Experimental field trials to test if alternative sea lion excluder devices (SLEDs) adequately prevent Australian sea lions from entering rock lobster pots

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Contents

Tables

Figures

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Executive Summary

This project tested the efficacy of two new sea lion excluder devices (SLEDs) in preventing entry of seals into southern rock lobster (*Jasus edwardsii*) pots designed by fishers from the South Australian Northern Zone Rock Lobster Fishery (NZRLF). Since 1 November 2013, the use of a spike SLED has been mandatory in commercial lobster pots fished in waters less than 100 m in the NZRLF, and mandatory in recreational rock lobster pots fished in waters less than 100 m in the Northern Zone since 1 November 2014.

Although results of experimental field trials showed that the spike SLED design was successful in mitigating the risk of interactions between Australian sea lions (*Neophoca cinerea* - ASL) and lobster pots, industry has raised concerns over the practicability and operational safety of the spike design under commercial fishing conditions, and led to the development, by industry, of alternate SLED designs. The ability of these alternative SLED designs to prevent entry by ASL into lobster pots needs to be determined. After consultation with the NZRLF and PIRSA Fisheries and Aquaculture, two alternate SLED designs were chosen for field tests with seals: the squeezy neck SLED in a standard lobster pot and a box-pot.

Each SLED design was assessed in relation to: 1) the ability to prevent seal pups from entering and becoming entrapped in pots; and 2) the ability to reduce larger animals from entering and / or successfully depredating pots. It was not possible to conduct rock pool trials of SLEDs with ASL pups, as the most accessible and suitable ASL colonies for such a trial were not breeding during the time-frame of the project. Therefore, in order to determine if smaller seals were prevented from entering pots with alternative SLED designs, 4-5 month old long-nosed fur seal pups (*Arctocephalus forsteri* - LNFS) were used as proxies for ASL pups. Field trials were undertaken between May and July 2017 at Cape Linois, Kangaroo Island with LNFS pups, where a rock pool trial was undertaken to assess the ability of LNFS pups to enter a pot with either a squeezy neck SLED or a box-pot opening. These two alternative SLED designs were also experimentally tested with juvenile and adult ASL at Hopkins Island, Spencer Gulf.

The results of the rock pool trials in May 2017 showed that it was possible for an LNFS pup to fully enter a lobster pot without a SLED. However, it was difficult to draw conclusions about the efficacy of the different SLEDs at excluding pot entry of LNFS pups as pups were not highly motivated to enter pots, and morphometric data collected during the trial showed that pups were smaller than ASL pups of an age that have the potential to interact with lobster pots. To address these issues, the minimum opening a pup of a given size could pass through was directly assessed in July 2017 (when LNFS pups are approximately seven months old), using a set of rings with diameters ranging from 135 mm up to 270 mm. None of the 29 LNFS pups assessed could pass through a ring with an opening of 150 mm. Ring tests were also conducted with 21 ASL pups estimated to be around three months of age at Dangerous Reef, Spencer Gulf in July and August 2017, none of which could pass through a ring with an opening of 150 mm. The fact that none of the LNFS or ASL pups tested could be passed through a 135 mm diameter ring confirms the size of the current SLED opening can prevent even small seal pups from fully entering into a lobster pot. It is not possible to determine from these data if a pup would be able to pass through a rectangle opening with a minimum side length of 150 mm. This is because as the length of the minimum side increases, the diagonal length increases providing a wider opening that a pup could potentially fit through, given that they can spread themselves to be more oval than round. Although the diagonal length for the squeezy-neck is greater than for the box-pot (301 mm), the minimum side length of 135 mm is narrow enough to prevent entry by seal pups regardless of the width, and therefore diagonal length of the opening. Therefore, for a *rectangular* or *square* opening SLED one side needs to be a minimum of 135 mm in length to prevent pot entry by seal pups and for a *circular* opening SLED the minimum diameter that should prevent pot entry by even small seal pups is 150 mm.

The results of the field trials conducted at Hopkins Island, Spencer Gulf, showed that all attempted entries into pots by juvenile and adult ASL were unsuccessful for both the spike SLED and the box-pot. In contrast to the previous trial at Hopkins Island conducted by Goldsworthy et al. (2010) when ASL removed all lobsters from the control pot, no ASL succeeded in removing lobsters from any of the pots during the current trial. It is possible that the size of the lobsters (~ 1 kg) used were too large to be easily removed, as on a

number of occasions individuals nosed and mouthed lobsters within the pot, and ASL frequently attempted to remove the legs of lobsters that were protruding through the side of the pots.

Introduction

The South Australian fishery for southern rock lobster (*Jasus edwardsii*) is separated into two zones; Southern Zone and Northern Zone. The Northern Zone Rock Lobster Fishery (NZRLF) covers an area of approximately 207,000 km^2, between the border with Western Australia (WA) and the mouth of the River Murray, and operates all year. The area of the fishery overlaps with 85% of the breeding population of the endemic Australian sea lion (*Neophoca cinerea*, ASL). The ASL is a listed Threatened species under the South Australian *National Parks and Wildlife Act 1972*, as Specially Protected Fauna under the *Western Australian Wildlife Conservation Act 2005*, as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and is a listed Endangered Species under the International Union for the Conservation of Nature (IUCN). The most comprehensive survey of the species in South Australia (SA) reported a 24% decline in pup abundance in the last 8 – 11 years (Goldsworthy et al. 2015). Mortality due to interactions with fisheries and marine-debris are considered primary threats to the recovery of ASL populations (DSEWPaC 2013).

Interactions between ASL and lobster pots led to fishers in the NZRLF developing modifications to their pots in order to prevent seals removing baits and/or catch from pots (Anon. 1996). This modification consisted of a spike protruding from the floor of the pot into the neck of the pot collar. As well as ASL removing catch and / or bait from lobster pots, observations from SA and WA indicated that it was possible for smaller ASL to become trapped and subsequently drown in lobster pots (Gales et al. 1994; Mawson and Coughran 1999). Gales et al. (1994, p. 367) reported "a significant proportion of pups from one colony" had drowned in lobster pots, but the estimated age of the pups was not given. Campbell et al. (2008) estimated that the age range of ASL vulnerable to capture in rock lobster pots in WA was 5 - 22 months based on the locations and times of bycatches reported in logbooks. The mean maximum dive depth undertaken by ASL in this age range recorded for individuals from Seal Bay, Kangaroo Island was 29 m for individuals between 5.4 and 7.1 months, 68 m for individuals between 13.4 and 15.7 months and 78 m for individuals between 22.1 and 22.9 months (Fowler et al. 2006). A more recent study of movement and diving ability of ASL pups reported a maximum dive depth of 46 m for a six month old pup from Lilliput Island and a maximum distance travelled of 56.5 km by a six month old pup from Olive Island (Lowther and Goldsworthy 2012).

While the addition of a spike to a lobster pot was initially used to stop seals removing catch and bait, the efficacy of this type of modification at preventing pot entry and therefore reducing the risk of ASL becoming trapped and drowning was unknown. Therefore, different configurations of a spike were experimentally tested in field trials in the Western Australian West Coast Rock Lobster Fishery (Campbell et al. 2008) and in the South Australian Southern Rock Lobster Fishery (Goldsworthy et al. 2010). These studies showed that ASLs were motivated and able to enter and take lobsters from standard pots (control pots), but had a reduced ability to enter a pot when a spike (fixed steel vertical bar) was present. The number of successful entries into a pot decreased as the height of the spike increased (relative to the bottom of the pot collar), and both studies demonstrated that the addition of a spike extending just below, or flush with the base of the pot-collar had no significant effect on the catch rate or size of lobsters (Campbell et al. 2008; Goldsworthy et al. 2010).

