https://doi.org/10.61350/sbj.37.7

Growing mortality rates among Northern Gannets entering wildlife rehabilitation: the challenge in diagnosing aspergillosis as the underlying cause

Aaron Pahl[1]*

*Correspondence author: aaronpahl@yahoo.com

[1]University of Alabama at Birmingham, 1700 University Boulevard, Birmingham, Alabama, 35233

AP ORCID: 0000-0001-8732-438X

Abstract

Since 1988, the Northern Gannet *Morus bassanus* (hereafter 'Gannet') population has exhibited an extremely low and downward trending release rate when admitted to wildlife rehabilitation facilities in the United States. Across more than 4,000 Gannets admitted to rehabilitation facilities between 1988 and 2023, patients demonstrated an overall release rate of 13.7%. More concerning is that Gannet release rates have not exceeded 10% since 2018 and dropped to 5.5% in 2019. The challenge is that Gannets admitted to rehabilitation facilities often exhibit no external signs of injury making it difficult for rehabilitators to diagnose their reason for admission. However, they are frequently in such poor body condition that they require immediate euthanasia or die within 24 hours of admission. In many instances, their clinical signs are listed as exhaustion, trauma, or emaciation. Based on data collected from 39 rehabilitation facilities along the East Coast of the United States and one facility in Canada, 46.4% of patients were admitted due to exhaustion or emaciation. To determine cause of death with more accuracy, more than 90 Gannet patients (2.2%) were necropsied. The results indicated that over 60% of the necropsied patients were suffering from aspergillosis.

Keywords

Morus bassanus, respiratory issue, mortality, wildlife rehabilitation, avian rehabilitation, avian disposition

Introduction

The Northern Gannet *Morus bassanus* (hereafter 'Gannet') is an avian marine species that only visits the shore to breed, with juveniles believed to remain entirely at sea during their first three years of life (Mowbray 2020). Of an estimated global population of 1.5 million–1.8 million mature individuals, there are roughly 116,825 breeding pairs in North America that migrate from their breeding colonies in Eastern Canada to the Gulf of Mexico typically flying around, but not over, Florida, USA (Gunter & Burke 1977; Chardine *et al.* 2013; Mowbray 2020).

Based on their population extent and size, Gannets are considered a species of Least Concern (BirdLife International 2018). However, the United States Department of the Interior considers them a species of conservation concern specifically within the Federal waters of the mid-Atlantic United States (Spiegel *et al*. 2017). Substantial research has been conducted on the species in their breeding colonies in the Eastern North Atlantic and North America, but little research has been conducted outside their colonies (Mowbray 2020).

Every year, hundreds of migrating adult and juvenile Gannets are found injured or dead along the Florida coast. Most do not survive beyond the first 24 hours. A study of over 386,000 avian patients across more than 580 species admitted to Florida wildlife rehabilitation facilities between 2009 and 2023 showed an overall average release rate of 35% (Pahl 2024). In that study, Gannets represented more than 3,000 patients with the lowest survival rate of the 92 most frequently treated species (Pahl 2024). This study includes more than 1,000 additional Gannet patients from Florida and along the East Coast with an overall release rate of 12.7%. Even more concerning than the low overall release rate is that over the years the release rate continued to spiral down. In 1993, 34.2% of Gannet patients were released. By 2022, the release rate had dropped to a mere 5.9%. The question is, why?

The answer may, at least in part, be due to aspergillosis. When admitted, many Gannet patients appear exhausted and emaciated but show little to no evidence of trauma or disease. Aspergillosis is one of the most frequent fungal infections in birds, both captive and wild, with *Aspergillus fumigatus* being the most common cause (Huang & Mayer 2018; Sabino *et al*. 2019).

Aspergillosis is a fast-growing fungus with infection often resulting due to exposure to an overwhelming amount of spores or the patient being immunosuppressed (Speer 2016). The birds' high body temperatures and the humid environment of the airways create an ideal location for the fungus, allowing it to multiply rapidly (Speer 2016). Seabirds are considered extremely susceptible to aspergillosis, but few cases are reported in wild birds. Most infections are thought to be the result of being brought into captivity at rehabilitation facilities (Speer 2016). Aspergillosis lesions can present as white-yellow nodular to confluent plaques, visible green-grey mould, and sporulation occurs primarily in the air sacs and lungs (Beernaert *et al*. 2010; Fischer & Lierz 2015). As the illness does not include obvious external features, it can be challenging to diagnose. Gannets may have a large global population, but their low release rate along the United States East Coast warrants concern and requires further investigation.

Materials and methods

Ethical statement

An ethical review was considered but deemed to not be necessary based on the nature of this study.

Data sources and terminology

Gannet patient records (N = 4,431) were collected from several United States government agencies, laboratories, and rehabilitation facilities along the East Coast, along with a wildlife rehabilitation facility in Nova Scotia, Canada (N = 7) for a total of 4,438 patient records. These records included varying amounts of patient information with only 2,505 records (56.4%) indicating final disposition while the

remaining 1,933 (43.6%) records included additional information such as patient age, cause of injury, exact intake date, final disposition date, intake weight, sex, white blood cell (WBC) count, packed cell volume (PCV), and total solids (TS).

Mortality data were obtained on an additional 518 Gannets that were not admitted to rehabilitation facilities. Some mortality data came from laboratories conducting necropsies.

The US federal permit defines final disposition terminology as Released; Transferred; Pending; Euthanised; Died; and Dead On Arrival (DOA). The designation DOA was added to the federal permit form in 2010. Some facilities expand beyond the federal reporting terminology to provide greater detail about patient disposition by including the designations "Euthanised +24 hours" and "Dead +24 hours." These distinctions provide more specificity; however, the distinctions were only used by a few facilities and were not used consistently through the years resulting in the underreporting of patients under these categories.

Data normalisation

The rehabilitation data collected did not employ a controlled vocabulary and included a wide variety of acronyms, misspellings, and slight variations in terminology. To alleviate those variations the data including age, patient injury, and weight were normalised.

Patient age was consolidated into three categories based on plumage: fledgling, juvenile, and adult. The two patients identified as fledglings were most likely reporting errors given that Gannets do not migrate to the United States until after they have transitioned from fledglings into juveniles. Since determining sex in Gannets externally is almost impossible, sex had to be determined through an examination of the internal gonads, which meant that very few records included information in that field (Redman *et al*. 2002). All patient weights were converted to kilograms. Patient injuries were normalised and consolidated into 33 categories. In cases where a patient was suffering from multiple ailments (e.g. broken leg, bumblefoot, emaciation, and mites) the most severe was selected (e.g. broken leg). The incomplete nature of some patient records did not allow for further elaboration. For example, exhaustion was commonly used as a reason for admission for patients with no other visible injuries. Due to the limited number of patients laboratory tested for aspergillosis, the terms fungal infection and aspergillosis are used interchangeably.

