Foraging depths of Vasse-Wonnerup waterbirds

FOUR OR MORE PHOTOS ILLUSTRATING DIFFERENT FORAGING DEPTHS, E.G.

- WADING ON EXPOSED MUD
- WADING IN SHALLOWS
- UPENDING
- DIVING (E.G. MUSK DUCK, p298 of Frith 1967/77 OR BLUE-BILLED DUCK, p299 of Frith 1967/77)
- DIVING FROM THE AIR (E.G. TERN)
- RAPTOR?
- WF CHAT?

JAK Lane
Wetlands Conservation Program
Science and Conservation Division

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GOVERNMENT OF
WESTERN AUSTRALIA

Department of **Biodiversity,**
Conservation and Attractions

Cover illustration

XXXX

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SUMMARY

This report

1. INTRODUCTION

This report is a compendium of measurements, estimations and other information relating to the foraging depths of all waterbird species known from the Vasse-Wonnerup System 'Ramsar Site' (wetland of international importance), at Busselton, Western Australia.

While there are several significant threats to the waterbird populations of Vasse-Wonnerup, water level control is currently the most critical management issue.

Many waterbird species have quite narrow depth ranges within which they are able to successfully find and collect food. If the current high diversity of waterbirds on Vasse-Wonnerup is to be maintained, water levels must be managed to provide the depths, and adequate areas thereof, that these 90-odd species require.

Water level management is a vexed issue at Vasse-Wonnerup, with flood prevention, storm surge control, fish kill mitigation, noxious odours and disease-carrying mosquitoes all impacting on the decision-making process.

This report aims to assist in the decision-making process by providing the most accurate and up-to-date information available regarding waterbird foraging depths. Depths for other activities, principally roosting and nesting, are not addressed in this report.

2. APPROACH TAKEN

'#' in front of a PDF file name indicates I have read, and extracted what I want, from this reference. I started applying this signification to PDFs today (JL 21st March 2018)

While there appear to be no published accounts reporting the precise depths in which the various waterbird species forage on Vasse-Wonnerup, measurements for some species have been published from a small number of sites elsewhere in Australia, and overseas. These measurements appear further below (Section 3), species by species.

The species by species accounts are followed by a Table of morphometric measurements (tarsus[1], bill and/or total body lengths, as appropriate) of each species, and foraging depths calculated from these measurements. The published foraging depths of section xx are repeated here in condensed form, for comparison.

Barbosa (1993): 'Charadrii species studied in this paper with the exception of *Burhinus oedicnemus,* inhabit aquatic environments such as lakes and rivers or spend about 70 % of the yearly cycle in tidal environments such as marshes, mudflats, beaches, and estuaries (Burger, 1984). These habitats exhibit important environmental changes determined by tidal oscillations that affect habitat use and access to resources (Burger *et al.,* 1977; Connors *et al.,* 1981). Several authors (i.e. Goss-Custard, 1977; Baker, 1979) found a significant correlation between leg length, specially tarsal length, and water depth as a longer tarsometatarsus [the bone of the 'tarsus'] facilitates walking in deep water (Rylander, 1980)'.

A complete list of all waterbird species recorded on Vasse-Wonnerup is provided in Appendix xx, together with some abundance data.

Appendices xx – yy provide extracts from key references of section xx.

Last but certainly not least is an Appendix with more-general information concerning waterbird foraging depths, in particular a selection of passages from introductory and concluding sections of several significant scientific papers on this topic. The introductory passages provide additional context and references to other, earlier papers. The concluding passages also add context and, in several cases, useful practical guidance for wetland managers.

X. FORAGING DEPTHS OF WATERBIRDS – GENERAL REMARKS/INFORMATION

Dann, P. (1987). *The Feeding Behaviour and Ecology of Shorebirds.* Pp. 10-20. In: Lane B.A. (Ed.) *Shorebirds in Australia.* Royal Australasian Ornithologists Union, Melbourne.

Plauny, H.L. (2000). *Shorebirds.* Fish and Wildlife Habitat Management Leaflet No. 17 (July 2000). Natural Resources Conservation Service Wildlife Management Institute, USDA, and Wildlife Habitat Council. 14pp.

Halse S.A., Williams, M.R., Jaensch, R.P. & Lane, J.A.K. (1993). *Wetland characteristics and waterbird use of wetlands in south-western Australia.* Wildlife Research, 20(1), 103-126.

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[1] Tarsus length 'measured to 0.1mm from the midpoint of the hindside of the joint between the tibia and tarsus, to the midpoint of the joint between tarsus and middle toe in front' (Marchant & Higgins 1990).

‘While larger birds will use deeper water in which to forage, they generally prefer shallow water when food is available (Gawlik 2002), as it is more profitable, using less energy to forage (Lovvorn 1994)’.

Lovvorn, J.R. (1994). *Biomechanics and foraging profitability - an approach to assessing trophic needs and impacts in foraging ducks.* Hydrobiologia 280: 223-233.

Gawlik, D.E. (2002). *The effects of prey availability on the numerical response of wading birds.* Ecological Monographs 72, 329-346. DOWNLOADED 24TH NOV 2017].

EXTRACTS FROM: Ecological Associates (2010). *Literature review of the ecology of birds of The Coorong, Lakes Alexandrina and Albert Ramsar wetlands.* Ecological Associates report CC-014-1-D prepared for Department for Environment and Heritage, Adelaide.

‘Worldwide the greatest diversity and abundance of foraging waterbirds is found in water depths of between 10 and 20 cm (Isola *et al.* 2000, Taft *et al.* 2002). Natural or artificial waterbodies that offer an array of water depths and vegetation associations tend to have rich communities of invertebrates, and carry higher numbers of species and individuals of waterbirds (Broome and Jarman 1983). Piscivores feed on fish in shallow water in preference to those in deeper water (Gawlik 2002). The density of prey at which the birds will stop searching increases with increasing depth being almost twice as high at 28 cm as it is at 10 cm (Gawlik 2002). In the Coorong, Paton and Rogers (Brookes *et al.* 2009), found that foraging performance in the three most abundant Calidris species (Sharp-tailed Sandpiper, Red-necked Stint, and Curlew Sandpiper) declined rapidly with slight (2-3 cm) increases in water depth, and also with small shifts (<10 m) above the waterline, indicating their narrow niche in association with very shallow water’.

Brookes, J. D., S. Lamontagne, K. T. Aldridge, S. Benger, A. Bissett, L. Bucater, A. C. Cheshire, P. L. M. Cook, B. M. Deegan, S. Dittman, P. G. Fairweather, M. B. Fernandes, P. W. Ford, M. C. Geddes, B. M. Gillanders, N. J. Grigg, R. R. Haese, E. Krull, R. A. Langley, R. E. Lester, M. Loo, A. R. Munro, C. J. Noell, S. Nayar, D. C. Paton, A. T. Revill, D. J. Rogers, A. Rolston, S. K. Sharma, D. A. Short, J. E. Tanner, I. T. Webster, N. R. Wellman, and Q. Ye. 2009. An ecological assessment framework to guide management of the Coorong. Final report of the CLLAMMecology Research Cluster. CSIRO: Water for a Healthy Country National Research Flagship, Canberra.

Isola, C.R., Colwell, M.A., Taft, O.E. & Safran, R.J. (2000). *Interspecific differences in habitat use of shorebirds and waterfowl foraging in managed wetlands of California's San Joaquin Valley.* Waterbirds 23: 196-203.

Taft, O. E., Colwell, M.A., Isola, C.R. & Safran, R.J. (2002). *Waterbird responses to experimental drawdown: implications for the multi-specific management of wetland mosaics.* Journal of Applied Ecology 39:987-1001.

‘The substrate exposed and inundated through tidal movement particularly in the shallow gently sloping bed of water bodies provides important foraging habitat for a wide variety of waterbird species. Some species forage in the shallow receding or encroaching water, other species forage on the recently exposed sand or mud flats, and some forage at the moving interface of water over substrate as the tide encroaches and recedes. In the Coorong encroaching water in tidal systems tends to provide poor foraging habitat for migratory birds, with most birds tending to forage on outgoing tides (Daniel Rogers DEH, Pers. Comm. 07/08/2009)’.

‘Most wader species in Australia feed on intertidal mudflats at falling and low tide, irrespective of whether this occurs during the day or night (Geering *et al.* 2007). At rising and high tide many species generally spend time roosting in flocks above the high water mark. As the tide recedes they move onto adjacent intertidal mud and sand flats to feed (Geering *et al*. 2007). The force of wind moving over water can cause a surge of water, which can inundate the lee shore of a waterbody. The exposure and inundation of the substrate and vegetation along a shore by this process with change in wind direction, or by seiching (a short-period oscillation in an enclosed or semi-enclosed body of water), provides an important foraging habitat for many waterbird species. In large, long, gently sloping waterbodies like the Coorong lagoons, such water movement can inundate and expose large areas of mud and sand flats, fringing vegetation, and even aquatic vegetation, providing important foraging habitat for a wide variety of waterbird species. The wind also serves to concentrate food sources on the leeward side of a waterbody, with significant implications for the waterbird feeding efficiency. Waterbirds are known to favour leeward shores when foraging on such food sources as *Ruppia* turions and seeds, and Brine Shrimp’.

In a paper presenting results of modelling of shorebird foraging habitat availability in south-eastern Missouri, Twedt (2013) presented a Table of 'presumed foraging depth[s] (cm)' of *c.* 33 species of shorebirds in the southern United States. Several of these species have been recorded on Vasse-Wonnerup. Their 'presumed foraging depths' were given as Ruddy Turnstone <6cm, Red Knot <6cm, Pectoral Sandpiper <6cm, '*Calidris* spp. (peeps)' <6cm, Black-necked (i.e. Black-winged) Stilt <20cm, Black-bellied (i.e. Grey) Plover <9cm. There is some uncertainty as to the basis of these values, however it appears (p.671) they may have come from Davis (1996), Safran *et al.* (1997) and Isola *et al.* (2000). [See also http://www.mvm.usace.army.mil/Portals/51/docs/missions/projects/St%20Johns%20Bayou%20and%20New%20Madrid%20Floodway/Appendix%20H%20Part%202%20-%20Shorebird%20Model%20Validation.pdf for validation proposal].

Brandis *et al.* (2009). 'For long-legged waders, such as spoonbill and herons, key resources are wetlands of a particular water depth and ultimately prey availability. Prey availability differs from prey abundance in that not all prey items present may be accessible or detectable and therefore not be vulnerable to predation. As a result some long-legged waders are more sensitive to changes in prey density, water depth or period of inundation than others. In turn, prey availability has been hypothesised to limit population size and constrain the distribution of wading birds (see Gawlik 2002 and references therein). In a study of the effects of water depth and prey density on prey availability, Gawlik (2002) showed that tactile feeders such as ibis and storks respond strongly to changes in both. These species seek the highest quality feeding sites and do not attempt to exploit sites where water depth and prey density increase energetic and fitness costs. This contrasted with visual feeders such as the larger egrets and herons that feed across a greater range of water depths and continue to exploit prey to much lower densities. Gawlick (2002) hypothesised that species using only high quality feeding sites would require a greater area to meet their nutritional requirements as there would be fewer of these sites (Figure 2). Moreover these differences between tactile and visual feeders were hypothesised to account for the differential declines in wading birds in the Florida everglades (Bancroft *et al.* 2002)' and 'As in other wetland biomes, wading birds differ in their individual habitat requirements and some species (such as tactile feeders) are likely to be more sensitive to fine-scale changes in water depth and prey availability than others (Gawlik 2002). Brandis, K., Roshier, D. & Kingsford, R.T. (2009) *Environmental Watering for Waterbirds in The Living Murray Icon Sites — A literature review and identification of research priorities relevant to the environmental watering actions of flow enhancement and retaining floodwater on floodplains.* Report to the Murray–Darling Basin Authority Project number MD1248, June 2009.

Gawlick (2002) 'In this study, I manipulated prey density and water depth (i.e., prey availability) in 12 0.2-ha ponds to determine their relative effects on the numeric response of eight species of free-ranging wading birds (White Ibis, *Eudiocimus albus;* Wood Stork, *Mycteria americana;* Snowy Egret, *Egretta thula;* Glossy Ibis, *Plegadis falcinellus;* Great Egret, *Ardea alba;* Tricolored Heron, *Egretta tricolor;* Great Blue Heron, *Ardea herodias;* and Little Blue Heron, *Egretta caerulea)'.* and 'In summary, White Ibises, Snowy Egrets, and Wood Storks responded strongly to both fish density and water depth treatments with no interactions from other variables. For those species, there was a depth threshold between 19 cm and 28 cm that seemed to constrain the use of foraging sites. Little Blue Herons and Great Egrets responded primarily to fish density, with a weaker response to water depth. In both cases, birds did not avoid the deep-water treatments; they simply foraged there after they had fed in the shallower treatments. Glossy Ibises responded more strongly to water depth than to fish density, but effects from both variables were evident. Tricolored Herons only responded to water depth. Finally, the density of Great Blue Herons was relatively constant throughout the experiment (see Appendix, Fig. A8), and this species showed no significant response to either treatment at the levels provided (Table 1)'. Gawlik, D.E. (2002). *The effects of prey availability on the numerical response of wading birds.* Ecological Monographs 72: 329-346.

Powell (…) 'Predictions of habitat availability for a particular wading-bird species at a given study site were generated by solving the bank-depth equations for times when levels were below maximum foraging depth of that species. Custer and Osborn (1978b) demonstrated that the water depth used by wading birds was dependent on leg length. To allow for maximum foraging access to the study sites by the various wading-bird species, I used total leg length as the maximum foraging depth (Table 1)'. 'Roseate Spoonbills *(Ajaia ajaja)* ... Great Blue Herons *(Ardea herodias)* ... **Great Egrets *(Casmerodius albus [=Ardea alba egretta])*** ..., Snowy *(Egretta thula)* and Reddish (E. *rufescens)* egrets, Little Blue (E. *caerulea)* and Tricolored (E. *tricolor)* herons, and White Ibis *(Eudocimus albus)'*

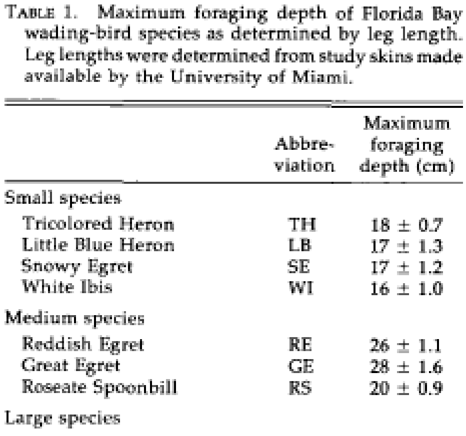


TABLE 1. Maximum foraging depth of Florida Bay wading-bird species as determined by leg length. Leg lengths were determined from study skins made available by the University of Miami.

	Abbreviation	Maximum foraging depth (cm)
Small species		
Tricolored Heron	TH	18 ± 0.7
Little Blue Heron	LB	17 ± 1.3
Snowy Egret	SE	17 ± 1.2
White Ibis	WI	16 ± 1.0
Medium species		
Reddish Egret	RE	26 ± 1.1
Great Egret	GE	28 ± 1.6
Roseate Spoonbill	RS	20 ± 0.9
Large species		

depths of Vasse-Wonnerup waterbirds

‘A key objective of this study was to discern the relative importance of factors that influence the distribution and abundance of shorebirds at the WTP. We conclude that the distribution and abundance of shorebirds on the tidal flats of the WTP are driven by the interplay of three main variables: population trends driven by factors outside the WTP, tidal flat exposure at each segment of coast, and benthos density on those tidal flats. While it is difficult to place a numeric value on their relative importance, all three factors contribute’. (Rogers *et al.* 2013). Rogers, D.I., Loyn, R.H. & Greer, D. (2013). *Factors influencing shorebird use of tidal flats adjacent to the Western Treatment Plant*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 250. Department of Sustainability and Environment, Heidelberg, Victoria.

Evans (1976: ‘In many cases, detailed observations or measurements are unavailable, and parts of the framework sketched in this paper remain theoretical and speculative. To illustrate general principles, I have ...’

Fredrickson (1991) 13.4.6. Strategies for Water Level Manipulations in moist-soil systems (USFWS Waterfowl Management Handbook; ‘Fish and Wildlife Leaflet 13.4.6’): ‘Water level manipulations are one of the most effective tools in wetland management, provided fluctuations are well-timed and controlled’. ‘Drawdowns serve as an important tool to attract a diversity of foraging birds to sites with abundant food resources. Drawdowns increase food availability by concentrating foods in smaller areas and at water depths within the foraging range of target wildlife. A general pattern commonly associated with drawdowns is an initial use by species adapted to exploiting resources in deeper water. As dewatering continues, these “deep water” species are gradually replaced by those that are adapted to exploit foods in invertebrate foods by wetland birds occurs when drawdowns to promote plant growth are scheduled to match key periods of migratory movement in spring. By varying drawdown dates among units, the productivity of each unit can be maintained and resources can be provided for longer periods. Slow drawdowns also prolong use by a greater number and diversity of wetland wildlife’.

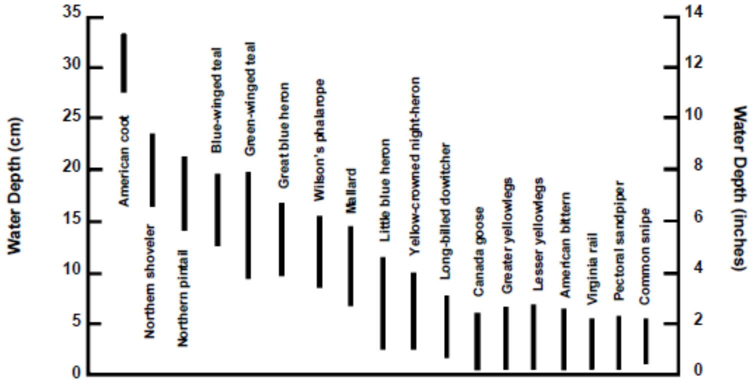


Fig. 2. Preferred water depths for wetland birds commonly associated with moist-soil habitats.

‘When water is discharged slowly from a unit, invertebrates are trapped and become readily available to foraging birds along the soil–water interface or in shallow water zones (Table 4). These invertebrates provide the critical protein-rich food resources required by pre-breeding and breeding female ducks, newly hatched waterfowl, molting ducks, and shorebirds. Shallow water for foraging is required by the vast majority of species; e.g., **only 5 of 54 species that commonly use moist-soil impoundments in Missouri can forage effectively in water greater than 10 inches.** Slow drawdowns lengthen the period for optimum foraging and put a large portion of the invertebrates within the foraging ranges of many species’. ‘Slow drawdowns are always recommended to enhance the duration and diversity of bird use (Table 4). Creating a situation in which the optimum foraging depths are available for the longest period provides for the efficient use of food resources, particularly invertebrate resources supplying proteinaceous foods. Partial drawdowns well in advance of the growing season (late winter) tend to benefit early migrating waterfowl, especially mallards and pintails. Early-spring to mid-spring drawdowns provide resources for late migrants such as shovelers, teals, rails, and bitterns. Mid- and late-season drawdowns provide food for breeding waders and waterfowl broods. These later drawdowns should be timed to coincide with the peak hatch of water birds and should continue during the early growth of nestlings or early brood development'.

Eldridge J (1992) 13.2.14. Management of habitat for breeding and migrating shorebirds in the Midwest, 11 (USFWS Waterfowl Management Handbook; 'Fish and Wildlife Leaflet 13.2.14'): 'The unique value of managed wetlands is their capacity to buffer the effects of both drought and flooding in surrounding wetland habitat'. 'During migration, many species look for a specific combination of habitat elements that include: · a wetland in partial drawdown, · invertebrate abundance of at least 100 individuals per square meter, · a combination of open mudflat and shallow water (3 to 5 cm; 1 to 2 inches) in a wetland basin with gradually sloping sides, and · very little vegetation. Any one of these elements may be available, but without invertebrates, the birds do not stay. The key to managing habitat for migrating shorebirds is to encourage invertebrate production and then make the invertebrates available to the birds. Aquatic invertebrates increase when wetlands are fertilized by mowing and grazing, but water control in the impoundment makes the job easier. The proper regime of drawdown and flooding can stimulate plant growth and decomposition and create a detrital food source for invertebrates. When the water is drawn down slowly (2 to 4 cm per week) during the appropriate times of the year, shorebirds are attracted to the available invertebrates. In general, water depth in which birds forage and body size of the birds correlate; larger birds tend to forage in deeper water. Some species may be attracted by shallow water, others, by mudflats. Some forage at the edge of the receding water line. If the interface between mud and water remains constant, they can deplete the invertebrates available to them. A slow, continuous drawdown provides the birds with new habitat and invertebrates. Each individual shorebird may only stay for a few days, but over several weeks, thousands of individuals of many species may benefit'. 'If the wildlife area has more than one impoundment, managers should draw them down asynchronously (see *Fish and Wildlife Leaflet* 13.4.6)'. 'Shorebirds feed primarily on Chironomidae (midge) larvae during migration through the Midwest'. 'Because midges are such a major component of the wetland environment, it should not be surprising that they follow the general rules of most aquatic invertebrates: species diversity increases with structural diversity of vegetation, · species diversity increases with water permanence. However, species diversity may not be the best goal of water management designed specifically for shorebirds. For shorebird management, midge biomass, not diversity, should be the primary goal'. 'On refuges with more than one managed wetland, water regimes should be manipulated asynchronously so that in any given year some shorebird habitat is available during both spring and fall. No management is complete without some level of evaluation to determine whether midge larvae and shorebirds have responded as expected to the water management. An attempt should be made to census shorebird populations on the managed wetlands and to sample midge larvae in the wetland sediment'. '.The number of midge larvae per square meter of mud flat can be extrapolated from the simple count of larvae in the core sample. This number should be at least 100 midge larvae per square meter to successfully attract and hold shorebirds'. 'The management regimes outlined in this report need extensive trial, but, given what is known about shorebird and midge biology, they should prove helpful in attracting shorebirds to refuges'.

Ringelman, JK (1990) 'Fish and Wildlife Leaflet 13.4.4'. Habitat management for molting waterfowl. Waterfowl Management Handbook (USFWS): 'The process of feather renewal, or molt, is a critical event in the lives of birds. Despite the obvious importance of the molt, relatively little attention has been devoted to managing waterfowl during this period. Unlike most birds, ducks, geese, and swans share the unusual trait of a complete, simultaneous wing molt that renders them flightless for 3 to 5 weeks during the postbreeding period'. 'The common needs of all molting waterfowl are wetlands, adequate food resources, and security from predators and disturbance'. 'However, because wing length increases with body mass, the duration of the flightless period ranges from 25 to 32 days for all waterfowl. Most waterfowl are able to fly when their primary feathers are 75 to 85% of their final length. However, because species and sexes molt asynchronously, protection from disturbance should extend from the time that the earliest species begins incubation (assuming that breeding birds molt locally) until 3 weeks after the young of the latest-nesting species begin flying (Fig. 2). When geese and ducks are present in a mixed population, this period of protection would extend over 3.5 months'. 'Knowledge of the habitat requirements and nutritional demands of molting waterfowl is far from complete. We do recognize that during the flightless period, waterfowl are completely dependent on the resources of a single wetland for about 1 month. The fact that some waterfowl undertake molt migrations of hundreds of miles, while bypassing myriad other seemingly "suitable" wetlands along the way, suggests that wetlands used by molting waterfowl possess unique qualities that we do not yet recognize. Until we better understand the features that make such areas suitable for molting birds, such habitats should be protected or managed with care'.

Fredrickson & Reid (1988) 13.2.1. Waterfowl use of wetland complexes. Waterfowl Management Handbook (USFWS): 'Foods are only accessible if (1) appropriate water depths are maintained during critical time periods, (2) habitats are protected from disturbance, and (3) habitats that provide protein and energy are close to one another. Disturbance is particularly damaging, because it affects access to and acquisition of requirements throughout the annual cycle (Table 2, Fig. 2). The subtle effects of bird watchers, researchers, and refuge activities during critical biological events may be as detrimental to waterfowl populations as hunting or other water-related recreational activities (boating, etc.)'. 'Identification of the proportions of each wetland type within refuge boundaries, and the potential for management within each wetland type, is essential. Wetlands on private or other public property within 10 miles of the refuge boundary should also be used to estimate resources within the foraging range of most waterfowl. As wetlands are lost on areas surrounding refuges, managers will be able to identify special values or needs for certain habitat types on refuges. For example, producing only row crops on refuge lands in extensive areas of agriculture may be less valuable than supplying natural vegetation and associated invertebrates to complement these high-energy agricultural foods'. 'Where man-made or modified wetlands are managed, manipulations that emulate natural wetland complexes and water regimes provide diverse habitats for a variety of waterbirds. Well-timed, gradual changes in water level are effective approaches that provide good conditions for producing foods and desirable foraging depths for game and nongame birds. In fall, many southern habitats are dry, but having pools full before waterfowl arrive and maintaining pools at capacity until after their departure may reduce access to many resources by waterfowl'.

Brand et al (2014) Effects of wetland management on carrying capacity of diving ducks and shorebirds in a coastal estuary: [San Francisco Bay study area] 'Our results indicated that reducing salinity to mesohaline levels and altering water depth to increase accessibility substantially increased energy available for these species in estuarine managed ponds'. 'We assumed that diving ducks foraged in water depths between 0.5 and 2.5 m (Accurso 1992). Smaller shorebirds, such as Least and Western sandpipers, required depths greater than zero (i.e., not dry) and < 0.04 m, and larger shorebirds such as American Avocet and Black-necked Stilt foraged at depths < 0.18 m (Safran *et al*. 1997; Collazo *et al*. 2002)'. 'Water depth strongly influences habitat availability for particular species of waterbirds (Velasquez 1992; Safran *et al*. 1997; Taft *et al*. 2002; Dias 2009)'.

Collazo et al (2002) Accessible habitat for shorebirds: Factors influencing its availability and conservation implications: [a study in the USA] 'We confirmed the importance of shallow waters for Dunlin and Semipalmated Sandpiper--numbers increased with increasing availability of 0-4 cm habitat. At Merritt Island, Dunlin use was inversely related to variability in water depth of 0-4 cm. Minimizing the frequency and amplitude of water level fluctuations associated with single-capped culverts is necessary to improve habitat quality'. 'Most shorebird species require water depths of less than ten cm (Helmers 1992; Verkuil et al. 1993; Davis and Smith 1998). Clearly, the amount of accessible habitat is a function of the proportion of habitat at specified water depths. Thus, shorebird habitat conservation goals will benefit from understanding how water levels influence accessibility, and its implications for shorebird use and prey base. This relationship is important to reconcile waterfowl and shorebird habitat needs, particularly if both groups coincide in time and space'. 'National Wildlife Refuge Water Management Plans prescribe monthly water level targets, or staff water gauge readings, to meet conservation priorities set by the refuge biologist and manager. During 1998 and 1999, water levels were drawn down on a steady, yet arbitrary rate to maximize "shallow" habitat while monitoring shorebird numbers weekly'. 'Depth categories were 0 cm (i.e., dry substrate), moist substrate 0-4 cm, 4-8 cm, and >8 cm'. 'We focused on depth categories 0-4 and 4-8 cm because they were considered suitable for the shorebird assemblage using Pea Island NWR, and the former emerged as important at Merritt Island NWR for Dunlin (Weber and Haig 1996; Kelly 2000)'. 'Available habitat was defined as the mean number of hectares accessible in the 0-8 cm depth category. We broadened "accessibility" beyond 0-4 cm because many shorebirds, including Dunlin, can forage opportunistically in waters 4-8 cm deep'. 'Accessibility defined as proportion of habitat at moist to 4 cm in depth (0-4 cm)'. 'The adjustments reflect the sensitivity of small calidrids to shallow water depths, particularly 0-4 cm (see also Weber and Haig 1996; Davis and Smith 1998; Kelly 2000), ...' 'Shorebirds are capable of dealing with a certain degree of environmental uncertainty such as variability in water depth (see Colwell and Landrum 1993; Skagen and Knoptf 1994). Moreover, fluctuations might minimize the risk of prey depletion (Weber and Haig 1997b). In the specific case of Merritt Island, however, water depth varied dramatically and frequently, effectively excluding birds for days at a time (Kelly 2000). Therefore, it is recommended that measures be taken to minimize the frequency and amplitude of water level fluctuations. This could be accomplished using double-capped culverts, particularly useful to prevent uncontrolled inflow of water due to lunar, wind-driven or spring tides'. 'MANAGEMENT RECOMMENDATIONS 1) Establish the relationship between accessible habitat and water levels. Define the "bounds" or limits of water levels that will maximize accessible habitat at pre-selected depth categories without jeopardizing other management considerations (e.g., submerged aquatic vegetation) or risk of extensive, unusual substrate desiccation. 2) Water control structures are an integral part of impoundment management. In some cases, there might be a need to ameliorate the frequency and amplitude of water level fluctuations to avoid discouraging shorebird use (e.g., Merritt Island). ...'

Matuszak et al (2012) Exclosure study on the exploitation of macrophytes by summering and moulting waterbirds at Lower Lake Constance [in Europe] 'In these experiments, we found that the summering and moulting waterbird community, dominated by Eurasian Coots (*Fulica atra* Linnaeus), caused a significant decline of the macrophyte biomass at 1.5-m depth (MWL), where they were responsible for a loss of over 40% of the total charophyte biomass. No grazing effect was found at a greater depth (2-m MWL). The available food consisted mostly of *Chara* spp. with a biomass density of about 350 g m^{-2} '. 'In 2008, we counted birds in 5-day intervals and assessed the flying ability of a subset (10%) of individuals present of each species during the censuses to estimate the respective total number of flightless birds at the study site. Flightless birds were determined by the absence of primaries and secondaries which leads to a change in body shape (Do¨pfner & Bauer, 2008a)'. 'Many waterbirds use food resources similar to those used by resident fish, and waterbirds avoid lakes or ponds with high densities of fish (Reichholf, 1975; Hurlbert et al., 1986; Winfield & Winfield, 1994; Haas et al., 2007)’. ‘Coots were the most common species at the study site and contributed from 25 to 90% of the total number of birds present’. ‘Coots formed the majority of individuals moulting at the study site (Fig. 5)’.

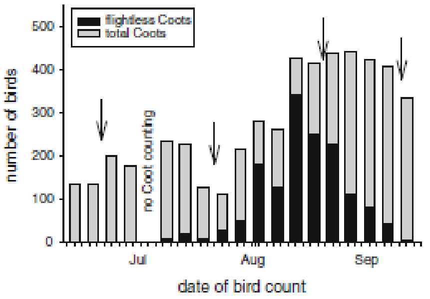


Fig. 5 Estimated numbers of flightless Coots at Mettnau Südbucht in 2008. Arrows mark the dates vegetation was sampled

‘Diving waterbirds prefer foraging in the shallowest waterwith adequate food supply (De Leeuw, 1997). Increasing water levels cause the waterbirds to switch to shallower sites (Von Krosigk & Ko¨hler, 2000)’. ‘Following precipitation, the water level at Lake Constance can rise within a few days, and the moulting and summering birds then have to dive deeper to reach adequately dense charophyte stands. Alternatively, the birds could switch to shallower sites where charophytes are less dense. Here, the energy gain could be smaller or competition with other birds higher. The tendency of decreasing water levels during summer makes it easier for birds to reach macrophyte stands of adequate density’. ‘Coots, the most numerous birds at Mettnau Su¨dbucht, preferably feed at depths \2 m (Bauer et al., 1973); ...’ ‘Coots preferred to forage at the shallower sites consistent with the conclusion of De Leeuw (1997) that waterbirds tend to dive with the least energy expenditure necessary to gain food’. ‘The daily consumption rate for Coots is *0.5–1.3% of the available biomass in shallow (\2 m deep) water (which is about 3,510 kg dry weight per ha). But, the damaging of grazing effect is much higher: the birds uproot more vegetation than they incorporate. Intensive grazing pressure leads to complete removal of charophytes which cannot easily be compensated (Torn et al., 2010). Secondary effects of bird grazing might also cause disadvantages to the plants, such as increasing turbidity due to foraging activity’.

Guillemain et al (2002) Ecomorphology and Coexistence in Dabbling Ducks: ‘All Anas species are morphologically similar, i.e. broad and elongated body with well- developed neck, and flat bill lined internally with lamellae. However, body length and lamellar density differ between species and these differences have been considered as the means by which duck species can coexist: because dabbling ducks almost never dive to forage, but may have to up-end to reach their food at the bottom of waterbodies, differences in body length allow species to segregate along a foraging depth gradient (Thomas 1982, P6ysa 1983, P6ysi et al. 1994, Green 1998)’. ‘Wintering dabbling ducks are not restricted to a single, body-size dependent foraging depth. Indeed, most studies have highlighted the great variability of foraging methods that is characteristic of wintering Anas (Thomas 1982, Dubowy 1988, Tamisier and Dehorter 1999). There is, however, evidence that dabbling ducks should preferentially select shallow foraging methods (i.e. only the bill submerged, eyes above the water surface), since these provide higher food intake rates and allow them to limit vigilance times through a greater ability to detect predators while foraging (Pbysi 1987, Guillemain et al. 2000, 2001). In the Reserve Naturelle des Marais d'Yves, in the Marshes of Rochefort, Western France (45'60'N, 01OOW), scan samples of duck behaviour showed that both mallard and teal foraged predominantly in shallow water at the beginning of winter, but that mallard subsequently switched to deeper foraging (their mean foraging depth [MFD] increased at an increasing rate across weeks ... while teal did not [Fig. 1]’. ‘It is likely that food depletion is the main cause for the foraging depth/seed size switches that we observed. Both species should first use large seeds in shallow areas, which provide the highest food intake rates, and turn to alternative strategies when these resources become exhausted’. ‘As this problem is likely to be widespread in duck wintering quarters, experiments with captive mallard and teal seem to be the most convenient direction for future research; such experiments have already shown, in mallard, that food depletion is indeed responsible for birds switching from shallow to deep foraging (Guillemain et al. 2000). It remains to be established whether depletion of larger seeds also leads teal to concentrate on smaller food items’. ‘In such a case, mallard and teal appear to select the food and foraging method which previous studies have found to be the most profitable in terms of energy intake and cost of vigilance’. **References:** Guillemain, M., Duncan, P. and Fritz, H. 2001. *Switching to a method which obstructs vision increases head-up vigilance in dabbling ducks.* - J. Avian Biol. 32: 345-350. P6ysd, H. 1987. *Feeding-vigilance trade-off in the Teal (Anas crecca): effects of feeding method and predation risk.* - Behaviour 110: 306-318.

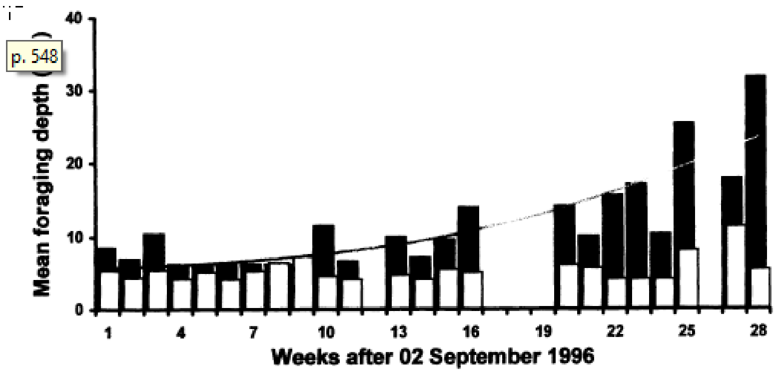


Fig. 1. Mean foraging depth of mallard (black bars, grey curve) and teal (white bars) at Yves during the winter 1996–1997 (data after Guillemain and Fritz 2002). The mean foraging depth of each species was calculated for each study day after the average proportion of birds using a given foraging method and the mean reachable depth by this species using this method (body measurements after Thomas 1982).

Bolduc & Afton (2008) Monitoring waterbird abundance in wetlands - The importance of controlling results for variation in water depth. 'In non-diving waterbirds, variation in morphological features, such as bill length and shape, bill lamellae distance, neck length, leg length, and body size, allow species to forage at different depths and on different foods (Baker, 1979; P¨ oys¨ a, 1983; Nudds and Bowlby, 1984; Zwarts and Wanink, 1984). Accordingly, water depth is paramount in explaining waterbird density, and determining whether or not habitat is available; waterbird diversity generally is highest at low water depth and correlated to hydrological diversity (Powell, 1987; Taft et al., 2002; Bolduc and Afton, 2004a; Kingsford et al., 2004; Robertson and Massenbauer, 2005; Holm and Clausen, 2006)' 'Researchers who have examined the influence of water depth on the abundance of non-diving waterbirds generally report the average water depth used by each species (Weber and Haig, 1996; Safran et al., 1997; Isola et al., 2000) or the range of water depths used (Davis and Smith, 1998; Ntiamoa-Baidu et al., 1998). The relationships of water depth and several biotic components of wetlands previously have been analyzed in several ways. For example, variation in bird abundance and water depth sometimes are analyzed separately and their relationship discussed afterward (e.g., Connor and Gabor, 2006). Also, water depth may be transformed into categories (ranges) and the latter compared (Hoover, 2006)'. '[Step] 3 Data analysis a. Compute mean bird abundance by 1-cm water depth class (including zeros) over all counts and habitats. b. Model mean bird abundance by 1-cm water depth vs. water depth using LOESS regression with quadratic function for local regressions'.

Ma et al (2010) Managing Wetland Habitats for Waterbirds - An international perspective.

Water Depth: 'Water depth directly determines the accessibility of foraging habitats for waterbirds because of the restrictions of bird morphology, such as the lengths of tarsometatarsi (for wading birds, Powell 1987; Baker 1979; Ntiamoa-Baidu et al. 1998; Collazo et al. 2002; Darnell and Smith 2004) or necks (for dabbling ducks, Poysa 1983). Larger species with longer necks, bills, and legs can feed in deeper habitats than smaller taxa. Non-diving waterbirds, such as wading and dabbling birds, generally require shallow water to forage, and their access to foraging habitat is limited by water depth. In contrast, diving waterbirds require deep water, and their access to foraging habitat is limited by the minimum water depth that allows them to dive **(Fig. 1).** Because the wading and dabbling birds are the dominant waterbird groups in most regions worldwide, the greatest waterbird diversity and density generally occur at a relatively shallow water depth, where the depth requirements of different waterbird groups overlap (e.g., 10–20 cm, Elphick and Oring 1998, 2003; Colwell and Taft 2000; Isola et al. 2002; Taft et al. 2002). Habitats with deeper water, however, support the greatest density of waterbirds in areas where diving birds are dominant (Stapanian 2003), and where the wetlands provide roosting sites for waterfowl (Hattori and Mae 2001). From a management perspective, the overlapping of water depth requirements among waterbird groups suggests that wetlands can be managed to meet the water depth needs for different waterbird groups. At the same time, it may be necessary to manage wetlands exclusively for species associated with the extreme ends of the depth spectrum (e.g., diving waterbirds and small shorebirds), especially where such species constitute a large component of the waterbird community (Taft et al. 2002). In addition to limiting access to foraging habitats, water depth affects the net energy intake of waterbirds because foraging efficiency decreases with increasing water depth. Gawlik (2002) indicated that for wading birds that forage on prey in the water column, the locomotion of the birds might be slowed in deep water because of increased water resistance with depth. Moreover, deeper water can also reduce foraging efficiency because prey can escape not only horizontally, as is the case in shallow water, but also vertically. In addition, prey in deep water may be more difficult to detect, especially if the water is turbid. Consequently, drawdown can increase the foraging efficiency of wading birds by concentrating fish and other prey in limited, low-lying areas (Kushlan 1978; Bancroft et al. 2002; Sustainable Ecosystems Institute 2007). Foraging efficiency for the non-diving herbivores may also be reduced in deeper water. When foraging in shallow water, these birds feed by dipping their heads and necks only (neck-dipping), but when feeding in deeper water, they must tilt their entire body forward (up-ending). The latter results in a lower food intake rate and higher energy expenditure (Guillemain and Fritz 2002; Nolet et al. 2002). This suggests that waterbirds obtain a higher net energy intake in shallow than deep water, even with the same food abundance. Holm and Clausen (2006) also indicated that non-diving herbivores prefer foraging submerged vegetation in shallow water until depletion, even when food is more abundant in deeper water. Because larger species of waterbirds generally have longer necks, bills, and legs, they usually can access greater range of water depths than smaller species (Baker 1979; Isola et al. 2002). The range of accessible water depths also depend on foraging behavior. Compared to shorebirds, waterfowl can use diverse foraging behaviors (such as surface dabbling, tipping-up, and head-submerging), each of which is suitable for foraging at a different water depth (Isola et al. 2002). Therefore, waterfowl and large wading birds can use a wider range of water depths than small shorebirds.

Water Level Fluctuation: Water level fluctuation in wetlands can be caused by seasonal flooding, tides, and agricultural irrigation or drawdown. The effect of water level fluctuation on waterbirds varies among groups and seasons. Generally, water level fluctuation creates habitats with diverse water depths changing in time and space. This provides more foraging opportunities and consequently supports a high species richness and abundance of waterbirds (Dimalexis and Pyrovetsi 1997; Ntiamoa-Baidu et al. 1998). Water level fluctuation, however, may create “ecological traps” and be detrimental for the breeding, brood-rearing, and molting of waterbirds (Kaminski et al. 2006). For example, breeding attempts are abandoned when water rises submerge nests and water drops make birds more vulnerable to mammalian predators after nesting. Many studies have shown that the brood densities of waterbirds are greater on wetlands with stable water levels than on seasonally flooded wetlands because stable water level benefits the breeding of waterbirds by providing suitable nest sites (e.g., Ogden 1991; Connor and Gabor 2006). Impoundments with stable water level also can attract more dabbling ducks than intertidal flats with periodic tidewater (Gordon et al. 1998), although shorebirds may prefer the latter.

Vegetation: Beyond providing food such as seeds, leaves, tubers, and rhizomes for herbivorous waterbirds, vegetation is an important habitat element and greatly influences the habitat use of waterbirds. ...’ ‘Dimalexis and Pyrovetsi (1997) also indicated that fish-eating waterbirds, such as herons and egrets, avoid foraging in water bodies with submerged vegetation because of the reduced efficiency in searching for prey’.

Salinity: Salinity is an important factor in the management of salt ponds for waterbird habitats. Generally, water of high salinity is harmful to waterbirds. ...’ ‘The different responses of various invertebrates to water salinity means that the preferred water salinity at foraging sites of waterbirds varies with waterbird group and prey composition’. ‘All these suggest that, in saline environments, regulating water salinity according to the prey of waterbirds is critical in supporting foraging habitats for diverse waterbirds’.

Food and Its Accessibility to Waterbirds: ‘Waterbirds use diverse foods, including seeds (dabbling ducks, geese, cranes), leaves (geese), tubers and rhizomes (geese, swans), invertebrates (shorebirds, waterfowl), and some vertebrates, such as fish and amphibians (wading birds)’. ‘Food preferences of waterbirds can vary greatly among species, even among those within the same group. For example, on ...’ ‘Food accessibility to waterbirds depends on both intrinsic and extrinsic factors. Intrinsic factors include bird morphology (neck length, leg length, body size, and feeding structures), foraging methods, and diet selectivity. Extrinsic factors include water depth, vegetation density, and prey vulnerability’.

Wetland Size: ‘Generally, waterbird species foraging close to the shore persist in both large and small ponds and are considered area-independent species, while species foraging in open and deep-water habitats are considered area-dependent species and are restricted to relatively large ponds (Paracuellos 2006). A recent review paper indicated that area sensitivity was detected in about. half the wetland species studied (Bayard and Elphick, unpublished data)’. ‘Although the total size of a wetland determines waterbird diversity, the size of accessible habitat is more crucial in determining the suitability of the wetland for a particular waterbird group (Gawlik 2002)’.

Wetland Connectivity: ‘Generally, an individual wetland seldom meets all the requirements (foraging, resting, roosting, nesting sites, etc.) of diverse waterbirds’.

Other Habitat Variables: ‘In addition to the habitat variables mentioned previously, other variables related to the characteristics of sediments (e.g., organic matter content and particle size) and water quality (e.g., clarity, temperature, dissolved oxygen, and pH) can also directly or indirectly affect the use of wetlands by waterbirds. For example, the ...’ ‘Kersten et al. (1991) have demonstrated that the dissolved oxygen in the water affects the foraging of waterbirds by changing the vertical distribution of prey. At their study site in Camargue, France, the nocturnal respiration of macrophytes depleted the dissolved oxygen in the surrounding water, which forced the mosquito fish (Gambusia spp.) to concentrate at the surface in open water during early morning. ...’.

Implications for Management of Wetlands: The variation in habitat requirements among waterbird species and groups suggests that wetland management must be based on the region-specific knowledge about waterbird communities, including the species and their abundances and habitat requirements. The managers also need to understand the seasonal dynamics of waterbirds, so that management can be timed to meet the special needs of breeding, stopover, and wintering periods (Isola et al. 2002; Parsons 2002). However, because different waterbird species have various, and even contrasting, habitat requirements, the same management measures could have completely different effects on different species and groups (Craig and Beal 1992; Mitchell et al. 2006). This suggests that management solutions benefiting all species may not exist (Stralberg et al. 2009). Consequently, optimal wetland management to multi-species comes from assessing priorities and trade-offs among different species and groups of conservation concern (Elphick 2004; Thébault et al. 2008; Stralberg et al. 2009). Many studies have indicated that hydrology is the most important variable ....’. ‘Habitat use, however, might not correctly reflect the habitat requirements of waterbirds or the quality of wetland habitats (van Horne 1983). Future research should assess habitat requirements and quality in terms of net energy acquired, time budgets of different behaviors, and population demographics (e.g., nesting and breeding success, survival rate) of waterbirds’.

