Augmenting Small Populations of Plovers: An Assessment of Cross-Fostering and Captive-Rearing

ABBY N. POWELL*
FRANCESCA J. CUTHBERT
Department of Fisheries and Wildlife
University of Minnesota
1980 Folwell Avenue
St. Paul, MN 55108, U.S.A.

Abstract: *This study compared the growth and behavioral development of parent-reared, cross-fostered, and captive-reared Killdeer (*Charadrius vociferus*) chicks. Common species were used to test these techniques for possible application to rare and endangered forms. Parent-reared chicks were raised naturally in the wild, cross-fostered chicks were raised by Spotted Sandpipers (*Actitis macularia*) in the wild, and captive-reared chicks were raised in captivity by humans. Both hatching and fledging success were significantly increased by captive-rearing, and cross-fostering produced approximately the same number of fledged young as natural parent-rearing. Captive-reared Killdeer chicks spent more time resting and less time feeding, and stayed closer to siblings than cross-fostered or parent-reared chicks; these behavioral differences were not seen after release to the wild. Growth rates among the three groups were similar. All of the young Killdeer responded to Killdeer alarm calls. There was no evidence that captive-reared and cross-fostered Killdeer were negatively affected by their early experiences. Captive-rearing is a viable management technique for augmenting small populations of endangered shorebirds, such as the Piping Plover (*Charadrius melodus*). It is recommended over cross-fostering because captive-rearing is more flexible as a technique, produces more young, does not affect another species, and does not produce potential imprinting problems.*

Promoviendo el crecimiento de pequeñas poblaciones de Chorlitejos: una evaluación de la adopción cruzada y la crianza en cautiverio

Resumen: *Este estudio comparó el crecimiento y desarrollo del comportamiento de pichones de chorlitejo culirrojo (*Charadrius vociferus*) criados bajo tres regímenes distintos: criados por sus progenitores, criados bajo adopción cruzada y criados en cautiverio. Especies comunes fueron usadas para testear estas técnicas para su posible aplicación en especies raras y en peligro de extinción. Los pichones criados por sus progenitores fueron criados en estado salvaje, los pichones criados bajo adopción cruzada fueron criados por andarríos maculados (*Actitis macularia*) en estado salvaje, y los pichones criados en cautiverio fueron criados por humanos. El éxito en eclosionar y comenzar a volar fue significativamente incrementado por medio de la crianza en cautiverio; la adopción cruzada produjo aproximadamente el mismo número de jóvenes que comenzaron a volar que la crianza por progenitores naturales. Los pichones de chorlitejo culirrojo criados en cautiverio pasaron más tiempo descansando y menos tiempo alimentándose, y estuvieron más cerca de sus hermanos que los criados por adopción cruzada o por sus progenitores naturales; estas diferencias en el comportamiento no fueron observadas luego de ser puestos en libertad. Las tasas de crecimiento de los tres grupos fueron similares. Todos los chorlitejos culirrojos juveniles respondieron a las llamadas de alarma de otros chorlitejos culirrojos. No existió evidencia de que los chorlitejos culirrojos criados en cautiverio y en adopción cruzada estuviesen afectados negativamente por sus experiencias tempranas. La crianza en cautiverio es una técnica de manejo viable para promover el crecimiento de poblaciones pequeñas de pájaros costeros como el "piping plover" (*Charadrius melodus*). Se recomienda antes que la adopción cruzada porque la crianza en cautiverio es más flexible como técnica, produce más juveniles, no afecta otras especies, y no produce problemas potenciales de "imprinting".*

**Current address: Department of Biology, San Diego State University, San Diego, CA 92182-0413, U.S.A.*
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Introduction

The size and genetic variability of small populations can be increased through augmentation techniques such as captive-rearing and cross-fostering (Ryman & Laikre 1991). The risk of extinction owing to genetic and environmental stochasticity is increased in populations that have been reduced below a critical number of individuals (Gilpin & Soulé 1986). Once a population is extirpated from a portion of its native range, reintroduction of captive-bred or captive-reared animals is difficult for both biological and political reasons (Wemmer & Derrickson 1987; Cade 1988; Griffith et al. 1989; Kleiman 1989; Tate 1990). In addition, these reintroductions are expensive, controversial, and less likely to succeed than augmentation of existing populations. To date, many reintroduction efforts have not been tested well beforehand and have had inconclusive or poor results (Ptacek & Schwilling 1983; Byrd et al. 1984; Scott & Carpenter 1987; Zwank & Wilson 1987; Griffith et al. 1989). Preliminary testing of augmentation techniques and the use of surrogate species can predict the success of an effort to increase recruitment and subsequent survival of small populations (Zwank & Derrickson 1981; Brewer & Morris 1984; Scott & Carpenter 1987; Wallace & Temple 1987; Page et al. 1989).

