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Primary Industries

Stock assessment report 2020 – Sea Urchin and
Turban Shell Fishery

Red Sea Urchin (*Heliocidaris tuberculata*)

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Executive summary

This stock assessment report provides a determination of stock status of the NSW SUTS Fishery- Red Urchin stock, consistent with Status of Australian Fish Stocks (www.fish.gov.au/). It describes the biology, stock structure, fishery statistics and proposed stock indicators for the Sea Urchin and Turban Shell (SUTS) Fishery – Red Sea Urchin (*Heliocidaris tuberculata*, hereafter referred to as Red Urchin).

The aims of the report are to 1) define the stock structure and provide a summary of the biology of Red Urchin; 2) assess and determine the biological status of the NSW Red Urchin stock; 3) summarise the available fishery statistics and additional data sources to inform the assessment and aid in the determination of a Total Allowable Catch; 4) outline information and data limitations and uncertainty in the assessment; and 5) provide comment on the strategic direction for future research and assessment.

Stock status and rationale

The status of the NSW SUTS Fishery- Red Urchin stock is classified as **sustainable**. However, it is important to understand that this classification is complex. It is reliant on an assumed biomass of Red Urchin, expected to be maintained at or about levels of an unfished stock, in areas closed to commercial fishing that comprise about 30% of the total area inhabited by Red Urchin in NSW, including SUTS Fishery specific closures since 1994 (~18% of area). Moreover, the status of the Red Urchin stock from areas open to commercial fishing is likely depleting. Regions 3 and 4 have contributed >60% of the total catch in the last 3-4 years. In both Regions, recently decreasing and current catch rates (kg/hr), at or among historically low levels, together with patterns of catch indicate localised depletion of Red Urchin biomass and recent levels of fishing mortality that are not sustainable. Similarly, in Region 2 (~25% of total catch) peaks in catch and catch rate (kg/hr) are followed by decreases in catch rates (kg/hr), that in 2019 have increased from among historically low levels in immediately preceding years. Region 1 (~12% of total catch) has reported relatively low peaks of catch interspersed with years of catch of about 1 t, with catch rates at low levels of catch maintained at >40 kg/hr and less than half that rate at or after peaks in catch, suggesting relatively low levels of population resilience to fishing. Across all Regions, in areas open to fishing, fishery performance (catch and catch rate) indicates biomass has been depleting due to fishing and is below a reasonable target and fishing mortality has been too high for the last 3-5 years to ensure a sustainable and productive fishery seeking to operate at an economically optimal level.

A review of indicators (weight-of-evidence approach) has been used to assess the SUTS Fishery – Red Urchin stock. The stock is considered a panmictic population. Red Urchin population dynamics is poorly understood and there is a paucity of relevant demographic and biological information.

There are several uncertainties in the assessment of Red Urchin stock: i) productivity of the stock and how that may change through time is not known; ii) reliability of catch rate as an indicator of stock status becomes increasingly uncertain with low numbers of fishers and catch composition varies; there is also a component of hyper-stability in catch rate, which may lead to under-estimation of levels of biomass depletion derived from it; iii) factors impacting on the operation of the fishery and its markets influence fishery-dependent measures of performance. For example, changes to management arrangements (e.g. Regional

Catch Limits - that resulted in the closure of Region 3 to commercial Red Urchin harvest in October 2019; Minimum Legal Size introduced in 2020) and extraneous factors affect fishing operations (e.g. market demands for smaller or larger fish) influencing catch and catch rate unrelated to abundance. Moreover, NSW 2019-20 bushfires (declared a natural disaster) and the COVID-19 pandemic have had a substantial impact on very recent fishery operations. Finally, recreational and Aboriginal catches are poorly understood, although they are not considered to be substantial. These factors provide uncertainty in interpreting changes in possible stock indicators and limit confidence in providing a consistent inference of change in biomass and fishing mortality and hence a stock status.

Fishery-independent surveys conducted in 2000/01 supported estimates of total biomass, depletion caused by fishing, and infer some serial depletion. Outputs from these surveys also supported the initial determination of a total allowable catch. No subsequent surveys of Red Urchin have been undertaken.

Anecdotal information from fishers suggested population densities in some areas open to the fishery are substantially below (50-25%) those in closed areas.

Management controls, including Regional Catch Limits (RCLs) and the introduction of a Minimum Legal Size (MLS) in late 2019, for the commercial fishery, have resulted in limiting fishing mortality and provide increased protections to the resource.

Stakeholder engagement

- SUTS Fishery licence holders, or representatives were presented with assessment data and its interpretation, feedback was offered to inform current and future assessments.
- Issues relating fishing mortality and sustainable fishing practices were discussed.
- Considerations were offered to inform the interpretation of patterns of catch and catch rates, including impacts of extreme natural events and diver experience.
- Interest in investing in GPS logger technology to support cost-effective assessment, compliance and management was also identified.
- Anecdotal evidence discussed supported and was consistent with the assessment.

Information and data limitations and uncertainty

- NSW SUTS Fishery data typically derived from relatively few active fishers.
- Some commercial catch records (0-16% p.a.) have poorly described spatial information, requiring subjective allocation to subzones.
- Anecdotal evidence suggests fishing by sectors other than the commercial sector can substantially contribute to high local fishing mortality of sea urchins.
- Other factors, including freshwater influx, eutrophication and sea temperature may affect abundance and productivity. These have not been explicitly considered.

Future research and assessment needs

- A harvest strategy together with a data monitoring and assessment plan.
- Quantify size-at-maturity and commercial fishery size structure.
- Standardisation of catch rates.
- Fishery-independent surveys – potential cost sharing across multidisciplinary sectors.

1. Introduction

This stock assessment report for the Sea Urchin and Turban Shell (SUTS) Fishery – Red Sea Urchin (*Heliocidaris tuberculata*, CAAB 25 247002, hereafter referred to as Red Urchin) contributes to the descriptions of this fishery and previous reports and assessments of this species (Andrew et al. 1996, 1998, Chick 2018, 2019, DPI 2018a, 2019a, Worthington and Blount 2003). It has been prepared to present and reference, relevant information to inform an assessment of the NSW Red Urchin stock, determination of stock status using criteria for the Status of Australian Fish Stocks (www.fish.gov.au/), and to aid in the determination of a Total Allowable Catch (TAC).

The aims of the report are to 1) define the stock structure and provide a summary of the biology of the species; 2) assess and determine the biological status of the NSW Red Urchin stock; 3) summarise the available fishery statistics and additional data to inform the assessment; 4) outline information and data limitations and uncertainty in the assessment; and 5) provide comment on the strategic direction for future research and assessment.

The SUTS Fishery is a multi-species, restricted fishery, with fishers endorsed to harvest three species of Turban Shell and three species of Sea Urchin (including Red Urchin). The fishery is spatially structured into 5 Regions (Figure 1), managed through a combination of input controls, including limited access and output controls, including a Total Allowable Commercial Catch (TACC) and individual quota, applied only to Red Urchin (DPI 2019a).

1.1. Biology and stock structure

Red Urchin are found on near shore coastal reef, typically at depths <10 m and within the Fringe habitat (*sensu* Underwood et al. 1991). Red Urchin have a relatively contained spatial distribution extending on the Australian mainland from the central north coast of NSW (Coffs Harbour) to the southern margins of the state (Disaster Bay) (Worthington and Blount 2003). However, they are also located on shallow reefs around Lord Howe Island, Norfolk Island and the Kermadec Islands (Gall 2016). Red Urchin have been reported to have a protracted spawning period, extending nine months outside of the Austral summer, and produce relatively small (95 µm) negatively buoyant eggs (Laegdsgaard et al. 1991). Fertilized eggs typically develop over a period of 3-5 weeks (22°C) via planktotrophic (feeding) larvae (Hoegh-Guldberg and Emlet 1997). Gall (2016) examined the genetic structure of Red Urchin and environmental tolerances of their larvae, finding that they are panmictic population (throughout mainland Australian and the Lord Howe, Norfolk and Kermadec Islands) and their limited latitudinal distribution is not a function of limited larval dispersal capacity, but rather larval intolerance of colder temperature. The most recent information describing population size structure or density is that done in 2000 by Worthington and Blount (2003).

Red Urchin can form dense aggregations but are also found at lower densities along broad areas of NSW near-shore reef. Worthington and Blount (2003) reported significant variation in density among Regions of the Fishery, and at a range of densities in all survey sites in Regions 1-4, up to a maximum of 1.66.m⁻². Whereas in Region 5, densities were substantially lower (<0.05.m⁻²), with no Red Urchin in 80% of survey sites.

On the basis of this evidence provided, the determination of stock status of Red Urchin is presented at the biological stock level.

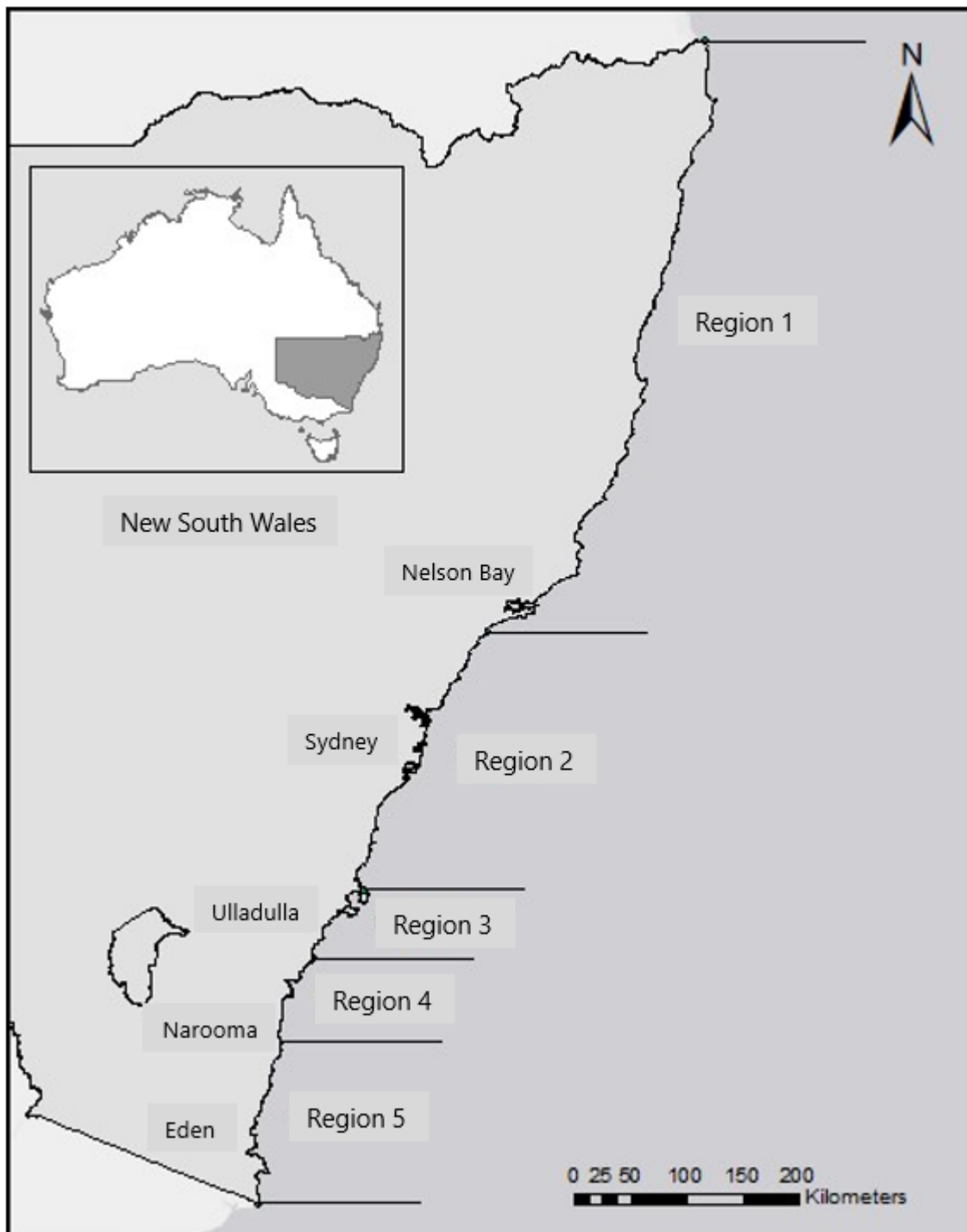


Figure 1 Map of NSW showing Regions of the NSW SUTS Fishery and locations informing breakpoints between Regions.

2. Stock status and assessment method

The status of the NSW SUTS Fishery- Red Urchin stock is classified as **sustainable**. However, it is important to understand that this classification is complex. It is reliant on an assumed biomass of Red Urchin, expected to be maintained at or about levels of an unfished stock, in areas closed to commercial fishing that comprise about 30% of the total area inhabited by Red Urchin in NSW, including SUTS Fishery specific closures since 1994 (~18% of area), all of Region 5 (i.e. from Narooma to the NSW/Victorian border) and about 45 km of coast encompassed by Marine Parks. Moreover, the status of the Red Urchin stock from areas open to commercial fishing only is likely depleting. This is a consequence of fishery performance in each Region, derived from patterns of catch and catch rate, generally weighted by the catch contribution of each Region to annual catch.

Over the first few years of this fishery (from 2000) large catches (e.g. 63 t, 73% of total catch in 2000 from Region 3) were harvested at high catch rates (>100 kg/hr and >230 kg/day). Subsequent smaller peaks in catch and catch rate reflected a focus of fishing into areas previously not fished. Catch and catch rates in Regions 3 and 4 in the years immediately after 2000, and in Region 2 after 2007, declined substantially, suggesting a relationship between catch rate and available biomass and indicating substantial depletion of the available biomass due to fishing. Peaks in catch within the last 4-5 years are smaller than those previously reported and at lower and declining or low and stable catch rates.

Regions 3 and 4 have consistently contributed >50% of the total catch and >60% in the last 3-4 years. In both Regions recently decreasing and current catch rates (kg/hr), that are at or among historically low levels, together with patterns of catch indicate some localised depletion of Red Urchin biomass and recent levels of fishing mortality that are not sustainable. Similarly, in Region 2 (~25% of total catch) peaks in catch and catch rate (kg/hr) are followed by decreases in catch rates (kg/hr), that in 2019 have increased from among historically low levels in immediately preceding years. Region 1 (~12% of total catch) has reported relatively low peaks of catch interspersed with years of catch of about 1 t, with catch rates at low levels of catch maintained at >40 kg/hr and less than half that rate at or after peaks in catch, suggesting relatively low levels of population resilience to fishing. Across all Regions, in areas open to fishing, fishery performance (catch and catch rate) indicates biomass has been depleting due to fishing and is below a reasonable target and fishing mortality has been too high for the last 3-5 years to ensure a sustainable and productive fishery seeking to operate at an economically optimal level.

A review of indicators (weight-of-evidence approach) has been used to assess the SUTS Fishery – Red Urchin stock. The stock is considered a panmictic population, with status defined for the population along the NSW coast, as single unit stock. There is limited knowledge of the population dynamics of Red Urchin, particularly a paucity of age/size and growth, maturity and size structure data (including of the commercial catch) and limited information to infer a stock/recruitment relationship.

A number of factors contribute to uncertainty in the assessment: i) productivity of the stock and how that may change through time is not known. This heightens uncertainty regarding the assumption of the level of biomass in closed areas particularly, although this can be offset against inferred population growth from patterns of catch and catch rate from areas open to fishing assuming no density dependent limitations; ii) reliability of catch rate as an

indicator of stock status becomes increasingly uncertain with low numbers and increasingly variable fishers through time, and there is substantial latent effort in the fishery; catch composition varies, including Red Urchin only and mixed species catches; and there is likely a component of hyper-stability in catch rate, which may lead to under-estimation of levels of biomass depletion derived from it.

Factors impacting the operation of the fishery and its markets and hence fishery-dependent measures of performance derived from them, unrelated to Red Urchin abundance, add to existing uncertainties in the assessment. For example, bushfires (declared a natural disaster) throughout NSW early in 2020, and the COVID-19 pandemic have had a substantial impact on recent fishery operations and will limit confidence in the interpretation of fishery-dependent measures of fishery performance otherwise used to inform the assessment and determine stock status. Further, Recreational and Aboriginal catches are poorly understood, although they are not considered to be substantial. These factors provide uncertainty in interpreting changes in possible stock indicators and limit confidence in providing a consistent inference of change in biomass and fishing mortality and hence a stock status.

Fishery-independent surveys conducted in 2000 supported estimates of total biomass and the determination of a total allowable commercial catch of 60 t, "...to be spread across regions according to the remaining biomass." (Worthington and Blount 2003). Repeated surveys provided biomass depletion estimates of 45% and 39%, in areas open to fishing in Regions 3 and 4, respectively, as the highest levels of annual catch were harvested from areas open to fishing in these Regions. They also described shifts in effort through time, from June 1999 to September 2000, suggesting serial depletion of dense aggregations of Red Urchin in Region 3. No subsequent surveys of Red Urchin have been undertaken.

Anecdotal information from fishers in 2018 suggest population densities in some areas open to fishing are substantially below (50-25%) those in closed areas (TAFC 2018, 2019), indicating that the peaks in catch in the early 2000's and relatively low levels of fishing that have occurred over the last ~18 years has maintained a relatively low biomass in areas open to fishing and that the resilience of Red Urchin stocks to short periods of high, and then persistent periods of even low levels of fishing, is not high.

Management controls provide substantial protections to the Red Urchin stock. These controls include spatial closures (about 30% of the NSW coast, including Red Urchin specific spatial closures); regional catch limits; and a minimum legal size for the commercial fishing sector (DPI 2019a, 2019b). These controls limit fishing mortality and provide greater certainty in the protection of spawning biomass whilst limiting annual regional catches to more "biologically prudent" levels (TAFC 2018, 2019), relatively consistent with previous regional estimates of biomass from Worthington and Blount (2003). These controls are more likely to support improved fishery performance within areas open to the fishery and demonstrate the resource can support the current status of sustainable, without reliance on the biomass of Red Urchin in areas closed to the fishery. The opportunity exists to invest in the development of a monitoring and assessment strategy to provide greater certainty in the status of the stock and inform a harvest strategy that could support additional catch and/or curate a more resilient stock and increase the value of the resource.

3. Fisheries statistics

The fishery for sea urchins in NSW was largely unexploited prior to the late 1990's, with small annual catches (<2 t) described for the 15 years prior to 1998 (Worthington and Blount 2003). Although Andrew et al. (1996) reported 5 t of sea urchins harvested in 1994, with the majority understood to be *Centrostephanus rodgersii*. Worthington and Blount (2003) also reported sporadic attempts to develop the NSW sea urchin fishery in the 1970's and 1980's, without success. No information on catch or effort is available prior to 1989, and records prior to July 1999 are not available as validated catches. Species specific annual catches for the SUTS Fishery, from 2000, and Region and Subzone boundaries are provided in Appendix 1.

This report includes data available from logbook returns from fishers in the commercial fishery for the period January 2000 to August 2020, for Red Urchin. Fishery data are presented at the scale of the whole fishery and SUTS Fishery Region and Subzone and from FisherDays where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only (RU only) were harvested. Effort and catch rate data presented exclude records where reported effort <0.25 and >8 hr day⁻¹ and for catch rates, where there were <10 FisherDays yr⁻¹.

