2020

DOC RESEARCH AND DEVELOPMENT SERIES 365

Potential factors affecting the calling rates and detectability of crake and rail species: a review

Emma M. Williams

Department of Conservation
Te Papa Atawhai

New Zealand Government

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

This report is available from the departmental website in pdf form. Titles are listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Series*.

ISSN 1177–9306 (web PDF)
ISBN 978–0–9951392–7–5 (web PDF)

This report was prepared for publication by the Publishing Team; editing by Amanda Todd and layout by Lynette Clelland. Publication was approved by the Director, Terrestrial Unit, Department of Conservation, Wellington, New Zealand.

Published by Creative Services, Department of Conservation, PO Box 10420, The Terrace, Wellington 6143, New Zealand.

In the interest of forest conservation, we support paperless electronic publishing.

CONTENTS

Potential factors affecting the calling rates and detectability of crake and rail species: a review

Emma M. Williams

Department of Conservation, Private Bag 4715, Christchurch 8140, New Zealand.
Email: emwilliams@doc.govt.nz

Abstract

Wetlands provide habitat for some of New Zealand's most secretive and difficult to detect threatened bird species, including crakes and rails (family Rallidae). However, it is currently difficult to measure population trends for these birds in relation to conservation management activities due to a lack of standard monitoring methods. This report reviews the use of call-count methods for surveying and monitoring members of the family Rallidae worldwide to determine whether they could form the basis for developing monitoring techniques in New Zealand. This review shows that common covariates that influence the calling rates, and thus the detectability of crakes and rails, include: temporal variables (time of day, time of year and year), environmental variables (moon phase, moon light, cloud cover, rainfall, wind speed, temperature, date of last natural disturbance, water level, tidal stage and salinity content), variables relating to population demographics (sex of bird, reproductive status/stage, migratory behaviour and population density), 'nuisance' variables (location, observer disturbance and background noise) and four potential interactions between these. These variables could be accounted for in monitoring programmes by undertaking repeat counts under standardised conditions or recording all relevant variables to allow their effects to be corrected for during later analysis. Future research should quantify the effects of these variables on the calling rates and detection probabilities of New Zealand crakes and rails to develop monitoring methods that are best suited to our wetlands.

Keywords: inventory, monitoring, wetland birds, conservation management, call counts, threatened species, crakes, rails, Rallidae, New Zealand.

1. Introduction

Call-count-based methods are commonly the only methods available for detecting cryptic species, i.e. those species that are secretive, well-hidden and/or located in inaccessible areas (Williams 2016). However, there are many examples where call-count-based methods have insufficient power to be useful as index methods (e.g. Clarke et al. 2003), which is particularly likely when detectability is affected by variables that are also hard to detect (as is the case for cryptic species by definition).

Small sample sizes and low/variable detections limit the inferences that can be made about cryptic species populations, making it unlikely that low-precision methods such as indices will be useful for measuring them (Williams 2016). Consequently, many authors argue, quite rightly, that under these circumstances monitoring methods that can measure or account for changes in detectability should be used so that the number of individuals that were not detected can also be estimated (Alldredge et al. 2007; Diefenbach et al. 2003; Farnsworth et al. 2002; Royle & Nichols 2003). However, to do this, managers must first identify which variables are likely to affect detectability and quantify these effects (Williams et al. 2018).

New Zealand wetlands provide habitat for some of the country's most cryptic threatened species, including the Australasian bittern (matuku, *Botaurus poiciloptilus*) (Fig. 1), marsh crake (koitareke, *Porzana pusilla*/*Zapornia pusilla*) (Fig. 2) and spotless crake (pūweto, *P. tabuensis*/ *Z. tabuensis*) (Fig. 3). However, these habitats currently occupy less than 10% of their historic range (Cromarty & Scott 1996; Ausseil et al. 2011) and little is known about how this loss of habitat has affected these bird species. Therefore, there is a need to develop monitoring methods for cryptic wetland bird species that can a) determine their status, distribution and threats; b) identify and protect their key sites; and c) measure the responses of their populations to conservation management practices.

Development of inventory and monitoring techniques for New Zealand's crakes and rails (family Rallidae) is likely to start with development of call-based methods initially. This is because bird calls provide distinct cues that can be detected even when the individual is hidden in thick vegetation and call-based methods generally require less development compared with other potential techniques (such as thermal imagery, the use of dogs and camera traps) before they can be used.

Some progress has already been made in identifying the factors that affect the call rate of Australasian bitterns (Williams 2016; Williams et al. 2018), which has led to the development of monitoring methods that can be used on males of this species (O'Donnell et al. 2013; O'Donnell & Williams 2015;). However, while male bitterns represent a great flagship species for wetlands, they are not entirely suitable as indicator or surrogate species that can show representative population changes in response to management practices. For example, adult male bitterns are sizable, aggressive and have large seasonal home ranges that span multiple wetlands (EMW unpubl. data), suggesting that they will be less vulnerable to site-specific threats such as invasive predators than smaller crake-like species. Consequently, male bitterns may be less sensitive and therefore less informative with regard to management changes that are being applied at a local level.

Figure 1. Australasian bittern (matuku). *Photo: M.F. Soper*

Figure 2. Marsh crake (koitareke). *Photo: Emma Williams*

Figure 3. Spotless crake (pūweto), *Photo: Geoffrey Dabb*

Crakes and rails inhabit the same habitats as bitterns but are sensitive to all invasive predator species and produce multiple clutches per season (O'Donnell et al. 2015). Consequently, populations of these birds may have the capacity to change more rapidly than bitterns, potentially making their population changes a better indicator of short-term management outcomes. Therefore, there is a need to identify and quantify any variables that may influence the call-based detectability of New Zealand crake and rail species.

This report reviews published articles on the use of call-count methods to survey and monitor members of the Rallidae family worldwide to assess their suitability for forming a basis for the development of techniques in New Zealand. In particular, the study examined which variables are likely to affect the behaviours and detectability of New Zealand crake and rail species to determine the optimal times and conditions for monitoring these threatened species and to develop general monitoring protocols for wetland bird species.

2. Methods

Peer-reviewed articles on the family Rallidae were located by searching Google Scholar for each genus using the search terms 'call' and 'vocalisation'. This yielded 61 articles that discussed the calling rates of 45 of the 137 species in this family (Appendix 1). For each article, any variables that were reported were classified into one of three subjective categories for each species discussed: × if the publication tested the variable but no effect was apparent; ✓ if the publication tested the variable and the results suggested that an effect existed; and ? if the publication reported on the variable speculatively or if the variable was tested but the results were ambiguous. Of the 45 species examined, the best-studied species were the sora (*P. carolina*; n = 18), black rail (*Laterallus jamaicensis*; n = 17), Virginia rail (*Rallus limicola*; n = 14), clapper rail (*R. crepitans*; n = 11), king rail (*R. elegans*; n = 6), yellow rail (*Coturnicops noveboracensis*; n = 6) and common moorhen (*Gallinula chloropus*; n = 6).[1] For all other species, there were less than five publications per species.

To provide a simple assessment of how widely a variable was reported, the percentage of species that each variable was attributed to was calculated. These reporting rates represent the percentage of species examined (i.e. out of the 45 species for which information could be found) that had some information regarding that variable (regardless of the trend or any ambiguity).

1. Note: The total number of publications per species does not equal the total number of publications reviewed because several publications provided information on multiple species.