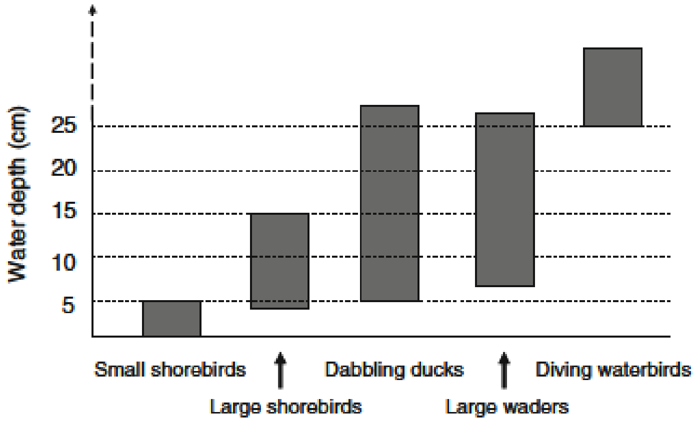


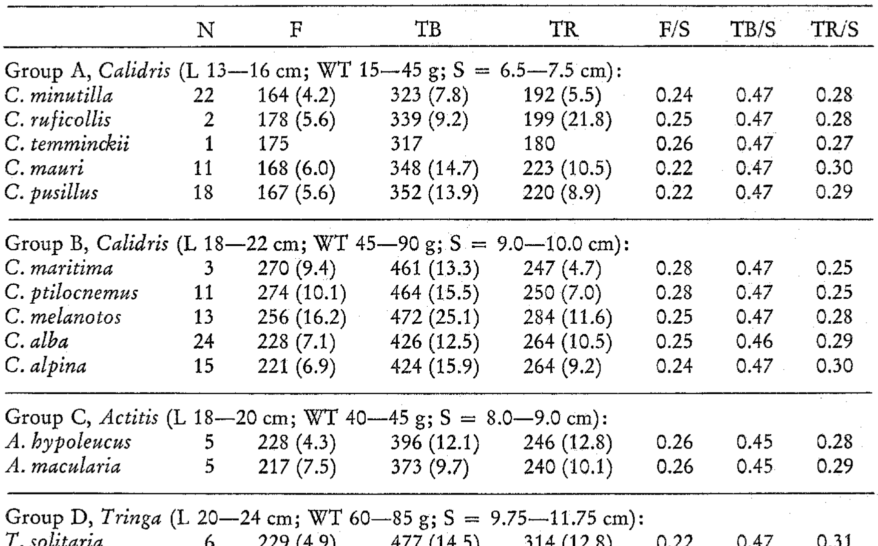
Fig. 1 Variation of water depths at foraging sites among waterbird groups. Small shorebirds (such as sandpipers) forage in water less than 5 cm deep; large shorebirds (such as godwits) forage in water up to 15 cm deep; dabbling ducks (such as teals and mallards) and large waders (such as herons, egrets and ibis) forage in water up to 30 cm deep. Diving waterbirds (such as cormorants and grebes) require a minimum water depth of >25 cm and can forage in water up to several meters deep (Refer to data in Pöysä 1983; Baldassarre and Fischer 1984; Fredrickson and Reid 1986; Accurso 1992; Davis and Smith 1998; Elphick and Oring 1998; Ntiamoa-Baidu et al. 1998; Colwell and Taft 2000; Isola et al. 2002; Bolduc and Afton 2004)

Accurso LM (1992) Distribution and abundance of wintering waterfowl on San Francisco Bay, 1988–1990. MS thesis, Humboldt State University, Arcata, CA [PDF NOT FOUND].

X. LEG MORPHOLOGY OF WATERBIRDS

Rylander (1980) measured the lengths of the femur (F), tibiotarsus (TB) and TR were measured in 158 specimens representing 6 genera and 21 species in the family Scolopacidae. The representation of males and females was about the same for each species, although the sex was unknown in some cases. The measurements of 15 species were presented in Rylander’s Table 1, together with the ratios F/S, TB/S, and TR/S, where S = F+TB+TR.

Table 1. Mean Lengths of Femur (F), Tibiotarsus (TB) and Tarsometatarsus (TR). S = F + TB + TR. Unit of measurement, 0.1 mm. Standard deviations in parentheses. No. of males and females represented in each sample approximately equal.



	N	F	TB	TR	F/S	TB/S	TR/S
Group A, *Calidris* (L 13—16 cm; WT 15—45 g; S = 6.5—7.5 cm):							
C. minutilla	22	164 (4.2)	323 (7.8)	192 (5.5)	0.24	0.47	0.28
C. ruficollis	2	178 (5.6)	339 (9.2)	199 (21.8)	0.25	0.47	0.28
C. temminckii	1	175	317	180	0.26	0.47	0.27
C. mauri	11	168 (6.0)	348 (14.7)	223 (10.5)	0.22	0.47	0.30
C. pusillus	18	167 (5.6)	352 (13.9)	220 (8.9)	0.22	0.47	0.29
Group B, *Calidris* (L 18—22 cm; WT 45—90 g; S = 9.0—10.0 cm):							
C. maritima	3	270 (9.4)	461 (13.3)	247 (4.7)	0.28	0.47	0.25
C. ptilocnemus	11	274 (10.1)	464 (15.5)	250 (7.0)	0.28	0.47	0.25
C. melanotos	13	256 (16.2)	472 (25.1)	284 (11.6)	0.25	0.47	0.28
C. alba	24	228 (7.1)	426 (12.5)	264 (10.5)	0.25	0.46	0.29
C. alpina	15	221 (6.9)	424 (15.9)	264 (9.2)	0.24	0.47	0.30
Group C, *Actitis* (L 18—20 cm; WT 40—45 g; S = 8.0—9.0 cm):							
A. hypoleucus	5	228 (4.3)	396 (12.1)	246 (12.8)	0.26	0.45	0.28
A. macularia	5	217 (7.5)	373 (9.7)	240 (10.1)	0.26	0.45	0.29
Group D, *Tringa* (L 20—24 cm; WT 60—85 g; S = 9.75—11.75 cm):							
T. solitaria	6	229 (4.9)	477 (14.5)	314 (12.8)	0.22	0.47	0.31

TB+TR/TR	0.5*TB+TR/TR
2.68	1.84
2.70	**1.85**
2.76	1.88
2.56	1.78
2.60	1.80
2.88	1.93
2.86	1.93
2.66	**1.83**
2.61	1.81
2.61	1.80
2.61	**1.80**
2.55	1.78
2.52	1.76
2.49	1.74
2.38	**1.69**

Four of the species of Table 1 have been recorded on Vasse-Wonnerup: Species examined include the following that have been recorded on Vasse-Wonnerup: Red-necked Stint *Calidris ruficollis*, Pectoral Sandpiper *Calidris melanotos*, Common Sandpiper *Calidris (now Actitis) hypoleucos* and Wood Sandpiper *Tringa glareola*.

While TB/S (range 0.45–0.47) varied little between species, F/S (0.21–0.28) and TR/S (0.25–0.33) varied considerably. Rylander suggested that the differences in TR/S between some species in each group could be explained by differences in habitat preferences and behaviours.

The ratio TB+TR/TR is useful in considering the relationship between tarsus length and 'belly deep'. Illustrations such as those of Kilbourne *et al.* (2016) suggest that 'belly deep' is at most TR plus half of TB length. In the case of the Scolopacidae measured by Rylander (*ibid.*) this amounts to 1.69-1.93 of TR. BUT PHOTOS SUGGEST THE RELATIONSHIP IS EXTREMELY VARIED. COULD USE PHOTOS TO COMPARE RATIOS OF TARSUS TO 'BELLY DEEP' FOR A SAMPLE (ALL?) V-W WATERBIRD SPECIES (measure from photos: 1. tarsus, 2. 'knee' joint to leg feathering, 3. 'knee' joint to belly, and 4. ground to 'knee' joint (vertical), 5. ground to leg feathering (vertical), 6. ground to belly (vertical) (and 4-6 from 'ankle' rather than ground?).

Rylander, M.K. (1980). *The ecological significance of tarsometatarsal [i.e. tarsal] length in Sandpiper.* Journal of Ornithology 121: 180-185.

'The allometric relationship between the femur and the remaining leg length (tbt + tmt; Fig. 4) [tibiotarsus, tarsometatarsus] indicates that relatively long-legged birds have relatively shorter femurs compared to short-legged species. This result fits our prediction that the length of femur is limited and restricted by the size of the body. Furthermore, the negative partial correlation between (tbt - tmt) and total leg length means that the tibiotarsus and the tarsometatarsus become increasingly similar in lengths with increasing leg length. This supports Storer's (1960) prediction that long-legged birds need to maintain stability when crouching. The above results indicate that there may be some general selection pressures on the legs of birds associated with leg length',
and
'The species of the Wading group were predicted to have a higher leg length index than was expected by the norm to increase the available foraging area, and this is indeed the case. We also predicted that the tmt index should be high in relation to the norm to reduce the cost of protracting the leg by lifting the tarsometatarsus out of the water. This was not confirmed, although there is a trend in that direction (*P* = 0.055)' (Zeffer *et al.* 2003).

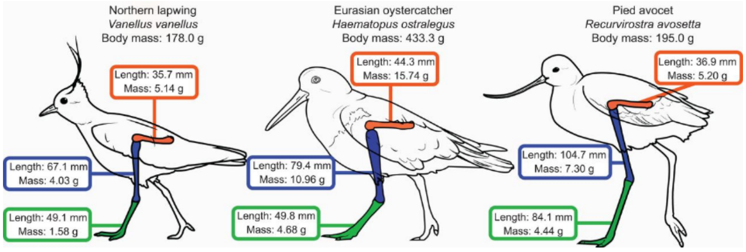
'Appendix 2. Lengths (mm) of the three largest skeletal bone elements of the leg, femur (fem), tibiotarsus (tbt) and tarsometatarsus (tmt). Each row represents one individual. The measurements are based on material from the collections of Swedish museums (see text)'. [All Vasse-Wonnerup species – only] (Zeffer *et al.* 2003).

	fem	tbt	tmt
Anas superciliosa	47.0	73.8	40.3
Anas superciliosa	50.8	77.4	41.3
Anas superciliosa	54.0	84.3	45.5
Anas superciliosa	53.9	83.9	47.7
Fulica atra	53.9	91.3	56.1

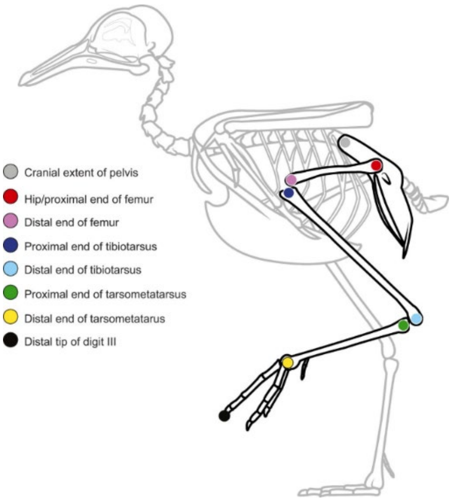
Fulica atra	58.4	100.0	61.0
Fulica atra	58.0	101.6	62.3
Phalacrocorax carbo	56.2	100.1	60.4
Phalacrocorax carbo	58.1	102.7	61.7
Phalacrocorax carbo	56.2	103.2	62.1
Phalacrocorax carbo	61.3	108.8	63.8
Phalacrocorax carbo	61.1	108.1	65.4
Phalacrocorax carbo	62.1	110.3	66.1
Phalacrocorax carbo	65.5	114.9	66.5
Phalacrocorax carbo	61.5	109.6	67.1
Phalacrocorax carbo	66.1	116.5	67.5
Phalacrocorax carbo	67.3	117.5	70.4

Zeffer, A., Johansson, L.C. & Marmebro, A. (2003). *Functional correlation between habitat use and leg morphology in birds (Aves).* Biological Journal of the Linnean Society 79: 461-484.

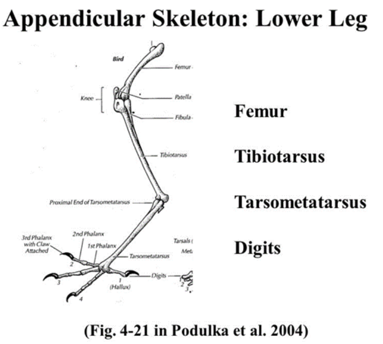
The TARSOMETATARSUS is the bone of the 'TARSUS'.



Kilbourne, B.M., Andrada, E., Fischer, M.S. & Nyakatura, J. A. (2016). *Morphology and motion: hindlimb proportions and swing phase kinematics in terrestrially locomoting charadriiform birds.* J. Exp. Biology 219: 1405-1416. [DOWNLOADED 21ST NOV 2017].



Kilbourne, B.M., Andrada, E., Fischer, M.S. & Nyakatura, J. A. (2016). *Morphology and motion: hindlimb proportions and swing phase kinematics in terrestrially locomoting charadriiform birds.* J. Exp. Biology 219: 1405-1416. [DOWNLOADED 21 NOV 2017].



Appendicular Skeleton: Lower Leg

Femur

Tibiotarsus

Tarsometatarsus

Digits

(Fig. 4-21 in Podulka et al. 2004)

X. WIND EFFECTS

'Models predicting tidal flat area were more effective if the measured height of lowest tide (not predicted height of lowest tide) was used as the dependent variable (Table 10). This was because although the height of the observed lowest tide was significantly related to predicted lowest tide, it was far from identical. In Williamstown tide data collected continuously from 2000 to 2009, predicted lowest tide height only explained 48.8% of the variation in observed tide height. (Observed lowest tide height = 1.30 + 0.90 x Predicted tide height, $n = 6307$, $R^2 = 0.488$, $P < 0.001$.) The discrepancies are thought to be driven by wind conditions, which can have a considerable influence on observed water height in confined shallow embayments such as Port Phillip Bay with a tidal range of only ~1 m' (Rogers *et al.* 2013).

Rogers, D.I., Loyn, R.H. & Greer, D. (2013). *Factors influencing shorebird use of tidal flats adjacent to the Western Treatment Plant.* Arthur Rylah Institute for Environmental Research Technical Report Series No. 250. Department of Sustainability and Environment, Heidelberg, Victoria.

'The tidal flats of the WTP are not particularly extensive, mainly because Port Phillip Bay has a restricted tidal range of about 1 m. Moreover, with such a small tidal amplitude, wind conditions can also have a strong effect on water levels at the shoreline, with southerly winds driving water levels higher' (Rogers *et al.* 2013).

Taylor, I.R. & Taylor, S.G. (2005) *The effect of wind on the foraging behaviour of Black-winged Stilts in SE Australia.* Wader Study Group Bulletin 106, 47–50.

Verkuil, Y., Koolhaas, A. & Van Der Winden, J. (1993). *Wind effects on prey availability: how northward migrating waders use brackish and hypersaline lagoons in the Sivash, Ukrain.* Netherlands Journal of Sea Research 31: 359-374.

3. PUBLISHED FORAGING DEPTHS OF VASSE-WONNERUP SPECIES

Waterbird species recorded on Vasse-Wonnerup, and for which there are published accounts of measured foraging depths, are listed below, in taxonomic order, together with details relating to those published depths. For a complete list of Vasse-Wonnerup species, including those for which no published measurements of foraging depths have been found, see Appendix 1. For general descriptions of feeding behaviours of all species see HANZAB. For waterfowl (ducks, geese and swans) and shorebirds also see Frith (1982), [Lane? …………]

Ducks & allies Family Anatidae

Musk Duck *Biziura lobata*

HANZAB (Marchant & Higgins 1990) ''Rarely seen on land; can walk but clumsily with pronounced waddle and upright stance using stiff tail as prop. Slither over obstacles on land or in water …' and 'Dive readily, slipping below the surface with hardly a ripple' and 'Most characteristic feeding method is diving' and '[will] peck at water-surface for insects' and '[Habitat] Widespread in se. and sw. parts of continent, on terrestrial wetlands, estuarine habitats and sheltered inshore waters. Almost entirely aquatic …' and 'Expert diver; recorded diving in water 6 m deep, probably reaching bottom (Frith 1982). Rarely on land' and 'Obtain food by diving in deep water to at least 6m. Usually dives 25-30 s (max 60 s)' and 'Also take food from surface and peck at overhanging vegetation (Frith 1982). Occasionally emerge from water in parks to take bread, walking with difficulty, supported by tail (Seyfort 1984; Coscarelli 1988)'.

Musk Duck are large-bodied diving ducks, anatomically specialised for underwater swimming. ~~While their diving depths do not appear to have been studied specifically, they are thought to dive to at least 6m (Frith 1982).~~ During their attempts to capture Musk Duck at night 'in clear water, 1-3m deep', at Murray Lagoon in South Australia, McCracken *et al.* (2003) found that they 'typically swam underwater for … great distances (50-100m) before re-surfacing'.

'Throughout their juvenile period they are fed by the female, probably entirely when very young but with decreasing regularity as they grow older' and The female dives and surface carrying food in the bill; the young approach with their food-begging cry and remove it' (Frith 1982).'

Sedgwick (1954) reported the dive times (average c. 60 seconds) of a single male Musk Duck at the Victoria Reservoir near Perth. The depth of water where the bird was diving was estimated by an observer who had seen the reservoir empty to be 'about 40 feet [12.2m]'.

Osterrieder *et al.* (2014) reported 608 dives by 65 foraging Musk Ducks, apparently to the bottom of (uniformly) 2m deep, steep-sided ponds in Victoria.

Musk Duck have also been observed foraging in shallow water, 'dredging with their heads and necks under the surface', at Barrenbox Swamp NSW (Gamble 1966).

HANZAB (Marchant & Higgins 1990) reported Musk Duck tarsus lengths (means) of 52.6mm (males; n=7) and 44.8mm (females; n=5) significant diff.

Black Swan *Cygnus atratus*

HANZAB (Marchant & Higgins 1990) 'Feed by upending or plucking vegetation from below or on water surface' and 'On land, slow rolling gait; may graze on waterside pasture' and 'feed in shallow or deep open water, on wetland margins, exposed mudflats, or ashore, wherever floating or submerged aquatic plants, emergent vegetation or soft terrestrial herbage can be reached (Frith *et al.* 1969; Loyn 1975; Briggs 1979)' and 'Terrestrial habitats used especially when flooded or moist; dry ground usually avoided' and 'Use of underwater habitat limited to depths reached by up-ending; *c.* 1 m (Frith *et al.* 1969)' and 'Food taken mainly while swimming, either at surface or from bottom, up-ending in deep water to reach depths down to 1 m. Occasionally stand in shallow water while feeding from bottom or water surface or graze on land'.

Smith *et al.* (2012): 'They [Black Swans] generally prefer to feed on actively growing plant parts (Mitchell & Perrow, 1998) and in New Zealand, they have been observed to include the rhizomes of seagrass in their diet (Dixon, 2009). They are not known to feed on tubers, and the ingestion of invertebrates is thought to be incidental (Marchant & Higgins, 1990)'. 'There [in NZ], while their grazing was thought to reduce macrophyte dominance (Mitchell & Wass, 1996), it was thought not to affect algal biomass (Wass & Mitchell, 1998)'. 'The swans were observed to graze from an existing pool of open water of at least 40 cm water depth in the eastern part of the wetland, westward into shallower areas where they swam and grazed. By June, they were grazing while walking in very shallow water away from trees. The swans were observed to break off the soft green stems of *E. equisetina* above the water, ingesting at least some of these stems, and were rarely observed feeding with their heads below water' 'Swans apparently preferred to graze where the water was deeper, and by the end of winter had grazed most of the vegetation above the water line where the depth of water was consistently at least 20 cm. The possible preference for deeper water was suggested in grazing patterns and entrance to exclusion plots through small openings in the mesh, in preference to feeding on the abundant vegetation unhindered by fences in nearby shallow areas. However, swans may exercise this preference only when their densities are low, as they grazed through shallower areas of the wetland in 2006 when their densities were higher and water levels were lower. Similarly, the lack of grazing below water here suggests that the otherwise common practice of foraging with heads under water (Marchant & Higgins, 1990) was not a preferred or necessary habit here at this time. Swans are likely to prefer deeper water for various reasons. Deeper water provides safety from groundbased predators, namely, the European Fox *Vulpes vulpes* L. at night and the domestic dog *Canis familiaris* L. during the day. Although these potential predators occur in low numbers, probably just one or two at the wetland at any given time, they pose a continuous and unpredictable risk on dry land and in shallow water. Swans are particularly at risk here during flightless stages such as juveniles or moulting adults. A preference to eat while swimming (Marchant & Higgins, 1990) would also result in swans favouring sufficiently deep water to avoid walking, which may be energetically more demanding'. 'Habitat choice and food preferences can be influenced by other site variables, such as distances from objects associated with the wetland, such as trees, other vegetation types, roads, open water and the nests or roosts of predators (Middleton, 1992). The grazing in shallow areas in 2006 away from trees could be explained by an avoidance of potential tree-perching predators, such as the Wedge-tailed Eagle *Aquila audax* (Latham)'. 'Other research on wetlands of the Clarence River floodplain (Smith, 2010) has shown that foraging Black Swans occurred in highest numbers on wetlands with higher surface areas of intermediate water levels (20–50 cm), while fewer occurred on deeper water (>100 cm), where there is little or no attached vegetation, and even fewer on wetlands with consistently low water levels (<20 cm)'.

Paton, PA (1986) 'It is known that black swans *Cygnus atratus* in the southern Coorong feed extensively on the leafy parts of *Ruppia* (Delroy *et al.* 1965)'.

Black Swan 'occasionally stand in shallow water while feeding from bottom or water surface or graze on land' ((HANZAB (Marchant & Higgins 1990)), however this has not been observed on Vasse-Wonnerup. Paton *et al.* (2011) were unable to determine the water depth(s) where swans were foraging (n=1365) in the Coorong in January 2011 as 100% of the birds were swimming, rather than standing or walking. It can, however, be deduced from their observations that all foraging was in water depths greater than 'belly deep', which can be calculated as >(2 x male tarsus length) = >(2 x 100mm), that is >20cm.

Black Swans do not dive, but may forage by 'upending'. The greatest depth that they can reach is probably (pers. obs.) about half their body length, plus their neck and total head length, and has been estimated at 1m (Marchant & Higgins 1990) ~~Obtain and compare Frith 1982~~. DONE ->. 'the birds [Black Swans] can secure food only to about one metre below the surface, so abundant aquatic vegetation growing up to this level is essential to support a permanent population' (Frith 1982). 'in deep water it up-ends, reaching food over a metre below the surface' (Frith 1982). 'owing to their smaller size and shorter neck, they are unable to secure food from such deep water as the adults' and 'When living in deeper water they largely depend on their parents to uproot the bottom-growing plants, ...' (Frith 1982).

Under the heading 'Field Identification', HANZAB (Marchant & Higgins 1990) write 'Length 110-140cm of which head and neck about half'. On this basis, the maximum depth reached by an up-ending swan might be estimated as 0.75 x (110–140) = 82–105cm, which is in reasonable agreement with the Marchant & Higgins estimate of 1m.

Frith (1967/77, 1982) reported mean total lengths ('The length recorded for each species is the straight line distance from the tip of the bill to the tail-tip' (Frith 1982, p. xiii)) of 1292mm (range 1175–1423, n=244) for adult males and 1161mm (range 1065–1300, n=219) for adult females. On this basis, the maximum depth reached by average-sized, up-ending, adult swans might be estimated as 0.75 x 1292 = 969mm (males) and 0.75 x 1161 = 871mm (females), which is a little less than the HANZAB (Marchant & Higgins 1990) estimate of 1m. Juveniles?

Measurements from side-on photographs of Black Swans in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.722 (n=5). Application of this ratio to the Black Swan total lengths of Frith (1967/77, 1982) results in 'maximum reach' estimates of 0.722 x 1292 = 933mm (males) and 0.722 x 1161 = 838mm (females).

In a study of swan foraging in Golden Bay, NZ, Dixon (2009) concluded inter alia that 'the most common feeding mode employed by the swans was ... head and neck submerged while floating on the water'. The swans also foraged by up-ending, 'when feeding in water deeper than the neck plus half the body length', however this behaviour was rare.

Mean adult male and adult female neck lengths were reported by Frith (1967/1977, 1982) as 782mm (range 702-880, n=194) and 675mm (range 572-765m, n=103) respectively, while HANZAB (Marchant & Higgins 1990) reported total head lengths (back of skull to tip of bill) of 141.4mm (range 136.2-145.2, n=6) for males and 129.6mm (range 127-133.2, n=6) for females. Summation produces mean adult 'neck plus total head' lengths of 923mm (males) and 805mm (females). Using these figures, maximum depth reached by average-sized adult swans might be estimated as 1.5 x 923 = 1384mm (males) and 1.5 x 805 = 1208mm (females), which are substantially in excess of the Marchant & Higgins estimate of 1m. Juveniles? SEPARATE MALES AND FEMALES REACH.

HANZAB (Marchant & Higgins 1990) reported Black Swan tarsus lengths (means) of 94.5mm (males; n=5) and 89.2mm (females; n=6). ~~On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 19cm (males) and c. 18cm (females).~~

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.42. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 13.4cm (males) and c. 12.7cm (females).

Australian Shelduck *Tadorna tadornoides*

HANZAB (Marchant & Higgins 1990) 'Feed in evening and early mornings by grazing at water margins or by up-ending in water. Walk fast and strongly' and 'On water, swim buoyantly and well, only diving to escape predators during moult when flightless' and 'Equally at home in terrestrial and aquatic habitats, grazing on dry-land plants or aquatic plants in shallow water or on mudflats or shores' and 'Swim well, but rarely dive; on water, feeding only where bottom can be reached from surface' and 'Employ many feeding techniques such as grazing, surface-dabbling, upending in shallow water, paddling, sifting biotic ooze, combing shorelines and other opportunistic behaviour'.

Australian Shelducks employ many foraging techniques from grazing on land, to surface dabbling while walking on damp sediments, to up-ending in deeper waters (Marchant & Higgins 1990). They are not known to dive for food.

Paton (2010) observed that 'Within the Coorong, Grey Teal, Chestnut Teal, Australian Shelduck and Pacific Black Duck ... largely forage by dabbling in shallow water where they can stand, or if in deeper water, forage by up-ending so that they can reach plant material below the surface'.

Paton, PA (1986): 'In 1965, Delroy (1974) set out to establish the importance of these two plants to waterfowl in the Coorong. From March 1965 to January 1966, he collected the contents of oesophagi and stomachs from three species of duck [Grey Teal, n=36; Chestnut Teal, n=7; Australian Shelduck, n=14] in the South Lagoon of the Coorong. The results demonstrate an almost total dependence on turions and seeds of *Ruppia* sp. and tubers of [*Lamprothamnium*] *papulosum* during the summer months. The foliage of *Ruppia* and seeds of *Lepilaena cylindrocarpa* were minor components of the diet'.

Paton *et al.* (2011) observed that shelducks were foraging (n=998) in the following water depths in the Coorong in January 2011: 'damp' 4%, 'ankle' 11%, 'half knee' 1%, 'knee' 1%, 'swim' 83%. From this we can deduce that while 15% of birds were foraging in depths of 0cm to ≈1cm, 83% were foraging in water depths greater than 'belly deep', which can be calculated as > (2 x male tarsus length) = > (2 x 65mm), that is > 13cm.

Frith (1967/77, 1982) reported mean total lengths of 673mm (range 590-720, n=68) for adult males and 610mm (range 555-675, n=183) for adult females. ~~On this basis, the maximum depth reached by average-sized up-ending shelducks might be estimated as 0.6 x (they have shorter necks than swans, both in absolute terms and relative to total length) 673mm = 404mm (male) and 0.6 x 610 = 366mm (female).~~

Measurements from side-on photographs of Australian Shelduck in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.62 (n=5). Application of this ratio to the Australian Shelduck total lengths of Frith (1967/77, 1982) results in 'maximum reach' estimates of 0.62 x 673 = 417mm (males) and 0.725 x 610 = 378mm (females).

HANZAB (Marchant & Higgins 1990) reported Shelduck tarsus lengths (means) of 65.4mm (males; n=4) and 58.5mm (females; n=4). ~~On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 13cm (males) and c. 12cm (females).~~

HANZAB (Marchant & Higgins 1990) reported Shelduck tarsus lengths (means) of 65.4mm (males; n=4) and 58.5mm (females; n=4). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.44. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 9.4cm (males) and c. 8.4cm (females).

Australian Wood Duck *Chenonetta jubata*

HANZAB (Marchant & Higgins 1990) 'Typically loaf … and graze … throughout day near water's edge … also dabble at water's edge; rarely on water (Kingsford 1986a); but readily fly out and settle on water when disturbed from banks. Easy, goose-like walk …. Swim awkwardly, seldom dive' and 'Forage in short grass or herbage, mainly on land but also in shallow water at edges of wetlands' and 'Prefer grassland and pasture, especially short green growth such as clover …' and 'Feeding zone in water restricted to, or just below, surface; rarely upend (Kingsford 1989a)' and 'Most food obtained by grazing on land. Also takes insects on both land and water by rushing at them quickly (Frith 1982) or picking them from water surface (Briggs, no date); observed actively taking insects on water (Kingsford 1989a). Rarely upends and dabbling may be to obtain grit rather than food'.

While Wood Ducks have been recorded picking insects off the water, they apparently rarely up-end and are predominantly grazers of grass, clover and other green herbage on land (Marchant & Higgins 1990). Kingsford (1989) reported that dabbling occurred only to obtain grit, that the nutritional requirements for breeding come from plant food and that the diet of ducklings resembled that of adults. They do swim and so potentially could obtain some food, if present, at the surface of any depth of water. Their bills are very short, mean 28mm (males; n=46) and 27mm (females; n=29) (Marchant & Higgins ibid.).

Frith (1967/77, 1982) reported mean total lengths of 482mm (range 463-505, n=46) for adult males and 467mm (range 443-489, n=29) for adult females. On this basis, the maximum depth reached by average-sized up-ending Wood Ducks might be estimated as 0.575 x 482 = 277mm (males) and 0.575 x 467 = 268mm (females). It is emphasised that these are extreme limits, probably rarely achieved, and that most feeding by Wood Ducks at Vasse-Wonnerup is likely to be grazing on pastures.

Measurements from side-on photographs of Wood Ducks in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.575 (n=2). Application of this ratio to the Wood Duck total lengths of Frith (1967/77, 1982) results in 'maximum reach' estimates of 0.575 x ... = ...mm (males) and 0.575 x ... = ...mm (females).

HANZAB (Marchant & Higgins 1990) reported Wood Duck tarsus lengths (means) of 51.2mm (males; n=16) and 50.4mm (females; n=8). ~~On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 10cm (males) and c. 10cm (females).~~

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.17. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 6.0cm (males) and c. 5.9cm (females). SWIMMING DEPTH WILL BE GREATER, AT LEAST BECAUSE BODY (BELLY) OF SWAN WILL BE PARTIALLY IMMERSED.

Pink-eared Duck *Malacorhynchus membranaceus*

HANZAB (Marchant & Higgins 1990) 'Feed with bill submerged to eyes and rarely, if ever, up-end' and 'Bill specialized for filter-feeding (Crome 1985) limits foraging to water and soft mud; almost entirely aquatic, usually feeding away from shore (Frith *et al.* 1969). Prefer shallow stagnant turbid water with abundant aquatic fauna' and 'Use of underwater habitat limited to depths that can be reached by up-ending; do not dive' and 'Most food taken by filtering, water and food being drawn in at tip of bill and expelled between lamellae at side (Frith 1959; Crome 1985)' and 'Feeding occurs while standing in shallow water or when swimming with heads submerged up to the eyes. Sometimes submerge head in shallow water to filter near the bottom; rarely up-end. Often feed in formation, with birds at rear catching animals disturbed by those in front

(Frith 1959)’ and ‘Birds feed in one of three ways: solitarily; in parallel; or by spinning or 'vortexing' in pairs. Commonly when swimming (generally irrespective of depth of water) but also when walking on soft ooze’ and ‘Four methods of filter-feeding from the surface can be recognized depending on position of head and bill. (1) Bill just at water surface; flaps dip into water but tip held just above surface. In this way birds skim food from the surface … (2) Bill plunged to level of nostrils (which are specially high on the bill); eye just above surface and bill at shallow angle in water … (3) Head plunged completely below water … (4) Up-ending when bill thrust down to limit of reach. Often used to work bottom muds. Not seen to dive. Methods (1) and (2) can be used on the move; method (1) when walking. Commonly these filtering methods used on water with birds moving as a flotilla …’ and ‘Methods (3) and (4) only used in stationary feeding activities without necessarily reaching the bottom in deep water’.

Pink-eared Ducks are specialised filter feeders, typically foraging by swimming with bills at the surface or submerged, or while walking on soft ooze. They sometimes submerge their head in shallow water to filter near the bottom, but rarely up-end (except to work bottom muds) and do not dive for food. They may forage while swimming on any depth of water, provided food is within reach (Marchant & Higgins 1990). Mean bill lengths are 67.0mm (males; n=82) and 61mm (females; n=83) (Marchant & Higgins ibid.).

Frith (1967/77, 1982) reported mean total lengths of 418mm (range 384-448, n=80) for adult males and 392mm (range 364-418, n=84) for adult females. ~~On this basis, the maximum depth reached by average-sized up-ending Pink-eared Ducks might be estimated as 418 x 0.6 = 251mm (male) and 0.6 x 392 = 235mm (female).~~ It is emphasised that these are extreme limits, probably rarely achieved, and that most feeding by Pink-eared Ducks on Vasse-Wonnerup is likely to be in the top few centimetres of the water column.

Measurements from side-on photographs of Pink-eared Ducks in flight produce a mean ‘tip of bill to mid-body’ / ‘total length’ ratio of 0.61 (n=4). Application of this ratio to the Pink-eared Duck total lengths of Frith (1967/77, 1982) results in ‘maximum reach’ estimates of 0.62 x 418 = 255mm (males) and 0.725 x 392 = 239mm (females).

HANZAB (Marchant & Higgins 1990) reported Pink-eared Duck tarsus lengths (means) of 34.4mm (males; n=12) and 33.0mm (females; n=14; significant diff.). Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.13. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 3.9cm (males) and c. 3.7cm (females).

Australasian Shoveler *Anas rhynchotis*

HANZAB (Marchant & Higgins 1990) ‘Bill specialized for filter-feeding, limits foraging to aquatic habitats on open water or soft mud in fertile wetlands with abundant prey’ and ‘Foraging usually restricted to depth that can be reached by upending (c. 0.3 m) (Frith *et al.* 1969), but recorded diving in greater depths (Black 1959)’ and ‘Food obtained by dabbling in mud or at surface where lamellae on fringe of spatulate bill used to filter food from water. Usually swim fairly swiftly with head half or almost wholly submerged, bill moving rapidly. Occasionally upend to feed on bottom, chase prey across surface (Frith 1982) and dive: mean length of dives 8.5 s (7-10; 7 dives) in 1-2 m water (Black 1959). Small flocks often feed in V -formation, those in front disturbing food that those behind catch (Frith 1982)’.

HANZAB (Marchant & Higgins 1990) reported that shoveler dabble in mud or at the water surface. When foraging while swimming they usually have half to almost all of the head wholly submerged. They occasionally up-end to feed on the bottom (their food is mainly animal matter) and occasionally dive beneath the water surface to forage – at Lake Rotorua in New Zealand to an estimated depth of 6–8 feet [1.8–2.4m] (Black 1959).

Frith (1967/77, 1982) reported mean total lengths of 495mm (range 450-530, n=72) for adult males and 477mm (range 460-490, n=101) for adult females. ~~On this basis, the maximum depth reached by average-sized up-ending shoveler might be estimated as 0.6 x 495mm = 297mm (male) and 0.6 x 477 = 286mm (female).~~ ACCORDING TO HANZAB, Frith *et al.* (1969) I CAN’T FIND THIS DEPTH IN THIS REF. TRY A RELATED REF. reported the depth that shoveler could reach by up-ending to be c. 0.3m.

Measurements from side-on photographs of Australasian Shovelers in flight produce a mean ‘tip of bill to mid-body’ / ‘total length’ ratio of 0.588 (n=5). Application of this ratio to the Australasian Shoveler total lengths of Frith (1967/77, 1982) results in ‘maximum reach’ estimates of 0.588 x 495 = 291mm (males) and 0.588 x 477 = 280mm (females).

HANZAB (Marchant & Higgins 1990) reported Australasian Shoveler tarsus lengths (means) of 37.6mm (males; n=16) and 35.4mm (females; n=8; significant diff.). Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.22. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 4.6cm (males) and c. 4.3cm (females).

Grey Teal *Anas gracilis*

HANZAB (Marchant & Higgins 1990) ‘Young dive freely and adults occasionally do so to feed’ and ‘Feed by filtering at surface of water or in soft muds and upend in shallow waters’ and ‘Walk readily on land’ and ‘Mainly aquatic, feeding in shallow open water <1 m deep or in flooded marginal vegetation; occasionally in deep water, especially where floating aquatic vegetation; also out of water on exposed shores and mudflats, damp grassland, pasture or crops (Frith *et al.* 1969;

Briggs 1979; Goodrick 1979; Norman *et al.* 1979)' and 'Food obtained by up-ending, dabbling at water surface, dredging mud at water's edge …'.

This species of teal forages by up-ending to reach submerged food, by dabbling at the water surface, and by dredging mud at the water's edge (Marchant & Higgins 1990). It is not known to dive for food.

Paton (2010) observed that 'Within the Coorong, Grey Teal, Chestnut Teal, Australian Shelduck and Pacific Black Duck ... largely forage by dabbling in shallow water where they can stand, or if in deeper water, forage by up-ending so that they can reach plant material below the surface'

Paton, PA (1986): 'In 1965, Delroy (1974) set out to establish the importance of these two plants to waterfowl in the Coorong. From March 1965 to January 1966, he collected the contents of oesophagi and stomachs from three species of duck [Grey Teal, n=36; Chestnut Teal, n=7; Australian Shelduck, n=14] in the South Lagoon of the Coorong. The results demonstrate an almost total dependence on turions and seeds of *Ruppia* sp. and tubers of [*Lamprothamnium*] *papulosum* during the summer months. The foliage of *Ruppia* and seeds of *Lepilaena cylindrocarpa* were minor components of the diet'.

Frith (1967/77, 1982) reported mean total lengths of 445mm (range 407-477, n=208) for adult males and 418mm (range 370-440, n=149) for adult females. ~~On this basis, the maximum depth reached by average-sized up-ending Grey Teal might be estimated as 0.6 x 445mm = 267mm (male) and 0.6 x 418 mm = 251mm (female).~~

Measurements from side-on photographs of Grey Teal in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.606 (n=7). Application of this ratio to the Grey Teal total lengths of Frith (1967/77, 1982) results in 'maximum reach' estimates of 0.606 x 445 = 270mm (males) and 0.606 x 418 = 253mm (females).

~~HANZAB (Marchant & Higgins 1990) reported Grey Teal tarsus lengths (means) of 35.0mm (males; n=12) and 33.6mm (females; n=11). On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 7cm (males) and c. 7cm (females).~~

HANZAB (Marchant & Higgins 1990) reported Grey Teal tarsus lengths (means) of 35.0mm (males; n=12) and 33.6mm (females; n=11). significant diff.). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.17. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.1cm (males) and c. 3.9cm (females).

Chestnut Teal *Anas castanea*

HANZAB (Marchant & Higgins 1990) 'Feed by dabbling and probing at water's edge, upending in shallows, pecking at surface matter …' and 'Inhabit terrestrial wetlands and estuarine habitats, mainly in coastal regions of se . and sw. Aust. (Aust. Atlas)' and 'Aquatic; feed particularly along edges of wetlands or over sand or mudflats, in shallows with aquatic or emergent plant growth' and 'Food taken from water surface or just below' and 'When swimming, food obtained by dabbling, up-ending to feed from bottom or pecking at surface'.

Chestnut Teal forage in a range of depths, from dabbling while walking on damp flats to up-ending while swimming on deeper waters (Marchant & Higgins 1990). They are not known to dive for food.

Paton (2010) observed that 'Within the Coorong, Grey Teal, Chestnut Teal, Australian Shelduck and Pacific Black Duck ... largely forage by dabbling in shallow water where they can stand, or if in deeper water, forage by up-ending so that they can reach plant material below the surface'

Paton, PA (1986): 'In 1965, Delroy (1974) set out to establish the importance of these two plants to waterfowl in the Coorong. From March 1965 to January 1966, he collected the contents of oesophagi and stomachs from three species of duck [Grey Teal, n=36; Chestnut Teal, n=7; Australian Shelduck, n=14] in the South Lagoon of the Coorong. The results demonstrate an almost total dependence on turions and seeds of *Ruppia* sp. and tubers of [*Lamprothamnium*] *papulosum* during the summer months. The foliage of *Ruppia* and seeds of *Lepilaena cylindrocarpa* were minor components of the diet'.

Paton *et al.* (2011) observed that Chestnut Teal were foraging (n=504) in the following water depths in the Coorong in January 2011: 'damp' 5%, 'ankle' 2%, 'knee'0.6%, 'thigh' 2%, 'belly' 0.4%, 'swim' 91% (n=504; Paton *et al.* 2011). Thus while some birds were foraging in depth as shallow as 0cm (i.e. wet sand or mud), the great majority were foraging in depths greater than 'belly deep', which can be calculated as > (2 x male tarsus length) = > (2 x 38mm), that is > 8cm.

Frith (1967/77, 1982) did not report total lengths of Chestnut Teal, which Marchant & Higgins (1990) gave under the heading 'Field Identification' as 40-50cm (males) and 35-45cm (females). ~~On this basis, the maximum depth reached by an up-ending Chestnut Teal might be estimated as 0.6 x (40-50) = 24-30cm (male) and 0.6 x (35-45) = 21-27cm (female).~~

'General texts ... imply that they [Chestnut Teal] are slightly larger than Grey Teal' (Frith 1967/77, 1982). The HANZAB measurements (wing, tail, bill, tarsus, toe) of Chestnut Teal, both males and females, are greater than those of Grey Teal.

Measurements from side-on photographs of Chestnut Teal in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.582 (n=4). Application of this ratio to the Chestnut Teal total lengths of ... ~~Frith (1967/77, 1982)~~ results in 'maximum reach' estimates of 0.582 x ... = ...mm (males) and 0.582 x ... = ...mm (females).

HANZAB (Marchant & Higgins 1990) reported Chestnut Teal tarsus lengths (means) of 38.1mm (males; n=9) and 36.1mm (females; n=4). significant diff.). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.16. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.4cm (males) and c. 4.2cm (females).

Pacific Black Duck *Anas superciliosa*

HANZAB (Marchant & Higgins 1990) 'Catholic in choice of habitat and found on all types of fresh and salt water from pools to open sea' and 'Feed by filtering at surface of water or in soft muds (suzzling) and upending in shallow water. … Not recorded diving for food (see, e.g., Woodall1984)' and 'Readily come on land and walk or run easily' and 'feed in shallow or deep water, often among aquatic or marginal vegetation, or out of water on wetland shores, exposed mudflats or pastures, especially where moist or flooded; rarely on dry ground (Frith *et al.* 1969; Briggs 1979; Norman *et al.* 1979; Bekle 1983)' and 'Broad habitat tolerance' and 'Underwater, feeding limited to depths reached by upending' and 'Food obtained by dabbling at surface, up-ending to reach submerged food and grazing … Also recorded diving in shallow water (Sedgwick 1958)'.

Black Duck forage by dabbling at the water surface and by up-ending to reach submerged food (Marchant & Higgins 1990). Sedgwick (1958) reported several instances of diving in shallow water, and on one occasion in water about two feet [0.6m] deep. On Vasse-Wonnerup this species has been observed feeding on struggling fish, both 'fry' (Lane *et al.* 2007) and, on one occasion (date?), a mullet (sea or yellow-eye) that was almost too large to swallow (J. Lane, pers. obs.).

Paton (2010) observed that 'Within the Coorong, Grey Teal, Chestnut Teal, Australian Shelduck and Pacific Black Duck ... largely forage by dabbling in shallow water where they can stand, or if in deeper water, forage by up-ending so that they can reach plant material below the surface'

Frith (1967/77, 1982) reported mean total lengths of 568mm (range 506-608, n=132) for adult males and 534mm (range 470-584, n=105) for adult females. ~~On this basis, the maximum depth reached by average-sized up-ending Pacific Black Duck might be estimated as 0.6 x 568mm = 341mm (male) and 0.6 x 534 mm = 320mm (female).~~

Measurements from side-on photographs of Pacific Black Duck in flight produce a mean 'tip of bill to mid-body' / 'total length' ratio of 0.636 (n=5). Application of this ratio to the Pacific Back Duck total lengths of Frith (1967/77, 1982) results in 'maximum reach' estimates of 0.636 x 568 = 361mm (males) and 0.636 x 534 = 340mm (females).

HANZAB (Marchant & Higgins 1990) reported Black Duck tarsus lengths (means) of 55.7mm (males; n=26) and 54.8mm (females; n=54). not significant diff.). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.28. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 7.1cm (males) and c. 7.0cm (females).

Hardhead *Aythya australis*

HANZAB (Marchant & Higgins 1990) 'Dive for food, leaping forward and submerging smoothly; occasionally dabble in shallow water' and '[Habitat] On terrestrial wetlands and occasionally sheltered estuarine and inshore waters. Almost entirely aquatic' and 'Dive for food; thought to reach bottom in water 3 m deep (Frith *et at.* 1969)' and 'Most food obtained by diving, birds leaping forward and submerging …, swimming up to 40 m underwater using feet. Also sieve waterside mud, up-end, … [Frith 1982]'.

While Hardhead may sieve mud at the water's edge, and up-end, they obtain most of their food (aquatic plants and animals) by diving. Hardhead have been reported swimming up to 40m while underwater (Marchant & Higgins 1990) and these authors quoted Frith *et al.* (1969) as thinking that Hardhead reached the bottom in water 3m deep. However, while Frith *et al.* (ibid.) did write *'There are no data on the ultimate depths the three species [hardhead, musk duck, and blue-billed duck] can reach but it is known that the greatest depths in Barrenbox swamp are not sufficient to separate them'*, the values of these 'greatest depths' were not indicated.

HANZAB (Marchant & Higgins 1990) reported Hardhead tarsus lengths (means) of 39.9mm (males; n=13) and 38.5mm (females; n=12) not significant diff.

Blue-billed Duck *Oxyura australis*

HANZAB (Marchant & Higgins 1990) 'rarely seen on land' and 'Contrary to Frith (1982) walk on land with awkward penguin-like gait' and 'Dive for intervals of 10-30 s, straining soft mud with sweeping action of head and bill. Filter-feed on surface with similar action' and 'Almost wholly aquatic' and 'Dive freely; recorded diving in water 3 m deep, probably reaching bottom (Frith 1982). Rarely on land, although may walk clumsily for short distance (Wheeler 1960)' and 'Obtain food mostly by diving in deep water for about 15 s (max. 30 s), slipping underwater head first with minimum of disturbance to surface'.

