PREY OF PEREGRINE FALCONS FROM THE NEW JERSEY COAST AND ASSOCIATED CONTAMINANT LEVELS

ROBERT J. STEIDL,[1] Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003

CURTICE R. GRIFFIN, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003

THOMAS P. AUGSPURGER,[2] U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, 927 North Main Street, Pleasantville, NJ 08232

DANIEL W. SPARKS,[3] U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, 927 North Main Street, Pleasantville, NJ 08232

LAWRENCE J. NILES, New Jersey Division of Fish, Game, and Wildlife, Endangered and Nongame Species Program, P.O. Box 236, Tuckahoe, NJ 08625

Abstract: Peregrine falcon *(Falco peregrinus)* populations have been successfully reestablished in many regions of the United States. However, populations in some coastal areas have been slow to recover from declines caused by environmental contaminants. We assessed diets of a reestablished falcon population from coastal New Jersey. Twenty-nine of 37 prey species (78%) collected were migratory birds that comprised 65% of diets by occurrence (215 of 332 prey items) and 69% by biomass. Migratory birds, however, comprised higher proportions in diets of falcons that nested near the Atlantic coast (78%) than those that nested farther inland (57%, P <0.0001). Organochlorine pesticide and mercury levels collected from a sample of lower trophic level prey were below levels thought to impair falcon reproduction.

Key words: contaminants, diets, *Falco peregrinus*, New Jersey, peregrine falcon, prey.

Many peregrine falcon populations declined and several populations were eliminated from much of their breeding range by the mid-1960s (Hickey 1969, Ratcliffe 1980). The principal reason for these declines was reproductive failure caused by environmental contaminants (Peakall 1976, Risebrough 1986). Following a decline in use of these contaminants, many falcon populations have increased in size and have shown signs of reproductive recovery (Cade et al. 1988).

Peregrines were subsequently reintroduced into many areas of North America (Barclay and Cade 1983). These reintroduced birds now provide the foundation for several populations, including the population in New Jersey. From 1979 to 1988, the population introduced to coastal New Jersey reproduced at apparently normal levels,

---

[1]Present Address: School of Renewable Resources, 325 Biological Science East, University of Arizona, Tucson, AZ 85721

[2]Present Address: U.S. Fish and Wildlife Service, Ecological Services, P.O. Box 33726, Raleigh, NC 27636

[3]Present Address: U.S. Fish and Wildlife Service, Ecological Services, 620 S. Walker Street, Bloomington, IN 47404

yet their eggshells were 16.4% thinner than pre-DDT eggshells during 1984-88 (Steidl et al. 1991). This amount of eggshell thinning approached the critical level of 17%, above which all other peregrine populations have shown severe declines or were extirpated (Peakall and Kiff 1988). Reproductive failure in some peregrine falcon pairs from coastal New Jersey (Steidl et al. 1991) motivated us to assess the prey of these falcons. In 1987 and 1988, we collected prey remains during the nestling period and, in 1989, we determined levels of organochlorines and mercury in a sample of common prey species.

We thank C. D. Jenkins and K. E. Clark for assistance throughout our study, and R. Dickerman and M. LeCroy, American Museum of Natural History, D. Parris, New Jersey State Museum, and A. F. O'Connell for assisting with prey identification. We acknowledge funding provided by New Jersey Division of Fish, Game, and Wildlife (Endangered and Nongame Species Program), U. S. Fish and Wildlife Service, and the Oregon Cooperative Wildlife Research Unit. This manuscript has benefited from comments by R. Bromley, S. DeStefano, W. D. Edge, S. Olson-Edge, and G. D. Therres.

STUDY AREA AND METHODS

We studied 3 pairs of peregrine falcons nesting atop towers on the Atlantic coast (Sea Isle City, Tuckahoe) and on Delaware Bay (Heislerville) in southern New Jersey. Towers were located on salt marsh estuaries dominated by salt marsh cordgrasses *(Spartina alterniflora* and *S. patens)*. The pairs along the Atlantic coast nested 2.5 and 7.5 km from the ocean and the pair on Delaware Bay nested 23 km from the ocean, <1 km from the Bay.

