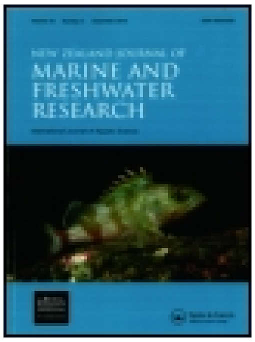

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CRITERIA FOR AGING AND SEXING NEW ZEALAND OYSTERCATCHERS

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ABSTRACT

Criteria based on external characters are presented for aging and sexing the three New Zealand species of oystercatcher, *Haematopus ostralegus finschi* Martens, 1897, *H. unicolor* Forster, 1844, and *H. chathamensis* Hartert, 1927. Four classes are discerned: juveniles have brown dorsal plumage, a brown iris and grey legs; second-year birds have an orange-red iris and pale pink legs; sub-adults have a dull red iris and pink legs; adults have a scarlet iris and bright coral pink legs. The three species can be sexed by discriminant analysis of the sexually dimorphic characters bill length (x_1), bill length:bill depth (x_2) and bill length:bill width (x_3). Linear functions and discriminating values for predicting sex are:

H. ostralegus finschi $0.46x_1+3.15x_2+2.94x_3$, 77.41;
H. unicolor $0.12x_1+6.52x_2+2.85x_3$, 58.05; and
H. chathamensis $-0.93x_1+1.50x_2+7.48x_3$, -20.86.

Similarly, the sexes of immature *H. ostralegus finschi* can be predicted:

juveniles $0.73x_1+5.76x_2+3.10x_3$, 116.57;
second-year birds $0.57x_1+5.12x_2+0.98x_3$, 84.84; and
sub-adults $0.55x_1+1.88x_2+1.08x_3$, 65.90.

INTRODUCTION

Kinsky (1970) currently recognises three species of oystercatcher in New Zealand: the South Island pied oystercatcher, *Haematopus ostralegus finschi* Martens, 1897, a pied form with Holarctic affinities (Fleming 1962); the variable oystercatcher, *H. unicolor* Forster, 1844, an Australasian form (Falla 1953) with pied, black, and intermediate colour phases; and the Chatham Islands oystercatcher, *H. chathamensis* Hartert, 1927, a pied form restricted to the Chatham Islands 800 km east of mainland New Zealand.

While trapping and colour-banding samples of the three species for studies of their systematics, ecology, and dispersal (Baker, unpublished 1972), it was necessary to develop a reliable method for aging and sexing the birds. Little information is available in the literature on the variations due to age and sex in oystercatchers. The only descriptions of age variation refer to the basic dichotomy between juveniles

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(first year) and adults, as given by Buller (1905), Falla (1939), Oliver (1955) and Falla *et al.* (1966) for New Zealand species, and Witherby *et al.* (1922) for European *H. ostralegus*. Yet Harris (1967) pointed out that British birds remain in immature plumage for two summers, and that it is possible to discern at least three age classes on plumage and bill characters. The only published attempt to develop a field method of sexing oystercatchers is that of Heppleston & Kerridge (1970), again for European *H. ostralegus*. This paper presents an analysis of criteria by which the New Zealand species of oystercatcher can be aged and sexed.

METHODS AND MATERIALS

TRAPPING TECHNIQUES

As the South Island pied oystercatcher is by far the most abundant species of oystercatcher in New Zealand (Falla *et al.* 1966, Baker 1973), methods of aging and sexing were developed using samples of these birds, and were later extended to the other two species. Outside the breeding season samples were trapped with a projectile net (Dill & Thornsberry 1950), because at this time the birds were gathered into easily located and accessible flocks. During the breeding season, adults were trapped at the nest, using an automatic drop-trap. The trap comprised a cubic cage (side of approximately 60 cm), open at the bottom, and set above the nest with a split peg supporting the front edge. The trip mechanism consisted of the split peg attached to the rear of the trap with fine nylon thread. On entering the trap to reach the nest, the bird tripped the taut nylon thread, which pulled the split peg apart and dropped the cage. Sampling localities are shown in Fig. 1, and sample details in Table 1.

Birds were trapped and banded from 1967 to 1971 inclusive. Thus a sample of known age was built up, with the oldest recoveries in 1971 being fifth-year birds banded as juveniles in 1967.

