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SURVIVAL OF HERRING GULL AND DOMESTIC CHICKEN EMBRYOS AFTER SIMULATED FLOODING

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ABSTRACT.—The eggs of Herring Gulls (*Larus argentatus*) and several other marsh nesting species undergo periodic flooding. We conducted an experiment to test the effects of simulated tidal flooding on Herring Gull and domestic chicken (*Gallus gallus*) eggs. Experimental variables were salinity, temperature, length of immersion, and state of incubation when immersion occurred. In general, Herring Gull eggs had a higher hatching success after immersion and at lower temperatures than did chicken embryos. Herring Gull embryos equally survived immersion during the first and third week of development, whereas more chicken embryos survived immersion during the first week. There were no significant differences between species with respect to the duration of the immersion.

Herring Gulls (*Larus argentatus*) have recently begun breeding in salt marshes of New Jersey that are subject to tidal flooding (Burger 1977), and presently most of their colonies are located on coastal salt marshes or salt marsh islands (Kane and Farrar 1977). Herring Gulls prefer to nest under *Iva* bushes on the higher parts of the islands, but in the last few years many gulls have nested in lower *Spartina alterniflora* areas that are subject to tidal flooding (Burger 1977, Burger and Shisler, unpubl.).

Immersion of eggs during tidal flooding in the breeding season may result in the death of embryos, but the eggs of bird species that are normally subject to inundation may be more resistant to harmful effects of flooding. For example, many species of ducks have eggs with water-repellent surfaces (Welty 1975), which probably help resist the entry of water. Inundation of Clapper Rail (*Rallus longirostris*) nests by high tides has no apparent effect on hatching success (Mangold 1974). In New Jersey, Laughing Gulls (*Larus atricilla*) normally nest in salt marshes that are subject to salt-water flooding (Bent 1921, Bongiorno 1970) and Burger (1979) found that Laughing Gull eggs have a 63% hatching success even after being immersed in salt water for two hours during the third week of incubation.

In order to determine effects of flooding on survival of embryos, we immersed Herring Gull and domestic chicken (*Gallus gallus*) eggs and varied four factors that we thought might be related to death of embryos. The factors studied were salinity and temperature of the water, duration of immersion, and stage of incubation.

MATERIALS AND METHODS

Field research was conducted on Clam Island, a salt marsh island in Barnegat Bay, New Jersey (39°45′N, 74°08′E). The vegetation of Clam Island is primarily *Spartina alterniflora* and *S. patens* grass with scattered *Iva frutescens* and *Baccharis halimifolia* bushes. The island is divided into four sub-islands, three of which contained 1,200 pairs of nesting Herring Gulls during this study. The majority of the Herring Gulls nested in the higher bush areas of the island. Two hundred pairs of Laughing Gulls nested on the fourth sub-island.

The island was checked for nests and eggs one to three times per week from 16 April until 15 May 1978, when it was checked every other day until 10 July. New nests were marked with flags and numbered with metal tags; eggs were numbered with a black felt-tip marker when first discovered. Nests and contents were checked until 10 July, when the fate of all eggs could be determined.

When clutches were at the right stage of incubation we collected eggs and randomly assigned one of eight treatments for that stage of incubation to the group of eggs. Eggs removed from a nest for treatment were replaced with an egg from another nest so that the parents would continue to incubate and not vacate the nest. We marked the eggs removed for treatment with a black felt-tip marker so that they could be returned to their original nest.

All of the eggs were taken from nests which initially had three-egg clutches, and 89% of the nests had three eggs when treated. We treated only eggs from nests whose date of clutch completion with three eggs was known and we considered the time of clutch completion to be the beginning of the first week of incubation. Eggs within the same nest always received the same treatment and were treated only once.

We treated eggs by immersing them completely for the prescribed time in a bucket of water of the chosen salinity and temperature. The levels of the four factors that we used for immersion treatments were as follows: for salinity, ocean water taken from Barnegat Bay and fresh water; for water temperature, 7–9°C and 26–28°C; for duration of immersion, half an hour and two hours; and for stage of incubation, the first and third weeks of incubation.

