THE PHYSIOLOGICAL EFFECTS OF ELECTROFISHING

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ABSTRACT.

Electrofishing is a valuable tool frequently used to assess and manage fish populations. Techniques and equipment for electrofishing have been perfected over the years, but there are drawbacks that some users fail to recognize. One of these drawbacks, physiological stress, can damage or kill a fish weeks after initial contact with the electrical current. This paper summarizes effects produced by using ac, dc, and pulsed dc systems. Specific examples are described. Severity of the shock, which is determined by strength of the field and total exposure time, can be controlled by the user to minimize physiological impacts. Suggestions are made to help reduce physiological stress caused by electrofishing.

INTRODUCTION

Biologists have been electrofishing for many years. It is customarily assumed that most shocked fish recover shortly after capture and release. However, that is not always the case. This paper examines some physiological stresses caused by electrofishing and supplies the biologist with examples of how to prevent injuring fish. It is hoped that this paper acts as a refresher to the user so that electrofishing can continue to be the nonconsumptive sampling tool it was designed to be.

DISCUSSION

Electrofishing is a technique whereby electrical energy is put into the water and fish, intercepting this energy, are drawn toward the probes and incapacitated in such a way that they can be captured with nets. The movement of fish toward the source of electricity is called galvanotaxis and is believed to be a result of direct stimulation of the central and autonomic nervous systems which control the fish's voluntary and involuntary reactions. The involuntary contraction of the fish's muscles causes a forced swimming toward the probe. These are all complex physiological responses which won't be discussed in great detail, however, I will give a general synopsis of these interactions.

When a fish intercepts an electrical current in water, electrical stimuli are transmitted via sensory nerve fibers to modulators (brain and spinal cord) and via motor nerve fibers to affectors (glands and muscles). Neurons within nerve fibers carry impulses by a "wave of electrical depolarization" that moves along nerve fibers producing an electrical potential or polarization that is dependent upon the semipermeable membrane of the neurons. Stimuli must reach a minimum strength or threshold intensity quickly and last long enough to cause impulses to be transmitted. If this does not happen, and stimuli are of low intensity and short duration, impulses will not be transmitted. However, there are instances when

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stimuli of low intensity and short duration can cause impulses to be transmitted. In these instances, there is a cumulative effect (summation) and the impulse is transmitted by the "all or none" phenomena. In general, it's the fish's attraction to the positive electrode, the anode, that makes electrofishing possible. This is caused by a brain reflex in the fish that causes a forced swimming toward the anode (Vibert 1963).

External Factors Affecting Electrofishing Success

It is well known that electrofishing techniques are selective to larger fish. A bigger fish has more total surface area than a smaller fish, thus receives or is exposed to more current or total energy, and is, therefore, easier to collect. Larger fish usually receive a greater shock because total body voltage increases with length. I've broken the external factors that affect electrofishing into four main groups: size, species, physiological condition, and environmental conditions.

Size. The total surface area of a fish can influence the success of capturing it with electric current. Sometimes this principle may be a little deceiving because we tend to think of big fish more in terms of length and weight rather than total surface area. For example, it would appear to be easier to collect a 6-inch northern pike (*Esox lucius*) than it would be to collect a 6-inch bluegill (*Lepomis macrochirus*). However, the total surface area of the bluegill is greater than the fusiform shaped pike (Figure 1).

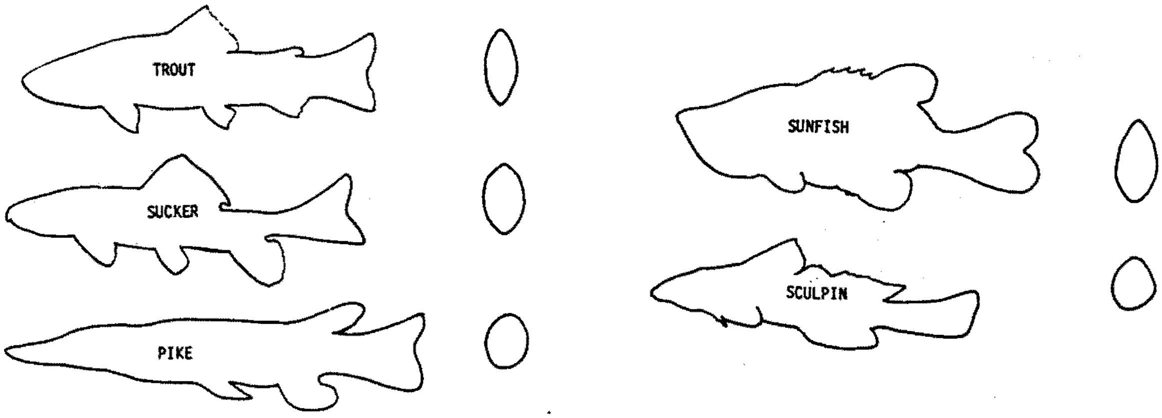

Figure 1. Morphology and cross section of various fish species. (Not drawn to scale.)

Two examples that demonstrate size selectivity of electrofishing gear are: 1) electrofishing gear was about 25% effective in collecting 2 1/2 inch long brook trout (*Salvelinus fontinalis*) and about 70% effective in collecting 8 1/2 inch long brook trout (Figure 2) (McFadden 1961); and 2) small fish have less total surface area, therefore, the fish absorbs less energy and recovers quicker. Common shiners (*Notropis cornutus*) ranging from 85-95 mm long, took about two minutes to fully recover after receiving a dc current, while smaller fish, 65-70 mm long, took about 45 seconds to recover (Figure 3) (Adams et al. 1972).

