WARMWATER STREAMS

TECHNIQUES MANUAL:

FISHES

C.F. Bryan
Editor
Louisiana Cooperative Fishery Research Unit

Contributions from the
Warmwater Streams Committee

April 1984
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Southern Division
American Fisheries Society

W A R M W A T E R   S T R E A M S

TECHNIQUES MANUAL:

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PREFACE

Among the first goals set down by the Warmwater Streams Committee was this Manual. While its production proved to be no great undertaking, certainly less than the Warmwater Streams Symposium, this book seemed as though it would never be completed. This may be as it should, because collecting fishes is as much art as science, and the state of this art has "grown" as much from the experiences of those who have done it, as from those who would stem creativity and stereotype the methods for statistical purposes. Presumably, so long as there are professionals who attempt to collect fishes using ever-improving technology, manuals such as this will not be complete. The contributors to this manual, to the recent volume similarly titled and released by our parent organization, and to the FAO Technical Paper No. 33 have attempted to summarize an enormous body of literature on fish collecting methods. Perhaps this manual differs from those documents primarily in that it gives a fairly explicit account of how southeastern fisheries biologists collect fishes from streams. It is not a textbook. While we fully expect to revise its contents with input from biologists from other regions of the country, with this Manual we hope to have begun to fulfill one of the charges given by John Cairns to aquatic biologists and paraphrased as follows: develop methods to quantitatively, efficiently, and objectively evaluate aquatic habitats.

April, 1984
C. F. Bryan

As promised above the first of chapter revisions is in this reprinting.

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C. F. Bryan

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ELECTROFISHING

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INTRODUCTION

Electrofishing is used in stream sampling to determine species composition, relative abundance, size distribution, and population structure. It is also used to examine aspects of the life histories of individual species (food habits, age and growth, etc.) and to make brood fish collections. Although somewhat selective, it is less biased than many other sampling methods and most fish can be released unharmed (Edwards and Higgins 1973).

Electrofishing techniques and gear have undergone progressive development since Haskell described the method in 1939. Vibert (1970) edited a detailed symposium on sampling with electricity. Output can be either alternating current (ac) or direct current (dc). The gear for each type of current can be adapted for use in a boat or can be portable. Our intent here is to distinguish the basic types of electrofishing gear, suggest stream types for which each is best suited, compare electrofishing with other (similar) methods, provide addresses where equipment can be purchased and point out safety precautions to be taken when electrofishing.

GEAR DESCRIPTION

Electrofishing Boats

Novotony and Priegel (1974) provided a detailed report on electrofishing boats and suggested improved designs and operational guidelines. Their work has served as a guide for the construction of basic dc and ac electrofishing boats (Figures 1, 2 and 3).

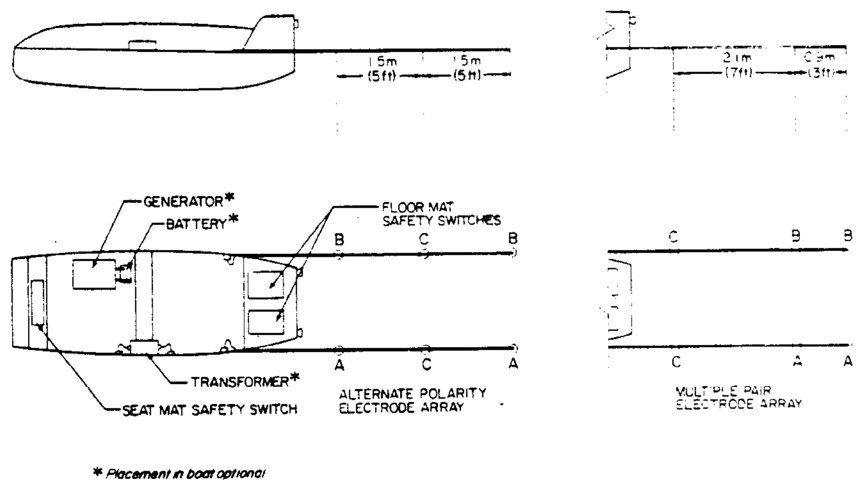

Figure 1. Configuration of the electrodes and the location of the major components of the ac electrofishing boat (Novotony and Priegel 1974).

Electrodes: Novotony and Priegel (1974) detailed the following requirements of an effective electrofishing electrode system:

"(1) establishment of an effective electric current distribution in the water to be sampled;
(2) avoidance of local regions of unnecessarily large current densities which waste power and are potentially harmful to fish;
(3) adjustability to meet changes in water conductivity;
(4) ability to negotiate weeds and obstructions;
(5) ease of assembly and disassembly; and
(6) avoidance of unnecessary physical disturbance to water to permit easy visual observation of fish."

A survey by Simpson and Reynolds (1977) disclosed wide variation in the electrode arrangement of dc and pulsed dc units. About 40% had ring-mounted anodes with 10 to 12 drops 0.5 to 0.8 m long; others had one to eight anodes, each usually less than 1.2 m long. Cathodes were either side- or back-mounted on 60% of the units; either front-mounted electrodes or the boat bottom served as the negative on 20%. Anodes were most commonly constructed of copper and cathodes of aluminum.

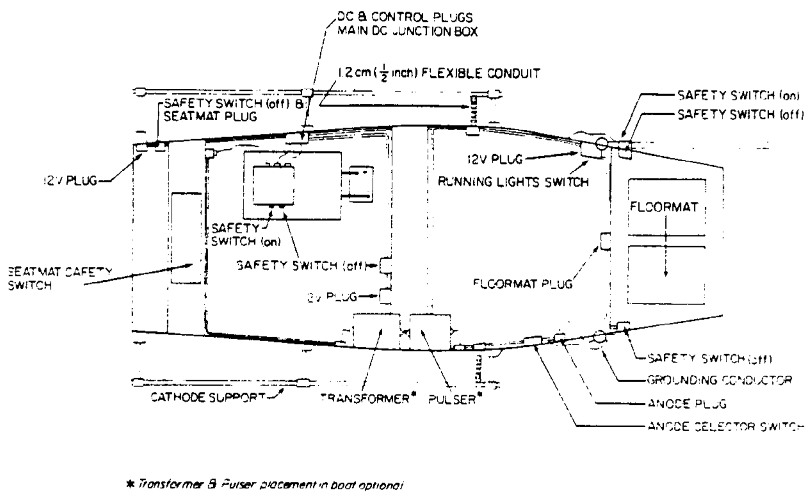

Figure 2. Major components location--experimental ac-pulsed dc electrofishing boat (Novotony and Priegel 1974).

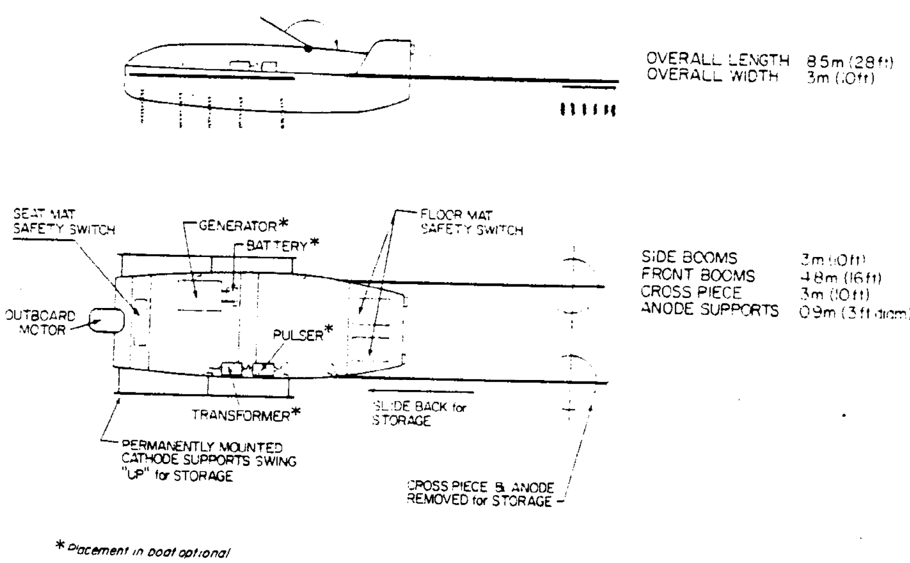

Figure 3. Electrode configuration of experimental ac-pulsed dc electrofishing boat (Novotony and Priegel 1974).

Hartley (1967) and Novotony and Priegel (1974) advocated using the largest possible cathode in a dc system. Vincent (1971) suggested that the surface area of the cathode should be 30 times the surface area of the anode. The shape of the cathode is not critical and several different configurations have been utilized successfully. Stubbs (1966) reported using the hull of the aluminum electrofishing boat as the cathode. Newburg (1973) used two rocket-shaped cathodes of galvanized sheet metal with a combined outside surface area of 5.2 m^2 (56 ft^2).

Novotony and Priegel (1974) mounted five 1.2 m (4 ft.) lengths of 2.5 cm (1 in.) diameter flexible conduit on each side of the boat. Size and spacing of the individual elements of the cathode were important if the cathode consisted of a number of separate, but electrically connected, electrodes. Closely spaced elements of the cathode tend to interfere because they must utilize the same space to distribute the cathode current. Much lower cathode resistance was obtained by keeping the individual elements well spaced. In Novotony and Priegel's (1974) dc arrangement, the elements of the cathode were approximately 0.6 m apart. Some have attached metal plates to the sides or bottom of fiberglass boats to serve as cathodes. The cathode design should be such that the manuverability of the boat is not affected.

The anode should produce maximum current densities near the water's surface to aid fish collection in high turbidity or heavy vegetation. Novotony and Priegel (1974) discussed relative merits of spherical anodes and ring-shaped anodes with cylindrical droppers mounted on booms and suspended 2 to 3.5 m in front of the boat. Peterman (1978) used both spherical anodes and ring-shaped anodes with droppers; the ring-shaped anodes with droppers offered greater flexibility over a wide range of water conductivity, greater control of current output, and less chance of snagging on obstructions.

Cuinant (1967) stated that an anode with a large diameter reduces the voltage necessary between the anode and ambience, diminishes the risk to personnel, reduces necessary electric power, and produces less internal damage to fish in the immediate proximity of the electrode. Novotony and Priegel (1974) also mentioned the greater "effective zone" of large electrodes because of the increased current density at moderate distances. Ring-shaped anodes with cylindrical droppers meet the requirements of effective electrodes by having a very small danger zone, a maximum effective zone and the smallest possible perception zone.

Respondents to Simpson and Reynolds (1977) reported most alternating current electrofishing boats had three to six electrodes suspended in front of the boat from two or three booms or from a crosspiece mounted on two booms. Electrodes averaged 1.8 m long and were usually of copper or aluminum.

Generally, cylindrical electrodes were used in ac electrofishing. The design of an ac electrode is not as critical as that of a dc electrode which ideally should produce maximum current density at the water's surface to attract the fish to the surface. The ac electrode is designed to simply immobilize, not attract fish to the surface. The cylindrical design of ac electrodes allows better manuverability of the boat around obstacles and creates less surface turbulence. This aids in observing stunned fish, especially when electrofishing at night.

Disadvantages of cylindrical electrodes include relatively poor current distribution, and zones of high current density near the electrode. These disadvantages can be overcome by using paired electrodes mounted in a continuous line (Figure 3).

Generator: Electrofishing systems, whether ac or dc, employ various types of generators. An ac generator with voltage outputs of 115 volts and 230 volts ac, 60 hz., single phase is probably most versatile. Such a generator would be compatible with either the Coffelt or Smith-Root variable voltage pulsators. The power rating of the generator is determined by the maximum water conductivity to be fished, the size of the electrode that can be supported by the boat and by weight limitations. Generally, a generator with maximum power that meets the weight limitations is preferred. Most agencies use generators ranging from 3 to 5 kilowatts in their boats. Generators that run quietly should be chosen for obvious safety and health reasons. We prefer hooded and shrouded recreational type generators.

Variable Voltage Pulsators: In Simpson and Reynolds' (1977) survey of fishery biologists in the United States, about two-thirds of the biologists used at least one device to modify electrical current; variable voltage pulsators (40%) were the most popular.

