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Initial insights on the impact of COVID-19 on boat-based recreational fishing in Western Australia

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A B S T R A C T

The COVID-19 global pandemic and subsequent implementation of measures to reduce contact within the community have affected fisheries worldwide, yet few studies have reported the impacts on recreational fisheries. This study investigates boat-based recreational fishing in Western Australia from March to August 2020, where COVID-19 measures relevant to recreational fishers included various travel restrictions, and social and physical distancing measures. Information from surveys of licensed recreational fishers and fisheries compliance officers, and camera footage from key boat ramps is presented. A lower proportion of Perth metropolitan fishers went fishing compared with regional fishers. Metropolitan fishers also reported fewer days fished and lower participation in demersal and shore-based line fishing than regional fishers. In contrast, compliance officers observed more fishing activity in both metropolitan and regional locations. Fishing plans were mostly affected by travel restrictions with more metropolitan fishers affected compared with regional fishers. Daily recreational vessel retrievals at key boat ramps varied between locations, with metropolitan fishers initially unable to travel to regional centres. There was no decline in vessel retrievals at metropolitan boat ramps during the most rigid restrictions and northern regional boat ramps experienced substantial increases in recreational vessel activity once travel restrictions eased. Studies of this kind highlight the value of utilising established recreational fishing monitoring programmes to provide a responsive and scientific basis for policymakers to address societal behavioural changes associated with atypical events such as COVID-19.

1. Introduction

The global pandemic associated with COVID-19 (severe acute respiratory syndrome coronavirus 2, SARS-CoV-2) has affected commercial, artisanal and recreational fisheries worldwide [1–7]. Impacts have varied in accordance with the level of government action to reduce transmission of the virus within the community [8,9]. To date, there have been few published studies reporting the impacts on recreational fishing [10–12], an activity which involves numerous participants and provides societies with a range of important social and economic benefits [13]; with food provisioning and maintaining mental wellness of particular importance in times of a pandemic. In Europe, Australia and New Zealand, bans on recreational fishing and restrictions on regional movement resulted in marked reductions in recreational fishing activity [14]. In contrast, in the USA and Canada, nil or minimal government action to restrict fishing activity [5,12] coupled with active campaigns to promote recreational fishing [15] has seen increases in sales of fishing gear and fishing effort [10].

In Western Australia, 25% of the state population participates in recreational fishing each year [16], and this activity contributed AUD

\$2.4 billion to the state economy in 2015/16 [17]. The statewide population of 2.5 million is most highly concentrated in the southwest within the Perth metropolitan area. Monitoring of recreational fishing has been undertaken for many years by the State Government as required for legislative and management requirements for aquatic resources [18], using statewide mail and phone surveys, regional roving creel and boat ramp surveys, and boat ramp cameras [19,20]. This monitoring provides a good baseline understanding of seasonal patterns in fishing activity in marine waters adjacent to Perth (from 27° S to 115° 30' E), where approximately 70% of fishing occurs [21], and regional locations such as Shark Bay and Ningaloo [22,23]. Typically, recreational fishers in Western Australia travel northwards to fish in the austral winter and southwards in the austral summer [24].

Western Australia has been highly successful in managing the impacts of COVID-19 [25], in part due to effective action by the State Government very early in the pandemic. Participation in recreational activities were subject to complying with various travel restrictions, and social and physical distancing measures during 2020 (Table 1). There were several phases of restrictions within the state, ranging from full lockdown (with exceptions for critical activities) in March and April, to

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Table 1

Phases in the COVID-19 recovery roadmap for Western Australia and relevant travel restrictions and social distancing measures (Government of Western Australia, 2020).

Phase	Dates	Travel restrictions	Social distancing	Physical distancing
	29/03/2020–26/04/2020	Inter and intrastate border closures (from 1 April), with travel permitted only within 10 intrastate regions	Outdoor non-work gatherings of no more than 2 people (with no directive specifically for recreational fishing)	
1	27/04/2020–17/05/2020	No change	Indoor and outdoor non-work gatherings of up to 10 people (including recreational fishing)	
2	18/05/2020–05/06/2020	Intrastate travel restrictions relaxed, with travel permitted only within 4 intrastate regions	Indoor and outdoor non-work gatherings of up to 20 people	4 square metre rule
3	06/06/2020–26/06/2020	All intrastate travel restrictions removed, including access to Rottnest Island, except for entry into remote Aboriginal communities	Non-work gatherings permitted up to 100 people	2 square metre rule
4	27/06/2020–17/07/2020	No change	All existing gathering limits removed	No change
5	18/07/2020–10/12/2020	No change	n/a	2 square metre rule removed
6	11/12/2020 (to January 2021)	Removal of closed interstate border (to controlled border) and travel restrictions for remote Aboriginal communities	n/a	n/a

unimpeded intrastate travel after May once the transmission of the virus had been contained. Recreational fishing was initially discouraged during the lockdown, except for fishing groups from the same household and, after concerns about high levels of recreational vessel activity, the peak body representing recreational fishers sent clear messaging to its members to refrain from fishing [26]. This led to concerns about the negative impact travel restrictions were having on the recreational fishing sector and regional centres, which are reliant on seasonal fishing-based tourism.

As intrastate restrictions were progressively lifted, recreational fishing became designated as a permitted activity and travel restrictions were progressively eased, in compliance with Phases 1 and 2 of the State Government's COVID-19 Recovery Roadmap [27]. Anecdotal reports suggested that large numbers of recreational fishers, and their families, from the Perth metropolitan area correspondingly headed north to popular destinations such as Kalbarri and Shark Bay. Subsequently, concerns were raised in the media by regional local governments about the sustainability of levels of post-COVID recreational fishing and the ensuing effects on fish stocks in areas of high conservation value [28]. A series of media reports and direct lobbying from regional stakeholders led the Minister of Fisheries to request specific advice from the Department of Primary Industries and Regional Development (DPIRD) on the impact of COVID-19 on recreational fishing.

This study investigates the impact of COVID-19 restrictions on boat-

based recreational fishing in Western Australia, which occurs in marine waters adjacent to a coastline spanning 12,889 km (occupying a third of the Australian continent). Existing data and monitoring programmes were adapted to quantify the impacts on recreational fishing. This study presents findings from a survey of boat-based recreational fishers and fisheries compliance officers, and boat ramp camera footage undertaken during COVID-19 restrictions from March to August 2020. Specific aims were to: (i) compare fishing activity between metropolitan and regional licensed fishers; (ii) report observations of fishing activity by compliance officers; (iii) construct a timeline of recreational vessel activity at key boat ramps; and (iv) compare recreational vessel activity at key boat ramps with March to August in previous years. This study demonstrates the need for agencies to be highly responsive and have capability to provide data to government to support policy decisions within the short time frame associated with atypical events such as the COVID-19 pandemic.

2. Methods

2.1. Study area

The state of Western Australia extends from the tropical north (latitude 14S) to the temperate south (latitude 35S). Residential Statistical Areas for the state's population include the Perth metropolitan (herein referred to as metropolitan) and nine Regional Development Commissions and interstate (herein referred to as regional; Fig. 1). A Recreational Boat Fishing (RBF) licence is required to undertake any general recreational fishing from powered vessels anywhere in Western Australia (without exemption). On average, 130,000 RBF licences have been issued annually since the licensing system was introduced in 2010. Boat-based recreational fishing occurs statewide, with established spatial and temporal patterns in recreational fishing determined from biennial statewide surveys from 2011/12–2017/18 [24]. Fishing methods used by recreational fishers in Western Australia include: line fishing (i.e. boat-based fishing for pelagic, game, demersal and near-shore finfish species, and shore-based); diving (i.e. snares and loops for Western Rock Lobster, either while snorkelling or with breathing apparatus); and potting (i.e. passive traps for Western Rock Lobster and active drop nets for Blue Swimmer Crab). An RBF licence is not required when fishing on charter fishing vessels.

