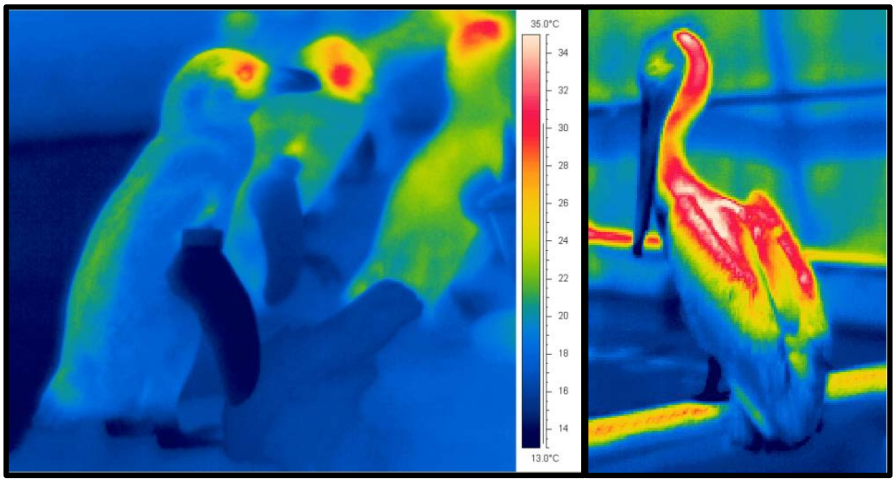

OWCN 2010-2011 Final Report: *Validation of thermography to assess body temperature and waterproofing of captive and rehabilitated seabirds*

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FINAL REPORT

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Cover Photos: Thermographs of captive and rehabilitated seabirds: a captive African Penguin at Monterey Bay Aquarium (left) and a Brown Pelican roosting at San Francisco Bird Rescue (right).

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SUMMARY

This report summarizes the research activities conducted in the first year of a three year study intended to validate the use of infrared thermography and thermal microchip technologies to assess body temperature and waterproofing of seabirds during oil spill response. We summarize research activities conducted on captive exhibit animals at the Monterey Bay Aquarium and rehabilitated birds at two captive facilities, San Francisco and Los Angeles Bird Rescue centers (LA and SF, respectively).

Our objectives were to: 1) validate use of thermography as a proxy for measuring core body temperature, 2) validate the use of thermography for determining plumage insulation integrity and recovery of waterproofing prior to release (thermal stability), 3) establish species-specific thermal conductance estimates for active and non-active individuals to determine the range of thermal variability related to activity state, and 4) measure differences in physiological state (molting vs. non-molting) to estimate the variability in body temperature and thermal conductance related to peripheral perfusion associated with growing new feathers in the skin.

We conducted four trials over 27 sampling days during a six-month period and obtained 3,186 thermographs from more than 120 birds, including penguins, murres, grebes, loons, scoters, shearwaters, fulmars, and pelicans. During trial 1, we established baseline surface temperatures for multiple body regions for captive Common Murres and African Penguins in the controlled exhibit setting at Monterey Bay Aquarium. We also examined physiological influences on surface temperature including molt and feather development (chick vs. adult) in penguins. In trials 2 and 3, we sampled oiled and non-oiled loons, grebes and murres rehabilitated at both LA and SF Bird Rescue Centers. We examined impacts of behavioral and environmental factors influencing the optimal time of day and activity on surface temperature; we hope to pursue this line of inquiry in the next year of study. In trial 4, we began to validate the use of thermal microchips as a proxy for core body temperature. Based on positive results of this trial in this first year of study, we will propose to further develop the application of a pool-mounted microchip reader in the second year of study to automate temperature readings of flocks of seabirds during spill response. We presented our findings at the Effects of Oil on Wildlife conference in New Orleans, LA in 2012, and our manuscript was included in the conference proceedings (Appendix A).

INTRODUCTION

This study was designed to meet the Oiled Wildlife Care Network's (OWCN) goal of *improving animal care* by refining oil spill rehabilitation methods of rapid and non-invasive assessment of waterproofing for flocks of birds post-wash using infrared thermal camera imagery (thermography). Validation of this new tool using subcutaneous thermal microchips for comparison is a critical first step toward effective and accurate assessment of core and peripheral body temperatures in seabirds during rehabilitation. Thermography could provide a substantial improvement to current methods used to monitor birds during spill events which rely on experienced observers monitoring of behavioral changes of individual birds in flocks after placement in pools (OWCN 2000).

During oil spills, when large numbers of birds are present in pools, experienced staff time is limited. This technique might greatly reduce the amount of personnel time needed to assess waterproofing. Thermographic assessment is far less invasive and stressful than the current protocol and is expected to decrease the necessity of repeated handling of individual birds to assess waterproofing. Current OWCN protocol requires that prior to being able to stay outside overnight in pools birds are captured so that cloacal temperatures can be measured directly with a thermometer. This is a labor and time-intensive task that adds substantial stress and added risk to stranded animals and their caregivers alike. Thermographic scanning of entire flocks in pools could quickly identify individuals displaying "heat loss" signal, thus decreasing the need for extended behavioral observations or manual restraint.

An additional benefit to using thermal microchips is the potential to use these small and relatively inexpensive tags to more accurately and rapidly track clinical care of individuals throughout the rehabilitation process during an oil spill response. Tracking individual clinical care has been a persistent problem during spill response efforts, when large numbers of birds must be evaluated, cared for, washed, and fed over a short period of time while maintaining accurate clinical paper records. Microchips do not exhibit the same problems experienced when leg bands were used during prior stranding events, including duplicate band numbers, number series and color combinations for birds originating from different response centers and bands falling off or becoming unreadable during the cleaning process. Microchips are programmed with a unique identifier to allow for clinical data to be obtained quickly and relayed digitally via hand-held readers.

Our objectives were to: 1) validate use of thermography as a proxy for measuring core body temperature, 2) validate the use of thermography for determining plumage insulation integrity and recovery of waterproofing prior to release (thermal stability), 3) establish species-specific thermal conductance estimates for active and non-active individuals to determine the range of thermal variability related to activity state, and 4) measure differences in physiological state (molting vs. non-molting) to estimate the variability in body temperature and thermal conductance related to peripheral perfusion associated with growing new feathers in the skin.

METHODS

Study Design.

We conducted thermography trials on seabirds in two different environments – 1) in a captive setting (Monterey Bay Aquarium [MBA]) we took thermal images of animals that were habituated to captivity, on exhibit, and had regular exposure to human presence, and 2) we also examined wild birds that presented to two rehabilitation facilities (San Francisco and Los Angeles Bird Rescue) due to injury, feather fouling or illness. The two Bird Rescue centers are primary oil spill response centers for California, where OWCN protocols are routinely used, and will approximate the captive environment of oiled birds during a spill event. By studying birds in these settings, we were able to assess the reliability of thermography to quantify normal range of variability in surface temperature (MBA) and detect heat loss as a result of compromised waterproofing from the point of intake to release (Bird Rescue).

Use of a controlled environment at MBA reduced variation due to ambient conditions such as air and water temperature, and permitted thermographic measurements of specific anatomic structures (eye, mouth, feet, and skin). Thermographs taken at Bird Rescue were taken at close range and with time-matched physical measurements of core body temperature collected by veterinary staff during routine health check-ups.

Thermography is a non-invasive imaging procedure that is used to record surface temperature using an infrared camera (FLIR, S65 ThermaCAM). Jessup et al. (2009) utilized thermography to assess the efficacy of washing and rinsing captive otters under different treatment scenarios (fresh vs. hard water, warm vs. cold). Jessup et al. (2009) was able to measure the recovery of waterproofing of the treated otter's coat using a combination of thermal microchips and thermography.

Trial 1 – Normal Body Temperature Variation among Body Regions in Captive Birds at MBA

Our goal was to obtain baseline "normal" surface body temperatures for healthy, waterproof, captive seabird species which are susceptible to chronic or catastrophic oiling in the wild. Our focal animals were Common Murres and African Penguins. Our aim was to quantify normal variability in heat signatures in healthy birds. Because certain tissues may limit (e.g. feathers, fat) or increase heat loss (e.g. the facial skin of an African Penguin), we expected to find significant variation in thermographic readings among body regions.

In association with regular feeding times (penguins), captive birds at MBA were examined and photographed. Thermal images were taken to include the following angles: head close-up, right and left lateral body, dorsal, ventral, feet and face. The same range of images were collected opportunistically for the same individuals while engaged in active (feeding, bathing, swimming) and non-active behaviors (resting, roosting, and preening). Opportunistically, we were able to sample variation due to change in a physiological state, molting, for three individual penguins.