We collected prey remains in and around nests in both 1987 and 1988. Most remains were collected at weekly visits during the nestling period, although lesser amounts were collected during incubation and after nestlings fledged. Prey remains were compared to museum specimens for identification. We determined the minimum number of individuals collected by grouping all conspecific remains and determining the maximum number of representative body parts (e.g., 3 left wings and 2 right wings yielded 3 individuals). To determine species biomass in falcon diets, we used mass of prey as reported in Terres (1982).

We used a shotgun with steel shot to collect 53 individuals of 4 avian species within 3 km of falcon eyries. These species accounted for 50% of falcon diets by occurrence and 51% by biomass based on the prey we collected during the nestling period. Two composite samples of each species (1-5 individuals/composite) from 2 areas on both the Atlantic and Delaware Bay coasts were collected during the nestling period of 1989 (late April to early June). Prey were prepared for analysis by removal of feathers, feet, beak, and gastrointestinal tract, and then were wrapped in solvent-rinsed, air-dried aluminum foil and frozen.

We examined prey for levels of organochlorines and mercury. Organochlorine analyses were performed by Mississippi State Chemical Laboratory and mercury analyses were performed by Research Triangle Institute following methods described by U.S. Fish and Wildlife Service (1991a). Detection limits were 0.01 ppm wet weight for organochlorines, 0.05 ppm

wet weight for total PCBs, and 0.02 ppm dry weight for mercury. Spike recoveries ranged from 92-112%; residue levels were not adjusted for percent recovery. To calculate composite means, we assigned a value of half the detection limit to contaminants that occurred below these limits only when contaminants were present in at least half of our samples. For DDT and metabolites, we report only p, p' isomers because no o, p' isomers occurred above detection limits in any samples.

RESULTS AND DISCUSSION

Diets

We collected 332 individual prey items representing 37 avian species at peregrine eyries during the nestling periods of 1987 and 1988 (Table 1). Migratory species dominated the diets of these coastal falcons: 29 of 37 species (78%) were migratory and comprised 65% by occurrence and 69% by biomass of diets of all pairs. The only resident species that contributed substantially to falcon diets were blue jays *(Cyanocitta cristata)*, common grackles *(Quiscalus quiscula)*, and fish crows *(Corvus ossifragus)*, which comprised 7-15% by occurrence (Table 1). Because the pair along Delaware Bay (Heislerville) fledged no young in either year (Steidl et al. 1991), the number of prey collected from this pair was limited (n = 16); therefore, we restricted further analyses to prey collected from Atlantic coast nests.

Mass of prey captured was similar between years for each pair (t <1.1, P >0.28), so we combined years for analyses. Mass (±SE) of prey from the Tuckahoe pair (221.5 ± 11.4, n = 190) was significantly heavier than prey from the Sea Isle City pair (167.7 ± 10.2, n = 126) (t = 3.4, P = 0.0007); mass of prey from the Heislerville pair was 217.0 (SE = 46.5; n = 16).

Although falcon pairs from the Atlantic coast nested <25 km apart, their prey use differed considerably. Only 15 of 35 species (43%) were taken by both pairs. Migratory birds comprised most of the prey taken by both pairs, but the diet of the pair nearest the ocean (Sea Isle City) contained a higher percentage of migrants (78% by occurrence) than the pair farther inland (Tuckahoe = 57%; G = 19.6, P < 0.0001). Further, the number of migratory transients (birds that migrate through but do not nest in southern New Jersey) in falcon diets also differed between pairs. The diet of the pair nearest the ocean contained a higher percentage of these birds (44% vs 12% by occurrence) (G = 40.3, P < 0.0001).

Differences in prey composition and prey mass between pairs of peregrine falcons seemed to be related to the distance pairs nested from the ocean. The coast and its strip of adjacent estuarine tidal flats are a corridor for migratory birds; hence, differences in prey composition between pairs were a function of the number of migrants taken, which was probably affected by the location of an eyrie. Prey composition from an inland coastal eyrie in Maryland was similar to that of our more inland Atlantic Coast eyrie, Tuckahoe (Barber and Barber 1988). Previous studies suggested that prey selected by peregrines generally reflected prey abundance near eyries (Ratcliffe 1980, Hunter et al. 1988).

