A Review of Human Disturbance Effects on Nesting Colonial Waterbirds

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Abstract.—We reviewed 64 published investigations concerning effects of human disturbance on nesting colonial waterbirds. We summarized and reviewed articles, based on taxonomy, examining investigator, ecotourist, recreator, watercraft, and aircraft activity effects on physiology, reproductive behavior, reproductive success, and population trends of waterbirds. Though most studies found significant negative effects, taking careful measures minimized impact on some species. Guidelines for minimizing investigator and visitor disturbance are outlined. Little practical information for visitor management is available. Increasing pressure from the ecotourism industry to visit waterbird colonies makes research that develops scientifically-defensible tourism policies imperative. *Received 27 December 1997, accepted 27 April 1998.*

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The number of people involved in recreational activities specifically geared toward viewing wildlife is increasing rapidly (Budowski 1976; Boyle and Sampson 1985; Kenchington 1989). For many years, it was assumed that such activities were harmless to wildlife and could actually aid in conservation efforts by generating revenue and publicity. However, it has become clear that even visitation by those most interested in conserving wildlife can have detrimental effects (Boyle and Sampson 1985).

Nesting colonial waterbirds are particularly vulnerable to human intrusion (Manuwal 1978). Their high visibility, animated behavior and physical beauty tend to attract human visitors. When approached by humans, nesting colonial waterbirds often flush from nests in an attempt to either intimidate a potential predator or to flee from danger themselves (Conover and Miller 1978; Anderson and Keith 1980; Burger 1982). During such times, nest contents can be spilled, exposed to predation, or perish from exposure to the elements during temporary or permanent abandonment (Kury and Gochfeld 1975; Anderson and Keith 1980).

This sensitivity of nesting waterbirds, in combination with increasing pressures of visitation on areas containing their colonies (deGroot 1983; Burger 1995, Great Barrier Reef Marine Park Authority 1997), presents a difficult situation for land and resource managers. Though visitation of nesting areas can generate conservation interest and revenue, disturbance, paradoxically, can cause birds to abandon the site that managers are attempting to preserve. Before allowing visitation to waterbird colonies, wildlife managers need to know the short- and long-term effects of human visitation on the colony in question, as well as how to minimize those impacts.

Because this type of information is difficult to find, this paper attempts to synthesize information on the effects of human disturbance on nesting colonial waterbirds. From this review, we develop general guidelines for ecotourism and other forms of human visitation. Though it would be a valuable enterprise, we do not evaluate the relative contribution of each individual study. Instead, we attempt to identify which species are most vulnerable to human disturbance, when disturbance is most likely to cause adverse impacts, and precautions that can be taken to minimize negative effects. We also discuss the limitations of these guidelines and suggest topics for further research.

RESULTS

We reviewed 64 articles from 20 scientific journals, five books and one report dating from 1971-1998. For each of five orders of birds, we summarized effects of disturbance on waterbird physiological parameters, behavior, reproductive success, nest distribution patterns, and breeding population size trends. We also discuss techniques used to minimize disturbance effects.

Sphenisciformes (penguins)

A total of 17 investigations examined effects of scientific activity, tourism, and aircraft operations on penguin physiology, behavior and reproductive success. Due to their apparent indifference to the presence of humans, penguins were thought to be relatively immune to human disturbance. However, human approach resulted in significant increases in Adelie Penguin (*Pygoscelis adeliae*) heart rates, even when no evidence of stress was behaviorally manifested (Culik *et al.* 1990; Wilson *et al.* 1991). Nimon *et al.* (1996) found that Gentoo Penguins (*Pygoscelis papua*) approached gradually by a human to a distance of three meters did not exhibit any change in heart rate, but that any sudden human movement at this distance resulted in a 50% increase. Investigator handling of Adelie Penguins caused an increase in body temperature of up to two °C, a rise which in one case lasted for several hours after capture (Boyd and Sladen 1971; Regel and Putz 1997).

