Responses of Australian sea lions, Neophoca cinerea, to anthropogenic activities in the Perth metropolitan area, Western Australia

AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS

Aquatic Conserv: Mar. Freshw. Ecosyst. (2016)

Published online in Wiley Online Library
(wileyonlinelibrary.com). DOI: 10.1002/aqc.2668

Responses of Australian sea lions, Neophoca cinerea, *to anthropogenic activities in the Perth metropolitan area, Western Australia*

SYLVIA K. OSTERRIEDER[a,b,*], CHANDRA SALGADO KENT[a] and RANDALL W. ROBINSON[b]

[a]*Centre for Marine Science and Technology, Department of Imaging and Applied Physics, Curtin University, Bentley, Australia*

[b]*Institute for Sustainability and Innovation, College of Engineering and Science, Victoria University, Melbourne, Australia*

ABSTRACT

1. Tourist-based activities, partly due to their rapid increase, have raised concerns regarding the impacts of anthropogenic activity on marine fauna. Documented effects on pinnipeds in proximity to humans include changes in behaviour, site use and potentially higher aggression levels towards people. Effects vary considerably between populations and sites, thus requiring separate assessment of human impacts on activity and energy budgets.

2. Responses of the endangered Australian sea lion, *Neophoca cinerea*, to human visitation were recorded from November 2013 through April 2014. Exposure levels and response types to anthropogenic activities were assessed at two easily accessible locations with different management schemes, Seal (landing prohibited) and Carnac (landing permitted) islands, Western Australia. Exposure levels were measured as both stimulus type (i.e. 'People', 'Paddlers', 'Small', 'Medium', and 'Large vessels', 'Tour vessels', and 'Jet skies'), and people ('Direct', 'Attract', 'Interact', 'View', 'Incidental', 'Water', 'Low-level'), and vessel activities ('Interact', 'Approach/Follow', 'Anchor noise', 'Engine noise', 'Close to beach', 'Moderate/Fast travel', 'Slow travel', 'Transit', 'Drift/At anchor', 'Aircraft noise').

3. Exposure levels varied significantly between the islands in numbers, stimuli type, duration and minimum approach distances. The instantaneous behaviours of 'Lift head', 'Interact' and 'Sit' were the most frequent responses. 'Aggressive' and 'Retreat' responses, the highest disturbance levels measured, occurred on Carnac approximately once per day, but rarely on Seal Island. 'Aggressive' behaviour towards 'People' was observed only on Carnac Island and elicited only by 'People'. 'People', 'Tour vessels', and scenic 'Aircrafts' on both islands as well as 'Jet skis' on Carnac Island had the highest probability of triggering responses. Owing to their relatively high visitation at Seal Island, 'Paddle powered vessels', followed by 'Tour vessels' elicited the highest number of responses, compared with 'People', 'Small', and 'Medium vessels' at Carnac Island. The majority of responses occurred when any stimulus type was at short-range ($\leq$10 m), and 'People' 'Viewing' *N. cinerea* elicited most. Vessels triggered more responses at larger ranges than 'People'.

4. To limit close-range access to *N. cinerea*, one possibility is to close the beach at Carnac Island to human visitation and increase the minimum approach distance by vessels and 'People' by installing marker buoys at least 15 m from the shore.

Received 28 October 2015; Revised 14 March 2016; Accepted 26 March 2016

KEY WORDS: coastal; island; disturbance; endangered species; habitat management; mammals; pinnipeds; anthropogenic activities

*Correspondence to: Sylvia Osterrieder, Centre for Marine Science and Technology, Department of Imaging and Applied Physics, Curtin University, Building 301, Wark Avenue, Bentley, Western Australia 6102, Australia. Email: sylvia.osterrieder@gmail.com

The copyright line was changed on 04 July 2016 since first publication.

INTRODUCTION

Conservation of animal populations requires accurate knowledge of the potential impacts that anthropogenic activities may have on their health and survival. Impacts from anthropogenic activities are wide-ranging, and the level of severity depends upon factors including the type of activity, duration and their proximity to the animals. Marine ecotourism such as whale and dolphin watching is increasing in popularity and often includes direct (swimming with) and indirect (observational) interaction. More recently, excursions to observe other fauna such as seals and sea lions at haul-out locations, have also increased. In the Southern Hemisphere alone, 1.3 million people visit pinnipeds every year (estimated average from 1995 to 2000), with an annual value of US $12.6 million (Kirkwood *et al.*, 2003). Activities range from swimming with seals and sea lions to watching them from boats, planes or land (Boren *et al.*, 2002; Kirkwood *et al.*, 2003; Lovasz *et al.*, 2008; Cowling *et al.*, 2014).

The Australian sea lion, *Neophoca cinerea*, endemic to Western and South Australia (Gales *et al.*, 1994; Goldsworthy *et al.*, 2008), is classified as Vulnerable by the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 and by the two states in which it occurs (National Parks and Wildlife Act 1972, South Australia; Wildlife Conservation Act 1950, Western Australia), and is listed as Endangered on the IUCN Red List of Threatened Species (Goldsworthy, 2015). In Australia, *N. cinerea* is increasingly targeted by marine tourism. Seal Bay at Kangaroo Island in South Australia is the most popular location to watch *N. cinerea* in the wild, receiving up to 110,000 visitors in any one year since the 1950s (Kirkwood *et al.*, 2003). Haul-out islands off Port Lincoln, South Australia and Jurien Bay, north of Perth in Western Australia (WA) also receive large numbers of visitors (Kirkwood *et al.*, 2003).

Pinniped tourism is very popular and economically beneficial (Kirkwood *et al.*, 2003). However, there is public and scientific concern that these activities may have detrimental effects on the health of marine wildlife populations (Gerrodette and Gilmartin, 1990). Various studies have endeavoured to document behavioural changes, for example aggressive displays, avoidance or habituation, physiological responses, and direct threats to the survival of animals, such as entanglement and increased risk of boat strikes (Gerrodette and Gilmartin, 1990; Constantine, 1999; Stevens and Boness, 2003; Newsome and Rodger, 2008; French *et al.*, 2011). There is evidence that animals may reduce time spent resting or hauling out, possibly affecting their energy budget; or may leave pups unattended, which, while currently untested, could potentially increase pup mortality (Kovacs and Innes, 1990; Jansen *et al.*, 2010). Assessing the magnitude of effects is complex as age, sex, degree of exposure, and stage in the breeding cycle may influence responses to disturbance and level of impact (Boren *et al.*, 2002; Cowling *et al.*, 2015). Furthermore, most studies have been limited to assessing short-term (over the course of a day) and immediate responses of individuals, rather than long-term impacts (over months and years) on the population. This is probably a result of the challenges involved in long-term monitoring owing to long-term required funding, and the non-trivial nature of disentangling the effects of human disturbance from changes in a complex environment.

To reduce the impact of human/pinniped interactions, various regulations and guidelines have been initiated (e.g. spatial and temporal restrictions or limitations in vessel speed and visitor numbers) to both maintain the health of the marine environment and to protect animals and tourists during interactions (Orams, 1999). In Australia, several patrolled marine parks and sanctuary zones, with limited access for visitors to view and interact with animals, have been established (Gales, 1995; Kirkwood *et al.*, 2003; Cassini *et al.*, 2004; Salgado Kent and Crabtree, 2008; Young *et al.*, 2014). Where close approaches are allowed, there are guidelines recommending safe distances for viewing and for reducing disturbance to pinnipeds. Although regulations and guidelines are in place for management, the scientific basis for these management decisions in relation to *N. cinerea* is limited (DEC, 2007; Lovasz *et al.*, 2008; Salgado Kent and Crabtree, 2008; Young *et al.*, 2014).

In metropolitan waters around Perth, for example, moving/approaching *N. cinerea* slowly and keeping a minimum distance of 5–10 m are recommended (DEC and DoF, 2011). At this location, the largest numbers of *N. cinerea* haul out on Seal and Carnac islands, which are two of the six main local haul-out sites (Gales *et al.*, 1992). Owing to the close proximity of the islands to Perth (~2 million people) and their ease of access, both islands are heavily used for tourism and recreational activities, including viewing *N. cinerea* in the wild (Orsini and Newsome, 2005). On Seal Island, located within a marine park, landing by either vessels or people is prohibited. In comparison, the beach on Carnac Island is divided into two different zones with only the sanctuary zone off limits to the public. While the designation of the zone was based on the area used most often by *N. cinerea* in a study in 2005 (Orsini and Newsome, 2005), a follow-up study, 2 years later, showed that *N. cinerea* used the beach outside the sanctuary zone just as frequently (Salgado Kent and Crabtree, 2008). It was determined that the most effective approach for reducing disturbance on Carnac Island was to expand the sanctuary zone over the entire beach (Salgado Kent and Crabtree, 2008).

Beyond the study at Carnac Island, the effectiveness of small sanctuaries, or no-go zones, in reducing disturbance in the Perth metropolitan area, and other areas, is not accurately known (Gormley *et al.*, 2012; Hartel *et al.*, 2015). Owing to the competing interests in use and access to the islands by conservationists, recreational users, and commercial operators, as well as the underlying need for conservation of the species, the effectiveness of sanctuary zone size and applied management strategies must be assessed (Salgado Kent and Crabtree, 2008). Establishing baseline data and determining impacts of various types of use is critical for improving the design of reserves and management outcomes (Kelleher, 1999).

This study investigates the responses of *N. cinerea* to anthropogenic activity at two sites (Seal Island and Carnac Island) with different management strategies. Various activity types were documented as pinnipeds have been shown to respond differently to varying stimuli (Cassini, 2001; Boren *et al.*, 2002; Jansen *et al.*, 2010). Specifically, stimulus types (i.e. vessel types and people), their activities, and *N. cinerea*'s response behaviours were categorized, and recorded. Distances between the stimuli and responding *N. cinerea* were also recorded. Thus, the influence of stimulus types, their activities, and distances on *N. cinerea* behaviour were investigated.

The specific objectives of this study were to: (1) compare the numbers of vessels/people present, and to quantify their activities at Seal and Carnac islands, two islands with contrasting management types, to provide context to the response of *N. cinerea* for wider application; (2) compare the frequency and level of disturbance to *N. cinerea* at the two islands, in relatively close proximity to urban areas (0.9 and 10 km); and (3) assess the influence of anthropogenic activity types and their proximity to the animals through measurements of the frequency and level of *N. cinerea* responses. Understanding the key impacts of tourism on *N. cinerea* behaviour is necessary for improved, scientific-based, long-term management, and where necessary, recovery plans for endangered species, such as *N. cinerea*, on both a local, regional and national scale. To do this requires an understanding of the context within which the animals have been observed (Objectives 1 and 2).

METHODS

Study sites

Six islands are known to be used as haul-out sites by male *N. cinerea* off the Perth metropolitan coast, Western Australia (Figure 1). Of the six islands, the islands included in this study – Seal Island (–32.29° S, 115.69° E) and Carnac Island (–32.12° S, 115.66° E; Figure 1) – have the largest proportions of *N. cinerea* hauling out; more than 30 during the peak season (Osterrieder *et al.*, 2015). Usually less than 10 *N. cinerea* haul out at the other metropolitan haul-out islands (Department of Parks and Wildlife, unpublished data).

