Assessing the efficiency of alternative pot designs for the Southern Rock Lobster (*Jasus edwardsii*) fishery

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Executive Summary

This project was an industry-led initiative to investigate the potential for alternative pot designs to increase catch efficiency in the South Australian Southern Rock Lobster Fishery (SARLF). It was a collaboration among SARDI Aquatic and Livestock Sciences, PIRSA Fisheries and Aquaculture, the Northern Zone Rock Lobster Fishermen’s Association (NZRLFA), the South Eastern Professional Fishermen's Association (SEPFA), and Southern Rock Lobster Limited (SRL). The project comprised the most comprehensive program of pot-design testing ever undertaken for Southern Rock Lobster fisheries in Australia.

Southern Rock Lobster (*Jasus edwardsii*) are a valuable fishery resource contributing approximately AUD $250 million to the Australian economy annually. Within South Australia, Southern Rock Lobster are the most valuable fisheries resource, with an annual landed value (GVP) in 2020/21 of AUD ~$83 million (BDO EconSearch 2022a, b). The South Australian Rock Lobster Fishery uses baited pots to capture Southern Rock Lobster (*Jasus edwardsii*) in two management zones, the Northern Zone (NZ) and Southern Zone (SZ). Fishing gear types in South Australia are regulated under the *Fisheries Management (General) Regulations 2017*. Rock lobster pots traditionally used in each management zone are ‘beehive’ in shape and regulations relating to pot specifications are slightly different in each management zone. In both management zones, Total Allowable Commercial Catch (TACC) (quota) is set annually using region-specific harvest control rules relating to performance indicator estimates of relative abundance for legal-size lobster (Catch Per Unit Effort (CPUE); kg/potlift) and pre-recruit abundance (PRI; N undersize/potlift). In the 2021/22 season, the TACC in the NZ was 296 tonnes (250 t inner region, 46 t outer region) and in the SZ it was 1,320 tonnes (Linnane et al. 2022).

Economic analyses indicate inter-annual variation in economic returns in both zones since 2011/12, and recent decreases in net economic return since 2018/19 driven by COVID-19 market impacts and international trade disputes reducing export demand. Under TACC arrangements, improving the catch efficiency of fishing operations offers an opportunity to reduce input costs and improve net economic return with minimal risk to stock sustainability. However, to inform regulatory changes relating to rock lobster pot specifications, impacts on the catch efficiency of alternative pot designs for legal-size lobsters, undersize and spawning lobsters (discards), and bycatch/byproduct must be assessed. In addition, given the use of catch rates of legal-size and undersize lobster as primary and secondary performance indicator inputs into harvest strategy decision rules, any increases in catch efficiency from alternative pot designs need to be accounted for, and incorporated into, stock assessments and harvest strategies that underpin fishery management decisions.

The objectives of the project were:

1) to assess the catch efficiency of alternative pot designs for capturing Southern Rock Lobster through CPUE indices of: (i) legal-size lobsters; (ii) undersize lobsters; (iii) spawning (ovigerous) female lobsters and (iv) primary bycatch species; and

2) for one alternative pot design proposed by industry, develop and apply methods to calibrate raw CPUE for the alternative pot design for use in harvest strategy decision rules.

Testing of alternative pot designs was undertaken in a staged approach and included five phases of testing and data collection in the NZRLF between 2016/17 and 2021/22, and 2 phases of testing in the SZRLF in 2016/17 and 2018/19. At the completion of each phase of testing, results were reviewed by the project steering committee and testing approaches were developed for the following fishing season. The five phases of testing resulted in data for analyses across nine treatments (pot design comparisons) between 2017/18 and 2021/22 of which five treatments were tested in the NZRLF and four treatments were tested in the SZRLF. Overall, testing resulted in data from a total of 14,537 individual potlifts recorded from 17 fishers over 904 sampling days in 26 Marine Fishing Areas (MFAs).

The design with the greatest potential for increases in catch efficiency was the Western Australian (WA) batten pot. WA batten pots were consistently found to have higher catches of legal-size and undersize lobsters compared to traditional beehive pots. Statistical methods, developed to control for temporal (e.g. month) and spatial (e.g. MFA, depth) covariates, as well as lobster abundance, also indicated a higher catch efficiency of legal-size and undersize lobsters in WA batten pots compared to traditional beehive pots. Specifically, using a sample of geo-statistically matched pairs, ratios of the means of legal-size lobster catch weight ($\hat{\rho}_{C_W PUE}$) and undersize lobster (number) ($\hat{\rho}_{PRI}$) obtained from the two pot designs were 0.62 and 0.68, respectively.

Applying the sample ratio for legal-size lobster ($\hat{\rho}_{C_W PUE} = 0.62$) with respect to effort, NZRLF fishers adopting WA batten pot designs may reduce effort (potlifts) by up to 38%. Using the sample ratio for undersize lobster (number) ($\hat{\rho}_{PRI} = 0.68$), potential increases in undersize catches of up to ~32% for NZRLF fishers using WA batten pot designs would be offset by the overall reduction in effort (potlifts) required to take TACC.

Analyses of bycatch and byproduct sampled during testing indicated that the taxonomic composition of bycatch was similar in WA batten pots and traditional beehive pots. However, generally lower catches of all bycatch and byproduct taxa were observed from WA batten pots relative to traditional beehive pots. Further reductions in bycatch discard rates may occur for NZRLF fishers using WA batten pots where effort is reduced to take TACC.

The number of dead lobsters recorded during testing in the NZRLF was similar between WA batten pots and traditional beehive pots indicating that WA batten pots are not likely to increase lobster mortality rates via depredation. A reduction in the absolute number of dead lobsters landed each season could also be expected where effort is reduced to take TACC.

Exploratory analyses indicated no strong benefit in modelling legal-size catch weight and PRI catch ratios against any available dependent variable except month. The ratios of the means of legal-size catch weight and undersize catch (PRI) (number), from the paired samples by month, provide suitable conversion factors to account for the observed (and future predicted) variations in catch efficiency obtained from the traditional beehive pot design with respect to the WA batten pot design. Two methods to account for the measured differences in WA batten pot catch efficiency in future harvest strategy decision rules were developed. These were:

- remove data from vessels (licences) that are using the WA batten pot from the 2022-season yearly values of legal-size CPUE and PRI (applicable when the majority of licences continue to use the traditional beehive pot).
- apply the monthly ratio correction factors for legal-size CPUE ($\rho_{C_W PUE}$) and PRI (ρ_{PRI}) to legal-size CPUE and PRI estimated from all daily catches of licences using WA batten pots.

This study has several important implications. It highlights how modern-day arrangements of fishery co-management can lead to a framework of applied experimentation and statistical evidence to serve purposes for multiple stakeholders. The relative improvements in catch efficiency recorded from WA batten pots confirm their potential to lower the amount of fishing effort and costs required to attain TACCs. The project's results also give confidence to fishers in the NZRLF to invest in the purchase of WA batten pots. For fishery scientists and managers, the data provided through the project allow future stock assessment and management of the NZRLF to account for the relative increases in CPUE of legal-size and undersize lobster (PRI) attributed to WA batten pots.

The study also indicates that adoption of WA batten pots in the NZRLF, in conjunction with TACC, may have positive impacts on the sustainable fishing for Southern Rock Lobster via i) potential decreases in overall undersize lobster discard rates; ii) a reduction in catches of bycatch and byproduct, and potential improvements to bycatch discard rates; and iii) potential decreases in overall lobster mortality (depredation) rates.

The results of this project will positively impact on the economic performance of the NZRLF by providing all stakeholders with the information required to support implementation of a more efficient pot design that will assist in reducing fishing costs and increase profitability without compromising resource sustainability.

Keywords

Southern Rock Lobster, *Jasus edwardsii*, spiny lobster, fishing gear, rock lobster pot, batten pot crustacean fishery, catch efficiency, catch composition.

1 Introduction

Fishing operations have sought to improve catch efficiency to either improve catch landings or financial reward for centuries (Palomares and Pauly 2019). For modern commercial fishing operations, increases in catch efficiency lower the daily input costs of fishing operations, leading to increased profitability. Where a fishery's landings are fixed through regulated output controls such as quotas, advances in fishing-gear technology that improve catch efficiency may reduce the time to attain quota and improve economic returns.

Catch per unit effort (CPUE) is commonly used as an indicator of relative biomass and abundance in stock assessment and management of fisheries worldwide. Changes in effective fishing effort arising from increases in the technological efficiency of fishing operations can affect the utility of CPUE as a fishery performance indicator. The need to account for changes in effective effort ('technological creep') is well recognised in stock assessment and fishery management, but necessarily, is often analysed post-hoc using historical information collected as part of regulated reporting arrangements (Kleiven et al. 2022). Such information can be costly to obtain as it requires detailed review and analyses to account for changes in fishing gear efficiency.

Modern-day arrangements of fishery co-management, where industry stakeholders, scientists and regulators partner to share responsibility for resource sustainability, offer the opportunity to best account for changes in fishing gear efficiency using fishery-dependent structured experiments that benefit the fishing industry by providing statistical evidence to support investment in gear type changes, and research and management agencies in providing information that can be used in stock assessment to account for changes in catch efficiency. Such approaches ensure that any increases in catch efficiency and profitability associated with gear type changes do not come at the expense of stock assessment precision or stock sustainability.

Southern Rock Lobster (*Jasus edwardsii*) (Hutton 1875) are a valuable fishery resource contributing approximately AUD $250 million annually to the Australian economy (SRL 2023). The species inhabits rocky reefs, between 1 and 200 m depth, along the coastlines of southern mainland Australia, Tasmania, and New Zealand. In Australia, their range extends from Geraldton in Western Australia (29° S, 114° E) to Coffs Harbour in northern New South Wales (30° S, 172° E; Brown & Phillips 1994). Within South Australia, Southern Rock Lobster are the most valuable fisheries resource, with an annual landed value (GVP) in 2020/21 of AUD ~$83 million (BDO EconSearch 2022a, b).

The South Australian Rock Lobster Fishery uses pots baited with Australian Salmon (*Arripis truttaceus*), Blue Mackerel (*Scomber australasicus*), European Carp (*Cyprinus carpio*) or other fish species to capture Southern Rock Lobster (*Jasus edwardsii*) in two management zones, the Northern Zone and Southern Zone. The Northern Zone Rock Lobster Fishery (NZRLF) is extensive, covering all South Australian marine waters between the mouth of the Murray River and the border between South Australia and Western Australian, an area of approximately 207,000 km^2 (Figure 1). In 2015/16, based on the outcomes from Linnane et al. (2016), spatial management of the NZRLF was implemented and individual quotas for 'Inner' and 'Outer' sub-regions were introduced. The Southern Zone Rock Lobster Fishery (SZRLF) includes all South Australian waters between the mouth of the Murray River and the border between South Australia and Victoria, an area of approximately 22,000 km^2. Both zones are managed through a combination of input controls (limited entry, closed seasons/areas, pot limits, pot dimension restrictions), and output controls (quotas - Total Allowable Commercial Catch (TACC); minimum legal-size limits; and prohibition on the taking of ovigerous females).

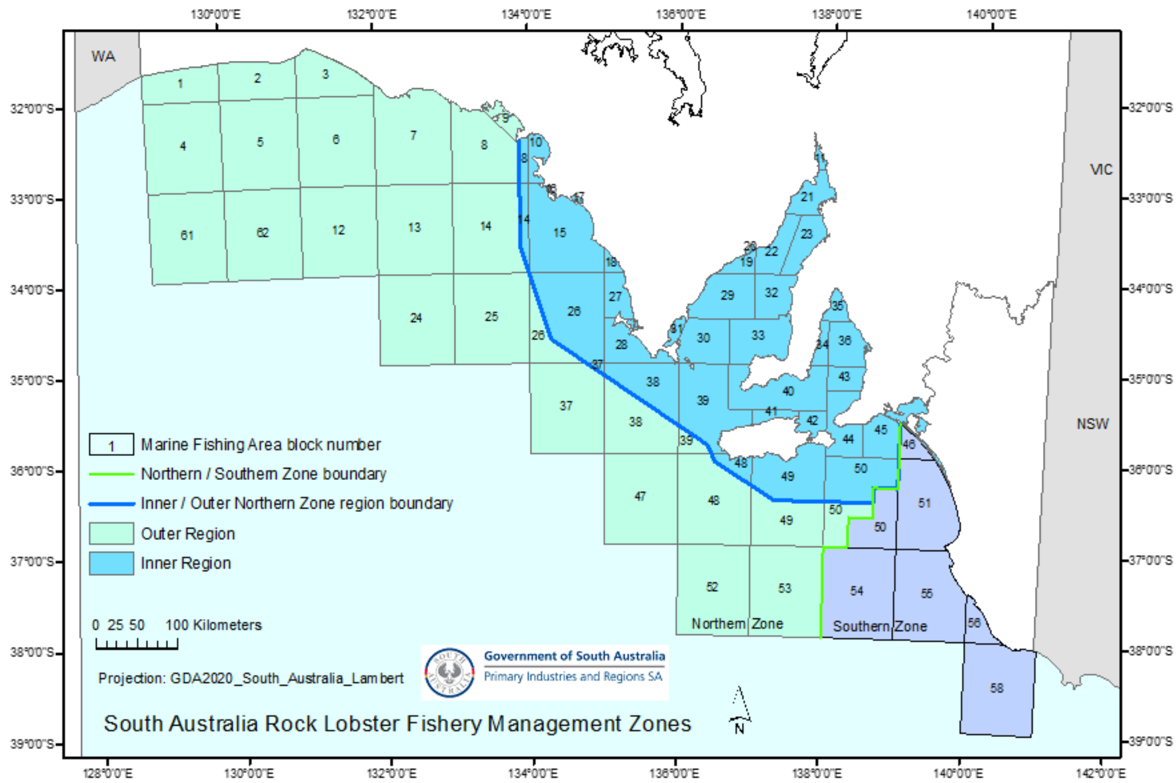


Figure 1. The Northern Zone and Southern Zone management areas of the South Australian Rock Lobster Fishery.

Fishing gear types in South Australia are regulated under the *Fisheries Management (General) Regulations 2017*. Rock lobster pots traditionally used in each management zone are 'beehive' in shape and regulations relating to pot specifications are slightly different in each management zone. In the NZ, rock lobster pots must:

- weigh not more than 40 kilograms;

- be not more than 61 cm high and not more than 122 cm wide at the base;
- have its cove mouth at the top of the pot;
- have two rectangular escape gaps not less than 5.7 cm high and 28 cm wide located not more than 11 cm above the base of the pot; and
- if fishing in waters <100m, have a Sea Lion exclusion device (SLED) comprising either: a) a metal rod ('spike') that is securely fastened to the centre of the base and extends perpendicular to a height not less than level with the base of the neck of the pot or b) a 'squeezy neck' comprised of a rigid metal frame rectangular or square in shape with two opposite sides opening to not more than 135 mm securely attached to the pot neck or circular in shape opening to not more than 150 mm in diameter securely attached to the pot neck. **Note, at the time of this report squeezy neck SLEDs were not regulated and their use had to be applied for under a Ministerial Exemption*.

In the SZ, rock lobster pots must:

- not exceed 150 centimetres at its widest part; or 120 centimetres in height;
- have two rectangular escape gaps not less than 5.5 cm high and 15 cm wide located not more than 11 cm above the base of the pot, or if there are no escape gaps, the pot must be covered in a mesh that will easily allow a 5 cm cylindrical rod to pass through; and
- have a cove mouth at the top of the pot (noting that SLEDs are not a regulation requirement in the SZ).

In both management zones, TACCs are set annually using region-specific harvest control rules relating to performance indicator estimates of CPUE for legal-size lobster (kg/potlift) and pre-recruit abundance (PRI) (N undersize/potlift) (PIRSA 2021). The TACC is divided among licence holders as individual transferable quotas (ITQs). Each licence holds one quota unit entitlement for each pot entitlement held. In the 2021/22 season, the annual TACC in the NZ was 296 tonnes (t: 250 t in the inner region, 46 t in the outer region) and in the SZ was 1,320 tonnes. Daily catches of lobster are monitored through mandatory commercial logbooks and quota monitoring catch and disposal records.

Recent economic analyses indicate inter-annual variation in economic returns in both zones since 2011/12, and decreases in net economic return since 2018/19 largely driven by COVID-19 market impacts, and international trade disputes reducing export demand (BDO EconSearch 2022a, b). Under TACC arrangements, improving the catch efficiency of fishing operations offers an opportunity to reduce the input costs and improve net economic return with minimal risk of compromising management effectiveness.

Previous research relating to the effects of different pot designs on rock lobster catch has focussed on target-size selectivity (Arana et al 2011; Broadhurst et al. 2017; Broadhurst and

Millar 2018; Treble et al. 1998), bycatch reduction and exclusion (Asanopoulos et al. 2018; Goldsworthy et al. 2010; Linnane et al. 2011) and depredation reduction (Brock et al 2006). Less research focus has been placed on assessing whether lobster catch efficiency can be improved through pot design alterations. However, testing of alternative pot designs in fishing operations for Western Rock Lobster (*Panulirus cygnus*) in Western Australia indicated increases in legal-size lobster catches of up to 50% from broad-based batten pots with side-entry points under particular soak time and season conditions (Winzer at al. 2011). Corresponding decreases in capture rates of undersize lobsters were also indicated. Although the study acknowledged that further testing was required due to low sample sizes, research showed the potential to reduce seasonal fishing costs in the West Coast Rock Lobster Fishery by up to AUD$4 million per season if 50% of the fleet were to switch to the alternative pot type (Winzer et al. 2011). In a separate study, Montgomery (2005) recorded higher catches of Eastern Rock Lobster (*Jasus verreauxi*) in D-shaped and rectangular traps compared to beehive shaped traps, further indicating the potential of alternative pot designs to influence lobster catch efficiency.

This FRDC-funded project is an industry lead initiative aimed at investigating the potential for alternative pot designs to increase catch efficiency in the South Australian Southern Rock Lobster Fishery. By maximising potential economic return, the project addresses two FRDC strategic priorities: 1) optimise food and fibre production using our land and marine resources; and 2) identify the means by which Australia can lift productivity and economic growth.

2 Need

All Southern Rock Lobster fisheries within Australia are managed under TACCs. As a consequence, these fisheries are not regulated by controlling capture efficiency or fishing effort, so improving the catch efficiency of commercial fishing operations offers an opportunity to substantially improve net economic return with minimal risk of compromising management effectiveness. Alternative pot designs have the potential to increase catch rates and fleet efficiency thereby lowering overall operating costs and improving profitability.

However, before amendments to the *Fisheries Management (General) Regulations 2017* relating to rock lobster pot designs can occur, changes in the catch efficiency of alternative pot designs for legal-size lobsters, undersize and spawning female lobsters (discards), and bycatch must be assessed. This is best achieved through structured fishing experiments that enable robust comparison of catch rates of: legal-size lobster, undersize lobster; (iii) spawning (ovigerous) female lobsters; and (iv) bycatch from alternative and traditional pot designs.

In addition, given the use of legal-size and undersize catch rates as primary and secondary performance indicator inputs into harvest strategy decision rules for both management zones in South Australia, any increases in catch rate estimated from alternative pot designs need to be accounted for and subsequently incorporated into stock assessments and the harvest strategies that underpin fishery management decisions.

3 Objectives

1. Assess the catch efficiency of alternative pot designs for capturing Southern Rock Lobster through CPUE indices of: (i) legal-size lobsters; (ii) undersize lobsters; (iii) spawning (ovigerous) female lobsters and (iv) primary bycatch species.

2. For one alternative pot design proposed by industry, develop and apply methods to calibrate raw CPUE for the alternative pot design for use in harvest strategy decision rules.

4 Methods

4.1 Overview

Alternative pot designs were either constructed by SARLF fishers or obtained from interstate. Testing was undertaken by commercial fishers in a staged approach. There were five phases of testing and data collection in the NZRLF between 2016/17 and 2021/22 (Figure 2), and 2 phases of testing in the SZRLF in 2016/17 and 2018/19 (Figure 3). A Ministerial Exemption (permit) was required to undertake pot design testing in each season as alternative pot designs did not conform to pot specifications listed within the *Fisheries Management (General) Regulations 2017*.

At the completion of each phase of testing, the results were presented to the project steering committee comprised of Executive Officers of the NZRLF and SZRLF, PIRSA fishery managers and SARDI research scientists. The results from each phase of testing informed the choice of designs to be tested in the next phase of the project in the following fishing season or whether testing of a pot design was discontinued.

The five phases of testing resulted in data for analyses of nine treatments (pot design comparisons) between 2017/18 and 2021/22. Five treatments (treatments 1–5) were tested in the NZRLF over four fishing seasons and four treatments (treatments 6–9) were tested in the SZRLF over one fishing season (Table 1, Figures 2 & 3).

Table 1. Pot design comparisons (treatments) tested in the project.

Treatment	Alternative Pot design	Traditional pot design
Northern Zone		
1	WA batten pot (squeezy neck)	Traditional NZRLF beehive (spike)
2	Toumazos double entry (squeezy neck)	Traditional NZRLF beehive (spike)
3	WA batten pot (spike)	Traditional NZRLF beehive (spike)
4	WA batten pot (squeezy neck)	Traditional NZRLF beehive (squeezy neck)
5	Traditional NZRLF beehive (squeezy neck)	Traditional NZRLF beehive (spike)
Southern Zone		
6	Traditional SZRLF beehive (180mm squeezy neck)	Traditional SZRLF beehive (no SLED)
7	Double chamber (no SLED)	Traditional SZRLF beehive (no SLED)
8	Traditional SZRLF beehive (135mm squeezy neck)	Traditional SZRLF beehive (no SLED)
9	WA batten pot (no SLED)	Traditional SZRLF beehive (no SLED)

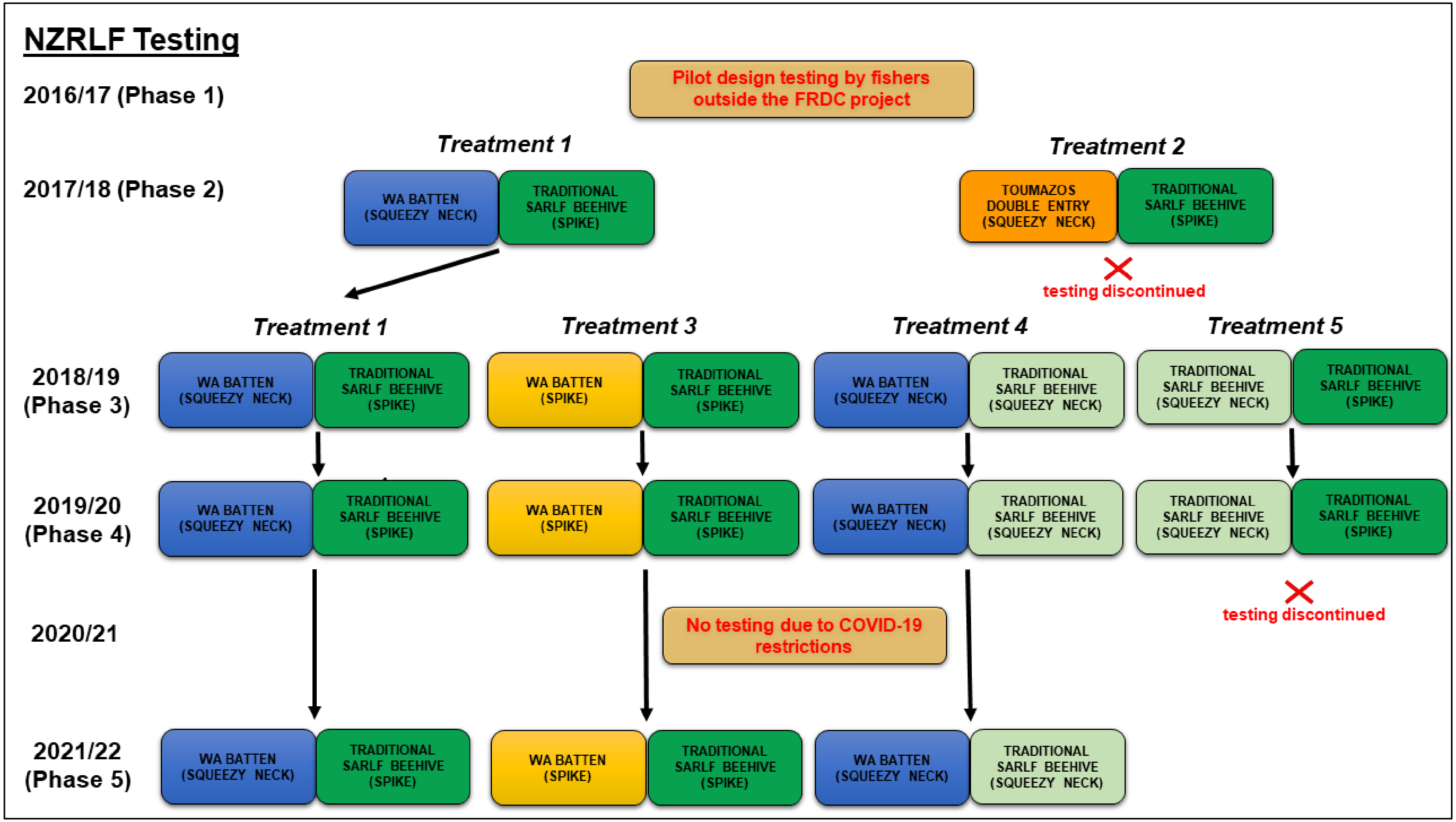


Figure 2. Phased approach to alternative pot design testing in the Northern Zone Rock Lobster Fishery between 2016/17 and 2021/22.

