Status and trends of White-tailed Tropicbirds *Phaethon lepturus* in the Seychelles.

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**Abstract**

The successful design and implementation of monitoring programmes is an important tool in the effective management of biodiversity, especially in developing nations where resources are scarce and threats are high. We combined monitoring efforts from five of the region’s most vital nesting sites for an indicator species, the white-tailed tropicbirds *Phaethon lepturus*.We present the first regional summary on the level and trends of breeding success at each of the sites; at Aldabra atoll on average 15.2% of nests were successful compared with 33% on Cousin Island, 40.2% on Aride Island, 51.6% on Cousine Island and 55% on Denis Island. In addition, at Aldabra there was a significant negative temporal trend in breeding success observed. The Aride Island population showed a continuous negative trend in nest density, whereas the Cousine island nest density increased. Disparity in methods, duration and longevity of the programmes prevented direct statistical comparisons between sites. It was not possible to determine causes of trends, though the regional outlook enabled some interpretation of the potential drivers of change at site level. Recommendations are therefore made to improve the effectiveness of these conservation efforts and streamline the monitoring programmes for *P. lepturus* across the Seychelles.

Keywords: Seychelles, Tropicbirds, Management, Ecology, Breeding

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**Introduction**

The Western Indian Ocean has recently been identified as a key area to prioritize for the conservation of global marine biodiversity in the face of climate change (Ramírez et al. 2017). With 115 islands stretching across an exclusive economic zone of 3.2 million km2 the Seychelles is a challenging location for articulated monitoring efforts. Monitoring programmes are widespread across the Seychelles islands and if successfully designed and implemented they have potential to form an integral role in informing conservation management. However, poorly designed programmes or lack of institutional capacity often result in data piling up. Without rigorous and regular analysis programmes are unable to fulfil their original aims—delivering information on trends in key aspects of biodiversity, providing early warning of problems, generating evidence of conservation success or failure and highlighting ways to make management more effective (Lindenmayer et al. 2012).

Indicator species whose status reflects or predicts the condition(s) of the broader environment are often the focus of monitoring efforts. Seabirds possess several attributes that make them useful as environmental indicators (Bost & Maho, 1993), as they provide both a measure of health of the species as well as an indication of overall state of the surrounding ecosystem (Parsons et al. 2008; Piatt et al. 2007). The Seychelles supports the greatest abundance of tropical seabirds in the Indian Ocean, estimated to be ca 3.4 million pairs (le Corre et al. 2012). It is the main breeding ground for White-tailed Tropicbirds (*Phaethon lepturus)* with anestimated 56% of the Western Indian Ocean breeding population (le Corre et al. 2012). *P. lepturus* is a pelagic seabird that undertakes long foraging trips and feeds mainly on surface-dwelling prey, such as flying fish and squid (Schreiber & Clapp 1987). The specificity of their foraging strategy limits their rate of provisioning when food is scarce, creating a “feast or famine” feeding situation (Schaffner, 1990) which indicates changes in lower trophic levels. Additionally, *P. lepturus* is ground nesting (Burger and Lawrence 2000) and therefore nesting success are highly susceptibile to habitat integrity and environmental perturbations like XXX and XXX.Determining trends in this indicator species at a regional scale is a required first step for effective management of this species as well as providing managers with an early warning system of broader scale environmental changes.

Although *P. lepturus* is listed as ‘Least Concern’ on the IUCN red list, the species is suspected to be in decline owing to predation by invasive species at nesting sites (IUCN Red List). As a pelagic species with large home ranges, monitoring of a single location is often not enough to assess regional trends. Fortunately, monitoring of *P. lepturus* breeding success has been conducted on a number of Seychelles islands. However, despite the monitoring programmes in place across the Seychelles, the regional conservation status of *P. lepturus* is unknown. Neither is it clear whether the monitoring programmes in place are adequate to answer the questions of population and breeding status or broader environmental change. Here, for the first time, we compile regional data to determine the status of *P. lepturus* in the Seychelles. Our primary objectives are to: (1) identify trends in breeding success across sites; (2) where possible assess trends in nesting density across sites; (3) where possible identify trends in breeding seasonality across sites; and (4) determine the extent to which the current monitoring programme methods enable *P.lepturus* to be used as indicators. Lastly, we aim to use these results to suggest changes to monitoring programmes for *P. lepturus* across the Seychelles to ensure monitoring efforts fulfil research aims, and to allow direct comparability between sites.

