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Mitigating operational interactions with short-beaked common dolphin (*Delphinus delphis*): application of the South Australian Sardine Fishery industry Code of Practice 2016-17

Alice I. Mackay and Simon. D. Goldsworthy

SARDI Publication No. F2010/000726-8
SARDI Research Report Series No. 970

SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

November 2017

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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This is the eleventh annual report on the application of the SASF Code of Practice (CoP) and we would like to acknowledge the previous work conducted by Associate Professor Tim Ward, Alex Ivey, Dr Jonathan Carrol, Dr Paul Burch and Dr Derek Hamer.

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The report was approved for release by Associate Professor Tim Ward.

EXECUTIVE SUMMARY

This is the eleventh report on the effectiveness of the industry Code of Practice (CoP) in mitigating operational interactions of the South Australian Sardine Fishery (SASF) with short-beaked common dolphins (*Delphinus delphis*). The report presents observer data, fishery logbook catch and effort data, and wildlife interaction data collected during the 2016-17 fishing season.

The objectives of the study were to examine patterns of observer coverage, compare observed and reported rates of dolphin encirclement and mortality, and assess the efficacy of the CoP in mitigating interactions with dolphins using data collected by observers and reported in fishery logbooks and wildlife interaction forms between 1 July 2007 and 30 June 2017. The study also examined fishing patterns (i.e. catch per unit effort; CPUE) with and without an observer present.

During the 2016-17 fishing season, 12% (117) of the total 975 purse seine net-sets were observed. In general, observer coverage in 2016-17 was evenly distributed, both spatially and temporally, with respect to total fleet effort. Eight encirclement events involving a total of 32 dolphins were observed and one mortality was recorded. A further 51 encirclements were reported in fishery logbooks involving 169 dolphins with one injury and no mortalities reported. In 2016-17, encirclement rates with and without an observer present were seven encirclement events per 100 net-sets and nine encirclement events per 100 net-sets, respectively. An interaction involving a single common dolphin entangled outside of the net during hauling was also observed; the fate of this individual after it was released is unknown.

The first step in the CoP is to actively search for wildlife prior to setting the net. In 2016-17, searches were undertaken prior to a net being set during all but one of the 117 observed shots and nine net-sets were delayed after dolphins were sighted. Active searching prior to the net being set resulted in 93.1% of observed net-sets not resulting in an encirclement event. Of the 32 encircled dolphins, one mortality was observed and all other individuals were released without injury. During one fishing operation a single dolphin was observed entangled on the outside of the net as it was hauled. The fate of this individual after it was released was unknown. These results indicate that the application of the CoP by searching prior to setting the net can reduce the number of dolphin encirclements that occur, and that the quick release of dolphins once encircled can reduce the likelihood of mortality.

Previous studies have shown that CPUE was consistently lower, and the proportion of zero-catch shots higher when an observer is present, than when an observer is absent (e.g. Ward et al.

2015). This has led to concerns that fishing behaviour may be different when an observer is present. While $CPUE_{net\text{-}set}$ was also lower with an observer present than without an observer, this difference was only statistically significant for one vessel. Since 2012-13, the average number of net-sets per night across the fleet was higher when an observer was present than without an observer. This pattern continued in 2016-17, however the difference in average net-sets per night with and without an observer present was not significant. Given the different factors that can effect $CPUE_{net\text{-}set}$ in the SASF (e.g. vessel size and season), it is not possible to determine whether differences in $CPUE_{net\text{-}set}$ with and without an observer were a result of a difference in fishing behaviour when an observer is present, or unrepresentative observer coverage in some years.

Examining fishing patterns between observer present and observer absent data for 2007-08 and 2016-17 showed the proportion of zero-catch shots were higher for observed compared to unobserved shots. Of the 94 observed net-sets in 2016-17, 20% (n=23) resulted in zero catch compared to 15% in unobserved shots. The reason for zero-catch in four of these net-sets was that the shot was aborted in order to release dolphins after an encirclement. In contrast, 48% of observed shots with zero catch recorded were either because fish catches were too small to pump or fish patches were missed.

It is important that observer coverage is evenly distributed, so that comparisons of the spatial and temporal distribution of fishing effort and catch between observed and unobserved shots can be used to determine if observer data are representative of reported fishing effort. To improve information on the application of the CoP for net-sets without an observer, it is recommended that fishers continue to record information on interactions similar to that currently recorded by observers and that a consolidated Wildlife Interaction Form (WIF) and observer form are provided to industry to do so. Maintaining representative observer coverage in the fishery will enable further analyses of fishing related metrics, such as the occurrence of zero-catch hauls, and over the longer term, will provide information on the temporal and spatial co-occurrence of dolphins with fishing effort.

Keywords: South Australian Sardine Fishery, Code of Practice, wildlife interactions, dolphins, mitigation.

1. INTRODUCTION

1.1. Background

Evidence of fine-scale population sub-structuring of short-beaked common dolphins (*Delphinus delphis*) off southern and south-eastern Australia have raised concerns over cumulative population level impacts from fishery interactions on this species (Bilgmann et al. 2014a). The common dolphin is a widely distributed small cetacean species that occurs in both tropical and temperate waters of the Atlantic, Pacific and Indian Oceans (Perrin 2002, Bilgmann et al. 2014a). Operational interactions with common dolphins are recorded in the South Australian Sardine Fishery (SASF) (e.g. Ward et al. 2015b) and the gillnet sector of the Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF) (AFMA 2017). Population sub-structuring has been reported between locations along the south coast of Australia and from samples collected off New South Wales and the south-east of Tasmania (Bilgmann et al. 2008, 2014a, Möller et al. 2012). However, given the documentation of long-range longitudinal movement of individuals from different genetic populations into the region (Bilgmann et al. 2014), further information on population sub-structuring and temporal and spatial movement patterns are required to resolve the level of population sub-structure of common dolphins off southern Australia waters. Abundance data for common dolphins off South Australia (SA) are restricted to a winter and summer 2011 aerial survey of Spencer Gulf, Gulf St Vincent and Investigator Strait, SA (Möller et al. 2012), and an aerial survey in winter 2013 between Ceduna and Coffin Bay, SA (Bilgmann et al. 2014b). In both regions, aerial surveys were conducted out to the 100 m depth contour.

There are no abundance estimates of common dolphins in offshore waters and no information on the spatial or temporal movements of common dolphins, either along the coast, or between offshore and inshore areas within the region. Abundance data are required in order to be able to assess the cumulative impacts of fisheries bycatch on this species in Australia.

Fishery-independent data on the occurrence and nature of operational interactions between the SASF and common dolphins have been collected since 2004. Operational interactions between common dolphins and the SASF, where most fishing is undertaken at night time, primarily occur when individuals become encircled in the purse seine net after the net has been set. An initial observer program was undertaken by the South Australian Research and Development Institute (SARDI) between November 2004 and June 2005, and indicated high interaction rates (three encirclement events per 10 net-sets) with common dolphins (Hamer et al. 2008). An encirclement event was defined as one or more dolphins being present inside the purse seine net after it had

been set. Hamer et al. (2008) found that the majority of observed operational interactions with dolphins occurred in fishing hotspots, due to aggregation of large schools of sardines or by fishing vessels, and concluded that spatial closures would not be suitable for mitigating interactions. The fishery was closed for two months in 2005 while an Industry Code of Practice (CoP) was developed for the SASF and the effectiveness of the CoP to mitigate interactions with common dolphins was monitored by independent onboard observers (Hamer et al. 2008). This observer program reported an 87% reduction in dolphin encirclement rates and a 97.1% reduction in mortality rates after the CoP had been developed (Hamer et al. 2008).

The CoP, administered by the South Australian Sardine Industry Association (SASIA), is continuously reviewed by a Wildlife Interaction Working Group that includes members from the SASF industry, the Department of Primary Industry and Regions South Australia (PIRSA), SARDI and the South Australian Department of Environment Water and Natural Resources (DEWNR) (SASIA 2015). The CoP has been refined over time to reduce the number of interactions with dolphins and improve release procedures if an encirclement occurs. The key components of the CoP are avoiding interactions by searching for dolphins prior to setting the net, searching for dolphins as soon as the net is pursed and initiating a release procedure as soon as possible if dolphins are detected. In addition, the CoP encourages at-sea communication between skippers to report the location of dolphins in real time and reduce fishing effort by co-ordinating fishing activities so that if excess fish are caught, these can be transferred between vessels.

An independent on-board observer program has operated in the fishery since July 2006. Observers collect information on dolphin interaction and mortality rates, as well as data relating to the application of the CoP, such as whether a search has been made prior to the net being set and the release method used if an encirclement has occurred. These data have been used to provide annual assessments of the effectiveness of the CoP at mitigating interactions with common dolphins (e.g. Ward et al. 2010, 2011, 2012, 2013, 2015a, b, Mackay and Goldsworthy, 2016). The target level of observer coverage since the 2006-07 season has been 10% of fishing operations, with the exception of 2007-08 to 2009-10 seasons when target coverage was set at 30%. The increase in observer coverage in these fishing seasons was in response to higher observed encirclement and mortality rates in 2006-07 compared to the 2005-06 fishing season (Ward et al. 2010). The level of observer coverage was subsequently reduced to 10% after refinements to the CoP (Ward et al. 2011). Ward et al. (*in press*) note that the current level of observer coverage, which is based on a power analysis undertaken by Hamer et al. (2008), is intended to be able to identify major declines in the application or effectiveness of the CoP, but

not for obtaining precise estimates of total number of dolphins interacting with the SASF. Since the 2012-13 season, the unit of effort to measure observer coverage has been the percentage of total shots (i.e. net-sets) observed. The average observer coverage for the 2012-13 to 2015-16 fishing seasons has been 10.3% of net-sets (range 9.6-10.6%).

Observed encirclement rates of dolphins have reduced from 37 encirclements per 100 net-sets in 2004-05, before the introduction of the CoP, to 9 encirclements per 100 net-sets in 2015-16 (Mackay and Goldsworthy, 2016). Observed mortality rates of dolphins have reduced from 39 dolphins per 100 net-sets in 2004-05 to 3 dolphins per 100 net-sets in 2014-15 (Mackay and Goldsworthy 2016). Observer data have also been used to estimate the total number of encirclement events and dolphin mortalities per fishing season. Two methods have been used; a simple ratio method where the observed rates are extrapolated to the fleet or a modelling approach using Generalised Linear Models (GLMs) (e.g. Ward et al. 2013, 2015a, b, Mackay and Goldsworthy, 2016).

Data on interactions with dolphins and other wildlife are also recorded in fishery logbooks and via PIRSA Wildlife Interaction Forms (WIFs) Since 1999, it has been a legislative requirement to report all fishery interactions with wildlife under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*, and since 2007 under the *Fisheries Management Act 2007* (FMA), and all commercial fisheries must report wildlife interactions through the WIFs.

Between 2004-05 and 2011-12, the total number of dolphin encirclement events and mortalities estimated from observer data have been consistently higher than the total number of encirclement events and mortalities reported in fishery logbooks (Ward et al. 2015b). However, the discrepancy between reported rates and observed rates has reduced over time. In 2004-05, logbooks reported approximately 5% of the total number of encirclement events estimated from observer data, while in 2015-16 the estimated and reported number of encirclement events was similar (67 reported, 66 GLM estimate, 75 ratio estimate; Mackay and Goldsworthy, 2016). In 2011, SASIA initiated a real time wildlife monitoring program to assess wildlife interaction rates on a daily basis and by vessel to improve reporting rates relative to observed interaction rates (SASIA 2015).

