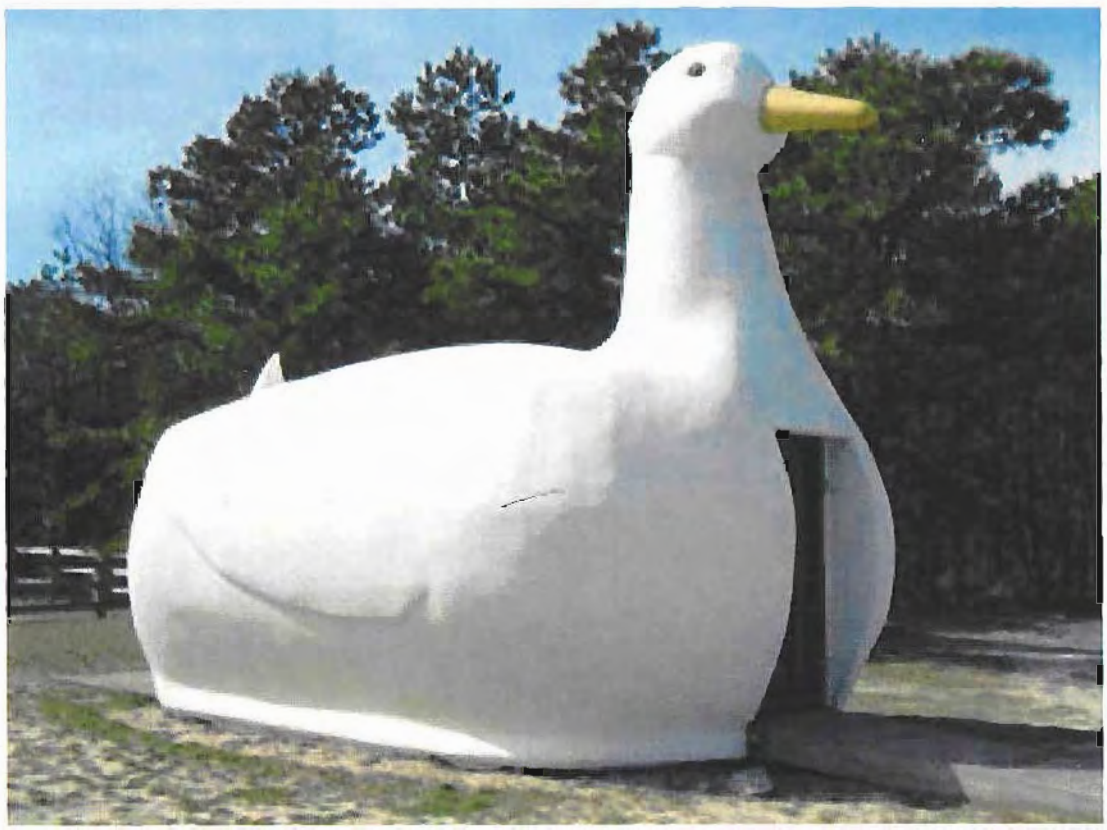
WATER QUALITY TRENDS AT SELECTED STREAMS IMPACTED BY DUCK FARM OPERATIONS



Suffolk County Department of Health Services

Steve Levy, Suffolk County Executive
Humayun J. Chaudhry, D.O., M.S., Commissioner

February 2008

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Cover photo: "The Big Duck", Flanders, NY

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Executive Summary

Duck farming has played an important role in the history and economy of eastern Long Island since the early 1900s, with as many as 70 duck farms once operating in the towns of Brookhaven, Riverhead, and Southampton, and more than 3.5 million ducks harvested annually. With the onset of regulations designed to mitigate pollutant levels in duck farm discharges however, and the expense associated with implementing waste treatment practices, many farms have gone out of business. Over the last few decades, the increasing suburbanization of once rural areas and the attractive nature of waterfront land values have facilitated the industry decline. Today, only four farms remain in operation: the Crescent Duck Farm on Meetinghouse Creek, the Jurgielewicz and Titmus Duck Farms on the Forge River, and the Massey Duck Farm on Seatuck Creek.

Dramatic environmental impacts associated with nutrient-rich duck farm effluents have been well documented in past studies conducted in Moriches Bay and Great South Bay by researchers from the Woods Hole Oceanographic Institution (Redfield, 1951 & 1952; Ryther, 1954; Ryther et al., 1957). Data presented here, although limited in many cases, show elevated levels of nutrients (nitrogen and phosphorus) in waters associated with active duck farm operations, and generally indicate that nutrient concentrations have declined in creeks formally impacted by duck farm operations. Trends in other water quality parameters potentially affected by duck farm operations, specifically coliform bacteria and dissolved oxygen levels, were less apparent in part due to the general paucity of data, but possibly also because of influences from various physical factors not examined here (temperature, sunlight, stream flow, water depth, precipitation, etc).

Notable in the data were changes in nutrient concentrations at a station adjacent to the Crescent Duck Farm on Meetinghouse Creek, where improvements in duck waste treatment practices and the removal of a direct discharge to surface waters have substantially reduced nitrogen (ammonia) levels in the creek. However, despite considerable efforts, concentrations remain elevated above background levels and continue to represent a significant nitrogen input to downstream waters of the Peconic Estuary.

In another instance of an active operation, the Jurgielewicz Duck Farm continues to discharge partially treated waste to surface waters of West Mill Pond (a tributary to the Forge River), and has recently been implicated as a factor contributing to the hyper-eutrophication of the tidal portion of the river, as well as the associated depletion of oxygen levels, the production of malodorous hydrogen sulfide gas, and the occurrence of fish and crustacean mortalities. Results of sampling done in West Mill Pond, where increasing levels of ammonia-nitrogen and phosphorus have been documented, provides an interesting contrast to that being done concurrently in East Mill Pond, formally the site of two duck farms, where nutrient levels have exhibited a declining trend.

Water Quality Trends at Selected Streams Impacted by Duck Farm Operations

Introduction

This report was prepared in response to a request from the Suffolk County Planning Department for an analysis of the water quality of streams formally impacted by duck farms. The information presented is intended to supplement ongoing efforts by the Planning Department to characterize historic duck farm activities in the county and to assess potential restoration priorities.

Duck farming has played an important role in the history and economy of eastern Long Island since the early 1900s. At one time there were over 70 duck farms operating in the towns of Brookhaven, Riverhead, and Southampton, with more than 3.5 million ducks harvested annually (BTCAMP, 1992). Unfortunately, duck farm operations characteristically produce dramatic environmental impacts, both immediate and long-term. Duck farm effluents act to enrich nearby surface waters with excessive amounts of nitrogen and phosphorus, which in turn stimulate recurring algal blooms and result in the depletion of essential oxygen levels. Duck waste deposits are potentially an additional source of enrichment as the highly organic sediments decompose and release nutrients to the water column (benthic flux).

In an effort to address water pollution impacts from duck farm operations, legislation adopted in the 1960s and 1970s established effluent discharge limitations and required the use of various waste treatment technologies. Due to the expense of complying with the regulations however, and in more recent years the attractiveness of waterfront land values, the vast majority of duck farms have gone out of business. Today, only four duck farms remain active: the Crescent Duck Farm on Meetinghouse Creek, the Jurgielewicz and Titmus Duck Farms on the Forge River, and the Massey Duck Farm on Seatuck Creek.

Streams discussed here include those associated with both active and formally active duck farms, and include tributaries of the Peconic Estuary (Terry's Creek, Sawmill Creek, and Meetinghouse Creek), Moriches Bay (Forge River), and Great South Bay (Mud Creek/Robinson's Pond and the Carmans River) (Figure 1). The data addressed was collected by the Suffolk County Department of Health Services (SCDHS) Office of Water Resources from 1970-1999 as part of their routine stream sampling program, and by the SCDHS Office of Ecology from 1976-2006 under various environmental management programs (i.e., the Long Island 208 Study, the Brown Tide Comprehensive Assessment and Management Program, and the Peconic Estuary Program). Additional sampling was conducted in Mud Creek and Robinson Pond in 2006 to provide data for an ecosystem restoration study being conducted by the Planning Department in conjunction with the US Army Corps of Engineers, and from 2005-2007 in the Forge River as part of an intensive sampling program investigating the occurrence of hyper-eutrophic conditions and water column hypoxia. Although the data set is extensive, the frequency of data collection was limited in many cases. Trends that are identified should be understood with that in mind.

Figure 1. Map of Suffolk County Showing Tributary Locations

Tributaries of the Peconic Estuary

By the late-1930s there were at least 21 duck farms discharging wastes into tributaries of the Peconic Estuary, with an estimated annual production of over one million ducks (State of NY Conservation Dep't., 1938). Only one farm, the Crescent Duck Farm on Meetinghouse Creek, remains in operation today. Figure 2 depicts sampling locations in Meetinghouse Creek and in two creeks formally impacted by duck farms, Terry's Creek and Sawmill Creek. Sampling in each creek was initiated in the 1970s, and has continued on an intermittent basis to the present.

Terry's Creek

Terry's Creek is located in the Hamlet of Aquebogue in the Town of Riverhead. It flows in a southeasterly direction towards Flanders Bay, and is bordered by agricultural and formerly agricultural land on the northeast and along its upper reaches, and by Indian Island County Park on the southwest. Three duck farms, Wesley Warner, Anna Drop, and Broad Cove, formerly discharged effluent into the creek. The farms ceased operations in 1968, 1972 and 1982, respectively. When SCDHS monitoring was initiated in 1974, only the Broad Cove Duck Farm, located downstream of the sampling locations, was in operation.

The data described here combines that collected from two sites: Station 615-5, located on the east side of Route 105 in Aquebogue, and Station 120, located on the north side of Hubbard Avenue. Station 615-5 was monitored from 1974 through 1999, and Station 120 from 1976 to the present. The stations are relatively close, and values obtained from samples collected from each station on the same day are in good agreement. Descriptive statistics for nutrient and coliform parameters, including mean, maximum and minimum values, and number of samples (N), are included in Table 1.

Nitrogen: Most of the nitrogen found in Terry's Creek was in the form of nitrate and nitrite (NO_x) (Figure 3B and Figure 4) in concentrations that ranged from <0.05 – 3.42 mg/l and averaged 2.11 mg/l. NO_x levels exhibited somewhat of a declining trend from the mid 1970's through the late 1980's, but over the long-term, have shown little variation. In comparison, ammonia (NH_3) levels in Terry's Creek were relatively low (averaging 0.050 mg/l), and also varied little throughout the sampling period. Elevated NO_x and low ammonia levels suggest that the introduction of nitrogen during the study period was primarily through agriculturally polluted groundwater.

Phosphorus: Phosphorus levels in Terry's Creek appear to exhibit a declining trend through the study period (Figure 3C, Figure 4). Although this trend may be associated with cessation of duck farm related input (possibly through a decline in sediment regenerated phosphorus), the assumption remains uncertain due to the limited sampling frequency, particularly during the early monitoring years. Total phosphorus (TP) concentrations ranged from <0.025 – 0.72 mg/l, and averaged 0.159 mg/l, while those for dissolved phosphorus (DP) ranged from <0.025 - 0.67 mg/l and averaged 0.127 mg/l.

Coliforms: The frequency of coliform sampling in Terry's Creek was also very limited, and assessment of long-term trends therefore difficult. As shown in Figure 3D, both total and fecal coliform levels varied widely, with concentrations ranging from <20 to >16,000 coliforms/100 ml. As would be expected, highest coliform levels were typically found in the warmer months.