**Material and methods**

**Study Sites**

We analysed data available from five islands in the Seychelles: Aldabra Atoll, Aride Island, Cousin Island, Cousine Island, and Denis Island (Figure 1). These sites cover the main breeding sites in Seychelles for *P.lepturus* (Aldabra, Cousin, Cousine & Aride) as well as Denis island, of which little is known about the *P.lepturus* population. Although other islands also have *P. lepturus* breeding populations, most are un-monitored. All monitoring programmes were developed separately and despite being based on the guidelines found in the “Seabird monitoring handbook for Seychelles” (ref, date), guidelines are limited to a description of the methods to obtain breeding success data, and not specifically how to set up a long-term monitoring programme. The sites vary in size, geomorphology, elevation, protected status, management types, predator threats and estimated *P. lepturus* population size (Table 1). The studies varied in area covered, monitoring duration, frequency, methods and monitoring area habitat type (Table 2).

Table 1: Details of the five islands in the study, including protection status, size, geomorphology, location, management/ownership,population estimates, nest predators and other potentially disruptive species.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Island** | **Protection status** | **Land area (ha)** | **Geomor-phology** | **Location** | **Max height asl (m)** | **Management** | **Population estimates** | **Nest predators** | **Other Disruptive\* species** |
| Aldabra Atoll | UNESCO World Heritage site (1982); Special Reserve (1975) | 15,254 | Coralline | 9.2255**°**S,  46.1310**°**E | 8 | Public Trust | 2000 pairs 1 | Black rat*,* grey heron, Aldabra drongo4  Coconut crab1 | Red-tailed tropicbirds |
| Aride | Special Reserve (1975) | 74 | Granitic | 4.2000**°**S, 55.6667**°**E | 134 | NGO | 1,446 pairs 2 | Seychelles skink, wright’s skink and Seychelles fody5 | *Pisonia grandis* (bird-catcher tree), big headed ants (until 2016), ticks. |
| Cousin | IUCN class 1A Special Reserve (1975) | 27 | Granitic | 4.3314**°**S, 55.6631**°**E | 69 | NGO | 2110 pairs 3 | Seychelles skink, wright’s skink and Seychelles fody, ghost crabs6 | *Pisonia grandis* |
| Cousine | Privately owned | 26 | Granitic | 4.3500**°**S, 55.6333**°**E | 72 | Private | 450–850 pairs8 | Seychelles skink, wright’s skink and Seychelles fody, ghost crabs 7, Seychelles magpie-robin. | *Pisonia grandis, giant tortoise,* big- headed ants. |
| Denis | Privately owned | 140 | Sand cay | 3.8000**°**S, 55.6667**°**E | <4 | Private | Unknown | None perceived, cats removed in 2000, rats removed in 2002. |  |
| 1Diamond 1971, 2Burger and Lawrence 2000, 3Bowler et al. 2002, 4Recorded but unpublished, 5Observed but unpublished, 6Phillips 1987,  7Malan et al. 2010, 8Skerrett et al. 2001, \*Observed to or thought to hinder breeding success by increasing nest desertion or causing parent mortality. | | | | | | | | | |

**Monitoring nesting success**

For all five islands, nesting *P. lepturus* were defined as an adult with an egg or a chick on a nest. Nests were checked (and new nests searched for) between every 2–3 days and every two weeks, depending on the island (see Table 2). To determine nest outcome, the stage at which the nest was last observed active was recorded. If a nest was observed to have been occupied by an egg or a young (partially feathered) chick and it was subsequently observed empty or with signs of predation/death on the succeeding visit, it was assumed that the nest had failed. If a nest was observed to be occupied by a fully feathered chick and then found empty in the subsequent visit without signs of predation/death, it was assumed that fledging had occurred and therefore that the nest was successful (hereafter breeding success). For those sites that monitored all nests within a specific area (Aride, Aldabra, Cousine) the number of nests is hereafter referred to as nesting density and is used as a proxy for breeding population size. New nesting attempts were only included in the dataset when the attempt was at the egg incubation stage to avoid including nesting attempts that had already successfully reached chick stage. Each nesting attempt was characterised by the date of the first record, whether the attempt resulted in a successful fledged chick or not.