While Blue-billed Duck may take food from the water surface, they obtain most by diving (Marchant & Higgins 1990). Frith (1967/77) stated that this species obtained most of its food from the bottom of its wetland habitat (rather than from the surface or water column) and observed it diving in water up to 10 feet [3.0m] deep. 'Blue-billed Ducks are diving ducks and secure most of their food from the bottom of the swamp' (Frith 1967/77, 1982). BUT NOTE THAT FRITH ALSO WRITES: 'Both dive, but the Blue-billed Duck collects a large part of Its food on the surface, unlike the Musk Duck, which uses little from this source' (Frith 1967/77, 1982).

HANZAB (Marchant & Higgins 1990) reported Blue-billed Duck tarsus lengths (means) of 37.3mm (males; n=16) and 37.1mm (females; n=8) significant diff.

Grebes Family Podicipedidae

Australasian Grebe *Tachybaptus novaehollandiae*

HANZAB (Marchant & Higgins 1990) 'Found on all sorts of rather shallow freshwaters … tending to be found mostly near shore and in fringing vegetation rather than on open water' and 'Dive with small forward jump and splash …' and 'In Vic., recorded on shallow (<0.5 m) freshwater marshes, dominated by herbs; deep(>1m) freshwater marshes, dominated by rushes; deep open freshwater marshes without emergents; permanent natural lakes, over 1 m deep; reservoirs, over 1 m deep with some aquatics (Corrick & Norman 1980; Corrick 1982)' and 'Feeding methods … include diving (55% observations), swimming with head and neck immersed … sometimes interspersed with brief pursuit-diving (0.5-4.0 s; Fjeldsa 1988) including also approaching food from underwater (England 1974); floating in one position, peering through carpets of surface vegetation, often in sunbathing pose; stealing in crouched pose upon insects perched on floating vegetation; picking from water surface; snatching insects from emergents, from banks or from overhead, sometimes by leaping. Feeding dives consist of small jump, splash, and downward swing of neck'.

This grebe dives for food, and also forages on the water surface while swimming (Marchant & Higgins 1990).

HANZAB (Marchant & Higgins 1990) reported Australasian Grebe tarsus lengths (means) of 36.8mm (males; n=5) and 34.0mm (females; n=5) significant diff.

Hoary-headed Grebe *Poliocephalus poliocephalus*

HANZAB (Marchant & Higgins 1990) 'Typically found well away from shoreline on large open waters, estuarine, brackish or freshwater, often in large dense flocks' and 'Probably prefer large (100-500 m wide) sheets of open water, 0.5-3.0 m deep, with submerged vegetation. Avoid water covered by dense weed …' and '[Food] Chiefly aquatic arthropods, obtained largely (± 90%) by deep diving' and 'feeds less on surface than other small grebes (J. Fjeldsa). Periods of swimming with head and neck immersed … followed by brief, shallow dives for large prey' and 'Sometimes pick from water surface …'.

The Hoary-headed Grebe forages mainly by 'deep diving' (depth not specified), and sometimes by pecking from the water surface while swimming (Marchant & Higgins 1990).

HANZAB (Marchant & Higgins 1990) reported (from Storer 1987) Hoary-headed Grebe tarsus lengths (means) of 38.3mm (males; n=10) and 36.7mm (females; n=13) significant diff.
Storer, R.W. (1987). ... Emu 87, 150-157.

Darters Family Anhingidae

Australasian Darter *Anhinga novaehollandiae*

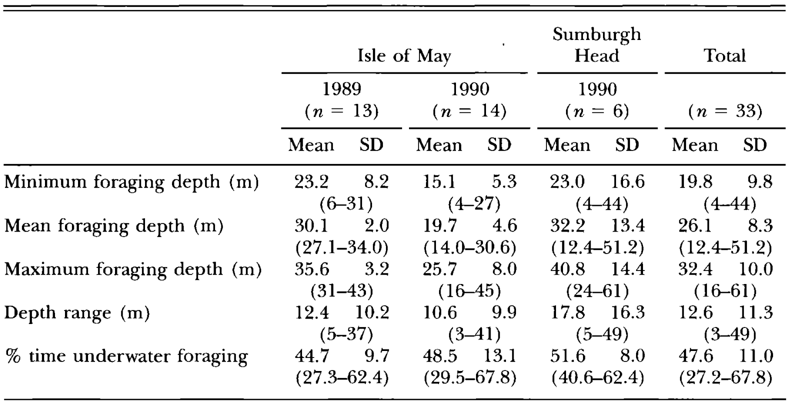
HANZAB (Marchant & Higgins 1990) '… walk with clumsy waddle' and 'Swim on surface moving feet alternately; body may be submerged with only head and neck showing' and '… when diving, feet used together. Feed by stalking fish underwater …' and 'Fish stabbed … by tips of partly opened bill; tips of bill also used as forceps to pick insects off water and plants' and 'Most common on permanent waterbodies with extensive sheets of open water at least 0.5 m deep … (Vestjens 1975; Corrick & Norman 1980; Gosper 1981; Jaensch *et al.* 1988; Morton *et al.* 1989)' and 'Also feed in deeper parts … (Vestjens 1977; Gosper 1981)' and 'Dive well. Capture benthic fish, but can also take prey from middle and surface layers of water (Dostine & Morton 1989)' and 'Food captured by diving under water in depths ≥60 cm. Body usually submerged while swimming with head and neck above water' and 'Fish pierced through ventral region by tip of slightly open bill (Serventy 1939) (Vestjens 1975)'.

HANZAB (Marchant & Higgins 1990) stated that darters feed mainly on fish, captured by diving under water in depths ≥ 60cm. Dostine & Morton (1989) reported from their study in the Northern Territory that darters captured both relatively slow-moving benthic fish and agile fish from mid- to surface layers of the water profile. Serventy (1939) reported that most of the fishes caught by nine female darters, collected mainly (eight birds) from Peel-Harvey Estuary and Leschenault Inlet in south-western Australia, were 'more or less actively moving ones, in contrast to the forms [species] preyed on by the Cormorants'.

Cormorants Family Phalacrocoracidae

Wanless *et al.* (1997). 'The European Shag *(Phalacrocorax aristotelis)* is a medium-sized (average body mass approximately 1750 g), pursuit-diver that feeds predominantly on small marine fish, particularly sandeels *(Ammodytes marinus),* which it catches on or just above the seabed (Harris and Wanless 1991, Lumsden and Haddow 1946, Snow 1960, Wanless *et al.* 1991). While visual observations have suggested that the species feeds mainly in shallow (<10 m) water (Dewar 1924), recent studies using depth gauges have shown that shags regularly dive to 40 m and show a time-at-depth profile that is characteristic of flat-bottomed diving (Barrett and Furness 1990, Wanless *et al.* 1991, Wilson *et al.* 1991)'. 'The maximum depth attained by birds from Isle of May was about 45 m; the maximum at Sumburgh Head was 61 m (Table 1)'. 'This study confirmed that dive depth in European Shags is markedly greater than suggested by visual observations (Dewar 1924). The maximum depth of 61 m attained by a bird at Sumburgh Head is the deepest dive so far measured and suggests that the record of a bird drowned in a fishing net set at 80 m in the Mediterranean (Guyot 1988) accurately reflects the diving ability of this species'. 'the maximum foraging depth of European Shags appears to be less than that of Blue-eyed Shags *(P. atriceps)* (107- 116 m, Croxall *et al.* 1991, Kato *et al.* 1992), but slightly greater than Japanese Cormorants *(P. capillatus)* (45 m, Watanuki *et al.* 1996)'. 'Studies of several other species of cormorant feeding in relatively shallow water (<10 m deep), and based on visual observations, have also found significant relationships between water depth at the feeding location and different stages of the dive (e.g., Trayler *et al.* 1989, Wanless and Harris 1991, Wilson and Wilson 1988)'. Wanless, S., Harris, M.P., Burger, A.E. & Buckland, S.T. (1997). *Use of time-at-depth recorders for estimating depth and diving performance of European Shags.* J. Field Ornithol., 68(4), 547-561.

TABLE 1. Mean ± SD (range) foraging depth parameters and % time underwater spent foraging by European Shags on the Isle of May in 1989 and 1990 and Sumburgh Head 1990.



	Isle of May				Sumburgh Head		Total	
	1989 (*n* = 13)		1990 (*n* = 14)		1990 (*n* = 6)		(*n* = 33)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Minimum foraging depth (m)	23.2	8.2	15.1	5.3	23.0	16.6	19.8	9.8
	(6–31)		(4–27)		(4–44)		(4–44)	
Mean foraging depth (m)	30.1	2.0	19.7	4.6	32.2	13.4	26.1	8.3
	(27.1–34.0)		(14.0–30.6)		(12.4–51.2)		(12.4–51.2)	
Maximum foraging depth (m)	35.6	3.2	25.7	8.0	40.8	14.4	32.4	10.0
	(31–43)		(16–45)		(24–61)		(16–61)	
Depth range (m)	12.4	10.2	10.6	9.9	17.8	16.3	12.6	11.3
	(5–37)		(3–41)		(5–49)		(3–49)	
% time underwater foraging	44.7	9.7	48.5	13.1	51.6	8.0	47.6	11.0
	(27.3–62.4)		(29.5–67.8)		(40.6–62.4)		(27.2–67.8)	

Little Pied Cormorant *Microcarbo melanoleucos*

HANZAB (Marchant & Higgins 1990) 'Walk with slow waddle. Swim on surface using both feet alternately; during take-off and when diving, uses both feet. When stalking prey underwater, feet held out to side of body like oars' and 'Feed mainly on arthropods and some fish' and 'Feed in open water, but able to-use smaller wetlands and smaller areas of open water in vegetated wetlands than other species of cormorant' and 'On large lakes feed in shallow margins where native crustaceans most abundant (Vestjens 1977; Miller 1979; Morton *et al.* 1989)' and 'Prey caught during succession of brief dives … (Miller 1979)' and 'Sometimes swim on surface with only head submerged apparently looking for prey'.

This species dives for its food, mostly invertebrates and fish.

During a study of diet and foraging behaviour on the Peel-Harvey Estuary, south-western Australia, Trayler *et al.* (1989) observed Little Pied Cormorants feeding mainly in water 1–2m deep, on several occasions in water < 1m deep, and only rarely in depths > 2m.

At Blackman Bay in Tasmania, Bolger (1959) observed this species, and Great Cormorants, closely following and feeding on fish disturbed by wading Little Egrets (see that species for its wading depth limit).

At Kaikoura in New Zealand, Little Pied Cormorants foraged 'close inshore, sometimes in the intertidal zone, and seldom in depths greater than 2–3m' (Stonehouse 1967). Table 2 of that paper (see Appendix …) provides more detail, indicating that Stonehouse observed Little Pied Cormorants diving in depths of 1–2m, 2–3m and 3–4m, but not in depths of 5–7m or > 8m.

HANZAB (Marchant & Higgins 1990) reported Little Pied Cormorant tarsus lengths (means) of 38.6mm (males; n=19) and 37.8mm (females; n=21) not significant diff.

Great Cormorant *Phalacrocorax carbo*

HANZAB (Marchant & Higgins 1990) 'Forage in sheltered marine and inland waters' and 'Walk with goose-like waddle. Swim using both feet alternately; during take-off and when diving, use both feet together. Forage underwater for fish and arthropods' and 'Gather at drying pools and spillways of weirs to feed on trapped and stunned fish (Hobbs 1956; McNally 1957)' and 'In Kaikoura, NZ, feed in shallow water in lakes and rivers, and in littoral zone, 1-3 m depth, in coastal waters (Stonehouse 1967)' and 'Most food taken by pursuit-diving using wings and feet for propulsion (Buller 1888) though recorded wading in shallows searching for food under pebbles (Falla & Stokell 1945)' and 'Also recorded catching ducklings from below … (Fisher 1963)' and '.

While Great Cormorants have been recorded wading (tarsus length c. 65mm) in shallow riverine ripples in New Zealand, submerging their heads as if grubbing under stones (Falla & Stokell 1945), most foraging by this widespread species involves pursuit-diving (Butler 1888 in Marchant & Higgins 1990).

Trayler *et al*. (1989) did not report the foraging depths of Great Cormorants on Peel-Harvey Estuary as this species was in low numbers.

Paton *et al.* (2011) were unable to determine the water depth(s) where Great Cormorants were foraging (n=297) in the Coorong in January 2011; all birds were swimming.

At Blackman Bay in Tasmania, Bolger (1959) observed Great Cormorants, and Little Pied Cormorants, closely following and feeding on fish disturbed by wading Little Egrets (see that species for its wading depth limit).

At Kaikoura NZ, Great Cormorants foraged 'close inshore, sometimes in the intertidal zone, and seldom in depths greater than 2–3m' (Stonehouse 1967).

HANZAB (Marchant & Higgins 1990) reported Great Cormorant tarsus lengths (means) of 68mm (males; n=78) and 64mm (females; n=228~~. On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 14cm (males) and c. 13cm (females).~~

The HANZAB illustration of this species suggests that the 'ground-to-belly distance' is approximately equivalent to the lower leg (≈ tarsus) length.

Little Black Cormorant *Phalacrocorax sulcirostris*

HANZAB (Marchant & Higgins 1990) 'Walk with goose-like waddle. In water, swim using feet alternately; use both feet together … when diving. Swim rapidly underwater with legs behind body. Catch prey underwater by pursuit-diving' and 'Large flocks feed co-operatively [Miller 1979]: surround schools of fish in open water and … flocks advance across surface, birds at rear flying ahead, landing and diving in front of feeding flock [Serventy 1939]' and 'Inland, feed mainly in open water >1 m deep (Miller 1979; Dostine & Morton 1988) and large enough to allow cooperative feeding (Miller 1979)' and 'Less often on shallow or vegetated waters' and 'Most prey caught by pursuit-diving using feet for propulsion'.

Little Black Cormorants catch their prey (mostly fish, but also invertebrates) mainly by pursuit-diving (Marchant & Higgins 1990).

Trayler *et al*. (1989) reported that (unlike Little Pied Cormorants) Little Black Cormorants often fed in the limited number of regions of Peel-Harvey Estuary where water depth was *in excess of* 2m. These authors also recorded Little Black Cormorants feeding in 1–2m, but not in depths less than 1m. Similarly, in a study of cormorant ecology in inland New South Wales, Miller (1979) seldom observed Little Black Cormorants foraging in water less than 1m deep.

Paton *et al.* (2011) were unable to determine the water depth(s) where Little Black Cormorants were foraging (n=144) in the Coorong in January 2011; all birds were swimming.

Pied Cormorant *Phalacrocorax varius*

HANZAB (Marchant & Higgins 1990) 'Walk with goose-like waddle. In water, swim at surface using both feet alternately; during takeoff and when diving, use both feet together. Forage underwater, mainly for fish' and '[Habitat] Mainly marine' and 'Along coast, abundant in estuaries (Corrick 1982; Gosper 1981; Fjeldsa 1985; Jaensch *et at.* 1988)' and 'Observed feeding across 16 km of sea between Fremantle and Rottnest I., W A, but less common in central sector >5 km from shore (Storr 1964)' and 'All food [Mostly fish with a few crustaceans] caught by pursuit-diving. Often leap clear of surface before plunging but will also dive without jumping. Propulsion by feet but use half-spread wings for steering (Butler 1948)'.

According to Marchant & Higgins (1990), Pied Cormorant catch all of their food (mostly fish, with a few crustaceans) by pursuit-diving.

Trayler *et al.* (1989) reported that Pied Cormorants often fed in the limited number of regions of Peel-Harvey Estuary where water depth was in excess of 2m. These authors also recorded Pied Cormorants feeding in 1–2m, but not in depths less than 1m.

At Kaikoura NZ, Pied Cormorants 'sometimes [foraged] close inshore, but more often in depths of 3–10m at distances 100–300m from shore' (Stonehouse 1967). Table 2 of that paper (see Appendix …) provides more detail, indicating that Stonehouse observed Pied Cormorants diving in depths of 1–2m, 2–3m, 3–4m, 5–7m and > 8m.

Paton *et al.* (2011) were unable to determine the water depth(s) where Pied Cormorants were foraging (n=47) in the Coorong in January 2011; all birds were swimming.

Pelicans Family Pelecanidae

Australian Pelican *Pelecanus conspicillatus*

HANZAB (Marchant & Higgins 1990) 'Feed in flocks, simultaneously plunging heads below water' and 'Ungainly, waddling gait on land' and 'Mainly found on waterbodies with large sheets of open water, free of dense aquatic vegetation; can use waters where depth … and salinity limit food supply and inhibit use by other waterbirds' and 'Gather at receding floodwaters or seasonal wetlands to feed on trapped fish (Hobbs 1961; Crawford 1972)' and 'Use of underwater habitat limited to depths accessible by dipping from surface' and 'When feeding alone, swim surreptitiously towards prey … , plunging head into water when prey encountered (Pizzey 1980)' and 'Also scoop prey from shallow water (Hobbs 1961) and pick up food from land with tip of bill' and 'Also observed surface-plunging from 1-2 m, submerging head and neck for 5 s after entering water (Clayton 1969)' and 'Flocks often feed co-operatively, birds swimming in loose line, repeatedly stabbing bills into water, driving fish ahead of them into shallows where they then circle among prey. Also been seen herding ducklings in same way (Carruthers 1969)'.

The Australian Pelican commonly catches its prey (mainly fish and small crustaceans) by plunging bill and head into the water at a shallow or steep angle, while swimming (see Marchant & Higgins 1990 for a lengthier description of technique and diet). They have also been observed 'surface-plunging' from 1–2m [DOUBLE-CHECK MEANING], fully submerging their head and neck (Hobbs 1961). Co-operative feeding flocks may drive fish into shallows to capture them, however it is uncommon for pelicans to forage naturally while walking or standing (J. Lane, pers. obs).

Marchant & Higgins (1990)[2] reported mean pelican bill lengths of 453mm (male) and 382mm (female).

Median bill lengths of … live pelicans (sex undetermined) captured in south-western Australia in the 1970s and 1980s ranged c. …mm – c. …mm (n=…; J. Lane, unpublished data). [SEE 'RMCR - Pelican measurement, plumage, moult, colours etc [PDF PART 3of4]' FOR DATA TO WORK WITH – NEED TO CALCULATE MEANS]. DID WE DO ANY TOTAL HEAD +BILL MEASUREMENTS?

Marchant & Higgins (1990) reported the following mean tarsus lengths of pelicans:

- Live birds, 'methods unknown', data sourced from ABBBS: 115.4mm (male; n=98), 107.5mm (female; n=21).
- Museum 'skins': 133.8 (male; n=7), 124.5mm (female; n=5).

Median tarsus lengths of 485 live pelicans (sex undetermined) captured in south-western Australia in the 1970s and 1980s ranged c. 142mm – c. 160mm (n=485; J. Lane, unpublished data). [SEE 'RMCR - Pelican measurement, plumage, moult, colours etc [PDF PART 3of4]' FOR DATA TO WORK WITH – NEED TO CALCULATE MEANS].

Serventy *et al.* (1971) provided the following lengths, in mm, of eight specimens: 'culmen [bill] 401 (340-470); tarsus 121 (116-129)' and 'Length [total], 5ft – 6ft 2 in. [1.52–1.88m]'. Under the heading 'Field Identification', Marchant & Higgins (1990) gave 'Length' as 1.6–1.8m.

Vestjens (1983) 'Males are larger and taller than females and have longer bills. The bill length of 18 adult males ranged from 409 to 500 mm, and that of nine adult females from 346 to 398 mm'.

Johnstone & Storr (1998) provided the following: 'Bill exposed length 380–477 (N=12), entire length [of bill] 410–500, …, tarsus 120–135 [mm]'.

So, bill plus head plus neck length (i.e. absolute max reach) = …??

Paton (2010) observed that 'At times, a number of pelicans will work co-operatively [on the Coorong] to herd and concentrate fish into a confined area before plunging head and beak underwater to scoop up fish. The depths at which pelicans can harvest fish will be limited by the extent to which they can extend their necks and bills below the surface'.

Paton *et al.* (2011) were unable to determine the water depth(s) where pelicans were foraging (n=515) in the Coorong in January 2011; all birds were swimming. It can, however, be deduced from this observation that all foraging was in depths greater than 'belly deep', which can be calculated as > (2 x male tarsus length) = > (2 x ..mm), that is > ..cm.

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.33. Application of this ratio to the 'live birds' tarsus lengths of HANZAB produces 'belly depths' of c. 15cm (males) and c. 14cm (females). Application to the 'Museum skins' tarsus lengths produces 'belly depths' of c. 18cm (males) and c. 17cm (females).

Herons, Egrets, Bitterns Family Ardeidae

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[2] These are the mean lengths of the *largest samples* reported in this publication (Marchant & Higgins 1990).

Australasian Bittern *Botaurus poiciloptilus*

HANZAB (Marchant & Higgins 1990) 'Mostly singly, sometimes in pairs or loose groups of up to 12, in beds of rush, reeds or sedge in freshwater wetlands' and 'Sometimes stand on platforms or banks at edge of water; stalk with great stealth through shallow water' and 'Terrestrial wetlands and, occasionally, estuarine habitats' and 'Favour wetlands with tall dense vegetation, where forage in still shallow water up to 0.3 m deep, often at edges of pools or waterways, or from platform or mat of vegetation over deep water (Bright 1935; Whiteside 1989; R.P. Jaensch)' and 'When hunting, … lunging by pivoting on legs, keeping neck and back straight (Whiteside 1989). Also lunge from crouched position, sometimes lifting feet from surface to do so (Howard 1963; see Falla 1963)' and 'Also recorded baiting fish with small pieces of grass (Onians 1933)'.

Howard (1963) observed a small Australasian Bittern (initially identified incorrectly as a Little Bittern; see Falla 1964) "standing 'knee-deep' in water" in a small lagoon at Meremere NZ. What was possibly the same bird was observed several months later 50 yards from the first sighting, foraging 'up to knee-deep in water' among *Carex* tussocks and dead sticks.

In a study of this species' behaviour on the Whangamarino wetlands, NZ, Whiteside (1989) found that, 'at times', individuals 'fed' (i.e. foraged; while standing or walking) 'with their legs completely under water'. By implication, most foraging was while standing or walking in shallower water, with legs partially exposed. All of 72 'behaviour records' (31 feeding; 27 walking; 14 comfort) were on wet (including inundated) substrate; none was on dry substrate.

Following a pilot study of Australasian Bitterns on rice fields in New South Wales, (Herring *et al.* 2014) reported that 'Bitterns were recorded in a range of water depths, from 10–31 cm'.

Menkhorst, P. & Silcocks, A. (2004). *Observations of an Australasian Bittern eating a small mammal.* Australian Field Ornithology 21, 37–39.

Menkhorst, P. (2012) *The food and foraging rate of an Australasian Bittern.* Australian Field Ornithology 29, 133-142. [NOTHING FOR THIS REPORT IN THIS PAPER].

HANZAB (Marchant & Higgins 1990) reported Australasian Bittern tarsus lengths (means) of 105.9mm (males; n=16) and 97.3mm (females; n=15). On this basis, the 'knee-deep' observations of Falla (1964) produce foraging depths of 1 x 106mm = c. 11cm (males) and 1 x 97mm = c. 10cm (females). *Maximum* foraging depths (i.e. belly-deep or 'legs completely under water' as reported by Whiteside 1989), may be estimated as 2 x (tarsus length) = c. 21cm (males) and c. 19cm (females). **REPLACE ALL '2x' SENTENCES, I.E. ALL SPECIES, WITH 'BELLY DEPTH' SENTENCES.**

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.33. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 14.1cm (males) and c. 12.9cm (females).

White-necked Heron *Ardea pacifica*

HANZAB (Marchant & Higgins 1990) 'Seen singly or in small groups in water at margins of freshwater swamps, dams or in moist grasslands, rarely in brackish or salt water. Forage by stalk or stand-and-wait techniques' and 'Widespread in terrestrial wetlands, grasslands and, less often, in estuarine habitats; … (Badman 1979). Forage in shallow water (<70 mm deep) or wet grassland over soft substrate (Recher & Holmes 1982), …; able to forage in deep, steep-banked waterbodies by plunging from perches (Tucker 1976)' and 'Most food taken after standing and waiting before seizing but will also walk slowly or quickly, glean from foliage, peer among foliage and wing-flick (Recher & Holmes 1982; Recher *et al.* 1983)' and 'May also plunge into water from overhanging limb, spearing bill forward but keeping wings out of water (Tucker 1976; Klapste 1976), rake with feet (Hancock & Elliott 1978), pick dead food from surface of water (Sanders 1923)'.

According to Marchant & Higgins (1990), White-necked Herons take most food after standing and waiting, but also walking. This species of heron may also plunge into deep water from an overhanging limb, spearing with its bill while keeping its wings out of the water (Tucker 1976). Tucker, E. (1976). … Aust. Bird Watcher 6: 299. NEEDS BIRDLIFE AUSTRALIA LOGIN Foraging habitat also includes wet grassland over soft substrate. Recher & Holmes (1982)

At Jabiru in the Northern Territory, most White-necked Herons observed hunting were doing so in water less than 70mm deep (Recher & Holmes 1982). Table 3 of that paper provides more detail, as follows.

Water Depth (mm)	**0–1**	**1.1–49**	**50–99**	**100–149**	**150–199**	**200–250**	**Observations**
% of observations	14.3	17.1	57.1	11.4	0	0	70

In Table 2 of Recher *et al.* (1983), the data were presented somewhat differently, and a small correction made, as follows.

Water Depth (mm)	**0–1**	**1.1–49**	**50–99**	**100–149**	**150–199**	**200–250**	**Observations**
% of foraging time	14.3	17.1	56.1	11.4	0	0	105 minutes

HANZAB (Marchant & Higgins 1990) reported White-necked Heron tarsus lengths (means) of 134.1mm (males; n=10) and 130.3mm (females; n=9). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 27cm (males) and c. 26cm (females). These theoretical maxima are substantially greater than the *actual* foraging depths reported by Recher *et al.* (1983).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.78. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 23.9cm (males) and c. 23.2cm (females).

Eastern Great Egret *Ardea modesta*

HANZAB (Marchant & Higgins 1990) 'When foraging, wade slowly, stand motionless for long periods, leaning forward with neck extended, then suddenly stabbing at prey …' and 'Forage by wading in open shallow water (up to 0.3 m deep) (Recher & Holmes 1982; Schulz 1989); generally avoid dry or deeply flooded areas (Morton *et al.* 1989), although can take fish from surface of deep steep-sided waterbodies by plunging from perch or flying low over surface (Mackay 1967; Tucker 1976)' and 'Hunt usually by standing and waiting for prey, by walking slowly, rarely by walking quickly. When hunting, … kink in neck being straightened suddenly to snatch prey from water (Warburton 1953)' and 'Have also been observed plunging onto fish from air, snatching them while flying (Mackay 1967) or entering water (Tucker 1976)'.

Great Egret usually forage by standing and waiting for prey, or while walking slowly (Marchant & Higgins 1990). '… all depended on slow stalking through the water' (Hobbs 1957).

Recher *et al.* (1983): 'Almost all Great Egrets hunted in water that was 150 to 200 mm deep (Table 2)'. 'Great Egrets hunted from fully erect to partially crouched positions'.

Table 2. Percent of time [Great Egrets] foraged at different depths of water on the Magela Creek Floodplain, Northern Territory and the Hawkesbury River, New South Wales.'

Water Depth (mm)	**0–1**	**1.1–49**	**50–99**	**100–149**	**150–199**	**200–250**	**Observations**
% of foraging time	0	0	0	0.8	72.8	26.4	530 minutes

Recher *et al.* (1983): 'Tarsus length: 152 ±4 mm (n=11, Australian Museum, Sydney).'

Estuaries of South Africa edited by Brian Allanson, Dan Baird 'The average wading depth of Little Egrets is 100 mm; the larger Great White Egrets and Grey Herons forage in depths of 160 mm and 190 mm respectively …'

HANZAB (Marchant & Higgins 1990) reported Great Egret tarsus lengths (means) of 156.8mm (males; n=11) and 141.6mm (females; n=6). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 31cm (males) and c. 28cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.74. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 27.3cm (males) and c. 24.6cm (females).

Cattle Egret *Ardea ibis*

HANZAB (Marchant & Higgins 1990) 'foraging among grazing stock, in flooded pastures or floodplains' and 'When foraging, walk slowly, peering at ground, with quick dashes after prey; also take parasites and other insects from backs and bellies of cattle' and 'Regularly forage away from water on low-lying grasslands, improved pastures and croplands (Chalmers 1972)' and 'Wetlands used are mainly shallow, open and fresh; they include meadows, swamps with low emergent vegetation and abundant aquatic flora, and shallow open water in deep swamps; occasionally use swamps with tall emergent vegetation … (Corrick & Norman 1980; Gosper 1981; Corrick 1982). Recorded from edges of estuaries in NZ, but use of saline habitats rare (Heather 1982)' and 'In Gippsland, Vic., prefer shallow wetlands, Apr.- May; low-lying grasslands, June- Sept.; improved pasture, lucerne plantings and cropland on higher ground, Oct. (Chalmers 1972)' and 'Usually follow cattle, horses, sheep, goats or other large animals, snapping up disturbed insects (Jenkins & Ford 1960; McKilligan 1984) or worms forced to surface by trampling of cows (Heather 1982; Jackson & Olsen 1988)' and 'Also use cattle as vantage point from which to sally after insects'.

This species forages mainly by following livestock such as cattle and horses and snapping up disturbed insects and other small prey (Marchant & Higgins 1990). While one to several birds have occasionally been recorded on pastures adjoining the Vasse-Wonnerup wetlands, they do not make significant use of the wetlands and so are not considered here.

HANZAB (Marchant & Higgins 1990) reported Cattle Egret tarsus lengths (means) of 85.0mm (males; n=20) and 82.3mm (females; n=20). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 17cm (males) and c. 16cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.60. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 13.6cm (males) and c. 13.2cm (females).

White-faced Heron *Egretta novaehollandiae*

HANZAB (Marchant & Higgins 1990) 'Widespread; in variety of wetland and terrestrial habitats; in all shallow, fresh and marine wetlands, particularly intertidal mudflats; …' and 'Walk deliberately; prey taken by stealthy approach, by standing and waiting with neck extended or by crouching with head withdrawn' and 'Forage in open areas over soft or firm substrate; in shallow water (rarely exceeding depth of tarsus); on shores or exposed surfaces in wetlands; … (Recher & Holmes 1982; Lowe 1983; Moore 1984)' and 'Most food taken either when wading or walking slowly through water or by standing and waiting …' and 'Feeding method varies with prey: slow prey taken with head held vertically; fish approached in crouch, head plunged rapidly into water ahead of heron'.

White-faced Heron forage mainly while wading or walking slowly through water or by standing and waiting (Marchant & Higgins 1990).

Paton *et al.* (2011) observed that White-faced Herons were foraging (n=33) in the following water depths in the Coorong in January 2011: 'dry' 3%, 'damp' 15%, 'half knee' 12%, 'knee' 70%. Thus 18% of birds were foraging in 0cm (mostly damp rather than dry) and all birds were foraging in water depths equal to or less than 'knee deep', which can be calculated as ≤ (1 x male tarsus length) = ≤ 97mm, that is ≤ 10cm.

Recher *et al.* (1983):

Table 2. Percent of time [White-faced Herons] foraged at different depths of water on the Magela Creek Floodplain, Northern Territory and the Hawkesbury River, New South Wales.'

Water Depth (mm)	**0–1**	**1.1–49**	**50–99**	**100–149**	**150–199**	**200–250**	**Observations**
% of foraging time	9.9	56.2	19.9	14.1	0	0	530 minutes

Recher *et al.* (1983): 'Tarsus length: 97 ±2 mm (n=21, Australian Museum, Sydney).'

Lowe, K.W. (1983). *Feeding behaviour and diet of the White-faced Heron (Ardea novaehollandiae) in Westernport Bay, Victoria.* Corella 7: (in press).

HANZAB reported White-faced Heron tarsus lengths (means) of 96.7mm (males; n=9) and 90.5mm (females; n=5) from adult specimens in New Zealand and somewhat shorter measurements from recently dead adult birds in Australia (males 82–92mm; n=3; females mean 83mm; n=9). On the basis of the NZ specimens, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 19cm (males) and c. 18cm (females), whereas, on the basis of the Australian specimens, foraging depths may be c. 1cm or so less.

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.68. Application of this ratio to the NZ tarsus lengths produces 'belly depths' of c. 16cm (males) and c. 15cm (females). On the basis of the Australian specimens, 'belly depths' may be c. 1cm or so less.

Little Egret *Egretta garzetta*

HANZAB (Marchant & Higgins 1990) 'Seen … in tidal estuaries, mangroves, mudflats, saltmarshes, margins of shallow wetlands and rivers, … When foraging, active high-stepping gait with jerky dashes after prey' and 'Forage mainly in shallow open water (0.1-0.15m deep); also on shores or exposed flats or banks; … (Recher & Holmes 1982); able to use deep water, where flying birds take fish from surface (Mackay 1967)' and 'Most common [feeding] behaviour is to stand erect searching for prey, then walk quickly or run in pursuit' and 'Foot-stirring used to dislodge prey from beneath debris or vegetation, … (Garnett & Cox 1983)' and 'Has also been seen to plunge for fish from air (Mackay 1967), and hover (Demey 1986)'.

While the Little Egret has been observed taking fish from the surface while flying, its usual foraging behaviour is to stand and wait, walk, or run in pursuit of prey (Marchant & Higgins 19990).

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Little Egret (nominate subspecies *garzetta*) and other waterbirds were foraging on coastal lagoons in Ghana by recording 'the level of water relative to exposed vertical leg length (in 0.1 intervals on a scale of 0.0–1.0, and 1.0 when birds were standing belly deep in water). These relative leg lengths were converted to [water] depth from scale drawings or from photographs of the birds concerned'. The 'exposed vertical leg length' of Little Egret was determined to be 135mm. The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Little Egret and 18 other waterbird species (11 *in toto* recorded on Vasse-Wonnerup) were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Little Egret (subspecies *garzetta*)	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (13.5cm)**	**Water depth as % of male tarsus length (10.1cm)**	**Water depth as % of female tarsus length (9.73cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	3.8	28	38	39
Median (50%)	5.7	42	56	59

3rd Quartile (75%)	9.6	71	95	99
‘Maximum’ (100%)	11.4	84	113	117

Note, in particular, that 25% of foraging was in water depths ≤ 38–39% of male-female tarsus lengths; 50% was in depths ≤ 56–59% of tarsus lengths; 75% was in depths of ≤ 95–99% of tarsus lengths, and 100% of foraging was in ≤ 113–117% of tarsus lengths.

Measured tarsus lengths of males of subspecies *nigripes,* resident in Australia, are almost identical (99.3%) to those of nominate subspecies *garzetta* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Little Egret foraging in Ghana do not, therefore, require adjustment to be potentially applicable (males, at least) to Little Egret in Australia.

Subspecies	Distribution	Source materials	Tarsus (males; mm)	Tarsus (females; mm)	Signif.
nigripes	Australia +	SE Aust., adults, skins	100.3 (5.30; 95-112; 7)	–	–
garzetta	Africa +	Adult & juvenile, skins	101 (8.24; 78-112; 17)	97.3 (6.36; 88-110; 17)	ns

Paton *et al.* (2011) observed two Little Egrets foraging (n=2) in knee-deep water in the Coorong in January 2011. This depth can be calculated as (1 x male tarsus length) = 100mm, that is 10cm.

Recher *et al.* (1983): ‘Little Egrets hunted mostly in open water 100 to 150 mm in depth (Table 2) …’ ‘Typically a bird paused in an erect position with the neck fully extended and scanned for prey.’

Table 2. Percent of time [Little Egrets] foraged at different depths of water on the Magela Creek Floodplain, Northern Territory and the Hawkesbury River, New South Wales.’

Water Depth (mm)	0–1	1.1–49	50–99	100–149	150–199	200–250	Observations
% of foraging time	0	24.9	68.9	4.4	1.6	0	180 minutes

HANZAB (Marchant & Higgins 1990) reported a mean tarsus length of adult male Little Egrets as 100.3mm (n=7), while an unsexed adult bird had a tarsus length of 91.8mm and two juveniles had lengths of 84.4 and 89.0mm. Recher *et al.* (1983) reported a mean tarsus length of 99 ±2mm (sexes pooled, n=5). On the basis of these measurements, maximum foraging depths for at least adult males and probably the species (the sexes are of similar size) may be estimated as 2 x (tarsus length) = c. 20cm.

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.70. Application of this ratio to the HANZAB (100.3mm) and Recher (99mm) tarsus lengths produces ‘belly depths’ of c. 17.0cm (16.8 & 17.1cm).

Eastern Reef Egret *Egretta sacra*

HANZAB (Marchant & Higgins 1990) ‘Widely distributed in maritime littoral and estuarine habitats’ and ‘In littoral and estuarine habitats, feed mainly at low tide in shallow water; in pools and channels in rock platforms, mudflats and river beds’ and ‘May fish in deeper water in flight (‘terning’) when sallying from rocks or other perches (Recher & Recher 1972; Edgar 1978)’ and ‘Approach prey by slow stalking … , walking’ and ‘lunging up to 2 m from perch in pouncing dive’ and ‘Almost always feed actively, flying from rock to rock or walking slowly along water's edge. Rarely stand and wait or pursue prey (Recher & Recher 1972)’ and ‘Also seen to … hover while stabbing at water from air (Loyn 1985, 1987)’.

This species forages mainly by stalking while walking, rarely by standing and waiting (Marchant & Higgins 1990).

HANZAB (Marchant & Higgins 1990) reported Eastern Reef Egret tarsus lengths (means) of 81.4mm (males; n=6) and 79.5mm (females; n=10). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 16cm (males) and c. 16cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.33. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 10.8cm (males) and c. 10.6cm (females).

Nankeen Night-Heron *Nycticorax caledonicus*

HANZAB (Marchant & Higgins 1990) ‘Generally solitary, nocturnal when feeding, stalking slowly or standing hunched in wait for prey before striking’ and ‘Mainly nocturnal; forage over soft or firm substrate; …, on exposed shores, banks and flats in wetlands, or in swampy vegetation; … (Gosper 1981; Recher & Holmes 1982; Schulz 1989). Can forage in deep water, by making aerial sallies or plunging from perches (Mathews 1909a; Hobbs 1956)’ and ‘Usually stand and wait in erect or crouched posture or walk slowly (Recher & Holmes 1982). Also drop from up to 2 m onto aquatic prey, emerging from water with difficulty (Hobbs 1956), drop briefly on to water surface with wings raised (Mathews 1909a)’.

Night-Heron forage by standing and waiting or stalking while walking slowly (Recher & Holmes 1982).

Night-Heron have also been reported feeding in water 'about three feet deep', by springing feet first into the water from protruding tree stumps while simultaneously taking tadpoles in their bills (Hobbs 1956). Where they could not obtain sufficient support from submerged aquatic plants for subsequent take-off, returning to their perches involved significant effort. They may also 'drop briefly on to water surface with wings raised' (HANZAB, from Mathews, G.M. (1909). Emu 9: 1-16).

HANZAB (Marchant & Higgins 1990) reported Nankeen Night-Heron tarsus lengths (means) of 82.1mm (males; n=58) and 79.3mm (females; n=21). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 16cm (males) and c. 16cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.74. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 12.8cm (males) and c. 12.4cm (females).

Ibises, Spoonbills Family Threskiornithidae

Glossy Ibis *Plegadis falcinellus*

HANZAB (Marchant & Higgins 1990) 'Walk and wade' and 'Probe for food mainly in shallows and on land' and 'Forage in shallow water over soft substrate or on grassy or muddy verges of wetlands, preferring those providing variety of water depths (Morton *et al.* 1989); avoid dry ground' and 'Food taken … while probing soft sediments, or taken from surface … (Gowland 1988)' and 'sometimes [feed] abreast in shallow water or on soft substrate (Gowland 1988)'.

This species forages by walking in shallow waters or on the verges of wetlands, preferring those providing a variety of water depths (HANZAB from Moreton, S.R., Brennan, K.G. & Armstrong, M.D. (1989). *Distribution and abundance of waterbirds in the Alligator Rivers, Northern Territory.* Report to Australian National Parks & Wildlife Service, Canberra.) and avoiding dry ground. They are uncommon on the coast but occasionally on estuaries (Marchant & Higgins 1990).

Taylor & Taylor (2015): Study at Fivebough Swamp in NSW. 'Glossy Ibis **showed a strong preference for feeding in areas of water couch grass (*Paspalum distichum*) less than 10 cm tall interspersed among open water,** and avoidance of areas dominated by bulrush (*Typha spp*.), common spike rush (*Eleocharis acuta*) and open non-vegetated water'. 'We quantified details of habitat use by Glossy Ibis, water and vegetation depths, percentage vegetation cover and invertebrate populations ...' '**We recorded the water depth at which each bird was feeding by comparison with the birds' leg lengths. We used the average tarsus length of 90 mm** for males and females combined as the sexes could not be separated reliably in the field (Marchant and Higgins 1990)'. 'We tested selection of water depths of foraging birds by chi-square analysis, comparing observed values with expected random values calculated from measurements of water depths during the grid sampling'. 'The **maximum depth** Glossy Ibis waded into the water during feeding was **17 cm** [based on an assumed leg length of 90mm – see method above]'. 'Probing depths ranged from bill tip to the entire head being immersed. **Mean wading depth** when foraging in water couch grass did not differ significantly from that in open water (water couch grass, **77.0 ±2.6 mm,** $n = 200$; open water, **84**.0 ±3.2 [mm], $n = 60$; $F_{1,258} = 2.22$, $P = 0.14$)'. NEED TO REVIEW 'INTERIM FORAGING DEPTHS' TABLE ON BASIS OF THESE MEASUREMENTS.

Gowland, P.N. (1988). … RAOU Microfiche 35. (Glossy Ibis foraging in water). IS THIS? …

Gowland, P.N. (1983) A guide to the ecology and management of bird pest species of commercial agriculture in the Ord River Irrigation Area, No.2. Waterbirds. *RAOU Microfiche Series M35.* Royal Australiasian Ornithologists Union, Melbourne.

HANZAB (Marchant & Higgins 1990) reported Glossy Ibis tarsus lengths of 96.8–107.7mm (males; n=3) and 79.4mm (mean, females; n=5). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 20cm (males) and c. 16cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.76. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 17.0–19.0cm (males) and c. 14.0cm (females).

Australian White Ibis *Threskiornis molucca*

HANZAB (Marchant & Higgins 1990) 'Inhabit wetlands of almost any sort, including estuaries and tidal mudflats' and 'Walk and wade slowly, probe for food very deliberately, in the ground or under water' and 'Prefer feeding in shallow water over soft substrate or on muddy flats and shores' and 'Walk slowly, using long curved bill to probe substrate or to peck food from surface of both land and shallow water'.

White Ibis forage while walking slowly, probing the substrate or pecking food from the surface of both land and shallow water (Marchant & Higgins 1990).

Paton *et al.* (2011) observed that Australian White Ibis were foraging (n=20) in the following water depths in the Coorong in January 2011: ‘dry’ 10%, ‘damp’ 75%, ‘knee’ 15%. Thus 85% of birds were foraging in 0cm (mostly damp rather than dry) and all birds were foraging in water depths equal to or less than ‘knee deep’, which can be calculated as ≤ (1 x male tarsus length) = ≤ 103mm, that is ≤ 10cm.

Safran, R.J., Colwell, M.A., Isola, C.R. & Taft, O.E. (2000). *Foraging site selection by non-breeding white-faced ibis*. The Condor 102:211-215.

HANZAB (Marchant & Higgins 1990) reported White Ibis bill lengths (means) of 190.5mm (males; n=78) and 154.0mm (females; n=86).

HANZAB (Marchant & Higgins 1990) reported White Ibis tarsus lengths (means) of 103mm (males; n=4) and 85.8mm (females; n=12). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 21cm (males) and c. 17cm (females). But compare with other sample of females.

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.63. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 16.8cm (males) and c. 14.0cm (females).

Straw-necked Ibis *Threskiornis spinicollis*

HANZAB (Marchant & Higgins 1990) ‘Typically found … feeding on wet or dry ground in grassland or cultivated land; also … in shallows or round margins of wetlands, mainly freshwater. Feed by probing into ground or vegetation with strong bill’ and ‘Feed in damp or dry grassland, often away from wetlands, or in aquatic shallows <0.25 m deep (Carrick 1959), …’ and ‘Long curved bill used for probing … [and] into shallow water (McKilligan 1979)’.

This species is commonly observed foraging on grasslands, wet or dry, but may also feed in aquatic shallows <0.25m deep (HANZAB from Carrick, R. (1959). *The food and feeding habits of the Straw-necked Ibis, Threskiornis spinicollis (Jameson), and the White Ibis, T. molucca (Cuvier) in Australia.* CSIRO Wildlife Research 4(1): 69-92.)

Paton *et al.* (2011) observed that Straw-necked Ibis were foraging (n=16) in the following water depths in the Coorong in January 2011: ‘dry’ 19%, ‘damp’ 81%. Thus all birds were foraging in 0cm of water, on mostly damp rather than dry substrate.

HANZAB (Marchant & Higgins 1990) reported Straw-necked Ibis bill lengths (means) of 167.2mm (males; n=8) and 137.7mm (females; n=6).

HANZAB (Marchant & Higgins 1990) reported Straw-necked Ibis tarsus lengths (means) of 93.1mm (males; n=8) and 78.7mm (females; n=7). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 19cm (males) and c. 16cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.71. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 15.9cm (males) and c. 13.5cm (females).

Royal Spoonbill *Platalea regia*

HANZAB (Marchant & Higgins 1990) ‘Habitually wade; feed by sweeping bill in smooth lateral arcs’ and ‘Structure of bill limits feeding to shallow water <0.4 m deep over substrate of sand, mud or clay (Vestjens 1975); birds often feed among aquatic or emergent vegetation or submerged logs that shelter prey (Vestjens 1975; Lowe 1982)’ and ‘Take food from on or above substrate (Lowe 1982)’ and ‘Five methods of feeding described [All descriptions from Vestjens 1975]: **Slow Sweeping**: … when bill at extremity on one side of body, leg on opposite side moved forward, disturbing food items in substrate. Bill can be partly or completely submerged, with part of head and neck as well. **Intensive Search:** bill moved rapidly from side to side as bird wades slowly, quickly or even runs with flapping wings; usually tries to relocate food encountered by slow sweeping; often successful. **Dragging:** in very shallow water bill dragged first on one side then the other; usually unsuccessful … **Probing:** the bases of waterplants or submerged logs explored with rapid stabbing movements. **Grabbing:** food items grabbed from shallow water, plants or ground with tip of bill’ and ‘Apart from that captured by grabbing, all food located by feel, the bill closing only on objects touching inside of spoon (Vestjens 1975) … The food therefore usually floating or swimming within water column (Vestjens 1975)’.

