

## Research Article

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# Frigatebirds *Fregata*: impacts of potential taxonomic change on population and conservation status

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## Summary

Frigatebirds have been in taxonomic oblivion for nearly a century. A new genetic study by Martins *et al.* (2022) provides a stimulus and potential basis for a long-overdue modern review, which might lead to recognition of up to five new species-level taxa, two of which would be “Critically Endangered” globally and may already be effectively extinct. Even some of the more widespread frigatebird taxa are subject to multiple anthropogenic threats and, outside strictly protected and managed areas, may already be in serious decline. Seabird experts and organisations need urgently to review all available data relevant to frigatebird taxonomy and populations, collect additional material for genetic analysis, undertake new assessments of conservation status, and (in collaboration with appropriate regulatory authorities) propose and execute appropriate conservation and management actions.

## Introduction

The paper by Martins *et al.* (2022) provides the first genetic phylogeny for the whole family Fregatidae, and thus a basis for starting a modern comprehensive re-assessment of the taxonomy and status of frigatebirds. The present paper is intended as a first step towards this, with recommendations for potential research and conservation initiatives.

This monogeneric family is one of the most conservative, in terms of plumage and structure, amongst seabirds. Despite this, pioneering investigation, especially by Mathews (1914) and Lowe (1924), described nearly 20 taxa, often based on quite subtle differences, later consistently grouped into five species, two of which (*Fregata andrewsi*, *F. aquila*) are monotypic (and endemic to single islands). Subsequently, several of the subspecies allocated to the other three species were no longer recognised (but without critical study) and recent authorities (e.g. Dickinson and Remsen 2013, del Hoyo and Collar 2014, Gill and Donsker 2019) treated *F. ariel* to comprise three subspecies, *F. minor* to comprise five subspecies, and *F. magnificens* to comprise one to three subspecies.

More recently, increasing appreciation of geographical variation in plumage and measurements, allied to genetic data for *F. magnificens* (Hailer *et al.* 2010, Rocha-Olivares and González-Jaramillo 2014, Nuss *et al.* 2016), promoted re-evaluation of some taxa, with proposals to elevate *F. ariel trinitatis* and *F. magnificens rothschildi* to species rank (Olson 2017, Rasmussen 2020). Although these proposals have not been widely supported (to date), the genetic data now available in Martins *et al.* (2022) enable a fresh assessment, especially as they support the above proposals and indicate that several additional taxa merit recognition at some level.

To be fully convincing, a new assessment would doubtless need to review morphological and phenetic characteristics (including bill/eye-ring colour) in conjunction with behavioural and vocal evidence, and evaluate these in the light of the arrangements suggested by mitochondrial DNA (mtDNA) data. Some taxonomic and/or nomenclatural issues will need additional (ideally nuclear) genetic data to resolve, especially in the *F. minor* complex.

Nevertheless, the new genetic data alone allow new hypotheses to be proposed. Below I suggest two potential arrangements, one (in brief, at the end) intended to provide an interim position, with minimal changes to current taxonomy (i.e. no new species proposed); the other (in more detail, below) to reflect the likely need to recognise new species.

These arrangements affect neither *F. andrewsi* Mathews, 1914 (endemic to Christmas I., Indian Ocean and sister to the *F. minor* group) nor *F. aquila* Linnaeus, 1758 (endemic to Ascension I, central South Atlantic Ocean and sister to the *F. magnificens* group), both of which are already assessed as “Vulnerable” under International Union for Conservation of Nature (IUCN) criteria.

The phylogeny derived from mtDNA fragments by Martins *et al.* (2022) is appended (Figure 1). Sample sites and sample sizes below relate to that study, which included virtually all samples used by Hailer *et al.* (2010) and all sites (but only about half of the samples) used by Nuss *et al.* (2016), unless otherwise indicated.

To complement the review of potential taxonomic implications, I summarise data on population size (in the species accounts below and in [Supplementary material A, Tables S1–S4](#)) for all currently (or recently) known breeding sites. These data, especially any evidence for recent (last c.50 years) population change, are used to inform likely conservation status for all taxa recognised. A concluding section makes recommendations for potential priority research and conservation initiatives.

### Potential progressive taxonomy and status

Type localities are cited exactly as stated in the original description; any additional clarification is in parentheses.

***Fregata magnificens*** Mathews, 1914 [Galapagos] Magnificent Frigatebird

**Type locality:** Barrington Island [Isla Santa Fe], Galapagos Archipelago [Ecuador].

**Breeding range:** Galapagos Archipelago: nowadays (Coulter 1984) essentially restricted to Genovesa (Tower), San Cristobal (Chatham), Isabela (Albemarle), Seymour Norte (North Seymour).

**Breeding population:** 1,000 pairs (Coulter 1984, Cepeda and Cruz 1994).

**Genetic sampling:** North Seymour I. [Isla Seymour Norte], Galapagos I ( $n = 20$ ; Hailer *et al.* 2010).

**Taxonomic status:** Treated as monotypic by Dickinson and Remsen (2013) and Gill and Donsker (2019), whereas del Hoyo and Collar (2014) recognise subspecies *rothschildi* and *lowei* (see below). Hailer *et al.* (2010) showed that *F. m. magnificens* has complete genetic differentiation from *F. (m.) rothschildi* of “mainland” Central and South America, with a divergence time of “probably ... several hundred thousand years”. Significantly larger than *F. (m.) rothschildi* in several measurements (Hailer *et al.* 2010). In terms of recognising *F. magnificens* and *F. rothschildi* as distinct species, the genetic data are surely decisive, especially in the light of the different patterns of gene flow shown by populations of *F. m. rothschildi* from Mexico (Rocha-Olivares and González-Jaramillo 2014) and Panama. Although this view (Rasmussen 2020) did not prevail with the South American Classification Committee (SACC), that group contained no seabird experts and its stated reasons for rejection are questionable (see [Supplementary material B](#)). The new overall phylogeny for the genus (Martins *et al.* 2022) would also support species status for both taxa.

**Conservation status:** As a taxon endemic to the Galapagos Is, with breeding restricted to a small number of sites and with a population estimate of only 1,000 pairs, based on data now 40 years old, a new evaluation of the local conservation status of this species would seem rather important. Any evidence of population decline and/or actual or potential threats might well result in “Vulnerable” status under IUCN criteria.

***Fregata januarua*** Miranda-Ribeiro, 1919 [Brazilian] Magnificent Frigatebird

**Type locality:** Between Rio de Janeiro and Santos [eastern Brazil].

**Breeding range:** Coastal eastern Brazil from Moleques do Sul Is (Santa Catarina) north to Cabo Frio and the Santana Archipelago (Rio de Janeiro) and the Abrolhos Is; Fernando de Noronha Archipelago. Hybridises (shares haplotypes) with *F. (m.) rothschildi* at Île du Grand Connétable (Guyane/French Guiana). As Antas (1991) noted, there are no records of breeding colonies on the north or

north-east coasts of Brazil and thus a substantial gap (c.2,400 km) to the Grand Connétable colony.

**Breeding population:** Based on Antas (1991), Diamond and Schreiber (2002, 2020) estimated c.3,300–3,500 pairs. However, more recent data from: (1) Mancini *et al.* (2016) for the Abrolhos Is (330–427 pairs in 2012) and Sela Gineta, Fernando de Noronha Archipelago (215 pairs in 1992); (2) Goldberg *et al.* (2021) for Cagarra/Redondo Is (c.2,640 pairs) and Jorge Grego Is (756 individuals); (3) Muscat *et al.* (2014) for the Alcatrazes Archipelago (7,000 individuals and 2,500 nests in 2014, compared with 250 nests in 1920) suggest that the current breeding population may be 6,000–7,000 pairs.

**Genetic sampling:** Nuss *et al.* (2016)/Martins *et al.* (2022): Grand Connétable ( $n = 37/14$ ); Fernando de Noronha ( $n = 8$ ; Martins *et al.* 2022 only); Abrolhos ( $n = 18/7$ ); Cabo Frio ( $n = 14/6$ ); Cagarras ( $n = 9/6$ ); Alcatrazes ( $n = 18/7$ ); Currais (9/9); Moleques do Sul (22/8); also (Martins *et al.* 2022) Rio de Janeiro ( $n = 8$ ) and Sao Paulo ( $n = 9$ ).

**Taxonomic status:** This taxon has seldom, if ever, been recognised as a valid subspecies, let alone a cryptic potential species, since its original description and its subsequent treatment by Murphy (1936) as identical to *F. m. rothschildi*.

