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An investigation of the bycatch of rebuilding species in the SESSF

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Acknowledgements

The metier analysis used to estimate the unavoidable bycatch of rebuilding species were informed by discussions with the South East Resource Assessment Group (SERAG) and Shark Resource Assessment Group (SharkRAG). Many of the figures presented in this report were developed by Malcolm Haddon. Geoff Tuck, Robin Thomson and Dan Corrie provided valuable comments that improved this document.

Executive Summary

This version of this report has been modified to avoid identifying locations fished by less than 5 vessels.

Commonwealth harvest strategy policy requires that for an overfished stock that is solely managed by AFMA, a rebuilding strategy be implemented to allow stock rebuilding to above its limit reference point within a specified timeframe. The rebuilding strategies require that targeted fishing must cease and that incidental mortality be constrained as much as possible. In the Southern and Eastern Scalefish and Shark Fishery (SESSF) there are currently five stocks that are managed under rebuilding strategies, Blue Warehou (*Seriolella brama*), Orange Roughy (*Hoplostethus atlanticus*), the eastern stock of Gemfish (*Rexea solandri*), Redfish (*Centroberyx affinis*) and School Shark (*Galeorhinus galeus*).

This study quantifies the unavoidable bycatch of Blue Warehou, the eastern stock of Gemfish, Redfish and School Shark using a metier approach and investigates potential targeting of these stocks. Some stocks of Orange Roughy are also managed under a rebuilding strategy, however, the deep water nature of Orange Roughy fisheries does not require a specific analysis to quantify unavoidable bycatch. The metier analysis uses recent logbook data to classify groups of fishing operations with common characteristics (e.g. species composition, location, depth) into metiers which are then used to estimate the ratio of primary species to rebuilding species catch. Provisional total allowable catches (TACs) for 2021/22 are then used to estimate the unavoidable bycatch of Blue Warehou, eastern Gemfish, Redfish and School Shark. The robustness of the metier approach to the impact of omitting recent logbook data is also evaluated. Potential targeting of rebuilding species is investigated using plots of the spatial and temporal distribution of catches, depth of fishing, catch per unit effort and annual catch by vessel.

The estimation of rebuilding species bycatch from the metier analysis makes three strong assumptions about catches reported in logbooks. Firstly, the metier analysis uses landed catches reported in logbooks and does not incorporate discards. Discarded catch estimates for Blue Warehou, eastern Gemfish and Redfish are estimated by Deng et al. (2020), however, they are quite uncertain with CVs >40%. Discard estimates for School Shark have not been available since observers were removed from gillnet and line vessels in 2016, however, EM data will be used to estimate School Shark discards in 2021. Finally, estimates of unavoidable bycatch for rebuilding species assume that provisional TACs for primary species are caught by metiers in approximately the same proportions as they were in recent logbook data. While these assumptions are shared by other methods that have been used to estimate rebuilding species bycatch (e.g. Klaer and Smith, 2012), they need to be taken into account when utilising these estimates for management purposes.

The March 2021 version of this document updates a commercial in confidence version provided to AFMA in December 2020 to mask information from fewer than five vessels and incorporate feedback on presentations of the work given to the December 2020 SERAG and SharkRAG meetings. SERAG supported the metier based approach to estimate the unavoidable bycatch of rebuilding species using recent logbook data and recommended that it be updated annually. The SharkRAG requested that the metier analysis used to quantify the unavoidable School Shark bycatch be updated to use only recent data (to avoid the influence of recent management changes) and incorporate the spatial location of fishing. School Shark management includes the restriction that School Shark should be landed at a ratio of no more than 1 weight unit of school shark to 5 units of Gummy Shark. Some additional figures that examine the ratio of School

Shark to Gummy Shark catch have been added. Minor grammatical corrections were made to the final document after the March 2021 SharkRAG meeting.

Blue Warehou catches are predominately associated with the demersal trawl sector fishing on the shelf targeting Flathead on the east coast of Australia and a mix of species west of Tasmania. There has been little change in the spatial distribution of Blue Warehou catches even though catch has declined from 1000t in 1998 to <50t in the last five years. There is no evidence of targeting with no trawl vessels reporting consistently large catches in recent years. The estimate of unavoidable Blue Warehou bycatch in 2021/22 is 29t (21-40t).

Eastern Gemfish catches are predominately associated with the demersal trawl sector fishing on the slope targeting Pink Ling on the east coast of Australia and Blue Grenadier and Pink Ling west of Tasmania. There is also some eastern Gemfish catch associated with the hook sector targeting Blue-eye Trevalla. While eastern Gemfish catches have varied between 20 and 200t since the late 1990s there has been little change the spatial distribution of catch. Eastern Gemfish catch in 2019 increased to 70.4t from 29.9t in 2018. There is no evidence of targeting with no trawl vessels reporting consistently large catches in recent years. The estimate of unavoidable eastern Gemfish bycatch in 2021/22 is 81t (68-96t).

Redfish catches are predominately associated with the demersal trawl sector fishing on the shelf targeting Flathead on the southern NSW coast. The majority of the Redfish catch is taken of NSW, while there are some catches off Victoria and Tasmania these are small compared with those from NSW. Redfish catches have declined from 1750t in the late 1990s to <50t since 2016. Two trawl vessels have reported consistently higher catches of Redfish over the last decade. These catches are low in absolute terms and are likely from vessels operating out of southern NSW ports, however, they warrant further investigation by AFMA. The estimate of unavoidable Redfish bycatch in 2021/22 is 32t (27-39t).

Around 80% of School Shark landings are associated with the gillnet and hook sectors targeting Gummy Shark, while 15% of the School Shark landed were taken by the demersal trawl sector fishing on the slope targeting Blue Grenadier and Pink Ling west of Tasmania. The spatial distribution of School Shark landings has changed substantially since the late 1990s in response to spatial management changes in the fishery. There is substantial spatial variability in the ratio of School Shark to Gummy Shark landings in the gillnet and hook sectors. School Shark bycatch rates are highest in western South Australia and western Tasmania at >35%, however, overall School Shark catch is low at ~25t per annum. Bycatch rates off South Australia and Victoria are around 17%, in western Bass Strait they are 11% and for eastern Bass Strait and eastern Tasmania they are 3% of Gummy Shark catch. School Shark landings have remained stable between 140t and 260t since the introduction quota in 2001. There is no evidence of gillnet or hook vessels reporting consistently large landings School Shark in recent years which therefore indicates they are not targeting. Two trawl vessels have reported higher than average catches of School Shark over the last few years, while these catches are low in absolute terms and are likely from vessels fishing on the shelf west of Tasmania they may warrant further investigation by AFMA. The estimate of unavoidable School Shark bycatch in 2021/22 is 194t (162-230t).

Introduction

In 2019 there was a request from the AFMA Commission for a companion species and targeting analysis to provide updated estimates of unavoidable bycatch for rebuilding stocks. A companion species analysis that utilised an existing metier analysis of the SESSF (Briton, 2019) was presented to the December 2019 SERAG meeting. The metier analysis was based on SESSF logbook data from 2012-2017 and did not include the most recent year of available data. SERAG thought the approach was promising, however, more work was required to evaluate the impacts of omitting the current years data and asked for the method to be compared to the approach of Klaer and Smith (2012).

At the 2020 SESSFRAG Data Meeting it was agreed that CSIRO was to repeat the metier analysis undertaken in 2019 with the current 2014-19 data and undertake a targeting analysis for rebuilding species. A comparison of the metier based approach to estimate companion species catches with the approach of Klaer and Smith (2012) was deferred to a later time.

This study estimates the companion species catch of Blue Warehou, eastern Gemfish and eastern Redfish using the approach of Briton (2019) with logbook data from 2014 - 2019. The robustness of the method to the omission of recent data is evaluated by comparing estimates of the companion species catch of Blue Warehou, eastern Gemfish and eastern Redfish obtained using logbook data from 2012 - 2017 with those obtained using logbook data from 2014 - 2019. A targeting analysis is undertaken for Blue Warehou, eastern Gemfish and eastern Redfish using a weight of evidence approach based on Haddon et al. (2016).

Changes in March 2021

This document updates a commercial in confidence version provided to AFMA in December 2020. Following feedback from the December 2020 SERAG and SharkRAG meetings the following changes were made.

- Tables of scalefish catches by metier and estimates of predicted 2021 bycatch of Blue Warehou, eastern Gemfish and Redfish that were presented to the December 2020 SERAG meeting have been added.
- The metier analysis used to quantify School Shark bycatch has been updated to incorporate fishing locations using the shark fishing zones. Estimates of predicted School Shark bycatch in 2021 are provided by metier groups that account for spatial variability in bycatch rates.

Methods

Metier analysis - rebuilding scalefish species

A metier is defined as a group of fishing operations targeting one or more species using a specific gear at a particular time and location (Briton, 2019). This study uses a metier based approach to quantify the unavoidable bycatch of Blue Warehou, eastern Gemfish, Redfish and School Shark. Metiers are identified using multivariate statistical methods. The metier analysis was undertaken using the R package `vmstools` (Deporte et al., 2012) using logbook data from 2014 - 2019. Details of the approach are provided in Briton (2019).

Scalefish bycatch estimates for 2021

Bycatch of Blue Warehou, eastern Gemfish and eastern Redfish in 2021 is estimated utilising the updated metier analysis that was applied using logbook data from 2014 - 2019. The following steps were taken to estimate companion species catches of rebuilding species:

- Step 1: Using logbook data for 2018 and 2019 the average annual catch of all species was calculated by metier.
- Step 2: Metiers associated with substantial catches of rebuilding species were identified along with the main target species (e.g. Flathead, Pink Ling, etc).
- Step 3: For each metier, the catch of each rebuilding species is quantified per unit of target species (e.g. 1 t of Pink Ling caught by the East Slope Trawl metier catches 1 kg of Blue Warehou, 16 kg of eastern Gemfish and 1 kg of eastern Redfish).
- Step 4: TACs in 2021 for target species are allocated among the metiers in the same proportion as the 2018 and 2019 data and the ratios from Step 3 are used to estimate the 2021 unavoidable bycatch of each rebuilding species.

The above approach makes the following assumptions:

- The distribution of target species catches among the metiers does not change,
- The distribution or abundance of the rebuilding species does not change and
- Discarded catch estimates are accurate (i.e. discarding behaviour does not change when there are not observers present).

All of these assumptions also apply to the approach of Klaer and Smith (2012) and the evaluation of the potential impacts of violating any of these assumptions is beyond the scope of this study.

Uncertainty in the rebuilding species bycatch estimates is quantified using a non-parametric bootstrap (i.e. resampling the data) treating the metier in each year as the primary sampling unit.

Robustness to omission of recent data

An evaluation of the impact of omitting recent data from the metier analysis is undertaken by comparing the estimates of unavoidable bycatch of Blue Warehou, eastern Gemfish and eastern

Redfish obtained using logbook data from 2012 - 2017 with those obtained using logbook data from 2014 - 2019.

Metier analysis for School Shark

The metier analysis that was undertaken for rebuilding scalefish species was presented to SharkRAG in December 2020. SharkRAG had concerns that the metier analysis used data from a period where there had been spatial management changes in the Gummy Shark fishery and that it did not adequately capture the spatial variability in School Shark catches and also that the effect of variable discarding and the 1:5 school to gummy rule might skew results.

Aggregation of clusters to metiers

To address the concerns of SharkRAG the metier analysis was repeated using logbook data from 2016-2019 (a period where there have been no changes in spatial management) and with a shelf/slope depth split at 183m. Clusters identified by the multivariate analysis were then only aggregated to form metiers after evaluating the spatial variability in School Shark catches using shark fishing zones. Some aggregation of the shark zones was undertaken to group zones with similar rates of School Shark bycatch. The New South Wales zone (`NSW`) has negligible School Shark catch and remains a separate zone (`NSW`). Eastern Tasmania (`ET`) and Eastern Bass Strait (`EBS`) were combined into a single eastern Tasmania zone (`EastTas`). Central South Australia (`CSA`), Eastern South Australia (`ESA`) and Eastern South Australia / Victoria (`SAV-E`) were combined into a South Australia / Victoria zone (`SA-Vic`). Western Tasmania (`WT`) and Western Bass Strait (`WBS`) remain separate zones `WestTas` and `WestBS`. There is little reported catch in the Western Australia (`WA`) zone in 2016-2019 so it was combined with Western South Australia (`WSA`) to form `WestSA`.

The spatial variability of School Shark catches was assessed for metier clusters in the Danish seine, gillnet, hook, and the eastern and western components of the trawl sectors separately. Metier groups were then formed to aggregate clusters that had similar rates of School Shark bycatch and were spatially adjacent.

School Shark bycatch estimates for 2021

Estimates of School Shark bycatch in 2021 were calculated using steps 1-4 described for rebuilding scalefish species applied to the metier groups described above and the provisional TACs of primary species for 2021-22.

Targeting analysis

A weight of evidence approach based on Haddon et al. (2016) is used to investigate the spatial and temporal characteristics of the incidental catches of Blue Warehou, eastern Gemfish and eastern Redfish. Plots of standardized CPUE and annual depth of fishing (reproduced from Sporcic (2020)) and the spatial distribution of catches are examined for evidence of changes in fishing behaviour or the distribution of the rebuilding species. Finally, plots of annual catch by vessel are presented.

Blue Warehou

Investigations in 2019 by Robin Thomson and Tamre Sarhan (AFMA) into the under reporting of Blue Warehou in logbooks compared to CDRs suggest that some operators may be reporting Blue Warehou (*Seriolella brama*) as Black Trevally (*Caranx lugubris*) in e-Logs. While Black Trevally is one of many common names for Blue Warehou, *Caranx lugubris* is a tropical species and unlikely to be caught in any great quantities in the SESSF. While AFMA have contacted operators to request they report *Seriolella brama* as Blue Warehou in logbooks, to make sure that we are not missing any logbook records relating to Blue Warehou we treat any *Caranx lugubris* reported in zones 10-60 as Blue Warehou throughout this document.

The majority of Commonwealth catches of Blue Warehou come from the demersal trawl fishery and it is therefore the focus of the investigation of potential targeting of Blue Warehou. Blue Warehou are closely related to Silver Warehou and historically catches have often been reported mixed, or with all warehou species combined and referred to as Tassie trevally (Sporcic et al., 2015). This practice was most prevalent in the late 1980s with it unclear which species was caught and recorded in Commonwealth logbooks. Consequently, logbook catches of Blue Warehou in the 1990s presented in this study should be interpreted with caution.

Eastern Gemfish

The majority of Commonwealth catches of eastern Gemfish come from the demersal trawl fishery and it is therefore the focus of the investigation of potential targeting of eastern Gemfish.

Redfish

The majority of Commonwealth catches of eastern Redfish come from the demersal trawl fishery and it is therefore the focus of the investigation of potential targeting of eastern Redfish.

School Shark

School Shark are predominately landed as bycatch of the gillnet and hook sectors targeting Gummy Shark, however, there is also some School Shark bycatch associated with the trawl sector and the hook sector targeting Blue-eye Trevalla. Because the majority of School Shark landings are associated with Gummy Shark catch, and because the ratio of School Shark to Gummy Shark landings are legally capped to 1:5, this ratio is reported.

Results

Metier analysis - rebuilding scalefish species

Scalefish bycatch estimates for 2021

The metier analysis shows that majority of the bycatch of Blue Warehou, eastern Gemfish and eastern Redfish is associated with the trawl metiers catching Blue Grenadier, Flathead and Pink Ling (Table 1). Blue warehou and eastern Redfish bycatch comes mostly from the shallower mixed shelf and Flathead metiers, with Blue Warehou being caught by both the eastern and western trawl metiers while Redfish catches come predominately from the east. Most of the eastern Gemfish bycatch is taken by Blue Grenadier and Pink Ling metiers on the slope, however, the hook metier for Blue-eye Trevalla also catches around 5 tonnes per annum.

Estimated 2021 bycatch of Blue Warehou, Eastern Gemfish and Redfish that are associated with fishing for Flathead, Blue Grenadier and Pink Ling are provided in Table 2.

Robustness to the omission of recent data

There were no significant differences in the bycatch rate of Blue Warehou and Redfish between the metier analysis undertaken using 2016 - 2017 data (Table 3) and the analysis using 2018 - 2019 data (Table 4). For Gemfish however, the bycatch rates were significantly different between the two analysis. This suggests the method is not robust to the omission of recent logbook data and should be updated annually if it is used to provide estimates of rebuilding species bycatch.

Table 1: Average annual logbook catch (tonnes) of primary and rebuilding scalefish species by metier in 2018 and 2019.

Sector	Metier	Blue-eye Trevalla	Blue Grenadier	Flathead	Orange Roughy	Pink Ling	School Whiting	Blue Warehou	eastern Gemfish	Redfish
Eastern trawl	Flathead	0.0	1.5	793.0	0.0	7.0	6.2	2.2	0.9	6.3
Eastern trawl	Mixed Shelf	19.9	7.8	132.6	7.6	9.8	25.2	3.5	7.0	17.5
Eastern trawl	Mixed Slope	2.0	407.4	3.0	0.9	122.3	0.1	0.2	25.6	0.9
Eastern trawl	Orange Roughy	0.3	0.3	0.0	849.2	0.0	0.0	0.0	0.0	0.0
Eastern trawl	Pink Ling	0.3	41.8	0.8	0.1	153.0	0.0	0.0	4.3	0.2
Eastern trawl	Royal Red Prawn	0.0	0.1	0.0	0.0	2.1	0.0	0.0	1.1	0.0
Western trawl	Blue Grenadier	0.5	3438.1	0.0	0.0	18.9	0.0	0.0	2.3	0.1
Western trawl	Mixed Deepwater	0.2	53.0	0.0	119.1	22.0	0.0	0.0	0.4	0.2
Western trawl	Mixed Shelf	2.7	8.7	6.3	0.0	2.1	0.0	12.6	0.3	0.0
Western trawl	Mixed Slope	9.6	801.3	1.3	2.4	189.4	0.0	4.1	12.9	0.8
Western trawl	Pink Ling	0.6	74.1	0.0	0.0	155.8	0.0	0.1	3.3	0.2
Danish seine	Flathead	0.0	0.0	944.2	0.0	0.7	4.4	0.2	0.0	0.1
Danish seine	Mixed	0.0	0.6	30.8	0.0	0.4	13.6	1.2	0.0	0.0
Danish seine	School Whiting	0.0	0.0	56.8	0.0	0.2	527.3	1.1	0.0	0.2
Gillnet	Gummy Shark	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0
Gillnet	Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Hook	Blue-eye Trevalla	257.8	2.9	0.0	0.0	74.9	0.0	0.0	5.6	0.0
Hook	Gummy Shark	0.2	0.0	1.1	0.0	0.7	0.7	0.0	0.0	0.1
Hook	Mixed Scalefish	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
Hook	Pink Ling	12.2	1.5	0.0	0.0	215.2	0.0	0.0	0.4	0.0

Table 2: Estimated catch (tonnes) of primary species metiers and associated bycatch of Blue Warehou, Eastern Gemfish and Redfish in 2021 with 95% confidence intervals.

	Primary Species				Rebuilding Species		
Metier Group	**Blue Grenadier**	**Flathead**	**Pink Ling East**	**Pink Ling West**	**Blue Warehou**	**eastern Gemfish**	**Redfish**
Blue Grenadier Metier	10258.2	0	0	56.5	0	6.8 (5.4 -8.4)	0.4 (0.4 - 0.5)
Flathead Metiers	11.2	2231.7	20.9	0	7.1 (4.8 - 10.5)	9.4 (7.4 - 11.6)	28.4 (24.9 - 32.3)
East Ling Metiers	471	3.9	378.7	0	0.2 (0.1 - 0.3)	31.5 (27.4 - 36.2)	1.2 (0.6 - 2.0)
West Ling Metiers	1377	2	0	744.8	6.6 (4.3 - 10.1)	25.9 (22.4 - 29.9)	1.5 (0.5 - 3.0)
Other Metiers	65.6	95.4	27.2	73.1	15.1 (12.0 - 19.0)	7.5 (5.7 - 9.6)	0.6 (0.4 - 0.9)
Estimated 2021 catch	**12182.9**	**2333**	**426.8**	**874.4**	**29.1 (21.2 - 39.9)**	**81.0 (68.3 - 95.8)**	**32.2 (26.7 - 38.7)**

Table 3: Estimated bycatch rates (est) of Blue Warehou, Eastern Gemfish and Redfish with 95% confidence intervals associated with Pink Ling metiers obtained using logbook data for 2016 and 2017.

				Blue Warehou			eastern Gemfish			Redfish		
Sector	**Metier**	**% Pink Ling**	**Pink Ling**	**est**	**2.50%**	**97.50%**	**est**	**2.50%**	**97.50%**	**est**	**2.50%**	**97.50%**
Eastern trawl	Mixed Slope	14.60%	1	0.007	0.002	0.013	0.051	0.044	0.06	0.006	0.004	0.008
Eastern trawl	Pink Ling	30.40%	1	0.001	0	0.001	0.008	0.007	0.01	0	0	0.001
Western trawl	Mixed Slope	19.40%	1	0.005	0.001	0.012	0.016	0.014	0.019	0.001	0.001	0.002
Western trawl	Pink Ling	24.50%	1	0.001	0.001	0.002	0.005	0.004	0.006	0	0	0
Hook and line	Blue-eye	2.70%	1	0	0	0	0.074	0.059	0.092	0	0	0
Total	**-**	**91.60%**	**1**	**0.003**	**0.001**	**0.005**	**0.018**	**0.015**	**0.021**	**0.001**	**0.001**	**0.002**

Table 4: Estimated bycatch rates (est) of Blue Warehou, Eastern Gemfish and Redfish with 95% confidence intervals associated with Pink Ling metiers obtained using logbook data for 2018 and 2019.

