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, D.J. Hamer and P. Burch

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SARDI Aquatic Sciences
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EXECUTIVE SUMMARY

A Code of Practice (CoP) for Threatened, Endangered and Protected Species (TEPS) has previously been shown to be successful in mitigating the operational interactions of the Australian Sardine Fishery (SASF) with the short-beaked common dolphin (*Delphinus delphis*). Encirclement and mortality rates estimated from observer data for 2005-06 were 87% and 97% lower, respectively, than estimates for 2004-05, before the CoP was introduced. Estimates of total encirclement and mortality for the seven month sampling period (November-June) in 2005-06 were reduced to 169 (95% CI = 103-261) and eight (0-47) dolphins, respectively, down from 1728 (1384-2131) encirclements and 377 (227-589) mortalities, for the corresponding period in 2004-05. Discrepancies between encirclement and mortality rates calculated from observer data and recorded in fishery logbooks were reduced from factors of 27 and 54, respectively, to factors of less than two.

Extrapolations from observer data for 2006-07 (1 July - 30 June) suggested that 681 (95% CI = 520-877) dolphins were encircled and 79 (32-164) dolphins died, whereas only 101 encirclements and 10 mortalities were recorded in logbooks. The rates of encirclement and mortality calculated from observer data were 15 and 24 times higher, respectively, than rates calculated from logbook data when observers were not present. These differences were statistically significant ($p < 0.001$).

Following these increases in the interaction rates with the short-beaked common dolphin in 2006-07, the target level of observer coverage in the SASF was increased to 30% and the CoP was revised to stipulate requirements for: 1) effective searching for dolphins prior to setting the net; 2) no setting when dolphins were detected in the fishing area; 3) thorough searches for encircled dolphins immediately after setting was completed; 4) rapid initiation of release procedures when encircled dolphins were detected and 5) mandatory opening of front of the net if dolphins could not be released quickly by other means. Other initiatives included: mandatory crew inductions to the CoP; the development of vessel-specific CoP response flowcharts; bi-monthly skippers meetings to identify potential improvements to the CoP; quarterly meetings of the TEPS Working Group to consider up-to-date data summaries and make recommendations (if required) regarding improvements to the CoP; and formal annual public reporting of the fishery's interactions with TEPS.

Over the last three years (2007-08 to 2009-10), rates of encirclement and mortality calculated from observer data have been below 50 and six dolphins per hundred net sets, respectively. The estimated number of encirclements over the entire financial year fell from 416 (334-512) dolphins in 2007-08 to 202 (152-265) dolphins in 2008-09 and 349 (280-340) dolphins in 2009-10. Similarly, the number of mortalities has fallen from 51 (26-92) dolphins in 2007-08 to 19 (2-45) dolphins in 2008-09 and 8 (1-29) dolphins in 2009-10. Similarly, Logbook data suggest that in 2009-10 there were 179 encirclements and five mortalities. The encirclement and mortality rates for 2009-10 calculated from observer data were 2.9 ($p < 0.001$) and 2.0 ($p = 0.73$) times, respectively, the rates calculated from logbook data when no observer was present.

The efficacy of the CoP in mitigating interactions of the SASF with short-beaked common dolphins can be attributed to: i) the reduction in encirclement rates resulting from the success of the avoidance procedures (i.e. actively searching for dolphins prior to fishing and delaying setting when dolphins are present); and ii) the reduction in mortality rates resulting from the reduced response times (due in part to the active search for encircled dolphins immediately after the net is set) and the evolution and adoption of a highly successful release procedure (opening the front of the net).

This study provides evidence that an industry Code of Practice can successfully reduce the interaction rates of a purse-seine fishery with a delphinid. However, the SASF CoP includes a requirement for accurate reporting of operational interactions with TEPS. The TEPS Working Group has identified the need to further reduce the discrepancy between interaction rates reported by observers and those recorded in logbooks as a high priority for the SASF.

The refined CoP for the SASF explicitly aims for world's best practice and a process for continuous improvement in mitigating interactions with TEPS. The TEPS Working Group routinely considers options for further reducing rates of encirclement and mortality. Fishery-independent observers will continue to monitor future interactions to ensure compliance with the CoP. Skippers and the TEPS Working Group will continue to meet regularly to assess the need for further improvements to the code. A study is underway to investigate the population size, distribution and movement patterns of the short-beaked common dolphin in waters off southern Australia. A demographic study based on the large collection of samples currently held at the South Australian Museum has also been proposed. The results of these studies could facilitate quantitative assessment of the impacts of fishery bycatch on the population(s) of short-beaked common dolphin off southern Australia.

1.0 INTRODUCTION

Oceans cover approximately 70% of the Earth's surface and marine capture fisheries are an important source of protein for humans (FAO 2008). The additional land clearing required to replace fish protein with terrestrial livestock production would have significant negative impacts on global biodiversity and greenhouse gas production. It is essential that wild living resources harvested from the oceans are available to sustain the world's future human population. The challenge for the fishing industry, resource managers, fisheries scientists and conservationist is to ensure that the world's marine fisheries are managed sustainably (Worm et al. 2006, 2009).

For the last two decades, it has been widely recognised that fisheries must be ecologically sustainable, which means that not only must the target stock be maintained at productive levels but that negative impacts on other components of the ecosystem must also be minimised (e.g. Garcia 1997, 2000). Mitigating the operational interactions of fisheries with Threatened, Endangered and Protected Species (TEPS) is an important element of the ecosystem-based approach to fisheries management. In many countries, including the USA and Australia, the need for fisheries to assess and mitigate interactions with TEPS is prescribed in Federal and State fisheries and conservation legislation.

Purse-seining is used to target schooling pelagic fishes that support some of the world's largest fisheries, including those for tunas (e.g. *Thunnus* spp), sardine (*Sardinops sagax*) and anchovy (*Engraulis* spp.). Like several other fishing methods (Alverson et al 1994), purse-seining has been shown to have operational interactions with marine mammals, especially dolphins (Delphinidae) and porpoises (Phocoenidae). The best known example of this interaction is in the tuna fishery in the eastern tropical Pacific in which several hundred thousand spotted (*Stenella attenuata*), spinner (*S. longirostris*) and common (*Delphinus* spp.) dolphins were killed each year until gear modifications and changes to fishing practices were implemented and succeeded reducing mortality rates by more than 95% (Francis and Orbach, 1992; Joseph, 1995; Wade, 1995; Gosliner, 1999; Archer et al. 2001, 2004).

A 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 TEPS Code of Practice (CoP) and the establishment of a TEPS Working Group (involving licence holders, skippers, fisheries managers and scientists) in 2005. The rates of encirclement and mortality calculated from observer data in 2005-06 were reduced by 87% (down from 178 to 22 dolphins per hundred net-sets) and 97% (down from 39 to one dolphin per hundred net-sets), respectively, compared to rates calculated in 2004-05, before the introduction of the CoP. It was estimated that eight mortalities occurred across the entire fleet during the seven-month study period after the CoP was introduced, whereas approximately 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 less than factors of two (down from factors of 27 and 54, respectively). Hamer et al. (2009a) emphasized the important role that establishing and maintaining an effective working relationship between industry and scientists had played in achieving this important conservation outcome.

