# Centrostephanus Subsidy Program: Initial Evaluation

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Initial evaluation of harvesting subsidy for Longspined sea urchins in Tasmania

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## Executive summary

An assessment was conducted on the effectiveness of subsidising commercial harvesting of *Centrostephanus rodgersii* (Longspined sea urchins) to address the ecological effects of its incursion into Tasmanian rocky reefs.

The commercial fishery for Longspined sea urchins in Tasmania has been subsidised from late 2016 to early 2019 at a cost of $0.75/kg in an effort to control increasing sea urchin numbers and associated destructive grazing of kelp forests. The Abalone Industry Reinvestment Fund Committee took over the administration of the subsidy on January 18th 2019 and changed the structure of the subsidy on March 11th 2019 to reflect different regions of the coast.

Recent significant increases in total commercial catch have necessitated an evaluation of subsidy expenditure for the Longspined urchin harvest. This project evaluated the spatial and economic effectiveness of the subsidy and investigated various alternative structures for the subsidy, including the effect of removing or reducing the subsidy. Areas where knowledge is lacking and targeted data collection is needed were identified.

Main findings:

- Comparing divers' hourly revenue using catch rate and pay from processor and subsidy explains differing effort between subsidy zones
- Spatially-structured subsidies are required to make hourly revenue for divers ($/hr) similar across regions, which would facilitate spread of effort.
- Cost to government of harvesting verses culling depends on level of subsidy relative to processor pay and the speed of culling compared to harvesting.
- Culling tends to be more cost-effective than harvesting when the cull rate is ~2.7x faster if the subsidy is $1/kg or more.
- The cost per harvesting trip (from the diver survey) is generally higher in the south
- Nearly all survey respondents indicated that their mean dive depth has increased over time as they are depleting urchins from more readily accessible reef
- Fine-scale measurements are needed to gain a better understanding of diver effort and subsidy effectiveness

## Aim and objectives

The aim of this research was to:

- Provide an initial evaluation of the existing subsidy structure
- Gather information from divers and processors to identify key challenges in the harvesting process, including economic benefits and costs of harvesting urchins commercially
- Test possible alternative structures for the subsidy, including reduction or cessation
- Identify key areas of data collection needed to best assess the subsidy program over the next 1-3 years and to allow the formulation of an optimal harvesting strategy for Longspined urchins.

## Background

*Centrostephanus rodgersii* (the Longspined sea urchin or Centro) is not endemic to Tasmania, nor is it considered an introduced marine pest. Rather, evidence suggests that this species has recently undergone a range extension from spawning communities in coastal NSW south to the Tasmanian coastline (Johnson et al. 2005, Ling 2008). The Longspined sea urchin has a pelagic larval stage of ~ 100 days (Huggett et al. 2005), providing potential for long-distance dispersal via ocean currents (Ling et al. 2009b), specifically the poleward advance of extensions of the East Australian Current over the past 60 years associated with climate change (Ridgway 2007, Banks et al. 2010). Longspined sea urchin was first reported on the east coast of Tasmania in 1978 (Edgar and Barrett 1997) but it now extends down most of the east coast (Johnson et al. 2005, Ling and Keane 2018). The first major fisheries-independent survey conducted in 2001/02 established a baseline estimate of the biomass of this species in Tasmania at 6.7 million individuals (Johnson et al. 2005). A repeat survey conducted 15 years later estimated the population to have grown to almost 20 million individuals (Ling and Keane 2018).

The main impact of increased populations of Longspined sea urchins is the damage to kelp forests. Longspined sea urchins are powerful grazers, responsible for the formation of urchin barrens across their entire range, with eastern Tasmania no exception (Ling et al. 2009a, Johnson et al. 2011, Marzloff et al. 2016). Once established on a reef, an increase in urchin density and subsequent grazing pressure of this species leads to discrete patches of bare rock surrounding sea urchin crevices, forming local barren patches termed ‘incipient’ barrens (Johnson et al. 2005). If urchin density continues to increase in incipient barrens, and especially if localised shelters/crevices are abundant, the grazed patches grow and join together into larger patches, leading to the formation of an ‘extensive’ urchin barren (Flukes et al. 2012), a habitat largely devoid of macroalgae (Lawrence 1975, Chapman 1981, Andrew and Underwood 1989). Longspined sea urchins are able to persist on extensive barrens by feeding on microalgae, coralline algae, drift algae and invertebrate material (Johnson and Mann 1982, Ling 2008). In Tasmania, as densities of *C. rodgersii* shallower than 40m have increased from ~1,500 to ~2600 urchins per hectare between 2001/02 and 2016/17, barren cover has likewise increased from ~3.4% to ~15.2% during this time (Ling and Keane 2018).

Establishment and growth of populations of Longspined sea urchins and associated barren areas in Tasmania is having a major impact on rocky reef habitat and the recreational and commercial fisheries that rely on healthy kelp forest. Financially, the greatest impact is to the rock lobster and abalone fisheries. A forum examining the issues around the impacts of Longspined sea urchin was held on 14 December 2018, attended by a wide spectrum of stakeholders, researchers and Government. IMAS has invested in significant research towards this problem, in particular investigating the effectiveness of various removal strategies such as culling and commercial harvesting of Longspined urchins, rebuilding populations of their main predators, and surveying grazing damage to kelp forests.

## History of the subsidy

The commercial harvest has removed more than 1100 tonnes of Longspined urchins over the last 10 years, with more than half this amount harvested in the most recent season. Commercial harvesting began in March 2009. The total annual harvest began at less than 10 tonnes a year and gradually increased to 100 tonnes in 2014, followed by a sudden decline in 2015 when the main processor at the time ceased operating (Figure 1). It was at this time that discussions began about how to encourage and support urchin harvesting in an attempt to rekindle the industry.

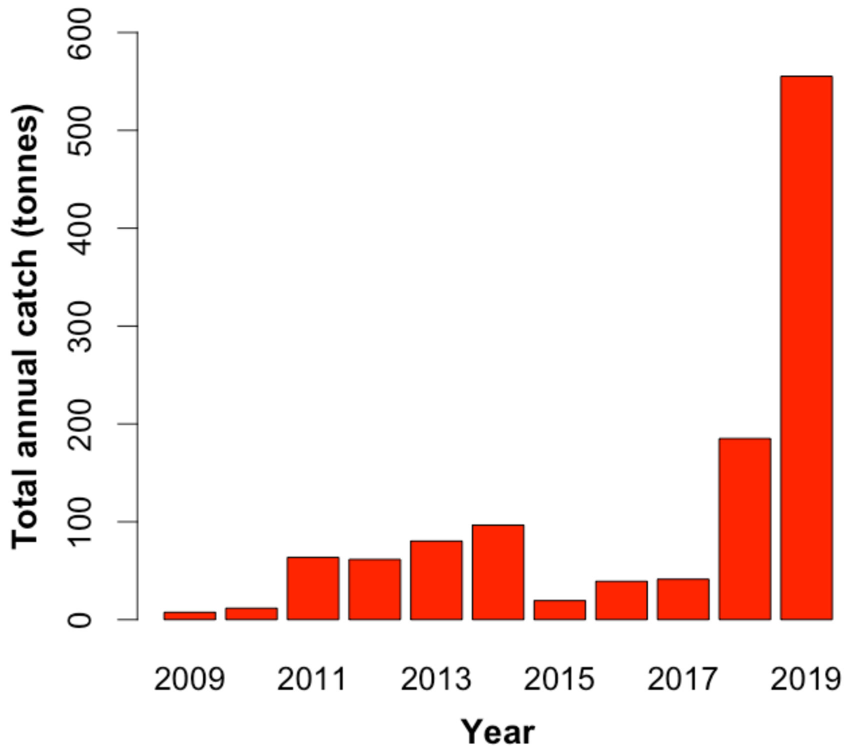


Figure 1. Annual catch of Longspined sea urchin in tonnes (* when main processor at the time ceased operating).