Rehabilitation facility data

The "Licensed Wildlife Rehabilitators List" of individuals and facilities permitted to rehabilitate wildlife in the state of Florida currently includes 47 facilities with active avian permits (Florida Fish and Wildlife 2023). As part of a wider study, data were collected from more than 50 currently active or inactive facilities spanning 2009 to early 2023, of which 29 facilities treated Gannets (Pahl 2024). Of the data collected from Florida rehabilitation facilities, 91.7% (N = 3,449) fell within that timespan while the remaining 8.3% (N = 313) fell between 1988 and 2008 and came from a single facility. As these data were obtained from a single facility and represented low yearly patient numbers, fewer than ten patients in 13 of the 21 years, its inclusion or exclusion from calculations is clearly indicated.

Of the 29 facilities in Florida that treated Gannets, six treated over 80% of the admitted patients. At the other end of the spectrum, six facilities treated only a single patient (Table S1).

The data from Florida facilities included one patient with a TS of 20 g/dL, which appears to be a typo of 2.0 g/dL. One patient with a WBC of 80,000 cells.μL^{-1} also appears to be an error, but at this time there is no way to confirm this. This patient was tested three days later resulting in a 38,800 cells.μL^{-1} WBC count. In addition, 33 patients were recorded as spending 100 days or more in care. Those durations also appear to have been entered in error and were removed from all duration of care calculations.

Data were also collected from 11 rehabilitation facilities along the United States East Coast (ten) and Canada (one) representing 676 patients (Figure 1). The data for ten of those facilities came from WildOne (Wildlife Center of Virginia 2025). Tri-State Bird Research & Rescue represented 53.3% of the patients outside of Florida while 34.1% of those were admitted in Delaware.

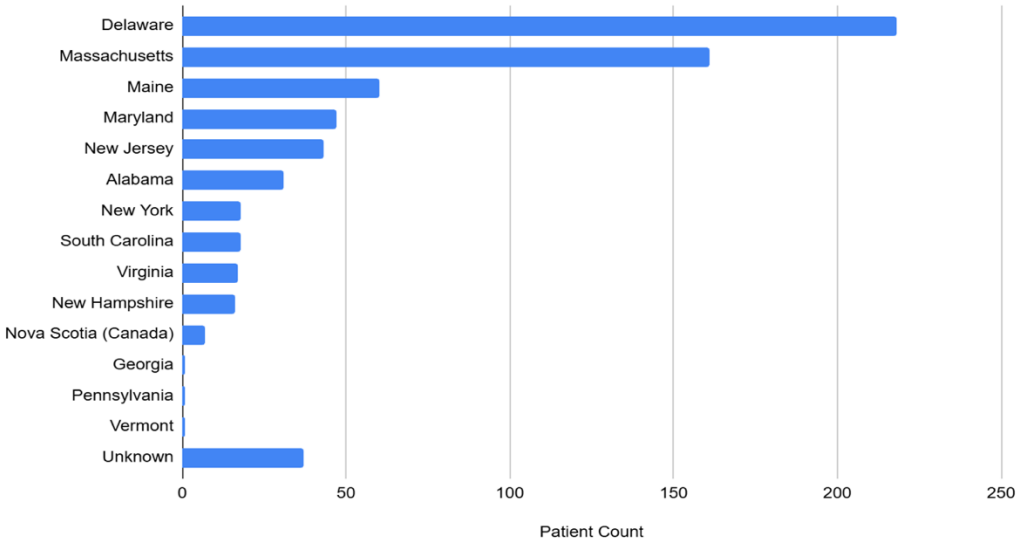

Figure 1: Number of Northern Gannet *Morus bassanus* patients admitted to rehabilitation facilities per USA state (excluding Florida) and Nova Scotia.

Necropsy

To better determine the cause of admission and ultimately death, 86 deceased Gannet patients were necropsied at the Marine Science Center between November 2020 and March 2023. The Marine Science Center is an avian rehabilitation center, turtle hospital, and education center located in Ponce Inlet, Florida along the Atlantic Ocean.

At the Marine Science Center, necropsies were performed by five individuals including a veterinarian, a veterinary technician, an intern, and two avian rehabilitation staff members. This study's principal investigator conducted 55 (64%) necropsies, a staff member conducted 25 (29%) necropsies, and the remaining six (7%) necropsies were performed by the veterinarian, veterinary technician, and intern.

Necropsy forms were used to record any findings. Due to specimens' varied internal conditions not every necropsy resulted in a completed form. For example, patient sex was often not visible due to the patients' injuries.

Necropsies were performed within 33 days of a patient's death with five patients missing a date of death. The vast majority (89.5%) of necropsies took place within six days of the patient's death with 41.9% performed the same day the patient died, and 16.3% performed the day after the patient's death. Patients not necropsied the day they died were stored in a refrigerator or frozen prior to necropsy. Due to budgetary and time constraints, no samples collected during necropsies at the Marine Science Center were sent off for external lab testing.

The PCV, WBC, TS, weight, sex, and age of patients necropsied at the Marine Science Center were included in the rehabilitation data calculations. Due to risks surrounding Highly Pathogenic Avian Influenza's (H5N1) arrival in Florida in February of 2022, no other Gannets were admitted or necropsied that year.

More than 60% of the necropsies revealed lesions consistent with aspergillosis. Seeing a pattern developing from the necropsies, and in an effort to confirm the diagnosis of aspergillosis, five Gannets were sent to an accredited state laboratory in Florida to perform full independent necropsies and analysis. To describe better the extent of what was suspected to be aspergillosis in the necropsied Gannets, five levels of severity were defined based on the analysis captured in the original necropsy forms and the laboratory results (Table S2).

External laboratory testing

In January and February 2023, five Gannets from Florida, including one from the Marine Science Center and four from a nearby facility, were sent to the Bronson Animal Disease Diagnostic Laboratory (BADDL) to receive complete necropsies including sample testing. BADDL is part of the Florida Department of Agriculture and Consumer Services and provides scientific expertise in investigating animal diseases (*Florida Department of Agriculture & Consumer Services* n.d.). It is a level 1 laboratory accredited by the American Association of Veterinary Laboratory Diagnosticians as a full-service veterinary diagnostic laboratory and the only accredited laboratory in Florida (*Florida Department of Agriculture & Consumer Services* n.d.).

Five patients that died consecutively, exhibited no external signs of trauma or disease, and died recently enough to avoid decomposition were selected. Four died or were euthanised the day they arrived at the rehabilitation facility and one was DOA. All specimens were frozen immediately upon death and sent to the lab for testing.