Seal Island is a sanctuary zone where landing is not permitted, located in the Shoalwater Islands Marine Park, ≈0.9 km from the coast and ≈45 km south of Perth (Figure 1). Here, *N. cinerea* can be

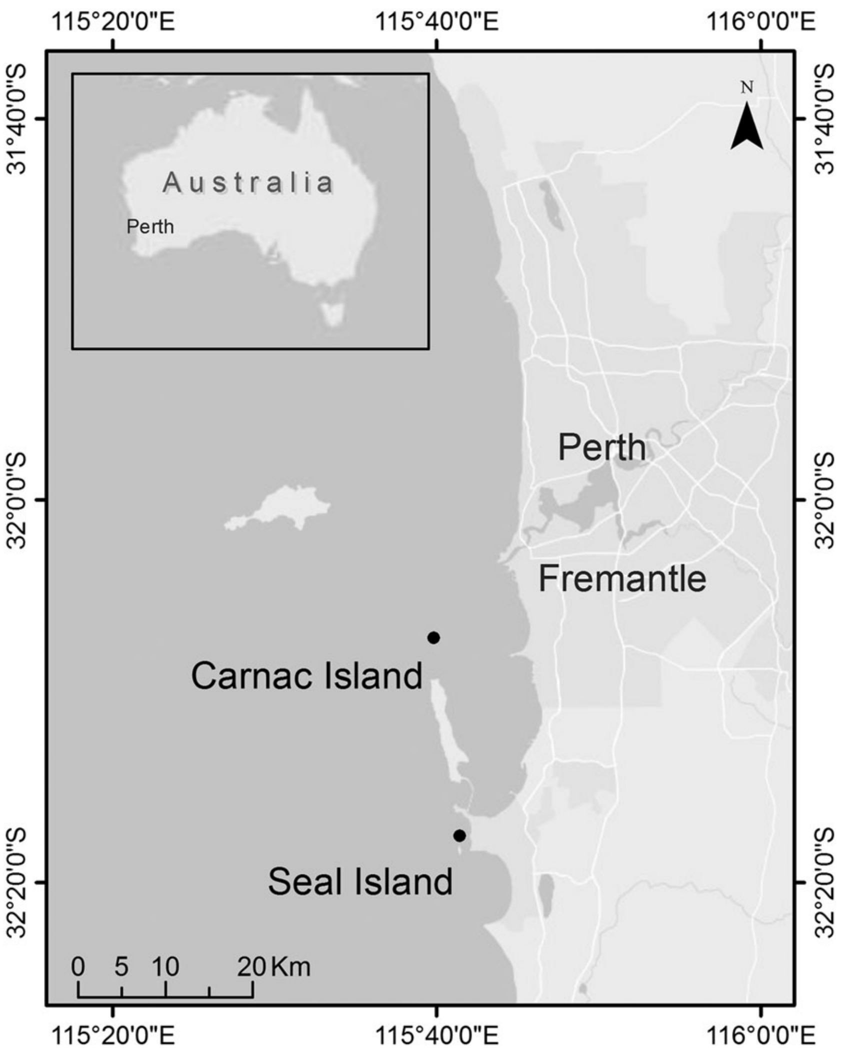

Figure 1. Seal Island and Carnac Island, largest *N. cinerea* haul-out sites in the Perth metropolitan area, Western Australia.

viewed on a kayaking or boat tour and the sanctuary zone's 'look, but don't take' area offers the highest level of protection allowing boating, snorkelling and nature appreciation activities, but prohibits fishing (DEC and DoF, 2011). *Neophoca cinerea* predominantly haul out on the beach of ≈0.27 ha (estimated from a Google Earth, 2014 image from 1 January 2014) on the eastern side of the island. They also haul out adjacent to the shrubs or caves at the southern bay on occasion, but have not been seen to haul out on the other sides of the island that comprise mostly rocky outcrops.

Carnac Island (≈10 km south-west of the Fremantle coast and 15 km south of Perth; Figure 1) is an A class nature reserve, with part of the island designated as a sanctuary zone. Access to most of the island is prohibited, but the southern part of the eastern beach is available for public access during the day (CALM, 2003). The eastern beach is ≈0.78 ha (estimated from a Google Earth, 2014 image from 1 January 2014) and *N. cinerea* mainly haul out on this sandy beach. Charter and tour vessels travel to Carnac Island, though less frequently than to Seal Island. Both, Seal and Carnac islands, can also be easily accessed by private recreational vessels.

Experimental design

Count data for Seal and Carnac islands, either conducted by an observer located on the islands, or remotely using a locally installed, live video camera, were collected over a period of two years, between June 2012 and April 2014 (Figure 2(a)). Within this period, individual responses to anthropogenic activities were recorded over 5 months, from the end of November 2013 until the end of April 2014.

Observations at Seal Island were predominantly made from a vantage point located on the island with a view of the entire beach, using either the naked eye or binoculars (Nikon Eagleview 8–24 × 25). Transfer issues restricted travel to Seal Island between July and August 2012 and on 9 October 2012 (Figure 2(a) and (b)). As a result, observations during those times were made from a vantage point on the mainland (32.2855° S, 115.7035° E), with the entire beach area in view, using either a telescope (115 mm Tasco reflecting with either a 25 mm, 20 mm or 10 mm eye piece with 36×, 45× or 90× magnification, respectively) or a spotting scope (Televid 77 with 20× to 60× zoom).

Data for Carnac Island were predominantly collected remotely, via an at the time of operation live, remote controlled camera (AVT284 IP Camera with remote Pan, Tilt, and Zoom capability and 22× optical zoom) with a radio link to a local Department of Parks and Wildlife office (using a Proxim 8150 PTP microwave radio link). The camera was located overlooking the eastern

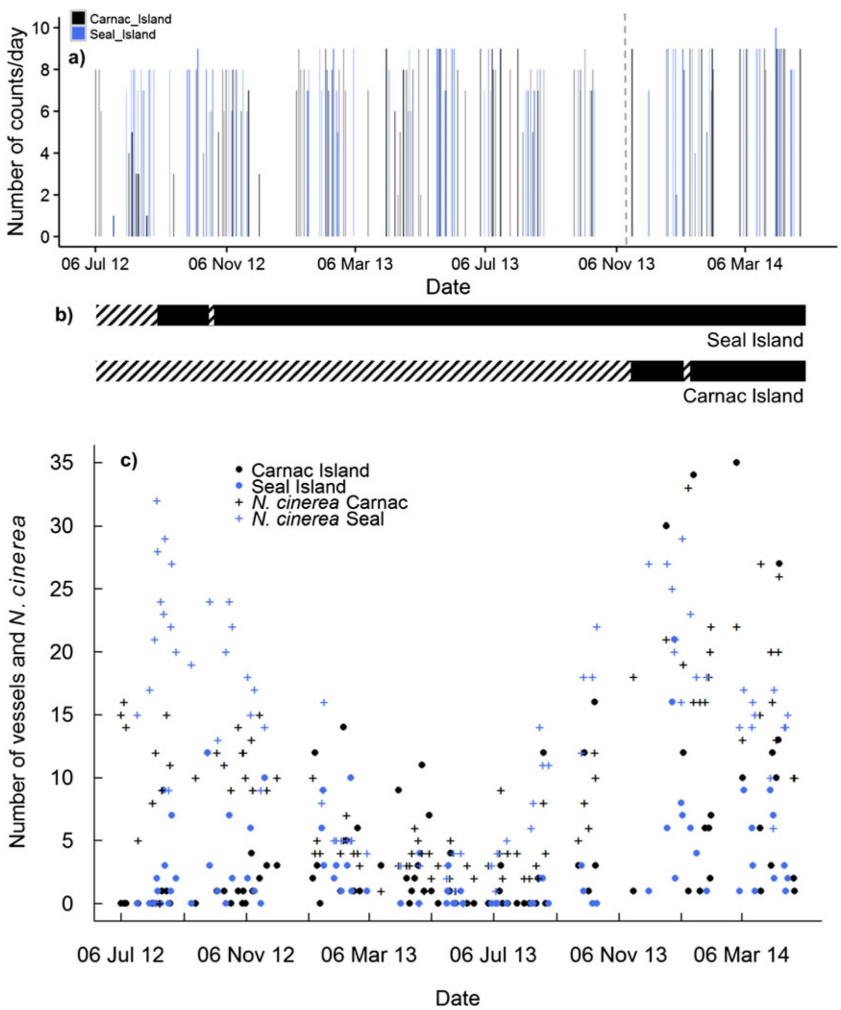

Figure 2. (a) Sampling frequency with number of counts conducted per sampling day (Carnac Island is demarcated in black, Seal Island in blue, and dashed line at end of November 2013 indicates the start of the collection of disturbance data). (b) Sampling method used throughout the sampling period displayed in Figure 2(a) (black stripes = remote, including Seal Island observations from the vantage point in Shoalwater using the telescope or spotting scope, and Carnac Island observations with the remote controlled, live camera). (c) Maximum number of vessels (○) and *N. cinerea* (+) observed on Carnac Island (black) and Seal Island (blue) each day during 166 survey days between June 2012 and April 2014.

beach. Direct observations made on Carnac Island from the same vantage point as the camera were conducted between the end of November 2013 and the end of April 2014, with the exceptions of the 8 and 13 January 2014 (Figure 2(a) and (b)). To minimize disturbance caused by the researchers upon arrival, the vantage points on Seal and Carnac islands were approached from a small bay at the back of the beach (Seal Island), or by landing in gaps between *N. cinerea* (Carnac Island), always remaining as far away from *N. cinerea* as possible. While on-island, observations were always conducted from a range >20 m, movement minimized (e.g. no sudden standing up) and conversation kept to a level thought to be inaudible at the ranges where *N. cinerea* had hauled out.

Remote observations were limited to counts of vessels and 'People' (i.e. people in the water or on the beach, not attached to any floatation device, and herein classified as 'People') to ensure comparable and accurate data were collected. More detailed behavioural data were collected only when observers were on the islands. The telescope and spotting scope were considered to give sufficient magnification for easy and accurate counts, and the remotely operated camera has previously been shown to reflect counts accurately (Salgado Kent and Crabtree, 2008).

Counts of vessels, 'People' and N. cinerea

All vessels approaching or passing within approximately 400 m of the beach were counted by one to three observers during island-based monitoring. In addition, counts were made of all 'People' and *N. cinerea* within view, either on land or in the water. Counts were generally conducted during 5 to 10 min scans, and were made every hour primarily between 08:00 and 16:00 h, with the exceptions of inclement weather or when technical difficulties cut some days short. *Neophoca cinerea* known to be present during the count but temporarily out of view (i.e. sighted when going behind rocks and again when coming back into view) were also recorded.

Hourly counts conducted remotely were carried out by panning from north to south, from one side of the beach to the other, to count vessels, 'People' and *N. cinerea* (Salgado Kent and Crabtree, 2008). The zoom on the live camera was used to aid counts when necessary, particularly to distinguish *N. cinerea* from some rocks on the far, southern part of the beach.

Behavioural responses to anthropogenic activities

An observer recorded arrival and departure times of anthropogenic stimulus types (e.g. vessels, and 'People', Table 1), including the time 'People' entered or left the water or the beach, on a dictaphone. These arrival and departure times were used to calculate the total number of 'People' and vessels, except on five days when high activity and numbers of vessels at Carnac Island (up to a maximum of 36 vessels and 20 'People' at any one time) made this unfeasible. During these periods, counts were conducted every 5 to 15 min instead to determine totals and numbers of *N. cinerea* present during each behavioural response taken from the nearest count. At all other times on

Table 1. Definition of stimulus categories

Stimulus type	Description
People	People in the water or on the beach, not attached to a floatation device or vessel. On Carnac 'People' occurred in the water and on the beach. On Seal Island people were restricted (legally) to the water (except for on 10 occasions when people accessed the island illegally)
Paddle powered/(Paddlers)	Small vessels ≤3 m in length with no engine (e.g. kayak, paddleboard, canoe, row boat, body board)
Small vessels	Vessels up to 6 m in length (e.g. recreational/fishing vessels, dinghies)
Medium vessels	Vessels >6 m and ≤15 m in length with a single deck (including government department vessels and power/speed boats)
Large vessels	Vessels >15 m in length or fitted with multiple decks (e.g. charter boats, catamarans, party boats, commercial dive vessels, and sailing boats)
Tour vessels	Vessels visiting the islands with the aim of observing *N. cinerea* (these were usually medium sized vessels on Seal Island and large vessels on Carnac Island)
Jet ski	Jet propelled personnel water craft
Aircraft	Planes (usually scenic and military) and helicopters

Carnac Island and at all times on Seal Island vessel numbers were accounted for at each response. During these 'busy' periods, particular attention was paid to those closest to *N. cinerea* and vessels involved in activities anticipated to have greater impacts (e.g. varying the engine throttle or playing music) to capture detailed behavioural response information. Overall documented responses of interactions anticipated to have 'lower' impacts were not affected. Rather, the more detailed information was used separately – for focal behavioural response analysis.

'People's and vessels' activities (Tables 2 and 3), including the times the activities were undertaken, were also recorded. Groups of 'People' were defined as one or more closely-spaced humans displaying similar or associated behaviour. Groups of vessels (such as several kayaks travelling in close proximity) were considered in the same way.