Figure 2. Locations of Sampling Stations and Duck Farms (former and active) in Tributaries of the Peconic Estuary

Table 1. Nutrient and Coliform Statistics: Mean, Maximum, & Minimum Values, and Number (N) of Cases
Peconic Estuary and Moriches Bay Tributaries

Embayment	Statistic	Ammonia (NH_3-N)	Nitrite + Nitrate (NO_x-N)	Total Nitrogen (TN)	Dissolved Inorganic Nitrogen (DIN)	Total Phosphorus (TP)	Dissolved Phosphorus (DP)	Ortho-Phosphate (o-PO_4-P)	Total Coliform	Fecal Coliform
Peconic Estuary Tributaries:										
Terry's Creek	Mean	0.050	2.11	2.43	2.15	0.159	0.127	0.259	692	256
	Max	0.240	3.42	4.0	3.52	0.720	0.670	0.610	>16,000	>16,000
	Min	< 0.01	< 0.05	0.76	0.138	< 0.025	< 0.025	< 0.01	< 20	< 20
	N	76	72	54	72	64	62	18	74	74
Sawmill Creek	Mean	0.507	0.620	1.50	1.14	0.248	0.059	0.118	1,015	218
	Max	3.85	4.21	8.3	5.98	2.40	0.267	0.460	46,000	>16,000
	Min	< 0.01	0.031	0.10	0.036	< 0.025	< 0.025	< 0.005	< 20	< 20
	N	88	86	60	85	64	61	20	87	87
Meetinghouse Creek (Station 41)	Mean	0.269	7.12	8.0	7.41	0.167	0.022	---	627	116
	Max	1.60	10.4	15.9	10.7	3.05	0.488	---	50,000	16,000
	Min	< 0.01	0.122	1.12	0.151	< 0.01	< 0.01	---	< 20	< 20
	N	196	197	196	195	198	193	---	198	195
Crescent Duck Farm (Meetinghouse Creek Station 4)	Mean	9.15	6.42	16.2	15.5	1.33	1.10	0.96	1,822	645
	Max	44.0	35.1	59.8	59.8	14.0	10.0	3.21	160,000	43,000
	Min	0.10	0.554	3.99	3.69	< 0.01	< 0.01	0.107	< 20	< 20
	N	314	314	297	313	312	164	57	315	315
Moriches Bay Tributaries:										
Forge River West (West Mill Pond)	Mean	3.48	1.44	7.3	5.0	---	---	1.83	552	215
	Max	10.60	3.61	10.0	11.3	---	---	6.50	40,000	16,000
	Min	< 0.02	0.613	2.02	0.850	---	---	0.014	30	< 20
	N	66	66	28	64	---	---	47	54	54
Forge River East (East Mill Pond)	Mean	0.79	1.27	1.69	2.05	---	---	0.094	699	231
	Max	12.50	3.70	2.72	13.3	---	---	1.0	16,000	16,000
	Min	<0.02	0.027	0.98	0.037	---	---	< 0.01	< 20	< 20
	N	63	64	25	63	---	---	44	50	50

Note: Nutrients are in mg/l as N or P; Coliforms are No./100 ml

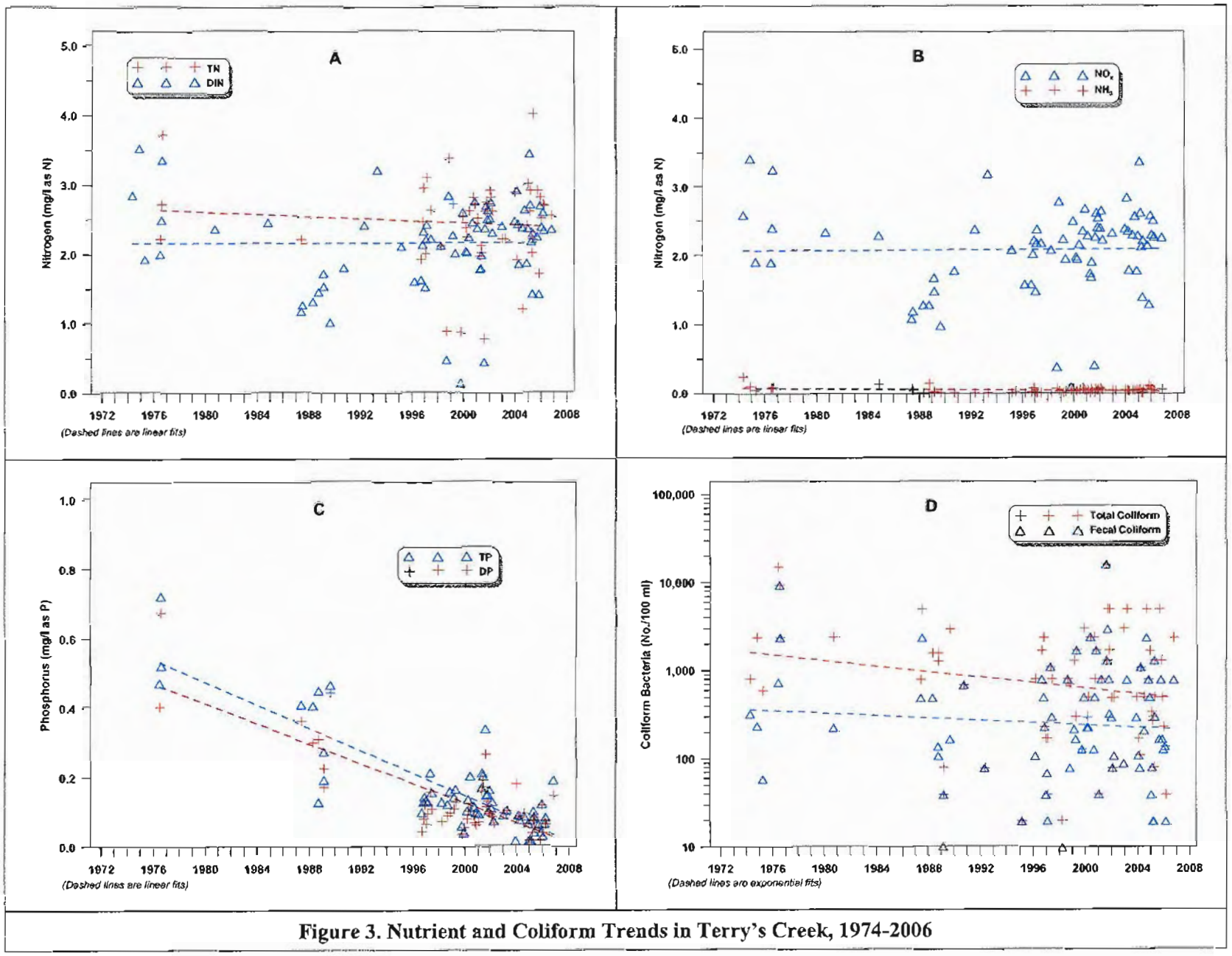

Figure 3. Nutrient and Coliform Trends in Terry's Creek, 1974-2006

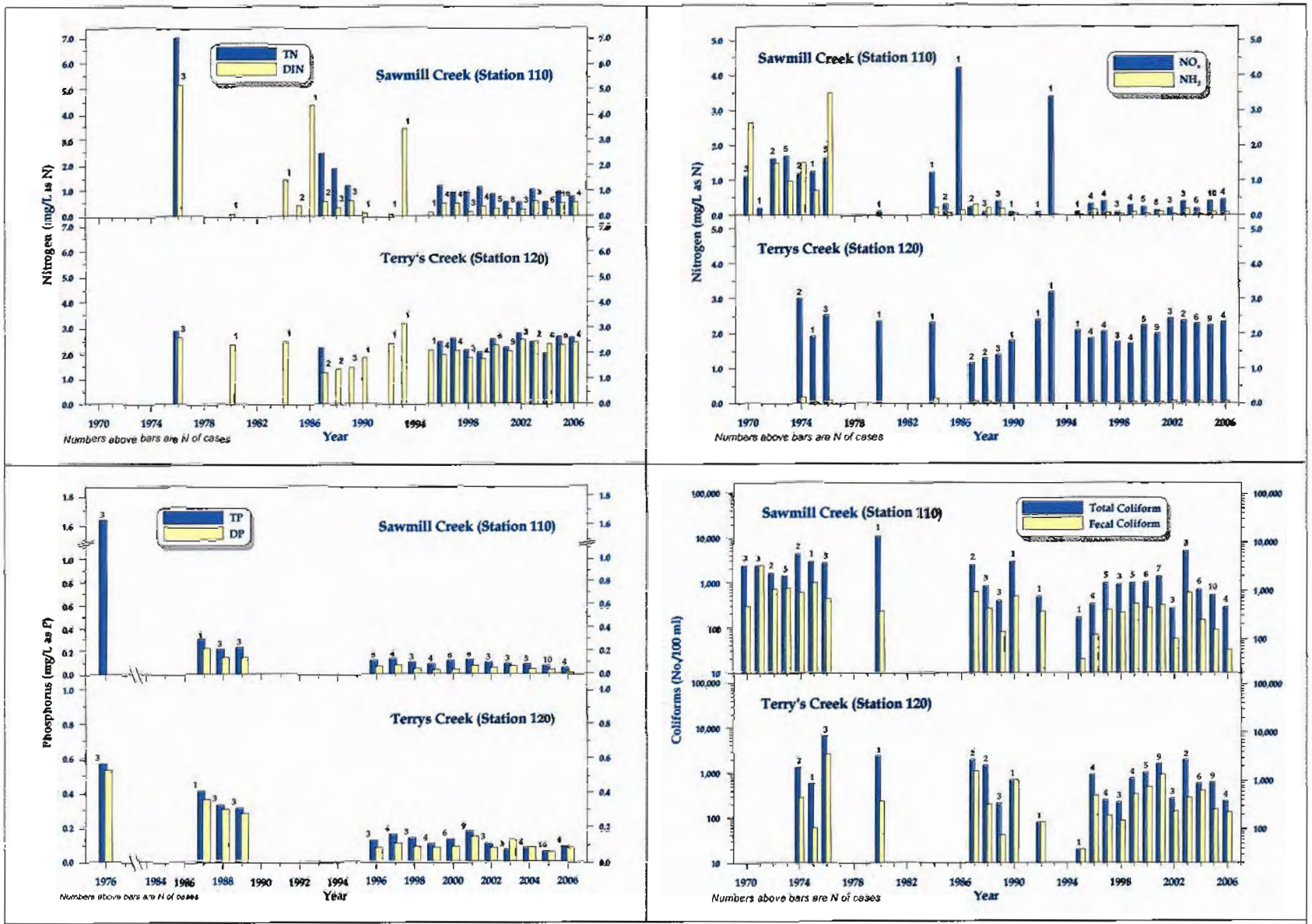

Figure 4. Annual Average Nutrient and Coliform Concentrations in Terry's Creek and Sawmill Creek

Dissolved Oxygen: Dissolved oxygen (D.O.) levels were determined only at Station 120 in Terry's Creek. Although data collected during the early years are extremely limited, it appears that D.O. levels have increased since 1976 when two of three samples were below the 5.0 mg/l New York State guideline (Figure 5).

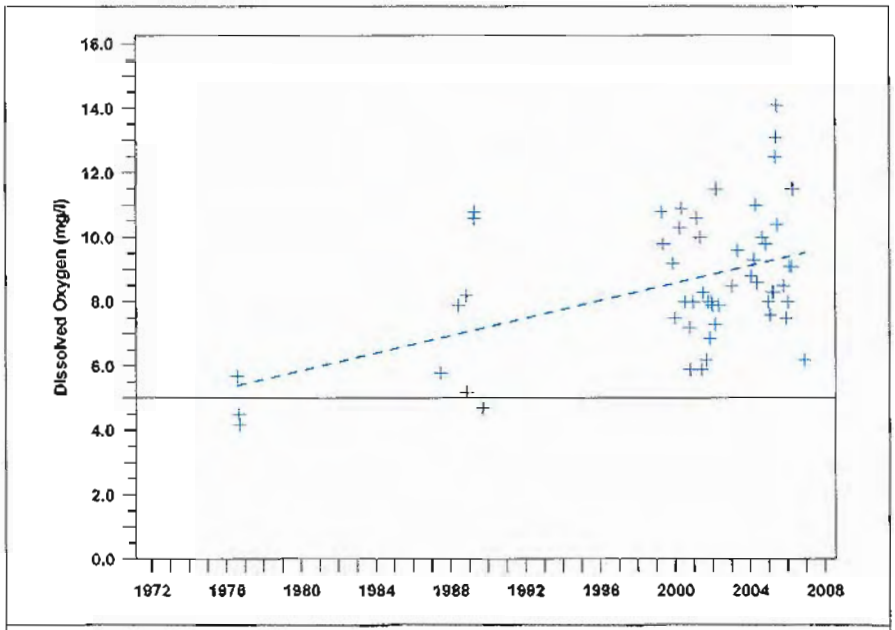

Figure 5. Dissolved Oxygen Levels in Terry's Creek, 1976 – 2006

Sawmill Creek

Sawmill Creek is located south of Terry's Creek (Figure 2), and discharges to the Peconic River just west of the river's mouth. Its lower reach is bordered by Indian Island County Park and the Riverhead Golf Course, with its upper reach extending into agricultural lands in Riverhead. Four duck farms formerly discharged into Sawmill Creek: Schubert, Hubbard (Sunrise), Bonneview, and Riverside. The Riverside Farm closed in 1964, the Shubert farm in 1983, and Bonneview and Hubbard in 1984.

Samples were collected from three locations: station 610-10 (from 1970 - 1987), station 610-5 (from 1984 - 1999), and station 110 (from 1996 to the present). The data have been combined as the stations are relatively close; and data collected on the same day, or during similar time periods, are in generally good agreement.