Species. Each species is unique and reacts differently to an electrical current. Vulnerability to electrofishing varies among species because of differences in anatomy and behavior (Reynolds 1983). Some species have large thick scales to protect them from the penetrating electrical energy (e.g., common carp, *Cyprinus carpio*). Others, like the catfish (Ictaluridae), have no scales for protection. Some small-scaled species, like trout (Salmonidae) and eels (Anguillidae), are easier to collect than thick-scaled species. There are also species that are adapted to staying on the bottom. These species have high specific gravity, may lack a swim bladder, or have a rudimentary one like some darters (Percidae) and sculpins (Cottidae), have fewer scales,and tend to roll over and become lodged in rock crevices when shocked, making them hard to see and difficult to collect. Other species that are pelagic are not easily captured by electrofishing because they stay in waters that are too deep to be electrofished. Species that exhibit territorial behavior are easily captured because they are not normally frightened by an approaching electrofishing operation. By targeting a species, the collector can do things to improve the chances of collecting them by electrofishing. For example, by increasing the pulses per second on a backpack shocker, one can collect smaller fish that would normally not be collected.

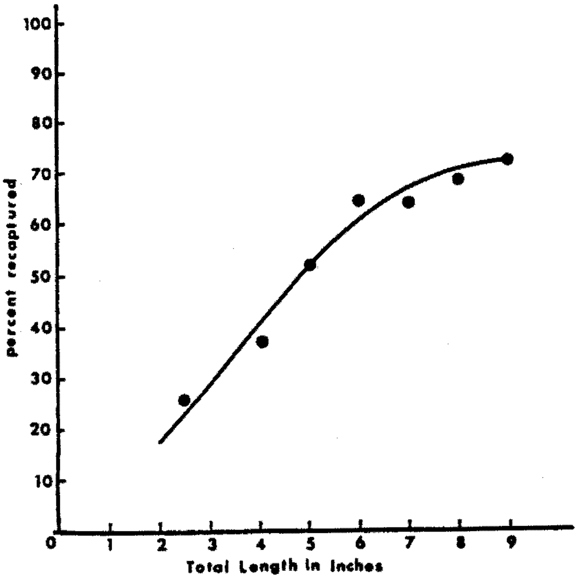

Figure 2. Percentage of marked trout of various lengths recaptured with 230-volt, 2500-watt, direct-current electrofishing gear (McFadden 1961).

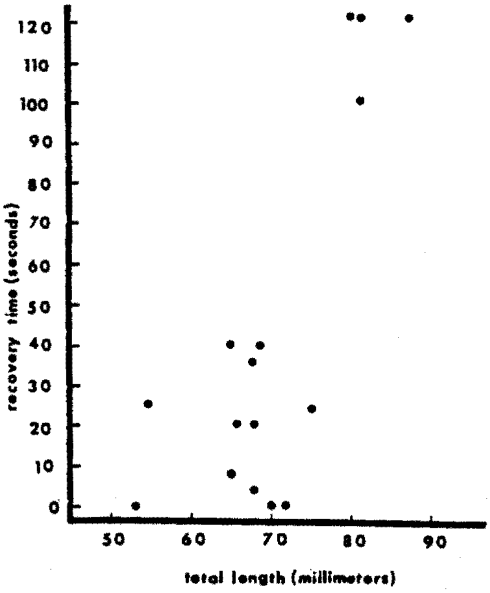

Figure 3. Relation between recovery time measured in seconds, and total length of common shiners (Adams et al. 1972).

Resistance, or the ability of individual fish to conduct electricity, varies greatly among species. The resistance of a fish acts to reduce the voltage gradient that it encounters from head-to-tail, and it is that change in gradient that is needed to make electrofishing possible. Normally a head-to-tail gradient of from 0.1 to 1 V/cm of fish is required to collect fish with an electrical current. The resistance of various species affects their ability to be collected with electrofishing gear. The four species listed in Table 1 show a range of resistivity (Halsband 1967).

Table 1. Calculated resistances for various types of fish (adapted from Halsband 1967).

Species	Resistance (ohm/cm)
Trout	818
Perch	981
Carp	1,149
Gudgeon	1,228

The trout has less resistance than the carp and is thus more susceptible to electric current. The higher the resistivity of a fish, the more current it can absorb without effect. Resistance can also change with temperature. Table 2 shows how the resistivity of carp changes with temperature. At low temperatures (5°C) the resistivity of carp is very high, requiring more electricity to drive a current through the fish. At warmer temperatures (25°C) the carp's resistance is low and it takes less electricity to cause a response in the fish. This is a little misleading, in fact, since the carp is a warmwater species. At warmer temperatures, it is able to avoid an electrical field easier because it is at its peak metabolically and physiologically.

Table 2. Effects of temperature on resistivity of carp (Adapted from Whitney and Pierce 1957).

