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Historical distribution and abundance of the Australian sea lion (Neophoca cinerea) on the west coast of Western Australia

R. Campbell

Cover picture: *First known drawing of N. cinerea (circa 1803). From Bonnemains et al. 1988.*

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Government of Western Australia

Fish for the future

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Fisheries Research in Western Australia
The Fisheries Research Division of the Department of Fisheries is based at the Western Australian Marine Research Laboratories, PO Box 20, North Beach (Perth), Western Australia, 6920. The Marine Research Laboratories serve as the centre for fisheries research in the State of Western Australia.

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The primary function of the Fisheries Research Division is to provide scientific advice to government in the formulation of management policies for developing and sustaining Western Australian fisheries.

Contents

Historical distribution and abundance of the Australian sea lion (Neophoca cinerea) *on the west coast of Western Australia*

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SUMMARY

Analysis of historical patterns of abundance of the Australian sea lion on the west coast of Western Australia suggests that the population size was greater prior to the impacts of colonization and commercial sealing/whaling between the 18th and 20th centuries. In addition, it is evident that there has been a reduction in the number of breeding sites along the west coast, particularly around the greater Perth metropolitan area. There is limited evidence of the impact of indigenous hunting on the abundance and distribution of this species. The major impacts on Australian sea lion populations were a combination of subsistence and commercial harvesting events from the 1700s to the 1920s. In more recent times, low levels of bycatch of Australian sea lions have been reported by a number of commercial fisheries, including the western rock lobster fishery (WRLF). Population surveys over the last three decades suggest that the west coast population is small but stable, though the impact of fishery-related mortality on this species is unknown. There is no evidence to suggest that commercial operations of the WRLF have had an adverse impact on populations of the Australian sea lion.

1.0 INTRODUCTION

Interactions of commercial fishing operations and marine mammal populations are of considerable interest to researchers and fisheries managers alike (DeMaster *et al*. 2001). Monitoring of bycatch is an integral component of many fishing industries, and also can provide limited ecological data for the non-target species affected (e.g. Hookers sea lion in Woodley & Lavigne 1993). In Western Australia, one of the key fishing industries is for the western rock lobster, *Panulirus cygnus*, an industry worth between 200 and 400 million dollars annually. The fishery is based on pot catch along the southern half of the west coast, and low levels of bycatch of the Australian sea lion, *Neophoca cinerea*, have been reported (Gales & Wyre unpub. rep., Mawson & Coughran 1999, Shaughnessy *et al.* 2003). The level and impact of this incidental mortality on the sea lion population is currently unknown.

Pinnipeds are a group of marine mammals that contain the seals, fur seals, sea lions and walrus. The fur seals, sea lions and walrus comprise the family Otariidae and are characterised by their use of land for breeding and parturition and the sea for foraging (Boyd 1991). Land habitats can be described as either breeding colonies, where parturition and breeding activities take place, and haulout areas where animals rest during the non-breeding season (Reynolds & Rommell 1999). The Australian sea lion (*Neophoca cinerea*) is the only endemic species of pinniped found in Australian waters. Current population estimates of 10-12,000 animals make this one of the rarest sea lions in the world (Gales *et al.* 1994, Dennis & Shaughnessy 1996). It ranges from the Houtman Abrolhos Islands on the west coast of Western Australia to The Pages in South Australia (Fig. 1). The range previously extended into the Bass Strait but commercial exploitation in the 1700-1800s resulted in regional extinction in this area (Fig. 1). There are over 60 individual breeding colonies, mostly on offshore islands, which are distributed in a broad regional pattern. There are three main regions of breeding colonies; the west coast of Western Australia, south coast of Western Australia and South Australia (Fig. 2). This species displays an unusual supra-annual, asynchronous breeding cycle (Gales *et al.* 1994). The breeding cycle is 17.5 months long, unlike the usual annual cycle of other pinnipeds, and the timing of breeding events varies between colonies (Ling & Walker 1978, Higgins 1993, Gales *et al*. 1994), unlike the synchronous cycle of the annual breeders (Boyd 1991). This pattern may be maintained by the exclusive return of females to their birth colony to breed (Gales *et al*. 1994), which would have a profound effect on population genetic structure.

Analysis of population genetic structure is an increasingly valuable tool in biological resource management. It has been widely applied in areas such as commercial fish stocks (e.g. Shark Bay snapper in Johnson *et al.* 1986) and endangered species (Hector's dolphin in Pichler *et al.* 1998). Recent analysis of population genetic structure of *N. cinerea* has revealed high levels of population subdivision (Campbell 2003). High rates of fixation of a maternally inherited marker (control region of the mitochondrial DNA, or mtDNA) among colonies suggest that females show almost exclusive natal site fidelity, meaning that females are only locally recruited to a breeding colony. Male dispersal appears limited to within a geographic region, as defined by the distribution of breeding colonies (see Fig. 2), though there are cases of significant subdivision within a region (Campbell 2003). This suggests that there is little contemporary gene flow between the west coast and the other regions. This pattern of male-biased dispersal is common to many mammals (Greenwood 1980, Storz 1999), however the level of population subdivision is unparalleled in other pinniped species (Stanley *et al*. 1996, Slade *et al.* 1998, Goldsworthy *et al*. 2000). The pattern of almost exclusive female natal site fidelity is important for conservation management practices, as each genetically distinct colony should be considered a management unit (Moritz 1994).

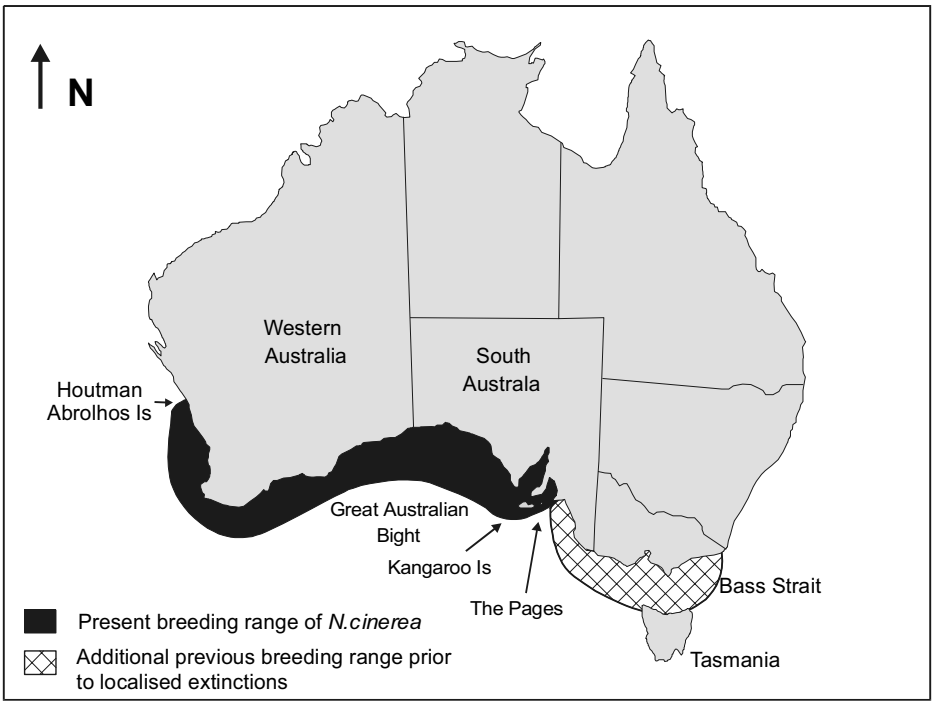

Figure 1. Distribution of the Australian sea lion showing extant and locally extinct populations. Localised extinctions were the result of commercial hunting during the 18th-20th centuries (from Ling 1978).

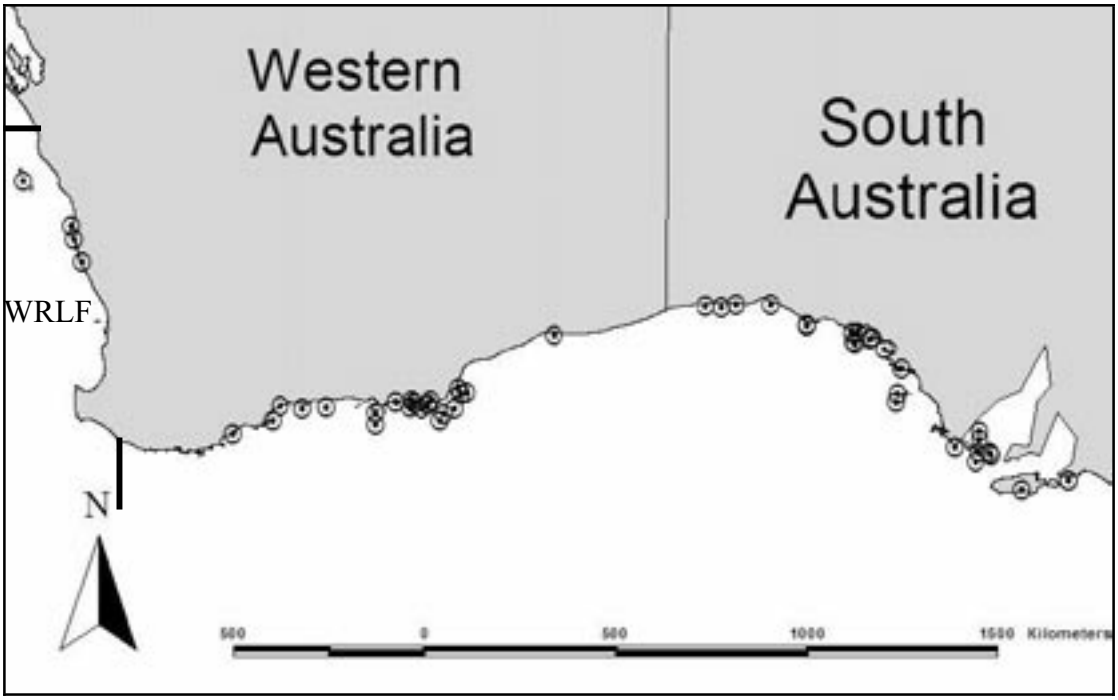

Figure 2. Distribution of individual breeding colonies of the Australian sea lion. Colonies, indicated by '⊙', are concentrated in three areas, the west coast of Western Australia, south coast of Western Australia and South Australia. The northern and southern boundary lines define the general area of the WRLF off the west coast of Western Australia and a small portion of the south coast.

On the west coast of Western Australia there is a high level of mtDNA haplotype fixation. Three of the four breeding colonies (North Fisherman Island, Beagle Island and the Abrolhos Islands), ranging over 200 kilometres, are fixed for the same haplotype. The remaining colony, Buller Island is fixed for a different haplotype, indicative of the very high level of population subdivision. Strict interpretation of population genetics theory suggests that the three former colonies display unlimited female-mediated gene flow, which would be in contrast to the general pattern. However, this pattern could also arise through relatively recent founder events (within 5-8,000yrs), and not be indicative of ongoing contemporary gene flow. A precautionary approach would be to assume that female-mediated gene flow between colonies is negligible, and that each of these colonies should be treated as a separate management unit. This is supported by the frequent incidence of fixed genetic differences between colonies across comparable geographic distances in other areas (Campbell 2003).

Relatively little is known about the biology and behaviour of this species, but recent investigation into the foraging behaviour suggests that this species is predominantly a benthic forager. Lactating females are known to feed in depths up to 90 metres, and they appear to be pushed to their metabolic limits, more so than any other species of pinniped (Costa & Gales 2003). Young sea lions (approximately 7-18 months old) have been recorded foraging in depths up to 60 metres and range up to 10 kilometres from their birth colony (Fowler & Costa 2004). Known prey items include cephalopods, crustaceans and some benthic fishes, as determined by the presence of identifiable parts in scats (Gales & Cheal 1992). However, these prey items represent only a portion of the diet as this technique was shown to be an unreliable indicator of the diet of captive *N. cinerea* (Gales & Cheal 1992).

Little is known of the life history traits of this species, though peaks of high pup mortality have been reported for two colonies in South Australia (50-60%, Shaughnessy 1999). The cause of these peaks of pup mortality is unknown. An average pup mortality rate among colonies on the west coast of Western Australia of 0.12 ± 0.08 was determined over the period 1989-2001, though this is likely to be an under-estimate (Gales *et al.* 1992, Campbell 2003). Some of the known causes of pup mortality observed at the Kangaroo Island breeding colony were crushing by conspecifics (19%), usually adult males, and malnutrition due to a number of behavioural responses or assumed mortality of the mother (43%, Higgins & Tedman 1990). Unknown factors represented a significant proportion of mortalities (28%) and these may have been due to illness and disease. A range of viral and bacterial infections has been reported in pinnipeds worldwide, including *N. cinerea* (Cousins *et al.* 1993, Kennedy 1999). Occasional epidemics (i.e. morbillivirus) have occurred where up to 50% of an entire population has died (i.e. European harbour seals in Dietz *et al.* 1989, Jensen *et al.* 2002). Large scale mortality events have also occurred in populations of Galapagos Islands pinnipeds in years of El Niño, due to increased water temperature and decreased prey abundance (Trillmich & Limberger 1985).