Table 2. Information on each *P*.*lepturus* monitoring programme for the five islands in this study.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Island** | **Area monitored (ha)** | **Dates of data collection** | **Frequency of monitoring** | **Methods** | **Nest Distribution** | **Nest Habitat Type** | **Last assessment** |
| Aldabra Atoll | ?? | Feb 2009– Nov 2016 | Continuous year-round monitoring, every 2 weeks | Survey of all nests in area | Only on lime stone islets or coastal outcrops. Only monitored on Picard the islets within the adjacent channel. | Lime stone cavities or cavities in dense vegetation on small islets and coastal outcrops. |  |
| Cousin Island | 20 | 2005–2007, 2009–2016 | Once/twice a year Feb and/or July | Survey of ca. 100 nests | Ubiquitous | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |  |
| Aride Island | 5 | Jan 2011– Dec 2016 | Continuous year-round weekly monitoring | XXX | Ubiquitous though only monitored on coastal plateau. | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |  |
| Cousine Island | James?? | Jan 2007– Dec 2011 | Weekly | X fixed nest sites monitored | Ubiquitous though only monitored on accessible eastern side. | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |  |
| Denis Island | ?? Jankse | Nov 2015–Sept 2016 | Weekly | X fixed nest sites monitored | Ubiquitous though more abundant in forest. Monitored island wide??? | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |  |

Aldabra Atoll

Aldabra Atoll is a raised coral atoll, approximately 1150km southwest of the main Seychelles island of Mahé (Figure 1), and consists of four main islands totalling 155 km2 area around a central 195.9 km2 lagoon. *P. lepturus* nest predominantly on islets within the lagoon. The habitat of the islets (area between 41 and 570 m² (mean 249 m²) consists of pitted limestone crevices and salt tolerant vegetation with varying degrees of coverage. Tropicbird breeding was monitored consistently on 13 lagoon islets and an outcrop of Picard Island. During each nesting survey, the entire monitoring area was searched to ensure all new nests were recorded. The last assessment of *P. lepturus* breeding success on Aldabra was in 1980 (Prys-Jones et al.).

Aride Island

Aride is the northernmost granitic island of the Seychelles Archipelago and is situated 15 km away from Cousin Island and 50 km from the main island of Mahé (Figure 1). Aride’s 74 ha consist of 5 ha of flat plateau and 69 ha of mountainous terrain. The island has been restored from a degraded coconut plantation. A colony of *P. lepturus* nests across the island but monitoring is consistently conducted on the plateau along coastal and inland areas of forest. During each nesting survey, the entire monitoring area was searched to ensure all new nests were recorded. The last assessment of breeding success was in 2005 (Ramos et al).

Cousin Island

Cousin is 2 km from Cousine Island and 35km from the main island of Mahé (Figure 1). Cousin’s 27 ha consist of 21.6 ha of flat plateau and 5.4 ha of mountainous terrain. The island has been restored from a degraded coconut plantation. A colony of *P. lepturus* nests throughout this habitat but are predominantly monitored on the plateau both along the coast and inland. Tropicbird monitoring efforts have been consistent since 2005 until present (with two years of missing data: 2008 and 2012). The survey effort is defined by a set number of nests rather than a specific area. Approximately 100 nests at incubation stage are selected once per year in February (although additional surveys were conducted in July on several years) and each nesting attempt is followed until the outcome (and stage) can be determined, providing a snapshot of percentage breeding success. The last assessment of breeding success was 1987 (Phillips).

Cousine Island

Cousine Island, 2 km west of Cousin and 32 km NE of the main island of Mahé (Figure 1). The island is close in proximity, size and habitat to Cousin Island and likewise has been restored from a degraded coconut plantation. A colony of *P. lepturus* breeds across the island but monitoring has concentrated throughout the accessible plateau on the eastern side. All known nest sites in this area (ca. 90 sites) are continuously monitored throughout the year for new nests and to record nest outcomes. The last assessment of breeding success was conducted in 2003 to 2005 (Malan et al, 2010).

