Fisheries

SOUTH AUSTRALIAN RESEARCH & DEVELOPMENT INSTITUTE
PIRSA

Effectiveness of the industry Code of Practice in mitigating operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphis*)

Ward, T. M. Ivey, A. and Carroll, J.

SARDI Publication No. F2010/000726-6
SARDI Research Report Series No. 876

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

November 2015

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

SOUTH AUSTRALIA

Government of South Australia
Primary Industries and Regions SA

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Effectiveness of the industry Code of Practice in mitigating the operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphis*)

Report to PIRSA Fisheries and Aquaculture

T. M. Ward, A. Ivey and J. Carroll

SARDI Publication No. F2010/000726-6
SARDI Research Report Series No. 876

November 2015

This publication may be cited as:
Ward, T. M., Ivey, A. and Carroll, J. (2015). Effectiveness of an industry Code of Practice in mitigating the operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphis*). Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000726-6. SARDI Research Report Series No. 876. 35pp.

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.pir.sa.gov.au/research

DISCLAIMER

The authors warrant that they have taken all reasonable care in producing this report. The report has been through the SARDI internal review process, and has been formally approved for release by the Research Chief, Aquatic Sciences. Although all reasonable efforts have been made to ensure quality, SARDI does not warrant that the information in this report is free from errors or omissions. SARDI does not accept any liability for the contents of this report or for any consequences arising from its use or any reliance placed upon it. The SARDI Report Series is an Administrative Report Series which has not been reviewed outside the department and is not considered peer-reviewed literature. Material presented in these Administrative Reports may later be published in formal peer-reviewed scientific literature.

Printed in Adelaide: November 2015

SARDI Publication No. F2010/000726-6
SARDI Research Report Series No. 876

Author(s): T. M. Ward, A. R. Ivey and J. Carroll

Reviewer(s): L. McLeay and G. Grammer

Approved by: S. Mayfield
Science Leader - Fisheries

Signed: 

Date: 18 November 2015

Distribution: PIRSA Fisheries and Aquaculture, South Australian Sardine Industry Association, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

Circulation: Public Domain

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This report was funded by PIRSA Fisheries and Aquaculture. The efforts of Mr Paul Watson, Executive Officer, South Australian Sardine Industry Association (SASIA) in liaising with SARDI, conducting crew inductions and organising skippers' meetings are gratefully acknowledged. We thank licence holders and their representatives, skippers and crews of the South Australian Sardine Fishery (SASF) for providing observers with access to vessels and for providing logbook data. Observers from SARDI and Protec Marine Pty. Ltd. collected much of the data on which this report is based. Dr Lachlan McLeay, Dr Gretchen Grammer and Dr Stephen Mayfield reviewed a draft of the report. The report was approved for release by Dr Stephen Mayfield (SARDI Aquatic Sciences).

EXECUTIVE SUMMARY

This is the ninth report on the effectiveness of the industry Code of Practice (CoP) in mitigating operational interactions of the South Australian Sardine Fishery (SASF) with the short-beaked common dolphin (*Delphinus delphis*). The report presents observer and logbook data from 1 July 2004 to 30 June 2015; it focuses on 2014-15.

The study describes patterns of observer coverage; compares fishing patterns with and without an observer; compares encirclement and mortality rates recorded by observers and in logbooks when an observer was not present; estimates logbook reporting rates; and assesses the efficacy of the CoP in mitigating interactions with dolphins.

Levels of observer coverage and interaction rates varied among years, months, and vessels. Differences in observer coverage complicated data analysis and interpretation. Future observer coverage should be representative of fishing effort among years, months, and vessels.

In 2014-15, observers monitored 93 of the 872 net-sets recorded in logbooks (10.7% coverage). Observers reported a total of 7 encirclements (23 dolphins) and two mortalities. Logbooks recorded 70 encirclements (195 dolphins) and four mortalities. In 2014-15, sardine $CPUE_{net\text{-}set}$ and $CPUE_{night}$ were lower with an observer present.

Rates of encirclement recorded in 2014-15 by observers and in logbooks when an observer was not present were similar (i.e. ~8 encirclements per 100 net-sets). The industry program to monitor dolphin interactions that was initiated in 2011 has helped to reduce the discrepancy between the numbers of interactions recorded in logbooks and those calculated using observer data.

Simple extrapolation from observer data suggest that 66 encirclements occurred in the fishery in 2014-15, compared to the 70 encirclements recorded in logbooks. This is the first year in which encirclements reported in logbooks exceeded the number calculated from observer data. Estimates of encirclement and mortality obtained from a Generalised Linear Model were similar to those obtained from simple extrapolation from observed interaction rates.

1.0 INTRODUCTION

1.1 Previous research

The study by Hamer *et al.* (2008) documented the successful mitigation of the operational interactions of the South Australian Sardine Fishery (SASF) with the short-beaked common dolphin (*Delphinus delphis*) following the implementation of a Threatened, Endangered and Protected Species (TEPS) Code of Practice (CoP) and the establishment of a TEPS Working Group involving licence holders, skippers, fisheries managers and scientists. The rates of encirclement and mortality calculated from observer data in 2005-06 were reduced by 87% and 97%, respectively, compared to rates calculated in 2004-05, before the introduction of the CoP (Hamer *et al.* 2008). It was estimated that eight mortalities occurred across the entire fleet during the seven-month study period after the CoP was introduced, whereas ~377 dolphins were estimated to have died during the initial seven-month observer program in 2004-05. The reduction in interaction rates was attributed to avoidance methods used to prevent encirclements occurring and release procedures used to reduce the mortality rates of encircled dolphins. Hamer *et al.* (2009a) emphasised the importance of establishing and maintaining effective working relationships between industry and scientists in mitigating fishery interactions with marine mammals.

A study published shortly after Hamer *et al.* (2008) suggested that a high level of genetic differentiation existed between populations of short-beaked common dolphin in South Australia and south-eastern Tasmania and emphasised the need for effective mitigation of the operational interactions of the SASF with this species (Bilgmann *et al.* 2008). Bilgmann *et al.* (2009) noted that although Hamer *et al.* (2008) had demonstrated that the CoP was effective in mitigating the operational interactions of the SASF with the short-beaked common dolphin, the performance of the CoP was only assessed over the relatively short initial period of seven months. It was noted that successful bycatch mitigation programs typically involve longer ongoing observer coverage, expert review and continuous improvement of mitigation practices (Hall 1998; Cox *et al.* 2007). Bilgmann *et al.* (2009) identified the need for continued independent monitoring of the SASF to estimate the magnitude of ongoing interactions and assess the long-term efficacy of the CoP.

1.2 Refined Code of Practice

The refined CoP for the SASF (http://www.sasardines.com.au/environment/) explicitly aims for world's best practice and a process for continuous improvement in mitigating

interactions with TEPS. Each crew member participates in the CoP induction prior to the start of each fishing season. Flowcharts that document the role of each crew member in mitigating interactions with TEPS have been developed and placed in the wheelhouse of each vessel. Before beginning work, every new crew member is formally inducted to the CoP and advised of their specific roles and responsibilities in mitigating interactions with TEPS. Skippers meetings are held every one or two months to discuss the effectiveness of avoidance and release procedures and identify options for improvement of the CoP. The TEPS Working Group, which has been expanded to include a representative of the South Australian Department of Environment, Water and Natural Resources (DEWNR), meets quarterly to consider data summaries for the preceding three months and, if warranted, identify refinements to the CoP or other aspects of the mitigation process. Formal reports on the interaction rates of the SASF with the short-beaked common dolphin are published annually (e.g. Hamer *et al.* 2007; 2009b; Hamer and Ward 2007; Ward *et al.* 2010; 2011a; 2012; 2013; 2014).

In 2004-05, prior to the introduction of the CoP, fishers did not actively search for dolphins prior to fishing or delay setting the net when dolphins were present. The CoP requires that fishers actively search for dolphins before setting the net and delay setting the net when dolphins are observed near the vessel. The implementation of the avoidance procedures listed in the CoP has reduced dolphin encirclement rates in the fishery (e.g. Ward *et al.* 2013).

In 2005-06, after the introduction of the initial CoP, a wide range of procedures were used to release dolphins. For example, specifically-designed weights were used to submerge the corkline and allow dolphins to swim out of the net. Similarly, purpose-built panels of net (TEPS gates) were sometimes opened to allow dolphins to escape. On other occasions, crew members (and at times observers) in small vessels physically removed dolphins from the net. At other times, the front of the net was opened to allow dolphins to exit.

Corkline weights and the TEPS gate are no longer recognised in the refined CoP because they are difficult to deploy and dolphins do not always exit through the relatively small openings provided by these methods. Physical removal is also avoided, in part because of potential risks to crew safety. The release procedure now recommended in the CoP (i.e. opening the front of the net) was chosen because it has been successful in allowing dolphins to escape.

In October 2011, the South Australian Sardine Industry Association (SASIA) initiated industry-based collection of TEPS interaction data. The Executive Officer of SASIA collects copies of fishery logbook sheets from each skipper and collates these data to support the provision of real-time feedback to industry. This improvement has allowed industry to quickly address emerging issues relating to the CoP at the regular skippers meetings.

1.3 Aim and objectives

This is the ninth report on the effectiveness of the industry CoP in mitigating the operational interactions of the South Australian Sardine Fishery (SASF) with short-beaked common dolphin. The report presents observer and logbook data from 1 July 2004 to 30 June 2015; focusing on the period 1 July 2014 to 30 June 2015.

The objectives of the study were to:

1) examine patterns of observer coverage;
2) compare fishing patterns with and without an observer;
3) compare rates of dolphin encirclement and mortality recorded by observers and in fishery logbooks when an observer was not present;
4) compare the number of encirclements and mortalities estimated to have occurred each financial year using observer data with the numbers recorded in logbooks;
5) assess the efficacy of the CoP in mitigating interactions with dolphins.

2.0 METHODS

2.1 Data collection

Data on interactions between fishing operations and TEPS are obtained from the fishery logbook program and observer program.

Logbook program

Fishers are required to complete fishery logbooks that document the date, location and timing of each net-set, weight of each catch and details of interactions with TEPS (e.g. number of dolphins encircled, number of mortalities). The logbook records for each vessel must be submitted to SARDI Aquatic Sciences before the fifteenth day of the following month. Since 2007, fishers have been required to report TEPS interactions on a separate Wildlife Interaction Form which allows the reporting of the shot number when a TEPS interaction occurs. Data from both fishery logbooks and Wildlife Interaction Forms are validated, stored and collated by SARDI Aquatic Sciences.

Observer program

The initial observer program was conducted by SARDI Aquatic Sciences from November 2004 to January 2006. From February 2006 until present, the observer program has been operated by Protec Marine Pty. Ltd. In its first financial year of operation the observer program ran from 14 November 2004 to 6 June 2005 and in its second year from 20 September 2005 to 20 June 2006. From July 2006 onwards the observer program has operated continuously, with the exception of October-December 2009 and October-November 2010 when no observations were made.