Foraging and comfort behaviors of Adelie Penguins were also affected by human interference. Foraging trips for birds marked by tail-feather clipping were on average 50% longer than those of unmarked birds (Wilson *et al.* 1989). The frequencies of "head shakes", "both-wings-shakes", "rapid-wing-flaps", and "ruffle-shakes" all at least doubled when an investigator approached from ten to two meters (Ainley 1974).

Human disturbance also negatively influenced penguin productivity and breeding population trends, effects that varied with colony density. For example, repeated human approaches and nest-checks lowered the productivity of breeding Adelie Penguins (*Pygoscelis adeliae*) (Giese 1996). Human passage through a low-density colony of African Penguins (*Spheniscus demersus*) resulted in desertion of nests and subsequent predation by Kelp Gulls (*Larus dominicanus*) (Hockey and Hallinan 1981). When a human approached a dense colony of African Penguins to within ten meters, half of all chicks and adults fled the colony (Hockey and Hallinan 1981). Repeated approaches to colonies also frightened prospecting Adelie and African penguins, potentially lowering recruitment (Ainley *et al.* 1983; Hockey and Hallinan 1981). Activities associated with field research stations and ecotourism were suggested as the primary cause of decline in several Adelie breeding populations (Thomson 1977; Muller-Schwartze 1984; Wilson *et al.* 1990; Woehler *et al.* 1994), although this hypothesis has yet to be critically examined (see below).

Three studies found that helicopter and airplane disturbance had immediate and devastating impacts on breeding penguins (Sladen and Leresche 1970; Culik *et al.* 1990; Wilson *et al.* 1991). Desertion rates of 20-30% were observed when helicopters approached within 1,000 m of an Adelie colony (Sladen and Leresche 1970). Culik *et al.* (1990) found significant increases in heart and desertion rates of Adelie Penguins when helicopters approached within even 1,500 m of the colony. Helicopter activity also caused panic responses in nearly all birds transiting to and from nests, delaying return to nests after foraging trips (Wilson *et al.* 1991).

Though most studies found an effect of human disturbance on breeding penguins, some studies suggested that humans had very minimal impacts on penguin breeding populations. Fraser and Patterson (1997) observed that Adelie Penguin colonies in protected areas that had little contact with humans showed more dramatic declines than those colonies that were exposed to increasing amounts of ecotourism and research over the same period (43% versus 19%, respectively). They suggested that long-term environmental changes were more important than human disturbance in the dynamics of these colonies. Preliminary results of an ecotourism-impact study at the same location seem to support this idea (Patterson *et al.* in press). In another example, repeated human approachs to within ten m of African Penguins on landing beaches had no effect on the size and/or demographic composition of these groups (Van Heezik and Seddon 1990). Furthermore, when regularly disturbed, they became less behaviorally responsive over time (Van Heezik and Seddon 1990).

Procellariformes (albatrosses, petrels, shearwaters, and storm-petrels)

Of five investigations in this group, four examined the effects of human development and research activities on the reproductive behaviors of shearwaters and fulmars, respectively; the fifth documented the behavioral response of Laysan Albatrosses (*Diomedea immutabilis)* to human approach.

Hill and Barnes (1989) censused Wedge-tailed Shearwater (*Puffinus pacificus*) nesting sites on both sides of Heron Island, Australia in 1985. While one side of the island is protected (as a national park) and the other is nearly completely developed (containing a research station and resort), no differences in burrow density were found. Shearwaters compensated for the loss of habitat in developed areas by using construction debris and felled trees as nesting substrate. Although there are limitations to such compensation, the study provides evidence of how birds may ameliorate disturbance effects through behavioral plasticity. Importantly, the health of this species' population is not indicative of the status of other fauna on this island, where other seabird species have been extirpated (Hill and Rosier 1989).

Ollason and Dunnet (1978) found that human disturbance had detrimental effects on the Northern Fulmar (*Fulmaris glacialis*). Capturing birds resulted in lowered breeding success in the year of capture and also reduced the likelihood of returning to breed in the subsequent year. In addition, breeding success was significantly reduced when more than 12 observers visited the island for three to four sequential days during July (the chick-rearing period) (Ollason and Dunnet 1980).