In order to assess the efficacy of the spike design at preventing ASL pups from entering lobster pots, Goldsworthy et al. (2010) also undertook a trial in a rock pool at an ASL breeding colony. While this trial showed that it was possible for an ASL pup to fully enter a pot that had no SLED, no attempts were made by pups to enter a pot with a spike SLED. Therefore, Goldsworthy et al. (2010) assessed the minimum pot opening that a pup could fully pass through by collecting morphometric data of ASL pups estimated to be 4-5 months old at English Island, Spencer Gulf. The ASL pups they measured had previously been tagged at Dangerous Reef, Spencer Gulf, and represented both the size range of pups that were capable of travelling distances of at least 20 km from natal colonies and the age of pups that would be beginning to undertake diving to the sea floor (Fowler et al. 2006). Their results indicated that a spike extending to the base of the lobster pot collar, would reduce the minimum opening from 270 mm to 135 mm, and would prevent entry into the pot for the smallest of the pups they measured (Goldsworthy et al. 2010).

Since 1 November 2013, it has been mandatory for all commercial pots fished in waters less than 100 m in the NZRLF to be fitted with a spike SLED. It has also been mandatory in all recreational rock lobster pots fished in waters less than 100 m in the Northern Zone since 1 November 2014. Specifically, each rock lobster pot

must have a metal rod fixed to the centre of the base of the pot that extends, at a minimum, to the base of the pot collar (Figure 1).

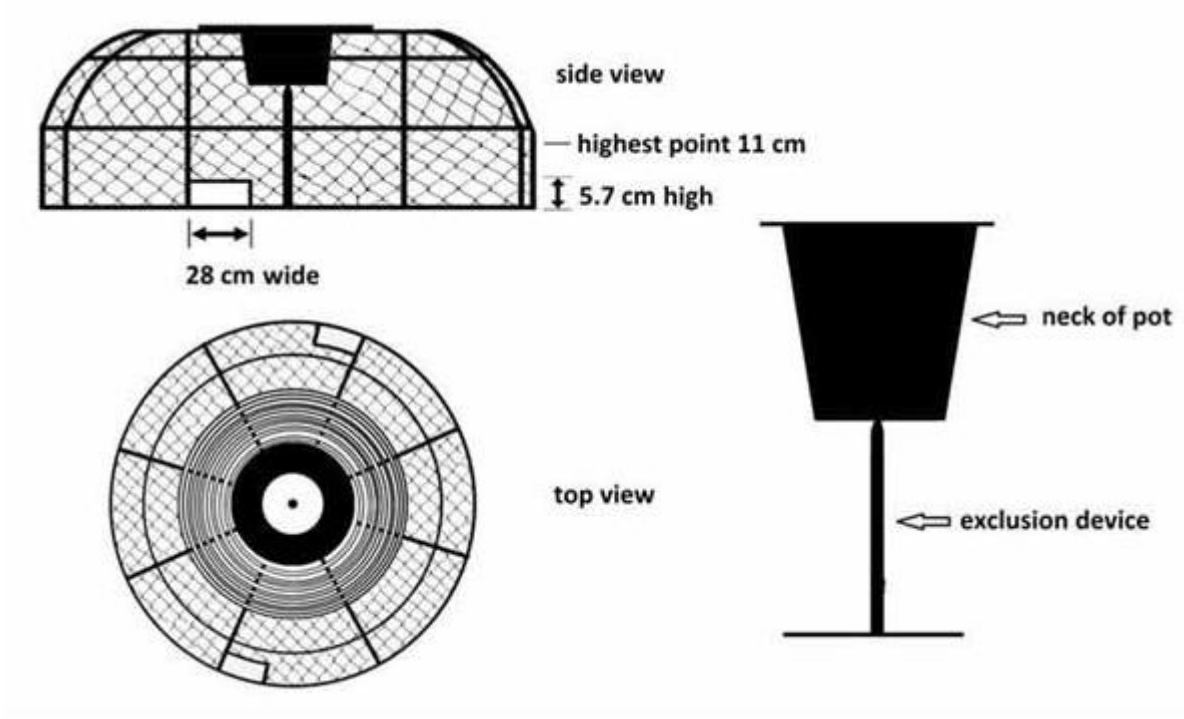

Figure 1: Specifications of sea lion excluder devices (SLED) mandatory for lobster pots set in water less than 100 m deep in the Northern Zone Rock Lobster Fishery. Available at http://www.pir.sa.gov.au/fishing/fishing_gear/permitted_devices

Concerns over the practicability and operational safety of the spike design under commercial fishing conditions led fishers in the NZRLF to develop alternative SLED designs. Some of these alternative SLEDs were fished, under permit, by industry over the 2013-14, 2014-15 and 2015-16 fishing seasons. These trials identified designs that were practical to fish and did not appear to affect lobster catch rates, and although no bycatch of ASL pups was recorded in ~10% of fishing effort that was observed (SARDI unpublished data), the ability of these SLEDs to prevent ASL from entering lobster pots needs to be determined.

This project reports on the results of field experiments to test the efficacy of two industry developed SLED designs to adequately prevent seals from entering rock lobster pots. As the current study needed to be completed before the start of a subsequent study that will assess catch per unit effort (CPUE) in modified pots in the fishery in October 2017 (FRDC project 2016-258)[1], it was not possible to conduct rock pool trials of SLEDs with ASL pups, as the most accessible and suitable ASL colonies for such a trial were not breeding during the time-frame of the project. Therefore, in order to determine if smaller seals were prevented from entering pots with alternative SLED designs, 4-5 month old long-nosed fur seal (*Arctocephalus forsteri*) pups were used as proxies for ASL pups. Alternative SLED designs were also experimentally tested with juvenile and adult ASL at Hopkins Island, Spencer Gulf.

[1] FRDC Project (2016-258) – Assessing the efficiency of alternative pot designs for the Southern Rock Lobster Fishery

Need

1) Robust experimental testing of industry developed SLEDs is required in order to provide information on the efficacy of these devices at mitigating ASL entry into lobster pots relative to the mandated spike SLED.

2) Results of this project are required to identify if SLED designs are suitable to be included in alternative lobster pot designs which will be tested during the proposed FRDC project (2016-258) "Assessing the efficiency of alternative pots designs for the Southern Rock Lobster Fishery".

Objectives

Undertake field trials to determine the relative effectiveness of up to four industry-developed alternative sea lion excluder devices (SLEDs) at reducing the success of rock lobster pot-entry by:

1. Undertaking sea trials at Hopkins Island, Spencer Gulf, with juvenile and adult Australian sea lions; and

2. Undertaking rock-pool trials with 2-5 month old long-nosed fur seal pups (as proxies for ASL pups) at Cape Linois, Kangaroo Island.

Method

Identification of sea lion excluder devices to be tested

After consultation with representatives of the NZRLF and PIRSA Fisheries and Aquaculture, two industry designed SLEDs were chosen for field tests. These were:

1. "Squeezy neck" – consisting of a standard lobster pot with a modified collar, where the bottom of the collar has a letter box shaped opening held in shape by a metal rectangle (135 x 270 mm) (Figure 2)

2. A box shaped pot with three openings, each 150 x 245 mm with plastic mesh extending behind the opening (Figure 3a). For the trials undertaken in rock pools, the "box-pot" SLED opening was tested in a pot collar as the weight and size of the box-pot meant it was too large to carry into the Cape Linois field site (Figure 3b).

Figure 2. Standard South Australian Rock Lobster pot fitted with modified "squeezy neck" pot collar

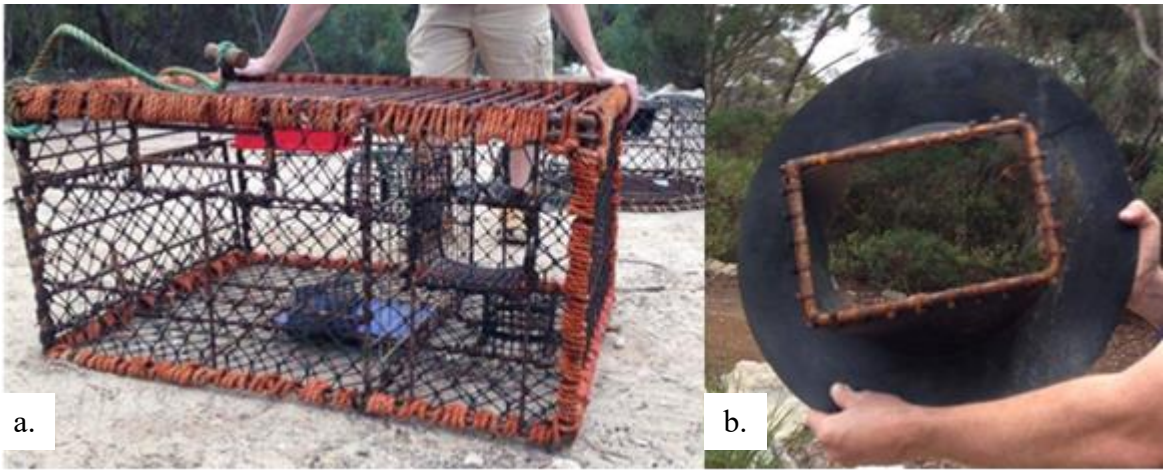

Figure 3. Box-pot with three openings (a, left) and an opening with the same dimensions attached to a pot collar (b, right).