A sexed sample ($n = 244$) of South Island pied oystercatchers was obtained by subsampling most of the netted catches of winter birds ($n = 191$) and by trapping breeding birds at the nest ($n = 53$). The winter birds were sexed by dissection, whereas the sexes of the breeding birds were determined by observing copulatory behaviour or by cloacal examination (for up to 2 weeks after egg-laying, many females could be distinguished by the distended nature and pink colouration of the cloaca). The relatively low numbers of variable and Chatham Islands oystercatchers precluded the establishment of a dissected reference collection for these two species, so only birds caught at the nest (variable oystercatcher, $n = 58$, Chatham Islands oystercatcher, $n = 16$) and sexed on the above breeding criteria were used to develop the sexing method now described. The following standard measurements were recorded for each bird with dial calipers accurate to 0.1 mm, using the specifications of Baldwin *et al.* (1931): exposed culmen, bill depth at base, and bill width at base.

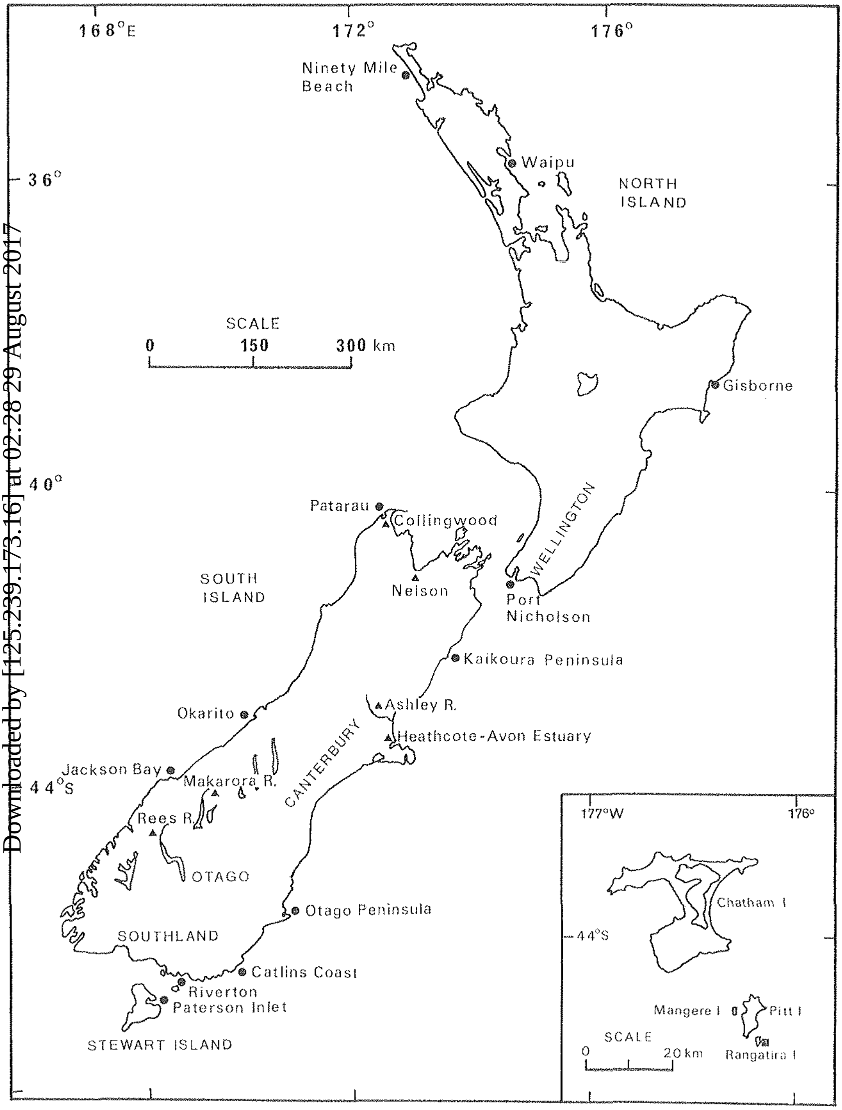

FIG. 1—Sketch map of New Zealand, showing sampling localities and place names mentioned in the text (▲ South Island pied oystercatcher, *Haematopus ostralegus finschi*, ● Variable oystercatcher, *H. unicolor*, ■ Chatham Islands oystercatcher, *H. chathamensis*). The Chatham Islands are shown in the inset.

