DIAGNOSIS OF HYPOTHERMIA IN SEABIRDS FROM COASTAL CALIFORNIA

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ABSTRACT

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This study established cloacal temperature (T_{Cl}) cut-off values to diagnose hypothermia in near shore seabirds rescued along the coast of California. All birds died when T_{Cl} was < 38.2 °C. When *Aechmophorus* grebes were excluded, 100% died when T_{Cl} was < 38.4 °C. Mortality increased 2–3× when T_{Cl} was lower than receiver operating curve-determined criteria for diagnosing hypothermia based on attitude: < 38.8 °C for mixed species, < 39.1 °C for Common Murres *Uria aalge*, and < 38.2 °C for *Aechmophorus* grebes. Reductions in T_{Cl} as small as 1.0 °C had significant physiologic effects.

Key words: hypothermia, cloacal temperature, near shore seabird, murre, grebe

INTRODUCTION

Monitoring and managing body temperature (T_b) is critical for the successful capture and release of seabirds for physiological or ecological studies. It is also essential for rehabilitation of seabirds during oil spills or other large mortality events that can impact hundreds of birds a day (e.g., harmful algal blooms or prey crash events; Gibble & Hoover 2018). Affected birds are at high risk of hypothermia due to a compromised ability to generate metabolic heat and reduced feather insulation quality (OWCN 2014). However, published normal T_b data are rare for seabird species (range: 37.9–43.3 °C), and even less is known about what values represent hypothermia (McNab 1966, Jenssen *et al*. 1985, Bevan & Butler 1992, Grémillet & Plös 1994, Wilson *et al*. 1995, Wilson & Grémillet 1996, Ancel *et al.* 1997, Grémillet *et al.* 1998, Cabanac & Guillemette 2001).

In mammals, hypothermia is diagnosed when T_b is below the reference range (Di Girolamo *et al*. 2016). In humans, even mild hypothermia (T_b = 2–5 °C below normal) is associated with significant complications, such as increased cardiac events, dysrhythmias, blood loss, wound infections, and mortality (Kirkpatrick *et al*. 1999, Martin *et al.* 2005, Kimberger & Kurz 2008, Petrone *et al.* 2014). In rabbits, each 1 °C decrease in T_b below normal doubled the risk of death (Di Girolamo *et al*. 2016). A relationship between lower T_b and higher mortality was also observed in oiled Common Murres *Uria aalge* (COMU) (Duerr *et al*. 2016). However, no peer-reviewed criteria for diagnosing hypothermia in seabirds was found in the literature. This lack of information makes it difficult to recognize, much less develop, the best treatment protocols for hypothermic seabirds.

Therefore, the goal of this study was to establish criteria to diagnose hypothermia in seabirds admitted to a rehabilitation center using the current recommended method for measuring T_b during an oil spill response (i.e., placement of the tip of a commercially-available digital rectal thermometer, designed for use in humans, in the cloaca; OWCN 2014). A second goal was to quantify the magnitude of reduction in cloacal temperature (T_{Cl}) necessary to observe clinically significant consequences associated with hypothermia. Assuming similar physiologic effects occur in seabirds compared to humans, we expected that reductions in T_{Cl} of as small as 1.0 °C would have physiological consequences.

METHODS

Medical records were obtained for 1 098 rescued seabirds that were admitted to a seabird specialty rehabilitation center in southern California (International Bird Rescue, 3601 South Gaffey Street, San Pedro, California 90731, USA) over a five-year interval: 2009–2013. Only data from records that met the inclusion criteria were analyzed (Table 1). Medical record data for attitude was assumed to be associated with thermal status (bright: normothermia, quiet: hypothermia). Due to similarities in phenotype and natural history, and difficulties in differentiating between *Aechmophorus* grebes without detailed morphometric measurements, medical record data from Clark's *A. clarkii* (CLGR) and Western *A. occidentalis* (WEGR) grebes were combined (PRBO 2012, La Porte *et al*. 2014).

TABLE 1
Inclusion criteria for study data obtained from medical records of 1098 rescued near shore birds admitted to a seabird specialty rehabilitation center in California (2009–2013)

General	
Admitted directly to rehabilitation center without prior treatment and within 24 h of capture	
Species represented by > one individual	
Complete medical record information	
Record field	*Details*
Admit cloacal temperature	°C/°F
Final disposition	Released, died/euthanized
Age category indicating fully-developed insulation of plumage	Adult, sub-adult or compatible body mass
Attitude	Bright, quiet

Unless stated otherwise, statistical significance was set at $P < 0.05$, and analyses were performed using Social Science Statistics web based calculators (Stangroom 2021a).