The Tasmanian Abalone Council Ltd (TACL) met in February 2015 to discuss options for supporting commercial harvesting of Longspined urchins from Tasmanian waters. Payment of a subsidy through the Abalone Industry Development Fund (AIDF) to commercial urchin divers began in late 2016 (for the 2016/17 harvest season) at $0.75 per kg wet weight.

To date, the only requirement for receiving the subsidy is a commercial dive license. An abalone license is not required. Catch weight is confirmed by a log recording from the processor who receives the catch. In addition, the subsidised urchins are harvested from diveable depths (up to 25m) as this is solely a dive fishery in Tasmania. It should be noted that diving depth has increased with the use of Nitrox in recent years (to be discussed in Diver Survey section).

The initial goals of the subsidy in 2016 as agreed upon by the TACL were:

1. To remove Longspined sea urchins from productive abalone harvesting areas (up to 20m deep) where incipient barrens have developed and which may, in time, transition to wide scale barrens thus reducing productivity of the abalone fishery
2. Where possible, to collaborate with the emerging Tasmanian urchin industry to build a long-term strategic approach to restoring and maintaining the ecological balance between abalone and urchin populations on Tasmania's East Coast
3. To determine the most economically efficient way of achieving objective 2 by trialling, monitoring and continuously improving the approach/strategy

Late 2018 saw the formation of the Abalone Industry Reinvestment Fund (AIRF) and associated committee with representatives from government, industry, divers/harvesters, processors, and researchers. The AIRF contains funds of $5.1 million to be paid over 5 years into the trust by the Government to support and increase the sustainability and productivity of the Tasmanian abalone fishery. The money is made up of 2 out of 7% of the royalties that the abalone industry pays to the Government. The AIRF committee is responsible for the governance of the fund.

The goals of the subsidy as administered by the AIRF in 2019 are similar to the initial goals:

- Stop the growth of existing barrens
- Prevent establishment of new barrens
- Promote recovery of extensive barrens

The structure of the subsidy from late 2016 until March 10th 2019 was a flat rate of $0.75/kg wet weight of harvest. On March 11th 2019 the subsidy changed to a spatially explicit structure (Figure 2), with the price per kg depending on latitudinal zones along the east coast of Tasmania. The subsidy per kg harvest is currently set at $0.50/kg the northern zone (north of 41°36'37 or the border of commercial fishing blocks BA and AZ), $0.75 in the central zone (between 42°29'25 and 41°36'37) and $1/kg in the southern zone (south of 42°29'25 or the border between commercial fishing blocks BI and BJ).

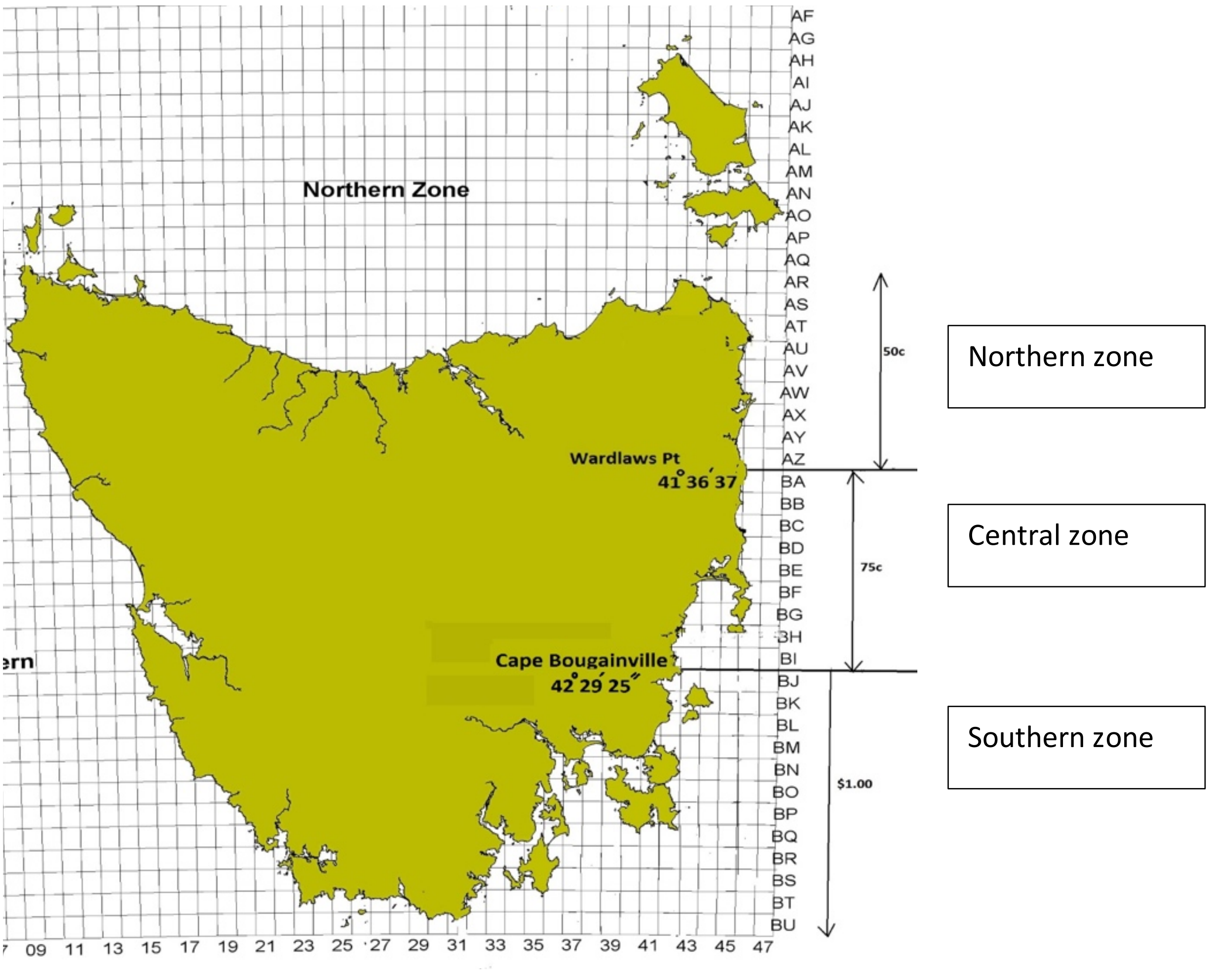


Figure 2. Map showing zones of subsidy as in effect on March 11th 2019.

## Reefs of historical importance to abalone fishery

Particular reefs may be more valuable than others in terms of their potential for productive abalone habitat. Abalone blocks outlined in the table below have a higher historical annual catch on the east coast of Tasmania (Mundy and McAllister 2018) (Table 1). We cross reference these abalone blocks with the resurvey from Ling and Keane (2018) to show which areas have shown an increase in urchin barren cover (Table 1). We then highlight the location of historically productive abalone blocks where urchin barrens have increased using a map of the east coast of Tasmania, showing commercial (urchin) fishing blocks (Figure 3). In summary, the reefs at risk of further barren formation with abalone fishing potential are highlighted as Eddystone and north, Freycinet and Schouten Island, Maria Island and Fortescue Bay.

