Electrofishing Safety

Session Purpose

- Increase knowledge and skills in electrofishing safety that will result in reduced incidents and injuries to you as a crew member while maintaining efficient job performance.

Objectives
(The participant will be able to…)

- Recognize and appreciate the risks inherent in electrofishing sampling
- Discuss the purpose and value of safety policy documents
- Describe approaches to improve safety at electrofishing projects (including an employee safety program)

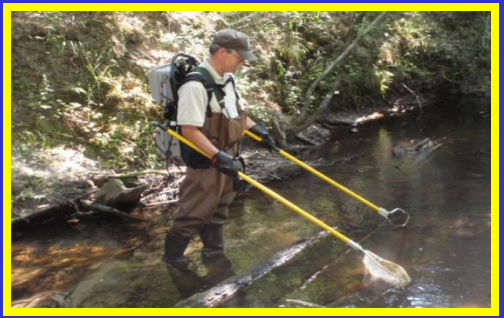
Objectives
(The participant will be able to…)

- Describe equipment safety features of various gear types (e.g., boat, backpack, shore-based)

- Review personal protective gear types and their use

In the Electrofishing Safety course (CSP2202) there are additional materials…

- ***Presentations and*** **videos**
- **U.S. Fish & Wildlife Service safety policy (and at FWS Electrofishing Safety Policy)**
- **Job Hazard Analysis forms with electrofishing examples**



Risk in Context of EF Gear Circuitry

It doesn't take much current… (the "1 – 10 – 100 rule")

Estimated Effects of 60 Hz AC Currents

1 milliAmp	Barely perceptible
16 milliAmps	Maximum current an average adult male can grasp and "let go"
20 milliAmps	Paralysis of respiratory muscles
100 milliAmps	Ventricular fibrillation threshold
2 Amps	Cardiac standstill and internal organ damage
15/20 Amps	Common fuse or breaker opens circuit

Contact with 20 milliamps of current can be fatal.

Dry skin is a good insulator but insulative capacities decline dramatically when wet.

This is one reason for wearing rubber gloves while electrofishing.

Risk Information from a Navy Study

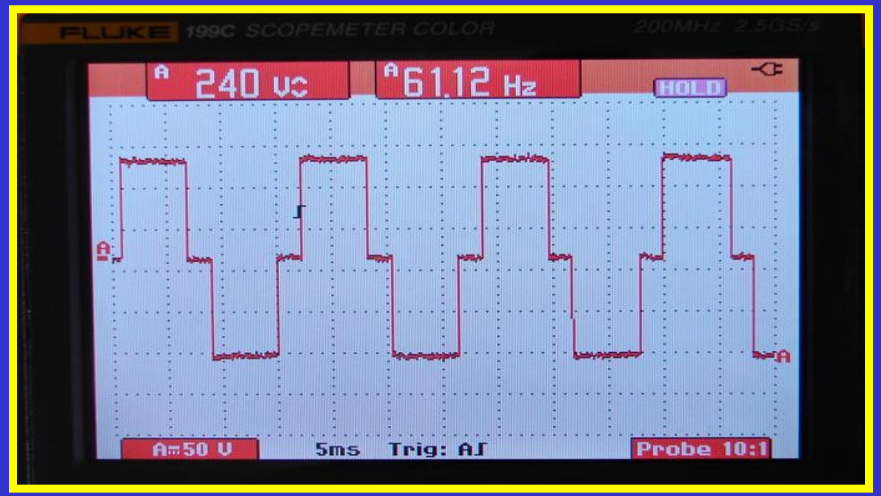
- Danger threshold for humans is ~ 50 mA peak current

- Resistance of diver in wet suit is ~ 500 ohms
- Resistance of unprotected diver is ~ 100 ohms

- Ohms Law: Resistance = Volts ÷ Amps or Volts = Resist x Amps
- So, Volts = 100 ohms x 50 mA = 5 volts!
- A person 6 ft. tall is 6 ft. x 12 inches x 2.54 cm/inch = 183 cm
- Voltage gradient through body = 5 V / 183 cm = 0.027 V/cm
- We typically use 0.4 to 0.7 V/cm to capture fish

50 – 60 Hz AC Appears More Hazardous to Humans than DC

Human nerves are sensitive to 60 Hz AC. Automatic external defibrillators (AED's) often use a 60 Hz "biphasic" (= AC) waveform to stop fibrillation.



Backpack-generated AC

Even if the shock itself doesn’t hurt someone…

- the shock instead may cause the crew member to fall against equipment, a hard surface, into the electric field, etc.

We need to…

- elevate safety concerns to our top priority (is any piece of data really worth serious injury?)

- base our operations on safety principles; truly make it “Safety First” (for instance, put safety gear at the top of the equipment checklist)

Safety Policies

- *A definition*: written safety guidelines binding to employees

- More agencies in U.S. developing safety policies (beginning in the 1980's)
  - Federal (FWS initial policy was in 1985), state, universities
  - Primary motivations include concern for crew member safety and avoidance of litigation
  - FWS policy used as a basis for some other federal and state agency policy development

- Safety policy document
  - Safety information transfer tool
  - Decision-making tool

FWS Safety Policy

- Fish & Wildlife Service
  Occupational Safety and Health
  Part 241 Safety Operations
  Chapter 6 Electrofishing 241 FW 6

  http://www.fws.gov/policy/241fw6.html

- Recently revised December, 2016

- Review and revision, if necessary, every 5 years

FWS Safety Policy

TABLE OF CONTENTS	
Topics	**Sections**
Overview	6.1 What is the purpose of this chapter? 6.2 What is electrofishing? 6.3 What is the scope of this chapter? 6.4 What are the authorities for the chapter? 6.5 What terms do you need to know to understand this chapter?
Responsibilities	6.6 Who is responsible for ensuring compliance with the electrofishing policy?
Training	6.7 What are the training requirements for team leaders, other crew members, motorboat operators, and those using electrosedation?
Design Specifications	6.8 What design specifications are applicable to all electrofishing operations? 6.9 What design specifications are applicable to portable electrofishing equipment? 6.10 What design specifications are applicable to electrofishing boats and rafts?
Personal protective equipment and safety practices	6.11 What personal protective equipment and safety practices are applicable to all electrofishing operations? 6.12 What additional personal protective equipment and safety practices are applicable to portable electrofishing units? 6.13 What additional personal protective equipment and safety practices are applicable to electrofishing boats and rafts?

If Your Agency Does Not Have a Policy...

- Recommend to administration that agency temporarily adopt USFWS regulations
  - Action requires sign-off by directorate
- If cannot get sign-off, adopt FWS or some other agency policy as your office policy
  - Put adopted policy along with a cover letter of explanation in files
- Convene a panel to derive a safety policy
  - Be sure to offer the draft policy to agency electrofishers for their review and comment; consider comments and revise as warranted

Safety policy panel

Biologists (practical experience, “risk-taking”)
Electrical engineers (technology experts, “risk-adverse”)
Safety officers (policy and legal experts, likely “risk-adverse”)

Need a panel to develop and review the agency electrofishing safety policy at regular intervals (3 yrs., 5 yrs. ?)

Various perspectives and expertise of panel members a strength but policy discussions often a tug-of-war

Technique or Procedure Not Covered in Safety Policy

- Write memo to file explaining procedure and detailing safety precautions

Nugget

- Have a written safety policy to guide your electrofishing sampling

Employee Safety Program

- First step: adopt written safety guidelines
- Next step: institute an employee safety program
  - Three elements: training, equipment, and operations
  - Prior to field work, new crew members should receive training on equipment, procedure, and risks involved

Employee Safety Program

- Training
  - training plan: may be outlined in safety policy document; see 241 FW 6.7
  - materials: policy (e.g., 241 FW 6.6), *Electrofishing Safety course* (*CSP2202*)
  - documentation (by recording on the *Acknowledgement of Electrofishing Orientation.pdf* form or on a learning management system as DOI Learn)
  - Electric concepts and risk awareness: very low current levels can seriously injure