3. Variables associated with calling rates in crakes and rails

A wide variety of variables were suggested as potentially affecting the calling rates of members of the Rallidae family. These included three temporal variables (time of day, time of year and year), ten environmental variables (moon phase, moon light, cloud cover, rainfall, wind speed, temperature, date of last natural disturbance, water level, tidal stage and salinity content), four variables relating to population demographics (sex of bird, reproductive status/stage, migratory behaviour and population density), three nuisance variables (location, observer disturbance and background noise) and four interactive effects. In addition, the use of playback was often recommended for monitoring Rallidae species to increase their detectability (Ribic et al. 1999).

In general, temporal variables were associated with the highest percentage of species (reporting rate = 60%), followed by several population demographic variables (reporting rate = 42%) and variables associated with the use of playback (reporting rate = 38%). All other variables were reported or discussed in fewer than five publications.

3.1 Temporal variables

3.1.1 Time of day

Among the three temporal variables that have been identified, time of day appeared to affect the largest number of species (21 species, reporting rate = 47%; Table 1). However, the exact relationship between the time of day and calling rate is unclear. For example, Ripley (1977) stated that Rallidae species call 'more commonly in early mornings or evenings but sometimes during day and night', suggesting that diurnal trends may be appropriately classified into daily periods. Indeed, peak calling periods that corresponded to a particular time period (i.e. morning, evening or night) were most commonly reported (18 publications, reporting rate = 38%). However, Conway (2009; 2011) suggested that Rallidae calls peak in relation to sunrise and sunset, which was supported by nine of the publications included in this review (10 species, reporting rate = 22%). Regardless of the relationship reported, none of the publications reviewed here tested both relationships within the same study, making it difficult to determine whether their results reflected true relationships or were a product of what was tested. Only one study offered a biological explanation for these diurnal patterns – Akhtar et al. (2015) suggested that the calling rate of the white-breasted waterhen (*Amaurornis phoenicurus*) peaked in the early morning when individuals were actively searching for food and so concluded that these calls represented attempts to communicate the individual's intentions/findings regarding food to conspecifics.

3.1.2 Time of year

The time of year (usually reported by month) also appeared to be an important variable to consider, being reported for 12 of the 45 species (reporting rate = 27%; Table 1). However, most time of year effects appeared to coincide with or were near to the breeding season, suggesting that they were related to the reproductive status and stage. For example, Polak (2005) found that the calling rate of water rails (*R. aquaticus*) peaks in April and June, around the time of egg laying, which is consistent with the postulation that these calls are associated with mate guarding and mate attraction (Catchpole 2003; Cramp & Simmons cited in Ręk 2015). In addition, some publications reported multiple peaks in calling across the year (Conway & Gibbs 2011), which may have coincided with the production of multiple clutches or females becoming available again for mating following nest failures.

Table 1. Temporal variables reported in peer-reviewed publications for extant Rallidae species. × = no effect, ✓ = effect detected, ? = effect ambiguous. Reporting rates represent the percentage of species examined (i.e. out of the 45 species for which information could be found) that had some information regarding that variable (regardless of the trend or any ambiguity). Superscript letters indicate references (see footnote). See Appendix 1 for scientific names.

SPECIES	TIME TO SUNRISE/ SUNSET	TIME OF DAY (MORNING/ EVENING/NIGHT)	TIME OF YEAR	YEAR
American coot		?[g]		
American purple gallinule		?[g]		
Austral rail		?[z]		
Azure gallinule		✓[v]		
Black rail	✓[l]; ?[m,n]	x[e,g,o,p]; ✓[n,q,r,s]	✓[e,n,s,t,u]	✓[e,n,r]
Buff-banded rail		?[i]	?[j]	
Clapper rail			✓[e,ab]	✓[e,r]
Common moorhen		?[g]	?[h]	
Corncrake	✓[f]	✓[f]		
Grey-breasted crake	✓[k]			
King rail		x[g]		
Ocellated crake			?[a]	
Plain bush-hen	?[a]			
Red-legged crake	✓[ac]	?[z]	?[z]	
Red-necked crake	✓[j]	✓[j]		
Ruddy crake			?[a]	
Slaty-legged crake	?[a]	✓[i]; ?[h]		
Sora		x[e,g]	✓[e,d,w]; ?[a]	
Speckled crake		?[c]		
Spotted crake		✓[y]		
Virginia rail			✓[e,d,w]	
Water rail			✓[aa]	
Watercock	?[a]			
White-breasted waterhen		✓[b]	✓[b]	
White-throated rail	?[a]			
Yellow rail	?[d]	✓[d], x[e]		
Yellow-breasted crake			?[x]	
Number of references	9	18	15	3
Reporting rate	10 (22%)	17 (38%)	12 (27%)	2 (4%)

References: [a] Ripley (1977); [b] Akhtar et al. (2015); [c] Teixeira & Puga (1984); [d] Gibbs et al. (1991); [e] Conway & Gibbs (2011); [f] Mason (1950); [g] Nadeau et al. (2008); [h] Lewthwaite & Yu (2001); [i] Pratt et al. (1980); [j] Mittermeier et al. (2013); [k] Stiles & Levey (1988); [l] Reynard (1974); [m] Spautz et al. (2005); [n] Conway et al. (2004); [o] Spear et al. (1999); [p] Tecklin (1999); [q] Repking (1975); [r] Flores & Eddleman 1991 cited in Conway & Gibbs 2011; [s] Legare et al. (1999); [t] Kerlinger & Wiedner (1991); [u] Repking & Ohmart (1977); [v] Smith et al. (2005); [w] Gibbs & Melvin (1993); [x] Renaudier & de Guyane (2010); [y] Ręk (2015); [z] Barnet t et al. (2014); [aa] Polak (2005); [ab] Conway et al. (1993); [ac] Brazil (2009).

A second possibility is that monthly peaks in calling rates are byproducts of migration (i.e. a lack of calling is due to the absence of birds rather than a change in their detectability). Seasonal migrations have been reported for yellow rails, red-necked crakes (*Rallina tricolor*), white-throated crakes (*L. albigularis*), grey-breasted crakes (*L. exilis*) and azure gallinules (*Porphyrio flavirostris*) (Harvey et al. 2014; Mittermeier et al. 2013; Reynard 1974; Stiles & Levey 1988; Taylor 1998). Like calling, the timing of these migratory behaviours will also be affected by a suite of variables – for example, the migration of red-necked crakes, white-throated crakes and grey-breasted crakes is linked with the wet season (Stiles & Levey 1988; Taylor 1998, pp. 54; Mittermeier et al. 2013;). In general, seasonal migration patterns and the factors that affect the timing of these have not been well studied in New Zealand or other countries for Rallidae species. Therefore, more data on Rallidae movements would be useful for developing monitoring methods that use calling rates as a surrogate for abundance.

3.1.3 Year

Year was reported to affect the calling rate for 2 of the 45 species (reporting rate = 4%; Table 1). The existence of a year effect is concerning as it indicates that calling rate is unpredictable or is driven by factors that are difficult to measure or identify (and therefore will not be included in models). However, given the high ambiguity of most variables and the lack of understanding regarding the biological significance of calling, a reporting rate of 4% is reasonable (assuming that most publications considered observations from multiple years, which is not stated in many cases). Nevertheless, it would be prudent to collect call-rate data across multiple years and to test for a year effect.

Table 2. Environmental variables reported in peer-reviewed publications for extant Rallidae species. × = no effect, ✓ = effect detected, ? = effect ambiguous. No references could be found for two potential variables, 'date of last natural disturbance' and 'salinity content'. Reporting rates represent the percentage of species examined (i.e. out of the 45 species for which information could be found) that had some information regarding that variable (regardless of the trend or any ambiguity). Superscript letters indicate references (see footnote). See Appendix 1 for scientific names.