				Blue Warehou			eastern Gemfish			Redfish		
Sector	**Metier**	**% Pink Ling**	**Pink Ling**	**est**	**2.50%**	**97.50%**	**est**	**2.50%**	**97.50%**	**est**	**2.50%**	**97.50%**
Eastern trawl	Mixed Slope	16.70%	1	0.002	0.001	0.002	0.21	0.184	0.24	0.007	0.005	0.011
Eastern trawl	Pink Ling	20.90%	1	0	0	0	0.028	0.023	0.033	0.001	0	0.003
Western trawl	Mixed Slope	25.80%	1	0.021	0.014	0.033	0.068	0.06	0.077	0.004	0.001	0.009
Western trawl	Pink Ling	21.20%	1	0.001	0	0.001	0.021	0.018	0.026	0.001	0.001	0.002
Hook and line	Blue-eye	10.20%	1	0	0	0	0.074	0.059	0.095	0	0	0
Total	**-**	**94.70%**	**1**	**0.006**	**0.004**	**0.01**	**0.074**	**0.064**	**0.087**	**0.003**	**0.001**	**0.005**

Metier analysis - School Shark

Aggregation of clusters to metiers

School Shark bycatch rates are presented separately for Danish seine, gillnet, hook and the eastern and western components of the trawl sector. Clusters with similar School Shark bycatch rates that were spatially adjacent were aggregated into metier groups as described below.

Danish seine sector

Danish Seine metiers target Flathead and School Whiting, they land a small amount of Gummy Shark (~25t per annum) and <1t per annum of School Shark (Table 5). School Shark landings do not appear to vary spatially, therefore Danish seine clusters were aggregated into a single metier for the estimation of 2021 School Shark bycatch.

Table 5: Average annual primary species and School Shark catch in tonnes from Danish seine by metier cluster and zone 2016-2019.

Cluster	Metier Zone	% School Shark	School Shark	Gummy Shark	Flathead	School Whiting
Flathead	EastTas	0.02%	0.21	10.9	1088.0	11.8
Flathead	NSW	0.00%	0.00	0.2	47.7	0.3
Flathead	SA-Vic	0.00%	0.00	0.0	0.0	0.0
Flathead	WestBS	0.03%	0.01	0.2	20.6	0.4
Flathead	WestSA	0.00%	0.00	0.0	0.0	0.0
Flathead	WestTas	0.00%	0.00	0.0	0.0	0.0
School Whiting	EastTas	0.01%	0.03	3.2	38.5	378.4
School Whiting	NSW	0.00%	0.00	0.0	0.4	1.7
School Whiting	SA-Vic	0.00%	0.00	0.0	0.0	0.0
School Whiting	WestBS	0.00%	0.01	0.4	5.2	186.5

Gillnet sector

The rate of landed School Shark bycatch from the Eastern Tasmanian zone is low at 2.8% of Gummy Shark catch (Table 6). Bycatch rates from the South Australian-Victorian and Western Bass Strait zones is 16.1% and 12.8% respectively. Rates of School Shark bycatch in Western Tasmania and Western South Australia and are high at 94.8% and 140.3% of Gummy Shark catch respectively, however, absolute catch is relatively low at ~9t and 0.5t per annum. With the exception of the NSW zone being aggregated with eastern Tasmania, gillnet clusters are retained as separate metier groups.

Table 6: Average annual primary species and School Shark catch in tonnes from gillnets by metier cluster and zone 2016-2019.

Cluster	Metier Zone	% School Shark	School Shark	Gummy Shark
Gummy Shark	EastTas	2.8%	20.1	726.8
Gummy Shark	SA-Vic	16.1%	18.1	112.4
Gummy Shark	WestBS	12.8%	34.8	272.2
Gummy Shark	WestSA	140.3%	0.6	0.4
Gummy Shark	WestTas	94.8%	9.3	9.8

Hook sector

For the hook sector, the rate of School Shark bycatch for Blue-eye Trevalla metiers is <1% of target species catch on the east coast of Australia and between 1.5% and 2.5% to the west of Tasmania (Table 7). We therefore separated Blue-eye metiers into two groups, east and west of Tasmania. For Pink Ling metiers the rate of School Shark bycatch ranges from zero off NSW to 1.5% in Western Bass Strait, we therefore aggregated Pink Ling to a single metier group. School Shark bycatch rates vary widely from 0-6.8% off New South Wales and eastern Tasmania to 35-40% off western Tasmania and in western Bass Strait. The small amount of catch from NSW was aggregated with the eastern Tasmanian zone while the other zones have been retained.

Table 7: Average annual primary species and School Shark catch in tonnes from the hook sector by metier cluster and zone 2016-2019.

Cluster	Metier Zone	% School Shark	School Shark	Gummy Shark	Blue-eye Trevalla	Pink Ling
Blue-eye Trevalla	EastTas	0.8%	1.0	0.6	102.7	22.6
Blue-eye Trevalla	NSW	0.0%	0.0	0.0	38.4	0.0
Blue-eye Trevalla	SA-Vic	2.4%	1.9	0.8	57.1	20.7
Blue-eye Trevalla	WestBS	1.5%	0.2	0.1	10.0	2.9
Blue-eye Trevalla	WestSA	0.0%	0.0	0.0	35.5	1.9
Blue-eye Trevalla	WestTas	1.6%	0.7	0.3	26.8	18.0
Pink Ling	EastTas	0.1%	0.1	0.2	5.9	77.1
Pink Ling	NSW	0.0%	0.0	0.0	0.2	0.9
Pink Ling	SA-Vic	1.4%	0.2	0.1	1.6	11.0
Pink Ling	WestBS	1.5%	0.1	0.0	0.5	7.1
Pink Ling	WestTas	1.0%	1.3	0.9	6.6	122.2
Gummy Shark	EastTas	6.8%	4.3	62.9	0.1	0.6
Gummy Shark	NSW	1.4%	0.0	0.5	0.0	0.0
Gummy Shark	SA-Vic	21.6%	48.7	225.0	0.1	0.0
Gummy Shark	WestBS	9.5%	2.0	21.3	0.0	0.0
Gummy Shark	WestSA	36.4%	11.5	31.6	0.0	0.0
Gummy Shark	WestTas	40.3%	1.0	2.4	0.0	0.0

Eastern trawl sector

Eastern trawl metiers target mostly Flathead and to a lesser extent School Whiting on the shelf, mostly Pink Ling on the slope and Orange Roughy in deep water. There is also a metier targeting Royal Red Prawn off the NSW coast. Orange Roughy and Royal Red Prawn metiers have no reported School Shark catch in 2016 - 2019 and are not considered further (Table 8). There are ~500kg per annum of School Shark landings reported from the Pink Ling and Mixed metiers fishing on the slope (>183m) these are assigned to the `EasternTrawl_Slope` metier. School Shark catches from shelf metiers targeting Flathead are higher in Eastern Tasmanian and Eastern Bass Strait at ~2.5t per annum, these are assigned to the `EasternTrawl_Shelf_Tas` group. School Shark catches off NSW are low, ~250kg per annum, these are assigned to the `EasternTrawl_Shelf_NSW` group.

Western trawl sector

Western trawl metiers target mostly Blue Grenadier and Pink Ling on the slope, however, there is some mixed species catches of Gummy Shark, Flathead, Squid, Latchet, King Dory and Gemfish. There is also a Deepwater Flathead metier. There is little spatial variability in the School Shark landings of the Blue Grenadier, Deepwater Flathead and Pink Ling metiers so these metiers are not spatially disaggregated (Table 9). Landings of School Shark by the Mixed Shelf metier are substantially higher in Western Tasmania and Western Bass Strait than South Australia so this metier is separated into Western Tasmanian / Bass Strait and South Australian groups. There is little spatial variability in the School Shark landings by the Mixed Slope metier so it is not disaggregated.

Aggregated School Shark metiers

The aggregation of clusters with similar School Shark bycatch rates that were spatially adjacent is provided in Table 10.

School Shark bycatch estimates for 2021

Estimates of School Shark bycatch in 2021 by main metier groups are provided in Table 11.

Table 8: Average annual primary species and School Shark catch in tonnes from the eastern trawl sector by metier cluster and zone 2016-2019.

Cluster	Metier Zone	% School Shark	School Shark	Gummy Shark	Blue Grenadier	Blue-eye Trevalla	Flathead	Orange Roughy	Pink Ling	Royal Red Prawn	School Whiting
Flathead	EastTas	0.1%	1.0	21.1	1.4	0.1	669.9	0.0	8.1	0.0	0.2
Flathead	NSW	0.0%	0.1	3.6	0.0	0.0	272.2	0.0	1.2	0.0	13.8
Flathead	EastTas	0.7%	0.3	2.1	3.2	0.0	30.5	0.0	4.0	0.0	0.0
Flathead	NSW	0.5%	0.1	0.1	0.5	0.0	10.7	0.0	1.5	0.2	0.0
Mixed Shelf	EastTas	3.3%	1.2	6.4	3.2	0.0	22.9	0.0	3.3	0.0	0.7
Mixed Shelf	NSW	0.0%	0.0	1.2	0.0	0.0	18.2	0.0	0.5	0.0	28.9
Mixed Slope	EastTas	0.2%	0.5	4.0	273.6	21.1	2.7	6.8	35.2	0.0	0.1
Mixed Slope	NSW	0.0%	0.0	0.6	3.1	0.0	1.4	0.0	14.1	6.3	0.4
Orange Roughy	EastTas	0.0%	0.0	0.0	0.6	0.4	0.0	601.3	0.0	0.0	0.0
Orange Roughy	NSW	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pink Ling	EastTas	0.0%	0.1	1.2	68.2	0.3	0.6	0.1	151.4	0.0	0.0
Pink Ling	NSW	0.0%	0.0	0.2	2.9	0.0	0.2	0.0	36.1	0.7	0.0
Royal Red Prawn	NSW	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	1.4	137.9	0.0

Table 9: Average annual primary species and School Shark catch in tonnes from the western trawl and GAB sectors by metier cluster and zone 2016-2019.

Cluster	Metier Zone	% School Shark	School Shark	Gummy Shark	Blue Grenadier	Blue-eye Trevalla	Deepwater Flathead	Flathead	Pink Ling
Blue Grenadier	EastTas	0.2%	0.0	0.0	11.4	0.0	0.0	0.0	0.2
Blue Grenadier	SA-Vic	0.2%	0.5	0.3	294.9	1.2	0.4	0.1	26.0
Blue Grenadier	WestBS	0.6%	0.8	0.0	111.5	0.0	0.0	0.0	9.9
Blue Grenadier	WestTas	0.1%	1.5	0.1	1857.6	0.4	0.1	0.1	29.4
Deepwater Flathead	SA-Vic	2.7%	0.6	1.3	1.1	0.0	20.0	0.0	0.5
Deepwater Flathead	WestBS	0.0%	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Deepwater Flathead	WestTas	4.7%	0.0	0.1	0.0	0.0	0.7	0.0	0.0
Mixed Shelf	SA-Vic	8.9%	0.8	1.7	0.2	0.0	5.1	1.6	0.3
Mixed Shelf	WestBS	43.0%	0.2	0.1	0.0	0.0	0.0	0.4	0.0
Mixed Shelf	WestSA	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mixed Shelf	WestTas	46.5%	1.8	0.9	0.4	0.0	0.6	1.9	0.2
Mixed Slope	SA-Vic	3.0%	5.5	6.7	118.7	6.8	9.5	2.5	39.3
Mixed Slope	WestBS	6.7%	1.6	0.1	17.9	0.1	0.0	0.0	6.6
Mixed Slope	WestTas	4.1%	2.3	0.3	41.1	0.5	0.0	0.0	14.3
Pink Ling	SA-Vic	0.4%	0.2	0.2	18.2	0.2	0.1	0.0	26.8
Pink Ling	WestBS	0.7%	0.2	0.0	10.3	0.0	0.0	0.0	19.1
Pink Ling	WestSA	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Pink Ling	WestTas	0.2%	0.4	0.1	44.1	0.4	0.0	0.0	101.9

Table 10: Average annual primary species and School Shark catch in tonnes from aggregated metier groups 2016-2019.

Sector	Metier Group	Metier Zone	% School Shark	School Shark	Gummy Shark	Blue Grenadier	Blue-eye Trevalla	Deepwater Flathead	Flathead	Pink Ling
Danish Seine	All	All	0.0%	0.2	28.2	0.6	0.0	0.0	1013.1	1.2
Gillnet	Gummy Shark	EastTas	2.9%	20.7	703.5	0.0	0.0	0.0	0.2	0.0
Gillnet	Gummy Shark	SA-Vic	15.5%	16.0	103.2	0.0	0.0	0.0	0.0	0.1
Gillnet	Gummy Shark	WestBS	11.8%	24.1	204.9	0.0	0.0	0.0	0.0	0.0
Gillnet	Gummy Shark	WestTas	144.4%	7.5	5.2	0.0	0.0	0.0	0.0	0.0
Hook	Blue-eye Trevalla	EastAus	0.9%	1.3	0.7	2.0	122.2	0.0	0.0	25.0
Hook	Blue-eye Trevalla	WestTas-SA-Vic	1.8%	3.1	1.3	0.9	132.6	0.0	0.0	39.7
Hook	Gummy Shark	EastTas	6.6%	5.8	87.3	0.0	0.1	0.0	0.2	0.7
Hook	Gummy Shark	SA-Vic	16.9%	50.1	295.9	0.0	0.0	0.0	0.9	0.0
Hook	Gummy Shark	WestBS	9.3%	2.4	26.1	0.0	0.0	0.0	0.0	0.0
Hook	Gummy Shark	WestSA	34.5%	16.3	47.0	0.0	0.0	0.0	0.1	0.0
Hook	Gummy Shark	WestTas	21.7%	0.9	3.9	0.0	0.0	0.0	0.0	0.0
Hook	Pink Ling	All	0.8%	1.9	1.1	1.6	15.3	0.0	0.0	225.3
Eastern Trawl	All Shelf	EastTas	0.2%	1.3	28.7	7.1	0.1	0.1	691.0	13.5
Eastern Trawl	All Shelf	NSW	0.0%	0.1	5.7	0.1	0.0	0.1	232.3	3.3
Eastern Trawl	All Slope	All East	0.1%	0.8	8.9	421.6	21.4	0.0	5.8	231.1
Western Trawl	Blue Grenadier	All West	0.1%	4.0	0.7	3694.8	1.4	0.7	0.3	66.1
Western Trawl	Deepwater Flathead	All West	4.3%	0.9	1.2	1.5	0.0	17.3	0.1	0.6
Western Trawl	Mixed Shelf	SA-Vic	10.1%	0.6	1.3	0.2	0.0	3.7	0.6	0.2
Western Trawl	Mixed Shelf	WestTasBS	50.5%	2.7	1.0	0.7	0.0	0.4	3.0	0.3
Western Trawl	Mixed Slope	All West	4.5%	12.7	8.1	184.6	6.8	11.3	2.2	67.5
Western Trawl	Pink Ling	All West	0.3%	0.7	0.4	72.4	0.6	0.1	0.0	150.0

Table 11: Estimates of primary species and School Shark landings in tonnes in 2021 based on 2018-2019 logbook data and provisional 2021 TACs. School Shark landing estimates are provided with 95% confidence intervals.

Sector	Grouped Metiers	Metier Zone	Gummy Shark	Blue Grenadier	Blue-eye Trevalla	Flathead	Pink Ling East	Pink Ling West	School Shark
Gillnet	Gummy Shark	All	1085.1	0.0	0.0	0.4	0.0	0.1	72.9 (60.4 - 86.4)
Hook	Gummy Shark	All	481.5	0.0	0.2	1.2	0.3	0.5	79 (69.1 - 90.1)
Hook	Blue-eye Trevalla	All East	0.5	1.4	86.8	0.0	17.8	0.0	0.9 (0.6 - 1.3)
Hook	Blue-eye Trevalla	All West	0.9	0.7	94.0	0.0	0.0	28.1	2.2 (1.6 - 2.9)
Hook	Pink Ling	All East	0.5	0.8	7.4	0.0	108.8	0.0	0.9 (0.7 - 1.2)
Hook	Pink Ling	All West	0.9	1.3	12.2	0.0	0.0	180.5	1.5 (1.2 - 1.9)
Eastern Trawl	All Shelf	All	41.2	8.5	0.1	1104.7	20.1	0.0	1.7 (1.4 - 2)
Eastern Trawl	All Slope	All East	10.7	507.1	25.8	6.9	278.0	0.0	1 (0.5 - 1.5)
Western Trawl	Ling Total	All West	10.9	332.5	9.5	2.8	0.0	281.4	17.3 (14.5 - 20.6)
Western Trawl	Blue Grenadier	All West	2.3	11327.1	4.4	0.8	0.0	202.7	12.3 (8.6 - 17.3)
Other Metiers		All	37.2	3.1	0.1	1216.0	1.4	1.1	4.4 (3.4 - 5.1)
Total catch			**1671.8**	**12182.5**	**240.4**	**2332.8**	**426.5**	**694.3**	**194.2 (162.2 - 230.4)**

Targeting analysis - Blue Warehou

Catch

Catches of Blue Warehou have declined from over 900t in 1998 to between 4 and 50 tonnes in the last five years (Table 12). Blue Warehou catches are predominately taken by trawl with small catches taken by Danish seine and gillnets. Trawl catches summarised by year and month of fishing shows that catches of Blue Warehou are higher over winter in most years (Figure 1).

Table 12: Catch of Blue Warehou in tonnes by gear type, Danish seine, Gillnet, Hook and line, Trawl and all Other gears. Log Total represents the total catch reported in logbooks and CDR the total landed catch from catch disposal records.

Year	Danish seine	Gillnet	Hook	Other	Trawl	Log Total	CDR
1998	0.6	80.5	0.1	0.6	821.4	903.2	1001.5
1999	0.7	270.2	3.0	2.5	314.6	591.0	642.5
2000	0.5	74.1	0.7	1.6	393.3	470.2	515.4
2001	1.4	25.2	0.3	0.0	258.6	285.5	328.6
2002	1.0	4.8	0.0	0.0	284.6	290.5	317.4
2003	1.1	1.8	0.1	0.0	230.9	234.0	253.7
2004	0.4	1.3	0.0	0.0	230.8	232.4	262.0
2005	0.4	1.3	0.8	0.0	286.5	289.1	258.9
2006	0.3	0.8	0.2	0.0	378.2	379.5	387.3
2007	0.8	1.2	0.1	0.0	175.7	177.8	196.1
2008	5.4	1.1	0.0	0.0	156.7	163.3	157.5
2009	1.7	1.6	0.0	0.0	131.9	135.2	138.3
2010	2.9	3.8	0.1	0.0	122.6	129.3	131.8
2011	1.5	8.2	0.0	0.0	93.6	103.3	110.7
2012	0.6	4.4	0.0	0.0	47.3	52.3	50.7
2013	1.5	2.0	0.0	0.0	64.5	68.0	66.5
2014	0.4	0.1	0.0	0.0	14.8	15.3	14.6
2015	0.7	0.0	0.0	0.0	4.7	5.4	3.6
2016	2.2	0.1	0.0	0.0	16.5	18.8	9.1
2017	0.7	0.4	0.0	0.0	15.3	16.4	26.3
2018	3.3	0.1	0.0	0.0	35.6	39.0	47.3
2019	1.2	0.4	0.0	0.0	16.2	17.8	22.1

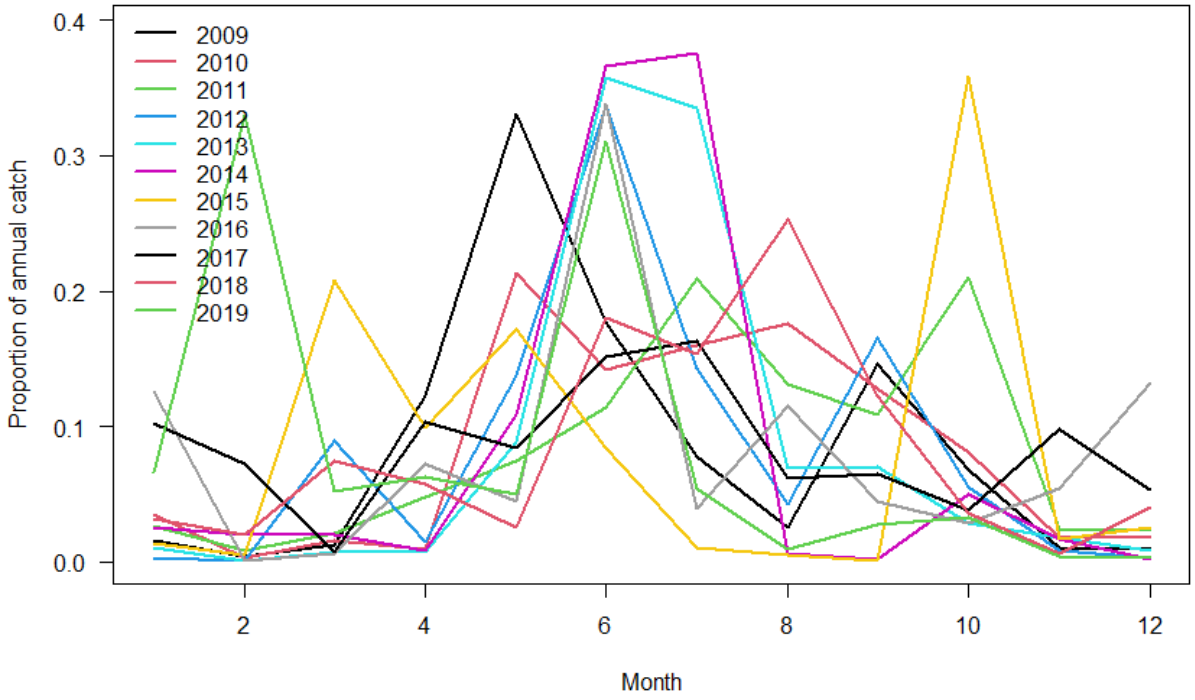

Figure 1: Monthly proportion of annual trawl catch of Blue Warehou.

