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FORAGING OF WHITE-BELLIED SEA-EAGLES *Haliaeetus leucogaster* IN RELATION TO MARINE FISH FARMS IN TASMANIA

JASON M. WIERSMA[1] and ALASTAIR RICHARDSON

School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania 7001.
[1]Present address: Forest Practices Authority, 30 Patrick Street, Hobart, Tasmania 7000.
Email: Jason.Wiersma@fpa.tas.gov.au

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The ranging and foraging behaviour of adult male White-bellied Sea-Eagles *Haliaeetus leucogaster,* at three marine fish farms and three non-aquaculture sites, were studied in the breeding season (August–December 2000) by radio-telemetry. At non-aquaculture sites (Sea-Eagle nests >8 km from fish farms), areas of Sea-Eagle home ranges averaged 77.2 square kilometres (minimum convex polygon) and 92.2 square kilometres (95% kernel), with a primary hunting area within four kilometres of the nest; soaring hunting flights averaged 16 kilometres, and short-stay perch-hunting sequences averaged 1.2 kilometres. At aquaculture sites (Sea-Eagle nests <3 km from fish farms), elongated home ranges averaged 56.7 square kilometres (MCP) and 219.6 square kilometres (95% kernel); soaring hunting flights averaged 24 kilometres, and short-stay perch-hunting forays averaged 3.6 kilometres. Foraging efficiency may be lower at aquaculture sites, with possible consequences for energetics and therefore breeding success.

INTRODUCTION

The White-bellied Sea-Eagle *Haliaeetus leucogaster* is listed as a threatened species in Tasmania (*Vulnerable* under the Tasmanian *Threatened Species Protection Act 1995*), and on mainland south-eastern Australia (*Vulnerable* in Victoria, *Endangered* in South Australia (Threatened Species Unit 2005; Thurstans 2009a, b)). Most of the identified threats concern human impacts on breeding habitat and nesting sites. Other potential negative effects include human impacts on foraging habitat or behaviour, and consequently on foraging efficiency and energy-budgets for parental duties and breeding success (see Fraser *et al.* 1996; Steidl and Anthony 2000; Grubb *et al.* 2002). One such possible impact is the establishment of sea-cage fish farms for Atlantic Salmon in coastal Tasmania, but the eagles' use of, or dependence on, fish-farm environments has not been described.

In Tasmanian coastal waters salmon have been farmed in sea-cages since the mid-1980s, with 10,000 tonnes produced annually in cages each holding about 30,000 fish, which grow from 800 grams to 4.5 kilograms within 15 months (DPIF 1996). Rapid growth requires large inputs of food, with consequent local enrichment of the marine environment that causes toxic algal blooms; a further problem with over-feeding is outgassing (toxic plumes of sulphur dioxide arising from faecal build-up on the sea floor – pers. comm. salmon industry and Department of Primary Industries and Fisheries (DPIF) staff). Concentrations of benthic waste, oxygen and turbidity levels are monitored stringently, and the diversity and abundance of marine invertebrate populations are monitored annually (DPIF 1996). However, no vertebrate species are monitored, despite sea-cage fish farms in other cold temperate waters adversely affecting the diversity of local biota (pers. comm. salmon industry and DPIF staff).

Nutrient enrichment in the vicinity of fish farms has the potential to increase the size, condition and possibly abundance of fish and bird species on which Sea-Eagles prey. The Sea-Eagles frequent waters around these fish farms, catch native and escaped fish in adjacent waters (the sea-cages themselves are predator-proofed), and scavenge dead fish. There is some anecdotal evidence suggesting an increase in nesting density of the eagles in aquaculture regions. However, there has been no objective assessment of the effect of fish farms on the eagles, either positive (via food supply) or negative (via pollution, disturbance, accidents or consequences for foraging energetics and hence for breeding ecology). Home-range size reflects food availability (Newton 1979; Brown 1980; Olsen 1995), which in turn affects foraging effort (Hunt *et al.* 1992; Berkelman *et al.* 1999; Steidl and Anthony 2000). There is little rigorous data on home-range size of White-bellied Sea-Eagles (up to 100 km^2 – Marchant and Higgins 1993), or hunting behaviour or success.

The aim of this study was to investigate the effect of marine fish farms on the foraging ecology of the White-bellied Sea-Eagle, at aquaculture and non-aquaculture sites, during the Sea-Eagles' breeding period. This was done by comparing home-range size and foraging behaviour.

STUDY AREA AND METHODS

Study area

Paired coastal sites were selected on the basis of whether or not there were marine (sea-cage) fish farms within the foraging range of individual breeding pairs of Sea-Eagles, the nest sites of which were known. Sites were classified as 'aquaculture' (Sea-Eagle pair's nest <3 km from a fish farm) or 'non-aquaculture' (Sea-Eagle pair's nest >8 km from a fish farm), on the basis that radio-tracked Sea-Eagles carried prey on average 2–4 kilometres to the nest, but were unlikely to transport prey more than eight kilometres (observation of 22 prey carrying events on six tagged Sea-Eagles). The sites for the aquaculture categories were Esperance Point and Garretts Bight near Dover (43º20'S, 147º04'E) in southern Tasmania and Spring Bay on the Tamar River estuary (41°15'S, 146°59'E) in northern Tasmania; and for the non-aquaculture categories, Fortescue Bay and Taranna on the Tasman Peninsula (43°05'S, 147°52'E) in south-eastern Tasmania and Native Point on the Tamar River estuary (Figure 1). There were thus three sites in each category.

The six nest sites active during the study were selected as far as possible for similarity in habitat (e.g. distance from water, size of forest patch). Each Sea-Eagle nest was situated in a bay approximately 100 metres from the foreshore. The nesting habitat was primarily dolerite bedrock with a sandy beach, and the forest surrounding each nest site was mature dominant and subdominant Manna Gum *Eucalyptus viminalis* and Black Peppermint *E. amygdalina*, with a midstorey of Blackwood *Acacia melanoxylon*, Silver Wattle *A. dealbata*, Black Sheoak *Allocasuarina littoralis* and other shrubs, with a grassy and shrubby ground layer.

