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BACTERIAL KIDNEY DISEASE

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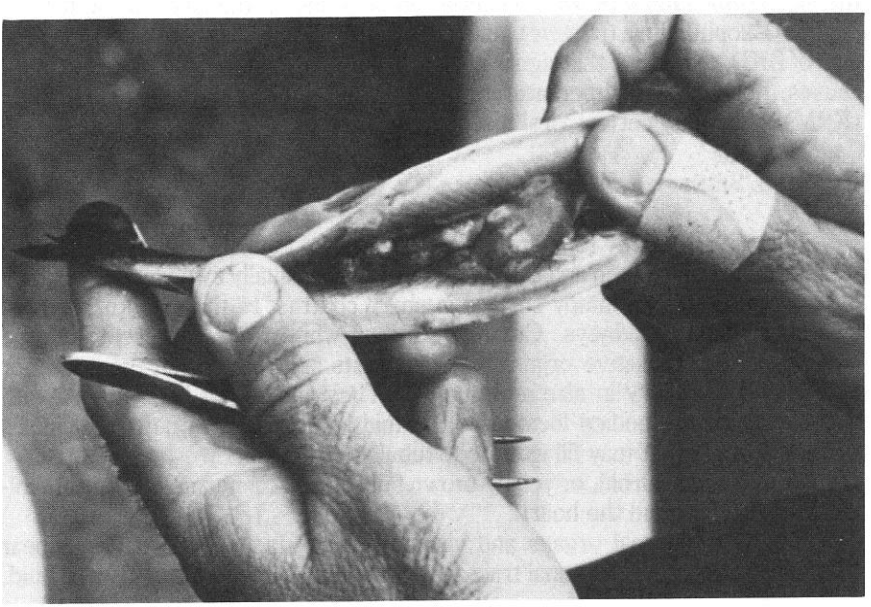
Bacterial kidney disease (BKD) of salmonid fishes is a slowly progressive, systemic infection with a protracted course and an insidious nature. Characteris-



Bacteriai kidney disease in trout and salmon is s.ometimes characterized by large abscesses in the kidney. (G. Cameniscb Missouri Dept. of Consenr~

tics of the causative organism, the disease, its epizootiology, and methods of control were recently reviewed by Fryer and Sanders (1981). The bacterium causing BKD is a small Gram-positive diplobacillus named *Renibacterium salmoninarum* (Sanders and Fryer 1980). The pathogen can be transmitted from fish to fish (Mitchum and Sherman 1981) or from adults to their progeny via eggs (Bullock 1980; Bullock et al. 1978). Infected fish may take months to show signs of disease. Water temperature, water hardness, numbers of organisms present, diet, and the species and strain of fish all affect the course and severity of outbreaks (Sanders and Fryer 1981; Paterson et al. 1981a; Bullock 1980). Bacterial kidney disease is one of the most difficult bacterial diseases of fish to treat (Wolf and Dunbar 1959; Snieszko et al. 1955). Research is underway to develop methods to minimize the effect of BKD infections and to improve control measures (Paterson et al. 1981a).

SIGNS OF INFECTION

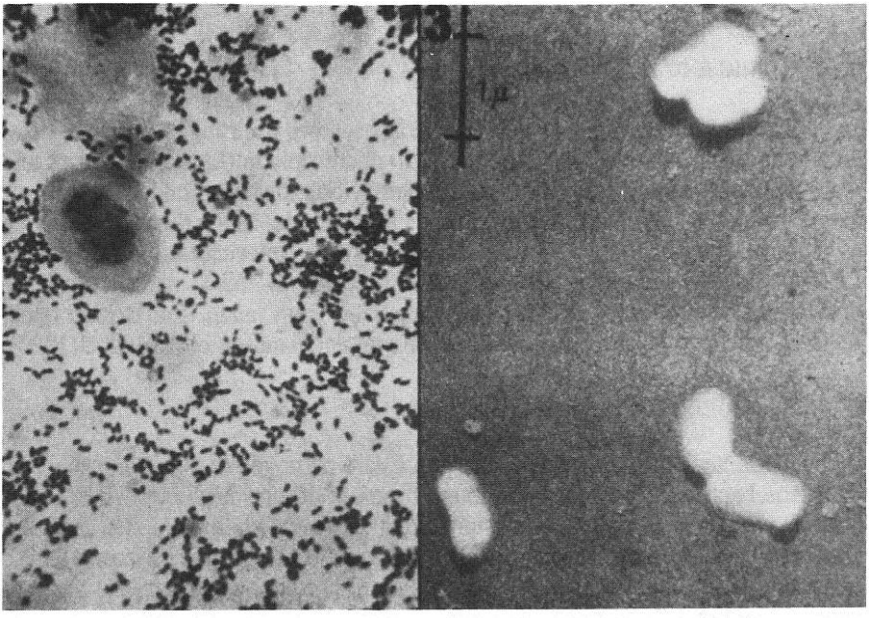
Acute outbreaks occur only occasionally. Sub-clinical cases are commmon and can lead to acute losses if affected fish are stressed.