CPUE and depth of fishing

Standardized CPUE for eastern Blue Warehou (zones 10-30) has been at a record low for over a decade (Figure 2). The distribution of fishing depths has been quite variable since 2013, however, the number of logbook records reporting eastern Blue Warehou has declined to less than 300 since 2013 so this variability may be associated with reduced availability of Blue Warehou rather than a change in fishing patterns (Figure 3).

Standardized CPUE for western Blue Warehou (zones 40-50) has remained well below the highs of the late 1980s and early 1990s for last two decades (Figure 4). CPUE increased slightly in 2017, however, it has subsequently declined. Depth of fishing for western Blue Warehou over the last decade has been shallower than preceding decades, however, like in the east, the number of logbook records has declined substantially (Figure 5).

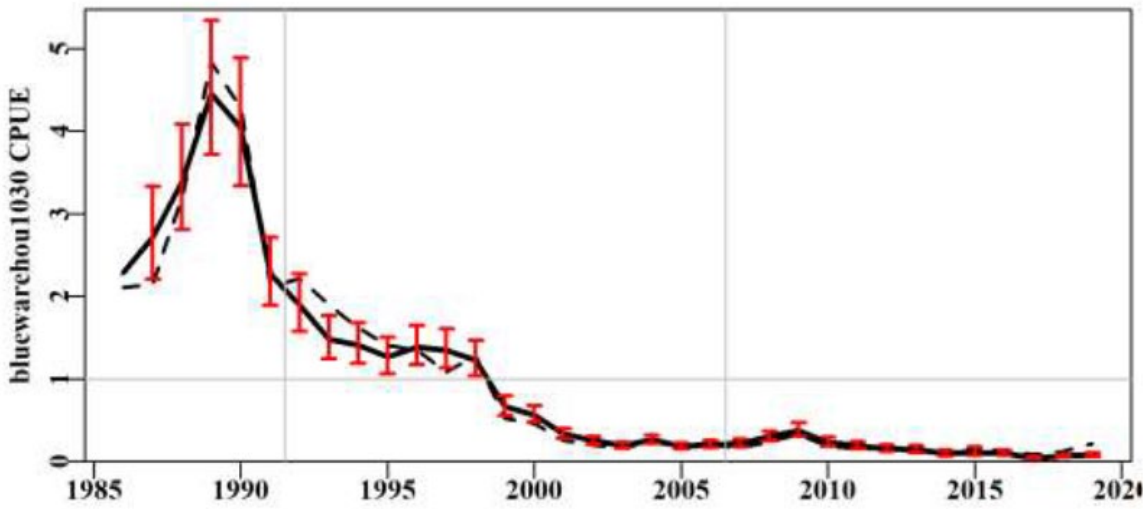

Figure 2: Standardized trawl CPUE of eastern Blue Warehou between 1986 and 2019. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

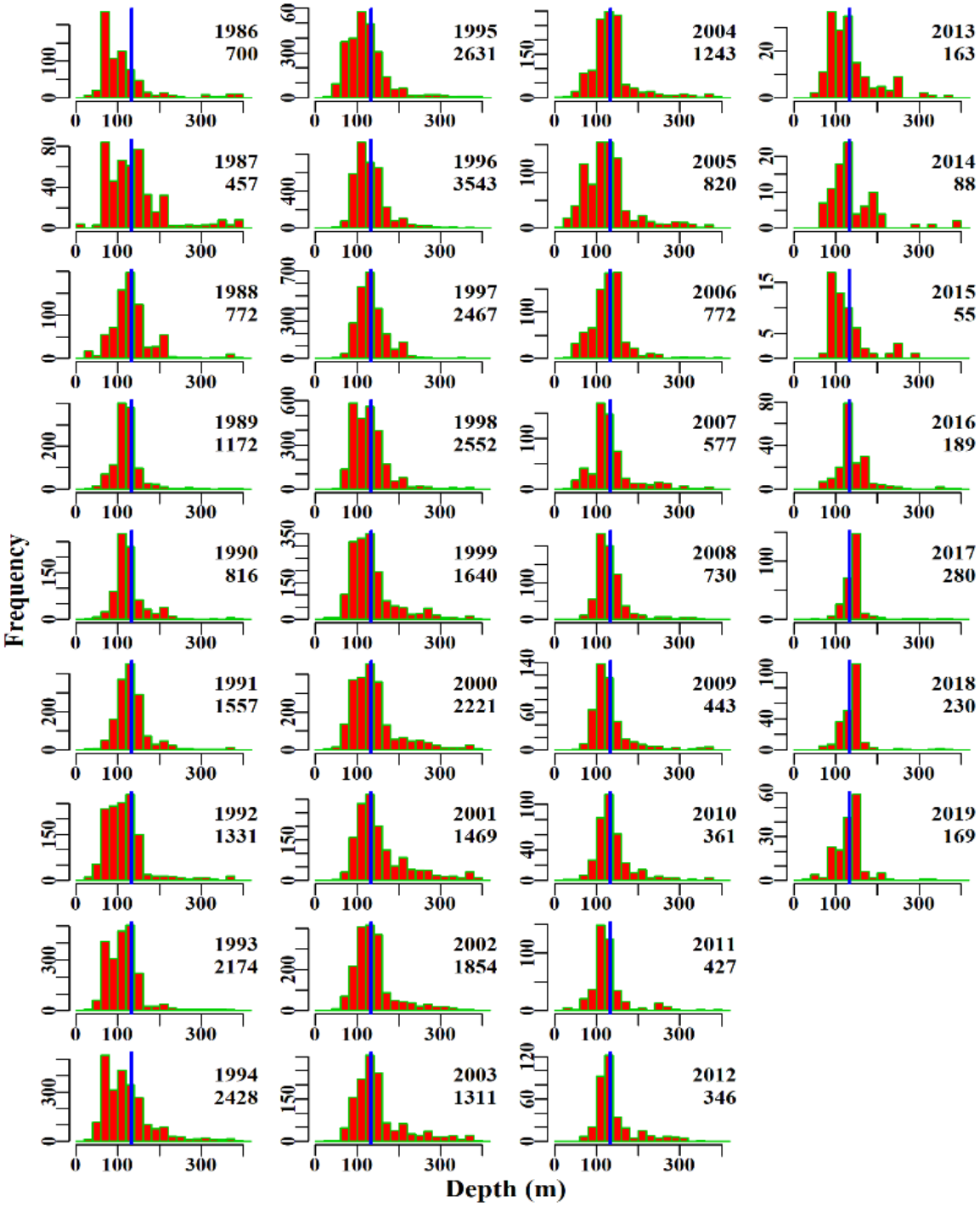

Figure 3: Histogram of annual fishing depths of eastern Blue Warehou between 1986 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

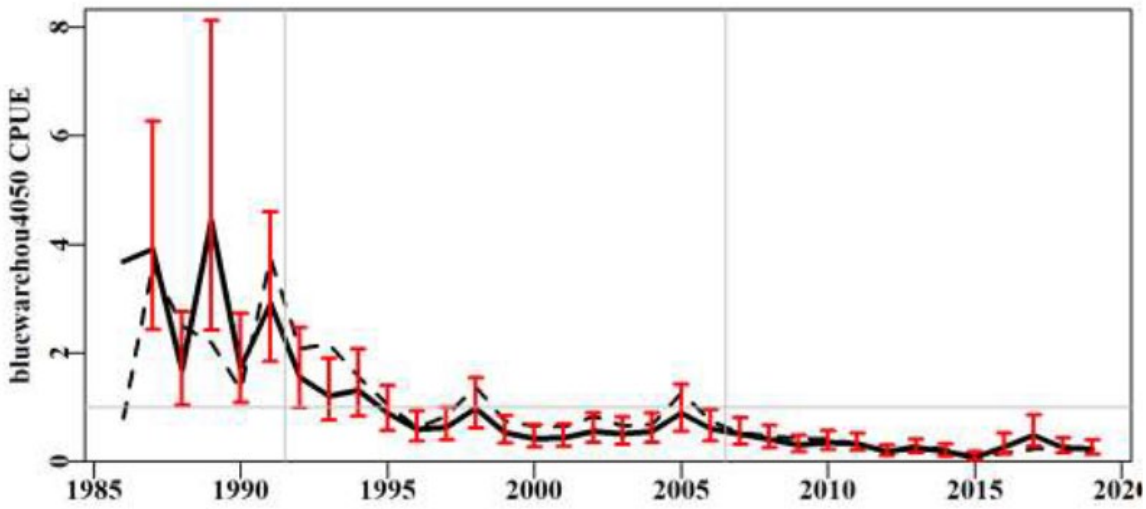

Figure 4: Standardized trawl CPUE of western Blue Warehou. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

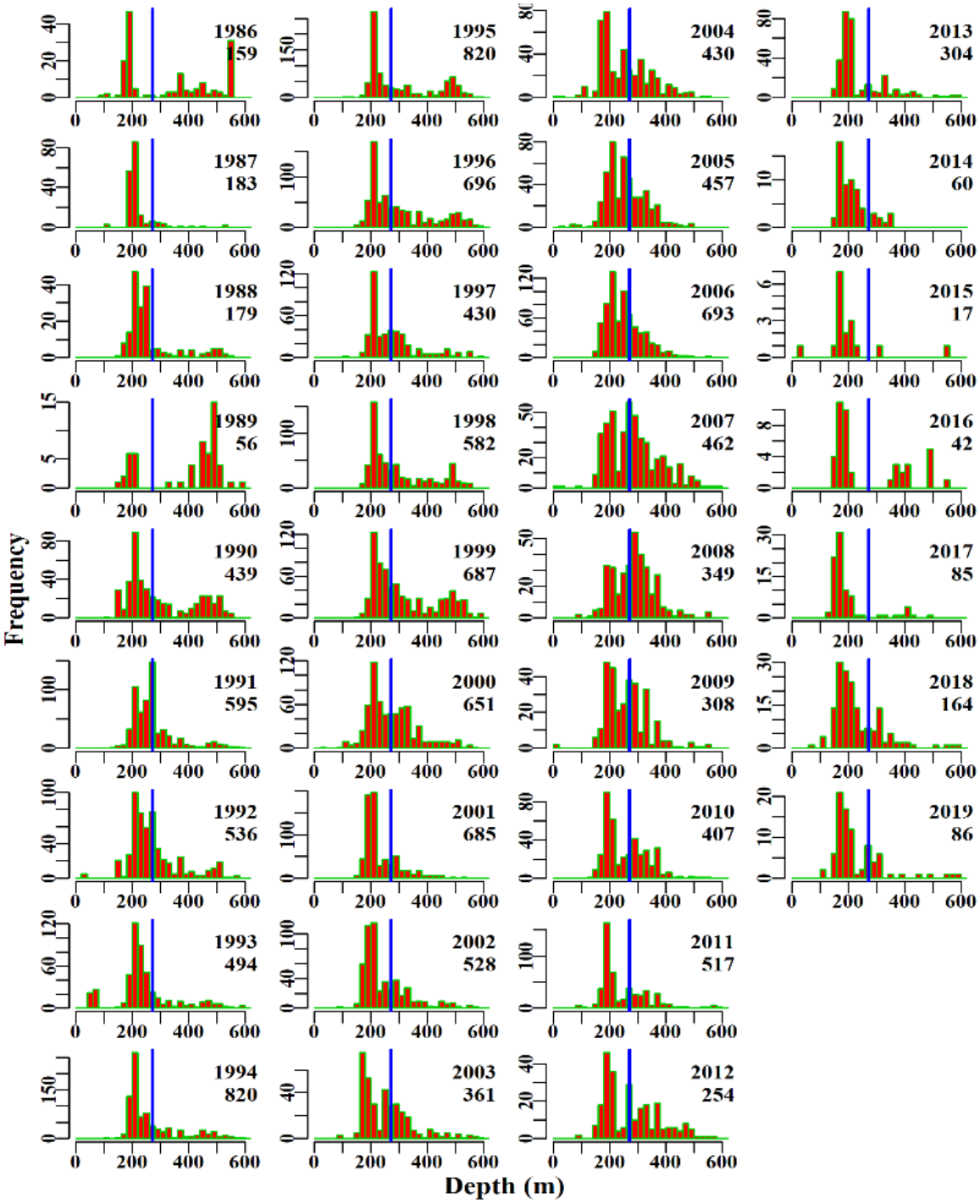

Figure 5: Histogram of annual fishing depths of western Blue Warehou between 1986 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

Spatial distribution of fishing

In the late 1990s and early 2000s large catches of Blue Warehou were taken by trawl vessels operating off the south coast of New South Wales, along the eastern and western coast of Tasmania and western Victoria (Figure 6). Between 2004 and 2011, while landed catches declined from 200-350 tonnes to 90 tonnes the spatial pattern of catches was little changed (Figure 7). In recent years (2012-2019) catches have declined still further to be less than 50t per annum since 2013 (Figure 8). With recent landed catches at such low levels, identifying potential changes in the spatial distribution of Blue Warehou catches becomes more challenging, however, Figure 8 provides no evidence that the distribution of the stock has changed.

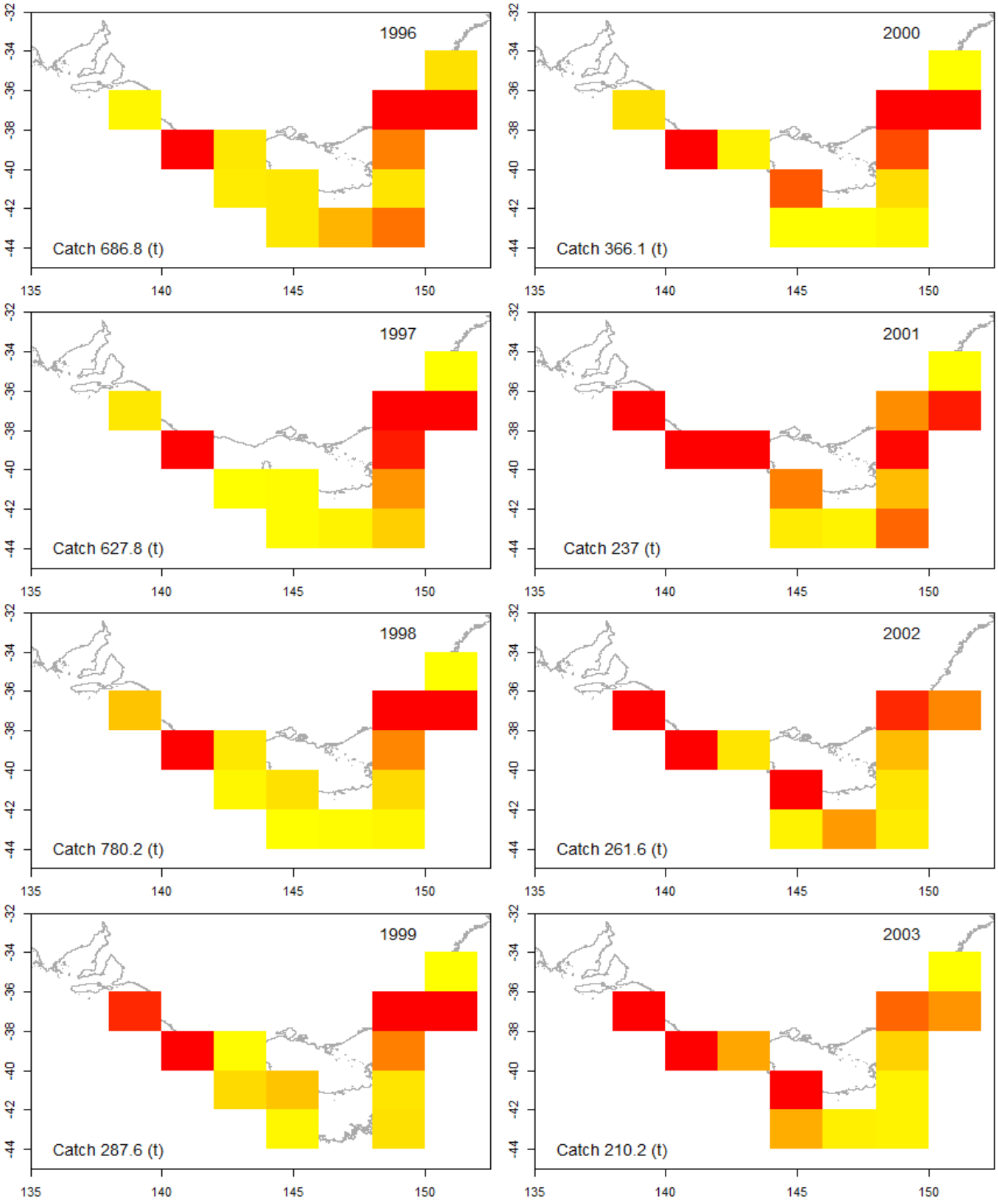

Figure 6: Spatial distribution of annual Blue Warehou catch of trawl vessels 1996 - 2003. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

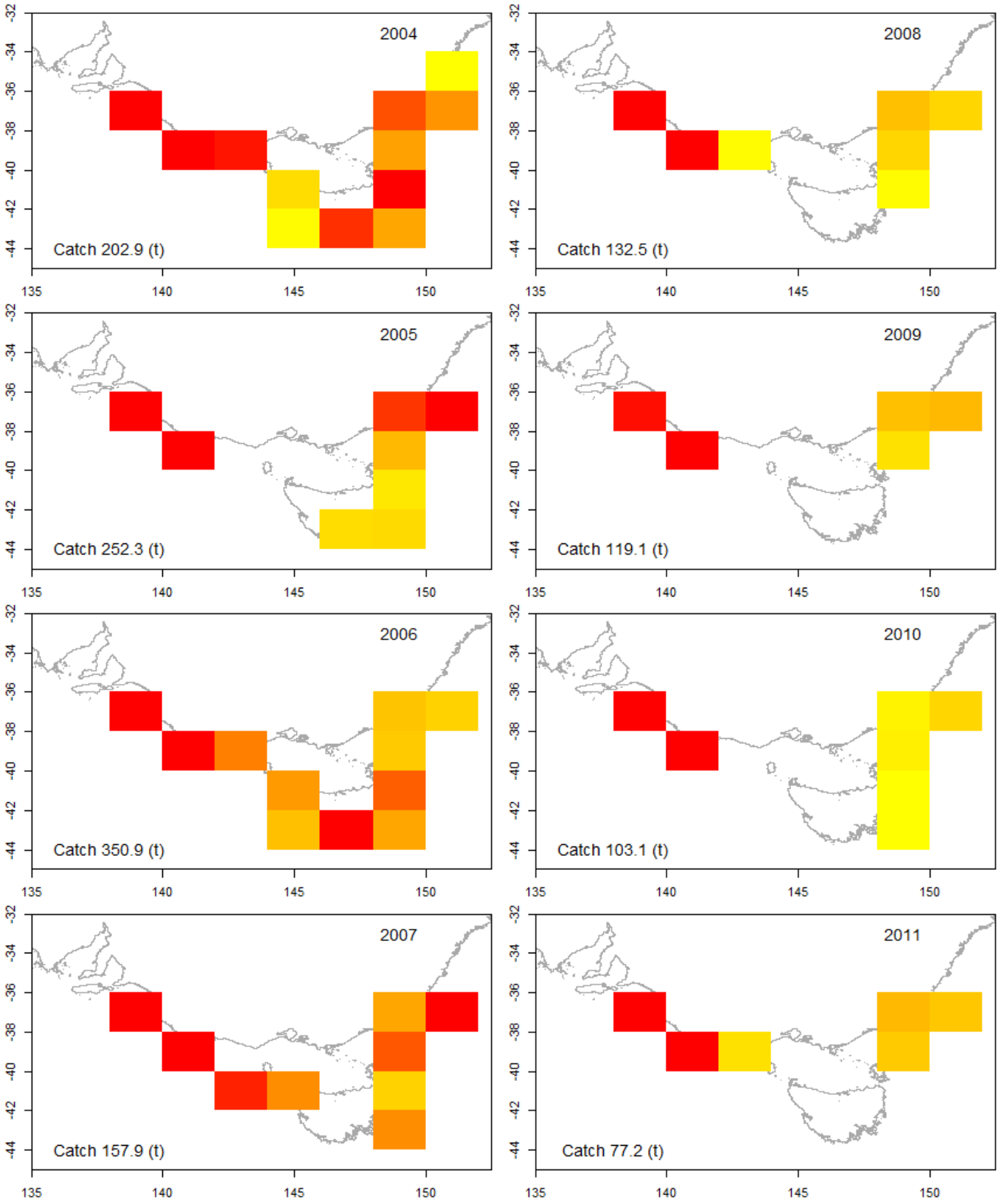

Figure 7: Spatial distribution of annual Blue Warehou catch of trawl vessels 2004 - 2011. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