Non-rehabilitation data

The 518 Gannet records that did not come from rehabilitation facilities came from governmental organisations in New York and Florida. Florida Fish and Wildlife has a public avian mortality reporting form. However, the data submitted through this form included significant deficiencies including misidentifications and the potential double reporting of animals. The data provided from this source are

treated as minimally reliable and only intended to provide a more complete picture of Gannet mortality across Florida.

Minimal data were also collected from state, county, and city organisations across Florida tasked with monitoring public spaces such as parks and beaches. The data obtained by these organizations should be considered reliable. The New York data were obtained from the New York State Department of Environmental Conservation (NYSDEC). The NYSDEC accepts dead wildlife for necropsy including 26 Gannets between 1979 and 2023.

Results

Rehabilitation disposition

The 4,438 Gannets admitted to rehabilitation facilities between 1988 and 2023 included in this study had an average release rate of 13.7%, after removing the DOA patients (Table S3). The 3,762 Gannets admitted in Florida had an average release rate of 14% while the 676 patients admitted outside of Florida had an average release rate of 12.3%, after removing the DOA patients. The Gannets annual release rate has been trending down since 1988 with 2019 to 2022 all under 10% (Figure 2).

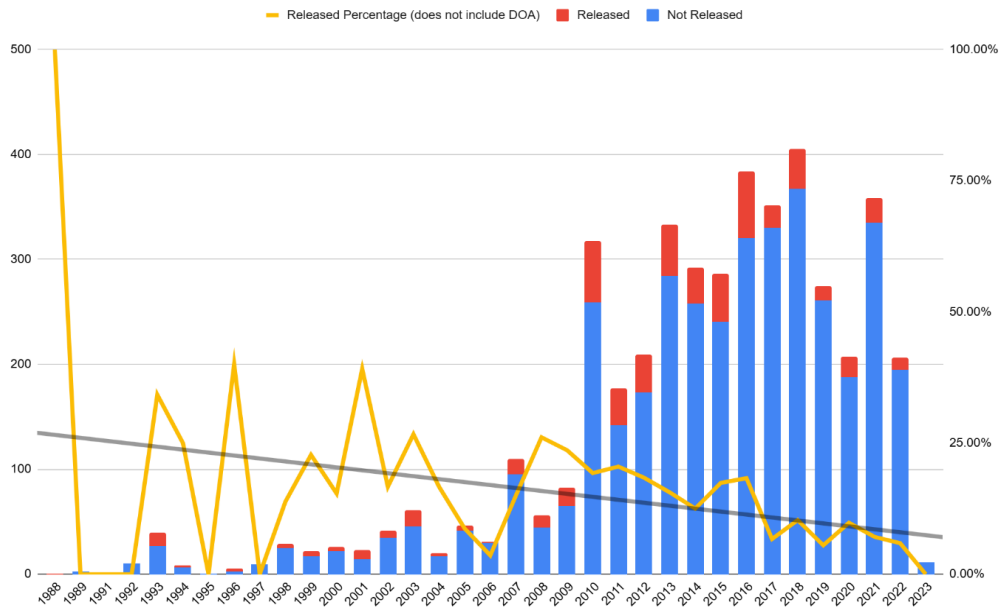

Figure 2: Total number of Northern Gannet *Morus bassanus* rehabilitation patients admitted in each year, across all states, separated into those that were released and those that were not released. In addition, the figure shows the release rate percentage each year, with a trend line (gray) showing a consistent downward trend in the release rate.

Rehabilitation patient analysis

Within the data, a very small percentage (3.2%) of patients included an identified sex, of which 63.1% were male with 2.2% being released (Table 1). Of the 1,396 (31.5%) patients that included an age, adults had a slightly higher admission and release rate compared to juveniles (Table 1). Between 1988 and 2008 the volume of patients with a known age was too low and inconsistent to draw supported conclusions but between 2012 and 2022 the percentage of adults being admitted decreased steadily (Figure S1).

Table 1. Ages and sex of all Gannets admitted to and released from wildlife rehabilitation facilities, separated out between Florida and the East Coast facilities. The table also includes the percentage of patients released based on age and sex.

	Florida				East Coast				Total			
	Patients		Released		Patients		Released		Patients		Released	
	N	%	N	%	N	%	N	%	N	%	N	%
Adult	440	56.4	48	10.9	306	49.7	37	12.1	746	53.4	85	11.4
Juvenile	338	43.3	30	8.9	310	50.3	36	11.6	648	46.4	66	10.2
Fledgling	2	0.3	0	0.0	0	0	0	0	2	0.1	0	0
Total	780		78	10.0	616		73	11.9	1,396		151	10.8
Male	40	70.2	0	0.0	49	58.3	2	4.1	89	63.1	2	2.2
Female	17	29.8	0	0.0	35	41.7	0	0.0	52	36.9	0	0.0
Total	57		0	0.0	84		2	2.4	141		2	1.4

Within the Florida data, adult patient numbers decreased even more dramatically, decreasing from 97% of all patients in 2010 to 6% of all patients in 2022 (Figure 3). In Florida, 25.3% (952) of patients included a cause of injury or disease while 91.1% (616) of East Coast patients included a cause of injury or disease. Over 80% of patients fell into the five most frequent injury categories with more than 90% falling into the top eight categories (Table S4).

The most frequent cause of injury was exhaustion followed by emaciation. An additional 353 patients were suffering from emaciation, but emaciation was only considered to be a secondary ailment. Emaciation resulted in a 4.9% release rate while aspergillosis and suspected aspergillosis both had release rates of 0% across a combined 122 patients. There were an additional 35 patients that had suspected or confirmed cases of aspergillosis as a secondary ailment.

Aspergillosis predominantly affected juvenile patients (83.5%) whereas trauma predominantly affected adult patients (65%; Figure 4). There were slightly more (52%) adults with a known injury than juveniles. In addition to the primary and secondary ailments patients faced, 138 (22.8%) were found to have external mites and 32 (5.3%) were found to have internal parasites. Of the 1,155 patients that included a

duration of care under 100 days, the average stay for a Gannet was 5 days ± 10.7 (± SD; median = 1 day) (Table S5).

Patients suffering from emaciation spent an average of 2 days ± 4.9 (median = 1 day) in care, whereas patients suffering from exhaustion spent an average of 7 days ± 13.1 (median = 2 days) in care. Of the patients suffering from emaciation, 65% had a final disposition within one day.

There were a total of 1,477 patient records from Florida and the East Coast that included an intake month. The month of May registered the highest intake activity with 190 admissions evenly split between Florida and East Coast results. December registered the second highest patient volumes (182) with 81% of the admissions occurring in Florida. (Figure 5).