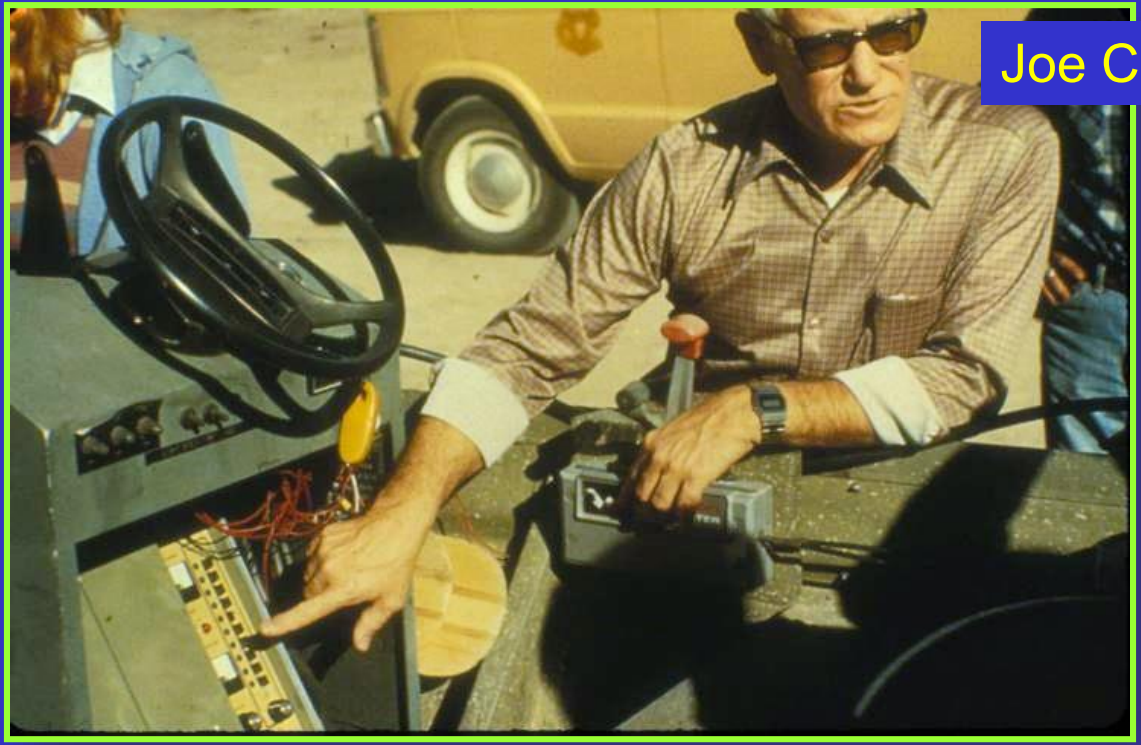
Employee Safety Program: Training

- Electric concepts: for example, in-water probe can demonstrate the extent of the electric field

A. Lawrence Kolz

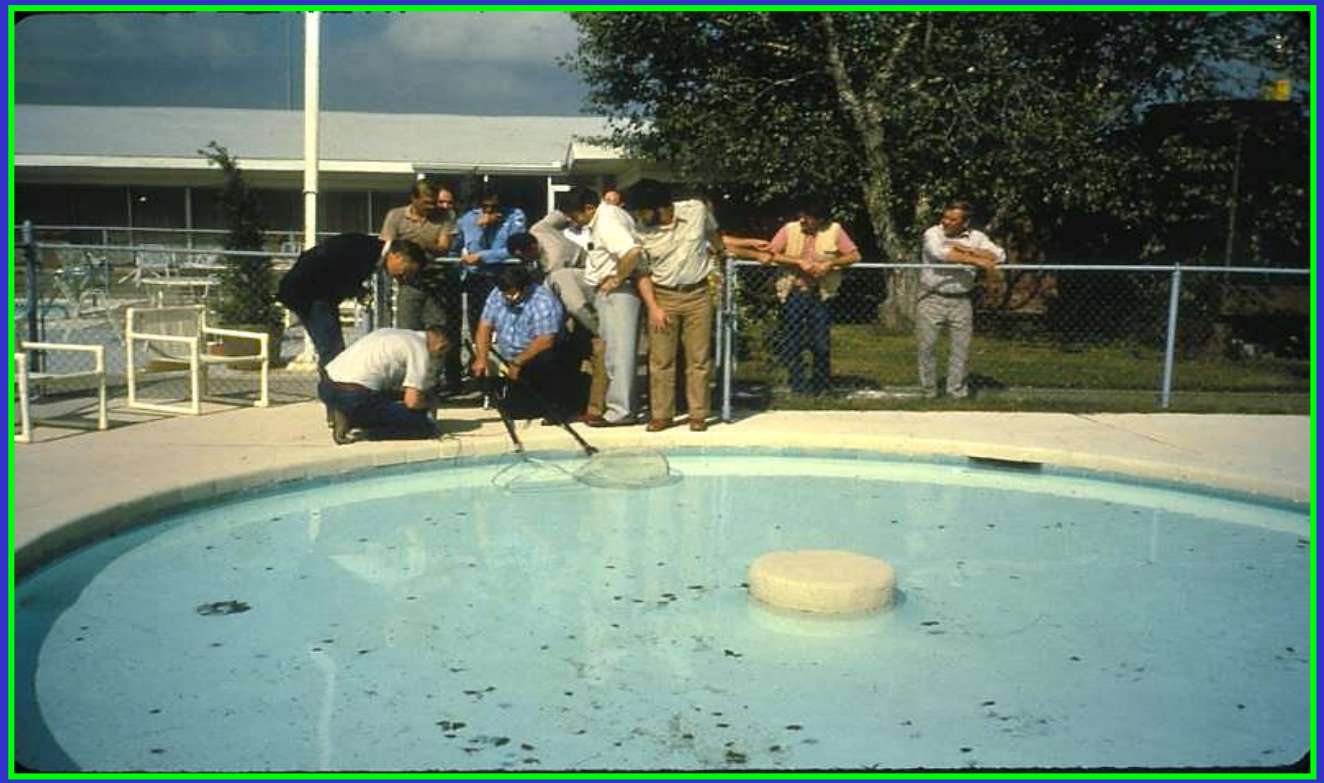
Employee Safety Program: Training

- Explain system components, function, operation, and safety features in a non-working environment



Employee Safety Program: Training

- Demonstrate gear functioning and safety features in a non-working (fishless) environment



Employee Safety Program: Training

- New staff observe actual use of equipment, sampling protocols, and safety procedures

Employee Safety Program: Training

- CPR & First Aid: important for at least 2 crew members to have certification

Employee Safety Program: Training

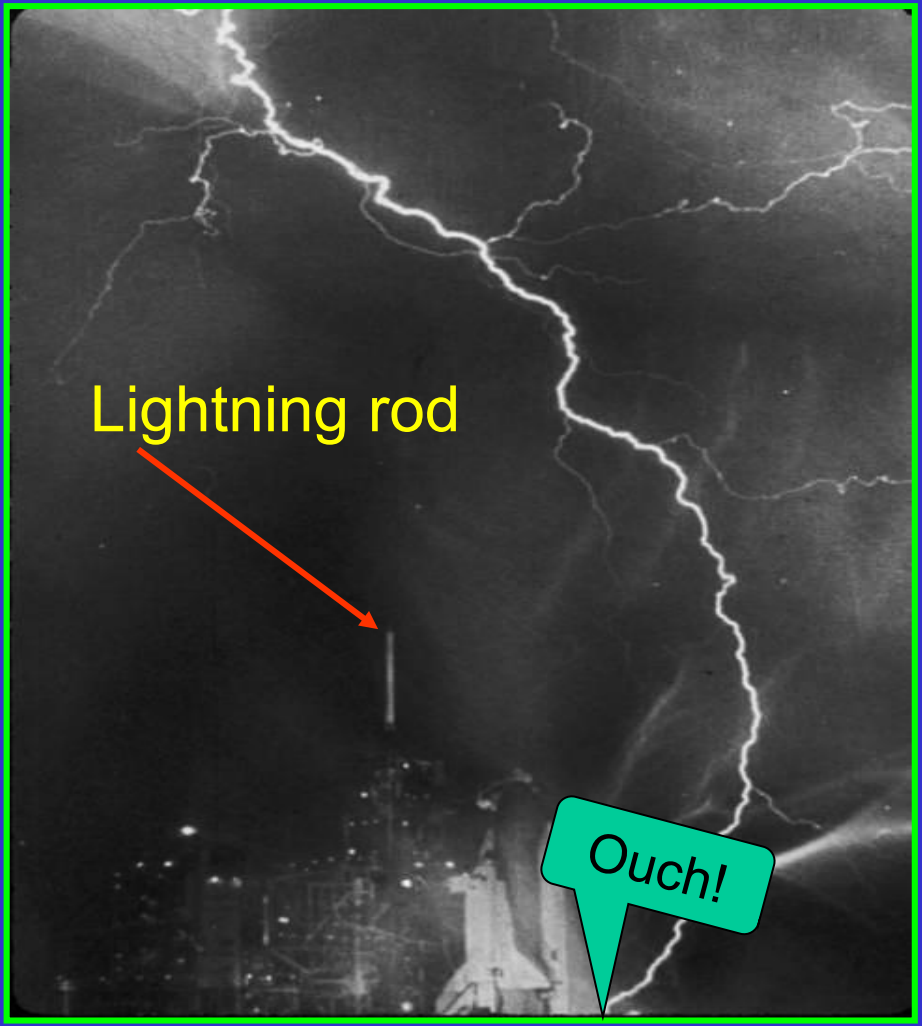
- Also consider…
  - Wader safety training in a swimming pool
    - Video by Utah State University
  - Practice emergency actions when suddenly become submerged with a backpack shocker (in a swimming pool)
    - This type of training done by provincial fisheries agency in Alberta, Canada
  - Operating equipment for a required number of hours under supervision of a person experienced with that particular equipment type (a “practical”)