2.2. Survey of licensed fishers and compliance officers

An online survey to understand the impact of COVID-19 on recreational fishing in Western Australia was conducted between June and November 2020. The survey was administered to two sample groups: boat-based recreational fishers (hereon referred to as licensed fishers) and fisheries compliance officers (hereon referred to as compliance officers). The sampling frame for licensed fishers comprised fishers who were in possession of a RBF licence during the 12 months prior to the start of the survey. A stratified random sample was selected proportional to the number of licence holders in residential Statistical Areas. A sample with 16,500 licence holders was selected with a minimum sample size of 840 in regions with low population totals (Table 2). The sampling frame for compliance officers included all Fisheries and Marine Officers (FMO) employed by DPIRD that were rostered on duty from March to August 2020.

Surveys were administered by the ECU Survey Research Centre [29]. Surveys of licensed fishers occurred from 30 June to 10 September 2020 and compliance officers from 3 to 25 November 2020. The temporal scope of the survey covered fishing activity from 29 March 2020 (see Table 1) to the time of the survey (up to 31 August 2020, see Table 2). The survey of licensed fishers was conducted in three waves to allow a within-survey comparison of online data collection. Initially, email invitations were sent with a link to participate in the online survey. Two follow-up reminder emails were sent to non-responding licence holders

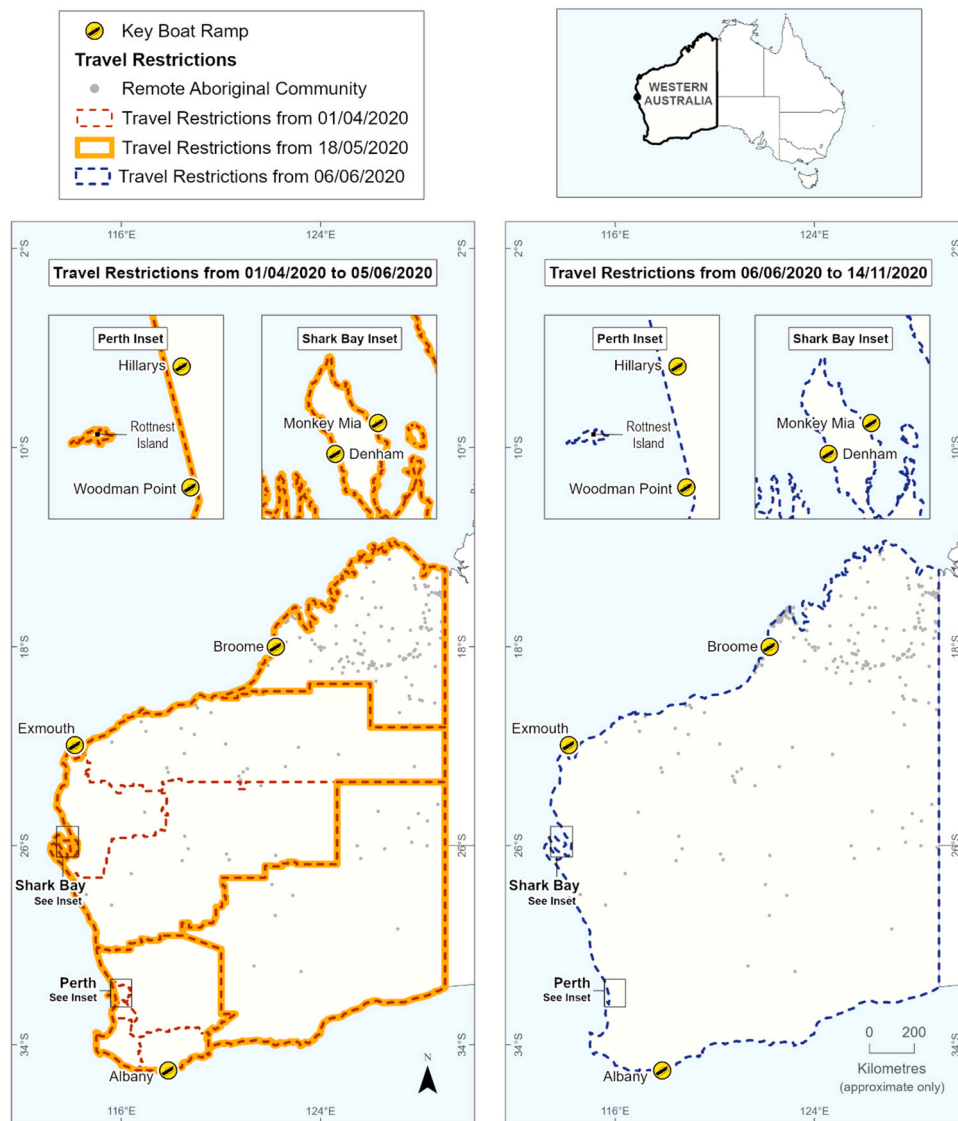


Fig. 1. Map of Regional Development Commissions in Western Australia, which define residential Statistical Areas and intrastate borders during different phases of the COVID-19 pandemic.

Table 2

Response rates for surveys of Recreational Boat Fishing (RBF) licence holders and Fisheries and Marine Officers (FMO) on the impact of COVID-19 restrictions on recreational fishing in Western Australia from 29 March to 10 September 2020.

	RBF Wave 1	RBF Wave 2	RBF Wave 3	RBF Total	FMO
Survey start date	30/06/2020	20/07/2020	10/08/2020	30/06/2020	03/11/2020
Survey end date	24/07/2020	22/08/2020	10/09/2020	10/09/2020	25/11/2020
Initial sample	5,500	5,500	5,500	16,500	83
Sample loss	132	138	131	401	25
Net sample	4,460	4,528	4,528	13,516	58
Refusal	167	181	182	530	6
Full response	741	653	659	2,053	52
Survey response rate	17%	14%	15%	15%	90%

on days 10 and 17 after the initial email invitation to minimise non-response bias. While there are no age limits for the RBF licence, sample selection excluded licence holders younger than 18 years or

older than 95 years (~6% of licence holders). Non-responding licence holders were not substituted.

The survey questionnaire for licensed fishers related to their own fishing activity, while questions for compliance officers related to fishing activity they observed. Respondents were asked if they had planned beforehand to go recreational fishing (fishers) or worked (compliance officers) in Western Australia during the COVID19 restrictions and whether they went fishing (fishers) or observed fishing (compliance officers), as well as how often and the type of fishing. Respondents were asked to compare recreational fishing during COVID-19 with their plans (fishers) or observations (compliance officers) in previous years. Respondents who noticed changes were asked whether any changes could be attributed to: the number of fishing trips; fishing in their local Regional Commission; fishing in other Regional Commissions; types of fishing; or any other reasons why fishing activities were different. Finally, respondents were asked if recreational fishing was affected by: the decision to isolate; travel restrictions; social distancing (e.g. restricted numbers allowed on boat); personal reasons (e.g. time, health, other activities); access (e.g. access to boat, equipment); cost (e.g. fuel, equipment); fishing quality (e.g. catch rates, environmental conditions); or any other reasons why fishing activities were affected.

The survey response rate (expressed as a percentage) was defined as the number fully responding (i.e. respondents who completed all survey questions) divided by the net sample (i.e. initial sample minus sample loss). Sample loss (2.4% of initial sample) was attributed to bounced emails, or replies indicating incorrect or unchecked emails. Non-response was only attributed to firm refusals (3.9% of net sample), and excluded unused emails (i.e. never clicked survey link or replied by email). A sample of 2053 responses was achieved with similar survey response rates across all waves (Table 2), which is lower than survey response rates of 25% achieved from online surveys (DPIRD unpublished).

Chi square tests ($\alpha = 0.05$) were used to test for an association with demographic and past fishing variables for the licensed fisher and their reported fishing during COVID-19 (1 = fished, 2 = did not fish). Demographic variables included residence (1 = metropolitan, 2 = regional), gender (1 = female, 2 = male), and age (1 = 18–29, 2 = 30–44, 3 = 45–59, 4 = 60 years or older). Past fishing variables included avidity (i.e. number of days fished in previous 12 months, 1 = 1–4, 2 = 5–14, 3 = 15 days or more), and bioregion fished (i.e. the only or main bioregion if more than one fished, 1 = North Coast, 2 = Gascoyne Coast, 3 = West Coast, 4 = South Coast). Chi square and Fisher tests were used to test for an association with fishing type, change and attribution response variables between residential stratum (1 = Metropolitan, 2 = Regional). Separate analyses were conducted for each response variable and for data from the licensed fishers and compliance officer surveys, where fishing activity occurred or was observed.

