Fish Kills in Coastal Waters 1980-1989

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* * *

Comments on this report or questions about current and future estuarine activities should be addressed to :

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Introduction

Although fish-kill reporting programs around the Nation vary greatly, they indicate that fish kills have not been a pervasive problem in the Nation's estuarine and coastal areas. However, recurring kills or "hotspots" do occur in some areas.

This report summarizes results of efforts across the Nation to identify, report, and assess the causes of fish kills in coastal rivers, streams, and estuarine waters between 1980 and 1989. The location, extent, severity, timing, and cause of over 3,600 fish-kill events are documented. Data are shown for the 22 states bordering the Atlantic, Gulf of Mexico, and Pacific coasts (Figure 1).

It would be ideal if information was available on the effects of pollutants on all aquatic organisms. However, this is not the case and very little is known about how the variety of pollutants released to the environment affects these organisms. One approach to understanding these effects is to compile information on fish kills.

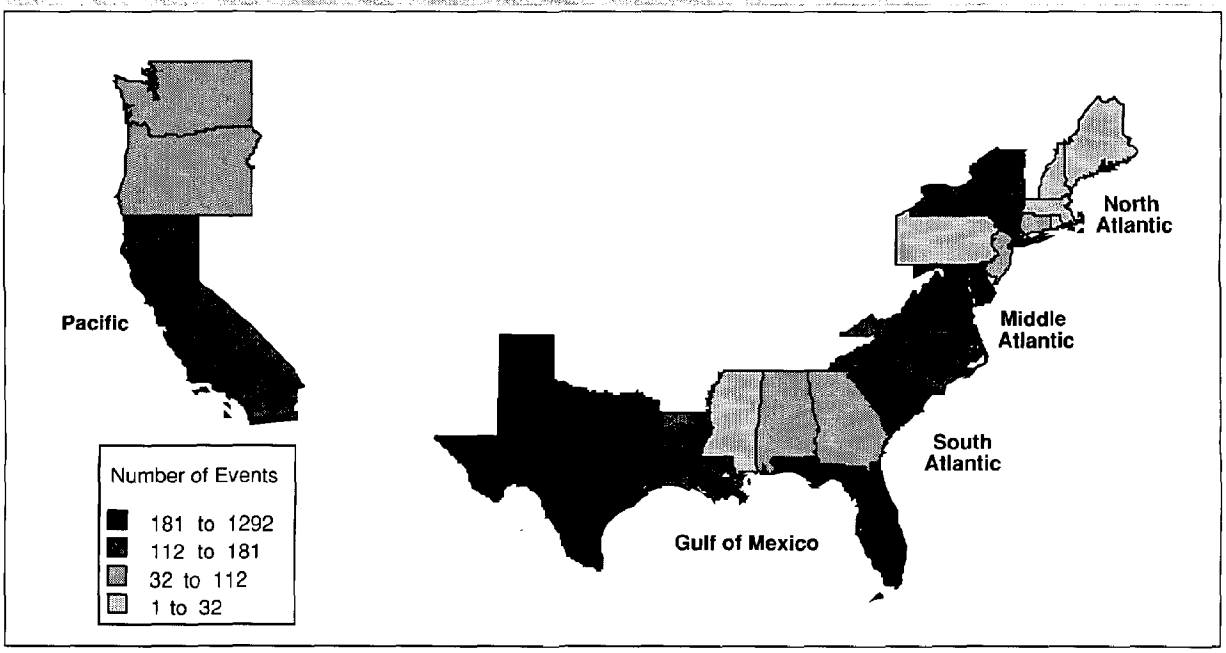
Although assessments based solely on fish kills provide only partial and conservative inferences of pollutant effects, they can provide useful information on the spatial and temporal dimensions of potential problems. For example, the information compiled in this report contains data on the date, location, and probable cause of kills. Analyzed together, these factors can help identify areas where recurring problems exist.

The data also provide a temporal record that can be used to help evaluate evidence of trends in water quality. Fish-kill events can be related to specific human activities such as an accidental pesticide spill or the discharge of high levels of chlorine disinfectant from a wastewater treatment plant. Events are also linked to natural phenomena such as oxygen depletion resulting from sustained periods of hot weather, coupled with low-flow conditions; or in many cases, to a more complex combination of human-related and natural factors such as oxygen depletion resulting from algal blooms stimulated by nutrients carried in nonpoint source runoff.

The information compiled should be useful to environmental managers and planners at the Federal, State, and local level to pinpoint "problem" areas. Compiling this information into a consistent national framework provides decisionmakers concerned with regional or national issues with the ability to target areas of concern or devise a more uniform approach to data collection.

These data are being used in two on-going projects in the National Oceanic and Atmospheric Administration's (NOAA) Strategic Environmental Assessments (SEA) Division. First, fish-kill information will be used to evaluate the effects of agricultural pesticide use in coastal

Figure 1. *Fish-Kill Events Reported in 22 Coastal States, 1980-1989*



areas (Pait et al., 1991). Second, they will be used to assess nutrient enrichment problems in the Nation's estuaries through NOAA's National Estuarine Eutrophication Survey (Hinga et al., 1991).

State Programs

State agencies investigate and document fish-kill events because they typically signal a severe environmental stress on a waterbody. Each agency's immediate goal is to identify and correct the cause of the problem. Events are documented so that a record of the magnitude and probable cause exists in case an attempt is made to recover costs for the resource injury.

Eighteen of 22 coastal states indicated that responding to an environmental emergency was the primary purpose of their fish-kill reporting program(s). However, only 11 states indicated that fish-kill events are used as an environmental indicator in their water-quality assessments or in Federal assessments such as the biennial reports required by section 305(b) of the Clean Water Act (Environmental Law Institute, 1988) (Appendix B).

EPA Fish-Kill Data Base

The U.S. Environmental Protection Agency (EPA) fish-kill reporting program is a continuation of the U.S. Public Health Service program that tracked events from 1960 to 1971. It is the only program that (until recently) has collected information nationwide on fish-kill events. Although EPA has not published a report since 1976, it continued to collect information on fish kills until recently. EPA encourages states to continue to collect data on fish kills for inclusion in the 305(b) water-quality assessment reports.

In January 1991, EPA discontinued its fish-kill reporting program due to competing program priorities.

State participation in the program was voluntary and has declined significantly since 1979. In 1988, only 12 of 22 coastal states reported fish kills to EPA. Agencies in several states appeared to have been unaware of EPA's program. In addition, the data collected only included pollution-related fish kills and not those attributed to natural phenomena. Consequently, a significant cause of fish kills (natural phenomena) is not accounted for in the EPA data base. The EPA data base was only of limited use for this report (about a third of the information presented is from the EPA data base).

Table 1. *Summary of Reported Fish-Kill Events in Coastal States, 1980-1989*

Item	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Number of states reporting	21	21	16	15	17	18	20	20	19	18
Number of events	279	358	283	283	263	340	519	424	464	442
Events that reported number of fish killed	243	308	226	252	222	303	453	331	375	368
Total estimated number of fish killed (millions)	138	97	12	22	41	33	24	4	32	6
Average size of kill (thousands)	567	316	51	86	184	108	52	12	85	16
Largest kill reported (millions)	50	30	2	4	22	8	2	1	18	3
Reports where extent of area affected was stated	106	114	70	67	54	61	77	68	52	34
Flowing waterbodies:										
Number of events	80	85	61	57	48	47	63	52	43	25
Miles of stream affected	232	309	77	96	173	94	170	73	66	30
Lakes and reservoirs:										
Number of events	26	29	9	10	6	14	14	16	9	9
Acres affected	16	113	1	1	<1	2	3	6	1	1

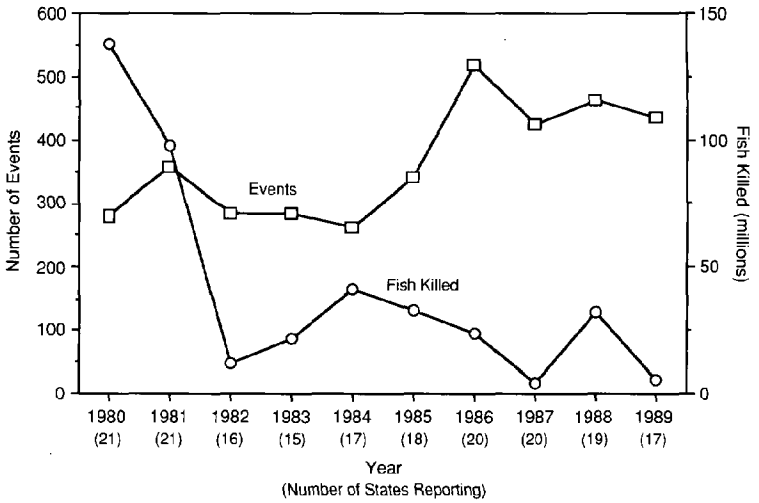
Data Collection and Verification

Data were obtained by either a state compiling and sending NOAA hard copy or digital files, or by the project team making a site visit. Site visits were made to Maryland, Virginia, Oregon, and Washington.

Information on fish-kill events and on the operation of reporting program(s) was collected from each state and entered into a NOAA data base. Data collected on each reported fish-kill event included: 1) name and type of waterbody; 2) location (county, nearest town, and latitude and longitude coordinates where available); 3) date of kill; 4) cause of kill; 5) species and number of fish killed; 6) extent of area affected; and 7) duration of critical effects. Special emphasis was placed on obtaining information describing the cause of each event.

When the data provided for an event were insufficient to characterize the cause, the label "unspecified" was assigned. For a "land-use" cause, 60 percent of all records were assigned "unspecified"; for incident, 62 percent; and for direct cause, 21 percent. In cases where the cause reported did not reflect a naturally or human-induced change in water quality, the event was omitted. For example, kills caused by commercial fishing operations, recreational fishermen discards, underwater explosions, vandalism, spawning stress, stocking stress, catch and release stress, and entrapment in live bait boxes were omitted.

Figure 2. *Summary of Fish-Kill Events from 1980-1989 for 22 Coastal States*



Major Data Elements for Each Event

Land-use Cause identifies the type of land use from which a pollutant associated with an event originated (e.g., agricultural, industrial, urban, impoundment, silviculture, wildland, mining, or military operations). Events associated with eutrophication, low-dissolved oxygen, etc., were termed "water-related."

Source identifies the physical entity or activity from which a pollutant associated with an event originated (e.g., farm, industrial plant, wastewater treatment plant, or canal).

Incident describes the action that introduced a pollutant to a waterbody (e.g., runoff, routine or accidental releases, spill, spraying, natural, drawdown, and dredging or drilling activities).

Direct Cause lists the actual cause for a fish kill (e.g., low-dissolved oxygen, pesticide, stranding, pH, temperature, or nutrients).

Specific Pollutant names the specific agent that caused a fish kill.

To verify the information collected, all data were reviewed by the participating State agencies.

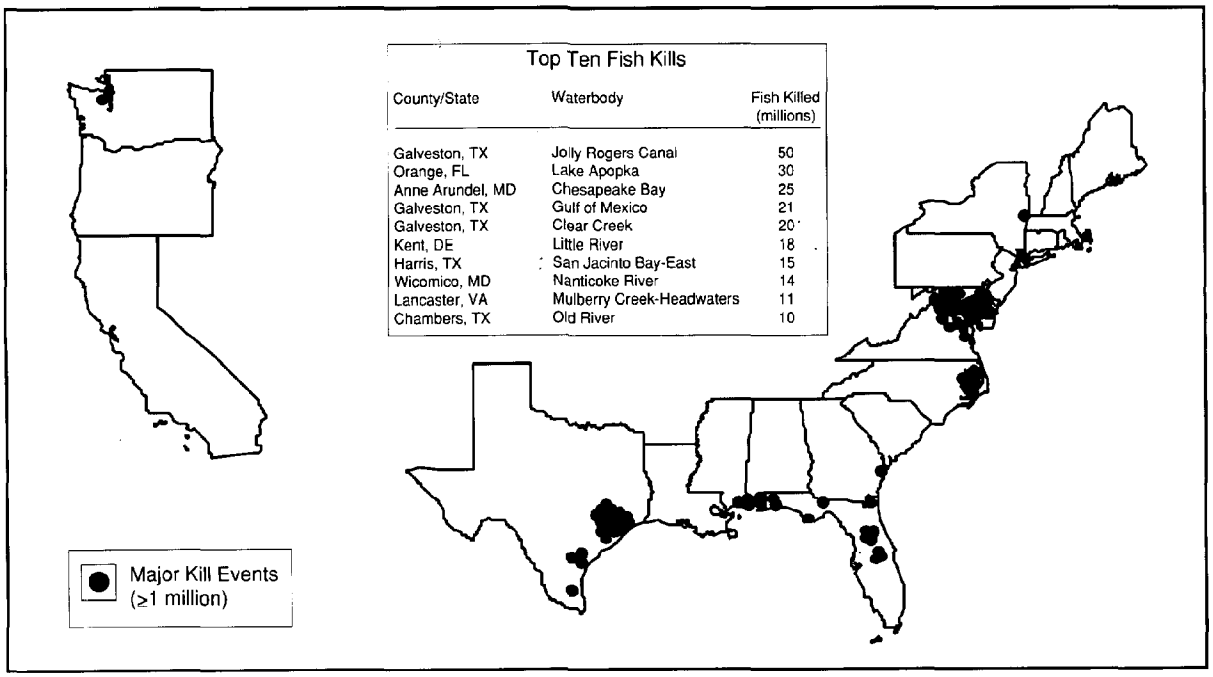
This NOAA-developed data base was also compared to EPA's data base. Event records or parts of records were added, where appropriate. Sixty-two percent of the events in the NOAA data base came from State agencies, 7 percent from local agencies, and 31 percent from EPA.

Information was also collected on selected characteristics of each State's reporting program(s) to better understand the Nation's infrastructure for fish-kill reporting. Information on program organization, investigation procedures, on-site and off-site testing of fish tissue and water samples, documentation, distribution of fish-kill-related information, and use of the data and publications is presented in Appendix B.

Limitations of the Data

Interpretation of the data presented and any conclusions drawn must be tempered with a clear understanding of the limitations of the data.

Figure 3. *Sites of Major Fish-Kill Events from 1980-1989 for 22 Coastal States*



How Complete are the Data? An important part of data collection was to determine by state the proportion documented of all probable fish kills occurring over the 10-year period. Twelve of the 22 states indicated that their reporting programs documented more than 50 percent of all probable kills during the period. The states that reported the most complete coverage (76-100%) were Maine, New Hampshire, Massachusetts, Pennsylvania, Delaware, North Carolina, and South Carolina. The two states that reported the least amount of coverage (1-25%) were California and Washington (Appendix B).

Not all the events documented contained the same information regarding direct causes and numbers of fish killed. Information varied by state and within states, depending on available resources and the perceived severity of an event. Nevertheless, almost 80 percent of all events contained some information on the direct cause and 84 percent contained at least an approximation of the number of fish killed.

Factors that Influenced Reporting. The extent to which a fish-kill event is reported and how completely it is documented depends on several factors.

- *How a state assigns responsibility for investigating fish kills.* In some states, a single agency is responsible. In others, responsibility is assigned by geographic region or type of waterbody (fresh versus marine). In this case, fish-kill information is more dispersed and, therefore, more difficult to collect.

- *The staff available to investigate events.* In states with small budgets for fish-kill reporting programs, there may be an inadequate number of staff to investigate all events.

- *The emphasis a state places on the type of event to investigate.* For example, some states only investigate kills of economically important fish species, while other states respond to all kills.

- *The size of the population surrounding a waterbody.* Fish kills are reported more often around densely populated areas at least in part because more people witness and report the event. Kills occurring in sparsely settled areas often go unreported.

- *The timeliness of the investigation.* If the investigation does not take place promptly, fish wash downstream, sink, or are eaten by scavengers, lowering the number and possibly the species of fish reported killed. In addition, the contaminant or

environmental condition causing an event may be diluted or degraded so that a direct cause can no longer be attributed to a kill.

Although no absolute conclusions can be drawn from fish-kill data alone, combining the data with other information on pollution releases and environmental quality can provide useful insights to analysts and decisionmakers.

National Results

From 1980 to 1989, over 3,650 fish-kill events were reported in 533 coastal and near coastal counties in 22 states. These events involved over 407 million fish. The number of events reported was highest in 1986 (519), and the greatest number of fish killed was in 1980 (138 million) (Table 1). The land-use cause, incident, and direct cause most frequently cited were urban land use, natural events, and low-dissolved oxygen.

Trends and Seasonal Variations. During the 10-year period, the number of states reporting events in estuarine and coastal waters varied from 15 in 1983 to 21 in 1980 and 1981 (Figure 2). Consequently, fish-kill events are difficult to evaluate accurately over time. However, an upward trend exists in the number of events and a downward trend in the number of fish killed nationwide (Figure 2).

Seasonal variations play an important role in the timing of fish-kill events. As might be expected, the largest number of events (64%) and the highest number of fish killed (86%) were during the warmest months of the year (May through September). The month with the single greatest number of events was August, while the greatest number of fish killed was in June.

Geographical Distribution. States reporting the most fish-kill events were Florida (1,292), Maryland (455), Texas (355), and South Carolina (191). The top five counties with the greatest number of events were Palm Beach, FL (383); Broward, FL (277); Anne Arundel, MD (182); Dade, FL (87); and Beaufort, SC (73) (Appendix A).

States reporting the most fish killed were Texas (159 million), Florida (77 million), Maryland (68 million), Delaware (28 million) and North Carolina (26 million) (Appendix A). The top five counties with the greatest number of fish killed were Galveston, TX (106 million); Orange, FL (36 million); Anne Arundel, MD (36 million); Kent, DE (24 million); and Harris, TX (23 million) (Appendix A).

Sources and Causes. The land-use causes most frequently cited were urban (13%), industrial (7%), and agriculture (4%). The top three incidents introducing pollutants into a waterbody were naturally occurring conditions (16%), runoff (7%), and routine releases (5%). The direct causes most frequently cited were low-dissolved oxygen (41%), wastewater (5%), eutrophication (5%), and pesticides (4%).

Major Fish Kills. Eighty-six individual events occurred where an estimated one million or more fish were killed. These events took place in 39 counties within 14 states. The greatest concentration of these events was in Galveston (8) and Chambers (5) counties in Texas; Anne Arundel (8) and Wicomico (5) counties in Maryland; and Beaufort County (6), North Carolina.

The largest reported fish kill occurred in the Jolly Rogers Canal, Jamaica Beach, Galveston County, Texas, where an estimated 50-million fish died (Figure 3). The kill occurred in June 1980 and was attributed to low-dissolved oxygen from unspecified sources. The only species reported killed was gulf menhaden *(Brevoortia patronus)*.

Many different combinations of land-use causes and direct causes result in major fish-kill events (Table 2). However, the majority of these events is characterized by low-dissolved oxygen, high temperatures (summer months), a large area of water with poor circulation, and involves small fish such as menhaden (*Brevoortia sp.*) that tend to school in large numbers and are very intolerant of low-dissolved oxygen conditions. Although events occur where a relatively toxic substance is released or spilled causing considerable damage to fish, these events occur less frequently and tend to be more localized, killing fewer fish.

The families of fish most commonly involved in a kill event are *Clupeidae* (menhaden, shad, herring), *Centrarchidae* (sunfish, bluegill, bass), and *Cyprinidae* (carps, minnows, dace, chubs, shiners). Of the above, *Clupeidae* are involved in 36 percent of all

fish-kill events and account for 61 percent of the total number of fish killed.

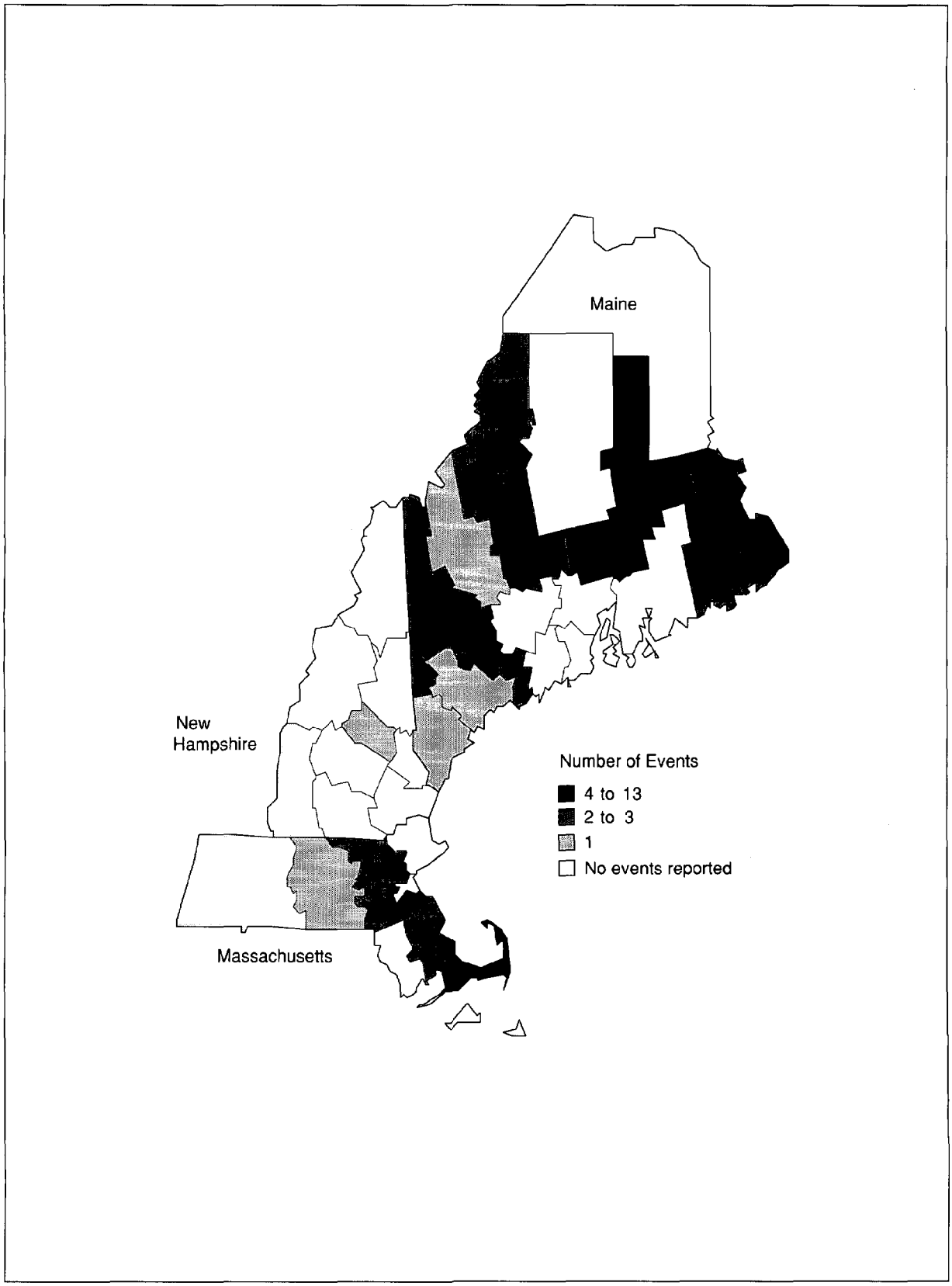
Five sections follow that present results for individual coastal regions: North Atlantic; Middle Atlantic; South Atlantic; Gulf of Mexico; and Pacific. The concluding comments section discusses potential uses of the data. Information on the number of events and fish killed by region, State, and county, and information on State reporting programs are provided in Appendices A and B.