Employee Safety Program: Equipment

Equipment

- Equipment built to code (see 241 FW 6.8) and with adequate safety devices/precautions have protected biologists from injury

- However, do not blindly depend upon a single safety device (e.g., do not depend upon a safety switch functioning properly to handle energized electrodes); have backup devices or approaches



Components of an Electrofishing System (the gear)

- Power supply: battery or generator, provides electrical energy to power the equipment

- Control box (or pulsator): controls the waveform characteristics (type, volts, amps, frequency, pulse width, duty cycle) and has *safety circuitry*

- Metering: provides knowledge of the actual electrical outputs (volts, amps, frequency, etc.)

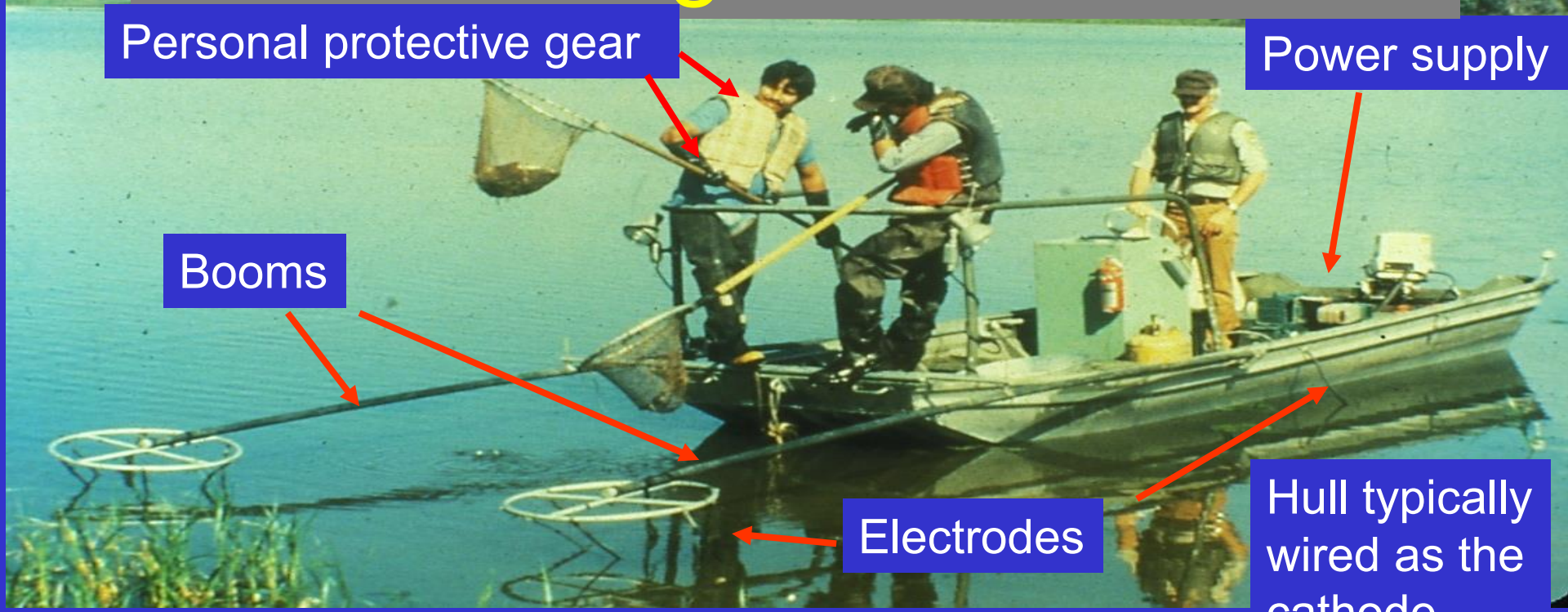
Components of an Electrofishing System (the gear)

- Interconnection system: the conductors (wires), conduit, condulets, junction boxes, cable, plugs, etc. that carry the electricity from the power source and control box to the electrodes; also includes the *safety switch* circuit.

- Electrodes: metal structures that couple the circuitry of the gear with the water; many configurations; under control of the biologist

- Auxiliary equipment: primarily with boats; lights, pumps, aerators, etc. that provide peripheral electrical services

Electrofishing Boats and Rafts



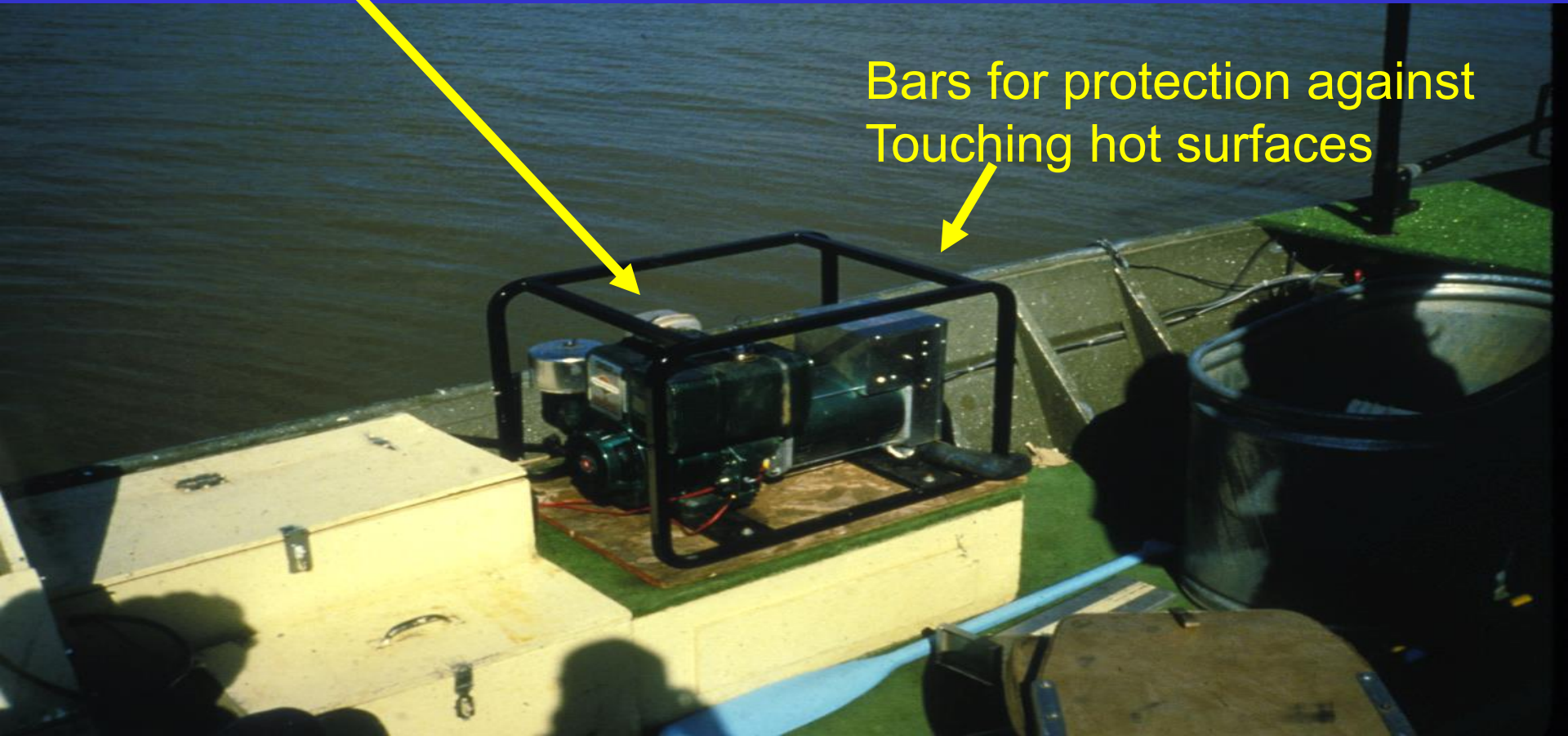
Boat Electrofishers

Power Supply

Exhaust build-up can lead to a increase in carbon monoxide levels; some configurations pip exhaust to outside stern or via elevated pipe.