Prey Contaminants

Contaminant levels in peregrine falcon prey collected during the nestling period did not vary appreciably among those species sampled (Table 2). The 3 resident species contained contaminant levels similar

Table 1. Prey of peregrine falcons nesting in coastal New Jersey, 1987-88 (N% = percent frequency by occurrence, B% = percent biomass).

	Sea Isle City			Tuckahoe			Heislerville			All Nests		
Prey species	*n*	N%	B%	*n*	N%	B%	*n*	N%	B%	*n*	N%	B%
Little blue heron (*Egretta caerulea*) mb[a]	4	3.2	2.4							4	1.2	0.8
Black-crowned night-heron (*Nycticorax nycticorax*) mb							1	6.3	23.3	1	0.3	1.2
American black duck (*Anas rubripes*) rb				2	1.1	5.6				2	0.6	3.6
Clapper rail (*Rallus longirostris*) mb	9	7.1	13.4	1	0.5	0.7				10	3.0	4.7
Black-bellied plover (*Pluvialis squatarola*) mt	1	0.8	1.1	1	0.5	0.6				2	0.6	0.7
Killdeer (*Charadrius vociferous*) mb				1	0.5	0.2				1	0.3	0.1
Greater yellowlegs (*Tringa melanoleuca*) mt				1	0.5	0.5				1	0.3	0.3
Lesser yellowlegs (*Tringa flavipes*) mt				2	1.1	0.4				2	0.6	0.2
Willet (*Catoptrophorus semipalmatus*) mb	17	13.5	22.7	40	21.1	26.8	4	25.0	32.5	61	18.5	25.9
Whimbrel (*Numenius phaeopus*) mt	1	0.8	2.6							1	0.3	0.8
Ruddy turnstone (*Arenaria interpres*) mt	4	3.2	2.2							4	1.2	0.7
Red knot (*Caldris canutus*) mt							1	6.3	4.5	1	0.3	0.2
Sanderling (*Calidris alba*) mt	6	4.8	4.7	1	0.5	0.4				7	2.1	1.7
Semipalmated sandpiper (*Calidris pusilla*) mt	2	1.6	0.3	1	0.5	0.1				3	0.9	0.1
Least sandpiper (*Calidris minutilla*) mt	1	0.8	0.1							1	0.3	0.1
Dunlin (*Calidris alpina*) mt	3	2.4	0.9	2	1.1	0.3				5	1.5	0.5
Short-billed dowitcher (*Limnodromus griseus*) mt	35	27.8	19.1	15	7.9	4.1	3	18.8	9.9	53	16.0	9.2
Laughing gull (*Larus atricilla*) mb	3	2.4	5.0	33	17.4	27.8				36	10.9	19.2
Forster's tern (*Sterna forsteri*) mb				1	0.5	0.3				1	0.3	0.2

Table 1. (continued)