However, based on mtDNA (Martins *et al.* 2022), it is sister (with strong, i.e. 0.92, support) to the rest of the *F. magnificens* complex (i.e. *F. magnificens*+*F. rothschildi*). Moreover, Nuss *et al.* (2016) found “no mtDNA haplotype sharing between the Brazilian and Caribbean populations, indicating, at least based on mtDNA, that these populations are effectively isolated”. The colony at Grand Connétable (Guyane/French Guiana), apparently the only recorded breeding site between Tobago (south-easternmost Caribbean) and Fernando de Noronha (Diamond and Schreiber 2002, 2020), showed a mixture of the unique haplotypes characteristic of each of the Caribbean (*rothschildi*) and Brazilian (*januarua*) taxa, suggesting they intermix/hybridise there.

These results, showing no mtDNA sharing, except at the only site where the two taxa meet, should be sufficient to restore subspecies rank to *januarua*. Its recognition as a species may be appropriate but needs to include a critical comparison with *F. rothschildi* of plumage, bare part characteristics, and morphometrics. Confirmation with nuclear genetic data would also be valuable.

**Conservation status:** Antas (1991) did not regard this taxon as having significant conservation problems in Brazil, and this might still be the case. However, with the recognition that the taxon is endemic to Brazil, the susceptibility of frigatebirds to disturbance and loss of breeding habitat and the small number of important breeding sites (c.10, with two sites, Cagarra/Redondo Is and Alcatrazes Archipelago, holding three-quarters of the total), a reappraisal of its status would seem timely. Note that the substantial increase at Alcatrazes is attributed mainly to strict and effective enforcement of no public access (Olmos *et al.* 1995, Muscat *et al.* 2014); other sites may enjoy less effective protection and face increasing pressures.

***Fregata rothschildi rothschildi*** Mathews, 1915 [Caribbean] Magnificent Frigatebird

**Type locality:** Aruba [Leeward Antilles, southern Caribbean].

**Breeding range:** Islands of Gulf of Mexico east to Dry Tortugas, Bahamas, and Caribbean Sea, east to Trinidad and Tobago and the Guianas; Pacific coast of Central and South America in Mexico, Costa Rica, Panama, Colombia, and southern Ecuador (note that it breeds very locally in its Pacific range).

**Breeding population:** Nominally 60,000–72,000 pairs, comprising: Mexico; three sites with 51,000–61,000 pairs in late 1980s (Everett and Anderson 1991, Diamond and Schreiber 2002, 2020); however, this does not take account of the decrease of the Baja California population from 20,000+ pairs in 1986–1987 to 1,300 pairs in 2015–2017 (Marrón *et al.* 2021); Panama; c.2,200 pairs at four to five sites, with 1,300 pairs at Isla Iguana and c.900 pairs at three other sites in the Gulf of Panama in 2005–2006 (Angehr and Kushlan 2007; see also the Annex to [Supplementary material, Appendix B](#)); Colombia – a few pairs only; Ecuador; c.1,500 pairs at two sites in early 1990s (Ridgely and Greenfield 2001); Caribbean; c.8,000 pairs in c.1980 (van Halewyn and Norton 1984); 6,100–6,900 pairs in 2005 (Bradley and Norton 2009). Nowadays, the overall population most unlikely to exceed 40,000–45,000 pairs.

**Genetic sampling:** **Atlantic:** Mexico (Contoy I.,  $n = 29$ ; Rocha-Olivares and González-Jaramillo 2014); Belize (Halfmoon Caye,  $n = 13$ ; Man O'War Caye,  $n = 24$ ); Florida (Dry Tortugas,  $n = 29$ ); Bahamas ( $n = 29$ ); Cayman Is (Little Cayman,  $n = 30$ ); Jamaica ( $n = 30$ ); British Virgin Is ( $n = 21$ ); Barbuda ( $n = 7$ ; Nuss *et al.* 2016); French Guiana (Grand Connétable,  $n = 37$ ; Nuss *et al.* 2016),  $n = 14$ ; Martins *et al.* 2022). **Pacific:** Mexico (Baja California,  $n = 1$ ; Isla Santa Margarita,  $n = 29$ ; Tunitas,  $n = 27$ ; Isabel,  $n = 17$ ; last three all Rocha-Olivares and González-Jaramillo 2014); Mazatlan,  $n = 4$ ); Panama (Isla Iguana,  $n = 25$ ; Pearl Is,  $n = 3$ ; Panama Bay Is,  $n = 4$ ); Colombia ( $n = 1$ ). Sampling locations (from Hailer *et al.* 2010) are shown in [Supplementary material B](#).

**Taxonomic status:** Lumped with *F. m. magnificens* by Dickinson and Remsen (2013) and Gill and Donsker (2019), but treated as a distinct subspecies by del Hoyo and Collar (2014) and Gill *et al.* (2023). Martins *et al.* (2022) show as sister taxon/species to *F. (rothschildi) lowei* (see below) and jointly sister to *F. magnificens*. Evidence of appreciable gene flow between Pacific and Atlantic populations (see especially Rocha-Olivares and González-Jaramillo 2014), with little evidence of population structure.

Best treated as either a monotypic species or, preferably, with *F. m. lowei* as a subspecies (see below).

**Conservation status:** On the basis of its large population and wide distribution, “Least Concern” might still be appropriate (even with the exclusion of the Galapagos and Brazilian taxa). However, the Caribbean population decreased by c.25% over c.25 years (Bradley and Norton 2009), and with continuing extirpations in this region (see table in Diamond and Schreiber 2002, 2020), “Near Threatened” might be more realistic. The current status of the Mexican population (c.80% of total) is key to any reassessment. It is of great concern, therefore, that the population breeding in Baja California has declined by c.95% (from c.20,000 pairs to c.1,300 pairs) over the last 30 years (Marrón *et al.* 2021). New data for the other two main sites in Mexico and a new assessment of overall conservation status is thus an urgent priority.

*Fregata rothschildi lowei* Bannerman, 1927 [Cabo Verde] Magnificent Frigatebird

**Type locality:** Boavista, Cape Verde Islands [Cabo Verde, east-central Atlantic Ocean].

**Breeding range:** Endemic to Cabo Verde [Cape Verde Is]; once more widespread in the archipelago, then restricted to [Ilhéu de] Baluarte and [Ilhéu de] Curral Velho, off Boa Vista (Hazevoet 1995).

**Breeding population:** None currently. 10–12 pairs in 1965 (de Naurois 1969, le Grand *et al.* 1984); no more than five pairs 1988–1992 (Hazevoet 1995). Seven consecutive seasons (1999–

2006) of reproductive failure at Baluarte and Curral Velho marked the apparent effective breeding extinction of this taxon, with a total population in 2005–2006 of four to five adult individuals (Lopez-Suarez *et al.* 2007), reducing to two birds (one of each sex) with the male being seen on a nest in 2012 but the female found dead in October 2012 (López Suárez *et al.* 2012).

**Genetic sampling:** Martins *et al.* (2022):  $n = 16$  (Boa Vista,  $n = 12$ ; Curral Velho,  $n = 2$ ; Baluarte,  $n = 1$ ; Lagoa I., Santiago,  $n = 1$ ).