Nitrogen: As shown in Figure 6A and 6B, nitrogen levels in Sawmill Creek exhibited a decreasing trend from the 1970s through the late 1980s, after which they remained relatively low. On average, most of the DIN was present as NO_x, although in 1970 and 1976, NH_3 was by far predominant (Figure 4). Overall, concentrations of NO_x ranged from 0.031 - 4.2 mg/l with an average of 0.62 mg/l, while NH_3 levels ranged from <0.01 - 3.85 mg/l and averaged 0.51 mg/l. The high NH_3 and NO_X levels during the early sampling period (Figure 6B) suggest both duck farm and agricultural activities as possible pollution sources. The decline in nitrogen levels in

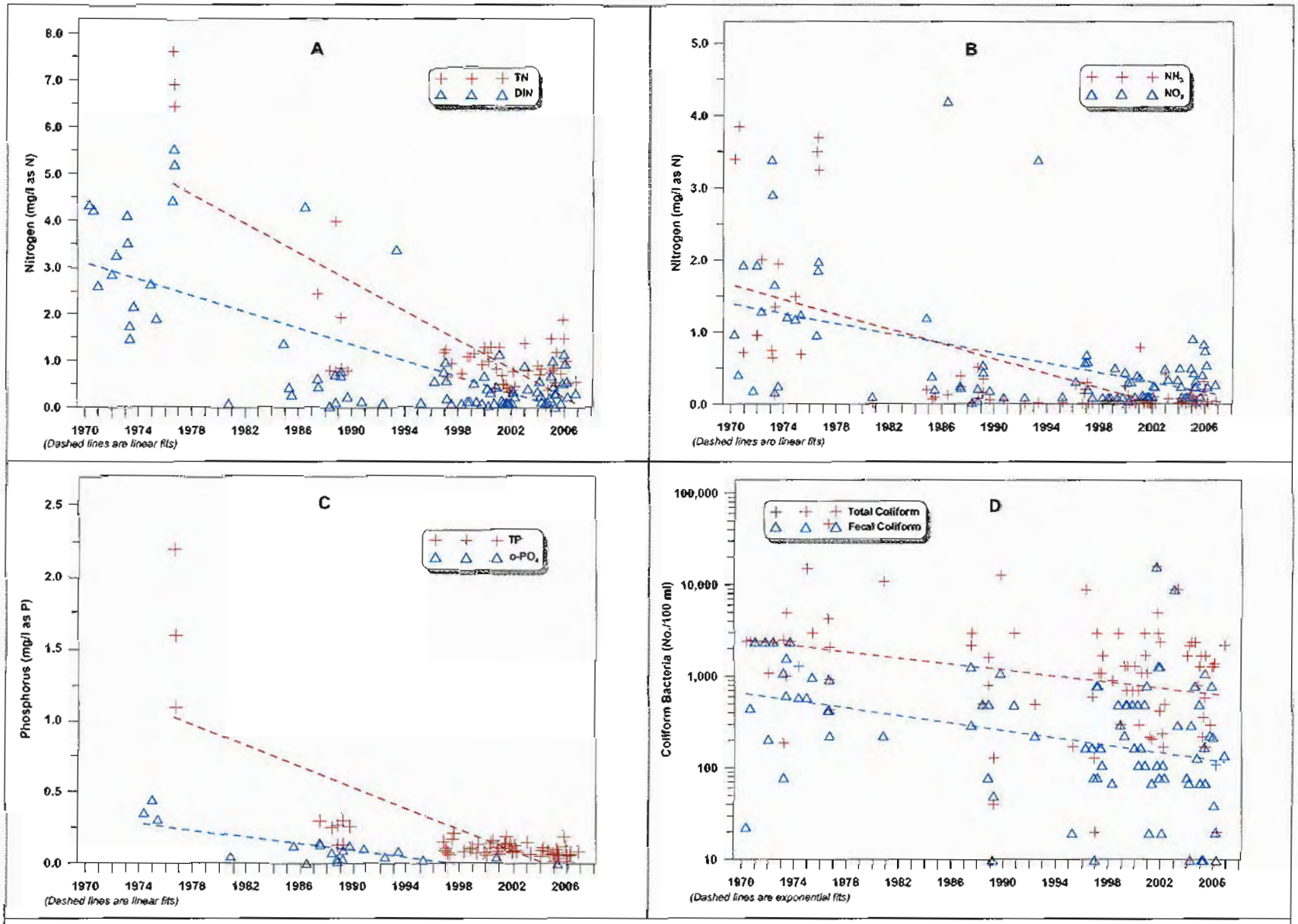

Figure 6. Nutrient and Coliform Trends in Sawmill Creek, 1970 - 2006

the 1980s may have resulted from a combination of the cessation of duck farm operations and a decrease in agricultural activities in the immediate watershed.

Phosphorus: As in Terry's Creek, phosphorus levels in Sawmill Creek exhibited a decreasing trend through the period of study (Figure 4 and Figure 6C). However, as with Terry's Creek, the significance of this is questionable due to an extremely limited sampling frequency during early monitoring years. Total phosphorus (TP) concentrations ranged from <0.025 – 2.4 mg/l, and averaged 0.25 mg/l, while DP levels ranged from <0.025 - 0.27 mg/l and averaged 0.059 mg/l (Table 1).

Coliforms: Coliform sampling in Sawmill Creek was on a more frequent basis than in Terry's Creek, although still less than robust during the early monitoring years. Existing data show somewhat of a declining trend from the mid-1970s in both total and fecal coliform levels (Figure 6D), the significance of which (at least in regard to duck farms) is questionable. Concentrations varied widely, ranging from < 20 to 46,000 organisms/100 ml for total coliform, and from < 20 to >16,000 for fecal coliform.

Dissolved Oxygen: Because the frequency of dissolved oxygen measurements during the early monitoring years was extremely limited, apparent trends are difficult to assess. With that in mind, results shown in Figure 7 seem to indicate an increasing trend in oxygen levels, with fewer and less severe violations of the NYS 5.0 mg/l standard during the latter years.

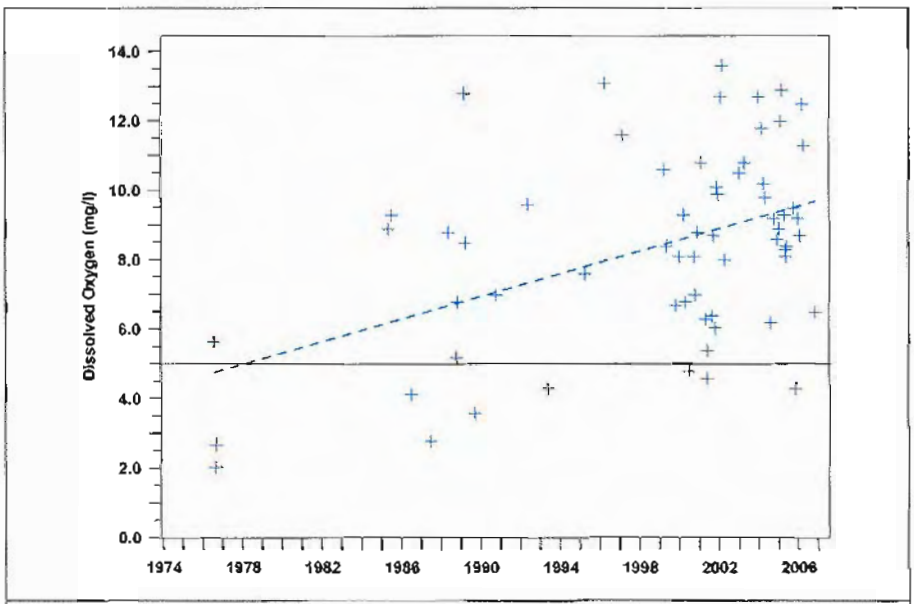

Figure 7. Dissolved Oxygen Levels in Sawmill Creek, 1976 - 2006

Meetinghouse Creek

Meetinghouse Creek is located to the northeast of Terry's Creek (Figure 2), and is currently the most impacted of the three western Peconic tributaries discussed here. The Crescent Duck Farm, which began operating in 1908 and continues to produce an estimated 800,000 ducks per year, is located just north of the tidal portion of the creek. Prior to 1987, the farm discharged directly to the surface waters of the creek, and was considered a significant point source of nutrients to the waters of Flanders Bay. According to the NYSDEC, the effluent discharge from the farm in 1981 was estimated at 400,000 gallons per day (BTCAMP, 1982). Following the cessation of the surface water discharge in June 1987, the level of nutrients in Meetinghouse Creek were significantly reduced (BTCAMP, 1992). Concentrations remained significantly elevated with respect to levels upstream of the farm however, prompting questions regarding the effectiveness of the treatment system (aeration lagoons). In an effort to further reduce nutrient additions to the creek, eight acres of artificial wetlands were constructed in 1995 to treat waste in conjunction with the lagoons. In 2006, additional treatment equipment, including an anaerobic composter and two *sequencing batch reactors* (SBRs), were installed.

Samples have historically been collected at two sites in the freshwater reaches of the creek. Station 41, located upstream of the duck farm on the south side of Rt. 25, has been monitored since 1990. Station 4 is located just downstream from the duck farm on the south side of the railroad tracks, and was first sampled in 1976 during the Long Island 208 Study (LIRPB, 1976).

Nitrogen: Nitrogen levels at both sampling locations, predominantly in the form of dissolved inorganic-N (DIN), have been elevated throughout much of the respective sampling periods (Figure 8A & 9A). At station 41, NO_x was the main constituent of DIN (Figure 8B), reflecting concentrations in area groundwater that are typically elevated due to agricultural inputs. Total nitrogen (TN) levels at this site ranged from 1.12 – 15.9 mg/l and averaged 8.0 mg/l over the sampling period, while concentrations of NO_x ranged from 0.12 – 10.4 mg/l and averaged 7.1 mg/l (Table 1). Ammonia levels were comparatively insignificant at station 41, ranging from <0.01 – 1.6 mg/l and averaging 0.27 mg/l. A slight decline in NO_x levels (and by relation TN and DIN) occurred over the sampling period (Figure 8B), possibly due to changes in agricultural practices in the creek's watershed (i.e., the conversion from row crop farming to viniculture and/or of agricultural land to realty subdivisions). Average TN levels declined from a high of 9.7 mg/l in 1991 to 6.3 mg/l in 2006, while average NO_x concentrations declined from 8.6 to 5.5 mg/l (Figure 10).

At station 4, nitrogen levels reflect ammonia additions from duck farm discharges as well as elevated NO_x concentrations in area groundwater. Over the sampling period, TN levels ranged from 3.99 – 59.8 mg/l and averaged 16.2 mg/l (Table 1). Ammonia was generally the predominant form of nitrogen through 1998, with NOx becoming predominant thereafter as ammonia levels declined (Figure 10). The highest nitrogen levels were recorded in 1976, when the five samples collected averaged 35.4 mg/l for TN and 28.1 mg/l for NH_3. Similar levels were found when sampling was resumed at this site in 1987, with concentrations in samples collected through May averaging 33.8 mg/l for TN and 27.7 mg/l for NH_3. Levels declined precipitously thereafter (Figures 9A and 9B), coinciding with the removal of the duck farm's surface water discharge. Further reductions in nitrogen (ammonia) levels in the creek were noted during the 1990's and thereafter, likely due to additional improvements in waste treatment practices at the