Logistic regression models with a logit link function were conducted to investigate response variables as a function of demographic (residence, gender, age) and past fishing (avidity, bioregion) predictor variables. Separate analyses were conducted for each fishing type, change and attribution question. Models were selected according to the measurement scales for predictor variables with odds ratios (OR: the ratio of the probability of an outcome occurring in one categorical group to the probability of it occurring in another) determined from model coefficients [30]. Binomial logistic regressions were selected for: fishing type response variables (0 = no, 1 = yes) and number of days fished (1 = 1–14, 2 = 15 days or more) for the data subset of licensed fishers who fished during COVID-19 ($n = 1116$); and attribution response variables for the data subset of respondents who planned to fish during COVID-19 ($n = 1501$). Multinomial logistic regressions with categorical response codes were selected for response variables relating to attribution for change in fishing activity (1 = more, 2 = less, 3 = same). The ORs for multinomial regressions compared the difference between ‘less’ with ‘same’ and ‘more’ with ‘same’ categories. Survey wave was included in exploratory models, but was not included as a predictor variable in any of the final models due to non-significance, and interactions were not considered. Analyses of data from licensed fishers focused on unweighted (i.e. raw) data [31]. Analyses excluded 552 licensed fishers who had no plans to go recreational fishing and one officer working in another Department during COVID-19 (where they did not have the opportunity to observe any recreational fishing). Analyses were performed in R using the *chisq.test*, *fisher.test* and *glm* functions from the *stats* package [32], and the *multinom* function from the *nnet* package (ver. 7.3-53) [33]. Plots were prepared using the *likert* function from the *HH* package (ver. 3.1-42) [34].

2.3. Boat ramp camera footage

Footage was obtained for vessel retrievals at key boat ramps from March to August in 2020. Background data were also available for the same ramps in 2011, 2013 and 2016, enabling a comparison to be made with information prior to the pandemic [24]. Two metropolitan boat ramps (Hillarys and Woodman Point) were selected as the ramps with the greatest recreational vessel activity in Western Australia. Regional boat ramps (Broome, Exmouth, Monkey Mia, Denham and Albany) were

selected to provide broad coverage of the state’s regional centres with substantial recreational fishing tourism, as well as the availability of footage during the survey period.

Time-lapse footage was recorded 24-h a day through Mobotix M15 or M16 cameras [35]. The interval between the time-lapse images ranged from 7 to 10 s, which was brief enough to reduce the size of the files for long-term storage, but not to miss vessel retrievals at the ramps. Trained survey staff manually read all available footage for each ramp, with the time and date of retrieval, the vessel type (e.g. powerboat, commercial vessel, government vessel, yacht, jetski, kayak), and any outage of 1 min or more was recorded. For analyses, retrieval data were subset to powerboats as negligible fishing was assumed to be undertaken from the other vessel categories. A census of camera data was not available for all ramps due to gaps in camera footage (known as outages). Where the cumulative daily outage was greater than 4 h, the whole day was excluded from the data set used for analysis (615 out of 4784 days across all boat ramps). Additionally, analyses excluded data at a boat ramp in months where fewer than 16 days had valid data (20 out of 156 months across all boat ramps).

Generalised linear models (GLMs) were employed to determine, independently for each of the 7 ramps, whether the number of daily vessel retrievals observed were related significantly to the year, month and/or day type, and whether two-way interactions between these factors were significant. For each analysis, a Negative Binomial GLM with a log link function was used, employing the *glm.nb* function from the *mass* package (ver. 7.3-53) [33]. The log-transformed duration of valid camera footage for each daily record (hours) was used as an offset variable to account for outages in the footage. Preliminary analyses investigated the use of Poisson GLMs to model the number of vessel retrievals, with likelihood ratio tests demonstrating the Negative Binomial distribution was more appropriate than the Poisson distribution for analysis of the vessel retrieval data at these 7 ramps. Explanatory variables (year, month, day type and all two-way interactions) were included in all GLMs as fixed effects. Due to the unbalanced nature of the data, the analysis for each ramp was limited to a balanced combination of years and months. For example, since the Hillarys ramp had no valid data for June 2011 or March to May 2016, the analysis for this site was limited to the years 2011, 2013 and 2020 and the months March, April, May, July and August.

Model selection involved stepwise regression using Akaike Information Criterion (AIC), to identify the two-way interactions necessary to retain in each model. Planned comparisons [36], using the *glht* function in the *multcomp* package [37], were employed on the reduced model to test the hypotheses that the number of vessel retrievals observed at a given ramp were different (two-sided test) among years across the various months and day types. In the presence of significant interactions, planned comparisons among years were undertaken within each month and/or day type, with p-values adjusted using the Bonferroni correction.

3. Results

3.1. Survey of licensed fishers

The survey of 2053 licensed fishers included 1501 respondents who planned to go fishing during COVID-19, with varying proportions of respondents among demographic and past fishing variables (Table 2). A higher proportion of respondents were regional residents (58%) or male (88%) (Table 3). By age group, 45–59 years accounted for 36% of the sample, followed by 60 years and over (32%), 30–44 years (25%) and 18–29 years (7%). Avid fishers (i.e. fished 15 days or more in the previous 12 months) accounted for 56% of the sample, followed by 5–14 days (32%) and 1–5 days (12%). The highest proportion of respondents mainly fished in the West Coast (52%), followed by the South Coast (35%), North Coast (7%) and Gascoyne Coast (6%). There were differences between respondents who fished and did not fish during COVID-19 for all demographic and past fishing variables, except gender

Table 3

Demographic and past fishing response variables for Recreational Boat Fishing (RBF) licence holders who participated in a survey on the impact of COVID-19 restrictions on recreational fishing in Western Australia from 29 March to 10 September 2020. Chi square test for association of response variables between fished or did not fish during COVID-19.

Variable	Fished N = 1,116 n (%)	Did not fish N= 385 n (%)	Overall N= 1,501 n (%)	χ^2	p
Residence				11.30	< 0.001
Metropolitan	445 (40)	192 (50)	637 (42)		
Regional	671 (60)	193 (50)	864 (58)		
Gender				0.00	0.99
Female	131 (12)	46 (12)	177 (12)		
Male	985 (88)	339 (88)	1324 (88)		
Age group				13.02	< 0.01
18–29	84 (8)	24 (6)	108 (7)		
30–44	295 (26)	73 (19)	368 (25)		
45–59	401 (36)	141 (37)	542 (36)		
≥ 60 years	336 (30)	147 (38)	483 (32)		
Avidity				75.26	< 0.001
< 5 days	93 (8)	87 (23)	180 (12)		
5–14 days	336 (30)	142 (37)	478 (32)		
≥ 15 days	687 (62)	156 (41)	843 (56)		
Bioregion				23.59	< 0.001
North	89 (8)	17 (4)	106 (7)		
Gascoyne	78 (7)	8 (2)	86 (6)		
West	555 (50)	232 (60)	787 (52)		
South	394 (35)	128 (33)	522 (35)		

(Table 3).

3.1.1. Fishing activity

Of the 1116 licensed fishers who reported fishing, there was a difference in the number of days fished ($\chi^2 = 16.65$, $p < 0.01$, Table 4), with most metropolitan respondents (57%) fishing less than 5 days, and more regional respondents (54%) fishing 5 days or more (Fig. 2). Fewer metropolitan respondents participated in demersal fishing (48%) compared with regional respondents (60%, $\chi^2 = 14.27$, $p < 0.001$). Similarly, fewer metropolitan respondents participated in shore-based line fishing (32%) compared with regional respondents (45%, $\chi^2 = 18.13$, $p < 0.001$). By method, fishers reported (in order of proportion) participation in demersal line fishing (55% overall, Table 4), boat-based nearshore and estuarine line fishing (51%), shore-based line fishing (40%), pelagic line fishing (21%), potting (16%), diving (13%) and game fishing (3%).

