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TOURISM AND MAGELLANIC PENGUINS (*SPHENISCUS MAGELLANICUS*): AN EXAMPLE OF APPLYING FIELD ENDOCRINOLOGY TO CONSERVATION PROBLEMS

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Resumen. – El turismo y los Pingüinos de Magallanes (*Spheniscus magellanicus*): un ejemplo de aplicación de metodos de la fisiología endocrina a un problema de conservación. – Las actividades humanas y cómo afectan a la crianza y supervivencia de poblaciones de aves son de gran interés para los biólogos de la fauna. Mientras que los estudios de comportamiento y abundancia sirven bien para documentar cambios, es importante determinar los mecanismos fisiológicos que impulsan los patrones del cambio demográfico que se observan en las poblaciones de aves afectadas por las actividades humanas. Presentamos una revisión de los estudios que examinan cómo la presencia de disturbios humanos debido al ecoturismo modifica la fisiología del estrés endocrinológico de los Pingüinos de Magallanes (*Spheniscus magellanicus*), tanto en los adultos como en los pichones. Explicamos cómo, en una población que demuestra pocos efectos negativos obvios del disturbio humano según las medidas típicas demográficas y de comportamiento, sigue habiendo alguna modificación fisiológica potencialmente significativa que ocurre en los pingüinos visitados por los turistas. Mientras que las consecuencias de estas modificaciones fisiológicas a largo plazo siguen siendo desconocidas, levantan preocupaciones de impacto negativo que puede resultar del ecoturismo.

Abstract. – How human activities affect the breeding and survival of avian populations is of concern to wildlife biologists. While behavior and abundance studies can document change, it is also important to determine what physiological mechanisms drive the patterns of demographic change observed in bird populations affected by human activities. Here we review studies examining how the endocrine stress physiology of adult and chick Magellanic Penguins (*Spheniscus magellanicus*) is modified by tourist visitation. In a colony that shows few obvious negative behavioral or other population-level effects due to human disturbances, we describe some potentially significant physiological modifications that may occur because of visitation. While the long-term consequences of these physiological modifications remain unknown, they raise concerns that there may be negative impacts due to tourist visitation. *Accepted 19 October 2007*.

Key words: Tourism, impacts, Magellanic Penguin, *Spheniscus magellanicus*, endocrinology, conservation, human activity, endocrine stress physiology.

INTRODUCTION

While some human activities are neutral to the surrounding environment, most human behaviors negatively influence avian breeding and survival. Only a few species have evolved as human commensals, i.e., House Sparrows (*Passer domesticus*) and Rock Doves (*Columba livia*), thus requiring humans for their survival. In contrast, countless studies, including many presented at this conference, examine

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the negative consequences of "disturbed environments" on the population dynamics of avian species. Most of these studies document some modification in species distribution and or reproductive success. Monitoring changes in demographic patterns in response to human disturbances is needed to quantify the consequences of human activities.

Ultimately, however, how a bird responds to disturbances in its environment – whether it stays or goes or, if it stays, whether it is able to successfully raise young – is driven by internal physiological decisions. These decisions are driven by the internal neuronal and hormonal monitoring of the animal's condition. Thus, understanding the changes in physiological capabilities that drive the demographic and/or behavioral response to human disturbance may allow stronger inferences to be made as to why certain individuals or species do better in disturbed environments than do others.

In addition to the utility of physiological monitoring as a tool to determine why certain species are negatively affected by human activities, further analysis of physiological parameters may be relevant even in species that appear to be tolerating human disturbances. Indeed, we have all attempted to show "behavioral" calm while changes in internal physiological attributes (i.e., heart beat, hormonal surges) are occurring due to some stressor. Thus, while outward differences in behavior may not be apparent, internally changes may be dramatic. There is a growing body of information suggesting the negative aspects of experiencing stressful situations may not be evident in the lives of individuals until a much later age. This phenomenon of a delayed response is particularly pertinent in species that are long lived, for which down-stream effects might not be seen for many years (see reviews by Kaiser & Sachser 2005, Owen *et al.* 2005). In seabirds, for example, it has been shown that exposure to elevated glucocorticoids shortly after hatch causes cognition problems, as measured by the ability to perform on food acquisition memory tests in Red-legged Kittiwake (*Rissa brevirostris*) juveniles (Kitaysky *et al.* 2001). Thus, stressors at an early age may have negative consequences much later in life. Due to the inherent difficulty of measuring subtle but long-term impacts in the wild, to our knowledge, no one has documented such down-stream effects of human activities in free-living avian species. However, these negative consequences could be significant for the ultimate survival and reproductive success of a species.