Since 2013, observer and logbook data have also been analysed to investigate if the presence of an observer influences fishing behaviour (Ward et al. 2013, 2015a, b). Analyses have shown that sardine catch per unit effort (CPUE) has been consistently lower in observed compared to unobserved shots, and that the proportion of shots with zero sardine catch has been higher in observed than unobserved shots since 2007-08 (Mackay and Goldsworthy, 2016). There has

been concern that lower CPUE and higher proportion of zero-catch shots may reflect fishers behaving differently when an observer is present. The relative importance of different factors that could relate to consistently lower CPUE when an observer is present are difficult to interpret as observer coverage has not always been representative of fishing effort either spatially, temporally or across the fleet (Ward et al. 2015a).

1.2. Objectives

This is the eleventh report on the effectiveness of the SASF industry CoP in mitigating operational interactions with short-beaked common dolphins.

The objectives of the project were to:

1) Report on the degree to which observer coverage is representative of fishing effort;
2) Compare rates of dolphin encirclement and mortality recorded by observers and in fishery logbooks when an observer was absent;
3) Use a ratio approach to estimate the total number of encirclements per year from observer data and compare these to the total number recorded in fishery logbooks;
4) Assess the efficacy of the CoP in mitigating interactions with dolphins;
5) Compare $CPUE_{net\text{-}set}$ and proportion of zero-catch shots for observed and unobserved net-sets.

2. METHODS

2.1. Data collection

Fishery logbook and WIF data

Records of the date and time, location and weight of catch of each net-set are required to be completed in the SASF Catch and Effort Logbooks a long with a unique logbook number. Commercial fisheries are also required to report all interactions with Threatened, Endangered and Protected species (TEPS) under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. In July 2007, PIRSA Fisheries and Aquaculture implemented new arrangements for commercial fisheries to report wildlife interactions via the implementation of the South Australian Managed Fisheries Wildlife Interaction Form (WIF). The form is generic across fisheries and the information recorded includes the fisher's licence number, unique logbook number, date and time of an interaction and the species and number of individuals involved in each interaction. The nature of the wildlife interaction is recorded as one of four categories: 'caught', 'entangled', 'impact/collision' or 'other', and the status of the wildlife individual(s) as a consequence of the interaction is categorised as 'alive', 'alive / injured' or 'dead'. Information on the fate of individuals is recorded as 'released', 'retained', or 'discarded' and space is provided on the form to record additional comments or information about interactions. An annual summary of TEPS interactions recorded by commercial fisheries through WIFs are reported each financial year (e.g. Mackay 2017). Comments provided with WIF records are used to assess the nature of, and response to interactions. Only WIF records relating to dolphin interactions with the SASF are considered for this report.

Observer program

SARDI Aquatic Sciences undertook an initial observer program between November 2004 and January 2006. Since July 2006, a continuous independent observer program has been operated by Protec Marine Pty Ltd. The target level of observer coverage since the 2006-07 season has been 10% of fishing operations, with the exception of 2007-08 to 2009-10 seasons when target coverage was set at 30%. Up to the 2012-13 fishing season the unit of effort for observer coverage was percentage of total nights fished. Since the 2012-13 season, the unit of effort for observer coverage has been a percentage of total shots (i.e. net-sets) observed.

Observers monitor each fishing activity from a high unobstructed vantage point, and search for dolphins in the illuminated area surrounding the vessel immediately prior to the net being set.

Once the net is set the observer then searches for dolphins within the net for the duration of the fishing operation. Observers record the date, time and location of each net-set, the vessel name and, since 2007, the corresponding Catch and Effort logbook number for each observed net-set. The time of each stage of the fishing operation is also recorded at 'start net-set', 'begin pursing', 'begin hauling', 'end hauling', 'begin pumping' and 'finish net-set'.

Specific data recorded by observers allow an assessment of the application of the CoP, and include if search procedures are followed, if delays in setting or relocation occur, if dolphins are observed prior to setting the net, and steps undertaken if an encirclement occurs. Information recorded if a dolphin encirclement event occurs includes the number of individuals involved, the stage of fishing that dolphin(s) are first observed, how individual dolphins are caught (e.g. free in net, or entangled), the release method used, the success of release and any mortalities that may occur and the unique WIF identifier. The CoP initially included several release procedures which have been refined over time. The current release procedure in the CoP is to immediately open the front of the net to ensure a large escape opening, and if this is not successful to abort the fishing operation by releasing the end of the net (SASIA, 2015).

2.2. Data integration

Each vessel's Catch and Effort Logbook returns must be submitted to SARDI Aquatic Sciences before the fifteenth day of the following month. Submitted WIFs are linked to the corresponding Catch and Effort logbook and data are error checked and validated. Observer forms are also cross validated to logbook and WIF data.

As a consequence of changes in metric of fishing effort used for dolphin interactions, from percentage of total nights fished to percentage of total net-sets, we have restricted analyses in this report to data from 2007-08 onwards which is resolvable at the net-set level. Restricting analyses to these data ensures that all net-sets can be matched between Catch and Effort Logbook, WIF, and observer datasets. Information on operational interactions between the SASF and dolphins between 2004-05 and 2007-08 are available in Ward et al. (2015b).

Prior to 2007-08, there are trips where Catch and Effort logbook data reported catch at an aggregated trip level, but observer data for the same trip show that more than one shot was undertaken.

Table 1a-c summarises the final data used in analyses in the current report. As the current analyses are based on the metric net-set, there are some slight variations in some of the numbers

reported compared to Ward et al. (2015b) that are mainly due to removing Catch and Effort logbook records where a search was undertaken but no net was set. Data integration has not changed the total number of mortalities recorded by observers or reported in fishery logbooks by financial year.

Table 1a-c. Summary of final datasets used in analyses after data integration was completed between fishery logbooks, Wildlife Interaction Forms and observer data.

a. Total observed and unobserved fishing effort (net-sets) by financial year

Financial year	Total net-sets	Total net-sets with observer	Total net-sets without observer	% of net-sets observed
2007_08	880	181	699	20.6%
2008_09	932	224	708	24.0%
2009_10	1097	267	830	24.3%
2010_11	1015	91	924	9.0%
2011_12	1108	73	1035	6.6%
2012_13	861	81	780	9.4%
2013_14	774	82	692	10.6%
2014_15	847	88	759	10.4%
2015_16	887	94	793	10.6%
2016_17	975	117	858	12.0%

b. Total number of encirclement events from observed and unobserved net-sets by financial year

Financial year	Total encirclement events	Observed encirclement events	Logbook encirclement events
2007_08	61	28	33
2008_09	63	21	42
2009_10	67	29	38
2010_11	41	11	30
2011_12	104	9	95
2012_13	99	9	90
2013_14	93	10	83
2014_15	70	6	64
2015_16	67	8	59
2016_17	59	8	51

c. Total number of dolphins encircled and total number of dolphin mortalities in observed and unobserved net-sets by financial year.

Financial year	Total dolphins encircled	Observed total dolphins encircled	Logbook total dolphins encircle	Total dolphin mortalities	Observed dolphin mortalities	Logbook dolphin mortalities
2007_08	159	85	74	15	11	4
2008_09	158	53	105	5	5	0
2009_10	188	90	98	5	2	3
2010_11	125	39	86	7	2	5
2011_12	304	36	268	5	1	4
2012_13	226	24	202	4	1	3
2013_14	240	35	205	1	0	1
2014_15	195	21	174	4	2	2
2015_16	195	31	164	2	1	1
2016_17	197	28	169	1	1	0

2.3. Observer coverage

The representativeness of observer effort is related to the temporal and spatial effort of the fleet. The operators of the observer program are requested to distribute observer effort as evenly as practicable among vessels, across months and by regions fished. The representativeness of observer coverage for 2016-17 was examined relative to the temporal and spatial distribution of fishing effort both across the fleet and by vessel. Temporal coverage was assessed by examining the percentage of total net-sets per month that were observed. The harvest strategy for the fishery defines two spatial management zones; the Gulf Zone and the Outer Zone (Figure 1, PIRSA 2014). All net-sets were coded to indicate in which management zone they occurred (i.e. northern, central, south or east regions in the Gulf Zone and west or east regions in Outer Zone; west or east. Total fishing effort was displayed by aggregating all net-sets within 10 km grid squares in ArcMap 10.3.1. The locations of all observed net-sets with and without a dolphin encirclement event were also plotted. Spatial and temporal observer coverage was assessed by month by visually comparing the spatial distribution of net-sets with and without an observer present. To assess observer coverage across the SASF fleet, the number of net-sets with and without an observer was calculated for each vessel that fished in 2016-17. Each vessel was randomly assigned a unique identifying number to ensure data confidentiality.

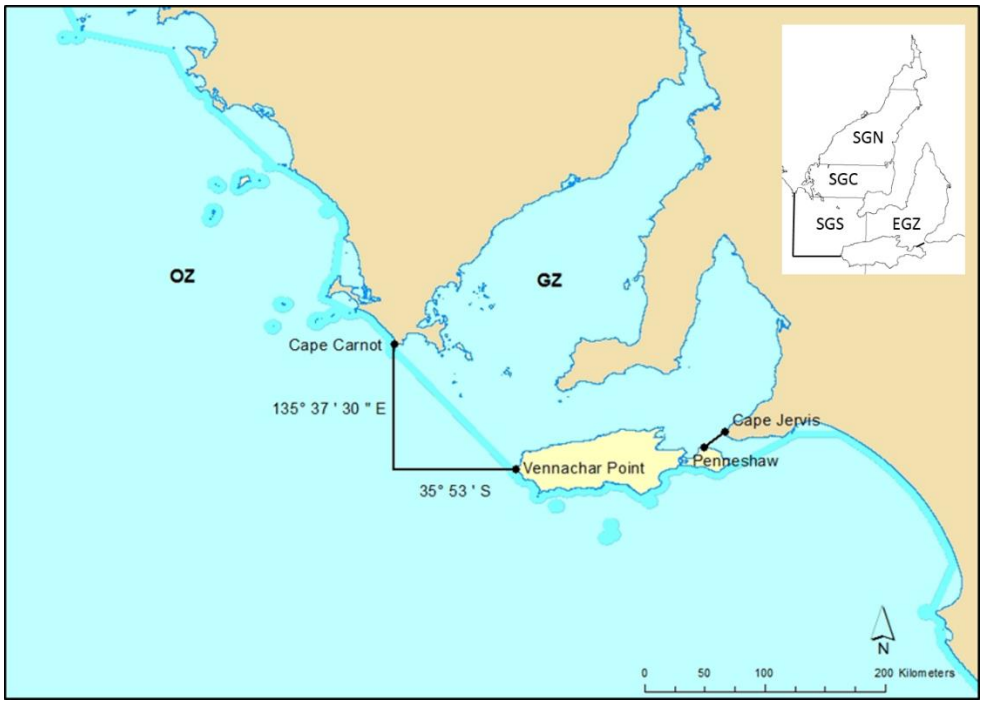

Figure 1. The two spatial management zones for the South Australian Sardine Fishery. GZ = Gulf Zone, OZ = Outer Zone. The inset shows the sub-regions within the Gulf Zone that were applied during analyses. SGN = Spencer Gulf North, SGC = Spencer Gulf Central, SGS = Spencer Gulf South and EGZ = Eastern Gulf Zone.

2.4. Interaction rates

Operational interactions between the SASF and common dolphins recorded by observers and reported in the WIF were analysed using three metrics; encirclement events, number of dolphins encircled and number of mortalities.

An encirclement event was defined as one or more dolphins being present inside the purse seine net after it had been set. For each encirclement event the total number of individuals encircled and the status of individuals (alive or dead) was recorded.