Burger and Gochfeld (in press), on the other hand, documented the ability of Laysan Albatross (*Diomedea immutabilis*) to habituate to human disturbance. Both adults and chicks infrequently visited by humans responded aggressively at greater distances to an approaching investigator than did those that had experienced frequent visitation. This study was conducted during only a fraction of the entire breeding season (during May, when chicks were approximately 60 days old), and no reproductive parameters were measured.

Pelecaniformes (pelicans, gannets, boobies, and cormorants)

Twelve studies examined the effects of investigator, aircraft, and ecotourism on pelecaniform reproductive success and behavior. In the case of pelicans, clutch size, hatching success, fledging success, and overall reproductive success were lowered as a result of human (Schrieber and Risebrough 1972; Anderson and Keith 1980; Boellstorff *et al.* 1988) and aircraft (Bunnel *et al.* 1981) disturbance. Disturbance caused either temporary or permanent abandonment of nests, which were often depredated by gulls (*Larus spp.*), crows (*Corvus brachyrhynchos* and *C. ossifragus)* and ravens (*Corvus corax*). Eggs and young chicks of abandoned nests also perished from exposure or were crushed as adults left the nest. Even a single disturbance early in the nesting season had dramatic negative impacts on reproductive success of nesting Brown Pelicans (*Pelecanus occidentalis*); once disturbed, breeding areas usually remained unoccupied for the rest of the breeding season (Anderson and Keith 1980). Even in areas far from the site of actual disturbance, pelicans were sensitive to the presence of humans, fleeing at the sound of associated gull alarm calls (Anderson and Keith 1980). Anderson (1988) estimated that Brown Pelicans suffered negative effects from human activities at 600 m distance;

however, Rodgers and Smith (1995) found that Brown Pelicans could be approached to less than 100 m on foot, and less than 75 m in a boat, without flushing.

Human disturbance also lowered productivity of cormorant colonies (Kury and Gochfeld 1975; Ellison and Cleary 1978; DesGranges and Reed 1981). When a person entered a Double-crested Cormorant (*Phalacrocorax auritus*) colony, adults often flushed from their nests, exposing contents to predation or the elements (Kury and Gochfeld 1975; Ellison and Cleary 1978; DesGranges and Reed 1981). Investigator disturbance also discouraged late-nesting birds from settling in affected areas (Ellison and Cleary 1978). Duffy (1979) criticized the Ellison and Cleary (1978) study for using nests begun late in the season; he suggested that late-nesters are often inexperienced and would not be representative of the colony or species. Henny *et al.* (1989) noted a coincident increase in human habitation and decrease in Double-crested Cormorant productivity in northwestern Washington; however, some populations (e.g. Double-crested Cormorants in Quebec) expanded during periods of disturbance and systematic persecution (DesGranges and Reed 1981). Rodgers and Smith (1995) suggested that Double-crested Cormorants in Florida could be approached to 100 meters without causing ill-effects.

Only two studies have investigated the impact of human disturbance on Galapagos Islands waterbirds despite the popularity of the archipelago as an ecotourist destination. Tindle (1979) observed no significant effect of tourist visitation on Magnificent or Great frigate-birds (*Fregata magnificens* and *F. minor*) behavior or reproductive success. Burger and Gochfeld (1993) found that booby (*Sula dactylagra, S. sula,* and *S. nebouxii*) behavior (walking from, flying from, or remaining at their nest sites) was related to their distance from tourist trails. Boobies with nest sites within two meters of the trail fled the nest up to 95% of the time during tourist visits. Frequencies of alarm calls and head and body turns were higher after tourist groups passed than before. Boobies also avoided nesting close to the tourist trail, despite similarity in nesting habitat.

Nettleship (1975) regarded human visitation as the likely cause of decline for a breeding population of Northern Gannets (*Sula bassana*) in Ontario. Undisturbed populations increased during the same period.

Charadriformes (gulls, terns, noddies, skimmers, and alcids)

We found 23 studies that examined the impact of human disturbance on breeding species in this order. Most research documented effects of investigator activities, although a few investigated effects of recreators and aircraft.

