Dietary breadth and foraging habitats of the White-bellied Sea Eagle (*Haliaeetus leucogaster*) on West Australian islands and coastal sites.

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By

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Declaration

I declare that this thesis is a synthesis of my own research and has not been submitted as part of a tertiary qualification at any other institution.

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2014

Abstract

This study looks at dietary preference of the *Haliaeetus leucogaster* in the Houtman Abrolhos and on coastal and near shore islands between Shark Bay and Jurien Bay. Prey species were identified through pellet dissection, which were collected from nests and feeding butcheries, along with prey remains and reference photographs. Data extracted from this process was compared against known prey types for this species. Potential foraging distances were calculated based on congeneric species data and feeding habits and used to calculate foraging habitat in the study sites and expected prey lists to compare against observed finds. Results were compared against similar studies *on Haliaeetus leucogaster* based in other parts of Australia.

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Chapter 1: General Introduction

1.1 Diet studies in raptors

Dietary studies of any species are an important part of ecological study. These studies are particularly important in raptors, as raptors are specifically adapted to their ecosystem (Olsen, 1995). As such, diet can provide information on how a species has adapted to its environment, and comparative diet analysis can show how it has responded to changes in resource abundance or variation across its range (Olsen, 1995; Lewis et al. 2004). Raptors are large birds of prey which feed on a range of terrestrial and aquatic animals. This species group is distributed all over the world in a range of different habitats (Marchant and Higgins, 1993).

The widespread nature of raptors and their position at the top of most food webs makes raptors a key species group to operate as a biological indicator or umbrella species of ecosystem health (Sergio, et al., 2005; Sergio et al., 2006; Ozaki et al., 2006). Dietary studies can reveal important information on changing environmental conditions, the species adaptation to these conditions, and the distribution of a species (Olsen, 1995).

1.2 Sea eagles

The genus *Haliaeetus* contains eight species of sea eagle, which vary in size and distribution but share similar diets (Ferguson-Lees and Christie, 2001). These eight species include the Stellar's Sea Eagle (*Haliaeetus pelagicus*) and the White-tailed Sea Eagle (*Haliaeetus albicilla*) found in Europe, the Bald Eagle (*Haliaeetus leucocephalus*) found in North America, the Sanford Sea Eagle (*Haliaeetus sanfordi)* found in the Solomon Islands, the African Fish Eagle (*Haliaeetus vocifer*) found in Africa, the Madagascar Fish Eagle (*Haliaeetus vociferoides*) found in the forests of Madagascar, Pallas's Fish Eagle (*Haliaeetus leucoryphus*) found through central Asia and the White-bellied Sea Eagle (*Haliaeetus leucogaster)* found in the coastal and inland water systems of India, Thailand, Malaysia, Southern China, the Philippines, New Guinea and Australia (Figure 1.1; Ferguson-Lees and Christie, 2001; Marchant and Higgins, 1993).

Figure 1.1 The global distribution of the H. leucogaster taken from Marchant and Higgins, (1993; adapted from: www.outline-world-map.com, 2009).

1.3 Thesis Scope

To date studies on diet for *H. leucogaster* have been restricted to the east coast of Australia or other parts of the species' distribution outside Australia (Favaloro, 1944; Emison & Bilney, 1982; Marchant & Higgins, 1993; Debus, 2008; Thurstans, 2009a; b; Wiersma & Richardson, 2009; Hodge & Hodge, 2011; Dennis et al., 2011a). This study expands the dietary investigations to include selected sites in Western Australia. This has been done by using existing dietary collections including regurgitated pellets and prey remains, and photographic reference images of prey remains taken at sites, to inform on dietary preference and variation within three main regions, and to map the potential extent of foraging areas used by *H. leucogaster*. The regions from which the samples were collected and the photographs taken, were the Abrolhos Islands, Shark Bay and near shore islands off Greenhead, and Jurien Bay.

1.4 Justification for the study

The aims of this study required multiple levels of investigation. The first level focused just on the sites in the Houtman Abrolhos. The population of *H. leucogaster* on West Wallabi Island is large, relative to other populations on islands in the Abrolhos. Anecdotal evidence suggests that one explanation for this could be the presence of wallabies on this island. Wallabies may form an attractive food source which may contribute to the larger population density of birds. Alternatively, the island is large in comparison to the other islands, and density may be a result of more habitat availability. This study aims to determine whether or not there was evidence of wallaby remains in regurgitated pellets or among prey remains at the nest or butchery sites examined. Therefore to investigate this aim, the study focused on both the collections from Wallabi Island in the Abrolhos, as well as the collections from other islands in the Abrolhos group, as a whole. Determining that there was no variance between the diets of *H. leucogaster* among different islands in the Houtman Abrolhos would support the idea that the population size on Wallabi Island is not based on the presence of wallabies but upon another factor. The remaining aims address whether the relative isolation of the Abrolhos Island group has an effect on the diet of *H. leucogaster*, and whether or not the types of prey items detected differed from what may be expected based on the underlying habitat and environment types.

The islands of the Houtman Abrolhos are approximately 80 kms (approximately 43 nautical miles) off the coast of Western Australia. This makes them relatively isolated when compared to other coastal and near shore islands of Western Australia. By comparison the islands off Shark Bay and the islands off the area around Jurien Bay and Greenhead are only four to five km from the mainland respectively. The relative isolation of the Abrolhos Island group could contribute to a difference in the proportion or type of prey in the diet. For example, mainland or near shore island sites may have a higher proportion of prey associated with terrestrial rather than marine environments.

The samples were examined at two levels, by region and by site. This spatial hierarchy was used to address the specific aims of the study.

1.5 Aims

Broadly this study aimed to investigate the dietary preference and breadth of *H. Leucogaster* in several areas along the coast of Western Australia. The investigation into this broader aim was structured by investigating the following research aims: to; 1) determine if there was a difference in the diet between the island populations of *H. leucogaster* in the Houtman Abrolhos; 2) determine if there was a difference in the diet between birds of different regional areas of the coast of Western Australia; 3) determine if there was a difference in the type of prey taken at near shore islands, offshore islands versus mainland sites; and 4) to map potential foraging areas, using data from other studies over maps of the coast of Western Australia to get an idea of the territory which is being utilised by *H. Leucogaster* in this region.

Chapter 2: *Haliaeetus leucogaster*

2.1 Biology

H. leucogaster is a large, territorial raptor, which is easily recognisable due to its size and distinctive white and grey plumage (Figure 2.1). Adult plumage is monomorphic, and the birds show sexual dimorphism in size, with the females being larger than males (Marchant and Higgins, 1993). Immature birds have brown plumage which is replaced by white plumage as they mature. The birds reach maturity at 6 years and begin breeding at around this age. Pairs mate for life, and find a new partner only after the death of the previous partner; they often reuse previous breeding sites. The lifespan of *H. leucogaster* is around 30 years (Marchant and Higgins, 1993; DIPW, 2011).

H. leucogaster breeds annually, with clutch sizes normally two but may be between one and three. Siblicide is reported among raptors but not in the literature for this species (Marchant and Higgins, 1993).

Figure 2.1 Adult H. leucogaster on killing post located on Dirk Hartog Island in Shark Bay Western Australia credit Lawrence Hillary DPaW.

2.2 Ecology

Nesting sites for the *H. leucogaster* are usually chosen based on their proximity to water. This distance varies among regions (Thurstans, 1998). The areas that the *H. leucogaster* inhabits are fairly diverse; however, they are usually associated with coastal areas or river systems. The home range of the eagle is estimated to be large, up to 100km^2, and the eagle potentially forages within this whole area (Marchant and Higgins, 1993). However satellite tracking data shows that they usually forage within about 9kms of their nesting site (Wiersma, 2009). Wiersma (2009) provides the only satellite tracking data that is available for this species, and that study is based in Tasmania. There may be possible regional variation in foraging distances. The nest spacing varies with regions. The estimates for nest spacing range between 1 pair per 5-7km to 1 pair per 65km (Olsen, 1995; Thurstans, 1998; Ferguson-Lees and Christie, 2001).

There is no reliable estimate of population size of *H. leucogaster.* This is due to the fact that counting breeding pairs is often the only way to estimate population size

(Olsen, 1995). However, the number of breeding pairs does not take into the account adult non-territorial, non-breeding, *H. leucogaster* which live within existing territories (Olsen, 1995; Hunt, 1998).

2.3 Diet

H. leucogaster is a large opportunistic carnivorous bird which hunts in a range of different habitats including deep waters, terrestrial sites, lakes, wetlands and coastal areas (Favaloro, 1944; Marchant and Higgins, 1993). From these varied sources it gathers a range of birds, mammals, fish, reptiles and carrion (Marchant and Higgins, 1993; Ferguson-Lees and Christie, 2001.

H. leucogaster hunts predominately in aquatic areas on the wing, diving down to capture its prey in its talons at or just below the water surface. Longer, more flattened dives are utilized to capture prey which is located near the water's edge and shorter, winding dives are used to capture prey which is in the water or on its surface (Olsen, 2006). *H. leucogaster* also obtain prey by stealing from other bird species, as well as birds of their own species (Marchant and Higgins, 1993; Ferguson-Lees and Christie, 2001).

H. leucogaster, as birds of prey, produces pellets after eating. Prey is ripped apart by the eagle, using its beak and swallowed whole, travels from the oral cavity down through the esophagus and crop and into the proventriculus of the bird, and then into the gizzard (King, 1984; Fox 1995; Klasing, 1998). At the gizzard, the food separates. The elements which are digestible will continue to pass through the digestive tract, and the indigestible elements form a pellet (Klaphake, 2005). The pellet then moves back to the proventriculus before it is expelled from the eagle's body. The process then repeats with the next meal the bird eats (Duke, 1975).

Chapter 3: Study sites

The sites for this study fall between 25°28'15.14"S and 30°23'11.97"S latitude, and represent the central coastal and offshore area of Western Australia. These sites include island and near-shore and mainland sites from the Houtman Abrolhos, Shark Bay and Jurien Bay.

3.1 The Abrolhos Island Group

The Abrolhos islands are a chain of islands located in the Indian Ocean, approximately 80 kilometres off the coast of Western Australia, approximately 43 nautical miles west of Geraldton (Figure 3.1).

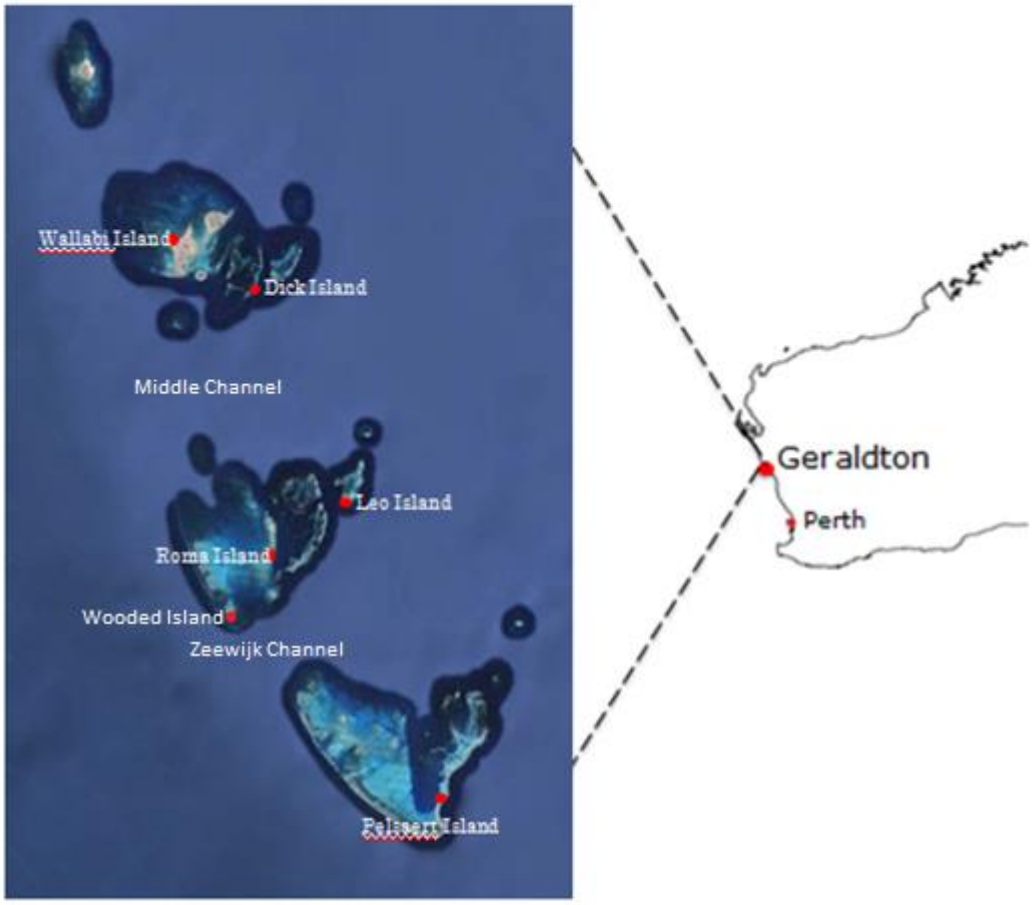

Figure 3.1 Map showing sample locations (red dots) in the Houtman Abrolhos Island group.

The islands lie on the edge of Australia's continental plate and directly in the path of the Leeuwin current (DoF, 2012).This gives the area the ability to support both tropical and temperate biota. The chain is made up of three main island groups, the Wallabi Island group, the Pelsaert Island group and the Easter Island group. The sites for this study; Pelsaert Island, Leo Islands, Roma Island, Wooded Island, Dick Island and Wallabi Island, are located within these main groups (Figure 3.1). These island groups are separated from the mainland by the Geelvink Channel and from each other by the Middle and Zeewijk Channels (DoF, 2012; Figure 3.1). The islands are fairly flat, with the elevation level ranging for the main part between three and five metres above sea level. The highest point on the Abrolhos is Flag Hill on East Wallabi Islands, at 14m above sea level (DoF, 2012). The climate on the islands is a Mediterranean type with hot, dry summers and cool, wet winters. The average high temperature is 29.6°C and an average low of 15.3°C (BOM, 2014). The average annual precipitation level is 461mm (Pearce, 1997).

The Abrolhos Islands are home to an extensive range of flora and fauna. There have been 239 species of vascular flora recorded across the three island groups, and 260 species of benthic algae and ten seagrass species have been recorded in the waters (DoF, 2012). There are 110 species of bird reported to use the islands of the Abrolhos for at least part of their lifecycle, 23 species of terrestrial reptile currently live on the islands and two species of amphibian were previously recorded on the island, but no longer live there. There are two mammal species native to the Abrolhos islands. One of these two species, the Tammar Wallaby (*Macropus eugenii*), is only found in the Wallabi Island group. Over the years other mammals such as the black rat, rabbits, household mouse and cats have been introduced to the islands but, with the exception of mice, these introduced species have been eradicated (DoF, 2012). As of 1997, 389 species of fish have been recorded in the waters surrounding the Abrolhos, as well as two species of marine reptile and five species of marine mammal. The waters of the Abrolhos also have extensive coral species, molluscs, invertebrates, crustaceans, and echinoderms (DoF, 2012).

The islands also support a Western rock lobster and saucer scallop fishery, as well as a pearl aquaculture industry which operates in the Pelsaert island group waters (DoF, 2012). Other uses of the region are recreational including: snorkelling, diving and deep sea fishing.

3.2 Shark Bay

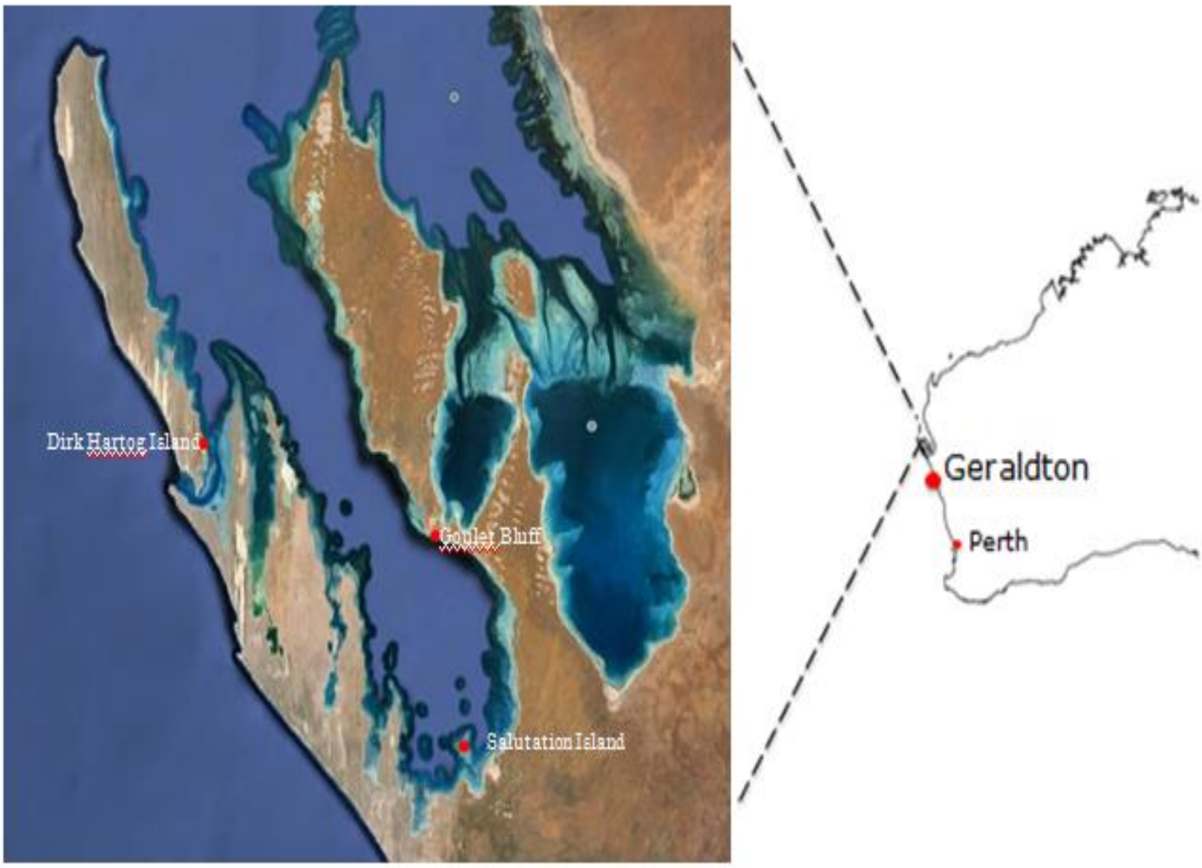

Figure 3.2 Map showing sample locations (red dots) in the Shark Bay region.