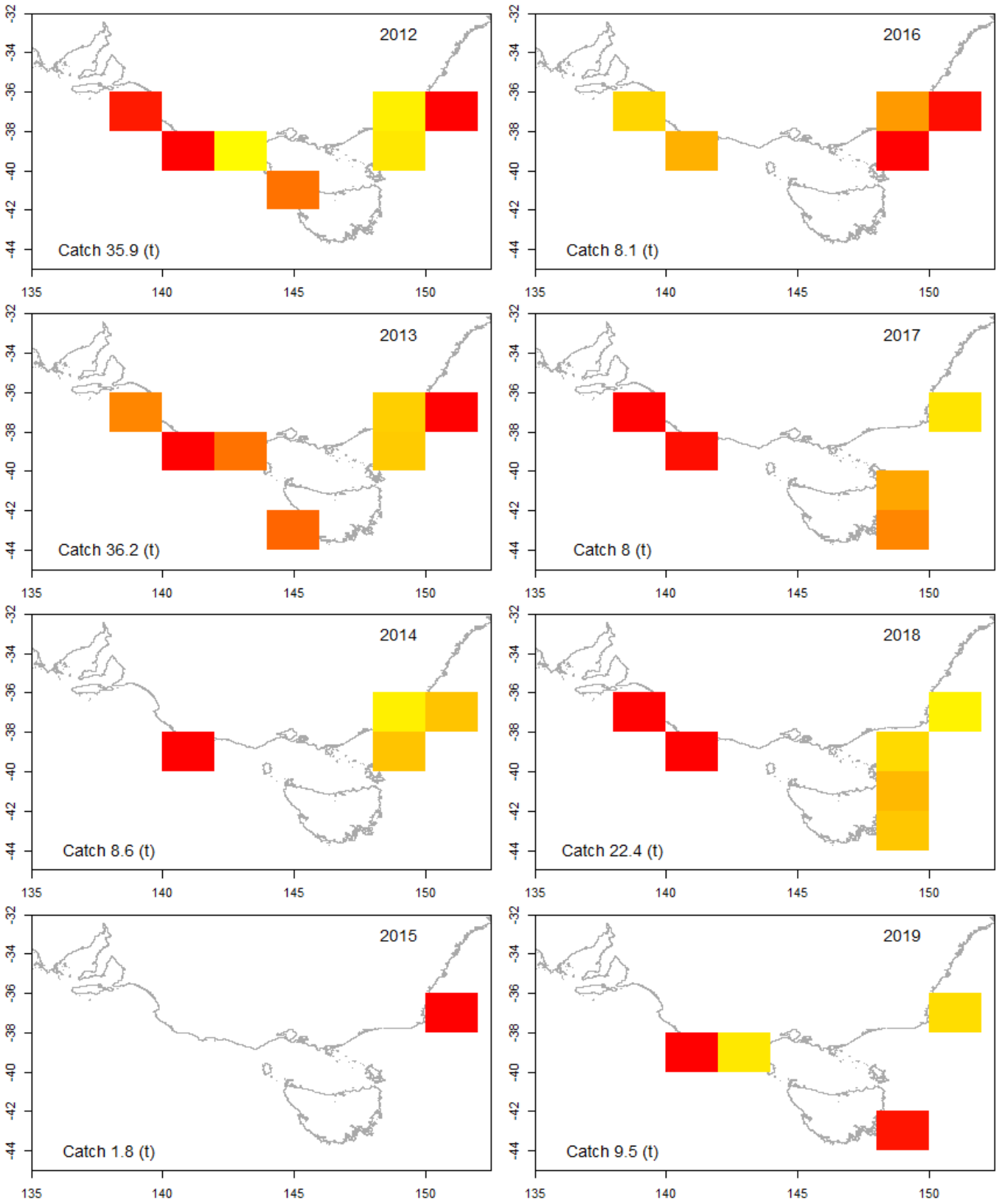

Figure 8: Spatial distribution of annual Blue Warehou catch of trawl vessels 2012 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

Catch by vessel

Annual Blue Warehou catch by vessel shows no evidence of any vessels reporting consistently large catches in recent years that may suggest potential targeting of Blue Warehou (Figure 9).

Figure 9: Bubble plot of annual Blue Warehou catch of trawl vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting Blue Warehou (lower).

Targeting analysis - eastern Gemfish

Catch

Catches of eastern Gemfish have declined from around 200t in 1998 to 25 - 50 tonnes between 2014 and 2018 (Table 13). Eastern Gemfish catch increased to 70 tonnes in 2019. While eastern Gemfish catches are predominately taken by trawl, 10-15% has been taken by the hook and line sector in recent years. Trawl catches summarised by year and month of fishing shows that catches of eastern Gemfish are higher over winter in most years (Figure 10).

Table 13: Catch of eastern Gemfish in tonnes by gear type, Danish seine, Gillnet, Hook and line, Trawl and all Other gears. Log Total represents the total catch reported in logbooks and CDR the total landed catch from catch disposal records.

Year	Danish seine	Gillnet	Hook	Other	Trawl	Log Total	CDR
1998	0.0	2.1	1.9	0.1	191.0	195.2	210.9
1999	0.0	1.1	4.7	0.3	119.6	125.7	159.2
2000	0.0	1.0	1.2	0.1	72.0	74.3	93.0
2001	0.0	1.7	1.3	0.0	69.0	72.0	86.4
2002	0.0	1.9	2.1	0.0	44.2	48.3	61.7
2003	0.6	0.2	1.6	0.0	53.7	56.1	74.8
2004	0.0	0.0	3.1	0.0	60.9	64.0	75.9
2005	0.0	0.0	4.3	0.0	70.6	74.9	88.2
2006	0.1	0.0	5.1	0.0	70.6	75.8	86.9
2007	0.0	0.0	7.6	0.0	74.0	81.7	79.5
2008	1.4	0.0	14.5	0.0	110.7	126.6	107.4
2009	0.8	0.0	12.0	0.0	67.5	80.3	85.8
2010	0.0	0.0	13.0	0.0	75.5	88.5	92.5
2011	0.6	0.0	8.1	0.0	59.7	68.3	70.6
2012	0.5	0.0	7.1	0.0	57.1	64.7	71.9
2013	0.2	0.0	4.8	0.0	45.3	50.4	57.7
2014	1.0	0.0	9.8	0.0	25.2	36.0	36.1
2015	0.1	0.0	4.7	0.0	28.7	33.5	35.3
2016	0.7	0.0	4.8	0.0	18.7	24.1	22.1
2017	0.0	0.0	4.5	0.0	31.9	36.4	37.0
2018	0.1	0.0	3.3	0.0	30.4	33.8	29.9
2019	0.0	0.0	8.9	0.0	63.0	72.0	70.4

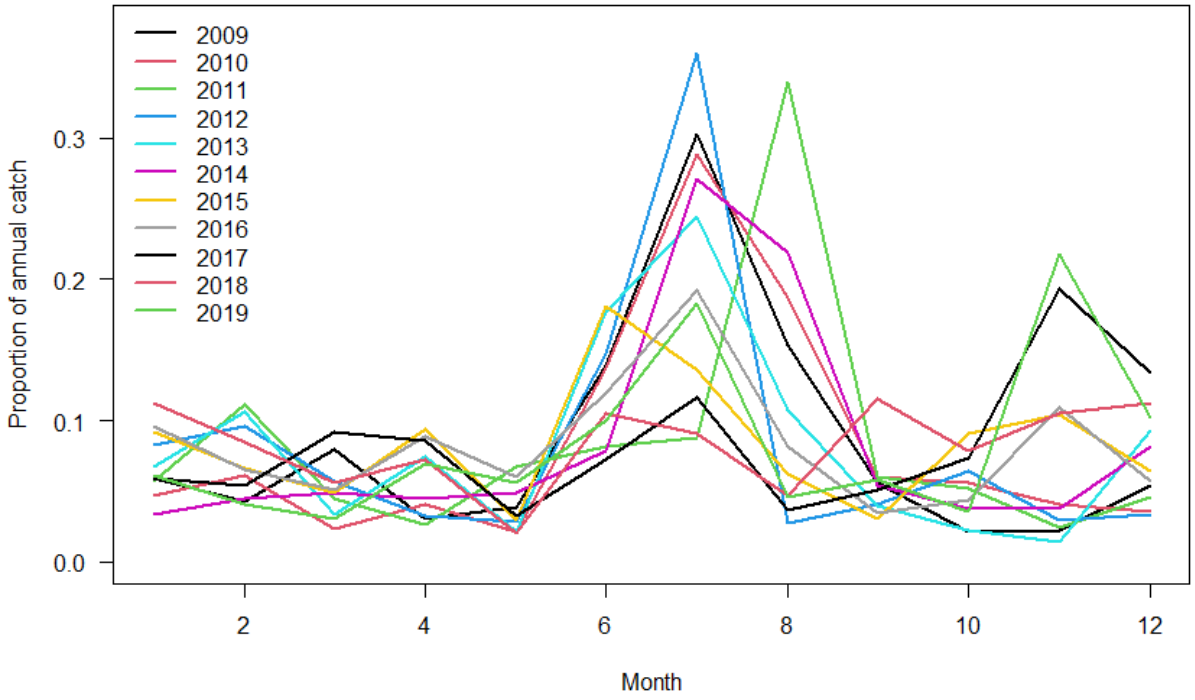

Figure 10: Monthly proportion of annual trawl catch of eastern Gemfish.

CPUE and depth of fishing

Standardized CPUE for the non-spawning trawl fishery for eastern Gemfish has remained relatively stable since 2014 at around 10% of the peak in 1987 and around 25% of the level in the mid-1990s (Figure 11). The distribution of fishing depths for non-spawning fishery is bimodal in most years with eastern Gemfish caught both the shelf and the slope (Figure 12).

Standardized CPUE for the spawning trawl fishery for eastern Gemfish has increased from its lowest point in 2016 to be around half the level reached in 2008-2010 (Figure 13). The depth of fishing in the spawning fishery for eastern Figure 14 shows a reduction in the proportion of shots shallower than 400m in the mid-2000s, compared with the 1990s and early 2000s. In the last three years there has been an increase in the proportion of shots shallower than 400m.

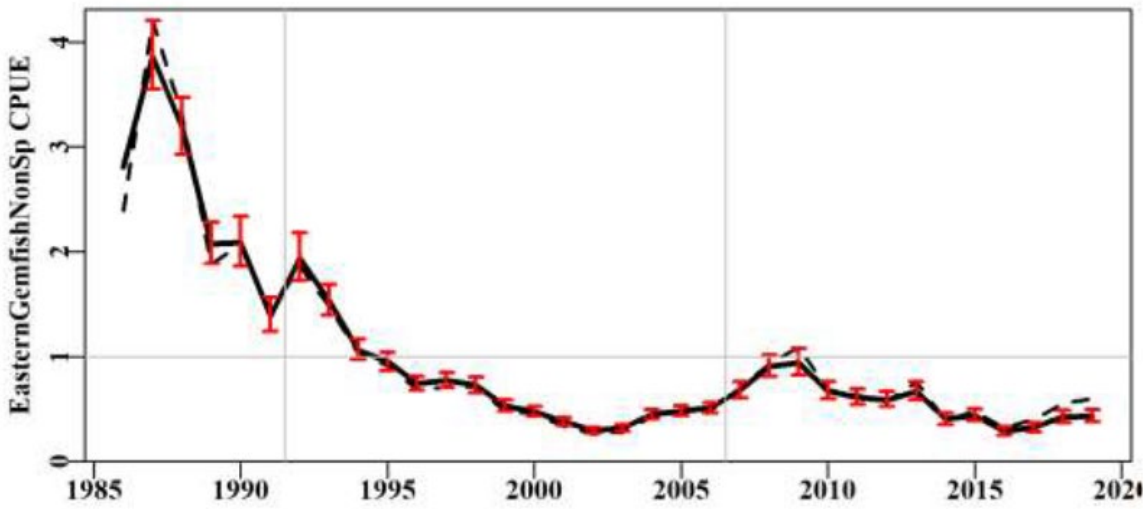

Figure 11: Standardized CPUE for the non-spawning trawl fishery for eastern Gemfish. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

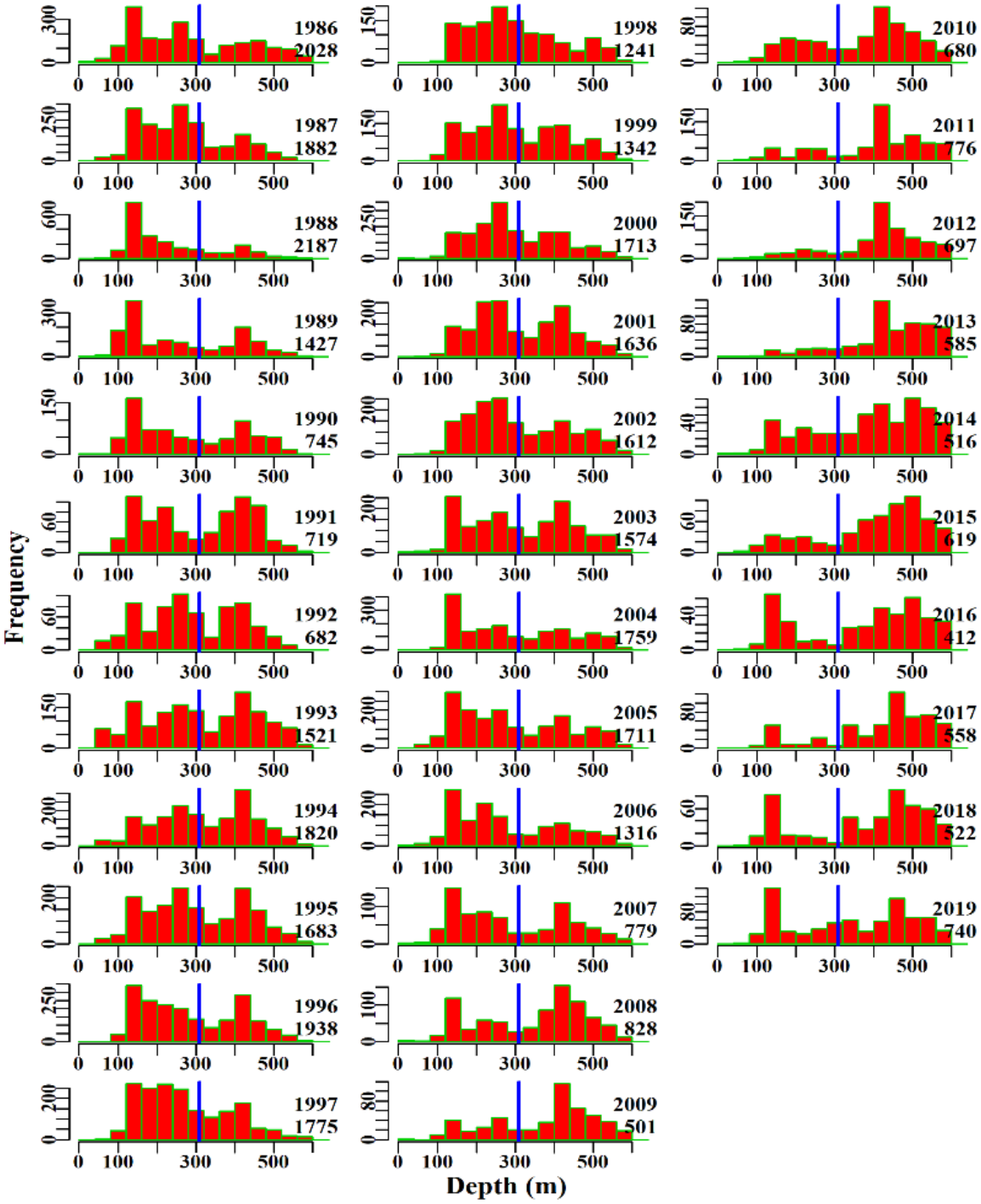

Figure 12: Histogram of annual fishing depths for the eastern Gemfish non-spawning fishery between 1986 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

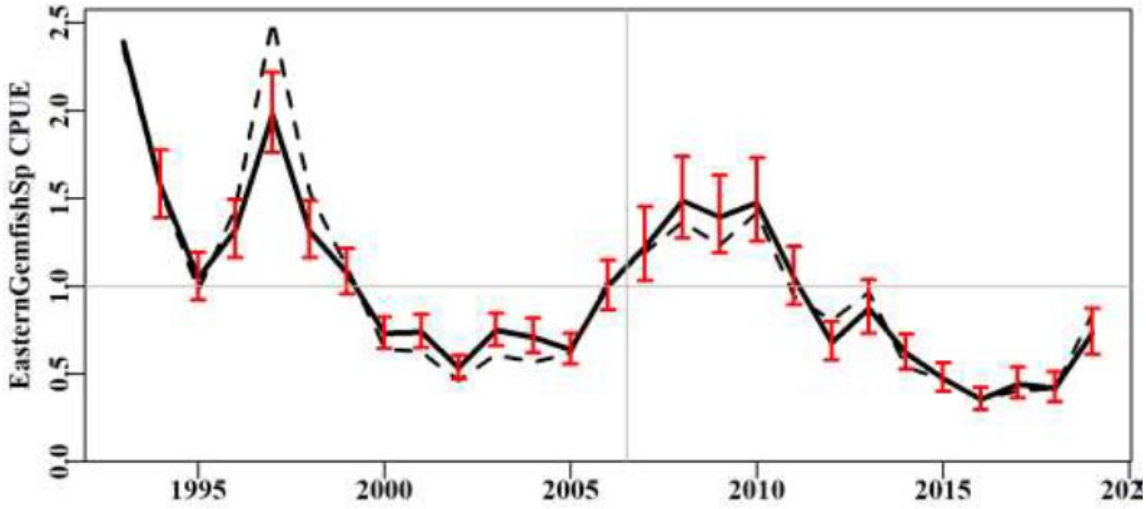

Figure 13: Standardized CPUE for the non-spawning trawl fishery for eastern Gemfish. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

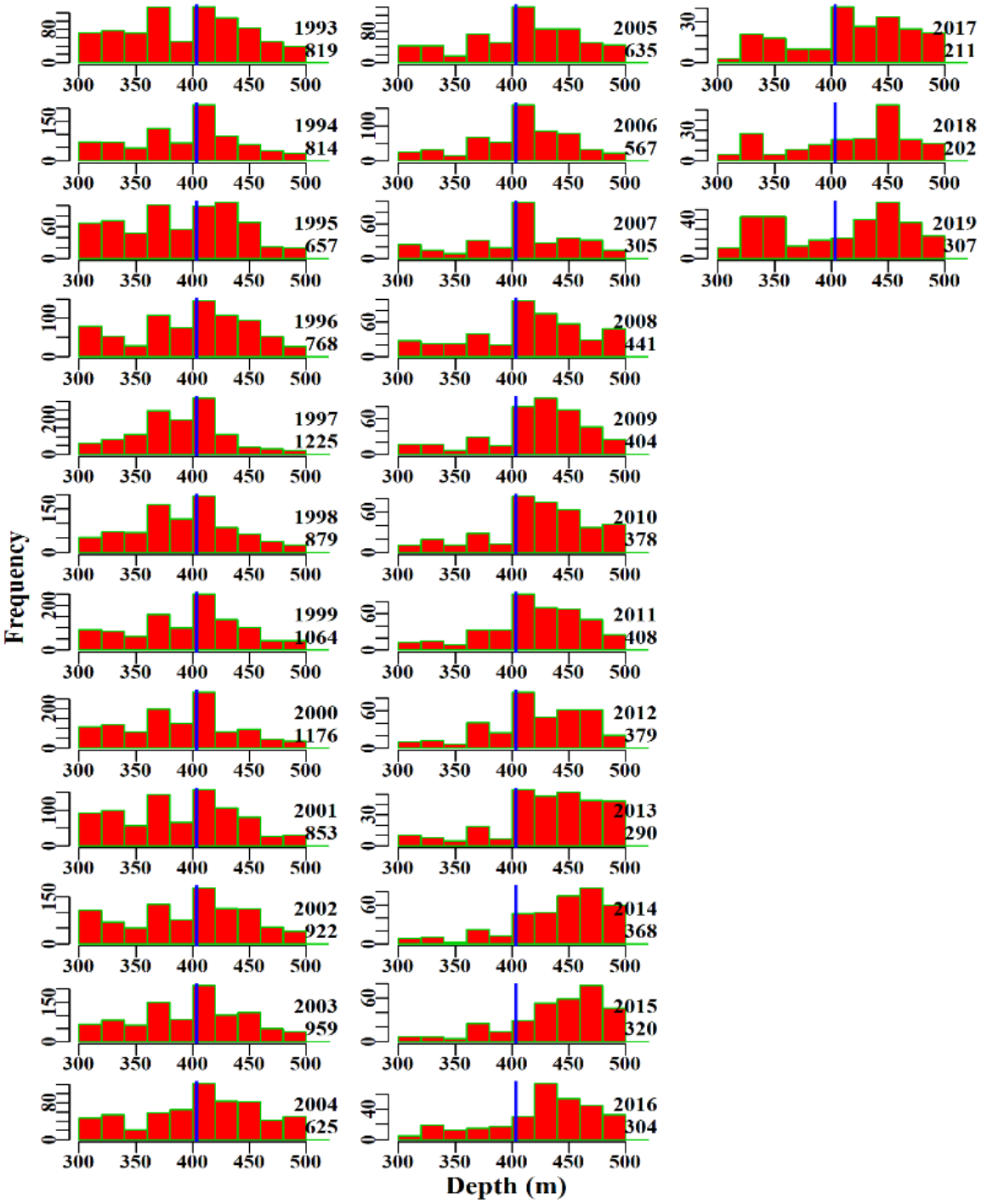

Figure 14: Histogram of annual fishing depths for the eastern Gemfish spawning fishery between 1993 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

Spatial distribution of fishing

Since the late 1990s there has been little change in the spatial distribution of eastern Gemfish catches with the majority of catches taken from New South Wales, western Victoria and the east coast of Tasmania (Figures 16-18). Some catch is also taken from the west coast of Tasmania and since 2014 the proportion of eastern Gemfish catch taken there has increased (Figure 15). Catches of Gemfish in western Victoria and South Australia are assumed to be part of the western stock and are not shown on Figures 16-18.