Investigator disturbance lowered reproductive success of gulls, terns, skimmers, and alcids (Gillet *et al.* 1975; Robert and Ralph 1975; Conover and Miller 1978; Anderson and Keith 1980; Cairns 1980; Brubeck *et al.* 1981; Burger 1981; Gochfeld 1981; Nisbet 1981; Fetterolf 1983; Pierce and Simons 1986; Piatt *et al.* 1990; Safina and Burger 1983; Rodway *et al.* 1996). Nests were lost through abandonment, intraspecific aggression, or intra-/inter-specific predation following human intrusion. All of these studies involved high levels of disturbance that are normally associated with nest-monitoring activities (entering colonies, marking nests, handling chicks, etc.). However, two studies reported that the negative influences of investigators on Ring-billed Gulls (*Larus delawarensis*) were nearly eliminated when careful measures were taken (Fetterolf 1981; Brown and Morris 1994, 1995). Some of these measures included visiting colonies early in the day to avoid thermal stress, avoiding unnecessary handling of chicks, and moving slowly when inside colonies.

Non-scientist disturbance also affected nesting charadrids, lowering reproductive success, reducing population sizes and affecting behavior. Hunt (1972) found that hatching success was inversely related to the level of disturbance introduced by picnickers. Indirect evidence suggested that recreator disturbance was responsible for the decline of a Western Gull (*Larus occidentalis*) population (Hand 1980). Erwin (1980) found that recreator disturbance precluded gull and tern nesting on barrier beaches in New Jersey. Tern colonies in New Jersey that were exposed to ecotourist activity were smaller and had lower reproductive success than did other colonies (Burger *et al.* 1995). Finally, though reproductive parameters were not measured, Burger (in press) found that terns were sensitive to motor boats and personal watercraft activity; the greatest number of terns flew above the colony during close or high-speed watercraft approaches.

Sometimes human disturbance had little apparent impact. A mixed colony of Northern Fulmars (*Fulmarus glacialis*), Shags (*Phalacrocorax aristotelis*), Herring Gulls (*Larus argentatus*), Black-legged Kittiwakes (*Rissa tridactyla*), Common Murres (*Uria aalge*), Razorbills (*Alca torda*), and Atlantic Puffins (*Fratercula arctica*) in Scotland demonstrated virtually no reaction behaviorally or reproductively to flights by fixed-wing aircraft within 100 m of the colony (Dunnet, 1977). Black Noddies (*Anous minutus*) nesting on Heron Island, Australia had similar nesting densities in protected and developed areas (Barnes and Hill 1989).

Two studies examined the response of nesting charadrids to human approach. Mixed colonies of Common Terns (*S. hirundo*) and Black Skimmers (*Rynchops niger*) in Virginia and North Carolina flushed at average distances of 142 and 130 m when humans approached the colony directly (Erwin 1989). Rodgers and Smith (1995) found that these same species flushed at an average of 80 m distance in Florida. Least and Royal Terns (*Sterna antillarum* and *S. maxima*) in Virginia and North Carolina were less sensitive, and flushed at average distances of 64 and 106 m (Erwin 1989).

Ciconiiformes (herons, egrets, and ibises)

Nine studies examined the effects of a variety of human disturbances on this group of birds, including investigator, logging, and ecotourism activity. In the case of the Black-crowned Night Heron (*Nycticorax nycticorax*), the effects of human disturbance on nesting birds were limited to those incurred by scientific investigators. Tremblay and Ellison (1979) found that nest checking and marking provoked abandonment of newly-constructed nests and intensified predation of nest contents by gulls and ravens. Frequent investigator disturbance also discouraged late-nesting in these herons. Parsons and Burger (1982), however, suggested that Black-crowned night Heron chicks habituated to investigator disturbance and handling. At three weeks of age, all regularly-handled experimental chicks remained in their nests during disturbance. All control chicks, however, left the vicinity of the nest, sometimes fleeing the nesting tree altogether. In contrast, Davis and Parsons (1991) found that Snowy Egret (*Egretta thula*) chicks did not habituate to human intrusion, but no differences in survivorship were found between chicks handled twice daily from hatching and chicks handled only during banding (age 7-10 d). Frequency of visitation also had no effect on the reproductive success of Tricolored Herons (*Egretta tricolor*) during courtship and early egg-laying (Frederick and Collopy 1989).