Our study was initiated because captive-rearing and cross-fostering seemed to have potential as management tools for augmenting small populations of shorebirds (such as endangered species in the families Charadriidae, Recurvirostridae, and Scolopacidae), but few studies have quantified the practical and biological differences between these techniques (Drewien & Bizeau 1978; Cade et al. 1988). Captive-rearing involves collecting eggs from the wild, raising the young in captivity, and then releasing them back into the wild. Cross-fostering involves collecting eggs from the wild and substituting them in the nest of another species for hatching and rearing in the wild. In both cases, parent birds are able to renest and rear a second brood in the wild. Both captive-rearing and cross-fostering can significantly increase the reproductive success of individual breeding pairs and also bypass the expense and difficulties of keeping adults in captivity and inducing them to breed (Wemmer & Derrickson 1987; Clark & Harvey 1988; Kleiman 1989; King 1990). These techniques may be particularly suitable for managing small shorebird populations because this avian group has a rapid rate of physical and behavioral development (three to five weeks), a short period of parental dependency, and foraging is primarily innate. The possibility of imprinting to humans is diminished because most species of the Suborder Charadrii exhibit plumage monomorphism (therefore male chicks do not have to learn female plumage), young are raised with siblings, and there is little similarity between human foster parents and their avian "adopted" young (Immelmann 1972).

This study compared the growth and behavioral development of cross-fostered and captive-reared Killdeer (*Charadrius vociferus*) with naturally raised young in order to evaluate the potential of these techniques for enhancing recruitment into populations of endangered plovers. Killdeer were used as a surrogate species because they are common yet taxonomically similar to the endangered Piping Plover (*Charadrius melodus*). Spotted Sandpipers (*Actitis macularia*) were used as foster parents to Killdeer in cross-fostering experiments.

Study Area and Methods

Research was conducted on two islands with little human activity in northern Lake Michigan. Beaver Island (45° 45′ N, 85° 30′ W) is the largest island in Lake Michigan, and High Island (45° 45′ N, 85° 40′ W) is located 6.45 kilometers west of Beaver Island. All areas contained nesting habitat for Killdeer, Spotted Sandpipers, and Piping Plovers. Observations on wild Killdeer and cross-fostering experiments were conducted from mid-May to mid-August 1987–1989. Capture, banding, cross-fostering, and captive-rearing were conducted under U.S. Fish and Wildlife Service permits. As Killdeer nests were located, clutches were assigned to one of three experimental treatment groups: parent-reared, cross-fostered, or captive-reared.

Parent-Rearing

Parent-reared chicks were raised by their natural parents in the wild. All nests were monitored to determine hatching success and causes of nest failure. Chicks were captured and individually color banded at hatching.

Cross-Fostering

Cross-fostered Killdeer chicks were raised by Spotted Sandpipers in the wild. After a suitable Spotted Sandpiper nest was located, a complete clutch of Killdeer eggs was transferred to the nest for incubation, hatching, and rearing of young Killdeer. Spotted Sandpiper eggs were removed at the time of transfer, and nests were subsequently observed from a distance to ensure that adults resumed incubation.

Captive-Rearing

Preliminary experiments on captive-rearing took place in 1988 on High Island. Newly-hatched chicks were collected rather than eggs, however, since artificial incubation could not be accomplished at the site due to a lack of electricity. Killdeer chicks collected for captive-rearing were initially held in a gas-powered brooder. In

1989 captive-rearing was conducted at the University of Michigan Biological Station, Pellston, Michigan.