Analyses were performed on all data that met the inclusion criteria. Species-specific analyses were also performed for $n > 20$. Cloacal temperature data were assessed for normal distribution (Kolmogorov-Smirnov, kurtosis, skewness statistics) and the following values were calculated: mean, standard deviation, median, minimum value, maximum value, T_{Cl} below which all individuals died, and the percent birds' attitude that was described as quiet on admit examination at this temperature (Stangroom 2021b, 2021c).

Between-species comparisons of independent means and 95% confidence intervals (CI) of normally distributed T_{Cl} data were performed using Student's *t*-test and were supported by non-parametric Mann-Whitney statistics to determine if species could be combined for further analyses (Stangroom 2021d, 2021e). Mean difference and 95% CI for T_{Cl} were calculated for species with significantly different values (Stangroom 2021e, 2021f). An ANOVA analysis with post hoc Tukey's honestly significant difference test correction was used to determine if between species differences in mean T_{Cl} persisted within attitude groups: bright or quiet (Stangroom 2021g).

Species-specific comparisons of independent means and 95% CI of normally distributed T_{Cl} data were performed using *t*-test, and were supported by non-parametric Mann-Whitney statistics, to assess for an association between T_{Cl} and attitude (bright versus quiet) (Stangroom 2021d, 2021e). When differences were observed, descriptive statistics were calculated for each sub-population.

Receiver operating characteristic (ROC) analyses using an easyROC model (MaxSpSe) that simultaneously maximized sensitivity and specificity were used to evaluate T_{Cl} cut-off values to predict attitude; and area under the curve (AUC), sensitivity (Se), and specificity (Sp) were calculated (Lopez-Raton *et al*. 2014, Goksuluk *et al.* 2016). The percent birds that died or were diagnosed with quiet attitude were calculated for values ≥ and < the ROC-derived cut-off T_{Cl} values. The Se and Sp of T_{Cl} cut-off values were used to correctly categorize the attitude and disposition of individual birds not included in the species-specific analyses (MedCalc 2021). Binomial analyses were used to assess the probability that differences in percent mortality and percent quiet attitude above and below cut-off T_{Cl} values were stochastic (Stangroom 2021h).

Due to the high consequences of false negatives (missing a diagnosis of hypothermia leading to death) and low consequences of false positives (diagnosing hypothermia in a normothermic bird leading to provision of supplemental heat with a low chance for overheating)—and because the selected ROC model balanced Se and Sp—when a range of ROC-derived T_{Cl} cut-off values were available to set a criterion for hypothermia, the highest cut-off T_{Cl} was chosen to maximize sensitivity.

RESULTS

Seventy-six records met inclusion criteria: 43 COMU, 23 CLGR/WEGR, four Pacific Loons *Gavia pacifica*, and two each of Common Loon *G. immer*, Red-throated Loon *G. stellata*, and Surf Scoter *Melanitta perspicillata*. The most common causes for exclusion were receipt of treatment or held > 24 h at another rehabilitation center prior to admit exam, species represented by only one individual, and incomplete records. The descriptive statistics for T_{Cl} obtained during the admit exams for all coastal seabirds, COMU, and CLGR/WEGR are listed in Tables 2 and 3. All datasets were normally distributed.

Mean T_{Cl} values of seabirds described as having a quiet attitude on admit examination were lower than those described as bright: 1.4 °C for all seabirds, 1.0 °C for CLGR/WEGR, 1.5 °C for COMU (*t*-test, all *P* values < 0.004; Table 2). Mean COMU T_{Cl} was significantly higher than CLGR/WEGR (1.0 °C, 95% CI 0.4–1.5 °C; *t*-test, $P < 0.001$; Mann-Whitney $P < 0.001$). However, within the quiet attitude category, T_{Cl} for COMU and CLGR/WEGR was not significantly different (ANOVA, $P = 0.34$).

