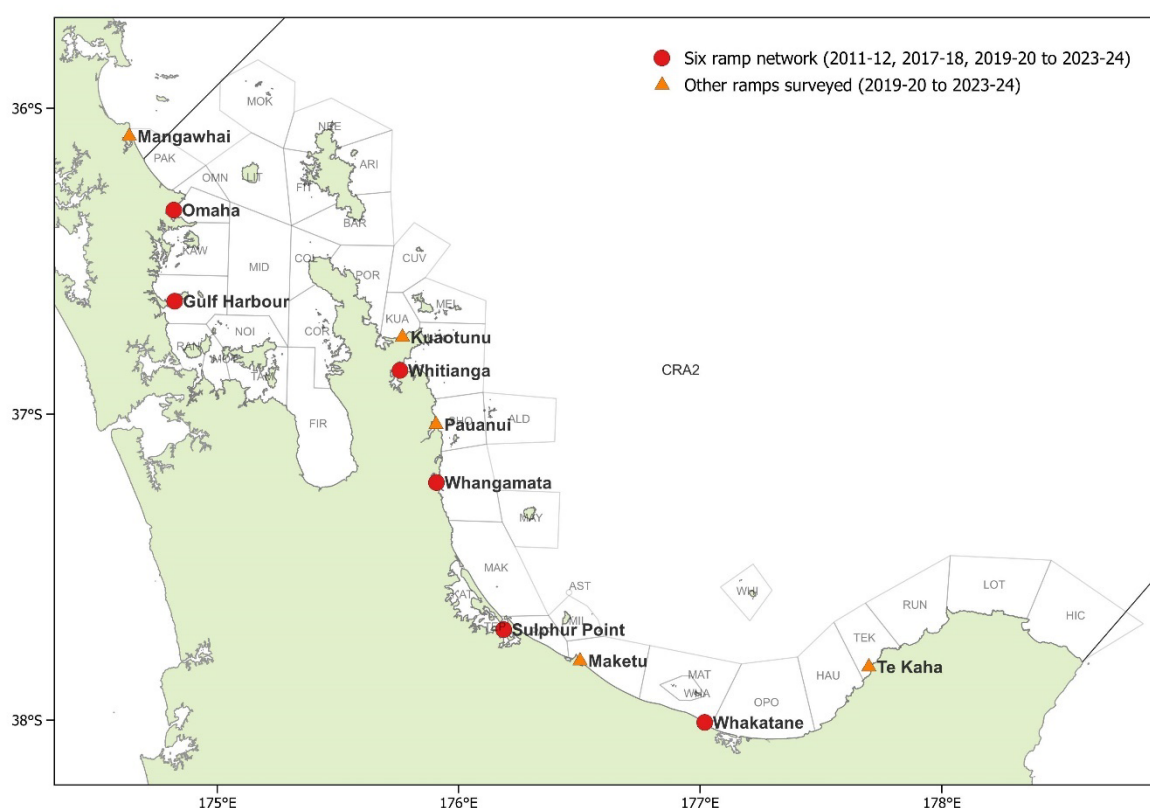


Figure 1: Boat ramps where creel surveys were undertaken in this survey of the private-vessel recreational fishery in the CRA 2 Quota Management Area. The six-ramp network was surveyed in 2011–12, 2017–18 and from 2019–20 to 2023–24. All 11 ramps were surveyed from 2019–20 to 2023–24. Inshore blocks with three letter codes were used to record where fishing activity took place.

2.2 Data collection

We monitored rock lobster landings in the CRA 2 private-vessel recreational fishery using creel methodology during the spring-summer months (October to February) from 2019–20 to 2023–24 (Table 1). Data collection followed a stratified random sampling design. The design was stratified by day type (weekends/public holidays; weekday) with greater sampling intensity directed at weekends/public holidays when fishing effort was expected to be greater.

Table 1: Stratified random sampling design for the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2019–20 to 2023–24. Surveys were limited to the spring-summer period (October to February) of each year.

Day type	Survey days	Actual days	Sampling intensity
Weekends/Public holidays	18	56	32%
Midweek days	23	96	24%

Initially, this project was intended to survey 11 boat ramps from 2019–20 to 2023–24, providing relative harvest estimates, which could be scaled to the absolute harvest estimate provided by the 2022–23 NPS. However, comparable creel data for the 2011–12 and 2017–18 fishing years exists on Fisheries New Zealand’s *rec_data* database (Fisher & Dick 2020) for 6 of the 11 initially selected ramps. Although having a lower sampling intensity than the surveys conducted in this study, these two earlier fishing years provided a longer time series and coincided with previous NPS years, which provided additional harvest estimates for scaling. Therefore, the analyses presented here focus primarily on the longer time series of six-ramp surveys (2011–12, 2017–18, 2019–20 to 2023–24), but also include some 11-ramp analyses (limited to 2019–20 to 2023–24), where appropriate.

Creel survey interviews stored on the *rec_data* database, including those conducted by NIWA, have followed a standard format since the early 1990s. Data collected from vessels that were fishing included fishing location, methods, time spent fishing, as well as details of species caught and their length or tail width in the case of red rock lobster. Interviewers were instructed to measure the tail width, without rounding, for every red rock lobster that was retained by fishers, to ensure that lobster data was as accurate as possible. The incidence of rock lobster landings is far lower than for other species such as snapper, and the time spent measuring species other than rock lobster increases the likelihood of a rock lobster landing passing undetected, and unmeasured. Therefore, to maximise the likelihood of intercepting boats with lobster, if other boats returned to the ramp when a group of fishers were being interviewed, interviewers only counted (i.e., they did not measure individual fish) landings of other species.

The 2011–12 and 2017–18 surveys included all-day sessions conducted from 07:30 to 21:00 each day (Table 2). However, from 2019–20 to 2023–24, interviewers were required to be at the boat ramp for only four hours per session. This was timed to coincide with the likely maximum number of fishers returning from a fishing trip. The surveys at Gulf Harbour (GU), Sulphur Point (SU), Whakatane (WK) and Whitianga (WT) were designed to collect data that would serve the objectives of two Fisheries New Zealand projects, MAF2019-01 (Web-camera project) and MAF2019-05 (CRA 2 / this project). The time schedule for MAF2019-01 data collection took precedence at those ramps. However, surveys at Kuaotunu (KU), Maketu (MK), Mangawhai (MW), Omaha (OO), Pauanui (PN) and Whangamatā (WM) were dedicated to MAF2019-05 data collection and were scheduled for slightly later in the day to target returning CRA fishers. This CRA-specific timing was derived from exploratory analyses of the 2011–12 and 2017–18 all-day surveys stored on the *rec_data* database (Hartill 2019). Additional days, dedicated to CRA 2 surveys were also conducted at all ramps (except Te Kaha [TK]) on the CRA 2 schedule. The ramp at Te Kaha is remote and was surveyed slightly earlier in the day throughout the survey period due to logistical and safety reasons.

Table 2: Timing of creel survey sessions in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18, and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. CRA 2 / Web-camera shared days were those conducted in tandem with another creel survey project (MAF201901). CRA 2 only days were those conducted solely for collecting CRA 2 data. TK: Te Kaha is a remote location and had its own schedule due to logistic and safety reasons.

Fishing year	Days / ramps	Weekend/public holiday	Weekday
2011–12	All six ramps	07:30–21:00	07:30–19:00
2017–18	All six ramps	07:30–21:00	07:30–19:00
2019–20 to 2023–24	CRA 2 / Web-camera shared days		
	- ramps: KU, MK, MW, OO, PN, WM	14:00–18:00	15:00–19:00
	- ramps: GU, SU, WK, WT	12:30–16:30	14:30–18:30
	CRA 2 only days (all ramps except TK)	14:00–18:00	15:00–19:00
	CRA 2 all days (TK)	12:00–16:00	13:00–17:00

2.3 Data analysis

Dataset preparation

Data was extracted from the *rec_data* database as a single flat file of creel survey data from the session, boat, fisher and catch tables.

First, a *survey* dataset was prepared for computing bag and tail width frequencies as well as annual mean weights, none of which required probabilistic analyses. Data was limited to the 2011–12, 2017–18, and 2019–20 to 2023–24 fishing years, private-vessel outings, completed outings (i.e., interviewed at the boat ramp at the end of the outing), from only the 11 ramps and only during the spring-summer months (October to February).

Next, a *survey_s* dataset, referring to scheduled sampling, was prepared by further subsetting the ‘*survey*’ dataset. Survey days, including data from all ramps, were removed from the 2011–12 and 2017–18 surveys if sessions had not been conducted at all six ramps. Survey days were removed from the 2019–20 to 2023–24 surveys if a day was unscheduled or if more than half of the scheduled sessions across the 11 ramps had been missed (e.g., due to extreme weather). To ensure consistency over time, only boats intercepted during a fixed time frame were retained in the dataset. The time frame was 14:00 to 18:00 for weekends and public holidays, and 15:00 to 19:00 for midweek days. This dataset is summarised in the section on sampling activity.

Lastly, a *survey_i* dataset was prepared by imputing for missed boats in the *survey_s* dataset and used for probabilistic harvest estimates. All boats were counted during a survey session, but, for some boats, the fishers could not be interviewed because the interview clerk was already busy with another boat. During the data analysis stage, catch and effort for missed boats were imputed from another vessel that had been successfully intercepted during the same survey session. The imputation procedure imputed data from another vessel intercepted at the same ramp during the same session by using a computational algorithm to choose the ‘nearest-neighbour-in-time’, first looking back and then forward in time (Hartill et al. 2011). Any fishing activity outside of the CRA 2 QMA was removed from this dataset after imputation.

Bag frequency

Bag frequencies were computed for the six-ramp network in 2011–12 and 2017–18 and for the 11-ramp network from 2019–20 to 2023–24. Interviewers counted the number of red rock lobster landed by each fisher for a given outing. The frequency of lobster bag sizes is presented for retained lobster only.

Up to and including the 2019–20 survey year, the daily bag limit was six lobster per person; however, this was changed to three lobster per person from 1 July 2020 (Fisheries New Zealand 2023). This date was after the end of the 2019–20 survey year (28 February 2020) and before the start of the subsequent survey year (1 October 2020). Consequently, the daily bag limit was three lobster per person for all survey years from 2020–21 through to 2023–24. Bag sizes of 3+ and 6+ are presented as an indication of the number of bags where the daily bag limit had been exceeded.

Tail width frequency

Tail width frequencies were computed for the six-ramp network in 2011–12 and 2017–18 and for the 11-ramp network from 2019–20 to 2023–24. Interviewers measured red rock lobster tail widths to the nearest millimetre below, which is consistent with the minimum legal-size measurement. Interviewers endeavoured to measure as many lobsters as possible; however, it was not possible to measure every lobster counted (e.g., fishers may refuse to have their catch measured). Measurements were differentiated by sex due to differences in the growth rate between males and females.

Interviewers were instructed not to round tail width measurements, but some instances of rounding were apparent during analyses. Rounding was assumed to have occurred at a specific ramp during a specific year if more than 40% of the measurements (minimum 10 measurements) were on the five- or ten-mm frequency interval (ignoring the 60-mm interval in females since this coincides with the size limit). If rounding was assumed to have taken place, all tail width measurements for that respective year and boat ramp were removed from the mean weight estimation described below.

Mean weight

Lobster tail widths were converted to weight using the length-weight equation:

$$W = aTW^b \quad (1)$$

where W is the weight of the animal in kg, TW is the tail width of the animal in millimetres, and a and b are regression parameters (Table 3).

Table 3: Length-weight relationships for CRA used in this study to convert from tail width (mm) to weight (kg) for females and males.

Regression parameter	Female	Male	Reference
a	0.000013	0.00000416	Fisheries New Zealand 2023
b	2.545	2.935	Fisheries New Zealand 2023

The mean individual weight of lobster was subsequently estimated for each year. However, this calculation excluded the data where rounding was assumed to have taken place.

Relative harvest index (unscaled)

An annual relative harvest index was calculated separately for the six-ramp network and the 11-ramp network.

The number of lobster landed on a survey day across the six or 11 surveyed ramps was calculated as:

$$n_i = \sum_j n_{i,j} \quad (2)$$

where $n_{i,j}$ is the number of lobster landed on survey day i at surveyed ramp j . The total weight of lobster in kilograms landed per survey day across the surveyed ramps was calculated as:

$$w_i = n_i \bar{w} \quad (3)$$

where $\bar{w}$ is the mean individual weight of lobster for a given year. The mean daily weight of lobster landed across the surveyed ramps in each stratum was estimated as:

$$\bar{w}_h = \frac{1}{n_h} \sum_i w_{i,h} \quad (4)$$

where $w_{i,h}$ is the i^{th} daily weight in stratum h and n_h is the number of survey days in stratum h . Weightings were based on the average number of days in each day type (summer weekend/public holiday; summer weekday) as a proportion of the total number of days in the survey year (October–February). The population mean daily weight of lobster landed across the surveyed ramps for the year was estimated as:

$$\mu_y = \sum_h (\alpha_h \cdot \bar{w}_h) \quad (5)$$

where α_h is the stratum weighting, calculated as the proportion of each day type occurring in a survey year. The variance of the mean daily weight of lobster for each stratum was estimated as:

$$s_{\mu_h}^2 = \frac{1}{n_h - 1} \sum_i (w_{i,h} - \bar{w}_h)^2 \quad (6)$$

The variance of the population mean daily weight of lobster landed across the surveyed ramps for the year was estimated as:

$$\sigma_{\mu_y}^2 = \sum_h \frac{(\alpha_h^2 \cdot s_{\mu_h}^2)}{n_h} \quad (7)$$

Finally, the coefficient of variation CV was calculated for each survey year as:

$$CV = \frac{\sqrt{\sigma_{\mu_y}^2}}{\mu_y} \quad (8)$$

Scaled harvest index derived using a sequential model

The six- and 11-ramp harvest indices produced by these analyses were relative, as the data collected during the survey could not be used as the sole means to estimate all forms of recreational harvesting from the CRA 2 QMA. Therefore, it was necessary to apply a scalar to each index to produce scaled harvest indices for the CRA 2 stock. Scalars were derived as the ratio of a relative harvest estimate to an absolute harvest in a given (concurrent) year. In most cases, we had multiple concurrent years, and the scalar was therefore derived by taking the geometric mean of the absolute estimates and dividing it

by the geometric mean of the relative estimates. Absolute estimates of recreational CRA 2 harvests exist for 2011–12 (Holdsworth 2016, Wynne-Jones et al. 2014), 2017–18 (Wynne-Jones et al. 2019) and 2022–23 (Heinemann & Gray 2024). Multiplying the relative harvest index (all years) by the scalar produced the scaled harvest index presented in this report.