Vessel categories included 'Paddle powered', 'Small', 'Medium', 'Large' and 'Tour vessels' as well as 'Jet skis', and 'Aircrafts' (Table 1). Vessel activities included 10 categories ranging from

Table 2. Definition of human activities associated with vessels ordered from highest to lowest anticipated impact

Activity classification	Description
Interact	Vessels interacting with *N. cinerea*, including: animals following a vessel, swimming or porpoising around a vessel
Approach/Follow *N. cinerea*	Vessels which are seeking to interact with *N. cinerea* by approaching for a better view, driving in circles around *N. cinerea* or following/chasing *N. cinerea*
Anchor noise	Setting or retrieving the anchor with associated rattling noise of the anchor chain and splashing when dropping the anchor
Engine noise	Activities producing higher level of engine noise than when travelling, including revving engine, reversing, travelling with particularly noisy engines
Close to beach	Activities within the vicinity of the beach, including approaching, staying close to or leaving the beach, and landing on the beach
Moderate/fast travel	Travelling at moderate to fast speeds (including rapid circles)
Slow travel	Travelling at a slow speeds (such as paddling)
Transit	Approaching, passing, leaving or returning to the vicinity of the island, including paddle powered vessels placed in the water from a vessel anchored off Carnac Island
Drift/At anchor	Activities with no or low movement and/or noise levels associated with them, including drifting, vessels anchored, or no activity
Aircraft noise	Planes or helicopters flying overhead

Table 3. List of categories used for recording anthropogenic activities in the order of the highest to lowest anticipated impact levels (if different activities were performed at the same time, the highest activity was recorded). Abbreviated activity names used in text and figures are marked in bold

Activity	Description
Direct/Invasive Interaction	Invasive activities in direct contact or attempting direct contact with *N. cinerea*, including touching *N. cinerea* directly or with a tool (e.g. stick), feeding *N. cinerea* (including throwing fish towards *N. cinerea*), throwing objects towards *N. cinerea*, and splashing water at *N. cinerea*
Deliberately **Attract**ing Attention	Activities seeking *N. cinerea*'s attention and provoking responses, without *N. cinerea*'s engagement, including splashing water (to attract *N. cinerea*, but not splashing directly at them), imitating *N. cinerea* noises (barking), clapping, honking, and banging vessel, hitting paddles on the water's surface, following *N. cinerea* (usually swimming), circling *N. cinerea* (e.g. standing/crowding around *N. cinerea* in a circle), yelling, screaming, whistling, loud talking, laughing, loud speaker systems on vessels, playing music, barking dog, jumping into the water
Mutual **Interact**ion	Interacting, people and *N. cinerea* engaged with each other, i.e. people playing with *N. cinerea* (in the water), such as mimicking *N. cinerea* behaviour and achieving a similar response from the *N. cinerea*
Viewing	Activities involved in viewing *N. cinerea* such as standing and observing *N. cinerea*, taking photos, being in close proximity to *N. cinerea*, approaching, passing or leaving *N. cinerea*, retreating from aggressive *N. cinerea*
Incidental Activities	Activities not aimed to provoke *N. cinerea* responses, typically occurring on the beach or in shallow (knee-deep) water, including playing on the beach, dragging a boat onto the beach or into the water, picnicking, talking at a conversation level (including humans on a vessel), walking on the beach, in the wash zone or in shallow water (but not passing *N. cinerea*)
Water-related Activities	Activities undertaken in the water (more than knee-deep) including swimming, snorkelling, diving, playing in water (but not interacting with *N. cinerea*), entering and leaving water from the boat, fishing
Low-level Recreational Activities	Activities, not fitting in previous categories and only when of low level noise, and without rapid movements such as 'quiet', i.e. barely audible talking humans not moving or moving little on the boat or beach,

activities anticipated to have a low impact, such as ‘Drifting’ and ‘At anchor’, to those anticipated to have a high impact such as ‘Interactions with *N. cinerea*’ (Table 2). Activities undertaken by ‘People’ fell into one of seven categories ranging from ‘Low-level’ recreational activities to ‘Direct’, invasive interactions (Table 3). *Neophoca cinerea*’s behavioural responses to the activities were classed as ‘Aggressive’, ‘Retreat’, ‘Enter water’, ‘Interact’, ‘Travel’, ‘Sit’, ‘Lift head’, ‘Move head’, ‘Look’, and ‘No response’ (Table 4). If multiple activities occurred at the same time (e.g. standing close to and watching *N. cinerea* – ‘Viewing’ activity) and clapping hands or screaming (‘Attract’ activity), the activity with the highest anticipated impact was recorded (‘Attract’ in this example; Table 3). Similarly, if a *N. cinerea* responded with multiple behavioural responses (e.g. ‘Moving its head’ to look towards the stimulus and ‘Sitting’ up at the same time) the highest response level was recorded (‘Sit’ in this case; Table 4). Ethograms were compiled based on proven techniques from previous studies (Beentjes, 1989; Cassini *et al*., 2004; Salgado Kent and Crabtree, 2008; Bowles and Anderson, 2012), and adjusted to capture those relevant to this study. For each interaction, numbers of *N. cinerea* responding, frequency of responses and *N. cinerea*’s behavioural response types were recorded. *Neophoca cinerea* do not have readily identifiable patterns and do not often have scars which aid discrimination among individuals. Therefore, on some rare occasions, during periods when greater numbers were hauling out and multiple individuals responded to the different stimuli, it was not always possible to assign responses to particular individuals.

Whenever possible, distances and angles from the observer to the stimuli (vessel or ‘People’), from the observer to the *N. cinerea* closest to the stimulus, and from the observer to any *N. cinerea* responding to anthropogenic activities (regardless of the distance) were measured using laser rangefinder and compass (TruPulse 360 R with accuracies of ± 0.5 m in distance to high quality targets such as *N. cinerea* and stimuli types, and $\pm 1°$ azimuth). The distance between the stimulus and the nearest *N. cinerea* (unless another *N. cinerea* was responding to the stimulus which was then measured) was calculated using basic trigonometry. Distances were not measured on 18 January 2014 at Carnac Island, on 28 December 2013 and 3 April 2014 at Seal Island, nor after 10:05 h on 8 March 2014 on Seal Island because of the unavailability of the rangefinder or the lack of functioning replacement batteries. *Neophoca cinerea* in the water did not typically present a sufficiently reflective target for the rangefinder and could not be measured. When appropriate, distance from the closest vessel or ‘People’ to the closest *N. cinerea* was estimated in *N. cinerea* body lengths (≈ 2 m) and was used for estimating distances up to 10 m. ‘People’ within arm’s reach of a *N. cinerea* were recorded as at 1 m and those touching a *N. cinerea*, as 0 m. Distances were measured when *N. cinerea* responded to groups of vessels or ‘People’ (in the water or on beaches) and when groups were seen to approach *N. cinerea*.

Table 4. Definitions of response types of *N. cinerea* responses to vessel and human activities, in order from highest to lowest level anticipated responses (if different responses occurred in combination with each other, the most severe was recorded)

N. cinerea response	Description
Aggression	Aggressive behaviour displayed towards a stimulus (e.g. gaping or lunging at ‘People’)
Retreat	*N. cinerea* walking or swimming away from vessels or ‘People’ to deliberately increase the distance between vessel/’People’
Enter water	*N. cinerea* entering water, including running into water
Interact	Socializing with vessels or ‘People’, includes behaviours such as porpoising, spy hopping, following and swimming in circles around vessels or ‘People’
Sit	*N. cinerea* sitting upright, including when near or facing a stimulus
Travel	*N. cinerea* swimming or walking in a specific direction (e.g. swimming or walking past ‘People’)
Lift head	*N. cinerea* lifting its head off the sand, such as when looking at a stimulus
Move head	*N. cinerea* moving its head by turning its head and looking around when sitting up or after lifting its head, such as when looking at vessels or ‘People’
Look	Opening or moving eyes to look at a stimulus (i.e. vessels or ‘People’)

Analytical approach

Overall numbers of each vessel type and 'People', and numbers of *N. cinerea* were based on data collected over the entire study period. However, for comparing responses of *N. cinerea* with anthropogenic disturbance at Carnac and Seal islands, a subset of data was used from the same period at both islands (from 20 November 2013 to 27 April 2014), to ensure observations had comparable seasonal conditions. Observation effort at the two islands differed by 8 h (equivalent to approximately one survey day of 20), thus effort was accounted for by normalizing the frequency of activities and responses at each of the islands to an hourly rate. 'Aircrafts' were considered in analyses of the total numbers of groups of stimulus types visiting and in the total number of responses elicited by anthropogenic activities. However, owing to their relatively low overall numbers and different types of behaviours, they were excluded from all other analysis. All analyses and figures were produced using R version 3.2.0 (R2014) run through RStudio Version 0.98.1103 – © 2009–2014 RStudio, Inc.

Number of vessels and 'People'

The number and composition of different stimulus types at Carnac and Seal islands were compared using Pearson's Chi^2 tests with Yates' continuity correction (Yates, 1934). While sampling effort was approximately 6% greater on Seal Island than on Carnac Island, Chi^2 tests are robust with unequal sample sizes (McHugh, 2013). Furthermore, the difference in sampling effort between the islands was small.

The duration of visits and minimum approach distances of stimulus types at Carnac and Seal islands were compared using Kruskal–Wallis tests (Kruskal and Wallis, 1952). Comparisons of duration and minimum approach distances between Carnac Island and Seal Island for the different vessel types and 'People' were also analysed using Kruskal–Wallis tests.

For all analyses on numbers of each stimulus type, duration of their visits, and their minimum approach distances, multiple tests were conducted using the entire dataset and several subsets of the data. Therefore, the family-wise error rate (the probability of rejecting at least one null hypothesis erroneously) could be expected to increase since the tests are no longer independent. A sequential Bonferroni correction on the *P*-values considered as significant was therefore applied (Rice, 1989). Eight Chi^2 tests were performed on the exposure of *N. cinerea* to the number of stimuli and were considered significant when $P < 0.006$. Duration and minimum approach distance of different vessel types and 'People' were considered significant when $P < 0.006$ and $P < 0.005$ to account for the eight and nine Chi^2 tests conducted, respectively.

Behavioural responses to anthropogenic activities

On occasion, individual *N. cinerea* responded several times to a single stimulus, sometimes in quick succession, such as 'Lifting their head' to 'Look' at the stimulus and then 'Sitting up' within a few seconds or minutes. If the same individual (*N. cinerea* A, for example) responded to the same stimulus within a 5 min period only one response, the behaviour considered to represent the greatest response, was used in analyses. If, however, *N. cinerea* A responded to a different stimulus at a different location, or a different individual (*N. cinerea* B) responded to the same stimulus as *N. cinerea* A, these were counted as separate responses. Once the 5 min period was completed, a response to the original stimulus by *N. cinerea* A was counted as a new response. During a subsample of 310 responses, the number of repeat responses (i.e. responses to the same stimulus by the same individual) occurring more than 5 min after the initial responses and prior to the stimulus departing the area occurred <3% of the time. Ongoing 'Interactions' between humans and *N. cinerea* can feasibly extend over 5 min (for example a *N. cinerea* may follow a vessel or play with a person for a prolonged period). Continued 'Interactions' of this sort (also exceeding 5 min) with one stimulus group were analysed as a single 'Interaction' response.

The number of *N. cinerea* responses to each stimulus type were compared among each other and between islands. In addition, a comparison of number of responses for each behaviour type was made among the stimulus types and the two islands. Either the Chi^2 test, or in cases with small sample sizes Fisher's exact test (Fisher, 1922; Yates, 1934), were used. A sequential Bonferroni correction was carried out and *P*-values of $P < 0.005$, $P < 0.005$, $P < 0.008$ and $P < 0.007$ were considered as significant for analyses of the number of responses for each behavioural type level to: groups of vessels vs. groups of 'People' regardless of the location, a stimulus regardless of the type (vessels and 'People' combined) at Carnac Island vs. Seal Island, groups of 'People' at Carnac Island vs. Seal Island, and groups of vessels at Carnac Island vs. Seal Island, respectively (Rice, 1989). To assess whether the percentage of *N. cinerea* responding (of those hauled out at any one time) was related to the number of vessels and 'People' visiting the island at that time, a linear regression was applied to the data and the corresponding R^2 value was calculated.

To investigate the influence of stimulus activities (regardless of whether they were on a vessel, swimming, or on land), *N. cinerea* behavioural responses to each activity level were calculated per hour of sampling effort and plotted. Response behaviours per hour of sampling effort were also calculated for each stimulus type and plots were used for comparisons.