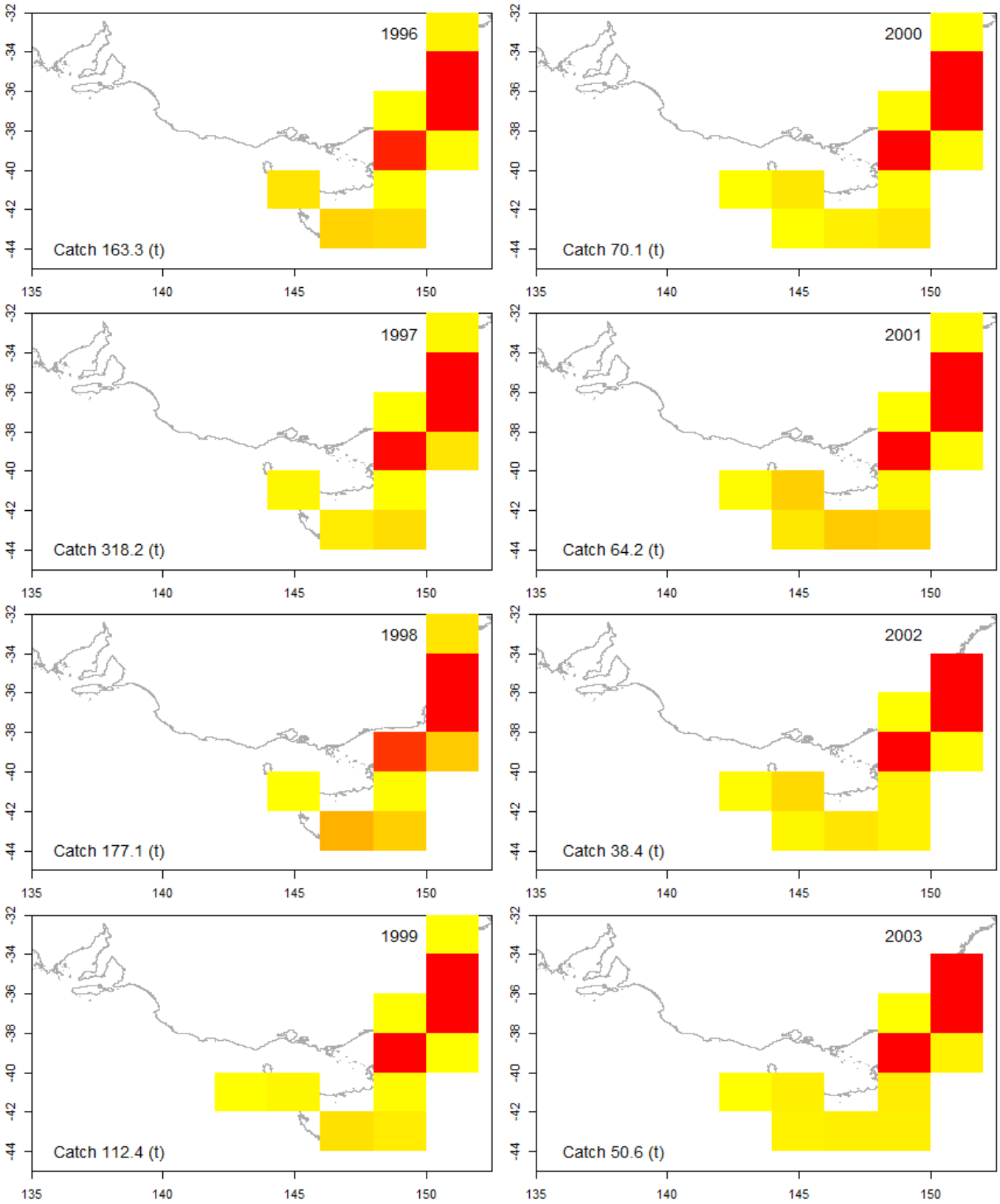

Figure 16: Spatial distribution of annual eastern Gemfish catch of trawl vessels 1996 - 2003. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

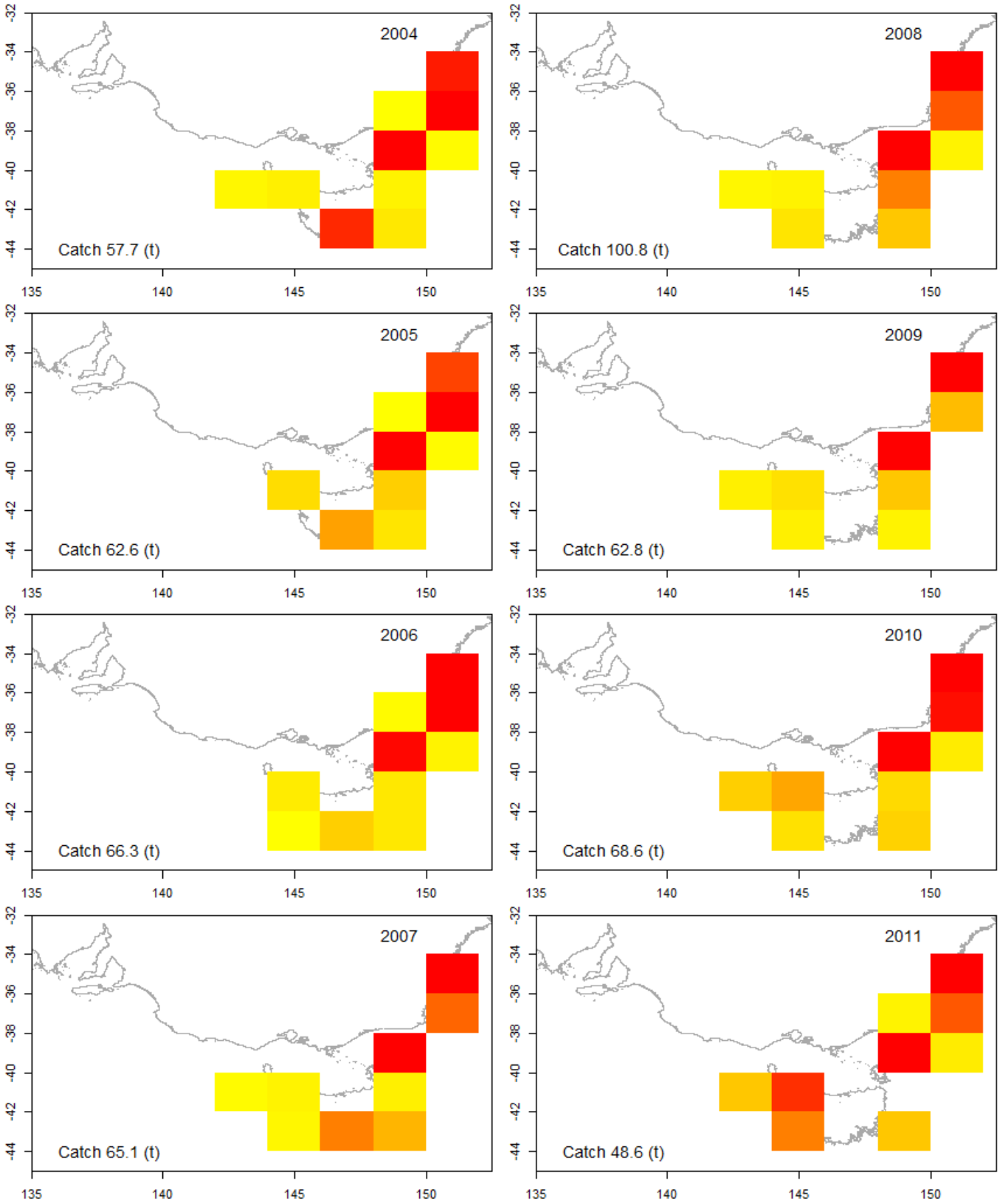

Figure 17: Spatial distribution of annual eastern Gemfish catch of trawl vessels 2004 - 2011. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

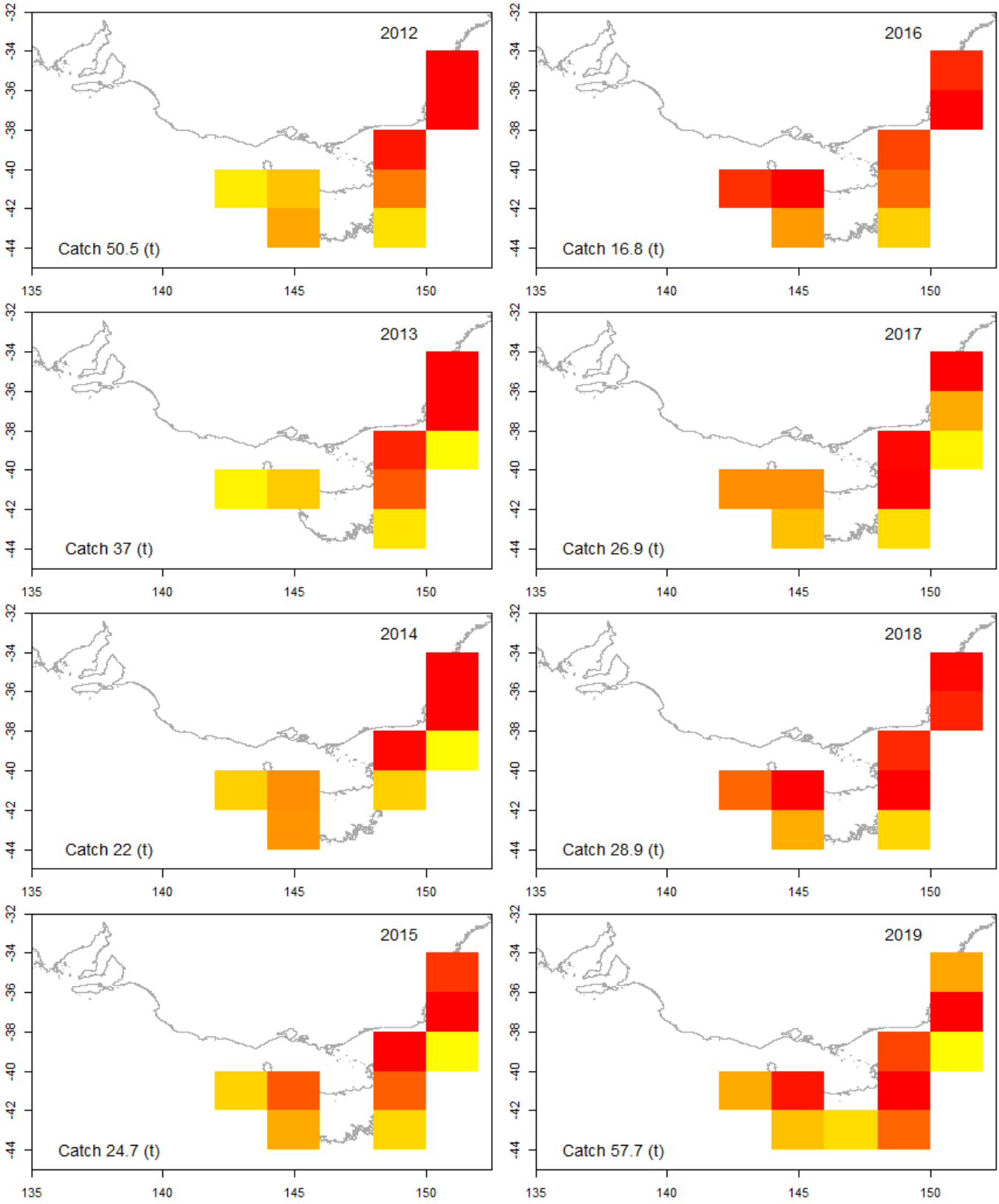

Figure 15: Spatial distribution of annual eastern Gemfish catch of trawl vessels 2012 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

Catch by vessel

Annual eastern Gemfish catch by vessel shows no evidence of any vessels reporting consistently large catches in recent years (Figure 18). The larger catch in 2019 appears to be relatively evenly distributed among individual trawl vessels.

Figure 18: Bubble plot of annual eastern Gemfish catch of trawl vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting eastern Gemfish (lower).

Targeting analysis - Redfish

Catch

Catches of Redfish have declined from over 1700t in 1998 to between 25 and 45 tonnes in the most recent four years (Table 14). Redfish catches are almost exclusively taken by trawl. Trawl catches summarised by year and month of fishing shows that catches of eastern Redfish are higher over winter in most years, although there is level of variability among years (Figure 19).

Table 14: Catch of Redfish in tonnes by gear type, Danish seine, Gillnet, Hook and line, Trawl and all Other gears. Log Total represents the total catch reported in logbooks and CDR the total landed catch from catch disposal records.

Year	Danish seine	Gillnet	Hook	Other	Trawl	Log Total	CDR
1998	0.4	1.1	0.7	3.8	1544.4	1550.4	1751.7
1999	0.3	2.2	0.6	2.8	1107.4	1113.3	1257.7
2000	0.6	1.5	0.6	0.1	752.2	755.0	836.1
2001	0.3	2.8	0.1	0.0	737.9	741.1	795.3
2002	0.2	4.6	0.0	0.0	800.8	805.7	885.0
2003	28.4	0.2	0.0	0.0	586.2	614.8	678.6
2004	0.6	0.0	0.0	0.0	473.2	473.9	499.3
2005	1.0	0.0	0.0	0.0	482.2	483.2	532.8
2006	0.2	0.0	0.0	0.0	324.6	324.8	321.9
2007	0.1	0.0	0.0	0.0	214.3	214.4	230.6
2008	0.3	0.0	0.1	0.0	183.1	183.5	201.3
2009	0.3	0.0	0.1	0.0	158.7	159.2	182.3
2010	0.2	0.0	0.0	0.0	151.3	151.6	166.0
2011	0.0	0.2	0.0	0.0	86.3	86.5	98.9
2012	0.0	0.1	0.0	0.0	65.6	65.6	72.5
2013	0.4	0.0	0.1	0.0	61.9	62.4	66.2
2014	1.1	0.0	0.6	0.0	85.1	86.7	95.7
2015	0.0	0.0	0.0	0.0	52.0	52.0	59.0
2016	0.3	0.1	0.0	0.0	36.5	36.8	42.5
2017	0.0	0.1	0.1	0.0	24.9	25.1	27.1
2018	0.1	0.0	0.0	0.0	29.5	29.6	33.2
2019	0.4	0.0	0.0	0.0	21.4	21.8	27.1

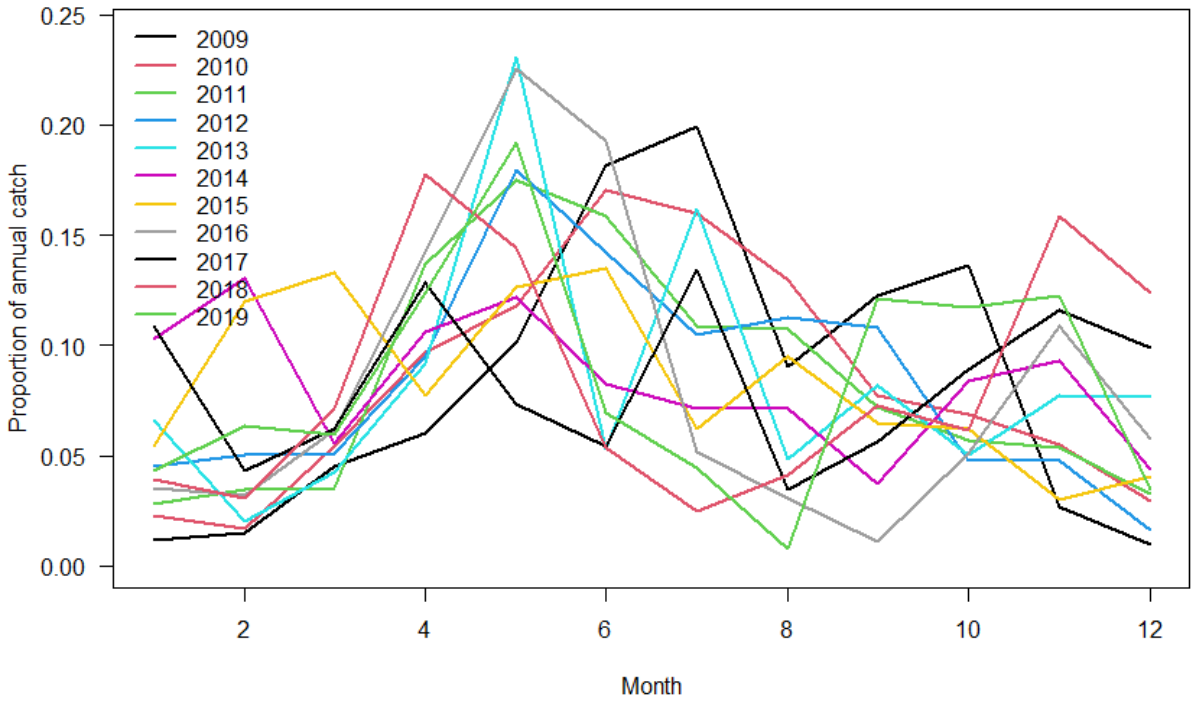

Figure 19: Monthly proportion of annual trawl catch of eastern Redfish.

CPUE and depth of fishing

The standardized CPUE for eastern Redfish (zones 10-20) peaked in 1993 and with the exception of a brief period in the late 1990s has steadily declined since then (Figure 20). Historically the majority of fishing for Redfish was shallower than 150m, however, there was some catch down to 400m (Figure 21). In the last five years the proportion of logbook records reporting Redfish deeper than 150m has declined.

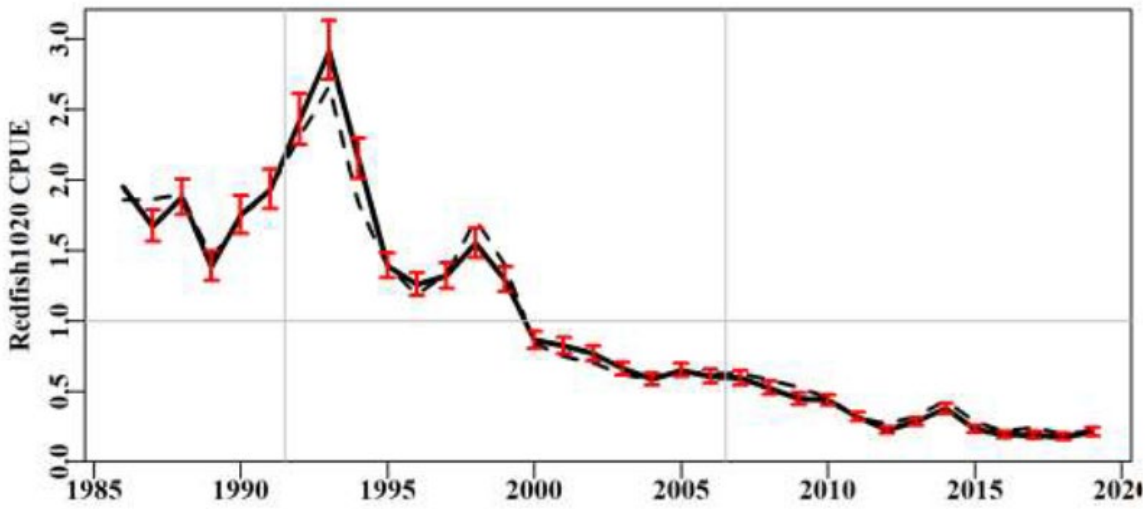

Figure 20: Standardized trawl CPUE of eastern Redfish. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

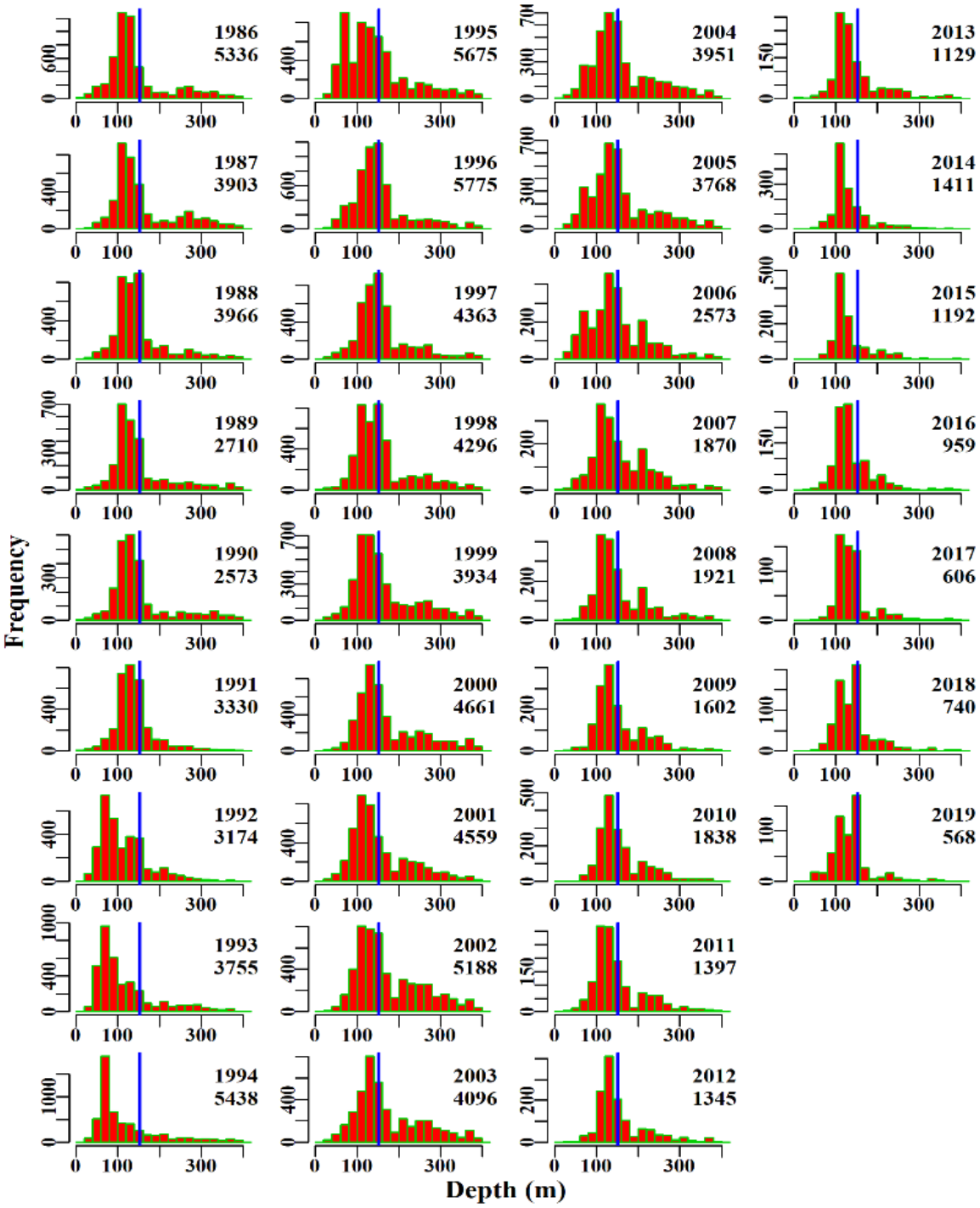

Figure 21: Histogram of annual fishing depths of Redfish between 1986 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

Spatial distribution of fishing

Since the late 1990s the majority of eastern Redfish catch has been taken off the coast of New South Wales (Figures 22-24). While there has been some catch off the east coast of Tasmania and in some years the west coast of Tasmania and Victoria, these catches have been small compared with the hot spot off New South Wales.