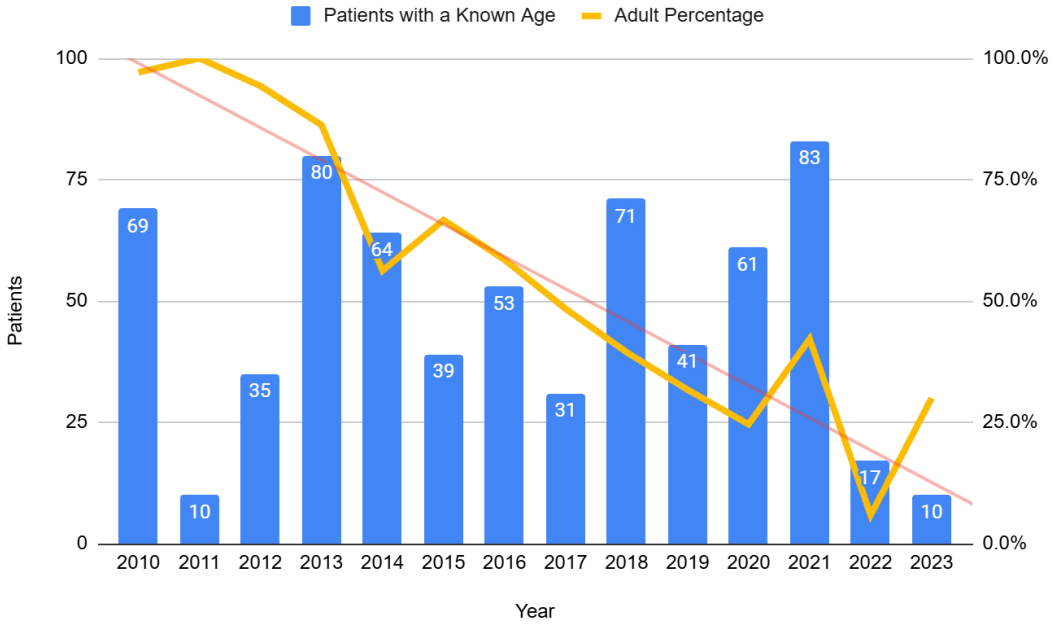

Figure 3: The intake percentage of adult Northern Gannet *Morus bassanus* rehabilitation patients admitted in Florida between 2010 and 2023 with a known age. The figure includes the volume of patients with a known age, including adults and juveniles.

There were 774 patients that included intake weights resulting in an average of 1.92 ± 0.33 kg (Table 2). Adults had higher average weights than juveniles and emaciated patients had the lowest average weights at 1.66 kg (Table 2).

Average patient intake weights also differed by disposition with released patients having the highest average weight at 2.14 kg. There were 307 (51%) adult and 293 (49%) juvenile Gannets with an identified weight. Juveniles were concentrated in the lower weight range with 78.2% falling below 2.00 kg compared to 49.5% of adults. The majority of patients (62.1%) with a recorded weight fell between 1.50 and 1.99 kg (Table S6).

Table 2: The weights of Gannets with a known weight in kilograms. The table also compares adults and juveniles while including the final disposition in relation to patient weights. Average ± Standard Deviation, Minimum–Maximum weight; Total patients.

Status	Adult	Juvenile	Total
Died	1.97 ± 0.24 1.45–2.95; 123	1.81 ± 0.21 1.33–2.54; 89	1.87 ± 0.24 1.01–2.95; 297
DOA	1.89 ± 0.25 1.49–2.37; 13	1.68 ± 0.07 1.61–1.74; 3	1.77 ± 0.27 1.09–2.37; 22
Euthanized	2.09 ± 0.38 1.43–4.27; 116	1.85 ± 0.27 0.96–3.08; 138	1.94 ± 0.35 0.91–4.27; 292
Necropsy	2.00 ± 0.28 1.59 –2.50; 11	1.67 ± 0.32 1.33–3.40; 38	1.75 ± 0.39 1.33–3.6; 62
Released	2.27 ± 0.30 1.66 –2.82; 43	1.94 ± 0.21 1.71–2.54; 25	2.15 ± 0.31 1.66–2.82; 96
Transferred	1.84 ± 0 1.84 –1.84; 1		2.08 ± 0.33 1.76–2.70; 5
Total	2.05 ± 0.33 1.43–4.27; 307	1.82 ± 0.27 0.96–3.40; 293	1.92 ± 0.33 0.96–4.27; 774

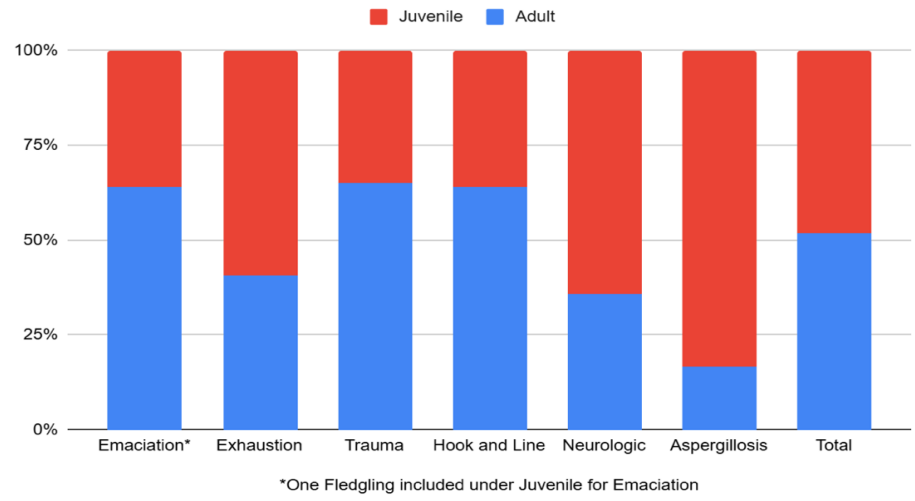

Figure 4: The six most frequent reasons why a Northern Gannet *Morus bassanus* with a known age was admitted across all patients, separated by age.

