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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*)

T.M. Ward, A. Ivey and P. Burch

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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

October 2013

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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EXECUTIVE SUMMARY

This is the seventh report by SARDI Aquatic Sciences on the 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 14 November 2004 to 30 June 2013.

The objectives of this report are to: (i) describe and compare patterns of dolphin encirclement and mortality recorded in fishery logbooks and by observers; (ii) estimate the number of dolphins encircled and mortalities that occur in the SASF each financial year; and (iii) assess the efficacy of the refined Code of Practice (CoP) in mitigating the interactions of the SASF with dolphins.

In 2012-13, observers monitored 84 of the 857 net-sets in the SASF (9.8% coverage). Observers reported that a total of 27 common dolphins were encircled (32.1 dolphins per hundred net-sets) in 10 encirclement events and that one mortality occurred (1.2 dolphins per hundred net-sets).

Logbook data for the SASF in 2012-13 (857 net-sets) recorded 226 encircled dolphins in 99 encirclement events and four mortalities from four of these events.

The rates of dolphin encirclement and mortality recorded in logbooks in 2012-13 when an observer was not present were 25.7 and 0.4 dolphins per hundred net-sets, respectively. The rates of encirclement and mortality recorded by observers were 1.2 and 3.1 times higher, respectively, than those recorded in logbooks when an observer was not onboard.

Extrapolation from observer rates and total fishing effort suggest that 275 dolphins were encircled and 10 mortalities occurred in 2012-13, compared to the 226 dolphins encircled and 4 mortalities recorded in logbooks.

General Linear Modelling suggested that encirclement rates varied significantly among months. Model generated estimates of numbers of dolphins encircled per year were higher in 2006-07 and 2010-11 than estimates from simple extrapolations.

The discrepancy between the interaction rates recorded in fishery logbooks in the absence of an observer and those reported by observers has reduced since the industry initiated a program to monitor dolphin interactions in real-time in 2011.

Catch Per Unit Effort (CPUE) in logbooks was lower when an observer was present than when no observer was aboard in 2005-6, 2008-9 and 2012-13 when the discrepancy between observed and unobserved interaction rates were low.

Information provided in this report reaffirms the success of the CoP in reducing rates of encirclement and mortality.

1.0 INTRODUCTION

1.1 South Australian Sardine Fishery

The South Australian Sardine Fishery (SASF) operates primarily in southern Spencer Gulf and was established in 1991 to provide fodder for the grow-out of wild-caught southern bluefin tuna (*Thunnus maccoyi*). It is Australia's largest single-species fishery (by weight) with total annual catches over the last five years of ~34,000 t, including 4,000 tonnes taken outside of traditional fishing areas off western Eyre Peninsula since 2010 (Figure 1).

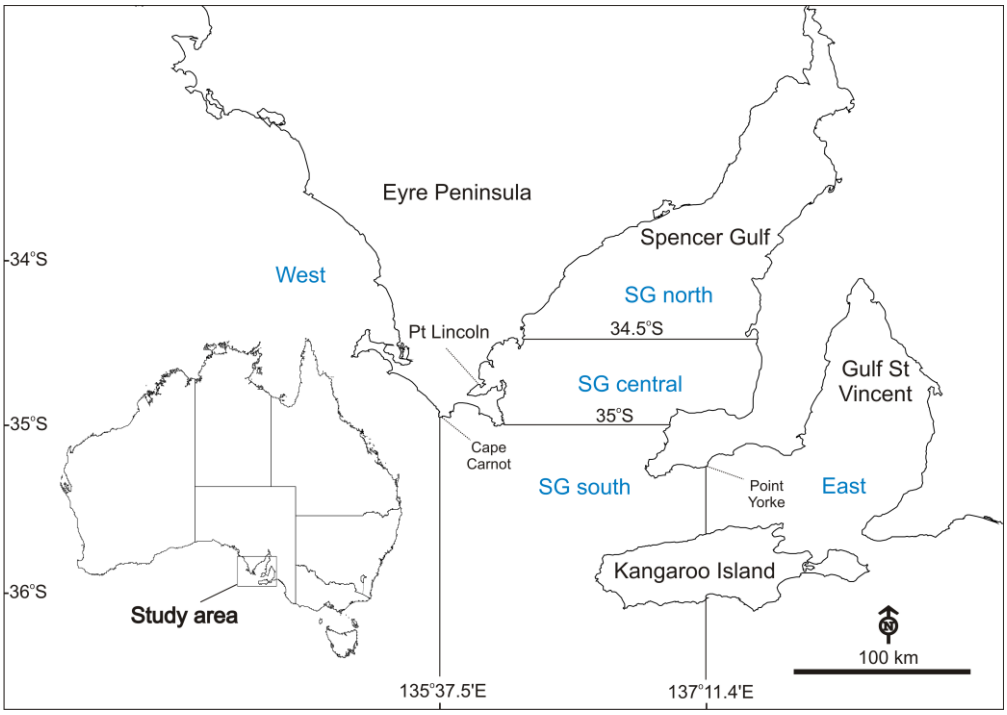

Figure 1. Location of the study, fishing areas and sites mentioned in the text.

The SASF is a limited-entry fishery with 14 licence holders. It is managed using a Total Allowable Commercial Catch (TACC) and Individual Transferable Quotas (ITQs). There are also restrictions on the length and depth of the purse-seine net (1,000 and 200 m, respectively) and mesh size (14 to 22 mm). The full costs of the policy, research and compliance programs used to manage the fishery are recovered from licence holders through fishery license fees.

Licence holders are actively involved in management of the SASF and conduct frequent meetings with Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture and South Australian Research and Development Institute (SARDI) Aquatic Sciences. There is a formal management plan and a defined harvest strategy (Shanks 2005). The revised harvest strategy for the SASF indicates that the baseline TACC (30,000 tonnes) will be maintained while the latest estimate

of spawning biomass remains between the reference points of 150,000 and 300,000 t and there is no other evidence of serious stock decline.

Fishery-independent stock assessments using the Daily Egg Production Method (DEPM) were carried out annually from 1995 to 2007 and are now conducted biennially (e.g. Ward et al. 2013). Fishery Assessment Reports that integrate fishery-independent and fishery-dependent data using an age-structured model and that review fisheries management arrangements are completed biennially (in alternate years to the Spawning Biomass Reports). Catch and Disposal Records are monitored and there is an extensive compliance program to ensure catches do not exceed the TACC.

1.2 Previous Research

The study by Hamer et al. (2008) documented the successful mitigation of the operational interactions of the 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 (Appendix 1). 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 encirclement and release procedures used to reduce the mortality rates of encircled dolphins. Discrepancies between encirclement and mortality rates calculated from observers and logbook data were reduced to factors of less than two (down from factors of 27 and 54, respectively). Hamer et al. (2009a) emphasised the important role that establishing and maintaining an effective working relationship between industry and scientists had played in mitigating common dolphin interactions and mortality rates in this fishery.

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. Successful bycatch mitigation programs typically involve longer ongoing observer coverage, expert review and continuous improvement of mitigation practices (Cox et al. 2007; Hall 1998). 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.

1.3 Refined Code of Practice

The refined CoP for the SASF explicitly aims for world's best practice and a process for continuous improvement in mitigating interactions with TEPS (Appendix 2). Each crew member participates in the CoP induction prior to the start of each fishing season. Flowcharts documenting 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 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 a the 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, 2011b, 2012).

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 (Table 3). However, after the introduction of the CoP, fishers consistently search for dolphins before setting the net and consistently 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 (Table 3, Figure 7).

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 (SASIA 2009, opening the front of the net) has been successful in allowing dolphins to escape (Table 3).