Denis Island

Denis Island is ca. 43 km north of Aride Island and 80 km north-east of the main island of Mahé (Figure 1). Denis holds a small population of *P. lepturus* which nest across the island. Nest monitoring is island-wide and follows similar methods to Aride, Cousine and Aldabra whereby a specific area (Table 2) of the island has been monitored consistently from Nov 2015 to Sept 2016. All new nests in the area monitored and nest outcome recorded. This is the first assessment of *P. lepturus* breeding success for Denis Island.

**Data analysis**

We analysed present overall breeding success, and temporal trends in breeding success and nesting density wherever possible. However, d,age of the monitoring programmes, monitoring

We explored temporal for Aldabra, Aride, and Cousine, where monitoring takes place continuously over the years and surveys span several years. To do that, we employed a set of Generalised Additive Models (GAM) in each location with nest density or breeding success as a response variable. Nest density was defined as the number of new nests recorded within the monitoring area per month while breeding success as a binomial variable (nest fledged = 1; nest failed = 0). We employed a normal and binomial error structure for the density and success models respectively. We included two independent variables as smooth terms, ‘date’ and ‘month’ in order to assess long term trends while accounting for the possible seasonality in the response variables. Survey effort was constant over the year in all these tree locations, and as we are not performing comparisons across sites it was not necessary to account for potential sources of variation among the areas surveyed.

Data for Cousin and Denis Islands were insufficient to perform this analysis and therefore only annual average breeding success was included for these sites. Cousin data was collected using a selection of nests chosen at one point in the year and this selection was followed until all outcomes were accounted for, no additional nests were added. Also, in Cousin, the number of nests monitored was not constrained by survey area, simply a sample of nests were chosen. The Denis Island monitoring programme was in-place for just under one full year. Whilst not comprehensive, the data obtained from these sites was sufficient to obtain a general indication of breeding success. In any case, evaluating the differences in methods is also a key aim of this study and we therefore take this up in the discussion.

**Results**

Table 3 shows a summary of overall breeding success results for each site. Breeding success (% of successful nests) was highest at Denis Island followed by Cousine Island and lowest at Aldabra Atoll during the periods in which these sites were monitored. The proportion of nest failures at egg stage did not vary greatly between sites.

Table 3. Number of *P. lepturus* nests monitored in study period, overall nesting success (% successful nests, i.e. fledglings) and the proportion of nests that failed at egg or chick stage at each site (%).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Island** | **Total nests monitored** | **# Mean annual nests monitored** | **# Mean annual nests successful (fledged)** | **# (%) of failed nests failed at egg/chick stage** | **Mean annual nesting success (± SE)**  **\* Mean monthly success** |
| Aldabra Atoll | 333 | 42 | 6.4 | 66 / 34 | 15.2% (± 2.29) |
| Aride | 1033 | 172 | 69 | 62/38 | 40.2% (± 3.8) |
| Cousin | 854 | 93 | 37 | 64/36 | 33% (± 4.04) |
| Cousine | 537 | 107 | 52.2 | 72/28 | 51.6% (± 2.9) |
| Denis | 39 | na | na | 61/39 | 55%\* (± 9.3) |

No variation in nesting density (the number of new nesting attempts recorded per year) was observed at Aldabra, a decline in nesting density was observed over time at Aride (df=1.6, x2=35.2, p=<0.05; Fig 2A; Table 4) and an increase in nesting density was observed on Cousine (df=1.9, x2=29.2, p=<0.05; Fig 2A; Table 4).

***trend-all-locations__20161114***

***Figure 2:*** *Long-term trends in (A) Nesting density of new P. lepturus and (B) probability of nesting success on five islands in Seychelles. Shaded areas indicate the corresponding standard error of the model predictions. Vertical bars indicate standard deviation for Denis island.*

Breeding success remained constant over the years in which monitoring was carried out on all islands except Aldabra, where a decreasing trend was observed over time (df=1, x2=7.61, p=<0.05; Fig 2B; Table 4).

