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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 2015-16

Alice I. Mackay and Simon. D. Goldsworthy

SARDI Publication No. F2010/000726-7
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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

December 2016

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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Dr Jonathan Carroll and Dr Lachlan McLeay reviewed a draft of the report. The report was approved for release by Assoc. Professor Tim Ward.

EXECUTIVE SUMMARY

This is the tenth 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 2015-16 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. The study also looked at fishing patterns with and without an observer, using data collected by observers and reported in fishery logbooks and wildlife interaction forms between 1 July 2007 and 30 June 2016.

During the 2015-16 fishing season, 10.6% (94) of the total 887 purse seine net-sets were observed. In general, observer coverage in 2015-16 was evenly distributed, both spatially and temporally, with respect to total fleet effort. Nine interactions involving a total of 31 dolphins were observed and one mortality was recorded. Eight of these interactions involved at least one dolphin being encircled within a net-set, while the ninth involved a single dolphin becoming momentarily entangled on the outside of the net. A further 59 encirclements were reported in fishery logbooks involving 164 dolphins with one mortality reported. Encirclement rates with and without an observer present were nine encirclement events per 100 net-sets and seven encirclement events per 100 net-sets, respectively.

The first step in the CoP is to actively search for wildlife prior to setting the net. In 2015-16, searches were undertaken prior to a net being set during all observed shots and five net-sets were delayed after dolphins were sighted. Active searching prior to the net being set resulted in 91% of observed net-sets not resulting in an encirclement event. Of the 30 encircled dolphins, 27 individuals were released without injury, while two were reported to show some sign of injury. 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 that mortalities occur. To improve information on the application of the CoP for net-sets without an observer, it is recommended that fishers record information on interactions similar to that currently recorded by observers.

Previous studies have shown that catch per unit effort (CPUE) has been consistently lower when an observer is present than when an observer is not present. This has led to concerns that fishers

may be behaving differently when an observer is present. Overall, sardine $CPUE_{net\text{-}set}$ was significantly lower for shots with an observer than without an observer in 2015-16, however this pattern was not consistent across vessels.

Examining fishing patterns since 2007-08 showed that in all years the proportion of zero catch shots were higher in observed compared to unobserved shots. Of the 94 observed net-sets in 2015-16, 16% (n=15) resulted in zero catch. The reason for zero catch for six of these net-sets was that the shot was aborted in order to release dolphins after an encirclement occurred. Other reasons for zero catch shots included fish catches being too small to pump or fish not schooling. However, for shots where an encirclement event did not occur, the overall proportion of zero sardine catch shots was higher when an observer was present.

Given the different factors that can effect $CPUE_{net\text{-}set}$ in the SASF, it is not possible to determine how much of the difference in $CPUE_{net\text{-}set}$ with and without an observer could be a result of a difference in fishing behaviour when an observer is present, or how much of the difference has been driven by unrepresentative observer coverage in some years.

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. The reasonably even distribution of observer coverage in 2015-16 allowed comparisons of $CPUE_{net\text{-}set}$, with and without an observer present, to be conducted at a vessel level across the fishing season. 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.

1. INTRODUCTION

1.1. Background

The short-beaked common dolphin (*Delphinus delphis*) 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). Evidence of fine-scale population sub-structuring of common dolphins in South Australian waters have raised concerns over population level impacts of cumulative fishery interactions on this species (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 2014). Although 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), there is also evidence that long range longitudinal movement of individuals between different areas may occur (Bilgmann et al. 2014a). Abundance data for the species off South Australia (SA) are restricted to a winter and summer aerial survey of Spencer Gulf, Gulf St Vincent and Investigator Strait, SA, in 2011 (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 in the region.

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 primarily occur when individuals become encircled in the purse seine net after it 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 with common dolphins (Hamer et al. 2008). Hamer et al. (2008) found that the majority of observed operational interactions with dolphins occurred in fishing hotspots and concluded that spatial closures would not be suitable for mitigating interactions. The authors suggested that dolphins were either attracted by the aggregation of large schools of sardines, or by fishing vessels (Hamer et al. 2008). 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 South Australian Sardine Industry Association (SASIA) CoP 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 wildlife prior to setting the net, searching for wildlife as soon as the net is pursed and initiating a release procedure as soon as possible if wildlife are detected. In addition, the CoP encourages at-sea communication between skippers to report the location of dolphins in real time and co-ordinate fishing activities so that if excess fish is caught, it 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). 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 seasons was in response to an increase in 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. Since the 2012-13 season, the unit of effort to measure observer coverage has been the percentage of total shots (net-sets) observed.

Data on interaction rates with dolphins and other wildlife are also recorded in fishery logbooks. 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). All commercial fisheries must report wildlife interactions through the PIRSA Wildlife Interaction Forms (WIFs).

Observed encirclement rates of dolphins have reduced from 37 encirclements per 100 net-sets in 2004-05, before the introduction of the CoP, to 6 encirclements per 100 net-sets in 2014-15 (Ward et al. 2015b). Observed mortality rates of dolphins have reduced from 39 dolphins per 100 net-sets in 2004-05 to 2 dolphins per 100 net-sets in 2014-15 (Ward et al. 2015b). Observed encirclement and mortality rates have been extrapolated to the fleet to estimate the total number of encirclement events and dolphin mortalities per fishing season, using either a simple ratio method or Generalised Linear Models (GLMs) (e.g. Ward et al. 2013, 2015a, b).

Since 2004-05, 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. 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 2014-15 the estimated and reported number of encirclement events was similar (70 reported, 66 estimated) (Ward et al. 2015b). 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. There has been concern that recorded differences in CPUE 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 either spatially, temporally or across the fleet (Ward et al. 2015a). Fisher behaviour in the presence of an observer may also influence CPUE. For example, CPUE may be lower if fishers act more cautiously and avoid areas or circumstances where dolphin interactions may be more likely to occur, and fishers may be more inclined to use release procedures, where there is a higher chance of losing catch, when an observer is on-board.

Objectives

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

The objectives of the project are to:

1) Examine patterns of observer coverage, including the degree to which these are representative of fishing;
2) Compare rates of dolphin encirclement and mortality recorded by observers and in fishery logbooks when an observer was not present;
3) Compare the number of encirclements and mortalities estimated to have occurred each financial year using observer data with the numbers recorded in logbooks;
4) Assess the efficacy of the CoP in mitigating interactions with dolphins; and
5) Compare fishing patterns with and without an observer.

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. 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 interactions with 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, date and time of an interaction and the species and number of individuals involved in each interaction. The nature of the TEPS interaction is recorded as one of four categories; 'caught', 'entangled', 'impact/collision' or 'other', and the status of the TEPS 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 year (e.g. McLeay et al. 2015, Mackay et al. 2016). Comments provided with WIF records were used to assess the nature of, and response to interactions.

Observer program

SARDI Aquatic Sciences undertook an initial observer program between November 2004 and January 2006. Since July 2006, a continuous 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%. Since the 2012-13 season, the unit of effort for observer coverage has been a percentage of total shots (net-sets) observed. Prior to this the unit of effort for observer coverage was percentage of total nights fished 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 times of each stage of the fishing operation are recorded; ‘start net-set’, ‘begin pursing’, ‘begin hauling’, ‘end hauling’, ‘begin pumping’ and ‘finish net-set’.

Specific data that are recorded which allow an assessment of the application of the CoP 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, the release method used, the success of release and any mortalities that may occur. 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 fishing trip is recorded in the Catch and Effort logbook with a unique logbook number, and the number of net-sets undertaken. The logbook and net-set numbers are also recorded on a WIF if a dolphin interaction occurs. For all trips with an observer onboard the observer records the Catch and Effort logbook number, the number of all shots undertaken, and if a dolphin interaction occurs, records the unique WIF identifier.

