Australian Marine Mammal Centre
Final Report

- **Project No**. – 09/35
- **Title -** Using the foraging behaviour of the threatened Australian sea lion to assess habitat quality and inform the zoning of marine parks in South Australia
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- **Organisation** – SARDI

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1. Activity Summary

A clear summary of approximately 500 words outlining the work undertaken and any significant findings (for publication on the Department's web site)
The Australian sea lion (ASL) is Australia's only endemic and least numerous seal species. The species is listed as *vulnerable* under the *threatened* species category of the Commonwealth EPBC Act, *vulnerable* under the South Australian National Parks and Wildlife Act (1972) and has recently been upgraded to *endangered* by the IUCN Redlist. Bycatch of ASL, especially in demersal gillnet and lobster fisheries, has been identified as the principal threat to ASL populations (Goldsworthy *et al.* 2010). Spatial closure options to mitigate bycatch in gillnet fisheries, and gear-modifications to exclude ASL entry into lobster pots, are currently being developed. These management measures have the potential to address key threatening processes for this species, but they will not mitigate all threats to ASL populations. There is limited information on the habitat requirements, prey species and abundances needed to maintain ASL populations, and on the potential impact that human activities may be having on ASL populations (Goldsworthy *et al.* 2009). An Ecosystem-based management (EBM) approach that manages both the direct threats to ASL populations and their habitats is therefore likely to be required to secure the future of the species. This approach will include fisheries management actions to mitigate bycatch threats, land-based reserve systems to protect and manage breeding and haul-out sites, and Marine Protected Areas (MPAs) to protect and manage critical foraging habitats. The South Australian Department for Environment, Water and Natural Resources (DEWNR) declared the provisional outer boundaries of 19 marine parks in 2009 (DEH 2009). Within this park network, the location and size of a series of sanctuary zones (areas of minimal human disturbance) are being finalised. Adult female Australian sea lions were fitted with animal-borne video cameras and GPS loggers to characterise the degree of congruence between habitat electivity of a marine predator and habitat type deemed important enough for inclusion in sanctuary zones. At a

coarse level, there was consistent overlap between the preferred habitats of Australian sea lions and areas designated as important through the sanctuary zonation process. With more reliable technology (specifically more robust cameras with greater longevity) adult female Australian sea lions could provide a useful and cost-effective means for assessing and mapping benthic habitat. Australian sea lions may also be a tractable sentinel species for monitoring the effectiveness of management actions in marine parks over time.

2. The Outcomes/Objectives

List of the Project Objectives

1. Use GPS tracking and crittercams to determine critical habitats and movement corridors of ASL
2. Mapping the benthic habitats of regions used and not-used by ASL; c) undertook foraging and habitat modelling to determine habitat features with high and low ASL foraging affinity (electivity)
3. Compare human-based (scientifically-derived sanctuary zone locations) and ASL-based measures of habitat quality and assessed their coincidence
4. Provide a framework for similar approaches in Commonwealth and WA State waters.

The degree to which the Activity has achieved each of the objectives

Objectives 1 & 2:

GPS and video data were collected from adult female ASL at Lewis Island (n=2) and Dangerous Reef (n=4) in the southern Spencer Gulf (SG), and Lilliput Island (n=4) in the Nuyts Archipelago (NA) between September 2008 and March 2012 (Figure 1). This numbers were substantially lower than those predicted in the initial proposal, and were entirely due to catastrophic failure of video camera devices on many occasions (see 'Effectiveness' below).

Critical habitat requirements for adult female Australian sea lions in terms of coarse-scale habitat variables (depth, slope, rugosity) were determined using a series of individual Cox Proportional Hazard models (CPH) using First Passage Time as the dependent variable (Freitas et al. 2008, 2009, 2012). In NA, a single model explained the habitat preference of four of the five individuals tracked. However, while the model was identical in structure between individuals, the manner in which each responded to explanatory variables differed considerably (Table 1). One common theme of all individuals (with the exception of Lilliput 1) was a preference for areas characterized by deeper bathymetry (Table 1). Individuals Lilliput 2 and 4 showed a preference for regions with rugged, variable bathymetry (Table 1). Individuals Lilliput 1 and 5 showed a strong preference for areas characterized by a steep bathymetric slope (Table 1). In SG, a similar pattern was observed, with the same single model identified at NA best explaining habitat preference for four of the six individuals. The hazard (probability of leaving an area as a function of FPT duration) of animals' #DR2 and #DR3 leaving an area (diminished FPT) increased when benthic habitat became more rugged. In contrast to all other individuals in SG, animal #DR2 was more likely to remain in deeper water (Table 1). The adult female who travelled east (#DR3) showed a strong preference for deeper regions that were characterized by steeply sloping bathymetry.

