Section 5.0 Fish Kill Standard Operating Procedure

SCOPE AND APPLICATION

A fish kill is a sudden and significant death of large numbers of fish and shellfish, occurring in a defined area. Fish kills can occur at various times during the year and can result from natural causes or from anthropogenic activities. The location and natural resources affected by such events determine which agencies are responsible for initial response, investigation, and when necessary, sample procurement and testing as well as enforcement. This SOP will focus on diadromous fish resources that occur in marine and coastal river watersheds of Massachusetts but can also be applied to other marine fish and shellfish species that are jurisdictional to DMF.

Monitoring Objectives

The main purpose of Section 5.0 is to provide standardized protocols for documenting the occurrence of fish kills, and when possible, determining the causes and impacts of fish kills, and assessing the extent of damages to affected habitats and monetary value of diadromous resources. A supplementary goal of this SOP is to streamline the fish kill investigation protocols of DMF with those of *MassWildlife* (DFW), the Massachusetts Department of Environmental Protection Bureau of Waste Site Cleanup/ Emergency Response (MassDEP BWSC/ER) and the Massachusetts Department of Agricultural Resources (DAR) and other interested agencies, and to establish jurisdictional processes for notifications and first response, as well as the preparation, storage and chain-of-custody protocols for sample deliveries for laboratory testing. This SOP adopts direct guidance from the joint DFW and DEP Fish Kill SOP (MassDEP 2013) and the American Fishery Society fish kill guidance document (AFS 1992), and strives to relate our practices to MassDEP (2013).

Natural fish kills

Common causes of natural fish kills include oxygen depletion events during the winter and summer months, diseases and parasites, and thermal stress during the spawning season. Natural fish kills are most often the result of low dissolved oxygen (DO) concentrations created by a combination of environmental conditions and biological factors. Weather patterns, water temperature, plant growth, fish abundance and condition, along with the presence of viruses and bacteria, are all factors that can influence a DO-related fish kill, and at times be a primary driver in fish kills.

Many fish species can tolerate temporary reductions in DO, however, fish become stressed during prolonged periods of low DO and fish kills may result from insufficient respiration or susceptibility to viral or bacterial infections. A description of the symptoms and condition of species affected by oxygen depletions and other causes are described in Southwick and Loftus (2003 and 2017; Appendix 5A.1). Symptoms of oxygen depletion may include fish aggregating and gulping for air at the water surface or waterbody edges. Other symptoms of oxygen depletions may include a change in the clarity and color of the water and a foul odor may be released. Fish of all sizes are usually affected; however, smaller fish can survive longer under these conditions because they can have lower metabolic requirements and a greater gill surface to body ratio than larger fish. Various scenarios of DO-related fish kills are summarized below.

Nutrients and aquatic vegetation. Moderate levels of nutrients and aquatic vegetation are beneficial to fish populations. During the day plants utilize sunlight to produce oxygen via photosynthesis. During the night plants and animals consume oxygen and produce carbon dioxide (CO_2). In waterbodies with excessive plant growth, the amount of oxygen produced during the day may not be sufficient to sustain aquatic life when multiple nights are followed by overcast days. Fish populations become stressed when oxygen levels are depleted and fish kills may result from these conditions which commonly occur during warm months (June through September), known as "summer kills."

Winter fish kills can occur in waterbodies with excessive plant growth. Ice and snow cover for extended periods of time cause anoxic (oxygen depleted) conditions along the bottom. In the absence of sunlight penetration through the ice, plants stop producing oxygen and oxygen levels become depleted due to the subsequent decay of dead plants and other organic material. Winter fish kills may not be discovered until after the ice has melted.

Planktonic algae. Phytoplankton can become overabundant in waterbodies that receive excessive nutrients from substrate sediments, surface water inputs, groundwater, or runoff. High phytoplankton density in shallow waters may create the same oxygen cycling process generated by rooted plants. If the phytoplankton die-off, the loss of DO generation and rapid decomposition can cause oxygen depletion and a fish kill may result.

Turnover. In temperate regions, turnover is a natural process that occurs in ponds and lakes. During summer, the heat and calm weather causes the water to stratify into layers. The upper layer (epilimnion) is exposed to the sun and receives oxygen from the atmosphere and photosynthesizing plants. The metalimnion is a thin layer where temperature and density changes rapidly. The hypolimnion is a cold, denser, lower layer that lacks sunlight and resists mixing with the upper layers. In this layer, bacteria utilize oxygen to decompose dead animals and plants which can lead to anoxia due to lack of mixing with the upper layers. Turnover occurs naturally in the autumn as the epilimnion cools and the layers gradually begin to mix creating a uniform temperature (commonly near 10°C) throughout the waterbody. In winter, inverse stratification occurs as surface waters cool below the temperature of water near the bottom.