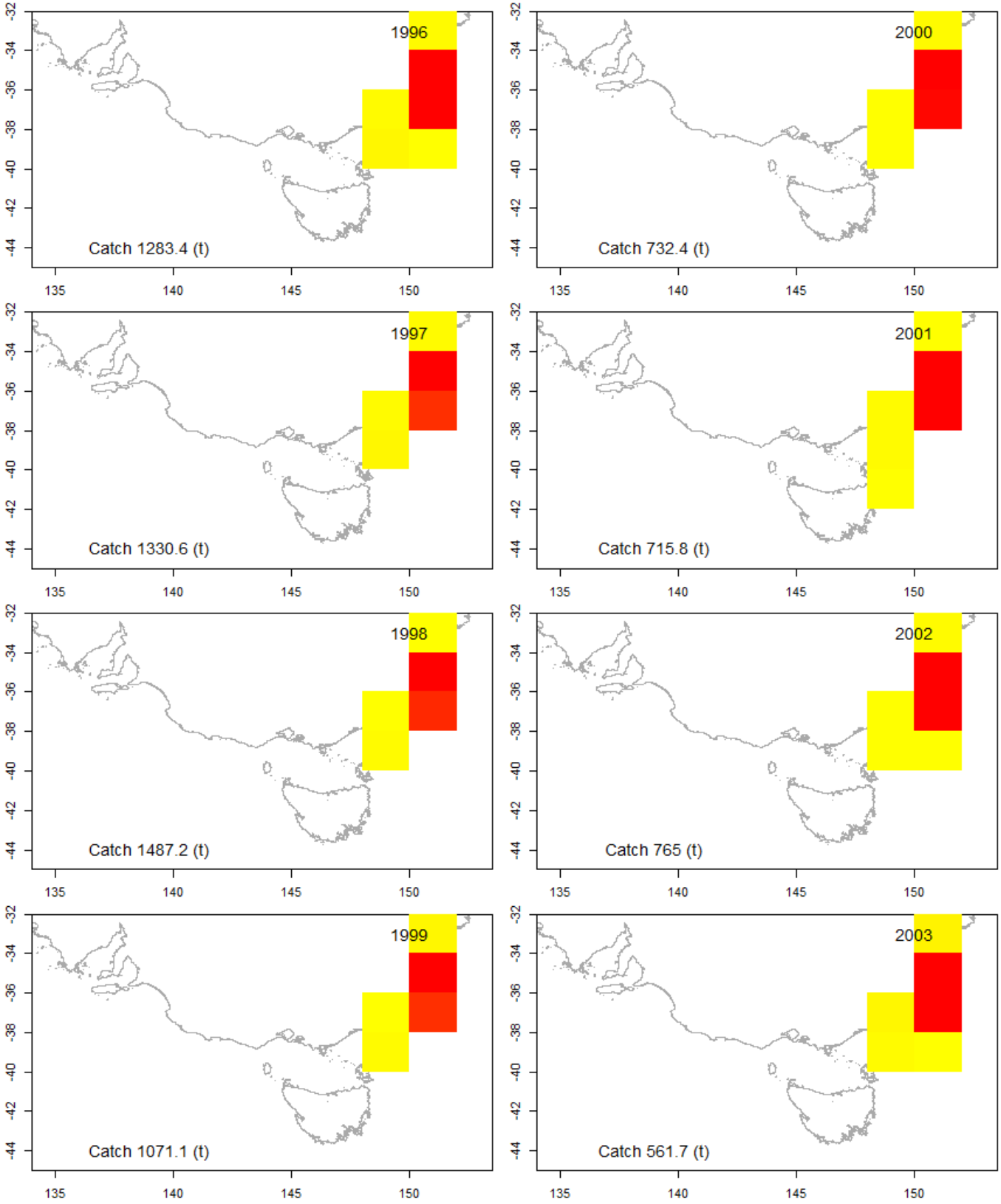

Figure 22: Spatial distribution of annual eastern Redfish catch of trawl vessels 1996 - 2003. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

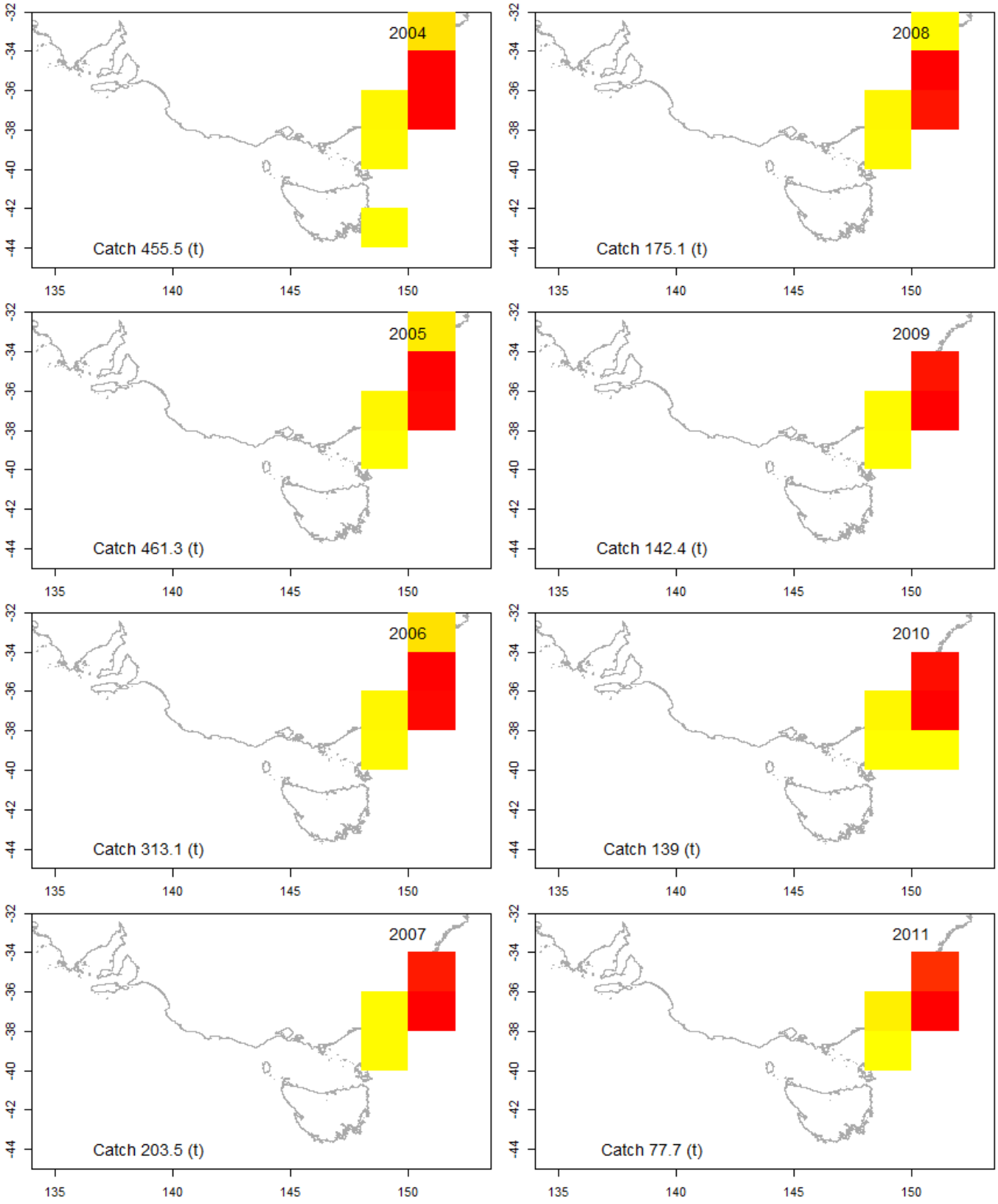

Figure 23: Spatial distribution of annual eastern Redfish catch of trawl vessels 2004 - 2011. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

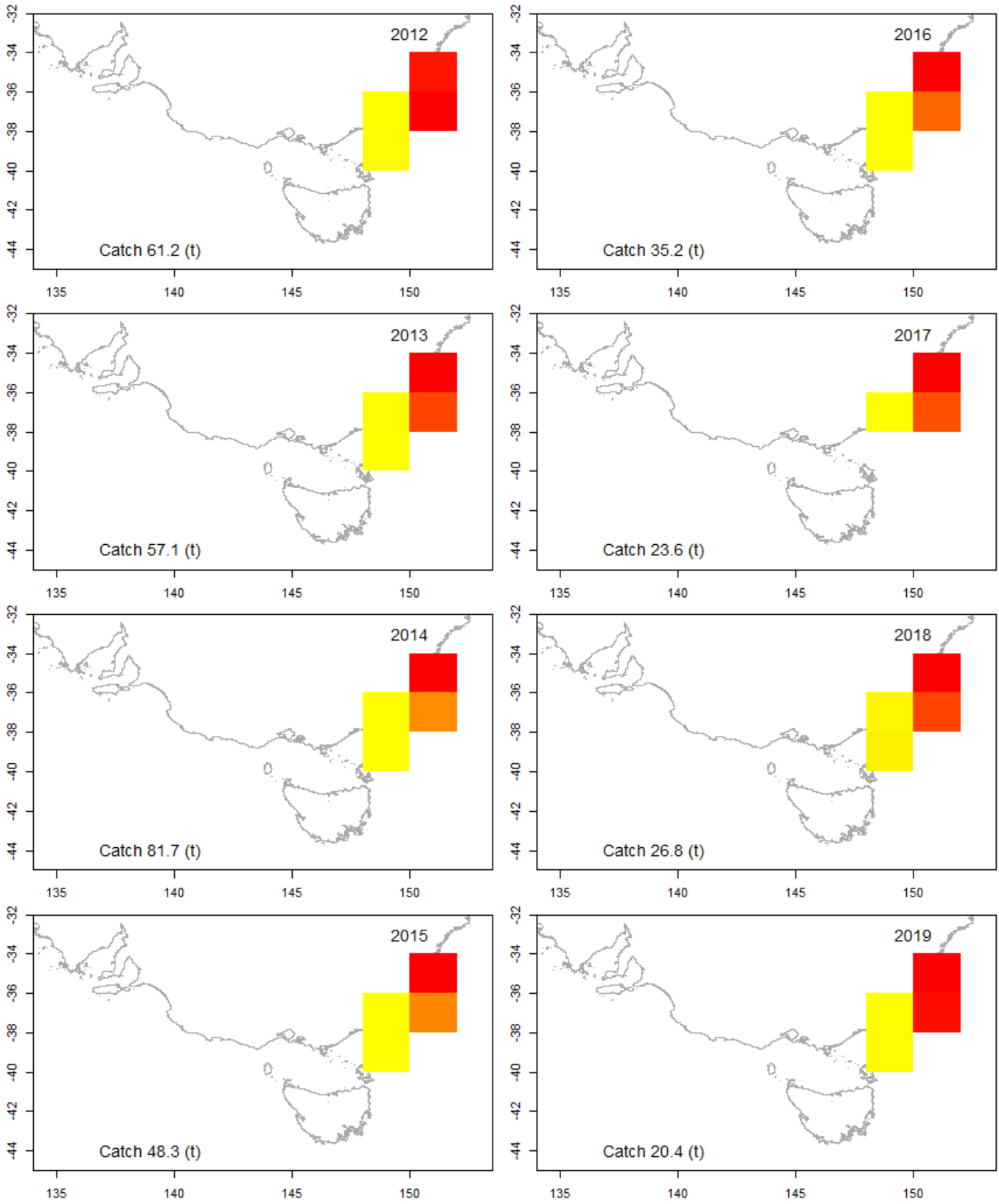

Figure 24: Spatial distribution of annual eastern Redfish catch of trawl vessels 2012 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

Catch by vessel

Annual eastern Redfish catch by vessel shows two vessels with catches that are consistently larger than other vessels over past decade (Figure 25). While these catches remain small in absolute terms and one of these vessels did not report any Redfish catch in 2019 it may warrant further investigation.

Figure 25: Bubble plot of annual eastern Redfish catch of trawl vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting eastern Redfish (lower).

Targeting analysis - School Shark

Catch

Landings of School Shark averaged approximately 210t between 2001 and 2009 and dropped to an average of 190t following the introduction of lower quotas from 2010 (Table 15). School Shark are predominately landed by gillnet and hook gears, however, around 15% of the catch has been landed by demersal trawlers operating west of Tasmania in recent years. Gillnet catches summarised by year and month of fishing show catches of School Shark decline slightly in winter and spring but are otherwise reasonably consistent over the season (Figure 26). A similar pattern is apparent for hook catches (Figure 27). Trawl catches are highest over winter with little variability among years (Figure 28).

Table 15: Catch of School Shark in tonnes by gear type, Danish seine, Gillnet, Hook and line, Trawl and all Other gears. Log Total represents the total catch reported in logbooks and CDR the total landed catch from catch disposal records.

Year	Danish seine	Gillnet	Hook	Other	Trawl	Log Total	CDR
1998	0.1	506.9	31.7	0.6	22.0	561.4	-
1999	0.1	436.0	33.1	0.9	15.5	485.6	-
2000	0.0	395.4	35.5	0.6	19.5	451.1	-
2001	0.1	153.1	11.9	0.2	17.3	182.6	189.0
2002	0.1	173.4	14.2	0.0	17.5	205.2	222.7
2003	0.1	174.0	20.2	0.0	14.0	208.3	212.8
2004	0.2	169.1	14.2	0.1	14.1	197.7	214.2
2005	0.1	193.0	7.0	0.0	8.7	208.9	205.3
2006	0.1	192.1	8.7	0.0	11.1	212.0	206.4
2007	0.5	182.0	7.7	0.0	7.7	197.8	172.1
2008	0.9	216.1	8.4	0.0	9.0	234.4	228.6
2009	0.2	227.8	11.1	0.0	13.9	253.1	258.4
2010	0.3	149.8	16.2	0.0	13.8	180.1	198.4
2011	1.1	146.5	20.7	0.0	14.1	182.4	196.6
2012	0.5	100.5	23.6	0.0	11.4	136.0	142.7
2013	0.2	79.5	51.9	0.0	18.4	150.0	157.5
2014	0.1	108.4	80.2	0.0	11.3	200.0	221.0
2015	0.6	83.1	50.4	0.2	12.6	146.9	161.6
2016	0.3	86.0	33.2	0.0	14.4	133.9	157.8
2017	0.3	108.8	95.4	0.0	21.1	225.6	259.8
2018	0.1	73.4	55.4	0.0	24.6	153.5	177.0
2019	0.2	63.1	109.5	0.1	28.7	201.7	223.9

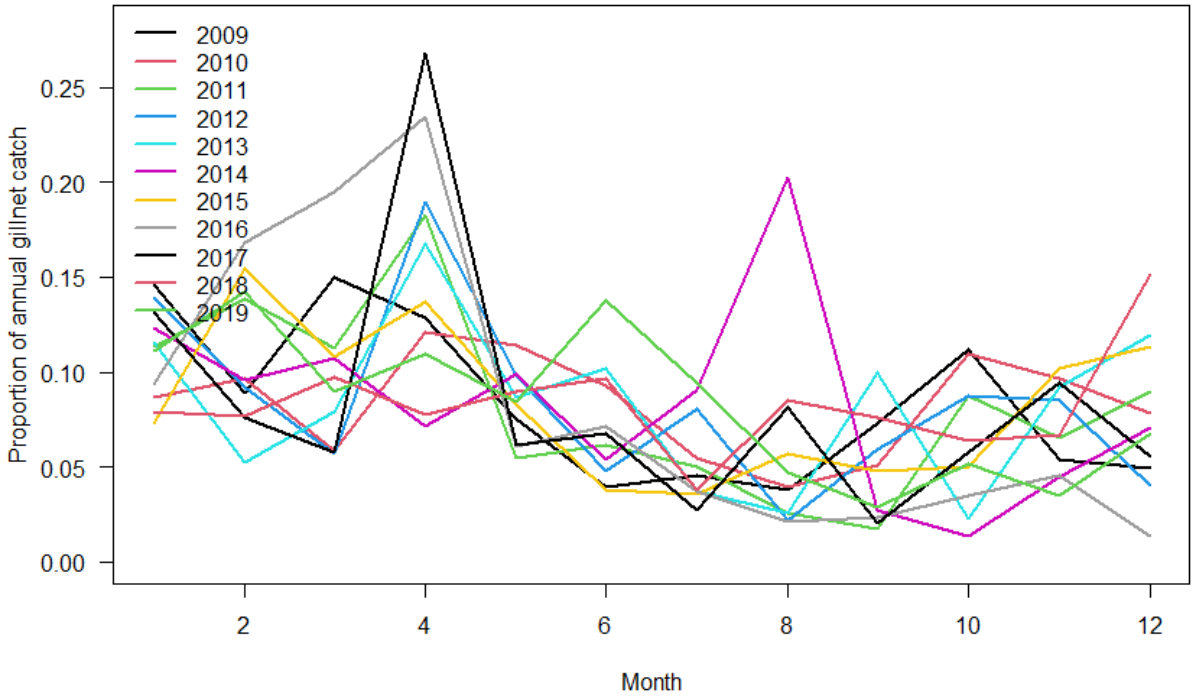

Figure 26: Monthly proportion of annual gillnet catch of School Shark.

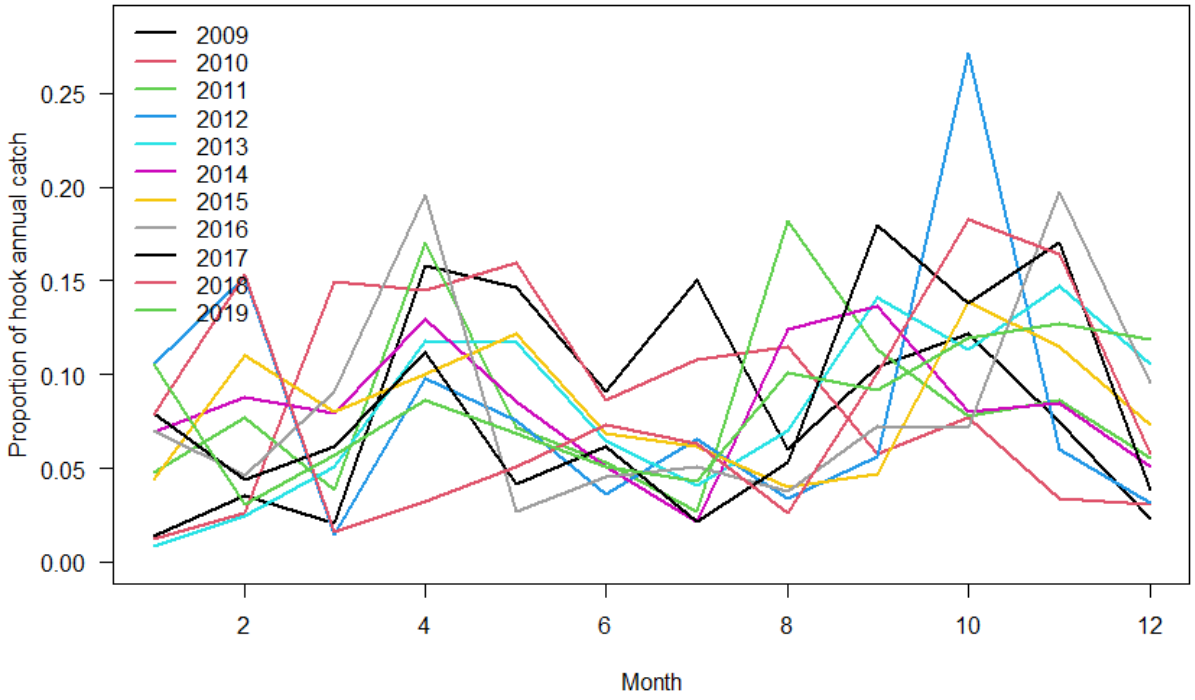

Figure 27: Monthly proportion of annual hook catch of School Shark.