Variable voltage pulsators are available from several companies and in some cases agencies have constructed their own pulsators; most have input voltages of 115 v and 230 v ac, and provide both dc and ac output as conditions dictate. It is advantageous to use a pulsator that allows selection of different pulse frequencies. Voltage selections should range from 100 to 1,000 volts. The unit should have an ammeter to determine if sufficient current is present for successful electrofishing.

Boat and Motor: Specifications of boats and motors utilized in electrofishing vary but should be compatible for either dc or ac electrofishing. Many agencies use aluminum commercial fishing boats that have wide beams and flat hulls in lengths of 4.9 to 5.5 m. A metal boat allows all metal parts to be grounded to the frame of the boat to reduce the risk of a difference in potential among the various electrical components. Fiberglass boats can be used, but it is essential to ground all metal objects to the generator to lessen the risk of a short in the system. Agencies generally select outboard motors with a horsepower rating of 50 or greater. Some have used inboard jet and outboard jet boats (Peterman 1978), which worked well in the Yellowstone River and in waters as shallow as 18 cm. For convenience and manuverability, use electric start and remote steering with all motors on electrofishing boats. In addition, power trim and tilt will greatly facilitate electrofishing in shallow water.

To a large extent, the type of stream or river to be sampled will determine the boat and motor selected. Major factors to consider in boat and motor selection are water depth, water velocity, substrate type, and access. Streams should be $\geq$ 0.6 m deep, and $\geq$ 9.1 m wide for boat manuverability.

Portable Electrofishing

Backpack or portable shockers are usually used in small streams (less than 15.2 m wide) where toxicants or nets are impracticable or prohibited. Basically the backpack or the stream-side shocker are used, but there are almost as many designs in operation today as there are biologists using them.

Electrodes: The design and material used for probes varies greatly. For ac electrofishing, Seehorn (1967) described a set of electrodes for most small streams; one is an aluminum dipnet with a handle 16.5 - 21.3 cm long and the other electrode is a 30.7 cm telescoping radio antenna (Figure 4). A piece of rubber hose slipped over the base of the antenna serves as a handle and insulation. A microswitch is attached to the rubber handle for safety. The dipnet handle is insulated by a 9.5 cm section of heat-shrinkable plastic tubing. An alternate method would be to use a wooden dipnet handle.

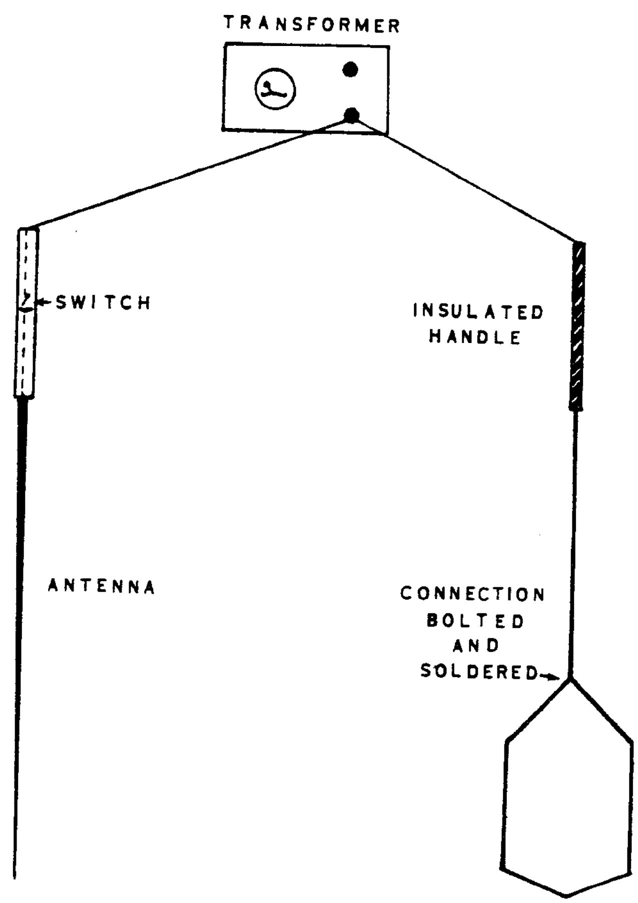

Figure 4. Antenna-dipnet electrodes (Seehorn 1967).

For pulsed dc electrofishing the anode should be in the form of a loop or ring. The diameter of the loop should be at least 8 cm, but no more than 30 to 40 cm. Large anodes reduce the zones of high current density and lessen fish mortality, but excessively large anodes increase water current drag and may be cumbersome. The anode ring is mounted on a wooden or fiberglass pole 1.5-1.8 m in length.

Cathodes should be as large in surface area as is practicable. Screens of copper or aluminum are popular. These have been attached to the waders; but screens suspended from floats can be pulled behind the biologist.

Power Supply: Most commercial backpack electrofishing units are designed to operate with a pulsed dc current powered by a small motorcycle battery. Battery powered shockers are quiet and safe, however, operating time for a fully-charged battery is only 1 to 2 hours. Output voltage is continuously reduced as the battery is operated.

AC backpack shockers have lightweight gasoline-powered 110 generators as the power supply. The gasoline-powered generator produces a steady voltage output. Reliability of early models was poor, but recently they have improved. Aquabug International, Inc. makes a very reliable 110 V gasoline-powered generator. The output voltage is regulated either through one of the commercially available control boxes, by rewinding the generator, or by a step-up transformer. The control box or step-up transformer gives the biologist the option of several voltage selections depending upon water conductivity. Seehorn (1967) described the procedure for adapting a small step-up transformer to a 110 V gasoline-powered generator, but those have been replaced by the Stancor PM 8419 (70 milliamps) or the Stancor PM 8420 (90 milliamps) transformers that provide voltages ranging from 250 to 500 volts. The generator, motor and transformer are usually mounted on a light-weight aluminum or plastic backpack frame.

The stream-side shocker consists of a large generator, a voltage control box, a reel of cable and electrodes. The generator may be stationed on the bank near the center of the study area, or in a raft or boat behind the sampling crew, eliminating the need for a long cable. A large cathode screen can be placed on the stream bottom in highly conductive streams ($>$ 100 umhos/cm) but in water of low specific conductance ($<$ 100 umhos/cm) the electrical field will be too small.

STREAM OR STREAM REACH

In 1981 Kauffman (personal communication) surveyed state agencies and universities regarding their use of electrofishing gear. This survey revealed that site inspection determined whether a boat or portable unit was to be used in a stream. No agency reported predefined stream characteristics (velocity, depth, etc.) that determined equipment choice. Inspection reveals whether water depth, shoal areas, rapids, and waterfalls would create hazardous electrofishing conditions or limit use of a boat.

Portable units are most useful in shallow streams < 15 m in width. Backpack shockers are not effective in streams with pools deeper than 1.5 m. Electrofishing becomes increasingly difficult when a stream is highly turbid, or rapidly flowing after heavy rains.

GEAR APPLICATION

DC Boat Electrofishing: When sampling rivers the voltage should be adjusted to produce maximum amperage without exceeding the rating of the generator or the variable voltage pulsator. The setting will vary according to water conductivity. The lesser conductive waters will require higher voltages for successful electrofishing and as conductivity increases the voltage should be decreased.

Move downstream at slow speeds when sampling deep pools or runs, allowing fish to be attracted to the anode. In shallow water, the boat should move faster than the current, or fish may scatter into deeper areas of the channel. Dropoffs and pools should be sampled thoroughly by slowly circling the area several times. As the boat moves downstream all available habitat should be sampled, particularly the cover associated with river banks. Sampling efficiency may be increased by having a second "pick up" boat follow the electrofishing boat to net fish that surface out of reach of the netters in the electrofishing boat.

AC Boat Electrofishing: About 80% of the highest ac current output will accommodate the variances in water conductivity and maximum electrofishing success. Since fish will not be attracted to the anodes, more fish may be overlooked by the netters in boats travelling rapidly downstream. In turbid water many fish will be missed unless they float to the surface. A pick-up boat trailing the electrofishing boat will help recover fish that rise slowly to the surface.

Night electrofishing can be more effective especially in clear water with low conductivity. In the summer months, more fishes may be collected at night when they move into shallower water.

Portable Electrofishing: When sampling a small stream with a backpack unit it is usually better to wade upstream. Care should be taken to sample all areas including undercut banks, large rocks, tree roots, snags, brush and leaf debris. Riffles and runs should not be overlooked. When sampling areas of heavy cover with a dc backpack unit, apply current briefly to attract fish from the cover to the anode.

Ancillary Equipment: Certain other equipment may be necessary for either ac or dc boat electrofishing. A live well should either be built into the boat or a portable one should be constructed, because many boat live wells are not large enough to hold sufficient fish. A dc agitator powered by the boat battery should be installed on the tank. Additionally, a small oxygen cylinder may prove useful when handling sensitive fish such as large striped bass.

Dip nets should have long (3 m) insulated handles or fiberglass handles. Mesh size depends upon the size fish to be sampled. Polaroid glasses are helpful in sighting stunned fish below the water's surface. Measuring boards, weight scales, and record forms may be necessary, depending upon data requirements. A selection of basic electrician's and mechanic's tools may prove useful in the event of equipment failure or maintenance problems. A volt-meter will help pinpoint electrical circuit failures.

Accessory equipment useful when backpack electrofishing includes a fish holding device constructed of hardware cloth, netting, or a trash can with holes drilled in it. If the operator does not have a net mounted on one of his electrodes, a second man should be equipped with a dip net for collecting stunned fish.

Advantages of DC: Electrofishing with direct current does not cause as many fish mortalities as electrofishing with alternating current (Taylor et al. 1957). Continuous dc and pulsed dc current induces fish to swim toward the anode and allows them to be netted more easily. To attract fish to the surface near the anode, the anode should be properly designed to produce maximum current densities close to the surface and the current structured at suitably low pulse rates. Fish may be drawn to the anode from depths exceeding 1-1.5 m, instead of being immobilized and unnoticed by the collector. Peterman (1978) reported capturing shovelnose sturgeon from depths of 2.4 to 3.7 m in the Yellowstone River under ideal sampling conditions.

Some data indicate that species selectivity is possible when electrofishing with pulsed dc (Novotony and Priegel 1974). Pulse rates ranging from 40-120 pps attract trout, carp, bullheads, largemouth and smallmouth bass close to the anode before being stunned. Pulse rates from 5-40 pps attract walleye, yellow perch, bluegills, white and yellow bass to the anodes. Apparently, low-pulsed dc has an effective zone twice as large as dc at 100 pulses per second (100 pps), and is intermediate between unpulsed dc and ac in the distance at which fish are affected.

Disadvantages of DC: The effective range of dc is not as great as ac, which in clear water or waters of low conductivity, may limit electrofishing success. Pulsed dc electrofishing is usually better than continuous dc, because of the minimal range of the latter.

Disadvantages of AC: Fish stunned by ac may not be seen in turbid waters or washed away in swifter waters. Also, catfish and certain other bottom dwellers, particularly those fish with a reduced or rudimentary air bladder, may be especially difficult to collect as are fish in heavy cover.

Vincent (1971) noted that alternating current is the poorest type of current for electrofishing trout from western rivers. His reasons were (1) in the absence of galvanotaxis, capturing fish was difficult; (2) ac was most dangerous to the shocking crew; and (3) tissue damage to fish was common. Some of those findings may be applicable in warmwater streams.

<u>Manpower Requirements</u>: Boat electrofishing requires a minimum of two men. The boat driver operates the boat and regulates the setting of the voltage pulsator. The second man stands on the deck near the bow of the boat and nets the fish as they are stunned. A third man may be used as a second netter. When using backpack units, one man carries the anode and may net the stunned fish, if one of his electrodes is a dip net. The second man may tow the fish holding device, the cathode, and assists in netting fish.

<u>Time Requirements</u>: The amount of time required to obtain the sample will be dictated by the objectives of the study, and the size, current, and diversity of microhabitats within the stream reach. If a population estimate by the Petersen or Schnable method is to be made, the amount of time will be determined by the number of recaptures required for the selected confidence interval. If the sample is used to obtain proportional stock density (PSD) of bass, Reynolds and Simpson (1978) recommended a minimum of 8-12 stock-size bass (i.e., 20 cm). Time should be allowed to thoroughly sample representative sections of all microhabitats so that all susceptible fish have been sufficiently exposed to the gear.