The generator should be direc wired or bolted to the hull or reference metal for continuity.

Generator securely mounted with exhaust directed over side

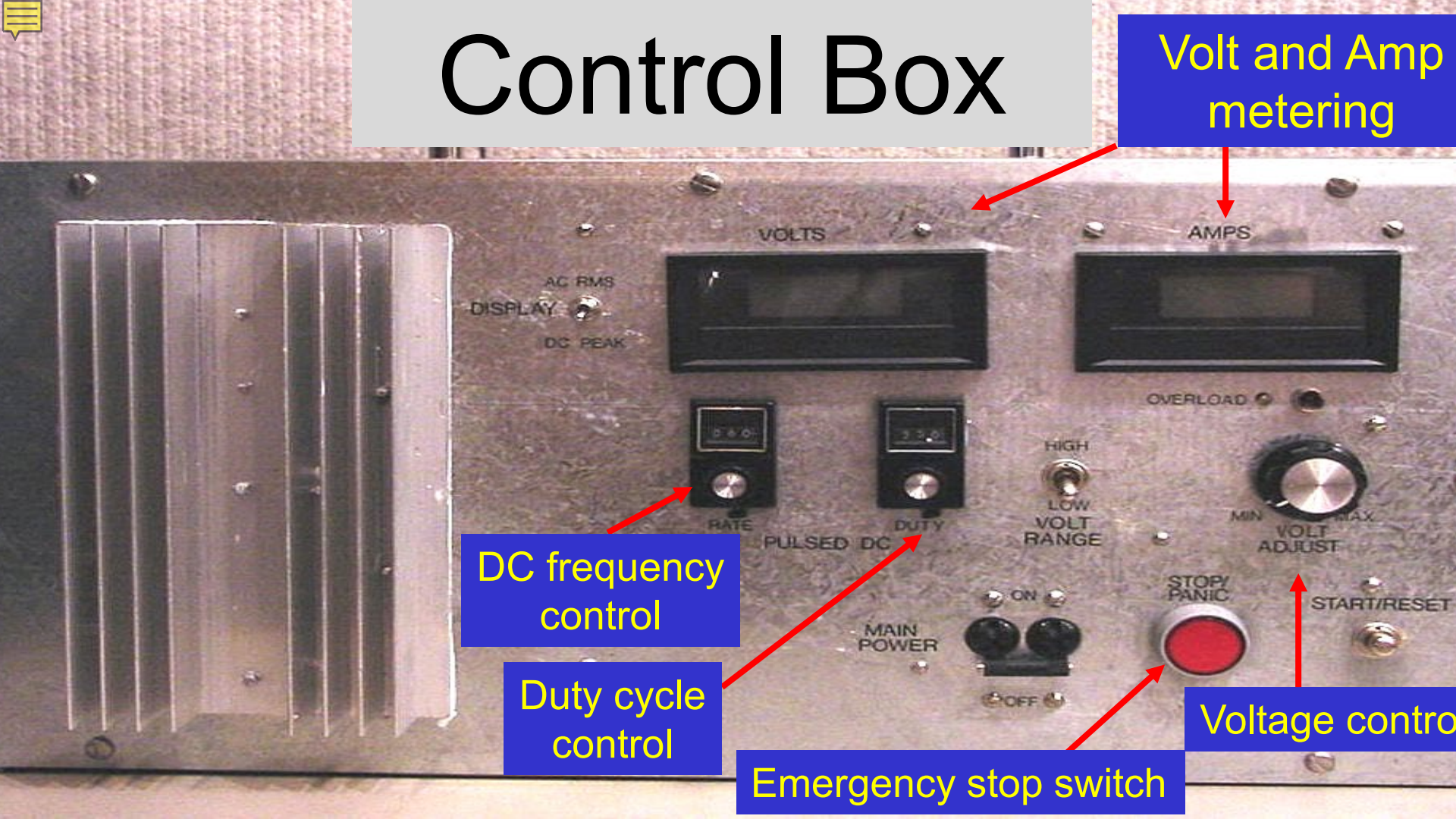


Exhaust stand-pipe to direct exhaust away

Noise levels from generators

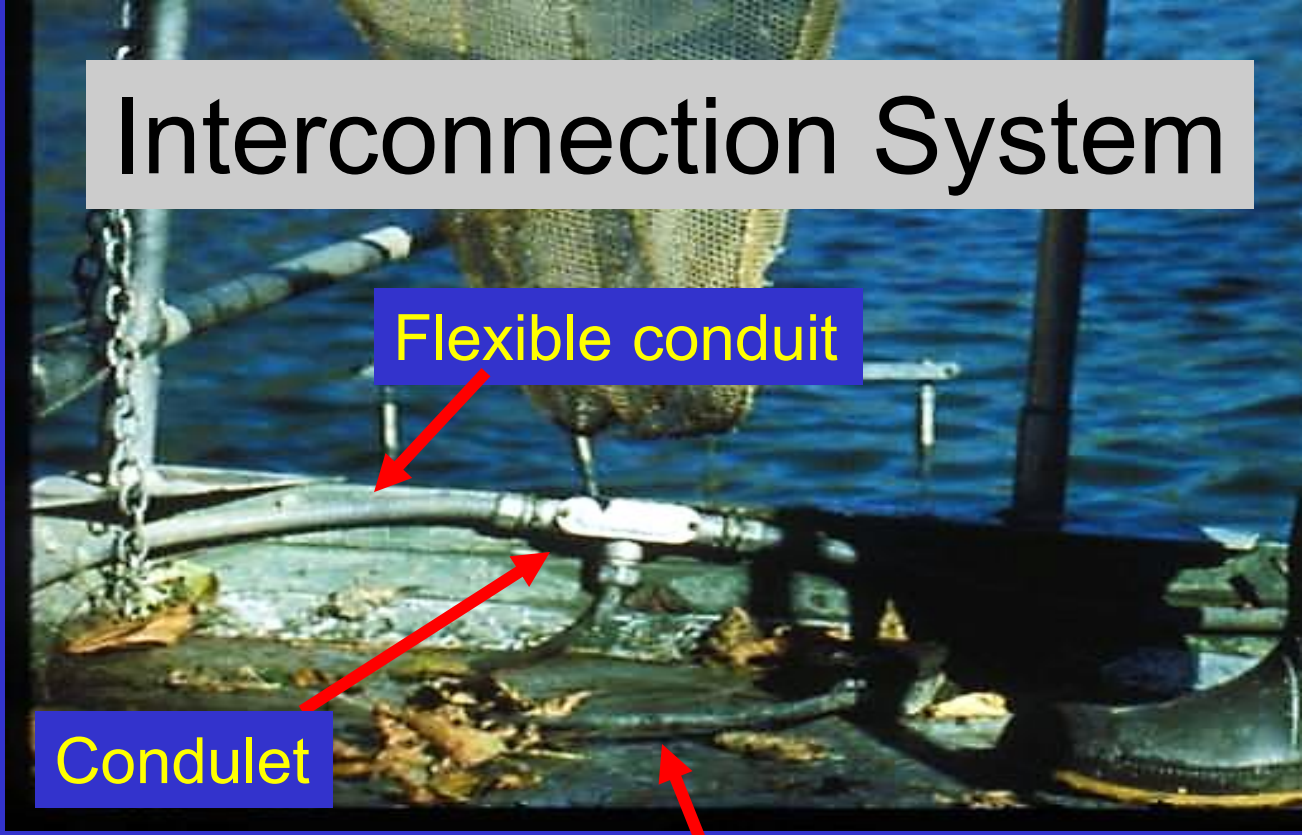
- OSHA has standards for levels of loudness (decibels) and times of exposure (hours).
  - OSHA Noise Level Standard, 29 CFR 1910.95
  - see USFWS policy **241 FW 6.11 (D):** If using a generator, a noise survey to document Sound Pressure Level (SPL) exposures to electrofishing crew members must be performed. When subjected to sound levels at or above 85 decibels (dBA), regardless of time exposed, crew members must wear hearing protection to reduce sound levels (see 242 FW 3). Also, whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level of 85 dBA, a continuing effective hearing loss prevention program, in accordance with 242 FW 3, must be administered.
  - New <u>inverter generators</u> are less noisy than typical conversations

Control Box


Volt and Amp metering
VOLTS
AMPS
AC RMS
DISPLAY
DC PEAK
OVERLOAD
HIGH
LOW
VOLT RANGE
MIN
MAX
VOLT ADJUST
RATE
DUTY
PULSED DC
DC frequency control
Duty cycle control
ON
MAIN POWER
OFF
STOP/ PANIC
START/RESET
Emergency stop switch
Voltage contro

Interconnection System

- Conductors of sufficient gage should be contained within conduit whenever possible
- All splices to wiring are made in weather-resistant condulets (with exceptions noted later)



Power cable (leading to foot safety switch)

USGS policy: low voltage safety circuit conductors must be in a 300 V rms minimum cable if contained in the same conduit as the high voltage conductors

Pay attention to conductor capacities (voltage & current)

Power cable rating

- Conductor Voltage. The insulation value for all wiring must meet or exceed the maximum voltages generated by the power source or pulsator. In general, the branch circuit conductors will require the highest breakdown voltage capacity to sustain the peak magnitudes of the voltage pulses. For insulated wires that are specified with a V rms rating, the peak breakdown voltage (AC, DC, or PDC) can be estimated to equal 1.41 times the V rms rating (example: 600 x 1.41 = 846 V DC).