There were significant differences for fishing type based on various demographic and past fishing variables (Table 5). Regional respondents were more likely to have fished more often during COVID-19 than metropolitan respondents, and participate in demersal line fishing, shore-based line fishing and potting. Males were less likely to go nearshore and estuarine line fishing than females. Older respondents (≥ 60 years) were more likely to fish more days during COVID-19 than younger respondents (18–59 years), but less likely to go pelagic, demersal line fishing, and diving. Avid fishers were more likely to have fished more often during COVID-19, and more likely to participate in pelagic, demersal line fishing, and potting, but less likely to participate in shore-based line fishing. Respondents who fished in regional waters were more likely to participate in diving and less likely to participate in potting than respondents who fished in the West Coast.

3.1.2. Change in fishing activity

The impact of COVID-19 on overall recreational fishing was minimal for almost a half of respondents (47%, Fig. 2), who reported they fished the same as planned. However, there was a difference in change in fishing activity by residence during COVID-19 ($\chi^2 = 13.04$, $p < 0.01$, Table 4), with 51% of metropolitan respondents fishing less than planned, while 50% of regional respondents fished the same as planned. There were also differences between metropolitan and regional

Table 4

Summary statistics for the association of fishing activity, change and attribution response variables between metropolitan and regional stratum during COVID-19 using (i) Chi square test for Recreational Boat Fishing (RBF) licence holders and (ii) Fisher test for Fisheries and Marine Officers (FMO). Significant comparisons ($\alpha = 0.05$) are shaded in grey.

Variable	RBF	FMO	
	χ^2	p	p
Fishing during COVID-19			
Number of days fished	16.65	<0.01	1.00
Pelagic line fishing	7.36	<0.01	1.00
Game fishing	4.90	0.03	0.09
Demersal line fishing	14.27	<0.001	0.48
Nearshore line fishing	0.74	0.39	0.55
Shore-based line fishing	18.13	<0.001	1.00
Diving	1.07	0.30	0.47
Potting	1.20	0.27	0.33
Change in fishing activity			
Change in fishing activity	13.04	<0.01	0.41
Number of fishing trips	14.11	<0.001	0.30
Fishing in local region	19.82	<0.001	0.74
Fishing in other regions	23.61	<0.001	0.25
Types of fishing	7.72	0.02	0.78
Attribution for change			
Decision to isolate	0.16	0.69	0.66
Travel restrictions	9.62	<0.01	1.00
Social distancing	0.77	0.38	0.06
Personal	0.37	0.54	0.49
Access	0.23	0.63	1.00
Cost	0.29	0.59	0.17
Fishing quality	0.25	0.61	1.00

respondents in the number of fishing trips ($\chi^2 = 14.11$, $p < 0.001$), fishing in local region ($\chi^2 = 19.82$, $p < 0.001$), fishing in other regions ($\chi^2 = 23.61$, $p < 0.001$), and types of fishing ($\chi^2 = 7.72$, $p = 0.02$).

Gender and avidity were not significant predictors for any change in fishing activity. For the comparison between 'less' with 'same' for change in fishing activity response variables, residence was the only significant predictor (Table 5). Regional respondents were less likely to report a change in fishing activity (40%) compared with metropolitan respondents (51%). Similarly, regional respondents were less likely to report 'less' fishing trips, fishing in local region, fishing in other regions, and types of fishing, compared with metropolitan respondents. For the comparison between 'more' with 'same' for change in fishing activity response variables, there were significant differences for three demographic (residence and age) and past fishing (bioregion) variables (Table 5). Regional respondents were less likely to report 'more' fishing in local region, and fishing in other regions, compared with metropolitan respondents. Older fishers were less likely to report 'more' change in fishing activity and number of fishing trips. Respondents who fished in regional marine waters (in the previous 12 months) were more likely to report 'more' change for all response variables relating to change in fishing activity than respondents that fished in the West Coast bioregion (in the past 12 months).

3.1.3. Attribution for change

Changes in fishing activities during COVID-19 were attributed to (in order of importance): travel restrictions (53%), social distancing (45%), the decision to isolate (37%), personal reasons (26%), fishing quality (11%), access (9%) and cost (4%, Fig. 2). More metropolitan respondents (57%) were affected by travel restrictions compared with

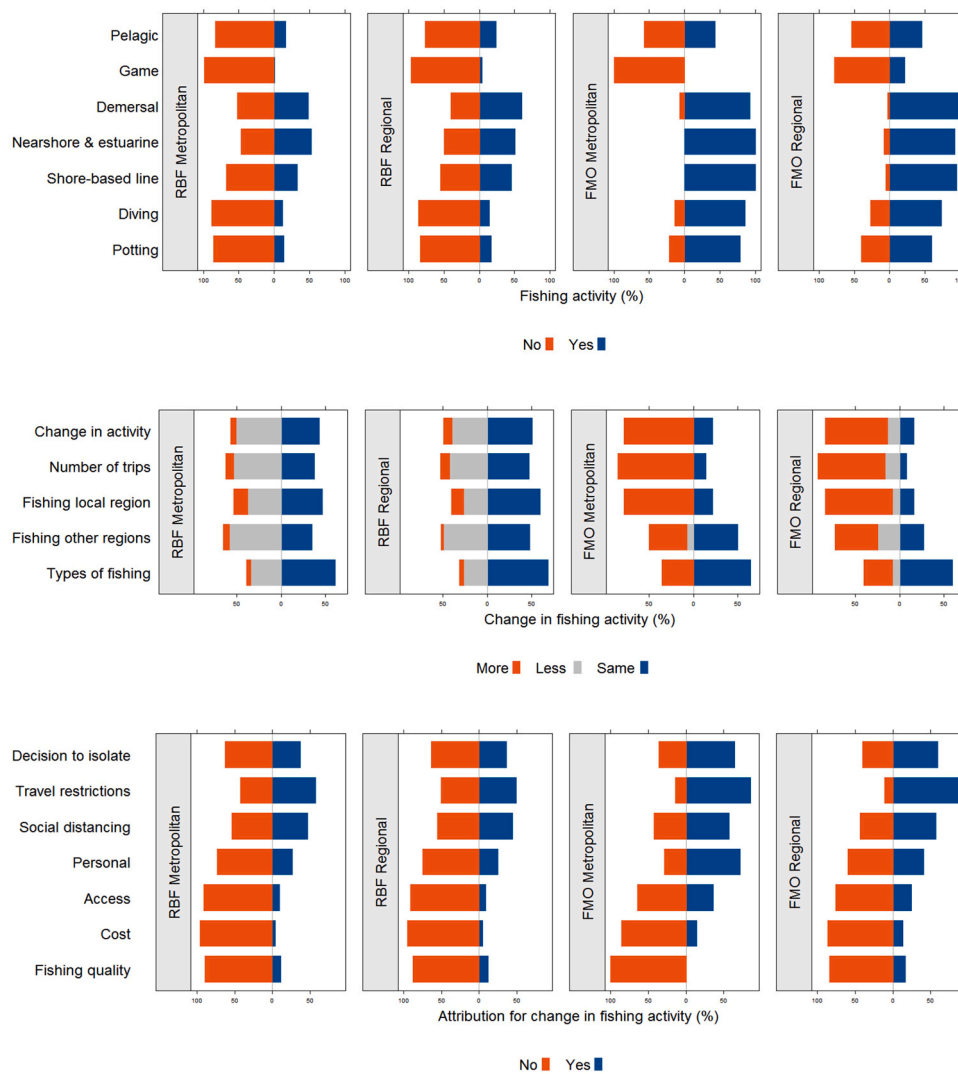


Fig. 2. Comparison of changes in fishing activity and attribution for change for Recreational Boat Fishing (RBF) licence holders and Fisheries and Marine Officers (FMO) in metropolitan and regional Western Australia during COVID-19 (29 March to 10 September 2020).

regional respondents (49%, $\chi^2 = 9.62$, $p < 0.01$, Table 4).

Gender and bioregion were not significant predictors for any attribution of change in fishing activity (Table 5). Regional respondents were less likely to attribute change to travel restrictions. With respect to age, older respondents were less likely to attribute change to travel restrictions and cost, but were more likely to attribute change to the decision to isolate. Avid respondents were more likely to attribute change to social distancing.

3.2. Survey of compliance officers

The survey of compliance officers was completed by 51 respondents who observed recreational fishing during COVID-19. There were no differences in response frequencies between metropolitan-based and regional-based compliance officers in fishing activity, change in fishing activity and attribution for change (Table 4).