Response distances

The relationship between stimulus range and frequency of occurrence of a response was investigated through histograms. To ensure all possible errors were accounted for across all ranges between stimulus and *N. cinerea* (maximum error ranges over all measured distances averaged 1.77 m (±0.96 SD) due to triangulation error), and for ease of viewing, the distances were analysed in 5 m bins. This was also plotted for the stimulus groups and activity types.

RESULTS

Numbers of vessels, 'People' and *N. cinerea*

Vessels, 'People' in the water or on the beach, and *N. cinerea* were observed on 127, 57 and 163 days, respectively, during a total of 166 survey days (Figure 2). On Seal Island, 619 hourly counts were made during 78 days, and on Carnac Island 709 hourly counts were conducted on 88 days.

Between 20 November 2013 and 27 April 2014, when behavioural responses to anthropogenic activities were recorded from observation points on the islands, 134 h of observations were conducted over 19 days on Carnac Island and 142 h during 20 days on Seal Island. Eight of the days spent on each island were weekend days or public holidays. Over the 6-month period, a maximum of 35 and 21 vessels and a maximum of 19 and six 'People' were recorded at any one time on Carnac and Seal islands, respectively (Figure 2). During this period, 402 and 521 groups of vessels and 164 and 38 groups of 'People' were observed on Carnac and Seal islands, respectively. Owing to the high number of vessels visiting during 5 days at Carnac Island, several vessels were unaccounted for and the total number of groups of vessels on Carnac Island is therefore probably an underestimate by an order of tens of vessels (cf. Orsini, 2004).

Significantly more vessels visited the islands than 'People' ($P < 0.0001$, Table 5), and both varied significantly. The total number of groups of vessels was greater on Seal Island than on Carnac Island; however, the number of groups of vessels on Carnac Island was underestimated on 5 days. The composition of vessel types during these days was similar to the overall composition of vessel types on the remaining days. It is likely that the sample accurately represents the data, hence, the total number of vessels is reported with the inclusion of the 5 days. The exposure of *N. cinerea* to different vessel types differed between Seal and Carnac islands (Table 5, Figure 3). While 'Small vessels', 'Paddle powered', and 'Tour vessels' visited Seal Island most frequently, Carnac Island was mostly visited by 'Medium' and 'Large vessels' ($P < 0.0001$ for each vessel type except for 'Large vessels', Table 5, Figure 3). 'Large vessels' were only observed on Seal Island on one occasion. Carnac Island was visited by more than four times as many groups of 'People' as Seal Island ($P < 0.0001$, Table 5).

The duration of time stimulus source spent in proximity to *N. cinerea* varied significantly among

Table 5. Results of Chi^2 and Kruskal–Walis tests comparing the number of groups of vessels of different types and ‘People’ visiting, the duration of visits, and the minimum approach distances to *N. cinerea* at Carnac and Seal islands. Numbers in bold represent significant values, type of test added as $^{+}$ Chi^2 test or * Kruskal–Wallis rank sum test, and X^2 or KW-X^2, respectively, in brackets following the *P*-value. (Sample size for ‘Large vessels’ were too small for calculations and not included.)

	P-value:Number stimuliCarnac vs. Seal	*P*-value:Duration stimuliCarnac vs. Seal	*P*-value:Min approach distance stimuliCarnac vs. Seal
Overall	<**2.2**$^{-16}$ (91.895)$^{+}$	**3.608**$^{-07}$ (25.893)*	<**2.2**$^{-16}$ (179.29)*
People	<**2.2**$^{-16}$ (78.594)$^{+}$	0.4378 (0.602)*	0.687 (0.162)*
Paddle powered	<**2.2**$^{-16}$ (147.63)$^{+}$	0.6561 (0.198)*	0.310 (1.034)*
Jet ski	**0.00343** (8.565)$^{+}$	0.9746 (0.00101)*	0.371 (0.801)*
Small vessel	<**2.2**$^{-16}$ (105.98)$^{+}$	**0.000933** (10.956)*	**3.065**$^{-06}$ (21.775)*
Medium vessel	**5.971**$^{-16}$ (65.447)$^{+}$	0.0319 (4.606)*	0.434 (0.609)*
Tour vessel	<**2.2**$^{-16}$ (94.308)$^{+}$	NA	<**0.005** (7.881)*
Carnac only, stimuli overall	NA	**0.000203** (26.219)*	<**2.2**$^{-16}$ (17.349)*
Seal only, stimuli overall	NA	0.0487 (11.141)*	**9.111**$^{-10}$ (50.89)*
Bonferroni corrected *P*-value for significance	0.006	0.006	0.005

$^{+}$$Chi^2$ test
*Kruskal–Wallis rank sum test

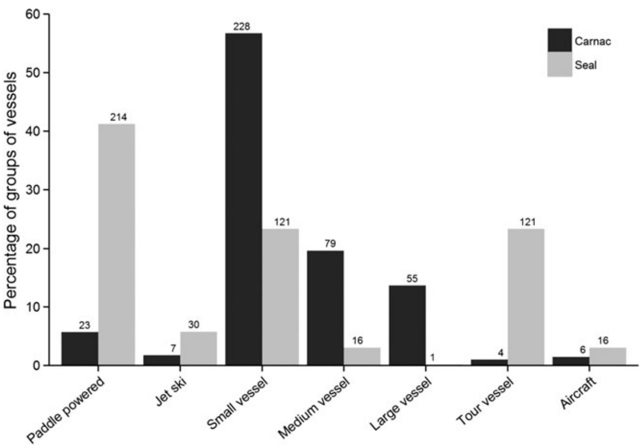

Figure 3. Percentage of groups of vessels observed visiting Carnac Island and Seal Island. Percentages are of the total at each island rather than the total combined at both islands. Values on top of each bar display the number of times each vessel type was observed (with Carnac Island having 134 h, and Seal Island 142 h of sampling effort between November 2013 and end April 2014).

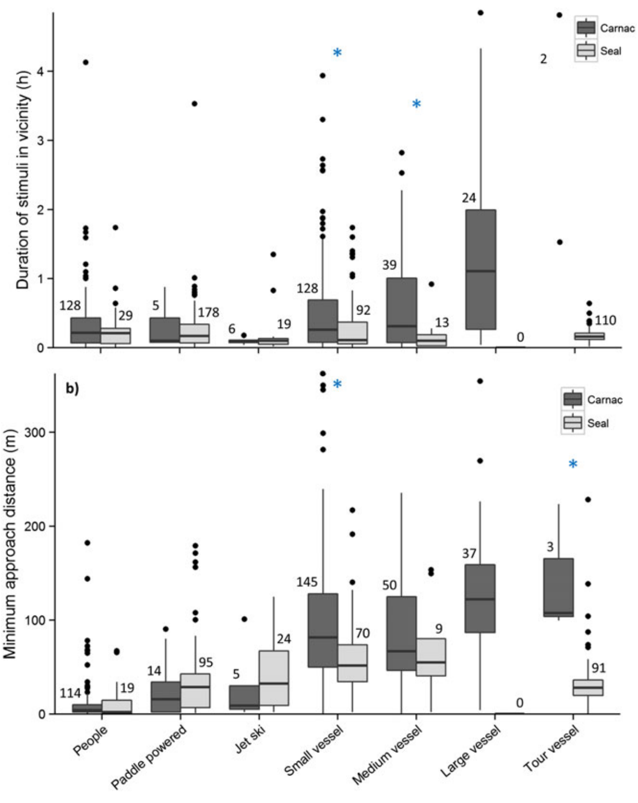

Figure 4. (a) Duration (h) and (b) minimum approach distance (m) of ‘People’ and vessels staying in the vicinity of Carnac Island and Seal Island. Values next to each bar display sample size of recorded approach and departure times for groups of vessels and ‘People’ observed (with Carnac Island having 134 h and Seal Island having 142 h sampling effort between November 2013 and end April 2014). * = significant differences between the islands.

stimulus types at Carnac Island (*P* = 0.0002, Table 5, Figure 4), but not at Seal Island (*P* = 0.05) spending on average 0.56 h (±0.79 SD) at Carnac Island and 0.23 h (±0.30 SD; *P* <0.0001) at Seal Island. At Carnac Island, the variation among vessel types was greater with ‘Jet skis’ staying the shortest periods (on average 6 min), and ‘Tour vessels’ and ‘Large vessels’ staying up to several hours at Carnac Island; longer than any vessel type at Seal Island. The sample size, however, was too small to test for differences (Figure 4).

Minimum approach distances varied significantly among vessel types and ‘People’ on each island (*P* <0.0001, Table 5, Figure 4) as well as between Seal and Carnac islands (*P* <0.0001). The average distance to which groups of vessels approached

N.cinerea was 57.5 m (±64.1 SD) and 34.4 m (±33.5 SD) on Carnac Island and Seal Island, respectively. 'People' approached *N. cinerea* more closely than any other stimuli type at both islands, on average 10.8 m at Carnac Island and 15.7 m at Seal Island.

Number of responses

In total, 1348 responses were recorded. Of those, 1300 responses were associated with vessels and 'People', and 48 with 'Aircrafts'. Of the responses to 'Aircrafts', nine occurred on Carnac Island and 39 on Seal Island (Figure 3). 'Aircrafts' were not included in statistical analysis owing to their combination of relatively small sample size, lack of determined range, and non-distinct noise source direction. Of the responses to vessels, 250 occurred at Carnac Island and 568 on Seal Island. The total numbers of responses to 'People' were 373 on Carnac Island and 109 on Seal Island, significantly more than to vessels in relation to the total number of stimuli ($P < 0.0001$, Table 6).

Overall, 40% and 39% of all groups of vessels on Carnac Island and Seal Island, respectively, elicited one or more responses from one or more *N. cinerea* (Figure 5). 'Aircrafts' flying over or past the islands, triggered responses in 67% and 81% of their passes from one or more *N. cinerea* at Carnac Island and Seal Island, respectively. *Neophoca cinerea* responded to 66% and 74% of all groups of 'People' at Carnac Island and Seal Island, respectively. The percentage of different vessel types that triggered responses in one or more *N. cinerea* varied little between the islands apart from 'Jet skis' and 'Large vessels'. A regression applied to assess whether the percentage of *N. cinerea* responding (of those hauled out at any one time) was related to the number of vessels and 'People' visiting the island at the time, did not reveal a linear relationship (Seal Island: adjusted $R^2_{\text{'People'}} = 0.01$, adjusted $R^2_{\text{vessels}} = 0.0007$; Carnac Island: adjusted $R^2_{\text{'People'}} = 0.006$, adjusted $R^2_{\text{vessels}} = 0.001$). There was also no obvious

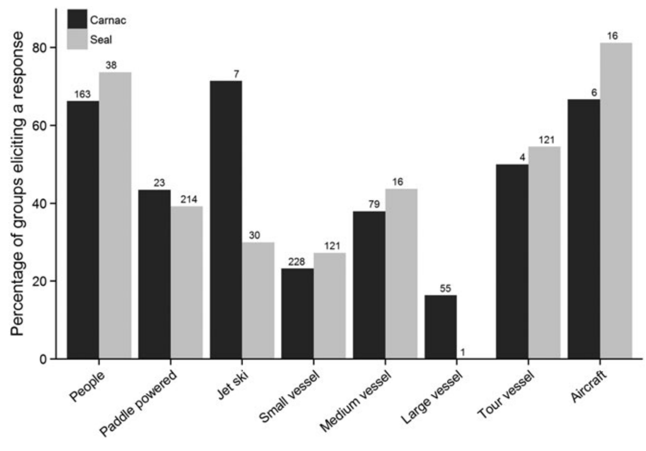

Figure 5. Percentage of groups for the different stimulus types (different vessels and 'People') that elicited one or more responses from one or more *N. cinerea* (with Carnac Island having 134 h and Seal Island having 142 h observation effort between November 2013 and end April 2014). Values on top of each bar display the sample size of groups of vessels or 'People'.

Table 6. Results of Chi^2 and Fisher's exact tests comparing the number of *N. cinerea* responses elicited by groups of vessels and 'People' at Carnac and Seal islands. Numbers in bold represent significant values, type of test added as $^+$ Chi^2 test or * Fisher's exact tests, and X^2 or odds ratio, respectively, in brackets following the *P*-value. (Aggressive responses were not observed at Seal Island, and therefore not included analyses.)