Human disturbance associated with logging operations affected colony size, nest occupancy rate, and fledging rate of Great Blue Herons (*Ardea herodias*) nests (Werkschul *et al.* 1976). Nesting activity also shifted away from the point of disturbance. Vos *et al.* (1985) found the response of nesting Great Blue Herons to disturbance was dependent upon the type of intruder (boater, horseback rider, or person on foot). Herons were most sensitive to land-related intrusions; 61% of these disturbances resulted in nest abandonment.

When appropriate buffers were set up and monitored; however, human visitation of heronries resulted in no ill-effects (Burger *et al.* 1995). Heronries surrounded by a buffer zone of only 50 m that were visited daily by tourists suffered no short-term reproductive losses, and birds seemed generally unconcerned with human presence near the colony. However, when a group of tourists at an unwardened site entered a heronry, nest mortality rates of 15-28% per heron species resulted (Burger *et al.* 1995).

Goering and Cherry (1971) concluded that investigator disturbance associated with nest-checks did not adversely affect productivity of a colony of mixed species (Cattle Egret, *Ibubulcus ibis*; Little Blue Heron, *Florida caerulea*; Snowy Egret, *Leucophoyx thula*; Louisiana Heron, *Hydranassa tricolor*; Black-crowned Night Herons); nesting success of sites disturbed less frequently (once every eight days) was lower than of sites disturbed more frequently (once every two days). However, they failed to consider the possibility that certain species may habituate to disturbance, leaving nests disturbed more often at an advantage. They also analyzed reproductive data from all five species as a whole, and did not examine differing responses among species.

Erwin (1989) approached mixed colonies of wading birds (Black-crowned Night Herons; Snowy Egrets; Great Egrets, *Casmerodius albus*; Tricolored Herons; Little Blue Herons, *Egretta caerulea*; Cattle Egrets, *Bubulcus ibis*; Glossy Ibises, *Plegadis falcinellus*; and White Ibises, *Eudocimus albus*) to determine the average distance at which each species flushed; most flushed between 30-50 m. He suggested a buffer zone of 100 meters to minimize disturbance. Rodgers and Smith (1995) also found that a buffer of 100 m was sufficient to prevent flushing in colonies of similar species composition.

DISCUSSION

There is increasing recognition that the effect of human disturbance on waterbird colonies is highly dependent on the nature of the disturbance (Burger *et al.* 1995; Klein *et al.* 1995). Generally, there are three main categories of human disturbance. First, there are scientific investigators, people who often need to closely monitor demographic parameters of colonial waterbirds. Their work often presents the most intense kinds of disturbance: entering colonies, handling nest contents, and capturing adults. However, most scientists are quite aware of the potentially harmful effects of their work. Scientists often limit activities to small segments of a colony and are careful to take precautions which are known to reduce or ameliorate negative effects of intrusion (Brown and Morris 1995). Second, there are ecotourists, people who travel primarily to experience free-ranging wildlife (Burger *et al.* 1995). Ecotourists (including wildlife photographers) can also introduce high levels of disturbance to nesting waterbirds. They often approach wildlife to close distances, return repeatedly to the same places, and visit wildlife areas year-round (Burger *et al.* 1995). Wildlife photographers, attempting to enter colonies to secure the best images, can be particularly disruptive. Third, there are recreators, people who visit natural areas for reasons other than viewing or interacting with wildlife. Recreators can disturb nesting colonial waterbirds as well, but often to a lesser extent. Hikers, joggers, bikers, boaters, etc. are more likely to come into contact with wildlife incidentally and usually do not remain in close proximity to wildlife for extended periods of time. Though they tend to limit their activities to certain times of the year, peak use of natural areas is coincident with the breeding season of colonial waterbirds (e.g. during summer) (Burger *et al.* 1995; Klein *et al.* 1995). Ecotourists and recreators are not likely to be aware of the negative impacts that their presence may have on wildlife. Moreover, their behavior can be less predictable than those of scientists. Below, we refer to ecotourists and recreators collectively as "visitors", to distinguish this type of human activity from that of scientific investigators. Though ecotourists and recreators represent differing types and levels of disturbance, there is not enough research on these groups to warrant discussion of each individually. We also use the terms "nesting colonial waterbird" and "waterbird" interchangeably.