In spring, a combination of increasing wind action after ice-out and rising warmer water at the bottom increases the size of the epilimnion and decreases the size of the hypolimnion. Under certain environmental conditions, turnover can result outside of the natural changing of seasons. For example, the high winds of thunderstorms can cause sudden mixing of anoxic water from the hypolimnion with the epilimnion. The result is a rapid reduction in DO at water column depths occupied by fish which may induce a fish kill.

Thermal Stress. Fish kills caused by thermal stress are common in the spring. Prolonged inactivity during winter months, followed by the stress of spring spawning, leave adults in a weakened state and less resilient to environmental changes. Sudden periods of hot weather can rapidly increase water temperatures in shallow areas of where spawning may occur. The compounding stress may lead to lethal conditions as the adults may become susceptible to infections from bacteria and parasites.

Surface Flow Reduction. Fish kills caused by low flows can occur during the summer months when drought conditions often result but can also occur during abnormally dry periods in the spring and autumn. Migratory species, such as river herring and American shad are susceptible as they migrate between fresh and marine waters. Sudden changes in flow levels (such as flash-flooding immediately followed by drought conditions) can induce fish kills as fish can become stranded in shallow water or dried-up sections of rivers or susceptible to low DO.

<u>Anthropogenic fish kills</u>

Fish kills can also result from direct responses to human influences on water or habitat quality or indirect or delayed influences from pollutants. In contrast to various natural causes that often involve single species and a certain size range, fish kills resulting from anthropogenic activities often affect multiple species of all sizes.

Water usage and withdrawals. Numerous waterbodies in the Commonwealth are utilized as public water supplies by municipalities or as irrigation reservoirs for agricultural. The demand for water increases typically during summer but can continue into the fall during droughts. Various scenarios of water usage and withdrawals during these periods can cause fish kills of juvenile diadromous fish. Water withdrawals can impact young-of-year (YOY) river herring as water quality and suitable nursery habitat are reduced. In addition, water withdrawals and diversions for agriculture irrigation can cause physical damage to fish during pumping and strand emigrating YOY in shallow channels and dewatered areas.

Pollution. In pollution-related events, the magnitude of the fish kill is variable and depends on the concentration of pollutants and tolerance of species to different pollutants as some species are more tolerant than others. Pollutants can enter waterbodies either through direct ("point-source") input or indirectly ("non-point source").

Point Source. The term "point source" as defined in section 502(14) of the Clean Water Act means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel from which pollutants are or may be discharged (USEPA 2014). Various examples of point source pollution include discharge of industrial wastes from factories, chemicals from industrial plants, sewage outflow pipes, and concentrated livestock operations.

Aquatic Herbicides. Herbicide application is a point source pollutant commonly used to treat excessive aquatic plant growth. In Massachusetts, a variety of herbicide agents including Flouridone (Sonar), Glycosphate (Rodeo) have been applied to waterbodies for the purpose of controlling various species of invasive flora such as *Hydrilla sp.*, milfoil and fanwort. Results of various case studies of herbicide treatments in Massachusetts waters are referenced in Mattson et al. (2003). Approval to apply chemicals to control nuisance aquatic vegetation is granted under authority of the Mass*DEP* General Laws c. 111, s. 5E (Mass*DEP* 2016). Treatment should be administered gradually and at certain times of the year. Treatments of dense invasive plants can create excess decaying plant matter. This in turn triggers rapid growth of bacteria and can create lethal conditions for a variety of aquatic life as oxygen levels in the water become depleted.

Piscicides. Use of piscicides is a tool for fisheries managers to manipulate fish communities for a variety of purposes including reclamation (Schnick 1974), controlling or eradicating harmful exotic fish, quantification of populations (Parker 1970; Shireman et al. 1981), disease control, or to restore endangered species (Bettoli and Maceina 1996). Application of piscicides such as rotenone is effective in the complete eradication of undesirable fish communities or for sampling a fish population (Finlayson et al. 2000). Few piscide applications have occurred in Massachusetts in recent decades.