For the purposes of this report the main area of interest is the region of overlap of Australian sea lion populations and the western rock lobster fishery (WRLF) along the west coast of Western Australia (Fig. 3). This area supports a population of approximately 800-960 Australian sea lions and can be broken down into three smaller geographical zones; the Houtman Abrolhos Islands (Fig. 4), the mid-west coast (Fig. 5) and the greater Perth area, (including Garden Island, Carnac Island and Rottnest Island (Fig. 6). There are four known breeding colonies along the west coast including the northernmost extent of the breeding range at the Abrolhos Islands. Three breeding colonies are found in the mid-west coast region, Beagle Island, North Fisherman Island and Buller Island and a number of other islands in this area are used as haulouts (Fig. 5). The offshore islands around Perth, in particular Carnac Island and Seal Island (Fig. 6), are known haulout areas.

Historical abundance and distribution were examined separately in these three areas along a chronological scale. Major events of disturbance and observations of abundance were assessed over time in an attempt to track population changes in these areas. Reports of breeding events were also investigated in order to assess the historical distribution of this species. Information regarding these parameters for the south coast of Western Australia are included (Appendix A), but not examined as rigorously.

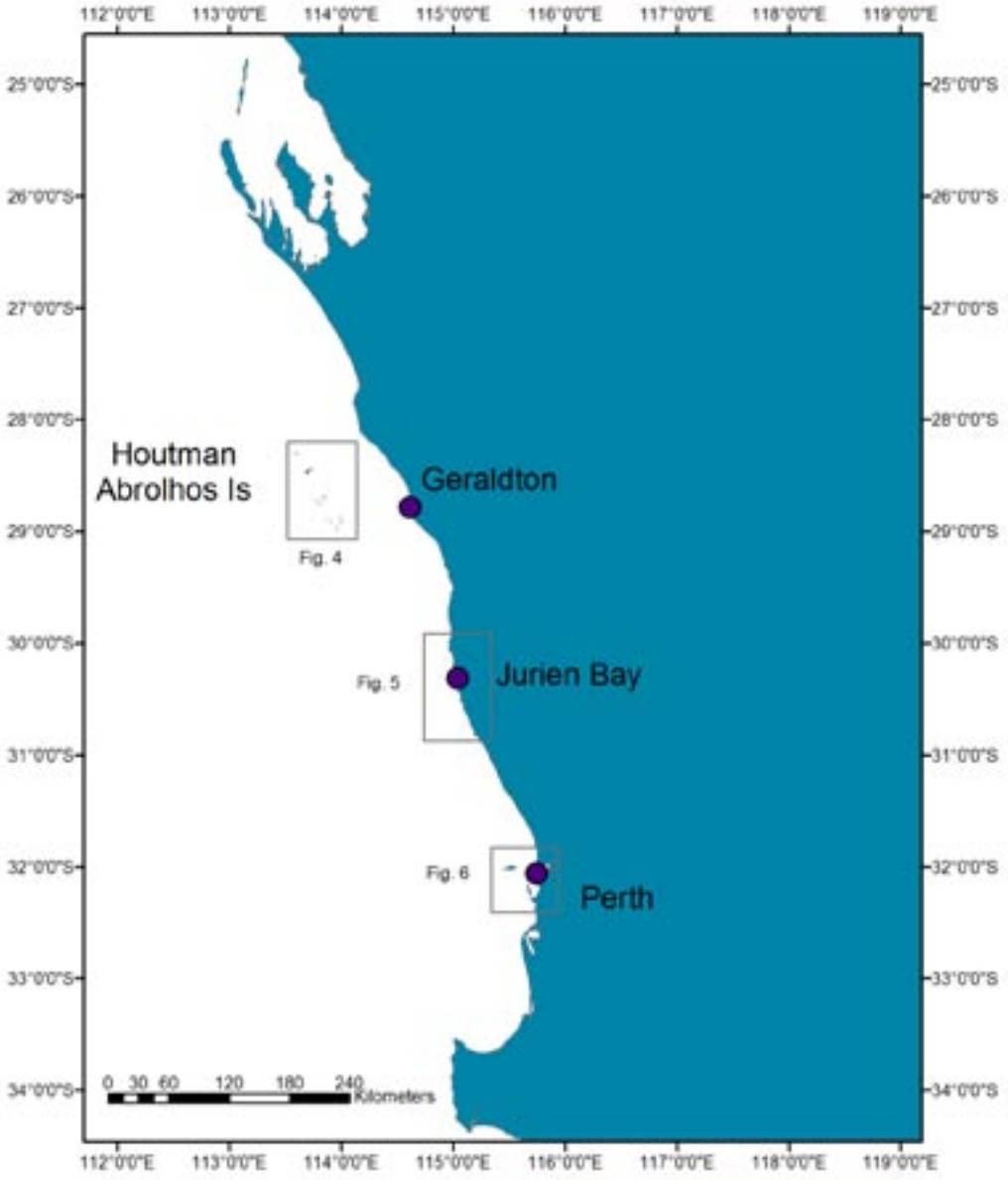

Figure 3. Major sites of Australian sea lion haulout and breeding activity on the west coast of Western Australia. This area represents the region of overlap between Australian sea lions and the Western Rock Lobster Fishery.

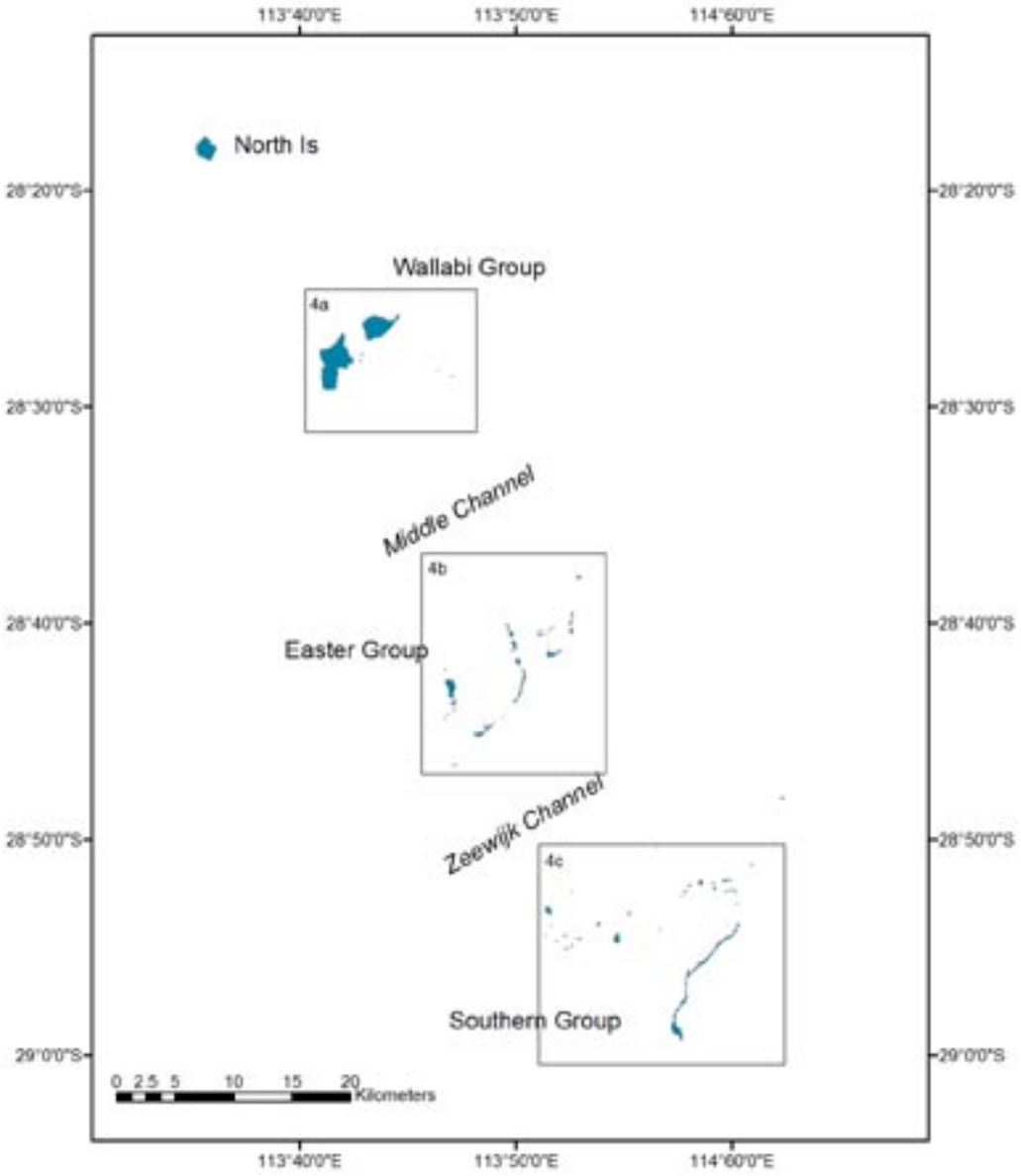

Figure 4. The Houtman Abrolhos Is. chain.

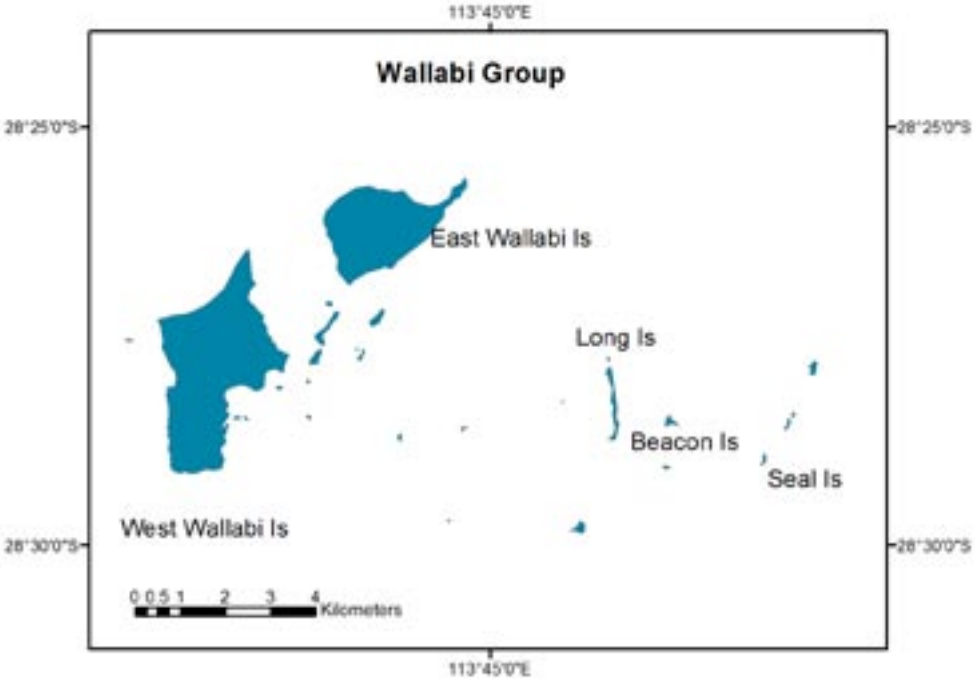

Figure 4a. The Wallabi Group and sites of significance of Australian sea lion activity.

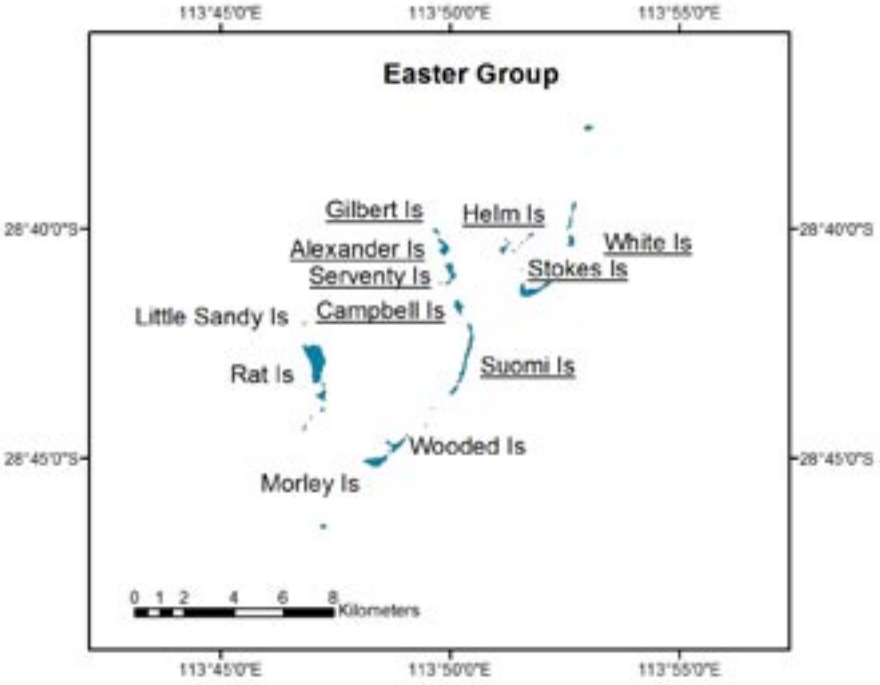

Figure 4b. The Easter Group showing contemporary breeding sites (underlined) and other significant areas.