Images were quantified using FLIR ThermoCAM Researcher Pro 2.8 SR-1© software (FLIR Systems AB, Sweden) to determine the average body surface temperatures for each body region by drawing a circle, line, or polygon over the body region of interest and taking the program-calculated average and standard deviation for that region based on each temperature pixel within the shape (For an example, see Figure 4). Circle radii were adjusted to account for the distance of the study animal from the camera (i.e., the size of the penguin in the thermograph). Normal body temperatures were based on reported values for each species, or based on OWCN criteria 102–105°F (39–41°C).

Opportunistically, we obtained thermal photographs of several Tufted Puffins, a Laysan Albatross ("Makana"), a Horned Puffin, a Pigeon Guillemot, several Magellanic Penguins, two African Penguin chicks (Pebble and Portola), a variety of shorebirds including avocets, stilts, dowitchers, phalaropes, and waterfowl, including Buffleheads and Ruddy Ducks.

Trial 2 – Waterproof Assessment of oiled and non-oiled loons and grebes at LA Bird Rescue

During one, week-long trip to LA Bird Rescue, 24-28 April 2011, we tested the utility of thermography for assessing waterproofing in nearshore species such as grebes, loons, and murres. Because of oil seep activity in the southern CA region south of Point Conception, individual oiled birds present to the LA center quite regularly. We took advantage of one minor oiling episode to study the waterproofing process for 7 oiled birds in a typical rehabilitation setting.

Trial 3 – Waterproof Assessment of murres and grebes at SF Bird Rescue

During May to August, we conducted 13 days of thermographic measurements on a variety of species at SF Bird Rescue in Fairfield, CA. During research trips to SF Bird Rescue, we continued to test the application of thermography for assessing waterproofing in pelagic seabirds, including shearwaters and fulmars. We continued to obtain baseline thermographs of rehabilitated seabirds during active feeding, preening, and resting to quantify temperature variability due to variations in activity level for a diversity of species under a range of ambient environmental conditions. Finally, we sought to build a greater library of images to determine thermal stability in other roosting birds such as pelicans and cormorants. With the interest of SF Bird Rescue staff and veterinarians, we opportunistically imaged sites of injury, wound healing, abscesses, and injection in a variety of species.

Trial 4 – Validation of Thermography with Microchips at SF Bird Rescue

To facilitate independent assessments of body temperature and thermal stability, small (12mm) temperature-reporting microchips[1] were injected subcutaneously in the dorsal neck of 4 Common Murres at SF Bird Rescue. This placement has been used successfully for Adélié Penguins in the Antarctic (Ballard et al. 2001). This routine procedure is currently performed in numerous veterinary and wildlife applications and does not require anesthesia or surgery. We selected study birds based on a relatively stable body condition (i.e. increasing or stable weight), those which had been housed in the cold water pool for one or more days, and those for which the chances of survival were thought to be good (per M. Bellizzi). Once injected, microchips were scanned intermittently with a pool-mounted reader (Destron Fearing, MN) at a 6 to 10" sampling distance. Bases on positive results of this trial in this first year of study, we propose to further develop the application of a pool-mounted microchip reader in the second year of study to automate temperature readings of flocks of seabirds during spill response.

RESULTS

Trial 1 – Normal Body Temperature Variation among Body Regions in Captive Birds at MBA

During March, April, and May 2011 we made 9 visits to MBA and took 1,232 thermographs. We focused our efforts on the adult African Penguins (AFPE) and Common Murres (COMU), representing two of the most commonly oiled groups of seabirds, penguins and alcids (Underhill et al. 1999, Carter et al. 2001).

African Penguins

We quantified surface temperatures with thermography of 12 "normal" adult, non-molting AFPE on display during feeding events at 10:30 am and 3:00 pm. (Fig. 1). For this study, we assumed that these long-term captive animals represented thermally stable and healthy individuals and thus represented the "normal" thermal state.

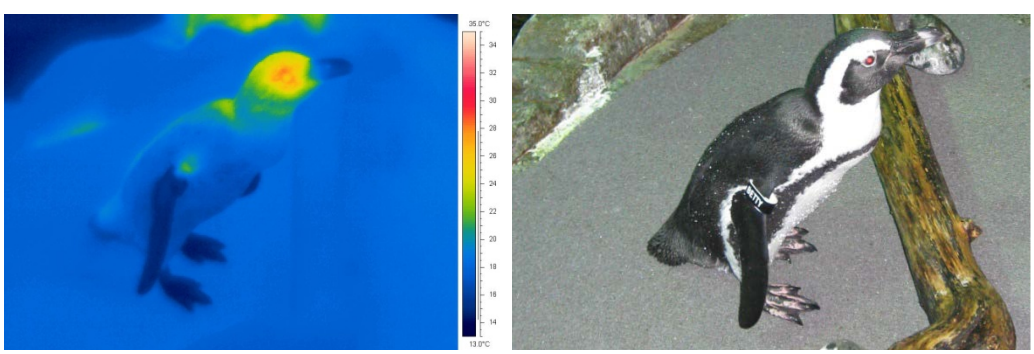

Figure 1. Infrared thermograph (left) and digital image (right) of "Betty", an adult, 2.5 year-old African Penguin at the Monterey Bay Aquarium on 4/7/2011. Colors in the thermograph correspond to the temperatures (°C) on the scale on the right, which ranges from 13 to 35°C.

[1] Bio-thermal LifeChip, Destron Fearing, MN, USA.

Temperatures recorded by the thermograph represent *surface* body temperature, not necessarily *core* body temperature. On thermographs, areas with good insulation (feathers and/or subcutaneous fat), with poor blood profusion, and/or that have cold water droplets on the surface (from swimming) will appear cool (blues). Areas with poor insulation, with abundant blood profusion, and/or that have been out of the cold water for some time will appear warmer (reds and oranges). During this first trial, we learned that physiological, behavioral, and developmental variables may affect the normal thermographic signatures. Digital photographs were taken in tandem with infrared thermographs for later reference to verify individual identities and in identifying behaviors or other environmental conditions that might affect the interpretation of the thermographs (Fig. 1).

We accounted for physiological variability in body surface temperature by taking thermographs of molting (n = 3) and non-molting (n = 12) adult AFPE. We accounted for behavioral/activity variability in body surface temperature by taking thermographs of swimming/diving (n = 6) and roosting/feeding (n = 6) COMU, and we accounted for developmental variability in body surface temperature by comparing thermographs of juvenile (n = 2) and adult (n = 12) AFPE.

We found individual variability and difference among thermograph signals of molting and non-molting individuals (Table 1). For example, an AFPE ("Betty") was undergoing catastrophic molt and was 50-60% molted (Fig. 2) during the early stages of our study. The resulting thermograph not only showed a significant (>2 degree) difference compared with a normal, non-molting bird in the areas with actively growing feathers, but also a major loss or shunting of heat in the flippers and other body parts (Fig. 2, Fig. 5).

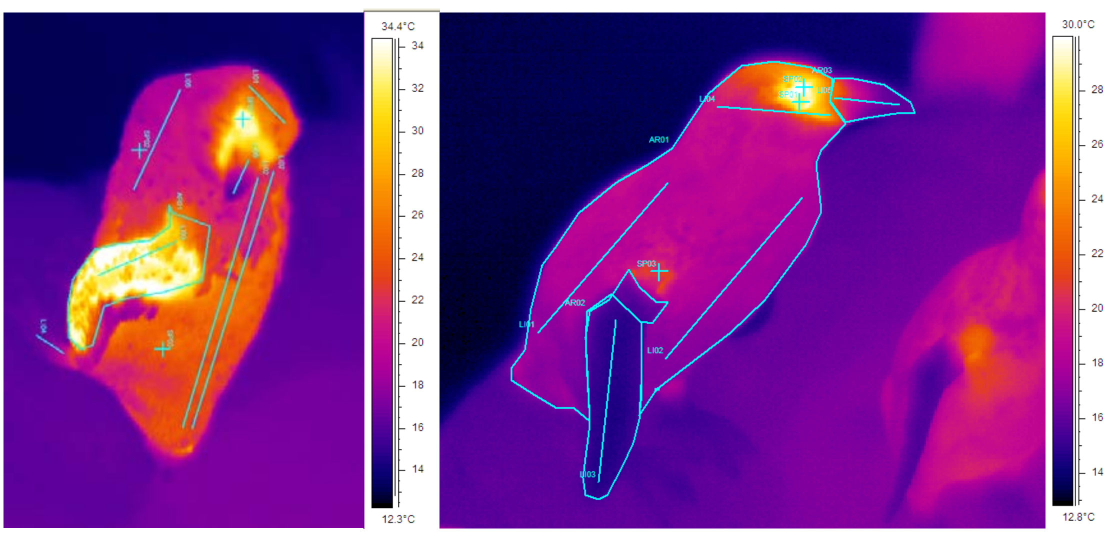

Figure 2. Contrasting physiological states of two African Penguins, one is molting (left, #514) and shows an enhanced heat loss signal (especially flipper) and the other shows the normal non-molting thermal state (right, #490).