Four scenarios were used to generate scalars. The *NPS63* scenario was based on the NPS absolute estimates available for fishing years 2011–12, 2017–18 and 2022–23, and the six-ramp relative creel estimates available for the same years.

$$\hat{\omega}^{NPS63} = \frac{\sqrt[3]{\hat{H}_{2012}^{NPS} \cdot \hat{H}_{2018}^{NPS} \cdot \hat{H}_{2023}^{NPS}}}{\sqrt[3]{\hat{H}_{2012}^{creel6} \cdot \hat{H}_{2018}^{creel6} \cdot \hat{H}_{2023}^{creel6}}} \quad (9)$$

An *NPS62* scenario was similar to the *NPS63* scenario but did not include 2011–12 to generate the scalar.

$$\hat{\omega}^{NPS62} = \frac{\sqrt{\hat{H}_{2018}^{NPS} \cdot \hat{H}_{2023}^{NPS}}}{\sqrt{\hat{H}_{2018}^{creel6} \cdot \hat{H}_{2023}^{creel6}}} \quad (10)$$

A *BWMR_NPS6* scenario was based on the Holdsworth (2016) absolute estimate for 2011–12, the NPS absolute estimates for 2017–18 and 2022–23, and the six-ramp relative creel estimates available for the same years.

$$\hat{\omega}^{BWMR_NPS6} = \frac{\sqrt[3]{\hat{H}_{2012}^{BWMR} \cdot \hat{H}_{2018}^{NPS} \cdot \hat{H}_{2023}^{NPS}}}{\sqrt[3]{\hat{H}_{2012}^{creel6} \cdot \hat{H}_{2018}^{creel6} \cdot \hat{H}_{2023}^{creel6}}} \quad (11)$$

Lastly, an *NPS11* scenario was based on the NPS absolute estimate for 2022–23 and the 11-ramp relative estimate for the same year.

$$\hat{\omega}^{NPS11} = \frac{\hat{H}_{2023}^{NPS}}{\hat{H}_{2023}^{creel11}} \quad (12)$$

Parametric bootstrapping was then used to evaluate uncertainty in the scalars. Using each absolute estimate and its standard error, 1000 bootstrap samples were drawn. Similarly, using the creel relative annual mean weight of lobster and its standard error, 1000 bootstrap samples were drawn for each year separately for each of the six- and 11-ramp indices. Under the *NPS63* scenario, three vectors were generated for the NPS absolute estimates (2011–12, 2017–18, 2022–23) and three vectors generated for the creel six-ramp relative estimates (2011–12, 2017–18, 2022–23). The row-wise geometric mean of the NPS vectors produced a single vector that was divided by a similar row-wise geometric mean of the creel six-ramp vectors to produce a single vector of scalars. The vector of scalars was multiplied by each vector of relative estimates for the creel six-ramp data. This process was repeated for each of the four scenarios and produced a probability distribution of harvest estimates for each year given the scalar uncertainty, which was compared to the recreational lobster allowance for CRA 2 (34 t).

To further assess the scaling procedure, a probability distribution of harvest estimates was generated using three-year averages of creel data. Bootstrapped harvest estimates for years 2021–22, 2022–23 and 2023–24 (described above) were averaged row-wise to produce a single vector, which represented the average harvest estimates over the three years. This represented a multi-year averaged probability distribution of harvest estimates, given scalar uncertainty, which was compared to the recreational allowance (34 t).

Scaled harvest index derived using an integrated model

An integrated maximum likelihood model was developed to provide an alternative scaling approach, which integrated all absolute estimates (NPS: 2011–12, 2017–18, 2022–23, BWMR 2011–12) and the six-ramp creel relative harvest index into a single model. This model was implemented using the R package, *TMB* (Kristensen et al. 2016). The 11-ramp index was not included in this model due to the overlap in the data source. Six ramps were common to both the six-ramp and 11-ramp creel network.

The harvest estimate observations and their standard error for each data source served as the model inputs. This included the absolute estimates in tonnes and the relative estimates in kilogram per day. The parameters to be estimated were the six-ramp scalar with a starting value of one and the annual estimated harvest (2011–12, 2017–18, 2019–20 to 2023–24) with starting values of 30 tonnes for each year.

The model was specified in C++ and returned a negative log-likelihood (NLL) to be minimised in R using the *nlm* function in the R package, *stats* (R Core Team 2023). The total NLL to be minimised was computed from multiple components. Individual NLL contributions were taken from each year and the NLL contribution for a given year consisted of three sub-components. The first sub-component was computed from the NPS harvest observation (tonnes), the harvest to be estimated (tonnes), and the NPS harvest standard error. The second component was similarly computed from the BWMR harvest observation (tonnes), the harvest to be estimated (tonnes) and the BWMR harvest standard error. The third sub-component was computed from the six-ramp creel harvest observation (kg per day), the harvest to be estimated (tonnes) multiplied by the scalar (inverted) to be estimated, and the six-ramp creel harvest standard error. Simulated distributions of mean harvest were also generated for each of the three sub-components to assess the uncertainty in the model. The model is still in the developmental phase and results should be treated as preliminary.

All analyses were performed using R v4.3.0 (R Core Team 2023). The map was produced using QGIS 3.36.3 (QGIS Development Team 2024).

3. RESULTS

3.1 Sampling activity

Sampling took place at boat ramps through the spring-summer (October to February) in 2011–12, 2017–18, and from 2019–20 to 2023–24 (Table 4). See Table A1 in the Appendix for survey dates. Sampling intensity was relatively lower in 2011–12 and 2017–18 than for 2019–20 to 2023–24, which had more coverage of weekdays. Overall, there were 2373 survey days conducted across the 11 ramps (Table 5).

Of the 26 510 boat outings recorded across the 11 ramps, 10 309 fishing boat outings were intercepted with a successful interview (outcome: I) taking place (Table 6). A further 16 201 outings were recorded, but these were either fishing outings where a proposed interview was refused (outcome: F), boat was missed while interviewing another boat (outcome: N), boat engaged in non-fishing activities (outcome: O), or the interview was refused and the outing purpose could not be determined (outcome: R). Overall, 26 962 fisher interviews were recorded (Table 7), but only 1210 of these had at least one landed red rock lobster (Table 8). The number of fisher interviews was highest in 2019–20 (5579) and 2020–21 (4936), dipped substantially in 2021–22 (2985), and rebounded in 2022–23 (4024), with little change in 2023–24 (3885). A total of 2054 tail width measurements were recorded (Table 9). However, unlike the trend in lobster measurements, there were substantially more fishers with landed lobster counted in 2021–22 (249) than in both 2022–23 (140) and 2023–24 (148).

Data were imputed for those boats that were counted but the fishers not interviewed (Table 10). This resulted in the imputation of data for 16 933 additional interviews and 989 length measurements for the surveyed CRA 2 ramps.

Table 4: Sampling activity for the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Surveys conducted from 2012–13 to 2016–17 are not included in this report.

Fishing year	Day type	Days in stratum	Number of ramps	Sampling days	Sampling intensity
2011–12	Weekend	57	6	12	0.21
	Weekday	95	6	8	0.08
2017–18	Weekend	56	6	14	0.25
	Weekday	95	6	7	0.07
2019–20	Weekend	58	11	18	0.31
	Weekday	94	11	23	0.24
2020–21	Weekend	58	11	18	0.31
	Weekday	93	11	23	0.25
2021–22	Weekend	57	11	18	0.32
	Weekday	94	11	23	0.24
2022–23	Weekend	57	11	18	0.32
	Weekday	94	11	22	0.23
2023–24	Weekend	56	11	18	0.32
	Weekday	96	11	23	0.24

Table 5: The number of survey days by boat ramp location in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. See Section 2.2 for boat ramp full names.

Fishing year	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT	Total
2011–12	Weekend	12	–	–	–	12	–	12	–	12	12	12	72
	Weekday	8	–	–	–	8	–	8	–	8	8	8	48
2017–18	Weekend	14	–	–	–	14	–	14	–	14	14	14	84
	Weekday	7	–	–	–	7	–	7	–	7	7	7	42
2019–20	Weekend	17	16	18	17	18	17	18	16	15	16	18	186
	Weekday	21	22	23	23	23	23	23	21	21	23	23	246
2020–21	Weekend	17	18	18	18	18	17	18	18	18	18	18	196
	Weekday	23	23	23	22	21	23	23	23	22	20	23	246
2021–22	Weekend	17	18	18	18	17	9	18	17	18	13	18	181
	Weekday	21	23	23	22	20	14	23	23	21	17	23	230
2022–23	Weekend	17	18	18	18	17	18	18	17	16	14	15	186
	Weekday	20	22	22	22	22	19	21	22	21	18	20	229
2023–24	Weekend	17	17	17	18	18	17	17	18	17	16	17	189
	Weekday	21	21	20	21	22	22	21	23	23	23	21	238
Total		232	198	200	199	237	179	241	198	233	219	237	2 373

Table 6: Number of boat outings by outcome in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Data before imputation. F: fishing but refused; I: Interviewed; N: Not interviewed; O: other activity; R: refused. See Section 2.2 for boat ramp full names.

Outcome	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT	Total
F	377	6	3	15	176	15	185	7	863	13	14	1 674
I	1 176	843	184	624	1 425	579	2 388	156	816	1 272	846	10 309
N	851	378	18	48	1 690	279	1 005	2	384	964	593	6 212
O	628	215	113	526	1 893	729	1 438	30	308	1 063	703	7 646
R	19	18	18	137	256	20	34	2	48	90	27	669
Total	3 051	1 460	336	1 350	5 440	1 622	5 050	197	2 419	3 402	2 183	26 510

Table 7: Number of fishers interviewed (outcome I, Table 6) in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. See Section 2.2 for boat ramp full names.

Fishing year	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT	Total
2011–12	425	–	–	–	323	–	766	–	374	569	260	2 717
2017–18	267	–	–	–	467	–	908	–	298	551	345	2 836
2019–20	541	427	127	492	973	496	1 330	5	348	483	357	5 579
2020–21	380	515	127	373	694	290	1 054	201	441	578	283	4 936
2021–22	141	399	44	190	354	128	717	81	314	365	252	2 985
2022–23	571	487	71	364	470	197	881	74	247	284	378	4 024
2023–24	659	596	94	303	509	225	419	80	324	374	302	3 885
Total	2 984	2 424	463	1 722	3 790	1 336	6 075	441	2 346	3 204	2 177	26 962

Table 8: Number of fishers with landed CRA recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. See Section 2.2 for boat ramp full names.

Fishing year	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT	Total
2011–12	3	–	–	–	16	–	20	–	8	27	5	79
2017–18	–	–	–	–	11	–	3	–	6	11	14	45
2019–20	–	–	–	19	34	47	30	–	12	17	31	273
2020–21	–	48	20	30	10	46	31	7	21	40	23	276
2021–22	–	49	13	17	81	3	19	11	13	12	31	249
2022–23	3	28	13	29	23	7	9	8	6	5	9	140
2023–24	4	29	17	19	19	26	15	6	–	8	5	148
Total	12	197	101	114	194	129	127	32	66	120	118	1 210

Table 9: Number of landed CRA measurements recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. See Section 2.2 for boat ramp full names.

Fishing year	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT	Total
2011–12	5	–	–	–	30	–	26	–	30	52	5	148
2017–18	–	–	–	–	15	–	2	–	18	23	16	74
2019–20	2	91	130	37	67	101	65	–	39	31	49	612
2020–21	–	52	47	51	13	98	70	16	34	69	3	453
2021–22	–	47	26	34	18	1	4	28	5	13	32	208
2022–23	6	49	33	74	32	8	8	8	8	12	17	255
2023–24	6	56	38	29	25	48	68	11	–	13	10	304
Total	19	295	274	225	200	256	243	63	134	213	132	2 054

Table 10: The number of observations (boats, interviews, lengths) in the dataset before (*survey_s*) and after imputation (*survey_i*) in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24.

Data type	Outcome	Initial	After imputation
Boats	F - fishing but refused	1 674	289
	I - interviewed	10 309	16 983
	N - not interviewed	6 212	60
	O - other activity	7 646	9 170
	R - refused	669	8
	Total	26 510	26 510
Interviews (I)		26 962	43 895
Interviews (I) with landed CRA		1 210	1 789
CRA measurements		2 054	3 043

3.2 Bag frequencies

There were 1522 fisher outings where at least one CRA was landed (Table 11). An individual bag size of one lobster was more frequent than any other bag size in all survey years except in 2020–21 when there were more bags with three lobster (Figure 2). The 6+ and 3+ categories indicate bag sizes where the daily bag limit was exceeded. There appeared to be an initial increase in the frequency of two- and three-lobster bags in 2020–21, followed by a subsequent reduction in these bag sizes in 2021–22, but an increase in the frequency of one-lobster bags.

Table 11: Number of CRA bags recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Data before imputation.

Fishing year	Number of ramps	Number of bags
2011–12	6	143
2017–18	6	116
2019–20	11	293
2020–21	11	316
2021–22	11	306
2022–23	11	159
2023–24	11	189
Total	—	1 522

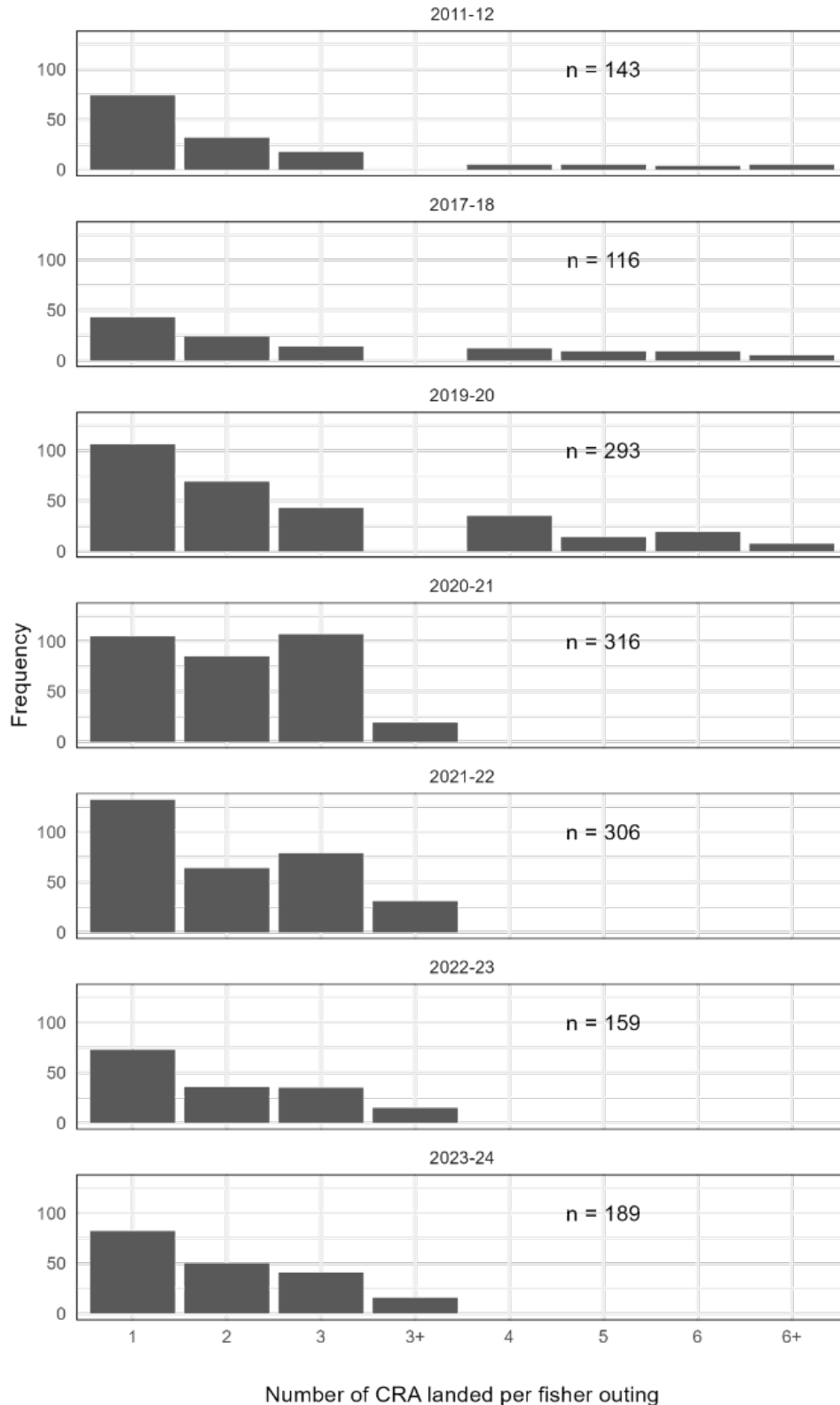


Figure 2: Bag frequencies of red rock lobster recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. The daily bag limit was reduced from six to three lobster per person on 1 July 2020 (i.e., effective from the start of the 2020–21 survey year). The x-axis categories ‘3+’ and ‘6+’ indicate bag sizes of more than 3 and more than 6, respectively.

3.3 Tail width frequencies

There were 926 measurements of female lobster and 1380 measurements of male lobster during the study period (Table 12). With rounded tail width measurements removed, most measured lobster were above the minimum legal size for females (60 mm) and males (54 mm) in all years (Figure 3). Female tail width ranged from 40 to 93 mm, while male tail width ranged from 41 mm to 101 mm.