Table 2. *Land-Use Cause and Direct Cause of Major Fish Kills from 1980-1989 for 22 Coastal States*

Land-use cause/ Direct cause of kill	Total reports	% reports	Number of fish (millions)	% fish killed
Industry				
Eutrophication	1	1	5	1
Wastewater	1	1	1	<1
Mixed Chemicals	1	1	1	<1
Pesticides	1	1	1	<1
Subtotal	**4**	**5**	**8**	**<1**
Urban				
Low-Dissolved Oxygen	1	1	1	<1
Eutrophication	1	1	1	<1
Wastewater	2	2	22	6
Mixed Chemicals	1	1	30	8
Nutrients	1	1	6	2
Subtotal	**6**	**7**	**60**	**16**
Impoundments				
Low-Dissolved Oxygen	2	2	6	2
Temperature	1	1	2	1
Subtotal	**3**	**3**	**8**	**2**
Water-Related				
Low-Dissolved Oxygen	16	19	64	17
Temperature	5	6	36	10
Eutrophication	3	3	5	1
Stranding	2	2	15	4
Storm Event	1	1	3	1
Salinity Change	3	3	7	2
Subtotal	**30**	**35**	**129**	**35**
Unspecified	43	50	169	45
Total	**86**	**100**	**375**	**100**

North Atlantic

Figure 4. *Reported Fish-Kill Events by County, 1980-1989*



The North Atlantic had the least number of events and least number of fish killed among regions. This can be partially explained by the climate and physical features of the estuaries in this region. The number of events reported each year was greatest during the summer months. The greatest number of events occurred in Penobscot County, Maine. Wastewater discharges, low-dissolved oxygen, and chemical releases were the three leading direct causes of fish kills.

The Data

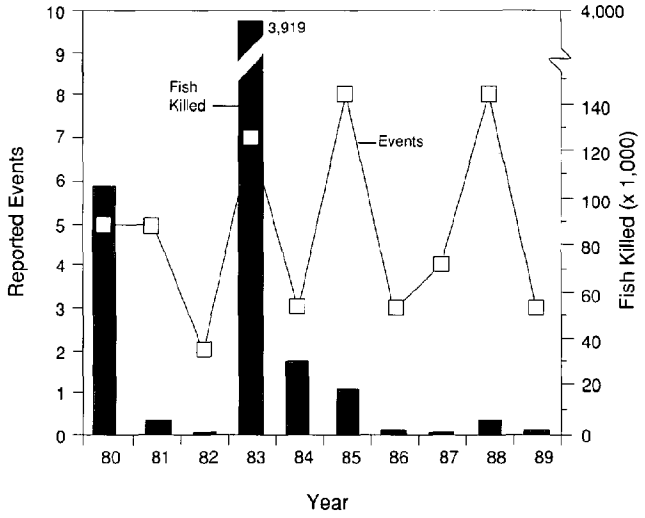
In this region, 92 percent of reports included the number of fish killed, 84 percent included the direct cause of the event, 77 percent included the land-use cause, and 67 percent included the type of incident (Appendix A). This region had the second most complete reporting of the number of fish killed and direct causes among regions. Of the states in this region, Maine's reporting was the most complete and New Hampshire's was the least complete.

Fish-Kill Events

Fish-kill events were reported in 15 of the 31 counties in the study area (16 counties in Maine, 8 in New Hampshire, and 7 in Massachusetts) (Figure 4).

The North Atlantic had the fewest number of reported events (48) and least number of fish killed (4,090,300). Maine accounted for over half of the fish-kill events reported in the region with 28, followed by Massachusetts (19) and New Hampshire (1).

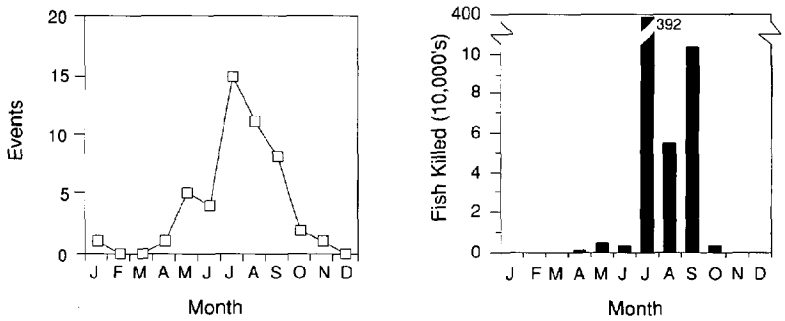
Figure 5. *Number of Events and Fish Killed, 1980-1989*



Massachusetts accounted for the majority of the fish killed in the region, with almost 3.9 million or 96 percent of all reported fish killed between 1980 and 1989. However, most of the total for Massachusetts can be attributed to one event that occurred in July 1983 in Wellfleet Harbor in Cape Cod Bay. Over 3.9 million fish were reported killed in this event. The incident was reported as a natural event, and the direct cause cited was low-dissolved oxygen. No other single event in the region accounted for more than 100,500 fish killed.

Trends. The number of events reported from 1980 to 1989 does not appear to show a trend (Figure 5). However, an apparent seasonal pattern exists in the region. The majority of events and the greatest number of fish killed were reported in July, August, and September (Figure 6). This seasonal pattern exists across the Nation, with the majority of kills occurring during the summer months.

Figure 6. *Number of Events and Fish Killed by Month, 1980-1989*



Sources and Causes

A number of factors may account for the relatively low number of fish kills observed in the North Atlantic. The climate of this region is colder than other regions. Therefore, fish are subjected to less thermal stress. The generally fast-flowing rivers in the region and the strong tides and basin geometry in many of its estuaries result in well mixed and aerated waterbodies not highly susceptible to stratification and associated low-dissolved oxygen levels. This is in contrast to the more placid coastal plain rivers and shallow drowned-river systems in the Middle Atlantic, South Atlantic, and Gulf of Mexico. Finally, the North Atlantic covers the smallest land area of the five regions, has the lowest percentage of agricultural land (a potentially important land-use cause), and contains only 4 percent of all the existing point sources in the five coastal regions (NOAA, 1990). As a result, impacts due to human activities are less severe in this region.

The sources and causes of fish kills can be broken down into two different types of events. One type is related to human activities such as routine releases of wastewater or mixed chemicals from a variety of different sources (e.g., trucking accidents, various industries, sewage treatment plants, and pig farms).

Routine releases were the most frequently cited incidents causing these fish kills (Figure 7). The majority of the routine releases was emitted from industrial plants. Wastewater discharges, low-dissolved oxygen, and pH were the three leading direct causes of fish kills (Figure 8). Industry and agriculture were the two leading land-use causes associated with fish kills in the region (Figure 9).

The other type of event that led to a substantial number of kills in the region is naturally occurring phenomenon caused by a combination of environmental factors (i.e., water and air temperatures, wind, precipitation, and resident flora). Most of these events can be attributed to one or more of the following: low-dissolved oxygen; predatory stress; high temperatures; algal blooms; and/or bacterial infections.

In ***Maine***, all 28 of the reported events indicated the *direct cause* of the kill. Wastewater was the direct cause in nine of the 28 events. Twenty-five of the 28 reported events indicated the *land-use cause* of the kill. Industrial land use was the land-use cause in 19 of the 25 events. In 25 of the 28 reported events, a direct cause was linked with a land-use cause.

In ***New Hampshire***, the *direct cause* of the only reported fish-kill event was inorganic chemicals/metals, and the *land-use cause* was urban land use.

In ***Massachusetts***, 12 of the 19 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in four of the 12 events. Eleven of the 19 reported events indicated the *land-use cause* of the kill. Agricultural land use was the land-use cause in six of the 11 events. In nine of the 19 reported events, a direct cause was linked with a land-use cause.

Figure 7. *Number of Fish-Kill Events by Type of Incident**

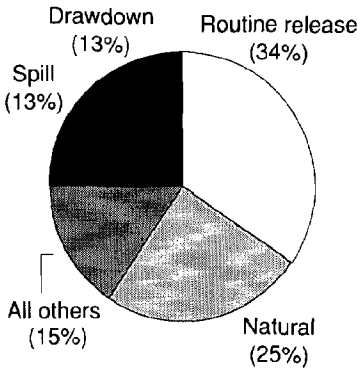


Figure 8. *Number of Fish-Kill Events by Direct Cause**

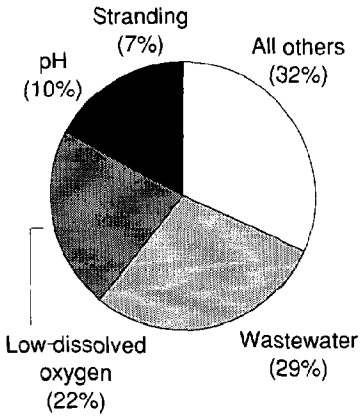
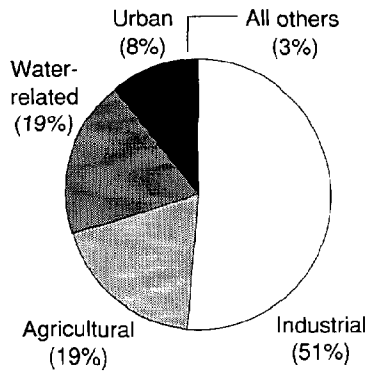


Figure 9. *Number of Fish-Kill Events by Land-Use Cause**



**Does not include information from unspecified events.*

Data tables containing the number of events and fish killed by county, state, region, year, direct cause, land-use cause, and incident are in Appendix A.

Hotspots and Recurring Kills

The greatest number of kills (13) in the region occurred in Penobscot County, Maine. Twelve of these were attributed to releases from industrial land use. This county contains 45 industrial sources, six of which are related to production of paper products.

Mattanawcook stream in Penobscot County was the site of nine fish-kill events between 1986 and 1989, eight of which were caused by a single pulp/paper processing operation located on this stream. In 1989, the State took legal action against the plant. As a result, this plant has not been involved in any other reported fish-kill events. No other stream in the region had more than two events during the 10-year period.

The only other area in the region where a large number of kills was reported was Barnstable County, Massachusetts, with ten kills between 1980 and 1989. However, most were due to natural causes.

State Reporting Programs

Each of the three North Atlantic states uses a different approach when collecting fish-kill data. The discussion below highlights which agencies in each state are involved in fish-kill reporting and when they are most likely to make an on-site investigation of a fish-kill event. Information concerning each state's program organization, investigative procedures, and use of data are summarized in Appendix B.

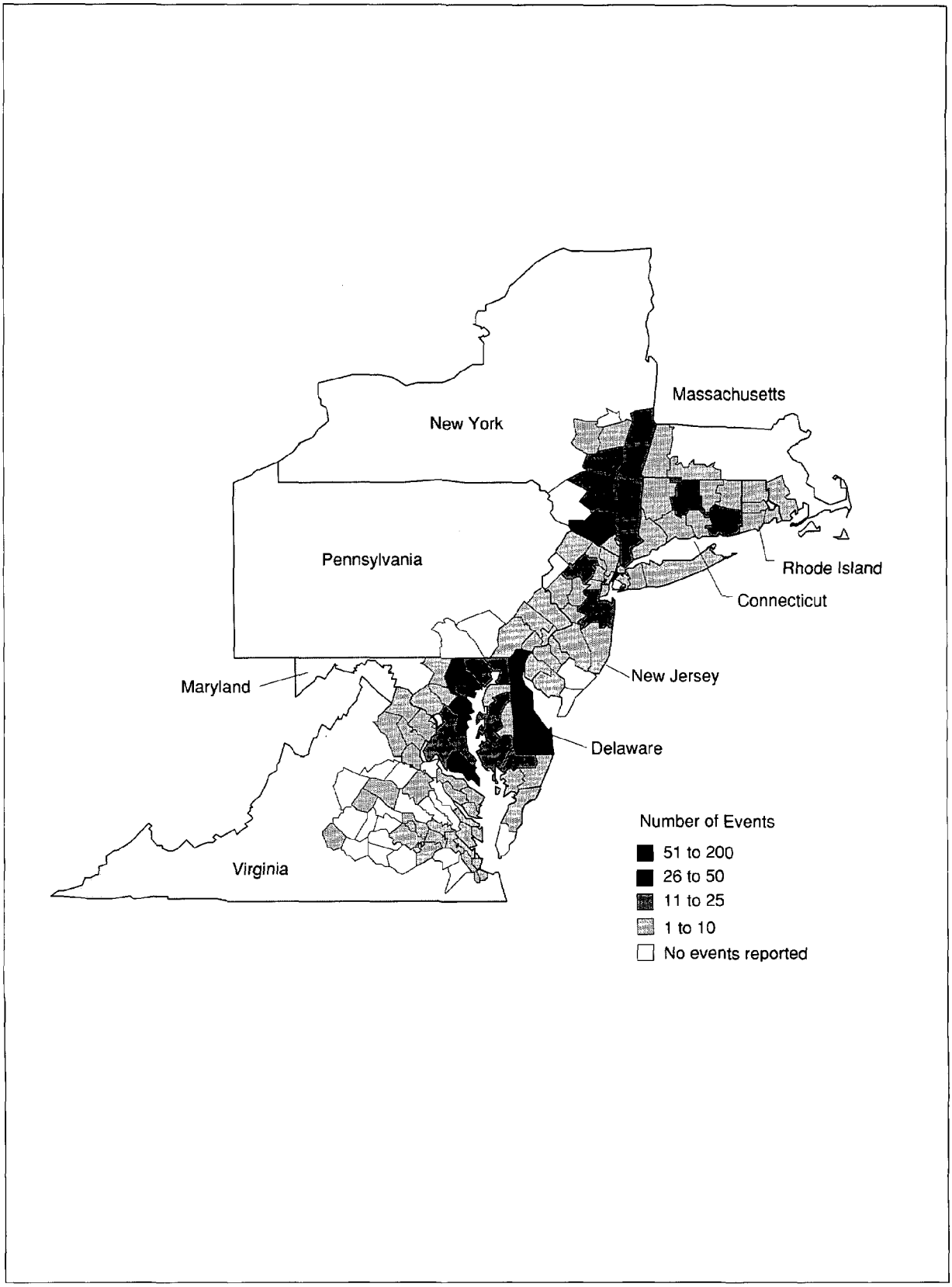
Maine has three agencies that may be involved in the fish-kill investigation process: the Department of Environmental Protection (DEP); Department of Inland Fisheries and Wildlife; and the Department of Marine Resources. DEP is the only organization that provided fish-kill data to NOAA. The state indicated that field visits are likely to be made when an event is reported (i.e., more than 75 percent of the time).

New Hampshire's Marine Division, within the Department of Fish and Game, has primary responsibility for all fish kills occurring in the state. They also provided fish-kill data for this report. They conduct field investigations of fish-kill events approximately 5 percent of the time and are more likely to respond to an event if large numbers of fish are involved in the kill.

Massachusetts has the largest program of the three North Atlantic states. The responsibility is shared between two agencies: Division of Marine Fisheries (marine- and coastal-related kills), and the Division of Fisheries and Wildlife (freshwater kills). Both provided fish-kill data to NOAA. They also reported that field visits are standard procedure when an event is reported (i.e., more than 75 percent of the time).

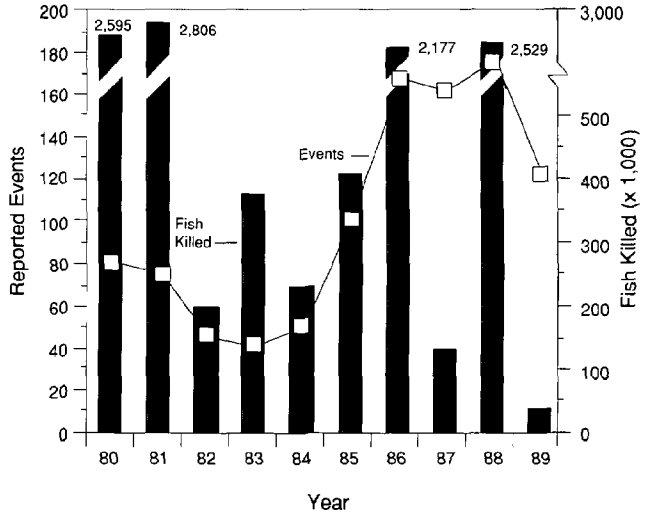
Middle Atlantic

Figure 10. *Reported Fish-Kill Events by County, 1980-1989*



The Middle Atlantic had the second highest number of events and number of fish killed among regions. This can be partially explained by the climate and physical features of the estuaries in this region. The number of events reported each year was greatest during the summer months. The greatest number of events occurred in Anne Arundel County, Maryland. Low-dissolved oxygen, disease, and wastewater discharges were the three leading direct causes of fish kills.

Figure 11. *Number of Events and Fish Killed, 1980-1989*



The Data

Assessment of the important sources and causes of events in this region is hampered by the gaps in cause-related information reported by each state. In this region, 65 percent of the reports included the number of fish killed, 69 percent included the direct cause of the event, 48 percent included the land-use cause, and 45 percent included the type of incident (Appendix A). The Middle Atlantic had the most incomplete reporting of the number of fish killed and direct causes among regions. Of the states in this region, Connecticut's reporting was the most complete and New Jersey's was the most incomplete.

Fish-Kill Events

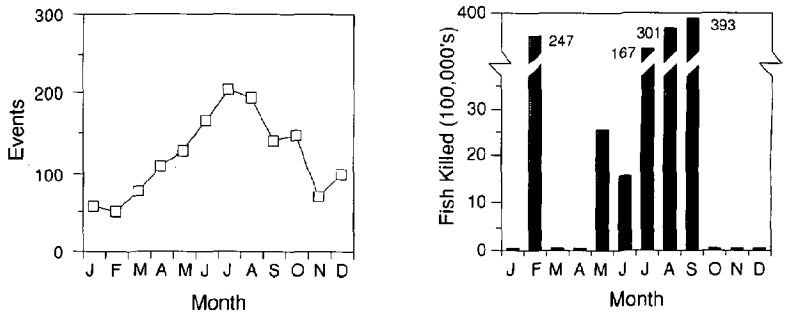
Fish-kill events were reported in 113 of the 149 counties (including the District of Columbia) in the study area (5 counties in Massachusetts, 5 in Rhode Island, 8 in Connecticut, 20 in New York, 20 in New Jersey, 7 in Pennsylvania, 3 in Delaware, 21 in Maryland including the District of Columbia, and 60 in Virginia) (Figure 10).

This region had the second highest number of reported events (1,033) and fish killed (115,339,200). Maryland accounted for over one-third of the fish-kill events reported in the region (455), followed by New York (151); Delaware (120); New Jersey (112); Virginia (98); Connecticut (55); Rhode Island (18); Pennsylvania (16); and Massachusetts (8).

Maryland also had the highest number of fish killed in the region, with about 68 million or 59 percent of all reported fish killed between 1980 and 1989. Twenty events in Maryland involved the death of over a million fish. Eight of these occurred in Anne Arundel County and five in Wicomico County.

Trends. The number of events reported from 1980 to 1989 shows an upward trend (Figure 11). From 1980 to 1984, the largest number of fish-kill events occurring in a single year was 81 in 1980. However, from 1985 to 1989, at least 100 events occurred each year, with the largest being 177 in 1988. A seasonal pattern also exists in

Figure 12. *Number of Events and Fish Killed by Month, 1980-1989*



this region. Most events were reported between June and August (Figure 12). However, the greatest numbers of fish killed were reported in February, August, and September. This seasonal pattern exists across the Nation, with the majority of kills occurring during the summer months.

Sources and Causes

A number of factors may account for the relatively high number of fish kills in the Middle Atlantic. The shallow drowned-river systems in the region and the weak tides and basin geometry in many of its estuaries result in poorly mixed and aerated waterbodies susceptible to stratification and associated low-dissolved oxygen levels. This region also has the greatest human population density and the greatest percentage of urban land among regions (NOAA, 1990).

Naturally occurring events dominate the region, with the top two direct causes reported as low-dissolved oxygen levels and disease (Figures 13 and 14). In addition, a significant impact is caused by routine wastewater releases and/or spills occurring in urban and industrial land-use areas (Figure 15). These events reflect kills related to inputs from human activities.

In ***Massachusetts***, five of the eight reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause reported in two of the five events. Three of the eight reported events indicated the *land-use cause* of the kill. Industrial land use was the land-use cause in two of the three events. In only three of the eight events was a land-use cause reported along with a direct cause.

In ***Rhode Island***, 13 of the 18 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in nine of the 13 events. Five of the 18 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause in two of the five events. A direct cause was associated with a land-use cause in only five of the 18 reported events.

In ***Connecticut***, 42 of the 55 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in nine of the 42 events. Seventeen of the 55 reported events indicated the *land-use cause* of the kill. Industrial land use was the land-use cause in six of the 17 events. In only 16 of the 55 reported events was a direct cause linked with a specific land use.

In ***New York***, 116 of the 151 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 18 of the 116 events. Ninety-three of the 151 reported events indicated the *land-use cause* of the kill. Impoundments were the land-use cause identified in 33 of the 93 events. In 86 of the 151 reported events, a land-use cause was reported along with a direct cause.

In ***New Jersey***, 64 of the 112 reported events indicated the *direct cause* of the kill. Pesticides were the direct cause in nine of the 64 events. Thirty-three of the 112 reported events indicated the *land-use cause* of

Figure 13. *Number of Fish-Kill Events by Type of Incident**

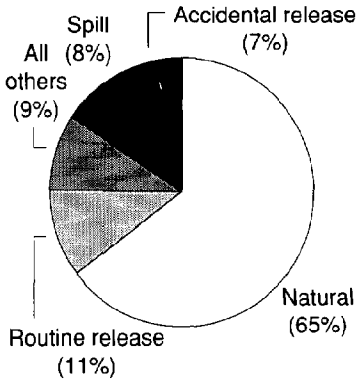


Figure 14. *Number of Fish-Kill Events by Direct Cause**

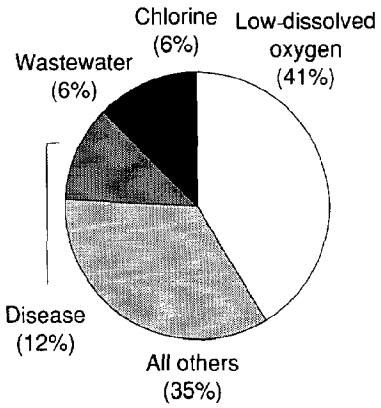
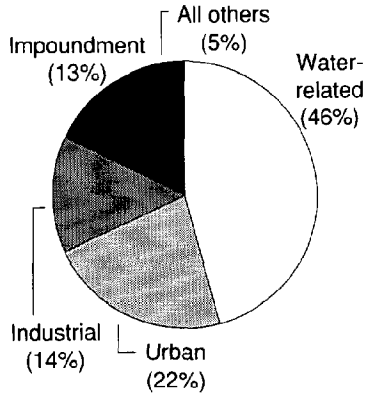


Figure 15. *Number of Fish-Kill Events by Land-Use Cause**



Does not include information from unspecified events.

the kill. Urban land use was the land-use cause in 16 of the 33 events. A direct cause was associated with a specific land use in only 31 of the 112 reported events.

In ***Pennsylvania***, ten of the 16 reported events indicated the *direct cause* of the kill. Pesticides were the direct cause in three of the ten events. Thirteen of the 16 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause in six of the 13 events. In 10 of the 16 reported events, a direct cause was linked with a land-use cause.

In ***Delaware***, 72 of the 120 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 36 of the 72 events. Thirty-three of the 120 reported events indicated a *land-use cause* of the kill. Urban land use was the land-use cause in ten of the 33 events. In only 30 of the 120 reported events was a land-use cause reported along with a direct cause.