Table 1. Average surface temperatures among body regions for non-molting (12 individuals) and molting (3 individuals) adult African Penguins at the Monterey Bay Aquarium, where n is the number of thermographs analyzed. Images illustrating the body regions in the table can be found in Figure 4.

		Non-Molting			Molting			
Aspect	Location	Average Temp (°C)	SD	n	Average Temp (°C)	SD	n	Difference (Molting-Non Molting, °C)
Dorsal	Tail	20.5	0.6	20	24.3	1.2	3	3.9
	Lower Back	20.5	0.3	22	23.8	0.3	3	3.3
	Middle Back	21.3	0.3	22	24.6	0.6	3	3.4
	Upper Back	21.5	0.3	21	25.7	1.0	3	4.2
	Lower Neck	21.5	0.4	21	23.3	1.8	3	1.9
	Eye	30.6	0.6	6	30.7	0.7	2	0.1
Lateral	Scapular	21.6	0.5	32	23.6	1.0	8	1.9
	Tail	20.3	0.6	32	24.0	1.0	10	3.7
	"Hip"	20.3	0.5	31	23.6	0.7	10	3.2
	Flipper	17.7	0.3	32	30.1	2.3	9	12.3
	Above flipper	22.8	1.0	32	25.2	1.8	10	2.4
	Back	21.6	0.4	32	24.5	0.6	10	2.9
	Belly	22.0	0.4	8	24.1	1.1	5	2.1
	Neck	22.1	0.5	31	23.8	1.9	8	1.6
	Eye	30.9	0.4	7	33.9	0.4	6	3.0
Ventral	Lower ventrum	19.6	0.3	15	23.8	0.7	4	4.1
	Middle ventrum	19.6	0.3	17	24.6	0.8	5	5.0
	Upper ventrum	19.8	0.3	17	22.0	1.3	5	2.3
	Bill	17.7	0.7	15	20.2	1.4	5	2.5
	Right eye	29.2	0.7	12	33.4	0.4	3	4.2
	Left eye	29.1	0.7	10	32.9	0.5	4	3.8

Variability in Surface Temperature among Body Regions.

Increased temperature of the eye and surrounding skin patch compared to other body regions was expected because of the lack of insulation in that area (Figs. 1, 2). An area of increased body surface temperature that was unexpected, however, was just above the flipper in the shoulder area (Fig. 3). We found this area was consistently warmer than the surrounding regions in nearly every thermograph of a penguin we examined. The potential reasons for increased surface temperature at this location include: 1) increased vasculature in this area (i.e., near the brachial artery), 2) vasculature closer to the body surface, and/or 3), decreased insulation in this area (less fat and/or fewer feathers). This warm shoulder patch occurred above flippers with and without bands, so banding was ruled out as a cause of this thermal anomaly. Surface temperatures of the flippers, on the other hand, were consistently cooler than the other body regions. Since flipper plumage is less dense than the rest of the body plumage, swimming in cold water may cool the flipper itself, not just the surface. Because of this potential for heat loss, adult penguins probably shunt blood away from the flippers to prevent a decrease in core body temperature, resulting in a decrease in flipper surface temperature.

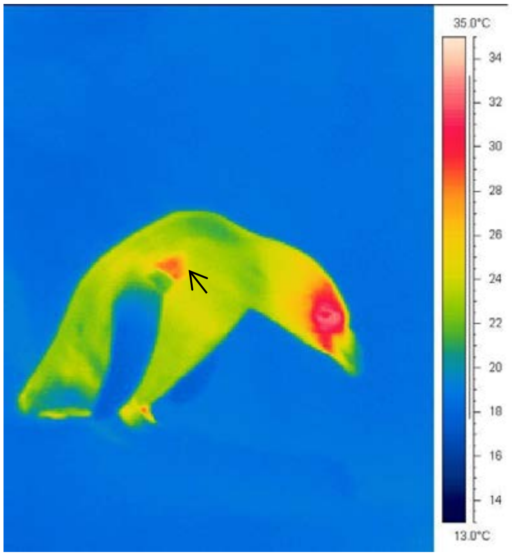

Figure 3 Thermograph of a typical AFPE at the Monterey Bay Aquarium. This photo illustrates the typical heat signatures of AFPEs: relatively hot surface temperatures around the eye and eye skin patch, relatively cool flippers, and a warm patch just above the flipper in the shoulder area (denoted with arrow).

Body surface temperatures of molting (compared to non-molting) penguins were greater for all body areas, especially the flippers (Table 1, Fig. 5). Increased body surface temperature in molting penguins may be attributed to 1) decreased insulation in areas where feather coverage is scarce or non-existent, 2) increased profusion of warm blood to the skin surface to support growing feathers, and/or 3) decreased frequency and duration of swimming bouts, which can decrease core and surface temperatures. A visual change in body surface temperature during molting is illustrated with thermographs in Figure 6.

In general, body surface temperatures were greater for adult AFPEs than for chicks, except for the eyes, flippers, and bill (Fig. 7). This may be partially explained by the greater average air temperature in the adult AFPE exhibit ($\bar{x}$ = 72°F) compared to the chick quarantine area ($\bar{x}$ = 68°F), or perhaps the downy chick plumage provides better insulation than the adult plumage, preventing heat loss and decreasing body surface temperature.

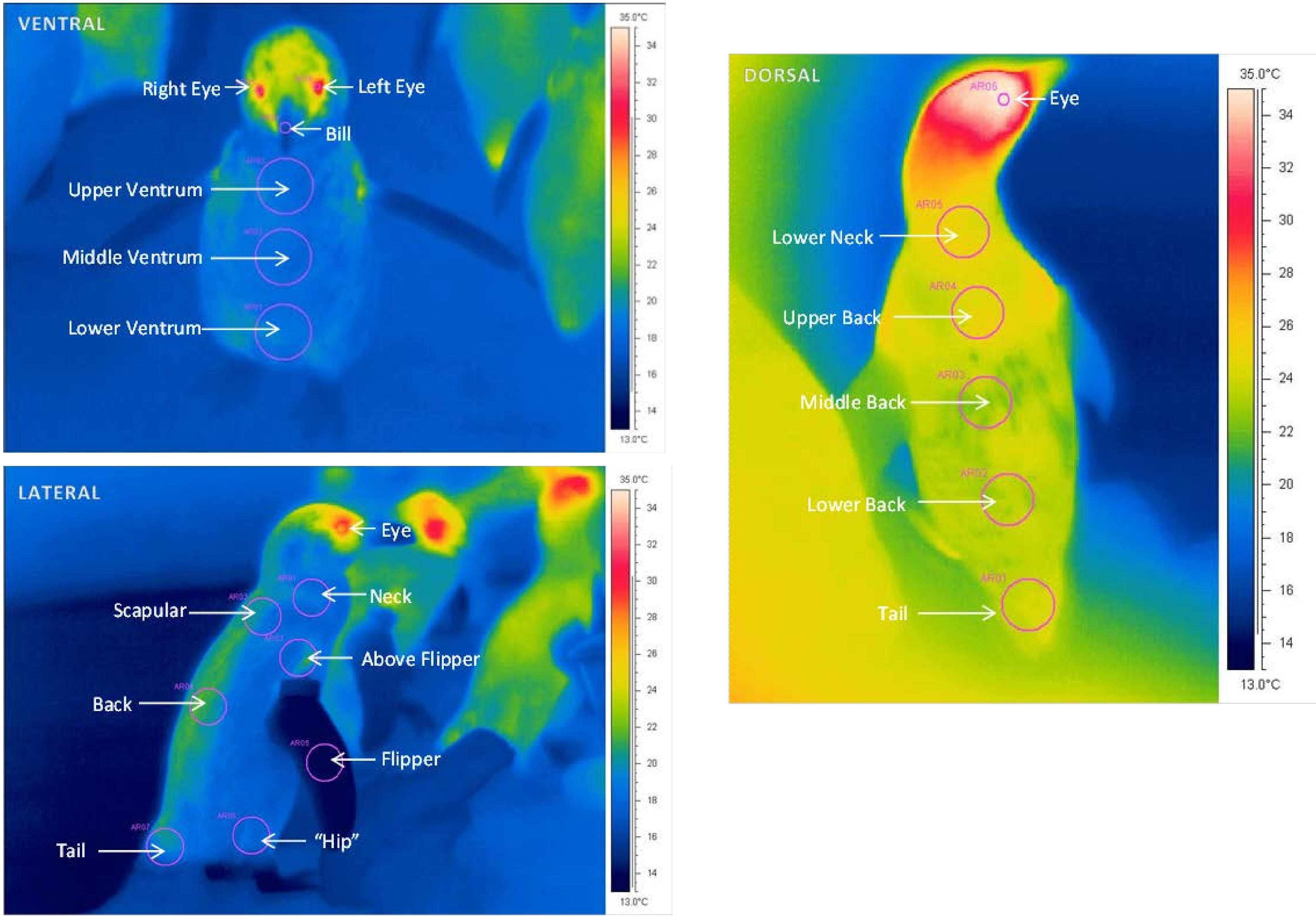

Figure 4. Locations used to obtain average body surface temperatures of African Penguins (see Table 1 for results).