In October 2011, the South Australian Sardine Industry Association (SASIA) initiated industry-based collection of TEPS interaction data. The Executive Officer of SASIA collects fishery logbook sheets as soon as possible from each skipper and collates the data prior to submitting it to SARDI. This improvement has allowed industry to quickly address trends at the regular skippers meetings.

1.4 Aim and Objectives

This study reports on the interactions of the SASF with the short-beaked common dolphin (*Delphinus delphis*) during the period from 2004-05 to 2012-13. The objectives of the study are to: i) describe and compare patterns of dolphin encirclement and mortality recorded in fishery logbooks and by observers; (ii) estimate the number of dolphins encircled and mortalities that occur in the SASF each financial year; and (iii) assess the efficacy of the refined CoP in mitigating the interactions of the SASF with the short-beaked common dolphin.

2.0 METHODS

2.1 Data Collection

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

2.2 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 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.

2.3 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.

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. 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 due to the presence of dolphins 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 dolphin 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. Data recorded on Observer Datasheets were validated, stored and collated by SARDI Aquatic Sciences.

2.4 Integrating Observer and Logbook Data

Historically it has not been possible to match observer records with the corresponding logbook data because the fishery logsheet number was not recorded by observers. Matching these records by date and vessel was also problematic because fishery logbooks record the date of departure and landing while observers record the date of each shot. Since 2010, observers have recorded the fishery logsheet number so that observer records after this time can be matched with corresponding fishery logsheets. For historical observer records the corresponding logbook and observer records were matched using repeated fields such as vessel, date and catch in the logbook data. A new binary field was created in the logbook data to identify whether an observer was present.

2.5 Observer Coverage

The level of observer coverage between 2004/05 and 2012/13 has varied (Table 1). In January 2013, PIRSA Fisheries and Aquaculture changed the formal measure of observer coverage from nights to net-sets. Observers are placed on vessels to cover the spatial and temporal range of the fishery. To determine whether observer coverage was representative of fishing activity, Chi squared tests of the number of shots with and without an observer by month ($p<0.01$) and region (Figure 1; $p<0.01$) were undertaken. There was insufficient data to determine whether observer coverage was representative in individual financial years.

2.6 Interaction Rates from Observer Data

Simple rate calculation and extrapolation to total fishery

Rates of encirclement and mortality were calculated from observer data and applied to total fishing effort (net-sets) for each year to estimate the total number of dolphins involved in interactions. Interaction rates in the absence of an observer were determined by subtracting the observed interactions and net-sets from the logbook records and recalculating rates and estimates. Confidence intervals for the simple extrapolation rates were obtained using a Poisson approximation to the Normal distribution

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

where, λ is the rate estimated by observers.

Generalised linear model interpretation of interaction rates

To account for spatial and temporal variability in observer coverage, the dolphin encirclement rate was estimated using a generalised linear model (GLM; McCullagh and Nelder 1983). A Negative Binomial GLM with a log link function (Venables and Ripley 2002), appropriate for over-dispersed count data, was fitted to the number of dolphins encircled from all observer shots that could be matched to fishery logbook data. Since the purpose of the analysis was to estimate annual changes in total number of dolphins encircled over time, financial year was included in the null model. Month and Region of fishing (Figure 1) were included as covariates to account for any spatial or temporal variability in dolphin encounter rates. Models were fitted in a stepwise forwards process with the performance of candidate models assessed using Akaike Information Criteria (AIC) and likelihood ratio tests (Kutner et al. 2005). Due to the small number of observed events, it was not possible to consider interaction terms in the modelling process.

The optimal model from above was applied to all fishery shots to estimate dolphins encircled in each shot. Records were aggregated to estimate the number in each financial year. Confidence intervals on the annual number of dolphins encircled were estimated using a bootstrap procedure (Efron and Tibshirani 1993) with 10,000 iterations applying the percentile method.

It was not possible to account for any spatial or temporal variability in the observed rate of dolphin mortalities using a GLM because the rate of observed mortality was too low. Instead, the number of mortalities in the fishery each financial year has been

extrapolated directly from the observed rate using the simple rate calculation described above.

2.7 CPUE Comparison

To determine whether the presence of an observer influences fishing effectiveness, the catch per unit effort (CPUE) was calculated for shots with and without observers present for financial years between 2004/05 and 2012/13.

3.0 RESULTS

3.1 Fishing Patterns

Data from fishery logbooks show that the level of fishing effort within a financial year ranged from 1239 net-sets in 2004-05 to 857 net-sets in 2012-13 (Table 1 Figure 2). In most years, the highest fishing effort was recorded between January and June (Figures 3 and 4). In some fishing seasons, significant effort also occurred in December (e.g. 2005-06) and July (2009-10, Figure 3). Most fishing was conducted in lower Spencer Gulf (Figures 5 and 6). Recent changes in spatial management of the SASF have directed some effort outside of traditional fishing areas, most of this fishing has been conducted in Gulf St Vincent and western Eyre Peninsula.

Table 1. Number of net-sets, % observer coverage, dolphin encirclements and mortalities (numbers and events) recorded in logbooks and observer data in 2004-05, before the introduction of the industry CoP, and 2005-06 to 2012-13, after its introduction.

Year	Total Net-sets (Logbooks)	Observed Net-sets (Datasheets)	% Observer Coverage	Encirclements No. (events)		Mortalities No. (events)	
				Logbook	Observer	Logbook	Observer
2004-05	1239	49	4.0	59 (23)	87 (18)	7 (4)	19 (11)
2005-06	1008	89	8.8	68 (35)	20 (9)	7 (7)	1 (1)
2006-07	931	82	8.8	101 (43)	60 (14)	10 (5)	7 (4)
2007-08	876	189	21.6	158 (59)	89 (28)	14 (10)	11 (8)
2008-09	902	233	25.8	159 (61)	53 (21)	5 (3)	5 (3)
2009-10	1070	266	24.9	179 (60)	87 (26)	5 (5)	2 (2)
2010-11	1014	91	9.0	126 (40)	39 (11)	7 (7)	2 (2)
2011-12	1107	73	6.6	303 (104)	36 (9)	5 (4)	1 (1)
2012-13	857	84	9.8	226 (99)	27 (10)	4 (4)	1 (1)

Direct comparisons of observer data and fishery logbooks suggested that in the earlier years 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.

3.2 Patterns of Dolphin Encirclement and Mortality

Logbook program

The total number of encircled dolphins recorded in fishery logbooks increased from 59 (in 23 separate encirclement events) in 2004-05 to 179 (60 events) in 2009-10 (Table 1; Figure 2). In 2010-11, 126 encircled dolphins (40 events) were recorded in logbooks. Encircled dolphins recorded in logbooks increased to 303 (104 events) in 2011-12. In 2012-13, 226 encircled dolphins were recorded in logbooks (99 events). In contrast, the number of mortalities recorded in logbooks was relatively stable, ranging between four and fourteen between 2004-05 and 2012-13 (Table 1; Figure 2).

Observer program

During 2004-05 and 2005-06, the observer program was conducted between November and June only (Figure 3), after which observations were made over the entire financial year (with the exception of October-December 2009 and October-November 2010, due to logistical reasons). The number and percentage of net-sets observed each year increased from 49 (5.0%) in 2004-05 to 233 (26.2%) in 2008-09, with the largest increase occurring between 2006-07 and 2007-08 (Table 1). In 2010-11, observed net-sets decreased to 91 (9.0%). Observer coverage decreased further to 73 (6.9%) in 2011-12. The highest levels of fishing and observer effort occurred consistently during the second half of the financial year (Figure 3 and 4). In 2012-13, 84 net-sets were observed, representing 9.8% of the commercial effort in that year.