Here, we summarize multiple studies on the interaction between Magellanic Penguins (*Spheniscus magellanicus*) and tourists at the breeding colony of Punta Tombo, Argentina. The situation at Punta Tombo is one that – using most easily observed and monitored behavioral and population parameters – appears to be a case of neutral effects of human/bird interaction.

Details of human disturbances on penguins at Punta Tombo have been examined and reported in previous studies (Yorio & Boersma 1992, Fowler 1999). Briefly, Punta Tombo (44°02'S, 65°11'W) is the largest breeding colony for Magellanic Penguins in the world. Tourist attendance was more than 105,000 visitors during the 2006–2007 season (Office of Turismo, Chubut, Argentina, unpubl.). Penguins in areas visited by tourists show very little behavior that suggests humans disturb them. The reproductive parameters of penguins in tourist areas (e.g., egg production and size, hatching rate, chick growth and survival) as well as settlement patterns in adults seem similar to areas of the colony not visited by tourists (PDB unpubl.). Our intent was to explore aspects of the physiological responses of penguins to tourist disturbances.

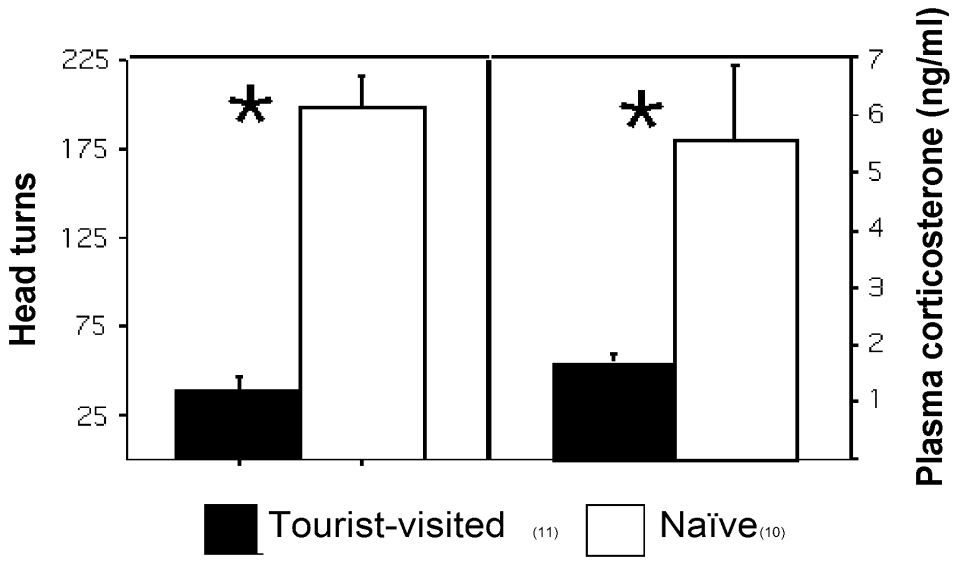

FIG. 1. Defensive head turns (left) and plasma corticosterone levels (right) after 15 min of a standardized human visits in Magellanic Penguin (*Spheniscus magellanicus*) adults nesting in either tourist visited (n = 11) or naïve (n = 10) areas of the Punta Tombo colony, Argentina. Modified from data presented in Figure 1 *in* Walker *et al.* (2006).