Radio-tracking

Six adult male Sea-Eagles (determined on morphometric data, e.g. Marchant and Higgins (1993), and behaviour) were trapped according to the method of Wiersma *et al.* (2001) and fitted with two-stage radio-transmitters with a battery life of 18 months (Telonics Australia). Each device weighed approximately 28 grams (<1% of a male Sea-Eagle's body mass), and was attached to the base of the two central rectrices by a tail clip encompassing a plate and bolt (Figure 2), in preference to a harness (to avoid entanglement). Sea-Eagles were tracked from 0800 hours EST to around sunset (approximately1800 h EST), from August to December 2000, using a three-element hand-held yagi antenna.

Radio-telemetry was used to locate Sea-Eagles in the field, then direct observation was used to follow them and record their position (with a hand-held Magellan 315 GPS) and foraging behaviour. Most tracking was done by boat (at a discreet distance to minimise interference), with the GPS mounted on the cockpit and pre-programmed to record locations when a change of course was detected. When tracking over land (coastal contour-hugging flights), foraging locations were estimated from landmarks on a map or, for distant birds, biangulation of radio signals (i.e. two fixes per position). Location data were manually downloaded onto a laptop, with GPS error incorporated from the unit's 'position error' function. This overall approach, of ground-truthing radio fixes rather than triangulating, and analysis of position data using ArcView 3.2 (Hooge and Eichenlaub 1997), minimised the problem of position and habitat-association error (see Harris *et al.* 1990; Nams and Boutin 1991; Kenward and Walls 1994; North and Reynolds 1996). Mean position error differed between land and sea: 8.5 metres over water (n = 86 fixes), 30 metres at less than one kilometre inland (n = 10 fixes), and 100 metres at greater than one kilometre inland (n = 16 fixes).

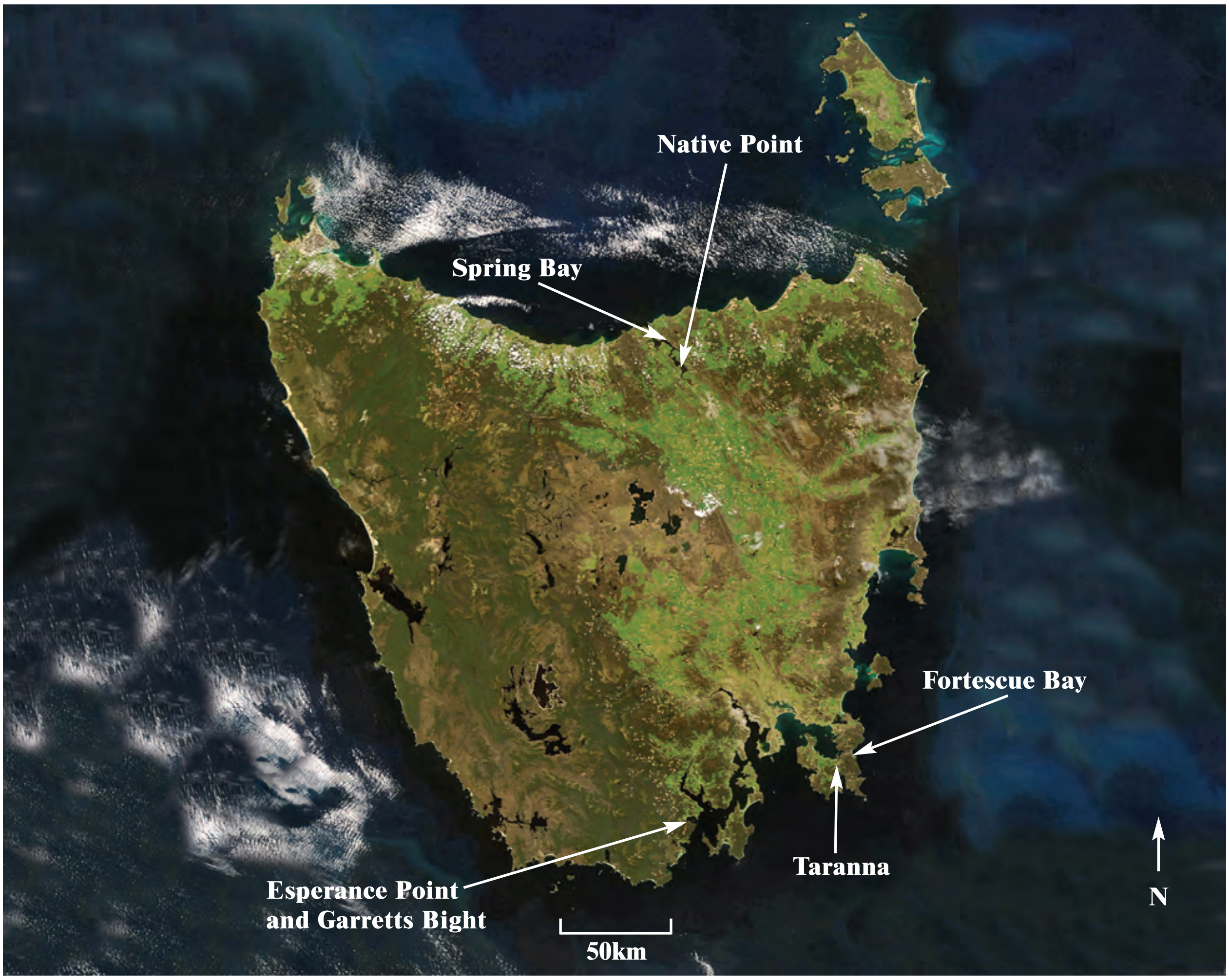

Figure 1. *Map of Tasmania, showing locations of study sites. Image courtesy of NASA's Earth Observatory.*