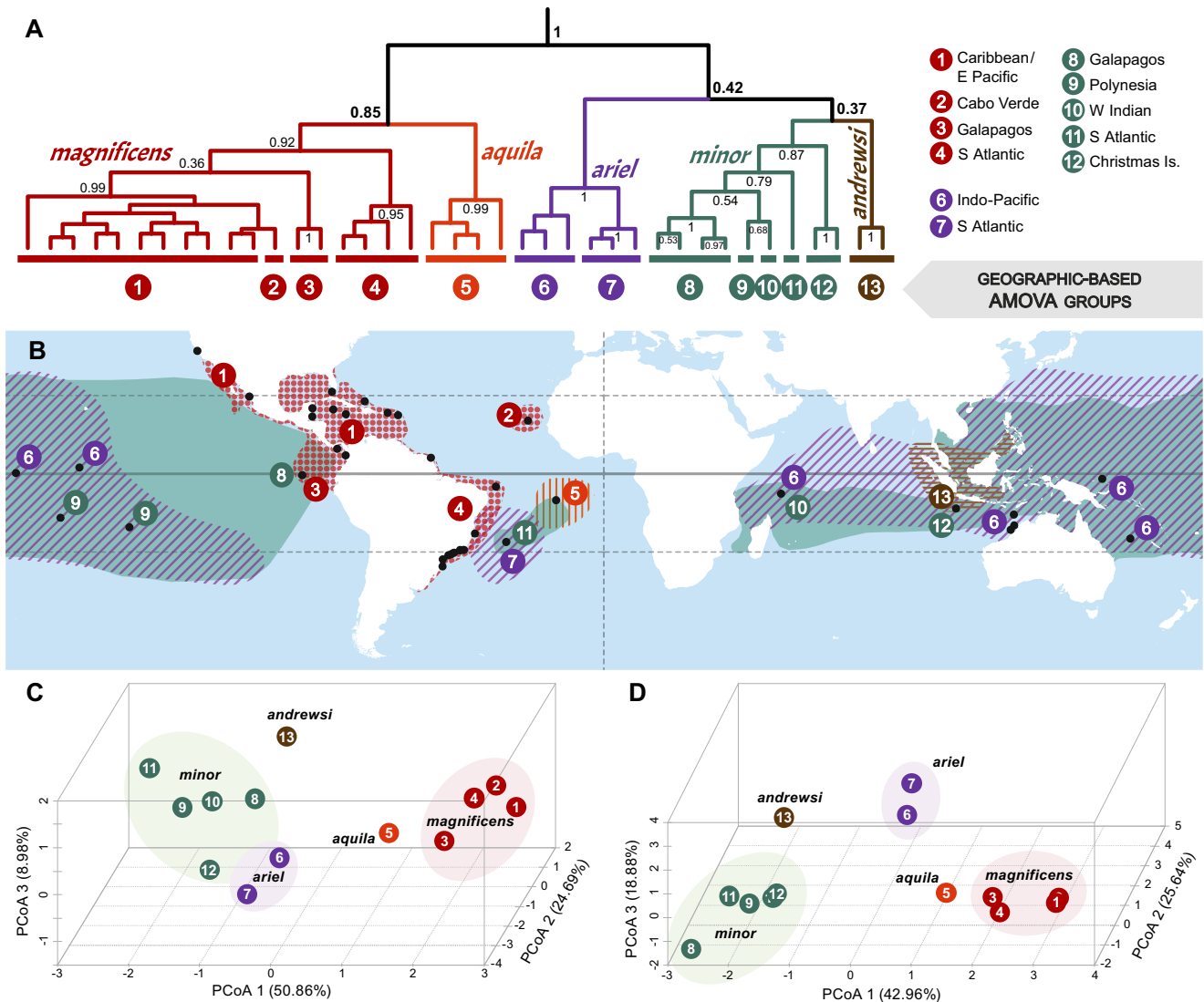
**Taxonomic status:** Recognised as a distinct subspecies of *F. magnificens* by del Hoyo and Collar (2014); other authorities explicitly or implicitly include within *F. m. rothschildi* or a monotypic *F. magnificens*. The genetic samples associate *lowei* with the *F. rothschildi* element of the *F. magnificens* complex. They are in a distinct (but poorly supported) subclade with some samples from Mexico and Panama, sister to the rest of *rothschildi*. However the *lowei* samples are almost completely (94%) distinct in respect of mtDNA, just one specimen having a haplotype shared with another population.

Bannerman (1927) and his contemporaries (e.g. Lowe, Rothschild) had no doubt that a distinctive frigatebird occurred at the Cape Verde Is, characterised by larger size (especially bill) and female breast-pattern. However, Hazevoet (1995) could find no diagnostic characters in 15 specimens he examined (almost certainly those at the American Museum of Natural History and Yale Peabody Museum); he also stated “there is considerable overlap, however, in measurement data obtained from different populations”. The basis (data) for this is unclear but is different from that of Hailer *et al.* (2010) who found significant differences in measurements between *magnificens* and *rothschildi*. A fresh critical reappraisal of measurement and plumage characters of *lowei*, in comparison with *rothschildi*, would be highly desirable. Notwithstanding, the genetic data alone should be sufficiently decisive for retaining (del Hoyo and Collar 2014) or restoring *lowei* as a subspecies.

**Conservation status:** “Long-term overexploitation ever since the archipelago was first colonised in the mid-15th century is likely the key factor behind the decline in population numbers ... of Cape Verde’s seabirds, particularly shearwaters, boobies, tropicbirds and frigatebirds” (López-Suárez *et al.* 2007). See also Hazevoet (1994).

The Magnificent Frigatebird was listed as “Critically Endangered” in the first Red List of Cape Verde (Hazevoet 1996). Baluarte and Curral Velho are legally protected areas (Integral Reserves), with access subject to special permit and restricted to scientific purposes. The area of Curral Velho, including the islet, is also a designated site under the Ramsar Convention (López-Suárez *et al.* 2007). However, López-Suárez *et al.* (2007) note that “despite some improvements in the environmental legislation and the adhesion to international treaties to protect Cape Verde biodiversity during recent years, large numbers of seabirds and sea turtles continue to be illegally harvested. Law enforcement and public awareness are deficient and there still exists a considerable degree of permissiveness among the environmental authorities”.

López Suárez *et al.* (2012) conclude, on the basis of the evidence summarised above under “Breeding population” that the Magnificent Frigatebird of Cabo Verde is now effectively extinct. Given enhanced research on Cape Verde seabirds in the last few years (e.g. BirdLife International 2020, Semedo *et al.* 2021), it is unclear whether there remains any realistic prospect of avoiding the complete extinction of this endemic frigatebird. If not, it will serve as a stark reminder of the fate that might still befall other insular-endemic frigatebirds.



**Figure 1.** Genetic differentiation in *Fregata*, from Martins *et al.* (2023). Reproduced with permission. A. Inferred phylogenetic relationships in relation to different geographical groups defined from hierarchical analysis of molecular variance. B. Spatial distribution of genetic groups. Black dots represent sampling sites.

*Fregata trinitatis* Mirando-Ribeiro, 1919 Trindade [Lesser] Frigatebird

Syn: *F. ariel wilsoni* Lowe, 1924 (type: S. Trinidad Island).

**Type locality:** South Trindade Island [Brazil].

**Breeding range:** [South] Trindade I.; breeding at nearby Martin [Martim] Vaz has frequently been suspected or cited but no definitive evidence exists (see Antas 1991, Olson 2017).

**Breeding population:** No current or recent definite reports of breeding. Olson (2017) recounts in detail the limited observations associated with the few records (mostly by visiting collectors) of breeding. Olson (1981) is the last record of confirmed breeding (estimated minimum of 15 pairs and likely no more than 50 individuals) on an islet at Punta do Sul, Trindade I. in January 1976. Mancini *et al.* (2016) report a maximum count of two non-breeding individuals between December 2006 and April 2007. Port *et al.* (2016) conducted comprehensive land and boat-based surveys and recorded a maximum of six individuals (two adult males, two adult females, two juveniles) between 19 February 2013 and 19 April 2013. The presence of juveniles must imply successful breeding in a preceding year.

**Genetic sampling:** Martins *et al.* (2022):  $n = 16$  (Trindade,  $n = 13$ ; Martin Vaz,  $n = 3$ ).

**Taxonomic status:** All authorities currently treat as a subspecies of *F. ariel*. Olson (2017) provided considerable detail of all relevant measurements and of as much plumage information as specimens and observations allowed. He concluded that *F. trinitatis* is differentiated from *F. a. ariel* by its different proportions (stouter wing and shorter bill) and by distinctive differences in immature plumage; he recommended its treatment as a species distinct from *F. ariel*.

The proposal to the SACC to elevate *F. ariel trinitatis* to species rank (Pacheco 2018) did not pass (split vote), primarily due to an intervention from seabird expert Steve Howell (not a member of SACC), who indicated that Olson's plumage information was insufficiently precise to allow consistent critical comparison with the four plumage cycles now recognised in other frigatebird taxa.

The recent genetic data (Martins *et al.* 2022) show that, with strong support, *F. (a.) trinitatis* (endemic to the south-west Atlantic) is sister to all material of *F. ariel* from its Indo-Pacific range. Although based only on mtDNA, this seems strong, potentially



decisive, support for species status for *F. trinitatis*. Clarification of plumage differences from *F. ariel* is obviously highly desirable (if extant material and observations permit) but, in my opinion, should not constitute a reason for delaying species recognition.

**Conservation status:** With no breeding reported for over 50 years and a population (endemic to a single island) that nowadays may not exceed four adult birds, *F. ariel trinitatis* is recognised as a “Critically Endangered” taxon on the Brazilian Red List (MMA 2022). As a species, *F. trinitatis* would qualify as “Critically Endangered” under IUCN Red List criteria.

It may be that *F. trinitatis* is already effectively extinct. If there are feasible actions which might assist its survival, a campaign, stemming from its overdue recognition as a “Critically Endangered” species, would likely represent the very last chance to save it.

***Fregata ariel ariel*** (G. R. Gray, 1845) [Indo-Pacific] Lesser Frigatebird

Syn: *F. ariel tunnyi* Mathews, 1914 (type: Bedout Island [off north-west Australia]).