Killdeer eggs were collected from the wild and placed in an incubator at 39° C (Malone & Proctor 1966). Efforts were made to collect eggs during the first week of incubation to allow time for parent birds to renest, and no eggs were collected within ten days of hatching. Chicks were removed from the incubator as they hatched, placed into a box, and kept at 35° C. Tubifex worms mixed with water were provided in shallow pans. On the day after hatching, captive chicks were individually color banded and placed in 2 × 4 meter outdoor pens. Siblings remained together from hatching to release. Each pen held two broods, placed together by proximity of hatching dates. Pens were constructed of wire mesh over a wooden frame and were covered with a slanted wooden roof 3 meters high. Preliminary work showed that visual contact with neighboring chicks elicited escape behavior, and chicks tried to squeeze through the fencing. Plastic garden edging 30 centimeters high placed around the bottom perimeter of each pen eliminated this problem. Concrete floors were covered with sand, and driftwood and rocks provided spatial heterogeneity for exercise and visual stimulus. Heat lamps placed at one end of the pens provided warmth as needed. Chicks were fed a mixture of tubifex worms, mealworms, earthworms, and crumbled commercial moist cat food. Both food and water were presented in pans of shallow water over a sand substrate, with a flat rock protruding from the center. In addition, chicks fed on insects attracted to the heat lamps.

When chicks were fully feathered and had been observed flying (at approximately 35 days), they were released in sibling groups on an isolated beach at Cheboygan State Park, Cheboygan, Michigan. Logistical constraints prohibited transporting fledglings to High or Beaver Islands for release. The site had little human activity, and the trauma of moving the fledglings was minimized by the short distance from the rearing site.

Observations and Data Collection

Twelve one-minute observations were made of each individual chick for two-hour observations per sibling unit each day. Data recorded included time spent on feeding, resting, preening, and other activities, habitat use and distance to attending adult (for parent-reared and cross-fostered chicks), and distance to closest sibling. Observations were made in daylight hours, and not during inclement weather. Human exposure to chicks in all experimental treatment groups was minimized, and all observations were made from blinds. Wild broods were observed from a distance where parent birds did not elicit alarm calls or alert behaviors directed toward us. Observations of chick behavior were made from hatching to fledging and continued after captive-reared chicks were released in the wild. Captive chicks were weighed every other day, and parent-reared and cross-fostered chicks were weighed every other day when possible. Study areas were searched in subsequent years for banded Killdeer that returned to the area to breed.

Tape-recorded Killdeer alarm calls were played from a portable tape recorder inside observation blinds. Tapes were played to captive chicks once each observation period, and their responses were recorded. Responses of wild broods to their parents' alarm calls, and to adjacent conspecifics, were recorded during observations of cross-fostered and parent-reared chicks.

Hatching success was determined as percentage of eggs laid per clutch that hatched, and fledging success as percentage of young hatched that survived to fledging. Overall reproductive success is reported as the number of fledglings produced per nesting pair of adults. Data on captive-rearing efforts in 1988 are not included in the analysis because of low sample sizes and inconsistent treatments. Means are reported ± one standard error. Comparisons between the experimental groups were made with ANOVAs, and Tukey tests for multiple comparisons were used when appropriate (Zar 1984). Time budget data were normalized using arcsine transformations before analysis (Sokal & Rohlf 1981). Data for individual chicks were pooled into sibling groups because variability among sibling groups was greater than among siblings. Individual growth rates (K) were calculated using logistic equations and compared by Mann-Whitney tests (Ricklefs 1967).

Results and Discussion

Nesting Chronology

Killdeer and Spotted Sandpiper nesting chronology differed in northern Michigan. Killdeer began egg laying in late April and continued through June. Most first nest attempts for Killdeer occurred between early and mid-May in 1987, 1988, and 1989. Later nests were usually second attempts following an initial nest failure; a second wave of nesting peaked in late May. Spotted Sandpipers began laying eggs approximately one month later than Killdeer, with the majority of nests begun in the first half of June.

Nesting chronology led to some difficulties with cross-fostering because Spotted Sandpipers initiated nesting later than Killdeer. Synchronization of nesting between the foster and target species is important if the goal of cross-fostering is to increase recruitment. To induce a target species to renest and hence increase the overall reproductive success of individual breeding pairs, the removal of eggs for fostering or captive-rearing should be conducted early in the incubation

Table 1. Reproductive success of parent-reared, cross-fostered, and captive-reared Killdeer (mean ± SE).