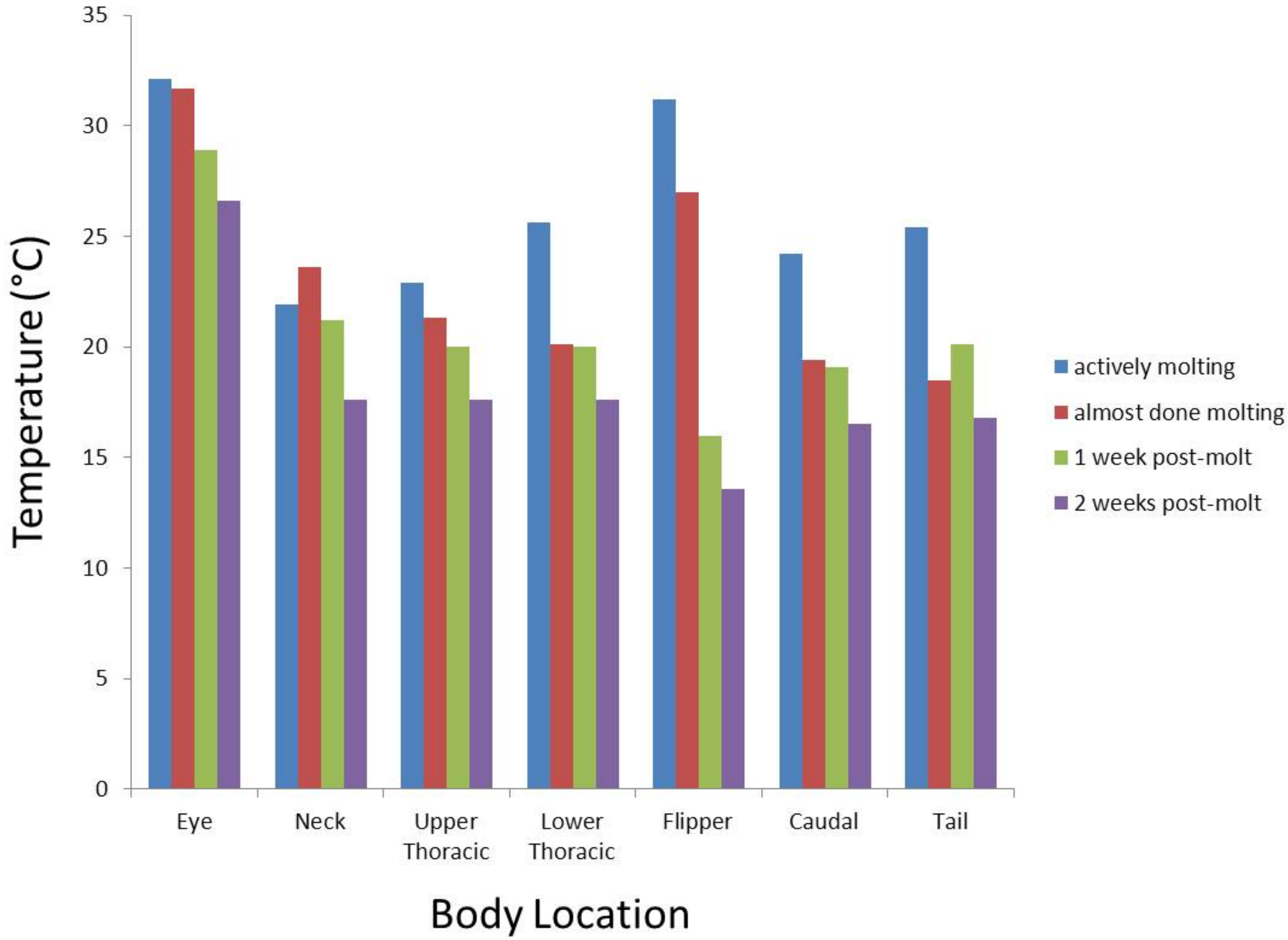

Figure 5 Temperature differences among body locations over a 4-week period, during and after molting for a 2.5 year-old African Penguin ("Betty"). Temperatures represent average temperatures for specific body areas (see below for a visual of how body regions were defined).

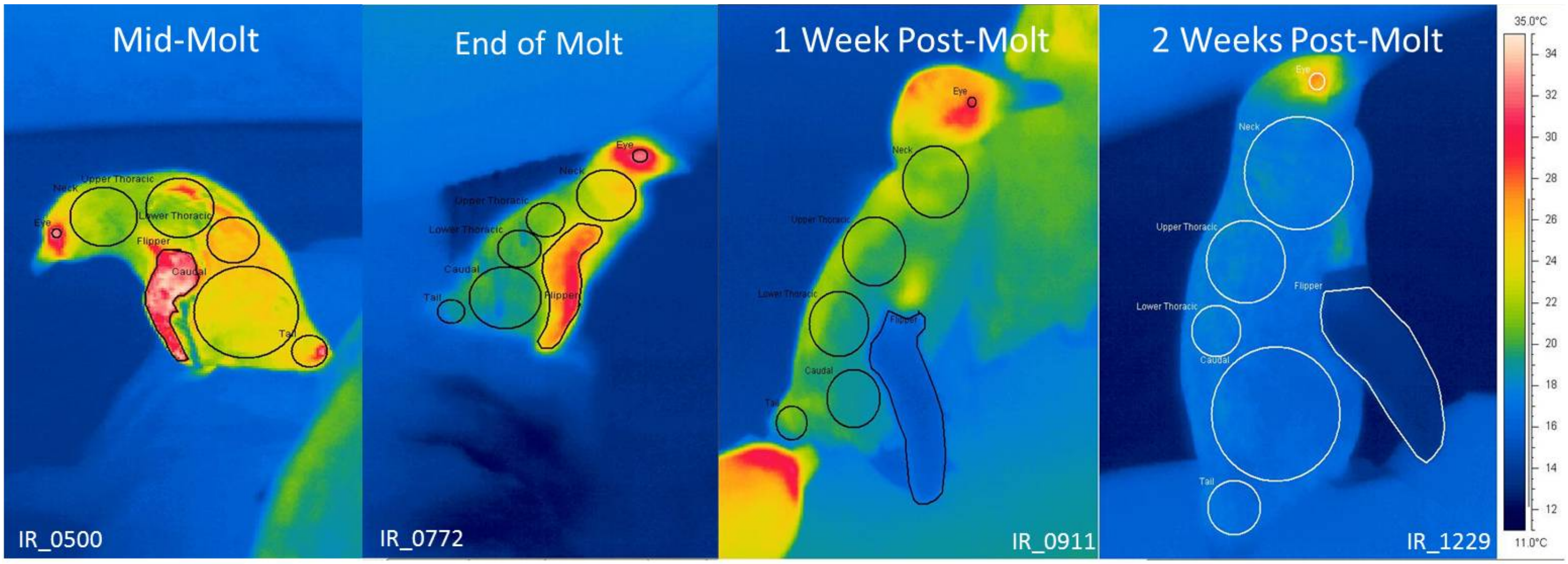

Figure 6 Changes in body surface temperature between March 17, 2011 and April 4, 2011 for an African Penguin ("Betty"), during and after molting. Circles and polygons indicate body regions for which temperature data were averaged and compared for the previous figure.