Catch rates (kg/hr, kg/day) in assessment reports for Red Urchin prior to 2019 have presented data from daily records reporting Red Urchin including records from FisherDays where other SUTS Fishery species were harvested and where Red Urchin only were harvested. Further, there is anecdotal evidence of fishers, endorsed to fish for both Red Urchin and abalone (in the NSW Abalone Fishery), harvesting both species on the same day, with Red Urchin catch described as incidental or an opportunistic by-product, as fishers generally target abalone or other SUTS Fishery species. There was an assumption that this practice occurred at a frequency that limited the reliability of Red Urchin catch and effort records to inform fishery indicators of stock status (TAFC 2018). However, catch records integrated from the Abalone and SUTS Fisheries provide the number of FisherDays reported in the Abalone Fishery and SUTS Fishery (where Red Urchin were caught) and where both Red Urchin and abalone were caught on the same FisherDay (Chick 2019). There were relatively few FisherDays where both abalone and Red Urchin were harvested. From 2000 to 2005, a total of 31 and a maximum of 9 FisherDays in a year recorded both Red Urchin and abalone being harvested. In the following decade there were no records of Red Urchin and abalone being harvested on the same FisherDay. From 2017 to 2019 (to August that year) between 8 – 13 FisherDays p.a. reported the harvest of both Red Urchin and abalone (Chick 2019).

3.1. Catch, effort and catch rate information

3.1.1. Commercial

State-wide fishery – catch, effort and catch rate

Catch of Red Urchin peaked in 2000 at 85.5 t during a significant developmental phase in the fishery, with effort reported at >800 hrs (Figure 2 and Table 1). From 2004 to 2015 annual catches remained below 9 t and effort was generally <200 hours, with the exceptions in 2007 and 2008 where catches were ~15 t p.a., as a result of the exploitation of the previously lightly fished stock of Red Urchin in Region 2, subzones K1 and K2, and to a lesser extent Region 1, subzones E1 and F1 (see section - Subzone – catch). Since 2016, annual catch and effort has exceeded 17.5 t and >540 hours. Prior to 2016, the number of active fishing

businesses fluctuated between 8 and 14 p.a. and was typically 8-9 active businesses each year (Table 1). Since 2016, the number of active fishing business has been >10 p.a., with 17 different fishing businesses active in the fishery in 2019, the highest number of active fishing businesses harvesting Red Urchin. In 2020 (to the end of August), catch and effort was 5.1 t and 210 hrs, respectively. These levels represent less than half of the catch and effort reported to the end of August in either of the previous 3 years.

In the SUTS Fishery, fishers can harvest Red Urchin and/or other SUTS Fishery species on the same FisherDay, whilst still reporting species specific catch and effort units. In 2000 and 2001, there were >230 FisherDays and >550 hr reported harvesting Red Urchin together with other SUTS species (RU + SUTS) and >85 FisherDays and >200 hr reported harvesting Red Urchin only (RU only) (Figure 3A and Table 2). The proportion of FisherDays on Red Urchin only was 0.5 and 0.3 of FisherDays reporting Red Urchin and other species in those years (2000 and 2001) (Figure 3B and Table 2). Over the 16 years from 2003 to 2017, the proportion of Red Urchin only FisherDays averaged 0.3 of all other FisherDays reporting Red Urchin. In 2018, 180 FisherDays and 425 hours were reported for the harvest of Red Urchin only compared with 108 FisherDays and 284 hours reported for the harvest of Red Urchin with other SUTS species (Figure 3A and Table 2). This was the only year where effort harvesting Red Urchin only had exceed that harvesting Red Urchin with other SUTS species. In 2019, fewer hours and FisherDays were spent harvesting Red Urchins only than fishing Red Urchins with other SUTS species, although the proportion of FisherDays was 0.78, the next highest proportion after that in 2018.

Catch rates (kg/hr and kg/day) from records where both Red Urchin and SUTS species (RU+SUTS) and Red Urchin only (RU only) were harvested provide relatively consistent patterns of change throughout the 20 years of the fishery (Figure 4 and Table 3). Substantial peaks in catch rates occurred around times of high catches and decrease in the immediate years thereafter, with lower catches, suggesting reduced biomass and periods of low catch allowing some recovery of the stock. In 2016, catch more than doubled from recent previous years, and has been sustained to the most recent full year of data (2019). During the same period catch rates on Red Urchin only have decreased and are among the lowest levels in the history of the fishery. In contrast, those on Red Urchin with other SUTS species have generally increased, albeit to relatively low levels for catch per hour (RU+SUTS) (Figure 4 and Table 3).

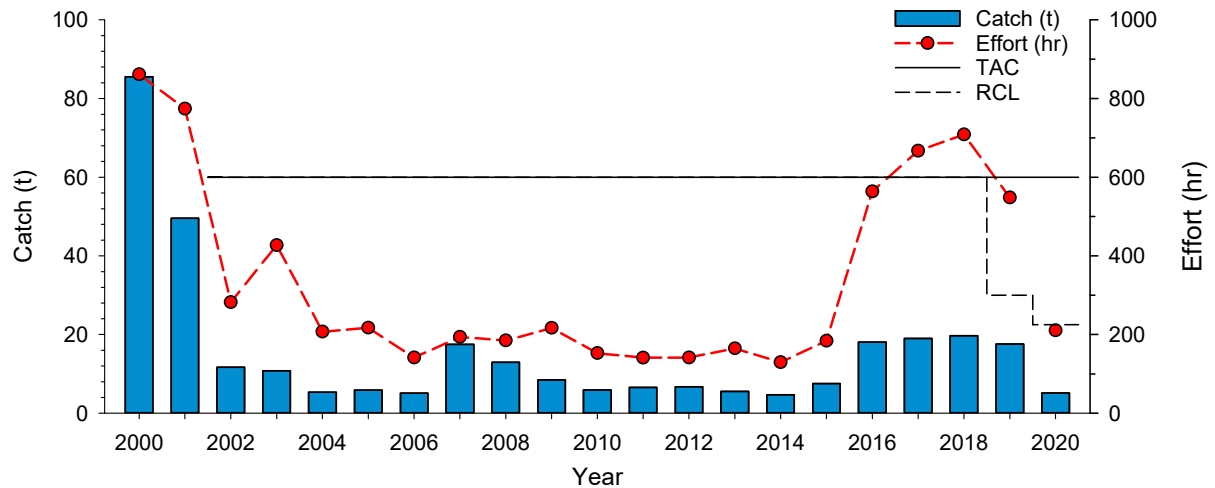


Figure 2 Annual catch (t), effort (hr), Total Allowable Catch (TAC) and total Regional Catch Limit (RCL) on Red Urchin in the Sea Urchin and Turban Shell (SUTS) Fishery, from 2000 to 2020* (*data to August).

Table 1 Annual catch (t), effort (hr) and number of active fishers harvesting Red Urchin in the SUTS Fishery, from 2000 to 2020* (*data to August) (Note: Effort excludes records with <0.25 or >9 hrs effort per day)

Year	Catch (t)	Effort (hr)	No. active fishers (RU)
2000	85.5	861	10
2001	49.7	774	13
2002	11.7	282	6
2003	10.8	427	9
2004	5.4	207	11
2005	5.9	217	14
2006	5.3	142	9
2007	17.5	194	8
2008	12.9	185	8
2009	8.5	217	12
2010	5.9	153	9
2011	6.6	141	9
2012	6.7	142	8
2013	5.5	165	9
2014	4.7	130	8
2015	7.5	184	9
2016	18.1	564	11
2017	19.0	667	16
2018	19.7	709	13
2019	17.6	548	17
2020*	5.1	210	9

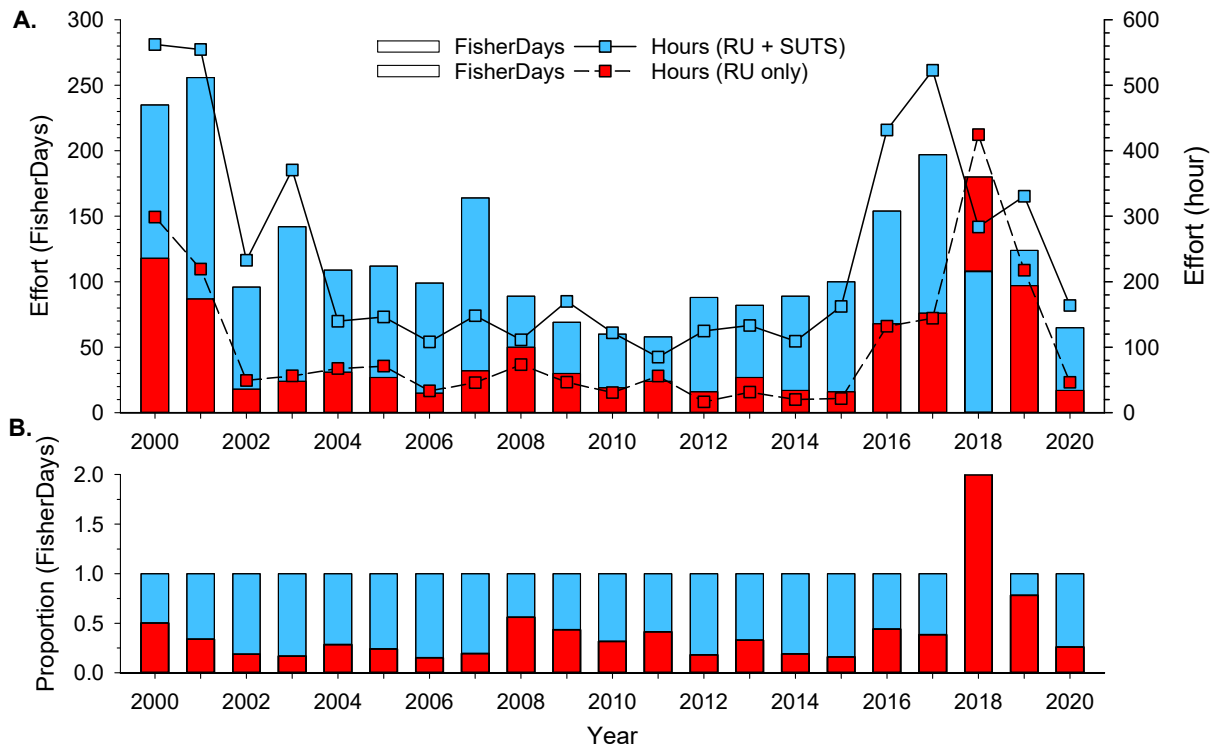


Figure 3 Whole Fishery – Effort – A. Number of FisherDays and hours where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only (RU only) were reported; and B. FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

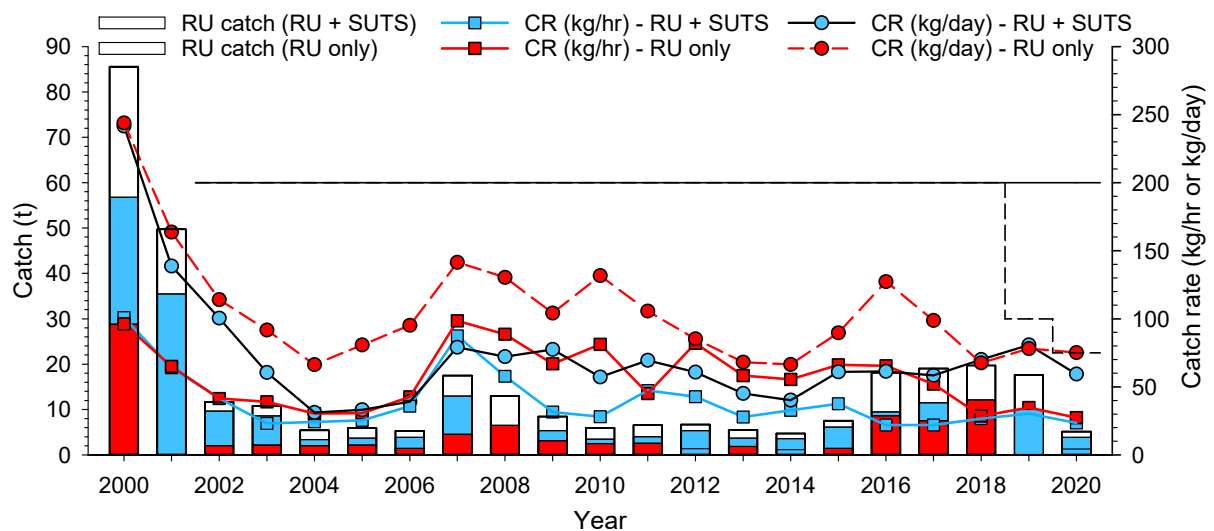


Figure 4 Whole Fishery – Catch and catch rate – Total catch (open bars), catch of Red Urchin on FisherDays where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only (RU only) were reported; Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year. TAC (solid line). Regional Catch Limit (dashed line).

Table 2 Whole Fishery – Effort – Number of FisherDays and hours where Red Urchin and other SUTS species were reported (RU + SUTS) and Red Urchin only were reported (RU only); and FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

Year	FisherDays (A) (RU + SUTS)	FisherDays (B) (RU only)	Proportion FisherDays (B/A)	Effort (hr) (RU + SUTS)	Effort (hr) (RU only)
2000	235	118	0.50	562	299
2001	256	87	0.34	555	219
2002	96	18	0.19	233	50
2003	142	24	0.17	371	56
2004	109	31	0.28	140	68
2005	112	27	0.24	146	71
2006	99	15	0.15	108	33
2007	164	32	0.20	148	46
2008	89	50	0.56	111	74
2009	69	30	0.43	170	47
2010	60	19	0.32	122	31
2011	58	24	0.41	85	56
2012	88	16	0.18	125	17
2013	82	27	0.33	133	32
2014	89	17	0.19	109	20
2015	100	16	0.16	162	22
2016	154	68	0.44	432	132
2017	197	76	0.39	523	144
2018	108	180	1.67	284	425
2019	124	97	0.78	331	218
2020*	65	17	0.26	164	47

Table 3 Whole Fishery – Catch and catch rate – Catch of Red Urchin on FisherDays where Red Urchin and other SUTS species were reported (RU + SUTS) and Red Urchin catch from FisherDays (RU only); Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year.

Year	Catch (t) (RU + SUTS)	Catch (t) (RU only)	CR (kg/hr) (RU + SUTS)	CR (kg/hr) (RU only)	CR (kg/day) (RU + SUTS)	CR (kg/day) (RU only)
2000	56.76	28.78	100.9	96.2	241.5	243.9
2001	35.48	14.24	64.0	64.9	138.6	163.6
2002	9.65	2.05	41.4	41.4	100.5	114.0
2003	8.59	2.20	23.2	39.0	60.5	91.6
2004	3.38	2.06	24.2	30.4	31.0	66.3
2005	3.70	2.18	25.3	30.6	33.1	80.7
2006	3.87	1.43	35.7	42.6	39.1	95.2
2007	12.95	4.53	87.4	98.5	79.0	141.4
2008	6.43	6.52	57.7	88.6	72.2	130.4
2009	5.35	3.13	31.4	66.9	77.5	104.2
2010	3.43	2.50	28.0	81.2	57.1	131.7
2011	4.02	2.53	47.3	45.1	69.4	105.6
2012	5.34	1.36	42.8	82.0	60.7	85.2
2013	3.70	1.84	27.8	58.2	45.2	68.1
2014	3.58	1.13	32.7	55.5	40.2	66.4
2015	6.10	1.43	37.6	66.2	61.0	89.6
2016	9.45	8.65	21.9	65.5	61.4	127.2
2017	11.50	7.50	22.0	52.0	58.4	98.7
2018	7.56	12.14	26.6	28.6	70.0	67.5
2019	10.01	7.57	30.3	34.8	80.7	78.0
2020*	3.86	1.28	23.6	27.4	59.4	75.1

Region – catch, effort and catch rate

Catch among Regions and as a proportion of annual catch has varied substantially through time (Figure 5A and B and Table 4). In 2000 and 2001, large catches of 62 t and 30 t and >~60% of the total annual catch were harvested from Region 3. During the same years, catches of 21 t and 12 t (both ~25% of total annual catch) were harvested from Region 4. From 2002 to 2013, catches from Region 2 supported the majority of relatively small annual catches (range 1.7 t to 10.6 t). From 2016, the highest absolute and proportion of annual catch from Regions 3 and 4 has oscillated and for Region 3 absolute and proportional catch in 2018 and 2019, respectively were the highest since 2001 (Figure 5A and B and Table 4).

In Region 1, from 2000 to 2017 there have been very few FisherDays where Red Urchin only have been harvested (range 0-7 FisherDays), including 9 years where no FisherDays reported harvesting Red Urchin only (Figure 6A and Table 5). Further, during the majority of these years only one active fisher was operating (Table 5). In 2018, 61 FisherDays and 130 hours were reported harvesting Red Urchin only, the highest levels reported and from 6 active fishers. In 2019, effort and catch substantially declined. Peaks in catch have occurred in 2001 (5 t), 2007 (6 t) and 2017 (3 t), below the RCL. Catch rates (RU + SUTS) have fluctuated, although both measures have been among historically lowest levels in recent years. In 2019, catch rates substantially increased from levels in 2018 but remain among the lowest levels for 10-15 years (Figure 7 and Table 6). There has been no Red Urchin only fishing in 2020.

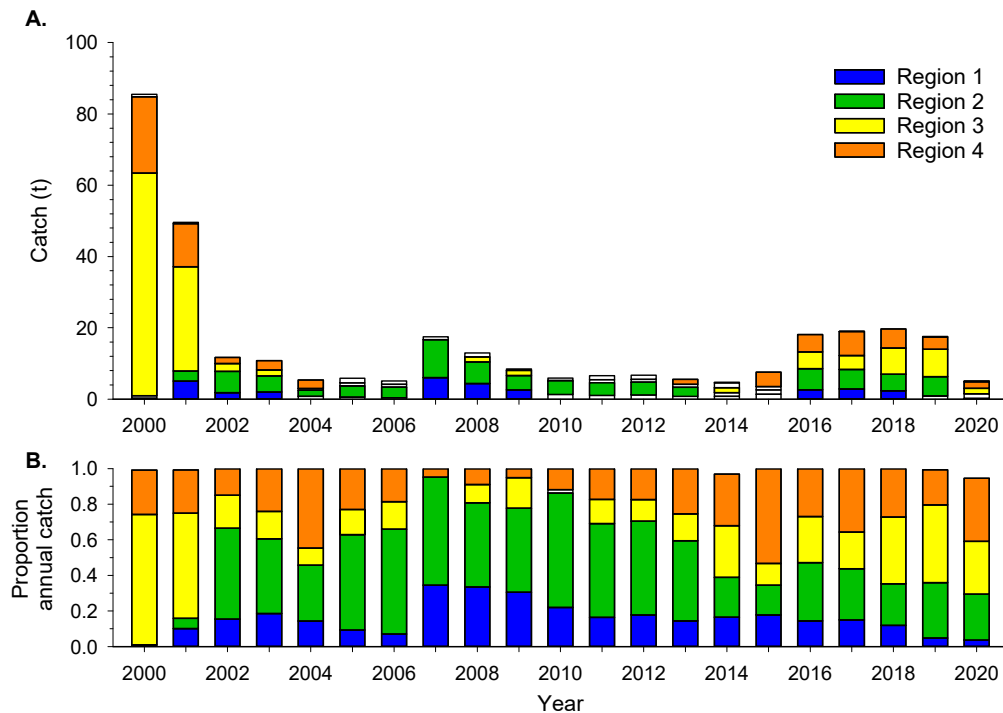


Figure 5 A. Catch (t); and B. Proportion of annual catch for Regions 1-4, from 2000 to 2020* (*data to August).

Table 4 Catch (t) (percent) for Regions 1-4, from 2000 to 2020* (*data to August).