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 these data. Since 2013, net-set has been the formal measure of observer effort.

As a consequence of changes in metric of fishing effort used for dolphin interactions, 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).

In earlier years, 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 shots where a search was undertaken but no net was set. Data integration has not changed the total number of mortalities recorded by observers of 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
2007_08	880	181	699
2008_09	932	224	708
2009_10	1097	267	830
2010_11	1015	91	924
2011_12	1108	73	1035
2012_13	861	81	780
2013_14	774	82	692
2014_15	847	88	759
2015_16	887	94	793

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

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

Financial year	Total dolphin encircled	Observed total dolphins encircled	Logbook total dolphin 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

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. The representativeness of observer coverage for 2015-16 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 net-sets with an observer present by month. The harvest strategy for the fishery defines two spatial management zones; the Gulf Zone and the Outside Zone (Figure 1, PIRSA 2014). All net-sets were coded to indicate in which management zone they had occurred. 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 an encirclement 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 2015-16. Each vessel was randomly assigned a unique identifying number to ensure data confidentiality.

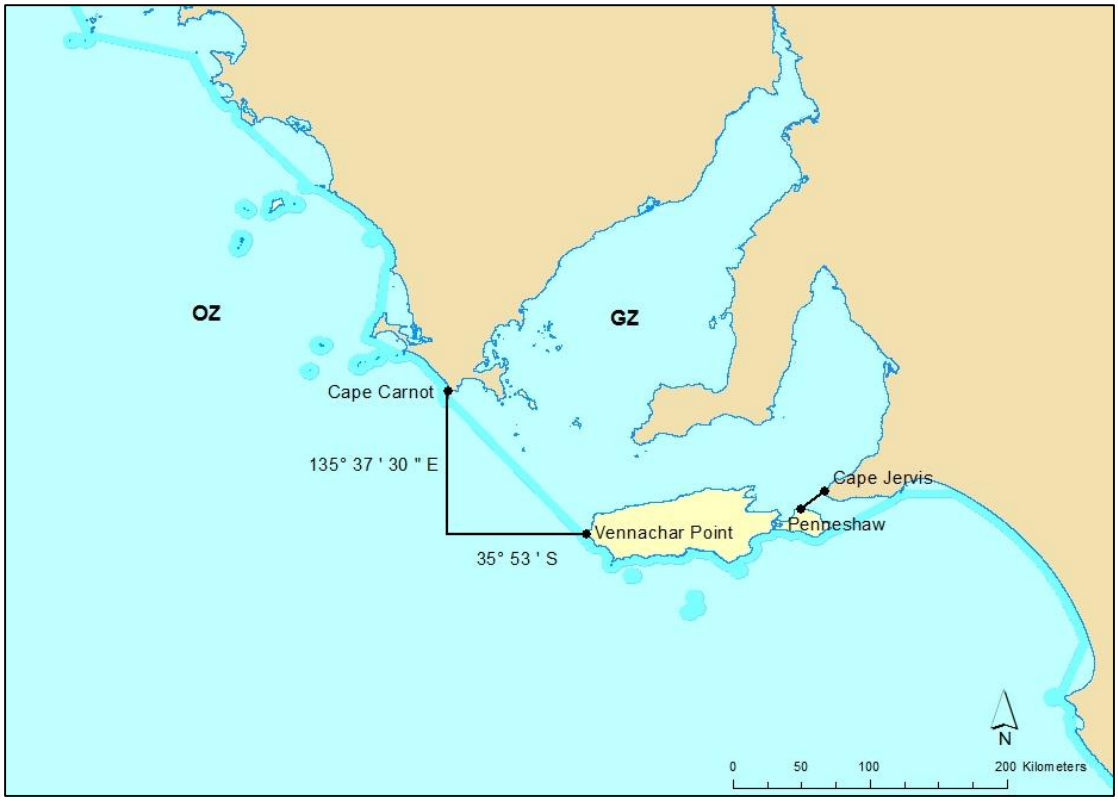

Figure 1. The two spatial management zones for the South Australian Sardine Fishery. GZ = Gulf Zone, OZ = Outer Zone.

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) are recorded.

Rates of encirclements per net-set and mortality per net-set were calculated and compared between net-sets with and without an observer present.

Two methods were used to estimate the total number of encirclement events in the SASF in 2015-16. The first method used a simple ratio estimation approach and a stratified ratio estimation approach, where a) calculated encirclement rates from observed net-sets were multiplied by the total fishing effort (net-sets) undertaken by the fishery, and b) observed encirclement rates were

calculated for each of the two spatial management zones in the fishery (Gulf Zone and Outer Zone) and multiplied by the total fishing effort (net-sets) undertaken in each zone.

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 2015-16) was:

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

To estimate total number of dolphin mortalities Ward et al. (2015a, 2015b) used a Poisson GLM which retained the covariates financial year, month and catch. For this report, using the restricted dataset (2007-08 to 2015-16) after step-wise model selection the best model to estimate total dolphin mortalities only retained the covariate financial year, of which only the years 2007-08 ($p<0.001$) and 2009-10 ($p<0.01$) were significant. GLMs with a negative binomial error distribution and a zero-inflated error distribution were also tested but these did not converge. The distribution of total mortalities per net-set relative to the total number of observed net-sets with no mortalities means that there are limited data to fit complex models, and care therefore needs to be taken not to over-parameterise the model.

Fishery reporting rates of interactions were assessed by comparing the total number of encirclement events reported in the WIF in 2015-16 to the total number of encirclement events estimated from the observer data using the simple ratio extrapolation method and GLM. The total number of dolphin mortalities was estimated from observer data using the simple ratio extrapolation method.

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

As with previous reports (Ward et al. 2015a, b) an assessment of the efficacy of the CoP in mitigating interactions with dolphins were based on the observed ability to avoid interactions (search and delay) and successful release of dolphins if they became encircled and/or entangled in the net.

2.6. Comparison of fishing patterns with and without an observer

Differences in CPUE per net-set ($CPUE_{net\text{-}set}$) with and without an observer have previously been reported (Ward et al. 2015a, b), with lower $CPUE_{net\text{-}set}$ when an observer was present reported in all years, except 2011-12. $CPUE_{net\text{-}set}$ for observed and unobserved net-sets were compared at a vessel and month level using the 2015-16 data, in order to investigate factors that may be driving the observed differences.

Previous analyses of data collected since the 2004-05 fishing season have used GLMs to investigate how different factors relate to sardine $CPUE_{net\text{-}set}$ (Ward et al. 2015a, 2015b). The explanatory variables investigated were financial year, month, region, vessel and presence/absence of an observer. We extended these models to include whether an encirclement occurred as a categorical variable using the data from 2007-08 to 2015-16. Forward and backward step-wise selection was used to select the best GLM for each of the data subset based on AIC. Patterns of $CPUE_{net\text{-}set}$ were investigated for each significant explanatory variable retained in the best GLM model.

3. RESULTS

3.1. Observer coverage in 2015-16

During the 2015-16 season, a total of 887 purse seine shots were undertaken in the fishery, of which 94 (10.6%) were observed. A further 43 'shots' were recorded in the Catch and Effort logbooks, where searching was undertaken but no net was set. Reasons for not setting a net included that no fish seen or fish not schooling, weather too rough, that TEPS were present or mechanical or gear issues had occurred.

Most (75%) fishing effort occurred between February and May. Observer coverage of fishing effort per month ranged from 7-14% of net-sets (Figure 2). None of the 36 net-sets undertaken in November were observed. Target observer coverage of 10% was reached or exceeded in six of the nine months when fishing occurred. Eleven vessels were active in the SASF in 2015-16, with the individual vessel percentage of net-sets observed ranging between 3% and 17% of total fleet fishing effort. The percentage observer coverage of each individual vessel's total net-sets ranged from 7% to 19% (Figure 3).