Shark Bay is a World Heritage site located approximately 800kms north of Perth, in Western Australia (UNESCO, 2014). It is the western most point of Western Australia. Shark Bay has a semi-arid climate with hot dry summers and mild winters. The average high temperature is 35°C and an average low of 10°C (BOMa, 2014). The average annual precipitation level is 228mm (BOMa, 2014). Shark Bay consists of two bays, formed by two peninsulas, with 30 islands of varying size located within the bay (Figure 3.2; UNESCO, 2014).

The flora and fauna of Shark Bay are extensive and the site has been listed as a World Heritage site since 1991 (UNESCO, 2014). One of largest seagrass banks in the world occurs in this area and 12 different species have been found in this region (DEC, 2008; UNESCO, 2014). There have been 820 plant species recorded in Shark Bay and its surrounding islands. The marine areas surrounding Shark Bay are important to many marine mammal species such as dugongs and bottlenose dolphins, turtles, whales, rays and sharks (Riley, 2005), and contains over 300 fish species. Other animals also use the areas of Shark Bay, including 26 threatened mammal species, over 200 bird species and over 100 reptile species (Riley, 2005). One of the threatened mammal species which is found in this area is the Greater Stick-nest Rat *(Leporillus conditor).* This species was previously thought to be extinct except on two islands off South Australia (Ryan, Moseby and Paton, 2003). Recent programs have re-introduced this species to Shark Bay and the protected nature of this area has allowed the species to survive (Moseby, Bice, 2004).

The area of Shark Bay has a small population of approximately 1000 people and the area is mainly used for fishing and tourism (DPW, 2009). The fishery industry in Shark Bay focuses on prawns and scallops. In terms of tourism, approximately 160 000 people come to the area every year, drawn by the wild bottlenose dolphins which interact with people at the beaches of Monkey Mia (DPW, 2009).

3.3 Jurien Bay

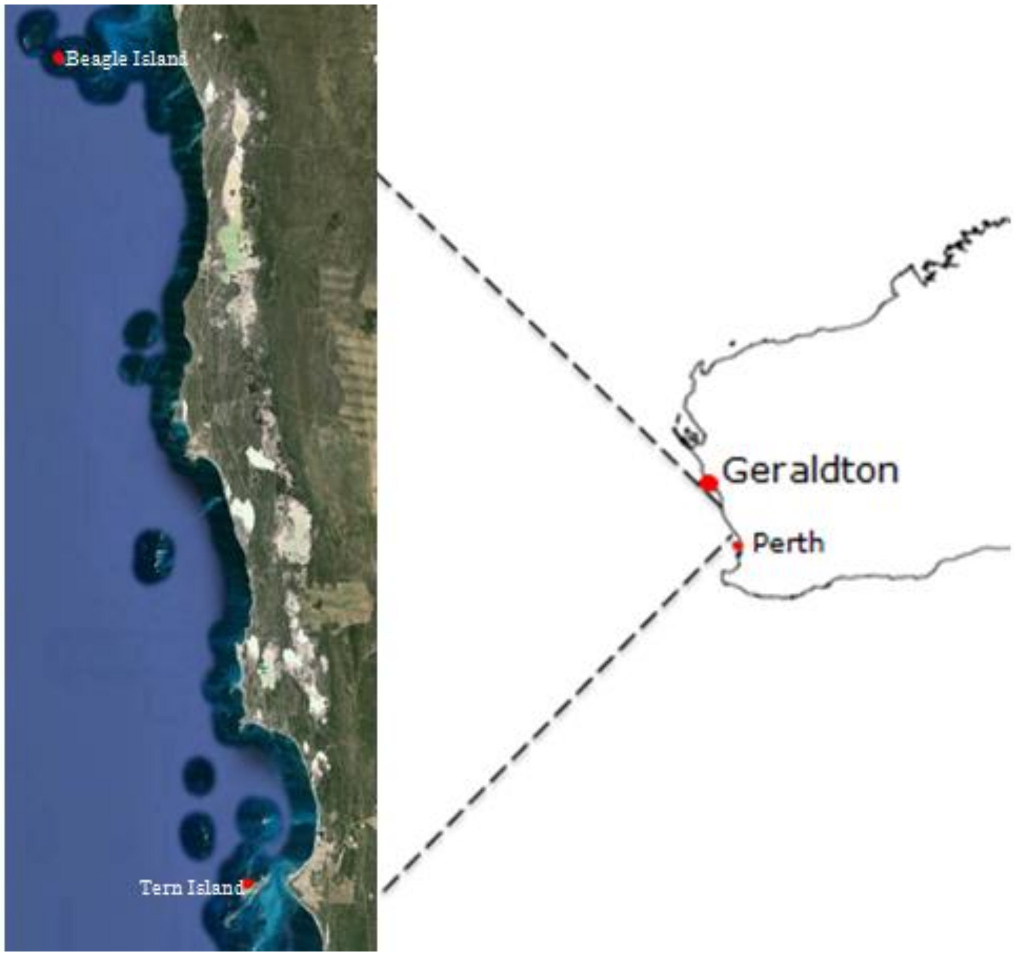

Figure 3.3 Map showing sample locations (red dots) in the Jurien Bay study region.

There are a number of islands off of the coast of Western Australia around Jurien Bay and Green Head approximately 250 kms north of Perth. Some of these islands include Tern Island, Beagle Island, Fishermans Island 1, Fishermans Island 2, Osprey Island, Boullanger Island, and Favourite Island (Figure, 3.3). These islands all fall under the Jurien Bay Marine Park and The Turquoise Coast Group nature reserve (EPA, 2001). These islands vary significantly in size and distance from the coast. These islands are fairly low lying with Fishermans Islands reaching an altitude of 10 metres above sea level in some areas (EPA, 2001).

Some of these islands are identified as extremely important to the breeding population of the west coast Australian sea lion population (EPA, 2001). The climate on these islands is a Mediterranean climate with hot, dry summers and cool, wet winters. The average high temperature is 30°C and an average low of 9.3°C (BOM, 2014b). The average annual precipitation level is between 567.7mm and 625mm.

The flora of the islands of the Turquoise coast has been documented with 121 species of vascular plants found to exist in this area; however islands, especially the smaller ones typically have a low diversity of vegetation (EPA, 2001). Three of the islands in this region represent the only breeding sites (apart from the Abrolhos islands) for sea lions on the west coast of Australia. Other islands in the region are used as resting sites for these animals (EPA, 2001). There are two land mammal species found on some of the islands in this area. Other species observed on various islands include 17 reptile species and 64 bird species. Crustacean such as the western rock lobster and molluscs such as abalone are also found in the waters surrounding the islands (EPA, 2001), along with various fish species which have not been extensively catalogued yet.

The islands of the Turquoise coast are used extensively for recreation, including activities such as: fishing, swimming, snorkelling, and bird watching. The area is also used by the commercial fisheries (EPA, 2001).

Chapter 4: Methods

4.1 Sampling method

The prey remain samples and pellets which were examined as part of this study were collected from nest sites, butcheries, roosts and killing posts of *H. leucogaster* located on six islands in the Abrolhos Island Group: Pelsaert Island, Dick Islands, Roma Island, Leo Island, Wooded Island, West Wallabi Island (referred to as Wallabi Island from this point onwards); Fishermans Island 2, Beagle and Tern Island off the coast of Jurien bay; and three sites in Shark Bay: Goulet Bluff, Dirk Hartog Island and Salutation Island, during several seasons between 2012 and 2014. During this time period photographic reference images of the sites and of the prey remains were also taken at the same sites.

The samples were collected opportunistically by officers of Department of Parks and Wildlife, seabird researchers and my supervisor as part of ongoing research projects in these areas. The pellet and prey remain collections were made from butcheries, roost, killing posts and nest sites throughout the year. Other collections were made before or after the official breeding seasons to prevent disturbing the birds or the nest sites. Butcheries or killing posts are areas where raptors feed which are separate to their nesting sites (Smith, 1985).

Sample collections were not replicated, therefore it is not possible to distinguish a time series in the data or variation between months or season, and so all data are treated as a 'snapshot' of diet at the time of sampling (Table 4.1). Samples were stored in individual sealed plastic bags and transferred to a -20°C freezer where they were kept until processing.

Table 4.1 The number and type of sample collected by region, site and date for the complete study.

Classification	Region	Site	Latitude	Longitude	Collection Date	Pellet No.	Prey remains	Photographic reference images	Habitat type
Offshore Island	Abrolhos	Leo Island	-28.6885	113.859972	04/Apr/2014	3	Absent	Present	Island
		Pelseart Island	-28.9565	113.962825	Nov-Dec/2012	7	Absent	Absent	Island
		Wallabi Island	-28.4554	113.68412	Nov-Dec/2012	3	Absent	Present	Island
		Roma Island	-28.7324	113.78705	Nov-Dec/2012	1	Absent	Absent	Island
		Dick Island	-28.4953	113.76772	Nov-Dec/2012	3	Absent	Absent	Island
		Wooded Island	-28.7507	113.80286	Nov-Dec/2012	0	Present	Absent	Island
					Total	17			
Nearshore Islands	Shark Bay	Salutation Island	-26.5448	113.766193	22/Apr/2013	20	Present	Absent	Island
		Dirk Hartog Island	-26.0833	113.233333	05/Aug/2014	4	Absent	Present	Island
	Jurien Bay								
		Tern Island	-30.3138	114.993889	05/Jun/2014	1	Present	Absent	Island
		Beagle Island	-29.8072	114.875561	03/Jul/2014	3	Present	Present	Island
		Fishermans Island 2	-30.1293	114.943171	12/Jun/2014	0	Present	Present	Island
					Total	28			
Mainland	Shark Bay	Goulet Bluff	-26.2266	113.723653	09/Apr/2014	4	Absent	Absent	Mainland
					Total	4			

4.2 Dissection

4.2.1 Pellets

Pellet dissection is an established method of identifying components of raptor diet. (Sharp et al. 2002a, 2002b; Olsen et al. 2006; Debus et al. 2007).

The pellets were removed from storage and separated into dry or wet samples based on condition. Samples which were classed as wet samples were dried in a 45°C oven for 24 hours prior to dissection.

Each pellet was photographed, weighed (dry weight) using a digital scale, and measured. Length and width measurements were made using Vernier callipers to the nearest 0.1 mm at the widest and longest dimensions of the pellet. Weights were recorded to the nearest 0.001 grams. Prior to dissection, pellets were soaked in water for one hour-24 hours depending on the primary makeup of the pellet. Feather samples required less soaking time to dissect while pellets which were predominately bone required longer before they could be pulled apart.

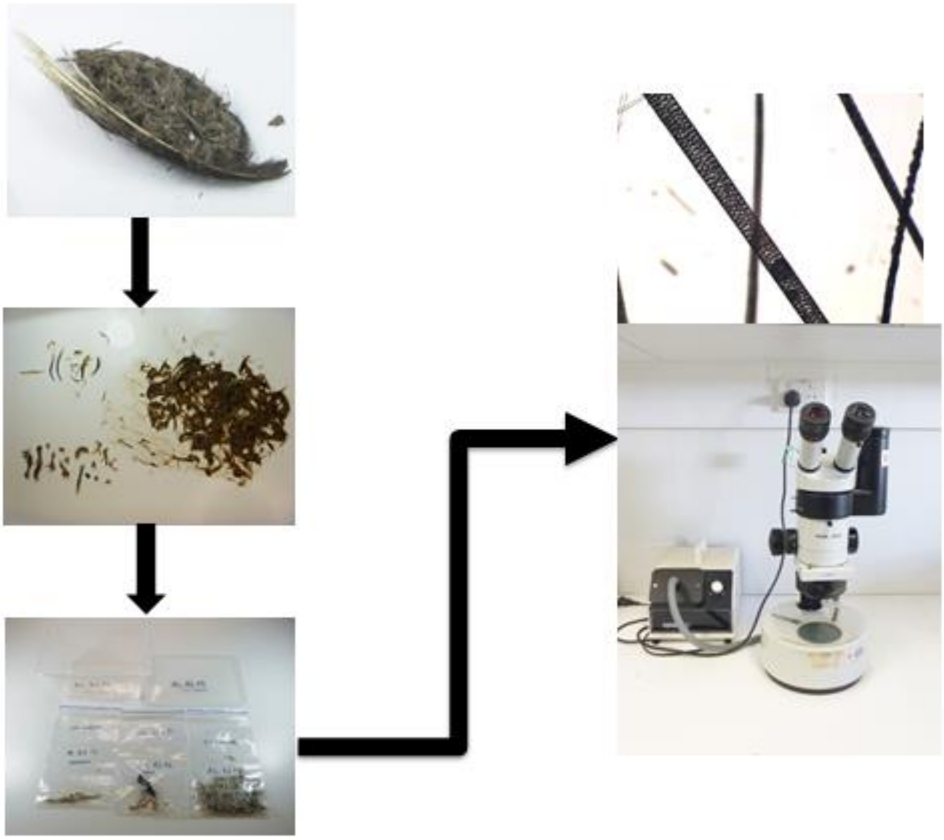

Figure 4.1 Image showing a pellet dissection work flow. The first image shows a typical pellet prior to dissection. The second image shows the pellet in the process of being separated. The next image shows the components of the pellet in the sub groups it was separated in; hair, scale, bone, feather or unknown. The final image shows a microscope, for the further identification of the samples, similar to microscopic analysis performed on the hair sample picture which was identified as being Greater Stick-nest Rat (Leporillus conditor).

Pellet material was then sorted with the aid of a magnifying lamp and divided into subgroups of; hair, feather, scales, bone and unknown elements. These subgroups were washed to remove dirt and sand particulates. Material was washed using a nested sieve with a 500µm mesh sieve placed on top of a 250µm and a 125µm sieve. After the samples were washed, each sieve layer was examined to determine if any of the sub group elements had managed to pass through the first sieve. Any elements which were found in the lower sieves were placed with their respective sub group for drying.

The samples were dried in a 45°C oven (between three hours to 24 hours), and placed in small plastic bags. The sample sub-groups for each pellet were weighed, and dry weights were recorded for the hair, feather, scales, bones and unknown particulates.

4.2.2 Prey remains and Photographic reference images

All visible prey remains were also collected at some nest sites and butcheries between 2012 and 2014 (Table 4.1). Prey remains were sorted, photographed and weighed, then set aside for identification. Prey remains are an indication of prey consumed, but it is likely that not all components of an eagle's diet were sampled at any butchery site. Similarly, it was not possible to determine how many individual prey items were present, as much of the material was in an advanced state of decay or had been pulled in to many pieces by the birds. Therefore the first occurrence of a species or taxon was recorded only. In other instances the sample was classified as bird, fish or mammal as appropriate. Photographic reference images were also taken of prey remains at some nest or butchery sites where samples were not able to be collected. These records were treated in the same manner as prey remains.

4.3 Prey types and Identification

Where possible samples were identified using reference images of species known to occur in the study regions. Hair samples were identified to species level using the technique described by Brunner and Coman (1974) and appropriate reference samples (Triggs and Brunner 2002) by *Scats About* (http://www.scatsabout.com.au/).

Where it was not possible to assign a sample to species level, the samples were separated into the following sub groups: hair, scale, feather, bone and unknown. Hair samples were classified as mammal; scale samples were classified as either fish or reptile; bone samples were classified as belonging to fish, reptile, bird or mammal and feather samples were classified as bird. The bone samples removed as parts of the pellet analysis were considered part of the pellet, and not as separate prey remains due to the fact that they were located within the pellet. Unknown samples contained vegetation, insects and elements which could not be identified as belonging to the other four sub group categories. Elements such as dirt and rock particles were removed during the process of washing the pellets.