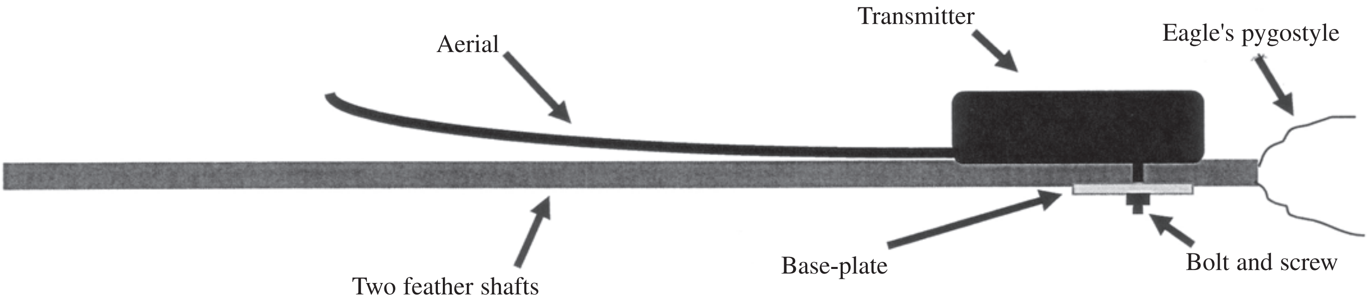

Figure 2. *Schematic of method used to attach radio transmitters to Sea-Eagles' central rectrices (lateral view). Length of transmitter is 30 centimetres (including aerial).*

Foraging behaviour

The searching behaviour of Sea-Eagles was classified as either short-stay perch-hunting or as soaring, because still-hunting could not be distinguished from other perching (e.g. resting) and was thus excluded from analysis. Soaring was defined as when a Sea-Eagle used an updraught to gain altitude then followed the contour of the coast in search of prey, ending when the Sea-Eagle made a quick, short stoop at prey. Short-stay perch-hunting consisted of short flights from perch to perch, followed by a brief scan before moving on, and was used when prey was moving; Sea-Eagles used the cover of vegetation to remain concealed until an opportunity arose for an attack. For both types, the start of a foraging attempt was taken as the time when the bird left a perch, and it ceased when the bird landed.

Data analysis

Foraging areas were calculated using the Animal Movement extension to ArcView (Hooge and Eichenlaub 1997). Foraging range was calculated using the minimum convex polygon (Powell 2000) to estimate the area and perimeter distance. The most commonly used foraging areas (25, 50 and 95% probability contours) were calculated using the kernel estimator (Powell 2000).

Habitat associations

Habitat variables were investigated to determine whether foraging patterns correlated with specific habitat types (Aebischer *et al.* 1993; Kenward and Walls 1994), within and between aquaculture and non-aquaculture sites. Marine vegetation data were obtained from the Tasmanian Aquaculture and Fisheries Institute (CMap 2000), and terrestrial vegetation data were obtained from the Department of Primary Industries, Water and Environment for analysis using ArcView (Hooge and Eichenlaub 1997). Comparisons of 'used' versus 'available' habitat were quantified using habitat data within the GIS program, to identify habitats selected (Johnson 1980). Terrestrial vegetation data were available only as point data. An arbitrary quadrat was developed in ArcView to standardise the method for analysing habitats used and habitats available on sea and land. Along either side of a foraging path a 50-metre buffer was delineated, to account for observer-estimated position error and GPS error. Potentially available habitat was quantified by a series of transect lines that were similarly buffered; transects were 200 metres apart (from the transect centres) parallel to flight paths to provide continuous sampling (Figure 3). Potentially available habitat was standardised as all habitats within a 7.5 kilometre (an area greater than the average foraging distance) radius of each pair's nest. However, the analysis considered only four of the six sites, because there was no bathymetry dataset for the Tamar River. Habitat preference (habitats used vs. habitats available) was analysed by the G-test (Fowler and Cohen 1992).

RESULTS

Sea-Eagle activity peaked between 0930 hours and 1500 hours. Soaring was the most frequent form of hunting, and almost all foraging flights occurred either over water or inland within one kilometre inland from the coastline. Four adult male Sea-Eagles (two aquaculture, two non-aquaculture) carried prey similar distances to their respective nests (~2 km: Table 1). Male Sea-Eagles consistently hunted in the vicinity of the nest throughout the breeding period, but ranged farther afield if prey was not captured near the nest. On many occasions during the study, Sea-Eagles travelled more than two kilometres to capture small prey detected by still-hunting (hunting from roost sites). Boats used for supplying feed to, and maintaining, the farmed salmon regularly attracted Sea-Eagles from up to six kilometres away, much as fishing vessels also attract Sea-Eagles.

TABLE 1

Distances travelled by breeding adult male White-bellied Sea-Eagles with prey, during August–December 2000, as determined by radio-telemetry (n = no. food-bearing trips per bird).

Site	Range (km)	n	Mean (km)
1	0.8–5.8	8	2.7
2	0.2–4.1	7	2.1
3	0.05–6.2	6	2.0
4	0.1–3.3	7	1.7