Regardless of species, all individuals with an admit T_{Cl} < 38.2 °C died ($n = 18$), and ≥ 89% of these birds were described as being quiet. All murres ($n = 8$) with an admit T_{Cl} < 38.4 °C died and 100% were described as being quiet. The ROC analysis identified cut-off T_{Cl} values to predict quiet attitude of 38.8 °C for all near shore seabirds (87% Se, 80% Sp), 38.2 °C for CLGR/WEGR (92% Se, 87% Sp), and 39.1 °C for COMU (82% Sp, 75% Sp). The likelihood of being diagnosed as quiet was 4–19× higher and mortality was 2–3× higher when the admit T_{Cl} was less than the population-specific ROC-determined cut-off value (all $P \leq 0.001$; Table 2). When we applied T_{Cl} values below which all birds died and ROC cut-off T_{Cl} values calculated for all seabirds, CLGR/WEGR, and COMU—to individual birds from species not included in the CLGR/WEGR and COMU analyses—the ROC-derived T_{Cl} cut-off temperature (38.8 °C) maximized sensitivity (100%) while maintaining specificity > 60% (Table 4).

DISCUSSION

In this study, 100% of seabirds admitted to a rehabilitation hospital with T_{Cl} < 38.2 °C died. When *Aechmophorus* grebes were excluded, 100% of all other seabird species with admit examination T_{Cl} < 38.4 °C died. The likelihood of mortality was 2–3× higher when T_{Cl} was lower than ROC-determined cut-off T_{Cl} values (38.2–39.1 °C). A similar relationship between lower T_{Cl} and higher mortality was observed in oiled COMU that were treated at a seabird rehabilitation facility located in northern California. No COMU survived if the admit T_{Cl} was < 36.1 °C, and birds with admit T_{Cl} > 39.4 °C had the highest survival rates (Duerr *et al.* 2016). These T_{Cl} values were substantially lower for 100% mortality and slightly higher for improved survival than those observed in this study. The etiologies for the differences in survival are unknown, but potential causes were attributed to variations in standard operating procedures used during oil spill response; 100% of population affected by oiling; and different facility, thermometers, and sub-population of murres.

As expected, in this study, reductions as small as 1.0 °C in T_{Cl} had significant physiologic effects in seabirds, and clinical signs of hypothermia were highly associated with lower T_{Cl}. At T_{Cl} values associated with 100% mortality, ≥ 89% of individuals were described as having a quiet attitude. In addition, the likelihood of diagnosing hypothermia was 4–19× higher when T_{Cl} was less than ROC-determined T_{Cl} cut-off values. As expected, when T_{Cl} values below which all birds died, and ROC cut-off temperatures, were applied to individual birds from species not included in the WEGR and COMU analyses, higher cut-off values for T_{Cl} resulted in increasing sensitivity and decreasing specificity for predicting

TABLE 2
Descriptive statistics, statistical comparison between bright versus quiet birds, and receiver operating curve (ROC) results for cloacal temperature (T_{Cl}, °C) calculated from medical record data for rescued near shore birds admitted to a seabird specialty rehabilitation center in California (2009–2013)

Statistical test	Species		
	All[a]	CLGR/WEGR[b]	COMU[c]
n	76	23	43
Mean	38.9	38.3	39.3
Median	39.0	38.2	40
Standard deviation	1.07	0.96	1.01
Kurtosis	-0.60	0.30	0.74
Skewness	-0.27	0.47	-0.88
K-S test[d]	0.33	0.51	0.43
Minimum	36.2	36.5	36.2
Maximum	40.8	40.6	40.8
Mean difference between bright versus quiet birds	1.4[e]	1.0[f]	1.5[e]
(95% Confidence Interval)	(1.0–1.8)	(0.3–1.7)	(0.9–2.1)
T_{Cl} below which all birds died	38.2	38.2	38.4
% birds described as quiet below this temperature	94%	89%	100%
ROC cut-off T_{Cl} for quiet attitude	38.8[g]	38.2[h]	39.1[i]
ROC sensitivity	0.87	0.92	0.82
(95% confidence interval)	(0.69–0.96)	(0.64–1.0)	(0.48–0.98)
ROC specificity	0.80	0.87	0.75
(95% confidence interval)	(0.66–0.91)	(0.69–0.96)	(0.43–0.95)
% birds died < T_{Cl} cut off	78%[j]	100%[j]	82%[j]
% birds died ≥ T_{Cl} cut off	50%	36%	46%
% birds described as quiet < T_{Cl} cut off	81%[j]	89%[j]	76%[j]
% birds described as quiet ≥ T_{Cl} cut off	14%	21%	4%