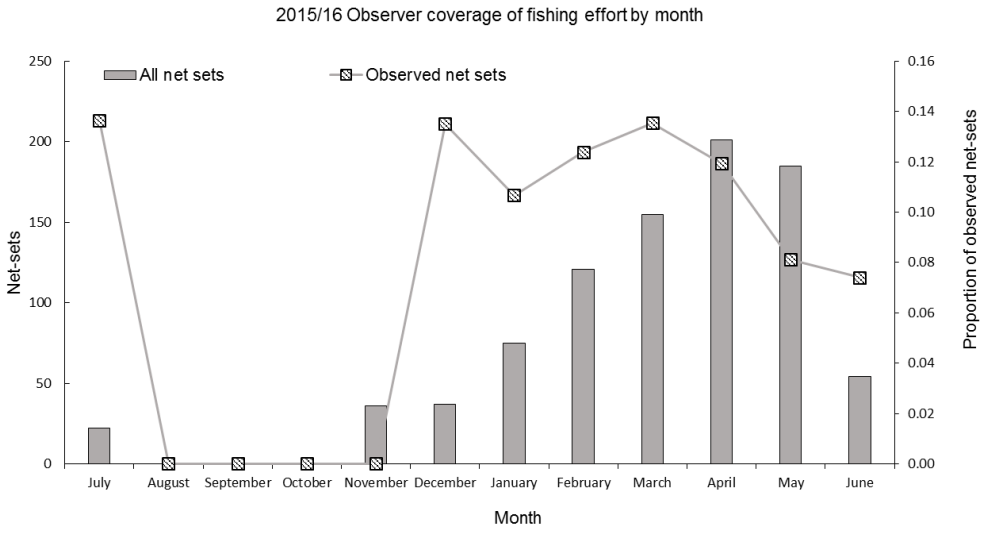

Figure 2. Total fishing effort (net-sets) (bars) and proportion of observer coverage by month for 2015-16

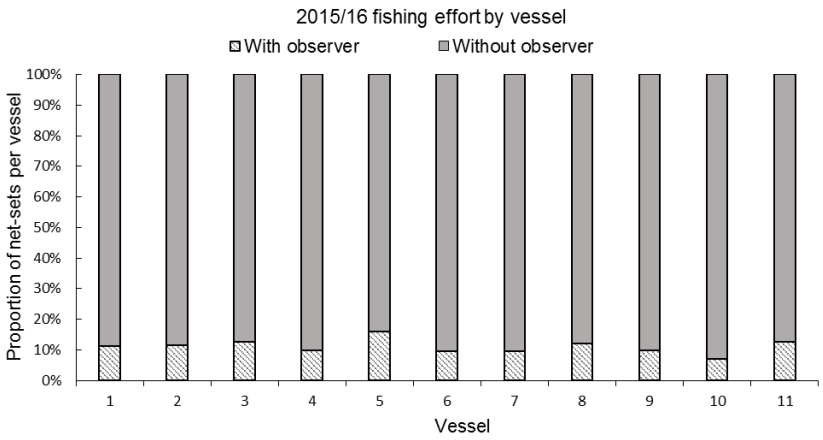

Figure 3. Proportion of fishing effort (number of net-sets) observed by vessel (vessel identifying number assigned randomly).

The majority (69%) of fishing effort occurred in the Gulf Zone management area of the fishery. Observer coverage of fishing effort resulted in 10% of all net-sets in the Gulf Zone being observed and 12% of all net-sets in the Outer Zone being observed (Figure 4). A visual comparison of the spatial distribution of observed and unobserved net-sets by month did not indicate a difference in fishing location.

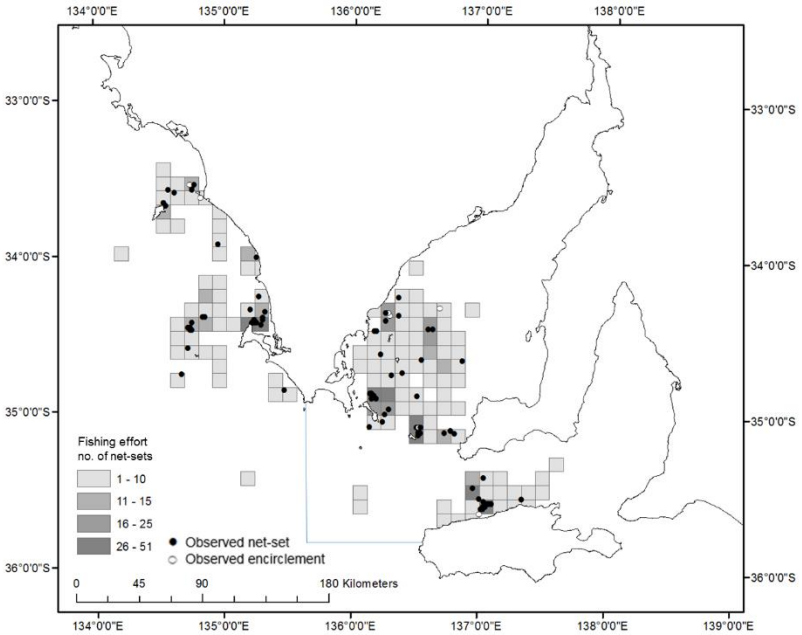

Figure 4. Spatial distribution of fishing effort in SASF during the 2015-16 fishing season. Black circles = observed net-sets without encirclements, white circles = observed net-sets with encirclements. Blue lines are boundaries between the two Gulf Zone and Outer Zone.

3.2. Encirclement rates 2015-16

Nine interaction events with dolphins were recorded by observers in the 2015-16 fishing season, involving a total of 31 dolphins from 94 observed net-sets. Eight of these interactions involved at least one dolphin being encircled after the net had been pursed. One interaction occurred when a single dolphin was observed trying to enter the net from the outside, after the net had been set. This dolphin became entangled in the mesh by its teeth for a few seconds before releasing itself and swimming away. The observed *encirclement* rate in 2015-16 was 0.085, or nine encirclement events per 100 net-sets. Seven encirclements occurred in 60 observed net-sets in the Gulf Zone, and one encirclement occurred in 34 observed net-sets in the Outer Zone. The observed encirclement rate in the Gulf Zone was 12 encirclement events per 100 net-sets, and the encirclement rate in the Outer Zone was 3 encirclement events per 100 net-sets.

Logbook data, (no observer present), reported a further 59 encirclement events from 793 fishing net-sets that involved a total of 164 dolphins, giving an encirclement rate of seven encirclement events in every 100 net-sets. Of these, 55 encirclement events were reported from 550 net-sets in the Gulf Zone, and four encirclement events from 243 net-sets in the Outer Zone. The encirclement rate reported in logbooks in the Gulf Zone was 10 encirclement events per 100 net-sets, and the reported encirclement rate in the Outer Zone was 2 encirclement events per 100 net-sets.

Figure 5 shows the estimates of total encirclement events between 2007-08 and 2015-16 using a) the ratio estimate method based on observer only and logbook only data, and b) GLM predictions based on observer data, and the total number of encirclements reported in logbooks. In total, 67 dolphin encirclement events were reported in logbooks in 2015-16. Using a simple ratio method where the observed encirclement rate of 0.085 was applied to total fishing effort produced a total estimate of 75 encirclement events. Using a stratified ratio approach, the total estimate of encirclement events was 78 (Gulf Zone = 73, Outer Zone = 5). The best GLM estimated that 69 encirclement events occurred in 2015-16. In general, the GLM predicted lower total numbers of encirclement events compared to the ratio method. This difference is likely due to uneven observer coverage, relative to fishing effort, in relation to the covariates catch, month and region, as the total number are predicted from the observer data.