A study published shortly after Hamer et al. (2008) suggested that the existence of a high level of genetic differentiation between populations of short-beaked common dolphin in South Australia and south-eastern Tasmania and emphasized the need for effective mitigation of the operational interactions of the SASF with this species (Bilgmann et al. 2008). Although Hamer et al. (2008) 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 (Hamer et al. 2008; Bilgman et al. 2009). Successful bycatch mitigation programs typically involve longer ongoing observer coverage, expert review and continuous improvement of mitigation practices (Waugh et al. 2008; Wiley et al. 2008). Bilgman 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.

In the period since the study by Hamer et al. (2008), the level of observer coverage in the SASF has been increased, the CoP has been refined and additional measures have been taken to address interactions with the short-beaked common dolphin. The refined CoP for the SASF explicitly aims for world's best practice and a process for continuous improvement in mitigating interactions with TEPS. Each crew is re-inducted to the CoP 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 government conservation agency (South Australian Department of Environment and Heritage), 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).

This study reports on the interactions of the SASF with the short-beaked common dolphin (*Delphinus delphis*) during the period from 2004-05 to 2009-10. Data for 2004-05 and 2005-06, which were also presented in Hamer et al. (2008), are included here to provide a context for results from the more recent years. 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 dolphin encirclements 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.

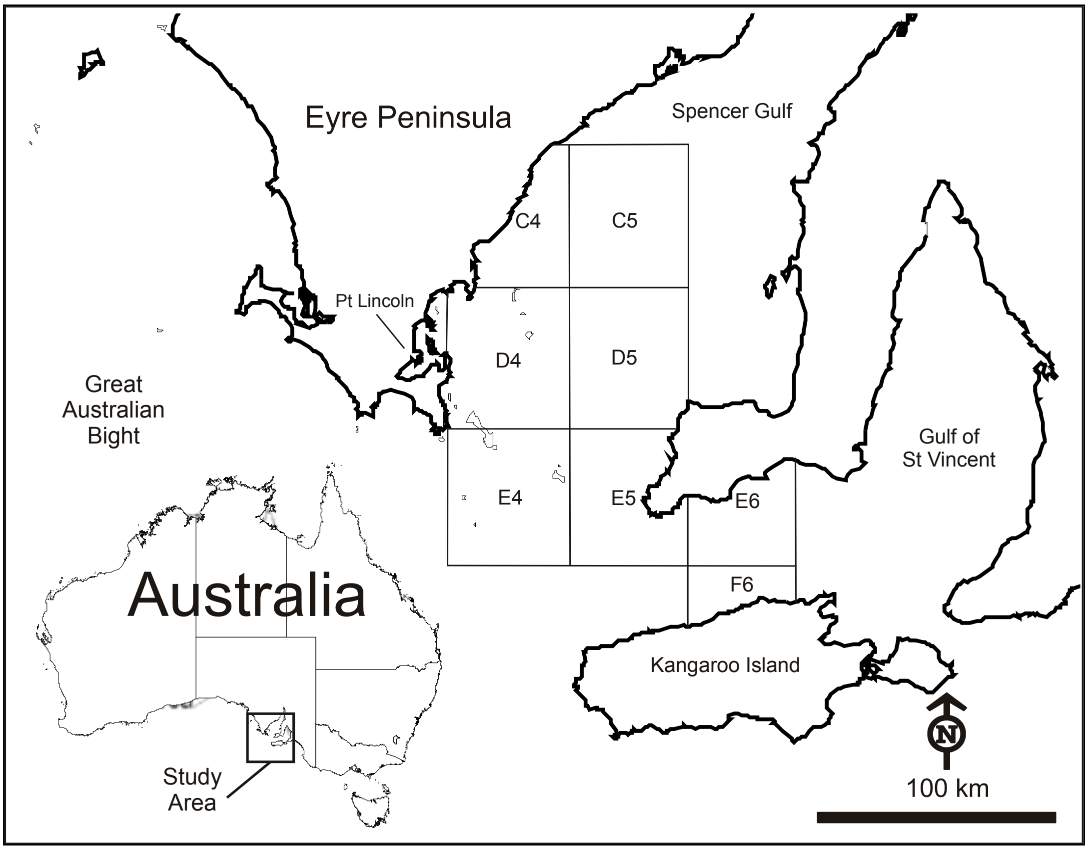

Figure 1. Location of the study, fishing areas and sites mentioned in the text.

2.0 METHODS

2.1 South Australian Sardine Fishery

The South Australian Sardine Fishery (SASF) is Australia's largest single-species fishery (by weight) with total annual catches over the last five years ranging from ~25,000 to ~42,000 tonnes. The SASF operates primarily in southern Spencer Gulf (Fig. 1) and was established in 1991 to provide fodder for the grow-out of wild caught southern bluefin tuna (*Thunnus maccoyi*). However, a significant proportion of the catch is now taken for human consumption and recreational fishing bait.

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), but 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 fishers through license fees.

Licence-holders are actively involved in management of the SASF and conduct frequent meetings with PIRSA Fisheries and SARDI Aquatic Sciences. There is a formal Management Plan and defined Harvest Strategy (Shanks 2005). The revised Harvest Strategy for the SASF indicates that the baseline TAC (30,000 t) will be maintained while the latest estimate of spawning biomass remains between the limit reference points of 150,000 and 300,000 t and there is no other evidence of serious stock decline.

Fishery-independent stock assessments (e.g. Ward et al. 2009) using the Daily Egg Production Method are done regularly (annually from 1995 to 2007 and now biennially). Fishery Assessment Reports that integrate fishery-independent and 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.

2.2. Logbook program

Fishers are required to complete Monthly Logbooks that document the date, location and timing of each net-set, the weight of each catch and the details of interactions with TEPS (e.g. number of encirclements, number of mortalities). The Monthly

Logbook for each vessels must be submitted to SARDI Aquatic Sciences before the fifteenth day of the following month. Since 2007, fishers have also been required to complete Wildlife Interaction Forms when interactions with TEPS occur. Data from Logbooks and Wildlife Interaction Forms are validated, stored and collated by SARDI Aquatic Sciences.

2.3 Observer program

An Observer Program was conducted by SARDI Aquatic Sciences from November 2004 to January 2006 and by Protec Marine Pty. Ltd. from February 2006 to June 2010. 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 setting the net 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 encirclements, number of mortalities), the nature and success of avoidance and release procedures used and the timing of their implementation. The avoidance procedures used were searching for dolphins prior to setting the net (deemed successful if no dolphins were detected and no encirclement occurred) and delaying the setting of the net (deemed successful if setting was delayed and no dolphins were encircled when the net was set). The release methods considered in the report are: no action (where no effort was made to release encircled dolphins); corkline weights (where weights were used to sink the corkline to provide an opening for dolphin egress); TEPS gate (panel of net was unclipped from corkline to provide an opening for dolphin egress); physical removal (where dolphins were removed from the net by crew members in a skiff); and opening the front of net (where the front of the net was let go to provide opening for dolphin egress). Data recorded on Observer Datasheets were validated, stored and collated by SARDI Aquatic Sciences.

2.3 Data analysis

Effort data from Monthly Logbooks were collated into 10 x 10 km grid squares using MapInfo© 9.0. Effort data from Observer Datasheets were collated into both 10 x 10 km grid squares and the larger fishing areas (Figure 1). Effects of year, month and fishing area (main effects only, data were too sparse to assess interactions) on the rates of encirclement and mortality recorded by observers were examined with a Generalized Linear Model with Type III sums of squares, a negative binomial probability distribution and a log link function (SPSS© 18.0). Months and fishing areas where less than 10 net sets were observed were excluded from these analyses. The effect of year on response time was examined using a one-way analysis of variance; post-hoc pair-wise comparisons were made using a least significant difference test.

