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Fish Kills in Florida's Canals, Creeks/Rivers, and Ponds/Lakes

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ABSTRACT

Reports from 637 fish kills that occurred between 1984 and 2002 in Florida canals (n = 264), creeks/rivers (n = 64) and ponds/lakes (n = 309) were examined to assist management agencies that need to understand and respond to fish kill events. Critical investigation of 407 fish kills showed that 75% were caused by probable natural processes, 13% were from unknown causes, and 12% were human-induced. Fish kills occurred in every month of the year but were most abundant in summer from June through September as was the abundance of rainfall and warmer water temperatures. Canals, creeks/rivers, and ponds/lakes showed strong significant correlations ($p < 0.05$) between average monthly rainfall and monthly frequency of fish kills with correlation coefficients of 0.86, 0.73, and 0.72, respectively. The Florida lakes that had fish kills, where water chemistry data were available (n = 25), tended to be alkaline with mean pH and alkalinities of 7.7 and 55 (mg/l as $CaCO_3$), respectively. The fish kill lakes were also mostly productive with total phosphorus, total nitrogen, chlorophyll, and Secchi depth averaging 69 µg/L, 1290 µg/L, 36 µg/L, and 1.2 m, respectively. These water chemistry averages were all significantly lower in nearby lakes that experience no fish kills, with the exception of Secchi depth, which was significantly higher ($p \leq 0.05$). We recommend that state agencies in charge of fish populations use resources to systematically investigate all fish kills and maintain reports that can later be merged with ambient limnological data to better understand and potentially predict the occurrences of fish kills.

Key words: fish kill, Florida, human causes, limnological data, natural causes.

INTRODUCTION

Fish kills occur in virtually every aquatic environment worldwide from a wide variety of natural and human-induced causes. Natural causes include but are not limited to old age, extreme temperature fluctuations, starvation, and disease and can range from blue tilapia (*Tilapia aurea*) kills caused by cold weather events (Snodgrass 1989) to low dissolved oxygen caused by imports of bird droppings (Venugopalan et al. 1998). Human-induced kills include but are not limited to known and accidental additions of sewage/organics, pesticides, acids, petroleum products, and fertilizers to waters containing fish (Olmsted and Cloutman 1974, Meade 2004). These fish kills can be small in localized areas or extremely large, killing millions of fish. In December 1997, nearly 220 million liters of acidic process water from phosphate plant in Mulbery, Florida, accidentally entered the Alafia River traveling almost 60 km into Tampa Bay killing an estimated 1,300,000 fish (Florida LAKEWATCH 2003).

Point source additions of chemicals and/or nutrients have often been shown to result in fish kill events. However, point source pollution problems have been dramatically reduced since the turn of the 20th century, and most fish kills examined in the current and recently past literature are reportedly due to natural events and mostly related to dissolved oxygen problems in nutrient-rich systems (Barica 1975, Trim and Marcus 1990, Townsend et al. 1992, Mhlange et al. 2006). If however, the nutrient-rich lake suffering from fish kills was artificially enriched by man, including nonpoint source additions, then the term natural would not be appropriate. Many professionals suggest that most fish kills are brought on by climatological events that change the water chemistry of the receiving water (Barica 1978, Mericas and Malone 1984, Townsend et al. 1992).

When a fish kill occurs, whether the result of natural or other causes, the public becomes greatly concerned. Management agencies need to provide resources to investigate the kills to address these concerns and determine if management or legal actions are required. Several good manuals are available describing techniques for evaluating fish kills (e.g., USFWS 1990, AFS 1992). Unfortunately, by the time anyone arrives at the scene of a fish kill, the water chemistry and/or chemical that caused the kill has generally changed or moved down stream. For this reason several researchers have attempted to develop models to predict the occurrence of fish kills in lake systems so management agencies can prepare for these events (Barica 1975, Mericas and Malone 1984, Miranda et al. 2001, Quinlan et al. 2005). Additionally, examining the history of many fish kills can yield descriptions of lake types and times of year that fish kills will occur to assist in preparation.