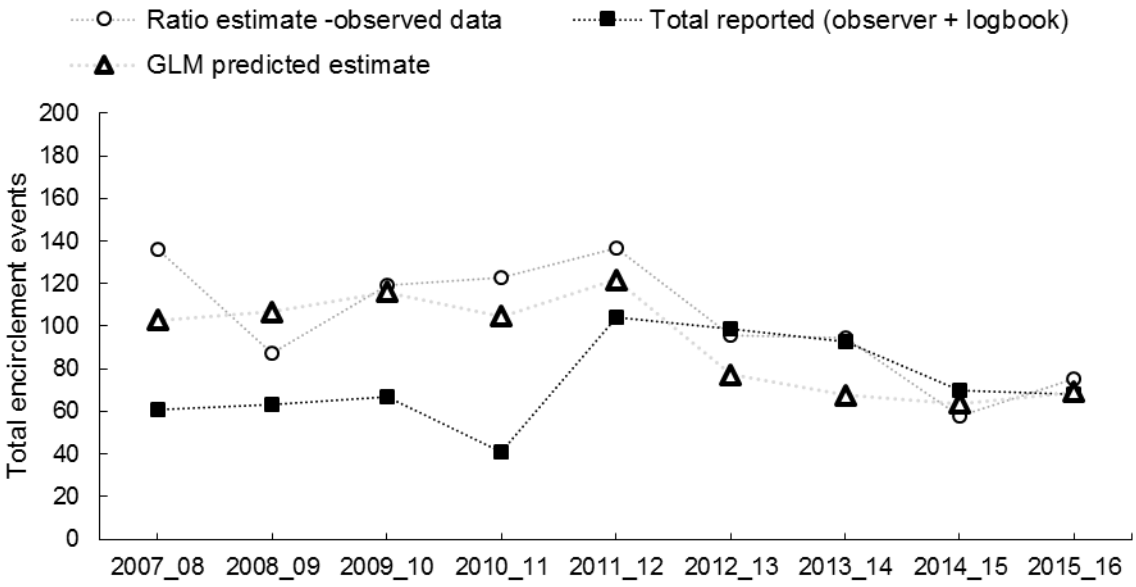

Figure 5. Estimated total number of encirclement events per financial year based on a) observed shots b) logbook shots c) observer and logbook shots combined and d) GLM prediction.

3.3. Dolphins encircled and mortality rates 2015-16

In total 30 individual dolphins were observed encircled in net-sets during the 2015-16 fishing season. The number of dolphins observed during an encirclement ranged from 1-12 individuals (mean = 3.2, SD = 3.4). Two encirclement events involved a single dolphin, two involved two dolphins, one involved three, four and five dolphins, respectively, and one involved 12 dolphins (Figure 5). The number of dolphins reported during an encirclement event when an observer was not present ranged from 1-8 individuals (mean = 2.8, SD = 1.8) (Figure 6).

Applying a simple ratio to extrapolate from observer data, the estimated number of dolphins encircled in 2015-16 was 257, based on a mean of 3.4 dolphins per encirclement event and a total estimate of encirclement events of 75. Using a simple ratio 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, whereas the observed number of dolphins per encirclement can vary greatly (Figure 6).

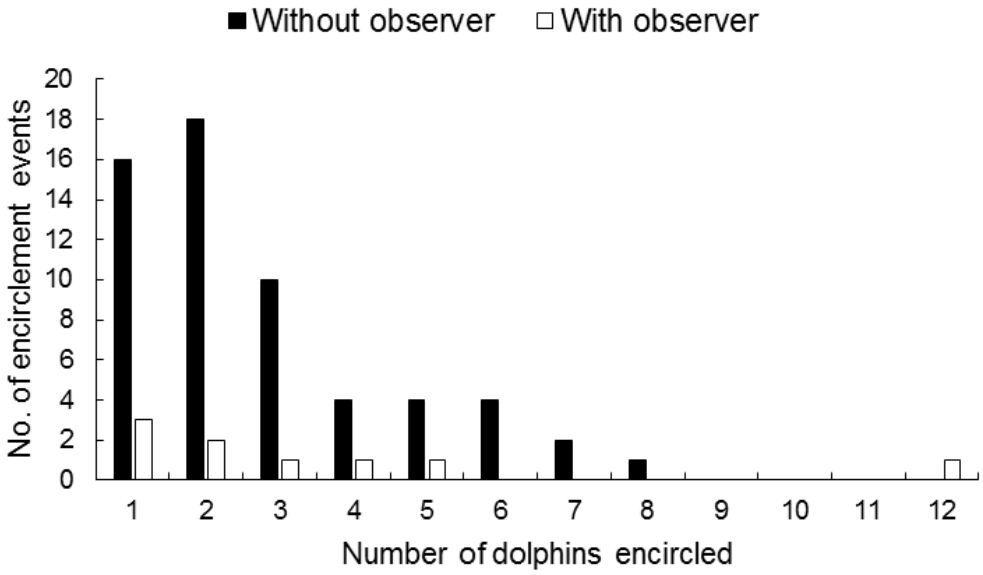

Figure 6. Number of dolphins per encirclement event for net-sets with and without an observer present.

Of the 30 dolphins that were observed encircled in 2015-16, one dolphin mortality was recorded, giving an observed rate of 0.03 dolphin mortalities per encirclement. Extrapolating this rate using the estimated observed encirclement rate of 0.096 for 2015-16 provides an estimate of total mortality of 9 individuals in 2015-16. If the two dolphins which were observed entangled but released injured, did not survive, the estimated observed rate would be 0.07 dolphin mortalities per encirclement, producing an overall estimate of total mortality of 20 individuals for the 2015-16 fishing season. Again, using a simple ratio method to extrapolate mortality rates assumes that the chance of mortality is constant for each encirclement event.

Of the 164 dolphins that were reported as encircled in shots without observers in 2015-16, one dolphin mortality was recorded, giving a reported mortality rate of 0.017 dolphin mortalities per encirclement. Extrapolating this rate using the logbook reported encirclement rate of 0.074 for 2015-16 provides an estimate of total mortality of three individuals from logbook only data in 2015-16.

3.4. Comparison of observed and reported rates of operational interactions

The encirclement rate recorded in fishery logbooks for the 2015-16 season when no observer was present was 0.074, compared to an encirclement rate of 0.085 for observed net-sets. The difference in the observed encirclement rate and the reported encirclement rate has reduced in recent years (Figure 7).

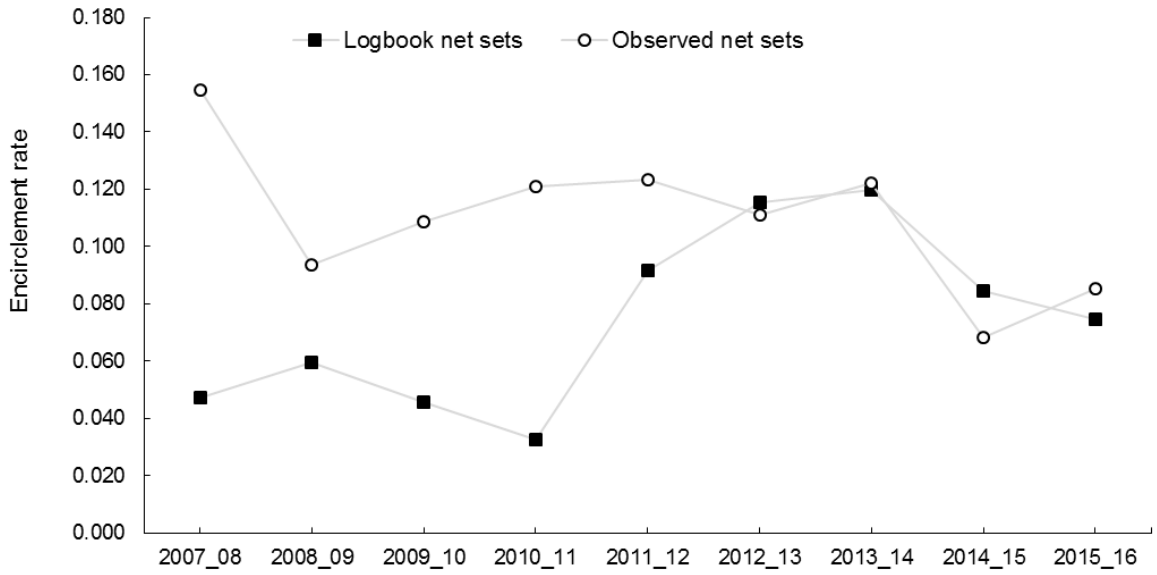

Figure 7. Encirclement rates (number of encirclements / total net-sets) for net-sets with an observer and net-sets without an observer.

