RAINFALL – OCEAN FAUNAL INTERACTIONS, CARTERET COUNTY, NORTH CAROLINA

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Abstract: Rainfall data collected at the Institute of Marine Sciences (IMS) for the years 1983–2011 varied between 0.51 (12.9 mm) and 0.75 (19.1 mm) inches/day/yr. Storms, hurricanes and natural events greatly influenced the data. Hurricanes, run off, flooding and El Nino, and La Nina events influenced increases and decreases in precipitation pre-1990 and post-1990. Shark, finfish and shrimp catches varied in response to storm effects on the nearby river and ocean water temperatures. Significant statistical differences existed between rainfall and shark catches.

Key Words: rainfall; storms; hurricanes; sharks; finfish; shrimp.

INTRODUCTION

Environmental data has been recorded at the Institute of Marine Sciences (IMS), Morehead City, Carteret County, North Carolina since 1947, rainfall since 1967 (Porter 1985). Porter (1985) analyzed IMS 1979–1981 rainfall noting yearly means of 0.147 inches: 3.73 mm/day/yr. Questions arose: have rainfalls been static during subsequent years 1983–2011; has rainfall at IMS and the adjacent Atlantic Ocean been influenced by storms and hurricanes: and did rainfall and hurricane runoff, flooding and other influences affect shark, finfish and shrimp catches? Answers would shed light on these rainfall/faunal interrelationships.

METHODS

Rainfall, was collected, during the years 1983–2011, using a rain and snow gauge, U.S. Weather Bureau spec. no. 450-231, Science Associates inc. Model 503 gauge set unobstructed a few meters away from IMS and nearby vegetation. Rainfall was measured as inches/day (1 in. = 25.4 mm). Yearly, rainfall data was collated and depicted graphically as: means, standard deviations, standard errors of the means and ranges (Fig. 1) using R, ver. 2.15.0 R Development Core Team 2012 computer program.

An analysis of variance (ANOVA) tested yearly 1973–2011 rainfall and shark catch trends. Linear regressions, $y = a + b \times$ were fitted to Onslow Bay 1972–2011 shark longline catch trends (Fig. 2).

OBSERVATIONS

Rainfall

Yearly rainfall increased significantly after 1988 ($f = 778$, 38 df*) from averages of 705 mm (47.03 in/yr) in pre 1998 to 1,209 mm (51.6 in/yr) during 1999–2011. Yearly

IMS rainfall varied 0.51 in/day (12.95 mm/day) during 1983–1999 and 0.75 in: (19.1/day mm) during 2000–2011 (Table 1).

Heaviest rainfalls occurred during August 1999 (Hurricane Dennis, 19 inches, 506 mm), September 1999 (Hurricane Floyd 20 inches (500 mm) and September 2005 (Hurricane Ophelia 17.5 inches (445 mm) Table 1. Yearly, rainfall increased after 1990, ANOVA $f = 7.38$, 38 df*.

Hurricanes

IMS and adjacent ocean areas were subject to 18 hurricanes between 1983–2011 (Fig. 1). Most occurred in August (7) and September (8) (Table 1). Hurricanes Floyd and Fran caused the most runoff and flooding in eastern North Carolina and influenced water temperatures. Hurricane Fran (September 1996) was the fiercest, arriving at 130 mph (220 km/hr) and caused 10 ft. (3 m) storm surges. Hurricane Floyd (1999) velocity was 197 km/hr and caused 10 ft (3 m) storm surges.

Hurricanes Dennis (September 1984) caused 3 deaths, Fran (September 1996) 14, Floyd (September 1999) 35, and Irene (September 2011) 13 (Table 1).

Sharks

Yearly shark longline catches between 1973–2011 in Onslow Bay, expressed as catch/unit/effort (CPUE), varied between 0.167 sharks/hook in 1973 and 0.18 in 2003 (Fig. 2). Linear regressions of these variations were: $y = -0.165 \times - 1.024$, $r^2 = 0.47$ (yrs 1973–1990) $f = 0.0478$ and $y = 0.5152 \times - 2.013$, $r^2 = 0.0804$, (years 2000–2011). Long-line catches were greater during pre-1990 and lower post 1990 (when ocean water temperatures shifted significantly $f = 6.40$, df 38 (from cooler pre 1990 to warmer 1990 yrs (Schwartz et al. 2010).

FIG. 1. Rainfall, depicted by year as inches/yr: mean, standard deviations, open bars; standard errors of the mean, stippled bars; range, solid lines at the bottom of each year. 1 in = 25.4 mm.

FIG. 2. Yearly shark longline catch per unit effort (CPUE) during 1972–2011.