In comparison with response frequencies reported by fishers, compliance officers spent more time observing fishing activity with 96% of respondents observing recreational fishing on 20 or more days (Fig. 2). By method, compliance officers observed (in order of proportion) a higher proportion of demersal line fishing (96%), shore-based line fishing (96%), boat-based nearshore and estuarine line fishing (94%), diving (76%), and potting (65%). Compliance officers also

observed more changes in fishing activity, particularly (in order of proportion) a higher proportion of more fishing trips (78%), fishing in their local region (76%), and fishing in other regions (47%). Compliance officers also had a higher proportion for the various attributions, particularly (in order of proportion) a higher attribution of change to travel restrictions (88%), decision to isolate (61%), and personal reasons (49%).

3.3. Boat ramp camera footage

Daily retrievals of recreational vessels varied throughout the state and at different stages of government enacted travel restrictions (Fig. 3). In early March, daily retrievals at all boat ramps (excluding Denham) did not exhibit any decrease during the lockdown, when travel between regions and all non-essential social activities were prohibited without exemption. The greatest number of daily retrievals occurred at metropolitan boat ramps with more than 400 retrievals observed at Hillarys and Woodman Point on several days. In contrast, for the regional boat ramps, the highest maximum daily retrievals occurred at Broome and Albany (~75), followed by Exmouth (~50), and Monkey Mia and Denham (both < 20). In phase 1, where recreational fishing was an approved activity, although travel between regions was still prohibited, maximum daily retrievals increased at Denham (~40), and decreased at

Table 5

Odds Ratios (95% confidence intervals) from logistic regressions for fishing activity, change and attribution during COVID-19 among Recreational Boat Fishing (RBF) licence holders by fisher demographics (residence, gender and age) and fishing behaviour (avidity and bioregion) (^B indicates binomial logistic regressions and ^M indicates multinomial logistic regressions, 95% confidence intervals of non-significant Odds Ratios include the value 1). Significant comparisons ($\alpha = 0.05$) are shaded in grey.

Variable		Residence (Metro, Regional)	Gender (Female, Male)	Age Group (18–59, ≥60 yrs)	Avidity (1–14, ≥15 days)	Bioregion (West, Regional)
Fishing activity						
Number of days fished ^B	(1–14, ≥15 days)	1.66 (1.09–2.56)	0.89 (0.52–1.56)	1.52 (1.04–2.21)	9.40 (5.35–18.14)	1.04 (0.70–1.55)
Pelagic line fishing ^B	(No, Yes)	1.03 (0.92–1.85)	0.86 (0.56–1.36)	0.62 (0.44–0.88)	1.47 (1.08–2.02)	1.35 (0.97–1.88)
Game fishing ^B	(No, Yes)	2.51 (0.92–8.07)	0.60 (0.24–1.81)	0.68 (0.25–1.61)	1.79 (0.78–4.59)	1.44 (0.62–3.64)
Demersal line fishing ^B	(No, Yes)	1.71 (1.30–2.27)	1.32 (0.91–1.91)	0.58 (0.45–0.76)	1.61 (1.26–2.07)	0.82 (0.62–1.08)
Nearshore and estuarine line ^B	(No, Yes)	0.79 (0.60–1.04)	0.67 (0.46–0.96)	1.27 (0.98–1.64)	1.23 (0.97–1.57)	1.25 (0.96–1.64)
Shore-based line fishing ^B	(No, Yes)	1.43 (1.08–1.90)	1.34 (0.91–2.00)	0.99 (0.75–1.29)	0.74 (0.58–0.95)	1.62 (1.23–2.12)
Diving ^B	(No, Yes)	1.11 (0.73–1.69)	1.46 (0.82–2.81)	0.18 (0.10–0.32)	1.39 (0.96–2.06)	1.19 (0.79–1.78)
Potting ^B	(No, Yes)	1.71 (1.17–2.51)	1.02 (0.62–1.75)	1.39 (0.98–1.96)	1.79 (1.25–2.59)	0.44 (0.30–0.64)
Change in fishing activity						
Change in fishing activity ^M	Same, Less	0.69 (0.52–0.91)	0.96 (0.65–1.42)	1.12 (0.86–1.46)	1.06 (0.82–1.36)	0.93 (0.71–1.23)
	Same, More	0.88 (0.52–1.51)	0.67 (0.36–1.24)	0.32 (0.16–0.61)	1.27 (0.79–2.03)	1.84 (1.09–3.11)
Number of fishing trips ^M	Same, Less	0.66 (0.49–0.87)	1.15 (0.77–1.70)	1.02 (0.78–1.33)	1.11 (0.86–1.44)	0.89 (0.68–1.18)
	Same, More	0.74 (0.45–1.21)	0.74 (0.41–1.34)	0.48 (0.28–0.82)	1.36 (0.87–2.11)	1.68 (1.04–2.73)
Fishing in local region ^M	Same, Less	0.57 (0.42–0.78)	1.02 (0.67–1.54)	1.32 (0.99–1.75)	1.01 (0.76–1.31)	0.92 (0.68–1.24)
	Same, More	0.51 (0.34–0.77)	0.88 (0.51–1.50)	0.67 (0.44–1.03)	1.35 (0.93–1.97)	1.75 (1.16–2.63)
Fishing in other regions ^M	Same, Less	0.64 (0.48–0.85)	1.22 (0.84–1.78)	1.03 (0.79–1.34)	1.14 (0.89–1.47)	0.93 (0.70–1.22)
	Same, More	0.19 (0.10–0.38)	1.55 (0.53–4.51)	0.82 (0.42–1.62)	0.55 (0.30–1.01)	2.93 (1.48–5.82)
Types of fishing ^M	Same, Less	0.73 (0.54–0.98)	1.48 (0.96–2.29)	1.09 (0.82–1.45)	0.94 (0.72–1.23)	0.90 (0.67–1.21)
	Same, More	0.59 (0.32–1.11)	1.01 (0.44–2.31)	0.53 (0.26–1.08)	1.31 (0.73–2.35)	2.14 (1.12–4.07)
Attribution for change						
Decision to isolate ^B	(No, Yes)	0.87 (0.68–1.10)	1.22 (0.88–1.72)	1.57 (1.26–1.97)	1.02 (0.82–1.26)	1.25 (0.99–1.59)
Travel restrictions ^B	(No, Yes)	0.71 (0.56–0.89)	1.16 (0.85–1.59)	0.75 (0.60–0.93)	1.15 (0.94–1.42)	1.02 (0.81–1.28)
Social distancing ^B	(No, Yes)	0.95 (0.75–1.19)	1.26 (0.92–1.75)	0.82 (0.65–1.02)	1.32 (1.07–1.62)	0.87 (0.70–1.10)
Personal ^B	(No, Yes)	0.97 (0.74–1.25)	0.91 (0.64–1.31)	1.23 (0.96–1.57)	0.81 (0.64–1.03)	0.93 (0.72–1.20)
Access ^B	(No, Yes)	0.91 (0.61–1.36)	1.16 (0.67–2.15)	0.99 (0.67–1.44)	0.96 (0.67–1.38)	0.99 (0.66–1.46)
Cost ^B	(No, Yes)	1.24 (0.71–2.21)	1.01 (0.50–2.34)	0.50 (0.26–0.90)	0.71 (0.43–1.17)	0.95 (0.54–1.66)
Fishing quality ^B	(No, Yes)	1.05 (0.73–1.51)	1.15 (0.70–1.98)	1.24 (0.88–1.73)	1.01 (0.73–1.39)	1.13 (0.79–1.61)

Broome (~45) and Exmouth (~25). At Hillarys, Woodman Point, Monkey Mia and Albany the maximum number of retrievals did not change. In phase 2, where travel restrictions were eased with the number of intrastate regions reducing from nine to four, maximum daily retrievals increased at Broome (~60), Exmouth (~50) and Denham (~50), decreased at Hillarys (~300) and Woodman Point (~400) and Albany (~50), but did not change at Monkey Mia (~20). In phases 3 and 4, when unrestricted travel was permitted between regions, vessel activity followed expected seasonal patterns, increasing at ramps in northern regions at this time. Maximum daily retrievals were reported at Broome (~90), Exmouth (~125), Monkey Mia (~50) and Denham (~100), but decreased at Hillarys (~300), Woodman Point (~400) and Albany (~40).