3.5. 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 all 94 shots observed in 2015-16. Five observed shots were delayed due to the presence of dolphins detected during searching. No encirclement was recorded in any shot following a delay. Dolphins were encircled during eight shots where they had not been seen 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 92% (Table 2). A ninth interaction involved a dolphin trying to enter the net from the outside

and becoming momentarily entangled before releasing itself. The release action taken in six of the eight observed encirclement events was to immediately let the front of the net go, while for one encirclement the net was opened at the end of the set. In two separate shots, two dolphins were observed to be entangled and had to be cut out of the net. Of these four individuals, two were reported as showing good signs of life when released.

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

Year	Number of searches	Number of delays	Search success %	Search and delay success %
2004-05	0	0		
2005-06	89	6	89.9	100
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
2012-13	84	4	90.5	50
2013-14	81	15	93.8	66.7
2014-15	93	13	92.5	84.6
2015-16	95	5	91.1	91.6

Dolphins were observed in the vicinity of nets, after the net was pursed, in 33% (n = 31) of observed shots. The observer noted that dolphins turned up while the net was being hauled or being pumped. The proportion of observed shots with dolphins present after the net was pursed varied between months (25-80%), with no dolphins recorded present after the net had been pursed in December or January. However the number of observed shots in these months were low (n = 5, n = 8, respectively). Most observed sightings (88%) occurred in the Gulf Zone. Estimates of the number of dolphins present ranged from a single individual up to 150 individuals.

As interactions with dolphins in net-sets without observers are reported in the WIF, 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 logbook comments. Analyses of available comments from WIFs showed that, where recorded, ‘letting the front of the net go’, or ‘aborting the shot’ was

the procedure used for 84% (62-100%) of encirclements reported between 2007-08 and 2015-16. In 2015-16, the release procedure that was reported in logbooks for 49 encirclement events, that involved a total of 150 individual dolphins, was 'opening the net'. For seven encirclement events, dolphins were reported to have escaped over the submerged corkline of the net. The one dolphin mortality reported in logbooks was of an individual that was entangled and already deceased when first detected.

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)

3.6. Comparison of fishing patterns with and without an observer

$CPUE_{net\text{-}set}$ was significantly different between vessels (Kruskal-Wallis chi-squared = 196.22, df = 10, p-value < 0.0001) and ranged from 7.2 t.net-set^{-1} to 65 t.net-set^{-1}. Overall, sardine $CPUE_{net\text{-}set}$ was significantly lower for observed shots compared to unobserved shots in 2015-16 (t-test, df = 124.27, p-value = 0.048). While the difference in $CPUE_{net\text{-}set}$ between shots with and without an observer varied between vessels, this was only significantly different for one vessel (t-test df = 17.63, p-value<0.001).

The general pattern of lower CPUE in observed net-sets continued in the 2015-16 fishing season (Figure 9). Significantly lower $CPUE_{net\text{-}set}$ in observed net-sets occured in 2008-09, 2009-10, 2012-13, 2013-14, 2014-15 and 2015-16 (Table 4).

After step-wise selection, the best GLM model with a Poisson error distribution to explain $CPUE_{net-set}$ for the complete dataset of all shots undertaken between 2007-08 and 2015-16 retained the explanatory categorical variables financial year, vessel ID, encirclement event, month, observer and region. All categorical variables were significant (p<0.001), with the exception of one vessel ID and two months, February and August.

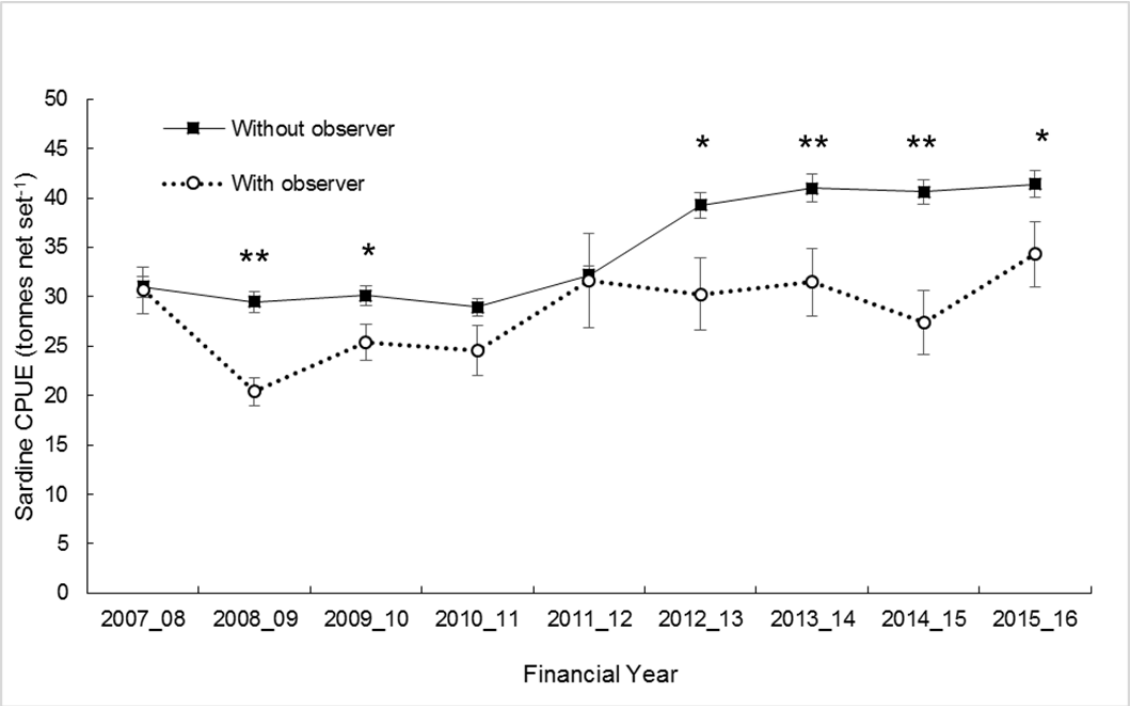

Figure 8. Mean $CPUE_{net-set}$ and ± SE for all shots with and without an observer between 2007-08 and 2015-16 fishing seasons. Significant differences indicated by * = p<0.05, ** = p<0.001

Table 4. Results of t-tests the CPUE of observed and unobserved net-sets by financial year.

Year	df	p
2007-08	256.76	0.846
2008-09	474.21	**<0.001**
2009-10	443.7	**<0.05**
2010-11	112.15	0.248
2011-12	77.803	0.894
2012-13	101.05	**<0.05**
2013-14	109.68	**<0.001**
2014-15	117.46	**<0.001**
2015-16	124.27	**<0.05**

Relationship between $CPUE_{net\text{-}set}$ and the presence of an observer

Figure 9 shows the distribution of sardine catch per net-set, with and without an observer, for all net-sets undertaken between 2007-08 and 2015-16. Overall, a significantly higher proportion of net-sets with an observer present had zero sardine catch than net-sets without an observer present ($\chi^2 = 58.50$, p<001, Figure 9).