On Aride nesting density showed a seasonal pattern with a peak in nesting attempts during September and October, a secondary peak between April and June and a low in December and January (df= 3.8, x2=49.1, p=<0.05; Fig 3; Table 4). Seasonality in nest density is present though weaker on Cousine (df= 3.1, x2=12.7, p=<0.05; Fig 3; Table 4) and virtually nonexistent on Aldabra.

seasonality-new-nest_20161114

***Figure 3:*** *Seasonality in nesting density of P. lepturus. Shaded areas indicate the standard error of the model predictions.*

***Table 4:*** *Generalised additive model output for nesting density and breeding success. Trend refers to temporal change and season refers to changes observed on an annual cycle (seasonality).*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Island** | **Term** | **e.d.f.** | **χ2** | ***p*** |
| success | Aldabra | trend | 1.00 | 7.61 | 0.006 |
| Aride | trend | 1.00 | 0.14 | 0.706 |
| Cousine | trend | 1.00 | 0.06 | 0.802 |
| nests | Aldabra | season | 0.64 | 1.17 | 0.151 |
| trend | 2.11 | 5.68 | 0.090 |
| Aride | season | 3.78 | 49.1 | 0.000 |
| trend | 1.60 | 35.2 | 0.000 |
| Cousine | season | 3.09 | 12.7 | 0.003 |
| trend | 1.99 | 9.25 | 0.014 |

**Discussion**

To identify trends in nesting population density and breeding success and to test the value of the data within a seabird hotspot region we combined monitoring efforts from five important nesting sites for *P.lepturus* in the Seychelles.

***Overall breeding success***

This first national study of *P.lepturus* breeding success showed great variability between the study sites. The lowest breeding success was recorded at Aldabra Atoll, the most isolated site and the only site with invasive rats present. Aldabra has one of the lowest records of breeding success for *P.lepturus* throughout their range, though similar to that found at Fernando de Noronha archipelago, in Brazil – the largest colony of *P. lepturus* in the South Atlantic. Here 14.3% of nesting attempts were successful and predation at egg stage accounted for 50% of the attempts with the low success being attributed mainly to predation by crabs and nest exposure (Leal et al. 2016). The lowest breeding success for *P.Lepturus* has been recorded at Europa Island at 6.9% for non-rat controlled habitats (Ringler, et al., 2015). Aldabra therefore conforms to results obtained from other studies where invasive predators are present and supports the claim that in the case of Tropicbirds, predation by invasive species (mainly rats – Russel & La Corre 2009; Sarmento et al., 2014) and native species (mainly large crabs - Phillips, 1987; Schaffner, 1991) is the main cause of mortality during breeding. It is reasonable to conclude that for sites with no long-term negative trend detected, differences observed in overall breeding success are predominantly due to the level and combination of predators at site level. Aldabra has a different combination of potential predators to the other sites (Coconut crabs, rats, grey heron, drongo) as well as potential nest site competition by sympatric red-tailed tropicbirds *Phaethon rubricauda*

that may account for the lower overall breeding success.

The remainder of our sites have breeding success averages that are more aligned with that found elsewhere; 30% at Ascension Island (Stonehouse 1962), 21% at Cayo Luis Peia, Puerto Rico (Schaffner 1991). The highest breeding success recorded globally is across eight islands in Bermuda where success averaged 70.6% and all sites are managed as nature reserves with active exclusion of mammal predators including rats, cats and dogs (Madeiros, 2008). This study was unable to directly compare the overall levels of breeding success between sites due to the variability in monitoring duration and timing.

**Breeding success trends**

The low breeding success observed at Aldabra does not account for why breeding success has been decreasing at this site over this study period. This decline is reinforced by the earlier studies of *P.lepturus* at Aldabra, which found breeding success to be much higher 30–35 years ago (47.5% recorded by Diamond in 1975; and 46% recorded by Prys-Jones in 1980). Of all the known and potential predators listed for Aldabra, all except rats are also monitored and none have shown increasing trends (SIF unpublished data). An increase in drought periods reported for Aldabra (Haverkamp et al., 2017) is unlikely to have directly impacted *P.Lepturus* breeding success due to their choice of limestone crevices as sheltered nest sites rather than vegetation cover. Sheltered nests have more stable ambient temperatures and site selection offsets difficulties imposed by the weather (Hart, Downs, and Brown 2016b). There also appears to have been no changes in nesting seasonality with none apparent in earlier studies (Diamond, 1975; Prys-Jones, 1980) as well as this one. In-fact the differences in seasonality observed between Aldabra, Aride and Cousine may well be as a consequence of the level in which *P.Lepturus* are nesting in rock crevices or in vegetation at each site, though this is not investigated further in this study. In conclusion for Aldabra; this monitoring programme was sufficient to detect a trend and to some extent rule out several factors that may have caused such a trend but overall it was not possible to distinguish the drivers of a decline in breeding success. Further investigation into internal factors such as nest site competition and predation as well as external factors such as food availability are required.