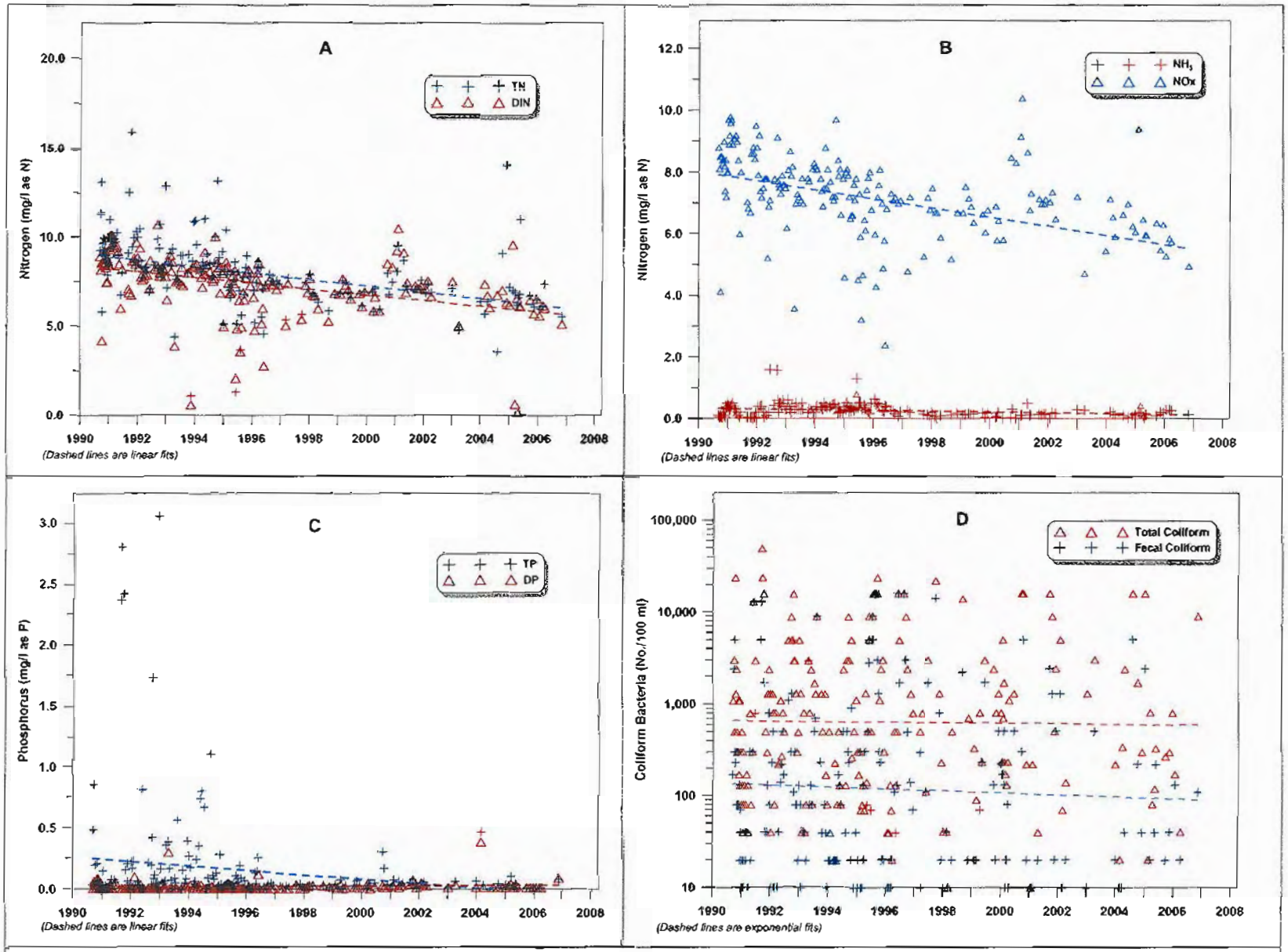

Figure 8. Nutrient and Coliform Trends at Meetinghouse Creek Station 41, 1990 - 2006

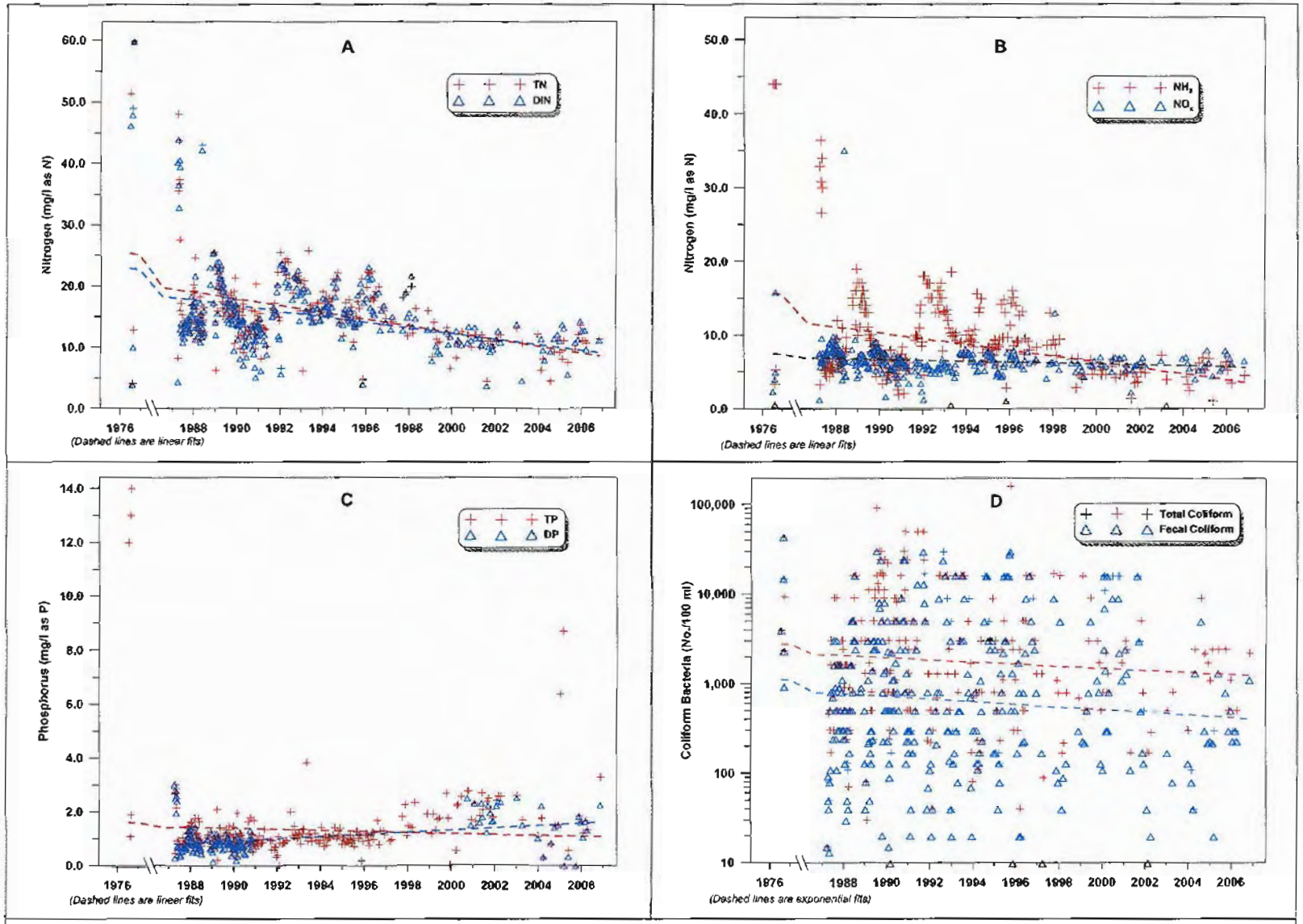

Figure 9. Nutrient and Coliform Trends at Meetinghouse Creek Station 4 (Crescent Duck Farm), 1976 - 2006

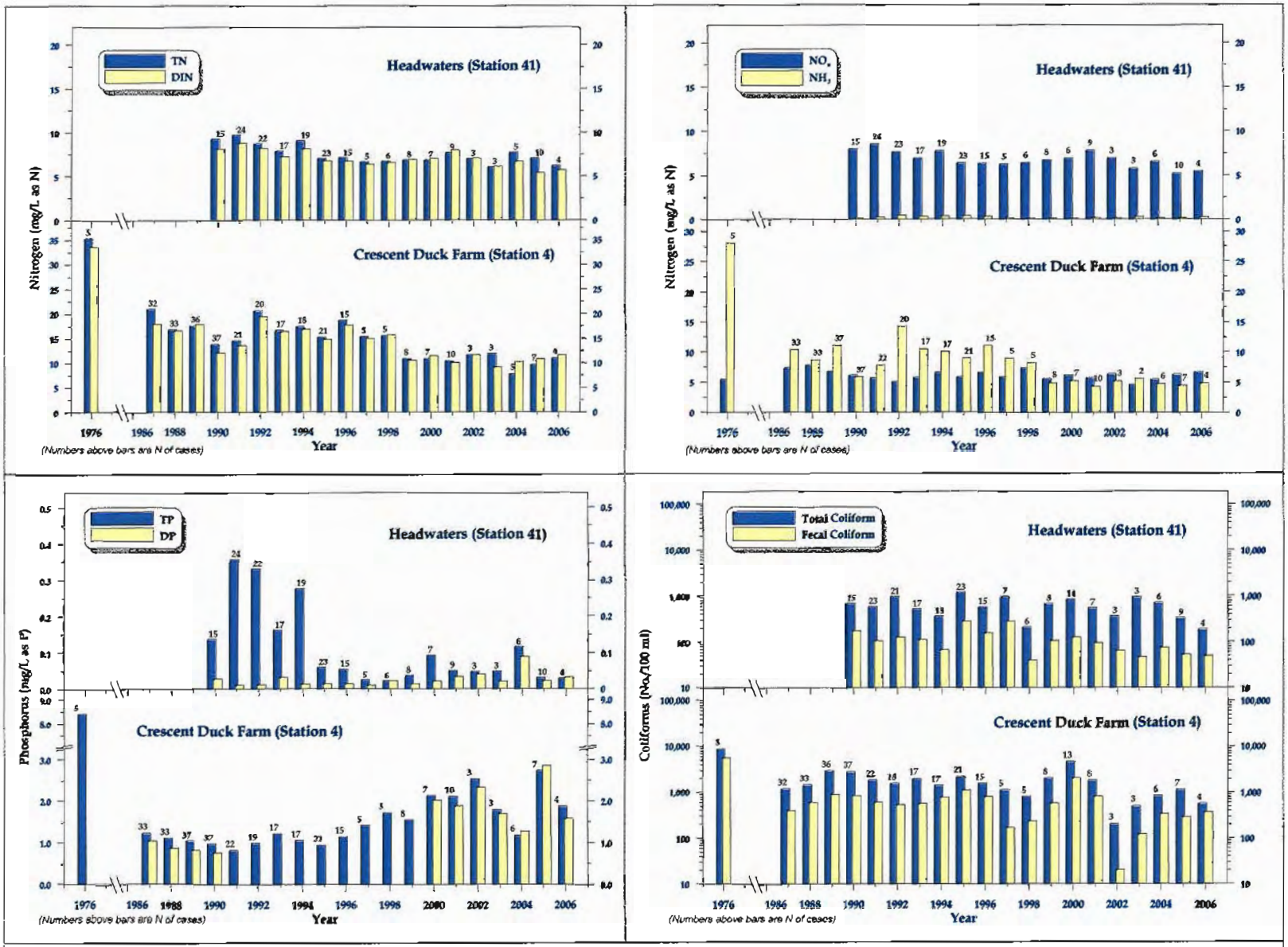

Figure 10. Average Annual Nutrient and Coliform Concentrations at Meetinghouse Creek Stations 4 and 41, 1976 – 2006

duck farm. Despite the improvement in water quality however, ammonia levels remained significantly elevated in relation to concentrations found upstream. From 1987 through 1998, average ammonia levels at the Crescent Duck Farm site varied between 5.9 and 14.3 mg/l, and declined to less than 5 mg/l from 1999-2006 (Figure 10). In comparison, the highest average ammonia concentration recorded at station 41 upstream was 0.45 mg/l.

Phosphorus: Contrasting phosphorus levels at the two Meetinghouse Creek sites also demonstrate effects from the duck farm on creek water quality. Average TP and DP levels at station 41 were similar to those in Terry's Creek and Sawmill Creek (Table 1), with individual results rarely exceeding 1.0 mg/l (Figure 8C). At station 4 just south of the duck farm however, average phosphorus levels were an order of magnitude higher, likely due to additions of phosphorus laden duck waste. TP levels at station 4 ranged from <0.01 – 14 mg/l and averaged 1.33 mg/l over the sampling period. As with nitrogen, TP and DP concentrations at station 4 exhibited a precipitous decline from the late 1970s to the late 1980's. Unlike nitrogen however, phosphorus levels exhibited an increasing trend from the late 1990's through 2002 (Figure 9C and Figure 10). Average concentrations subsequently declined in 2003 & 2004, before increasing again in 2005 to the highest average concentration recorded since 1976. Other than being an artifact of the duck waste treatment process at the Crescent Duck Farm, no explanation for the fluctuation in phosphorus levels is apparent.

Coliforms: Coliform levels were frequently elevated at both sampling locations, but considerably more so at station 4 downstream of the duck farm. As with Terry's and Sawmill Creeks, both total and fecal coliform levels varied widely in Meetinghouse Creek (Figures 8D and 9D), with higher values occurring more frequently during warmer months (June-September). Concentrations at station 4 ranged from 20 to 160,000 coliforms/100 ml for total coliform and from <20 to 43,000 coliforms/100 ml for fecal coliform (Table 1). Similarly, total coliform levels at station 41 ranged from <20 to 50,000 coliforms/100 ml and fecal coliform from <20 to 16,000 coliforms/100 ml. On average over the sampling period however, levels at the Crescent Duck Farm (station 4) were approximately three times higher than those at station 41 upstream, likely reflecting inputs from the duck farm discharge. Average values (geometric means) at station 4 were 1,822 (total) and 645 (fecal) coliforms/100 ml, while those at station 41 were 627 (total) and 116 (fecal) coliforms/100 ml.

