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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., Burnell, O. and Carroll, J.

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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

February 2015

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

Government of South Australia
Primary Industries and Regions SA

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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EXECUTIVE SUMMARY

This is the eighth 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*). It presents observer and logbook data from 1 July 2004 to 30 June 2014 and focuses on 2013-14.

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.

Levels of observer coverage and interaction rates varied among years, months, vessels and regions. These differences complicated data analysis and interpretation.

In 2013-14, observers monitored 80 of the 786 net-sets undertaken in the SASF (10.2% coverage). Observers reported a total of 10 encirclements (35 dolphins) and no mortalities. Logbooks recorded 93 encirclements (240 dolphins) and one mortality.

Rates of encirclement recorded in 2013-14 by observers and in logbooks when an observer was not present were similar (i.e. ~13 and ~12 encirclements per 100 net-sets, respectively).

Extrapolation from observed interaction rates and total fishing effort suggest that 98 encirclements would have occurred in the fishery, compared to the 93 encirclements recorded in logbooks. This corresponds to a logbook reporting rate of 95%.

Findings of this report reaffirm the success of the CoP in reducing rates of encirclement and mortality of dolphins in the SASF. 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.

Total interaction levels reported in logbooks and extrapolated from observed rates need to be treated with caution because existing data cannot be used to evaluate how well the CoP is implemented in the absence of an observer. Future observer coverage should be representative of fishing effort by month, vessel and region. Total encirclements should be re-estimated using statistical methods that account for variability in levels of observer coverage and interaction rates. A review of the format of both fishery logbooks and observer datasheets is needed to ensure that these datasets can be matched efficiently and effectively.

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 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). It was noted by Bilgmann *et al.* (2009) 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 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, each 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, Hamer and Ward 2007, Hamer *et al.* 2009b, Ward *et al.* 2010, 2011a, 2012, 2013).

In 2004-05, before the introduction of the CoP, fishers did not actively search for dolphins prior to fishing or delay setting the net when dolphins were present. However, after the introduction of the CoP, fishers consistently search for dolphins before setting the net and delay setting when dolphins are observed near the vessel. The success of these avoidance procedures is reflected in the reductions in dolphin encirclement rates since the introduction of the CoP (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/escape.

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 and does not have negative implications for crew safety.

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 trends at the regular skippers meetings.

1.3 Aim and objectives

This is the eighth 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 (*Delphinus delphis*). The report presents observer and logbook data from 1 July 2004 to 30 June 2014. However, the focus of the report is on the period 1 July 2013 to 30 June 2014.

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. Prior to July 2007, the fishery logbook did not include reporting of the individual shot number where TEPS interactions occurred, so interactions are only available by trip. 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 the 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 the repeated fields licence number and departure date. 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. Various fields (e.g. vessel, data location) were used to validate matches of logbook and observer data. Validation of the matching was performed wherever data were available to do so.

2.3 Observer coverage

The level of observer coverage has varied between 2004-05 and 2013-14 (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 a better measure of fishing effort. Observers have been requested to distribute effort 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 undertaken 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 Generalized Linear Models (GLMs) of catch per net-set in relation to the categorical factors: financial year, month, region, vessel and presence/absence of an observer. The performance of various models was assessed using Akaike Information Criterion (AIC). This process was formalised for sardine $CPUE_{net\text{-}set}$ using the bestglm R package (McLeod and Xu 2014).

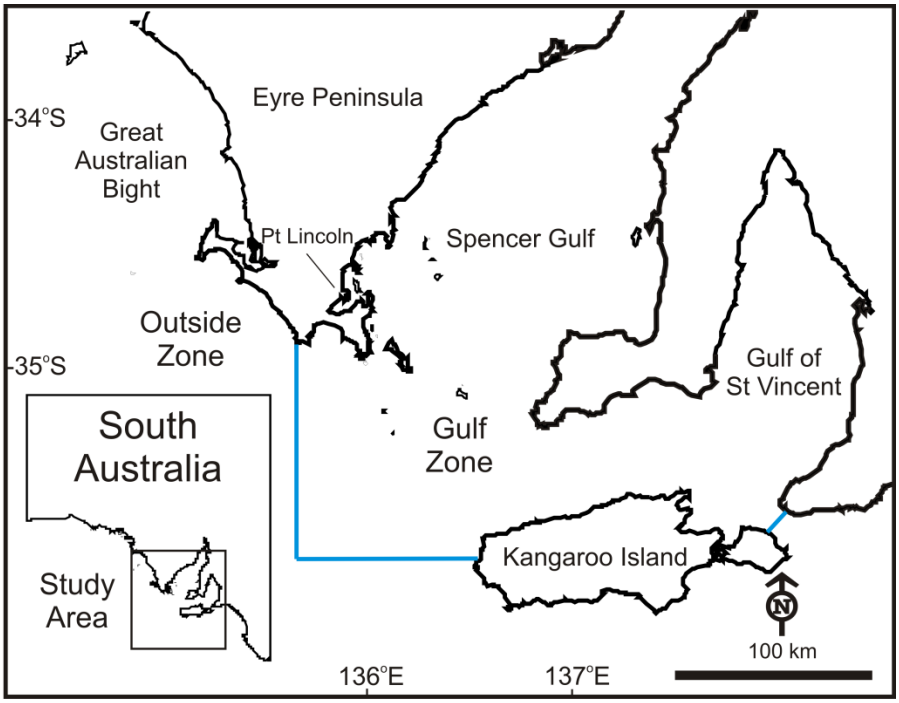

Figure 1. Map showing location of fishery and Gulfs and Outside Zones.

2.5 Patterns and rates of encirclement and mortality

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

The mean number of dolphins encircled per event and the 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 encirclement 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. Confidence intervals for these extrapolations were obtained using a Poisson approximation to the Normal distribution

$$\lambda \pm 2\sqrt{\lambda}$$

Where, λ is the rate encirclement or mortality rate estimated from observer data.

2.7 Reporting rates

Reporting rates were calculated by dividing the number of encirclements and mortalities reported in logbooks each year by the total number of encirclements and mortalities estimated for that year from the observer data.

2.8 Code of Practice assessment

The avoidance procedures used were 1) searching for dolphins prior to setting the net (deemed successful if no dolphins were detected and no encirclement occurred) and 2) 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 in the report are: (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, 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 in 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 2013-14.