Figure 3. Areas with higher historical abalone catch that also are transforming into barrens

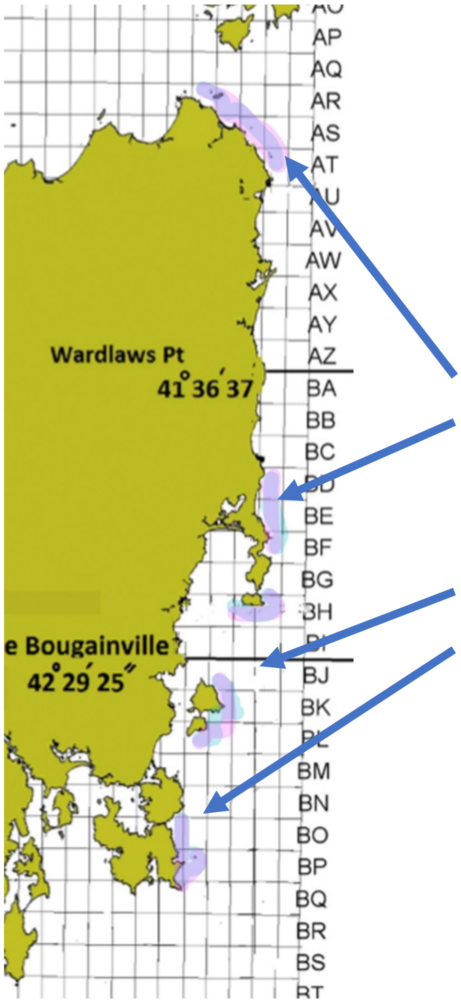


Table 1. Abalone blocks, showing historical catch and whether barren cover increasing from surveys.

| Abalone blocks with decent historical catch | Which urchin blocks are these? | Barrens increasing? | |
|---|---|---|---|
| 31 | AR-AT,44-46 | Yes | Eddystone |
| 27 | BE-BH, 45-46 | Yes | Freycinet and Schouten |
| 24 | BJ-BL, 43-44 | Yes | Maria |
| 22 | BO42-BP42 | Yes | Fortescue |
| 21 | BQ42 | Not sure | |
| 20 | BP39, BQ40 | No | |
| 16 | BR36, BS36 | No | |
| 14 | BS, BT 33-35 | No | |
| 13 | BR33 | No | |

## Expenditure of subsidy

Subsidy expenditure began in late 2016. By the end of the harvesting season in mid 2017, around $30,000 had been spent on the subsidy. This amount increased to $135,000 for the 2017/18 season, with an estimated ~$360,000 to be spent on the 2018/19 season (Figure 4).

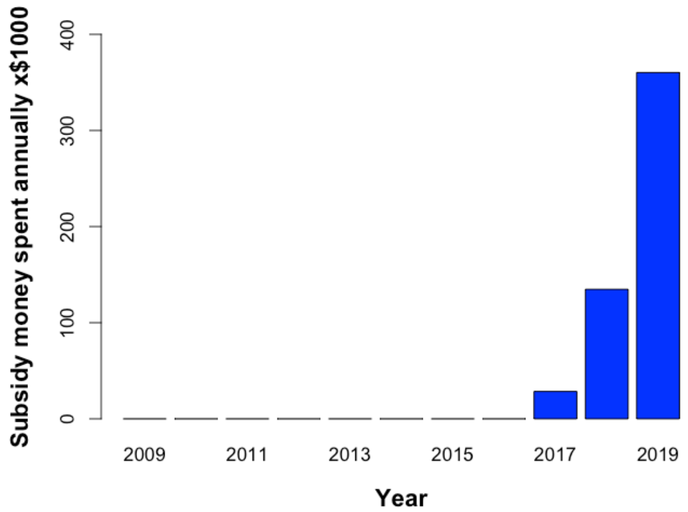


Figure 4. Annual subsidy expenditure.

The average annual expenditure per kg of harvest has decreased from $0.75/kg to around $0.65/kg since the structural change to the subsidy in 2019, reflecting that most divers remained harvesting in the north despite the reduced subsidy. Likewise, the average annual subsidy expenditure per urchin removed has decreased from around $0.25/urchin to $0.22/urchin (Figure 5). To calculate $/urchin we assumed 3 urchins per kg.

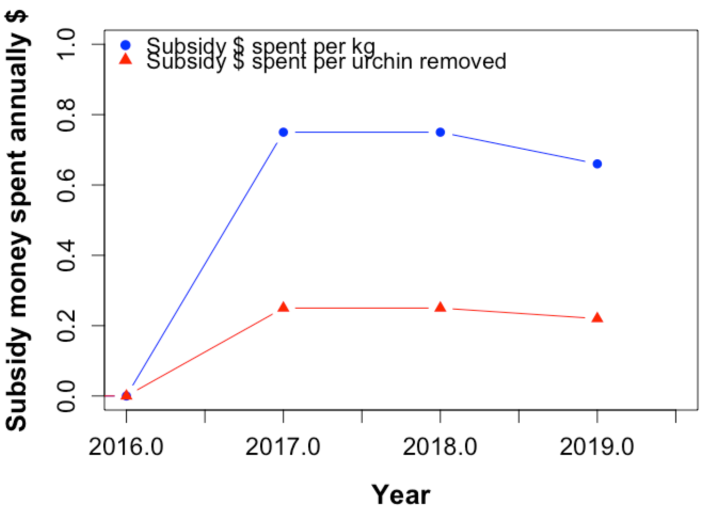


Figure 5. Annual expenditure of subsidy from 2016 to 2019 shown with the average subsidy spent per kg ($/kg) (blue dots) and subsidy spent per urchin removed ($/urchin) (red triangles).

## Spatial structure of the fishery/subsidy

One of the main goals of the subsidy is to prevent barren formation along the entire east coast of Tasmania. Until 2017, >95% of harvesting was located in the northern zone (Figure 6). In 2018, the catch in the northern zone increased to around 150 tonnes, 80% of the total catch for that year. In the most recent harvesting season 2019, the catch in the northern zone increased again to almost 400 tonnes, but the proportion of catch in this zone dropped to around 77% of the total catch, with catch total and proportion increasing in the central and southern zones (Figure 6). This shows that catch and effort have been almost entirely concentrated in the north, but with around 25% catch from further south in the most recent two seasons.