Temperature °C	Fish Resistivity (ohm/cm)
5	2,690
10	1,840
15	1,400
20	975
25	508

Physiological condition. As seen with the carp-temperature example given above, the physiological condition of a fish can affect its ability to be captured. If a fish has already been stressed by some metabolic disturbance, it will not be able to escape as easily as if it were a perfectly healthy fish in its normal environment. Many things can cause the physiological condition of a fish to change: the fish may have recently undergone stresses associated with spawning, been exposed to toxic chemicals, or be in water that is of marginal quality because of temperature changes, pollution, or other factors. A freshwater fish that has been shocked is stressed and tends to lose ions to the water around it. It takes awhile for that fish to recover and osmoregulate normally again. These features will be discussed in greater detail elsewhere in the paper.

To minimize the effects of electrofishing, and to insure that a healthy fish is returned to the water after shocking, there are a couple simple things that can be done. Place the fish in holding tanks containing a 1 1/2% salt solution or a light anesthetic such as MS-222 or quinaldine to reduce additional stressing. The salt helps the fish replace lost ions and the anesthetic slows the metabolism and helps to minimize any additional stresses that might occur from holding or handling. It is also important that fish held for processing are not overcrowded or kept in poorly oxygenated waters.

Environmental Conditions. These factors are closely related to physiological condition. When fish are at their optimal temperature for instance, they are likely to be at their peak physiologically and best able to escape an electrical field. A warmwater species is more adept at escaping in 25°C water than in 10°C water. If a fish is in a situation where temperature is causing stress, electrofishing will capture that fish easily--but it may also make that fish more susceptible to internal injuries. A fish at its peak physiologically, and in its favored habitat, will be more adept at avoiding electric fields. One example that comes to mind is the northern pike. There are many contradictory reports in the literature concerning its ability to be captured by electrofishing (Vibert 1967, Novotny and Priegel 1974, and Sternin et al. 1976). The difficulty in capturing this species is probably due to a combination of factors: its excellent lateral line senses that enable it to detect the presence of electrical fields or the approach of a boat; its natural habitat of heavily vegetated waters that offer avenues of escape and may affect the size and effectiveness of the electrical field; the pike's fusiform body, which reduces surface area; and its swimming habits (strong spurts of speed) which might carry it out of an electrical field.

Seasonal climatic changes can also affect electrofishing by causing changes in water temperature which greatly affect fish and conductivity of water. In addition, in late fall and during winter months, many fish move into deeper waters where electrofishing equipment cannot reach them. The spring may be the best time of the year to sample fish in temperate regions because many fish are moving into the warming shallower nearshore areas where they are readily accessible to electrofishing. Electrofishing has been shown to be most efficient when used to sample small, shallow, clear water streams during low flow conditions.

Internal (physiological) Effects of Electrofishing

A fish goes through a number of different behavior patterns before it becomes fully tetanized from electricity. Vibert's (1963) paper is one of the best references I've seen for describing the reactions of fish in an electrical field. These reactions won't be discussed in this paper, but the conditions created internally by fish reacting to these currents are important clues as to how severely a fish may or may not be injured.

There are many internal changes that can occur to a fish that has been electrofished. I like to use the analogy of what happens to the long distance runner after running for a period of time to help understand what happens to a fish when it enters an electrical field. After running for a certain distance, a runner builds up carbon dioxide in the bloodstream. The muscles outpace the ability of the bloodstream to supply oxygen. As a result, lactic acid accumulates in the muscles and interferes with their function. The muscles tighten up or "tie up," fatigue sets in, and the runner cannot maintain his speed. This effect has been labeled many names by running enthusiasts (e.g., the "wall," "balk," "tie-up," etc.), but the end result is the same. For readers who are non-runners, and have experienced a muscle cramp, the effects are from a lactic acid build-up. At any rate, a runner is unable to resume his speed until that build-up of lactic acid is removed from the bloodstream.

When a fish first comes into contact with an electrical field there is an increased respiratory action. Some researchers have even observed a violent coughing in the first 30 to 60 seconds after shocking has stopped (this fish is trying to get oxygen across the gills and into the bloodstream). Then, depending on its orientation in the field, there is a series of rapid muscular contractions as the fish is drawn toward the anode. Like any working muscle, these contractions cause a build-up of lactic acid and an increased oxygen debt. As the fish undergoes a further depression of its motor activities, and is drawn nearer the anode, it becomes impossible to ventilate or to remove the lactic acid and it suffers an increased oxygen debt. The fish has just "worked" as hard as the runner.

In man, the blood lactate levels developed after exercise decline within one hour after the exercise, but in fish, the decline in blood lactate to resting levels takes much longer (4 to 12 hours). This is probably due to the slower rate of diffusion of lactate across living membranes at lower temperatures (Black 1958, Black et al. 1960).

Physiological monitoring of fish through blood chemistry studies are ways of monitoring stress in fish. Schreck (1976) diagrammatically depicted several hypothetical levels or adaptive stages that a fish goes through once it has been stressed (Figure 4). This example can also be used to describe what happens to a fish when the stressor is an electric shock. The wiggly line in Figure 4 represents the normal oscillations of fish under normal conditions. Once a stressor, in this case an electric shock, is applied, the fish immediately responds to that stressor through an alarm response. There is an internal resistance to that alarm. The fish has a choice of moving out of the electrical field or suffering the consequences. One of the physiological consequences of this stressor is that the rapid contraction of muscles causes a build-up of lactic acid in the blood. What can a fish do now that it has changed its physiological state? Several things can occur. As Schreck (1976) has shown, the fish can go through several levels or adaptive stages during which time it will either recover (adapt) or die. If the shock has not been too severe (severity is directed related to the total electrical energy absorbed by the fish and to the length of time spent in the field), the fish recovers after a period of time and returns to normal (line 2). There may be a period of time after the shock that the fish remains quiet, rests on the bottom, or is compensating for the energy absorbed, but has not quite recovered to normal (line 1). After a while, it too recovers to normal. If the fish can't compensate, it might end up in one of the other hypothetical stages (lines 3-5). In these stages, blood lactate has increased to such a level that the fish either adapts or dies. Once the lactic acid reaches a certain level in a fish (e.g. line 5), it may be unable to fully recover. That fish may appear to be alright at release, but it will eventually die. This point of no return caused by lactic acid build-up is a killing phenomena known as lactic acidosis and was discovered by Black (1958) while conducting hyperactivity studies on fish. Since then it has been reported by other researchers studying fish (Caillouet 1968, 1971) and has also been shown to cause death in humans (Huckabee 1961).