Vestjens (1975) reported that Royal (and Yellow-billed) Spoonbills at Lake Cowal, NSW, ‘fed in every available area of water up to 400mm deep. Shallow pools in secluded areas were favoured but only occurred when water was low’. ‘Some birds fed with only half the bill submerged; others submerged the bill, head and part of the neck and then the legs and lower part of the body were also under water. Royal Spoonbills fed with head and part of the neck under water more often than Yellow-billed’. Yellow-billed dipped their bills into the water ‘at about an angle of 60° to the horizontal’ before sweeping it from side to side. Royals dipped their bills into the water ‘nearly vertically’ before sweeping and moving it back and forth.

Under the heading 'Field Identification', Marchant & Higgins (1990) wrote 'Length 74-81cm, of which body less than half'. Mean bill lengths from two of their sources (K.W. Lowe – exposed culmen; Vestjens 1975 – method unknown) are 212mm (males; n=6) and 178mm (females; n=4), and 180mm (males; n=3) and 164mm (females; n=9), respectively. Mean tarsus length measurements (largest sample) are given as 122.5mm (males; n=6) and 108.5mm (females; n=4).

Based on the above specimen measurements, maximum wading depth (estimated as 2 x tarsus length) of Royal Spoonbills can be calculated as 2 x 122 = c. 24cm (males) and 2 x 108.5 = c. 22cm (females). Maximum depth reached (head and neck submerged; estimated as 0.6 x total length) can be calculated as 0.6 x (74–81cm) = 44–49cm. These may be compared with Vestjens' (1975) observation that this species 'fed in every available area of water up to 400mm deep'. Such comparison suggests that '2 x tarsus length' produces (surprisingly, given the leg proportions illustrated in Plate 80 of Marchant & Higgins) a substantial under-estimate of maximum foraging depth for this species, whereas '0.6 x total length' is an over-estimate. '0.5 x total length' produces depths of 37–40cm.

Paton *et al.* (2011) observed that Royal Spoonbill were foraging (n=7) only in knee-deep water in the Coorong in January 2011. This particular depth can be calculated as (1 x tarsus length) = c. 116mm, that is ≈12cm, which is substantially less than maximum foraging depth.

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 2.00. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 24.5cm (males) and c. 21.7cm (females).

Yellow-billed Spoonbill *Platalea flavipes*

HANZAB (Marchant & Higgins 1990) '[Habitat] Terrestrial wetlands, wet grasslands and, rarely, sheltered marine habitats. Structure of bill limits feeding to shallow water <0. 4 m deep over substrate of sand, mud or clay; birds forage in open water, or near emergent vegetation or submerged logs that shelter prey (Vestjens 1975)' and 'Five methods of feeding described [All descriptions from Vestjens 1975]: **Slow Sweeping**. … when bill at extremity on one side of body leg on opposite side moved forward, disturbing food items in substrate. **Intensive Search**. Bill moved rapidly from side to side as bird wades … usually attempting to relocate food encountered by Slow Sweeping; usually successful. **Dragging**. In very shallow water bill dragged first on one side, then the other; usually unsuccessful … **Probing**. Bases of waterplants or submerged logs explored … **Grabbing**. Food items grabbed from shallow water, plants or ground with bill tip. Apart from that captured by grabbing, all food located by feel, bill closing only on objects touching inside of bill. Food must therefore be floating or swimming within water column'.

For an account of Yellow-billed Spoonbill foraging depths by Vestjens (1975), see Royal Spoonbill (above).

Under the heading 'Field Identification', Marchant & Higgins (1990) wrote 'Length 76–92cm, of which body less than half'. Mean bill lengths sourced by these authors from Vestjens (1975) are 231mm (males; n=5) and 205mm (females; n=8). Two tarsus length measurements (from museum skins) are given as 130mm and 138.1mm (both males).

Based on the above specimen measurements, maximum wading depth (estimated as 2 x tarsus length) of Yellow-billed Spoonbills can be calculated as 2 x 134 = c. 27cm. Maximum depth reached (head and neck submerged; estimated as 0.6 x total length) can be calculated as 0.6 x (76–92cm) = 46–55cm. These may be compared with Vestjens' (1975) observation that this species 'fed in every available area of water up to 400mm deep'. Such comparison suggests that '2 x tarsus length' produces (surprisingly, given the leg proportions illustrated in Plate 80 of Marchant & Higgins) a substantial under-estimate of maximum foraging depth for this species, whereas '0.6 x total length' is an over-estimate. '0.5 x total length' produces depths of 38–46cm.

Paton *et al.* (2011) observed a single Yellow-billed Spoonbill foraging (n=1) in knee-deep water in the Coorong in January 2011. This particular depth can be calculated as (1 x male tarsus length) = 134mm, that is ≈13cm. ASSUMES BIRD WAS MALE, which is substantially less than maximum foraging depth.

HANZAB (Marchant & Higgins 1990) reported Yellow-billed Spoonbill bill lengths (means) of 231mm (males; n=5) and 205mm (females; n=8).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.86. Application of this ratio to the HANZAB tarsus lengths (two males only) produces 'belly depths' of c. 24.2cm and c. 25.7cm.

Osprey, Kite, Eagles, Harriers Family Accipitridae

Eastern Osprey *Pandion cristatus*

HANZAB (Marchant & Higgins 1993) 'Solitary raptor usually of coasts and estuaries …' and 'Capture fish by plunging feet-first into water' and 'may submerge to depth of about a metre or grab fish at surface' and 'drop steeply to water, extending talons and lifting wings just before entering, often submerging completely. Occasionally stoop to surface with only feet entering water (Cupper & Cupper)' and 'Rise easily out of water, shaking plumage a metre or so above surface (MacGillivray 1926)' and Birds sometimes taken in flight (Mooney 1987)' and 'waterproof plumage, spicules on feet, and exceptionally long curved claws adaptations for catching and grasping fish …' and 'Nostrils can be closed to prevent water entering while submerged (Hollands)'.

HANZAB (Marchant & Higgins 1993) reported Osprey tarsus lengths (means) of 59.7mm (males; n=18) and 63.3mm (females; n=13; significant diff.). ~~On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 12cm (males) and c. 13cm (females).~~

White-bellied Sea-Eagle *Haliaeetus leucogaster*

HANZAB (Marchant & Higgins 1993) 'Solitary eagle of coasts, estuaries, rivers, inland lakes and adjacent terrestrial habitats; sometimes over other habitats. Snatch food from surface of water in glide or shallow dive; scavenge, rob other raptors' and 'Prefer large open terrestrial wetlands, …. nature of shoreline or emergent vegetation apparently unimportant, provided open water remains' and 'Search for prey and carrion from perch or on wing. … Take live prey from on or near surface of water, plunging to at least 40 cm depth (Favaloro 1944)' and 'sometimes almost completely submerging [plunge-dive], for surface-swimming fish, sea-snakes, … (McGilp 1934; Favaloro 1944; Fleay 1948; Green 1959; Hollands; Gould)' and 'will dive repeatedly to drive Coot from flock and exhaust it (R.J. Bilney)' and 'Commonly recorded taking juveniles from colonial nesting species such as cormorants, Darter, Australian White Ibis. Feathering only on base of tarsus, permitting legs to plunge into water and handle bloodied prey without staining and matting feathers (R.J. Bilney)'.

HANZAB (Marchant & Higgins 1993) reported Sea-Eagle tarsus lengths (means) of 99.6mm (males; n=8) and 104mm (females; n=10; significant diff.) and middle toe lengths of 63.5mm (males; n=4) and 73.2mm (females; n=6; significant diff.). On this basis, this species 'maximum preferred reach depth' might be estimated (ignoring feathers at 'base of tarsus' – see HANZAB illustrations) as 1 x (tarsus length + half mid-toe length) = 99.6 + 31.75 = 131.35mm (males) and 104 + 36.6 = 140.6mm (females), i.e. as c. 13cm (males) and c. 14cm (females).

Whistling Kite *Haliastur sphenurus*

HANZAB (Marchant & Higgins 1993) 'most terrestrial habitats except dense forest; often near water' and 'Often a scavenger, attracted to carrion … swoop down to snatch dead fish or other floating objects from surface of waters …' and 'All sorts of wetlands used where open water available. Frequent shallow estuarine waters … saltmarsh' and 'Opportunistic hunter (D.J. Baker-Gabb)' and 'When taking live prey, dive-attack, hitting prey with feet' and 'Stoop to take fish; descend rapidly to about 20 cm above water and snatch fish from water with talons' and 'Harry and rob conspecifics and other animals including herons and egrets …'.

HANZAB (Marchant & Higgins 1993) reported Whistling Kite tarsus lengths (means) of 57.0mm (males; n=13) and 59.4mm (females; n=15; not significant diff.) and middle toe lengths of 37.3mm (males; n=15) and 38.9mm (females; n=24; not significant diff.). On this basis, the Whistling Kite's 'maximum preferred reach depth' might be estimated (see HANZAB illustrations) as 1 x (tarsus length + half mid-toe length) = 57.0 + 18.65 = 75.6mm (males) and 59.4 + 19.45 = 78.85mm (females), i.e. as 8cm (males) and 8cm (females).

Swamp Harrier *Circus approximans*

HANZAB (Marchant & Higgins 1993) 'Mainly confined to wetlands, fresh or salt; often deep swamps with tall emergent vegetation of rush, reeds or sedge … and areas of open water. Other habitats: shallow open swamps; swamps with other emergent vegetation, …, saltmarsh; saltpans; and saltfields (Parker 1969; Crawford 1972; Vestjens 1977; Corrick & Norman 1980; Gasper 1981; Corrick1982; Jaensch *et al.* 1988)' and '[Food] Take small mammals, up to size of adult hare, rabbits, birds and eggs, large insects, frogs, fish and reptiles' and 'Catch prey on ground or water, rarely on wing (D.J. Baker-Gabb). When taking Eurasian Coots from water may remain above until Coot too exhausted to dive, sometimes plunging into water (Hollands). Also tired out Dusky Moorhen by holding under water, trying either to move or drown prey (Coventry 1989)' and 'Stoop to catch fish, grasping them in feet under water (Habraken 1979); sometimes half-submerge when attacking swimming duck (Potter 1950); wade in shallow water to catch fish and tadpoles (Stead 1932). Once observed snatching small live fish from surface of water (H. Naarding). Recorded recovering dead duck from water by dragging slowly through water to shore; once on shore easily flew holding prey (McLennan 1976)' and 'At Werribee (Vic.), three times as many waterbirds as land birds taken (Baker-Gabb 1982a; Mooney 1983b), Eurasian Coots most numerous (16%) throughout year, with most taken autumn and winter. Live Coots and smaller waterbirds regularly taken; larger birds, e.g. ibis, always eaten as carrion'.

HANZAB (Marchant & Higgins 1993) reported Swamp Harrier tarsus lengths (means) of 93.8mm (males; n=8) and 99.5mm (females; n=10; significant diff.). and middle toe lengths of 42.4mm (males; n=8) and 47.7mm (females; n=10; significant diff.). On this basis, the Swamp Harrier's 'maximum preferred reach depth' might be estimated (see HANZAB illustrations) as 1 x (tarsus length + half mid-toe length) = 93.8 + 21.2 = 115.0mm (males) and 99.5 + 23.85 = 123.35mm (females), i.e. as c. 12cm (males) and c. 12cm (females).

Rails, Crakes, Water-hens, Coot Family Rallidae

Purple Swamphen *Porphyrio porphyrio*

HANZAB (Marchant & Higgins 1993) '[Habitat] Terrestrial wetlands and adjacent grasslands; also estuarine and littoral wetlands' and 'During much of the day, keep to denser reed beds where climb, wade through or roost in vegetation over water, but also move out into adjacent wet pasture and sward to graze' and 'Swim infrequently though well …' and 'When feeding, have parrot-like habit of holding food firmly in one foot' and 'occasionally feed on open mudflats (Pierce 1980; Fordham 1983; Norman & Mumford 1985)' and 'Feed on ground and in water; in swamps, damp pastures, and grasslands' and 'will immerse head and swim to reach new growth, but not seen diving'.

HANZAB (Marchant & Higgins 1993) reported Swamphen tarsus lengths (means) of 96.4mm (males; n=114) and 89.6mm (females; n=66; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 19cm (males) and c. 18cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.81. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 17.4cm (males) and c. 16.2cm (females).

Buff-banded Rail *Gallirallus phillipensis*

HANZAB (Marchant & Higgins 1993) 'Feed by picking items off ground or surface of vegetation, but some prey also secured from under water' and 'Forage round vegetated margins of wetlands on mud among or next to tall grass, reeds, rushes and samphire; also on grassy banks or flats next to wetlands; among other concealing vegetation such as bushes and willows; mudflats (Hodgkins 1948; Sharland 1958; Sawyer 1968; Mason & Wolfe 1975; Mason 1980; Elliott 1987; Vic. Atlas)' and 'Feed on ground; usually solitarily; seldom in groups of up to 15 (Stokes *et al.* 1984). Probe and peck in mud, shallow water and on beaches (Stokes *et al.* 1984), occasionally in pastures (Bravery 1970)'.

HANZAB (Marchant & Higgins 1993) reported Buff-banded Rail tarsus lengths (means) of 40.8mm (males; n=30) and 38.8mm (females; n=18; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 8cm (males) and c. 8cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.24. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 5.1cm (males) and c. 4.8cm (females).

Baillon's Crake *Porzana pusilla*

HANZAB (Marchant & Higgins 1993) 'Singly or in pairs in aquatic vegetation in wetlands. Secretive but not shy, though nervous; periodically dash for cover for no obvious reason, though soon re-emerge' and 'Pass easily between reeds, run on aquatic vegetation that grows on or just below water surface, and climb in vegetation. Prefer to forage on floating vegetation, sometimes in open' and 'when disturbed on floating vegetation, scuttle madly as plants sink gradually beneath weight; sometimes run or rest on branches of waterside trees; swim readily and dive' and '[Habitat] Vegetated, permanent to ephemeral terrestrial and coastal wetlands' and 'Wetlands usually have dense vegetation, often with abundant floating plants, but also occur in open waters with clumped vegetation (Barlow & Sutton 1975; Mason & Wolfe 1975; Ogle & Cheyne 1981; Moore 1983)' and 'Occasionally on saltmarsh, especially in NZ; in Nelson and Marlborough Sounds, only found in saltmarsh (Elliott 1989), and all records at Waimea Inlet are of birds on mudflats, round tidal creeks or in saltmarsh (Owen & Sell1985; CSN)' and 'May prefer wetlands subject to fluctuating water levels (Bryant 1942; Moore 1983). Occur on floating vegetation in deep water (R.P. Jaensch)' and 'Forage on mud in and next to reeds and other fringing vegetation. Also feed while wading in either clear water or water covered with *Azalia* and other floating vegetation to a depth of c. 3 cm (Barlow & Sutton 1975; Mason & Wolfe 1975; Moore 1983)' and 'Glean among floating vegetation, saltmarsh, freshwater reeds, mudflats, and shallow water, occasionally wading up to level of body (Moore 1983; R.P. Jaensch). Swim well and reported to dive for food (BWP). Suggested that may compete with Spotless Crake for food (Ripley 1977), but forage in different areas (R.P Jaensch) and confirmation needed'.

HANZAB (Marchant & Higgins 1993) reported Baillon's Crake tarsus lengths (means) of 25.3mm (males; n=16) and 24.9mm (females; n=12; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.30. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 3.3cm (males) and c. 3.2cm (females).

Australian Spotted Crake *Porzana fluminea*

HANZAB (Marchant & Higgins 1993) 'in well-vegetated freshwater or brackish wetlands; also in samphire and other scrubby cover round saltmarshes …' and 'Gait a slow, stalking walk with tail constantly flicking; and sudden crouching run with tail cocked when disturbed. Swim and dive readily, but only over short distances in cover or across channels or streams' and 'Prefer to forage on open mud or wade in very shallow water, though never far from cover; often forage farther out from cover than other crakes but dash back at hint of danger' and '[Habitat] Well-vegetated margins of permanent or ephemeral terrestrial and maritime wetlands. … Found round estuaries, tidal creeks, saltmarshes, … Though said to be less dependent on dense *cover* than Spotless Crakes (Bryant & Amos 1949), usually among dense vegetation such as samphire, …, reeds and rushes … (Bright & Taysom 1932; Bryant & Amos 1949; Hobbs 1961; Ford 1962; Eckert 1971; Cox 1974; Chinner 1977; Czechura 1983; Jaensch 1989)' and 'Mainly forage at margins of wetlands in shallow (<5 cm) water or on mud or peat near or among reeds, rushes, saltmarsh, grass or other shrubs (Bryant & Amos 1949; Ford 1962; Vestjens 1972; Badman 1979; Patterson 1989) …' and 'Glean and probe on mudflats and in reed beds. Wade in shallow water and swim, probing and lunging under water and at emergent vegetation. Often submerge whole head. Large items brought ashore … (Bryant & Amos 1949)'.

HANZAB (Marchant & Higgins 1993) reported Australian Spotted Crake tarsus lengths (means) of 30.1mm (males; n=33) and 28.6mm (females; n=16; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.64. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.9cm (males) and c. 4.7cm (females).

Spotless Crake *Porzana tabuensis*

HANZAB (Marchant & Higgins 1993) '[Habitat] Permanent or ephemeral, terrestrial and littoral wetlands, usually with continuous blocks of tall emergent reeds, rushes, sedges or other vegetation (Hadden 1970; Ogle & Cheyne1983; Kaufmann 1987) …' and 'Usually forage on mud or in shallow water, either in the open or beside concealing vegetation, at margins of wetlands (Bryant & Amos 1949; Howard 1962; Vestjens 1972; Patterson1989). Prefer to feed at base of reeds, rather than in sedges and rushes (Bryant & Amos 1949)' and 'Usually feed on ground; …' and 'Glean on mudflats, in reed beds, shallow water, tideline and drift line of rivers, … ; also swim readily'.

HANZAB (Marchant & Higgins 1993) reported Spotless Crake tarsus lengths (means) of 29.6mm (males; n=27) and 28.2mm (females; n=17; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.74. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 3.8cm (males) and c. 3.7cm (females).

Black-tailed Native-hen *Tribonyx ventralis*

HANZAB (Marchant & Higgins 1993) 'seen … in almost any open dry area close to water and cover and in scrubby or timbered areas' and 'Wade, and swim readily with buoyant carriage and tail erect; seldom wade' and '[Habitat] Opportunistic; permanent or ephemeral terrestrial wetlands …' and 'During irruptions (and at other times), may use many habitats, …' and 'Forage at edge of water or on open ground near wetlands …' and 'feed in water and on ground. Glean from ground and surface of water. Feed gregariously or in pairs, alternately running and stopping in order to disturb insects. Submerge head and shoulders in water (Christian 1909)'. Christian, E.J. (1909) … Emu 9:95-97.

HANZAB (Marchant & Higgins 1993) reported Native-hen tarsus lengths (means) of 61.7mm (males; n=15) and 56.5mm (females; n=14; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 12cm (males) and c. 13cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.27. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 7.8cm (males) and c. 7.2cm (females).

Dusky Moorhen *Gallinula tenebrosa*

HANZAB (Marchant & Higgins 1993) 'Swim well and buoyantly, …' and 'Up-end in water when feeding; dive when pressed' and 'Permanent or ephemeral terrestrial and coastal wetlands, usually fresh, but sometimes brackish to saline; including swamps, creeks, rivers, lagoons estuaries, billabongs and artificial wetlands. Require open water (S.T. Garnett); margins of wetlands often vegetated with emergent or floating vegetation, …' and '[wetlands] may not have peripheral vegetation (van Tets 1969)' and 'Seldom far from edge of wetland (S.T. Garnett); and 'Forage in open shallow water (to at least 30 cm deep), among floating vegetation or in open water of wetlands, usually within 100m of cover; also on adjacent land; often on grass and herb fields near water' and 'Feed in water and on land. Food taken from up to 30 cm below surface' and 'Prefer feeding in shallow water where there is much vegetation (Martin et *al.* 1979). Sometimes run after insects, …' 'While swimming, glean from surface and up-end for 2–7 s, with head, body and wings submerged and tail and legs in air; do not dive; when feeding, tail always remains above water (Garnett 1978; Martin et *al.* 1979).

Under the heading ‘Field Identification’, HANZAB (Marchant & Higgins 1993) write ‘Length 35–40cm’. On this basis, the maximum depth reached by an up-ending Moorhen might be estimated as 0.6 x (35–40) = 21–24cm, which is less than the above estimates of 30cm. A factor of 0.8 needs to be applied (to an average length of 37.5cm) to obtain a depth of 30cm.

Measurements from side-on photographs of Dusky Moorhen in flight produce a mean ‘tip of bill to mid-body’ / ‘total length’ ratio of 0.587 (n=3). Application of this ratio to the Dusky Moorhen total lengths (‘Field Identification: Length 35–40cm’) of HANZAB ~~Frith (1967/77)~~ results in ‘maximum reach’ estimates of 0.587 x 350 = 205.45mm and 0.587 x 400 = 234.8mm. ~~0.587 x ... = ...mm (males) and 0.587 x ... = ...mm (females).~~

HANZAB (Marchant & Higgins 1993) reported Moorhen tarsus lengths (means) of 63.3mm (males; n=19) and 60.2mm (females; n=16). ~~On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 13cm (males) and c. 12cm (females).~~

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.36. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 8.6cm (males) and c. 8.2cm (females).

Eurasian Coot *Fulica atra*

HANZAB (Marchant & Higgins 1993) ‘Dive well but only for short time, often jump before diving’ and ‘Prefer shallow, permanent or ephemeral wetlands with high diversity of submerged or emergent aquatic vegetation, often with open and deeper water (>2m) for diving (Anon. 1973; Briggs 1979; Martin *et al.* 1979; Corrick & Norman 1980; Broome & Jarman 1982; Czechura 1983; Jaensch 1983)’ and ‘Forage in open, deep or shallow water in wetlands, especially where submerged aquatic vegetation occurs; on floating mats of aquatic vegetation ; in grassy areas next to wetlands (Small 1960; Anon. 1973; Ross 1978; Czechura 1983; Jaensch *et al.* 1988)’ and ‘Usual methods of feeding: scrape algae off submerged stems, stones and tree-stumps (Martin *et al.* 1979); pick food off surface of water while swimming (Bridgewater 1935); feed among vegetation stirred up by other waterfowl (Sedgwick 1940); break off young emergent plant shoots and soft white bases (North); up-end in depths up to 40 cm, occasionally immersing whole body, in bouts 1-13 s long … (Hurter 1972); dive, having pressed air out of feathers, by leaping up, tilting forward, and diving almost vertically with neck extended, then bring food to surface to sort and eat. In A'asia, depths of diving recorded from 80 cm (Martin *et al.* 1979) to 2.6 m (Bakker & Fordham 1993); in Europe, average 1-2m to maximum 6.5 m (Hofer 1958). Height of preceding jump and average duration of dive increase with depth; maximum duration c. 20 s (Glutz von Blorzheim *et al.* 1973)’.

Gayet et al. (2011): [A study in France] ‘Indeed, the waterbirds whose presence was the most closely correlated to that of Mute Swan pairs were Coot (*Fulica atra*), Common Pochard (*Aythya ferina*) and Red-Crested Pochard (*Netta rufina*), all foraging on deep macrophyte beds as do the swans. All these species, including swans, may therefore be attracted to the same fishponds without massive interspecific competition occurring, due to abundant submerged aquatic vegetation resources.

Matuszak et al (2012) Exclosure study on the exploitation of macrophytes by summering and moulting waterbirds at Lower Lake Constance [in Europe] ‘In these experiments, we found that the summering and moulting waterbird community, dominated by Eurasian Coots (*Fulica atra* Linnaeus), caused a significant decline of the macrophyte biomass at 1.5-m depth (MWL), where they were responsible for a loss of over 40% of the total charophyte biomass. No grazing effect was found at a greater depth (2-m MWL). The available food consisted mostly of *Chara* spp. with a biomass density of about 350 g m^{-2} ’ ‘Coots, the most numerous birds at Mettnau Su¨dbucht, preferably feed at depths \2 m (Bauer et al., 1973); ...’ ‘Coots preferred to forage at the shallower sites consistent with the conclusion of De Leeuw (1997) that waterbirds tend to dive with the least energy expenditure necessary to gain food’.

Under the heading ‘Field Identification’, HANZAB (Marchant & Higgins 1993) write ‘Length 35–39cm’. On this basis, the maximum depth reached by an up-ending Moorhen might be estimated as 0.6 x (35–39) = 21–23cm. A factor of 1.1 needs to be applied (to an average length of 37cm) to obtain a depth of 40cm.

Measurements from side-on photographs of Eurasian Coot in flight produce a mean ‘tip of bill to mid-body’ / ‘total length’ ratio of 0.635 (n=2). Application of this ratio to the Eurasian Coot total lengths (‘Field Identification: Length 35–39cm’) of HANZAB ~~Frith (1967/77)~~ results in ‘maximum reach’ estimates of 0.635 x 350 = 222.25mm and 0.635 x 390 = 247.65mm. ~~0.587 x ... = ...mm (males) and 0.587 x ... = ...mm (females).~~

HANZAB (Marchant & Higgins 1993) reported Coot tarsus lengths (means) of 56.2mm (males; n=6) and 54.2mm (females; n=10). ~~On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 11cm (males) and c. 11cm (females).~~

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.26. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 7.1cm (males) and c. 6.8cm (females).

Oystercatchers Family Haematopodidae

Australian Pied Oystercatcher *Haematopus longirostris*

HANZAB (Marchant & Higgins 1993) 'on sandy beaches, intertidal mudflats and rocky shores …' and 'When foraging, walk sedately along muddy or sandy flats and bars exposed at low tide, probing and pecking with bill' and 'Forage on intertidal mudflats, beaches, saltmarsh, reef and rocks. Mostly forage at low water (Weston 1991a); feed extensively in wash-zone of ocean beach on ebb and flow tide (C.J. Chafer). Peck and jab into soft substrates' and 'Occasionally place whole head under water … (M.A. Weston)'.

Lauro, B. and Nol, E. 1995. Feeding behaviour, prey selection and bill size of Pied and Sooty Oystercatchers in Australia. Wilson Bulletin 107, 629-640.

Paton *et al.* (2011) observed that Pied Oystercatchers were foraging (n=162) in the following water depths in the Coorong in January 2011: 'dry' 7%, 'damp' 92%, 'ankle' 1%. Almost all birds were thus feeding in 0cm (mainly damp substrate rather than dry). No birds were feeding at greater than ankle-depth, that is ≈1cm.

HANZAB (Marchant & Higgins 1993) reported Pied Oystercatcher tarsus lengths (means) of 56.6mm (males; n=14) and 58.9mm (females; n=15; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 11cm (males) and c. 12cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.52. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 8.6cm (males) and c. 9.0cm (females).

Stilts, Avocets Family Recurvirostridae

Black-winged Stilt *Himantopus himantopus*

HANZAB (Marchant & Higgins 1993) 'In wetlands, feeding at edge of water and while wading' and 'Often seen strutting gracefully through water. Occasionally swim' and 'Feed mainly by picking daintily at surface of water or mud, chasing fast-moving prey, or scything water in manner of Avocet' and 'Occur on most types of wetlands …' and 'Forage in shallow water or saturated mud in fresh or nontidal saline wetlands, often close to emergent vegetation. Occasionally on wet flats or along margins of deep channels in tidal estuaries (Pierce 1980; Powlesland & Robertson 1987; Barlow 1989)' and 'Forage in water up to belly, on damp pasture … and on tidal mudflats. Nine feeding methods described. (1) PECK: most common method used for aquatic or surface prey; … on wind-blown marshes, may stand in one place to wait for prey … (Pierce 1986b; LB. Kahl) … (2) PLUNGE: peck with bill and head immersed. (3) SNATCH to capture flying insects. (4) BILL-PURSUIT (uncommon): rapidly open and close bill on surface of water. (5) FILTERING (uncommon): rapidly dabble bill, sweeping from side to side in mud and weed. (6) PROBE: insert bill into substrate. (7) SCYTHE: … sweeping bill in arc of 100-300 mm ... (8) LATERAL PROBING (uncommon): place slightly open bill under substrate. (9) RAKING: sweep bill through fine shingle to reveal prey, which is then pecked up (Pierce 1985). Also take invertebrates displaced by flood, by hovering over them with legs trailing in water, seizing them and returning to shore to swallow (Johnson 1990)'' and 'In Aust., tend to continue feeding by sight in shallower water when ambient conditions deteriorate'.

Marchant & Higgins (1990) describe this species of stilt as foraging 'in shallow water ['up to belly'] or saturated mud in fresh or non-tidal saline wetlands, often close to vegetation'.

HANZAB: 'recorded at salinities between 10 and 145 ppt (Jessop 1987); and in sw. WA, in waters ranging from 0. 127 to 21.52 g/l (Goodsell 1990)'.

Pierce (1985): 'At muddy ponds in Australia, pied [Black-winged] stilts and Australian avocets *(Recurvirostra novaehollandiae)* often feed alongside each other, the avocets usually scything and the stilts pecking and plunging. Even during windy periods, I have observed a tendency among Australian pied stilts to peck in shallower water rather than switch to scything'.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Black-Winged Stilts (subspecies *himantopus*) and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Stilt and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Black-winged Stilt (subspecies *himantopus*)	**Water depth (cm)**	**Water depth as % of ‘exposed vertical leg length’ (17.4cm)**	**Water depth as % of male tarsus length (12.7cm)**	**Water depth as % of female tarsus length (11.5cm)**
‘Minimum’ (0%)	0	0	0	0
1st Quartile (25%)	2.25	13	18	20
Median (50%)	4.75	27	37	41
3rd Quartile (75%)	7.1	41	56	62
‘Maximum’ (100%)	14	80	110	122

Note, in particular, that 25% of foraging was in water depths ≤ 18–20% of male-female tarsus lengths; 50% was in depths ≤ 37–41% of tarsus lengths; 75% was in depths of ≤ 56–62% of tarsus lengths, and 100% of foraging was in ≤ 110–122% of tarsus lengths.

Tarsus lengths of subspecies *leucocephalus*, resident in Australia, are smaller (*c.* 93%; male 92.5%, female 92.8%) than those of subspecies *himantopus* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP).

Subspecies	**Distribution**	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
leucocephalus	Australia +	SE Aust., adult, skins	117.9 (4.56; 114-125; 10)	105.2 (5.92; 92.6-117; 12)	**
		Tropical Aust. (n. WA and NT), adult, skins	117.1 (5.58; 112-125; 5)	108.2 (7.52; 99.5-120; 5)	ns
		Average	117.5	106.7	-
himantopus	Africa +	Not specified, skins	127 (5.47; 118-137; 25)	115 (6.44; 104-126; 22	yes

If the water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded *himantopus* foraging are adjusted by this percentage (93%) they change from 0, 2.25, 4.75, 7.1 & 14cm to 0, 2.1, 4.4, 6.6 & 13cm. Thus, 25% of foraging by *leucocephalus* would be in water depths ≤ 2.1cm; 50% in depths ≤ 4.4cm; 75% in depths ≤ 6.6cm, and 100% in depths ≤ 13cm.

Goriup (1982) in a study of the nominate subspecies *himantopus* in Portugal in May-June 1979: ‘Both.sexes frequently waded when feeding, tending to stay in water not deeper than the knee, although wading up to belly-depth did occur’ and ‘Stilts were observed feeding in all habitats from dry land to belly-deep water, but mostly at the silty margins of the water’. Goriup (1982). Goriup, P.D. (1982). *Behaviour of Black-winged Stilts*. British Birds 75: 12-24.

Curry (1981): ‘Forrestdale dries out completely most years. Waders other than Black-winged Stilts occur there only when maximum depth falls below 0.4m and margins are exposed below the rush zones. Thousands of waders use the lakebed as it dries up over about 9 weeks, irrespective of when this happens (late spring to autumn)’. Curry, P. (1981). *The Forrestdale phenomenon.* The Stilt. No.1, p.5.

Paton (2010) used bar charts to show the foraging depths ‘used by’ Black-winged Stilt (n=350) and other waders in the Coorong in January 2003-2006. For Black-winged Stilt these were: ‘0cm’ 3% of birds, ‘<2cm’ 31%, ‘2-5cm’ 34%, ‘6-10cm’ 26%, and ‘10-20cm’ 4% (percentages determined by eye from the graphs).

HANZAB (Marchant & Higgins 1993) reported Black-winged Stilt bill lengths (means) of 63.4mm (males; n=8) and 59.9mm (females; n=11; diff. significant).

Marchant & Higgins (1993) reported Black-winged Stilt tarsus lengths (means) of 117.9mm (males; n=10) and 105.2mm (females; n=12; diff. significant) for specimens from south-eastern Australia. On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 24cm (males) and c. 21cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.66. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 19.6cm (males) and c. 17.5cm (females).

Red-necked Avocet *Recurvirostra novaehollandiae*

HANZAB (Marchant & Higgins 1993) ‘Typically encountered in flocks on freshwater, brackish or saline wetlands including salt-fields and claypans’ and ‘will feed while swimming’ and ‘Typically feed in shallow water, on soft mud, wading up to belly (Bryant 1947; Wheeler 1955; Sonter 1984; Jessop 1987; Bellchambers & Carpenter 1990)’ and ‘Wade in shallow water, rapidly sweeping through water and soft mud with long upturned bill slightly open, close to bottom’ and ‘Will place head and neck under water and even up-end, still using scything motion (Wheeler 1955; Lane 1984b). Swim readily; glean insects from surface of water (Beruldsen 1972)’.

The Red-necked Avocet forages while wading in shallow water and also while swimming. It may glean insects from the water surface, feed with head and neck under water, and even up-end to reach its prey (Marchant & Higgins 1993, quoting Wheeler 1955, Lane 1984 and Beruldsen 1972).

Wheeler, W.R. (1955). … Emu 55: 279-295.

Lane, B.A. (1984). *Rep. Trip Lake Eyre North.* Unpubl. Rep. RAOU.

Beruldsen, G.R. (1972). … Aust. Bird Watcher 4:129-130.

Paton (2010) used bar charts to show the foraging depths 'used by' Red-necked Avocet (n=334) and other waders in the Coorong in January 2003-2006. For Red-necked Avocet these were: '0cm' 7% of birds, '<2cm' 12%, '2-5cm' 25%, '6-10cm' 35%, '10-20cm' 18%, and '>20cm' 2% (percentages determined by eye from the graphs).

Paton *et al.* (2011) observed that avocets were foraging (n=35) in the following water depths in the Coorong in January 2011: 'damp' 9%, 'ankle' 6%, 'half knee' 20%, 'knee' 17%, 'thigh' 14%, 'belly' 6%, 'swim' 29%. They were thus foraging in a broad range of depth from 0cm (damp substrate) to greater than belly-depth, which can be calculated as > (2 x male tarsus length) = > (2 x 89mm), that is > 18cm.

HANZAB (Marchant & Higgins 1993) reported Red-necked Avocet tarsus lengths (means) of 88.9mm (males; n=18) and 86.3mm (females; n=11; diff. not significant). On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 18cm (males) and c. 17cm (females).

HANZAB (Marchant & Higgins 1993) also reported Avocet bill lengths (means) of 93.3mm (males; n=25) and 89.8mm (females; n=18; diff. significant) and total head lengths (means) of 129.0mm (males; n=33) and 126.8mm (females; n=23; diff. not significant). Under the heading 'Field Identification', Marchant & Higgins (ibid.) describe length (total) of this species as 40-48cm. Neck length is not reported. If it is assumed that foraging reach while up-ended is approximately half of total length, then maximum foraging depth when swimming may be *c.* 20-24cm.

See Boettcher *et al.* (1995) for American Avocet (*Recurvirostra americana*). Compare tarsus measurements of the two species.

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.68. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 14.9cm (males) and c. 14.5cm (females).

Banded Stilt *Cladorhynchus leucocephalus*

HANZAB (Marchant & Higgins 1993) 'Wade in shallows; feet partly webbed and birds swim well, often far from shore' and 'mainly saline or hypersaline waters of inland and coast; typically large, open and shallow (McGilp & Morgan 1931; Carnaby 1947; Crawford 1975; Kolichis 1976; Badman 1989; Hewish 1989a)' and 'Forage by wading in shallow or swimming in deeper water (Wheeler 1955; Watson 1959; Storr 1965; Jessop 1987; Sonter 1987)' and 'Forage by pecking, probing and scything on saltlakes, either by wading in shallow water or swimming (feet, partly webbed), often some distance from shore. At L. Eyre in 1984, observed pecking from surface of water, seldom probing with bill far into water or mud … (Lane 1984). Will up-end putting head under water (Jones 1945a). Also glean insects from surface of water while swimming (Beruldsen 1972)' and observed turning on water to create vortex, which brings up food (G.F. van Tets)'.

Paton (2010) used bar charts to show the foraging depths 'used by' Banded Stilt (n=890) and other waders in the Coorong in January 2003-2006. For Banded Stilt these were: '0cm' 11% of birds, '<2cm' 37%, '2-5cm' 14%, '6-10cm' 22%, '10-20cm' 10%, and '>20cm' 5% (percentages determined by eye from the graphs). Paton (2010) also observed that '... wading birds are limited to areas of shallow water where they can wade ... with one exception. Banded Stilts will also forage in areas of open water in the centre of the Coorong by floating and swimming on the surface. Here they will pick aquatic invertebrates, particularly Brine Shrimps, out of the water column, provided those invertebrates are close to the surface'.

Paton *et al.* (2011) observed that Banded Stilt were foraging (n=1457) in the following water depths in the Coorong in January 2011: 'ankle' 2%, 'half knee' 2%, 'knee' 1%, 'thigh' 9%,'swim' 85%. Thus some birds were foraging in as little as ≈1cm of water, however most were foraging at greater than belly-depth, which can be calculated as > (2 x male tarsus length) = > (2 x 87mm), that is > 17cm.

HANZAB (Marchant & Higgins 1993) reported Banded Stilt tarsus lengths (means) of 86.8mm (males; n=32) and 80.8mm (females; n=18; diff. significant). On this basis, maximum foraging depths *while wading* may be estimated as 2 x (tarsus length) = c. 17cm (males) and c. 16cm (females).

HANZAB (Marchant & Higgins 1993) also reported Banded Stilt bill lengths (means) of 71.4mm (males; n=26) and 66.3mm (females; n=16; diff. significant). Total head lengths were not reported. Under the heading 'Field Identification', Marchant & Higgins (ibid.) describe length (total) of this species as 35-43cm. Neck length is not reported. If it is assumed that foraging reach while up-ended is approximately half of total length, then maximum foraging depth when swimming may be *c.* 18-22cm.

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.46. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 12.7cm (males) and c. 11.8cm (females).

Plovers, Dotterels Family Charadriidae

Pacific Golden Plover^{M} *Pluvialis fulva*

HANZAB (Marchant & Higgins 1993) ‘Mainly coastal, occurring on estuaries, intertidal mudflats, rocky reefs, beaches and saltmarshes; occasionally far inland’ and ‘Glean and probe for prey on mudflats, salt marsh, in wave-wash, among tide-wrack on beaches and in pasture’ and ‘run, take short pauses, then peck (Evans 1975)’. Evans, P.R. (1975). … Sunbird 6: 25-30.

HANZAB (Marchant & Higgins 1993) reported Pacific Golden Plover tarsus lengths (means) of 43.8mm (males; n=27) and 43.6mm (females; n=23; diff. not significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 9cm (males) and c. 9cm (females). However, this species typically forages on exposed substrate, not by wading.

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.59. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 7.0cm (males) and c. 6.9cm (females).

Grey Plover^{M} *Pluvialis squatarola*

HANZAB (Marchant & Higgins 1993) ‘Almost entirely coastal; forage on intertidal mudflats, and roost on sandy beaches and spits; occasionally occur in coastal saltmarshes and salt works; rarely seen inland. Feed in typical stop-start plover fashion; enter water often, unlike Pacific Golden Plover’ and ‘Glean and probe for prey on mudflats, beaches and occasionally pasture in HANZAB region. Feed with running, stopping and pecking action’.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Grey Plover and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of methods). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Grey Plover and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Grey Plover	**Water depth (cm)**	**Water depth as % of ‘exposed vertical leg length’ (7.1cm)**	**Water depth as % of male tarsus length (4.68cm)**	**Water depth as % of female tarsus length (4.70cm)**
‘Minimum’ (0%)	0	0	0	0
1st Quartile (25%)	0	0	0	0
Median (50%)	0.6	8	13	13
3rd Quartile (75%)	1.0	14	21	21
‘Maximum’ (almost 100%)	1.9	27	41	40
Max. Outlier	5.4	76	115	115

Note, in particular, that 25% of foraging was in water depths ≤ 0% of male-female tarsus lengths; 50% was in depths ≤ 13% of tarsus lengths; 75% was in depths of ≤ 21% of tarsus lengths; almost 100% was in ≤ 41–40% of tarsus lengths, and the maximum outlier was foraging in a water depth that was 115% of tarsus lengths.

Tarsus lengths of Grey Plover migrating to Australia are only very slightly larger (102%; males & females) than those of Europe (migrating to Africa) (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Grey Plover foraging in Ghana do not, therefore, require adjustment to be potentially applicable to Grey Plover migrating to Australia.

Distribution	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
Australia +	Throughout range, adults, skins	47.3 (1.94; 44.1-49.9; 7)	48.0 (1.88; 45.3-52.3; 21)	ns
Africa +	Netherlands, Aug.-May, skins	46.8 (1.48; 44-50; 58)	47.0 (1.82; 45-50; 19)	ns

HANZAB (Marchant & Higgins 1993) reported Grey Plover tarsus lengths (means) of 47.3mm (males; n=7) and 48.0mm (females; n=21; diff. not significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 9cm (males) and c. 10cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.59. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 7.5cm (males) and c. 7.6cm (females).

Red-capped Plover *Charadrius ruficapillus*

HANZAB (Marchant & Higgins 1993) 'Inhabit variety of coastal habitats, especially shelly or sandy beaches with muddy or sandy flats nearby; also bare areas in and round some coastal and inland wetlands' and 'Usually feed on dry substrates in manner typical of plovers, with rapid runs on twinkling legs, interrupted by abrupt pauses; seldom wade' and 'Forage on intertidal mudflats, sandy beaches, lakesides, stream banks, saltmarshes, pasture and gibber plain. Feed in stop-run-peck manner typical of *Charadrius,* locating prey by sight. Seldom wade …'.

Paton (2010) used bar charts to show the foraging depths 'used by' Red-capped Plovers (n=521) and other waders in the Coorong in January 2003-2006. For Red-capped Plover these were: '0cm' 90% of birds, and '<2cm' 10% (percentages determined by eye from the graphs). Paton (2010) also commented that 'Red-capped Plovers largely forage on exposed mudflats ... They forage less frequently on mudflats that are covered with shallow water' and '... the Red-capped Plover ... forages extensively over exposed mudflats and includes terrestrial invertebrates in its diet ...'.

Paton *et al.* (2011) observed that Red-capped Plovers were foraging (n=25) in the following water depths in the Coorong in January 2011: 'dry' 8%, 'damp' 44%, 'ankle' 48%. Thus all birds were foraging in depths of 0cm (mainly damp rather than dry substrate) to ≈1cm.

In a preliminary study at Fivebough Swamp a shallow natural wetland in NSW, Taylor (2003) found that 'Red-capped Plovers appeared [i.e. were present] close to the end of the drying phase, and the period of maximum numbers lasted only about 4 weeks'. From a mean depth of around 22 cm, the entire 190 ha swamp dried completely in 90 days.

Taylor, I.R. & A. Richardson (2000). *The ecology and management of waterbirds on Fivebough Swamp*. The Johnstone Centre of Parks Recreation and Heritage, Report No. 141, Charles Sturt University, Albury.

HANZAB (Marchant & Higgins 1993) reported Red-capped Plover tarsus lengths (means) of 25.7mm (males; n=43) and 25.6mm (females; n=36). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.55. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.0cm (males) and c. 4.0cm (females).

Greater Sand Plover^{M} *Charadrius leschenaultii*

HANZAB (Marchant & Higgins 1993) 'Feed in typical stop-start fashion of plovers' and 'Feed on surface of wet mud or sand of open intertidal flats rather than in shallow water (Sibson 1948; Ewart 1973); occasionally on sand in estuarine lagoons (Pegler 1983)' and 'Forage on intertidal mudflats, saltmarsh, shores of lakes and rivers, and pasture. Feed in typical stop-run-peck manner of *Charadrius* plovers …' and 'Will wade up to belly, occasionally putting head underwater (Glutz 1975)'.

HANZAB (Marchant & Higgins 1993) reported Greater Sand Plover tarsus lengths (means) of 36.9mm (males; n=49) and 36.7mm (females; n=65). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 7cm (males) and c. 7cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.61. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 5.9cm (males) and c. 5.9cm (females).

Black-fronted Dotterel *Elseyornis melanops*

HANZAB (Marchant & Higgins 1993) 'Feed in walk- or run-stop-peck manner; probe to depth of about one-third of length of bill' and 'Generally forage on soft fine wet deposits of silt or mud; usually at edge of water, but also occasionally in shallow water (Hindwood & Hoskin 1954; Smith 1966; Medway 1972; Heather1977; Maclean 1977; Child & Child 1984; Powlesland & Robertson 1987)' and 'Feed in typical walk- or run-stop-peck behaviour of *Charadrius* plovers; also tap and peck, probe into mud to depth of about one-third length of bill, and glean; often move back and forth over same stretch of wet mud (Heather 1977;Tarburton 1989; B.D. Heather)'.

In a study on two coastal saline lagoons in New South wales, Taylor (2004) found that Black-Fronted Dotterel 'showed a strong preference for feeding in areas of moist, firm mud', rather than 'substrates still covered by water' or 'wet mud with a surface layer of water' or 'dry, hard mud', and that 'the species was ... highly dependent on receding [as opposed to rising] water levels to provide suitable foraging conditions'. 'The adjacent water in the lagoon was surveyed at two depth categories of 1-13 mm and 14-26 mm, the maximum representing the greatest depth in which the Black-fronted Plover was seen to feed and equal to their tarsus length (Barter 1991)'. 'At 15-minute intervals, the foraging depths of all individuals feeding in water were recorded by comparison with the birds' tarsus length (26 mm, Barter 1991)'. 'When foraging in water, the birds waded in depths up to 26 mm, equal to their tarsus length, but their densities were

significantly higher below 13 mm than above'. 'The birds' basic foraging method consisted of visual scanning followed by a few steps or a short, fast run, and peck at the substrate or water surface. Their maximum probing depth on exposed mud or sand was about 8 mm or half their bill length. When catching prey in water, the birds pecked at the surface and only rarely immersed the front of their heads'. (See Appendix for charts).
Barter, M. (1991). *Morphometrics of Victorian Black-fronted Plovers*. Stilt 18: 13-14.