We examine reports from 637 systems where fish kills occurred between 1984 and 2002 in Florida canals (n = 264), creeks/rivers (n = 64) and ponds/lakes (n = 309) to assist management agencies that need to understand and respond to fish kill events. Specifically, we list the reported causes of fish kills in Florida, examine historical rainfall records to determine if there is a relation between storm events and the occurrence of fish kills, and compare water chemistry data in lakes that experienced fish kills with nearby lakes that have not experienced fish kills to define the lake types that have the highest probability of fish kills in Florida.

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METHODS

Annually, the South Florida Water Management District (SFWMD) receives multiple reports of fish kills in drainage canals that they are responsible for investigating. The canals are located throughout South Florida. Between 1991 and 2000 SFWMD investigated 264 fish kill events, recording date and location of kill, species and number of fish killed, and general weather conditions. The Florida Fish and Wildlife Conservation Commission (FFWCC) also receive multiple reports of fish kills on an annual basis from three main water body types, canals, creeks/rivers, and ponds/lakes, located across Florida. We organized reports from 373 fish kill events reported to FFWCC between 1984 and 2002. The FFWCC fisheries biologist investigating the fish kill events recorded date and location of kill, species and number of fish killed, and what they believed, after investigating, was the primary cause of the fish kill. All hard-copy reports from SFWMD and FFWCC were entered into a spreadsheet to be merged with additional data.

The geographically closest monthly average rainfall records from airports in Gainesville, Orlando, Tampa, and Miami were mined and merged by year and month with the corresponding fish kill data. Rainfall data were available for all fish kill events. These data were plotted by month for each water body type to determine seasonal patterns in fish kill and rainfall events. Correlation analyses were also run by habitat type to determine the relations between average monthly rainfall and frequency of occurrence of fish kill events. Florida LAKEWATCH (Canfield et al. 2002) water chemistry data were available for 25 of the lakes (from 10 different counties) that had fish kill events recorded and one lake within 10 km of each of the 25 lakes that did not have a fish kill during that same time frame, including: pH, total alkalinity (mg/L as $CaCO_3$), total phosphorus (µg/L), total nitrogen, (µg/L), chlorophyll (µg/L), and Secchi depth (m). These data were examined to determine averages and ranges of water chemistry in lakes that have experienced fish kills and nearby lakes that did not. All statistical computations were conducted using JMP (SAS 2007).

RESULTS

Of the 407 reported fish kills investigated by FFWCC personnel, 14 specific causes were identified (Table 1). Approximately 13% of the fish kill events were caused by unknown factors. Low dissolved oxygen in biologically productive waters was the number one cause of fish kills, accounting for 64% of all the investigated kills. Fish kills following herbicide treatments were the second highest cause, accounting for just over 7%. All potentially natural causes (dissolved oxygen, cold, spawning mortality, bacterial infection, toxic algae, and largemouth bass virus) accounted for 75% of all investigated kills. The remaining known human-induced fish kill events (alum treatment, pesticide application, tournament release, storm water, agricultural discharge, chemical spill, sewage spill, and herbicide treatments) accounted for 12% of the investigated kills.

In all 637 reported fish kills, 14 different species and/or groups of species were recorded for individual events, with about 3% of the events composed of unidentifiable fish remains. Multiple species (37%), *Lepomis* sp. (15%), largemouth bass *Micropterus salmonoides* (12%), *Dorosoma* sp. (10%) *Tilapia* sp. (7%) and *Ameiurus* sp. (6%) accounted for 87% of all the fish kill events. The vast majority (81%) of the fish kills totaled less than 1000 fish with approximately 6% exceeding 10,000 fish.

Table 1. Summary of the causes of 407 fish kills reported to and investigated by Florida Fish and Wildlife Conservation Commission between 1984 and 2002.