Pay attention to conductor capacities (voltage & current)

- Conductor Current. Conductor size (i.e., for copper wire) will be approved for rated RMS amperage of equipment as listed in the following table. Always check manufacturer specifications for conductors (see 241 FW 6.8)

RMS Amperage	
11	20 AWG
16	18 AWG
22	16 AWG
32	14 AWG
64	9 AWG
73	8 AWG
158	3 AWG
181	2 AWG

The peak current (AC, DC, or PDC) can be estimated to equal 1.41 times the Amp RMS rating (example for 9 AWG: 64 x 1.41 = 90 Amps DC).

Watertight safety-shroud receptacle & plug

Be sure to check voltage capacity of the receptacles and plugs

Not as weather-resistant as
a shroud receptacle & plug

Foot Pedal Switch

Safety switches do not interrupt the main line. Instead, they are on low voltage circuits (>24 Volts) that operate a relay in the control box.

Foot switches should be checked for proper function before each sampling event. Foot switches can fail. Although the failure usually is in the off or “open” position, a failure could result in a continuously on or “closed” circuit. Foot switches do require maintenance.

Lights for Sampling

120 V circuit

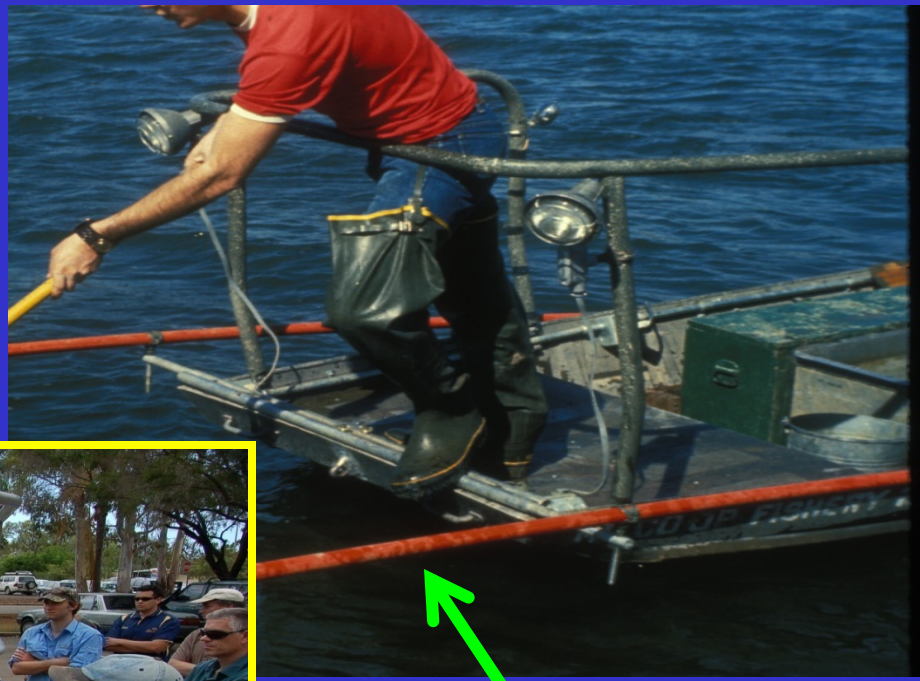
Protective covering

Additional lights on bottom of railing

Lights and Auxiliary Circuits

- Try to run all lights on a 12 volt circuit
- Lighting using LEDs is a great option
- At least, wire deck lights on a 12 volt circuit to allow generator to be turned off when working up fish or checking equipment
- Other electrical equipment as pumps should be on a 12 volt circuit

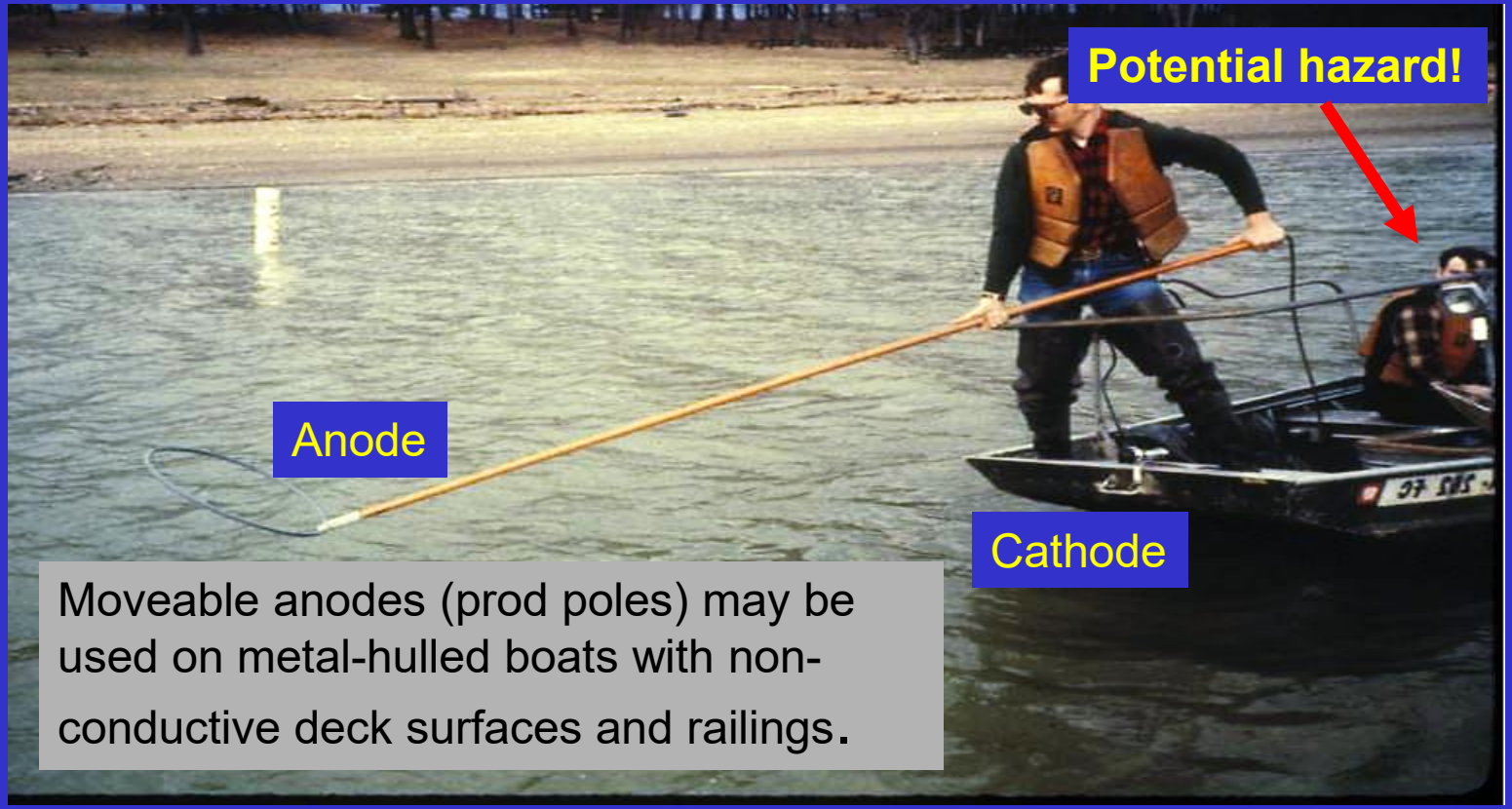
Railings & Booms



Fixed electrode booms

Can accommodate a single boom arrangement

Booms: Moveable Anodes



Moveable anodes (prod poles) may be used on metal-hulled boats with non-conductive deck surfaces and railings.