Year	Region 1 Catch (t) (%)	Region 2 Catch (t) (%)	Region 3 Catch (t) (%)	Region 4 Catch (t) (%)
2000	0.27 (0.3)	0.68 (0.8)	62.50 (73.1)	21.37 (25)
2001	5.02 (10.1)	2.85 (5.7)	29.28 (59)	12.07 (24.3)
2002	1.81 (15.5)	5.97 (51)	2.17 (18.5)	1.75 (15)
2003	2.00 (18.6)	4.53 (42)	1.67 (15.5)	2.58 (23.9)
2004	0.77 (14.3)	1.69 (31.4)	0.52 (9.6)	2.40 (44.7)
2005	0.55 (9.3)	3.15 (53.5)	0.83 (14.2)	1.35 (23)
2006	0.36 (7.1)	3.00 (58.8)	0.79 (15.5)	0.95 (18.6)
2007	6.03 (34.5)	10.60 (60.6)	0.00 (0)	0.85 (4.9)
2008	4.34 (33.5)	6.11 (47.2)	1.33 (10.3)	1.16 (9)
2009	2.58 (30.5)	4.00 (47.2)	1.45 (17.2)	0.43 (5.1)
2010	1.30 (22)	3.80 (64.2)	0.12 (2.1)	0.70 (11.8)
2011	1.08 (16.4)	3.45 (52.6)	0.90 (13.6)	1.14 (17.3)
2012	1.19 (17.7)	3.53 (52.7)	0.82 (12.2)	1.17 (17.4)
2013	0.80 (14.4)	2.50 (45.1)	0.83 (15)	1.41 (25.4)
2014	0.78 (16.5)	1.05 (22.4)	1.37 (29.1)	1.36 (29)
2015	1.34 (17.8)	1.26 (16.7)	0.92 (12.2)	4.02 (53.3)
2016	2.61 (14.4)	5.93 (32.8)	4.69 (26)	4.87 (26.9)
2017	2.84 (15)	5.46 (28.7)	3.92 (20.6)	6.74 (35.5)
2018	2.35 (11.9)	4.61 (23.4)	7.38 (37.5)	5.37 (27.2)
2019	0.86 (4.9)	5.46 (31.1)	7.66 (43.6)	3.47 (19.8)
2020*	0.19 (3.6)	1.33 (25.9)	1.52 (29.6)	1.82 (35.3)
Min*	0.27 (0.3)	0.68 (0.8)	0.00 (0)	0.43 (4.9)
Max*	6.03 (34.5)	10.60 (64.2)	62.50 (73.1)	21.37 (53.3)
Mean (5 Yr)*	2.00 (12.8)	3.66 (26.5)	3.66 (28)	4.47 (32.5)
Mean (10 Yr)*	1.51 (15.1)	3.56 (37)	2.24 (21.2)	2.72 (26.4)

* excludes 2020

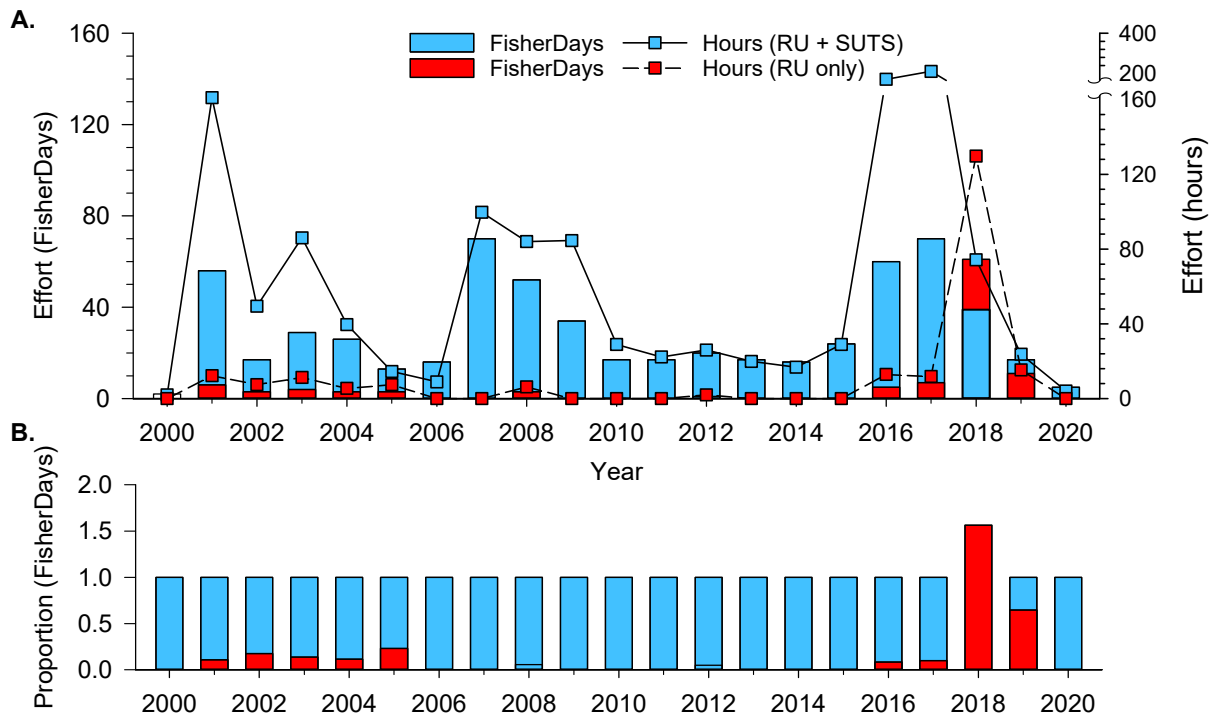


Figure 6 Region 1 – Effort – A. Number of FisherDays and hours where Red Urchin and other SUTS species were reported (RU + SUTS) and where Red Urchin only were reported (RU only); and B. FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

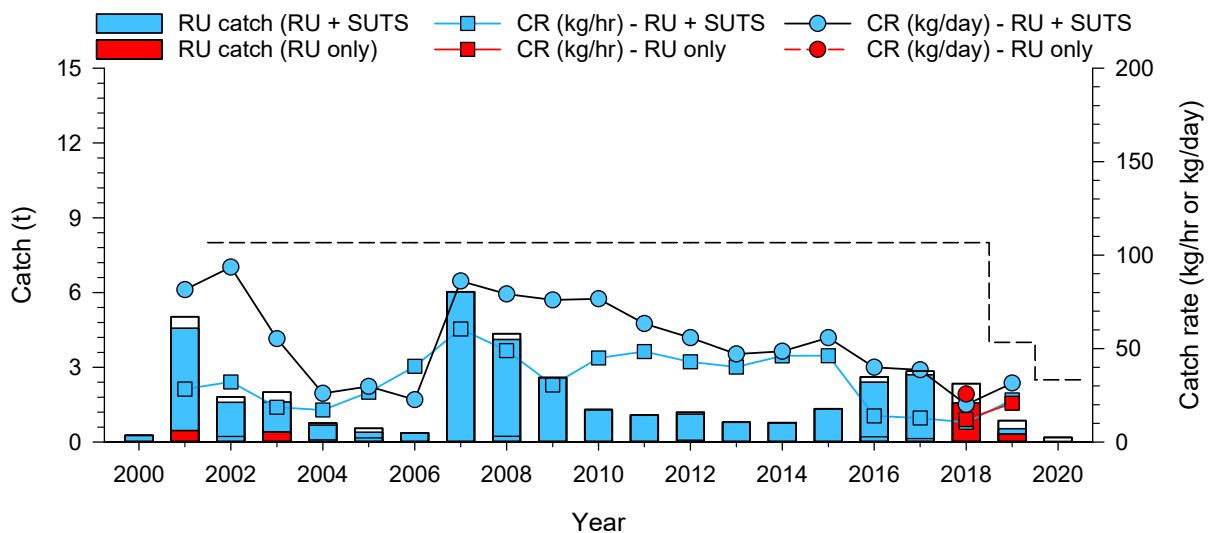


Figure 7 Region 1 – Catch and catch rate – Total catch (open bars), catch of Red Urchin on FisherDays (RU + SUTS) and from FisherDays (RU only); Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year. Dashed line represents the Regional Catch Limit.

Table 5 **Region 1 – Effort – Number of FisherDays and hours where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only were reported (RU only); FisherDays (RU only) as a proportion of FisherDays (RU + SUTS); total hours and number of active fishers, from 2000 to 2020* (*data to August).**

Year	FisherDays (A) (RU + SUTS)	FisherDays (B) (RU only)	Proportion (B/A)	Total effort (hr) Red Urchin	Effort (hr) (RU + SUTS)	Effort (hr) (RU only)	No. active RU fishers
2000	2	0	0.00	2.0	2.0	0.0	2
2001	56	6	0.11	173.3	161.0	12.3	1
2002	17	3	0.18	57.0	49.5	7.5	2
2003	29	4	0.14	97.4	86.0	11.4	2
2004	26	3	0.12	45.2	39.7	5.5	5
2005	13	3	0.23	22.1	14.6	7.5	6
2006	16	0	0.00	9.0	9.0	0.0	3
2007	70	0	0.00	99.7	99.7	0.0	6
2008	52	3	0.06	90.4	84.1	6.3	5
2009	34	0	0.00	84.6	84.6	0.0	1
2010	17	0	0.00	29.0	29.0	0.0	1
2011	17	0	0.00	22.3	22.3	0.0	1
2012	20	1	0.05	28.0	26.0	2.0	1
2013	17	0	0.00	19.9	19.9	0.0	1
2014	16	0	0.00	16.8	16.8	0.0	1
2015	24	0	0.00	29.0	29.0	0.0	1
2016	60	5	0.08	184.1	171.1	13.0	2
2017	70	7	0.10	222.3	210.5	11.8	3
2018	39	61	1.56	204.1	74.4	129.7	6
2019	17	11	0.65	39.2	23.8	15.4	5
2020*	5	0	0.00	4.2	4.2	0.0	1

Table 6 **Region 1 – Catch and catch rate – Catch of Red Urchin on FisherDays where Red Urchin and other SUTS species were reported (RU + SUTS) and catch where Red Urchin only were reported (RU only); Catch rate (kg/hr and kg/day) for FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year.**

Year	Catch (t) (RU + SUTS)	Catch (t) (RU only)	CR (kg/hr) (RU + SUTS)	CR (kg/hr) (RU only)	CR (kg/day) (RU + SUTS)	CR (kg/day) (RU only)
2000	0.27	0.00				
2001	4.56	0.46	28.3		81.5	
2002	1.59	0.22	32.1		93.6	
2003	1.60	0.40	18.6		55.2	
2004	0.68	0.09	17.1		26.0	
2005	0.39	0.16	26.6		29.8	
2006	0.36	0.00	40.4		22.6	
2007	6.03	0.00	60.5		86.1	
2008	4.11	0.23	48.9		79.1	
2009	2.58	0.00	30.5		76.0	
2010	1.30	0.00	44.9		76.6	
2011	1.08	0.00	48.4		63.3	
2012	1.12	0.07	42.9		55.8	
2013	0.80	0.00	40.2		47.1	
2014	0.78	0.00	46.1		48.5	
2015	1.34	0.00	46.2		55.8	
2016	2.40	0.21	14.0		40.0	
2017	2.71	0.14	12.9		38.7	
2018	0.78	1.56	10.5	12.1	20.0	25.6
2019	0.54	0.32	22.5	20.7	31.5	
2020*	0.19	0.00				

In Region 2, in the 12 years from 2002 the total number of FisherDays (RU + SUTS and RU only) has remained relatively stable (~52 FisherDays; range 43-75) (Figure 8A and Table 7). However, the number of FisherDays (RU only) and associated hours, increased and from 2007 to 2013 and from 2016 to 2019, FisheryDays (RU only) were relatively high in absolute number (≥ 14 and ≥ 34 FisherDays, respectively) and as a proportion (≥ 0.37 and 0.58 , respectively) of FisherDays (RU + SUTS) (Figure 8A and B and Table 7). In 2016, hours (RU + SUTS and RU only) increased to levels higher than previously recorded (>150 and 60 hr, respectively). In 2017 and 2018, both series of effort increased again, recording their highest levels of 162 hr and 125 hr, respectively. In 2019, hours of both series (RU + SUTS and RU only) and Red Urchin only FisherDays declined. Catches of Red Urchin from mixed species (RU + SUTS) and Red Urchin only FisherDays show peaks in 2007 and 2008 (6.2 t and 4.9 t), respectively and lower peaks again in 2017 and 2016 (2.8 t and 3.9 t, respectively) (Figure 9 and Table 8). Similarly, catch rates (kg/hr and kg/day) of Red Urchin from mixed species (RU + SUTS) and Red Urchin only (RU only) FisherDays demonstrate similar patterns to catch with high levels within the same years and subsequent declines over the following 5-6 years from 2007 or 2008 and, from 2016 to 2018, for both kg/hr and kg/day from FisherDays (RU only), likely reflecting declines in fishable biomass over the same periods. In 2019, all catch rate series increased from among historically low levels in 2018, with catch rate (kg/hr) on Red Urchin from mixed species (RU + SUTS) FisherDays more than doubling (Figure 9 and Table 8).

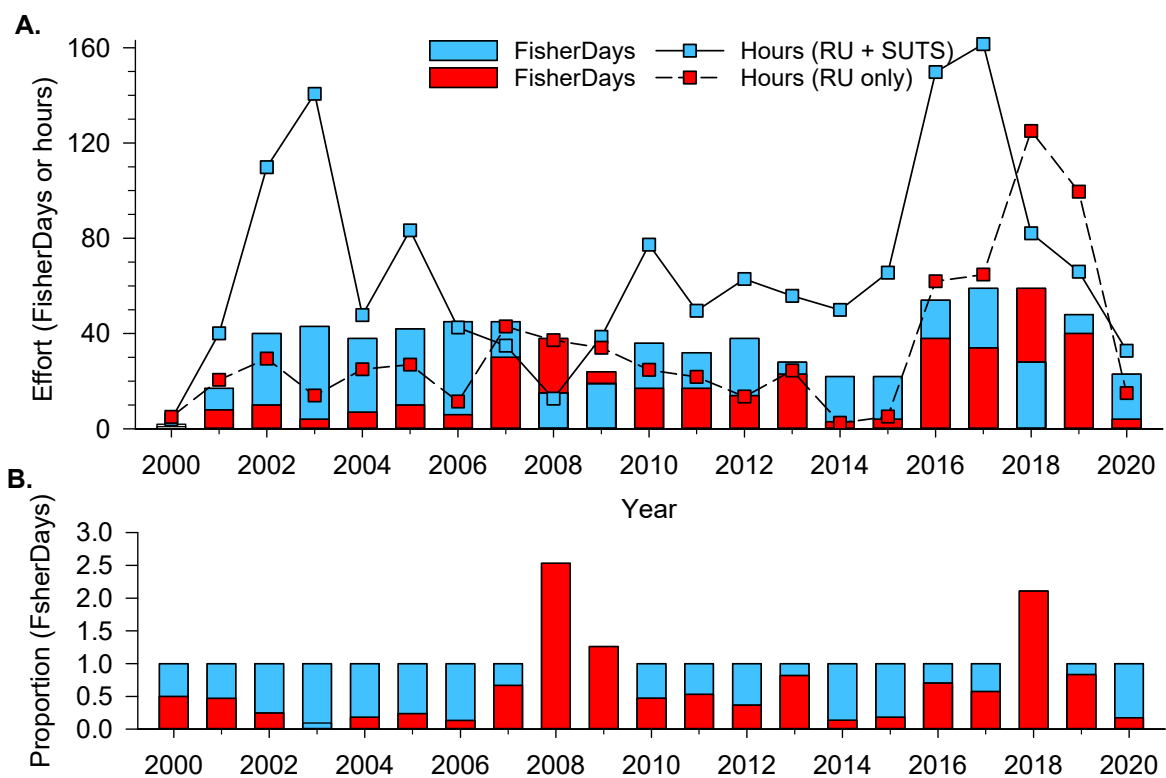


Figure 8 Region 2 – Effort – A. Number of FisherDays and hours where Red Urchin and other SUTS species were reported (RU + SUTS) and where Red Urchin only were reported (RU only); and B. FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

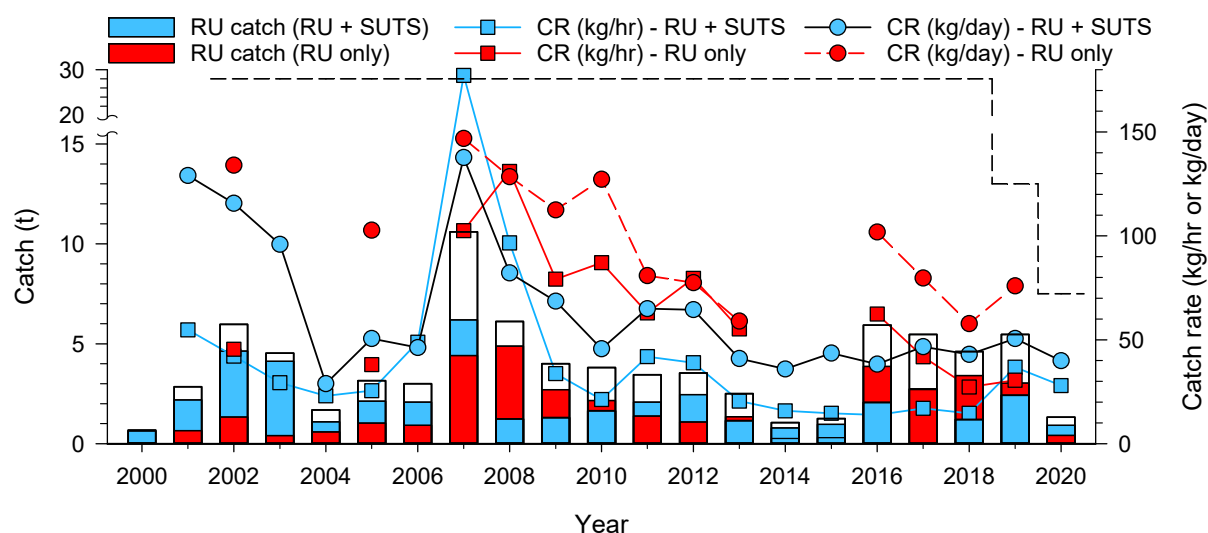


Figure 9 Region 2 – Catch and catch rate – Total catch (open bars), catch of Red Urchin on FisherDays (RU + SUTS) and from FisherDays (RU only); Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year. Dashed line represents the Regional Catch Limit.

Table 7 Region 2 – Effort – Number of FisherDays and hours where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only were reported (RU only); FisherDays (RU only) as a proportion of FisherDays (RU + SUTS); total hours and number of active fishers, from 2000 to 2020* (*data to August).