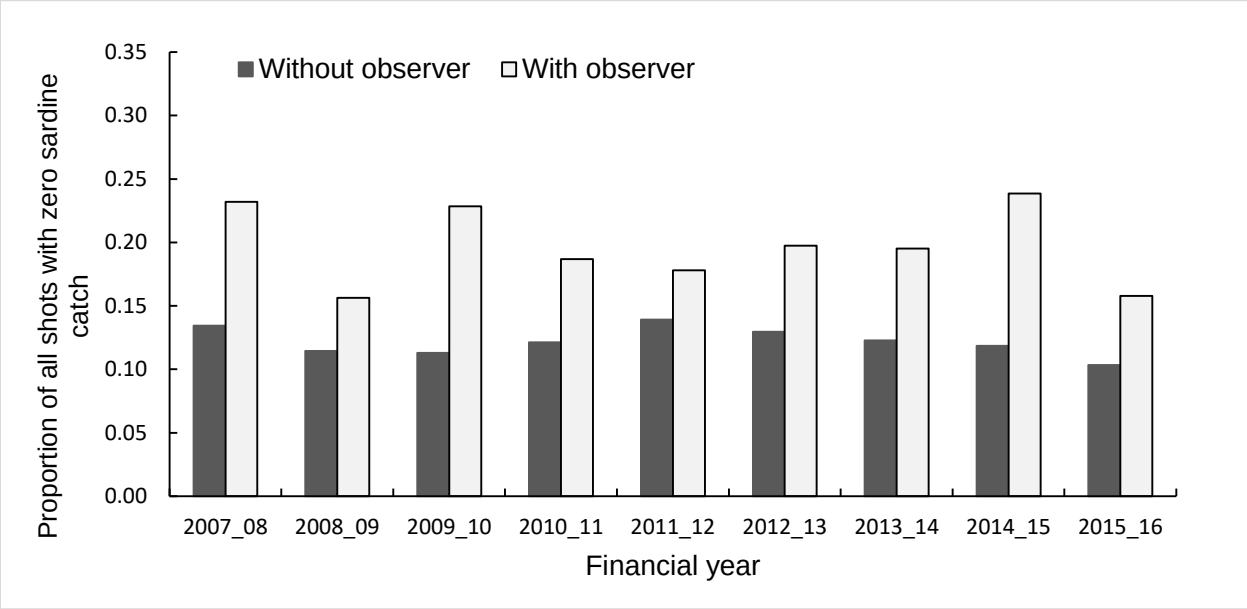

Figure 9. Proportion of all shots, with and without an observer, undertaken in the SASF between the 2007-08 and 2015-16 fishing seasons with zero sardine catch recorded.

Relationship between encirclement events and $CPUE_{net\text{-}set}$

The overall relationship between encirclement events and $CPUE_{net\text{-}set}$ shows that there is a higher distribution of low sardine catch when an encirclement event occurs for both net-sets with or without an observer present (Figure 10a and b).

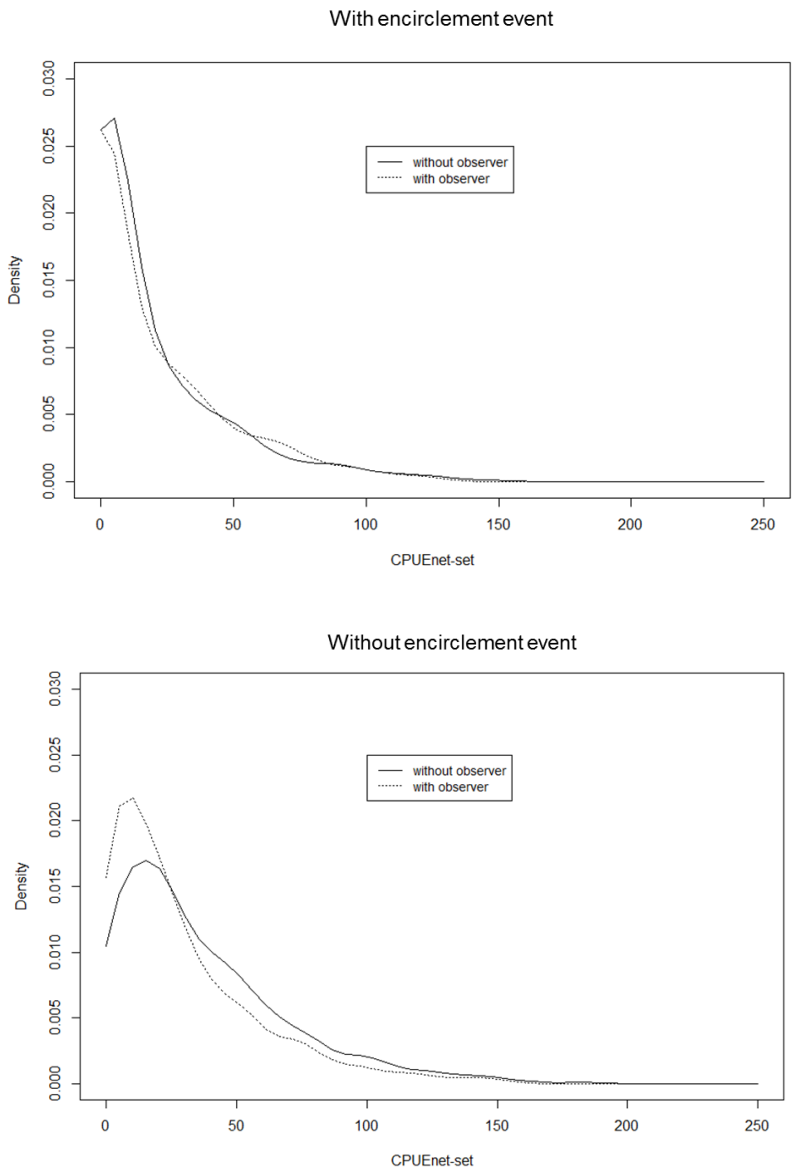

Figure 10a and b. Distribution of average catch brailed per net-set with and without an observer for net-sets with an encirclement and without an encirclement. Catch data from all net-sets from 2007-08 to the 2015-16 fishing seasons was used.

Figure 11 details the proportion of zero catch net-sets recorded for observed and unobserved shots with an encirclement event, between 2007/08 and 2015/16. In five (2008-09, 2009-10, 2011-12, 2013-14, 2015-16) of the nine years, there was no significant difference in the proportion of zero-catch net-sets for observed and unobserved shots with an encirclement. However, in 2007-08 ($\chi^2 = 10.19$, $p < 0.01$) and 2010-11($\chi^2 = 10.19$, $p < 0.01$), the proportion of zero-catch net-sets was significantly greater in observed shots, whereas in 2012-13 ($\chi^2 = 5.99$, $p < 0.01$) and 2014-15

(χ^2 = 6.7, p <0.01) the proportion of zero-catch net-sets was significantly greater in unobserved shots with encirclements.

For net-sets where an encirclement event did not occur, the overall proportion or zero catch net-sets was higher when an observer was present than when an observer was absent. This pattern occurred in all years, and the proportion of zero catch net-sets was significantly higher with an observer present in 2007-08 (χ^2 = 14.47, p <0.001), 2008-09 (χ^2 = 4.4, p <0.05), 2009-10 (χ^2 = 39.72, p <0.001) and 2014-15 (χ^2 = 9.9, p <0.001).