	P-value: Number responses vessels vs. 'People'	*P*-value: Number responses Carnac vs. Seal	*P*-value: Number responses to 'People'Carnac vs. Seal	*P*-value: Number responses to vessels Carnac vs. Seal
Overall	**<2.2^{-16}** (74.755)$^+$	0.317 (0.999)$^+$	0.491 (0.474)$^+$	**2.116^{-05}** (13.725)$^+$
Retreat	**3.516^{-08}** (0.0696)*	**4.234^{-03}** (8.181)$^+$	NA	NA
Enter water	**3.01^{-11}** (44.17)$^+$	0.353 (0.862)$^+$	**1.225^{-04}** (0.1589)*	0.561 (0.337)$^+$
Interact	**2.511^{-14}** (58.085)$^+$	0.994 (5.106^{-05})$^+$	0.581 (0.305)$^+$	0.0305 (4.68)$^+$
Travel	**2.372^{-03}** (0.274)*	1 (2.672^{-28})$^+$	0.439 (0.604)*	0.718 (0.131)$^+$
Sit	**6.926^{-08}** (29.085)$^+$	0.625 (0.239)$^+$	0.818 (0.0530)$^+$	**3.451^{-03}** (8.552)$^+$
Lift head	**3.78^{-03}** (8.386)$^+$	0.983 (4.524^{-04})$^+$	0.61 (0.260)$^+$	0.274 (1.199)$^+$
Move head	**1.314^{-03}** (14.622)$^+$	0.63 (0.232)$^+$	NA	0.273 (1.201)$^+$
Look	**3.257^{-03}** (0.240)*	0.714 (0.135)$^+$	NA	NA
Bonferroni corrected *P*-value for significance	0.005	0.005	0.008	0.007

$^+$Chi^2 test
*Fisher's exact tests
NA: sample size too small for calculation

non-linear pattern associated with the total number of vessels or 'People' at either island.

Response distances

Out of the total 1300 responses (623 and 677 on Carnac Island and Seal Island, respectively, excluding aircrafts), the distance between a stimulus and a responding *N. cinerea* was measured for 482 responses; 280 on Carnac Island and 202 on Seal Island. For the remaining 973 responses, a number of factors inhibited measuring the response distance; including lack of available range finder on survey, multiple *N. cinerea* responding either simultaneously or in short succession, multiple active stimuli, or a fast-moving stimulus. Responses were triggered between 0 and 345 m, with a mean of 29.6 m (±39.18 SD). The majority of responses of *N. cinerea* elicited by vessels or 'People' were observed from the shortest ranges (≤10 m) to *N. cinerea*, and decreased with increasing distance, most prominently at Carnac Island (Figure 6). The number of responses measured between 0 and 5 m at Carnac Island was double that at Seal Island, and *N. cinerea* appeared to respond to vessels and 'People' at greater distances at Carnac Island (Figure 6). Responses triggered from medium ranges (15–50 m), were predominantly due to 'Tour vessels' and to a lesser extent to 'Paddle powered vessels' at Seal Island, and 'Small vessels' at Carnac Island (Figure 7).

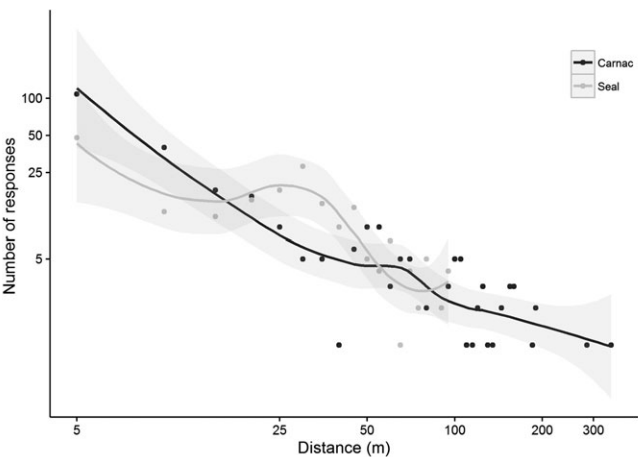

Figure 6. Number of *N. cinerea* responses occurring at 5 m binned distances at Carnac Island (n = 280) and Seal Island (n = 202), displayed on log 10 transformed axis. Loess smoothers for Carnac Island (black) and Seal Island (grey) with 95% confidence intervals were added to aid visual interpretation.

All activities carried out by 'People' (regardless of whether on board, in the water or on the beach) potentially induced a response within 10 m, and the probability of a response increased within 5 m range (Figure 8). Overall, the shortest ranges causing the highest number of responses were from 'Viewing' (11.9 m ± 11.27 SD) and 'Low-level' activities (41.4 m ± 43.61 SD), followed by 'Interacting' (5.73 m ± 1.77 SD). The number of responses decreased with increasing distances for most activities (Figure 8). Distance had less effect than activity when humans were involved in 'Attracting' greater numbers of response occurrences at longer distances. Although the frequency of responses to 'Low-level' activities decreased with increasing distance, many responses were still triggered beyond 30 m.

Response behaviours

'Lift head', 'Interaction' and 'Sit' were the most frequent behavioural responses triggered by both vessels and 'People' (Figure 9). All behavioural responses were more likely caused by 'People' than vessels on a per visit basis (P <0.005 for each response level; Table 6, Figure 9). The number of responses provoked by 'People' did not vary significantly between Carnac and Seal islands (P = 0.5, Table 6). 'Aggressive' behaviours, however, occurred only at Carnac Island, in response to 'People'. 'Retreat' behaviours occurred mainly at Carnac Island, also mostly in response to 'People' (P = 0.004 Carnac/Seal for 'Retreat' behaviour; Figure 9). At Carnac Island, 'Viewing' elicited the most responses, however, on Seal Island 'People' involved in 'Interact', 'Attract', 'Viewing' or 'Water' activities all elicited responses (Figure 10). 'Lift head' accounted for half of the total number of responses at Seal Island provoked by vessels and was triggered at a rate of about 1 h^{-1} at Carnac Island and >2 h^{-1} at Seal Island (Figure 9). The relationships between the different types of response to each stimulus group are shown in Table 6 and displayed in Figures 10 and 11. 'Small' and 'Medium vessels' elicited most responses at Carnac Island. Of the vessel activities and anthropogenic activities on

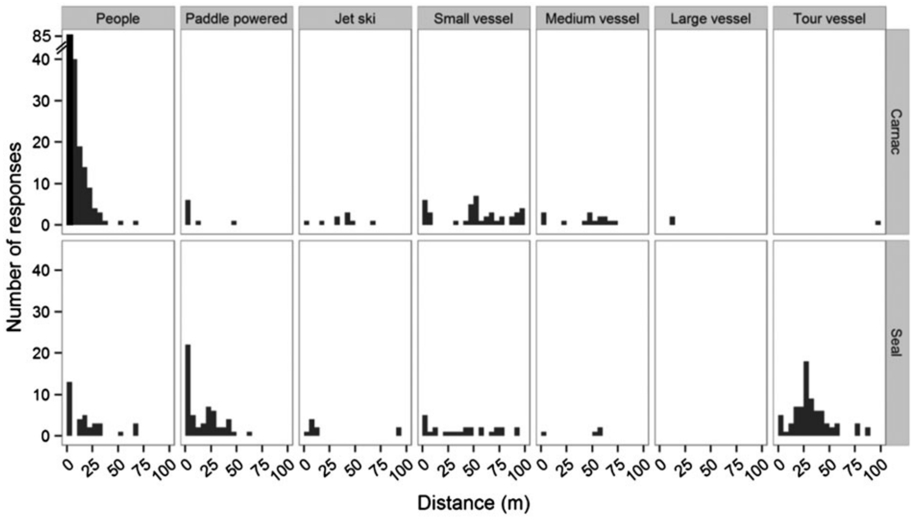

Figure 7. Number of *N. cinerea* responses elicited by groups of ‘People’ and vessels at Carnac Island and Seal Island, in 5 m bins and truncated at 100 m.

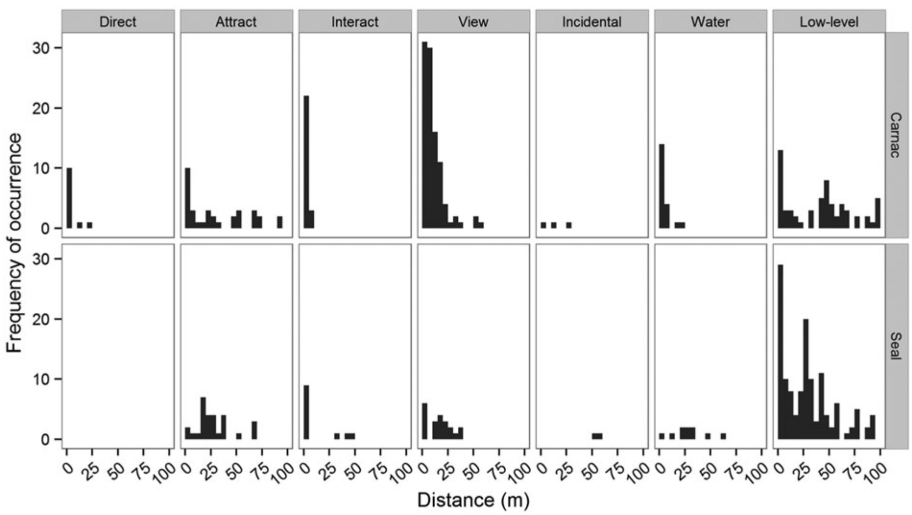

Figure 8. Frequency of *N. cinerea* responses elicited by ‘People’s’ activities on board, in the water and on the beach at Carnac Island and Seal Island, in 5 min bins and truncated at 100 m.

vessels at Carnac Island, ‘Anchor’ and ‘Engine’ noises elicited most responses in *N. cinerea* (Figure S2). At Seal Island, most vessel related responses were triggered by ‘Low-level’ activities (Figure S2).

DISCUSSION

Neophoca cinerea regularly respond to anthropogenic activities and the response type and frequency can be dependent on the stimulus itself, its range and the activity. In this study, anthropogenic stimulus and activity types varied at two differently managed islands. While response levels were, in general, similar at both locations, the most severe behavioural response levels, ‘Aggressive’ and ‘Retreat’, occurred mostly at Carnac Island, predominantly elicited from approaches by ‘People’ and probably because of their proximity (≤10 m) to *N. cinerea*. The majority of responses were generated from stimuli that achieved the closest range and decreased with increasing range. Responses elicited at greater ranges were more likely to occur when stimuli were undertaking activities associated with elevated noise levels or actions directed at attracting *N. cinerea*’s attention.

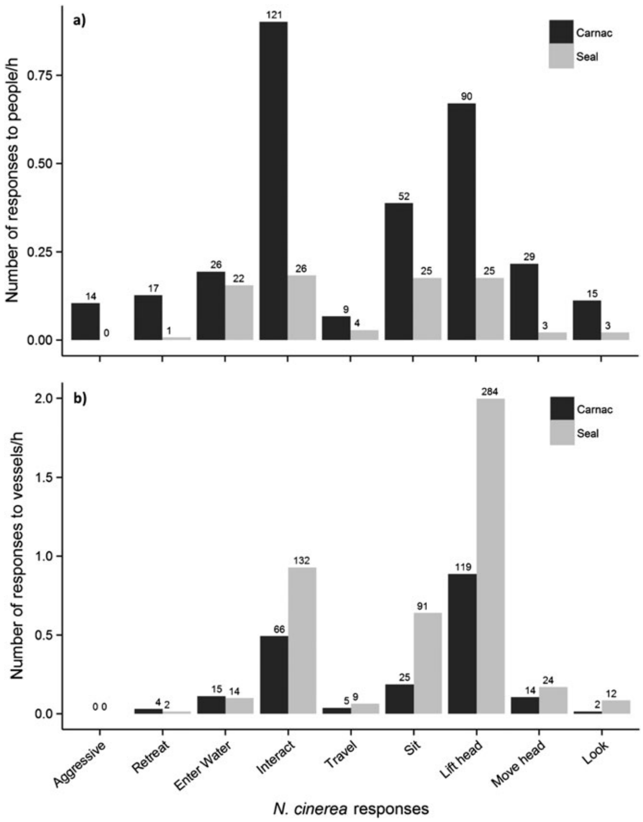

Figure 9. Number of *N. cinerea* responses per hour of sampling elicited by (a) 'People' and (b) vessels at Carnac Island and Seal Island (excluding 'Aircrafts'). Numbers above each bar indicate the total number for each behaviour observed (Carnac: 134 h, Seal: 142 h sampling effort between November 2013 and end April 2014).