Confidence intervals for the rate of encirclements and mortalities were calculated using exact Poisson methods (Blaker 2000). The differences between rates of encirclement and mortality from fishing events with observers present and those without observers was determined using a two-sided exact Poisson test with an alpha of 0.05 (Fay 2010). Total encirclements and mortalities for each financial year were estimated from the rate per net-set where observers were present, multiplied by the total number of net sets in the season. Uncertainties around all estimates are presented as 95% CIs.

3.0 RESULTS

3.1 Fishing patterns

Data from Fishery Logbooks suggest that that the level fishing effort within a financial year ranged from 884 net-sets in 2007-08 to 1069 net-sets in 2009-10 (Table 1). In most years, most fishing effort was recorded between January and June (Figure 2). In some fishing seasons, significant effort occurred in December (e.g. 2005-06) and July (2009-10). Most fishing was conducted in lower Spencer Gulf (Figure 3).

Direct comparisons of Observer Datasheets and Fishery Logbooks suggested that 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 nets sets made annually in the SASF is higher than indicated in Table 1.

3.2 Patterns of dolphin encirclement and mortality

Logbook program

The number of encirclements recorded in Fishery Logbooks increased from 63 dolphins (in 28 separate encirclement events) in 2004-05 to 179 (60 events) in 2009-10 (Table 1). In contrast, the number of mortalities recorded in Fishery Logbooks was relatively stable, with seven dolphin mortalities (six events) recorded in 2004-05 (seven months of data only) and five mortalities (five events) recorded in 2009-10.

The rates of encirclement calculated from logbook data increased from 6 (95% CI = 5-8) dolphins per hundred net-sets in 2004-05 to 13 (10-16) and 11 (9-13) dolphins per hundred net-sets in 2005-06 and 2006-07, respectively, and remained stable at 16-18 dolphins per hundred net-sets from 2007-08 to 2009-10 (Figure 4). The rates of mortality calculated from logbook data did not exceed two dolphins per hundred net-sets in the period between 2004-05 and 2009-10 (Figure 4).

Observer program

In 2004-05 and 2005-06, the Observer Program was conducted between November and June only (Figure 2), whereas since 2006-07 observations were made over the entire financial year (with the exception of October-December 2009). The number and percentage of net-sets observed each year increased from 49 (5%) in 2004-05 to 233 (26.2%) in 2008-09, with the largest increase occurring between 2006-07 and 2007-08 (Table 1). Although the highest levels of fishing and observer effort consistently occurred during the second half of the financial year, a high proportion of net-sets was often observed during the first half of the financial year, when fishing effort was low (Figure 2).

The number of dolphins encircled while an observer was onboard fell from 87 dolphins (18 events) in 2004-05 to 20 dolphins (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 net-sets monitored by observers. 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).

The rates of encirclement recorded by observers fell from 178 (95% CI = 142-219) dolphins per hundred net-sets in 2004-05 to 23 (14-35) dolphins per hundred net-sets in 2005-06, but increased to 73 (56-94) dolphins per hundred net-sets in 2006-07 (Figure 3). The observed rates of encirclement in 2007-08, 2008-09 and 2009-10 were 47 (38-58), 23 (17-30) and 33 (26-40) dolphins per hundred net-sets, respectively (Figure 4). The rates of encirclements varied significantly among years, months and areas (Table 3). The highest relative encirclement rates occurred in 2004-05 and 2006-07 and in the high effort months of January to May and the important fishing areas D4, D5 and E4 (Figure 5).

The number of observed mortalities fell from 19 dolphins (11 events) in 2004-05 to one dolphin in 2005-06, but increased to seven dolphins (four events) in 2006-07. In 2007-08, 11 dolphin mortalities (eight events) were recorded by observers and that number fell to five dolphins (three events) and two dolphins (two events) in 2008-09 and 2009-10, respectively.

The number of encirclements observed remained relatively stable and the decline in the number of dolphin mortalities observed mainly reflected the increase in the percentage of encircled dolphins that survived, which rose from 78% in 2004-05 to 95% in 2005-06 (Figure 6). Although the percentage of encircled dolphins that subsequently survived fell to 88% in 2006-07, it increased to reach 98% in 2009-10.

The observed mortality rates fell from 39 (95% CI = 23-61) dolphins per hundred net-sets in 2004-05 to one (0-6) dolphins per hundred net-sets in 2005-06, but increased to 9 (3-18) dolphins per hundred net-sets in 2006-07, before declining to six (3-10), two (1-5) and one (0-3) dolphins per hundred net-sets in 2007-08, 2008-09 and 2009-10, respectively.

The GLM suggested that rates of mortalities varied significantly among years but not among months and areas (Table 3). The relative mortality rate was highest in 2004-05 and lowest in 2009-10 (Figure 5). Although differences were not statistically significant, perhaps due to the low number of mortalities in recent years, the mortality rates were relatively high in the months of high fishing effort from February to July and the main fishing areas C5, D4, D5, E4, and E5 (Figure 5). Some convergence criteria for the GLM for mortality were not satisfied and the fit was poor (deviance/degrees of freedom = 0.180), so model outputs should be interpreted with some caution.

3.2 Estimates of dolphin encirclement and mortality

Extrapolation from observer data collected during the seven month study period in 2004-05 suggest that a total of 1728 (95%CI = 1384-2131) and 377 (227-589) dolphins were encircled and died, respectively (Figure 7), whereas logbook data indicated that only 63 dolphins were encircled and seven died (some encirclements and mortalities recorded by observers were not recorded in logbooks). Estimates of total encirclements and mortalities calculated from observer data for the corresponding seven month sampling period in 2005-06, i.e. 169 (103-261 dolphins) and eight (0-47) dolphins, respectively, were lower and more similar to the numbers recorded in logbooks (98 and five dolphins, respectively).

In 2006-07, extrapolations from observer data suggested that 681 (95% CI = 520-877) dolphins were encircled and 79 (95% CI = 32-164) dolphins died, whereas only 101 encirclements and 10 mortalities were recorded in logbooks. The rates of encirclement and mortality calculated from observer data were 15 and 24 times higher, respectively, than rates calculated from logbook data when observers were not present. These differences were both statistically significant ($p < 0.001$).

Extrapolations from observer data for 2007-08 suggested that 416 (95% CI = 334 – 512) dolphins were encircled and 51 (95% CI = 26 – 92) died whereas logbook data indicated that 158 encirclements and 14 mortalities occurred. Encirclement and mortality rates calculated from observer data were five ($p < 0.001$) and 13 ($p < 0.001$)

times, respectively, the rates calculated from logbook data when observers were not present.

In 2008-09, the observer-based estimate and logbook-count of encirclement, i.e. 202 (95% CI = 152-265) and 159 dolphins, respectively, were more similar than the estimate and count of mortality, i.e. 19 (6-45) 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. This difference was not statistically significant ($p = 0.054$). No mortalities were recorded in logbooks when an observer was not present.

The estimates of encirclement and mortality extrapolated from observer data for 2009-10, i.e. 349 (95% CI = 280-430) and 8 (1-29) dolphins, respectively, were less than double the numbers recorded in logbooks (179 encirclements and five mortalities). The encirclement and mortality rate calculated from observer data were 2.9 ($p < 0.001$) and 2.0 ($p = 0.73$) times, respectively, the rates calculated from logbook data when no observer was present.

