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8. The weights for stage 10 lobsters ranged from 0.72 to 1.83 g [$\bar{X}$ = 1.15, standard deviation (S.D.) = 0.26, N = 86] and the stage 11 animals ranged from 1.34 to 3.04 g ($\bar{X}$ = 1.99, S.D. = 0.52, N = 46).
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Behavioral Thermoregulation: Orientation Toward the Sun in Herring Gulls

Abstract. *Orientation toward the sun combined with postural changes minimized the net radiation gain on the adult herring gull during the breeding season. The decrease in absorbed solar radiation was due to reduced surface area exposed to direct sunlight and to reduced absorptivity since, when the bird orients toward the sun, the angle of incidence is such that only the white surfaces receive direct sunlight. At low wind velocities (0 to 0.6 meter per second) and ambient temperatures above the lower critical temperature, the birds rotated 180 degrees during the day, always facing the sun.*

The ability to select or construct a favorable thermal environment is an important aspect of thermoregulation in birds. This is especially true during the breeding season, since a minimum of thermal stress from temperature, wind, and solar radiation is extremely important to the eggs, the nestlings, and the incubating adult. Various behavior patterns in response to thermal stress during the breeding season have been observed in the wild. Desert birds have been observed to build nests in the shade (*1*), to build roofed nests in exposed situations (*2*), or to orient the nest to avoid midday sun (*3*). Calder (*4*) has shown that hummingbirds build their nests under branches, thus avoiding radiation loss to the cold night sky. Except for a few studies (*5*), investigations to date deal with birds that build protective nests or that nest in a sheltered area. The synergistic effects of wind, solar radiation, and ambient temperature on the energetics of birds nesting in open areas with little nest construction need further investigation.

This report deals with the effects of wind, solar radiation, and ambient temperature on the energetics of the herring gull (*Larus argentatus*). Four basic questions were asked. (i) Which is more stressful to the gull, low ambient temperature (T_a) or high T_a? (ii) What effect does solar radiation have on the energetics? (iii) Can plumage color affect the use of solar radiation? (iv) What behavioral and physiological mechanisms can the gull use to overcome thermal stress?

We studied a herring gull colony during the 1977 breeding season, at the U.S. Steel calcite quarry in Rogers City, Michigan. The birds were on the territory from the first of April through July. The environmental parameters measured in the field were solar radiation (R_s), diffuse radiation (R_d), atmospheric radiation (R_a), ground radiation (R_g), reflected radiation (R_r), wind velocity, ambient temperature, ground temperature (T_g), and sky temperature (*6*). We also monitored the dorsal and ventral surface temperatures of the birds when they were facing toward and away from the sun (*7*). Standard metabolic rate, body temperature, and foot temperature were measured in the laboratory over an ambient temperature range of −10° to 35°C (*8*).

The lower critical temperature (T_{LC}), not sharply defined, lies between 5° and 10°C; the metabolic rate at ambient temperatures between T_{LC} and −10°C increases only 1.7-fold (Fig. 1). This suggests that the adult gulls (1000 g) are well adapted to a cold climate. In general, birds can increase their metabolism three to five times basal by shivering thermogenesis. A threefold increase would mean that the herring gull could maintain its body temperature without solar radiation at an ambient temperature of approximately −45°C.

During April and May in the field, at T_a's between 5° and 12°C, birds sitting on the nest in direct sunlight panted, which indicates that the upper critical temperature (30°C without sunlight) was shifted down. Birds standing at T_a's between 5° and 12°C were not observed to pant. This is explained by the fact that the feet are important avenues of heat loss, the foot temperature exceeding the T_a at all temperatures above the T_{LC} (Fig. 1). Other investigators (*9*) have shown that the feet of the herring gulls are important to heat loss.