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

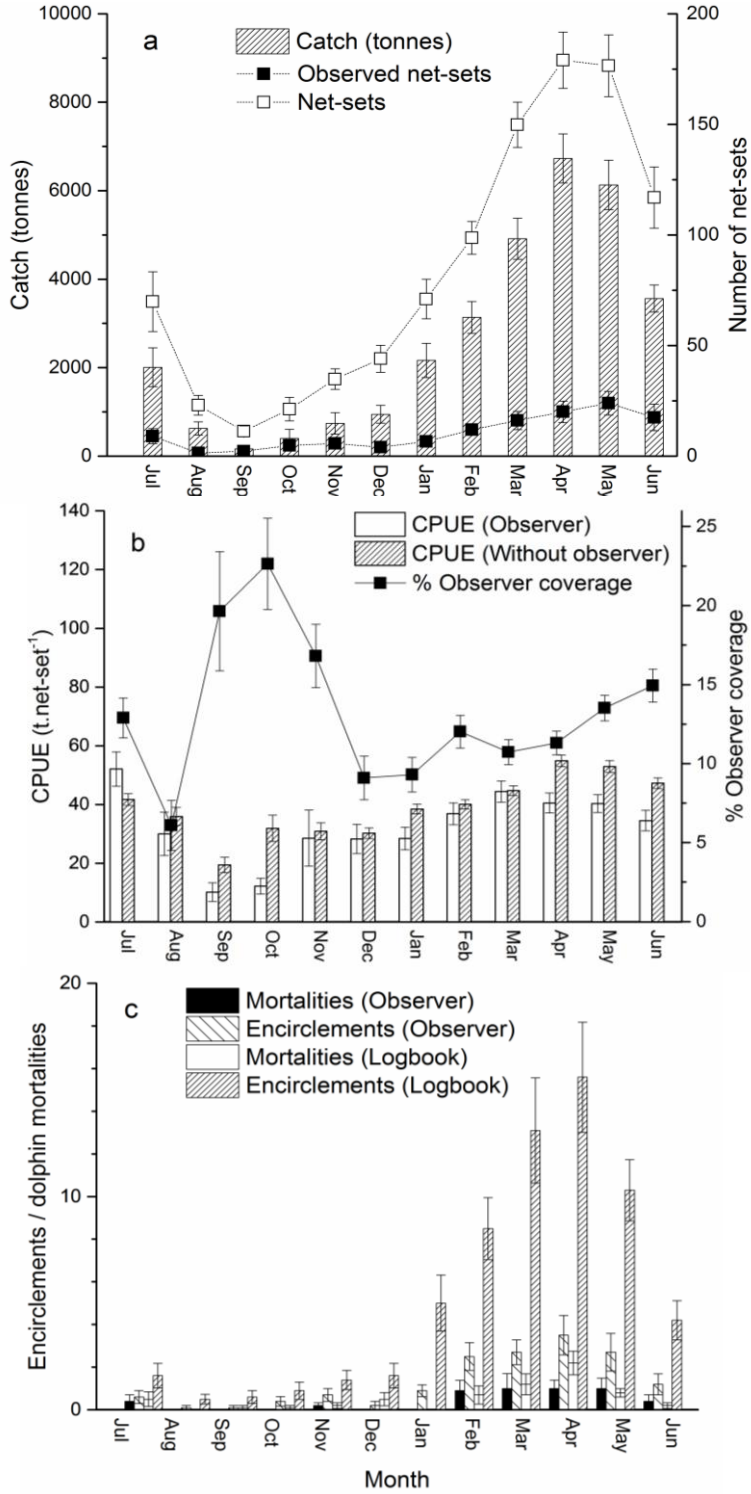

Figure 2. (a) Average sardine catch, observed net-sets and total net-sets by month in the SASF from 2004-05 to 2013-14. Error bars are mean ± SE. **(b)** Sardine CPUE (Observer), sardine CPUE (Logbook) and the percentage of observed net-sets in the South Australian Sardine Fishery from 2004-05 to 2013-14. Error bars are mean ± SE. **(c)** Number of encirclements and mortalities by month in the SASF from 2004-05 to 2013-14. Bars are mean ± SE.

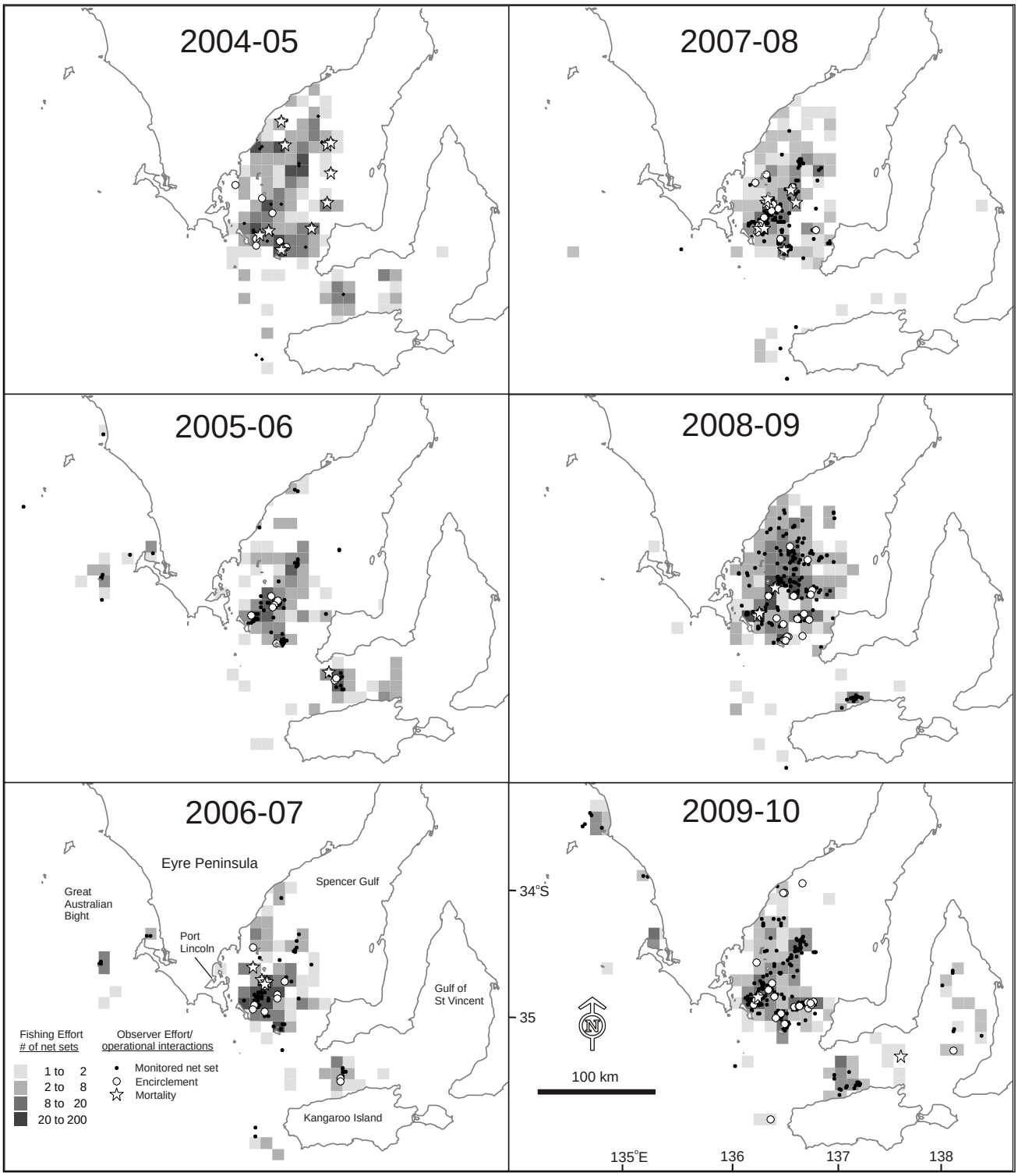

Figure 3. Spatial distribution of fishing effort, location of observed net-sets, encirclements and mortalities in the SASF during 2004-05 to 2009-10.