Objective 3:

Predicted suitable habitat (PSH) for each individual at each study location is presented in Figures 3 and 4. The highly individual nature of habitat usage described above translated into individual differences in the availability of PSH. In SG, the consistency of sanctuary zones in terms of total available individual PSH varied from less than 1% to complete coverage (mean 50 ± 16.1%; Table 1). Conversely, the proportion of all PSH available to each individual that was protected within sanctuary zones was remarkably consistent, ranging between ~12-29% (mean 19.8± 3.16%; Table 1). In the NA, sanctuary zone habitat composition was on average the same as SG (NA mean 64% ±9.37%; Welch Two Sample t=0.75, df=7, p=0.48) and sanctuary zones covered a similar proportion of all available PSH for each individual (21.4±1.88%; Welch Two Sample t=0.42, df=7, p=0.69; Table 1).

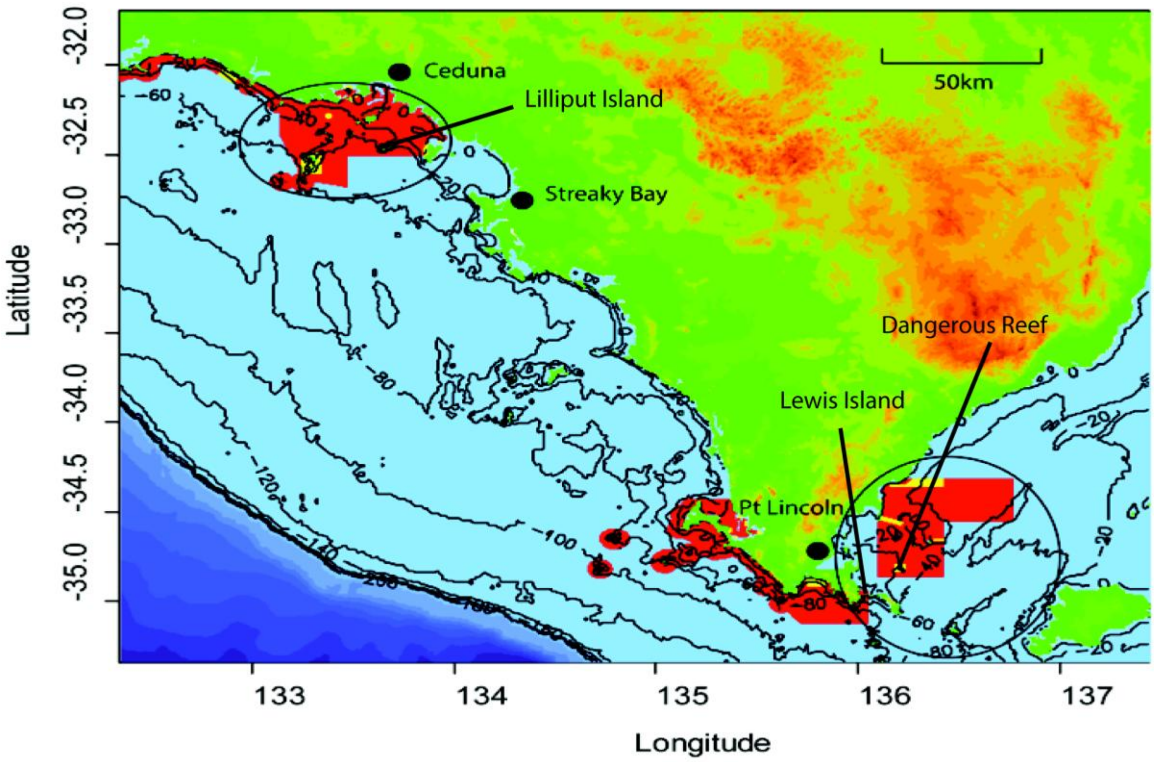

Figure 1. Location of the study regions (circled) on the western Eyre Peninsula and the Spencer Gulf. The Nuyts archipelago off Ceduna consists of several small islands, many of which host breeding colonies of ASL. The colony on Lilliput Island produces approximately 60 pups each breeding season. Southern Spencer Gulf hosts the largest breeding colony of the species (Dangerous Reef) which produces ~600 pups per breeding season. Red areas show regions designated as state Marine Parks. Yellow areas within Marine Parks show the approximate location and size of sanctuary zones proposed by DEWNR Coastal and Marine branch, after MARXAN modelling and consultation with subject matter experts in the region. Bathymetry shown in 20m increments.