It is known from previous studies by Lustick (*10*) and Hamilton and Heppner (*11*) that dark plumage absorbs more solar radiation than light plumage. In the visible spectrum, where 40 percent of the solar energy lies, white plumage absorbs approximately 10 percent (*10*) of the solar energy while the gray plumage absorbs approximately 50 percent (*12*). Thus, if the darker surface of the gulls were facing toward the sun the birds would gain more heat from radiation than if they faced the sun with their white surfaces. In direct sunlight, the surface temperature of the gray plumage increased to as much as 15°C above T_a, compared to 4°C above T_a for the white plumage (Fig. 2). The temperatures of the surfaces not receiving direct sunlight

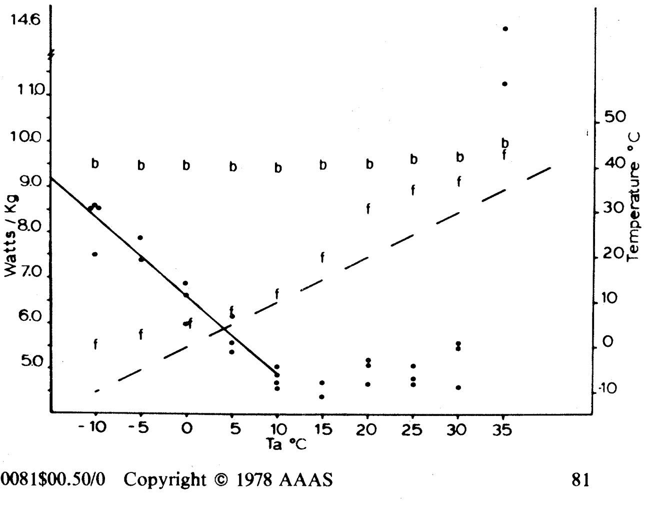

Fig. 1. The relationship of metabolic rate (solid circles), mean foot temperature (*f*), and mean body temperature (*b*) to ambient temperature (T_a). The regression line relating metabolism to T_a was fitted by the method of least squares (W/kg = 6.63 − 0.174 T_a). The dashed line is the temperature equilibration line. A total of six adult gulls were used in this study.

Table 1. Estimates of mean net radiation exchange when herring gulls are faced toward the sun (ventral surfaces) and when they have their dorsal surface toward the sun. Radiation calculations are based on 93 surface temperature measurements. M, metabolic rate derived from Fig. 1; H_r, net radiation; H_e, evaporative heat loss at 10°C; H_c, forced convective heat loss.

14 April 1977 time (hours)	Dorsal surface in sun H_r (W/m^2)	Ventral surface in sun H_r (W/m^2)	T_a (°C)	Dorsal in sun $M + H_r + H_c + H_e$ (W/m^2)	Ventral in sun $M + H_r + H_c + H_e$ (W/m^2)
1000	97.6	27.9	4	117.0	59.0
1100	62.7	-31.4	3	77.7	4.5
1200	92.7	-47.4	3	105.6	-10.8
1300	85.8	-54.4	5	82.1	-28.1
1400	101.1	-43.9	5	114.8	-16.6
1500	71.1	-62.1	5	89.7	-33.6
1600	55.8	-11.2	5	71.7	16.2
1700	38.4	-27.9	6	55.3	- 5.9
1800	-10.5	-31.3	5	15.8	- 2.8

approximated the air temperature. Wind velocity could affect surface temperatures, but at ground level the wind velocities were usually low (0 to 0.6 m per second). When wind velocities were higher (2.2 to 3 m/sec) the birds would orient toward the wind for T_a's between 3° and 12°C.