4.4 Statistical Methodology

Data analysis was performed using IBM SPSS for Windows Version 22.0. Normal distribution of data was determined by running normality testing on the length, width and total dried weight. The normality testing involved normality plots, descriptive statistics and box and whisker plots. Data for the length and width of the pellets were found to be normally distributed. The dried weight was not normally distributed, and was log transformed. The log transformed total pellet dried weight values were used after this testing instead of the original total pellet dried weight.

The samples were examined in multiple groupings, to correspond with the aims of the study. The first grouping examined the sites of the Abrolhos Islands, only. The second grouping examined Wallabi Island, against all other Abrolhos Islands, as a group. The third grouping examined the second level seen in Figure 4.2, the regional areas of Abrolhos Islands, against Shark Bay, and Jurien Bay. The fourth grouping examined the first level seen in Figure 4.2, the geographical extents, separating the offshore islands, from the near shore islands and the mainland site. The sites which were the Abrolhos Island sites became the offshore islands in this grouping, and the islands from both Shark Bay and Jurien Bay became the near shore sites.

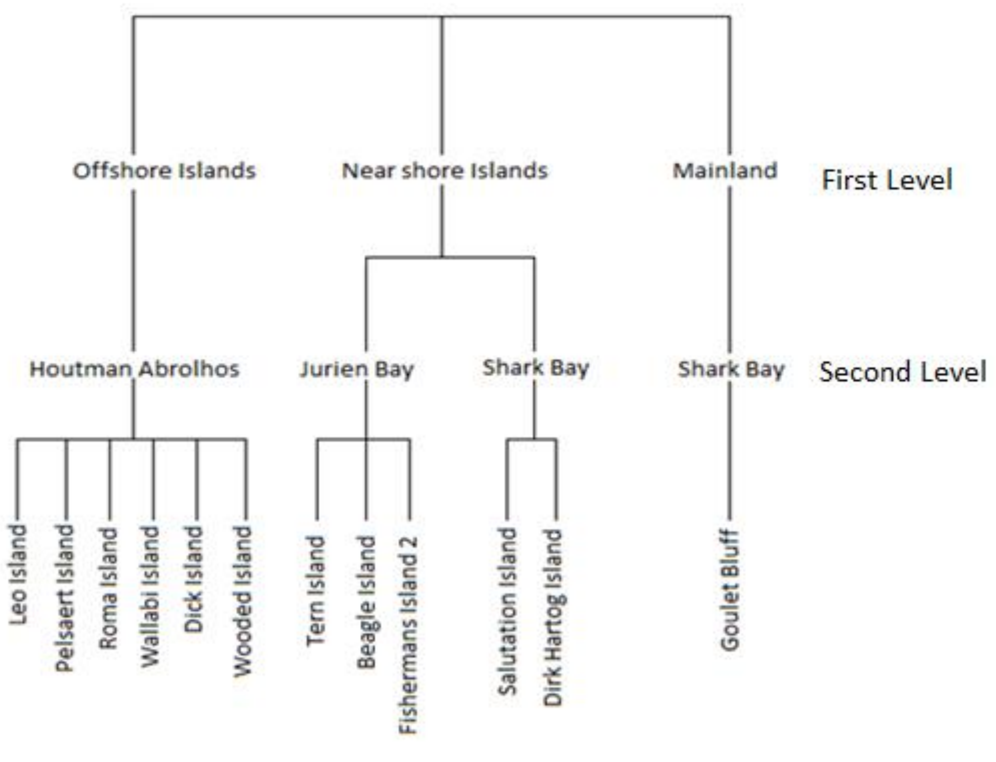

Figure 4.2 Hierarchal breakdowns of levels at which the data was examined.

To look at the variation at different scales, multiple One-way Analysis of Variances were used to see if the percentage composition of feathers, bones, hair, scales and unknown elements were different in pellets among islands in the Abrolhos group, and between regions and geographical extents.

Independent samples T tests were run on the data for the Abrolhos Islands in comparison to Wallabi island data using percentages of total dry weight for each sub group (hair, bone, scale, feather and unknown). These tests were run to determine whether or not there was a significant difference in the proportion of the subgroups for each comparison group.

Levene's tests were used to determine the equality of variances and based on the level of significant of the results equal variances were assumed Given the difference in sample size, post hoc testing using Hochberg's GT2 method (Field, 2009), was run on the analysis of variance results for each stage to determine that if there was a significant difference between the sites.

4.5 Identification of potential foraging habitat and prey species lists

Potential foraging habitat was identified by overlaying a circular polygon on a Landsat image in Google Earth 7.1.2.2041 (Google Inc.). The radius of the polygon was 9km based on previous satellite and GPS telemetry in this, and congeneric species, that suggests birds were unlikely to hunt more than 10km from their nest site (Krone et al 2009; Wiersma and Richardson, 2009). Polygons were generated using the buffer tool, and potential foraging area (km^2) by region was calculated using minimum bounding polygons in ArcGIS 10.0 (ESRI 1999-2010).

The underlying habitats (marine and terrestrial) were used to construct a list of potential prey species (Appendix 1). Lists were constructed by examining publications based in the regions and extracting lists of species which were found in the areas that could have formed part of the diet of *H. leucogaster*. This included vertebrate fauna from terrestrial, marine and freshwater systems found at Shark Bay, on the Abrolhos Islands and on the islands off Jurien Bay. Potential prey species were also gathered from OZCAM (http://ozcam.org.au/), the Online Zoological Collection of Australia Museums (CHAFC, 2014). An advanced search was run restricting the areas to the three study sites examined, each of which was examined individually, and the species found in these areas were recorded.

The island size and distance from the mainland for each island was calculated using Google Earth Pro 7.1.2.2041 (Google Inc.). Straight-line distance from the mainland was calculated using the line tool between the most easterly point of the island to the closest part of the mainland. This distance was recorded in kilometres. The island size was measured by drawing a polygon along the edge of the island and calculating the area within the polygon in square kilometres (km^2).

Chapter 5: Results

5.1 Variation in Pellet Composition

Pellets were collected from five sites in the Abrolhos, three sites in Shark Bay and two sites in Jurien Bay. A total of 49 pellets were collected from these sites, with a total dry weight of 280.1 grams.

Of the pellets collected 83.7% contained feathers, 93.9% contained bones, 4.1% contained hair samples and 38.8% contained scales. All pellets contained some proportion of non-food material. This was usually vegetation or small bits of rock or similar that became bound to the pellet during formation in the bird's crop. This material was not accidentally picked up with the pellet at the time of collection.

Feathers formed the most abundant component, followed by bone and then scales. Only a small proportion of the pellets contained hair (Table 5.1). There were obvious differences in the appearance of the pellets according to the main component of which the pellet was formed (Figure 5.1). A figure displaying all pellets is in Appendix 2.

Table 5.1 Weight of each subgroup examined for the whole study.

	Feather	Bone	Hair	Scale	Unknown	Total
Total (g)	113.7	54.6	2.3	28.9	48.4	280.1
Total (%)	40.6	19.5	0.8	10.3	17.3	100

Figure 5.1 Plate showing the variances in pellets examined, based on the predominate feature. 1) Feather 2) Scale 3) Bone.

5.2 Prey remains

Prey remains were collected from one site in the Houtman Abrolhos, one site in Shark Bay and three sites in Jurien Bay (Table 4.1). The prey remains were predominately bones and skeletal remains or fish and/or reptile scales. A total of 1006.94g of prey remains were collected. From these remains, Stout Longtom (*Tylosurus gavialoides)* and an Australian sea lion *(Neophoca cinerea)* were easily distinguished and identified. (Figure 5.2)

Figure 5.2 Prey remains collected from the Abrolhos Islands, Shark Bay and Jurien Bay. 1). Stout Longtom jaw collected from Salutation Island in Shark Bay 2). Small seal (potentially stillborn) collected from Fisherman's Islands. 3-8). Various prey remains collected.

5.3 Photographic reference images

Photographic reference images were collected from two sites in the Houtman Abrolhos, one site in Shark Bay and two sites in Jurien Bay (Table 4.1). From these images, the Bluebarred parrotfish (*Scarus ghobban*) was easily distinguished and identified.

Figure 5.3 Photographic reference image showing Bluebarred parrotfish (Scarus ghobban) photographed at a nest site on West Wallabi Island. Credit Jill Shephard.

5.4 Evidence of variation of feeding behaviour in *H. leucogaster* among the Abrolhos Island Group

Feather and bone were the main components of all of the pellets found the in Abrolhos Island group. Bones discovered originated from birds or mammals. However across all sites, feathers formed the main component (Table 5.2; Figure 5.4).

Table 5.2 Pellet summary tables showing the composition of the pellets collected from Pelsaert Island, Leo Island, Roma Island, Dick Island and Wallabi Island, in the Houtman Abrolhos, as percentages from the initial dry weight of the pellet. N=number of pellets.

	N	Total Weight (g)	Feather (%)	Bone (%)	Hair (%)	Scale (%)	Unknown (%)
Pelsaert Island	7	42.4	63.3	10.3	0	0	3.8
Leo Island	3	11.7	50.6	25.4	0	0	12.2
Roma Island	1	4.8	36.3	25.4	0	0	11.5
Dick Island	3	17.1	51.3	8.3	0	0	22.2
Wallabi Island	3	24.3	50.4	13.8	0	0	17.8

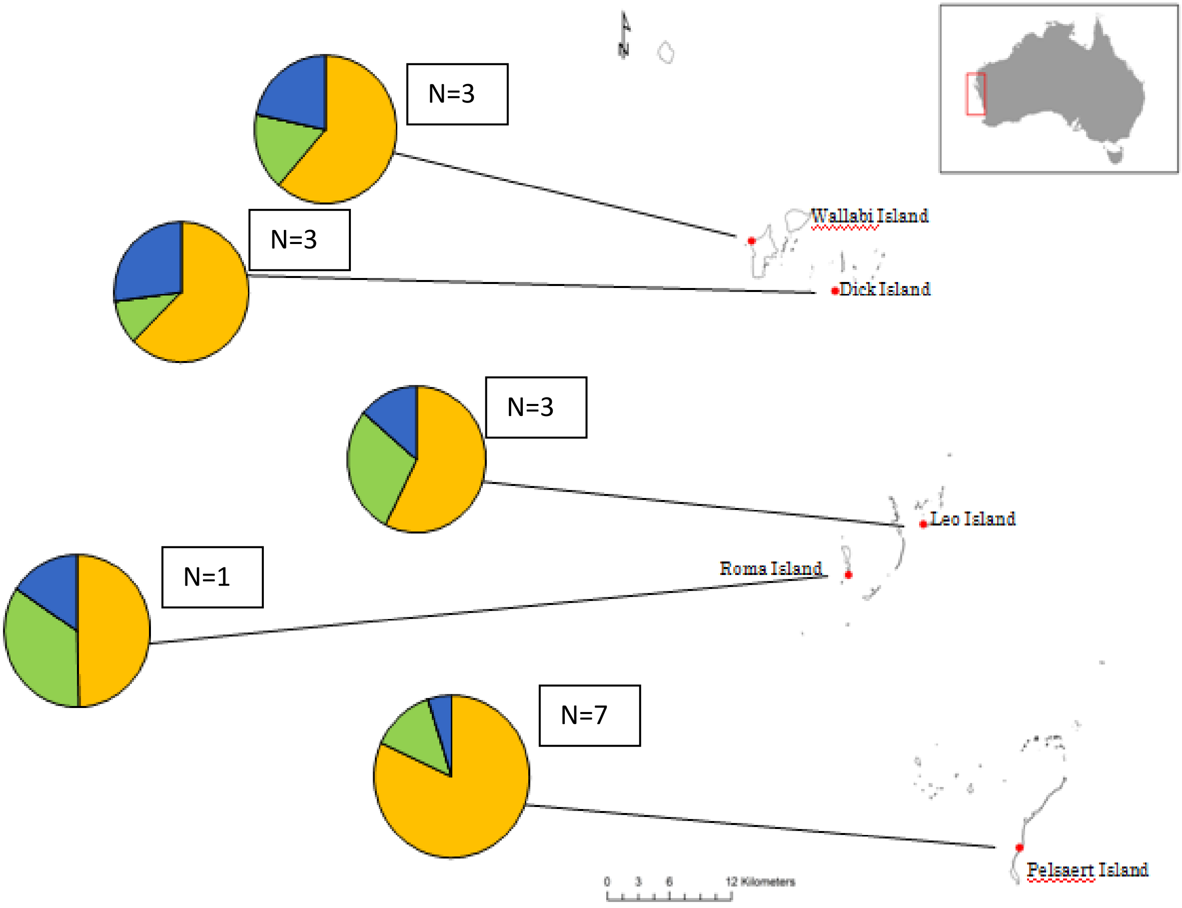

Figure 5.4 Average pellet compositions for each of the islands in the Houtman Abrolhos. Key: Yellow= Feathers, Green= Bone, Pink= Hair, Purple= Scale, Blue= Unknown.

The data for the Abrolhos samples showed limited differences, as seen in the proportions of each component in the pie charts. Hair and scale samples were not present in any of the pellets found in the Abrolhos.

The analysis of variance determined that there was no significant difference between the islands for any of the subgroups (Table 5.3). There, however, appears to be a large amount of variation in the mean percent composition of the different subgroups between islands (Figure 5.5).

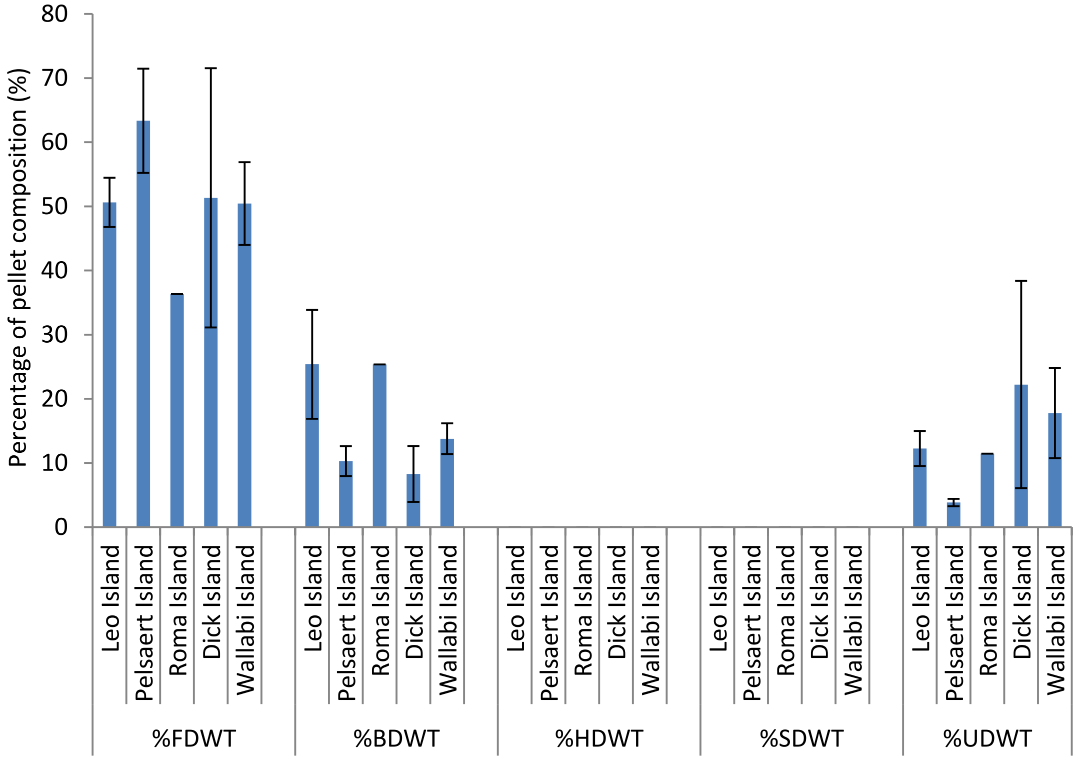

Figure 5.5 Average pellet composition (in total dry weight), (mean ± s.e.) of pellets collected in the Houtman Abrolhos, separated by subgroups and location of samples. %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %HDWT = % of total dried weight which was hair, %SDWT = % of total dried weight which was scale, %UDWT = % of total dried weight which was unknown elements.

Table 5.3 Analysis of variance results table for the total composition of the pellets collected from Pelsaert Island, Leo Island, Roma Island, Dick Island and Wallabi Island, in the Houtman Abrolhos. %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %UDWT = % of total dried weight which was unknown elements.

		N	Mean	STDEV	DF	F-value	Sig
	Pelsaert Island	7	63.3	21.5			
	Leo Island	3	50.6	6.7			
% FDWT	*Roma Island*	1	36.3	0	*4, 12*	*0.537*	*0.711*
	Dick	3	51.3	35			
	Wallabi	3	50.4	11.2			
	Pelsaert Island	7	10.3	6.1			
	Leo Island	3	25.4	14.7			
% BDWT	*Roma Island*	1	25.4	0	*4, 12*	*2.650*	*0.085*
	Dick	3	8.3	7.5			
	Wallabi	3	13.8	4.2			
	Pelsaert Island	7	3.8	1.6			
	Leo Island	3	12.2	4.7			
%UDWT	*Roma Island*	1	11.5	0	*4, 12*	*1.368*	*0.302*
	Dick Island	3	22.2	28			
	Wallabi Island	3	17.8	12.2			

5.5 Evidence for the Consumption of Wallabies

The data collected was examined for Wallabi Island and the other Abrolhos Island sites. Feathers still formed the main component of the pellets, followed by bird or mammal bones (Table 5.4); however, there is little variation in the proportion of prey types when comparing Wallabi to the other islands (Figure 5.6).