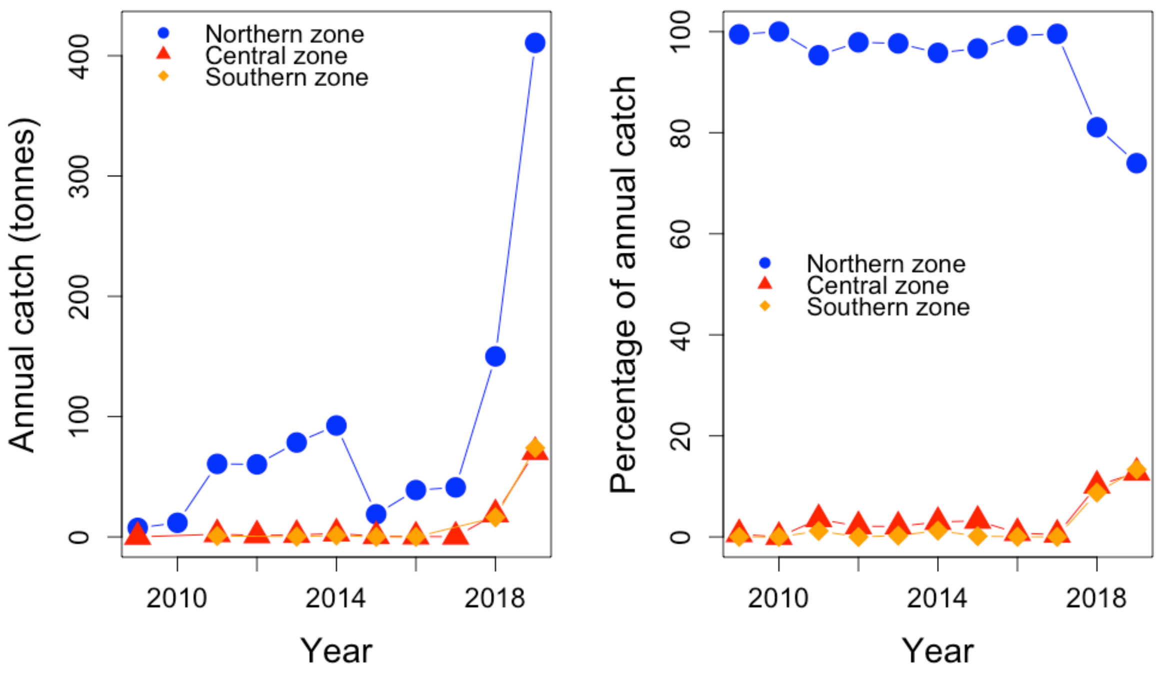


Figure 6. Annual catch (tonnes) of Longspined urchins for each of the subsidy zones over time (left) and how catch for each zone compares to the total catch for that year (%) (right).

The greatest amount of subsidy money has been spent in the northern zone, increasing from around $40,000 in 2017 to almost $250,000 in 2019 (Figure 7).

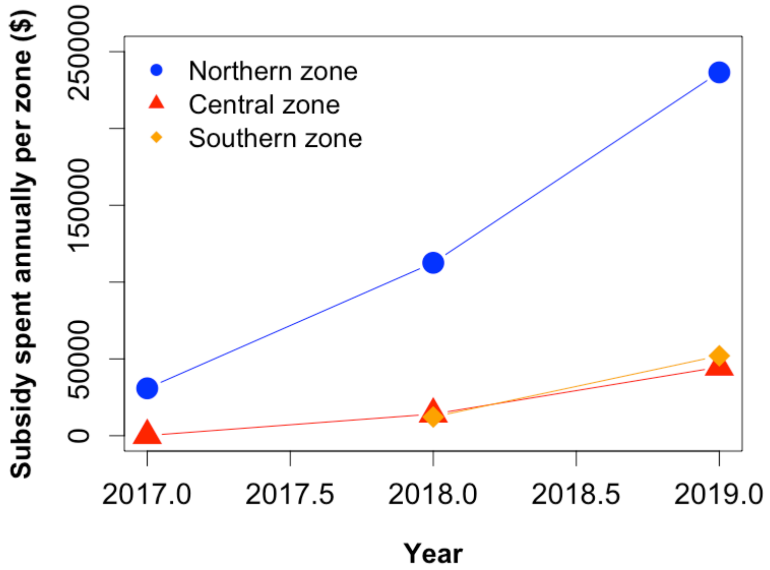


Figure 7. Subsidy dollars spent annually for each of the subsidy zones between 2017 (2016/17 season) and 2019 (the 2018/19 season).

The average monthly expenditure of the subsidy shows a dip in $/urchin in March 2019 when the structure of the subsidy was changed (Figure 8). The average monthly expenditure is variable from March 2019 as effort moves between the subsidy zones.

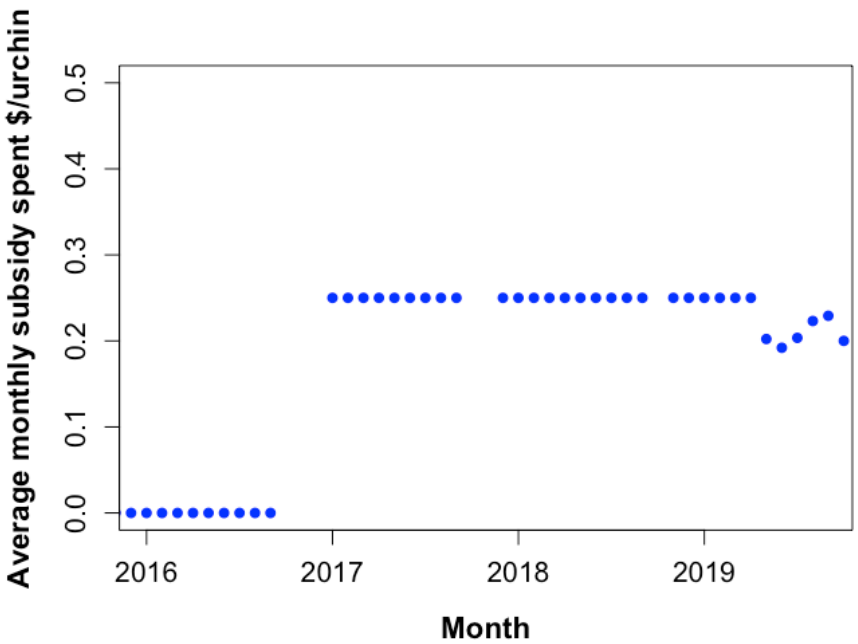


Figure 8. The average monthly subsidy expenditure ($ per urchin) showing the beginning of the subsidy in late 2016 to the end of the 2019 season.

One main reason for a consistently higher effort in the north is due to substantially higher catch rates here (Figure 9). When averaging over all years, the catch rate in the northern zone is nearly 300 kg/hr, compared to 230 kg/hr in the central zone and 190 kg/hr in the south. For the most recent harvesting season, the trend very similar.

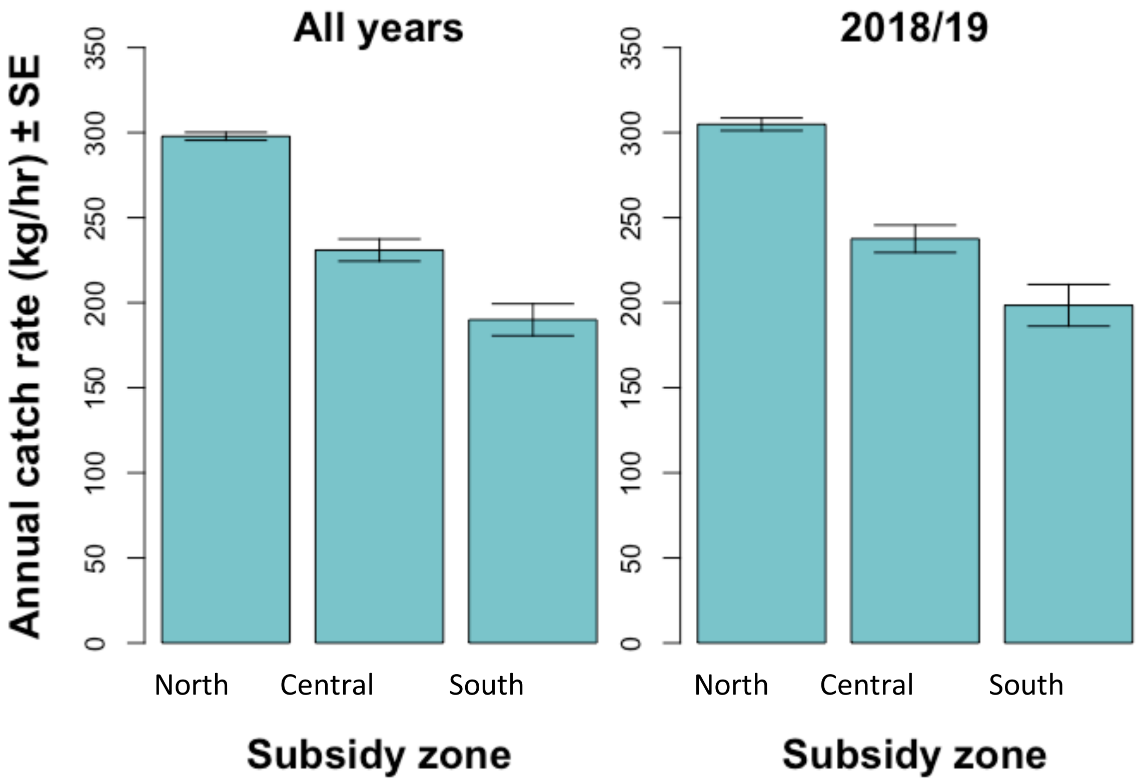


Figure 9. CPUE from 2009 to 2019 for each of the latitudinal subsidy zones.