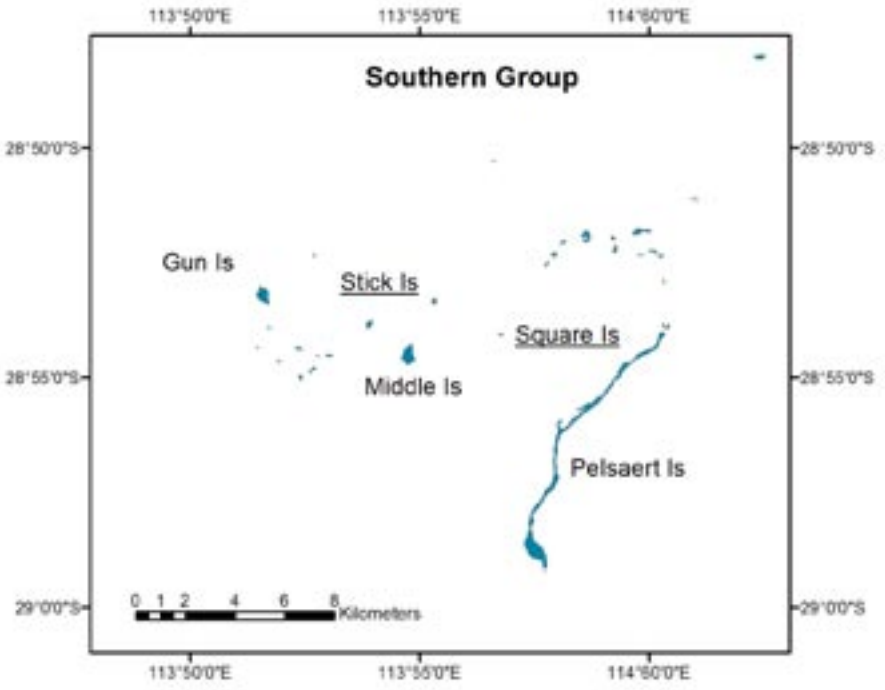

Figure 4c. The Southern Group of islands with recorded breeding sites (underlined) and areas of sea lion and human interaction.

Figure 5. Mid-west coast of Western Australia showing breeding colonies (underlined) and other areas of reference for the Australian sea lion.

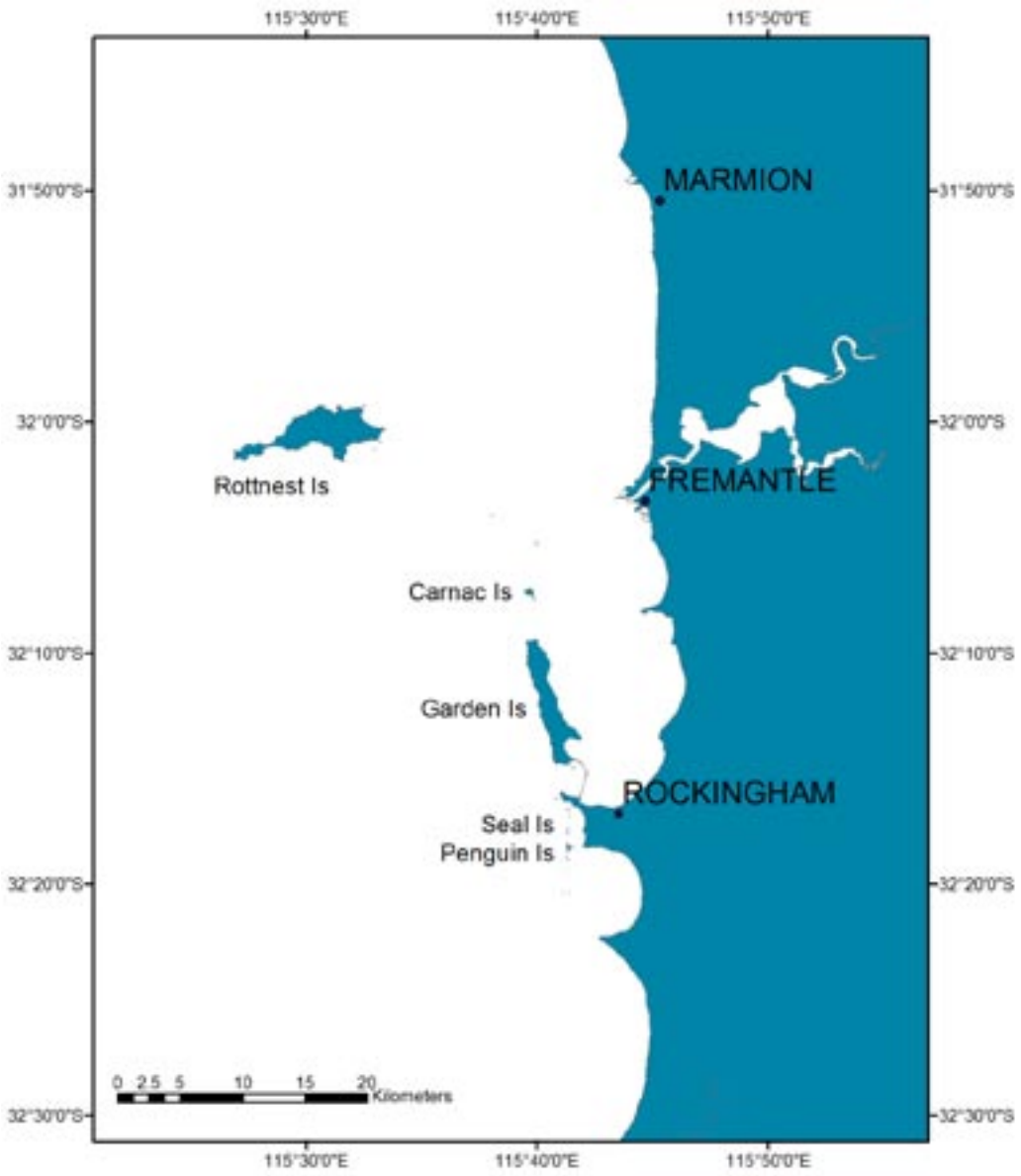

Figure 6. Sites of reported historical Australian sea lion activity in the greater Perth area. There are no records of contemporary breeding events in this area.

2.0 METHODS

Information regarding the distribution and abundance of Australian sea lions was found in a variety of sources. The journals and log books of early explorers provided valuable information regarding the presence of seals on the offshore islands that were visited. Identification of individual species of pinniped can be confirmed by physical and behavioural descriptions. However, references to seals by some explorers were often not species specific and no identifying descriptions were provided. Towards the latter part of the 18th century a large fur market was developing in China (Gill 1966) and some explorers made the distinction between the valuable fur seal and the less valuable hair seal (sea lions). The increase of machine usage due to the Industrial Revolution created a need for oil and this was sourced from a variety of marine animals including pinnipeds (Gill 1966). These commercial activities lead to the widespread reporting and investigation of the presence of fur seals, hair seals and elephant seals (sea elephants).

Records of numbers of pelts and volumes of oil are available from cargo lists of ships that berthed in Australia and help provide an estimate of pristine populations of many marine mammals (e.g. Cumpston 1977, Ling 1999). However, there was often no distinction of the source of oil, and it is known that a number of species of pinniped (i.e. elephant seals, fur seals and sea lions) and also sea birds were collected together for this purpose (Ling 1999).

Estimates of pristine abundance can be generated by examining the records of historical culls and harvests, as they provide an accurate minimum population size. Maximum population size is a difficult parameter to estimate, and in this study a theoretical maximum of twice the minimum has been assumed as a reference point. Calculation of density measures were performed based on these estimates of population size and the size of the terrestrial breeding area. These estimates of density were then used to extrapolate pristine population size in adjacent habitats. The sizes of breeding colonies were calculated using the spatial analysis program Arcview v3.2. This was performed only for populations or colonies in the same general geographic area, as it was assumed that population density would be influenced by geographical variation in habitat type and resource availability. This technique is reliant upon the assumption that island topography and dimension had no effect on density and provides a rough estimate of pristine population size, though its limitations are recognized.

Determining historical distribution and the identification of the previous range of breeding colonies of *N. cinerea* was achieved by examination of explorers' and naturalists' accounts. Observations of young pups and suckling and/or breeding behaviour were used to determine the presence of breeding colonies. Physical descriptions of small black or brown pups indicate a breeding colony, since the black coat is the natal coat which is moulted after approximately 4-5 months, and pups do not swim freely before this age (Gales *et al*. 1994).

More recent accounts of natural history regarding the distribution of *N. cinerea* are also contained in research articles based on work undertaken on the offshore islands along the west coast. Oral histories from people operating on the west coast (e.g lobster fisherman & biologists) also provide valuable information on the presence of potential breeding colonies and patterns of abundance over time scales of 40-50 years.

Estimation of abundance of pinniped populations is inherently difficult. Census techniques are predominantly based on counting a single age class, usually newborn pups, and determining population size from this based on life history parameters (Berkson & DeMaster 1985). For *N. cinerea*, this model was based on life history parameters of other species due to the paucity of

biological data, and therefore has potential for considerable error (Gales *et al*. 1994). Estimates of population size from oral histories and beach counts of all classes of animals are even more unreliable and must be approached with extreme caution (Eberhardt *et al.* 1999). The numbers of animals visibly present on a beach is influenced by a number of environmental factors and varies widely throughout the day and the year. However, these data do provide estimates of minimum population size, and they provide an index of abundance which may detect large scale changes over moderate time scales (> 20-30 years). The recording of breeding colonies is based on the qualitative measure of presence/absence of newborn pups and is considered more reliable than abundance estimates.

These data were defined and presented as being either historical (pre 1950) and contemporary (post 1950). This division roughly coincides with the passing of 5 generations of Australian sea lion and was determined to be an appropriate division in regards to local population dynamics. This division also roughly equates to the time of commencement of rock lobster fishing along the west coast and the first empirical accounts of sea lion abundance on the west coast of Western Australia. The historical period contains data mainly derived from catch records and observations by explorers and commercial sealers.

3.0 RESULTS

3.1 Abrolhos Islands and Northwards

Historical data

There are few reports of seals being seen in the Shark Bay area, though the majority of these can probably be dismissed as the misidentification of dugongs. An account of Freycinet's expedition of 1818 to Shark Bay by Arago named the area "The Bay of Seals" due to the great numbers of these animals (Alexander 1918). However, there is no mention of these animals on land, and the timing of the trip, September, would coincide with the seasonal presence of dugongs near the eastern shore of Dirk Hartog Island (Preen 1989, D. Holley pers. comm.). A confirmed report of a sea lion in this area came from King (1826) in 1821, who had previously observed and recorded hair seals, and reported seeing one on the rocks on Dirk Hartog Island. There have also been a number of sea lions observed around South Passage in Shark Bay over the last 10 years (N. Gales pers. comm.).

Reports of seals on the Abrolhos Islands can be traced back to the earliest episodes of European visitation. The Dutch East Indies (V.O.C.) ship "Batavia" was wrecked near Beacon Island in the Wallabi Group in 1629 (Fig 4a). Camps were set up on several islands including Beacon Island and West Wallabi Island for a few months (Drake-Brockman 1963). The account of the survivors of the wreck is well known as one of the bloodiest events in Australia's history as the slaughter of many of the ship's company ensued. They named the present day Long Island, Seal Island, presumably due to the numbers of seals upon it (Drake-Brockman 1963). There is no mention of either the numbers of animals present, or the numbers taken for sustenance or fuel oil, though it is contended that a great number of seals were consumed during this time (Gales *et al.* 1994). Rush lamps were ubiquitous in the day, and these were run on seal or whale oil (Ling 1999). It was reported that the remains of sea lion bones were found in the fires near the campsite on West Wallabi Island (Anon. 1964). However, a more comprehensive analysis of bone remains found in the fires on Beacon Island and West Wallabi Island showed that there

were sea lion remains only on Beacon Island (Marwick 1999). It was postulated that seals may also have been consumed on West Wallabi Island and butchered away from the campsite, thus leaving no bones around the campfires.

