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2 **The Efficiency of Searchers Recovering Seabirds and Waterfowl Killed in the 1997**  
3 ***M/V Kure Oil Spill in Northern California***

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14 ABSTRACT.-- Studies on the efficiency of searchers looking for the carcasses of  
15 beached birds were carried out in northern California following the 1997 M/V Kure oil  
16 spill in Humboldt Bay. Experimental protocols were designed to mimic as closely as  
17 possible the circumstances of the actual incident. The performance of 20 searchers or  
18 search teams was monitored during 477 encounters between searchers and carcasses in  
19 three habitats, sandy beach, rocky beach, and marsh. Searcher efficiency varied widely,  
20 from 12.5% to 55.3%, depending on carcass coloration, habitat, and carcass size. The  
21 most important factor in determining searcher efficiency was consistently body size.

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22 There was significant heterogeneity in the probability of finding the carcasses of large  
23 bodied birds, some carcasses being very easy to find and some very difficult.

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## INTRODUCTION

27 Beached bird surveys are used throughout the world as a way of monitoring the health  
28 of seabird populations and of assessing the scale of natural or human induced die-offs  
29 (Camphuysen and Huebeck, 2001) . These surveys provide useful indices of relative  
30 mortality, but do not provide estimates of total mortality because birds are never  
31 recovered. Birds may (1) sink at sea, (2 ) be removed by scavengers or other processes,  
32 or (3) be missed by surveyors (Ford *et al.*, 1996). Based on the results of 17 experiments  
33 in which researchers released carcasses at sea and then searched the shoreline for them,  
34 Piatt and Ford (1996) found that typically only about 1 in 5 birds that die at sea are ever  
35 found. Searcher efficiency, the success rate of beached bird surveyors in finding  
36 carcasses, is an important factor determining the proportion of carcasses that are  
37 eventually be recovered.

38 It is surprisingly easy for surveyors to miss beached birds. Wide or wrack filled  
39 beaches are visually difficult environments, and birds can easily be hidden in small  
40 depressions, blend in with other types of wrack, or be too far away to recognize. Monnat  
41 and Guerneur (1979) record that on a sunny day on an "unobstructed beach" 2 km long,  
42 only one carcass of nine (11%) was detected by a team of observers when "it seemed  
43 impossible to us that an oiled bird could escape detection." They also note that P. Hope  
44 Jones found that "an observer trained in the research of oiled birds" missed an average of

45 1 in 5 birds on an "easy-to-search beach" in the Orkneys. Fowler and Flint (1997) found  
46 detection rates varying from 44% to 94% for King Eiders following an oil spill off St.  
47 Paul Island in 1996, though the large body size of the birds and the snow fall  
48 encountered during their study were unusual for beached bird surveys.

49 Searcher efficiency is also an important issue for researchers studying bird or bat  
50 mortality in a terrestrial setting. Accurate estimation of pesticide or wind-turbine induced  
51 mortality requires that carcass counts be corrected for the likelihood that searchers will  
52 find carcasses in a variety of contexts such as croplands, grassland, stubble fields, etc.  
53 (see for example Osborn *et al.*, 2000; Erickson *et al.*, 2000; Johnson *et al.*, 2004; or  
54 Barrios and Rodríguez, 2004). Although the linear nature of shorelines would seem to  
55 make searching easier than in terrestrial habitats, the buildup and movement of wrack,  
56 wave action, and the sometimes uneven topography of beaches result in many carcasses  
57 being overlooked.

58 Aside from Fowler and Flint, we know of no published data that measure searcher  
59 efficiency in the kind of habitat typically encountered in beach surveys. The data  
60 presented here result from studies carried out in 1998 as part of the damage assessment  
61 for the 1997 *M/V Kure* oil spill in Humboldt Bay, California, and were designed to  
62 replicate as closely as possible the actual methodologies used by spill responders.  
63 Searcher efficiency studies were carried out in three habitats that were typical of the area  
64 affected by the spill and of the Pacific coast of the continental USA in general: sandy  
65 beach, rocky beach, and marsh. Modes of search were based on techniques actually used  
66 by survey personnel during the response to the *M/V Kure* oil spill, including walking, all-  
67 terrain vehicles (ATVs), and light trucks. The goal was to estimate the likelihood that

68 searchers would detect beachcast seabird carcasses, and to determine some of the factors  
69 that influence the carcass detection rate.