No significant long-term trends were apparent in the data for station 41, where annual means for total coliform ranged from 187 - 1,189 coliforms/100 ml and those for fecal coliforms from 39 - 282 coliforms/100 ml (Figure 10D). At the duck farm site (station 4), both total and fecal coliform levels were significantly elevated in 1976, with means of approximately 8,800 (total) and 5,600 (fecal) coliforms/100 ml. Concentrations were considerably lower in 1987 when the next series of samples was collected, likely associated with the cessation of a surface water discharge at the farm, but remained elevated with respect to levels at station 41 upstream. In discussing the increase in coliform (and ammonia) levels in Meetinghouse Creek soon after the discharge stopped, the BTCAMP study noted that the occurrence cast doubt on the effectiveness of the duck farm's on-site containment system (BTCAMP, 1992). Although a definite cause for the increase in contaminant levels wasn't identified, the study also noted that if overflow or seepage of wastewater from the lagoons was causing the water quality impacts, the farm would be required by their SPDES permit to institute corrective action. Although sampling has been

limited, coliform levels at the duck farm site since 2002 have either been similar to or less than those upstream, possibly reflecting recent improvements in waste treatment at the farm.

Dissolved Oxygen: Except for a limited number of readings taken in 1976 at station 4, routine measurements of dissolved oxygen in Meetinghouse Creek didn't begin until the late 1990's. As shown in Figure 11, concentrations at both stations 4 and 41 exhibited an increasing trend from 1999-2006. During the first three years of the trend (1999-2001) however, the higher frequency of results below the 5.0 mg/l standard may be more related to lower groundwater levels characteristic of those years (and likely reduced stream flow), rather than a reflection of activities at the duck farm.

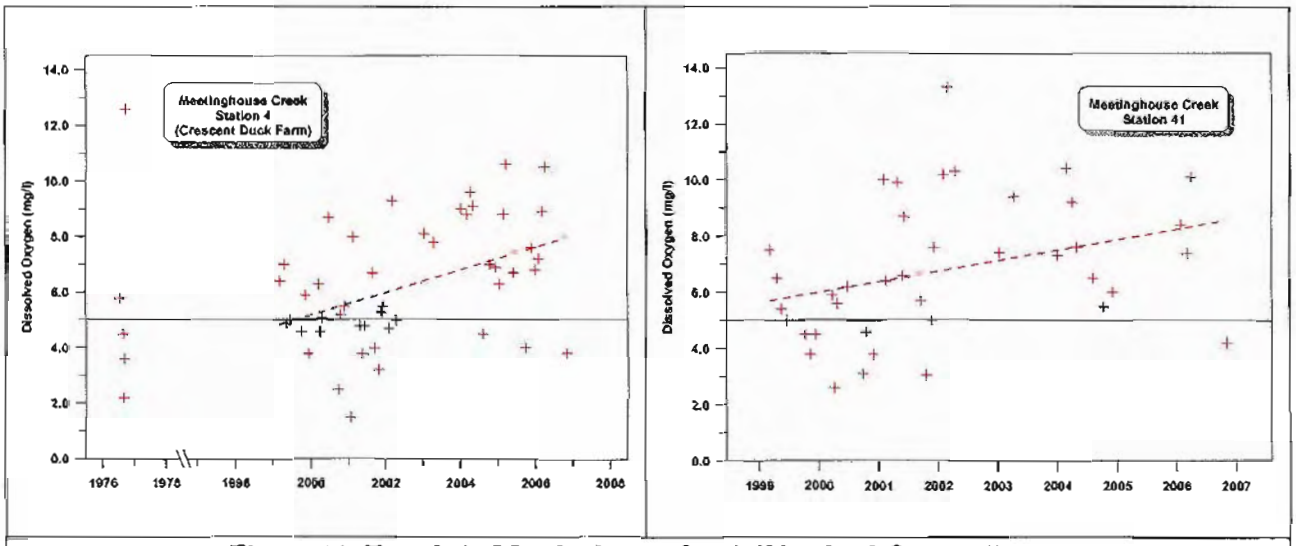

Figure 11. Trends in Meetinghouse Creek Dissolved Oxygen Levels
(dashed lines are linear fits)

Tributaries of Moriches Bay

At one time or another, more than forty duck farms discharged into tributaries of Moriches Bay, including ten farms on the Forge River (and its tributaries), six farms on the Terrell River, and over twenty in the Seatuck Creek and Speonk River areas. Results of sampling done in the two branches of the Forge River, at West Mill Pond and East Mill Pond (Figure 12), are addressed here. Data collected by the SCDHS Office of Water Resources in Terrell River has not been included, because the sampling location was actually in Mill Pond (Kalers Pond), the water quality of which has no relation to duck farm operations that occurred to the south.

Forge River

The Forge River has two duck farms remaining of the ten that formally discharged into this tributary, both located on the western branch of the river. The Jurgielewicz Duck Farm currently discharges to surface waters of West Mill Pond, and the Titmus Duck Farm maintains a subsurface (groundwater) discharge upstream of the Jurgielewicz location. Monitoring of the outflows from both West Mill Pond and East Mill Pond has been ongoing since the early 1970s.

Figure 12. Sampling Stations and Duck Farm Locations in Tributaries to Western Moriches Bay

The two sampling locations provide an interesting contrast of water quality conditions in areas currently and formally impacted by duck farm operations.

Impacts to the waters of the Forge River and Moriches Bay from duck farm operations, including hyper-eutrophication, the loss of benthic organisms, and the occurrence of massive blooms of "small form" algae (*Nanochloris* and *Stichococcus*), have been well documented by earlier studies (Ryther, 1954; O'Connor, 1972). The decline of the once prosperous oyster industry in eastern Great South Bay was also attributed to pollution from Moriches Bay and Forge River duck farms (Redfield, 1951; Redfield, 1952; Ryther et al., 1957).

Nutrient sampling during the early years at the Forge River sites was limited to ammonia (NH_3), nitrite + nitrate (NO_x), and ortho-phosphate ($o\text{-}PO_4$), with total nitrogen (TN) and total phosphorus (TP) samples collected only recently (2005-2007). Distinct differences in water quality trends have been noted between the east and west branches of the river that are likely associated with the closure of duck farms on the east branch, and the continued operation of a farm on the west branch. Average NH_3 and TN levels in West Mill Pond are four times greater than those of East Mill Pond (Table 1), and $o\text{-}PO_4$ is greater by more than an order of magnitude.

Nitrogen: In West Mill Pond, ammonia levels exhibited an increasing trend over the sampling period (Figure 13A and Figure 14), while those of NO_x remained comparatively stable. Concentrations of NH_3 ranged from <0.02 - 10.6 mg/l, and averaged 3.5 mg/l (Table 1), while those of NO_x ranged from 0.61 - 3.61 mg/l, and averaged 1.44 mg/l. In contrast, ammonia levels in East Mill Pond were highest in the earlier years (1971-1972) and declined precipitously thereafter, remaining low through 2007 (Figure 13C). Concentrations ranged from <0.02 - 12.5 mg/l and averaged 0.79 mg/l. Further illustrating the decline in ammonia levels, samples collected pre and post-1976 in East Mill Pond averaged 2.38 and 0.15 mg/l, respectively. Levels of NO_x were similar to those in West Mill Pond, likely reflecting levels typical of area groundwater, and ranged from 0.027 - 3.70 mg/l with an average value of 1.27 mg/l.

Phosphorus: Similar trends are seen in fluctuations in phosphorus levels at the two sites. In West Mill Pond, concentrations of $o\text{-}PO_4$ increased steadily from the early 1970's through 2007 (Figure 13B and Figure 14), while those in East Mill Pond exhibited somewhat of a declining trend (Figure 13D). Phosphorus concentrations in West Mill Pond ranged from 0.014 - 6.5 mg/l with an average of 1.83 mg/l, while those in East Mill Pond varied from < 0.01 - 1.0 mg/l and averaged 0.094 mg/l (Table 1).

Coliforms: As in the other creeks studied, coliform levels in East and West Mill Ponds exhibited considerable variation, with no long term trends apparent (Figure 15). Concentrations were similarly elevated at both sampling locations, likely due primarily to storm water runoff and resident waterfowl, although area septic systems may also be a factor. Average values (geometric means) in West Mill Pond were 552 (total) and 215 (fecal) coliforms/100 ml, while those in East Mill Pond were 699 (total) and 231 (fecal) coliforms/100 ml (Table 1).

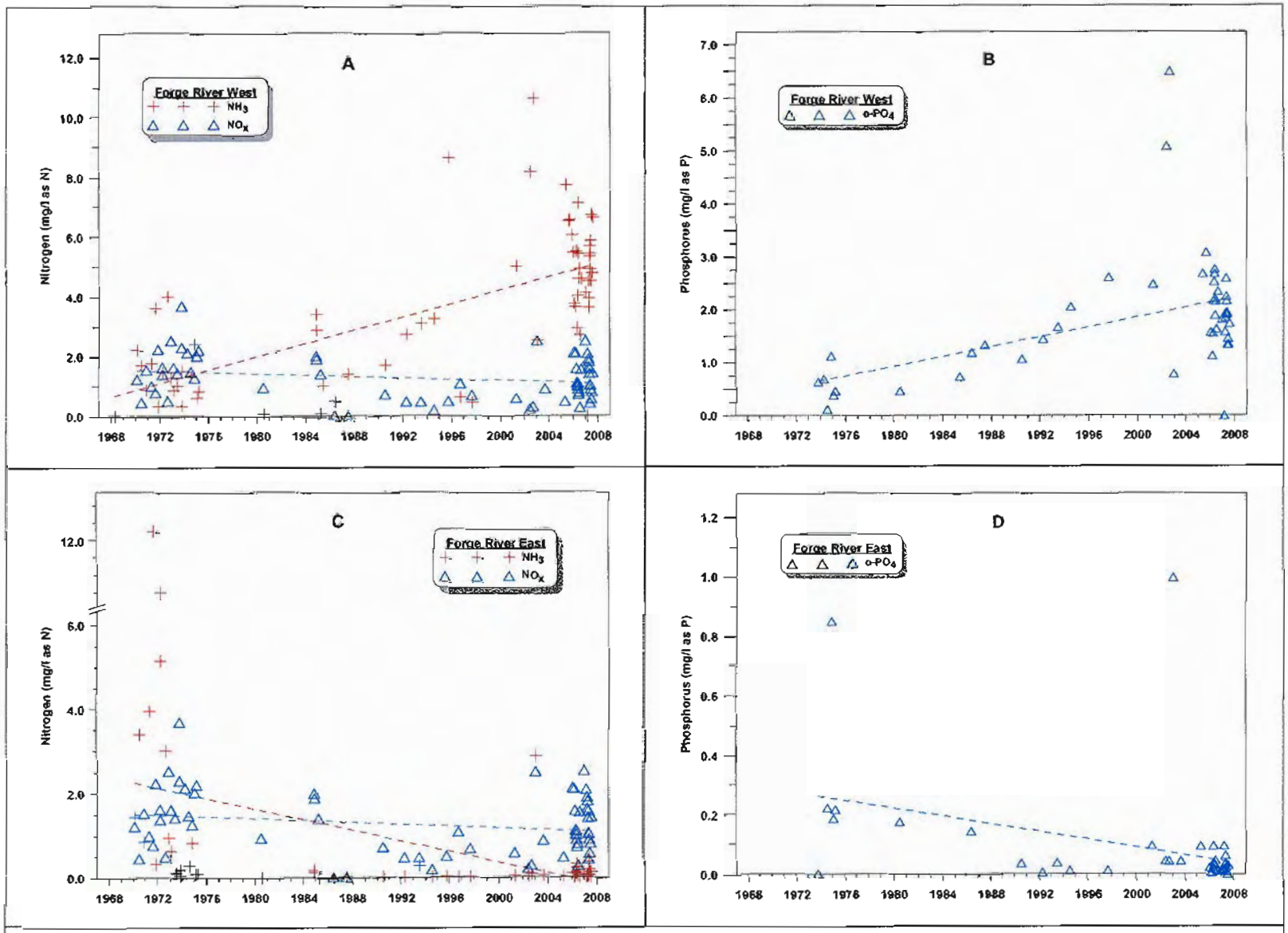

Figure 13. Nutrient Trends in the Forge River at West & East Mill Ponds (dashed lines are linear fits)