Nonpoint Source. Nonpoint source pollution is the transfer of pollutants into waterbodies from many diffuse sources including runoff from land, precipitation, atmospheric deposition and drainage (USEPA 2014). Nonpoint sources of pollution are common in developed areas and can include the following:

-Excess fertilizers, herbicides and pesticides from agricultural lands, golf courses and residential areas

-Toxic chemicals from urban runoff and energy production

-Sediment from construction sites, agriculture and forest lands, and eroding streambanks

-Bacteria and nutrient input from septic systems and livestock operations

-Hydromodification (alteration of the natural flow of water through dams, landscaping, stream channel modification, streambank and shoreline erosion control measures

Water intake operations. In many areas, ponds, lakes, rivers and estuaries serve as water supplies for agricultural operations, water treatment, desalination and power generation. Such operations rely on intake systems to withdraw water for irrigation and in the case of power plants for cooling system operations. Conventional water intake systems are fitted with screens to prevent large organisms and debris from entering and obstructing the systems, however, they can impact various aquatic organisms and habitat. Impacts of water intakes on diadromous fish populations have been well documented (Christensen et al. 1977; Goodyear 1977; McCaughran 1977; Saila and Lorda 1977; Swartzman et al. 1977; Hanson et al. 1977) Adverse effects of water intake systems on aquatic organisms can be divided into the following major categories: a) *entrainment* of fish eggs and larvae and other small organisms; b) *impingement* of larger organisms on the intake screening systems; and c) impacts from discharge of thermal effluent on the aquatic community and habitat.

Impingement and entrainment. Impingement occurs when organisms sufficiently large to avoid passing through the screens are trapped against them by the force of the flowing water. Juvenile and adult fish may be killed quickly due to mechanical abrasion and suffocation or may become stressed and eventually killed due to exposure to disease and predation. Entrainment occurs when marine organisms small enough to pass through the screens enter or are drawn into the intake system. Entrainment often occurs to juvenile species and mortality is high as they pass through to the treatment facilities, turbines or irrigated fields with various mortality rates reported for adults (Chittenden 1973).

Thermal effluent discharge. Many power plants require water for their cooling systems however, this results in heated water being released back into the receiving environment. Sedentary species (i.e. shellfish), juvenile fish (Ruelle et al. 1977, Beitinger et al. 1999; Madden et al. 2013) and habitats in close proximity to the discharge site can be impacted due to exposure to processed water that has higher than ambient temperature, ash from fossil fuel plants, or radioactive wastes from nuclear plants.

Water Drawdowns. The drawing down of water levels at the control structures of lakes, ponds, and reservoirs is a management practice that can be used for specific goals such as invasive plant control or water quality improvements. The timing is typically the winter to avoid impacts to aquatic life. Fish kills are not common during drawdowns with standard practices yet can occur outside of winter months, from isolated dewatering, and disruption of hypolimnetic anoxic waters.

Jurisdictional Boundaries

This section directs DMF staff in responding to reports of diadromous fish kills, and can serve as a guide for all fish, shellfish and other invertebrates found within Massachusetts marine and estuarine waters as well as "coastal waters" (rivers and impoundments) as described in the Massachusetts General Laws (MGL) Chapter 130, Section 1:

Chapter 130: § 1. Definitions; rules of construction. "Coastal waters", all waters of the Commonwealth within the rise and fall of the tide and the marine limits of the jurisdiction of the Commonwealth, but not waters within or above any fishway or dam nor waters above any jurisdictional boundary legally established pursuant to MGL Chapter 130: § 5 in rivers and streams flowing into the sea.

The provisions of MGL Chapter 130, § 5 empower the Directors of DMF and DFW to determine the jurisdictional boundaries in rivers and streams flowing into the sea for purposes of fisheries management authority. Approximate locations delineating the jurisdictional boundaries between the two agencies are listed in Appendix 5A.2. In most coastal systems of the Commonwealth, the boundary separating the jurisdiction between the two agencies is located either at the "head of tide" or at the first obstruction on a coastal stream. Exceptions to these boundaries are described in a Memorandum of Understanding (MOU) between DFW and DMF prepared in 2003 for the purposes of creating a uniform regulatory process for the two agencies. The provisions of the MOU recognize that management of anadromous striped bass (*Morone saxatilis*) and river herring, alewife (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*) shall fall within the regulatory authority of MA DMF in all waters of the Commonwealth. Jurisdiction for all other diadromous species is split between DFW and DMF at the coastal boundaries.