Cause of Kill	Number of Kills	Percent of all Kills
Dissolved Oxygen	262	64.4
Unknown	54	13.3
Possible Herbicide Treatment and Low Dissolved Oxygen	29	7.1
Cold	23	5.7
Spawning Mortality	18	4.4
Agricultural Discharge	4	1
Chemical Spill	4	1
Sewage Spill	4	1
Bacterial Infection	2	0.5
Storm Water	2	0.5
Alum Treatment	1	0.2
Largemouth Bass Virus	1	0.2
Pesticide Application	1	0.2
Tournament Release Mortality	1	0.2
Toxic Algae	1	0.2
Total	407	100

Fish kills occurred in every month, in all three water body types (Figure 1). The majority of the fish kills in all aquatic habitats occurred in summer, June through September, which is also when the greatest monthly rainfall was recorded. Additionally, this is the time of year with the highest water temperatures, which decreases the ability of water to carry oxygen. For canals, creeks/rivers, and ponds/lakes, 74%, 75%, and 66%, respectively, of the fish kills occurred in summer between June and September. Total rainfall in June through September accounted for 65%, 62%, and 63% of the total annual average rainfall recorded at the nearest airport station to fish kill events in canals, creeks/rivers, and ponds/lakes, respectively. Strong significant correlations ($p < 0.05$) between average monthly rainfall and monthly frequency of fish kills was also found for canals, creeks/river, and ponds/lakes, with correlation coefficients of 0.86, 0.73 and 0.72, respectively.

Florida lakes that have had fish kills, where water chemistry data were available ($n = 25$), tended to be alkaline lakes with mean pH and alkalinities of 7.7 and 55 (mg/l as $CaCO_3$), respectively (Table 2). These averages were significantly higher ($p \leq 0.05$) than the average pH and alkalinity of the 25 nearby lakes that did not experience fish kills (6.6 and 24.3 mg/L as $CaCO_3$, respectively). The fish kill lakes were mostly productive with total phosphorus, total nitrogen, chlorophyll and Secchi depth averaging 69 µg/L, 1290 µg/L, 36 µg/L, and 1.2 m, respectively. Nutrient and chlorophyll data in the fish kill lakes were again significantly higher than these data in the lakes experiencing no fish kills, and Secchi