These two designs were tested against a control pot (standard lobster pot with a neck opening of 270 mm diameter), and a lobster pot with a mandated spike SLED that extended from the base of the pot to the bottom of the pot collar.

Pup morphometric measurements

Morphometric measurements of ASL and LNFS pups were collected following the method used by Goldsworthy et al. (2010). Large Vernier callipers were used to measure maximum head height, head width, shoulder height and shoulder width. The weight, maximum girth, total length and sex of each pup was also

recorded. For ASL pups, girth was measured behind the flippers, and for LNFS pups it was measured in front of the flippers, as these positions represented the widest point along the length of the body for each species. To ensure that no individual was measured twice, pups were marked before release, by clipping a small patch of hair on the rump. Goldsworthy et al. (2010) collected morphometric data from 14 ASL pups at English Island, Spencer Gulf, which had previously been flipper tagged at Dangerous Reef (20 km away) and were estimated to be 4-5 months old. The movement of these pups between colonies, indicates that the size range of the pups measured is representative of the size range at which pups are mobile and potentially encountering lobster pots. To augment the data collected by Goldsworthy et al. (2010), additional morphometric data for ASL pups were collected at Seal Bay, Kangaroo Island between November and March 2017 and at Dangerous Reef, Spencer Gulf in July and on 12 and 30 August 2017. Morphometric data for LNFS pups were collected at Cape Linois, Kangaroo Island in May and July 2017 (Table 1).

Table 1: Total number of seal pups that morphometric data were collected for by species, data and location.

Species	Location	Date	Total number of pups
Long-nosed Fur Seal	Cape Linois, Kangaroo Island	April 2017	30
Long-nosed Fur Seal	Cape Linois, Kangaroo Island	July 2017	29
Australian Sea Lion	Seal Bay, Kangaroo Island	November 2016-March 2017	61
Australian Sea Lion	Dangerous Reef, Spencer Gulf	19-20 July 2017	9
Australian Sea Lion	Dangerous Reef, Spencer Gulf	12 August 2017	6
Australian Sea Lion	Dangerous Reef, Spencer Gulf	30 August 2017	6

Of the 61 ASL pups measured by the South Australian Department of Environment, Water and Natural Resources (DEWNR) staff at Seal Bay, Kangaroo Island, during the 2016 breeding, 11 individuals were estimated to be 4-5 months of age. Pups measured at Dangerous Reef, Spencer Gulf in July and August 2017 were estimated to be around three months of age based on size and the estimated timing of breeding at that colony.

Morphometric data for LNFS pups were collected for 30 individuals in April 2017 and 29 individuals in July 2017, at Cape Linois. The second data collection was undertaken to augment measurements of pups in April 2017 (when pups were about 5 months old) that were smaller than ASL pups measured at English Island by Goldsworthy et al. (2010). Although LNFS pups measured in July (which were approximately 8 months old) were larger than those measured in April, measurements of shoulder width and height were still less than those recorded for 4-5 month old ASL pups (Figure 4).

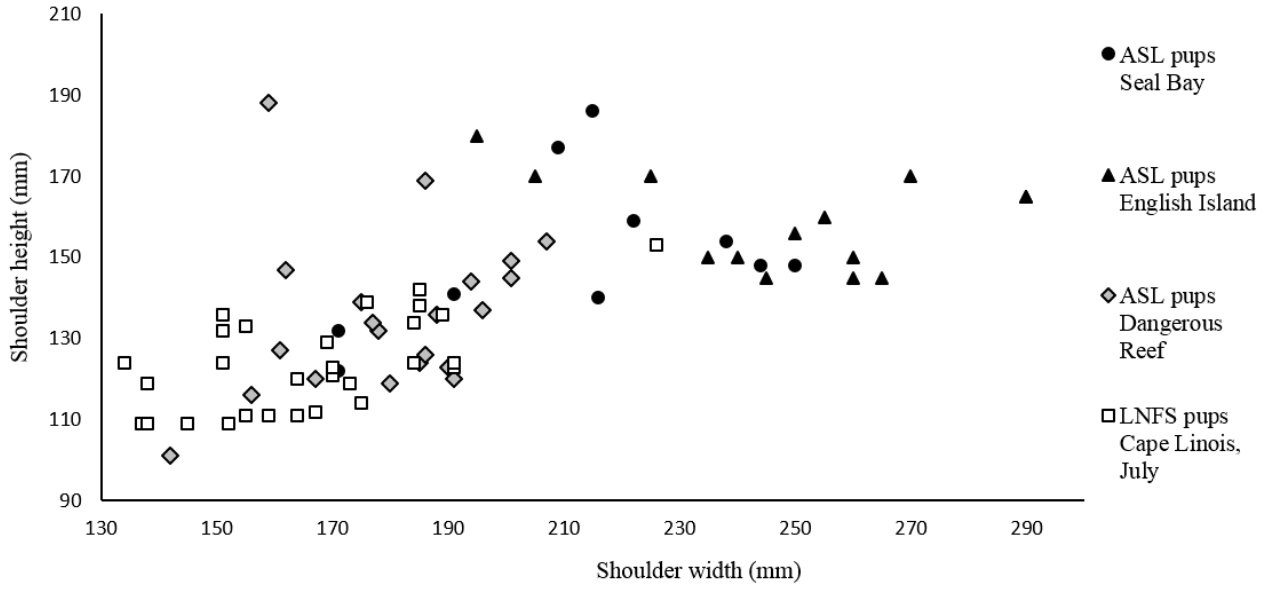

Figure 4. Scatterplot of shoulder width and height of four groups of pups: Australian sea lion pups (ASL), estimated to be around three months of age at Dangerous Reef, Spencer Gulf in July and August 2017, at four months or older recorded at English Island, Spencer Gulf in 2008, at 4-5 months of age at Seal Bay, Kangaroo Island during the 2016/17 breeding season and long-nosed fur seal pups (LNFS) estimated to be 7-8 months old at Cape Linois, Kangaroo Island in July 2017.

Although the measurements of shoulder width and height of LNFS pups in July were still smaller than ASL pups estimated to be 4-5 months old, the girth of LNFS pups fell within the range of those collected for ASL pups at English Island, with 24 of the 29 LNFS pups had a girth equal or larger than the minimum girth of an ASL pup measured at English Island (Figure 5). These data show the difference in the relationship between girth and shoulder width between the two species. Girth is therefore considered a more appropriate measure to use to determine if data collected from LNFS pups could be considered a proxy for 4-5 month old ASL pups.