TABLE 1. Survival of Herring Gull and domestic chicken embryos after different immersion treatments. Percentage of eggs pipped in each treatment is given in parentheses. Treatments were compared with the controls with a 2 × 2 Chi-square contingency table. All of the domestic chicken treatments were compared with only one control. Asterisks indicate significant differences from the control. See text for an explanation of the factors used in the treatments. Temperatures are in °C.

	Herring Gull				Domestic chicken			
	First week		Third week		Fifth day		Fifteenth day	
Treatment	No. of eggs treated	No. of eggs pipped	No. of eggs treated	No. of eggs pipped	No. of eggs treated	No. of eggs pipped	No. of eggs treated	No. of eggs pipped
Salt 7° 30 min	29	7 (24)**	30	19 (63)**	20	13 (65)	20	0 (0)**
Fresh 7° 30 min	41	9 (22)**	31	12 (39)**	20	13 (65)	20	0 (0)**
Salt 26° 30 min	42	37 (88)	29	23 (79)	20	16 (80)	20	10 (50)*
Fresh 26° 30 min	33	12 (36)**	30	21 (70)*	20	19 (95)	20	15 (75)
Salt 7° 120 min	30	21 (70)	29	20 (69)*	20	17 (85)	20	0 (0)**
Fresh 7° 120 min	45	24 (53)**	28	16 (57)**	20	13 (65)	20	0 (0)**
Salt 26° 120 min	47	34 (72)	27	6 (22)**	20	14 (70)	20	1 (5)**
Fresh 26° 120 min	30	17 (57)**	30	1 (3)**	20	18 (90)	20	15 (75)
Total	297	161 (54)**	234	118 (50)**	160	123 (77)	160	41 (26)**
Control	63	54 (86)	72	64 (89)	20	18 (90)		

* $P < .05$.
** $P < .01$.

We regulated the temperature of fresh-water treatments by slowly adding warmer or cooler water directly to the water in which the eggs were immersed. We maintained the cold, salt-water treatments at the correct temperature by using an ice-water bath, while for the warm, salt-water treatments we either used a warm-water bath or added warm, salt water directly to the water in the bucket. In a few cases we did not have ice available to cool water for 7–9°C treatments so we could only randomly assign one of four treatments. We measured water temperatures with a mercury thermometer. The temperatures included the possible range that Herring Gull eggs might encounter if tidal flooding were to take place in the study area. Water temperatures during April off southern New Jersey are about 7–9°C (NOS Publications 1972), while water in tidal pools and shallow areas during the latter part of the breeding season may become quite warm. A temperature of 26–28°C was arbitrarily chosen as an upper environmental water temperature. However, this is still about 10–12°C below the temperature at which Herring Gull eggs are normally incubated (Drent 1970).

For a control we removed eggs from nests and carried them to the place where we carried out treatments. We did not immerse the eggs and after half an hour we returned the eggs to the nests from which they were taken. In this manner we could determine the percentage of first-week and third-week eggs expected to pip under field conditions. We used 21 nests (63 eggs) for the first-week control and 24 nests (72 eggs) for the third-week control. This procedure allowed us to eliminate the effect of handling on the eggs and the disturbance effect on the parent gulls. In all tests we considered an embryo to have survived treatment if it pipped the egg.

For comparative purposes we conducted similar experiments on domestic chicken eggs. We obtained White Leghorn chicken eggs for incubation from the Shamrock Poultry Farms of North Brunswick, New Jersey. The eggs, laid 25–26 July 1978, were stored at about 13°C until 27 July, when they were transported to Rutgers University and incubation began. The eggs were incubated in a forced-draft electric incubator at a temperature of 36.6–37.0°C and a relative humidity of 60–65%; they were turned at least once every 12 hours. Chicken eggs were tested in the same manner as those of gulls. We randomly assigned a treatment to each egg until we had 20 eggs for each treatment. Chicken eggs take about 21 days to hatch (Welty 1975), whereas Herring Gull eggs take about 27 days (Drent 1970). Therefore, we treated chicken eggs assigned to the "first-week treatment" on the fifth day of incubation and eggs assigned to the "third-week treatment" on the fifteenth day of incubation. The stages of incubation at which the chicken eggs were treated were therefore analogous to the ends of the first and third weeks of incubation for the Herring Gull. For a control we removed chicken eggs from the incubator and carried them to the treatment room, but we did not immerse the eggs and immediately returned them to the incubator. Upon the hatching of the first egg we checked the eggs every six hours and recorded which ones had hatched.