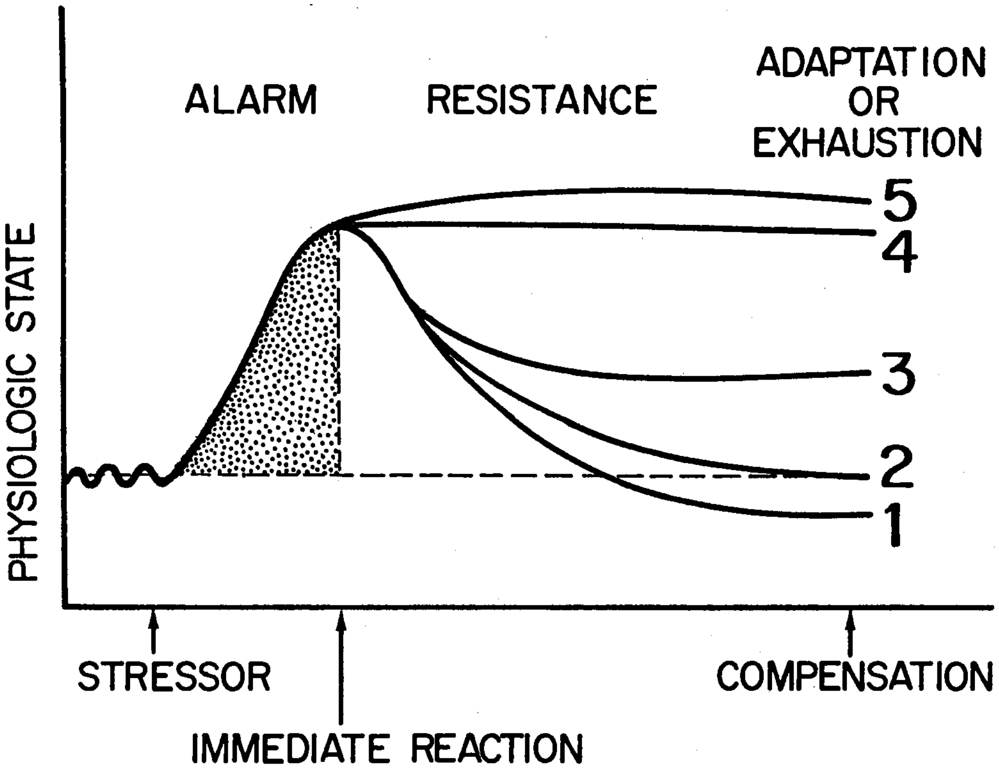

Figure 4. The potential responses of physiological systems (physiologic state) such as hormones, metabolic rates, and circulatory-respiratory characteristics over time following the application of a stressor (Schreck 1976).

What I have discussed may be an over-simplification of a complex physiological phenomena. Recently, it has been determined that the cause of death is not the result of acid accumulations in the blood, but rather the result of intercellular acidosis. The white muscle cells that produce lactic acid in fish are unable to remove the hydrogen ions from the intercellular spaces at the same rate as that in the blood, and death results (Wood et al. 1983, Holeton and Heisler 1983).

The point to be made about Figure 4 is that once a stressor has been applied, there is some time period during which the metabolism or physiology of the fish will be affected, and during this time period, the fish will either return to normal or will be pushed out of normality. These stress reactions can occur rapidly and can be influenced by the size of the fish and water temperature or other factors (R. Wydoski, USFWS pers. comm.). In general, electrofishing creates a general stress lasting several hours.

Two experiments, one by Schreck et al. (1976) and one by Sternin et al. (1976) have measured the blood lactate and oxygen levels in shocked fish.

Schreck et al. (1976) observed changes in lactate levels in the blood of rainbow trout (*Salmo gairdneri*) immediately after shocking (dc current) (Figure 5). The lactic acid levels in the blood doubled immediately after the fish were shocked and remained high for one hour and recovered to preshock levels after approximately six hours. The rapidity of lactate increase after shocking reflects the severity of the period of anaerobic muscular activity. Schreck's et al. (1976) lactate increases after shocking were much the same as those found by other researchers for different species (Johnson et al. 1956, Caillouet 1967, Burns 1978). The recovery is also similar to that observed in rainbow trout that have undergone strenuous muscular excerise (Black et al. 1960). Other blood chemistry changes occur as a result of shocking. For example, glucose follows a reaction similar to lactate except the increase is not as abrupt and recovery takes longer (up to 12 hours) (Schreck et al. 1976). The U. S. Environmental Protection Agency has recommended that fish collected by electrofishing not be used in physiological or bioassay studies because of blood chemistry changes (Weber 1973).