The number of dolphins encircled while an observer was onboard declined from 87 from 18 events in 2004-05 to 20 from nine events in 2005-06, even though 89 net-sets were monitored compared to 49 net-sets the previous year (Table 1). In 2006-07, 60 dolphins were encircled (14 events) during the 82 observed net-sets. In the three years from 2007-08 to 2009-10, the number of dolphins encircled remained relatively stable (i.e. 53-89 dolphins in 21-28 events), despite the increase in the number of net-sets observed (189 net-sets in 2007-08 to 266 net-sets in 2009-10). In 2010-11, the number of encircled dolphins fell to 39 (11 events) although only 91 net-sets were observed (Table 1; Figure 2). In 2012-13, 27 dolphins were observed encircled (ten events) in 84 observed net-sets.

The number of observed dolphin mortalities declined from 19 (11 events) in 2004-05 to 1 in 2005-06, but increased to 7 (4 events) in 2006-07 (Table 1). In 2007-08, 11 mortalities (8 events) were recorded by observers and that number fell to 5 (3

events), 2 (2 events) and 2 (2 events) in 2008-09, 2009-10 and 2010-11, respectively. In 2011-12 and 2012-13, 1 mortality was observed.

The number of encircled dolphins observed remained relatively stable and 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 (Figure 7). Although there was a decrease in release success to 88% in 2006-07, it increased to 98% in 2009-10. In 2012-13, 96% of encircled dolphins were successfully released when an observer was present.

3.3 Rates of Dolphin Encirclement and Mortality

Observed rates

The rate of dolphin encirclement recorded by observers declined from 178 (95% CI 139-216) dolphins per hundred net-sets in 2004-05 to 22 (12-33) dolphins per hundred net-sets in 2005-06, but increased to 73 (54-92) dolphins per hundred net-sets in 2006-07 (Figure 8). The observed rates of encirclement in 2007-08, 2008-09, 2009-10, 2010-11 and 2011-12 were 47 (37-57), 23 (16-29), 33 (26-40), 43 (29-57) and 49 (33-66) dolphins per hundred net-sets, respectively (Figure 8). In 2012-13, the rate of encirclement recorded by observers was 32 (20-45) dolphins per hundred net-sets.

The observed mortality rates declined from 39 (95% CI 21-57) dolphins per hundred net-sets in 2004-05 to 1 (0-3) dolphins per hundred net-sets in 2005-06 (Figure 8), but increased to 9 (2-15) dolphins per hundred net-sets in 2006-07, before declining to 6 (2-9), 2 (0-4), 1 (0-2), 2 (0-5) and 1 (0-4) dolphins per hundred net-sets in 2007-08, 2008-09, 2009-10, 2010-11 and 2011-12, respectively. In 2012-13 the rate of dolphin mortality recorded by observers was 1 (0-4) dolphins per hundred net-sets.

Logbook rates excluding observed events

In 2004-05 more interactions were observed than recorded in logbooks (Figure 8). In 2005-06, the rate of encirclement reported in logbooks when an observer was not onboard was 5 dolphins per hundred net-sets (95% CI 4-7). In 2008-09, this rate increased to 16 (13-19) dolphins per hundred net-sets, similar to the rate when an observer is present (23 (16-29); Figure 8). The rate of encirclement in the absence of an observer declined to 9 dolphins per hundred net-sets (7-11) in 2010-11; lower than the rate recorded by observers over the same period (43 (29-56); Figure 8). In 2011-12, the rate of dolphin encirclement in the absence of an observer rose to 26

dolphins per hundred net-sets (23-29), approximately half the rate recorded by observers. In 2012-13, the rate of dolphin encirclement in the absence of an observer (26 dolphins per hundred net-sets (22-29)) was similar to the rate calculated from observer data (32 (20-45)).

The rate of mortality calculated from logbook records excluding observed events was consistently lower than the rate calculated from observed events (Figure 8).

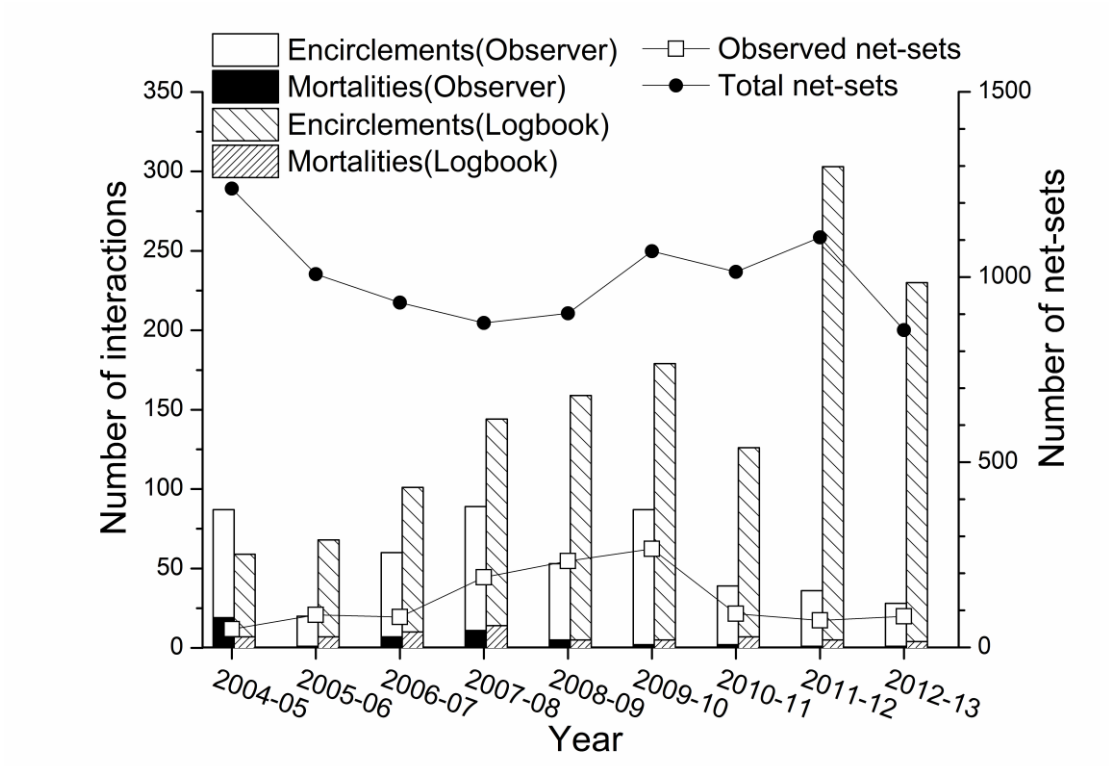

Figure 2. Fishing effort (logbook net-sets), observer effort (observed net-sets), and number of dolphin encircled and mortalities for financial years from before (2004-05) and after (2005-06 to 2012-13) the introduction of the industry CoP in the SASF.