Decks

Rafts

Railings

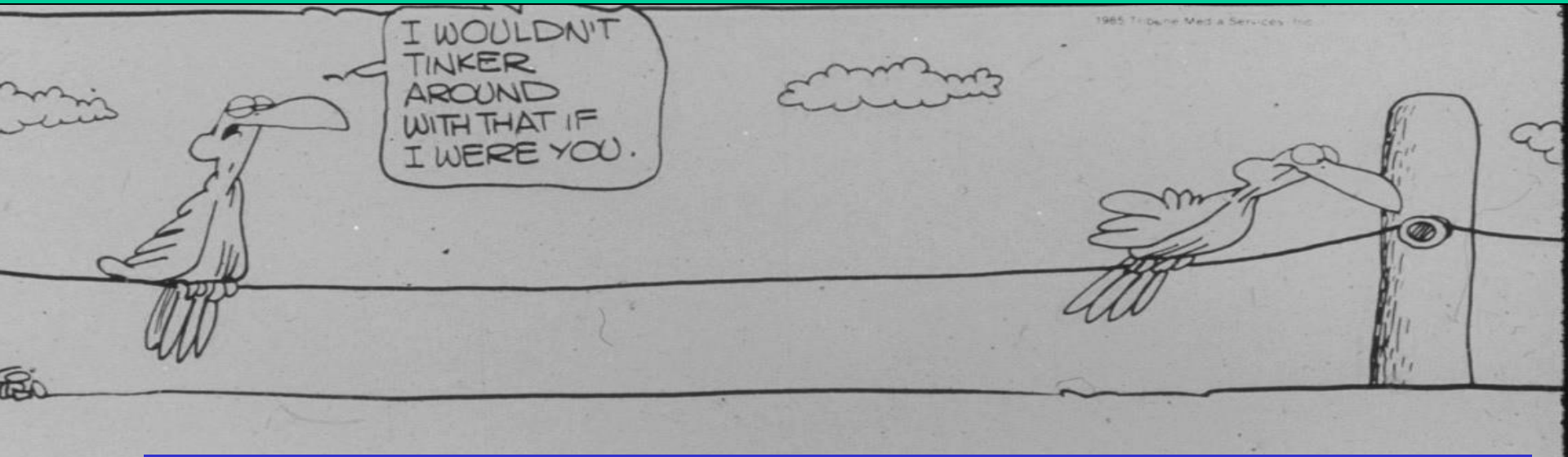
Anode spheres

Dropper cathodes

Establishing Equi-potential Surfaces on a Boat or Raft

- A unique aspect of boats and rafts is the advantage of being able to establish equipotential surfaces. Having all metal surfaces in a boat/raft electrically connected reduces shock hazard.

The Idea…



In an electrofishing boat, you want to be a “bird-on-a-wire”, surrounding yourself will metal surfaces at the same voltage potential (equipotential)

- Checking for equipotential surfaces; a multimeter should read less than one Ohm between significantly-sized pieces of metal
- Connect all metal to a “reference” metal structure (the boat hull on a metal-hull boat or the metal rowing frame on a raft)
- Objects generating a charge (generator, pulsator) should be hard-wired to the hull

- In rafts, reference all metal surfaces to the metal rowing frame

Generator Continuity

A hard-wired generator that has a “ground wire” running from the case of the generator to the hull (reference metal); without a ground wire, this particular generator would be floating since it is sitting on a non-conductive surface.

Pulsator (Control Box) Continuity

This control box is potentially “floating”, that is, not in continuity with the hull or reference metal. Control box must either be hardwired to the hull or in continuity with the hull through the power input cable from the generator. Of course, the generator must be in continuity itself with the hull, preferably by hard-wiring.

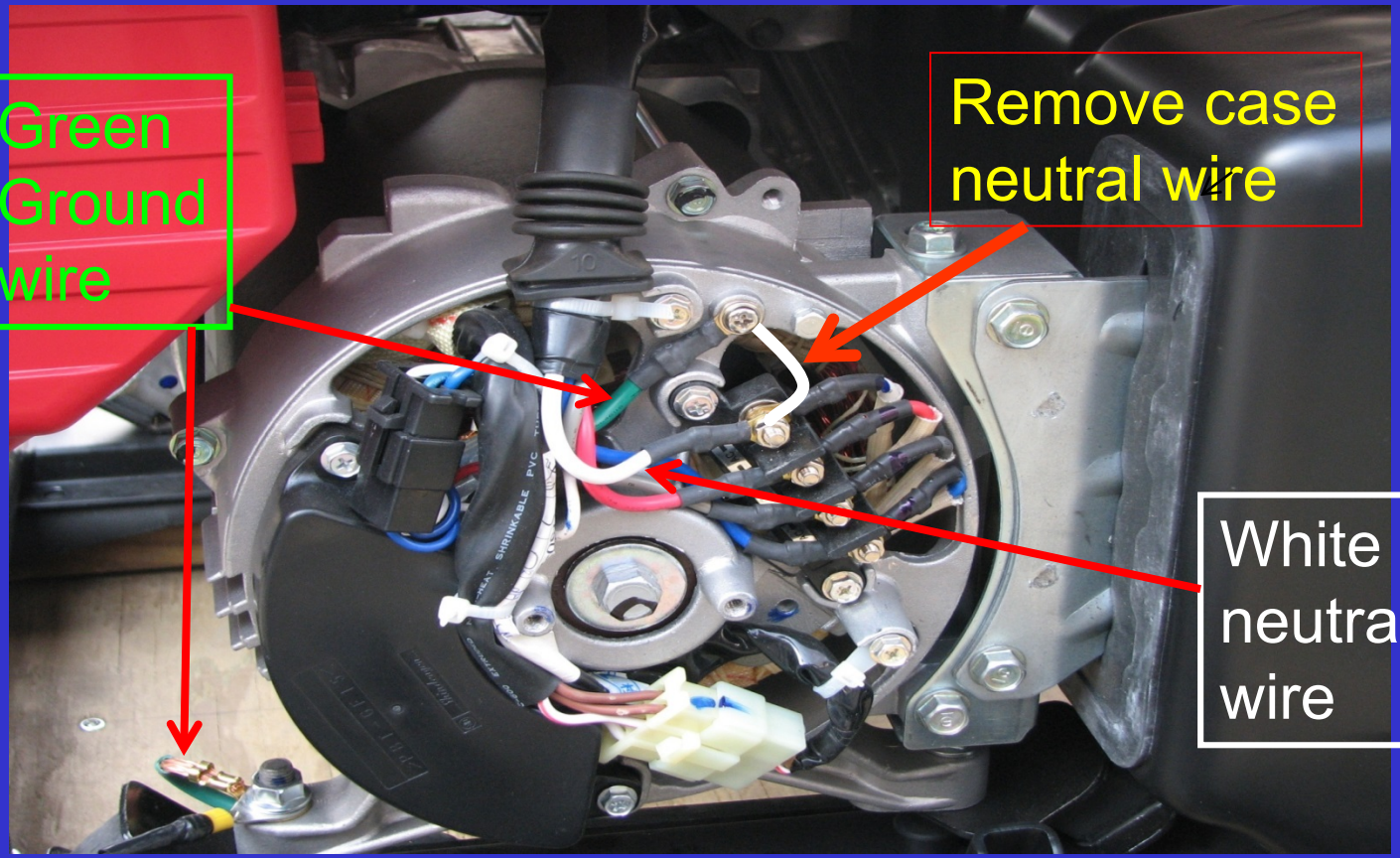
Generator Case Neutral

Presently, many generators are sold with a case neutral* connection (designed for use in building construction).

For electrofishing, the generator **must not** have a case neutral connection unless design provisions are made as, for example, incorporation of an isolation transformer; otherwise, equipment damage can result

Now, generators without a case neutral connection are more common off-the-shelf items (especially for the recreation vehicle market).

Generator Case Neutral



The outer cap has been removed to expose the internal wiring of the generator

Additional Equipment

- For the FWS, additional equipment on electrofishing boats as fire extinguishers and other safety devices come under watercraft safety policy 241 FW 1, which in turn follows the U.S. Coast Guard minimum requirements.
  - See Boatsafe.com (http://boatsafe.com/) for an equipment list

Additional Equipment

- A First Aid kit, watertight and well-equipped, must be available.