3.3 Code of Practice assessment

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 2). However, after the introduction of the CoP, fishers consistently searched for dolphins before setting the net and consistently delayed setting when dolphins were detected near the vessel. The success of these avoidance procedures is reflected in the reductions in dolphin encirclement rates in recent years (Table 2, Figure 4, 5).

In 2004-05, before the introduction of the CoP and when rates of encirclement were high, 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 swim away.

Over time, the number of release procedures used in SASF (and specified in the CoP) has been reduced. Corkline weights and the TEPS Gate are no longer used because they are difficult to deploy and dolphins to 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 which is now recommended in the CoP, i.e. opening the front of the net, is highly successful in allowing dolphins to escape (Table 2). The only time that opening the front of the net does not succeed in releasing dolphins alive is when it is not undertaken early enough.

The average response time (i.e. the period between encircled dolphins being detected and action being taken) in 2004-05, before the introduction of the CoP, was 61.9 minutes ($\pm$25.1 95% CI). The average response time but did not exceeded 16 minutes in any year since 2005-06 (Figure 9). The average response time in 2004-05 is significantly different from that in all other years (One-way ANOVA, df = 5, 111, F = 10.5, p < 0.001). A pairwise comparison did not find any significant difference in the average response time for any of the years after the introduction of the CoP. Since the introduction of the CoP the maximum observed response time was 64 minutes. The increases in the survival rates of encircled dolphins in recent years (e.g. 97% in 2009-10) reflect both the reduction in response times and the effectiveness of the release procedure that is now used (i.e. opening the front of the net).

Table 1. Number of net-sets, % observer coverage, dolphins encirclements and mortalities (numbers and events) recorded in Fishery Logbooks and Observer Datasheets in 2004-05, before the introduction of the industry Code of Practice, and 2005-06 to 2009-10, after its introduction. Note that for 2004-05 and 2005-06 data are only included for the seven month period of the observer program in those years (November–June).

Year	Total Net-sets (Logbooks)	Observed Net-sets (Datasheets)	% Observer Coverage	Encirclements No. (events)		Mortalities No. (events)	
				Logbook	Observer	Logbook	Observer
2004-05	973	49	5.0	63 (28)	87 (18)	7 (6)	19 (11)
2005-06	753	89	11.8	98 (47)	20 (9)	5 (5)	1 (1)
2006-07	931	82	8.8	101 (43)	60 (14)	10 (5)	7 (4)
2007-08	884	189	21.4	158 (59)	89 (28)	14 (10)	11 (8)
2008-09	890	233	26.2	159 (61)	53 (21)	5 (3)	5 (3)
2009-10	1069	266	24.9	179 (60)	87 (26)	5 (5)	2 (2)

Table 2. Number of applications and percentage success of the avoidance and release procedures identified the industry Code of Practice in preventing encirclement and mortality of dolphins in the SASF during 2004-05 to 2009-10. The Code of Practice was introduced in 2005-06.

Year	Avoidance Procedures		Release Procedures				
	Search No. (% success)	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)

Table 3. Results of the Generalised Linear Models of effects of year, month and fishing area (Figure 1) on encirclement and mortality rates of short-beaked common dolphins in the South Australian Sardine Fishery.

	Encirclements			**Mortalities**		
Goodness of fit	Value	df	Value/df	Value	df	Value/df
Deviance	813.5	827	0.984	148.9	827	0.180
Akaike's Information Criteria (AIC)	1336.4			286.9		
Finite Sample Corrected AIC	1337.7			288.92		
Model effects	Wald Chi Sq.	df	p	Wald Chi Sq.	df	p
Intercept	70.5	1	< 0.001	78.5	1	< 0.001
Year	89.0	5	< 0.001	48.2	4	< 0.001
Month	65.9	10	< 0.001	7.1	5	0.212
Fishing area	26.6	7	< 0.001	26.6	4	0.139

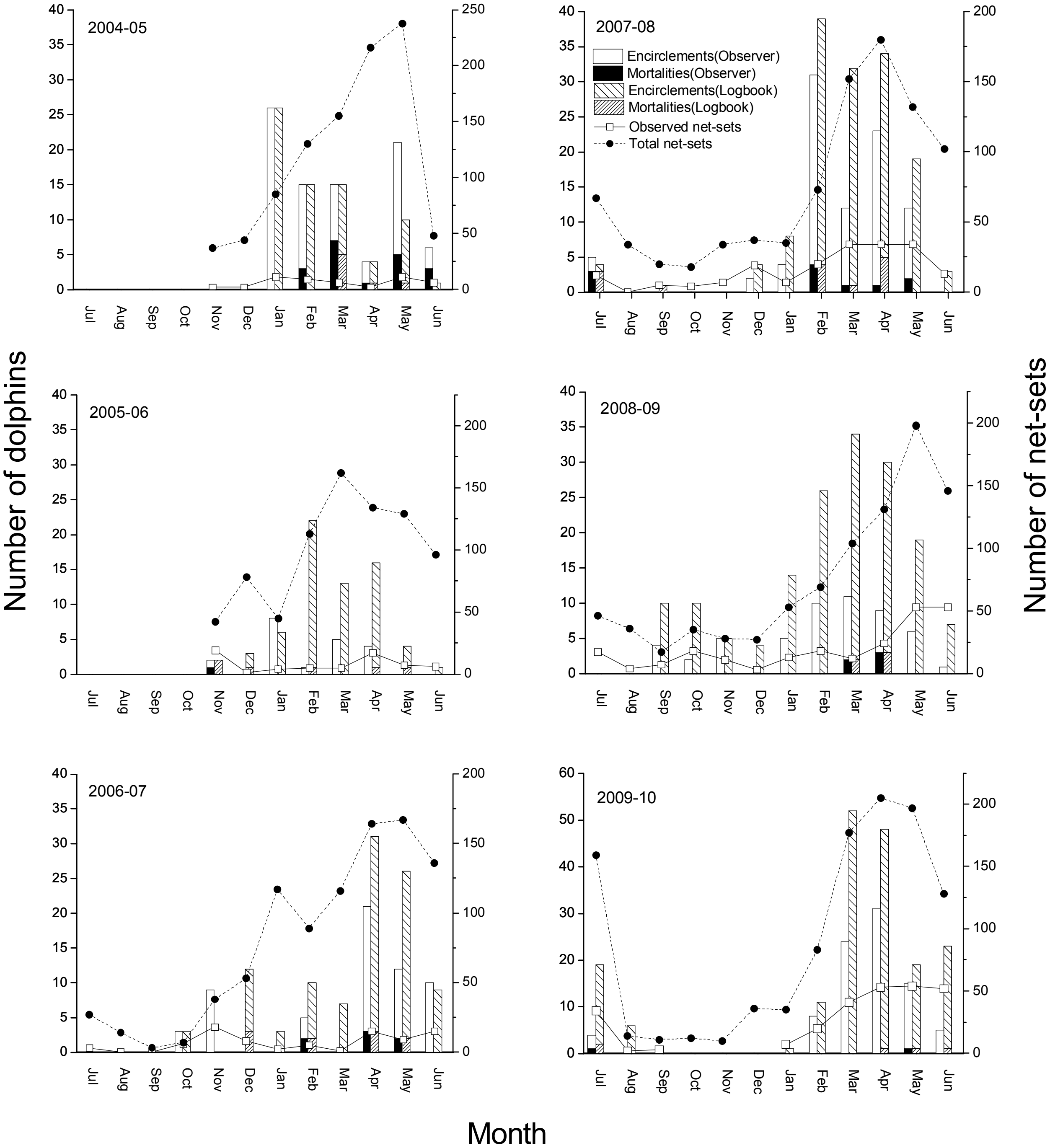

Figure 2. Fishing effort (logbook net-sets), observer effort (observed net-sets), and number of dolphin encirclements and mortalities before (2004-05) and after (2005-06 to 2009-10) the introduction of the industry Code of Practice in the South Australian Sardine Fishery.