TABLE 1—Sampling data for New Zealand oystercatchers, *Haematopus* spp., used in age and sex determination

SPECIES	LOCALITY	LATITUDE (° ′S)	LONGITUDE (° ′E)	DATE	*n*
South Island Pied Oyster-catcher, *H. ostralegus finschi*	Parapara Beach, Collingwood	40 43	172 42	Apr 1971	25
	Nelson Harbour	41 16	173 17	Aug 1969	4
	Ashley Bridge, Near Ashley River	43 20	172 20	Oct 1970	6
	Avon-Heathcote Estuary	43 33	172 44	Mar 1967–Jun 1971	162
	Makarora River, 3–5 km N. of Lake Wanaka	44 13	169 12	Nov 1969	12
	Rees River, at head of Lake Wakatipu	44 43	168 13	Oct 1970	35
				Total	**244**
Variable Oystercatcher, *H. unicolor*	Ninety Mile Beach	34 30	172 40	Jan 1971	10
	Waipu Beach	36 00	174 28	Jan 1970	8
	Murawai Beach, Gisborne	38 43	177 57	Jan 1971	2
	Somes I. and Ward I., Port Nicholson	41 17	174 51	Nov 1970	4
	Patarau, N.W. Nelson	40 41	172 30	Dec 1969	5
	Sugarloaf Point, Kaikoura Peninsula	42 24	173 41	Dec 1969	2
	Okarito Lagoon	43 12	170 11	Dec 1970	2
	Jackson Bay	43 58	168 40	Dec 1970	2
	Otago Peninsula	45 55	170 38	Dec 1970	4
	Tahakopa Bay, Waipati Beach and Porpoise Bay, Catlins coast	46 22	169 08	Dec 1970	6
	Howell's Point, Riverton	46 07	168 00	Dec 1970	11
	Paterson Inlet, Stewart Island	47 04	168 05	Dec 1970	4
				Total	**60**
Chatham Islands Oyster-catcher, *H. chathamensis*	Rangatira Island	44 21	175 43W	Nov 1970	16
				Total	**16**

STATISTICAL TECHNIQUES

Differences between mean dimensions of males and females were tested by single classification analysis of variance, using pairwise comparisons for each character (Johnston & Selander 1971).

Because it is extremely difficult to objectively assess grouping patterns based on simultaneous consideration of many characters, the data were subjected to two-group discriminant analysis. The procedure followed was that of Anderson (1966), using the computer program DISCRIM 2 coded in FORTRAN IV by Dr Dennis M. Power, Santa Barbara

TABLE 2—Colour characters used in age determination of the South Island pied oystercatcher, *Haematopus ostralegus finschi*

AGE CLASS	DORSAL PLUMAGE	IRIS	BILL	LEG
Juvenile	Very brown, with buff edges to feathers	Brown	Pale orange with dark tip	Grey
2nd year	Browny-black	Orange-red	Orange	Light pink
Sub-adult	Black	Red	Orange	Pink
Adult	Black	Scarlet	Bright orange	Coral pink to purple

Museum of Natural History. Discriminant analysis maximizes between-group variation relative to within-group variation, and thus achieves the best separation possible of the groups under test. In the analysis following, discriminant variates (Z) were computed for each group (= sex) such that, for group 1:

$$Z_1 = \lambda_1 x_{11} + \lambda_2 x_{21} + \lambda_3 x_{31}$$

and for group 2:

$$Z_2 = \lambda_1 x_{12} + \lambda_2 x_{22} + \lambda_3 x_{32}$$

Once the discriminant variates have been computed, an unknown specimen can be scored by substituting values of x_1, x_2 and x_3 in the prediction equation:

$$Z = \lambda_1 x_1 + \lambda_2 x_2 + \lambda_3 x_3$$

The specimen is then assigned to group 1 or 2, depending on whether Z is closer to Z_1 or Z_2 respectively. In practice, assignment to groups is based on the middle discriminant variate $MZ = 0.5(Z_1 + Z_2)$ which serves as a discriminating point between the two samples.

RESULTS

AGE DETERMINATION

Age classes of South Island pied oystercatchers can be recognised on the basis of progressive changes in the colours of the dorsal plumage, iris, bill, and leg, as shown in Table 2. The colour changes were determined from retraps and sight records of colour-banded birds. Juvenile birds moult their brownish first-year plumage in the spring following their first winter, and assume the darker plumage of second-year birds. At approximately the same time the iris changes gradually from brown through yellow to orange-red, the bill loses its dark tip, and the legs become light pink in colour. Sub-adult colours appear in the summer moulting period, marking the end of the second year of life. Of 74 banded sub-adults subsequently retrapped or sighted as 4 year olds, 58 (78.4%) had maintained their third-year colouring and 16 (21.6%)

TABLE 3—Mean bill measurements and ratios of adult New Zealand oystercatchers, *Haematopus* spp., and immature stages of *H. ostralegus finschi* (figures in parentheses are *F* values for the significance of the difference between means for males and females; * = 0.05 > P > 0.01, ** = 0.01 > P > 0.001, *** = P < 0.001)