Additional Equipment

Type 1 Safety Can (metal)

Type 1 Safety Can (polyethylene)

Type 2 Safety Can (metal)

Type 2 D.O.T. transport Safety Can (metal)

Additional Equipment

Non-conductive handle

Electrofishing dip-net

Backpack Electrofishers

Safety Features

Smith-Root
LR-24

(other than circuit breakers, thermal sensors, fusible links)

Emergency stop switch

Audio alarm
1-4 beeps/sec
depending upon
average power
output

Flashing red light

Lower right of frame

Splash cover must
be latched

Immersion sensor

Internal tilt switch (forward 55-, side
45-, backward 35-degrees)

Quick-
release
harness

Internal
anode
out-of-
water
switch

Anode switch

Shore-based Electrofishing

Safety note: nobody on generator

Tow Barge Electrofishing

If you need more power or sampling over a long distance, then go with a tow barge system

Tow Barge Electrofishing

Junction box for anodes and safety circuits

Cathode plate on bottom

Personal Protective Equipment: Proper "Clothing"

Life jackets

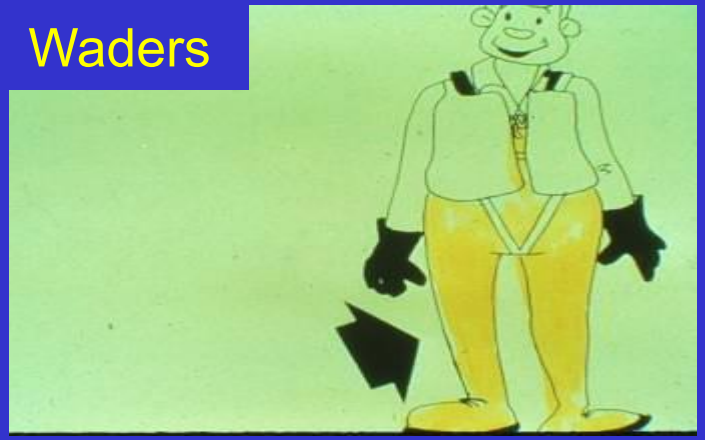
Type II bulkier, has a "collar", and will turn most unconscious people face-up in water

Type III

Life Jackets

Suspender-type PFDs self-inflate when become wet; a new trigger mechanism is available that inflates the PFD when 30 cm of water depth pressure is sensed

Waders



Boat crew members must wear, at a minimum, rubber-soled boots or other boots rated for electrical hazard protection

Waders are not electrically rated. However, the light-weight “breathable” waders may not protect from shock when the water depth is above the knees and long pants are not worn underneath waders. Breathable waders can only be worn using backpack electrofishers.

Waders

There is a commonly-held perception that when a person's waders fill with water, that person will sink. This is not true.

Drills for crew members falling into deep water wearing waders or even "dummy" backpack units in a swimming pool supervised by a lifeguard can alleviate misconceptions and increase the capacity of crew members to get themselves out of unsafe situations.

If you are interested in an example of this type of training, see the *Wader Safety* video in the *Electrofishing Safety* course.

Gloves

Rubber gloves

Neoprene gloves

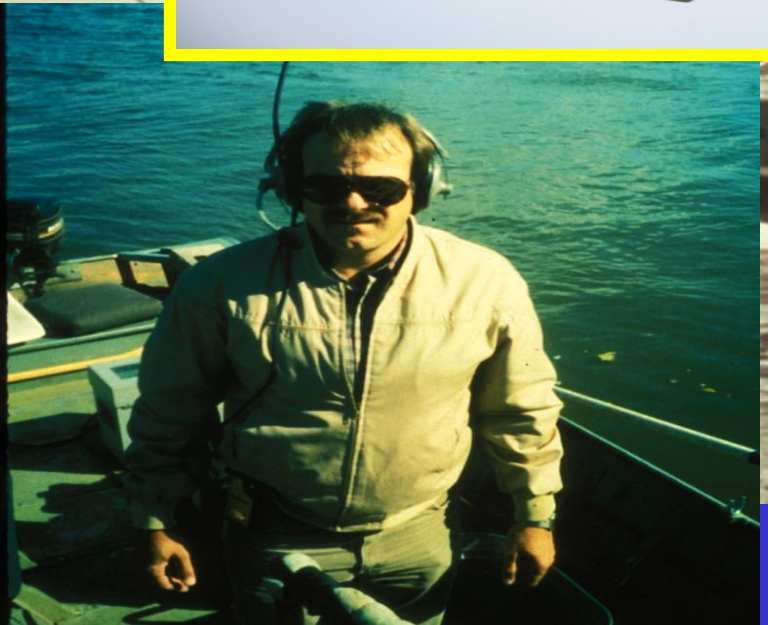
Leather over-gloves are designed to be worn on linesman gloves

Linemans gloves not necessary. Good sturdy synthetic rubber (e.g., neoprene) gloves sufficient. See FWS policy. However, Class 0 linemans gloves (up to 1000 V) with leather protectors may be a useful glove system.

Use of Gloves

Very good practice to handle control box with rubber gloves

Hearing Protection



Headphone communicators- nice!

Equipment Checks

- Do not start to dissemble pulsators immediately after use due to shock potential from the capacitors. Capacitors are made to self-bleed off but check with manufacturer for time required (typically 5 minutes). This also means that the electrodes should be unplugged before disassembly.

General Operations

- Before you begin, crew members should be briefed on equipment, safety procedures, and potential hazards in the sampling site.
- Verify that 2 people are certified in first aid and CPR

General Operations

- Verify that personnel follow proper safety procedures and use proper personal protective equipment
- Inspect all external wiring, cables, connectors, and safety switches

General Operations

Assembling and disassembling equipment

- When handling electrodes, the power source (generator) must be off; unplug the booms when handling electrodes
- Handling electrodes with the power source on and connected has resulted in significant injuries to crew members
- Never handle electrodes with the generator running and electrodes connected to the control box.

General Operations

Assembling and disassembling equipment

- Do not start to dissemble pulsators immediately after use due to shock potential from the capacitors. Capacitors are made to self-bleed off but check with manufacturer for time required (typically 5 minutes). This also means that the electrodes may be “hot” immediately after shut-down.

General Operations: Refueling

- Turn off all equipment before refueling the generator and allow hot surfaces to cool. We recommend that you fill all tanks before each operation to avoid the potential for explosion or fire while refueling.

- Only refuel away from any open flame or flame-generating device.

- Place portable fuel tanks on dock or pavement for refueling. Do not refuel portable fuel containers on a plastic surface (e.g., a plastic lined pick-up truck bed).

General Operations

Make sure all team members know when the power is on and off

General Operations

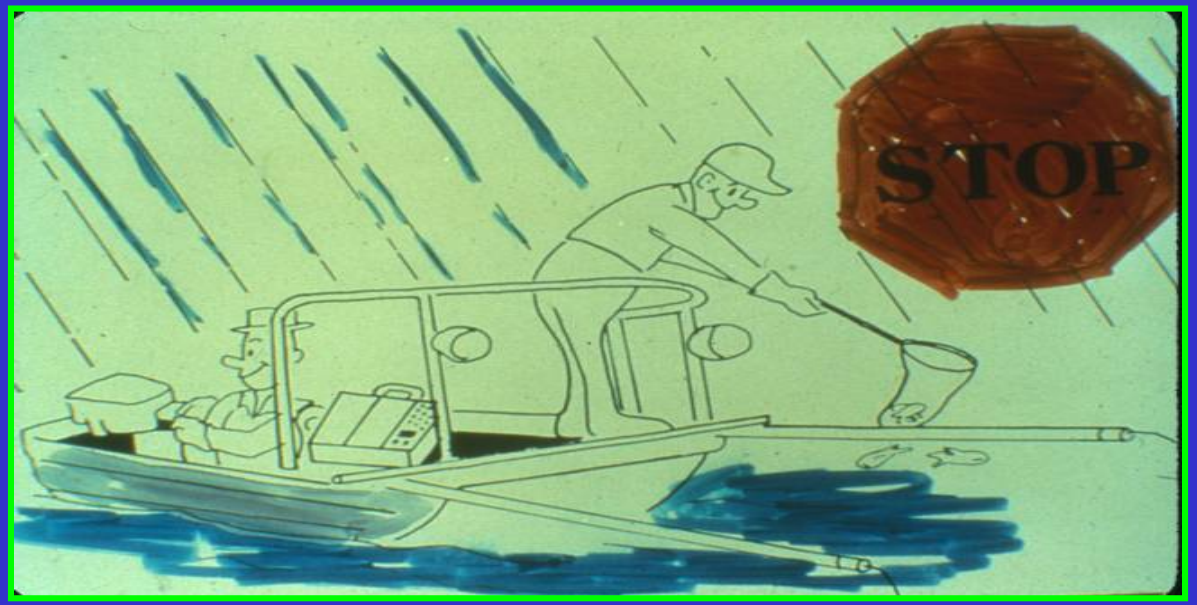
Protect the public…

and yourself

Discontinue electrofishing if anyone outside of the electrofishing team approaches within 30 feet (for backpack operations) or 100 feet (for all other electrofishing operations).