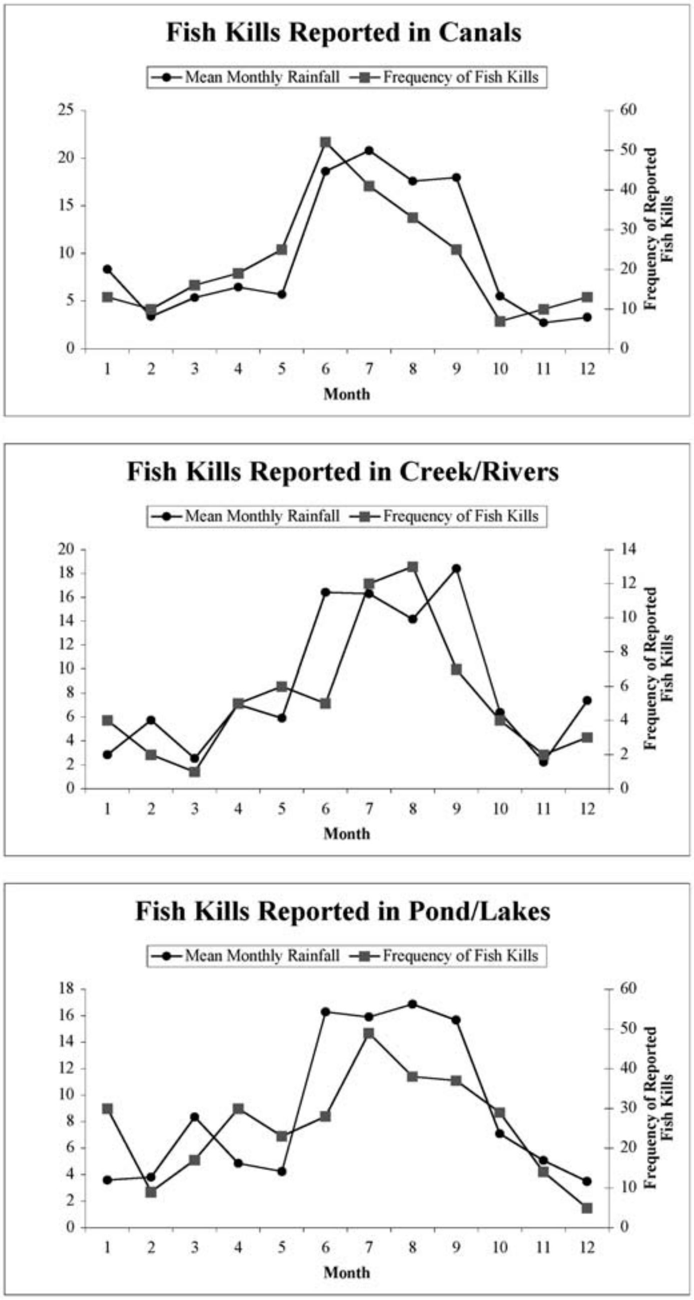

Figure 1. Frequency of occurrence of reported fish kills and average monthly rainfall plotted by month for canals, creeks/rivers and ponds/lakes.

depth was significantly higher (Table 2). Total phosphorus, total nitrogen, chlorophyll and Secchi depth in lakes experiencing no fish kills averaged 22 µg/L, 840 µg/L, 14 µg/L, and 2.4 m, respectively. All averages for the fish kill lakes also exceed the lake classification of eutrophic as defined by Forsberg and Ryding (1982). However, examining the whole range of data shows that some fish kills do occur in oligotrophic to mesotrophic lakes with minimum total phosphorus, total nitrogen and chlorophyll concentrations of 8 µg/L, 297 µg/L and 2 µg/L, respectively.

DISCUSSION

Florida is a popular angling destination where almost every day of the year thousands of people take to the water to catch a trophy largemouth bass, a fish dinner, or just enjoy the sport. When a fish kill occurs, often the first assumption is that something is terribly wrong with the water body. Suspicions are raised as to whether human activity, such as a chemical spill, may have caused the fish to die. Sometimes these suspicions are warranted but most times they are not. An examination of 407 reported fish kills in Florida show that the majority (75%) is probably due to naturally occurring processes. This is consistent with findings of Trim and Marcus (1990), who examined reports from 805 fish kills and found that natural processes was the number one cause (42%) of fish kills in South Carolina between 1978 and 1988.

Naturally occurring fish kills can be related to physical processes (e.g., rapid fluctuations in temperature), water chemistry changes (e.g., low dissolved oxygen and/or changes in pH), or they can be biological in nature (e.g., viruses, bacterial infection and/or parasites). Many of these processes are difficult to determine because by the time an investigator arrives at a fish kill, fish have rotted or been partially eaten, and water chemistry has changed or moved down stream. Thus, many of the Florida fish kill reports with unknown causes (13%) could have been of natural origin. Additionally, U.S. Fish and Wildlife Service (1990) suggests it is easier to detect human-induced fish kills because there is generally a point source or obvious evidence of a spill, reducing the probability that the unknown causes are human induced.

The time of year a fish kill occurs can help in the determination of potential causes for the kill, and early on researchers reported observations that many fish kills occur in the summer after storm events (Swingle 1968, Barica 1975). The examination of fish kills in Florida's canals, creeks/rivers, and ponds/lakes strongly support both observations. The vast majority of fish kills in Florida occur between June and September, and the frequency is highly correlated to the amount of rainfall during those months and the elevated temperature of the water.