**Type locality:** Restricted to “Raine Island, Torres Strait” (north-east Queensland, Australia) by Mathews (1914).

**Breeding range:** Cocos (Keeling) Is, Christmas I. (Indian Ocean), islands off tropical west, north, and north-east Australia (Timor, Arafura, and Coral Seas), south Indonesia islands (probably extirpated; see de Korte 1991); islands/atolls near New Caledonia (Coral Sea), very locally in Melanesia (possibly extirpated); widespread in south-western and especially central Polynesia, east locally to Cook Is, Tuamotu Is, and Marquesas Is. Probably extirpated from Marshall Is, Palau, Tokelau Is, and Gambier Is.

**Breeding population:** Perhaps 70,000–75,000 pairs (but most data approximate, some incomplete or absent, and many dating from the 1980s; see [Supplementary material A, Tables S1 and S2](#)). Australian population (c.18,000 pairs, mainly in the 1980s; possibly stable); Melanesia (no data); New Caledonia (c.3,000 pairs 2009–2021; increasing following rat eradications). North-central Polynesia (Kiribati and the US Minor Outlying Is) still holds the bulk of the breeding population (c.40,000 pairs, 15,000 in 2015, at Malden alone), but populations in the Phoenix Is (Kiribati) likely decreased by c.72% in c.40 years to 2006 (see below). Elsewhere (i.e. in south and south-east Polynesia) breeding populations are generally few and small; the main colonies with recent data are at Vanua Masi (Fiji: c.5,000 birds in 2010), Ringgold Is (Fiji: c.5,000 pairs in c.2010), Suvarrow (Cook Is: 5,500 chicks in 2008), and Reitoro (Tuamotu Is: 1,200 birds in 2003).

**Genetic sampling:** North-west Australia ( $n = 9$ ): Adele I. (Kimberley Is,  $n = 5$ ); West I. (Lacepede Is,  $n = 3$ ); Middle I. (Ashmore Is,  $n = 1$ ); Papua New Guinea: Bismarck Archipelago: Ekalau I., St Matthias [Mussau] Is,  $n = 1$ ; New Caledonia: Chesterfield Is,  $n = 1$ ; Kiribati: Line Is,  $n = 6$ ; US Minor Outlying Is: Baker I.,  $n = 1$ .

**Taxonomic status:** Genetically homogeneous. The samples from north-west Australia are essentially topotypical for *F. a. tunnyi*, which was based on small size differences; synonymised with nominate by Rothschild (1915) and not recognised subsequently. The other samples, although few, span a considerable proportion of the range of *F. a. ariel*, within which area no other subspecies have been proposed.

**Conservation status:** “Least Concern”; although few data to enable any assessment of changes in recent decades. Phoenix Is (Kiribati) populations decreased by c.72% in c.40 years; c.38,000 pairs in 1964–1965 (Sibley and Clapp 1967) to 10,600 pairs in 2003 (Pierce *et al.* 2006). Some adjacent important populations, e.g. Line

Is (Kiribati), might well have decreased similarly but few modern data exist. Populations at Howland, Jarvis, and Baker islands (US Minor Outlying Is) virtually extirpated between 1964 (22,500 + breeding birds) and the 1980s (1,500 birds) but, following cat eradication, recovered to c.22,000 breeding birds by 2007 (Rauzon *et al.* 2011). Australian populations appear stable (but few data after the 1980s); apparently increasing on Cocos (Keeling) Is (James and McAllan 2014), but a recent count of 711 nests (Clarke *et al.* 2021 unpublished report) would not seem to support this. The combined populations of *F. a. ariel* and *F. m. minor* at Surprise I., d’Entrecasteaux Reefs (New Caledonia) increased from 398 pairs (1996) and c.150 pairs (2002–2005) to 1,586 pairs in 2017, following a successful rodent eradication in 2005 (Philippe-Lesaffre *et al.* 2023).

***Fregata ariel iredalei*** Mathews, 1914 [Indian Ocean] Lesser Frigatebird

**Type locality:** Aldabra [Seychelles].

**Breeding range:** West Indian Ocean: Europa I., Aldabra Is, Cargados Carajos [St Brandon] Is, Chagos Is. Extirpated at Maldivé Is and Tromelin; formerly bred and still roosts at many other sites (Safford and Hawkins 2013).

**Breeding population:** c.7,000 pairs (see [Supplementary material A, Table S3](#) for details) comprising: Aldabra: 3,500–6,600 in 2011–2012 (Šúr *et al.* 2013); Europa: I.: 1,000–1,200 in 1993–1996 (Le Corre and Jouventin 1997); St Brandon: c.500 in 1968 (based on c.96% of 2,000 birds; Staub and Guého 1968); Chagos Is: 70 in 2008–2018 (Carr *et al.* 2021).

**Genetic sampling:** Martins *et al.* (2022): Amirante Is ( $n = 1$ ).

**Taxonomic status:** Treated as a subspecies of *F. ariel* by all authorities. Described on the basis of small size and small bill (in relation to nominate), differences sustained by Mathews and Iredale (1921) and Lowe (1924) but not critically examined since. Staub and Guého (1968) and Pocklington *et al.* (1972) independently reported dimorphism in breast plumage and colour of bill and orbital ring (bluish-grey bill, black eye-ring or pink bill with rose eye-ring) in adult breeding females on Île du Sud, St Brandon. The single specimen sampled genetically had a unique haplotype, not found in the specimens of *F. a. ariel*. On this basis, it appears as sister (with weak support) to *F. a. ariel* in the phylogenetic tree of Martins *et al.* (2022). The characteristics and validity of this subspecies need fresh investigation. Meantime, it would seem appropriate to retain it.

**Conservation status:** As a subspecies, the scale of historical population declines (and extirpations; only four breeding sites now active) suggest that at least “Near Threatened” status might be merited. The two main breeding sites remaining, i.e. Aldabra and Europa, St Brandon likely declined recently (Safford and Hawkins 2013), may have stable populations. As a species, however, the likely “Least Concern” status of the nominate subspecies (see above) would be decisive overall.

***Fregata minor minor*** (J. F. Gmelin, 1789) [Australian] Great Frigatebird

Syn: *F. minor peninsulae* Mathews, 1923 (type: North Queensland).

Syn: *F. minor mathewsi* Lowe, 1924 (type: Raine I., north-east Queensland).

**Type locality:** Not specified originally. Restricted to the “eastern half of Indian Ocean” by Rothschild (1915) and then to “Christmas Island” [Indian Ocean] by Lowe (1924). However, James and McAllan (2014) show that this latter restriction is invalid, because the original description was a plate in Edwards (1758–1764), which illustrates a female with a pink bill. Females from Christmas I., uniquely amongst Indian Ocean populations, have blue bills (and

represent *F. (m.) listeri*; see later). A new type locality designation is thus needed. Given the previous restriction to the eastern Indian Ocean, Cocos (Keeling) Is would seem the only feasible choice.

**Breeding range:** Cocos (Keeling) Is; Indonesia (locally in Flores and Banda Seas); islands in Timor Sea (off north-west Australia); in the Coral Sea off north-east Queensland and off New Caledonia (subspecies?); off New Ireland and northern Solomons (subspecies?); Paracel [Xisha] Is (South China Sea; subspecies?).

**Breeding population:** Likely fewer than c.5,000 pairs (see [Supplementary material A, Tables S3 and S4](#)). Cocos (Keeling) Is: 1,000+ pairs in 1982 (Stokes *et al.* 1984); Indonesia: Kakabia, Moromaho (both Flores Sea), Gunung Api, Pulau Manuk (both Banda Sea), collectively 1,700–3,500 pairs 1981–1987 (de Korte 1991), but only 1,100–2,200 pairs in 2009 (de Jong 2011 unpublished report, in litt. January 2023). In Australia: Ashmore Reef, Timor Sea (40 nests in 2010; Clarke *et al.* 2011); Adele I., off north-west Western Australia (200–300 nests in 1990; Coate 1997); north-east Queensland: c.1,500 pairs in the mid-1980s (Marchant and Higgins 1990). If this subspecies (i.e. rather than *palmerstoni*): New Caledonia: confined to d’Entrecasteaux Reefs (Surprise I.: tens of pairs; Robinet *et al.* 1997), Loyalty Is (Walpole I.: 50 pairs; Barré and Dutson 2000), Hunter I. (60 pairs; Borsa and Baudat-Franceschi 2023), and Chesterfield Is (350–480 pairs, 1991–2009; Borsa *et al.* 2010); Papua New Guinea (numbers unknown and possibly extirpated): St Matthias (Mussau) Is (off New Ireland): Tench I. (Dutson 2011); islands off Bougainville (Hadden 2004); Paracel Is, South China Sea (nearly extirpated; 7–8 pairs in 2003–2005; Cao *et al.* 2007).