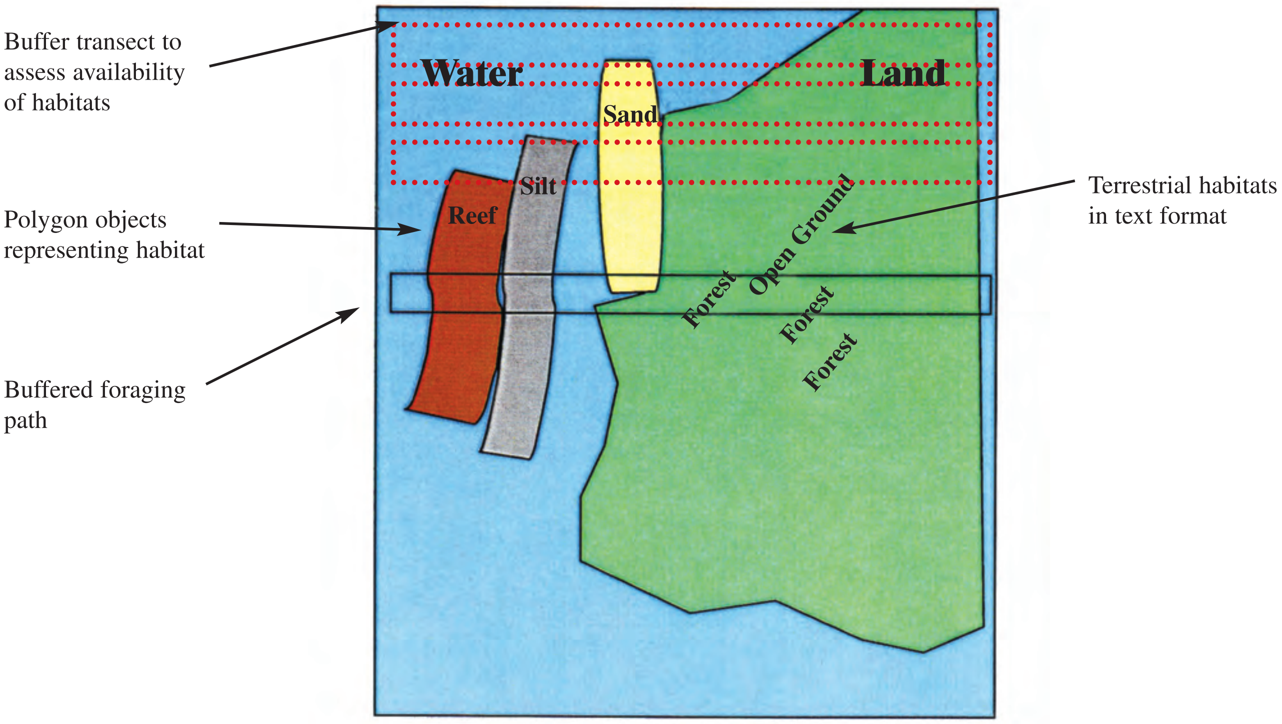

Figure 3. *Schematic of buffered transect method used to quantify habitat variables (see Methods section): dashed lines sampling available habitat; solid line representing habitat use as foraging flight path.*

For instance, a fishing boat discarded many Gurnard *Helicolenus percoides* offshore from a Sea-Eagle's nest, and the resident eagle collected several over the following two hours (pers. obs.).

When making foraging flights, on almost all occasions the male left the vicinity of the nest and began soaring, to return later with prey. Although few captures were observed during this study, previous observations suggested that Sea-Eagles most commonly catch prey by a swoop from soaring flight (pers. obs.).

Sea-Eagles were rarely able to exploit salmon directly from fish farms, owing to the large size of the fish and the anti-predator netting. However, they were able to exploit other, sometimes large, native prey in the vicinity. Sea-Eagles were seen several times with large prey caught near sea-cages (pers. obs.).

Home range

The kernel 95 per cent contour gave a much larger area than did the minimum convex polygon, and the difference was greater for aquaculture than non-aquaculture sites (Table 2). At non-aquaculture sites, mean foraging range was 77.2 square kilometres by MCP (32.6–128.2 km^2, n = 3), and 92.2 square kilometres by kernel (86.2–99.7 km^2, n = 3: Tables 2, 3). At aquaculture sites, mean foraging range was 56.7 square kilometres by MCP (34.4–89.3 km^2, n = 3), and 219.6 square kilometres by kernel (83.4–472.0 km^2, n = 3: Tables 2, 3). Sea-Eagles at aquaculture sites had both larger and more elongated home ranges, with consequently larger perimeters, than those at non-aquaculture sites, whose home ranges were more rounded (see example for Esperance Point and Garretts Bight aquaculture sites – Figure 4). However, these differences were not significant (area: t_5 = 1.2, P = 0.28; perimeter: t_5 = 1.0, P = 0.36; Figure 5), possibly owing to the small sample size.

Kernel contours showed that small parts of the Sea-Eagles' home range were used frequently, with core areas of use around the nest site (Table 3; Figure 6a–f). The small areas represented by the 95 per cent kernel contours appeared to be important hunting areas. Home ranges at non-aquaculture sites showed a primary hunting area away from the nest. The elongated shape of eagle home ranges at aquaculture sites showed a series of hunting 'hotspots', some of which included fish farms, thus suggesting that male Sea-Eagles extended their foraging ranges to include fish farms, and selectively hunted there. The foraging ranges of two males at adjacent aquaculture sites overlapped, such that both visited some of the same fish farms and also intruded near each other's nest site (Figures 4; 6e,f). Sea-Eagles at aquaculture sites spent a large proportion of their time in the vicinity of fish farms, scavenging dead fish.

Foraging distances

On average, male Sea-Eagles at aquaculture sites made longer soaring flights (24 km) than did Sea-Eagles from non-aquaculture sites (16 km: Figure 7), though not significantly so (t_1 = 3.25, P = 0.19). There was a significant difference in perch-hunting distances, with male Sea-Eagles at aquaculture sites making longer flight sequences (3.6 km versus 1.2 km: Figure 7; t_1 = 10.7, P = 0.05). Perch-hunting flight sequences were much shorter than soaring flights and occurred less often, but the proportion of soaring to perch-hunting was consistent between sites (Figure 7). The size and shape of foraging ranges (see *Home range*, above) revealed that males at non-aquaculture sites did most of their foraging near the nest or within four kilometres of

TABLE 2

Foraging ranges of breeding adult male White-bellied Sea-Eagles, during August–December 2000: aquaculture and non-aquaculture sites, by minimum convex polygon (MCP) and kernel estimators.