SPECIES	MOON PHASE	MOON LIGHT	CLOUD COVER	RAIN-FALL	WIND SPEED	TEMP.	WATER LEVELS	TIDAL STAGE
American coot						?[d]		
American purple gallinule						?[d]		
Ash-throated crake							?[i]	
Black rail	x[b]	✓[b,f]			?[g]			✓[b,f,h]
Clapper rail			?[d]		?[d]	?[d]		✓[b,h,k]
Common moorhen						?[d]		
King rail			?[e]					
Mangrove rail								?[e]
Red-legged crake				?[l]				
Rouget's rail	?[e]	?[e]						
Virginia rail	?[b]	?[b]			?[e]			
Water rail				?[j]	?[j]			
Watercock			?[e]	?[e]				
White-breasted waterhen							✓[a]	
Yellow rail					x[b,c]			
Number of references	2	3	2	3	6	1	2	5
Reporting rate	3 (7%)	3 (7%)	3 (7%)	3 (7%)	5 (11%)	4 (9%)	2 (4%)	3 (7%)

References: [a] Akhtar et al. (2015); [b] Conway & Gibbs (2011); [c] Bart et al. (1984); [d] Nadeau et al. (2008); [e] Ripley (1977) ; [f] Spear et al. (1999); [g] Reynard (1974); [h] Conway (2009); [i] Smith et al. (2005); [j] Jenkins & Ormerod (2002); [k] Zembal & Massey (1987); [l] Coates & Bishop (1997).

3.2 Environmental variables

Ten environmental variables were discussed in the literature. These included moon phase, moonlight, cloud cover, rainfall, wind speed, temperature, water level, tidal stage, date of last natural disturbance and salinity content (Table 2). Reports on most of these variables were speculative, with a non-ambiguous relationship only being apparent for variable tidal stage, which was reported to affect the calling rates of black rails (three publications) and clapper rails (three publications) but was ambiguous for mangrove rail (*R. longirostris*; one publication) (Table 2). No information was available on the biological significance of tidal stage, but Conway (2009) speculated that nest success may be influenced by the timing of high tides.

Evidence for a relationship between the two moon-related variables and calling rate was apparent but not well defined. For example, Ripley (1977) described Rouget's rail (*Rougetius rougetii*) as being 'particularly fond of calling on moonlit nights' but did not state how this information was obtained for 12 of the 45 species (reporting rate = 27%; Table 1). However, most time-of-year effects appeared to coincide with or were near to the breeding season, suggesting that they were related to the reproductive status and stage. For example, Polak (2005) found that the calling rate of water rails (*R. aquaticus*) peaks in April and June, around the time of egg laying, which is consistent with the postulation that these calls are associated with mate guarding and mate attraction (Catchpole 2003; Cramp & Simmons cited in Ręk 2015). In addition, some publications reported multiple peaks in calling across the year (Conway & Gibbs 2011), which may have coincided with the production of multiple clutches or females becoming available again for mating following nest failures.

A second possibility is that monthly peaks in calling rate are byproducts of migration (i.e. a lack of calling is due to the absence of birds rather than a change in their detectability). Seasonal migrations have been reported for yellow rails, red-necked crakes (*Rallina tricolor*), white-throated crakes (*L. albigularis*), grey-breasted crakes (*L. exilis*) and azure gallinules (*Porphyrio flavirostris*) (Harvey et al. 2014; Mittermeier et al. 2013; Reynard 1974; Stiles & Levey 1988; Taylor 1998). Like calling, the timing of these migratory behaviours will also be affected by a suite of variables – for example, the migration of red-necked crakes, white-throated crakes and grey-breasted crakes is linked with the wet season (Stiles & Levey 1988; Taylor 1998, p. 54; Mittermeier et al. 2013). In general, seasonal migration patterns and the factors that affect the timing of these have not been well studied in New Zealand or other countries. Although the effect of moon-associated variables on avian calling rates is not well defined for Rallidae species, it has been discussed in relation to other avian species. In particular, moon-related effects are well reported in nocturnal species (Williams 2016), with postulations tending to relate to the foraging efficiency and/or territorial activities of animals increasing on moonlit nights due to an improved visibility (as observed for brown skua, Catharacta Antarctica, and whip-poor-wills, *Caprimulgus vociferous*; Mougeot & Bretagnolle 2000; Wilson & Watts 2006).

In terms of the other variables, the literature contained inconclusive discussions on cloud cover in relation to three species (clapper rail, king rail and watercock (*Gallicrex cinerea*); two publications), temperature in relation to four species (clapper rail, American purple gallinule (*P. martinica*), American coot (*Fulica americana*) and common moorhen; one publication), rainfall in relation to three species (red-legged crake (*R. fasciata*), water rail and watercock; three publications) and water levels in relation to two species (white-breasted waterhen and ash-throated crake (*Mustelirallus albicollis*); two publications) (Table 2). Wind speed was shown to have no effect on the calling rate of yellow rails (two publications), but it was suggested (ambiguously) that high winds would reduce the call detectability of four species (black rail, clapper rail, Virginia rail and water rail; four publications). In addition, Conway (2009) recommended that the salinity content and date of last natural disturbance variable should be recorded during standardised North American marsh bird surveys despite no prior relationship being reported between either of these variables and calling rate and no reasons being provided for their inclusion or postulations regarding their biological significance.

3.3 Population demographics / biological variables

Four variables relating to population demographics were reported in the literature: sex of the bird, reproductive status/stage, migratory behaviour and population density. Reproductive status or stage was associated with calling rate in eight species (white-breasted waterhen (Fig. 3), black rail, clapper rail, Virginia rail, water rail, spotted crake (*P. porzana*), sora and spotless crake; 13 publications) and in four additional species anecdotally (corncrake (*Crex crex*), yellow rail, red-legged crake and slaty-legged crake (*R. eurizonoides*); five publications) (Table 3). The relationship between calling rate and population density varied between species, with a density-dependent relationship being detected in sora, Virginia rail, mangrove rail and clapper rail (six publications), an anecdotal relationship being reported for Tasmanian native hen (*Tribonyx* *mortierii*), black rail, grey-breasted crake and Inaccessible Island rail (*Atlantisia rogersi*; two publications) and no apparent relationship for common moorhen (*Gallinula chloropus*; two publications) (Table 3). Calling rate also appeared to vary with the sex of the calling bird in common moorhen, black rail and red-legged crake (five publications; Table 3). Migratory information was particularly sparse. Yellow rails are thought to migrate (1 publication), while migration was ambigiously linked with another three species (azure gallinule, grey-breasted crake and red-necked crake; three publications).

Results from call-based methods would be easily misinterpreted if the call rates were density dependent, particularly where single call-rate values relate to multiple densities (Caughley, 1977), and this would be difficult to account for in an analysis without prior information on the actual population numbers (i.e. by using some form of spatially explicit capture recapture to distinguish between individuals; Dawson & Efford, 2009; Stevenson et al., 2015). Similarly, sex-dependent calling rates would be difficult to measure and account for in an analysis without prior information on sex ratios in the population. However, since few publications reported these relationships, they should be considered as potential variables that remain to be tested.

Table 3. Demographic variables reported in peer-reviewed publications for extant Rallidae species. × = no effect, ✓ = effect detected, ? = effect ambiguous. Reporting rates represent the percentage of species examined (i.e. out of the 45 species for which information could be found) that had some information regarding that variable (regardless of the trend or any ambiguity). Superscript letters indicate references (see footnote). See Appendix 1 for scientific names.