Regression analyses for metropolitan boat ramps indicated that the main effects of year (Hillarys: $p < 0.01$; Woodman Point: $p < 0.01$, Table 6), month (Hillarys: $p < 0.001$; Woodman Point: $p < 0.001$) and day type (Hillarys: $p < 0.001$; Woodman Point: $p < 0.001$) were the primary variables describing the variability in monthly vessel retrievals. All two-way interactions were not significant. For Hillarys, retrievals in 2020 were significantly greater than retrievals in 2013 and 2011 (Table 7). Retrievings for Hillarys in 2016 were not included in the model due to large outages in March, April and May (Fig. 4). Vessel retrievals for Woodman Point in 2020 were significantly greater than the retrievals in all previous years (Table 7).

For northern regional ramps, the interaction between year and month was the primary descriptor for variability in vessel retrievals (Broome: $p = 0.01$; Exmouth: $p < 0.01$; Monkey Mia: $p < 0.001$; Denham: $p < 0.001$; Table 6). Variability in retrievals in the two most northern ramps was also explained by day type (Broome: $p < 0.001$; Exmouth: $p < 0.001$). Comparisons of individual years within each month indicated where significant differences between years occurred for the northern boat ramps (Table 6). Retrievings at Denham were significantly higher in 2020 than 2011 and 2013 for May and July, as well as during August when compared with 2011. At Monkey Mia,

retrievals in April were significantly lower in 2020 than 2011 and 2016. Conversely, retrievals at this ramp were higher during June, July and August when comparing 2020–2011, and higher during July in 2020 than 2016. At the two most northern ramps, comparison of retrievals among years within each month only indicated two statistical differences, with retrievals in April at Broome higher in 2020 than 2013, and those during May at Exmouth being lower in 2020 than 2016 and 2013.

The variability in retrievals at Albany was best described by the main effects of year ($p < 0.001$, Table 6), month ($p < 0.001$) and day type ($p < 0.001$), and the interaction between year and day type ($p = 0.06$). Comparisons of individual years within each day type demonstrated that there was no difference between years during weekdays (Table 7). Vessel retrievals at this ramp during weekends in 2016 were significantly lower than 2011. There were no significant differences of retrievals at this ramp when comparing 2020 and the other years during weekdays or weekends.

4. Discussion

4.1. Recreational fishing during COVID-19 restrictions

This study has demonstrated differences in patterns of recreational fishing activity in Western Australia during COVID-19 restrictions from March to August 2020. Implementation of online surveys for licensed recreational fishers improved understanding of the impacts on fishers at a statewide level. While the types of fishing overall (e.g. higher proportions of nearshore and demersal fishing) were comparable with previous surveys, lower recreational tourism due to travel restrictions had greater impacts for metropolitan fishers with evidence of less fishing for some groups, such as older and less avid fishers. Changes among fishers indicated less fishing activity across all measures (number of fishing trips, fishing in local region, fishing in other regions, and types of fishing). In contrast, changes among compliance officers indicated more fishing activity across all measures. By examining boat ramp camera

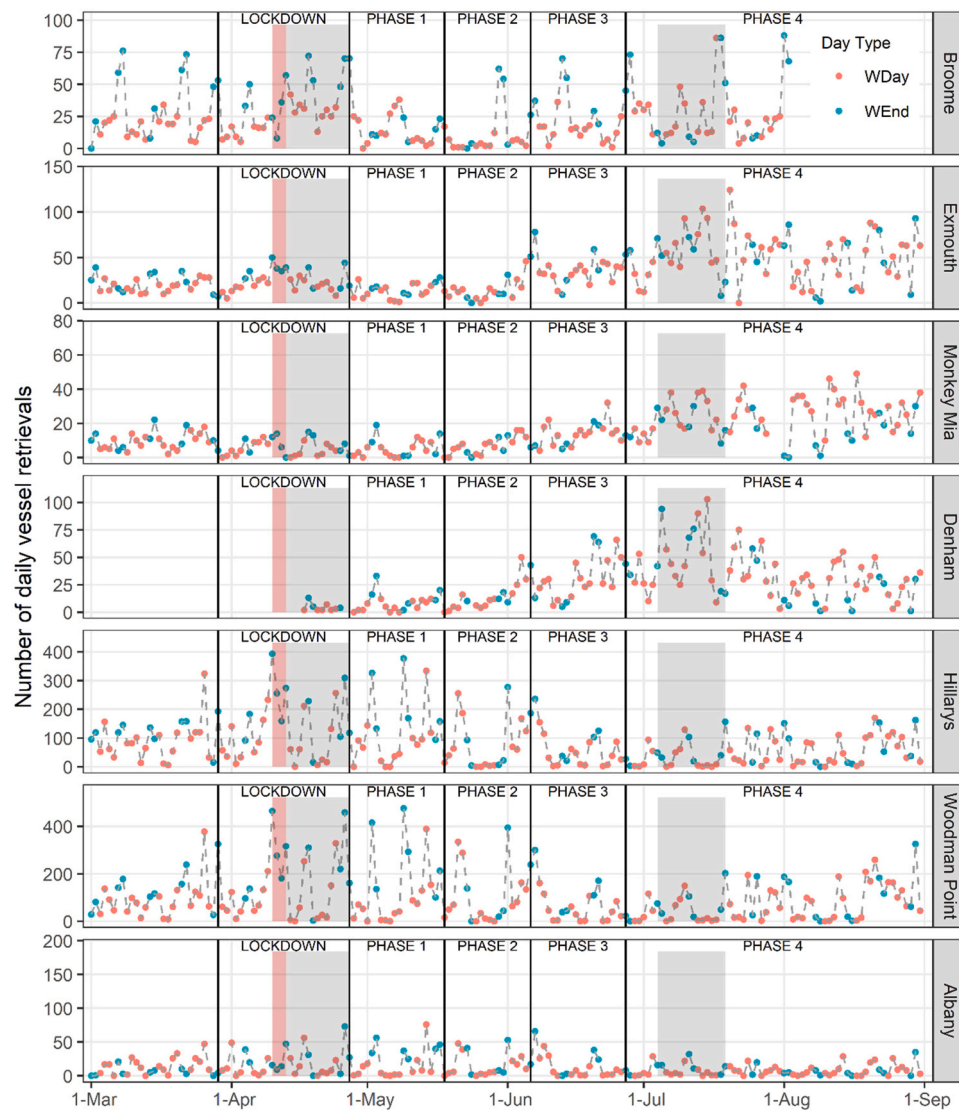


Fig. 3. Daily vessel retrievals from boat ramp camera monitoring in Western Australia from March to August 2020. Retrievals include non-fishing vessel activity. The Easter long weekend and school holiday periods are shown as pink and dark grey shaded areas, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

data, changes in fishing activity, in response to the various government measures introduced to combat the spread of COVID-19, were determined in near ‘real-time’. Different patterns of fishing activity were observed from the camera data between metropolitan and regional boat ramps.

Interestingly, the three sources of data did not reveal consistent patterns with respect to change in fishing activity. As the study of licensed fishers does not estimate effort, a possible explanation may be that more people went fishing but individually fished fewer days. This could explain the individual experience of less fishing reported by fishers, but the collective experience of more fishing observed by compliance officers. Another explanation might be that the survey of fishers was conducted across different phases of the State Government response to COVID-19, while the compliance officer survey was only conducted in November during phase 4, when fishers were allowed to travel freely within the state. It is also acknowledged that the scope of each survey differed which precludes a direct comparison of fishing activity between survey methods.

4.2. Recreational fishing during COVID-19 restrictions compared with previous years

The boat ramp camera data provided an opportunity to compare whether fishing activity during COVID-19 differed from historical patterns at key boat ramps statewide. At the metropolitan boat ramps, an initial increase in recreational vessel activity occurred in the early phases followed by a return to baseline levels as travel restrictions were eased. In contrast, activity levels in regional centres were initially less than, or similar to, baseline levels, but following restrictions on interstate travel and corresponding increased regional tourism, recreational vessel activity increased to above expected levels. The typical seasonal pattern of recreational fishing that has been observed in Western Australia was not apparent during COVID-19 restrictions [24]. In comparison with previous years, the relative change in the number of vessel retrievals obtained from cameras differed for metropolitan and regional boat ramps and the stage of government measures. This resulted in higher than previously observed levels of vessel activity in some regional areas of Western Australia.