Distance has been identified in many studies as the main factor in altering pinniped behaviour, eliciting stronger responses when disturbance occurred within closer ranges (Cassini, 2001; Boren *et al*., 2002; Labrada-Martagón *et al*., 2005; Szaniszlo, 2005; Shaughnessy *et al*., 2008; Strong and Morris, 2010; Pavez *et al*., 2014; Young *et al*., 2014). Here, 'Viewing' activities were associated with low levels of noise, as any discernible sound (e.g. screaming, banging objects or splashing water) reclassed the activity to a higher level. 'Viewing' elicited one of the highest rates of response (apart from 'Low-level' activities) and were mostly conducted at relatively short ranges where animals could perceive them without auditory cue (Schusterman and Balliet, 1971; Schusterman, 1972). In phocids, such close range approaches of various stimulus types caused Saimaa ringed seals (*Phoca hispida saimensis*) (Niemi *et al*., 2013) and harbour seals (*Phoca vitulina*) at various locations to exhibit avoidance behaviour and enter the water (Allen *et al*., 1984; Suryan and Harvey, 1999; Henry and Hammill, 2001; Jansen *et al*., 2010; Anderson *et al*., 2012; Osinga *et al*., 2012). In this study, more than 40% of all responses elicited by 'People' were attributed to 'Viewing' activities with most of these approaches being classified as

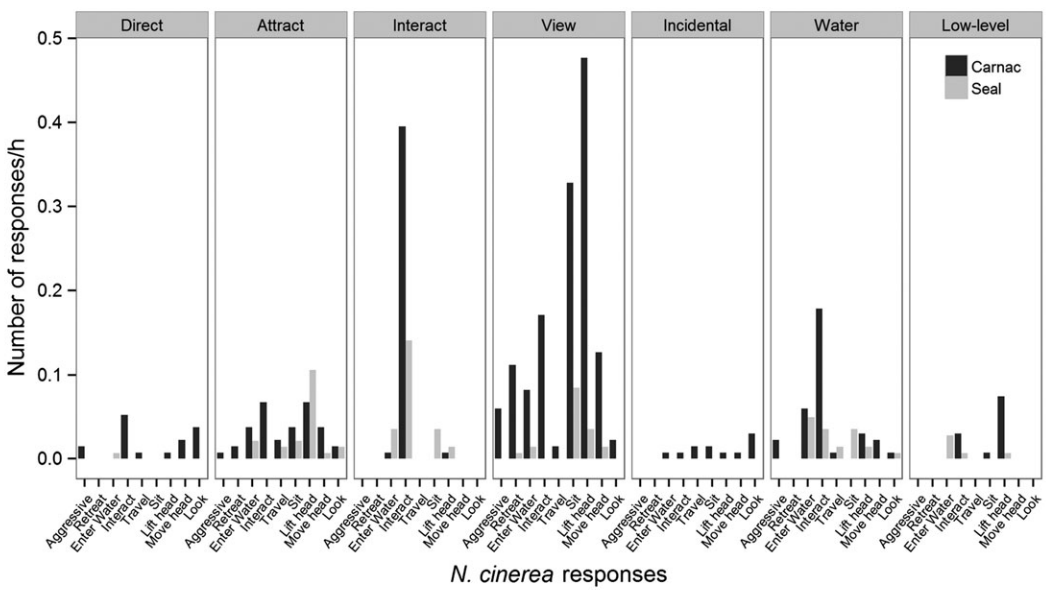

Figure 10. Number of *N. cinerea* responses elicited per hour as a result of groups of 'People' undertaking different activities at Carnac Island and Seal Island (Carnac: 134 h, Seal: 142 h sampling effort between November 2013 and end April 2014).

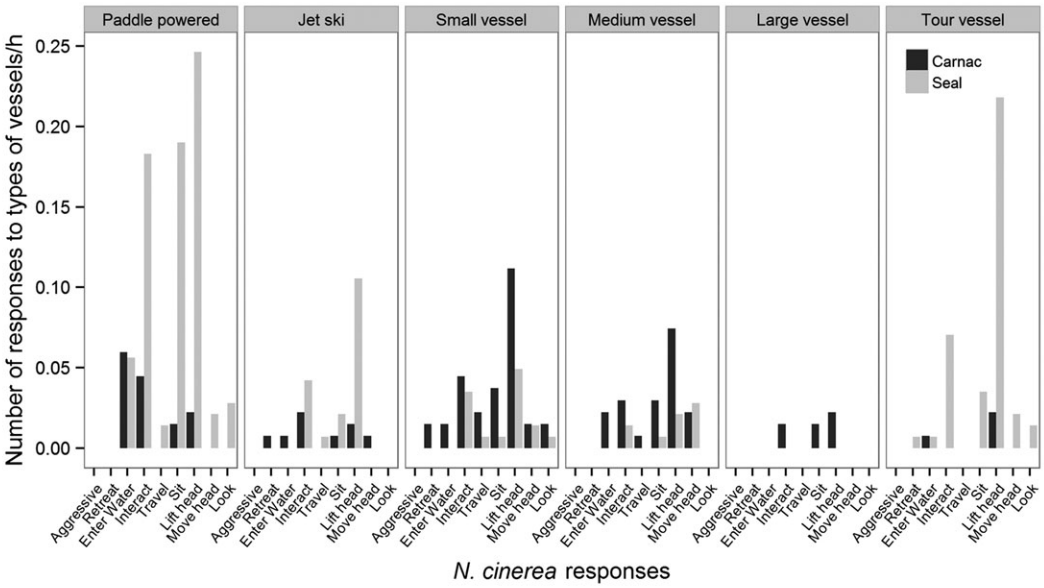

Figure 11. Number of *N. cinerea* responses per hour of sampling elicited by different vessel types at Carnac Island and Seal Island (excluding 'Aircrafts'; Carnac: 134 h, Seal: 142 h sampling effort between November 2013 and end April 2014).

breaches of the required 5 m minimum distance. These findings are consistent with a study of *N. cinerea* at Seal Bay, South Australia, which exhibited elevated response rates, including aggressive and avoidance behaviours, when approached within 10 m and even more so when approached within 5 m (Lovasz *et al*., 2008).

While distance has a significant effect on responses elicited, human behaviour also has been noted to significantly contribute to disturbance of otariids (*Arctocephalus australis*; Cassini, 2001; Labrada-Martagón *et al*., 2005; Pavez *et al*., 2014), and phocids. Vessel activities that involve higher in-air noise levels have been shown to have similar effects to direct, i.e. interactive human disturbance. *Neophoca cinerea* in this study 'Lifted their heads' to 'Engine' and 'Anchor' noise, similar to Australian fur seals (*Arctocephalus pusillus*) that exhibited increased response rates at higher noise levels of vessels (Tripovich *et al*., 2012). It should be noted that the presence of noise in this study was based on its perceived presence by researchers located within proximity of the animals, and was not based on measurements of in-air noise levels. However, otariid's hearing sensitivity includes the frequency band in which much of the energy from an engine, human speech, and anchor noise occurs (Gramming *et al*., 1988; Richardson *et al*., 1995; Badinoa *et al*., 2012; Muslow *et al*., 2014). During visits to Seal Island, the 'Tour vessel's' amplified guides were regularly audible to the researchers on the island, and probably the cause of frequent *N. cinerea* responses. This probably also contributes to the peak of responses occurring at 25–30 m at Seal Island, reflecting the most common shortest range to which the 'Tour vessel' approached. Similarly, anthropogenic activity in association with noise was identified as likely to cause disturbance in harbour seals, during a non-breeding season in Iceland (Granquist and Sigurjonsdottir, 2014). Elevated noise levels of passing 'Aircrafts', such as scenic flights resulted in responses in *N. cinerea*, similar to responses of Steller sea lions (*Eumetopias jubatus*) and *P. vitulina* to low-flying aircraft (Osborn, 1985; Henry and Hammill, 2001; Kucey, 2005; Szaniszlo, 2005).

'Aggressive' gaping and launching behaviours in *N. cinerea* towards 'People' were primarily evoked by close proximity 'Viewing' and occasionally 'Direct' invasive activities. Proximity of 'People' to *N. cinerea* occurred mainly at Carnac Island owing to easy (and non-restricted) beach access at a limited number of specific points, and was probably the main trigger of 'Aggressive' behaviours and higher numbers of 'Retreat' responses here compared with

Seal Island. Approaches from land are potentially perceived as a more immediate and greater threat than approaches by vessels, and the resulting behaviours have been observed in other pinnipeds (Stirling, 1972; Boren *et al*., 2002; Osinga *et al*., 2012).

While stimulus type had a significant influence on the level of *N. cinerea* responses, stimulus types varied in exposure level, minimum approach distance and duration between the two islands. Although not directly studied here, draft associated with vessel type may limit a vessel's approach range to a beach, and thus the distance at which different vessel types may trigger responses from hauled out *N. cinerea*; simply put, larger vessels did not approach as closely as smaller vessels at either island. Furthermore, the relative proximity of the island to the mainland coast also affected the type of vessel that visited the islands. The close proximity of Seal Island to shore and its location within the sheltered waters of Shoalwater Bay, allowed 'Paddlers' to access the island easily and 'Tour vessels' to offer multiple trips per day to view *N. cinerea*. Thus, the high number of 'Paddle powered' vessels able to approach the island to within a few metres may explain the high number of responses at Seal Island. In addition, 'Paddlers' elicited responses mostly during 'Low'-level activities, i.e. mostly by their presence alone, indicating range, rather than activity per se, was the driving factor. Such 'surprise' appearances (i.e. no engine noise) at close range and higher mobility have been thought to have similar impacts on pinnipeds elsewhere (Allen *et al*., 1984; Osborn, 1985; Suryan and Harvey, 1999; Henry and Hammill, 2001). In comparison, there were fewer responses to other vessel types, particularly large vessels associated with large drafts, which on average were at greater distances from *N. cinerea*.

Carnac Island's longer distance from shore is probably the reason for the greater number of large vessels visiting compared with Seal Island. Moreover, the draft associated with larger vessels meant that they remained further from the beach than smaller vessels. Furthermore, Carnac Island has a relatively large area of sandy beach with non-restricted access by people during the day, resulting in greater numbers of people on the beach than 'no access' Seal Island. In general, 'People' approached *N. cinerea* more closely than 'Paddlers', possibly explaining their greater probability of eliciting behavioural responses. The number of 'Paddlers' visiting Carnac Island was approximately 10 times lower than at Seal Island, maybe due to the increased distance from the mainland coast.

Apart from Carnac Island's greater distance from shore, the intention to visit Carnac Island as a 'day trip', rather than the 'stop-off' that Seal Island represents, may also explain the longer times vessels stayed at Carnac Island than at Seal Island. 'People' visit Carnac Island mainly for other recreational purposes and 'Viewing' *N. cinerea* is a secondary activity (Orsini and Newsome, 2005). Conversely, as landing on Seal Island is prohibited, viewing *N. cinerea* is the primary reason for visitation which most groups carried out for relatively short times resulting in *N. cinerea* being exposed to human activity for shorter individual periods.

The total number of vessels and 'People' can have variable influences on pinniped reactions (Jansen *et al*., 2015). Here, the proportion of responding *N. cinerea* did not appear to vary with increasing or decreasing numbers of vessels or 'People', which is similar to some studies where response behaviours remained comparatively consistent (Kovacs and Innes, 1990; Strong and Morris, 2010). However, in other studies varying behavioural responses occurred with differing numbers of people in the vicinity, such as adult male *N. cinerea*, during the breeding season reportedly responding to individual people at greater distances than to groups of people (Lovasz *et al*., 2008). In contrast, females and other age groups observed in the same study did not show variation when approached by people on their own or in groups. Lovasz *et al*. (2008) speculated that the breeding season may play a role in responses, but was not able to ascertain what that might be. Quite the opposite, however, has been observed in *A. australis* (Cassini *et al*., 2004).