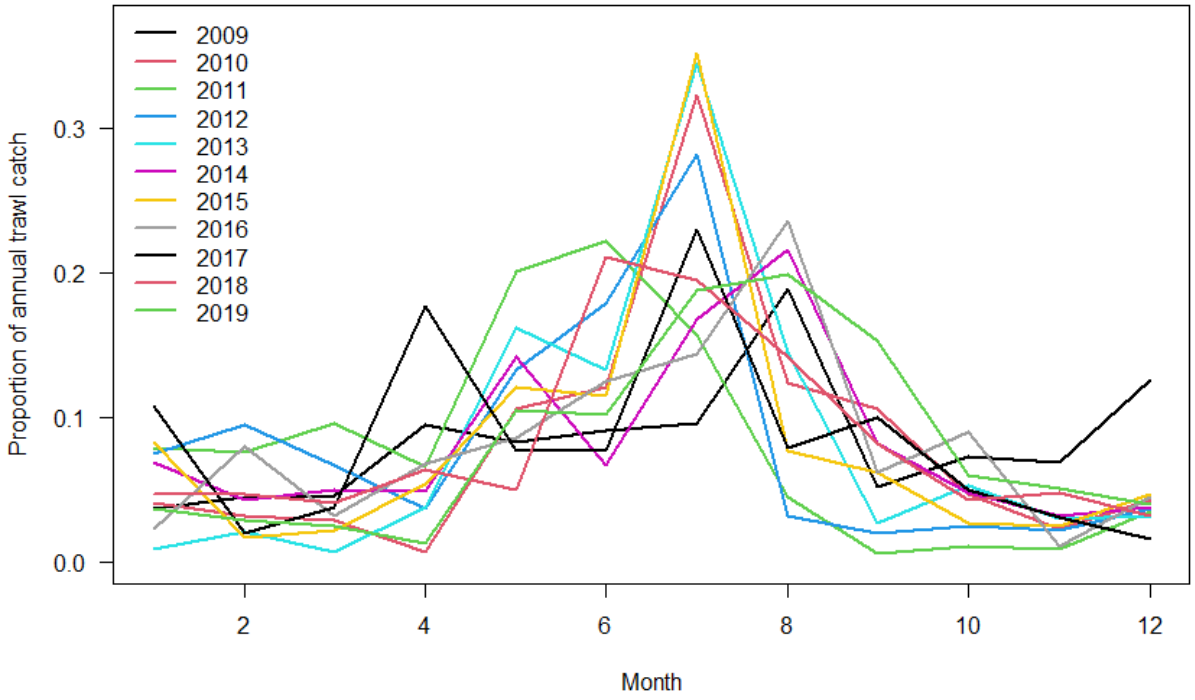

Figure 28: Monthly proportion of annual trawl catch of School Shark.

CPUE and depth of fishing

Gillnet is not thought to index School Shark abundance since 2005 because management measures, including closures, have changed fishing behaviour. The introduction of closures in South Australia to protect Australian Sea Lions lead to a shift from gillnet to hook gear in that state. Standardized trawl CPUE for School Shark has increased steadily from a low in the early to mid-2000s to reach its highest level in over two decades in recent years (Figure 29).

The depth of fishing for trawl caught School Shark is bimodal with a shallow mode around 120m that has been relatively consistent over time (Figure 30). The second mode for deeper fishing is less consistent and varies between 350 and 500m.

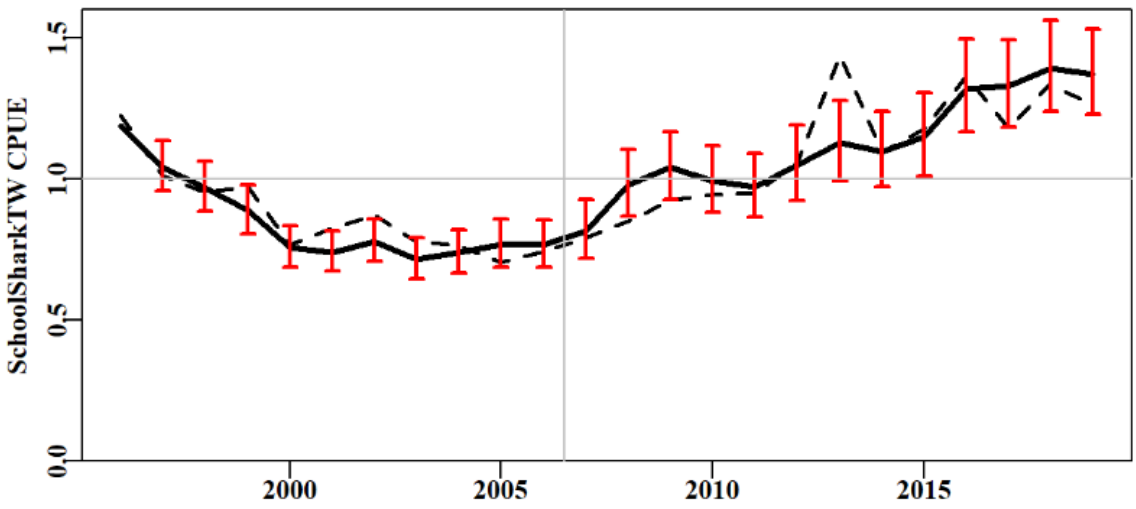

Figure 31: Histogram of annual fishing depths of trawl caught School Shark between 1996 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

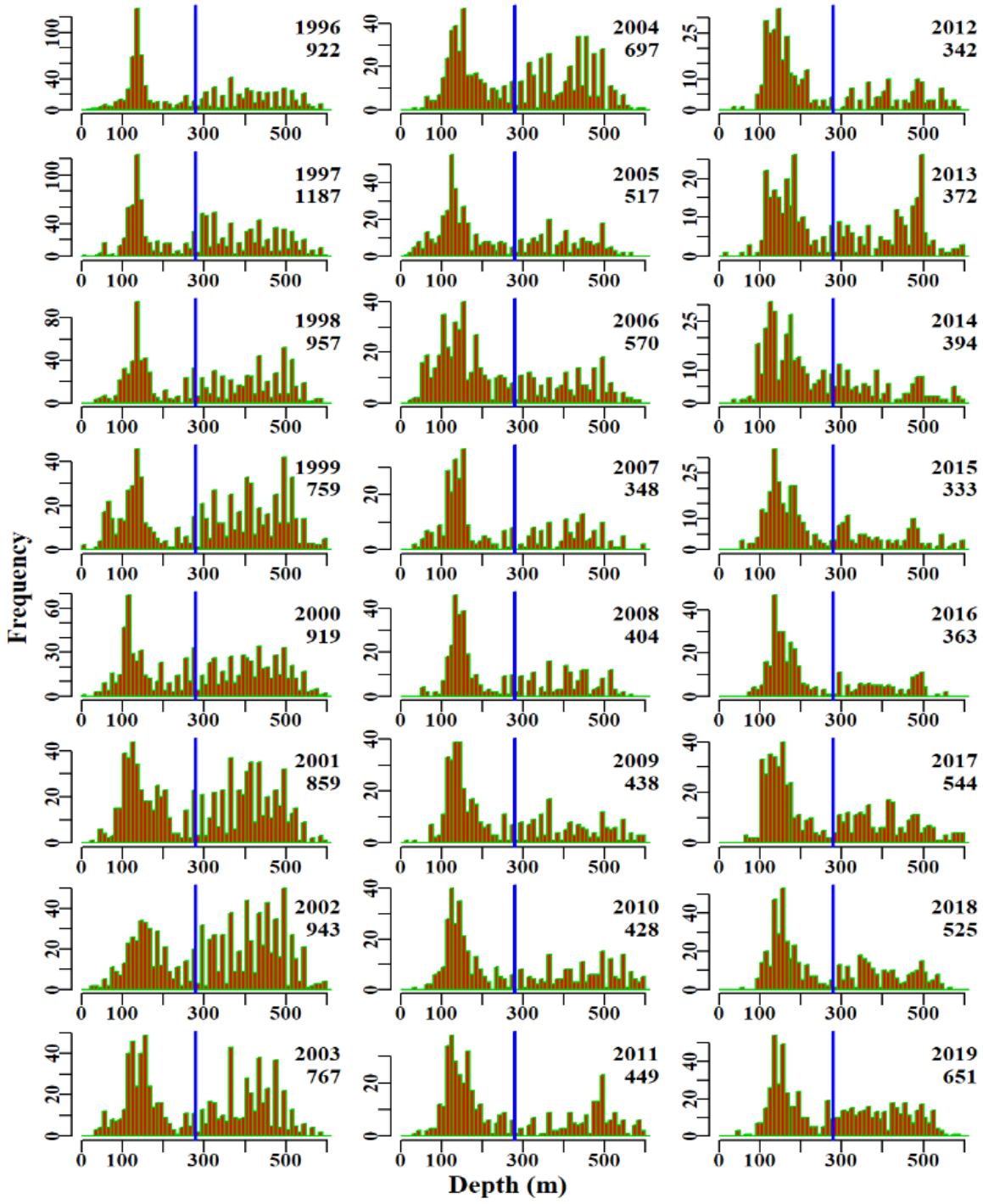

Figure 32: Histogram of annual fishing depths of trawl caught School Shark between 1996 and 2019. Year and number of logbook records are printed on the right hand side of each plot. Blue line represents mean fishing depth.

Spatial distribution of fishing

The spatial distribution of School Shark catches taken by gillnet vessels has contracted in recent years associated with changes in spatial management. Since 2016, gillnet catches of School Shark have been concentrated in Bass Strait, west of Tasmania to Kangaroo Island (Figure 33). Recent catches of School Shark taken by hook and line vessels are concentrated around western and central South Australia and off the south coast of Tasmania (Figure 34). Trawl catches of School Shark in recent years have been concentrated off the west coast of Tasmania and eastern Victoria (Figure 35).

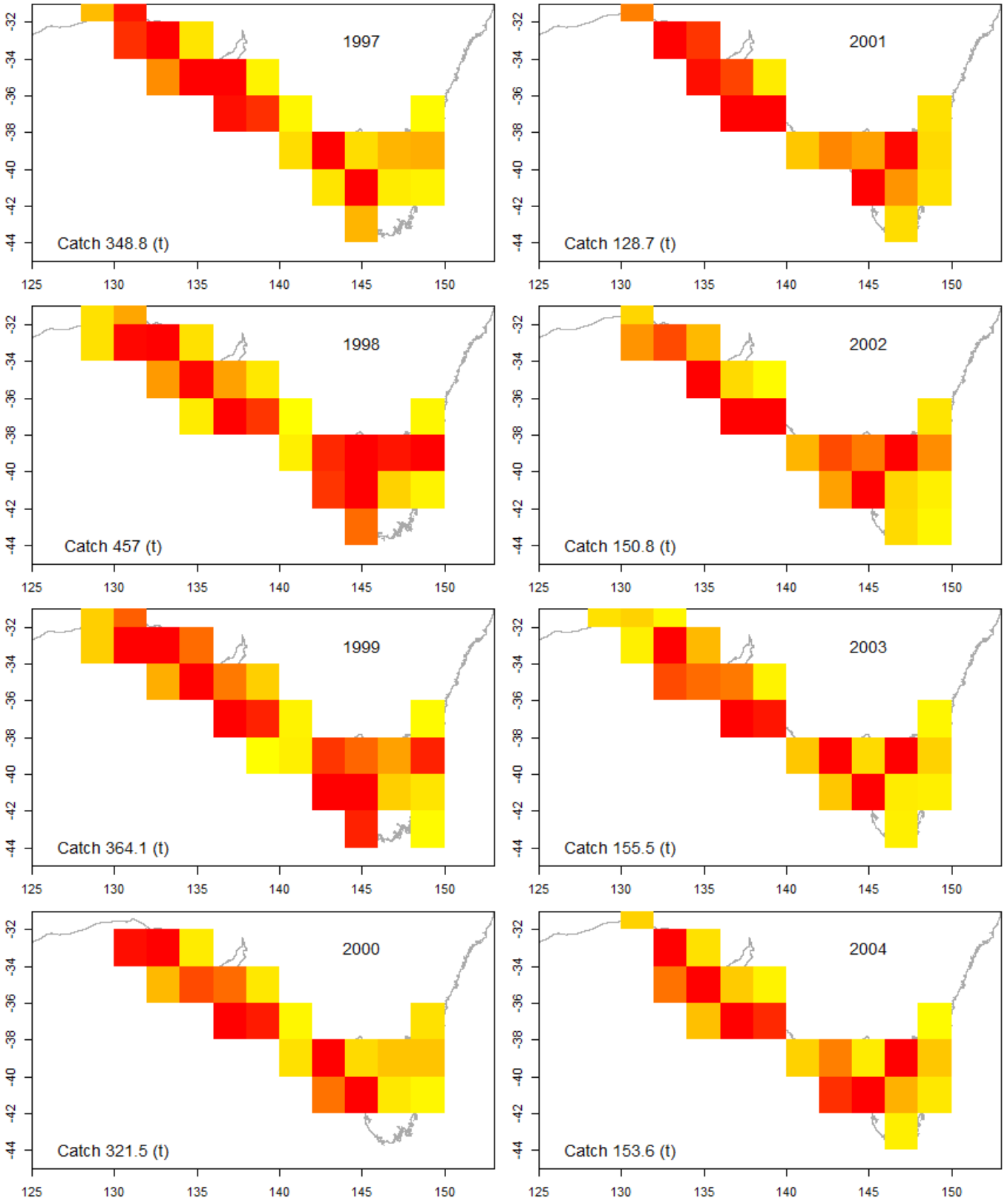

Figure 36: Spatial distribution of annual School Shark catch of gillnet vessels 1997 - 2004. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

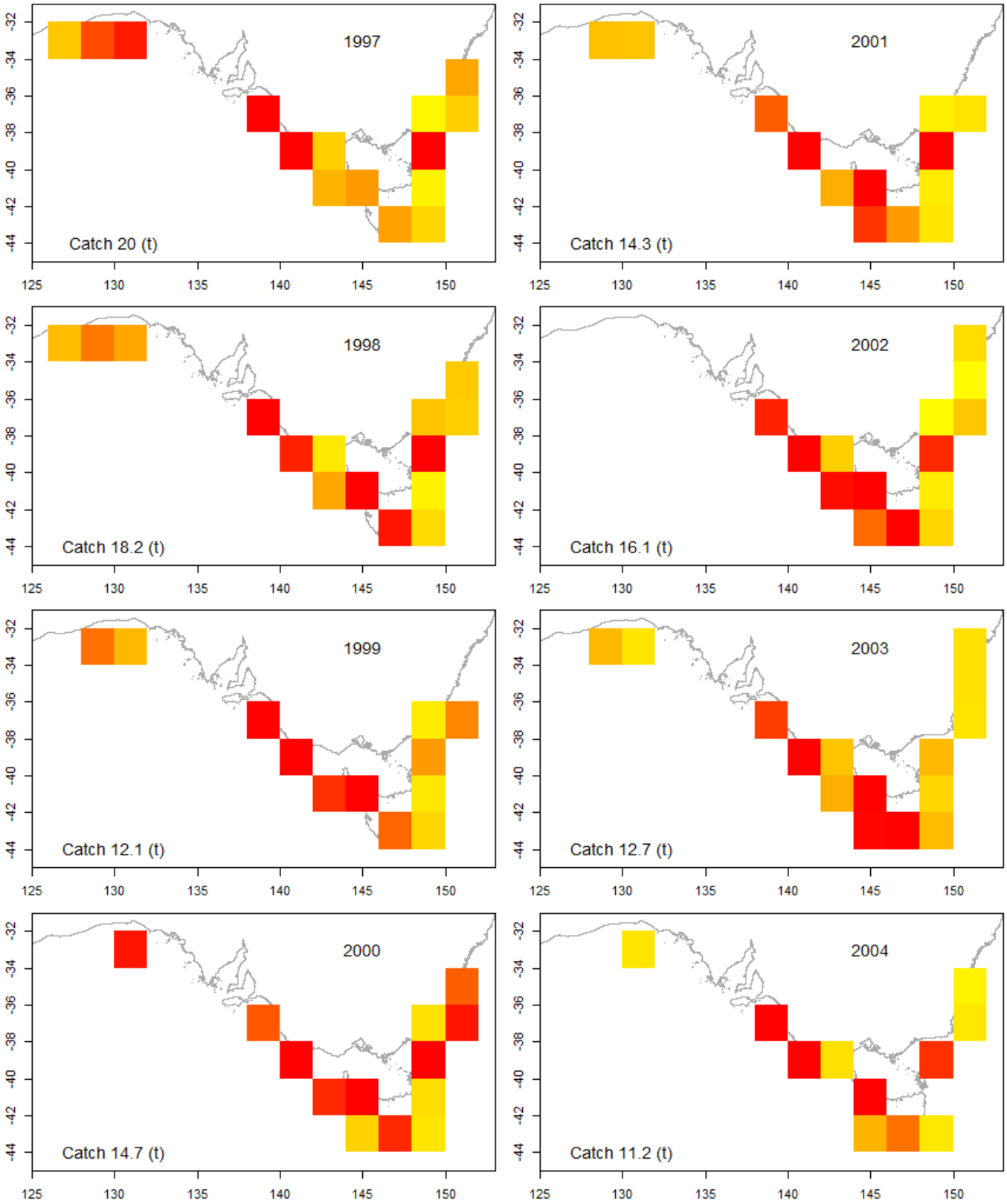

Figure 37: Spatial distribution of annual School Shark catch of trawl vessels 1997 - 2004. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

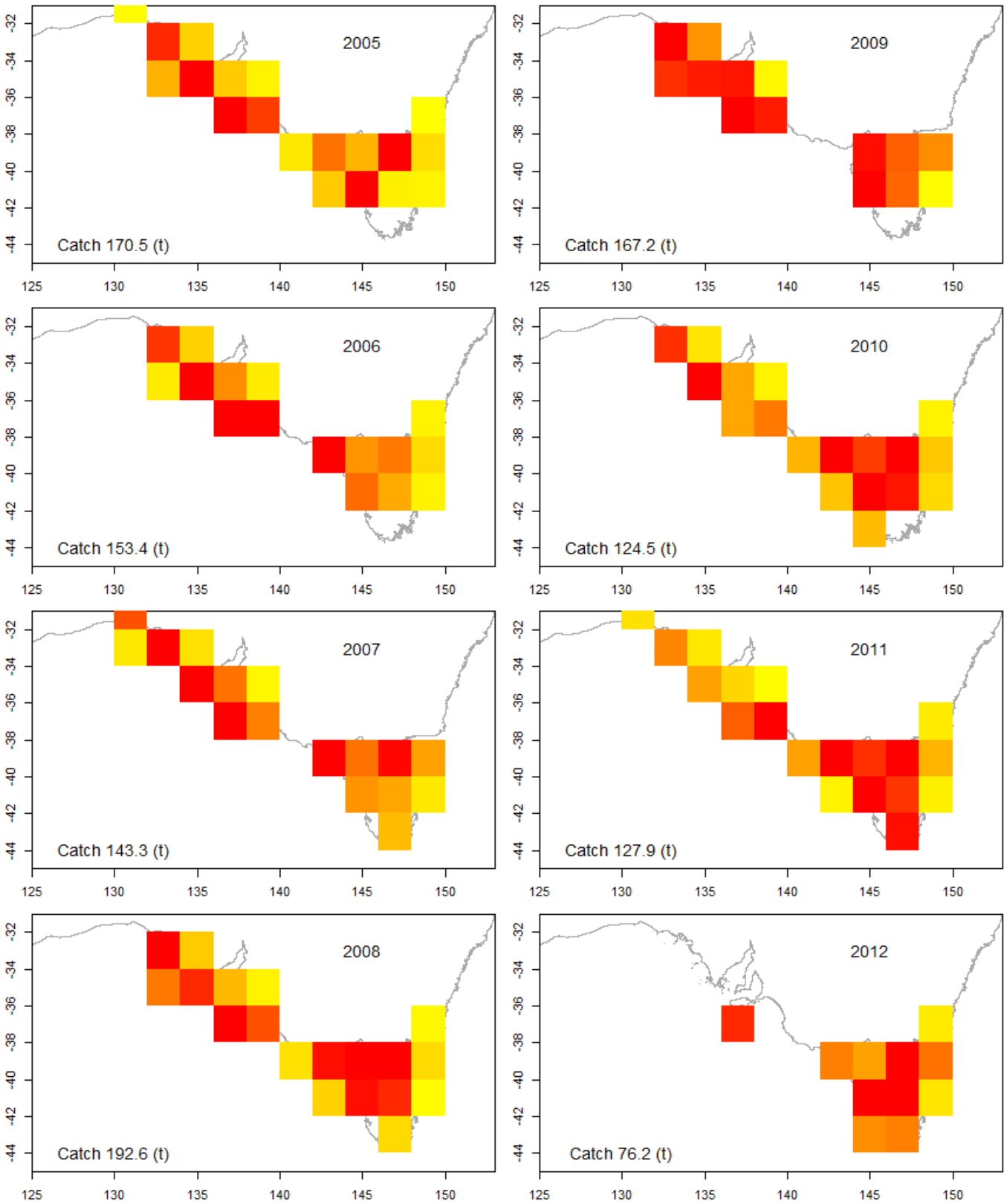

Figure 38: Spatial distribution of annual School Shark catch of gillnet vessels 2005 - 2012. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