What behavioral mechanisms are there to minimize heat stress from intense solar radiation? It is difficult for a bird the size of the herring gull to seek cover, although the juveniles do. As was pointed out, they can stand and lose heat through the feet (T_a = 3° to 12°C), or they could enter the water and lose heat through the feet at a faster rate (*9*). During the breeding season the birds were reluctant to leave their territory during the day, and only a few birds were seen in the water. During April and May at Rogers City, when the sun was at an angle (55° at 1300 hours on 14 April), we observed that the birds oriented toward the sun. On days with low wind velocities and T_a's between 3° and 12°C, the birds actually rotated 180° during the day, always facing the sun. When they face the sun their posture is such that the darker dorsal surface receives diffuse and atmospheric radiation while the white ventral surface receives solar, reflected, and ground radiation (Fig. 2). Orientation toward the sun and postural adjustments to vary the angle of incidence of solar radiation can minimize radiative heat gain by (i) reducing the exposed surface area (*13*) (silhouette is minimal) and (ii) exposing the less absorptive white surfaces to the solar radiation. In the laboratory (T_a = 10°C), the skin temperature of gulls receiving direct radiation (697 W/m^2 shortwave and 348 W/m^2 longwave) on their white plumages and on their gray plumages was 38.11° ± 0.25° and 40.6° ± 1.03°, respectively. The higher skin temperatures under the dark plumages suggest that dark plumages acquire a greater radiative heat load than do white plumages.

Since we know the radiation environment, the plumage surface temperatures (in and out of the sunlight), the surface area, and the percent absorptivity of the plumage, we were able to estimate the net radiation exchange both when the birds had their backs to the sun and when they faced the sun (Table 1). Between 1000 and 1700 hours, birds with their backs (darker plumage) to the sun always had a net radiation gain, whereas birds facing the sun (1100 to 1800 hours) had a net radiation loss. Obviously there are convective, evaporative water loss, and metabolic effects that influence the energy balance of these birds. Since wind velocity at the level of the bird varied between 0 and 0.6 m/sec, we estimated the forced convective heat loss (*14*) at a mean wind speed of 0.3 m/sec. Mean heat loss by evaporation, determined in the laboratory at air temperatures of 10°C, was found to be 5.5 W/m^2. When the various factors influencing the energy balance are summed (Table 1), the birds with their backs to the sun still have a large heat load, probably more than can be lost through dry feet alone. Birds facing the sun are closer to a thermal balance (heat gain more closely approximating heat loss) than birds with their backs to the sun. On cloudy days (absence of R_s), when shaded, and at higher wind velocities, the gulls showed no solar orientation.

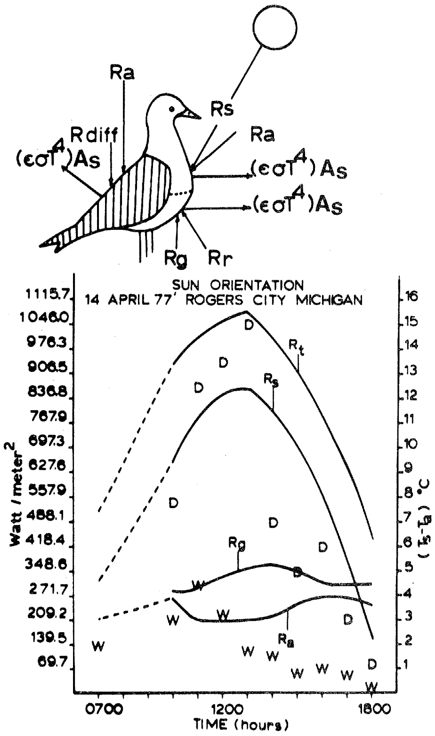

Fig. 2. The total down radiation (R_t), the solar radiation (R_s), the total ground radiation (R_g longwave plus R_r reflected shortwave), the atmospheric radiation (R_a), and the difference between surface and ambient temperature when the bird faces the sun with white surface (*W*) and gray back (*D*). In calculating the net radiation, the radiation intensities were multiplied by the surface area receiving that radiation and in the case of R_s by the proper absorptivity. Radiation loss from the bird was determined by ($\epsilon\sigma T^4$) A_s where ϵ is the emissivity of the surface, σ is the Stefan-Boltzmann constant. T is the surface temperature in degrees Kelvin and A_s is the surface area (square centimeters). A total of 93 surface temperatures were monitored.