SPECIES	SEX OF BIRD	REPRODUCTIVE STATUS OR STAGE	MIGRATORY BEHAVIOUR	DENSITY
Azure gallinule			?[j]	
Black rail	✓[d,f,l]	✓[f,i]		?[b]
Clapper rail		✓[b,s,t]		✓[f,u,v]
Common moorhen	✓[f,g]			x[f,g]
Corncrake		?[b,e]		
Grey-breasted crake			?[h]	?[h]
Inaccessible Island rail				?[b]
Mangrove rail				✓[t,v]
Red-legged crake	?[y]	?[p,x]		
Red-necked crake			?[q]	
Slaty-legged crake		?[b]		
Sora		✓[b,f,k]; ?[l]		✓[f,k]
Spotless crake		✓[f,o]		
Spotted crake		✓[m,n]		
Tasmanian native hen				?[b]
Virginia rail		✓[f,k,w]; ?[b]		✓[f,w]
Water rail		✓[r]		
White-breasted waterhen		✓[a]		
Yellow rail		?[c]	✓[e]	
Number of references	5	17	4	8
Reporting rate	3 (7%)	12 (27%)	4 (9%)	9 (20%)

References: [a] Akhtar et al. (2015); [b] Ripley (1977) ; [c] Gibbs et al. (1991); [d] Reynard (1974); [e] Mason (1950); [f] Conway & Gibbs (2011); [g] Brackney & Bookhout (1982); [h] Stiles & Levey (1988); [i] Legare et al. (1999); [j] Harvey et al. (2014); [k] Kaufmann (1971); [l] Kaufmann (1983); [m] Cramp & Simmons in Ręk (2015); [n] Ręk (2015); [o] Kaufmann (1988); [p] Robson (2015); [q] Mittermeier et al. (2013); [r] Polak (2005); [s] Conway et al. (1993); [t] Bogner & Baldassarre (2002); [u] Zembal & Massey (1987); [v] Zembal & Massey (1981); [w] Glahn (1974); [x] Phillipps & Phillipps (2011); [y] Coates & Bishop (1997).

3.4 Nuisance variables

Three nuisance variables were identified as having potentially important effects on the detectability of crake and rail species. These included a location (site) variable, which affected black rail, clapper rail, Virginia rail, white-browed crake (*A. cinerea*) and sora (six publications), an observer variable, which affected black rail (two publications), and a background noise variable, which affected yellow rail and Virginia rail (two publications), as well as grey-breasted crake, black rail and sora, albeit anecdotally (three publications) (Table 4).

Table 4. Interactive, nuisance and other variables that have been reported in peer-reviewed publications for extant Rallidae species. × = no effect, ✓ = effect detected, ? = effect ambiguous. Reporting rates represent the percentage of species examined (i.e. out of the 45 species for which information could be found) that had some information regarding that variable (regardless of the trend or any ambiguity). Superscript letters indicate references (see footnote). See Appendix 1 for scientific names.

SPECIES	LOCATION	OBSERVER	NOISE	TIME OF YEAR/ BREEDING STAGE * TIME OF DAY	TIME OF YEAR * LOCATION	TIME OF YEAR * YEAR	OBSERVER * PLAYBACK	CALL BROADCAST
American coot								✓[c,f]; ?[e]
American purple gallinule								✓[c,d];?[e]
Austral rail								✓[z]
Bare-eyed rail								✓[g]
Black rail	✓[c,k,l]	✓[c,k]	?[m]		✓[c,i,j]	✓[c,k]		✓[c,d,e,l,n]
Clapper rail	✓[c,ab]						✓[c,d]	✓[c,d,e,q,ab]
Common moorhen								✓[c,d,e; xq]
Galapagos crake								✓[o]
Grey-breasted crake			?[h]					?[h]
King rail				?[v]				✓[c,d,e,f,q]
Ocellated crake								✓[p]
Red-necked crake								✓[g]
Slaty-legged crake								x[a]
Sora	✓[c,u]		?[v]	✓[c,r,s]		✓[c,r,s,t]		✓[c,d,e,f,w,x,y]
Virginia rail	✓[c,u]		✓[ae]	✓[c,r]	✓[c,d,ac]	✓[c,r,ad]		✓[c,d,e,f,r,v,w,x,ac,ad]
Water rail								✓[aa]
White-browed crake	✓[a]							
Yellow rail			✓[b]	✓[b]				✓[c,d; ?e]
Number of references	6	2	5	6	6	2	5	22
Reporting rate	5 (11%)	1 (2%)	5 (11%)	3 (7%)	5 (11%)	1 (2%)	5 (11%)	17 (38%)

References: [a] Pratt et al. (1980); [b] Gibbs et al. (1991); [c] Conway & Gibbs (2011); [d] Conway & Nadeau (2010); [e] Ribic et al. (1999); [f] Erwin et al. (2002); [g] Mittermeier et al. (2013); [h] Stiles & Levey (1988); [i] Kerlinger & Wiedner (1991); [j] Repking & Ohmart (1977); [k] Flores & Eddleman 1991 cited in Conway & Gibbs 2011; [l] Conway et al. (2004); [m] Reynard (1974); [n] Spautz et al. (2005); [o] Franklin et al. (1979); [p] Lucindo et al. (2015); [q] Soehren et al. (2009); [r] Johnson & Dinsmore (1986); [s] Robertson & Olsen (2014); [t] Kwartin (1995); [u] Griese et al. (1980); [v] Ripley (1977) ; [w] Lor & Malecki (2002); [x] Allen et al. (2004); [y] Glahn (1974); [z] Barnett et al. (2014); [aa] Jenkins & Ormerod (2002); [ab] Zembal & Massey (1987); [ac] Gibbs & Melvin (1993); [ad] Manci & Rusch (1988); [ae] Kaufmann (1983).

3.5 Interactive variables

Four pairs of interactive variables were reported, three of which involved the time of year (five species, 12 publications; Table 4). These included an interactive effect between time of year (or breeding stage) and calling at different times of the day, which was found for three species (yellow rail, sora and Virginia rail; four publications) and suggested anecdotally for one species (king rail; one publication), as well as interactive effects between time of year and both location (black rail and Virginia rail; five publications) and year (black rail, sora and Virginia rail; six publications). However, since breeding status and stage will always vary among locations and years and are not directly measured in most studies,[2] it is likely that these three interactions are the product of the same factor, i.e. that the daily calling-rate patterns are defined by the breeding status/stage for these species.

The fourth interactive variable involved an observer effect when playback was used with clapper rails (two publications; Table 4). However, as playback was the principle focus of these studies, no independent passive listening data were available for comparison, creating the possibility that this effect was simply a traditional 'observer effect' rather than being dependent on the detection method that was used (i.e. passive or playback). Given the paucity of studies that have modelled the factors that influence calling rates, a wide range of interactions among variables is possible. Therefore, an open mind will be required throughout analysis.

4. Implications for monitoring New Zealand crakes and rails

This review shows that few conclusive studies have been undertaken to identify and quantify the factors that affect the calling rates (and therefore detectability) of crake and rail species. Furthermore, the results that have been obtained by the limited number of studies that do exist have tended to be ambiguous because several factors will affect the calling rate concurrently and may interact, confounding our ability to separate these analytically. For example, Nadeau et al. (2008) found that the calling rate of common moorhens was higher in the morning than in the evening, but also noted that the air temperature was significantly higher in the evening. Furthermore, the same authors also reported that clapper rails had significantly higher calling rates in the morning than at night, but noted cloud cover and wind speed were significantly different between the two time periods (both higher in the morning). Therefore, unless these variables are controlled for through modelling or the sample sizes are particularly large, it will not be possible to determine the importance of these effects and quantify their effect sizes (Williams 2016) – a notion that is supported by the high ambiguity that was observed for environmental effects (which are harder to control for) compared with temporal and interactive effects.