The lack of breeding success trends detected at the other sites within this study is reinforced by comparisons with previous reports; on Cousine 51.6% nesting success was recorded compared to 25% by Malan (2010); Cousin averaged 33% in this study compared to the 36% recorded by Phillips in 1987, Aride averaging 40.2% compared to the 21-37% recorded by Ramos et al. in 2005.

**Nesting density trends**

Our results also showed that nesting density remained stable at Aldabra, showed a slight upwards trend at Cousine and a continuous negative trend on Aride. This decline on Aride was previously reported; Bowler et al. (2002) showed that the nesting population of *P. lepturus* suffered an apparent decline of 60% between 1989 and 1998, and our results and unpublished census data also support the continuation of this decline. There are two key factors that suggest population decline on Aride is caused by adult survival at the site; firstly, that Aride continues to maintain relatively high and stable breeding success along with Cousine and Cousin, and secondly, that neighbouring island Cousin maintains a stable population trend (1987 to 2014, unpublished census data) and Cousine island shows an increasing population trend (this study and 2003 to 2017 unpublished census data). For these islands that are within close geographical proximity it is reasonable to expect *P. lepturus* to be under similar influence of external factors (climatic variations and food availability) indicating that the Aride breeding population decline is not linked with external factors.

Additional work by Ramos et al. (2005) found that breeding success on Aride was significantly correlated with the El Niño Multivariate Index (i.e El Niño resulted in lower breeding success) but there was little evidence that productivity was influenced by local factors (hard tick infestations and intra and inter-specific competition) in general. Further to this, Catry et al (2009) determined that annual adult survival could not be linked to inter-annual variability in oceanographic conditions, but may be more influenced by *Pisonia grandis* fruiting events, which, overall, accounts for 23.2% of the adult mortality (*P.grandis* produces sticky seeds which can trap and kill seabirds). Based on survival rates they predicted that the probability of extinction of this population would be 99% in 170 years and suggested some active management by maintaining some open areas both at canopy and ground level. *P. grandis* is native to Seychelles and thrives in acidic guano enriched soils. It is common across Aride, Cousin and Cousine, and causes mortality across all seabird species that nest in its vicinity. Cousin for example has 69% *P. grandis* coverage (Hill et al. 2002), and despite *P. grandis* induced adult mortality of *P.lepturus* no decline in population has yet been recorded. One possible interpretation is that, although *P. grandis* is native to the archipelago, its fast post‐restoration establishment (Aride, Cousin and Cousine were all once coconut plantations) has led to possibly higher density than pre-plantation levels, because slower growing climax vegetation is yet to mature. However, this doesn’t explain the differences observed between Aride and Cousin/Cousine. Another factor may be the internal management of *P.grandis*; with Cousine island actively raking *P.grandis* seeds during fruiting events and Cousin raking all pathways regularly. On Aride the pathways are also raked weekly but not actively targeting *P. grandis*. A 1170m2 costal path area was cleared between 2009 and 2011 and planted with native trees. The new vegetation management plan set up by the Island Conservation Society (Aride management) is planning to further clear 1.5 Ha of *P. grandis* in different areas to tackle the seabird entanglement issue (Calabrese 2017). If during the first year the areas are successfully cleared and maintained, the clearing effort will be increased in targeted areas for *P. lepturus*. Monitoring of *P. lepturus* will continue in order to assess the effectiveness of *P. grandis* removal on the breeding population. Raking *P. grandis* seeds in the monitoring area (5 Ha of plateau) should also be considered and included in the vegetation management plan. To conclude; we are not certain why the Aride breeding population is in decline but by pooling studies on *P.lepturus* between neighboring islands it has been possible to narrow down the possible causes. Further investigation is required into site specific internal factors influencing adult mortality.