	N	*Eggs/Clutch*	*Chicks/Clutch*	*Hatching Success (%)*	*Fledglings/ Adult Pair*	*Fledging Success (%)*
Parent-Reared	24	3.59 ± 0.20	2.18 ± 0.39	54.4	0.55 ± 0.24	26.5
Cross-Fostered	16	3.87 ± 0.13	1.18 ± 0.50	46.8	0.67 ± 0.33	48.3
Captive-Reared	6	3.67 ± 0.33	3.00 ± 0.37	81.8	2.30 ± 0.62*	77.8

** Significant differences, $p < 0.05$.*
Captive-rearing efforts from 1988 are not included.

period. Synchronization is also important for release of captives and fledglings of fostered young. Well planned timing ensures that cross-fostered and captive-reared fledglings have the opportunity to adjust to release, interact with wild fledglings, and practice flight before migration.

Reproductive Success and Survival

The average clutch size for all experimental groups of Killdeer was 3.7 ± 0.12 eggs per clutch. Of twenty-four nests used for observations on parent-rearing, ten were destroyed by predators before the eggs hatched, and three contained a total of five infertile eggs, resulting in a hatching success of 54.4%. The percentage of chicks that survived to fledging was 26.5%, resulting in 0.55 fledglings produced per nest (Table 1). Results for cross-fostered nests were similar to parent-reared nests. Eight of sixteen cross-fostered nests were destroyed by predators, and no eggs were infertile. Fledging success for cross-fostering was 48.3%, resulting in 0.67 fledglings produced per nest (Table 1). Although fewer chicks hatched per clutch in cross-fostered nests than in parent-reared nests, Spotted Sandpiper foster parents and natural Killdeer parents had similar overall reproductive success owing to slightly higher chick survival in cross-fostered families. Egg predation on parent-reared and cross-fostered nests was by coyote (*Canis latrans*), domestic dog (*Canis familiaris*), and American Crow (*Corvus brachyrhynchos*). Captive-rearing produced significantly more fledglings ($F = 5.24, P = 0.01$) through increased hatching and fledging success than either parent-rearing or cross-fostering. Overall reproductive success for captive-rearing was 2.3 fledglings produced per clutch (Table 1).

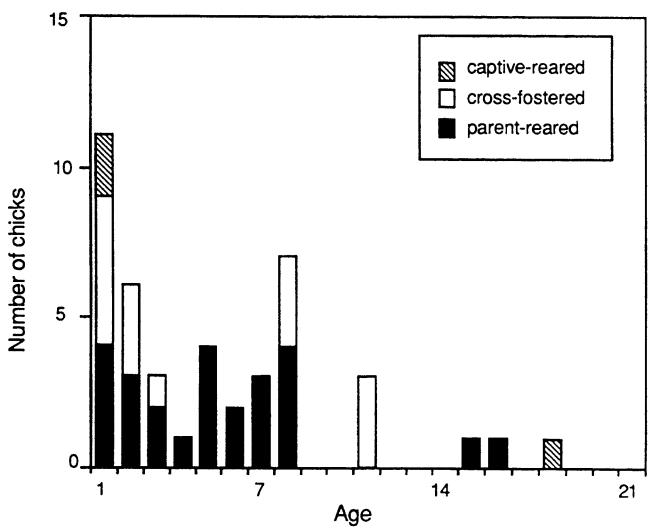

Figure 1. Mortality of parent-reared, cross-fostered, and captive-reared Killdeer chicks. Bars represent age of known death or date last seen. Chicks older than twenty-one days are considered fledged.

Chick mortality for all experimental groups primarily occurred during the first week after hatching (Fig. 1). It was difficult to determine causes of chick mortality in the wild, although chicks often disappeared after periods of bad weather. Potential predators in the study area included American Crows, Ring-billed Gulls (*Larus delawarensis*), Herring Gulls (*Larus argentatus*), coyotes, and, on Beaver Island, domestic dogs and cats (*Felis catus*).