EXTERNAL SIGNS

1. Infected fish may appear normal. In rainbow and brown trout, there may be a "buckshot" appearance due to the presence of numerous small, open ulcers in the skin that expose the underlying musculature.
2. In brook trout and coho salmon fingerlings and yearlings, large "boils" filled with a pinkish, creamy fluid that contains massive numbers of *Renibacterium* salmoninarum bacteria can be found on the sides of the fish.
3. ExophthaJmia (popeye), due to osmo-regulatory disruption, is a common sign of BKD. However, this sign is not diagnostic since it may also be due to other causes, such as gas supersaturation (gas bubble disease), enteric redmouth (ERM) infections, certain viral diseases, or parasites.

INTERNAL SIGNS

1. As indicated by its name, BKD severely affects the kidneys, and, to a, lesser extent, the spleen and liver. The kidneys are usually swollen, convex, and have a corrugated or lumpy surface in sharp contrast to the smooth, concave surface of healthy kidneys. Creamy, soft, off-white cysts represent massive colonies of the causative organism. Such cysts are common in the posterior kidney and may vary in size and number. They should not be confused with normal stanneous bodies located in the mid-kidney or with nephrocalcinosis (kidney stones) that may fill excretory tubules of the kidney,
2. A bloody, turbid, or yellow-brown fluid often accumulates in the abdominal cavity and around the heart.
3. Other internal organs and visceral fat may appear normal or appear unusually white. The intestinal tract may contain a white or yellow viscous fluid.



Bacteria that cause fish diseases require special techniques for their detection. In the left photo, cells of *Renibacterium salmoninarum* have been stained with crystal violet. The right-hand photo is an electron photomicrograph of the same organism. (J. Fryer, Oregon State University)

DIAGNOSIS

The diagnosis of BKD in salmonids can be confirmed by the detection and identification of *Renibacterium salmoninaruln organisms* in the tissues. Fluorescent antibody techniques applied to fresh, frozen, or formalin-fixed infected posterior kidney tissue will usually reveal the presence of large numbers of small "bean-like" organisms (Mitchum and Sherman 1981; Paterson et al. 1979; Bullock and Stuckey 1975). Gram stains of similar material will reveal many tiny, Gram-positive diplobacilli which often occur in pairs. Fish that are apparently healthy can carry small numbers of the causative organism that are difficult to detect in Gram-stained smears (Sanders et al. 1978). Smears prepared from scrapings of the posterior intestinal tract of asymptomatic carriers may contain more organisms than smears of kidney tissue taken from the same fish (Mitchum and Sherman 1981). Diagnosis of BKD cannot be based, with any certainty, on the observation of a few isolated BKD-like organisms seen in a few microscope fields (Fryer and Sanders 1981). If this situation is encountered, more detailed sampling of the population in question should be initiated with particular attention to yearling trout or the oldest salmon fingerlings available at the site (Paterson et al. 1979; Snieszko et al. 1955).

EPIZOOTIOLOGY

GEOGRAPHIC AND HOST RANGES

The geographic range of BKD generally follows the range of certain salmonid fishes. The disease has been found to occur only in the salmon, trout and char of the sub-family Saknoninae of the family Salmonidae (Sanders and Fryer 1980). Bacterial kidney disease is common in hatcheries along the western slope of the Cascade Range on the west coast of North America, around the Great Lakes, and along the Appalachians from Georgia to the Canadian Maritime provinces. The disease has also been reported from Japan, the British Isles, Iceland, and several European countries (Fryer and Sanders 1981; Bullock 1980).