Site	*n* fixes	MCP (km^2)	Kernel (km^2)	Difference (km^2)
Aquaculture sites:				
Garretts Bight	59	34.4	103.3	68.9
Esperance Pt	39	89.3	472.0	382.7
Spring Bay	46	46.4	83.4	37.0
Mean		**56.7**	**219.6**	**162.9**
Non-aquaculture sites:				
Taranna	48	32.6	90.7	58.1
Fortescue Bay	33	70.8	86.2	15.4
Native Pt	52	128.2	99.7	28.5
Mean		**77.2**	**92.2**	**34.0**

it, whereas males at aquaculture sites ranged much farther from the nest, often at distances up to 11 kilometres. Males at aquaculture sites apparently flew greater distances because they included fish farms in their foraging area.

Habitat utilisation

At two aquaculture and two non-aquaculture sites, some habitats were used disproportionately (Table 4). Sea-Eagles used littoral and marine habitats, and probably traversed terrestrial habitats mainly en route to marine habitats; one male (at Taranna, a non-aquaculture site) also apparently foraged over terrestrial open areas. Sea-Eagles selectively used habitats around fish farms when foraging (95% kernel: Figure 6). Sea-Eagles spent considerable time in the vicinity of fish farms where no dead fish were available, suggesting that the eagles were attracted to fish farms for a variety of reasons.

TABLE 3

Mean foraging areas (kernel) for six breeding adult male White-bellied Sea-Eagles, during August–December 2000: 95%, 50% and 25% probability contours.

Probability contour	Foraging area (km^2)	
	Aquaculture sites (n = 3)	Non-aquaculture sites (n = 3)
95%	219.6	92.2
50%	17.6	15.4
25%	3.2	7.0

DISCUSSION

Sea-Eagles had different-sized and -shaped foraging ranges at aquaculture versus non-aquaculture sites: those nesting within three kilometres of fish farms extended their foraging ranges to include the vicinity of sea-cages. Sea-Eagles at aquaculture sites were attracted to fish farms, presumably because they perceived sea-cages as worth including in their foraging range. In consequence, males at aquaculture sites flew farther and had larger areas and perimeters to patrol, and in one case also had the potential for increased territorial conflict near a nest site. Thus, the presence of fish farms appears to influence the foraging ecology of breeding male White-bellied Sea-Eagles.

MCP home ranges for both categories of Sea-Eagle sites, and 95 per cent kernel home ranges for non-aquaculture sites, were similar to the published value of up to 100 square kilometres for White-bellied Sea-Eagles in Tasmania (Marchant and Higgins 1993). However, the 95 per cent kernel home range for eagles at aquaculture sites averaged twice that value, and ranged up to almost five times as large. The mean soaring distance for eagles at non-aquaculture sites was similar to a value of 14 kilometres of lake shore used by a female Sea-Eagle, which ranged two kilometres from the nest, in Victoria (Marchant and Higgins 1993).

There are no comparable published values for elsewhere in Australia. There are also no comparative quantified data on hunting behaviour for this species.

The results of this study suggest that fish farms likely increase the energy expenditure of male Sea-Eagles during the breeding period, because they have larger foraging ranges, and travel much farther when provisioning their families, than do males at non-aquaculture sites. Larger home ranges also suggest that food supply may be lower in the vicinity of fish farms. The Sea-Eagles may be drawn to an apparent (but not