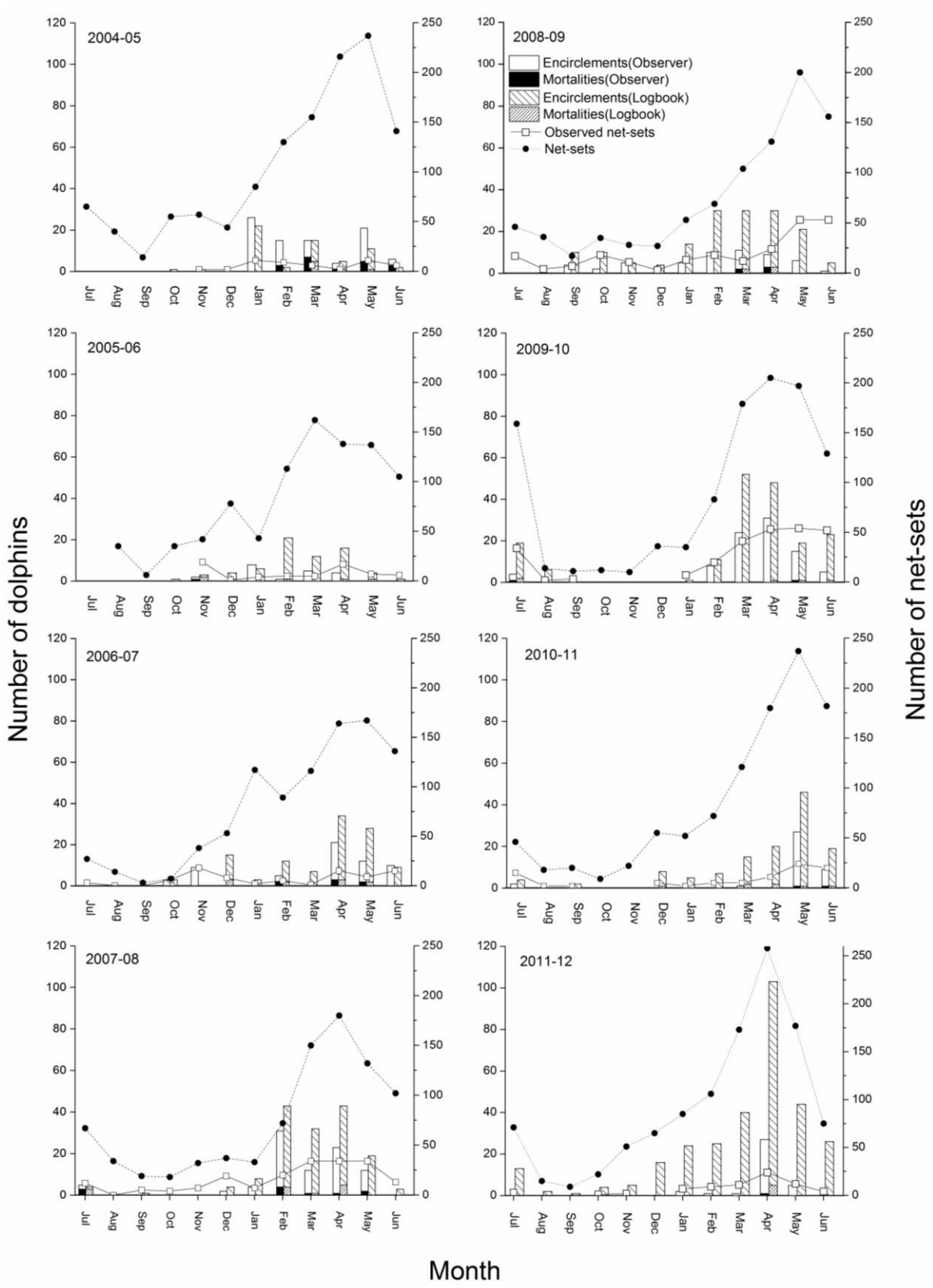

Figure 3. Monthly fishing effort (logbook net-sets), observer effort (observed net-sets), and number of dolphins encircled and mortalities before (2004-05) and after (2005-06 to 2011-12) the introduction of the industry CoP in the SASF.

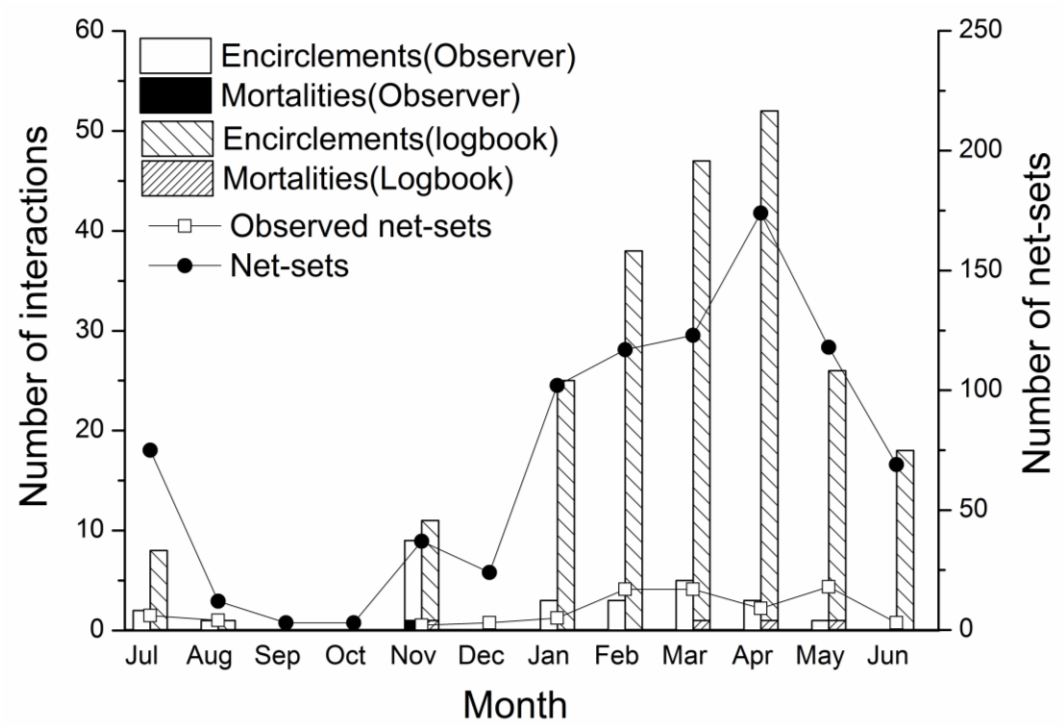

Figure 4. Fishing effort (logbook net-sets), observer effort (observed net-sets), and number of dolphin encircled and mortalities for the 2012-13 financial year.