HANZAB (Marchant & Higgins 1993) reported Black-fronted Dotterel tarsus lengths (means) of 26.1mm (males; n=15) and 26.3mm (females; n=14). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.60. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.2cm (males) and c. 4.2cm (females).

Red-kneed Dotterel *Erythrogonys cinctus*

HANZAB (Marchant & Higgins 1993) 'Margins of terrestrial wetlands. Prefer temporary or permanent freshwater wetlands, …' and 'Rarely at brackish or saline wetlands' and 'Forage along muddy margins on shore (McGill 1944; Maclean 1977) or wading in shallow water (1-1.5 cm); occasionally swim in deeper water; observed in water at least 30 cm deep (Littlejohns 1931; McGill 1944; Boehm 1950; Maclean 1977; Schulz 1986; Johnson 1990). Do not feed on dry land (Maclean1977)' and 'Glean and probe surface and subsurface of wet mud and, less often, sand, or wade up to belly in shallow water (1-1.5 cm); swim, placing head under water to take prey; do not feed on dry ground and avoid pebbly substrates (Littlejohns 1931; McGill 1944; Boehm 1950; Maclean 1977; Schulz 1986; Johnson 1990).

In a preliminary study at Fivebough Swamp a shallow natural wetland in NSW, Taylor (2003) found that 'Peak numbers of Red-kneed Dotterel … lasted only around three weeks when the maximum extent of their preferred water depths [not specified] occurred'. From a mean depth of around 22 cm, the entire 190 ha swamp dried completely in 90 days.

Taylor, I.R. & A. Richardson (2000). *The ecology and management of waterbirds on Fivebough Swamp*. The Johnstone Centre of Parks Recreation and Heritage, Report No. 141, Charles Sturt University, Albury.

HANZAB (Marchant & Higgins 1993) reported Red-kneed Dotterel tarsus lengths (means) of 41.4mm (males; n=48) and 40.5mm (females; n=42). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 8cm (males) and c. 8cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.31. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 5.4cm (males) and c. 5.3cm (females).

Banded Lapwing *Vanellus tricolor*

Marchant & Higgins (1990) HANZAB (Marchant & Higgins 1993) 'preferring areas of very short grass …; also on stony ground, bare margins of dry swamps. Sometime near water but seldom wade' and 'when foraging, slow walk followed by short crouching run to catch prey …' and 'In WA, often found near water (Storr 1985a,b, 1987; Storr & Johnstone 1988) including wetlands, rock holes and windmills' and 'Once recorded feeding in shallow water (Boehm 1955, 1960)' and 'Stalk and glean insects and seeds, mainly in pasture, grassland and on roadsides' and 'Occasionally wade and feed in shallow water (Boehm 1960)'.

HANZAB (Marchant & Higgins 1993) reported Banded Lapwing tarsus lengths (means) of 47.5mm (males; n=13) and 47.6mm (females; n=10; not significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 8cm (males) and c. 8cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.46. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 6.9cm (males) and c. 6.9cm (females).

Painted Snipe Family Rostratulidae

Australian Painted Snipe *Rostratula australis*

HANZAB (Marchant & Higgins 1993) 'Mainly in shallow freshwater wetlands or saltmarshes, generally with good cover of grasses, low scrub, lignum, open timber or samphire' and 'generally remain in dense cover when feeding, …' and 'Terrestrial shallow freshwater (occasionally brackish) wetlands; ephemeral and permanent: …' and 'Glean from edge of water and from mudflats. Probe in soft ground and scythe with bill in shallow water (BWP)'.

HANZAB (Marchant & Higgins 1993) reported Australian Painted Snipe tarsus lengths (means) of 39.2mm (males; n=10) and 41.6mm (females; n=20; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 8cm (males) and c. 8cm (females).

'The rice height at this site was considerably shorter than at least four of the other seven APS sites (…), which supported rice over 30 cm in height, with water depths of 12–17 cm at the time APS were present' (Herring & Silcocks 2014).

Herring, M. & Silcocks, A. (2014). *The use of rice fields by the endangered Australian Painted Snipe (Rostratula australis): a rare opportunity to combine food production and conservation?* Stilt 66, 20–29.

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.24. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.9cm (males) and c. 5.2cm (females).

Sandpipers, Knots, Stint & allies Family Scolopacidae

Pin-tailed Snipe^{M} *Gallinago stenura*

HANZAB (Higgins & Davies 1996) 'Usually found when flushed unexpectedly from cover' and 'Forage in wet mud, … (Ali & Ripley 1980)' and 'In Aust., usually on freshwater wetlands … such as swamps, … with vegetation ranging from dense grassy vegetation … to sparsely vegetated mudflats (Storr & Johnstone 1979; Anon. 1984; Shannon *et al.* 1984; Storr 1984; Jaensch 1990)' and 'Feed by probing soft ground with sensitive, flexible tip of long bill (BWP)'.

HANZAB (Higgins & Davies 1996) reported Pin-tailed Snipe tarsus lengths (means) of 32.2mm (males; n=50) and 33.3mm (females; n=52; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 7cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.27. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.1cm (males) and c. 4.2cm (females).

Black-tailed Godwit^{M} *Limosa limosa*

HANZAB (Higgins & Davies 1996) 'Mainly forage on wide intertidal mudflats or sandflats, in soft mud or shallow water; occasionally in shallow estuaries' and 'Often wade up to belly in water (Liddy 1960). Probe for long periods, often immersing head' and 'Also glean from ground and vegetation'.

Liddy, J. (1960). … Emu 60:203-210.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Black-tailed Godwit (nominate subspecies *limosa*) and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Godwit and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Black-tailed Godwit (subspecies *limosa*)	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (12.3cm)**	**Water depth as % of male tarsus length (7.29cm)**	**Water depth as % of female tarsus length (8.12cm)**
'Minimum' (0%)	6.3	51	86	78
1st Quartile (25%)	6.3	51	86	78
Median (50%)	7.2	59	99	89
3rd Quartile (75%)	8.0	65	110	99
'Maximum' (100%)	8.0	65	110	99

Note, in particular, that 25% of foraging was in water depths *equal to* 86-78% of male-female tarsus lengths; 50% was in depths ≤ 99–89% of tarsus lengths, and both 75% & 100% was in depths ≤ 110–99% of tarsus lengths.

Tarsus lengths of males of subspecies *melanuroides,* migrating to Australia, are much smaller (males 86%; females 82%) than those of subspecies *limosa* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP).

Subspecies	**Distribution**	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
melanuroides	Australia +	Australia, skins, ages combined	62.4 (2.08; 60.1-67.0; 8)	66.4 (2.51; 63.2-63.9; 7)	**
limosa	Africa +	Europe & w. USSR, summer, skins, adults	72.9 (4.37; 63-86; 39)	81.2 (4.38; 71-91; 63)	yes

If the water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded *limosa* foraging are adjusted by this percentage (*c.* 84%) they change from 6.3, 6.3, 7.2. 8.0 & 8.0cm to 5.3, 5.3, 6.0, 6.7 & 6.7cm. Thus, 25% of foraging by the 'Australian' subspecies *melanuroides* would be in a water depth of 5.3cm; 50% in depths ≤ 6.0cm, and both 75% & 100% in depths ≤ 6.7cm.

Spencer (2010), in a study of migratory shorebird ecology on the Hunter estuary, south-eastern Australia, determined, on the basis of total leg lengths of preserved skins from the Australian Museum, a mean black-tailed godwit 'wadeable depth' of 104.8mm (standard error ±6.4mm; n=8). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 62.4–66.4 mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) 'Common subspecies in our region is *melanuroides'*.

HANZAB (Higgins & Davies 1996) reported subspecies *melanuroides* tarsus lengths (means) of 62.4mm (males; n=8) and 66.4mm (females; n=7; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 12cm (males) and c. 13cm (females). CALCULATE ALSO FOR SUBSPECIES LIMOSA? AND OTHER SPECIES COMMON TO V-W AND Ntiamoa-Baidu *et al.* (1998)?

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.64. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 10.2cm (males) and c. 10.9cm (females).

Bar-tailed Godwit^M *Limosa lapponica*

HANZAB (Higgins & Davies 1996) 'Coastal, favouring estuarine and tidal mudflats, …' and 'Typically feed along edge of water, with longer-billed females in deeper water than males; forage in loose groups, walking steadily over mud or in shallow water, …' and 'Probe in mud, often in water up to 15 cm deep; probe vertically, rotating head slightly as bill pushed into substrate (Evans 1975)' and 'Sometimes glean from surface of substrate (BWP)'.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Bar-tailed Godwit (nominate subspecies *lapponica*) and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Godwit and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Bar-tailed Godwit (subspecies *lapponica*)	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (8.4cm)**	**Water depth as % of male tarsus length (5.23cm)**	**Water depth as % of female tarsus length (5.55cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	0.6	7	11	11
Median (50%)	2.2	26	42	40
3rd Quartile (75%)	5.6	67	107	101
'Maximum' (100%)	7.0	83	134	126

Note, in particular, that 25% of foraging was in water depths ≤ 11% of male-female tarsus lengths; 50% was in depths ≤ 42–40% of tarsus lengths; 75% was in depths of ≤ 107–101% of tarsus lengths, and 100% of foraging was in ≤ 134–126% of tarsus lengths.

Tarsus lengths of males of subspecies *menzbieri,* migrating to sw. Australia, are only very slightly larger (101.3%) than those of subspecies *lapponica* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). Assuming that the same is true for females, the water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Bar-tailed Godwit foraging in Ghana [subspecies *taymyrensis* – see Wilson *et al.* 2007 and Wetlands International 2006, 2018] do not require adjustment to be potentially applicable to Bar-tailed Godwit migrating to sw. (and nw.) Australia.

Subspecies	**Distribution**	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
menzbieri	SW & NW Australia +	NW Aust., skins	53.0 (1.49; 51.6-55.0; 4)	51.2 (one specimen)	-
Lapponica NEED TO REPLACE THIS ROW WITH subspecies *tamyrensis*	Africa +	Adult, breeding, skins	52.3 (2.04; 48-57; 36)	55.5 (2.70; 51-59; 25)	yes

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean bar-tailed godwit 'wadeable depth' of 79.6mm (standard error ±2.1mm; n=10). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 52.9–57.8 mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) '… band-recovery suggests *menzbieri* occurs in s. WA [Confirmed by Wilson *et al.* 2007]. Plumage and small number of recoveries show subspecies *baueri* to be much the most common subspecies occurring se. Aust. and NZ'.

HANZAB (Higgins & Davies 1996) reported subspecies *baueri* Bar-tailed Godwit tarsus lengths (means) of 53.1mm (males; n=25) and 57.8mm (females; n=13; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 11cm (males) and c. 12cm (females).

HANZAB (Higgins & Davies 1996) reported subspecies *menzbieri* Bar-tailed Godwit tarsus lengths (means) of 53.0mm (males; n=4) and 51.2mm (females; n=1). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 11cm (males) and c. 10cm (females). NEED LARGER SAMPLE, ESPECIALLY AS FEMALES SHOULD BE LARGER.

Wilson, J.R., Nebel, S. & Minton, C.D.T. (2007). *Migration ecology and morphometrics of two Bar-tailed Godwit populations in Australia*. Emu 107(4): 262-274. [REQUESTED FROM LIBRARY 26TH NOV 2017 – HAVE SINCE OBTAINED A COPY]. Measurements reported by these authors were wings, bills, and total-head lengths, **but not tarsus lengths – even though they said so in their Abstract!**

Evans (1976); '[Evans was in UK] Species affected by wave action include Bar-tailed Godwits, which often feed in water up to 15 cm deep, ...'. 'Bar-tailed Godwits, for example, can pick food from hard surfaces such as coral reefs, probe into sand to obtain polychaetes and bivalves, or swish their bills from side to side through soft mud or water to sieve out annelids (Evans 1975)'.

BWP reported subspecies *baueri* tarsus lengths (means) of 53.6mm (males) and 59.3mm (females). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.54. Application of this ratio to the BWP tarsus lengths produces 'belly depths' of c. 8.3cm (males) and 9.1cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.64. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 8.7cm (males) and c. 8.4cm (females).

Whimbrel *Numenius phaeopus*

HANZAB (Higgins & Davies 1996) 'Mainly coastal, on tidal and estuarine mudflats, …' and 'Forage on intertidal mudflats, and along muddy banks of estuaries and in coastal lagoons, …' and 'On beaches, feed at low tide, running in quick bursts and capturing prey away from water (Lane)' and 'On non-breeding grounds, mainly coastal, following tidal cycles and feeding at edge of water'.

Velasquez & Navarro (1993) reported from their study on the Quele River estuary, Chile, that: 'Between 22 and 39 Whimbrels [subspecies *hudsonicus*] fed daily on the study area during the period of observation. Whimbrels started feeding when the bank was still covered by a layer of water about 5 cm deep [and foraged from shallow water to exposed, *wet* sediments]'.

Subspecies *variegatus* tarsus lengths (means) of …mm (males; n=…) and …mm (females; n=…). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. …cm (males) and c. …cm (females). HANZAB DOESN'T GIVE ADEQUATE TARSUS DETAILS.

[BWP reported subspecies *hudsonicus* tarsus lengths (means) of 56.5mm (males; n=12) and 59.9mm (females; n=14).] [HANZAB reported subspecies *hudsonicus* tarsus lengths (means) of 56.7mm (males; n=14) and 59.9mm (females; n=18), significant diff.]

BWP reported subspecies *variegatus* tarsus lengths (means) of 57.5mm (males; n=46) and 61.0mm (females; n=40). Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.54. Application of this ratio to the BWP tarsus lengths of *variegatus* produces 'belly depths' of c. 8.9cm (males) and 9.4cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.54. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. ...cm (males) and ...cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.54. Application of this ratio to the BWP tarsus lengths produces ‘belly depths’ of c. 8.9cm (males) and c. 9.4cm (females).

Eastern Curlew^{M} *Numenius madagascariensis NOT YET RECORDED ON V-W.*

HANZAB (Higgins & Davies 1996) ‘Essentially coastal, on beaches, estuaries, mangrove swamps and saltmarsh’ and ‘Feeding actions slow and deliberate; stalk slowly and sedately about sandy or muddy flats, picking from surface but mainly probing deeply with long bill’.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of the somewhat smaller (males 90%; females 92%) ‘western’ Curlew *Numenius arquata* were foraging on coastal lagoons in Ghana (see Little Egret above for details of methods). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Curlew and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Curlew	**Water depth (cm)**	**Water depth as % of ‘exposed vertical leg length’ (11.1cm)**	**Water depth as % of male tarsus length (7.91cm)**	**Water depth as % of female tarsus length (8.45cm)**
‘Minimum’ (0%)	0	0	0	0
1st Quartile (25%)	1.7	15	21	20
Median (50%)	6.4	58	81	76
3rd Quartile (75%)	9.1	82	115	108
‘Maximum’ (100%)	10.2	92	129	121

Note that 50% of foraging was in water depths ≤ 81-76% of tarsus lengths, and 100% were foraging in water depths of ≤ 129–121% of tarsus lengths.

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean Eastern Curlew ‘wadeable depth’ (also referred to as ‘maximum wading depth’) of 128.5mm (standard error ±2.3mm; n=4). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 88.2–91.6mm. Ratio b/a =

Paton (2010) commented that ‘... Eastern Curlews can extend their foraging out into slightly deeper water [than] stilts, avocets and godwits [see his Fig. 8.1b for depths at which stilts and avocets were recorded foraging on the Coorong]’.

Dann (2014) *Prey availability, and not energy content, explains diet and prey choice of Eastern Curlews Numenius madagascariensis in southern Australia.* [THIS PAPER HAS NOTHING USEFUL RE FORAGING DEPTHS]

BWP reported ‘western’ Curlew (nominate subspecies *arquata*) tarsus lengths (means) of 79.1mm (males; n=38) and 84.5mm (females; n=34; diff. significant).

HANZAB (Higgins & Davies 1996) reported Eastern Curlew tarsus lengths (means) of 88.2mm (males; n=7) and 91.6mm (females; n=21; diff. significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 18cm (males) and c. 18cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.59. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 14.0cm (males) and c. 14.6cm (females).

Terek Sandpiper^{M} *Xenus cinereus*

HANZAB (Higgins & Davies 1996) ‘Feed mainly by chasing mobile prey on surface, but also probe deeply; sometimes feed in shallow water, using sideways sweeping action like that of avocets’ and ‘Mostly forage in open on soft wet intertidal mudflats, especially near mangroves (Ewart 1973; Lane; Vic. Atlas); occasionally in samphire (Chafer 1984). Seldom near edge of water (Lane); may wade into water (Eckert 1968)’ and ‘On open beaches, feed at high tide on stranded seaweed, and at low tide along edge of water or in lower littoral zone on bare rock (Taylor 1981; Schulz 1989)’ and ‘Peck at sand and surface of shallow pools; also peck floor of shallow pools or up to 2 cm below surface of water (Schulz 1989)’ and ‘glean from surface of mud or in water’ and ‘Chase prey along sand or water’ and ‘snap at and catch insects in air (Brown 1982; Schulz 1989)’. [Schulz, M. (1989). … Stilt 14:53-55].

HANZAB (Higgins & Davies 1996) reported Terek Sandpiper tarsus lengths (means) of 28.7mm (males; n=13) and 28.6mm (females; n=12; diff. not significant). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.65. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 4.7cm (males) and c. 4.7cm (females).

Common Sandpiper[M] *Actitis hypoleucos*

HANZAB (Higgins & Davies 1996) ‘Generally forage in shallow water and on bare soft mud at edges of wetlands; often where obstacles project from substrate, e.g. rocks or mangrove roots (Smith 1964, 1966; Loyn 1975; Noske 1975; Longmore 1978; Bamford 1988; Lane)’ and ‘Carnivorous: [food includes] ‘molluscs, crustaceans and insects’ and ‘… snatch low-flying insects (Smith 1964)’ and ‘Outside area [Australasia], observed to locate prey visually on ground (especially among stones and cracks), low vegetation or in faeces of mammals; rarely probe, though may push bill sideways under debris on beaches; sometimes wash prey before eating (BWP)’.

HANZAB (Higgins & Davies 1996) reported Common Sandpiper tarsus lengths (means) of 24.6mm (males; n=13) and 24.6mm (females; n=15; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.29. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 3.2cm (males) and c. 3.2cm (females).

Grey-tailed Tattler[M] *Tringa brevipes*

HANZAB (Higgins & Davies 1996) ‘Usually forage in shallow (c. 2 cm deep) water, on hard intertidal substrates … (Hindwood & Hoskin 1954; Domm & Recher 1973; Prendergast *et al.* 1985; Lane)’ and ‘Also on exposed intertidal mudflats … (Hindwood & Hoskin 1954; Andrew 1962; Loyn 1975; Pegler 1980; Forest 1982). Occasionally on intertidal sandflats …’ and ‘Locate prey by sight or by probing rocky shores … (Domm & Recher 1973), and along edge of water of beaches and mudflats’ and ‘Catch crabs in shallow water, often immersing head completely … (Andrew 1962; Keast 1949)’ and ‘Seen chasing and catching small fish in rock pools (Hindwood & Hoskin 1954). Chase amphipods out of water and take some prey ashore … (Andrew 1962)’.

HANZAB (Higgins & Davies 1996) reported Grey-tailed Tattler tarsus lengths (means) of 32.3mm (males; n=13) and 32.3mm (females; n=12; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.73. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 5.6cm (males) and c. 5.6cm (females).

Common Greenshank[M] *Tringa nebularia*

HANZAB (Higgins & Davies 1996) ‘Feeding actions typical of genus, but have more stalking character; typically seen walking briskly along shoreline or chasing small fish through shallows’ and ‘feed by picking, probing, sweeping and lunging, last two associated with crouching and dashing gait in water’ and ‘Occur on a wide variety of inland wetlands and sheltered coastal habitats’ and ‘Forage at edges of wetlands, in soft mud on mudflats, in channels, or in shallows round edge of water (Sibson 1965; Ewart 1973; Park 1983; Wakefield 1984; Gibson 1986)’ and … ‘Detailed extralimital summary by Nethersole-Thompson & Nethersole-Thompson (1979)’. … ‘Wade in shallow water along edge of water in tidal estuaries, muddy claypans, saltworks and saltpans. Glean from surface of mud, vegetation or water. Pursue insects on surface of water, with bill half opened and partially immersed and head and neck outstretched; also pursue insects in air (Smith 1966). Fish taken by dash-and-lunge technique; … Swim, up-end, submerge entire body, … (Nethersole-Thompson & Nethersole-Thompson 1979; BWP). Take fish *Galaxias* by following movements of fish with bill partly immersed, then striking rapidly (Wheeler 1955).

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Common Greenshank and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of methods). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Greenshank and 18 other waterbird species (11 recorded on Vasse-Wonnerup) were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Common Greenshank	**Water depth (cm)**	**Water depth as % of male tarsus length (6.02cm)**	**Water depth as % of female tarsus length (6.08cm)**
‘Minimum’ (0%)	0	0	0
1st Quartile (25%)	1.0	17	16
Median (50%)	3.1	51	51

3rd Quartile (75%)	5.2	86	86
'Maximum' (100%)	6.6	110	109

Thus, 25% of foraging by Greenshank was in water depths ≤ 17–16% of male-female tarsus lengths; 50% was in depths ≤ 51% of tarsus lengths; 75% was in depths of 86% of tarsus lengths, and 100% of foraging was in depths ≤ 110–109% of tarsus lengths.

Tarsus lengths of Common Greenshank migrating to Australia are only very slightly smaller (*c.* 98%; males & females) than those of Europe (migrating to Africa) (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Common Greenshank foraging in Ghana do not, therefore, require adjustment to be potentially applicable to Common Greenshank migrating to Australia.

Distribution	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
Australia +	Aust., skins, adults	59.0 (2.82; 53.8-63.6; 14)	59.6 (2.61; 54.2-65.0; 29)	ns
Africa +	Not specified, skins	60.2 (2.5; 56-64; 25)	60.8 (2.56; 57-66; 24	ns

Paton (2010) used bar charts to show the foraging depths 'used by' Common Greenshank (n=121) and other waders in the Coorong in January 2003-2006. For Common Greenshank these were: '0cm' 6% of birds, '<2cm' 16% of birds, '2-5cm' 25%, 'and 6-10cm' 52% (percentages determined by eye from the graphs). Paton (2010) also observed that 'Common Greenshanks ... actively chase schools of small fish, darting and zigzagging after them'.

Paton *et al.* (2011) observed that greenshanks were foraging (n=409) in the following water depths in the Coorong in January 2011: 'dry' 1%, 'damp' 8%, 'ankle' 12%, 'half knee' 18%, 'knee' 53%, 'thigh' 2%, 'belly' 6%. Thus, while the foraging depth range was from 0cm (mainly damp) to greater than belly-depth, most birds were foraging in knee-deep water, which can be calculated as (1 x female tarsus length) = 60mm, that is 6cm. Greater than belly depth = > (2 x female tarsus length) = > (2 x 60mm), that is > 12 cm.

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean greenshank 'wadeable depth' of 89.0mm (standard error ±1.3mm; n=10). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 55.1–60.1mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) reported Common Greenshank tarsus lengths (means) of 59.0mm (males; n=14) and 59.6mm (females; n=29; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 12cm (males) and c. 12cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.77. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 10.4cm (males) and c. 10.5cm (females).

Marsh Sandpiper^M *Tringa stagnatilis*

HANZAB (Higgins & Davies 1996) 'feed by wading in shallow water … pecking from surface of water and, sometimes, sweeping bill from side to side … probe in deeper water and crouch to pick along edge of water; also dash after prey in deep water; occasionally swim' and 'Usually forage in shallow water at edge of wetlands. May wade far from shore (Vic. Atlas), though Drake (1981) only saw birds feeding within 1-2 m of edge of water. Probe wet mud of mudflats or among marshy vegetation (Favaloro 1943; Drake 1981; Lane)' and 'Usually feed in shallow water, often wading deeper than level of tarsus; … sometimes swim. Generally pick at surface of water or mud …'.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Marsh Sandpiper and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Marsh Sandpiper and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Marsh Sandpiper	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (7.5cm)**	**Water depth as % of male tarsus length (5.22cm)**	**Water depth as % of female tarsus length (5.25cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	1.1	15	21	21
Median (50%)	2.1	28	40	40
3rd Quartile (75%)	3.2	43	61	61
'Maximum' (100%)	6.1	81	117	116
Max. Outlier	7.0	93	134	133

Thus, 25% of foraging by Marsh Sandpiper was in water depths ≤ 21% of male-female tarsus lengths; 50% was in depths ≤ 40% of tarsus lengths; 75% was in depths of 61% of tarsus lengths; almost 100% was in depths ≤ 117–116% of tarsus lengths, and the maximum outlier was foraging in a water depth that was 134–133% of tarsus lengths.

Tarsus lengths of Marsh Sandpiper migrating to Australia are only very slightly different (males 101%; females 98%) than those migrating to Africa (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Marsh Sandpiper foraging in Ghana do not, therefore, require adjustment to be potentially applicable to Marsh Sandpiper migrating to Australia.

Distribution	Source materials	Tarsus (males; mm)	Tarsus (females; mm)	Signif.
Australia +	Aust., adults, skins	52.7 (0.81; 51.8-54.1; 6)	51.6 (2.40; 46.7-54.8; 11)	ns
Africa +	Whole range, skins	52.2 (2.36; 47-56; 29)	52.5 (2.74; 48-57; 48)	ns

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean Marsh Sandpiper 'wadeable depth' of 81.6mm (standard error ±2.3mm; n=5). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 51.6–52.7mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) reported Marsh Sandpiper tarsus lengths (means) of 52.7mm (males; n=6) and 51.6mm (females; n=11; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 11cm (males) and c. 10cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.61. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 8.5cm (males) and c. 8.3cm (females).

Common Redshank^{M} *Tringa totanus*

HANZAB (Higgins & Davies 1996) 'When feeding, form loose flocks on open mudflats. Gait a brisk walk, stopping every few steps to pick; probe infrequently; often wade; can swim' and 'Observed feeding in shallow water, on wet bare mud or sand, or on algal deposits, round edges of wetlands; may be near rocks or samphire (McKean *et al.* 1976); Sedgwick 1976; Day 1984; Jaensch & Blyth 1988)', and '… and method of feeding vary with season' and 'Feed on rocky, sandy or muddy shores. Fast walk-and-peck action; probe only occasionally; scythe mud with open bill'.

Krupa *et al.* (2009): 'In colder days the birds [Redshanks] were forced to forage in deeper water, which was caused by lower accessibility of prey in shallower water (Goss-Custard 1969)'.

Goss-Custard, J.D. (1969). *The winter feeding ecology of the Redshank Tringa totanus*. Ibis 111: 338-356.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Common Redshank (probably nominate subspecies *totanus*) and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Common Redshank and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Common Redshank (subspecies *totanus*)	Water depth (cm)	Water depth as % of 'exposed vertical leg length' (6.8cm)	Water depth as % of male tarsus length (4.64cm)	Water depth as % of female tarsus length (4.62cm)
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	0.5	7	11	11
Median (50%)	1.0	15	22	22
3rd Quartile (75%)	2.9	43	62	63
'Maximum' (100%)	6.1	90	131	132
Max. Outlier	8.2	121	177	177

Note, in particular, that 25% of foraging was in water depths ≤ 11% of male-female tarsus lengths; 50% was in depths ≤ 22% of tarsus lengths; 75% was in depths of ≤ 62–63% of tarsus lengths; almost 100% of foraging was in ≤ 131–132% of tarsus lengths, and the maximum outlier was foraging in a water depth that was 177% of tarsus length.

It is unclear whether the tarsus lengths of the subspecies migrating to Australia (thought to be *ussuriensis*) are significantly different from those of nominate subspecies *totanus* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP), and therefore whether the water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Common Redshank foraging in Ghana require some adjustment (males 109%; females 107%) to be potentially applicable to Common Redshank migrating to Australia.

Subspecies	Distribution	Source materials	Tarsus (males; mm)	Tarsus (females; mm)	Signif.

ussuriensis	Australia +	Mongolia & L. Baikal region	50.4 (2.5; 5)	49.4 (2.1; 5)	ns
		E. Russia & N. Manchuria	46.5 (-; 2)	46.0 (-; 2)	ns
totanus	Africa +	Adult breeding, skins	46.4 (2.2; 41-51; 28)	46.2 (1.4; 44-52; 23)	ns

HANZAB (Higgins & Davies 1996) reported Common Redshank tarsus lengths (means) of 50.4mm (males; n=5) and 49.4mm (females; n=5; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 10cm (males) and c. 10cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.77. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 8.9cm (males) and c. 8.7cm (females).

Wood Sandpiper[M] *Tringa glareola*

HANZAB (Higgins & Davies 1996) 'forage on mud or in shallows, probing or pecking at surface; swim expertly' and 'Forage on moist or dry mud at edges of wetlands, either along shores, among open scattered aquatic vegetation, or in clear shallow water (Robinson 1948; Hindwood & McGill 1953a; Boehm 1960; Lane; Vic. Atlas)' and 'Wade in shallow fresh water, often up to belly, gleaning prey from surface of water (Hindwood & McGill 1953a); probe, sometimes with head and neck submerged, and sweep bill from side to side under water'.

In their study of the foraging ecology of Wood Sandpipers and Ruffs in wetlands of the Sajna River valley, northern Poland, Krupa *et al.* (2009) found that Wood Sandpipers foraged mostly (66.0% of probes) in water up to the tarsus joint; less (26.1%) in water depths above the tarsus joint, and little (7.9%) in water covering the toes at most.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Wood Sandpiper and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Wood Sandpiper and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Wood Sandpiper	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (4.5cm)**	**Water depth as % of male tarsus length (3.74cm)**	**Water depth as % of female tarsus length (3.87cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	0.35	8	9	9
Median (50%)	0.4	9	11	10
3rd Quartile (75%)	0.7	16	19	18
'Maximum' (almost 100%)	1.1	24	29	28
Max. Outlier	4.5	100	120	116

Note, in particular, that 25% of foraging was in water depths ≤ 9% of male-female tarsus lengths; 50% was in depths ≤ 11–10% of tarsus lengths; 75% was in depths of ≤ 19–18% of tarsus lengths; almost 100% was in ≤ 29–28% of tarsus lengths, and the maximum outlier was foraging in a water depth that was 120–116% of tarsus lengths.

Tarsus lengths of Wood Sandpipers migrating to Australia are only very slightly smaller (males 98%; females 99%) than those of Europe (migrating to Africa) (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Wood Sandpiper foraging in Ghana do not, therefore, require adjustment to be potentially applicable to Wood Sandpiper migrating to Australia.

Distribution	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**
Australia +	Aust., skins, adults	36.7 (1.59; 34.6-39.2; 10)	38.3 (1.84; 32.9-40.6; 18)	*
Africa +	Not specified, skins	37.4 (1.74; 34-40; 44)	38.7 (1.46; 37-42; 41)	yes

HANZAB (Higgins & Davies 1996) reported Wood Sandpiper tarsus lengths (means) of 36.7mm (males; n=10) and 38.3mm (females; n=18; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 7cm (males) and c. 8cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.64. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 6.0cm (males) and c. 6.3cm (females).

Ruddy Turnstone^{M} *Arenaria interpres.*

HANZAB (Higgins & Davies 1996) ‘Foraging behavior distinctive: feed busily by probing, pecking and prying into crevices, using sturdy bill to flip over stones, shells, seaweed and other objects’ and ‘Mainly forage … from strand-line to wave-zone (Hornsby 1978; Lane)’ and ‘Also forage on … mudflats (Loyn 1975)’ and ‘occasionally among low vegetation in saltmarsh, on exposed beds of seagrass (Robertson & Dennison 1979)’.

HANZAB (Higgins & Davies 1996) reported Turnstone tarsus lengths (means) of 25.6mm (males; n=19) and 25.6mm (females; n=20; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.42. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 3.6cm (males) and c. 3.6cm (females).

Great Knot^{M} *Calidris tenuirostris*

HANZAB (Higgins & Davies 1996) ‘Gait and feeding actions similar to those of Red Knot, but walk more slowly, and work more steadily across mud or through shallows, probing one spot at a time with several deep jabs and immersing entire bill and face’ and ‘Forage on intertidal flats, in soft mud or sand; usually in shallow water, often at edge of water as tide recedes (Garnett 1989; Lane; Vic. Atlas). Occasionally forage on ocean beaches (Pegler 1983). Once seen foraging, well out from shore, in small shallow unvegetated swamp (Smith *et al.* 1971)’ and ‘Feed mainly on intertidal mudflats, rapidly and repeatedly jabbing bill into mud. Often feed along edge of tide and sometimes in shallow water (Lane)’.

HANZAB (Higgins & Davies 1996) reported Great Knot tarsus lengths (means) of 35.0mm (males; n=25) and 35.5mm (females; n=31; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 7cm (males) and c. 7cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.65. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 5.8cm (males) and c. 5.9cm (females).

Red Knot^{M} *Calidris canutus*

HANZAB (Higgins & Davies 1996) ‘Gait and feeding similar to Great Knot, but walk faster and probe more rapidly’ and ‘In Aust. and NZ, feed mainly by probing vertically into substrate with full length of bill and slowly rotating head’ and ‘feed mainly by fast, intense, methodical probing with head held low and bill nearly vertical; also peck at surface’ and ‘Sometimes immerse head fully or wade up to belly’.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Red Knot (nominate subspecies *canutus*) and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Red Knot and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Red Knot (subspecies *canutus*)	**Water depth (cm)**	**Water depth as % of ‘exposed vertical leg length’ (4.2cm)**	**Water depth as % of male tarsus length (3.14cm)**	**Water depth as % of female tarsus length (3.16cm)**
‘Minimum’ (0%)	0.3	7	10	9
1st Quartile (25%)	0.3	7	10	9
Median (50%)	0.7	17	22	22
3rd Quartile (75%)	3.0	71	96	95
‘Maximum’ (100%)	3.8	90	121	120

Note, in particular, that 25% of foraging was in water depths ≤ 10–9% of male-female tarsus lengths; 50% was in depths ≤ 22% of tarsus lengths; 75% was in depths of ≤ 96–95% of tarsus lengths, and 100% of foraging was in ≤ 121–120% of tarsus lengths.

The tarsus lengths of the subspecies migrating to Australia (thought to be *rogersi*) are slightly different (*c.* 97%; males & females) from those of nominate subspecies *canutus* (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). However, the difference is small enough for the water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Red Knot foraging in Ghana to be applicable, without adjustment, to Red Knot in Australia.

Subspecies	**Distribution**	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**

rogersi	Australia +	SA & east coast Aust., ages combined, skins	30.6 (1.02; 29.1-32.4; 15)	30.6 (1.19; 28.8-32.8;16)	ns
		WA, ages combined, skins	30.5 (1.50; 28.2-32.3; 5)	29.1, 31.4, 30.8	ns
		Breeding grounds of Chukotskiy & Anadyr, prob. adults, skins	30.4 (1.3; 28.6--32.7; 10)	30.9 (1.3; 29.5-32.8; 10)	ns
canutus	Africa +	Migrants, Netherlands, killed at lighthouses	31.4 (1.32; 28.6-33.9; 48)	31.6 (1.22; 29.6-34.9; 41)	ns

HANZAB (Higgins & Davies 1996) reported Red Knot tarsus lengths (means) of 30.6mm (males; n=15) and 30.6mm (females; n=16; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.72. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 5.3cm (males) and c. 5.3cm (females).

Red-necked Stint^{M} *Calidris ruficollis*

HANZAB (Higgins & Davies 1996) 'When feeding, move forwards … , picking constantly and rapidly at muddy surface and occasionally probing, …; generally keep to dry or wet mud but occasionally wade into shallows and immerse face or even entire head while rapidly probing' and 'Mostly forage on bare wet mud on intertidal mudflats or sandflats, or in very shallow water (Dann 1983; Garnett 1989); mostly in areas with film of surface water, close to edge of water; also, though less often, in very shallow water, <2.5 cm deep and ≤30 cm from edge of water (Thomas 1968b; Thomas & Dartnall 1971b). During high tides, may forage in non-tidal wetlands (Vic. Atlas), feeding in wet mud above edge of water or in shallow water, usually 1-2 cm, rarely up to 4 cm, deep, and ≥30 cm from shore (Thomas & Dartnall 1971b). May also forage in samphire'.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of the closely-related and morphologically very similar Little Stint *Calidris minuta* were foraging on coastal lagoons in Ghana (see Little Egret above for details of methods). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Little Stint and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Little Stint	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (3.3cm)**	**Water depth as % of male tarsus length (2.12cm)**	**Water depth as % of female tarsus length (2.17cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	0.2	6	9	9
Median (50%)	0.3	10	14	14
3rd Quartile (75%)	0.5	15	24	23
'Maximum' (almost 100%)	0.5	15	24	23
Max. Outlier	2.7	82	127	124

Note that 50% of foraging was in water depths ≤ 14% of tarsus lengths; almost 100% was in depths of ≤ 24–23% of tarsus lengths; and the maximum outlier was foraging in a water depth that was 127–124% of tarsus lengths.

Dann (1999a) found that the preferred feeding zone for Red-necked Stints at Western Port, Vic., was wet mud (86%). They 'took prey from the surface of the substrate, or from within the sediment or associated flora while standing in or out of the water'. They 'were never observed to submerge their heads'. Some individuals (8%) fed in 'dry mud' areas (defined as 'areas above the water's edge not retaining a surface film of water'). In strong winds (>15 knots), 100% of feeding by Stint was in 'wet mud' areas (defined as 'areas above the water's edge retaining a surface film of water').

Dann, P. (1999b). Feeding periods and supratidal feeding of Red-necked Stints and Curlew Sandpipers in Western Port, Victoria. *Emu*. 99:218-222.

CHECK: 'Shorebirds of Australia edited by Andrew Geering, Lindsay Agnew, Sandra Harding' and '**Australian Saltmarsh Ecology** By Neil Saintilan' and

UNABLE TO LOAD THE FOLLOWING GGOGLE RESULT: [DOC]Estimation of tidal flat area at different tide heights - Department of ... www.delwp.vic.gov.au/__.../ARI-Technical-Report-250-Shorebird-use-tidal-flats-Wester... The shorebirds **feed** on benthic invertebrates in the tidal flats, and high ... **Red-necked Stint** declined in abundance at the

WTP during the 2000s, but no more ..... by deploying two automatic water **depth** recorders (Odyssey Pty Ltd) on the tidal ...

Paton (2010) used bar charts to show the foraging depths 'used by' Red-necked Stint (n=1801) and other waders in the Coorong in January 2003-2006. For Red-necked Stint these were: '0cm' 37% of birds, '<2cm' 53%, and 2-4cm' 3% (percentages determined by eye from the graphs). Paton (2010) also observed that 'In the tidally-influenced sections of the Murray Estuary, stints and sandpipers ... forage predominantly when the tides are falling'.

Paton *et al.* (2011) observed that stints were foraging (n=3021) in the following water depths in the Coorong in January 2011: 'dry' 13%, 'damp' 17%, 'ankle' 45%, 'half knee' 15%, 'knee' 9%. Thus while the foraging depth range was from 0cm (mainly damp) to knee-depth, most birds were foraging in damp to half-knee depths. Knee-depth can be calculated as (1 x tarsus length) = 20mm, that is 2cm. Most birds were foraging in 0 (damp) – 1cm water.

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean Red-necked Stint 'wadeable depth' of 28.1 mm (standard error ±0.6mm; n=10). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 19.7–20.3mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) reported Red-necked Stint tarsus lengths (means) of 19.9mm (males; n=70) and 20.3mm (females; n=56; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 4cm (males) and c. 4cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.44. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 2.9cm (males) and c. 2.9cm (females).

Long-toed Stint^M *Calidris subminuta*

HANZAB (Higgins & Davies 1996) 'Prefer muddy or vegetated edges of coastal and near-coastal freshwater and brackish wetlands …' and 'Feed in shallow water and among fairly dense low vegetation, picking prey from surface of mud or water; sometimes feed in open at edge of water with other stints or forage on floating weed or algae' and 'Forage on wet mud or in shallow water, often among short grass, weeds and other vegetation on islets or round edges of wetlands. Occasionally feed in open water, well away from shore, especially in drying ephemeral wetlands. Recorded foraging in shallows round edge of flooded samphire; … (Eckert 1965; Smith 1968, 1969; Curry 1979)' and 'Mainly feed on fresh waters; singly or in small flocks in shallow water, on floating weed or algae (Hayman *et al.* 1986), or in low vegetation … (Smith 1968)' and 'glean from surface of mud and water; sometimes probe or turn head to flick over debris (Hutton 1992)'.

HANZAB (Higgins & Davies 1996) reported Long-toed Stint tarsus lengths (means) of 21.8mm (males; n=42) and 22.0mm (females; n=44; no significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 4cm (males) and c. 4cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.39. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 3.0cm (males) and c. 3.1cm (females).

Pectoral Sandpiper^M *Calidris melanotos*

HANZAB (Higgins & Davies 1996) 'on wide variety of freshwater and brackish wetlands, both coastal and inland' and 'when feeding, move slowly and steadily along grassy fringe or in shallows with head down and legs flexed, combining picking with rapid shallow probing' and 'Move slowly while feeding, probing with rapid strokes (Bent 1962). Slowly walk on grass fringing water or in very shallow water. Rarely seen on open mudflats. Probe repeatedly in small area. Adopt characteristic semi-crouched position while gleaning (Smith 1963)'.

HANZAB (Higgins & Davies 1996) reported Pectoral Sandpiper tarsus lengths (means) of 28.7mm (males; n=43) and 27.1mm (females; n=35; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 4cm (males) and c. 4cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.42. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.1cm (males) and c. 3.8cm (females).

Sharp-tailed Sandpiper^M *Calidris acuminata*

HANZAB (Higgins & Davies 1996) 'Found on wide variety of coastal and inland wetlands and commonly on intertidal mudflats and coastal lagoons' and 'Forage on both wet and dry mud at edges of wetlands, often also feeding and roosting among flooded vegetation such as tussock grass or samphire' and 'Forage at edge of water of wetlands or intertidal mudflats; either on bare wet mud or sand, or in shallow water (Sibson 1966; Ewart 1973; Dann 1981, 1983; Vic. Atlas); also among inundated vegetation of saltmarsh, grass or sedges (Boehm 1960; Thomas 1968; Pegler 1983; Wakefield

1984; Garnett 1986)' and 'Feed mostly at edge of water on mudflats, wetlands and sewage ponds. After rain, may feed on short pasture (Smith 1964). Often in hypersaline environments (Lane). At L. Reeve, Vic., foraged in wet areas of algal mat and on bare mud'.

Paton (2010) used bar charts to show the foraging depths 'used by' Sharp-tailed Sandpiper (n=959) and other waders in the Coorong in January 2003-2006. For Sharp-tailed Sandpiper these were: '0cm' 20% of birds, '<2cm' 62%, '2-4cm' 15%, and '4-6cm' 2% (percentages determined by eye from the graphs).

Paton *et al.* (2011) observed that Sharp-tailed Sandpipers were foraging (n=34) in the following water depths in the Coorong in January 2011: 'damp' 33%, 'ankle' 47%, 'half knee' 15%. Thus the foraging range was from 0cm (damp) to half-knee, which can be calculated as (0.5 x tarsus length) = (0.5 x 30mm), that is 1.5cm.

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean Sharp-tailed Sandpiper 'wadeable depth' of 44.6mm (standard error ±0.6mm; n=10). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 28.9–30.5mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) reported Sharp-tailed Sandpiper tarsus lengths (means) of 30.5mm (males; n=71) and 28.9mm (females; n=70; significant diff CHECK.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.50. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.6cm (males) and c. 4.3cm (females).

Curlew Sandpiper^M *Calidris ferruginea*

HANZAB (Higgins & Davies 1996) 'favour estuarine mudflats and muddy edges of freshwater and brackish wetlands, both coastal and inland. Gait like that of other small calidrids. Feed on wet mud by pecking and probing; or wade in water; large groups often seen wading up to belly with heads submerged while probing; swim well' and 'Forage on mudflats and nearby shallow water. In non-tidal wetlands, usually wade, mostly in water 15-30 mm , but up to 60 mm, deep; also forage farther out or on mud or sand covered by film of water (Thomas & Dartnall1971a). At Port Hedland Saltworks, WA, observed feeding while swimming on large hypersaline ponds 1-2m deep (C.D.T. Minton)' and 'At high tide, feed among low sparse emergent vegetation, such as saltmarsh (Hindwood & Hoskin 1954; Loyn 1975; Vic. Atlas); sometimes in flooded paddocks (Loyn 1975, 1978) or inundated saltflats (Garnett 1989); rarely on pasture (Smith 1967)' and 'Usually forage in water, near shore (Thomas & Dartnall 1971a; Dann 1981a) or on bare wet mud at edge of wetlands (Dann 1983); also probe in shallow water; jab at edge of water where film of water remains on sand; glean from mud, from surface of water, or in drier areas above edge of water' and 'May wade up to belly (Hindwood & Hoskin 1954). At Port Hedland Saltworks … up to hundreds regularly feed by swimming and picking food from surface of water … (C.D.T. Minton)'.

Ntiamoa-Baidu *et al.* (1998) estimated the water depths in which flocks of Curlew Sandpiper and other waterbirds were foraging on coastal lagoons in Ghana (see Little Egret above for details of method). The water depths selected by 0%, 25%, 50%, 75% and 100% of the flocks of foraging Curlew Sandpiper and other waterbird species were depicted graphically by those authors (Figure 3; Appendix …) and are presented, following extraction by eye, in the Table below.

Proportion of foraging Curlew Sandpiper	**Water depth (cm)**	**Water depth as % of 'exposed vertical leg length' (4.5cm)**	**Water depth as % of male tarsus length (2.93cm)**	**Water depth as % of female tarsus length (3.10cm)**
'Minimum' (0%)	0	0	0	0
1st Quartile (25%)	0.3	7	10	10
Median (50%)	0.6	1.3	20	19
3rd Quartile (75%)	3.0	67	102	97
'Maximum' (100%)	3.8	84	130	123

Note, in particular, that 25% of foraging was in water depths ≤ 10% of male-female tarsus lengths; 50% was in depths ≤ 20–19% of tarsus lengths; 75% was in depths of ≤ 102–97% of tarsus lengths, and 100% of foraging was in ≤ 130–123% of tarsus lengths.