Measuring physiological responses to disturbances can be difficult in the field. Some researchers have used changes in heart rate as their preferred measurement for indicating a disturbance response in animals (e.g., Culik *et al.* 1990, Cabanac & Guillemette 2001). Here, we choose to use a hormonal response to stress: the concentration of the glucocorticoid hormone corticosterone that circulates in the blood in response to a perturbation in the environment. While less familiar than the hormonal "flight or flight" response resulting from surges in the hormone adrenaline (or epinephrine), glucocorticoids produce the same ultimate result: the ability to access stored energy to "deal with" the particular stressor, albeit over a slower and longer period than that of the "adrenaline rush". A delay in appearance of glucocorticoids in plasma is due to its release being triggered by a cascade of signals down the hypothalamo-pituitary-adrenal (HPA) axis following a disturbance. As the increase in glucocorticoids in the blood is thus delayed, researchers have the potential to both quantify a "before stress" level of the hormones (i.e., "baseline") as well as measure the increases in levels expressed in response to the stressor. Thus, glucocorticoid hormones provide a powerful tool to assess an animal's physiological response to stressors.

TOURISM EFFECTS ON MAGELLANIC PENGUINS

We examined how Magellanic Penguins living in areas visited by tourists at Punta Tombo compare – physiologically – to penguins living in areas restricted from tourists. All work was conducted at Punta Tombo Provincial Reserve, Chubut, Argentina, during the austral summers of 1996–2003. For details of the study site and methods, see Walker *et al.* 2005a, 2005b, 2006. Briefly,

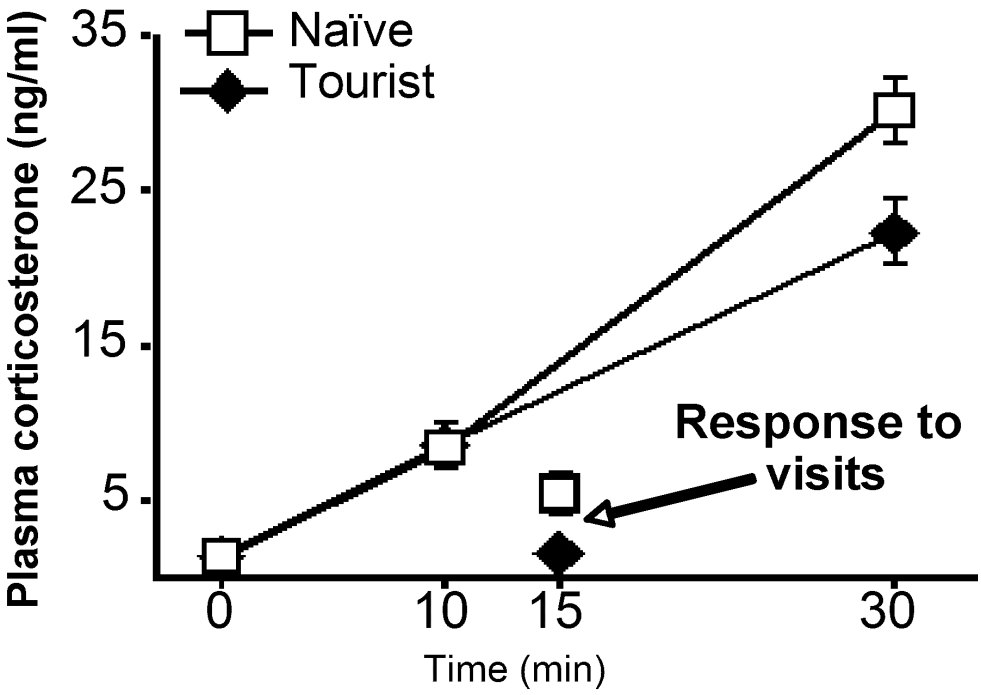

FIG. 2. Corticosterone concentration increase in response to 30 min of capture and restraint in Magellanic Penguins (*Spheniscus magellanicus*) in tourist-visited (n = 10) or naïve (n = 10) areas of the colony as compared to levels of corticosterone in penguins in both groups (n = 11 and n = 10 for tourist-visited and naïve, respectively) subjected to 15-min of a standardized human visit. Original data from Figure 2 *in* Walker *et al.* (2006).

for stress hormone measurements, birds (both adults and chicks) were removed from the nest and a blood sample taken within 3 min of capture, thus representing the baseline (i.e., pre-existing) level of corticosterone. In some instances, penguins were then held for 30–60 min and sequential blood samples were collected to measure how corticosterone levels increased in response to a unique "stressor" (i.e., being held). To measure impacts of tourist visitation, penguins were captured after a standardized 15-min visitation protocol (see Walker *et al.* 2006) and a blood sample taken to quantify how corticosterone levels changed in response to a tourist visit. All animal handling protocols were approved by the IACUC committee at the University of Washington, Seattle, USA.