Investigator disturbance impacts

Because scientists have long been interested in effects of their own activities, investigator disturbance has been relatively well studied (Table 1). In many cases, because of intrusive methods, investigators had significant impacts on reproductive performance

Table 1. Types of human disturbance examined and parameters measured to detect its effects in past investigations. Numbers refer to papers listed below.

	Disturbance type		
	Investigator	Visitor	Aircraft/Watercraft
Physiological parameters	6, 18, 40, 48, 63	18, 40, 59, 63	18, 48, 63
Behavior	1, 2, 8, 9, 11, 15, 17, 25, 29, 35, 41, 42, 44, 58, 61, 63	1, 2, 12, 13, 15, 24, 35, 31, 37, 50, 56, 58, 59, 63	14, 21, 54, 63
Reproductive success	2, 5, 7, 8, 16, 19, 20, 22, 25, 26, 27, 28, 30, 41, 42, 43, 45, 46, 47, 49, 51, 52, 53, 57	2, 3, 13, 26, 27, 36, 45, 56, 59, 63	10, 63
Nest distribution patterns (relative to disturbance)	22, 62	3, 4, 12, 23, 33, 34, 60, 62, 64	63
Breeding population size trends (over multiple seasons)	26, 55, 62	3, 4, 23, 26, 32, 33, 34, 38, 39, 55, 62, 64	32, 39, 55

1. Ainley 1974
2. Anderson and Keith 1980
3. Anderson 1988
4. Barnes and Hill 1989
5. Boellstorff *et al.* 1988
6. Boyd and Sladen 1971
7. Brown and Morris 1994
8. Brown and Morris 1995
9. Brubeck *et al.* 1981
10. Bunnel *et al.* 1981
11. Burger 1981
12. Burger and Gochfeld 1993
13. Burger *et al.* 1995
14. Burger in press
15. Burger and Gochfeld in press
16. Cairns 1980
17. Conover and Miller 1978
18. Culik *et al.* 1990
19. Davis and Parsons 1991
20. DesGranges and Reed 1981
21. Dunnett 1977
22. Ellison and Cleary 1978
23. Erwin 1980
24. Erwin 1989
25. Fetterolf 1983
26. Fraser and Patterson 1997
27. Giese 1996
28. Gillet *et al.* 1975
29. Gochfeld 1981
30. Goering and Cherry 1971
31. Hand 1980
32. Henny *et al.* 1989
33. Hill and Barnes 1989
34. Hill and Rosier 1989
35. Hockey and Hallinan 1981
36. Hunt 1972
37. Kury and Gochfeld 1975
38. Muller-Schwarze 1984
39. Nettleship 1975
40. Nimon *et al.* 1996
41. Nisbet *et al.* 1981
42. Ollason and Dunnet 1978
43. Ollason and Dunnet 1980
44. Parsons and Burger 1982
45. Patterson *et al.* in press
46. Piatt *et al.* 1990
47. Pierce and Simons 1986
48. Regel and Putz 1997
49. Robert and Ralph 1975
50. Rodgers and Smith 1995
51. Rodway *et al.* 1996
52. Safina and Burger 1983
53. Schreiber and Risebrough 1972
54. Sladen and LeResche 1970
55. Thomson 1977
56. Tindle 1979
57. Tremblay and Ellison 1989
58. Van Heezik and Seddon 1990
59. Vos et al. 1985
60. Wersckhul *et al.* 1976
61. Wilson *et al.* 1989
62. Wilson *et al.* 1990
63. Wilson *et al.* 1991
64. Woehler *et al.* 1994