Year	FisherDays (A) (RU + SUTS)	FisherDays (B) (RU only)	Proportion (B/A)	Total effort (hr) Red Urchin	Effort (hr) (RU + SUTS)	Effort (hr) (RU only)	No. active fishers
2000	2	1	0.50	9.0	4.0	5.0	2
2001	17	8	0.47	60.7	40.1	20.6	7
2002	40	10	0.25	139.3	109.8	29.5	5
2003	43	4	0.09	154.7	140.7	14.0	3
2004	38	7	0.18	72.8	47.8	25.0	7
2005	42	10	0.24	110.4	83.4	27.0	9
2006	45	6	0.13	54.0	42.6	11.5	7
2007	45	30	0.67	77.9	35.0	43.0	6
2008	15	38	2.53	50.0	12.8	37.3	5
2009	19	24	1.26	72.8	38.7	34.1	5
2010	36	17	0.47	102.2	77.3	24.8	6
2011	32	17	0.53	71.4	49.6	21.8	5
2012	38	14	0.37	76.6	63.0	13.6	7
2013	28	23	0.82	80.4	55.8	24.5	4
2014	22	3	0.14	52.5	49.9	2.6	5
2015	22	4	0.18	70.8	65.6	5.2	3
2016	54	38	0.70	211.8	149.8	62.0	7
2017	59	34	0.58	226.3	161.5	64.8	10
2018	28	59	2.11	207.2	82.1	125.1	7
2019	48	40	0.83	165.5	66.0	99.6	10
2020*	23	4	0.17	47.8	32.8	15.0	7

Table 8 Region 2 – Catch and catch rate – Catch of Red Urchin on FisherDays where Red Urchin and other SUTS species were reported (RU + SUTS) and catch where Red Urchin only were reported (RU only); Catch rate (kg/hr and kg/day) for FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year.

Year	Catch (t) (RU + SUTS)	Catch (t) (RU only)	CR (kg/hr) (RU + SUTS)	CR (kg/hr) (RU only)	CR (kg/day) (RU + SUTS)	CR (kg/day) (RU only)
2000	0.64	0.04				
2001	2.19	0.65	54.7		129.0	
2002	4.63	1.34	42.1	45.4	115.7	134.0
2003	4.12	0.40	29.3		95.9	
2004	1.10	0.59	23.0		28.9	
2005	2.12	1.03	25.5	38.0	50.5	102.7
2006	2.08	0.92	48.8		46.2	
2007	6.19	4.41	177.2	102.5	137.7	146.9
2008	1.23	4.88	96.6	131.0	82.1	128.4
2009	1.30	2.70	33.7	79.2	68.6	112.5
2010	1.64	2.16	21.2	87.1	45.6	127.2
2011	2.08	1.37	41.9	63.0	64.9	80.9
2012	2.45	1.08	38.9	79.6	64.4	77.4
2013	1.15	1.35	20.5	55.2	40.9	58.9
2014	0.79	0.26	15.8		35.9	
2015	0.96	0.30	14.6		43.6	
2016	2.06	3.87	13.8	62.4	38.2	101.8
2017	2.75	2.71	17.0	41.8	46.6	79.7
2018	1.20	3.41	14.6	27.2	42.9	57.7
2019	2.42	3.04	36.7	30.5	50.5	75.9
2020*	0.92	0.41	28.0		39.9	

Region 3 recorded the highest levels of effort in the fishery in 2000, including FisherDays and hours from mixed species (RU + SUTS) and Red Urchin only (RU only) FisherDays, with 152 and 90 FisherDays and 386 and 214 hr, reported respectively (Figure 10 and Table 9). By 2002, and for the next 15 years, effort reported harvesting Red Urchin (from FisherDays (RU + SUTS) or (RU only)) in any year was <21 FisherDays and <41 hours. From 2016, both the number of Red Urchin only (RU only) and mixed species (RU + SUTS) FisherDays and hours increased to recent peaks in 2018 and 2019, respectively. In 2018, 44 FisherDays and 104 hours (both RU only) were reported. These levels of effort were about double those reported harvesting Red Urchins as part of mixed species FisherDays in the same year (Table 9). These patterns of effort reversed in 2019, where 40 FisherDays and 162 hours (RU + SUTS) were reported compared with 28 FisherDays and 68 hours reported harvesting Red Urchin only (RU only). The changes in effort over a one year period are coincident with a reduction in the number of active fishing businesses from 11 to 9 (Table 9). Patterns of catch generally reflect

those of effort, with record high catches of Red Urchin in 2000 followed by a substantial and rapid decline (Figure 11 and Table 10). Catch rates peaked in 2000 at 241 kg/day (RU only) and 270 kg/day (RU + SUTS) and hourly catch rates of > 100 kg/hr (RU only and RU + SUTS) (Figure 11 and Table 10). Catch rates in years immediately after 2000 declined rapidly and within 3 years were <50% of those in 2000. From 2002 to 2015 less than a total of ~2 t of Red Urchin harvested each year and commonly <1 t (Figure 11 and Table 10). From 2016 to 2018, catches of Red Urchin, from Red Urchin only FisherDays, have been >2 t and exceeded the catch of Red Urchin from mixed species FisherDays (RU + SUTS). In 2018, 4.9 t of Red Urchin was harvested from Red Urchin only FisherDays, double that from FisherDays (RU + SUTS). In 2019, as reported for effort, this pattern of catch was reversed, with 4.8 t of Red Urchin harvested from mixed species FisherDays compared with 2.9 t harvested from Red Urchin only FisherDays (Figure 11 and Table 10). Notably, these levels of catch resulted in a breach of the Regional Catch Limit and closure of the Region to further Red Urchin harvest within 2019. Between 2016 and 2017, catch rates (kg/hr and kg/day) all declined, with catch rates of kg/hr being about half of that in 2016. In 2019, catch rates (kg/hr) are at or among the lowest levels for a decade, whilst catch rate (kg/day) have increased from recent low levels in 2017 but remain substantially below levels in 2016 (Figure 11 and Table 10). These patterns of catch and catch rate indicate persistent fishing within the last 4-5 years has substantially depleted the fishable biomass that had rebuilt in this Region during the previous 10-15 years, after initial heavy depletion of essentially virgin stock size during 2000-2001.

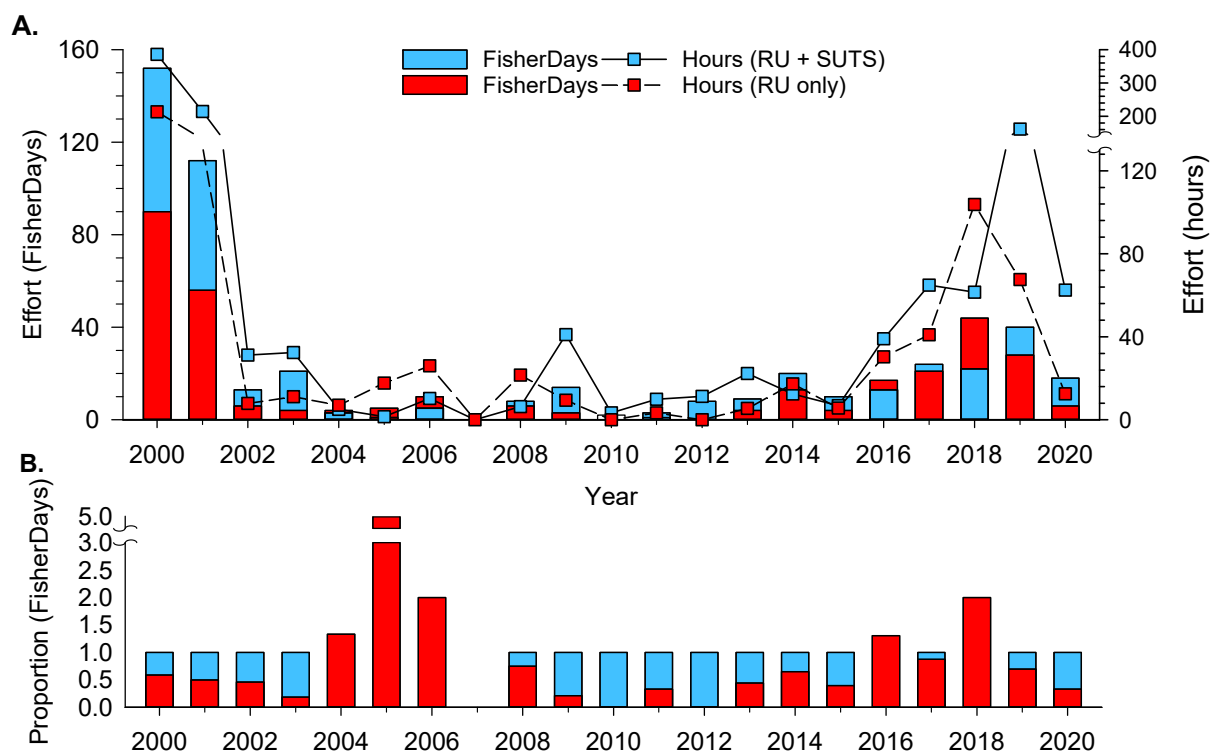


Figure 10 Region 3 – Effort – A. Number of FisherDays and hours where Red Urchin and other SUTS species were reported (RU + SUTS) and where Red Urchin only were reported (RU only); and B. FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

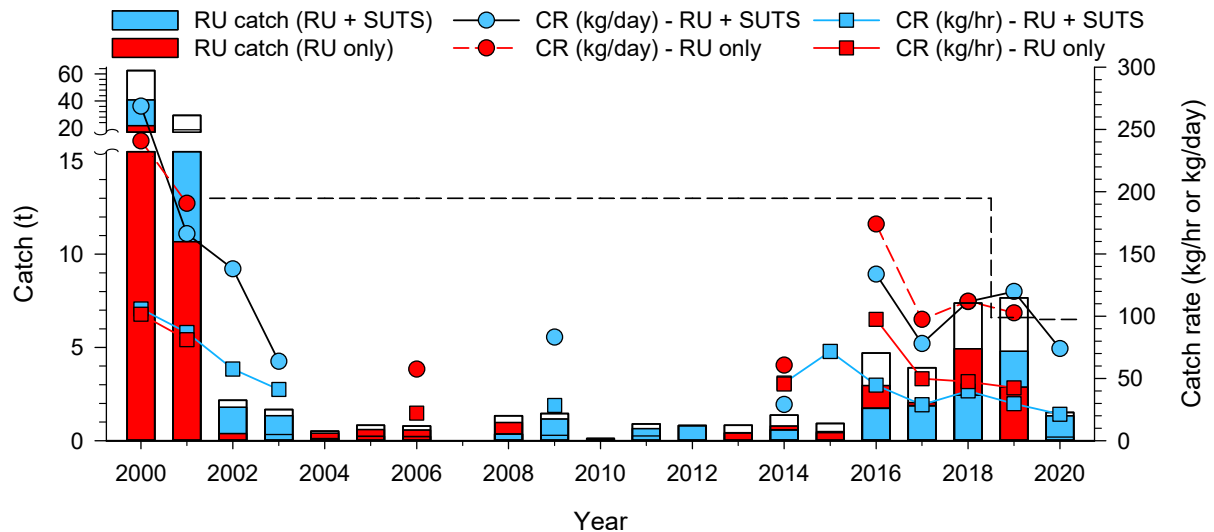


Figure 11 Region 3 – Catch and catch rate – Total catch (open bars), catch of Red Urchin on FisherDays (RU + SUTS) and from FisherDays (RU only); Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year. Dashed line represents the Regional Catch Limit.

Table 9 Region 3 – Effort – Number of FisherDays and hours where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only were reported (RU only); FisherDays (RU only) as a proportion of FisherDays (RU + SUTS); total hours and number of active fishers, from 2000 to 2020* (*data to August).

Year	FisherDays (A) (RU + SUTS)	FisherDays (B) (RU only)	Proportion (B/A)	Total effort (hr) Red Urchin	Effort (hr) (RU + SUTS)	Effort (hr) (RU only)	No. active fishers
2000	152	90	0.59	599.5	386.0	213.5	7
2001	112	56	0.50	345.9	214.3	131.6	8
2002	13	6	0.46	39.1	31.2	7.9	4
2003	21	4	0.19	43.6	32.5	11.2	6
2004	3	4	1.33	12.0	5.0	7.0	2
2005	1	5	5.00	19.2	1.5	17.8	3
2006	5	10	2.00	36.3	10.3	26.0	3
2007	0	0		0.0	0.0	0.0	0
2008	8	6	0.75	27.9	6.4	21.5	3
2009	14	3	0.21	50.6	41.1	9.5	5
2010	2	0	0.00	3.3	3.3	0.0	2
2011	3	1	0.33	13.2	9.8	3.3	2
2012	8	0	0.00	11.3	11.3	0.0	2
2013	9	4	0.44	27.8	22.3	5.5	4
2014	20	13	0.65	29.8	12.5	17.3	4
2015	10	4	0.40	12.5	6.8	5.7	4
2016	13	17	1.31	69.3	39.0	30.3	8
2017	24	21	0.88	105.9	64.9	41.1	11
2018	22	44	2.00	165.3	61.5	103.8	11
2019	40	28	0.70	229.3	161.7	67.6	9
2020*	18	6	0.33	75.1	62.5	12.6	5

Table 10 Region 3 – Catch and catch rate – Catch of Red Urchin on FisherDays where Red Urchin and other SUTS species were reported (RU + SUTS) and catch where Red Urchin only were reported (RU only); Catch rate (kg/hr and kg/day) for FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year.

Year	Catch (t) (RU + SUTS)	Catch (t) (RU only)	CR (kg/hr) (RU + SUTS)	CR (kg/hr) (RU only)	CR (kg/day) (RU + SUTS)	CR (kg/day) (RU only)
2000	40.83	21.67	105.8	101.5	268.6	240.7
2001	18.61	10.67	86.8	81.1	166.1	190.6
2002	1.79	0.38	57.5		138.0	
2003	1.34	0.33	41.2		63.6	
2004	0.12	0.40				
2005	0.24	0.60				
2006	0.22	0.57		22.1		57.4
2007	0.00	0.00				
2008	0.36	0.97				
2009	1.16	0.29	28.3		83.1	
2010	0.12	0.00				
2011	0.65	0.25				
2012	0.82	0.00				
2013	0.43	0.40				
2014	0.58	0.79	46.4	45.5	29.0	60.7
2015	0.49	0.43	71.7			
2016	1.74	2.96	44.6	97.5	133.7	173.9
2017	1.87	2.04	28.9	49.8	78.0	97.4
2018	2.46	4.92	40.0	47.4	111.6	111.9
2019	4.79	2.87	29.6	42.5	119.8	102.6
2020*	1.33	0.19	21.3		73.9	

In Region 4, from 2000 to 2011, the number of FisherDays (RU + SUTS) and FisherDays (RU only) declined from >60 and >20 FisherDays, respectively, to <7 FisherDays in 2011 (Figure 12A and Table 11). Hours (RU + SUTS) and (RU only) generally reflected patterns in FisherDays although were more volatile in the early 2000's. Over the same period the proportion of FisherDays (RU only) averaged ~0.3 of FisherDays (RU + SUTS), excluding years 2009 and 2011 where that proportion was >1, with total FisherDays <15 (Figure 12B and Table 11). From 2012 to 2019, the number of FisherDays (RU + SUTS) has been relatively stable (mean 29 FisherDays yr⁻¹; range 18-44), whilst hours (RU + SUTS) have increased from ~30 hr yr⁻¹ to >60 hr yr⁻¹. FisherDays and hours (RU only) both increased substantially from 2012 to 2018, with 26 FisherDays and 78 hours (RU only) reported in 2018, the highest levels of effort reported on Red Urchin only fishing since 2000 (Figure 12 and Table 11). In 2019, FisherDays and hours (RU only) decreased by about 25% and 50% respectively, from the 2018 peak.

Catch in Region 4, as similarly described for Region 3, peaked in 2000 (21 t) with catches from FisherDays (RU + SUTS) and FisherDays (RU only) being 14 t and 7.5 t, respectively (Figure 13 and Table 12). Annual total catches rapidly declined over the following 2 years to <3 t, and from 2005, for the following 10 years, <1.5 t yr⁻¹. From 2000 to 2006, catch rates (kg/hr and kg/day) from FisherDays (RU + SUTS and RU only) declined rapidly, from >85 kg/hr and >180 kg/day, respectively to <25 kg/hr and <20 kg/day (Figure 13 and Table 12), as fishing substantially depleted the Red Urchin fishable biomass. From 2015 to 2017, Red Urchin catch increased from ~4 t to ~7 t (Figure 13 and Table 4), with the catch from mixed species FisherDays (RU + SUTS) and Red Urchin only FisherDays (RU only) increasing from 3.3 t to 4.1 t and <0.7 t to 2.7 t, respectively (Table 12). Catch rates (kg/hr and kg/day) from FisherDays (RU + SUTS) indicate fishers investing more time to maintain increasing daily catch rate (up to 169 kg/day in 2018) at a stable catch rate of about 45 kg/hr. However, both daily and hourly catch rate (RU + SUTS) decreased substantially in 2019, to 117 kg/day and 28 kg/hr, respectively. Catch rates from FisherDays (RU only) decreased by 30-50% between 2017 and 2018 and a further ~20% in 2019, to 38 kg/hr and 72 kg/day (Figure 13 and Table 12). As described for Red Urchin stocks in Region 3, these patterns of catch and catch rate indicate the relatively rapid depletion fishable biomass that has rebuilt in this Region during previous years of relatively low fishing pressure, after high levels of fishing mortality and biomass reduction, likely from virgin biomass levels, during 2000-2001.

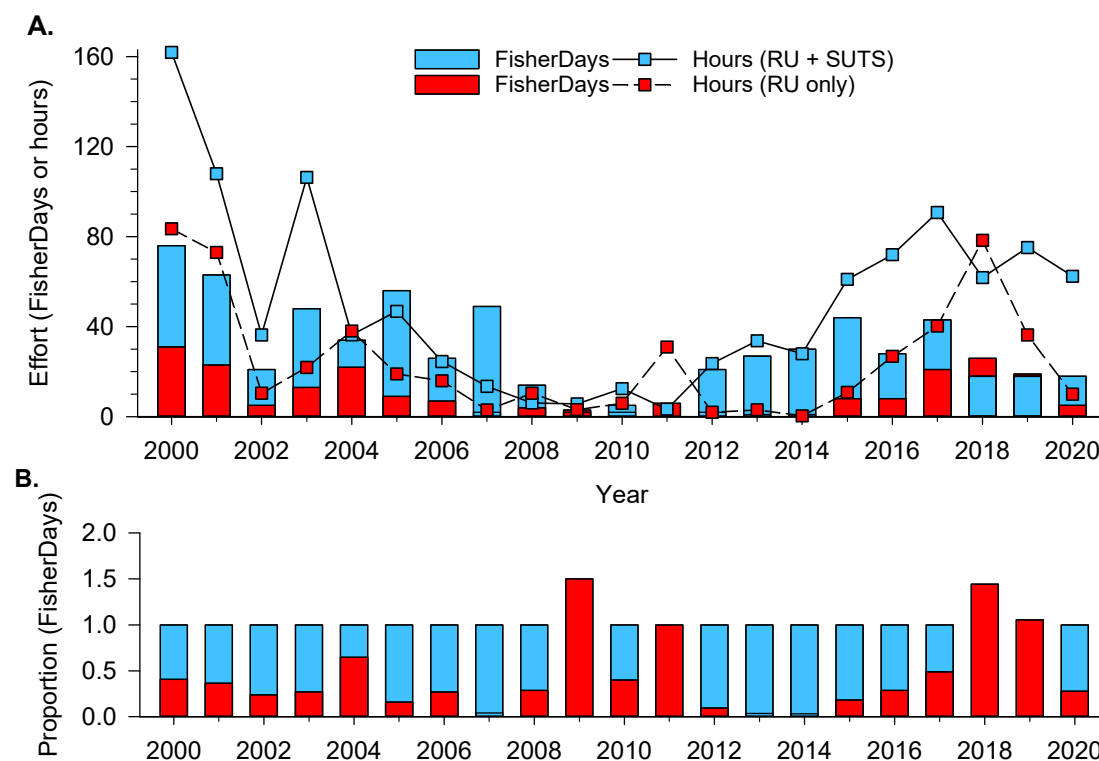


Figure 12 Region 4 – Effort – A. Number of FisherDays and hours where Red Urchin and other SUTS species were reported (RU + SUTS) and where Red Urchin only were reported (RU only); and B. FisherDays (RU only) as a proportion of FisherDays (RU + SUTS), from 2000 to 2020* (*data to August).