No parent-reared fledglings were seen as adults in subsequent years. One cross-fostered bird was seen as a two-year-old and was observed courting and copulating with a wild Killdeer. The cross-fostered adult defended a territory and was observed in the presence of its wild mate on several occasions. This individual was raised on the eastern shore of High Island, and its territory was located 3.5 kilometers away on the western shore of the island. One of the nineteen captive Killdeer fledglings that were released returned to the study area as a yearling. This bird was seen among a flock of wild Killdeer on the mainland approximately 50 kilometers from its release site.

Captive-rearing increased the number of young produced by a given number of breeding pairs by almost threefold. Breeding success of captive-reared adults was difficult to determine because of low natal site fidelity in Killdeer (Lenington & Mace 1975; Haig & Oring 1988*a*). Page et al. (1989) reported that released captive-reared Snowy Plovers (*Charadrius alexandrinus*) successfully bred, fledged young, and increased productivity within a local population in California. Captive-reared Snowy Plover adults showed reproductive success similar to wild parent-reared Snowy Plovers. If captive-reared Killdeer fledglings have a similar survival rate to breeding age as wild Killdeer fledglings, captive-rearing considerably increases recruitment into the wild population.

Growth Rates

Mean hatching weight was 9.8 ± 0.13 grams for parent-reared chicks, 9.67 ± 0.11 grams for cross-fostered chicks, and 9.58 ± 0.12 grams for captives. When growth rates for parent-reared, cross-fostered, and captive-reared Killdeer were fitted to a logistic curve, no differences among experimental groups were found ($K = 0.159$, $K = 0.148$, $K = 0.143$), although captive-reared chicks reached a higher asymptotic weight. Because the sample size for weights of parent-reared chicks was small, data were compared to those of Bunni (1959), who also collected prefledgling weights of wild Killdeer in northern Michigan. No differences were found between the growth rates of parent-reared Killdeer chicks in this study and those measured in 1959 ($K = 0.151$).

Habitat

Significant differences were found between habitat use by parent-reared and cross-fostered chicks. Both groups spent approximately half their time in dense vegetation (parent-reared, 42.04 ± 3.85%; cross-fostered, 57.33 ± 8.13%). Vegetation was used as cover during brooding or predator avoidance, and for foraging. Cross-fostered chicks spent 46.27 ± 3.76% of their time foraging along shorelines, while parent-reared chicks spent 33.96 ± 7.74% of their time foraging in open habitat (parent-reared on shoreline, 8.70 ± 4.53%, $F = 41.39$, $p = 0.0001$; cross-fostered in open, 11.68 ± 2.75%, $F = 8.27$, $p = 0.006$). Open habitat was defined as areas with little vegetative cover and included lawns, bare ground, and beaches. Released captive fledglings used the dune vegetation for resting and predator avoidance and foraged along the shoreline and open beach.

Killdeer exploit a wide range of habitat types for rearing young (Bunni 1959). In contrast, Spotted Sandpipers nest exclusively in vegetation adjacent to bodies of water and rear broods along the shorelines (Oring et al. 1983). In general, Killdeer parents moved their broods over longer distances than did Spotted Sandpipers. Both species led their chicks to water for foraging, but because Spotted Sandpipers nested near water, they did not need to move their broods far from the nest site. Fledging success of cross-fostered young was slightly higher than parent-reared young; this may be attributed to the quality of Spotted Sandpiper brood-rearing habitat, which had less pressure from predation and human disturbance. The cross-fostered Killdeer that was seen as an adult was using shoreline habitat for its breeding territory; however, shoreline habitat is used by Killdeer as well as by Spotted Sandpipers, so it is difficult to attribute habitat preference to early experience in this case (Berndt & Winkel 1980).