It is speculated that most Rallidae calls function in mate guarding and attraction (Catchpole 2003; Cramp & Simmons cited in Ręk 2015), making it likely that calling rates will fluctuate with reproductive or behavioural factors, as well as other unmeasurable factors that affect breeding status and stage, such as hormone levels (i.e. Ręk 2015) . Therefore, where possible, it would be useful to obtain data regarding the time of year and breeding status/stage to allow these to be accounted for during analysis. However, information on the reproductive status and stage is generally more difficult to obtain than calling rates due to the cryptic nature of the majority of Rallidae, so these factors will have lower reporting rates and be less well understood than environmental and temporal factors. Consequently, where these data are unavailable, time of month should be modelled for New Zealand Rallidae, while keeping in mind the potential for a causal relationship with breeding status and stage.

Options for accounting for variables in monitoring programmes include undertaking repeat counts under standardised conditions and recording relevant variables so that their effects can be corrected for during later analysis. Future research should identify which of the variables identified in this review influence the calling rates and detection probabilities of New Zealand crakes and rails to develop monitoring methods that are most suited to our wetlands. In

[2] The reason for this lack of information regarding breeding status and stage varies between publications but is generally due to difficulties in measuring this covariate or because this was out of scope for the study.

reality, our ability to determine the optimum time for detecting Rallidae calls in New Zealand will depend on the strength of these causal relationships and our ability to represent them meaningfully. This will only be possible using modelling techniques and may require the inclusion of several interactive effects. As such, Table 5 outlines the hypotheses and relationships that are recommended for consideration when modelling the calling rates of Rallidae species in New Zealand based on the findings of this review.

Table 5. Explanatory variables for consideration when modelling the calling rates of New Zealand crake and rail species.

VARIABLE		HYPOTHESES/RELATIONSHIPS TO CONSIDER	RELATIONSHIP TYPE
Time of year	TOY	• Calling peaks during a particular month • Calling peaks during the reproductive season	1. Categorical (fixed) 2. Categorical (fixed)
Time of day	TD	• Calling rate increases in relation to sunrise/sunset times • Calling peaks during a certain time period, e.g. morning, evening, night	1. Polynomial/categorical (fixed) 2. Binomial/categorical (fixed)
Water level	WL	• Calling rate increases with flooding events because nests have failed • Calling rate decreases with flooding events because birds have moved	1. Binomial/linear (fixed) 2. Binomial/linear (fixed)
Rainfall	Rn	• Calling rate is not related to rainfall	1. Linear (fixed)
Cloud cover	Cld	• Calling rate is not related to cloud cover provided moon visibility is also included in the model	1. Linear (fixed)
Moon phase	MPh	• Calling rate increases as the moon approaches the full moon phase	1. Linear (fixed)
Moon visibility	MV	• Calling rate increases when the moon is visible (no cloud) and has risen	1. Linear (fixed)
Wind speed	WS	• Calling rate decreases with increased wind speed	1. Linear (fixed)
Temperature	T	• Calling rate is not related to temperature provided time of day is also included in the model	1. Linear (fixed)
Background noise	Ns	• Calling rate increases as background noise decreases because calls register on sound files better • Calling rate increases as background noise increases because birds give more alarm calls	1. Linear (fixed) 2. Binomial/linear (fixed)
Year	Yr	• Calling rate is not related to year because it is predictable and stable across years	1. Linear (fixed)
Recorder	Rec	• Calling rate does not vary between recording devices (our equivalent of an observer effect)	1. Random

5. Acknowledgements

Thanks to Hugh Robertson and Colin O'Donnell for improving earlier drafts of this manuscript. Funding was provided by the Arawai Kākāriki Wetland Restoration Fund.

6. References

Akhtar, S.; Kabir, M.; Begum, S.; Hasan, M. 2015: Activity pattern of white-breasted waterhen (*Amaurornis phoenicurus*) at Jahangirnagar university campus, Savar, Dhaka, Bangladesh. Bangladesh *Journal of Zoology 41(2)*: 189–198.

Alldredge, M.W.; Pollock, K.H.; Simons, T.R.; Collazo, J.A.; Shriner, S.A. 2007: Time-of-detection method for estimating abundance from point-count surveys. *The Auk 124(2)*: 653–664.

Allen, T.; Finkbeiner, S.L.; Johnson, D.H. 2004: Comparison of detection rates of breeding marsh birds in passive and playback surveys at Lacreek National Wildlife Refuge, South Dakota. *Waterbirds 27(3)*: 277–281.

Ausseil, A.-G.E.; Chadderton, W.L.; Gerbeaux, P.; Stephens, R.T.T.; Leathwick, J.R. 2011: Applying systematic conservation planning principles to palustrine and inland saline wetlands of New Zealand. *Freshwater Biology 56(1)*: 142–161.

Barnett, J.M.; Imberti, S.; Roesler, I. 2014: Distribution and habitat use of the Austral Rail *Rallus antarcticus* and perspectives on its conservation. *Bird Conservation International 24(1)*: 114–125.

Bogner, H.E.; Baldassarre, G.A. 2002: The effectiveness of call-response surveys for detecting least bitterns. *The Journal of Wildlife Management 66(4)*: 976–984.

Brackney, A.; Bookhout, T.A. 1982: Population ecology of common gallinules in southwestern Lake Erie marshes. *Ohio Journal of Science 82(5)*: 229–237.

Brazil, M. 2009: Birds of East Asia: China, Taiwan, Korea, Japan, and Russia. Princeton Field Guides. Christopher Helm, London. Pp. 202–203.

Catchpole, C.K.; Slater, P.J. 2003: Bird song: biological themes and variations. Cambridge University Press, Cambridge. 256 p.

Caughley, G. 1977: Analysis of vertebrate populations. John Wiley and Sons, London. 234 p.

Clarke, R.H.; Oliver, D.L.; Boulton, R.L.; Cassey, P.; Clarke, M.F. 2003: Assessing programs for monitoring threatened species – a tale of three honeyeaters (Meliphagidae). *Wildlife Research 30*: 427–435.

Coates, B.J.; Bishop, K.D. 1997: A guide to the Birds of Wallacea – Sulawesi, The Moluccas and Lesser Sunda Islands, Indonesia. Dove Publications, Alderley, Queensland. 535 p.

Conway, C.J. 2009: Standardized North American marsh bird monitoring protocols. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ. 57 p.

Conway, C.J. 2011: Standardized North American marsh bird monitoring protocol. *Waterbirds 34(3)*: 319–346.

Conway, C.J.; Eddleman, W.R.; Anderson, S.H.; Hanebury, L.R. 1993: Seasonal changes in Yuma clapper rail vocalization rate and habitat use. *The Journal of Wildlife Management 57*: 282–290.

Conway, C.J.; Gibbs, J.P. 2011: Summary of intrinsic and extrinsic factors affecting detection probability of marsh birds. *Wetlands 31(2)*: 403–411.

Conway, C.J.; Nadeau, C.P. 2010: Effects of broadcasting conspecific and heterospecific calls on detection of marsh birds in North America. *Wetlands 30(2)*: 358–368.

Conway, C.J.; Sulzman, C.; Raulston, B.E. 2004: Factors affecting detection probability of California black rails. *The Journal of Wildlife Management 68(2)*: 360–370.