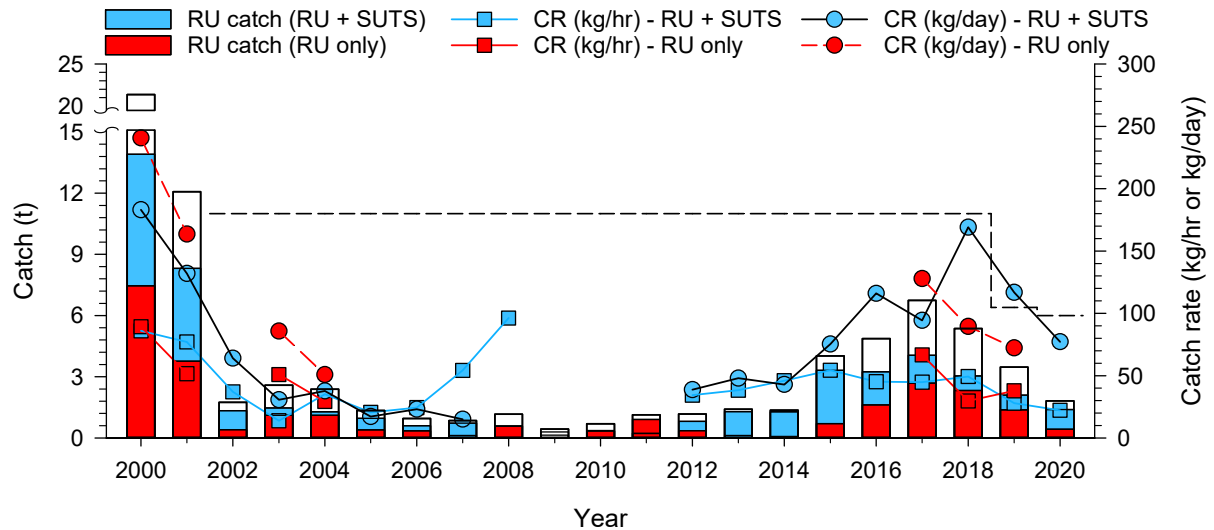


Figure 13 Region 4 – Catch and catch rate – Total catch (open bars), catch of Red Urchin on FisherDays (RU + SUTS) and from FisherDays (RU only); Catch rate (kg/hr and kg/day) from FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2020* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year. Dashed line represents the Regional Catch Limit.

Table 11 Region 4 – Effort – Number of FisherDays and hours where Red Urchin and other SUTS species (RU + SUTS) and Red Urchin only were reported (RU only); FisherDays (RU only) as a proportion of FisherDays (RU + SUTS); total hours and number of active fishers, from 2000 to 2020* (*data to August).

Year	FisherDays (A) (RU + SUTS)	FisherDays (B) (RU only)	Proportion (B/A)	Total effort (hr) Red Urchin	Effort (hr) (RU + SUTS)	Effort (hr) (RU only)	No. active fishers
2000	76	31	0.41	245.4	161.9	83.5	6
2001	63	23	0.37	181.0	108.0	73.0	9
2002	21	5	0.24	46.8	36.3	10.5	5
2003	48	13	0.27	128.3	106.3	21.9	8
2004	34	22	0.65	74.5	36.4	38.1	8
2005	56	9	0.16	65.8	46.8	19.0	8
2006	26	7	0.27	40.5	24.5	16.0	5
2007	49	2	0.04	16.5	13.5	3.0	3
2008	14	4	0.29	16.6	6.1	10.5	2
2009	2	3	1.50	8.8	5.7	3.2	3
2010	5	2	0.40	18.5	12.5	6.0	1
2011	6	6	1.00	34.3	3.3	31.0	4
2012	21	2	0.10	25.7	23.7	2.0	2
2013	27	1	0.04	36.8	33.8	3.1	3
2014	30	1	0.03	28.4	28.0	0.4	5
2015	44	8	0.18	71.9	61.0	10.8	6
2016	28	8	0.29	98.8	72.0	26.8	6
2017	43	21	0.49	131.1	90.8	40.3	9
2018	18	26	1.44	140.2	61.8	78.4	8
2019	18	19	1.06	111.5	75.2	36.3	9
2020*	18	5	0.28	72.4	62.4	10.0	3

Table 12 Region 4 – Catch and catch rate – Catch of Red Urchin on FisherDays where Red Urchin and other SUTS species were reported (RU + SUTS) and catch where Red Urchin only were reported (RU only); Catch rate (kg/hr and kg/day) for FisherDays (RU + SUTS) and FisherDays (RU only), from 2000 to 2019* (*data to August). Catch rate data excludes FisherDays with effort <0.25 and >8 hr and <10 FisherDays per year.

Year	Catch (t) (RU + SUTS)	Catch (t) (RU only)	CR (kg/hr) (RU + SUTS)	CR (kg/hr) (RU only)	CR (kg/day) (RU + SUTS)	CR (kg/day) (RU only)
2000	13.91	7.46	85.9	89.3	183.0	240.6
2001	8.31	3.76	77.0	51.5	132.0	163.6
2002	1.34	0.41	37.0		64.0	
2003	1.47	1.11	13.8	50.8	30.6	85.7
2004	1.28	1.12	35.1	29.3	37.6	50.7
2005	0.96	0.39	20.5		17.1	
2006	0.60	0.35	24.4		23.0	
2007	0.73	0.12	54.2		14.9	
2008	0.59	0.57	96.2			
2009	0.30	0.14				
2010	0.36	0.34				
2011	0.23	0.91				
2012	0.81	0.36	34.4		38.8	
2013	1.29	0.12	38.4		48.0	
2014	1.29	0.08	46.0		42.9	
2015	3.31	0.70	54.3		75.3	
2016	3.25	1.62	45.1		116.0	
2017	4.06	2.69	44.7	66.6	94.3	127.9
2018	3.04	2.32	49.2	29.7	169.0	89.4
2019	2.10	1.37	28.0	37.8	116.8	72.2
2020*	1.39	0.43	22.3		77.2	

Subzone – catch

Annual catches have generally been aggregated among relatively few subzones through time, with relatively high levels of catch commonly reported from these subzones, or groups of subzones for short periods of time (2-4 years) (Tables 13 and 14 and Figures 14-17). The subzone distribution of annual catch in 2000 and 2001 was concentrated in 3-5 subzones within Region 3, with subzones M2 and N2 reporting catches >15 t and >30 t, respectively in 2000 and >7 t and >10 t, respectively in 2001 (Figure 14 and Table 13). Since 2001, annual catches from these subzones have remained <1 t, with the exception of catch from M2 from 2017-2019, where ~2-3 t was harvested (Tables 13 and 14 and Figures 14-17). The historical peak in annual catch and increased catch rates in 2007, were primarily supported by previously unexploited Red Urchin stocks in subzones E1 and F1 in Region 1 and K1 and K2, in Region 2 (Figure 15 and Table 13). More recent increases in annual catch (i.e. from 2016) have been supported by a broader distribution of catch among subzones in all Regions, with 5-6 subzones across each Region contributing >1 t (Figures 16 and 17 and Table 14).

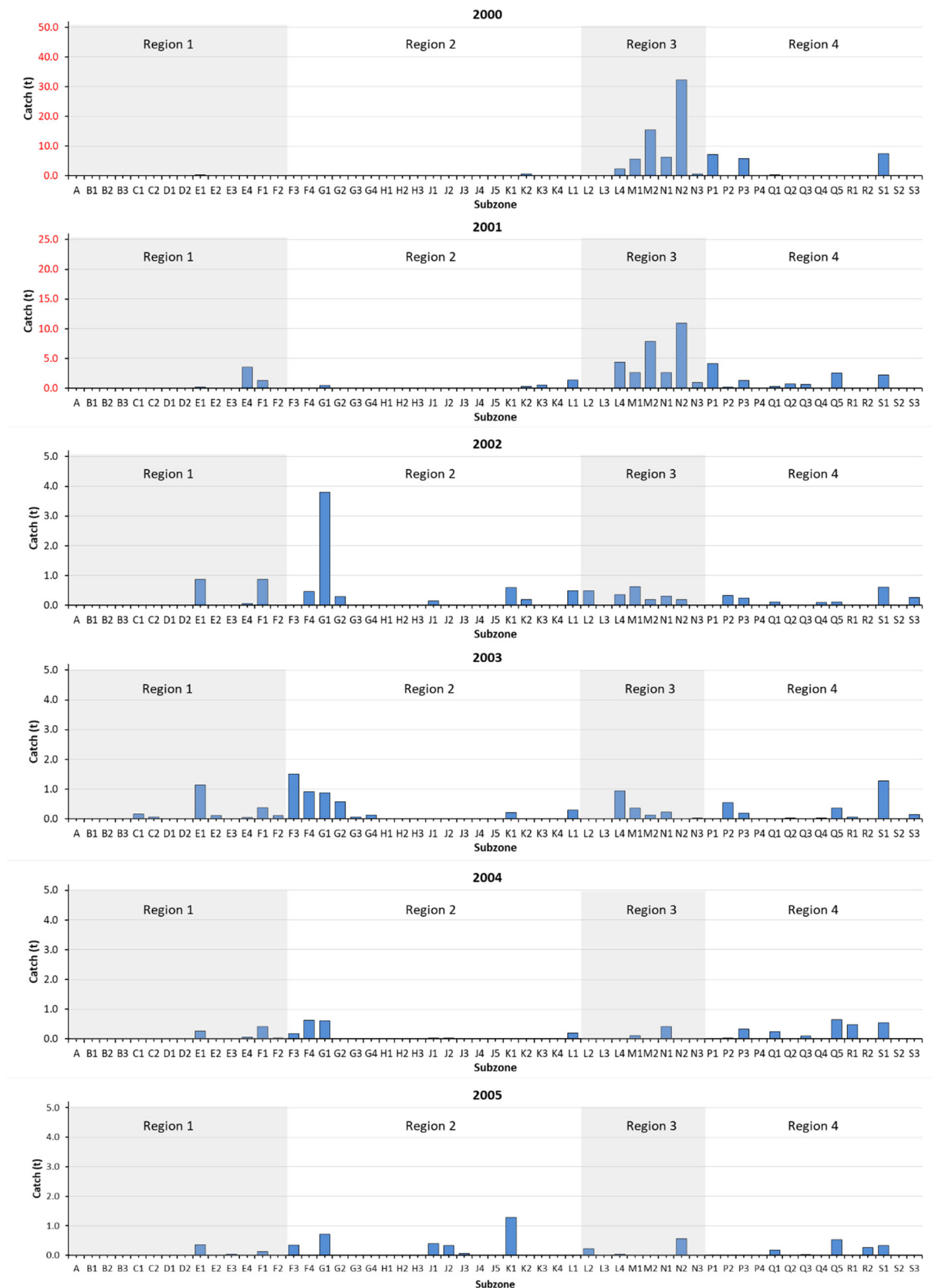


Figure 14 Subzone catch (t) within Regions 1-4 (t), from 2000 to 2005.

Y-axes in 2000 and 2001 are an order of magnitude and five times, respectively, greater than in other years.

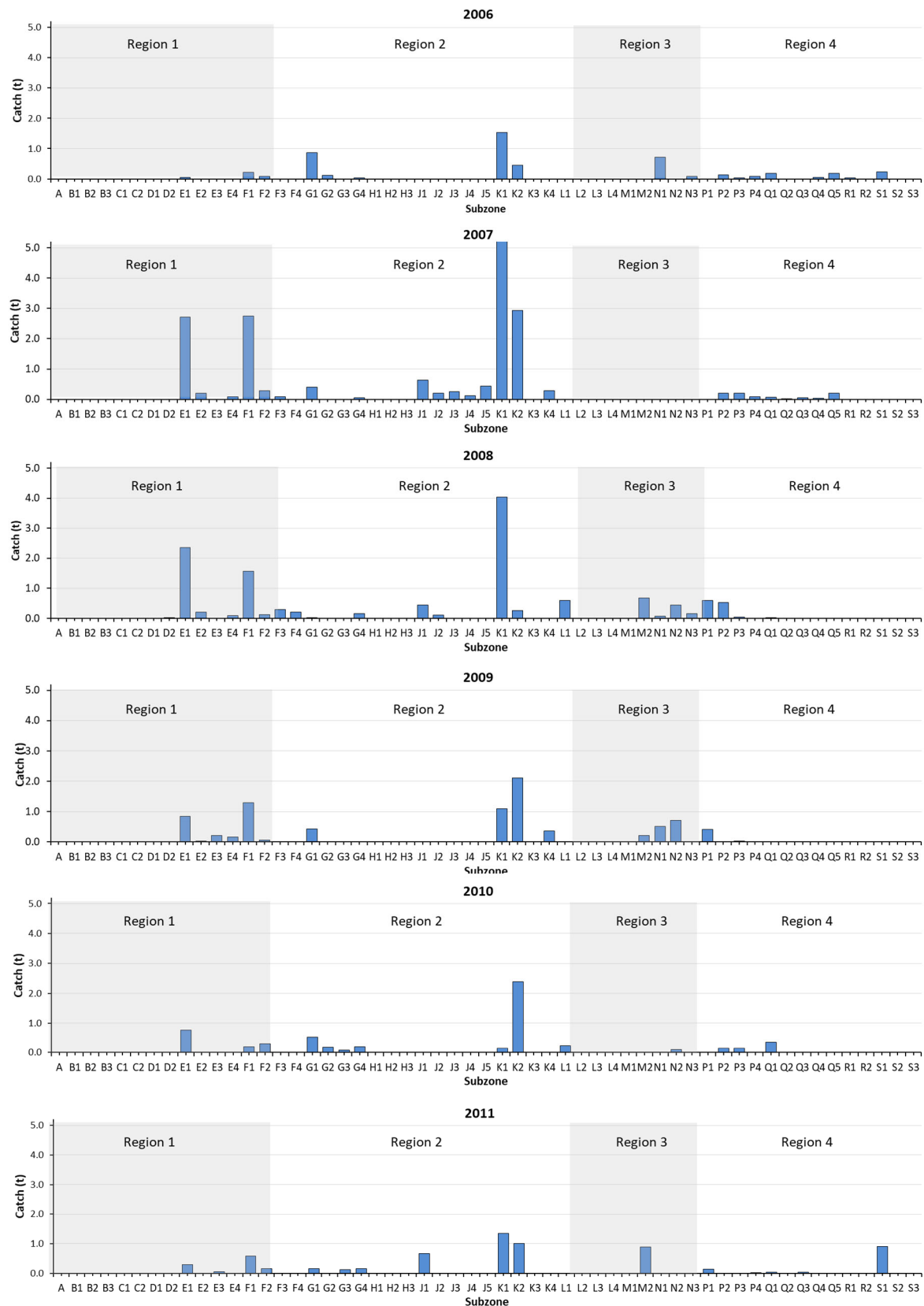


Figure 15 Subzone catch (t) within Regions 1-4 (t), from 2006 to 2011.

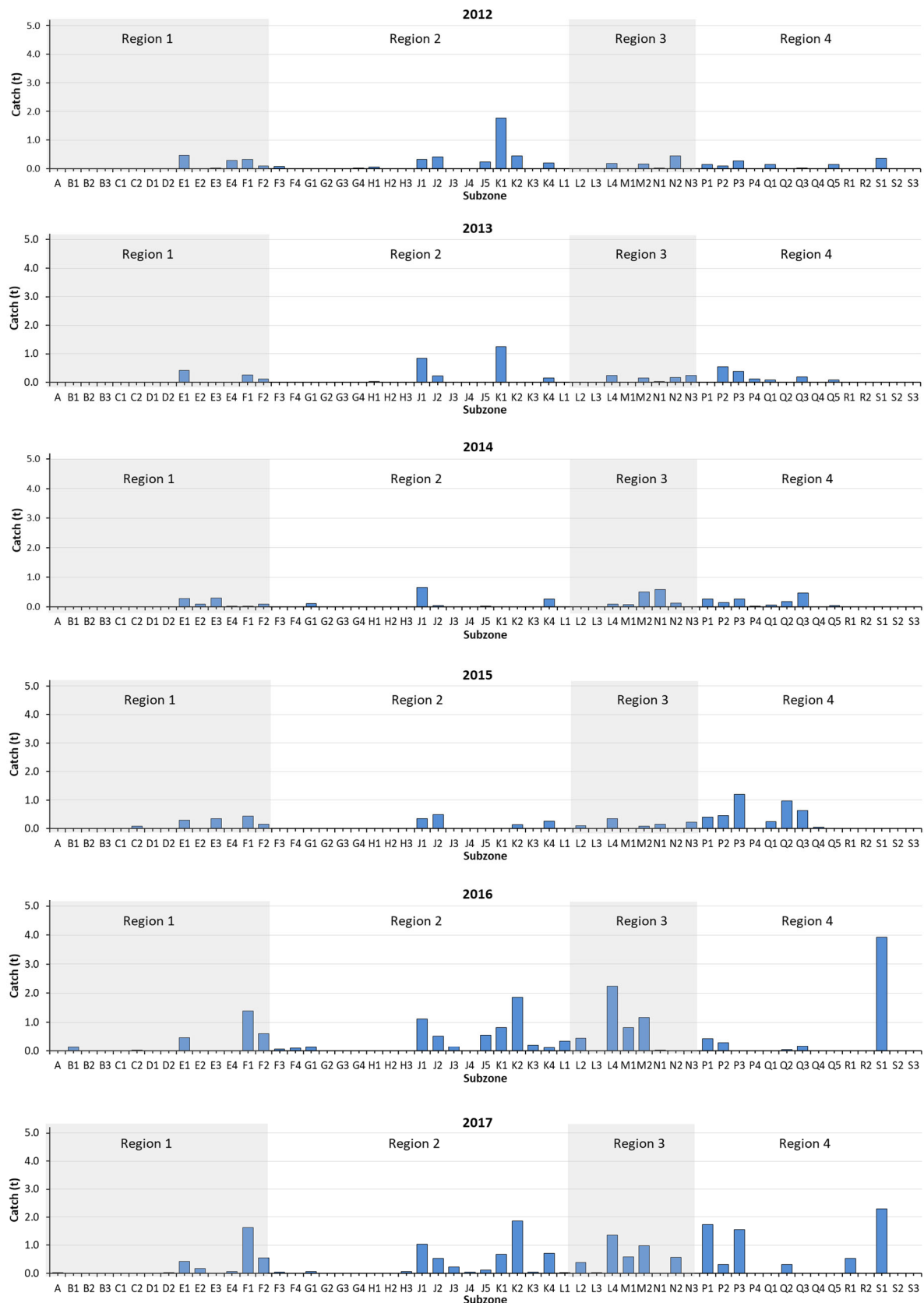


Figure 16 Subzone catch (t) within Regions 1-4 (t), from 2012 to 2017.