In ***Maryland***, 333 of the 455 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 200 of the 333 events. Of the 455 reported events, 249 indicated the *land-use cause* of the kill. Water-related land use was the land-use cause in 188 of the 249 events. A direct cause was associated with a specific land use in 241 of the 455 reported events.

In ***Virginia***, 60 of the 98 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 12 of the 60 events. Fifty of the 98 reported events indicated the *land-use cause* of the kill. Industrial land use was the land-use cause in 17 of the 50 events. In 49 of the 98 reported events, the land-use cause was linked with the direct cause.

Data tables containing the number of events and fish killed by county, state, region, year, direct cause, land-use cause, and incident are in Appendix A.

Hotspots and Recurring Kills

Two counties in Maryland reported the highest number of fish-kill events for the Middle Atlantic region. One hundred and eighty-two events were reported in Anne Arundel County (accounting for 31% of all reported fish kills in the region), and 47 events occurred in Baltimore County. Most of these kills were attributed to low-dissolved oxygen levels.

The waterbody having the most events in this region was the Magothy River Basin (43 events) in Anne Arundel County, Maryland. This river has a history of over-enrichment problems. However, this situation was further exacerbated in February 1986 when the waste from a break in a sewage line was discharged into the river. Twenty-four of the 43 reported events for this river occurred between May and October 1986. The Hudson River/Raritan Bay area, which traverses seven New York counties and four New Jersey counties, was another waterbody for which numerous events were reported. Nineteen fish-kill events were reported for this waterbody between 1980 and 1989. However, most of the records for these events did not contain information on the cause of the kills.

State Reporting Programs

Each of the nine Middle Atlantic states uses a different approach when collecting fish-kill data. The discussion below highlights which agencies in each state are involved in fish-kill reporting and when they are most likely to make an on-site investigation of a fish-kill event. Information concerning each state's program organization, investigative procedures, and use of data are summarized in Appendix B.

Massachusetts (see the North Atlantic region).

Rhode Island has three different divisions within the Department of Environmental Management (DEM) that may be involved in the fish-kill investigation process. These divisions are Enforcement (handles initial response and assessment), Fish and Wildlife (responds only if kill occurs in a pond or lake, or if only one fish species is involved and less than 100 fish are killed), and Water Resources (handles pollution-related kills and works jointly with Fish and Wildlife on large kills). The Water Resources Division is the only office that provided fish-kill data for this report. However, because each division should provide full documentation to each other for all fish kills, data provided should be complete for the state. Before May 1988, the state had no formal fish kill response policy. Now, field visits are made when: a large number of fish is involved (this state's cutoff is 100 fish); the public becomes concerned; and/or personnel are available to respond.

Middle Atlantic

Connecticut has two divisions (Water Management and Fisheries) under the Department of Environmental Protection (DEP) that respond to and document fish kills. The Water Management Division is primarily concerned with kills caused by industrial discharges, while the Fisheries Division responds to and investigates all kills. Only Fisheries provided fish-kill data for this report (their response included data from both divisions). The Fisheries contact indicated that field visits are generally standard procedure when an event is reported.

New York has five divisions within its Department of Environmental Conservation (DEC) that may be involved in the fish-kill investigation process: Fish and Wildlife; Law Enforcement; Water; Hazardous Substances Regulation; and Marine and Coastal Resources. The Fish and Wildlife Division provided statewide fish-kill data for this report. An on-site investigation is made when a large number of fish is involved in the kill and/or when the public becomes concerned.

New Jersey has two divisions within the Department of Environmental Protection that respond to fish-kill events. The Fish, Game, and Wildlife Division handles inland kills, while the Marine Fisheries Division responds to coastal water kills. However, only the Fish, Game, and Wildlife regional offices provided fish-kill data for this report. Field visits are likely to be made when a large number of fish is involved or when the public becomes concerned.

Pennsylvania's fish-kill program consists of three agencies: the Department of Environmental Resources' Bureau of Water Quality; the Fish Commission's Bureau of Law Enforcement; and the Emergency Management Agency. Due to a staff shortage at the Fish Commission, fish-kill data for this report were obtained from the EPA data base. Field visits to fish-kill sites are made the majority of the time (i.e., more than 75 percent of the time).

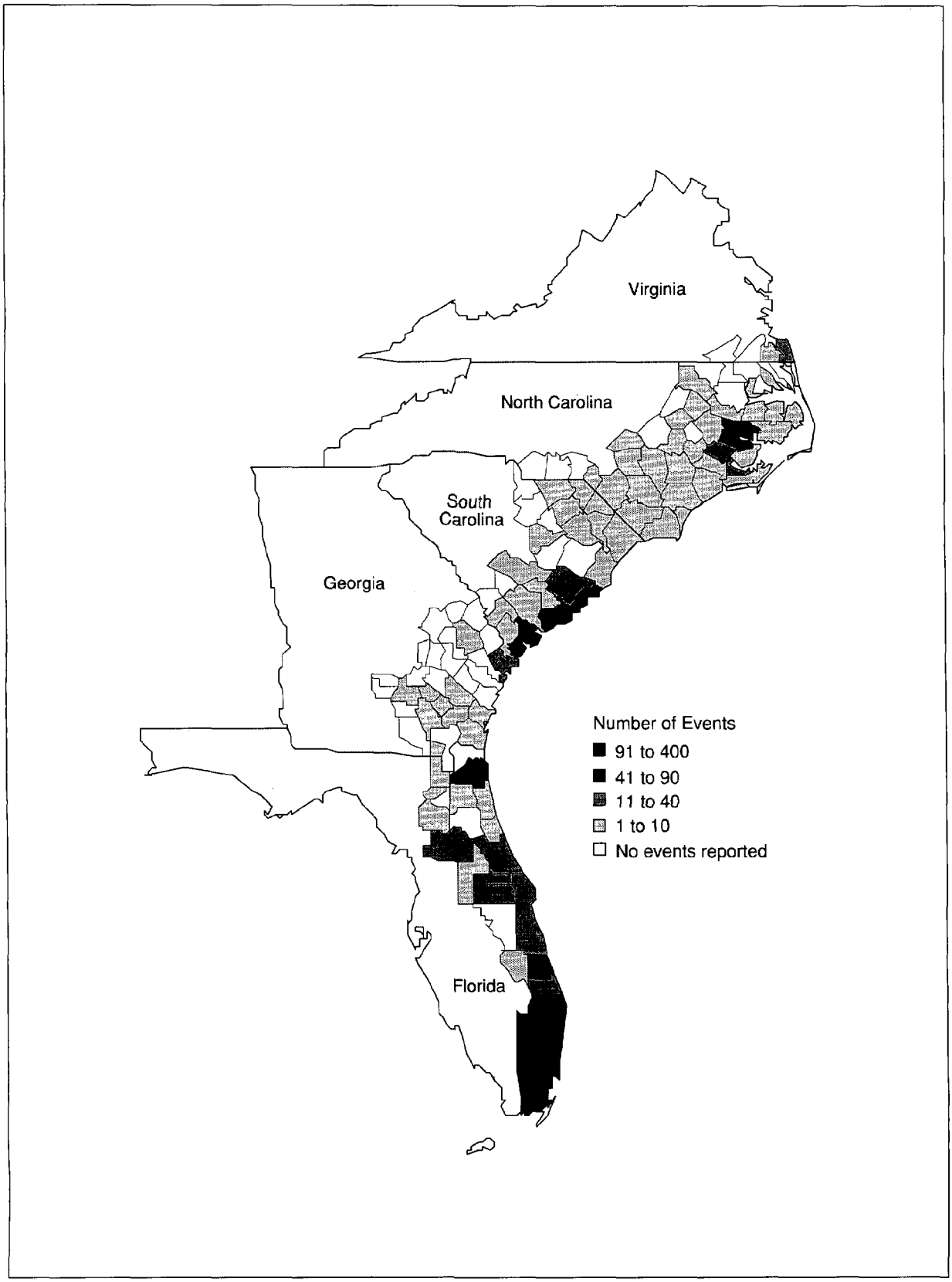
Delaware's program is conducted by the Department of Natural Resources and Environmental Control's (DNREC) Division of Fish and Wildlife. The Fish and Wildlife Division provided fish-kill data for this report. It reports that field visits are standard procedure and they respond more than 75 percent of the time.

Maryland's program is conducted by the Water Quality Monitoring Division, Department of the Environment. The Water Quality Monitoring Division provided fish-kill data for this report. Field visits are likely to be made when a large number of fish is involved in a kill or when the public becomes concerned.

Virginia has two agencies that may be involved in the fish-kill investigation process: the Water Control Board (WCB) and the Department of Game and Inland Fisheries. The WCB provided fish-kill data for this report. Field visits are likely to be made when a large number of fish is involved in the kill, the public becomes concerned, and/or personnel are available to respond.

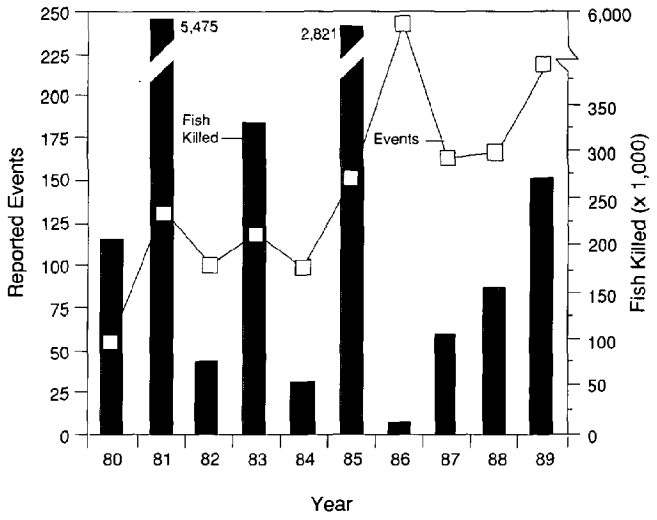
South Atlantic

Figure 16. *Reported Fish-Kill Events by County, 1980-1989*



The South Atlantic had the highest number of events and the third highest number of fish killed among regions. This can be partially explained by the climate and physical features of the estuaries in this region. The number of events reported each year was greatest during the summer months. The greatest number of events occurred in Palm Beach County, Florida. Low-dissolved oxygen, eutrophication, and pesticides were the three leading direct causes of fish kills.

Figure 17. *Number of Events and Fish Killed, 1980-1989*



The Data

In this region, 96 percent of the reports included the number of fish killed, 84 percent included the direct cause of the event, 26 percent included the land-use cause, and 25 percent included the type of incident (Appendix A). The South Atlantic had the most complete reporting of the direct cause and number of fish killed among regions. Of the states in this region, Florida's reporting was the most complete and Georgia's was the most incomplete.

Fish-Kill Events

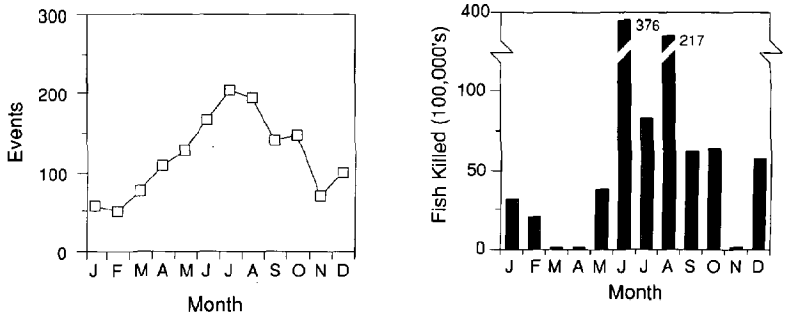
Fish-kill events were reported in 79 of the 125 counties in the study area (4 in Virginia, 44 in North Carolina, 24 in South Carolina, 29 in Georgia, and 24 in Florida) (Figure 16).

This region had the highest number of reported events (1,450) and third highest number of fish killed (95,291,300). Florida accounted for almost three quarters of the fish-kill events reported in the region with 1,042, followed by South Carolina (191); North Carolina (153); Georgia (33); and Virginia (31).

Florida also had the highest number of fish killed in the region, with over 64 million or 67 percent of all reported fish killed between 1980 and 1989. Eight events occurred in Florida in which over a million fish were killed. Four of these occurred in Marion County and two in Orange County. (For more information on Florida, see inset on page 21).

Trends. The number of events reported from 1980 to 1989 shows an upward trend (Figure 17). From 1980 to 1984, the largest number of fish-kill events occurring in a single year was 133 in 1981. However, from 1985 to 1989, at least 150 events occurred each year, with the largest being 243 in 1986. An apparent seasonal pattern also exists in this region. The majority of events and the greatest number of fish killed were reported between June and August (Figure 18). This seasonal pattern exists across the Nation, with the majority of kills occurring during the summer months.

Figure 18. *Number of Events and Fish Killed by Month, 1980-1989*



Sources and Causes

A number of factors may account for the relatively high number of fish kills observed in the South Atlantic. The shallow drowned-river systems in the region and the weak tides and basin geometry in many of its estuaries result in poorly mixed and aerated waterbodies susceptible to stratification and associated low-dissolved oxygen levels. This region also has the second largest total estuarine drainage area, the highest intensity of pesticide application, and the second highest application rate of nutrients among regions (NOAA, 1990).

Kills associated with runoff from urban and agricultural land use dominate the region, with the top two direct causes reported as low-dissolved oxygen levels and eutrophication (Figures 19, 20 and 21). In addition, naturally occurring events had a significant impact on the waterbodies in this region (Figure 19).

In ***Virginia***, 21 of the 31 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause reported in eight of the 21 events. Fifteen of the 31 reported events indicated the *land-use cause* of the kill. Water-related land use was the land-use cause in eight of the 15 events. In 15 of the 31 reported events, a land-use cause was reported along with a direct cause.

In ***North Carolina***, 108 of the 153 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 38 of the 108 events. Seventy-nine of the 153 reported events indicated the *land-use cause* of the kill. Water-related land use was the land-use cause in 42 of the 79 events. In 78 of the 153 reported events, a direct cause was associated with a land-use cause.

In ***South Carolina,*** 138 of the 191 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 60 of the 138 events. Nineteen of the 191 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause in 12 of the 19 events. In only 17 of the 191 reported events was a direct cause linked with a specific land-use cause.

In ***Georgia,*** 27 of the 33 reported events indicated the *direct cause* of the kill. Wastewater discharge was the direct cause in six of the 27 events. Twenty-two of the 33 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause identified in 11 of the 22 events. In 22 of the 33 reported events, a land-use cause was reported along with a direct cause.

In ***Florida,*** 929 of the 1,042 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 728 of the 929 events. Two hundred and thirty-nine of the 1,042 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause in 158 of the 239 events. In only 228 of the 1,042 reported events was a direct cause associated with a specific land-use cause.

Data tables containing the number of events and fish killed by county, state, region, year,

Figure 19. *Number of Fish-Kill Events by Type of Incident**

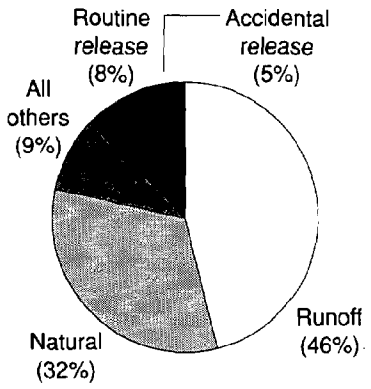


Figure 20. *Number of Fish-Kill Events by Direct Cause**

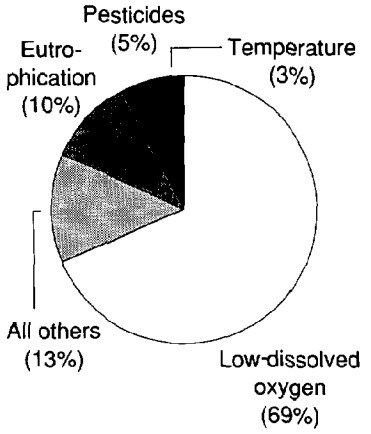
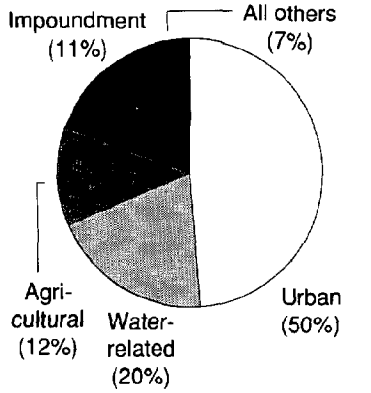


Figure 21. *Number of Fish-Kill Events by Land-Use Cause**



**Does not include information from unspecified events.*

direct cause, land-use cause, and incident are in Appendix A.

Hotspots and Recurring Kills

Two counties in Florida reported the highest number of fish-kill events for the South Atlantic region. Three hundred and eighty-three events were reported in Palm Beach County (accounting for 37% of all reported fish kills in the region), and 277 events occurred in Broward County. Most of these kills were attributed to low-dissolved oxygen levels.

The St. Johns River Basin which traverses six Florida counties (Brevard, Clay, Duval, Marion, Seminole, and Volusia) was the waterbody for which the most events (29) were reported in this region. This river has a history of over-enrichment problems. The river also receives discharges of irrigation water from surrounding agricultural farms (citrus and sugarcane fields). Over half of the events were caused by low-dissolved oxygen conditions. The Pamlico River, which flows through three North Carolina counties (Beaufort, Hyde, and Pamlico), was another waterbody for which numerous events were reported. Twenty-three fish-kill events were reported for this waterbody between 1981 and 1989. The majority of the reports cited some type of naturally occurring condition as the direct cause such as low-dissolved oxygen levels, disease, bacteria, fungus, and/or changes in salinity.

Florida and North Carolina have set up special programs to monitor these two waterbodies because these coastal waters were under severe environmental stress.

Florida - A Special Case

Florida ranks first in number of events (1,292) and number of fish killed (over 77 million) among states. Several reasons help to explain this. First, the entire state (54,153 sq. mi.) is defined as "coastal" (Bureau of Census, 1988). The state with the second largest area is California (39,575 sq. mi.) (NOAA, 1987).

Second, Florida has a large number of artificial canals, lakes, and impoundments located in and around residential subdivisions. These waters are prone to eutrophication problems. Kills occurring in them are easily observed and frequently reported because of their proximity to the surrounding communities.

Third, the state's high year-round temperatures and extremely high summer temperatures greatly contribute to kills associated with low-dissolved oxygen levels and eutrophication.

State Reporting Programs

Each of the five South Atlantic states uses a different approach when collecting fish-kill data. The discussion below highlights which agencies in each state are involved in fish-kill reporting and when they are most likely to make an on-site investigation of a fish-kill event. Information concerning each state's program organization, investigative procedures, and use of data are summarized in Appendix B.

Virginia (see the Middle Atlantic region).

North Carolina's fish-kill program is primarily covered by three agencies: the Department of Environment, Health, and Natural Resources (responds to all kills to help determine cause); the Department of Crime Control and Public Safety (involved with emergency management and pollution testing); and the Wildlife Commission (deals with surveying kill sites to determine number and species of fish killed, and their economic value). In addition, through a cooperative effort between two divisions (Environmental Management and Marine Fisheries) in the Department of Environment Health and Natural Resources, the Pamlico Estuarine Response Team (PERT) was formed in 1988 to respond to the increasing number of fish-kill events in the Pamilco River/Sound. The Department of Environment, Health, and Natural Resources' Division of Environmental Management provided fish-kill data for this report. It reported that field visits are standard procedure, and they respond more than 75 percent of the time.

South Carolina's fish-kill program is run by two agencies: the Bureau of Solid and Hazardous Waste Management in South Carolina's Department of Health and Environmental Control (SCDHEC); and the Department of Wildlife and Marine Resources. The Department of Wildlife and Marine Resources is primarily concerned with kills occurring in public waters, while the SCDHEC responds and investigates all kills. Only SCDHEC provided fish-kill data for this report. An on-site

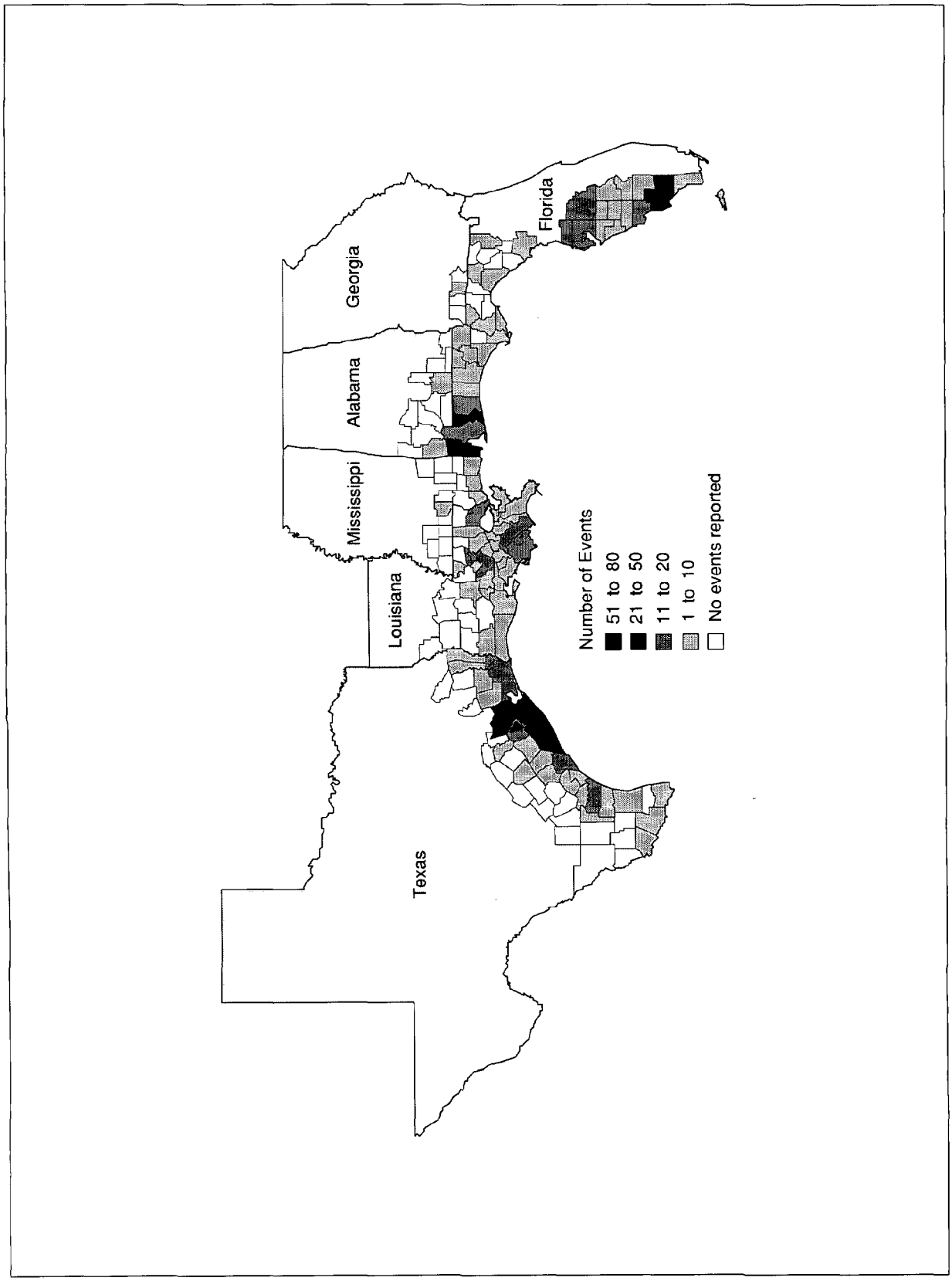
investigation is made when a large number of fish is involved in the kill and/or when the public becomes concerned.