Tarsus lengths of Curlew Sandpiper migrating to Australia are only very slightly different (males 101%; females 99%) than those of Europe (migrating to Africa) (see Table below for means, standard deviations, ranges and numbers of birds measured; sourced from HANZAB and BWP). The water depths in which Ntiamoa-Baidu *et al.* (*ibid.*) recorded Curlew Sandpiper foraging in Ghana do not, therefore, require adjustment to be potentially applicable to Curlew Sandpiper migrating to Australia.

Distribution	**Source materials**	**Tarsus (males; mm)**	**Tarsus (females; mm)**	**Signif.**

Australia +	Indon. & Aust., adults	29.6 (1.14; 27-32.3; 29)	30.6 (1.20; 28.5-33; 21)	**
Africa +	Western & central Europe, May-Oct., skins	29.3 (1.01; 28-31; 20)	31.0 (1.04; 29-32; 25)	yes

Dann (1999a) found that the preferred feeding zone for Curlew Sandpiper at Western Port, Vic., was shallow water (40%). They 'fed in, or from the surface of, the sediment while standing in or out of the water. Like [Red-necked] stints', they were not seen to feed from the water's surface'. Only 25% fed in 'wet mud' areas and 23% fed at the water's edge. In strong winds (>15 knots) almost 100% of feeding by Curlew Sandpipers was in 'wet mud' areas (defined as 'areas above the water's edge retaining a surface film of water').

Dann, P. (1999b). Feeding periods and supratidal feeding of Red-necked Stints and Curlew Sandpipers in Western Port, Victoria. *Emu*. 99:218-222.

The Minister approved this conservation advice on 14/05/2015 and included this species in the critically endangered category, effective from 26/05/2015. *Calidris ferruginea* (curlew sandpiper) Conservation Advice: 'Curlew sandpipers forage on mudflats and nearby shallow water. In non-tidal wetlands, they usually wade, mostly in water 15–30 mm, but up to 60 mm deep'.

Paton (2010) used bar charts to show the foraging depths 'used by' Curlew Sandpiper (n=73) and other waders in the Coorong in January 2003-2006. For Curlew Sandpiper these were: '<2cm' 30% of birds, '2-4cm' 67%, and '4-6cm' 3% (percentages determined by eye from the graphs).

Spencer (2010) determined, on the basis of total leg lengths of preserved skins, a mean Curlew Sandpiper 'wadeable depth' of 47.0mm (standard error ±1.1mm; n=10). In the same paper, Spencer reported tarsus length measurements of this species, sourced from Higgins & Davies (1996), as 28.4–30.6mm. Ratio b/a =

HANZAB (Higgins & Davies 1996) reported Curlew Sandpiper tarsus lengths (means) of 28.4mm (males; n=33) and 29.8mm (females; n=23; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 6cm (males) and c. 6cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.61. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 4.6cm (males) and c. 4.8cm (females).

Ruff^{M} *Philomachus pugnax*

HANZAB (Higgins & Davies 1996) 'found on variety of coastal and inland wetlands, preferring muddy margins of freshwater and brackish swamps and lakes; …' and 'Forage methodically along muddy margins …picking and probing rapidly at mud; sometimes dart after food; wade freely through flooded grass and in pools, often submerging entire head; on saline lakes, may also swim … pecking at surface' and 'generally fresh, brackish or saline wetlands with exposed mudflats at edges' and 'Mainly forage on exposed mudflats (Fisher 1964; Ford 1966; McKean *et al.* 1976), in shallow water (Carter & Smith 1968; Curry 1979), or occasionally on dry mud (Curry 1979; R.P. Jaensch)' and 'Probe and peck in water, on dry land and among dead vegetation at edge of water. Sometimes crane neck to glean items above head (Curry 1979). May wade up to belly, swim and follow plough when foraging (BWP).

In their study of the foraging ecology of Wood Sandpipers and Ruffs in wetlands of the Sajna River valley, northern Poland, Krupa *et al.* (2009) found that Ruffs foraged mostly (57.5% of probes) in water depths above the tarsus joint (and often while submerging the whole head beneath the water surface); less (38.8%) in water up to the tarsus joint, and little (3.7%) in water covering the toes at most.

HANZAB (Higgins & Davies 1996) reported Ruff tarsus lengths (means) of 50.2mm (males; n=77) and 42.9mm (females; n=31; significant diff.). On this basis, maximum foraging depths may be estimated as 2 x (tarsus length) = c. 10cm (males) and c. 9cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.61. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 8.1cm (males) and c. 6.9cm (females).

Gulls, Terns Family Laridae

Fairy Tern *Sternula nereis*

HANZAB (Higgins & Davies 1996) 'Forage in shallow water (>10cm deep) of sheltered coasts, embayments and estuaries. Usually close inshore, often near shoreline, over submerged banks or in adjacent shallow channels (Storr 1964a,b; Ford 1967; Peter 1990; J.M. Peter) … Also in coastal lagoons and near-coastal lakes (Hitchcock 1937; Ford 1967; Newman 1981; Peter 1994)'.' and 'Catch fish by PLUNGING in shallow water (Hitchcock 1937; Oliver);

observed diving from heights of up to 5 m (Peter 1994). Fly to and fro 3–10 m above sea … before plunging into water, rising again after a few seconds (D.W. Eades; G.R. Parrish)'.

Paton (2010) observed that 'Terns can forage across the width of the Coorong in both shallow and deep water provided fish are within a few centimetres of the surface, and provided the water is deep enough to absorb an aerial plunge. For the small species of tern, like Fairy and Whiskered Terns, 30cm of water depth may be sufficient'.

Dunlop (2015): 'Fairy Terns forage by plunge diving for small schooling fishes.'

Ismar, S.M.H., Trnski, T., Beauchamp, T., Bury, S.J., Wilson, D., Kannemeyer, R., Bellingham, M & Baird, K. (2013). *Foraging ecology and choice of feeding habitat in the New Zealand Fairy Tern Sternula nereis davisae*. Bird Conservation International 1-16. [DOWNLOADED 1ST DEC 2017]

Jeffries, D.S., Bull, L.S., Lagnaz, E.G., Pulham, G.A., Wilson, D.S., Wilson, P. & Zimmerman, R.L. (2016). *New Zealand fairy tern (Sternula nereis davisae) foraging behaviour at Te Arai Stream.* Notornis 63, 42-45. [DOWNLOADED 1ST DEC 2017]

Menkhorst *et al.* (2017) state that Fairy Terns forage by ' … catching prey with shallow plunge-dives'.

Gull-billed Tern *Gelochilodon nilotica*

HANZAB (Higgins & Davies 1996) 'Inhabit coastal and inland wetlands, coasts and estuaries, and croplands and grasslands' and 'often hawk for insects and swoop down to take prey from surface of ground or water' and 'Prefer shallow, often ephemeral, terrestrial wetlands, either fresh or saline, especially lakes, swamps and lagoons, particularly those with mudflats; sometimes on inundated ground, including saltpans, claypans and saltmarsh (Morgan 1931; Jaensch 1983; Storr 1984, 1985; Gibson 1986; Woodall 1986; Bamford 1988)' and 'Forage on terrestrial wetlands and, occasionally, sheltered coasts. Food taken from surface of water or from surface of exposed mud or sand at or near edge of water (Serventy 1955; Lindgren 1956; Rix 1970; Henderson & McBain 1980; Woodall 1986; Rose 1989; Vic. Atlas). May also forage over dry land, …' and 'Three methods of foraging observed: (1) HAWKING: take insects on wing (Bridgewater 1932; CSN 35); (2) DIPPING: fly 2-10m above water, swooping down to take items from surface of water, mud, or pasture (McKenzie 1955; Wheeler 1959; Ford 1961; Henderson & McBain 1980; Woodall 1986). May settle on water to glean items (Bridgewater 1932; Lingren 1956). … (3) PLUNGING: Rare; recorded circling above and diving for herring *Nematalosa,* herded by cormorants (Carruthers 1969)'.

Gaglio et al. (2015): 'Many tern species are described as feeding primarily on aquatic organisms, which they snatch from the surface or capture by plunge-diving, dipping or contact dipping (Ainley 1977, Gochfeld & Burger 1996). However, some terns also forage on terrestrial prey. The Gull-billed Tern *Gelochelidon nilotica*, for example, eats more insects than fish, snatching insects from the air (Richards 1990, Gochfeld & Burger 1996), while marsh terns (*Chlidonias* spp.) depend heavily on insects, spiders, earthworms, amphibians and lizards (Richards 1990, Gochfeld & Burger 1996)'.

Tarsus measurements are not relevant to foraging depth of this species, as it forages while flying, not walking. HANZAB (Higgins & Davies 1996) reported Gull-billed Tern bill lengths (means) of 43.3mm (males; n=7). Three female specimens measured 38.8-43.4mm.

Menkhorst *et al.* (2017) state that the Gull-billed Tern 'does not plunge-dive but plucks prey from surface'.

Caspian Tern *Hydroprogne caspia*

HANZAB (Higgins & Davies 1996) 'Inhabit wide variety of coastal habitats, especially estuaries and sandy beaches …' and 'When foraging, patrol in slow lazy flight, 3-15m above water …; pause to hover before making dramatic plunge after fish' and 'Usually forage in open wetlands, including lakes and rivers, often preferring sheltered shallow water near margins; also in open coastal waters (Tarr 1960a; Sibson 1963; Pierce 1983, 1984; Oliver; Vic. Atlas). Prefer wetlands with clear water to those with muddy turbid water (Pierce 1980). Rarely in choppy or deep water (Favaloro 1947; Sibson 1963)' and 'Usually feed by shallow plunging: hover up to 15 m above water, … then dive, fully submerging, and quickly re-emerge (HASB; BWP)' and 'Usually swallow fish in flight, head first'.

Paton *et al.* (2011) observed on the Coorong in January 2011 that all caspian terns were foraging (n=611) while flying. What can be said about depths?

Lyons, D.B. & Roby, D.D. (2007). *Foraging Patterns of Caspian Terns and Double-crested Cormorants in the Columbia River Estuary.* Northwest Science 81(2), 91-103. [DOWNLOADED 1ST DEC 2017]

McEneaney, T. (...). *Piscivorous birds of Yellowstone Lake – Their history, ecology and status.* Yellowstone Lake 6th Biennial Scientific Conference. 121-134. [DOWNLOADED 1ST DEC 2017]

Paton, D.C. & Bailey, C.P. (2013). *Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site - Waterbirds 2013.* School of Earth & Environmental Sciences, University of Adelaide, for the South Australian Department of Environment, Water and Natural Resources. [DOWNLOADED 1ST DEC 2017] GREAT PHOTO OF SANDPIPERS FEEDING ON TOP OF EXPOSED ALGAL MASS

Tarsus measurements are not relevant to foraging depth of this species, as it forages while flying, not walking. HANZAB (Higgins & Davies 1996) reported Caspian Tern bill lengths (means) of 71.3mm (males; n=16) and 68.7mm (females; n=20; no significant diff.).

Menkhorst *et al.* (2017) state that the Caspian Tern foraging technique is a 'dramatic plunge-dive'.

Whiskered Tern *Chlidonias hybridus*

HANZAB (Higgins & Davies 1996) 'Inhabit wide variety of freshwater and brackish wetlands, both coastal and inland' and 'Feeding flight similar to that of other marsh terns: patrol 5-10 m above water, flying into wind …, dipping to snatch prey from surface; also hawk for insects over swamps, damp grass or croplands; … often plunge-dive for fish' and 'Prefer shallow terrestrial freshwater wetlands, either permanent and ephemeral, including lakes, swamps, …, flooded saltmarsh and farmland' and 'Usually forage on terrestrial wetlands … with vegetated margins or emergent aquatic plants, including grass, sedges, reeds and rushes (Bourke 1956; Portbury & Buntine 1961; Dostine & Morton 1989)' and 'Forage aerially over wetlands … ; also feed from surface of water, just below surface of water, and glean from emergent vegetation (Bourke 1956; Hobbs 1976; Crawford 1977; Dostine & Morton 1989; HASB)' and 'Three main methods of feeding: (1) PLUNGING: hover then dive, with wings raised, from 2–4 m above water (Hall 1902; Wall 1970; Heather & Jones 1979). (2) DIPPING: fly low over water, skimming surface to take insects from on or just below surface of water (Crawford 1977). (3) HAWKING: take insects up to 40 mm long; may hawk over dry plains (Bourke 1956; Crawford 1977).

Paton (2010) observed that 'Terns can forage across the width of the Coorong in both shallow and deep water provided fish are within a few centimetres of the surface, and provided the water is deep enough to absorb an aerial plunge. For the small species of tern, like Fairy and Whiskered Terns, 30cm of water depth may be sufficient'.

Gaglio et al. (2015): '... marsh terns (*Chlidonias* spp.) depend heavily on insects, spiders, earthworms, amphibians and lizards (Richards 1990, Gochfeld & Burger 1996)'.

Tarsus measurements are not relevant to foraging depth of this species, as it forages while flying, not walking. HANZAB (Higgins & Davies 1996) reported Whiskered Tern bill lengths (means) of 30.6mm (males; n=27) and 27.7mm (females; n=21; significant diff.).

Menkhorst *et al.* (2017) state that the Whiskered Tern 'often makes shallow plunge-dives into water'.

White-winged Black Tern^{M} *Chlidonias leucopterus*

HANZAB (Higgins & Davies 1996) 'Inhabit wide variety of coastal and inland, freshwater and brackish wetlands; also irrigated croplands' and 'feeding flight rather leisurely, erratic and buoyant; beat steadily into wind, with quick shallow wing-beats, often dipping to surface to take prey; seldom plunge-dive; often hover while hawking for insects over water or grassland' and 'Mainly forage aerially, over water or muddy or sandy edges of wetlands; also adjacent land, especially if inundated (Ford 1956; Wall1963; Smith 1965; Keeley & Sagar 1968; Rix 1970; Crawford 1972, 1977; Pierce 1974; Todd & Lloyd 1980; Atherton *et al.* 1985). Food usually taken low over water or ground, or from surface of water; less often, from ground. Very rarely, dive into water (Hutchison 1971; Pierce 1974; Todd & Lloyd 1980). Often hawk above wetland vegetation, such as reeds and rushes, saltmarsh and mangroves (Alexander 1917; Sibson 1954; Douglas 1956; Lindgren 1956; Watson 1956; Storr 1984) and flooded farmland … (Sibson 1954; Pierce 1974; Crawford 1977)' and '~~In non-breeding areas,~~ mainly forage on coastal estuaries and freshwater wetlands; occasionally reported over terrestrial vegetation (Ford 1956; Lindgren 1956; Watts 1981)' and 'Use three main [foraging] methods: (1) PLUNGING: shallow dives from 2 to 4 m, usually with wings raised; only partly submerge (Todd & Lloyd 1980; BWP); (2) HAWKING: take insects (e.g. flying ants) in air (Smith 1965; Keeley & Sagar 1968; Crawford 1977; CSN 19 Suppl., 21, 32, 35); (3) DIPPING: fly 2-4 m above water, dipping down to take items on or just below surface of water (Rix 1970; Crawford 1977); may skim bill along surface (Amiet 1957). May also GLEAN insects while on ground or mud or while wading in shallow water among saltmarsh vegetation (Sibson 1954; Todd & Lloyd 1980)'.

HANZAB (Higgins & Davies 1996) reported White-winged Black Tern tarsus lengths (means) of 20.0mm (males; n=11) and 19.4mm (females; n=14; not significant diff.). On this basis, maximum foraging depths *while walking* may be estimated as 2 x (tarsus length) = c. 4cm (males) and c. 4cm (females). Marchant & Higgins (1990) reported White-winged Black Tern bill lengths (means) of 25.7mm (males; n=11) and 24.3mm (females; n=14; significant diff.).

Menkhorst *et al.* (2017) state that the White-winged Black Tern foraging techniques involves ‘dipping to pluck prey items from [the] surface’ and ‘they do not plunge-dive’.

Crested Tern *Thalasseus bergii*

HANZAB (Higgins & Davies 1996) ‘Forage by plunging steeply from several metres above water, often submerging completely; also dip to snatch prey from surface of water’ and ‘[Habitat] Mostly coastal, on exposed ocean beaches or in sheltered embayments, such as bays, harbours, inlets, estuaries and lagoons (Keast 1943; Morris 1975; Gibson 1977; Harris & Last 1982; Pegler 1983; Storr & Johnstone 1988; Peter 1990)’ and ‘Feed from surface of sea to ≤1m deep, mainly in inshore waters, … (Wheeler 1947; D'Ombrain 1954; Storr 1964b; Hornsby 1978; Langham & Hulsman 1986; Smith & Ogilvie 1989; Walker 1992). Also in estuaries and sheltered inlets, sometimes in shallow waters over submerged beds of seagrass (Harris & Last 1982; Peter 1990)’ and ‘Dive from heights of 5-8 m, but only penetrate a few centimetres below surface of water (Bossley & Boord 1992)’ and ‘Mainly feed by PLUNGING from 7-10 m, diving head or feet first; submerge completely (SHALLOW PLUNGING), diving up to 50 cm below surface (Hulsman 1977a).

Chiaradia *et al.* (2002): ‘Crested Terns feed their chicks several times a day, foraging 3–20 km from their colony and diving up to 1 m below the surface to obtain food (Hulsman 1977; Hoedt *et al.* 1995)’.

Hulsman, K. (1977). *Daily attendance of terns and gulls at One Tree Island.* Sunbird 8, 9–19.

Hoedt, F.E., Dimmlich, W.F. & Dann, P. (1995). *Seasonal variation in the species and size composition of the clupeoid assemblages in Western Port, Victoria.* Marine and Freshwater Research 46, 1085–1091.

McLeay et al. (2010): ‘Adult crested terns foraged [Gulf St Vincent, South Australia] predominantly (>60% TSA) over waters <20 m in depth, which was significantly shallower than waters available within their entire foraging range’.

Paton *et al.* (2011) observed on the Coorong in January 2011 that all Crested Terns were foraging (n=420) while flying. What can be said about depths?

Gaglio et al. (2015): ‘Off the coast of Western Australia, Surman & Wooller (2003) compared the foraging ecology of five sympatric species of terns during breeding (Greater Crested Tern, ...), and reported the presence of insects in the diet only for Sooty Terns’ and ‘In an Australian population studied over a five-year period, a total of 2,146 and 3,921 prey were identified from 1,400 and 1,561 regurgitates collected from chicks and adults, respectively. Insects contributed a low proportion of the total biomass (<0.5%) and species were not identified (McLeay *et al.* 2009)’.

Tarsus measurements are not relevant to foraging depth of this species, as it forages while flying, not walking. HANZAB (Higgins & Davies 1996) reported Crested Tern bill lengths (means) of 65.8mm (males; n=21) and 62.0mm (females; n=17; significant diff.).

Menkhorst *et al.* (2017) state that the Crested Tern forages by ‘plunge-diving steeply and ‘also snatch[es] prey from water surface’.

Silver Gull *Chroicocephalus novaehollandiae*

HANZAB (Higgins & Davies 1996) ‘Inhabit wide variety of coastal habitats and inland wetlands’ and ‘Opportunistic scavenger, well adapted to urban living, scavenging for food wherever it can be found’ and ‘When feeding on intertidal beaches, forage on sand or in clumps of beachcast seaweed (Gurr 1954; Sharland 1956; Storr & Johnstone 1988). Sometimes forage in shallow water (≤5 cm deep); sometimes in moist sand …, on wet mudflats …; or in shallow lagoons, pools and floodwaters (Symon 1938; Learmonth 1958; Wheeler & Watson 1963; Loyn 1975; Woodall1986; Walker 1988)’ and ‘In deeper water, take food from, or a few centimetres below, surface of water, either while swimming or flying close to water (Wheeler & Watson 1963; Storr 1964; Woodall 1986; Wood 1991); rarely, dive to depths of *c.* 30 cm (Wheeler & Watson 1963)’ and ‘Use wide variety of foraging methods ... [including] FEEDING ON GROUND: … Foot tremble in soft substrates to bring food to surface (Symon 1938; Wheeler & Watson 1963; Dawson 1966; Collins & Collins 1976, 1981). … FEEDING IN OR OVER WATER: Dipping: hover over water or mud, occasionally dipping down to pick prey from surface … (Wheeler & Watson 1963; Brown 1982). May also feed [while] flying with lower mandible immersed in water (Egan 1990). Surface-seizing: swim on salt lakes, taking brine-shrimp from just below surface (Wheeler & Watson 1963; Storr 1964). Foot-paddling: while floating, use feet to bring food to just below surface, then seize prey (Wheeler & Watson 1963). … Dive up to 30 cm below water from heights of 2-4 m in pursuit of fish (Wheeler & Watson 1963; CSN 24). … Take crabs by dipping head into shallow water or jumping out of water and taking shallow dive (M’Clymont 1906). Will dive underwater to take fish from nets (Cole 1908)’.

Paton *et al.* (2011) observed that silver gulls were foraging (n=4174) in the following water depths in the Coorong in January 2011: ‘dry’ 3%, ‘damp’ 10%, ‘ankle’ 46%, ‘half knee’ 3%, ‘knee’ 9%, ‘thigh’ 1%, ‘belly’ 0.1%, ‘swim’ 17%, ‘fly’ 10%. The foraging depth range was thus 0cm (mainly damp substrate) to greater than belly-depth, which can be calculated as > (2 x female tarsus length) = > (2 x 48mm), that is > 10cm.

HANZAB (Higgins & Davies 1996) reported Silver Gull tarsus lengths (means) of 48.0mm (males; n=16) and 46.6mm (females; n=18; not significant diff.). On this basis, maximum foraging depths *while walking* may be estimated as 2 x (tarsus length) = c. 10cm (males) and c. 9cm (females). Marchant & Higgins (1990) reported Silver Gull bill lengths (means) of 36.5mm (males; n=17) and 34.4mm (females; n=17; significant diff.).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.30. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 6.2cm (males) and c. 6.1cm (females).

Honeyeaters, Australian Chats Family Meliphagidae

White-fronted Chat *Ephthianura albifrons*

HANZAB (Higgins *et al.* 2001) 'Forage mainly on bare or grassy ground; occasionally also in outer foliage of trees and shrubs' and 'Occur in damp open habitats, especially near wetlands bordered by samphire *Halosarcia* or saltbush *Atriplex*, and grasslands (Hobbs 1961; Storr 1965; Wheeler 1967a,b; Williams & Main 1976; Gibson 1977; Morris *et al.* 1981; Aust. Atlas)' and 'Mainly feed on bare or grassy ground, and occasionally among foliage of herbs, shrubs or trees (Boehm 1957; Williams 1971; North; Aust. Atlas; Vic. Atlas; D.R. Milledge). Also feed aerially (Legge 1902; Major 1989). Detailed study at Laverton Saltworks, Vic. (Major 1989)' and 'When feeding on ground, walk or run in short bursts (Green 1995; Hall); sometimes forage by wading in shallow water (Sharland 1958)' and 'Mainly feed by gleaning insects from ground or catching flying insects close to ground; very occasionally sally for flying insects (Major 1989)'.

HANZAB (Higgins *et al.* 2001) reported White-fronted Chat tarsus lengths (means) of 17.2mm (males; n=29) and 17.2mm (females; n=26; not significant diff.). On this basis, maximum foraging depths *while walking* may be estimated as 2 x (tarsus length) = c. 3cm (males) and c. 3cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.08. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 1.9cm (males) and c. 1.9cm (females).

Reed-Warblers Family Acrocephalidae

Australian Reed-Warbler *Acrocephalus australis*

HANZAB (Higgins *et al.* 2006) '[Habitat] Typically in dense, low, aquatic or riparian vegetation, mainly reeds, rushes, sedges and other vegetation with similar vertical structure, in and round nearly any type of fresh, brackish or saline wetlands' and **Behaviour:** 'Forage mainly in dense aquatic or riparian vegetation, making observations difficult (Anon. 1907; Littler 1910; Fleming 1976; Lenz 1989b; Gynther 1994; R. Johnson); forage in vegetation, on bare ground or mud within or next to reeds' and 'FORAGING SITES: Mainly forage in dense aquatic or riparian vegetation, mainly rushes, reeds, sedges and grasses, less often in shrubs or trees (Anon. 1907; Littler 1910; Bryant 1941; Wheeler 1944; Fleming 1976; Lenz 1989b; Gynther 1994; R. Johnson), and sometimes on exposed mud near water's edge or among vegetation (Littler 1910; R. Johnson) … FORAGING HEIGHTS: Usually forage on or near ground, either on bare mud or in low dense vegetation, such as rushes, sedges, grass or shrubs (Littler 1910; Fleming 1976; Lenz 1989b; Gynther 1994; Vic. Atlas; R. Johnson); occasionally in taller shrubs and trees, such as eucalypts (Wheeler 1944; Gynther 1994). FORAGING METHODS: Glean arthropods from tree trunks and branches, floating debris and reeds, often clinging sideways to stems of reeds (Gynther 1994; Green 1995). Also chase and sally after insects in flight, usually over water (Fleming 1976; Vic. Atlas). Near Goodna, … made short foraging forays into air above Bulrushes' and 'Near Rockingham … one seen foraging 'like a wader' in shallow water, appearing to use feet to splash water or to stamp on mud, as though to disturb prey (O'Connor 1994)'.

HANZAB (Higgins *et al.* 2006) reported Australian Reed-Warbler subspecies *gouldi* tarsus lengths (means) of 25.2mm (males; n=10) and 24.4mm (females; n=6; not significant diff.). On this basis, maximum foraging depths *while walking* may be estimated as 2 x (tarsus length) = c. 5cm (males) and c. 5cm (females).

Measurement of the 'ground-to-belly distance' and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.15. Application of this ratio to the HANZAB tarsus lengths produces 'belly depths' of c. 2.9cm (males) and c. 2.8cm (females).

Grassbird Family Megaluridae

Little Grassbird *Megalurus gramineus*

HANZAB (Higgins *et al.* 2006) 'Typically skulk in dense vegetation of wetland habitats' and 'Usually creep through vegetation in mouse-like manner, but also run quickly or hop buoyantly over ground or vegetation' and 'Once observed wading in very shallow water of lake c. 2 m from reeds (O'Connor 1994)' and 'Foraging behaviour virtually unknown. Forage on ground (Lawrence 1944; Vic. Atlas) and in low vegetation … (…; Watkins & Jaensch 1981; …)' and 'Move about reeds quietly, almost mouse-like, while foraging (McGill 1970)'.

HANZAB (Higgins *et al.* 2006) reported Little Grassbird tarsus lengths (means) of 20.0mm (males; n=22) and 19.9mm (females; n=8; not significant diff.). On this basis, maximum foraging depths *while walking* may be estimated as 2 x (tarsus length) = c. 4cm (males) and c. 4cm (females).

Measurement of the ‘ground-to-belly distance’ and lower leg (≈ tarsus) length in the HANZAB illustration of this species produces a ratio of 1.05. Application of this ratio to the HANZAB tarsus lengths produces ‘belly depths’ of c. 2.1cm (males) and c. 2.1cm (females).

^{M} denotes Migratory species (all transequatorial)

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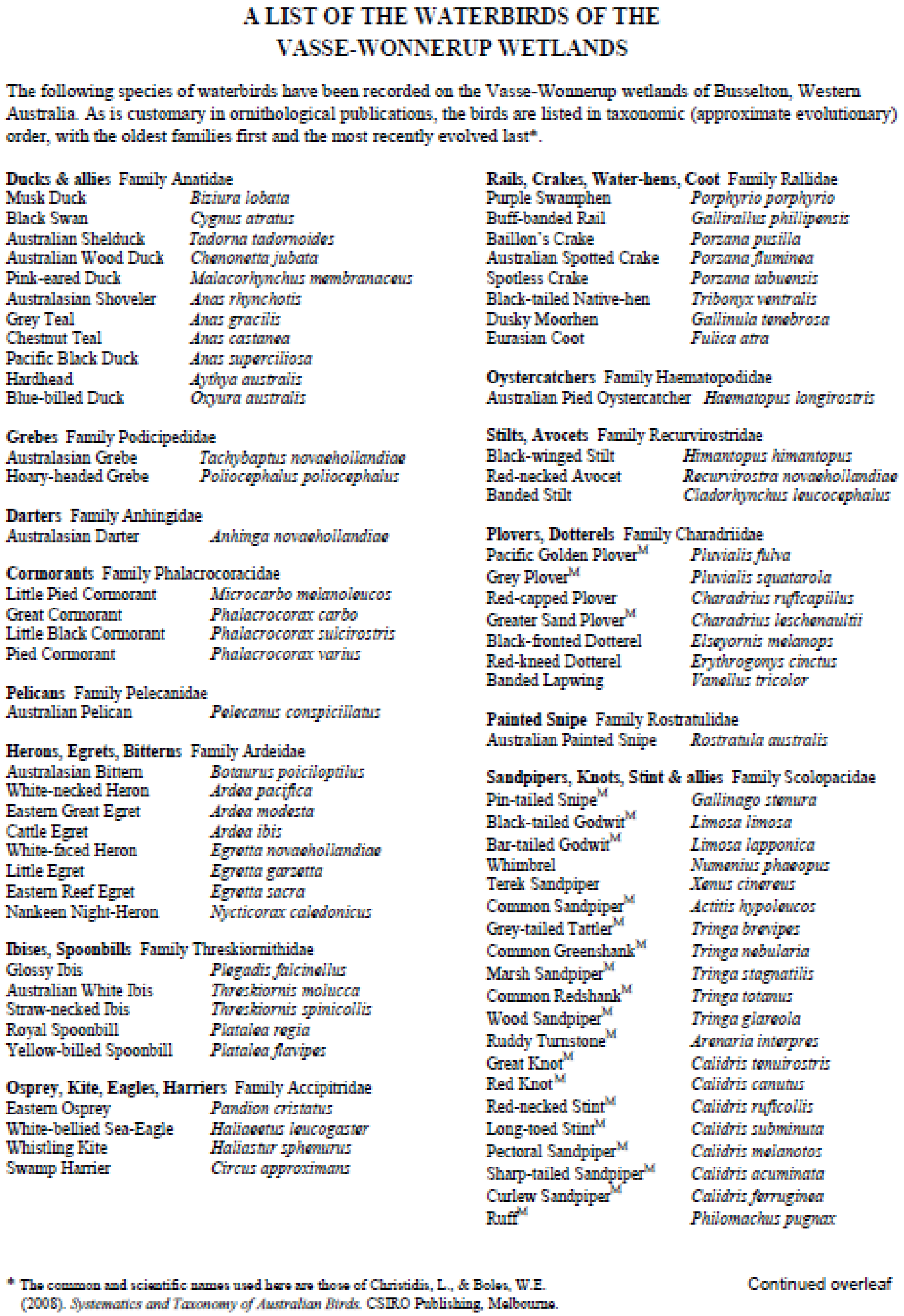
****** TO DO NEXT: CONTINUE EXTRACTING FORAGING DEPTH INFO FROM THE LITERATURE, CONCENTRATING ON V-W SPECIES, WORKING THROUGH THE LINKS I HAVE SAVED TO THIS PROJECT FOLDER. ADD THE INFO TO THIS DOCUMENT AND TO THE 'MsWORD' TABLE THAT I'VE STARTED.**

APPENDICES

Appendix 1. A list of the waterbirds of the Vasse-Wonnerup wetlands.

The following information sheet was prepared by J. Lane in March 1997 and revised in May 1997 and April 2010.



A LIST OF THE WATERBIRDS OF THE VASSE-WONNERUP WETLANDS

The following species of waterbirds have been recorded on the Vasse-Wonnerup wetlands of Busselton, Western Australia. As is customary in ornithological publications, the birds are listed in taxonomic (approximate evolutionary) order, with the oldest families first and the most recently evolved last*.

Ducks & allies Family Anatidae

Musk Duck	*Biziura lobata*
Black Swan	*Cygnus atratus*
Australian Shelduck	*Tadorna tadornoides*
Australian Wood Duck	*Chenonetta jubata*
Pink-eared Duck	*Malacorhynchus membranaceus*
Australasian Shoveler	*Anas rhynchotis*
Grey Teal	*Anas gracilis*
Chestnut Teal	*Anas castanea*
Pacific Black Duck	*Anas superciliosa*
Hardhead	*Aythya australis*
Blue-billed Duck	*Oxyura australis*

Grebes Family Podicipedidae

Australasian Grebe	*Tachybaptus novaehollandiae*
Hoary-headed Grebe	*Poliocephalus poliocephalus*

Darters Family Anhingidae

Australasian Darter	*Anhinga novaehollandiae*

Cormorants Family Phalacrocoracidae

Little Pied Cormorant	*Microcarbo melanoleucos*
Great Cormorant	*Phalacrocorax carbo*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Pied Cormorant	*Phalacrocorax varius*

Pelicans Family Pelecanidae

Australian Pelican	*Pelecanus conspicillatus*

Herons, Egrets, Bitterns Family Ardeidae

Australasian Bittern	*Botaurus poiciloptilus*
White-necked Heron	*Ardea pacifica*
Eastern Great Egret	*Ardea modesta*
Cattle Egret	*Ardea ibis*
White-faced Heron	*Egretta novaehollandiae*
Little Egret	*Egretta garzetta*
Eastern Reef Egret	*Egretta sacra*
Nankeen Night-Heron	*Nycticorax caledonicus*

Ibises, Spoonbills Family Threskiornithidae

Glossy Ibis	*Plegadis falcinellus*
Australian White Ibis	*Threskiornis molucca*
Straw-necked Ibis	*Threskiornis spinicollis*
Royal Spoonbill	*Platalea regia*
Yellow-billed Spoonbill	*Platalea flavipes*

Osprey, Kite, Eagles, Harriers Family Accipitridae

Eastern Osprey	*Pandion cristatus*
White-bellied Sea-Eagle	*Haliaeetus leucogaster*
Whistling Kite	*Haliastur sphenurus*
Swamp Harrier	*Circus approximans*

Rails, Crakes, Water-hens, Coot Family Rallidae

Purple Swamphen	*Porphyrio porphyrio*
Buff-banded Rail	*Gallirallus philippensis*
Baillon's Crake	*Porzana pusilla*
Australian Spotted Crake	*Porzana fluminea*
Spotless Crake	*Porzana tabuensis*
Black-tailed Native-hen	*Tribonyx ventralis*
Dusky Moorhen	*Gallinula tenebrosa*
Eurasian Coot	*Fulica atra*

Oystercatchers Family Haematopodidae

Australian Pied Oystercatcher	*Haematopus longirostris*

Stilts, Avocets Family Recurvirostridae

Black-winged Stilt	*Himantopus himantopus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Banded Stilt	*Cladorhynchus leucocephalus*

Plovers, Dotterels Family Charadriidae

Pacific Golden Plover[M]	*Pluvialis fulva*
Grey Plover[M]	*Pluvialis squatarola*
Red-capped Plover	*Charadrius ruficapillus*
Greater Sand Plover[M]	*Charadrius leschenaultii*
Black-fronted Dotterel	*Elseyornis melanops*
Red-kneed Dotterel	*Erythrogonys cinctus*
Banded Lapwing	*Vanellus tricolor*

Painted Snipe Family Rostratulidae

Australian Painted Snipe	*Rostratula australis*

Sandpipers, Knots, Stint & allies Family Scolopacidae

Pin-tailed Snipe[M]	*Gallinago stenura*
Black-tailed Godwit[M]	*Limosa limosa*
Bar-tailed Godwit[M]	*Limosa lapponica*
Whimbrel	*Numenius phaeopus*
Terek Sandpiper	*Xenus cinereus*
Common Sandpiper[M]	*Actitis hypoleucos*
Grey-tailed Tattler[M]	*Tringa brevipes*
Common Greenshank[M]	*Tringa nebularia*
Marsh Sandpiper[M]	*Tringa stagnatilis*
Common Redshank[M]	*Tringa totanus*
Wood Sandpiper[M]	*Tringa glareola*
Ruddy Turnstone[M]	*Arenaria interpres*
Great Knot[M]	*Calidris tenuirostris*
Red Knot[M]	*Calidris canutus*
Red-necked Stint[M]	*Calidris ruficollis*
Long-toed Stint[M]	*Calidris subminuta*
Pectoral Sandpiper[M]	*Calidris melanotos*
Sharp-tailed Sandpiper[M]	*Calidris acuminata*
Curlew Sandpiper[M]	*Calidris ferruginea*
Ruff[M]	*Philomachus pugnax*

Continued overleaf

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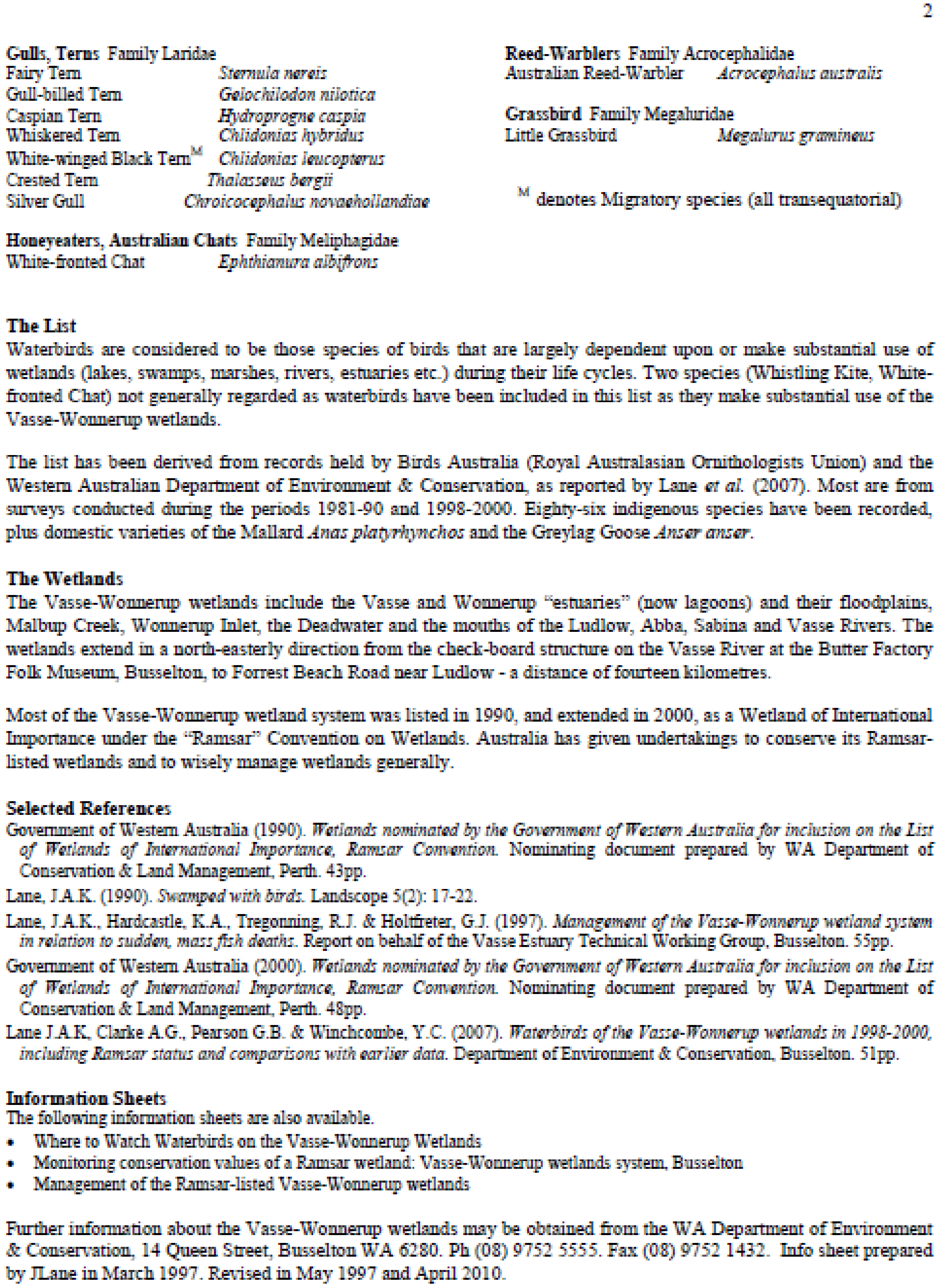
* The common and scientific names used here are those of Christidis, L., & Boles, W.E. (2008). *Systematics and Taxonomy of Australian Birds*. CSIRO Publishing, Melbourne.

Appendix 1 Continued.



Gulls, Terns Family Laridae

Fairy Tern	*Sternula nereis*
Gull-billed Tern	*Gelochilodon nilotica*
Caspian Tern	*Hydroprogne caspia*
Whiskered Tern	*Chlidonias hybridus*
White-winged Black Tern M	*Chlidonias leucopterus*
Crested Tern	*Thalasseus bergii*
Silver Gull	*Chroicocephalus novaehollandiae*

Honeyeaters, Australian Chats Family Meliphagidae

White-fronted Chat	*Ephthianura albifrons*

Reed-Warblers Family Acrocephalidae

Australian Reed-Warbler	*Acrocephalus australis*

Grassbird Family Megaluridae

Little Grassbird	*Megalurus gramineus*

M denotes Migratory species (all transequatorial)

The List

Waterbirds are considered to be those species of birds that are largely dependent upon or make substantial use of wetlands (lakes, swamps, marshes, rivers, estuaries etc.) during their life cycles. Two species (Whistling Kite, White-fronted Chat) not generally regarded as waterbirds have been included in this list as they make substantial use of the Vasse-Wonnerup wetlands.

The list has been derived from records held by Birds Australia (Royal Australasian Ornithologists Union) and the Western Australian Department of Environment & Conservation, as reported by Lane *et al.* (2007). Most are from surveys conducted during the periods 1981-90 and 1998-2000. Eighty-six indigenous species have been recorded, plus domestic varieties of the Mallard *Anas platyrhynchos* and the Greylag Goose *Anser anser*.

The Wetlands

The Vasse-Wonnerup wetlands include the Vasse and Wonnerup "estuaries" (now lagoons) and their floodplains, Malbup Creek, Wonnerup Inlet, the Deadwater and the mouths of the Ludlow, Abba, Sabina and Vasse Rivers. The wetlands extend in a north-easterly direction from the check-board structure on the Vasse River at the Butter Factory Folk Museum, Busselton, to Forrest Beach Road near Ludlow - a distance of fourteen kilometres.

Most of the Vasse-Wonnerup wetland system was listed in 1990, and extended in 2000, as a Wetland of International Importance under the "Ramsar" Convention on Wetlands. Australia has given undertakings to conserve its Ramsar-listed wetlands and to wisely manage wetlands generally.

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Lane, J.A.K., Hardcastle, K.A., Tregonning, R.J. & Holtfreter, G.J. (1997). *Management of the Vasse-Wonnerup wetland system in relation to sudden, mass fish deaths.* Report on behalf of the Vasse Estuary Technical Working Group, Busselton. 55pp.

Government of Western Australia (2000). *Wetlands nominated by the Government of Western Australia for inclusion on the List of Wetlands of International Importance, Ramsar Convention.* Nominating document prepared by WA Department of Conservation & Land Management, Perth. 48pp.

Lane J.A.K, Clarke A.G., Pearson G.B. & Winchcombe, Y.C. (2007). *Waterbirds of the Vasse-Wonnerup wetlands in 1998-2000, including Ramsar status and comparisons with earlier data.* Department of Environment & Conservation, Busselton. 51pp.

Information Sheets

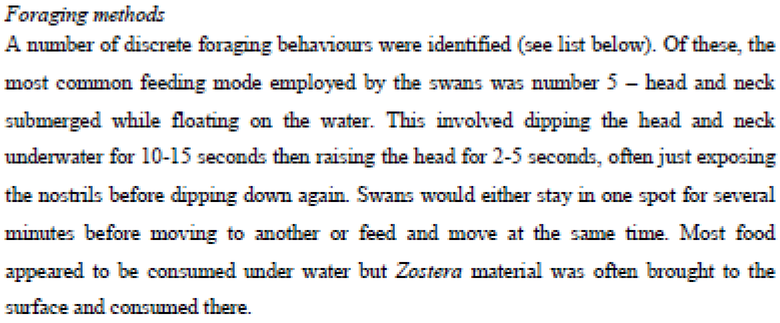
The following information sheets are also available.

- Where to Watch Waterbirds on the Vasse-Wonnerup Wetlands
- Monitoring conservation values of a Ramsar wetland: Vasse-Wonnerup wetlands system, Busselton
- Management of the Ramsar-listed Vasse-Wonnerup wetlands

Further information about the Vasse-Wonnerup wetlands may be obtained from the WA Department of Environment & Conservation, 14 Queen Street, Busselton WA 6280. Ph (08) 9752 5555. Fax (08) 9752 1432. Info sheet prepared by JLane in March 1997. Revised in May 1997 and April 2010.

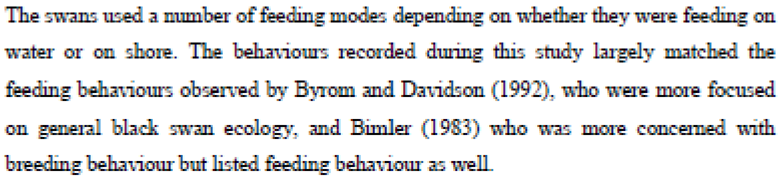
Appendix … Foraging depths of Dixon (2009).