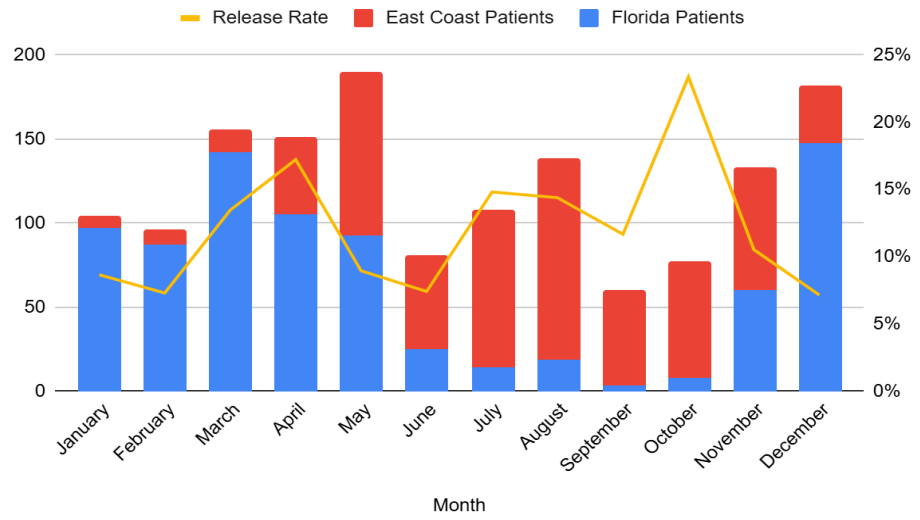

Figure 5: The volume of Northern Gannets *Morus bassanus* admitted to wildlife rehabilitation facilities in each month, separated out between patients admitted in Florida and the East Coast. In addition, the figure shows the release rate of those patients for each month.

No patient with a weight below 1.50 kg was released and only 2.4% of patients under 1.74 kg were released (Table S6). Between 2009 and 2022, 52 Gannets included a WBC count ranging from 5,120 to 80,000 cells.μL^{-1} with an average of 22,741 ± 16,604 (median = 19,999; Figure 6).

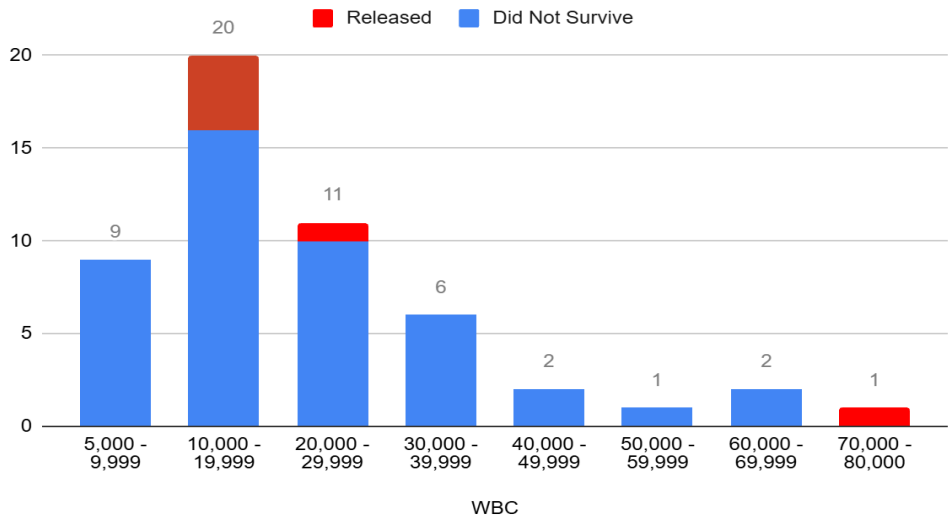

Figure 6: The white blood cell (WBC) count in cells per microliter for all Northern Gannet *Morus bassanus* patients with a known WBC count, including both those that were released and those that died.

There were 303 patient records that included a PCV value with a range from 8%–73% and an average of 31.7 ± 11.4% (median 33%) (Figure S2). Of those 303 patients, 23 (7.6%) were released with the majority having a PCV value between 30% and 40%. TS levels were included in 281 patient records ranging from 0.2–20 g/dL, with an average of 3.08 ± 2.06 g/dL (median = 2.8 g/dL; Figure S3). There were 86 Gannets necropsied at the Marine Science Center. There were clear lesions of a fungal infection strongly suspected of being aspergillosis in 60 patients (69.8%). An additional five patients showed early lesions of a fungal infection (Table 3).

The 81 (94%) necropsied patients with a known duration of care spent an average of 2.2 days in care, with only four patients spending more than six days in care. The patients showing clinical signs of aspergillosis spent an average of 1.5 days in care, while those without clinical signs of aspergillosis spent an average of 5.3 days in care. Almost half, 49.2%, of the patients showing clinical signs of aspergillosis spent zero days in care.

Table 3: The findings from necropsies conducted on Gannets in Florida, including the primary cause of death, average duration of care, and any additional ailments found. *Only includes patients with a known duration of care (81/86).

Primary Cause of Death	**N**	**Average Duration of Care***	**%**
Aspergillosis	60	1.5	69.8
Suspected Aspergillosis	5	0.2	5.8
Trauma	13	7.1	15.1
Emaciation	2	6	2.3
Fish hook	2	0.5	2.3
Clinically Healthy	1	N/A	1.2
Unknown	3	0.5	3.5
Additional Ailments	**N**		**%**
Emaciation	54		62.8
Feather Mites or Lice	26		30.2
Trauma	19		22.1
Roundworm	12		14.0
Parasites	9		10.5
Fish hook	1		1.2

Of the 65 patients showing lesions of a fungal infection, 58 records included patient age. The vast majority with fungal infections were juvenile patients (93%) compared to adult patients. Of the patients showing lesions, 29 (45%) had lesions that had spread outside of the respiratory system. Among the patients with lesions outside the respiratory system, two had lesions on the breast muscle, one had lesions on the right leg, and one had lesions outside the trachea. The remaining 25 patients had lesions throughout the body cavity.

According to the previously defined levels of aspergillosis, 30% of the patients expressed the highest level (5). As an additional ailment, 62.8% of the necropsied patients were considered emaciated while 22.1% were suffering from trauma (Table 3). All 21 Gannets necropsied in 2020 were suffering from a suspected fungal infection thought to be aspergillosis (Table 4).

External laboratory necropsy findings

All five Gannets sent to the BADDL testing facility showed no external signs of trauma or cause of death and tested negative for Avian Influenza A Virus (AIAV). All specimens were described as being somewhat emaciated, with two being covered in mites. BADDL confirmed that all five Gannets had cases of Aspergillosis, with two having *Aspergillus fumigatus* and three having *Aspergillosis sp*.

Table 4: The total number of necropsies conducted on Gannets in Florida separated by year and including the percent of patients found to be suffering from aspergillosis.

Year	N	% with Aspergillosis
2020	21	100
2021	34	62
2022	20	80
2023	11	64
Total	86	76

Non-rehabilitation analysis

In addition to the patient information collected from Florida rehabilitation facilities, Gannet data were also collected from Florida Fish and Wildlife (N = 467), city and county agencies in Florida (N = 25), and the NYSDEC (N = 26) collectively spanning the years 1979–2023. This represented about 10% of the Gannet data collected in this study.

The data from Florida Fish and Wildlife showed a significant jump in Gannet mortalities in 2007 (164 deaths compared to an average of 25 deaths/year). This represented nearly a 7x increase. The NYSDEC patients (N = 26) were mostly juveniles (N = 23) and evenly distributed between males (N = 13) and females (N = 12). Seven patients weighed over 3 kg, including one that weighed 4.716 kg, which was

more than the rest of the rehabilitation data combined. Aspergillosis was the most prevalent condition and was found in 23% of the NYSDEC patients.