Table 5.4 Pellet summary tables showing the composition of the pellets collected from Wallabi Island and the other islands located in the Houtman Abrolhos as a whole, as percentages from the initial dry weight of the pellet. N= number of pellets.

	N	Total Weight (g)	Feather (%)	Bone (%)	Hair (%)	Scale (%)	Unknown (%)
Other Abrolhos sites	14	76.1	56.1	14.2	0	0	10.1
Wallabi Island	3	24.3	50.4	13.8	0	0	17.8

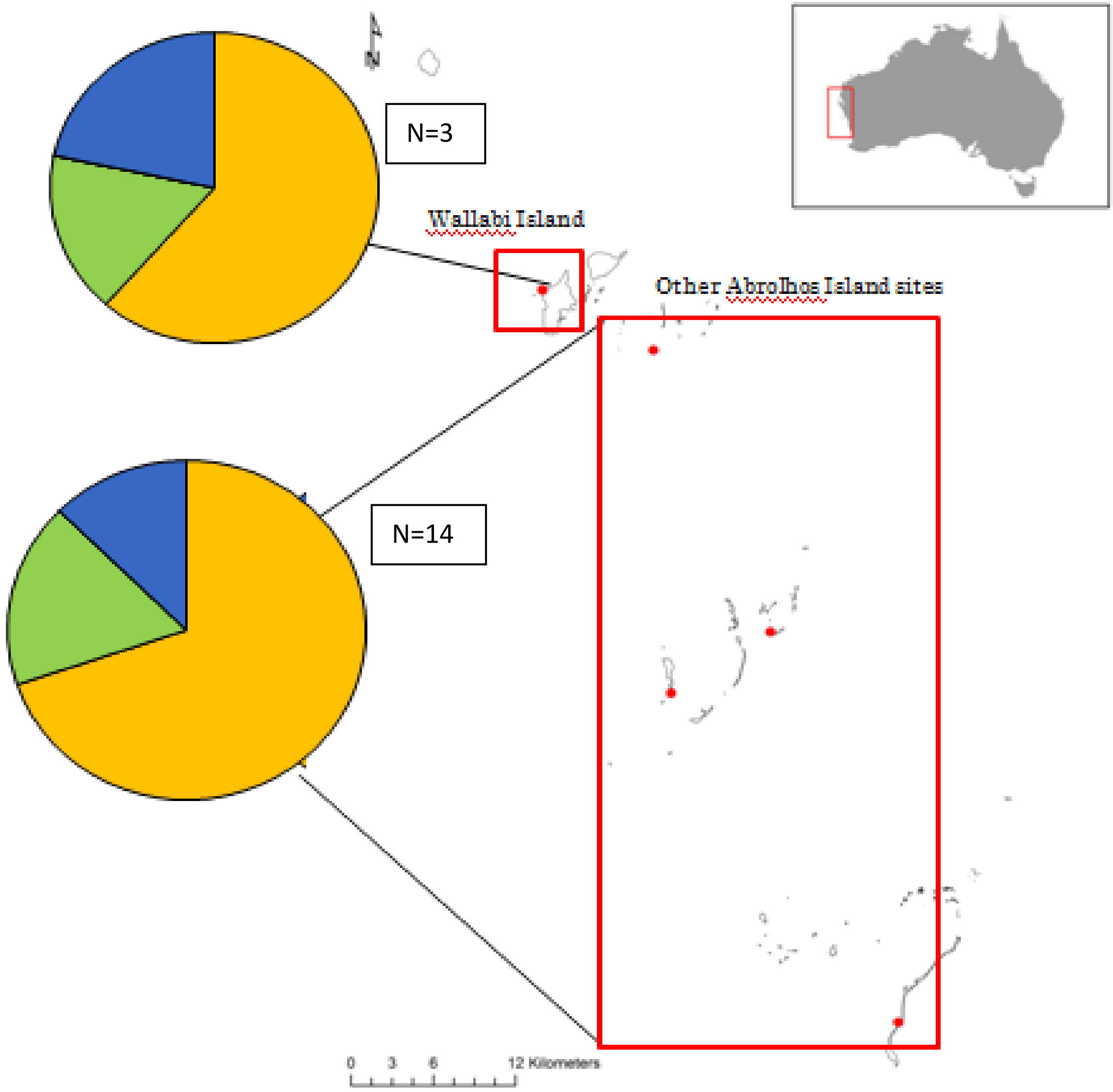

Figure 5.6 Average pellet compositions for Wallabi Island and the other islands in the Houtman Abrolhos as a group. Key: Yellow= Feathers, Green= Bone, Pink= Hair, Purple= Scale, Blue= Unknown.

The Independent samples T test, assuming equal variances due to the Levene's statistic, showed that there was no significant difference between the two sites, for any of the subgroups (Table 5.5). Notably there was no hair found in any of the samples (n=17), particularly in the Wallabi Islands samples.

Table 5.5 Independent sample T Test results table for total composition of the pellets collected from Wallabi Island and the other islands in the Houtman Abrolhos. Levene's test for equality of variances was found to be not significant so equal variances were assumed. %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %UDWT = % of total dried weight which was unknown elements.

		N	***Mean***	***STDEV***	***DF***	***t-value***	***Sig***
%FDWT	*Other Abrolhos Island*	14	56.1	21.9	*15*	*0.429*	*0.674*
	Wallabi Island	3	50.4	11.2			
%BDWT	*Other Abrolhos Island*	14	14.2	10.7	*15*	*0.062*	*0.951*
	Wallabi Island	3	13.8	4.2			
%UDWT	*Other Abrolhos Island*	14	10.1	13.5	*15*	*-0.902*	*0.381*
	Wallabi Island	3	17.8	12.2			

5.6 Variance in Pellet Composition between Regions

All of the samples examined for the regions have feathers and bones present in them. However, the Shark Bay sites also have hair and scales, while the Jurien Bay sites also have scales (Table 5.6). Feathers were the most prominent component, followed by bone. The bone samples collected from Jurien Bay and the Abrolhos regions were mammal or bird. In the Shark Bay site the total proportion of the sample which was made up of feather decreased, although it was still the main component, and larger proportions of bone and scale were found in the pellets. The bones from the Shark bay region were mammal or bird and fish. The pellet compositions are quite different at this level of analysis (Figure 5.7).

The relative proportions of sub-groups were also different, particularly when comparing the Shark Bay sites with the other regions, Abrolhos Islands and Jurien Bay islands (Figure 5.8).

The analysis determined that all subgroups were significantly different. Multiple pair wise comparisons were run, assuming equal variances. Shark Bay was determined to be significantly different from the Abrolhos Islands and Jurien Bay in feather dry weight and bone dry weight. The scale and hair samples were not present across all sites, and the unknown samples were not significantly different across the three sites (Table 5.7).

The fact that hair was only found in one region while the other regions showed no trace of the hair sub-group is important. The hair sample which was found was identified as a sample from the Greater stick-nest rat *(Leoporillus conditor).*

Table 5.6 Pellet summary tables showing the composition of the pellets collected from the Houtman Abrolhos, Shark Bay and Jurien Bay, as percentages from the initial dry weight of the pellet. N= number of pellets.

	N	**Total Weight (g)**	**Feather (%)**	**Bone (%)**	**Hair (%)**	**Scale (%)**	**Unknown (%)**
Abrolhos Islands	17	100.3	55.1	14.1	0	0	11.5
Shark Bay	28	167.2	28.9	26.6	2.1	18.5	15.7
Jurien Bay	4	12.6	67.6	7.8	0	4.6	13.9

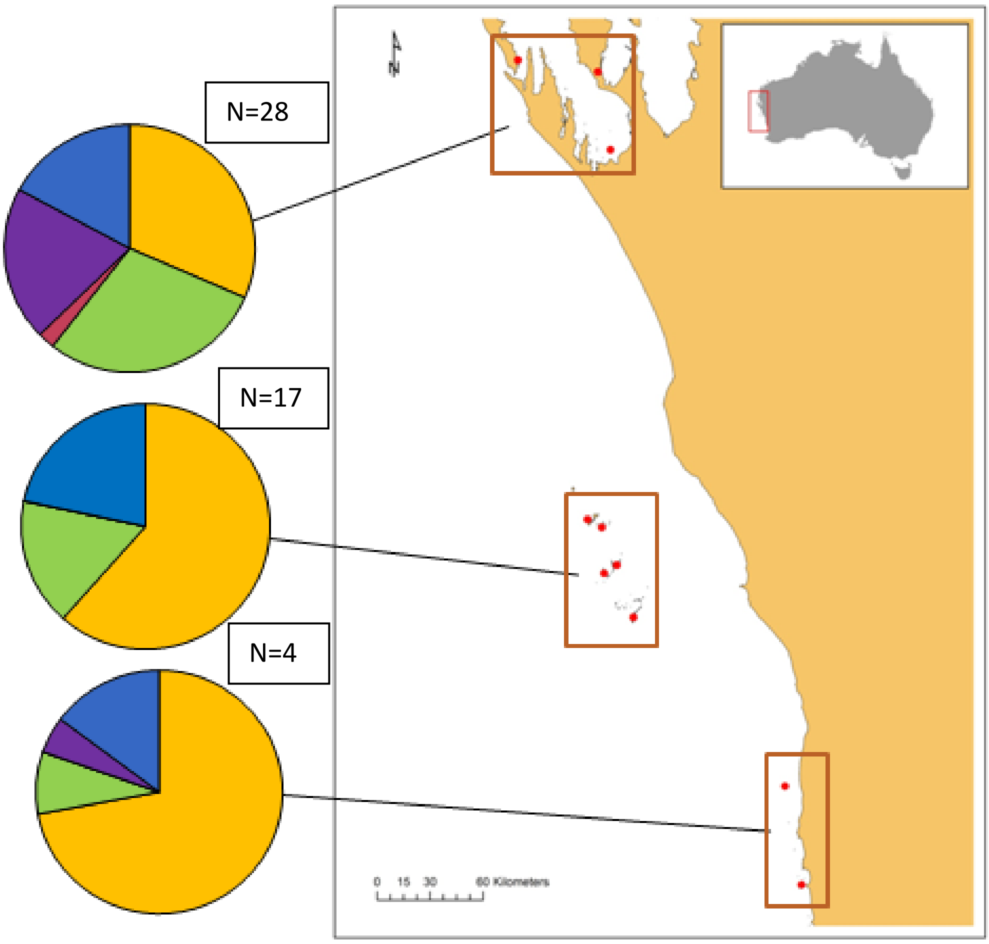

Figure 5.7 Average pellet compositions for each of the sample regions. Key: Yellow= Feathers, Green= Bone, Pink= Hair, Purple= Scale, Blue= Unknown.

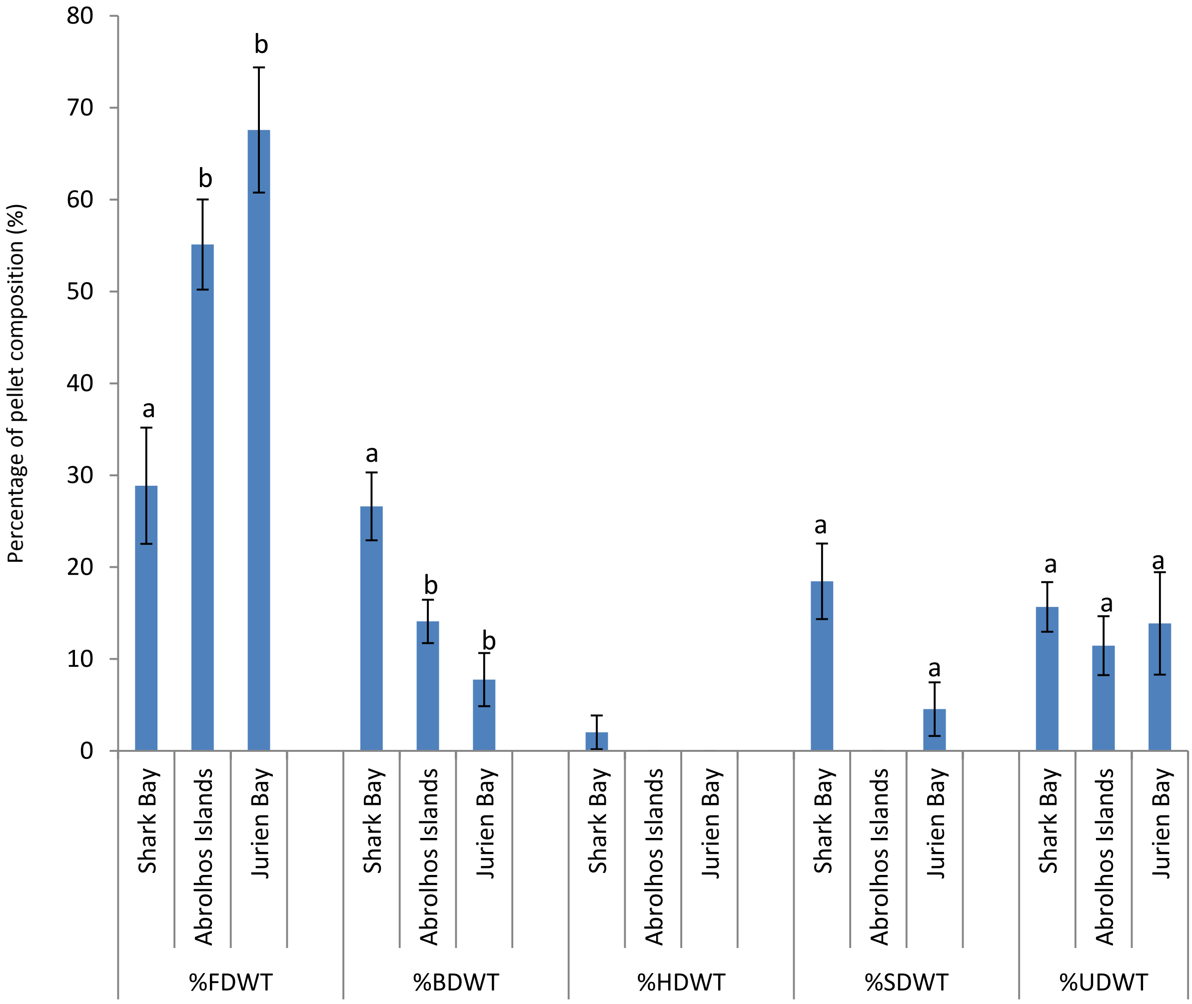

Figure 5.8 Average pellet composition (in total dry weight, (mean ± s.e.) of pellets collected in each of the sample regions, separated by subgroups and location of samples. Letters show the results of one-way ANOVAs. Regions with the same letter are not significantly different (P>0.05) %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %HDWT = % of total dried weight which was hair, %SDWT = % of total dried weight which was scale, %UDWT = % of total dried weight which was unknown elements.

Table 5.7 Analysis of variance results table for the average total composition of the pellets collected from the Abrolhos Islands, Shark Bay and Jurien Bay. %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %HDWT = % of total dried weight which was hair, %SDWT = % of total dried weight which was scale, %UDWT = % of total dried weight which was unknown elements.

		N	Mean	STDEV	DF	F-value	Sig
	Abrolhos Islands	17	55.1	20.3			
%FDWT	*Shark Bay*	28	28.9	33.5	*2,46*	*6.359*	*0.004*
	Jurien Bay	4	67.6	13.6			
	Abrolhos Islands	17	14.1	9.8			
%BDWT	*Shark Bay*	28	26.6	19.6	*2,46*	*4.599*	*0.015*
	Jurien Bay	4	7.8	5.8			
	Abrolhos Islands	17	0	0			
%HDWT	*Shark Bay*	28	2.0	9.7	*2,46*	*0.442*	*0.646*
	Jurien Bay	4	0	0			
	Abrolhos Islands	17	0	0			
%SDWT	*Shark Bay*	28	18.5	21.8	*2,46*	*6.751*	*0.003*
	Jurien Bay	4	4.6	5.8			
	Abrolhos Islands	17	11.5	13.2			
%UDWT	*Shark Bay*	28	15.7	14.3	*2,46*	*0.499*	*0.611*
	Jurien Bay	4	13.9	11.2			

5.7 Offshore/ Near-shore/ Mainland

Feathers were the main component in pellets in both the near shore and the offshore sites (Table 5.8; Figure 5.9). In the offshore sites the feathers made up a large proportion of the pellet while in the near shore site the feather proportion was more comparable to the scale and bone components. Mainland samples had no scales, hair, or feathers and the bones which were present were fish bones. The offshore sites had no hair or scales. The pellet compositions for all sites differed significantly (Figure 5.10).

The analysis of variance determined that all subgroups were found to be significantly different, except for hair, where only one region had a sample. The offshore and near shore sites are significantly different to the mainland site in most components, including feather dry weight, bone dry weight and unknown dried weight (Figure 5.10, Table 5.9). Hair and scale samples were only found at near shore sites.