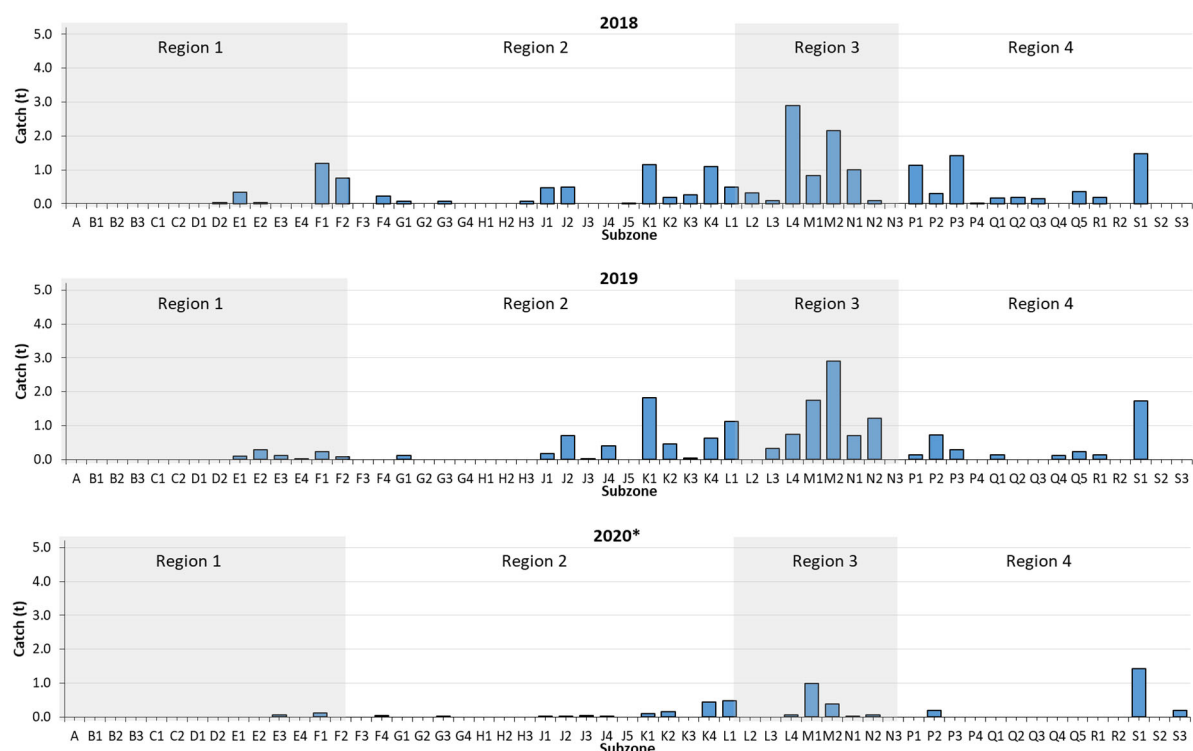


Figure 17 Subzone catch (t) within Regions 1-4 (t), in 2018 and 2020* (*data to August).

3.1.2. Recreational and Aboriginal Fishery

In NSW, there is a recreational daily bag limit of ten sea urchins (Red Urchin and/or other sea urchin species). Recreational fishery statistics for the harvest of sea urchins are limited. During 2018-19, NSW recreational fishery retained harvest estimates for all sea urchins was about 1 t (~2400 individuals) (Murphy et al. 2020), the majority of which are considered Longspined Sea Urchin. No recreational catch estimates for sea urchins are available from previous state and national recreational fishing surveys, with sea urchins either not having been reported (West et al. 2015) or included into a species reporting group 'Other Taxa' along with various other 'non-fish' species (Henry and Lyle, 2003).

There are limited data to inform the level of catch from Aboriginal fishers in NSW. Synthesis of catch composition from Indigenous fisheries indicated that the SUTS Fishery overlaps with Indigenous fisheries (Schnierer and Egan 2016) and sea urchins were identified by Aboriginal fishers in a 1999 survey, as a species either targeted or harvested. Further, in the Tweed region, annual catch of sea urchins (unidentified species) by Aboriginal fishers was estimated at 1.8% of total harvest. Schnierer (2011) described the importance of marine invertebrate species as culturally important but did not specify sea urchins in their study.

3.1.3. Illegal Unregulated and Unreported

The level of Illegal Unregulated and Unreported (IUU) fishing has not been quantified.

NSW Fisheries Compliance provide annual summaries of seizures of fish and invertebrates due to non-compliance (dpi.nsw.gov.au/fishing/compliance/fisheries-compliance-enforcement). These reports indicate regular seizures of sea urchins (range 482-1274 sea urchins p.a.) within financial years between 2014-15 and 2018-19.

Table 13 Subzone catch (t) each year from 2000 to 2010.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Subzone											
A	-	-	-	-	-	-	-	-	-	-	-
B1	-	-	-	-	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-	-
C1	-	-	-	0.17	-	-	-	-	-	-	-
C2	-	-	-	0.06	-	-	-	-	-	-	-
D1	-	-	-	-	-	-	-	-	-	-	-
D2	-	-	-	-	-	-	-	-	0.02	-	-
E1	0.27	0.22	0.88	1.14	0.27	0.37	0.05	2.71	2.36	0.84	0.78
E2	-	-	-	0.11	-	-	-	0.20	0.20	0.03	-
E3	-	-	-	-	-	0.05	-	-	-	0.21	-
E4	-	3.55	0.06	0.04	0.07	-	-	0.08	0.08	0.15	-
F1	-	1.25	0.87	0.37	0.41	0.13	0.22	2.75	1.56	1.29	0.21
F2	-	-	-	0.11	0.03	-	0.09	0.28	0.12	0.07	0.32
F3	-	0.05	-	1.50	0.19	0.35	-	0.08	0.30	-	-
F4	-	0.05	0.45	0.90	0.63	-	-	-	0.21	-	-
G1	0.02	0.47	3.80	0.87	0.62	0.72	0.87	0.40	0.02	0.43	0.53
G2	-	-	0.29	0.58	-	-	0.11	-	-	-	0.19
G3	-	0.07	-	0.06	-	-	-	-	-	0.01	0.07
G4	-	-	-	0.13	-	-	0.04	0.05	0.16	-	0.22
H1	-	-	-	-	-	-	-	-	-	-	-
H2	-	-	-	-	-	-	-	-	-	-	-
H3	-	-	-	-	-	-	-	-	-	-	-
J1	-	-	0.15	-	0.03	0.46	-	0.63	0.44	-	-
J2	-	-	-	-	0.02	0.33	-	0.21	0.10	-	-
J3	-	-	-	-	-	-	-	0.25	-	-	-
J4	-	-	-	-	-	-	-	0.12	-	-	-
J5	-	-	-	-	-	-	-	0.43	-	-	-
K1	-	-	0.60	0.20	-	1.29	1.53	5.21	4.03	1.09	0.16
K2	0.63	0.31	0.19	-	-	-	0.44	2.94	0.26	2.11	2.38
K3	-	0.50	-	-	-	-	-	-	-	-	-
K4	0.04	-	-	-	-	-	-	0.28	-	0.36	-
L1	-	1.41	0.48	0.29	0.20	-	-	-	0.60	-	0.25
L2	-	-	0.50	-	-	0.24	-	-	-	-	-
L3	-	-	-	-	-	-	-	-	-	-	-
L4	2.35	4.33	0.35	0.95	-	0.04	-	-	-	-	-
M1	5.65	2.60	0.63	0.36	0.11	-	-	-	-	0.02	-
M2	15.42	7.83	0.20	0.12	-	-	-	-	0.67	0.22	0.02
N1	6.25	2.59	0.30	0.23	0.41	-	0.71	-	0.07	0.52	-
N2	32.26	10.95	0.20	-	-	0.56	-	-	0.44	0.70	0.10
N3	0.57	0.99	-	0.02	-	-	0.08	-	0.15	-	-
P1	7.19	4.11	-	-	-	-	-	-	0.59	0.40	-
P2	-	0.20	0.32	0.54	0.04	-	0.14	0.20	0.53	-	0.17
P3	5.83	1.30	0.24	0.20	0.34	0.00	0.03	0.21	0.03	0.03	0.17
P4	0.05	-	-	-	-	-	0.09	0.09	-	-	-
Q1	0.25	0.32	0.11	-	0.24	0.18	0.18	0.08	0.00	-	0.36
Q2	0.21	0.73	-	0.02	0.01	0.00	-	0.00	-	-	-
Q3	0.05	0.67	-	-	0.10	0.02	-	0.05	-	-	-
Q4	0.05	-	0.09	0.01	-	-	0.05	0.03	-	-	-
Q5	0.18	2.53	0.11	0.35	0.65	0.53	0.19	0.20	-	-	-
R1	0.09	-	-	0.06	0.48	0.01	0.04	-	-	-	-
R2	-	-	-	-	0.01	0.26	-	-	-	-	-
S1	7.49	2.22	0.62	1.27	0.54	0.34	0.23	-	-	-	-
S2	-	-	-	-	-	0.01	-	-	-	-	-
S3	-	-	0.27	0.14	-	-	-	-	-	-	-

Table 14 Subzone catch (t) each year from 2011 to 2020* (*data to August).

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*
Subzone										
A	-	-	-	-	-	-	0.01	-	-	-
B1	-	-	-	-	-	0.13	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	0.09	0.02	-	-	-	-
D1	-	-	-	-	-	-	-	-	-	-
D2	-	-	-	-	-	-	0.01	0.03	-	-
E1	0.29	0.46	0.42	0.27	0.30	0.47	0.42	0.33	0.11	-
E2	-	-	-	0.09	-	-	0.17	0.04	0.29	-
E3	0.05	0.02	-	0.30	0.35	-	-	-	0.12	0.06
E4	-	0.29	-	0.02	-	-	0.06	-	0.02	-
F1	0.58	0.32	0.25	0.02	0.44	1.39	1.62	1.19	0.24	0.13
F2	0.16	0.10	0.13	0.08	0.16	0.60	0.55	0.75	0.08	-
F3	-	0.08	-	-	-	0.05	0.04	-	-	-
F4	-	-	-	-	-	0.09	-	0.23	-	0.04
G1	0.16	-	-	0.11	-	0.13	0.07	0.07	0.11	-
G2	-	-	-	-	-	-	-	-	-	-
G3	0.13	-	-	-	-	-	-	0.08	-	0.01
G4	0.15	0.02	-	-	-	-	-	-	-	-
H1	-	0.05	0.03	-	-	-	-	-	-	-
H2	-	-	-	-	-	-	-	-	-	-
H3	-	-	-	-	-	-	0.07	0.07	-	-
J1	0.67	0.33	0.85	0.65	0.36	1.11	1.04	0.48	0.18	0.03
J2	-	0.41	0.23	0.03	0.49	0.52	0.53	0.49	0.70	0.01
J3	-	-	-	-	-	0.14	0.22	-	0.02	0.04
J4	-	-	-	-	-	-	0.05	-	0.40	0.03
J5	-	0.24	-	0.01	-	0.56	0.12	0.01	-	-
K1	1.34	1.77	1.24	-	-	0.83	0.68	1.16	1.82	0.10
K2	1.00	0.44	-	-	0.14	1.87	1.87	0.18	0.45	0.16
K3	-	-	-	-	-	0.20	0.05	0.27	0.03	-
K4	-	0.20	0.15	0.26	0.27	0.11	0.70	1.10	0.63	0.45
L1	-	-	-	-	-	0.34	0.02	0.49	1.12	0.47
L2	-	-	-	-	0.11	0.45	0.39	0.32	-	-
L3	-	-	-	-	-	-	0.03	0.08	0.34	-
L4	-	0.18	0.25	0.08	0.35	2.25	1.36	2.89	0.74	0.06
M1	-	-	-	0.07	-	0.82	0.58	0.83	1.76	1.00
M2	0.90	0.17	0.15	0.50	0.09	1.17	0.99	2.16	2.90	0.39
N1	-	0.03	0.03	0.59	0.16	0.01	-	1.01	0.71	0.01
N2	-	0.44	0.17	0.13	-	-	0.57	0.10	1.22	0.06
N3	-	-	0.24	-	0.22	-	-	-	-	-
P1	0.13	0.14	-	0.26	0.40	0.44	1.73	1.12	0.13	-
P2	-	0.09	0.55	0.13	0.46	0.30	0.32	0.29	0.72	0.20
P3	-	0.27	0.38	0.25	1.21	-	1.56	1.42	0.28	-
P4	0.02	-	0.11	0.00	-	-	-	0.02	-	-
Q1	0.04	0.15	0.08	0.06	0.26	-	-	0.17	0.13	-
Q2	-	-	-	0.17	0.98	0.04	0.31	0.18	-	-
Q3	0.03	0.03	0.20	0.46	0.63	0.17	-	0.14	-	-
Q4	-	-	-	-	0.06	-	-	-	0.12	-
Q5	-	0.14	0.09	0.03	0.01	-	-	0.35	0.23	-
R1	-	-	-	-	0.02	-	0.53	0.20	0.14	-
R2	-	-	-	-	-	-	-	-	-	-
S1	0.91	0.36	-	-	-	3.92	2.30	1.48	1.73	1.43
S2	-	-	-	-	-	-	-	-	-	-
S3	-	-	-	-	-	-	-	-	-	0.19

4. Discussion

The status of the NSW SUTS Fishery - Red Urchin stock is classified as sustainable. This outcome is driven by the assumed biomass of Red Urchin stock within areas closed to fishing (~30% of fishable area with biomass assumed to be maintained at levels similar to when the fishery-independent surveys were done in 2000) and current measures of fishery performance indicating that fishing mortality has been too high for the last 3-5 years and biomass has been depleting in areas open to fishing. There is uncertainty in understanding the productivity of the stock, how that may change through time and also, the reliability of the catch rate data series to inform change in biomass or its level relative to that prior to fishing and changes in fishing mortality. Some of this uncertainty stems from changes in fisher operations through time (e.g. new entrants to the fishery, fishing to specific markets), changes in management arrangements and impacts on markets from extraneous factors (e.g. 2019-20 bushfires, declared natural disasters and the COVID-19 pandemic that have affected fishing operations in the 2020 fishing season) and the reliability of fishery-dependent measures used to assess the stocks and determine stock status, currently and into the future.

Cost-effective measures to inform relative levels of biomass and levels of fishing mortality are typically derived from fishery-dependent data sources i.e. information provided by fishers, typically commercial fishery catch and effort reports (i.e. logbook data). Alternate sources of information that can inform measures of biomass and fishing mortality can include fishery-independent data (e.g. surveys of stock density at areas that represent that of the fished and unfished stock can provide relative measures of the change in stock or, used together with estimates of the area inhabited by the species, to estimate absolute measures of biomass); a combination of both fishery-dependent and -independent methods. Such as 'structured fishing', where fishing activity is directed to occur within defined boundaries (space and time) such that typical fishery-dependent measures and/or additional fishery-dependent information, such as the size of fished individuals, can be used to inform estimates; Technological advances in data collection, management and analyses also offer opportunities to provide cost-effective means of informing fishery and stock performance, whilst still fishery-dependent, the use of GPS loggers to inform small spatial scale fishing activity and changes in fishing operations through time, and particularly with the integration of these data with traditional catch data, offers myriad alternate measures, including as yet untested measures of changes in relative density and biomass of fished stocks. Developing a time series of these data on the assumption of their later value would require some investment against risk but may result in the more timely application of these data to inform assessments and management decisions.

Given the absence of recent alternate data to inform stock status, the principal source of information available for the NSW SUTS Fishery – Red Urchin stock are fishery-dependent, traditional logbook data. Unfortunately, uncertainty in fishery-dependent indicators of stock status reduces the level of confidence in an assessment and determination of stock status. A fisher and their fishing operations, and hence fishery-dependent indicators of stock status are influenced by many factors. For example, changes in management arrangements (e.g. spatial or temporal scales of reporting, different species catch and effort reporting requirements, size limits, spatial closures) as well as factors beyond those immediately related to management arrangements, such as market forces (e.g. demand for larger or smaller sizes). As a consequence, changes in these factors through time make it more challenging to rely on

fishery-dependent data to assess the stock and inform stock status. Although, strong contrasts in these data through time and consistency among the different data series provide greater confidence in their interpretation.

The NSW SUTS Fishery is a multi-species, restricted fishery, with an annual total allowable commercial catch determined for Red Urchin, which is allocated equally to endorsed commercial fishers. Typically, few endorsed fishers have fished Red Urchin, although this number has generally increased in recent years. Red Urchin catch and effort has subsequently increased and in 2018 (~20 t and ~700 hr) had reached levels only exceeded by those in 2000 and 2001 (50-85 t and >750 hr), when Red Urchin biomass had been, essentially, unfished. In the 14 years from 2001 annual harvests have been relatively small (generally <10 t p.a.), with sporadic local peaks as new areas of the fishery became the focus of fishing activity. Catches within the last 3-4 years have been more evenly distributed throughout the fishery. Effort (FisherDays and hours) harvesting Red Urchin only in the SUTS Fishery increased from about 2015 to 2018, across Regions 2-4. In 2018, more FisherDays and hours were reported fishing for Red Urchin only than for Red Urchin and other SUTS species. In 2019, in Regions 3 and 4 effort (hours) on fishing for Red Urchin only has decreased to less than half that effort on fishing for Red Urchin and mixed SUTS species. Measures of catch rate (kg/hr and kg/day) from catch and effort series splitting FisherDays where Red Urchin only and Red Urchin and other SUTS species were fished, has attempted to remove some of the variability and uncertainty of these measures. The relatively consistent response of both measures of catch rate and from both series of data provide greater confidence in their reliability to inform the assessment of Red Urchin stock. Despite these attempts there are still issues related to the reliability of using catch rate as an indicator of stock status, including the relatively few fishers contributing to some data and its likely hyper-stability associated with changes in the spatial distribution of catch at scales below the management unit (Region), which may mask within Region serial depletion and result in more optimistic inferences of fishery performance.

Estimates of density, size structure and biomass from 2000 (Worthington and Blount 2003) described a time in the fishery very close to unfished (virgin) biomass. The sampling design included fishery-independent surveys of the density of Red Urchin at stratified random sites along NSW near shore reef south of Port Stephens. The survey was repeated at a number of sites, including a subset of sites sampled previously and that were open and closed to fishing. Results of sampling before and after fishing indicated decreases in Red Urchin density to 55% and 61% in areas open to fishing in Regions 3 and 4, respectively (i.e. those Regions with the highest original density and highest levels of fishing). It also identified decreases in density to 69% of initial estimates in closed areas in Region 3, attributing this decline to illegal catches. Further, fishing was concentrated to areas relatively close to processing facilities and high densities of Red Urchin. The concentration of fishing in these areas resulted in the density at some survey sites being reduced to 12-15% of initial biomass. In 2000, the NSW Total Allowable Catch Setting and Review Committee recommended a total allowable commercial catch of 60 t, to be spread across the regions, and including a rotational opening and closing of areas, according to estimated biomass, and enforced until more information about the productivity of the population became available. No rotational harvest strategy has been enacted and areas closed to the fishery are assumed to support similar levels of biomass to those surveyed in 2000.

Red Urchin catch has been substantially less than the allocated TACC of 60 t, <20 t since 2001, and only >17.5 t.yr⁻¹ in the four years from 2016-2019 (inclusive). Recent and continued

increases in annual catch from about 2015 to 2019 and the number of active businesses has demonstrated a renewed and growing commercial interest in accessing the NSW Red Urchin resource and an increasing risk to its sustainable harvest. Management measures introduced recently, including a size limit and reduced Regional Catch Limits, together with existing area closures substantially mitigate that risk. The development of the SUTS Fishery for Red Urchin will rely on information to reliably monitor and assess the stock, including in areas open and closed to the fishery, and for the assessment to support a harvest strategy capable of confidently managing the sustainable harvest of the entire stock and securing a viable and valuable fishery with an ongoing sustainable status.