Cromarty, P.; Scott, D. 1996: A directory of wetlands in New Zealand. Department of Conservation, Wellington. 394 p.

Dawson, D.; Efford, M. 2009: Bird population density estimated from acoustic signals. *Journal of Applied Ecology 46(6)*: 1201–1209.

Diefenbach, D.R.; Brauning, D.W.; Mattice, J.A. 2003: Variability in grassland bird counts related to observer differences and species detection rates. *The Auk 120(4)*: 1168–1179.

Erwin, R.; Conway, C.; Hadden, S. 2002: Species occurrence of marsh birds at Cape Cod National Seashore, Massachusetts. *Northeastern Naturalist 9(1)*: 1–12.

Farnsworth, G.L.; Pollock, K.H.; Nichols, J.D.; Simons, T.R.; Hines, J.E.; Sauer, J.R. 2002: A removal model for estimating detection probabilities from point-count surveys. *The Auk 119(2)*: 414–425.

Franklin, A.B.; Clark, D.A.; Clark, D.B. 1979: Ecology and behavior of the Galapagos Rail. *The Wilson Bulletin 91(2)*: 202–221.

Gibbs, J.P.; Melvin, S.M. 1993: Call-response surveys for monitoring breeding waterbirds. *The Journal of Wildlife Management 57(1)*: 27–34.

Gibbs, J.P.; Shriver, W.G.; Melvin, S.M. 1991: Spring and summer records of the Yellow Rail in Maine (Informes de individuos de Coturnicops noveboracensis en Maine durante la primavera y el verano). *Journal of Field Ornithology 62*: 509–516.

Glahn, J.F. 1974: Study of breeding rails with recorded calls in north-central Colorado. *The Wilson Bulletin 86(3)*: 206–214.

Griese, H.J.; Ryder, R.A.; Braun, C.E. 1980: Spatial and temporal distribution of rails in Colorado. *The Wilson Bulletin 92(1)*: 96–102.

Harvey, M.G.; Lane, D.F.; Hite, J.; Terrill, R.S.; Ramirez, S.F.; Smith, B.T.; Klicka, J.; Campos, W.V. 2014: Notes on bird species in bamboo in northern Madre De Dios, Peru, including the first Peruvian record of acre tody-tyrant (*Hemitriccus cohnhafti*). *Occasional Papers Museum of Natural Science Louisiana State University No. 81.* Louisiana State University, Baton Rouge, LA. 38 p.

Jenkins, R.K.; Ormerod, S.J. 2002: Habitat preferences of breeding Water Rail *Rallus aquaticus*. *Bird Study 49(1)*: 2–10.

Johnson, R.R.; Dinsmore, J.J. 1986: The use of tape-recorded calls to count Virginia Rails and Soras. *The Wilson Bulletin 98(2)*: 303–306.

Kaufmann, G.W. 1971: Behavior and ecology of the sora, *Porzana carolina*, and Virginia rail, *Rallus limicola*. Unpublished PhD thesis, University of Minnesota, Minneapolis, MN.

Kaufmann, G.W. 1983: Displays and vocalizations of the Sora and the Virginia Rail. *The Wilson Bulletin 95(1)*: 42–59.

Kaufmann, G.W. 1988: The usefulness of taped Spotless Crake calls as a census technique. *The Wilson Bulletin 100(4)*: 682–686.

Kerlinger, P.; Wiedner, D. 1991: Vocal behavior and habitat use of black rails in south Jersey. *Records of New Jersey Birds 16*: 58–62.

Kwartin, N.B. 1995: Use of audio broadcasts in capture and survey methods for Sora rails (*Porzana carolina*) during migration in the marshes of the upper Patuxent river, MD. Unpublished MSc thesis, University of Maryland, College Park, MD.

Legare, M.L.; Eddleman, W.R.; Buckley, P.A.; Kelly, C. 1999: The effectiveness of tape playback in estimating black rail density. *The Journal of Wildlife Management 63(1)*: 116–125.

Lewthwaite, R. W.; Yu, Y.-t. 2001: Hong Kong Nightbird Survey. *Hong Kong Bird Watching Society 213*.

Lor, S.; Malecki, R.A. 2002: Call-response surveys to monitor marsh bird population trends. *Wildlife Society Bulletin 30(4)*: 1195–1201.

Lucindo, A.d.S.; Antunes, A.Z.; Kanashiro, M.M.; Dias, M.M. 2015: Birds at Santa Bárbara Ecological Station, one of the last Cerrado remnants in the state of São Paulo, Brazil. Biota *Neotropica 15(4)*: e0155.

Manci, K.M.; Rusch, D.H. 1988: Indices to distribution and abundance of some inconspicuous waterbirds on Horicon Marsh (Indices de Distribución y Abundancia de Aves Inconspicuas de Área Anegadiza Horicon). *Journal of Field Ornithology 59*: 67–75.

Mason, A. 1950: The behaviour of Corncrakes. *British Birds 43*: 70–78.

Mittermeier, J.C.; Cottee-Jones, H.E.W.; Purba, E.C.; Ashuri, N.M.; Hesdianti, E.; Supriatna, J. 2013: A survey of the avifauna of Obi island North Moluccas Indonesia. *Forktail 29*: 128–137.

Mougeot, F.; Bretagnolle, V. 2000: Predation risk and moonlight avoidance in nocturnal seabirds. *Journal of Avian Biology 31(3)*: 376–386.

Nadeau, C.P.; Conway, C.J.; Smith, B.S.; Lewis, T.E. 2008: Maximizing detection probability of wetland-dependent birds during point-count surveys in northwestern Florida. Wilson *Journal of Ornithology 120(3)*: 513–518.

O'Donnell, C.F.J.; Clapperton, B.K.; Monks, J.M. 2015: Impacts of introduced mammalian predators on indigenous birds of freshwater wetlands in New Zealand. *New Zealand Journal of Ecology 39(1)*: 19–33.

O'Donnell, C.F.J.; Williams, E.M. 2015: Protocols for the inventory and monitoring of populations of the endangered Australasian bittern (*Botaurus poiciloptilus*) in New Zealand. *Department of Conservation Technical Series 38*. Department of Conservation, Wellington. 40 p.

O'Donnell, C.F.J.; Williams, E.M.; Cheyne, J. 2013: Close approaches and acoustic triangulation: techniques for mapping the distribution of booming Australasian bittern (*Botaurus poiciloptilus*) on small wetlands. *Notornis 60(4)*: 279–284.

Phillipps, Q.; Phillipps, K. 2011: Phillips' field guide to the birds of Borneo. John Beaufoy Publishing, Oxford. 370 p.

Polak, M. 2005: Temporal pattern of vocal activity of the Water Rail *Rallus aquaticus* and the Little Crake *Porzana parva* in the breeding season. *Acta Ornithologica 40(1)*: 21–26.

Pratt, H.D.; Engbring, J.; Bruner, P.L.; Berrett, D.G. 1980: Notes on the taxonomy, natural history, and status of the resident birds of Palau. The Condor: *Ornithological Applications 82(2)*: 117–131.

Ręk, P. 2015: High functional complexity despite an extremely small repertoire of calls in the Spotted Crake (*Porzana porzana*). *The Auk 132(3)*: 613–623.

Renaudier, A.; de Guyane, C. 2010: Rare birds in French Guiana in 2005–07. *Cotinga 32*: 75–83.

Repking, C.F. 1975: Distribution and habitat requirements of the black rail (*Laterallus jaimacensis*), along the lower Colorado River. Unpublished MSc thesis, Arizona State University, Tempe, AZ.