Reporting a Fish Kill

First Response. For fish kills involving marine resources under DMF jurisdiction (as described in MGL 130 s. 1), staff biologists under the Recreational and Diadromous Fisheries Program are designated as the primary responders. In certain cases, investigations can involve other state agencies, municipalities and federal agencies and may require the expertise of professionals from several disciplines. For example, the U.S. Endangered Species Act gives the U.S. Fish and Wildlife (USFWS) Service and the National Marine Fisheries Service (NMFS) the authority to investigate fish kills if endangered or threatened fish are harmed or if the affected area is critical habitat for such species (DOC-NOAA 1999). In the event of fish kills that involve known pollutants, DEP should be notified and monitoring on the extent and value of marine and diadromous resource damage should be coordinated with DEP.

The following steps to take following the notification of a fish kill were adopted from the joint MassDEP and FWE fish kill SOP (MassDEP 2013) with the addition of references to specific DMF actions:

Notifications of fish kills from the public

1. All reports of fish kills in coastal waters received by DMF staff should be reported Diadromous Fish Project staff in Gloucester (for the region of Newbury to Hull) and New Bedford (for the region of Cohasset to RI Border).

2. The Diadromous Fish Project staff will determine if the resources impacts are diadromous fish or other jurisdictional marine species. If the resources are not diadromous fish, then regional staff from the Recreational Fish Project or Shellfish Project will be contacted. Once the fish kill responsibility is assigned, DMF staff should contact the DFW Fish Kill Coordinator.

3. Call the DFW Fish Kill Coordinator at (508) 389-6334 (office) or at the DFW Fish Kill Notification phone at (508) 450-5869. If the DFW Fish Kill Coordinator is not available, leave a message including the name and number of the witness and the location of the fish kill. .

4. The lead DMF staff should document the event by opening a Fish Kill Notification form (available on DMF Wiki site and W:\drive).

5. If the fish kill may involve pollutants or other anthropogenic influences, the lead DMF staff should contact the DEP Emergency Response team as described in the following section.

6. For fish kills that require an investigation (based on size/severity/species) the MA Environmental Police (MEP) should be notified. Contact the MEP Hingham Radio Room at 1-800-632-8075.

7. Communications with media outlets must be first approved by the Department of Fish and Game press secretary.

Notifications of pollution-related fish kills

1. Upon investigation of any fish kill in which pollution is suspected, the investigating agency will contact DEP via the DEP 24-hour Emergency Response number (888) 304-1133. All fish kill notifications and referrals received by the DEP BWSC ER, including marine and estuary fish kills, will be considered a Significant Incident Category 9 under the BWSC Significant Incident SOP. BWSC

ER personnel will take the lead on investigating the source, sample collection and delivery, and begin case development.

2. In the case of pollution-related fish kills that appear to be the result of negligent or intentional activity, BWSC will contact DEP Environmental Strike Force (ESF). ESF personnel will take the lead on investigating the source, sample collection and delivery and begin case development.

3. For fish kills resulting from pesticide applications, the Massachusetts Department of Agricultural Resources (DAR) is the lead agency responsible for the administration of the Pesticide Control Act (M.G.L. Chapter 132B, Section 1-15), including the administration of the Federal Insecticide, Fungicide and Rodenticide Act. DMF will notify the fish kill response coordinator for the DAR (Pesticide Bureau) in cases where pesticides are likely causal factors. DAR personnel will be responsible for the collection and analysis of water and fish samples, and identifying contaminants, sources, and responsible parties.

Response and Assessment Procedures

Upon arrival at the site, and confirmation that a fish kill has occurred or is occurring, the following procedure should be followed.

1. Talk to any witnesses or observers. Take a statement from any person at the scene who may be have pertinent information. Record name and contact phone numbers.

2. Consult with local officials such as the local Herring Warden or Shellfish Constable, Department of Natural Resources (DNR) official, Municipal Board of Health (BOH), or Conservation Commission as necessary.

3. Determine and delineate the extent of the kill area on a chart or map. As needed, stakes, marker tape or buoys can be deployed to temporally mark the extent of the kill area(s).

4. Inspect the site to determine the cause of the kill. If visual observations or other evidence confirm an obvious chemical contaminant contact DEP ER who will take the lead on the investigation. Do not sample the area until ER personnel are onsite and give authorization.

5. If no chemical contamination is implicated or if clearance to sample is given by DEP personnel, proceed with an investigation. Begin filling out the Fish Kill Investigation Report Form (Appendix 5A.3) and continue to use it throughout site inspection.

6. Photographs should be taken of the site landscape and dead or affected fish and any other materials suspected of being associated with the fish kill. The date, time, and location of sequential photographs and the name of the photographer should be recorded in a field notebook.