Table 1. Coefficient (β), Hazard function (e^{β}) and associated standard errors for individual Cox Proportional Hazard models. Negative and positive β indicate preference and dislike of

the associated habitat type, respectively. The hazard function places β in a quantitative framework; values <1 indicate a reduced hazard of leaving areas of the associated habitat type. For example, individual Lilliput 1 has a coefficient for 'Slope' of -3.28 and associated hazard function of 0.03; this reflects a strong preference for bathymetric slope with a risk of leaving an area decreasing by 97% for each degree increase in slope.

Nuyts Archipelago

Individual		Depth	Ruggedness	Slope	% predicted habitat (available and covered by sanctuary zone)	(proportion of sanctuary zone)
Lilliput 1	β	0.06	1.78	-3.28	23.8%	80.3%
	e^{β}	1.06	0.04	0.03		
	$\pm SE(\beta)$	0.01	0.38	1.26		
Lilliput 2	β	-0.23	-2	4.86	27.9%	59.6%
	e^{β}	0.79	0.14	0.13		
	$\pm SE(\beta)$	0.01	0.41	1.49		
Lilliput 3	β	-0.09	0.06	0.49	16.9%	90.8%
	e^{β}	0.92	1.06	1.65		
	$\pm SE(\beta)$	0.01	0.09	0.36		
Lilliput 4	β	-0.03	-3.02	22.19	21.1%	45.1%
	e^{β}	0.97	0.05	$4.3x10^{9}$		
	$\pm SE(\beta)$	0.01	0.67	2.43		
Lilliput 5	β	-0.03	0.59	-2.34	17.3%	44.1%
	e^{β}	0.98	1.81	0.09		
	$\pm SE(\beta)$	0	0.15	0.53		

Southern Spencer Gulf

Individual		Depth	Ruggedness	Slope	% predicted habitat (available and covered by sanctuary zone)	(proportion of sanctuary zone)
DR 1	β	0	-1.99	8.54	14.8%	86.7%
	e^{β}	1.03	0.14	$5.12x10^{3}$		
	$\pm SE(\beta)$	0	0.10	0.35		
DR 2	β	-0.24	2.79	□□	25.5%	60.4%
	e^{β}	0.78	16.26	□□		
	$\pm SE(\beta)$	0.05	3.96	□□		
DR 3	β	0.06	3.05	-8.77	11.9%	<1%
	e^{β}	1.06	21.26	0		
	$\pm SE(\beta)$	0.01	1.03	3.74		
DR 4	β	□□	-0.31	□□	12.0%	100.0%
	e^{β}	□□	1.51	□□		
	$\pm SE(\beta)$	□□	0.07	□□		
Lewis 1	β	□□	-0.18	□□	28.9%	37.1%
	e^{β}	□□	0.84	□□		
	$\pm SE(\beta)$	□□	0.07	□□		
Lewis 2	β	0.32	-5.53	□□	25.8%	15.7%
	e^{β}	1.37	0	□□		
	$\pm SE(\beta)$	0.03	0.72	□□		

Objective 4:

Animal-borne video and environmental devices (AVED) have provided a wealth of data on the distribution and structure of habitats in regions that an individual encounters either in transit or actively foraging. These data allowed DEWNR geoswath operators to capture high-resolution data outside their mapping area, and to corroborate their interpretation of habitat structure over large areas with video footage. Given that adult female ASL in both regions of this study seldom spend longer than 72 hours at sea (Lowther and Goldsworthy 2010; Lowther and Goldsworthy 2011; Lowther, Hamer *et al.* 2011), the development of solid-state memory and miniaturized video cameras (such as the Sony 'Go Pro'™) should provide a cost-effective off-the-shelf starting point for custom-manufactured recording devices that can collect data throughout entire foraging trips.

The use of adult female Australian sea lions as tools in combination with a more appropriate AVED system could streamline and enhance the process of benthic mapping and subsequent selection of appropriate habitat types for zoning marine parks. However it is important to note that our technique is reliant on the long-term foraging site fidelity displayed by adult female Australian sea lions and may not be appropriate for other Australian otariids (Australian and New Zealand fur seals).