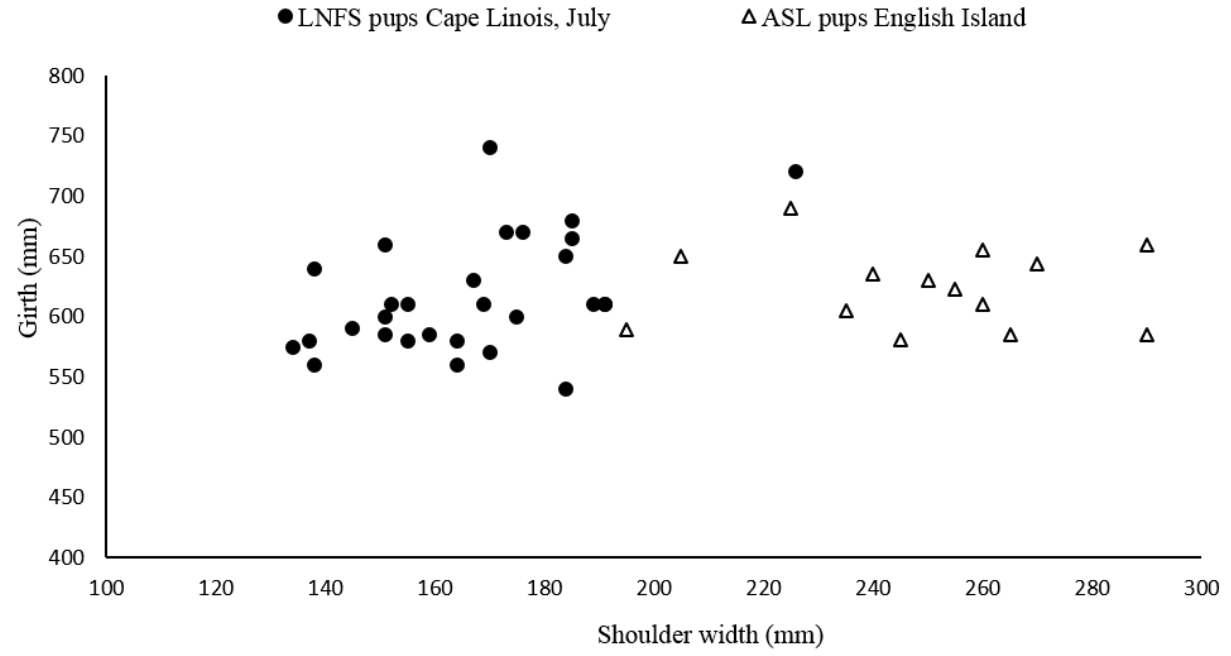

Figure 5. Scatterplot of shoulder width and girth recorded for Australian sea lion pups (ASL), estimated to be four months or older recorded at English Island, Spencer Gulf in 2008 and long-nosed fur seal pups (LNFS) estimated to be 7-8 months old at Cape Linois, Kangaroo Island in July 2017.

The girths of LNFS pups measured in July and ASL pups measured at English Island were lower than those recorded for ASL pups estimated to be 4-5 months of age at Seal Bay. The average girth of the 21 ASL pups measured at Dangerous Reef in July and August was smaller than ASL pups measured at English Island and Seal Bay and represent the size of pups estimated to be around three months old (Figure 6).

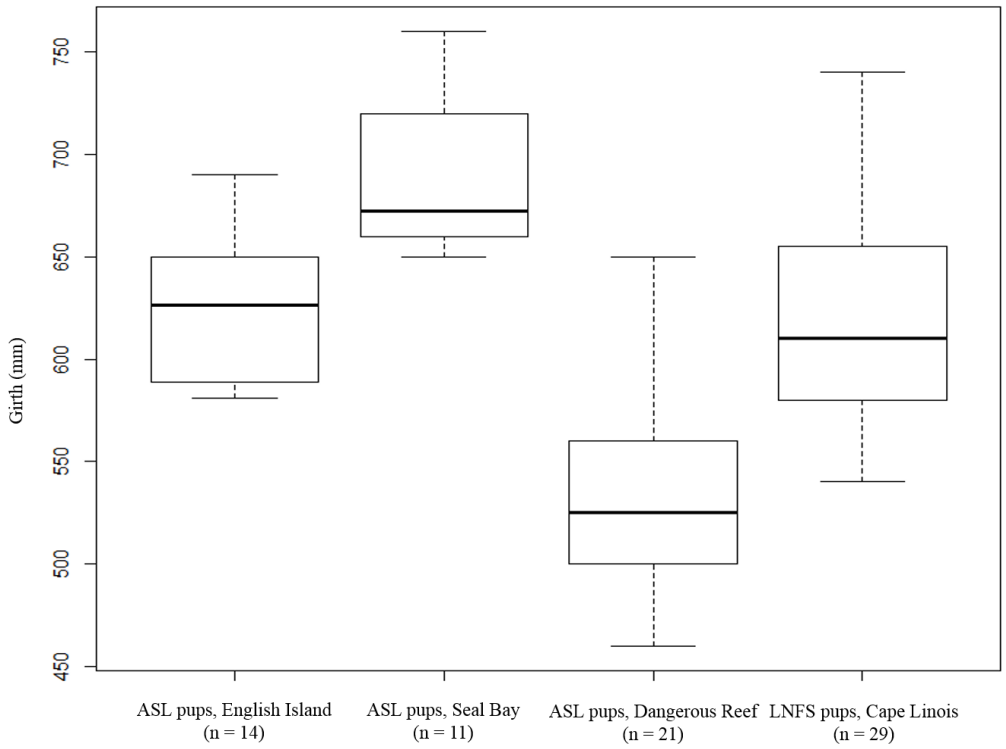

Figure 6. Boxplot of girth measurements of Australian sea lion (ASL) pups at two locations estimated to be 4-5 months of age, and long-nosed fur seal pups (LNFS) at Cape Linois in July 2017.

Minimum opening a pup of a given size can pass through

In order to assess the minimum pot opening that each measured seal pup could pass through, additional data were collected for LNFS pups during the second field trip to Cape Linois in July 2017 and for ASL pups (estimated to be around 3 months of age) at Dangerous Reef in July and August 2017. Nine metal rings were fabricated with diameters ranging between 135 mm and 270 mm (Table 2). The minimum and maximum diameters tested represented the size of the opening (distance between the edge of the pot collar and spike) in the mandated spike SLED, and the diameter of a pot with no SLED. Once all morphometric data had been collected for an individual pup, several rings were gently passed over the head and along the body of the individual to determine the smallest ring size the pup could fully pass through (Figure 6). It was not possible to test the rings with ASL pups at Seal Bay in July, as all pups encountered were between 8 to 14 months old and therefore much larger than the size of pups of interest, i.e. 4-5 month old pups that that would be the first age that could potentially interact with pots.

Table 2: The diameter of the nine rings used to test the minimum opening that seal pups could be passed through.

Ring ID	Diameter	Ring ID	Diameter	Ring ID	Diameter
1	135 mm	4	180 mm	7	230 mm
2	150 mm	5	200 mm	8	245 mm
3	165 mm	6	215 mm	9	270 mm

Figure 7. Example of a ring being passed over a long-nosed fur seal pup.

Rock pool trials with long-nosed fur seal pups

The efficacy of the three SLED designs at preventing pot entry by LNFS pups was assessed in rock pools at Cape Linois, Kangaroo Island, between 24 and 28 April, 2017. With the exception of one trial on 24 April when only one pot was used, two pots were placed in the water concurrently. These were a pot with a mandated spike design, a pot with a squeezy neck and a pot with the box-pot opening in a standard collar. A control pot with no SLED was also tested. Once a suitable rock pool was identified, two pots were tested concurrently and each pot was equipped with two GoPro video cameras; one filming across the top of the pot collar, the other inside the pot. Pots were deployed for two hours, which was the maximum battery length for the cameras. Pots were monitored continuously to ensure that if a pup entered a pot, the pot could be removed from the rock pool immediately and the pup released.

Field trials with ASL at Hopkins Island, Spencer Gulf

Experiments to test efficacy of the three SLED designs at preventing pot entry by juvenile ASL were undertaken at Hopkins Island, Spencer Gulf in May 2017. The site was accessed using the SARDI research vessel Ngerin which anchored adjacent to the island. A small tender was then used to deploy the pots in water depth of 5 – 6 m off the main beach where ASL haul-out and the tender remained with the pots for the duration of each trial. The four pots trialled were a control pot, a standard pot with a spike, a standard pot with a squeezy neck and the box-pot. The rectangular openings on the box-pot were the same dimensions as the box-pot entry trialled with fur seal pups at Cape Linois. Eleven trials were conducted at Hopkins Island between 8 and 11 May 2017, and one trial at Blyth Island on 12 May 2017. All trials at Hopkins Island consisted of three pot types, each pot type with two video cameras, tested concurrently. For the single trial at Blythe Island, all four treatments were deployed, with the control and box-pots each having a single camera recording the inside of the pot.