Rates of encirclements per net-set and mortality per net-set were calculated and compared between observed and unobserved net-sets.

Two methods were used to estimate the total number of encirclement events in the SASF in 2016-17. The first method used a simple ratio estimation, where calculated encirclement rates from observed net-sets were multiplied by the total fishing effort (i.e. number of net-sets) undertaken by the fishery.

The second method was to fit generalised linear models (GLMs) to the observer data and use significant covariates associated with encirclement events to predict net-sets without an observer present. Forward and backward step-wise selection (Venables and Ripley 2002) was used to select the best model. The process was automated using the step function in R (R version 3.2.3), which uses Akaike Information Criterion (AIC) to evaluate the importance of each covariate to model fit.

The binomial GLM previously used by Ward et al. (2015a, b) to estimate total encirclements for all data between 2004-05 and 2014-15 retained the explanatory variables financial year, region and catch.

After step-wise selection the best GLM to predict the total number of encirclement events using the restricted observer dataset (2007-08 to 2016-17) was:

GLM (Encirclements ~ Catch + Region, family = binomial)

Fishery reported rates of interactions were assessed by comparing the total number of encirclement events reported in the WIF in 2016-17 to the total number of encirclement events estimated from the observer data using the simple ratio estimation method and GLM.

2.5. Assess the efficacy of the CoP in mitigating interactions with dolphins

As with previous reports an assessment of the efficacy of the CoP in mitigating interactions with dolphins was based on the observed ability to avoid interactions by search and delay and successful release of dolphins if they became encircled and/or entangled in the net. Fishers also provided additional data relating to the implementation of the CoP for 21 of the 51 encirclements reported on Wildlife Interaction Forms in 2016-17 when an observer was absent. These data included release method used and time taken from when dolphins were first noticed inside the net to the release procedure being initiated.

2.6. Spatial and temporal overlap between fishing operations and dolphins

The spatial and temporal overlap between the fishery and dolphins was assessed for all observed net-sets between 2007-08 and 2016-17 by reviewing all observer forms which have a section where observers should record presence of dolphins outside the net. Comments were used to determine if dolphins were present outside the net after it was set, and if present the estimated number of individuals. For records where observers estimated the number of dolphins as a range (e.g. 50-60) the lower number was used for analyses. For those records where observers did not provide an estimate of the number of dolphins that were recorded to be present on the outside of the net (29 of 583 records), the number of individuals was recorded as one. The observed sighting rate was calculated as the number of net-sets with dolphins present outside the net divided by the total number of observed net-sets.

2.7. Comparison of fishing patterns with and without an observer

Differences in CPUE per net-set ($CPUE_{net\text{-}set}$) when an observer was present and absent have previously been reported (Ward et al. 2015a, b), with lower $CPUE_{net\text{-}set}$ recorded when an observer was present in all years, except 2011-12. Using the 2016-17 data, $CPUE_{net\text{-}set}$ for observed and unobserved net-sets were compared using t-tests at a vessel level and the chi-squared test was used to compare the proportion net-sets with observed and unobserved net-sets with zero catch recorded.

3. RESULTS

3.1. Observer coverage in 2016-17

During the 2016-17 season, a total of 975 purse seine shots were undertaken in the fishery, of which 117 (12%) were observed. A further 35 records were submitted in the Catch and Effort logbooks, where searching was undertaken but no net was set. The most frequent reasons recorded for not setting the net was that fish were not schooling and / or the weather was too rough.

Approximately 89% of fishing effort occurred between February and June. Observer coverage of fishing effort per month ranged from 9-20% of net-sets (Figure 2). None of the three net-sets in October, or 11 net-sets undertaken in November 2016 from the Outer Zone management area of the fishery, were observed. Target observer coverage of 10% of fleet effort was reached or exceeded in six of the nine months when fishing occurred. Eleven vessels were active in the SASF in 2016-17, with individual vessel effort accounting for 5-16% of total fleet fishing effort, and five vessels undertaking 55% of total fleet effort. The percent of observer coverage for each individual vessel's total net-sets ranged from 10% to 14% (Figure 3). At a vessel level, percentage observer coverage of net-sets in a given month ranged from no net-sets being observed to 38% of net-sets being observed. In April, when 23% of all fishing effort in 2016-17 was undertaken, three vessels which accounted for 21% of all fishing effort in that month did not have any observer coverage.

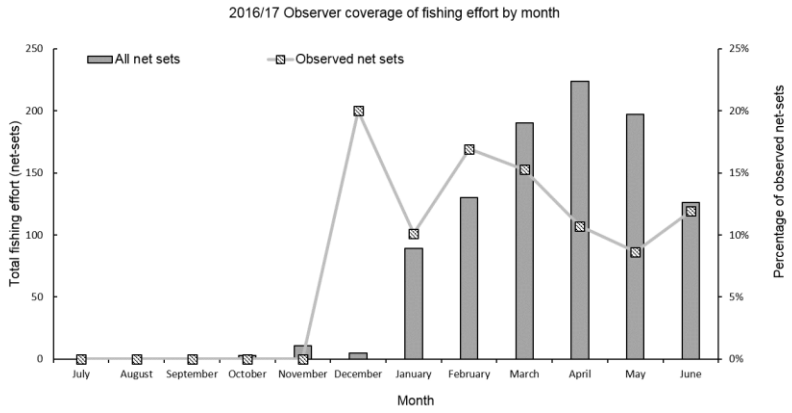

Figure 2. Total fishing effort (net-sets; grey bars) and percentage of net-sets observed (line) by month for the 2016-17 fishing season.

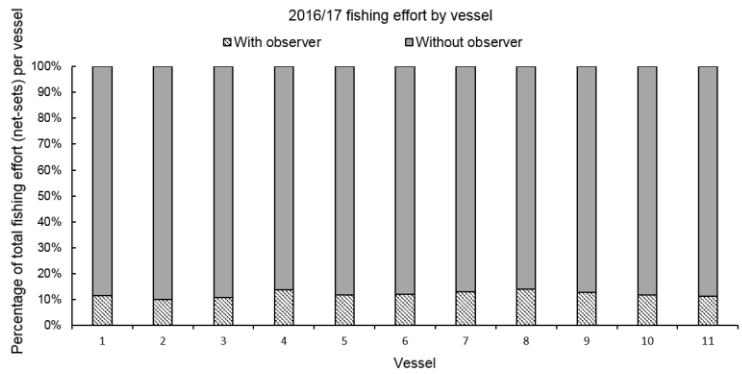

Figure 3. Percent of fishing effort (total number of net-sets) observed for each vessel in 2016-17. Note that vessel identifying number was assigned randomly.

The majority (66% of net-sets) of fishing effort occurred in the Gulf Zone management area of the fishery with all net-sets occurring between January and June 2017. Observer coverage of fishing effort resulted in 11% of all net-sets in the Gulf Zone being observed, and by month ranged from a minimum of 5% coverage in April to a maximum of 24% coverage in March (Figure 4). Net-sets in the Outer Zone accounted for 34% of total fishing effort, with 13% of all net-sets observed. Observer coverage in the Outer Zone ranged from a minimum of 4% of net-sets in May to a maximum of 28% of net sets in April (Figure 4). The spatial distribution of observer effort was fairly representative of fishing effort over the 2016-17 season (Figure 5).

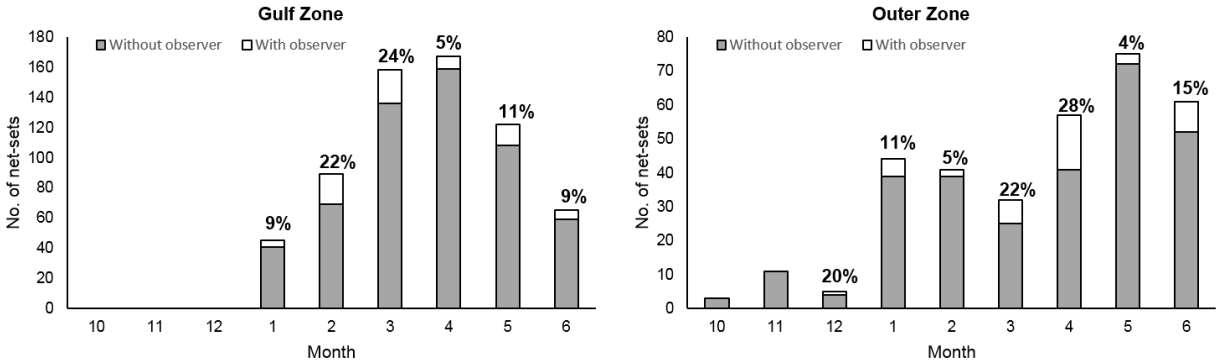

Figure 4. Total fishing effort (net-sets) with and without an observer by month for the Outer Zone (left) and Outer Zone (right) management areas. Note different scales on the y-axis. Numbers above bars indicate the percent of net-sets observed.

3.2. Encirclement events 2016-17

Eight encirclement events were recorded by observers in the 2016-17 fishing season, involving a total of 32 dolphins from 117 observed net-sets. An interaction involving a single common dolphin entangled outside of the net during hauling was also observed. The observer noted that the dolphin was released by the crew and swam away, but then a dolphin was sighted “floating” on the surface outside the net during hauling but disappeared when “dozens” of other dolphins turned up outside the net. The fate of this individual outside of the net was recorded as “unknown” and it is unclear whether this was the dolphin that had been entangled on the outside of the net and then released. Calculation of encirclement rates and number of individuals encircled are based on the 32 dolphins observed encircled during eight observed encirclement events.

The overall observed encirclement rate in 2016-17 was 0.068, or seven encirclement events per 100 net-sets. Logbook data, recorded with an observer present, reported a further 51 encirclement events from 858 fishing net-sets that involved a total of 169 dolphins, giving an encirclement rate of 0.059 or 6 encirclement events in every 100 net-sets (Figure 6).

Observed and reported encirclement rates varied by month in 2016-17 with the highest observed encirclement rate occurring in June (Figure 7). High rates in June were a result of three observed encirclement events being recorded from 15 observed net-sets in this month, of which two occurred on the same trip.

Encirclement rates also varied by management zone, with all 8 observed encirclement events recorded during 74 observed net-sets in the Gulf Zone (i.e. 11 encirclement events per 100 net sets); no encirclement events were observed in 43 net-sets in the Outer Zone. Of the 51 encirclement events reported in logbooks when an observer was not present, 40 were reported from 572 net-sets in the Gulf Zone, and 11 encirclement events from 286 net-sets in the Outer Zone, giving a logbook reported encirclement rate of seven encirclement events per 100 net-sets in the Gulf Zone, and four encirclement events per 100 net-sets in the Outer Zone. Within the Gulf Zone, observed and reported encirclement rates were highest in the east as a result of one encirclement event being recorded during two observed net-sets in that area, and three encirclement events being reported in logbooks from 15 net-sets (Figure 8). Overall, 75% of all observed encirclement events and 63% of all reported encirclement events occurred in the Spencer Gulf Central region.