In general, the physiological effects of human disturbances can be very different depending on the life-history stage of the animal being examined. For example, during periods of higher physiological demand, such as molt, it is known that stress responses can be muted, allowing an animal to focus energetic demands where needed (Romero 2002). In addition, age may play a significant role in how stress affects individuals. Specifically, adults and chicks/juveniles may have different reactions to disturbances, as the latter are undergoing development and growth, a

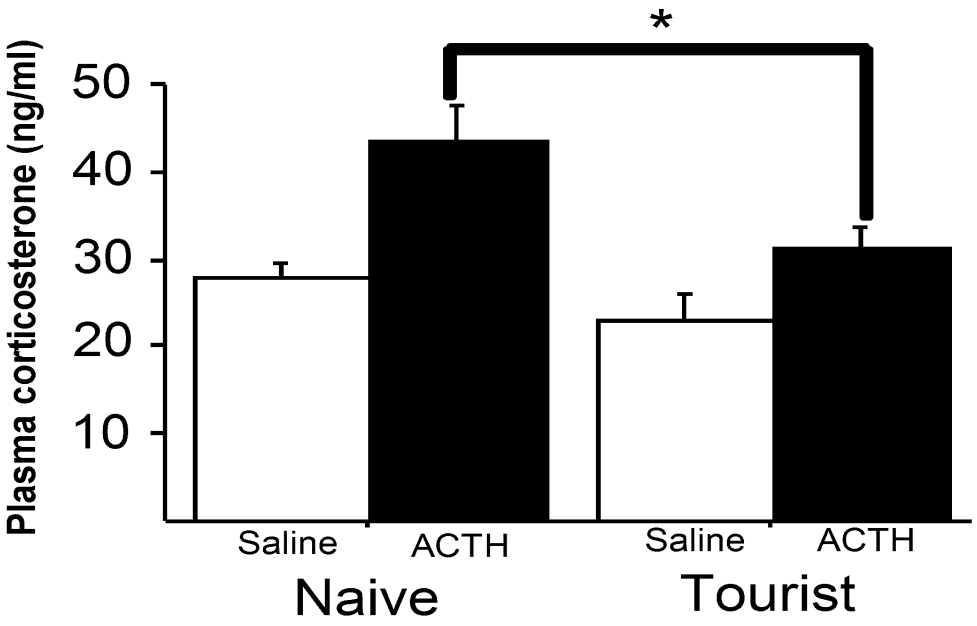

FIG. 3. Plasma corticosterone levels at 45 min post-injection of either saline or ACTH for both tourist-visited and naïve adult Magellanic Penguins (*Spheniscus magellanicus*) (n = 8 birds for each treatment in each area). Data modified from Figure 3 *in* Walker *et al.* (2006).

period known to be affected by stress hormones. So, while adults are subjected to negative consequences of stress hormones, these effects may be temporary, especially if escape from the stressor is rapid. In contrast, stress effects during early stages of life may alter such complex process as expression of genes and developmental pathways. Thus, stress effects in young may have much longer-term consequences. Here we present our findings for human disturbance effects on adult Magellanic Penguins first, followed by that of our preliminary studies examining stress effects in Magellanic Penguin chicks.

Physiological parameters in adult Magellanic Penguins. Our work on Magellanic Penguin adults can be divided into three aims: 1) to quantify if, after experiencing a "standardized" 15-min of human visitation, the behavioral calm that is observed in penguins in tourist areas (as compared to naïve birds) was also accompanied by a lower concentration of corticosterone than in naïve birds; 2) to determine if, when given a unique stressor (i.e., not a human visit), penguins in areas with and without tourists were equally able to respond by increasing corticosterone, and how this response compared to the corticosterone changes in response to human visitation alone; and 3) to examine if there were any differences between tourist and naïve birds in the physiological capability of the adrenal glands (the last stage of the HPA axis) to produce corticosterone. The results of this study could indicate true physical differences in birds nesting in the two areas.