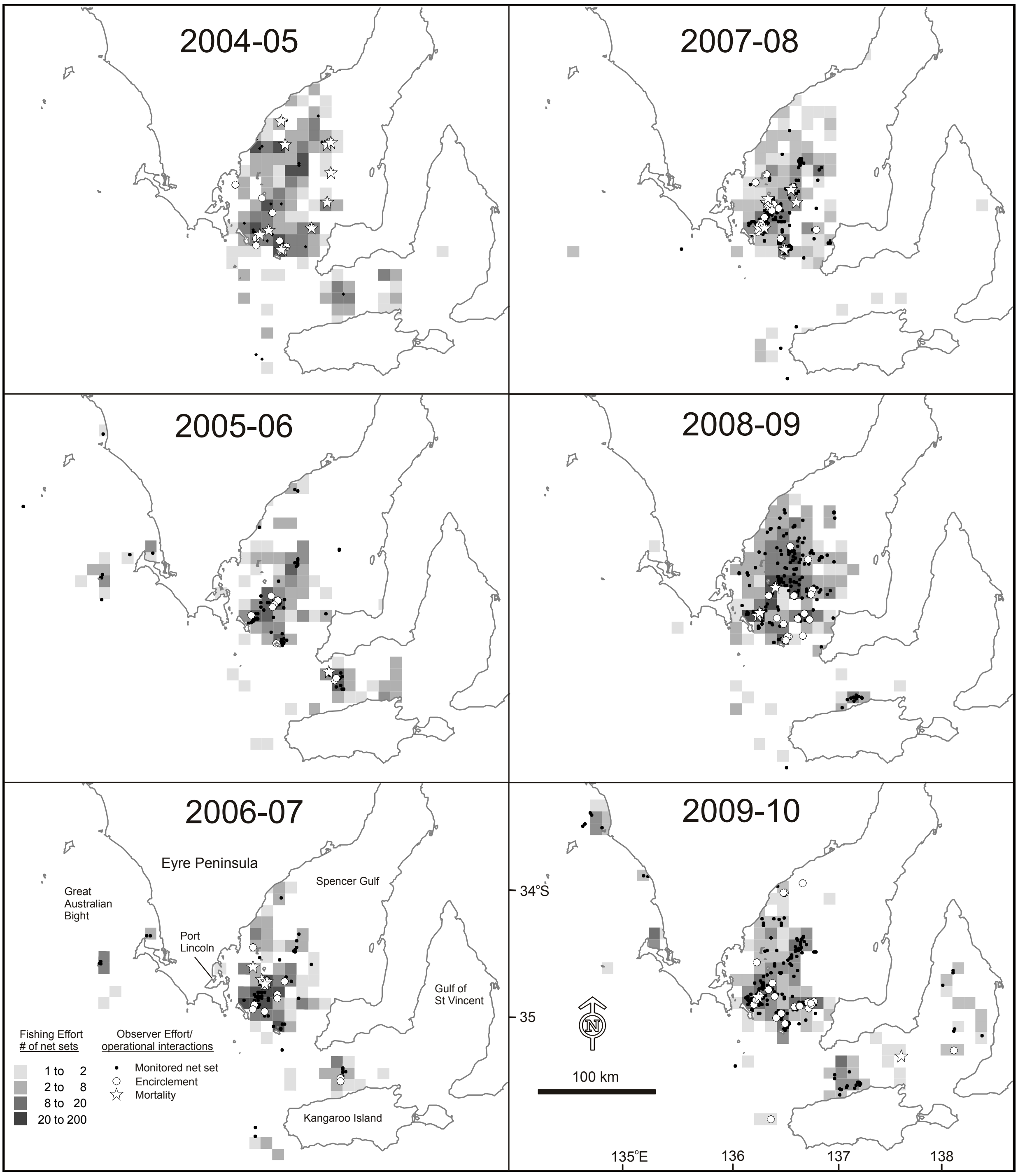

Figure 3. Spatial distribution of fishing effort, location of observed encirclement and mortality events in SASF during 2004-05 to 2009-10.