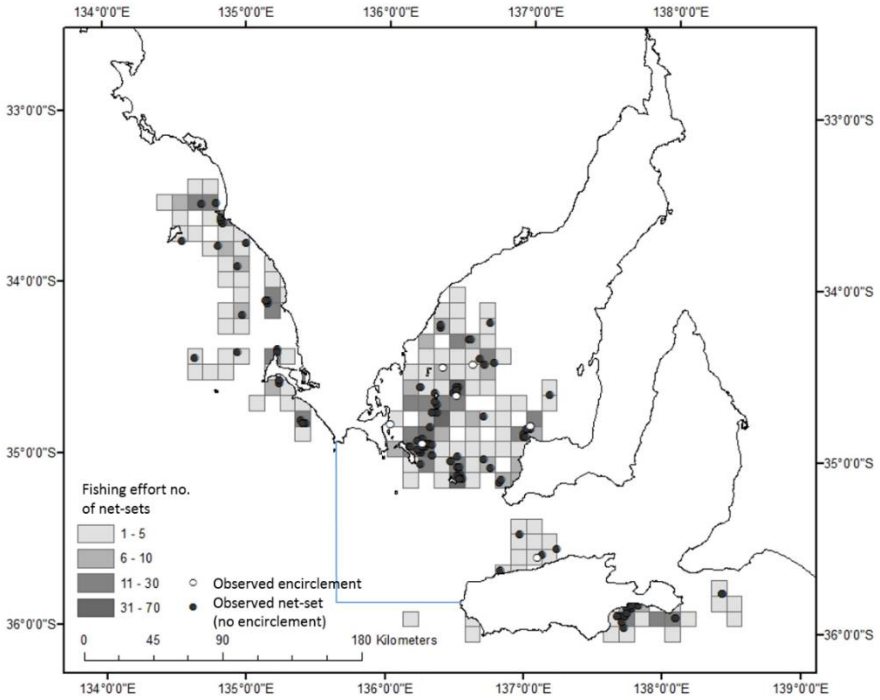

Figure 5. Spatial distribution of fishing effort in SASF during the 2016-17 fishing season. Black circles = observed net-sets without encirclements, white circles = observed net-sets with encirclements. Blue lines are boundaries between the two Gulf Zone and Outer Zone. Note two encirclement events are overlapping.

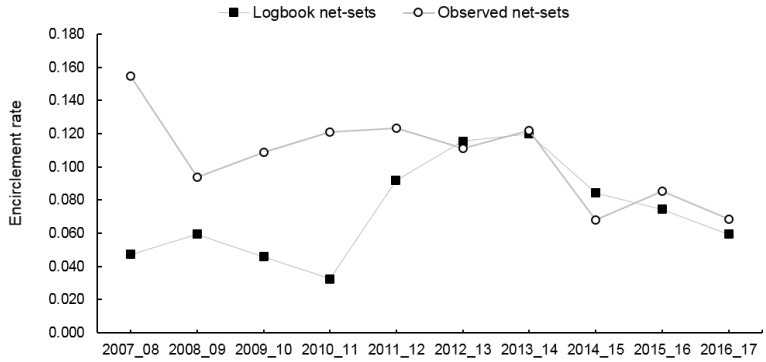

Figure 6. Encirclement rates (number of encirclements / total net-sets) for observed and unobserved logbook net-sets.

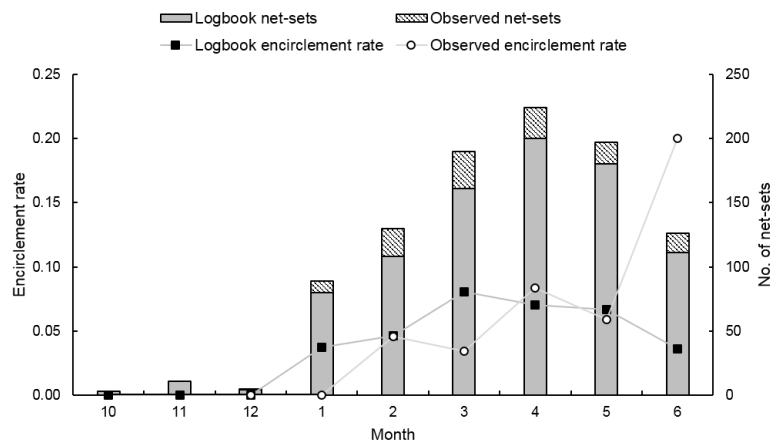

Figure 7. Observed and unobserved (logbook) encirclement rates and number of net-sets an observer by month for the 2016-17 fishing season

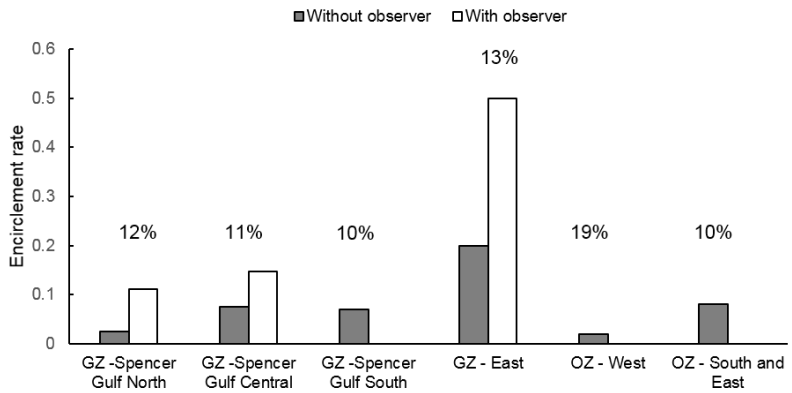

Figure 8. Observed (white bars) and unobserved (grey bars) encirclement rates by region for the 2016-17 fishing season. GZ = Gulf Zone, OZ = Outer Zone. Numbers above bars indicate the percent of total net-sets observed.

Observed and unobserved (logbook reported) encirclement rates, also varied between vessels (Figure 9). The overall encirclement rate per vessel (total number of encirclement events, observed and unobserved, divided by total fishing effort) ranged from 0 to 0.12. Two vessels, which accounted for 26% of all net-sets in 2016-17 reported (logbooks) encirclement rates of 0.06 and 0.05 compared to observed encirclement rates of 0.06 and 0.08, respectively. Vessel 5, which accounted for 5% of all net-sets in 2016-17 had 12% observer coverage and no observed or reported encirclements. The encirclements reported by these five vessels accounted for 39% of the total encirclements for 2016-17. Vessel 4 and 11, which each undertook 8% of all net-sets in 2016-17, had observed encirclement rates that were much higher than logbook encirclement

rates. For vessel 4, three encirclement events were recorded from 11 observed net-sets resulting in an observed rate of 27 encirclement events in 100 net-sets compared to a reported rate of nine encirclement events in 100 net-sets. For Vessel 11, two encirclement events were recorded from nine observed net-sets resulting in an observed rate of 22 encirclement events in 100 net-sets compared to a reported rate of 1 encirclement event in 100 net-sets. For five vessels, which had between 10-14% observer coverage, all encirclement events were reported in logbooks (Figure 10).

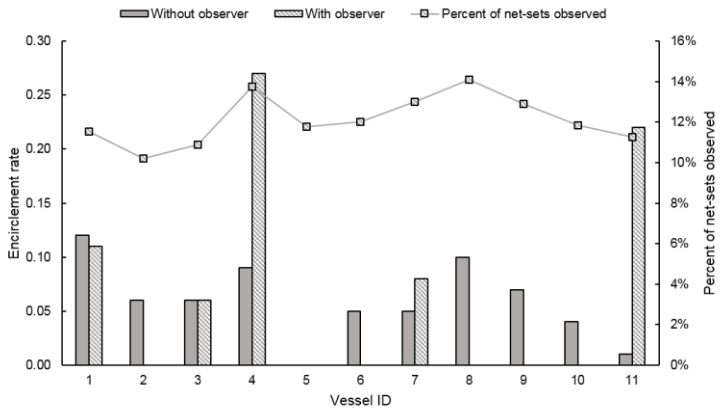

Figure 9. Observed and unobserved (logbook) encirclement rates and percent of net-sets observed per vessel for the 2016-17 fishing season. Vessel IDs were assigned randomly. Vessel 5 did not have any observed or unobserved (logbook reported) encirclements.

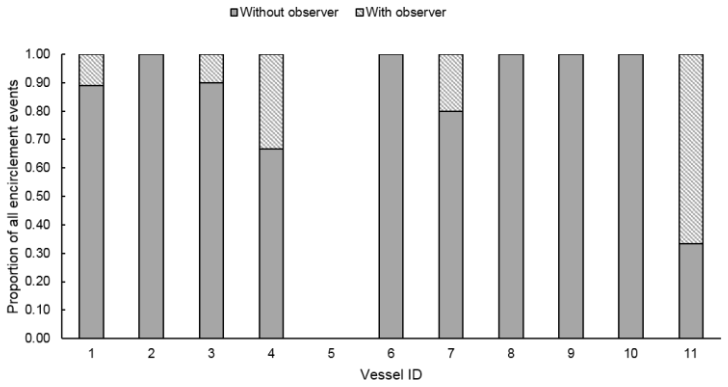

Figure 10. Proportion of each vessels total encirclement events in 2016-17 that were observed or unobserved (reported in logbooks).

A comparison of encirclement event estimates showed that the sum of events was lower than both ratio and GLM predictions from 2007-2011; however, after, 2011, the three methods, including ratio, GLM, and sum of reported and observed events, had similar values (Figure 11).

For the 2016-17 season, the observed encirclement rate of 0.068 was applied to total fishing effort using the simple ration estimate method produced a total estimate of 66 encirclement events, or 7 encirclement events every 100 net-sets. As no encirclements were observed in the Outer Zone during the 2016-17 fishing season an estimate of encirclements, stratified by management area, could not be produced. After step-wise selection, using all observer data collected since 2007-08, the best GLM retained the variables catch and region and predicted a total of 67 encirclements in 2016-17, or 7 encirclement events every 100 net-sets.

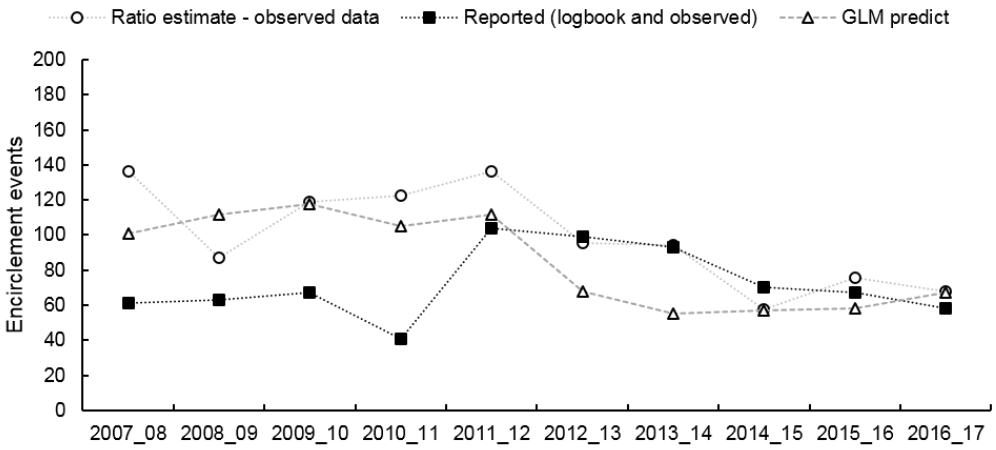

Figure 11. Total reported (logbook and observed) and estimated number of encirclement events per financial year. Estimates were produced using a) ratio method using observed shots (white circles) and b) GLM prediction (black squares).

