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Aerobatic Rolls by Ravens on Santa Cruz Island, California

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Common Ravens (*Corvus corax*) are skillful fliers known for their aerobatic maneuvers, particularly rolls (Dawson 1923, Goodwin 1976, Wilmore 1977, Coombs 1978). Santa Cruz Island, one of the eight Channel Islands off the shore of southern California, supports a large population of ravens that exhibit a high frequency of rolling. The significance of rolling, and raven aerobatics in general, is uncertain; such behavior has been attributed to courtship (Bent 1946, Angell 1978), play (Hoffmann 1927, Fagen 1981), or both (Dawson 1923, Wilmore 1977). Angell (1978) noted that rolls often coincided with vocal communication, and Dawson (1923) reported that aerobatics seemed more frequent when ravens were in groups. The purpose of this study was to describe rolling by ravens on Santa Cruz Island, to test some hypotheses about the significance of rolling, and to compare frequency of occurrence of this behavior among island and mainland ravens.

Santa Cruz Island (SCI), located 40 km south of Santa Barbara, Santa Barbara County, is about 25,000 ha in area and is characterized by rugged and precipitous topography. Data were collected during three seasons: fall (28 October to 21 November 1980), winter (17–26 January 1981), and spring (23–27 March 1981). Daily during these periods, I walked or drove along roads and observed ravens in flight. For each bird in view for more than 5 s, I described any aerobatic maneuver involving a roll (defined as rotation about the longitudinal axis) and, whenever possible, recorded the size of the group in which the raven occurred. Few ravens remained in view longer than 30 s; in order to help standardize observations, I recorded no further data on those that did. I classified wind speed each day according to four qualitative categories: none, light, moderate, and strong. From 1981 to 1983 I observed mainland ravens in flight in Arizona, California, Colorado, Nevada, Oregon, and Utah, noted the number of birds in view for 5–30 s, and recorded any rolls performed.

Rolls were performed during 205 of a total of 1,272 raven observations on SCI. Of 410 individual rolls observed, 95% were half-rolls, in which the bird folded its wings back at the wrist, rolled rapidly onto its back for about 1 s, then reversed rotation and returned to an upright position, simultaneously extending its wings. Half-rolls were performed both to the left and to the right; rolls to the left, however, were more frequent ($\chi^2 = 12.36$, df = 1, $P < 0.001$), totaling 60% of 321 half-rolls in which direction could be determined. I observed individual birds roll in both directions in sequence 19 times. Three percent of all rolls were full-rolls, which were performed in one steady motion, slower than a half-roll, with both wings mostly or fully extended. One percent of rolls were double-rolls and were performed as two continuous full-rolls. Twice I observed a raven perform an Immelmann turn in reverse; the bird rolled onto its back and then proceeded into a one-half inside-loop, which it concluded gliding upright in the opposite direction.

Ravens often followed one roll with another; 62% of rolls were performed in sequences of 2–11. The remainder were single rolls. During a sequence, ravens proceeded from one roll to the next with only a brief glide of 1–3 s between rolls. While performing half-rolls, the birds lost lift when inverted and regained it when righted, producing an undulating flight path. Ravens often called when beginning each roll in the sequence. I once observed a raven perform a sequence that included 6 half-rolls, 2 full-rolls, and 2 double-rolls.

Ravens in coastal southern California begin nesting in late March (Willett 1912); if aerobatic rolls are important in courtship, a higher frequency should be evident in spring. Roll frequencies, however, were similar ($\chi^2 = 2.68$, df = 2, $P > 0.05$) among seasons (Table 1). Rolling may serve as a social display; if so, frequency should be higher when other ravens are close by. Roll frequency, however, was independent of the number of other ravens with which the rolling bird was associated ($\chi^2 = 8.44$, df = 4, $P > 0.05$). I consider play the most likely cause of rolling by ravens on SCI: corvids have the most complex play known in birds (Ficken 1977), and ravens in particular are known for their spectacular aerobatic play (Fagen 1981). Ravens are inverted briefly during a half-roll, and inverted postures are a feature of raven

TABLE 1. Distribution of observations of rolling by ravens among seasons, among raven groups, and among days of different estimated wind speeds, on Santa Cruz Island, California.

	Total observations	Roll observations	Frequency of rolling
Season			
Fall	771	114	0.15
Winter	293	52	0.18
Spring	208	39	0.19
Group size			
1	251	38	0.15
2	434	76	0.18
3	69	13	0.19
4	60	7	0.12
5 or more	65	3	0.05
Wind speed			
None	585	84	0.14
Light	239	28	0.12
Moderate	272	59	0.22
Strong	176	34	0.19

play behavior described elsewhere (Gwinner 1966, Thorpe 1966, Wilmore 1977).

Mainland ravens rolled during 12 of a total 318 observations and performed 16 half-rolls and one full-roll. The frequency of rolling on SCI (0.16) was much higher ($\chi^2 = 32.88$, df = 1, $P < 0.001$) than the frequency on the mainland (0.04). Ravens on Santa Catalina Island, another of the Channel Islands, also exhibit a noticeably high frequency of rolling (Bruce E. Coblentz pers. comm.). Play costs time and energy (Fagen 1981), and characteristics of both islands may alleviate these costs. SCI and Santa Catalina Island support large populations of feral livestock, which may provide an abundant supply of carrion for ravens. Moreover, both islands are oceanic, are situated in an area of prevailing westerly winds, and are characterized by rugged topography; all probably combine to create frequent updrafts along ridges. Roll frequencies on SCI were different ($\chi^2 = 12.37$, df = 3, $P < 0.01$) on days of different wind velocity; ravens rolled more often on days of moderate or strong wind, suggesting that wind facilitates this behavior. The birds lose lift when rolling, particularly during roll sequences, and updrafts provide a means of maintaining altitude without prolonged soaring or flapping between rolls.

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