Strong thunderstorms with abundant rainfall can dramatically change water chemistry of a lake in many ways; so several mechanisms probably work independently and/or in concert to produce a fish kill. Barica (1978) singled out a drop in temperature in a eutrophic lake leading to low dissolved oxygen and the collapse of an *Aphanizomenon flos-aquae* bloom, which subsequently caused a fish kill. Townsend et al. (1992) documented a fish kill in Donkey Camp Pool, Australia, caused by a large storm that increased an organic load with a high oxygen demand. In Florida, almost two million fish were killed in Rodman Reservoir after a September storm brought almost 35 cm of rain (Eric Nagid, FFWCC, pers. comm.). This rain changed the organic color of the aquatic macrophyte-dominated reservoir from 30 (Pt-Co) to approximately 360 (Pt-Co), shading out the submersed vegetation, which then depleted the oxygen because plants were not able to photosynthesize. Thus, while fish kill frequency is strongly correlated to rainfall events, the exact mechanisms that cause individual fish kills are probably different and lake dependent. Systematically investigating fish kills will most often yield information needed to determine the exact mechanism of individual fish kills (USFWS 1990; AFS 1992).

Table 2. Mean, standard error, and range for six water chemistry variables measured in 25 of the lakes (from 10 different counties) that had fish kill events recorded and one lake within 10 km of each of the 25 lakes that did not have a fish kill during that same time frame. The means were compared with an analysis of variance and all parameters were significantly different ($p \leq 0.05$).

	Fish Kill Reported (n = 25)			No Kill Reported (n = 25)		
Parameter	Mean	Standard Error	Range	Mean	Standard Error	Range
PH	7.7	0.2	4.7-9.0	6.6	0.3	4.5-8.8
Total alkalinity (mg/L as $CaCo_3$)	55.1	7.5	4.2-120.0	24.3	7.2	0.5-117
Total Phosphorus (µg/L)	69	25	8-638	22	4	5-80
Total Nitrogen (µg/L)	1291	174	297-4016	841	131	170-2617
Chlorophyll (µg/L)	36	8	2-130	14	3	1-72
Secchi (m)	1.2	0.2	0.2-2.6	2.4	0.4	0.6-5.7

In addition to producing storms and rainfall, summer pushes the water chemistry of lakes into conditions favorable for the occurrence of fish kill events. Lakes in summer are subject to much higher surface temperatures, decreasing the physical ability of water to hold oxygen. Many lakes are also stratified during the summer making it difficult for oxygen to diffuse to greater depths. Data from over 400 Florida lakes showed that individual lakes also have the highest algal abundance in summer between June and October (Brown et al. 1998). Especially in Florida, many of the shallow lakes are also dominated by aquatic macrophytes that reach a peak biomass in the summer (Hoyer et al. 1996). Given these factors, the more biological activity in a lake the greater the chances some climatic event will switch an oxygen balance to more respiration than photosynthesis. The evidence from 25 Florida lakes that experienced fish kills suggests that more productive eutrophic lakes have a higher probability of experiencing a fish kill; therefore, any summer period natural or human-induced limnological change in these productive lakes that causes algal or aquatic plant populations to collapse or respire more than photosynthesize has the potential to cause a fish kill.

Our findings are consistent with decades of conventional wisdom in the primary literature and centuries of aquaculture practices. Fish kills generally occur in nutrient-rich systems, in the summer during the hottest months. These kills can be triggered by storms and increased rainfall that also coincide with the summer period. Many different mechanisms working independently or in concert can be responsible for a fish kill, depending on the limnology of an individual water body. In addition to these generalities, this research shows that fish kills can occur in any month of the year, and they can occur in oligotrophic and mesotrophic lakes as well. We recommend that state agencies in charge of fish populations use resources to systematically investigate all fish kills and maintain reports that can later be merged with ambient limnological data. Analyses like these will help agencies better understand and potentially predict the occurrences of fish kills.

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