Two to three SLED designs were deployed concurrently, with each pot seeded with between two and six lobsters, equipped with two GoPro video cameras (one filming across the top of the pot collar, the other inside the pot) and deployed for two hours (maximum battery charge). A control pot was deployed on each trial in order to maintain ASL interest in interacting with the pots. For the box-pot, the GoPro fitted inside the pot was positioned so that all three openings were visible. Pots were continuously monitored from a small vessel so that they could be quickly retrieved if a sea lion were to enter a pot or become stuck while trying to enter a pot. On the fourth day of the trial a change in swell direction meant that water clarity deteriorated and it was no longer possible to visually monitor the pots. Blyth Island was identified as a suitable alternative location to continue the trials after it was no longer possible to work at Hopkins, and one trial was conducted there after the necessary amendment had been obtained for the PIRSA Ministerial Exemption. All lobsters remaining at the end of the trial were sold back to the supplier.

Video analysis

Prior to analysis, videos were resized using VLC media player 2.2.6. Each video recorded from the top of the pots was then analysed using the software BORIS (Friard and Gamba, 2016). All periods when a seal was present on screen in the vicinity of the pot during a trial, and all attempted entries by seals into the pot collar / box opening were recorded. An entry was defined as all times when a seal placed its entire head into the collar

of the pot. Estimated seal presence during each trial is a minimum estimate, as the presence of seals outside the field of view of the camera was not recorded. For the box-pot, only videos recorded from the inside of the pot were analysed, as these provided a clear view of all openings.

For each video, where an attempted entry by a seal was recorded from the top of the pot, the corresponding video footage recorded from the inside of the pot was analysed to determine if the attempted entry was "successful". Following Campbell et al. (2008) and Goldsworthy et al. (2010), a successful entry into a pot was recorded when an individual was observed with its head below the bottom of the pot collar. For the current project a successful entry meant that the head was sufficiently below the bottom of the pot collar that the external ears of the seal were visible. For each entry attempt, video data from the inside of the pot was used to classify the maximum extent of entry in one of the following four categories;

1) nose inside but not below the bottom of the pot collar;

2) nose below the bottom of the pot collar;

3) eyes below the bottom of the pot collar, and

4) whole head in pot.

For each attempted entry based on videos recorded during the Hopkins Island trial, data were also collected on whether the ASL had any features which could be used to individually identify it.

Results

Results of ring gauge tests

The minimum opening size that a pup could be passed through was assessed for 29 LNFS pups in July 2017. No pup could pass through a ring with a diameter of 165 mm or less although for three pups this ring could be passed as far as their shoulders while all could pass through with a diameter ≥ 245 mm. Of the 29 pups tested, 27 pups could pass through a minimum diameter of 230 mm, 24 through a ring with a minimum diameter of 215 mm and 11 pups could pass through a ring with a minimum diameter of 180 mm (Figure 7). It was not possible to pass a 135 mm or 150 mm ring past the shoulder of any of the 29 pups tested, even those with girths below 580 mm (the minimum girth recorded for 4-5 month old ASL at English Island).

The rings were tested on a total of 21 ASL pups estimated to be around three months of age at Dangerous Reef, Spencer Gulf. Nine pups were measured on July 2017 and a further six pups on both 12 and 30 August 2017. The girth of these pups ranged from 460 mm to 650 mm, and all were able to pass through the 200 mm diameter ring, 19 through the 180 mm diameter ring, and three pups were able to be passed through the 165 mm diameter ring (Figure 7). These three individuals had a smaller mean girth (502 mm) than the mean girth recorded for ASL pups at English Island or Seal Bay which were 624 mm and 690 mm respectively.

No pup of either species could be passed through a ring with a diameter of 135 mm. This ring diameter is the same opening size of the current spike and the minimum opening size of the squeezy neck SLED. No pups of either species could be passed through a ring with a diameter of 150 mm opening. As ASL pups at Dangerous Reef were estimated to be approximately three months of age they are unlikely to be at a stage of development where they would be undertaking trips to sea and be potentially at risk of encountering lobster pots.

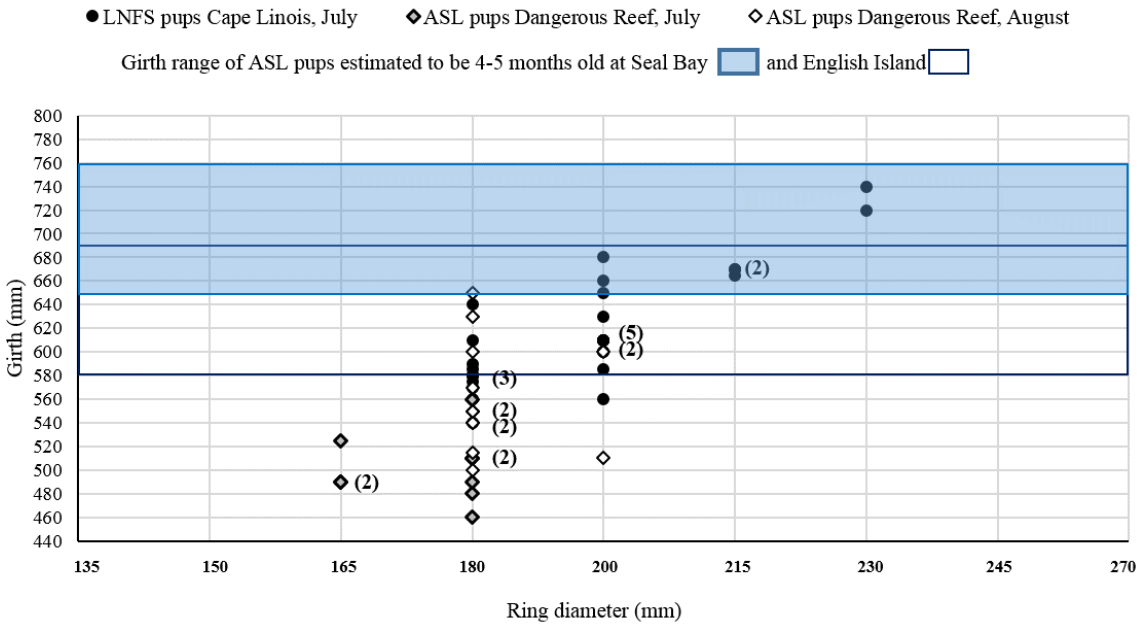

Figure 8. Black dots represent the minimum ring diameter (mm) that a long-nosed fur seal (LNFS) pup with a given girth (mm) could be fully passed through. Grey and white diamonds represent the minimum ring diameter that an Australian sea lion (ASL) pup at Dangerous Reef with a given girth (mm) could fully pass through in July and August, respectively. Numbers in parentheses indicate sample size. The navy box indicates range of girth measurements recorded for Australian sea lion pups measured at English Island in 2008 (taken from Goldsworthy et al. 2010). The light blue box indicates the range of girth measurements recorded for Australian sea lion pups at Seal Bay during the 2016/17 breeding season that were estimated to be 4-5 months of age (n=11).

Rock pool trials

In total, 24 hours of video were recorded during rock pool trials at Cape Linois, Kangaroo Island: 3.5 hours with the control pot, 8.2 hours with the spike SLED, 7.6 hours with the squeezy neck SLED and 4.7 hours with the box-pot SLED. On average fur seal pups were present in rock pools during 26% of observations (0-69%)

(Table 3). However, it took some trial and error to find a means of encouraging fur seal pups to try and enter the pots. As fur seal pups at this age are nutritionally dependent on milk and do not forage independently pots were not seeded with either bait or lobsters. For most of the trials, although fur seals were present in the vicinity of pots, they did not try to enter them. From trial five onwards, a tennis ball on a string floating above the pot that could then be pulled inside the pot was used to attempt to get pups interested in investigating the pot.