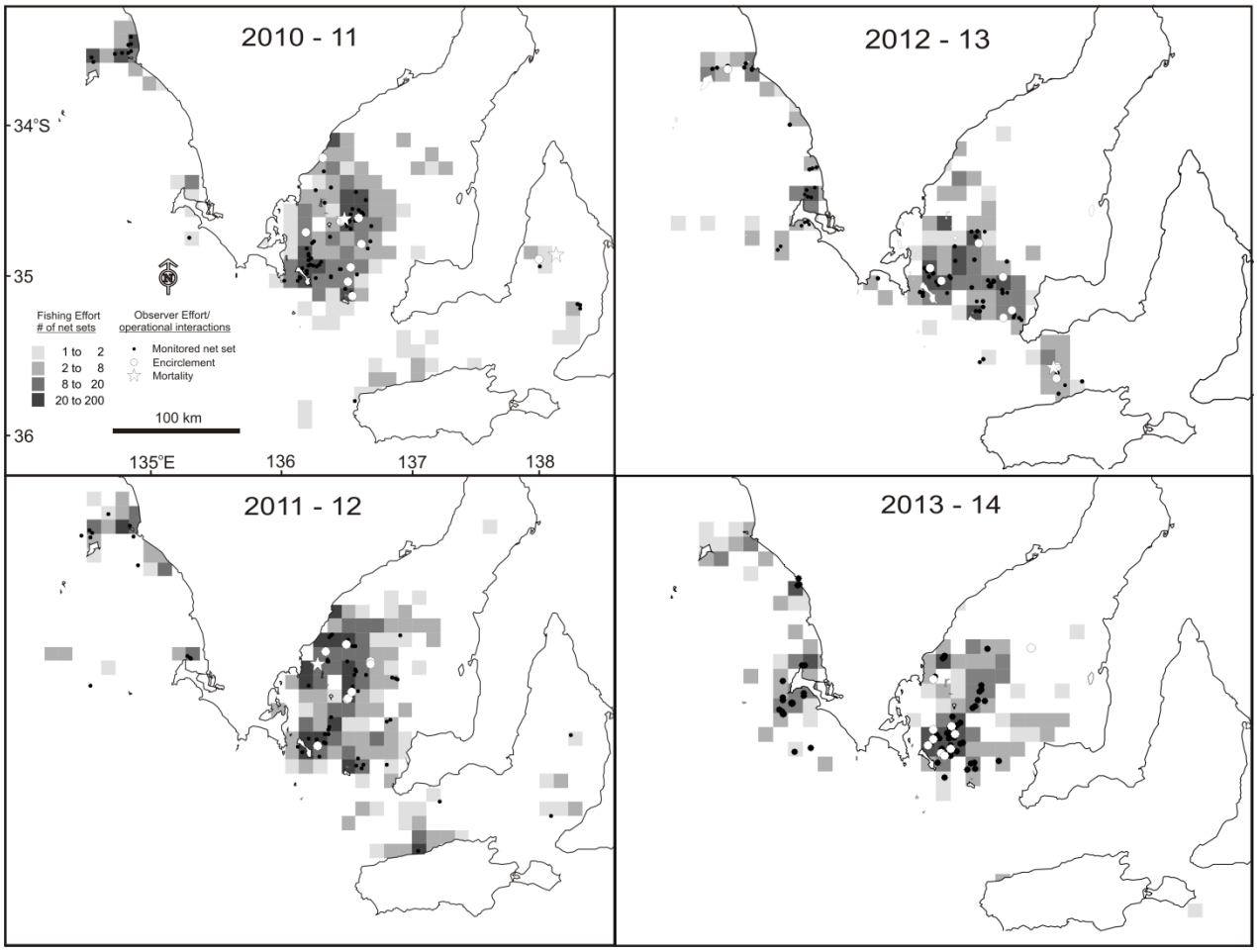

Figure 3 (**continued).** Spatial distribution of fishing effort, location of observed net-sets, encirclements and mortalities in the SASF during 2010-11 to 2013-14.

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% in 2007-08 to 2009-10, before being reduced to 10% from 2010-11 onwards. Actual observer coverage was consistently below the target level up until 2013-14 when it exceeded the target (10.2%). The number and percentage of net-sets observed each year increased from 49 (3.9%) in 2004-05 to 233 (25.2%) in 2008-09 before falling to 70 (6.3%) in 2011-12 and stabilising at 9.7% and 10.2% in 2012-13 and 2013-14, respectively (Table 1).

Levels of observer coverage (net-sets) varied among financial years, months, vessels and regions (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 (0-15.3%), months (6.4-18.7%) and regions (8.9 and 11.3%) 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	10	9959	468.30	**<0.0001**
Month	12	9959	45.17	**<0.0001**
Region	2	9959	3.05	0.08
Vessel	21	9959	93.20	**<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 and exceeded 39 t.net-set^{-1} in 2012-13 and 2013-14 (Figure 4). Sardine $CPUE_{net\text{-}set}$ with an observer was generally lower than without an observer (16.7 to 33.3 t.net-set^{-1}) and this difference was significant in 2005-06, 2008-09 and 2013-14 (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 rose to 46.6 t.night^{-1} in 2013-14 (Figure 4). Sardine $CPUE_{night}$ with an observer was generally lower than without an observer (21.3 to 48.6 t.night^{-1}and this difference was significant in 2008-09, 2010-11 and 2011-12 (Table 4).

The differences in the patterns of sardine $CPUE_{net\text{-}set}$ reflect, in part, differences among years in the mean number of net-sets per night with and without an observer (Figure 4, 5). More net-sets per night were made with an observer aboard in 2012-13 and 2013-14, whereas less net-sets were made with an observer aboard in 2010-11 and 2011-12 (Figure 5, Table 5).

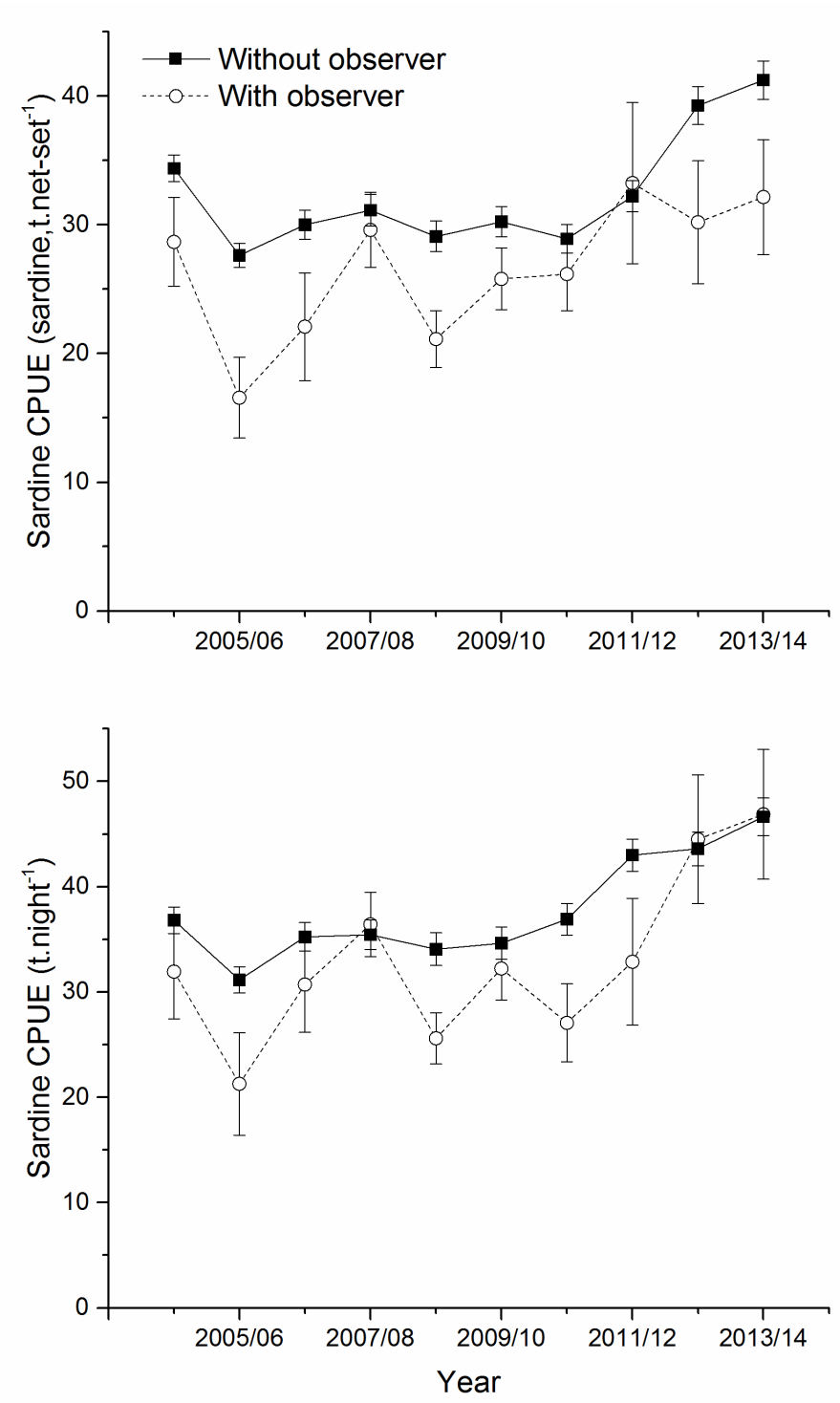

Figure 4. Sardine catch per unit effort (CPUE) in net-sets and nights from logbook records with and without an observer between 2004-05 and 2013-14. Error bars are standard errors.