Long-lasting interactions between *N. cinerea* and vessels or 'People' in the water were a common occurrence in this study (26.5% of all responses), similar to *Arctocephalus forsteri* approaching kayaks or interacting with swimmers from a swim tour (Boren *et al*., 2002; Cowling *et al*., 2014). In contrast, at Seal Bay, South Australia, *N. cinerea* have been recorded to only rarely respond to interacting behaviours (Lovasz *et al*., 2008). In this study, one example of long-lasting duration occurred at Carnac Island when no other vessel or 'People' were in the vicinity. One adult and three sub-adult *N. cinerea* 'Entered the water' immediately when one of the marine park rangers removed star pickets from the beach (always remaining at >10 m range). The first sub-adult to haul out after leaving the beach did so more than 1 hour after the incident, and more than 40 min after the rangers' vessel had left. This is comparable with *Zalophus californianus* mostly re-hauling out within 10 min after disturbance ceased, though they could take up to 3.5 h (Labrada-Martagón *et al.*, 2005). Anthropogenic impacts may, therefore, have altered *N. cinerea*'s natural behaviour in this study considerably, especially when *N. cinerea* 'Entered the water' or began 'Interactions', although 'Interactions' may have occurred voluntarily.

Arctocephalus pusillus have shown increased levels of aggression among themselves when exposed to higher sound levels (Tripovich *et al.*, 2012). In contrast, similar behavioural changes as a response to noise were not observed in this study, and aggressive behaviours towards stimuli were comparatively rare. This difference may be explained by age and sex composition of the study populations, as well as timing within the breeding cycle (Boren *et al.*, 2002; Labrada-Martagón *et al.*, 2005; Tripovich *et al.*, 2012; Cowling *et al.*, 2014; Pavez *et al.*, 2014). How human impacts affect different age and sex classes is known to vary between different species of pinnipeds. Females were more sensitive to anthropogenic activities in *P. vitulina* (Selvaggi *et al.*, 2004), whereas sub-adult males were more responsive to anthropogenic activities in South American sea lions *Otaria bryonia*, and adult male *N. cinerea* elsewhere reacted at slightly greater distances than females and other age classes (Lovasz *et al.*, 2008). In *O. bryonia*, more frequent disturbance was elicited at a breeding site compared with a haul-out site, whereas female *P. vitulina* displayed less pronounced responses, appearing reluctant to leave their pups (Anderson *et al.*, 2012; Pavez *et al.*, 2014).

The high frequency of anthropogenic activities, the resulting disturbance, and the time to return to previous behaviours may have an important effect on *N. cinerea* activity and energy budgets of individual animals. The accumulation over time of these may lead to long-term effects. *Neophoca cinerea* have a ~2.3 times higher field metabolic rate and a ~6.2 times higher basal metabolic rate than terrestrial animals of comparable size (Costa and Gales, 2003). Based on this knowledge, the energy demands on individual *N. cinerea* are relatively high. *Neophoca cinerea* are benthic foragers and their foraging trips are highly demanding and energy intensive (Costa and Gales, 2003). Hauling out may help conserve energy and contribute to recuperation between foraging trips (Riedman, 1990). Interrupting *N. cinerea*'s recovery time from strenuous foraging trips may, therefore, alter their activity budgets and increase energetic requirements. This could mean that *N. cinerea* frequently responding to anthropogenic activity while resting, must increase time spent foraging to gain sufficient energy to offset the time spent at higher activity levels, which, consequently, could result in less time spent resting. If *N. cinerea* spend less time resting between foraging trips, they may be more susceptible to disease and other threats if their fitness is reduced (Taillier, 2014). This study did not attempt to track movements of identified individuals over time or investigate impacts on overall numbers of animals hauled out. However, pinnipeds may face displacement from preferred sites and move to less suitable habitat as a result of ongoing disturbance (Allen *et al.*, 1984; Stevens and Boness, 2003; Kucey, 2005). The impact of anthropogenic activities on overall numbers of *N. cinerea* hauling out at Carnac and Seal islands is unknown, but recommended to be investigated in future studies.

Habituation to people has been suspected in *N. cinerea* at Seal Bay, South Australia. *Neophoca cinerea* show more disturbance at a rarely disturbed site compared with a long-term, frequently visited site where people are able to approach within close range (Stirling, 1972; Lovasz *et al.*, 2008). Carnac and Seal islands are both visited frequently and *N. cinerea* may show some level of habituation, especially considering the high number of interactions with vessels and 'People'. However, quantifying habituation in animals so commonly visited over such a prolonged period as occurs at the islands studied would not be trivial.

Some biases may have been introduced by the inability to equally measure all distances between responding animals and stimuli. However, the difference between the distribution of total minimum approach distances and that of response distances illustrate that the sample size across ranges was sufficient to detect the inverse relationship of response with range. Furthermore, while behavioural changes of *N. cinerea* were excluded when there was uncertainty as to whether the response was to anthropogenic activities, some responses might have been misclassified as a response to humans, when they were not. The authors, however, believe that these cases were rare and that responses were more likely underestimated. In particular, while measurements were taken of vessels, 'People', and closest *N. cinerea* during heavy visitation periods (although priority was placed on 'People', vessels in close proximity to *N. cinerea* and vessels involved in conspicuous activities), some *N. cinerea* responses or measured distances may have been missed. 'Look', for example, was often an inconspicuous behaviour, particularly if *N. cinerea* faced away from the researchers, and was therefore possibly underestimated. A previous study, conducted at Carnac Island during summer months, approximately 6 months prior to the *N. cinerea* peak season, investigated responses to people. This documented relatively high numbers of responses in the three response categories measured (lift head, sit and look) and include repeated responses to the same stimuli (Orsini, 2004; Orsini *et al.*, 2006). Hourly sampling periods, observing these responses were conducted on one *N. cinerea* at a time, totalling 240 *N. cinerea* sampling periods. The sampling method and measurements, however, differ from that of this study, in particular that the observer was positioned within close proximity to the animals and thus while detecting a greater number of low level responses, may also have contributed to them (Orsini, 2004; Orsini *et al.*, 2006).

Suggestions for management

This study showed that not only did distance play a major role in eliciting responses in *N. cinerea*, but human and vessel activity types were also contributors. These factors should be included as primary considerations for programmes aiming at reducing disturbance. The impact of disturbance on individual energetics has not been investigated here and, similar to response levels, are likely to vary between species and location. However, it is feasible that many of the following suggestions, and indeed the current management protocols put in place by the Department of Parks and Wildlife, Western Australia, would reduce responses of *N. cinerea* if applied to haul-out locations of pinniped species elsewhere. Thus by increasing the minimum approach distance for vessels and people to 30 m, disturbance would be expected to decrease significantly as high rates in this study were observed at the current minimum approach distance restrictions of 5–10 m (DEC and DoF, 2011). The frequent breaches of the current limit was a notable feature in this study, thus enforced minimum distances may improve the effectiveness of the regulations. In a separate study in South America, fencing limited the distance people were able to access, approach, and view *A. australis* from land, and significantly decreased human disturbance, including attacks on people which were reduced from four in a month to zero (Cassini *et al.*, 2004). 'Aggressive' behaviour towards 'People' and 'Retreat' behaviours, were observed more than once a day on Carnac Island in 74% of all *N. cinerea* observation days in this study. Limiting the approach distance and/or beach access may reduce the highest response levels and lower the chances of danger to both humans and pinnipeds. Designating all of Carnac Island (rather than a section of the beach) as a sanctuary zone, as presently exists on Seal Island, may assist in reducing disturbance. It would perhaps also provide visitors with a stronger awareness of their responsibilities when interacting with wild animals. As a control measure, marker buoys installed 15 m off the waterline at low tide at Carnac and Seal islands may reduce the disturbance of *N. cinerea* thermoregulating in the wash zone during periods of higher air temperatures (Marlow, 1975; Riedman, 1990). Creating a demarcation of a boundary with buoys where vessels and 'People' should not pass may help reduce 'People' accidentally beaching their kayaks (as occurred during 50% of the field days at Seal Island) and also increase awareness of the sanctuary zone. In addition, standardizing control measures across *N. cinerea* haul-out locations may assist in generating more consistent behaviour from the public to limit disturbance. This study has not investigated the impacts of disturbance on the energetics of *N. cinerea*. The following suggestions are therefore made based on a precautionary approach, given that the level of effects of disturbance on *N. cinerea* energetics has yet to be quantified.

In general, it is probable that most visitors are not aware they are causing a disturbance to *N. cinerea* or what effects these disturbances may have on colonies and the overall population (Orsini and Newsome, 2005). Clear signage and other forms of information and educational material, including increased direct communication from patrol officers, may improve awareness of the importance of haul-out and resting behaviours to *N. cinerea* health and body condition. Furthermore awareness of the potential impacts of noise may alter peoples' behaviours so that noise levels and overall disturbance are reduced when in close proximity to animals (Newsome and Rodger, 2008). In a previous study, the combination of approaching slower, maintaining greater ranges, and having quieter passengers reduced disturbance of *P. vitulina* by 60–80% (Hoover-Miller *et al*., 2013).

In conclusion, this study has shown that a considerable number of responses and behavioural changes were elicited by anthropogenic activities. Significant differences occurred between Seal and Carnac islands in levels of exposure, including the exposure duration and types of stimuli, as well as in the elicited response levels. However, most responses occurred in close ranges to *N. cinerea*. If minimum approach distances in guidelines are increased, and the public is made aware that calm and quiet behaviour around Seal and Carnac islands would significantly reduce the potential impacts of anthropogenic activity, the number of responses due to disturbance may be reduced. Longer-term studies measuring the cumulative duration of interactions, assessing the effects of anthropogenic activities on *N. cinerea*'s energy budgets, and determining the impacts of fitness and habitat displacement at an individual and population level are recommended. However, it should also be noted that pinniped responses to humans varies widely between species and that context is an important factor in the application of protocols to mitigate disturbance.

ACKNOWLEDGEMENTS

The Department of Parks and Wildlife (Western Australia) made this project possible with substantial logistical support provided including transport to and from the islands and loan of a spotting scope, as well as provision of local and scientific knowledge. Transport to and from islands was also provided by the Department of Fisheries and Cockburn Volunteer Sea Search and Rescue. The Fremantle Sailing Club provided access to their boat ramp. The project was also supported by Malcom Perry through maintenance of the research vessel and Mick Todd through loan of his telescope. Many volunteers contributed substantial time assisting in the field and entering data into spreadsheets in the office. The authors are grateful to Miles Parsons for providing editorial and analytical advice which significantly improved the quality of this manuscript, Sven Gastauer for providing advice on R code, and Julie Sims who gave useful advice on data analysis. The authors appreciate the constructive feedback and helpful advice from both reviewers and the editor to improve this manuscript. Finally, this project was supported by funding from the Holsworth Wildlife Research Endowment. This project was also conducted under a Department of Parks and Wildlife permit (number SF009371) and university animal ethics approvals (AEETH24/11 granted by Victoria University, Melbourne and AEC_2013_32 granted by Curtin University, Perth). The authors have no conflicting interests to declare.

REFERENCES

Allen SG, Ainley DG, Page GW, Ribic CA. 1984. The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. *Fishery Bulletin* **82**: 493–500.

Anderson SM, Teilmann J, Dietz R, Schmidt NM, Miller LA. 2012. Behavioural responses of harbour seals to human-induced disturbances. *Aquatic Conservation: Marine and Freshwater Ecosystems* **22**: 113–121.

Badinoa A, Borellib D, Gaggeroc T, Rizzutod E, Schenonee C. 2012. Normative framework for ship noise: present situation and future trends. *Noise Control Engineering Journal* **60**: 740–762.

Beentjes MP. 1989. Haul-out patterns, site fidelity and activity budgets of male Hooker's sea lions (*Phocarctos hookeri*) on the New Zealand mainland. *Marine Mammal Science* **5**: 281–297.

Boren L, Gemmell NJ, Barton KJ. 2002. Tourist disturbance on New Zealand fur seals *Arctocephalus forsteri*. *Australian Mammalogy* **24**: 85–95.

Bowles AE, Anderson RC. 2012. Behavioral responses and habituation of pinnipeds and small cetaceans to novel objects and simulated fishing gear with and without a pinger. *Aquatic Mammals* **38**: 161–188.

CALM. 2003. Carnac Island Nature Reserve - Management Plan 2003. Report, Department of Conservation and Land Management.

Cassini MH. 2001. Behavioural responses of South American fur seals to approach by tourists – a brief report. *Applied Animal Behaviour Science* **71**: 341–346.

Cassini MH, Szteren D, Fernández-Juricic E. 2004. Fence effects on the behavioural responses of South American fur seals to tourist approaches. *Journal of Ethology* **22**: 127–133.

Constantine R. 1999. Effects of tourism on marine mammals in New Zealand. Report, Department of Conservation.

Costa DP, Gales NJ. 2003. Energetics of a benthic diver: seasonal foraging ecology of the Australian sea lion, *Neophoca cinerea*. *Ecological Monographs* **73**: 27–43.