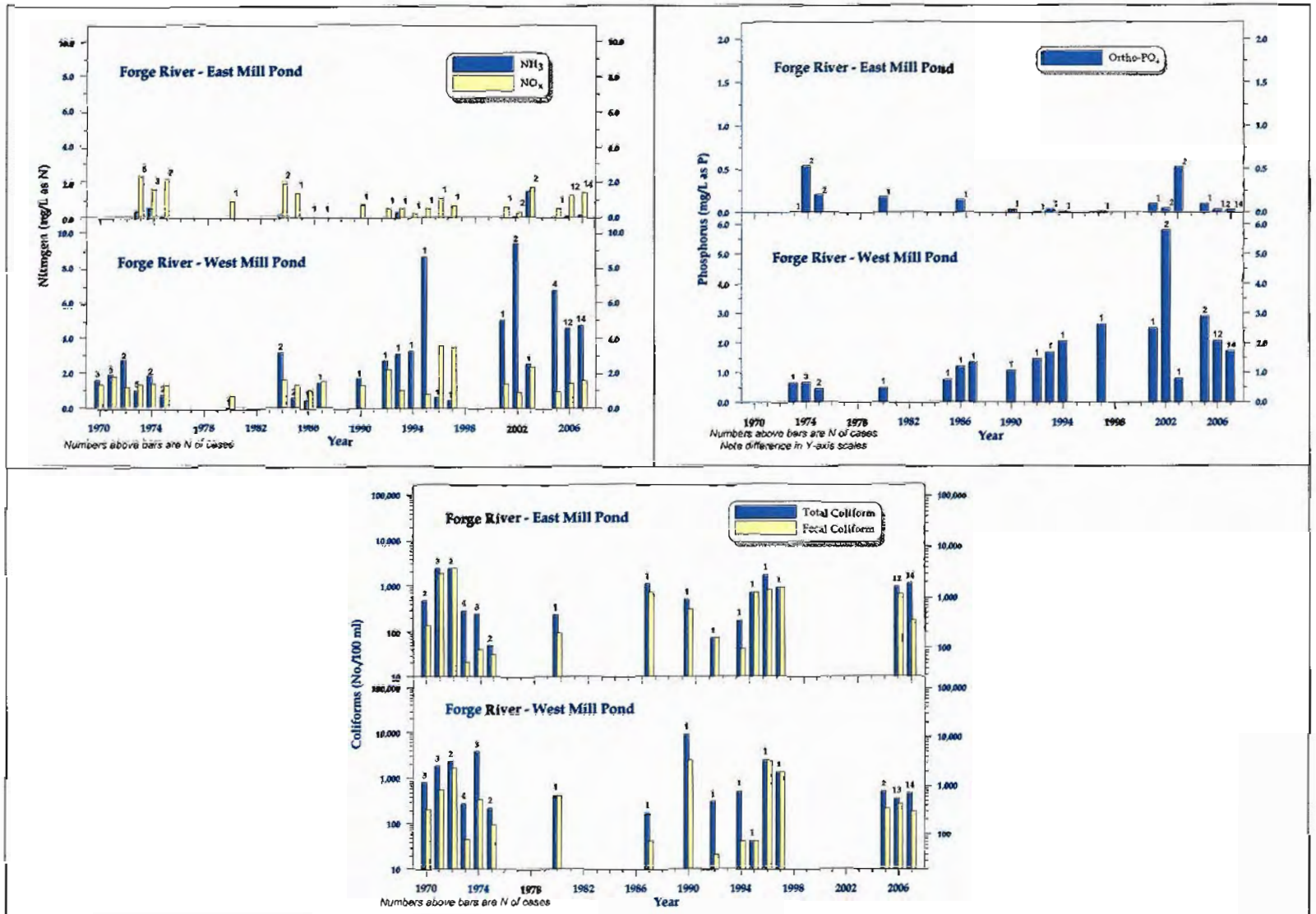

Figure 14. Average Annual Nutrient and Coliform Concentrations in East and West Mill Ponds, 1970 - 2007

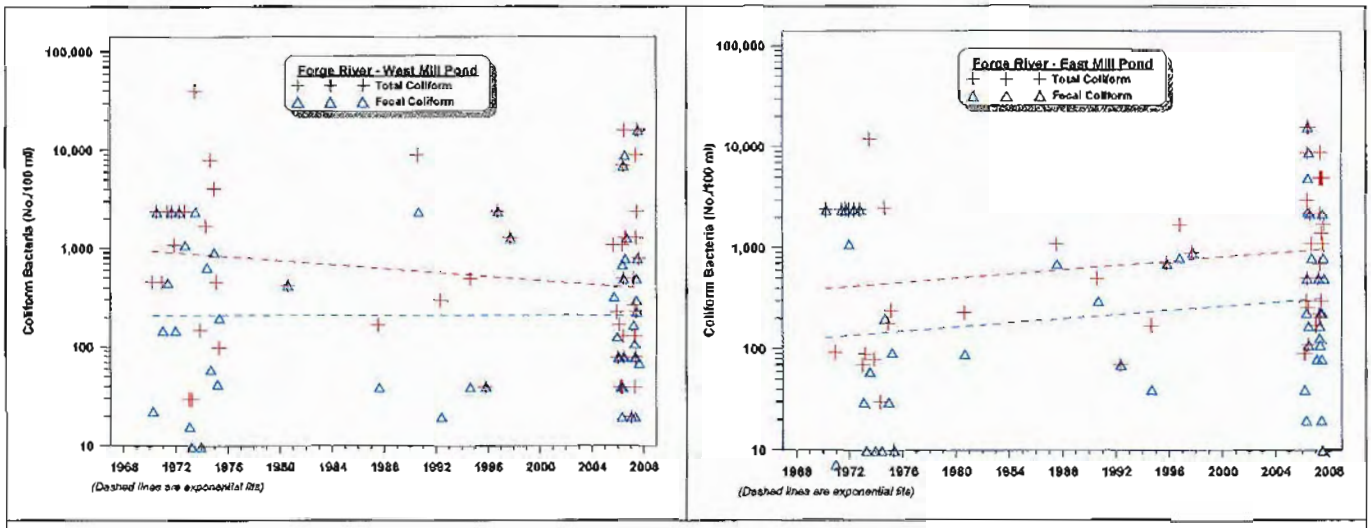

Figure 15. Trends in Coliform Levels in East and West Mill Ponds

Dissolved Oxygen: The limited number of dissolved oxygen measurements taken during the early monitoring years prevents an accurate assessment of long-term trends. Sampling done in recent years (2005-2007) reveals a range of oxygen levels at both sites that generally fluctuate with water temperature, although as shown in Figure 16, more results from West Mill Pond fall below the 5.0 mg/l NYS standard than those from East Mill Pond.

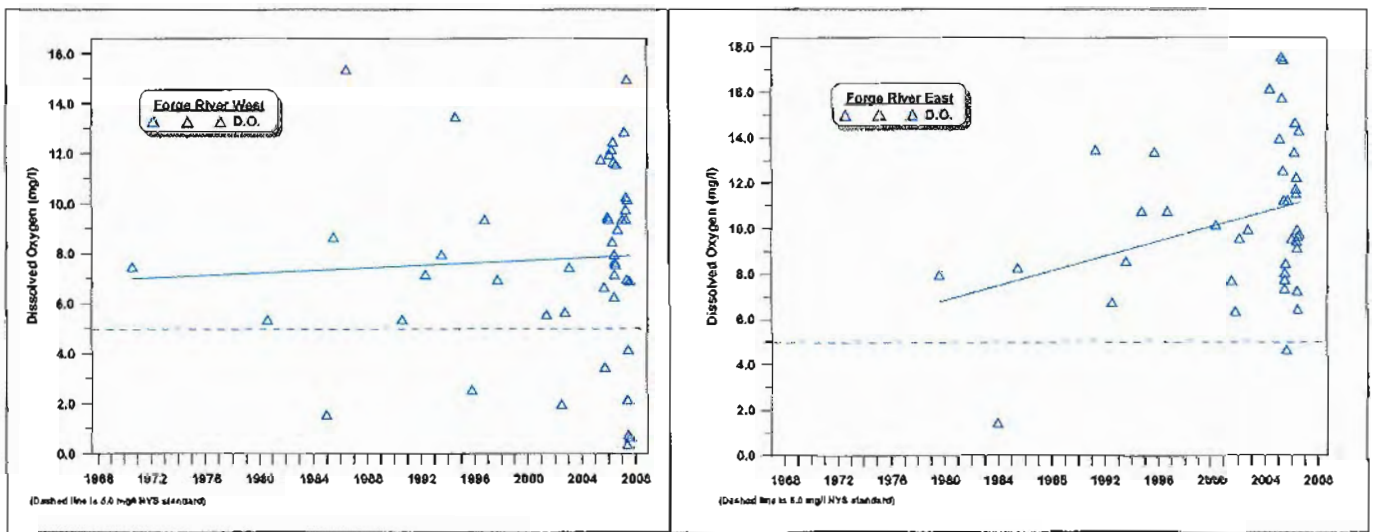

Figure 16. Dissolved Oxygen Trends in the Forge River at West and East Mill Ponds
(solid lines are linear fits)

Tributaries of Great South Bay

At least three duck farms previously discharged into tributaries of eastern Great South Bay, two into the Carmans River in the hamlet of South Haven, and one into Mud Creek in Patchogue. Discussion here will be limited to sampling done in the Mud Creek/Robinsons Pond area (Figure 17), formally the site of the Gallo Duck Farm, and in a section of Carmans River near the former Robinson Duck Farm (Figure 18).

Mud Creek/Robinsons Pond

Samples have historically been collected at two locations in the Mud Creek/Robinsons Pond area by the SCDHS Office of Water Resources (OWR). One site, located in Mud Creek north of Robinson's Pond (station 216-15), was sampled from 1970 to 1973. The second site, located at the south end of Robinsons Pond (station 216-5), was sampled from 1973 to 1997. Additional samples were collected at five locations (stations 1 - 5) in 2006, at the request of the Suffolk County Planning Department. Station 1 is located in the vicinity of OWR station 216-15; stations 2 and 3 are located in the western and eastern branches of Mud Creek, respectively; and stations 4 and 5 are located in the vicinity of the Gallo Duck Farm.

For purposes of comparison, data for the station located in lower Mud Creek (216-15) and that for the two sites in Robinsons Pond (station 216-5 and station 1), are combined in Figure 19. Average nutrient and coliform values for the five sites sampled in 2006 are plotted in Figure 20. Descriptive statistics for nutrient and coliform parameters, including mean, maximum and minimum values, and number of samples (N), are included in Table 2.

Nitrogen: Although the data is limited, results for samples collected at stations 216-5 and 216-15 show a clear decline in nitrogen levels from the mid-1970s through the 1990s (Figure 19A). Data from samples collected in 2006 at station 1 (adjacent to station 216-5) indicate the trend has continued. Concentrations of total nitrogen (TN) decreased from an average of 7.0 mg/l in 1976, to 2.9 mg/l in 1994, and 0.87 mg/l in 2006. The diminishing nitrogen levels were predominantly due to fluctuations in ammonia concentrations (Figure 19B), which declined precipitously in the early 1980s following cessation of operations at the Gallo Duck Farm. Ammonia levels recorded prior to July 1980 (at stations 216-5 and 216-15) averaged 4.0 mg/l. Post 1984 ammonia levels (at stations 216-5 and station 1) averaged 0.52 mg/l. Levels of NO_x exhibited comparatively little variation over the sampling period, ranging from 0.121 – 1.70 mg/l and averaging 0.76 mg/l.

At the five stations sampled in 2006, TN levels consisted mostly of dissolved inorganic nitrogen (DIN), predominantly as NO_x (Figure 20). The highest NO_x concentrations were recorded at stations 2 and 3 (1.0 & 0.8 mg/l), located in the west and east branches of Mud Creek, and were likely associated with groundwater and/or septic inputs. Interestingly, the lowest average nitrogen levels (including those for NH_3, NO_x and TN) were found at station 4, located at the site of the discharge outfall of the former Gallo Duck Farm (Figure 17).