			BILL MEASUREMENTS AND RATIOS (Mean ± S.E. in mm)				
AGE CLASS	SEX	n	Length (L)	Depth (D)	Width (W)	L : D	L : W
South Island pied oystercatcher							
Haematopus ostralegus finschi							
Juvenile	♂	23	80.1±0.81	15.0±0.13	12.1±0.16	5.2±0.10	6.5±0.09
			(63.86***)	(1.80)	(2.11)	(10.47**)	(11.77**)
	♀	15	89.8±0.85	15.3±0.19	12.4±0.21	6.0±0.14	7.5±0.11
2nd year	♂	24	81.0±0.97	15.3±0.16	12.5±0.17	5.2±0.09	6.4±0.12
			(77.91***)	(1.44)	(1.01)	(9.98**)	(10.39**)
	♀	16	91.3±1.01	15.5±0.18	12.6±0.20	6.0±0.14	7.3±0.13
Sub-adult	♂	30	80.7±0.92	15.2±0.10	12.5±0.13	5.3±0.08	6.5±0.14
			(73.68***)	(1.61)	(1.88)	(8.22**)	(7.79**)
	♀	12	91.4±1.26	15.5±0.15	12.7±0.17	5.9±0.07	7.2±0.12
Adult	♂	76	82.2±0.37	16.0±0.15	13.2±0.31	5.2±0.14	6.3±0.19
			(181.62***)	(1.96)	(1.47)	(6.91**)	(6.99**)
	♀	56	91.5±0.55	16.2±0.16	13.3±0.22	5.7±0.11	7.0±0.12
Variable oystercatcher							
H. unicolor							
Adult	♂	29	81.7±0.94	18.1±0.19	15.5±0.16	4.5±0.20	5.5±0.11
			(161.94***)	(3.12)	(2.98)	(10.68**)	(11.48**)
	♀	31	90.6±1.16	18.3±0.17	15.7±0.13	5.0±0.17	6.3±0.15
Chatham Islands oystercatcher							
H. chathamensis							
Adult	♂	8	67.8±0.97	16.2±0.14	13.1±0.09	4.2±0.11	5.2±0.08
			(17.66***)	(7.07*)	(11.10**)	(12.39**)	(13.72**)
	♀	8	76.8±1.99	16.9±0.23	14.1±0.28	4.5±0.14	5.6±0.12

had achieved adult colouring. Twenty-one of the above fourth-year sub-adults were resighted in 1971 as 5 y olds, and of these 15 (71.4%) were in adult colours. The change from sub-adult to adult colourings occurs in the autumn moulting period of these age classes. Only birds in adult colourings breed, so it seems possible that some birds may breed when 4 y old; however, the majority do not reach breeding condition until they are at least 5 y of age. These findings agree closely with those of Harris (1967) for European oystercatchers (*Haematopus ostralegus*).

Variable and Chatham Islands oystercatchers can also be grouped on the basis of similar colour changes to those described for the South Island pied oystercatcher; similar significance may reasonably be inferred.

SEX DETERMINATION

The absence of obvious and non-overlapping sexually dimorphic characters in the external morphology of oystercatchers has in the past made the correct separation of sexes difficult. Similar difficulties associated with sexing the fulmar, *Fulmarus glacialis* Linnaeus, 1761, the great black-backed gull, *Larus marinus* Linnaeus, 1758, and the red-billed gull, *Larus novaehollandiae scopulinus* Forster, 1844 have largely been resolved by discriminant analysis of bill length and bill depth (*see* Dunnet & Anderson 1961; Harris 1964; and Mills 1971 respectively). Heppleston & Kerridge (1970) extended this method of sexing to European oystercatchers *Haematopus ostralegus*, but found it was mathematically equivalent to using the less sophisticated ratio of bill length : bill depth. However, their results were somewhat unsatisfactory, because they had to use different ratios for sexing samples of birds from different wintering areas of the British Isles.

Adult New Zealand oystercatchers are highly sexually dimorphic in bill length, but not in either bill depth or bill width (Table 3). However, males have short stout bills and females have long thin bills, so it is possible to maximize dimorphism in bill dimensions by calculating the ratios bill length : bill depth and bill length : bill width (*see* Table 3). These ratios and bill length were therefore subjected to discriminant analysis, and appropriate discriminant weights (λ values), discriminant variates for each sample, discriminating points (*MZ* values), and discriminant functions were calculated for the three species (Table 4). The sample of South Island pied oystercatchers (76 males and 56 females) was sexed with 96% accuracy (6 errors), the sample of variable oystercatchers (29 males and 31 females) was sexed with 93% accuracy (4 errors) and the sample of Chatham Islands oystercatchers (8 males and 8 females) was sexed with 94% accuracy (1 error). The highly significant F values associated with the discriminant analysis for each species indicates that the functions are statistically robust in determining sex, and that they may be legitimately used as prediction functions for sexing unknown specimens.