Table 1. Year and dates of 18 hurricanes occurring during 1983–2011 and the Atlantic Ocean caused flooding and deaths.

Year	Date	Hurricane	Death (n)
1984	13 September	Adriane	3
1985	27 September	Gloria	1
1986	17 August	Charley	1
1991	19 August	Bob	1
1993	23 September	Emily	2
1994	27 November	Gordon	-
1996	12 July	Bertha	1
1996	6 September	Fran	6
1998	21 August	Bonnie	1
1999	30 August	Dennis	-
1999	16 September	Floyd	35
1999	18 October	Irene	1
2003	18 September	Isabelle	3
2004	2 August	Alex	1
2004	14 August	Charley	3
2005	14 October	Ophelia	-
2010	19 September	Igor	1
2011	27 August	Irene	7

Finfish

Commercial finfish landings varied greatly, similar to shark catches (Table 2): greater during pre 1983–1990 yrs, smaller during post warmer years 1991–2011.

Shrimp

Shrimp catches varied, similar to finfish catches, greater during cooler water years (1973–1999 and smaller during warmer water years (2000–2011) (Table 2).

DISCUSSION

Most people are oblivious that North Carolina's IMS rainfall and ocean faunas were intricately interrelated as a result of precipitation, storms, and distant El Nino and La Nina influences. Local precipitations cause runoff and flooding that affected river nutrient loads in the adjacent ocean (Drinkwater 1986; Christian et al. 1991; Bales 2003; Boyles et al. 2004; Paerl et al. 2006; Cahoon 2013).

Hurricane precipitation drastically affected Atlantic ocean water temperatures between 1972–1994 vs. 1995–2011; as cooler waters occurred between 1972–1999 vs. warmer waters during 2000–2011 (Goldenberg 2001; Schwartz et al. 2010). Schwartz et al. (2010) noted water temperature shifts and the effects on shark longline catches in Onslow Bay. As ocean water temperatures, increased ice cap melting is occurring and in turn increasing hurricane activity in various parts of the world (Delworth et al. 2007). El Nino events (where Pacific ocean waters are warmer) decreased winter and increased summer precipitation. La Nina reversed these events and increased summer and fall hurricanes (Boyles et al. 2004). Decreased

Table 2. Finfish and shrimp catch landings (lbs) for years 1983–2011. Hurricane years denoted by * symbol. Commercial finfish and shrimp landings (in lbs) off Carteret county, North Carolina 1893–2011. 1 lb = 0.454 kg.

Year	Fish	Shrimp	Hurricane (*)
1983	129,082,192	468,060	
1984	157,372,451	408,549	*
1985	103,000,310	612,184	*
1986	16,489,509	458,782	*
1987	64,340,750	552,421	
1988	82,644,057	680,820	
1989	69,105,946	617,56	
1990	71,340,370	266,259	
1991	109,336,418	241,674	*
1992	6,1979,839	182,070	
1993	75,154,144	500,134	*
1994	79,980,308	351,330	*
1995	68,035,721	447,861	
1996	68,406,569	395,738	**
1997	85,259,462	261,998	
1998	67,959,697	598,648	*
1999	46,028,001	519,672	***
2000	59,470,409	270160	
2001	57,581,859	118,369	
2002	73,094,559	157,435	
2003	50,737,774	549947	*
2004	53,801,249	257,952	**
2005	14,725,137	107,596	*
2006	2,468,225	188,664	
2007	2,068,381	343,011	
2008	1,907,796	180,354	
2009	2,139,498	94,610	
2010	2,510,089	119,269	*
2011	2,080,902	75,834	*

local precipitation affected North Carolina invertebrate faunas (Kirby- Smith and Ustach 1986); Bell and Hall (1999), while sharks (Dogfish and blacknose sharks) simply swam away from hurricane front influences (Gibson 1980; Fiedler and Bernard 1987; Fraser and Shelmerdine 2002; Heupel et al. 2003) and once their skin hair cells sensed hurricane hydrostatic pressure changes. Black tipped sharks vacated an area during heavy rainfalls (Heupel et al. 2003). Pelagic tuna and bottom fishes also responded similarly by swimming away from an affected area (Power and May 1994; Russel 1997; Watterson et al. 1998; Kirby et al. 2000).

CONCLUSIONS

Thus, rainfalls are a result of many intricately interrelated events. Rainfall varied at IMS every year. Variations influenced runoff, flooding, while ocean temperature changes influenced shark, finfish, and shrimp populations. Knowledge of these interrelationships would help us better utilize our ocean faunas, on which we depend, and understand the input of rainfall, storms and hurricanes on an area.

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