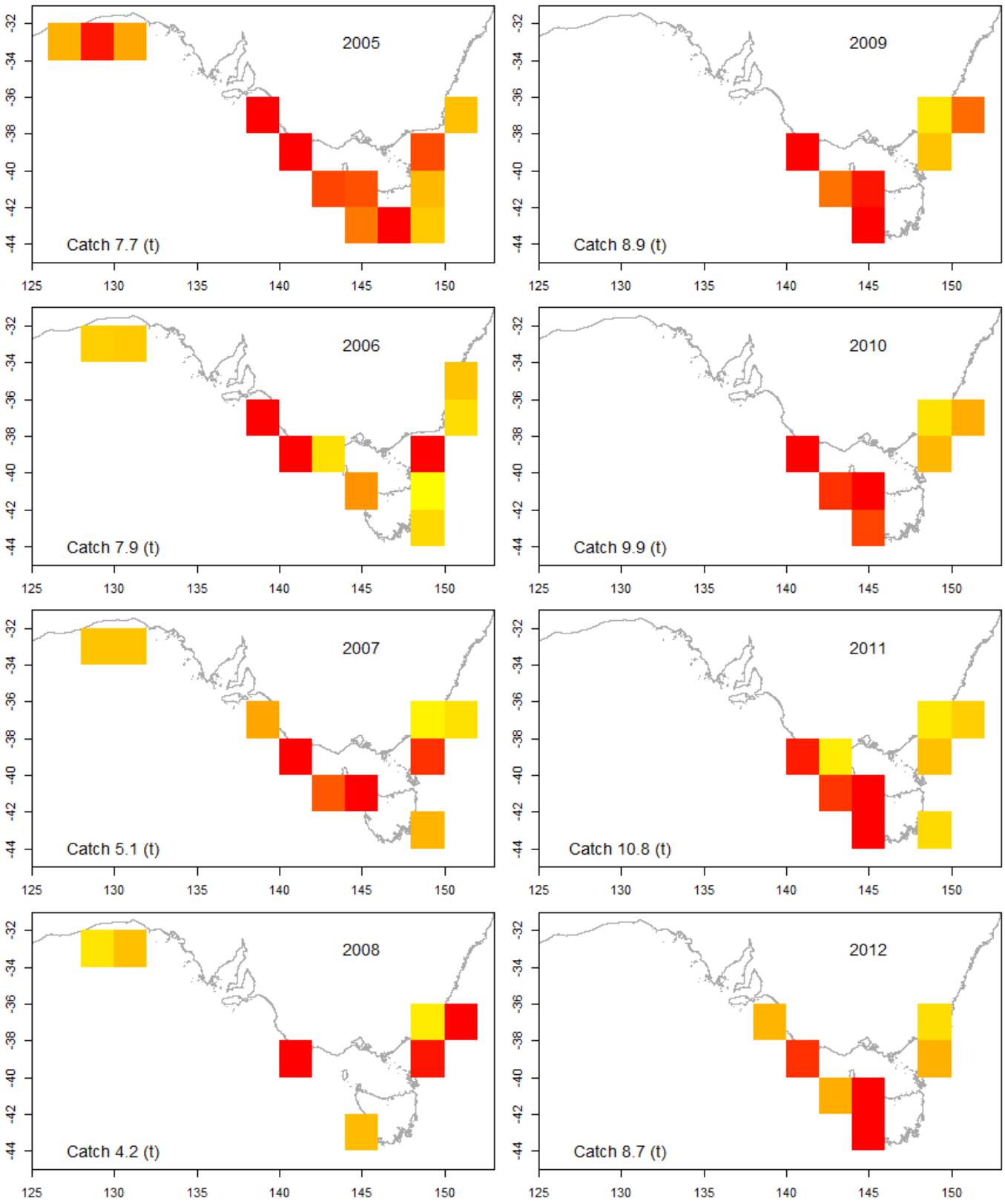

Figure 39: Spatial distribution of annual School Shark catch of trawl vessels 2005 - 2012. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

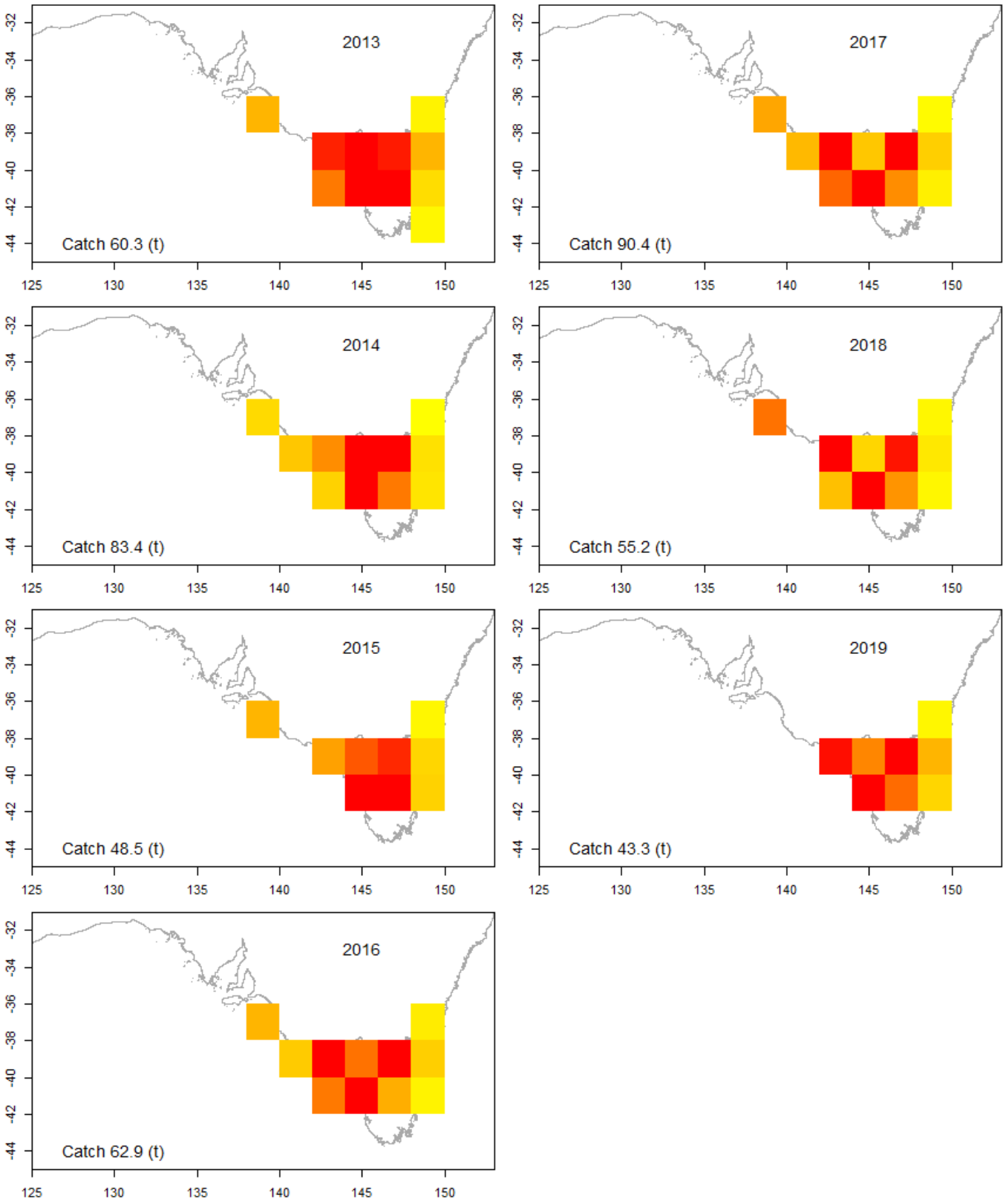

Figure 33: Spatial distribution of annual School Shark catch of gillnet vessels 2013 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

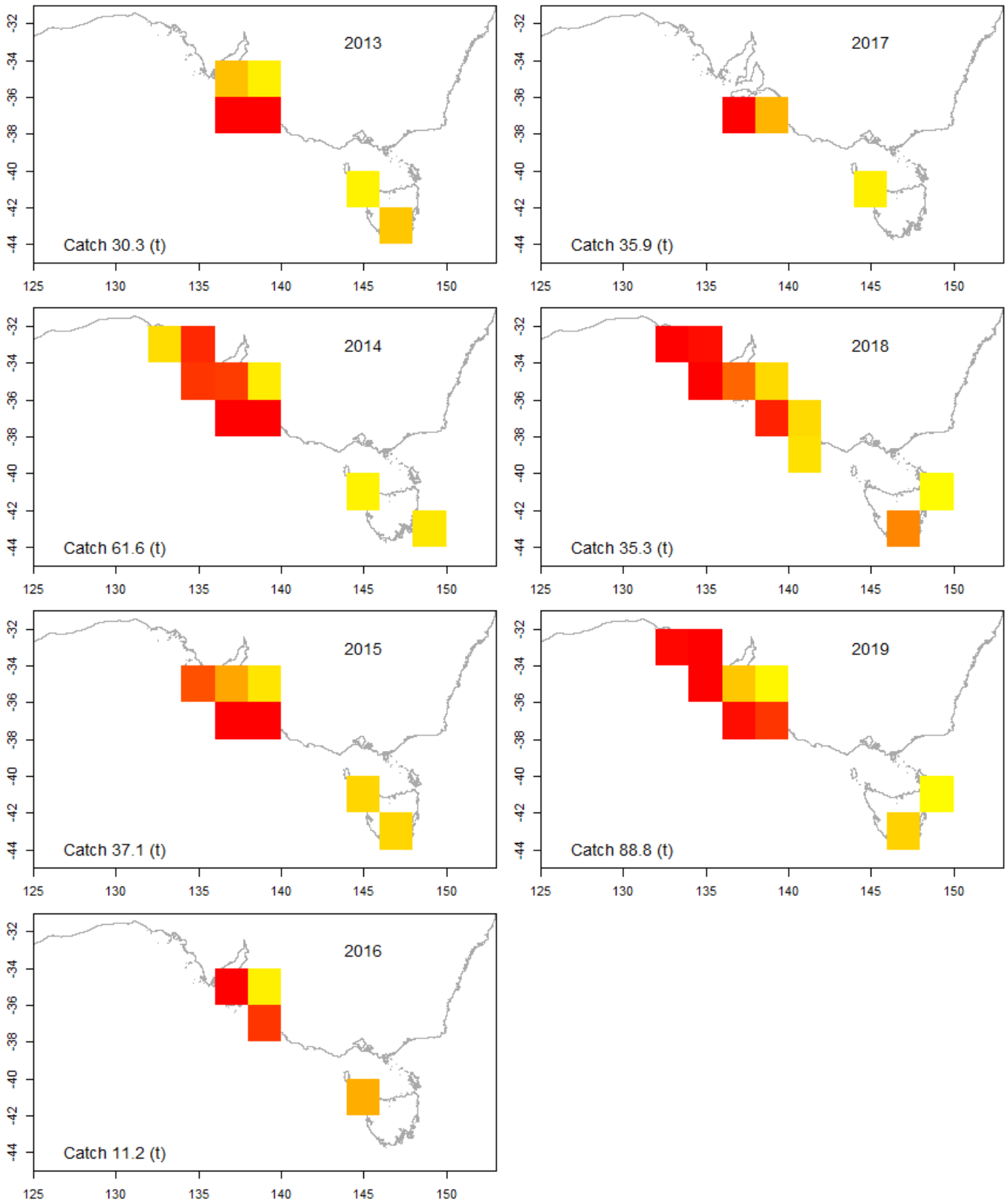

Figure 34: Spatial distribution of annual School Shark catch of hook vessels 2013 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

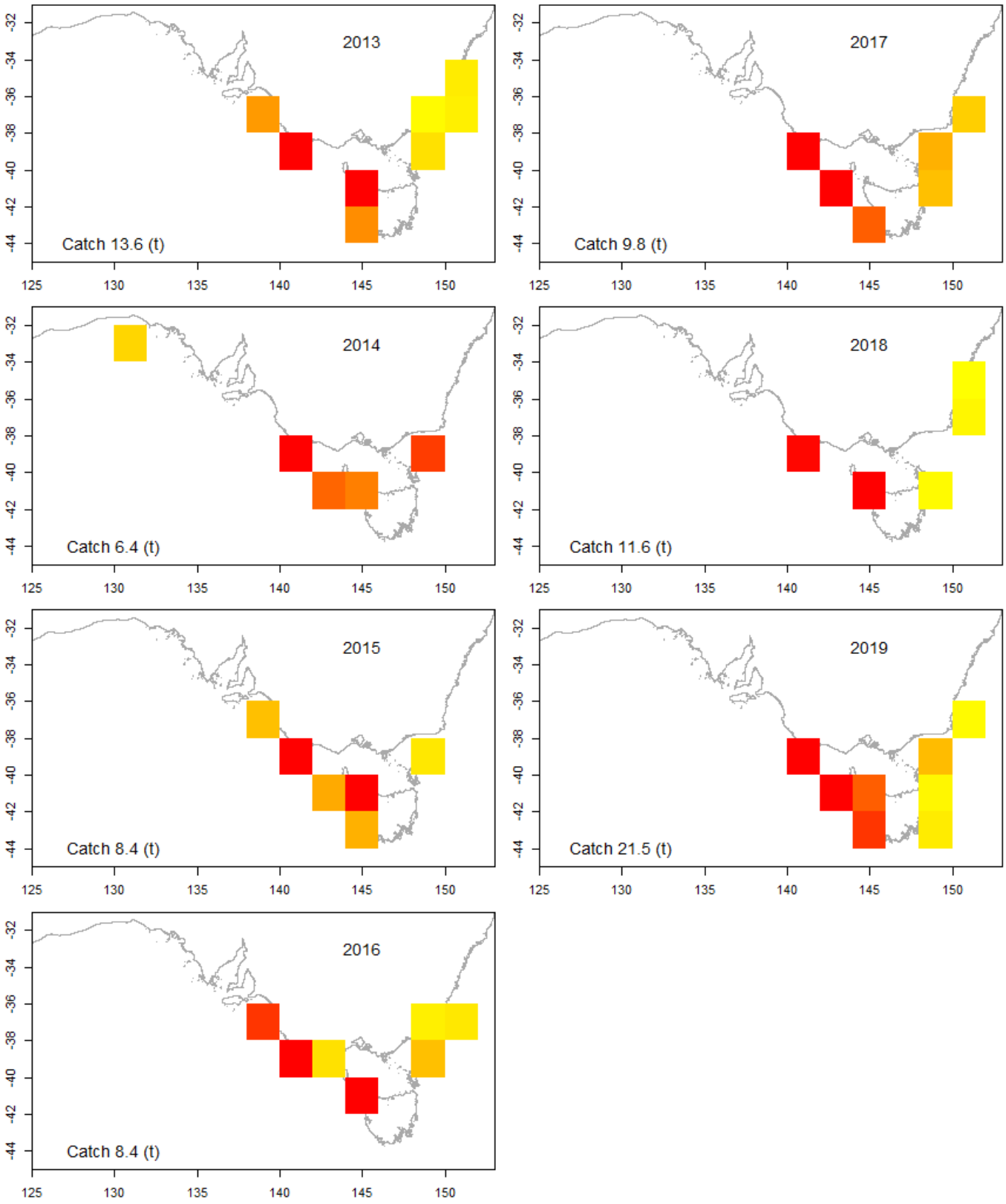

Figure 35: Spatial distribution of annual School Shark catch of trawl vessels 2013 - 2019. Logbook catch is provided in the bottom left corner of each annual plot. Note locations with catches from less than 5 vessels are not shown.

Catch by vessel

There is no evidence of gillnet or hook vessels reporting consistently large catches School Shark in recent years which therefore does not indicate targeting (Figure 40 and Figure 40). Two trawl vessels have reported higher than average landings of School Shark over the last few years (Figure 41). While these landings are low in absolute terms and are likely from vessels fishing on the shelf west of Tasmania they may warrant further investigation by AFMA.

Figure 40: Bubble plot of annual School Shark catch of gillnet vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting School Shark (lower).

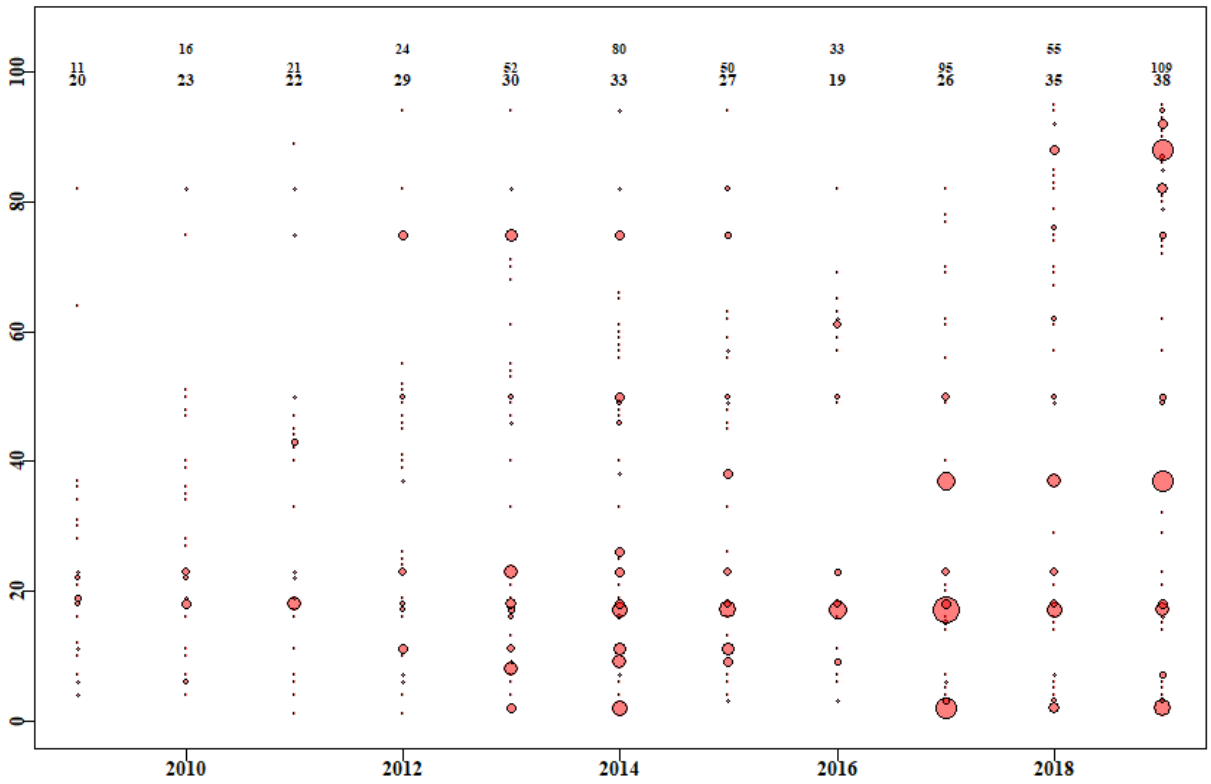

Figure 42: Bubble plot of annual School Shark catch of hook vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting School Shark (lower).

Figure 41: Bubble plot of annual School Shark catch of trawl vessels. Larger bubbles indicate larger annual catches. Numbers at the top of each year represent logbook catch (upper) and number of vessels reporting School Shark (lower).

Discussion

This study has quantified the unavoidable bycatch of Blue Warehou, the eastern stock of Gemfish, Redfish and School Shark using a metier based approach and investigated potential targeting of these stocks using a weight of evidence approach. The metier analysis was not robust to the exclusion of recent data and will need to be updated annually to provide estimates of rebuilding species bycatch. The scalefish species are predominately caught by the demersal trawl sector, while School Shark is primarily caught by the gillnet and hook and line sectors.

The metier analysis of School Shark bycatch incorporating spatial location has provided useful information on how the ratio of School Shark to Gummy Shark landings changes over the spatial distribution of the fishery. It is interesting that School Shark are reported at higher ratios that 1:5 for some metiers, presumably reflecting that the rule is applied at a relatively high level of aggregation. School to gummy ratios are consistently high in western Bass Strait and Western Tasmania with hook catches in western SA also high. There is little indication of targeting, with only two trawl vessels showing weak sign of targeting. The analysis of the predominately trawl caught species aggregated over the spatial cells so the spatial variability in the ratio of target to bycatch species was lost. Incorporating the spatial component is important in any future bycatch analysis, particularly for eastern Redfish which is predominately caught off the NSW coast.

Spatial variability in the ratio of School Shark to Gummy Shark catch in the gillnet and hook sectors was explored at an aggregated spatial scale using the revised metier analysis. In its December 2020 meeting, SharkRAG requested additional figures that explore the ratio of School Shark to Gummy Shark catches. There was insufficient time and funding to undertake this as part of the current contract, however, it will be explored as in future versions of this report.

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FOR FURTHER INFORMATION

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