ELSEVIER

Biological Conservation 110 (2003) 97–100

BIOLOGICAL CONSERVATION

www.elsevier.com/locate/biocon

Testing a key assumption of wildlife buffer zones: is flight initiation distance a species-specific trait?

Daniel T. Blumstein[a], Laura L. Anthony[b], Robert Harcourt[c], Geoff Ross[d]

[a]*Department of Organismic Biology, Ecology, and Evolution, 621 Charles E. Young Drive South, University of California, Los Angeles, CA 90095-1606, USA*

[b]*Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia*

[c]*Graduate School of the Environment, Macquarie University, Sydney, NSW 2109, Australia*

[d]*Botany Bay National Park, PO Box 375, Kurnell, NSW 2231, Australia*

Received 23 April 2001; accepted 9 March 2002

Abstract

The distance at which animals flee an approaching predator is known as the 'flight initiation distance' (FID). Wildlife managers use FID to develop buffer zones to reduce human impacts on wildlife. Many variables have been demonstrated to influence FID leading one to question whether it can be viewed as a species-specific trait. We tested this critical assumption for developing buffer zones by experimentally approaching eight species of shorebirds found at six sites around Botany Bay, 15 km south of Sydney, Australia. Botany Bay encompasses a range of human impacted areas, from urban developments with high levels of human presence, through to National Parks and wildlife protection areas where human presence is significantly lower. We found that both species and site influenced the distance birds flew away from an approaching human. Importantly, however, there was no significant statistical interaction between site and species demonstrating that 'flighty' species were consistently flighty while more tolerant species were consistently tolerant. Taken together, these results suggest that FID can therefore be viewed as a species-specific trait for these shorebirds. The great variability in FID suggests that wildlife managers should be somewhat conservative in developing buffer zones, but they can use previously published FID data for a given species as guidelines for setting buffer zones.

Keywords: Flight initiation distance; Buffer zones; Human impacts on wildlife; Set-back distances

1. Introduction

Animals commonly flee approaching humans and this deceptively simple observation has generated two complementary lines of research. The exact distance at which they begin to flee, variously called 'flight-initiation distance—FID' (e.g. Ydenberg and Dill, 1986; Bonenfant and Kramer, 1996), 'flush distance' (e.g. Holmes et al., 1993; Richardson and Miller, 1997), and 'escape flight distance' (e.g. Madsen and Fox, 1995), has been used by behavioral ecologists and wildlife managers. Behavioral ecologists have realized that, like many other antipredator behaviors, individuals should vary FID dynamically so as to minimize the costs of disturbance while maximizing the chance of survival (Ydenberg and Dill, 1986; Bonenfant and Kramer, 1996). Studies have demonstrated that FID can be influenced by many variables (e.g. flock size—Burger and Gochfeld, 1991, angle of approach-Burger and Gochfeld, 1990, 1991, time of year—Richarson and Miller, 1997, time of day—Delaney et al., 1999, reproductive state—Bauwens and Thoen, 1981, distance to refuge—Dill and Houtman, 1989, whether or not a population is hunted—Louis and Le Berre, 2000, type of disturbance—Rodgers and Smith, 1997, etc.). However, behavioral biologists also recognize that antipredator behavior has heritable components (Riechert and Hedrick, 1990) and that there are species-specific types of antipredator behavior (Edmunds, 1974; Morse, 1980). Of central concern in this paper is that FID is also used by wildlife managers to quantify human disturbance (e.g. Buehler et al., 1991; Carney and Sydeman,

E-mail addresses: marmots@ucla.edu (D.T. Blumstein), quamoomoo@hotmail.com (L.L. Anthony), rharcour@gse.mq.edu.au (R. Harcourt), towratern@aol.com (G. Ross).

0006-3207/02/$ - see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0006-3207(02)00180-5

1999) and define 'set-back distances' (e.g. Rodgers and Smith, 1995; Holmes et al., 1993; Giese, 1998) or 'buffer zones' (e.g. Holmes et al., 1993; Rodgers and Smith, 1997; Carney and Sydeman, 1999)—areas beyond which people can be said to minimally disturb or impact wildlife. While managers acknowledge the variability in FID (e.g. Carney and Sydeman, 1999), they nevertheless use estimates of a species' FID to attempt to minimize human impact. Here we evaluate the key untested assumption made when developing set-back distances or buffer zones: that FID is a species-specific trait.