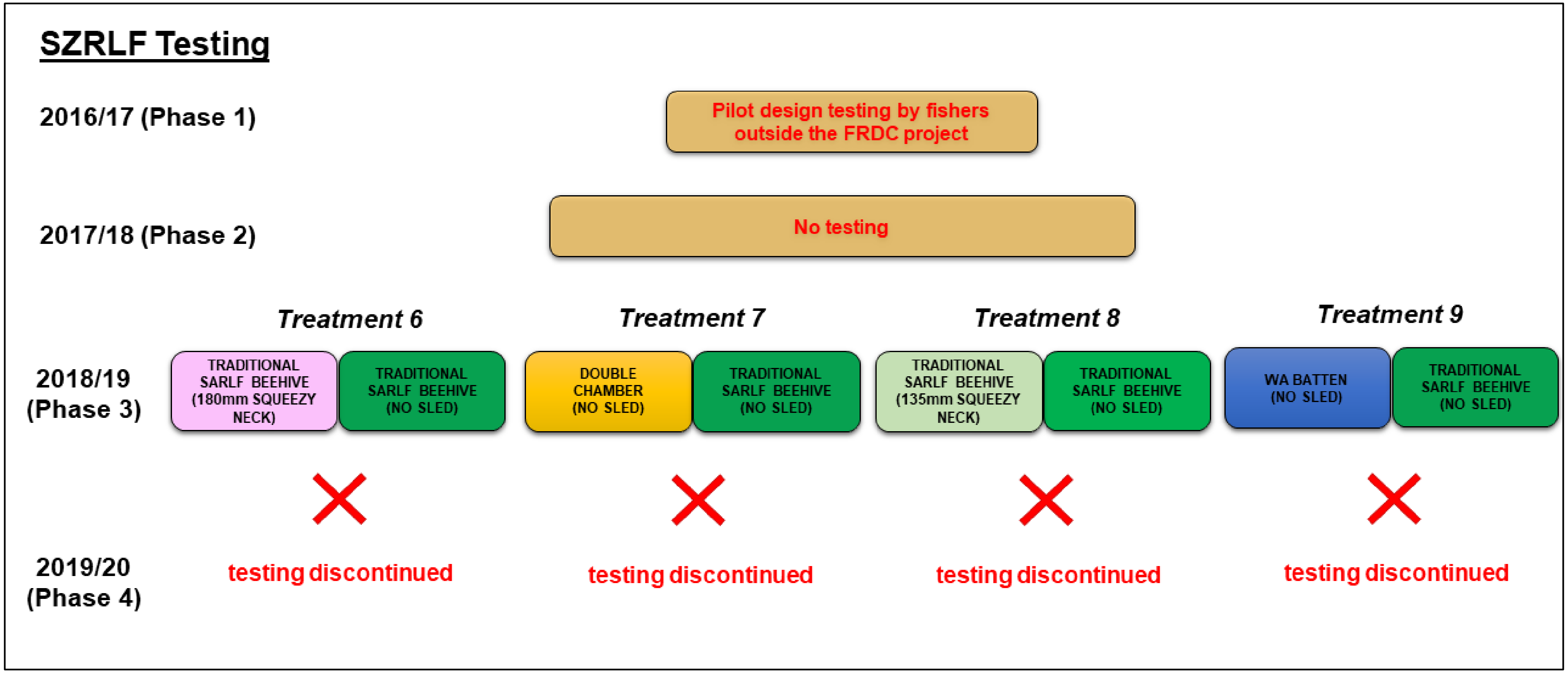


Figure 3. Phased approach to alternative pot design testing in the Southern Zone Rock Lobster Fishery between 2016/17 and 2018/19.

4.2 Phase 1-5 treatments

4.2.1 Phase 1 testing

Phase 1 was undertaken as a feasibility study, outside of the FRDC project, in the 2016/17 fishing season in the NZRLF and the SZRLF. Fishers in each zone trialled up to 10 pot designs of interest to inform the choice of designs to proceed into formal testing in Phase 2 of the project in 2017/18.

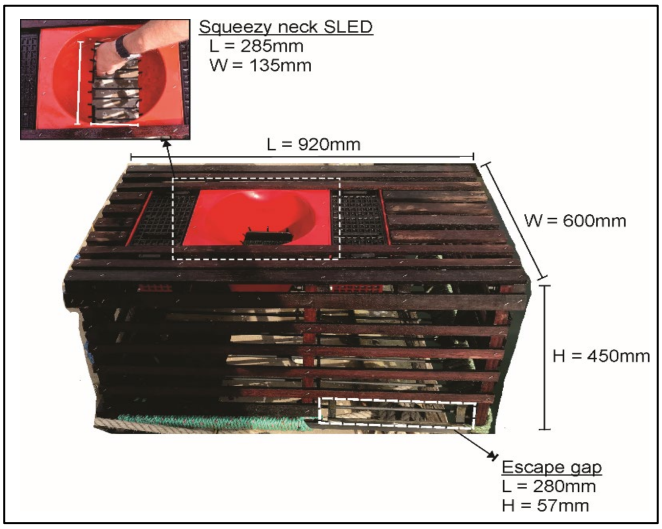
4.2.2 Phase 2 testing

Phase 2 was undertaken in 2017/18. Two treatments were tested in the NZRLF:

Treatment 1 – the WA batten pot (squeezy neck) versus traditional NZRLF beehive (spike) (Figure 4).

Treatment 2 – the Toumazos double entry (squeezy neck) versus traditional NZRLF beehive (spike) (Figure 5).

No formal testing of pot designs was undertaken in the SZRLF in Phase 2. The SZRLF continued informal trials of pot designs to proceed to formal testing in Phase 3 of the project in 2018/19.



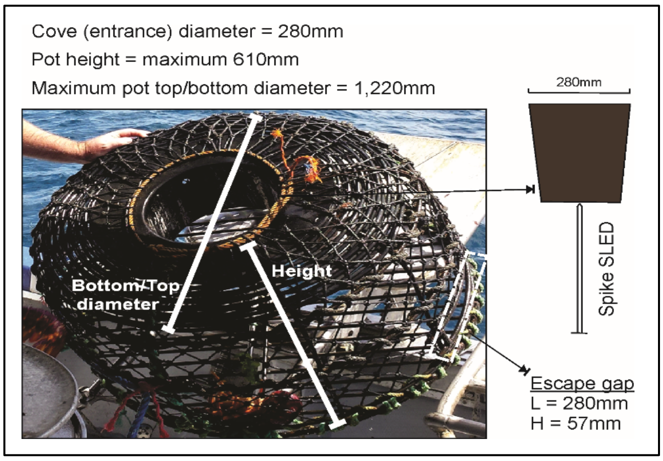


Figure 4. Treatment 1 – WA batten pot (squeezy neck) (left) versus traditional NZRLF beehive (spike)(right).

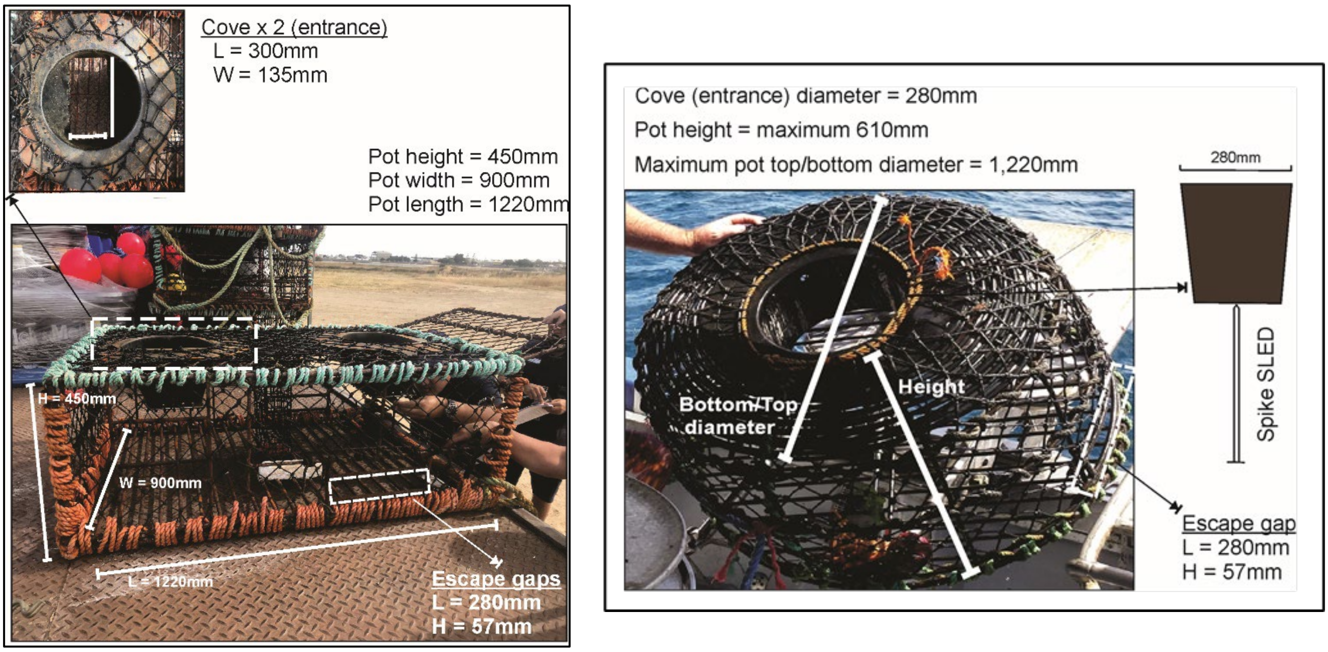


Figure 5. Treatment 2 – Toumazos double entry (squeezy neck) (left) versus traditional NZRLF beehive (spike)(right).

4.2.3 Phase 3 testing

Phase 3 was undertaken in 2018/19 in both the NZRLF and the SZRLF.

4.2.3.1 Northern Zone Rock Lobster Fishery

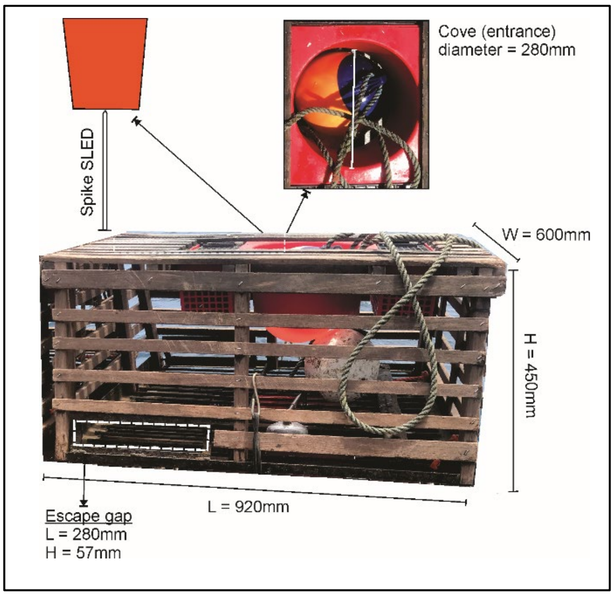
Four treatments were tested in the NZRLF in 2018/19:

Treatment 1 (continued) – WA batten pot (squeezy neck) versus the traditional NZRLF beehive (spike) (Figure 4).

Treatment 3 – WA batten pot (spike) versus traditional NZRLF beehive (spike) (Figure 6).

Treatment 4 – WA batten pot (squeezy neck) versus traditional NZRLF beehive (squeezy neck) (Figure 7).

Treatment 5 – Traditional SARLF beehive (squeezy neck) versus traditional NZRLF beehive (spike) (Figure 8).



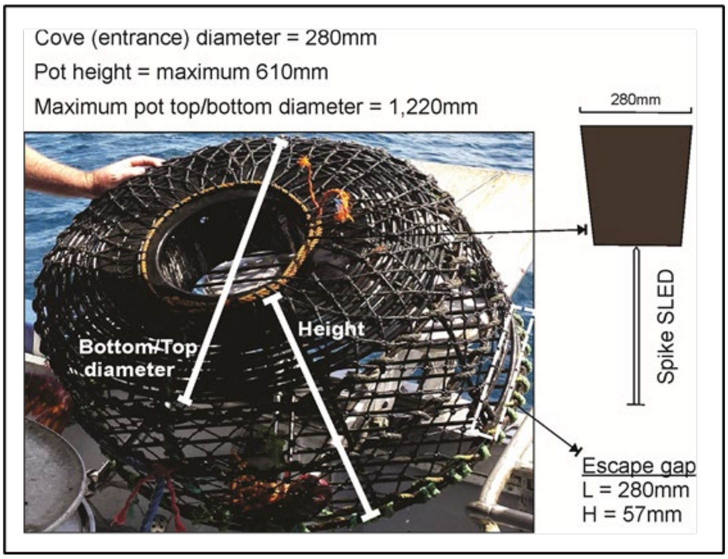
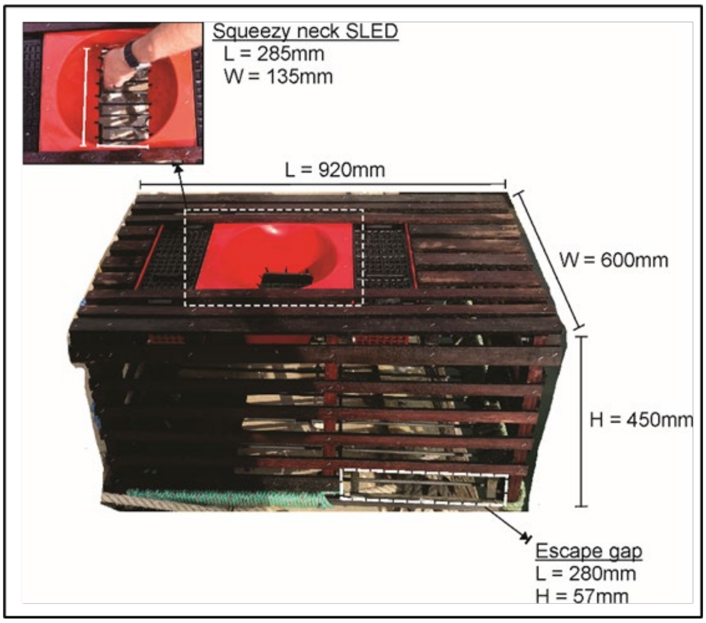


Figure 6. Treatment 3 – WA batten pot (spike) (left) versus traditional NZRLF beehive (spike) (right).



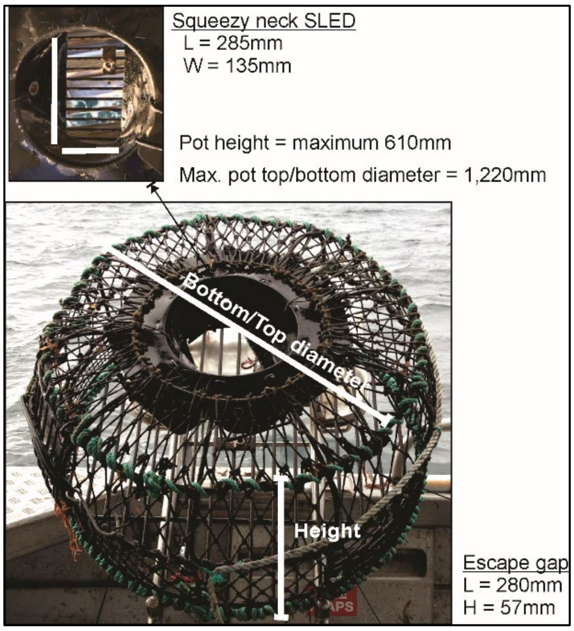
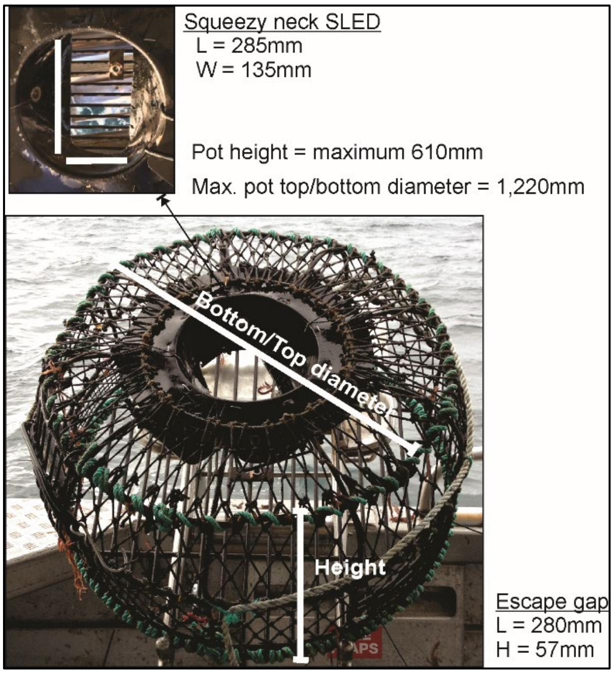


Figure 7. Treatment 4 – WA batten pot (squeezy neck) (left) versus traditional NZRLF beehive (squeezy neck) (right).



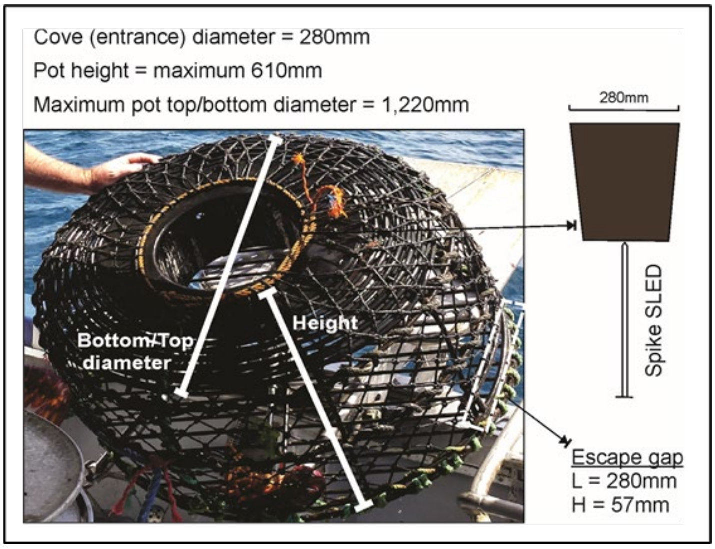


Figure 8. Treatment 5 – Traditional NZRLF beehive (squeezy neck) (left) versus traditional NZRLF beehive (spike)(right).

4.2.3.2 Southern Zone Rock Lobster Fishery

Four treatments were tested in the SZRLF in 2018/19:

Treatment 6 – Traditional SZRLF beehive (180mm squeezy neck) versus traditional SZRLF beehive (no SLED) (Figure 9);

Treatment 7 – Double chamber (no SLED) versus traditional SZRLF beehive (no SLED) (Figure 10);

Treatment 8 – Traditional SZRLF beehive (135 mm squeezy neck) versus traditional SZRLF beehive (no SLED) (Figure 11); and

Treatment 9 – WA batten pot (no SLED) versus traditional SZRLF beehive (no SLED) (Figure 12).

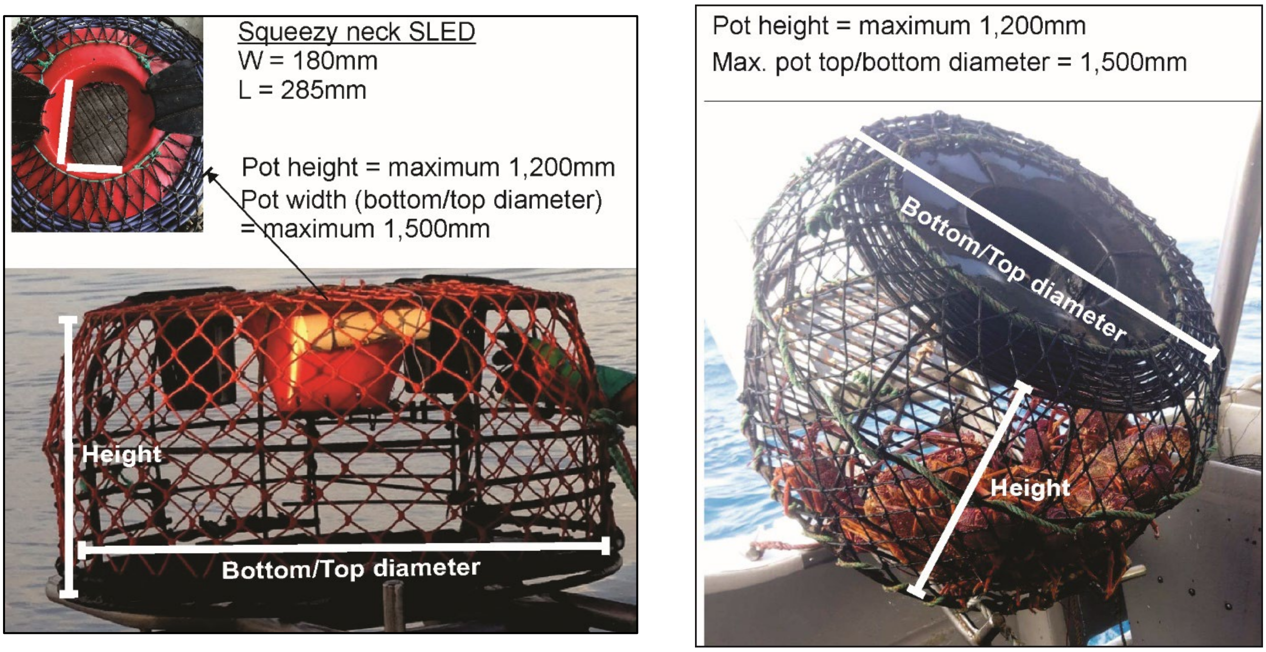


Figure 9. Treatment 6 – Traditional SZRLF beehive (180mm squeezy neck) (left) versus traditional SZRLF beehive (no SLED)(right).

Double chamber (Design IP withheld)

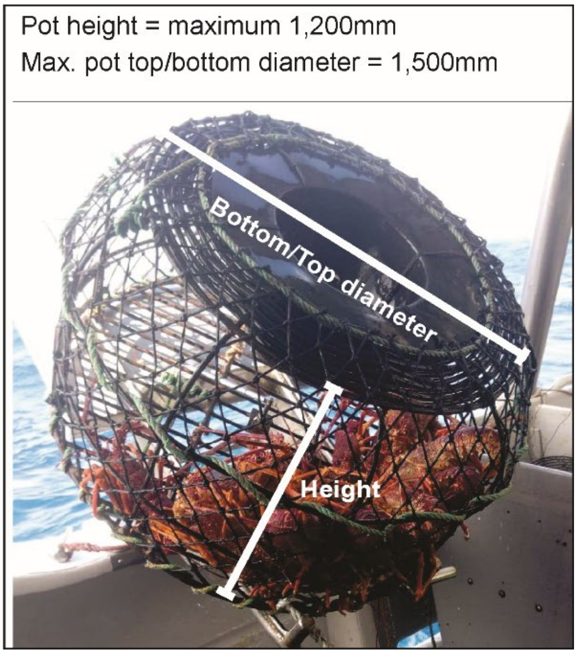


Figure 10. Treatment 7 – Double chamber (design intellectual property withheld) versus traditional SZRLF beehive (no SLED).