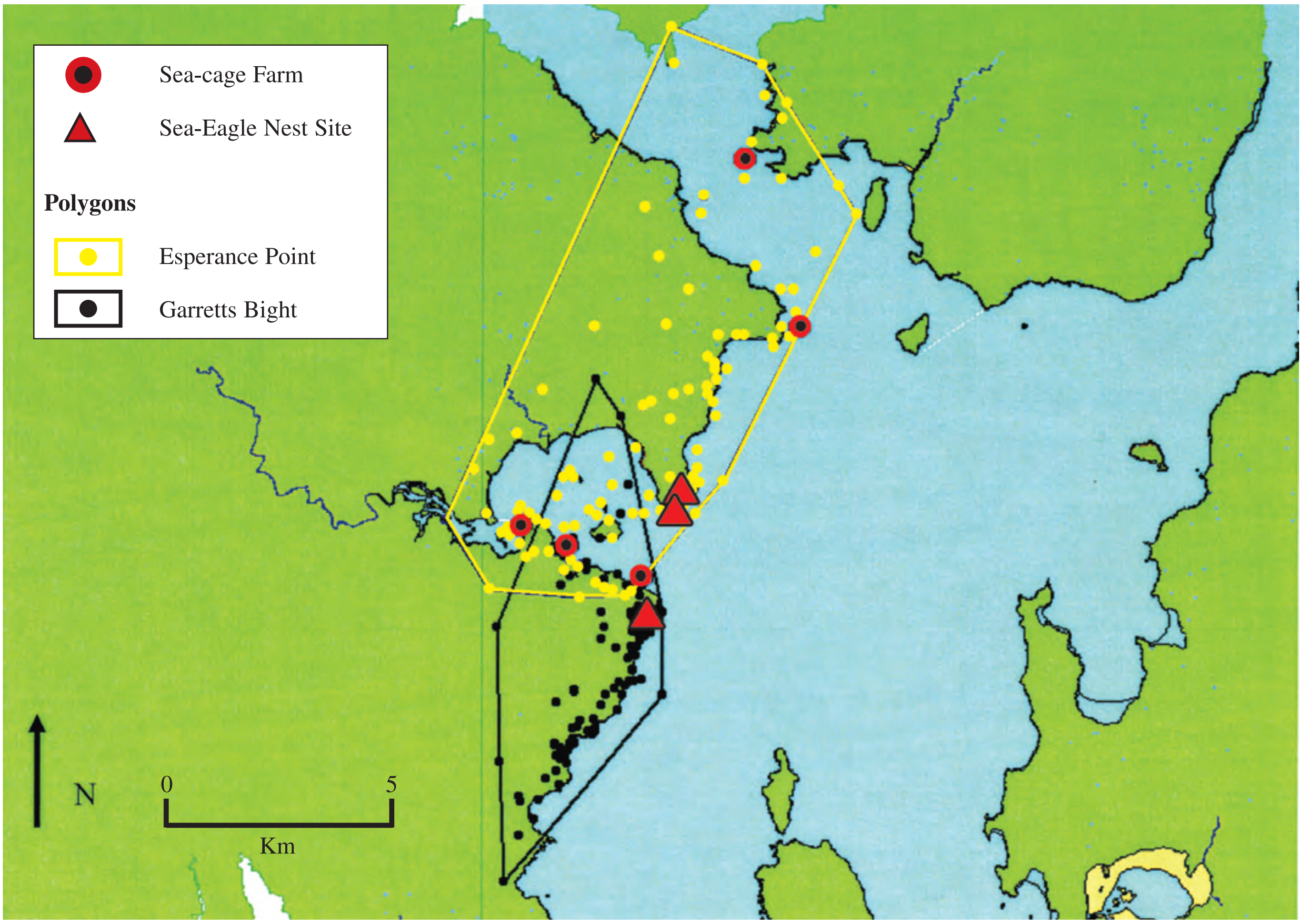

Figure 4. *Minimum convex polygons for foraging ranges of two adult male White-bellied Sea-Eagles during August–December 2000, showing locations of eagle nest sites and marine fish farms: Esperance Point and Garretts Bight (aquaculture sites).*

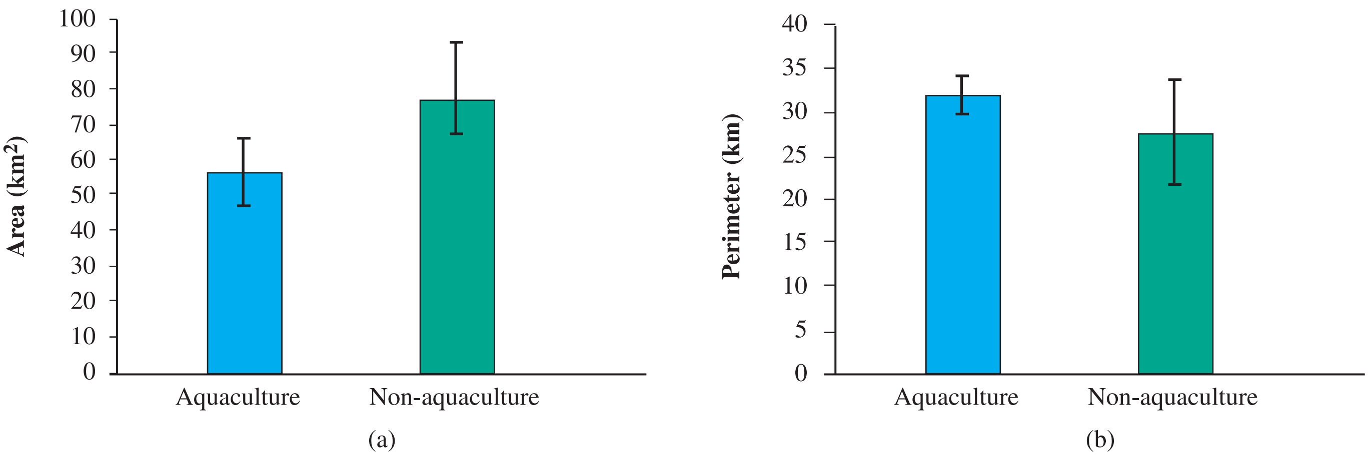

Figure 5. *Average home-range (a) area (n = 6) and (b) perimeter (n = 6) for adult male White-bellied Sea-Eagles at aquaculture sites and non-aquaculture sites, Tasmania, from minimum convex polygons, August–December 2000.*

