SHELL-DROPPING BEHAVIOR OF WESTERN GULLS (*LARUS OCCIDENTALIS*)

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ABSTRACT.—Western Gulls (*Larus occidentalis*) at Bodega Bay, California drop shelled prey items to break them. I presented Washington clams (*Saxidomus nuttalli*) of known weight to free-flying gulls to investigate factors affecting shell-dropping behavior. All adult gulls dropped clams, whereas only 55% of immature gulls did so. The other 45% of immature gulls that were given clams pecked at them on the ground instead. Gulls dropped clams on both hard and soft substrates. Flight distance and kleptoparasitism seemed important in influencing drop location. Adult Western Gulls dropped heavy clams from lower heights than they dropped light clams. Heavy clams, however, break less easily than light clams when dropped from the same height. Energetic constraints and/or kleptoparasitism could explain this apparent contradiction. *Received 15 July 1981, accepted 12 December 1981.*

MANY gulls obtain food by dropping shells. Known cases include Kelp Gulls (*Larus dominicanus*), Mew Gulls (*Larus canus*), Herring Gulls (*Larus argentatus*), and Glaucous-winged Gulls (*Larus glaucescens*) (Oldham 1930, Tinbergen 1953, Barash et al. 1975, Siegfried 1977, Kent 1981). Northwestern Crows (*Corvus caurinus*) also drop shells (Zach 1978, 1979). Studies of shell dropping in the past have considered the character of the dropping surface (Barash et al. 1975; Siegfried 1977; Zach 1978, 1979; Kent 1981), age-related differences in dropping behavior (Barash et al. 1975, Siegfried 1977), size selection of dropped prey (Siegfried 1977; Zach 1978, 1979; Kent 1981), and the degree to which dropping height approached an energetic optimum (Siegfried 1977; Zach 1978, 1979).

Despite these studies, we still know little about what factors govern the height from which clams are dropped. Siegfried (1977) suggested that the substrate at the drop site might influence dropping height. He failed to consider, however, how prey weight might affect dropping height. Prey weight could conceivably influence dropping height in the following three ways: (1) Gulls may drop heavy objects from lower heights than they drop light ones due to energetic considerations. (2) Heavy objects may be easier to break than light ones [Siegfried (1977) found this to be true for mussels], and thus they might be dropped from lower heights. (3) Kleptoparasitism may increase with prey size, and this may influence dropping height.

Do birds adjust dropping height based on prey weight? If so, which, if any, of the above factors might influence this? In this paper I analyze shell-dropping behavior in Western Gulls (*Larus occidentalis*) at Bodega Bay, California. In particular, I focus on the following questions: (1) What is the effect of shell weight on dropping height? (2) How does clam weight influence the probability of breakage at different heights? (3) Are shells dropped randomly or do substrate type, kleptoparasitism, and/or other ecological parameters affect where shells are dropped? (4) How does clam-dropping proficiency vary between immature and adult gulls?

METHODS

I presented individual Western Gulls with different mollusks. These gulls belonged to a small population (24–30 individuals) that roosted along the west side of Bodega Harbor, California. Observations were made daily with 8 × 35 binoculars and at low tide when the entire mudflat was exposed. For observations, I divided a 280-m × 178-m section of mudflat into 17 70-m × 35-m quadrats using stakes to mark the boundaries of each quadrat. A nearby parking lot, 125 m from the tidal flats, was also used for observations.

Initially I provided gulls with a number of different mollusks (*Macoma secta, Tresus nuttallii, Saxidomus nuttalli, Clinocardium nuttallii, Protothaca staminea*, and *Polinices lewisii*) to determine which species were selected and dropped. Because all of the above

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species (except *Macoma*) were dropped, I decided to give gulls only *Saxidomus nuttalli*, because this mollusk was the only species that could be found in sufficient numbers to provide an adequate sample size. All *Saxidomus* given to gulls were marked and weighed. These marked clams were presented one at a time to gulls so that the fate of individual clams could be determined. For each drop, I recorded quadrat number (i.e. location where the clam was dropped), age of bird (immature or adult), height of drop, and number of drops needed to break a clam. Adult gulls were differentiated from immature gulls by plumage. Height was indirectly measured by using a stopwatch to record the time it took for a clam to fall after being dropped by a gull. Time (t) was converted to height (d) by using the formula $d = \frac{1}{2}at^2$, where a is the acceleration due to gravity.

Gulls often fought over clams. They also frequently dropped a given clam more than once. The following data on dropping height exclude all cases during which gulls were chased and represent only the first drop of each clam. Only these data were recorded, because the first drop is essentially an unbiased one. When a clam is dropped successively, a gull might alter dropping behavior on succeeding tries based on information learned from the previous drop.

After determining the size of clams dropped from different heights, I filled small clams with lead weights and wet cotton and presented them to gulls to determine whether or not a clam being dropped is independent of its size. These clams originally weighed between 120 and 130 g but weighed over 270 g when filled.

To measure the effect of height on the likelihood of a dropped clam breaking, I dropped different sized clams (from 40–400 g) onto mud from heights of 4.5, 6, 10, 12, 15, and 24 m. Clams were divided into two separate weight classes. Clams weighing between 1 and 100 g were defined as "light" clams, and clams weighing between 101 and 400 g were defined as "heavy" clams. Clams were dropped repeatedly until they broke. The percent breakage, for a given height, was calculated by dividing the total number of clams (of a given weight class) that broke by the total number of clams (from that same weight class) that were dropped.

RESULTS

Western Gulls dropped a wide variety of shelled mollusks in the study area. All species of mollusks I presented to gulls were taken and dropped. Small sizes of *Macoma secta*, however, were more frequently pecked open than dropped. When adult gulls were given *Saxidomus* of different sizes and weights, all clams were dropped except those exceeding 268 g. Yet, gulls picked up, flew with, and dropped smaller sized clams that exceeded 268 g when filled with lead weights.

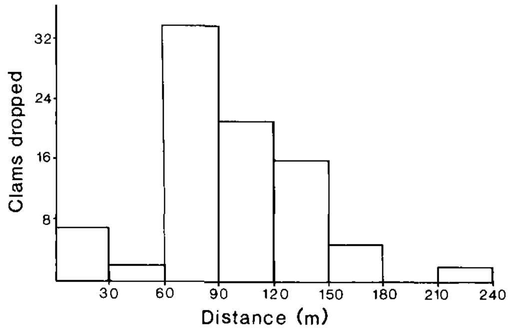

Fig. 1. Frequency distribution of distance flown by gulls from site where clams were picked up to where they were dropped.

Adult gulls.—Clams were dropped (on the mudflat) an average of 118 m from where they were picked up (Fig. 1). Clam weight and substrate type (parking lot or mudflat) were strongly correlated: average clam weights on the two substrates were 134.3 g and 106.7 g, respectively (ANOVA, $F_{1,88} = 11.3$; $P < 0.005$). On the mudflat, gulls dropped clams more often in some quadrats than in others ($\chi^2 = 37.8$; df = 17; $P < 0.005$). This relationship varied slightly, however, between substrate types. Although dropping height was not significantly different between substrates, gulls tended to drop clams from lower heights in the parking lot (ANCOVA, $F_{73} = 1.94$; $P > 0.16$) (Fig. 2).

Immature gulls.—When immature gulls were presented with *Saxidomus* clams (under 268 g), only 55% dropped clams. Gulls that did not drop clams pecked at the clams or carried them to small pools of water, waited for them to open, and then pecked at exposed flesh. Among immature gulls that did drop clams, no significant correlation existed between clam weight and dropping height (Pearson $r = 0.08$, $n = 32$, $P > 0.34$) (Fig. 3). Immature gulls generally drop light clams on the mudflat from much lower heights than do adult gulls. They drop clams from an average height of 6.3 m, compared to 13.5 m for adults. Moreover, immature gulls require more drops to break clams than do adults (2.1 ± 1.3 drops for immatures, 1.7 ± 1.1 for adults) (ANOVA, $F_{1,20} = 6.65$; $P < 0.025$). This fact is not biased by age-related, clam-size selection, because weights of clams given to gulls did not vary between

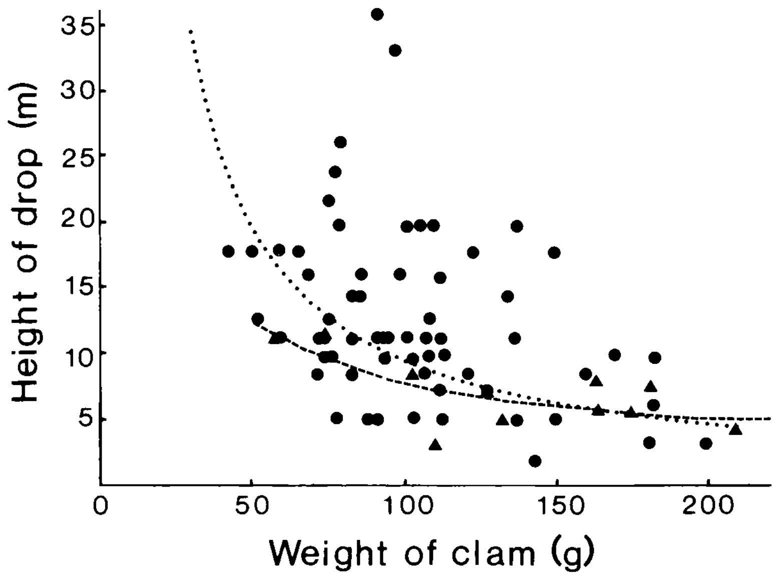

Fig. 2. Drop height on the mudflat (dotted line) and the parking lot (dashed line) as a function of clam weight for adult Western Gulls. Circles represent clams dropped on mudflat; triangles represent clams dropped on parking lot. Curve described by the function 1/height = (k)(weight). $r = 0.508$.

adults and immatures (mean weight of clams picked up by immature and adult gulls was 106.9 ± 36.33 and 108.5 ± 36.05, respectively) (ANOVA, $F_{1,132} = 0.141$; $P > 0.71$).

Artificially dropped clams.—When I dropped clams from various heights, I found that the relationship between dropping height and percent breakage of clams follows a sigmoid function (total number of clams dropped = 54, curve fit by eye) (Fig. 4). Thus, for all but extremely small or extremely great heights, heavier clams are harder to break (from a given height) than light ones. Clams that landed flat on one of the valves were more often cracked than those that landed on the umbo. Thus, to a certain extent, chance determines whether or not a clam breaks when it is dropped from a given height.

DISCUSSION

Clam dropping allows gulls to gain access to a valuable food source. Dropping and breaking the shell enables a gull to eat more meat than it can by pecking or spearing small portions of exposed flesh. Not all gulls, however, drop clams proficiently. Barash et al. (1975) found an "age related progression of increased clam slamming efficiency" in Glaucous-winged Gulls. Specifically, yearling Glaucous-winged Gulls dropped clams at lower than optimal heights. Barash et al. (1975) suggested that clam dropping is a learned behavior. My results support their interpretation. Only 55% of immature Western Gulls drop clams. They do so from lower heights and do not adjust dropping height to clam weight. As a result, they require more drops to break clams.

Because gulls can physically lift but do not fly with and drop clams exceeding 268 g, either clam weight or a combination of size and weight deters gulls from dropping large clams. The fact that gulls drop *Polinices,* which are extremely heavy (over 268 g), and also drop small stuffed clams (in excess of 270 g) indicates that weight alone does not deter gulls from flying with and dropping large clams.

Siegfried (1977) found that Kelp Gulls dropped shells more frequently on hard substrates than on soft ones. Barash et al. (1975) found the same for Glaucous-winged Gulls. My results were not consistent with these observations. Overall, clams were dropped more frequently on a soft substrate (mud) than on a hard one (parking lot). Heavy clams, however, were dropped more often on the parking lot. The parking lot is 125 m away from where gulls received clams, which is certainly not a pro-

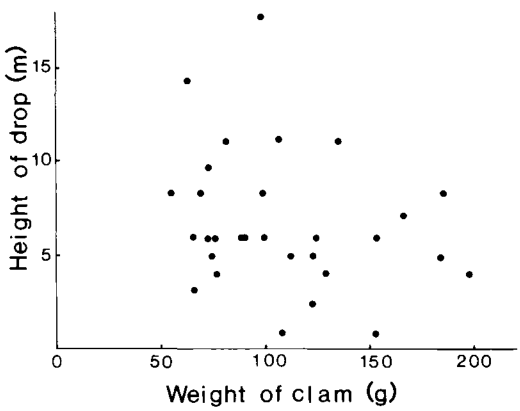

Fig. 3. Drop height on the mudflat in relation to clam weight for immature Western Gulls.

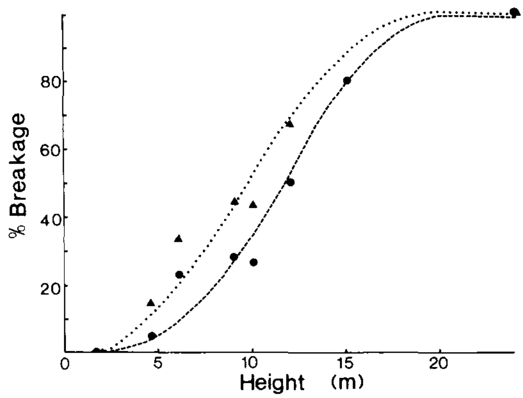

Fig. 4. Percentage of clams that break as a function of drop height. Curves fitted by eye. Dotted curve (and corresponding triangles) represent light clams (clams weighing between 0–100 g), dashed curve (and corresponding circles) represent heavy clams (clams weighing between 101–400 g).

hibitively long distance for gulls to fly to drop clams. Indeed, clams dropped on the mudflat were dropped an average of 118 m from where they were picked up. Hence, one would expect all sizes of clams to be dropped on the parking lot more frequently than on the mudflat, as less drop height is required to break a clam on the parking lot. Why then were only heavy clams dropped more frequently on the parking lot? There are two possible explanations that might account for the general trends observed. (1) The relative size of the tidal flat is much larger than the relative size of the parking lot, and this might explain why more clams (of all sizes) were not dropped on the parking lot. (2) There are some costs to dropping clams on the parking lot (perhaps increased kleptoparasitism), and these costs can be offset only by dropping large clams there. These two explanations are not mutually exclusive. Together, they may explain the observed results.

On the mudflat, gulls preferred certain specific areas to others. Physical characteristics of the mudflat do not appear to influence this preference; other ecological parameters seem more important. For example, it would seem energetically favorable for a gull to minimize flight distance from pick-up to drop site. On the other hand, the likelihood of being robbed should decrease as the distance between the gull and its potential pursuers increases (Siegfried 1977). Because the highest concentration of gulls is often found around concentrations of food (i.e. where I was giving clams to gulls), gulls that pick up clams often fly away to escape potential robbery. Thus, there should be an energetic balance between flying far enough to escape potential robbers and flying farther than necessary. That gulls usually dropped clams (on the study plot) intermediate distances away from where they were obtained supports this idea (Fig. 1).

The inverse correlation between clam weight and dropping height for adult gulls is anomalous, as heavy *Saxidomus* are less likely to break from a given height than light ones (Fig. 4). Because the probability of clams breaking increases with increasing height, more clams would break on the first drop if they were dropped from greater heights. Why, then, do gulls drop heavy clams from lower heights than light ones? Bernstein et al. (1973) stated that steep ascending flight for Fish Crows (*Corvus ossifragus*) is energetically expensive. Zach (1979) found that Northwestern Crows minimize the total amount of ascending flight when dropping whelks. He suggested this behavior may be an adaptation by Northwestern Crows to reduce energetic costs. The same reasoning might explain why Western Gulls do not fly high with heavy clams. They may be minimizing ascending flight with heavy clams if energetic costs are prohibitively high. On the other hand, a gull could conceivably spend more energy trying to break a heavy clam than a light one, because more calories are available in heavy clams than in light ones.

Another possible reason gulls drop heavy clams at a lower height than they drop light ones is that the chances of being robbed may increase with drop height. It takes longer for a gull to fly down to guard a clam that has been dropped from a high altitude than it does from a low altitude. Hence, clams that are dropped from great heights are left unguarded longer than those dropped a small distance. Perhaps gulls are more likely to risk losing small clams to piracy than large ones. The risk of piracy to terns may increase with prey size (Hopkins and Wiley 1972). Terns with larger prey, however, may be more vigilant (Dunn 1973).

One final explanation for the observed relationship between drop height and clam weight for Western Gulls may have to do with the anomalous nature of the prey item used. *Saxidomus* are deep burrowing clams that are probably not frequently utilized by Western Gulls. Moreover, other mollusks that are more frequently dropped by Western Gulls might exhibit a different size-related probability of breakage than *Saxidomus* does. In other words, for other mollusks, small sizes may be harder to break than larger sizes. Siegfried (1977) indicated that this may be true for black mussels (*Choromytilus meridionalis*). Although this remains untested for the natural prey of Western Gulls, if it were true, it might indicate that the observed shell-dropping behavior of Western Gulls may be an artifact of a behavior that is utilized when dropping other prey items.

These arguments indicate that a nexus of factors probably influences the optimal strategy for dropping clams. With light clams, risk of piracy may be lower, food loss when piracy occurs is not as great, and energetic costs for higher flight may be lower. Light clams should therefore be dropped at heights where the probability of breakage is great. With heavy clams, risk of piracy may be higher, food loss when piracy does occur is also high, and it is probably energetically expensive to fly higher. Gulls should therefore minimize the amount of ascending flight when carrying heavy clams. Although the above predictions are speculative, I hope that they will lay the ground work for future work on shell-dropping behavior in birds.

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