Repking, C.F.; Ohmart, R.D. 1977: Distribution and density of black rail populations along the lower Colorado River. *The Condor: Ornithological Applications 79(4)*: 486–489.

Reynard, G.B. 1974: Some vocalizations of the Black, Yellow, and Virginia Rails. *The Auk 91(4)*: 747–756.

Ribic, C.A.; Lewis, S.J.; Melvin, S.; Bart, J.; Peterjohn, B. 1999: Proceedings of the Marsh Bird Monitoring Workshop. U.S. Fish and Wildlife Service, Laurel, MD. 52 p.

Ripley, S.D. 1977: Rails of the world: A monograph of the family Rallidae. Toronto, Canada: M.R. Feheley Publishers Limited.

Robertson, E.P.; Olsen, B.J. 2014: Density, sex, and nest stage affect rail broadcast survey results. *The Journal of Wildlife Management 78(7)*: 1293–1301.

Robson, C. 2015: Birds of South-East Asia: Concise Edition. Bloomsbury Publishing. 304 p.

Royle, J.A.; Nichols, J.D. 2003: Estimating abundance from repeated presence-absence data or point counts. *Ecology 84(3)*: 777–790.

Smith, P.; del Castillo, H.; Batjes, H.; Montiel, M.; Wainwright, B. 2005: An avifaunal inventory of Estancia Laguna Blanca, departamento San Pedro, northeastern Paraguay. FAUNA Paraguay Technical Publication No. 2. FAUNAParaguay. Paraguay.

Soehren, E.C.; Tucker Jr, J.W.; Crow, D.G. 2009: Effectiveness of call-broadcast surveys for breeding marsh birds along coastal Alabama. *Southeastern Naturalist 8(2)*: 277–292.

Spautz, H.; Nur, N.; Stralberg, D. 2005: California Black Rail (*Laterallus jamaicensis coturniculus*) distribution and abundance in relation to habitat and landscape features in the San Francisco Bay Estuary. Pp. 465–468 in Ralph, C.J.; Rich, T.D. (Eds): Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference. March 20–24 2002, Asilomar, California, Volume 1 Gen. Tech. Rep. PSW-GTR-191. U.S. Deparment of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Spear, L.B.; Terrill, S.B.; Lenihan, C.; Delevoryas, P. 1999: Effects of temporal and environmental factors on the probability of detecting California Black Rails (Efectos de los Factores Temporales y Ambientales en la Probabilidad de Detectar Individuos de *Laterallus jamaicensis coturniculus*). *Journal of Field Ornithology 70(4)*: 465–480.

Stevenson, B.C.; Borchers, D.L.; Altwegg, R.; Swift, R.J.; Gillespie, D.M.; Measey, G.J. 2015: A general framework for animal density estimation from acoustic detections across a fixed microphone array. *Methods in Ecology and Evolution 6(1)*: 38–48.

Stiles, F.G.; Levey, D.J. 1988: The Gray-Breasted Crake (*Laterallus exilis*) in Costa Rica: vocalizations, distribution, and interactions with White-Throated Crakes (*L. albigularis*). The Condor: *Ornithological Applications 90(3)*: 607–612.

Taylor, B. 1998: Rails: a guide to the rails, crakes, gallinules and coots of the world. Yale University Press, New Haven. 600 p.

Tecklin, J. 1999: Distribution and abundance of the California black rail (*Laterallus jamaicensis coturniculus*) in the Sacramento valley region with accounts of ecology and call behavior of the subspecies. Draft report for the California Department of Fish and Game, Contract Nos. FG6154WM and FG6154-1WM.

Teixeira, D.M.; Puga, M. 1984: Notes on the speckled crake (*Coturnicops notata*) in Brazil. The Condor: *Ornithological Applications 86(3)*: 342–343.

Williams, E.M. 2016: Developing monitoring methods for cryptic species: a case study of the Australasian bittern, *Botaurus poiciloptilus*. Unpublished PhD thesis, Massey University, Palmerston North. 239 p

Williams, E.M.; Armstrong, D.P.; O'Donnell, C.F.J. 2018: Modelling variation in calling rates to develop a reliable monitoring method for the Australasian Bittern *Botaurus poiciloptilus*. *Ibis 161(2)*: 260–271. doi: 10.1111/ibi.12611

Wilson, M.D.; Watts, B.D. 2006: Effect of moonlight on detection of Whip-poor-wills: implications for long-term monitoring strategies. *Journal of Field Ornithology 77(2)*: 207–211.

Zembal, R.; Massey, B. 1981: A census of the light-footed clapper rail in California. *Western Birds 12(2)*: 87–99.

Zembal, R.; Massey, B.W. 1987: Seasonality of vocalizations by Light-Footed Clapper Rails (Estacionalidad en la vocalización de Rallus *Longirostris levipes*). *Journal of Field Ornithology 58(1)*: 41–48.

Appendix 1

Scientific name and IUCN classification of the species examined

The following table lists the scientific names and the International Union of Conservation of Nature (IUCN) Red List classifications of the 137 Rallidae species that were examined to determine factors affecting calling rate. Note that the taxonomy of many Rallidae species is currently under review, which are reported as 'Not recognised by IUCN'.

COMMON NAME	SCIENTIFIC NAME	CLASSIFICATION
African crake	*Crex egregia*	Least Concern
African rail	*Rallus caerulescens*	Least Concern
African swamphen	*Porphyrio madagascariensis*	Not recognised by IUCN
Allen's gallinule / lesser gallinule	*Porphyrio alleni* (formerly *Porphyrula alleni*)	Least Concern
American coot	*Fulica Americana*	Least Concern
American purple gallinule	*Porphyrio martinicus*	Least Concern
Andaman crake	*Rallina canningi*	Least Concern
Andean coot	*Fulica ardesiaca*	Least Concern
Ash-throated crake	*Porzana albicollis*	Least Concern
Auckland rail	*Lewinia muelleri*	Vulnerable
Austral rail	*Rallus antarcticus*	Vulnerable
Australasian swamphen	*Porphyrio melanotus*	Not recognised by IUCN
Australian spotted crake	*Porzana fluminea*	Least Concern
Azure gallinule	*Porphyrio flavirostris*	Least Concern
Band-bellied crake	*Zapornia paykullii*	Near Threatened
Bare-eyed rail	*Gymnocrex plumbeiventris*	Least Concern
Barred rail	*Hypotaenidia torquata*	Least Concern
Black crake	*Zapornia flavirostra*	Least Concern
Black rail	*Laterallus jamaicensis*	Near Threatened
Black-backed swamphen	*Porphyrio indicus*	Not recognised by IUCN
Black-banded crake	*Porzana fasciata*	Least Concern
Blackish rail	*Pardirallus nigricans*	Least Concern
Black-tailed crake	*Zapornia bicolor*	Least Concern
Black-tailed native-hen	*Tribonyx ventralis*	Least Concern
Blue-faced rail / bald-faced rail	*Gymnocrex rosenbergii*	Vulnerable
Bogotá rail	*Rallus semiplumbeus*	Endangered
Brown crake	*Zapornia akool*	Least Concern
Brown wood-rail	*Aramides wolfi*	Vulnerable
Brown-banded rail	*Lewinia mirifica*	Data Deficient
Buff-banded rail	*Hypotaenidia philippensis*	Least Concern
Calayan rail	*Gallirallus calayanensis*	Vulnerable
Chestnut forest-rail	*Rallicula rubra*	Least Concern
Chestnut rail	*Eulabeornis castaneoventris*	Least Concern
Chestnut-headed crake	*Rufirallus castaneiceps*	Least Concern
Clapper rail	*Rallus crepitans*	Least Concern
Colombian crake	*Neocrex colombiana*	Data Deficient
Common gallinule	*Gallinula galeata*	Not recognised by IUCN
Common moorhen	*Gallinula chloropus*	Least Concern
Corncrake	*Crex crex*	Least Concern
Dot-winged crake	*Porzana spiloptera*	Vulnerable
Dusky moorhen	*Gallinula tenebrosa*	Least Concern