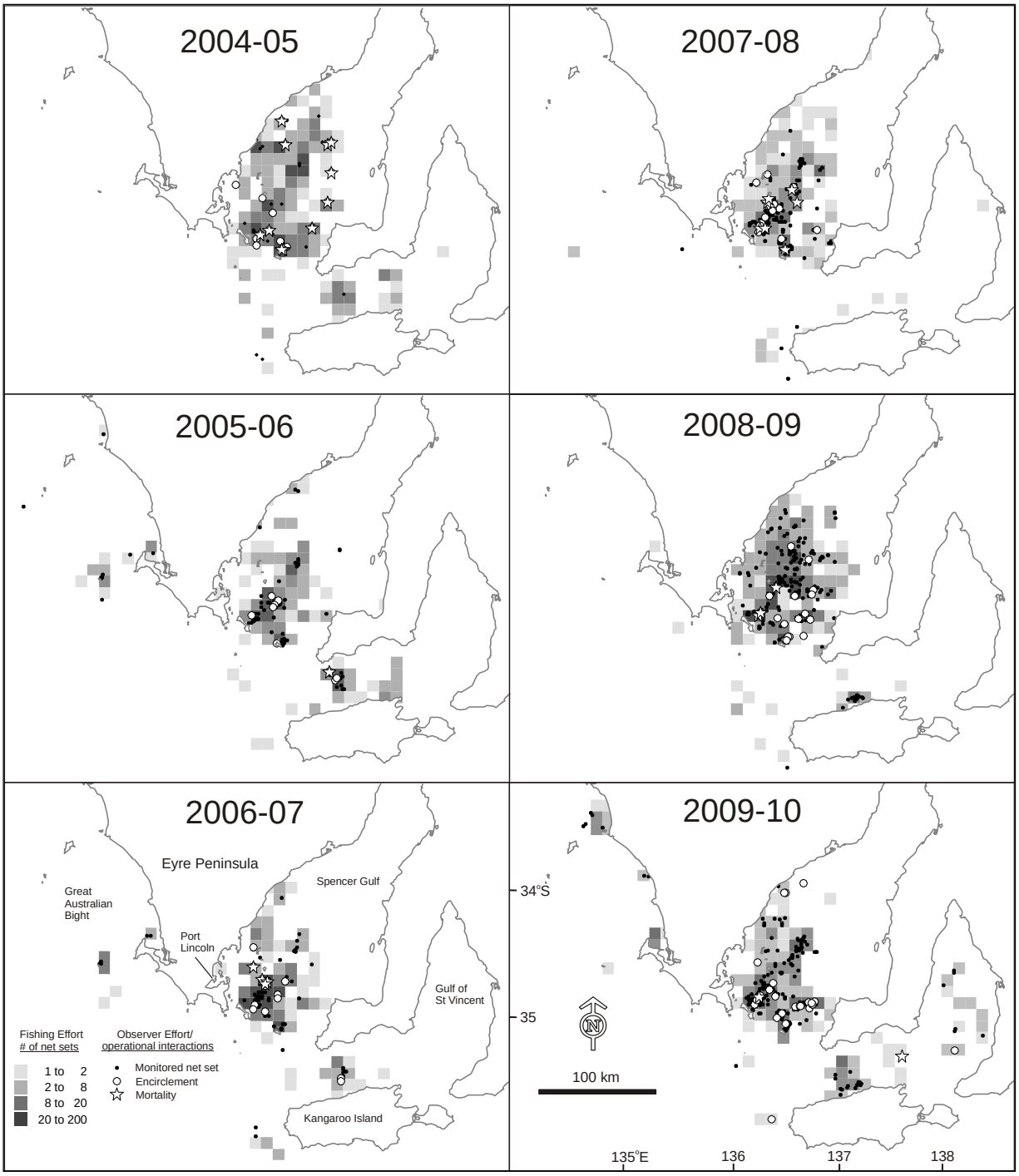

Figure 5. Spatial distribution of fishing effort, location of observed net sets, encirclement and mortality events in SASF during 2004-05 to 2009-10.

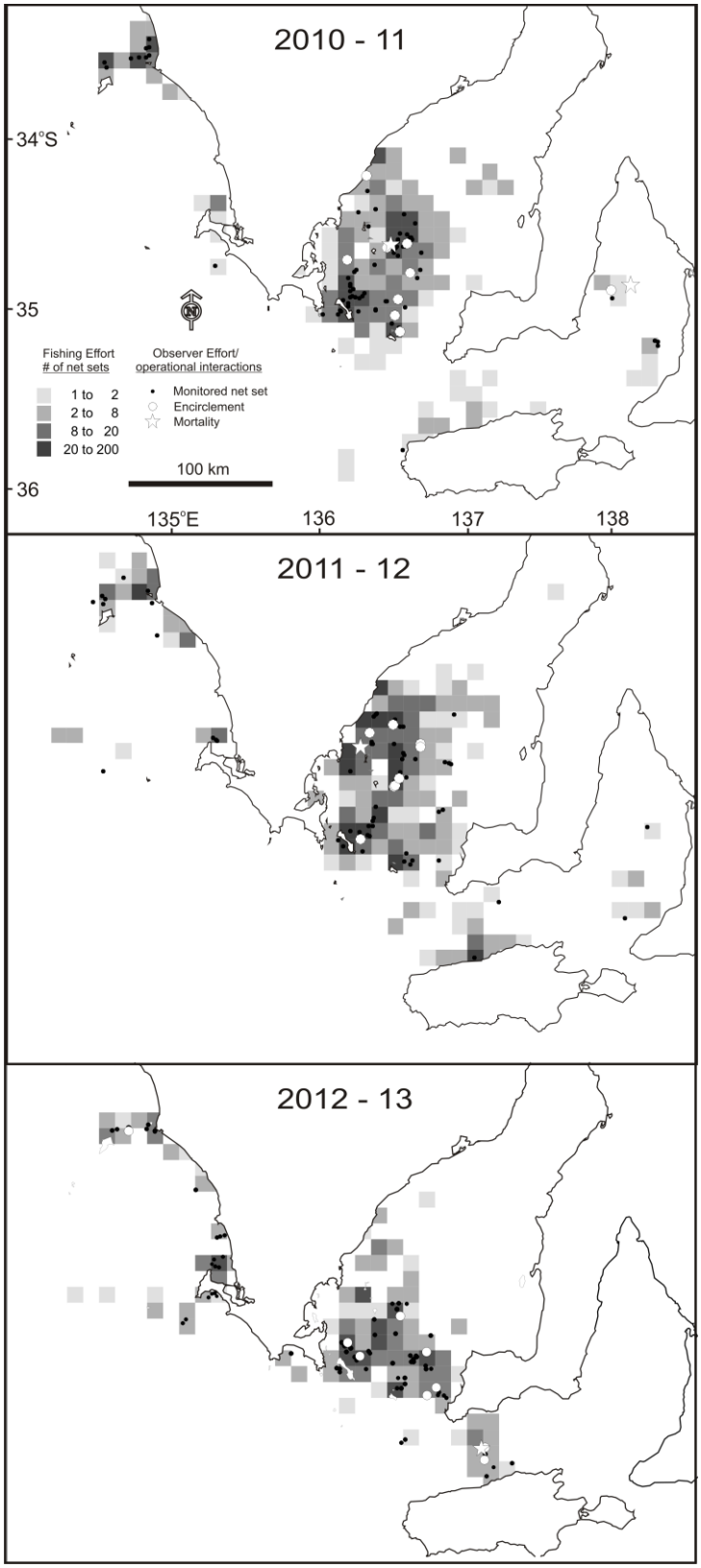

Figure 6. Spatial distribution of fishing effort, location of observed net sets, encirclement and mortality events in SASF during 2010-11, 2011-12 and 2012-13.

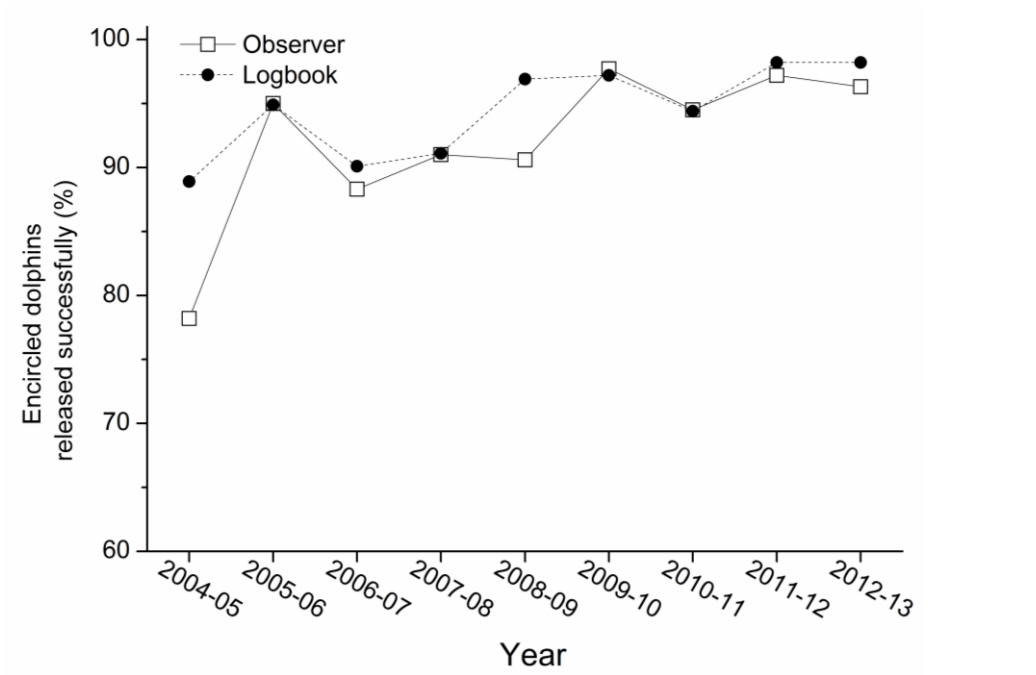

Figure 7. Percentage of encircled dolphins that were successfully released in the South Australian Sardine Fishery from 2004-05 to 2012-13 based on data from observer data and fishery logbooks.