Table 3. T-test comparing sardine CPUE (t.net-set^{-1}) from logbook records with and without an observer between 2004-05 and 2013-14.

Year	Sample Size (n)	Degrees of freedom	t-value	p-value
2004/05	1248	50.89	-0.7442	0.4602
2005/06	1006	91.62	-3.4100	**0.0010**
2006/07	954	87.59	-1.7470	0.0841
2007/08	890	259.73	-0.1254	0.9003
2008/09	925	354.08	-2.4947	**0.0131**
2009/10	1132	410.56	-1.8879	0.0598
2010/11	1047	118.62	-1.3824	0.1695
2011/12	1107	78.96	-0.0474	0.9623
2012/13	860	92.47	-1.6969	0.0931
2013/14	790	117.06	-3.0113	**0.0032**

Table 4. T-test comparing Sardine CPUE (t.night^{-1}) from logbook records with and without an observer between 2004-05 and 2013-14.

Year	Sample Size (n)	Degrees of freedom	t-value	p-value
2004/05	975	41.82	-1.2353	0.2236
2005/06	691	54.43	-1.6000	0.1154
2006/07	696	61.62	-1.0938	0.2783
2007/08	667	196.62	0.0014	0.9989
2008/09	688	322.29	-3.4098	**0.0007**
2009/10	815	282.75	-1.2555	0.2103
2010/11	696	100.36	-2.9461	**0.0040**
2011/12	704	67.90	-2.1571	**0.0345**
2012/13	623	57.13	-0.3008	0.7647
2013/14	591	56.23	-0.2381	0.8127

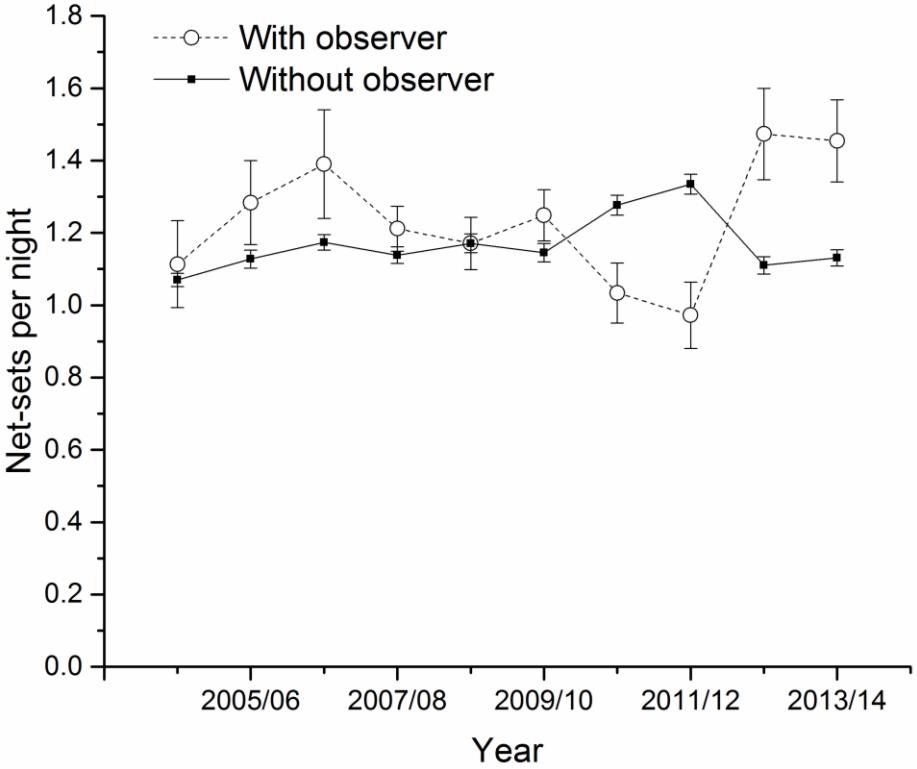

Figure 5. Net-sets per night from logbook records with and without an observer between 2004-05 and 2013-14. Error bars are standard errors.

Table 5. T-test comparing fishing effort (net-sets.night^{-1}) from logbook records with and without an observer between 2004-05 and 2013-14.

Year	Sample size (n)	Degrees of freedom	t-value	p-value
2004/05	975	37.72	0.2230	0.8247
2005/06	691	52.72	1.8600	0.0685
2006/07	696	54.20	1.5910	0.1174
2007/08	667	170.90	1.0426	0.2986
2008/09	688	218.20	-0.2220	0.8245
2009/10	815	228.79	1.1873	0.2363
2010/11	696	91.24	-3.1635	**0.0021**
2011/12	704	71.04	-4.6170	**<0.0001**
2012/13	623	53.70	2.4314	**0.0184**
2013/14	591	51.82	2.7893	**0.0074**

Sardine $CPUE_{net\text{-}set}$ differed among vessel, financial year, month and observer presence/absence but was not significantly different among regions (Table 6). The model baseline reference point for sardine $CPUE_{net\text{-}set}$ was 27.7 t.net-set^{-1}; this model estimate was for the (arbitrary) first vessel with no observer in January 2004-05 in the Gulfs Zone. The relative effect on sardine $CPUE_{net\text{-}set}$ of other vessels ranged from -17.5 t.net-set^{-1} to +26.9 t.net-set^{-1} relative to the baseline estimate. The relative estimated change in sardine $CPUE_{net\text{-}set}$ for 2005-06 was -7.2 t net-set^{-1} and for 2013-14 was +8.2 t.net-set^{-1}. The relative estimated change in sardine $CPUE_{net\text{-}set}$ in October was -7.4 t.net-set^{-1} and in April was +4.8 t.net-set^{-1}. The observer effect on sardine $CPUE_{net\text{-}set}$ was -6.0 t.net-set^{-1} relative to the baseline estimate.

Table 6. Best-fit Generalised Linear Model (GLM) of CPUE (t.net-set^{-1}) between 2004-05 and 2013-14 with factors of vessel, observer, financial year and month.

Factor	Degrees of freedom	Sum of Squares	Mean Square	F-statistic	p-value
Vessel	20	2009199	100460	141.83	**<0.0001**
Observer	1	35127	23918	49.59	**<0.0001**
Financial Year	9	215261	23918	33.77	**<0.0001**
Month	11	83750	77614	10.75	**<0.0001**

Residual standard error: 26.61 on 9917 degrees of freedom, Multiple R-squared: 0.2501, Adjusted R-squared: 0.2470, F-statistic: 88.69 on 41 and 9971 DF, p-value: < 0.0001

Sardine $CPUE_{night}$ differed among vessel, financial year, month, observer presence/absence and regions (Table 7). The model baseline reference point for sardine $CPUE_{night}$ was 25.4 t.night^{-1}; this model estimate was for the (arbitrary) first vessel with no observer in January 2004-05 in the Gulfs Zone. Model estimated sardine $CPUE_{night}$ for other vessels ranged from -16.0 t.night^{-1} to +25.9 t.night^{-1} relative to the baseline estimate. The relative estimated change in sardine $CPUE_{night}$ for 2005-06 was -7.1 t night^{-1} and for 2013-14 was +9.8 t.night^{-1}. The relative estimated change in sardine $CPUE_{night}$ in October was -7.9 t.night^{-1} and in April was +4.9 t.night^{-1}. The observer effect on sardine $CPUE_{night}$ was -5.6 t.night^{-1}. The region effect on sardine $CPUE_{night}$ in the Outside Zone was -5.6 t.night^{-1}.