7. Water quality measurements should be made along the entire extent of the kill and in nearby un-impacted areas (reference area). Take a minimum of three measurements in each area. Measure water quality at a center point of the fish kill area and at 25 m to either side of the center point. Add measurements at 25 m intervals as needed. Measure 5 m from the shoreline at 0.3 m depth and 1.0 m depth. Document any changes in the measurement locations necessitated by site-specific conditions. Document the exact location of each measurement in the field notebook and the Fish Kill Investigation Report Form. Water quality instruments should follow QA/QC procedures provided in SOP 2.0. Testing should include the following parameters:

a. Water temperature
b. DO
c. Salinity
d. Specific conductivity
e. pH
f. Turbidity

8. *Biosample collection.* In cases of fish kills in which pollution is not suspected, the following protocols should be followed in the collection and preparation of biological samples:

a. Wear gloves and other protective wear when collecting samples.

b. Place live samples in ambient water (do not use water from another source).

c. If fish are dead, place 5-10 of each species (in freshest condition) in separate ziplock bags and cover with ice to be subsequently frozen. Make sure each bag is labeled with a Chain of Evidence (COE) tag.

d. Inspect and dissect a few of the fish samples saved. Record internal and external observations of physical abnormalities (refer to the Fish Kill Investigation Form 5A.3 for a list of physical conditions).

e. Record all relevant observations in the field notebook and on data sheets.

f. Photographs should be taken of dead or affected fish and other organisms.

g. Specimens should be identified by species, and size and weight measurements should be made and recorded on the Fish Kill Subsampling Form (Appendix 5A.4). Where possible, life stage, sex and maturity information should be recorded.

9. *Fish Number Estimation.* The investigator should attempt to derive an estimate of the total number of organisms affected as the result of the fish kill. The appropriate method of estimation is dependent on the size, location, and accessibility of the fish kill area. In many cases it will not be possible to obtain a complete enumeration due to large numbers of fish dispersed a wide area (Ryon et al. 2000). Therefore, various survey sampling methods described by Labay and Buzan (1999) and Southwick and Loftus (2017) can be performed.

a. <u>Complete enumeration</u>: Complete counts can be applicable for small-scale fish kills that occur within a defined area that is accessible to investigators.

b. <u>Survey Sampling:</u> Survey sampling is applicable for large-scale fish kills in which complete counts are is not possible. Survey sampling relies on conducting counts and collecting samples from a representative portion of the area affected to derive an estimate of the entire kill. For statistical and legal purposes, the sampling method must be as defensible as possible. The following guidelines should be applied for two common methods of survey sampling: shoreline counts and area sampling.

-Sample units are areas in which all fish are counted and measured and expanded over the entire area affected to derive a total estimate of fish killed.

-Sample units must be chosen at random to avoid introducing bias in the sampling design and estimates of the total number of fish killed. Select a suitable random number generator and document the usage.

-Precision depends on sample size and number of fish counted and is reflected by the coefficient of variance (CV) in the estimate. Sample designs should seek a CV of ≤25% and document the factors the cause exceedances.

<u>Shoreline count</u>: In coastal areas which are affected by both tide and wind, dead fish usually accumulate along the shoreline. Determine the length of the affected area. Subdivide the shoreline by appropriate (to scale) sampling segments of fixed length. Determine the total number of segments. Randomly select at least five segments to sample. All dead fish from selected segments are counted and measured, and the counts are expanded with a subsampling ratio (n) over the entire affected shoreline to estimate the total number of fish killed.

Apply the following equation to generate the subsampling ratio:

$n = N_t/N_s$

where N_t is the total number of segments and N_s is the segment numbers to be sampled.

. <u>Area sampling</u>: May be applicable for fish kills that occur in shallow ponds and inlets as well as open water such as embayments where counts must be made by boat. Set at least three transects that span the affected area. Determine the length of each transect. Randomly select along each transect at least five segments (quadrats) of standard dimensions in the range of 1-5 m^2. Therefore, the minimum number of quadrats sampled would be 15.

All dead fish from selected quadrats are counted and measured, and the counts are expanded with a subsampling ratio (*n*) over the entire affected area to estimate the total number of fish killed. Apply the following equation to generate the subsampling ratio:

$n = N_q/N_s$

where N_q is the total number of quadrats and N_s is the transect numbers to be sampled. All dead fish from selected quadrats are counted and measured, and the counts are expanded over the entire affected area to estimate the total number of fish killed.