SOURCES AND RESERVOIRS OF INFECTION

Renibactwium salmoninarum is an obligate pathogen of salmonid fishes. To date, the bacterium has not been found to infect other species of fish or other animals. Salmon, trout, and char inhabiting hatchery water supplies must be considered as possible reservoirs of infection (Mitchum and Sherman 1980; Frantsi et al. 1975). Under good environmental conditions, carriers harbor subclinical infections throughout their lives. Eggs taken from infected broodstocks and adult salmon have been identified as a major source of introduction of BKD at hatcheries previously free of the disease. Outbreaks of BKD can occur a year or more after receipt of contaminated eggs. The slow progress of infections is disarming and makes it diflicult to prevent the spread of the infection to other stocks in the hatchery, to other hatcheries, or to new geographic areas.

MODES OF TRANSMISSION

Bacterial kidney disease is easily transmitted from parent to progeny with eggs. The bacterium is so intimately related to the egg or to the developing embryo that egg disinfection procedures using organic iodine disinfectants do not prevent transmission of the disease via eggs (Bullock et al. 1978). This seriously complicates containment of BKD and explains why egg and fish exchanges have played a significant role in the historical spread of the disease in North America and around the world.

Fish to fish (horizontal) transmission of BKD has been reported both in hatcheries and in the wild. Frantsi et al. (1975) reported hatcherv-reared Atlantic salmon fingerlings contracted BKD from "naturally" infected-wild fish in the hatchery water supply. Mitchum et al. (1979) showed that wild trout could transmit the disease to stocked hatchery trout that had been previously free of the disease.

Many of the early studies on the transmission of BKD dealt with the feeding of infected fish products. Until the mid-1960's, salmon fingerlings were fed a wet diet containing raw ground salmon viscera, ground carcasses of spent broodfish, salmon eggs, and other fresh fish products together with beef liver, spleen and other animal organs. The raw salmon products often carried *R. salmoninamm* and other fish disease agents. These wet diets helped spread and establish BKD and other serious diseases in many Pacific Northwest salmon hatchery stocks (Wood 1974).

Susceptibility and Resistance Factors

In hatcheries rearing Pacific salmon, bacterial kidney disease is detected most frequently in spring chinooks, cohos and sockeyes (Sanders and Fryer 1980). A cross between pink and chum salmon (called a "chumpy") was found to be extremely susceptible (Wood 1974). According to Winter et al. (1980), some strains of steelhead trout are resistant to BKD. Unfortunately, however, BKD-resistant strains also showed the greatest susceptibility to *Vibrio anguillamm,* another bacterial pathogen often encountered by migrating smelts in estuaries. Michigan workers report fewer problems with BKD in the culture of salmon than in trout 0. Hnath, Wolf Lake State Fish Hatchery, Mattawan, MI, personal communication). Among trout and char, the brook trout is probably the most susceptible species. Rainbow and brown trout would rank next in susceptibility while steelhead trout are the most resistant (Mitchurn and Sherman 1981).

Environmental conditions also play a role. Work by Warren (1963) showed that BKD is most severe in hatcheries supplied with soft water and less severe in hard water hatcheries. Many interrelated factors, including mineral metabolism, must be considered. Recent work by Paterson et al. (1981a) showed that, at one hatchery, the lowest incidence of BKD occurred in yearling Atlantic salmon fed diets with increased levels of trace minerals (Fe, Cu, Mn, Co, I, and F) and low levels of calcium. On the other hand, a high incidence of BKD occurred in similar fish fed a standard commercial ration. The commercial feed had a calcium content ranging from 2.0 — 2.7% of the diet. This calcium level may have actually increased trace element requirements in the fish because of increased mineral mobility.

Incubation Period

Fingerlings hatched from infected eggs seldom show signs of the disease until they are at least 6 months of age or about 3 inches in length. As water temperatures rise in the spring, yearling trout may suffer serious losses (Paterson et al. 1981a; Wolf and Dunbar 1959). Sanders et al. (1978) found that the experimental incubation period varied with the water temperature. At temperatures above 11°C. initial losses occurred 30 to 35 d after exposure. At temperatures between 7 and 11C, the incubation period was 60 to 90 d or longer.

SEASONAL Incidence

Outbreaks of BKD occur in cultured trout populations more often in the spring than at any other time of the year. Reported cases more than double in frequency in March, peak in May, and nearly cease in July. Rising temperatures greatly influence the onset of BKD. Warm summer temperatures may also enhance the production of immunological factors that suppress the disease in the fish. Some of the apparent decline in the number of summertime cases of BKD is due to the stocking of yearling trout which removes many of the infected fish from the hatchery. The increased spring time prevalence of BKD outbreaks in cultured trout should be considered when schedules are established for fish health inspections or for routine monitoring of mortalities for fish pathogens.