Table 5.8 Pellet summary tables showing the composition of the pellets collected from the varying geographical extents, near shore site, offshore sites and mainland sites, as percentages from the initial dry weight of the pellet. N= number of pellets.

	N	**Total Weight (g)**	**Feather (%)**	**Bone (%)**	**Hair (%)**	**Scale (%)**	**Unknown (%)**
Offshore islands	17	100.3	55.1	14.1	0	0	101.5
Near shore islands	28	153.2	38.5	21.7	2.1	19.1	11.9
Mainland	4	26.6	0	42.2	0	0	40.7

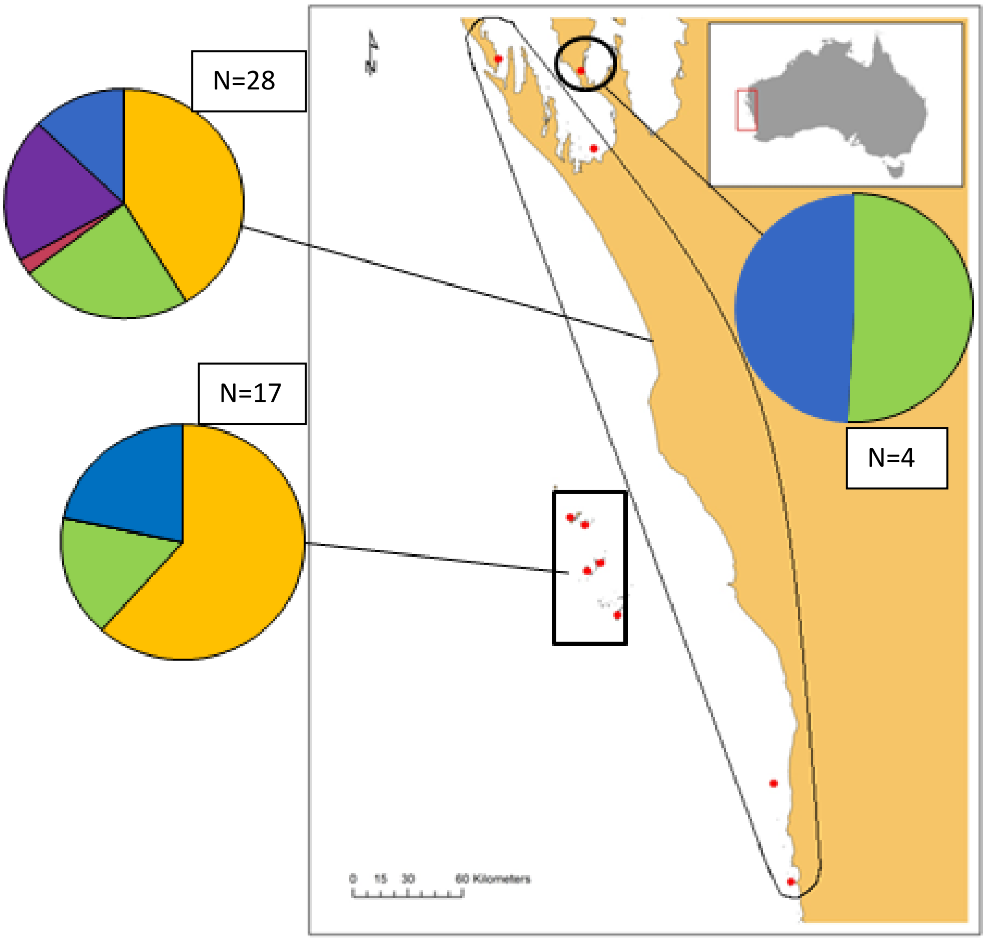

Figure 5.9 Average pellet compositions for the varying geographical extents, near shore site, offshore sites and mainland sites. Key: Yellow= Feathers, Green= Bone, Pink= Hair, Purple= Scale, Blue= Unknown.

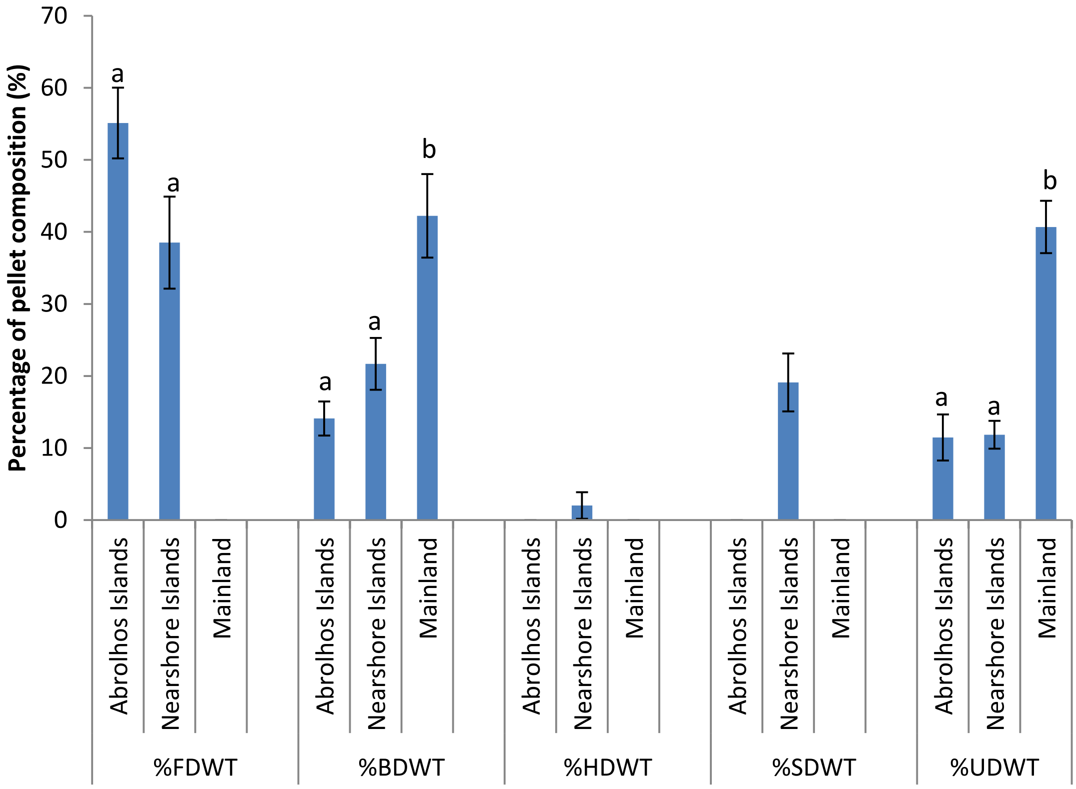

Figure 5.10 Average pellet composition (in total dry weight), (mean ± s.e.) of pellets collected in the varying geographical extents, near shore site, far sites and mainland sites, separated by subgroups and location of samples. Letters show the results of one-way ANOVAs. Regions with the same letter are not significantly different (P>0.05). %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %HDWT = % of total dried weight which was hair, %SDWT = % of total dried weight which was scale, %UDWT = % of total dried weight which was unknown elements.

Table 5.9 Analysis of variance results table for the pellets collected from the varying geographical extents, near shore site, far sites and mainland sites, separated by subgroup. %FDWT = % of total dried weight which was feather, %BDWT = % of total dried weight which was bone, %HDWT = % of total dried weight which was hair, %SDWT = % of total dried weight which was scale, %UDWT = % of total dried weight which was unknown elements.

		N	***Mean***	***STDEV***	***DF***	***F-value***	***Sig***
	Offshore Islands	17	55.1	20.3			
%FDWT	*Near shore Islands*	28	38.5	33.8	*2,46*	*6.316*	*0.004*
	Mainland	4	0	0			
	Offshore Islands	17	14.1	9.8			
%BDWT	*Near shore Islands*	28	21.7	19	*2,46*	*5.149*	*0.010*
	Mainland	4	42.2	11.6			
	Offshore Islands	17	0	0			
%HDWT	*Near shore Islands*	28	2	9.7	*2,46*	*0.442*	*0.646*
	Mainland	4	0	0			
	Offshore Islands	17	0	0			
%SDWT	*Near shore Islands*	28	19.1	21.3	*2,46*	*8.207*	*0.001*
	Mainland	4	0	0			
	Offshore Islands	17	11.5	13.2			
%UDWT	*Near shore Islands*	28	11.9	10.2	*2,46*	*12.282*	*0.000*
	Mainland	4	40.7	7.3			

5.8 Foraging Polygons

Placing polygons, with a radius of 9kms over the study sites, show that there is virtually no overlap of the foraging area with the birds on the near shore and mainland sites, while there is significant overlap of areas with the birds of the Abrolhos (Figure 5.11). However this may be an effect of less available island space in the Abrolhos. The potential foraging areas for the sites were outlined in red in Figure 5.25. For Shark Bay sites is the potential foraging area is 2771.8 km^2, the potential foraging area is 1761.5

km^2 for the Abrolhos islands and the potential foraging area is 1321.7 km^2 for the Jurien Bay islands (Figure 5.12).

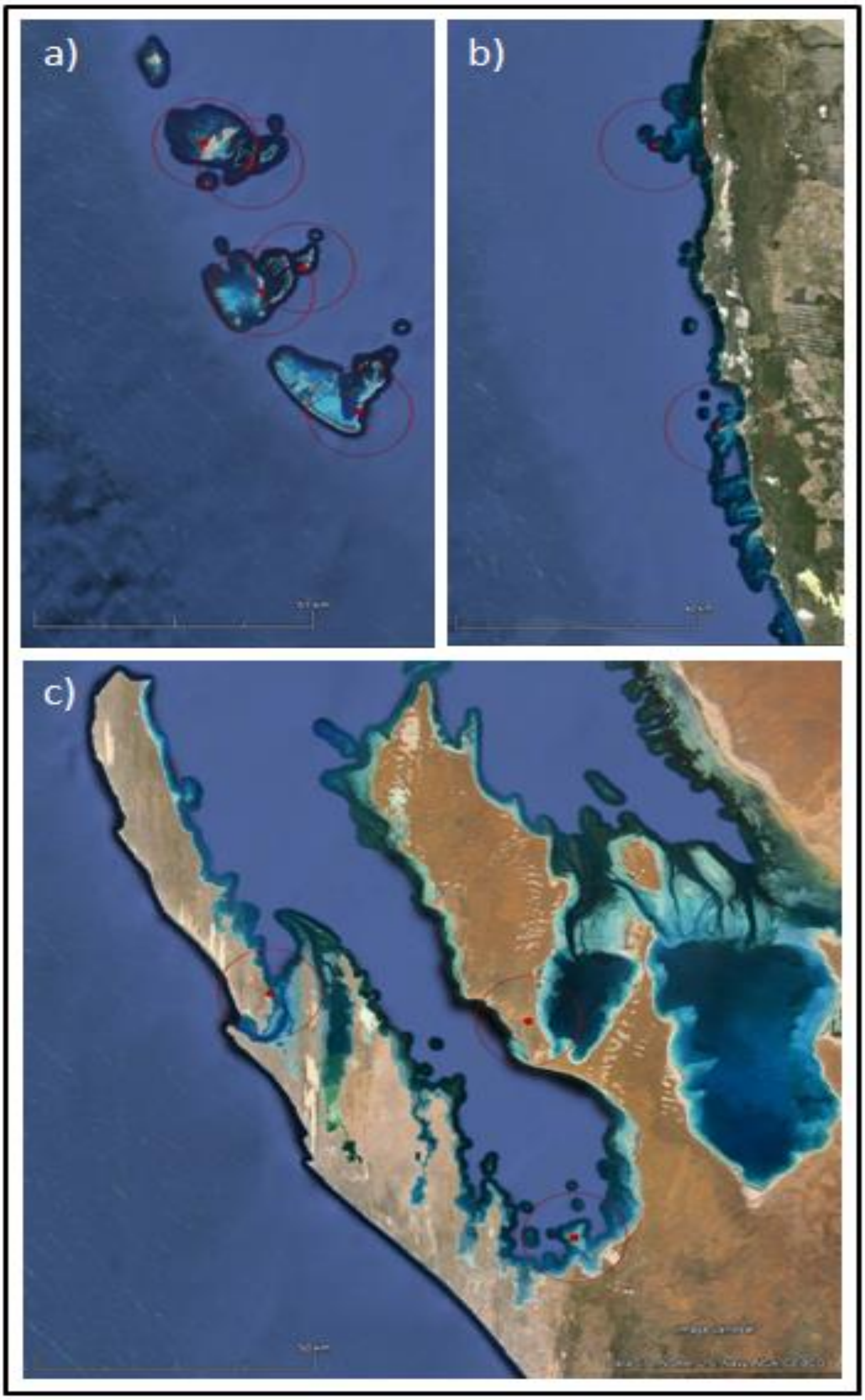

Figure 5.11 Plotted foraging territories of the study sites of the Houtman Abrolhos (a), Shark Bay (c) and Jurien Bay (b) showing the foraging range likely to be used by H. leucogaster. Red dots= site of pellet collection, red circle= 9km foraging radi.

Figure 5.12 Plotted foraging territories of the study sites, showing potential foraging areas. Key: Red dots= site of pellet collection, black circle= 9km foraging radi, red polygon= potential foraging area for the region, black polygon= Hypothetical total foraging are for complete study.

Underlying habitat types were determined for the regions sampled, and all sites had both marine and terrestrial habitat types within the foraging regions outlined. From these areas a very large number of potential prey species were identified (Appendix 1). Prey remains which were able to be identified were compared to the potential prey species list to see if the species was recorded for the region in question.

The prey consumption varied at each of the different sites with the birds in the Abrolhos Islands group showing a preference for birds, given the high proportion of feathers found in the pellets, and the birds in the Shark Bay mainland site showing a preference for fish, given that the pellets from this site contained fish bones, with no feathers or hair present.

Chapter 6: Discussion

This study forms the first investigation into the white-bellied sea eagle diet in Western Australia. Previous studies on this species have been based in the eastern states of Australia (e.g. Wiersma and Richardson, 2009; Olsen 2006a; b; O'Donnell, 2012 and Debus, 2012) or in Indonesia and Malaysia (e.g. Azman, 2013; Iqbal, 2013; Thiollay, 2002).

6.1 Abrolhos Islands

The pellet samples of the Abrolhos were found to be made up predominately of feathers and bone. This is interesting as the area within the foraging polygon, mapped over the site, contained multiple aquatic regions. However no fish elements were found to be readily identifiable in the pellets. There were no bones, which could be classified as fish upon examination and no scales present. There are several possible explanations for this, as some of the sites were located within close proximity to bird colonies or nesting sites. These birds may have proved a more readily available, easily obtained food source. Other explanations for the results are focused on the method of diet examination utilised rather than the species preference. Determining a species diet through pellet examination solely has been discovered to be an imperfect method (Debus, 2008). This is supported in this study through the evidence of fish predation as seen in the photographic reference images. This means that the lack of fish remains in the pellets may be due to these elements being more readily digestible rather than fish being absent in the diet.

6.2 Abrolhos Islands compared to West Wallabi Island

The samples of West Wallabi Island, like all the other sample sites of the Abrolhos were made up of feathers and bone, predominately, as well as containing some unknown particulates. This suggests that it follows a similar pattern as the Abrolhos site as a whole; that there may be a more readily available food source, in the form of birds, or that all of the diet is not represented by pellet collections. The absence of hair in the pellets of Wallabi Island is particularly interesting. Given that anecdotal evidence suggests that the reason behind the large population of *H. leucogaster* on Wallabi Island, relative to the populations of the Abrolhos is due to the presence of wallabies on the island, and therefore in the diet. Given that, if the wallaby was part of the diet, it would be expected that evidence of the wallabies would be found in the diet analysis. This means that the evidence collected in the pellets points to another reason to explain the relatively larger population on Wallabi Island, compared to the other islands populations. One possible explanation is the fact that Wallabi Island is much larger than the other islands where white-bellied sea eagle populations are based in the Abrolhos. This study supports this reasoning with the area of Wallabi Island being approximately 6.21km^2, while the area of Leo Island is 0.24km^2, the area of Pelsaert islands is 1.68km^2, the area of Roma Island is 0.004km^2, and the area of Dick Island is 0.03km^2. Therefore the fact that Wallabi Island has more space available may be the reason why a bigger population has been established there. However it is possible that there is no evidence of wallaby in the sample due to the limitations of the study rather than an absence of wallabies in the diet, and further investigation is required.

6.3 Regional variation

The varying concentrations of subgroups are relevant given the conclusions which can be drawn for each region. Samples from Shark Bay show that even though the population is located so close to the mainland, and one of the sites is actually a mainland site, fish are present, quite significantly in the diet. This is shown through the presence of scales, and the fish bones collected in the pellets. The pellets collected at this site, also suggest the greatest variability of food sources, seen at any of the regional sites as they have mammals, specifically the Greater stick-nest rat (*Leoporillus conditor*), birds, fish and potentially reptiles.

The pellet samples from the Abrolhos, as previously mentioned contain no evidence of fish, while the prey remains seen in the photographic reference images do suggest fish predation.