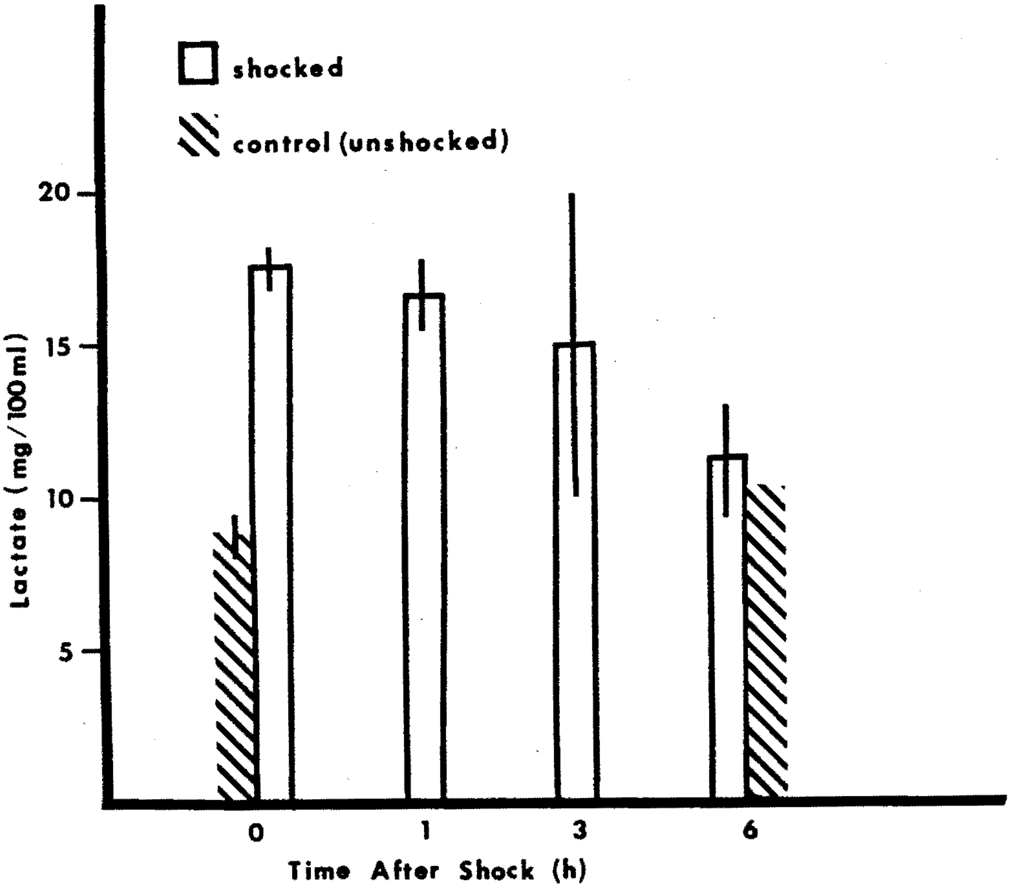

Figure 5. Average concentrations (mg/100 ml) of lactate (vertical line at top of each bar shows range) levels in plasma of electroshocked and unshocked rainbow trout (adapted from Schreck et al. 1976).

Fish differ greatly in their ability to carry oxygen in the blood (Table 3). The amount of oxygen in the blood can play an important role in breaking down metabolites released into the blood following electrofishing or in determining the overall vitality of a fish. Temperature of the water (the cooler the better) and life stage of the fish can also affect the amount of oxygen in the blood.

Table 3. Oxygen capacity of blood of different fish (Sternin et al. 1976).

Species	Percent of total volume of blood
Pike	5.4 - 7.8
Cod	6.5 - 7.8
Trout	9.5 - 13.4
Eel	10.2 - 15.6
Carp	11.5 - 16.8

Pike have relatively low amounts of oxygen in the blood, carp have high amounts and trout are somewhere in between. These individual variances in oxygen content will affect the ability of fish to recover from electrofishing.

Sternin et al. (1976) examined what happens to oxygen levels in the blood of rainbow trout that were shocked for 20 seconds with ac, dc, and pulsed dc currents (Figure 6). With ac (line 3), the initial consumption of oxygen at shock was a 150% increase over what the body would normally consume, and it took 120 minutes to recover to preshock conditions. When shocking with ac, a fish exerts much more energy because its body is receiving the total swing of current from negative to positive poles (a sine wave). With ac, a fish assumes a position perpendicular to the electrical current produced between the two electrodes in an effort to minimize the voltage gradient received by its body. The fish undulates in rhythm with the ac cycle contracting its muscles as many times per second as the cycle until tetany occurs. Fish do not swim toward the electrodes when shocked with ac. Unmodified ac is most damaging and can be very traumatic to fish.