2. Methods

We focused on eight common shorebirds (silver gull, *Larus novaehollandiae*; bar-tailed godwit, *Limosa lapponica*; crested tern, *Sterna bergii*; white ibis, *Threskornis molucca*; Australian pelican, *Pelecanus conspicllantus*; white-faced heron, *Ardea novaehollandiae*; masked lapwing, *Vanellus miles*; pied oystercatcher, *Haemtopus longirostris*) found in the intertidal region of Botany Bay (34°00′S, 151°13′E), 15 km S of Sydney, Australia. Botany Bay is surrounded by a mix of retail, industrial and residential development and protected native bushland. Commercial oyster leases and Australia's second largest oil refinery line the south shores of the bay. Australia's busiest airport (Sydney International Airport), and Australia's second largest commercial container port (Port Botany) is on the north shore. Beaches and coastal reserves are found on both shores, and between the airport and the oil refinery.

In the austral autumn (24 February–21 May) we assessed FID by walking towards these eight species at six sites. The sites included an area abutting an oil refinery (Penrhyn), commonly-visited beaches (Kyeemagh, Sandringham, Saint Georges River Sailing Club), residential areas (Taren point), and native bushland in an area closed to the public (Towra Point Nature Reserve). The sites were chosen because they contain important over-winter habitat for migratory shorebirds (G. Ross, unpublished data), and because they represented a range of habitat types and human impacts. Habitats included mangroves, sandy beaches, lawns with ornamental shrubs, and rock jetties. Human impacts were assessed by counting the number and type of human activities seen while studying the birds and included: boating, horseback riding, walking/running on the beach, dog walking, collecting invertebrate bait and fishing. The sites were an average of 4.4 km apart (range = 1.2–8.2 km). We assumed that the range of habitat types and human impacts would generate sufficient variation in FID that we could determine the degree to which FID was a species-specific trait. We tested this by determining whether there was a significant effect of site on FID. We also assumed that individuals seen at a site more-or-less remained at that site. Observations of color banded individuals suggest that some species at Botany Bay exhibit site fidelity within and between years (G. Ross, unpublished data on several hundred color-banded terns, and a number-banded bar-tailed godwit was captured in the same location where it was banded 17 years previously).

To quantify FID, we identified individuals 'resting' or foraging that were not initially disturbed by our presence. We then walked towards them at a constant pace of 0.5–1.0 m/s. We noted the distance at which the subject walked or flew away, walked to the spot where the bird was initially seen, and then returned to the starting location. Although we did not re-target the same individual during a given visit, we waited at least 2 mins before targeting another species at the same site. Multiple observations were collected at a site only if individuals targeted subsequently could not have seen the previous experimental approach. We made an average of 67 visits per site (range = 60 at Penrhyn—89 at Saint Georges River Sailing Club).

Flight initiation distances were $\log_{10}(x+1)$ transformed for analysis to normalize their distribution. We fitted a two-way ANOVA with an interaction to these FIDs to test the following hypotheses critical to the assumption that FID is a species-specific trait. Does FID vary by species? Does FID vary by site? Is there a significant interaction between species and site?

3. Results and discussion

We conducted 726 flushes distributed among the eight species (Table 1). Species were not equally abundant at each site. Birds either walked away or flew off in response to human approach. However, with the exception of the bar-tailed godwit ($\bar{X}$ distance that birds walked away = 25.7 m, $\bar{X}$ distance that birds flew away = 19.8 m, $P = 0.011$) there was no significant difference in the average FID for individuals that flew off compared to individuals that walked away (all P-values > 0.35). We therefore combined walking and flying to generate our estimate of FID. Our experimental

Table 1
The distribution of observations by site

Species	Kyeemagh	Penrhyn	Sandringham	SGSC[a]	Taren Point	Towra Point
Silver gull	59	35	66	65	33	14
Bar-tailed godwit	11	40	8	73	22	23
Crested tern	20	9	3	27	2	0
White ibis	0	5	0	15	36	5
Australian pelican	4	26	1	5	8	4
White-faced heron	1	0	0	8	15	15
Masked lapwing	4	6	1	5	5	13
Pied oystercatcher	0	2	1	11	15	5