**Genetic sampling:** Unsampled.

**Taxonomic status:** The range of this nominate subspecies, and its relationship with *aldabrensis* to the west and *palmerstoni* to the east, needs to be determined by critical examination of specimens and appropriate genetic sampling (including additional sampling throughout the ranges of the other two recognised Indo-Pacific subspecies).

**Conservation status:** As a subspecies, possibly stable (and thus potentially “Least Concern”) within its core Australian range. However, Indonesian breeding populations are considerably at risk (see de Korte 1991), declined by c.38% in 22 years to 2009 (de Jong 2011 unpublished report; see above), with recent local extirpation, i.e. probably no longer (2022) breeds at Kakabia (Gaston 2022) nor Moromaho (de Jong 2011 unpublished report). Re-evaluation, ideally with recent data from Australia and Cocos (Keeling) Is, seems warranted. As a species, i.e. including *aldabrensis* and *palmerstoni*, likely “Least Concern” (possibly “Near Threatened”) under IUCN criteria.

The combined populations of *F. a. ariel* and *F. m. minor* at Surprise I. (d’Entrecasteaux Reefs, New Caledonia) increased from 398 pairs (1996) and c.150 pairs (2002–2005) to 1,586 pairs in 2017, following a successful rodent eradication in 2005 (Philippe-Lesaffre *et al.* 2023).

***Fregata minor aldabrensis*** Mathews, 1914 [Indian Ocean] Great Frigatebird

**Type locality:** Aldabra [Seychelles].

**Breeding range:** West Indian Ocean: Europa I., Aldabra Is, Cargados Carajos [St Brandon] Is, Cosmoledo, Chagos Is (subspecies uncertain), Maldivé Is (subspecies uncertain; recently extirpated, though roosts still present); formerly bred at Seychelles Is, Amirante Is, Tromelin, Glorieuses Is, and possibly on islets off Agalega Is, Mauritius, and Rodrigues. Roosts at many sites outside the current breeding range. More details in Safford and Hawkins (2013) and [Table 2](#).

**Breeding population:** c.5,000 pairs (see [Supplementary material A, Table S3](#) for details), comprising: Aldabra: 3,000–4,400 in 2011–2012 (Šúr *et al.* 2013); Europa I.: 700–1,100 in 1993–1996 (Le Corre and Jouventin 1997); St Brandon: c.20 in 1968, based on c.4% of 2,000 birds (Staub and Guého 1968); Cosmoledo: 8 in 1989 (Rocamora *et al.* 2003); Chagos Is: 640 in 2008–2018 (560 at Great Chagos Bank Atoll, 80 on Grand Coquillage) (Carr *et al.* 2021), compared with 164 pairs in 2006 (McGowan *et al.* 2008).

**Genetic sampling:** Martins *et al.* (2022): Amirante Is ( $n = 2$ ).

**Taxonomic status:** Treated as a subspecies of *F. minor* by all authorities. Originally distinguished (from nominate *minor*) on basis of “dark oil-green sheen, dark wing-coverts” and large size (Mathews and Iredale 1921). Bill and/or orbital ring colour of adult females may also be diagnostic, at least Aldabra birds having pink bills and pink orbital rings (Diamond 1975), in contrast to the blue bill and red orbital ring characteristic of the nominate subspecies (and some other populations/subspecies) of *F. minor*.

Genetically closest to *F. m. palmerstoni* but few samples from the whole Indo-Pacific range of *F. minor* (and *F. m. minor* is unsampled).

**Conservation status:** As a subspecies, the nature of historical population declines (and extirpations; only five breeding sites now active) suggest that “Near Threatened” status might be merited. The two main extant populations (Aldabra, Europa) appear to be stable; that on the Chagos Is may have increased in recent years but data are few (see above). As part of an *F. minor* species, however, the conservation status of the other subspecies would be decisive overall.

***Fregata minor palmerstoni*** (J. F. Gmelin, 1789) [Pacific] Great Frigatebird

Syn? (see below): *F. [minor] strumosa* “Kittlitz” Hartert, 1891 (type: “Ostlicher Ozean”, inferentially restricted to Laysan Island [Hawaiian Is] by Mathews 1914 and Lowe 1924).

**Type locality:** Palmerston Atoll [northern Cook Is].

**Breeding range:** Hawaiian Is; Mariana Is; Palau; Marshall Is; locally in Polynesia from Kiribati and American Samoa (status on Fiji unclear) east to Sala y Gomez and Islas Desventuradas (Chile). Extirpated at Isla de Pascua (Easter I; Marin 2023), probably also at Mariana Is, Tokelau Is, Gambier Is, and possibly at Marshall Is (Gauger Metz and Schreiber 2020) and Caroline Is (Palau). Possibly this subspecies in Melanesia (see under *F. m. minor*).

**Breeding population:** Gauger Metz and Schreiber (2020, [Table 2](#)) estimate 50,000–62,000 pairs for the combined north (Hawaiian Is), central, south, and eastern Pacific but some data and sources, except for the Hawaiian Is, are unclear. Unlikely nowadays to be more than 25,000–30,000 pairs overall (see [Supplementary material A, Table S4](#)), comprising: Marshall Is (6,300–7,300 birds at Taongi I. in 1964; Amerson 1969); Hawaiian Is (8,315–10,500 pairs, mainly in the 1970s; Harrison *et al.* 1984); Kiribati (Line Is 10,000–11,000 pairs; 6,000 at Kiribati in the mid-1980s; E.A. Schreiber in litt.); 1,500 at Vostok in 1965 (Clapp and Sibley 1967); 2,427 at Caroline I. in 1990 (Kepler *et al.* 1992 unpublished report); Phoenix Is (c.750 pairs in 2006; Pierce *et al.* 2006); US Minor Outlying Is (c.4,000 birds in 2002–2007; Rauzon *et al.* 2011). Limited numerical data for rest of range in south and south-east Polynesia, where breeds in small numbers on a very few islands off Tonga (and perhaps Fiji), American Samoa (Rose Atoll), east to Cook Is, French Polynesia, Pitcairn Is, and Islas Desventuradas. The total breeding population in this range nowadays may not exceed 3,000 pairs, with the main sites (>500 pairs) at Suvarrow (Cook Is; 329 chicks in 2008; Jones 2008), Hatuta’a (Marquesas Is; >1,000 pairs in 2010; Thibault *et al.* 2013), and Reitoro (Tuamotu Is; 810 birds in 2003; Pierce *et al.* 2003).

**Genetic sampling:** Martins *et al.* (2022): Suvarov [Suwarrow], northern Cook Is ( $n = 1$ ); Raroia Atoll, Tuamotu Is ( $n = 1$ ).

**Taxonomic status:** Treated as a subspecies of *F. minor* by all authorities. Genetically closest to *F. m. aldabrensis* and jointly sister to *F. [minor] ridgwayi* but only three samples analysed from the whole Indo-Pacific range of *F. minor*. However, these do include a near-topotypical specimen of *F. m. palmerstoni*. Pending further critical study and additional sampling, it would seem sensible to retain *palmerstoni* as a subspecies of *F. minor*.

Furthermore, Schreiber and Schreiber (1988) showed that breeding birds from Christmas I. (Pacific Ocean) [= Kiritimati I., Kiribati] have significantly shorter bills, longer tails, and lighter mass than those from Johnston Atoll (see also Gauger Metz and Schreiber 2020, Appendix 1). Given that orbital-ring colour of females varies within Pacific populations, e.g. red in central and north-east Pacific, lilac on Baker I., pink to purple on Christmas Is (Pacific Ocean) (all from Gauger Metz and Schreiber 2020), blue at Ducie and Oeno (Pitcairn Is) (Harrison *et al.* 2021), critical comparison, especially of north and south Pacific populations, would be valuable, including assessing the potential validity of *F. minor strumosa* Hartert, 1891 for birds from the Hawaiian Is and vicinity. The subspecific identity of breeding birds from Melanesia also needs resolving.