The next report of sea lions on the Abrolhos Islands came from another shipwreck almost 100 years later in 1727. The "Zeewyck", another V.O.C. vessel, ran aground on a fringing reef of the Southern Group (Fig 4c). A majority of the ship's company survived and made a camp on Gun Island and lived there for 10 months whilst building a boat to sail to Batavia (Edwards 1970). The journal of one of the survivors indicates that they subsisted on sea lions and sea birds, and killed at least 153 sea lions in the Southern Group alone (Van der Graeff 1726/27). This harvest was completed within the first four months of their stay and there is no further mention of sea lions in the journal. It was not stated whether this was due to the scarcity of animals, the limited need of extra foodstuffs or the concentrated effort in building the sloop to effect their departure.

Another vessel, "Venus", was wrecked on 10th April 1851 and the five survivors were reported to have lived for six months on Middle Island, subsisting on fish, seal meat and rice (Henderson 1988). There was no record of the number of animals taken, though a conservative estimate can be postulated from the numbers taken by the approximately 80 "Zeewyck" survivors over a period of ten months. This would lead to an estimated range of 20-40 sea lions having been consumed, these being predominantly from the Southern Group though this may have included animals from the Easter Group as well. The party was equipped with a sailing vessel as their rescue was affected by two of the survivors sailing to Champion Bay on the mainland. It is possible that they safely navigated between the Easter and Southern Groups to procure food.

Just prior to this episode, a number of other visitors to the islands reported seeing hair seals upon many of the islands of the entire chain. G.F. Moore, aboard the schooner "Champion", visited the islands in January 1840 and whilst in the Easter group mentioned that the islands appeared to be a favourite resort for hair seals, and that the crew killed many of them (Grey 1841). He went ashore at many of the islands in this group, and in particular observed many large seals on the small group of islands in the north-east (Fig. 4b). Stokes (1846), aboard the "HMS Beagle", reported seeing only a few hair seals on Pelsart Island, and a few hair seals on Rat Island in April and May 1840, only a couple of months after Moore's visit. Neither account makes mention of seals in the Wallabi chain. John Gilbert, the collector for naturalist John Gould, visited the islands in 1843 and made several collections of sea lions for Gould and described them in some detail. "This animal is extremely numerous on all the low islands of the Houtman's Abrolhos Islands, particularly those having sandy beaches. I frequently came upon several females and their young in a group under the shade of the mangroves." (in Lucas & Le Souëf 1909). He mentioned seeing many seals on Pelsart Island and noticed a number of tracks worn through from one side of the island to the other. This is consistent with a resident breeding population. He stated that all the islands of the Wallabi Group were thickly inhabited with seals. He specifically observed groups of 7-9 animals lying together on the beach on the islands of the Wallabi group, some with suckling young (Gilbert 1843).

Commercial sealing and fishing activity in the Abrolhos Islands were proposed by Anthony Curtis in the early 1840s (Camilleri 1965). He commissioned the vessel "Waterwitch" in 1843 for the purpose of coastal trading, and by 1844 had a profitable business exporting salted fish from the Abrolhos Islands. There was no mention of the numbers of seal skins or oil procured, or the success of this part of the venture. The vessel was sold only four years later to the Pelsart Fishing Company (P.F.C.), who proposed a similar venture in the Abrolhos Islands including

commercial sealing. This company operated from 1847-1849 and advertised salted fish, trepang and guano in the Perth Gazette, but there was no mention of commercial quantities of sea lion skin or oil.

A published account of the American whaler "Pacific", which spent the best part of four years (1885-1859) operating along the Western Australian coast, records the crew's sealing activity at the Abrolhos Islands (Whitecar 1860). "The ship's crew indulged in a great and novel sport in the destruction of seals which were found in great numbers throughout the islands."(p. 257 in Whitecar 1860). Many young seals were observed and it was noted that July (1858) was the breeding season for this species. It was also mentioned that the livers were considered a delicacy and that the skins of these hair seals were useful for repairs to the rigging. Whitecar describes finding the ruins of a tryworks on Middle Island, used for rendering whale and seal blubber. This may have been the remnants of a work station of either Anthony Curtis, the PFC, or of some other whaling vessel operating along the coast.

Many hundreds of American whaling vessels plied their trade along this coast for the best part of the 19th century following the migrating humpback whales, southern right whales, and pods of sperm whales sighted off the southern and western coasts (Wace & Lovett 1973). The Abrolhos Islands represented one of the few safe anchorages along the west coast and were also a reported source of fresh water and timber. It is more than likely that a number of whaling crews during the 19th century would have participated in sealing for both sport and for the aforementioned food and materials, whilst anchoring among the islands.

A report of a trading vessel "Hope", which berthed at Fremantle in 1863, lists a cargo of several tons of guano and 90 seal skins (Gibbs 1990). It was speculated that this vessel had come from north of Fremantle, and may have been operating from the Abrolhos Islands, where there were seals and known deposits of guano. Although Australian sea lions were not highly valued for their pelts, skins were still collected for the leather market (Ling 1999). This is the only report of a harvest of seal skins along the west coast of Western Australia found in Gibbs' compilation of ship's registration and cargo records. However, it is possible that sealing along the west coast was more common place than these records indicate, as there is no record of the "Pacific", which was involved in sealing around the Abrolhos Islands. There are very few reports of the cargo content of the American whaling and trading vessels of this era in historical accounts recorded in Australia.

John Forrest was commissioned to survey the islands for guano deposits in 1879 and he reported in his journal of seeing and shooting a few sea lions on Little Rat Island (south of Rat Island). He reports a great many sea lions on Little Sandy Island, just to the north of Rat Island. He also visited the Wallabi and Southern groups but makes no mention of sea lions on any of the islands in these groups (Forrest 1886).

A.J. Campbell (1889) noted that seals were found principally in the Easter and Southern groups of islands, but were not particularly abundant. This level of abundance was confirmed by Helms (1902), who visited islands throughout the entire chain. These trips coincided with the operation of a guano industry run by Charles Broadhurst on the islands, when considerable numbers of men were stationed on islands in the Easter and Pelsart groups (Broadhurst 1987). There are no records of sea lions being hunted for food or sport in these times though it is possible that such activities would have taken place. There was one report from the early part of the 20th century of guano industry workers occasionally taking seals for food (M. Glazier pers. comm., professional rock lobster fisherman). Charles Broadhurst was reported to have a poor reputation in terms of his treatment of his indentured labour. Reports of food shortages

on the island may have lead to the need for the workers to supplement their diet and this may have included fish and seals (M. Stanbury-Curator Maritime Museum of W.A., unpub. data). W.B. Alexander (1922) surveyed the islands in 1913 and made mention of seeing only a few individuals, similar to numbers seen on most other parts of the West Australian coast.

In addition to the direct hunting of sea lions, it is likely that a great deal of the mangrove habitat was destroyed during the 18-1900s for repairs to ships and as fuel for trypots. The loss of this habitat may have adversely affected the survival of the sea lion population, as females nursing young pups use this habitat as protection from hot environmental conditions (pers. obs.).

Contemporary data

G.M. Storr visited both the Wallabi group (1965) and North Island (1960) and conducted vertebrate surveys and did not record a single Australian sea lion for either location. He reported that local fisherman saw the occasional seal at both locations. Two surveys of the Wallabi group in the 1960's by students of Aquinas College reported only a single sea lion (Anon. 1964, O'Loughlin 1965). Two surveys by the college in the Southern Group reported "two calves" on Stick Island and a small group of seals on Gun Island (O'Loughlin 1969). A similar survey by the college students in the Easter Group reported very few sea lions (Green 1972). Incidental observations of sea lions during a survey of the islands in 1988 reported the sea lion as common, and that breeding occurs on some of the sand cays (Hatcher *et al*. 1988), though there was no reference to absolute numbers.

Two surveys of sea lion abundance have been conducted in the last 15 years. Gales *et al*. (1994) counted 13 newborn pups in 1989 and estimated that pup production (P) for the entire chain as 20 based on the timing of the visit with regards to the progress of the breeding season. Campbell (2003) conducted a survey at the completion of the breeding season of 1999 and counted 19 pups, consistent with the numbers estimated by Gales *et al*. (1994). In both surveys, pups were found only in the Easter and Southern Groups. A few animals were seen in the Wallabi chain in each survey, mostly sub-adult and adult males hauled out on West Wallabi and Long Island. It is suggested that population size, N, is between 3.8-4.8P for *N. cinerea* (Gales *et al*. 1994). This leads to an estimated population size of 76-96 animals at the Abrolhos Islands.

Professional fisherman and naturalists who have lived and worked on the islands over the past 70-80 years have reported seeing small groups of animals, predominantly in the Southern and Eastern Groups. Observations from six people who have fished and worked in the Wallabi Group over the last 30-40 years suggest that very few animals are resident here. Adult males have been observed occasionally, and small numbers of sea lions have been seen on Seal Island, but there have been no reports of breeding in this group.

A majority of users (five out of six professional fishermen and fisheries inspectors) in the Easter Group suggested that numbers of sea lions in this group have been relatively stable over the last 60 years. One account (P. Miragliotta, professional fisherman) suggested that there had been a considerable decrease at one haulout site between 1930 and 1959. Professional fishermen and fisheries inspectors observed small numbers of animals on several islands, including Rat, Little Sandy, Stokes, White and Helm and the chain of islands between Wooded and Gilbert (see Fig. 4b). Observations of young pups and breeding activity have been recorded on Gilbert Island, Alexander Island, Serventy Island, Stokes Island, White Island and Helm Island over the last 20 years. (Gales *et al*. 1994, Campbell 2003, K. Nardi-Fisheries Officer pers. comm.). A record of a young black pup, as well as aggressive male behaviour on Wooded Island. in 1938-39 was provided by P. Miragliotta (pers. comm.). One black pup was also recorded on

Rat Island, sometime in the 1960s (M. Cramer-Maritime historian pers. comm.). P. Miragliotta (professional fishermen) suggested that numbers had dwindled at a haulout spot near Wooded Island, over the period of his use of the islands from 1930-1960. He frequently observed upwards of 30 animals there in 1930-40 era but noticed a decline by the time he had finished fishing in 1959. Observations from 1947 onwards in the Easter Group by Neil McLaughlin (Chief Inspector-Fisheries WA) were that only small groups of animals (3-7 individuals) were present in this area, though these observations were not as frequently made as those of P. Miragliotta. Recent surveys of the islands have recorded very few animals at this haulout (pers. obs., N. Gales pers. comm.), and there have been no observations of such large numbers of animals anywhere in the entire chain over the past 40 years.

Observations in the Southern Group by five individuals suggest that numbers of sea lions have been stable but low over the past 40 years. Animals were sighted in small groups of 3-7, predominantly on two islands, Stick and Square (Fig. 4c). One individual has also observed black pups on these two islands from 1960 to present (M. Glazier pers. comm.). Animals were also sighted around Pelsart Island and Gun Island, but these were usually single animals hauled out. The skipper of the carrier boat "Emmalou" suggested that numbers of animals seen on Square Island may have declined over the period 1960-1980, though this was based on a limited number of observations (F. Bombora pers. comm.). He reported seeing a maximum of 7-10 animals at any time in a group.

Historical abundance estimates

An estimate of pristine population abundance for the entire chain can be made based on the harvest data of the Zeewyck. The population of the Southern Group must have been a minimum of 150 and a suggested maximum of 300. A density measure based on the area of assumed breeding colonies in this group can then be applied to the Easter Group based on the known breeding sites in this chain. A density of 80-160 animals per km^2 for the Southern Group produces an estimate of 140-280 animals in the Easter Group. No estimate of the population size of the Wallabi Group was calculated as knowledge of breeding events in this group is limited. This leads to an estimated minimum population size of 290 animals for the entire chain and a maximum of 580.

3.2 Mid-west coast

Historical data

This region contains the three remaining breeding sites of the Australian sea lion on the west coast, including Beagle Island, the largest colony in WA (Fig. 5). The first recorded observation of sea lions in this area comes from the account of Abraham Leeman, who was marooned by the skipper of the "Waeckende Beoy" with a small crew on an island in this area in 1656 (Henderson 1982). There are records of three separate landings by Leeman's party on the islands on the mid-west coast. He reports that two of the islands were home to a large colony of sea lions and that on the first island they killed approximately 10 seals for food. They made a more permanent camp on an island further south, again home to a large colony of seals, and it was here that the party set about repairing the boat for the journey to Batavia. This entailed raising the height of the gunnels by 2 feet using wood battens and seal skins. For a boat of about twenty feet this would have needed somewhere between 20-40 animals. Seal meat was also dried for the journey to Batavia. Towards the end of the stay on the island Leeman noticed that the seals were becoming scarce, and so hastened the departure. The islands that

he reported may have included at least one of the three breeding colonies in this area. There is some evidence to suggest that the island used for the boat building was Green Islet (Henderson 1982), near the breeding colony of Buller Island (Fig. 5). This island is a recorded haulout area but there is no evidence of historical or contemporary breeding activity here (Gales & Wyre unpub. rep., N. Gales pers. comm.).