Georgia has three divisions within its Department of Natural Resources that may be involved in the fish-kill investigation process: Environmental Protection (initial contact and response that confirms a fish-kill event); Coastal Resources (investigates marine and coastal water kills); and Game and Fish Division (investigates freshwater events). The Coastal Resource and the Game and Fish Divisions provided fish-kill data for this report. They reported that field visits are standard procedure and that they respond more than 75 percent of the time.

Florida's fish-kill reporting is primarily covered by two agencies: the Department of Environmental Regulation (DER) which consists of a central office and six district offices; and the Game and Freshwater Fish Commission which consists of a central and five regional offices. The central office and one of the district offices of the DER, four of the regional offices of the Game and Freshwater Fish Commission, and the Bioenvironmental Services Division of Duval County all provided fish-kill data for this report. The central DER office reported that field visits are likely to be made when the public becomes concerned.

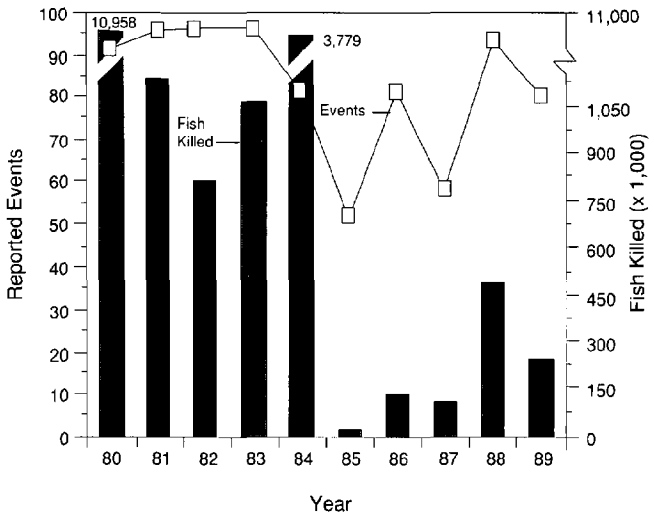
Gulf of Mexico

Figure 22. *Reported Fish-Kill Events by County, 1980-1989*



The Gulf of Mexico had the third highest number of events and the highest number of fish killed among regions. This can be partially explained by the climate and physical features of the estuaries in this region. The number of events reported each year was greatest during the summer months. The greatest number of events occurred in Galveston County, Texas. Low-dissolved oxygen, storm events, and wastewater discharges were the three leading direct causes of fish kills.

Figure 23. *Number of Events and Fish Killed, 1980-1989*



The Data

In this region, 75 percent of the reports included the number of fish killed, 84 percent included the direct cause of the event, 54 percent included the land-use cause, and 50 percent included the type of incident (Appendix A). The Gulf of Mexico had the fourth most complete reporting of the direct cause and number of fish killed among regions. Of the states in this region, Alabama's reporting was the most complete and Louisiana's was the most incomplete.

Fish-Kill Events

Fish-kill events were reported in 100 of the 164 counties in the study area (4 counties in Georgia, 43 in Florida, 14 in Alabama, 17 in Mississippi, 39 in Louisiana, and 47 in Texas) (Figure 22).

This region had the third highest number of reported events (830) and the highest number of fish killed (188,161,000). Texas accounted for almost half of the fish-kill events reported in the region (355), followed by Florida (250); Louisiana (172); Alabama (44); Mississippi (7); and Georgia (2).

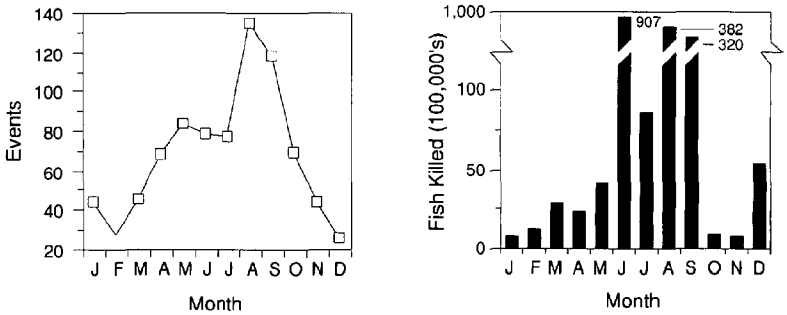
Texas also had the highest number of fish killed in the region, with approximately 159 million or 85 percent of all reported fish killed between 1980 and 1989. Twenty-one events in Texas involved the death of over a million fish. Eight of these occurred in Galveston County and five in Chambers County.

Trends. The number of events reported from 1980 to 1989 does not show any trend (Figure 23). However, an apparent seasonal pattern exists in this region. Most events were reported during May, August, and September (Figure 24). However, the greatest numbers of fish killed were reported in June, August, and September (Figure 24). This seasonal pattern exists across the Nation, with the majority of kills occurring during the summer months.

Sources and Causes

A number of factors may account for the relatively high number of events and fish killed

Figure 24. *Number of Events and Fish Killed by Month, 1980-1989*



in the Gulf of Mexico. This region has the highest percentage of agricultural land, application of fertilizers and pesticides, industrial point sources, and municipal wastewater treatment plants among regions (NOAA, 1990). Estuaries in this region have an average depth of eight feet, the shallowest among regions, which restricts their ability to assimilate the loadings of pollutants mentioned above (NOAA, 1990). These factors, in addition to the hot/humid climate, contribute to waterbodies that are frequently nutrient-enriched and thermally stressed. The result is frequent low-dissolved oxygen levels, particularly in the summer, that can lead to fish kills.

Naturally occurring events dominate the region, with the top two direct causes reported as low-dissolved oxygen levels and wastewater (Figures 25 and 26). In addition, a significant impact is caused by runoff from storm events in urban areas and/or by routine and accidental releases from industrial land uses (Figure 27). These events reflect kills related to impacts from human activities.

In ***Florida***, 219 of the 250 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause reported in 116 of the 219 events. Of the 250 reported events, 109 indicated the *land-use cause* of the kill. Urban land use was the land-use cause in 56 of the 109 events. In only 106 of the 250 events was a land-use cause reported along with a direct cause.

In ***Georgia***, one of the two reported events indicated the *direct cause* of the kill. Wastewater was the direct cause in this event. Both of the reported events indicated the *land-use cause* of the kill. Industrial and urban land use were the land-use causes for these events. A direct cause was associated with a land-use cause in one of the two reported events.

In ***Alabama***, 40 of the 44 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 23 of the 40 events. Sixteen of the 44 reported events indicated the *land-use cause* of the kill. Urban land use was the land-use cause in ten of the 16 events. In only 16 of the 44 reported events was a direct cause linked with a specific land-use cause.

In ***Mississippi***, six of the seven reported events indicated the *direct cause* of the kill. A change in salinity was the direct cause in three of the six events. Five of the seven reported events indicated the *land-use cause* of the kill. Water-related land use was the land-use cause identified in all five of the events. In five of the seven reported events, a land-use cause was reported along with a direct cause.

In ***Louisiana***, 146 of the 172 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause in 63 of the 146 events. Of the 172 reported events, 108 indicated the *land-use cause* of the kill. Impoundments were the land-use cause in 36 of the 108 events. A direct cause was associated with a specific land-use cause in 107 of the 172 reported events.

In ***Texas***, 291 of the 355 reported events indicated the *direct cause* of the kill. Low-

Figure 25. *Number of Fish-Kill Events by Type of Incident**

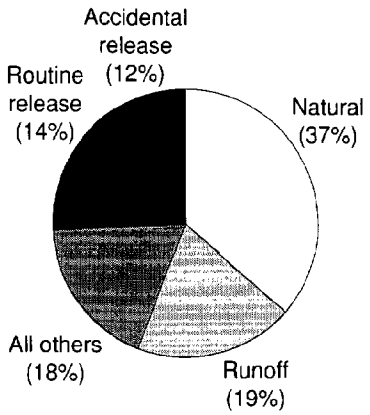


Figure 26. *Number of Fish-Kill Events by Direct Cause**

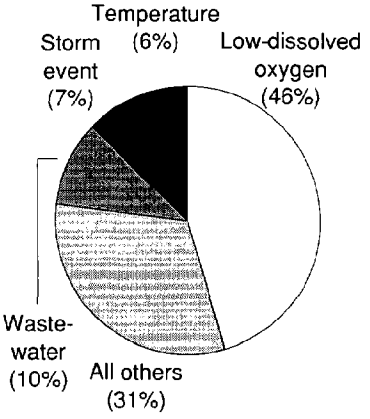
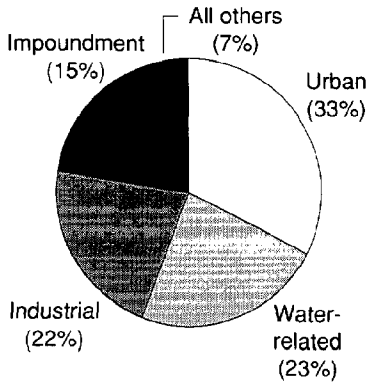


Figure 27. *Number of Fish-Kill Events by Land-Use Cause**



**Does not include information from unspecified events.*

dissolved oxygen was the direct cause in 119 of the 291 events. Of the 355 reported events, 208 indicated the *land-use cause* of the kill. Water-related land use was the land-use cause in 67 of the 208 events. A direct cause was associated with a specific land-use cause in 201 of the 355 reported events.

Data tables containing the number of events and fish killed by county, state, region, year, direct cause, land-use cause, and incident are in Appendix A.

Hotspots and Recurring Kills

Two counties in Texas reported the highest number of fish-kill events for the Gulf of Mexico region: Galveston County (72) and Harris County (66). Galveston County had the highest number of fish killed (almost 106 million) of all the counties in the entire study area. Half of these kills were attributed to low-dissolved oxygen levels that were not associated with a land-use cause.

Galveston Bay was the waterbody for which the most events (28) were reported in this region. Large portions of Brazoria, Chambers, Galveston, Harris, and Liberty counties are in the Galveston Bay estuarine drainage area (EDA). Taken together, these counties contain the highest concentration of point sources in the Nation's coastal area. Fifteen percent of all industrial point sources and municipal wastewater treatment plants in the study area are located in the Galveston Bay EDA. Seventeen of the 28 kills in the Galveston Bay EDA were related to low-dissolved oxygen and temperature. Five of the 17 events were caused by releases of cooling water from power plants.

The only other area in the region where a large number of kills was reported was Collier County in Florida, with 49 events between 1980 and 1989. Most of these kills were due to low-dissolved oxygen and/or excessive nutrient loadings.

State Reporting Programs

Each of the six Gulf of Mexico states uses a different approach when collecting fish-kill data. The discussion below highlights which agencies in each state are involved in fish-kill reporting and when they are most likely to make an on-site investigation of a fish-kill event. Information concerning each state's program organization, investigative procedures, and use of data are summarized in Appendix B.

Florida (see the South Atlantic region).

Georgia (see the South Atlantic region).

Alabama has two agencies that may be involved in the fish-kill investigation process: the Department of Environmental Management (DEM) and the Department of Conservation and Natural Resources. The DEM provided the fish-kill data for this report. Field visits to fish-kill sites are made more than 75 percent of the time.

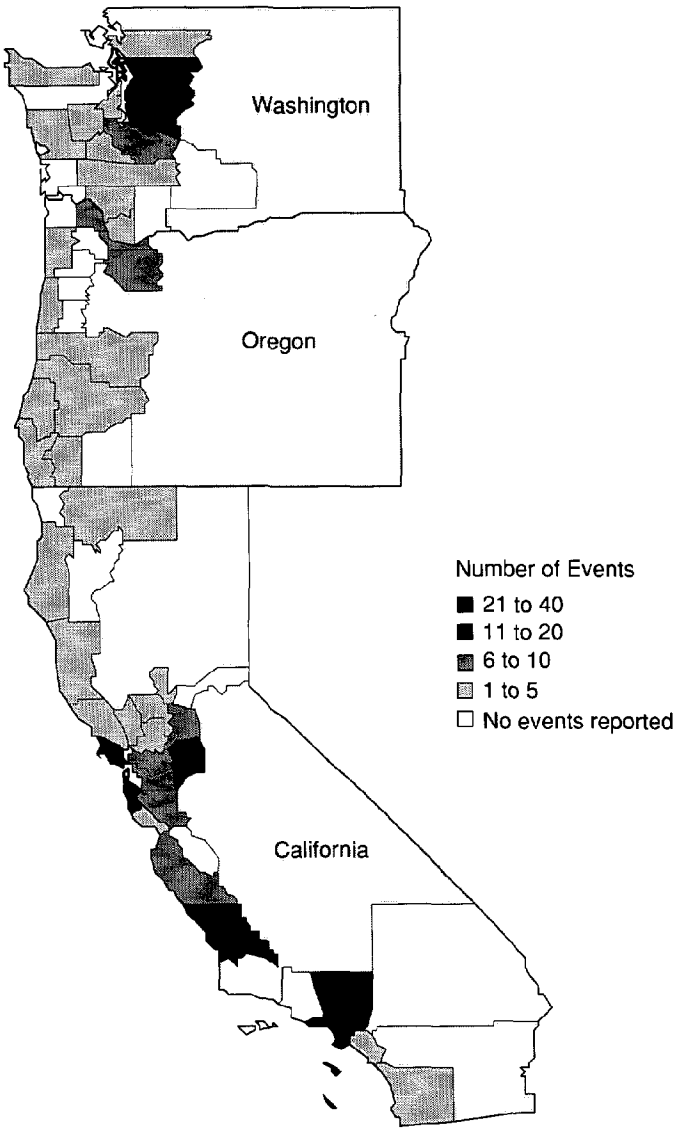
Mississippi has two agencies that may be involved in the fish-kill investigation process: the Department of Environmental Quality (DEQ); and the Department of Wildlife, Fisheries and Parks. The two bureaus within DEQ are Pollution Control (responsible for all state waters) and Marine Resources (may investigate some coastal kills). The Bureau of Pollution Control is the office that provided the fish-kill data for this report. Field visits to fish-kill sites are made more than 75 percent of the time.

Louisiana's fish-kill program is conducted by three agencies: the Department of Environmental Quality (DEQ); the Department of Wildlife and Fisheries (DWF); and the Department of Agriculture. The DWF investigates kills caused by naturally occurring fish diseases, while the DEQ responds to and investigates all kills. DEQ provided the fish-kill data for this report. The DEQ contact indicated that field visits are generally made when an event is reported.

Texas has two different agencies that respond to and document fish kills: the Texas Park and Wildlife Department (TPWD) and the Texas Water Commission (TWC). The TWC has the lead on water-quality problems relating to discharges, while the TPWD responds to, investigates, and is responsible for recovering damages to fish and wildlife for all kills. The TPWD provided statewide fish-kill data for this report. Field visits are likely to be made when: a large number of fish is involved in a kill; the public becomes concerned; personnel are available to respond; a responsible party can be identified; and/or the kill may be related to a particular cause or contaminant.

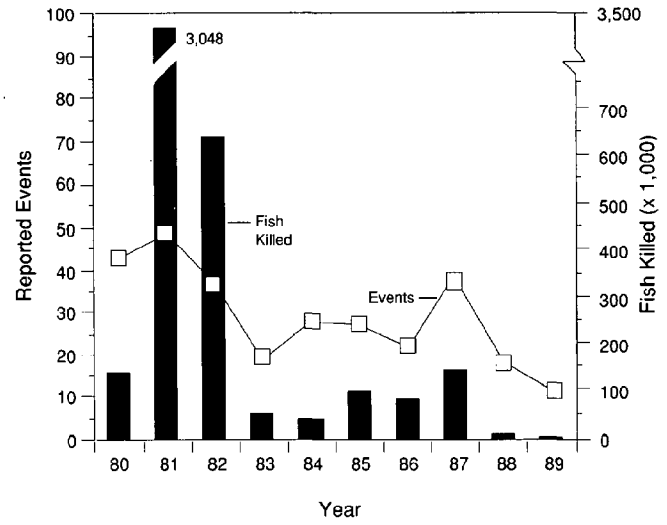
Pacific

Figure 28. *Reported Fish-Kill Events by County, 1980-1989*



The Pacific had the fourth highest number of events and number of fish killed among regions. This can be partially explained by the climate and physical features of the estuaries in this region. The number of events reported each year was greatest during the summer months. The greatest number of events occurred in King County, Washington. Low-dissolved oxygen, pesticides, and animal wastes were the three leading direct causes of fish kills.

Figure 29. *Number of Events and Fish Killed, 1980-1989*



The Data

In this region, 88 percent of the reports included the number of fish killed, 73 percent included the direct cause of the event, 47 percent included the land-use cause, and 39 percent included the type of incident (Appendix A). The Pacific had the third most complete reporting of the direct cause and number of fish killed among regions. Of the states in this region, California's reporting was the most complete and Washington's was the most incomplete.

Fish-Kill Events

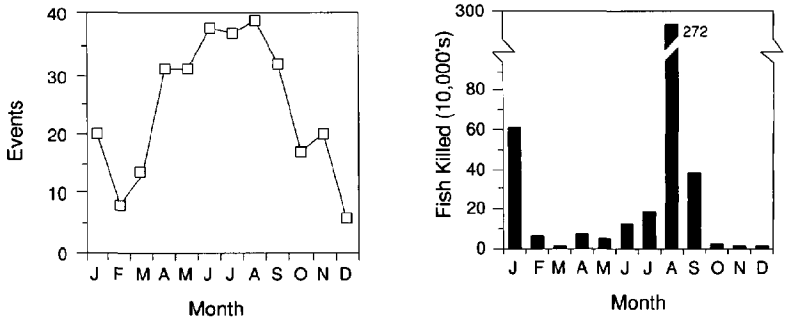
Fish-kill events were reported in 47 of the 64 counties in the study area (29 counties in California, 16 in Oregon, and 19 in Washington) (Figure 28).

This region had the fourth highest number of reported events (293) and fish killed (4,281,100). California accounted for over half of the fish-kill events reported in the region with 148, followed by Washington (105); and Oregon (40).

Washington had the highest number of fish killed in the region, with over 3.3 million or 77 percent of all reported fish killed between 1980 and 1989. Seventy-nine percent of these fish were killed in a single event that occurred in August 1981 in Cultus Bay, located in Island County. The event lasted for one day and was reported as a natural event that occurred in a poorly designed marina. The direct cause cited was low-dissolved oxygen.

Trends. The number of events reported from 1980 to 1989 shows a general downward trend (Figure 29). From 1980 to 1982, at least 37 events occurred each year, with the largest being 49 in 1981. However, from 1983 to 1989, no more than 28 fish-kill events occurred in a single year (except in 1987 when 38 events were reported). In addition, an apparent seasonal pattern also exists in this region. Most events were reported between April and September (Figure 30). However, the greatest numbers of fish killed were reported in January, August, and September. A seasonal pattern exists across the Nation, with the majority of kills occurring during the summer months.

Figure 30. *Number of Events and Fish Killed by Month, 1980-1989*



Sources and Causes

The Pacific region spans the widest geographic and climatic range of the five regions. In California, from San Francisco Bay south, the weather is generally warm and portions of the coast are densely populated. In this area, the prevalent direct cause of kills is low-dissolved oxygen and pesticides which occur in the agricultural drainage canals and freshwater reservoirs in the state. In contrast, Oregon and Washington tend to have more problems with spills and routine releases (e.g., chemicals from industrial plants in Oregon and animal wastes from dairy farms in Washington).

The top two direct causes of fish kills reported for the entire region were low-dissolved oxygen levels and pesticides (Figure 32). Kills related to impacts from human activities dominate the region, such as spills and routine or accidental releases occurring in agricultural, urban, and industrial land-use areas (Figures 31 and 33). In addition, almost a quarter of the events in the region is related to naturally occurring events (Figure 31).

In ***California,*** 110 of the 148 reported events indicated the *direct cause* of the kill. Low-dissolved oxygen was the direct cause reported in 25 of the 110 events. Forty-four of the 148 reported events indicated the *land-use cause* of the kill. Impoundments were the land-use cause in 13 of the 44 events. In only 44 of the 148 events was a land-use cause reported along with a direct cause.

In ***Oregon***, 29 of the 40 reported events indicated the *direct cause* of the kill. An assortment of chemicals/metals (i.e., organic chemicals, inorganic chemicals/metals, and mixed chemicals) was the direct cause in 13 of the 29 events. Twenty-four of the 40 reported events indicated the *land-use cause* of the kill. Industrial land use was the land-use cause in 13 of the 24 events. A direct cause was associated with a land-use cause in 22 of the 40 reported events.

In ***Washington,*** 76 of the 105 reported events indicated the *direct cause* of the kill. Animal waste was the direct cause in 21 of the 76 events. Sixty-nine of the 105 reported events indicated the *land-use cause* of the kill. Agricultural land use was the land-use cause in 26 of the 69 events. In 64 of the 105 reported events, a direct cause was linked with a specific land-use cause.

Data tables containing the number of events and fish killed by county, state, region, year, direct cause, land-use cause, and incident are in Appendix A.

Hotspots and Recurring Kills

King County (39 events) in Washington and San Joaquin County (27 events) in California reported the highest number of fish-kill events in the region. The kills in King County were attributed to a variety of direct causes and land-use causes with no single type of event being dominant. However, the most frequently cited direct cause was chlorine that had been routinely released from an urban land-use area (e.g., water

Figure 31. *Number of Fish-Kill Events by Type of Incident**

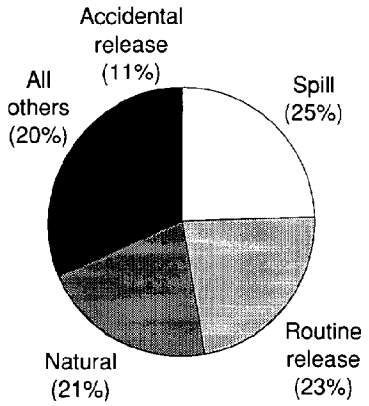


Figure 32. *Number of Fish-Kill Events by Direct Cause**

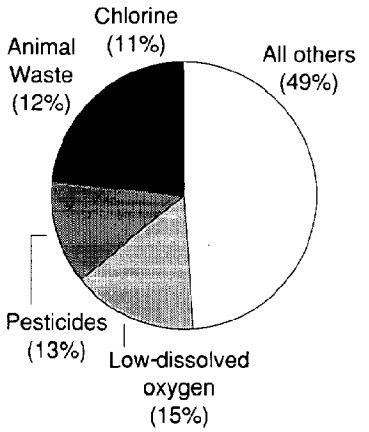
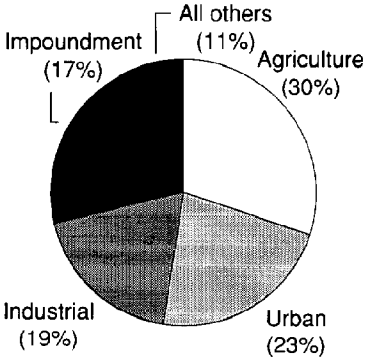


Figure 33. *Number of Fish-Kill Events by Land-Use Cause**



**Does not include information from unspecified events.*

treatment facility, construction site, water pipeline, and chlorinated wells). In contrast, the majority of the kills in San Joaquin County did not have a direct cause or an associated land-use cause. Eight of the 27 events reported low-dissolved oxygen levels as the direct cause of the event.