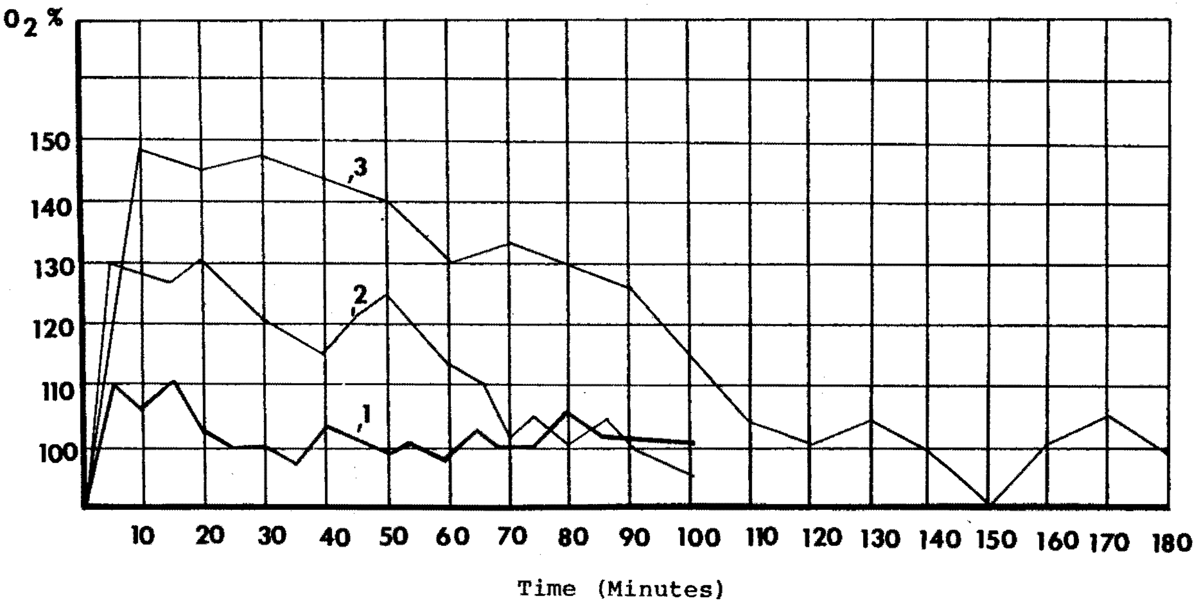

Figure 6. Time of restoration of oxygen metabolism in trout after 20-second exposure to different kinds of current; 1) pulsating, 2) direct, and 3) alternating (Sternin et al. 1976).

With dc (line 2), the initial consumptive of oxygen at shock was 130% and recovery occurred in 80 minutes. With pulsed dc (line 1), the increase in oxygen consumption was 110% at shock, and the fish recovered to preshock conditions in 30 minutes.

It is apparent that there is quite an oxygen demand put on fish as a result of shocking, and that ac current has the most effect, causing the largest consumption of oxygen and requiring a longer time to repay that oxygen debt. The physiological responses are dependent upon the severity and duration of the shock. The rapid increase in breathing amplitude after shocking is a method used by the fish to repay the oxygen debt suffered by the tissues. Shocked fish are not fully recovered simply because they have regained their equilibrium and are able to swim away. It takes a period of time for a stressed fish to fully recover to its normal preshock condition.

While studying the effects of dc and pulsating dc currents on fish, Taylor et al. (1957) recorded the heartbeat of a 9-inch rainbow trout shocked with a dc tetanizing current. The actions of the heart were recorded on a kymogram (Figure 7). The humped lines represent the heartbeats of the trout and the solid line beneath it indicates when the current was applied. After the current was first applied, the heartbeat increased a beat, and then skipped several beats before resuming its regular pace. It resumed its regular pace while continuing to receive the shock. So, although the shock caused a drastic effect on the fish initially, the effect was not long lasting (a few seconds) and death from shocking must be related to something other than cardiac arrest. Wood et al. (1983) also confirmed that cardiac failure was not the cause of death in severely exercised fish.

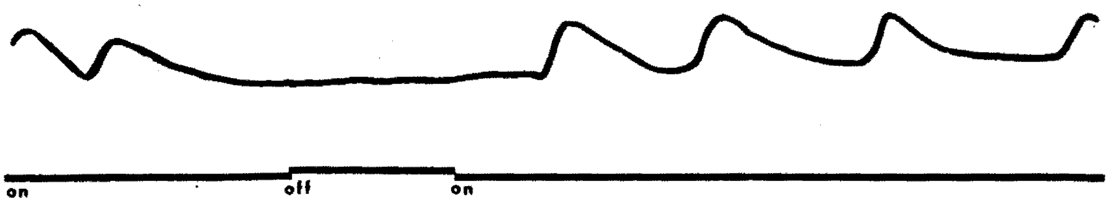

Figure 7. Kymogram showing the heart action of a 9-inch rainbow trout during direct stimulation with a tetanizing current. The lower line indicates when the circuit is turned on and off (adapted from Taylor et al. 1957).

Physical Injury to Fish Caused by Electrofishing

Hauck (1949), using ac current, observed an increased respiratory action in all fish subjected to an electrical current. Schreck et al. (1976) observed breathing amplitude increases from 50-350% in fish immediately after shocking. The rapid increase in breathing amplitude is an effort by fish to supply oxygen to the tissues, to pay off the oxygen debt created by the shock (Heath 1973). Hauck (1949) noticed that in some fish there was paralysis of the muscles on the side nearer the electrode, causing the fish to swim in an arc around the source of power. Fish also hemorrhaged from the gills or vent. He must have been shocking the fish severely because he also saw intestines protruding from the vent. Dark vertical bars or stripes (burn scars) were created on fish that touched "live" electrodes (Figure 8). This effect has also been reported for other electrofishing operations (Elson 1950, Horak and Klein 1967, Sternin et al. 1976). Some fish receiving burn scars are unable to move any portion of their bodies behind the dark band. Burn marks, similar to those in Figure 8, can also occur on fish that have come into close contact with the electrodes without actually touching them. In these instances, the force of the electricity damages the autonomic nerve fibers which regulate melanophore constriction and the melanin granules are dispersed, darkening the affected area (Nilsson et al. 1983). Similar bands have also been produced physically by probing the vertebral area of fishes with a hypodermic needle (J. Cech, Jr., University of California-Davis, pers. comm.).