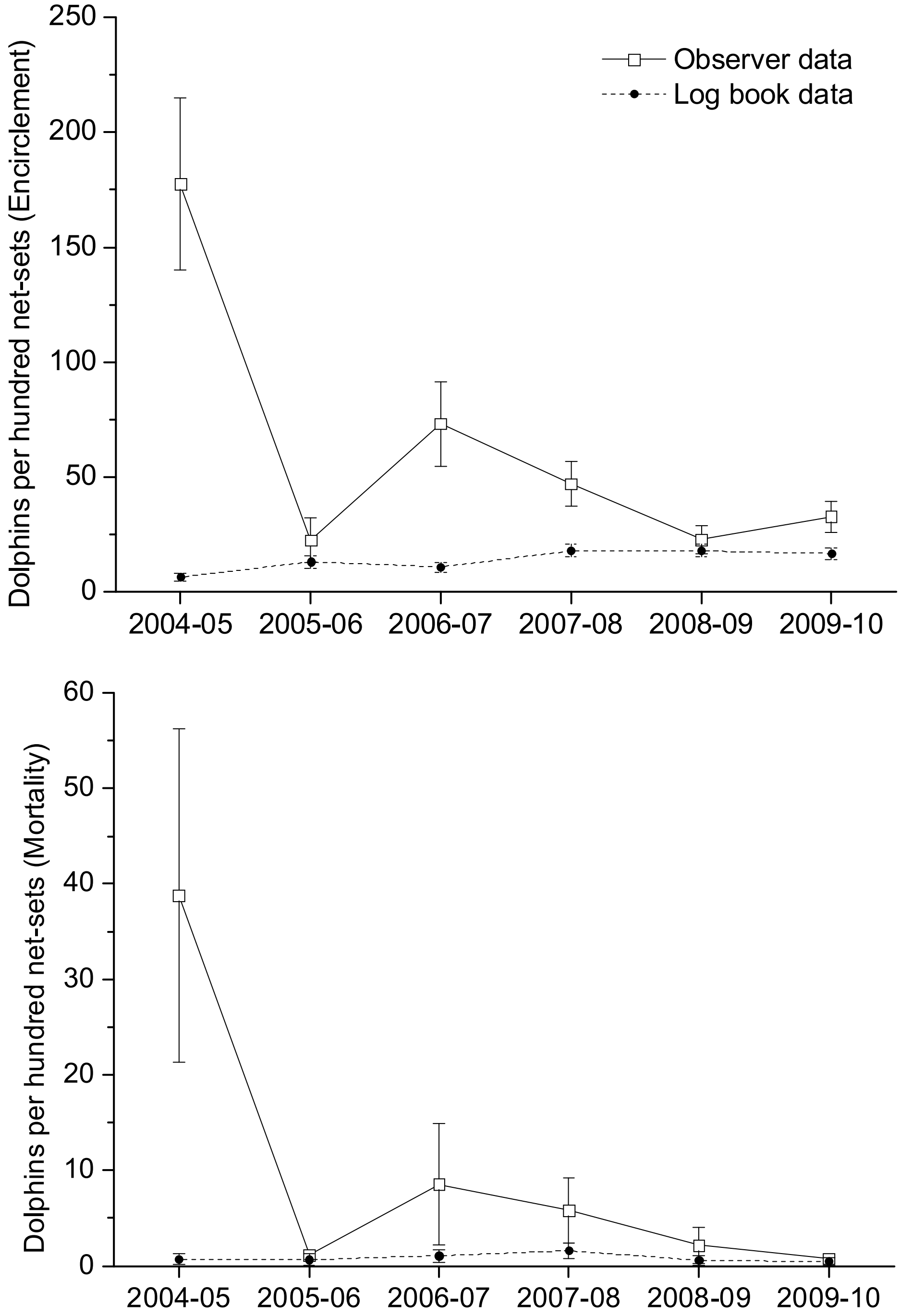

Figure 4. Rates of encirclement and mortality of short-beaked common dolphins in the South Australian Sardine Fishery between 2004-05 and 2009-10 calculated from observer and logbook data. Error bars are 95% confidence intervals.

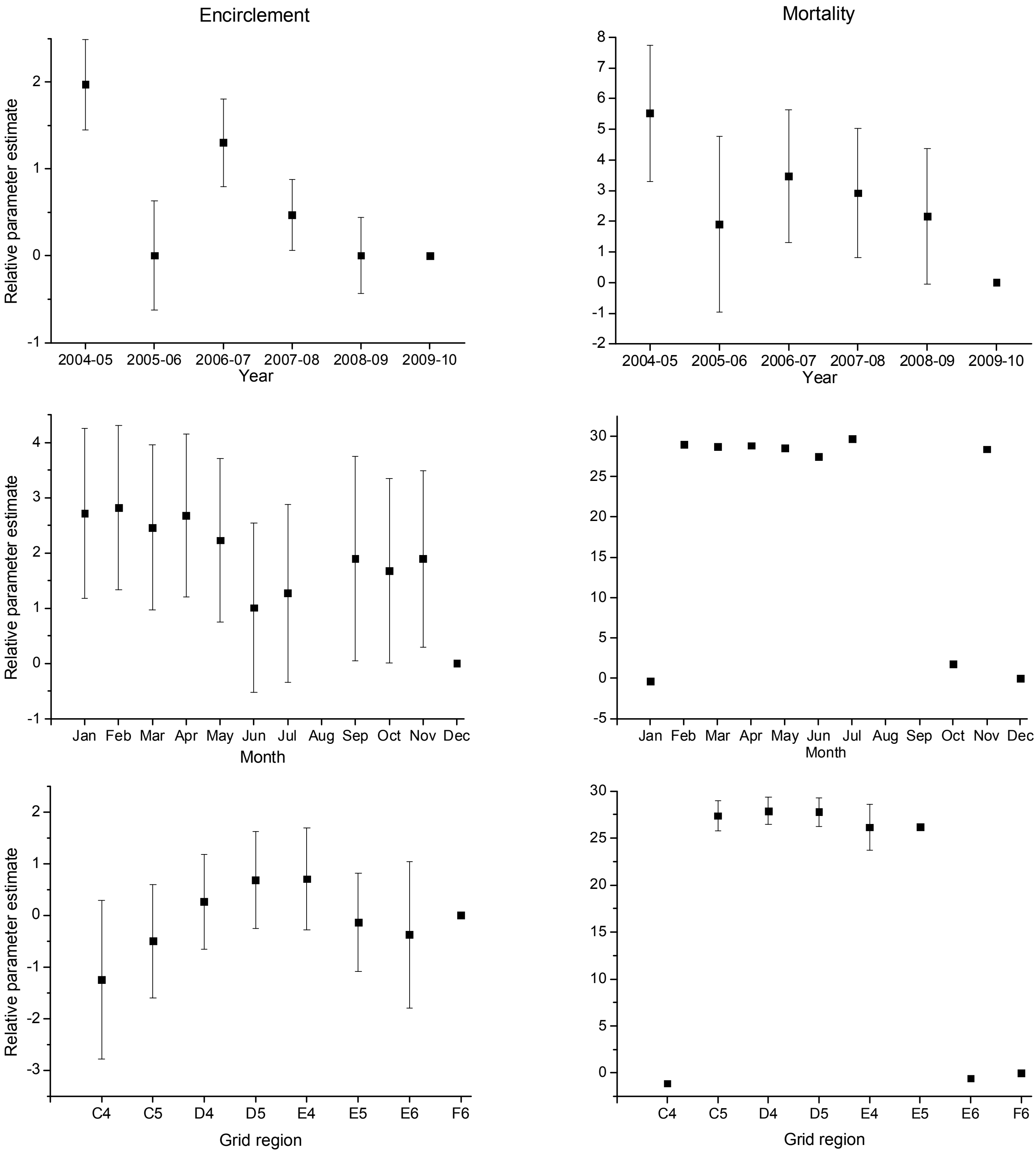

Figure 5. Plots of relative variation (parameter estimates from Generalized Linear Models) in numbers of dolphins encircled and killed per net set by year, month and grid region in South Australian Sardine Fishery. Error bars are 95% confidence intervals, where none are presented the parameter estimated were unbounded.

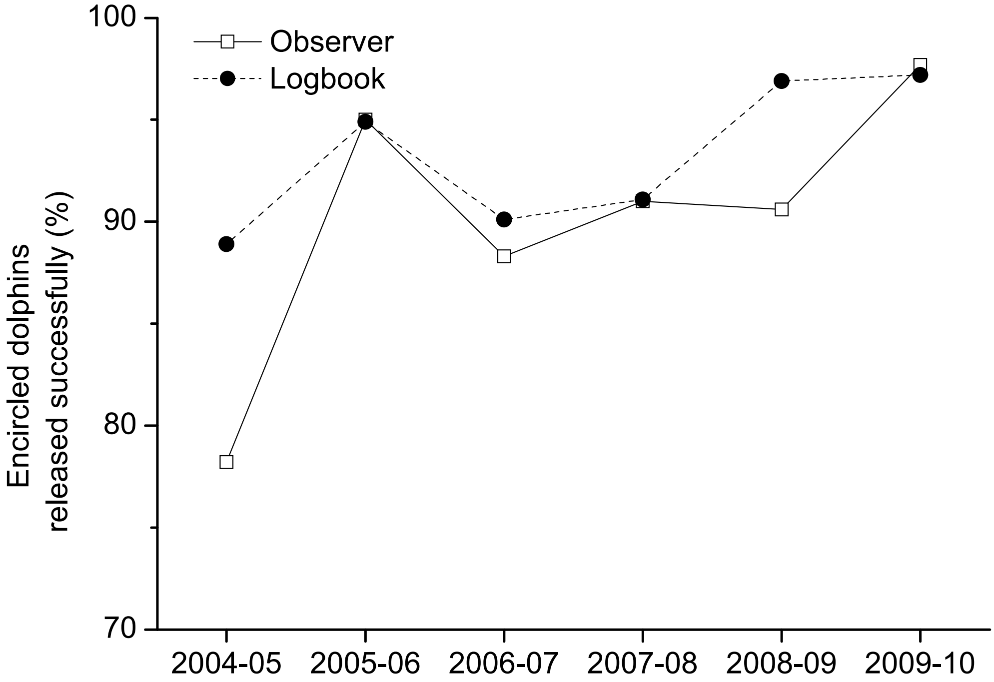

Figure 6. Percentage of encircled dolphins that were successfully released in the South Australian Sardine Fishery from 2004-05 to 2009-10 based on data from Observer Datasheets and Fishery Logbooks.