Johnson Creek, located in Oregon's Clackamas and Multnomah counties, was the waterbody for which the most events (9) were reported in this region. This creek is a tributary of the Willamette River. Twenty-five percent of all the fish killed in Oregon were killed in this creek. The majority of the events cited the direct cause as a mixture of chemicals from unspecified sources. Whatcom Creek in Whatcom County, Washington, was another waterbody for which numerous events (5) were reported between 1981 and 1989. Most of the records for these events did not contain information on the associated land-use cause. However, pesticides were cited as the direct cause in three of the events.

State Reporting Programs

Each of the three Pacific states uses a different approach when collecting fish-kill data. The discussion below highlights which agencies in each state are involved in fish-kill reporting and when they are most likely to make an on-site investigation of a fish-kill event. Information concerning each state's program organization, investigative procedures, and use of data are summarized in Appendix B.

California has two divisions (Marine Resources and Inland Fisheries) under the Department of Fish and Game (DFG) that investigate and document fish kills. DFG's Environmental Services Division (the central clearinghouse for California's fish-kill records) provided fish-kill data for this report. The Environmental Services contact indicated that field visits are generally standard procedure when an event is reported.

Oregon has two agencies that may be involved in the fish-kill investigation process: the Department of Environmental Quality (DEQ) and the Department of Fish and Wildlife (DFW). The DEQ is specifically interested in kills caused by pollution, while the DFW responds to all kills. Both agencies provided fish-kill data for this report. Field visits are more likely to be made when a large number of fish is involved in a kill.

Washington's program is conducted by the Department of Ecology. It provided fish-kill data for this project and reported that field visits to fish-kill sites are made more than 75 percent of the time.

Concluding Comments

Fish-kill reporting programs provide an incomplete picture of the Nation's fish-kill problems. Even so, they indicate that fish kills have not been a pervasive problem in the Nation's estuarine and coastal areas. Taken together, the data generated by these State and local programs also provide a basis for quantifying and understanding certain aspects of fish kills. Several conclusions regarding the uses and limitations of these data are important to note.

Compiling State Data is Difficult. Although all 22 coastal states maintain some form of fish-kill reporting program, data compilation is difficult. Reporting responsibilities within most states are often shared by several agencies. Consequently, data are in varied formats and gaps occur in some states as a result of lapses in State programs or data lost during the transfer of program responsibilities. The analysis problem is further compounded because no Federal agency or national organization maintains a comprehensive and up-to-date data base for the Nation.

Data Content Varies Among States. There is a wide variation in organization, level of activity, priorities, investigative procedures, documentation requirements, and reporting formats among states. As a result, the data content of the information characterizing fish kills varies from state to state. This lack of consistency in data content makes it difficult to reconcile differences in state-to-state and regional comparisons.

Little Evidence of Impacts on Fish Populations. Fish kills in coastal waters do not appear to occur with sufficient frequency or involve enough fish to pose a significant threat to fish populations in most areas. None of the State programs surveyed indicated population impacts resulting from fish kills. Even if the estimates reported are doubled to account for incomplete reporting, the number of fish killed is still relatively small compared to estimates of existing populations in most areas.

Assessing Trends is Difficult. Although the number of events in coastal areas has increased over the past decade, the number of fish killed has decreased. The cause of these apparent trends is not clear. The rise in the number of events may indicate a decline in water quality during this period, or reflect an increased emphasis on reporting. Because the data are incomplete and lack uniformity, conclusive statements at the national or regional level cannot be made. However, a recurring seasonal pattern appears in all states, indicating most events take place during the summer, from May to September.

Hotspots Can Sometimes be Targeted. Fish-kill data are most frequently used by State agencies to identify areas experiencing acute environmental stress. Ideally, the agency uses the data to quickly determine the source of the stress and correct the problem. However, repeat kills may sometimes occur before action is taken. The fish kills in Mattanawcook Stream in Maine are a good example of how fish-kill data were used to identify and correct a discharge problem from a single source (page 11). In other cases, fish-kill events have lead to a more in-depth investigation of water-quality problems. The Pamlico Estuarine Response Team (PERT), formed in North Carolina, is an example of how fish-kill data have been used to target an area experiencing ongoing water-quality problems (page 21).

Low-Dissolved Oxygen Causes Most Kills. Low-dissolved oxygen was reported as the direct cause of a kill in 41 percent of the cases reporting cause. Although spills or accidental releases from point sources still occur, the majority of human-induced kills is now attributed to runoff from various nonpoint sources. Conversations with State fish-kill officials indicate that kills caused by pollutants from point sources (industries and wastewater treatment plants) have been reduced in the last 10 to15 years due to improvements in treatment. They also noted a decrease in kills associated with compounds such as DDT and other chlorinated pesticides that are now used less frequently or are banned entirely.

References

Bureau of the Census. 1988. *County and City Data Book (1988).* U.S. Department of Commerce, Washington, D.C. p. 68

Environmental Law Institute. 1988. *Clean Water Deskbook.* Washington, D.C. p. 77

Hinga, K.R., D.W. Stanley, C.J. Klein, D.T. Lucid, and M.J. Katz (eds). 1991. *The National Estuarine Eutrophication Project: Workshop Proceedings.* Rockville, MD: National Oceanic and Atmospheric Administration and the University of Rhode Island Graduate School of Oceanography. 41 pp.

NOAA. 1987. *National Estuarine Inventory: Data Atlas, Volume 2: Land-Use Characteristics.* Rockville, MD: National Oceanic and Atmospheric Administration. 40 pp.

NOAA. 1990. *Estuaries of the United States: Vital Statistics of a National Resource Base.* Strategic Assessment Branch, Rockville, MD. 79 pp.

Pait, A. S., A. DeSouza, and D.R.G. Farrow. 1991. *Agricultural Pesticides in Coastal Areas: A National Summary.* Rockville, MD: National Oceanic and Atmospheric Administration. (In preparation)

Personal Communications

Federal Agencies

Farrow, D.; Strategic Environmental Assessments Division, National Oceanic and Atmospheric Administration, Rockville, MD (p. 1, para 7)

Harllee, N.; Monitoring and Data Support Division; Office of Water Enforcement and Permits; U.S. Environmental Protection Agency; Washington, D.C. (see Acknowledgements and EPA Fish-Kill Data Base, p. 2)

State Agencies

Alabama

Williford, E. J.; Alabama's Department of Environmental Management; Montgomery, AL. (p. 27)

California

Fransen, H.R.; Environmental Services Division; California's Department of Fish and Game; Rancho Cordova, CA. (p. 31)

Connecticut

Jacobson, R. A.; Water Management and Fisheries Division; Connecticut's Department of Environmental Protection; Hartford, CT. (p. 16)

Delaware

Miller, R. W.; Division of Fish and Wildlife; Delaware's Department of Natural Resources and Environmental Control; Dover, DE. (p. 16)

Florida

Champeau, T.; South Region, Florida's Game and Freshwater Fish Commission; Lakeland, FL. (p. 22)

Krummrich, J.; Northeast Region, Florida's Game and Freshwater Fish Commission; Lake City, FL. (p. 22)

McKinney, S.; Central Region, Florida's Game and Freshwater Fish Commission; Ocala, FL. (p. 22)

Morton, R. D.; Bioenvironmental Services Division, Duval County; Jacksonville, FL. (p. 22)

Olsen, L. A.; Florida's Department of Environmental Regulation; Tallahassee, FL. (p. 22)

Romeis, G.; South District Office, Florida's Department of Environmental Regulation; Fort Myer, FL. (p. 22)

Ross, Landon; Florida's Department of Environmental Regulation; Tallahassee, FL. (see Hot-Spots and Recurring Kills, p. 22)

Walton, A. S.; South District Office; Florida's Department of Environmental Regulation; Punta Gorda, FL. (p. 22)

Young, N.; Northwest Region, Florida's Game and Freshwater Fish Commission; DeFuniak Springs, FL. (p. 22)

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Coomer, C. Jr.; Fisheries Section; Game and Fish Division; Georgia's Department of Natural Resources; Atlanta, GA. (p. 22)

Shipman, S.; Coastal Resources Division; Georgia's Department of Natural Resources; Brunswick, GA. (p. 22)

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Albritton, R.; Louisiana's Department of Environmental Quality; Baton Rogue, LA. (p. 27)

Maine

Courtmanch, D.; Maine's Department of Environmental Protection; Augusta, ME. (see Maine, and Hot-Spots and Recurring Kills, p. 11)

Maryland

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Fiske, J. D.; Division of Marine Fisheries; Massachusetts' Department of Fisheries, Wildlife, and Environmental Law Enforcement; Sandwich, MA. (p. 11)

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Adams, C.; Bureau of Solid and Hazardous Waste Management; South Carolina's Department of Health and Environmental Control; Columbia, SC. (p. 21)

Kinney, R.; Waste Assessment and Emergency Response; Bureau of Solid and Hazardous Waste Management; South Carolina's Department of Health and Environmental Control; Columbia, SC. (p. 21)

Texas

Palafox, D.; Resource Protection Division; Texas Parks and Wildlife Department; Austin, TX. (p. 27)

Palma, V.; Resource Protection Division; Texas Parks and Wildlife Department; Austin, TX. (p. 27)

Virginia

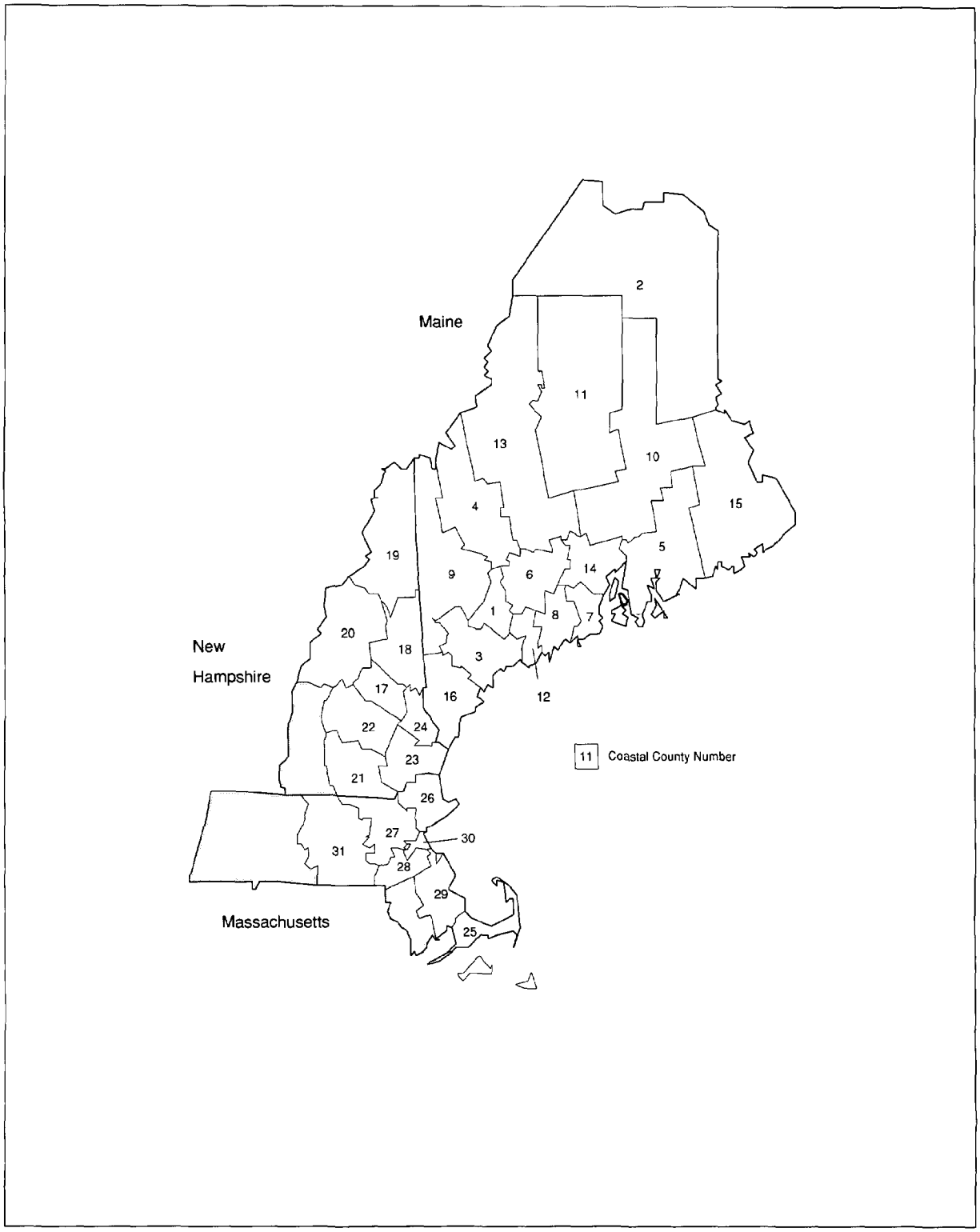
Sykes, M.A.; Pollution Remediation Program; Virginia Water Control Board; Richmond, VA. (p. 16)

Washington

LeVander, L.; Northwest Regional Office; Washington's Department of Ecology; Redmond, WA. (p. 31)

Kittle, L.; Central Office; Washington's Department of Ecology; Olympia, WA. (p. 31)

Appendix A - *North Atlantic*



Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Maine					
1 Androscoggin	3	80	100	100	0
2 Aroostook	*ND*	*ND*	*ND*	*ND*	*ND*
3 Cumberland	1	2	100	100	0
4 Franklin	1	1	100	100	0
5 Hancock	*ND*	*ND*	*ND*	*ND*	*ND*
6 Kennebec	*ND*	*ND*	*ND*	*ND*	*ND*
7 Knox	*ND*	*ND*	*ND*	*ND*	*ND*
8 Lincoln	*ND*	*ND*	*ND*	*ND*	*ND*
9 Oxford	2	1,005	50	100	0
10 Penobscot	13	31	92	100	0
11 Piscataquis	*ND*	*ND*	*ND*	*ND*	*ND*
12 Sagadahoc	3	460	100	100	0
13 Somerset	2	4	100	100	0
14 Waldo	*ND*	*ND*	*ND*	*ND*	*ND*
15 Washington	2	45	100	100	0
16 York	1	*NR*	0	100	0
Subtotal	**28**	**1,628**	**90**	**100**	**0**
New Hampshire					
17 Belknap	1	1	100	100	0
18 Carroll	*ND*	*ND*	*ND*	*ND*	*ND*
19 Coos	*ND*	*ND*	*ND*	*ND*	*ND*
20 Grafton	*ND*	*ND*	*ND*	*ND*	*ND*
21 Hillsborough	*ND*	*ND*	*ND*	*ND*	*ND*
22 Merrimack	*ND*	*ND*	*ND*	*ND*	*ND*
23 Rockingham	*ND*	*ND*	*ND*	*ND*	*ND*
24 Strafford	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**1**	**1**	**100**	**100**	**0**
Massachusetts					
25 Barnstable	10	39,207	90	70	1
26 Essex	*ND*	*ND*	*ND*	*ND*	*ND*
27 Middlesex	2	4	100	50	0
28 Norfolk	3	23	100	67	0
29 Plymouth	3	34	100	67	0
30 Suffolk	*ND*	*ND*	*ND*	*ND*	*ND*
31 Worcester	1	6	100	0	0
Subtotal	**19**	**39,273**	**95**	**51**	**1**
Total	**48**	**40,903**	**92**	**84**	1
National Total	**3,654**	**4,071,630**	**84**	**79**	**86**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.

Appendix A

Fish-Kill Events by Year, 1980-1989

	Maine		New Hampshire		Massachusetts[a]		Total	
Year	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
1980	2	1,030	1	1	2	19	**5**	**1,050**
1981	1	20	0	0	4	39	**5**	**59**
1982	2	6	0	0	0	0	**2**	**6**
1983	6	76	0	0	1	39,119	**7**	**39,195**
1984	2	310	0	0	1	3	**3**	**313**
1985	3	107	0	0	5	82	**8**	**189**
1986	3	12	0	0	0	0	**3**	**12**
1987	2	2	0	0	2	2	**4**	**4**
1988	6	62	0	0	2	2	**8**	**64**
1989	1	3	0	0	2	8	**3**	**10**
Total	**28**	**1,628**	**1**	**1**	**19**	**39,273**	**48**	**40,903**

Fish-Kill Events by Direct Cause, 1980-1989

	Maine		New Hampshire		Massachusetts[a]		Total	
Direct Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Low D. O.	5	488	0	0	4	39,126	**9**	**39,614**
Temperature	1	2	0	0	1	3	**2**	**5**
Sedimentation	0	0	0	0	0	0	**0**	**0**
Eutrophication	0	0	0	0	0	0	**0**	**0**
Disease	0	0	0	0	1	1	**1**	**1**
Stranding	2	6	0	0	1	3	**3**	**9**
Storm Event	1	*NR*	0	0	0	0	**1**	***NR***
Wastewater	9	1,019	0	0	3	17	**12**	**1,036**
Animal Waste	0	0	0	0	0	0	**0**	**0**
pH	4	6	0	0	0	0	**4**	**6**
Organic Chemicals	2	21	0	0	0	0	**2**	**21**
Inorganic Chemicals/Metals	2	70	1	1	0	0	3	**71**
Mixed Chemicals	1	7	0	0	0	0	**1**	**7**
Pesticides	0	0	0	0	2	45	**2**	**45**
Nutrients	0	0	0	0	0	0	**0**	**0**
Salinity Changes	0	0	0	0	0	0	**0**	**0**
Petroleum	1	10	0	0	0	0	**1**	**10**
Chlorine	0	0	0	0	0	0	**0**	**0**
Red Tide	0	0	0	0	0	0	**0**	**0**
Predation	0	0	0	0	0	0	**0**	**0**
Unspecified	0	0	0	0	7	79	**7**	**79**
Total	**28**	**1,628**	**1**	**1**	**19**	**39,273**	**48**	**40,903**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported; Low D.O., low-dissolved oxygen.
a. Not all counties in state included; state is split between regions.

Fish-Kill Events by Land-Use Cause, 1980-1989

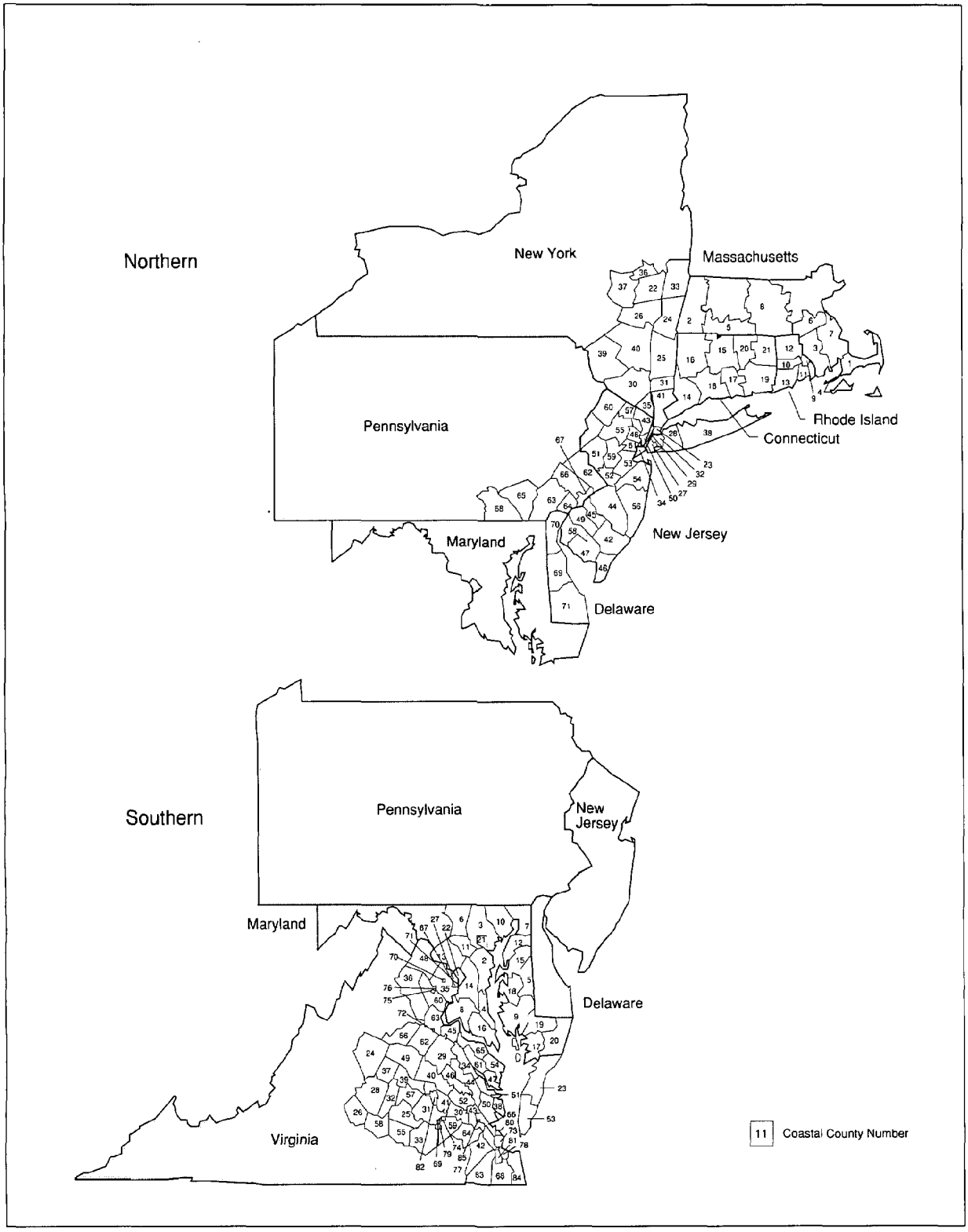
	Maine		New Hampshire		Massachusetts [a]		Total	
Land-Use Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Agriculture	1	*NR*	0	0	6	79	**7**	**79**
Industrial	19	1,147	0	0	0	0	**19**	**1,147**
Urban	1	5	1	1	1	3	**3**	**9**
Impoundment	1	1	0	0	0	0	**1**	**1**
Water-Related	3	460	0	0	4	8	**7**	**468**
Silviculture	0	0	0	0	0	0	**0**	**0**
Wildland	0	0	0	0	0	0	**0**	**0**
Mining	0	0	0	0	0	0	**0**	**0**
Military	0	0	0	0	0	0	**0**	**0**
Unspecified	3	15	0	0	8	39,183	**11**	**39,198**
Total	**28**	**1,628**	**1**	**1**	**19**	**39,273**	**48**	**40,903**

Fish-Kill Events by Incident, 1980-1989

	Maine		New Hampshire		Massachusetts [a]		Total	
Incident	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Runoff	1	*NR*	1	1	1	30	**3**	**31**
Routine Release	9	1,021	0	0	2	4	**11**	**1,025**
Accidental Release	1	*NR*	0	0	0	0	**1**	***NR***
Spill	3	32	0	0	1	13	**4**	**45**
Spraying	0	0	0	0	1	15	**1**	**15**
Natural	3	460	0	0	5	39,127	**8**	**39,587**
Drawdown	3	9	0	0	1	3	**4**	**12**
Dredging or Drilling	0	0	0	0	0	0	**0**	**0**
Unspecified	8	107	0	0	8	82	**16**	**189**
Total	**28**	**1,628**	**1**	**1**	**19**	**39,273**	**48**	**40,903**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.
a. Not all counties in state included; state is split between regions.