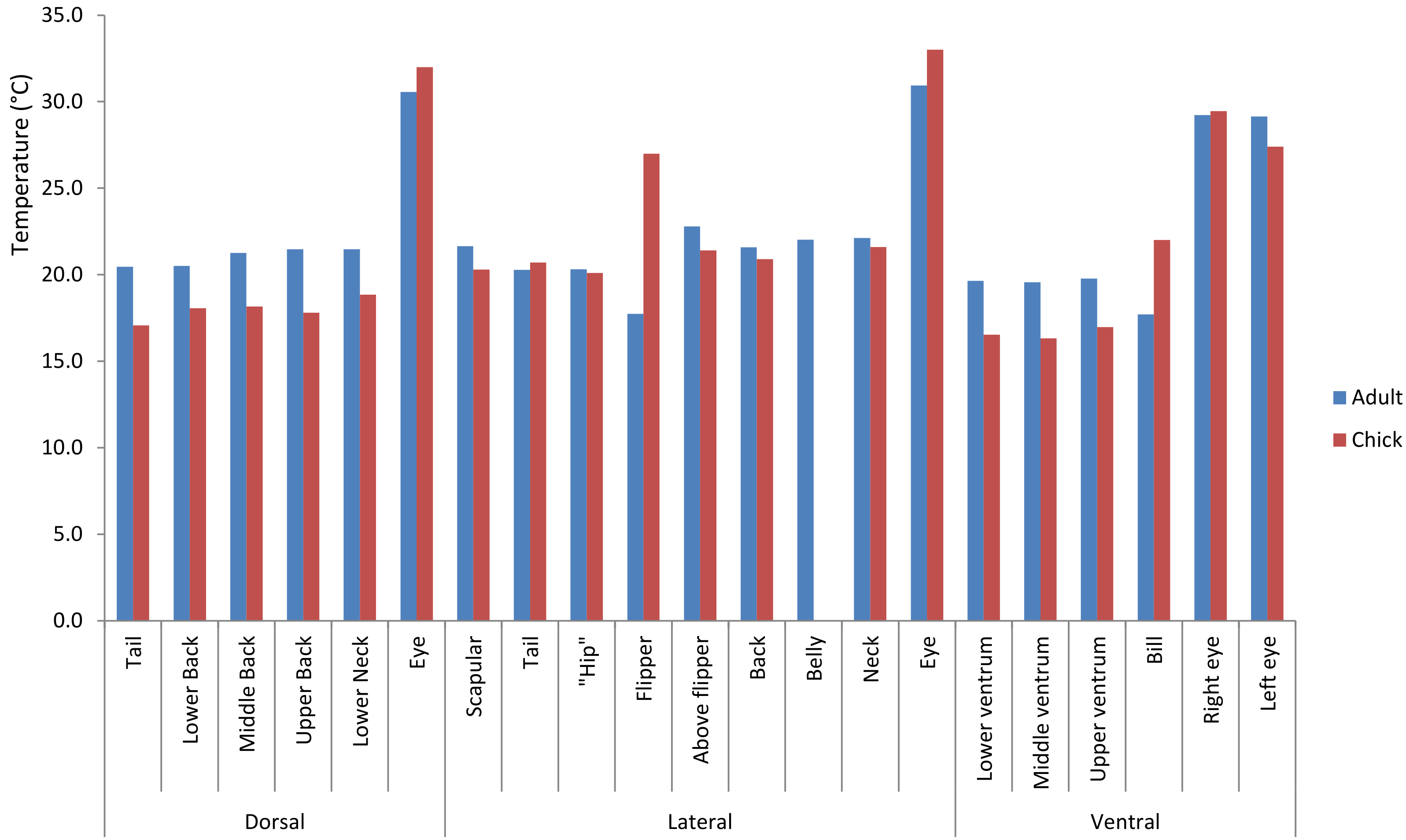

Figure 7. Body surface temperatures of African Penguin chicks (red bars) and adults (blue bars) by body region. No data was available for the lateral/belly region of chicks.

Common Murres

We analyzed thermographs from six captive murres (named Jelly Bean, Kiwi, Plum, Tomato, Marvin, and Ruby; Fig. 8) at the aquarium, for which there were at least two independent dates of sampling, to quantify variation in surface temperature among body regions (Fig. 9). Similar to the penguins results, we found the surface temperature of the eye was consistently greater than other areas and varied from 23.0 – 28.6 C (73.4 – 80.2 F) among individuals. The most variable region was the “eye stripe” or post-orbital depression where two feather tracks meet, creating an location where water/heat might be captured. In general, the upper parts of the body including the eye, head, and scapulars were greater than lower regions and extremities. We expected the feet and legs to be more variable in temperature, but under the controlled conditions inside the aquarium, these regions showed surprisingly little variation among individuals. It should be noted that we only analyzed images of birds taken on the haul out and not those swimming in the pool.

Figure 8 (Left) Thermograph of four Common Murres on haul out off at MBA. Left to right: Ruby, Kiwi, Plum, in back unknown being fed (3/31/11, IR_0933, MBA). (Right) Digital image of an aviculturist hand-feeding birds on a haul out (IMG_0500, MBA).

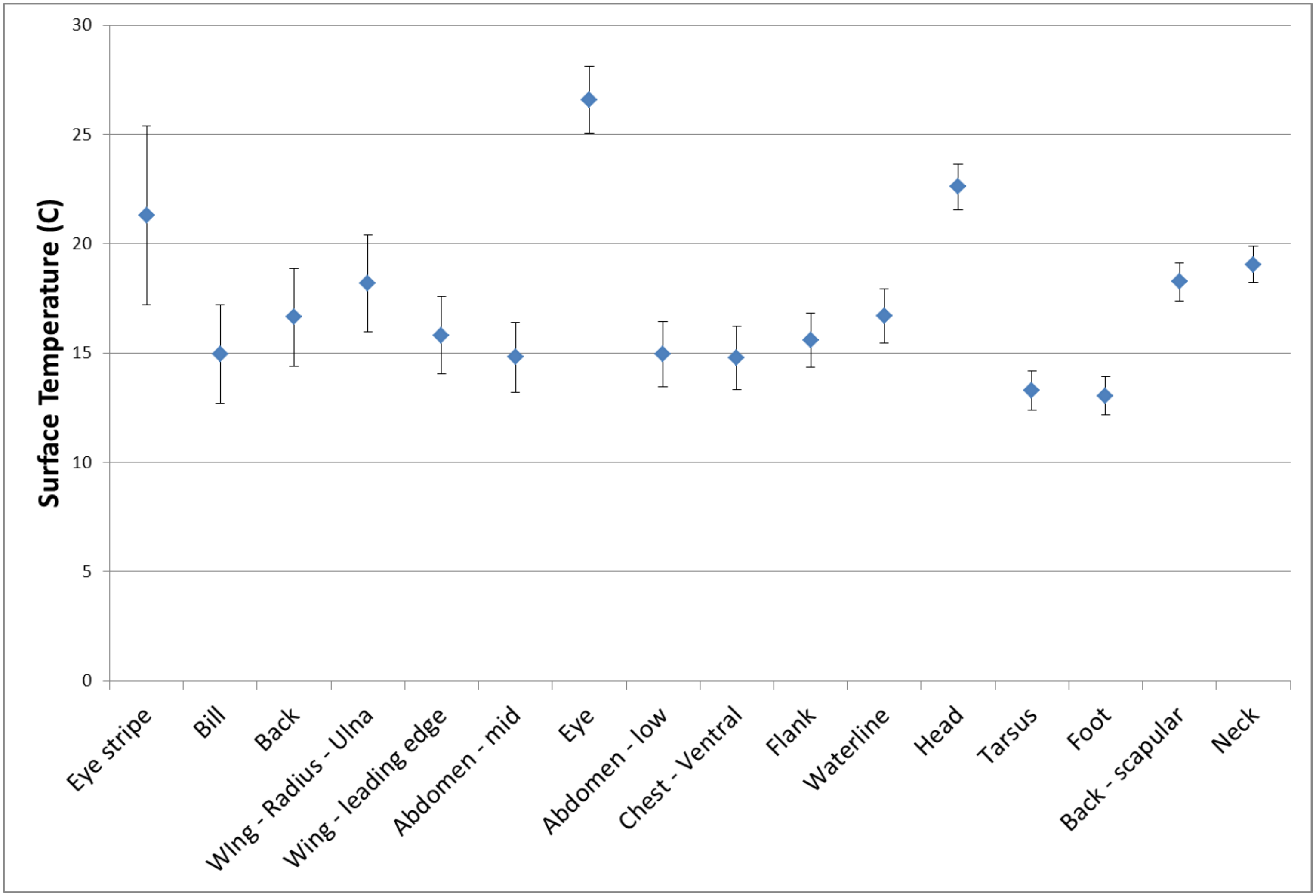

Figure 9. Variability in surface temperature (°C) among regions of the body of captive Common Murre (error bars = standard deviation) arranged from most variable (eye stripe) to least variable (neck).

Trial 2 – Waterproof Assessment of Diving loons and grebes at LA Bird Rescue

During April 2011 we spent 5 days at LA Bird Rescue in San Pedro, CA to take thermographs of individually oiled birds during the rehabilitation process. We took 506 thermographs from a variety of species (Table 2). Many of these birds had been oiled and washed and were in various stages of re-establishing their waterproofing; other birds were not oiled but were in care for other medical/physical reasons.

Common Name	Species
Common Murre	*Uria aalge*
Brown Pelican	*Pelecanus occidentalis*
Western Grebe	*A.occidentalis*
Clark's Grebe	*Aechmophorus clarkii*
Brandt's Cormorant	*P. penicillatus*
Northern Fulmars	*Fulmarus glacialis*
Pacific Loon	*Gavia pacifica*
Red-throated Loon	*Gavia stellata*
Surf Scoter	*Melanitta perspicillata*
Rhinoceros Auklet	*Cerorhinca monocerata*

Table 2. Focal species examined during thermography trials at Bird Rescue.

When assessing waterproofing using an IR photo, areas that were completely waterproof appeared cool (blues), because the feathers are preventing penetration of cold water, keeping the water on the surface of the feathers. We found areas that were not waterproof appeared warmer (reds, yellows, oranges, greens), because these areas are not well insulated and are giving off heat (Fig. 10).

We analyzed post-wash waterproofing thermographs for oiled (n = 7), fouled (n = 2) and non-oiled/fouled (n = 5) seabirds at both rehabilitation centers. Thermographs were compared with traditional (physical) waterproofing assessments to assess the efficacy of IR thermography. Of 20 waterproof-checking sessions conducted, the handler's assessment of waterproofing and the interpretation waterproofing by analyzing the thermograph had a 76% agreement rate, a 24% disagreement rate, and in 3 cases there was no handler assessment accompanying the thermograph for comparison.

The mean difference between the maximum and minimum ventral surface temperatures was 5.7 ± 0.9°C for waterproof birds, and 8.4 ± 2.1°C for non-waterproof birds, indicating that waterproof birds had less variation in surface temperature, which was expected for well-insulated birds. More waterproofing assessments were conducted, but not all the thermographs have been analyzed. Although we feel confident in the use of thermography to validate plumage insulation integrity (objective 2), we will continue to explore this application in year 2 of this study to further understand the impacts of behavioral, environmental, and physiological impacts on the assessment of waterproofing using thermography.

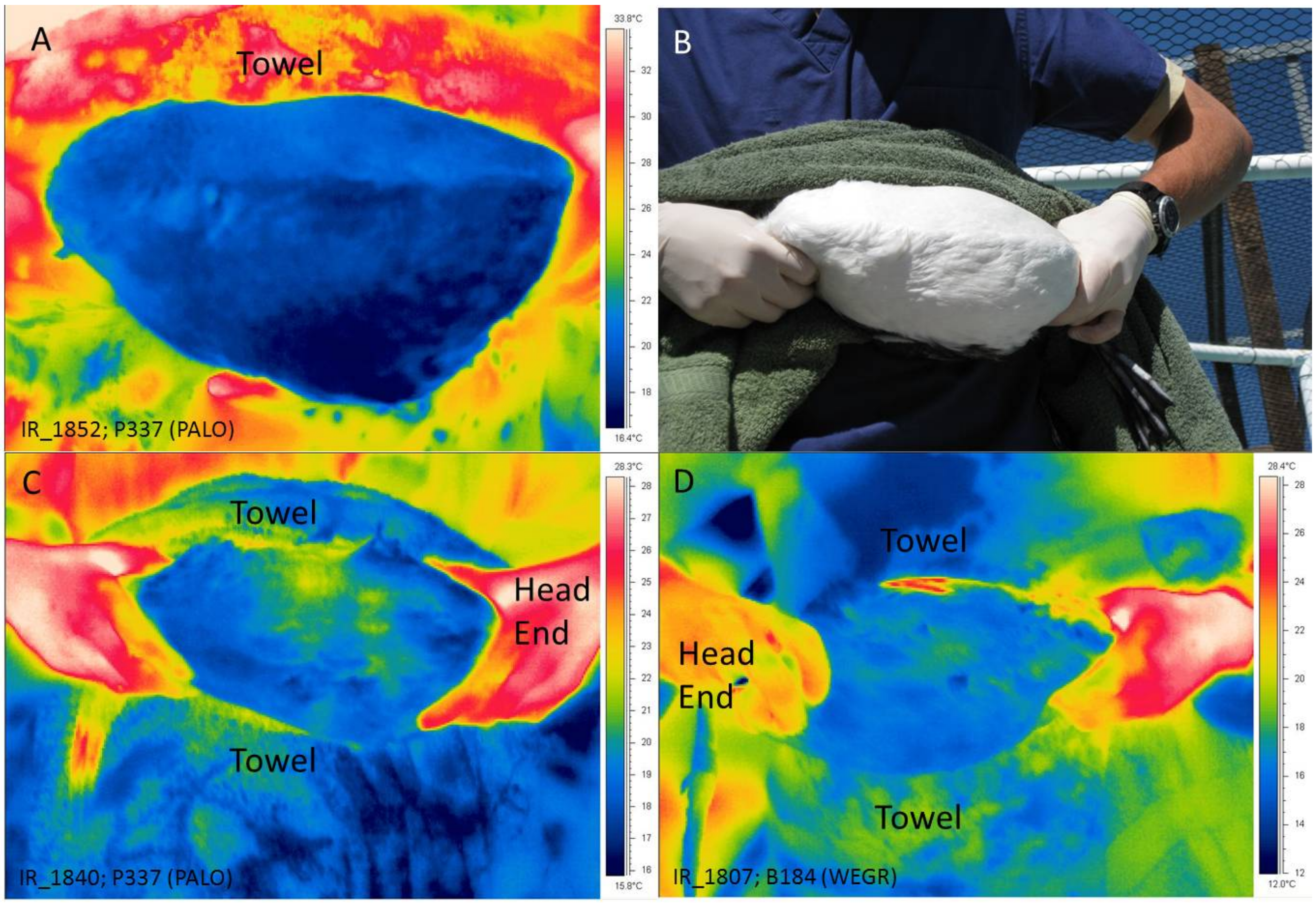

Figure 10 Assessment of waterproofing on ventral surface of various seabirds using IR thermography. A. IR photo of the ventral surface of a Pacific Loon (PALO; P337) after spending its first night in a pool. Upon physical examination, no wet spots were found (100% waterproof). B. Paired digital photo of P337 being held for an IR waterproofing check. C. IR photo of the ventrum of PALO P337 during the end-of-the day waterproofing check prior to spending its first night in the pool. No wet spots were found. The green areas on the ventrum are residual warm spots from where the handler touched the ventrum just prior to taking the photo. D. IR photo of the ventrum of a Western Grebe (WEGR; B184) after being in a pool for 2 hrs. Warmer spots (greens and yellows) on the ventrum perfectly mirrored the location of areas that were "wet to skin," as described by the handler who was physically assessing waterproofing (i.e. this bird was not waterproof).

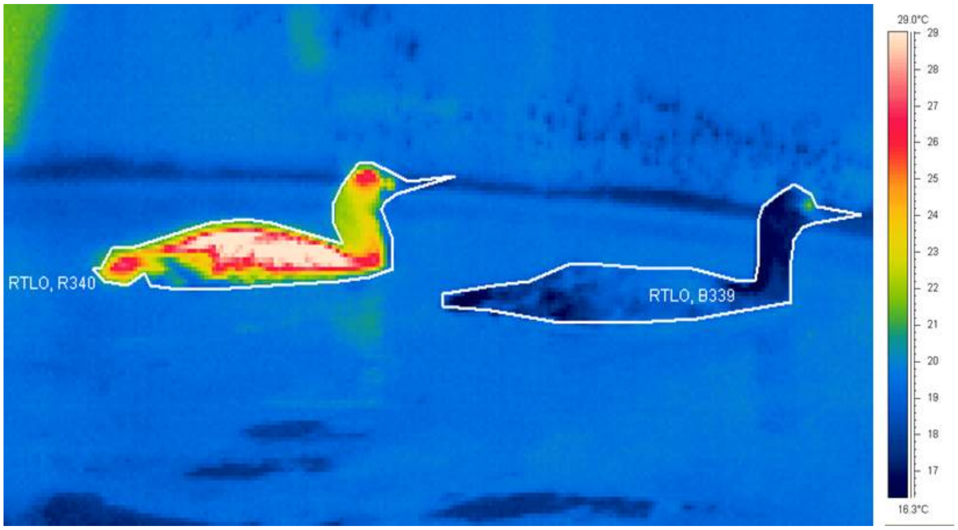

Figure 11. Two Red-throated Loons swim in a cold water pool. The difference in the thermal sign is a result of behavioral differences; the cooler bird (on right) just surfaced from a dive.

Behavioral Effects on Thermographs

We found that activity such as diving or preening behavior of the bird prior to the thermograph being taken resulted in a significant change in the apparent surface temperature. For example, if the bird had just dove, it may appear cooler because of conductive heat loss to water (Fig. 11). The amount of time spent in the pool may also influence the thermal properties of the bird, influencing the assessment of waterproofing (Fig. 12). Finally, environmental factors, such as amount of time spent in direct sunlight, also influences the thermal properties of the bird, because dark feathers absorb heat from the sun, making the birds appear very hot on the surface (Fig. 13). For example, surface temperatures of a group of grebes varied throughout the day depending on the amount of sun hitting their dark dorsal feathers. Surface temperatures were coolest (13-14.9° C, 56-59° F) early in the morning before the birds were exposed to direct sunlight, warmer (31-39° C, 87-102° F) around 09:00 am, and warmest (39-47.5° C, 88-117° F) at noon. Surface temperatures decreased (29-31° C, 84-88° F) as the amount of sun decreased throughout the afternoon.