of colonial waterbirds (Robert and Ralph 1975; Tremblay and Ellison 1979; Boellstorff *et al.* 1988; Rodway *et al.* 1996). Many investigators attempted to find ways to minimize their impact or, at a minimum, to document how their own activities influenced their data (Robert and Ralph 1975; Safina and Burger 1983; Rodway and Montevecchi 1996). For example, a modification of nest-monitoring techniques apparently eliminated negative effects of research activities on Ring-billed Gulls (Brown and Morris 1995). Such techniques, including limiting the number of intrusions and their duration, minimizing physical contact with birds and moving slowly while in colonies, seemed to minimize negative effects for most species (Table 2).

We must emphasize here the varied responses of individual species and populations to investigator disturbance. Some species habituated to regular human intrusion (Goering and Cherry 1971; Robert and Ralph 1975; Parsons and Burger 1982), while others did not (Anderson and Keith 1980; Fetterolf 1983). Additionally, sensitivity to disturbance for certain species seems to vary within the breeding season. Some species were sensitive early in the season (courtship and early incubation) (Kury and Gochfeld

Table 2. Recommendations for minimizing investigator disturbance.

Family	Species	Suggestions for minimizing disturbance	Citation
Sphenisciformes	Adelie Penguin, Jackass Penguin	- approach closer than 30 m only when necessary	18, 35, 58
		- move slowly and deliberately when close to nests	40, 58
		- avoid penguin landing beaches	58
		- use the same boat-landing areas consistently	58
		- conduct highly disturbing work during incubation, when adults least likely to desert nests	58, 63
		- avoid large beach groups	58
		- avoid penguin transiting areas	63
		- approach dense colonies slowly and directly	35
		- handle birds only once per day	6
Procellariformes	Northern Fulmar	- flush birds off of nests as seldom as possible	43
		- minimize # of visitors (<12) to colony	43
		- minimize duration of visits (<4 days) to colony	43
Pelecaniformes	Pelicans	- only enter colonies when absolutely necessary	5
		- do not conduct research in colonies containing less than 500 nests	5
	Cormorants	- enter colonies only when necessary	20, 22, 37
	Boobies	- walk slowly when in close proximity to nests	12
		- work for only brief periods in any part of colony	12
Charidriiformes	Gulls. Skimmers, and Terns	- avoid visiting colonies before laying is complete	17, 41, 49, 52
		- terminate research activities after hatching	8, 11, 25, 52
		- visit colonies early in the day to avoid thermal stress	7 , 29
		- avoid unnecessary handling of chicks	7, 11, 29
		- calm chicks which have been handled by covering with a hand briefly before departure	7
		- move slowly and deliberately inside colonies	7, 11
		- handle adults as briefly as possible	9
	Puffins	- disturb burrows only during nestling period	47, 51
Ciconiiformes	Herons	- delay visiting nests until one week before hatching	57
		- limit visitation to once every three days	57
		- avoid visiting colony during inclement weather	57
		- obtain reproductive data at a distance when possible	57
		- if planning to enter colonies to monitor reproductive success, do so repeatedly throughout the chick phase to enable habituation.	44

See Table 1 for citation number codes.

1975; Tremblay and Ellison 1979; Vos *et al.* 1985), some late in the season (chick phase) (Gillet *et al.* 1975; Gochfeld 1981; Fetterolf 1983), while others suffered from disturbance during both early and late reproductive stages (Conover and Miller 1978; Burger 1981, Anderson and Keith 1980).

Though much progress has been made in understanding researcher disturbance, there are two main weaknesses in the literature. First, there may be a tendency of scientists and journals alike to publish only studies that find significant disturbance effects. Publication of studies that find no effect should be encouraged, given the trend to regard research as harmful to waterbirds. Finally, researchers have been responsible for monitoring their own effects, presenting a potentially strong bias; studies should be conducted where the investigator is not aware that his or her effect is being monitored (Duffy 1994).

Table 3. Recommendations for minimizing visitor disturbance.