Not surprisingly, when compared to naïve birds, adult penguins living in tourist areas showed a behavioral difference with a signifi-

cant decrease in "alternate head stares," [an aggressive behavioral response – Eggleton & Siegfried (1979)] during a controlled 15-min. "tourist visit" (Fig. 1, left panel). Additionally, we found that corticosterone secretion in response to this visitation was also lower in penguins exposed to tourist as compared to naïve birds (Fig. 1, right panel). When captured and held outside their nest, Magellanic Penguin adults in areas with and without tourists elicited the typical increase in corticosterone levels in their blood (Fig. 2). Compared to a simple 15-min visit, the hormone levels in response to capture were significantly higher, suggesting all penguins perceive a visit as relatively less stressful than capture (Fig. 2). Interestingly, however, we discovered that after 30 min of capture, Magellanic Penguins in areas where tourists visited had a less robust corticosterone response than did penguins living in areas without tourists. This suggested that some (or multiple) aspect(s) of the HPA axis responsible for secreting corticosterone was modified in Magellanic Penguins living in tourist-visited areas. As an initial examination of where the HPA axis may differ in penguins exposed or not exposed to visitors, we tested the functioning of the adrenal glands by providing an excess of adrenocorticotropic hormone (ACTH), the precursor secretegogue responsible for corticosterone secretion at the adrenal gland. The hypothesis was that if the HPA axis was modified at the level of the adrenal gland in tourist-visited birds, then, when given excess ACTH (intended to maximally stimulate the adrenal), penguins exposed to tourists would show a modified level of corticosterone secretion compared penguins outside of tourist areas. Indeed, the maximum amount of corticosterone secreted in response to ACTH injection was lower for penguins exposed to tourists (Fig. 3). Note that an injection of saline was given to control for the effects of injection stress and to assure that our ACTH injection increased corticosterone in both groups (Fig. 3).

Behavioral observations suggest that Magellanic Penguin adults have habituated to the current level of tourist disturbance. They do not respond with obvious aggression nor do they flee from visitors. Data presented here also suggest that penguins regularly visited are physiologically habituated. Penguins in tourist areas had lower levels of the stress hormone corticosterone after 15 min of visitation than penguins outside visited areas. In addition, the presence of a human around the nest, regardless of whether penguins have a long history or no history of human disturbances, elicited a lower hormonal response than being captured and held outside of the nest. These physiological results provide evidence to suggest that Magellanic Penguins tolerate visitation.

The presence of glucocorticoids in the blood is intended to facilitate the ability to access stored energy in times of crisis. However, long-term exposure to elevated levels of these stress hormones can be detrimental (Johnson *et al.* 1992, Wingfield 1994). Thus, if penguins "learn" that a visitation is not harmful and can avoid elevated levels of glucocorticoids in response to these stressors, they concomitantly avoid the potential negative effects of "chronic stress." Interestingly, however, the response to the capture stress protocol was not the same for all penguins. Penguins that were behaviorally and physiologically habituated to tourist presence showed a reduced corticosterone secretion in response to capture and restraint. We further found that the physiological functioning of the adrenal glands was different: penguins in tourist areas are less capable of secreting corticosterone than are other penguins.

Is this decreased ability to respond to a stressor problematic? We do not know. However, it may be hypothesized that, in times of