Discussion

Wildlife rehabilitators admitted thousands of Gannets between 1988 and 2023, primarily from Florida (85%). However, similarities between the East Coast and Florida rehabilitation data are strong indicators that the challenges Gannets are facing are not isolated to Florida, but extend along the entire East Coast of the United States, a clear indicator of common challenges across the geographies. The combined release rate was 13.7%, excluding DOA patients, across Florida (14%) and the East Coast (12.3%). The average release rate dropped from 17.8% (1988–2016) to 7.6% (2017–2023). Considering the dramatic drop in release rates, several factors were evaluated to determine their influence on the double digit increase in deaths.

Age data, recorded in 31.5% of cases, included slightly more adults (53.4%) than juveniles (46.4%). However, there were stark differences between the Florida patients and the East Coast patients. In Florida, there was a steep upward trend in juvenile patient admissions starting at 3% of the patients (2010) and growing to 94% of the identified patients (2022), whereas the East Coast data showed a nearly flat average of 63%.

Body weight was a clear indicator of survivability. Healthy Gannets have an estimated weight range of 2.20–3.60 kg with most estimates falling on the higher end of that range (Redrobe 2015; Spiegel *et al*. 2017; Malvat *et al*. 2020; Mowbray 2020; Fitzgerald 2021). Out of the 774 rehabilitation patients with an identified weight, only 131 (17%) fell within that reported normal weight range and these patients showed the highest potential for survival. The majority of patients fell at the low end of that range. Released patients had a higher average intake weight than any other disposition category but still fell under the normal estimated weight range as might be expected.

Migrating Gannets may naturally have a lower weight range, or the reduced weight may be related to the injury or illness that brought the patient into the rehabilitation facility and not an indication of what a healthy Gannet weighs outside of their breeding colonies. Adult Gannet patients, on average, weighed 0.23 kg more than juvenile Gannet patients.

No bird weighing less than 1.66 kg (Florida) or 1.71 kg (East Coast) survived to release. In Florida, 25.5% fell below this threshold, with 39.3% of all Gannets died in care. On the East Coast, 14.5% were underweight, with a total of 28% in-care death rate. As weight increased, so did the likelihood of release, suggesting that facilities might consider using 1.70 kg as a treatment threshold. Weight alone may not determine survival, but it plays a critical role, especially as 56.5% of patients had a final disposition within 24 hours of intake. This limited window reduces the opportunity for effective intervention.

There were 52 patients that included WBC count data in their record. These patients had an average WBC count of 22,741 cells.μL^{-1}, well above the expected 2,000 to 6,000 cells.μL^{-1} in healthy colony birds (Fitzgerald 2021; Malvat *et al*. 2020). Only 13 patients (25%) in this study fell into the WBC count ranges represented in the existing two studies. The lowest overall WBC value in this study was 5,120 cells.μL^{-1}, which is above the assumed average of the first study mentioned. A higher WBC count could suggest greater stress in the patient or an underlying infection (Sakas 2012), which aligns with our study. It would make sense that Gannets at the end of their migration who may be injured, emaciated, or possibly

suffering from a disease such as aspergillosis would have elevated WBC counts. These patients were also possibly stressed from being captured and transported to a rehabilitation facility. These represent strong indicators as to why the WBC count results in this study are so much higher than in previous studies.

PCV values aligned with general avian norms (35 and 55%; Calhoun 2009; Vap 2010) in only 21.9% of Florida patients (with 18.75% released) and 63.1% of East Coast patients (with 6.1% released). Six of the seven released patients from the East Coast had a PCV within the normal range. Elevated PCV suggests dehydration, while low PCV values indicate anaemia, which results in reduced blood oxygen-carrying capacity, potentially worsening respiratory conditions like aspergillosis. (Harrison & Lightfoot 2006; Malvat *et al*. 2020; Haynes & Hollwarth 2022).

TS values, used to evaluate malnutrition or liver and kidney dysfunction were within the avian norms (3.5–5.5 g/dL ; Calhoun 2009) in just 24% of the 283 patients. There were 29 (10%) patients that fell above the average range and 187 (66%) that fell below 3.5 g/dL. There were 103 (36%) Gannet patients with TS levels at or below 2 g/dL. Previous studies have implicated aspergillosis as an important cause of seabird mortality, particularly in captive or rehabilitated birds. Factors such as poor air quality, high humidity, sanitation, and long-term food storage in rehabilitation facilities can contribute to increased spore counts, raising the risk of infection (Beernaert *et al*. 2010; Burco *et al*. 2014; Sabino *et al*. 2019). When seabirds inhale *Aspergillus* spores, the fungus can infect their respiratory system causing a variety of clinical signs, including respiratory distress, weight loss, and weakness.

We found that aspergillosis was frequently identified as a primary or secondary cause of admission, but was only diagnosed post-mortem. Given the level of infection found in necropsied patients and the Gannets short duration of care, it is probable that patients were being admitted with aspergillosis, and did not contract it while in care. Among the Gannets necropsied at the Marine Science Center, 75.6% were suspected aspergillosis cases. All five specimens sent to BADDL tested positive (two specimens had confirmed cases of *Aspergillus fumigatus* while the other three came back as *Aspergillus sp.*). The NYSDEC necropsies resulted in 23% of patients having confirmed cases of aspergillosis. Given those findings, there is a strong possibility that many of the other patients admitted into care were also suffering from aspergillosis, but it went undiagnosed.

Stress, nutritional deficiencies, trauma, and migration are all potential risk factors that can lead to aspergillosis, which coincides with Gannets migrating down the East Coast (Huang & Mayer 2018). Aspergillosis is often considered to be a primary or secondary respiratory infection in seabirds and is considered to be the most frequent fungal disease in multiple species, but there is very little evidence of Gannets suffering from the illness (Burco *et al*. 2014; Sabino *et al*. 2019; Mowbray 2020). Typically, birds with aspergillosis will present signs like weakness or exhaustion, difficulty breathing, and not flying (Huang & Mayer 2018). The acute form of aspergillosis usually causes death within seven days (Speer 2016).

Treatment with antifungals can take several months to be effective for patients suffering from minor cases of aspergillosis (Speer 2016; Huang & Mayer 2018). Many of the patients necropsied would fall significantly outside of the minor infection designation and patient's short duration of care makes it impractical to even begin the medication, let alone justify its cost. Of the 1,568 patients with known injuries, 855 (54.5%) showed clinical signs potentially linked to aspergillosis, and another 388 patients (24.7%) showed clinical signs as a secondary cause of injury for a combined 1,243 (79.3%) patients. However, due to the nondescript external clinical signs of aspergillosis, they cannot conclusively

diagnose aspergillosis, especially when the patient shows clinical signs as a secondary ailment. The majority of patients with potential clinical signs were suffering from emaciation and exhaustion, which could easily be a result of trauma or another ailment.