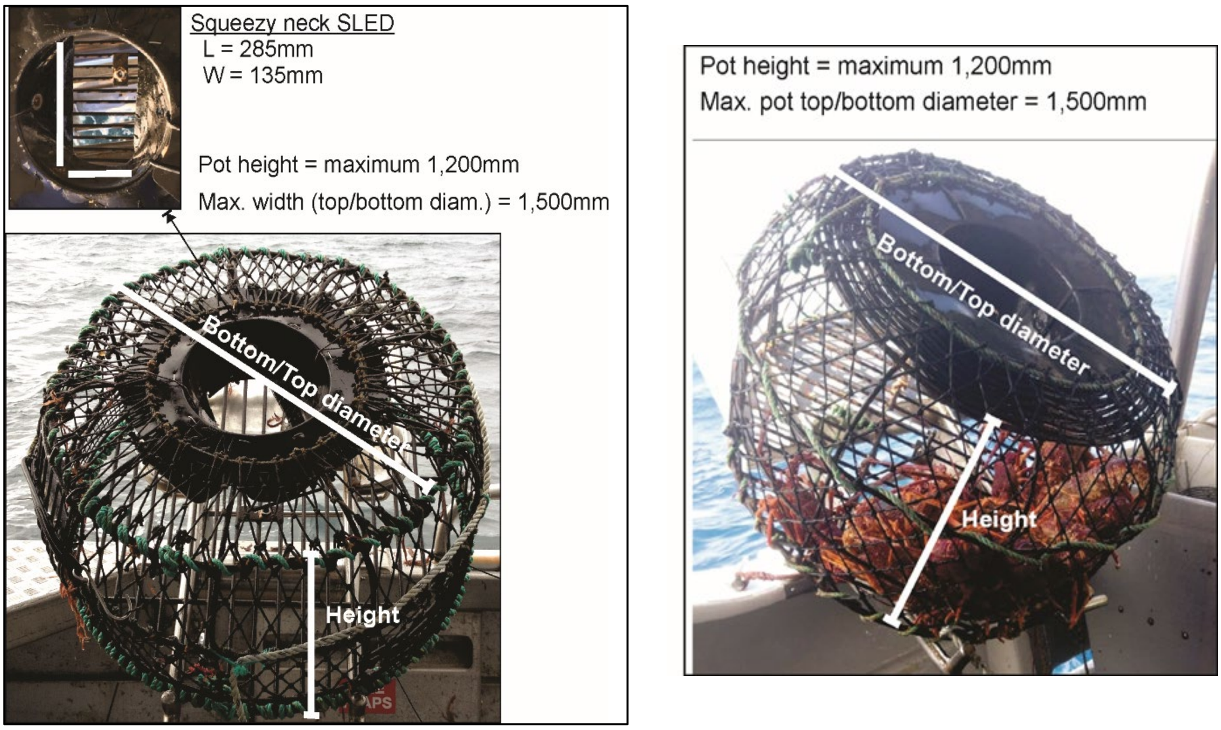


Figure 11. Treatment 8 –Traditional SZRLF beehive (135mm squeezy neck) versus traditional SZRLF beehive (no SLED).

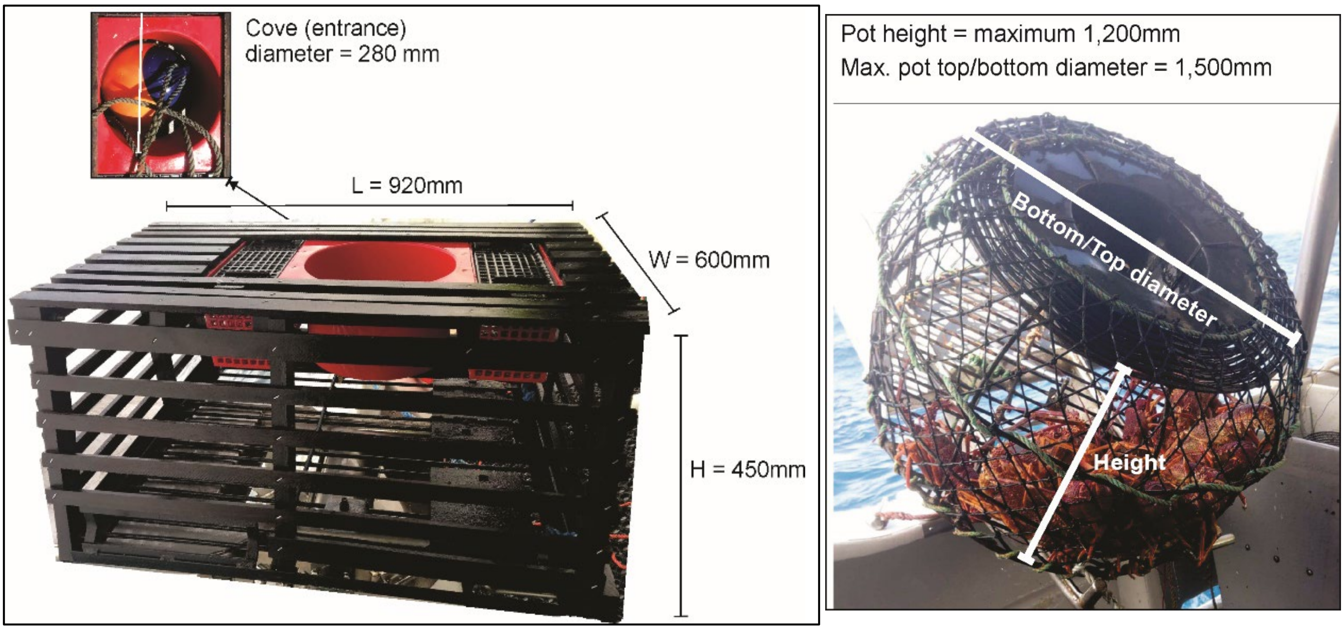


Figure 12. Treatment 9 – WA batten pot (no SLED) versus traditional SZRLF beehive (no SLED).

4.2.4 Phase 4 testing

Phase 4 testing was undertaken in the NZRLF in 2019/20 and continued the testing of treatments 1, 3 and 4 undertaken in 2018/19 (Figure 2). All testing of alternative pot designs in the SZRLF was discontinued at the completion of Phase 3 (Figure 3).

4.2.5 Phase 5 testing

Phase 5 testing was undertaken in the NZRLF in 2021/22 following postponement of testing in 2020/21 caused by fishery disruption from COVID-19 market impacts and international trade disputes. Phase 5 continued the testing of treatments 1, 3 and 4 undertaken in 2018/19 and 2019/20 (Figure 2).

4.3 Data collection

4.3.1 Sampling protocol

A field sampling protocol was developed and communicated to fishers to enable consistent testing and data collection during normal fishing operations. Fishers from each management zone were asked to register their interest in undertaking pot testing prior to the start of each phase. The following protocol was communicated:

1. full commitment to pot design testing over an entire fishing season.
2. one alternative design to be tested.
3. alternative pot designs to comprise a maximum of 50% of all fishing pots fished.

4. each alternative pot tested to be paired with a pot of traditional design to enable paired data collection and analyses to be performed. For example, if 20 alternative pots were tested and deployed on a day of fishing, then data from 20 alternative pots and data from 20 traditional pots were collected.
5. paired alternative and traditional pots to be marked with a tag to facilitate data collection (A1 = alternative pot 1; T1 = traditional pot 1).
6. during normal fishing operations, alternative pots and their traditional pot pairs to be set in immediate succession (Figure 13), and fishing to be conducted as per normal operations (i.e. pots should not be set closer together than normal).

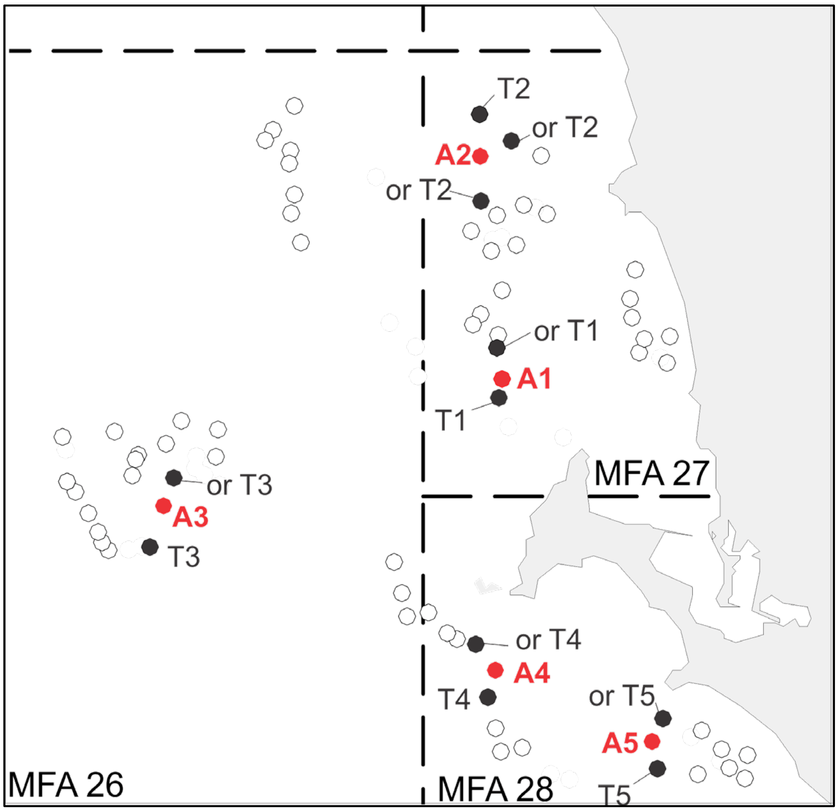


Figure 13. Example of required pot deployment sequence communicated to participating fishers.

4.3.2 Reporting methods and variables recorded

Data were obtained via two reporting methods: 1) catch sampling data (measured per pot); and 2) commercial logbook data (summarised daily). Following protocols currently used in the NZRLF and SZRLF commercial catch sampling program, fishers, and independent observers from the South Australian Research and Development Institute (SARDI) Aquatic Sciences recorded catch composition data from each alternative and traditional pot fished. This involved recording the number, size and sex of all lobsters caught in each alternative and traditional pot during each fishing day. The number of depredated lobsters and number and species of all byproduct (retained for sale) and bycatch (discarded) was recorded, as well as depth and the latitude-longitude positions of each pot fished.

Commercial logbook data are a mandatory regulatory requirement within the NZRLF and SZRLF and provide daily summaries of catch composition that are reported monthly. Where fishers could not record pot-specific catch sampling data, or could not have observers on board to record pot specific catch composition, they recorded daily summaries of the number of pots set for each design, and the number of legal-size and undersize lobsters caught from each design in their commercial logbooks. These data were reported at the spatial scale of Marine Fishing Area (MFA). The depth at which fishing took place was also recorded.

Fishers were unable to separate the catch obtained from each pot design on their vessels (i.e. the catch landed from each pot design had to be welled together during a fishing trip). Consequently, total catch weights obtained from each pot design could not be recorded at the end of a fishing trip. To estimate the catch weight from each design fished, fishers tallied the number of lobsters caught in each design during fishing operations. The total catch weight of legal-size lobsters landed during each trip was then apportioned to each pot design according to the number of legal-size lobsters recorded daily in commercial logbooks.

4.4 Data analyses

4.4.1 Catch efficiency metrics

Catch and effort data from both the catch sampling program and commercial logbooks were used to estimate the catch per unit effort (CPUE, kg/potlift) of legal-size lobsters, undersize (pre-recruit) lobsters (undersized/potlift), and mean weight (kg) and carapace length (CL) of all lobsters caught from alternative and traditional pot designs within each treatment. Bycatch data recorded in the catch sampling data were also compared for each treatment.

4.4.2 Effect of seal exclusion devices

Sea Lion exclusion devices (SLEDs) located within the cove (entrance) of lobster pots have the potential to restrict lobster entry and reduce catch rate, thereby potentially confounding catch rate comparisons between pots of similar design (e.g., WA batten pot (squeezy neck) or WA batten pot (spike)). Treatment 5 specifically assessed the influence of different SLED types (squeezy neck versus spike) on the CPUE of legal-size and undersize lobsters. Independent sample t- tests undertaken on data collected in treatment 5 assessed the null hypothesis that legal-size and undersize catch efficiency would not vary as a function of SLED type. Catches of legal-size and undersize lobsters did not vary significantly as a function of the SLED type used (t-test: legal-size $p=0.924$, $df=1098$; undersize $p=0.766$, $df=702$).

Because the effect of SLED type on lobster catch was not significant, for subsequent analyses, the type of SLED was not considered. This enabled pooling of data from treatments 1, 3 and 4 to focus on two data analysis objectives: i) to assess whether catch rates (CPUE, N/potlift) of primary bycatch species, byproduct species (Maori Octopus, Giant Crab) and depredated lobsters differed as a function of pot design; and ii) to develop statistical methods to analyse and correct for differences in legal-size and undersize lobster catch efficiency between WA batten pots and traditional beehive pots in the NZRLF.

4.4.3 Developing methods to estimate differences in catch efficiency between WA batten pots and traditional beehive pots

Statistical methods were developed to analyse and correct for differences in legal-size lobster catch in weight per potlift (CPUE) and undersize lobster catch in number per potlift (PRI) between WA batten pots and traditional beehive pots in the NZRLF. These two indices are the two primary inputs for use in harvest strategy decision rules in the NZRLF.

For this analysis, only observer data were used. To accurately estimate their relative catch efficiency, the observer data set was restricted to a subset (from treatments 1, 3 and 4) that permitted a more direct comparison of the two pot designs. Observer data of potlifts were sorted into the two pot-type populations. Using the latitude-longitude positions of each potlift, pairs of matching potlifts (one from each pot type population) were identified. Only matched pairs positioned less than 100m apart were included. By this selection procedure, each matched pair consisted of one WA batten pot and one traditional beehive pot set in close proximity during the same fishing day. This enabled direct comparison of catch performance (CPUE and PRI) from each pot design, set side-by-side on the same lobster fishing ground while controlling for covariates such as depth, month, licence and MFA. This method also allowed calculation of the overall CPUE and PRI indices across the potlifts for each pot design, and estimation of the ratio of an index by the two pot designs. Furthermore, we observed how these ratios vary with respect to lobster abundance.

A geo-statistical data matching procedure to produce pairs of potlifts (alternative WA batten pot versus traditional beehive pot) was performed using the *matchit* function within the MatchIt package (Ho, et al 2011) in R (R Core Team 2022). Data for WA batten pots and traditional beehive pots within treatments 1, 3 and 4 (as per section 4.4.2 above) in the NZRLF were pooled (ignoring SLED type). Then, for a given fishing trip, potlifts for each design were matched based on the Haversine distance between potlift pairs. The Haversine formula determines the great-circle distance between two points on a sphere given their longitudes and latitudes. The optimal matching algorithm produced 5,913 matched pairs of which 2,741 pairs were less than 100 m apart. Consequently, all spatial and temporal factors potentially affecting lobster catch were controlled for. Data from the 2,741 potlift-pairs were then used to statistically examine the null hypothesis that legal-size catch weight and undersize count is the same for the two pot types.

The catch efficiency analyses using the matched potlift-pairs sample then proceeded in two stages:

(1) computing the ratios of the means of legal-size lobster catch weight and undersize lobster (number) obtained from the two pot designs; and

(2) exploratory analysis to assess trends in the ratios of the means of legal-size lobster catch weight and undersize lobsters (number) as a function of lobster abundance, month, licence, MFA and depth.

The steps undertaken and outputs of these analyses for legal-size lobster catch in weight per potlift (CPUE) and undersize lobster catch in number per potlift (PRI) are presented in the results (sections 5.9.1, 5.9.2, respectively). We then provide two approaches to correct for differences in pot design catch efficiency for these performance indicators for use in harvest strategy decision rules in the NZRLF (section 5.10).

5 Results

5.1 Overview

The five phases of pot design testing between 2017/18 and 2021/22 resulted in data recorded from 17 fishers over 904 sampling days in 26 MFAs (Figure 14). A total of 14,537 individual potlifts were sampled.

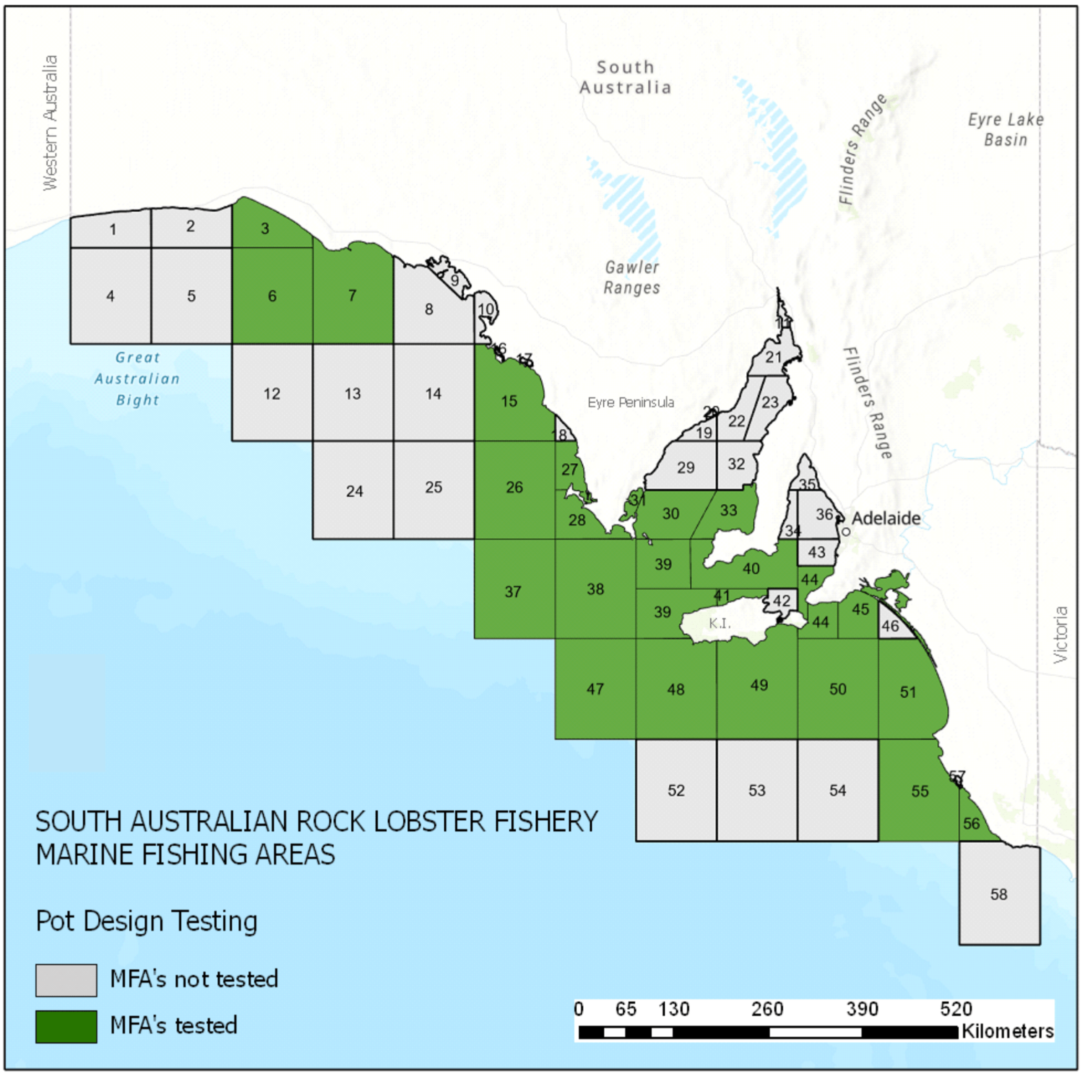


Figure 14. Marine Fishing Areas (MFAs) sampled during pot design testing between 2017/18 and 2021/22.

5.2 Phase 2 testing (NZRLF)

In 2017/18, pot-specific catch data were recorded from one fisher testing treatment 1 over 107 days (1,055 potlifts) and one fisher testing treatment 2 over 119 days (952 potlifts) (Table 2). Table 2 shows key summary statistics for catches of lobster sampled in treatment 1 and treatment 2. In treatment 1, the estimate of CPUE (kg/potlift) of legal-size lobster was 71% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (spike) pot. Catches of undersize lobster were also over double those recorded from the traditional NZRLF beehive (spike) pot. However, the mean size (weight and CL) of lobsters caught in the WA batten pot (squeezy neck) pot was slightly smaller than that caught in the traditional NZRLF beehive (spike) pot.

In treatment 2, the estimate of CPUE (kg/potlift) of legal-size lobster was 15% higher from the Toumazos double entry (squeezy neck) pot compared to the traditional NZRLF beehive (spike) pot. Catches of undersize lobster were also 59% higher from the Toumazos double entry (squeezy neck) pot. The mean size (weight and CL) of lobsters caught in the Toumazos double entry (squeezy neck) was slightly smaller than that caught in the traditional NZRLF beehive (spike) pot. Based on the results of Phase 2 in 2017/18, treatment 2 testing was discontinued.

Table 2. Lobster catch and effort from Phase 2 pot-design testing in the NZRLF in 2017/18.

Treatment					Legal size		Undersize		All lobsters	
	Pot designs	N Lic.	Days observed	N potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	Mean weight (kg)	Mean CL (mm)
1	**WA batten pot (squeezy neck)**	1	107	528	649.7	1.23	324	0.61	0.83	115
1	**Traditional NZRLF beehive (spike)**		107	527	379.9	0.72	137	0.26	0.90	118
2	**Toumazos double entry (squeezy neck)**	1	119	476	461.9	0.97	167	0.35	0.86	117
2	**Traditional NZRLF beehive (spike)**		119	476	402.2	0.84	104	0.22	0.93	119

5.3 Phase 3 testing

5.3.1 Northern Zone Rock Lobster Fishery

In 2018/19, pot-specific catch data were recorded from a total of 10 fishers in the NZRLF testing treatments 1, 3, 4 and 5. Table 3 shows key summary statistics for the catch sampling undertaken and estimates of legal-size and undersize catch rates for each treatment.

In treatment 1, similar to the results recorded in 2017/18, the estimate of CPUE (kg/potlift) of legal-size lobster was 51% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (spike) pot. Catches of undersize lobster were also 35% higher than those recorded from the traditional NZRLF beehive (spike) pot. The mean size (weight and CL) of lobsters caught in both designs was similar (Table 3; WA batten pot (squeezy neck): mean weight: 0.89 kg; CL 119, Traditional NZRLF beehive (spike): mean weight: 0.90 kg; CL 119).

In treatment 3, the estimate of CPUE (kg/potlift) of legal-size lobster was 24% higher from the WA batten pot (spike) compared to the traditional NZRLF beehive (spike) pot (Table 3). Catches of undersize lobster were also nearly double from the WA batten pot (spike) pot. The mean size (weight and CL) of lobsters caught in the WA batten pot (spike) pot was slightly smaller than that caught in the traditional NZRLF beehive (spike) pot (Table 3; WA batten pot (spike): mean weight: 0.92 kg; CL 119, traditional NZRLF beehive (spike): mean weight: 0.99 kg; CL 122).

Results for treatments 4 and 5 should be treated with caution due to relatively low sample sizes (<200 potlifts) (Table 3). In treatment 4, the estimate of CPUE (kg/potlift) of legal-size lobster was 23% lower from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (squeezy neck) pot. However, catches of undersize lobster were higher (57%) from the WA batten pot (squeezy neck) pot. The mean size (weight and CL) of lobsters caught in the WA batten pot (squeezy neck) pot was slightly smaller than that caught in the traditional NZRLF beehive (spike) pot (Table 3).

In treatment 5, the estimate of CPUE (kg/potlift) of legal-size lobster from the traditional NZRLF beehive (squeezy neck) pot was approximately double that of traditional NZRLF beehive (spike) pot. Catches of undersize lobster were also approximately double from the WA batten pot (squeezy neck) pot. The mean size (weight and CL) of lobsters caught in both pot designs tested in treatment 5 was similar (Table 3).

Table 3. Lobster catch and effort from Phase 3 pot-design testing in the NZRLF in 2018/19.