The pellet samples from the islands off Jurien Bay show a preference for birds, given the high concentrations of feathers and a secondary preference for fish, given the scales found. Prey remains for the site also suggest predation of mammals given the bones discovered. However no hair samples were present to corroborate this claim. With the overlaying of the foraging polygons previously presented, it can be seen that one of the study sites overlaps the mainland slightly. This means that the *H. leucogaster* populations which nest on the islands off Jurien Bay are still within foraging distance of the mainland. This would provide a wide range of potential prey species for the eagle to choose from, as it no longer only includes the animals found on the islands of Jurien Bay.

6.4 Geographical Variances for pellet compositions

The far, offshore sites were made up of the sites on the Abrolhos islands. Sites were considered offshore if they were over 60kms from the coast of Western Australia. The offshore site pellet samples were found to be made up of feathers and bone, predominately.

The near shore sites include sites which are located less than 10kms off the coast of Western Australia. This includes the islands of Jurien Bay and the two islands located in Shark Bay. The near shore site pellets are predominately feather, which indicates a preference for birds, and secondarily bone and scale. There are also small concentrations of hair and unknown particulates.

The mainland sites were sites which are connected to the mainland. This is made up of one site in Shark Bay. The mainland pellets were made up of bone and unknown elements. The bones found were all small fish bones. This is particularly interesting given the fact that the mainland site is the only site where the white-bellied sea eagle showed a preference for fish.

The pellet compositions varied quite significantly at this level of examination. Both the near shore and off shore sites showed a preference for birds, seen through the high concentrations of feathers, while the mainland white-bellied sea eagle populations showed a preference for fish.

6.5 Comparisons to other studies

Other studies into the diet of *H. leucogaster* in Australia have found large proportions of the diet to be made up of varying components related to the region of the study.

Sea eagle populations studied in New South Wales show a dietary preference for aquatic prey including fish, water birds and freshwater turtles (Debus, 2008). Fish form the main part of the diet (82%) when visual observations are recorded, and birds and turtles form the main component represented in pellet collections.

Diet studies of *H. leucogaster*, based on Northern Territory populations show a preference for aquatic reptiles (45%) and a secondary preference for fish (28%) and birds (24%). Mammals are represented in the diet of these populations, but only for 3% of the total diet (Corbett, 2009). The Corbett (2009) study in this area also investigated a temporal variation at this site which showed no significant difference in prey types found.

Olsen (2006b) investigated the diet of *H. leucogaster* in the Australian Capital Territory, and found that inland populations near Canberra favoured birds, unlike the Northern Territory study, where aquatic reptiles were favoured, or the New South Wales study where fish were favoured. Birds from the second site in this study, Burrijuck Dam, also located near Canberra showed a preference for fish and birds (Olsen, 2006b).

Other studies based in Canberra (Olsen, 2006a) showed a preference for birds (47.4%) and fish (36.2%), with reptiles forming 8.6% of the total diet and mammals forming 6%. Studies based in Queensland on *H. leucogaster* showed a preference for fish (52%) and a secondary preference for birds (44%), with 4% of the diet formed by reptiles and no evidence of mammalian prey (Smith, 1985). This study is also quite different to the *H. leucogaster* diet study based on the populations located on Franklin Islands, South Australia, where the dietary preferences were birds (60%), and the secondary preference was for both fish and mammals, (20% for both; Eckert, 1971).

Unlike the New South Wales based study (Debus, 2008) where fish were the preferred dietary species, or the Northern Territory based study (Corbett, 2009) where aquatic reptiles were the preferred species, the results of this study as a whole show a preference for birds as the main dietary component. This is shown through the feathers forming 40.57% of the total pellets, similar to studies conducted on *H. leucogaster* populations near Canberra (Olsen, 2006a; b;) and South Australian populations on Franklin Islands (Eckert, 1971). Mammals also make up a small part of the diet, of *H. leucogaster* populations studied, similar to populations studied in Northern Territory, and near Canberra (Corbett, 2009; Olsen 2006a). This is significantly different to the South Australian study where mammals were a secondary preference, making up 20% of the diet (Eckert, 1971).

The Abrolhos Island group and the Jurien Bay islands displayed a preference for birds as the main dietary component similar to one of the Canberra studies (Olsen 2006a) and the South Australian study (Eckert, 1971). The Shark Bay site showed a preference for birds and fish, similar to the second Canberra study (Olsen, 2006b) and the Queensland based study (Smith, 1985).

The offshore sites, which consist of the Abrolhos sites, were similar to the Canberra studies and the South Australian based studies (Olsen, 2006a; Eckert, 1975) with a dietary preference for birds. The near shore sites also show a preference for birds similar to the South Australian and Canberra based studies, but also have evidence of mammal predation in the diet similar to Canberra and Northern territory based studies (Olsen, 2006a; Eckert, 1975; Corbett, 2009). The mainland site showed a preference for fish, similar to the New South Wales based study (Debus, 2008) and the Queensland study (Smith, 1985), but unlike these studies there was no evidence of bird remains in the pellet at all. However this lack of evidence could be due to the limited number of pellets available for examination rather than an absence of birds in the diet.

6.6 Limitations

There are a number of limitations in the current study. Firstly, studies addressing the effectiveness of pellets as the sole provider of diet analysis have shown this to be an imperfect method of analysis (Real 1996). Principally the method doesn’t necessarily provide evidence for every animal eaten. There are small parts which are easily digestible and are therefore not present in the pellets even though the animals which contain these parts have formed part of the diet. Real (1996) suggests using a combination of direct observation, pellet analysis and prey remain examination to form a concrete picture of the diet of a raptor. Unfortunately for this study only pellets were available for all sites. Some sites also had prey remains and other sites also had photographic reference images of prey remains, however none of the sites also had direct observations recorded. Therefore from the information available only a partial image can be formed in terms of the diet of the *H. leucogaster*. There is also a limitation on the collections of the pellet. The pellets were collected from the sites in a one-off sampling trip. This means that there is currently no temporal replication, and therefore it is unclear whether or not there may be seasonal variation in the diet. Part of the reason that there is no temporal replication for the sites is that the sites in the Abrolhos are inaccessible during certain parts of the year due to the terrible weather conditions that the islands experience. There is also no way of knowing how many different birds contributed to the samples, or if degradation of pellets, or the more fragile remains occurred while being exposed to the elements before collection. Therefore this sampling is a 'snapshot' of the white-bellied sea eagle diet, an analysis of what was present at the time of sampling.

Another limitation is the lack of species level identification that was possible. For species level identification to occur, expensive and time consuming processes would need to be undertaken. The species level identification which did occur was with easily recognisable prey remains. The small elements such as bone pulled out from pellets was more difficult to identify to the group of species that it had originated from, direct species identification was not possible. Other bones, such as the fish bones found in the mainland site could have originated in a range of different fish, as it was difficult to distinguish between the species possible. This identification would be possible with recent advances in next generation sequencing DNA analysis (Deagle, 2013; O'Rorke, et al. 2012; Oehm, et al. 2011; Rosin, Z. and Z. Kwiecinski 2011; Sint, et al, 2011; Thomas, et al. 2014; Valentini, et al. 2009; Zarzoso-Lacoste et al, 2013; Zhang, et al. 2011). These techniques are more likely to detect evidence of soft elements which may be lost through digestion in the pellets and should be a priority in future studies.

6.8 Conclusions and future studies.

Five main conclusions can be drawn for the dietary breadth of the white-bellied sea eagle.

The first conclusion which can be drawn is that examination of the pellets from the Abrolhos site determined that there was no significant variance in the pellet composition for each of the islands populations. This was determined to be due to possible similar species available across the sites and potential overlap of the foraging areas of the islands.

The second conclusion which can be drawn is that examination of the pellets from Wallabi Island, in comparison to the pellets of the other Abrolhos islands determined that there was no significant variance in the pellet composition for either group. The lack of hair in the sample, refuted anecdotal evidence that suggested that the larger population on Wallabi Island was due to the presence of wallabies in the diet, and determined that the relatively larger population size must result from an alternative factor such as the availability of space for nesting.

The third conclusion which can be drawn is that examination of the pellets from the three different regions, Abrolhos Islands, Shark Bay and the islands off Jurien Bay determined that there was no significant difference between the islands of the Abrolhos and the islands off Jurien Bay, apart from the presence of scales in the Jurien Bay samples. The pellets from Shark Bay were determined to be significantly different from the other two sample sites, with large scale concentrations which were not present in the other sites and also the presence of hair. The other sites were predominantly feather based, indicating a dietary preference for birds, while the Shark Bay region pellets were predominately bone, indicating a different dietary preference. This shows that the regional location of the site appears to have an impact of the dietary composition of the white-bellied sea eagle populations located there. It appears, given the results discovered in this study that populations which are located further north have a higher degree of variation in the diet, and that populations which are located closer to the mainland also have this higher variation in their diet. It is also possible that this variation may be a result of the position of the site, in connection to the mainland, that the sites closer to the mainland have a higher variety of species, and therefore the birds in this location have a more varied diet.

The fourth conclusion which can be drawn is that examination of the pellets from the three different geographical extents, offshore, near shore and sites connected to the mainland, determined that there was a significant difference between all of the sites. The pellets from Shark Bay were determined to be significantly different from the other two samples sites, with large bone concentrations, which were not seen at this level at the other sites. These bones were all fish bones, indicating a dietary preference for fish, or limited number of seabird colonies located near the feeding sites. The other sites were predominantly feather based indicating a dietary preference for birds. The near shore sites showed the most variation in the pellet composition, indicating the more varied diet, of these populations. These results show that the populations which have access to the most varied sources, islands and close proximity to the mainland sites have the most varied diets while the populations which are located on just the islands or just the mainland do not show this level of variance.

The fifth conclusion which can be drawn is that examination of the pellets from all sites shows a range of different dietary preferences. The pellets of the Abrolhos show a dietary preference for birds, from the feathers found in the pellets. The same dietary preference can be seen in the pellets from the Jurien Bay region, as they were predominately feather, showing a preference for a diet of birds, with a secondary preference for fish or reptiles given the scales found in the pellets. The Shark Bay site showed a dietary preference which varied from the other two regional sites as bones formed a large portion of the pellets, these being mainly fish bones. This shows the sea eagles in the Shark Bay region had a dietary preference for fish and a secondary preference for birds, due to the feathers. The geographical extents showed a different pattern for dietary preference, showing that the mainland site sea eagles had a preference for fish, the sea eagles from the offshore sites having a preference for birds and the near shore sites showing a preference for birds as well.

There is room for additional studies in this field in specific areas. Expansion on the monitoring of all sites is possible and would potentially provide additional insights to the diet of the species, as well as any possible seasonal variations. The concept of seasonal variations in raptor diets is clear in northern hemisphere studies (Grubb, 1995; Harper, 1989; Zimmerman et al., 1996; Roberts, 2001; Tome, 1994), however this may be a factor of the variability between the seasons in the northern hemisphere which is more pronounced than that experienced at the study sites examined. There is also possible variation in the diet around the breeding seasons of the bird that may provide interesting results. Given that the Abrolhos Islands sites become inaccessible due to the weather conditions experienced during part of the year, a potential way to investigate a season variation would be to remove all pellets and prey remains from the known butchery, killing post and nesting sites, before the area became inaccessible. The next possible collection could then remove all the prey remnants and this would provide an insight into the dietary composition during the time when the islands are inaccessible.

There are also options to examine the current findings of the pellet analysis in conjunction with DNA analysis. Advances in DNA technology minimises misidentification, incomplete identification and bias which may be present given that small easily digestible elements are not present. This analysis usually uses faeces or stomach contents and can be used to reconstruct food webs more accurately across tropic levels than was possible before. These methods can be used at a later stage to build on the foundations discovered through this study.

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Appendix One: Prey Lists by Region

Abrolhos- Fish

Lethrinus miniatus

Glaucosoma hebraicum

Symphorus nematophorus

Gymnapistes marmoratus

Lotella rhacina

Kyphosus sydneyanus

Amphotistius kuhlii

Dasyatis brevicaudata

Trygonoptera ovalis

Urolophus circularis

Aetobatus narinari

Manta birostris

Aulohalaelurus labiosus

Furgaleus macki

Mustelus antarcticus

Carcharhinus obscurus

Carcharhinus plumbeus

Galeocerdo cuvieri

Rhincodon typus

Orectolobus ornatus

Orectolobus sp.

Heterodontus portusjacksoni

Myrichthys columbrinus

Gymnothorax eurostus

Gymnothorax prasinus

Gymnothorax undulatus

Gymnothorax woodwardi

Etrumeus teres

Sardinella lemuru

Sardinops neopilchardus

Spratelloides gracilis

Spratelloides robustus

Gonorhynchus greyi

Arius thalassinus

Paraplotosus albilabris

Plotosus lineatus

Aulopus purpurissatus

Synodus variegatus

Saurida undosquamis

Batrachomoeus rubricephalus

Halophryne ocellatus

Antennarius commersoni

Antennarius nummifer

Antennarius striatus

Histrio histrio

Tathicarpus butleri

Lotella fuliginosa

Dipulus caecus

Ogilbia sp.

Cypselurus sp.

Ablennes hians

Hemiramphus robustus

Hyporhamphus melanochir

Atherinomorus ogilbyi

Craterocephalus capreoli

Craterocephalus pauciradiatus

Hypoatherina temminckii

Leptatherina presbyteroides

Cleidopus gloriamaris

Sorosichthys ananassa

Velifer multiradiatus

Halicampus brocki

Hippocampus angustus

Lissocampus fatiloquus

Nannocampus subosseus

Pugnaso curtirostris

Solegnathus lettiensis

Pegasus volitans

Ablabys taenianotus

Centropogon latifrons

Cocotropus sp.

Dentrochirus brachypterus

Maxillicosta lopholepis

Neosebastes bougainvilli

Neosebastes pandus

Parapterios heterurus

Pterios volitans

Scorpaena sumptuosa

Scorpaenodes guamensis

Scorpaenodes scaber

Scorpaenodes steenei

Scorpaenopsis venosa

Inimicus sinensis

Lepidotrigla spinosa

Neopataecus waterhousi

Pataecus fronto

Leviprora inops

Onigocia oligolepis

Platycephalus endrachtensis

Platycephalus longispinis

Hypopterus macropterus

Acanthistius pardalotus

Acanthistius serratus

Cephalopholis argus

Cephalopholis miniata

Epinephelides armatus

Epinephelus bilobatus

Epinephelus coioides

Epinephelus fasciatus

Epinephelus lanceolatus

Epinephelus multinotatus

Epinephelus rivulatus

Hypoplectrodes cardinalis

Plectropomus leopardus

Plectropomus maculatus

Pseudanthias cooperi

Variola louti

Unidentified grammistid

Assiculus punctatus

Labracinus lineatus

Pseudochromis wilsoni

Paraplesiops meleagris

Trachinops brauni

Trachinops noarlungae

Belonepterygion fasciolatum

Glaucosoma hebraicum

Banjos banjos

Heteropriacanthus cruentatus

Priacanthus hamrur

Apogon aureus

Apogon cavitiensis

Apogon coccineus

Apogon doederleini

Apogon rueppellii

Apogon semiornatus

Apogon victoriae

Cercamia eremia

Cheilodipterus quinquelineatus

Fowleria aurita

Fowleria variegata

Siphamia cephalotes

Vincentia badia

Sillago analis

Pomatomus saltatrix

Carangoides equula

Decapterus muroadsi

Pseudocaranx dentex

Pseudocaranx wrighti

Seriola dumerili

Seriola hippos

Seriola lalandi

Trachurus novazelandiae

Coryphaena hippurus

Rachycentron canadus

Arripis georgianus

Lutjanus fulviflamma

Lutjanus quinquelineatus

Lutjanus russelli

Paracaesio xanthurus

Pentapodus porosus

Pentapodus emeryii

Pentapodus vitta

Scolopsis bilineatus

Parequula melbournensis

Diagramma pictum

Plectorhinchus flavomaculatus

Plectorhinchus schotaf

Lethrinus atkinsoni

Lethrinus genivittatus

Lethrinus miniatus

Lethrinus nebulosus

Acanthopagrus butcheri

Pagrus auratus

Rhabdosargus sarba

Parapeneus barberinoides

Parapeneus chrysopleurum

Parapeneus pleurostigma

Parapeneus spilurus

Upeneichthys lineatus vlamingii

Upeneichthys stotti

Schuettea woodwardi

Parapriacanthus elongatus

Parapriacanthus ransonneti

Pempheris analis

Pempheris klunzingeri

Pempheris schwenkii

Pempheris sp.