Contemporary data

Surveys of other vertebrate populations on the offshore islands have provided some estimates of abundance of sea lions. Ford (1963), in his study of reptile populations, estimated the population size of sea lions on Beagle Island as approximately 100 and on North Fisherman Island as 60. No estimate of the numbers of animals on Buller Island was made, though he stated that *N. cinerea* only used half of the island habitat. He also mentioned that Sandland Island was a breeding colony with a population of about 20 animals. There was no evidence presented to confirm the status of Sandland Island as a breeding colony, though it is presumed that some form of breeding behaviour was observed. Further reports of sea lion counts in this area by Ford are published in Abbott (1979); Beagle Island (50 animals, 26 May 1961), North Fisherman Island. (40, 12 December 1961), Sandland Island, (20, 1962), Buller Island. (30, 28 October 1961), South Cervantes Island. (18 including suckling young, 28 October 1961: 2, 29 October 1962). The observation of suckling young on South Cervantes Island in 1961 is of interest. No comment is made of the colour or size of the pups, but suckling behaviour could be an indication of a breeding event. Back calculation of the approximate times of the breeding seasons for the breeding colonies (from Gales *et al.* 1992) in this area shows that breeding was taking place at that time at nearby Buller Island. Observations of *N. cinerea* on the mainland coast and some of the nearshore islands were provided by a faunal survey (Chapman & Kitchener 1977).

A long series of observations by R.E. Johnstone (Curator W.A. Museum) from 1971-1985 on numbers of sea lions on North Fisherman Island provide a measure of abundance. These counts were made during traverses of the whole island, but counts of sea lion pups should not be considered as census counts as described in the methods (p. 6). The number of animals counted ranged from 2-76, and the numbers of black pups counted during the breeding season ranged between 5 and 22. He suggested that numbers of sea lions increased during the 1970s and then seemed to plateau after this time. However, individual plots of numbers of adults and pups versus time show no significant increase in abundance (Figs. 6a-b). The estimated timing of breeding events for this period was back-calculated from current estimates, and overlain on the observations by Johnstone (Fig. 7b, Gales *et al*. 1994, Campbell 2003). This showed that the timing of the breeding season on North Fisherman has been predictable over the last 30 years, and confirms the 17.5 month breeding cycle stated for this species on the west coast (Gales *et al*. 1992). Johnstone also provided anecdotal evidence of one female *N. cinerea* found dead on the beach with a piece of shark mesh net caught around the head, and another female was seen on North Fisherman Island with a shark hook embedded through the mouth and out the eye. He also reported an instance of a large bull sea lion being taken by a white pointer shark near the beach at North Fisherman Island. Another large white pointer shark was captured in a demersal set net, which had the remains of large portions of sea lion in its stomach. He has also observed a number of sea lions (mostly females and juveniles) feeding underwater from lobster pots. He noticed mature females opening the gates of pots from the outside and taking octopus primarily but also feeding on western rock lobster. He also reported individual animals learning to take out the pins, which were used to secure the gates of the pot in order to prevent sea lion predation, and opening the gates and taking prey items.

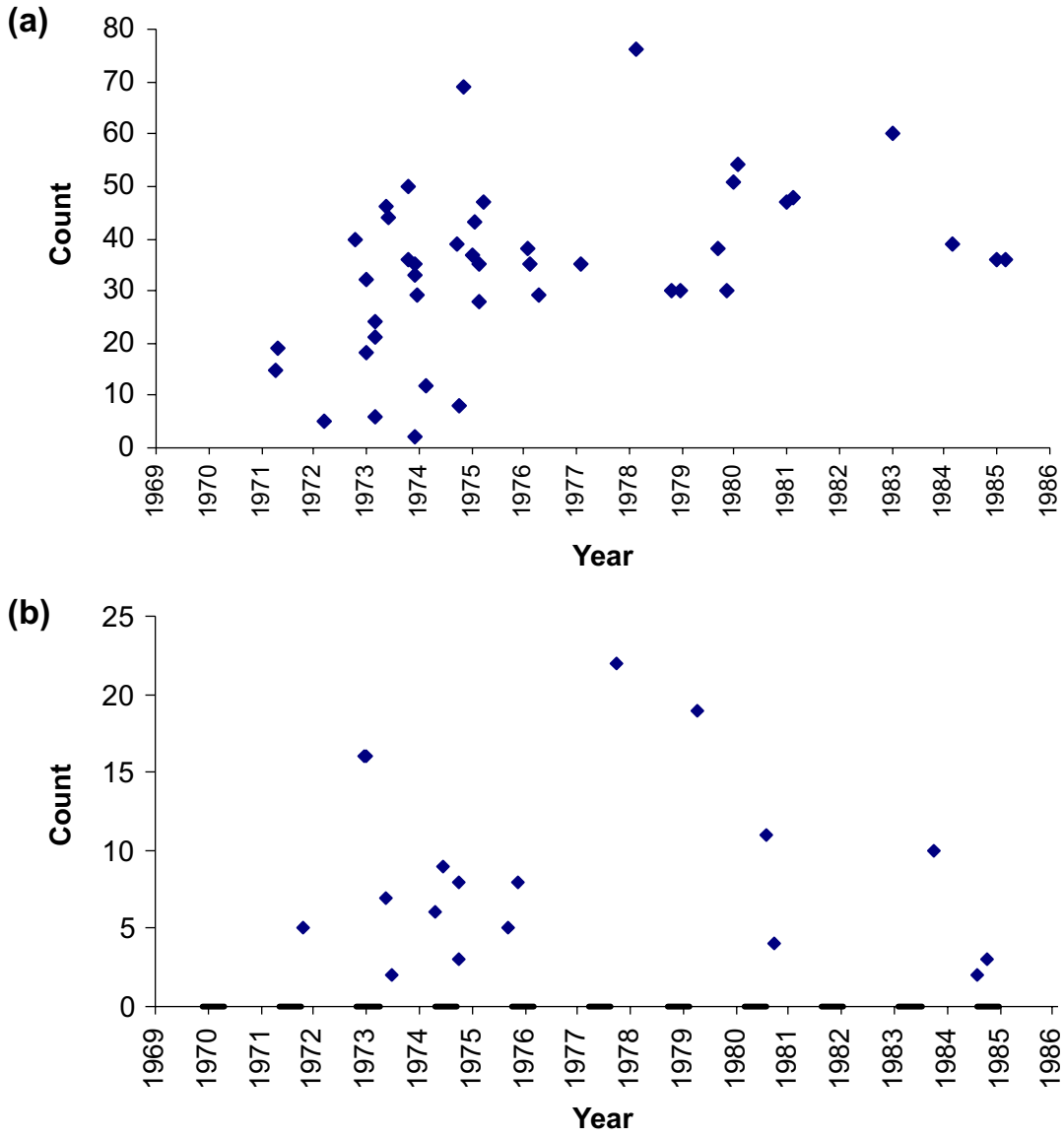

Figure 7. **(a)** Counts of sea lions on North Fisherman Is. by R. Johnstone (1971-1985). Data kindly supplied by R. Johnstone.
(b) Pup counts on North Fisherman Island by R, Johnstone (1971-1985). Estimates of the timing of the breeding season for this island are shown along the x-axis (–) calculated from contemporary observations of the timing of the breeding season. Data kindly provided by R. Johnstone.

Counts of sea lions on North Fisherman Island have also been provided by R. Wilson (Sea lion Charters, Greenhead) for the period 2001-2002 (Fig. 8). These data represent boat-based counts of animals on the eastern facing beach, an area which is heavily used by all age classes of animals. These data were taken over a period encompassing two breeding seasons and show the variation associated with beach counts of a breeding population. There is a noticeable increase in numbers of animals over the course of the observations, and also during the second breeding season as the season extends from winter to summer. Numbers of animals at the breeding colony increased throughout the duration of the breeding season with the arrival of pregnant females and attendant males. In addition this increase is likely to have been due to a behavioural response to warmer ambient temperature as animals move out of the vegetated areas of the island (pers. obs.) and not necessarily indicative of a population increase.

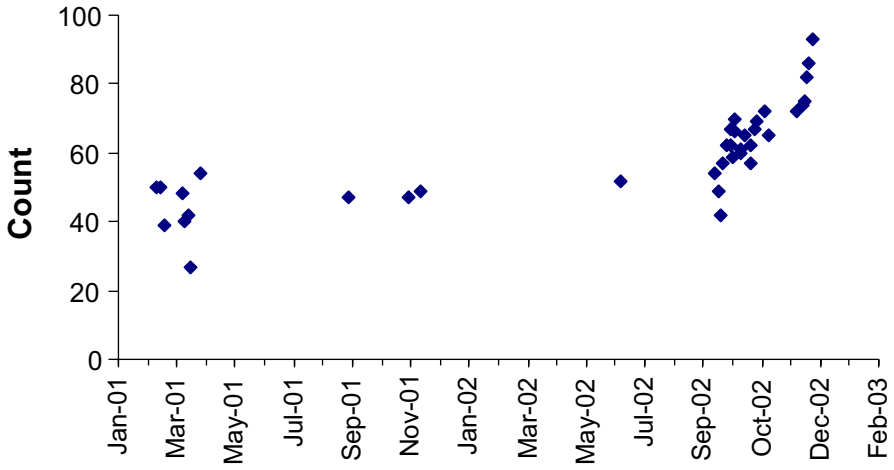

Figure 8. Counts of Australian sea lions on North Fisherman Island provided by R. Wilson (Sea lion Charters, Green Head). Counts were conducted from a boat and represent animals visible on the eastern facing beach of the island. Data kindly provided by D. Holley, Department of Conservation and Land Management.

Interviews with six users of the mid-west coast revealed mixed perceptions regarding the trend in abundance of *N. cinerea* over the last 40-50 years. Lloyd Wann (professional fisherman, pers. comm.) reported that there had been an increase in numbers of sea lions on both North Fisherman and Beagle Island in the 35 years he has fished in these areas. Other users report an increase recently in the number of interactions with sea lions, and an increase in the number of animals at haulout areas around population centres (i.e. Essex Rocks near Jurien Bay, I. Styles pers. comm.; North Fisherman Island, R. Wilson pers. comm.). One individual reported seeing considerable numbers of sea lions around the islands of Jurien Bay from his arrival in 1951, and saw no real change in the abundance of animals from then until the present (G Snook pers.comm.). Another rock lobster fisherman from the Buller Island region suggested that the abundance of sea lions had remained stable during the period 1962-1985 (K Pearce pers. comm.). Sean and his father, Michael Akerstrom, professional rock lobster fishermen in the area around Beagle Island, contend that numbers of sea lions in the area have increased in the last 30-40 years. One individual (R. Wilson) reported that the earliest visitors to this area (circa 1950) noticed large numbers of seals around Little Anchorage near Green Head, the anchorage for the first fishing fleet (Fig. 5). There are currently very few sea lions in this area, though it is not known whether these animals were directly removed or disturbed by the presence of the fleet. This information was conveyed secondhand and was derived from Kevin Fowler, who first visited the area in the 1940s.

Population estimates for the three breeding colonies of this area (Beagle Island, North Fisherman Island & Buller Island) based on pup counts were started in 1989 (Gales *et al.* 1994). These data suggest that numbers have been stable during this time (Fig. 9), though power estimates of this technique to discern even low increases or decreases in pup production are limited (Figs. 9a&b). There was variability in pup production among seasons at the different colonies, though total pup production for three breeding colonies combined was relatively constant. Variation in production of offspring among seasons is common for many long-lived mammal species (Coulson *et al*. 1999, Albon *et al*. 2000). Density-dependent effects on pup mortality have been demonstrated in a number of pinniped species and may be due to conspecific aggression (Campagna & Le Beouf 1988) and/or resource limitation (Doidge *et al.* 1984, Lunn *et al.* 1994). Density-dependent measures of pup mortality were examined by first converting pup production estimates to a density measure (P/100m^2) to account for variability

in island size. Mortality rate was regressed on pup density for the three individual colonies and was not significant in all three cases, however there appears to be a positive trend (Fig. 11). An analysis of covariance of pup mortality rates was then performed which showed that density had a significant positive effect on pup mortality overall ($F_{1,15}$=8.082, p=0.012). There was no significant difference in the rate of this effect between colonies (Table 1).