Treatment					Legal size		Undersize		All lobsters	
	Pot designs	N Lic.	Days observed	N potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	Mean weight (kg)	Mean CL (mm)
1	**WA batten pot (squeezy neck)**	6	310	2419	3711.7	1.53	739	0.31	0.89	119
1	**Traditional NZRLF beehive (spike)**		310	2420	2446.0	1.01	548	0.23	0.90	119
3	**WA batten pot (spike)**	1	93	383	374.5	0.98	59	0.15	0.92	119
3	**Traditional NZRLF beehive (spike)**		93	381	301.4	0.79	29	0.08	0.99	122
4	**WA batten pot (squeezy neck)**	1	31	62	53.6	0.86	22	0.35	0.87	117
4	**Traditional NZRLF beehive (squeezy neck)**		31	62	69.3	1.12	14	0.23	1.02	124
5	**Traditional NZRLF beehive (squeezy neck)**	2	24	87	60.0	0.69	11	0.13	0.85	117
5	**Traditional NZRLF beehive (spike)**		24	87	27.6	0.32	5	0.06	0.80	115

5.3.2 Southern Zone Rock Lobster Fishery

In 2018/19, pot-specific catch data were recorded from four fishers in the SZRLF, each testing one of four treatments (6, 7, 8 and 9). Table 4 shows key summary statistics for the catch sampling undertaken and estimates of legal-size and undersize catch rates for each treatment. Results for all treatments (design comparisons) should be treated with caution due to relatively low sample sizes (<200 potlifts).

In treatment 6, the estimate of CPUE (kg/potlift) of legal-size lobster was 34% higher from the traditional SZRLF beehive pot (180 mm squeezy neck) compared to the traditional SZRLF beehive (no SLED) pot. However, catches of undersize lobster were 90% lower from the traditional SZRLF beehive (180 mm squeezy neck) pot. The mean size (weight and CL) of lobsters caught was larger from the traditional SZRLF beehive pot (180 mm squeezy neck) (Table 4).

In treatment 7, the estimate of CPUE (kg/potlift) of legal-size lobster was 14% lower from the double chamber (no SLED) pot compared to the traditional SZRLF beehive (no SLED) pot (Table 4). However, catches of undersize lobster were 40% higher from the double chamber (no SLED) pot. The mean size (weight and CL) of lobsters caught in each design was similar.

In treatment 8, the estimate of CPUE (kg/potlift) of legal-size lobster was 25% lower from the traditional SZRLF beehive (135mm squeezy neck) pot compared to the traditional SZRLF beehive (no SLED) pot. Catches of undersize lobster were also 33% lower from the traditional SZRLF beehive (135mm squeezy neck) pot. The mean size (weight and CL) of lobsters caught in each design was similar (Table 4).

In treatment 9, the estimate of CPUE (kg/potlift) of legal-size lobster from the WA batten pot (no SLED) was 11% lower than that traditional SZRLF beehive (no SLED) pot (Table 4). Catches of undersize lobster were 44% lower from the WA batten pot (no SLED). The mean size (weight and CL) of lobsters caught in both pot designs tested in treatment 9 was similar.

Table 4. Lobster catch and effort from Phase 3 pot-design testing in the SZRLF in 2018/19.

Treatment					Legal size		Undersize		All lobsters	
	Pot designs	N Lic.	Days observed	N potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	Mean weight (kg)	Mean CL (mm)
6	Traditional SZRLF beehive (180mm squeezy neck)	1	43	86	274.0	3.19	2	0.02	1.26	133
6	Traditional SZRLF beehive (no SLED)		43	86	204.9	2.38	17	0.20	1.16	129
7	Double chamber (no SLED)	1	16	29	90.8	3.13	39	1.34	0.65	107
7	Traditional SZRLF beehive (no SLED)		16	28	101.5	3.62	27	0.96	0.67	108
8	Traditional SZRLF beehive (135mm squeezy neck)	1	45	87	170.2	1.96	9	0.10	0.91	120
8	Traditional SZRLF beehive (no SLED)		45	87	227.5	2.61	13	0.15	0.91	120
9	WA batten pot (no SLED)	1	32	64	146.1	2.28	31	0.48	0.75	112
9	Traditional SZRLF beehive (no SLED)		32	64	164.4	2.57	55	0.86	0.71	110

5.4 Phase 4 testing (NZRLF)

In 2019/20, pot-specific catch data were recorded from three fishers testing treatment 4 over 29 days (2,099 potlifts) and from four fishers testing treatment 5 over 15 days (989 potlifts). Table 5 shows key summary statistics for catches of lobster sampled in treatments 4 and 5. In treatment 4, the estimate of CPUE (kg/potlift) of legal-size lobster was 28% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (squeezy neck) pot. Catches of undersize lobster from the WA batten pot (squeezy neck) were approximately double those recorded from the traditional NZRLF beehive (squeezy neck) pot. The mean size (weight and CL) of lobsters caught in both designs was similar (Table 5, WA batten pot (squeezy neck): mean weight: 0.93 kg; CL 120 mm, Traditional NZRLF beehive (squeezy neck): mean weight: 0.96 kg; CL 121).

In treatment 5, the estimate of CPUE of (kg/potlift) legal-size lobster was similar from the traditional NZRLF beehive (squeezy neck) pot and the traditional NZRLF beehive (spike) pot (Table 5, traditional NZRLF beehive (squeezy neck) pot: CPUE 1.01 kg/potlift; traditional NZRLF beehive (spike): CPUE 1.06 kg/potlift). Catches of undersize lobster, and the mean size of all lobsters, were also similar from each design. Based on the results of testing undertaken in Phase 3 and 4 in 2018/19 and 2019/20, respectively, treatment 5 testing was discontinued in the project.

Table 5. Lobster catch and effort from Phase 4 pot-design testing in the NZRLF in 2019/20.

Treatment					Legal size		Undersize		All lobsters	
	Pot designs	N Lic.	Days observed	N potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	Mean weight (kg)	Mean CL (mm)
1	WA batten pot (squeezy neck)									
1	Traditional NZRLF beehive (spike)	Commercial logbook only								
3	WA batten pot (spike)									
3	Traditional NZRLF beehive (spike)	Commercial logbook only								
4	WA batten pot (squeezy neck)	3	29	1055	1459.1	1.38	388	0.37	0.93	120
4	Traditional NZRLF beehive (squeezy neck)		29	1044	1126.3	1.08	186	0.18	0.96	121
5	Traditional NZRLF beehive (squeezy neck)	4	15	493	497.5	1.01	109	0.22	0.96	121
5	Traditional NZRLF beehive (spike)		15	496	527.4	1.06	108	0.22	0.98	122

5.5 Phase 5 testing (NZRLF)

In 2021/22, pot-specific catch data were recorded from one fisher testing treatment 3 over 11 days (512 potlifts) and from two fishers testing treatment 4 over 29 days (2,498 potlifts). Table 6 shows key summary statistics for catches of lobster sampled in treatments 3 and 4. In treatment 3, the estimate of CPUE (kg/potlift) of legal-size lobster was 34% higher from the WA batten pot (spike) compared to the traditional NZRLF beehive (spike) pot. Catches of undersize lobster from the WA batten pot (spike) were approximately double those recorded from the traditional NZRLF beehive (spike) pot. The mean size (weight and CL) of lobsters caught in both designs was similar (Table 6).

In treatment 4, the estimate of CPUE (kg/potlift) of legal-size lobster from the WA batten pot (squeezy neck) was over double (118%) that of NZRLF beehive (squeezy neck) pot (Table 6, WA batten pot (squeezy neck): CPUE 1.59 kg/potlift; traditional NZRLF beehive (squeezy neck) pot: CPUE 0.73 kg/potlift). Catches of undersize lobster from the WA batten pot (squeezy neck) were also approximately double those recorded from the traditional NZRLF beehive (squeezy neck) pot. The mean size (weight and CL) of lobsters caught in both designs was similar (Table 6).

Table 6. Lobster catch and effort from Phase 5 pot-design testing in the NZRLF in 2021/22.

Treatment					Legal size		Undersize		All lobsters	
	Pot designs	N Lic.	Days observed	N potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	Mean weight (kg)	Mean CL (mm)
1	**WA batten pot (squeezy neck)**	Commercial logbook only								
1	**Traditional NZRLF beehive (spike)**									
3	**WA batten pot (spike)**	1	11	255	259.0	1.02	31	0.12	0.93	121
3	**Traditional NZRLF beehive (spike)**		11	257	194.4	0.76	16	0.06	0.94	122
4	**WA batten pot (squeezy neck)**	2	29	1250	1987.4	1.59	191	0.15	1.15	128
4	**Traditional NZRLF beehive (squeezy neck)**		29	1248	904.9	0.73	105	0.08	1.13	128

5.6 Bycatch and byproduct (NZRLF)

A total of 23 bycatch and two byproduct taxa were recorded during treatments 1, 3 and 4 testing of alternative WA batten pots (5,952 potlifts) against traditional NZRLF beehive pots (5,935 potlifts) in the NZ. Table 7 shows the top 10 taxa (bycatch and byproduct) recorded from each design in the NZRLF between 2017/18 and 2021/22. Further detail relating to bycatch and byproduct sampled during testing in the NZRLF and SZRLF is provided in Appendix 1 and 2, respectively.

The taxonomic composition of bycatch recorded from both designs was similar. Leatherjacket *spp*. (Family Monacanthidae), Hermit Crab (*Trizopagurus strigimanus*) and wrasse *spp*. (Family Labridae) comprised the largest percentage (>80%) of bycatch by number in both pot designs. However, with the exception of Ocean Jacket (*Nelusetta ayraud*), traditional NZRLF beehive pots caught more individuals overall (Table 7). Catch rates (CPUE) of leatherjackets (all leatherjacket taxonomic groups combined) and wrasse species (unidentified wrasse *spp.* and Bluethroat Wrasse (*Notolabrus tetricus*)) were 70% less and 48% less, respectively, in alternative WA batten pots than traditional beehive pots (Table 7). Catch rates of Hermit Crab were similar between each design.

Relatively low numbers of byproduct species were recorded (Table 7). Catch rate (CPUE) trends for byproduct species, Māori Octopus (*Pinnoctopus cordiformis*) and Giant Crab (*Psuedocarcinus gigas*) broadly resembled that for bycatch, being 57% less and 38% less, respectively, in alternative WA batten pots compared to traditional NZRLF beehive pots.

Table 7. Top 10 (N individuals, % numerical abundance) bycatch and byproduct taxa sampled in traditional beehive pots and WA batten pots in the NZRLF between 2017/18 and 2021/22. Top 4 taxa highlighted in bold. Byproduct spp. highlighted in *italics*.

N potlifts = 11,891	2017/18		2018/19		2019/20		2021/22		N individuals		% Numerical Abundance		CPUE (*100 pots)	
Taxa	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*	*Trad. Beehive*	*WA batten*
Leatherjacket *spp.*	**107**	**58**	**860**	**193**			**2**	**3**	**969**	**254**	**60.4**	**39.5**	**16.3**	**4.3**
Horseshoe Leatherjacket			**52**	**33**	**54**	**9**	**67**	**9**	**173**	**51**	**10.8**	**7.9**	**2.9**	**0.9**
Hermit Crab			**43**	**32**	**21**	**18**	**66**	**61**	**130**	**111**	**8.1**	**17.3**	**2.2**	**1.9**
Wrasse *spp.*	**1**		**80**	**32**			**18**	**17**	**99**	**49**	**6.2**	**7.6**	**1.7**	**0.8**
Maori Octopus	6	7	71	14	2	2	17	18	96	41	6.0	6.4	1.6	0.7
Blue Throat		2	20	15	5	1	5		30	18	1.9	2.8	0.5	0.3
Velvet Crab	1		22	33			1		24	33	1.5	5.1	0.4	0.6
Ocean Jacket Or China	1				17	22	4	20	22	42	1.4	6.5	0.4	0.7
Giant Crab			4	1			17	12	21	13	1.3	2.0	0.4	0.2
Port Jackson Shark			2	1	3	2	6	9	11	12	0.7	1.9	0.2	0.2

5.7 Lobster mortality (depredation) and spawning lobster CPUE

The CPUE of dead lobsters recorded during testing of alternative WA batten pots (5,952 potlifts) against traditional NZRLF beehive pots (5,935 potlifts) was similar at approximately 3.0 dead lobsters/100 potlifts (Table 8).

Table 8. Dead lobsters sampled in traditional NZRLF beehive pots and WA batten pots in the NZRLF between 2017/18 and 2021/22.

	N potlifts	2017/18	2018/19	2019/20	2021/22	All seasons	
		N dead	N dead	N dead	N dead	Total	CPUE (*100 pots)
WA batten	5,952	15	75	34	59	183	3.07
Traditional Beehive	5,939	11	89	44	36	180	3.03

Catches of spawning female lobsters were generally low for all seasons of sampling between 2017/18 and 2021/22 due to sampling being undertaken outside the main spawning period (July to October) (Table 9). The CPUE estimate of spawning lobsters from WA batten pots was approximately double that recorded from traditional NZRLF beehive pots (Table 9, WA batten pot CPUE: 0.59 lobsters/100 potlifts; traditional NZRLF beehive pots: CPUE 0.30 lobsters/100 potlifts).

Table 9. Spawning female lobsters sampled in traditional NZRLF beehive pots and WA batten pots in the NZRLF between 2017/18 and 2021/22.

	N potlifts	2017/18	2018/19	2019/20	2021/22	All seasons	
		N spawning	N spawning	N spawning	N spawning	Total	CPUE (*100 pots)
WA batten	5,952	9	7	16	3	35	0.59
Traditional Beehive	5,939	2	7	5	4	18	0.30

5.8 Fishery-dependent reporting - commercial logbook data

Overall, the trends in catch efficiency (legal-size and undersize CPUE) per treatment recorded from commercial logbook data in 2019/20 and 2021/22 generally supported those observed from observer data. However, while providing general measures of catch efficiency per design, commercial logbook data are not presented in detail here as they are considered less precise than data provided by observers. This is due to fishers not being able to record lobster catches from individual pot designs during testing.

For example, in treatment 4 in both 2019/20 and 2021/22, catch efficiency trends of legal-size and undersize lobsters estimated from commercial logbook data and observer data differed. Comparison of treatment 4 catch sampling data and commercial catch log data submitted independently for the same days fished in these seasons indicated daily differences in the number of legal-size lobsters reported from each design. Summaries of the same catch data submitted over multiple days, indicated that the total number of legal-size lobsters reported per trip, irrespective of design used, was more similar between the two data sources. Consequently, commercial catch log data obtained for treatment 4 are considered less reliable as they are likely influenced by the incorrect reporting of lobster numbers against specific pot designs. A full summary of the commercial catch log data collected during each season of testing is provided in Appendix 3.

5.9 Estimating ratios of catch efficiency between WA batten pots and traditional beehive pots

The sample of 2,741 matched pairs of potlifts enabled analyses of the differences in catch efficiency between the WA batten pot and the traditional beehive pot. The difference in performance of the two pot types is quantified primarily by their ratio, i.e., traditional beehive pot over WA batten pot, for the two performance indicators used in the harvest strategy decision rules for the NZRLF: legal-size lobster catch in weight per potlift (CPUE), and undersize lobster catch in number per potlift (PRI).

5.9.1 Legal-size lobster catch weight (CPUE)

5.9.1.1 Preliminary statistics by pot design

Catches of legal-size lobster in either WA batten pots or traditional beehive pots were highly variable, but on average, the WA batten pots caught 0.54 kg/potlift more legal-size lobsters than traditional beehive pots (Figure 15, Table 10).

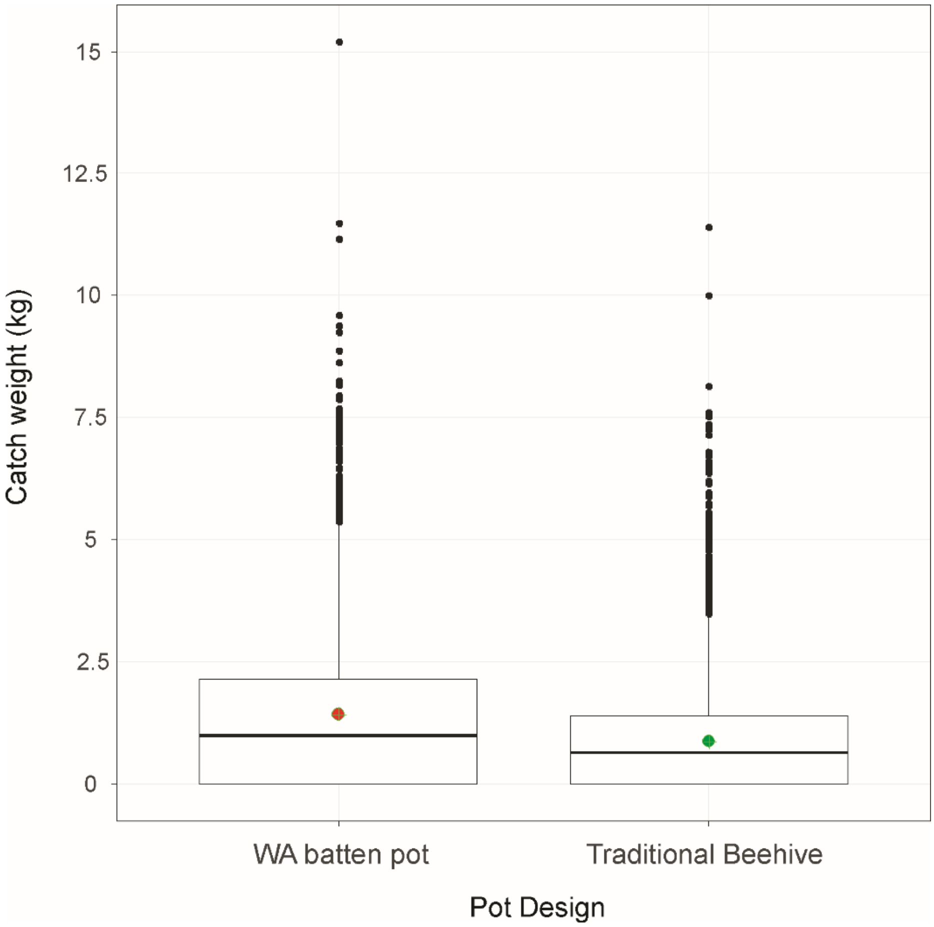


Figure 15. Box plot of catch weight of legal-size lobsters from WA batten pots and traditional beehive pots (N = 2,741 matched pot pairs). Red dot is the mean catch weight of legal-size lobsters from WA batten pots, and the green dot is the mean catch weight of legal-size lobsters from traditional beehive pots.

Table 10. Mean legal-size lobster catch sampled from 2,741 matched WA batten pot and traditional beehive pot-pairs.

Pot design	N (potlifts)	Mean	SE
WA batten pot	2,741	1.430	0.031
Traditional beehive pot	2,741	0.887	0.024

5.9.1.2 Relationship between pot designs: analysis of matched pairs

A suitable comparison test of the matched-pairs dataset is a one sample t-test of the paired differences (catch weight of the WA batten pot minus that of the traditional NZRLF beehive pot). This matched-pair t-test indicated that the mean of the paired differences was significantly different from zero ($t = 15.132$, df = 2,740, p-value < 0.001) implying that WA batten pots had a significantly higher catch rate (mean of 1.43 kg/potlift) of legal-size lobsters than traditional beehive pots (mean of 0.887 kg/potlift) overall.

Figure 16 shows a scatterplot of the catch weight (kg) for the two pot types for the 2,741 matched pairs in the sample. The very wide scatter of points obscures the relationship in catch weight between the two pot designs. Two additional features of these data constrain the ability to generate a direct functional relationship between the catch of the WA batten pot and beehive pot in any given matched pair: (1) many zero catches in one or both pots of each matched pair; and (2) high variability in catches from any individual potlift, and between the two pots of each matched pair. Furthermore, zero catches prevent the computation of the ratio for each matched pair because division by zero is undefined.

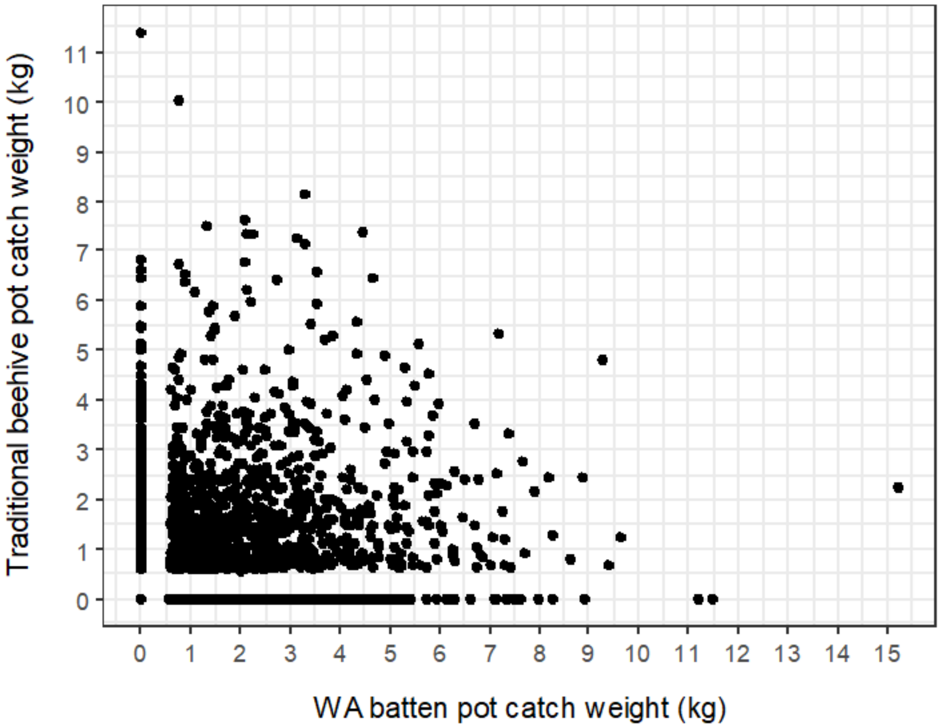


Figure 16. Scatter plot of mean catch weight of legal-size lobsters caught from the traditional beehive pot against the WA batten pot within each matched pot pair (N = 2,741).

The solution to these data challenges is to aggregate the data from the matched pairs into bins within which binned CPUE values can be computed. To measure the relationship in catch between the two pot designs, the ratio of mean catch weight for the traditional beehive pot design ($C_W PUE_{beehive}$) to the mean catch weight for the WA batten pot design ($C_W PUE_{WA}$) is then estimated as:

$$\rho_{C_W PUE} \coloneqq \frac{C_W PUE_{beehive}}{C_W PUE_{WA}}$$

Using the sample means from the sample of matched pairs in Table 10, this ratio parameter is estimated as $\hat{\rho}_{C_W PUE} = 0.62$. The estimated mean square error $\widehat{MSE}\left(\hat{\rho}_{C_W PUE}\right)$ using a linearised Taylor series estimator as derived by Wolter (2007) was 0.000385 (95% Confidence Intervals (CIs), 0.6196, 0.6212).

5.9.1.3 Exploratory analysis: Lobster abundance, Month, Licence, MFA, Depth

This section explores potential dependence of the ratio of the means of legal-size lobster catch weight from the two pot design pairs on the following variables:

- Lobster abundance
- Month
- Licence
- MFA; and
- Depth.

5.9.1.3.1 Lobster abundance

The abundance of lobsters at the site of each pot pair was considered a factor potentially influencing the catch ratio observed ($\rho_{C_W PUE}$). Figure 17 shows the estimated ratio ($\hat{\rho}_{C_W PUE}$) of the means, and 95% CIs, of legal-size catch weight from the two designs calculated for average catch weights measured for each pot pair in 0.2kg-wide bins. No discernible pattern or relationship for the ratio with respect to average catch weight (lobster abundance) is apparent. The weighted regression is fitted through the mid-point of each average catch weight interval along the horizontal axis, where the weighting is the reciprocal of the mean square error of the sample ratio in each average catch weight interval. The line of best fit appears horizontal, and statistically the slope is not significantly different from zero (p-value = 0.895). Thus, the catch weight ratio ($\rho_{C_W PUE}$) of beehive over WA pots is consistent across a wide range of abundance bins.