<u>Efficiency</u>: Vibert (1970) defines the efficiency of electrofishing as "the ratio between the number of fish caught in a certain area and the number of fish actually present in that area at the time of fishing". Historically, electrofishing has been used as a qualitative sampling method unless it was used for population estimates (e.g. mark and recapture, [depletion]). Recent work indicates electrofishing success rates may be used as measures of abundance of largemouth bass and bluegill sunfish (Reynolds and Simpson 1978), walleye fingerlings (Serns 1979), and smallmouth bass fingerlings (Kauffman in press). Electrofishing data on fishes of specific sizes and species can be compared by using correction factors such as those developed by Reynolds and Simpson (1978), or by comparing only with the catch/effort of the same species of defined sizes.

Many factors (visibility, temperature, etc.) that affect electrofishing efficiency affect other sampling methods, as well. Some can be controlled by the biologist, i.e., equipment design and technique, and sampling time. Data comparisons are only appropriate for samples gathered during the same season and time of day. Apparently, fish are more susceptible to the gear during spawning season and at night.

Other factors, more or less beyond the biologist's control, are species vulnerability, size selectivity, habitat preference, water conductivity, and depth. Species selectivity may be primarily a function of habitat preference. Reynolds and Simpson (1978) reported that bullheads, catfish, golden shiners and crappie were detected by boat units in less than 30% of the ponds they inhabited, and that larger fish were more easily caught but efficiency was not always directly related to length of the fish. Larimore (1961) reported an electric seine was less efficient in sampling catfish and darters. Serns (1979) observed no correlation between conductivity and fingerling walleye catch rate.

Nevertheless, catch per effort data on the same species of a defined size range may be compared, so long as information on factors that may affect efficiency are recorded. Thus, information on control settings of the electrofishing unit (voltage, amps, ac or dc, pulse frequency, and pulse width), water conductivity, visibility, temperature, and time electrofished should be recorded.

COMPARISON WITH OTHER GEAR

Boccardy and Cooper (1963) reported that electrofishing was less efficient than rotenone in capturing fish of all sizes. It is generally acknowledged that electrofishing is selective for larger fish, although exceptions to this have been reported (Pardue and Huish 1981). In comparing electrofishing, seining, and toxicant fish sampling on Salt River, Kentucky, Hoyt et al. (1979) found that seining gave the lowest estimates for average number of species collected, electrofishing was intermediate in number, and toxicants provided the highest number. Similarly, average standing crop estimates were lowest with seining, intermediate with electrofishing, and highest with toxicants.

Electrofishing is convenient, less likely (relative to seining) to be hindered by obstructions or irregular substrates, and requires only two people. However, as stream depth, width and velocity increases, electrofishing estimates of species abundances can be expected to decline. Trammel and gill nets in sampling streams are (UMRCC 1948) highly selective for certain species and sizes of fish. In swift waters they are difficult to hold in place and inefficient in sluggish streams when fish are not moving. Gill and trammel nets are not practical in small streams of shallow depths. Gill nets seldom take fish alive or unharmed unless they are harvested at very short intervals; whereas, electrofishing does little harm to fish, especially when using dc or pulsed dc.

Electrofishing may be the most convenient technique for determining species composition and relative abundance of a species in a stream. It is an accepted technique for obtaining fish population estimates through mark and recapture methods and is advantageous to use because it is less labor intensive than other techniques.

The influence of physical factors must be considered when comparing efficiencies of various gear types. Turbidity has a negative influence upon sampling efficiency. Increases in stream width, depth, and velocity can negatively influence electrofishing success. In larger streams more labor and specialized gear is required for successful toxicant sampling. The amount of cover present in a stream may cause many fish to be missed with ac electrofishing since they are not drawn to the anode. Pardue and Huish (1981) reported that fyke nets effectively captured the larger, abundant species in streams during high flow, but were ineffective in capturing the small species that escaped through the mesh.

SAFETY

Advances in safety practices have not kept pace with the technological advances made with the gear. Voltages have been stepped up, often > 600 v, with little attention given to equipment ratings. A survey of safety equipment of state agencies and universities utilizing electrofishing (Table 1) was conducted in 1981. At least 50% of the respondants required fire extinguishers, railings, rubber boots and gloves, while all the equipment listed was required or recommended by 66% of those surveyed.

Accident prevention is best accomplished through proper equipment design. Design features of equipment are described by Novotony and Priegel (1971) and in the U.S. Fish & Wildlife Administrative manuals (Regional Offices). Requiring rather than recommending equipment is probably the easiest way to reduce the frequency of accidents. A safety checklist modified from the U.S. Fish & Wildlife Service Electrofishing course is provided below:

Voltage: Rated voltages of insulation of conductors used to deliver output current from the pulsator to the electrodes must exceed the maximum potential output of the pulsator.

Conductor Size: The wire must be of sufficient size to handle maximum rated amperage.

Conductor Type: All conductors in the boat shall be enclosed in raceways except that heavy duty rubber covered cord can be used where flexibility is required. Connectors must meet the above specifications and be of a locking waterproof type. Power, lighting and safety switch systems should be in separate conduits or raceways.

Connections: No taped or spliced connections of wire shall be used inside the boat. If connections are necessary, the ratings of the connector must be the same as the wire.

Junction Boxes: All junction boxes with switching equipment must be water proof. Junction boxes without switches may be of the rain-proof type.

Circuit Breaker: In the absence of a built-in circuit breaker in the pulsator unit, power output conductors from the generator or alternator shall include a circuit breaker or fuse.

Central Control Box: All circuit breakers, switches and controls shall be within easy reach of the boat operator.

Deadman Switch: Each netter shall have a deadman switch, connected in series, to control power from the pulsator. The boat operator shall also be provided with a deadman switch connected in series with the netters. These power control circuits shall not exceed 24 volts.

Table 1. Safety equipment used by respondants to a survey by J. Kauffman (1981).

Equipment	Percent			Number of Responses
	Required	Recommended	Not Utilized	
Boat				
Fire extinguisher	55	36	9	58
First aid kit	41	46	13	54
Hearing protection	18	48	34	56
Railing	80	18	2	65
Rubber boots	66	32	2	56
Boat and/or Portable				
Rubber gloves	58	40	2	57
Operators trained in CPR	16	60	24	57
Operators trained in first aid	16	60	24	58

Electrodes: Except in extreme soft water conditions where very large cathode surfaces are imperative, metal boat hulls shall not be used as the cathode, and the cathode shall otherwise be electrically insulated from the hull, including the anode. Both anode and cathode shall be insulated from their respective booms. Booms and dip net handles shall be constructed with non-conductive materials (such as "Epoxiglas", a foam-filled fiber glass manufactured by the A. B. Chance Co. to handle high-voltage power lines).

An Isolating Transformer: Shall be required on the output of all generator/alternators in the absence of pulsator control units containing such transformers.

Lighting: All lighting and auxiliary circuits should not exceed 24 volts. Onboard lighting is necessary for electrofishing at night; a 115 VAC lamp in a shielded non-conductive cage can be used.

Net: Non-conductive handle (fiberglass or epoxiglass poles).

Labelling: All areas of access or possible access to high voltage shall be labelled with appropriate warning signs and color coding. Any moving equipment or hot machinery shall also be labelled with appropriate warning signs, and/or color coding.

Battery Enclosure: An acid-proof, non-metallic enclosure and holder shall be provided for wet cell batteries.

Noise: Personal hearing protection shall be used when noise level is above 90 dba.

Exhaust From Power Source: Exhaust from the motor generator (alternator) shall be piped away from the boat operator. Piping should be enclosed in protective screening to protect personnel from burns.

Fuel Storage: Fuel storage and transportation shall be in an approved container.

Refueling Generator: To refuel the generator (alternator) all equipment shall be turned off and hot surfaces allowed to cool.

Guard Rails: Safety rails shall be provided around the netting area. Rails should be at least 36" high. Construction should be of at least 2 cm (.75 inch) diameter heavy wall steel pipe or 3 cm (1.25 inch) diameter heavy wall aluminum pipe. Work deck should have a non-skid type surface.

Fire Extinguisher and First Aid Kits: Each boat shall be equipped with at least one 5 lb. ABC type fire extinguisher mounted for easy access and away from high fire potential sources. The first aid kit should be in a watertight container.

Life Vests: All occupants shall wear Coast Guard approved life vests at all times they are on board the boat. Life vests shall meet the Type II or III requirements.

Safety Gear: For boat electrofishing, each person should wear either rubber 30 cm (12") high boots or hip boots and gauntlet rubber gloves. For stream shocking, waders and gauntlet rubber gloves should be worn.

Inspection: The boat and shocking equipment should be inspected prior to each use.

A safety program incorporates First Aid training in the program. Accidents are inevitable so first aid training should be easily incorporated into the work schedule with the American Red Cross multimedia First Aid (1 day) and CPR (1 day) courses.

EQUIPMENT PRICE LIST

Variable Voltage Pulsators:

Smith-Root Inc.
14014 N.E. Salmon Creek Avenue
Vancouver, Washington 98665
1982 Price Range, $3,150.00 - $3,440.00

Coffelt Electronics Company, Inc.
2019 West Union Avenue
Englewood, Colorado 80110
1982 Price Range, $1,290.00 - $3,090.00

Back Pack Electrofishing Units:

Coffelt Electronics Company, Inc.
Same address as above. Gas powered and battery powered models are available.
1982 Price Range, $1,395.00 - $1,520.00
Smith-Root, Inc.
Same address as above. Battery and gas powered models are available.
1982 Price Range, $1,865.00 - $2,085.00

Aquabug International, Inc.
100 Merrick Road
Rockville Center, New York 11570
Reliable gas powered generator.
Aquabug - Model No. AQB-300.
Available in a 110-115 volt AC type. Weight, 19 lbs.
1982 Price, $275.00

Booms For Electrofishing Boats:

Athletic House
400 State Street
Knoxville, Tennessee 37902
Fiberglass vaulting poles, irregular or seconds, 15 ft. or longer, 1-1/2" - 1-5/8" diameter.
1982 Price, $21.00 each

Dip Net Handle, Hoop, and Housing Bracket:

St. Croix of Park Falls
P.O. Box 279
Park Falls, Wisconsin 54552
NCD-400 handle, extra heavy duty, 10 ft. fiberglass covered aluminum handle with crutch tip, 3 layers of fiberglass over aluminum tubing.
1982 Price, $33.21
NCD 400 handle housing bracket, raw ball lock casting with hoop and handle holes bored.
1982 Price, $6.81

Alternate Source for Dipnet Hoop:

Whale Enterprises, Inc.
1001 Industrial Park
Piedmont, Alabama 36272
Phone: (205) 447-8691
All steel hoop. 1/2" outside diameter. Bow size, 17" x 20".
Stock No. D18-48 5A. This hoop will fit NCD-400 handle from St. Croix.
1982 Price, $ .95

Ear Plugs:

E. A. R. Division
Cabot Corporation
7911 Zionsville Road
Indianapolis, Indiana 46268
Foam compressible type.
1982 Price, $ .15 each

Electrofishing Boats:

Completely outfitted electrofishing boats are available from Smith-Root, Inc. and Coffelt Electronics Company, Inc. See address above. These can be purchased with a variety of options. Price dependent upon options desired. Contact manufacturers for specifications, options available, and prices.

Power Transformers (for building a backpack electrofishing unit):

J Supply Company
P.O. Drawer F
Anniston, Alabama 36202

(or local electrical supply company)

Stancor # PM 8419 - 70 ma - 240/480 volts
Stancor # PM 8420 - 90 ma - 260/520 volts
1982 Price, $13.36 (PM 8419)
$17.75 (PM 8420)

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HOOK AND LINE SAMPLING

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INTRODUCTION

The fish hook was one of the earliest tools invented by man; primitive gorges, or double-ended points made of stones, shells, antlers and bones, were used to catch fish in the early Paleolithic, or Old Stone Age before 8000 B.C. Just prior to the beginning of the Neolithic or New Stone Age, recurved single-pointed fish hooks made of bone were developed. The first metal fish hooks were fashioned of copper about 5000 B.C., and with the discovery (around 4000 to 3000 B.C.) that one part of tin mixed with nine parts of copper produced stronger and more workable metal, fish hooks were made of bronze. Fish hooks of iron appeared between 2000 and 1000 B.C. Modern steel fish hooks were first produced in Europe near the end of the fourteenth century (McClane 1974).