Prey species	Sea Isle City *n*	Sea Isle City N%	Sea Isle City B%	Tuckahoe *n*	Tuckahoe N%	Tuckahoe B%	Heislerville *n*	Heislerville N%	Heislerville B%	All Nests *n*	All Nests N%	All Nests B%
Least tern *(Sterna antillarum)* mb	2	1.6	0.3	1	0.5	0.1				3	0.9	0.1
Rock dove *(Columba livia)* rb				3	1.6	2.1				3	0.9	1.3
Mourning dove *(Zenaida macroura)* rb	4	3.2	2.4							4	1.2	0.8
Yellow-billed cuckoo *(Coccyzus americanus)* mb	1	0.8	1.3							1	0.3	0.4
Northern flicker *(Colaptes auratus)* rb				4	2.1	1.3				4	1.2	0.8
Eastern kingbird *(Tyrannus tyrannus)* mb	3	2.4	0.6							3	0.9	0.2
Purple martin *(Progne subis)* mb				2	1.1	0.2				2	0.6	0.1
Blue jay *(Cyanocitta cristata)* rb	11	8.7	4.3	36	18.9	7.0	2	12.5	4.7	49	14.8	6.1
Fish crow *(Corvus ossifragus)* rb	7	5.6	13.6	14	7.4	13.6	1	6.3	11.8	22	6.6	13.6
Hermit thrush *(Catharus guttatus)* mb	1	0.8	0.1							1	0.3	0.0
American robin *(Turdus migratorius)* mb	3	2.4	1.0	3	1.6	0.5				6	1.8	0.6
Gray catbird *(Dumetella carolinensis)* mb	1	0.8	0.2							1	0.3	0.1
European starling *(Sturnus vulgaris)* rb	1	0.8	0.4							1	0.9	0.2
Rose-breasted grosbeak *(Pheucticus ludovicianus)* mt	1	0.8	0.2							1	0.3	0.1
Savannah sparrow *(Passerculus sandwichensis)* mb	1	0.8	0.1	1	0.5	0.0				2	0.6	0.1
Red-winged blackbird *(Agelaius phoeniceus)* mb	2	1.6	0.5	1	0.5	0.1				3	0.9	0.2
Common grackle *(Quiscalus quiscula)* rb	5	4.0	2.7	23	12.1	6.3	4	25.0	13.2	32	9.7	5.5
Northern oriole *(Icterus galbula)* mb	1	0.8	0.2							1	0.3	0.1
TOTALS	126	100	100	190	100	100	16	100	100	332	100	100

[a] Migratory and breeding status in southern New Jersey: rb = resident breeder, mb = migratory breeder, mt = migratory transient.

to those of willets *(Catoptrophorus semipalmatus)*, the only long-distance migrant sampled. Most of our data on prey use were collected during the nestling period. However, if prey consumed prior to egg laying differed from that consumed during the nestling period, contaminant burdens in prey sampled after egg formation and laying may not accurately represent burdens in eggs. For example, willets were the most common prey species consumed during the nestling period (Table 1), but have not yet returned to this region before falcons lay eggs.

Dietary levels of contaminants affecting peregrine reproduction have not been tested directly; therefore, assessing critical levels is subjective. Only the effects of DDE have been studied sufficiently to suspect that dietary levels >1 ppm (wet weight) may impair reproduction (Peakall et al. 1990). Levels of PCBs >5 ppm (wet weight) and mercury >0.5 ppm (dry weight) have reduced egg hatchability, altered courtship behavior, delayed nesting, and impaired other aspects of reproduction in other birds (Peakall 1976, Eisler 1986, 1987, Scheuhammer 1987). Contaminant

Table 2. Arithmetic mean and range of organochlorides and mercury residues (ppm wet weight) from bodies of selected peregrine falcon prey from coastal New Jersey, 1989.

Species	*n*[a]	DDE	DDT	DDD	Total PCBs[b]	Chlordanes[b]	Dieldrin	Mercury
Willet[c]	4 (5)	0.49	0.02	0.01	0.4	0.02	0.02	0.21
		0.32-0.75	nd[d]-0.05	nd-0.02	0.2-0.6	0.02-0.02	0.01-0.02	0.18-0.22
Common grackle	4 (5)	0.70	0.02	0.01	0.1	0.10	0.02	0.06
		0.54-0.90	nd-0.06	nd-0.02	nd-0.2	0.07-0.12	0.01-0.04	0.04-0.07
Blue jay	4 (3)	0.32	0.03	0.02	0.9	0.12	0.02	0.06
		0.08-0.47	0.02-0.06	nd-0.02	0.1-3.1	0.04-0.27	0.01-0.04	0.03-0.08
Fish crow	1 (1)	0.90	nd	nd	1.7	0.11	0.02	0.20

[a] No. composite samples analyzed (mean no. individuals per composite).
[b] Sum of all metabolites and congeners.
[c] Samples contained a mean of 0.93 (range = 0.59-1.20) ppm Arsenic.
[d] Not detected.