Table 3 Summary of the length of observations, percentage time with seal pups present in the vicinity of pots and the number of attempted and successful entries for each trial by treatment type. Grey shaded rows indicate trials in which at least one attempt to enter a pot was recorded. *Note it was not possible to determine if any attempted entries were made during trial seven as both top cameras failed to record. No successful entries were observed on videos recorded inside pots during this trial.

Date	Trial no.	Treatment	Total observation (minutes)	% of observation with fur seal pup present	No. of attempted entry	No. of successful entries
24/04/17	1	Squeezy neck	41.47	45%	0	0
25/04/17	2	Control	105.2	1%	0	0
25/04/17	2	Squeezy neck	96.9	20%	0	0
25/04/17	3	Control	108.2	44%	7	1
25/04/17	3	Squeezy neck	105	69%	0	0
26/04/17	4	Spike	96	0%	0	0
26/04/17	4	Squeezy neck	96	0%	0	0
27/04/17	5	Spike	103	18%	0	0
27/04/17	5	Squeezy neck	114	23%	6	0
27/04/17	6	Box	109	59%	60	2
27/04/17	6	Spike	118	50%	82	13
28/04/17	7	Box	75	*	*	0
28/04/17	7	Spike	79	*	*	0
28/04/17	8	Box	101	13%	1	0
28/04/17	8	Spike	96	45%	0	0

"Successful" entries by fur seal pups were recorded for the control pot, spike pot and box-pot SLED. On 25 April, a pup completely entered into the control pot. The pot was immediately pulled from the rock pool, and the pup removed. Morphometric data were collected from it before it was released unharmed. Thirteen "successful" entries were recorded in the pot with the spike and two were recorded in the box-pot SLED. Examples of successful entries are illustrated in Figure 9.

Figure 9 Successful entry by a long-nosed fur seal pup into a pot with a spike SLED (left) and a pot with a box-pot SLED (right).

ASL trials at Hopkins Island

A total of 63 hours of video footage was recorded: 21 hours with the control pot, 20 hours with the squeezy neck SLED, 12 hours with the box-pot and 10 hours with the spike SLED. The time that ASL spent in the vicinity of pots, i.e. were visible in front of the camera, varied greatly between trials, with no ASL interactions recorded during three of the trials (Table 4). The total proportion of time that ASL were visible from the cameras in the vicinity of each pot type varied between treatments; ranging from a minimum of 6% of total observation time for the box-pot to a maximum of 12% of observations in the vicinity of the control pot (Figure 10). While these data provide a means of assessing the time ASL spent in the vicinity of the four types of pot, they do not reflect variation in the number of attempted entries for treatment types, both within and between trials (Figure 11). For example, in Trial 3 attempts were made to enter both the pot with the spike and squeezy neck SLED, but not the control pot.

Table 4. Summary of the length of observations and percentage time with ASL recorded present on camera in the vicinity of pots for each trial conducted at Hopkins Island (Trial 1 to 11) and Blythe Island (Trial 12), Spencer Gulf.

		Control		Spike		Box		Squeezy	
Date	Trial no.	Length (mins)	% time ASL present	Length (mins)	% time ASL present	Length (mins)	% time ASL present	Length (mins)	% time ASL present
8/05/2017	1	120	0%	120	0%			120	0%
8/05/2017	2	105	4%	118	24%			110	6%
9/05/2017	3	111	14%	111	42%			107	11%
9/05/2017	4	105	11%	101	5%			100	2%
9/05/2017	5	120	0%	120	0%			120	0%
10/05/2017	6	108	63%			125	16%	112	45%
10/05/2017	7	110	1%			121	1%	105	1%
10/05/2017	8	103	0%			103	0%	103	0%
10/05/2017	9	86	7%			86	17%	91	8%
11/05/2017	10	108	22%			111	13%	105	7%
11/05/2017	11	120	16%			122	4%	103	22%
12/05/2017	12	33	0%	50	17%	53	3%	49	7%

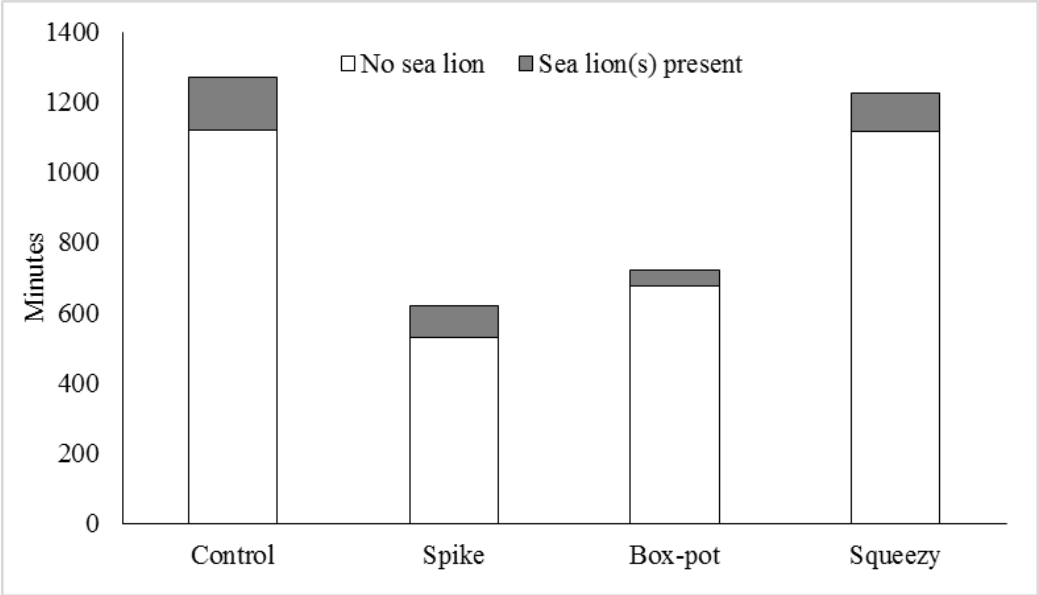

Figure 10 Duration of observations with and without Australian sea lion present in the vicinity of the pot for each treatment.

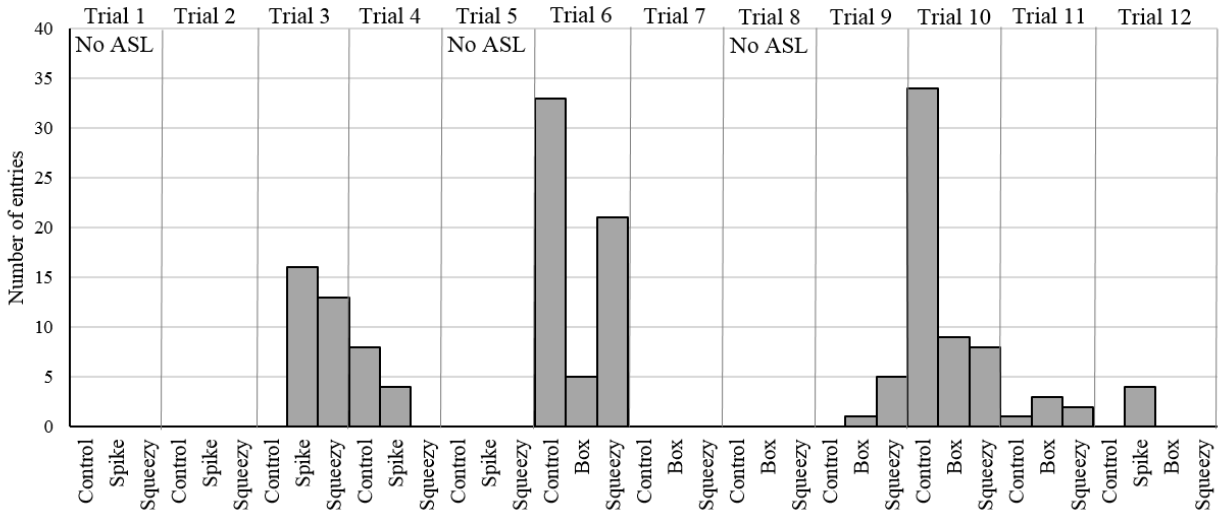

Figure 11. Number of entries by Australian sea lion (ASL) by treatment type and trial number.