4.1. Stakeholder engagement

Contemporary data supporting the assessment of Red Sea are fishery-dependent i.e. sourced from logbook data provided by commercial fishers in the NSW SUTS Fishery. NSW DPI Fisheries convened a meeting of SUTS Fishery licence holders, or their representatives and presented a summary of the assessment data, at spatial scales of the whole fishery and Regions 2-4. The objective being to present the data and its interpretation and gain feedback and any other information, from stakeholders who have contributed to the data, to help inform the current and future assessments.

Points raised by stakeholders and grouped by the sub-headings below, included:

Biology and population structure

- Knowledge of a relationship between larval settlement, recruitment and an adequate density of adult stock. Noting that fishing adult stock to low densities will likely result in low or no settlement and recruitment, leading to small future stock abundance.
- Substantial natural, albeit extreme, events can impact population size and structure. Notably, the 2016 winter storm substantially impacted populations of Red Urchin on areas of reef exposed to NE facing sea conditions. Red Urchin inhabit shallow reef area and the extreme and persistent swell conditions resulted in increased natural mortality of Red Urchin at local and Regional scales.
- Some concern of fishing practices of a small number of fishers resulting in the harvest of all sizes of Red Urchin, prior to the introduction of the size limit (Oct 2019), and the consequential significant reduction of Red Urchin populations at a local scale and limited current and future stock available to fish in these areas.

Fishery operations and data interpretation

- Rotational harvest of areas currently closed to fishing may provide opportunities to the fishery, be supported through development of a risk assessment process, and was noted to be an initial rationale for their implementation over a decade ago.
- Patterns and interpretation of catch and catch rate information may be informed by investigating:
 - o the possible effects of new entrants to the fishery through time; and
 - o considering the impact of the 2016 winter storm.
- Early adoption of GPS logging technology on commercial vessels was proposed to provide additional, cost-effective information into future assessments and improve compliance, whilst reducing risk from commercial fishing in any change to the management of areas open and closed to the fishery.

- Stakeholders provided anecdotal evidence of consistency and general support for the interpretation of the assessment data indicating that Red Urchin biomass was depleting, and fishing mortality was too high in areas open to the commercial fishery.

4.2. Information and data limitations and uncertainty

NSW SUTS commercial fishery data for Red Urchin are sourced from a relatively small number of active fishers. Years with few fishers and/or more new entrants results in more uncertain interpretation of trends in fishery-dependent data, that may less likely represent the biological status and performance of the fishery and stock. New entrants to the SUTS Fishery are likely to experience a period of learning such that average levels of catch rate may be depressed as a function of diver experience rather than levels of stock abundance.

A proportion of commercial catch records (0-16% p.a.) have GPS coordinates that do not map to subzones. This has required subzone to be manually attributed to some records based on subjective interpretations of latitude and recent catch history of the reporting fisher. In some instances, reported GPS locations suggest commercial fishing activity in subzones closed to the fishery and near the boundary of open subzones. However, the accuracy of GPS reporting (e.g. fishers manually transcribing GPS coordinates onto paper log sheets at a boat ramp after a day's diving) may not accurately reflect the actual area fished. The majority of these records have been manually altered to report fishing in the subzone open to fishing, erring on the stewardship of fishers and inaccuracy of transcribing GPS coordinates. Moreover, there are a number of records that include multiple reports per day, as a result of fishers reporting catches to different subzones within the same day and/or reporting catch by fishing bin (as has been required in the NSW Abalone Fishery). This has occurred in all years and has required a series of data manipulations to aggregate reported records from each fisher and date to a unique field of FisherDay, thereby supporting the data presented in this report.

Anecdotal evidence and limited studies describe small scale spatial and temporal patterns of fishing by sectors other than the commercial sector can substantially contribute to high fishing mortality of sea urchins, including Red Urchin at a local scale. The level and impact of non-commercial fishing activity on sea urchin populations, particularly around urban centres is generally accepted to be substantial although accurate estimates of fishing activity (e.g. catch) from these sectors is unknown.

Factors other than fishing, including land-based effects of freshwater influx, eutrophication and other environmental factors, such as sea temperature may affect changes in the abundance and productivity of sea urchins. Identifying and quantifying the effect of these factors would help to determine the relative impact of fishing to changes in abundance of sea urchins. Red Urchin, which have a planktotrophic larval stage, are more vulnerable than species with lecithotrophic larvae to declines in density, including through fishing, leading to reduced fertilization success and ongoing population decline (Uthicke et al. 2009). These extraneous factors have not been explicitly considered in the assessment of the NSW SUTS Fishery - Red Urchin stock. Similarly, significant disruptions to fishing operations in 2020, particularly 2019-20 NSW bushfires, declared natural disasters, and the COVID-19 pandemic, impacted transport infrastructure, markets and business operations as well as local social structure and personal lives, have affected fishing operations in the 2020 fishing season.

4.3. Future research needs

- A harvest strategy together with a data monitoring and assessment plan would provide greater certainty in the interpretation of data and inform the assessment, including determination of stock status and deliver against fishery objectives that could include prescriptive criteria to open and close areas of the fishery and/or curate a more resilient stock capable of servicing market demands and increase the value of the resource and fishery.
- Determine the population size structure of (at least) the fished stock and describing spatial and temporal changes would begin development of cost-effective data sources to support future assessments and management options, including understanding the effectiveness of a minimum legal size (e.g. in relation to size at maturity).
- Quantifying the size-at-maturity for Red Urchin across the fishery is a high priority.
- Options for standardising CPUE could be investigated, although multi-species data and the relatively small numbers of fishers even at the relatively broad spatial scale of Region may limit the value of this measure.
- Identifying and quantifying the risks of Recreational and Aboriginal fishing to the sustainability of (at least) local populations would assist in the assessment.
- Ultimately, repeating the fishery-independent surveys done in 2000 (or a select subset of sites from that survey) would result in securing a more confident stock status determination of 'Sustainable', greatly reduce uncertainty in the assessment and likely, TACC determination. However, the resources required to complete such a survey would have to be considered against alternate data and the likely benefit to the fishery. Such a survey could address data needs of all species harvested within the NSW SUTS fishery, potentially also inform the status of the NSW Abalone Fishery and contribute across multidisciplinary research sectors (e.g. habitat mapping (ground truthing aerial/satellite imagery)).

4.4. Conclusions

The stock status determination of Sustainable reflects the assumed stable and consistent biomass of Red Urchin in areas closed to Red Urchin fishing, that contributes to the productivity of the fished stock and the performance of the fishery, inferred from fishery-dependent data. These data suggest fishing mortality has been too high and biomass has been depleted by fishing in areas open to fishing. Unknown levels of productivity and possible changes in productivity through time limit our knowledge of the biological dynamics of populations of Red Urchin. However, over the first few years of this fishery (principally 2000 and 2001) relatively large catches (73% of total catch in 2000 from Region 3) were harvested at high catch rates and subsequent smaller peaks in catch and catch rate reflected a focus of fishing into areas previously not fished (e.g. 2007 into subzones E1, F1 (Region 1) and K1 and K2 (Region 2). In the immediately preceding years in both Regions 3 and 4, catches and catch rates declined substantially, reflecting the level of depletion of the Red Urchin biomass caused by fishing. In Regions 3 and 4, over a period of about a decade catches and catch rates were essentially insignificant. More recent peaks in catch (from about 2016) are smaller than those previously reported and at lower and generally declining catch rates (kg/hr). The biomass of Red Urchin available to fishing in these Regions is likely depleting and unable to maintain current levels of catch at average catch rates. The

introduction of a legal minimum length (95 mm), together with revised Regional Catch Limits (enforced and resulting in the closure of Region 3 in 2019) provide increased protections for the Red Urchin resource. However, it is notable that RCLs are generally in excess of a level that would materially limit fishing mortality to sustainable levels in most regions, given they are in excess of maximum annual catches reported in each Region since 2001, with the recent exception of that in Region 3 in 2019. Together with current spatial closures, this suite of management measures provides protections to the stock that may otherwise be exposed to levels of fishing mortality that would result in a more definitive and adverse assessment and stock status determination. There remains a strong need for a harvest strategy and data monitoring and assessment plan to provide improved transparency and certainty in decision making; confidence in the assessment of the Red Urchin resource and determination of stock status; deliver positive outcomes for the development of the fishery; and deliver opportunities to increase the value of the resource, to all stakeholders.

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Appendix 1 – Sea Urchin and Turban Shell Fishery – summary fishery statistics

SUTS Fishery species catch

The total reported catch (t) of each of the species described in the Sea Urchin and Turban Shell (SUTS) Fishery, from 2000 to 2020 (data to Aug 2020) are provided in Figure A1-1 and Tables A1-1 (Sea Urchin) and A1-2 (Turban Shell). Species catch as a percentage of total annual catch of all SUTS species is provided in Figure A1-2 and Tables A1-1 (Sea Urchin) and A1-2 (Turban Shell). The catch of Turban Shell was reported to species from mid-2009. Prior to this date all Turban Shell catch was reported to the code 'Turban Shell – other'. Similarly, the code 'Sea Urchin – other' is a reporting code available to fishers.

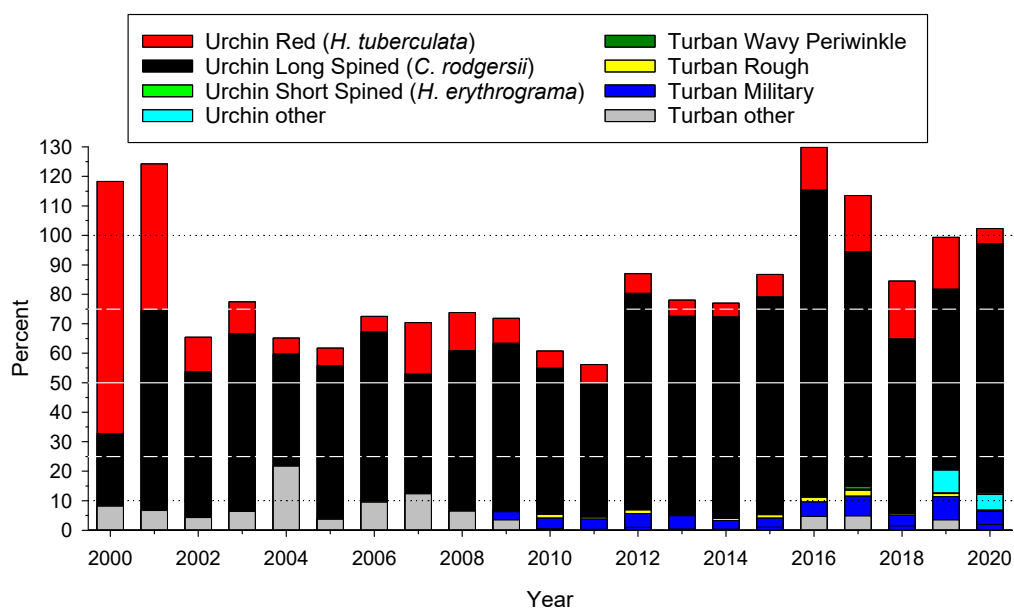


Figure A1 - 1 Annual catch (t) of all SUTS Fishery species, from 2000 to 2019* (*data to August).

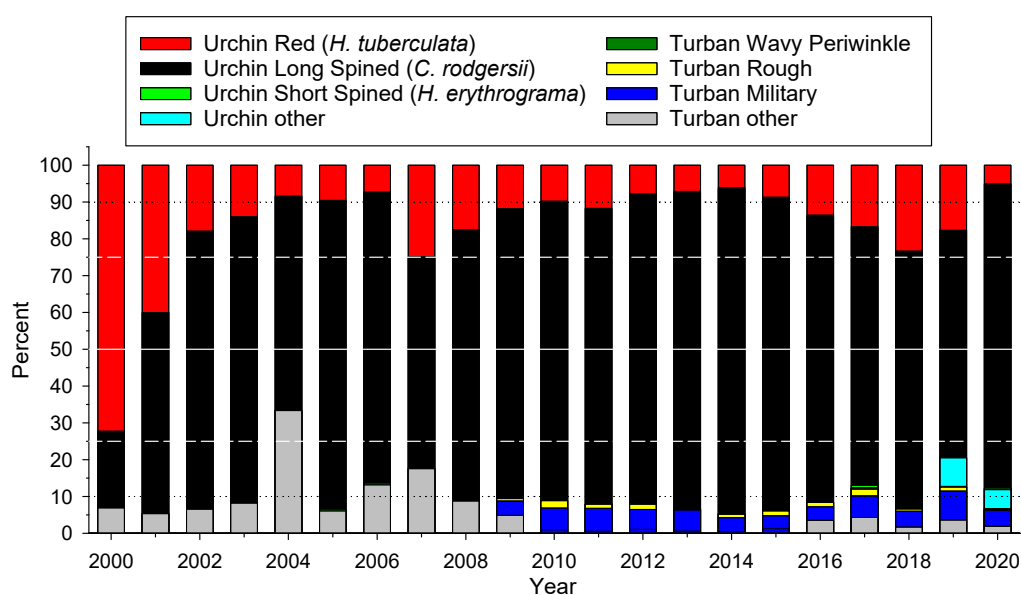


Figure A1 - 2 Species catch as a percentage of total annual catch of all SUTS Fishery species, from 2000 to 2019* (*data to August).

Table A1 - 1 Annual catch (t) of each species of Sea Urchin and percent of total annual catch of all SUTS species (%), from 2000 to 2020* (*data to August).

Year	Urchin-Red Urchin Catch (t) (%)	Urchin-Long Spined Catch (t) (%)	Urchin-Short Spined Catch (t) (%)	Urchin_other Catch (t) (%)
2000	85.5 (72.3)	24.5 (20.72)	0.1 (0.06)	
2001	49.7 (40.03)	67.7 (54.49)	0.2 (0.14)	
2002	11.7 (17.87)	49.4 (75.49)	0.04 (0.06)	
2003	10.8 (13.93)	60.3 (77.85)	0.01 (0.02)	
2004	5.4 (8.34)	38.0 (58.24)	0.04 (0.06)	
2005	5.9 (9.53)	51.8 (83.9)	0.3 (0.47)	
2006	5.3 (7.3)	57.3 (79.06)	0.4 (0.48)	
2007	17.5 (24.84)	40.5 (57.58)	0.03 (0.04)	
2008	12.9 (17.53)	54.4 (73.69)		
2009	8.5 (11.79)	56.6 (78.79)		
2010	5.9 (9.75)	49.5 (81.41)		
2011	6.6 (11.67)	45.1 (80.36)		
2012	6.7 (7.7)	73.3 (84.26)	0.01 (0.01)	0.01 (0.01)
2013	5.5 (7.1)	67.3 (86.23)	0.1 (0.12)	
2014	4.7 (6.11)	68.3 (88.61)		
2015	7.5 (8.69)	73.8 (85.11)	0.04 (0.04)	
2016	18.1 (13.57)	103.9 (77.87)	0.1 (0.05)	0.1 (0.05)
2017	19.0 (16.74)	79.7 (70.23)	0.8 (0.7)	0.02 (0.01)
2018	19.7 (23.31)	58.6 (69.31)	0.3 (0.32)	0.3 (0.37)
2019	17.6 (19.11)	61.3 (63.83)	0.04 (0.04)	7.7 (5.61)
2020*	5.1 (5.02)	84.6 (82.68)	0.5 (0.45)	5.3 (5.14)

Table A1 - 2 Annual catch (t) of each species of Turban Shell, percent of total annual catch of all SUTS species (%), number of active fishers harvesting Red Urchin and total catch of all SUTS Fishery species, from 2000 to 2020* (*data to August).

Year	Turban-Wavy Periwinkle Catch (t) (%)	Turban-Rough Catch (t) (%)	Turban-Military Catch (t) (%)	Turban-other Catch (t) (%)	SUTS Fishery Total catch (t)	No. active fishers (RU)
2000				8.2 (6.92)	118.3	10
2001				6.6 (5.34)	124.2	13
2002				4.3 (6.58)	65.5	6
2003				6.4 (8.2)	77.4	9
2004				21.7 (33.35)	65.2	11
2005				3.8 (6.09)	61.7	14
2006				9.5 (13.16)	72.5	9
2007				12.3 (17.54)	70.4	8
2008				6.5 (8.78)	73.9	8
2009		0.5 (0.64)	2.8 (3.89)	3.5 (4.88)	71.9	12
2010		1.2 (2.01)	3.6 (5.9)	0.6 (0.94)	60.8	9
2011	0.04 (0.06)	0.6 (1.13)	3.5 (6.21)	0.3 (0.56)	56.2	9
2012	0.1 (0.09)	1.2 (1.44)	4.7 (5.38)	1.0 (1.1)	87.0	8
2013	0.03 (0.04)	0.2 (0.21)	4.4 (5.69)	0.5 (0.62)	78.1	9
2014	0.1 (0.11)	0.7 (0.92)	2.9 (3.8)	0.4 (0.46)	77.1	8
2015	0.04 (0.04)	1.2 (1.33)	3.1 (3.55)	1.1 (1.24)	86.7	9
2016	0.1 (0.09)	1.6 (1.16)	4.9 (3.71)	4.7 (3.51)	133.4	11
2017	0.4 (0.32)	2.1 (1.81)	6.7 (5.88)	4.9 (4.3)	113.5	16
2018	0.1 (0.09)	0.5 (0.57)	3.7 (4.34)	1.4 (1.69)	84.5	13
2019	0.2 (0.01)	1.1 (0.67)	7.9 (7.75)	3.6 (2.99)	99.3	17
2020*	0.2 (0.21)	0.3 (0.27)	4.4 (4.32)	2.0 (1.92)	102.3	9

Table A1 - 3 Regions and Subzones of the SUTS Fishery.