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71 METHODS

72 STUDY AREA

73 On November 5, 1997, the cargo ship *M/V Kure* struck a loading dock in Humboldt  
74 Bay, California, rupturing a fuel tank and spilling about 4,500 gallons of fuel oil into the  
75 bay. The resultant slick moved out of the bay on successive ebb tides and drifted  
76 northward, resulting in the deposition of oil and dead or injured birds along a 50 km  
77 stretch of coastline extending from the mouth of Humboldt Bay (40° 44.27' N, 124°  
78 15.03' W) north beyond Trinidad Head (41° 8.77' N, 124° 8.47' W). Oil spill response  
79 personnel searched beaches both within the bay and along the outer coast, ultimately  
80 recovering 951 seabirds and waterfowl. As part of the subsequent National Resource  
81 Damage Assessment (NRDA) for the spill, it was estimated that a total of 2012 birds  
82 were actually killed in the incident (Carter, 2003).

83 As part of the NRDA procedure, a study was undertaken in March, 1999 to estimate  
84 searcher efficiency for seabirds and waterfowl in the types of habitat affected by the spill:  
85 outer coast sandy beach, outer coast rocky beach, and bay interior marsh. The sandy  
86 beach study site extended for 4 km from Mad River to Little River north of the Humboldt  
87 Bay entrance, the rocky beach study site was located on a 350 m stretch of Luffenholtz  
88 Beach near the town of Trinidad, and the marsh study site was located on a 7 hectare plot  
89 on Indian Island in central Humboldt Bay.

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#### BIRDS

94 Carcasses were obtained from the California Department of Fish and Game and the  
95 Burke Museum, University of Washington, and consisted primarily of Common Murres,  
96 gulls, grebes, ducks, and cormorants (Table 1). To determine searcher efficiency relative  
97 to smaller birds (which are rare in most collections of beach cast birds), we used Brown-  
98 headed Cowbirds which ranged in size from about 15.2-20.3 cm in length. Cowbirds  
99 have relatively dark ventral coloration matching their dorsal coloration, whereas most  
100 small seabirds and shorebirds are lighter colored on their undersides. To make these  
101 specimens more comparable to small birds affected by the spill, we sprayed the  
102 undersides of these birds with a light coat of white paint.

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#### STUDY AREAS

105 In all three habitats, the general methodology was to place carcasses at randomly  
106 selected locations, simulating the process of deposition that would occur naturally. These  
107 habitats were then searched by experienced spill response personnel using the same  
108 techniques that were used during the *M/V Kure* oil spill response, recording the positions  
109 and status of each carcasses that they found. Depending on terrain, searches were carried  
110 out on foot, from ATV's, or from light pickup trucks. Because search techniques varied  
111 somewhat among the three habitats, experimental techniques also varied as described  
112 below.

113        *Sandy Beach.*-- The sandy beach study area varied in width, from about 10 m to 100m.  
114        The area behind the beach was generally either marsh grass, particularly near river  
115        outlets, or low sandy bluffs. Placement of carcasses and search trials took place on  
116        March 1-2, 1999. Distances between adjacent carcasses were based on a uniform random  
117        variate ranging from 0 to 200 meters, with an average distance of 100 meters between  
118        carcasses. If the randomized position fell on an unusable stretch of shoreline such as a  
119        creek mouth, the carcass was placed in the first position possible. Once the position  
120        along the beach was determined, carcasses were randomly placed between the waterline  
121        and the upper wrack line. Latitude / longitude positions were recorded using a GPS, and  
122        the placement was also marked using flagging that was not visible from the beach, but  
123        could be seen from the back of the dunes behind the beach face. The entire length of  
124        beach was about 4 km (40 birds at 100 m average spacing).