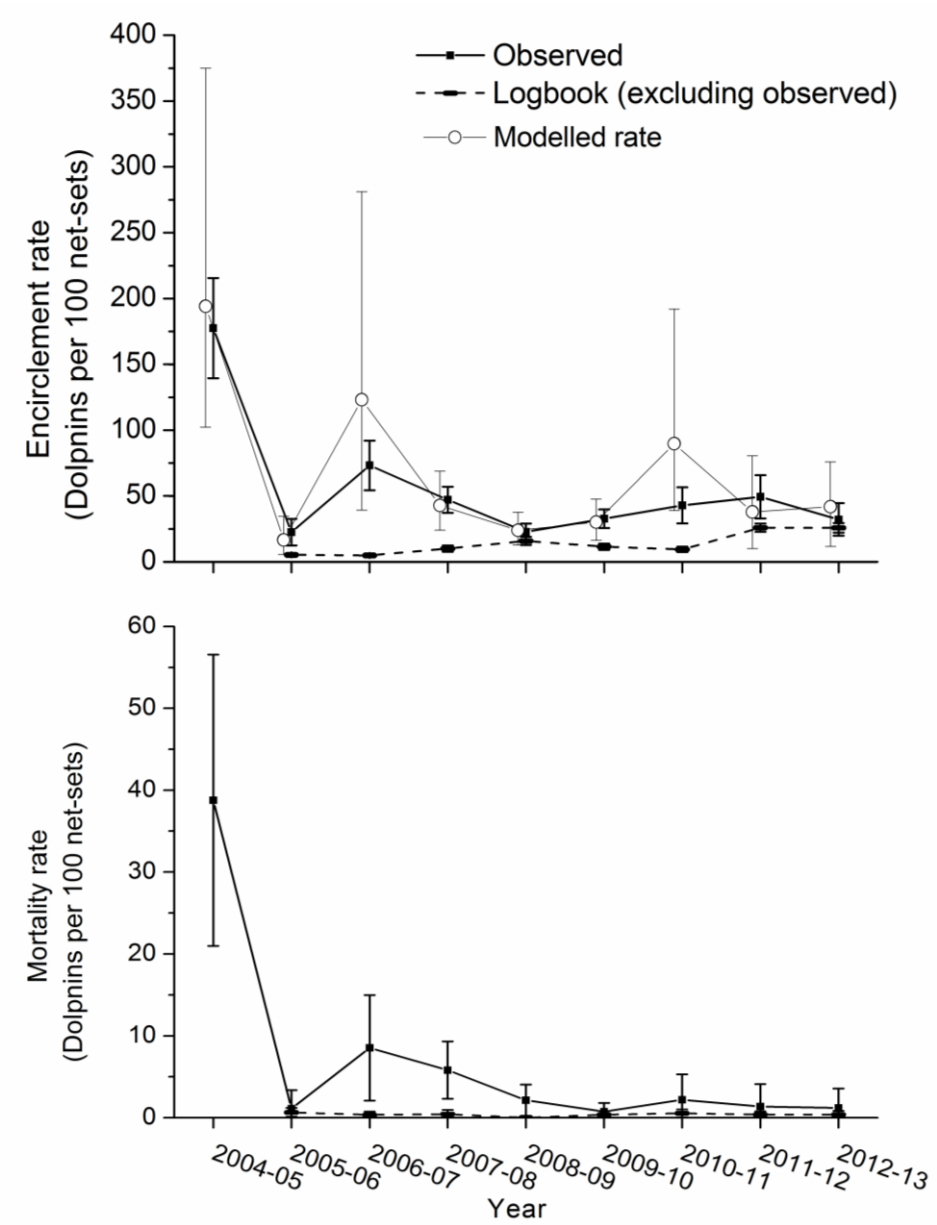

Figure 8. Rates of encirclement and mortality of short-beaked common dolphins in the South Australian Sardine Fishery between 2004-05 and 2012-13 calculated from observer data, logbook data and modelled using a GLM. Error bars are 95% confidence intervals. Note logbook data is calculated excluding observed interactions, in 2004-05 observed interactions exceeded logbook interactions.

3.4 Estimates of Dolphins Encircled and Mortalities

Extrapolation from observer data collected during the seven month study period in 2004-05 suggested that a total of 2200 (95% CI 1728-2672) dolphins were encircled resulting in 480 (260-701) mortalities (Figure 9), whereas logbook data indicated that only 68 dolphins were encircled and seven died (some encirclements and mortalities recorded by observers were not recorded in logbooks).

Estimates of total dolphins encircled and mortalities calculated from observer data for 2005-06, i.e. 227 (125-328) and 11 (0-34), respectively, were lower and less divergent to the numbers recorded in logbooks (68 and 7), respectively (Figure 9).

In 2006-07, extrapolations from observer data and fishing effort suggested that 681 (505-857) dolphins were encircled resulting in 79 (19-140) mortalities, whereas only 101 encircled dolphins and 10 mortalities were recorded in logbooks. The rate of encirclement and mortality calculated from observer data were 15 and 24 times higher, respectively, than the rates calculated from logbook data when observers were not present (Figure 9).

Extrapolations from observer data for 2007-08 suggested that 413 (95% CI 326–500) dolphins were encircled resulting in 51 (20–82) mortalities whereas logbook data indicated that 158 dolphins were encircled and 14 mortalities occurred. Rates of encirclement and mortality calculated from observer data were 5 and 13 times, respectively, the rates calculated from logbook data when observers were not present (Figure 9).

In 2008-09, the observer-based estimate and logbook-count of dolphins encircled, i.e. 205 (95% CI 149-262) and 159 dolphins, respectively, were more similar than the estimate and count of mortality, i.e. 19 (2-36) and five dolphins, respectively. The encirclement rate calculated from observer data was 1.4 times the rate calculated from logbook data when no observer was present. No mortalities were recorded in logbooks when an observer was not present (Figure 9).

The estimates of dolphins encircled and mortalities extrapolated from observer data for 2009-10, was 350 (95% CI 275-425) and 8 (0-19) dolphins, respectively. These estimates are almost twice that recorded in logbooks (179 dolphins encircled and 5 mortalities). The encirclement and mortality rate calculated from observer data were

2.9 and 2.0 times, respectively, the rates calculated from logbook data when no observer was present (Figure 9).

Extrapolations from observer data for 2010-11 suggested that 435 (95% CI 295–574) dolphins were encircled resulting in 22 (0–55) mortalities, whereas logbook data indicated that 126 dolphins were encircled and 7 mortalities occurred. Encirclement and mortality rates calculated from observer data were 4.5 and 4.1 times, respectively, than the rates calculated from logbook data when observers were not present (Figure 9).

In 2011-12, estimates of total dolphins encircled and mortalities based on observed rates were 546 (95% CI 364-728) and 15 (0-45), respectively, compared to 282 dolphins encircled and five mortalities recorded in logbook data. Observed rates of encirclement and mortality were 2.1 and 3.5 times, respectively, the rate calculated for trips without an observer (Figure 9).

The estimate of total dolphins encircled and mortalities based on observed rates declined in 2012-13 to 275 (95% CI 169-382) and 10 (0-31), respectively (Figure 9), and was similar to the numbers reported in logbooks (1.2 and 3.1 times, respectively).

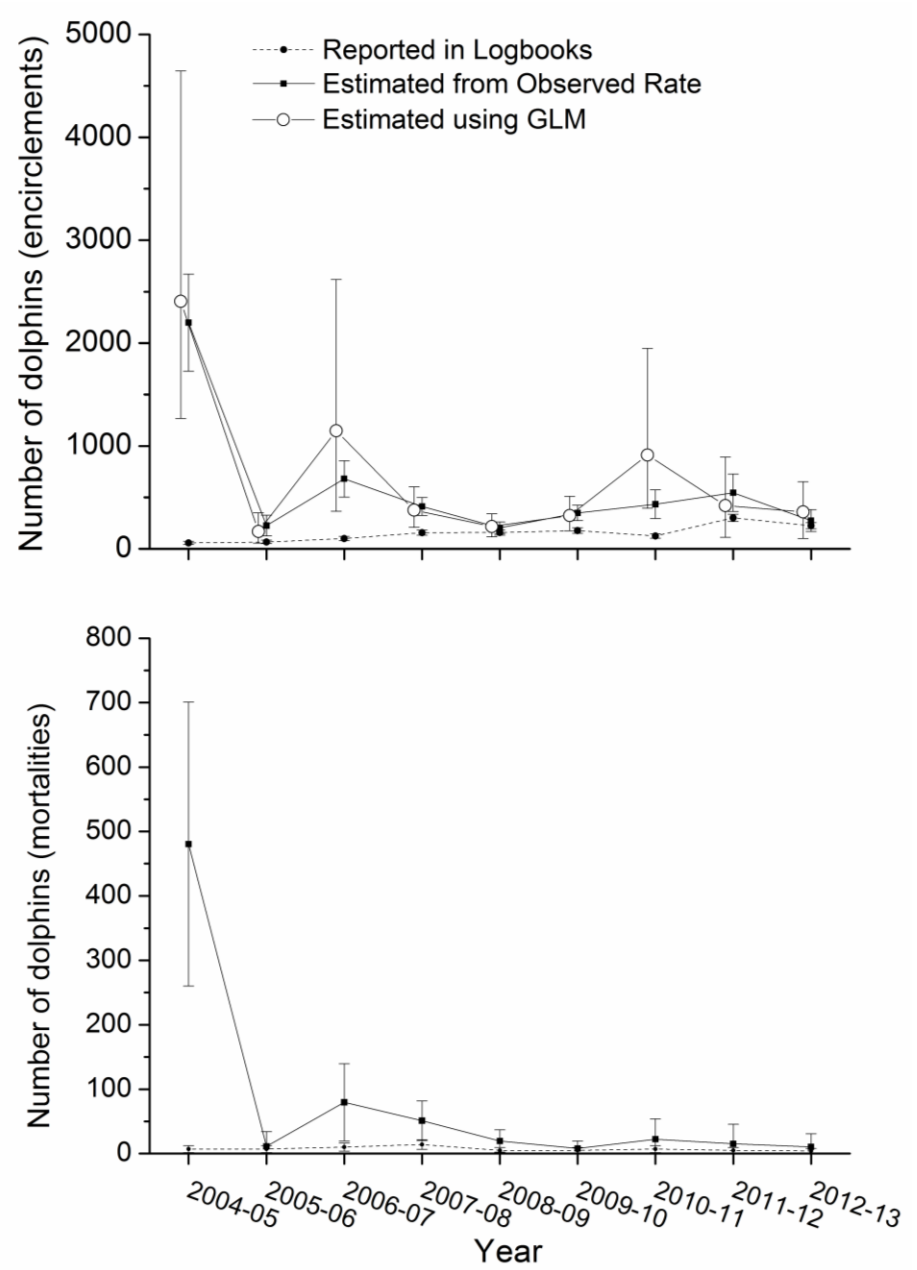

Figure 9. Estimated numbers of dolphins encircled and mortalities in the South Australian Sardine Fishery each financial year based on numbers recorded in fishery logbooks, extrapolation from observed rates and estimated using a GLM. Error bars are 95% confidence intervals.

3.5 Generalised Linear Modelling of Interaction Data

GLM results demonstrated that models 2 and 3, those fitted to Region and Month were both significant compared with the null model (Table 2). Including Region along with the month of fishing (model 4) was not an improvement from model 3, suggesting that the month of fishing and financial year alone best explain observed encirclements.

Table 2. Generalised linear model (GLM) results modelling the relationship between observed encirclements and covariates Region and Month for Financial Years between 2004-05 and 2012-13. Notation: Dev = residual deviance; df = residual degrees of freedom; AIC = Akaike's information criterion; ΔAIC is the change in AIC between the best and candidate model; p-value = likelihood ratio test between presented model and next most parsimonious model. Model 1 is the null model (Encirclements vary by Financial Year only).

	Model	Dev	df	AIC	ΔAIC	p-value
1	Encirclements ~ Financial Year (null)	345.8	969	1333.3	3.7	-
2	Encirclements ~ Financial Year + Region	346.7	965	1331.7	2.1	0.05
3	Encirclements ~ Financial Year + Month	349.7	958	1329.6	0	<0.01
4	Encirclements ~ Financial Year + Month + Region	351.1	954	1330.6	1.0	0.14

Extrapolating the observed encirclement rates to the fishery logbook data provided estimates of total dolphins encircled that ranged from 2405 and 1147 in 2004-05 and 2006-07, respectively, to 217 in 2008-09 (Figure 8 and 9). The extrapolated number of dolphins encircled in 2012-13 was 359, declining from 419 in 2011-12. Model estimates of encirclement rates were generally similar to the simple extrapolation, except for 2006-07 and 2010-11, when the model estimates were 1.7 and 2.1 times higher than the simple extrapolations.

3.6 Code of Practice Assessment

Interpretation and analysis of the success of release procedures is difficult due to the complex nature of each encirclement interaction and that multiple procedures are commonly undertaken during a single interaction. A summary of the application and success of the avoidance and release procedures outlined in the CoP is provided in Table 3. The use of corkline weights and TEPS gate are not included in the current CoP.

Table 3. Number of applications and percentage success of the avoidance and release procedures identified in the industry CoP in preventing encirclement and mortality of dolphins in the SASF during 2004-05 to 2012-13. The CoP was introduced in 2005-06. Note that avoidance procedure can be successful if a shot is not made due to the presence of dolphins and multiple release procedures can be implemented in a single encirclement event. A release procedure is considered unsuccessful if a mortality occurred.

Year	Avoidance Procedures No. (% success)		Release Procedures No. (% success)				
	Search	Delay	No action	Corkline Weights	TEPS Gate	Physical removal	Open front of net
2004-05	0	0	32 (15.6)	8 (53.3)	2 (50.0)	18 (88.9)	20 (80.0)
2005-06	6 (100.0)	15 (100.0)	0	4 (50.0)	7 (42.9)	3 (100.0)	13 (92.3)
2006-07	96 (85.4)	19 (89.5)	0	0	4 (100.0)	2 (100.0)	6 (83.3)
2007-08	216 (87.0)	50 (78.0)	0	0	2 (100.0)	6 (66.7)	11 (72.7)
2008-09	243 (91.4)	24 (95.8)	0	0	1 (0.0)	5 (80.0)	2 (100.0)
2009-10	280 (90.7)	101 (93.1)	0	0	0	0	10 (90.0)
2010-11	95 (88.4)	17 (94.1)	1 (100.0)	0	0	4 (50.0)	7 (100.0)
2011-12	67 (89.3)	3 (100.0)	1 (100.0)	0	0	0	7 (100.0)
2012-13	87 (88.5)	9 (77.7)	0	0	0	3 (66.6)	8 (87.5)

3.7 CPUE Comparison

Over the course of the study CPUE without an observer onboard ranged from 27.5 and 34.7 t.net-set^{-1} between 2004-05 and 2011-12 and then rose to 41.7 t.net-set^{-1} in 2012-13. CPUE with an observer onboard was generally similar to CPUE without an observer, except for 2005-06 and 2008-09, when CPUE dropped to 19.5 and 23.4 t.net-set^{-1}, respectively (Figure 10). In 2012-13, CPUE without an observer present rose to 41.7 t.net-set^{-1} and CPUE with an observer present was 32.1 t.net-set^{-1}.

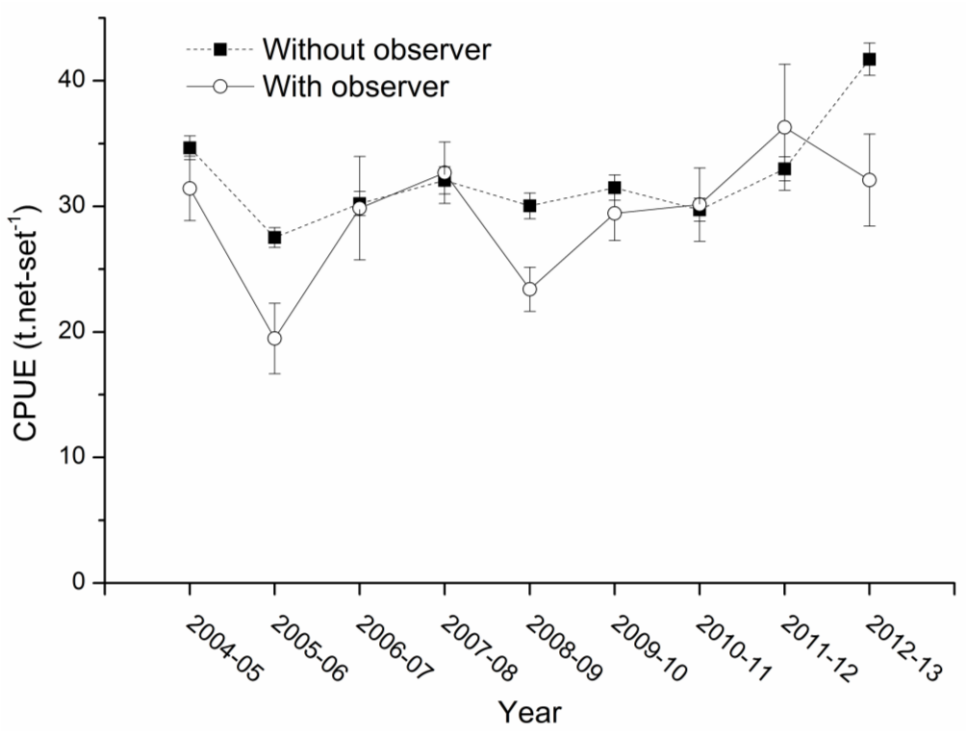

Figure 10. Catch per unit effort (CPUE) determined from logbook records for shots made with and without an observer onboard. Error bars are standard error.

4.0 DISCUSSION

The industry CoP has proven to be effective in reducing the interaction rates of the SASF with the short-beaked common dolphin. In 2004-05, before introduction of the CoP, the observed rate of dolphin encirclement in the SASF was 178 (95% CI 140 215) dolphins per hundred net-sets but after the CoP was introduced this rate did not exceed 73 dolphins per hundred net sets in any year. More importantly, the observed mortality rate in 2004-05 was 39 (21-57) dolphins per hundred net sets but did not exceed 9 dolphins per hundred net sets after the CoP was introduced.

The use of a GLM to investigate spatial and temporal variability in interaction rates showed that the rate of encirclement varied significantly among months. Despite this difference, estimates of numbers of dolphins encircled per year from the GLM were similar to those estimated using the simple extrapolation method in most years. The exceptions were 2006-07 and 2010-11 where the estimated number of dolphins encircled obtained using the GLM were higher than those from the simple extrapolations. The GLM could not be used to estimate total mortalities due to the infrequent occurrence of these events.

The overall reduction in the encirclement rate since the introduction of the CoP reflects the success of the avoidance procedures specified in the CoP in preventing interactions from occurring. Before the code was introduced, fishers seldom searched for dolphins prior to setting the net or delayed setting the net when dolphins were observed near the vessel. However, over the last six years these practices have been increasingly adopted in the fishery and are now standard operating procedures, being documented in the vessel-specific flowcharts that outline the role of each crew member in mitigating interactions with TEPS and which are located in the wheelhouse of each vessel.

The large reduction in the mortality rates since the introduction of the CoP reflects the co-occurrence of several changes in fisher behaviour. Most importantly, the reduction in encirclement rates has reduced the potential for mortality events to occur. However, the increase in the proportion of encircled dolphins successfully released has also played an important role and is the result of both reductions in the time taken to respond to encirclements and improvements in the procedures used to release dolphins. The reduction in response time since 2004-05 reflects: i) the requirement for all crew members to scan the area inside the net to determine if

dolphins are present as soon as the net is set (pursed); ii) the obligation to immediately report observed encirclements to the skipper; and iii) the skipper's responsibility to enact release procedures as soon as practical and make releasing the dolphin(s) the priority for the fishing operation. The improvement in the release procedure reflects the adoption of "opening the front of the net" as the agreed response to encirclements. It is notable that the only observed mortality event in 2012/13 occurred when physical removal was attempted before the front of the net was opened.

The success of the CoP is best shown in the large reductions in the estimates of total dolphins encircled and mortalities in the SASF since the code was introduced. Extrapolation from observer data suggests that in 2004-05, before the introduction of the CoP, 2,200 (95% CI 1728-2672) and 480 (260-701) dolphins were encircled and died, respectively, whereas it was estimated that 227 (125-328) dolphins were encircled and 11 (0-34) died in 2005-06, after its introduction. Total observer data over the last four years (2008-09 to 2012-13) suggest that fewer animals have been encircled (1605) and died (56) than during the twelve months prior to the CoP. In 2012-13, 275 (169-381) dolphins were estimated to have been encircled and 10 (0-30) dolphins to have died. The number of mortalities estimated to have occurred in 2012-13 was less than 3% of the number recorded in 2004-05.

The investigation of CPUE with and without an observer (Figure 10) has implications for the interpretation of the observed interaction rates. The three years where the CPUE with an observer present was lower than without an observer (2005-6, 2008-9 and 2012-13) correspond with the three years with low observed encirclement rates and the lowest discrepancy between observed and unobserved encirclement rates. This suggests that reduced observed encirclement rates in these years were in part reflective of a change in fisher behaviour when an observer was onboard the vessel.

The ongoing concern regarding the interaction of the SASF with the short-beaked common dolphin has been the discrepancy between the rates of interactions reported by observers and recorded in logbooks. In 2010-11, the encirclement and mortality rates calculated from observer data were 4.5 and 4.1 times, respectively than the rates calculated from logbook data when no observer was present. In contrast, the rates of encirclement and mortality recorded by observers in 2012-13 were 1.2 and 3.1 times, respectively, the rate recorded without an observer. This represents a 73% reduction in the discrepancy between observed and unobserved rates of

encirclement. The reduction in this discrepancy has occurred since the initiation of the industry based, near real-time monitoring system and it appears that this system has gone some way towards rectifying this discrepancy.

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