[a] All = Mixed species population of near shore seabirds including *Aechmophorus* grebes, Common Murres *Uria aalge*, loons (*Gavia* spp), and Surf Scoters *Melanitta perspicillata*
[b] CLGR/WEGR = Mixed population of Clark's *A. clarkii* and Western *A. occidentalis* Grebes
[c] COMU = Population of Common Murres
[d] K-S test = *P*-value for Kolmogorov-Smirnov test
[e] *t*-test and Mann-Whitney $P < 0.001$
[f] *t*-test, $P = 0.004$; Mann-Whitney, $P = 0.003$
[g] ROC area under the curve (AUC) = 0.88, $P < 0.001$
[h] ROC AUC = 0.84, $P < 0.001$
[i] ROC AUC = 0.90, $P < 0.001$
[j] Binomial probability difference between mortality or attitude due to chance, $P \leq 0.001$

mortality and hypothermia. In general, ROC-derived T_{Cl} cut-off temperatures were most sensitive when used to predict mortality and most specific when used to diagnose hypothermia (Table 4).

Mean T_{Cl} and ROC cut-off values for quiet attitude for CLGR/WEGR (38.2 °C) were significantly lower than for COMU (39.1 °C). This difference was solely driven by data from birds diagnosed with bright attitudes. Healthy and injured CLGR/WEGR admitted into wildlife rehabilitation centers are generally observed to be among the most vocal and aggressive seabird species (NLA pers. obs., communications with International Bird Rescue staff). Thus, the lower cut off T_{Cl} for attitude observed in CLGR/WEGR was attributed to a genus-specific inherent trait to maintain defensive behaviors until T_{Cl} dropped to values associated with mortality. Thus, when attitude is a sole criteria, hypothermia is likely underdiagnosed in *Aechmophorus* grebes. Alternatively, normal resting T_{Cl} in *Aechmophorus* grebes may be lower than most other seabird species admitted to this California rehabilitation hospital. Further study of larger, more widely distributed populations is necessary to evaluate whether the difference observed in this population also applies to the general CLGR/WEGR population.

In summary, given the variance in mean T_{Cl} between species and individuals, and the limited sample sizes and diversity of species,

TABLE 3
Descriptive statistics for cloacal temperature (°C) calculated from medical record data for rescued near shore birds admitted to a seabird specialty rehabilitation center in southern California (2009–2013)

Statistical test	All[a]		CLGR/WEGR[b]		COMU[c]	
	Bright	Quiet	Bright	Quiet	Bright	Quiet
n	46	30	12	11	30	13
Mean	39.4	38.1	38.8[d,f]	37.8[d,g]	39.7[e,f]	38.3[e,g]
Median	39.6	38.0	38.6	37.8	39.8	38.1
Standard deviation	0.77	0.92	0.92	0.74	0.58	1.06
Kurtosis	-0.05	1.82	-0.01	0.92	0.57	2.74
Skewness	-0.55	0.68	0.55	0.27	-0.56	0.56
K-S test[h]	0.48	0.37	0.5	0.87	0.76	0.83
Minimum	37.4	36.2	37.4	36.5	38.4	36.2
Maximum	40.8	40.8	40.6	39.3	40.8	40.8

[a] All = Mixed species population of near shore seabirds including *Aechmophorus* grebes, Common Murres *Uria aalge*, loons (*Gavia* spp.), and Surf Scoters *Melanitta perspicillata*
[b] CLGR/WEGR = Mixed population of Clark's *A. clarkii* and Western *A. occidentalis* Grebes
[c] COMU = Population of Common Murres
[d] $P = 0.005$, *t*-test mean WEGR quiet versus WEGR bright
[e] $P < 0.001$, *t*-test mean COMU quiet versus bright
[f] $P = 0.01$, *t*-test mean COMU bright versus WEGR bright
[g] $P = 0.34$, *t*-test mean COMU quiet versus WEGR quiet
[h] K-S test = *P*-value for Kolmogorov-Smirnov test