levels in prey we examined were generally below these critical levels which may reflect the lower trophic level positions of the species we sampled. It is important to note, however, that the lack of isomer-specific analyses limits our ability to interpret PCB residues. Non-ortho-substituted and mono-ortho-substituted chlorinated biphenyls, structurally similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin, are potent reproductive toxicants (Kubiak et al. 1989, Giesy et al. 1994) capable of producing adverse effects at levels well below those we found or those levels typically associated with PCB concentrations reported on an Arochlor or total basis. Further, contaminant levels in falcon prey depend on diet, foraging habitat, and migratory status of prey (Lindberg et al. 1985, DeWeese et al. 1986). Migratory birds usually contain higher contaminant loads than resident birds (e.g., Lincer et al. 1970, DeWeese et al. 1986, Ellis et al. 1989), presumably from use of persistent pesticides in their wintering areas. Higher contaminant levels typically found in piscivorous species (Lincer et al. 1970, Lindberg et al. 1985) suggest that other important prey species we documented, such as gulls, terns, and herons, may be an important source of contaminants to peregrines in estuarine environments. Of particular importance would be any of these estuarine species that comprise a significant component of peregrine diets the weeks prior to egg formation and laying.

Assuming reintroduced falcons were free of contaminants when released, considerable evidence suggests that peregrines from this region may be accumulating significant contaminant burdens. Carcass concentrations of 1.6 ppm DDE and 3.6 ppm PCBs in a fledgling peregrine found dead in 1989 and elevated concentrations of 9.6-27 ppm DDE and 14-99 ppm total PCBs found in breeding age birds (6-10-yrs old) that nested in coastal New Jersey indicate significant accumulation of organochlorines (U. S. Fish and Wildlife Service. 1991b). Substantial total PCB (6-19 ppm) and DDE (5-18 ppm) residues were also found in New Jersey peregrine eggs collected between 1981 and 1984 (Gilroy and Barclay 1988). Further, eggshells collected during 1981-84 averaged 9.4% thinner than pre-DDT eggshells (Gilroy and Barclay 1988), whereas those collected during 1984-88 decreased to 16.4% thinner than pre-DDT eggshells (Steidl et al. 1991).

Peregrine falcons in several coastal areas of the world have shown more signs of reproductive impairment than birds nesting in inland areas (Walton et al. 1988, Newton et al. 1989). This is likely because coastal regions are concentration areas for migratory birds as well as contaminants (Livingston 1976). Although productivity of reestablished peregrines in New Jersey has remained above the level thought necessary to sustain the population, some evidence suggests that this population of coastal falcons could continue to accumulate potentially harmful contaminant burdens. We suggest that future monitoring efforts sample contaminant residues in falcon prey that are most important during egg formation, especially piscivorous species, based either on levels of prey near specific eyries, or preferably, on prey consumed by peregrines during egg formation.

LITERATURE CITED

Barber, J. C., and M. M. Barber. 1988. Prey of an urban peregrine falcon-Part II. Maryland Birdlife 44:37-38.

Barclay, J. H., and T. J. Cade. 1983. Restoration of the peregrine falcon in the eastern United States. Bird Conserv. 1:3-37.

Cade, T. J., J. H. Enderson, C. G. Thelander, and C. M. White, Eds. 1988. Peregrine falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID. 949pp.

DeWeese, L. R., L. C. McEwen, G. L. Hensler, and B. E. Petersen. 1986. Organochlorine contaminants in passeriformes and other avian prey of the peregrine falcon in the western United States. Environ. Toxicol. And Chem. 5:675-693.

Eisler, R. 1986. Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildl. Serv. Biol. Rep. 85 (1.7), Laurel, MD. 72pp.

_____. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildl. Serv. Biol. Rep. 85(1.10), Laurel, MD. 90pp.

Ellis, D. H., L. R. DeWeese, T. G. Grubb, L. F. Kiff, D. G. Smith, W. M. Jarman, and D. B. Peakall. 1989. Pesticide residues in Arizona peregrine falcon eggs and prey. Bull. Environ. Contam. Toxicol. 42:57-64.

Giesy, J. P., J. P. Ludwig, and D. E. Tillitt. 1994. Deformities in birds of the Great Lakes region: assigning causality. Environ. Sci. Technol. 28:128-135.