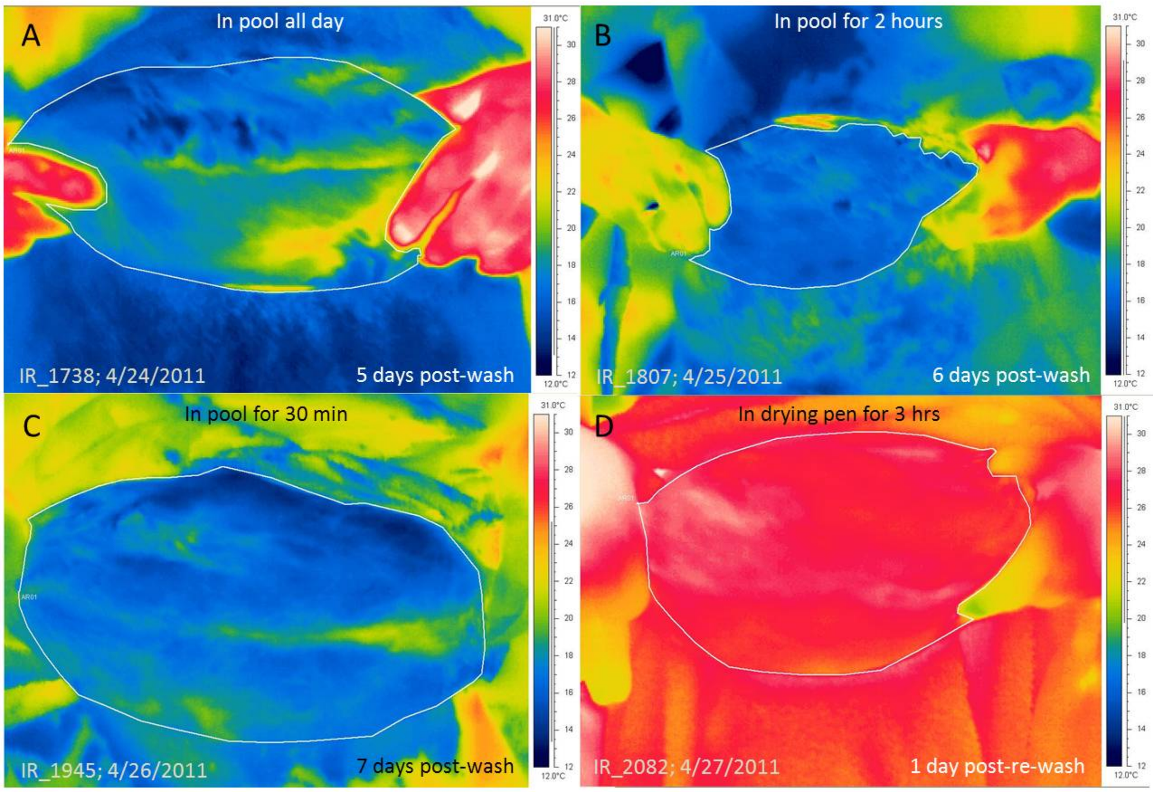

Figure 12. Infrared thermographs of a Western Grebe (WEGR; B184) over time and in various stages of waterproofing. WEGR B184 was oiled upon admission, was subsequently stabilized, and was washed on 4/19/2011. It was first photographed 5 days after wash (A) during a waterproof check after being in a pool all day. The handler reported that B184 was wet to skin on the left upper chest and along the midline, which matches up with the warmer (greens, yellows, oranges) areas in the IR photo. B184 was brought inside overnight on 4/24/2011, was completely dry in the morning, and put back out in a pool on the morning of 4/25/2011. A ventral waterproof check 2 hours after being in the pool (B) revealed significantly improved waterproofing over the previous day, but small areas on the right ventrum were wet to skin (areas described by handler matched warm (green) areas in IR photo. B184 was brought inside on 4/25/2011, was left inside overnight, was completely dry in the morning, and put back out in a pool on the morning of 4/26/2011. A ventral waterproof check 30 min after being in the pool (C) revealed areas that were wet to skin all over the ventrum (see green and yellow areas of photograph). B184 was re-washed and dried on 4/26/2011 to try to improve waterproofing on ventrum, and was moved to a pool the morning of 4/27/2011. A ventral shot after coming back inside for further drying after a short stint in the pool on 4/27/2011 (D) indicated a fairly uniform warm surface temperature across the surface of the ventrum. White lines show and outline of the ventral surface examined and used for analysis.

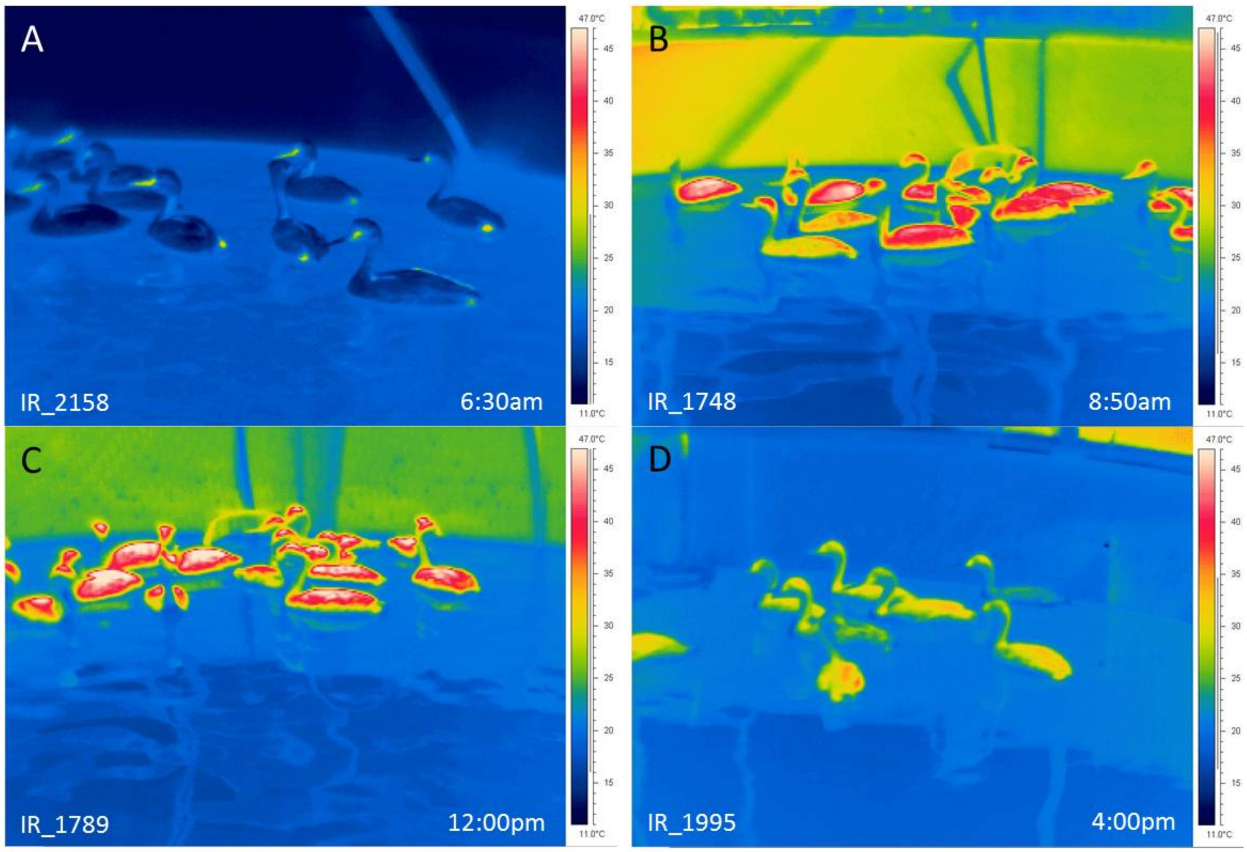

Figure 13. Variation in surface temperature among a group of waterproof Western Grebes swimming in a pool at LA Bird Rescue. Surface temperatures of the grebes varied throughout the day depending on the amount of sun hitting their dark dorsal feathers. Surface temperatures decreased (29-31° C, 84-88° F) as the amount of sun decreased throughout the afternoon (D). Temperature scales for all photos are standardized.

Trial 3 – Waterproof Assessment of previously oiled and non-oiled seabirds at SF Bird Rescue

We conducted ten 1-2 day trips to San Francisco Bird Rescue and obtained 1,448 thermographs from more than 40 birds, including murres, grebes, loons, scoters, pelicans and two pelagics – a sooty shearwater and a northern fulmar. We sampled two oiled birds, one Common Loon (CO-0024/ B45) and one Common Murre (CO-11-0025/ G441).The loon, collected 5/4/2011 at Stillwater Cove, Pebble Beach, was fouled with black, visible oil covering 51-75% of its body and waterline, this bird was emaciated (mass = 1680g), slightly anemic (PCV = 38) and moderately dehydrated, but noted as bright, active and alert (BAR) with a low temperature of 102.4 F upon intake. The murre, collected 5/3/11 on Morro Bay State Beach, was fouled on 2-25% of its body, emaciated (815g), anemic (PCV = 22), midly dehydrated with an elevated temperature of 107 F.