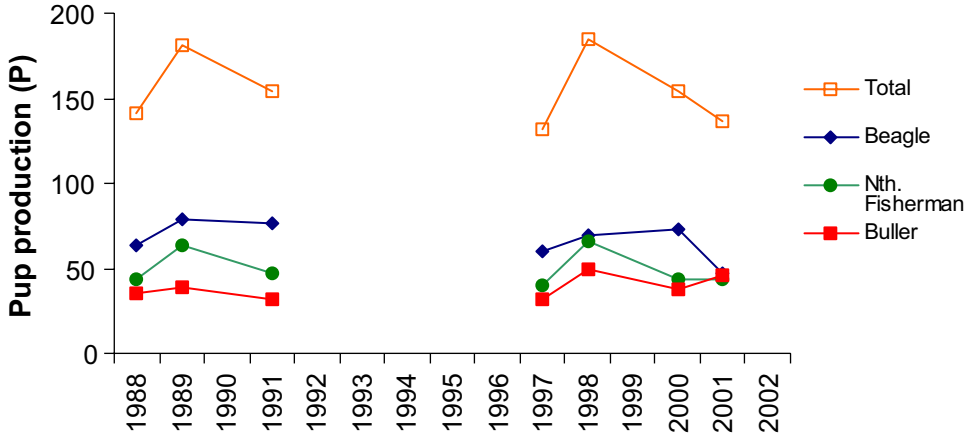

Figure 9. Pup production estimates for three west coast breeding colonies, and their combined total (mid-west coast population) between 1998 and 2001. Note that no data were collected between 1992 and 1996. Figure reproduced from Campbell (2003).

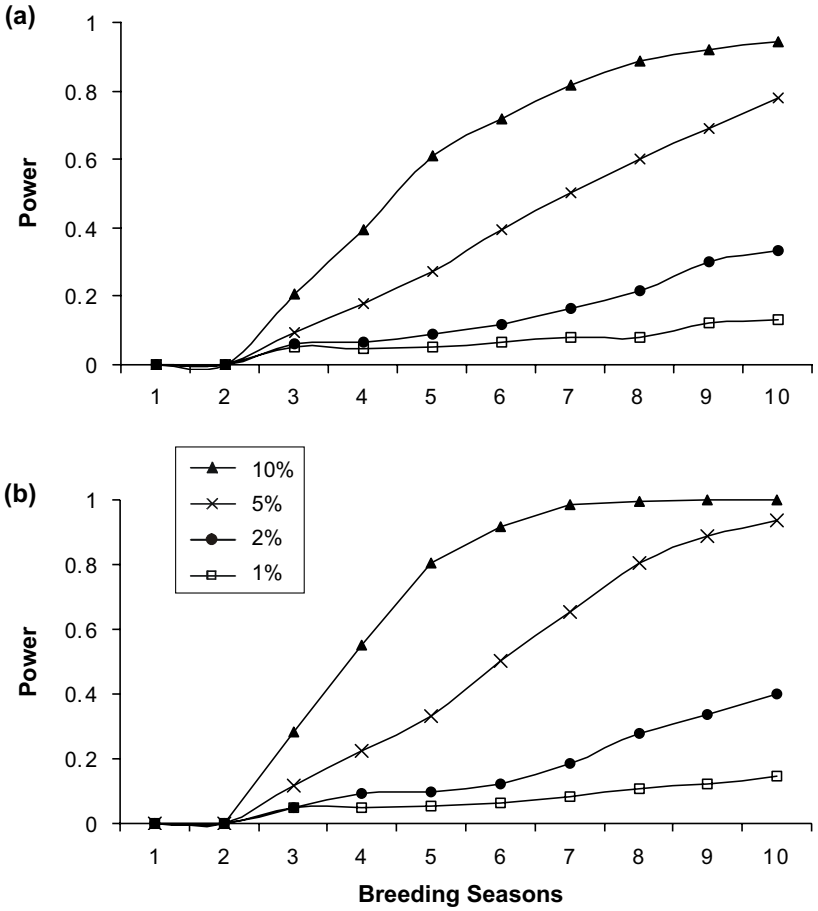

Figure 10. **(a)** Power estimates of detecting an exponential population decrease for a range of rates in the mid-west coast population over ten successive breeding seasons. **(b)** Power estimates of detecting population increases. Figure reproduced from Campbell (2003).

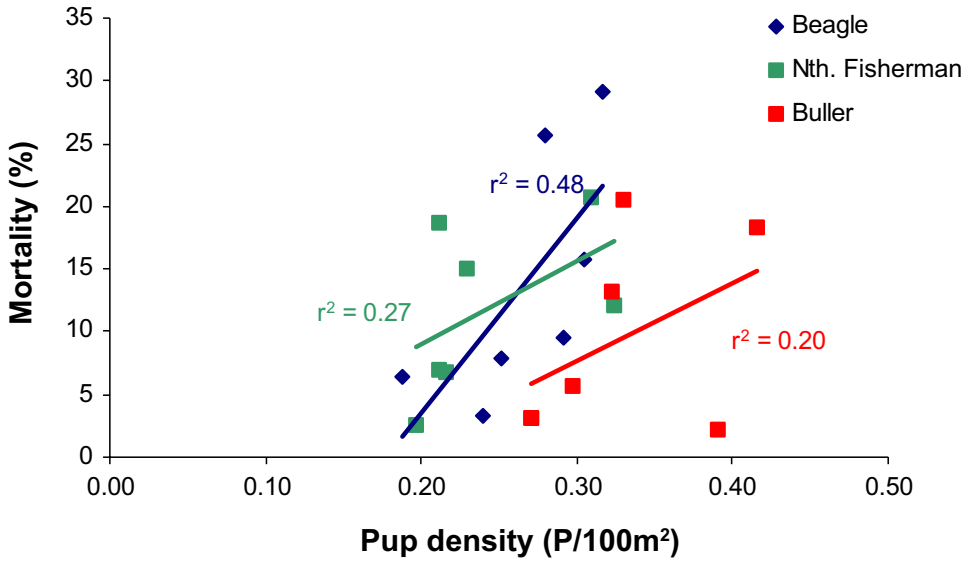

Figure 11. Pup mortality rates regressed on pup production density for the three colonies for breeding seasons between 1989 and 2001. Figure reproduced from Campbell (2003).

Table 1. Analysis of covariance of density and breeding colony on pup mortality.

Source	Sums squares	df	Mean Squares	F	P
Density	0.042	1	0.042	8.082	0.012
Colony	0.006	2	0.003	0.608	0.558
Colony*density	0.009	2	0.004	0.841	0.451
Error	0.078	15			

Analysis of historical documents suggests that there may have been additional breeding colonies in this region. The account of Leeman's marooning along the mid-west coast mentions two islands with significant numbers of sea lions on them (Henderson 1982). It is believed that one of these islands was Green Islet, near Buller Island (Fig. 5). This island is used as a haulout area, though there is no evidence to suggest that it previously supported a breeding colony (Gales & Wyre unpub. rep.). There is some evidence to suggest that isolated breeding events have occurred on Snag Island (L. Wann pers. comm.) and Lipfert Island (R. Wilson pers. comm.). A maximum of two black pups with females and a mature male were observed on Snag Island during the 1950s but no further observations have been made. There were no direct observations of breeding events taking place on Lipfert Island, but it was reported as anecdotal information. Sandland Island was listed as a sea lion breeding colony by Ford (1963), incidental to his survey of reptiles of the mid-west coast islands. He estimated the population of the island to be about 20 animals, though there was no mention of the number or colouration of the pups. There was no further mention of this island as a breeding colony in several accounts of sea lion distribution and abundance along the west coast (Abbott 1979, Gales *et al*. 1994), and recent surveys by the Department of Conservation and Land Management have found no evidence of breeding on this island, or evidence of past breeding events (N. Gales & D.Coughran-Wildlife Officer CALM pers. comm.). This island is a known haulout, and several mother-pup pairs have been observed here (N. Gales & L. Wann, pers comm.), however the pups observed were fully moulted individuals, capable of traveling the short distance from the nearby breeding colony of North Fisherman Island.

Levels of bycatch of *N. cinerea* from commercial fishing industries were also investigated. Bycatch events were reported to be sporadic with clusters of captures in localised areas. One fisherman reported catching only one sea lion in 30 years of fishing the waters around Buller Island and Green Islets (K. Pearce pers. comm.). Lloyd Wann, who has fished the shallow waters between Sandy Cape and Leeman, reported only three captures in 35 years of fishing. A professional rock lobster fisherman operating around Beagle Island reported occasional captures of more than one individual sea lion in a season, though in most years there were no captures (S. Akerstrom pers. comm.). Another fisherman who operates in shallow waters around the greater Jurien Bay area has reported catching an average of 1 animal every 2-3 seasons, with a maximum of 2 in a single season (M Collinson pers. comm.). Gary Snook, who fished the waters between Cervantes and Green Head, reported that he had never caught a single sea lion in more than 30 years of rock lobster fishing between 1966 and 1998.

It appears that bycatch is concentrated in three areas, around the Beagle Island breeding colony, between North Fisherman Island and Sandy Cape (L. Wann pers. comm.) and in the Jurien Bay area. However the distribution of catches is biased in this case by the activity of the participants in the survey. All captures occurred in less than 10 fathoms and it is reasonable to assume that bycatch rates will be influenced by fishing effort. In all the reported cases, the sea lions caught were small, approximately 1 metre or less in length. It is estimated that these animals are less than 18 months of age, though further study would be required to accurately determine the age and size range of animals that are vulnerable to capture. The timing of the preceding breeding season may influence the numbers of potentially vulnerable juveniles in the population, and could result in inter-annual catch rate variability. Examination of human related *N. cinerea* deaths between 1980 and 1996 showed that the WRLF industry was responsible for less than half of all investigated mortalities (Mawson & Coughran 1999). However, these data were based on observations by officers of the Department of Conservation and Land Management, and may represent an underestimate of the rates of mortality for all causes.

Reports of direct mortality of sea lions by operators in the WRLF were received from a number of independent sources. Three professional fishermen interviewed relayed information that isolated cases of the removal of so called “trouble” seals had occurred in the Sandy Cape region in the 1970s. It was suggested that 1-2 individual fishermen were probably responsible for these events. It is believed that these were isolated cases and occurred either from boats whilst fishing, or at anchor near the coast (T. Forster & E Little- Fisheries Inspectors pers. comm.). Several inspectors who worked for the Fisheries Department in this area throughout the 1970s suggested that the incident rate of shooting would have been very low (N. McLaughlin, E Little pers. comm.). Based on this evidence, the upper limit of animals killed was estimated at 10. Sandland Island is adjacent to Sandy Cape and there may have been considerable disturbance to the population in this area. This island does not currently support a breeding population though reports from the 1960s suggest that this was once the case. It is possible that had Sandland Is been a small breeding colony, it could have been disrupted by shooting and disturbance.

Reports of sea lion interactions with commercial fishing pots also appear to be centered around the major haulout and breeding areas, and usually takes place in shallow waters (<10 fms). Individual fishermen have observed adult females placing their head into the neck of a pot, which causes the lobsters to move to the edge of the pot and around the escape hatch. The sea lion then removes its head from the pot and moves around to the escape outlet and removes lobsters by the tail (S. Akerstrom pers. comm.). Several fishermen have also reported removal or breakage of bait lids by sea lions and the robbing of bait.

Historical abundance estimates

These data do not allow for an accurate estimate of pristine population size along the mid-west coast. It is likely that the historical population was at least as large as the current estimates of population size, but there is no clear evidence of a large population decline.