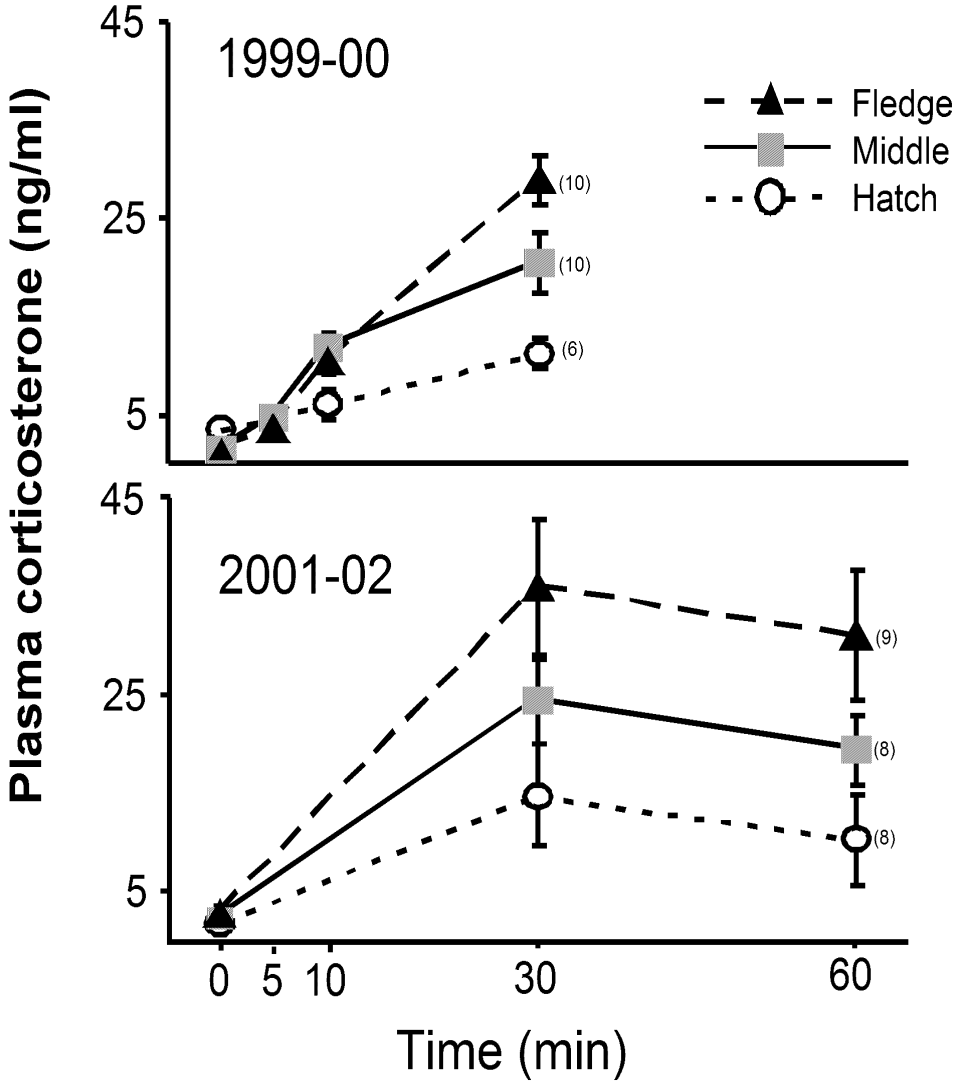

FIG. 4. Patterns of corticosterone increase for Magellanic Penguin (*Spheniscus magellanicus*) chicks of three age categories (Hatch: 5–6 days old, Middle: 45–60 days old, Fledge: 90–120 days old) subjected to the capture stress protocol in two breeding seasons. Originally appeared as Figure 1 *in* Walker *et al.* (2005b).

stress, a lower corticosterone response would indicate a lesser ability to access stored energy and respond appropriately to the stressor. How this inability may be manifest over the course of the many years of a Magellanic Penguin's life (> 30 years) is unknown. Our data suggest that perhaps the effects of human visitation to Magellanic Penguin adults are more complex than what is observed by behavioral and physiological studies. Thus, where habituation to a visit is indicated to be a positive response, penguins may have modified their