Trial 4 – Validation of Thermography with Microchips at SF Bird Rescue

On 29 July, we implanted temperature-sensing microchips subcutaneously into three Common Murres (R172 [=P1031], B415, R1824) and on 5 August, we implanted a fourth bird (G938). We arranged to receive sample thermal microchips and a loaner microchip reader and antenna from Destron Fearing, a company specializing in animal identification products. In this trial, we mounted the antenna on a haul-out in the pool and set up a data logger (microchip reader) next to the pool (Fig. 14). The microchip reader logged the unique microchip number and the temperature of the tissue directly surrounding the microchip each time the bird was detected by the antenna. We obtained body temperature data for 3 of 4 birds and for 2 of the implanted murres over a 24 hour period (Fig. 15), We found that the read-range of this antenna was sufficient to detect birds sitting within 0 to 6 inches of the haul-out; but it was inadequate to detect birds swimming in the pool at a range >8 inches. Currently, we are in discussions with a representative from BioMark, a distributer for Destron Fearing, and a specialist in electronic identification to design and implement an improved antenna system with a better detection range. We hope to purchase a system this year and conduct more trials during the second year of this study.

Figure 14. A Common Murre on a haul-out, checking out the microchip antenna (yellow racket-shaped object).

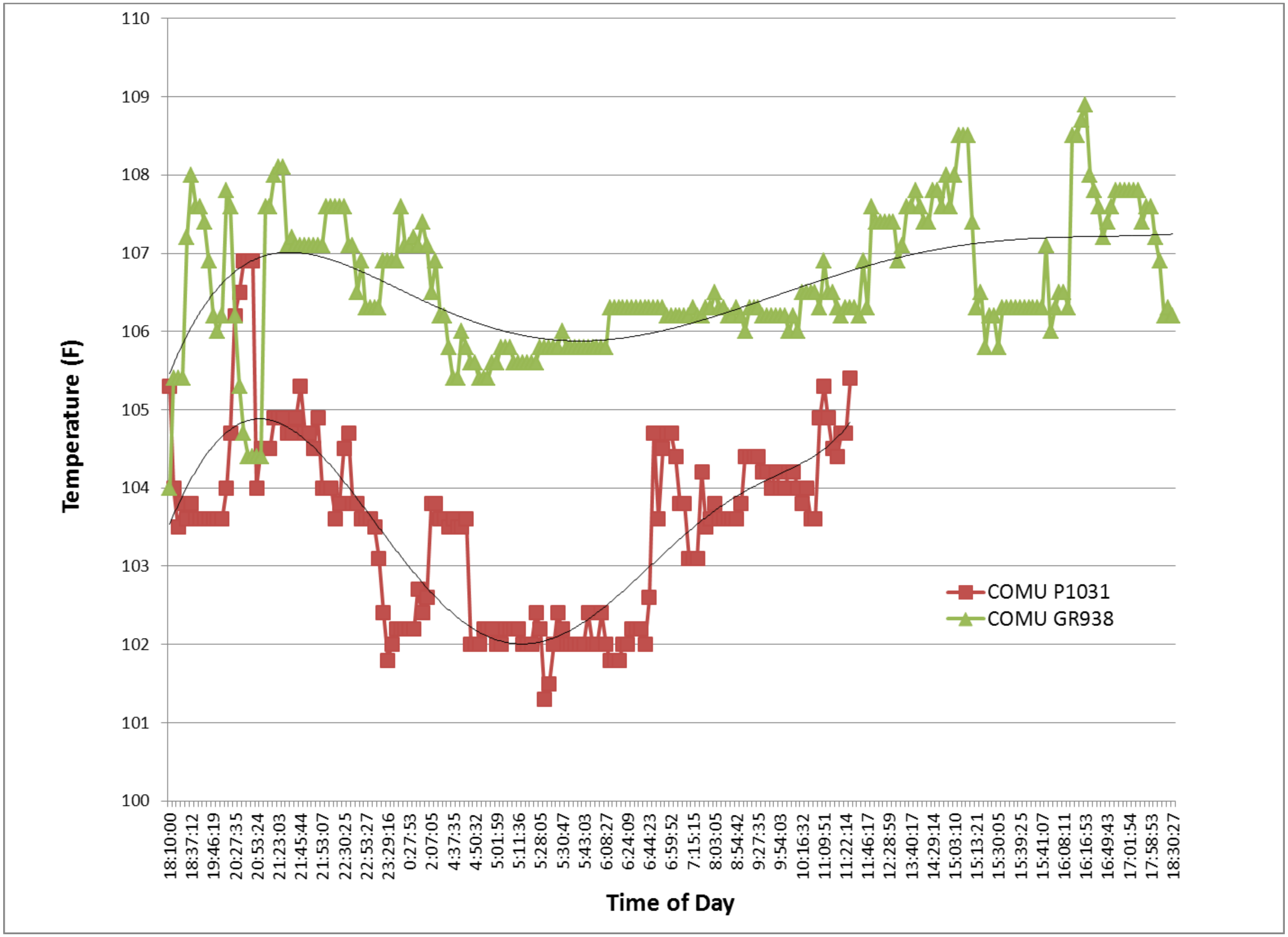

Figure 15. A 24-hour record of subcutaneous temperature readings of two Common Murres (P1031, GR938) taken every 5 mins in Pool A, SF Bird Rescue.

DISCUSSION

In the first year of our study, we assessed normal surface body temperatures of healthy, captive penguins and murres at the Monterey Bay Aquarium for comparison to core body temperature for those species in relatively controlled captive environment (objective 1), and quantified variability associated with changes in physiological state (molting or not molting; objective 4). We found that thermography underestimates core body temperature, even in an un-insulated structure, the eye. A study by Wilson and Grémillet (1996) found that body temperatures of African Penguins ranged from 37.3 °C when the birds were sleeping on land, to 40.8 °C during bursts of high-speed swimming during the day. Although, according to thermographs, the eye of African penguins was the warmest body region, all measurements of eye temperature were lower than the expected core body temperature for this species (Wilson and Grémillet 1996). We were unable to compare cloacal temperatures to thermograph-derived temperatures in this study because we were not permitted to obtain cloacal temperatures from birds on exhibit. However, during an opportunistic thermography session during the bi-yearly Magellanic Penguin examinations, we had one opportunity to compare a cloacal temperature with thermograph-derived surface temperature measurements. In this case the cloacal temperature of "Pingo," during a stressful physical examination, was 39.8°C, whereas the eye temperature, as measured by analysis of the matching thermograph, was 31.0°C. Although there is some doubt in the veterinary medical community with regard to the value of the cloacal temperature as an indicator of bird health (Dr. Mike Murray, personal communication), all of the results from this study suggest that surface temperatures, measured using infrared thermography, underestimate core body temperature of penguins. Thermography was valuable, however, for assessing variability in body surface temperatures of molting vs. non-molting penguins (objective 4), and shows great promise in assessing thermal stability in seabirds during the rehabilitation process.

Based on the results of Trial 2, we hope to improve our ability to tease apart the influence of behavioral and environmental factors in the second year of this study using activity data loggers (TDRs) and subcutaneous temperature-sensing microchips to better estimate core body temperature of seabirds. Use of these technologies will assist us in addressing activity-mediated variability in temperature (objective 3). Although we had hoped to implant seabirds with thermal microchips (referred to as PIT tags in the proposal for year one of this project) during the first year of this study, we thought that our results would be more accurate and meaningful if we focused our efforts on mastering the use of the IR camera and learning its capabilities and weaknesses. However, in recent months we have been researching different brands of thermal microchips, microchip readers, and antennas to determine the combination that will be most cost-effective, accurate, and feasible for use during an oil spill response.

The mean difference between the maximum and minimum ventral surface temperatures was 3°C greater for non-waterproof compared with waterproof birds, indicating that waterproof birds had less variation in surface temperature, which was expected for well-insulated birds.

(See Appendix A: Nevins & Young 2012). Although we feel confident in the use of thermography to validate plumage insulation integrity (objective 2), we will continue to explore this application in year 2 of this study to further understand the impacts of behavioral, environmental, and physiological impacts on the assessment of waterproofing using thermography.

Throughout these initial trials, we discovered other potential applications of thermography toward greater understanding of bird rehabilitation. Another aspect that could potentially be explored further in other studies is the application of thermography to assessing wound/injection sites.

Permits

We obtained permission to conduct this study by the UC Davis Institutional Animal Care and Use Committee (IACUC, Protocol #16336, 2/11/2011). We also obtained permission to conduct this work by animal care research committees of San Francisco Bay Oiled Bird Care and Education Center, International Bird Research and Rescue Center (IBRRC, dated 12/30/2010, Dr. Hayden Nevill) and the Monterey Bay Aquarium (MBA, dated 3/9/2011, Sue Lisin).

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Appendix A: Nevins, H. and C. Young 2012, pg. 106-111 *In* Proceedings of the Effects of Oil on Wildlife (EOW), New Orleans, LA, 2012.