Dixon, H.D.J. (2009). *Effect of black swan foraging on seagrass and benthic invertebrates in western Golden Bay.* Thesis presented in partial fulfilment of the requirements for Master of Science in Ecology, Massey University, Palmerston North, NZ.
https://muir.massey.ac.nz/bitstream/handle/10179/1214/02whole.pdf;jsessionid=10A2FB77CE73DC6006504092E55399F2?sequence=1

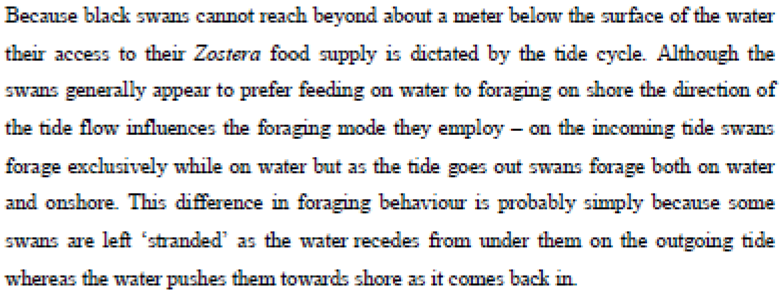


Foraging methods

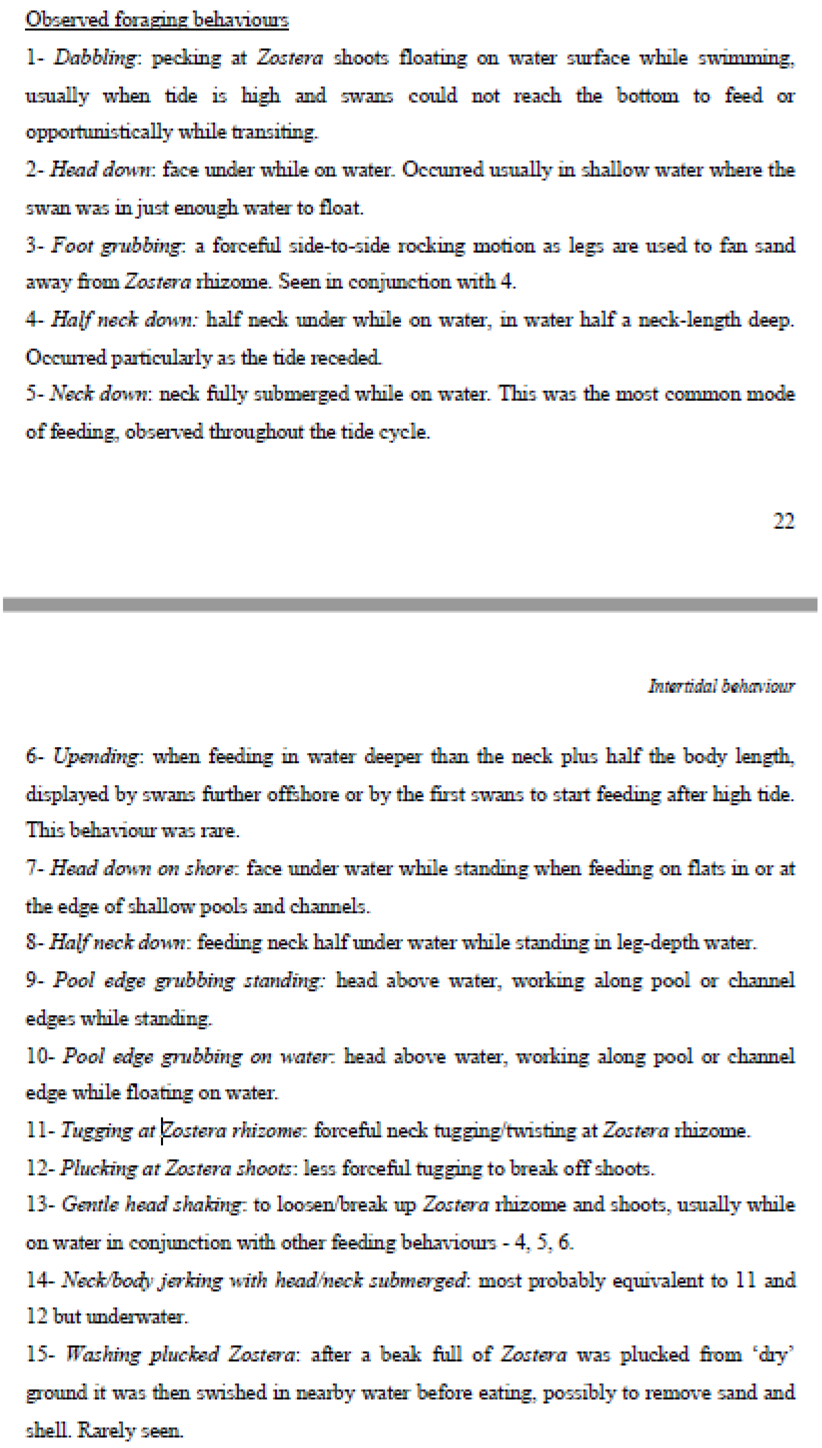
A number of discrete foraging behaviours were identified (see list below). Of these, the most common feeding mode employed by the swans was number 5 – head and neck submerged while floating on the water. This involved dipping the head and neck underwater for 10-15 seconds then raising the head for 2-5 seconds, often just exposing the nostrils before dipping down again. Swans would either stay in one spot for several minutes before moving to another or feed and move at the same time. Most food appeared to be consumed under water but *Zostera* material was often brought to the surface and consumed there.



The swans used a number of feeding modes depending on whether they were feeding on water or on shore. The behaviours recorded during this study largely matched the feeding behaviours observed by Byrom and Davidson (1992), who were more focused on general black swan ecology, and Bimler (1983) who was more concerned with breeding behaviour but listed feeding behaviour as well.



Because black swans cannot reach beyond about a meter below the surface of the water their access to their *Zostera* food supply is dictated by the tide cycle. Although the swans generally appear to prefer feeding on water to foraging on shore the direction of the tide flow influences the foraging mode they employ – on the incoming tide swans forage exclusively while on water but as the tide goes out swans forage both on water and onshore. This difference in foraging behaviour is probably simply because some swans are left ‘stranded’ as the water recedes from under them on the outgoing tide whereas the water pushes them towards shore as it comes back in.



Observed foraging behaviours

1- *Dabbling*: pecking at *Zostera* shoots floating on water surface while swimming, usually when tide is high and swans could not reach the bottom to feed or opportunistically while transiting.

2- *Head down*: face under while on water. Occurred usually in shallow water where the swan was in just enough water to float.

3- *Foot grubbing*: a forceful side-to-side rocking motion as legs are used to fan sand away from *Zostera* rhizome. Seen in conjunction with 4.

4- *Half neck down:* half neck under while on water, in water half a neck-length deep. Occurred particularly as the tide receded.

5- *Neck down*: neck fully submerged while on water. This was the most common mode of feeding, observed throughout the tide cycle.

6- *Upending*: when feeding in water deeper than the neck plus half the body length, displayed by swans further offshore or by the first swans to start feeding after high tide. This behaviour was rare.

7- *Head down on shore*: face under water while standing when feeding on flats in or at the edge of shallow pools and channels.

8- *Half neck down*: feeding neck half under water while standing in leg-depth water.

9- *Pool edge grubbing standing:* head above water, working along pool or channel edges while standing.

10- *Pool edge grubbing on water*: head above water, working along pool or channel edge while floating on water.

11- *Tugging at Zostera rhizome*: forceful neck tugging/twisting at *Zostera* rhizome.

12- *Plucking at Zostera shoots*: less forceful tugging to break off shoots.

13- *Gentle head shaking*: to loosen/break up *Zostera* rhizome and shoots, usually while on water in conjunction with other feeding behaviours - 4, 5, 6.

14- *Neck/body jerking with head/neck submerged*: most probably equivalent to 11 and 12 but underwater.

15- *Washing plucked Zostera*: after a beak full of *Zostera* was plucked from 'dry' ground it was then swished in nearby water before eating, possibly to remove sand and shell. Rarely seen.

Appendix … Measurements and foraging depths of Recher *et al.* (1983).

Recher, H.F., Homes, R.T., Davis, W.E. & Morton, S. (1983). *Foraging behaviour of Australian herons.* Colonial Waterbirds 6: 1-10.

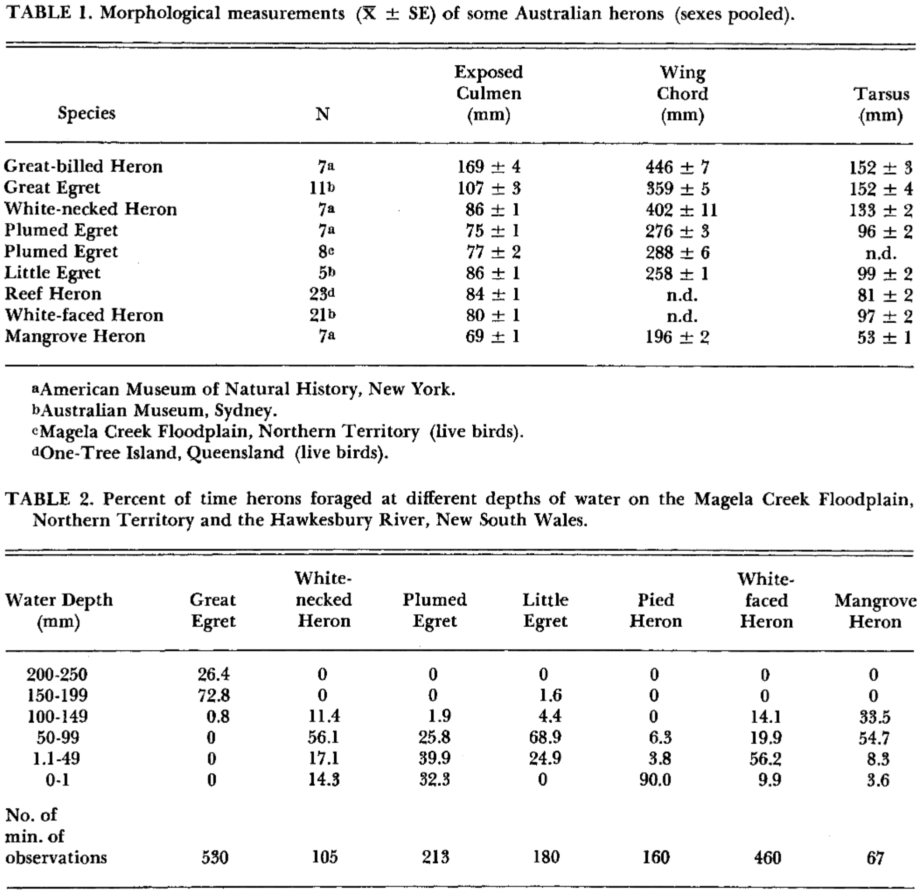


TABLE 1. Morphological measurements ($\bar{X}$ ± SE) of some Australian herons (sexes pooled).

Species	N	Exposed Culmen (mm)	Wing Chord (mm)	Tarsus (mm)
Great-billed Heron	7[a]	169 ± 4	446 ± 7	152 ± 3
Great Egret	11[b]	107 ± 3	359 ± 5	152 ± 4
White-necked Heron	7[a]	86 ± 1	402 ± 11	133 ± 2
Plumed Egret	7[a]	75 ± 1	276 ± 3	96 ± 2
Plumed Egret	8[c]	77 ± 2	288 ± 6	n.d.
Little Egret	5[b]	86 ± 1	258 ± 1	99 ± 2
Reef Heron	23[d]	84 ± 1	n.d.	81 ± 2
White-faced Heron	21[b]	80 ± 1	n.d.	97 ± 2
Mangrove Heron	7[a]	69 ± 1	196 ± 2	53 ± 1

[a] American Museum of Natural History, New York.
[b] Australian Museum, Sydney.
[c] Magela Creek Floodplain, Northern Territory (live birds).
[d] One-Tree Island, Queensland (live birds).

TABLE 2. Percent of time herons foraged at different depths of water on the Magela Creek Floodplain, Northern Territory and the Hawkesbury River, New South Wales.

Water Depth (mm)	Great Egret	White-necked Heron	Plumed Egret	Little Egret	Pied Heron	White-faced Heron	Mangrove Heron
200-250	26.4	0	0	0	0	0	0
150-199	72.8	0	0	1.6	0	0	0
100-149	0.8	11.4	1.9	4.4	0	14.1	33.5
50-99	0	56.1	25.8	68.9	6.3	19.9	54.7
1.1-49	0	17.1	39.9	24.9	3.8	56.2	8.3
0-1	0	14.3	32.3	0	90.0	9.9	3.6
No. of min. of observations	530	105	213	180	160	460	67

TABLE 4. Comparative foraging behavior of Australian herons.

Behavior	Brown Bittern	Black Bittern	Little Bittern	Nankeen Night-Heron	Mangrove Heron	Eastern Reef Heron	Plumed Egret	Little Egret	Great Egret	Cattle Egret	Pied Heron	White-faced Heron	White-necked Heron	Great-billed Heron
	3	1,3	3	6,3	1,2,3	4	6	6	6,3	6,3	6	3	6,3	3
Stand & Wait		1	8	6	1,2,8	4		6	6		6			
Crouch & Wait						4				6	6	1,2	6	
Gleaning	8,9	1		1	1	4	6	6	6,10	6	6	6,2	6	
Walk slowly (*upright*)		1		1	1,2,5	4					6	1,2		
Walk slowly (*crouched*)					2	4		1	1		1		1	
Scan					5	4		6	6	1	6	1,2	6	
Walk quickly						4		6,8				1,2		
Running						4								
Hopping						1	1	1		1	1			
Leapfrog Feeding								6				2		
Wing Flicking							6				6	2	6	
Peering														
Foot stirring						4	6	6,7 10,8			6	1,2,13 10		
Foot raking													9	
Foot paddling						4								
Hovering											11			
Dipping											11			
Foot dragging						4								
Plunging					2									
Diving					5	4								
Feet First diving				12	5									
Following large mammals								8		3,1	8			
Following other birds								1,7	1			2		
Following large fish						4		1						
Rob nests				8										
Piracy						4			1		9			
Feed at night	8	1,8	8	1,3	1,2	4								3
Feed during day		1,8		1,12	1,2	4	6	6	6	6	6	6,2	6	3

Source: (Key):
1. Personal observation (HFR).
2. Personal observation (WED).
3. Commonly reported behavior.
4. Recher & Recher 1972 & 1968b.
5. Hindwood 1933.
6. Recher & Holmes 1982.
7. Hobbs 1980.
8. Reader's Digest 1976.
9. Hancock & Elliott 1980.
10. Hobbs 1957.
11. Gochfeld 1976.
12. Hobbs 1956.
13. Lowe 1983.

Appendix … Measurements and foraging depths of Recher & Holmes (1982).

Recher, H.F. & Holmes, R.T. (1982). *The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory.* Supervising Scientist for the Alligator Rivers Region. Technical Memorandum 4.

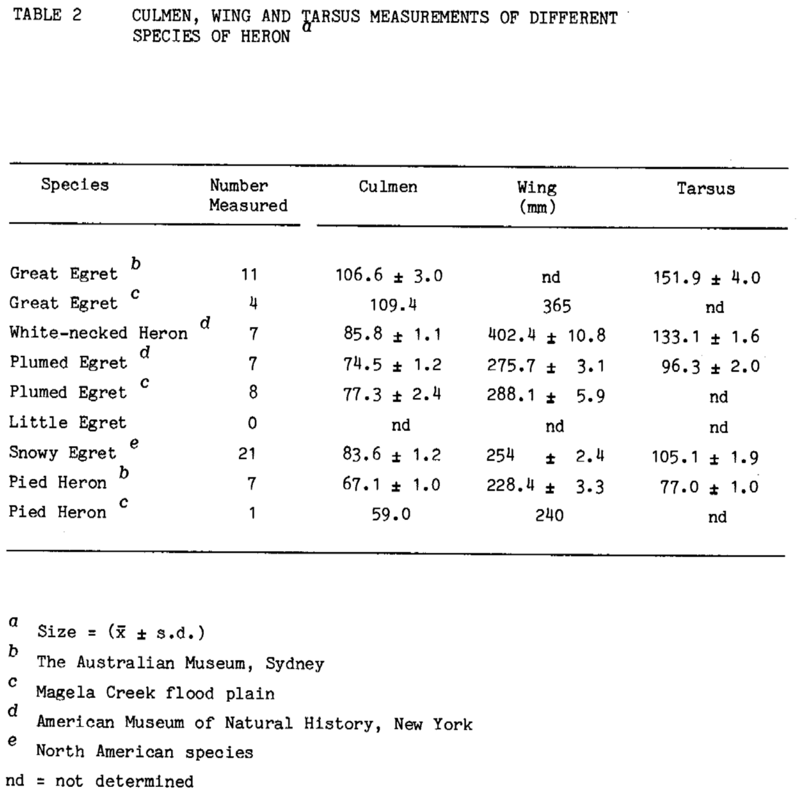


TABLE 2 CULMEN, WING AND TARSUS MEASUREMENTS OF DIFFERENT SPECIES OF HERON [a]

Species	Number Measured	Culmen	Wing (mm)	Tarsus
Great Egret [b]	11	106.6 ± 3.0	nd	151.9 ± 4.0
Great Egret [c]	4	109.4	365	nd
White-necked Heron [d]	7	85.8 ± 1.1	402.4 ± 10.8	133.1 ± 1.6
Plumed Egret [d]	7	74.5 ± 1.2	275.7 ± 3.1	96.3 ± 2.0
Plumed Egret [c]	8	77.3 ± 2.4	288.1 ± 5.9	nd
Little Egret	0	nd	nd	nd
Snowy Egret [e]	21	83.6 ± 1.2	254 ± 2.4	105.1 ± 1.9
Pied Heron [b]	7	67.1 ± 1.0	228.4 ± 3.3	77.0 ± 1.0
Pied Heron [c]	1	59.0	240	nd

[a] Size = ($\bar{x}$ ± s.d.)

[b] The Australian Museum, Sydney

[c] Magela Creek flood plain

[d] American Museum of Natural History, New York

[e] North American species

nd = not determined

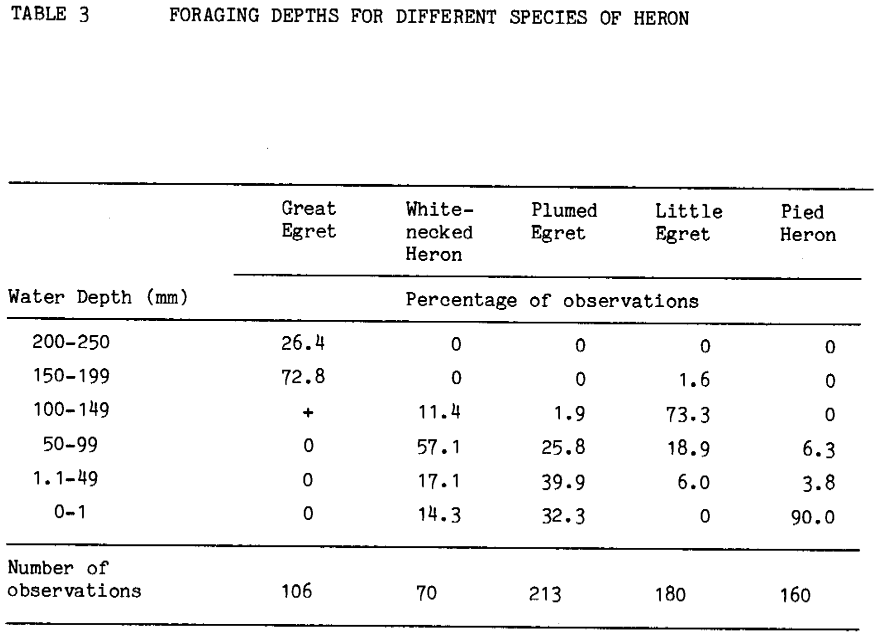


TABLE 3 FORAGING DEPTHS FOR DIFFERENT SPECIES OF HERON

	Great Egret	White-necked Heron	Plumed Egret	Little Egret	Pied Heron
Water Depth (mm)	Percentage of observations				
200-250	26.4	0	0	0	0
150-199	72.8	0	0	1.6	0
100-149	+	11.4	1.9	73.3	0
50-99	0	57.1	25.8	18.9	6.3
1.1-49	0	17.1	39.9	6.0	3.8
0-1	0	14.3	32.3	0	90.0
Number of observations	106	70	213	180	160

Appendix … Foraging depths of Paton *et al.* (2011).

Paton, D.C., Bailey, C.P & Northeast, P.J. (2011). *Waterbird responses to Goolwa Channel water-level management and Barrage releases, and developing habitat suitability models for waterbirds in the Coorong and Lower Lakes.* School of Earth and Environmental Sciences, University of Adelaide, South Australia. 34pp.

'In general most water birds species that wade are largely restricted to foraging in shallow water near the edge of the water, while those that swim or fly while foraging are not restricted and may avoid very shallow areas' (Paton *et al.* 2011, p29).

'**Table 8.** Water depths used for foraging by a range of waterbirds in the Coorong in January 2011. The percentage of birds foraging at different depths is provided. Water depths were determined by noting the extent to which the legs were covered with water (ankle to belly). Those relative measures will be converted to actual depths from measurements of the birds' legs in due course. Foraging above the water line is indicated as either foraging on damp substrates or dry substrates. Water depths cannot be determined for those species that swim or fly while foraging, but the approximate locations for these species can be estimated as a distance from the shoreline (see Table 9). Note that some species have limited data.'

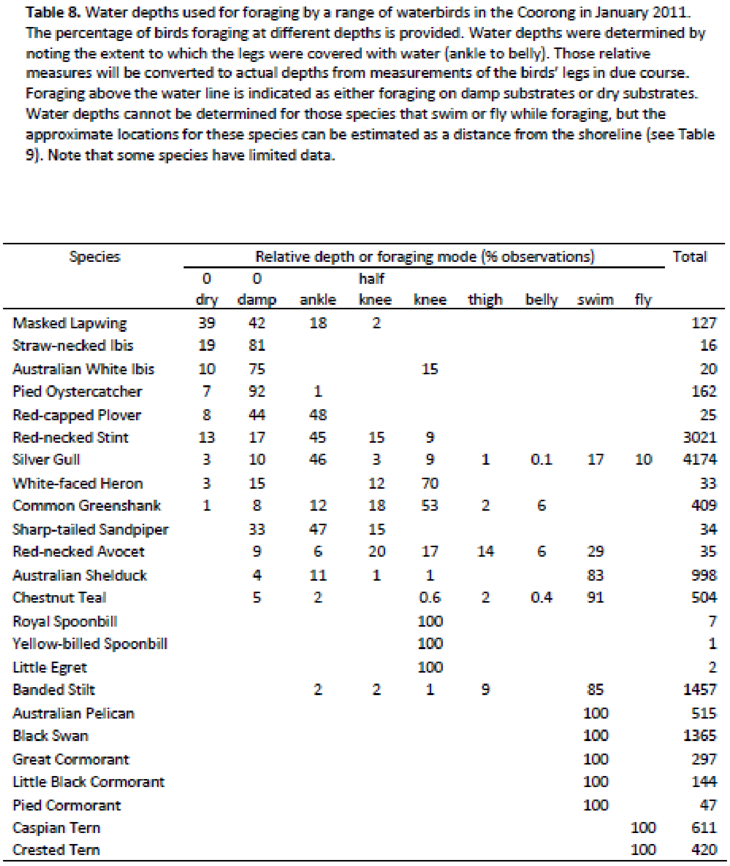


Table 8. Water depths used for foraging by a range of waterbirds in the Coorong in January 2011. The percentage of birds foraging at different depths is provided. Water depths were determined by noting the extent to which the legs were covered with water (ankle to belly). Those relative measures will be converted to actual depths from measurements of the birds' legs in due course. Foraging above the water line is indicated as either foraging on damp substrates or dry substrates. Water depths cannot be determined for those species that swim or fly while foraging, but the approximate locations for these species can be estimated as a distance from the shoreline (see Table 9). Note that some species have limited data.

Species	Relative depth or foraging mode (% observations)									Total
	0 dry	0 damp	ankle	half knee	knee	thigh	belly	swim	fly	
Masked Lapwing	39	42	18	2						127
Straw-necked Ibis	19	81								16
Australian White Ibis	10	75			15					20
Pied Oystercatcher	7	92	1							162
Red-capped Plover	8	44	48							25
Red-necked Stint	13	17	45	15	9					3021
Silver Gull	3	10	46	3	9	1	0.1	17	10	4174
White-faced Heron	3	15		12	70					33
Common Greenshank	1	8	12	18	53	2	6			409
Sharp-tailed Sandpiper		33	47	15						34
Red-necked Avocet		9	6	20	17	14	6	29		35
Australian Shelduck		4	11	1	1			83		998
Chestnut Teal		5	2		0.6	2	0.4	91		504
Royal Spoonbill					100					7
Yellow-billed Spoonbill					100					1
Little Egret					100					2
Banded Stilt			2	2	1	9		85		1457
Australian Pelican								100		515
Black Swan								100		1365
Great Cormorant								100		297
Little Black Cormorant								100		144
Pied Cormorant								100		47
Caspian Tern									100	611
Crested Tern									100	420

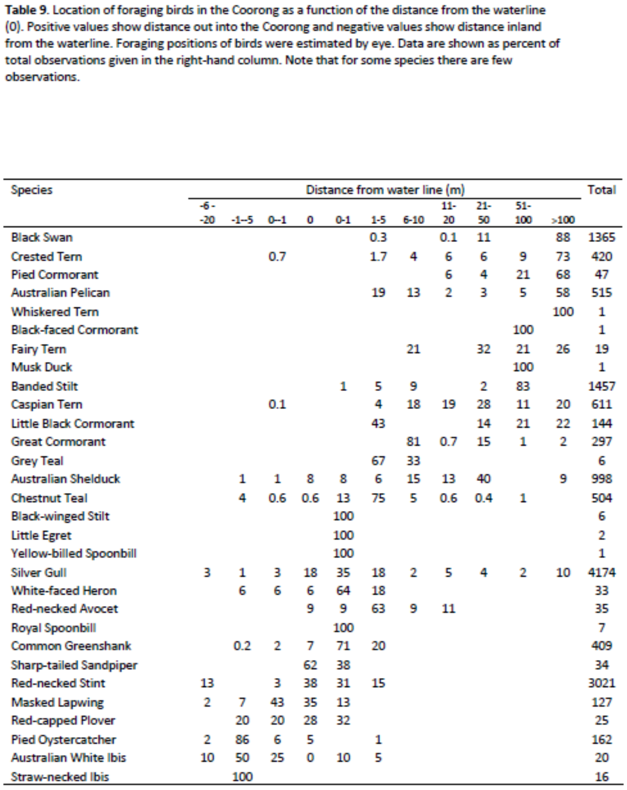


Table 9. Location of foraging birds in the Coorong as a function of the distance from the waterline (0). Positive values show distance out into the Coorong and negative values show distance inland from the waterline. Foraging positions of birds were estimated by eye. Data are shown as percent of total observations given in the right-hand column. Note that for some species there are few observations.

Species	Distance from water line (m)											Total
	-6 - -20	-1--5	0--1	0	0-1	1-5	6-10	11-20	21-50	51-100	>100	
Black Swan						0.3		0.1	11		88	1365
Crested Tern			0.7			1.7	4	6	6	9	73	420
Pied Cormorant								6	4	21	68	47
Australian Pelican						19	13	2	3	5	58	515
Whiskered Tern											100	1
Black-faced Cormorant										100		1
Fairy Tern							21		32	21	26	19
Musk Duck										100		1
Banded Stilt					1	5	9		2	83		1457
Caspian Tern			0.1			4	18	19	28	11	20	611
Little Black Cormorant						43			14	21	22	144
Great Cormorant							81	0.7	15	1	2	297
Grey Teal						67	33					6
Australian Shelduck		1	1	8	8	6	15	13	40		9	998
Chestnut Teal		4	0.6	0.6	13	75	5	0.6	0.4	1		504
Black-winged Stilt					100							6
Little Egret					100							2
Yellow-billed Spoonbill					100							1
Silver Gull	3	1	3	18	35	18	2	5	4	2	10	4174
White-faced Heron		6	6	6	64	18						33
Red-necked Avocet				9	9	63	9	11				35
Royal Spoonbill					100							7
Common Greenshank		0.2	2	7	71	20						409
Sharp-tailed Sandpiper				62	38							34
Red-necked Stint	13		3	38	31	15						3021
Masked Lapwing	2	7	43	35	13							127
Red-capped Plover		20	20	28	32							25
Pied Oystercatcher	2	86	6	5		1						162
Australian White Ibis	10	50	25	0	10	5						20
Straw-necked Ibis		100										16

Appendix … Foraging depths of Helmers (1992).

Helmers, D. L. (1992). *Shorebird Management Manual.* Western Hemisphere Shorebird Reserve Network. Manomet, MA. 58pp.

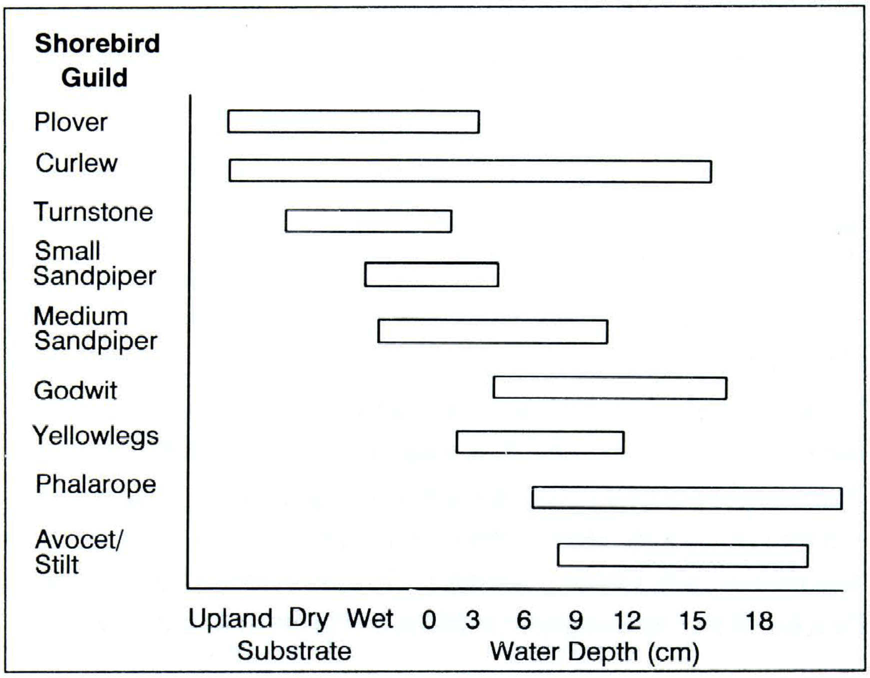


Figure 2.4 *Water depth (cm) and substrate preferences of shorebird foraging guilds.*

Appendix … Foraging depths of Velasquez & Navarro (1993).

Velasquez, C.R. & Navarro, R.A (1993). *The influence of water depth and sediment type on the foraging behaviour of whimbrels.* Journal of Field Ornithology 64(2): 149-157.

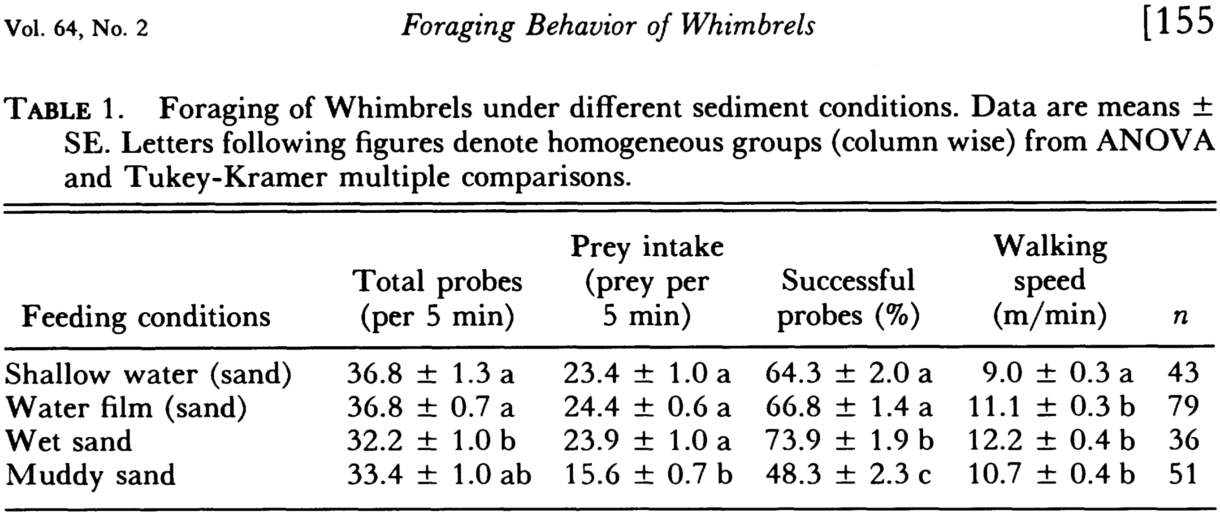


TABLE 1. Foraging of Whimbrels under different sediment conditions. Data are means ± SE. Letters following figures denote homogeneous groups (column wise) from ANOVA and Tukey-Kramer multiple comparisons.

Feeding conditions	Total probes (per 5 min)	Prey intake (prey per 5 min)	Successful probes (%)	Walking speed (m/min)	*n*
Shallow water (sand)	36.8 ± 1.3 a	23.4 ± 1.0 a	64.3 ± 2.0 a	9.0 ± 0.3 a	43
Water film (sand)	36.8 ± 0.7 a	24.4 ± 0.6 a	66.8 ± 1.4 a	11.1 ± 0.3 b	79
Wet sand	32.2 ± 1.0 b	23.9 ± 1.0 a	73.9 ± 1.9 b	12.2 ± 0.4 b	36
Muddy sand	33.4 ± 1.0 ab	15.6 ± 0.7 b	48.3 ± 2.3 c	10.7 ± 0.4 b	51

Appendix … Foraging depths of Boettcher *et al.* (1995).

Boettcher, R., Haig, S.M & Bridges, W.C. (1995). *Habitat-related factors affecting the distribution of nonbreeding American Avocets [Recurvirostra Americana] in coastal South Carolina.* Condor 97(1): 68-81.

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TABLE 2. Categorization of habitat variables.

Variable	Range	Classes
Salinity (ppt)	≤10	Low
	11–20	Medium
	>20	High
% Exposed mudflat	Deep water	Flood
	0–30	≤30%
	40–70	40–70%
	80–100	>70%
Mean ind. water depth (cm)	0	No water
	1–5	Above foot to mid-tarsometatarsus
	5–10	Mid-tarsometatarsus to tibiotarsus
	10–13.5	Tibiotarsus to mid-tibia
	13.5–17	Mid-tibia to belly
	>17	> belly deep
DVIWL (cm)[a]	0	none
	1–5	Small Increase
	6–10	Large Increase
	−1–−5	Small Decrease
	−6–−10	Large Decrease

[a] Daily variation in impoundment water levels.

'*Mean individual water depth (*MIWD; 1992 only) is the daily average water depth of areas in sections where avocets were observed; it does not reflect conditions in areas where they did not occur. The purpose of this measure was to determine whether avocets, when presented with a wide range of water depths, occurred in similar depths over time. With IWD data, the following categories were created based on measurements from museum skins: (1) bottom of foot to top of foot (1 cm); (2) tarsometatarsus length (bottom of foot to tibiotarsus; 10 cm); and (3) tibia length (tibiotarsus to belly; 7 cm). MIWD was calculated by dividing the sum of daily numeric IWDs by the corresponding number of avocets in each section. This yielded a large continuum of values across sections and days that was divided into six classes.'

'During both years, mean individual water depth (MIWD) had a significant effect (1991: $P < 0.0001$, 1992: $P < 0.0001$) on the distribution of birds among sections; at least 75% were observed in sections with water 10-17 cm deep (Fig. 2B)'.

HABITAT SELECTION IN NONBREEDING AMERICAN AVOCETS 75

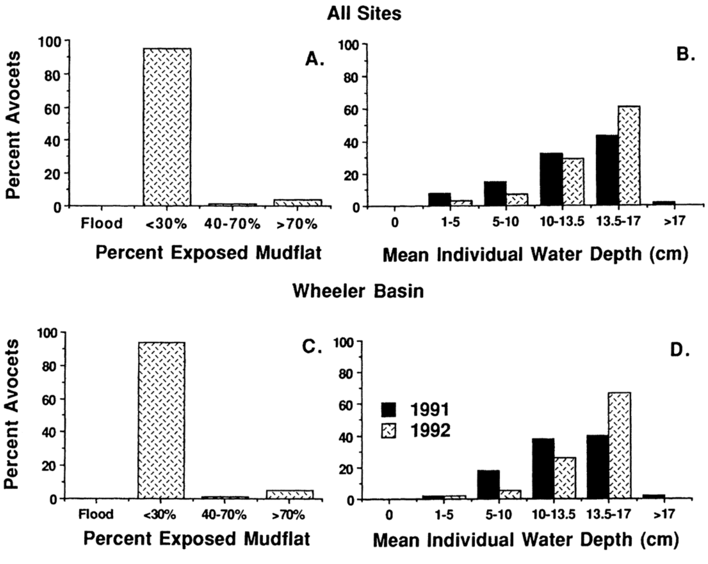


FIGURE 2. Percentage of avocets among classes of percent exposed mudflat and mean individual water depth across all sites (A) and (B) and at Wheeler Basin (C) and (D) on South Island, SC.

Appendix … Sherry (2006).

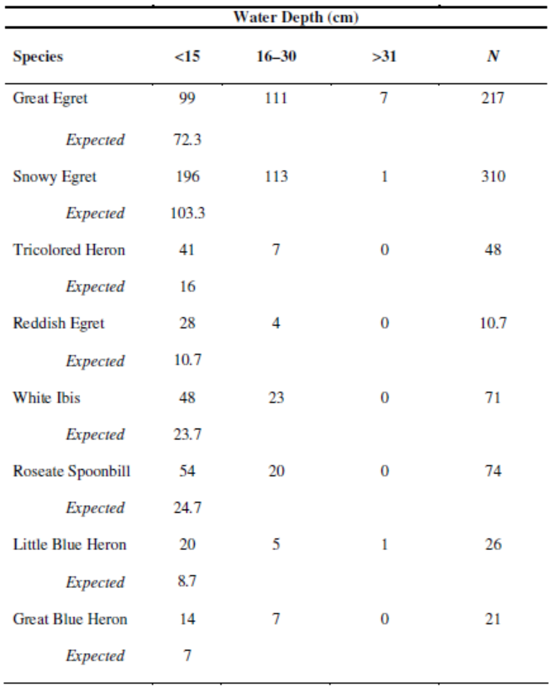
Sherry, D.A. (2006). *Foraging ecology of wintering wading birds along the Gulf of Mexico coast.* Dissertation submitted to Texas A&M University in partial fulfillment for degree of Doctor of Philosophy, December 2006.

'**Great Egrets [Ardea alba]** occurred most often in the 16-30 cm water depths and to a lesser extent in the <15 cm (*D* = -71.3, *p* < 0.001), whereas Snowy Egrets showed just the opposite pattern (*D* = –102.3, *p* < 0.001) (Fig.4.27 A, B).' [at *MATAGORDA ISLAND NATIONAL WILDLIFE REFUGE;*

'Likewise, **White Ibises** (**Eudocimus albus)** (D = –22.6, p < 0.001) and Roseate Spoonbills (D = –23.6, p < 0.001) also used water depths less than 15 cm more often than expected (Fig. 4. 29 A, B).'

PROBLEM: SEE PAGE 129 OF THIS THESIS.

Table 4.5. Number of wading bird species observed and expected in different microhabitat categories (water depth cm) in Texas coastal salt marsh MINWR during 1997-2000 fall and winter. Expected frequencies shown here are for Kolmogorov goodness-of-fit tests for each species separately, based on the assumption that all habitat categories were equally accessible.



	Water Depth (cm)			
Species	<15	16–30	>31	*N*
Great Egret	99	111	7	217
Expected	72.3			
Snowy Egret	196	113	1	310
Expected	103.3			
Tricolored Heron	41	7	0	48
Expected	16			
Reddish Egret	28	4	0	10.7
Expected	10.7			
White Ibis	48	23	0	71
Expected	23.7			
Roseate Spoonbill	54	20	0	74
Expected	24.7			
Little Blue Heron	20	5	1	26
Expected	8.7			
Great Blue Heron	14	7	0	21
Expected	7			

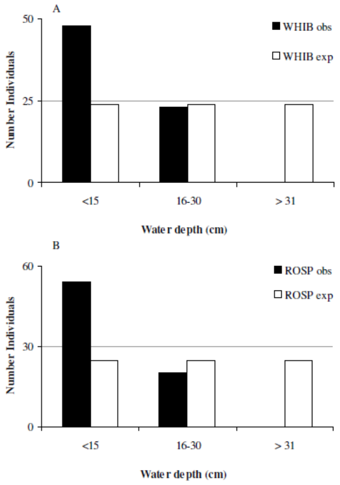


Figure 4.29. A) Patterns of microhabitat use by White Ibises and B) by Roseate Spoonbills at MINWR, Texas during 1997-2000 fall and winter. White bars represent number of individuals expected and black bars indicate number of individuals observed.

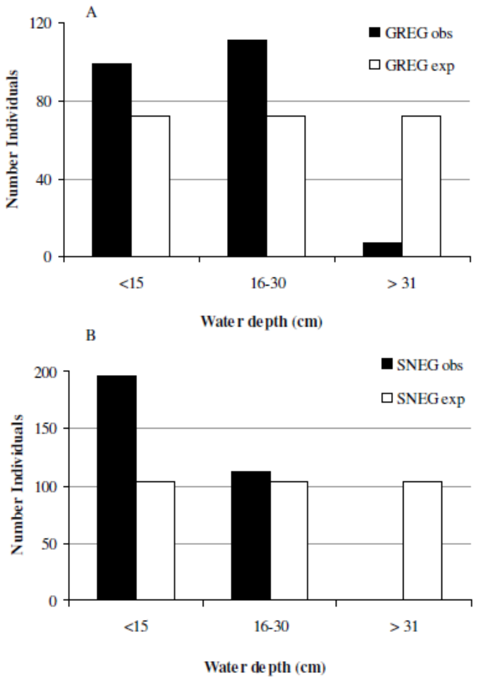


Figure 4.27. A) Patterns of microhabitat use by Great Egrets and B) by Snowy Egrets at MINWR, Texas during 1997-2000 fall and winter. White bars represent number of individuals expected and black bars indicate number of individuals observed.

Appendix … Spencer (2010).

Spencer, J. (2010). *Migratory shorebird ecology in the Hunter estuary, south-eastern Australia* (Doctoral thesis, Australian Catholic University). Retrieved from http://researchbank.acu.edu.au/theses/306

‘Small-scale differences in shorebird species distribution are usually related to their leg and bill length, as prey availability is determined by the depth to which a bird can wade and the maximum depth a bird can insert its bill into the sediment (Dann 1987). As a result, species are often segregated in their feeding habitats according to their preferences for water depth and sediment penetrability (Dann 1981b).’

‘Generally, shorebird species are uncomfortable in water deeper than their upper thigh and will move to higher grounds (Ntiamoa-Baidu *et al*. 1998).’

‘Wetland availability on Ash Island is driven by fortnightly spring tidal cycles, local rainfall and evaporation (Howe 2008), which affect the distribution of shorebirds as they generally prefer habitats with shallow water or wet substrates not deeper than their thigh (Dann 1987; Skagen & Knopf 1994; Parsons 2002) (see Table 4.1).’

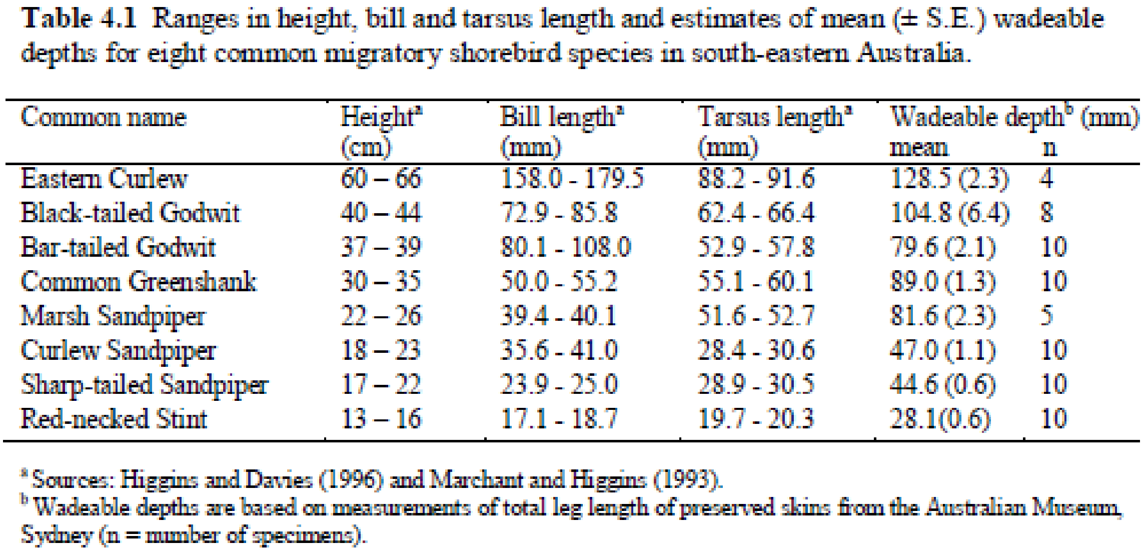


Table 4.1 Ranges in height, bill and tarsus length and estimates of mean (± S.E.) wadeable depths for eight common migratory shorebird species in south-eastern Australia.

Common name	Height[a] (cm)	Bill length[a] (mm)	Tarsus length[a] (mm)	Wadeable depth[b] (mm) mean	n
Eastern Curlew	60 – 66	158.0 - 179.5	88.2 - 91.6	128.5 (2.3)	4
Black-tailed Godwit	40 – 44	72.9 - 85.8	62.4 - 66.4	104.8 (6.4)	8
Bar-tailed Godwit	37 – 39	80.1 - 108.0	52.9 - 57.8	79.6 (2.1)	10
Common Greenshank	30 – 35	50.0 - 55.2	55.1 - 60.1	89.0 (1.3)	10
Marsh Sandpiper	22 – 26	39.4 - 40.1	51.6 - 52.7	81.6 (2.3)	5
Curlew Sandpiper	18 – 23	35.6 - 41.0	28.4 - 30.6	47.0 (1.1)	10
Sharp-tailed Sandpiper	17 – 22	23.9 - 25.0	28.9 - 30.5	44.6 (0.6)	10
Red-necked Stint	13 – 16	17.1 - 18.7	19.7 - 20.3	28.1(0.6)	10

[a] Sources: Higgins and Davies (1996) and Marchant and Higgins (1993).
[b] Wadeable depths are based on measurements of total leg length of preserved skins from the Australian Museum, Sydney (n = number of specimens).

‘Foraging efficiency can also be influenced by leg length (maximum ‘wadeable depth’) (see Table 4.1)…’

‘Availability of prey is often determined by the maximum depth at which a shorebird can insert its bill into the substrate and maximum leg length (Dann 1987).’