Phosphorus: Although the number of samples collected was extremely limited, ortho-phosphate levels in lower Mud Creek/Robinson pond also seem to exhibit a declining trend from the mid-1970s through the 1990s (Figure 18C). Concentrations decreased from a high of 4.0 mg/l in 1974 to < 0.2 mg/l in the ten samples collected from 1992-2006, averaging 0.85 mg/l for the

Figure 17. Mud Creek and Robinson Pond Sampling Station and Former Duck Farm Locations

Figure 18. Carmans River Sampling Station and Former Duck Farm Locations

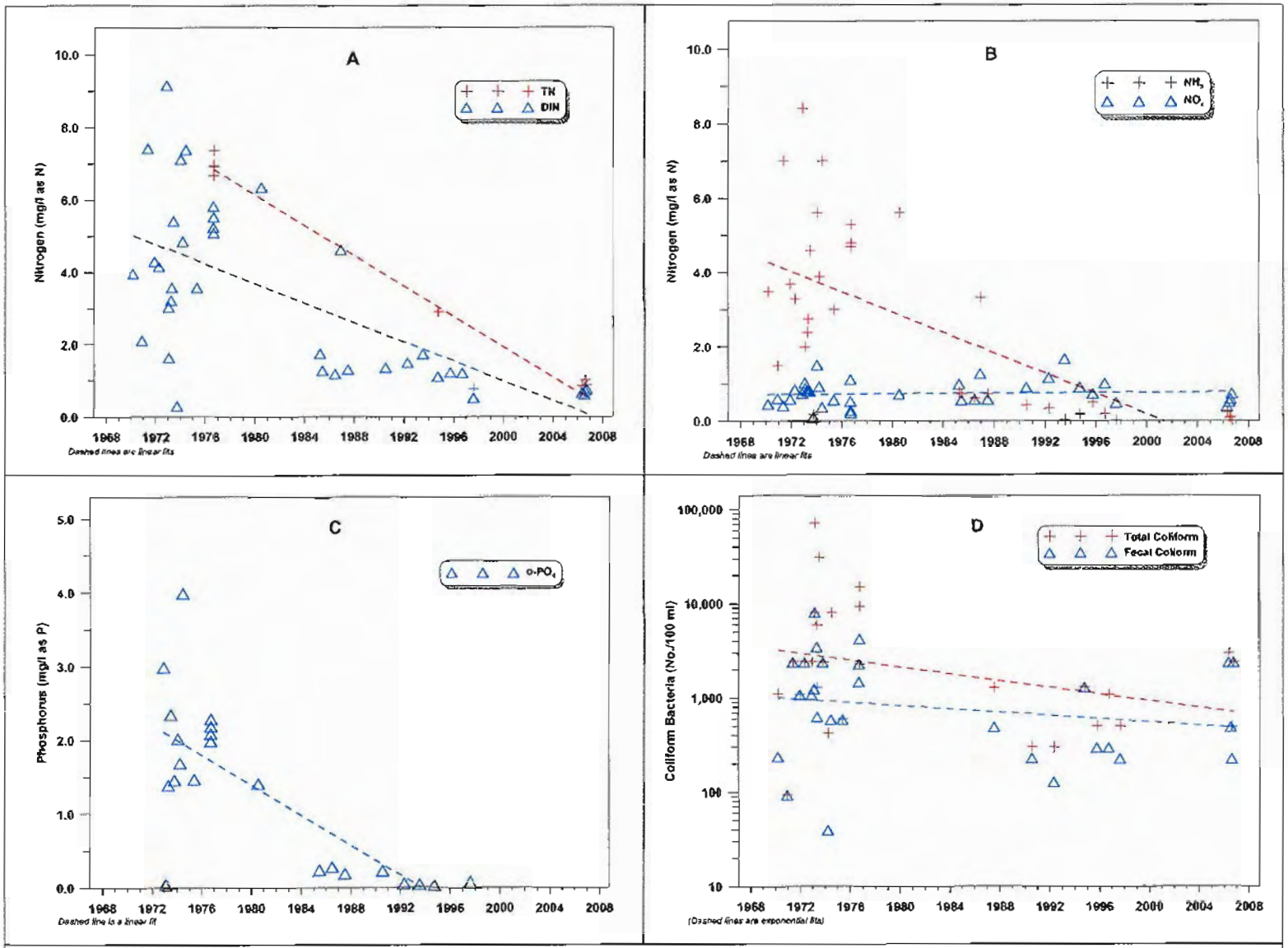

Figure 19. Nutrient and Coliform Trends in Lower Mud Creek and Robinsons Pond, 1970-2006
(data for stations 216-5, 216-15 & 1 combined)

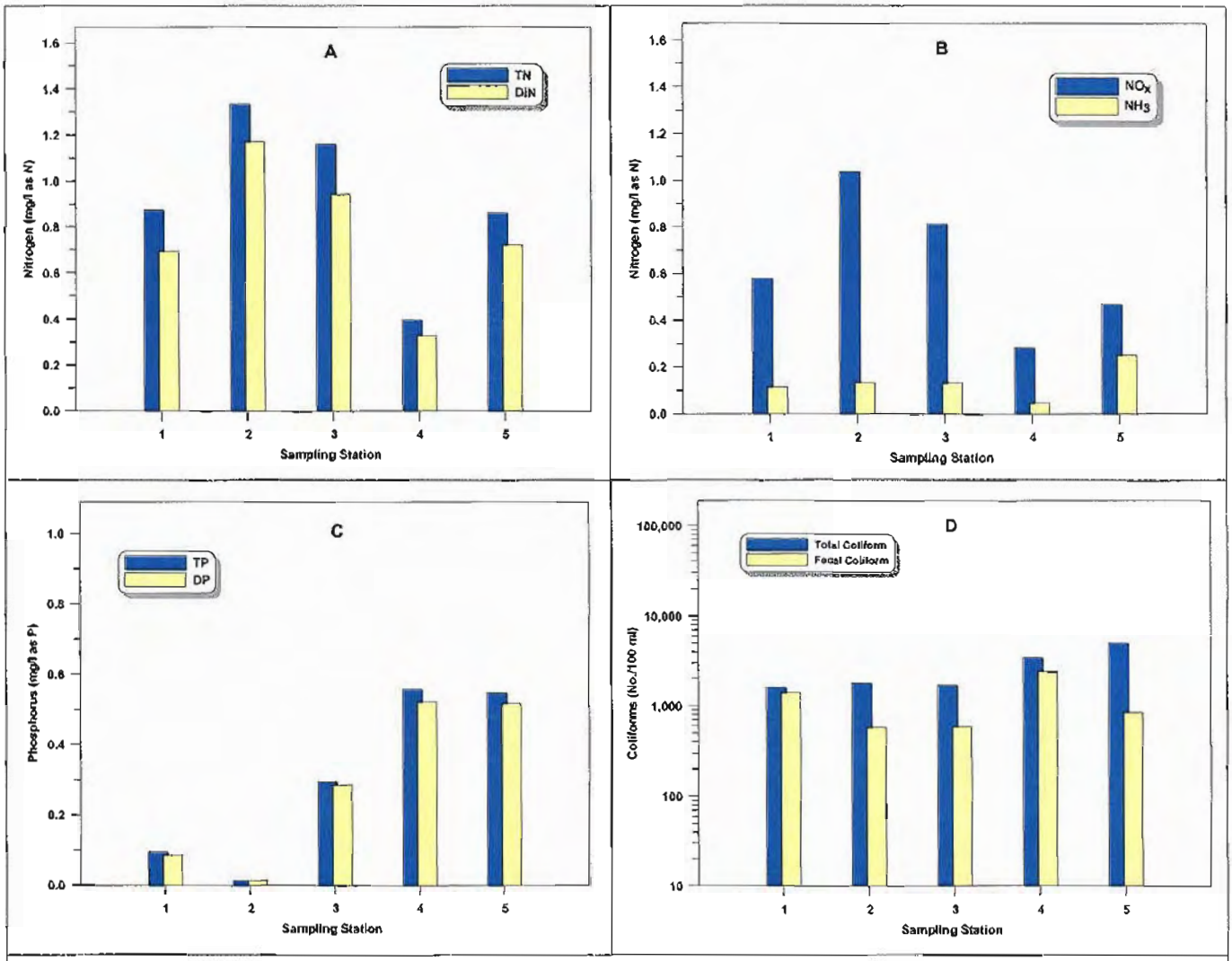

Figure 20. Average Nutrient and Coliform Values for Mud Creek/Robinson Pond Stations 1 – 5
(2006 Monitoring)

sampling period. Monitoring done in 2006 showed the highest phosphorus levels at station 5, with average concentrations declining in a downstream direction (Figure 20C).

Coliforms: As with nitrogen and phosphorus, coliform levels in lower Mud Creek/Robinsons Pond seem to indicate a declining trend from the mid 1970s through the 1990s (Figure 19D). Again, due to the limited number of samples collected (7 samples in 24 years), the significance of the trend is questionable. Subsequent monitoring done in 2006 also revealed occasionally elevated coliform levels in Mud Creek, but results indicated that storm water runoff was a major contributing factor. Sampling was conducted on two occasions in 2006 (16-May and 5-October) when rainfall in the previous 24-hours totaled between 0.5 and 1.1 inches. At each of the five sites sampled on those dates, total coliform results were the highest recorded that year, with values ranging from 2,400 to 16,000/100 ml.

Table 2. Nutrient and Coliform Statistics: Mean, Maximum, & Minimum Values, and Number (N) of Cases
Great South Bay Tributaries

Embayment	Statistic	Ammonia (NH_3-N)	Nitrite + Nitrate (NO_x-N)	Total Nitrogen (TN)	Dissolved Inorganic Nitrogen (DIN)	Total Phosphorus (TP)	Dissolved Phosphorus (DP)	Ortho-Phosphate (o-PO_4-P)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
Lower Mud Creek & Robinson Pond (data for stations 216-5, 216-15 & station 1 combined)	Mean	2.52	0.759	3.50	3.27	---	---	0.854	1,900	791
	Max	8.40	1.70	7.34	9.17	---	---	4.0	72,000	8,100
	Min	< 0.02	0.121	0.77	0.311	---	---	0.038	93	40
	N	37	37	10	37	---	---	14	30	29
Mud Creek Station 1	Mean	0.114	0.570	0.87	0.681	0.096	0.087	< 0.2	1,158	902
	Max	0.250	0.752	1.00	0.752	0.130	0.113	< 0.2	3,000	2,400
	Min	< 0.02	0.404	0.79	0.608	0.051	0.060	< 0.2	500	230
	N	4	4	4	4	4	4	2	4	4
Mud Creek Station 2	Mean	0.134	1.03	1.33	1.16	< 0.025	< 0.025	< 0.2	1,212	412
	Max	0.240	1.20	1.50	1.28	< 0.025	< 0.025	< 0.2	3,000	1,300
	Min	0.080	0.765	1.14	1.01	< 0.025	< 0.025	< 0.2	300	130
	N	4	4	4	4	4	4	2	4	4
Mud Creek Station 3	Mean	0.130	0.802	1.16	0.932	0.296	0.286	< 0.2	1,009	341
	Max	0.150	1.01	1.40	1 13	0.362	0.351	0.200	3,000	1,300
	Min	0.110	0.600	0.90	0.750	0.227	0.194	< 0.2	230	100
	N	4	4	4	4	4	4	2	4	4
Mud Creek Station 4	Mean	0.046	0.272	0.40	0.315	0.558	0.522	0.350	1,963	424
	Max	0.064	0.300	0.51	0.360	0.829	0.751	0.400	9,000	9,000
	Min	< 0.02	0.200	0.33	0.200	0.347	0.308	0.300	500	80
	N	4	4	4	4	4	4	2	4	4
Mud Creek Station 5	Mean	0.252	0.462	0.86	0.713	0.548	0.518	< 0.2	2,083	502
	Max	0.710	0.721	1.33	0.999	1.37	1.37	< 0.2	16,000	2,400
	Min	0.086	0.289	0.58	0.430	0.128	0.136	< 0.2	700	230
	N	4	4	4	4	4	4	2	4	4
Carmans River S/O Rt. 27A (Station 240-15)	Mean	0.018	0.856	---	0.874	---	---	0.012	520	250
	Max	0.040	1.11	---	1.12	---	---	0.016	800	800
	Min	< 0.02	0.28	---	0.29	---	---	0.008	170	80
	N	6	6	---	6	---	---	2	5	5
Carmans River N/O Rt. 27 (data for Stations 240-28 and 240-30 combined)	Mean	0.167	0.689	---	0.836	---	---	0.012	421	214
	Max	0.82	0.91	---	1.30	---	---	0.017	>2,400	>2,400
	Min	< 0.02	0.482	---	0.540	---	---	0.008	60	< 20
	N	7	8	---	8	---	---	6	8	8

Note: Note: Nutrients are in mg/l as N or P; Coliforms are No./100 ml

Dissolved Oxygen: Historic dissolved oxygen measurements (pre-2006) were only taken at the Robinson's Pond station (216-5). No trends were apparent in the data, although there were two occasions when levels dropped below 2 mg/l (Figure 21). In the 2006 monitoring, ample dissolved oxygen concentrations were noted at stations 1 through 3, where average levels ranged from 6.5 - 8.8 mg/l. At stations 4 and 5 in the vicinity of the former Gallo Duck Farm however, seven of eight measurements taken were below 5.0 mg/l NYS standard. Levels at station 4 ranged from 0.4 - 7.2 mg/l, with an average value of 2.7 mg/l, while concentrations at station 5 ranged from 2.4 - 4.5 mg/l and averaged 3.7 mg/l.