Our study suggests that moderate T_a's with intense solar radiation are more stressful than low T_a's with or without solar radiation and that the color of the plumage seems to be important in the use of solar radiation. During the breeding season when the birds are tied to land, changes in orientation and posture in direct sunlight at T_a's near and above the T_{LC} are important to thermoregulation. In July, when the sun is more directly overhead and the air temperatures are higher, orientation is of little importance (although posture would still be important) in minimizing the heat gain from solar radiation. At this time the majority of the birds are in the water, where heat is lost easily through the feet.

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Attenuation of Amnesia in Rats by Systemically Administered Enkephalins

Abstract. *The pentapeptides methionine-enkephalin and leucine-enkephalin are both able to reduce experimentally induced amnesia in rats. In contrast to the possible analgesic activity of these peptides, the anti-amnesic effect is seen after systemic administration of dosages of 30 micrograms or lower. The nature of the anti-amnesic effect is different for the two peptides.*

The pituitary hormone β-lipotropin (β-LPH) has behavioral activity, as exemplified by its ability to attenuate experimentally induced amnesia for a passive avoidance response in rats when administered prior to the memory retrieval test (*1*). Similar anti-amnesic activity has been reported for the adrenocorticotrophic hormone (ACTH) peptide ACTH 4-10 (*1*, *2*), a peptide whose amino acid sequence is identical to β-LPH 47-53. It has been suggested that β-LPH functions as a prohormone for behaviorally active peptides (*3*). Hughes *et al.* (*4*) identified two naturally occurring pentapeptides, which they termed methionine-enkephalin (Met-enkephalin) and leucine-enkephalin (Leu-enkephalin). The fact that the amino acid sequence of Met-enkephalin corresponds to β-LPH 61-65 prompted me to study the effects of these pentapeptides in an amnesia test. The results show that both peptides were active in reducing amnesia.

A common design for studies of amnesia is to train an animal on a one-trial passive avoidance task and to administer the amnesic agent shortly after the conclusion of training. Amnesia is then defined and measured as a loss of performance at a later retrieval test. I used CO_2 to induce amnesia. A variety of control studies have demonstrated that CO_2-induced loss of performance in amnesia tests is specific, that is, results from interference with some memory process (*5*). In the present experiments male Wistar rats, weighing approximately 200 g, were trained in a passive avoidance step-through apparatus (*6*). Rats were placed on an elevated illuminated run-