Aspergillosis can be associated with audible expiration, gurgling, or sudden changes in voice pitch, but those clinical signs do not guarantee the patient is suffering from aspergillosis. Some severely infected patients necropsied at the Marine Science Center showed no such signs. The air sacs are typically the primary site of infection with the rest of the respiratory system often included depending on the severity of the case (Beernaert *et al.* 2010). Plaques develop on the surface of the air sacs as the bird attempts to eliminate the aspergillosis infection (Beernaert *et al.* 2010). The necropsied patients frequently showed signs of extensive tissue growth that transformed the thin, transparent, air sac membranes into thickened yellow walls. Aspergillosis can also disseminate haematogenously to other body systems, but it is thought to be a rare occurrence (Beernaert *et al.* 2010; Huang & Mayer 2018). Across the 65 necropsied Gannets with lesions of aspergillosis in this study, 29 (45%) had fungal growths extending outside of the respiratory system.

An endoscopy or radiograph can help determine the potential distribution of lesions. However, both procedures carry significant risks for a newly admitted and stressed patient (Huang & Mayer 2018). This is especially important because treatment for aspergillosis begins with stabilising the patient and reducing stress—both of which would be undermined by performing an endoscopy (Huang & Mayer 2018).

The challenge with patients suffering from exhaustion, emaciation, aspergillosis, neurological symptoms, and astatic is that these conditions may also indicate an underlying issue. Unfortunately, these data do not identify if there was an underlying issue or the nature of that issue. The available literature does provide some possibilities on what could cause the underlying issues.

A recent study of Gannets at the Bass Rock colony in Scotland tracked 38 juveniles. Nearly one-third died less than two months after leaving the colony with much of that mortality thought to be the result of poor navigational skills (Lane *et al.* 2021). In general, younger animals have a higher mortality rate than adults, with an estimated 65% of Gannets not surviving to adulthood (Dewey 2009; Mowbray 2020; Lane *et al.* 2021). One of the main theories used to explain the higher mortality rate in juveniles is a lack of experience and physical immaturity that leads to lower foraging success (Lane *et al.* 2021; Jones & Daoust 2021). Reduced foraging success would certainly lead to emaciation and could prompt birds to pursue bycatch from fishing vessels. In a Canadian study from 1998–2011, Gannets were recorded as being attracted to fishing vessels, which resulted in mortalities (Hedd *et al.* 2015).

The reduction in strength due to age and lack of nutrition may also weaken the Gannets' immune system increasing the likelihood of succumbing to aspergillosis. The nutritional deficiency may also be impacted by climate change by shifting the location and distribution of marine fishes while reducing the quality and availability of prey (Mowbray 2020; D'Entremont *et al.* 2021). This is especially relevant during the Gannets' breeding season when the sea surface temperature is elevated leading to increased foraging effort. This requires further travel while reducing the quantity and quality of prey caught and fed to immature birds (D'Entremont *et al.* 2021). For example, Atlantic Mackerel *Scomber scombrus* is considered a critical prey species for young Gannets during the breeding season, and its reduced availability impacts the parents' ability to successfully rear chicks leading to reduced reproductive

success (D'Entremont *et al*. 2021). The combination of climate change and overfishing can compound the problem by further reducing prey availability and heightening the chances of Gannets suffering injury from fishing hooks and lines.

Conclusion

The 91 necropsies and 43.6% of patients that included more than just final disposition data provide an opportunity to understand how different variables may be contributing to the Gannet's low release rate while providing opportunities to determine how best to treat patients with the information available. However, continued research and efforts to record more in-depth patient data would help alleviate some of the gaps in the data and provide a more complete view of the Gannet's plight. It is also important to note that this study only looks at admitted or dead patients and does not include any indication of how many healthy individuals survive off the East Coast of the United States.

The data collected can provide a framework for both how to treat incoming Gannets and identify what further research needs to be done to gain better insights into the species. Patient weight can give rehabilitators a simple but accurate understanding of how likely a patient is to be released while providing a clear threshold for care. Understanding a patient's chance of release, and likelihood of death, should be used to inform if and when a patient is euthanised. One of a rehabilitator's most important responsibilities is ensuring that no patient unduly suffers. Factoring in a patient's TS and PCV can help support any findings based on the patient's weight especially if a patient's TS levels indicate that they are too weak to handle a normal diet. With these criteria in mind, rehabilitators can begin to reduce the number of patients that died in care rather than getting euthanised on arrival.

While wildlife rehabilitators are incredibly busy caring for their patients, collecting data is also critical to understanding the state of any species. Some data categories could easily be collected like age, weight, intake and disposition dates, while other categories would require more of a commitment like WBC, TS, PCV. Performing necropsies on patients, not just Gannets, provides a wealth of information for the rehabilitator in the moment and for long term research. Necropsies were vital in understanding how many patients were suffering from aspergillosis when external clinical signs were inconclusive and/or nondescript. The necropsy findings suggest that a much larger percentage of Gannet patients are suffering from aspergillosis than indicated by their reason for admission, and this disease should play a central role in any future studies into Gannet mortality.

Acknowledgment

I would like to thank the Marine Science Center, Tri-State Bird Rescue & Research, and all of the other facilities that shared their data for this project.

Disclosure Statement

The author reports there are no competing interests to declare.

References

Beernaert, L. A., Pasmans, F., Van Waeyenberghe, L., Haesebrouck, F., & Martel, A. 2010. Aspergillus infections in birds: a review. *Avian Pathology* 39(5): 325–331. https://doi.org/10.1080/03079457.2010.506210

BirdLife International. 2018, August 10. *IUCN Red List of Threatened Species: Morus bassanus*. IUCN Red List of Threatened Species; Name. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22696657A132587285.en

Burco, J. D., Massey, J. G., Byrne, B. A., Tell, L., Clemons, K. V., & Ziccardi, M. H. 2014. Monitoring of Fungal Loads in Seabird Rehabilitation Centers With Comparisons to Natural Seabird Environments in Northern California. *Journal of Zoo and Wildlife Medicine* 45(1): 29–40. https://doi.org/10.1638/2012-0051r1.1

Calhoun, D. M. 2009. ABCs of a CBC: an Introduction to Avian and Mammalian Complete Blood Count. *Wildlife Rehabilitation* 26: 133–142.