Angling gear and methods are diverse and include casting with natural baits or artificial lures, still fishing, jigging, snagging, set lines, trot lines, long lines (Lagler 1978), jugging (Ludgate 1950, Starrett and Barnickol 1955), and trolling. Stocks of many marine species such as tuna, salmon, swordfish, mackerel and cod have been assessed based on catches by a variety of hook and line methods (Nedelec 1975).

Although selective for species and size, hook and line is useful for collecting freshwater fishes. Fish may be collected with hook and line for stocking or for use as brood fish in hatcheries (Crumpton and Smith 1975). Hook and line can be an effective and relatively inexpensive means of confirming survival of stocked non-native sport species (Jones 1979).

Angling is sometimes used to detect presence or indicate abundance and production of selected species in streams (Primmer 1975, O'Connor and Power 1976). While hook and line data are seldom expanded to

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estimate fish abundance, sport fishing gear has been used to estimate populations by mark and recapture, particularly in lakes. Holbrook et al. (1972), Grinstead and Wright (1973), Aggus and Rainwater (1975), Hickman and Hevel (1975) and Seawell and Hevel (1978) estimated largemouth bass populations in reservoirs from tournament catches of marked fishes. Waters (1960) estimated trout populations in small lakes using angling and other gear to capture trout for marking and for recapturing marked fish. Those techniques should be applicable to warmwater streams.

Sport fishing gear has been used to determine sport fishing quality, success, and harvest rates (Graham 1974, Warner 1978). Information on recreational sport fishing success is occasionally collected directly through creel census (Byrd 1959, Hassler et al. 1981, Kornegay 1981, Mullis and Guier 1981). Because such information is usually difficult and expensive to obtain, some government agencies sample by hook and line to anticipate success by the angling public or to evaluate angling vulnerability of a variety of piscivores and hybrids (Thrasher 1974, Crumpton and Smith 1975, Inman et al. 1976, Weithman and Anderson 1976, Zolczynski and Davies 1976). Angling has also been used by agencies to evaluate such management practices as fish attractors (Wege 1981, Wilbur 1970), stocking exotic fishes, regulation changes and creation of commercial fisheries. The effects of environmental alterations on sport fishes have also been evaluated using hook and line gear (Elser 1965, Allen et al. 1970).

Since all gear are selective, data from combinations of sampling methods may be necessary to prevent drawing erroneous conclusions. Agencies often employ hook and line with other methods to sample fishes to study age and growth relationships (Dudley and Golden 1974, Terrell and Fox 1974, Mullis and Davies 1977, Otto 1979), condition, food habits, size and age composition, and gonad development. Fish caught by hook and line have been tagged and released to study movement and behavior (McCleave and Horrall 1970, Dupont 1976) and mortality (Hassler et al. 1981). When relatively small samples of fish are desired for tissue contamination analysis or for hematological or bacteriological study (Esch and Hazen 1980), hook and line sampling can be a relatively quick and inexpensive way of obtaining specimens. Further, hook and line fishing may be useful in determining predator-prey structure (Funk 1974) or in estimating population status of certain recreational and commercial fishes when the relationship between population size and angling yield has been established (Lagler and DeRoth 1953).

GEAR DESCRIPTION

In the simplest form, a hook at the end of a line is attached to a float or to a main line from which hang many similar dropper lines with hooks (Everhart et al. 1975). The line may be tied to the end of a somewhat flexible staff in the form of a bankside sapling or tree limb, a bamboo pole, or pole of synthetic fiberglass or graphite. The more refined gear includes a rod with line guides and a reel for line storage. Rods and reels are modified for four specific types of freshwater fishing: bait-casting, spinning, spin-casting, and fly-casting.

A landing net or gaff will help prevent the escape of specimens during the final stages of capture. A boat increases the mobility of the sampler, but, in small streams, samplers may wish to use waders, hip boots, or wading shoes.

The initial investment for hook and line sampling gear can range from less than $5.00 for a few hooks and 20 feet of line tied to a cane pole and baited with earthworms to several hundred dollars for a custom rod and quality reel. Artificial freshwater fishing lures currently range from $ .50 to $5.00 each.

Angling equipment and supplies can usually be purchased locally at sporting good stores, hardware stores, department stores, service stations in rural areas, or supply houses such as the following:

Sears, Roebuck, & Company
4640 Roosevelt Blvd.
Philadelphia, Pennsylvania 19132

Browning
Route 1
Morgan, Utah 84050

Eddie Bauer, Inc.
Third and Virginia
Seattle, Washington 98130

Cabela's
812 13th Avenue
Sidney, Nebraska 69162

The Tackle Box
Dillingham Avenue
Falmouth, Massachusetts 02540

STREAM AREA APPLICATION

Angling is relatively non-site specific provided that fish of a size and species suitable to take a baited hook are present. The area or size of stream segment that can be sampled with hook and line is limited only by the mobility of the angler. Large streams may require the use of a boat to sample all suitable habitat.

APPLICATION OF GEAR

The baited hook or artificial lure must be presented within the reach of the target fish in a manner which will encourage the fish to ingest it. Little additional action needs to be imparted to the hook baited with natural organisms, particularly live ones, but artificial lures may require erratic retrieval to impart action. The baited hook or artificial lure should be fished near cover, feeding areas, or other areas which attract, hold, and concentrate fish.

Hook and line sampling requires a minimum of manpower. Each unit of angling gear is operated by only one person. It is beneficial to have as many anglers as possible to minimize bias from differing skills of each fisherman. Two anglers are a minimum number when angling data are to be quantified. When quantitative data are not important, the number of angling units is not important except from the standpoint of time required for capture of adequate samples.

A rigid sampling scheme must be used when catch data are quantified as in estimating population abundance. The number of fishermen, lure, tackle, and the sampling time should be standardized to insure comparable results. Sampling stations and specific station assignments of anglers must be selected randomly to minimize sampling bias. Anglers should be rotated from station to station to reduce error associated with skill level. The minimum sampling period should be 30 minutes per station. Total angling effort will vary with the habitat; however, 10 angler-hours should be considered a minimum effort for a stream segment. Data should be reported as catch, by weight or number of fish, per hour of angling (CPUE). Specific angling techniques for several species of warmwater fishes are discussed by Harlan and Speaker (1956).

COMPARISON WITH OTHER GEAR

Although hook and line sampling may provide accurate, reliable, and timely data on fish populations, it may supplement other, more widely accepted scientific fish collecting techniques or be used in circumstances where other methods are not effective. Angling gear can be used in relatively remote locations that are difficult to sample with bulky gear. Where water conditions (such as very low or high conductivity, low temperature, turbidity, high flow, or excessive depth) preclude electrofishing, nets, or chemicals, hook and line can be effective.

Hook and line sampling requires a smaller expenditure of manpower than most other sampling techniques, particularly if the target species is concentrated. If the objective is to determine the distribution of a species, a large area can be sampled by angling in a relatively small amount of time. Hook and line is also appropriate when so few fish are needed that use of larger gear is not justified.

Other standard gear can lead to poor public relations. Toxicants or electrofishing reduce fishermen success in specific locations for a period of time, and nets can limit fishermen access. Hook and line fishing interferes less with the public, and it is more esthetically pleasing and ecologically innocuous.

Legal restrictions, other than a valid fishing license, on hook and line sampling for scientific purposes are rare. Public waters can almost always be legally sampled with hook and line.

Hook and line sampling results are easily translated to the fishing public. It is easy for sportsmen to relate hook and line data to their own fishing experience, since other conventional gear may collect species and sizes of fishes that fishermen seldom see.

Fishes collected with hook and line are usually in good condition and can be released after taking scale samples and measurements of length and weight. Many species collected by angling are suitable for use as brood fish in hatchery operations.

Fish caught by angling may be used for food habit studies if artificial lures or non-native natural baits are used. Non-native natural bait found in the stomach samples is, of course, disregarded. Comparatively little digestion occurs in fishes caught by hook and line relative to those taken by most passive gear. The bias of gorging by piscivorous species collected using toxicants is not encountered with fishes collected by angling. However, fishes caught by hook and line may regurgitate food items during or after capture.

The collection of fish with hook and line by fishery managers can lead to adverse public reaction. Many sport anglers perceive all fishing as recreation, and the scientific collection of fish with hook and line may be misunderstood. Angling sportsmen pay for the bulk of the costs of fishery management, and they believe their money is being wasted when they observe public employees fishing on the job. This has led administrators to curtail sampling by angling by fisheries professionals in many southern states.

Data collected by hook and line are difficult to quantify and expand for population estimates. Angling data may be quantified and expanded to indicate sport angler success rates. Size and species composition estimates from hook and line CPUE may be used to predict the potential of a stream or reach to sustain a particular fishing pressure.

All sampling gear is somewhat selective for particular species or sizes of fish. Hook and line is normally selective for predatory species and against fishes too small to ingest baited hooks or lures. However, the choice of bait or lures can influence selectivity of the gear. Webster (1954) found that angling was selective for brook trout in an Adirondack pond. Bennett (1962) stated that angling is one of the best methods for capturing largemouth bass.

Le Clerc and Power (1980) compared the size selectivity of fly-fishing, spin-fishing, and gill nets for brook trout, Salvelinus fontinalis, and ouananiche, Salmo salar, in a large Quebec river. They found that fly-fishing was the least selective of the three gear types because it captured the greatest range of fish sizes, and gill nets were most selective. Anglers had the added advantage of mobility which allowed rapids to be more evenly sampled. Warner (1978) captured landlocked salmon in a small Maine lake with angling and trap nets. When the data were summarized, anglers caught more fish than trap nets, and the rate of harvest was greater for angling than for trap netting.

Hickman and Hevel (1975) used mark-recapture techniques in comparing population estimates of largemouth bass in a Missouri lake obtained by utilizing a bass tournament and an electroshocker for collection of recaptures. The two independent estimates were very close, suggesting that either the estimates were accurately depicting the population, or both techniques sampled only a portion of the total population. Waters (1960) also used mark and recapture procedures for evaluating angling and traps for brook trout in small lakes. Estimates obtained by "angling and recapture by angling" were believed to be too high, probably because marked fish had acquired a resistance to the lure. Estimates from "trap and recapture by trap" were too low when hoop nets were used but were too high when hardware cloth traps were used. Estimates obtained by making initial collections and recaptures of marked fish by different methods (i.e. "trap and recapture by angling" and "angling and recapture by trap") were considered best, since they were compatible with known numbers present and numbers previously planted, and they agreed well with each other. Swingle et al. (1965) discovered that population estimates of largemouth bass in a 3.5 acre pond, using electroshocking and angling to collect recaptures, were in error by about 50%. They attributed this to bias resulting from sampling only a portion of the total population.

SAFETY PRECAUTIONS

Angling is perhaps the safest of the standard fish sampling techniques. The gear is relatively non-hazardous, and no more danger is involved than in recreational angling. Caution should be taken to avoid impalement of samplers by careless use of hooks. Standard life saving equipment should be kept available in case of accidental falls into the water including an approved personal flotation device for each person sampling from a boat or a throwable preserver and a rope if sampling is being conducted from the shore. A first aid kit should always be included in any checklist of sampling equipment.

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SNORKELING AND SCUBA DIVING

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INTRODUCTION

Snorkel and SCUBA diving methods are being employed with increasing frequency in sampling stream fish populations. Early uses were limited mainly to observations of fish behavior (Ellis 1961, 1962; Keenleyside 1962) and censuses of fish populations (Grenfell 1961). Northcote and Wilkie (1963) first attempted evaluation of snorkeling as a census tool by comparing their results with those from toxicant samples. Goldstein (1978) compared one-time snorkel surveys with repetitive seining surveys and found that more comprehensive and less biased data were obtained by snorkeling along transects. Snorkeling and SCUBA were used by Hickman (1981) to estimate abundance of the endangered snail darter.