3.3. Dolphins encircled and mortality rates 2016-17

The number of dolphins reported encircled in observed net-sets ranged from 1-12 individuals (mean = 4, SD = 3.5, Figure 12), with a total of 32 individual dolphins reported encircled during the 2016-17 fishing season, resulting in one mortality. The number of dolphins reported encircled in unobserved (logbook reported) net-sets ranged from 1-9 individuals (mean = 3.32, SD = 1.8), with a total of 169 dolphins reported encircled in unobserved (logbooks) net-sets during the 2016-17 fishing season, with no mortalities reported, and one released dolphin recorded in the “injured” category. The accompanying comment in the WIF noted the injured individual was alive after being released, but moving slowly. For encirclement events recorded without an observer, the most prevalent number of individuals encircled was 3 dolphins, while for data recorded with an observer, 1 and 4 dolphins had a slightly higher prevalence (Figure 12).

Applying a simple ratio estimation to extrapolate from observer data, the estimated number of dolphins encircled in 2016-17 was 264, based on a mean of 4 dolphins per encirclement event and a total estimate of encirclement events of 66. Using a simple ratio estimation method to extrapolate the mean number of dolphins per encirclement to total fishing effort assumes that the number of dolphins per encirclement event is consistent. However, results demonstrate that the number of dolphins per encirclement during net-sets can vary greatly (Figure 12).

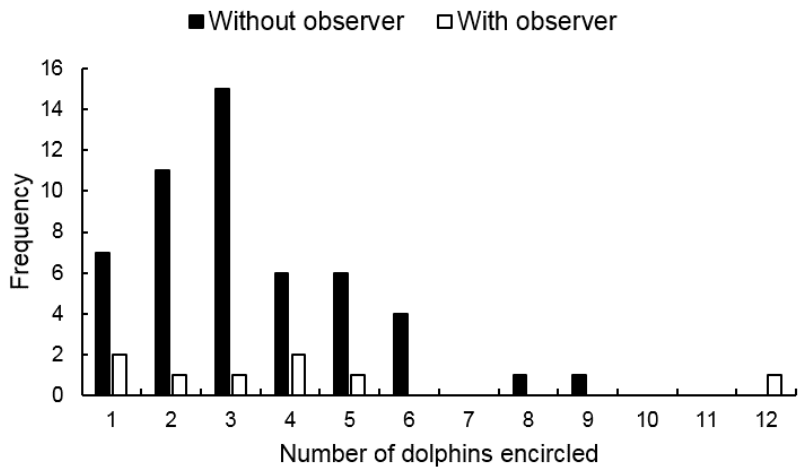

Figure 12. Frequency of total number of dolphins per encirclement event for observed and unobserved net-sets.

3.4. Code of Practice Assessment

The first method of mitigating interactions with dolphins specified by the CoP is that prior to the net being set, a search for wildlife is undertaken in the vicinity of the target fish. If wildlife are detected the shot should be delayed and / or relocated to a new area. A search was recorded as having been undertaken prior to the net being set in 116 of 117 of observed shots in 2016-17. The shot where an observer noted that no search appeared to have been undertaken prior to the net being set resulted in an encirclement of two dolphins and the mortality of one of the dolphins. The dolphins were sighted during hauling and a skiff was deployed to herd both dolphins out of the net, after which the front of the net was let go. One dolphin escaped over the corkline; the other became entangled in the net, but was already deceased when released by the crew in the skiff.

In total, 17 delayed shots were observed prior to nine fishing operations being undertaken, with the number of delays ranging from 1-4. Therefore, single fishing operations were sometimes

delayed more than once. One instance was also recorded where a fishing operation was delayed four times as a result of the presence of dolphins after which no shot was taken as weather conditions started to deteriorate. An encirclement was recorded for two shots following a single delay that involved one and three dolphins each. Dolphins were encircled during seven shots where they had not been detected prior to setting the net. Therefore, the success rate in detecting that dolphins were absent from the vicinity of the vessel prior to fishing commencing was 93.1% (Table 2). The presence of a dolphin inside the net was first noted at the start of hauling for two of the eight encirclement events, and at the end of hauling for the other six events. The release action taken in six of the eight observed encirclement events was to immediately let the front of the net go. On average, the release procedure commenced within 20 minutes (range 5-50 minutes) of the dolphins being first observed in the net; four release procedures commenced in less than 10 minutes, one in 24 minutes and two at 50 minutes. The reasons for the longer time to the release procedure commencing during one of these encirclement events was that the dolphins (four individuals) were first observed at the commencement of hauling and were released when the front of the net was dropped and a dinghy was used to herd them out of the net. During the second encirclement event a problem with the net occurred during hauling, once the 12 dolphins in the net were sighted, a skiff was used to open the net and hauling commenced. The corkline subsequently became submerged and all 12 dolphins swam out of the net. The presence of dolphin inside the net was first noted at the start of hauling for two of the eight encirclement events, and at the end of hauling for the other six events.

As interactions with dolphins in unobserved net-sets are reported in the WIFs, details on searching or delaying prior to setting the net or the release method used if an encirclement is recorded are not always captured in the WIF comments. However, comments were provided with all encirclements recorded in WIFs for 2016-17. Comments showed that for 80% of encirclement events, the release procedure was letting the front of the net go, followed by aborting the shot (16% of encirclement events) (Table 3). For two encirclement events dolphins were reported to have escaped from the net by swimming over the corkline after it was submerged due to too many fish in the net. Additional data were also provided for 21 of the encirclement events reported in WIFs. For two events, dolphins were first observed at the beginning of hauling, while for 90% of the 21 encirclement events dolphins were initially observed during the end of hauling. The time between an encirclement first being observed until a release was initiated was provided for 19 encirclement events and took, on average 13 minutes (range 1-35 minutes).

Table 2. Number of searches and delays recorded in observed net-sets undertaken in the SASF between 2004-05 and 2015-16. Data reported from 2004-05 to 2014-15 are taken from Ward et al. (2015b). A search or delay is considered a success if the resulting shot does not result in an encirclement and shows the success rate in detecting that dolphins were absent from the vicinity of the vessel prior to fishing commencing

Year	Number of searches	Number of delays	Search success %	Search and delay success %
2004-05	0	0		
2005-06	89	6	89.9	100.0
2006-07	82	7	85.4	71.4
2007-08	189	34	90.5	70.6
2008-09	233	31	92.7	87.1
2009-10	265	34	92.5	79.4
2010-11	91	2	89.0	50.0
2011-12	73	1	87.7	100.0
2012-13	84	4	90.5	50.0
2013-14	81	15	93.8	66.7
2014-15	93	13	92.5	84.6
2015-16	95	5	91.1	91.6
2016-17	116	17	93.1	88.0

Table 3. Number of release procedures used, and the percentage success of procedures in parentheses for releasing encircled dolphins from observed net-sets undertaken in the SASF between 2004-05 and 2015-16. Data reported from 2004-05 to 2014-15 are taken from Ward et al. (2015b). A release procedure was considered successful if all encircled dolphins were release alive from the net.

Financial year	No action No. (% success)	Physical removal No. (% success)	Open front of net / abort shot No. (% success)
2004-05	32 (16)	18 (89)	5 (60)
2005-06	0	3 (100)	6 (83)
2006-07	0	2 (100)	12 (67)
2007-08	0	6 (67)	21 (71)
2008-09	0	5 (80)	12 (92)
2009-10	0	0	20 (95)
2010-11	1 (100)	4 (50)	7 (100)
2011-12	1 (100)	0	7 (100)
2012-13	0	3 (67)	7 (86)
2013-14	2 (100)	0	8 (100)
2014-15	0	3 (67)	7 (86)
2015-16	0	3 (83)	6 (83)
2016-17	0	1 (0)	7 (86)

3.5. Spatial and temporal overlap between fishing operations and common dolphins

Mackay and Goldsworthy (2016) reported on observer records of the presence of common dolphins in the vicinity of nets after the net was pursed from the 2015-16 fishing season. The current report extends this initial analysis to all observer records since 2007-08.

In 2016-17, dolphins were observed in the vicinity of nets after they were set in 57% (n = 67) of observed shots (Figure 13). The proportion of observed shots with dolphins present after the net was pursed varied between months (range 33-82%), with dolphins recorded present in all months with observer effort except for the single net set observed in December 2016. Estimates of the number of dolphins present ranged from a single individual up to 200 individuals. The majority of sightings (88%) of dolphins, outside nets after they were set, were recorded in the Gulf Zone.

The 2016-17 fishing season represents the highest proportion of observed shots where dolphins were recorded present after the net was set since 2007-08. On average, 43% of observed shots over this period have recorded dolphins present outside the net, although this proportion has varied between years (range 20-57%) (Figure 13). From 2007-08 to 2016-17, the highest sighting rates have been recorded in March and April (Figure 14). This apparent seasonal increase may in part reflect higher observer effort in these months, although May is the month with the highest observer effort overall (Figure 15). For August to December, the months with the lowest observer effort, the average reported sighting rate was 0.27, meaning that dolphins were present on the outside of the net approximately once every three shots. In 2016-17, observed sighting rates were four times higher in the Gulf Zone than the Outer Zone, and were highest in the northern part of Spencer Gulf, where dolphins were recorded present after the net was set for all 10 observed shots in that area (Figure 16). This spatial pattern in encounter rates reflects the longer-term pattern of higher encounter rates in the Gulf Zone, particularly in Spencer Gulf (Figure 16).

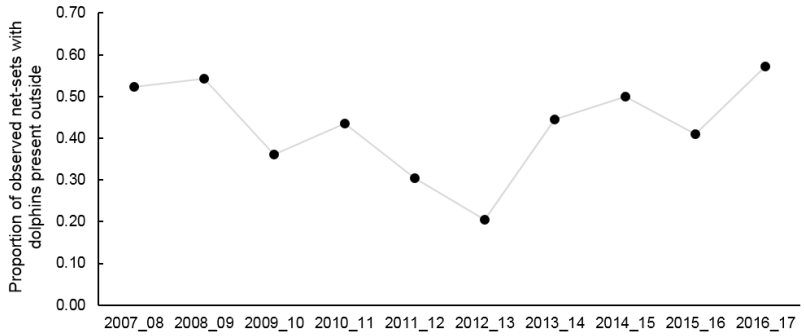

Figure 13. Proportion of observed net-sets by financial year where dolphins were recorded outside the net

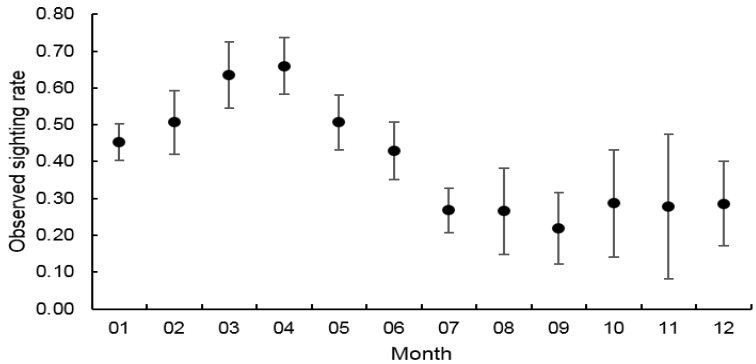

Figure 14. Mean monthly observed sighting rates of dolphins present outside the net, after setting, for all observed shots 2007-08 to 2016-17. Error bars are standard errors.