General Operations

Bad weather



Stop fishing during heavy rain or thunderstorms

If light rain/mist, can fish until all surfaces covered in an unbroken sheen of water

General Operations

Boat hit by lightning:

Stop fishing during heavy rain or thunderstorms

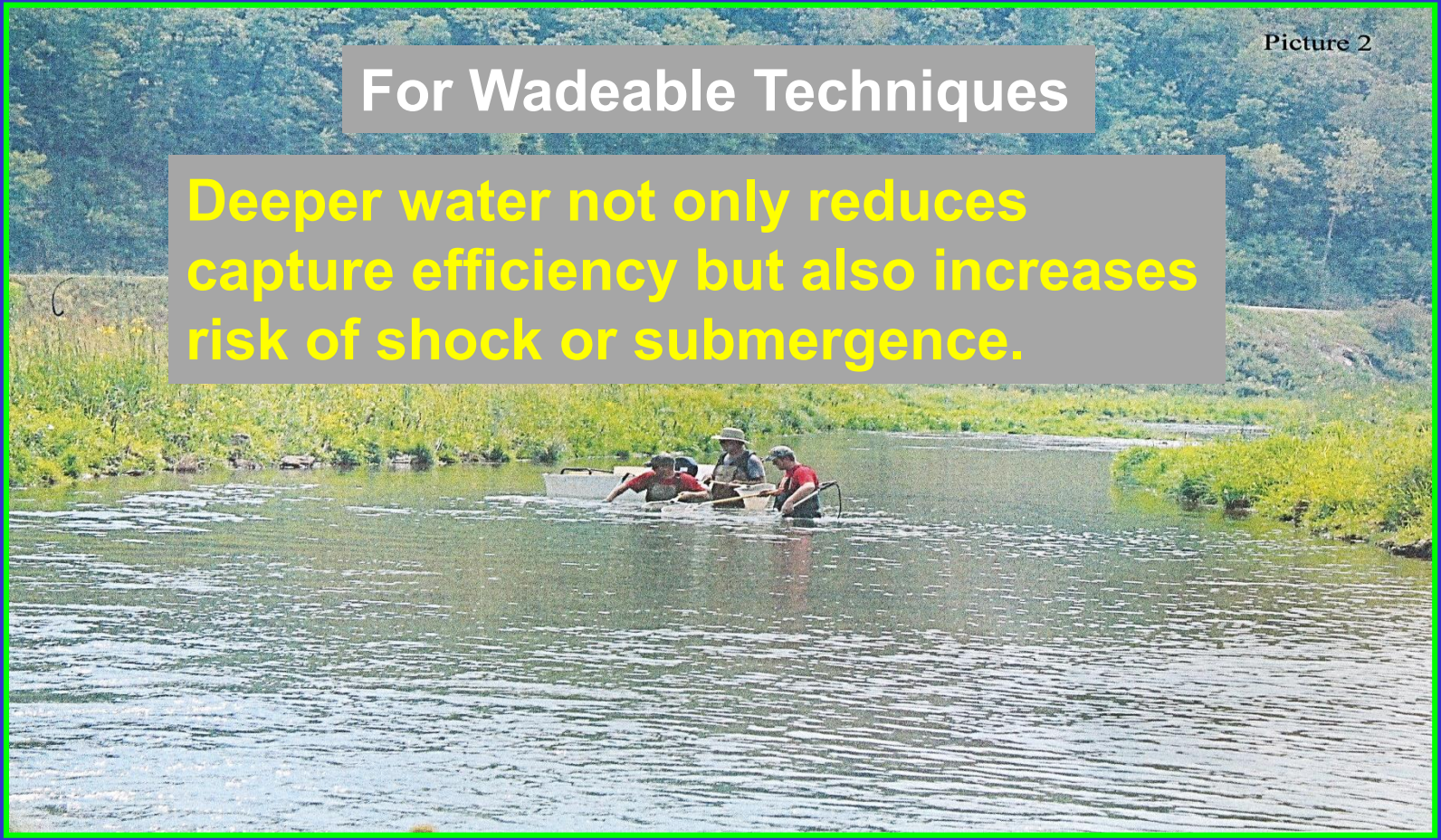
General Operations

Large crews and/or the public. What is the team leader's role?

Boat-Specific Operations

- Due to the length of dip nets, pay special attention as you swing around to transfer a fish after being netted to the livewell.

Portable-Specific Operations



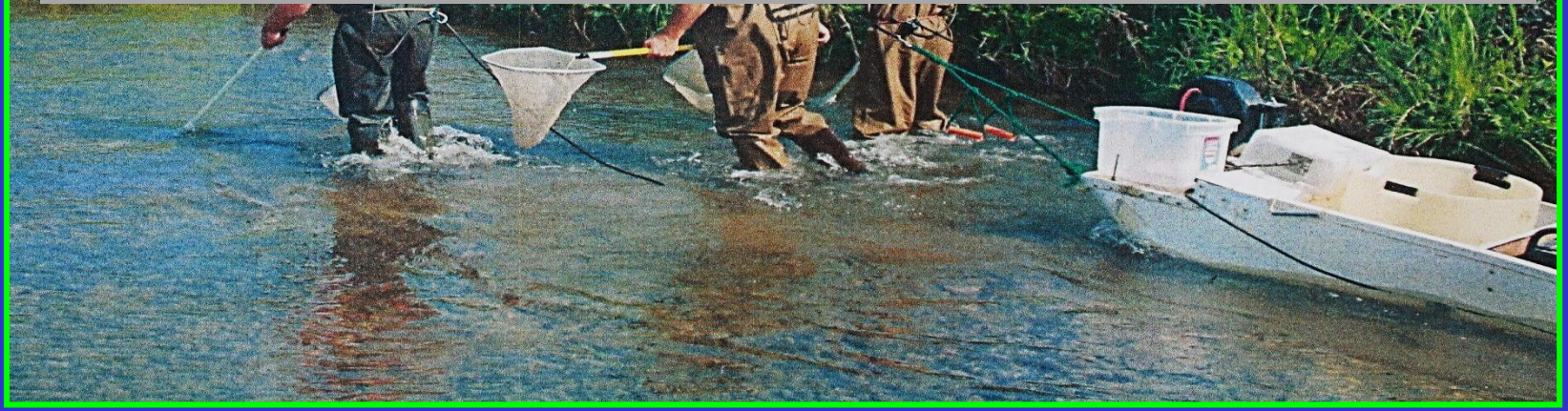
For Wadeable Techniques

Deeper water not only reduces capture efficiency but also increases risk of shock or submergence.

Portable-Specific Operations

For Tow-Barge Techniques

FWS safety policy: the power source must be continuously manned to rapidly cut-off power when necessary. This is usually the default mode of operation in boats and rafts but would require tow-barges to be pushed from the stern and shore-based generators/pulsators to have one crew member assigned to them.



Portable-Specific Operations

For Shore-based Techniques

A crew-member must be included whose job is to operate the shore-based generator/pulsator and remain in close reach of safety switches.

Portable-Specific Operations

The FWS safety policy prohibits use of netted anodes except for sea lamprey ammocete sampling.

Advantage is that the electrode handler can net fish. May increase sampling efficiency.

Disadvantages are:

- can't clean electrode surface
-could accidentally engage a team member into the circuit
-anode out-of-water switch may not protect (30 mA threshold)
-two jobs for the electrode handler
-fish exposed to most intense part of the field

Portable-Specific Operations

A shock delivered by a netted anode could cause a crew member to fall against a hard surface and be injured

No gloves

General Operations

The job hazard analysis (JHA) for each site should contain emergency instructions and documented routes to medical facilities and made available to all team members.

A one-page brief on standard operating procedure can be beneficial and be easier to communicate than a JHA.

JHA examples and forms located in the Electrofishing Safety class (CSP2202) materials

A lot of stuff but always keep in mind- we've come a long way

You have made it. Congratulations!

- If you would like to get a course completion certificate for the Electrofishing Safety course (CSP2202), access the exam at the course website.