Fishery scientists who use snorkeling or SCUBA for information gathering should have considerable taxonomic experience and be certified for SCUBA. Snorkeling or SCUBA are not effective in streams with Secchi disc readings < 1 m or current velocity > 1 m/s. Snorkeling is effective in depths less than 1.5 m, and SCUBA is more efficient at greater depths.

Through underwater observation, the behavior of species or species groups can be observed while gathering data on occurrence, relative abundance, distribution, and habitat selection. Secondly, qualitative and quantitative information can be obtained with minimal habitat disturbance, which is especially important in streams with threatened or endangered species.

GEAR DESCRIPTION

The following is a list of equipment and supplies needed for snorkeling or SCUBA in streams.

All materials can be obtained at local dive shops and other materials at a hardware store except seines.

Snorkel		SCUBA	
Mask and snorkel	$ 50	Mask	$ 40
Wet or dry suit*	150 to 800	Wet or dry suit*	150 to 800
Weight belt w/lead weights*	50	Weight belt w/lead weights	50
Dive fins*	33	Dive tank	155
Transect rope*	5	Dive fins	33
Transect bars*	5	Dive knife	25
Seine*	50	Regulator w/console (gauges)	200
Data sheets	-	Back pack	35
Cooler and aerator (for live specimen collection only)*	50	Buoyancy compensator	150
Sample jars w/Formalin*		Dive flag and float	10
		SCUBA utility box	36
		Dive compass	35
		Dive light*	50
		Transect rope*	5
		Transect bars*	5
		Underwater seine*	20
		Data sheets	-
		Cooler and aerator (for live specimen collection only)*	50
		Sample jars w/Formalin*	-

*Optional items depending upon conditions and sample needs.

STREAM REACH

Snorkel or SCUBA methods can be applied in streams of various sizes (stream width 3 m to 1,000 m) by adapting the number of personnel and the length of time spent to a particular site. It is essential that at least 30 percent of an area or site be viewed by the divers. Increased size of the area to be sampled is the main determinant of increasing costs of the operation.

PROCEDURES

Qualitative

Random searching is often used to make a preliminary reconnaissance of a study area, recording habitat types and qualitative information on fauna observed. Random searches may reveal a particular species or habitat type requiring specific search techniques. Specific search techniques may include searching with lights at night, closely grouped divers searching as they drift downstream over shoal areas, divers in pairs searching heavy cover or deep pools, etc. The actual technique depends upon habits of the target species and the habitat being sampled. When qualitative information on the entire community is required, all techniques should be used to gain insight into species composition, distribution, and relative abundance at that site.

Abundance Estimates

Transects may be used to obtain quantitative data with variations of one method used for different portions of the sample area. Quantitative information on benthic fish in riffle or raceway areas can be obtained with one to four divers depending on stream size and manpower availability. An additional diver should stand by in case of emergency whenever SCUBA equipment is used.

Fish abundance (fish numbers/transect) is estimated by divers swimming transects delineated by a highly visible rope anchored to the substrate (Figure 1). Size of the transects will vary with the number of divers, water clarity and overall dimensions of the stream reach sampled. Transect width can be calculated by multiplying the number of divers times an empirically determined dimension on either side of the diver, depending on water clarity. To maintain a standard interval, each diver holds a fiberglass pole connected by a short length of chain to the adjacent diver's pole; a length of rope with knots tied to delineate the proper interval is a suitable substitute. Transect length is maintained by the length of rope used. The divers swim or float with the current (depending on current velocity) in a downstream direction counting all fish observed. The "interval" pole or rope is scraped along the bottom to flush benthic fish that might otherwise be overlooked. After fish have been identified and counted, they are allowed to pass by the poles or rope to prevent their being recounted. All observations in the transect area are combined to obtain the total number for each species seen and entered on an acetate data sheet (of a format suited to the study objectives; see the Chapter on Statistics for examples) with a waterproof marker.

The above general technique can be used to estimate abundance of species inhabitating pools. However, transects can be worked by divers swimming upstream or downstream if current permits. Unique habitats such as heavy cover should be included in the transects to include species which seek out those areas.

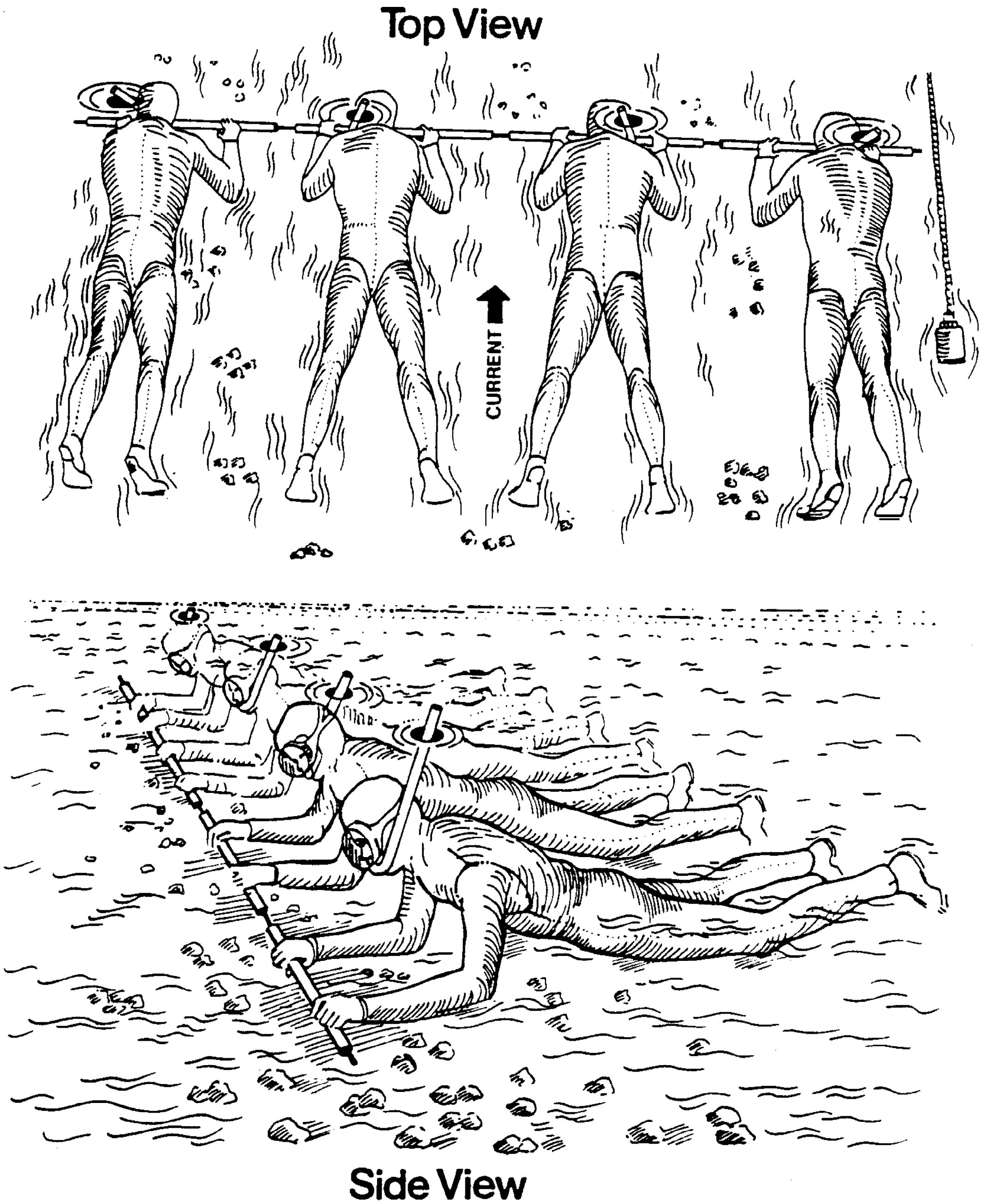

Figure 1. Top and side views of snorklers searching for benthic fishes along a transect.

A minimum of three transects per stream reach is needed to provide sufficient data for statistical analysis. The relative abundance of a particular species is the mean number per transect (water surface area or volume of water searched). To estimate numbers per stream reach, the stream must be surveyed for its physical characteristics. The total area of all transects and numbers of each species observed can be expanded to express densities per taxon in the stream. All microhabitats must be searched to ensure accurate estimates for those species likely to inhabit the stream reach.

Deepwater Seining

Deepwater seining by SCUBA divers requires at least five divers, one standby diver, and one boat tender. The procedure is basically the same as is commonly used for seining shallow areas. Seines may be as fine as 3 mm (one-eighth inch) square mesh with float and leadlines and brails. Two divers hold the seine stationary on the bottom with the mouth opening upstream. Fish are driven into the bag seine by herders equipped with flushing poles. After the fish have been driven into the seine, it is quickly closed and brought to the boat or shore where the fish are processed.

Activities are coordinated by means of ropes (Figure 2). Divers maintain contact with the boat by an anchor rope; a second rope extended downstream from the anchor to the seine is used to coordinate activities between divers herding the fish and those holding the seine. One end of this rope is held by one diver at the seine, while the middle diver of the herding crew holds the other end. By tugging on this rope a predetermined number of times, the diver at the seine signals the herders that the seine is set. A signal is returned to the seine holder that the fish "drive" has begun. Herding may begin at the anchor and follow the rope downstream to the seine. Some distance (determined by water clarity) before arriving at the seine the middle herder slows down and the divers on either side maneuver fish toward the seine (Figure 3). Under conditions of reduced visibility a knot can be put in the rope to mark the point at which the middle diver should slow down. After capture, one diver delivers the seine to the boat while the others move the anchor downstream and reposition themselves.

Cobble or fine-grain substrates are most suitable for this method. Fish can be maneuvered or flushed more effectively from these substrates, since there are fewer crevices or hiding places. When visibility is < 1 m, collecting is difficult and much less productive. Moderate current (0.1 m to 0.5 m/s) seems to be ideal; whereas, little or no current makes it more difficult to maneuver fish into the seine.

Alternative Collection Methods

The slurp gun (Figure 4), hand net, or spear gun are used for small, selective samples of fish. Those devices require only one diver when snorkeling or at least four persons (two divers, one standby diver, and one boat operator) when using SCUBA. The barrel of the slurp gun should be within six inches of the target before pulling the plunger and sucking the fish into the barrel. The barrel is closed off immediately by hand or by placing it against the substrate. For collecting small fish, a hand net is as effective as a slurp gun, and it is less expensive and requires less maintenance.

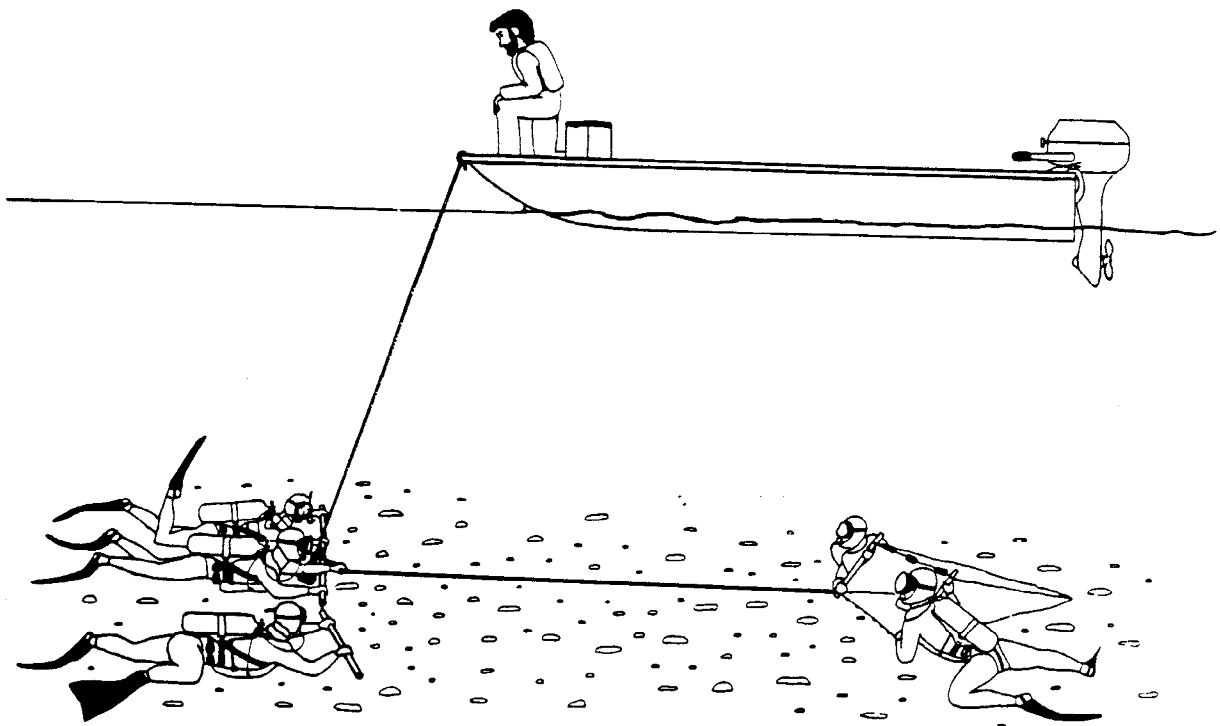

Figure 2. Deployment of SCUBA divers for seining deep reaches.