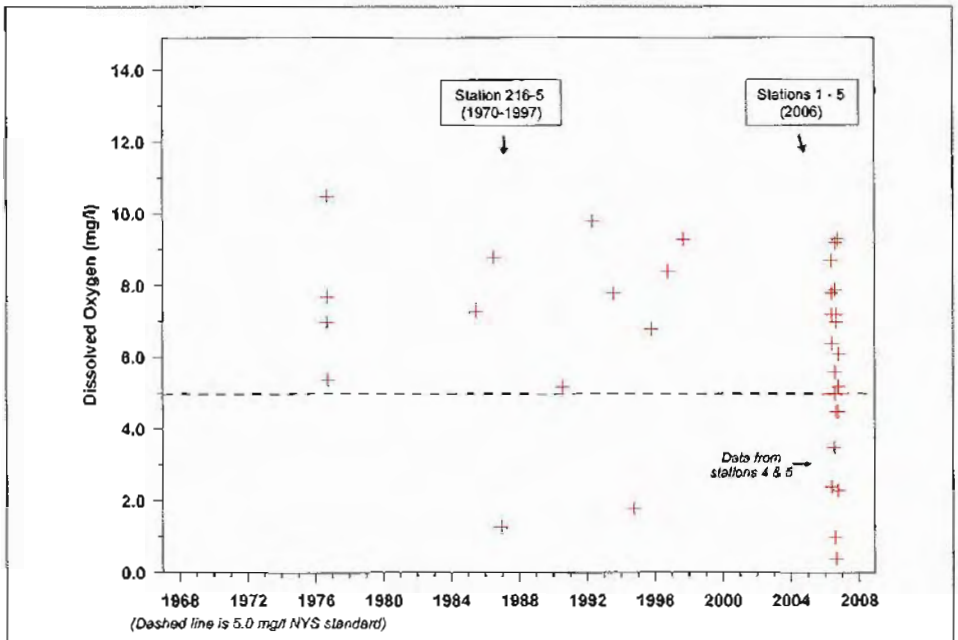

Figure 21. Dissolved Oxygen Levels in Mud Creek and Robinsons Pond
(data for station 216-5 and stations 1-5 combined)

Carmans River

Two duck farms formally operated in the Carmans River watershed, the Lescowicz Duck Farm on Little Neck Run, and the Robinson Duck Farm located on the west side of the Carmans River just south of Rt. 27 (Figure 18). The Robinson Duck Farm site is now the Robinson Duck Farm County Park, and is the subject of a habitat restoration feasibility study being conducted by the Suffolk County Department of Planning. Only data for the Carmans River is discussed here.

The SCDHS Office of Water Resources (OWR) routinely monitors a number of sites on the Carmans River, from Cathedral Pines County Park on the north to the lower fresh water reaches in South Haven. Stations in the vicinity of the Robinson Duck Farm however, have been sampled relatively infrequently. Station 240-15, located on the south side of the railroad tracks, and presumably south of the former duck farm discharge, was sampled once in 1968 and on five occasions between 1987 and 1999. Two sites that are in close proximity just north of the duck farm site, stations 240-28 and 240-30, were collectively sampled on only eight occasions from 1974 to 1999. Station 240-110, located a considerable distance north of the duck farm site near

Rt. 495, was the principal OWR monitoring location on the river with more than 100 samples collected from 1966 - 2000.

From the limited data available, average levels of nitrogen, phosphorus and coliforms in the vicinity of the former duck farm were similar at each of the three sites examined (Table 2). Nitrite + nitrate (NO_x) was the predominant form of nitrogen at each, averaging 0.69 mg/l at stations 240-28 and 240-30 (data combined) and 0.86 mg/l at station 240-15. Ammonia concentrations were comparatively low, averaging 0.17 mg/l at station 240-28/30 and 0.02 mg/l at station 240-15. Levels of ortho-phosphate were also insignificant, with each site averaging 0.012 mg/l. Mean total coliform levels were somewhat higher at station 240-15 (520 coliforms/100 ml) than at stations 240-28/30 (421 coliforms/100 ml), but not indicative of any trend. Water quality at each of these three sites is also comparable to that at the sentinel station to the north (240-110), except NO_x was somewhat higher at station 110 and coliforms somewhat lower.

Discussion

Because the monitoring data available for the streams discussed in this report is generally limited, particularly during times when most of the duck farms in question were active, the significance of apparent water quality trends, and their association with former duck farm operations, is uncertain. In general however, it appears that the cessation of duck farm operations, and in the case of the Crescent Duck Farm, improvements in duck waste treatment, has facilitated a reduction in the level of eutrophication in affected tributaries, and resulted in improved water quality.

Levels of ammonia-nitrogen (NH_3-N), a typical contaminant in duck farm effluents, have exhibited declining trends in Sawmill Creek, East Mill Pond (Forge River East), and in Mud Creek/Robinsons Pond, that are possibly associated with the cessation of duck farm operations in those areas. In the portion of Meetinghouse Creek where the Crescent Duck Farm continues to operate, an observed decline in NH_3-N levels was almost certainly related to improvements in waste treatment at the farm. Ammonia concentrations in Meetinghouse Creek remain elevated above background levels however, and continue to represent a significant nitrogen input to downstream waters of the Peconic Estuary. Phosphorus levels at the duck farm site also remain elevated, averaging almost an order of magnitude higher than the upstream Meetinghouse Creek site, and have actually exhibited an increasing trend over the past decade. In other Peconic Estuary tributaries examined, Terry's Creek and Sawmill Creek, phosphorus levels have exhibited somewhat of a declining trend (Figures 3, 4 & 6). Whether these can definitely be attributed to the cessation of duck farm discharges remains uncertain however, due to the generally limited sampling frequency at these sites. In lower Mud Creek/Robinsons Pond however, phosphorus (and ammonia) levels exhibited a precipitous decline in the mid 1980s that seems to coincide with the closure of the Gallo Duck Farm.

In the western branch of the Forge River, to which the Jurgielewicz Duck Farm continues to discharge, ammonia and phosphorus levels have both exhibited an increasing trend in recent years (Figures 13 & 14). This is in marked contrast to water quality in the eastern branch of the river, formally the site of at least two duck farms, where ammonia and phosphorus levels have

exhibited a declining trend. The Forge River is currently the subject of a multi-agency sponsored investigation into causes of existing hyper-eutrophication and hypoxia in its tidal reaches, to which the duck farm discharge has been identified as a contributing factor.

Levels of coliform bacteria have exhibited a wide degree of variability at all sites sampled, with highest values typically occurring during warmer months as would be expected. Fluctuations in coliform concentrations are generally difficult to assess, particularly in cases of limited sampling frequency, due to the variety of factors that can potentially affect their numbers (water temperature, runoff, waterfowl, failing septic systems, etc). During periods when duck farms were in operation, especially prior to the onset of regulations requiring effluents to be chlorinated, it's likely that duck farm discharges were significant sources of coliform bacteria (and potentially pathogens and viruses) to receiving waters. Because the onset of SCDHS monitoring was subsequent to the passage of these regulations, and came well after the majority of farms had already closed, it's likely that coliform levels found in most creeks are associated more with either precipitation, resident waterfowl, or possibly area septic systems, than former duck farm activities.

Dissolved oxygen (D.O.) levels were also measured on an infrequent basis in the creeks addressed here, and identification of significant long-term trends impossible in most cases. Noteworthy were levels in Meetinghouse Creek, which exhibited an increasing trend from 1999-2006 at both sampling locations (Figure 11). Low oxygen levels noted at the start of the trend (1999-2001) however, occurred during a period of low groundwater, and may have been associated more with water depth and/or reduced stream flow than other causes, including duck farm operations. In recent sampling done in the Forge River (2005-2007), dissolved oxygen concentrations in both East and West Mill Ponds were widely variable, and occasionally approached super-saturated levels. Concentrations in West Mill Pond however, downstream of the Jurgielewicz Duck Farm discharge, were below 1.0 mg/l on a number of occasions during the summer of 2007, likely reflecting impacts from the enriched duck farm effluent.

Summary and Conclusions

- Stream data collected by the Suffolk County Department of Health Services (SCDHS) Office of Water Resources from 1970-1999, and by the SCDHS Office of Ecology from 1976-2006, were analyzed for trends in water quality that may be attributed to former duck farm operations.
- Because the available monitoring data is generally limited, however, particularly during times when most of the duck farms in question were active, the significance of apparent water quality trends, and their association with former duck farm operations, is uncertain. In general, it appears that the cessation of duck farm operations, and in the case of the Crescent Duck Farm, improvements in duck waste treatment, has facilitated a reduction in the level of eutrophication in affected tributaries, and resulted in improved water quality.
- Sampling done in Terry's Creek revealed a slight decline in phosphorus levels that may have been associated with the cessation of duck farm operations. The significance of the trend however, is lessened by the limited number of samples collected during early monitoring years. Nitrogen levels in Terry's Creek have primarily been comprised of nitrate + nitrite (NO_x), likely mirroring agriculturally derived levels in area groundwater, and remained

relatively stable through the sampling period. Significant levels of ammonia (NH_3) nitrogen, typically a by-product of duck farm operations, were not detected in Terry's Creek.

- In Sawmill Creek, concentrations of both nitrogen (consisting of NH_3 and NO_x) and phosphorus were elevated during the early to mid-1970s and declined through the 1980s. The cessation of duck farm operations and a reduction in agricultural activities in the creek's watershed may have both been partly responsible for the trend.
- The contrasting water quality of two sites in Meetinghouse Creek, located upstream and downstream of an active duck farm (Crescent Duck Farm), demonstrate the adverse effects that duck farm effluents have on receiving waters. Although both sites show elevated levels of NO_x that are characteristic of agriculturally polluted groundwater in the area, discharges from the duck farm have significantly elevated levels of ammonia-N in the lower reaches of the creek.
- Although efforts to improve waste treatment practices at the Crescent Duck Farm have significantly reduced effluent ammonia concentrations, levels remain elevated above background concentrations and continue to represent a significant point source of nitrogen to the Peconic Estuary. Inexplicably, as nitrogen levels at the duck farm site have declined, phosphorus levels appear to be increasing.
- In the west branch of the Forge River, where two duck farms remain in operation, ammonia is the predominant form of nitrogen, and both nitrogen and phosphorus levels have exhibited an increasing trend. Water quality in the east branch of the river (East Mill Pond), an area no longer subject to duck farm effluent, exhibited declining trends in concentrations of both nitrogen (particularly ammonia) and phosphorus.
- The Suffolk County Department of Planning is collaborating with the US Army Corps of Engineers on a Mud Creek Ecosystem Restoration Feasibility Study designed to explore opportunities for restoring freshwater wetland and riparian habitats that were altered by operations at the former Gallo Duck Farm.
- Historic data collected by the SCDHS, in conjunction with results of recent sampling done at the request of the Planning Department, indicate that levels of both ammonia and phosphorus in the lower Mud Creek/Robinson Pond area exhibited a significant decline in the mid-1980s, following cessation of operations at the Gallo Duck Farm.
- Trends in dissolved oxygen levels in the streams monitored were for the most part, insignificant, due to infrequent measurements during early monitoring years. Factors other than duck farm operations that may have affected oxygen levels include streamflow, water depth, and water temperature.
- In West Mill Pond (Forge River), levels of hypoxia (low oxygen) noted during the summer of 2007 were likely associated with the enriched effluent from the Jurgielewicz Duck Farm. Concurrent measurements done in East Mill Pond, where duck farms no longer discharge, showed ample oxygen levels to exist.
- Coliform levels in the streams addressed exhibited a wide degree of variability, with long-term trends generally unapparent. Factors associated with elevated coliforms were not limited to duck farm operations. In Meetinghouse Creek, coliform levels the Crescent Duck Farm site were elevated above those upstream, and likely associated with the duck farm effluent. In the Forge River however, levels in both West Mill Pond and East Mill Pond were frequently

elevated, likely reflecting area septic influences as well as resident waterfowl, rather than active or former duck farm operations. In Mud Creek/Robinsons pond, influences from storm water runoff were apparent, as maximum levels at all stations sampled in 2006 occurred on days that followed rain events.

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