Cameras placed inside pots recorded a total of 167 attempted entries. The largest number of attempted entries were recorded with the control pot (76), followed by the squeezy neck SLED (49), spike SLED (24) and then the box-pot (18). The proportion of entries that resulted in the head of the ASL being completely below the bottom of the pot collar was highest for the control pot (37%) followed by the squeezy neck SLED (8%). No successful entries were recorded for either the spike SLED or box-pot (Table 5).

Table 5. The percent of successful entries into lobster pots of four different treatment types by Australian sea lions (ASL). A successful entry was recorded when the head of the individual was fully below the pot collar. Values in parenthesis are the total number of attempted entries for each treatment.

Treatment	Percent of successful entries by ASL
Control	37% (76)
Spike SLED	0% (24)
Box-pot	0% (18)
Squeezy neck SLED	8% (49)

How far an individual entered inside the pot varied between treatment types and also between trials of those treatments (Figure 12). It was not possible to determine the maximum extent to which an ASL entered the control pot on five occasions, as lobster(s) within the pot obscured the view of the camera, but on each of these occasions, the individual had at a minimum entered far enough into the pot so that its nose was below the bottom of the collar.

In contrast to the trials undertaken at Hopkins Island by Goldsworthy et al. (2010), no lobsters were directly removed from pots by ASL during any of the trials of the current project. While no whole lobsters were taken from pots, ASL attempted to capture lobsters within pots on a number of occasions, and did predate on lobsters during the trial by removing legs through the side of pots or removing antennae through the neck of pots.

Pot entries by ASL during the trial cannot be treated as independent events. Within some trials, the majority of attempted entries appeared to be by the same individual. Although it was not possible to individually identify all ASL that attempted to enter pots, some individuals had markings which meant they could be identified. One individual was identified interacting with pots during four different trials. Within each of those trials the individual carried out between 5% and 100% of all entry attempts recorded.

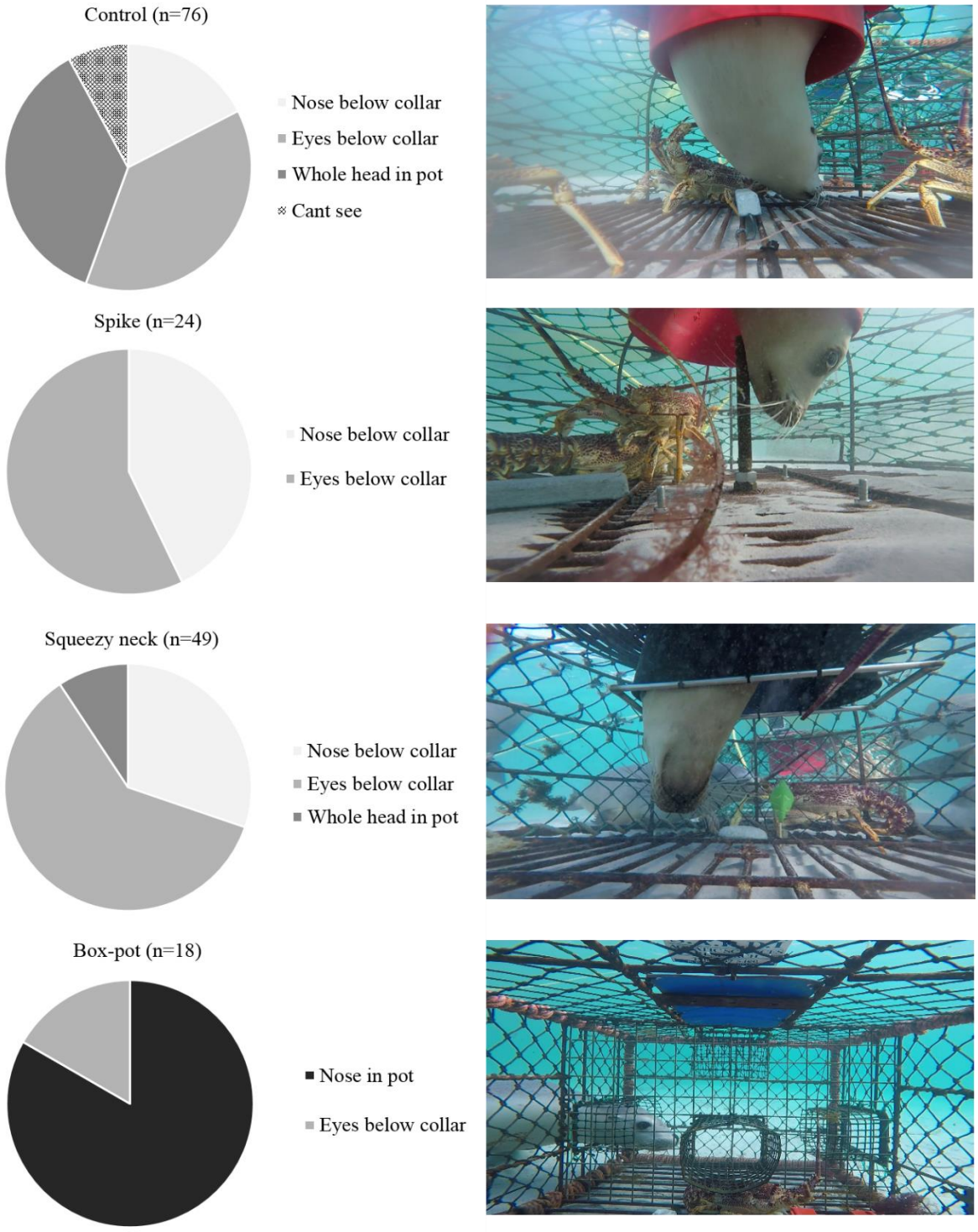

Figure 12. Proportion of all entries recorded for Australian sea lions for the standard lobster pot (control), pot with a spike sea lion excluder device (SLED), a squeezy neck SLED and a box-pot from trials at Hopkins Island. The proportions are categorised by the maximum distance of the seal's body that was visible inside the pot during an entry attempt.

Discussion

It can be challenging to develop modifications to fishing gear that successfully mitigate bycatch of non-target species while still maintaining profitable target catch rates. This is particularly the case when the non-target species is highly motivated to interact with fishing gear in order to depredate bait or catch. The current spike SLED that is mandated in commercial and recreational lobster pots in the Northern Zone of the South Australian Rock Lobster Fishery is based on a pot modification that was developed and used by some fishers as a means of preventing seals from removing catch and / or bait from lobster pots (Anon. 1996). The efficacy of this spike design at mitigating entry into rock lobster pots by sea lions was field tested in Western Australia (Campbell et al. 2008) and further experimentally tested in South Australia (Goldsworthy et al. 2010). The current study assessed two industry SLED designs that were developed to address concerns about the practicability of fishing pots with a spike SLED.

The risk that an ASL could become trapped in a lobster pot, and subsequently drown, is directly related to the size of the individual relative to the size of the pot opening. Campbell et al. (2008) estimated that the minimum age of ASL vulnerable to capture was five months and reported that fishermen estimated that ASL captured in rock lobsters pots without SLEDs in Western Australia were 61-91 cm in length. Four to five months is the age that ASL pups start developing foraging behaviour and diving ability (Fowler et al. 2006), and ASL pups in this age-range have been recorded to move between colonies in Spencer Gulf that are approximately 20 km apart (Goldsworthy et al. 2009). Based on these observations, 4 month old pups represent the minimum size-range of ASL that need to be successfully excluded from entering rock lobster pots. The mandated spike SLED reduces the dimensions of the opening of the pot collar from 270 mm to 135 mm. This opening size was assessed by Goldsworthy et al. (2010) to be small enough to prevent entry of ASL pups into spike protected pots based on morphometric data collected from ASL pups estimated to be 4-5 months of age.