Appendix A - *Middle Atlantic*



Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Middle Atlantic (Northern)					
Massachusetts					
1 Barnstable	*Data found in the North Atlantic region.*				
2 Berkshire	1	<1	100	0	0
3 Bristol	5	232	100	60	0
4 Dukes	*ND*	*ND*	*ND*	*ND*	*ND*
5 Hampden	2	126	100	100	0
* Nantucket	*ND*	*ND*	*ND*	*ND*	*ND*
6 Norfolk	*Data found in the North Atlantic region.*				
7 Plymouth	*Data found in the North Atlantic region.*				
8 Worcester	*Data found in the North Atlantic region.*				
Subtotal	**8**	**358**	**100**	**63**	**0**
Rhode Island					
9 Bristol	*ND*	*ND*	*ND*	*ND*	*ND*
10 Kent	6	46	100	83	0
11 Newport	2	22	50	50	0
12 Providence	7	17	71	71	0
13 Washington	3	52	100	67	0
Subtotal	**18**	**136**	**83**	**72**	**0**
Connecticut					
14 Fairfield	8	1,337	88	75	0
15 Hartford	11	23	82	82	0
16 Litchfield	4	27	100	75	0
17 Middlesex	8	161	100	63	0
18 New Haven	9	1,100	100	78	0
19 New London	11	143	91	73	0
20 Tolland	2	2	100	100	0
21 Windham	2	1	100	100	0
Subtotal	**55**	**2,794**	**93**	**76**	**0**
New York					
22 Albany	8	549	75	63	0
23 Bronx	2	20,000	100	100	2
24 Columbia	11	229	73	91	0
25 Dutchess	11	11	100	91	0
26 Greene	11	45	73	73	0
27 Kings	*ND*	*ND*	*ND*	*ND*	*ND*
28 Nassau	1	*NR*	0	100	0
29 New York	*ND*	*ND*	*ND*	*ND*	*ND*
30 Orange	28	208	93	75	0
31 Putnam	11	59	100	82	0
32 Queens	1	20	100	100	0
33 Rensselaer	17	11,635	76	65	1
34 Richmond	2	100	100	100	0
35 Rockland	9	30	78	67	0
36 Schenectady	*ND*	*ND*	*ND*	*ND*	*ND*

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Middle Atlantic (Northern)					
New York (cont.)					
37 Schoharie	1	<1	100	100	0
38 Suffolk	7	38	100	57	0
39 Sullivan	*ND*	*ND*	*ND*	*ND*	*ND*
40 Ulster	14	136	100	79	0
41 Westchester	17	82	94	82	0
Subtotal	**151**	**33,142**	**88**	**77**	**3**
New Jersey					
42 Atlantic	*ND*	*ND*	*ND*	*ND*	*ND*
43 Bergen	10	*NR*	0	80	0
44 Burlington	8	*NR*	0	75	0
45 Camden	3	*NR*	0	67	0
46 Cape May	*ND*	*ND*	*ND*	*ND*	*ND*
47 Cumberland	1	*NR*	0	0	0
48 Essex	3	<1	33	33	0
49 Gloucester	9	*NR*	0	67	0
50 Hudson	2	*NR*	0	0	0
51 Hunterdon	3	*NR*	0	67	0
52 Mercer	6	2	17	33	0
53 Middlesex	11	101	9	73	0
54 Monmouth	13	*NR*	0	46	0
55 Morris	11	<1	9	55	0
56 Ocean	4	*NR*	0	50	0
57 Passaic	6	*NR*	0	50	0
58 Salem	5	*NR*	0	60	0
59 Somerset	9	*NR*	0	44	0
60 Sussex	3	*NR*	0	0	0
61 Union	5	*NR*	0	100	0
Subtotal	**112**	**103**	**4**	**57**	**0**
Pennsylvania					
62 Bucks	3	22	100	67	0
63 Chester	8	144	100	75	0
64 Delaware	3	36	67	67	0
65 Lancaster	*ND*	*ND*	*ND*	*ND*	*ND*
66 Montgomery	1	<1	100	0	0
67 Philadelphia	1	5	100	0	0
68 York	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**16**	**207**	**94**	**63**	**0**
Delaware					
69 Kent	46	236,781	98	53	3
70 New Castle	38	396	100	54	0
71 Sussex	36	43,056	97	70	3
Subtotal	**120**	**280,233**	**98**	**58**	**6**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.

Fish-Kill Events by County,1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Middle Atlantic (Southern)					
Maryland					
2 Anne Arundel	182	359,847	66	82	8
3 Baltimore	47	14,340	91	60	1
4 Calvert	17	27,715	88	76	1
5 Caroline	3	11	100	33	0
6 Carroll	7	30	100	71	0
7 Cecil	18	231	67	33	0
8 Charles	14	10,061	86	36	1
9 Dorchester	15	18,852	73	93	1
10 Harford	21	1,382	76	90	0
11 Howard	4	6	75	75	0
12 Kent	7	1,522	71	57	0
13 Montgomery	4	7	75	50	0
14 Prince George's	9	222	67	33	0
15 Queen Anne's	14	111	71	64	0
16 St. Mary's	28	23,727	86	82	2
17 Somerset	7	39	86	43	0
18 Talbot	14	17,674	93	86	1
19 Wicomico	13	203,252	85	77	5
20 Worcester	1	100	100	100	0
21 Baltimore City	23	179	65	78	0
22 District of Columbia	7	5,520	71	71	0
Subtotal	**455**	**684,828**	**75**	**73**	**20**
Virginia					
23 Accomack	2	2	50	0	0
24 Albemarle	*ND*	*ND*	*ND*	*ND*	*ND*
25 Amelia	*ND*	*ND*	*ND*	*ND*	*ND*
26 Appomattox	1	*NR*	0	0	0
27 Arlington	3	15	100	67	0
28 Buckingham	*ND*	*ND*	*ND*	*ND*	*ND*
29 Caroline	2	428	100	100	0
30 Charles City	1	1	100	0	0
31 Chesterfield	5	42	100	60	0
32 Cumberland	*ND*	*ND*	*ND*	*ND*	*ND*
33 Dinwiddie	*ND*	*ND*	*ND*	*ND*	*ND*
34 Essex	*ND*	*ND*	*ND*	*ND*	*ND*
35 Fairfax	8	48	100	88	0
36 Fauquier	2	<1	50	50	0
37 Fluvanna	1	<1	100	100	0
38 Gloucester	1	1,000	100	0	0
39 Goochland	*ND*	*ND*	*ND*	*ND*	*ND*
40 Hanover	*ND*	*ND*	*ND*	*ND*	*ND*
41 Henrico	5	24	100	100	0
42 Isle of Wight	*ND*	*ND*	*ND*	*ND*	*ND*
43 James City	2	60	100	100	0
44 King and Queen	*ND*	*ND*	*ND*	*ND*	*ND*

Abbreviations: *NR*, number of fish killed not reported; *ND*, no data was received.

Fish-Kill Events by County,1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Middle Atlantic (Southern)					
Virginia (cont.)					
45 King George	*ND*	*ND*	*ND*	*ND*	*ND*
46 King William	*ND*	*ND*	*ND*	*ND*	*ND*
47 Lancaster	3	126,400	67	0	2
48 Loudoun	1	2	100	100	0
49 Louisa	1	1	100	100	0
50 Mathews	1	4	100	0	0
51 Middlesex	2	20	50	0	0
52 New Kent	1	<1	100	0	0
53 Northampton	*ND*	*ND*	*ND*	*ND*	*ND*
54 Northumberland	4	11,052	100	50	1
55 Nottoway	*ND*	*ND*	*ND*	*ND*	*ND*
56 Orange	*ND*	*ND*	*ND*	*ND*	*ND*
57 Powhatan	*ND*	*ND*	*ND*	*ND*	*ND*
58 Prince Edward	*ND*	*ND*	*ND*	*ND*	*ND*
59 Prince George	3	20	100	67	0
60 Prince William	4	46	100	100	0
61 Richmond	2	23	100	50	0
62 Spotsylvania	*ND*	*ND*	*ND*	*ND*	*ND*
63 Stafford	2	1	100	50	0
64 Surry	*ND*	*ND*	*ND*	*ND*	*ND*
65 Westmoreland	4	70	75	25	0
66 York	3	10,015	100	33	1
Virginia (Independent Cities)					
67 Alexandria	3	21	100	33	0
68 Chesapeake	*Data found in the South Atlantic region.*				
69 Colonial Heights	1	1,503	100	100	0
70 Fairfax	*ND*	*ND*	*ND*	*ND*	*ND*
71 Falls Church	*ND*	*ND*	*ND*	*ND*	*ND*
72 Fredericksburg	*ND*	*ND*	*ND*	*ND*	*ND*
73 Hampton	2	22	100	50	0
74 Hopewell	8	201	88	75	0
75 Manassas	*ND*	*ND*	*ND*	*ND*	*ND*
76 Manassas Park	*ND*	*ND*	*ND*	*ND*	*ND*
77 Newport News	2	22	100	50	0
78 Norfolk	6	35	100	83	0
79 Petersburg	2	<1	50	50	0
80 Poquoson	2	503	100	50	0
81 Portsmouth	5	8	80	80	0
82 Richmond	3	*NR*	0	67	0
* Southampton	*Data found in the South Atlantic region.*				
83 Suffolk	*Data found in the South Atlantic region.*				
84 Virginia Beach	*Data found in the South Atlantic region.*				
85 Williamsburg	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**98**	**151,591**	**88**	**61**	**4**
Middle AtlanticTotal	**1,033**	**1,153,392**	**65**	**69**	**33**
National Total	**3,654**	**4,071,630**	**84**	**79**	**86**

Abbreviations: *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Fish-Kill Events by Year, 1980-1989

	Massa-chusetts [a]		Rhode Island		Connect-icut		New York		New Jersey		Pennsyl-vania		Delaware		Maryland [b]		Virginia [a]		Total	
Year	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
1980	1	1	1	*NR*	5	19	4	1,555	5	*NR*	6	54	16	5,587	20	250,242	23	2,084	**81**	**259,542**
1981	0	0	2	2	5	9	3	10,000	7	2	4	132	12	10,725	22	142,184	20	117,564	**75**	**280,617**
1982	0	0	1	2	2	4	0	0	0	0	3	4	4	11	28	106	8	20,019	**46**	**20,145**
1983	1	190	0	0	4	12	12	149	0	0	0	0	20	37,556	0	0	5	4	**42**	**37,912**
1984	0	0	2	40	6	37	16	203	0	0	0	0	6	16	14	13,743	7	10,005	**51**	**24,043**
1985	0	0	0	0	9	162	24	222	0	0	1	5	11	5,053	53	35,573	4	87	**102**	**41,101**
1986	1	30	1	*NR*	7	1,028	22	131	10	101	0	0	13	70	103	216,255	12	67	**169**	**217,682**
1987	2	10	1	20	11	1,304	19	71	28	*NR*	2	12	15	1,333	77	9,505	6	1,550	**161**	**13,806**
1988	2	2	3	15	5	217	21	20,438	36	1	0	0	16	218,871	86	13,260	8	86	**177**	**252,889**
1989	1	125	7	57	1	4	30	372	26	<1	0	0	7	1,012	52	3,961	5	125	**129**	**5,656**
Total	**8**	**358**	**18**	**136**	**55**	**2,794**	**151**	**33,142**	**112**	**103**	**16**	**207**	**120**	**280,233**	**455**	**684,828**	**98**	**151,591**	**1,033**	**1,153,392**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.

a. Not all counties in state included; state is split between regions.

b. Maryland totals include the District of Columbia.

Fish-Kill Events by Direct Cause, 1980-1989

	Massa-chusetts[a]		Rhode Island		Connect-icut		New York		New Jersey		Pennsyl-vania		Delaware		Maryland[b]		Virginia[a]		Total	
Direct Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Low D. O.	2	12	9	69	9	2,441	18	20,110	8	1	0	0	36	278,045	200	252,165	12	50	**294**	**552,892**
Temperature	0	0	0	0	2	9	10	77	1	*NR*	0	0	9	350	5	246,953	11	212	**38**	**247,601**
Sedimentation	0	0	0	0	0	0	0	0	3	*NR*	0	0	1	1,001	3	11	0	0	**7**	**1,011**
Eutrophication	0	0	1	2	0	0	1	1	4	*NR*	0	0	0	0	0	0	1	10,000	**7**	**10,003**
Disease	0	0	0	0	4	91	15	24	3	*NR*	0	0	2	16	63	4500	0	0	**87**	**4,631**
Stranding	0	0	0	0	0	0	4	129	0	0	0	0	1	5	11	155,758	3	<1	**19**	**155,892**
Storm Event	0	0	0	0	0	0	1	170	0	0	0	0	0	0	10	6,135	1	10	**12**	**6,315**
Wastewater	1	<1	1	2	2	1	10	46	8	*NR*	3	14	4	24	14	5,641	3	11,003	**46**	**16,732**
Animal Waste	0	0	0	0	1	<1	4	287	1	*NR*	0	0	0	0	5	1,016	0	0	**11**	**1,303**
pH	0	0	0	0	0	0	3	36	2	*NR*	0	0	1	<1	1	10	2	2	**9**	**48**
Organic Chemicals	0	0	0	0	0	0	0	0	4	101	0	0	1	<1	1	86	2	40	**8**	**227**
Inorganic Chemicals/Metals	0	0	2	3	8	65	11	167	3	*NR*	0	0	4	3	4	211	5	11	**37**	**461**
Mixed Chemicals	2	126	0	0	6	11	0	0	4	*NR*	1	12	3	201	2	41	1	1	**19**	**392**
Pesticides	0	0	0	0	3	2	8	75	9	*NR*	3	122	4	59	3	<1	4	1,522	**34**	**1,779**
Nutrients	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**6**
Salinity Changes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Petroleum	0	0	0	0	2	6	12	135	8	*NR*	1	1	4	14	1	10	7	501	**35**	**668**
Chlorine	0	0	0	0	4	4	16	139	6	*NR*	2	26	2	1	9	211	6	16	**45**	**396**
Red Tide	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	1	20	**3**	**24**
Predation	0	0	0	0	0	0	1	<1	0	0	0	0	0	0	1	*NR*	1	6	**3**	**6**
Unspecified	3	220	5	60	13	159	35	11,740	48	2	6	31	48	516	122	12,081	38	128,197	**318**	**153,007**
Total	**8**	**358**	**18**	**136**	**55**	**2,794**	**151**	**33,142**	**112**	**103**	**16**	**207**	**120**	**280,233**	**455**	**684,828**	**98**	**151,591**	**1,033**	**1,153,392**

Abbreviations: *e*, number of events; *k*, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported; Low D.O., low-dissolved oxygen.

a. Not all counties in state included; state is split between regions.
b. Maryland totals include the District of Columbia.

Fish-Kill Events by Land-Use Cause, 1980-1989

	Massa-chusetts[a]		Rhode Island		Connect-icut		New York		New Jersey		Pennsyl-vania		Delaware		Maryland[b]		Virginia[a]		Total	
Land-Use Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Agriculture	0	0	0	0	3	7	5	457	1	0	3	122	3	3	5	19	2	4	**22**	**612**
Industrial	2	126	1	2	6	41	17	302	11	101	4	24	7	241	5	202	17	11,245	**70**	**12,284**
Urban	1	<1	2	3	2	1	26	160	16	0	6	45	10	69	38	11,346	10	29	**111**	**11,653**
Impoundment	0	0	0	0	1	4	33	265	2	0	0	0	9	211	13	2,235	4	1,544	**62**	**4,258**
Water-Related	0	0	2	5	5	92	11	10,010	3	0	0	0	4	1,211	188	523,498	14	10,056	**227**	**544,872**
Silviculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Wildland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Military	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	3	18	**4**	**20**
Unspecified	5	232	13	126	38	2,649	58	21,945	79	3	3	16	87	278,498	206	147,528	48	128,696	**537**	**579,694**
Total	**8**	**358**	**18**	**136**	**55**	**2,794**	**151**	**33,142**	**112**	**103**	**16**	**207**	**120**	**280,233**	**455**	**684,828**	**98**	**151,591**	**1,033**	**1,153,392**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.

a. Not all counties in state included; state is split between regions.
b. Maryland totals include the District of Columbia.

Fish-Kill Events by Incident, 1980-1989

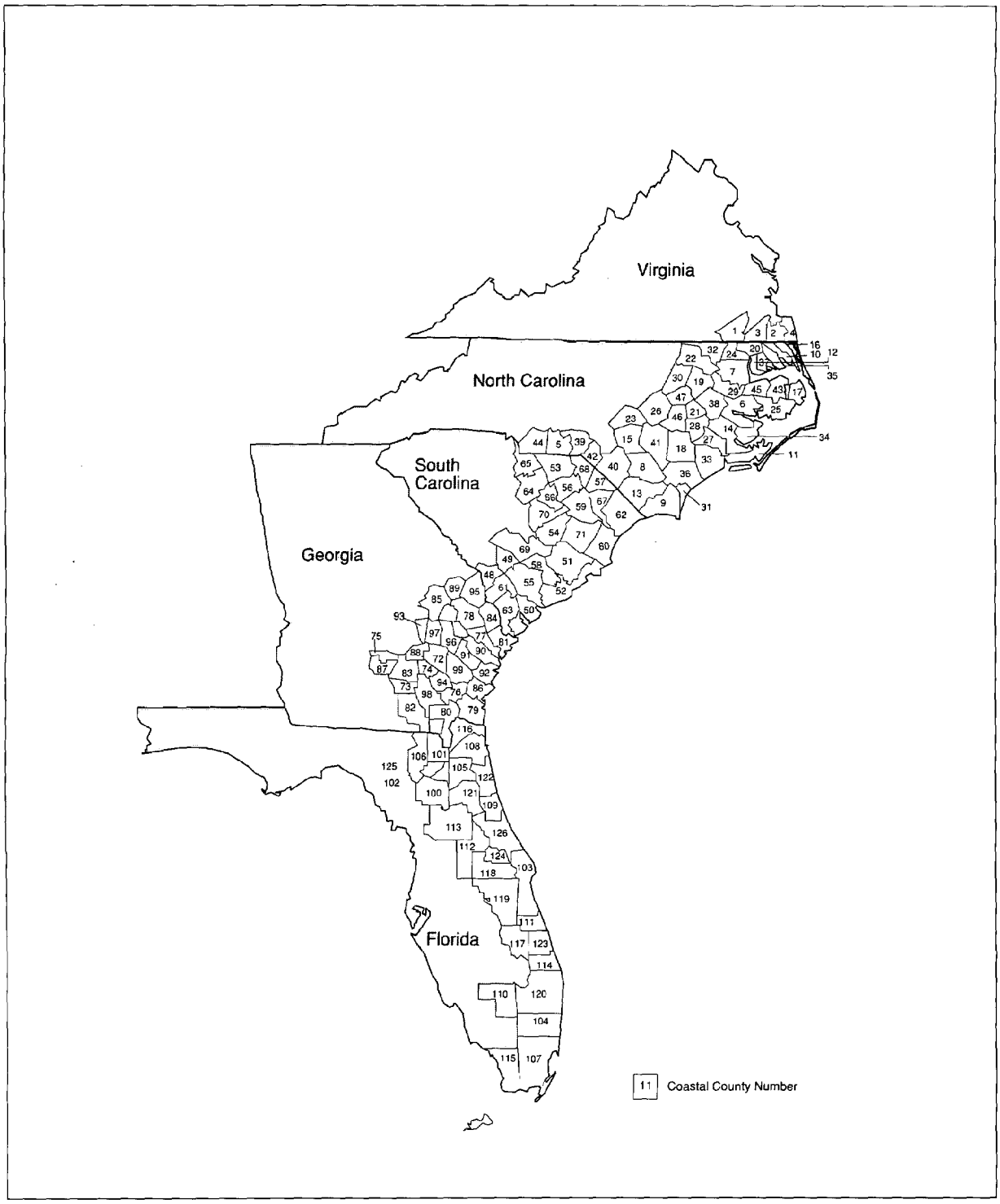
	Massa-chusetts[a]		Rhode Island		Connect-icut		New York		New Jersey		Pennsyl-vania		Delaware		Maryland[b]		Virginia[a]		Total	
Incident	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Runoff	0	0	0	0	3	2	1	<1	4	*NR*	0	0	2	201	7	58	2	12	**19**	**273**
Routine Release	1	<1	2	4	1	<1	6	35	2	*NR*	3	12	7	36	14	5,713	13	11,175	**49**	**16,975**
Accidental Release	0	0	0	0	1	*NR*	7	283	2	*NR*	1	29	6	25	15	6,558	4	44	**36**	**6,938**
Spill	0	0	0	0	5	45	12	68	3	*NR*	0	0	2	10	8	215	7	1,515	**37**	**1,854**
Spraying	0	0	0	0	0	0	6	124	1	*NR*	1	19	1	54	2	12	1	15	**12**	**224**
Natural	0	0	3	6	6	104	39	10,326	8	*NR*	0	0	26	366	199	525,351	16	10,096	**297**	**546,249**
Drawdown	0	0	0	0	0	0	5	131	0	0	0	0	2	37	2	216	1	*NR*	**10**	**384**
Dredging or Drilling	0	0	0	0	0	0	0	0	0	0	0	0	1	1,001	1	<1	0	0	**2**	**1,001**
Unspecified	7	358	13	126	39	2,642	75	22,175	92	103	11	147	73	278,504	207	146,705	54	128,734	**571**	**579,495**
Total	**8**	**358**	**18**	**136**	**55**	**2,794**	**151**	**33,142**	**112**	**103**	**16**	**207**	**120**	**280,233**	**455**	**684,828**	**98**	**151,591**	**1,033**	**1,153,392**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.

a. Not all counties in state included; state is split between regions.

b. Maryland totals include the District of Columbia

Appendix A - South Atlantic



Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Virgina					
1 Southampton	*ND*	*ND*	*ND*	*ND*	*ND*
2 Chesapeake	7	130	100	57	0
3 Suffolk	*ND*	*ND*	*ND*	*ND*	*ND*
4 Virginia Beach	24	25,369	96	71	1
Subtotal	**31**	**25,499**	**97**	**68**	**1**
North Carolina					
5 Anson	*ND*	*ND*	*ND*	*ND*	*ND*
6 Beaufort	55	103,930	80	76	6
7 Bertie	*ND*	*ND*	*ND*	*ND*	*ND*
8 Bladen	1	2	100	100	0
9 Brunswick	1	2	100	0	0
10 Camden	*ND*	*ND*	*ND*	*ND*	*ND*
11 Carteret	5	38	60	20	0
12 Chowan	1	1	100	100	0
13 Columbus	4	8	100	100	0
14 Craven	15	1,216	60	80	0
15 Cumberland	2	40	100	100	0
16 Currituck	*ND*	*ND*	*ND*	*ND*	*ND*
17 Dare	2	30,001	100	100	1
18 Duplin	4	3	75	50	0
19 Edgecombe	3	2	100	0	0
20 Gates	*ND*	*ND*	*ND*	*ND*	*ND*
21 Greene	*ND*	*ND*	*ND*	*ND*	*ND*
22 Halifax	1	15	100	0	0
23 Harnett	2	1	50	100	0
24 Hertford	*ND*	*ND*	*ND*	*ND*	*ND*
25 Hyde	6	60,058	100	50	2
26 Johnston	*ND*	*ND*	*ND*	*ND*	*ND*
27 Jones	1	<1	100	0	0
28 Lenoir	3	31	100	67	0
29 Martin	1	2	100	0	0
30 Nash	*ND*	*ND*	*ND*	*ND*	*ND*
31 New Hanover	6	237	100	67	0
32 Northampton	*ND*	*ND*	*ND*	*ND*	*ND*
33 Onslow	7	606	86	86	0
34 Pamlico	8	60,070	75	100	2
35 Pasquotank	4	23	100	25	0
36 Pender	1	10	100	100	0
37 Perquimans	*ND*	*ND*	*ND*	*ND*	*ND*
38 Pitt	3	22	100	100	0
39 Richmond	*ND*	*ND*	*ND*	*ND*	*ND*
40 Robeson	3	4	100	67	0
41 Sampson	6	8	100	83	0
42 Scotland	1	<1	100	0	0
43 Tyrrell	1	*NR*	0	0	0
44 Union	*ND*	*ND*	*ND*	*ND*	*ND*
* Wake	*ND*	*ND*	*ND*	*ND*	*ND*
45 Washington	4	37	75	75	0

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Appendix A

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
North Carolina (cont.)					
46 Wayne	1	30	0	100	0
47 Wilson	1	*NR*	0	100	0
Subtotal	**153**	**256,397**	**82**	**71**	**11**
South Carolina					
48 Allendale	*ND*	*ND*	*ND*	*ND*	*ND*
49 Bamberg	*ND*	*ND*	*ND*	*ND*	*ND*
50 Beaufort	73	343	96	70	0
51 Berkeley	11	72	91	64	0
52 Charleston	53	332	83	83	0
53 Chesterfield	2	<1	50	0	0
54 Clarendon	*ND*	*ND*	*ND*	*ND*	*ND*
55 Colleton	5	165	80	100	0
56 Darlington	7	35	100	57	0
57 Dillon	1	2	100	100	0
58 Dorchester	9	24	89	67	0
59 Florence	8	192	88	88	0
60 Georgetown	1	100	100	100	0
61 Hampton	1	12	100	100	0
62 Horry	9	68	100	78	0
63 Jasper	2	21	100	50	0
64 Kershaw	*ND*	*ND*	*ND*	*ND*	*ND*
65 Lancaster	*ND*	*ND*	*ND*	*ND*	*ND*
66 Lee	*ND*	*ND*	*ND*	*ND*	*ND*
67 Marion	3	12	100	33	0
68 Marlboro	2	11	100	50	0
69 Orangeburg	1	<1	100	0	0
70 Sumter	3	1	67	33	0
71 Williamsburg	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**191**	**1,393**	**91**	**72**	**0**
Georgia					
72 Appling	*ND*	*ND*	*ND*	*ND*	*ND*
73 Atkinson	*ND*	*ND*	*ND*	*ND*	*ND*
74 Bacon	2	14	100	0	0
75 Ben Hill	*ND*	*ND*	*ND*	*ND*	*ND*
76 Brantley	1	1	100	100	0
77 Bryan	*ND*	*ND*	*ND*	*ND*	*ND*
* Brooks	*Data found in the Gulf of Mexico Region.*				
78 Bulloch	1	1	100	100	0
79 Camden	2	16	100	0	0
80 Charlton	*ND*	*ND*	*ND*	*ND*	*ND*
81 Chatham	15	26,949	100	0	1
82 Clinch	*ND*	*ND*	*ND*	*ND*	*ND*
83 Coffee	2	4	100	100	0
* Decatur	*Data found in the Gulf of Mexico Region.*				
84 Effingham	*ND*	*ND*	*ND*	*ND*	*ND*

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.