The main factor affecting catch rate is urchin biomass, which is highest in the north according to the fisheries-independent surveys (Johnson et al. 2005, Ling and Keane 2018). Other factors that could affect the catch rate include divers moving deeper to find higher densities of urchins, the use of Nitrox for a greater dive time at higher density depths, individual diver experience, and time of year. In 2019, most of the divers in the northern zone switched to using Nitrox at some point in the season (Shane Blackwell personal communication) compared to only 1 in the south.

Monthly average catch rate in the northern zone has slightly decreased over time (Figure 10), although not for the most recent season. This may be as divers discover news reefs (such as Merricks Reef) and move to deeper depths with Nitrox. Once the GPS and depth logging devices are installed in the fishery (these have been built and are almost ready) we will be able to see any change of depth or movement to new reefs in fine detail.

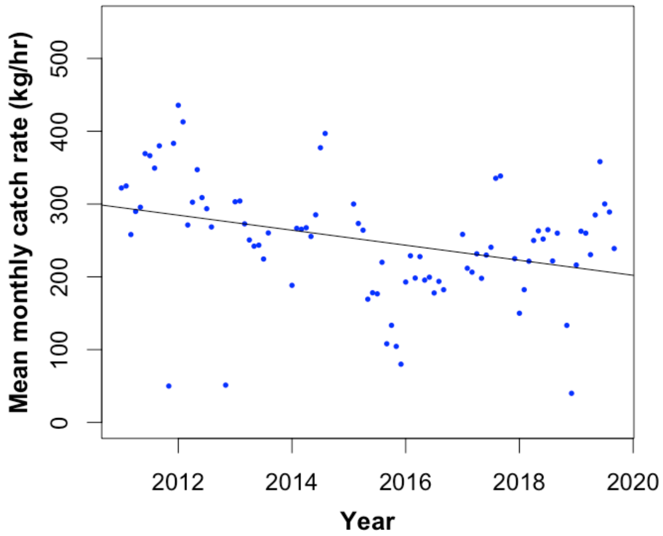


Figure 10. Catch rate over time by month, line is linear model fit of monthly averages.

There is no noticeable trend in mean annual catch rate over time for the east coast of Tasmania, especially if including standard deviation around the mean (Figure 11).

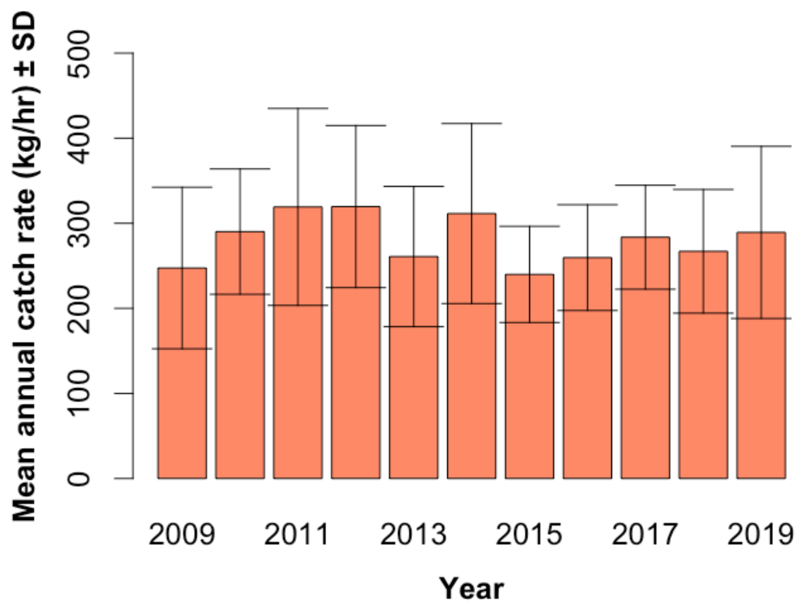


Figure 11. Mean annual catch rate over time.

## Alternative spatial subsidy structures

The spatial structure of the subsidy has changed once since its inception (Table 2). In addition to the evaluation of the current subsidy structure, we explore two alternative structures for the subsidy, comparing the divers' estimated pay per kg for each of the zones. Discussions with processors and preliminary results from the diver survey indicate that the price paid by the processor is similar across all three zones, averaging $1.75/kg. However, this price is dependent on roe quality which in turn may have some spatial/temporal structure.

Table 2. Payment structure of the subsidy ($/kg) from the 2016/17 season to the current season. The final 2 rows show possible alternative structures for the subsidy.

| | Northern zone | Central zone | Southern zone |
|---|---|---|---|
| **2017 to March 2019** | $0.75 (subsidy) + $1.75 (processor) = **$2.50/kg** | $0.75 (subsidy) + $1.75 (processor) = **$2.50/kg** | $0.75 (subsidy) + $1.75 (processor) = **$2.50/kg** |
| **March 2019 to present** | $0.50 (subsidy) + $1.75 (processor) = **$2.25/kg** | $0.75 (subsidy) + $1.75 (processor) = **$2.50/kg** | $1.00 (subsidy) + $1.75 (processor) = **$2.75/kg** |
| **Alternative subsidy 1** | $0.25 (subsidy) + $1.75 (processor) = **$2/kg** | $0.5 (subsidy) + $1.75 (processor) = **$2.25/kg** | $0.75 (subsidy) + $1.75 (processor) = **$2.5/kg** |
| **Alternative subsidy 2** | $0 (subsidy) + $1.75 (processor) = **$1.75/kg** | $0.25 (subsidy) + $1.75 (processor) = **$2/kg** | $0.50 (subsidy) + $1.75 (processor) = **$2.25/kg** |

Multiplying average catch rate (kg/hr) for the 2018/2019 season (Figure 9 ) by pay ($/kg) from Table 2 gives an estimated hourly diver revenue for each of the subsidy structures ($/hr) (Figure 12). However, it is important to note that this does not take into account any costs or total working time (which vary by zone) and is based on the mean catch rate with no variation included. Estimated hourly revenue for the original subsidy structure ($0.75 flat rate) is clearly highest in the northern zone at around $700/hr. The relative hourly revenues give an indication of why the northern zone would have been preferred by divers harvesting in 2018. With the change in subsidy structure that occurred in 2019, there is a slight reduction in estimated hourly revenue in the north, a slight increase in the central zone and a noticeable increase in the southern zone, to around $600/hr. Using the pay structure for Alternative subsidy 1, where the subsidy in the northern zone is reduced to $0.25/kg (Table 2), the estimated revenue for the northern zone drops to around $610/hr, with the central zone and southern zone at $560/hr.

With Alternative subsidy 2, where the northern zone subsidy is $0/kg (Table 2), the estimated average revenue is reduced to $540/hr in north, $500 in the central zone, and $510 in the south.