Girella tephraeops

Kyphosus cornelii

Kyphosus sydneyanus

Microcanthus strigatus

Neatypus obliquus

Scorpis georgianus

Platax teira

Chaetodon assarius

Chaetodon aureofasciatus

Chaetodon auriga

Chaetodon citrinellus

Chaetodon kleinii

Chaetodon lineolatus

Chaetodon lunula

Chaetodon plebeius

Chaetodon speculum

Chaetodon trifascialis

Chaetodon trifasciatus

Chelmon marginalis

Chelmonops curiosus

Heniochus acuminatus

Parachaetodon ocellatus

Centropyge tibicen

Chaetodontoplus personifer

Pomacanthus semicirculatus

Enoplosus armatus

Abudefduf bengalensis

Abudefduf sexfasciatus

Abudefduf sordidus

Abudefduf vaigiensis

Amphiprion clarkii

Chromis atripectoralis

Chromis klunzingeri

Chromis margaritifer

Chromis viridis

Chromis westaustralis

Dascyllus aruanus

Dascyllus reticulatus

Dascyllus trimaculatus

Parma mccullochi

Parma occidentalis

Plectroglyphidodon dickii

Plectroglyphidodon johnstonianus

Plectroglyphidodon lacrymatus

Plectroglyphidodon leucozonus

Pomacentrus coelestis

Pomacentrus milleri

Pristotis jerdoni

Stegastes fasciolatus

Stegastes nigricans

Stegastes obreptus

Cirrhitichthys aprinus

Paracirrhites forsteri

Cheilodactylus gibbosus

Cheilodactylus rubrolabiatus

Dactylophora nigricans

Aldrichetta forsteri

Mugil cephalus

Sphyraena obtusata

Achoerodus gouldii

Anampses caeruleopunctatus

Anampses geographicus

Austrolabrus maculatus

Bodianus axillaris

Bodianus bilunulatus

Bodianus frenchii

Bodianus perditio

Cheilinus chlorurus

Cheilinus fasciatus

Cheilinus trilobatus

Cheilio inermis

Choerodon cauteroma

Choerodon cyanodus

Choerodon jordani

Choerodon rubescens

Choerodon schoenleinii

Cirrhilabrus temmincki

Coris auricularis

Coris aygula

Coris caudimacula

Dotalabrus alleni

Epibulus insidiator

Eupetrichthys angustipes

Gomphosus varius

Halichoeres brownfieldi

Halichoeres nebulosus

Halichoeres trimaculatus

Hemigymnus fasciatus

Hemigymnus melapterus

Hologymnosus annulatus

Labrichthys unilineatus

Labroides bicolor

Labroides dimidiatus

Macropharyngodon ornatus

Notolabrus parilus

Ophthalmolepis lineolatus

Pictilabrus laticlavius

Pseudojuloides elongatus

Pseudolabrus beserialis

Pteragogus flagelligera

Stethojulis bandanensis

Stethojulis interrupta

Stethojulis strigiventer

Suezichthys cyanolaemus

Thalassoma amblycephalum

Thalassoma hardwicke

Thalassoma lunare

Thalassoma lutescens

Thalassoma purpureum

Thalassoma septemfasciata

Thalassoma trilobatum

Odax acroptilus

Leptoscarus vaigiensis

Scarus chameleon

Scarus frenatus

Scarus ghobban

Scarus gibbus

Scarus rivulatus

Scarus schlegeli

Scarus sordidus

Opistognathus inornata

Opistognathus sp.

Parapercis haackei

Parapercis nebulosa

Limnichthys fasciatus

Atrosalarias fuscus holomelas

Cirripectes filamentosus

Cirripectes hutchinsi

Entomacrodus striatus

Istiblennius chrysospilos

Istiblennius meleagris

Meiacanthus grammistes

Omobranchus germaini

Parablennius postoculomaculatus

Petroscirtes breviceps

Petroscirtes mitratus

Plagiotremus rhinorhynchos

Plagiotremus tapeinosoma

Enneapterygius larsonae

Helcogramma decurrens

Norfolkia brachylepis

Norfolkia leeuwin

Cristiceps aurantiacus

Cristiceps australis

Heteroclinus sp.

Ophiclinus gracilis

Callionymus enneactes

Callionymus goodladi

Callionymus grossi

Diplogammus xenicus

Synchiropus papilio

Synchiropus rameus

Alabes parvulus

Lepadichthys frenatus

Amblygobius phalaena

Asterropteryx semipunctatus

Bathygobius cocosensis

Bathygobius fuscus

Callogobius mucosis

Callogobius sp.

Callogobius sp.

Eviota bimaculata

Eviota infulata

Eviota melasma

Eviota queenslandica

Eviota storthynx

Eviota sp.

Exyrias belissimus

Fusigobius duospilus

Gnatholepis scapulostigma

Gobiodon citrinus

Pleurosicya fringilla

Priolepis cincta

Priolepis nuchifasciatus

Valenciennea puellaris

Vanderhorstia ornatissima

Gunnellichthys curiosus

Acanthurus grammoptilus

Acanthurus triostegus

Naso fageni

Naso unicornis

Zebrasoma scopas

Zebrasoma veliferum

Siganus fuscescens

Grammatorcynus bicarinatus

Scomberomorus commerson

Sarda orientalis

Thunnus albacares

Bothus pantherhinus

Crossorhombus valderostratus

Engyprosopon grandisquama

Pseudorhombus quinquocellatus

Zebrias cancellatus

Cynoglossus broadhursti

Anacanthus barbatus

Aluterus scriptus

Cantheschenia longipinnis

Chaetodermis penicilligerus

Colurodontis paxmani

Eubalichthys caeruleoguttatus

Meuschenia hippocrepis

Monacanthus chinensis

Oxymonacanthus longirostris

Paramonacanthus choirocephalus

Pervagor janthinosoma

Scobinichthys granulatus

Stephanolepis sp.

Anoplocapros lenticularis

Anoplocapros robustus

Ostracion cubicus

Tetrosomus concatenatus

Arothron hispidus

Lagocephalus sceleratus

Torquigener pallimaculatus

Torquigener paxtoni

Torquigener pleurogramma

Torquigener vicinis

Diodon nicthemerus

Abrolhos- Mammals

Macropus eugenii	*Felis silvestris catus*	*Rattus rattus*
Rattus fuscipes	*Mus musculus*	*Oryctolagus cuniculus*

Abrolhos- Birds

Abrolhos Painted Button-quail

Atlantic Yellow-nosed Albatross

Australasian Gannet

Australian Kestrel

Australian Pelican

Australian Raven

Australian Shelduck

Banded Lapwing

Banded Stilt

Barn Owl

Bar-tailed Godwit

Black shag

Black Swan

Black-faced Cuckoo-shrike

Black-tailed Godwit

Black-winged Stilt

Bridled Tern

Brown Song lark

Brush Bronze wing

Buff-banded Rail

Cape Petrel

Caspian Tern

Common name

Common Noddy

Common Sandpiper

Crested Tern

Curlew Sandpiper

Darter

Eastern Curlew

Eastern Reef Egret

Fairy Tern

Flesh-footed Shearwater

Galah

Giant petrel

Great Cormorant

Great Knot

Great Skua

Greater Sand Plover

Great-winged Petrel

Greenshank

Grey breasted silver eye

Grey Plover

Grey tailed godwit

Grey Teal

Grey-headed Albatross

Grey-tailed Tattler

Hooded dotterel

Hooded Plover

Horsfield's Bronze Cuckoo

Large sand dotterel

Lesser Noddy

Little Corella

Little Grassbird

Little Penguin

Little Pied Cormorant

Little Shearwater

Little stint

Little Tern

Mountain duck

Nankeen kestrel

Oriental Pratincole

Osprey

Pacific Golden Plover

Pacific Gull

Painted quail

Pied Cormorant

Pied Oystercatcher

Pipit

Prion

Red capped dotterel

Red-capped Plover

Red-capped Robin

Red-necked Avocet

Red-necked Stint

Red-tailed Tropicbird

Reef heron

Richard's Pipit

Roseate Tern

Ruddy Turnstone

Rufous Song lark

Rufous Whistler

Sacred Kingfisher

Sanderling

Sharp-tailed Sandpiper

Silver Gull

Silvereye

Soft-plumaged Petrel

Sooty Oystercatcher

Sooty Tern

Southern Giant Petrel

Spotless Crake

Spotted Crake

Spotted scrub wren

Streaked Shearwater

Stubble Quail

Terek Sandpiper

Turnstone

Wandering Albatross

Wedge-tailed Shearwater

Whimbrel

White-backed Swallow

White-bellied Sea Eagle

White-browed Scrub wren

White-chinned Petrel

White-faced Heron

White-faced Storm Petrel

White-headed Petrel

White-tailed Tropicbird

White-throated Needle tail

Willie Wagtail

Wilson's Storm Petrel

Abrolhos- Reptiles/ Amphibians

Abrolhos Dwarf Bearded Dragon

Marbled Gecko

Clawless Gecko

Ornate Stone Gecko

Variegated Dtella

Binoe's Prickly Gecko

South-western Spiny-tailed Gecko

Barking Gecko

Marble-faced Delma

Gray's Legless Lizard

Burton's Legless Lizard

Spiny-palmed Snake-eyed Skink

West Coast Ctenotus

King's Skink

Spiny-tailed Skink

South-western Four-toed Lerista

West Coast Four-toed Lerista

West Coast Line-spotted Lerista

Western Worm Lerista

Common Dwarf Skink

Western Pale-flecked Morethia

Southern Pale-flecked Morethia

Carpet Python

Coastal Burrowing Snake

Green Turtle

Shark Bay -Fish

Allen's Glider goby

Shark Bay Clingfish

Baldchin Groper

Bearded Leatherjacket

Bengal Sergeant

Yellow fin Dotty back

Yellow fin Whiting

Yellowtail Demoiselle

Yellowtail Flathead

Yellowtail Grunter

Bar tail Goatfish

Bighead Gurnard Perch

Black Rabbit fish

Black-tail Sergeant

Blackhead Three fin

Black throat Three fin

Blue Tuskfish

Bluespotted Tuskfish

Breams

Broad-banded Sand-swimmer

Brokenline Wrasse

Brownfield's Wrasse

Brownspotted Wrasse

Cockerel Wrasse

Collette's Herring

Common Lionfish

Cook's Cardinalfish

Curlew Sandpiper

Deceitful Velvetfish

Fringe-eye Flathead

Ghost Cardinalfish

Ghostly Scorpionfish

Golden Trevally

Grey Fantail

Hairfin Goby

Harbour Cardinalfish

Indian Handfish

Kimberley Catfish

Ladder Pipefish

Large spotted Herring

Large tooth Flounder

Long fin Bannerfish

Longtail Garfish

Manyline Sweetlips

Marbled Parrotfish

Margined Coralfish

Marsh Sandpiper

Northern Sand Flathead

Ocellate Frogfish

Orange spotted Puffer

Painted Scorpionfish

Paxman's Leatherjacket

Perdix Cardinalfish

Pinkbanded Grubfish

Prophet's Pipefish

Ringtail Cardinalfish

Rosy Weedfish

Shark Bay Clingfish

Smallhead Catfish

Smallspine Turretfish

Spot-tail Anglerfish

Spotfin Anglerfish

Starry Puffer

Stars-and-stripes Puffer

Threefin Velvetfish

Tuskfish

Variegated Lizardfish

Wasp Roguefish

Wavy Grubfish

Weeping Toadfish

Western Butterfish

Western Scalyfin

Western School Whiting

Western Striped Cardinalfish

Western Trumpeter Whiting

Whitelip Catfish

Whitley's Toadfish

Widebody Pipefish

Yellow Boxfish

Banded Seaperch

Barramundi Cod

Blackspot Snapper

Coral Monocle Bream

False Scorpionfish

Goldspotted Rockcod

Long Green Wrasse

Moon Wrasse

Orangespotted Glidergoby

Poisonous Goby

Redspot Wrasse

Rough Leatherjacket

Sea Mullet

Sevenband Wrasse

Sharpnose Wrasse

Spot-tail Wrasse

Tailor

Tasselled Leatherjacket

Threadfin Emperor

Wedgehead Siphonfish

Western King Wrasse

False-eye Seahorse

Black Spinefoot

Blackspotted Sandgoby

Blennies

Coral Rockcod

Eye-bar Sand-goby

Filamentous Blenny

Germain's Blenny

Gobies

Greasy Rockcod

Immaculate Glidergoby

Piano Fangblenny

Rotund Blenny

Sand Gobies

Shorthead Sabretooth Blenny

Tasmanian Blenny

Whitebarred Goby

Bluespotted Dottyback

Common Hardyhead

Common Silverbiddy

Fanbelly Leatherjacket

Few-ray Hardyhead

Finger Dragonet

Fourline Striped Grunter

Greenies

Lined Dottyback

Longspine Dragonet

Mangrove Dragonet

Morrison's Dragonet

Murray Hardyhead

Northern Dragonet

North-west Hardyhead

Spotted Hardyhead

Largescale Saury

Miller's Damsel

Pretty Lagoongoby

Rosy Eviota

Soles

Spotfin Tongue Sole

Western Striped Grunter

Stripey

The Dory Austrocochlea

Tarwhine

Y-bar Shrimpgoby

White-edge Drombus

West Australian Puller

Western Gobbleguts

Western Gregory

Bronze Whaler

Sandbar Shark

Milk Shark

Spinner Shark

Tiger Shark

Creek whaler (*Carcharhinus fitzroyensis*)

Tawny nurse shark *(Nebrius ferrugineus)*

Common blacktip shark *(Carcharhinus limbatus)*

Grey reef shark *(Carcharhinus amblyrhynchos)*

Pigeye shark *(Carcharhinus amboinensis)*

Silvertip shark *(Carcharhinus albimarginatus)*

Tiger shark *(Galeocerdo cuvier)*

Western wobbegong *(Orectolobus hutchinsi)*

Spotted wobbegong *(Orectolobus maculatus)*

Banded wobbegong *(Orectolobus halei)*

Grey carpet shark *(Chiloscyllium punctatum)*

Epaulette shark *(Hemiscyllium ocellatum)*

Zebra shark *(Stegastoma fasciatum)*

Whale shark *(Rhincodon typus)*

Grey nurse shark *(Carcharias taurus)*

White shark *(Carcharodon carcharias)*

Shortfin mako *(Isurus oxyrinchus)*

Whiskery shark *(Furgaleus macki)*

Pencil shark *(Hypogaleus hyugaensis)*

Weasel shark *(Hemigaleus microstoma)*

Fossil shark *(Hemipristis elongata)*

Spinner shark *(Carcharhinus brevipinna)*

Nervous shark *(Carcharhinus cautus)*

Whitecheek shark *(Carcharhinus dussumieri)*

Bull shark *(Carcharhinus leucas)*

Blacktip reef shark *(Carcharhinus melanopterus)*

Dusky shark *(Carcharhinus obscurus)*

Sandbar shark *(Carcharhinus plumbeus)*

Lemon shark *(Negaprion acutidens)*

Milk shark *(Rhizoprionodon acutus)*

Whitetip reef shark *(Triaenodon obesus)*

Scalloped hammerhead *(Sphyrna zygaena)*

Great hammerhead *(Sphyrna mokarran)*

Smooth hammerhead *(Sphyrna zygaena*

Wongai Ningaui

Bull Shark

Dusky Whaler

Shark Bay-Mammals

Burrowing bettong

Rufous hare wallaby

Banded hare wallaby

Shark bay mouse

Western barred bandicoot

Humpback whales

Southern right whales

Bottle nose dolphins

Bay whaler

Manta ray

Dugong

Greater bilby

Greater stick-nest rat

Southern brown bandicoot

Woylie

Shark bay boodie

Alice Springs Mouse

Ash-grey Mouse

Dwarf Minke Whale

Bottlenose Dolphin

Boodie

Cat

Kangaroos

House Mouse

Lemon Shark

Lesser Hairy-footed Dunnart

Lesser Long-eared Bat

Little Long-tailed Dunnart

Little Red Flying-fox

Finlayson's Cave Bat

Fox

Gould's Wattled Bat

Hairy-footed Dunnart

Inland Broad-nosed Bat

Northern Freetail-bat

Pale Field-rat

Rabbit

Red Kangaroo

Sandy Inland Mouse

Spinifex Hopping-mouse

Stripe-faced Dunnart

Western Grey Kangaroo

White-striped Freetail-bat

White-tailed Dunnart

Shark Bay-Birds

Mallee fowl

Regent parrot

Western yellow robin

Blue-breasted Fairy-wren

Striated pardalote

Dirk Hartog Island southern emu-wren

Dirk Hartog black-and-white fairy-wren

Shark Bay variegated field wren

Black Crow

Bourke's Parrot

Brown Falcon

Cockatoos

Crested Pigeon

Crested Tern

Crows

Crested Bellbird

Dirk Hartog Black-and-white Fairy-wren

Eastern Yellow Robin

Fairy Tern

Chestnut Quail-thrush

Chestnut-rumped Thornbill

Chiming Wedgebill

Grey-fronted Honeyeater

Horsfield's Bronze-cuckoo

Inland Thornbill

Little Woodswallow

Masked Woodswallow

Nankeen Kestrel

New Zealand Fantail

New Zealand Pigeon

Osprey

Pallid Cuckoo

Pied Butcherbird

Pied Honeyeater

Red-capped Robin

Rock Parrot

Rufous Fieldwren

Rufous Fieldwren (dorre Is)

Silver Gull

Singing Honeyeater

Slender-billed Thornbill

Southern Boobook

Southern Emu-wren

Southern Emu-wren (dirk Hartog Is)

Southern Scrub-robin

Spiny-cheeked Honeyeater

Splendid Fairy-wren

Spotted Bowerbird

Thick-billed Grasswren

Thick-billed Grass-wren (western Ssp)