* Not shown on map.

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Georgia (cont.)					
85 Emanuel	*ND*	*ND*	*ND*	*ND*	*ND*
* Evans	*ND*	*ND*	*ND*	*ND*	*ND*
86 Glynn	3	82	100	0	0
* Grady	*Data found in the Gulf of Mexico Region.*				
87 Irwin	*ND*	*ND*	*ND*	*ND*	*ND*
88 Jeff Davis	*ND*	*ND*	*ND*	*ND*	*ND*
89 Jenkins	*ND*	*ND*	*ND*	*ND*	*ND*
90 Liberty	*ND*	*ND*	*ND*	*ND*	*ND*
91 Long	*ND*	*ND*	*ND*	*ND*	*ND*
92 McIntosh	*ND*	*ND*	*ND*	*ND*	*ND*
93 Montgomery	*ND*	*ND*	*ND*	*ND*	*ND*
94 Pierce	1	43	100	0	0
95 Screven	*ND*	*ND*	*ND*	*ND*	*ND*
96 Tattnall	*ND*	*ND*	*ND*	*ND*	*ND*
* Thomas	*Data found in the Gulf of Mexico Region.*				
97 Toombs	*ND*	*ND*	*ND*	*ND*	*ND*
98 Ware	5	7	100	100	0
99 Wayne	1	73	100	0	0
Subtotal	**33**	**27,192**	**100**	**100**	**1**
Florida					
100 Alachua	1	<1	100	100	0
101 Baker	2	2	100	100	0
102 Bradford	*ND*	*ND*	*ND*	*ND*	*ND*
103 Brevard	39	7,365	100	85	0
104 Broward	277	1,288	100	93	0
105 Clay	8	41	100	75	0
106 Columbia	*Data found in the Gulf of Mexico Region.*				
107 Dade	87	364	100	80	0
108 Duval	56	15,273	82	70	1
109 Flagler	1	30	100	100	0
110 Hendry	*Data found in the Gulf of Mexico Region.*				
111 Indian River	14	58	100	79	0
112 Lake	10	966	100	70	0
113 Marion	14	167,850	93	50	4
114 Martin	24	90	96	92	0
115 Monroe	*Data found in the Gulf of Mexico Region.*				
116 Nassau	*ND*	*ND*	*ND*	*ND*	*ND*
117 Okeechobee	9	200	100	100	0
118 Orange	18	360,234	89	72	2
119 Osceola	*ND*	*ND*	*ND*	*ND*	*ND*
120 Palm Beach	383	1,748	100	96	0
121 Putnam	*ND*	*ND*	*ND*	*ND*	*ND*
122 St. Johns	6	4,800	100	100	0
123 St. Lucie	61	290	100	90	0
124 Seminole	12	79,614	100	58	1
125 Union	2	1	50	100	0
126 Volusia	18	2,220	94	83	0
Subtotal	**1,042**	**642,432**	**98**	**89**	**8**
Total	**1,450**	**952,913**	**96**	**84**	**21**
National Total	**3,654**	**4,071,630**	**84**	**79**	**86**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Appendix A

Fish-Kill Events by Year, 1980-1989

	Virginia [a]		North Carolina		South Carolina		Georgia [a]		Florida [a]		Total	
Year	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*
1980	7	20,235	6	22	29	271	4	122	11	96	**57**	**20,745**
1981	10	5,109	19	100,130	22	124	3	75	79	442,039	**133**	**547,478**
1982	2	14	25	1,218	23	153	0	0	51	6,132	**101**	**7,517**
1983	4	7	11	30,538	15	360	7	21	81	2,666	**118**	**33,592**
1984	1	5	14	390	16	38	0	0	68	5,200	**99**	**5,634**
1985	0	0	26	113,492	24	73	7	208	94	168,378	**151**	**282,151**
1986	2	120	10	98	34	270	5	574	192	885	**243**	**1,948**
1987	4	6	21	10,170	16	70	2	5	120	510	**163**	**10,760**
1988	1	3	15	207	12	33	2	2	137	15,501	**167**	**15,746**
1989	0	0	6	132	0	0	3	26,186	209	1,024	**218**	**27,342**
Total	**31**	**25,499**	**153**	**256,397**	**191**	**1,393**	**33**	**27,192**	**1,042**	**642,432**	**1,450**	**952,913**

Fish-Kill Events by Direct Cause, 1980-1989

	Virginia [a]		North Carolina		South Carolina		Georgia [a]		Florida [a]		Total	
Direct Cause	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*	*e*	*k*
Low D. O.	8	360	38	61,203	60	726	5	69	728	159,783	**839**	**222,141**
Temperature	4	20,008	4	60,013	11	77	1	26,106	19	1,172	**39**	**107,376**
Sedimentation	1	<1	0	0	2	1	0	0	0	0	**3**	**1**
Eutrophication	3	14	12	40,196	15	135	0	0	99	533	**129**	**40,878**
Disease	0	0	8	131	0	0	0	0	0	0	**8**	**131**
Stranding	1	1	2	10	2	25	3	12	7	2,543	**15**	**2,591**
Storm Event	0	0	1	200	1	1	3	519	9	2,726	**14**	**3,446**
Wastewater	0	0	3	5	8	26	6	163	17	13,718	**34**	**13,912**
Animal Waste	1	12	4	42	0	0	2	45	1	10	**8**	**109**
pH	0	0	0	0	0	0	0	0	1	2	**1**	**2**
Organic Chemicals	0	0	0	0	1	10	2	81	1	200	**4**	**291**
Inorganic Chemicals/Metals	0	0	2	3	0	0	0	0	1	6	**3**	**9**
Mixed Chemicals	0	0	1	20	2	8	2	6	7	300,015	**12**	**300,049**
Pesticides	0	0	9	47	29	216	0	0	18	15,224	**56**	**15,488**
Nutrient	0	0	0	0	1	3	0	0	15	61,383	**16**	**61,386**
Salinity Changes	2	5	22	94,286	3	31	0	0	4	81	**31**	**94,403**
Petroleum	0	0	2	<1	2	2	3	82	1	<1	**8**	**85**
Chlorine	0	0	0	0	1	<1	0	0	0	0	**1**	**<1**
Red Tide	1	3	0	0	0	0	0	0	1	<1	**2**	**3**
Predation	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Unspecified	10	5,096	45	241	53	133	6	109	113	85,037	**227**	**90,615**
Total	**31**	**25,499**	**153**	**256,397**	**191**	**1,393**	**33**	**27,192**	**1,042**	**642,432**	**1,450**	**952,913**

Abbreviations: *e*, number of events; *k*, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported; Low D.O., low-dissolved oxygen.
a. Not all counties in state included; state is split between regions.

Fish-Kill Events by Land-Use Cause, 1980-1989

	Virginia [a]		North Carolina		South Carolina		Georgia [a]		Florida [a]		Total	
Land-Use Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Agriculture	2	32	10	83	2	20	5	122	26	11,787	**45**	**12,044**
Industrial	0	0	4	5	2	171	2	81	19	15,051	**27**	**15,308**
Urban	1	<1	1	3	12	59	11	689	158	362,108	**183**	**362,860**
Impoundment	4	20,014	21	30,666	3	25	1	1	15	2,563	**44**	**53,269**
Water-Related	8	47	42	144,828	0	0	3	26,114	21	2,035	**74**	**173,025**
Silviculture	0	0	1	20	0	0	0	0	0	0	**1**	**20**
Wildland	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Mining	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Military	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Unspecified	16	5,406	74	80,792	172	1,117	11	185	803	248,887	**1,076**	**336,387**
Total	**31**	**25,499**	**153**	**256,397**	**191**	**1,393**	**33**	**27,192**	**1,042**	**642,432**	**1,450**	**952,913**

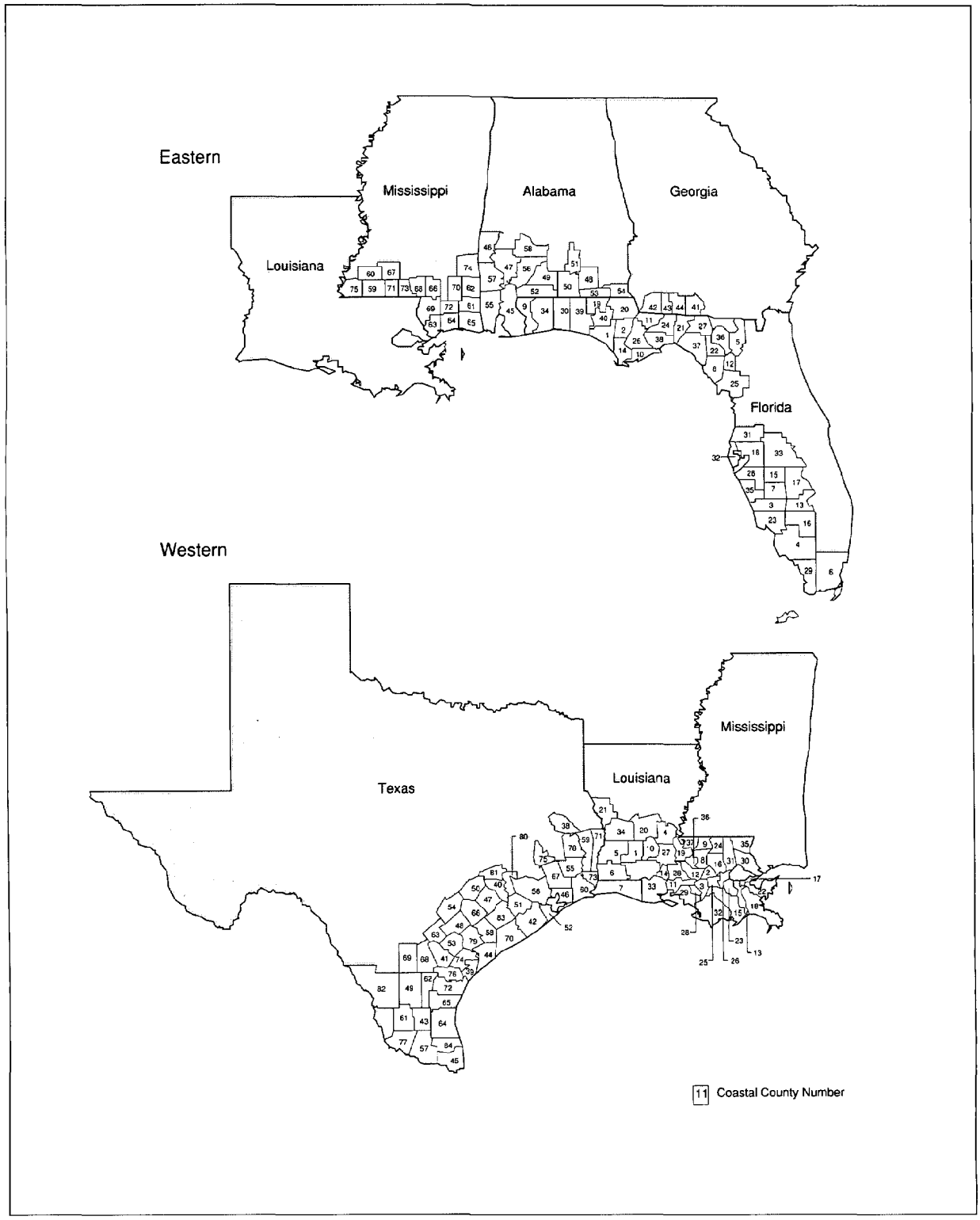
Fish-Kill Events by Incident, 1980-1989

	Virginia [a]		North Carolina		South Carolina		Georgia [a]		Florida [a]		Total	
Incident	**e**	**k**	**e**	**k**	**e**	**k**	**e**	**k**	**e**	**k**	**e**	**k**
Runoff	1	<1	6	55	3	23	3	519	151	375,989	**164**	**376,586**
Routine Release	0	0	1	1	1	21	6	66	19	9,006	**27**	**9,094**
Accidental Release	0	0	5	16	3	180	2	93	8	33	**18**	**322**
Spill	0	0	4	3	7	7	2	82	3	8	**16**	**100**
Spraying	0	0	2	2	3	28	0	0	3	51	**8**	**81**
Natural	12	20,061	65	195,517	3	1	3	26,114	32	3,751	**115**	**245,445**
Drawdown	0	0	1	<1	2	25	1	3	3	2,540	**7**	**2,569**
Dredging or Drilling	0	0	0	0	0	0	0	0	1	<1	**1**	**<1**
Unspecified	18	5,438	69	60,802	169	1,107	16	314	822	251,054	**1,094**	**318,715**
Total	**31**	**25,499**	**153**	**256,397**	**191**	**1,393**	**33**	**27,192**	**1,042**	**642,432**	**1,450**	**952,913**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.

a. Not all counties in state included; state is split between regions.

Appendix A - Gulf of Mexico



Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Gulf of Mexico (Eastern)					
Florida					
1 Bay	10	2,031	90	80	0
2 Calhoun	*ND*	*ND*	*ND*	*ND*	*ND*
3 Charlotte	9	10	89	100	0
* Cirtus	2	75	100	50	0
4 Collier	49	299	100	92	0
5 Columbia	1	15	100	100	0
6 Dade	*Data found in the South Atlantic Region.*				
7 De Soto	1	30	100	100	0
8 Dixie	*ND*	*ND*	*ND*	*ND*	*ND*
9 Escambia	26	5,513	85	85	0
10 Franklin	2	20,001	100	100	1
11 Gadsden	2	30,000	100	0	1
12 Gilchrist	*ND*	*ND*	*ND*	*ND*	*ND*
13 Glades	2	6	100	100	0
14 Gulf	4	411	100	75	0
* Hamilton	4	5	75	75	0
15 Hardee	1	3	100	100	0
16 Hendry	8	61	100	88	0
* Hernando	1	3	100	100	0
17 Highlands	5	893	100	100	0
18 Hillsborough	12	76	100	75	0
19 Holmes	1	0	100	0	0
20 Jackson	3	31	67	100	0
21 Jefferson	*ND*	*ND*	*ND*	*ND*	*ND*
22 Lafayette	*ND*	*ND*	*ND*	*ND*	*ND*
23 Lee	12	15	92	100	0
24 Leon	*ND*	*ND*	*ND*	*ND*	*ND*
25 Levy	1	27	100	100	0
26 Liberty	1	0	100	0	0
27 Madison	1	3	100	0	0
28 Manatee	2	2	100	100	0
29 Monroe	7	374	86	100	0
30 Okaloosa	5	1,411	80	80	0
31 Pasco	12	134	100	100	0
32 Pinellas	12	231	100	92	0
33 Polk	19	2,124	89	89	0
34 Santa Rosa	17	66,110	82	94	2
35 Sarasota	6	58	83	67	0
* Sumter	2	9	100	100	0
36 Suwannee	*ND*	*ND*	*ND*	*ND*	*ND*
37 Taylor	2	3	100	100	0
38 Wakulla	*ND*	*ND*	*ND*	*ND*	*ND*
39 Walton	6	110	100	67	0
40 Washington	2	4	100	100	0
Subtotal	**250**	**130,079**	**93**	**88**	**4**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Gulf of Mexico (Eastern)					
Georgia					
41 Brooks	*ND*	*ND*	*ND*	*ND*	*ND*
42 Decatur	*ND*	*ND*	*ND*	*ND*	*ND*
43 Grady	*ND*	*ND*	*ND*	*ND*	*ND*
44 Thomas	2	14	100	50	0
Subtotal	**2**	**14**	**100**	**50**	**0**
Alabama					
45 Baldwin	12	91,429	83	100	2
46 Choctaw	*ND*	*ND*	*ND*	*ND*	*ND*
47 Clarke	*ND*	*ND*	*ND*	*ND*	*ND*
48 Coffee	*ND*	*ND*	*ND*	*ND*	*ND*
49 Conecuh	*ND*	*ND*	*ND*	*ND*	*ND*
50 Covington	1	0	100	100	0
51 Crenshaw	*ND*	*ND*	*ND*	*ND*	*ND*
52 Escambia	*ND*	*ND*	*ND*	*ND*	*ND*
53 Geneva	*ND*	*ND*	*ND*	*ND*	*ND*
54 Houston	*ND*	*ND*	*ND*	*ND*	*ND*
55 Mobile	30	40,537	93	87	2
56 Monroe	*ND*	*ND*	*ND*	*ND*	*ND*
57 Washington	1	1	100	100	0
58 Wilcox	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**44**	**131,967**	**91**	**91**	**4**
Mississippi					
59 Amite	*ND*	*ND*	*ND*	*ND*	*ND*
60 Franklin	*ND*	*ND*	*ND*	*ND*	*ND*
61 George	*ND*	*ND*	*ND*	*ND*	*ND*
62 Greene	*ND*	*ND*	*ND*	*ND*	*ND*
63 Hancock	2	55	100	100	0
64 Harrison	2	4	50	100	0
65 Jackson	2	20,002	100	50	1
66 Lamar	*ND*	*ND*	*ND*	*ND*	*ND*
67 Lincoln	*ND*	*ND*	*ND*	*ND*	*ND*
68 Marion	1	20	100	100	0
69 Pearl River	*ND*	*ND*	*ND*	*ND*	*ND*
70 Perry	*ND*	*ND*	*ND*	*ND*	*ND*
71 Pike	*ND*	*ND*	*ND*	*ND*	*ND*
72 Stone	*ND*	*ND*	*ND*	*ND*	*ND*
73 Walthall	*ND*	*ND*	*ND*	*ND*	*ND*
74 Wayne	*ND*	*ND*	*ND*	*ND*	*ND*
75 Wilkinson	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**7**	**20,081**	**86**	**86**	**1**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Gulf of Mexico (Western)					
Louisiana					
* Acadia	5	961	80	80	0
1 Allen	*ND*	*ND*	*ND*	*ND*	*ND*
2 Ascension	5	12	80	80	0
3 Assumption	9	547	89	89	0
4 Avoyelles	*ND*	*ND*	*ND*	*ND*	*ND*
5 Beauregard	*ND*	*ND*	*ND*	*ND*	*ND*
6 Calcasieu	5	33	60	80	0
7 Cameron	3	3	33	100	0
8 East Baton Rouge	17	144	82	71	0
9 East Feliciana	*ND*	*ND*	*ND*	*ND*	*ND*
10 Evangeline	*ND*	*ND*	*ND*	*ND*	*ND*
11 Iberia	8	73	38	100	0
12 Iberville	14	222	79	71	0
13 Jefferson	7	13	43	71	0
* Jefferson Davis	2	*NR*	0	100	0
14 Lafayette	4	970	50	75	0
15 Lafourche	13	56	54	100	0
16 Livingston	1	6	100	100	0
17 Orleans	9	14	44	78	0
18 Plaquemines	5	873	80	100	0
19 Point Coupee	*ND*	*ND*	*ND*	*ND*	*ND*
20 Rapides	*ND*	*ND*	*ND*	*ND*	*ND*
21 Sabine	*ND*	*ND*	*ND*	*ND*	*ND*
22 St. Bernard	6	4	33	83	0
23 St. Charles	7	115	29	86	0
24 St. Helena	*ND*	*ND*	*ND*	*ND*	*ND*
25 St. James	5	24	80	100	0
26 St. John the Baptist	1	*NR*	0	100	0
27 St. Landry	1	4	100	100	0
28 St. Martin	1	*NR*	0	100	0
29 St. Mary	4	778	75	100	0
30 St. Tammany	13	109	69	85	0
31 Tangipahoa	6	7	67	83	0
32 Terrebonne	14	1,144	43	93	0
33 Vermilion	2	10	50	50	0
34 Vernon	*ND*	*ND*	*ND*	*ND*	*ND*
35 Washington	*ND*	*ND*	*ND*	*ND*	*ND*
36 West Baton Rouge	3	9	100	67	0
37 West Feliciana	2	460	50	100	0
Subtotal	**172**	**6,590**	**61**	**85**	**0**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Appendix A

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Gulf of Mexico (Western)					
Texas					
38 Angelina	*ND*	*ND*	*ND*	*ND*	*ND*
39 Aransas	10	6,297	30	70	0
40 Austin	2	5	100	100	0
41 Bee	*ND*	*ND*	*ND*	*ND*	*ND*
42 Brazoria	36	15,569	69	81	1
43 Brooks	*ND*	*ND*	*ND*	*ND*	*ND*
44 Calhoun	11	225	45	82	0
45 Cameron	8	13,785	63	88	1
46 Chambers	20	160,321	90	90	5
47 Colorado	*ND*	*ND*	*ND*	*ND*	*ND*
48 De Witt	*ND*	*ND*	*ND*	*ND*	*ND*
49 Duval	*ND*	*ND*	*ND*	*ND*	*ND*
50 Fayette	*ND*	*ND*	*ND*	*ND*	*ND*
51 Fort Bend	19	5,928	68	58	0
52 Galveston	72	1,059,707	81	90	8
53 Goliad	*ND*	*ND*	*ND*	*ND*	*ND*
54 Gonzales	*ND*	*ND*	*ND*	*ND*	*ND*
55 Hardin	1	*NR*	0	0	0
56 Harris	66	231,757	59	80	3
57 Hidalgo	1	1	100	100	0
58 Jackson	1	0	100	100	0
59 Jasper	3	245	100	100	0
60 Jefferson	20	1,821	75	80	0
61 Jim Hogg	*ND*	*ND*	*ND*	*ND*	*ND*
62 Jim Wells	1	*NR*	0	0	0
63 Karnes	*ND*	*ND*	*ND*	*ND*	*ND*
64 Kenedy	1	40	100	0	0
65 Kleberg	4	0	25	100	0
66 Lavaca	3	20	67	67	0
67 Liberty	6	27	33	83	0
68 Live Oak	*ND*	*ND*	*ND*	*ND*	*ND*
69 McMullen	*ND*	*ND*	*ND*	*ND*	*ND*
70 Matagorda	24	5,969	54	88	0
71 Newton	4	*NR*	0	75	0
72 Nueces	15	49,484	60	80	2
73 Orange	14	8,415	79	79	0
74 Refugio	3	5	67	67	0
75 San Jacinto	*ND*	*ND*	*ND*	*ND*	*ND*
76 San Patricio	5	33,260	60	100	1
77 Starr	1	1	100	100	0
78 Tyler	*ND*	*ND*	*ND*	*ND*	*ND*
79 Victoria	1	*NR*	0	0	0
80 Waller	*ND*	*ND*	*ND*	*ND*	*ND*
81 Washington	*ND*	*ND*	*ND*	*ND*	*ND*
82 Webb	*ND*	*ND*	*ND*	*ND*	*ND*
83 Wharton	3	*NR*	0	100	0
84 Willacy	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**355**	**1,592,880**	**66**	**81**	**21**
Total	**830**	**1,881,610**	**75**	**84**	**30**
National Total	**3,654**	**4,071,630**	**84**	**79**	**86**

Abbreviations: %, percent; #, number; *NR*, number of fish killed not reported; *ND*, no data was received.