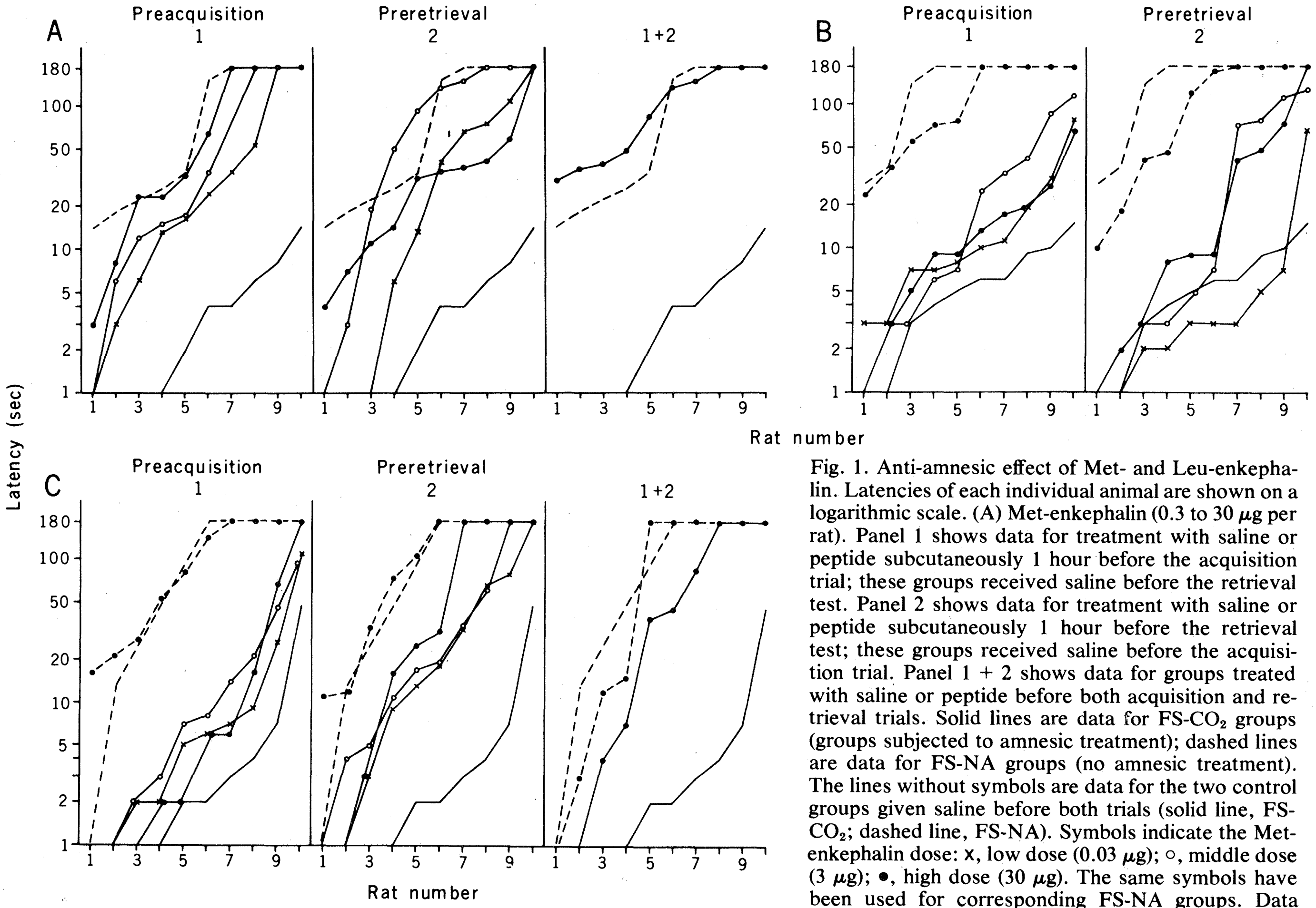

Fig. 1. Anti-amnesic effect of Met- and Leu-enkephalin. Latencies of each individual animal are shown on a logarithmic scale. (A) Met-enkephalin (0.3 to 30 μg per rat). Panel 1 shows data for treatment with saline or peptide subcutaneously 1 hour before the acquisition trial; these groups received saline before the retrieval test. Panel 2 shows data for treatment with saline or peptide subcutaneously 1 hour before the retrieval test; these groups received saline before the acquisition trial. Panel 1 + 2 shows data for groups treated with saline or peptide before both acquisition and retrieval trials. Solid lines are data for FS-CO_2 groups (groups subjected to amnesic treatment); dashed lines are data for FS-NA groups (no amnesic treatment). The lines without symbols are data for the two control groups given saline before both trials (solid line, FS-CO_2; dashed line, FS-NA). Symbols indicate the Met-enkephalin dose: x, low dose (0.03 μg); ○, middle dose (3 μg); ●, high dose (30 μg). The same symbols have been used for corresponding FS-NA groups. Data from FS-CO_2 and FS-NA control groups have been included in all three panels to facilitate comparisons among groups. (B) Anti-amnesic effect of Met-enkephalin at lower doses; low dose, 0.0003 μg; middle dose, 0.003 μg; high dose, 0.03 μg. (C) Anti-amnesic effect of Leu-enkephalin; low dose, 0.03 μg; middle dose, 3 μg; high dose, 30 μg. The dose symbols are the same as those for Met-enkephalin.

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