125        A total of 19 cowbirds carcasses were placed out on March 1, 1999. During the  
126        subsequent trials, searchers found many of the other waterbird carcasses, but failed to  
127        locate any of the cowbird carcasses. On the second day of this study, the ventral side of  
128        the cowbirds, originally a dark brown color, was painted white to make them more  
129        similar in appearance to small seabirds such as Marbled Murrelets and Cassin's Auklets.  
130        All data presented in this paper are based on these modified carcasses. A flip of a coin  
131        was used to determine whether a large-bodied or small-bodied carcass was to be placed at  
132        each position.

133        Carcasses were set in position on foot prior to high tide. At each site where a carcass  
134        was to be placed, the beach was visually divided into four quadrants above the high tide  
135        line and the quadrant chosen by two flips of a coin. The carcass was then randomly

136 placed within the appropriate quadrant. Whenever possible, personnel engaged in  
137 carcass placement moved between the ascending tide and the wrack line so that the rising  
138 tide would obscure footprints. Although some footprints inevitably remained along the  
139 beach, the study area already had a high density of footprints and it is unlikely that these  
140 provided additional cues to the searchers. At half hour intervals following high tide,  
141 searchers who were unfamiliar with the placement of the carcasses proceeded along the  
142 beach. Four searchers rode on ATVs, and four rode as passengers in a light pickup truck.  
143 To avoid cues from the tracks of vehicles in the sand, pickup truck drivers and ATV  
144 operators were instructed not to drive directly up to carcasses or to leave their vehicles  
145 and walk over to carcasses, but rather to verify their identification using binoculars.  
146 Details of sample sizes and number of searchers are provided in Tables 2 and 3.

147 During an oil spill response, searchers have limited time to survey any stretch of  
148 coastline. During the *M/V Kure* response, the records of searchers in vehicles showed  
149 that they examined about 4 km of beach in one hour. Searchers were therefore allowed  
150 one hour to examine the area where carcasses had been placed: carcasses found after one  
151 hour were not used in the calculation of search efficiency. After the last search on a  
152 given day was completed, carcasses were retrieved by the personnel who originally  
153 placed them. Carcasses that they were unable to relocate are not used in the calculation  
154 of search efficiency, since they may have rewashed or been removed by scavengers  
155 before searchers could find them.

156 *Rocky Beach.*-- Rocky beaches along this section of coast tend to be steep, difficult to  
157 access, and relatively short in length: the length of Luffenholtz beach varied between  
158 about 250 m and 350 m depending on the state of the tide. The rocky beach study site

159 varied from about 10m to 25 m in width, and was about 20% sand and 80% cobble and  
160 small boulders. Distances between adjacent carcasses were based on a uniform random  
161 variate ranging from 0 to 100 meters, with an average distance of 50 meters between  
162 carcasses. Since beach length varied, the number of birds placed out in a given trial was  
163 determined by the length of beach available at the time. The size class of the carcass  
164 placed at each location was determined by the flip of a coin. Since foot searchers on  
165 rocky beaches moved at a rate of about 1 to 1.5 km/hr during the actual spill response,  
166 searchers were allowed 15 minutes to complete each trial. Details of sample sizes and  
167 number of searchers are provided in Tables 2 and 3.

168 *Marsh.*-- Access to the marsh study area on Indian Island was by airboat, but carcass  
169 placement and search trials were carried out on foot. This area was above the high tide  
170 line, but was periodically inundated and criss-crossed with tidal channels 1-2 m in width.  
171 A set of two-dimensional uniform random coordinates were used to place the carcasses  
172 within the study area. Large or small-bodied carcasses were randomly placed at each  
173 randomized coordinate located using a GPS. Carcasses were left in position over the  
174 night of March 4-5 since earlier studies on carcass removal rates indicated that carcass  
175 persistence was high in this area. (Ford *et al.*, 2002). Details of sample sizes and number  
176 of searchers are provided in Tables 2 and 3.

177 Searchers in the marsh worked in pairs as during the response to the M/V Kure oil  
178 spill. Each team was given 2 hours to search the study area, consistent with the amount  
179 of time that searchers spent in marsh areas during the response. One pair searched before  
180 high tide and the other pair after high tide on each day of the study. Each individual

181 searcher participated only once in these trials. After locating a carcass, searchers noted  
182 its position using GPS and whether or not it had been scavenged.

