Waterbird Use of Brackish Wetlands Managed for Waterfowl

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Abstract: Waterbird use of managed and unmanaged brackish wetlands in coastal South Carolina was determined by 1,544 counts during a 19-month study. Significantly ($P < 0.05$) more individual birds and species used the managed sites in all seasons except summer. An unmanaged tidal impoundment was least used in all seasons. Multiple regression analysis indicated that bird use was inversely correlated to water level, particularly during spring. Shorebirds accounted for 53% of the use among managed sites follwed by waterfowl (27%), waders (14%) and other waterbirds (6%). The results have strong implications for multispecies management practices.

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Impoundments created during the eighteenth and nineteenth centuries for the cultivation of rice and indigo are significant ecological features in the South Carolina intertidal coastal zone. Most impoundments occupy freshwater estuaries; some, however, occur in saline environments. Historically, impoundments made up about 29% of the 204,146 ha of South Carolina's coastal marshland (Tiner 1977, Aichele 1984). Today, 51% of these have been abandoned or are no longer completely impounded; the remainder are managed mainly for wintering waterfowl (Miglarese and Sandifer 1982, Tompkins 1986*a,b*).

Most wildlife investigations in South Carolina impoundments have focused on wintering waterfowl (Epstein and Joyner 1986), although fish and other wildlife values have been recognized (Newsome 1967, Morgan et al. 1975). Feeding and nesting activities of the southern bald eagle (*Haliaeetus l. leucocephalus*), osprey

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(*Pandion haliaetus*), and American alligator (*Alligator mississippiensis*) have been linked with impoundments in South Carolina and other states, with greatest activity by eagles and alligators occurring within or near impoundments managed for waterfowl (Henny and Noltemeier 1975, Murphy and Coker 1978, Griffen et al. 1982, Wilkinson 1983). Moreover, the earthen dikes which surround impoundments provide an extension of upland-edge habitat which is used by numerous wildlife (Sandifer et al. 1980, Epstein et al. 1985, Feldhamer et al. 1987, Dell and Chabreck 1986)

Recent controversy concerning coastal impoundments in South Carolina initiated a multidisciplinary characterization of the ecology, management and use of brackish impoundments and adjacent tidal wetlands (DeVoe and Baughman 1986). This project generated baseline information on the response of selected wildlife to waterfowl management on brackish wetlands and was Task X of the South Carolina Coastal Wetland Impoundment Project. Here, we report on portions of that project related to waterbird use of managed and unmanaged tidal wetlands and characterize seasonal waterbird use of the study area.

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Methods

Study Area

The study area was located in northeastern coastal South Carolina on the Cat Island portion of the Tom Yawkey Wildlife Center, Georgetown. Bird use was documented on 6 managed sites and 2 unmanaged sites (Hurlbert 1984). The managed sites consisted of a series of 5 contiguous impoundments (sites 1 to 5, $\bar{x}$ = 5.3-ha) and 1 larger impoundment (Cooperfield, 13.8-ha). The unmanaged sites included a 13.6-ha section of tidal salt marsh adjacent to Cooperfield, and a 7.9-ha tidal impoundment.

All of the managed impoundments were equipped with 1 wooden water control structure, which had sliding flapgates and an inside flashboard riser (Williams 1987). Additionally, impoundments 1 to 5 had interconnecting flashboard riser spillways that could facilitate water circulation between and among impoundments. However, during this study these spillways were left closed, and water level (or depth) was controlled by the flapgate structure so that each unit could be studied individually (Epstein and Baughman 1986).

In managed impoundments, water level was manipulated to encourage the production of *Ruppia maritima, Eleocharis parvula, Scirpus robustus,* and other waterfowl food plants. These 3 species provided 83% of vegetative cover among the managed sites (Kelley and Porcher 1986). The *Ruppia-Eleocharis* association also covered 53% of the mud flat habitat during drawdowns in the managed sites.

Water levels in the 2 unmanaged sites were governed by tidal inundation and precipitation. Vegetative cover of the tidal impoundment was 93% *Spartina cynosuroides* and *S. alterniflora;* the tidal marsh was 57% *S. alterniflora* and 42% unvegetated mudflat/creek habitat.

Generally, water level manipulations included spring drawdowns and gradual re-flooding through summer with highest levels (50 to 70 cm) in September. Water levels were reduced about 10 cm every other month from October through March, when the flooding process was repeated. Specific details of water management and study area are reported by Epstein and Baughman (1986) and Kelly and Porcher (1986).

Sampling

We addressed the null hypothesis that waterbird use of managed impoundments and unmanaged marshland was equal. Counts of individual birds were made from 4 towers (4-m high) located on dikes and positioned to allow observation of study sites.

Date, time, temperature, wind speed and direction, percent cloud cover, water level (or depth), and precipitation were recorded at each station for each count. Salinity was measured using a refractometer. Sampling periods at each station lasted a minimum of 10 minutes or until all visible birds were counted. Birds were recorded as feeding or non-feeding. The same observer conducted all censuses. During the first field season (Jan-Dec 1983), the 2 unmanaged sites, Cooperfield, and 2 of the other 5 managed sites (selected randomly) were sampled approximately 4 times per week; that is, 5 of the 8 sites were sampled on each occasion. Between January and July 1984, all 8 sites were sampled 2 times per week. During the 19-month study, 1,544 census were taken on the 8 study sites. Seasonal periods were adapted from Bildstein et al. (1982*a*) and include: fall, 1 October to 31 December; winter, 1 January to 15 March; spring, 16 March to 31 May; and summer, 1 June to 30 September.

Dense vegetation prohibited visual counts of some species, thus vocalizations also were used to locate and count birds. An index for the number of calls was used exclusively to monitor clapper rail (*Rallus longirostris*) abundance. Selected sandpiper species [white-rumped (*Calidris fusciocollis*), least (*C. minutilla*), semipalmated (*C. pusillus*), and western (*C. mauri*)] were grouped as peeps. Similarly, *Limnodromus scolopaceus* and *L. grizeus* were grouped as dowitchers. Immature and unidentifiable gulls (*Larus* sp.) and yellowlegs (*Tringa* sp.) also were grouped. The raptor group included osprey, southern bald eagle, northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), and Peregrine falcon (*F. peregrinus*).

Analysis

The total number of waterbirds/area was summarized by count and study site before ln transformation. A one-way ANOVA was used to test for overall differences among sites. Duncan's multiple range test was used to detect differences between sample means (Helwig and Council 1979).

Analysis of variance was performed on birds/area and species/area by season and study site. Grouped species (i.e., gulls and yellowlegs) were omitted from species calculations. Clapper rail data were analyzed separately. Square-root transformations were used to normalize species data because they consisted primarily of small whole numbers (Steel and Torrie 1980). Percentage of feeding and non-feeding activity by birds were calculated by site and by bird group.

Simple correlation analysis was used to measure multicollinearity among environmental variables for Cooperfield and the tidal marsh because they were comparable in size. Analysis was made for the total data set and by season before testing for associations with bird numbers using stepwise multiple regression (Helwig and Council 1979). Where pairs of variables were correlated ($r > 0.7$) only 1 variable was used in subsequent regression analysis. The regression procedure was performed in ln (birds/ha + 1) by count for each of the 2 sites.

Calculations of bird use-days were made by multiplying the mean number of individuals of a species recorded on 2 consecutive samples by the number of days between those samples (Rundle and Fredrickson 1981). Use-days were calculated for all species, study sites, and seasons. Annual use-days (AUD) were averaged by season and year; however, fall is represented by only 1 field season.

Results

Seasonal Bird Use

During the study, 81 bird species were identified resulting in 78 taxa for analysis (i.e., peeps, dowitchers, gulls, etc.); 44 (56.4%) had ≥300 use-days during the 19-month study. Individual bird numbers differed ($P < 0.05$) during fall and summer but not during winter and spring. The number of species by season differed ($P < 0.05$) only in the summer, when fewer number of individual birds and species were present. Larger numbers of individual birds occurred during spring (58.7%) followed by winter (26.2%), fall (9.5%), and summer (5.6%) (Table 1). There was much annual variation in bird numbers by season and bird group. More use-days were recorded for surface divers, waterfowl, waders, and rail groups in 1983 than in 1984; while 69.2% of the shorebird use occurred in 1984.

Shorebirds accounted for 54.8% of all bird use for all study sites with highest numbers in spring (Table 1); 92.5% was associated with feeding activity. Thirteen of 17 shorebirds had >300 use-days and 6 [peeps, dowitchers, dunlin, lesser yellowlegs, semipalmated plover (*Charadrius semipalmatus*), and greater yellowlegs] provided 97.5% of the group's use.

Waterfowl were the second most abundant bird group (Table 1). As expected,

Table 1. Average seasonal bird-use days (percent by season) for 7 bird groups on managed and unmanaged sites, 1983–84.

Bird group	Winter	Spring	Summer	Fall[a]
Shorebirds	14,971 (25.7)	102,835 (78.9)	1,284 (10.4)	2,481 (11.8)
Waterfowl	35,832 (61.5)	20,953 (16.1)	247 (2.0)	2,492 (11.8)
Waders	4,680 (8.0)	4,784 (3.7)	7,760 (62.7)	9,960 (47.3)
Surface divers	946 (1.6)	486 (0.4)	1,452 (11.7)	3,347 (15.9)
Aerial divers	1,331 (2.3)	746 (0.6)	1,022 (8.3)	2,534 (12.0)
Rails[b]	310 (0.5)	415 (0.3)	481 (3.9)	93 (0.4)
Raptors	200 (0.3)	167 (0.1)	121 (1.0)	153 (0.7)
Total	58,270	130,386	12,367	21,060

[a]Data reflect fall 1983.
[b]Coots included with waterfowl.

they increased during fall, predominated in winter, and declined in spring (Table 1); 94.4% of the use was recorded as feeding activity. Four species [green-winged teal (*Anas crecca*), blue-winged teal (*A. discors*), wigeon (*A. americana*), and hooded merganser (*Lophodytes cucullatus*)] contributed 91.3% of the total use; 9 of 18 species had >300 use-days overall.

Nine of 15 wader species had >300 use-days, and 6 [white ibis (*Eudocimus albus*), great blue heron (*Ardea herodias*), great egret (*Casmerodius albus*), little blue heron (*Egretta caerulea*), snowy egret (*E. thula*), and tricolored heron (*E. tricolor*)] provided 91.3% of the group's use. Waders provided 12.2% of the overall use with highest occurrence during summer and fall (Table 1). Predominate activity was (78.5%) feeding.

Of 13 aerial divers, 6 [laughing gull (*L. atricilla*), ring-billed gull (*L. delawarensis*), Caspian tern (*Sterna caspia*), gulls (*L.* sp.), belted kingfisher (*Ceryle alcyon*), and royal tern (*S. maxima*)] had >300 use-days and provided 91.6% of the group's use. Both diver groups were more common during summer and fall (Table 1); 54.8% of their activity was recorded as feeding. Only 2 of 6 raptors [osprey (*Pandion haliaetus*) and northern harrier (*Circus cyaneus*)] which are wetland related birds, had >300 use-days; they also accounted for 75.5% of the group's seasonal use. Diver, raptor, and rail groups, collectively, accounted for 6.2% of the overall use (Table 1). The common moorhen (*Gallinula chloropus*) provided 92.1% of the rail use. Coots (*Fulica americana*) were included with waterfowl and contributed only 4.2% to the group's total use. Clapper rails were analyzed separately.

Seasonal Site Use

There was significant ($P < 0.05$) seasonal variation in bird use among sites; the most use sites were the managed ones (Table 2). The tidal impoundment was least used in all seasons. Similarly, fewer individuals used the tidal marsh than other sites in all seasons except summer. Of 77 wetland taxa (75 species plus peeps and

Table 2. Number of birds per observation by season and site, 1983–1984.

	Fall			Winter			Spring			Summer		
Site[a]	*N*	Mean[b]	Group[c]	*N*	Mean	Group	*N*	Mean	Group	*N*	Mean	Group
1	22	1.83	c	38	2.16	c	36	1.62		42	1.25	c
2	23	4.02	a	39	5.34	b	37	2.44	d	39	1.62	b
3	22	2.84	b	38	5.19	b	41	2.95	cd	42	2.03	a
4	20	2.47	b	38	8.11	a	41	3.72	c	51	1.65	b
5	21	1.77	c	34	5.77	b	33	7.90	b	47	1.48	b
TI	53	1.15	d	74	1.12	d	64	1.64	e	88	1.12	c
TM	53	1.36	d	74	1.52	d	64	1.54	e	88	1.53	b
COF	53	2.58	b	74	8.42	a	64	13.31	a	88	1.63	b

[a]TI, tidal impoundment; TM, tidal marsh; COF, Cooperfield.
[b]Mean number (log) of birds/0.4 ha by site.
[c]Sites with the same letter(s) within a season are not significantly different; Duncan's multiple range test, $P < 0.05$.

dowitchers), 56 (72.7%) were recorded using unmanaged sites versus 76 (98.7%) using the managed sites.

Shorebirds dominated the use of managed sites (52.5%), followed by waterfowl (26.9%) and waders (13.7%) (Table 3). Average species richness was higher on the managed sites (57, SD = 7) versus the unmanaged sites (43, SD = 14). The number of species differed ($P < 0.05$) by site for all seasons with high variation between seasons (Table 4). Fewer species of birds ($P < 0.05$) were recorded using the tidal marsh during summer (Table 4), although individual bird numbers remained high (Table 2). Waders were predominant during summer (Table 1). Higher bird numbers, percent use, and species richness also were recorded for the larger (Cooperfield) managed unit (Table 4). However, clapper rail use was much higher on unmanaged sites (Fig. 1).

Abiotic Factors

Bird use was inversely correlated to water level ($P < 0.0001$) on Cooperfield ($R^2 = 0.63$) and the tidal marsh site ($R^2 = 0.35$). Low R^2 values (<0.50) resulted for all seasons except spring. Spring water levels were inversely correlated with bird numbers on Cooperfield ($R^2 = 0.85$) and the tidal marsh ($R^2 = 0.47$) ($P < 0.0001$). Temperature and salinity explained less than 4% of the observed variation in models for both sites.

Discussion

The value of tidal estuarine wetlands as critical breeding, nesting, feeding, and wintering habitat for many wetland birds is well documented (Pitelka 1979, Erwin and Korschgen 1979). South Carolina's tidal wetlands provide important habitat for wading birds (Kushlan 1981) and are vital to numerous migratory species (Sprunt

Table 3. Average annual bird use-days (AUD/ha) for bird groups by study site, 1983–1984.

Bird group	Study Site[a] 1	2	3	4	5	TI	TM	COF	Total
Shorebirds	246	625	1,528	1,729	3,261	86	163	5,958	13,596
Waterfowl	290	1,080	590	1,259	763	27	33	2,864	6,906
Waders	189	1,072	775	481	258	87	285	705	3,852
Aerial divers	37	87	175	136	90	8	45	216	794
Surface divers	66	206	85	130	94	2	24	207	814
Rails	39	18	31	27	29	0	0.2	38	182.2
Raptors	12	5	8	8	8	11	8	17	77
Total AUD/ha	879	3,093	3,192	3,770	4,503	221	558	10,005	26,221
% Utilization	3.4	11.8	12.2	14.4	17.2	0.8	2.1	38.2	
Species richness	51	56	50	54	60	33	53	69	

[a]TI, tidal impoundment; TM, tidal marsh; COF, Cooperfield.

Table 4. Number of species per observation by season and site, 1983–1984.

	Fall			Winter			Spring			Summer		
Site[a]	N	Mean[b]	Group[c]	N	Mean	Group	N	Mean	Group	N	Mean	Group
1	22	0.60	c	38	0.54	c	36	0.47	d	42	0.44	d
2	23	1.11	a	39	0.86	a	37	0.79	bc	39	0.70	b
3	22	0.95	b	36	0.77	b	41	0.72	c	42	0.80	a
4	20	0.87	b	38	0.93	a	41	0.78	bc	51	0.70	b
5	21	0.65	c	34	0.76	b	33	0.86	ab	47	0.56	c
TI	53	0.29	d	74	0.26	e	63	0.26	e	88	0.27	e
TM	54	0.38	d	74	0.43	d	64	0.40	d	88	0.44	d
COF	54	0.66	e	74	0.72	b	64	0.91	a	88	0.52	c

[a]TI, tidal impoundment; TM, tidal marsh; COF, Cooperfield.
[b]Means reflect (sq. root) number of species/0.4 ha.
[c]Sites with the same letter(s) within a season are not significantly different; Duncan's multiple range test, $P < 0.05$.

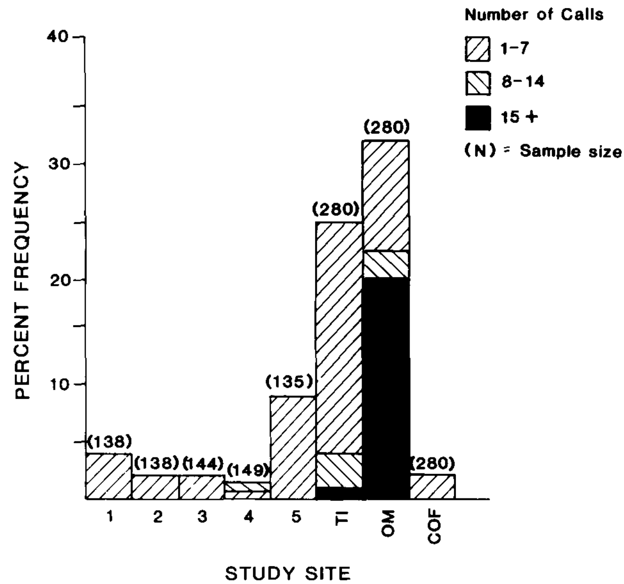

Figure 1. Percent frequency of clapper rail calls recorded by study site, 1983–84 (TI, tidal impoundment; OM, tidal or open marsh; COF, Cooperfield).

and Chamberlain 1970, Forsythe 1978). Similarly, the value of properly managed impoundments to wildlife in South Carolina and other states is well recognized (Provost 1959, Miglarese and Sandifer 1982, Fredrickson and Taylor 1982, Davidson and Chabreck 1984). Of 81 waterbird species identified during this study, approximately 90% are "characteristic" of South Carolina's brackish, intertidal zone (Forsythe 1978), suggesting that management did not adversely change the species composition of native fauna in the area. Except for clapper rails and northern harriers, most bird species and groups preferred the managed impoundment habitats to the unmanaged systems. There was variation by some species with respect to site and phase of management. However, these results reflect a management regime that was geared to enhance habitat and resource availability for wintering waterfowl.

The gradual drawdown from fall through late winter (Epstein and Baughman 1986) also made vegetation, invertebrates, prey fish, and deposited seed more available to other waterbirds. Bird use declined under dry conditions; moist soil conditions (−5 to 5 cm) resulted in higher use by migratory shorebirds and waterfowl. Water level (or depth) directly influences availability of prey and foraging habitat (Chabreck 1979, Fredrickson and Taylor 1982, Howard and Lowe 1984).

Feeding behavior dominated (89.3%) activities of birds using managed and unmanaged sites. Prey availability may have effected higher bird use on the managed sites. The progressive increase in prey (decapod crustaceans and ichthyofauna) numbers and biomass through summer was concentrated in impoundments with immigration and maturation of larval and juvenile forms (DeVoe and Baughman

1986). Recruitment patterns of prey into impoundments is highly dependent on the ingress and recruitment of a particular prey species to the adjacent estuary and periods of water exchange between the tidal marsh and managed system (Olmi 1986, Wenner 1986*b*, Wenner et al. 1986). Spring reflooding events were a major recruitment source for prey. Tidal exchange and increased water level through summer also allowed recruitment. However, as water level increased, the amount of tidal exchange decreased, thereby reducing the possible level of prey recruitment (DeVoe and Baughman 1986).

With water exchange much reduced by late summer, continued management of aquatic vegetation was highly dependent on external environmental factors (i.e., rainfall) to reduce salinities and water temperature. Birds concentrated in impoundments during periods of high salinity and temperature, and low dissolved oxygen (DO). Apparently, stressed fish and crabs were preyed on by birds and alligators (Epstein and Joyner 1986) so greatly in some managed sites that prey populations were reduced before a large-scale die-off could occur. Low DO levels increase prey availability at the surface and probably is a factor associated with high use by predatory birds (Kushlan 1976). Olmi (1986) and Wenner (1986*b*) found a corresponding reduction in decapod crustacean abundance and biomass during a stressful period.

When water levels inside impoundments reach or exceed the range of high tides, water exchange and circulation is reduced. Managers have the option to manipulate water control structures to prevent, regulate, or fully allow water exchange to occur. The management decision is usually based on many factors, primarily on the affects of water exchange (i.e., water fluctuation and quality) on the target species of management; here it was *Ruppia* and waterfowl. If fishing birds reduce the prey base in an impoundment there may be a subsequent decline of bird use until the gradual drawdown increases food and habitat availability.

Prey may become lethargic and easier to catch with cooler fall temperatures and were also preyed upon by high numbers of migratory birds. Waders and divers formed feeding aggregations in the managed sites and accounted for 83.1% of the fall use. There was less use of managed sites by foraging birds as prey abundance decreased (Wenner 1986*b*, Wenner et al. 1986), but more use by waterfowl in winter and shorebirds in spring. This suggests that fishing birds can reduce the standing crop of prey in some areas (Barlow and Bock 1984, Howard and Lowe 1984), but also suggest that managers can mimic natural water level fluctuations that increase food availability. Water level fluctuations are vital to some waterbirds (Kushlan 1976, Kushlan 1986).

Ruppia production can be erratic under stressful conditions. Thus, slight modifications to water management schedules may enhance waterbird use and water quality without adversely changing preferred habitats, particularly at times when primary production of the target plant species is low (Kelly and Porcher 1986).

Similarly, high shorebird use of managed sites corresponded with northward migration and low water levels during spring. Shorebird use of managed sites declined when impoundments were reflooded in late spring and subsequently increased on unmanaged tidal mudflat habitats. Thus, prolonging dewatered conditions during spring migration may extend and increase shorebird use as we observed in 1984.

The results suggest that management can be directed towards several wildlife groups, particularly during seasonal or critical periods. Nonetheless, controlled water level manipulations will vary with impoundment size, the site location within the estuarine tidal system, the size, number and type of water control structures, and the primary objectives of management.

Although Wenner (1986*a*) found that habitats within managed sites supported different and less diverse assemblages of macrofaunal invertebrates than the tidal marsh, shorebird use of managed sites was substantially higher than unmanaged sites. Examination of crops and stomachs of 5 shorebird species using the managed sites indicated that food items were consistent with those found in the managed impoundment habitats (Wenner 1986*a*). Heavy shorebird predation in managed impoundment habitats may explain some of the observed differences that were found between invertebrate communities of managed and unmanaged sites (Schneider and Harrington 1981, Quammen 1984).

The unmanaged tidal impoundment was used least in all seasons, having fewer numbers of individual birds and species. This may have resulted from the higher elevation of the bottom, dense emergent habitat, and no interspersion of open water. During summer, the tidal marsh had similar bird numbers but fewer species than the managed impoundments. Birds using the tidal marsh represented the natural assemblage of avifauna for that habitat type. The managed impoundment flora, however, was more diverse (7 major communities and 19 species) than the unmanaged sites (3 major communities and 5 species) (Kelly and Porcher 1986). Greater habitat diversity and resource availability probably effected high species richness among the managed impoundment habitats. The larger managed site had greater bird densities, species richness, and greater waterfowl and shorebird use than the smaller managed sites. The ability of large wetlands to attract bird populations has been attributed to habitat diversity, large food supplies (Weller and Fredrickson 1974, Swiderek 1982), and to the decoy effect of foraging birds (Ward and Zahavi 1973, Kushlan 1981).

Cooperfield, and sites 4 and 2 supported 75.3% of total waterfowl use and had greater coverage of desirable food plants (Kelly and Porcher 1986). The unmanaged sites supported <1% of the waterfowl use. Chabreck et al. (1974) found that duck use of brackish impoundments was similar to that of open marshes in Louisiana. This is not characteristic of tidal salt or brackish marshes in South Carolina due to the lack of or low natural food plant production. Impoundment management in South Carolina is very unlike that of Louisiana, of which many are managed as weirs. Additionally, Bildstein et al. (1982*b*) found that waterfowl comprised about 5% of bird use during winter in a nearby tidal salt marsh. Waterfowl food-habitat studies in South Carolina suggest that ducks prefer habitats characteristic of managed impoundments (Conrad 1965, Landers et al. 1976, Swiderek 1982).

Conclusion

Brackish marshes managed for waterfowl were used by more species and greater numbers of waterbirds than unmanaged sites. Precise water control and prompt management responses to changing conditions can be critical factors to successful management and underscores the importance of having on-site managers of wetland ecosystems. Impoundments in good "working" condition but under improper management may not provide the necessary conditions for high wildlife use.

Use of managed wetlands by waterbirds was directly related to season, size of area and water level. Manipulation of water levels to encourage waterfowl use also provided favorable conditions for other migratory birds.

These results suggest that multi-species management plans can be implemented on coastal, brackish impoundments. Modified waterfowl management strategies can increase resource availability and enhance conditions for many waterbird species and still maintain high waterfowl use. Further, resource managers have an option to choose a featured group or species of management other than waterfowl.

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