Table 12: Number of CRA tail width measurements recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24.

Fishing year	Number of ramps	Female	Male
2011–12	6	109	149
2017–18	6	99	108
2019–20	11	311	355
2020–21	11	175	331
2021–22	11	75	155
2022–23	11	92	133
2023–24	11	65	149
Total	–	926	1 380

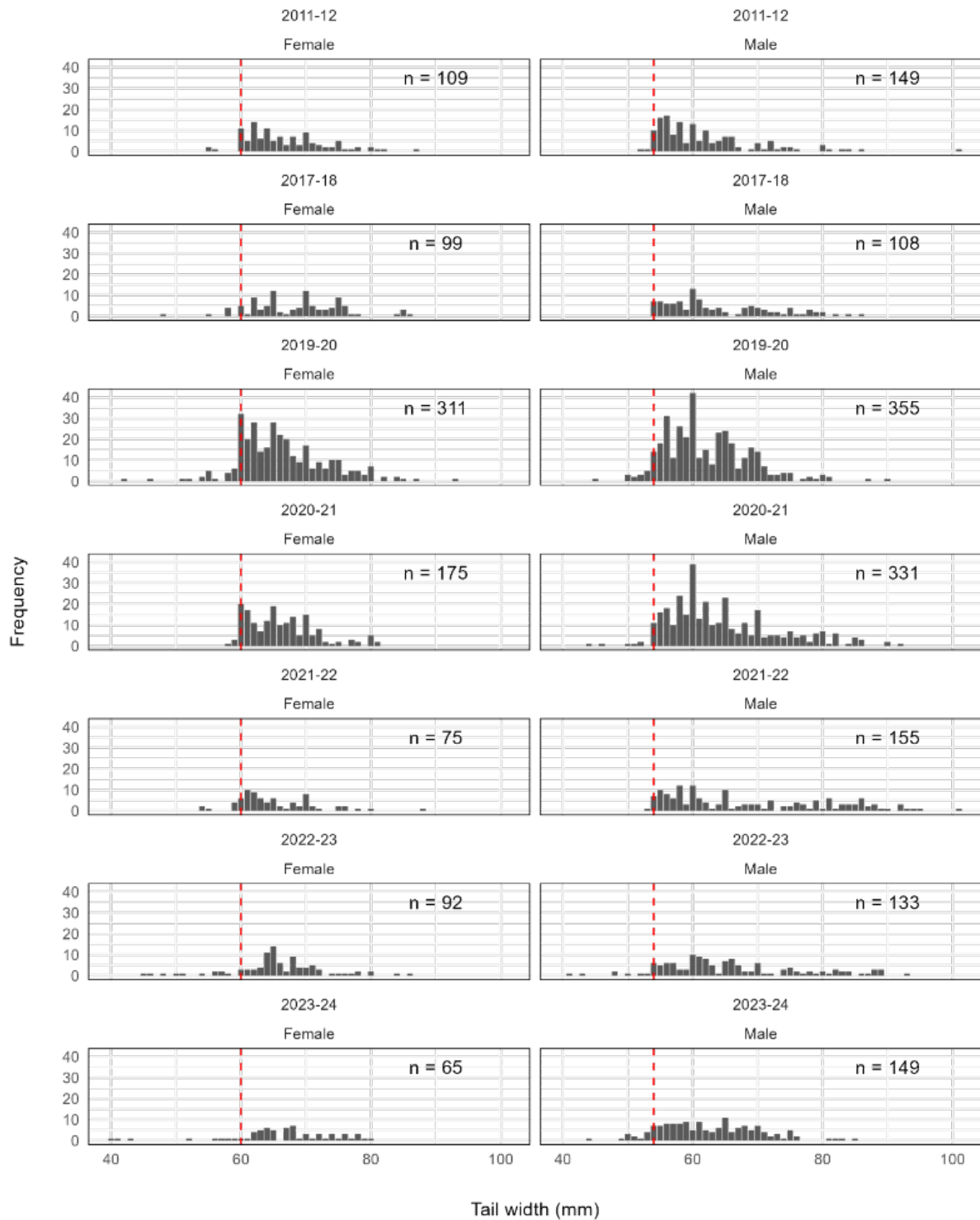


Figure 3: Tail width frequencies of female and male red rock lobster recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Minimum legal-size indicated for females (60 mm) and for males (54 mm).

3.4 Tail width-weight conversion

Tail widths were converted to individual weights and mean weights were estimated for each survey year (Table 13). The mean weight of individual lobster after rounded tail width measurements were removed fluctuated between 0.689 and 0.929 kg over the study period. The available number of useable tail width observations (non-rounded) declined substantially from 2019–20 onwards.

Table 13: The mean weight of CRA and the number of tail width observations in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Mean weights shown with and without rounded tail width measurements removed.

Fishing year	Number of ramps	Rounding removed		Rounding not removed	
		Mean weight (kg)	n	Mean weight (kg)	n
2011–12	6	0.700	258	0.700	258
2017–18	6	0.752	207	0.752	207
2019–20	11	0.689	666	0.689	666
2020–21	11	0.780	506	0.780	506
2021–22	11	0.929	230	0.930	258
2022–23	11	0.803	225	0.815	269
2023–24	11	0.743	214	0.782	385

3.5 Harvest estimation

The unscaled mean weight of lobster landings in CRA 2 estimated from both the six-ramp and 11-ramp networks showed a sharp decline from 2021–22 onwards (Table 14, Figure 4). As expected, the mean weight of lobsters landed per day in the 11-ramp index was consistently greater than that in the six-ramp index. This is because the total CRA landed on a given survey day in the 11-ramp network would always be greater than or equal to those recorded in the subset six-ramp network.

Table 14: The relative harvest index estimated from the six-ramp and 11-ramp creel network in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. SE: standard error, CV: coefficient of variation.

Fishing year	Six ramp			Eleven ramp		
	kg per day	SE	CV	kg per day	SE	CV
2011–12	6.98	2.06	29	–	–	–
2017–18	6.99	2.15	31	–	–	–
2019–20	9.29	2.01	22	18.36	3.22	18
2020–21	9.42	2.37	25	16.19	3.01	19
2021–22	9.30	2.20	24	16.43	3.69	22
2022–23	5.15	2.47	48	7.29	2.62	36
2023–24	3.01	0.90	30	6.40	1.32	21

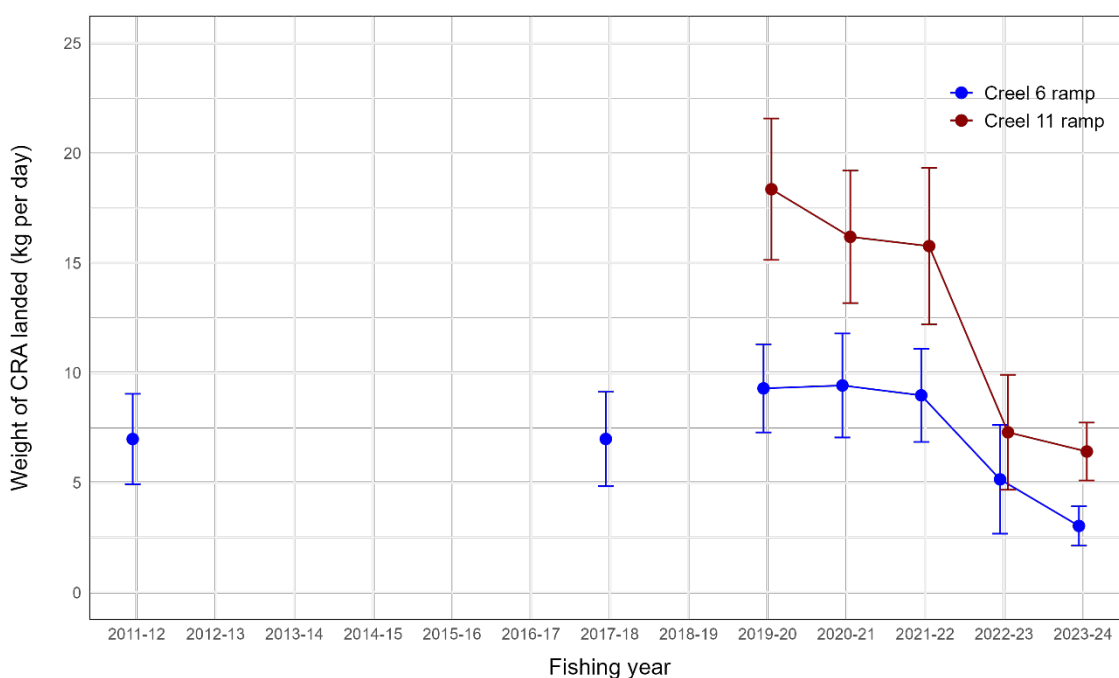


Figure 4: Average daily catch (kg) of red rock lobster recorded in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. The daily bag limit was reduced from six to three lobster per person on 1 July 2020 (i.e., effective from the start of the 2020–21 survey year). Error bars indicate standard error.

Scaled harvest index derived under various scaling scenarios

Four scalars were derived, and their bootstrapped distribution is shown in Figure A1. The four scaled harvest indices differed somewhat in the magnitude of the estimated harvest, but showed consistent trends (Table 15, Figure 5, Figure 6). The scaled indices all indicated that annual harvests were below the recreational harvest allowance of 34 t in all years, and all indices showed a decline in harvest from 2021–22. The scaled index derived from *NPS63* was consistently greater than *NPS62*, *BWMR_NPS6* and *NPS11*, except in 2023–24 when the *NPS11* scaled harvest was highest. Considering the uncertainty in the creel relative harvest index, the probability of the scaled estimates exceeding the 34 t recreational harvest allowance was low in 2011–12 and 2017–18 (noting that the actual allowance was 140 t at this time), reached a peak in 2019–20, 2020–21 and 2021–22, and then declined to near zero in 2022–23 and 2023–24 (Figure A2–A8, Table A2). Taking an average of the last three years of bootstrapped scaled harvest estimates (2021–22, 2022–23, 2023–24), the overall probability of exceeding the recreational harvest allowance was similarly low at 0.03 or less (Figure A9).

Table 15: Absolute harvest (t) estimated by the National Panel Survey (NPS), the Blue Water Marine Research (BWMR) creel survey (Holdsworth 2016), and the scaled harvest (t) estimated from creel surveys under various scaling scenarios in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Six ramps were surveyed in 2011–12 and 2017–18, while 11 ramps were surveyed from 2019–20 to 2023–24. Harvest in tonnes, SE: standard error, CV: coefficient of variation.

Fishing year	NPS			BWMR			NPS63			NPS62			BWMR NPS6			NPS11		
	Harvest	SE	CV	Harvest	SE	CV	Harvest	SE	CV	Harvest	SE	CV	Harvest	SE	CV	Harvest	SE	CV
2011–12	40.9	9.8	0.24	22.1	10.3	0.47	19.9	7.4	0.36	13.9	8.3	0.54	16.2	6.6	0.40	–	–	–
2017–18	14.2	5.1	0.36	–	–	–	19.9	8.1	0.38	13.9	6.8	0.46	16.2	6.9	0.42	–	–	–
2019–20	–	–	–	–	–	–	26.5	11.5	0.40	18.4	10.6	0.51	21.5	9.9	0.44	25.1	26.5	0.85
2020–21	–	–	–	–	–	–	26.8	12.8	0.44	18.7	11.6	0.54	21.9	11.0	0.47	22.2	24.7	0.90
2021–22	–	–	–	–	–	–	26.5	11.9	0.42	18.5	11.0	0.53	21.6	10.2	0.45	22.5	24.8	0.90
2022–23	10.0	3.1	0.31	–	–	–	14.7	5.9	0.41	10.2	4.1	0.41	11.9	5.2	0.45	10.0	3.1	0.31
2023–24	–	–	–	–	–	–	8.6	4.1	0.44	6.0	3.6	0.54	7.0	3.5	0.48	8.8	9.4	0.88

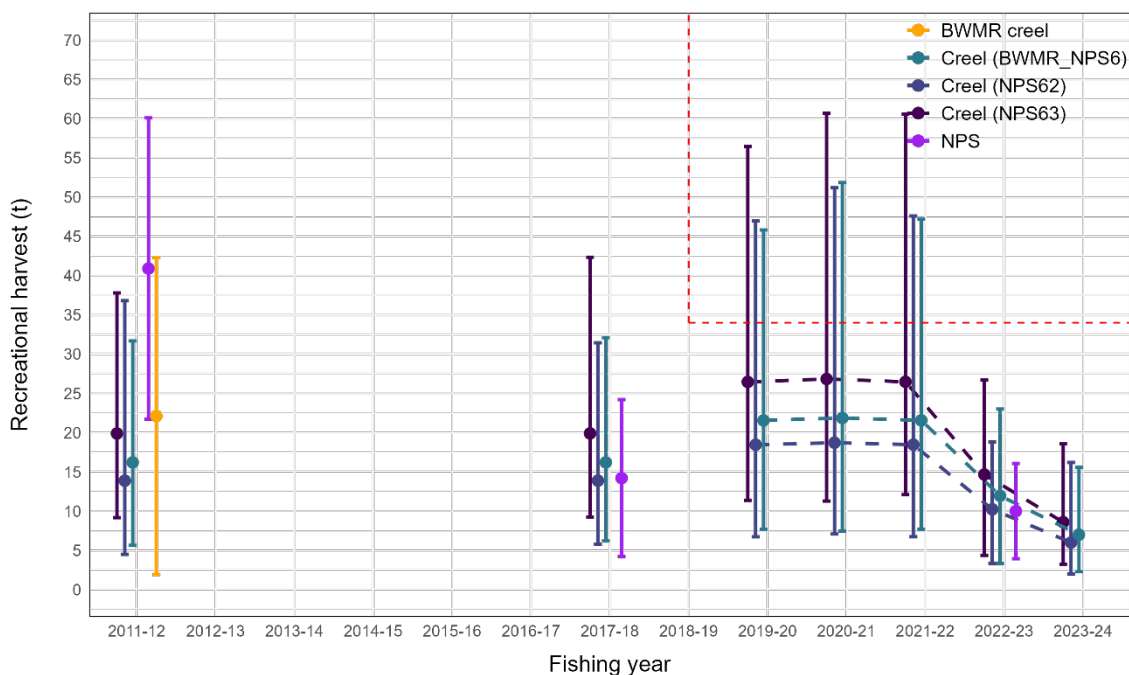


Figure 5: Absolute CRA harvest estimated by the National Panel Survey (NPS) and by the Blue Water Marine Research (BWMR) creel survey (Holdsworth 2016), and the scaled harvest estimated from six-ramp creel surveys under the *NPS63*, *NPS62* and *BWMR_NPS6* scaling scenarios in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Red dashed line indicates the recreational allowance of 34 t. Error bars indicate 95% confidence intervals.