Following Goldsworthy et al. (2010), the current study conducted rock pool trials to assess the ability of pups to enter pots with three types of SLEDs, but used LNFS pups as proxies as no suitable ASL colonies were breeding during the timeframe of the current study. However, two issues made it difficult to draw conclusions about the efficacy of the different SLEDs at preventing complete pot entry by seal pups. Firstly, LNFS pups were not highly motivated to enter pots, and only interacted with pots during 26% of observations. Secondly, the morphometric data collected during the trial showed that the LNFS pups measured in April were smaller than ASL pups estimated to be 4-5 months old measured by Goldsworthy et al. (2010) at English Island, or those measured at Seal Bay during the 2016/17 breeding season. However, the results of the rock pool trials showed that it was possible for LNFS pups to fully enter a lobster pot without a SLED. Given that LNFS pups in April were smaller than ASL pups measured at English Island, additional data on the minimum opening a pup of a given size could pass through was directly assessed in July 2017, by measuring pups and attempting to pass them through rings of different diameters.

The results of the trial using ring-gauges showed that none of the 29 LNFS pups tested in July 2017 could pass through a ring with an opening smaller than 150 mm, which is the minimum dimension of the box-pot opening. Three individuals potentially could have become stuck at the shoulder with an opening of 165 mm, but all other pups would have been excluded from an opening of this size. Although the measurements of LNFS pups in July 2017 showed that their shoulder widths and heights were still generally smaller than those recorded for 4-5 month old ASL pups, the girths recorded were more similar to girths of ASL pups of that age. For the 24 LNFS pups that had a girth equal to or greater than 580 mm, the minimum recorded for the reference ASL pup, none were able to pass through a ring with a diameter of 165 mm or less. It was not possible to pass a 135 mm or 150 mm ring past the shoulder of any of the 29 pups tested, even those with girths below 580 mm. Of the 29 pups tested, 27 pups could pass through a minimum diameter of 230 mm, 24 through a ring with a minimum diameter of 215 mm and 11 through a minimum diameter of 180 mm.

The 21 ASL pups measured at Dangerous Reef in July and August 2017 were estimated to be around three months of age and had on average smaller girths than the reference pups measured at English Island in 2008 at Seal Bay in 2016 that were estimated to be 4 – 5 months of age. None of these 21 ASL pups could be passed through a 135 mm diameter ring, confirming that the size of the current SLED opening can prevent even small ASL pups from fully entering into a lobster pot. No pups could be passed through the 150 mm ring indicating that a circular opening this size would also prevent full entry into a lobster pot by pups in this size range. It is not possible to determine from these data if a pup would be able to pass through a rectangle opening with a

minimum dimension of 150 mm. This is because as the minimum side length increases, so does the diagonal length, providing a wider opening that a pup could potentially fit through, given that they can spread themselves to be more oval than round shape in cross-section. For example, the box-pot SLED tested has a diagonal length of 287 mm. Of the 21 pups tested, all could pass through a ring with a minimum diameter of 215 mm and 19 through a ring with a minimum diameter of 200 mm. Although the diagonal length for the squeezy-neck is greater than that of the box-pot (301 mm), the minimum side length of 135 mm is narrow enough to prevent entry by seal pups regardless of the width, and therefore diagonal length of the opening. We are unable to determine from the current trial the point at which the length of the minimum side would potentially provide an opening large enough for a pup to fit through. Therefore, for a *rectangular* or *square* opening SLED, one side needs to be a minimum of 135 mm in length to prevent pot entry by seal pups and for a *circular* opening SLED the minimum diameter that should prevent pot entry by even small seal pups is 150 mm.

The differences in shoulder measurements between pups of the two species raises the question of how suitable LNFS pups are as a proxy for ASL. However, as the girth of LNFS pups measured in July 2017 were within the range of those recorded for ASL pups estimated to be 4-5 months of age at English Island, and Seal Bay, we feel the results of the ring tests on this species provide a proxy, in terms of the ring test, for the size of ASL pups that may be starting to accompany their mothers on foraging trips. The results of the ring tests provide unambiguous data on the size(s) of seal pups that can completely pass through different openings.

The results of the field trials conducted at Hopkins Island showed that all attempted entries into pots by juvenile and adult ASL were unsuccessful for both the spike SLED and box-pot. As with previous open-water lobster pot field trials using ASL, the size range of ASL interacting with pots at Hopkins Island was much larger than those at risk of entrapment. The definition of a "successful" entry followed that used by Campbell et al. (2008) and Goldsworthy et al. (2010) who defined it as any time an individual was able to get its head fully inside a lobster pot. While this provides a conservative measure of potential risk of entrapment, it was clear from the video footage collected during the current trial that entry "success" was also related to the level of motivation an animal demonstrated trying to get into a pot. In contrast to the previous trial at Hopkins Island conducted by Goldsworthy et al. (2010) when ASL removed all lobsters from the control pot, no ASL succeeded in removing lobsters from pots during the current trial. It is possible that the size of the lobsters (~ 1 kg) used were too large to be easily removed, as on a number of occasions individuals did nose and mouth lobsters within the pot, and ASL frequently attempted to remove the legs of lobsters that were protruding through the side of the pots. The proportion of entries that resulted in the head of the ASL being completely below the bottom of the pot collar was highest for the control pot (37%) followed by the squeezy neck SLED (8%). No successful entries were recorded for either the spike SLED or box-pot (Table 4). As well as reducing the risk of entrapment in pots, the ability of SLEDs to stop seals from entering pots will also reduce the opportunity for individuals to depredate catch. Although some successful entries were recorded with the squeezy neck SLED it was clear from the video footage that the design of the SLED restricted the seal's movement and how an individual could get its head inside a pot, relative to the control pot. As with the trial by Goldsworthy et al. (2010) the spike was successful in deterring seals from fully placing their heads within the pot during the trial. The lack of successful entries recorded for the box-pot appears to be due to the placement of the plastic sleeves behind the box-pot openings which restricted seals from accessing most of the entrance area to the pot. The design of this pot also ensures that seals are unable to access lobster catch in the main chamber of the pot. While these results suggest that the new SLED designs may be useful in preventing or reducing the depredation of lobsters by seals, there were clear differences in the motivation of different individual's to attempt to enter pots during the trials meaning that attempted entries were generally not independent events. Although not all individuals could be identified, for those that were uniquely marked it was clear that only a small proportion were responsible for most of the recorded entry attempts into pots and that some of these individuals interacted with pots during several trials. There were also individuals who never attempted to enter or look in pots, but spent time around the pots playing with the ropes. For example, during the second trial no entry attempts were made by any ASL even though individuals inspected the pots. The amount of time ASL spent with each of the treatments also varied between trials, and for three trials no ASL approached or inspected the pots even though there were animals hauled out on the beach.

Conclusion

- The results of the rock pool trials demonstrate that it is possible for small seal pups to become entrapped in lobster pots not fitted with SLEDs.

- The current SLED design with a maximum opening of 135 mm was shown, by directly passing pups through rings of different diameters, to be sufficient at preventing both small ASL and LNFS from being able to fully enter a lobster pot. As 135 mm is also the narrowest opening of the squeezy neck SLED, this design should also prevent entry into pots by small seals.

- A ring opening with a diameter of 150 mm also fully excluded all of the LNFS and ASL pups tested.

- It was not possible to determine from the experiments conducted whether a box-plot SLED with a minimum side length of 150 mm would be able to fully exclude a seal pup.

- The degree of motivation by individual ASL in attempting to remove lobsters from pots is likely to affect the frequency of "successful" pot entry. The field trial at Hopkins Island demonstrated that juveniles and larger ASL could get their eyes below the pot collar of each of the pot treatment types. While no lobsters were removed from any of the pots during the trial, ASL caused damage to lobsters by removing legs or antennae.

- Pots fitted with the squeezy neck and box-pot SLED restricted the ability of larger ASL to manoeuvre their heads within the pot chamber, and therefore will likely help to reduce the potential for depredation. However, the minimum length of one side of the box-pot SLED would need to be reduced to 135 mm to prevent pot entry by seal pups.

- This study did not assess lobster catch rates of different SLED designs, which is the second component required in assessing gear modifications that have been developed to mitigate bycatch of non-target species. A subsequent FRDC funded study (FRDC Project 2016-258) will assess catch per unit effort (CPUE) in modified pots in the fishery.

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