Hauck (1949) also observed loss of locomotion, balance, and impaired circulation among fish several days after shocking. He performed autopsies on these injured fish and found numerous internal injuries. These included fractured vertebrae, broken ribs, curvature of the spine (S-shape), blood clots, and hemorrhaging and rupturing of the major arteries and veins. The secret of successful electrofishing is to use the minimum power necessary to collect fish, because the total energy absorbed by the fish determines whether that fish will be injured or not.

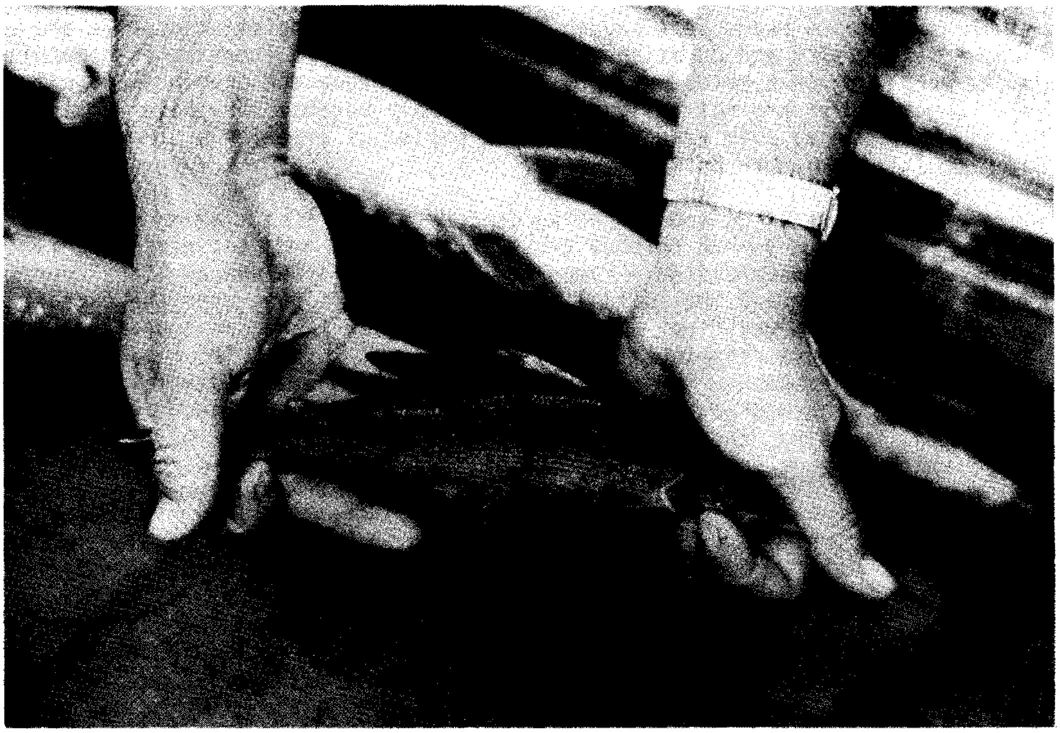

Figure 8. Dark stripes through and behind dorsal fin of arctic grayling are burn scars created from touching "live" electrodes when electrofishing (Photo courtesy of Larry Kolz).

Delayed Effects of Electrofishing

As stated earlier, the strength of the field, and duration or exposure time that a fish remains in an electrical field, determines whether the fish will live or die. Death can occur immediately after shocking, and in these instances is usually caused by respiratory failure, hemorrhaging, or fractured vertebrate. Death can also occur days or weeks later, and in these instances, is most likely the result of the combined effects of stress, exhaustion, or physical damage. In one early report, delayed mortality was called "lingering death" (Anonymous 1941). This incident occurred at a federal hatchery in Cortland, New York. Lightning struck a tree 150 feet from rearing ponds containing brown (*Salmo trutta*) and brook trout. Apparently the electrical charge traveled through the ground to the ponds where it stunned fish. Fish were observed having difficulty maintaining their equilibrium in the water. Some of the fish recovered in a short time, but others "died suddenly" a week later. Those fish that suffered delayed mortality showed the internal symptoms of hemorrhaging and the external symptoms of fractured vertebrae (S-shaped).

Other examples of delayed mortality are described by DeMont (1971) and Novotny (pers. comm.). DeMont observed mortality in threespine stickleback (*Gasterosteus aculeatus*) five days after shocking (Figure 9), although most mortality occurred in the first 24 hours. He used both ac and dc currents in his experiment, and observed about a 12% difference in mortality between the two, with ac being the most injurious. In a combined electrofishing, tag and mark operation in Wisconsin (D. Novotny, Wisc. Dept. of Nat. Res. pers. comm.), 25% mortalities were observed in largemouth bass (*Micropterus salmoides*) and walleyes (*Stizostedion vitreum*) two weeks after shocking. Most of the mortalities occurred after the first few days. It appears that the first 2 or 3 days after shocking is a critical period that determines whether a fish will survive. Holding and confining fish for observation after shocking, as well as handling, can also affect the mortality rates of electrofished fish.