***Monitoring Programmes***

We aimed to use the *P.lepturus* monitoring programmes to assess whether the monitoring programme design was adequate to not only detect trends but to also distinguish the main influencing causes. For *P.lepturus* to truly be used as an indicator of ocean ecosystem health the site specific factors influencing breeding success and breeding population density must be distinguished from external factors. Whilst at Aldabra it was possible to rule out several predators as the potential cause of the decline in breeding success, it was not possible to distinguish further. Likewise for Aride, by comparing breeding population trends between islands we were able to assign the probable cause to be site specific. In order to build upon current knowledge and efforts and improve the value of data for *P.lepturus* throughout the Seychelles werecommend anationwide monitoring plan should be implemented with consideration for the spectrum of resources available at each site. The following method recommendations are made:

1. A basic monitoring programme should consist of year-round monitoring of a designated area (with consideration for accessibility for regular monitoring and representative of typical nesting habitat) that is large enough to include a sample size of minimum 30 nests per year (30 is thought to be the minimum number in which all current programmes could continue based on nesting population size and accessibility of nest sites at these five sites). The designated area should then be monitored closely with sustained continuous effort to ensure all new nests are recorded and followed until breeding outcome is determined. This method allows for a multi-parameter monitoring programme, including data on overall breeding success but also seasonal and temporal breeding success and nest density to be recorded. The basic monitoring should record stage at failure.
2. Monitoring should be conducted a minimum of once every two weeks (though ideally more frequently) to ensure: a) that the number of new nests which fail in early stages are captured as much as possible and b) to endeavour to correctly record the stage at which nesting attempts failed.
3. Additional parameters may be included that do not enhance time or personnel required though add some complexity to the monitoring programme (and therefore must be explicitly described in a methods protocol). These may include: 1) a measure of nest site choice. Nest site is an important factor governing nest success, avoiding excessive cold and hot temperatures are essential for egg development stage as these can slow development and cause embryonic death (Grant 1982; Olson et al. 2006) and tropical seabird species have a more delayed onset of thermoregulatory capabilities when compared with those in temperate environments; therefore nest microhabitats and behavioural thermoregulation, are important factors during egg brooding and early chick development (Hart et al, 2017). Nest site choice can be recorded in terms of habitat type (e.g vegetation/rock crevice/tree limb etc) and site exposure (e.g level of shade, peripheral cover from weather, accessibility to predators etc). 2) Evidence or observation of predator interaction.
4. Any additional programmes that monitor the ecosystem that *P. lepturus* individuals interact with are beneficial and may be useful in determining or ruling out certain factors affecting nesting success. For example, monitoring trends in natural or invasive predators, vegetation phenology and climate variables.
5. Should a declining trend in breeding success be observed then further actions may be taken to determine cause, these may include the use of camera traps on nests to observe factors such as predation, chick feeding frequency and nest desertion by adult. If there is no obvious cause then further investigation of external factors such as climate, food availability may be investigated via satellite data coupled with geo-tagging birds.
6. To enable national level monitoring of *P. lepturus* a standardised protocol should be developed and followed at all sites coupled with a standard database format to ensure data management enables and leads to relatively frequent analysis which can provide site managers with the information to make appropriate and informed management responses.

*Conclusions*

The Western Indian Ocean has recently been identified as a key area to prioritize for the conservation of global marine biodiversity in the face of climate change (Ramírez et al. 2017). The Seychelles Archipelago supports the greatest abundance of seabirds in the tropical Indian

Ocean (Le Corre et al, 2012). Regional seabird population success and trend data is not readily available despite data being collected for many years at several locations. A greater effort must be made to streamline regional data and utilise the results to steer management practices and channel research resources towards the most critical areas. This study highlights a decline in nesting success at Aldabra atoll and a decline in nest abundance at Aride, both require further understanding and therefore management should focus research efforts and conservation resources at establishing likely causes of these declines. This is likely to be most successful by establishing holistic values across the region and managers working together to protect these values.

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