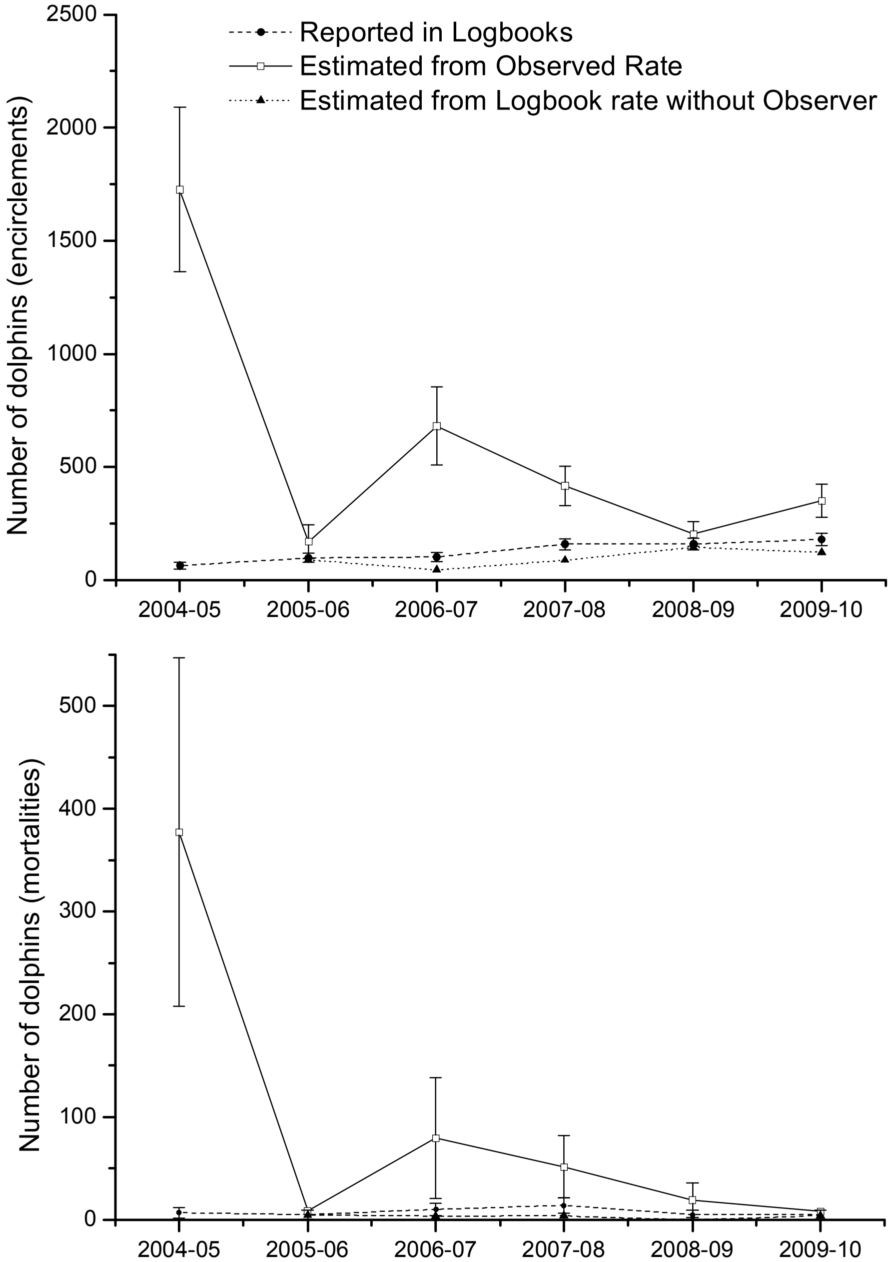

Figure 7. Numbers of dolphin encirclements and mortalities in the South Australian Sardine Fishery each financial year based on extrapolations from numbers recorded in fishery logbooks and rates calculated from observer and logbook (without observers) data. Error bars are 95% confidence intervals.

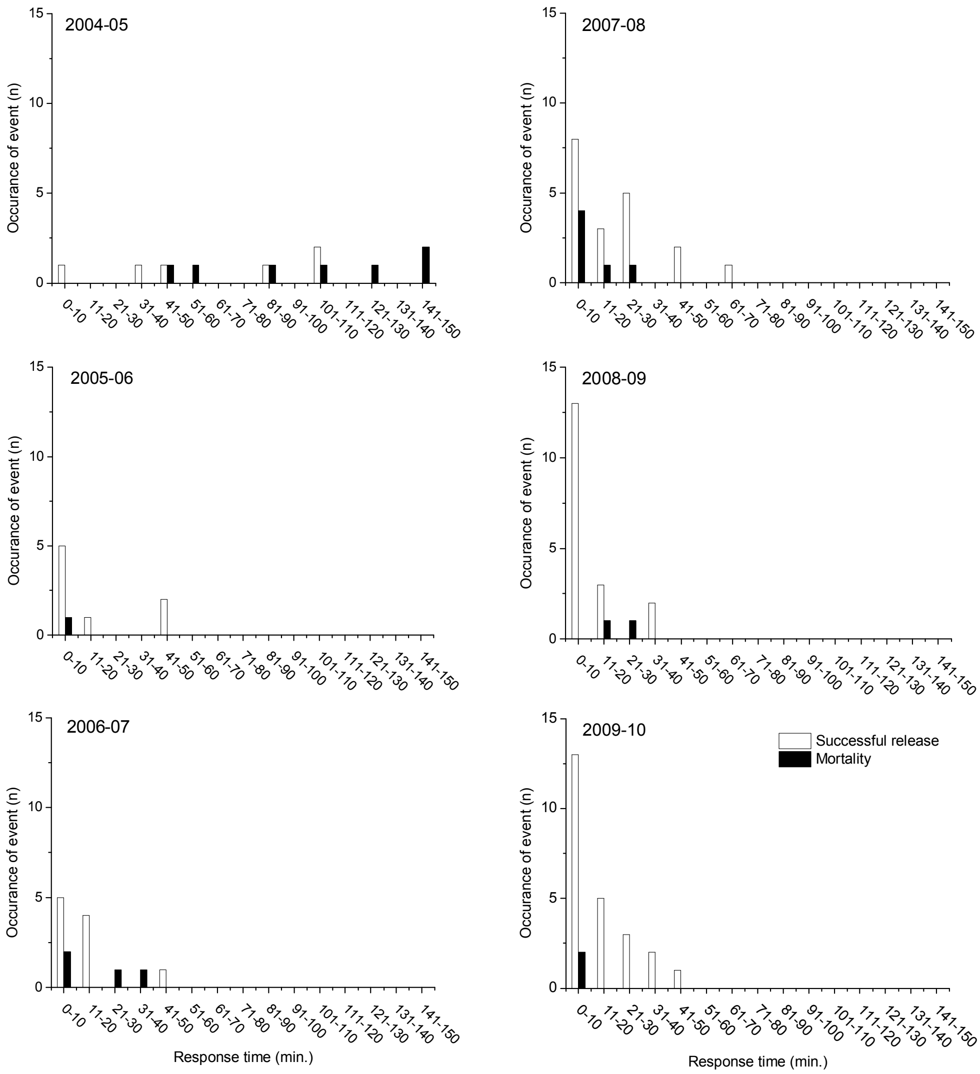

Figure 8. Response time (period between first sighting of an animal and initiation of release procedure) to encirclements and the incidence of subsequent mortality during; (a) 2009-10, (b) 2008-09, (c) 2007-08, (d) 2006-07, (e) 2005-06 after the introduction of the CoP and (f) 2004-05 before the introduction of the CoP. Note records where no release procedure was initiated are excluded.