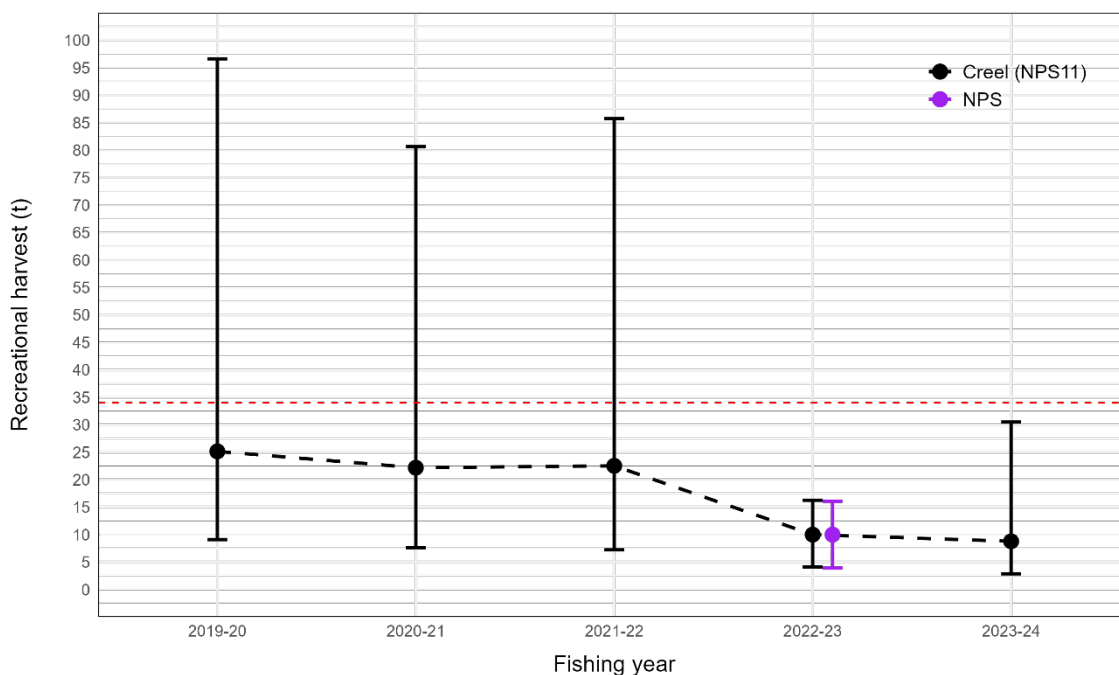


Figure 6: Absolute CRA harvest estimated by the National Panel Survey (NPS), and the scaled harvest estimated from 11-ramp creel surveys under the *NPS11* scaling scenario in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 from 2019–20 to 2023–24. Red dashed line indicates the recreational allowance of 34 t. Error bars indicate 95% confidence intervals.

Harvest estimation using an integrated modelling approach

The estimated parameters from the integrated model represented the six-ramp scalar and the scaled mean annual harvest estimates (Table 16). The CV values were high, ranging from 0.25 (2017–18) to 0.42 (2023–24). Simulated distributions of harvest means from the integrated model showed reasonably good model fit in most cases to observed point estimates (Figure 7). However, the model appeared to provide a poor fit for the 2011–12 NPS harvest estimate. The simulated distribution of the inverted scalar is shown in Figure 8. The predicted annual harvest was consistently below the 34 t recreational allowance although the confidence intervals for 2019–20 to 2021–22 overlapped the 34 t threshold (Figure 9). There was relative stability around 29 t from 2019–20 to 2021–22, but then a decline of 62% to 10.8 t in 2022–23 with a further decline to 9.5 t in 2023–24.

Table 16: Maximum likelihood parameter estimates from the integrated model. The estimate column represents the six-ramp scalar and the scaled mean annual harvest estimates (t). SE: standard error, CV: coefficient of variation, LCI: lower confidence interval, UCI: upper confidence interval.

Parameter	Estimate	SE	CV	LCI – 95%	UCI – 95%
creel_6_ramp_scalar	0.314	0.094	0.299	0.130	0.498
creel_6_ramp_2011–12	26.616	6.997	0.263	12.903	40.330
creel_6_ramp_2017–18	17.052	4.295	0.252	8.634	25.469
creel_6_ramp_2019–20	29.553	10.966	0.371	8.060	51.047
creel_6_ramp_2020–21	29.967	11.675	0.390	7.084	52.850
creel_6_ramp_2021–22	29.585	11.339	0.383	7.361	51.809
creel_6_ramp_2022–23	10.848	2.889	0.266	5.185	16.512
creel_6_ramp_2023–24	9.575	4.054	0.423	1.629	17.522

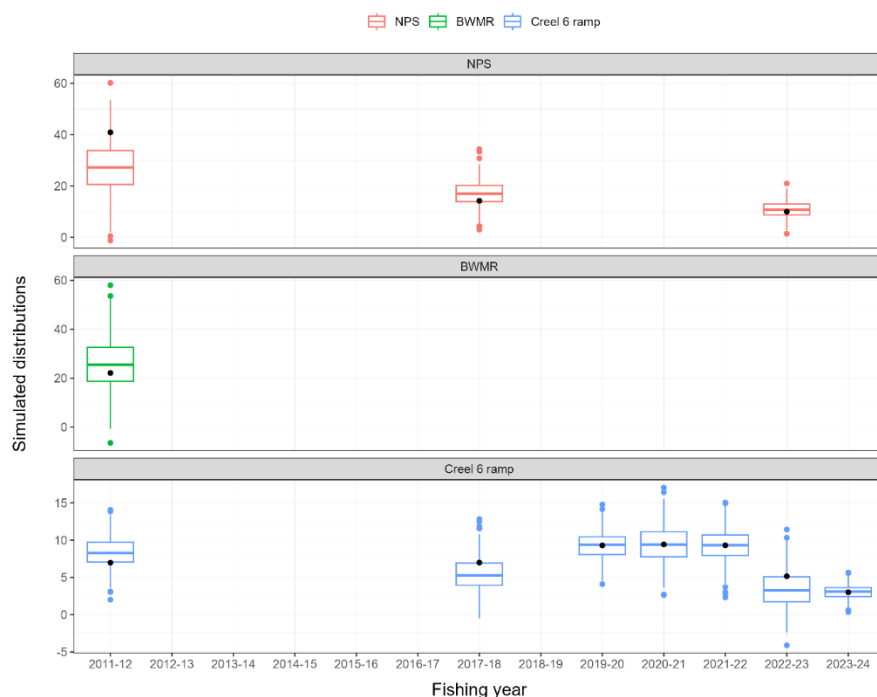


Figure 7: Simulated distributions of predicted harvest means and observed point estimates (black points) of annual CRA harvest for the National Panel Survey (t), Blue Water Marine Research (BWMR) creel survey (Holdsworth 2016) and the six-ramp creel survey (kg day^{-1}) of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Whiskers indicate $1.5 \times$ the interquartile range, coloured points indicate outliers.

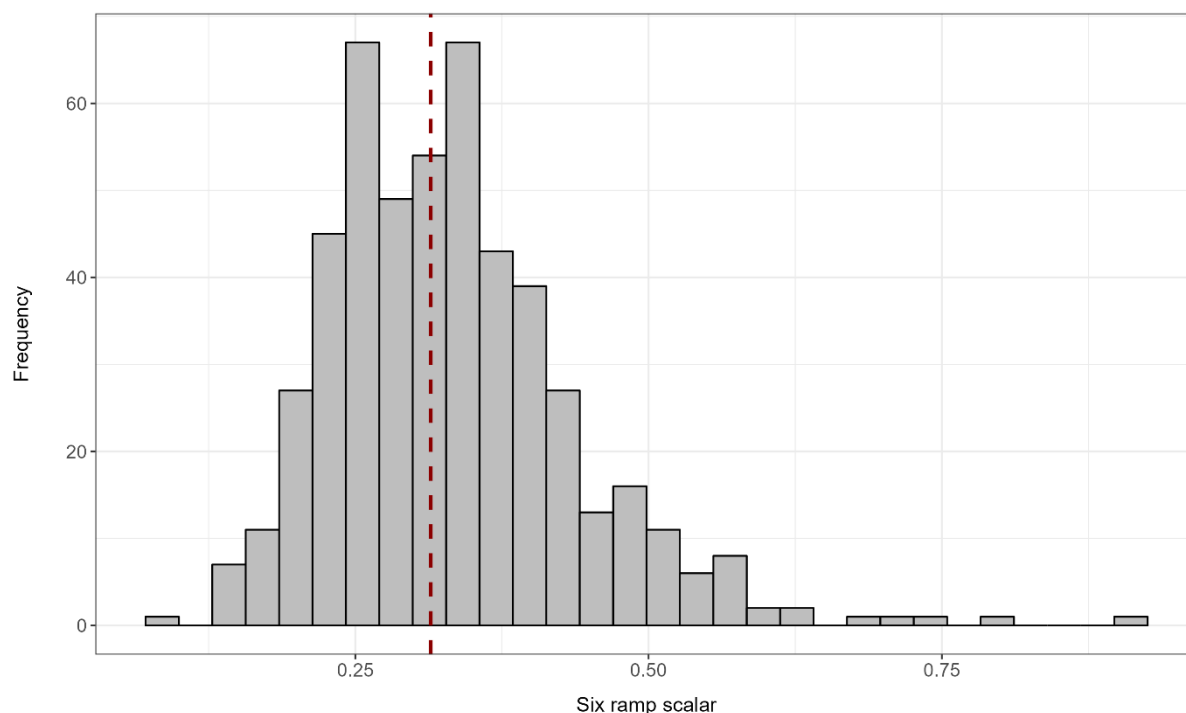


Figure 8: Simulated distribution of scalars from the maximum likelihood integrated model. The red dashed vertical line indicates the estimated six-ramp scalar.

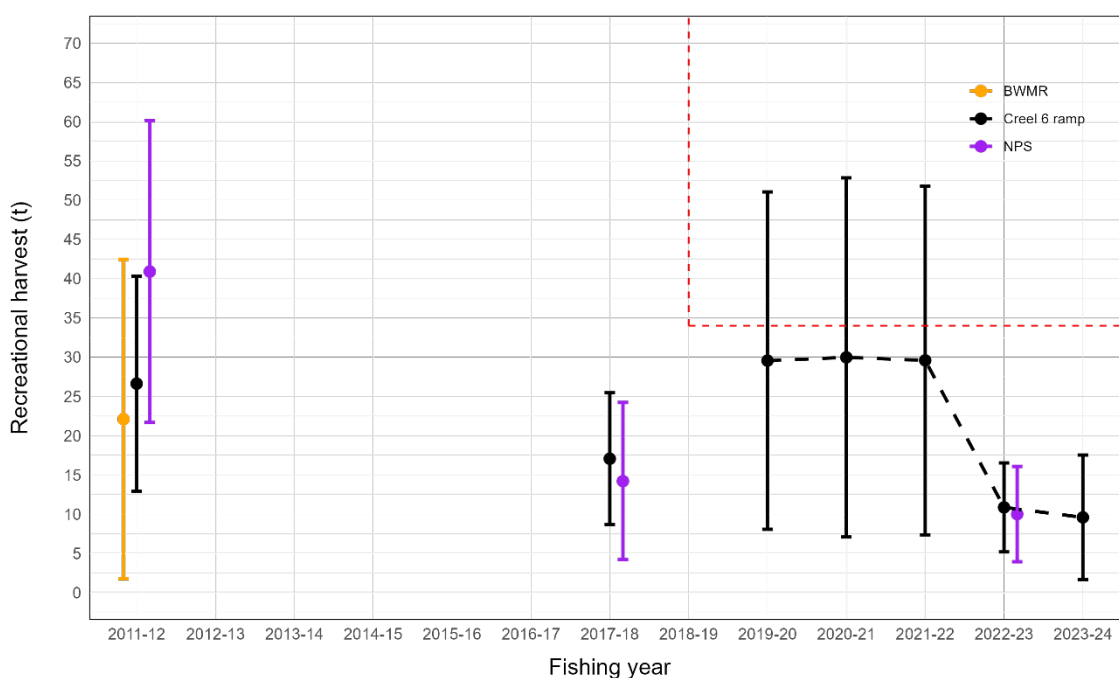


Figure 9: Annual scaled CRA harvest estimated by the maximum likelihood integrated model. Model input included absolute harvest estimates provided by the National Panel Survey (NPS) in 2011–12, 2017–18 and 2022–23 and the Blue Water Marine Research (BWMR) creel survey (Holdsworth 2016) in 2011–12. Model output: the scaled harvest estimated from six-ramp creel surveys of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. Red dashed line indicates the recreational allowance of 34 t. Error bars indicate 95% confidence intervals.

4. DISCUSSION

The recreational harvest was relatively high from 2019–20 to 2021–22, which aligned with the rebuilding of the stock reported in the 2022 stock assessment (Rudd et al. 2023). However, the harvest then declined sharply, in stark contrast to the projected trend in spawning stock biomass reported by Fisheries New Zealand (2023), suggesting that biomass may not be a strong driver of the recreational harvest.

This study surveyed the CRA 2 recreational private-vessel fishery at 11 boat ramps from 2019–20 to 2023–24, providing an 11-ramp relative harvest index. Six of the boat ramps monitored during this period had also been monitored during the 2011–12 and 2017–18 fishing years under previous Fisheries New Zealand projects. This allowed a temporal extension of our dataset, albeit at the expense of five ramps, which had not been monitored in the early years. Consequently, this study provided a longer, alternative, six-ramp relative harvest index. The two indices showed relatively similar trends for the 2019–20 to 2023–24 period, suggesting that the subset six-ramp network provided coverage of the CRA 2 recreational private-vessel fishery comparable to the 11-ramp network.

The survey schedule was disrupted in January and February 2023 by severe weather conditions. Following nearly a week of flooding, sampling scheduled for the 01 February 2023 was not possible at many ramps in Northland, Auckland, Coromandel, and Bay of Plenty due to a state of emergency, which included a government recommendation to stay off roads. Later, with the arrival of Cyclone Gabrielle, sampling scheduled for the 12 February 2024 was not possible at many ramps in Northland, Hauraki Gulf, Bay of Plenty and Hawkes Bay. Similarly, a national state of emergency was declared, and the government again advised against unnecessary travel. These two days were omitted from the analysis due to the disruption. However, due to the severe weather conditions, it would most likely be safe to

assume that very few if any lobster were landed on these days. A sensitivity run of the analysis with the two days added in with zero lobster catch produced nearly identical results to the analysis presented in this report.

Scaled harvest estimates were derived using two approaches. The sequential approach, adapted from Hartill et al. (2020), produced various scaled indices with reasonably good agreement. However, this approach received criticism for being sensitive to the choice of absolute estimates used in the scaling process (Breen 2022). The second approach, a new harvest estimation method, using an integrated model, was proposed by Breen (2022), and developed further by Marsh (2022). The model, which should still be considered developmental, integrates multiple data sources into a maximum likelihood estimation process, providing a robust scaling approach. It was not appropriate to incorporate the 11-ramp index into the integrated model alongside the six-ramp index. For the period 2019–20 to 2023–24, the six-ramp index is a subset of the 11-ramp index. Therefore, use of both indices would be a double use of the data. However, this aspect of the integrated model could be explored further.

A key assumption of this study is that the spring-summer period monitored in this study (October–February) provided sufficient coverage of the fishery to represent a relative annual harvest. This is a reasonable assumption, considering that very little CRA harvest has been reported in the winter period (Wynne-Jones et al. 2014, Holdsworth 2016, Hartill 2019, Wynne-Jones et al. 2019). With such low numbers of CRA harvested in the winter, any inter-annual variability in lobster landings during this season is not expected to influence the overall relative trend.

The second key assumption of this study is that the trends in effort and catch observed at a small number of monitoring sites are broadly representative of the wider recreational fishery taking place in surrounding waters. The 2011–12 discrepancy between the offsite diary-based NPS (Wynne-Jones et al. 2014) and all other estimates is concerning. Considering that the recreational CRA fishery has a low participation rate, it is possible that the catch by a few diarists may have unduly influenced the NPS harvest estimate in that year (Holdsworth 2016). However, the close alignment of the 2017–18 and 2022–23 scaled estimates with the concurrent NPS estimates is reassuring, especially as the two metrics show the same degree of change.