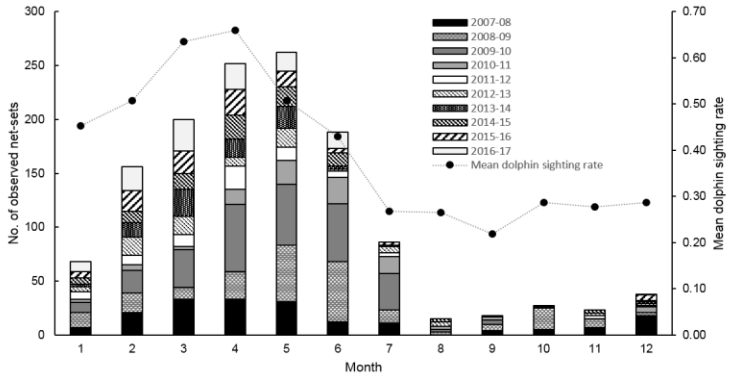

Figure 15. The number of net-sets (bars, pattern coded) and average sighting rates of dolphins recorded outside of nets, after setting (black circles, dashed lines), by year and month between 2007-08 and 2016-17

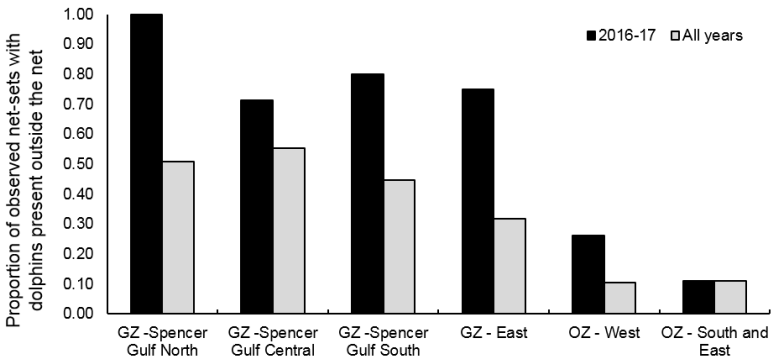

Figure 16. Proportion of observed net-sets with dolphins present after the net was set in 2016-17 (black bars), and for all years combined (grey bars). GZ = Gulf Zone, OZ = Outer Zone.

In 2016-17, the average estimated dolphin group size sighted outside the net after it was set was 29 (range 1-200); however, this varied by region with larger group sizes recorded in Spencer Gulf (Figure 17). The average estimated dolphin group size of dolphins outside the net after it was set recorded from 2007-08 and 2016-17 was 26 dolphins, with larger groups more frequently recorded in Spencer Gulf over this period (Figure 18). Most of the dolphin group sizes (68%) were estimated to contain 20 or fewer dolphins, with 20% of group sizes containing one to five dolphins (Figure 19). For the 29 records where observers did not estimate dolphin group size, a group size of “1” was used. Therefore average group size of dolphins present will be underestimated. Estimated group size also varied between months with largest average group size in 2016-17 recorded in June, which is similar to the longer dataset where largest average group sizes were recorded in June and September to November (Figure 20).

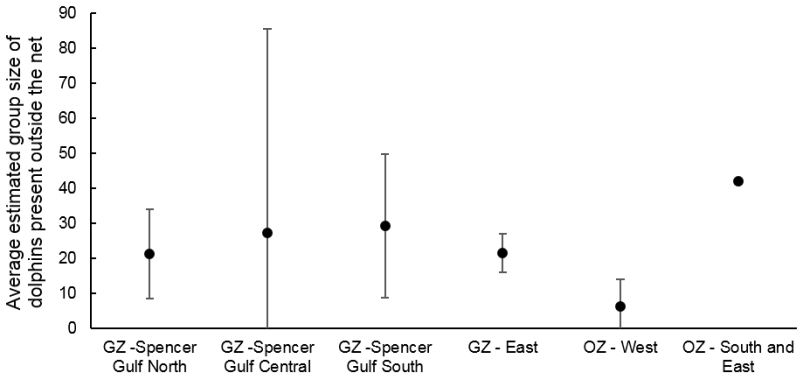

Figure 17. Average estimated number of dolphins present outside of nets reported by observers in 2016-17. Error bars are standard errors.

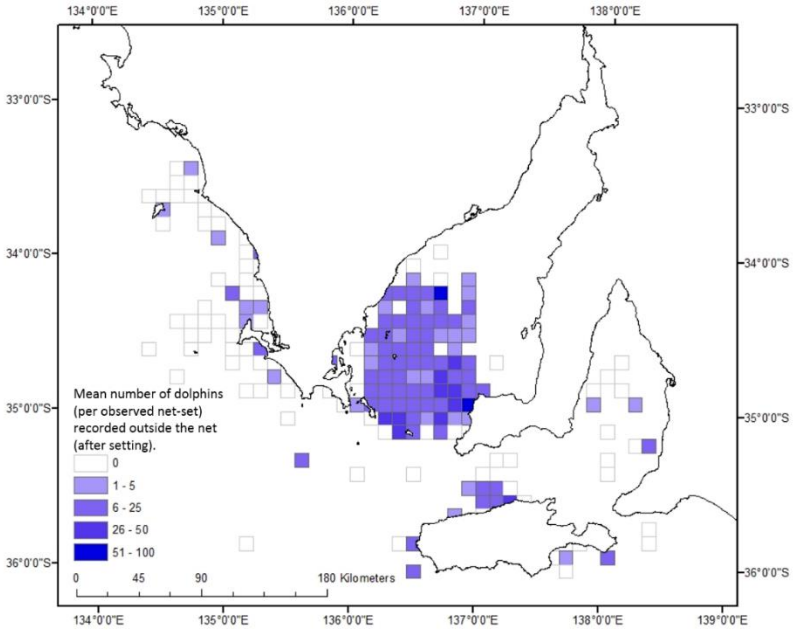

Figure 18. Mean number of dolphins per net-set, recorded present outside the net between 2007-08 and 2016-17.

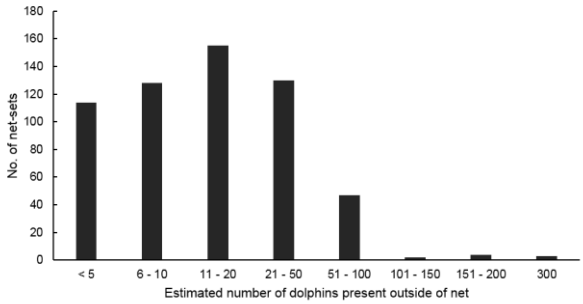

Figure 19. The number of net sets that contained group sizes of dolphins (grouped into bins) recorded by observers outside the net, after setting, between 2007-08 and 2016-17.

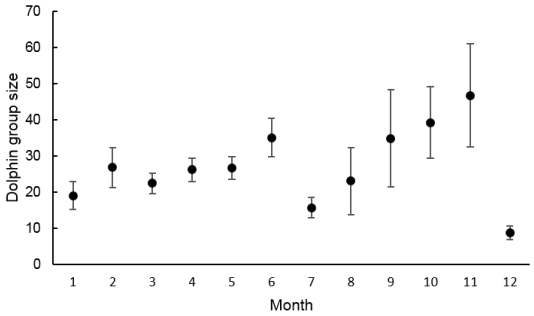

Figure 20. Average dolphin group size, by month, recorded by observers outside the net, after setting, between 2007-08 and 2016-17. Error bars are standard errors.

3.6. Comparison of fishing patterns with and without an observer

In 2016-17, the average number of net-sets made per night was higher for observed than unobserved net-sets, although this difference was not significant (Figure 21, Table 4, t-test, df = 147.2, p-value = 0.153). $CPUE_{net\text{-}set}$ differed significantly between vessels (Kruskal-Wallis chi-squared = 231.38, df = 10, p-value < 0.0001) reflecting the high variability in catch rates between vessels in the fleet: mean $CPUE_{net\text{-}set}$ per vessel in 2016-17 ranged from 5.7 t.net-set^{-1} to 65.0 t.net-set^{-1}, In 2016-17, sardine $CPUE_{net\text{-}set}$ was significantly lower for observed shots compared to unobserved shots (Figure 22, t-test, df = 143.19, p-value = 0.007). Significantly lower $CPUE_{net\text{-}set}$ in observed net-sets occurred in 2008-09, 2009-10, 2012-13, 2013-14, 2014-15, 2015-16 and 2016-17 (Figure 23, Table 5).

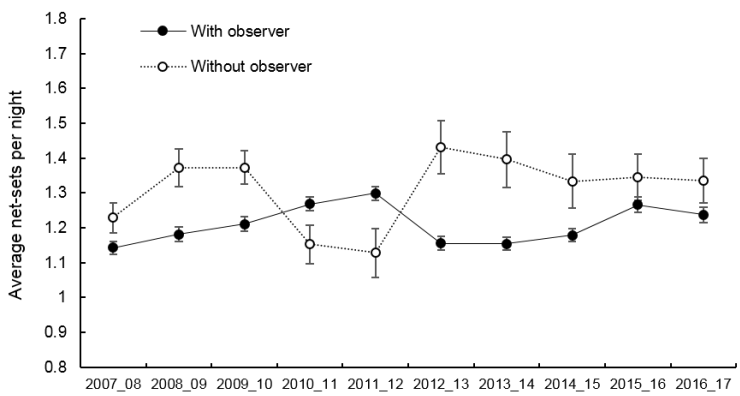

Figure 21. Average number of net-sets per night with and without and observer by financial year. Error bars are standard errors.

Table 4. T-test comparing the difference between the number of net-sets per night (per trip), with and without an observer between 2007-08 and 2016-17. P-values in bold type are significant.

Year	df	t-test	p
2007-08	258.86	-1.84	0.067
2008-09	299.57	-3.32	**<0.010**
2009-10	391.45	-3.14	**<0.010**
2010-11	125.7	1.95	0.053
2011-12	87.26	2.34	**<0.050**
2012-13	91.318	-3.51	**<0.001**
2013-14	90.357	-2.93	**<0.010**
2014-15	103.7	-1.93	0.056
2015-16	118.99	-1.12	0.266
2016-17	147.2	-1.45	0.153

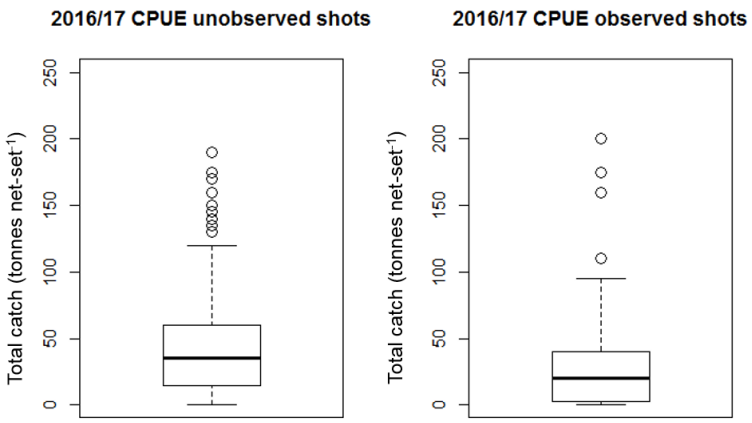

Figure 22. Boxplots of total catch (tonnes per net-set) for all net-sets undertaken with and without an observer during the 2016-17 fishing season. The horizontal line within the box indicates the median, and upper and lower boundaries present the 75th and 25th percentiles, respectively. The above and below whiskers indicate the 95th and 5th percentiles, respectively and dots represent outliers.

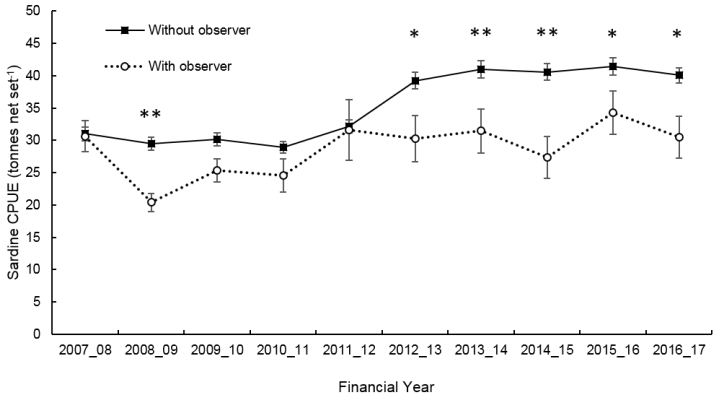

Figure 23. Mean $CPUE_{net\text{-}set}$ (± SE) for all shots with and without an observer between 2007-08 and 2016-17 fishing seasons. Significant between CPUE with and without an observer differences indicated by * = p<0.05, ** = p<0.001 for each fishing year.