**Conservation status:** As a subspecies, possibly still “Least Concern”, although anthropogenic threats are pervasive, local extirpations likely increasing, and reliable data on population trends almost non-existent. The least anecdotal evidences of decline are: (1) 50% decrease at Caroline I. (Kiribati) from 4,000–6,000 pairs in 1974 (Grossman and Grossman 1974) to 2,427 pairs in 1990 (Kepler *et al.* 1992 unpublished report); (2) a decrease in the Line Is (Kiribati) from Garnett’s (1984) estimate of 10,000+ pairs to c.750 pairs in 2006 (Pierce *et al.* 2006); (3) a decrease at Rose Atoll (American Samoa) from 200–750 birds in 1970–1976 (Amerson *et al.* 1982) to 11 pairs in 1990 (O’Connor and Rauzon 2004). Populations at Howland, Jarvis, and Baker islands (US Minor Outlying Is) were virtually extirpated by the 1980s but recovered to c.3,850 breeding birds by 2007 (Rauzon *et al.* 2011), following cat eradication. Overall, depending on the adjudged severity of threats, “Near Threatened” status might now be appropriate. As a species (notably whether including *F. [m.] ridgwayi* or not), the status of this subspecies would be key to any overall assessment.

***Fregata [minor] ridgwayi*** Mathews, 1914 [Galapagos] Great Frigatebird

**Type locality:** Culpepper Island [Isla Darwin], Galapagos Archipelago [Ecuador] (Murphy 1936; although Mathews 1914 implies that a bird from Wenman I. [Isla Wolf] is the type).

**Breeding range:** Galapagos Is (Ecuador), Cocos Is (Costa Rica), Revillagigedo Is (Mexico). No confirmed breeding records for mainland Ecuador (Ridgely and Greenfield 2001).

**Breeding population:** Perhaps 5,000 pairs. Galapagos Is: “few thousand pairs” on “many of the small islands” (Coulter 1984); Valle *et al.* (2006, Figure 1) shows 14 sites on seven (mainly outlying) island groups. Note that Gauger Metz and Schreiber (2020) cite “c.20,000 breeders on Genovesa (Tower)” but this is at variance with the “several hundreds of pairs” reported thence by Weimerskirch *et al.* (2017) and similar numbers inferred from Valle *et al.* (2006), who worked on the largest colony (200 pairs) on Genovesa. Cocos I. (Costa Rica): up to 1,000 pairs (Stiles 1984); Revillagigedo Is: Isla San Benedicto: 100 pairs (Howell and Webb 1990); 165 pairs (Pitman and Ballance 2002); >1,000 birds at Clipperton I. but no evidence of breeding (Pitman and Ballance 2002).

**Genetic sampling:** Martins *et al.* (2022): Galapagos Is ( $n = 10$ ).

**Taxonomic status:** Treated as a subspecies of *F. minor* by all authorities. Genetically sister (albeit with relatively weak support) to *F. minor aldabrensis+palmerstoni*. A critical review of other characteristics (measurements, plumage, bare part coloration) potentially differentiating it from the *F. minor* subspecies of the main Indo-Pacific, plus more and wider genetic sampling of these taxa, are needed to clarify whether *F. [m.] ridgwayi* is best treated as a subspecies of *F. minor*, or as a species of restricted range based on the Galapagos Is and two relatively adjacent sites.

**Conservation status:** The Galapagos population is key to the status of the taxon; although there seem to be no recent data, neither is there even anecdotal evidence of any population decline. However, if there are actual or potential threats to a taxon restricted to a small number of breeding sites, then “Near Threatened” status might well be appropriate. If treated as a subspecies of *F. minor*, then the conservation status of *F. m. palmerstoni* is key.

***Fregata nicolli*** Mathews, 1914 [Nicoll’s] Frigatebird

**Type locality:** South Trinidad [Trindade] Island [Brazil].

**Breeding range:** (formerly) Trindade and Martin Vaz Is, Brazil.

**Breeding population:** None. The last definite breeding record is from December 1924 to January 1925 on Trindade I. (Murphy 1936), reports of breeding then also at Dom Pedro Secundo Islet of the Martin Vaz Is being unreliable (Olson 2017). Antas (1991), Port *et al.* (2016), and Olson (2017) summarise subsequent sightings on Trindade I.: May 1950 (up to five birds); December 1975–February 1976 (up to four at a time); February–April 1986 (maximum of six); August 1994–April 2000 (five visits with sightings totalling c.100 birds); December 2006–January 2007 (three birds; Mancini *et al.* 2016); February–April 2013 (two adult males, one adult female, one juvenile), all lacking any evidence of breeding. Brief visits to Martin Vaz Is in March 1990, January 1995, and in 2002 all recorded no evidence of breeding (Antas 1991, Olson 2017).

**Genetic sampling:** Martins *et al.* (2022):  $n = 10$  (all Trindade I.).

**Taxonomic status:** Treated as a subspecies of *F. minor* by all authorities. Genetic data show as sister (with moderate – 0.79 – support) to a clade comprising both *aldabrensis+palmerstoni* and *ridgwayi*. Originally characterised by large bill and very broad pale wing band (Mathews and Iredale 1921). Measurements, plumage, and bare parts (bill “horn-colour but very rosy on the latericorn and the sides of the mandible; orbital ring is red”: Murphy 1936; apparently distinct from other taxa in the *F. minor* complex) need fresh critical study but it seems implausible that this taxon, endemic to the south-west Atlantic, is conspecific with the Indo-Pacific taxa in the *minor-ridgwayi* complex.

**Conservation status:** With no definite breeding records for nearly 100 years and a total population that might not exceed double figures (and confined to a single island), this taxon (as a subspecies) is already treated as “Critically Endangered” by the Brazilian Red List (MMA 2022). As a species, it would also be “Critically Endangered” under IUCN criteria.

*F. nicolli* may already be effectively extinct. If there are feasible actions which might assist its survival, a campaign (alongside that for *F. trinitatis*), stemming from its overdue recognition as a “Critically Endangered” species, would likely represent the very last chance to save it.

***Fregata listeri*** Mathews, 1914 [Lister’s] Frigatebird

**Type locality:** Christmas Island, Indian Ocean [Australia].

**Breeding range:** Christmas I., Indian Ocean.

**Breeding population:** 3,500 pairs (James and McAllan 2014).

**Genetic sampling:** Martins *et al.* (2022): Christmas I., Indian Ocean ( $n = 5$ ).



**Taxonomic status:** Not currently recognised taxonomically by any of the main authorities. Sister-taxon (genetically) to all the rest of the *F. minor* complex (i.e. *nicolli*, *aldabrensis*, *palmerstoni*, *ridgwayi*). Differs from other Indian Ocean taxa in bill colour (blue) and in much smaller size (Gibson-Hill 1950, Marchant and Higgins 1990), based on comparison with Cocos (Keeling) birds, the nearest population of *F. minor* to Christmas I.. Although critical review of all characters might be desirable, the existing evidence strongly suggests it merits species status.

**Conservation status:** As a single-island endemic, with a total population possibly less than 10,000 mature individuals, any evidence of population decline or existing or potential threats likely to cause this, would qualify it as “Vulnerable” under IUCN criteria. A review of its current conservation status should be a high priority. *Fregata andrewsi* Christmas Island Frigatebird, also endemic to Christmas I., is currently assessed as “Vulnerable”.

### Conservative current/interim taxonomy

If adjudged premature to recognise any new species-rank taxa, the arrangement below would seem the minimum interim changes to reflect an improved understanding of frigatebird relationships and status.

#### *F. magnificens*

*F. m. magnificens* (Galapagos Is)

*F. m. rothschildi* (islands of Gulf of Mexico east to Dry Tortugas, Bahamas, and Caribbean Sea east to Trinidad and Tobago and the Guianas; Pacific coast of Central and South America from Mexico locally to southern Ecuador)

*F. m. januaria* (coastal eastern Brazil from Moleques do Sul (Santa Catarina) north to Abrolhos Is; Fernando de Noronha Archipelago; interbreeding with *F. m. rothschildi* at Île du Grand Connétable (Guyane/French Guiana))

*F. m. lowei* (Cabo Verde)

#### *F. ariel*

*F. a. ariel* (Indo-Pacific to Polynesia; includes *iredalei*, *tunnyi*)

*F. a. trinitatis* (Trindade and Martin Vaz Is, Brazil; syn. *wilsoni*)

#### *F. minor*

*F. m. minor* (Indian Ocean to Coral Sea/western Pacific; includes *aldabrensis*, *peninsulae*, *mathewsi*)

*F. m. palmerstoni* (central and eastern Pacific, includes *strumosa*)

*F. m. listeri* (Christmas I., Indian Ocean)

*F. m. nicolli* (Trindade and Martin Vaz Is, Brazil)

*F. m. ridgwayi* (Galapagos Is, Ecuador, Cocos Is, Costa Rica, Revillagigedo Is, Mexico)

### Frigatebird breeding populations

Even by seabird standards, estimating frigatebird breeding populations is particularly challenging. Sites are often on small atolls, islands, or island groups, frequently remote and difficult to access. Observer visits are typically brief; obtaining accurate counts is thus compounded by frigatebirds having lengthy breeding seasons, complex breeding cycles, and a propensity for adults to defer breeding in years/seasons of poor environmental conditions.