Continued on next page

Appendix 1 continued

COMMON NAME	SCIENTIFIC NAME	CLASSIFICATION
Eastern water rail	*Rallus indicus*	Least Concern
Eurasian coot / common coot	*Fulica atra*	Least Concern
Forbes's forest-rail	*Rallicula forbesi*	Least Concern
Galapagos rail	*Laterallus spilonota*	Vulnerable
Giant coot	*Fulica gigantea*	Least Concern
Giant wood-rail	*Aramides ypecaha*	Least Concern
Gough moorhen	*Gallinula comeri*	Vulnerable
Grey-breasted crake	*Laterallus exilis*	Least Concern
Grey-headed swamphen	*Porphyrio poliocephalus*	Not recognised by IUCN
Grey-necked wood-rail	*Aramides cajaneus*	Least Concern
Grey-throated rail	*Canirallus oculeus*	Least Concern
Guadalcanal rail	*Hypotaenidia woodfordi*	Near Threatened
Guam rail	*Hypotaenidia owston*i	Extinct in the Wild
Hawaiian coot / ʻAlae keʻokeʻo	*Fulica alai*	Vulnerable
Henderson crake	*Zapornia atra*	Vulnerable
Horned coot	*Fulica cornuta*	Near Threatened
Inaccessible Island rail	*Atlantisia rogersi*	Vulnerable
Invisible rail / Wallace's rail / drummer rail	*Habroptila wallacii*	Vulnerable
Isabelline bush-hen	*Amaurornis isabellina*	Least Concern
Junin rail	*Laterallus tuerosi*	Endangered
King rail	*Rallus elegans*	Near Threatened
Lesser moorhen	*Gallinula angulate*	Least Concern
Lewin's rail	*Lewinia pectoralis*	Least Concern
Little crake	*Zapornia parva*	Least Concern
Little wood-rail	*Aramides mangle*	Least Concern
Lord Howe woodhen	*Hypotaenidia sylvestris*	Endangered
Madagascar rail	*Rallus madagascariensis*	Vulnerable
Madagascar wood-rail	*Mentocrex kioloides*	Least Concern
Mangrove rail	*Rallus longirostris*	Least Concern
Marsh crake (Baillon's crake)	*Porzana pusilla / Zapornia pusilla*	Least Concern
Mayr's forest-rail	*Ralicula mayri*	Least Concern
Mexican rail	*Rallus tenuirostris*	Near Threatened
New Britain rail / pink-legged rail	*Hypotaenidia insignis*	Near Threatened
New Caledonian rail	*Gallirallus lafresnayanus*	Critically Endangered
New Guinea flightless rail / Papuan flightless rail	*Megacrex inepta*	Least Concern
Nkulengu rail	*Himantornis haematopus*	Least Concern
Ocellated crake	*Micropygia schomburgkii*	Least Concern
Okinawa rail	*Hypotaenidia okinawae*	Endangered
Paint-billed crake	*Neocrex erythrops*	Least Concern
Pale-vented bush-hen / rufous-tailed bush-hen / rufous-tailed waterhen	*Amaurornis moluccana*	Least Concern
Philippine bush-hen	*Amaurornis olivacea*	Least Concern
Philippine swamphen	*Porphyrio pulverulentus*	Not recognised by IUCN
Plain-flanked rail	*Rallus wetmorei*	Endangered
Plumbeous rail	*Pardirallus sanguinolentus*	Least Concern
Purple swamphen	*Porphyrio porphyrio*	Least Concern
Red-and-white crake	*Laterallus leucopyrrhus*	Least Concern
Red-fronted coot	*Fulica rufifrons*	Least Concern
Red-gartered coot	*Fulica armillata*	Least Concern
Red-knobbed coot	*Fulica cristata*	Least Concern

Continued on next page

Appendix 1 continued

COMMON NAME	SCIENTIFIC NAME	CLASSIFICATION
Red-legged crake	*Rallina fasciata*	Least Concern
Red-necked crake	*Rallina tricolor*	Least Concern
Red-winged wood-rail	*Aramides calopterus*	Least Concern
Ridgway's rail	*Rallus obsoletus*	Near Threatened
Rouget's rail	*Rougetius rougetii*	Near Threatened
Roviana rail	*Hypotaenidia rovianae*	Near Threatened
Ruddy crake	*Laterallus ruber*	Least Concern
Ruddy-breasted crake	*Zapornia fusca*	Least Concern
Rufous-faced crake	*Laterallus xenopterus*	Vulnerable
Rufous-necked wood-rail	*Aramides axillaris*	Least Concern
Rufous-sided crake	*Laterallus melanophaius*	Least Concern
Russet-crowned crake	*Rufirallus viridis*	Least Concern
Rusty-flanked crake	*Laterallus levraud*i	Vulnerable
Sakalava rail	*Zapornia olivieri*	Endangered
Sharpe's rail	*Gallirallus sharpei*	Not recognised by IUCN
Slaty-breasted rail	*Lewinia striata*	Least Concern
Slaty-breasted wood-rail	*Aramides saracura*	Least Concern
Slaty-legged crake	*Rallina eurizonoides*	Least Concern
Snoring rail / Celebes rail / Platen's rail	*Aramidopsis plateni*	Vulnerable
Sora	*Porzana carolina*	Least Concern
Speckled crake	*Coturnicops notatus*	Least Concern
Spot-flanked gallinule	*Gallinula melanops*	Least Concern
Spotless crake	*Zapornia tabuensis/ Porzana tabuensis*	Critically Endangered
Spotted crake	*Porzana porzana*	Least Concern
Spotted rail	*Pardirallus maculatus*	Least Concern
Striped crake	*Amaurornis marginalis*	Least Concern
Swinhoe's rail	*Coturnicops exquisitus*	Vulnerable
Takahē / South Island takahē	*Porphyrio hochstetteri*	Endangered
Talaud bush-hen	*Amaurornis magnirostris*	Vulnerable
Talaud rail	*Gymnocrex talaudensis*	Endangered
Tasmanian native-hen	*Tribonyx mortierii*	Least Concern
Tsingy wood-rail	*Mentocrex beankaensis*	Near Threatened
Uniform crake	*Amaurolimnas concolor*	Least Concern
Virginia rail	*Rallus limicola*	Least Concern
Watercock	*Gallicrex cinereal*	Least Concern
Weka	*Gallirallus australis*	Vulnerable
Western water rail	*Rallus aquaticus*	Least Concern
White-breasted waterhen	*Amaurornis phoenicurus*	Least Concern
White-browed crake	*Amaurornis cinerea*	Least Concern
White-striped forest-rail	*Rallicula leucospila*	Near Threatened
White-throated crake	*Laterallus albigularis*	Least Concern
White-throated rail / Cuvier's rail	*Dryolimnas cuvieri*	Least Concern
White-winged coot	*Fulica leucoptera*	Least Concern
Yellow rail	*Coturnicops noveboracensis*	Least Concern
Yellow-breasted crake	*Hepalocrex flaviventer*	Least Concern
Zapata rail	*Cyanolimnas cerverai*	Critically Endangered