It is uncertain what has been driving the trend in the CRA 2 recreational harvest. Besides the underlying availability of rock lobster, reasons for harvest fluctuations may relate to several interacting factors, including the timing and nature of prevailing weather conditions, intentions to fish given perceived likely fishing success, and other societal factors, such as conflicting demands on a fisher's time and fuel prices. A rare three-year La Niña event lasted from July 2020 to March 2023 and affected local weather conditions with prolonged north to north-easterly winds. While this event was expected to have adversely affected fishing conditions, the trend in the harvest estimates does not support a direct effect of La Niña on the harvest. Similarly, any COVID-related restrictions, which may have restricted fishing outings, were no longer in place by the start of the 2022–23 fishing year. The daily bag limit change in July 2020 also did not appear to have an immediate effect on the overall harvest. However, the 2022–23 summer was characterised by severe local weather conditions, including repeated catastrophic flooding as well as Cyclone Hale and Cyclone Gabrielle. Weather conditions were markedly better in the spring-summer period of 2023–24, but this was not reflected in the harvest. Perhaps the closure of the Coromandel scallop fishery in late 2022 (Fisheries New Zealand 2023) discouraged combined lobster/scallop dive outings. Nevertheless, recreational harvest of CRA may fluctuate considerably from year to year without this variability being detected by the periodic NPS as seen in the period from 2019–20 to 2021–22.

While the underlying causes of inter-annual variability in the CRA 2 harvest may not be clear, inter-annual fluctuations appear to take place somewhat independent of biomass and on a finer temporal scale than can be detected by the periodic NPS. Evaluating the recreational allowance against the harvest and providing suitable inputs for stock assessment require ongoing harvest monitoring at an annual resolution. The results of this study, used in tandem with the periodic NPS, provide annual estimates for the recreational harvest in CRA 2 using a range of scenarios. However, it is suggested that the

harvest estimates predicted by the integrated model in this study be treated as preliminary, given that the model is still in the developmental phase.

5. POTENTIAL RESEARCH

The integrated model developed during this project shows promise but needs to be developed further if it is to become the preferred method for future CRA harvest estimation. The model output should be expanded, including adequate diagnostics, and the methods should be documented. The computer code should be managed on a version control repository. The model should also be generalised for use in other harvest estimation projects, such as the ongoing finfish harvest monitoring described by Maggs et al. (2024).

6. ACKNOWLEDGEMENTS

The authors wish to thank members of the Marine Amateur Fisheries Working Group for useful suggestions made during presentations of this programme in the past. We are also grateful to the large number of recreational fishers who have participated in creel surveys that provided much of the data used in our analyses, and to the part-time staff who interviewed these fishers. This work was funded by the Fisheries New Zealand project MAF2019-05. The authors also thank Steven Holmes, Jennifer Devine, and Richard O'Driscoll (NIWA) for their review of this report.

7. REFERENCES

- Breen, P.B. (2022). Alternative estimation of recreational catch from creel surveys. Presentation to the Marine Amateur Fisheries Working Group (MAFWG), online, 05 August 2022.
- Fisheries New Zealand (2023). Fisheries Assessment Plenary, November 2023: stock assessments and stock status. Compiled by the Fisheries Science Team, Fisheries New Zealand, Wellington, New Zealand. 689 p
- Fisher, D.O.; Dick, C.M. (2020). Database documentation: rec_data. *NIWA Fisheries Data Management Database Documentation Series*. 114 p.
- Hartill, B. (2019). Feasibility and design for a CRA 2 recreational harvest monitoring survey. *New Zealand Fisheries Assessment Report 2019/31*. 14 p.
- Hartill, B.W.; Watson, T. G.; Bian, R. (2011). Refining and applying a maximum-count aerial-access survey design to estimate the harvest taken from New Zealand's largest recreational fishery. *North American Journal of Fisheries Management*, 31(6): 1197–1210.
- Hartill, B.; Rush, N.; Payne, G.; Davey, N.; Bian, R.; Millar, A.; Armiger, H.; Spong, K. (2020). Camera and creel survey monitoring of trends in recreational effort and harvest from 2004–05 to 2018–19. *New Zealand Fisheries Assessment Report 2020/18*. 50 p.
- Heinemann, A.; Gray, A. (2024). National Panel Survey of Marine Recreational Fishers 2022–23. *New Zealand Fisheries Assessment Report 2024/51*. 116 p.
- Holdsworth, J.C. (2016). Amateur harvest estimates from an access point survey of marine fishers in the western Bay of Plenty, New Zealand in 2010–11 and 2011–12. *New Zealand Fisheries Assessment Report 2016/30*. 46 p.
- Kristensen, K.; Nielsen, A.; Berg, C.W.; Skaug, H.; Bell, B.M. (2016). TMB: Automatic differentiation and Laplace approximation. *Journal of Statistical Software* 70(5): 1–21.
- Maggs, J.Q.; Armiger, H.; Evans, O.; Taylor, R.; Davey, N.; Payne, G.; Miller, A.; Spong, K.; Parkinson, D.; Bian R.; Hartill, B.W. (2024). Trends in recreational boat effort and harvest from 2004–05 to 2022–23. *New Zealand Fisheries Assessment Report 2024/53*. 60 p.

- Marsh, C. (2022). Power analysis for integrated recreational catch estimation. Presentation to the Marine Amateur Fisheries Working Group (MAFWG), online, 27 September 2022.
- QGIS Development Team (2024). QGIS Geographic Information System. QGIS Association. <http://www.qgis.org>
- R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.
- Rudd, M.B.; Pons, M.; Webber, D.N.; Starr, P.J.; Roberts, J.; Goeden Z.D. (2023). The 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2023/43*. 108 p.
- Webber, D.N.; Starr P.J.; Haist, V.; Rudd, M.B.; Edwards, C.T.T. (2018). The 2017 stock assessment and management procedure evaluation for rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2018/17*. 87 p.
- Wynne-Jones, J.; Gray, A.; Hill, L.; Heinemann, A. (2014). National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.
- Wynne-Jones, J.; Gray, A.; Heinemann, A.; Hill, L.; Walton, L. (2019). National Panel Survey of Marine Recreational Fishers 2017–18. *New Zealand Fisheries Assessment Report 2019/24*. 108 p.

APPENDIX 1

Table A1: Number of survey sessions used in the *survey_s* dataset by survey date and ramp in the survey of the private-vessel recreational fishery at boat ramps in CRA 2 in 2011–12, 2017–18 and 2019–20 to 2023–24. GU: Gulf Harbour; KU: Kuaotunu; MK: Maketu; MW: Mangawhai; OO: Omaha; PN: Pauanui; SU: Sulphur Point; TK: Te Kaha; WK: Whakatane; WM: Whangamatā; WT: Whitianga. Day type ‘1’ is weekends/public holidays, ‘2’ is midweek days.

Date	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT
2011-10-02	1	2	—	—	—	2	—	4	—	2	2	3
2011-10-13	2	2	—	—	—	2	—	3	—	2	2	2
2011-10-23	1	2	—	—	—	2	—	4	—	2	2	2
2011-10-24	1	2	—	—	—	2	—	4	—	2	2	2
2011-11-02	2	2	—	—	—	2	—	3	—	2	2	2
2011-11-05	1	2	—	—	—	2	—	4	—	2	2	2
2011-11-06	1	2	—	—	—	2	—	4	—	2	2	2
2011-11-29	2	2	—	—	—	2	—	4	—	2	2	2
2011-12-15	2	2	—	—	—	2	—	4	—	2	2	2
2011-12-24	1	2	—	—	—	2	—	4	—	2	2	2
2011-12-27	1	2	—	—	—	2	—	3	—	2	2	2
2011-12-30	1	2	—	—	—	2	—	3	—	2	2	2
2012-01-08	1	2	—	—	—	2	—	2	—	2	2	2
2012-01-10	2	2	—	—	—	2	—	3	—	2	2	2
2012-01-14	1	2	—	—	—	2	—	4	—	2	2	2
2012-01-25	2	2	—	—	—	2	—	3	—	2	2	2
2012-02-06	1	2	—	—	—	2	—	5	—	2	2	2
2012-02-12	1	2	—	—	—	2	—	4	—	2	2	2
2012-02-15	2	2	—	—	—	2	—	3	—	2	2	2
2012-02-29	2	2	—	—	—	2	—	3	—	2	2	2
2017-10-01	1	1	—	—	—	1	—	3	—	2	2	2
2017-10-04	2	2	—	—	—	2	—	4	—	2	2	2
2017-10-15	1	2	—	—	—	2	—	4	—	2	1	2
2017-10-19	2	2	—	—	—	2	—	4	—	2	1	2
2017-10-23	1	1	—	—	—	2	—	4	—	2	2	3
2017-11-01	2	2	—	—	—	2	—	4	—	2	2	2
2017-11-04	1	2	—	—	—	2	—	4	—	2	2	2
2017-11-12	1	2	—	—	—	2	—	4	—	2	2	2
2017-11-25	1	2	—	—	—	2	—	4	—	2	2	2
2017-12-03	1	2	—	—	—	1	—	4	—	2	2	2
2017-12-14	2	2	—	—	—	2	—	4	—	2	2	2
2017-12-23	1	2	—	—	—	2	—	4	—	2	2	2
2017-12-29	1	2	—	—	—	2	—	4	—	2	2	2
2018-01-05	1	2	—	—	—	2	—	2	—	2	2	2
2018-01-07	1	2	—	—	—	2	—	4	—	2	2	2
2018-01-09	2	2	—	—	—	2	—	3	—	2	2	2
2018-01-13	1	2	—	—	—	2	—	4	—	2	2	2
2018-01-24	2	1	—	—	—	2	—	4	—	2	2	2
2018-02-04	1	1	—	—	—	2	—	2	—	2	2	2
2018-02-17	1	2	—	—	—	2	—	4	—	2	2	2
2018-02-28	2	2	—	—	—	2	—	3	—	2	2	2
2019-10-03	2	1	1	1	1	1	1	2	1	—	1	1
2019-10-06	1	—	1	1	1	1	1	2	1	—	1	1
2019-10-09	2	—	1	1	1	1	1	2	1	1	1	1
2019-10-14	2	1	1	1	1	1	1	1	1	1	1	1
2019-10-17	2	1	1	1	1	1	1	2	1	1	1	1
2019-10-20	1	1	1	1	1	1	1	2	—	1	1	1
2019-10-24	2	1	1	1	1	1	1	2	1	1	1	1
2019-10-27	1	1	1	1	1	1	1	2	—	1	1	1
2019-10-28	1	1	—	1	1	1	1	2	1	1	1	1
2019-11-05	2	1	—	1	1	1	1	1	1	1	1	1

Date	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT
2019-11-06	2	1	1	1	1	1	1	2	1	1	1	1
2019-11-09	1	1	1	1	1	1	1	2	1	1	1	1
2019-11-10	1	1	—	1	1	1	1	2	1	1	1	1
2019-11-13	2	1	1	1	1	1	1	2	1	1	1	1
2019-11-17	1	1	1	1	1	1	1	2	1	—	1	1
2019-11-20	2	1	1	1	1	1	1	2	1	1	1	1
2019-11-27	2	1	1	1	1	1	1	2	1	1	1	1
2019-11-30	1	1	1	1	1	1	—	2	1	1	1	1
2019-12-03	2	1	1	1	1	1	1	2	1	1	1	1
2019-12-06	2	1	1	1	1	1	1	2	1	1	1	1
2019-12-08	1	1	1	1	1	1	1	2	1	1	1	1
2019-12-12	2	1	1	1	1	1	1	1	—	1	1	1
2019-12-19	2	1	1	1	1	1	1	2	—	1	1	1
2019-12-23	1	1	1	1	1	1	1	2	1	1	1	1
2019-12-28	1	1	1	1	1	1	1	2	1	1	1	1
2019-12-31	1	1	1	1	1	1	1	2	1	1	—	1
2020-01-01	1	1	1	1	1	1	1	2	1	1	—	1
2020-01-03	1	1	1	1	1	1	1	1	1	1	1	1
2020-01-10	2	1	1	1	1	1	1	2	1	1	1	1
2020-01-12	1	1	1	1	1	1	1	2	1	1	1	1
2020-01-16	2	1	1	1	1	1	1	2	1	—	1	1
2020-01-18	1	1	1	1	1	1	1	1	1	—	1	1
2020-01-29	2	1	1	1	1	1	1	2	1	1	1	1
2020-02-01	1	1	1	1	—	1	1	2	1	1	1	1
2020-02-03	2	—	1	1	1	1	1	3	1	1	1	1
2020-02-09	1	1	1	1	1	1	1	2	1	1	1	1
2020-02-10	2	1	1	1	1	1	1	2	1	1	1	1
2020-02-13	2	1	1	1	1	1	1	1	1	1	1	1
2020-02-17	2	1	1	1	1	1	1	2	1	1	1	1
2020-02-19	2	1	1	1	1	1	1	2	1	1	1	1
2020-02-26	2	1	1	1	1	1	1	2	1	1	1	1
2020-10-01	2	1	1	1	1	1	1	2	1	1	1	1
2020-10-04	1	1	1	1	1	1	1	1	1	1	1	1
2020-10-07	2	1	1	1	1	1	1	2	1	1	1	1
2020-10-12	2	1	1	1	—	1	1	2	1	1	1	1
2020-10-15	2	1	1	1	1	1	1	2	1	1	1	1
2020-10-18	1	—	1	1	1	1	1	2	1	1	1	1
2020-10-22	2	1	1	1	1	1	1	2	1	—	1	1
2020-10-25	1	1	1	1	1	1	1	2	1	1	1	1
2020-10-26	1	1	1	1	1	1	1	2	1	1	1	1
2020-11-03	2	1	1	1	1	1	1	2	1	1	1	1
2020-11-04	2	1	1	1	1	1	1	2	1	1	1	1
2020-11-07	1	1	1	1	1	1	1	2	1	1	1	1
2020-11-08	1	1	1	1	1	1	1	2	1	1	1	1
2020-11-11	2	1	1	1	1	1	1	2	1	1	1	1
2020-11-15	1	1	1	1	1	1	1	2	1	1	1	1
2020-11-18	2	1	1	1	1	1	1	2	1	1	1	1
2020-11-25	2	1	1	1	1	1	1	2	1	1	1	1
2020-11-28	1	1	1	1	1	1	1	2	1	1	1	1
2020-12-01	2	1	1	1	1	1	1	1	1	1	1	1
2020-12-04	2	1	1	1	1	—	1	1	1	1	1	1
2020-12-06	1	1	1	1	1	1	1	1	1	1	1	1
2020-12-10	2	1	1	1	1	1	1	1	1	1	1	1
2020-12-17	2	1	1	1	1	1	1	2	1	1	1	1
2020-12-19	1	1	1	1	1	1	1	2	1	1	1	1
2020-12-26	1	1	1	1	1	1	1	1	1	1	1	1
2020-12-27	1	1	1	1	1	1	1	2	1	1	1	1
2020-12-29	1	1	1	1	1	1	1	1	1	1	1	1
2020-12-31	1	1	1	1	1	1	1	2	1	1	1	1