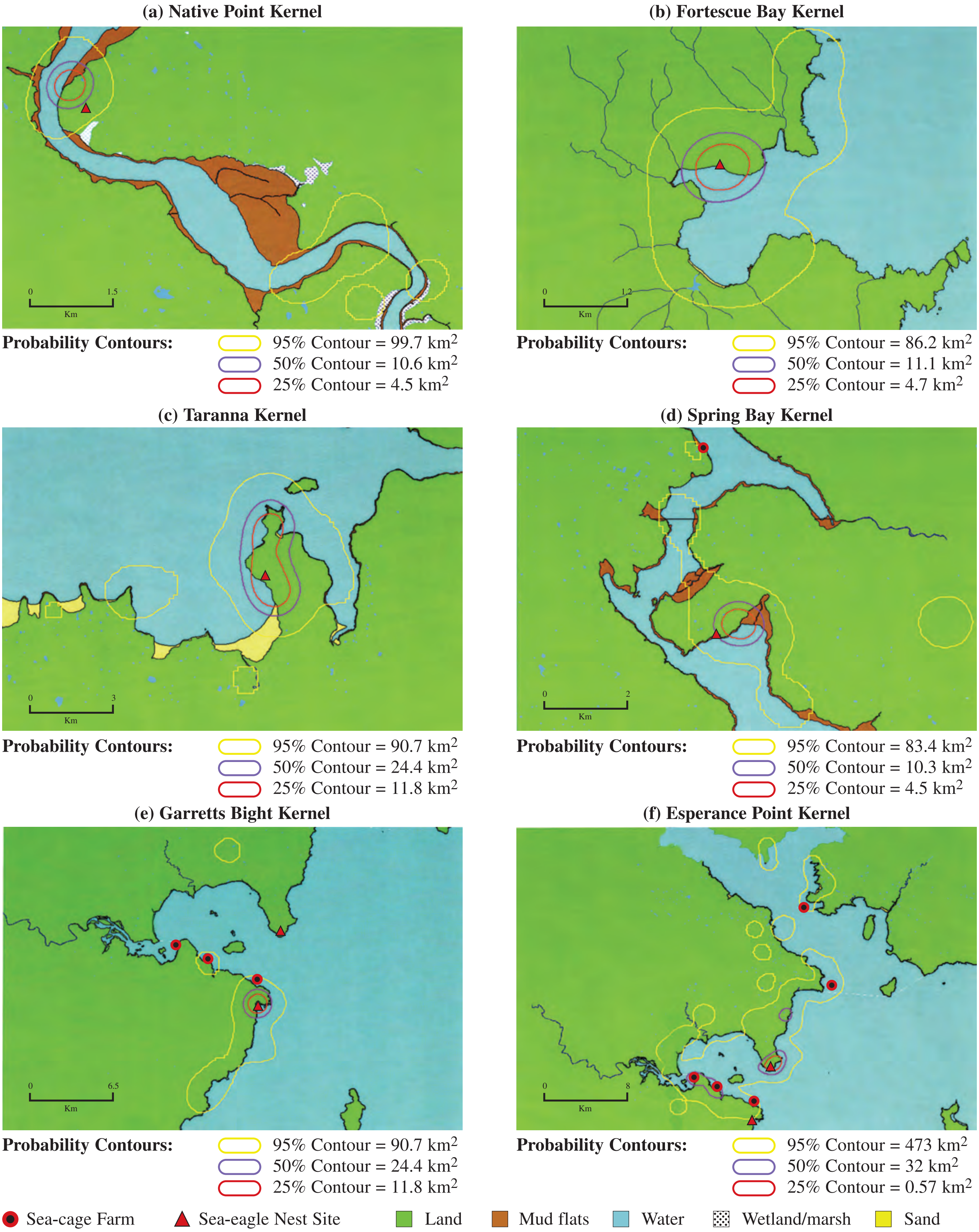

Figure 6. *Foraging ranges (kernel estimators) of adult male White-bellied Sea-Eagles in Tasmania, August–December 2000, showing locations of eagle nest sites and marine fish farms: (a) Native Point, (b) Fortescue Bay, (c) Taranna (non-aquaculture sites), (d) Spring Bay, (e) Garretts Bight, (f) Esperance Point (aquaculture sites).*

TABLE 4

Habitat use by breeding adult male White-bellied Sea-Eagles, during August–December 2000: 2 out of 3 aquaculture and 2 out of 3 non-aquaculture sites. 'Available' and 'used' are areas of each substrate class in the Sea-Eagles' foraging range, and traversed by the Sea-Eagles' foraging flight-path, respectively (measured as in Methods). Shells/burrows = areas containing large deposits of shells and burrows, distinct from Sandy substrate and Reef.

Site	Substrate	Available	Used	Significance
Non-aquaculture sites:				
Fortescue Bay	Sand	61	25	G5 = 4.09, P = 0.01
	Reef	279	60	
	Shells/burrows	79	60	
	Forest	17	4	
	Understorey	20	2	
Total		**456**	**151**	
Taranna	Reef	468	44	G5 = 12.0, P = 0.05
	Seagrass	162	24	
	Shells/burrows	251	9	
	Forest	184	10	
	Open	70	15	
Total		**1135**	**102**	
Aquaculture sites:				
Garretts Bight	Reef	481	107	G7 = 3.49, P = 0.01
	Sand	406	28	
	Shells/burrows	87	7	
	Silt	250	26	
	Forest	744	15	
	Understorey	130	8	
	Open	385	6	
Total		**2483**	**197**	
Esperance Point	Reef	441	61	G7 = 3.49, P = 0.01
	Sand	406	62	
	Seagrass	40	45	
	Shells/burrows	87	17	
	Silt	250	22	
	Forest	829	37	
	Open	385	17	
	Orchard	45	3	
Total		**2483**	**264**	

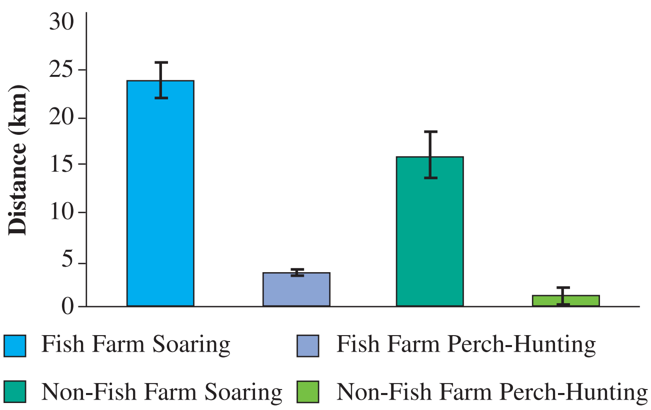

Figure 7. *Average foraging distances (± standard error) for breeding adult male White-bellied Sea-Eagles, during August–December 2000: aquaculture and non-aquaculture sites, for soaring (n = 116) and short-stay perch-hunting (n = 45).*

necessarily real) abundance of prey by the gatherings of other predators of fish (such as seabirds, sharks and school fish and seals) at fish farms, and thus enticed away from more productive hunting grounds closer to their nests. Seemingly abundant prey may be highly attractive, though rarely caught (Newton 1979). However, there are no data on marine wild fish populations around coastal fish farms in Australia.

The Sea-Eagles in this study foraged successfully at fish farms (where prey may be easy to catch), and soaring flight is energetically inexpensive (Brown 1980). Also, greater foraging distances may not necessarily reflect poor prey profitability in that one-kilogram salmon is highly rewarding energetically for a breeding Sea-Eagle (Stalmaster and Gessaman 1984; Elliott *et al.* 1998). Nevertheless, there is an energetic cost in transporting prey long distances. Also, increased territorial conflict around nests near fish farms may have consequences for nest attentiveness and hence breeding productivity (Newton 1979). Therefore, effects of fish farms on the White-bellied Sea-Eagle, in terms of foraging energetics and nest defence, remains to be confirmed.