Table 7. Best-fit Generalised Linear Model (GLM) of sardine CPUE (t.night^{-1}) between 2004-05 and 2013-14 with factors of vessel, observer, financial year and month.

Factor	Degrees of freedom	Sum of Squares	Mean Square	F-statistic	p-value
Vessel	20	1848705	92435	135.99	<0.0001
Observer	1	31087	31087	45.74	<0.0001
Financial Year	9	194447	21605	31.79	<0.0001
Month	11	117388	10672	15.7	<0.0001
Region	1	14884	14884	21.9	<0.0001

Residual standard error: 26.07 on 9916 degrees of freedom, Multiple R-squared: 0.2466, Adjusted R-squared: 0.2434, F-statistic: 77.29 on 42 and 9916 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 1).

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 falling to 99 and 93 encirclements in 2012-13 and 2013-14, respectively (Table 1). The number of mortalities recorded in logbooks increased from seven dolphins in 2004-05 to 15 dolphins in 2007-08 and declined to one dolphin in 2013-14 (Table 1).

Observer program

The number of encirclements that occurred while an observer was aboard declined from 18 in 2004-05 to nine in 2005-06, even though 86 net-sets were monitored compared to 49 net-sets the previous year (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).

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 and that number fell to two in 2009-10 and 2010-11 and to one in 2011-12 and 2012-13. No mortalities were observed in 2013-14.

3.5 Rates of encirclement and mortality

Logbook rates without an observer

The encirclement rates calculated from logbook data recorded without an observer rose from 1.5 (1-2) encirclements per hundred net-sets in 2004-05 to reach 6 (5-7) encirclements per hundred net-sets in 2008-09 before falling to 3 (2-4) encirclements per hundred net-sets in 2010-11 (Figure 7). The reported encirclement rate then increased to approximately 12 encirclements per hundred net-sets) in both 2012-13 and 2013-14.

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 7). The observed rates of encirclement between 2007-08 and 2013-14 ranged from 9 to 15 encirclements per hundred net-sets.

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 then declined to 6 (3-9) dolphins per hundred net-sets in 2007-08 and not more than 3 dolphins per hundred net-sets 2007-08 to 2012-13. No dolphin mortalities were observed in 2013-14.

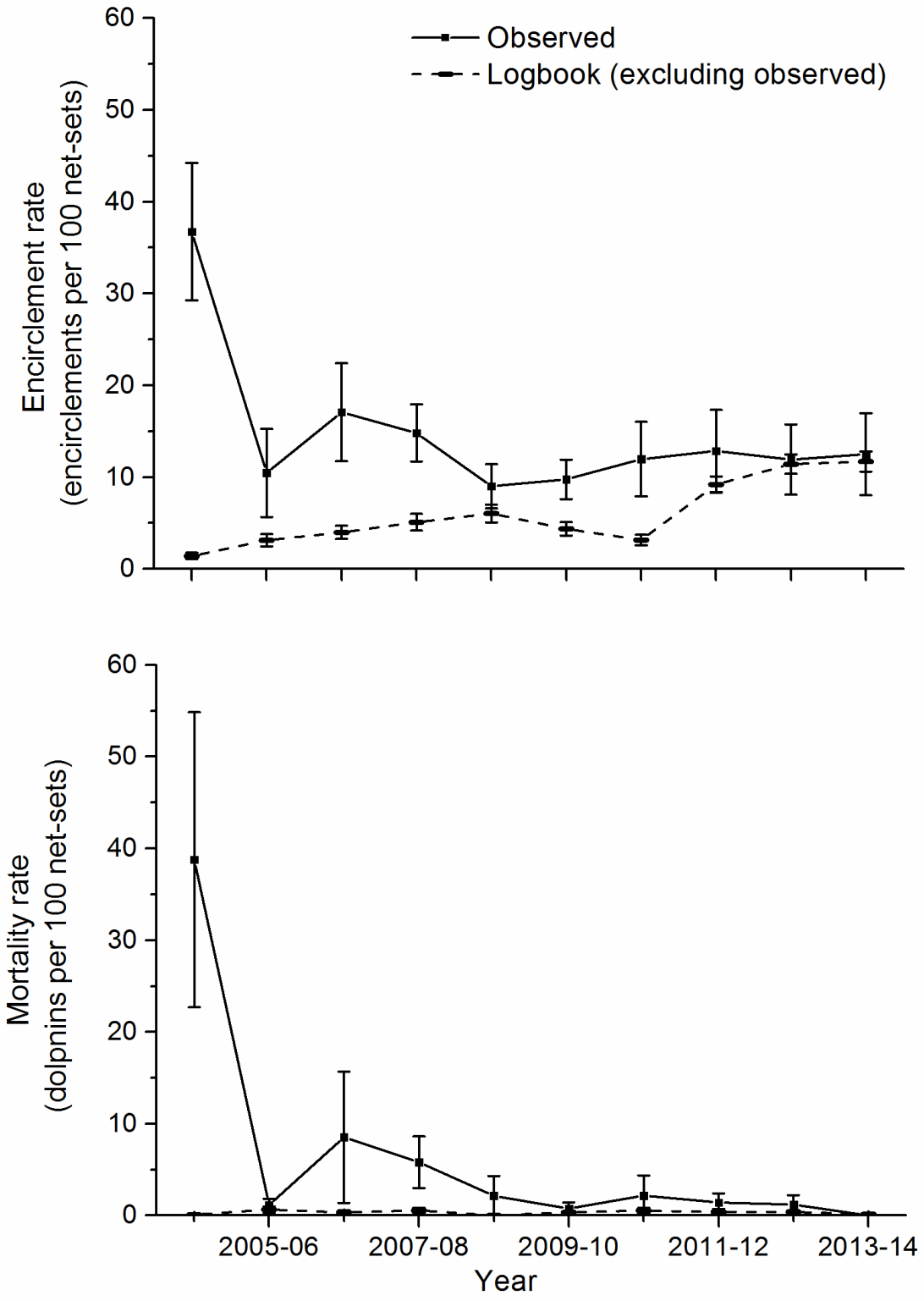

Figure 6. Rates of encirclement and mortality of short-beaked common dolphin in the between 2004-05 and 2013-14 calculated from observer data and logbook data collected when an observer was not present. Error bars are 95% confidence intervals.

3.6 Mean number of dolphins per encirclement and mortality event

The mean number of encircled dolphins recorded by observers was relatively stable, ranging from a high of almost five in 2004-05 to a low of just over 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 almost two in 2004-05 to one during 2009-10 to 2012-13.

The mean number of dolphins encircled calculated from logbook data recorded when an observer was not present was generally lower than the number recorded by observers, ranging from one in 2004-05, increasing to three in 2010-11 and was two in 2013-14 (Figure 7). The mean number of dolphins that died when a mortality event occurred recorded in logbook data when an observer was not present was one in 2004-05 and 2005-06, rose to three in 2006-07 then declined to one in 2012-13 and 2013-14.