Behavior

Behavioral data for the three experimental groups were divided into three age groups: less than one week old (corresponding to the period of highest mortality), between one and two weeks old, and older than two weeks (corresponding to the period of rapid feather development and decreased parental care). All experimental groups behaved similarly at ages less than one week old. On the day of hatching (not included in the analysis) chicks were brooded continually. No parent-reared or cross-fostered chicks were brooded during the day after fifteen days of age. Resting after one week of age usually did not include brooding except during periods of rain and cool temperatures. Chicks older than one day spent a majority of their time feeding. The experimental groups differed in time spent feeding and resting in the second and third age groups. Captive-reared chicks spent significantly less time feeding than parent-reared ($q_{0.05,12,3} = 3.77$, $q = 6.29$ age 1–2 weeks, $q = 5.28$ age > 2 weeks) and cross-fostered ($q_{0.05,12,3} = 3.77$, $q = 4.66$ age 1–2 weeks, $q = 3.88$ age > 2 weeks) chicks. Corresponding to decreased time spent feeding, captive-reared chicks spent more time resting than parent-reared ($q_{0.05,12,3} = 3.77$, $q = 5.22$ age 1–2 weeks, $q = 6.41$ age > 2 weeks) and cross-fostered ($q = 3.89$ age > 2 weeks) chicks (Fig. 2). All experimental groups increased time spent preening with age, corresponding to the development of juvenal plumage.

Observations were continued on captive-reared fledglings after release, but because of small sample sizes, no statistical comparisons were made. Time budgets for released captives were similar to those for the older age group of parent-reared young (feeding 79.0 ± 3.08%, resting 10.0 ± 2.82%, preening 8.75 ± 1.68%, and 2.25 ± 3.88% in other activities). After release, captive-reared Killdeer were observed locating and capturing natural prey items and never used the artificial food source provided at the release site. Captive-reared fledglings also located and used vegetative cover and were observed bathing along the shoreline of the lake within 30 minutes of release. The captive-reared fledglings remained within 200 meters of the release site for two weeks and often were observed in close proximity to wild Killdeer. Both captive-reared and cross-fostered fledglings joined wild Killdeer as they formed premigratory flocks in mid-August and showed appropriate behavioral interactions with their conspecifics (Phillips 1972).

There were no differences between the mean distances maintained between parent-reared and cross-