[a] Saint Georges River Sailing Club

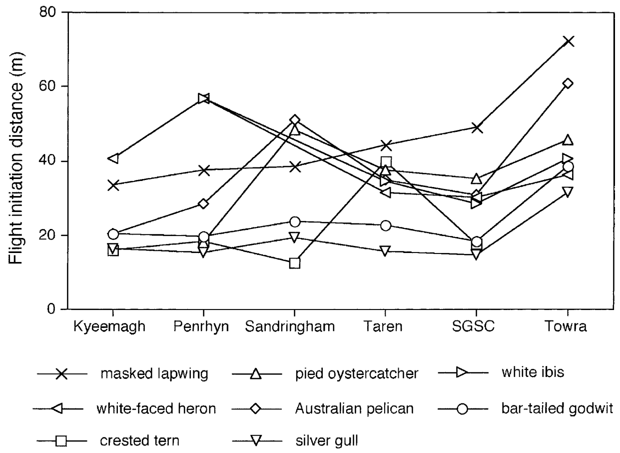

Fig. 1. Interaction plot illustrating the average flight initiation distance (m) of each of the eight species of shorebirds at each of the six sites in Botany Bay. While there were significant species effects and site effects, there was no significant interaction between species and site (see text for details).

approaches were minimally invasive; for a subset of 437 observations (when we could quantify the time to resume the initial behavior after the observer began walking back from the bird's initial position), we found that subjects took an average of 31.4 s to resume their initial behavior (range = 0–299 s).

Twenty-seven percent of the variation in FID (adjusted $R^2 = 0.271$) was significantly explained by the ANOVA model (model $P = 0.0001$). Both site ($P = 0.0001$) and species ($P = 0.0001$), but not the interaction between them ($P = 0.27$) explained significant variation in FID (Fig. 1). To compare these significant main effects, we calculated partial η^2 (Tabachnick and Fidell, 1996). The partial η^2 was three times greater for species than for site ($\eta^2_{\text{species}} = 0.114$; $\eta^2_{\text{site}} = 0.037$), suggesting that species is a relatively more important factor in explaining variation in FID.

Although the site where animals were studied influenced the overall distance at which they fled an approaching human, a significantly greater proportion of the variation was explained by species and, most importantly, there was no significant interaction between site and species. 'Flighty' species, such as masked lapwings, always fled at relatively long distances, while 'less flighty' species, such as silver gulls, always fled at relatively short distances. Taken together, these results suggest that FID can be viewed as a species-specific trait, and this finding has important implications for management.

First, because there may be significant intraspecific variation, exclusion zones should presumably be conservative (e.g. Rodgers and Smith, 1997) and data should be combined from different sites. However, because FID can be viewed as a species-specific trait, it should be possible to use species values from the literature as a initial guideline which can be subjected to a preliminary test at a site of interest. If FID values from the literature are consistent with the FID survey at a site of interest, managers will have saved both time and money by not having had to collect a large novel data set.

Second, understanding the great degree of intraspecific variation requires further study. It is likely that species respond differently to human impacts. Identifying those factors that influence FID would be a first step towards a greater understanding of human impacts. Curiously, we found no obvious relationship between the number, or variability, of human activities (quantified when we were collecting FID data) and FID for these eight species. This lack of pattern could be because unanalyzed variables explain variation in FID, or because the effect is weak and a larger data set of sites and species would be required.

It is likely that species are somewhat idiosyncratic in their response to humans. Some species (e.g. human commensals) are likely to habituate whereas others are likely to be sensitized to human activity. Greater insight into factors that explain this variation will require broadly comparative studies. At this point it is unclear whether species habituate similarly to human disturbance (i.e. whether all species loose fearfulness at a similar rate). If not, it may be possible to compare species with respect to an index of habituation and understand more about how and why species vary in their response to humans.

In conclusion, there is much to be learned by applying knowledge and general principles of antipredator behavior to wildlife management (e.g. Gill et al., 1996; Griffin et al., 2000; Blumstein, 2000). The main message of this present study is that FID can be viewed as a species-specific trait. Managers need not necessarily collect site-specific data on a species if FID data exist elsewhere. Future studies are designed to develop a more predictive model of FID.