The results highlight the importance of collecting baseline data on recreational fishing which allows the impacts of events, such as COVID-

Table 6

Analysis of deviance table for negative binomial GLMs fitted independently for vessel retrievals at seven key boat ramps in Western Australia. Significant comparisons ($\alpha = 0.05$) are shaded in grey.

Ramp	Factor	df	Full Model		Reduced Model	
			Deviance	p-Value	Deviance	p-Value
Broome	Year (2011, 2013, 2016, 2020)	3	12.97	<0.01	12.97	<0.01
	Month (Mar, Apr, May, Jun, Jul)	4	37.91	<0.001	37.90	<0.001
	Day type	1	127.66	<0.001	127.60	<0.001
	Year:Month	12	27.41	0.01	27.39	0.01
	Year: Day type	3	0.18	0.98	-	-
	Month: Day type	4	8.68	0.07	8.61	0.07
Exmouth	Year (2013, 2020)	1	7.82	0.02	7.69	0.02
	Month (Mar, Apr, May, Aug)	3	35.47	<0.001	34.87	<0.001
	Day type	1	21.85	<0.001	21.47	<0.001
	Year:Month	3	14.18	<0.01	13.95	<0.01
	Year: Day type	1	1.18	0.55	-	-
	Month: Day type	3	3.04	0.22	-	-
Monkey Mia	Year (2011, 2016, 2020)	2	30.91	<0.001	30.73	<0.001
	Month (Mar, Apr, Jun, Jul, Aug)	4	92.48	<0.001	91.95	<0.001
	Day type	1	0.34	0.56	0.34	0.56
	Year:Month	8	170.79	<0.001	169.79	<0.001
	Year: Day type	2	2.47	0.29	-	-
	Month: Day type	4	17.73	<0.01	18.27	<0.01
Denham	Year (2011, 2013, 2020)	2	6.97	0.03	6.91	0.03
	Month (May, Jun, Jul, Aug)	3	38.09	<0.001	37.79	<0.001
	Day type	1	0.01	0.93	0.01	0.93
	Year:Month	6	91.02	<0.001	90.33	<0.001
	Year: Day type	2	1.15	0.56	-	-
	Month: Day type	3	1.99	0.58	-	-
Hillarys	Year (2011, 2013, 2020)	2	12.23	<0.01	12.01	<0.01
	Month (Mar, Apr, May, Jul, Aug)	4	53.40	<0.001	52.45	<0.001
	Day type	1	57.66	<0.001	56.64	<0.001
	Year:Month	8	3.42	0.91	-	-
	Year: Day type	2	3.84	0.15	-	-
	Month: Day type	4	1.46	0.83	-	-
Woodman Point	Year (2011, 2013, 2016, 2020)	3	14.38	<0.01	13.96	<0.01
	Month (Mar, Apr, May, Jun, Aug)	4	24.21	<0.001	23.51	<0.001
	Day type	1	135.24	<0.001	131.35	<0.001
	Year:Month	12	12.20	0.43	-	-
	Year: Day type	3	5.64	0.13	-	-
	Month: Day type	4	1.50	0.83	-	-
Albany	Year (2011, 2016, 2020)	2	29.04	<0.001	27.85	<0.001
	Month (Mar, Apr, May, Jun, Jul, Aug)	5	56.22	<0.001	53.92	<0.001
	Day type	1	33.98	<0.001	32.57	<0.001
	Year:Month	10	16.86	0.08	-	-
	Year: Day type	2	6.75	0.03	5.74	0.06
	Month: Day type	5	5.09	0.40	-	-

19, to be investigated. Determining trends in recreational fishing activity can be challenging because surveys are rarely completed on an annual basis [38]. For example, in Australia, most jurisdictions provide statewide estimates of fishing effort and catch on a 3–5 year basis [39] and for smaller fisheries, estimates may only be available from periodic on-site surveys [23]. This makes it challenging to monitor changes in fishing activity in response to atypical events, such as COVID-19. This study reaffirms the value of long term monitoring using boat ramp

cameras in combination with periodic on-site and off-site surveys to provide insight into recreational fishery dynamics [40,41]. The collection of detailed recreational vessel activity on a daily basis enabled the effects of COVID-19 to be monitored in response to specific government measures. The collection of video imagery also provides a 'point of truth', which can be used to substantiate anecdotal reports and differences of opinion in relation to fishing activity and has been identified as a gold standard for validating survey estimates [42].

Table 7

Results (p-values) of two-way comparisons of differences in number of vessel retrievals in each pair of years at each boat ramp camera site with Bonferroni correction. Year to year comparisons were undertaken within each month and/or day type in the presence of significant interactions. Significant comparisons ($\alpha = 0.05$) are shaded in grey, with direction of z-score indicated in brackets.

Contrast	Month	Broome	Exmouth	Monkey Mia	Denham	Hillarys	Woodman Point	Albany WDay	Albany WEnd
2020 / 2016	Mar	0.56	0.99	0.09	-				
	Apr	0.56	0.99	<0.001 (-)	-				
	May	0.24	<0.001 (-)		-				
	Jun	0.99	-	0.90	-	-	0.02 (+)	0.47	0.28
	Jul	0.99	-	<0.001 (+)	-				
	Aug	-	-	0.06	-				
2020 / 2013	Mar	0.08	0.99	-	-				
	Apr	0.03 (+)	0.27	-	-				
	May	0.99	0.02 (-)	-	<0.001 (-)	<0.001 (+)	<0.001 (+)	-	-
	Jun	0.99	-	-	0.06				
	Jul	0.99	-	-	0.04 (-)				
	Aug	-	-	-	0.12				
2020 / 2011	Mar	0.52	-	0.99	-				
	Apr	0.09	-	<0.001 (-)	-				
	May	0.99	-		<0.001 (+)				
	Jun	0.99	-	<0.001 (+)	0.04	0.03 (+)	<0.01 (+)	0.99	0.11
	Jul	0.99	-	<0.01 (+)	0.01 (+)				
	Aug	-	-	0.02 (+)	0.01 (+)				
2016 / 2013	Mar	0.99	-	-	-				
	Apr	0.99	-	-	-				
	May	0.99	-	-	-				
	Jun	0.98	-	-	-	-	0.67	-	-
	Jul	0.99	-	-	-				
	Aug	-	-	-	-				
2016 / 2011	Mar	0.99	-	<0.001 (+)	-				
	Apr	0.99	-	0.78	-				
	May	0.01 (+)	-		-				
	Jun	0.99	-	0.01 (+)	-		0.82	0.16	<0.001 (-)
	Jul	0.99	-	0.99	-				
	Aug	-	-	0.99	-				
2013 / 2011	Mar	0.99	-	-	-				
	Apr	0.99	-	-	-				
	May	0.99	-	-	0.99				
	Jun	0.99	-	-	0.99	0.32	0.99	-	-
	Jul	0.99	-	-	0.99				
	Aug	-	-	-	0.99				

4.3. Attribution for change in recreation fishing activity

The pandemic has changed how people participate in recreational activities [43]. In Western Australia, motivations for recreational fishing have traditionally been higher for non-consumptive orientations (e.g. “to relax and unwind”), rather than consumptive orientations (e.g. “to catch a feed”) [44,45]. However, anecdotes from comments in both the fisher and compliance officer surveys suggest a possible change in motivations in response to COVID-19. Although comments mention mental health and wellness, other comments mention food provisioning and security. Understanding motivations for recreational fishing are a high priority for the recreational sector. Improved understanding will afford novel management approaches, such as Maximum Experiential Yield, and increasing opportunities for recreational fishing, particularly in

regional locations that fishers visit with flow on benefits to local tourism [46].