Chardine, J. W., Rail, J., & Wilhelm, S. 2013. Population dynamics of Northern Gannets in North America, 1984–2009. *Journal of Field Ornithology* 84(2): 187–192. JSTOR. https://doi.org/10.2307/24617968

D'Entremont, K. J. N., Guzzwell, L., Wilhelm, S. I., Friesen, V. L., Davoren, G. K., Walsh, C. J., & Montevecchi, W. A. 2021. Northern Gannets (Morus bassanus) breeding at their southern limit struggle with prey shortages as a result of warming waters. *Ices Journal of Marine Science* 79(1): 50–60. https://doi.org/10.1093/icesjms/fsab240

Dewey, T. 2009. *Morus bassanus (northern gannet)*. Animal Diversity Web. https://animaldiversity.org/accounts/Morus_bassanus/

Fischer, D., & Lierz, M. 2015. Diagnostic Procedures and Available Techniques for the Diagnosis of Aspergillosis in Birds. *Journal of Exotic Pet Medicine* 24(3): 283–295. https://doi.org/10.1053/j.jepm.2015.06.016

Fitzgerald, M. 2021. *Variability in the health and condition of breeding northern gannets (Morus bassanus)*. University College Cork, Ireland (pp. 1–43) [Masters thesis]. https://cora.ucc.ie/server/api/core/bitstreams/3f90af3a-d3a2-47b5-b327-cdcaa83518e7/content

Florida Department of Agriculture & Consumer Services. n.d.. *Bronson Animal Disease Diagnostic Laboratory (BADDL). Florida Department of Agriculture & Consumer Services. Retrieved September 6, 2023, from https://www.fdacs.gov/Consumer-Resources/Animals/Bronson-Animal-Disease-Diagnostic-Laboratory-BADDL*

Florida Fish and Wildlife. 2023. *Permitted Florida Wildlife Rehabilitators. https://myfwc.com/media/5423/licensedwildliferehabilitatorsbyregion.pdf*

Gunter, G., & Burke, W. D. 1977. Notes on the Status of the Gannet (Morus bassanus) in the Gulf of Mexico, with a Record from Mississippi. *Gulf Research Reports* 6(1). https://doi.org/10.18785/grr.0601.12

Harrison, G. J., & Lightfoot, T. L. 2006. *Clinical Avian Medicine* (Vol. II). Spix Publishing.

Haynes, E. L., & Hollwarth, A. 2022, November 7. *Interpreting avian haematology and biochemistry results*. Veterinary Practice. https://www.veterinary-practice.com/article/avian-haematology-biochemistry

Hedd, A., Regular, P. M., Wilhelm, S. I., Rail, J.-F., Drolet, B., Fowler, M., Pekarik, C., & Robertson, G. J. 2015. Characterization of seabird bycatch in eastern Canadian waters, 1998-2011, assessed from onboard fisheries observer data. *Aquatic Conservation: Marine and Freshwater Ecosystems 26*(3): 530–548. https://doi.org/10.1002/aqc.2551

Huang, J., & Mayer, J. 2018, March 18. *Avian Aspergillosis: What Every Veterinarian Needs to Know*. Today's Veterinary Practice. https://todaysveterinarypractice.com/exotic-medicine/avian-aspergillosis/

Jones, M, E, B., & Daoust, P. 2021. A Syndrome of Ischemic Leg Necrosis in Northern Gannets (Morus Bassanus). *Journal of Wildlife Diseases* 57(4): 865-874. https://doi.org/10.7589/jwd-d-20-00230

Lane, J. V., Pollock, C. J., Jeavons, R., Sheddan, M., Furness, R. W., & Hamer, K. C. 2021. Post-fledging movements, mortality and migration of juvenile northern gannets. *Marine Ecology Progress Series* 671: 207–218. https://doi.org/10.3354/meps13804

Malvat, Z., Lynch, S. A., Bennison, A., & Jessopp, M. 2020. Evidence of links between haematological condition and foraging behaviour in northern gannets (Morus bassanus). *Royal Society Open Science* 7(5): 192164. https://doi.org/10.1098/rsos.192164

Mowbray, T. B. 2020. Northern Gannet (Morus bassanus), version 1.0. *Birds of the World*. https://doi.org/10.2173/bow.norgan.01

Pahl, A. 2024. Florida Avian Rehabilitation Intake and Disposition Rates: 2009 to 2022. *Journal of Wildlife Rehabilitation* 44(2): 13-25.

Redman, K. K., Lewis, S., Griffiths, R., Wanless, S., & Hamer, K. C. 2002. Sexing Northern Gannets from DNA, Morphology and Behavior. Waterbirds 25(2): 230. https://doi.org/10.1675/1524-4695(2002)025[0230:sngfdm]2.0.co;2

Redrobe, S. 2015. Pelecaniformes (Pelicans, Tropicbirds, Cormorants, Frigatebirds, Anhingas, Gannets). *Fowler's Zoo and Wild Animal Medicine Volume 8*, 8: 96–99. https://doi.org/10.1016/b978-1-4557-7397-8.00012-8

Sabino, R., Burco, J. D., Valente, J., Veríssimo, C., Clemons, K. V., Stevens, D. A., & Tell, L. A. 2019. Molecular identification of clinical and environmental avian Aspergillus isolates. *Archives of Microbiology* 201(2): 253–257. https://doi.org/10.1007/s00203-019-01618-y

Sakas, P. S. 2012. Understanding Avian Laboratory Tests. In *Niles Animal Hospital and Bird Medical Center* (pp. 1–10). Retrieved April 16, 2025, from https://www.nilesanimalhospital.com/files/2012/05/Understanding-Avian-Laboratory-Tests.pdf

Speer, B. L. 2016. *Current therapy in avian medicine and surgery* (First Edition). Elsevier.

Spiegel, C. S., Berlin, A. M., Gilbert, A. T., Gray, C. O., Montevecchi, W. A., Stenhouse, I. J., Ford, S. L., Olsen, G. H., Fiely, J. L., Savoy, L., Goodale, M. W., & Burke, C. M. 2017. *Determining Fine-scale Use and Movement Patterns of Diving Bird Species in Federal Waters of the Mid-Atlantic United States Using Satellite Telemetry US Department of the Interior Bureau of Ocean Energy Management Office of Renewable Energy Programs*. U.S. Department of the Interior Bureau of Ocean Energy Management Office of Renewable Energy Programs. https://www.boem.gov/sites/default/files/documents/environment/boem-2017-069.pdf

Vap, L. M. 2010, April 1. *Avian and reptilian hematology: Scratching the surface (Parts 1 and 2) (Proceedings)*. DVM 360. https://www.dvm360.com/view/avian-and-reptilian-hematology-scratching-surface-parts-1-and-2-proceedings

Wildlife Center of Virginia. 2025, June 25. *WILD-ONe*. Wildlife Center of Virginia. https://wildlifecenter.org/professional-training/wild-one