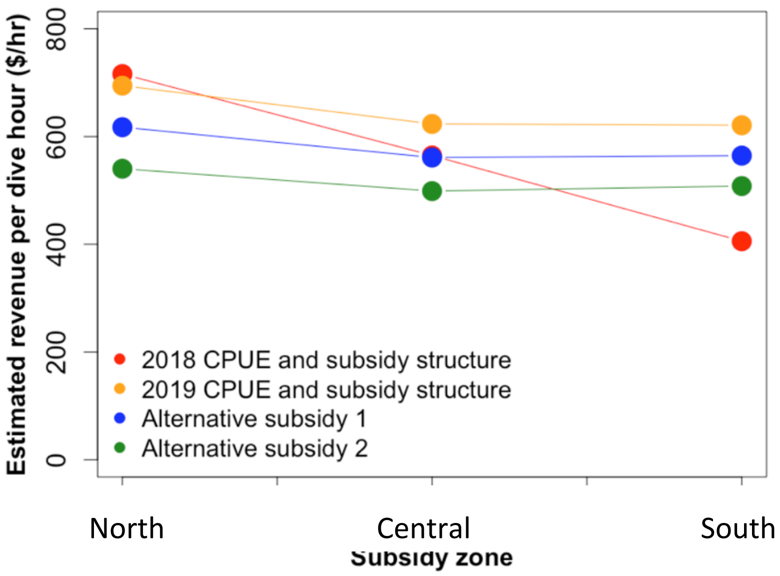


Figure 12. Estimated hourly revenue for harvesting seasons 2017/18 (red) and 2018/19 (orange) for the different subsidy zones, with possible future subsidy structure (green and blue). Note: the figure shows 'revenue' not 'hourly earning' of divers because it does not include costs or total working time.

This simple analysis shows that the change of subsidy structure that occurred in March 2019 did alter the average hourly revenue for each of the zones. However, divers in the northern zone under this structure were still earning substantially more per hour of harvesting. This may explain why the change in subsidy structure did not lead to a noticeable spread of effort. We predict that reducing the subsidy in the northern zone to $0 will result in a revenue that is still >$500/hr on average. However, it should be noted that this analysis does not take into account any of the costs that the divers are paying, nor the total trip time, and how these costs may differ from north to south. Costs will be explored through the diver survey section of this evaluation (preliminary analysis suggests that costs are higher in the south).

As a note of comparison: abalone divers' catch rate for the last 8 years averages at 50 to 60 kg/hr on east coast of Tasmania (Mundy and McAllister 2018), and beach price is around $10/kg (Emily Ogier pers comm.), meaning the average revenue for an abalone diver is $500/hr to $600/hr on the east coast. On the west coast catch rates can be up to 100 kg/hr, making revenue $1000/hr.

## Culling vs harvesting

Culling is an alternative removal method to harvesting in diveable depths. When harvesting, divers remove urchins generally in the mid-size range, leaving smaller urchins, and are limited to finding urchins with acceptable roe quality to the processor, which also means harvesting when urchins are not spawning (between approximately December and July). Divers use a net bag to transport urchins to the boat, and must schedule harvesting around the arrival time of the processor's truck. In comparison, divers that are culling can kill urchins of all size ranges at any time of year (by cracking them with a hammer or similar instrument) and are not limited to choosing urchins of high roe quality or transporting urchins to the boat and truck. In comparing the economic effectiveness of culling versus harvesting, it is necessary to compare the rate of culling with the rate of harvesting. We compare the number of urchins removed per hour, rather than weight in kg per hour, because culling can remove urchins of a much smaller size. The impact of removing smaller urchins in terms of weight removed will likely not be significant, but the area will have a lower urchin biomass for a longer period of time than if harvesting.

On extensive barrens and fringing incipient barren areas in Victoria, the rate of culling is reported to average 1800 (up to 2200) urchins per hour (personal communication John Minehan) (Table 3). This rate is reported to decrease in proportion to increasing kelp density. Reported rates of harvesting in Tasmania average at 300 kg/hr (Figure 9). If assuming 2.5 urchins to the kg, this equates to 742 urchins per hour.

Table 3. Comparing reported harvesting and culling rates in urchins removed per hour.

| | **Reported removal rate (urchins/hr)** | **Reference** | **Notes** |
|---|---|---|---|
| Culling | 1800-2200 | John Minehan pers. obs. | |
| Harvesting | 742 | Catch data DPIPWE based on 300kg/hr | 2.5 urchins/ kg |

If culling speed is 2000 urchins per hour and harvesting is 742 urchins per hour, then culling is 2000/742 = 2.7 times faster than culling. This is based on an assumption of 2.5 urchins to the kg. For culling to be more cost-effective option to harvesting, any increase in the rate of urchins removed per hour would have to outweigh the cost of not having any financial input from the processor. Currently, the main processor is paying around $1.75 /kg, or $0.60 per urchin removed by harvesting, compared to the average expenditure by the government of around $0.20 per urchin removed (Figure 5).

In the following analysis with the price from the processor set at $1.75/kg, we explore subsidy varying from $0.25/kg to $1.25/kg, or $0.1 to $0.1 per urchin removed (at 2.5 urchins per kg) (Table 4). We compare this to the estimated price of culling in $/urchin removed. For example, if the subsidy is $0.50/kg and the processor pays $1.75/kg, the government is paying $0.2 per urchin removed (at 2.5 urchins per kg). Even if culling is 3.25x faster than harvesting, the payment for culling would be $0.23 per urchin, making harvesting a cheaper option for subsidy of $0.5. However, if the government is paying $1/kg for harvest ($0.4 per urchin removed) then culling becomes a cheaper option if culling is at least 2.5 times faster than harvesting ($0.37 or less per urchin removed).

Table 4. Exploring the subsidy payment in $/kg and $/urchin, and the total cost paid to the diver when harvesting. We compare this to the total amount paid to the diver per urchin removed for a range of culling rates, estimating cull rate to be 2 to 3 times faster than harvesting. *** (bold) shows where it would be cheaper to pay for culling rather than subsidise harvesting.

| **HARVESTING Part paid by government** | | **HARVESTING Total paid to diver (processor + subsidy)** | | **Equivalent CULLING Cost per urchin for diver to obtain equivalent pay rate** | | | | |
|---|---|---|---|---|---|---|---|---|
| Subsidy i $/kg | Subsidy in $/urchin removed | Total paid to diver $/kg (processor pays $1.75) | Total paid to diver $/urchin | $/urchin if cull is 2.25x faster | $/urchin if cull is 2.5x faster | $/urchin if cull is 2.75x faster | $/urchin if cull is 3x faster | $/urchin if cull is 3.25x faster |
| 0.25 | **0.1** | 0.25+1.75 = 2 | 0.67 | 0.3 | 0.27 | 0.24 | 0.22 | 0.21 |
| 0.5 | **0.2** | 0.5+1.75 = 2.25 | 0.75 | 0.33 | 0.3 | 0.27 | 0.25 | 0.23 |
| 0.75 | **0.3** | 0.75+1.75 = 2.5 | 0.83 | 0.37 | 0.33 | 0.3 | **0.28*** ** | **0.26*** ** |
| 1 | **0.4** | 1+1.75 = 2.75 | 0.92 | 0.41 | **0.37*** ** | **0.33*** ** | **0.31*** ** | **0.28*** ** |
| 1.25 | **0.5** | 1.25+1.75 = 3 | 1 | **0.44*** ** | **0.4*** ** | **0.36*** ** | **0.33*** ** | **0.31*** ** |

In the southern zone, for example, if catch rate is around 190 kg/hr, 475 urchins per hour, then culling could remove 1282 urchins per hour. For an estimated 800,000 urchins at Fortescue Bay (Ling and Keane 2018), culling could remove half the population in 311 dive hours at a cost of $132,000 (at cull rate 2.75x faster), compared to subsidised harvesting for $160,000. Options to record culling include wrist slates, as used in Victoria, GoPro, or pay by hour instead of pay per urchin or kg.