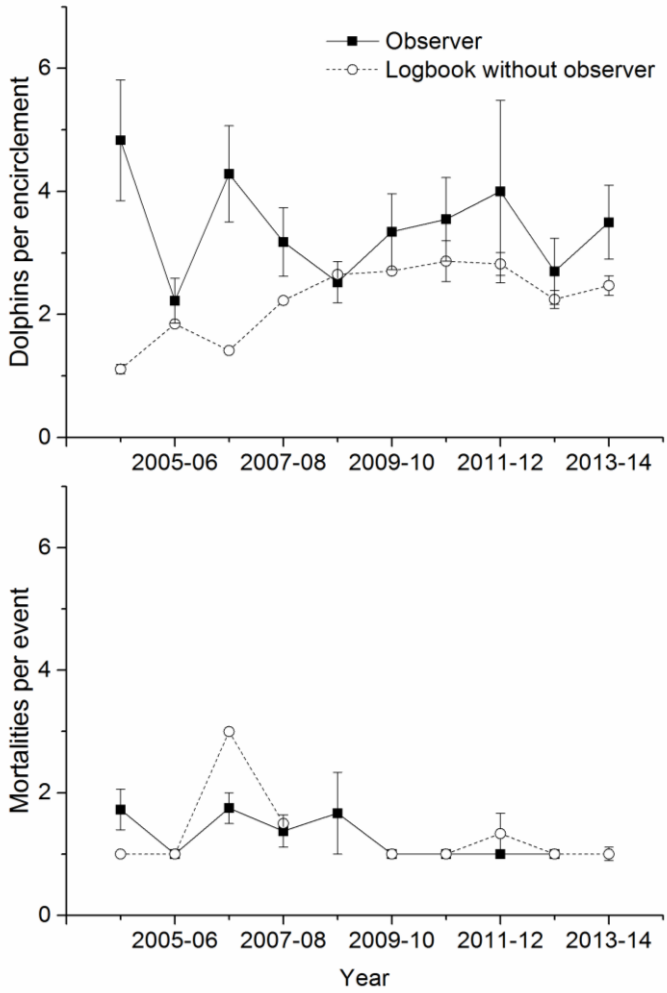

Figure 7. Mean number of dolphins encircled per encirclement event and mean number of dolphin mortalities per mortality event between 2004-05 and 2013-14 with and without an observer. Error bars are standard errors.

3.7 Total encirclements and mortalities

Extrapolation from the observer data suggests that in 2004-05, before CoP was introduced, a total of 458 encirclements occurred in the fishery (Figure 8). This fell to 105 encirclements in 2005-06 and increased to 163 in 2006-07 before falling to 98 in 2013-14.

Extrapolation from observer data suggests that 484 dolphin mortalities occurred in 2004-05 (Figure 8). This fell 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 and were 10 in 2012-13 and 0 in 2013-14.

3.8 Reporting rates

The discrepancy between the number of encirclements calculated from observer data and recorded in logbooks fell over time (Figure 8). In 2004-05, only 24 encirclements were reported in logbooks, which was approximately 5% of the number estimated from observer data (458), whereas in 2013-14 93 encirclements were reported in logbooks which is approximately 95% of the number estimated from observer data (98).

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

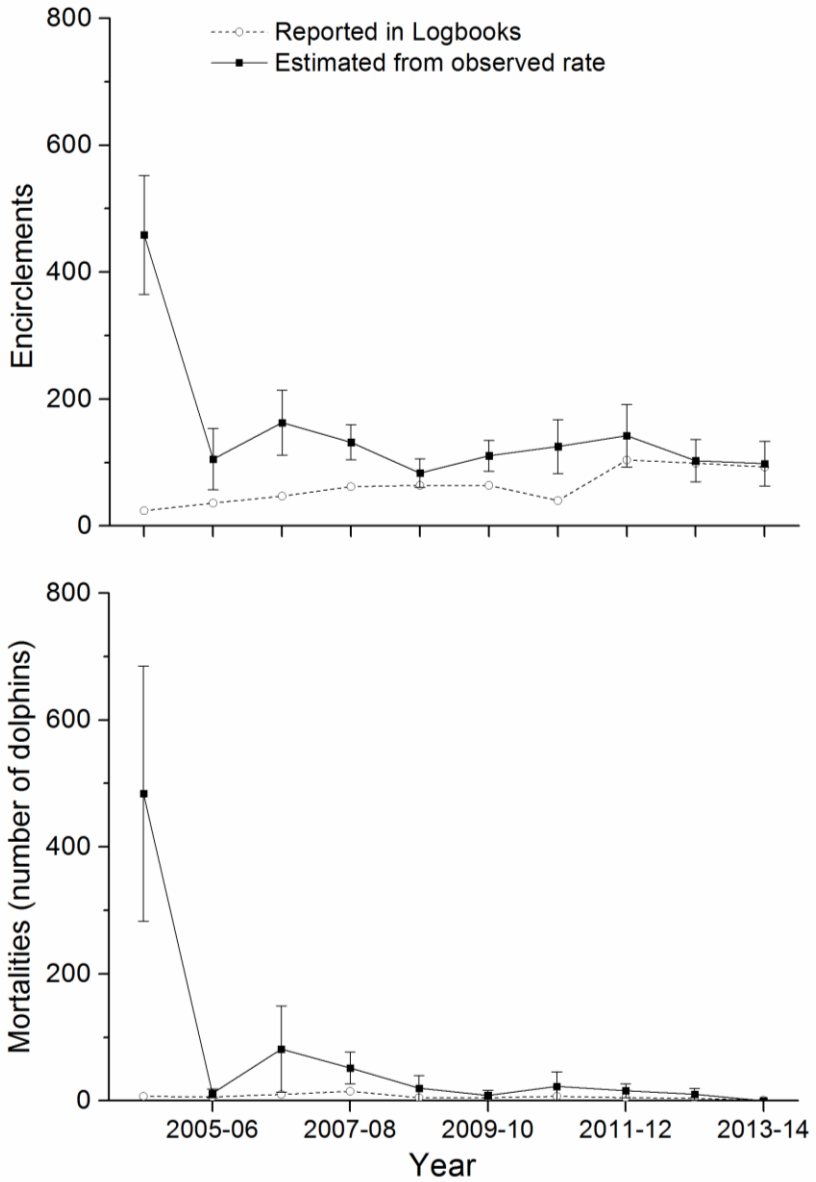

Figure 8. Numbers of encirclements and mortalities each financial year based on rates determined from observer data and total fishing effort and from the total numbers reported in logbooks.

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. Over 85% of net-sets made after a search had determined that dolphins were not present in the fishing area did not encircle dolphins. 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 2013-14. 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

Prior to the implementation of the CoP fishers often did not take any action to release dolphins. In these cases, all encircled dolphins were released alive on only 16% of occasions (Table 9). Before the implementation of the CoP and soon thereafter (e.g. up 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 this release procedure (i.e. opening the net) during this period. In recent years, the use of corkline weights and the TEPS gate have been removed as release options from CoP and 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 of 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 preventing for releasing encircled dolphins in the SASF during 2004-05 to 2013-14. The CoP was introduced in 2005-06. Note that multiple release procedures were sometimes implemented for a single encirclement. A release procedure was deemed considered 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)

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

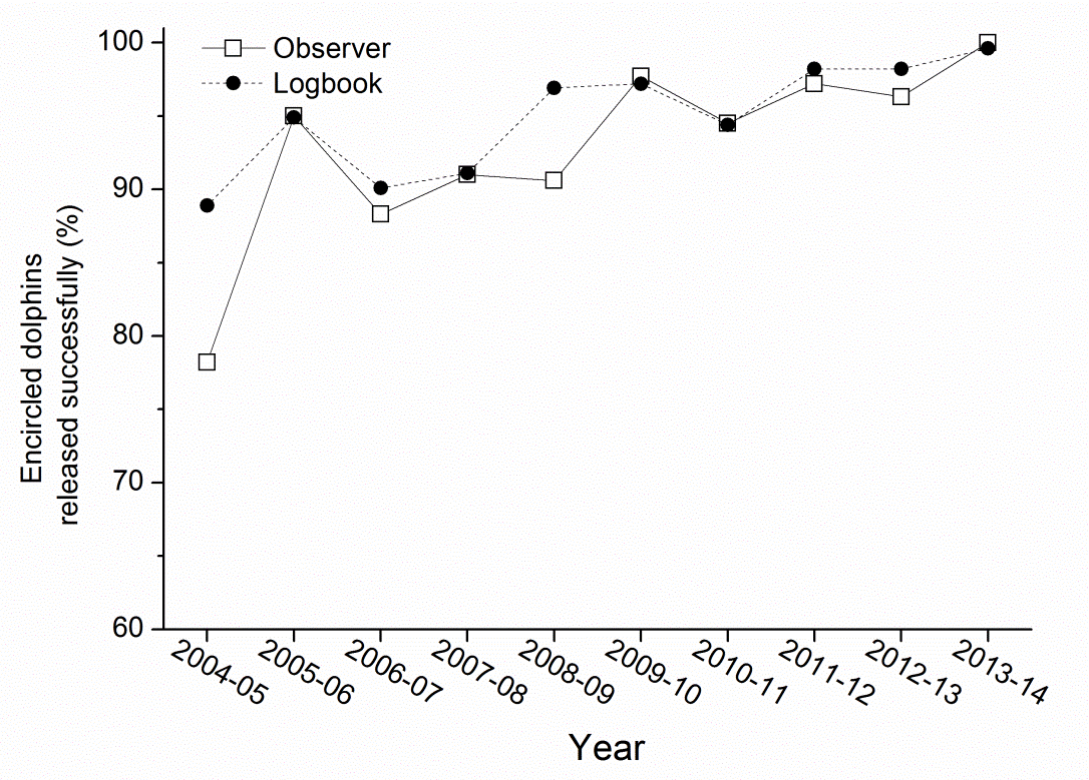

Figure 9. Percentage of encircled dolphins that were successfully released in the South Australian Sardine Fishery from 2004-05 to 2013-14 based on data from observer records and fishery logbooks.

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 met and exceeded the target level for the first time in 2013-14. As well as varying among years, observer coverage has not reflected differences in fishing effort among vessels, months and regions. 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. In particular, there is a need to ensure levels of observer coverage adequately represent seasonal variations in fishing effort.

Differences in sardine CPUE (both $CPUE_{net\text{-}set}$ and $CPUE_{night}$) 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 any measure of mean sardine CPUE was significantly higher with an observer present than without. This finding suggests that fishers may operate differently when an observer is aboard than when one is not.

The increase in 2012-13 and 2013-14 in the number of net-sets undertaken per night when an observer was aboard, i.e. since the measure of observer coverage changed from fishing nights to net-sets, also suggests fisher behaviour may differ with and without an observer.

Encirclement rates with an observer present have stabilised at approximately 12-13 encirclements per hundred net-sets over the last few years. Since 2012-13, a similar rate of encirclement has been recorded in logbooks (approximately 12 per hundred net-sets). In 2013-14, one dolphin mortality was reported in logbooks but no mortalities were observed. Up until 2012-13, there was a clear discrepancy between rates of encirclement and mortality calculated from observer data and from logbook

data recorded when an observer was not aboard. This discrepancy suggested that interaction rates were under-reported when an observer was not present (assuming that actual encirclement rates were similar with and without an observer). The recent reduction in these discrepancies occurred after the industry led program was established 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. Extrapolation from observed interaction rates and total fishing effort suggest that in 2013-14, 98 encirclements would have occurred in the fishery, compared to the 93 encirclements recorded in logbooks. This finding suggests a logbook reporting rate of approximately 95% (noting that this approach assumes that encirclement rates are similar with and without an observer). The extrapolated values should be treated with caution because 1) variations in observer coverage and interaction rates among years, months, vessels and regions are not accounted for by the simple statistical method used to estimate total encirclements and 2) because it is unknown how well the CoP is implemented in the absence of an observer.

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 successfully released. The overall reduction in the encirclement rate reflects the success of the avoidance procedures in preventing interactions from occurring. Before the code 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 that are documented in the vessel-specific flowcharts located in the wheelhouse of each vessel. The adoption of “opening the front of the net” as the agreed response to encirclements has been fundamental in improving the proportion of successful releases.

Observer data show that the industry CoP has been highly effective in reducing the interaction rates of the SASF with the short-beaked common dolphin. The discrepancy between interaction rates reported in logbooks and by observers has declined over time and was negligible in 2012-13 and 2013-14. However, total interaction levels reported in logbooks and extrapolated from observed rates need to

be treated with caution because existing data cannot be used to calculate how well the CoP is implemented in the absence of an observer.

Future observer coverage should be representative of fishing effort by month, vessel and region. Total encirclements should be re-estimated using statistical methods that account for variability in levels of observer coverage and interaction rates. A review of the format of both fishery logbooks and observer datasheets is needed to ensure that these datasets can be matched efficiently and effectively.