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## RESULTS

185 For this analysis, the searcher efficiency rate was defined as the probability that a  
186 searcher would locate a carcass that was present within the designated study area within  
187 the allotted time frame. Thus, if a searcher found 15 out of 20 carcasses, the estimated  
188 searcher efficiency rate would be 0.75 or 75%. Only carcasses that were still present  
189 after all trials were completed were used in the analysis.

190 Searcher efficiency rates for all combinations of habitat, search methods, and carcass  
191 sizes are given in Table 2. Searcher efficiencies ranged from 12.5% for small dark birds  
192 on a sandy beach to 55.3% for large birds on a rocky beach. In all cases, searcher  
193 efficiency was lower for small birds than for large birds. Searcher efficiency was highest  
194 on the rocky beach and similar in the marsh and sandy beach habitats. On sandy beaches,  
195 the type of vehicle used by searchers, pickup trucks or ATVs, had little effect on their  
196 efficiency.

197 Results of the Cochran's Q test are shown in Table 3. In 8 sets of replicated searches,  
198 there were no significant differences among searchers or among search teams. We  
199 therefore cannot reject the hypothesis that different individuals or search teams have the  
200 same efficiency rate. While it is likely that there minor differences between individual  
201 searchers, the lack of a significant difference in all 8 sets of trials suggests that the  
202 variation was not a major factor influencing estimates of searcher efficiency.

203 Searchers riding on ATVs were somewhat more effective than searchers riding in  
204 pickup trucks, respectively locating 33 of 98 carcasses compared to 27 of 98 carcasses.  
205 Based on the two-tailed binomial probability test, the likelihood of this degree of  
206 difference occurring randomly if the two rates are in fact equal is not significant  
207 ( $P=0.167$ ), and the hypothesis that the two search modes are equally efficient cannot be  
208 rejected.

209 We tested the hypothesis that all carcasses have the same probability of being found  
210 (as compared to some carcasses being very easy to find and others being very difficult)  
211 by simulating the situation where each searcher/carcass interaction was an independent  
212 random event in which all carcasses had equal likelihood of being found. We compared  
213 the observed number of carcasses that were found or missed by all searchers to the  
214 probability that this would have happened if all the carcasses were equally likely to be  
215 found each time a searcher passed them (Table 4). For large birds in all three habitats, it  
216 was much more likely that a bird would be found by all searchers or by no searchers than  
217 would have been the case if all birds were equally difficult to find, indicating that the  
218 carcasses of large birds varied in regard to the likelihood that they would be found. This  
219 was not true for small birds which did not show a significantly higher incidence of birds  
220 that were found by all searchers or that were missed by all searchers.

221 Habitat and body size are factors that potentially affect searcher efficiency, and these  
222 two factors may interact in ways that cannot be accounted for by either factor alone. We  
223 used a multivariate approach for examining whether carcass size and habitat affect the  
224 likelihood that a carcass will be found. Classical multiple regression models are not  
225 appropriate in this case since the frequency with which the carcasses were found is

226 strictly bounded between 0 and 4, and the residuals therefore do not have an expectation  
227 of zero and constant variance. The ordered logit regression model for ordered categorical  
228 dependent variables is designed for such instances (Davidson and MacKinnon, 1993).

229 Table 5 presents the results of an ordered logit analysis using carcass size as a  
230 “dummy” variable which takes on the value of 1 for large birds and 0 for small birds. To  
231 examine differences between habitat types, we estimated the model three times, each time  
232 including two habitat dummy variables and suppressing the third. Coefficients on the  
233 habitat variables are interpreted as the difference in effect between the “included” habitat  
234 type and the suppressed habitat type. The coefficient of the carcass size variable is  
235 exactly the same for all three models, as is the overall model fit. The model fit is good,  
236 producing a 42% reduction in the sum of square prediction errors when compared to the  
237 naïve model in which all observations are placed in the modal category of zero birds  
238 found.