Region	Sub-zone	Long (Northern Boundary)	Lat (Northern Boundary)	Long (Southern Boundary)	Lat (Southern Boundary)
1	A Tweed Heads to Ballina	153° 33' 07.2612"	28° 09' 52.3404"	153° 35' 25.0512"	28° 52' 38.3232"
	B1 Ballina to Sandon	153° 35' 25.0512"	28° 52' 38.3232"	153° 19' 57.9648"	29° 40' 25.8456"
	B2 Sandon to Red Rock	153° 19' 57.9648"	29° 40' 25.8456"	153° 14' 03.4764"	29° 58' 52.014"
	B3 Red Rock to Coffs Harbour	153° 14' 03.4764"	29° 58' 52.014"	153° 09' 11.6064"	30° 18' 31.8888"
	C1 Coffs Harbour to SW Rocks	153° 09' 11.6064"	30° 18' 31.8888"	153° 01' 43.7268"	30° 52' 24.6072"
	C2 SW Rocks to Pt Macquarie	153° 01' 43.7268"	30° 52' 24.6072"	152° 55' 02.7192"	31° 25' 36.0984"
	D1 Pt Macquarie to Harrington	152° 55' 02.7192"	31° 25' 36.0984"	152° 41' 27.8952"	31° 52' 39.8424"
	D2 Harrington to Tuncurry	152° 41' 27.8952"	31° 52' 39.8424"	152° 30' 43.9632"	32° 10' 25.1724"
	E2 Foster to Seal Rocks	152° 30' 43.9632"	32° 10' 25.1724"	152° 32' 09.9384"	32° 26' 02.3964"
	E3 Seal Rocks to Hawks Nest Beach	152° 32' 09.9384"	32° 26' 02.3964"	152° 11' 14.118"	32° 40' 07.0356"
	E4 Yacaaba Head and Islands	152° 11' 14.118"	32° 40' 07.0356"	152° 11' 09.4272"	32° 42' 40.032"
	E1 Broughton Island	152° 17' 43.5840"	32° 35' 25.0044"	152° 17' 43.5840"	32° 38' 38.7872"
	F1 Port Stephens to Anna Bay	152° 11' 09.4272"	32° 42' 40.032"	152° 07' 00.3864"	32° 46' 28.8192"
	F2 Anna Bay to Newcastle	152° 07' 00.3864"	32° 46' 28.8192"	151° 47' 57.5844"	32° 55' 03.9936"
	F3 Newcastle to Burwood Beach	151° 47' 57.5844"	32° 55' 03.9936"	151° 45' 43.9128"	32° 56' 42.108"
	F4 Burwood Beach to Swansea	151° 45' 43.9128"	32° 56' 42.108"	151° 39' 57.6648"	33° 05' 13.1604"
	G1 Swansea to Norah Head	151° 39' 57.6648"	33° 05' 13.1604"	151° 34' 36.1236"	33° 16' 44.8428"
	G2 Norah Head to The Entrance	151° 34' 36.1236"	33° 16' 44.8428"	151° 30' 15.4908"	33° 20' 35.0484"
	G3 The Entrance to Terrigal	151° 30' 15.4908"	33° 20' 35.0484"	151° 27' 00.8532"	33° 26' 46.644"
	G4 Terrigal to Broken Bay	151° 27' 00.8532"	33° 26' 46.644"	151° 19' 43.8888"	33° 34' 40.7532"
2	H1 Broken Bay to Sydney Harbour	151° 19' 43.8888"	33° 34' 40.7532"	151° 16' 51.2508"	33° 49' 58.152"
	H2 Sydney Harbour to Bondi Beach	151° 16' 51.2508"	33° 49' 58.152"	151° 16' 37.146"	33° 53' 30.9696"
	H3 Bondi Beach to Botany Bay	151° 16' 37.146"	33° 53' 30.9696"	151° 13' 19.992"	34° 00' 05.364"
	J1 Botany Bay to Port Hacking	151° 13' 19.992"	34° 00' 05.364"	151° 10' 08.8788"	34° 04' 29.5032"
	J2 Port Hacking to Marley Beach	151° 10' 08.8788"	34° 04' 29.5032"	151° 08' 28.788"	34° 06' 57.8916"
	J3 Marley Beach to Garie Beach	151° 08' 28.788"	34° 06' 57.8916"	151° 04' 06.816"	34° 10' 14.2464"
	J4 Garie Beach to Stanwell Park	151° 04' 06.816"	34° 10' 14.2464"	151° 59' 27.5388"	34° 13' 48.6264"
	J5 Stanwell Park to Wollongong Hbr	151° 59' 27.5388"	34° 13' 48.6264"	151° 54' 24.5016"	34° 25' 08.958"
	K1 Wollongong Hbr to Shellharbour	151° 54' 24.5016"	34° 25' 08.958"	150° 52' 35.7672"	34° 34' 44.2416"
	K2 Shellharbour to Bombo Beach	150° 52' 35.7672"	34° 34' 44.2416"	150° 51' 23.0616"	34° 39' 26.8092"
	K3 Bombo Beach to Werri Beach	150° 51' 23.0616"	34° 39' 26.8092"	150° 50' 06.702"	34° 44' 04.182"
	K4 Werri Beach to Shoalhaven Heads	150° 50' 06.702"	34° 44' 04.182"	150° 46' 10.686"	34° 53' 51.6264"
	L1 Shoalhaven Heads to Currarong	150° 46' 10.686"	34° 53' 51.6264"	150° 49' 20.4636"	35° 00' 49.5396"
	L2 Currarong to Pt Perpendicular	150° 49' 20.4636"	34° 58' 58.6668"	150° 48' 16.236"	35° 05' 39.9084"
	L3 Inside Jervis Bay	150° 48' 16.236"	35° 05' 39.9084"	150° 46' 06.0456"	35° 06' 43.992"
	L4 Nth tip Bowen Island to Wreck Bay	150° 46' 06.0456"	35° 06' 43.992"	150° 37' 30.6192"	35° 10' 06.0816"
3	M1 Wreck Bay to Bandalong	150° 37' 30.6192"	35° 10' 06.0816"	150° 32' 43.4652"	35° 14' 54.8016"
	M2 Bandalong to Ulladulla	150° 32' 43.4652"	35° 14' 54.8016"	150° 28' 43.5864"	35° 21' 20.6568"
	N1 Ulladulla to Termeil Point	150° 28' 43.5864"	35° 21' 20.6568"	150° 23' 44.3148"	35° 27' 37.6272"
	N2 Termeil Point to Brush (excl. Island)	150° 23' 44.3148"	35° 27' 37.6272"	150° 24' 27.1728"	35° 31' 45.7356"
	N3 Brush Island	150° 24' 37.2060"	35° 31' 18.6672"	150° 24' 37.2060"	35° 32' 19.4604"

Table A1 - 4 (continued) Regions and Subzones of the SUTS Fishery.

Region	Sub-zone	Long (Northern Boundary)	Lat (Northern Boundary)	Long (Southern Boundary)	Lat (Southern Boundary)
4	P1 Brush (excl. Island) to Pretty Beach	150° 24' 27.1728"	35° 31' 45.7356"	150° 21' 55.9548"	35° 34' 12.9864"
	P2 Pretty Beach to Sth Durras	150° 21' 55.9548"	35° 34' 12.9864"	150° 17' 46.986"	35° 39' 09.4428"
	P3 Sth Durras to North Head	150° 17' 46.986"	35° 39' 09.4428"	150° 16' 34.7772"	35° 43' 23.1924"
	P4 North Head to Batemans Bay	150° 16' 34.7772"	35° 43' 23.1924"	150° 10' 54.1416"	35° 42' 26.5284"
	Q1 Batemans Bay to Lilli Pilli Beach	150° 10' 53.9760"	35° 42' 34.6428"	150° 13' 32.07"	35° 46' 14.4624"
	Q2 Tollgate Islands	150° 15' 00.0000"	35° 44' 00.0000"	150° 15' 00.0000"	35° 46' 00.0000"
	Q3 Lilli Pilli Beach to Malua Bay	150° 13' 32.07"	35° 46' 14.4624"	150° 13' 51.1356"	35° 47' 34.5696"
	Q4 Malua Bay to Burrewarra Point	150° 13' 51.1356"	35° 47' 34.5696"	150° 14' 07.7244"	35° 50' 06.0324"
	Q5 Burrewarra Point to Moruya River	150° 14' 07.7244"	35° 50' 06.0324"	150° 09' 06.9732"	35° 54' 23.238"
	R1 Moruya River to Black Rock	150° 09' 06.9732"	35° 54' 23.238"	150° 09' 10.3464"	35° 59' 01.2876"
	R2 Black Rock to Tuross Lake	150° 09' 10.3464"	35° 59' 01.2876"	150° 08' 03.642"	36° 04' 01.7472"
	S1 Montague Island	150° 12' 58.7304"	36° 14' 13.7328"	150° 12' 58.7304"	36° 16' 00.9048"
	S2 Tuross Lake to Dalmeny	150° 08' 03.642"	36° 04' 01.7472"	150° 07' 37.8804"	36° 09' 43.956"
	S3 Dalmeny to Narooma	150° 07' 37.8804"	36° 09' 43.956"	150° 08' 01.3956"	36° 12' 39.096"
	T1 Narooma to Corunna Lake	150° 08' 01.3956"	36° 12' 39.096"	150° 07' 54.2136"	36° 17' 23.7228"
	T2 Corunna Lake to Bermagui	150° 07' 54.2136"	36° 17' 23.7228"	150° 04' 26.4072"	36° 25' 17.8788"
	U1 Bermagui to Cuttagee Inlet	150° 04' 26.4072"	36° 25' 17.8788"	150° 03' 18.2196"	36° 29' 16.6056"
	U2 Cuttagee to Thibbul Inlet (Murrah)	150° 03' 18.2196"	36° 29' 16.6056"	150° 03' 27.1296"	36° 31' 32.7576"
	U3 Thibbul to Bunga Head (Goalen and Pressure)	150° 03' 27.1296"	36° 31' 32.7576"	150° 03' 20.3508"	36° 33' 17.4264"
	U4 Bunga Head to Mimosa Rocks (Bunga)	150° 03' 20.3508"	36° 33' 17.4264"	150° 03' 16.7112"	36° 35' 04.8624"
5	V1 Mimosa Rocks to Bithry Inlet	150° 03' 16.7112"	36° 35' 04.8624"	150° 01' 12.2052"	36° 37' 46.8768"
	V2 Bithry Inlet to Barounda Inlet	150° 01' 12.2052"	36° 37' 46.8768"	149° 59' 41.7444"	36° 41' 09.3264"
	V3 Barounda Inlet to Tathra	149° 59' 41.7444"	36° 41' 09.3264"	149° 59' 28.0212"	36° 43' 29.1864"
	W1 Tathra to Wallagoot Lake	149° 59' 28.0212"	36° 43' 29.1864"	149° 57' 26.3844"	36° 47' 23.4816"
	W2 Wallagoot Lake to Short Point Beach	149° 57' 26.3844"	36° 47' 23.4816"	149° 55' 57.3996"	36° 52' 04.720"
	W3 Short Point Beach to Merimbula	149° 55' 57.3996"	36° 52' 04.720"	149° 54' 29.1924"	36° 54' 27.4104"
	X1 Merimbula to Long Beach	149° 54' 29.1924"	36° 54' 27.4104"	149° 55' 39.864"	36° 59' 00.2796"
	X2 Long Beach to Eden Wharf	149° 55' 39.864"	36° 59' 00.2796"	149° 54' 27.5904"	37° 04' 26.7456"
	Y11 Eden Wharf to Red Point	149° 54' 27.5904"	37° 04' 26.7456"	149° 57' 13.8672"	37° 06' 02.7792"
	Y12 Red Point to Leatherjacket Beach	149° 57' 13.8672"	37° 06' 02.7792"	149° 58' 06.9312"	37° 07' 31.0368"
	Y13 Leatherjacket Beach to Mowarry Point	149° 58' 06.9312"	37° 07' 31.0368"	150° 00' 16.5996"	37° 08' 29.1552"
	Y21 Mowarry Point to Saltwater Beach	150° 00' 16.5996"	37° 08' 29.1552"	150° 00' 11.484"	37° 10' 10.8336"
	Y22 Saltwater Beach to Long Point	150° 00' 11.484"	37° 10' 10.8336"	150° 01' 14.97"	37° 11' 09.1824"
	Y23 Long Point to Bittangabee Bay	150° 01' 14.97"	37° 11' 09.1824"	150° 01' 05.6892"	37° 12' 54.0364"
	Y24 Bittangabee Bay to Green Cape	150° 01' 05.6892"	37° 12' 54.0364"	150° 03' 07.2072"	37° 15' 45.0324"
	Y31 Green Cape to City Rock	150° 03' 07.2072"	37° 15' 45.0324"	150° 00' 46.4400"	37° 15' 19.7964"
	Y32 City Rock to Wonboyn	150° 00' 46.4400"	37° 15' 19.7964"	149° 58' 01.2900"	37° 15' 02.8692"
	Z1 Wonboyn to Jane Spiers Beach	149° 58' 01.2900"	37° 15' 02.8692"	149° 57' 23.1372"	37° 21' 13.2300"
	Z2 Jane Spiers Beach to Black Head Anchorage	149° 57' 23.1372"	37° 21' 13.2300"	149° 58' 21.5148"	37° 26' 26.358"
	Z3 Black Head Anchorage to Nadgee Lake	149° 58' 21.5148"	37° 26' 26.358"	149° 58' 21.1764"	37° 27' 54.9648"
	Z4 Nadgee Lake to Howe Beach	149° 58' 21.1764"	37° 27' 54.9648"	149° 58' 26.8788"	37° 29' 51.1224"
	Z5 Howe Beach to Cape Howe	149° 58' 26.8788"	37° 29' 51.1224"	149° 58' 34.5468"	37° 30' 19.152"

Appendix 2 – NSW commercial fishery data sources

The information and descriptions below relate to generic NSW commercial fishery reporting requirements and data sources. The structures of these data sources are not necessarily directly related to reporting in the NSW SUTS Fishery, although minor changes, such as species reporting (from the late 1990's), reporting to subzones (prior to July 2009) and reporting to GPS location (post-2009) coincide with broader changes to the data management structures adopted by the Department of Primary Industries – Fisheries, as outlined below.

Commercial logbook reporting changes

NSW catch and effort logbook data vary spatially and temporally across different eras, delineated by changes in catch reporting requirements and management. This section briefly summarises the catch and effort data available for each era and associated limitations and caveats (also refer to Table A2 - 1).

(1) Historical data (pre-1984) – annual catches (kg) reported by port of landing or individual estuaries, which can be aggregated into the ten broad ocean zones and seven estuary regions used in later eras (Figure A2 - 1). No information on fisher, vessels or effort is available, and catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Given the lack of appropriate effort data for this era, it is not possible to compile a CPUE series for any species in NSW state waters prior to July 1984.

(2) Historical data (July 1984–June 1997) – monthly catches (kg) reported by ten broad ocean zones or individual estuaries (Figure A2 - 1). Details of fishers, boats and effort by gear type (in days fished per month) are available. Catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Therefore, CPUE data for this period include only a subset of catch records for each species. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were included on NSW log sheets.

(3) Recent data (July 1997–June 2009) – monthly catches (kg) reported by ten broad ocean zones or individual estuaries (Figure A2 - 1). Details of fishers, boats and effort by gear type (in days fished per month) are available. Method was assigned to all catches. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were no longer included on NSW reporting. Catch, effort and CPUE data (in kg per fisher day) are available for this era.

(4) Recent data (July 2009–June 2016) – daily catches (kg) reported to individual estuaries and a finer spatial scale ($0.1^\circ \times 0.1^\circ$ C-square grid) for ocean waters. Many species complexes were split and catches reported by individual species. Details of fishers, boats and effort by gear type (by a single effort unit, e.g. hours fished, number of hooks or traps, or net length). Depth information is not reported by fishers, but could be interpolated from location data (i.e., from the mean depth of the reported C-square). To construct a longer time series of data (i.e., from 1984/85 or 1997/98 to present), these daily records are re-aggregated into monthly catches (kg) by fisher and gear type, with effort in days per month estimated from the number of distinct fishing dates in each month when the method was used, irrespective of whether the species was reported on those days, to be consistent with earlier reporting. Catch, effort and CPUE data (in kg per effort unit or kg per fisher day, using re-aggregated data) are available for this era. Significant reductions in effort (and consequently spikes in

CPUE) are evident in some species' data following these logbook changes in July 2009; long time series of CPUE that cross this period need to be interpreted with caution.

NB: Mixed zone reporting – prior to July 2009, some catches were reported against mixed ocean zones (e.g. OZ1 and OZ2 combined). To report by zones, these catch and effort data are divided and reallocated evenly to each of the zones involved. Most of the mixed zone records were for just two zones and less than 3% involved three or more zones. After June 2009, all catches were reported according to the finer-scale C-squares.

Table A2 - 1 Data sources of commercial fishery records and changes to fisher reporting requirements through time.

Time period	Data source	Reporting requirements
Pre-1984	HCatch	Catch unit – kg per month No fisher, vessel or effort information available Spatial scale – individual estuaries, port of landing, 7 broad regions
July 1984 – June 1997	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data not linked to individual methods, therefore, effort only assigned to catches when a single method was used in a given month Spatial scale – individual estuaries, 7 broad regions, 10 broad ocean zones
July 1997 – June 2009	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data provided for each method used Spatial scale – individual estuaries, 7 broad regions, 10 broad ocean zones
July 2009 – present	FishOnline	Catch unit – kg per fishing event (within each day) Effort unit – various, one per method; hours fished, net length or number of shots, hooks, lures or traps; hours trawled per day (days fished per month can be extracted from re-aggregated daily data)

Time period	Data source	Reporting requirements
		Catch data provided for each method used
		Spatial scale – individual estuaries, 7 broad regions; 0.1° x 0.1° C-square grid
		Voluntary E-reporting of catch records since 2011
		Compulsory E-reporting for quota reconciliation since 2017

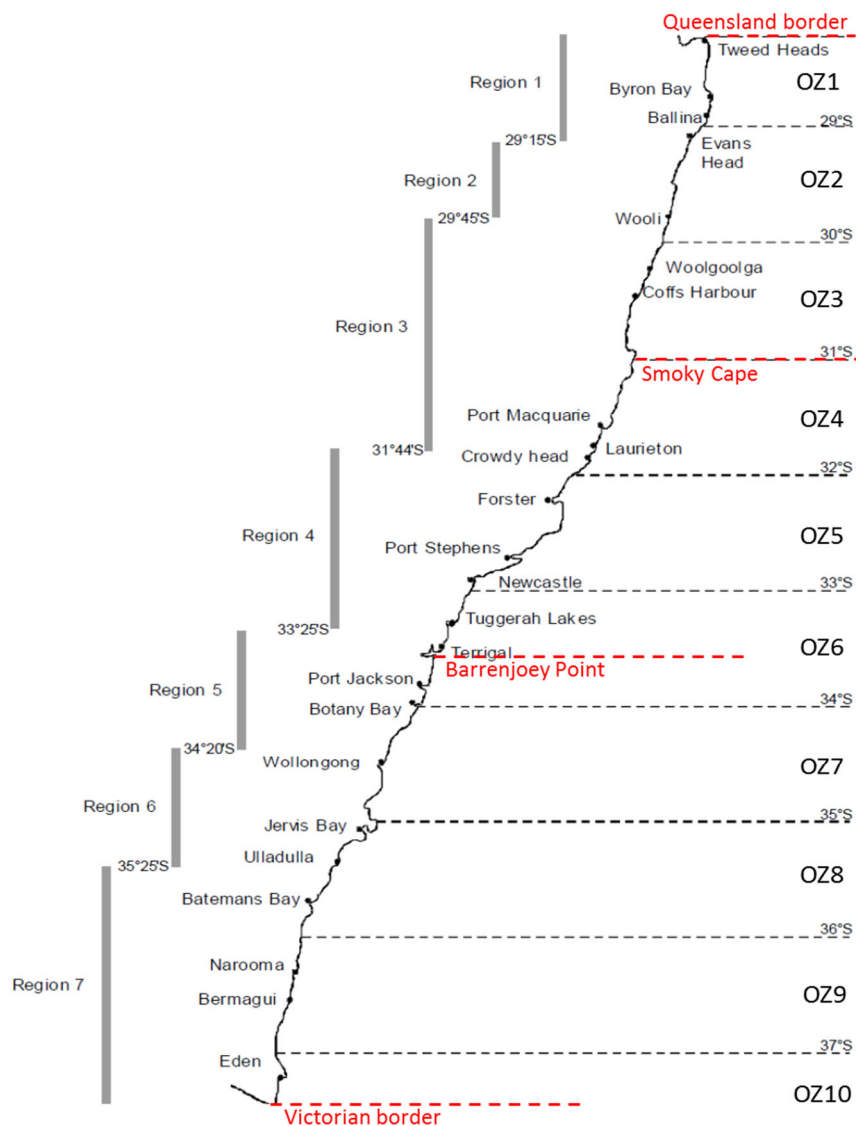


Figure A2 - 1 Map of NSW coastline indicating the main ports of landing, broad ocean fishing zones (OZ1 to OZ10) and estuary fishing regions (Regions 1 to 7) for catch and effort reporting. Important management landmarks, including Smoky Cape, Barrenjoey Point and the Queensland and Victorian borders are also indicated by dashed red lines.