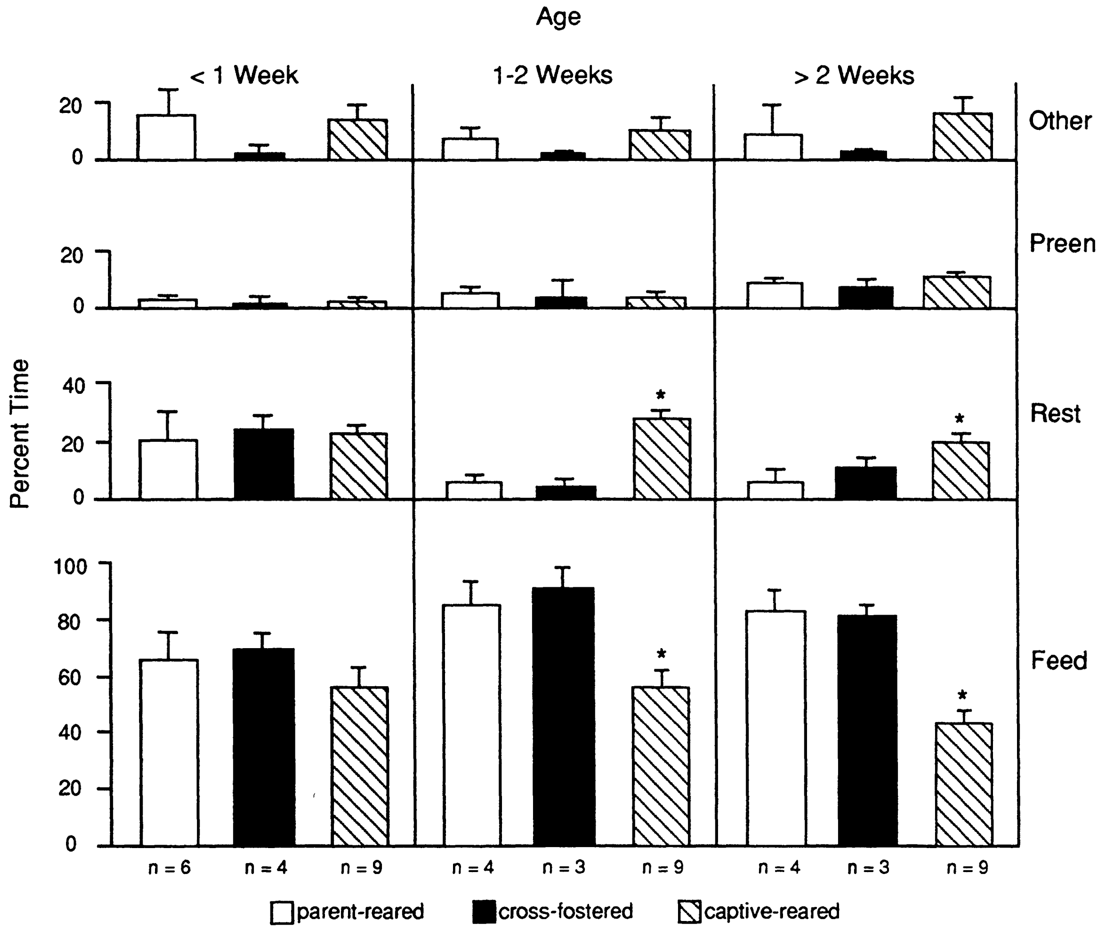

Figure 2. Mean percent time spent by parent-reared, cross-fostered, and captive-reared Killdeer in three age groups: n = *number of family units observed in each age category. Significant differences* (p < *0.05) are noted with an asterisk.*

fostered chicks and their attending parents. However, the distance between both groups of chicks and their parents increased significantly ($F = 50.07, p = 0.0001$) with age, with chicks younger than one week staying within 4 meters of their attending parent (parent-reared, 2.95 ± 0.49 meters; cross-fostered, 3.60 ± 0.67 meters). Chicks older than one week remained within 8 meters of attending parents but ranged up to 25 meters away (parent-reared, 7.92 ± 0.8 meters; cross-fostered, 7.12 ± 0.46 meters). Both natural and foster parents called to far-ranging chicks with contact vocalizations; chicks usually responded by running closer to the adult. The grouping of siblings was also similar between parent-reared (<1 week, 2.17 ± 0.44 meters; >1 week, 4.80 ± 0.65 meters) and cross-fostered chicks (<1 week, 2.32 ± 0.23 meters; >1 week, 4.46 ± 0.33 meters), again with distances between individuals increasing significantly with age ($F = 29.14, p = 0.0001$). In general, both parent-reared and cross-fostered chicks stayed closer to each other than to the attending parent, because the attending parent often stood in one place to watch the chicks and the surrounding area, while sibling groups moved around together foraging. Communication between parents and their chicks, and between siblings, was maintained by frequent contact vocalizations.

Captive-reared chicks stayed closer together than parent-reared and cross-fostered chicks ($F = 29.71, p = 0.0001$), and distances did not increase with age. A maximum distance of 4 meters was allowed by pen size, but the mean distance captive-reared chicks maintained between each other was 0.67 ± 0.3 meters. Although captive chicks stayed in close proximity at all times, they still gave frequent contact vocalizations to each other. Captive-reared fledglings remained in close groups (1.84 ± 0.75 meters) for several days after release. One week after release, the captive-reared fledglings remained in a loose group within an area approximately 400 meters along the shoreline. Fledglings flew in and out of this area, but distances traveled during this period are unknown.

Responses of Killdeer alarm calls were the same for parent-reared, cross-fostered, and captive-reared young. When exposed to alarm calls before age one week, all groups displayed antipredator behaviors of crouching and freezing in place. Older chicks gave their own alarm calls, and either ran to cover or crouched and froze in response to adult alarm calls. Chicks also responded with these behaviors when approached by humans; there was no evidence of habituation by chicks in any experimental group. Cross-fostered chicks responded to Spotted Sandpiper alarm calls as well as Killdeer alarm calls. Despite the different vocalizations used by fostered Killdeer chicks and their Spotted Sandpiper parents, the adult-brood interactions were similar to those observed in natural family units. The young were brooded frequently for the first few days after hatching, attending parents stood watch over foraging broods, and parents gave appropriate vocalizations to lead chicks or to send them to cover from predators. Captive-reared fledglings gave alarm calls and crouched and froze or ran to cover when approached by humans after release. Released captives gave alarm calls and ran to cover and froze when Ring-Billed Gulls flew over the area where they were foraging. No other potential predators were observed near the released captives.