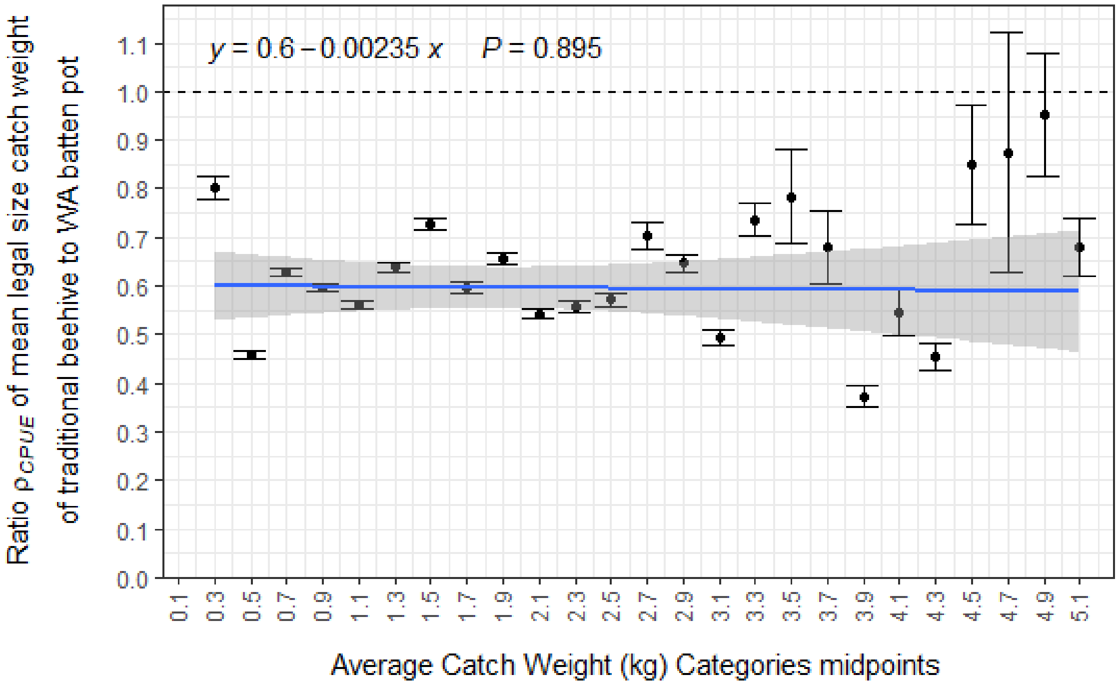


Figure 17. Legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot against average catch weight (0.2 kg-wide bins mid-points) with 95% confidence intervals (N= 2,741 matched pot pairs). Weighted regression (blue line) of legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot against average catch weight in a pot pair is also shown. Note, weightings used in regression are the reciprocal of the mean square error. Shading represents the 95% confidence interval band of the catch weight ratio conditional on the mid-point of the average catch weight bin. Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.1.3.2 Month

Figure 18 shows the estimated ratio ($\hat{\rho}_{C_WPUE}$) of the means of legal-size catch weight from the two designs calculated for each month between November and March. The ratios for each month were always below 1 indicating that the WA batten pot catches more legal-size lobsters than the traditional beehive pot irrespective of the month of the fishing season. The 95% CIs on the ratio are shown as error bars for each month. Monthly ratios for November to March, the main fishing months of the NZRLF season, are distinct except for November, as monthly CIs do not overlap indicating these ratios are significantly different at the 95% confidence level. Lower ratios were recorded for April and May at the end of the fishing season when there was less fishing activity undertaken (and fewer fishers undertaking pot testing) (Figure 18, Table 11). The separation in the monthly ratios (and narrow monthly CIs) implies measurable differences by month in the ratios (ρ_{C_WPUE}) and indicates that month is an important modelling predictor for legal-size catch efficiency differences between the two pot designs.

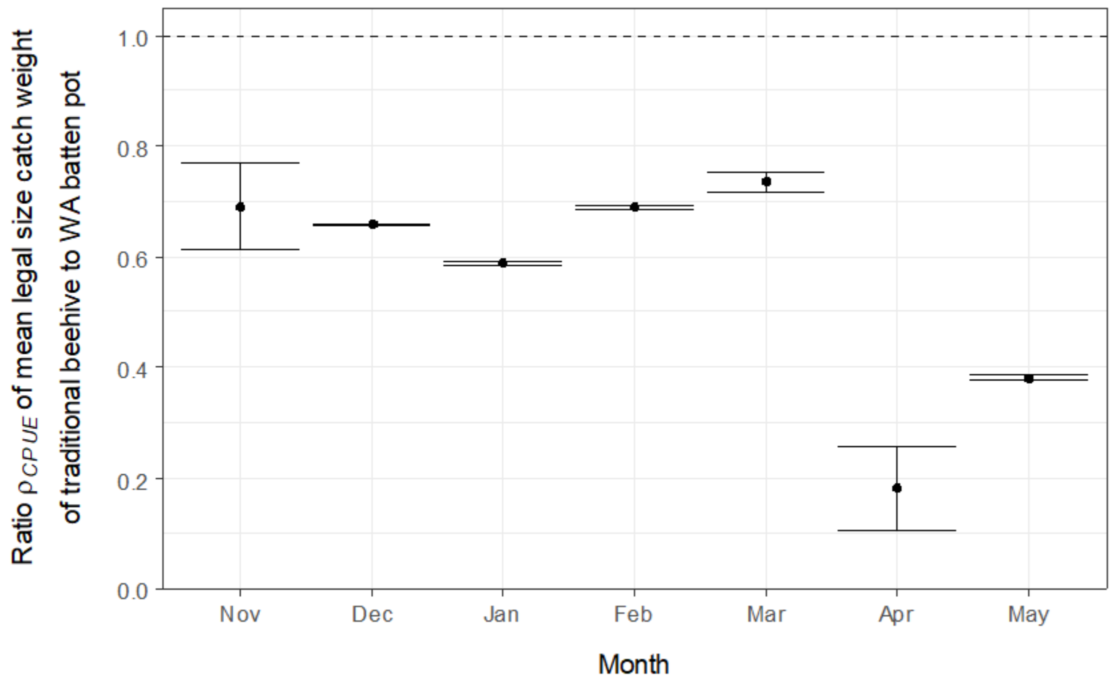


Figure 18. Legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot for each month between November and May, with 95% confidence intervals (N= 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

Table 11. Legal-size lobster catch weight ratios of the traditional beehive pot to the WA batten pot for each month between November and May, with 95% confidence intervals (N= 2,741 matched pot pairs).

Month	N (pot pairs)	Mean catch (kg) from traditional beehive pot	Mean catch (kg) from WA batten pot	Legal-size catch weight ratio of traditional beehive pot to WA batten pot	95% CIs - legal-size catch weight ratio of traditional beehive pot to WA batten pot
November	95	0.43	0.62	0.69	(0.6136, 0.7686)
December	817	0.87	1.33	0.66	(0.6550, 0.6602)
January	708	1.10	1.87	0.59	(0.5854, 0.5903)
February	720	0.88	1.28	0.69	(0.6853, 0.6915)
March	153	0.93	1.26	0.73	(0.7164, 0.7535)
April	10	0.33	1.86	0.18	(0.1034, 0.2572)
May	238	0.52	1.37	0.38	(0.3765, 0.3867)

5.9.1.3.3 Licence

Figure 19 shows the estimated ratio ($\hat{\rho}_{C_W PUE}$) of the means, and 95% CIs, of legal-size catch weight from the two designs calculated for each fishing licence. Ratios varied among licences indicating that WA batten pots performed better when used by some fishers relative to others. However, all but one licence recorded a $\hat{\rho}_{C_W PUE}$ < 1, indicating that nearly all fishers caught more lobsters in WA batten pots than in the traditional beehive pots (Figure 19). Fishers recording higher ratios tended to have wider 95% CIs around the sample ratio, indicating that they had more variability in their catches and/or set relatively fewer pots.

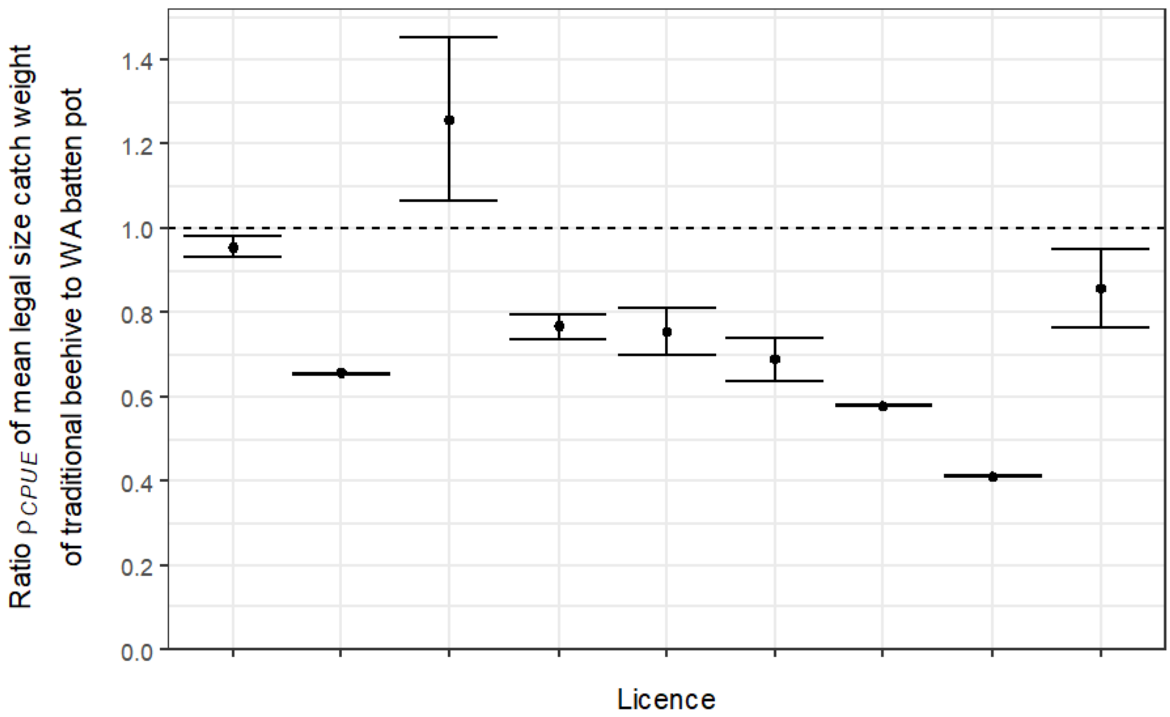


Figure 19. Legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot for each fisher licence, with 95% confidence intervals (N = 2,741 matched pot pairs). Note, individual licence numbers not displayed due to confidentiality. Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.1.3.4 Marine Fishing Area (MFA)

Figure 20 shows the estimated ratio ($\hat{\rho}_{C_W PUE}$) of the means, and 95% CIs, of legal-size catch weight from the two designs calculated for each MFA. The relatively wide CIs exhibited for some MFA ratios indicate small sample sizes of paired potlifts in those MFAs. While there are some differences in the ratio from one MFA to another, the variability within some MFAs limits the use of MFA as a modelling predictor for explaining legal-size catch rate differences between the two pot designs.

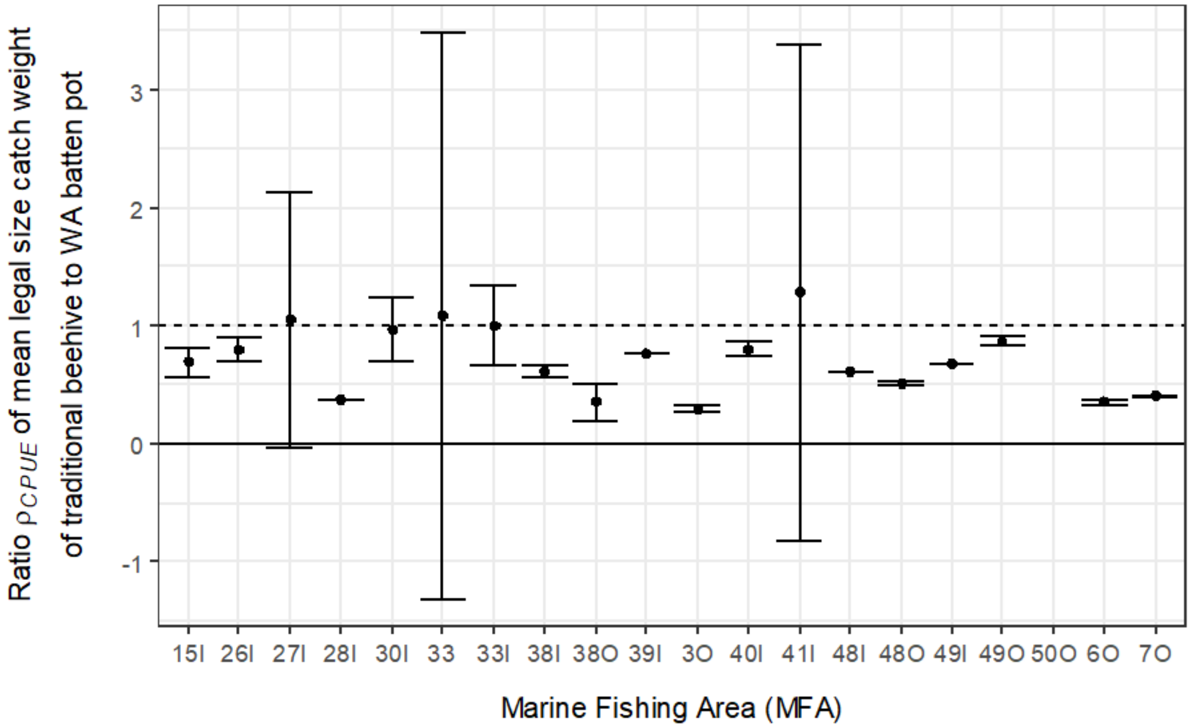


Figure 20. Legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot for each Marine Fishing Area, with 95% confidence intervals (N = 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.1.3.5 Depth

Figure 21 shows the estimated ratio ($\hat{\rho}_{C_WPUE}$) of the means, and 95% CIs, of legal-size catch weight from the two designs calculated for average depths binned in 10-metre-wide categories. No discernible pattern or relationship for the ratio with respect to depth is apparent thus limiting the use of depth as a modelling predictor for explaining legal-size catch rate differences between the two pot designs.

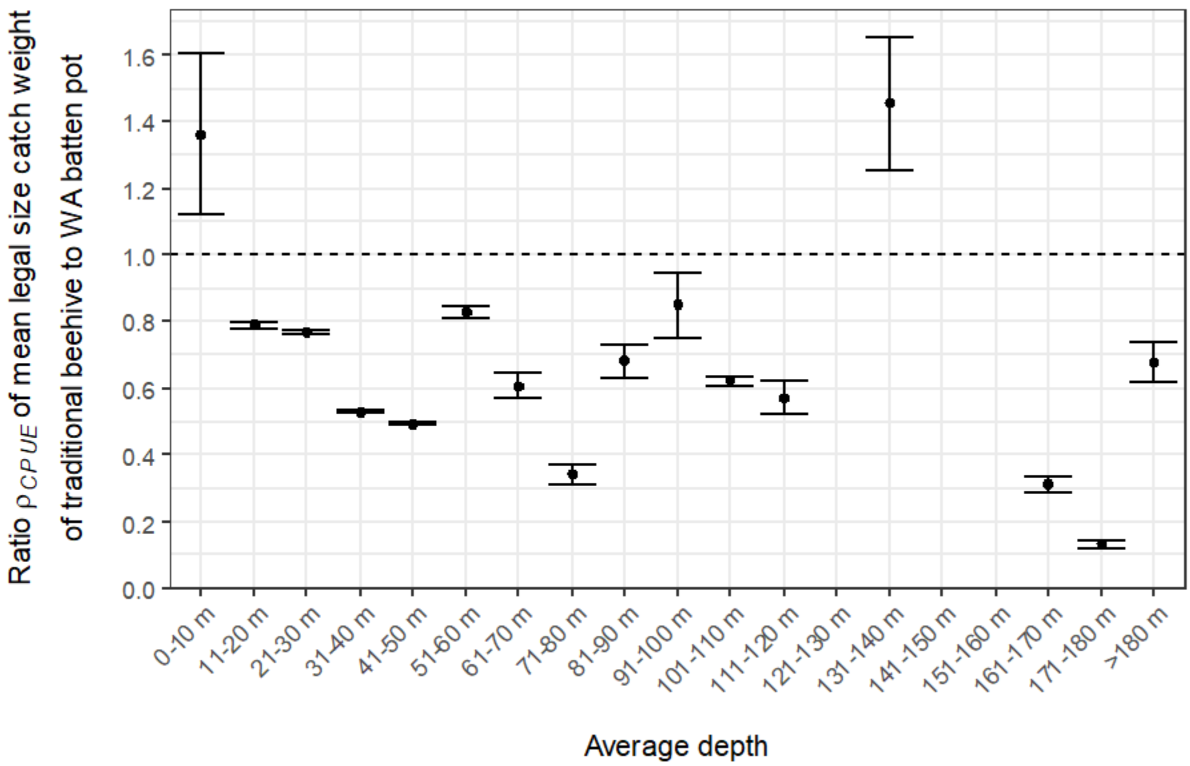


Figure 21. Legal-size mean catch weight ratio of the traditional beehive pot to the WA batten pot for average depths of the potlifts in a pair in 10-metre-wide depth bins, with 95% confidence intervals (N= 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.2 Undersize lobsters (PRI)

5.9.2.1 Preliminary statistics by pot design

Aggregated data from the 2,741 matched potlift-pairs indicated that, on average, the WA batten pots caught 0.09 undersize lobsters/potlift more than traditional beehive pots (Figure 22, Table 12). This was similar to the trends in catch observed from the two pot designs for legal-size lobsters (section 5.9.1.1).

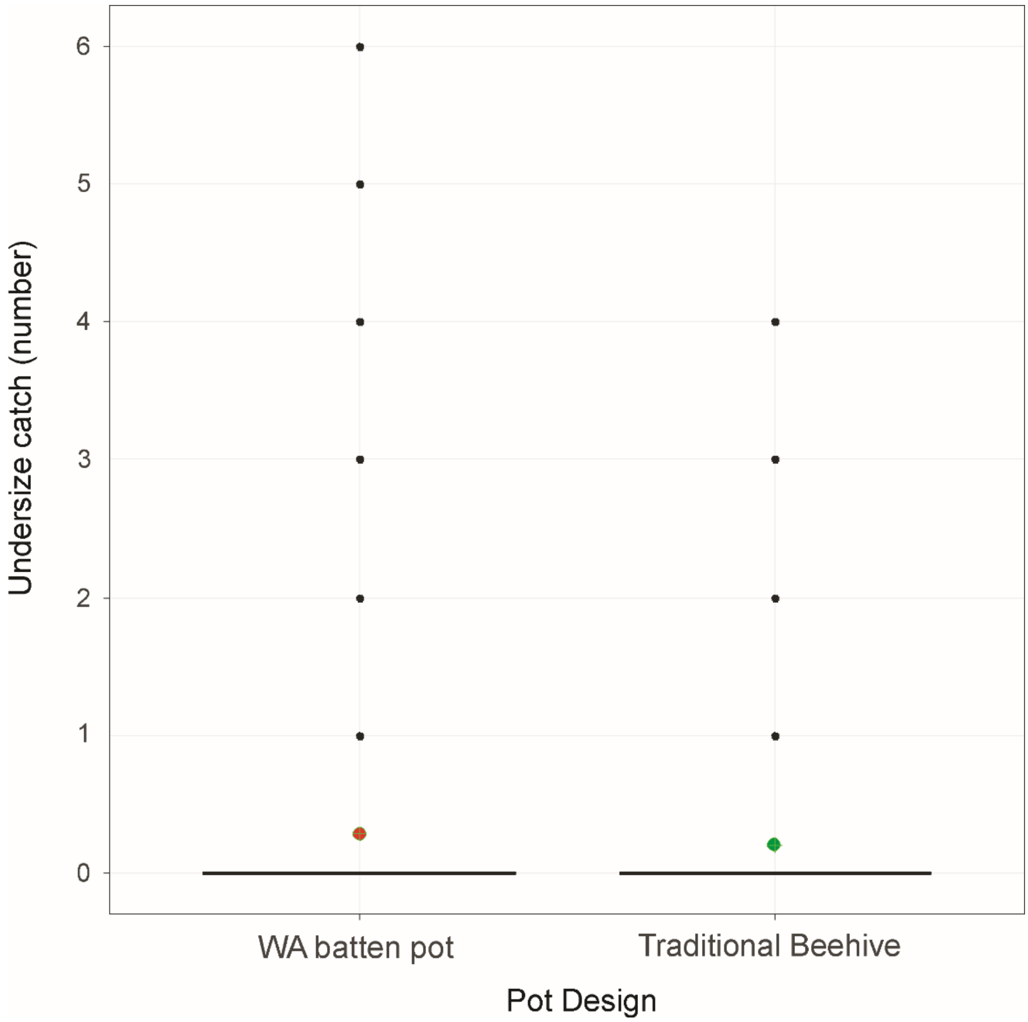


Figure 22. Box plot of catch of undersize lobsters (number) from WA batten pots and traditional beehive pots (N = 2,741 matched pot-pairs). Red dot is the mean undersize catch from WA batten pots, and the green dot is the mean undersize catch weight from traditional beehive pots. Ratio of 1 (equal catch from each pot design) represented by dashed line.

Table 12. Mean catch of undersize lobsters (number) sampled from 2,741 matched WA batten pot and traditional beehive pot-pairs.

Pot design	N (potlifts)	Mean	SE
WA batten pot	2,741	0.288	0.012
Traditional Beehive	2,741	0.196	0.010

5.9.2.2 Relationship between pot designs: analysis of matched pairs

A one-sample t-test of the paired differences in catch of undersize lobsters from the WA batten pot and traditional beehive pot indicated that the mean of the paired difference was significantly different from zero ($t = 6.638$, $df = 2{,}740$, p-value < 0.001) inferring that WA batten pots had a significantly higher catch rate of pre-recruits (mean of 0.288 undersize lobsters/potlift) than traditional beehive pots (mean of 0.196 undersize lobsters/potlift).

The matched pot-pair sample contained many pairs where at least one of the pot types had zero undersize catch. A total of 1,899 (69%) of the 2,741 matched pairs had zero undersize lobsters recorded in both pot types. This feature of the data makes analysis of the undersize catch paired ratio unfeasible because division by zero is undefined. Similar to the analyses undertaken in section 5.9.1.2, the solution to overcome this data challenge is again to aggregate the matched pairs into bins from which individual mean PRI values can then be calculated.

To measure the relationship of undersize catch between the two pot designs, the ratio of mean undersize catch for the traditional beehive pot design ($PRI_{beehive}$) to the mean undersize catch from the WA batten pot design (PRI_{WA}) is then estimated as:

$$\rho_{PRI} \coloneqq \frac{PRI_{beehive}}{PRI_{WA}}.$$

Using the sample means from the sample of matched pairs in Table 12, this ratio parameter is estimated as $\hat{\rho}_{PRI} = 0.68$. The estimated mean square error $\widehat{MSE}(\hat{\rho}_{PRI})$ using a linearised Taylor series estimator as derived by Wolter (2007) was 0.001577 (95% CIs, 0.6779, 0.6841).

5.9.2.3 Exploratory analysis: Lobster abundance, Month, Licence, MFA, Depth

This section explores, for PRI, any potential dependence of the ratio of the means of undersize lobster catch (by number) from the two pot designs on the following variables:

- Lobster abundance
- Month
- Licence
- MFA; and
- Depth.

5.9.2.3.1 Lobster abundance

Figure 23 shows the estimated ratio ($\hat{\rho}_{PRI}$) of the means, and 95% CIs, of undersize lobster catch (number) from the two designs calculated against the average count of pre-recruits recorded from a matched pair. The abundance of undersize lobsters at the site of each pot pair does not help to explain the ratio of the relative undersize catch efficiencies of the two pot designs. No discernible pattern or relationship for the ratio with respect to average number of undersize lobsters (lobster abundance) is apparent and the variability (95% CIs) increases as the average count of pre-recruits increases.

The slope of the regression, while positive, is not significantly different from zero (p-value = 0.313) indicating that the ratio (ρ_{PRI}) is consistent across a wide range of abundance bins (Figure 23). This consistency, and the high variability observed across different levels of undersize lobster abundance, indicates that the abundance of undersize lobsters is not a good predictor of catch rate differences between the two pot designs.

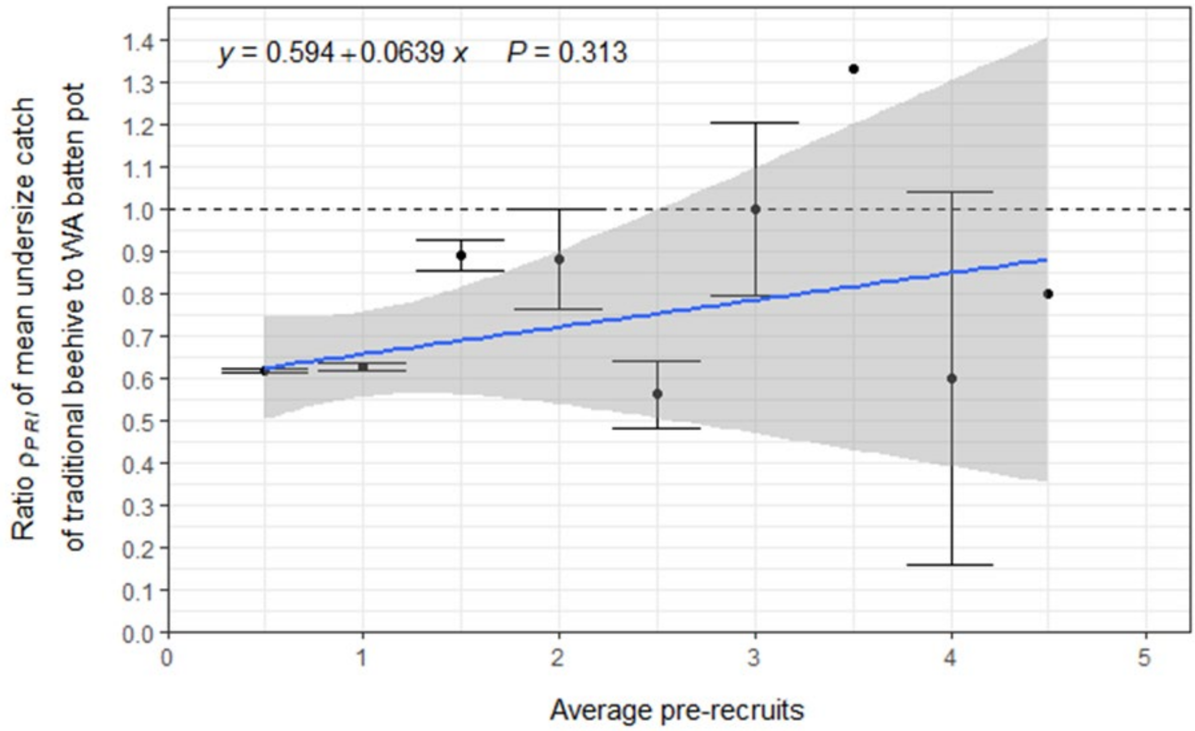


Figure 23. Sample ratio of mean undersize catch from the traditional NZRLF beehive pot over the WA batten pot by average undersize catch in a pot pair, with 95% confidence intervals (N=2,741 matched pot pairs). Weighted regression (blue line) of undersize mean catch ratio of the traditional beehive pot to the WA batten pot against the average undersize catch in a pot pair is also shown. Note, weightings used in regression are the reciprocal of the mean square error. Shading represents the 95% confidence interval band of the undersize catch ratio conditional on the average undersize catch count. Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.2.3.2 Month

Figure 24 and Table 13 show the estimated ratio ($\hat{\rho}_{PRI}$) of the means, and 95% CIs, of undersize lobster catch (number) from the two designs calculated for each month of the fishing season between November and May. The ratios for each month were always below 1 indicating that the WA batten pot catches more undersize lobsters than the traditional beehive pot irrespective of the month of the fishing season. A ratio ($\hat{\rho}_{PRI}$) could not be calculated for April or May (no undersize lobsters were recorded from traditional beehive pots in April and no undersize lobsters were recorded in either pot design in May). Ratios increased from November to February, indicating that gains in catch efficiency from WA batten pots decrease during this period. Consequently, month is considered an important modelling predictor for explaining differences in undersize catch rate between the two pot designs.

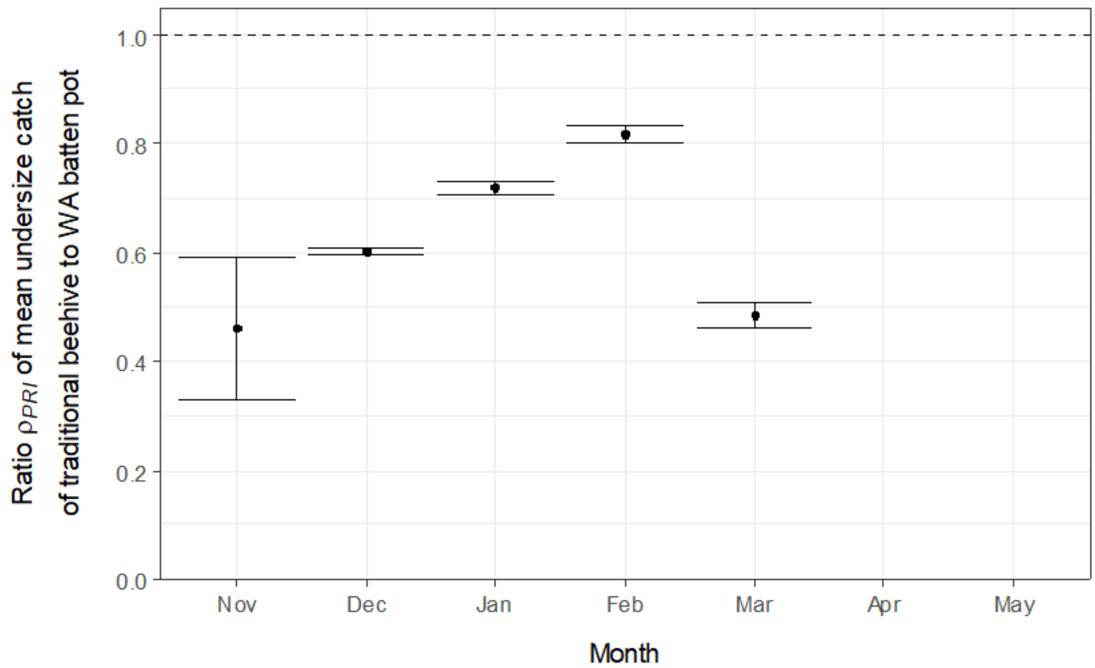


Figure 24. Undersize mean catch ratio of the traditional beehive pot to the WA batten pot for each month between November and May, with 95% confidence intervals (N= 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

Table 13. Undersize lobster catch (by number) ratios of the traditional beehive pot to the WA batten pot for each month between November and May, with 95% confidence intervals (N= 2,741 matched pot pairs).

Month	N (pot pairs)	Mean catch (number) from traditional beehive pot	Mean catch (number) from WA batten pot	Undersize catch ratio of traditional beehive pot to WA batten pot	95% CIs - undersize catch ratio of traditional beehive pot to WA batten pot
November	95	0.06	0.14	0.46	(0.3303, 0.5928)
December	817	0.19	0.32	0.60	(0.5956, 0.6090)
January	708	0.24	0.34	0.72	(0.7072, 0.7297)
February	720	0.24	0.30	0.82	(0.8005, 0.8333)
March	153	0.18	0.38	0.48	(0.4592, 0.5063)
April	10	0.00	0.40	N/A	N/A
May	238	0.00	0.00	N/A	N/A

5.9.2.3.3 Licence

Figure 25 shows the estimated ratio ($\hat{\rho}_{PRI}$) of the means, and 95% CIs, of undersize lobster catch (number) from the two designs calculated for each fishing licence. All but two licences recorded a $\hat{\rho}_{PRI}$ < 1, indicating that nearly all fishers caught relatively more undersize lobsters in WA batten pots than in the traditional beehive pots. Ratios ($\hat{\rho}_{PRI}$) also varied among licences indicating that WA batten pots performed better when used by some fishers relative to others. However, the ratios estimated for each licence exhibited wide 95% CIs, making it difficult to discern any trends in the undersize catch rates between pot types among fishers.

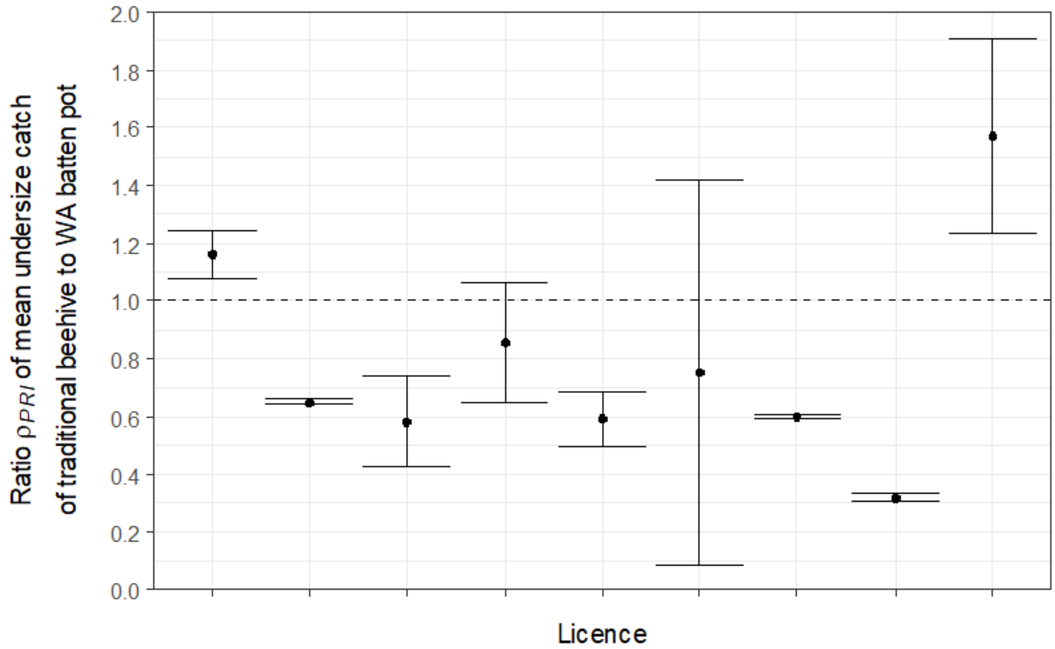


Figure 25. Undersize mean catch ratio of the traditional beehive pot to the WA batten pot for each fisher licence, with 95% confidence intervals (N = 2,741 matched pot pairs). Note, individual licence numbers not displayed due to confidentiality. Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.2.3.4 Marine Fishing Area (MFA)

Figure 26 shows the estimated ratio ($\hat{\rho}_{PRI}$) of the means, and 95% CIs, of undersize lobster catch (number) from the two designs calculated for each MFA. The wide CIs exhibited for some MFAs (e.g., MFAs 15I, 27I, 30I, 38O) indicate small sample sizes (paired potlifts) in those MFAs. No discernible pattern or relationship for the ratio with respect to MFA is apparent. Of note, six MFAs have no data because all pot pairs sampled in those MFAs had zero undersize catch, and thus a ratio was not able to be calculated. This further demonstrates the reduced utility of MFA as a suitable modelling predictor for explaining undersize catch rate differences between the two pot designs.

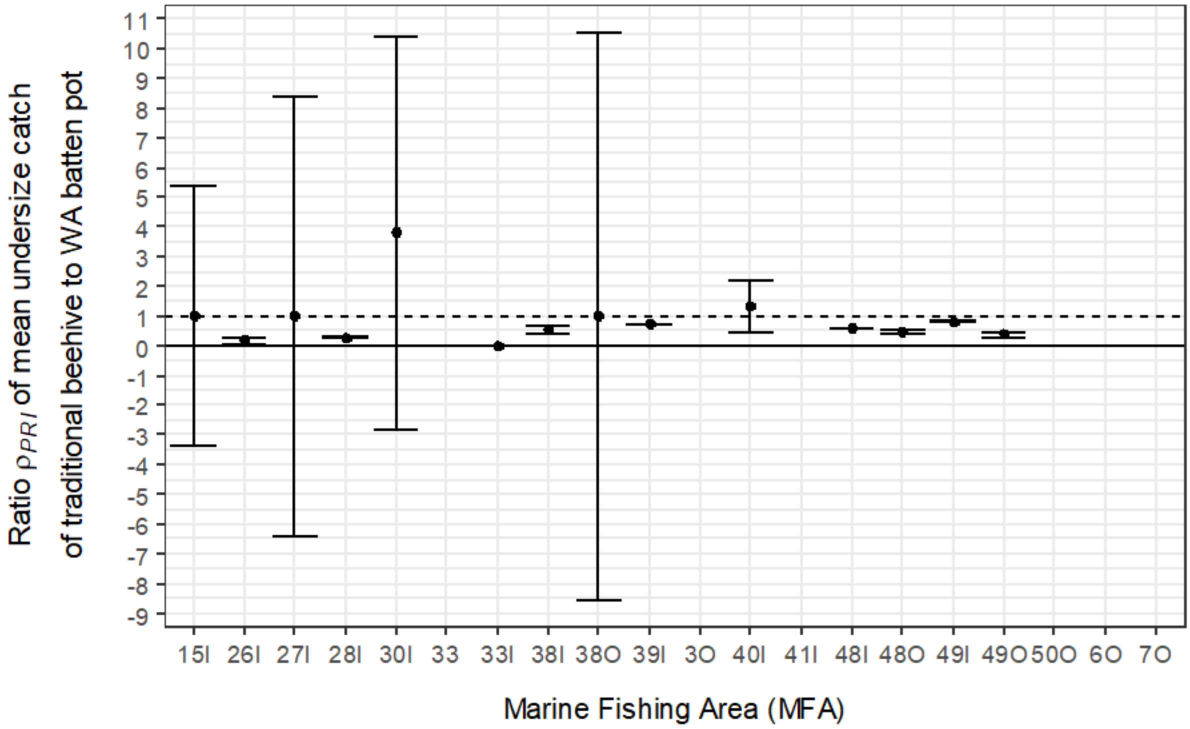


Figure 26. Undersize mean catch ratio of the traditional beehive pot to the WA batten pot for each Marine Fishing Area, with 95% confidence intervals (N = 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.9.2.3.5 Depth

Figure 27 shows the estimated ratio ($\hat{\rho}_{PRI}$) of the means, and 95% CIs, of undersize lobster catch (number) from the two designs calculated for average depths binned in 10-metre-wide categories. No discernible pattern or relationship for the ratio with respect to depth is apparent thus limiting the use of depth as a modelling predictor for explaining undersize catch rate differences between the two pot designs.

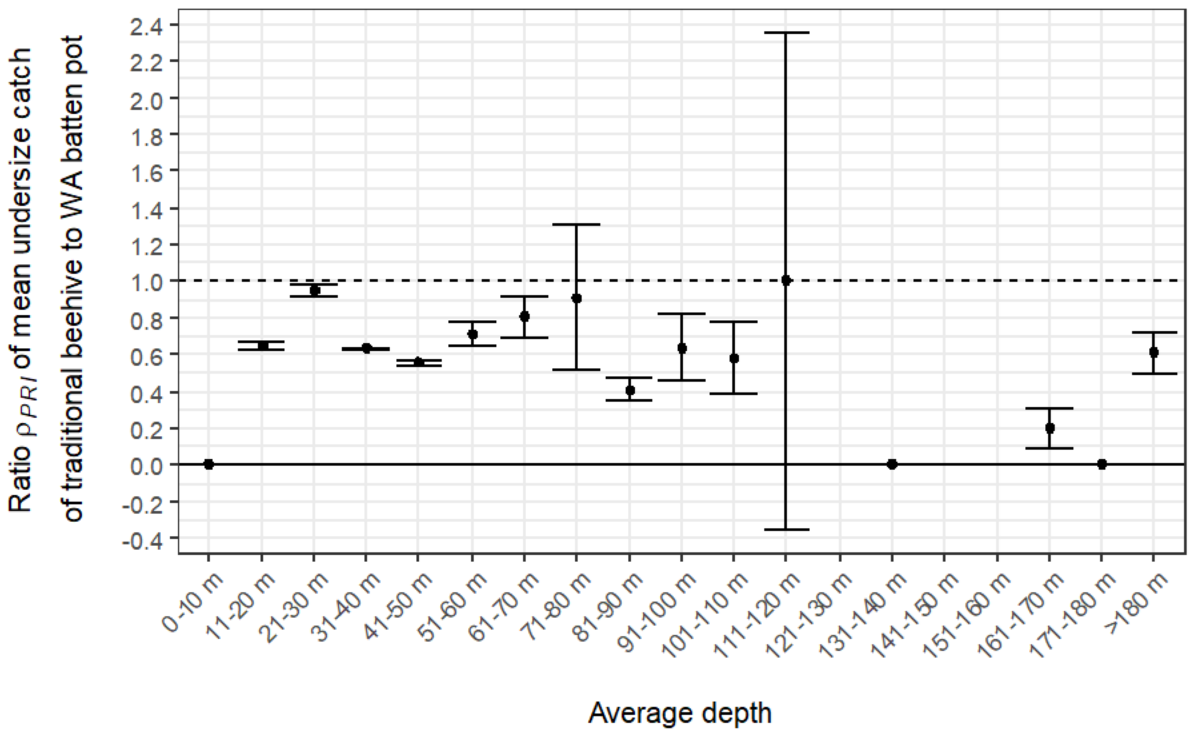


Figure 27. Undersize mean catch ratio of the traditional beehive pot to the WA batten pot for average depths of the potlifts in a pair in 10-metre-wide depth bins, with 95% confidence intervals (N= 2,741 matched pot pairs). Ratio of 1 (equal catch from each pot design) represented by dashed line.

5.10 Accounting for differences in pot design catch efficiency in future harvest strategy decision rules

In the NZRLF, WA batten pots are being used in regular commercial fishing for the first time in the 2022 season (1 November 2022 – 31 October 2023). In both the Inner and Outer regions of the Northern Zone, legal-size CPUE and the pre-recruit index (PRI) are the primary and secondary performance indictors used in the harvest strategy for TACC setting (PIRSA 2021). The harvest strategy is comprised of tables of values of legal-size CPUE and PRI, obtained from traditional beehive pots, that determine levels of quota (TACC) in the following fishing season.

This study has recorded consistently higher legal-size CPUE (greater catch of legal-size lobsters in weight per pot) and higher PRI (more undersize lobsters per pot) from the WA batten pot design. The analyses undertaken indicate that lobster abundance, MFA and depth are weak modelling predictors for explaining the higher catch efficiency of legal-size and undersize lobsters observed in WA batten pots. The absence of a relationship between legal-size catch weight ratio ($\rho_{C_W PUE}$) and undersize lobster catch (number) ratio (ρ_{PRI}) from the two designs across wide ranging values of lobster abundance is an important result. It indicates that the higher catch efficiency of WA batten pots is not well explained by lobster abundance, which is an important finding when considering how (ρ_{C_WPUE}) and (ρ_{PRI}) may be applied in a temporal context during annual stock assessments that consider varying levels of stock abundance.

The lack of a discernible relationship for the ratios (ρ_{C_WPUE}) and (ρ_{PRI}) with respect to MFA and depth also limits their use as modelling predictors for explaining differences in catch efficiency between the two pot designs (sections 5.9.1.3.2, 5.9.2.3.2). Some variation in these ratios as a function of licence (fishers) was apparent, indicating that WA batten pots performed better when used by some fishers relative to others. However, fishers recording relatively higher ratios tended to have wider 95% CIs around the sample ratio, indicating that they had more variability in their catches and/or set relatively fewer pots. Further, the use of fisher (licence) to account for increases in WA batten pot catch efficiency is limited as it would not be applicable to fishers who were not involved in project testing, new fishers, or fishers moving to operate under a different licence number.

The separation in the ratios (ρ_{C_WPUE}) and (ρ_{PRI}) with respect to month indicates that month may be important as a modelling predictor for explaining catch rate differences between the two pot designs. The sample ratios ($\hat{\rho}_{C_WPUE}$) and ($\hat{\rho}_{PRI}$) calculated from our paired sample by month (sections 5.9.1.3.2 and 5.9.2.3.2) provide suitable conversion factors to account for the observed (and future predicted) variations in catch efficiency obtained from the traditional beehive pot design with respect to the WA batten pot design. It should also be noted that although ratios ($\hat{\rho}_{PRI}$) could not be calculated for April or May, the harvest strategy for the NZRLF uses data from November to March.

The current harvest strategy was designed and tested with extensive projection modelling that used data from the traditional beehive pot design to compute the values of legal-size CPUE and PRI. A key objective of this FRDC project was to develop and apply methods to prevent the higher estimates of legal-size CPUE and PRI from WA batten pots from biasing the performance indicator inputs used within the harvest strategy to determine TACC. In the current 2022/23 NZRLF fishing season, 8 of the active 63 licences have adopted the WA batten pot for use. This strict separation of pot type by licence allows pot type to be accounted for in post-season calculations of legal-size lobster CPUE and PRI using the commercial logbook data that are currently used to compute these PIs. Through this project, two approaches were developed to correct for the higher catch rates of WA batten pots. The first method is applicable in fishing seasons when the majority of licences continue to use the traditional beehive pot. The second method, which employs the ratio results of section 5.9, is applicable if the majority of fishers (licences) adopt the WA batten pot.

5.10.1 Bias correction method 1

Where the majority of fishers (licence holders) in the NZRLF continue to use the traditional beehive pot in 2022, a direct method is proposed to obtain comparable estimates of legal-size

CPUE and PRI to inform quota setting for the 2023 NZRLF fishing season. The method is simply to remove the data from the vessels (licences) (N=8) that are using the new WA batten pot from the 2022-season yearly values of legal-size CPUE and PRI to be used in quota setting.

Using only catch returns from vessels using the traditional beehive pot design removes potential bias caused by inclusion of catch data from WA batten pot designs with higher catch efficiency. However, there is likely to be some difference between the previous CPUE index that used all licences and a modified index that omits the licences of WA batten pot users. While this difference is unlikely to be substantial because the majority of licences are continuing to use the traditional beehive pot in the 2022 season, it will be corrected for by recalibrating the beehive-pot-only performance indicators by rescaling their mean value to equal that of the nominal CPUE and PRI used in the years prior that included all licences.

To recalibrate, (1) modified CPUE and PRI will be computed for all years using catch and effort data that excludes all licences that used WA batten pot designs in the 2022 fishing season; (2) each time series will be compared with the same nominal (historical reported) CPUE and PRI time series computed using data that include all licences. This comparison will be done for seasons 2015 to 2019 to reflect more recent trends in catch rate versus licence, covering years up to the last season of the projection modelling used to choose the current harvest strategy; and (3) if estimates of legal-size CPUE and PRI calculated from data that excludes WA batten pots are measurably different from the nominal (historical) estimates, then a rescaling factor (re-calibration) will be applied to correct the mean of each index measured from data including only the traditional beehive-pot. Specifically, the new CPUE and PRI time series, with WA batten pots excluded, will be rescaled such that their means equal the means of the respective nominal time series used historically. These rescaled estimates could then be used in the harvest strategy to inform the TACC for the 2023/24 fishing season.

5.10.2 Bias correction method 2

If the WA batten pot is adopted by a majority of licences in the NZRLF fleet, a different correction method will be used and computed from the ratios from the matched-pair analysis presented in section 5.9 above, specifically, the monthly ratios for legal-size CPUE ($\rho_{C_W PUE}$) and PRI (ρ_{PRI}) (sections 5.9.1.3.1 and 5.9.2.3.2). These monthly ratio correction factors will be applied to CPUE and PRI from all daily catches that are taken by the WA batten pot. Because the month is known from data submitted through commercial logbooks, the corresponding monthly-specific correction factor can be selected and multiplied to correct (downscale) the reported WA batten pot catch.

The corrected yearly catch total for legal-size CPUE and PRI can then be computed by summing the reported (nominal) catches from traditional beehive pots (whose rescaling factors are 1) together with the monthly ratio-corrected catches from the WA batten pots (legal-size

CPUE (inner zone): November to April); PRI: November to March). This corrected catch total is then divided by the (nominal, raw) number of potlifts reported for those same months, giving the respective yearly values for CPUE and PRI that can be applied in the harvest strategy to inform setting of the TACC. To permit reliable correction, licence holders have agreed to use either all WA batten pots or all traditional beehive pots in their yearly fishing operations.

6 Discussion

Empirical measurement of catch efficiency as a function of pot design is rare for lobster fisheries as it requires large sample sizes to determine efficiency gains (Montgomery 2005; Winzer et al 2011). This study comprises one of the most comprehensive programs of pot design testing undertaken for a rock lobster fishery and highlights how modern-day arrangements of fishery co-management can lead to a framework of applied experimentation and statistical evidence to serve multiple stakeholder purposes. WA batten pots consistently recorded higher estimates of legal-size CPUE (greater catch of legal-size lobsters in weight per pot) and higher PRI (more undersize lobsters per pot). Geo-statistical methods, developed to control for temporal (e.g. month) and spatial (e.g. MFA, depth) covariates, as well as lobster abundance, also indicated, a higher catch efficiency of legal-size ($\hat{\rho}_{C_WPUE} = 0.62$) and undersize lobsters ($\hat{\rho}_{PRI} = 0.68$) in WA batten pots compared to traditional beehive pots, supporting the trends observed through each phase of testing.

For industry members of the NZRLF, the improvement in catch efficiency of legal-size lobster recorded from WA batten pots confirms their potential to lower the amount of fishing effort required to attain annual TACCs thereby lowering input costs and increasing profitability. The project's results also allow fishers in the NZRLF to have confidence in investing in the purchase of WA batten pots in the future. For fishery scientists and managers, the data and analytical methods provided through the project allow future stock assessment and management of the NZRLF to account for the relative increases in CPUE of legal-size and undersize lobster (PRI) attributed to WA batten pots. Such approaches are important to maintain scientific rigor in the calculation of performance indicators for the NZRLF and for application of the harvest strategy that underpins annual TACCs (PIRSA 2021).

6.1 Uncertainty within information sources and data

Information available for this project included data obtained from two reporting methods between 2017/18 and 2021/22: 1) catch sampling data from scientific observers (measured per pot); and 2) aggregated commercial logbook data (summarised daily). The higher CPUE estimates recorded from WA batten pots have financial implications for the NZRLF industry and for Southern Rock Lobster resource assessment and management. Consequently, it is important that the sources of uncertainty associated with project data collection are considered.

In all phases of WA batten pot testing, except phase 3 (treatment 4), gains in CPUE of legal-size lobster estimated from catch sampling data were recorded from WA batten pots. However, treatment-specific gains in WA batten pot CPUE estimated between 2017/18 and 2021/22 were highly variable, ranging from 24% in 2018/19 (phase 3) to 118% in 2021/22 (phase 5).

Analysis of data from geo-statistically matched pot-pairs (N=2,741) was also indicative of high variability in legal-size and undersize catches between the two pot designs. These trends highlight that lobster catches, irrespective of pot design, are highly variable per pot, and support the future need to undertake data collection, in collaboration with the fishing industry, from a large number of potlifts. This recommendation was highlighted in the study of Winzer et. al (2011), and further in our study by the relatively low estimate of legal-size CPUE recorded in treatment 4 (2018/19) from WA batten pots (0.86 kg/potlift) compared to traditional NZRLF beehive pots (1.12 kg/potlift). This result is considered spurious as it is inconsistent with all other project results and was obtained from the lowest number of potlifts sampled from any treatment or phase (N potlifts = 124).

Catch efficiency gains of legal-size and undersize lobster from WA batten pots estimated from commercial logbook data generally supported those estimated from the catch sampling data. The exception to this was in treatment 4 (2019/20 and 2021/22) where legal-size CPUE recorded for WA batten pots from commercial logbook data was different to that recorded from catch sampling data. Interrogation of a subset of the data reported independently via the two different methods on the same days fished, indicated some differences in the summaries provided through commercial logbook data. This result is not unexpected. The recording of lobster counts per design is a lesser priority for fishers during fishing operations, where they are occupied with navigation, safety, gear retrieval and catch storage. Vessels are also not usually able to store lobsters caught from different pot designs separately, reducing the ability to undertake counts of lobsters caught from different designs post-fishing. Further, fishers sometimes return lobsters that are damaged due to the reduced prices such lobsters receive. In contrast, catch sampling methods undertaken by observers require that all lobsters within a pot are measured once a pot is retrieved, and are therefore more accurate. The differences in catch records observed between the two data reporting methods highlight the value of having dedicated observers record pot-specific data during research projects.

6.2 WA batten pot - design considerations

Lobster fishers have long used wooden materials such as spruce, hemlock or pine to construct lobster traps (Southwest Harbor Public Library 2023). The WA batten pot, traditionally constructed of Jarrah (*Eucalyptus marginata*) or other hardwood, has been used to target Western Rock Lobster and Southern Rock Lobster in Western Australia since at least 1973 (de Lestang pers. comm). Its wooden construction may help to explain the relatively high catch efficiency observed. Even for pots mostly constructed of metallic materials, fishers often integrate wooden materials (e.g., cane) into the cove (pot-entry). The thoracic appendages and mouthparts of crustacean species are highly innervated with chemosensory and mechanosensory receptors. It is thought that these sensory structures may be more receptive of wooden materials compared to metal. If so, this could potentially explain why WA batten pots are more effective. Further research involving direct observations of foraging behaviour in response to different pot type materials would be required to test how material type influences pot catch efficiency.

The dimensions of traditional NZRLF beehive pots and WA batten pots are different. Notably, WA batten pots have less pot volume (~0.25 m^3) than traditional beehive pots (0.71 m^3) indicating that the relatively higher catch rates observed in WA batten pots may be more influenced by the material construction or shape of the pot than its pot volume. WA batten pots are also heavier, weighing over 40kg. This increased weight is a factor that should be considered by fishers if switching from traditional NZRLF beehive pots as it has Occupational Health, Welfare and Safety implications for deck-handling practices and vessel stability.

The jarrah construction material of WA batten pots also makes them more susceptible to breakage compared to beehive pots that are constructed largely of steel. Breakage was a key factor for WA batten pot testing being discontinued in the SZRLF in 2019/20 (Appendix 4). The seafloor habitat of the SZRLF is comprised mainly of reefs made of bryozoan or aeolianite limestone that makes fishing gear prone to damage. Breakage is less problematic in the NZRLF where fishing occurs on a variety of reef habitat comprised of granite and limestone that may be relatively more conducive to WA batten pot use. Further, Jarrah sourced from new growth forests in south-west Western Australia is biodegradable, so poses lesser environmental risk if battens are lost through pot breakage.

6.3 Effort reductions

For lobster fisheries that are managed using TACCs, reducing the number of potlifts undertaken per season has the potential to reduce fishing costs and improve net economic return without compromising resource sustainability. If the sample ratio $\hat{\rho}_{C_W PUE} = 0.62$, estimated from the sample of matched pairs (section 5.9.1.2), is considered with respect to effort, NZRLF fishers that choose to switch to WA batten pot designs may experience a reduction in effort (potlifts) of up to 38% (1 - $\hat{\rho}_{C_W PUE}$).

How any reduction in effort driven by improved pot catch efficiency translates to financial gain would be dependent on overall input costs, the TACC set, and catch rate attained in any particular fishing season. For example, under a current inner zone TACC in the NZRLF of 250 tonnes, and applying the 2021/22-season average legal-size catch rate (CPUE) from traditional beehive pots of 1.25kg/potlift, a total of 200,000 potlifts would be required to take the TACC. If the entire fleet had used the alternative WA batten pot type in the same period, a total of 124,000 potlifts would have been expected to harvest the TACC (i.e., 76,000 potlifts less). Any reductions in fishing effort, and by proxy financial gain, would be expected to be proportional to catch rate, i.e., decreasing as CPUE decreases. Nonetheless, the cost savings of employing a gear type that is up to 38% more efficient will be cumulative annually and should be considered over many fishing seasons of operation. Future quantification of actual economic efficiencies gained through the adoption of WA batten pots is recommended to validate the project results and further increase the likelihood of adopting more efficient pot designs.

6.4 Efficiency gain implications for spawning lobsters, undersize lobsters, bycatch and byproduct, and depredation

6.4.1 Spawning females and undersize lobsters

Catches of spawning lobsters were generally low in the project due to sampling being undertaken outside the main spawning period (July to October) (section 5.7). However, assuming that catchability of spawning and non-spawning legal-size female lobsters is similar with respect to pot-design, and applying the sample ratio $\hat{\rho}_{C_W PUE} = 0.62$ from the sample of matched pairs (section 5.9.1.2), catches of spawning lobsters may be increased by up to 38% if NZRLF fishers use WA batten pots during the spawning period of July to October. However, any potential increases in the rate of spawning female discards attributed to increases in WA batten pot efficiency would be offset by the reduction in effort required to take annual TACC.

It is considered advantageous to minimise rates of handling of undersize lobster due to potential impacts from post-release predation (Brown and Caputi 1983; Raby et al. 2013). Applying the sample ratio $\hat{\rho}_{PRI} = 0.68$ from the sample of matched pairs (section 5.9.2.25.9), catches of undersize lobsters per potlift may be increased by up to ~32% for NZRLF fishers using WA batten pots, resulting in relatively higher rates of undersize discarding in the NZRLF compared to traditional beehive pots. However, this number would be offset by a potential 38% reduction in the total number of potlifts undertaken if WA batten pots were used to attain annual TACC. Due to the relatively higher sample ratio for PRI ($\hat{\rho}_{PRI} = 0.68$) (= relatively lower catch efficiency) compared to sample ratio for legal-size lobsters ($\hat{\rho}_{C_W PUE} = 0.62$), overall discard rates of undersize lobsters for fishers using WA batten pots may be reduced relative to the use of traditional beehive pots.

6.4.2 Bycatch and byproduct

The taxonomic composition of bycatch recorded from both pot designs was similar (section 5.6). With the exception of Ocean Jacket and Hermit Crabs, traditional beehive pots caught more individuals of all bycaught species recorded during NZ testing. Relatively low numbers of the byproduct species Māori Octopus and Giant Crab were recorded during NZ testing. However, catch rate trends for these byproduct species broadly resembled that for bycatch, being lower from alternative WA batten pots compared to traditional beehive pots. These results indicate lesser potential impacts to bycatch and byproduct if WA batten pots are adopted by fishers. Decreases in bycatch discard rates would further be aided under a potential reduction in effort of up to ~38% for fishers in the NZRLF using WA batten pots to attain annual TACC.

6.4.3 Lobster mortality (depredation)

Most mortalities observed within rock lobster pots in the NZRLF are due to depredation by Māori Octopus (Brock and Ward 2004). The CPUE of dead lobsters recorded during testing in the NZRLF was similar between WA batten pots and traditional beehive pots. Although relatively low numbers of dead lobsters were recorded overall from both designs, testing indicated that WA batten pots are not likely to increase lobster mortality rates. Under a potential reduction in effort (potlifts) of up to ~38% effort for NZRLF fishers using WA batten pot designs, a reduction in the absolute number of dead lobsters landed each season could be expected.

6.5 Accounting for differences in pot design catch efficiency in future harvest strategy decision rules

Two approaches were developed to correct for the higher catch rates of WA batten pots. These approaches could be used more generally to account for changes in catch efficiency of any new gear type in the future. The first approach is applicable in fishing seasons when the majority of licences continue to use the traditional beehive pot and is recommended over method 2 as it is considered relatively more precise in relation to the current harvest strategy PIs.

The second method, which employs the ratio results, is applicable if the majority of fishers (licences) adopt the WA batten pot. The method uses computed ratios directly, rather than seeking to model the catch from traditional beehive pots as a Generalised Linear Model (GLM) function of WA batten pot catch and other covariates. GLMs require that the y-variate be distributed in approximate agreement with a member of the exponential family of distributions. This requirement does not hold for the data set available for two reasons: (1) there are many zeros in the matched pair data, and (2) there is no exponential distribution that provides a good description of the spread of predicted values.

WA batten pots often caught lobsters (both legal and undersize) when zero lobsters were caught by the matching traditional beehive pot and vice versa. These zeros do not pose a problem for legal-size CPUE and PRI as currently computed for use in stock assessment and in the harvest rule: the zeros simply get averaged into the ratio estimators used, either by month or year, or for any spatial breakdown. However, in GLM modelling, zero pot catches are highly problematic. They occur in much greater numbers than count-based exponential family distributions predict, such as the negative binomial, which is commonly applied to count data. When a WA batten pot in a matched pair is zero in a GLM fit, it will not provide a useful prediction since in a linear model a zero values times any (GLM estimated) coefficient will be zero. (i.e., ignoring other covariates for the purposes of this explanation, if the WA batten pot in a matched pair is a zero, it will only ever predict a zero for the beehive pot, but that is generally an underestimate, and therefore biased).

The statistical solution provided, of simply using the same ratio estimate formulas used in South Australian lobster assessment currently, yields correction ratios suitable for use with these previous standard indices, being fully consistent in definition with those. GLM coefficients estimated from the individual matched pairs will not have this consistency in definition, and probably would differ in ways that would be hard to interpret.

7 Conclusion

The objectives of this study were to:

1) assess the catch efficiency of alternative pot designs for capturing Southern Rock Lobster through CPUE indices of: (i) legal-size lobsters; (ii) undersize lobsters; (iii) spawning (ovigerous) female lobsters and (iv) primary bycatch species; and 2) for one alternative pot design proposed by industry, develop and apply methods to calibrate raw CPUE for the alternative pot design for use in harvest strategy decision rules.

These objectives have been achieved. The major outcomes of the project were:

i) Five phases and 9 treatments of pot design testing undertaken between 2017/18 and 2021/22 resulting in data from 14,537 individual potlifts recorded from 17 fishers over 904 sampling days in 26 MFAs.

ii) Consistently higher catch efficiency of WA batten pots relative to traditional beehive pots in the NZRLF with higher catches of legal-size and undersize lobsters recorded from WA batten pots.

iii) Development of ratio estimate methods to correct for differences in legal-size lobster catch in weight per potlift (CPUE), and undersize lobster catch in number per potlift (PRI) between alternative pot designs and traditional beehive pots in the NZRLF.

iv) Potential effort reduction of up to 38% for fishers in the NZRLF using WA batten pot designs.

v) Potential increases in the rate of discarding of spawning females attributed to increases in WA batten pot efficiency that are offset by an overall reduction in effort required for fishers in the NZRLF to take annual TACC.

vi) Potential increases in undersize catches of up to ~32% for NZRLF fishers using WA batten pot designs that are offset by an overall reduction in effort required to take annual TACC, and overall reduction in the discard rates of undersize lobsters.

vii) Similar taxonomic composition of bycatch recorded in WA batten pots and traditional beehive pots, but generally lower catches of all bycatch and byproduct taxa from WA batten pots relative to traditional beehive pots.

viii) Further improvements in bycatch discard rates possible under a potential reduction in effort (potlifts) of up to ~38% effort for NZRLF fishers using WA batten pot designs.

ix) Expected improvements to overall lobster mortality rates under a potential reduction in effort (potlifts) of up to ~38% effort for NZRLF fishers using WA batten pot designs.

x) Two methods to account for the measured differences in WA batten pot catch efficiency in future harvest strategy decision rules, namely:

- removal of data from vessels (licences) that are using the WA batten pot from the 2022-season yearly values of legal-size CPUE and PRI (applicable in fishing seasons when the majority of licences continue to use the traditional beehive pot).
- applying the monthly ratio correction factors for legal-size CPUE ($\hat{\rho}_{C_W PUE}$) and PRI ($\hat{\rho}_{PRI}$) (sections 5.9.1.3.1 and 5.9.2.3.2) to legal-size CPUE and PRI estimated from monthly catch totals from licences using WA batten pots in any given fishing season.

8 Implications

This study highlights how modern-day arrangements of fishery co-management can lead to a framework of applied experimentation and statistical evidence to serve multiple stakeholder purposes. The results from the project have several potential positive implications for industry members of the NZRLF. The relative improvements in catch efficiency recorded from WA batten pots throughout all phases of the project confirm their potential to lower the amount of fishing effort and costs required to attain annual TACCs. The project's results also allow fishers in the NZRLF to have confidence in investing in the purchase of WA batten pots. For fishery scientists and managers, the data provided through the project allow future stock assessment and management of the NZRLF to account for the relative increases in CPUE of legal-size and undersize lobster (PRI) attributed to WA batten pots.

The study also indicates that adoption of WA batten pots in the NZRLF, in conjunction with TACC, may have positive impacts on the sustainability of fishing for Southern Rock Lobster via i) potential decreases in overall undersize lobster discard rates; ii) a reduction in catches of bycatch and byproduct, and potential improvements to bycatch discard rates; and iii) potential decreases in overall lobster mortality (depredation) rates.

In summary, the results of this project will have a positive impact on the economic performance of the NZRLF by providing all stakeholders with the information required to support implementation of a more efficient gear type that will assist in reducing fishing costs and improve net economic return without compromising resource sustainability.

9 Recommendations

The following recommendations have been developed from this project:

1) Identification of pot design type (WA batten pot or traditional beehive pot) used by each licence in future seasons of fishing in the NZRLF.
2) The use of bias correction method 1 to obtain estimates of legal-size CPUE and PRI to inform quota setting for the 2023 NZRLF fishing season.
3) The future assessment and use of bias correction method 2 to obtain estimates of legal-size CPUE and PRI if the WA batten pot is adopted by a majority of licences in the NZRLF fleet in the future.
4) WA batten pot design specifications, including materials used, be included in future *Fisheries Management (General) Regulations 2017.*
5) The use of the WA batten pot design be considered in future Ecological Risk Assessments undertaken for the NZRLF.
6) Quantification of actual economic efficiencies gained through the adoption of WA batten pots to validate project findings and to further increase the likelihood of adoption of more efficient pot designs.
7) The results of the project be extended via research publications and conference presentations.

10 Extension and Adoption

Adoption of the project findings is evidenced by 8 of 63 licences choosing to switch entirely to the WA batten pot design in the current 2022/23 NZRLF season. Throughout the project, all stakeholders were kept updated through a specifically designed extension and communication strategy. This involved annual dedicated workshops with industry members and PIRSA Fisheries and Aquaculture managers, held following each phase (fishing season). In addition to workshops, Southern Rock Lobster Limited (SRL) were informed throughout the project of project progress and participating fishers were communicated with via phone to inform them of their individual pot-design testing results.

Project outcomes were presented annually to the Research Sub Committee (RSC) of the Rock Lobster Fishery Management Advisory Committee (RLFMAC). Media extension, undertaken in consultation with FRDC, included a radio interview conducted by Macquarie Radio (16 October 2018), ABC Radio (rural report) (23 October 2018), and a Government of South Australia - Minister for Primary Industries Press release (15 October 2018). Further extension and communication are planned through the production of a scientific paper(s) relating to project findings and attendance at annual national and/or international conferences relevant to fisheries research. Further media extension is predicted to follow these extension opportunities.

11 Project materials developed

Project materials developed from this project include a:

1) radio interview conducted by Macquarie Radio (16 October 2018),
2) radio interview conducted by ABC Radio (rural report) (23 October 2018),
3) Government of South Australia - Minister for Primary Industries - Press release (15 October 2018).

Future production of journal articles relating to project findings and abstract submission to annual national and/or international conferences relevant to fisheries research are planned. Further media extension is predicted to follow these extension opportunities.

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13 Appendices

Appendix 1. Summary of bycatch and byproduct sampled in each alternative pot design treatment tested in the NZRLF between 2017/18 and 2021/22. Top species recorded from each pot design are highlighted in bold.

Treatment	Pot design descriptor	Taxa	2017/18 N	2018/19 N	2019/20 N	2021/22	Total N	% contribution (all seasons)
1	**WA batten pot (squeezy neck)**	**Leather Jacket spp**	**58**	**191**			**249**	**58.6**
1	**WA batten pot (squeezy neck)**	**Horseshoe Leatherjacket**		**33**			**33**	**7.8**
1	WA batten pot (squeezy neck)	Velvet Crab		33			33	7.8
1	WA batten pot (squeezy neck)	Hermit Crab		32			32	7.5
1	WA batten pot (squeezy neck)	Wrasse spp		32			32	7.5
1	WA batten pot (squeezy neck)	Octopus	7	14			21	4.9
1	WA batten pot (squeezy neck)	Blue Throat	2	15			17	4.0
1	WA batten pot (squeezy neck)	Slimy Cod	1	2			3	0.7
1	WA batten pot (squeezy neck)	Conger Eel Or Eel		2			2	0.5
1	WA batten pot (squeezy neck)	Gummy Shark		1			1	0.2
1	WA batten pot (squeezy neck)	King Crab		1			1	0.2
1	WA batten pot (squeezy neck)	Port Jackson Shark		1			1	0.2
1	**Traditional NZRLF beehive (spike)**	**Leather Jacket spp**	**107**	**850**			**957**	**75.4**
1	**Traditional NZRLF beehive (spike)**	**Wrasse spp**	**1**	**77**			**78**	**6.1**
1	Traditional NZRLF beehive (spike)	Octopus	6	71			77	6.1
1	Traditional NZRLF beehive (spike)	Horseshoe Leatherjacket		52			52	4.1
1	Traditional NZRLF beehive (spike)	Hermit Crab		43			43	3.4
1	Traditional NZRLF beehive (spike)	Velvet Crab	1	22			23	1.8
1	Traditional NZRLF beehive (spike)	Blue Throat		20			20	1.6
1	Traditional NZRLF beehive (spike)	King Crab		4			4	0.3
1	Traditional NZRLF beehive (spike)	Slimy Cod	2	1			3	0.2
1	Traditional NZRLF beehive (spike)	Snapper		3			3	0.2
1	Traditional NZRLF beehive (spike)	Gummy Shark		2			2	0.2
1	Traditional NZRLF beehive (spike)	Port Jackson Shark		2			2	0.2
1	Traditional NZRLF beehive (spike)	Australian Salmon		1			1	0.1
1	Traditional NZRLF beehive (spike)	Knife Jaw		1			1	0.1
1	Traditional NZRLF beehive (spike)	Ocean Jacket Or China	1				1	0.1
1	Traditional NZRLF beehive (spike)	Stingray		1			1	0.1
1	Traditional NZRLF beehive (spike)	Sweep		1			1	0.1
1	Traditional NZRLF beehive (spike)	Wobbygong		1			1	0.1
2	**Toumazos double entry (squeezy neck)**	**Leather Jacket spp**	**110**				**110**	**61.1**
2	**Toumazos double entry (squeezy neck)**	**Horseshoe Leatherjacke**	**34**				**34**	**18.9**
2	Toumazos double entry (squeezy neck)	Wrasse spp	13				13	7.2
2	Toumazos double entry (squeezy neck)	Velvet Crab	8				8	4.4
2	Toumazos double entry (squeezy neck)	Blue Throat	7				7	3.9
2	Toumazos double entry (squeezy neck)	Ling	3				3	1.7
2	Toumazos double entry (squeezy neck)	Hermit Crab	2				2	1.1
2	Toumazos double entry (squeezy neck)	Octopus	2				2	1.1
2	Toumazos double entry (squeezy neck)	Slimy Cod	1				1	0.6
2	**Traditional NZRLF beehive (spike)**	**Leather Jacket spp**	**30**				**30**	**43.5**
2	**Traditional NZRLF beehive (spike)**	**Horseshoe Leatherjacke**	**23**				**23**	**33.3**
2	Traditional NZRLF beehive (spike)	Velvet Crab	7				7	10.1
2	Traditional NZRLF beehive (spike)	Blue Throat	5				5	7.2
2	Traditional NZRLF beehive (spike)	Wrasse spp	2				2	2.9
2	Traditional NZRLF beehive (spike)	Gummy Shark	1				1	1.4
2	Traditional NZRLF beehive (spike)	Octopus	1				1	1.4
3	**WA batten pot (spike)**	**Leather Jacket spp**		**2**		**1**	**3**	**33.3**
3	**WA batten pot (spike)**	**Wrasse spp**				**3**	**3**	**33.3**
3	WA batten pot (spike)	Horseshoe Leatherjacket				2	2	22.2
3	WA batten pot (spike)	Ling		1			1	11.1
3	**Traditional NZRLF beehive (spike)**	**Horseshoe Leatherjacket**				**58**	**58**	**64.4**
3	**Traditional NZRLF beehive (spike)**	**Leather Jacket spp**		**10**		**2**	**12**	**13.3**
3	Traditional NZRLF beehive (spike)	Wrasse spp		3		4	7	7.8
3	Traditional NZRLF beehive (spike)	Blue Throat				5	5	5.6
3	Traditional NZRLF beehive (spike)	Snapper				3	3	3.3
3	Traditional NZRLF beehive (spike)	Hermit Crab				1	1	1.1
3	Traditional NZRLF beehive (spike)	Morwong				1	1	1.1
3	Traditional NZRLF beehive (spike)	Octopus				1	1	1.1
3	Traditional NZRLF beehive (spike)	Sweep				1	1	1.1
3	Traditional NZRLF beehive (spike)	Velvet Crab				1	1	1.1
4	**WA batten pot (squeezy neck)**	**Hermit Crab**			**18**	**61**	**79**	**37.8**
4	**WA batten pot (squeezy neck)**	**Ocean Jacket Or China**			**22**	**20**	**42**	**20.1**
4	WA batten pot (squeezy neck)	Octopus			2	18	20	9.6
4	WA batten pot (squeezy neck)	Horseshoe Leatherjacket			9	7	16	7.7
4	WA batten pot (squeezy neck)	Wrasse spp				14	14	6.7
4	WA batten pot (squeezy neck)	King Crab				12	12	5.7
4	WA batten pot (squeezy neck)	Port Jackson Shark			2	9	11	5.3
4	WA batten pot (squeezy neck)	Ling			5	2	7	3.3
4	WA batten pot (squeezy neck)	Knife Jaw				2	2	1.0
4	WA batten pot (squeezy neck)	Leather Jacket spp				2	2	1.0
4	WA batten pot (squeezy neck)	Blue Throat			1		1	0.5
4	WA batten pot (squeezy neck)	Cuttlefish				1	1	0.5
4	WA batten pot (squeezy neck)	School Shark				1	1	0.5
4	WA batten pot (squeezy neck)	Wobbygong				1	1	0.5
4	**Traditional NZRLF beehive (squeezy nec**	**Hermit Crab**			**21**	**65**	**86**	**35.2**
4	**Traditional NZRLF beehive (squeezy nec**	**Horseshoe Leatherjacket**			**54**	**9**	**63**	**25.8**
4	Traditional NZRLF beehive (squeezy neck)	Ocean Jacket Or China			17	4	21	8.6
4	Traditional NZRLF beehive (squeezy neck)	Octopus			2	16	18	7.4
4	Traditional NZRLF beehive (squeezy neck)	King Crab				17	17	7.0
4	Traditional NZRLF beehive (squeezy neck)	Wrasse spp				14	14	5.7
4	Traditional NZRLF beehive (squeezy neck)	Port Jackson Shark			3	6	9	3.7
4	Traditional NZRLF beehive (squeezy neck)	Blue Throat			5		5	2.0
4	Traditional NZRLF beehive (squeezy neck)	Ling				4	4	1.6
4	Traditional NZRLF beehive (squeezy neck)	Knife Jaw				2	2	0.8
4	Traditional NZRLF beehive (squeezy neck)	Wobbygong				2	2	0.8
4	Traditional NZRLF beehive (squeezy neck)	Nannygai			1		1	0.4
4	Traditional NZRLF beehive (squeezy neck)	Snapper			1		1	0.4
4	Traditional NZRLF beehive (squeezy neck)	Whelk				1	1	0.4
5	**Traditional NZRLF beehive (squeezy nec**	**Horseshoe Leatherjacket**		**31**	**46**		**77**	**55.4**
5	**Traditional NZRLF beehive (squeezy nec**	**Blue Throat**		**10**	**7**		**17**	**12.2**
5	Traditional NZRLF beehive (squeezy neck)	Velvet Crab		8	7		15	10.8
5	Traditional NZRLF beehive (squeezy neck)	Leather Jacket spp			9		9	6.5
5	Traditional NZRLF beehive (squeezy neck)	Hermit Crab		4	4		8	5.8
5	Traditional NZRLF beehive (squeezy neck)	Gurnard Perch			4		4	2.9
5	Traditional NZRLF beehive (squeezy neck)	Sweep		3			3	2.2
5	Traditional NZRLF beehive (squeezy neck)	Port Jackson Shark			2		2	1.4
5	Traditional NZRLF beehive (squeezy neck)	Barber Perch Or Little Pete			1		1	0.7
5	Traditional NZRLF beehive (squeezy neck)	Brown Stripe Jacket			1		1	0.7
5	Traditional NZRLF beehive (squeezy neck)	Gummy Shark			1		1	0.7
5	Traditional NZRLF beehive (squeezy neck)	School Shark		1			1	0.7
5	**Traditional NZRLF beehive (spike)**	**Horseshoe Leatherjacket**		**15**	**31**		**46**	**46.5**
5	**Traditional NZRLF beehive (spike)**	**Blue Throat**		**2**	**9**		**11**	**11.1**
5	Traditional NZRLF beehive (spike)	Velvet Crab		6	5		11	11.1
5	Traditional NZRLF beehive (spike)	Leather Jacket spp			9		9	9.1
5	Traditional NZRLF beehive (spike)	Hermit Crab		2	5		7	7.1
5	Traditional NZRLF beehive (spike)	Gurnard Perch			3		3	3.0
5	Traditional NZRLF beehive (spike)	Octopus			3		3	3.0
5	Traditional NZRLF beehive (spike)	Port Jackson Shark			2		2	2.0
5	Traditional NZRLF beehive (spike)	Brown Stripe Jacket			1		1	1.0
5	Traditional NZRLF beehive (spike)	Cuttlefish		1			1	1.0
5	Traditional NZRLF beehive (spike)	Knife Jaw			1		1	1.0
5	Traditional NZRLF beehive (spike)	Morwong			1		1	1.0
5	Traditional NZRLF beehive (spike)	Ocean Jacket Or China			1		1	1.0
5	Traditional NZRLF beehive (spike)	Slimy Cod			1		1	1.0
5	Traditional NZRLF beehive (spike)	Wrasse spp			1		1	1.0

Appendix 2. Summary of bycatch sampled in each alternative pot design treatment tested in the SZRLF in 2018/19.

			2018_19	
Treatment	Pot design descriptor	Taxa	N	% contribution
6	Traditional SZRLF beehive (180mm squeezy neck)	Velvet Crab	3	50.0
6	Traditional SZRLF beehive (180mm squeezy neck)	Gummy Shark	1	16.7
6	Traditional SZRLF beehive (180mm squeezy neck)	Octopus	1	16.7
6	Traditional SZRLF beehive (180mm squeezy neck)	Port Jackson Shark	1	16.7
6	Traditional SZRLF beehive (no SLED)	Leather Jacket	2	28.6
6	Traditional SZRLF beehive (no SLED)	Velvet Crab	2	28.6
6	Traditional SZRLF beehive (no SLED)	Wrasse spp	2	28.6
6	Traditional SZRLF beehive (no SLED)	Octopus	1	14.3
7	Double chamber (no SLED)	Leather Jacket	9	40.9
7	Double chamber (no SLED)	Hermit Crab	5	22.7
7	Double chamber (no SLED)	Slimy Cod	4	18.2
7	Double chamber (no SLED)	Snapper	2	9.1
7	Double chamber (no SLED)	Conger Eel Or Eel	1	4.5
7	Double chamber (no SLED)	Horseshoe Leatherja	1	4.5
7	Traditional SZRLF beehive (no SLED)	Hermit Crab	4	44.4
7	Traditional SZRLF beehive (no SLED)	Leather Jacket	4	44.4
7	Traditional SZRLF beehive (no SLED)	Slimy Cod	1	11.1
8	Traditional SZRLF beehive (135mm squeezy neck)	Slimy Cod	3	42.9
8	Traditional SZRLF beehive (135mm squeezy neck)	Conger Eel Or Eel	1	14.3
8	Traditional SZRLF beehive (135mm squeezy neck)	Gurnard Perch	1	14.3
8	Traditional SZRLF beehive (135mm squeezy neck)	Leather Jacket	1	14.3
8	Traditional SZRLF beehive (135mm squeezy neck)	Port Jackson Shark	1	14.3
8	Traditional SZRLF beehive (no SLED)	Slimy Cod	3	27.3
8	Traditional SZRLF beehive (no SLED)	Ocean Jacket Or Chi	2	18.2
8	Traditional SZRLF beehive (no SLED)	Octopus	2	18.2
8	Traditional SZRLF beehive (no SLED)	Conger Eel Or Eel	1	9.1
8	Traditional SZRLF beehive (no SLED)	Hermit Crab	1	9.1
8	Traditional SZRLF beehive (no SLED)	Leather Jacket	1	9.1
8	Traditional SZRLF beehive (no SLED)	Port Jackson Shark	1	9.1
9	WA batten pot (no SLED)	Gurnard Perch	4	33.3
9	WA batten pot (no SLED)	Hermit Crab	4	33.3
9	WA batten pot (no SLED)	Leather Jacket	4	33.3
9	Traditional SZRLF beehive (no SLED)	Velvet Crab	7	38.9
9	Traditional SZRLF beehive (no SLED)	Hermit Crab	5	27.8
9	Traditional SZRLF beehive (no SLED)	Gurnard Perch	2	11.1
9	Traditional SZRLF beehive (no SLED)	Leather Jacket	2	11.1
9	Traditional SZRLF beehive (no SLED)	Octopus	1	5.6
9	Traditional SZRLF beehive (no SLED)	Wrasse spp	1	5.6

Appendix 3. Results of pot design testing obtained from commercial catch log data in 2019/20 and 2021/22.

In 2019/20, six NZRLF fishers submitted commercial catch log data for treatments 1, 3, 4 and 5. A summary of the effort reported (days fished, potlifts) and associated legal-size and undersize CPUE estimated for treatments 1, 3, 4 and 5 is provided in Table A3.1.

In treatment 1, the estimate of CPUE of legal-size lobster was 50% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (spike) pot (Table A3.1, CPUE: 1.44 kg/potlift; 0.96 kg/potlift, respectively). Catches of undersize lobster from the WA batten pot (squeezy neck) were approximately double those of the traditional NZRLF beehive (spike) pot (Table A3.1). These results support the trends estimated from catch sampling data for treatment 1 testing in phases 2 (2017/18) and 3 (2018/19) (sections 5.2.1 and 5.3.1, respectively).

In treatment 3, the estimate of CPUE of legal-size lobster was 47% higher from the WA batten pot (spike) compared to the traditional NZRLF beehive (spike) pot (Table A3.1, CPUE: 0.69 kg/potlift; 0.47 kg/potlift, respectively). Catches of undersize lobster from the WA batten pot (spike) were approximately double those recorded from the traditional NZRLF beehive (spike) pot (Table A3.1). It should be noted that pot testing within treatment 3 as reported through commercial catch logs was not balanced, i.e., the number of potlifts undertaken for each design was not similar. However, the increases in lobster catch efficiency observed from WA batten pot (spike) generally supported the trends estimated from catch sampling data for treatment 3 testing in phase 3 (2018/19) and phase 5 (2021/22) (sections 5.3.1 and 5.5.1, respectively).

In treatment 4, estimates of CPUE of legal-size lobster from the WA batten pot (squeezy neck) and NZRLF beehive (squeezy neck) pot were similar (Table A3.1, CPUE: 1.20 kg/potlift; 1.15 kg/potlift, respectively). Catches of undersize lobster from each design were also similar (Table A3.1). The similarity in CPUE estimates between the two designs did not support the results estimated from catch sampling data in phase 4 testing in 2019/20 (section 5.4.1). Comparison of treatment 4 catch sampling data and commercial catch log data submitted independently for the same days fished in 2019/20 indicated differences in the sum of legal-size lobsters reported from each design of -18.5% to +50%. Comparison of the same data summed over multiple days irrespective of design, indicated that the total number of legal-size lobsters reported per trip was more similar between the two data sources, differing by between - 2.1% and +1.6%. Consequently, treatment 4 CPUE estimates calculated in 2019/20 from commercial catch log data summarised daily should be treated with caution as they are likely to be influenced by the incorrect reporting of lobster numbers per design.

In treatment 5, estimates of CPUE of legal-size lobster from the traditional NZRLF beehive (squeezy neck) pot and NZRLF beehive (spike) pot were similar (Table A3.1). Catches of undersize lobster from each design were also similar. The estimates of CPUE recorded by fishers from each design within treatment 5 support the trends in CPUE estimated from observer data in phase 4 (2019/20) (section 5.4.1).

Table A3.1. Lobster catch and effort from fishery-dependent reporting in the NZRLF in 2019/20.

					Legal size				Undersize	
Treatment	Pot designs	N Licences	Days fished	N Potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	N	CPUE (N/potlift)
1	WA batten pot (squeezy neck)	1	111	555	800.8	1.44	843	1.52	239	0.43
1	Traditional NZRLF beehive (spike)		111	555	533.9	0.96	561	1.01	117	0.21
3	WA batten pot (spike)	1	75	913	627.4	0.69	676	0.74	141	0.15
3	Traditional NZRLF beehive (spike)		59	3,228	1519.8	0.47	1,598	0.50	201	0.06
4	WA batten pot (squeezy neck)	2	95	3,519	4231.7	1.20	4,375	1.24	746	0.21
4	Traditional NZRLF beehive (squeezy neck)		96	3,628	4180.7	1.15	4,339	1.20	852	0.23
5	Traditional NZRLF beehive (squeezy neck)	2	148	6,181	5516.0	0.89	5,271	0.85	863	0.14
5	Traditional SARLF beehive (spike)		148	6,215	5537.0	0.89	5,278	0.85	821	0.13

In 2021/22, six NZRLF fishers submitted commercial catch log data for treatments 1, 3, and 4. A summary of the effort reported (days fished, potlifts) and associated legal-size and undersize CPUE estimated for treatments 1, 3, and 4 is provided in Table A3.2.

In treatment 1, the estimate of CPUE of legal-size lobster was 19% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (spike) pot (Table A3.2, CPUE: 1.53 kg/potlift; 1.29 kg/potlift, respectively). Catches of undersize lobster from the WA batten pot (squeezy neck) were approximately double those recorded from the traditional NZRLF beehive (spike) pot (Table A3.2). These results support the trends estimated from catch sampling data for treatment 1 testing in phases 2 (2017/18) and 3 (2018/19) (sections 5.2.1 and 5.3.1, respectively), and from commercial logbook data in phase 4 (2019/20)

In treatment 3, the estimate of CPUE of legal-size lobster was 38% higher from the WA batten pot (spike) compared to the traditional NZRLF beehive (spike) pot (Table A3.2, CPUE: 0.91 kg/potlift; 0.66 kg/potlift, respectively). Catches of undersize lobster from the WA batten pot (spike) were approximately double those recorded from the traditional NZRLF beehive (spike) pot (Table A3.2). These results support the trends estimated from catch sampling data for treatment 3 testing in phase 3 (2018/19) (section 5.3.1), and from commercial logbook data in phase 4 (2019/20).

In treatment 4, the estimate of CPUE of legal-size lobster was 30% higher from the WA batten pot (squeezy neck) compared to the traditional NZRLF beehive (squeezy neck) pot (Table A3.2, CPUE: 1.44 kg/potlift; 1.11 kg/potlift, respectively). Catches of undersize lobster from the WA batten pot (squeezy neck) were 32% higher than recorded from the traditional NZRLF beehive (squeezy neck) pot. These results supported the trends estimated from catch sampling data for treatment 4 testing in phase 4 (2019/20) (section 5.4.1) but are lower than those estimated from catch sampling data in phase 5 (2021/22) (section 5.5.1). Comparison of treatment 4 catch sampling data and commercial catch log data submitted independently for the same days fished in 2021/22 indicated daily differences in the number of legal-size lobsters reported from each design of between -65.6% and +258.3%. Summaries of catch data submitted over multiple days, indicated that the total number of legal-size lobsters reported per trip, irrespective of design used, was more similar between the two data sources, differing by between -2.5% and +15.2%. Consequently, treatment 4 CPUE estimates calculated in 2021/22 from commercial catch log data should again be treated with caution as they are likely to be influenced by the incorrect reporting of lobster numbers per design.

Table A3.2. Lobster catch, effort and CPUE obtained from treatment 1, 3 and 4 testing recorded via fishery-dependent reporting in the NZRLF in 2021/22.

					Legal size				Undersize	
Treatment	Pot designs	N Licences	Days fished	N Potlifts	Total weight (kg)	CPUE (kg/potlift)	N	CPUE (N/potlift)	N	CPUE (N/potlift)
1	WA batten pot (squeezy neck)	2	208	9,057	13833.7	1.53	14,785	1.63	4569	0.50
1	Traditional NZRLF beehive (spike)		208	9,438	12206.6	1.29	13,046	1.38	2329	0.25
3	WA batten pot (spike)	1	67	1,608	1465.7	0.91	1,551	0.96	316	0.20
3	Traditional NZRLF beehive (spike)		67	1,608	1066.5	0.66	1,130	0.70	160	0.10
4	WA batten pot (squeezy neck)	3	257	10,056	14444.2	1.44	13,131	1.31	2474	0.25
4	Traditional NZRLF beehive (squeezy neck)		257	13,791	15325.2	1.11	14,492	1.05	2576	0.19

Appendix 4. WA batten pots broken during project testing.

Appendix 5. Details of statistical analysis used for bias correction Method 1.

In this appendix, we give the mathematical specifications for correction Method 1. The experimental testing and analysis of the two pot designs show that WA pots have higher catch rates and catch more undersize lobsters than traditional beehive pots. Here we specify a method to avoid bias in computing the two indices, CPUE and PRI, used as inputs to the yearly quota setting harvest control rule.

The principle of Method 1 is to use catch return data only from NZ licences that have continued with the traditional beehive pot. This retains consistency with the historical time series. Here we estimate a correction factor, S, to account for small mean differences of CPUE and PRI from the historical indices (using all licences) compared with the modified indices that use data only from licences that continued with the traditional pot in 2022.

The CPUE correction uses data from the Inner Region of the NZ for use in the Inner Region harvest control rule. For PRI, a single whole-zone index is used for both Inner and Outer harvest control rules, so the PRI correction factor is computed using whole-zone NZ data. The R markdown file in which Method 1 data computations were coded is Method1CorrectWAPots.Rmd.

The primary monthly time series data are summed from daily catch logs:

$$C_{\mathrm{W}} = C_{\mathrm{W}}\left[month, season\right]$$

$$C_{\mathrm{Undersize}} = C_{\mathrm{Undersize}}\left[month, season\right]$$

$$E = E\left[month, season\right]$$

$$E_{\mathrm{Undersize}}\left[month, season\right].$$

These data sums for legal catch in landed lobster weight (C_{W}), undersize (sublegal) numbers reported ($C_{\mathrm{Undersize}}$), total potlifts set (E), and number of potlifts in which the voluntary undersize field was not left blank ($E_{\mathrm{Undersize}}$) were computed over each month of all fishing seasons since 2015. C_{W} and E are available for the Inner Region since 2015 when that field to specify the NZ Region of each day's fishing was made explicit on catch logs. PRI for the whole NZ can be computed from years prior to 2015, but to be consistent, we compute the means of CPUE and PRI over the same years, 2015-2021. These means are used below to compute the scaling factors for each.

Recalling that NZ yearly CPUE is computed from catches over the months of November-April in each fishing season, and PRI over November-March, we compute seasonal values of the indices as follows:

$$CPUE[season] = \frac{\sum_{month=Nov}^{Apr} C_{\mathrm{W}}\left[month, season\right]}{\sum_{month=Nov}^{Apr} E\left[month, season\right]}$$

$$PRI[season] = \frac{\sum_{month=Nov}^{Mar} C_{\mathrm{Undersize}}\left[month, season\right]}{\sum_{month=Nov}^{Mar} E_{\mathrm{Undersize}}\left[month, season\right]}.$$

These are the standard CPUE and PRI indices used historically in NZ assessment and as inputs to the harvest strategy. These same computations were repeated but here excluding licences that used WA batten pots in the 2022 fishing season:

$$CPUE_{\mathrm{NoWAPots}}[season] = \frac{\sum_{month=Nov}^{Apr} C_{\mathrm{W}}^{\mathrm{NoWAPots}}\left[month, season\right]}{\sum_{month=Nov}^{Apr} E^{\mathrm{NoWAPots}}\left[month, season\right]}$$

$$PRI_{\mathrm{NoWAPots}}[season] = \frac{\sum_{month=Nov}^{Mar} C_{\mathrm{Undersize}}^{\mathrm{NoWAPots}}\left[month, season\right]}{\sum_{month=Nov}^{Mar} E_{\mathrm{Undersize}}^{\mathrm{NoWAPots}}\left[month, season\right]}.$$

The Method 1 scaling factors that will be used to correct the time series that exclude licences using the new WA pots for 2022 and possibly future years are computed from the means over 2015-2021:

$$\overline{CPUE} = \frac{1}{2021 - 2015 + 1} \cdot \sum_{season=2015}^{2021} CPUE[season]$$

$$\overline{PRI} = \frac{1}{2021 - 2015 + 1} \cdot \sum_{season=2015}^{2021} PRI[season]$$

$$\overline{CPUE}_{\text{NoWAPots}} = \frac{1}{2021-2015+1} \cdot \sum_{season=2015}^{2021} CPUE_{\text{NoWAPots}}[season]$$

$$\overline{PRI}_{\text{NoWAPots}} = \frac{1}{2021-2015+1} \cdot \sum_{season=2015}^{2021} PRI_{\text{NoWAPots}}[season]$$

In order to be consistent with the historical time series, we require that the mean of the corrected historical time series equal the mean of the historical time series:

$$S_{CPUE} \cdot \overline{CPUE}_{\text{NoWAPots}} = \overline{CPUE}$$

$$S_{PRI} \cdot \overline{PRI}_{\text{NoWAPots}} = \overline{PRI} \; .$$

Thus, the scaling factors were computed as follows:

$$S_{CPUE} = \frac{\overline{CPUE}}{\overline{CPUE}_{\text{NoWAPots}}}$$

$$S_{PRI} = \frac{\overline{PRI}}{\overline{PRI}_{\text{NoWAPots}}} \; .$$

The computed values for these scaling factors are S_{CPUE} = 0.9935 and S_{PRI} = 1.0427.

Under Method 1, the CPUE and PRI indices to be used as inputs to the harvest control rule for 2022 and possibly future NZ fishing seasons are:

$$CPUE_{Corrected}[season] = S_{CPUE} \cdot CPUE_{\text{NoWAPots}}[season]$$

$$PRI_{Corrected}[season] = S_{PRI} \cdot PRI_{\text{NoWAPots}}[season] \; .$$

Appendix 6. Details of statistical analysis used for bias correction Method 2.

In this appendix, we give the mathematical specifications for correction Method 2. This method for avoiding bias in CPUE and PRI due to the higher catch rates of WA batten pots will replace Method 1 in years when a large majority of potlifts are taken by this new gear. In that case, these primary inputs to the harvest control rule will need to use all potlifts, from both traditional beehive and the new WA design, and a correction will be applied to the catches from the WA potlifts.

The Method 2 correction uses the ratios computed from the matched pair experiments (Tables 13 and 15). Only the covariate of month was found to show significant differences in the relative catch rates for CPUE and PRI. These ratios by month (denoted $\rho_{\mathrm{CPUE}}[month]$ and $\rho_{\mathrm{PRI}}[month]$) give the matched pair comparisons of catch rate by WA batten pots as a ratio over the catch rate of traditional beehive pots.

The primary monthly time series data from daily catch logs are the same as Method 1 except that we need to differentiate the pot type used for each daily reported catch of legal weight and undersize number:

$$C_{\mathrm{W}} = C_{\mathrm{W}}\left[month, season, pottype\right]$$

$$C_{\mathrm{Undersize}} = C_{\mathrm{Undersize}}\left[month, season, pottype\right]$$

$$E = E\left[month, season\right]$$

$$E_{\mathrm{Undersize}}\left[month, season\right].$$

Historical data are not used under Method 2. In addition, no differentiation by pot type is needed for effort, only for the catches in weight and undersize number, when computing the corrected yearly values of CPUE and PRI.

The basic principle of Method 2 is to (downward) correct the catches from the WA pots to give the level of catch that would have been taken by traditional pots. The measured monthly ratios of catch per potlift $\rho_{\mathrm{CPUE}}[month]$ and $\rho_{\mathrm{PRI}}[month]$ given in Tables 13 and 15 quantify by direct experimental measurement the levels of catch per pot lift of traditional pots as a ratio of the matched WA pots. Only the individual catch records from the WA pots need to be corrected since the (uncorrected) traditional pots reflect the level of catch per potlift that we seek to approximate.

Again recalling that yearly CPUE is computed from catch returns over the months of November-April in each fishing season, and PRI over November-March, Method 2 corrected values of the indices are computed as:

$$CPUE_{\text{Corrected}}[season] = \frac{\sum_{month=Nov}^{Apr} C_{\text{W}}\left[month, season, pottype = beehive\right] + \sum_{month=Nov}^{Apr} \rho_{\text{CPUE}}[month] \cdot C_{W}\left[month, season, pottype = WA\right]}{\sum_{month=Nov}^{Apr} E\left[month, season\right]}$$

$$PRI_{\text{Corrected}}[season] = \frac{\sum_{month=Nov}^{Mar} C_{\text{Undersize}}\left[month, season, pottype = beehive\right] + \sum_{month=Nov}^{Mar} \rho_{\text{PRI}}[month] \cdot C_{\text{Undersize}}\left[month, season, pottype = WA\right]}{\sum_{month=Nov}^{Mar} E_{\text{Undersize}}\left[month, season\right]}$$

.

Thus, this Method 2 correction requires only multiplying the WA pot catches by the $\rho_{\text{CPUE}}[month]$ and $\rho_{\text{PRI}}[month]$ ratios separately by month in the sum of yearly catch. Otherwise, no further modifications of the standard ratio estimates used to compute NZ CPUE and PRI are needed.

However, because relatively high variation in the matched pair ratios were observed, Method 1 is preferred since it makes no assumptions about the relative performance of the two pot types, and it uses only the traditional pot catch returns as they have been historically.