Date	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT
2021-01-01	1	1	1	1	1	1	1	2	1	1	1	1
2021-01-10	1	1	1	1	1	1	—	2	1	1	1	1
2021-01-12	2	1	1	1	1	1	1	2	1	1	1	1
2021-01-16	1	1	1	1	1	1	1	2	1	1	1	1
2021-01-21	2	1	1	1	1	1	1	2	1	1	1	1
2021-01-27	2	1	1	1	1	1	1	2	1	1	1	1
2021-02-03	2	1	1	1	1	1	1	1	1	1	1	1
2021-02-09	2	1	1	1	1	1	1	2	1	1	1	1
2021-02-11	2	1	1	1	1	—	1	2	1	1	1	1
2021-02-14	1	1	1	1	1	1	1	2	1	1	1	1
2021-02-15	2	1	1	1	1	1	1	2	1	1	—	1
2021-02-17	2	1	1	1	1	1	1	2	1	1	—	1
2021-02-24	2	1	1	1	1	1	1	2	1	1	—	1
2021-10-01	2	1	1	1	1	—	—	2	1	1	—	1
2021-10-03	1	1	1	1	1	—	—	2	1	1	—	1
2021-10-06	2	1	1	1	1	—	—	2	1	1	—	1
2021-10-11	2	1	1	1	1	1	—	2	1	1	—	1
2021-10-14	2	1	1	1	1	1	—	2	1	1	—	1
2021-10-17	1	1	1	1	1	1	—	2	1	1	1	1
2021-10-21	2	1	1	1	1	1	—	2	1	1	1	1
2021-10-24	1	1	1	1	1	1	—	2	1	1	2	1
2021-10-25	1	1	1	1	1	1	—	2	1	1	2	1
2021-11-02	2	1	1	1	1	1	1	2	1	1	1	1
2021-11-03	2	1	1	1	1	1	1	2	1	1	2	1
2021-11-06	1	1	1	1	1	1	1	1	1	1	—	1
2021-11-07	1	1	1	1	1	1	1	2	1	1	1	1
2021-11-10	2	1	1	1	1	1	—	2	1	1	1	1
2021-11-14	1	1	1	1	1	1	1	2	1	1	—	1
2021-11-17	2	1	1	1	1	1	1	2	1	1	1	1
2021-11-24	2	1	1	1	1	1	1	2	1	1	1	1
2021-11-27	1	1	1	1	1	1	1	2	1	1	1	1
2021-11-30	2	1	1	1	1	1	1	2	1	—	1	1
2021-12-03	2	1	1	1	1	1	1	1	1	1	1	1
2021-12-05	1	1	1	1	1	1	1	2	1	1	1	1
2021-12-09	2	1	1	1	1	1	1	2	1	1	1	1
2021-12-16	2	1	1	1	1	1	1	2	1	1	1	1
2021-12-18	1	1	1	1	1	1	—	2	1	1	1	1
2021-12-26	1	1	1	1	1	1	1	2	1	1	1	1
2021-12-28	1	1	1	1	1	1	—	2	1	1	—	1
2021-12-29	1	1	1	1	1	1	—	2	—	1	1	1
2021-12-31	1	1	1	1	1	1	—	2	1	1	1	1
2022-01-07	1	1	1	1	1	1	1	2	1	1	1	1
2022-01-09	1	1	1	1	1	1	1	2	1	1	1	1
2022-01-11	2	1	1	1	1	1	1	2	1	—	—	1
2022-01-15	1	1	1	1	1	1	1	2	1	1	1	1
2022-01-20	2	1	1	1	1	1	—	2	1	1	1	1
2022-01-26	2	1	1	1	1	1	1	2	1	1	1	1
2022-02-02	2	1	1	1	—	1	1	2	1	1	1	1
2022-02-08	2	1	1	1	1	1	1	2	1	1	1	1
2022-02-10	2	1	1	1	1	1	1	2	1	1	1	1
2022-02-13	1	—	1	1	1	1	—	2	1	1	—	1
2022-02-14	2	—	1	1	1	1	—	2	1	1	1	1
2022-02-16	2	—	1	1	1	—	—	2	1	1	1	1
2022-02-23	2	1	1	1	1	1	1	2	1	1	—	1
2022-10-02	1	1	1	1	1	1	1	2	1	1	1	1
2022-10-05	2	1	1	1	1	1	1	1	1	1	1	1
2022-10-07	2	1	1	1	1	1	1	1	1	1	1	1
2022-10-10	2	1	1	1	1	1	1	2	1	1	1	1
2022-10-13	2	1	1	1	1	1	1	2	1	1	1	1

Date	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT
2022-10-16	1	1	1	1	1	1	1	2	1	1	1	1
2022-10-20	2	1	1	1	1	1	1	2	1	1	1	1
2022-10-23	1	1	1	1	1	1	1	2	1	1	1	1
2022-10-24	1	1	1	1	1	1	1	2	1	1	1	1
2022-11-01	2	1	1	1	1	1	—	2	1	1	1	1
2022-11-02	2	1	1	1	1	1	1	1	1	1	1	1
2022-11-05	1	1	1	1	1	1	1	2	1	1	1	1
2022-11-06	1	1	1	1	1	1	1	1	1	1	1	1
2022-11-09	2	1	1	1	1	1	—	2	1	1	1	1
2022-11-13	1	1	1	1	1	1	1	1	1	1	1	1
2022-11-16	2	1	1	1	1	1	1	—	1	1	1	1
2022-11-23	2	1	1	1	1	1	1	1	1	1	1	1
2022-11-26	1	1	1	1	1	1	1	2	1	1	1	1
2022-11-29	2	1	1	1	1	1	1	2	1	1	1	1
2022-12-02	2	1	1	1	1	1	1	2	1	1	1	1
2022-12-04	1	1	1	1	1	1	1	2	1	1	1	1
2022-12-08	2	1	1	1	1	1	1	2	1	1	1	1
2022-12-15	2	1	1	1	1	1	1	2	1	1	—	1
2022-12-17	1	1	1	1	1	1	1	2	1	1	—	1
2022-12-24	1	—	1	1	1	1	1	1	1	—	—	1
2022-12-27	1	1	1	1	1	1	1	2	1	1	1	1
2022-12-30	1	1	1	1	1	1	1	2	1	1	1	—
2023-01-06	1	1	1	1	1	1	1	1	1	1	—	—
2023-01-08	1	1	1	1	1	1	1	1	1	1	1	1
2023-01-10	2	1	1	1	1	1	1	2	1	1	—	—
2023-01-14	1	1	1	1	1	1	1	1	1	1	1	1
2023-01-19	2	1	1	1	1	1	1	2	1	1	1	1
2023-01-25	2	1	1	1	1	1	1	2	1	1	1	1
2023-02-05	1	1	1	1	1	1	1	2	1	—	1	1
2023-02-07	2	—	1	1	1	1	1	2	1	1	1	1
2023-02-09	2	1	1	1	1	1	1	2	1	1	1	1
2023-02-15	2	—	1	1	1	1	1	1	1	—	—	—
2023-02-19	1	1	1	1	1	—	1	1	—	1	—	—
2023-02-20	2	1	1	1	1	1	—	2	1	1	—	1
2023-02-22	2	1	1	1	1	1	1	2	1	1	1	1
2023-10-01	1	1	1	1	1	1	1	2	1	1	1	1
2023-10-04	2	1	—	1	1	1	1	2	1	1	1	1
2023-10-09	2	1	—	1	1	1	1	2	1	1	1	1
2023-10-12	2	1	1	1	1	1	1	2	1	1	1	1
2023-10-15	1	1	1	1	1	1	1	-	1	1	1	1
2023-10-19	2	1	1	1	1	1	1	1	1	1	1	1
2023-10-22	1	1	1	1	1	1	1	1	1	1	—	1
2023-10-23	1	1	1	1	1	1	1	1	1	1	1	1
2023-10-31	2	1	1	1	1	1	1	1	1	1	1	1
2023-11-01	2	1	1	1	1	1	1	2	1	1	1	1
2023-11-04	1	1	1	1	1	1	1	2	1	1	1	1
2023-11-05	1	1	1	1	1	1	1	2	1	1	1	1
2023-11-08	2	1	1	1	—	1	1	1	1	1	1	1
2023-11-12	1	1	—	1	1	1	1	1	1	1	1	1
2023-11-15	2	1	1	1	—	1	—	1	1	1	1	1
2023-11-22	2	1	1	1	1	1	1	2	1	1	1	1
2023-11-25	1	1	1	1	1	1	1	2	1	1	1	1
2023-11-28	2	1	1	1	1	1	1	2	1	1	1	—
2023-12-01	2	1	1	—	1	1	1	1	1	1	1	1
2023-12-03	1	1	1	1	1	1	1	2	1	1	1	1
2023-12-07	2	1	1	1	1	1	1	2	1	1	1	1
2023-12-14	2	1	1	1	1	—	1	2	1	1	1	1
2023-12-16	1	1	1	1	1	1	1	1	1	1	—	1
2023-12-23	1	1	1	1	1	1	1	2	1	1	1	1

Date	Day type	GU	KU	MK	MW	OO	PN	SU	TK	WK	WM	WT
2023-12-26	1	1	1	1	1	1	1	1	1	–	1	1
2023-12-29	1	1	1	1	1	1	1	1	1	1	1	1
2024-01-05	1	–	1	1	1	1	1	1	1	1	1	1
2024-01-07	1	1	1	1	1	1	1	1	1	1	1	1
2024-01-09	2	1	1	1	1	1	1	–	1	1	1	1
2024-01-13	1	1	1	1	1	1	–	1	1	1	1	1
2024-01-18	2	1	1	1	1	1	1	2	1	1	1	1
2024-01-24	2	1	1	–	1	1	1	2	1	1	1	1
2024-01-31	2	1	1	1	1	1	1	1	1	1	1	1
2024-02-08	2	–	1	–	1	1	1	–	1	1	1	1
2024-02-11	1	1	1	–	1	1	1	1	1	1	1	–
2024-02-12	2	–	1	1	1	1	1	2	1	1	1	1
2024-02-14	2	1	1	1	1	1	1	2	1	1	1	1
2024-02-17	1	1	1	1	1	1	1	1	1	1	1	1
2024-02-19	2	1	1	1	1	1	1	2	1	1	1	1
2024-02-21	2	1	1	1	1	1	1	2	1	1	1	–
2024-02-28	2	1	1	1	1	1	1	2	1	1	1	1

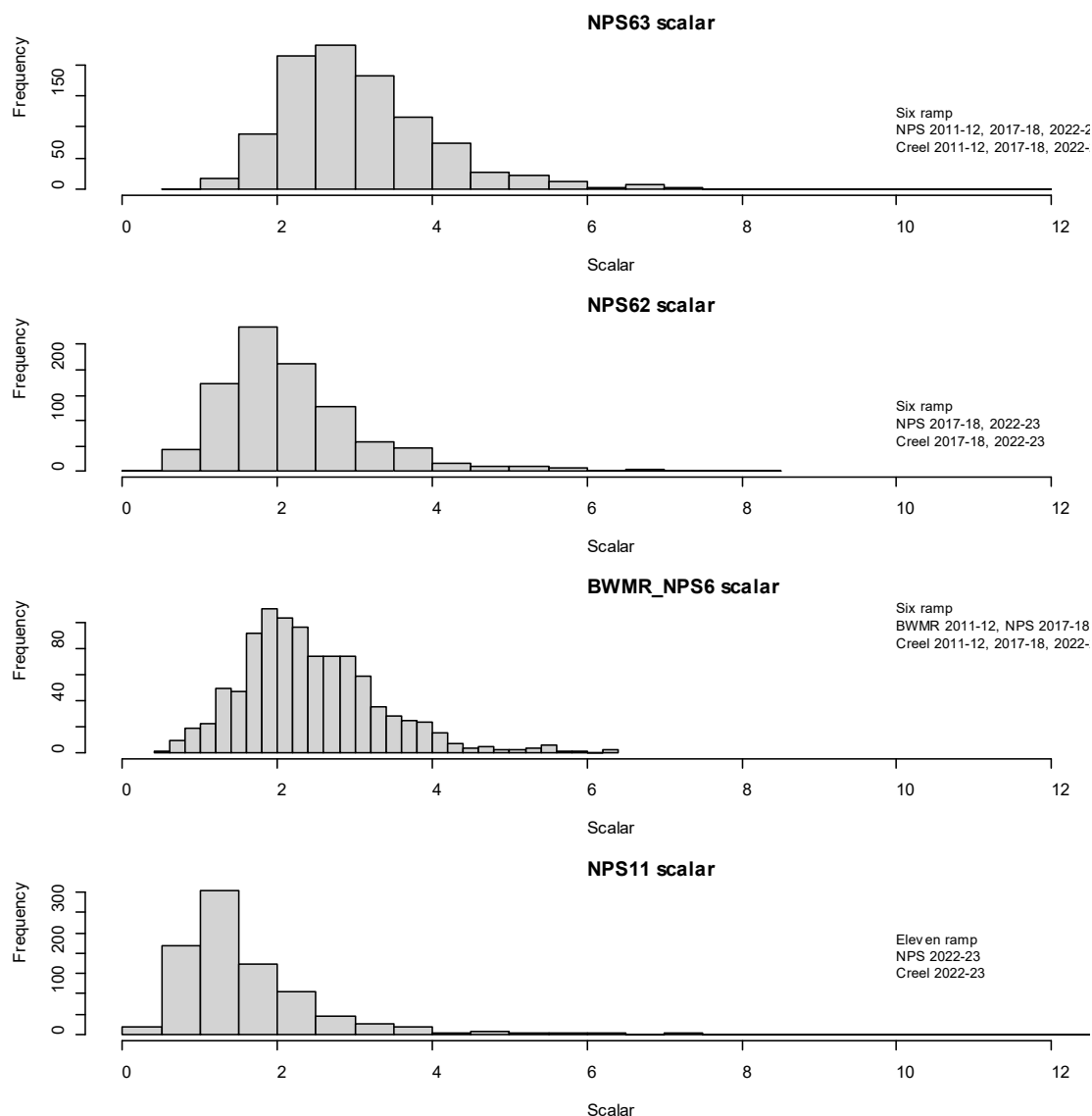


Figure A1: The distribution of 1000 bootstrapped (parametric) scalars derived under various scenarios indicating uncertainty in the ratio of relative harvest estimates to absolute harvest estimates. For each scenario, 1000 bootstrapped values were generated for the respective absolute harvest estimate (NPS: National Panel Survey; BWMR: Holdsworth 2016) and 1000 bootstrapped values for the respective relative harvest estimates. For each of the 1000 bootstrap records, the geometric mean of the absolute harvest estimates was divided by the geometric mean of the relative harvest estimates to produce one scalar value.

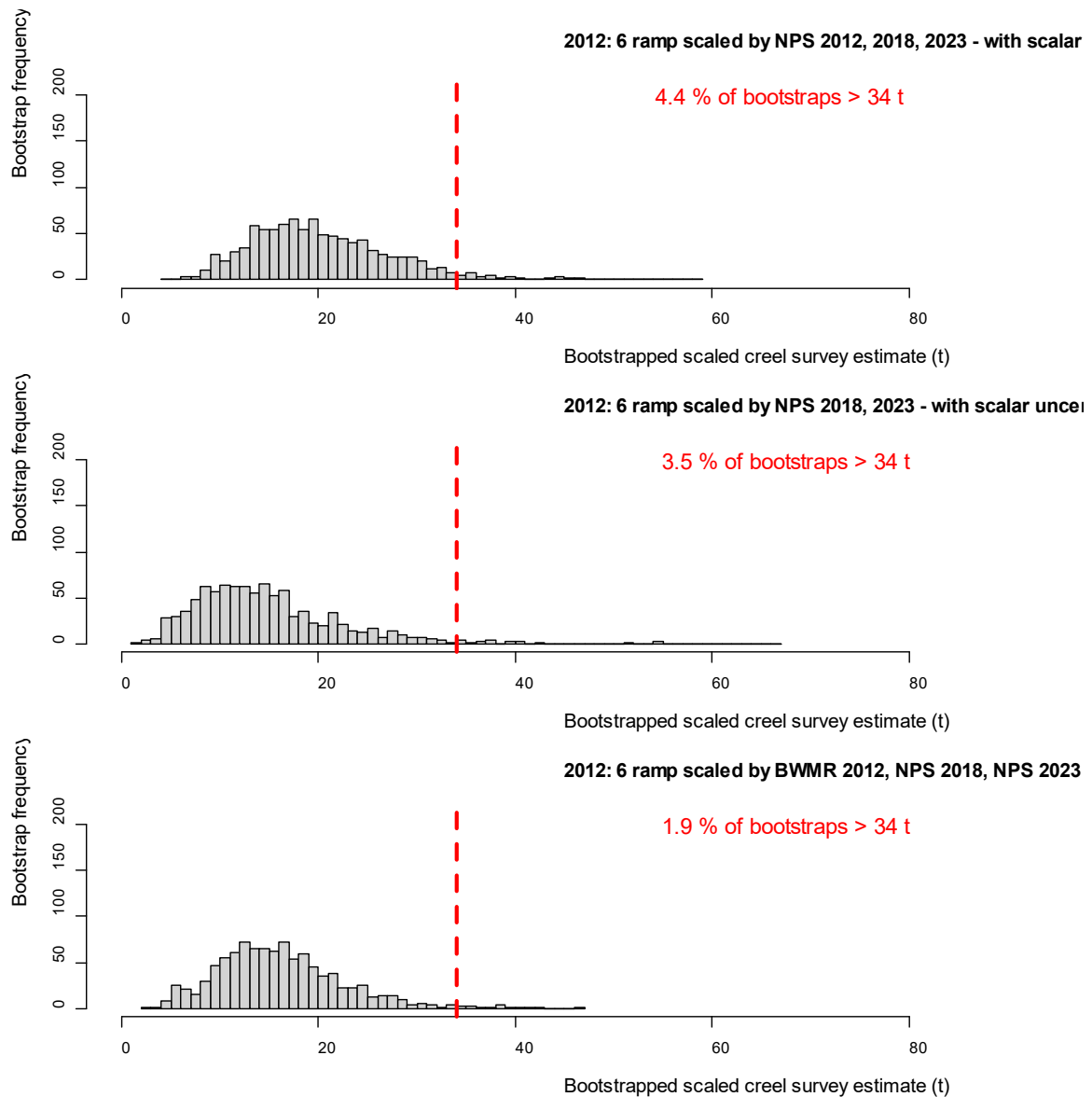


Figure A2: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2011–12 six ramp creel survey average daily catch to various scalar scenarios. Probability of exceeding the current recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t. Note that actual recreational allowance in 2011–12 was 140 t.