We found no evidence that captive-reared and cross-fostered Killdeer were negatively affected by their early experiences. All three experimental groups showed growth and activity patterns similar to other plover species (Bunni 1959; Pienkowski 1984; Flemming et al. 1988). Although captive-reared chicks spent a greater proportion of time resting and less time feeding than did wild chicks, these differences were artifacts of captivity, where a constant, consistently-located food supply and heat source were available. Observations of cross-fostered and captive-reared adults were limited but indicated recognition of conspecifics. There was no evidence of problems associated with imprinting, such as abnormal migration, inappropriate association with conspecifics, or failure to learn conspecific vocalizations (Harris 1969; Byrd et al. 1984; Rowley & Chapman 1986).

There are several reasons why imprinting problems and the effects of captivity were not manifested in this study. Cross-fostered and captive-reared groups were raised with siblings, thereby reducing the susceptibility of imprinting to foster parents (Immelmann 1972; Klint 1978). Also, Killdeer chicks have distinctive markings that mimic adult plumage. In addition to visual cues from siblings, chicks were exposed to Killdeer vocalizations from tape recordings, wild conspecifics, and each other. The techniques we used in our experiments were chosen to minimize potential negative effects. For example, we attempted to avoid habituation to humans in rearing young and conducting behavioral observations. Captives were raised in outdoor pens, where they were exposed to the natural environment and light-dark schedules, natural food items were provided whenever possible, and food was presented to simulate natural foraging. Finally, cross-fostered and captive-reared fledglings had the opportunity to gain independence in their natural habitat and to interact with wild conspecifics. All of these factors may have contributed to the success of these brood rearing regimes.

Conservation Implications

Evaluation of cross-fostering and captive-rearing as techniques for augmenting small populations of shorebirds indicated that although cross-fostering increased recruitment into the local population, overall reproductive success was significantly increased through captive-rearing. In addition, cross-fostering has its associated problems as a translocation technique. Cross-fostering can be subject to variability in nest synchronization between the two species; this can cause difficulties in egg transfer and grouping of fostered fledglings with wild birds to form premigratory flocks. Like parent-rearing, cross-fostering is affected by environmental variability such as predation and bad weather. Finally, caution should be used before undertaking cross-fostering techniques because of imprinting problems and the possibility of hybridization in some species (Harris 1969; Berndt & Winkel 1980; Pierce 1984; Rowley & Chapman 1986).

In contrast, both hatching and fledging of captive-reared young takes place in a controlled environment. Captive-rearing efforts can be conducted throughout the breeding season, according to the specific circumstances of the project. Eggs for captive-rearing can be collected either from the target population or from different populations to enhance genetic variability. Unlike captive breeding, adult birds do not have to be maintained in captivity, leaving the maximum number of individuals in the wild and reducing the potential for disease and parasite problems. Captive-rearing is better than cross-fostering because it is a more flexible technique, produces more young, does not affect another species, and reduces the potential for imprinting and disease. Captive-rearing is recommended to enhance genetic variability and long-term survival of Piping Plovers and other endangered Charadriids.

For example, Piping Plovers were listed in the U.S. as endangered and threatened in 1986, and recovery plans were developed separately for each of three geographically separated populations (U.S. Fish and Wildlife Service [USFWS] 1985). There is no genetic basis for this division of the species (Haig & Oring 1988*a*). The endangered Great Lakes Piping Plover population currently consists of seventeen breeding pairs, and genetic and environmental stochasticity greatly increase the risk of extirpation within a short time period (Powell 1991*a*). A gap in Piping Plover distribution is created with the loss of this population, reducing gene flow and isolating the Great Plains and East Coast populations

(Haig & Oring 1988*b;* Haig 1991). Management of the Great Lakes population consists of basic monitoring, habitat protection, public education, and the use of predator exclosures to protect nests. Despite these efforts, the Great Lakes population has not increased in six years (Powell 1991*a*). This study, and work on closely related surrogate species, indicate that captive-rearing could effectively enhance Piping Plover populations (Page et al. 1989). Because Piping Plovers show greater fidelity to their natal area than do Killdeer, recruitment into a local population is likely to be successful (Haig & Oring 1988*b;* Powell 1991*b*). We must emphasize the need to implement techniques such as captive-rearing after appropriate testing, and before the target population is too small to benefit from augmentation. Conservation of species as well as populations should be considered in determining appropriate management plans for populations at risk.

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