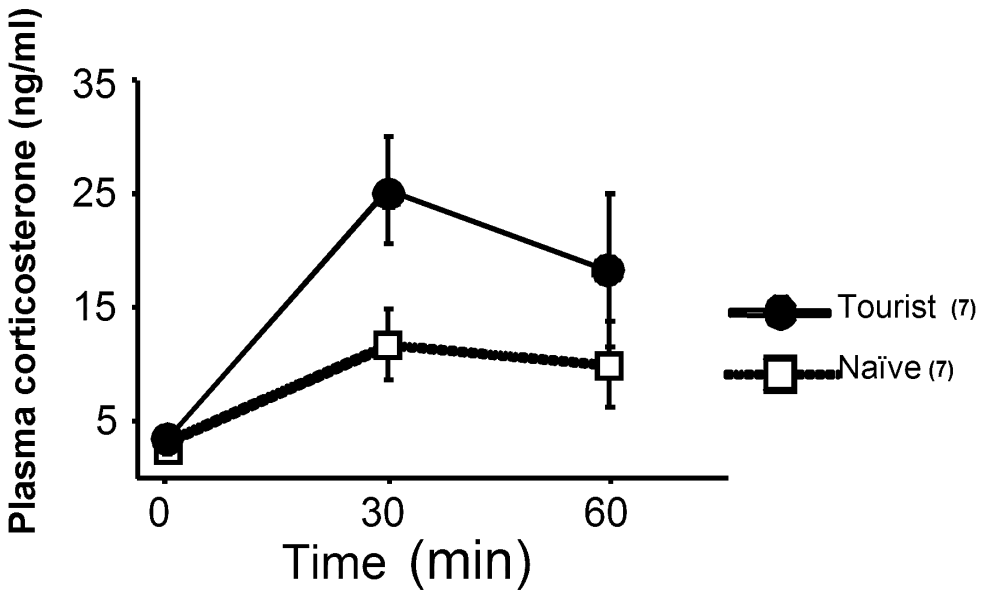

FIG. 5. Pattern of corticosterone secretion in response to capture and restraint in newly – hatched (< 5 day) Magellanic Penguin (*Spheniscus magellanicus*) chicks in both naïve and tourist visited areas of Punta Tombo, Argentina. Data taken from Figure 2 *in* Walker *et al.* (2005a).

physiology in ways that ultimately could be detrimental.

Physiological parameters in Magellanic Penguin chicks. Although stressors influence the course of development, very little work has been done on stress physiology in young animals in the field. In Magellanic Penguin chicks, we documented development of the HPA stress response. After the general course of development was determined, we examined if the HPA response to stress was altered when Magellanic Penguin chicks were raised in areas with tourist visitation.

A gradual development of the HPA stress response has been shown in a variety of altricial or semi-altricial species (Heath & Dufty Jr. 1998, Sims & Holberton 2000). In general, Magellanic Penguin chicks showed a similar gradual development of the HPA stress response (Fig. 4). This gradual development likely occurred because altricial or semi-altricial chicks are, by definition, unable to escape stressors. Thus, they would suffer from the high levels of glucocorticoids expressed in response to stressors from which they could not escape. Interestingly, we found that 5-days post-hatch Magellanic Penguin chicks living in areas with tourists expressed an adult like stress response. Typically, this robust of a stress response would not be present until 90–120 days post hatch (i.e., near fledging, Fig. 5). This atypical result is worrisome because, in developing young, glucocorticoids are known to depress growth rates when elevated for long periods. However, the data on hatching success, chick growth rates, survival, etc., showed no differences between Magellanic Penguin chicks, within and outside area visited by tourists.

The signal driving this premature expression of an adult-like stress response is

unknown. However, as the adrenal glands are fully functional at hatch (i.e., are capable of secreting corticosterone in response to artificially elevated levels of ACTH (Walker *et al.* 2005b), the upregulation of the stress response expression occurred at a higher level on the HPA axis, most likely in the brain. In addition, there is no information as to longer-term consequences of an early stress response expression. There may be no negative aspect to this response. However, there is some information that suggests that early exposure to elevated glucocorticoids has the potential to negatively affect individuals – albeit typically at periods later in life. This is apparent in human studies (e.g., Kaiser & Sachser 2005, Owen *et al.* 2005) and has been quantified in at least one experimental study discussed earlier (Kitaysky *et al.* 2001). Whether there are long-term consequences of the ability to express a stress response within 5-days post hatch in Magellanic Penguins remains unknown.

CONSLUSIONS

In summary, here we present an example of how in-depth physiological studies suggest potential areas of concern even when individuals appear to be functioning relatively well. Although the impacts of ecotourism may be subtle, the response of Magellanic Penguins to disturbances is likely more complex than previously thought. These include distinct changes in physiological capabilities in tourist-visited birds as well as potential long-term consequences that are difficult to measure without long-term research programs.

As human impacts continue to increase at a rapid pace, better understanding of the ways animals respond to disturbances and stressors will become increasingly important. The ultimate measure of stress is whether an animal moves or succumbs to a stressor. With better knowledge of what is driving behavioral changes – what physiological mechanisms are causing animals so succumb and/or "tolerate" disturbances – we will increase our ability to determine how to minimize the negative aspects of our actions.

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