3. Appropriateness

The appropriateness of the approaches used in the development and implementation of the Activity

Overall we consider our approaches to represent the most appropriate and, when circumstances allowed (i.e. enough data availability), the most current techniques and approaches available. We outline below the specific approaches in relation to each objective:

Objectives 1& 2:

Traditional measures used to assess habitat electivity (i.e. Resource Selection Functions) rely on the assumption that animals know about the location of all 'available' habitat (Fauchald and Tverra 2003). Our approach to characterising foraging and transiting behaviour through the use of First Passage Time (FPT) is well-grounded in the scientific literature (see Fauchald and Tveraa 2003). Modelling the relative risk (in terms of changes in FPT) and habitat use intensities using Cox Proportional Hazard (CPH) models has been conducted on numerous marine predators (white whales, walrus, polar bears and ringed seals) (eg. Freitas et al. 2008, 2009, 2012).

Objective 3:

Logistical issues and equipment failure severely reduced our capacity to collect fine-scale habitat data along animal tracks. In turn this hampered our ability to directly test congruence between fine-scale habitat composition of sanctuary zones and the habitat preferences of adult females. To test congruence between coarse-scale metrics of habitat, we used a 250m resolution digital elevation model of both regions to derive coarse-scale habitat metrics (depth, slope and rugosity). These metrics were available continuously along each animal track and could be used to characterise the composition of sanctuary zones. CPH models were then used to generate predictive maps based on the utilisation of different habitats along animal tracks (see references above). We then use the proportion of predicted suitable habitat protected by sanctuary zones, and the composition of each sanctuary zone in relation to habitats that may be suited to individuals to answer Objective 3. Given the logistical and technical setbacks we consider this to be the most appropriate approach to achieve this objective.

Objective 4:

As far as we are aware, this project represents the first attempt to utilise AVED in the context of planning the location and consistency of marine parks. We cannot stress enough the important lessons on the current inadequacy of AVED technology. Should this technique be considered for other regions then identifying ways to improve this technology is of paramount importance. Another critical lesson to be passed on to future projects of this nature is understanding the importance of collecting data from animals first in order to target secondary data collection (i.e. geoswath), or delaying projects if logistics preclude this. Given the pioneering nature of this project, we consider it a success insofar as we have identified the potential issues for other research bodies to consider prior to embarking on a similar project.

4. Effectiveness

The degree to which the Activity has effectively met its stated objectives

Objectives 1 & 2:

In light of our small sample size, the variation in individual habitat electivity at both sites was considerable. In the Nuyts Archipelago, each individual showed a strong preference for foraging against at least one of the three coarse-scale habitat types (bathymetric depth, slope and rugosity). Given the variability of between individuals in habitat preference, increased sampling may show that all available habitats in each region are utilized by some adult females, but may indicate which foraging habitats are preferred by most individuals, and conversely which are least favoured. Additional data would inform further on the predictive accuracy of our habitat models.

Objective 3:

This study highlights an important consideration, both in terms of the timing of secondary data collection (e.g. swath mapping or BRUV deployments) and ongoing monitoring of regions. Due to logistical and time constraints, geoswath mapping and BRUV deployments in the NA were conducted prior to AVED deployments (using telemetry data from an earlier study to inform on areas that may be important to sea lions). Consequently, the locations used by animals fitted with AVED did not show a high degree of congruence with swath mapped locations, limiting our ability to extract high resolution habitat data for electivity analysis. As such, it is imperative that tracking is conducted first, so that secondary data collection can be targeted to construct a more formal experimental test of fine-scale habitat electivity. Furthermore, the endurance of the camera system deployed in this study (in terms of absolute hours of footage and battery longevity) was insufficient to capture habitat information in both regions (active foraging and transiting) for each individual, limiting our capacity to test for habitat electivity at an individual level. Overly-complex AVED duty cycling and sensor configurations coupled with fragile internal components led to an unreliable system that failed catastrophically on numerous occasions, reducing the amount of video data for subsequent analysis. The use and modification of more robust and durable off-the-shelf technology should be explored to address this problem.

Objective 4:

In conducting this project, several key lessons (outlined in #2 'Outcomes/Objectives') have been learnt when employing AVED to assist and enhance marine park planning. If AVED are to be used in tandem with other methods of benthic mapping (e.g geoswath mapping) then the order in which these are done is critical to ensure data collection is maximised. In all cases, a more robust camera system is essential – the field of capturing location and dive data using biotelemetry devices is well-developed; instruments are robust enough to withstand the rigors of deployment on large, wild predators and are now capable of collecting extremely accurate (<50m resolution) GPS data at almost every surfacing event. AVED technology is currently insufficient to be used to record data across a complete foraging trip, however off-the-shelf technology is at a stage where it merely has to be 'animal-proofed'.

5. Communication

How results will be communicated to management