TABLE 4—Results of discriminant bill measurement analysis for sexing adult New Zealand oystercatchers, *Haematopus* spp., and immature stages of *H. ostralegus finschi* (*** = $P < 0.001$)

AGE CLASS	DISCRIMINANT WEIGHTS λ_1	λ_2	λ_3	DISCRIMINANT VARIATES ♂♂	♀♀	DISCRIMINATING POINT	DISCRIMINANT FUNCTIONS FOR SEX PREDICTION	FUNCTION F VALUES
South Island pied oystercatcher								
Haematopus ostralegus finschi								
Juvenile	0.73	5.76	3.10	108.91	123.37	116.57	$116.57 = 0.73x_1 + 5.76x_2 + 3.10x_3$	41.33***
2nd year	0 57	5.12	0.98	79.17	89.71	84.84	$84.84 = 0.57x_1 + 5.12x_2 + 0.98x_3$	31.94***
Sub-adult	0 55	1.88	1.08	61.15	68.82	65.90	$65.90 = 0.55x_1 + 1.88x_2 + 1.08x_3$	20.80***
Adult	0.46	3.15	2.94	72.96	81.26	77.41	$77.41 = 0.46x_1 + 3.15x_2 + 2.94x_3$	87.81***
Variable oystercatcher								
H. unicolor								
Adult	0.12	6.52	2.85	54.85	61.38	58.05	$58.05 = 0.12x_1 + 6.52x_2 + 2.85x_3$	31.48***
Chatham Islands oystercatcher								
H. chathamensis								
Adult	−0.93	1.50	7.48	−18.48	−23.24	−20.86	$-20.86 = -0.93x_1 + 1.50x_2 + 7.48x_3$	5.44***

The accuracy of the functions in predicting sex is maximal for the samples from which the functions were derived (Cooley & Lohnes 1971), and thus it is unlikely that further samples of birds of unknown sex will be sexed with the same accuracy as the original reference samples. Unfortunately, no other sexed samples were available to evaluate this loss of accuracy, but it is unlikely to be great judging from the large F values above.

The general utility of the prediction functions does not seem to be affected by geographic variation in bill dimensions. Although the sample of variable oystercatchers includes birds from much of their New Zealand range, over which considerable geographic variation in bill length, bill depth, and bill width has been shown to occur (Baker 1972), discriminant analysis is equally effective in predicting the sex of the birds in this sample. The sample of South Island pied oystercatchers is less representative of the range of this species, as only birds caught in the South Island are included in the analysis. However, this sample may include some northern birds because most of the 'wintering' birds were caught at the Heathcote-Avon Estuary during the migration period. After the breeding season ends, migrant breeders and their young pass through the estuary on their way to more northerly New Zealand wintering areas. At this time the Heathcote-Avon population swells to about double its winter size, and it was during this period that the largest catches were made. In addition, the breeding sample of 53 South Island pied oystercatchers may have had diverse wintering origins; most were captured in inland north Otago, which could draw birds from Stewart Island, Southland, Otago, Canterbury, and possibly even northern New Zealand. Birds colour banded at this inland breeding site have been sighted in winter on the Otago, Canterbury, and Wellington coasts.

The sexual dimorphism in bill length and ratios noted above for adults also occurs in the other age classes, though data are available only for *Haematopus ostralegus finschi* (Table 3). Results of discriminant analysis for juveniles, second-year birds and sub-adults are shown in Table 4. Using the discriminant functions, juveniles (23 males and 15 females) were sexed with 100% accuracy, second-year birds (24 males and 16 females) with 95% accuracy (2 errors) and sub-adults (30 males and 12 females) with 95% accuracy (2 errors). The highly significant F values again indicate that the prediction functions can be justifiably used to sex unknown specimens.

Similar sexual dimorphism in bill measurements has been reported for other species of oystercatchers: *Haematopus bachmani* Audubon, 1838; *H. palliatus* Temminck, 1820; *H. leucopodus* Garnot, 1826; and *H. ater* Vieillot & Oudart, 1834 (Ridgway 1919; Murphy 1925, 1936). Provided a sexed reference collection of each species is available, it seems likely that discriminant analysis of these bill characters could be used to sex unknown specimens.

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