239 The results of the ordered logit regression (Table 5) indicate a highly significant  
240 positive relationship between carcass size and searcher efficiency ( $P < 0.001$ ), with the  
241 larger birds being found more often. The habitat variables were less successful at  
242 explaining variation in the number of times that a carcass was found. Of the three  
243 contrasts, Sandy Beach x Rocky Beach, Sandy Beach x Marsh, and Rocky Beach x  
244 Marsh, only the comparison between Sandy Beach and Marsh was statistically  
245 significant. The level of significance of this comparison was marginal ( $P < 0.10$ ), with a  
246 positive sign indicating that birds are more likely to be found in the Marsh habitat  
247 compared to the Sandy Beach habitat.

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## DISCUSSION

250 Factors potentially influencing searcher efficiency include variation among observers,  
251 method of transport, habitat type, bird coloration, and bird size. Our results suggest that  
252 differences among searchers was not a major source of variation, nor was the mode of  
253 motorized transport (ATV or pickup), at least on sandy beaches. Hampton and Zafonte  
254 (2005), however, found that foot searchers recovered more birds per mile than did  
255 motorized searchers, and our estimates of searcher efficiency should not necessarily be  
256 considered representative of foot searches on sandy beaches.

257 The structure of the three study habitats, sandy beach, rocky beach, and marsh,  
258 differed in ways other than the substrate. Sandy beaches tended to be wider, lighter in  
259 color, and contain larger quantities of wrack than rocky beaches. The marsh study area,  
260 by comparison, was covered by ankle or knee high vegetation, and the muddy substrate  
261 made walking difficult. Given these differences, we found it surprising that searcher  
262 efficiencies in the different habitats were as similar as we found. For large birds,  
263 searcher efficiency ranged from 40.9% on sandy beaches (pickup truck) to 55.3% on a  
264 rocky beach, and for small birds from 12.5% to 27.9% in the same habitats. Based on our  
265 pair-wise comparisons, differences between habitats were not significant except for sandy  
266 beach and marsh which were marginally significant ( $P = 0.10$ , two tailed).

267 The weak statistical relationship between habitat and searcher efficiency that we found  
268 differs from the results of Fowler and Flint (1997) who found a highly significant  
269 difference between rocky and sandy beaches. In their study, King Eider carcasses  
270 deposited on rocky beaches were less likely to be found than carcasses deposited on  
271 sandy beaches. This may have resulted in part from snow fall that occurred on three days

272 of their study, making it much more difficult for searchers to locate snow covered  
273 carcasses among snow covered rocks than along relatively flat sandy beaches.  
274 Researchers working on the effects of wind turbines on birds in inland settings have also  
275 found evidence for variation in searcher efficiency among different habitats. Erickson *et*  
276 *al.* (2000) found a difference between searcher efficiency in grassland (57%) and wheat  
277 stubble (76%), and Osborn *et al.* (2000) found differences between searcher efficiency in  
278 cropland (82%) and grassland (63%), though neither of these differences were  
279 statistically significant. Johnson *et al.* (2004) studied searcher efficiency for bat  
280 carcasses on gravel pads and vegetated fields and estimated efficiencies of 20% and 77%  
281 respectively, a highly significant difference.

282 We found that bird size had a highly significant relationship with searcher efficiency,  
283 and that this effect that was apparent in all habitats. The importance of body size has  
284 previously been noted by Osborn *et al.* (2000) who found searcher efficiency rates for  
285 small and large size classes of birds of 67% and 92% respectively ( $p=0.025$ ), and by  
286 Erickson *et al.* (2000) who found values of 50% and 88% respectively ( $p<0.001$ ). In our  
287 study, body size may have interacted with coloration in determining searcher efficiency.  
288 Large bird carcasses were predominately dark-backed species with white undersides  
289 such as the Common Murre, but included nearly as many light colored species (mostly  
290 gulls), and some all dark species (cormorants). Our cowbird sample was colored in a  
291 manner comparable to bi-colored species such as Common Murres, Marbled Murrelets,  
292 Cassin's Auklets, and Dunlin. Among large birds in the sandy beach habitat, bi-colored  
293 alcid species were found less often ( $22 / 64 = 34.4\%$ ) than light colored gull species ( $33 /$   
294  $64 = 51.6\%$ ), indicating a marginally significant difference between the two color

295 patterns ( $\chi^2 = 3.708$ ,  $P=0.054$ ). The presence of dark colored birds in the large bird  
296 category would tend to increase the estimate of searcher efficiency for this grouping  
297 indicating since the difference in search efficiency between large and small birds is  
298 related to coloration as well as to size.