Fish-Kill Events by Year, 1980-1989

	Florida[a]		Georgia[a]		Alabama		Mississippi		Louisiana		Texas		Total	
Year	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
1980	25	56	0	0	7	194	0	0	2	158	58	1,095,440	**92**	**1,095,848**
1981	32	59,704	0	0	1	0	1	2	10	76	52	56,061	**96**	**115,843**
1982	24	3,662	0	0	2	10	0	0	5	4	66	78,534	**97**	**82,209**
1983	24	30,782	1	3	3	1	0	0	17	220	52	74,994	**97**	**106,000**
1984	26	22,911	0	0	12	118,753	0	0	22	412	22	235,828	**82**	**377,904**
1985	26	1,350	0	0	3	3	1	20	22	978	0	0	**52**	**2,352**
1986	30	10,938	0	0	3	70	2	55	38	3,323	9	1	**82**	**14,387**
1987	16	115	0	0	10	12,934	1	4	16	487	15	6	**58**	**13,546**
1988	21	317	0	0	2	2	1	0	17	115	53	48,687	**94**	**49,121**
1989	26	243	1	11	1	2	1	20,000	23	817	28	3,328	**80**	**24,401**
Total	**250**	**130,079**	**2**	**14**	**44**	**131,967**	**7**	**20,081**	**172**	**6,590**	**355**	**1,592,880**	**830**	**1,881,610**

Fish-Kill Events by Direct Cause, 1980-1989

	Florida[a]		Georgia[a]		Alabama		Mississippi		Louisiana		Texas		Total	
Direct Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Low D. O.	116	29,947	0	0	23	131,901	0	0	63	1,577	119	1,173,795	**321**	**1,337,220**
Temperature	17	421	0	0	0	0	1	20,000	5	753	18	39,617	**41**	**60,791**
Sedimentation	0	0	0	0	0	0	0	0	6	359	5	20	**11**	**379**
Eutrophication	15	51,206	0	0	1	2	0	0	4	5	6	13,015	**26**	**64,228**
Disease	4	19	0	0	1	<1	0	0	2	<1	8	20	**15**	**39**
Stranding	6	134	0	0	0	0	0	0	5	3	5	5,169	**16**	**5,306**
Storm Event	7	164	0	0	0	0	1	20	17	1,009	23	43,375	**48**	**44,569**
Wastewater	11	1,255	1	3	10	44	0	0	21	1,058	29	224,624	**72**	**226,984**
Animal Waste	3	815	0	0	0	0	0	0	3	7	1	1,000	**7**	**1,822**
pH	0	0	0	0	0	0	0	0	2	3	2	<1	**4**	**3**
Organic Chemicals	2	2	0	0	1	4	0	0	3	88	1	*NR*	**7**	**94**
Inorganic Chemicals/Metals	4	84	0	0	1	*NR*	0	0	3	577	18	51,713	**26**	**52,375**
Mixed Chemicals	10	11,647	0	0	3	12	0	0	5	4	6	6,598	**24**	**18,261**
Pesticides	10	379	0	0	0	0	1	*NR*	2	*NR*	13	3,765	**26**	**4,143**
Nutrients	12	1,557	0	0	0	0	0	0	2	5	5	404	**19**	**1,966**
Salinity Changes	0	0	0	0	0	0	3	59	1	*NR*	2	13	**6**	**72**
Petroleum	1	50	0	0	0	0	0	0	2	*NR*	20	28,594	**23**	**28,644**
Chlorine	0	0	0	0	0	0	0	0	0	0	2	75	**2**	**75**
Red Tide	1	1,909	0	0	0	0	0	0	0	0	8	<1	**9**	**1,909**
Predation	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Unspecified	31	30,489	1	11	4	3	1	2	26	1,142	64	1,083	**127**	**32,730**
Total	**250**	**130,079**	**2**	**14**	**44**	**131,967**	**7**	**20,081**	**172**	**6,590**	**355**	**1,592,880**	**830**	**1,881,610**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported; Low D.O., low-dissolved oxygen.
a. Not all counties in state included; state is split between regions.

Appendix A

Fish-Kill Events by Land-Use Cause, 1980-1989

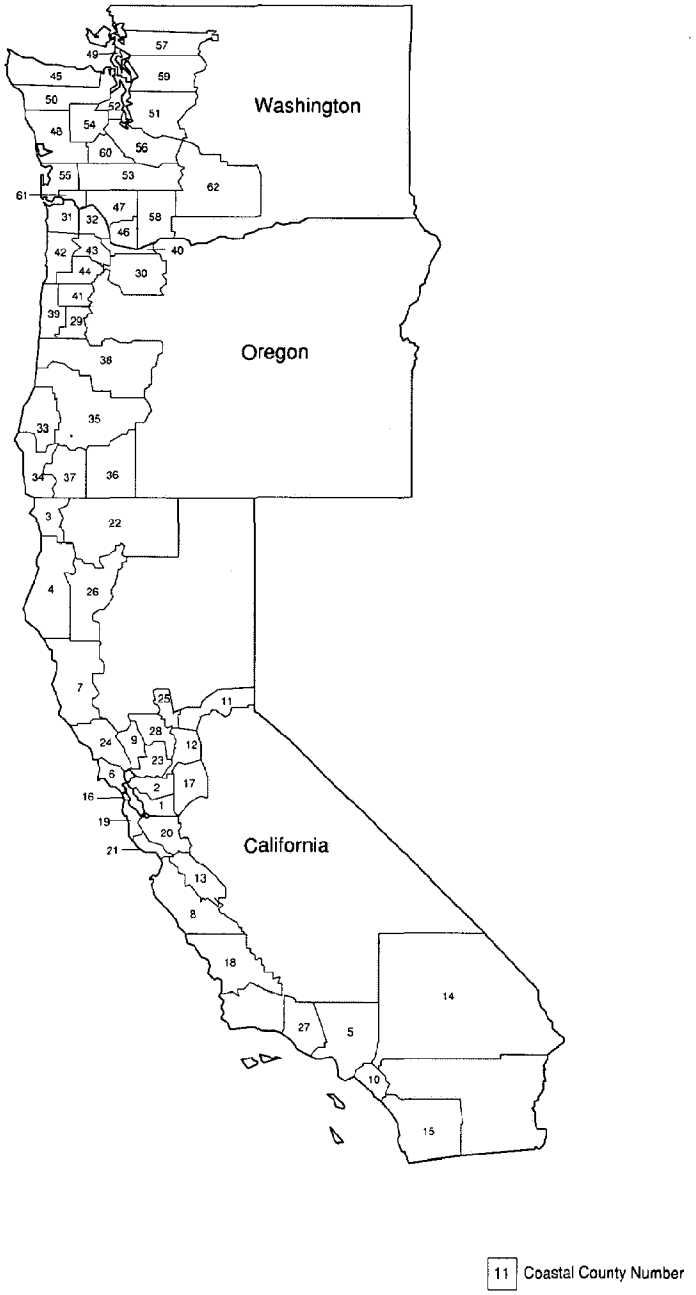
	Florida[a]		Georgia[a]		Alabama		Mississippi		Louisiana		Texas		Total	
Land-Use Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Agriculture	6	95	0	0	0	0	0	0	7	43	11	4,893	**24**	**5,031**
Industrial	12	61,000	1	11	1	10	0	0	29	2,179	54	12,332	**97**	**75,532**
Urban	56	3,153	1	3	10	42	0	0	21	85	58	273,098	**146**	**276,381**
Impoundment	16	1,457	0	0	4	134	0	0	36	1,073	13	31,260	**69**	**33,923**
Water-Related	18	2,215	0	0	1	68	5	20,079	14	927	67	594,179	**105**	**617,468**
Silviculture	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Wildland	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Mining	1	4	0	0	0	0	0	0	1	*NR*	5	2	**7**	**6**
Military	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Unspecified	141	62,154	0	0	28	131,713	2	2	64	2,283	147	677,116	**382**	**873,268**
Total	**250**	**130,079**	**2**	**14**	**44**	**131,967**	**7**	**20,081**	**172**	**6,590**	**355**	**1,592,880**	**830**	**1,881,610**

Fish-Kill Events by Incident, 1980-1989

	Florida[a]		Georgia[a]		Alabama		Mississippi		Louisiana		Texas		Total	
Incident	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Runoff	48	279	0	0	1	*NR*	0	0	8	57	23	21,348	**80**	**21,685**
Routine Release	6	10,056	0	0	3	11	0	0	23	1,945	26	798	**58**	**12,809**
Accidental Release	6	207	1	3	3	24	0	0	16	138	23	3,660	**49**	**4,032**
Spill	7	1,826	0	0	0	0	1	*NR*	2	460	32	1,835	**42**	**4,121**
Spraying	5	118	0	0	0	0	0	0	1	*NR*	4	3,760	**10**	**3,878**
Natural	26	2,570	0	0	6	204	5	20,079	43	1,251	71	615,259	**151**	**639,364**
Drawdown	1	1	0	0	0	0	0	0	4	6	2	190	**7**	**197**
Dredging or Drilling	1	1,000	0	0	0	0	0	0	6	358	10	10	**17**	**1,368**
Unspecified	150	114,022	1	11	31	131,729	1	2	69	2,376	164	946,018	**416**	**1,194,158**
Total	**250**	**130,079**	**2**	**14**	**44**	**131,967**	**7**	**20,081**	**172**	**6,590**	**355**	**1,592,880**	**830**	**1,881,610**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.
a. Not all counties in state included; state is split between regions.

Appendix A - Pacific



Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
California					
1 Alameda	6	516	100	83	0
2 Contra Costa	6	65	100	67	0
3 Del Norte	*ND*	*ND*	*ND*	*ND*	*ND*
4 Humboldt	1	<1	100	100	0
5 Los Angeles	12	5,739	100	83	0
6 Marin	11	25	100	82	0
7 Mendocino	2	1	100	100	0
8 Monterey	9	200	100	56	0
9 Napa	1	1	100	100	0
10 Orange	5	66	80	60	0
11 Placer	*ND*	*ND*	*ND*	*ND*	*ND*
12 Sacramento	7	28	86	43	0
13 San Benito	*ND*	*ND*	*ND*	*ND*	*ND*
14 San Bernardino	*ND*	*ND*	*ND*	*ND*	*ND*
15 San Diego	2	14	100	100	0
16 San Francisco	1	500	100	100	0
17 San Joaquin	27	396	100	78	0
18 San Luis Obispo	13	160	100	85	0
19 San Mateo	17	280	94	65	0
* Santa Barbara	5	363	80	60	0
20 Santa Clara	6	15	100	83	0
21 Santa Cruz	5	525	100	80	0
22 Siskiyou	1	101	100	100	0
23 Solano	3	3	100	0	0
24 Sonoma	5	107	100	100	0
25 Sutter	1	1	100	100	0
26 Trinity	*ND*	*ND*	*ND*	*ND*	*ND*
27 Ventura	*ND*	*ND*	*ND*	*ND*	*ND*
28 Yolo	2	162	100	100	0
Subtotal	**148**	**9,267**	**97**	**74**	**0**
Oregon					
29 Benton	*ND*	*ND*	*ND*	*ND*	*ND*
30 Clackamas	6	165	67	67	0
31 Clatsop	*ND*	*ND*	*ND*	*ND*	*ND*
32 Columbia	8	13	75	88	0
33 Coos	2	45	50	100	0
34 Curry	1	5	100	0	0
35 Douglas	3	283	100	67	0
36 Jackson	*ND*	*ND*	*ND*	*ND*	*ND*
37 Josephine	1	123	100	100	0
38 Lane	5	37	100	60	0
39 Lincoln	4	16	100	100	0
40 Multnomah	9	186	89	56	0
41 Polk	*ND*	*ND*	*ND*	*ND*	*ND*
42 Tillamook	1	2	100	100	0
43 Washington	*ND*	*ND*	*ND*	*ND*	*ND*
44 Yamhill	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**40**	**874**	**90**	**73**	**0**

Abbreviations: *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Fish-Kill Events by County, 1980-1989

State/County	Events	Killed (x100)	% of events where # killed was reported	% of events where cause of kill was reported	# of events where 1 million or more fish were killed
Washington					
45 Clallam	3	4	100	67	0
46 Clark	4	16	50	75	0
47 Cowlitz	2	*NR*	0	100	0
48 Grays Harbor	2	525	100	100	0
49 Island	2	25,700	50	100	1
50 Jefferson	*ND*	*ND*	*ND*	*ND*	*ND*
51 King	39	1,037	79	56	0
52 Kitsap	1	2	100	0	0
53 Lewis	1	99	100	100	0
54 Mason	2	3	100	0	0
55 Pacific	*ND*	*ND*	*ND*	*ND*	*ND*
56 Pierce	9	212	89	100	0
57 Skagit	3	20	33	100	0
58 Skamania	*ND*	*ND*	*ND*	*ND*	*ND*
59 Snohomish	16	859	75	81	0
60 Thurston	5	3,554	80	100	0
61 Wahkiakum	*ND*	*ND*	*ND*	*ND*	*ND*
* Whatcom	16	640	75	75	0
62 Yakima	*ND*	*ND*	*ND*	*ND*	*ND*
Subtotal	**105**	**32,670**	**76**	**72**	**1**
Total	**293**	**42,811**	**88**	**73**	**1**
National Total	**3,654**	**4,071,630**	**84**	**79**	**86**

Abbreviations: *NR*, number of fish killed not reported; *ND*, no data was received.
* Not shown on map.

Fish-Kill Events by Year, 1980-1989

	California		Oregon		Washington		Total	
Year	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
1980	23	713	13	195	7	519	**43**	**1,427**
1981	31	522	8	102	10	29,856	**49**	**30,480**
1982	24	6,258	5	59	8	129	**37**	**6,445**
1983	13	105	0	0	6	424	**19**	**529**
1984	12	315	7	2	9	178	**28**	**496**
1985	19	506	2	124	6	372	**27**	**1,002**
1986	5	13	5	392	12	462	**22**	**867**
1987	10	711	0	0	28	706	**38**	**1,417**
1988	9	124	0	0	9	13	**18**	**136**
1989	2	<1	0	0	10	12	**12**	**12**
Total	**148**	**9,267**	**40**	**874**	**105**	**32,670**	**293**	**42,811**

Fish-Kill Events by Direct Cause, 1980-1989

	California		Oregon		Washington		Total	
Direct Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Low D. O.	25	949	1	*NR*	7	25,986	**33**	**26,935**
Temperature	6	80	2	2	0	0	**8**	**82**
Sedimentation	1	150	0	0	0	0	**1**	**150**
Eutrophication	1	<1	1	2	1	1	**3**	**3**
Disease	5	90	0	0	2	<1	**7**	**90**
Stranding	6	439	3	400	3	262	**12**	**1,101**
Storm Event	1	51	0	0	0	0	**1**	**51**
Wastewater	8	676	0	0	6	952	**14**	**1,628**
Animal Waste	5	50	0	0	21	853	**26**	**903**
pH	0	0	0	0	3	30	**3**	**30**
Organic Chemicals	5	84	3	19	1	1	**9**	**103**
Inorganic Chemicals/Metals	7	313	6	195	3	3,160	**16**	**3,668**
Mixed Chemicals	4	108	4	176	5	104	**13**	**388**
Pesticides	17	279	3	7	7	555	**27**	**841**
Nutrients	1	5	0	0	0	0	**1**	**5**
Salinity Changes	2	149	0	0	0	0	**2**	**149**
Petroleum	5	47	3	<1	7	98	**15**	**145**
Chlorine	11	5,247	3	48	10	458	**24**	**5,753**
Red Tide	0	0	0	0	0	0	**0**	**0**
Predation	0	0	0	0	0	0	**0**	**0**
Unspecified	38	550	11	26	29	210	**78**	**786**
Total	**148**	**9,267**	**40**	**874**	**105**	**32,670**	**293**	**42,811**

Abbreviations: ***e***, number of events; ***k***, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported; Low D.O., low-dissolved oxygen.

Fish-Kill Events by Land-Use Cause, 1980-1989

	California		Oregon		Washington		Total	
Land-Use Cause	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Agriculture	10	226	5	52	26	1,026	**41**	**1,304**
Industrial	5	5,058	13	719	8	567	**26**	**6,344**
Urban	10	972	2	13	19	1,344	**31**	**2,329**
Impoundment	13	510	3	5	8	3,688	**24**	**4,203**
Water-Related	5	69	1	10	8	25,723	**14**	**25,801**
Silviculture	1	101	0	0	0	0	**1**	**101**
Wildland	0	0	0	0	0	0	**0**	**0**
Mining	0	0	0	0	0	0	**0**	**0**
Military	0	0	0	0	0	0	**0**	**0**
Unspecified	104	2,332	16	75	36	323	**156**	**2,730**
Total	**148**	**9,267**	**40**	**874**	**105**	**32,670**	**293**	**42,811**

Fish-Kill Events by Incident, 1980-1989

	California		Oregon		Washington		Total	
Incident	***e***	***k***	***e***	***k***	***e***	***k***	***e***	***k***
Runoff	3	33	0	0	4	487	**7**	**519**
Routine Release	4	5,600	5	51	17	1,182	**26**	**6,834**
Accidental Release	3	76	3	12	7	128	**13**	**217**
Spill	10	97	8	17	10	729	**28**	**843**
Spraying	1	101	0	0	6	206	**7**	**306**
Natural	12	134	3	12	9	28,844	**24**	**28,990**
Drawdown	3	432	1	110	3	545	**7**	**1,086**
Dredging or Drilling	2	158	0	0	0	0	**2**	**158**
Unspecified	110	2,637	20	671	49	551	**179**	**3,859**
Total	**148**	**9,267**	**40**	**874**	**105**	**32,670**	**293**	**42,811**

Abbreviations: *e*, number of events; *k*, number of fish killed in hundreds of fish; *NR*, number of fish killed not reported.

		NORTH ATLANTIC										MIDDLE ATLANTIC										SOUTH ATLANTIC								GULF OF MEXICO								PACIFIC		
		Maine	New Hampshire	Massachusetts [1]	Rhode Island	Connecticut	New York	New Jersey	Pennsylvania	Delaware	Maryland	Virginia	North Carolina	South Carolina	Georgia [1]	Florida	Alabama	Mississippi	Louisiana	Texas	California	Oregon	Washington
PROGRAM ORGANIZATION	Program initiated:	'72	'60	'60	'73	*ND*	'40	'65	'50	'80	'64	'69	'51	'80	'57	'75	'70	'79	'75	'75	'65	'81	'69
	Data available from:	'81	'70	'65	'73	*ND*	*ND*	*ND*	'67	'76	'64	'79	'80	'80	'57	'75	'80	'79	'75	'78	'65	'81	'69
	Are records maintained in a central office?	Y	N	N	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N
	Number of agencies in reporting process:	3	1	2	3	2	5	2	3	1	1	2	3	2	3	2	2	2	3	2	2	2	1
	Are records computerized?	N	N	Y	N	N	N	N	Y	N	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	N	Y
	Are annual reports maintained?	N	N	Y	N	N	Y	N	N	Y	Y	N	N	N	N	N	Y	N	N	N	Y	N	N
	FTEs (full-time equivalents) in 1989:	<1	1	6-10	<1	*ND*	>10	1-2	*ND*	<1	3-5	6-10	*ND*	1-2	>10	*ND*	>10	1-2	<1	6-10	*ND*	<1	1-2
	Level of program support: [2]	L	M	L/M	L	L	M	L	M	L	M	M	L	L	H/L	L	H	L	L	L	L	M	L
	Change in support during '85-'89: [3]	S	S	I/S	S	S	S	*ND*	*ND*	S	S	S	D	S	S/I	S	I	I	S	I	D	I	D
	Did reorganization occur during '85-'89?	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y
INVESTIGATIVE PROCEDURES & DATA USE	Percentage of trained personnel: [4]	100	25	100	50	0	*ND*	25	100	25	75	75	*ND*	0	100	*ND*	100	50	0	100	75	100	0
	Percentage of all fish kills reported: [4]	100	100	100	75	50	50	50	100	100	*ND*	*ND*	100	100	75	50	75	75	75	75	25	75	25
	Percentage of field or laboratory chemical analyses that determines cause: [4]	25	100	100	25	50	25	25	100	75	100	100	100	100	100	*ND*	100	*ND*	100	100	75	100	25
	Frequency of written report filed: [4]	100	100	100	100	100	*ND*	50	*ND*	100	50	100	100	100	100	100	100	100	75	100	75	100	25
	Use of fish-kill reports: [5]	A,B, C,F	B,C	A-E	A,C, F	A,B, C	A-F	B,C	A-C	A,C	A-F	B,C D,F	A-C, E,F	A-E	A-C	A,E, F	A-F	A-F	B-D	A-C	A-F	A-F	A-C

Notes: *ND* = No response

[1] Reflects comments from two different agencies

[2] L = not adequate; M = fairly adequate/adequate; H = very good

[3] D = decreased; S = same; I = increased

[4] Percent intervals: 0 = 0%; 25 = 1 - 25%; 50 = 26 - 50%; 75 = 51 - 75%; 100 = 76 - 100%

[5] A =To indicate an emergency situation requiring immediate response; B =To determine the amount of environmental/economic damage; C =To determine the source and/or parties responsible for the kill so fines and/or penalities can be assigned; D =To indicate the health of the aquatic resources; E =To indicate a trend in the health of the aquatic resources; F =To meet reporting requirements of the EPA 305(b) Water Quality Reports

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