Table 5. Results of t-tests comparing differences in the CPUE of observed and unobserved net-sets by financial year. P-values in bold type are significant.

Year	df	t-test	p
2007-08	256.76	0.19	0.846
2008-09	474.21	5.15	**<0.001**
2009-10	443.7	2.40	**<0.050**
2010-11	112.15	1.18	0.248
2011-12	77.803	-0.13	0.894
2012-13	101.05	2.40	**<0.050**
2013-14	109.68	2.85	**<0.001**
2014-15	117.46	4.25	**<0.001**
2015-16	124.27	2.00	**<0.050**
2016-17	143.19	2.72	**<0.050**

The overall lower $CPUE_{net\text{-}set}$ recorded when an observer was present is in part due to a significantly higher proportion of net-sets in 2016-17 having zero catch recorded when an observer was present ($\chi^2 = 4.0037$, p<05, Figure 24). The percentage of zero catch net-sets in 2016/17 was 22% with an observer present and 15% than without an observer present. The overall pattern of a higher proportion of zero catch net-sets for observed relative to unobserved net-sets, is consistent across all years, since 2007-08 (observed: mean 0.20, ± 0.03 S.D.; unobserved mean 0.12, ± 0.01 S.D.).

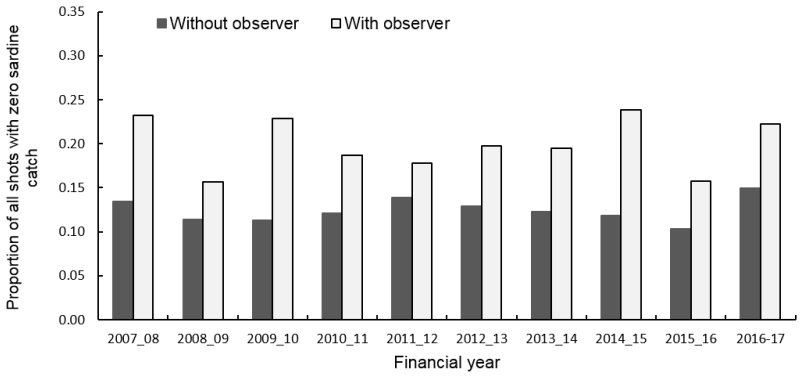

Figure 24. Proportion of all shots, with and without an observer, undertaken in the SASF between the 2007-08 and 2016-17 fishing seasons with zero sardine catch recorded.

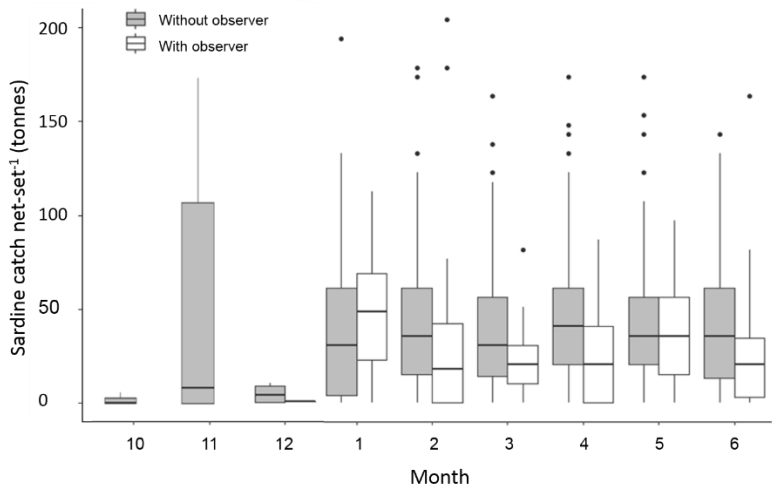

Figure 25. Boxplots of catch per net-set (tonnes) by month for all net-sets undertaken with and without an observer during the 2016-17 fishing season. The horizontal line within the box indicates the median, and upper and lower boundaries present the 75th and 25th percentiles, respectively. The above and below whiskers indicate the 95th and 5th percentiles, respectively and dots represent outliers.

An examination of monthly patterns of CPUE for individual vessels in 2016-17 showed that the relationship between $CPUE_{net\text{-}set}$ and the presence of an observer was not consistent across the fishing season (Figure 25). For individual vessels, observed net-sets had lower $CPUE_{net\text{-}set}$ in some months while in other months it was similar to or higher to unobserved net-sets. All but one vessel had higher $CPUE_{net\text{-}set}$ in the presence of an observer in at least one month. Paired t-tests of $CPUE_{net\text{-}set}$ with and without an observer present were conducted by financial year for each vessel fishing in that year (Table 5). The relationship between $CPUE_{net\text{-}set}$ and an observer being present varied between vessels both within and between years. In 2016-17, for each vessel, the overall mean $CPUEnet_{\text{-}set}$ was lower when an observer present compared to when an observer was absent. However, this was only significantly different for one vessel.

Table 5. The total number of vessels operating per financial year, and the number of vessels for that year which had significantly lower $CPUE_{net\text{-}set}$ when an observer was present. Significance tested by Welch two-sampled t-test.

Financial year	Total number of vessels operating	Number of individual vessels with significantly lower CPUE with an observer present
2007-08	13	1
2008-09	12	3
2009-10	13	5
2010-11	12	3
2011-12	13	0
2012-13	12	3
2013-14	10	2
2014-15	10	5
2015-16	11	1
2016-17	11	1

4. DISCUSSION

Observer coverage 2016-17

The overall target of 10% observer coverage of total fishing effort (net-sets) in the SASF during the 2016-17 fishing season was achieved, with 12% of net sets observed. Observer coverage relative to fishing effort varied between months. None of the net-sets undertaken in October or November 2016 were observed, while for all other months observer coverage ranged between 9% and 20% of total fishing effort. Overall, the target observer coverage of 10% of net-sets was generally achieved during the period with most fishing effort (February and May), and 11% of all net-sets in the Gulf Zone, where 66% of fishing was undertaken, were observed.

While observer coverage in 2016-17 was relatively evenly distributed at a temporal level with respect to total fleet fishing effort, it was less evenly distributed by management zone during certain months, with 5% of net-sets in the Gulf Zone being observed in April compared to 28% of net-sets in the Outer Zone. However, given the difference in fishing effort between these two zones in April, this actually represented 8 net-sets in the Gulf Zone being observed compared to 16 net-sets in the Outer Zone. The level of observer coverage also varied between individual vessels and ranged between 10% and 14% of net-sets, with the five vessels that undertook 55% of all net-sets in 2016-17 having 12-15% observer coverage. Although a minimum of 10% observer coverage was achieved on all eleven vessels in the fleet, there was high temporal variability in coverage, and in a given month, a vessel had zero to 38% of its fishing effort observed. For example, no net-sets were observed for three vessels which undertook 21% of all fishing effort in April.

There are a number of factors that can affect the practicalities of when an observer is available to go on a trip and the length of time that an observer is available. If an observer is only able to be present for one night of fishing, the vessel is likely to fish closer to port and may only undertake one net-set for that trip, or undertake that shot closer to port. On at least two occasions an observer was present for the first shot of a trip but returned to port before subsequent shots were undertaken. The number of net-sets undertaken on a fishing trip (observed or not) will also depend on a range of factors that vary temporally, including the presence of fish, whether fish are schooling, the amount of quota that remains for that licence, and distance to the fishing ground. This means that at a vessel level, the number of net-sets undertaken can vary greatly between months.

Observed interactions with dolphins in 2016-17

Of the nine interactions that were observed with dolphins in the 2016-17 fishing season, eight involved at least one dolphin becoming encircled within the purse seine net, while the ninth involved a single dolphin becoming entangled on the outside of the net after it had been set. In total 32 individual dolphins were encircled. Active searching had been undertaken prior to the net being set in all except one shot where an encirclement occurred. It is unclear why searches were not successful in detecting dolphins on the seven occasions prior to the net being set. The fate of the individual dolphin that was entangled on the outside of the net and released was unknown.

Comparing observed and logbook reported encirclement rates, numbers of encirclement events and mortalities

Since the implementation of the observer program in the SASF, rates of encirclements and mortalities have been compared between observed and unobserved (fishery logbook data) net-sets. In 2004-05, the encirclement rate calculated from logbook data was approximately 5% of that estimated from observer data (Ward et al. 2015b). The difference between observer and logbook data encirclement rates has reduced over time and the reported rate in 2016-17 was 87% of that estimated from observer data.

During the 2016-17 fishing season, 59 dolphin encirclement events were recorded in the SASF; 8 in observed net-sets and 51 in unobserved net sets. This equates to seven and six encirclements per 100 net sets for observed and unobserved net-sets, respectively. Using a simple ratio estimation method, the extrapolated number of total encirclement events in 2016-17, based on the observed rate, was 66. Using a binomial GLM, which retained the variables Catch and Region, the predicted number of total fleet encirclement events for the 2016-17 season was 67.

There are assumptions when applying a simple ratio method to estimate the total number of encirclement events. Firstly, it assumes that the probability of an encirclement occurring is equal across all net-sets in the fishery. However, encirclement rates, both observed and unobserved (logbook reported), varied across season and region, as well as between vessels. Hamer et al. (2008) reported a seasonal effect with encirclement events, with most occurring between February and March. During the 2016-17 season, the observed encirclement rates in February and March were 0.05 and 0.03, while the highest encirclement rate of 0.20 was observed in June. Observer records on the presence of dolphins outside the net after it had been set, showed higher

sightings rates during February and June, with dolphins present after the net had been set for 80% of shots observed in June 2017. The GLM method also assumes that the observed data are representative of the probability of an encirclement event occurring in net-sets that were not observed based on the variables given to the model. The best GLM retained the variables catch and region (Gulf or Outer Zone) as having the strongest relationships with probability of encirclement occurring.

In 2016-17, there was a marked difference in the observed encirclement rate by region, even though percentage coverage in the two regions was similar (11% and 13%, respectively); with the Gulf Zone encirclement rate 11 times higher than that observed in the Outer Zone. In contrast the logbook reported encirclement rate in the Outer Zone was more than half the rate reported for the Gulf Zone. The lack of observed encirclement events in the Outer Zone in 2016-17 meant that the simple ratio estimation approach cannot be stratified by region, but there are also spatial differences in the occurrence of encirclement events within the Gulf Zone. The Eastern region of the Gulf Zone had both the highest observed and reported encirclement rates in 2016-17, but only 2% of fishing effort occurred in this region. If the number of encirclement events are considered, the majority of observed and reported encirclement events (75% and 63%, respectively) occurred in the Central region of Spencer Gulf. The overlap between fishing operations and temporal occurrence of dolphins also varies by region. Analyses of records of dolphins present in the vicinity of the net after it was set, showed higher sighting rates in the Gulf Zone than the Outer Zone in 2016-17, and this pattern was consistent across all records from 2007-08 to 2016-17. The temporal and spatial variability of dolphin distribution in the region of the fishery will influence the probability of dolphins being present in the vicinity of fishing activities, and therefore the risk of an encirclement event occurring if individuals are not successfully detected prior to the net being set.