Cowling M, Kirkwood R, Boren LJ, Scarpaci C. 2014. The effects of seal-swim activities on the New Zealand fur seal (*Arctophoca australis forsteri*) in the Bay of Plenty, New Zealand, and recommendations for a sustainable tourism industry. *Marine Policy* **45**: 39–44.

Cowling M, Kirkwood R, Boren L, Scarpaci C. 2015. The effects of vessel approaches on the New Zealand fur seal (*Arctocephalus forsteri*) in the Bay of Plenty, New Zealand. *Marine Mammal Science* **31**: 501–519.

DEC. 2007. *Shoalwater Islands Marine Park Management Plan 2007–2017*, Management Plan: Perth, Western Australia.

DEC, DoF. 2011. Shoalwater Islands Marine Park. Marine parks...WA's submerged wonders. Recreation guide. Perth, Western Australia.

Fisher RA. 1922. On the interpretation of χ^2 from contingency tables, and the calculation of P. *Journal of the Royal Statistical Society* **85**: 87–94.

French SS, Gonzáles-Suárez M, Young JK, Durham S, Gerber LR. 2011. Human disturbance influences reproductive success and growth rate in California sea lions (*Zalophus californianus*). *PloS One* **6**: e17686.

Gales NJ. 1995. Hooker's sea lion recovery plan (*Phocarctos hookeri*). In *Threatened species recovery plan*, **17**. Threatened Species Unit, Department of Conservation: Wellington, New Zealand.

Gales NJ, Cheal AJ, Pobar GJ, Williamson P. 1992. Breeding biology and movements of Australian sea lions, *Neophoca cinerea*, off the west coast of Western Australia. *Wildlife Research* **19**: 405–416.

Gales NJ, Shaughnessy PD, Dennis TE. 1994. Distribution, abundance and breeding cycle of the Australian sea lion *Neophoca cinerea* (Mammalia: Pinnipedia). *Journal of Zoology* **234**: 353–379.

Gerrodette T, Gilmartin WG. 1990. Demographic consequences of changed pupping and hauling sites of the Hawaiian monk seal. *Conservation Biology* **4**: 423–430.

Goldsworthy SD. 2015. *Neophoca cinerea*. The IUCN Red List of Threatened Species 2015: e.T14549A45228341. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T14549A45228341.en. Downloaded on 19 January 2016.

Goldsworthy SD, Shaughnessy PD, McIntosh RR, Kennedy C, Simpson J, Page B. 2008. Australian sea lion populations at Seal Bay and the Seal Slide (Kangaroo Island): continuation of the monitoring program. Report, South Australian Research and Development Institute.

Gormley AM, Slooten E, Dawson S, Barker RJ, Rayment W, du Fresne S, Bräger S. 2012. First evidence that marine protected areas can work for marine mammals. *Journal of Applied Ecology* **49**: 474–480.

Gramming P, Sundberg J, Ternström S, Leanderson R, Perkins WH. 1988. Relationship between changes in voice pitch and loudness. *Journal of Voice* **2**: 118–126.

Granquist SM, Sigurjonsdottir H. 2014. The effect of land based seal watching tourism on the haul-out behaviour of harbour seals (*Phoca vitulina*) in Iceland. *Applied Animal Behaviour Science* **156**: 85–93.

Hartel EF, Constantine R, Torres LG. 2015. Changes in habitat use patterns by bottlenose dolphins over a 10-year period render static management boundaries ineffective. *Aquatic Conservation: Marine and Freshwater Ecosystems* **25**: 701–711.

Henry E, Hammill MO. 2001. Impact of small boats on the haulout activity of harbour seals (*Phoca vitulina*) in Métis Bay, Saint Lawrence Estuary, Québec, Canada. *Aquatic Mammals* **27**: 140–148.

Hoover-Miller A, Bishop A, Prewitt J, Conlon S, Jezierski C, Armato P. 2013. Efficacy of voluntary mitigation in reducing harbor seal disturbance. *The Journal of Wildlife Management* **77**: 689–700.

Jansen JK, Boveng PL, Dahle SP, Bengtson JL. 2010. Reaction of harbor seals to cruise ships. *The Journal of Wildlife Management* **74**: 1186–1194.

Jansen JK, Boveng PL, Ver Hoef JM, Dahle SP, Bengtson JL. 2015. Natural and human effects on harbor seal abundance and spatial distribution in an Alaskan glacial fjord. *Marine Mammal Science* **31**: 66–89.

Kelleher G. 1999. *Guidelines for Marine Protected Areas*, World Commission on Protected Areas of IUCN – The World Conservation Union: Gland, Switzerland, and Cambridge, UK.

Kirkwood R, Boren L, Shaughnessy P, Szteren D, Mawson P, Huckstadt L, Hofmeyr G, Oosthuizen H, Schiavini A, Campagna C, Berris M. 2003. Pinniped-focused tourism in the southern hemisphere: a review of the industry. In *Marine Mammals: Fisheries, Tourism and Management Issues*, Gales N, Hindell M, Kirkwood R (eds). CSIRO Publishing: Collingwood; 257–272.

Kovacs KM, Innes S. 1990. The impact of tourism on harp seals (*Phoca groenlandica*) in the Gulf of St. Lawrence, Canada. *Applied Animal Behaviour Science* **26**: 15–26.

Kruskal WH, Wallis WA. 1952. Haulout patterns of grey seals *Halichoerus grypus* in the Baltic Sea. *Journal of the American Statistical Association* **47**: 583–621.

Kucey L. 2005. Human disturbance and the hauling out behaviour of Steller sea lions (*Eumetopias jubatus*). Thesis, University of British Columbia, Vancouver, Canada.

Labrada-Martagón V, Aurioles-Gamboa D, Martínez-Díaz SF. 2005. Natural and human disturbance in a rookery of the California sea lion (*Zalophus californianus californianus*) in the Gulf of California, Mexico. *Latin American Journal of Aquatic Mammals* **4**: 175–185.

Lovasz T, Croft D, Banks P. 2008. Establishing tourism guidelines for viewing Australian sea lions *Neophoca cinerea* at Seal Bay Conservation Park, South Australia. In *Too Close For Comfort*, Lunney D, Munn A, Meikle M (eds). Royal Zoological Society of New South Wales: Mosman, NSW, Australia; 225–232.

Marlow BJ. 1975. The comparative behaviour of the Australasian sea lions, *Neophoca cinerea* and *Phocarctos hookeri* (Pinnipedia: Otariidae). *Mammalia* **39**: 159–230.

McHugh ML. 2013. The Chi-square test of independence. *Biochemia Medica* **23**: 143–149.

Muslow J, Houser DS, Finneran JJ. 2014. Aerial hearing thresholds and detection of hearing loss in male California sea lions (*Zalophus californianus*) using auditory evoked potentials. *Marine Mammal Science* **30**: 1383–1400.

Newsome D, Rodger K. 2008. Impacts of tourism on pinnipeds and implications for tourism management. In *Marine Wildlife and Tourism Management: Insights from the Natural Social Sciences*, Higham JES, Lück M (eds). CABI: Oxfordshire; 182–205.

Niemi M, Auttila M, Valtonen A, Viljanen M, Kunnasranta M. 2013. Haulout patterns of Saimaa ringed seals and their response to boat traffic during the moulting season. *Endangered Species Research* **22**: 115–124.

Orams M. 1999. *Marine Tourism: Development, Impacts and Management*, Routledge: London, UK and New York, USA.

Orsini JP. 2004. Human impacts on Australian sea lions, *Neophoca cinerea*, hauled out on Carnac Island (Perth, Western Australia): implications for wildlife and tourism management. Thesis, Murdoch University, Perth, Western Australia.

Orsini JP, Newsome D. 2005. Human perceptions of hauled out sea lions (*Neophoca cinerea*) and implications for management: a case study from Carnac Island, Western Australia. *Tourism in Marine Environments* **2**: 129–132.

Orsini JP, Shaughnessy PD, Newsome D. 2006. Impacts of human visitors on Australian sea lions (*Neophoca cinerea*) at Carnac Island, Western Australia: iImplications for tourism management. *Tourism in Marine Environments* **3**: 101–115.

Osborn LS. 1985. Population dynamics, behavior, and the effect of disturbance on haulout patterns of the harbor seal *Phoca vitulina richardsi*. Thesis, University of California, Santa Cruz, CA, USA.

Osinga N, Nussbaum SB, Brakefield PM, de Haes HAU. 2012. Response of common seals (*Phoca vitulina*) to human disturbances in the Dollard estuary of the Wadden Sea. *Mammalian Biology* **77**: 281–287.

Osterrieder SK, Salgado Kent C, Robinson RW. 2015. Variability in haul-out behaviour by male Australian sea lions *Neophoca cinerea* in the Perth metropolitan area, Western Australia. *Endangered Species Research* **28**: 259–274.

Pavez G, Muñoz L, Barilari F, Sepúlveda M. 2014. Variation in behavioral responses of the South American sea lion to tourism disturbance: Implications for tourism management. *Marine Mammal Science* **31**: 427–439.

Rice WR. 1989. Analyzing tables of statistical tests. *Evolution* **43**: 223–225.

Richardson WJ, Greene CR Jr, Malme CI, Thomson DH. 1995. *Marine Mammals and Noise*, Academic Press: San Diego, CA.

Riedman M. 1990. *The Pinnipeds: Seals, Sea Lions, and Walruses*, University of California Press: Berkeley, CA.

Salgado Kent CP, Crabtree B. 2008. The effectiveness of an established sanctuary zone for reducing human disturbance to Australian sea lions (*Neophoca cinerea*) at Carnac Island, Western Australia. *Tourism in Marine Environments* **5**: 29–42.

Schusterman RJ. 1972. Visual acuity in pinnipeds. In *Behavior of Marine Animals, Vol. 2*, Winn HE, Olla BL (eds). Plenum Press: New York; 469–492.

Schusterman RJ, Balliet RF. 1971. Aerial and underwater visual acuity in the California sea lion (*Zalophus californianus*) as a function of luminance. *Annals of the New York Academy of Sciences* **188**: 37–46.

Selvaggi E, Vedder L, Haaften van JL, Wensvoort P, Consiglio C. 2004. Effect of disturbance on daily rhythm and haul out behavior in the harbor seal (*Phoca vitulina*) in the tide estuary of Dollard. Proceedings of the Fifteenth Annual Conference of the European Cetacean Society, Rome, Italy, 6–10 May 2001, 92–97.

Shaughnessy PD, Nicholls AO, Briggs SV. 2008. Do tour boats affect fur seals at Montague Island, New South Wales. *Tourism in Marine Environments* **5**: 15–27.

Stevens MA, Boness DJ. 2003. Influences of habitat features and human disturbance on use of breeding sites by a declining population of southern fur seals (*Arctocephalus australis*). *Journal of Zoology* **260**: 145–152.

Stirling I. 1972. Observations on the Australian sea lion, *Neophoca cinerea* (Peron). *Australian Journal of Zoology* **20**: 271–279.

Strong P, Morris SR. 2010. Grey seal (*Halichoerus grypus*) disturbance, ecotourism and the Pembrokeshire Marine Code around Ramsey Island. *Journal of Ecotourism* **9**: 117–132.

Suryan RM, Harvey JT. 1999. Variability in reactions of Pacific harbor seals, *Phoca vituline richardsi*, to disturbance. *Fishery Bulletin* **97**: 332–339.

Szaniszlo WR. 2005. California sea lion (*Zalophus californianus*) and Steller sea lion (*Eumetopias jubatus*) interactions with vessels in Pacific Rim National Park Reserve: implications for marine mammal viewing management. Thesis, University of Victoria, Canada.

Taillier S. 2014. Great white shark probably choked to death on sea lion, authorities say. URL: http://www.abc.net.au/news/2014-07-17/greatwhite-shark-probably-choked-on-a-sea-lion2c-authorities-/5604410.

Tripovich JS, Hall-Aspland S, Charrier I, Arnould JPY. 2012. The behavioural response of Australian fur seals to motor boat noise. *PloS One* **7**: e37228.

Yates F. 1934. Contingency tables involving small numbers and the χ^2 test. *Supplement to the Journal of the Royal Statistical Society* **1**: 217–35.

Young C, Gende SM, Harvey JT. 2014. Effects of vessels on harbor seals in Glacier Bay National Park. *Tourism in Marine Environments* **10**: 5–20.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web site.