After the fish have been collected, identified, and the necessary data recorded, most specimens can be released unless project objectives require preservation. A voucher specimen of each species should be preserved for verification of identity.

Comparison With Other Gear

Sighting fish underwater is less selective than seining or backpack electrofishing, provided water clarity is sufficient ($\geq$ 1 m visibility) and the diver is a proficient taxonomist. Of course, if observations are recorded by each diver care must be taken not to count the same fish that partner divers have counted. Further, be warned that there may only be time to estimate the numbers in a school. Neither the seine nor the electroshocker are capable of obtaining virtually all fish in a particular transect within view of a group of divers. The amount of time and manpower required for sampling by diving, electrofishing, and seining a stream reach is approximately equal. Disadvantages of snorkeling or SCUBA include limitations due to visibility, current velocity, escape reactions of certain species of fish, availability of certified SCUBA divers, expense and safety, and the need for each individual to be proficient in fish identification.

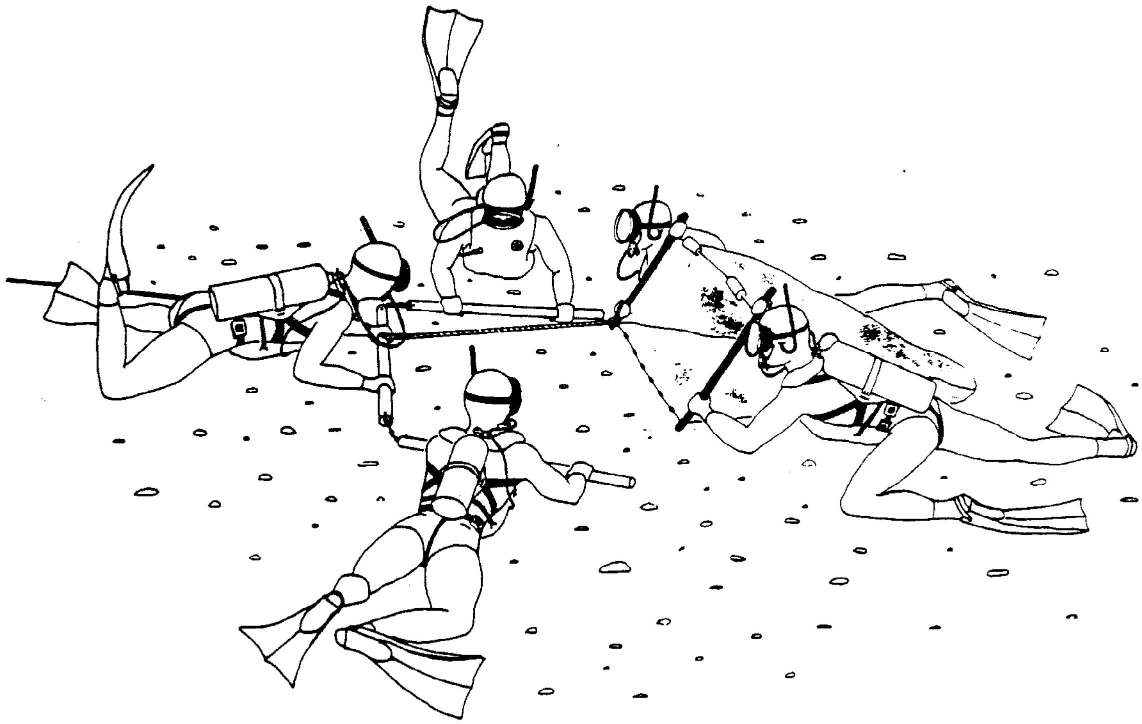

Figure 3. SCUBA divers are herding the fish into the bag seine.

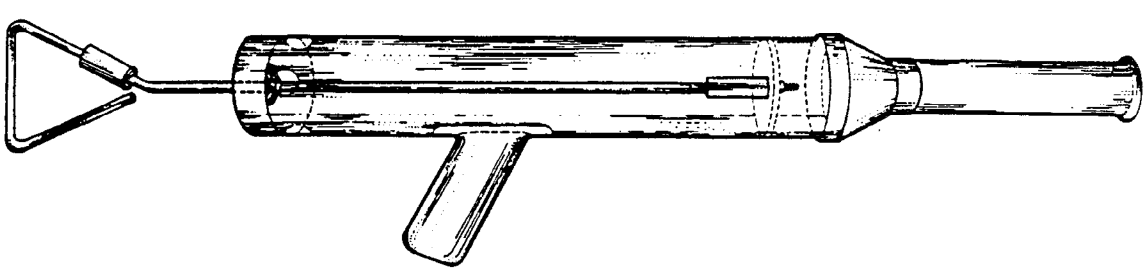

Figure 4. A slurp gun is useful for collecting fishes that will be transplanted.

Safety Precautions

Safety precautions related to snorkeling and SCUBA diving in streams are the same as normal diving operations with few additional potential hazards. Caution must be used when diving in fast currents as it is easy to become pinned against or under some stationary object in the stream. Hypothermia is also a threat when working in cool or cold water for prolonged periods. A custom wet suit should be worn by all divers in water under 18°C and a dry suit in water under 4°C. Gloves should be worn to prevent damage to fingers while bouncing the "driving" poles along the substrate. Heavy-duty wading boots or tennis shoes should be worn to prevent damage to the feet.

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N E T S

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INTRODUCTION

Nets of one kind or another have been employed to capture fish throughout recorded history. Nets can be used for impounding, snaring or trapping fish in mass, and because their materials and construction combine maximum dimensions with minimum weight, they are the largest fishing implements that can be handled per unit of manpower. Since they can be used with considerable efficiency, more fish can be taken by nets in a greater variety of aquatic environments than by almost any other method of capture (Rostlund 1952).

Fishing with nets can be generally characterized as "active" or "passive". Seines and dip nets are active collecting gear commonly used in stream sampling. Various types of trawls are towed by boat and are generally used in deep rivers with slow currents and in estuarine areas where fishes may not be susceptible to other gear. Passive nets are set in fixed positions to entrap or entangle fish. Gill, trammel, and hoop nets are frequently used in sampling streams, whereas pound and fyke nets are more commonly employed in marine and lake investigations.

SEINES

Seines are among the the oldest and most common types of gear used to collect fishes. Although there are many types of seines--bag, purse, haul, beach, etc.--only the "common-sense" or minnow seine is described here because of its utility in a variety of sizes of warmwater streams.

Most seines are essentially a rectangular piece of netting attached to a weighted line on the bottom and a float line at the top. Seines may vary in length up to 600 m (2000 ft) and in depth from 1.2 to 60.6 m (4 to 200 ft). Large seines generally have large mesh sizes; however, smaller mesh sizes can be used with large seines, if there is sufficient manpower available. The (minnow) seine recommended for streams should have a 6-mm (1/4 inch) bar (square) mesh size.

The size of the seine will depend upon the width and general gradient of the stream reach to be sampled. If the entire reach of the stream is to be seined, the length of the net should be 20 percent longer than the width of the stream. The depth of the seine should be 1.5 times the depth of the water. However, in larger streams shoreline seining with a 15-m (50 ft) seine may be appropriate.

Stream Reach

Seines can be used in a variety of stream environments, from a shallow riffle to a large estuarine stream. However, they should be used only where water depth is less than the depth of the seine and where the bottom is fairly free of snags (Bulow 1975). Hoover (1938) and Gerking (1949) showed that small drag (minnow) seines were 70 to 100 percent efficient in capturing marked fish from small warmwater streams. Data collected from streams with different morphometry are not necessarily comparable because different opportunities for escapement or gear bias result from the physical peculiarities of each stream reach that is seined. Thus, each stream reach seined should be described in detail.

Application

In shoreline seining the net is worked (pulled) through the water, generally in the direction of the current, while the lead line is kept on the bottom and in front of the float line. The offshore end of the seine should be slightly ahead (downstream) of the nearshore end, thereby forming a "J". The float line should not go under the water surface, and the lead line should always stay on the bottom. Before the haul, a clear shore downstream should be chosen for beaching. After a determined distance or time of seining, the net will then be "bagged" or bellied as the seine is beached. A distance of 25 m (82 ft) should be fished where practical; thus catch rates can be adjusted to a standard 25-m haul.

Seines may also be fished in a quadrant haul (Swingle 1956), depending upon the depth and width of the reach being sampled. When fishing in this manner, one end of the net is fully extended and positioned perpendicular to the shore; the other end remains stationary at or near the shore. A 90° sweep is made towards the shore with the moving end of the net. When both ends are equidistant from the shore, the net is worked onto dry ground.

High-velocity stream segments, or riffle areas, may be seined by staking the net with the investigators "driving" fish from under rocks or shore cover downstream toward the seine. However, such an effort may yield a less quantitative sample than the above methods.

Comparison With Other Gear

Seining is often the most expedient method for collecting fishes from small streams, as well as for collecting small fishes from larger streams. Seining is preferred over trawling in small streams and in larger streams where important littoral species can be obtained more easily than with a trawl. Seining is preferred over electrofishing when the latter is not readily available or when conductivity or turbidity of the water preclude efficient use of the gear. Seines are generally selective for smaller and less mobile fishes, and this should be considered when evaluating data.

DIP NETS

Dip nets should have a handle 1 to 1.5-m (3 to 5-ft) long, a 30-cm x 45-cm (1 x 1.5-ft) frame, and a net with a bar mesh size no greater than 6 mm (1/4 inch), depending upon the size of the target species. A dip net with a large, loosely-hung "bag" is usually most efficient. Dip nets are inexpensive and are useful in a variety of habitats; often they are the only means for sampling areas inaccessible to a seine or trawl, or where an electric shocker and toxicants are inappropriate.

Application

Dip nets can be used in any stream, but they are most appropriate in areas of streams where riffles, dense vegetation, or obstructions preclude use of other techniques. Although generally regarded as qualitative, dip net data can provide estimates of relative abundance of those species or sizes susceptible to the gear, if sampling is sufficiently rigorous for at least 15 minutes. Estimates of relative abundance so obtained can be used for comparisons between sampling sites, especially in small wadeable streams.

TRAWLS

Otter trawls of approximately 3 to 15 m (10 to 50 ft) in headrope length are used most often. Other types include the tucker and beam trawls, but these are designed for collecting larval and juvenile stages and will not be discussed. An otter trawl is basically a triangular, pocket-shaped net with weights on the foot rope and floats on the headrope. The spreading action of "otter boards" or "doors" on each leading edge (Figure 1) open the net as it is towed.