Gilroy, M. J., and J. H. Barclay. 1988. DDE residues and eggshell characteristics of reestablished peregrines in the eastern United States. Pages 403-411 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White, eds. Peregrine falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID.

Hickey, J. J., (editor). 1969. Peregrine falcon populations: their biology and decline. Univ. Wisconsin Press, Madison, WI. 569pp.

Hunter, R. E., J. A. Crawford, and R. E. Ambrose. 1988. Prey selection by peregrine falcons during the nestling stage. J. Wildl. Manage. 52:730-736.

Kubiak, T. J., H. J. Harris, L. M. Smith, T. R. Schwartz, D. L. Stalling, J. A. Trick, L. Sileo, D. E. Docherty, and T. C. Erdman. 1989. Microcontaminants and reproductive impairment in Forester's tern on Green Bay, Lake Michigan 1983. Arch. Environ. Contam. Toxicol. 18:706-727.

Lincer, J. L., T. J. Cade, and J. M. Divine. 1970. Organochlorine residues in Alaskan peregrine falcons *(Falco peregrinus* Tunstall*)*, rough-legged hawks *(Buteo lagopus* Pontoppidan*)* and their prey. Can. Field-Nat. 84:255-263.

Lindberg, P., T. Odsjö, and L. Reutergärdh. 1985. Residue levels of polychlorobiphenyls, DDE, and mercury in bird species commonly preyed upon by the peregrine falcon *(Falco peregrinus* Tunst*)* in Sweden. Arch. Environ. Contam. Toxicol. 14:203-212.

Livingston, R. J. 1976. Dynamics of organochlorine pesticides in estuarine systems: effects on estuarine biota. Pages 507-522 *in* M. Wiley, ed. Estuarine processes, Vol.1. Academic Press, New York, NY.

Newton, I., J. A. Bogan, and M. B. Haas. 1989. Organochlorines and mercury in the eggs of British peregrines *Falco peregrinus*. Ibis. 131:355-376.

Peakall, D. B. 1976. The peregrine falcon *(Falco peregrinus)* and pesticides. Can. Field-Nat. 90:301-307.

_____, and L. F. Kiff. 1988. DDE contamination in peregrines and American kestrels and its effect on reproduction. Pages 337-350 *in* T.J. Cade, J.H. Enderson, C.G. Thelander, and C.M. White, eds. Peregrine falcon populations: their management and recovery.The Peregrine Fund, Inc., Boise, ID.

_____, D. G. Noble, J. E. Elliott, J. D. Somers, and G. Erickson. 1990. Environmental contaminants in Canadian peregrine fal-

cons, *Falco peregrinus*: a toxicological assessment. Can. Field-Nat. 104:244-254.

Ratcliffe, D. 1980. The peregrine falcon. Buteo Books, Vermillion, SD. 416pp.

Risebrough, R. W. 1986. Pesticides and bird populations. Pages 397-427 *in* R. F. Johnston, ed. Current ornithology, Vol. 3, Plenum Press, New York.

Scheuhammer, A. M. 1987. The chronic toxicity of aluminum, cadmium, mercury, and lead in birds: a review. Environ. Pollut. 46:263-295.

Steidl, R. J., C. R. Griffin, L. J. Niles, and K. E. Clark. 1991. Reproductive success and eggshell thinning of a reestablished peregrine falcon population. J. Wildl. Manage. 55:294-299.

Terres, J. K. 1982. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf, New York, NY. 1109pp.

U. S. Fish and Wildlife Service. 1991a. Environmental contaminants in the prey of Delaware Bay peregrine falcons *(Falco peregrinus)*. U.S. Fish and Wildl. Serv., Pleasantville, NJ. 58pp.

_____. 1991b. Environmental contaminants in southern New Jersey peregrine falcons *(Falco peregrinus)*. U.S. Fish and Wildl. Serv., Pleasantville, NJ. 78pp.

Walton, B. J., C. G. Thelander, and D. L. Harlow. 1988. The status of peregrines nesting in California, Oregon, Washington, and Nevada. Pages 95-104 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White, eds. Peregrine falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID.