THE POPULATIONS, BREEDING BIOLOGY, AND ENVIRONMENTAL RELATIONS OF THE BLACK DUCK, GADWALL, AND BLUE-WINGED TEAL AT PEA AND BODIE ISLANDS, NORTH CAROLINA

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INTRODUCTION

The black duck (*Anas rubripes* Brewster), the gadwall (*Anas strepera* Linnaeus), and the blue-winged teal (*Anas discors orphna* Stewart and Aldrich) are the only species of waterfowl nesting in North Carolina (other than the native wood duck *(Aix sponsa (Linnaeus))*, inland. All three species reach the approximate southern limits of their respective nesting ranges along the Atlantic coast in the vicinity of Pea and Bodie islands on the "outer banks" of northeastern North Carolina. The black duck and the blue-winged teal nest continuously in the coastal marshes from Pea and Bodie islands northward into Canada. The gadwall colonies on the Atlantic coast are located between Pea Island, North Carolina and Long Island, New York and are disjunct by 1600-2200 miles from the normal range in Utah and the Dakotas.

The black duck has long been known to nest sparingly in coastal North Carolina (Green, 1939). The blue-winged teal and the gadwall apparently have been nesting at Pea Island only since this area became a national wildlife refuge in 1938 (Grey, 1940). The three species have nested regularly on Bodie Island only since the establishment of the Cape Hatteras National Seashore Recreational Area in 1954.

The principal field work for this study was carried out by the senior author during the nesting seasons of 1959 and 1960. Field work was accomplished on the following schedule: occasional week-end trips during April and May of both years; June, July, and August of 1959, and June 6—July 13, 1960, in residence on the study area.

Systematic searches for nests were made both years. However, arrival for full-time research in early June was too late for the main part of the egg laying and incubation periods. Thus the early phases of the breeding biology were not a primary part of the research plan. Some nesting data were gathered, however, and some records from earlier years were available in the refuge files.

During both summers brood counts were made at intervals on both of the fresh-water ponds at Pea Island, where most of the ducks were reared. Counts were conducted at least every other week in 1959 and every week in 1960. In 1959 only occasional estimates were made at Bodie Island, but in 1960 regular brood surveys were extended to this area. Brood counts were made by wading along the perimeters of the ponds and walking systematically over the marshes. As the broods were flushed, the species, location and habitat, number in the brood (as closely as possible), approximate age, and any behavioral characteristics noted were recorded. The age of ducklings was estimated by modified version of the five-age-class system of Southwick (1953). Three age classes were used, as follows: small downy—one day to approximately 1.5 weeks; large downy—approximately 1.5 weeks to 4 weeks; feathered but flightless—4 weeks to flight.

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A vegetational analysis was made of all habitat types in the vicinity of the fresh-water ponds on Pea Island. The basic plant communities of the refuge had already been recorded on a map by the refuge personnel, and this was the basis for the type maps reproduced in this report.

Most of the data on populations of waterfowl at Pea Island prior to 1959 was obtained from the refuge files. The main sources were the quarterly narrative reports, submitted by the refuge manager, and special, non-periodic reports and incidental notes. No written information was available for previous years from Bodie Island.

RESULTS

The Study Area. Pea and Bodie islands comprise a twenty-mile strip of North Carolina's "outer banks." The islands are separated by the two-mile-wide Oregon Inlet, Bodie Island lying to the north and Pea Island to the south. Bodie Island is a part of the Cape Hatteras National Seashore Recreational Area, while Pea Island is a national wildlife refuge encompassed within the National Seashore.

Both of these narrow, barrier islands have essentially the same topography. Immediately behind the ocean beach there is a 300 to 800-foot wide line of sand dunes rising from three to twenty feet above mean high tide. To the west of the dunes the land slopes off across sandy flats to brackish marshes. Pamlico Sound, brackish and 1-6 feet deep inshore, separates the outer bank islands from the mainland (Figure 1).

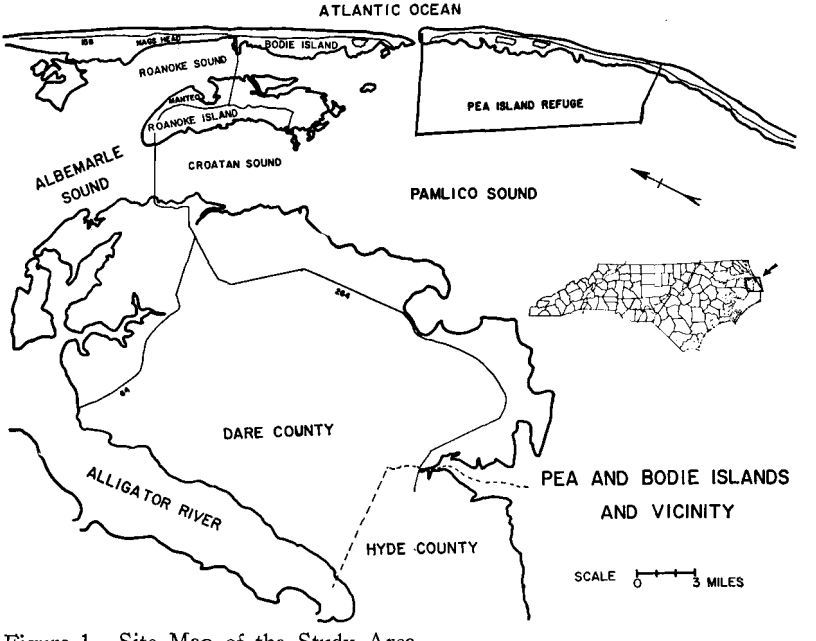

Figure 1. Site Map of the Study Area.

Of prime importance are the two fresh-water impoundments on Pea Island and the brackish pond and fresh-water borrow pits along the new highway on Bodie Island. The pond on Bodie Island (Figure 2) contains approximately 400 acres of water, marsh, and small islands. The borrow pits range in size from approximately one-fourth acre to five or six acres and extend intermittently along the road for four miles.

On Pea Island two large dyke systems have been constructed since the establishment of the refuge. Each consists of a three-sided dyke with the open edge facing the ocean dunes. Each system encloses a fresh-water pond and marsh. The dykes were built primarily with a drag-line. Soil was dredged

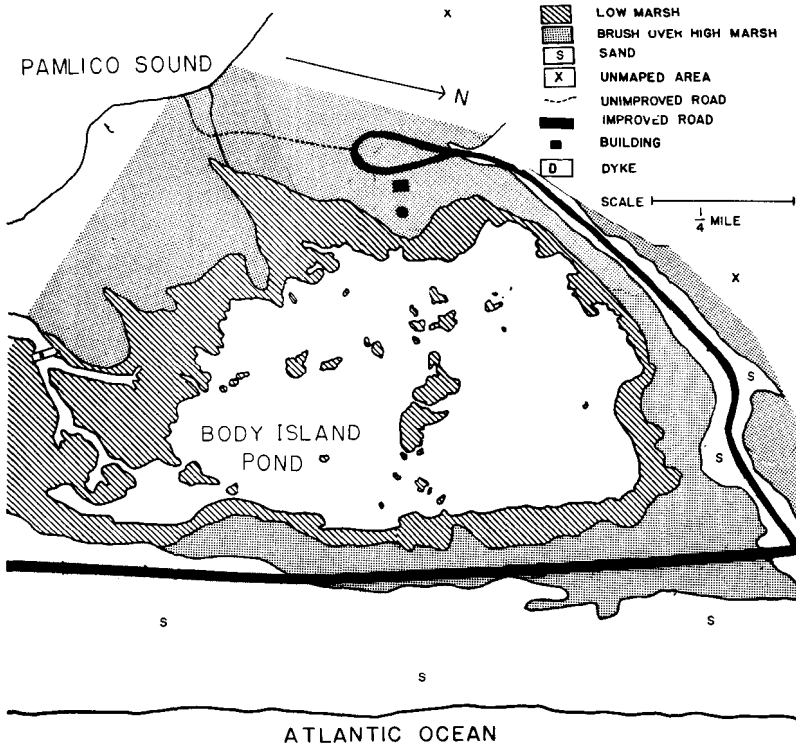

Figure 2. The Bodie Island Pond.

from the inside of the dyke, forming borrow pits. These pits average five to six feet in depth and are 20-40 feet wide. The open parts of the ponds average one to two feet deep during times of sufficient rain but may be completely dry during periods of extended summer drought.

The South Pond (Figure 3) was completed in 1940 and contains approximately 180 acres of water, including several small islands, and about 200 acres of fresh-water marsh. The North Pond (Figure 4) was completed in 1949 and contains 420 acres of water, including islands, and approximately 220 acres of fresh-water marsh.

The substrate is basically sand, but a heavy growth of marsh vegetation has produced a black organic muck six to ten inches deep beneath much of the marsh. Within these ponds the several islands are generally low and marshy, but a few are three to four feet above the water level and contain heavy stands of brushy vegetation.

The water level in the fresh-water marshes advances and recedes at irregular intervals. In times of plentiful rain the marsh is flooded, primarily along the eastern face, for a distance of 200 to 300 feet from the open pond edge. When drought prevails, however, an open sand flat may be exposed between the pond and the marsh.

The weather during the two years of the study was within the normal pattern expected for this region. No heavy storms or unusual weather conditions occurred, with the exception of a period of drought during the early summer of 1959. Table 1 gives the general weather conditions for the spring and summer months of 1959 and 1960. This table was compiled from the reports of the Bodie Island weather station, operated by the National Park Service. The most striking facts shown by this table are the moderating effects of the ocean and Pamlico Sound on the local climate.

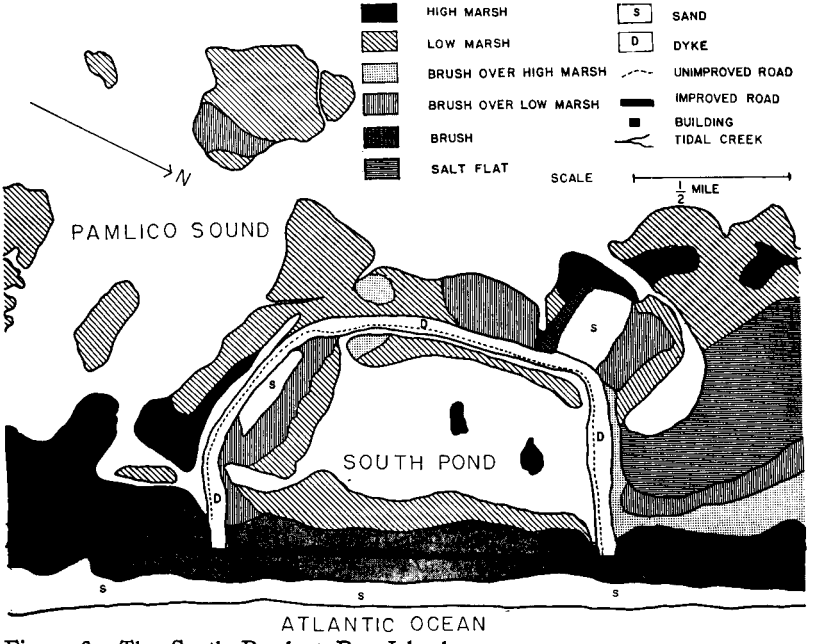

Figure 3. The South Pond at Pea Island.

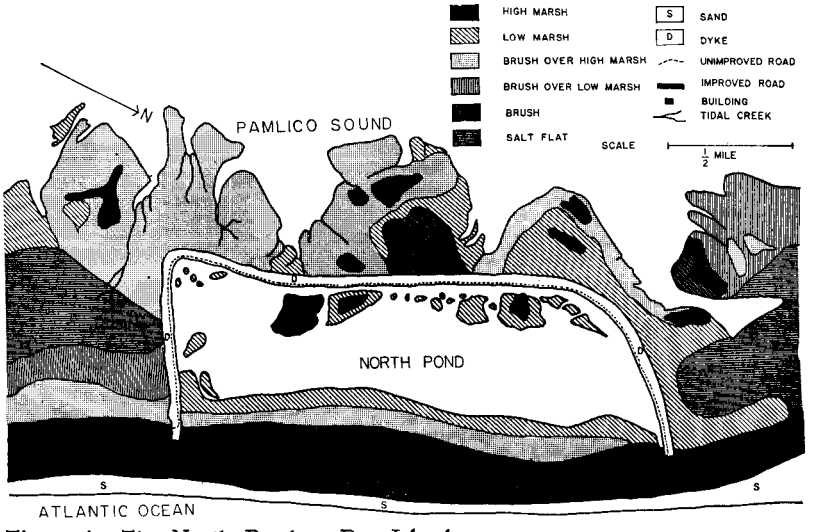

Figure 4. The North Pond at Pea Island.

TABLE 1

PRECIPITATION AND TEMPERATURE FLUCTUATIONS DURING SPRING AND SUMMER MONTHS OF 1959 AND 1960, AS COMPILED FROM THE BODIE ISLAND WEATHER STATION REPORTS

Year and Month	*Precipitation*	*TEMPERATURE* *Absolute Maximum*	*Average Maximum*	*Absolute Minimum*	*Average Minimum*
1959					
April	2.89	82	75.7	41	52.0
May	0.29	89	77.7	49	63.8
June	0.59	97	83.9	52	68.1
July	6.42	94	86.3	68	72.9
August	2.45	95	88.9	60	73.6
1960					
April	2.02	86	70.1	40	53.2
May	2.86	90	76.7	50	60.7
June	1.97	92	83.6	52	70.0
July	7.30	95	86.7	65	72.1
August	5.80	95	87.8	69	73.1

Water conditions on the study area were generally satisfactory for nesting both years. However, a critical point was reached, especially in the South Pond, during June of 1959, when the South Pond flats, and large areas of the North Pond flats, went completely dry. Both ponds held water in the borrow pits throughout this period, however. The pond at Bodie Island does not have borrow pits to hold a reserve water supply, and this pond went dry in both summers. The drought lasted from early June until mid-July in 1959. In 1960 rains refilled the ponds in late June.

Prior to construction, the pond sites at Pea Island were intersected by several tidal creeks. As the ponds filled, they were high in salinity. After construction no salt water was admitted, except during one break in the dyke in the early years of the ponds' existence. Hurricanes also allowed some salt water to get in, but the basic water source has been rain. The salinity fluctuated between 0.70 and 1.60 per cent of sea strength during the summers of 1959 and 1960. No salinity tests were made on the Bodie Island Pond, but it is fed to some extent by a small tidal creek and thus has a continuous renewal of a limited amount of brackish water. The pond depends primarily on rain-water, however, and when this source is lacking it goes dry.

The study area contains four major vegetation types: sand dunes, salt marsh, fresh-water marsh, and fresh-water ponds. All were utilized by the nesting ducks, and so a brief description of each is given below. The authority for the plant names used is Fernald (1950).

The sand dunes consist primarily of a long barrier strip along the inner edge of the ocean beach. Smaller dunes that form elevated knolls above the generally flat topography are also scattered over much of the island. Sea oats (*Uniola paniculata*) and American beachgrass (*Ammophila breviligulata*) are dominant on the higher dunes. The sea oats cap the dunes, with the beachgrass becoming dominant on the shoulders and smaller dunes. On Pea Island the pond dykes represent an artificial continuation of this type, and beachgrass is dominant over most of the dyke surfaces. Saltmeadow cordgrass (*Spartina patens*) also occurs on the lower dunes as a dominant.

The dunes grade slowly into the salt marsh on the sound side of the islands. Saltmeadow cordgrass is dominant, growing in a heavy mat over much of the marsh. In the higher parts of the salt marsh six-weeks fesque (*Festuca octoflora* Walt.) may replace the cordgrass. The higher parts of the salt marsh are also dotted with clumps of woody shrubs, the most common of which are: bay berry (*Myrica pensylvanica*), wax myrtle (*Myrica cerifera*), marsh elder (*Iva frutescens*), and groundsel tree (*Baccharis halimifolia*).

As the marsh becomes lower and more frequently flooded by high tides, triangle sedge (*Scirpus robustus*) becomes abundant, usually growing up through a mat of saltmeadow cordgrass. Along the inner edge of the intertidal zone, triangle sedge or spike-grass (*Distichlis spicata*) may form solid stands.

The intertidal flats and tidal-creek edges are dominated by smooth cordgrass (*Spartina alterniflora*). Salt-worts (*Salicornia* spp.) also form patches in this portion of the marsh. Much of the intertidal flats are devoid of vegetation, however.

Within the impoundments the fresh-water marsh is sufficiently different to require separate description. These fresh-water marshes have a more diverse flora than the salt marshes, which are often characterized by nearly solid stands of a single species.

Saltmeadow cordgrass provides a light cover over much of the fresh-water marsh, with many species growing within this matrix. The more common species in the higher areas are: the rushes (*Juncus scirpoides* and *Juncus Gerardi*), chairmaker's rush (*Scirpus americanus*), bushy beardgrass (*Andropogon virginicus abbreviatus*), panic grasses (*Panicum* spp.), seaside goldenrod (*Solidago sempervirens*), little and big beans (*Strophostyles* spp.), and pennywort (*Hydrocotyle umbellata*). Thickets of wax myrtle, marsh elder, and marsh mallow (*Hibiscus palustris*) are also present. Many such thickets have been cleared and are presently in the process of reversion to open marsh.

Where regular flooding occurs, a mixture of smartweed (*Polygonum* spp.) and fog-fruit (*Lippia lanceolata*) form dense patches. Beneath these dominants, pennywort is abundant. It is replaced along the edge of the open water by water-hyssop (*Bacopa monnieri*). Some narrow-leaved cattail (*Typha angustifolia*) occurs, but control work by the refuge staff keeps this species reduced to small, isolated patches.

The most abundant aquatic plant growing in the ponds is sago pondweed (*Potamogeton pectinatus*). Illinois pondweed (*Potamogeton illinoensis*) and clasping-leaved pondweed (*Potamogeton perfoliatus*) are also common in the open, shallow flats of both ponds. The naiad (*Najas guadalupensis*) grows in small amounts in the South Pond, and widgeon grass (*Ruppia maritima*) occurs occasionally in the North Pond. Water milfoil (*Myriophyllum spicatum*) is also common in the borrow pits of the South Pond. As the mud flats become exposed during the low water of summer, dwarf spike-rush (*Eleocharis parvula*) becomes abundant.

Status of the Black Duck, Gadwall, and Blue-winged Teal on the Eastern Coastal Marshes. This was determined by writing to tide-water national wildlife refuges from Maine to Georgia, and from the literature. The general nesting range along the Atlantic coast is thus presented before specific data from the study area are covered.

The southernmost refuge contacted was the Savannah River Refuge on the northern Georgia coast. None of the species being considered was reported nesting there.

During the summer of 1960 a pair of gadwalls raised a brood on the Cape Romain Refuge near Georgetown, South Carolina, in a situation much the same as at Pea Island. This is the most southern nesting record for any of the three species under consideration (Chamberlain, 1960).

At the Back Bay Refuge, in southeastern Virginia, black ducks and blue-winged teal were reported from the marshes just south of the refuge. No breeding gadwalls were reported.

In northeastern Virginia, the manager of the Chincoteague Refuge reported from seven to 41 broods of black ducks each year since 1953. Blue-winged teal also have nested regularly here in small numbers (one to five broods each year), and two to three pairs of gadwalls have nested each year since 1955. Small, natural or bulldozed islands within the impoundments formed the preferred nesting sites.

Across the Chesapeake Bay at the Bombay Hook Refuge, in Delaware, all three of these species were reported nesting. Black ducks and gadwalls were common nesters, but blue-winged teal were found only in limited numbers.

In 1948 the gadwall was discovered nesting in the tidal mashes of Somerset County, Maryland (Springer and Stewart, 1950). This represents the only report of this species nesting on the Atlantic coast in unprotected areas.

On the upper Eastern Shore of Maryland, Stotts (1960) has done extensive research (1953-1958) on a sizable nesting population of black ducks. In the preferred nesting sites, densities of as high as 21.4 nests per acre were found. Black ducks were also reported as commonly breeding throughout the tide-water areas of the eastern shore of the Chesapeake Bay section of Maryland

by Stewart and Robbins (1958). This is primarily unprotected marsh, and is ample evidence of the continuous nesting of this species in suitable habitats in much of the middle Atlantic coastal marshes.

Blue-winged teal were reported as common to uncommon breeders in the southern part of the eastern shore of the Chesapeake Bay area by Stewart and Robbins (1958).

In New Jersey the Egg Island Waterfowl Management Area has a nesting concentration of black ducks and gadwalls. In 1959 the nesting gadwall population reached a high of 63 pairs. *Spartina alterniflora,* along the edges of the tidal creeks, was given as the primary nesting cover for the gadwalls. A 20-acre, non-tidal pond was found to be the preferred rearing area for the older gadwall broods. The hatching peak there was generally June 22-30.

Only a few miles north of Egg Island, at the Brigantine Refuge, no nesting gadwalls were reported, although one or two pairs of adults were seen during the summer months of 1959 and 1960. The black duck was the dominant nester there, with 20 broods reported in 1959. Only two to three broods of blue-winged teal were found each year.

In 1947 a gadwall colony was discovered at Jones' Beach, Long Island. In July of that year, 18 pairs with 54 young were counted. The pond utilized by the broods was just behind the barrier dunes, much the same as at Pea Island (Sedwitz *et al.,* 1948).

At the Parker River Refuge in eastern Massachusetts only limited nesting of black ducks and blue-winged teal was reported. No gadwalls have been recorded nesting this far north on the east coast.

In Maine the Moosehorn Refuge is situated well within the normal, northern nesting range for the black duck, and upwards of 100 pairs utilize this refuge each summer. One to six pairs of blue-winged teal have been counted each breeding season.

In summary, the black duck and the blue-winged teal nest continuously in the coastal marshes from Cape Hatteras northward into Canada, while the gadwall nests only in several isolated colonies between Cape Romain, South Carolina and Long Island, New York.

Populations in the Study Area. This area was an important wintering ground for waterfowl long before the establishment of the Pea Island National Wildlife Refuge. These islands lie at the point of convergence of several heavily travelled migratory lanes, and for many years have held large wintering populations of greater snow geese, Canada geese, and many species of ducks.

Winter populations of black ducks and gadwalls on the Pea Island ponds reached peak numbers of 2,200 and 450 birds respectively in early December of 1959. After this time the weekly counts made by the refuge staff dropped until by late March only 250 black ducks and 75 gadwalls were estimated. The first blue-winged teal were recorded at this time also. No banding studies have been done to establish residence status, however.

When S. A. Walker, the first refuge manager, issued his first annual report in 1938, he estimated that about fifty young black ducks were raised on the refuge that year. In 1939 Grey (1940) reported the first brood of gadwalls on the refuge. By 1940 the South Pond had been completed, and all three of the species being studied were reported nesting on the refuge. Since 1940, the nesting colonies of all three species have become firmly established, with gadwalls and black ducks most abundant. The blue-winged teal population appears to have remained low until 1959, when the more detailed searches indicated increased numbers of nesting pairs.

The estimated production of each species from 1938 through 1958 is given in Table 2. No data were in the refuge files for 1946. These figures are most useful in indicating the general levels and trends of the nesting populations.

An accurate determination of the initiation of nesting in early spring was not possible within the framework of the present study. However, on May 9, 1959, eight broods of black ducks were found, some of which were about one-half grown. In 1960, a single black duck nest containing ten eggs was found on April 14. On May 15, 1960, a search of the dyke around the North Pond revealed seven duck nests: five gadwall, one black duck, and one blue-winged teal.

TABLE 2.

APPROXIMATE ANNUAL PRODUCTION OF NESTING DUCKS AT PEA ISLAND AS DETERMINED FROM REPORTS IN THE REFUGE FILES

Year	*Black Ducks*		*Gadwalls*		*Blue-winged Teal*	
	Broods	*Young*	*Broods*	*Young*	*Broods*	*Young*
1938	?	50	0	0	1	4
1939	15–20	119	1	10	0	0
1940	12–14	?	6–8	55–60	4–6	35–40
1941	6–8	?	4–5	?	1–2	?
1942	5–6	?	2–3	?	0	0
1943	25	120	8	60	4	20
1944	20	100	8	50	6	30
1945	5	25	12	60	1	4
1946	?	?	?	?	?	?
1947	15	175	30	300	1	3
1948	12	125	9	75	1	?
1949	?	175	44	325	?	40
1950	11	66	61	490	0	0
1951	18	128	77	619	1	6
1952	23	138	95	665	0	0
1953	20	140	88	630	4	10
1954	31	241	71	542	2	9
1955	41	287	93	681	2	9
1956	27	189	38	267	7	56
1957	63	461	54	378	3	18
1958	32	264	73	583	3	26

Based on the appearance of the young broods in the primary rearing cover (those areas used by the broods for approximately the first two weeks after hatching), the peak of hatching for the black duck was during the first two weeks of June both years. The blue-winged teal hatching peak corresponded closely to this in 1959, but in 1960 was spread throughout June. The later-nesting gadwalls reached a hatching peak that was spread over the last three weeks of June both years. Some renesting of gadwalls and blue-winged teal was recorded well into August.

Production varied considerably between 1959 and 1960. Comparative data were available only from Pea Island, where the 1960 production of black ducks and blue-winged teal was sharply reduced from 1959, while gadwall production showed a gain. This same trend was indicated for Bodie Island, but data were not adequate for definite comparisons. The production estimates for the various units are presented in Table 3.

TABLE 3

A COMPARISON OF THE 1959 AND 1960 DUCK PRODUCTION ON PEA AND BODIE ISLANDS *

Year	*Pea Island*				*Bodie Island Pond and Borrow Pits*	
	North Pond		*South Pond*			
	Broods	*Young*	*Broods*	*Young*	*Broods*	*Young*
1959						
Black Ducks	33	150	15	80	?	?
Gadwalls	50	343	1	5	?	?
Blue-winged Teal	18	74	5	31	?	?
Total	101	567	21	116	*33+	*250+
1960						
Black Ducks	23	112	6	29	20	110
Gadwalls	64	449	1	8	3	28
Blue-winged Teal	14	83	2	14	9	48
Total	101	644	9	51	32	186

* The calculations for 1959 from Bodie Island were based on a single count.

Determination of the average brood size for each age class was difficult due to mixing of broods and the problem of getting complete counts when the broods were in dense vegetation. Therefore all broods of doubtful number or size were eliminated from these calculations. In 1960, average sizes of gadwall and blue-winged teal broods were determined only for the two downy stages. Insufficient numbers of these species were feathered by the end of the field rearch period for estimates of the feathered but flightless category. Average sizes for all three age classes were possible for the earlier-nesting black ducks. Using the total averages available for both years of the study, brood size and mortality were estimated from first observation to flight. Table 4 summarizes these findings.

TABLE 4

ESTIMATED AVERAGE BROOD SIZE AND MORTALITY FROM APPEARANCE IN PRIMARY REARING COVER TO FLIGHT *

Species	*Small Downy*	*Large Downy*	*Feathered but Flightless*	*% Loss*
Black Duck	(25) 6.36	(25) 4.76	(29) 4.37	31
Gadwall	(70) 6.85	(45) 5.68	(16) 3.68	46
Blue-winged Teal	(24) 6.79	(14) 5.78	(04) 5.25	23

* The numbers in parentheses represent the number of broods used to calculate the average size of each age class for each species.

Breeding Biology. Observations on the earlier phases of nesting activities were sharply curtailed by the necessarily late start of full-time field work. The short visits to the study area in April and May allowed only the general progress to be followed. Therefore, major emphasis was placed on the period after the broods appeared in the primary rearing cover.

Twelve nests were located, and several of these are worthy of mention. Of particular interest were the five gadwall nests found on May 15, 1960. All were located on the outer slopes of the southern and western dykes of the North Pond, in sections covered by American beachgrass. Each nest was located opposite a tidal slough which extended to within 20-30 yards of the dyke. No nest was found elsewhere on the dykes, and no other sloughs extended as close to the dykes in other sections. Also of interest was one black duck nest which was located in a thin stand of saltmeadow cordgrass just behind the ocean dunes. This nest was about 250 yards from the ocean and approximately the same distance from any other water source.

Upon hatching the broods were apparently led directly to the primary rearing cover. On Pea Island all three species used the flooded edges of the fresh-water ponds almost exclusively. On Bodie Island extensive fresh-water marsh was not present, and the island edges assumed a greater importance. In the salt marsh the black ducks used the shallow sloughs and creeks as primary rearing areas.

As the broods reached the large downy stage, they moved into the secondary rearing cover, where they remained until attaining flight. The black ducks used the pond and island edges extensively at this time and also moved into the higher areas of fresh marsh some distance from water. Some broods also moved into the salt marsh at this stage. On Bodie Island the black duck broods utilized the sloughs along the south side of the pond to a large extent. The blue-winged teal occupied similar habitats but were usually more closely associated with water than were the black ducks.

The gadwall broods separated almost completely from the other species in their secondary rearing cover. At Pea Island they utilized the western borrow pit of the North Pond almost exclusively. The broods congregated in this area in large numbers, feeding in the sago pondweed patches. They preferred the open water and when disturbed bunched into larger flocks. This was quite different from the behavior of the black ducks and blue-winged teal, which sought dense cover when disturbed. A few broods of black ducks or blue-winged teal were often seen feeding in the borrow pits with the gadwalls early

in the morning, but as the day progressed they moved into cover, while the gadwalls remained in open water.

Most of the juvenile black ducks attained flight during the period from mid-June to mid-July in 1959; in 1960, the ducklings began flying at about the same time, but in mid-July a few broods of downy young were still present. Flying juvenile blue-winged teal began appearing the first week in July both years; flightless broods were still present in early August of 1959. The first gadwalls did not attain flight until the third week in July in 1959, and in 1960 no flying juveniles had been seen when the field work was ended on July 12.

When the juvenile birds attained flight they began to scatter. Flocks of mixed young and adult ducks were seen at times on Pea and Bodie islands, but the large concentrations of June were not recorded in later summer. This original outward movement of juvenile ducks is not properly denoted as migration, but rather occurs prior to the directional fall migratory movement (Hochbaum, 1955).

The first indication of the regular fall, southward migration was the appearance of large flocks of blue-winged teal from farther north on August 28, 1959, and August 22, 1960. The locally reared teal that had remained on the refuge until this time apparently joined these flocks and moved farther south to winter, as no blue-winged teal remain in the Pea Island area over winter. It is not known whether the black ducks and gadwalls raised on the study area migrate southward or remain in the general vicinity for the winter.

Predation. The possible waterfowl predators on Pea Island during the summer included: feral cats (*Felis domesticata* Fischer), common; otter (*Lutra canadensis* (Schreber)), common; mink (*Mustela vison* Schreber), uncommon; bald eagle (*Haliaeetus leucocephalus* (Linnaeus)), rare; fish crow (*Corvus ossifragus* Wilson), abundant; black racer (*Coluber constrictor* (Linnaeus)), abundant; water snakes (*Natrix sipedon* (Linnaeus)), abundant; and snapping turtles (*Chelydra serpentina* (Linnaeus)), abundant. In addition to these, on Bodie Island there was the gray fox (*Urocyon cinereoargenteus* (Schreber)), common: opossum (*Didelphis marsupialis* (Linnaeus), common; chain kingsnake (*Lampropeltis aetulus* (Linnaeus)), uncommon; and the raccoon (*Procyon lotor* (Linnaeus)), common.

Few actual instances of predation were observed. Two cases of mammalian predation, probably by feral cats, of nesting hens were found. A gadwall hen and a blue-winged teal hen were each found partially eaten at the sites of their nests. Also two instances of snapping turtles catching young gadwall ducklings were observed. Both occurrences were in open water. Several other ducklings were found dead but the causes of death could not be determined.

DISCUSSION

Populations. The black duck has long nested in the marshes of the outer bank islands of North Carolina, but the blue-winged teal and gadwall have apparently become nesters only since the establishment of the Pea Island National Wildlife Refuge. The blue-winged teal may actually have nested undetected in the area prior to the beginning of the refuge, as they have been recorded only in very small numbers until 1959. The gadwall seems difinitely to have begun nesting here only since 1939.

From 1940 to 1949 there was a gradual increase in numbers of nesting gadwalls and black ducks. After 1949, however, populations began to fluctuate widely on an annual basis. A linear regression test and analysis of variance did not reveal any evident trends in brood numbers, due to regression, during the 1950-1960 period. Thus, it appears that the gadwall and black duck populations fluctuated around mean densities controlled by annual limiting factors. An effort was made to correlate these annual fluctuations with temperature and water levels, but this analysis proved inconclusive.

The reported blue-winged teal population did not follow the upward trend of the other species. The apparent upsurge of teal broods in 1959 and 1960 may have been due, in part, to inaccurate or incomplete estimates prior to 1959. The annual counts in these years were not as detailed as in 1959 and 1960. On the other hand, the national wildlife refuges to the north of the study area all reported small populations of this species. In addition, the 1961 nesting popula-

tion of blue-winged teal was again reported as low, so no clear statement can be made at present about the status of this species.

The development of the refuge made three basic changes in the environment favorable to nesting ducks: (1) protection during the nesting season, (2) grazing of the lush marsh vegetation by horses and cattle stopped, and (3) fresh, non-tidal ponds established. These improvements in the nesting and rearing habitats apparently have fostered the nesting waterfowl population increase at the edge of the climatic range for breeding. Without these changes one would expect gradually tapering populations as the environmental barrier was approached. Climate, in conjunction with unprotected, marginal habitats, seems to do just this to the black duck and blue-winged teal populations in the marshes south of Cape Hatteras. The absence of these ducks as breeders on the more southern coastal refuges substantiates this hypothesis.

The gadwall has its center of nesting distribution in California, Utah, and South Dakota, and the colonies along the east coast have become established only in the past twenty to twenty-five years. This seems to be correlated more with man-made changes in habitat than with climate, as this species nests from prairie climates to both northern and southern coastal climates. The climate at Pea and Bodie islands, however, has been shown to be considerably moderated by the presence of the nearby ocean and Pamlico Sound. The one pair of gadwalls breeding at Cape Romain, South Carolina in 1960 possibly indicates that Pea Island need not be the usual or main southern nesting limit.

If we assume that habitat may be the most important factor in the expansion of the breeding range of the gadwall, a comparison of the eastern coastal marshes and the inland western marshes is in order. The Bear River Marsh in Utah is considered to be an area of near-optimum breeding conditions for the gadwall, according to Williams and Marshall (1938), so this area is suitable for the comparison.

The Pea Island and Bear River marshes both have extensive salt and brackish marsh habitats. The Bear River marshes are in the upper reaches of the Great Salt Lake Basin, and about twenty-five miles of dykes have been constructed there to hold fresh water. The vegetation on the two areas is also directly comparable in many instances. On one study area at Bear River, saltgrass (*Distichlis spicata*) comprised 26% of the vegetative cover. This species is also common on Pea and Bodie Islands. Alkali bullrush (*Scirpus paludosus*), which covered 59% of the area under study at Bear River, is very similar to triangle sedge *(Scirpus robustus)* of the coastal marshes; in a recent work both are considered more correctly placed in the same species. (Mason, 1957). The narrow-leaved cattail *(Typha angustifolia)* is present in fresh-water communities of both marshes, and in low saline flats the genus *Salicornia* is present. In the ponds of both refuges, sago pondweed *(otamogeton pectinatus)* is abundant. Thus, the vegetation of the two regions is strikingly similar, much more so than a comparison of climates would suggest.

One main difference remains between the coastal marshes and the inland marshes. Under natural, unmodified conditions the water levels on the western marshes are fairly stable, fluctuating only with precipitation, while the eastern coastal marshes are tidal. The construction of the large, fresh-water, non-tidal ponds at Pea Island (and other refuges on the east coast) has reduced this difference. In addition, the presence of the dykes and islands associated with these impoundments has created the preferred nesting topography for the gadwall, where it did not exist before (Hammond and Mann, 1956). The fact that the gadwall regularly nests in colonies may also be important in allowing large populations to develop in areas with relatively small amounts of stable water.

Gadwall colonies have become established in at least six locations along the east coast. Five of these are on state or federal land and are thus protected. Also five of these areas contain non-tidal ponds. In two instances these ponds are natural. On the three wildlife refuges, the use of the impoundments seems to vary somewhat. At Egg Island, New Jersey, where research has been going on for several years, a definite preference for these non-tidal ponds is exhibited by the older broods. At Pea Island the ponds are used by the gadwalls for the entire rearing period.

Large amounts of submerged plants (*Potamogeton,* spp., primarily) are present in the non-tidal ponds at Bombay Hook, Egg Island, and Pea Island. These plants provide a food supply similar to that on the western marshes.

Thus, many similarities in plant life exist between these eastern coastal and western inland marshes, both in generic and specific representation of plants and in plant life form. The main natural difference of stable water levels in the west versus daily tidal fluctuations in the east have been eliminated where impoundments have been built, or where non-tidal ponds occur naturally, in the coastal marshes. Protection allows normal growth of the marsh vegetation and undisturbed nesting. This combination of conditions, produced largely by the efforts of man, apparently has allowed the establishment and continuation of the several colonies of gadwalls in the eastern coastal marshes.

In the study area considerable annual fluctuations in brood production have occurred over the past ten years. The possible causes of these differences are many and range from local factors to factors operating throughout the Atlantic Flyway. Although this problem was not solved, one interesting point was noted. Seemingly, these limiting factors are operating independently on each species, and not on the nesting population as a whole, as in a given year one species may increase over the long-term average while another decreases. This is probably correlated with the very distinct niches that each species occupies on the nesting grounds.

A general comparison was made between the trends of the annual nesting population levels on our study area and those for the Atlantic Flyway, but no correlation could be discerned (Crissey, 1960).

Breeding Biology. In order to establish the difference in the time of nesting between the North Carolina study area and the primary nesting area for each species, the initial appearances of broods or time of peak of hatching was compared with the results of the major works on each species under study. The first brood of black ducks, based on a four-year average, was seen on May 16 in a Canadian study by Wright (1954). At Pea and Bodie Islands seven broods of black ducks, some at least two weeks old, were recorded on May 9, 1959. Stotts (1960) recorded a brood as early as March 29 in his Chesapeake Bay study (1953-1958) and found that the peak of the hatch was usually in mid-May. This suggests that the hatching period begins two to three weeks earlier along the south Atlantic coastal marshes than in Canada.

The peak of the gadwall hatch on the Bear River marshes came about July 20 (Williams and Marshall, 1938). At both Pea and Egg Islands the peak came in late June. Thus the mid- and south-Atlantic populations of gadwalls appear to nest two to three weeks earlier than those on the western marshes.

The smaller number of blue-winged teal nesting on our study area made an adequate comparison difficult, but it appears that this species reaches a peak of nesting about a week earlier here than in Iowa. The peak of the hatch at Pea and Bodie Islands was June 1-15, while in Iowa the peak came June 15-30 (Glover, 1956).

Brood size and mortality comparisons were also made between the North Carolina and the primary nesting area populations. It was necessary to combine or separate age groups in some cases due to the different systems of age classifications used by the various workers, which probably introduced some error. A comparison of Class I (up to one-fourth grown) broods indicates that, at the initial appearance of the broods of all three species, there was little difference in brood sizes between the several regions. However, when the mortality from first appearance to flight was calculated, a much heavier loss of black ducks and gadwalls was indicated for our area.

At Pea and Bodie Islands the average loss of black ducks was 31% of each brood, while in Canada Wright (1954) found an average loss of only 19%. In Maryland, the approximate loss of black ducks was only 09% (Stotts, 1956). At Pea Island the gadwall mortality from first appearance to flight was 46% of each brood, compared with a loss of 27% at Klamath Refuge, California (Miller and Collins, 1954), and 23% at Ogden Bay Refuge, Utah (Gates, 1962). The mortality data for the blue-winged teal at Pea and Bodie Islands must be viewed with added caution, because the average brood size for the feathered

but flightless age class was based on only four broods. However, the calculated loss was 23%, as compared with a loss of approximately 16% in Iowa (Glover, 1956).

Thus at Pea Island a greater loss was incurred than on any of the several primary breeding areas considered. This was especially noticeable in the gadwall and black duck and may indicate an adverse effect of climate near the southern limit of breeding. The average loss of only 09% in the Maryland black duck study casts doubt on this hypothesis, however, and local conditions may be of prime importance. Certainly the occurrence of large numbers of snapping turtles in the secondary rearing cover of the gadwall broods at Pea Island could, in itself, be a primary factor in the greater loss of ducklings. A more careful analysis must be conducted before these questions can be answered with any authority.

SUMMARY AND CONCLUSIONS

Pea and Bodie Islands, North Carolina have the most southern breeding populations of black ducks, gadwalls, and blue-winged teal on the Atlantic coast. The field work of the present study was carried out during the summers of 1959 and 1960. Methods consisted primarily of systematic brood counts and general brood observations. These islands contain four major vegetative types used by the nesting ducks: sand dunes, salt marshes, fresh-water marshes, and fresh-water ponds.

The black duck and blue-winged teal nest continuously along the east coast from Cape Hatteras, North Carolina northward. The gadwall nests only in isolated colonies at Pea Island, North Carolina; Chincoteague, Virginia; Bombay Hook, Delaware; Egg Island, New Jersey; Somerset County, Maryland; and Jones' Beach, Long Island. One brood was raised in 1960 at Cape Romain, South Carolina.

Black ducks apparently have long nested sparingly at Pea and Bodie islands, but gadwalls and blue-winged teal began nesting there only after the establishment of the Pea Island National Wildlife Refuge in 1938.

Black duck and gadwall populations increased gradually until about 1950, after which fluctuations become annual with no demonstrable trends. The blue-winged teal population remained low until 1959 when production apparently increased substantially. Approximate production on the Pea Island area for the two years of the study was: 1959—black duck 230, gadwall 348, blue-winged teal 105; 1960—black duck 144, gadwall 457, and blue-winged teal 97. Data from Bodie Island were available only for 1960, when 111 black ducks, 28 gadwalls, and 48 blue-winged teal were produced.

The major rearing areas for all species were the two fresh-water ponds on Pea Island (1020 acres of water and marsh), and the brackish pond and borrow pits on Bodie Island (approximately 500 acres of water and marsh). The primary rearing cover for all three species on Pea Island was the flooded marsh along the east side of each pond. The three species separated upon entering the secondary rearing cover. The black ducks went primarily into the higher marsh, while the blue-winged teal remained along the pond edges. The gadwalls congregated into large flocks in the open water of the Pea Island borrow pits.

Approximate mortality was calculated for all three species from first appearance in the marsh to flight. Estimated mortality for the young black ducks was 31%, for gadwalls 48%, and for blue-winged teal 23%. The high loss of gadwalls was probably correlated with increased vulnerability due to use of open water during the rearing period. Several species of predators were present. Most important were snapping turtles and feral house cats.

The conditions supporting a nesting population increase at the southern limits of the black duck and blue-winged teal ranges appear to be improved habitat and protection. These factors seemingly offset the expected reduction in nesting populations near the southern limit of the breeding range.

Comparison between the eastern coastal marshes and the western inland marshes, where the gadwall nests in abundance, shows striking vegetative similarities at the genus and species ranks. Stabilization of water levels in the impoundments of the coastal marshes increases this similarity significantly. This factor appears to be of great importance in determining the location and

success of the eastern gadwall colonies, which are disjunct by 1600-2200 miles from the primary nesting areas of this species.

The breeding biology of all three species was observed to be basically similar to that recorded for these birds in their more optimum nesting regions, with the exception that juvenile mortality was higher on the study area.

This study indicates that controlled water levels and protection may allow substantial increases in the nesting populations of the black duck, gadwall, and blue-winged teal on the eastern coastal marshes.

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ABSTRACT

A two-year study was made of the nesting ecology of the black duck (*Anas rubripes* Brewster), the gadwall (*Anas strepera* Linnaeus), and the blue-winged teal (*Anas discors orphna* Stewart and Aldrich), at their southern nesting limits along the Atlantic coast. Approximate production at Pea Island was: 1959—black duck 230, gadwall 348, blue-winged teal 105; 1960—black duck 144, gadwall 457, blue-winged teal 97. Production at Bodie Island, estimated only for 1960, was: black duck 111, gadwall 28, and blue-winged teal 48. The major rearing areas were the two man-made fresh-water impoundments on Pea Island (1020 acres of water and marsh) and the brackish pond on Bodie Island (500 acres water and marsh). Estimated juvenile mortalities were: black duck 31%, gadwall 48%, and blue-winged teal 23%. Major predators were feral cats (*Felis domesticus*) and snapping turtles (*Chelydra serpentina*). Comparison between the North Carolina coastal marshes and the mid-western duck-producing marshes revealed a striking vegetative similarity. Stabilization of the water levels at Pea and Bodie Islands, by impoundment, has increased this habitat similarity and apparently been of great importance in determining the location and success of the North Carolina gadwall colonies, which are disjunct by 1600-2200 miles from the major nesting areas of this species. The conditions supporting fairly high densities of nesting black ducks and blue-winged teal at the southern limits of their breeding ranges appear to be improved habitat and protection. The breeding biology of all three species was observed to be basically similar in North Carolina to that recorded for these birds in their major nesting regions.

SURVIVAL, RENESTING, AND RETURN OF ADULT WOOD DUCKS TO PREVIOUSLY USED NEST BOXES

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ABSTRACT

During 1961 adult female wood ducks (*Aix sponsa*) were removed from nest boxes on three ponds near Raleigh and banded with U. S. Fish and Wildlife Service leg bands. During the 1962 nesting season ducks were again removed from nests for banding and a large percentage of them were found to be ducks returning from the previous year.

An analysis of the first two years of the banding study revealed that (1) no nests were deserted as a result of banding during late incubation, (2) survival of adults as measured by the return of nesting birds was 47%, (3) there was a high rate (70%) of return of birds to individual boxes in which they had previously nested, and (4) some females produced two successful broods in a single season.

INTRODUCTION

During the past 25 years great interest has been shown in providing nesting sites for wood ducks. Most interest has been directed toward increasing production of this beautiful and important game bird. Much information has been obtained about nest box utilization, nesting dates, clutch sizes, and related nesting activities. Most studies have measured activities on a population level and few have attempted to measure the nesting of individual ducks. The study herein reported was conducted by banding incubating females in nest boxes and measuring their subsequent nesting.

REVIEW OF LITERATURE

Thousands of nest boxes have been erected for wood ducks in recent years primarily in northeastern United States. Some of these boxes have been used for studies on basic life history information about this bird. The Illinois Nat-