Each observer monitored fishing activities from a high, unobstructed vantage point such as the wheelhouse, wheelhouse-roof or bow, depending on the vessel and prevailing weather conditions. The observer searched for dolphins in the illuminated area surrounding the vessel immediately prior to the net being set and within the circumference of the net during the fishing operation.

Data recorded on observer datasheets included the vessel name, meteorological conditions, date, location and timing of each net-set, details regarding the interactions with TEPS (e.g. number of dolphins encircled, number of mortalities), nature and success of avoidance and release procedures used and timing of implementation.

2.2 Integrating observer and logbook data

For data collected between 2004 and 2007, observer records were matched with the corresponding logbook record using licence number and departure date. Matching was validated wherever data were available to do so. From 2008 onwards, logsheet numbers on observer datasheets were used to match observer records with the corresponding fishery logsheet. In all instances where an observer record existed, but no corresponding logbook record was submitted, a dummy logbook record was generated by SARDI Aquatic Sciences using data from the observer record.

2.3 Observer coverage

The level of observer coverage has varied between 2004-05 and 2014-15 (Table 1). In January 2013, PIRSA Fisheries and Aquaculture changed the formal measure of observer coverage from nights to net-sets, because net-sets is considered a better measure of fishing effort. Observers have been requested to distribute coverage as evenly as practicable among vessels, months and regions (Figure 1). To determine whether observer coverage was evenly distributed among these factors, Chi squared tests of the number of net-sets with and without an observer were perfomed for year, vessel, month and region.

2.4 Fishing patterns with and without an observer

Sardine catch-per-unit-effort (CPUE) with and without an observer were evaluated using Generalised Linear Models (GLMs) of catch per net-set ($CPUE_{net\text{-}set}$) and per night ($CPUE_{net\text{-}set}$) in relation to the categorical factors: financial year, month, region, vessel and presence/absence of an observer. Model performance was assessed using Akaike Information Criterion (AIC). The analyses were undertaken using the bestglm R package (McLeod and Xu 2014).

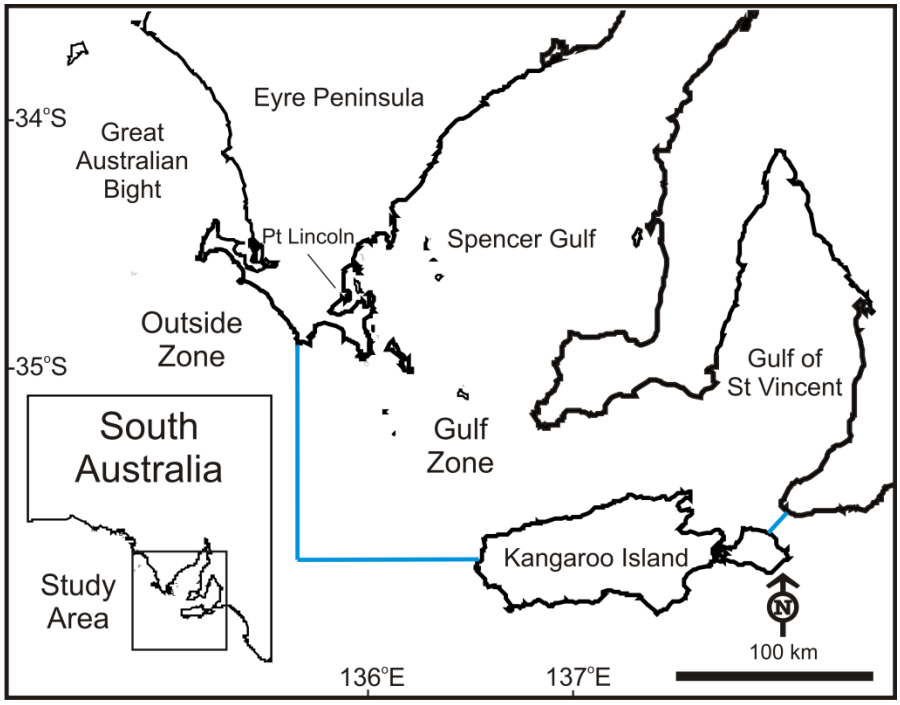


Figure 1. Map showing location of fishery and Gulf and Outside Zones.

2.5 Patterns and rates of encirclement and mortality

Rates of encirclement and mortality were estimated by dividing the number of encirclements and mortalities by the number of net-sets undertaken. Estimates were made separately using data recorded by observers and fishers in logbooks when an observer was not present.

The mean number of dolphins encircled per event and mean number that died (when a mortality event occurred) were also calculated for each year using both observer data and logbook data recorded when an observer was not present.

2.6 Total encirclements and mortalities

The total number of encirclements and mortalities per year was estimated by multiplying the rates of encirclement and mortality calculated from observer data by the total fishing effort (net-sets) for each year.

The total number of encirclements and mortalities per year were also estimated by fitting a Generalised Linear Model (GLM) to the data using the bestglm package (McLeod and Xu 2014; bestglm: Best Subset GLM. R package version 0.34. http://CRAN.R-project.org/package=bestglm). The best fitting GLM (as determined via

comparisons of AIC) was determined by selecting covariates from vessel, financial year, month, region, observer presence, and catch. For both mortalities and encirclements, financial year (F_YEAR) was determined to be a significant covariate ($p < 0.001$). For encirclements, month and catch were additionally significant ($p < 0.001$ and $p < 0.05$, respectively). The GLMs used to predict the total number of fishery-wide encirclements and mortalities were:

1) GLM (MORTALITY ~ F_YEAR + MONTH + CATCH, Family = poisson); and
2) GLM (ENCIRCLEMENTS ~ F_YEAR + REGION + CATCH, Family = poisson).

Standard errors were calculated from the GLM predictions. These predictions produced an estimated value of mortality or encirclements for each record, and these were then summed within a financial year to estimate the total value across the fishery.

2.7 Reporting rates

Reporting rates were calculated for each year by dividing the number of encirclements and mortalities reported in logbooks by the total number of encirclements and mortalities recorded by observers.

2.8 Code of Practice assessment

The avoidance procedures assessed in this report were: i) searching for dolphins prior to setting the net (deemed successful if no dolphins were detected and no encirclement occurred); and ii) delaying the setting of the net (deemed successful if setting was delayed and no dolphins were encircled when the net was subsequently set).

The release methods considered were: (i) no action (where no effort was made to release encircled dolphins); (ii) corkline weights (where weights were used to sink the corkline to provide an opening for dolphin exit/escape); (iii) TEPS gate (panel of net was unclipped from corkline to provide an opening for dolphins to exit/escape); (iv) physical removal (where dolphins were removed from the net by crew members in a skiff); and (v) opening the front of the net or aborting the set. Data recorded on observer datasheets were validated, stored and collated by SARDI Aquatic Sciences. A release procedure was deemed to be successful when all encircled dolphins were released alive.

3.0 RESULTS

3.1 Fishing patterns

Data from fishery logbooks show that total fishing effort within a financial year ranged from 1248 net-sets in 2004-05 to 786 net-sets in 2013-14 (Table 1). In most years, including 2014-15, the highest fishing effort was recorded between January and June (Figure 2). Catch and CPUE were also highest during this period. In some fishing seasons (Appendix 1A) significant effort also occurred in December (2005-06) and July (2009-10). Most fishing was conducted in lower Spencer Gulf (Figure 3). Recent implementation of spatial management in the SASF has resulted in greater fishing effort in waters off the western Eyre Peninsula (Figure 3).

Direct comparisons of observer data and fishery logbooks suggested that during the earlier years of this study some fishers did not always record data for each net-set separately (i.e. catches from several net-sets were sometimes recorded as coming from a single set). For this reason, it is likely that the number of net-sets made annually in the SASF is higher than indicated in Table 1.

Table 1. Number of net-sets, % observer coverage, number of encirclements and mortalities recorded in logbooks and by observers between 2004-05 and 2014-15.

Year	Total Net-sets (Logbooks)	Observed Net-sets (Datasheets)	% Observer Coverage (Target)	Number of Encirclements (total dolphins)		Number of Mortalities	
				Logbook	Observer	Logbook	Observer
2004-05	1248	49	3.9 (5)	24 (61)	18 (87)	7	19
2005-06	1006	86	8.5 (10)	36 (70)	9 (20)	6	1
2006-07	954	82	8.6 (10)	47 (120)	14 (60)	10	7
2007-08	890	189	21.2 (30)	62 (162)	28 (89)	15	11
2008-09	925	233	25.2 (30)	64 (160)	21 (53)	5	5
2009-10	1132	266	23.5 (30)	64 (179)	26 (87)	5	2
2010-11	1047	92	8.8 (10)	40 (126)	11 (39)	7	2
2011-12	1107	70	6.3 (10)	104 (303)	9 (36)	5	1
2012-13	864	84	9.7 (10)	99 (226)	10 (27)	4	1
2013-14	786	80	10.2 (10)	93 (240)	10 (35)	1	0
2014-15	872	93	10.7 (10)	70 (195)	7 (21)	4	2

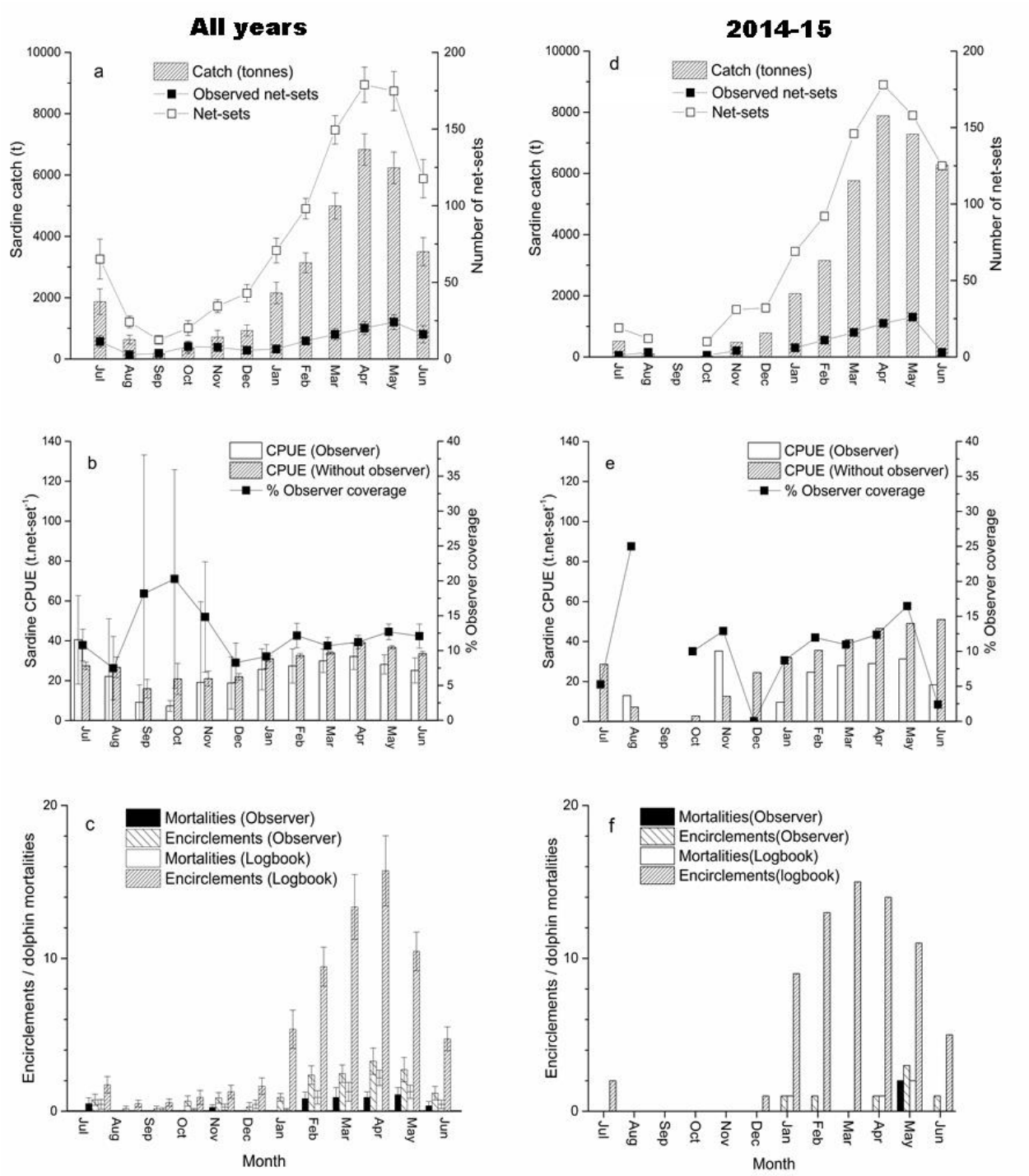


Figure 2. (a) Average sardine catch, observed net-sets and total net-sets by month in the SASF from 2004-05 to 2014-15. Error bars are mean ± SE. **(b)** Sardine CPUE (Observer), sardine CPUE (Logbook) and the percentage of observed net-sets in the SASF from 2004-05 to 2014-15. Error bars are mean ± SE. **(c)** Mean number of encirclements and mortalities by month in the SASF from 2004-05 to 2014-15. Bars are mean ± SE. **(d,e,f)** are respective figures for 2014-15.

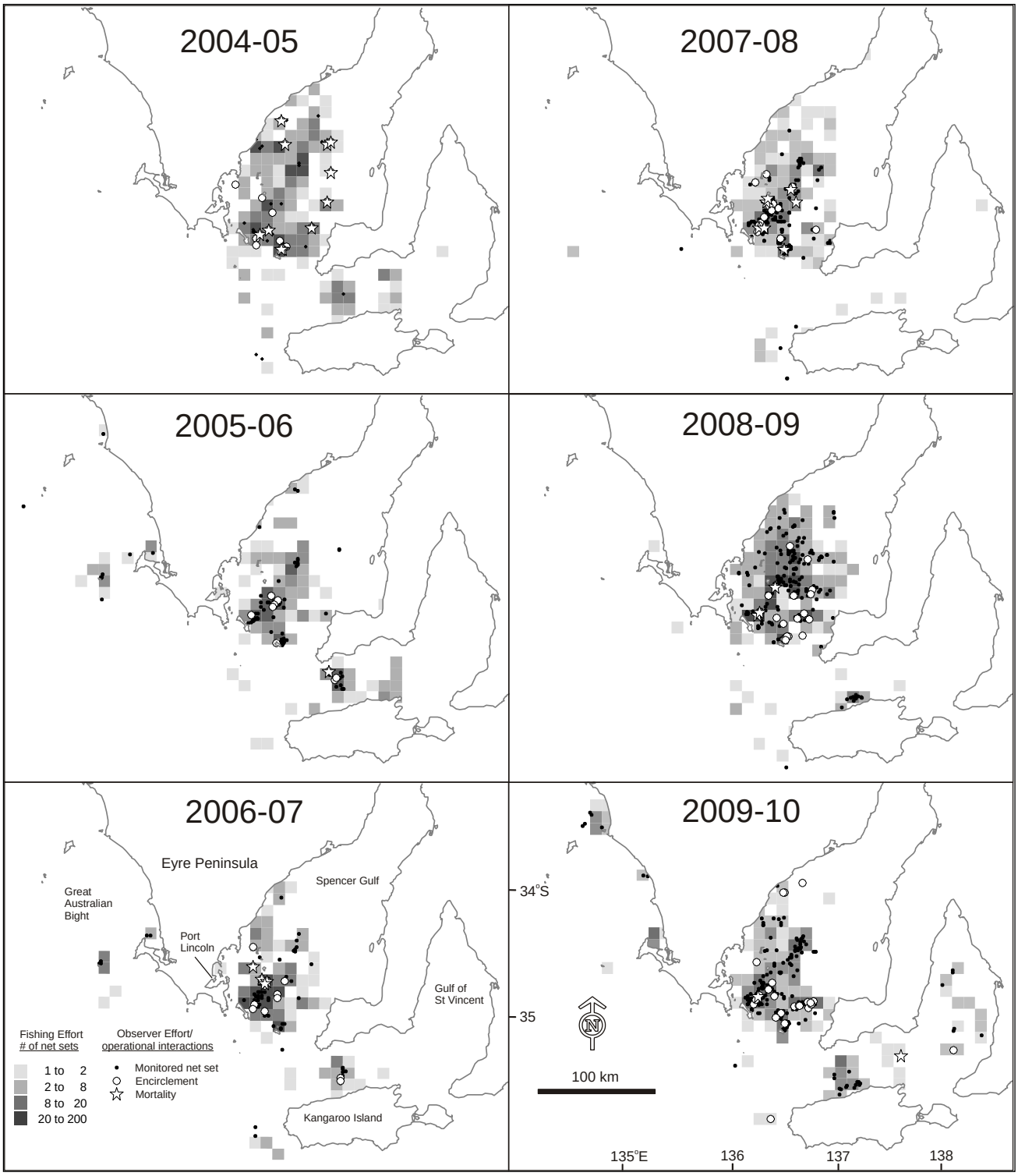


Figure 3. Spatial distribution of fishing effort, and the location of observed net sets, encirclements and mortalities in the SASF from 2004-05 to 2009-10.

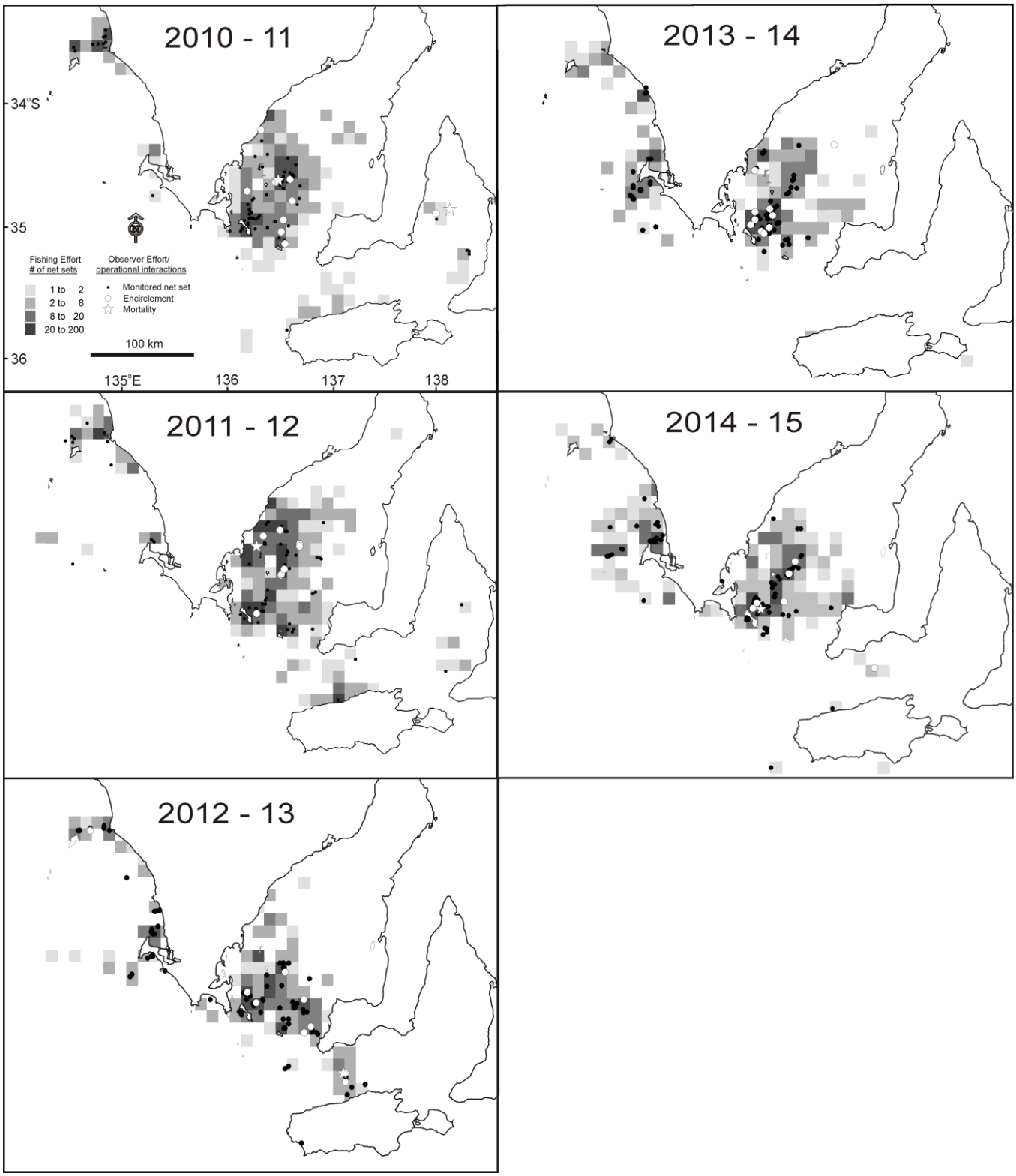


Figure 3 (**continued).** Spatial distribution of fishing effort, location of observed net sets, encirclements and mortalities in the SASF during 2010-11 to 2014-15.

3.2 Observer coverage

Target observer coverage was increased from 5.0% in 2004-05 to 10% in 2005-06 and 2006-07, and to 30% from 2007-08 to 2009-10, before being reduced to 10% from

2010-11 onwards Table 1). Actual observer coverage was consistently below the target level up until 2013-14 when it exceeded the target (10.2%). In 2014-15, observer coverage was 10.7%.

Levels of observer coverage (net-sets) varied among financial years, months, vessels (Table 2). The high level of variation in observer coverage among years reflects the inter-annual changes in target and actual coverage levels (Table 1). The differences in levels of observer coverage among vessels (0-17.0%) and months (7.8-20.3%) complicate comparisons of fishing patterns and interaction rates of vessels with and without an observer.

Table 2. Results of Chi-squared tests for differences in levels of observer coverage of net-sets among financial year, month, region and vessel.

Factor	Number	Cases	Chi squared	p-value
Financial Year	11	10831	473.10	**<0.0001**
Month	12	10831	44.02	**<0.0001**
Region	2	10831	2.72	0.0994
Vessel	22	10831	90.15	**<0.0001**

3.3 Fishing patterns with and without an observer

Sardine $CPUE_{net\text{-}set}$ without an observer ranged from 27.6 to 34.4 t.net-set^{-1} between 2004-05 and 2011-12, increased to 39 t.net-set^{-1} in 2012-13 and was 40.9 t.net-set^{-1} in 2014-15 (Figure 4). Sardine $CPUE_{net\text{-}set}$ with an observer was generally lower than without an observer and this difference was significant in 2005-06, 2008-09, 2013-14 and 2014-15 (Figure 4, Table 3).

Sardine $CPUE_{night}$ without an observer ranged from 31.2 to 36.9 t.night^{-1} between 2004-05 and 2010-11 and increased to 56.1 t.night^{-1} in 2014-15 (Figure 4). Sardine $CPUE_{night}$ with an observer was generally lower than without an observer and this difference was significant in 2008-09, 2010-11, 2011-12 and 2014-15 (Table 4).

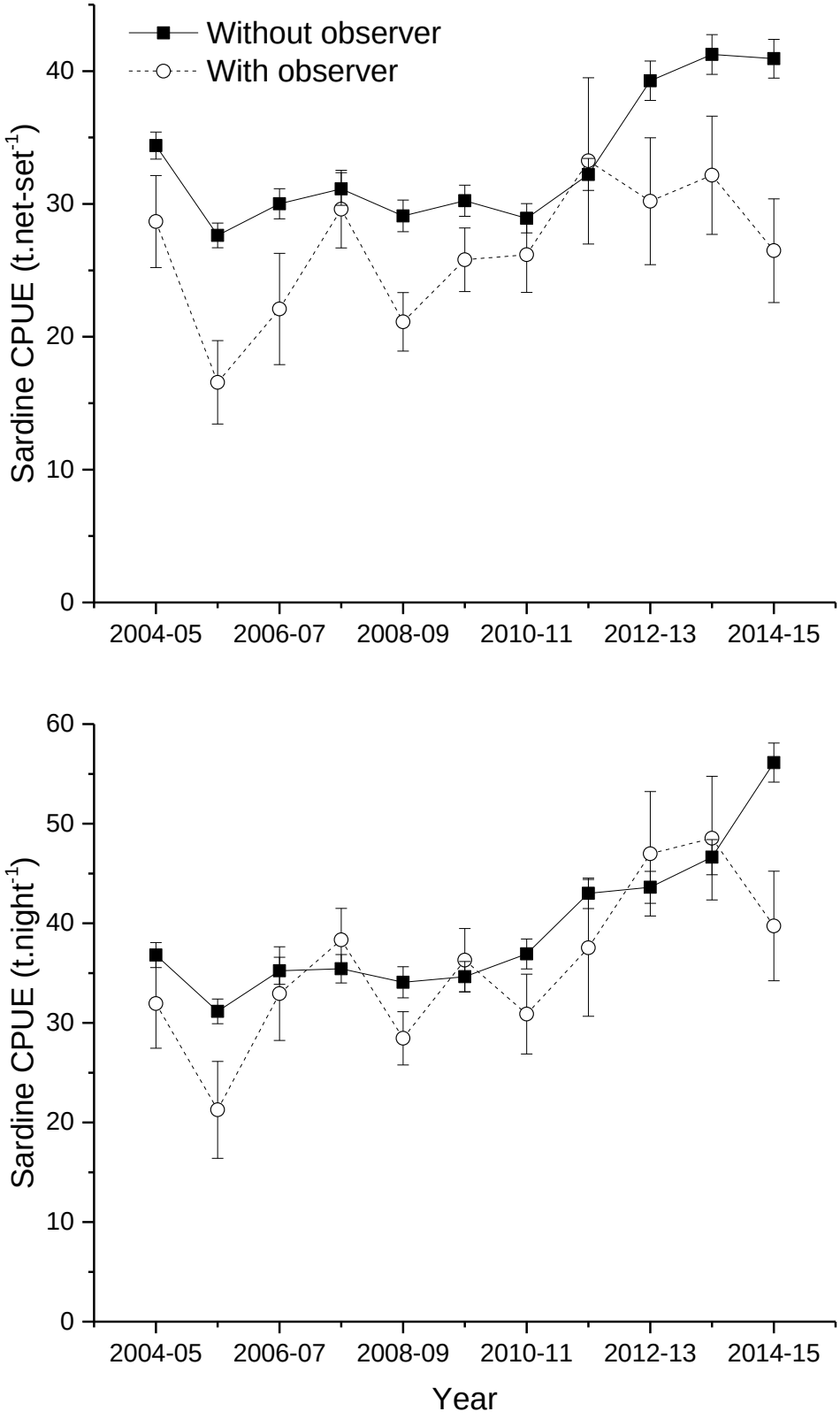


Figure 4. Sardine $CPUE_{net\text{-}set}$ and $CPUE_{night}$ from logbook records with and without an observer between 2004-05 and 2014-15. Error bars ±SE.

Table 3. T-test comparing Sardine $CPUE_{net\text{-}set}$ from logbook records with and without an observer between 2004-05 and 2014-15.

Year	n	t	p
$CPUE_{net\text{-}set}$			
2004-05	1248	-0.7442	0.4602
2005-06	1006	-3.4100	**0.0010**
2006-07	954	-1.7470	0.0841
2007-08	890	-0.1254	0.9003
2008-09	925	-2.4947	**0.0131**
2009-10	1132	-1.8879	0.0598
2010-11	1047	-1.3824	0.1695
2011-12	1107	-0.0474	0.9623
2012-13	860	-1.6969	0.0931
2013-14	790	-3.0113	**0.0032**
2014-15	872	-4.3064	**<0.0001**

Table 4. T-test comparing Sardine $CPUE_{night}$ from logbook records with and without an observer between 2004-05 and 2014-15.

Year	n	t	p
$CPUE_{night}$			
2004-05	975	-1.2353	0.2236
2005-06	691	-1.6000	0.1154
2006-07	696	-1.0938	0.2783
2007-08	667	0.0014	0.9989
2008-09	688	-3.4098	**0.0007**
2009-10	815	-1.2555	0.2103
2010-11	696	-2.9461	**0.0040**
2011-12	704	-2.1571	**0.0345**
2012-13	623	-0.3008	0.7647
2013-14	591	-0.2381	0.8127
2014-15	630	-2.807	**0.0063**

The differences in inter-annual patterns of Sardine $CPUE_{net\text{-}set}$ and $CPUE_{t.night\text{-}1}$ recorded with and without an observer reflect, in part, inter-annual differences in the mean number of net-sets per night with and without an observer (Figure 4, 5).

Significantly more net-sets per night were made with an observer aboard between 2012-13 and 2013-14, and significantly less net-sets were made with an observer aboard in 2010-11 and 2011-12 (Figure 5, Table 5). There was no significant difference in the number of net-sets per night with and without an observer in 2014-15.

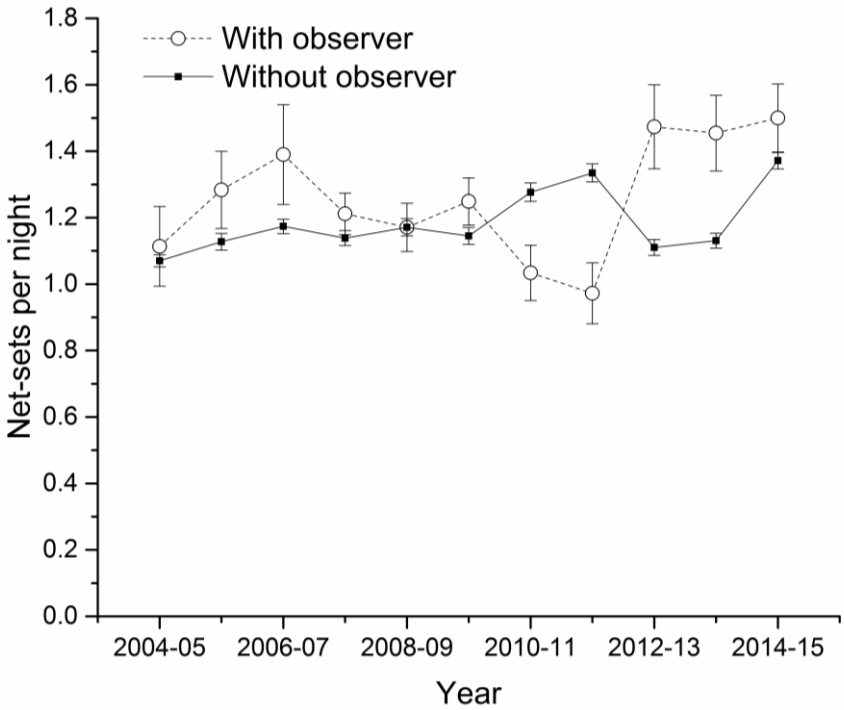


Figure 5. Net-sets per night from logbook records with and without an observer between 2004-05 and 2014-15. Error bars ±SE.

Table 5. T-test comparing fishing effort (net-sets.night^{-1}) from logbook records with and without an observer between 2004-05 and 2014-15.

Year	n	t	p
Effort (net-sets.night^{-1})			
2004-05	975	0.2230	0.8247
2005-06	691	1.8600	0.0685
2006-07	696	1.5910	0.1174
2007-08	667	1.0426	0.2986
2008-09	688	-0.2220	0.8245
2009-10	815	1.1873	0.2363
2010-11	696	-3.1635	**0.0021**
2011-12	704	-4.6170	**<0.0001**
2012-13	623	2.4314	**0.0184**
2013-14	591	2.7893	**0.0074**
2014-15	630	1.2227	0.2256

Sardine $CPUE_{net\text{-}set}$ differed among vessel, financial year, month and observer presence/absence but was not significantly different among regions (Table 6).

Table 6. Best-fit Generalised Linear Model (GLM) of CPUE (t.net-set^{-1}) between 2004-05 and 2014-15 with factors of vessel, observer, financial year and month.

Factor	Df	SS	MS	F	p-value
Vessel	21	2312096	110100	151.94	<0.0001
Observer	1	48862	48862	67.43	<0.0001
Financial Year	10	270284	27028	37.30	<0.0001
Month	11	88301	8027	11.08	<0.0001

Residual standard error: 26.92 on 10787 degrees of freedom, Multiple R-squared: 0.2581, Adjusted R-squared: 0.2552, F-statistic: 87.28 on 43 and 10787 DF, p-value: < 0.0001

Sardine $CPUE_{night}$ differed among vessel, financial year, month, observer presence/absence and regions (Table 7).

Table 7. Best-fit Generalised Linear Model (GLM) of Sardine CPUE (t.night^{-1}) between 2004-05 and 2014-15 with factors of vessel, observer, financial year and month.

Factor	Df	SS	MS	F	p-value
Vessel	21	2148647	102317	146.4	<0.0001
Observer	1	44534	44534	63.72	<0.0001
Financial Year	10	279901	27990	40.05	<0.0001
Month	11	121466	11042	15.8	<0.0001
Region	1	13267	13267	19.0	<0.0001

Residual standard error: 26.44 on 10786 degrees of freedom, Multiple R-squared: 0.257, Adjusted R-squared: 0.254, F-statistic: 84.81 on 44 and 10786 DF, p-value: < 0.0001

Some of the differences in Sardine CPUE with and without an observer are explained by a high level of observer effort in months and on vessels with low CPUE, this was particularly evident in 2005-06 and 2008-09 (Appendix 1B).

3.4 Patterns of encirclement and mortality

Logbook program

The total number of encirclements recorded in fishery logbooks increased from 24 in 2004-05 to 104 in 2011-12, before declining to 70 encirclements in 2014-15 (Table 1). The number of mortalities recorded in logbooks increased from seven dolphins in 2004-05 to 15 dolphins in 2007-08 before decreasing to one dolphin in 2013-14 (Table 1). Four dolphin mortalities were recorded in 2014-15.

Observer program

The number of encirclements that occurred while an observer was aboard declined from 18 in 2004-05 when 49 net-sets were monitored to nine in 2005-06 when 86 net-sets were monitored (Table 1). Observed encirclements were highest in 2007-08, when 28 encirclements were observed from 189 net-sets. Between 2010-11 and 2013-14, the number of observed encirclements ranged from nine to 11 from 70 to 92 net sets (Table 1). In 2014-15, seven encirclements occurred from 93 net-sets.

The number of observed dolphin mortalities declined from 19 in 2004-05 to one in 2005-06, but increased to seven in 2006-07 (Table 1). In 2007-08, 11 mortalities were recorded by observers; this decreased to two in 2009-10 and 2010-11 and one in 2011-12 and 2012-13. No mortalities were observed in 2013-14. Two mortalities from one event were observed in 2014-15; dolphins were entangled outside the net.

3.5 Rates of encirclement and mortality

Logbook rates without an observer

The encirclement rates calculated from logbook data recorded without an observer increased from 1.4 (95% CI = 1-2) encirclements per hundred net-sets in 2004-05 to 6 (5-7) encirclements per hundred net-sets in 2008-09, before decreasing to 3 (2-4) encirclements per hundred net-sets in 2010-11 (Figure 6). The reported encirclement rate then increased to 12 (11-13) encirclements per hundred net-sets in 2013-14 and decreased to 8 (7-9) encirclements per hundred net-sets in 2014-15.

The rate of mortality calculated from logbook data recorded without an observer did not exceed one dolphin per hundred net-sets in any year.

Observed rates

The encirclement rates recorded by observers declined from 37 (95% CI 29-45) encirclements per hundred net-sets in 2004-05 to 10 (5-15) encirclements per hundred

net-sets in 2005-06, but increased to 17 (11-23) encirclements per hundred net-sets in 2006-07 (Figure 6). Between 2007-08 and 2013-14, 9 to 15 encirclements occurred per hundred net-sets. A total of 8 (5-10) encirclements per hundred net-sets occurred in 2014-15.

The observed mortality rates declined from 39 (95% CI 22-55) dolphins per hundred net-sets in 2004-05 to 1 (0-2) dolphin per hundred net-sets in 2005-06 (Figure 6), and increased to 9 (2-16) dolphins per hundred net-sets in 2006-07. Observed mortality rates declined to 6 (3-9) dolphins per hundred net-sets in 2007-08 and were ≤3 dolphins per hundred net-sets between 2007-08 and 2012-13. No dolphin mortalities were observed in 2013-14. The observed mortality rate in 2014-15 was 2 (1-4) dolphins per hundred net-sets.

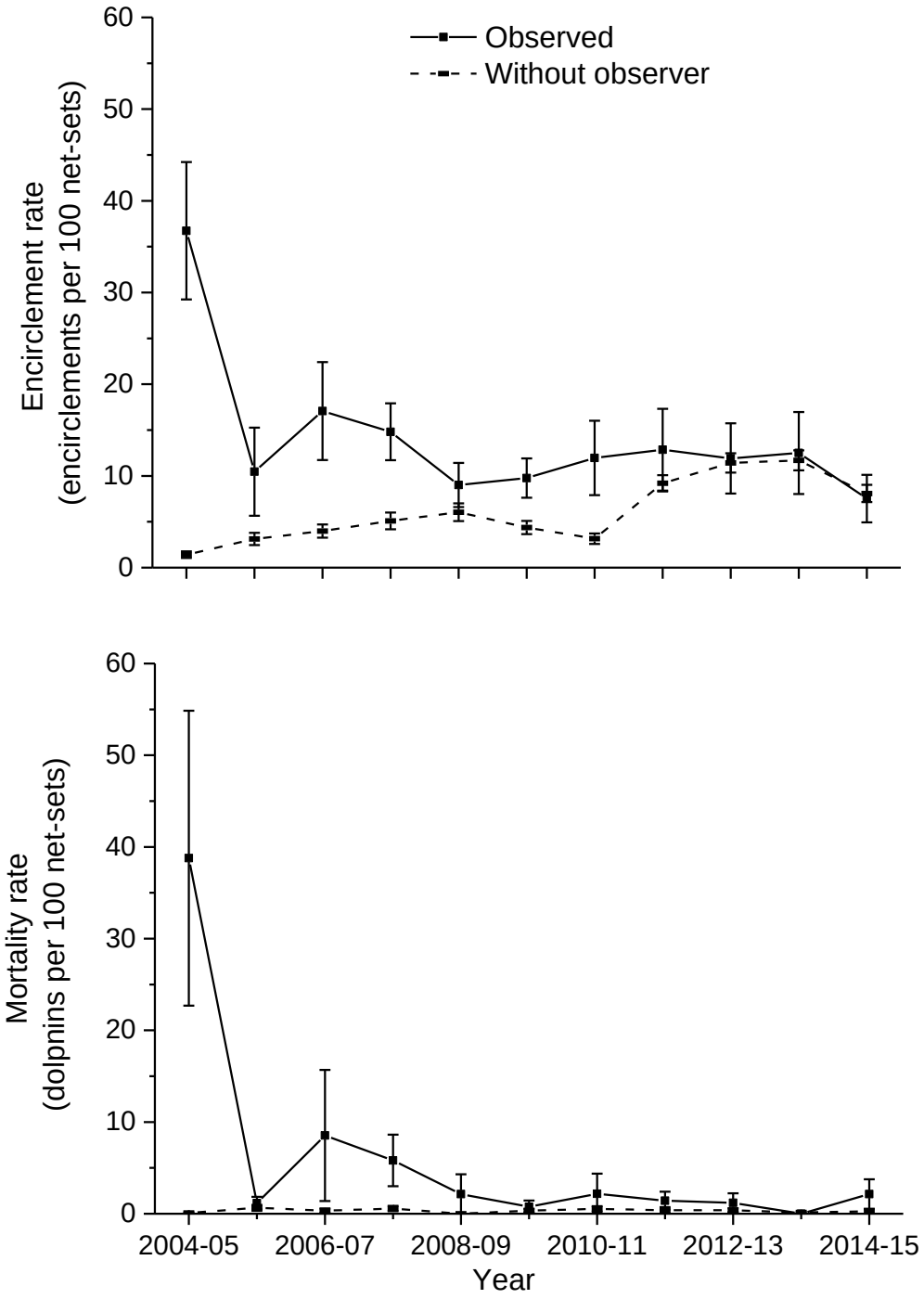


Figure 6. Rates of encirclement and mortality of dolphins between 2004-05 and 2014-15 calculated from observer data, and logbook data collected when no observer was present. Error bars are 95% confidence intervals.

3.6 Mean number of dolphins per encirclement and mortality event

The mean number of encircled dolphins per event recorded by observers was relatively stable, ranging from five in 2004-05 to two in 2005-06 (Figure 7). The mean number of dolphins that died when a mortality event occurred when an observer was present declined from two in 2004-05 to one during 2009-10 to 2012-13. No mortalities were observed in 2013-14. Two mortalities occurred in a single event in 2014-15.

The mean number of dolphins encircled per event calculated from logbook data recorded when no observer was present was generally lower than the number recorded by observers ranging from one in 2004-05 to three in 2010-11, and was two in 2013-14 (Figure 7). The mean number of dolphin mortalities per event reported in logbooks when no observer was present increased from one in 2004-05 and 2005-06 to three in 2006-07 and declined and remained stable at one in 2012-13 to 2014-15.

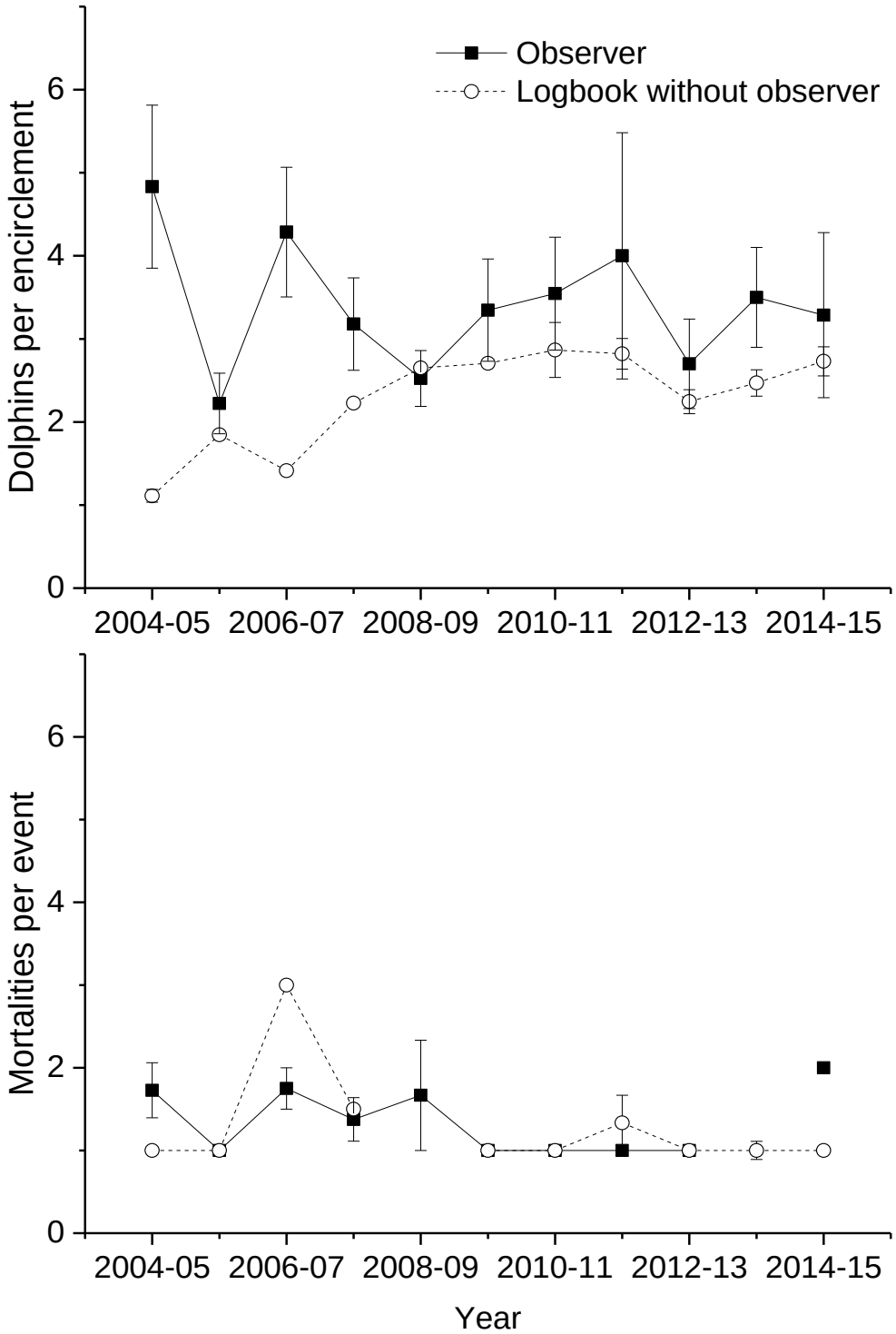


Figure 7. Mean number of dolphins encircled per encirclement event and mean number of dolphin mortalities per mortality event between 2004-05 and 2014-15 with and without an observer. Error bars are standard errors.

3.7 Total encirclements and mortalities

Simple extrapolation from the observer data suggests that in 2004-05, before the CoP was introduced, a total of 458 encirclements occurred in the fishery (Figure 8). This number decreased to 105 encirclements in 2005-06, increased to 163 in 2006-07 before decreasing to 66 in 2014-15. Use of a GLM to predict total encirclements produced similar estimates (Figure 8).

Extrapolation from observer data suggests that 484 dolphin mortalities occurred in 2004-05 (Figure 8). This declined to 12 dolphins in 2005-06 before increasing to 81 dolphins in 2006-07 and 52 dolphins in 2007-08. Estimates of total mortality did not exceed 23 dolphins per year from 2008-09 onwards. Simple extrapolation and the GLM suggested total mortalities of 19 and 15 dolphins, respectively, in 2014-15.

3.8 Reporting rates

The discrepancy between the number of encirclements calculated from observer data and recorded in logbooks has reduced over time (Figure 8). In 2004-05, only 24 encirclements were reported in logbooks, ~5% of the number estimated from observer data (458). In 2014-15, 70 encirclements were reported in logbooks and 66 and 60 estimated from observer data by simple extrapolation and the GLM, respectively.

The discrepancy between the number of dolphin mortalities calculated from observer data and those recorded in logbooks has reduced over time (Figure 8). In 2004-05, seven mortalities were reported in logbooks, which was less than 2% of the estimate from observer data (484). The number of mortalities reported in logbooks increased to reach a maximum of 15 in 2007-08, which equated to ~29% of the number estimated from observer data (52). Mortalities reported in logbooks fell to four in 2012-13, 40% of the estimated number of mortalities (10), and to one in 2013-14 when no mortalities were observed. In 2014-15 four mortalities were reported in logbooks, which is 22% of the number of mortalities estimated from observer data (19).

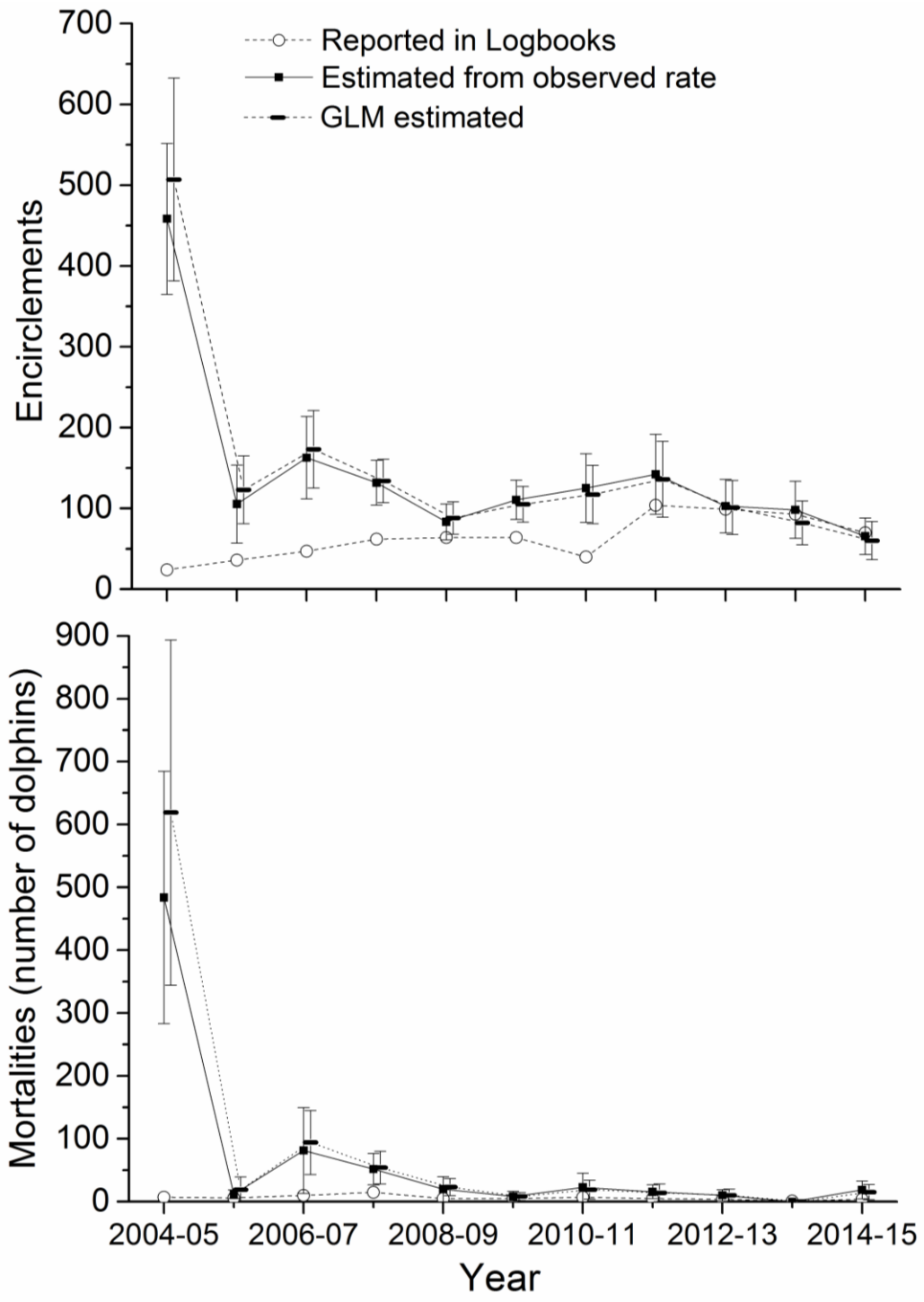


Figure 8. Numbers of encirclements and mortalities each financial year based on rates determined from observed rates and total fishing effort, GLM prediction and the total numbers reported in logbooks.

3.9 Code of Practice assessment

In 2004-05, prior to the implementation of the CoP, fishers did not search for dolphins prior to setting the net (Table 8). However, following the introduction of the CoP, searching was undertaken routinely prior to setting the net on all vessels. Searches were highly effective in detecting the presence of dolphins. Dolphins were not encircled in >85% of net-sets made after searching had determined that dolphins were not present in the fishing area. Delaying the setting of the net when a search had identified the presence of dolphins in the fishing area was 50-100% effective in preventing the encirclement of dolphins in the following shot.

Table 8. Success rates of avoidance procedures identified in the CoP in preventing the encirclement of dolphins in the SASF during 2004-05 to 2014-15. The CoP was introduced in 2005-06.

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

Prior to the implementation of the CoP in 2005-06, fishers often did not take any action to release dolphins. Encircled dolphins were released alive only 16% of the time when no action was taken (Table 9). Before the implementation of the CoP and up to 2007-08 several release procedures were often used with varying success (43-100%). During this period, the front of the net was often only opened and/or the shot aborted after several other release procedures had been tried, which may have reduced the effectiveness of opening the net. In recent years, the use of corkline weights and the TEPS gate have been removed as release options from the CoP. Opening the front of the net or aborting the shot has emerged as the most reliable and successful release

procedure. Since 2008-09, the success rate of opening the front of the net and/or the aborting the shot has ranged from 86% to 100%.

Table 9. Success rates of the procedures identified in the industry CoP for releasing encircled dolphins during 2004-05 to 2014-15. The CoP was introduced in 2005-06. Note that multiple release procedures were sometimes implemented for a single encirclement. A release procedure was deemed unsuccessful if a single mortality occurred.

	Release Procedures No. (% success)				
	No action	Corkline Weights	TEPS Gate	Physical removal	Open front of net or abort shot
2004-05	32 (16)	8 (53)	2 (50)	18 (89)	5 (60)
2005-06	0	4 (50)	7 (43)	3 (100)	6 (83)
2006-07	0	0	4 (100)	2 (100)	12 (67)
2007-08	0	0	2 (100)	6 (67)	21 (71)
2008-09	0	0	1 (0)	5 (80)	12 (92)
2009-10	0	0	0	0	20 (95)
2010-11	1 (100)	0	0	4 (50)	7 (100)
2011-12	1 (100)	0	0	0	7 (100)
2012-13	0	0	0	3 (67)	7 (86)
2013-14	2 (100)	0	0	0	8 (100)
2014-15	0	0	0	3 (67)	7 (100)

The decline in the number of mortalities observed mainly reflected the increase in the percentage of encircled dolphins that were released successfully, which increased from 78% in 2004-05 to 95% in 2005-06, before decreasing to 88% in 2006-07 and then increasing steadily to reach 100% in 2013-14 (Figure 9). In 2014-15, 91.3% dolphins encountered were released successfully when an observer was present. The pattern of release success recorded in logbooks followed a similar pattern to that recorded by observers.

The two mortalities observed in 2014-15 occurred when dolphins became entangled outside the net. These dolphins were physically removed from the net but did not survive. Two dolphins encircled during the same net-set were released successfully.

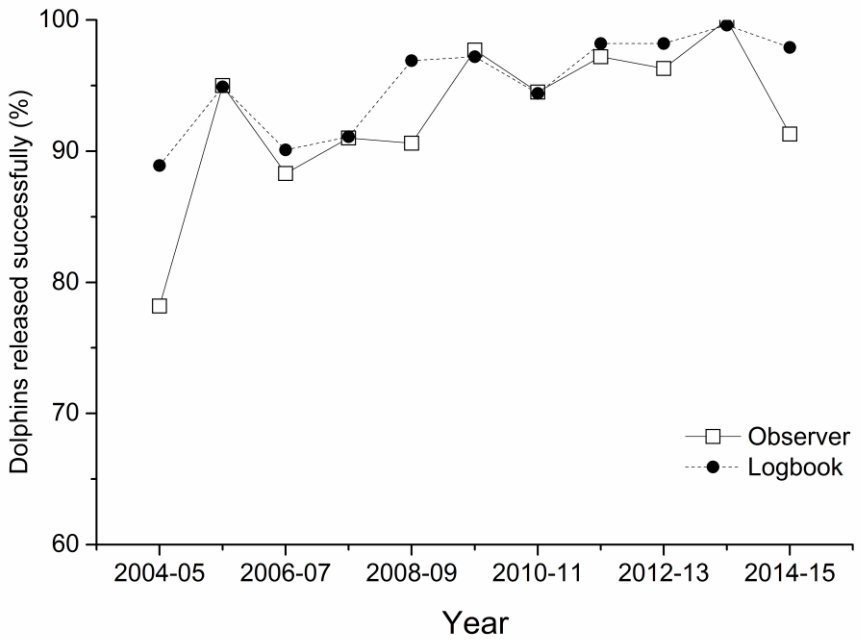


Figure 9. Percentage of dolphins that were successfully released in the SASF from 2004-05 to 2014-15 based on data from observer records and fishery logbooks.

4.0 DISCUSSION

Observer coverage has been altered over time to reflect variations in the observed interaction rates and discrepancies with data reported in logbooks. Differences between target and actual levels of observer coverage have reduced over the study period. Actual coverage exceeded the target level for the first time in 2013-14 and continued in 2014-15. Observer coverage varied among years and has not reflected differences in fishing effort among vessels and months. For example, in 2014-15 observer coverage fluctuated between ~0% in October and 25% in August. This non-representative sampling complicated analysis and interpretation of data. There is a need to ensure that future observer coverage achieves target levels and is stratified to ensure it is representative of different levels of fishing effort among these factors.

Differences in both measures of Sardine CPUE with and without an observer are complex and difficult to interpret, in part because of the uneven observer coverage among vessels, months and regions. For example, in several years there were high levels of observer coverage on small vessels with low catching and holding capacity during months where catch rates were low (e.g. October), which contributed to the low mean Sardine CPUE with an observer present. However, unrepresentative observer coverage does not explain the overall reductions in Sardine CPUE with an observer present. There was no year in which either measure of mean Sardine CPUE was significantly higher with an observer present than without. In 2014-15, both $CPUE_{t.netset}$ and $CPUE_{t.night}$ were significantly lower when an observer was aboard. The level to which observed fisher behaviour reflects fishing activities without an observer present is unknown.

The number of net-sets undertaken per night with and without an observer aboard was similar in 2014-15. This finding represents a change from 2012-13 and 2013-14 when the number of net-sets undertaken per night was higher when an observer was aboard. These were the first two years after the measure of observer coverage was changed from fishing nights to net-sets.

Encirclement rates with an observer present fell to ~8 encirclements per hundred net-sets in 2014-15 with a similar rate of encirclement recorded in logbooks. In 2014-15, the two observed dolphin mortalities occurred in a single event where dolphins became entangled outside the net. Two additional single dolphin mortality events were reported in logbooks. Overall results for 2014-15 demonstrate a further reduction in the rates of encirclement and a reduction in the previous discrepancy between encirclements rates

reported in logbooks and by observers. The reduction in this discrepancy has occurred since industry established a program to monitor the interaction rates of individual vessels in “real time”. This program included identifying vessels where interaction rates recorded without an observer were consistently lower than those recorded with an observer present.

The convergence of observed interaction rates and those recorded in logbooks without an observer present is reflected in the estimates of total encirclements and reporting rates. Simple extrapolation from observed interaction rates and total fishing effort suggest that in 2014-15, 66 encirclements would have occurred in the fishery, compared to the 70 encirclements recorded in logbooks. Estimates of encirclements obtained using the GLM were similar to those obtained by a simple extrapolation. This is the first year in which the reported number of encirclements exceeded the number estimated from observer rates.

Since the introduction of the CoP, there has been a large reduction in the encirclement rates and an increase in the proportion of encircled dolphins released successfully. The reduction in encirclement rates reflects the success of the avoidance procedures. Before the CoP was introduced, fishers did not search for dolphins prior to setting the net or delay setting the net when dolphins were observed near the vessel. However, these practices have been increasingly adopted in the fishery over the last nine years and are now standard operating procedures documented in the vessel-specific flowcharts for each vessel. The adoption of “opening the front of the net” as the agreed response to encirclements has been particularly important in improving the proportion of successful releases.

5.0 REFERENCES

Bilgmann, K., Möller, L.M., Harcourt, R.G., Gales, R. and Beheregaray, L.B. (2008). Common dolphins subject to fisheries impacts in Southern Australia are genetically differentiated: implications for conservation. *Animal Conservation* **11**, 518-528.

Bilgmann, K., Möller, L.M., Harcourt, R.G., Gales, R. and Beheregaray, L.B. (2009). Reply to 'Clarifying the interpretation of Hamer *et al.* (2008) by Bilgmann *et al.* (2008)'. *Animal Conservation* 1-2.

Cox, T. A., Lewison, R.L. Zydelis, R., Crowder, L.B., Safina, C. and Read, A.J.(2009). Comparing effectiveness of experimental and implemented bycatch reduction measures: The ideal and the real. *Conservation Biology* **21**:1155-1164.

Efron, B. and Tibshirani, R.J. (1993). An Introduction to the Bootstrap. New York, Chapman and Hall, Inc.

Hall, M. A. (1998). An ecological view of the tuna-dolphin problem: impacts and trade-offs. Reviews in Fish *Biology and Fisheries* **8**:1-34.

Hamer, D.J., Ward, T.M., Goldsworthy, S.D., McGarvey, R. and Rogers, P.J. (2007). Measurement, management and mitigation of operational interactions between common dolphins and the South Australian Sardine Fishery. SARDI Aquatic Science Publication No. F2006/000212. SARDI Research Report Series No. 174. 38pp.

Hamer, D.J. and Ward, T.M. (2007). Operational interactions between the South Australian Sardine Fishery and Common Dolphins in 2006/07: assessing the effectiveness of the industry Code of Practice. SARDI Aquatic Science Publication No. F2007/00198-1. SARDI Research Report Series No. 252. 30pp.

Hamer, D.J., Ward, T.M. and McGarvey, R. (2008). Measurement, management and mitigation of operational interactions between the South Australian Sardine

Fishery and short-beaked common dolphins (*Delphinus delphis*) *Biological Conservation* **141**, 2865-2878

Hamer, D.J., Ward, T.M. and McGarvey, R. (2009a). Objective reporting of scientific results is critical for maintaining relationships with industry and achieving conservation outcomes for fisheries. *Animal Conservation* **12,** 287-288.

Hamer, D.J., Ivey, A. and Ward, T.M. (2009b). Operational interactions of the South Australian Sardine Fishery with the Common Dolphin: November 2004 to March 2009. SARDI Aquatic Science Publication No. F2007/001098-2. SARDI Research Report Series No. 354. 32pp.

Kutner, M.H, Nachtsheim, C.J., Neter, J. and Li, W. (2005). Applied linear statistical models. Fifth edition. Singapore, McGraw Hill.

McCullagh, P. and Nelder, J.A. (1983). Generalized Linear Models. USA, Chapman and Hall.

McLeod, A.I. and Changjiang Xu (2014). bestglm: Best Subset GLM. R package version 0.34. http://CRAN.R-project.org/package=bestglm].

SASIA (2009). Code of practice for mitigation of interactions of the South Australian Sardine Fishery with threatened, endangered and protected species. South Australian Sardine Industry Association (SASIA). January 2009. Port Lincoln. 12pp.

Shanks, S. (2005). Management Plan for the South Australian Pilchard Fishery. Fisheries Division, Primary Industries and Resources South Australia, South Australian Government. Paper Mo. 47. South Australian Fisheries Management Series. 54pp.

Venables, W. N. and Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth edition. Springer.

Ward, T.M., Ivey, A.R. and Burch, P. (2010). Effectiveness of an Industry Code of Practice in mitigating the operational interactions of the South Australian

Sardine Fishery with the short-beaked common dolphin (*Delphinus delphinus*). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000726-1. SARDI Research Report Series No. 439. 38pp. 101.

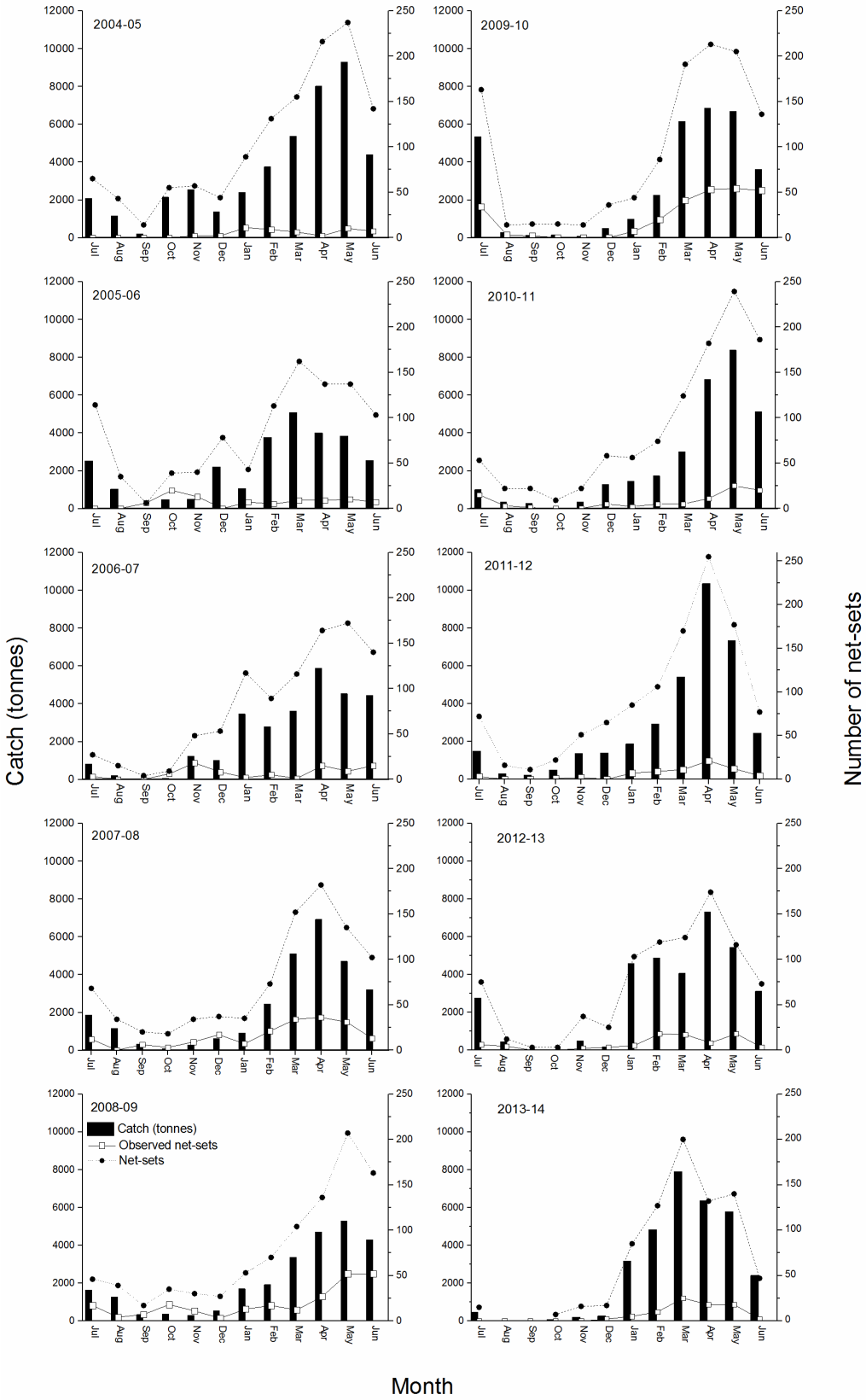
Ward, T.M., Ivey, A., Hamer, D.J. and Burch, P (2011). Effectiveness of an industry Code of Practice in mitigating the operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphis*). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000726-2. SARDI Research Report Series No. 583. 32pp.

Ward, T.M., Ivey, A.R. and Burch, P. (2011a). Spawning Biomass of sardine, *Sardinops sagax,* in watern off South Australia in 2011. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000566-4. SARDI Research Report Series No. 584. 31pp.

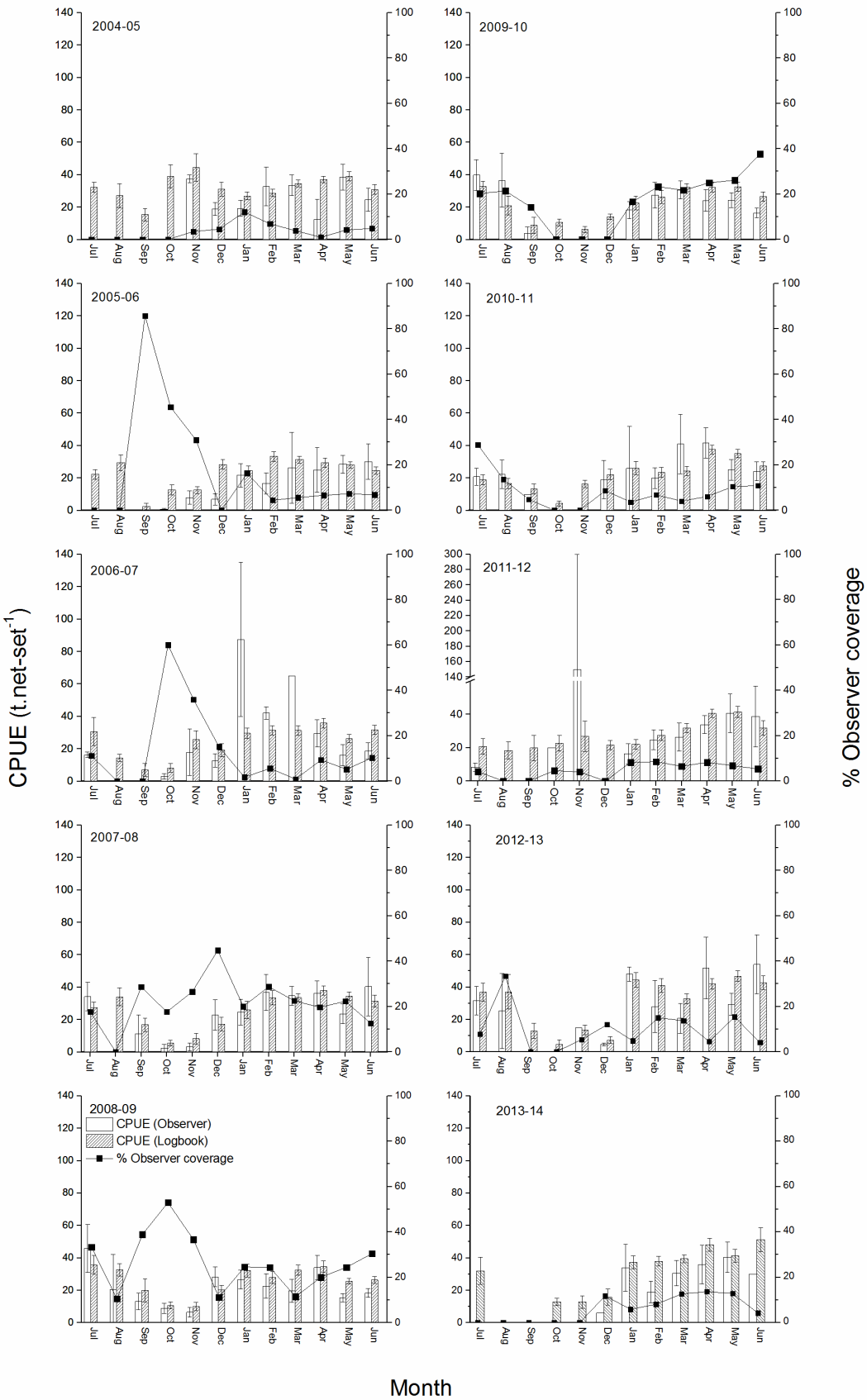
Ward, T.M., Ivey, A.R. and Burch, P. (2012). Effectiveness of an Industry Code of Practice in mitigating the operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphinus*). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000726-3. SARDI Research Report Series No. 666. 27pp.

Ward, T.M., Ivey, A.R. and Burch, P. (2013). Effectiveness of an Industry Code of Practice in mitigating the operational interactions of the South Australian Sardine Fishery with the short-beaked common dolphin (*Delphinus delphinus*). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000726-4. SARDI Research Report Series No. 743. 32pp.

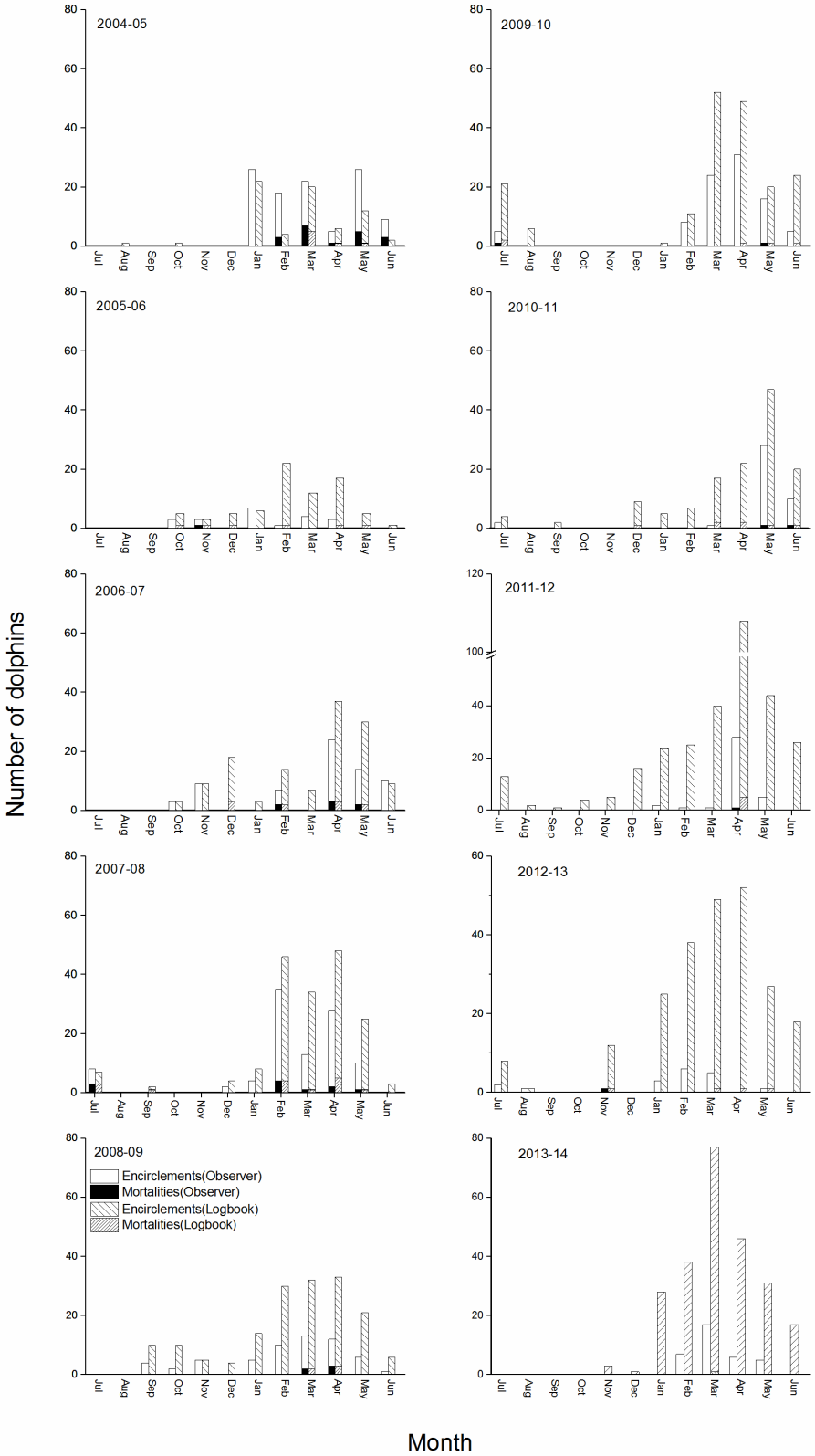
APPENDIX 1



Appendix 1A. Catch, observed net-sets and total net-sets in the SASF from 2004-05 to 2013-14.



Appendix 1B. Sardine CPUE (Observer), sardine CPUE (Logbook) and percentage of observed net-sets in the SASF from 2004-05 to 2013-14.



Appendix 1C. Number of encirclements and mortalities in the SASF from 2004-05 to 2013-14.