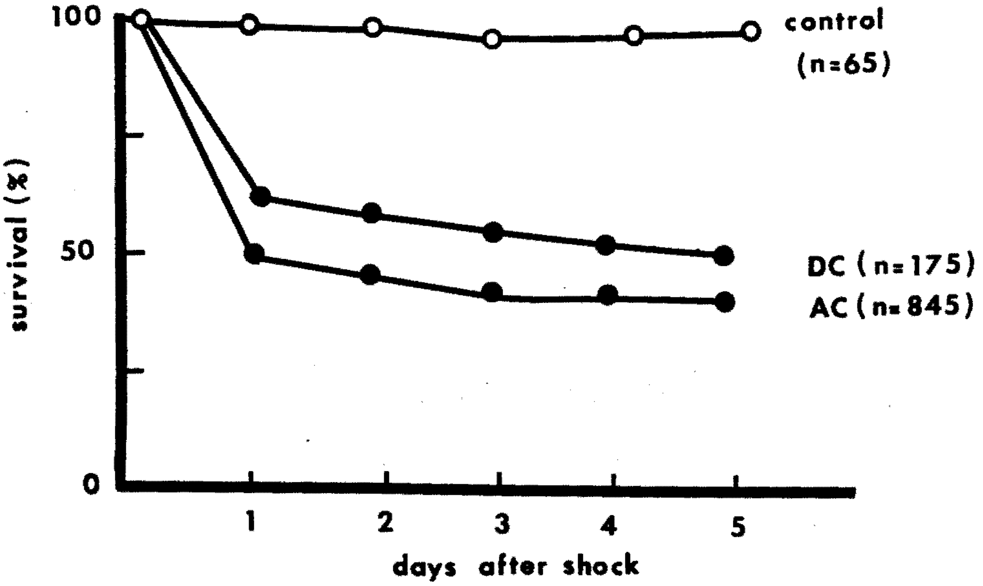

Figure 9. Delayed mortality observed in threespine sticklebacks electroshocked with ac and dc currents (adapted from DeMont 1971).

Comparison of the Effects of ac and dc Shocking of Fish

Some differences in the effects of shocking fish with ac, dc, and pulsed dc currents were discussed earlier. These included higher oxygen consumption, longer recovery period and higher numbers of fish suffering from delayed mortality when shocked with ac current.

Taylor et al. (1957) found quite a difference in the rates of mortality for rainbow trout subjected to three different currents. Ac current killed a greater percentage of fish than any other method (Table 4).

Table 4. Fish mortality rates (Taylor et al. 1957).

Form of Power	Number of fish shocked	Number of fish killed	Percent mortality
DC	91	0	0
Pulsed DC	1641	5	0.3
60 cycle AC	46	2	4.2

Spencer (1967) observed more damaged vertebraes in bluegills subjected to various ac currents than for those shocked with dc. Those percentages for damage ranged from 12.2% for 230 V ac to 1.5% for those shocked with dc currents (Table 5).

Table 5. Incidence of injured vertebrae in electroshocked bluegills exposed to different voltages and currents (Adapted from Spencer 1967) during exposure times ranging from 1-120 seconds.

Equipment	Average percentage injured
AC 230 V, 3.1 amp	12.2
AC 115 V, 2.0 amp	4.6
DC 115 V, 1.9 amp	1.5

These two examples point out the serious differences between ac and dc currents and their effects on fish. Pulsed dc is the favorite among most biologists today because of its ability to produce a good electrotactic response, minimize injuries, and is generally less costly to operate than other battery powered dc systems. All this is not to say, however, that ac should not, or cannot, be used. One should be particularly careful whenever using ac systems and recognize its dangers and drawbacks. Ac systems appear to be most suitable in situations where the water conductivities are very low (e.g., soft waters with less than 50 mg/l total alkalinity).

Suggestions for Field Application

1. Electrofishing works because fish are drawn involuntarily toward an anode or are incapacitated in such a way that they can be easily collected.
2. It is important to target the species pursued as size, species, physiological state, and habitat all influence electrofishing success.
3. Electrofishing stresses a fish. Fish can suffer extreme physiological changes as a result of electrofishing and it is important that the collector be aware of these stress potentials whenever using electrofishing equipment.
4. It is important that one monitor fish collected by electrofishing and observe their recovery to insure that power settings are not lethal. It is also important to remember that it is the total electrical energy absorbed by the fish that determines whether that fish will live or die.
5. Delayed mortality has been observed in fish collected by electrofishing. Most mortality occurs within the first 24 hours. Fish that show external signs of injury as a result of capture are most likely to show delayed mortality. Burn marks on fish are indicators of excessive electrical power.
6. Pulsed dc produces the least physiological damage to fish compared with those collected with dc or ac electrofishing equipment.

ACKNOWLEDGMENTS

Much of the information contained herein was taken from the unpublished "Principles and Techniques of Electrofishing" manual used for teaching the Electrofishing Course given by the Fisheries Academy. Much of the material contained in that manual was written or collected by Dr. Richard S. Wydoski, and I want to thank him for allowing me to use portions of that material for this presentation. I would also like to thank Larry Kolz, of the Denver Wildlife Research Center, for use of his arctic grayling photograph, and Carolyn Banks and Monte Stuckeyfor preparing the graphics.

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