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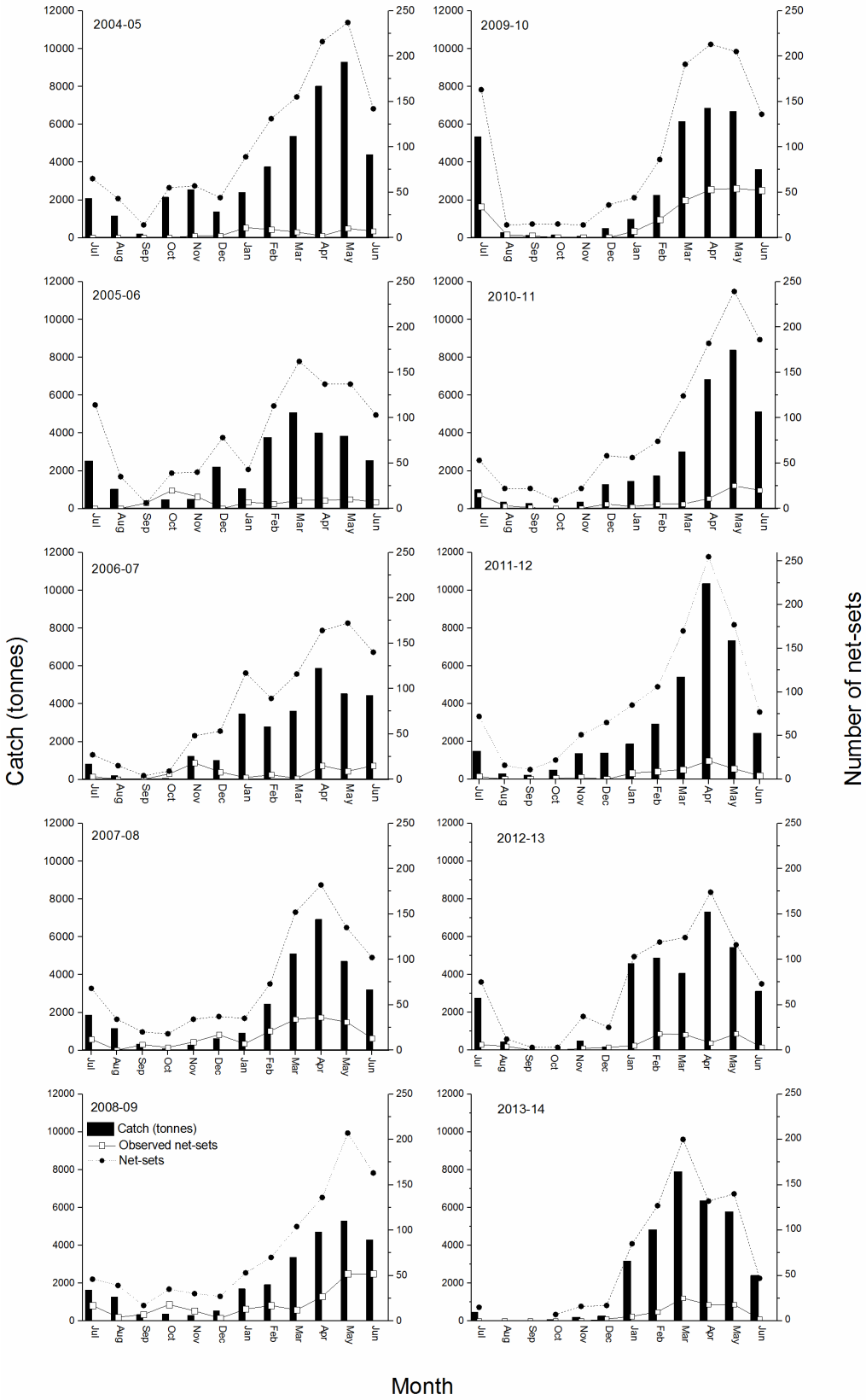
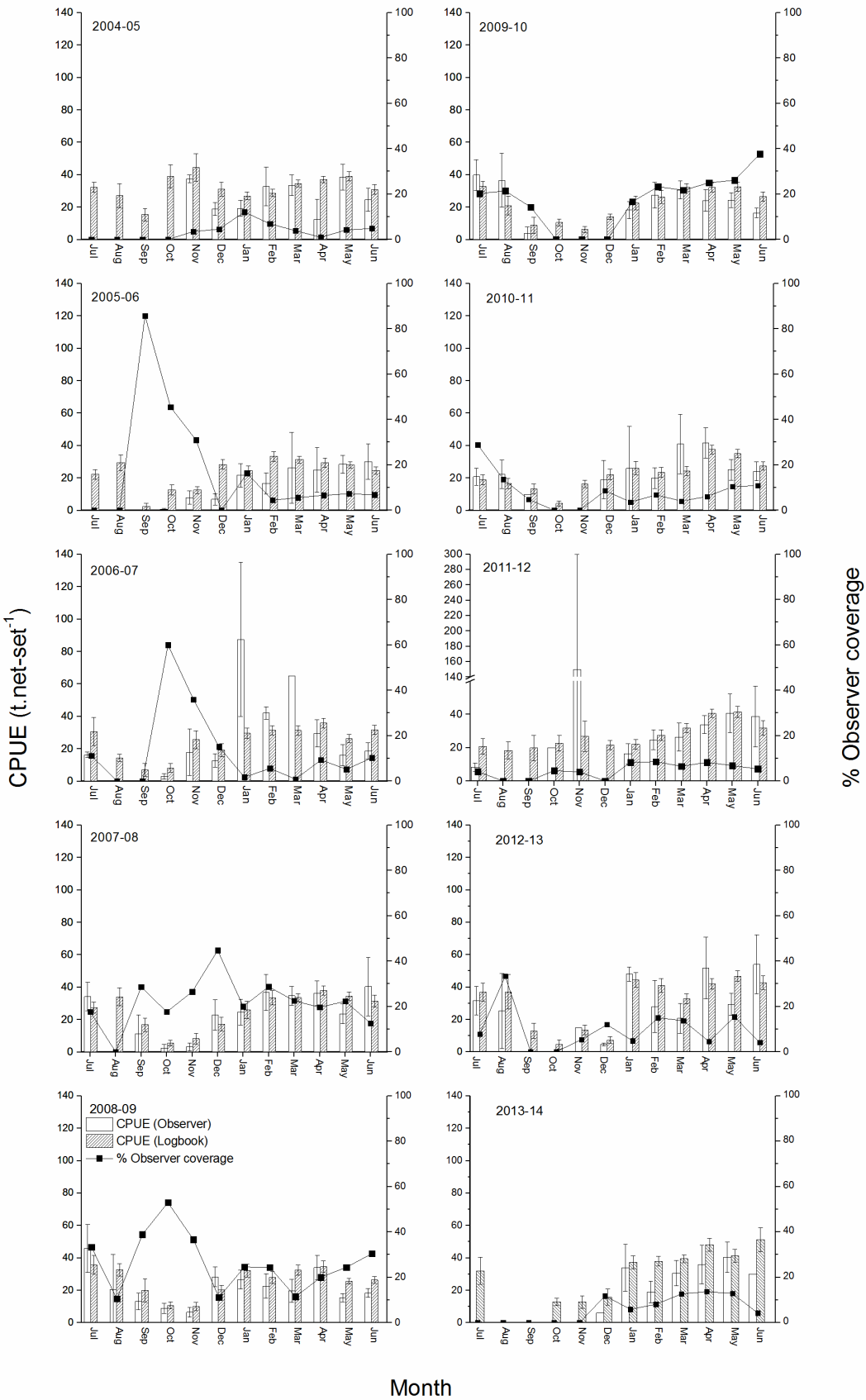
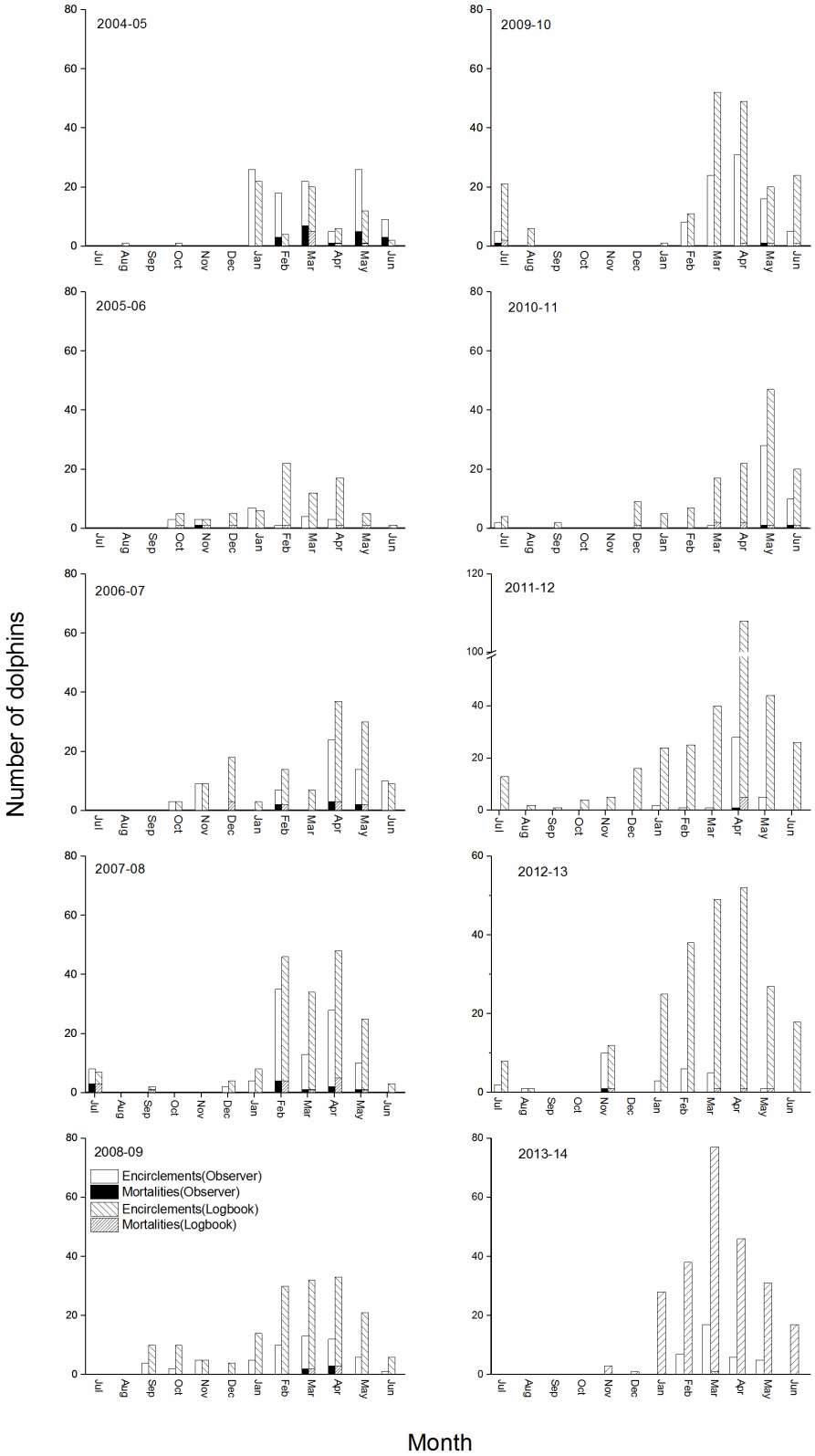
APPENDIX 1



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.