## Diver Survey

As part of this evaluation, we conducted a survey of 24 commercial divers harvesting Longspined sea urchins for the 2018/19 season. The survey included a written section (forms which are in the process of being completed and sent back to us now) and a face-to-face interview (that has yet to be conducted).

The aim of the survey was to gain an understanding of the benefits, costs and challenges associated with harvesting sea urchins. Through the survey we attempt to identify factors affecting location choice with the aim of predicting incentives that could motivate a diver to harvest from locations that are most at risk of barren formation. Here we outline some of the results from the survey.

### FISHING DEPTH

Reported average dive depths from respondents in the north average at shallower (12m) than in the south (16m) (Figure 13). Reported average maximum dive depth shows a similar trend, averaging shallower (15 m) in the north and deeper (22m) in the south. This makes sense considering that higher densities of urchins are located in deeper waters in the southern compared to the northern harvesting areas (Ling and Keane 2018).

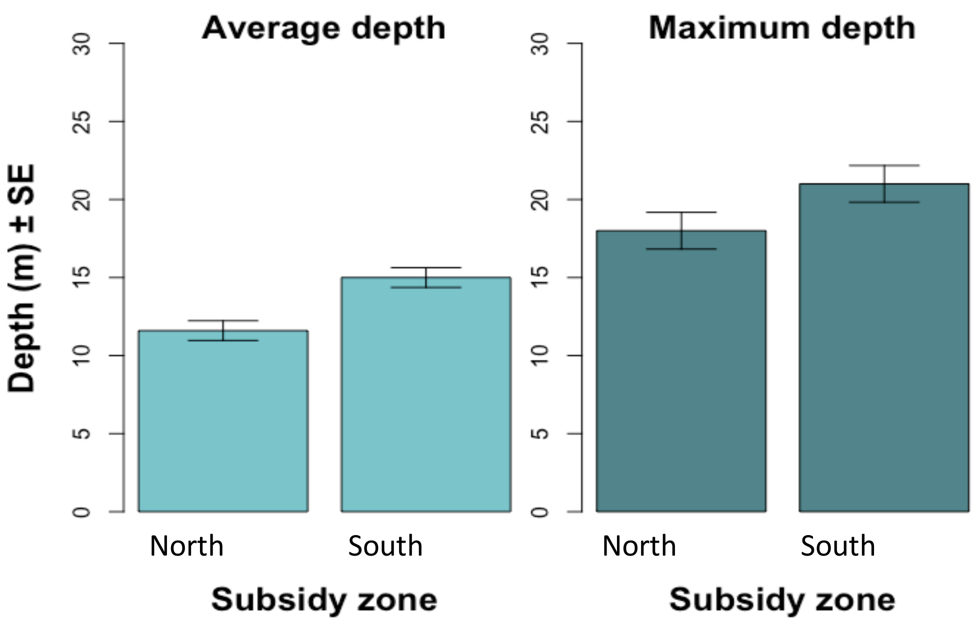


Figure 13. Reported average and maximum dive depths for a typical dive (error bars showing standard error), grouped by the respondent's most common harvesting location.

## CHOICE OF LOCATION

When choosing a location to harvest, respondents indicated that the most important factor is the weight required by the processor (Figure 14). Other 'very important' factors to location choice were weather exposure, years of experience and depth, although 'years of experience' was equally ranked to be of lower importance.

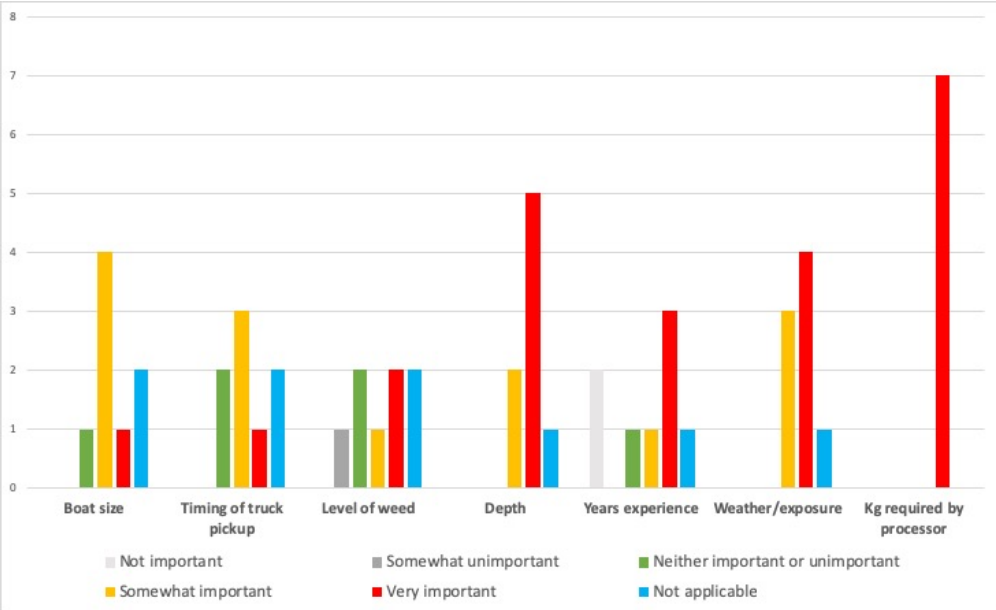


Figure 14. Respondents to the diver survey ranked the importance of various factors to choosing a location for harvesting.

Maximum catch may be limited by the size of the boat used by the diver. Survey respondents indicated maximum catch for their boat size, showing a general positive trend (Figure 15).

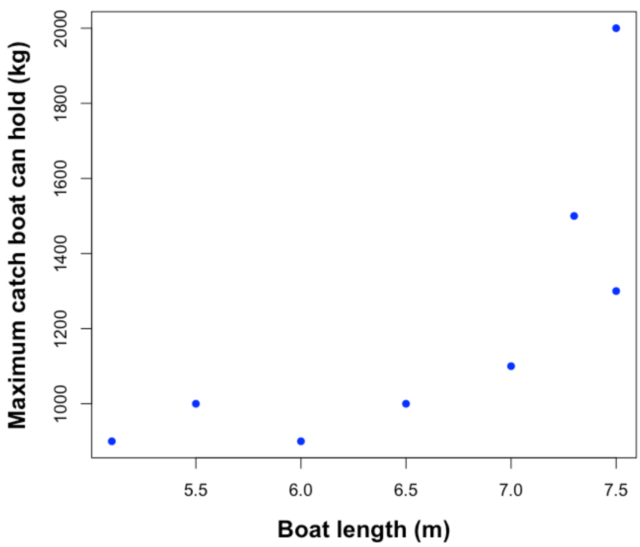


Figure 15. Maximum catch (kg) for boat length (m).

Survey respondents were asked to indicate any observed trend in dive depth, urchin size and catch rate for harvesting Longspined sea urchins. Nearly all respondents indicated an increase in their average dive depth (Figure 16). Greater than 60% respondents observed a decreasing size trend or no trend in urchin size over their time in the industry, with 40% indicating no observed change in size of urchin. Over 40% respondents indicated that catch rate has decreased, with ~30% noting no trend and ~20% indicating that it depended on other factors.