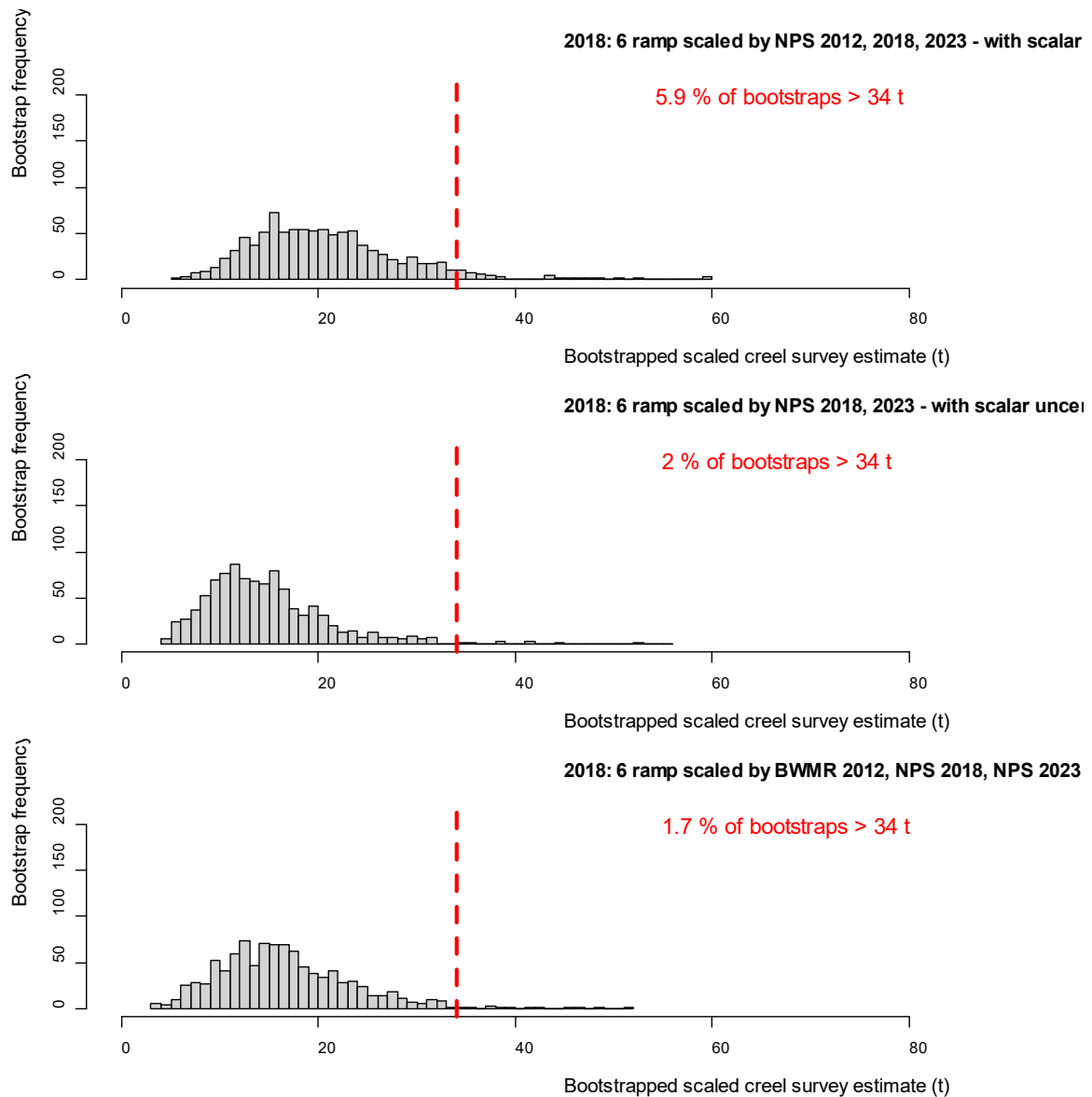


Figure A3: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2017–18 six ramp creel survey average daily catch to various scalar scenarios. Probability of exceeding the current recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t. Note that actual recreational allowance in 2017–18 was 140 t.

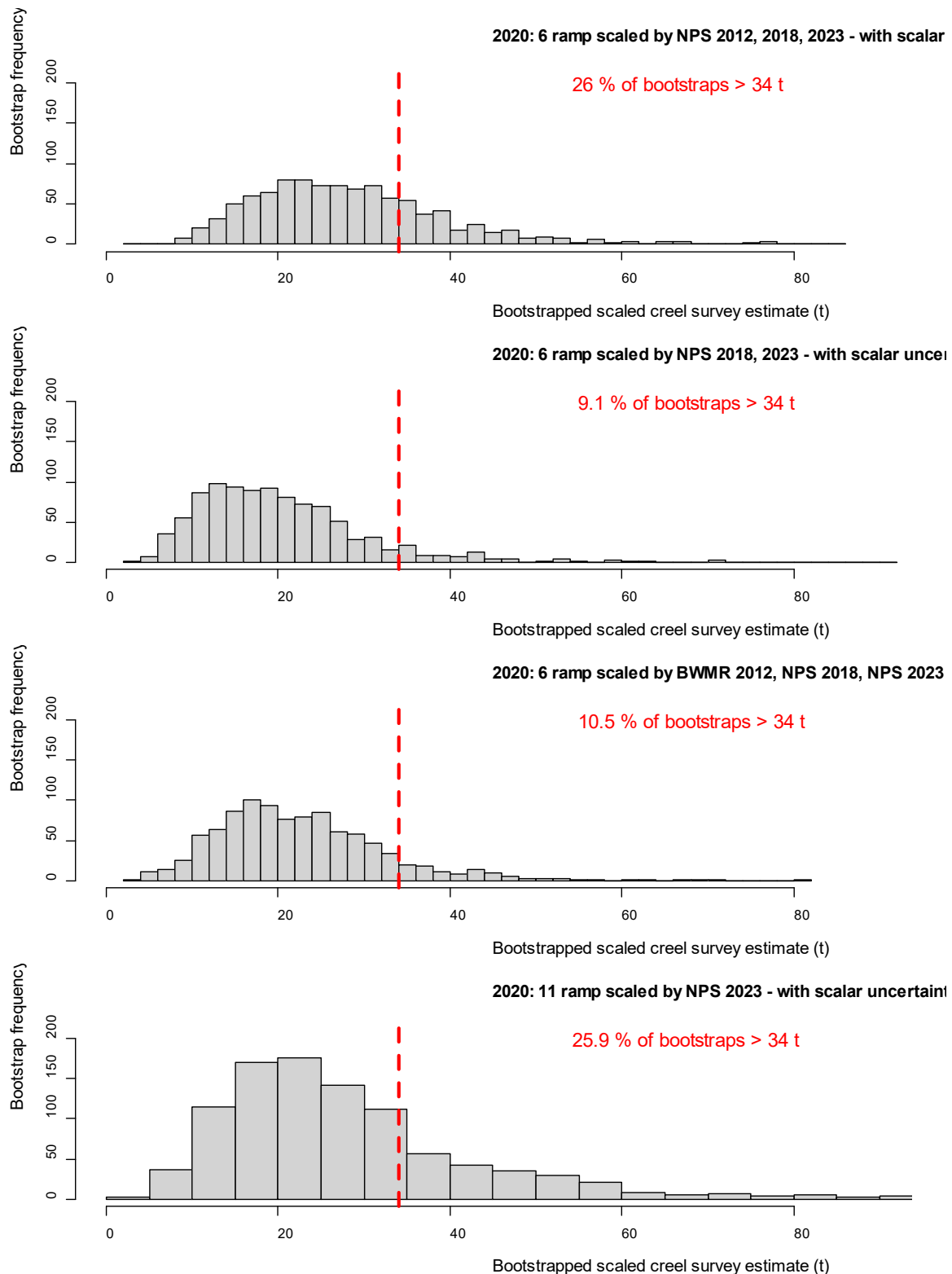


Figure A4: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2019–20 six and 11 ramp creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

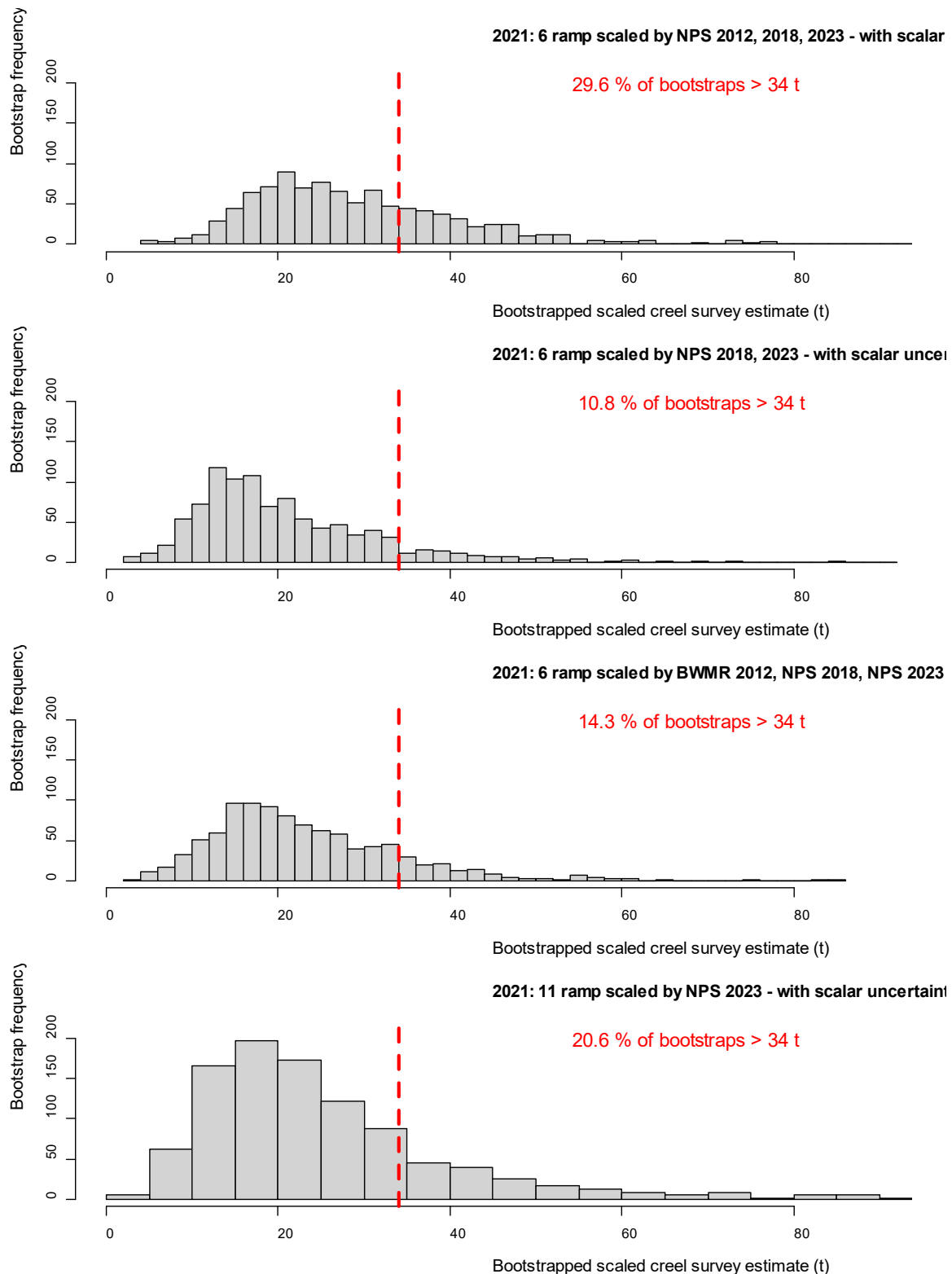


Figure A5: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2020–21 six and 11 ramp creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

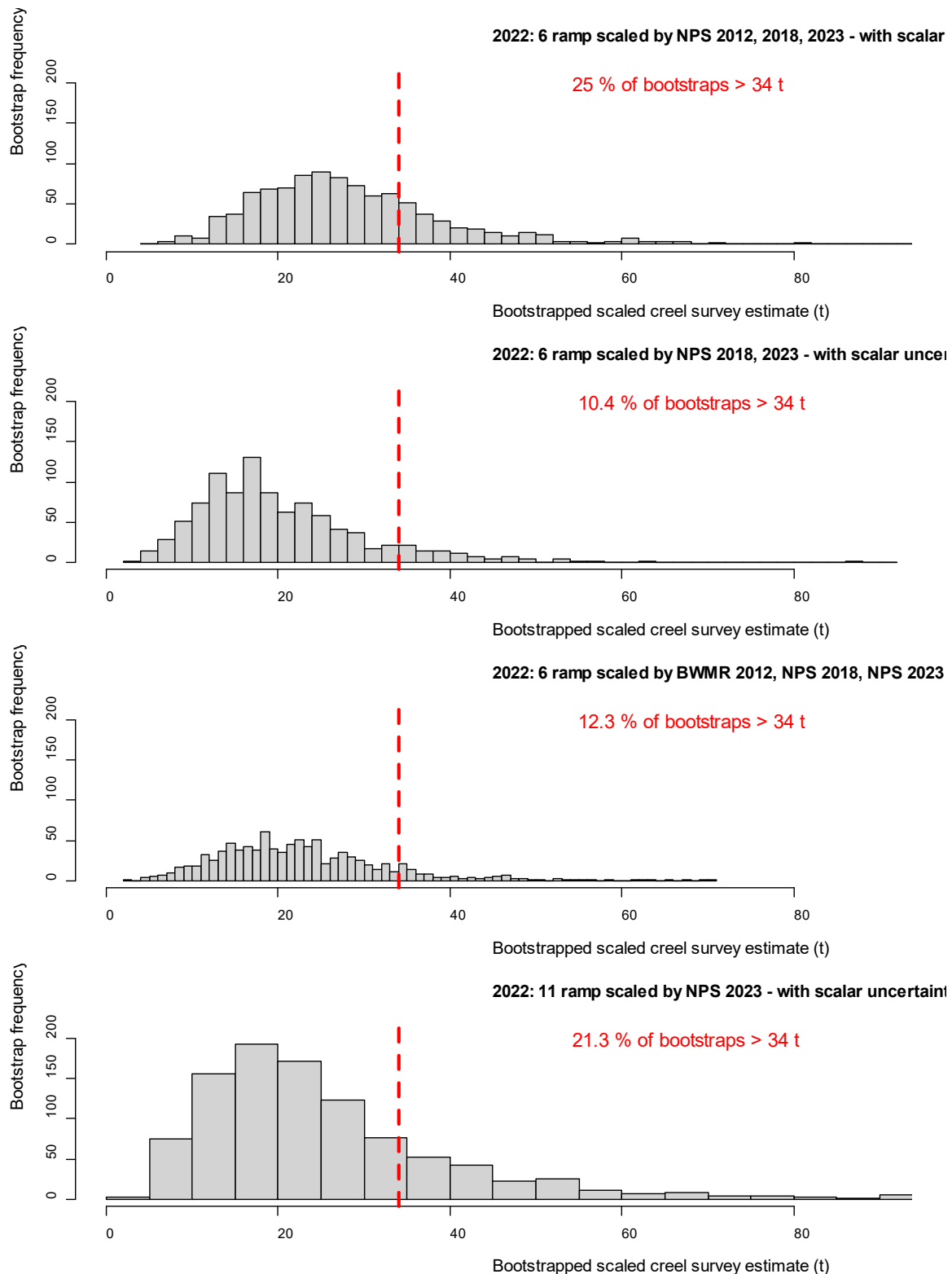


Figure A6: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2021–22 six and 11 ramp creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