299 Searcher efficiency for small birds on sandy beaches was lower than any published  
300 value that we have encountered. Small seabirds and shorebirds are numerous in the  
301 northern Pacific and other regions, including very common species such as Cassin's Auklet,  
302 Rhinoceros Auklets, sandpipers, and phalaropes, as well as endangered species such as  
303 the Marbled Murrelet. Since sandy beaches are a very common shoreline, counts of  
304 small beached birds may often be biased by a factor of 8:1. Such undercounting would  
305 affect both beached bird monitoring surveys and oil spill response efforts.

306 For large birds, there was a significant tendency for carcasses to be found on every  
307 search or to be missed on every search, indicating that the likelihood that a carcass would  
308 be found varied among carcasses: some carcasses were very easy to find, and some were  
309 very difficult. This variation probably resulted from differences in the color and  
310 orientation of the carcasses as well as variation in beach structure, beach color, and  
311 wrack volume in the vicinity. Overall, a large proportion of both large and small birds  
312 (33.3%) were never found by any searcher even in four trials. Individual variation in the  
313 probability that a carcass will be found (i.e. "recaptured") means that mark recapture  
314 models such as the Cormack-Jolly-Seber estimator (Pollock *et al.*, 1990) may yield  
315 biased results when applied to the recovery of beached birds. These models assume that  
316 all individuals are equally likely to be enumerated and that the population does not  
317 include a substantial number of individuals that are impossible to find. Mark recapture

318 models are a promising technique for estimating the total number of carcasses present in  
319 a given area after an oil spill (Fowler and Flint, 1997), but the effect of the violation of  
320 the assumption that all carcasses are equally likely to be found should be checked when  
321 these models are used.

322 Variation in the probability of locating a carcass also makes it more difficult to  
323 extrapolate searcher efficiency rates measured for individual searchers to teams  
324 composed of multiple searchers, or to take into account multiple searches of the same  
325 beach. Suppose, for example, that there were two birds on the beach, each with a 50%  
326 chance of being found by a single searcher. Then the probability that one of the carcasses  
327 will be found by at least one of the two searchers is  $1 - 0.5^2 = 0.75$ . If, on the other  
328 hand, one carcass had a 100.0% chance of being found, and the other had a 0.0% chance  
329 of being found, the average probability of locating a carcass would still be 50%. But  
330 only one of the two carcasses would ever be enumerated no matter how many search  
331 trials took place, and a mark recapture analysis would yield an estimate of 100% searcher  
332 efficiency.

333 Searcher efficiency is a significant factor determining the number of birds killed at sea  
334 by an oil spill or by natural causes. The most important correlates of the searcher  
335 efficiency rate are carcass size and coloration. When comparing the recovery rates of  
336 species that vary in size or coloration, efforts should be made to compensate for this  
337 variability. Searcher efficiency is also a critical factor if researchers attempt to estimate  
338 total mortality based on the recoveries of beached birds.

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402 Table 1. Species used in the bird carcass detection study.

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| <b>Species Number</b>    |            |
|--------------------------|------------|
| Common Murre             | <b>24</b>  |
| Herring Gull             | <b>3</b>   |
| Heermann's Gull          | <b>2</b>   |
| California Gull          | <b>2</b>   |
| Glaucous-winged Gull     | <b>1</b>   |
| Gull spp.                | <b>16</b>  |
| Double-crested Cormorant | <b>1</b>   |
| Cormorant spp.           | <b>3</b>   |
| Pied-billed Grebe        | <b>1</b>   |
| Grebe spp.               | <b>8</b>   |
| Ruddy Duck               | <b>1</b>   |
| Mallard                  | <b>2</b>   |
| Duck spp.                | <b>2</b>   |
| Goose spp.               | <b>1</b>   |
| Green Heron              | <b>1</b>   |
| Great Egret              | <b>1</b>   |
| Least Sandpiper          | <b>1</b>   |
| Brown-headed Cowbird     | <b>56</b>  |
| <b>Total carcasses:</b>  | <b>126</b> |