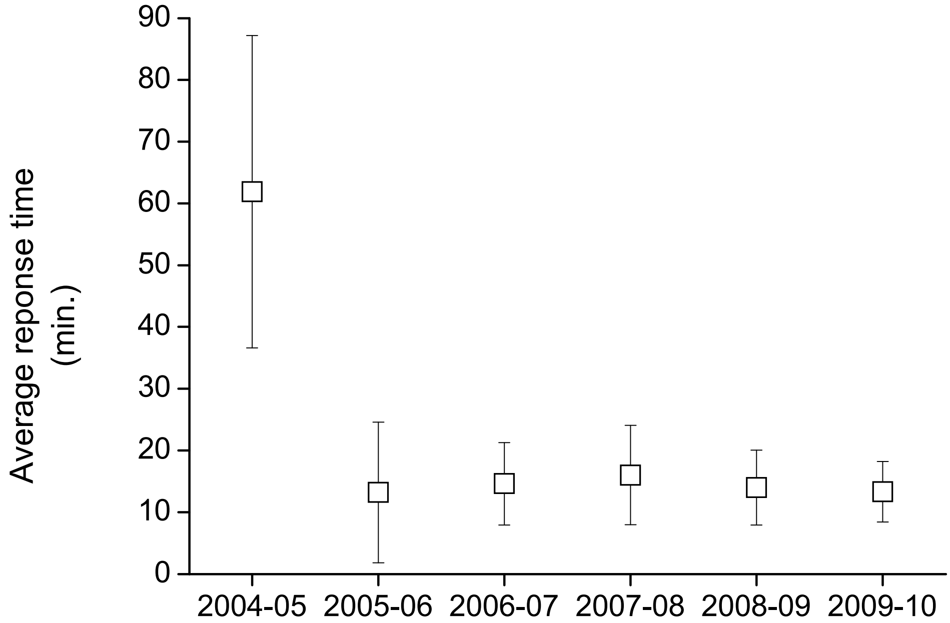

Figure 9. Average time elapsed between the detection of encircled dolphins and the initiation of release procedure. Error bars are 95% confidence intervals.

4.0 DISCUSSION

The most important finding of this study is that it confirms that an industry Code of Practice can be highly effective in reducing the interaction rates of a purse seine fishery with a delphinid. In 2004-05, before introduction of the CoP, the observed rate of encirclement in the SASF was 178 (95% CI = 142-219) 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 (23-61) dolphins per hundred net sets but did not exceed nine dolphins per hundred net sets after the CoP was introduced. In the final year of this study, when the CoP was in its most refined state, the observed encirclement and mortality rates were 33 (26-40) and one (0-3) dolphin per hundred net-sets, respectively.

The reduction in the encirclement rate reflects the success of the avoidance and release procedures specified in the CoP in preventing interactions from occurring. In 2004-05, before the code was introduced, fishers never searched for dolphins prior to setting net or delayed setting the net when dolphins were observed near the vessel. However, over the last five 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 survival rate of encircled dolphins has also played an important role and is the result of both reductions in the time taken to respond to encirclements (thus reducing stress) 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. In 2005-06, when the CoP was first implemented, several potential release procedures were identified, including corkline weights, TEPS gate, physical removal and opening the front of the net. The only release procedure specified in the most recent version of the CoP (SASIA 2009) is opening the front of the net to create a safe escape route for dolphins, which has been shown to be highly effective when it is undertaken early in the fishing operation.

The success of the CoP is best shown in the large reductions in the estimates of total encirclements and mortalities in the SASF each financial year since the code was introduced. Extrapolation from observer data suggests that in the seven month study period before the introduction of the CoP in 2004-05, 1728 (1384-2131) and 377 (227-589) dolphins were encircled and died, respectively, whereas it was estimated that 169 (103-261) dolphins were encircled and eight (0-47) died in the corresponding period after its introduction. Extrapolation from observer data suggest that over the last four years combined fewer animals have been encircled (1649 dolphins) and died (158 dolphins) than during the initial seven month study period. In 2009-10, it was estimated that a total of 349 (280-430) dolphins were encircled and eight (1-29) died. The rate of mortality recorded by observers in 2004-05 was more than fifty times higher than the rate recorded in 2009-10.

The remaining issue of concern regarding the interaction of the SASF with the short-beaked common dolphin is the discrepancy between the rates of interactions reported by observers and recorded in logbooks. In 2009-10, the estimates of encirclement and mortality extrapolated from observer data, i.e. 349 (95% CI = 280-430) and 8 (1-29) dolphins, respectively, were higher than the numbers recorded in logbooks (179 encirclements and five mortalities). The reason for this difference is that the encirclement and mortality rates calculated from observer data were 2.9 and 2.0 times, respectively, the rates calculated from logbook data when no observer was present. These findings imply that the interaction rates of the SASF with the short-beaked common dolphin continues to be under-reported in Fishery Logbooks. However, it should be noted that while the discrepancy in encirclement rates is statistically significant ($p < 0.001$), the discrepancy between mortality rates is not ($p = 0.73$). This anomaly in part reflects the inherent difficulties associated with conducting statistical analyses of rare occurrences (Ellison and Agrawal 2005).

The low rates of encirclement and mortality of the short-beaked common dolphin recorded by observers provides evidence of the efficacy of the industry CoP established by the SASF (Bilgman et al. 2008, 2009; Hamer et al. 2008, 2009a). Ironically, these low interaction rates will also make it difficult to measure future changes in the performance of the CoP with statistical precision and to formally compare observed and reported mortality rates. Nevertheless, accurate reporting of operational interactions with TEPS is a requirement of the CoP. The TEPS Working Group has identified that reducing the discrepancy between the interaction rates reported by observers and recorded in logbooks is a high priority for the fishery. A strategy to explicitly address this issue needs to be developed.

In line with the CoP' objectives of world's best practice and continuous improvement in the mitigation of operational interactions with TEPS, the TEPS Working Group has identified the need for ongoing consideration of options for further reducing rates of encirclement and mortality. In addition, fishery-independent observers will continue to monitor future interaction rates to ensure ongoing compliance with the code. Skippers and the TEPS Working Group will continue to meet regularly to assess the need for further improvements to the CoP or other aspects of the mitigation process. A study is underway to investigate the population size, distribution and movement patterns of the short-beaked common dolphin in waters off southern Australia. A demographic study based on the large collection of samples currently held at the South Australian Museum has also been proposed. The results of these two studies could facilitate quantitative assessment of the impacts of fishery bycatch on the population(s) of short-beaked common dolphin off southern Australia.

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