METHODS OF CONTROL

PREVENTION

Once established, BKD is an extremely difficult disease to manage. Avoidance is the first and strongest line of defense. Hatchery policies, careful planning, a good understanding of the etiology of BKD, and a thorough monitoring program are essential to a successful program of prevention and control. If these efforts fail, a number of other steps can be taken to contain the spread and minimize the overall effect of BKD.

Immunization of salmonids to prevent BKD or to reduce the effects of the disease is a new technique now under development. Paterson et al. (1981b) reviewed this subject and assessed the immunological response of Atlantic salmon to BKD antigens. In testing the efficacy of vaccine preparations, they found that injections of killed *R. salmoninarum* cells alone did not stimulate the production of protective antibodies in the fish. Immunization of Atlantic salmon younger than one year of age was not as effective in reducing the incidence of BKD in two-year-old smoltifying fish, as was the immunization of yearling fish during their second summer. Yearling Atlantic salmon immunized with a single injection of killed *R. salmoninarum* cells, emulsified in Freund's complete adjuvant, showed significantly fewer clinical signs of BKD. However, when the vaccinated and control groups were examined by means of indirect fluorescent antibody techniques, there was no difference in the prevalence of infected carriers among the two groups. Further studies are needed to evaluate what significance these results may have in terms of the severity of BKD in adult fish returning to the hatchery at spawning time.

In ongoing programs where BKD is already present in the adult spawning stock, there is a strong likelihood that the pathogen will be transmitted with the eggs they produce. In Pacific salmon hatcheries, erytbromycin phosphate has been used in attempts to prevent this vertical transmission of the disease agent. Two delivery methods are being evaluated.

Erythromycin phosphate has been injected subcutaneously into the median dorsal sinus just anterior to the dorsal fin of adult salmon and steelhead trout at the time returning fish enter hatchery holding ponds. The adults are given additional injections at 30-d intervals until 30 d prior to spawning. Each fish is given erythomycin phosphate at Il.0 mgikg of body weight. Eggs taken from infected females have been shown to carry drug levels that are inhibitory to *R. salmoninarum* in laboratory tests (Bullock 1980).

A second technique involves water-hardening freshly-fertilized eggs in a 2 ppm bath of erythromycin phosphate for up to one hour (Bullock 1980). The effectiveness of this method as a deterrent to BKD has not been verified in closely-controlled studies. Steve Leek 6. Leek, USFWS, Cook, WA, personal communication) reports a 94.9% eye-up in treated eggs versus an 88.7% eye-up in untreated controls.

Although active work on prophylactic measures to minimize the effects of BKD includes studies on immunization, chemotherapeutics, and nutrition, these techniques have not been integrated with effective inspection programs and improvements in fish cultural management. The key to controlling bacterial kidney disease rests with a fully integrated disease control approach that uses all available techniques.

THERAPY

At present, no drugs are known that will cure fish of BKD. Erythromycin and sulfamethazine control the disease for as long as the drugs are administered. However, when drug treatment is withdrawn, mortality due to BKD often resumes within a few weeks.

KEY STEPS TO REMOVE THE DISEASE AND/OR AGENT FROM FISH POPULATIONS

IMMEDIATE

Because BKD cannot be cured by chemotherapeutics, the only effective short-term cleanup procedure is to remove all infected or exposed fish from a facility and to disinfect the water supply and all rearing units. Pathogen-free eggs or fish can then be introduced and reared free of BKD if the cleanup operation was effective and the disease agent has not been inadvertently re-introduced. Wild stocks are difficult to adequately inspect; some have been found to be a source of BKD (Mitchum et al. 1979).

LONG TERM

Hatchery operations that are involved with anadromous fish species carrying BKD must incorporate every known approach in efforts to minimize the effect of the disease and to eventually eliminate it. The preventive measures discussed above can be used as part of a strategy of "dilution" of the infected population to result in an increasing number of healthy fish. As more healthy fish are stocked, the proportion of infected tish in wild populations can be reduced. Although Mitchum and Sherman (1981) found evidence of horizontal transmission of BKD in the wild, this does not appear to be a widespread problem in most wild salmonid populations. Population densities, stress, water characteristics, and the severity of the BKD infections undoubtedly play important roles. The same factors that influence the transmission and severity of BKD in hatcheries can be expected to influence the occurrence of BKD in wild populations. All things considered, the "dilution" strategy remains the only practical approach available for the eventual reduction of the disease in free-ranging fish populations.

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