Further study is required on breeding success of a larger sample of Sea-Eagle pairs, at aquaculture and non-aquaculture sites pre- and post establishment. Comparisons of foraging ecology could usefully be extended by larger sample sizes, of Sea-Eagles and their individual foraging success, than in this study. Further data are required on Sea-Eagle populations in aquaculture and non-aquaculture regions; causes of any additional Sea-Eagle mortality (e.g. from entanglement and oiling in waste fish pits) at fish farms; and marine fish populations in aquaculture and non-aquaculture areas. Although current monitoring of fish farms is effective in reducing algal blooms and salmon kills by minimising the build-up of noxious gasses, there has been insufficient consideration of the potential impact of fish farms on native vertebrate populations. Therefore, further attention (e.g. research and monitoring) should be given to the effect of fish farms on higher vertebrates such as Sea-Eagles, as those species are uncommon and vulnerable to human influences.

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REFERENCES

Aebischer, N. J., Robertson, P. A. and Kenward, R. E. (1993). Compositional analysis of habitat use from animal radio-tracking data. *Ecology* **74:** 1313–1325.

Berkelman, J., Fraser, J. D. and Watson, R. T. (1999). Madagascar Fish-Eagle prey preferences and foraging success. *Wilson Bulletin* **111:** 15–22.

Brown, L.H. (1980). 'The African Fish Eagle'. (Purnell: Cape Town.)

CMap (2000). Tasmanian Project. (Tasmanian Aquaculture Fisheries Institute, University of Tasmania: Hobart.)

DPIF (1996). Marine Farming Development Plan: Huon River and Port Esperance. (Marine Resources Division, Department of Primary Industries and Fisheries: Hobart.)

Elliot, J. E., Moul, I. E. and Cheng, K. M. (1998). Variable reproductive success of Bald Eagles on the British Columbia coast. *Journal of Wildlife Management* **62:** 518–630.

Fowler, J. and Cohen, L. (1992). 'Statistics for Ornithologists'. (British Trust for Ornithology: Tring, UK.)

Fraser, J. D., Chancellor, S. K., Buehler, D. A. and Seegar, J. K. D. (1996). The decline, recovery and future of the Bald Eagle population of the Chesapeake Bay, USA. In 'Eagle Studies'(Eds B. U. Meyburg and R. D. Chancellor). Pp. 181–187. (World Working Group on Birds of Prey: Berlin and London.)

Grubb, T. G., Robinson, W. L. and Bowerman, W. W. (2002). Effects of watercraft on Bald Eagle nesting in Voyageurs National Park, Minnesota. *Wildlife Society Bulletin* **30:** 156–161.

Harris, S., Cresswell, W. J., Forde, P. G. and Trewhella, W. J. (1990). Home-range analysis using radio-tracking data – a review of problems and techniques particularly as applied to the study of mammals. *Mammal Review* **20:** 97–123.

Hooge, P. N. and Eichenlaub, B. (1997). 'Animal Movement Extension to ArcView'. (Alaska Biological Science Center, US Geological Survey: Anchorage, AK, USA.)

Hunt, W. G., Jenkins, J. M., Jackman, R. E., Thelander, C. G. and Gershell, A. T. (1992). Foraging ecology of Bald Eagles on a regulated river. *Journal of Raptor Research* **26:** 243–256.

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology* **61:** 65–71.

Kenward, R. E. and Walls, S. S. (1994). The systematic study of radio-tagged raptors: Survival, home-range and habitat-use. In 'Raptor Conservation Today' (Eds B. U. Meyburg and R. D. Chancellor). Pp 303–315. (Pica Press: Mountfield, UK.)

Marchant, S. and Higgins, P. J. (Eds) (1993). 'Handbook of Australian, New Zealand and Antarctic Birds', Vol. 2: Raptors to Lapwings. (Oxford University Press: Melbourne.)

Nams, V. O. and Boutin, S. (1991). What is wrong with error polygon? *Journal of Wildlife Management* **55:** 172–176.

Newton, I. (1979). 'Population Ecology of Raptors'. (Poyser: Berkhamsted.)

North, M. P. and Reynolds, J. T. (1996). Microhabitat analysis using radio-telemetry locations and polytomous logistic regression. *Journal of Wildlife Management* **60:** 639–653.

Olsen, P. D. (1995). 'Australian Birds of Prey'. (NSW University Press: Sydney.)

Powell, A. R. (2000). Animal home ranges and territories and home range estimators. In 'Research Techniques in Animal Ecology: Controversies and Consequences' (Eds L. Boitani and T. K. Fuller) (Columbia University Press: New York).

Stalmaster, M. V. and Gessaman, J. A. (1984). Ecological energetics and foraging behavior of overwintering Bald Eagles. *Ecological Monographs* **54:** 407–428.

Steidl, R. J. and Anthony, R. G. (2000). Experimental effects of human activity on breeding Bald Eagles. *Ecological Applications* **10:** 258–268.

Threatened Species Unit (2005). Fauna Recovery Plan: Threatened Tasmanian Eagles 2005–2009. Department of Primary Industries, Water and Environment, Hobart.

Thurstans, S. D. (2009a). A survey of White-bellied Sea-Eagle *Haliaeetus leucogaster* nests in Tasmania in 2003. *Corella* **33:** 66-70

Thurstans, S. D. (2009b). Modelling the nesting habitat of the White-bellied Sea-Eagle *Haliaeetus leucogaster* in Tasmania. *Corella* **33:** 51-65.

Wiersma, J. M., Nermut, W. and Shephard, J. M. (2001). A variation on the 'noosed fish' method and its suitability for trapping the White-bellied Sea-Eagle *Haliaeetus leucogaster*. *Corella* **25:** 97–99.