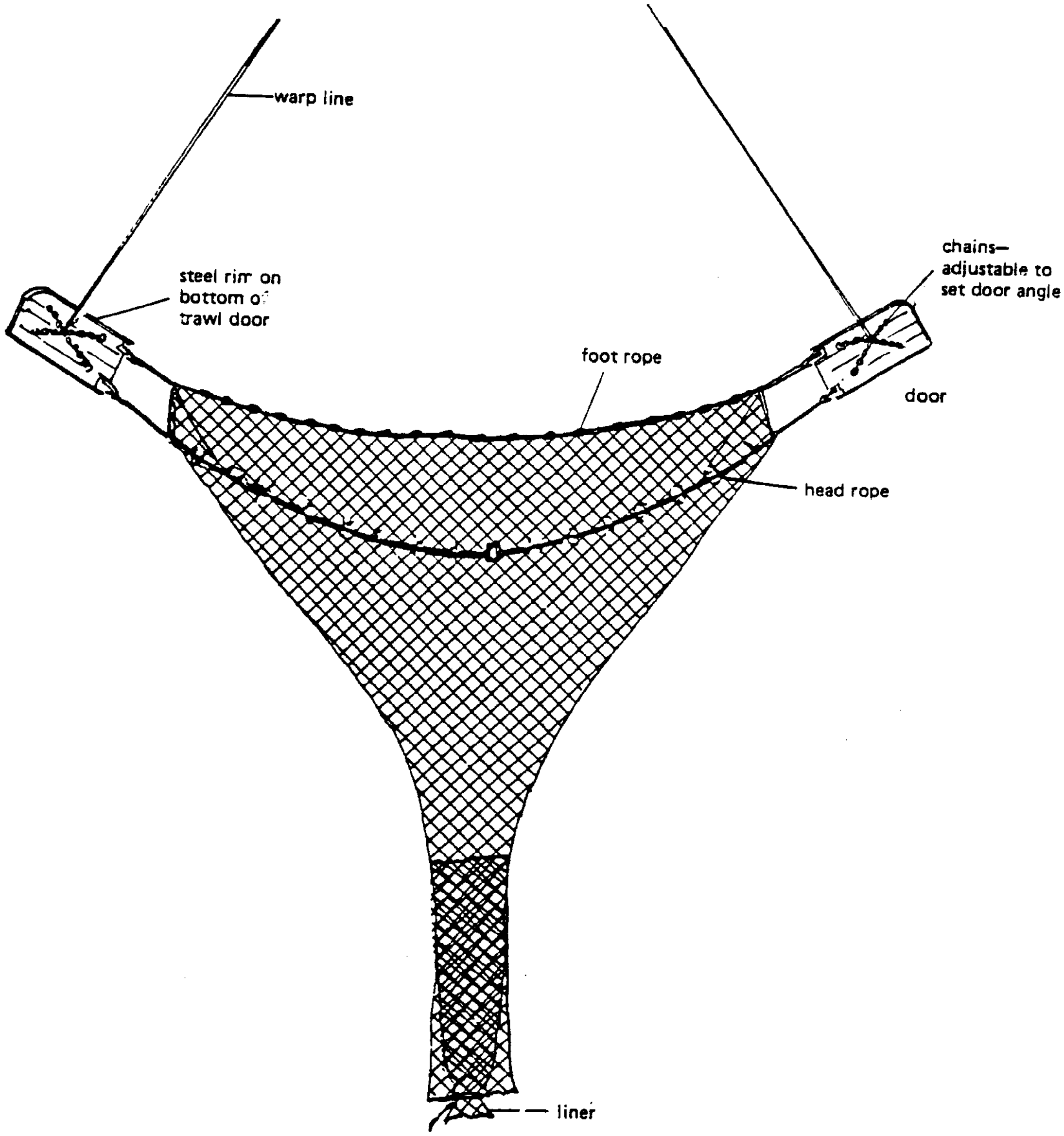

Figure 1. Otter trawl.

A 5-m (16-ft headrope) otter trawl, having a 2-cm (3/4-in) stretch mesh body and a 6-mm (1/4-in) mesh cod end or liner, is recommended for most streams. The doors should be approximately 30 x 60 cm and made of wood with steel rims on the lower surfaces that function both as weights and runners (Weber 1973).

Stream Reach

Otter trawls are effective in large tidal streams as well as in streams only large enough to operate a small boat. Flow velocity must be moderate or low and areas selected for bottom trawling must be relatively free of obstructions.

Application

The same trawl can be fished on the bottom, at midwater depth, or at the surface after making minor adjustments. Trawl doors can be adjusted by varying the length of chain to each corner. A longer front chain will cause the net to spread further. Increasing the outward tilt of the doors will cause the net to run deeper, and conversely, increasing the inward tilt of the doors will allow the net to run shallower. For bottom trawling in areas with firm substrates and few obstructions, the doors should be set to run deep (i.e. increase outward tilt). In areas with soft substrates or numerous obstructions, decreasing the outward tilt will cause the net to ride higher. To maintain the net in midwater, the outward tilt of the doors should be decreased, the tow speed increased, and the warp or tow line length decreased. For surface trawling, floats are added to the doors and headrope, and the doors tilted inward; the force of the water will cause them to spread and ride upward. Tow speed must be adjusted for the angle and weight of the doors to obtain the desired aspect for each particular sampling situation.

The warp length and boat speed are dictated by river depth, and desired fishing depth. As a rule 10 m (33 ft) is a minimum warp length, but it should increase with fishing depth, if towing speed is held constant. For bottom trawling at depths greater than 3 m (10 ft), a ratio of approximately 4:1 warp length to river depth is recommended.

Deployment should vary with the size of the stream, the size of the sampling boat, and the velocity of the stream. Either the boards and net are released astern over the motor, or the boat is turned in a circle while the net is dispensed inside the circle. In the first method, the boat is moved ahead at idle speed and the net (leadline down) is fed over the stern until it is stretched out behind the boat with the doors still on the transom. The doors are then placed behind the boat and tow ropes released until the desired warp length is attained . The boat speed is then increased until the desired speed is reached. As the tow ropes are fed out, the doors should be spreading the net. The second method is commonly used in larger, slow-moving streams. The net is allowed to trail astern to the inside of the circle, away from the boat propeller while the boat is at idle speed. As the desired trawling direction is approached, the doors are placed overboard, the tow lines released, and the course is straightened. The lines should be released continuously until the desired warp length is attained. The engine speed should, of course, be reduced while harvesting the net.

Tows should be made into the current at a speed approximately one meter per second in most cases. Although towing against the current may allow the fish to avoid the gear more easily, it reduces danger to the crew and damage to the gear, if the net is snagged while being propelled by the current. Minor hangs will not usually damage the net; however, numerous obstructions generally preclude efficient trawling.

Tows are generally 5 to 15 minutes in duration, depending upon bottom configuration and expected catch rate. Guillory et al. (1980) recommend 10-minute tows in southeastern coastal waters. At least three tows should be made per station to permit estimation of sample variance. Data are usually reported as numbers or weights of fish per standard tow length.

The otter trawl can be fished from a 5 m aluminum boat powered by a 20 HP motor in small sluggish streams; whereas, in larger rapidly-flowing rivers, nothing less than oceanographic sampling gear and vessels are recommended for reasons of safety. At least two people are required to fish the gear safely and effectively. A knife, hatchet, or wire cutters (depending on warp line composition) should be available for rapid disengagement of the net if an emergency arises. A float tied to a line and affixed to the cod end of the net will assist in net retrieval from the opposite direction should the gear be snagged on the bottom.

Comparison With Other Gear

A trawl is preferred over a seine where depth or current reduces seining efficiency or when soft sediments fill the seine or reduce maneuverability of the seiner. Midstream and deep channel areas of large rivers may be sampled with a trawl. Trawling is preferred over electrofishing or fish toxicants where excesssive turbidity prevents sighting narcotized fishes. Trawling is also preferred in areas where very high or low conductivities reduce electrofishing effectiveness and in streams too large to be sampled with chemicals.

Meaningful comparisons of trawl catch data require that sampling variations be minimized and sampling situations fully described. Characteristics of the sampling site, as well as date and time of sample collection, depth and velocity of water body, and tow speed and duration should be noted. Small fishes are generally more susceptible to trawls than larger forms, and this should be kept in mind when making comparisons and evaluating results.

Although certain large fishes may avoid a trawl, the juveniles and the smaller species taken may provide information on composition and relative abundance of the species susceptible to the gear. In deep rivers, surface and midwater trawling are also recommended for pelagic species.

GILL NETS

Gill nets are passive collecting devices that entangle fishes attempting to move through them. They are composed of a single panel of webbing between a lead line and float line, usually suspended vertically in the water (Bulow 1975). Gill nets vary in length, material, filament diameter, color, and mesh size, all of which contribute to the selectivity of the gear and must be considered when evaluating the data.

Gill nets that are most often used in streams range in length from 15 to 76 m (50 to 250 ft) and are usually about 2-m (6-8 ft) deep. Nets are hung with the panel webbing 50 percent longer than the length of the top and bottom lines to increase catch efficiency (Everhart et al. 1975). Mesh sizes frequently used in stream investigations are from 9 to 109 mm (3/8 to 4 in) bar measurement.

Experimental gill nets usually have 4.5 to 15 m (15 to 50 ft) panels of various mesh sizes. The variety of mesh sizes may entangle a broader size range of fish . The webbing is usually cotton, linen, ramil, or mono- or multilfilament nylon; monofilament nylon is regarded as most efficient (Larkins 1963). For sampling streams we recommend monofilament experimental gill nets 1.8-m (6-ft) deep with 6 sections of 7.6 m (25 ft) each, using 13, 25, 38, 51, 76, and 102 mm (1/2, 1, 1 1/2, 2, 3, and 4 in) mesh size (bar measurements), strung in that order (Figure 2). Where large fish are not expected, the larger mesh sizes may be excluded.

Hansen (1974) compared effects of different filament diameters on the selective action of monofilament gill nets and found that the net with smaller filament captured larger fish but caused more physical damage to the fish.

Clear monofilament nylon was reported to be best (Brandt 1964). Jester (1973) found that colored nets were selective and reported highest catch rates when visibility was reduced by plankton or suspended sediments.

Gill nets can be drifted, staked in horizontal or vertical aspects, or set in circles. Drift and set nets are used most often in streams. In fishing drift nets, the size and number of weights and floats are adjusted so that the net will fish at the desired depth (Rounsfell and Everhart 1953). Fishing depth is adjusted by spacing of the floats on the surface lines. Nets may be tied to a tree or rock on the shore and set perpendicular to the shore or extended downstream, where the lead line is held to the bottom by a weight or anchor.

Stream Reach

Experimental gill nets can be used in any stream reach of relatively uniform flow that is at least as long as the net and several feet deep. Stream reaches should have flow rates so that nets will hold as positioned. Leaves or debris may clog or collapse the net and impair or preclude fishing.

Application

Gill nets can be set near the shoreline, in midstream, or drifted, depending on stream flow and morphometry. Stationary nets may be set in straight lines, zig-zagged, or looped; they may be left to entangle fish

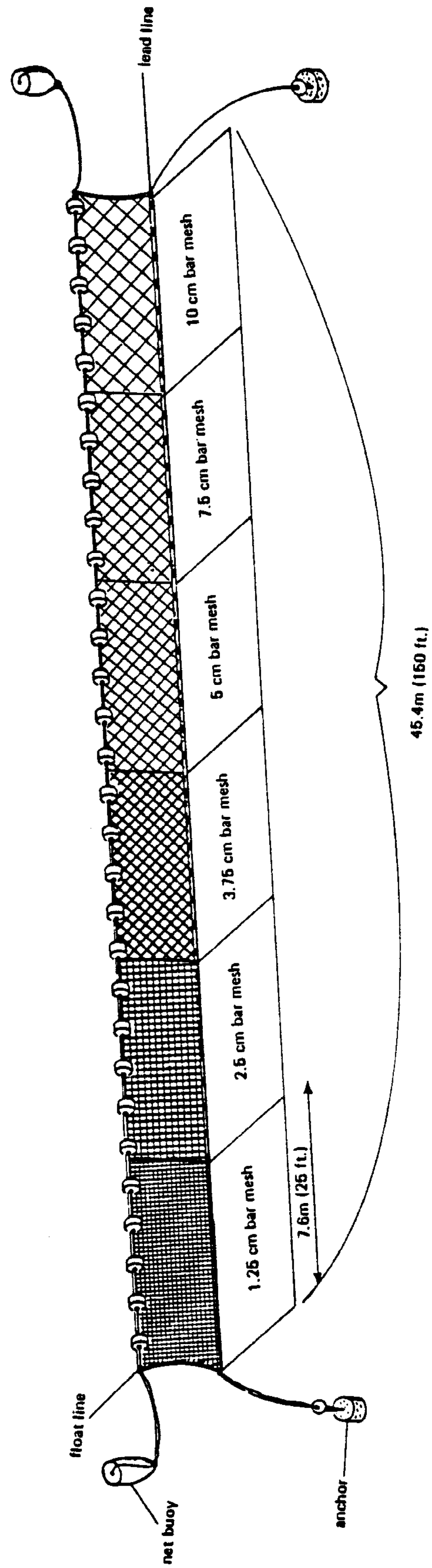

Figure 2. Experimental gill net.

in a passive way or fish may be "driven" to them with electrofishing gear or by agitating the water (Hamley 1980). However, if quantitative data are required the gear should be distributed randomly over the stream reach, or stratified within habitat types (Raj 1972).