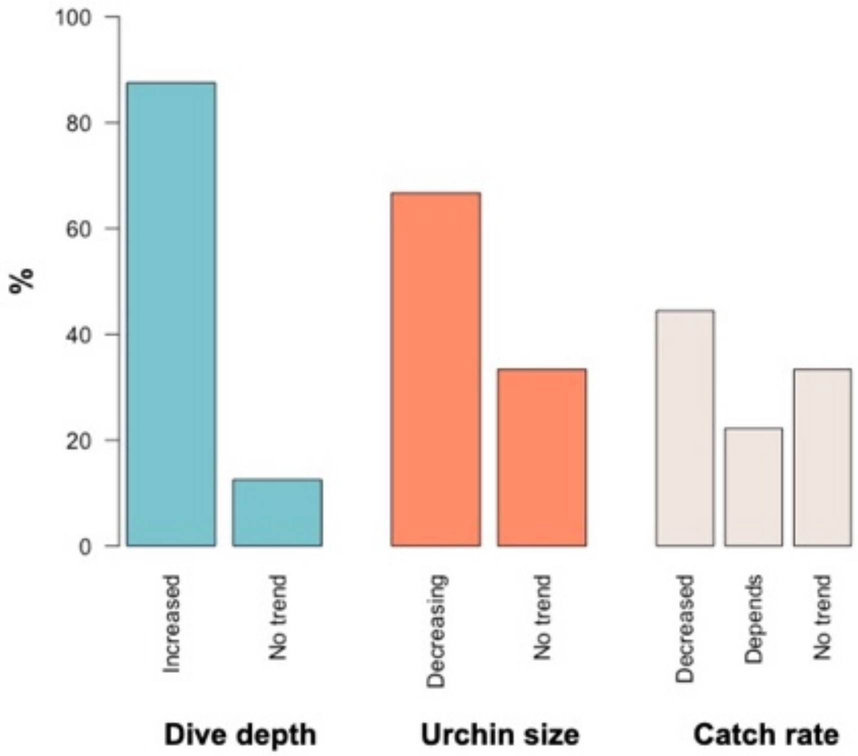


Figure 16. Observed trends in dive depth, urchin size and catch rate by survey respondents.

Respondents were asked to estimate their fuel costs for a short or trip, considering fuel for the car and fuel for the boat, also indicating whether their home port is in the north, central or southern subsidy zone. In general, fuel costs estimated by survey respondents are lower in the north, except for car fuel on a 'long' trip (Figure 17)

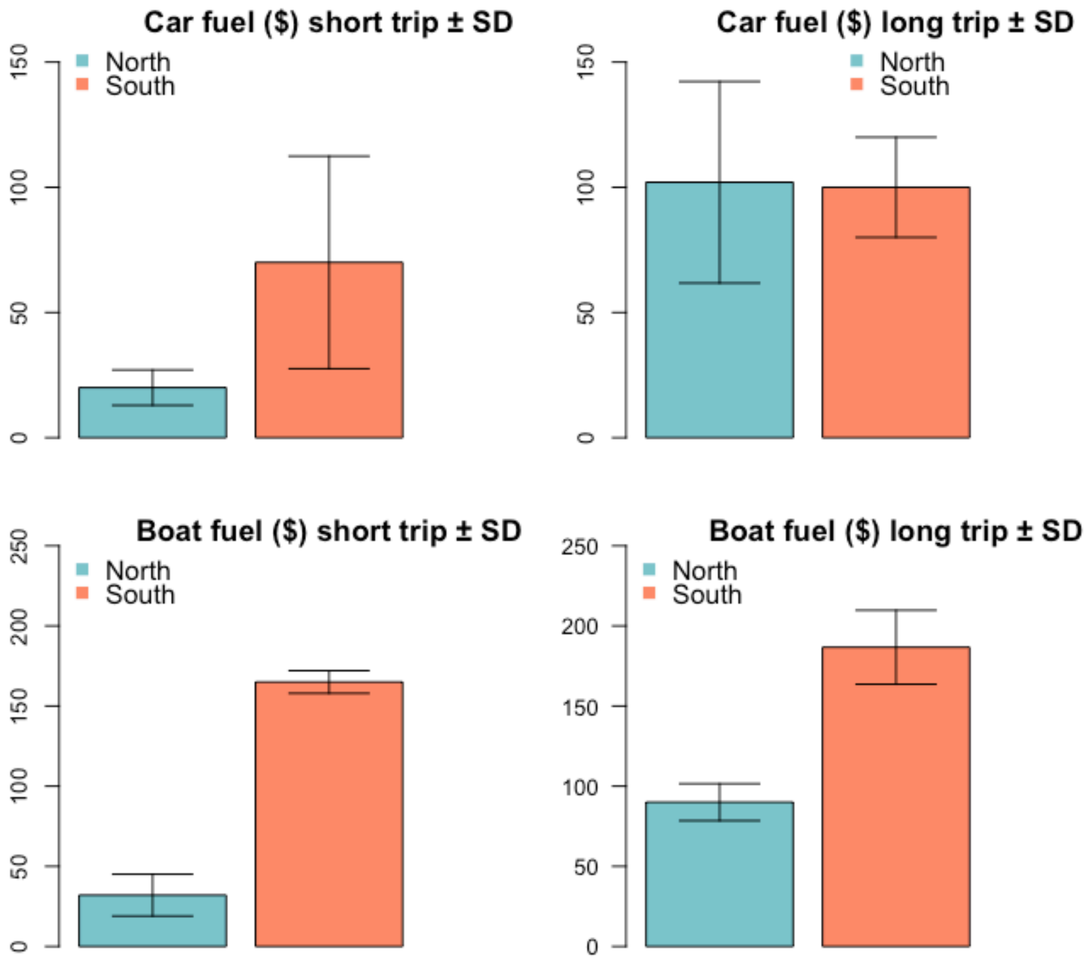


Figure 17. Respondents estimation of car and boat fuel costs for an average 'short' or 'long' trip, given their home port in either the northern, central or southern subsidy zone. Note: no survey respondents identified their home port to be in the central subsidy zone.

# Summary of findings

## Trip costs and revenue for divers

The latitudinal difference in the divers' average hourly reveune based on catch rate (kg/hr) and pay from processor and subsidy ($/kg) shows why the northern zone is preferred as a location for harvesting. Combining the lower revenue per hour of harvesting with the additional costs of harvesting in the southern zone (indicated by the diver survey) further explains why the southern zone is least preferred.

## Incentivising harvest

Incentivising harvest for particular subsidy zones requires a consideration of the hourly revenue and cost of harvesting in that zone compared to the other zones.

## Cost to government of culling vs harvesting

Based on calculations of $/urchin removed, it is more cost-effective to pay divers to cull in regions where the subsidy is greater than $1/kg. If the subsidy is set at $1/kg, it is more cost-effective to pay the diver to cull if culling is at least 2.5 times faster than harvesting. If the subsidy is $0.75/kg or less, it is generally more cost-effective to subsidise harvesting.

## Main findings:

- Comparing divers' hourly revenue using catch rate and pay from processor and subsidy explains differing effort between subsidy zones
- Alternative subsidy structures with increased disparity between regions would be required to standardise expected revenue ($/hr)
- Cost to government of harvesting verses culling depends on level of subsidy relative to processor pay and the speed of culling compared to harvesting (estimated to be 2.7x faster)
- The cost of car and boat fuel per harvesting trip is generally higher in the south
- Nearly all survey respondents noted that their average dive depth has increased over time
- Fine-scale measurements are needed to gain a better understanding of diver effort and subsidy effectiveness

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