Interpreting published data is further complicated by counts variously reflecting pairs, nests, chicks, birds, and adults. In this paper and especially in the Supplementary material tables, the first three of these categories are treated as synonymous and the last two are halved to convert to pairs when aggregating site counts across island groups, jurisdictions, and taxa.

Population data for *F. magnificens* (sens. lat., including *rothschildi*, *januaria*, *trinitatis*) and *F. (minor) ridgwayi* are summarised regionally/nationally in the preceding accounts; detailed site-specific data for *F. ariel* (including *iredalei*) and *F. minor* (including *aldabrensis*, *palmerstoni*, *listeri*) are provided in [Supplementary material A, Tables S1–S4](#).

Based on these, revised global estimates of annual breeding populations of all frigatebird taxa (i.e. including *F. aquila* and *F. andrewsi* for completeness) are provided in [Table 1](#). Note that these estimates make little or no adjustment for some important sites whose most recent data are from 40–50 years ago.

### Important breeding sites

Overall, although most sites have a published numerical estimate, few have more than one count and a majority have no published count in the last 40–50 years. Some sites for which the latter applies may well no longer host breeding frigatebirds. There are also numerous reliable reports of extirpations, especially from sites in the Caribbean, western Indian Ocean, Indonesia, and Polynesia (see below).

Nevertheless, it is probable that most breeding sites – and all major ones (i.e. >500–1,000 pairs) – are known (even if their current status may not be). The most important sites for breeding

**Table 1.** Estimated global annual breeding populations (pairs) of frigatebird taxa.

Taxon	Population	Taxon	Population
<i>F. magnificens</i> (sens. lat.)	50,000	<i>F. minor</i> (sens. lat.)	45,000–50,000
<i>F. m. magnificens</i>	1,000	<i>F. m. minor</i>	5,000
<i>F. (m.) januaria</i>	6,000–7,000	<i>F. m. aldabrensis</i>	5,500 (includes Chagos Is)
<i>F. r. rothschildi</i>	40,000–50,000 <sup>1</sup>	<i>F. m. palmerstoni</i>	25,000–30,000
<i>F. r. lowei</i>	0	<i>F. (m.) listeri</i>	3,500
<i>F. (m.) trinitatis</i>	0	<i>F. (m.) nicolli</i>	0
<i>F. ariel</i> (sens. lat.)	77,000–82,000	<i>F. (m.) ridgwayi</i>	5,000
<i>F. a. ariel</i>	70,000–75,000	<i>F. aquila</i>	6,250 (2001–2002; Ratcliffe <i>et al.</i> 2008)
<i>F. a. iredalei</i>	7,000	<i>F. andrewsi</i>	1,050–1,200 (2016–2017; Macgregor <i>et al.</i> 2021)

<sup>1</sup>Taking account of recent data for Baja California (Marrón *et al.* 2021).



frigatebirds, essentially those with more than c.1% of the overall breeding population, i.e. potentially relevant to the qualifying criterion for a BirdLife International Important Bird and Biodiversity Area (IBA), are indicated below.

*F. magnificens* (sens. lat.)

*F. m. magnificens*: **Ecuador** (Galapagos Is; input needed on island-specific sites)

*F. (m.) januaria*: **Brazil** (Moleques do Sul I.; Currais I.; Alcatrazes Archipelago; Cagarras/Redondo Is; Jorge Grego Is; Laje Branca I.; Cabo Frio; Santana Archipelago; Abrolhos Is (Redondo I.); Fernando de Noronha (Sela Gineta I.)

*F. (r.) rothschildi*: **Mexico** (Magdalena Lagoon complex; Bahía Pabellón; Bahía Santa Maria); **Panama** (Isla Iguana); **Ecuador** (Isla Santa Clara; Isla de la Plata?); **Cuba** (Cay Rabihorcado); **Puerto Rico** (Monito I.); **British Virgin Islands** (Great Tortuga); **Antigua and Barbuda** (Codrington Lagoon, Barbuda); **Trinidad and Tobago** (St Giles Is, Tobago); **French Guiana** (Île du Grand Connétable)

*F. r. lowei*: **Cabo Verde** (Boa Vista I.; endemic; virtually extirpated)

*F. (m.) trinitatis*: **Brazil** (Trindade I.; endemic; virtually extirpated)

*F. ariel* (sens. lat.)

*F. a. ariel*: **Australia** (Cocos (Keeling) Is; Adele Is; Lacepede Is; Bedout Is; Ashmore Is; Diamond Is, Coringa-Herald Is); **New Caledonia** (Chesterfield Is; Surprise I.); **Kiribati** (Malden; Enderbury; McKean; Rawaki (Phoenix); Orona); **US Minor Outlying Is** (Howland; Jarvis; Baker); **Fiji** (Vanua Masi; Ringgold Is); **Cook Is** (Suvarrow); **French Polynesia** (Reitoru, Tuamotu Is)

*F. a. iredalei*: **French Southern and Antarctic Lands** (Europa I.); **Seychelles** (Aldabra Is)

*F. minor* (sens. lat.)

*F. m. minor*: **Indonesia** (G. Api; P. Manuk); **Australia** (Cocos (Keeling) Is; Coringa-Herald Is)

*F. m. aldabrensis*: **British Indian Ocean Territory** (Chagos Is; Great Chagos Bank Atoll); **French Southern and Antarctic Lands** (Europa I); **Seychelles** (Aldabra Is)

*F. m. palmerstoni*: **USA**: Hawaiian Is (Nihoa, Laysan, Necker, Lisianski; all but Laysan 1969–1982 data); **Marshall Is** (Taongi; 1964 data); **Kiribati** (Kiritimati; Vostok 1974 data; Nikumaroro c.1983 data; Caroline

(Millenium) I.); **US Minor Outlying Is** (Jarvis); **Cook Is** (Suvarrow? chick count); **French Polynesia** (Hatuta'a, Marquesas Is)

*F. (m.) listeri*: **Australia** (Christmas I.; endemic)

*F. (m.) nicolli*: **Brazil** (Trindade I.; endemic; virtually extirpated)

*F. (m.) ridgwayi*: **Ecuador** (Galapagos Is; Genovesa; other islands?); **Costa Rica** (Cocos Is)

*F. aquila*: **UK Overseas Territory of St Helena and Tristan da Cunha**: Ascension I. (Boatswainbird I.; endemic)

*F. andrewsi*: **Australia** (Christmas I.; endemic)

## Breeding population changes

Data sufficiently reliable to infer population change are available for very few sites. Multi-year regular monitoring studies of frigatebirds seem even fewer; the only recent/current ones identified were Baker and Holdsworth (2013) and Philippe-Lesaffre *et al.* (2023).

The main sites with convincing evidence of substantial population decrease are summarised in Table 2.

Although there is overwhelming additional anecdotal evidence for decreases in frigatebird populations at many sites, there is also similar evidence of apparent stability at some sites and regions. For instance, there appears little evidence of declines for either *F. ariel* or *F. minor* in the Australian region, nor for either species at Europa I. or Aldabra in the western Indian Ocean.

There are also a few sites where breeding populations have increased following targeted removal of alien invasive species. Thus, the combined breeding populations of *F. ariel* and *F. minor* at Surprise I. (New Caledonia) increased from c.150 pairs in 2002–2005 to 1,586 pairs in 2017, following a successful rat eradication in 2005 (Philippe-Lesaffre *et al.* 2023). Similarly, at Howland, Jarvis, and Baker islands (US Minor Outlying Is) populations increased from actual or virtual elimination by the 1980s to a combined maximum of c.24,000 birds of *F. ariel* and 3,850 birds of *F. minor*

**Table 2.** Estimated decreases in breeding populations of frigatebirds. Where ranges are given, calculations used midpoint values.

Species/site	Count 1		Count 2		Interval	Change	Reference
	Pairs	Date	Pairs	Date	(years)	(%)	
<i>F. (magnificens) rothschildi</i>							
Baja California, Mexico	20,117+	1986–1987	1,300	2015–2017	c.30	95	Marrón <i>et al.</i> 2021
Caribbean	c.8,100	c.1980	6,100	c.2005	c.25	25	Bradley and Norton 2009
<i>F. ariel</i>							
Phoenix Is, Kiribati	c.38,000	1964–1965	10,600	2003	39	72	Sibley and Clapp 1967; Pierce <i>et al.</i> 2006
<i>F. ariel/F. minor</i>							
Coringa-Herald Is, Australia	c.3,200	1992–1997	419	1998–2007	c.20	87	Baker and Holdsworth 2013
<i>F. minor</i>							
Indonesia	1,700–3,500	1981	1,100–2,200	2003	22	38	de Korte 1991, de Jong 2011
Caroline I., Kiribati	4,000–6,000	1974	2,427	1990	16	48.5	Grossman and Grossman 1974, Kepler <i>et al.</i> 1994
Line Is, Kiribati	10,000+	c.1980–1982	750	2006	25	92.5	Garnett 1984, Pierce <i>et al.</i> 2006
<i>F. andrewsi</i>							
Christmas I. (Indian Ocean), Australia	4,500	1910	1,500	1978	68	67	James 2003
	1,500	1978	1,050–1,200	2017	39	25	Macgregor <i>et al.</i> 2021

by 2002–2007, following successful cat eradications by 1990 (Rauzon *et al.* 2011).