‘Water depth in saltmarsh habitats is most critical in determining prey availability to shorebird species. The amount of bare substrate or shallow water available is a function of factors such as; water level, topography, water manipulation, local rainfall, soil type and wind action (Skagen & Knopf 1994).’

Appendix … Dann, P. (1999). ***Foraging behaviour and diets of red-necked stints and curlew sandpipers in south- eastern Australia.*** **Wildlife Research 27: 61-68.**

‘Diet and feeding behaviour of red-necked stints (*Calidris ruficollis*) and curlew sandpipers (*Calidris ferruginea*) feeding in mixed flocks during the non-breeding season were investigated [between December 1978 and February 1980] in Western Port in Victoria, south-eastern Australia.’

‘The preferred feeding zone for red-necked stints was wet mud (86%) and for curlew sandpipers was shallow water (40%)’.

‘Stints were never observed to submerge their heads, and their bills were usually held slightly open while searching for food’.

‘The bill [of Curlew Sandpipers] was slightly open while probing and the head was often submerged.’

‘Red-necked stints preferred the wet mud zone (86%, *n* = 3720) whereas curlew sandpipers preferred shallow water (40%, *n* = 2105). Also, more curlew sandpipers fed at the water's edge and in deep water than was expected from a random distribution (Fig. 2).’

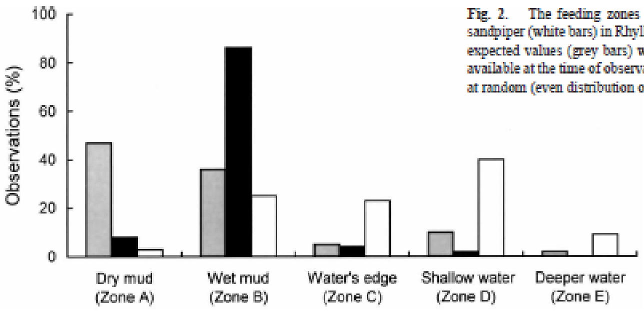


Fig. 2. The feeding zones of red-necked stint (black bars) and curlew sandpiper (white bars) in Rhyll Inlet for one hour either side of low tide. The expected values (grey bars) were determined from the areas of each zone available at the time of observation and are those predicted for birds feeding at random (even distribution over the available areas).

‘The details of feeding zones of both species in strong winds (>15 knots) were not significantly different from each other but were significantly different to the distributions otherwise recorded for either species (Fig.3).’

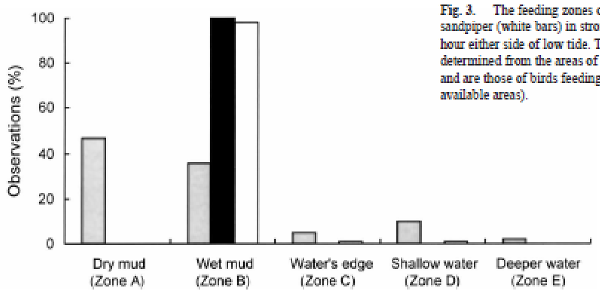


Fig. 3. The feeding zones of red-necked stint (black bars) and curlew sandpiper (white bars) in strong winds (>15 knots) in Rhyll Inlet for one hour either side of low tide. The expected values (grey bars) were determined from the areas of each zone available at the time of observation and are those of birds feeding at random (even distribution over the available areas).

Figure 5. Only the feeding zone (and substrate depth penetration) parameters are reproduced here.

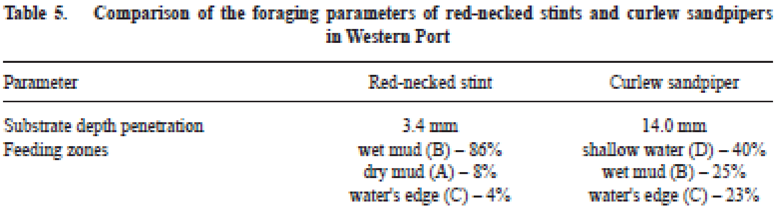


Table 5. Comparison of the foraging parameters of red-necked stints and curlew sandpipers in Western Port

Parameter	Red-necked stint	Curlew sandpiper
Substrate depth penetration	3.4 mm	14.0 mm
Feeding zones	wet mud (B) – 86% dry mud (A) – 8% water's edge (C) – 4%	shallow water (D) – 40% wet mud (B) – 25% water's edge (C) – 23%

Appendix … Thomas & Dartnall (1971).

Thomas, D.G. & Dartnall, A.J. (1971). *Ecological aspects of the feeding behaviour of two calidritine sandpipers [Red-necked Stint and Curlew Sandpiper] wintering in south-eastern Tasmania*. Emu 71(1): 20-26.

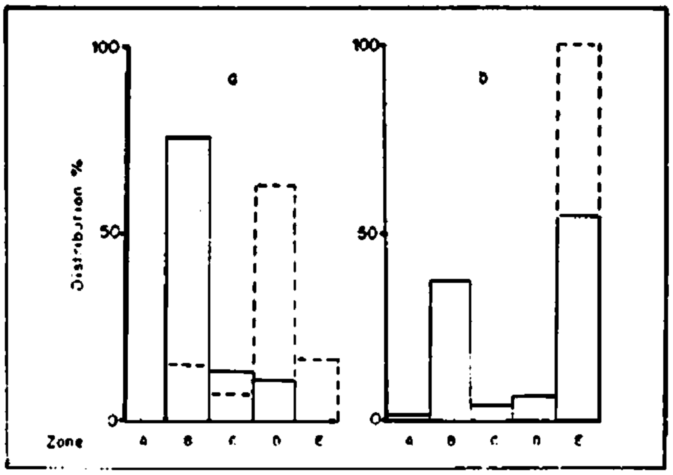


Figure 1. Foraging distribution of *C. ferruginea* (broken line) and *C. ruficollis* (unbroken line); (a) tidal areas, (b) non-tidal areas. No. of observations: (a) *ferruginea* 735, *ruficollis* 844; (b) *ferruginea* 90, *ruficollis* 781.

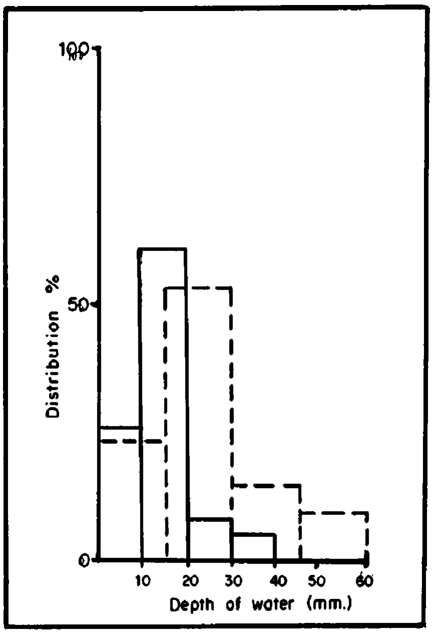


Figure 3. Foraging distribution of *C. ferruginea* (broken line) and *C. ruficollis* (unbroken line) in non-tidal areas according to depth of water.

'Five separate horizontal zones can be recognized in a tidal habitat (Recher 1966):

- *Zone A,* areas of sand and mud above the water's edge not retaining a surface film of water;
- *Zone B,* areas of sand and mud above the water's edge retaining a surface film of water;
- *Zone* C, the water's edge;
- *Zone D,* the area between the water's edge and a line 0.3 m beyond and parallel to the water's edge; and
- *Zone E,* the area beyond Zone D'.

'Similar zones can be recognized in non-tidal areas where Zone A corresponds to areas of dry mud and Zone B to areas of wet mud, with Zones C, D and E as for tidal areas. The distinction between Zones D and E is arbitrary, but has been retained here because it provides a useful measure of distributional differences. The foraging distributions of Curlew Sandpipers and Red-necked Stints are shown in Figure 1a for tidal areas during the early stages (0 – c.30% fall) of the ebb and in Figure 1b for non-tidal areas. Figure 1 is the sum of observations made on many occasions and is restricted to times when both species were present.'

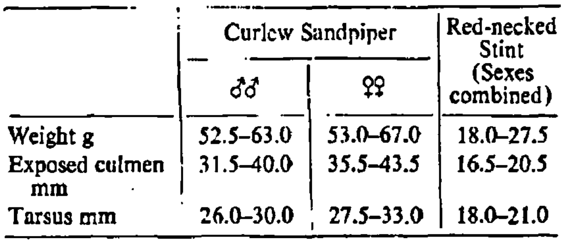
'The data for non-tidal areas were taken at a lagoon completely dependent on rainfall, which was full initially but dried out. Observations stopped when Zone E was no longer present. The lagoon is shallow with a depth of 25 mm when half-full, and when full still has large areas where the depth is less than this. Curlew Sandpipers always foraged in the deeper water. whereas Red-necked Stints foraged mostly over wet mud (Zone B) and while wading in Zone E (Fig. 1b). When the depth of water changes gradually, the arbitrary division of the area below the water's edge into Zones D and E is least satisfactory. A better measure is the depth of water in which the birds forage. Four divisions were recognized:

- less than half the tarsus immersed; [Stint < 0.5x(18.0+21.0)/2; Sandpiper < 0.5x((26.0+30.0)/2 + (27.5+33.0)/2))/2
- more than half the tarsus but none of the tibia immersed; [Stint > 0.5x(18.0+21.0)/2 and < (18.0+21.0)/2]; Sandpiper …
- all the tarsus and less than half the tibia immersed; [Stint > (18.0+21.0)/2 and < 1.5x(18.2+21.0)/2; Sandpiper …
- more than half the tibia immersed. [Stint > 1.5x(18.2+21.0)/2; Sandpiper …

Estimates were made when the unbent leg was vertical. It was assumed that the length of the tarsus was half the total length of the leg [tarsus + tibia], and wading depths were obtained from measurements of the tarsus made during this work (Table IV). As shown in Figure 3, Curlew Sandpipers forage in deeper water.

TABLE IV

Measurements of Curlew Sandpipers and Red-necked Stints



	Curlew Sandpiper		Red-necked Stint (Sexes combined)
	♂♂	♀♀	
Weight g	52.5–63.0	53.0–67.0	18.0–27.5
Exposed culmen mm	31.5–40.0	35.5–43.5	16.5–20.5
Tarsus mm	26.0–30.0	27.5–33.0	18.0–21.0

‘The data presented above support Cody's (1968) view that birds are largely opportunistic feeders and will eat all suitable items as they are encountered. Perhaps for the Curlew Sandpiper and Red-necked Stint ‘suitable’ should be interpreted as ‘within a given size range’. The differences in diet (Tables I and II) probably arise because each species encounters the different food-items in different proportions, a difference that will be enhanced by the different foraging methods’.

‘Curlew Sandpipers usually forage below the water's edge, and Red-necked Stints usually above it (Figs 1 and 2).’

Appendix … Baker (1979).

Baker, M.C. (1979). *Morphological correlates of habitat selection in a community of shorebirds (Charadriiformes).* Oikos 33: 121-126.

‘Habitat selection by six species of shorebirds (Least Sandpiper, Semipalmated Sandpiper, Dunlin, Short-billed Dowitcher, Lesser Yellowlegs, and Semipalmated Plover) was studied on [northern hemisphere] wintering and breeding ranges.’

‘Populations of Least Sandpiper *Calidris minutilla, S*emipalmated Sandpiper C. *pusilla,* Dunlin C. *alpina,* Short-billed Dowitcher *Limnodromus griseus,* Lesser Yellowlegs *Tringa flavipes,* and Semipalmated Plover *Charadrius semipalmatus* were studied in winter 1968-69 on coastal habitats in the Everglades National Park near Flamingo, Monroe Co., Florida. Summer observations were made on the breeding grounds near Churchill, Manitoba, during the months of June, July, and August 1968-69.

‘Tarsal length is correlated with water depth, with a stronger correlation in winter than in summer (Fig. 5).’ [Note that it is not possible to determine from this paper which data point in Fig. 5 corresponds with which species].

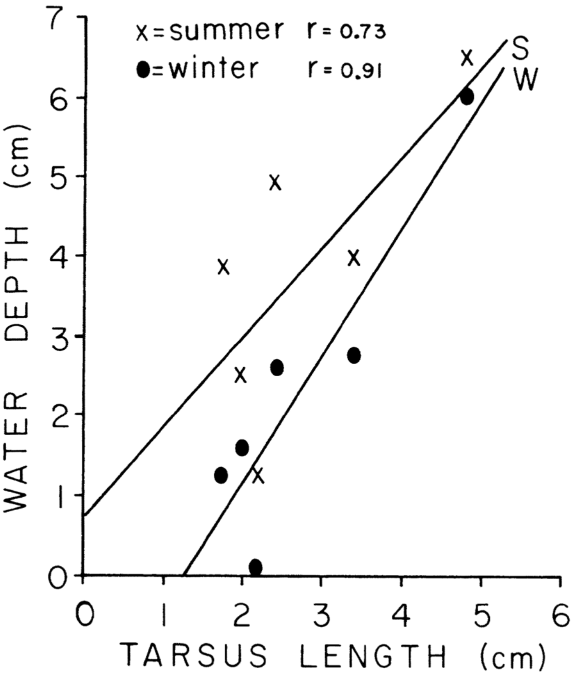


Fig. 5. Relationship of water depth along the feeding transect and tarsal length for six species of shorebirds in the breeding and wintering habitats.

Appendix … Bolduc & Afton (2008).

Bolduc, F. & Afton, A.D. (2008). *Monitoring waterbird abundance in wetlands: The importance of controlling results for variation in water depth.* Ecological Modelling 216: 402-408.

‘To illustrate our methodology, we created hypothetical survey data for two waterbird species that differed in their water depth and wetland selection. Species G (i.e., a generalist species) uses a large range of water depths and its abundance is maximized at a water depth of 15 cm. Species S (i.e., a specialist species) uses a narrow range of water depths and its abundance is maximized at a water depth of 5 cm. We built a curve of maximum abundance by 1-cm water depth classes for depths between 0 and 40 cm for each species, to compute hypothetical bird counts using the following equations: …’

Appendix … Ntiamoa-Baidu *et al.* (1998).

Ntiamoa-Baidu, Y., Piersma, T., Wiersma, P., Poot, M., Battley, P. & Gordon, C. (1998). *Water depth selection, daily feeding routines and diets of waterbirds in coastal lagoons in Ghana*. Ibis 140: 89–103.

'… waterbirds using two brackish water lagoon systems in coastal Ghana, the Songor and Keta Lagoons'. '… examined during October-November 1994'.

'The depth of water selected by waterbirds for foraging (but not for roosting) was correlated with tarsus length'.

'Water depth appears to be the key environmental factor controlling the availability of food for the waterbirds in the Ghanaian lagoons.'

'The key factors which influence habitat selection by mi grant waterbirds during the nonbreeding season are availability of food, safe roosting sites and the extent of disturbance (Hochbaum 1955, Myers 1984, Van Eerden 1984, Ens *et al.* 1990, 1994, Piersma 1994).'

'We believe that the detailed quantification of the ecological requirements of waterbird species, linked with appropriate descriptions of relevant ecological parameters, can be used profitably for large- scale assessments and monitoring of the ecological value of the wetlands to guide conservation and management activities.'

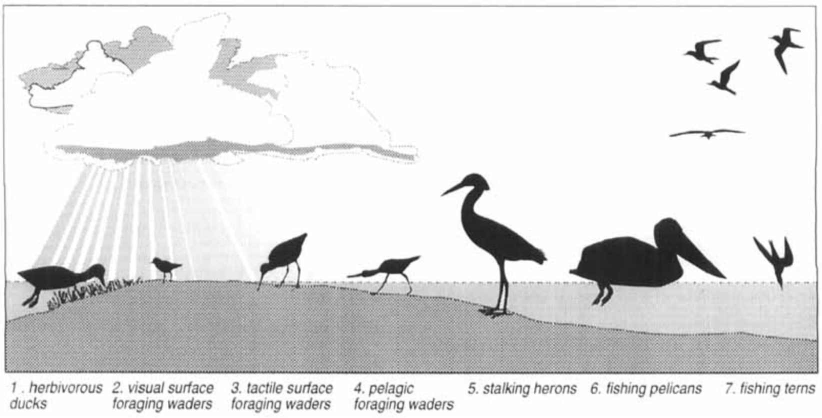


Figure 2. Pictorial representation of the seven waterbird guilds using the coastal lagoons of Ghana. See text for explanations

Table 1. *Body mass and leg lengths (as used in this study) of the different waterbird species that foraged upright in shallow water of the Keta and Songor Lagoons*

Species	Body mass (g)	Exposed leg length (mm)
Kittlitz's Plover	30	30
White-fronted Plover	45	31
Ringed Plover	50	35
Grey Plover	250	71
Common Sandpiper	55	31
Whimbrel	300	86
Turnstone	100	34
Wood Sandpiper	60	46
Redshank	105	68
Black-tailed Godwit	210	123
Bar-tailed Godwit	250	84
Curlew	800	111
Knot	120	42
Sanderling	55	33
Little Stint	25	33
Curlew Sandpiper	65	45
Marsh Sandpiper	70	75
Spotted Redshank	140	86
Black-winged Stilt	200	174
Avocet	260	143
Little Egret	500	135
Reef Heron	500	135
Grey Heron	1350	208

'The water depth in all the study areas was less than 40 cm, water temperatures ranged from a minimum of 22°C at night to 34°C in the afternoon and the salinities were high in all areas (40-100 ppt) except an area of seepage water at Totokpoe which was 27 ppt.'

'For each species in a flock, water depth was estimated from the level of water relative to exposed vertical leg length (in 0.1 intervals on a scale of 0.0-1.0, and 1.0 when birds were standing belly deep in water). These relative leg lengths were converted to depth from scale drawings or from photographs of the birds concerned. Table 1 summarizes the lengths of legs used in this study.'

'Figure 3 shows the ranges of water depth selected by foraging birds belonging to different guilds. Feeding habitats varied from dry mudflats to wet mud and shallow water of no more than 20 cm. Small waders, e.g. Ringed Plover, Sanderling and Little Stint, foraged on the dry banks, wet mud and water which was less than 3 cm deep; medium sized waders such as Black-winged Stilt, Greenshank and Bar-tailed Godwit required water depths up to 10 cm for feeding, while the relatively big egrets and herons fed in water up to 17 cm deep'.

'The choice of feeding habitats depended on food availability because the birds were not observed to feed in areas which were flooded a few days previously and were devoid of prey items. The depth of water selected for foraging was significantly correlated with the tarsus length of the bird ($r^2_{20} = 0.82$, $P < 0.001$; Fig. 4).'

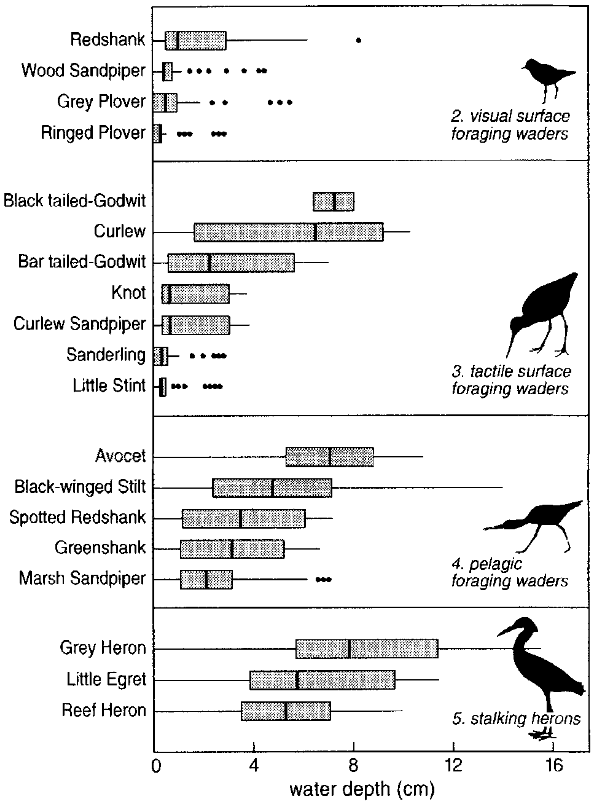


Figure 3. Water depths selected by foraging waterbird species representative of four of the seven waterbird guilds in Songor and Keta Lagoons in October–November 1994. The data are presented as box-plots, giving the median, the two central quartiles and the range (plus outliers indicated with dots) of water depth values estimated from exposed leg length. Sample sizes are presented in Table 3.

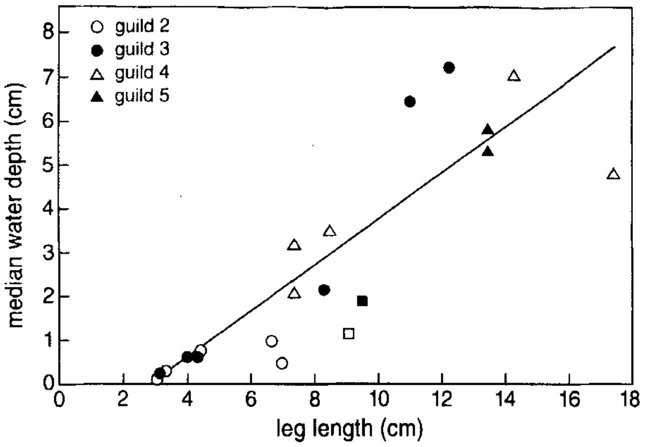


Figure 4. Water depths selected by foraging waterbirds as a function of exposed leg length in the different species. Details of the regression line are given in the text.

Water depth selection and management of the lagoons

'The choice of feeding habitats varied within and between the guilds and was mainly dependent on two factors: (1) the size of the bird (more specifically, the leg length and height above the ground) and (2) food availability. Water depth is considered to be a key environmental factor controlling the availability of food for the birds in the Ghanaian lagoons. Changes in the lagoon water depth which result directly from rainfall (leading to increases) and evapotranspiration (leading to decreasing depth) influence the salinity and temperature, which in turn affect survival of the prey organisms living in the lagoon. All ground-feeding waterbird guilds, representing the majority of waterbirds feeding in the lagoons, require very shallow water (no deeper than 20 cm). At the high water levels brought about by freshwater input from the catchment, many of the food resources present in the lagoons are no longer available. The length of time for which the water has been at the right depth is also relevant. Thus, the deeper areas of the lagoon and recently flooded areas devoid of prey items were not used by the birds. As the water receded, both fish and invertebrate prey became available for the birds. Surface-foraging waders such as Sanderling and Ringed Plover could obtain their prey only when the water depth was very low and the mudflats were exposed, as happened at the edges of the lagoon. When the lagoons dried up, as large sections did in the dry season, the fish, invertebrates and seeds stranded on the surface of the drying mud could be used for some time by surface foraging waders, but this is likely to be for only a short period. Periodic inundation and drying of large areas of the water body is a regular seasonal feature of both Songor and Keta Lagoons. Neither condition appears to favour the waterbirds. The maintenance of various water depths in different sections of the lagoon system, therefore, is a critical management issue that must be addressed in order to maintain or enhance the value of the Ghana coastal wetlands as waterbird habitat.'

*** START HERE MON. ADD TABLE … 'EXPOSED LEG LENGTH' VALUES TO THE EXCEL TABLE OF SPRECIES MEASUREMENTS.

Appendix … Ropert-Coudert, Y. & Kato, A. (2009).

Ropert-Coudert, Y. & Kato, A. (2009). *Diving activity of Hoary-headed and Australasian Grebes.* Waterbirds 32(1): 157-161.

‘One hide is located on the southern side of the lake where bathymetry ranged 80–140 cm (depth increases rapidly from the banks, see Fig. 1) and one is on the northern side where the bathymetry ranged 20–90 cm (the bottom of the lake on this side was always visible throughout the study period).’

‘We did observe an increase in dive duration when Hoary-headed Grebes fed in deeper water, which suggests that they would preferentially forage close to the bottom of the lake. The reverse would thus apply for Australasian Little Grebes suggesting that this species uses the whole water column. This assumption is partly supported by our observation that Hoary-headed Grebes on the shallow side of the lake were visible throughout their dives and foraged close to the bottom of the lake in all instances. In addition, this finding is consistent with what is known in the literature of the feeding ecology of these species.’

Consequently, the water depth of the lake had decreased by ca. 30–40 cm over the time of the study. RE-READ THIS PART OF PAPER.

Appendix … Trayler *et al.* (1989).

Trayler, K.M., Brothers, D.J., Wooller, R.D. & Potter, I.C. (1989). *Opportunistic foraging by three species of cormorants in an Australian estuary.* Journal of the Zoological Society of London. 218: 87-98.

'During December 1986 and January 1987, the foraging behaviour of cormorants in the Peel-Harvey Estuary was observed with binoculars from either a small boat or the shore.'

'Phalacrocorax melanoleucos almost invariably fed in water less than 2 m deep, whereas *P. varius* and *P. sulcirostris* often fed in the limited number of regions where the water exceeded this depth.'

'Cormorants are underwater pursuit-divers which use their feet to reach the bottom where they search for their prey (Schreiber & Clapp, 1987). This study has demonstrated that the durations of dives by *P. melanoleucos, P. sulcirostris* and *P. varius* in the Peel-Harvey Estuary each increase with increasing water depth. ... Our data also show that, in contrast to the situation with the little black cormorant, the little pied cormorant was observed on several occasions feeding in water less than 1 m in depth and only rarely in depths greater than 2 m. These differences in diving depths, which parallel those found with the same two species in inland lakes of eastern Australia (Miller, 1979), would presumably help reduce any potential interspecific competition for either food or feeding space. The marked tendency for *P. varius* to feed in deeper water than *P. melanoleucos* parallels the observations made by Stonehouse (1967) in coastal waters of New Zealand'.

TABLE II

Mean duration of dives and resting periods of three cormorant species in the Peel-Harvey Estuary, in relation to the depth of water in which they were feeding. Sample size is given in brackets

	Mean duration(s) (±S.E.) of dive in water depth of			Mean duration(s) (±S.E.) of rest on surface in water depth of		
	<1 m	1-2 m	>2 m	<1 m	1-2 m	>2 m
P. melanoleucos	6·8±1·10 (30)	12·5±0·75 (279)		2·6±0·43 (38)	4·7±0·29 (263)	
P. sulcirostris	—	13·4±2·07 (43)	19·3±1·10 (39)		4·3±0·66 (43)	7·5±1·32 (32)
P. varius	—	17·3±1·93 (80)	24·8±2·29 (117)		7·8±0·98 (63)	8·5±0·82 (108)

'While a wide range of species were ingested by all three cormorant species, the majority of the prey taken, particularly by the two smaller predators, was almost invariably slow-swimming, benthic-feeding crustaceans and teleosts that were abundant in the cormorants' feeding areas.'

Appendix … Stonehouse (1967).

Stonehouse, B. (1967). *Feeding behaviour and diving rhythms of some New Zealand shags, Phalacrocoracidae.* Ibis 109: 600-605.

‘Four species of shags feed regularly in coastal waters at Kaikoura (42°25’S, 173°42’E.) on the east coast of New Zealand's South Island. White-throated Shags [Little Pied Cormorants] *Phalacrocorax melanoleucos brevirostris* and Black Shags [Great Cormorants] *P. carbo novaehollandiae* feed close inshore, sometimes in the intertidal zone at high water, and seldom in depths greater than 2–3 m. Pied Shags [Pied Cormorants] *P. v. varius* sometimes feed close inshore, but more often in depths of 3–10 m. at distances of 100–300 m. from the shore. Spotted Shags *Stictocarbo punctata* feed in deeper water, often between one and ten miles (2–16 km) from the coast.’

‘Feeding dives of Pied and White-throated Shags [Pied and Little Pied Cormorants], easily observed from the peninsula cliffs and shore, have provided most of the data for this paper. Black [Great Cormorants] and Spotted Shags yielded only enough information for brief discussion and comparison.

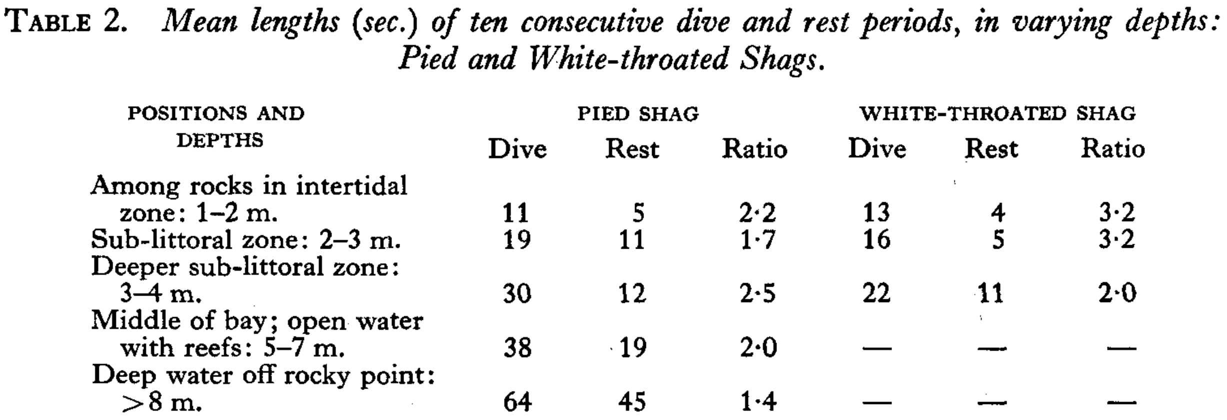


TABLE 2. *Mean lengths (sec.) of ten consecutive dive and rest periods, in varying depths: Pied and White-throated Shags.*

POSITIONS AND DEPTHS	PIED SHAG			WHITE-THROATED SHAG		
	Dive	Rest	Ratio	Dive	Rest	Ratio
Among rocks in intertidal zone: 1–2 m.	11	5	2·2	13	4	3·2
Sub-littoral zone: 2–3 m.	19	11	1·7	16	5	3·2
Deeper sub-littoral zone: 3–4 m.	30	12	2·5	22	11	2·0
Middle of bay; open water with reefs: 5–7 m.	38	19	2·0	—	—	—
Deep water off rocky point: >8 m.	64	45	1·4	—	—	—

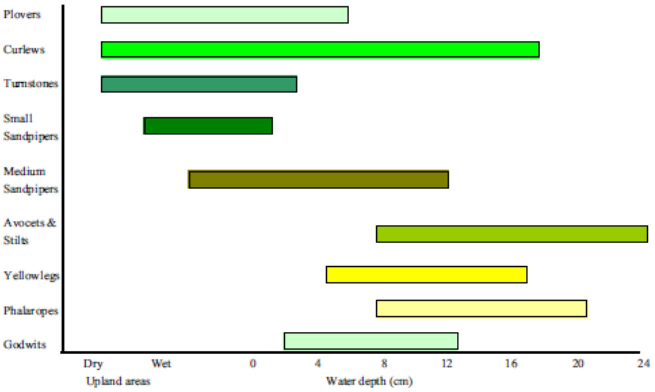
Appendix … Plauny (2000).

Plauny, H.L. (2000). *Shorebirds.* Fish and Wildlife Habitat Management Leaflet No. 17 (July 2000). Natural Resources Conservation Service Wildlife Management Institute, USDA, and Wildlife Habitat Council. 14pp.

‘Food and foraging sites

Interior grasslands, beaches, natural wetlands, and flooded agricultural fields provide foraging areas for a wide variety of shorebirds. Most shorebirds forage in water less than four inches deep, although some for- age in upland sites (e.g., curlews, upland sandpiper, woodcock) and in deeper water by swimming (e.g., phalaropes). Most shorebird diets consist of insects, aquatic invertebrates, mollusks and small fish. Through “resource partitioning,” several different species may forage together in suitable habitats. Each species seeks its preferred foods by using distinct feeding methods, which helps prevent direct competition among species for food. Some members of one species may assist the foraging efforts of another species without significant costs or benefits. For example, “beaters” stir up prey while “attendants” follow and forage in the disturbed substrate. Coastal shorebirds usually sort themselves into preferred feeding habitats as the high tide recedes. Least sandpipers feed on insects in drier marsh mud while dowitchers probe the substrate in shallow water for mollusks. Sanderlings search for crustaceans in wet sands, while greater yellowlegs feed in deeper water, snatching small fish from the surface’.

Typical foraging depths of various shorebirds (from Helmers 1992).



‘Managing wetlands for shorebirds

Integrated wetland management, management that maximizes benefits for wetland wildlife, also supports shorebirds as well as waterfowl and wading birds. Natural wetlands should be preserved whenever possible. In more artificial wetland settings, water control structures are commonly used to regulate water levels to stimulate the growth of wetland plants whose seeds and tubers are consumed by waterfowl (ducks and geese). Shorebirds take advantage of the rich invertebrate populations found in the saturated and flooded substrates of wetlands managed for moist soil plants.

Seasonal flooding and sequential draw down of moist soil wetland water levels provide productive shore- bird foraging substrates. In the late summer or early fall, dry areas can be reflooded (four to six inches) for the fall migration. Flooding in the early fall, before the first major freeze, also allows invertebrate food re- sources to survive the winter. Water levels can be drawn down in the spring by systematically draining areas that are regulated by flashboard risers or other water control structures. Landowners can start draw- down of fall-flooded areas at the rate of one inch per week, just before spring migration starts. Most for- aging shorebirds prefer water depths that vary from one to six inches.

Shallow disking of moist soil areas every two to three years removes thick, emergent vegetation that is not favored by shorebirds. Emergent plants grow along shorelines and extend above the surface of the water. Disking removes this vegetation and reconditions the wet soil by incorporating organic plant material, which attracts invertebrates. Draining and flooding practices should be planned, with the help of local wildlife pro fessionals, to mimic natural flooding cycles as much as possible to benefit shorebirds and other wetland wildlife’.

Helmers, D. L. (1992). *Shorebird management manual.* Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts, USA.

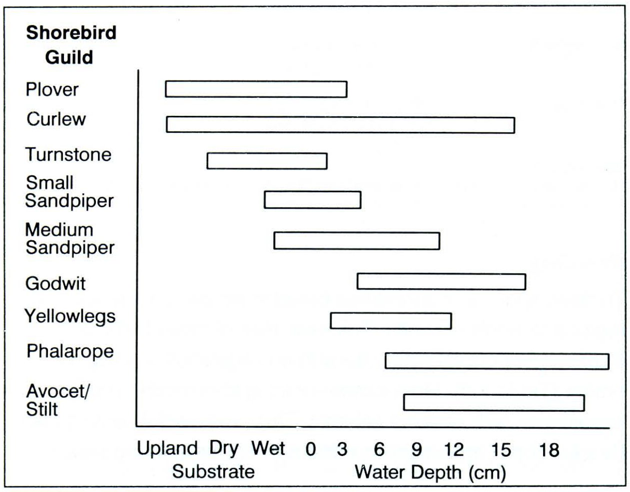
Appendix … Helmers (1992).

Helmers, D. L. (1992). *Shorebird management manual.* Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts, USA.

'Habitat Use

Migratory shorebirds within the same foraging guild use habitats of different water depth and vegetation height and density. Water depths for foraging shorebirds range from O cm (dry mud) to 18 cm (Figure 2.4). Vegetation density ranges from no cover to more than 75 percent cover. The majority of use, however, occurs at sites with less than 25 percent cover. Shorebirds prefer short vegetation, generally less than half the height of the bird, although some species, such as snipes and yellowlegs, will forage in taller vegetation'.

Figure 2.4 *Water depth (cm) and substrate preferences of shorebird foraging guilds.*



'***Managing for Shorebirds***

To provide quality habitat for migratory shorebirds, managers must identify what foods exist at the sites they manage, what foods are needed by likely shorebird species, and when migratory flocks will appear. Although shorebird habitat may seem extensive, food may not be readily available to shorebirds in the wetland. Management plans for migratory shorebirds should focus on developing a food base that will be continuously available over time.

<u>*Migration*</u>

Spring - Units suitable for spring shorebird management require fall flooding approximately 1 month before the first heavy freeze and the continued maintenance of flooded conditions to enable chironomids and other invertebrates to lay eggs and to assure survival of larvae over winter. During the spring migratory period, units should have extensive areas of open water or areas only partially covered with emergent vegetation (less than 50 percent). Units should be drawn down slowly (2-3 cm per week) to make invertebrates continuously available to shorebirds foraging in open, shallow water and mud flats. If more than one unit is being drawn down for shorebirds, manipulations should be staggered to extend the availability of habitat.

To indicate the potential for providing resources through time, a hypothetical wetland has been divided into five elevational zones based on flooding gradient. In this example, water depths in Zone 1 were 45 cm on April 1 and 25 cm on May 1 following a gradual drawdown. As water depths in the pool changed, the foraging areas shifted to new elevational zones and untapped food resources became available (Figure 2.5). The size of each foraging area varied greatly with elevation and water depth.

Summer/Fall- Units suitable for summer/fall shorebird management require two different strategies. First, to make invertebrates available, units that remained flooded through spring and early summer should be drawn down slowly or natural evaporation should be allowed to occur.

Second, units that remained dry should be shallowly flooded 2-3 weeks before summer/fall migration begins. This will allow time for invertebrates to repopulate the newly created habitat.

Also, the vegetation often needs to be manipulated by disking to assure shorebird response. The type of disking is critical. Disking converts plant biomass to a detrital base attractive to invertebrates. Shallow disking, which only partially buries plant biomass, is more desirable than deep disking which completely buries it. In other words, shallow disking acts as human-induced senescence and provides excellent substrates for invertebrates, whereas deep disking reduces the invertebrate food base'.

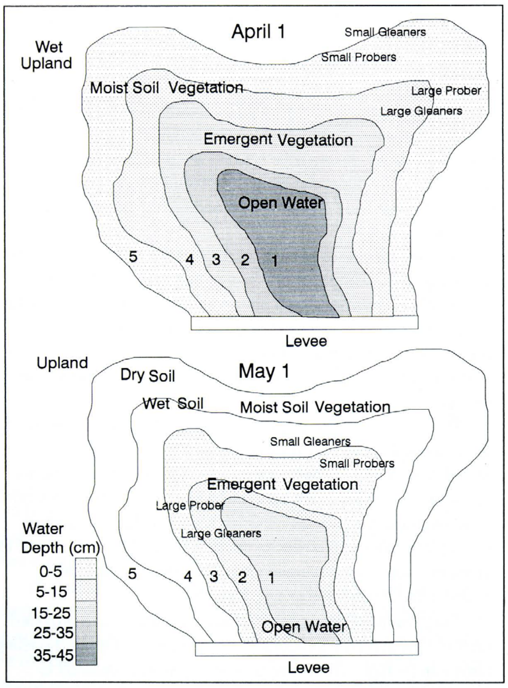


***Figure 2.5** Water depths, habitat types, and shorebird guild use within five elevational zones for one managed wetland unit. April 1 indicates initial flooding depths within zones (45-cm gauge depth) and May 1 indicates flooding depths after gradual drawdown (25-cm gauge depth). Water depths are measured at lowest elevation of pools.*

Appendix … Taylor (2004).

Taylor, IR (2004). *Foraging ecology of Black-fronted Plover [Dotterel] on saline lagoons in Australia: the importance of receding water levels.* Waterbirds 27(3): 270-276.

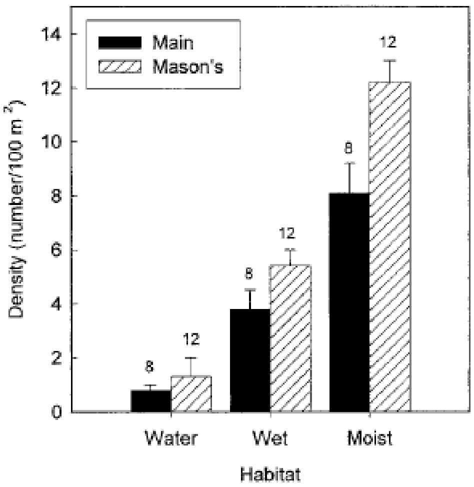


Figure 3. Comparisons of mean densities of Black-fronted Plovers feeding in the different substrate types at Main Lagoon and Mason's Park Lagoon.

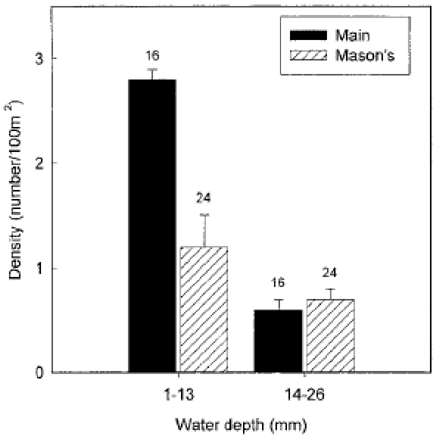


Figure 4. Comparisons of mean densities of Black-fronted Plovers feeding at different water depths at Main lagoon and Mason's Park Lagoon.

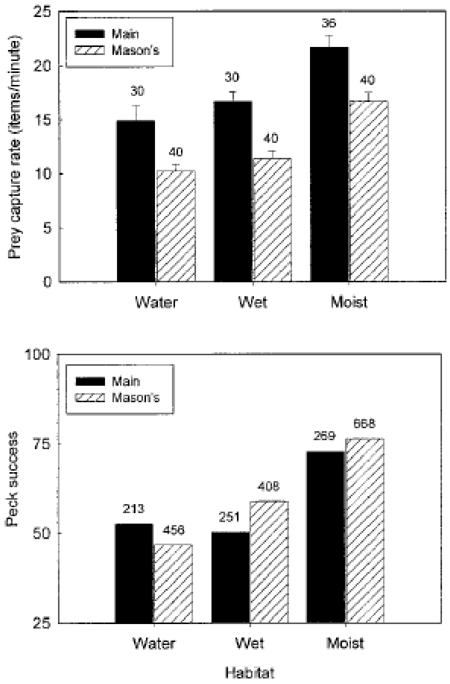


Figure 6. Comparisons of peck success and mean prey capture rates of Black-fronted Plovers feeding on different substrate types at Main Lagoon and Mason's Park Lagoon.

General (This general sub-section includes references and quotes concerning any waterbird species, including species not found in Australia).

Robertson, D. & Massenbauer, T. (2005) Applying hydrological thresholds to wetland management for waterbirds, using bathymetric surveys and GIS. Paper presented at the MODSIM [Modelling and Simulation] Congress, December 2005, Melbourne.

> ‘The primary importance of water depth over other habitat variables has been explained by waterbirds being opportunistic foragers (Bolduc 2002, Skagen and Knopf 1994, Euliss *et al.* 1991). Many waterbirds can readily alter diets and feeding locations to the food sources available, but the accessibility of food is limited by the bird’s morphological attributes.’

Colwell, M.A. & Taft, O.W. (2000). ***Waterbird communities in managed wetlands varying in water depth.*** **Waterbirds 23(1): 45-55. [Analysis of winter waterbird use of 25 ‘privately-managed, seasonal (palustrine, emergent)’ wetlands in the northern San Joaquin Valley, California].**

> ‘For nonbreeding waterfowl and shorebirds, water depth manipulation has its foundation in a rich literature on interspecific differences in foraging habitat use. For example, water depth at foraging locations differs among dabbling duck and shorebird species (e.g., Baker 1979; Poysa 1983; DuBowy 1988; Safran *et al.* 1997; Davis and Smith 1998), and these habitat differences correlate with species' morphologies. For waterfowl, depth at foraging sites correlated positively with species’ neck lengths (Poysa 1983); a similar correlation holds for water depth and leg length of shorebirds (Baker 1979).’
>
> ‘The relationship between water depth and foraging habitat use of individual species of wetland bird has been well documented (e.g., Baker 1979; Poysa 1983; DuBowy 1988; Safran et al. 1997), and this relationship has served as the basis for wetland management prescriptions.’
>
> From Summary: ‘We conclude that managers seeking to provide foraging habitat for a diverse community of wintering waterbirds should flood wetlands to average depths of l 0-20 cm, where topography can provide a range of depths attractive to a large number of species. However, this prescription is region-specific and influenced by the great diversity and abundance of waterfowl and shorebirds wintering in California's Central Valley’.

Aboushiba, A.B.H., Ramli, R. & Azirun, M.S. (2013). ***Foraging behaviour of five egret species in POME Pond area, Carey Island, Peninsular Malaysia.*** **Journal of Animal & Plant Sciences, 23(1): 129-135.**

The five species studied were Little Egret (*Egretta garzetta*) (n=1348), Cattle Egret (*Bubulcus cormorandus*) (n=1186), Great Egret (*Casmerodius albus*) (n=1023), Intermediate Egret (*Mesophoyx intermedia*) (n=956) and Chinese Egret (*Egretta eulophotes*) (n=262). n = total number of observations. ‘POME Pond’ = Palm Oil Mill Effluent Pond.

> ‘It was observed that morphological characteristics such as bill lengths and shapes, neck lengths and leg lengths are affecting egrets foraging behaviour. These physical characteristics influence egrets in obtaining their prey at various water levels below the length of tarsus. Most egrets prefer to forage along the ponds’ edges, at shallow water area where depth was below their tarsus and on floating objects as compacted waste material and dead fallen trees.’

Spencer, J. (2010). ***Migratory shorebird ecology in the Hunter estuary, south-eastern Australia*** **(Doctoral thesis, Australian Catholic University). Retrieved from http://researchbank.acu.edu.au/theses/306**

> ‘Small-scale differences in shorebird species distribution are usually related to their leg and bill length, as prey availability is determined by the depth to which a bird can wade and the maximum depth a bird can insert its bill into the sediment (Dann 1987). As a result, species are often segregated in their feeding habitats according to their preferences for water depth and sediment penetrability (Dann 1981b).’
>
> ‘Generally, shorebird species are uncomfortable in water deeper than their upper thigh and will move to higher grounds (Ntiamoa-Baidu et al. 1998).’
>
> ‘Wetland availability on Ash Island is driven by fortnightly spring tidal cycles, local rainfall and evaporation (Howe 2008), which affect the distribution of shorebirds as they generally prefer habitats with shallow water or wet substrates not deeper than their thigh (Dann 1987; Skagen & Knopf 1994; Parsons 2002) (see Table 4.1).’

> ‘Availability of prey is often determined by the maximum depth at which a shorebird can insert its bill into the substrate and maximum leg length (Dann 1987).’
>
> ‘Water depth in saltmarsh habitats is most critical in determining prey availability to shorebird species. The amount of bare substrate or shallow water available is a function of factors such as; water level, topography, water manipulation, local rainfall, soil type and wind action (Skagen & Knopf 1994).’