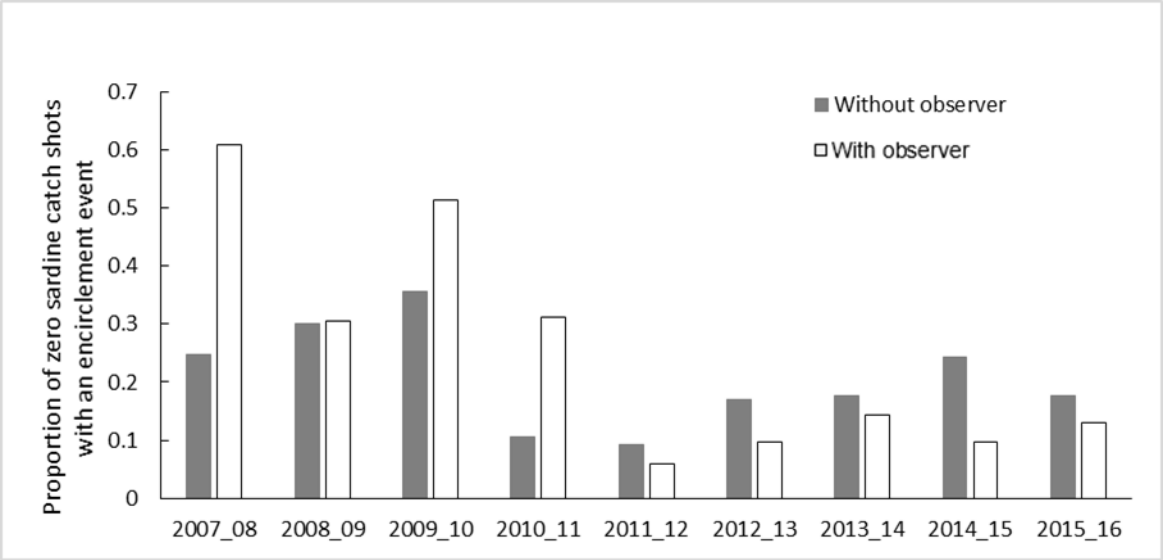

Figure 11. Proportion of all zero sardine catch net-sets, by financial year, where an encirclement event was reported, for net-sets with and without an observer present.

Vessel effect in the significant years

Paired t-tests of $CPUE_{net\text{-}set}$ with and without an observer 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. $CPUE_{net\text{-}set}$ was significantly lower for net-sets with an observer than without an observer for at least one vessel in each year. An examination of monthly patterns of CPUE for individual vessels within a year showed that the relationship between $CPUE_{net\text{-}set}$ and an observer being present was not consistent across the fishing season. In some months, observed net-sets had lower $CPUE_{net\text{-}set}$, while in other months $CPUE_{net\text{-}set}$ was similar for observed and unobserved net-sets. Some of the differences in $CPUE_{net\text{-}set}$ in observed and unobserved net-sets at a vessel level were likely due to observed sets being unrepresentative of total fishing effort by a vessel within a season or across fishing season.

Table 5. Results of Welch two-sampled t-test comparing $CPUE_{net\text{-}set}$ with and without and observer for each vessel and financial year. Results are presented as number of vessels with significantly lower $CPUE_{net\text{-}set}$ with an observer present by financial year.

Financial year	No. of vessels	No. of 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

4. DISCUSSION

Observer coverage 2015-16

The overall target of 10% observer coverage of total fishing effort (net-sets) in the SASF during the 2015-16 fishing season was achieved. Observer coverage relative to fishing effort varied between months. No net-sets undertaken in November 2015 were observed, while the percent of fishing effort observed in other months ranged between 7% and 14%. The target observer coverage of 10% of net-sets was generally achieved during the period when most fishing occurred. Most fishing effort occurred between February and May, and observer coverage during this period averaged 11% of all net-sets, although it was only 8% of all net-sets in May. The spatial distribution of observer coverage relative to fishing effort was 10% of net-sets in the Gulf Zone and 12% of net-sets in the Outer Zone.

In general, observer coverage in 2015-16 was relatively evenly distributed, both spatially and temporally, with respect to total fleet effort. The level of observer coverage of individual vessel fishing effort varied between 7% and 16% of net-sets; two vessels had less than 10% observer coverage (7% and 9%, respectively). Total net-sets undertaken by these two vessels represented, 9% and 8% of the total fleet fishing effort, respectively. Observer coverage for five vessels which accounted for over 60% of total fleet fishing effort in 2015-16, was between 10% and 13% of net-sets.

While 10% of observer coverage was not reached on two vessels 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. For example, 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. The number of net-sets on a fishing trip (observed or not) will also depend on a range of factors, including the presence of fish, whether fish are schooling, the amount of quota that remains for that licence, and distance to the fishing ground.

Observed interactions with dolphins in 2015-16

Of the nine observed interactions with dolphins in the 2015-16 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 the net had been set. In total 30 individual dolphins were encircled. Active searching had been undertaken prior to the net being set in all shots where an encirclement occurred. It is unclear why searches were not successful

in detecting dolphins on these eight occasions prior to the net being set. The individual dolphin that became entangled for a few seconds on the outside of the net during one shot was observed swimming away from the net unharmed. The observer estimated that 100-150 dolphins were present outside the net at the time that net hauling and pumping began.

Reporting rates and numbers of encirclements 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 in 2014-15 the number of encirclements reported in logbooks was higher than the number estimated from observer data (Ward et al. 2015b).

In total, 67 dolphin encirclement events were recorded in 2015-16; 8 in observed net-sets and 59 in unobserved net sets. This equates to seven and nine encirclements per 100 net sets for observed and unobserved net-sets, respectively. Using a simple ratio method, the extrapolated number of total encirclement events in 2015-16 was 75 and 66 from observed and unobserved net-sets, respectively. Using a binomial GLM method, the predicted number of total fleet encirclement events for the 2015-16 season was 69.

There are issues with using the simple ratio method to estimate the total number of encirclement events. Firstly, it assumes that the probability of encirclement is equal across all net-sets in the fishery, irrespective of potential seasonal and fishing area effects. There is evidence that both these factors are significant. In 2015-16, although dolphins were sighted in the vicinity of the net after pursing in 33% of all observed net-sets, this rate varied considerably across months (25-80% of all net-sets) and was highest in May. Hamer et al. (2008) also noted a seasonal effect with encirclement events, with most occurring between February and March. Furthermore, in 2015-16 there was a marked difference in the mean encirclement event rate by region, with the Gulf Zone encirclement event rate being four times that observed in the Outer Zone. In the GLM analyses of encirclement events, both region and month were retained as explanatory variables, and while the influence of region was significant ($p<0.01$), the only month that showed a significant relationship was June ($p<0.05$). These results suggest that it may be better to use a stratified ratio method approach based on to individual seasons and region.

Applying the ratio test assumes that the sightability of dolphins prior to net-set, is equal across all net-sets. However, factors that affect sightability include 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 2015-16 fishing season, all eight 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 89-92% 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 a dolphin being detected.

The mean number of dolphins observed per encirclement in 2015-16 was about 3, but varied between encirclement events (1-12). Using the ratio estimation approach and applying the mean number of dolphins observed per encirclement event and multiplying that against the estimated number of encirclement events (75 using the ratio approach), gives a total estimate of 257 dolphins encircled, compared to a total of 194 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 influence the calculated mean more than those with smaller numbers of dolphins. During the 2015-16 fishing season, three observed encirclement events involved a single dolphin, two involved two dolphins, one involved three, four and five dolphins respectively and one involved 12 dolphins. If, for example, the encirclement with the 12 dolphins had involved five dolphins, the overall mean number of encirclement dolphins per encirclement event would have reduced from 3.4 to 2.7, which would have produced a total estimate of 202 encircled dolphins. Estimating the total number of dolphins encircled using the mean and ratio method is sensitive to the distribution of the numbers of dolphins observed encircled. As a result, estimates obtained when using a ratio estimation approach based on the mean number of dolphins observed per encirclement event and the estimated number of encirclement events (75 using the ratio approach) should be treated with caution.