Acknowledgements

Research was conducted under animal use protocols approved by Macquarie University Animal Care Committee (#99021) and a permit issued to DTB by the New South Wales National Parks and Wildlife Service (permit #A2712). DTB was supported by the Australian Research Council; additional support came from the Macquarie University Department of Biological Sciences, and the National Parks and Wildlife Service. We thank Mark Schwartz and two anonymous reviewers for helpful comments on the manuscript.

References

Bauwens, D., Thoen, C., 1981. Escape tactics and vulnerability to predation associated with reproduction in the lizard *Lacerta vivipara*. J. Anim. Ecol 50, 733–743.

Blumstein, D.T., 2000. Understanding antipredator behavior for conservation. The Open Country 1 (2), 37–44.

Bonenfant, M., Kramer, D.L., 1996. The influence of distance to burrow on flight initiation distance in the woodchuck, *Marmota monax*. Behav. Ecol 7, 299–303.

Buehler, D.A., Mersmann, T.J., Fraser, J.D., Seegar, J.K.D., 1991. Effects of human activity on bald eagle distribution on the northern Chesapeake Bay. J. Wildl. Manage 55, 282–290.

Burger, J., Gochfeld, M., 1990. Risk discrimination of direct versus tangential approach by basking black iguanas (*Ctenosaura similis*): variation as a function of human exposure. J. Comp. Psychol 104, 388–394.

Burger, J., Gochfeld, M., 1991. Human distance and birds: tolerance and response distances of resident and migrant species in India. Env. Cons 18, 158–165.

Carney, K.M., Sydeman, W.J., 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22, 68–79.

Delaney, D.K., Gurbb, T.G., Seibr, P., Pater, L.L., Reiser, M.H., 1999. Effects of helicopter noise on Mexican spotted owls. J. Wildl. Manage 63, 60–76.

Dill, L.M., Houtman, R., 1989. The influence of distance to refuge on flight initiation distance in the gray squirrel (*Sciuris carolinensis*). Can. J. Zool 67, 233–235.

Edmunds, M., 1974. Defense in animals. Longman, New York.

Giese, M., 1998. Guidelines for people approaching breeding groups of Adélie penguins (*Pygoscelis adeliae*). Polar Record 34, 287–292.

Gill, J.A., Sutherland, W.J., Watkinson, A.R., 1996. A method to quantify the effects of human disturbance on animal populations. J. Appl. Ecol 33, 786–792.

Griffin, A.S., Blumstein, D.T., Evans, C.S., 2000. Training animals about predators: a critical review and synthesis. Cons. Biol. 14, 1317–1326.

Holmes, T.A., Knight, R.L., Stegall, L., Craig, G.R., 1993. Responses to wintering grassland raptors to human disturbance. Wild. Soc. Bull 21, 461–468.

Louis, S., Le Berre, M., 2000. Ajustement des distances de fuite a l'homme chez *Marmota marmota*. Can. J. Zool 78, 556–563.

Madsen, J., Fox, A.D., 1995. Impacts of hunting disturbance on waterbirds—a review. Wild. Biol. 1, 193–207.

Morse, D.H., 1980. Behavioral mechanisms in ecology. Harvard University Press, Cambridge.

Richardson, C.T., Miller, C.K., 1997. Recommendations for protecting raptors from human disturbance: a review. Wildlife Soc. Bull 25, 634–638.

Riechert, S.E., Hedrick, A.V., 1990. Levels of predation and genetically based anti-predator behaviour in the spider, *Agelenopsis aperta*. Anim. Behav 40, 679–687.

Rodgers Jr., J.A., Smith, H.T., 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Cons. Biol. 9, 89–99.

Rodgers Jr., J.A., Smith, H.T., 1997. Buffer zone disturbances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildl. Soc. Bul. 25, 139–145.

Tabachnick, B.G., Fidell, L.S., 1996. Using multivariate statistics, 3rd ed. HarperCollins College Publishers, New York.

Ydenberg, R.C., Dill, L.M., 1986. The economics of fleeing from predators. Adv. Study Behav 16, 229–249.