Recreational fishing and tourism are often linked with respect to providing opportunities for growth and diversification in fishing experiences, particularly for iconic target species in popular regional fishing destinations. The impact of COVID-19 has seen community and stakeholder aspirations achieved for increased tourism and participation in recreational fishing at popular regional centres in a very short time-frame. Western Australia is a large state with numerous regional centres that are economically reliant on tourism. Many businesses that rely on expenditure from interstate and intrastate recreational fishers reported economic hardship during the initial phases of COVID-19 restrictions. However, a dramatic turn-around in visitation numbers occurred when intrastate borders opened, with unusually higher

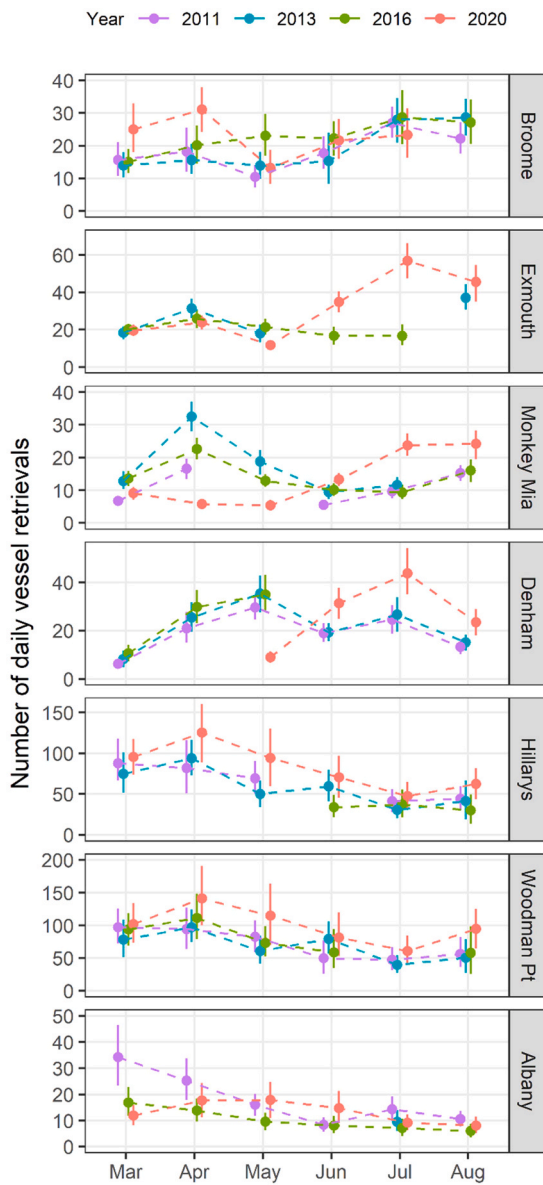


Fig. 4. Monthly bootstrapped means (and associated 95% confidence intervals) of daily vessel retrievals from boat ramp camera monitoring by year and month in Western Australia. Retrievals include non-fishing vessel activity. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

numbers of people visiting regional centres. During these phases, interstate and international travel continued to be restricted and it is likely many visitors were Western Australian residents who might otherwise have travelled interstate or overseas. While the influx of domestic visitors delivered economic benefits to regional centres, there were growing concerns about high levels of localised fishing effort and potential over-fishing. This has raised concerns about the longer-term impact on recreational fishing as the community adapts to sustained increased recreational tourism. Previous statewide surveys indicate predictable patterns of recreational fishing effort and businesses are organised to accommodate visitation associated with these patterns. The increased visitation to regional centres in response to COVID-19 has resulted in accommodation shortfalls, as well as higher demand for the tackle industry and boat sales, and realisation that expenditure patterns of Western Australians differ from those of interstate or overseas visitors. Further research is needed to better understand the concerns of stakeholders and regional shires, and to develop management approaches

that address these in addition to resource sustainability goals.

4.4. Policy and management responses

One of the primary roles for DPIRD is the sustainable management of Western Australia’s fishery and aquatic resources and the contributions of fisheries research is to provide mandated evidence-based scientific advice on status of fish stocks and fishing sectors including recreational fishing. While plenty of opinions are routinely offered on contentious issues (e.g. to fish or not to fish during the COVID-19 pandemic), scientific advice remains the basis for policy development and management of the state’s fisheries. The State Government acted promptly and firmly in response to COVID-19 in all areas of community activities including recreational fishing. While government directives in respect to higher level actions were broad, the interpretation of rules for specific activities were left to the Minister and peak body [26,47], as well as other government departments [48], journalists [49] and academics [50]. This led to varied responses of the recreational sector through different phases.

DPIRD was able to confirm the response of the recreational fishing sector during COVID-19 in close to ‘real-time’ with monthly updates provided to fishery managers, a situation that is not typically the case compared with commercial fishing that has access to on-going monitoring infrastructure e.g. Vessel Monitoring Systems. Response to questions around COVID-19 and changes in recreational fishing activity in Western Australia was only possible with routine statewide phone-diary surveys used in combination with key boat ramp cameras that can provide ongoing information 24/7. That we were able to utilise data from existing monitoring programmes underlies the importance of these programmes and associated survey infrastructure. In contrast, jurisdictions elsewhere saw on-site surveys suspended or disrupted for staff welfare reasons [1]. The challenge for survey researchers is to develop survey methods that allow for the rapid collection of reliable information on recreational fishing. The development of automated methods for interpretation of camera data would extend the application of this data collection tool, given that the costs of manually reading video imagery can be substantial [40].

Managing recreational fishing to meet competing ecological (e.g. stock sustainability), economic (e.g. regional tourism) and social (e.g. mental wellness) objectives with limited resources for monitoring small-scale fisheries remains challenging. Benefits of fish stocks being ‘rested’ under (short) periods of below normal levels of recreational fishing effort are potentially outweighed by subsequent (extended) periods of substantially higher fishing effort. Stock assessment scientists will need to consider how to accommodate spikes in fishing activity that extend beyond the typical ‘normal’ maxima observed without corresponding validated catch data under the reasonable assumption that catches change proportionally with effort for vulnerable/popular fish stocks in areas of high conservation value (e.g. Shark Bay, Ningaloo). Equally, fisheries managers will need to work with the recreational sector representative bodies and develop more flexible policy/management responses that adequately accommodate sudden changes in recreational fishing effort and resulting catches via innovative harvest strategies and TARC settings for vulnerable fish stocks, particularly in areas of high community interest.

5. Conclusions

This study provides initial insights into boat-based recreational fishing activity in Western Australia during the first 6 months of the COVID-19 pandemic. Using multiple lines of evidence, we have been able to confirm differences in fishing activity between Perth metropolitan and regional areas from March to August 2020, and differences in fishing activity at key regional locations compared with previous years where monitoring data was available. Importantly, the impact of COVID-19 on recreational fishing has been varied within the

recreational sector. Impacts due to the decision to isolate were greater for fishers 60 years or older, who presumably had genuine concern for their health. Impacts due to social distancing were greater for avid fishers, who were only permitted to fish with their family. Impacts due to travel restrictions were greater for metropolitan based fishers, who were unable to travel to regional centres during the early phases of COVID-19 due to State Government imposed travel restrictions. The current statewide recreational fishing survey (from 1 September 2020–31 August 2021) will provide an opportunity to review the medium-term impact of COVID-19 on recreational fishing, including changes in recreational tourism in comparison with previous surveys. Important areas for future research include determination of recreational catches for key species at the most popular recreational fishing destinations that experienced above normal levels of fishing activity and detailed economic analysis of the effects on regional businesses dependent upon visiting recreational fishers. This study and subsequent investigations will assist in informing policy changes required to manage impacts of recreational fishing, including regulatory measures that support resource sustainability, as well as initiatives that promote social and economic opportunities for recreational fishing, particularly in popular regional recreational fishing destinations. Studies of this kind underline the high value of long-term recreational monitoring programmes and demonstrate the need for responsive evaluations that provide scientific advice to policymakers to respond to the societal behavioural changes associated with atypical events such as COVID-19.

CRedit authorship contribution statement

Karina Ryan: Conceptualization, Data curation, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Cameron Desfosses:** Conceptualization, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Ainslie Denham:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Stephen Taylor:** Conceptualization, Writing - original draft, Writing - review & editing. **Gary Jackson:** Conceptualization, Writing - original draft, Writing - review & editing.

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