There are two sites with convincing evidence of a substantial population increase. At Malden (Line Is, Kiribati), *F. ariel* increased from c.7,000 breeding birds in 1964 (Garnett 1983 unpublished report) to c.15,000 pairs in 2015 (Pierce *et al.* 2015 unpublished report). This is remarkable and may reflect that this very isolated island has become a refugium for birds displaced from other islands in the region. At the Alcatrazes Archipelago (Brazil), *F. magnificens januaria* increased from 250 pairs in 1920 to 2,500 pairs in 2014, largely due to strict prohibition on public access (Muscat *et al.* 2014) and possibly also a refugium effect.

Overall, however, it appears that most frigatebird populations are in widespread and continuing decline; those in best shape nowadays are on islands sufficiently remote from frequent human visitation and/or breeding in officially protected areas with well-managed restrictions on access for visitors.

### Extirpations

There are many anecdotal reports, both historical (nineteenth and early twentieth centuries) and more recent, of known, probable, and possible extirpations of breeding populations. Excluding historical data, and thus relating to the last 50–70 years, the main actual or potential extirpations are as follows.

(a) *F. (magnificens) rothschildi*: USA (Marquesas Key, Florida; coastal Texas); Puerto Rico (four sites), US Virgin Is. (two islands), British Virgin Is. (Anegada; Sombrero I. off Anguilla I.), and possibly Grenadines, Guadeloupe, Haiti, Honduras (Swan I.), Navassa I. (USA/Haiti); all from Diamond and Schreiber (2020). (b) *F. (magnificens) trinitatis*: Trindade I., Brazil. (c) *F. rothschildi lowei*: Cabo Verde. (d) *F. ariel ariel*: probably extirpated from Indonesia, Melanesia, Micronesia, Marshall Is, Palau, Tokelau Is, Gambier Is, and nearly so from Austral Is and Marquesas Is. (e) *F. ariel iredalei*: Maldive Is, Tromelin I., and likely all sites listed under *F. minor aldabrensis* below. (f) *F. minor minor*: Indonesia (Kakabia, Moromaho). (g) *F. minor aldabrensis*: Maldive Is, Tromelin I., Seychelles Is, Amirante Is, Glorieuses Is, and possibly (more historically) islets off Agalega Is, Mauritius, and Rodrigues (Safford and Hawkins 2013). (h) *F. minor palmerstoni*: probably extirpated (or nearly so) at Mariana Is and Tokelau Is and possibly also at Marshall Is (Gauger Metz and Schreiber 2020) and Palau. (i) *F. (minor) nicolli*: Trindade I., Brazil.

### Key potential initiatives

This review shows that the conservation status of frigatebird taxa and populations, with the exception of those at a few strictly protected and managed sites, is universally poor, with three island-endemic taxa on the verge of complete extinction and all widespread taxa in serious decline in some or many areas. A review of all frigatebird taxa in relation to IUCN Red List criteria is needed; this should, ideally, be linked to a comprehensive review of frigatebird taxonomy, building on the pioneering preliminary study by Martins *et al.* (2022).

Such initiatives would undoubtedly provide an improved basis and fresh impetus for addressing frigatebird conservation; however, as much practical action as feasible should proceed in parallel. This needs to include potential last-ditch efforts to save the three island-endemic taxa currently reproductively extinct or near-extinct, as well as enhanced and effective implementation of appropriate

management at the main breeding sites of all taxa (see preliminary list of such sites above). All this will require concerted collaborative action by a considerable variety of interested parties.

### Potential projects, initiatives, and actions

The following suggestions would seem to merit consideration.

1. For all important breeding sites for frigatebirds:
  - a) update/complete the inventory of data on frigatebird breeding populations (see priority site-specific suggestions in [Supplementary material, Appendix C](#));
  - b) review site conservation/protection status, especially in relation to formal protected area designation and, as relevant and especially in relation to frigatebirds, the appropriateness of existing management plans and the effectiveness of their implementation;
  - c) based on 1(b) above, make recommendations for new protected areas and for improvements to management plans (and their implementation) for existing designated protected areas;
  - d) linked to 1(c) above, develop best-practice guidance, suitable for inclusion and implementation as part of management plans to address elimination, mitigation, or management of the main threats to frigatebirds (and other co-occurring colonial seabird species as appropriate): as a minimum this should include recommendations for: (i) elimination/control of invasive alien species; (ii) elimination/management of harvesting of seabirds by humans; (iii) management of visitors, especially tourists; (iv) strict controls on modification of breeding areas and habitats, especially in relation to potentially deleterious development and infrastructure;
  - e) for appropriate sites, develop new, and enhance current, monitoring studies of breeding populations.

As far as possible, all the above should be undertaken in collaboration and consultation with as many stakeholder constituencies as possible, especially local communities and local, regional, and national authorities and organisations.

It would seem vital, especially for potential activities relating to 1 (b)–1(d), to develop appropriate education and communication plans.

2. Develop and establish arrangements for a collaborative study of frigatebird genetics, complementary to and extending the recent pioneering studies.
3. Create the basis for a critical study of soft-part coloration (especially bill and orbital ring) of breeding adult female frigatebirds in order to assess implications for frigatebird taxonomy. (This might usefully involve “citizen science” in the acquisition and submission of photographic images of breeding birds.)
4. Establish an expert group to review plumage and morphometrics of frigatebirds (particularly of potentially cryptic taxa) in relation to their taxonomy.
5. Request the relevant expert authority (BirdLife International) to review data on frigatebirds in relation to IUCN Red List criteria. Ideally this should initially be done now, rather than seeking to await outcomes of studies such as outlined in (3) and (4) above.
6. Request BirdLife International to review its IBA inventory in the light of new and revised data on frigatebird populations, updating accounts for existing IBAs and recognising new IBAs

as appropriate. Ideally, once done, generating a summary list of IBAs triggered by frigatebirds would be very useful.

7. For *F. trinitatis*, *F. (minor) nicolli*, and *F. rothschildi lowei* communicate with local experts and organisations (in Brazil and Cabo Verde) to ascertain the potential feasibility of undertaking urgent actions to prevent the complete extinction of these taxa. Support for existing work on Trindade I. by Leandro Bugoni (Universidade Federal do Rio Grande in Brazil) and colleagues would seem paramount.

Relevant management-related actions have much wider implications than just frigatebird conservation. Frigatebirds are particularly iconic members of a guild of congregatory tropical seabirds (including especially boobies and terns), which regularly breed in close proximity on tropical islands. Together they face most, if not all, of the main threats characteristic of colonial tropical seabirds. All (but perhaps frigatebirds in particular) are highly susceptible to direct and indirect disturbance, whether through casual visitation, poorly managed tourism, and especially, habitat modification and destruction, typically arising from coastal development and its aftermath. At many sites they are also still badly affected by human harvesting of adults, chicks and eggs for food and by predation by alien invasive species (this last being amongst the most soluble of the threats). Inevitably, most of the main breeding sites for colonial tropical seabirds are vulnerable to climate change, especially through sea-level rise but also through potential impacts on prey populations (and, for frigatebirds, any reductions in the populations of seabirds which they kleptoparasitise for food). The impact of pesticides and pollutants (especially plastics) is currently poorly known but likely to become pervasive and possibly significant.

Of course, we have known and regularly reaffirmed much of this for the last 40 years (e.g. Croxall *et al.* 1984, 2012, Croxall, 1991, 2012, Nettleship *et al.* 1994, Bradley and Norton 2009, Dias *et al.* 2019), and generally failed to take sufficiently concerted and effective action to address the plight of tropical seabirds. It would be a signal indictment if three frigatebird taxa were allowed to go extinct in the early twenty-first century; it would be even more serious if we were unable to use new knowledge of frigatebird taxonomy and populations to help secure in perpetuity the future of the main sites on which frigatebirds depend, in association with globally important populations of other tropical seabirds and exceptional terrestrial and marine biodiversity.

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