RESULTS

HERRING GULL

The number of eggs pipped within each treatment was compared with the number of eggs pipped in the control group for the same week of incubation with a 2 × 2 Chi-square contingency table. Table 1 shows that the number of eggs pipped in five of the first-week treatments was significantly different from the number pipped in the first-week control, while the number pipped in seven of the third-week treatments was significantly different from the number pipped in the third-week control. The total number of eggs pipped from treatments carried out during the first week of incubation and from treatments carried out during the third week of incubation both differed significantly from the controls for that week of incubation (first week: $\chi^2 = 20.2$, $P < .001$; third week: $\chi^2 = 32.2$, $P < .001$). Overall,

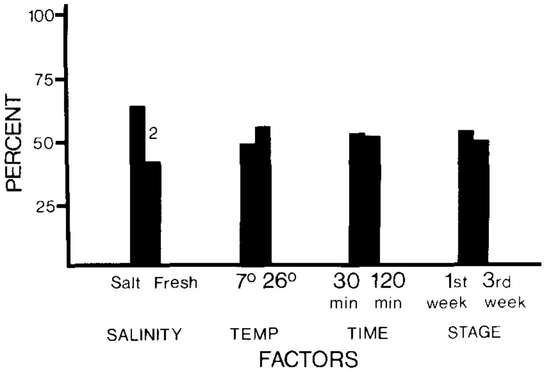

FIGURE 1. Percentage of Herring Gull eggs pipped after treatment within each level of salinity, temperature, immersion time, and stage of incubation. A "2" indicates a significant difference at the $P = .01$ level.

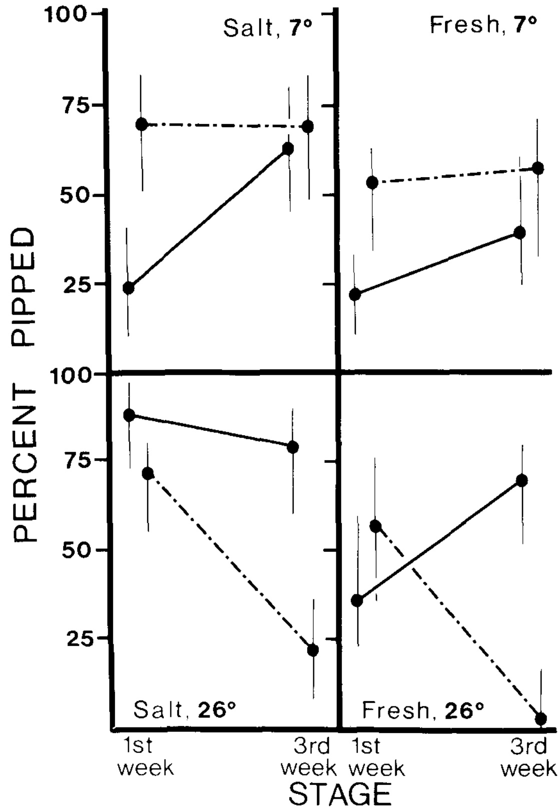

FIGURE 2. Percentage of Herring Gull eggs pipped after 16 different immersion treatments. Stage = stage of incubation at which eggs were treated. Solid lines connect half-hour treatment results; dashed lines connect two-hour treatment results. The lines connecting the treatment results are not meant for purposes of interpolation but are drawn-in to make the trends in survival easier to see. The vertical lines indicate 95% confidence intervals for the proportion of eggs that pipped.

immersion in water decreased the viability of Herring Gull embryos.

The pooled mean square from analysis of variance was used to compute F-tests and least significant differences (LSD). We used the LSD to compare the means of two-factor interactions. A comparison of the number of eggs pipped in the two levels of each of the four factors shows that survival differed significantly only between the two levels of salinity (see Fig. 1). About 63% of the eggs treated in salt water pipped, while 42% of the eggs treated in fresh water pipped ($F = 12.7$; df = 11,1; $P < .01$).