Variability in encirclement rates also exists between vessels (considering both observed and unobserved net-sets) and these differences are likely in part due to differences in areas and months fished and overall fishing effort relative to the whole fleet. In 2016-17, logbook reported (unobserved) encirclement rates per vessel ranged from zero to 0.12, while observed encirclement rates per vessel ranged from zero to 0.27.

Additionally, applying the ratio method assumes that the sightability of dolphins prior to the net being set, is equal across all net-sets. However, a number of factors affect sightability including sea state, swell height, wind, time of day, between vessel variation in the quality of lighting and the location of dolphins (if present) relative to the lighted zone around the vessel where they can

be seen. During the 2016-17 fishing season, seven of the observed encirclement events occurred despite an active search being undertaken prior to the net being set. Since the introduction of the CoP, searching for dolphins prior to setting the net has resulted in 89-93% of net-sets not resulting in an encirclement (Ward et al. 2015b). The reason why some searches are successful in detecting dolphins and avoiding an encirclement event and others are not, may be explained in part by sightability factors that change the probability of dolphin detection.

It is not possible to produce robust estimates of either the total number of dolphins encircled, or total number of mortalities within a fishing season based on observer data. The mean number of dolphins observed per encirclement in 2016-17 was 4, but varied between encirclement events (range 1-12). Applying the mean number of dolphins observed per encirclement event and multiplying that against the estimated number of encirclement events (66 using the ratio approach), gives a total estimate of 264 dolphins encircled in 2016-17. This compares to a total of 192 dolphins reported for both observed and unobserved net-sets. However, using the mean number of dolphins observed per encirclement means that events with a large number of dolphins encircled will affect the calculated mean more than those with smaller numbers of dolphins. During the 2016-17 fishing season, two observed encirclement events involved a single dolphin, one involved two dolphins, one involved three, one with five, one with twelve dolphins, and two involved four dolphins. Estimates of the total number of dolphins encircled using the mean and ratio method are sensitive to the range of total numbers of individuals observed during different encirclement events.

The observed mortality rate in 2016-17 was 0.03 dolphin mortalities per encirclement event. Total estimates of dolphin mortality have been calculated for previous fishing seasons using both a simple ratio estimate and by fitting a GLM to the observer data (e.g. Ward et al. 2015b). It is unknown whether extrapolated mortality rates (GLM or ratio approach) reflect mortality rates in unobserved net-sets. The probability of a mortality occurring is affected by a number of factors including the nature of the interaction, such as if an individual is swimming freely or entangled in the net, the speed and success that the individual is released from the net, and whether the individual is released with or without injury. Applying a simple ratio method assumes that the probability of mortality is equal for every dolphin that becomes encircled, whether it is swimming freely in the net, or entangled and released. It also assumes that the estimates of total encirclement events are robust, which given the issues discussed above are unlikely. While there is no information on survival rates of dolphins after encirclements, it seems likely that survival rates would be highest for individuals that are able to swim freely within the net after an

encirclement occurs and subsequently are able to swim freely out of the net when it is opened or the shot is aborted. The survival rates of dolphins observed to be injured following an encirclement are unknown.

Given the range of factors discussed above, caution must be taken when considering the likely precision of estimates of the total number of encirclements, dolphins encircled or of total dolphin mortality in a fishing season that can be obtained through modelling or by extrapolating observed rates to total fishing effort. However, comparisons of observer and logbook data provide useful information on encirclement rates and a means of determining underlying factors that may affect these.

Assessment of the Code of Practice

The agreed release procedure in the CoP, if a dolphin encirclement occurs, is to open the front of the net to ensure a large escape opening, and if this is not successful then the fishing operation is to be aborted by releasing the end of the net. The primary method for mitigating interactions with dolphins specified by the CoP, requires that a search for dolphins is undertaken in the vicinity of the target fish, prior to the net being set. If dolphins are detected the net-set should be delayed and / or relocated to a new area. During the 2016-17 fishing season, dolphins were encircled during seven shots where they had not been seen prior to setting the net. Therefore, searching prior to the commencement of fishing was successful in detecting that dolphins were not present in the vicinity of the fishing operations in 93% of observed net-sets where a search was undertaken. It is clear that searching prior to setting of the net is essential to minimise the potential for dolphins to become encircled during fishing operations. Analyses of observer records since 2007-08 on the presence of dolphins outside the net after being set, indicate a high temporal and spatial overlap between common dolphins and the fishery, with almost 60% of observed shots in 2016-17 recording dolphins present after the net was set.

In 2016-17, the release action taken in six (75%) of the eight observed shots where an encirclement had occurred, was to immediately let the front of the net go. For one encirclement event, the release method was to open the net at the end of the set, and in two separate encirclement events, both involving two entangled individuals, the dolphins had to be cut free of the net. On average, the release procedure commenced within 20 minutes (range 5-50 minutes) of the dolphins being first observed in the net. In 2016-17, the release procedure used in 80% of the 51 unobserved encirclement events reported in logbooks was ‘opening the net’. Details on the time taken to initiate a release was provided for 19 encirclement events and averaged 13

minutes (1-35 minutes). The additional data provided by industry with encirclement events in 2016-17 offers a means of assessing the application of the CoP for these events when an observer is not present. It is recommended that fishers continue to record such information and are provided a standardised form to facilitate this.

Sardine catch rates have been consistently lower in observed net-sets since the observer program was initiated (Ward et al., 2015b, Mackay and Goldsworthy, 2016). In the 2016-17 fishing season, sardine $CPUE_{net\text{-}set}$ was again significantly lower when an observer was present, but this difference was only statistically significant for one vessel. Overall $CPUE_{net\text{-}set}$ at a vessel level was lower when an observer was present during the 2016-17 fishing season, while average $CPUE_{net\text{-}set}$ varied by month. All but one vessel had higher $CPUE_{net\text{-}set}$ when an observer was present in at least one month of fishing. Overall, a significantly higher proportion of observed shots had zero sardine catch, relative to unobserved shots. The reasons for zero-catch shots recorded in fishery logbooks included that: fish were not schooling; fish were missed; Threatened Endangered or Protected Species (TEPS) were present; the weather was too rough; or there was an operational issue.

Determining which factors most influence $CPUE_{net\text{-}set}$ in the presence or absence of an observer is confounded by changes in release procedures used over time, variability in the ability to retain catch even if the net has been opened to release dolphins, and whether there are differences in the application of release procedures in the presence of an observer. It is apparent from the observer data that it is possible to retain relatively large catches of sardine even if the front of the net has been let go to release encircled dolphins.

It is not possible to determine which factors most influence $CPUE_{net\text{-}set}$ for unobserved net-sets as the CoP is based on behavioural changes by skippers and crew during fishing operations which cannot be assessed in the absence of an observer. Behavioural choices that will affect the relationship between $CPUE_{net\text{-}set}$ and encirclements include actively searching prior to setting the net, and not setting around dolphins if detected. If an encirclement event does occur, then behavioural choices will determine the release procedure used and the speed at which it is enacted. While there are a number of confounding factors that can influence CPUE in the SASF, it is unclear what other metric could be used to determine if operations in the fishery are similar in the presence or absence of an observer.

Implications

Fine-scale population sub-structuring has been reported for common dolphins in South Australian waters (Bilgmann et al. 2014). However, given the documentation of long-range longitudinal movement of individuals from different genetic populations into the region (Bilgmann et al. 2014) further information on population sub-structuring and temporal and spatial movement patterns of common dolphins off southern Australia waters would provide an additional means to assess the impact of fisheries interactions with this species for both Commonwealth and State sectors.

Hamer et al. (2008) noted that observed mortalities in the SASF, were generally associated with individuals that had displayed stress behaviour classified as “erratic swimming”, and recommended that the best release option for dolphins showing signs of stress was to open the front of the net or abort the set completely. The immediate action to be taken in the event of an encirclement under the current CoP (SASIA 2015) is to open the front of the net, and if encircled dolphins do not swim free then the fishing operation is to be aborted. If the CoP is followed, the amount of time an individual dolphin remains encircled should be as short as possible, which may reduce the likelihood of that individual experiencing high levels of stress that may lead to subsequent mortality.

Information on common dolphin abundance and distribution would facilitate the assessment of the potential cumulative impacts that dolphin mortalities in the SASF and other fisheries have on their populations. Two aerial surveys have been conducted to estimate common dolphin abundance in areas within South Australian waters. Möller et al. (2012) reported a preliminary estimate of abundance of 14,549 (95% CI = 9,462-22,371) common dolphins in the survey region of Spencer Gulf, Gulf St Vincent and Investigator Strait out to the 100 m depth contour during summer (March-June). The same region was surveyed in winter (August and September) and produced an abundance estimate of 20,749 (95% CI = 15,206-28,313). Bilgmann et al. (2014b) reported an abundance estimate of 21,366 (95% CI =12,221-37,356) common dolphins from an aerial survey in winter 2013 between Ceduna and Coffin Bay, SA, from the coast out to the 100 m depth contour. While these surveys provide estimates of the abundance of common dolphins in the region, both surveys were restricted to waters out to 100 m. Analyses of observer records collected since 2007-08 on the occurrence of dolphins outside nets in the SASF after they were set showed higher sighting in March and April, which were likely driven in part by higher observer effort in these months. While months with low observer effort had lower sighting rates, the largest

group sizes were recorded between September and December. Having a better understanding of the spatial and temporal distribution of dolphins in the region would provide a means of determining areas or times where the likelihood of encountering dolphins may be increased. There are no data on the spatial distribution or abundance of common dolphins in offshore waters or the spatial or temporal movements of common dolphins between offshore and inshore areas, or of long-range movements into or out of the region. The types of surveys that would provide information to assist in assessing direct and cumulative impacts, and the times and locations where dolphin interactions are more likely should be considered.

Conclusions

It is important that observer coverage is evenly distributed across the fleet so that comparisons of the spatial and temporal distribution of fishing effort and catch, between observed and unobserved shots, can be used to determine if observer data are representative of unobserved fishing effort. Observer coverage, in 2016-17 was, in general, relatively evenly distributed, both spatially and temporally with respect to total fishing effort. However, the spatial distribution of observer effort in some months between the Gulf and Outer Zones was less well distributed relative to the total fishing effort in each zone. Further information on the application and efficacy of the CoP could be obtained by structuring the observer coverage to ensure a high proportion of net-sets are observed in specific regions during months when higher observed and reported encirclement rates have been recorded. Maintaining representative observer coverage in the SASF improves our ability to interpret factors that may contribute to differences in observed and unobserved CPUE and fishing behaviour. It will also enable further analyses of fishing metrics such as the occurrence of zero-catch hauls, and over the longer term, will provide information on the temporal and spatial co-occurrence of dolphins with fishing effort.

Overall, the observed rates of dolphin encirclements in the SASF have declined since 2007-08, and in 2016-17 the application of the CoP (search and / or delay) was successful in detecting that dolphins were not present in the vicinity of the fishing operations in 93% of observed net-sets. Of the observed eight encirclements, involving a total of 32 dolphins, one mortality was recorded. These data demonstrate that the application of the CoP by searching prior to setting the net reduces encirclement rates, and that quick release of encircled dolphins reduces the number of mortalities. To improve information on the application of the CoP for unobserved net-sets, it is recommended that fishers record information on interactions (on WIFs), in a similar fashion to that currently recorded by observers.

Improved information on population sub-structuring and temporal and spatial movement patterns of common dolphins in South Australian waters may further inform the assessment and management of cumulative fisheries impacts.

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