whenever possible, it is prudent to use historical measurements from individuals and published species ranges to determine hypothermia cut-off values for T_{Cl}. However, because these data are frequently not available, when the primary goal is to reduce morbidity and mortality associated with hypothermia, use of the criteria with the highest sensitivity is recommended. Therefore, use of the ROC T_{Cl} criteria established for COMU (T_{Cl} < 39.1 °C) will minimize the chance of missing hypothermia in seabirds. However, based on results published for oiled COMU, it may be prudent to extend this cut-off value to 39.4 °C, or to use a value averaged with this study for mixed seabird populations (39.3 °C; Duerr *et al*. 2016). In CLGR/WEGR, the ROC-derived criteria for hypothermia was T_{Cl} < 38.2 °C. However, because all CLGR/WEGR died below this temperature, and because behavior traits make it likely that these birds will mask symptoms of hypothermia more than other species, this cut-off for T_{Cl} is likely too low. Use of the mixed species (38.8 °C) or COMU (39.1 °C) ROC-determined cut-off for T_{Cl} are alternative criteria that would minimize the risk of missing hypothermic grebes.

TABLE 4
Sensitivity (Se) and specificity (Sp) of receiver operating curve cut-off values for cloacal temperature used to predict death or diagnosis of quiet attitude calculated from medical record data for eight loons (*Gavia* spp) and two Surf Scoters *Melanitta perspicillata* admitted to a seabird specialty rehabilitation center in southern California (2009–2013)

Cloacal temperature cut off (°C)	Statistical test	Loons & Surf Scoters: Died %	Died 95% confidence interval	Quiet %	Quiet 95% confidence interval
38.2	Se	100	16–100	67	9–99
	Sp	38	9–76	57	18–90
38.4	Se	100	48–100	83	36–100
	Sp	60	15–95	100	40–100
38.8	Se	100	48–100	83	36–100
	Sp	60	15–95	100	40–100
39.1	Se	86	42–100	83	36–100
	Sp	67	9–99	50	7–93

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REFERENCES

ANCEL, A., HORNING, M. & KOOYMAN, G.L. 1997. Prey ingestion revealed by oesophagus and stomach temperature recordings in cormorants. *Journal of Experimental Biology* 200: 149–154.

BEVAN, R.M. & BUTLER, P.J. 1992. The effects of temperature on the oxygen consumption, heart rate, and deep body temperature during diving in the Tufted Duck *Aythya fuligula*. *Journal of Experimental Biology* 163: 139–151.

CABANAC, A.J. & GUILLEMETTE, M. 2001. Temperature and heart rate as stress indicators of handled Common Eider. *Physiology & Behavior* 74: 475–479. doi:10.1016/S0031-9384(01)00586-8

DI GIROLAMO, N., TOTH, G. & SELLERI, P. 2016. Prognostic value of rectal temperature at hospital admission in client-owned rabbits. *Journal of the American Veterinary Medical Association* 248: 288–297. doi:10.2460/javma.248.3.288

DUERR, R.S., ZICCARDI, M.H. & MASSEY, J.G. 2016. Mortality during treatment: factors affecting the survival of oiled, rehabilitated Common Murres (*Uria aalge*). *Journal of Wildlife Diseases* 52: 495–505. doi:10.7589/2015-03-054

GIBBLE, C.M. & HOOVER, B.A. 2018. Interactions between seabirds and harmful algal blooms. In: SHUMWAY, S.E., BURKHOLDER, J.M. & MORTON, S.L. (Eds.) *Harmful Algal Blooms: A Compendium Desk Reference*, 1st Edition. San Francisco, USA: John Wiley & Sons Ltd. doi:10.1002/9781118994672.ch6

GOKSULUK, D., KORKMAZ, S., ZARARSIZ G. ET AL. 2016. easyROC: An interactive web-tool for ROC curve analysis using R language environment. *The R Journal* 8: 213–230. doi:10.32614/rj-2016-042

GRÉMILLET, D. & PLÖS, A.L. 1994. The use of stomach temperature records for the calculation of daily food intake in cormorants. *Journal of Experimental Biology* 189: 105–115.

GRÉMILLET, D., TUSCHY, I. & KIERSPEL, M. 1998. Body temperature and insulation in diving Great Cormorants and European Shags. *Functional Ecology* 12: 386–394. doi:10.1046/j.1365-2435.1998.00199.x

JENSSEN, B.M., EKKER, M. & BECH, C. 1985. Thermoregulation in a naturally oil contaminated Black-billed Murre *Uria aalge*. *Bulletin of Environmental Contamination and Toxicology* 35: 9–14. doi:10.1007/bf01636473

KIMBERGER, O. & KURZ, A. 2008. Thermoregulatory management for mild therapeutic hypothermia. *Best Practice & Research: Clinical Anesthesiology* 22: 729–744. doi:10.1016/j.bpa.2007.11.002

KIRKPATRICK, A.W., CHUN, R., BROWN, R. ET AL. 1999. Hypothermia and the trauma patient. *Journal of Canadian Studies* 42: 333–343.