Sample Variance. The sample variance should be calculated from the fish counts recorded for N_s and used to derive CV. In cases, where large numbers of segments with zero fish are counted, variance can be calculated from the geometric mean of N_s.

<u>Fish Kill Valuations</u>

The assessments for large-scale fish kills of fish, shellfish and invertebrate species under DMF management jursidiction should include monetary valuations. Refer to Southwick and Loftus (2017), a guide produced by the American Fishery Society, for valuations on fish and other aquatic life. Replacement and restoration costs include the acquisition and transportation of fish from hatcheries or donor system to recipient waters, as well as the associated costs of vehicles, fuel, water, personnel and equipment. In addition, the costs of conducting the investigation including personnel, transportation, field equipment, sampling supplies and disposal of dead fish should be documented. Such information should be documented electronically (see Reporting) and be made available upon request for enforcement and litigation cases.

<u>Safety Equipment and Sampling Supplies</u>

All DMF staff that responds to fish kill are required to possess and employ safety and sampling equipment. In addition, all responders must have the required field data sheets for data and sample recording, photo, site and pollution documentation. Water chemistry instruments should be field calibrated before use following the specifications of SOP 2.0 in this QAPP. DMF staff should also have up-to-date contact information of town herring wardens and Department of Natural Resources staff, ELE and MassDEP personnel.

<u>Reporting</u>

All DMF fish kill investigations will be documented in a Fish Kill Investigation Report Form and Fish Counting Record Form (5A.3 and A5.4). Essential information will include initial time of notification, response actions, notes on observations, sampling times, names and contact information of witnesses, and other agency staff. These forms document the investigative process and may undergo judicial review if a polluter is brought to court for damages. In addition to paper filing, all fish kills will be documented in an Excel fish kill datafile with information fields related to the above mentioned forms.

Draft reports should be completed and submitted within 48 hours or the next two business days following the fish kill and an electronic copy sent the Diadromous Fish Project Leader depending on the severity of the fish kill, and upon request, these reports will be made available to DFW, MassDEP, ELE, and EOEEA for documentation, enforcement and litigation. In latter cases (pollution-related or intentional activities) where enforcement and litigation against and individual or party is warranted, a detailed final report is required. In such cases, DMF fish kill investigators are required to contribute the following documents:

a. Copy of the original field fish kill report form

b. Summarized discussion of the investigative procedure, findings and conclusions

c. Maps delineating kill area and sampling sites

d. Copies of Chain of Evidence Record

e. Laboratory analyses results

f. Pertinent biological data collected such as tables of fish species collected and their respective sizes

g. Literature references relative to known toxicities of the causative agent

h. Reference to state and federal laws violated

i. Monetary values of fish and other organisms killed and the cost of investigation (Southwick and Loftus 2017)

j. Photographs documenting the kill

k. Recommended action(s)

Follow-up Investigations and Reporting

Follow-up to fish kill investigations will be handled on a case by case basis. Information, data, analyses and recommendations from subsequent investigations will be recorded and archived (both paper and electronic files) with the original case at either the DMF New Bedford or Gloucester facilities and shall be made available upon request by agencies for enforcement and litigation cases.

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Appendix 5A.1. Fish kill site conditions and possible causes (source: Southwick and Loftus 2003).

Condition(s)	Possible cause
Fish gulping for air at the surface Low dissolved oxygen Green water	Oxygen depletion due to organic matter input from sewage treatment plants, livestock feedlot, irrigation run-off, or algal bloom (green water)
Fish gulping for air at the surface Adequate dissolved oxygen Discolored water	Restored oxygen levels after depletion by organic matter from sources (above) Toxic concentrations of Ammonia Toxic algal bloom (discolored water)
Fish dying after heavy rain	Run-off of pesticides or other chemicals from adjacent agricultural fields or discharged from spraying
Oily sheen on water	Seepage from refinery, drilling operation or pipeline; or petroleum spill from vessel or truck
Stream bank and substrate covered with an orange substance; high water conductivity	Discharge of brine water from drilling operations
Water has low pH (with or without orange discoloration of substrate); high water clarity	Discharge of acidic water from coal mine or chemical spill. Coniferous tree plantations close to water
Small fish dead along shoreline Sub-freezing air temperature	Excessive cold
Small fish dead below a dam or industrial plant discharging heated water	Fish killed by entrainment through intake valves, turbines or from exposure to thermal shock
Kill restricted to one species or size class	Spawning stress, disease pathogen