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405 Table 2. Search efficiency rates (expressed as percentage of total carcasses found) for  
 406 different habitats, search methods, and carcass sizes.

|                                   | <b>Small</b> | <b>Large</b> |
|-----------------------------------|--------------|--------------|
| <b>Sandy Beach (ATV)</b>          | 12.5%        | 43.9%        |
| n                                 | (32)         | (66)         |
| <b>Sandy Beach (Pickup Truck)</b> | 3.1%         | 40.9%        |
| n                                 | (32)         | (66)         |
| <b>Rocky Beach (On Foot)</b>      | 27.9%        | 55.3%        |
| n                                 | (43)         | (38)         |
| <b>Marsh (On Foot)</b>            | 24.0%        | 42.3%        |
| n                                 | (96)         | (104)        |

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414 Table 3. Comparison of searcher teams.

| <b>Date</b> | <b>Number of Trials</b> | <b>Transport</b> | <b>Habitat</b> | <b># of Birds</b> | <b>Chi-square adjusted</b> | <b>df</b> | <b>P<sup>ns</sup></b> |
|-------------|-------------------------|------------------|----------------|-------------------|----------------------------|-----------|-----------------------|
| Mar. 1      | 2                       | ATV              | Sandy          | 20                | 0.50                       | 1         | ns                    |
| Mar. 2      | 2                       | ATV              | Sandy          | 29                | 0.00                       | 1         | ns                    |
| Mar. 1      | 2                       | Pickup           | Sandy          | 20                | 0.00                       | 1         | ns                    |
| Mar. 2      | 2                       | Pickup           | Sandy          | 29                | 0.25                       | 1         | ns                    |
| Mar. 3      | 5                       | Foot             | Rocky          | 9                 | 2.80                       | 4         | ns                    |
| Mar. 5      | 3                       | Foot             | Rocky          | 12                | 4.33                       | 2         | ns                    |
| Mar. 4      | 2 teams                 | Foot             | Marsh          | 50                | 2.40                       | 1         | ns                    |
| Mar. 5      | 2 teams                 | Foot             | Marsh          | 50                | 3.56                       | 1         | ns                    |

415 ns = not significant

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424 Table 4. Test of heterogeneity of detection probabilities among carcasses

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| <b>Bird Size</b> | <b>Habitat</b> | <b>Number of Birds in Trial</b> | <b>Probability of Finding a Bird If All Birds Are Equally Likely to be Found</b> | <b>Observed Number of Birds Found or Missed by All Searchers</b> | <b>Probability of Observed If All Birds Are Equally Likely to be Found</b> |
|------------------|----------------|---------------------------------|--|--|--|
| Large            | Sandy          | 33                              | 0.417  | 13   | 0.0004 **  |
| Small            | Sandy          | 16                              | 0.078  | 12   | 0.5330 ns  |
| Large            | Rocky          | 8                               | 0.469  | 4  | 0.0123 *   |
| Small            | Rocky          | 8                               | 0.250  | 5  | 0.0752 ns  |
| Large            | Marsh          | 26                              | 0.423  | 8  | 0.0193 *   |
| Small            | Marsh          | 24                              | 0.240  | 7  | 0.7506 ns  |

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436 Table 5. Results of ordered logit analysis for the effect of carcass size and habitat.

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| <b>COMPARISON</b>              | <b>ESTIMATE</b> |
|--------------------------------|-----------------|
| Large versus Small Carcasses   | 1.484***        |
| Rocky Beach versus Sandy Beach | 0.550           |
| Marsh versus Rocky Beach       | 0.077           |
| Marsh versus Sandy Beach       | 0.627*          |
| Percent Reduction of SSE       | 42%             |
| Sample Size (N)                | 115             |

438 Note: \*\*\* denotes  $\alpha = 0.001$ ; \* denotes  $\alpha = 0.10$  (two-tailed)

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