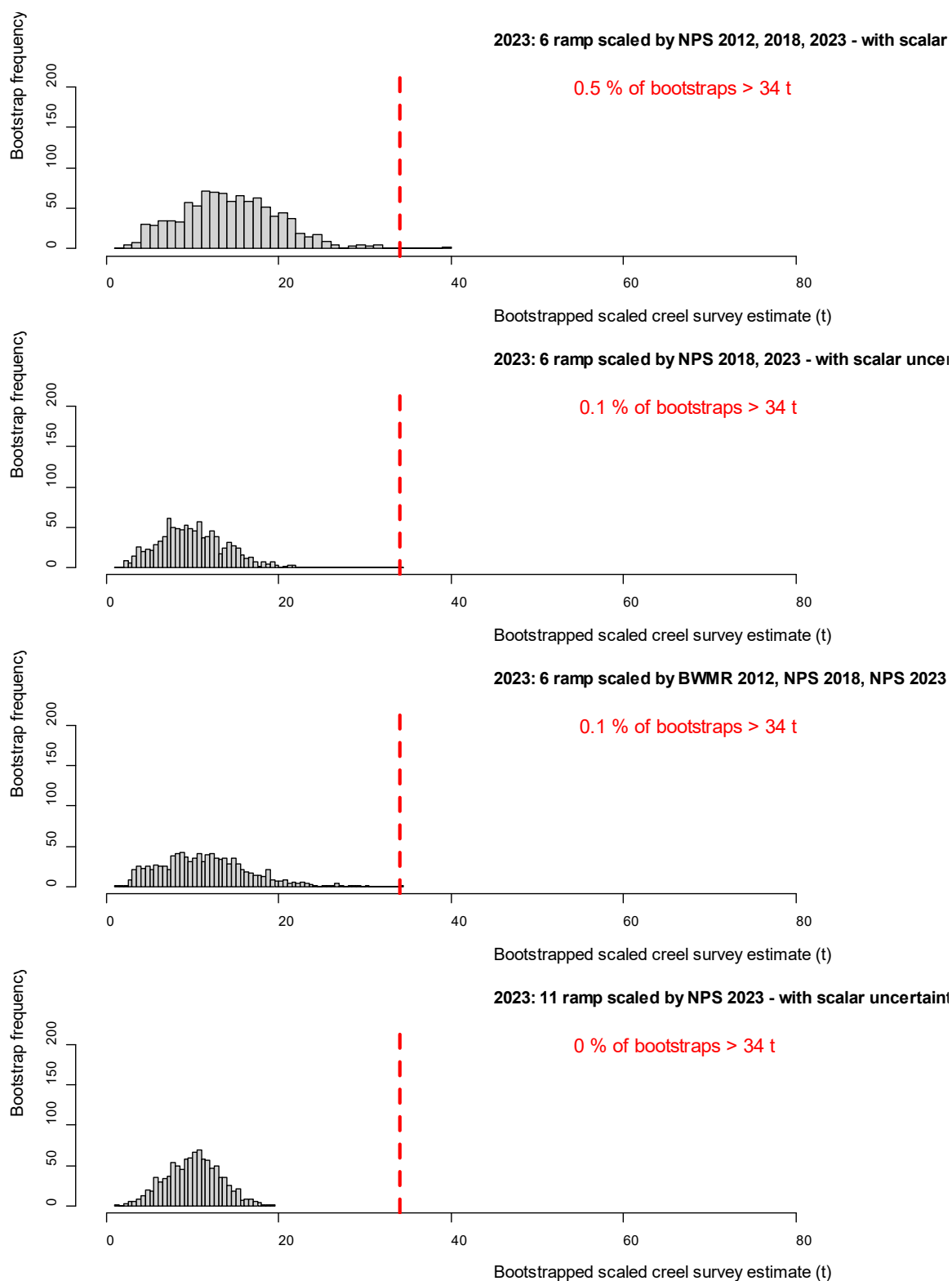


Figure A7: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2022–23 six and 11 ramp creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

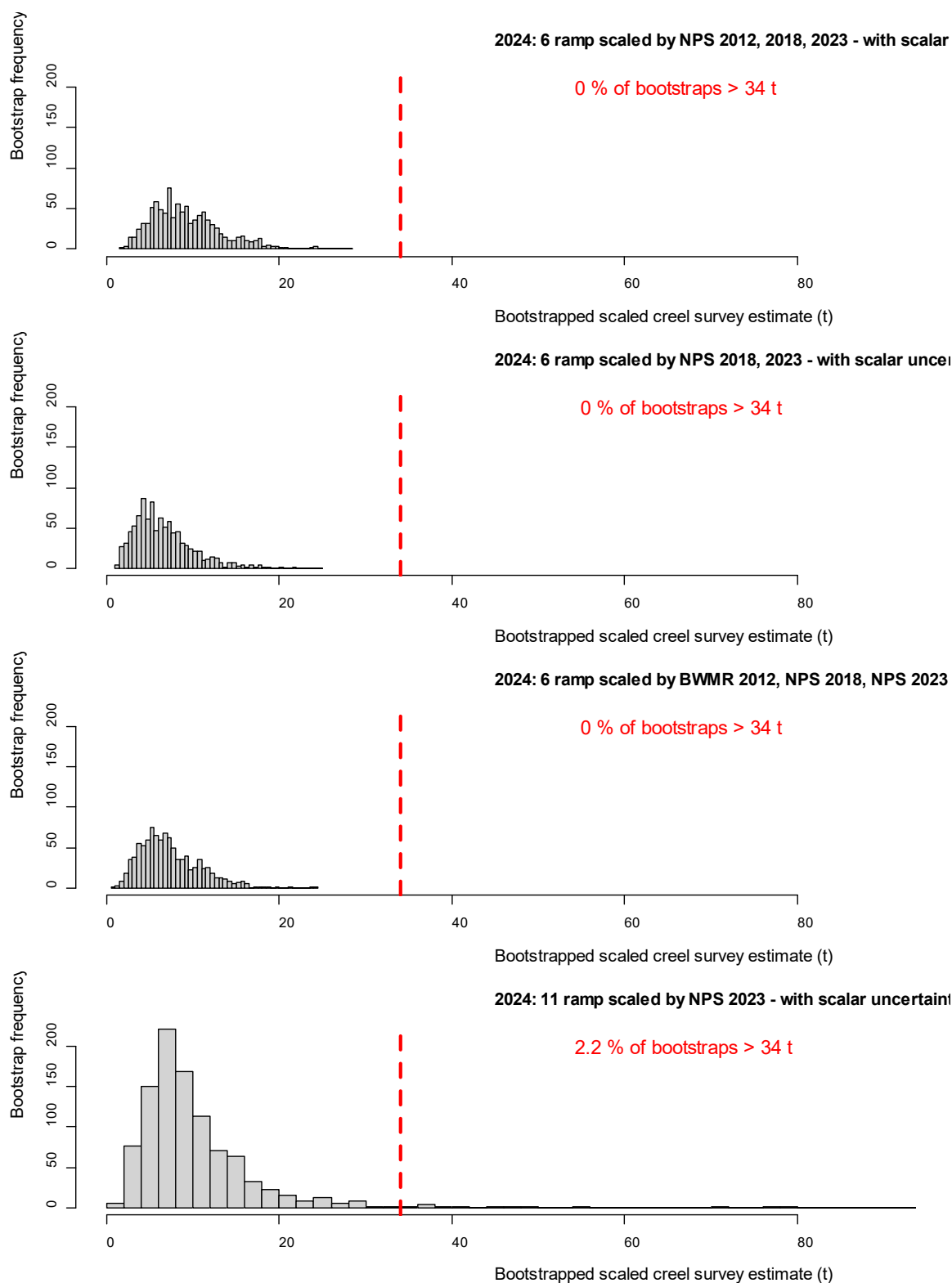


Figure A8: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling the 2023–24 six and 11 ramp creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

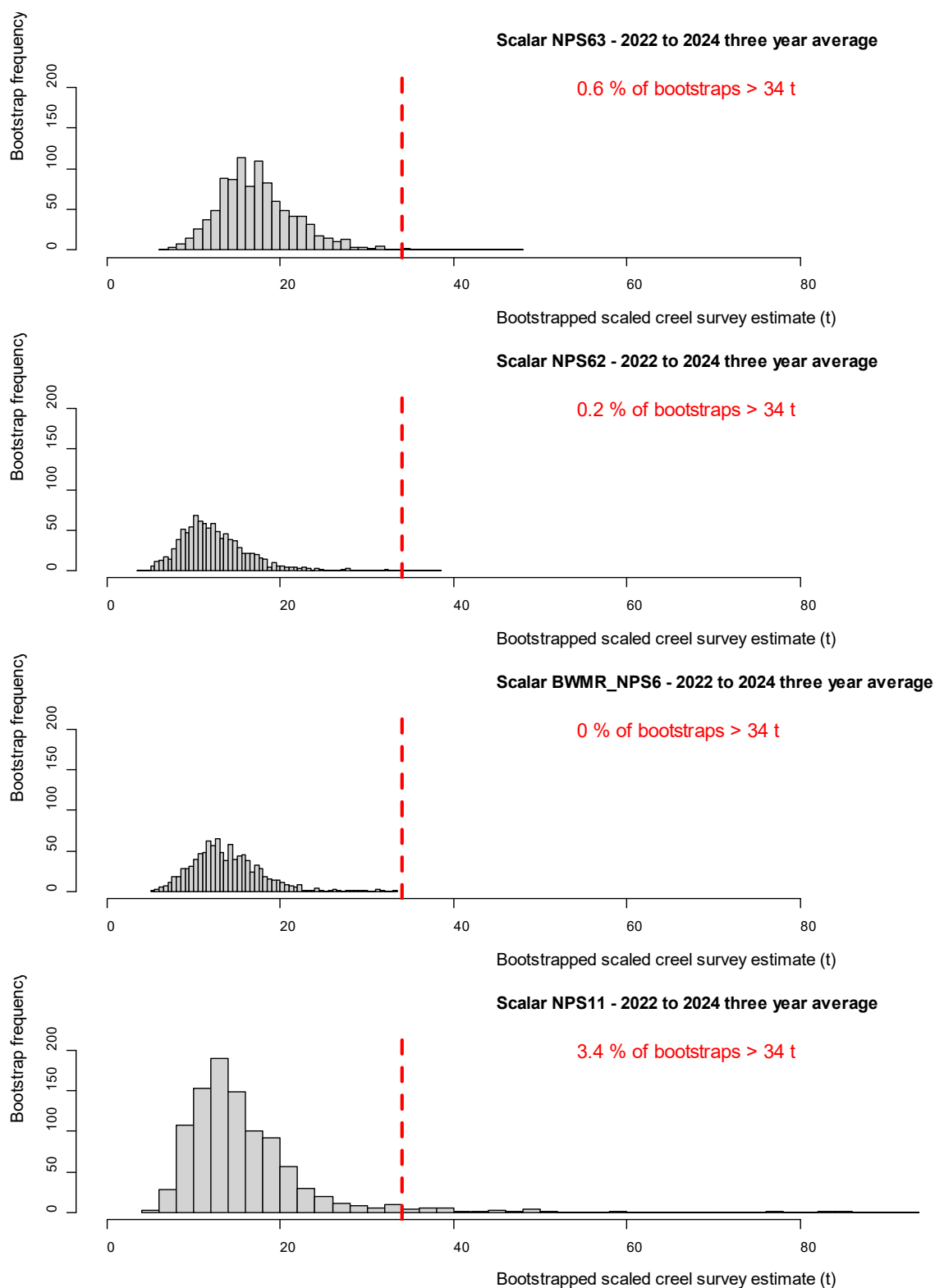


Figure A9: The distribution of bootstrapped (parametric) creel survey estimates resulting from scaling a three-year average creel survey average daily catch under various scalar scenarios. Probability of exceeding the recreational allowance (34 t) is indicated for each scenario as a percentage of bootstraps > 34 t.

Table A2: Estimated harvest (t) with standard error (SE), coefficient of variation (CV), lower confidence interval (LCI), upper confidence interval (UCI) and the probability of exceeding the 34 t recreational allowance ($P > 34$) for four scaling scenarios. NPS63: six-ramp creel index scaled to National Panel Survey (NPS) absolute estimates in 2011–12, 2017–18 and 2022–23. NPS62: six-ramp creel index scaled to NPS absolute estimates in 2017–18 and 2022–23. BWMR_NPS6: six-ramp creel index scaled to absolute estimates provided by Holdsworth (2016) for 2011–12 and the NPS for 2017–18 and 2022–23. NPS11: 11-ramp creel index scaled to the NPS absolute estimate in 2022–23.

Fishing year	<i>NPS63</i>					
	Harvest	SE	CV	LCI	UCI	$P > 34$
2011–12	19.9	7.4	0.36	9.2	37.8	0.04
2017–18	19.9	8.1	0.38	9.2	42.4	0.06
2019–20	26.5	11.5	0.40	11.4	56.5	0.26
2020–21	26.8	12.8	0.44	11.3	60.7	0.30
2021–22	26.5	11.9	0.42	12.1	60.6	0.25
2022–23	14.7	5.9	0.41	4.3	26.7	0.01
2023–24	8.6	4.1	0.44	3.2	18.6	0.00

Fishing year	<i>NPS62</i>					
	Harvest	SE	CV	LCI	UCI	$P > 34$
2011–12	13.9	8.3	0.54	4.5	36.8	0.04
2017–18	13.9	6.8	0.46	5.8	31.4	0.02
2019–20	18.4	10.6	0.51	6.7	47.0	0.09
2020–21	18.7	11.6	0.54	7.1	51.2	0.11
2021–22	18.5	11.0	0.53	6.7	47.6	0.10
2022–23	10.2	4.1	0.41	3.3	18.8	0.00
2023–24	6.0	3.6	0.54	2.0	16.2	0.00

Fishing year	<i>BWMR NPS6</i>					
	Harvest	SE	CV	LCI	UCI	$P > 34$
2011–12	16.2	6.6	0.40	5.6	31.7	0.02
2017–18	16.2	6.9	0.42	6.2	32.1	0.02
2019–20	21.5	9.9	0.44	7.7	45.8	0.11
2020–21	21.9	11.0	0.47	7.4	51.8	0.14
2021–22	21.6	10.2	0.45	7.7	47.2	0.12
2022–23	11.9	5.2	0.45	3.3	23.0	0.00
2023–24	7.0	3.5	0.48	2.3	15.5	0.00

Fishing year	<i>NPS11</i>					
	Harvest	SE	CV	LCI	UCI	$P > 34$
2011–12	–	–	–	–	–	–
2017–18	–	–	–	–	–	–
2019–20	25.1	26.5	0.85	9.1	96.6	0.26
2020–21	22.2	24.7	0.90	7.6	80.6	0.21
2021–22	22.5	24.8	0.90	7.2	85.7	0.21
2022–23	10.0	3.1	0.31	4.1	16.3	0.00
2023–24	8.8	9.4	0.88	2.8	30.5	0.02