Variegated Fairy-wren

Wedge-tailed Eagle

Weebill

Welcome Swallow

White-bellied Sea-eagle

White-browed Scrubwren

White-fronted Honeyeater

Willie Wagtail

Little Crow

Masked Owl

Australasian Grebe

Australian Spotted Crake

Grey Shrike-thrush

Malleefowl

Australian Tree Martin

Banded Lapwing

Black-faced Cuckoo-shrike

Brown Songlark

Crimson Chat

Grey Plover

White-fronted Chat

Orange Chat

Mauritius Olive White-eye

Oriental Pratincole

Red-capped Plover

Red-necked Stint	Silvereye	White-browed Babbler
Red throat	Southern Whiteface	

Shark Bay-Reptiles/ Amphibians

Green turtle

Loggerhead turtle

Sandhill frog

Sand swimming skink

Ornate stone gecko

Agamas

Ajana Ctenotus

Aluco Creeper

Shark Bay Heath Dragon

Australian Dragon Lizards

Australian Earless Lizards

Beaked Blind Snake

Baudin Island Spiny-tailed Skink

Black-naped Snake

Black-tipped Worm-lizard

Blind Snakes

Blue-gray Sea Snake

Buchanans Snake-eyed Skink

Burton's Snake-lizard

Bynoe's Gecko

Carnarvon Basin Dwarf Skink

Carpet Eel Blenny

Central Netted Dragon

Common Dwarf Skink

Dark Broad-blazed Slider

Elegant Seasnake

Elegant Slider

Estuary Snake Eel

Fine-faced Gecko

Goldfields Crevice-skink

Houtman Abrolhos Spiny-tailed Skink

Inland Snake-eyed Skink

Jan's Banded Snake

Javelin Legless Lizard

King Brown Snake

Marbled Gecko

Mottled Ground Gecko

Ornate Stone Gecko

Pygmy Spiny-tailed Skink

Pron's Snake-eyed Skink

Reddening Sand-dragon

Ring-tailed Dragon

Ringed Brown Snake

Robust Striped Gecko

Rosen's Snake

Shark Bay Sea Snake

Shark Bay Worm-lizard

Short-tailed Pygmy Monitor

Shrubland Morethia Skink

Single-toothed Pupasnail

Smooth Knob-tailed Gecko

Snake-eyed Skinks

Southern Blind Snake

Spotted Military Dragon

Stripe-tailed Monitor

Thick-tailed Gecko

West Coast Morethia Skink

West-coast Banded Snake

Western Beaked Gecko

Western Bearded Dragon

Western Blue-tongue

Western Dwarf Skink

Western Heath Dragon

Western Netted Dragon

Western Slender Blue-tongue

Western Spiny-tailed Gecko

Woodland Morethia Skink

Yellow-faced Whip Snake

Black-necked Whipsnake

Dwarf Bearded Dragon

Desert Skink

Goldfields Bullfrog

Crowned Gecko

Gould's Goanna

Kluge's Gecko

Leathery Turtle

North-western Shovel-nosed Snake

Northern Sandhill Frog

Ocellate Eel Blenny

Monk Snake

Pygmy Desert Monitor

Shark Bay Heath Dragon

Southern Sandhill Frog

Highfin Moray

White-spotted Ground Gecko

Thorny Devil

Turtle Frog

Unpatterned Robust Slider

Taper-tailed West-coast Slider

Wood Mulch-slider

Inland Broad-blazed Slider

Keeled Slider

Lozenge-marked Dragon

Micro Slider

Perth Slider

Hamelin Pool Ctenotus

Barred Wedgesnout Ctenotus

Blinking Broad-blazed Slider

Blunt-tailed West-coast Slider

Checker-sided Ctenotus

Dotted-line Robust Slider

Gascoyne Broad-blazed Slider

Leonhardi's Ctenotus

Leopard Ctenotus

Rich Ctenotus

Shark Bay Broad-blazed Slider

Shark Bay South-west Ctenotus

Slender Broad-blazed Slider

Stern Ctenotus

Western Limestone Ctenotus

Leristas

Excitable Delma

Fraser's Delma

Gwardar

Unbanded Delma

Marble-faced Delma

Sharp-snouted Delma

Menetias

Orange-crowned Toadlet

Pilbara Dtella

Woma

Tree Dtella

West-coast Laterite Ctenotus

Jurien Bay- Fish

Baldchin Groper

Brownfield's Wrasse

Brownspotted Wrasse

Elongate Hardyhead

Fanbelly Leatherjacket

Gobies

Hardhead

Marine Rainbowfish

Nightfish

Posidonia Clingfish

Pugnose Pipefish

Rosy Weedfish

Rough Leatherjacket

Southern Crested Weedfish

Southern Pygmy Leatherjacket

Southwestern Goby

Spotted Pipefish

Toothbrush Leatherjacket

Western Buffalo Bream

Western Galaxias

Blue Skimmer

Blue Trevally

Blue Weed Whiting

Bluespot Goby

Freshwater Cobbler

Longray Weed Whiting

Crescent Grunter

Eastern Gambusia

Red & Blue Damsel

Snapper

Lemon Sharks

Jurien Bay – Mammals

Ash-grey Mouse

Black Rat

Bush Rat

Cat

Chocolate Wattled Bat

Dugite

Dusky Whaler

Fossil Shark

Fox

Gould's Wattled Bat

Honey Possum

House Mouse

Leopard Seal

Lesser Long-eared Bat

Rabbit

Short-beaked Echidna

Southern Brown Bandicoot

Southern Forest Bat

Spinner Shark

Western Brush Wallaby

Dingo

Boullanger Island Dunnart

Fat-tailed Dunnart

Gilbert's Dunnart

Little Long-tailed Dunnart

Western Grey Kangaroo

Western Pygmy-possum

White-striped Freetail-bat

White-tailed Dunnart

Sea lions

Jurien Bay – Birds

White bellied sea eagle
Australian Hobby
Australian Magpie
Australian Pelican
Australian Raven
Australian Ringneck
Australian Shelduck
Australian Wood Duck
Baudin's Black-cockatoo
Black Swan
Black-faced Cuckoo-shrike
Black-faced Woodswallow
Blue-billed Duck
Blue-breasted Fairy-wren
Brown Falcon
Brown Honeyeater
Carnaby's Black-cockatoo
Cockatoos
Crested Bellbird
Crested Pigeon
Crested Tern
Crimson Chat
Eurasian Coot
Galah
Grey Fantail
Grey Plover
Hooded Plover
Little Grassbird
Little Shearwater
Magpie-lark
Musk Duck
Nankeen Kestrel
New Holland Honeyeater
New Zealand Fantail
Pacific Robin
Pallid Cuckoo
Pied Butcherbird
Pied Cormorant
Pink-eared Duck
Red-backed Kingfisher
Red-capped Robin
Regent Parrot
Rock Parrot
Rufous Songlark
Rufous Whistler
Singing Honeyeater
Spinifex Pigeon
Splendid Fairy-wren
Spotted Harrier
Twenty-eight Parrot
Wedge-tailed Eagle
Wedge-tailed Shearwater
Welcome Swallow
Western Corella
Western Fieldwren
Western Rosella
Western Thornbill
Western Wattlebird
White-breasted Robin
White-faced Heron
Willie Wagtail
Southern Boobook
Little Corella
Masked Woodswallow
Scarlet Robin
African Darter
Emu
Australian White-winged Triller
Australasian Bittern
Australasian Grebe
Budgerigar
Black-winged Stilt
Clamorous Reed Warbler
Western Spinebill
Yellow-rumped Thornbill
Fairy Martin
Weebill
Golden Whistler
Grey Teal
Hoary-headed Grebe
Mauritius Olive White-eye

Sanderling Western Gerygone Yellow-throated Miner

Jurien Bay – Reptiles/ Amphibians

Black-headed Monitor

Black-naped Snake

Bleating Froglet

Blunt-tail Legless Lizards

Blunt-tailed West-coast Slider

Bold-striped Slider

Buchanan’s Snake-eyed Skink

Bull Skink

Burton's Snake-lizard

Chain-striped South-west Ctenotus

Cloudy Stone Gecko

Common Dwarf Skink

Dotted-line Robust Slider

Dwarf Bearded Dragon

Elegant Slider

Fine-faced Gecko

Gould's Goanna

Gould's Hooded Snake

Gunther's Toadlet

Humming Frog

Jan's Banded Snake

Jewelled Sandplain Ctenotus

Keeled Legless Lizard

Keeled Slider

King Brown Snake

King's Skink

Leathery Turtle

Leopard Ctenotus

Marble-faced Delma

Moaning Frog

Motorbike Frog

Odd-striped Ctenotus

Ornate Stone Gecko

Robust Striped Gecko

Sand Frog

Sand-plain Worm-lizard

Shrubland Morethia Skink

Sign-bearing Froglet

Slender Tree Frog

South-western Crevice-skink

South-western Orange-tailed Slider

Southern Blind Snake

Southern Shovel-nosed Snake

Spotless Crake

Spotted Military Dragon

Spotted Sandplain Gecko

Thick-tailed Gecko

Turtle Frog

West Coast Morethia Skink

West-coast Banded Snake

West-coast Laterite Ctenotus

Western Australian Carpet Python

Western Banjo Frog

Western Bearded Dragon

Western Black-striped Snake

Western Blue-tongue

Western Heath Dragon

Western Limestone Ctenotus

Western Slender Blue-tongue

Western Spotted Frog

White-spotted Ground Gecko

Yellow-faced Whip Snake

Marbled Gecko

Mitchell's Short-tailed Snake

Oblong Turtle

Australian Frogs

Woma

Australian Emerald

Bardick

Black-fronted Dotterel

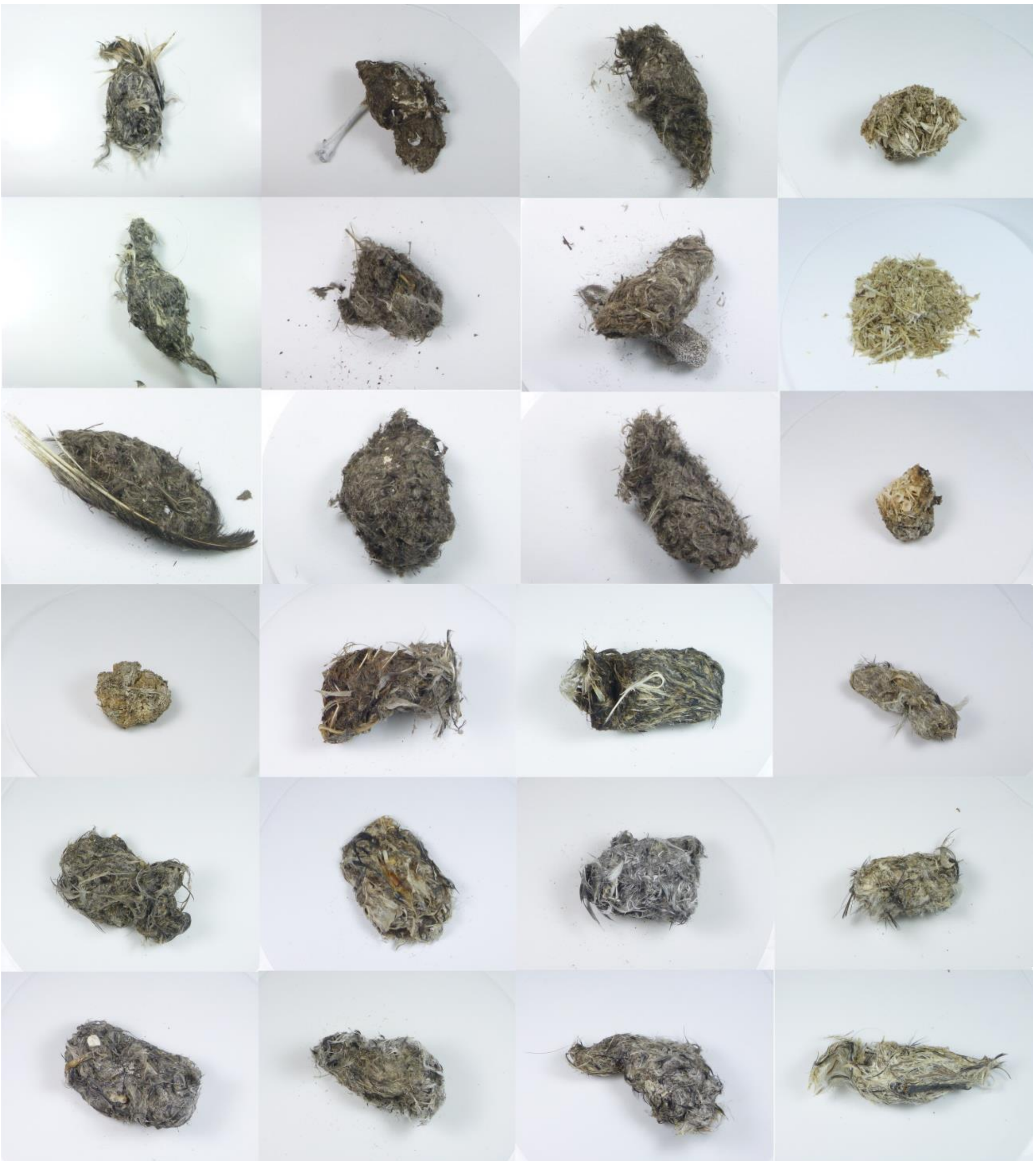
Fraser's Delma

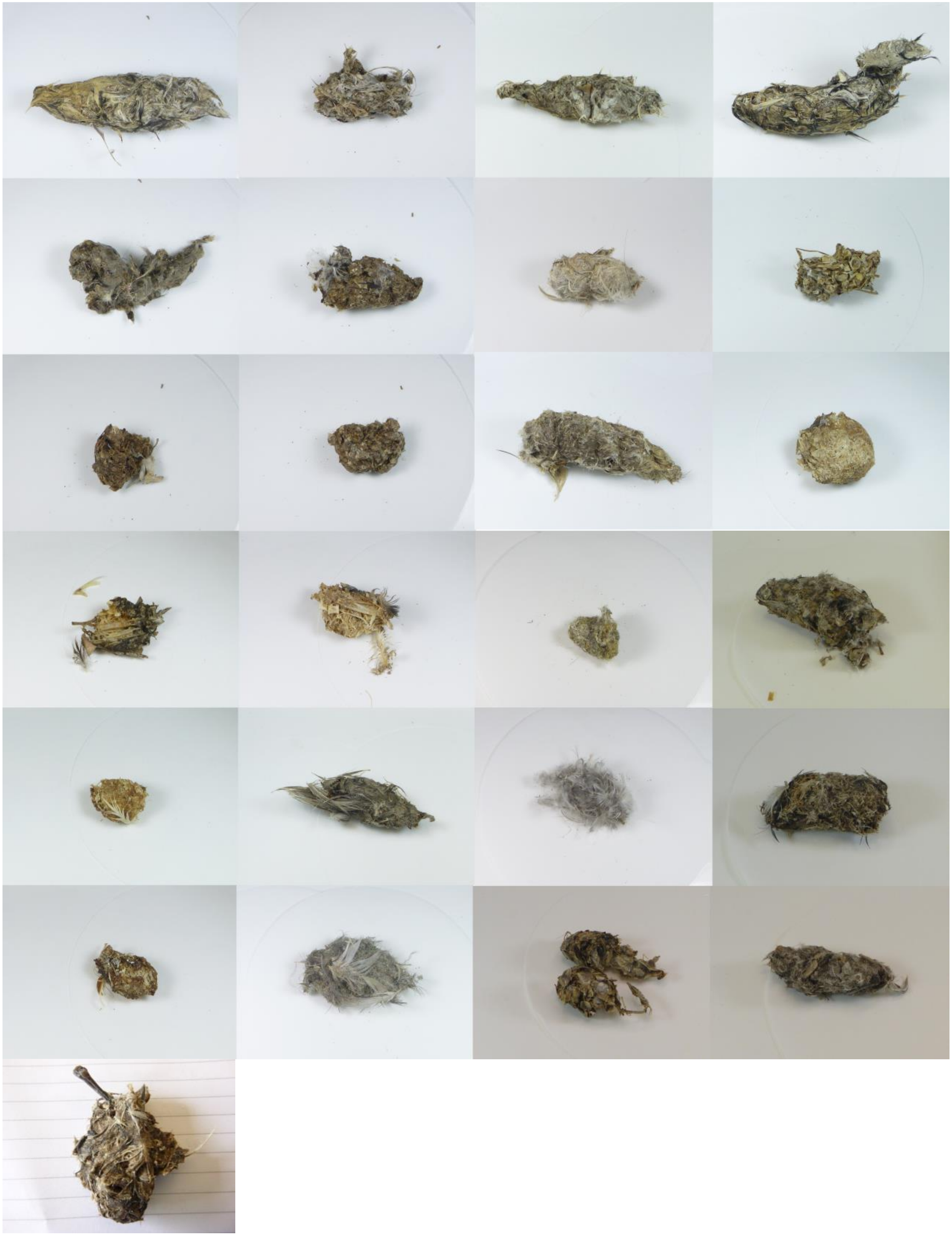
Side-barred Delma

Gwardar

Morethias	Silvereye	Tree Dtella

Appendix Two: All Pellets Examined





Appendix Three: Sample of the Prey Remains Examined