3.3 Greater Perth Metropolitan Area

Historical data

The earliest recorded visits to the coast of the present day metropolitan area were those of the Dutch explorers in the 17th century. A small crew from the "Waekende Beoy" went ashore at Rottnest Island in 1656 and saw only two seals, and Vlamingh in 1696 reported seeing very few seals on the island (Alexander 1914). There were no further recorded visits for another century until a French expedition in June 1801 (Freycinet 1809). A small party, led by Freycinet, went ashore and was stuck there for a number of days and reported catching and eating several seals. Freycinet revisited Rottnest Island later that month and made several key observations. He described these animals as "…being present in large numbers on various sandy beaches: they sometimes penetrate for considerable distances into the interior of the forests. We saw large ones: they were mostly grey; some were reddish, and others were black. These last were the smallest and, perhaps also the youngest; for we saw a female of an ashy grey colour suckling one of its young, which itself was black. The fur of these animals is fine and thick, and on this account might be of considerable value." (p 149, Freycinet 1809). These were the same animals first described by Peron whilst the expedition was in South Australia (Peron

This account was interpreted by Abbott (1979) as being a description of fur seals, however several key points indicate that these were Australian sea lions. The presence of animals well inland in the forest is typical of *N. cinerea* during the winter months, when they are known to range inland for hundreds of metres (Ling 1992). In contrast, New Zealand fur seals do not travel far from the waters edge due to thermoregulatory requirements (Reynolds & Rommell 1999). The physical descriptions of large, grey animals (most probably males) and the ashen-grey female with a young black suckling pup accurately describe Australian sea lions (Ling 1992). In particular the presence of a female suckling a black pup and observation of other black pups is indicative of breeding on the island. The timing of this event, June, precludes it being a New Zealand fur seal and its pup as they breed in December-January, and breeding is presently restricted to the south coast of Western Australia (Gales *et al.* 2000). Freycinet encountered greater numbers of seals on Garden Island than on Rottnest Island, and owing to the confrontational behaviour of these animals a great slaughter occurred (Freycinet 1809). No numbers or description of age classes were recorded, but this aggressive behaviour is indicative of female sea lions with young pups (pers. obs.), however there was no mention of pups as described on Rottnest Island. A visit was also made to Carnac Island and the presence of seals noted.

King visited Rottnest Island in January of 1821 and landed somewhere on the north-eastern end and reported seeing a great many seals, though was only able to kill 3 animals. He described these animals as being of the hair type as he had seen previously around Albany (King 1826). The timing of this visit does not coincide with the predicted breeding season based on Freycinet's observations in 1801, and suggests that there was a significant resident population on Rottnest Island.

The next visitors to this area were associated with the founding of the colony, and the number of reports of seals grows considerably. Botanist Charles Fraser visited the area in 1827 and reported a large number of seals on Carnac Island, but made no mention of seals on Garden Island, which he also visited (Fraser 1906). Captain Fremantle, in charge of "HMS Challenger", anchored in Cockburn Sound in April, 1829 and explored the environs. He gives a well worded account of the forays onto Garden Island (then called Bûache Island) in search of seals to render down for oil. They succeeded in killing over 30 animals on this island and killed a number (>13) on Carnac Island over a period of 10 weeks. However, he noticed that upon return visits to Carnac Island, seals became increasingly scarce. Small numbers of sea lions were also sighted on the adjacent shores near Cape Peron and Arthur's Head and single animals killed (Fremantle 1979).

Fremantle also mentions in his journal the aggressive behaviours of the seals and their ability to run surprisingly fast. One particularly large animal he described as being "An immense monster, so large that the four men could not carry him to the boat: most likely a Sea Elephant" (p. 34 Fremantle 1979). As previously mentioned in the account of Freycinet (1809), the aggressive behaviour of female Australian sea lions had been noted, particularly on this island. The large animal was possibly a male Australian sea lion, which can attain a weight of over 300 kilograms (Ling 1992). Male Australian sea lions are also aggressive, especially when defending females during the breeding season (pers. obs.). Elephant seals are infrequent visitors to these shores (Mawson & Coughran 1999) and are certainly much larger than Australian sea lions, but do not have the aforementioned mobility (Reynolds & Rommell 1999).

Fremantle noted that on Carnac Island there were many young seals and he suggested that this was the time of the breeding season (May-June 1829). He also observed signs of sea lions ranging all over the island, making tracks through the vegetation. This is in contrast to the distribution and age classes on the island today, where moderate numbers of adult and sub-adult males haulout on the eastern facing beach and are restricted to this area (Gales *et al*. 1992). The observations of Freycinet and Fremantle can be combined to examine the predicted timing of breeding seasons on these islands. Freycinet's observation of young black pup in June 1801 can be used as the mid-point of the breeding season and extrapolation of this date can yield estimates of future breeding seasons. This suggests that breeding may have taken place from December 1828 to April 1829. This coincides with the visit of Fremantle and may explain his observations of many young seals and his belief that this was the time of the breeding season. This exercise is reliant upon the assumption that the three potential breeding colonies of Rottnest Island, Garden Island, and Carnac Island had synchronous breeding seasons and that the observation of a pup on Rottnest Island was indicative of a breeding season and not an isolated breeding event. This is possible given the pattern evident today on the mid-west coast, where the colonies of Buller Island, Beagle Island and North Fisherman Island are virtually synchronous in their timing of breeding (Gales *et al*. 1994).

Another conflicting factor in the abundance of sea lions on Carnac Island may have been the seasonal movements of sea lion populations from Carnac Island to the breeding colonies of the mid-west coast. It is known that male sea lions which haulout on Carnac Island, seasonally migrate to the breeding colonies of the mid-west coast and return to the Perth area after the breeding season (Gales *et al.* 1992). Assuming that this pattern was established some time before colonisation, extrapolation of the timing of breeding of the mid-west breeding colonies back to this time suggests that the breeding season would have run from July-December 1829. This would overlap with the time of Fremantle's observations, which were approximately 10 weeks after April 1829, and may contribute to the decrease in numbers of sea lions observed on Carnac Island.

Observations by Stirling (1833) of large numbers of hair seals on the islands surrounding Perth prompted him to suggest that sufficient numbers were present to support a fishery. There was no mention of exact numbers, and it is possible that Stirling may have exaggerated his claim to assist in developing this new colony. His observation seems to run contrary to Fremantle's account only months earlier of the increasing scarcity of animals. Dr. T.B. Wilson visited Garden Island that same year and noticed only a single seal, and did not see any seals on Rottnest Island (Alexander 1918).

The distribution of seals in the greater metropolitan area were provided by Clarke (1842) in his descriptions of the wildlife of the offshore islands. He mentioned that Rottnest Island and Garden Island were frequented by hair seals, and that Carnac Island was home to an abundance of seals on a seasonal basis. It is not apparent whether this seasonal abundance is related to breeding behaviour on the island as suggested by Fremantle (1979), or is representative of the seasonal movement of male sea lions to the breeding islands on the mid-west coast as seen today (Gales *et al.* 1992). Clarke also reported that Penguin Island was a favourite resort for the hair seal.

Contemporary data

From 1840 onwards, there are few reports of sea lions being seen on Rottnest and Garden Island. In most cases, observations consist of single animals hauled out on beaches, and there are no records of any breeding behaviour on any of the islands (Anon. 1974, Group 1985, Wykes *et al*. 1999, Mawson & Coughran 1999). Abbott (1979) recorded the species as extinct on both Rottnest and Garden Island. A faunal survey in January 1956 on Carnac Island recorded only two Australian sea lions including one adult male (Phillips 1955/56). Back calculation of the timing of breeding for the mid-west coast breeding colonies (from Gales *et al*. 1992) suggests that the 1956 survey was undertaken during the breeding season. This explains the low numbers of Australian sea lions present on Carnac Island, and also suggests that the migration of males to the breeding colonies along the mid-west coast was occurring in the 1950s. Records of numbers of sea lions on Carnac Island were kept for the period 1975-1977, and numbers varied between 2 and 32. There are records of occasional animals hauled-out on Perth metropolitan beaches between 1980 and 1996 (Mawson & Coughran 1999). Sea lions are also regularly sighted on Little Island (n= 5-10, S. Prentice Sorrento Quay Dive pers. comm.), a small sand/limestone island to the north of Perth.

Historical abundance estimates

These data suggest that there has been a loss of breeding colonies within the Perth metropolitan area. Based on average colony size along the west coast the three potential breeding colonies of Carnac, Garden and Rottnest Islands would have supported a population of approximately 400-500 animals. Current estimates of population size in this area consist of haulout populations of approximately 20-50 sub-adult and adult males. A summary of population abundances derived from these data suggests that there has been a reduction in population size of Australian sea lions along the west coast of Western Australia (Table 2).

Table 2. Summary of population estimates of Australian sea lions in three regions on the west coast of Western Australia in two time periods, historical (1600-1950) and contemporary (1950 onwards).

	Houtman Abrolhos	Mid-west Coast	Greater Perth area
Historical	300-580	600-900	100-480
Contemporary	76-96	600-800	20-50

4.0 DISCUSSION

It is evident that the pristine population size of *N. cinerea* on the west coast of Western Australia was greater than at present. The removal of over 150 animals from the southern group of the Abrolhos Islands, far exceeds the current population estimates (76-96) for the entire chain. This harvest in 1727 does not appear to be the only evidence of a population reduction in this area. Another account of shipwreck survivors surviving on seals in the 1850s, and proposed commercial sealing activity and visiting whaling crews in the mid 1800s probably would have reduced the population across the entire chain. These events, in combination with the numerous scientific and explorers culls, may have had a severe impact on the population.

Observations at the Abrolhos Islands by professional fishermen and Fisheries Department officers suggest that the population has been low but stable over the last 50-60 years. It cannot be discounted that this population is suffering from reduced levels of genetic variability and an associated reduction in fitness given their small population size and relatively low levels of gene flow with other colonies (Amos & Balmford 2001, Campbell 2003). This may be adversely affecting the recovery rate of this population. The concept of a minimum population size suggests that once a population drops below a certain level, the chances of recovery are minimal (Gilpin & Soulé 1986, Shaffer 1987, Nunney & Campbell 1993). This is quite probable for this population of Australian sea lions, which is at increased risk being at the limit of their known distribution.

The removal of large parts of the mangal communities throughout the islands may have also contributed to the decline and lack of recovery of the population. Nursing females use these habitats as protection from hot conditions (pers. obs.), and the loss of considerable habitat may have reduced survival of young pups, particularly over the summer months. Lactating females make short foraging trips to sea, leaving their pups on land (Higgins 1993). It is possible that pups exposed to the elements during the heat of summer without vegetation for protection would die due to dehydration.

Alternatively, the population decline may be part of a range reduction due to adverse environmental conditions. Recent core analysis of corals in the Abrolhos Islands suggests that water temperature has increased by 1.5 C over the last two hundred years off the Western Australian coast (Kuhnert *et al.* 1999). This may have contributed to a population reduction as animals either migrated south to cooler waters, or the physiological demands of the warmer environment adversely affected life history parameters. There are no comparative life history data for *N. cinerea* to support this, but general ecological theory suggests that marginally distributed populations are at greatest risk from environmental change (Krebs 1985).

It is most likely that a combination of all the aforementioned factors are responsible for the historically reduced population size of Australian sea lions at the Abrolhos Islands. There are no records of fishing induced mortality either by intent or as bycatch. The level of interaction between sea lions and the WRLF appears to be negligible at the Abrolhos Islands, though the combination of all commercial fishing activities on the biomass and productivity of this area is unknown. At present there is insufficient knowledge concerning foraging behaviour and dietary preferences of *N. cinerea* to determine the possibility of resource limitation and/or competition with commercial and recreational fisheries.

There is relatively little historical information concerning the sea lion population in the mid-west coast region, which includes the three major breeding colonies of the west coast. There is only one recorded incident of a cull of sea lions by shipwreck survivors, most explorers kept far enough away from the surrounding limestone reefs. Leeman reported an abundance of sea lions on two islands he landed on, but soon reported that these animals became scarce after only minimal levels of harvesting. This decline in numbers may well have been a behavioural response of animals to avoid capture. The presence of both British and American whalers along the Western Australian coast means that harvesting of these colonies may have taken place. The lack of recorded culls in ship's registrations or cargo lists does not preclude this possibility but suggests that any level of fishing would have been minimal. It is likely that the surrounding limestone reefs and broken ground around these colonies may well have prevented them being subject to harvesting.

Anecdotal evidence from users of this coast suggests that numbers have either increased or stayed stable over the past 40 years. There is no evidence of a change in pup production for the central west coast area since population monitoring began in 1989, though longer term monitoring is required for accurate trend analysis. Beach counts from the 1970s on North Fisherman Island during the breeding season do not differ markedly from beach counts made over the past 4-5 breeding seasons. Using beach count during the breeding season as a proxy for pup production it could be suggested that pup production has not changed significantly in the last 30 years. However, this conclusion must be approached with caution as beach counts are an unreliable indicator of pup production (Eberhardt *et al.* 1999). Further investigation of the use of beach count data as an index of abundance may prove useful as the time series of these data are much greater than the current pup count data.

Recorded annual levels of WRLF induced mortality of *N. cinerea* were relatively low, and reported as being negligible (Table 1 in Mawson & Coughran 1999). However, these data are likely to be an underestimate (P. Mawson pers. comm.). Further study of this is currently being undertaken by the Department of Fisheries to reveal the true extent across the whole of the WRLF industry. Reported captures are geographically localised, mostly in proximity to breeding colonies or haulout areas. Current indications are that captures are highly variable both within and among fishing seasons. This is possibly influenced by the age of the youngest cohort, which is determined by the relative timing of the sea lion breeding season. Research is currently being undertaken to determine suitable methods to modify rock lobster pots to eliminate capture of juvenile Australian sea lions, and remove this source of human-induced mortality in the population. The level of mortality of *N. cinerea* from all human related activities may be enough to impact upon some of the smaller colonies. The high level of population subdivision and extreme female natal site fidelity means that recruitment of females is solely from within each individual colony. The combination of increased mortality and the potential effects of reduced genetic diversity among these small populations may limit their recovery rate and/or viability (Amos & Balmford 2001).