Family	Species	Approach distance (m)	Precautions which minimize disturbance	Citation
Sphenisciformes	Adelie Penguin, Jackass Penguin	30	- maintain a minimum buffer of 30 m	18, 35, 58
			- limit the # of colonies visited	58
			- avoid penguin landing beaches	58
			- use the same boat-landing areas consistently	58
			- visit during mid-day, when beach groups are smallest	58
			- avoid penguin transiting areas	63
			- when operating aircraft, approach colonies no closer than 1-2000 m	18, 54, 63
Procellariformes	Laysan Albatross	3?	- can approach to 3 m if approach is tangential	15
			- limit the number of colonies visited, leave some entirely undisturbed	15
Pelecaniformes	Pelicans	100-600?	- create a buffer (100-600 m?) between nests and human activities	3, 50
	Cormorants	50-100?	- do not enter colonies	20, 22, 37, 50
			- visit during late-nesting phases	20, 22, 37
			- construct blinds or observation posts at safe distances (?) from colonies	37, 50
	Boobies	10?	- create a buffer of 10 m between human and nesting activity?	12
Charidriiformes	Gulls, Terns	100-180	- do not enter colonies	25, 28, 29, 49, 50
	Skimmers	180-200?	- create a buffer zone of 180-200 m	24, 29, 50
	Common Tern	100-200?	- create a buffer zone of 100-400 m	14, 24, 50
			- limit approach of watercraft to 100 m	14
			- limit speeds of watercraft in vicinity of colonies	14
	Least and Royal Terns	100	- create a buffer zone of 100 m	24
Ciconiiformes	Herons	50-250?	- create buffers between nesting and human activities	13, 24, 50, 60
			- construct observation points at safe distances (?) from the colony	13, 24, 50

See Table 1 for citation number codes.

Visitor disturbance impacts

Although investigator disturbance has been relatively well studied, the effects of visitor disturbance have not. Thirty studies (Table 1) have been conducted on the effects of visitors on waterbirds; most concerned penguins. Many of these studies may be characterized as anecdotal accounts; they simply note an increase in human visitation and coincident change in waterbird productivity or population size or distribution (e.g. Nettleship 1975; Hand 1980; Wilson *et al.* 1990; Woehler *et al.* 1994). Most studies did not identify mechanisms through which reproductive failure might occur, examine the relative impacts of different types of human visitation, or control for confounding influences (but see Vos *et al.* 1985; Burger *et al.* 1995). Nevertheless, a few guidelines for minimizing negative impacts of visitor activities may be obtained from past studies (Table 3). A buffer of 30 m between human activity and nesting penguins (approach distance) was recommended by three studies (Table 3). For other groups, approach distance either remains unknown or appear variable, making generalizing difficult; a possible exception are Charidriformes, with an approach distance likely between 100-200 m. All groups appear sensitive to visitor intrusion (Table 3).

Knowledge gaps and future research

In general, little is known concerning the effects of visitor activity on waterbirds and, with the exception of work on penguins, most research has yielded little practical information. For instance, what types of visitors and which visitor activities are the most disturbing to waterbirds? At what distance are waterbirds first perturbed by human activity (approach distance)? Answering the second question above is needed to develop scientifically defensible ecotourism policies, yet only three studies have rigorously addressed the issue (Erwin 1989; van Heezik and Seddon 1990; Rodgers and Smith 1995).

Future disturbance investigations also should ensure that the impact of the methods of monitoring disturbance is not greater than the visitation disturbance itself. The most effective research methods for detecting visitation impacts will entail monitoring behavior and breeding biology at a distance or following short-term changes in population size and distribution. Since many other factors are known to influence population size and distribution (e.g. food availability, presence of predators, etc.), these should also be monitored. Though less invasive techniques may yield less accurate information (viewing nest contents from afar may be difficult), they are the only appropriate methods for this type of scientific inquiry. More attention needs to be focused on the development of minimally-invasive techniques that permit the collection of accurate data and result in minimal disturbance to the birds being studied (see Fitch and Shugart 1981; Nimon *et al.* 1996). Remote monitoring of nests with video cameras is one such possibility.

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