The percentage of eggs pipped in each salt-water treatment (Fig. 2) was greater than the percentage of eggs pipped in the comparable freshwater treatment. Embryos from half-hour treatments (solid lines) in 7°C water had a significantly lower mean survival than embryos from two-hour treatments (dashed lines) in 7°C water ($\bar{x} = 37\%$ vs. 62%, LSD = 23.3, $P < .01$). The mean survival after first-week treatments in 7°C water was less than the mean survival after third-week treatments in 7°C water, but the difference was not significant ($\bar{x} = 42\%$ vs. 57%, LSD at .05 level = 16.5).

Figure 2 also shows that the two-hour treatments in 26°C water for both fresh water and salt water show the same trend, while half-hour treatments in 26°C water for fresh water and salt water do not. Embryos treated in 26°C water for two hours during the third week of incubation had a very low survival. In 26°C treatments, significantly more embryos survived half-hour treatments than two-hour treatments ($\bar{x} = 68\%$ vs. 38%, LSD = 23.3, $P < .01$). This response was the opposite of that seen in cold-water treatments (see above). In 26°C treatments significantly more embryos survived first-week treatments than third-week treatments ($\bar{x} = 63\%$ vs. 43%, LSD = 16.5, $P < .05$). This response was also the opposite of that seen in 7°C treatments (see above).

Significantly more Herring Gull embryos survived third-week treatments for 30 min than survived first-week treatments for 30 min ($\bar{x} = 63\%$ vs. 43%, LSD = 16.5, $P < .05$). The survival of embryos after two-hour treatments showed an opposite response. Significantly more embryos survived first-week, two-hour treatments than third-week, two-hour treatments ($\bar{x} = 63\%$ vs. 38%, LSD = 23.3, $P < .01$).

DOMESTIC CHICKEN

Statistics for the chicken data were computed in the same manner as those for the Herring Gull data except that all treatments were compared with only one control. The number of eggs pipped in the fifth-day treat-

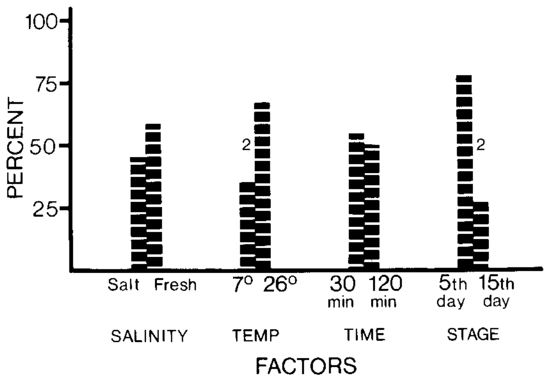

FIGURE 3. Percentage of domestic chicken eggs pipped after treatment within each level of salinity, temperature, immersion time, and stage of incubation. A "2" indicates a significant difference at the $P = .01$ level.

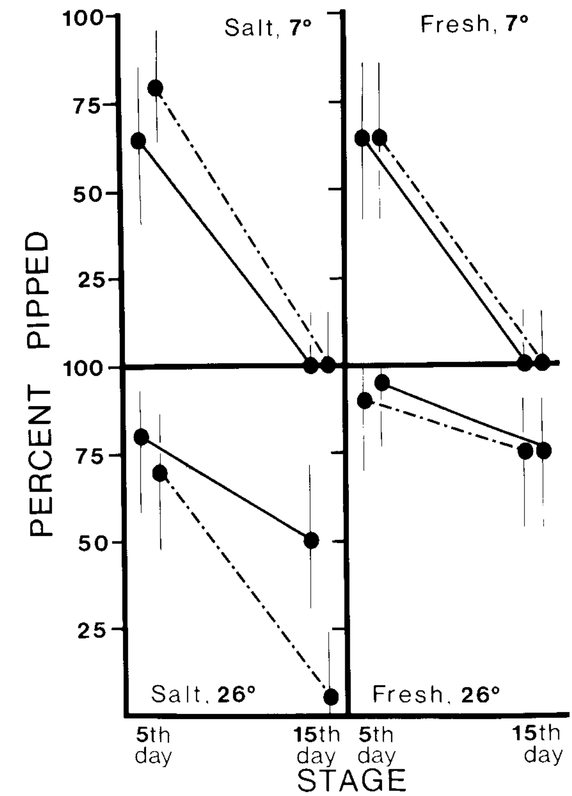

FIGURE 4. Percentage of domestic chicken eggs pipped after 16 different immersion treatments. See Figure 2 for explanation.

ments (Table 1) did not differ significantly from the control, while the number of eggs pipped in six of the fifteenth-day treatments differed significantly from the number of eggs pipped in the control. The total number of eggs pipped from first-week treatments did not differ significantly from the number pipped in the control ($\chi^2 = 1.11$, df = 1, $P < .2$), while the total number of eggs pipped from the third-week treatments did differ significantly from the number pipped in the control ($\chi^2 = 30.6$, df = 1, $P < .001$).

The differences in survival after 7°C and 26°C treatments and fifth-day and fifteenth-day treatments were significant for chicken embryos (F = 23.8, df = 10,1, $P < .01$; F = 55.2, df = 10,1, $P < .01$, respectively; Fig. 3). More chickens pipped from fresh-water treatments than from salt-water treatments but the difference was not significant (F = 4.3, df = 10,1, $0.05 < P < 0.10$).

Significantly more chicken embryos pipped from 26°C, freshwater treatments than from 7°C, freshwater treatments ($\bar{x}$ = 84% vs. 33%, LSD = 25.9, $P < .01$; Fig. 4). No significant differences in survival were found between 26°C and 7°C salt-water treatments ($\bar{x}$ = 51% vs. 38% respectively, LSD at the .05 level = 21.0). Salt-water immersion during the fifteenth day of incubation had a significantly greater effect on embryo mortality than fresh-water immersion during the fifteenth day of incubation ($\bar{x}$ = 14% vs. 38%, LSD = 21.0, $P < .05$).

For both 7°C and 26°C treatments, significantly fewer eggs pipped from fifteenth-day treatments than from fifth-day treatments. Seventy percent of the embryos pipped from the 7°C, fifth-day treatments, while none pipped from the 7°C, fifteenth-day treatments (LSD = 25.9, $P < .01$). Fifth-day treatments at 26°C had a mean survival of 84%, while fifteenth-day treatments at 26°C had a mean survival of 51% (LSD = 25.9, $P < .01$).

Submergence in water did not significantly affect the ability of the chickens to hatch after they pipped the eggshell. One treatment had four eggs that did not hatch after pipping, yet this did not differ significantly from the control, in which every egg that pipped hatched successfully ($\chi^2 = 2.74$, df = 1, $0.10 > P > 0.05$).

We opened some unhatched chicken eggs that had been treated during the fifteenth day of incubation. As would be expected, the eggs contained partly developed embryos whose development had presumably been arrested at the time of treatment.

COMPARISON OF RESULTS BETWEEN SPECIES

Differences between species (Fig. 5) were compared in a 2 × 2 Chi-square contingency table. For each level of salinity, water temperature, and stage of incubation, the survival of Herring Gull and domestic

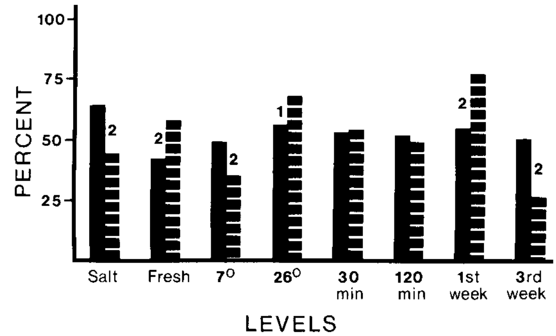

FIGURE 5. Comparison of percentage of Herring Gull (solid bar) and domestic chicken (hatched bar) eggs pipped within each level of salinity, temperature, immersion time, and stage of incubation. The fifth and fifteenth-day treatments of chicken eggs were compared with the first and third-week treatments of gull eggs respectively. A "1" or a "2" indicates significant differences at the .05 and .01 levels respectively.

chicken embryos was significantly different. Significantly more gull embryos pipped from salt-water treatments, 7°C treatments, and third-week treatments than chicken embryos. Significantly more chicken embryos pipped from fresh-water treatments, 26°C treatments, and first-week treatments than gull embryos. There were no significant differences between the species in their survival after 30 and 120 min of immersion. At least one gull embryo pipped from every treatment used, while there were four treatments from which no chickens pipped (see Table 1).

DISCUSSION

In salt marshes, Herring Gulls tend to nest in the higher areas where tidal flooding occurs less frequently (Burger and Shisler, unpubl.). When flooding around nests does occur, Herring Gulls enlarge their nests (Burger 1977), which helps prevent inundation of their eggs. Even when eggs are inundated they may be able to withstand the effects and hatch normally, as shown in our study.

The number of Herring Gull and domestic chicken embryos surviving the different immersion treatments used in this study varied widely. Our results indicate that the embryos of each species are affected differently by immersion in water. Before incubation begins and in the early stages of incubation, Herring Gull embryos can withstand temperatures lower than incubation temperatures for up to 3½ h while the parents are away at night (Drent 1970). Hunter et al. (1976) found that exposing Ring-billed Gull (*Larus delawarensis*) eggs at different stages of incubation to a 10°C temperature for 4–12 h significantly reduced hatchability of eggs. In our study, immersion of eggs in 7°C water did not kill significantly more gull embryos than immersion of eggs in 26°C water.

The effects of low temperatures on chicken embryos have been well documented. Chicken embryos in the early stages of development can withstand freezing while those in later stages are more susceptible to the effects of subnormal incubation temperatures (Dougherty 1926, Jull et al. 1948, Moreng and Shaffner 1951, Moreng and Bryant 1954, 1956). The results of our study are similar to these findings. Embryo survival at 7°C during the fifth day of incubation did not differ significantly from controls, while embryo survival after 7°C treatments during the fifteenth day of incubation was significantly less than controls.

Herring Gull eggs treated at 26°C for two hours during the third week of incubation had a very low survival for unknown reasons. Chicken eggs did not show this response.

Significantly more Herring Gulls pipped after salt-water treatments than after fresh-water treatments. The chicken embryos showed an opposite response. That fresh water can enter eggs was shown by Lippincott and De Puy (1923) who found that water was absorbed by eggs incubated in half an inch of water. These opposite responses to salinity are interesting because Herring Gulls typically inhabit coastal marine environments, to which they are apparently well adjusted. On the other hand, chickens are descendants of the Red Junglefowl (*Gallus gallus*; Wood-Gush 1959), a species found in the jungles and secondary growth of Asian forests (Whistler 1949, Collias and Collias 1967).

Duration of immersion affected rate of pipping of both Herring Gulls and chickens, but the differences were not significant for either species. This indicates that for periods of immersion less than two hours the effects of inundation generally do not increase with time. However, many Herring Gull embryos die if immersed in water of 26°C for two hours during the third week of incubation.

Since the gull data were collected in the field, these eggs were exposed to predation and other natural factors to which the chicken eggs were not. However, survival of the gull experimental eggs was compared with that of field controls, thereby eliminating the effects of field conditions and allowing comparisons to be made among the different treatments. Herring Gull eggs were probably subject to temperature fluctuations (Drent 1970), while incubation temperatures for the chicken eggs remained constant. Also, gull eggs were treated during all parts of the first and third weeks of incubation, whereas the chicken eggs were treated on only two days. Some of the differences between Herring Gull and domestic chicken survival after the same treatments may be attributable to these conditions. The gull eggs could have been artificially incubated upon clutch completion but this was not logistically possible and would not have indicated survival in natural situations.

The differences between gull and chicken embryo survival after the treatments used in this study suggest that the embryos of different bird species may have different rates of survival after immersion in water. Burger (1979) studied the effects of immersion in saltwater on Laughing Gull eggs. She found that 63% of the eggs immersed in salt water for two hours during the third week of incubation hatched. The temperature of the water used in her study (about 20°C) was between the temperatures used in this study, making direct comparison difficult. In general the hatching success of the Laughing Gull eggs in her study was higher than that found for Herring Gull eggs immersed in salt water in this study. Laughing Gull eggs may therefore be more resistant to the effects of tidal flooding than Herring Gull eggs. This would be expected since Laughing Gulls customarily breed in salt marshes (Bent 1921, Bongiorno 1970) and have been exposed to selection due to tidal flooding longer than Herring Gulls.

Burger (1977) found that the nesting success of Herring Gulls depended largely on the elevation of that part of the marsh where they were nesting. Gulls nesting in low areas subject to tidal flooding had a much lower nesting success than those nesting on areas that did not get wet during high or storm tides. On one island, 95% of the egg loss in areas subject to tidal flooding was due to flooding. However, in her study, eggs were actually washed from the nests by the high tides. Severe flooding may inundate eggs or may cause eggs in advanced stages of incubation to float away. Herring Gulls will usually not leave their nests until water is five cm over their nests, but when flooding does cause them to leave, predation by other gulls is a major cause of egg loss (Burger 1977). Thus, death of embryos due to immersion in water is a factor in situations where flooding inundates nests but does not wash out eggs.

We have shown that Herring Gull embryos can withstand the effects of salt-water inundation and still hatch, although survival is lowered. Herring Gulls can be expected to continue to move into new areas of salt marsh that are high enough to allow successful nesting. Young gulls unable to nest in prime habitat (high areas) will continue to nest in intermediate areas with lowered hatching success. Gulls nesting in the suboptimal lower areas will experience low hatching success and frequent washouts, resulting in abandonment of these areas. Gulls nesting in areas of intermediate height will hatch some eggs and lose others due to inundation, while gulls nesting in low areas will continue to be selected against because of frequent failure due to the washout of nests.

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RECENT PUBLICATIONS

A Guide to the Behavior of Common Birds.—Donald W. Stokes. 1979. Little, Brown and Co., Boston. 336 p. $9.95. This is a book on a thoroughly original and praiseworthy plan: a guide not to the identification of birds but to the understanding of what they are doing. The 25 chapters each deal with a common North American species, from Canada Goose to Song Sparrow. Within each chapter, three types of information help to reveal and interpret a bird's behavior in the field: 1) a calendar which lists the major areas of the species' behavior next to the months when they occur, 2) a guide to visual and auditory displays, and 3) description of seven major areas of behavior. The organization is clear and it seems workable. The text is illustrated with many useful sketches by the author, and decorated with fine pencil drawings by J. Fenwick Lansdowne. This guide is intended for those who like to *watch* birds and want to deepen their experience. Even those who are familiar with its species can probably learn to see more with its aid. Glossary and list of references.

The Adventure of Birds.—Charlton Ogburn. 1980. Morrow Quill Paperbacks, New York. 336 p. Paper cover. $6.95. Ogburn is an amateur of birds—a self-described ornithophile—and not in the least superficial. His book is aimed for those of like mind. It offers a good, general introduction to the biology of birds, treating their distribution, ecology, behavior, structure, annual cycle, and migration. Compared with other such books, it is less pedantic and more personal as the author brings in his own feelings and experiences. It is also uncommonly well-written, in part because Ogburn has read widely, not only in ornithology but also English/American literature. Drawings by Matthew Kalmenoff; references; index.

Breeding Biology of the Egyptian Plover, *Pluvianus aegyptius*.—Thomas R. Howell. 1979. Univ. California Publications in Zoology Vol. 113. 93 p. Paper cover. $10.50. Source: U. Calif. Press, 2223 Fulton St., Berkeley, CA 94720. The "Egyptian Plover" (actually a courser) has long attracted notice for its alleged habit of picking food from the jaws of basking crocodiles. Of greater biological interest is the fact that "it buries its eggs in the sand and has been alleged to leave them for most of the day, either to be incubated by or protected from solar heat, or some combination thereof." These breeding habits are the subject of this technical, yet well written report. It extends Howell's series of investigations of the behavioral and physiological adaptations for breeding in a hot climate. The monograph will have particular importance for those who study the physiology of incubation. Photographs, graphs, list of references.