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 was not possible to fit a GLM to estimate total mortality to the restricted datasets used in the current analyses, therefore total mortalities were only estimated using the ratio approach. Of the 30 dolphins that were observed encircled in 2015-16, 29 were released alive and 1 mortality was

recorded. The observed mortality rate in 2015-16 was 0.03 dolphin mortalities per encirclement event. Applying a simple ratio method to this rate produces an estimate of total mortality of nine dolphins. However, two dolphins that were released after becoming entangled in the net were observed as showing signs of injury that may have reduced their post-release probability of survival. If these individuals did not survive, the estimated observed mortality rate for 2015-16 would be 0.13 dolphins per encirclement, and the total mortality estimate would be 20 dolphins.

Models to estimate total mortality using the restricted dataset between 2007-08 and 2015-16, did not fit the data well. The distribution of total mortalities per net-set relative to the total number of observed net-sets with no mortalities means that there is limited data to fit complex models. In the restricted dataset used for this report, 98% of all observed net-sets reported no dolphin mortality, 1.3% (15 net-sets) reported a single dolphin mortality, 0.2% (2 net-sets) reported two dolphin mortalities and 0.2% (2 net-sets) reported three dolphin mortalities.

It is unknown whether extrapolated mortality rates reflect mortality rates in unobserved net-sets; the simple ratio method assumes an equal probability of mortality for every dolphin encircled. 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. 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.

Assessment of the Code of Practice

The first method of mitigating interactions with dolphins specified by the CoP is that prior to the net being set, a search for dolphins in the vicinity of the target fish is undertaken. If dolphins are detected the net-set should be delayed and / or relocated to a new area. Between the 2004-05 and 2014-15 seasons, actively searching for dolphins prior to fishing correctly detected that dolphins were not present in the vicinity of fishing operations in 90% of observed net-sets (Ward et al. 2015b). During the 2015-16 fishing season, dolphins were encircled during eight 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 91% of observed net-sets.

In 2015-16, the release action taken in five (63%) of the eight observed shots where an encirclement had occurred, was to immediately let the front of the net go. For one encirclement, the release method was to open the net at the end of the set, and in two separate encirclements, both involving two entangled individuals, the dolphins had to be cut free of the net. The release procedure commenced, on average within 6.8 minutes (0-19 minutes) of the dolphins being first observed in the net. Five observed shots were delayed due to the presence of dolphins being detected during searching and no encirclement was recorded in any shot following a delay.

In 2015-16, the release procedure used in 49 (83%) of the 59 unobserved encirclement events reported in logbooks was ‘opening the net’. Comments provided in the WIFs suggest that, ‘letting the front of the net go’, or ‘aborting the shot’ was the procedure used for 84% (62-100%) of encirclements reported in logbooks between 2007-08 and 2015-16. The single mortality reported was of a dolphin that was already deceased and entangled in the net when first observed. The release method used, and details on searching or delaying prior to setting the net are not always recorded in the WIF comments.

Sardine catch rates have been consistently lower for observed compared to unobserved fishery reported net-sets since the observer program was initiated (Ward et al. 2015b). Sardine $CPUE_{net-set}$ was again significantly lower in observed net-sets during the 2015-16 fishing season. However, this difference was only statistically significant for one vessel.

Ward et al. (2015b) found that the categorical variables vessel, observer presence, financial year and month all had a significant relationship with $CPUE_{net-set,}$ and noted that some of the difference in sardine CPUE could be explained by a high level of observer effort in months and on vessels with low CPUE, particularly in 2005-06 and 2008-09. However, it was not possible to determine whether fishing behaviour was the same with and without an observer (Ward et al. 2015b). To extend these analyses we undertook analyses of the restricted dataset between the 2007-08 and 2015-16 fishing seasons. The best GLM retained the explanatory variables financial year, vessel ID, encirclement event, month, observer and region. It should be noted that while vessel ID is a consistent categorical variable, it does not account for any differences in fishing efficiency that may result from changes in skippers over time.

Overall, a significantly higher proportion of observed shots had zero sardine catch. The reasons for zero-catch shots recorded in fishery logbooks included that: fish were not schooling; fish were missed; TEPS were present; the weather was too rough; or there was an operational issue. For shots where an encirclement event did not occur, the overall proportion of zero-catch shots was higher for observed shots. This pattern occurred in all years and was significant in 2008-09, 2009-10 and 2014-15, but the reason for this pattern is unclear. Of the 94 observed net-sets in 2015-16, 16% (n=15) resulted in zero-catch. The main reason recorded by observers for almost half of these zero-catch net-sets was that the shot had been aborted to release dolphins after an encirclement had occurred.

The proportion of zero-catch shots with an encirclement event was significantly higher with an observer in 2007-08, 2010-11, and without an observer in 2012-13 and 2014-15. 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 to abort the operation by releasing the end of the net. While an aborted shot will result in zero sardine catch, 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. Therefore, determining which factors most influence $CPUE_{net\text{-}set}$ with and without an observer is also 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 when an observer is present.

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 measured 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. To improve information on the application of the CoP for net-sets without an observer, it is recommended that fishers record information on interactions similar to that currently recorded by observers.

$CPUE_{net\text{-}set}$ with and without an observer was significantly different for some vessels in some fishing seasons, but determining the factors that contribute to significant differences between vessels was outside the scope of the current study. In addition, in earlier years, catch was

frequently recorded in fishery logbooks aggregated to trip level, whereas observers record catch for each individual shot. Therefore, it is not possible to determine if some of the higher $CPUE_{net-set}$ recorded in fishery logbooks, particularly in earlier years, was due to catch being aggregated at a trip level instead of reported as individual shots. Finally, it was not possible to determine what effect transfer of catch between vessels has on the interpretation of $CPUE_{net-set}$ results at an individual vessel level. This is because current reporting of transfer of sardine catch in logbooks does not provide information on which vessel has received catch and which has transferred catch. It is anticipated that the future eLog system will allow for better reporting of shared tonnages. While there are a number of confounding factors which can influence CPUE in the SASF, it is unclear what other metric could be used to determine if operations in the fishery are similar with and without an observer.

Implications

Fine-scale population sub-structuring has been reported for common dolphins in South Australian waters (Bilgmann et al. 2014). However, documentation of long-range longitudinal movement of individuals from different genetic populations into the region (Bilgmann et al. 2014) indicates that further information on population sub-structuring and temporal and spatial movement patterns of common dolphins off southern Australia waters are needed.

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 option to release dolphins showing signs of stress was to release 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 levels of stress that could result in subsequent mortality.

Assessment of the potential impacts that dolphin mortalities in the SASF and other fisheries have on the status of common dolphin populations is assisted by consideration of information available on the abundance and distribution of 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. The same region was surveyed in winter 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. 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.

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 reported fishing effort. Observer coverage, in 2015-16 was, in general, relatively evenly distributed, both spatially and temporally, with respect to total fishing effort. This observer coverage allowed differences in $CPUE_{net\text{-}set}$, with and without an observer present, to be directly compared at a vessel level across the fishing season. Maintaining representative observer coverage in the SASF will 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 2015-16 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 92% of observed net-sets. Of the observed eight encirclements, involving a total of 30 dolphins, one mortality was recorded. These data show 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 that occur. To improve information on the application of the CoP for net-sets without an observer, it is recommended that fishers record information on interactions similar to that currently recorded by observers.

In 2015-16, the encirclement rate was seven and nine encirclements per 100 net sets for observed and unobserved net-sets, respectively. Using a ratio method or a model based approach to

estimate total fleet interaction and mortality rates, assumes that observed rates are representative of interaction rates across the fleet.

Improved information on population sub-structuring and temporal and spatial movement patterns of common dolphins in South Australian waters may inform the assessment and management of cumulative fisheries impacts. Analyses of existing data of common dolphin samples held by the South Australian Museum would provide information on life history parameters to inform population models.

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