LA PORTE, N., KOPER, N. & LESTON, N. 2014. Assessing the breeding success of the Western Grebe (*Aechmophorus occidentalis*) after 40 years of environmental changes at Delta Marsh, Manitoba. *Waterbirds* 30: 30–42. doi:10.1675/063.037.0106

LOPEZ-RATON, M., RODRIGUEZ-ALVAREZ, M.X., SUAREZ, C.C. & SAMPEDRO, F.G. 2014. Optimal Cutpoints: An R package for selecting optimal cutpoints in diagnostic tests. *Journal of Statistical Software* 61: 1–36. doi:10.18637/jss.v061.i08

MARTIN, R.S., KILGO, P.D., MILLER, P.R. ET AL. 2005. Injury-associated hypothermia: an analysis of the 2004 national trauma data bank. *Shock* 24: 114–118. doi:10.1097/01.shk.0000169726.25189.b1

MCNAB, B.K. 1966. An analysis of the body temperatures of birds. *The Condor* 68: 47–55. doi:10.2307/1365174

MEDCALC. 2021. *Diagnostic test evaluation calculator*. Ostend, Belgium: Medcalc Software Ltd. [Accessed online at https://www.medcalc.org/calc/diagnostic_test.php on 22 March 2021.]

OWCN (OILED WILDLIFE CARE NETWORK). 2014. *Protocols for the Care of Oil-Affected Birds*. 3rd Edition. Davis, USA: Wildlife Health Center, School of Veterinary Medicine, University of California, Davis.

PETRONE, O., ASENSIO, J.A. & MARINI, C.P. 2014. Management of accidental hypothermia and cold injury. *Current Problems in Surgery* 51: 417–431. doi:10.1067/j.cpsurg.2014.07.004

PRBO (POINT REYES BIRD OBSERVATORY CONSERVATION SCIENCE). 2012. *Identification of commonly encountered bird species during California oil spills*. Version 2.0. [Manual accessed at https://data.pointblue.org/cadc2/uploads/Articles/OilSpill/species_placards_all_species_v2.pdf on 01 April 2021.]

STANGROOM, J. 2021a. *Social Science Statistics*. [Accessed at www.socscistatistics.com on 22 March 2021.]

STANGROOM, J. 2021b. *Easy Histogram Maker*. [Accessed at https://www.socscistatistics.com/descriptive/histograms/default.aspx on 22 March 2021.]

STANGROOM, J. 2021c. *The Kolmogorov-Smirnov Test of Normality*. [Accessed at https://www.socscistatistics.com/tests/kolmogorov/default.aspx on 22 March 2021.]

STANGROOM, J. 2021d. *Mann-Whitney U Test Calculator*. [Accessed at https://www.socscistatistics.com/tests/mannwhitney/default.aspx on 22 March 2021.]

STANGROOM, J. 2021e. *T-Test Calculator for 2 Independent Means.* [Accessed at https://www.socscistatistics.com/tests/studentttest/default.aspx on 22 March 2021.]

STANGROOM, J. 2021f. *A Single Sample Confidence Interval Calculator (T Statistic).* [Accessed at https://www.socscistatistics.com/confidenceinterval/default2.aspx on 22 March 2021.]

STANGROOM, J. 2021g. *One-way ANOVA calculator, including Tukey HSD*. [Accessed at https://www.socscistatistics.com/tests/anova/default2.aspx on 22 March 2021.]

STANGROOM, J. 2021h. *Binomial Test Calculator*. [Accessed at https://www.socscistatistics.com/tests/binomial/default2.aspx on 22 March 2021.]

WILSON, R.P. & GRÉMILLET, D. 1996. Body temperatures of free-living African Penguins (*Spheniscus demerus*) and Bank Cormorants (*Phalacrocorax neglectus*). *Journal of Experimental Biology* 199: 2215–2223.

WILSON, R.P., PÜTZ, K., GRÉMILLET, D. ET AL. 1995. Reliability of stomach temperature changes in determining feeding characteristics of seabirds. *Journal of Experimental Biology* 198: 1115–1135.