It is also possible that *N. cinerea* has experienced a reduction in the number of breeding colonies in this area. There is anecdotal evidence of isolated breeding events on both Lipfert and Snag Islands in the recent past, though the numbers of pups produced would have been negligible in terms of overall population size. These may have been isolated breeding events and not representative of a permanent breeding colony. There are a number of instances of such events in other species of pinniped (e.g. Hookers sea lion in Childerhouse & Gales 1998, Southern Elephant seal in Mawson & Coughran 1999).

A published account of breeding on Sandland Island is of greater concern as it was reported to be a small colony of approximately 20 animals (Ford 1963). Whilst conditions on this island are suitable for *N. cinerea* to breed, there was no mention of newborn pups or breeding behaviour. Subsequent surveys have uncovered no evidence of breeding events on the island, contemporary or historical. The observations of mother-pup pairs hauled out on Sandland Island may have been animals travelling from nearby North Fisherman Island, which resulted in Ford's statement. It has been reported that mother-pup pairs from the breeding colonies haul out on nearby islands (Gales *et al.* 1992).

The shooting of sea lions in the contemporary era appears to have been limited to a small area and probably only a handful of animals, and reportedly from onboard fishing vessels. This may minimize the impact on a particular breeding colony as animals may have come from any of the breeding colonies in the area. Although the sex and age of these animals is unknown, it is unlikely that the removal of a small number of animals in an isolated instance would have a significant impact on population size or viability. The combination of direct shooting and harassment could disrupt a small breeding colony, though there is no direct evidence that this has occurred anywhere along the west coast.

There is more compelling evidence concerning the loss of breeding colonies from the Perth area. Accounts of many of the early explorers mention considerable numbers of sea lions on the three major offshore islands. One specific account mentioned the presence of a black pup suckling on Rottnest Island, indicating the presence of a breeding population. It is quite probable that breeding populations were also found on Carnac and Garden Islands based on the accounts of behaviour of the animals and observations of habitat use on Carnac Island. The reported levels of seal culling on Rottnest Island were minimal and suggests that the colony may have never been very large. Increased human development on the island may have also disturbed the breeding colony without directly killing the breeding animals. It is more likely that the population of Garden Island was removed by the reported levels of harvesting. Two major reported events occurred in 1801 and 1829 (Freycinet 1809, Fremantle 1979). The basing of a small camp on Garden Island at the beginning of colonialisation may also have resulted in greater numbers of seals being killed than was reported. This under-reporting of culling is likely to be applicable to all islands in the Perth area. Additionally, the evidence of small crews of sealers working the south coast and up the west coast to Rottnest Island may have played a part in the demise of these breeding populations.

Carnac Island presents an interesting case as a stable haulout population exists here despite recorded events of harvesting. This current population consists mainly of males that seasonally migrate to the breeding islands of the Jurien Bay region (Gales *et al*. 1992). As this population is recruited from outside the area, it is more likely to persist in the face of occasional culls. However, locally recruiting breeding populations could easily be wiped out due to exploitation, as seems to be the case for the two neighbouring islands. This pattern of local extinction and the lack of recolonisation is repeated in many areas, and is explained by the extreme female natal

site fidelity suggested by the genetic analysis (Campbell 2003). The pristine population of the Perth area would undoubtedly have been greater than at present, as there are now no breeding colonies in this area. The size of these pristine breeding colonies is unknown, however it is suggested that they were of a similar size to the extant colonies of the west coast. An upper level estimate of pup production of 105 per breeding season for the three aforementioned breeding colonies of the greater Perth region would mean a population size of approximately 380-480 animals.

5.0 CONCLUSIONS

It would appear that the pristine population size of *N. cinerea* on the west coast of Western Australia was greater than at present. The population size may have been as large as twice the current size, based on the higher numbers once found in the Abrolhos Island, and the loss of breeding colonies in the Perth area. The philopatric behaviour of female Australian sea lions limits the chances of re-colonisation of these former breeding colonies. The major events responsible for changes in population size appear to have been culls and disturbances to breeding colonies that occurred from the 17th-19th centuries. The Abrolhos Islands population, in particular, may have suffered from the continual harvesting of animals during the height of commercial whaling in the 19th century. Reported changes in the environment and human-induced mortality may be limiting the recovery of this population to its pristine size. The unusual breeding patterns and generally small colony size of *N. cinerea,* combined with the lesser commercial value of this animal, may have spared it from large scale exploitation and probable extinction in many areas.

There is no direct evidence to suggest that the WRLF has had a significant impact on abundance of the Australian sea lion on the west coast of Western Australia in the 60 years of its operation. The greatest impacts on this species occurred prior to the establishment of this fishery. However, investigations are currently underway to better assess the impacts of fishing on this population and to eliminate the capture of juvenile *N. cinerea* in rock lobster pots.

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Appendix A

South Coast

There are numerous reports of encounters with seals along the south coast of Western Australia. A summary of these published encounters is presented below.

Vancouver (1791)- Mentions seeing seals in the vicinity of King George Sound (see. Fig. 1 App. A). Named Seal Island in the Sound. Described them as white throated with coarse hair. (Indicative of *N. cinerea*).

D'Entrecasteux (Alexander 1916)- Saw many seals throughout the Recherché Archipelago in 1792 (see Fig. 1 App.A) Described their pelage as being brown, grey and white (indicative of *N. cinerea*)

Baudin (1974) – Makes mention of the encounter with the American sealing vessel "Union" in Two Peoples Bay (east of King George Sound) in 1803. This is the first record of commercial sealing activity in this area, though many academics believe that Americans may have been active in this area for some time before (Ling 1999, Wace & Lovett 1973).

Flinders (1814)- Visited King George Sound and killed three seals. Sailed through the Recherché Archipelago and noted that seals were on nearly every island and were of the hair type. Reports that a large shark they had caught had the remains of an adult seal in it, which itself still had half of a spear in its side. Mentions that there does not appear to be sufficient numbers to warrant interest from Europe to set up an industry.

King (1826)- Sailed into King George Sound in 1817 and killed a number of seals on Seal Island for food and for repairs to rigging etc. Described them as hair seals. Also noticed local aborigines catching a seal and cooking it, and then using the oil to mix with ochre for decorative purposes. This account combined with that of Flinders confirms the use of seals as a resource by the indigenous population.

Quoy & Gaimard in 1826 (Alexander 1916)- Reported that during the French expedition through the Recherché Archipelago they encountered sealers on Middle Island with which they exchanged goods.

Lockyer (1827)- Lieutenant who first settled Albany. Reports the activity of sealers in the area in the 1820s, including the infamous "Black" Jack Anderson an American negro, who was based on Middle Island in the Recherché Archipelago. These sealing crews were believed to operate across the whole south coast and even up the west coast to Rottnest Island in search of seals.

Ling (1999)- Reports on the history of sealing in Australia and the first records of skin harvests in Western Australia are from 1823/24. The majority of the activity would have involved fur seals, and incidental captures of sea lions for oil and leather. The peak of the sealing industry in Australia was in the early 1800s, and by the end of the 1820s this industry had crashed due to overfishing.

Clarke (1842)- He describes in a series of letters to the "Perth Gazette" the history and process of sealing on the south coast. Middle and Mondrain Islands were the favoured bases for sealers in the Recherché, and Bald Island, near Albany, was another favoured camp area. Records of 3 sealing vessels operating along the south coast in the 1820s are mentioned in Henderson (1980).

T. Andrews (1959)- Diary entries of Andrews as a young boy who spent nearly ten months on Middle Island in 1889. Reported a visit from a crew of sealers in the area, one of whom had been bitten by a female seal and was brought to the island to convalesce. Introduction of a closed season for sealing from November-March was introduced in 1892 for the protection of the dwindling fishery (Shaughnessy 1999).

A W.A. Heritage Committee report (1989) concluded that the level of sealing in the south of the state was considered to be negligible based on the evidence of cargo records and the paucity of relics from the known sites of sealing activity. The last known episode of commercial sealing took place in 1919 when A. Scott was granted a permit to take fur seal and sea lion from the Recherché Archipelago. He took in two months 498 fur seals and 400 hair seals, and stated that with little effort he could procure 1750 hair seals next year (Scott 1920). This statement suggests that hair seals were abundant in this area, however current estimates suggest the population size of the entire south coast to be 2000-2500 animals (Campbell, unpub. thesis.). This level of harvest would virtually wipe out the entire population, and so it suggests that the current population size is less than that of the 1920s. However, it is equally likely that Scott was over-estimating the potential harvest in order to gain a permit, which was refused in subsequent years (W.A. Heritage Committee 1989).

Recent research has unearthed a greater level of exploitation of pinnipeds along the south coast than is recorded in the literature (A. Wolfe-Regional Manager Geraldton Maritime Museum, pers. comm.). Records of local sealing activity, most notably in the latter part of the 19th century, along the south coast were found in newspaper accounts. Albany was the main port along the south coast and nearly all local sealing ventures operated out of here. The majority of expeditions were to the Recherché Archipelago and are listed in Table 1. A small take of fur seals (n=5) was recorded for Eclipse Island (Australian Advertiser 1892), though this was once reported to be a favourite haunt for fur seals and sealers in 1820-1840 (Lockyer 1827, Clarke 1842), suggesting a possible decline at this colony by the 1890s. Inclusion of these additional reports of fur and hair skins in this study to the figures of Ling (1999) produces total recorded takes of 10,312 fur seals and 2032 sea lions from the south coast of Western Australia. These figures are underestimates of the total numbers killed due to wastage in processing, unrecorded takes by black marketeers and the difficulty in calculating the numbers of sea lions taken for oil. A Western Australian Heritage Committee report (1989) concluded that the level of sealing in the south of the state was considered to be negligible based on the evidence of cargo records and the paucity of relics from the known sites of sealing activity. However, the reported numbers in this study of sea lions taken exceeds that recorded for the Bass Strait area (1521) and is similar to the recorded numbers harvested from Kangaroo Island (2110, Ling 1999). This is of considerable interest as the Australian sea lion became extinct in the Bass Strait region by the 1820s due to the commercial harvesting. Further investigation of these data may provide information of the pristine population size and status of Australian sea lions along the south coast of Western Australia.

A faunal survey of the Recherché Archipelago in 1952 recorded the distribution and abundance of sea lions (Serventy 1952). Approximately 200 hair seals (*N. cinerea*) were encountered on 11 islands, and only one colony of fur seals on Salisbury Island was reported for the entire archipelago.

More recent causes of mortality of Australian sea lions include commercial fishing operations such as the Australian salmon fishery, whose operators have been reported to have shot several sea lions along the south coast (Mawson & Coughran 1999). Accounts of sea lion bycatch

in shark set nets in the Recherché Archipelago suggest that occasional captures occur. One commercial boat was recorded to have caught 4 sea lions in 1 week in the mid 1980's operating in the Eastern half of the archipelago (R. Johnstone pers. comm.). Independent observation of the levels of bycatch of sea lions suggest that this level of bycatch is not sustained throughout the industry and the general level of bycatch of Australian sea lions is negligible (McAuley & Simpfendorfer 2003).

The population size of Australian sea lions along the south coast of Western Australia, based on pup counts, is estimated to be between 1750 and 2210 (Gales *et al.* 1994, Campbell 2003). The status of this population is presently unknown due to the limited numbers of pup counts conducted. However, it appears that the revised level of harvesting of this species is in the vicinity of the current population size. This suggests that the current population size is historically reduced. It is apparent that fur seal numbers have dramatically increased since the times of commercial harvesting. Recent population estimates put the number of N.Z. fur seals on the south coast of W.A. to be around 15,000 and increasing annually at 10% (Gales *et al*. 1999). This evidence again supports the notion that the fur seal was the predominant target of commercial sealing.

List of Fisheries Research Reports

Not all have been listed here, a complete list is available online at http://www.fish.wa.gov.au/res

83 The Western Rock Lobster fishery 1985/86. Brown, R.S. and Barker, E.H. (1990).

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87 The recreational marron fishery in Western Australia summarised research statistics, 1971–1987. Morrissy, N.M. and Fellows, C.J. (1990).

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93 Biological synopsis of the black bream, *Acanthopagrus butcheri* (Munro) (Teleostei: Sparidae). Norriss, J.V., Tregonning, J.E., Lenanton, R.C.J. and Sarre, G.A. (2002).

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