Drift nets should, of course, be restricted to midchannel in large rivers. One end may be attached to a buoy, and the other to the boat, to provide for control as the whole system drifts downstream. After locating a relatively clear reach in which to drift, the depth of the net should be adjusted to prevent snagging the bottom.

All nets should be tagged with some type of identification to show ownership.

Gill nets are less effective when fish can see the nets, and may be less effective when they are saturated with fish. Gill nets are usually fished overnight; sets greater than 24 hours should be used only if catches are very small. Time of day and duration of set should be recorded and catch rates quantified by unit of time; i.e., 24 hours, including overnight, is a recommended set. Thus, catches can be expressed as numbers or weights of fishes per net length (or area) per 24 hours. However, in swift water or in areas with excessive debris, shorter durations should be used to keep the nets oriented and fishing properly.

Comparison With Other Gear

Gill nets are relatively inexpensive and can be used to sample streams where electrofishing gear is unavailable or inefficient due to conductivity or turbidity of the water. They require neither the continuous presence of an investigator nor more than two people at harvest. Gill nets are preferred over toxicants in large streams, particularly where endangered or threatened species are to be avoided.

The problem of estimating relative sizes of fish populations from gill net catches is generally similar to that presented in "quantitative" sampling of plankton, bottom fauna, and bacteria in fresh waters (Moyle 1950). Ricker (1968) noted that sampling methods and equipment may be ideal for collecting some species but not others.

Factors that influence catch results are mesh size, elasticity of the net, hanging coefficient of the net, visibility of the twine, shape of the fish, degree to which fish are enmeshed at parts of the body other than the pectoral area, and patterns of fish behavior (Clark 1960). However, Carlander (1957) noted that although measures of abundance based on gill net catches may often lead to errors, valuable information may be secured if enough samples are taken and if the data so secured are not regarded as measures but as estimates of abundance.

In many instances the primary purpose of sampling with gill nets, as with several other gear types, is to simply ascertain the presence or apparent absence of various species. Often the numbers of fish taken at various sampling sites can provide an indication of relative abundance (Cleary and Greenback 1954).

TRAMMEL NETS

The trammel net is a type of passive entanglement gear that is usually less damaging to fish than gill nets. Trammel nets are more effective in capturing some species, and are somewhat less size selective than gill nets. Unlike gill nets, trammel nets may have two or three walls of netting. A loosely hung, fine-mesh, net is usually strung between two coarser, tightly hung, nets. When a fish swims through the larger outer meshes, it encounters and pushes against the loose interior net so that a pocket is formed by the inner mesh, regardless of the direction from which the fish approaches. Nets with one coarse and one fine mesh usually catch fish moving from only one direction.

Reactions by fish to trammel net color can be expected to be about the same as to gill net colors. However, the triple wall of netting may be more visible.

Trammel nets usually range from 30 to 91 m (100 to 300 ft) in length and are from 1.2 to 2.4-m (4 to 8-ft) deep. For stream and river sampling, monofilament nylon trammel nets 30 by 1.2 m (100 by 4 ft) are recommended.

Stream Reach

As with gill nets, trammel nets can be used in large or small streams. The pool or reach should have relatively uniform flow, or be at least as long as the net and several feet deep. The stream reach should have flow rates that will not alter the net's position, and should not contain an excessive amount of leaves or debris.

Application

Trammel nets can be fished in the same manner as gill nets. Data reported, as with gill nets, should include the specific set information including location and time of day. Catch rates are reported per standard unit of time, usually per 24 hours, including overnight. Nets in streams with high flow rates, or large amounts of debris, should be harvested more frequently.

Comparison With Other Gear

Trammel nets are somewhat less selective than gill nets with regard to both species and sizes, but because they tend to become fouled with debris more easily than gill nets, they are often more time consuming to use. Trammel nets are preferred over gill nets when it is desirable to return the fish.

HOOP NETS

Hoop nets are cylindrical traps that are usually fished passively in moderate or low velocities. They are usually constructed of nylon mesh (tarred or untarred) hung on round frames (hoops) made of steel, fiberglass, willow, or flexible plastic pipe and have one or more funnel-shaped throats inside the net to retain the catch. A fyke net differs from a hoop net only in that it has two "wings" or leaders. Hoop net mesh sizes vary from 12.7 to 101-mm (1/2-in to 4-in) bar mesh, strung on hoops that vary from 0.3-m (1-ft) in diameter to as much as 2.4 m (8 ft), or more. Hoop nets recommended for stream sampling are constructed of seven hoops 1.3-m (4-ft) in diameter, with throats on the second and fourth, covered with 38-mm (1 1/2-in) bar mesh. In quiet water, leads can be added to make a fyke net or the hoop net can be baited, although large unbaited nets are often effective where there is little cover.

Application

Hoop nets can be fished in any stream deep enough to cover the throat, but are generally more efficient in areas deeper than the diameter of the hoop.

In flowing water hoop nets are usually set along a steep bank or on the outside bend of a stream. The mouth is directed downstream to minimize clogging with debris. Hoop nets are usually fished overnight and the catch reported per unit time. In setting the net, the cod end is first secured to a tree or anchored to the bottom. The net is then "payed out" with the current until fully extended, and then is allowed to settle to the bottom. The net should be marked with a buoy for easy retrieval except where vandalism is expected. If wings or leads are used, the distal float and leadlines should be buoyed and anchored. The use of wings or leads should be reported along with other specifications of the gear. To harvest, the hoop is raised at the mouth and the catch shifted toward the cod end, where the draw string can be untied for removal of the catch.

Comparison With Other Gear

Hoop nets are effective in taking catfish, crappies and other sunfishes, white bass, suckers, carp, drum, and buffaloes, especially in spring and fall on a rising stage. Since fishes taken in hoop nets are generally alive and in good condition, the gear is often preferred when live specimens are desired. Though hoop nets are selective for certain species, they often collect a segment of the community not caught by other gear. Fishes that avoid or are not susceptible to gill or trammel netting or electrofishing are often taken with hoop nets.

SELECTIVITY

It is necessary to be aware that although sampling may have been carefully designed and implemented, the catch will not be representative of the entire fish community because every fishing method is selective. Selectivity is affected by gear construction and operation, as well as schooling, feeding or spawning migrations of target species; such activities vary with time and location and render the fish more or less susceptible to capture.

For active gear such as trawls, an important factor in selection is the escape of small fish through the mesh. An estimate of the selectivity of trawls can be obtained by covering the cod end with a fine mesh bag to measure the proportion of small fish that may otherwise have escaped. Selectivity can then be defined by a curve which indicates the proportion of the total population, by each size group, retained by a unit operation of the gear (Ricker 1968). By plotting the proportion of fish retained in the cod end and their respective lengths versus those retained in the outer bag, curves are obtained that will yield the length of the species at which half of the fish are retained by a particular mesh. This length is called the 50 percent retention length (L_c) and is proportional to the cod end mesh size (m) as expressed in the equation:

$$F \text{ (Selection Factor)} = \frac{L_c}{m} \text{ (Dahm 1980).}$$

Interpretation of gill, trammel, and hoop net catches is somewhat complicated by the fact that fishes must catch themselves in passive gear. In many instances the primary purpose of sampling with such gear is simply to ascertain the presence or apparent absence of susceptible species at a sampling station with the results used to compile distribution information. Often, however, the numbers taken at various localities can furnish a clue to relative, if not absolute, abundance (Cleary and Greenback 1954).

As mentioned earlier, gear selectivity must be evaluated to get a representative picture of the community as a whole. There are several ways to estimate gill net selectivity. The following classification is from Hamley (1975) who reviewed and critically examined some of the more recent methods.

1. Selection for the ranges and shapes of selectivity curves have been inferred from girth measurements. The selection range of a gill net is assumed to contain those fishes whose maximum girth is larger but head girth smaller than the mesh perimeter.

2. Size and distribution of catches are often reported without further analysis, but they give only a rough idea of selectivity because the catch depends on abundance of each size class as well as selectivity of the gear for that size and species.

3. Direct estimates compare size distributions of gill net catches with a known standard, i.e., the size distribution of the species within the entire community. Direct estimates require no assumptions about the nature of the selectivity curves, and no comparison of catches by different mesh sizes if the following conditions obtain:

a) tagged fishes (or a known population) are released into the environment before gillnetting is begun, and

b) the same area is sampled simultaneously with gill nets and another gear of known selectivity.

4. Mortality estimates can be made from size distribution of gill net catches in time sequence, if catchability is assumed to be constant. As with direct estimates, mortality estimates require neither assumptions about the nature of selectivity curves nor comparisons of catches by different mesh sizes. The DeLury Method (DeLury 1947) is based upon the generalization that as a closed population is fished intensively, the catch per unit effort usually decreases as the population is reduced. If catchability remains constant, then:

$$(C_j/X)_t = s_j N_{jo} - s_j \sum_t C_{jt}, \text{ or}$$

$$\ln(C_j/X)_t = \ln(S_j N_{jo}) - S_j \sum_t X_t$$

where $(C_j/X)_t$ = catch per unit effort during period t,

N_{jo} = the initial population of size class j,

$\sum_t C_{jt}$ and $\sum_t X_t$ = catch and effort accumulated to time t, and

S_j = selectivity estimated by linear regression of $(C_j/X)_t$ on $\sum_t C_{jt}$, or of $\ln (C_j/X)_t$ on $\sum_t X_t$.

Hamley (1975) states that while any method of estimating fishing mortality can also estimate selectivity if the calculations are done separately for each size-class of fish, the Delury Method offers several advantages. It requires no prior assumptions about the nature of the selectivity curves, no comparison between different gear, and no independent population estimates. Its main disadvantage is the difficulty of experimentally satisfying its underlying assumptions, particularly that selectivity remains constant with time. For a full discussion of the method see Hamley (1972, 1975).

5. Indirect estimates compare size distributions of catches in gill nets of different mesh sizes and require no knowledge of the size distribution within the population. Instead, they rely on suitable assumptions about the nature of the selectivity curves. Indirect estimates can be made by the following:

a) Constructing Type B curves show selectivity of different mesh sizes for one size class of fish which yield Type A curves that show selectivity of one mesh size for different sizes of fish, and

b) Fit a predetermined distribution using an a priori model of the selectivity curves by which Type A curves are estimated algebraically from catch data.

In summary, the most reliable method of estimating net selectivity is the direct method. However, since the direct method is usually expensive, the indirect approach of comparing two or more mesh sizes is often used . Indirect methods may be more desirable because they use available data, but are biased because they assume a homogeneous selectivity curve for all mesh sizes.

Results from the inference from girth measurements are promising but need further study. The major disadvantages of the mortality estimates are the difficulty in obtaining enough samples and satisfying the assumption of constant catchability (Hamley 1975).

After gill net selectivity has been estimated, the length composition of the population can be estimated by dividing the number caught in each length group by the appropriate selectivity factor. Once length selection is determined, other selection factors such as sex, age, and maturity may be estimated.

Trammel nets are not as selective as gill nets and should catch a wider range of sizes and species. After selectivity has been determined, statistical analyses similar to those used for gill net data should be performed.

MATERIALS: SOURCES AND PRICES

There are several large commercial outlets in the southeastern United States which can provide most of the nets that might be required for stream investigations. These suppliers and the many smaller local outlets can often accommodate the investigator with modifications of commercial gear tailored to meet specific sampling needs. The addresses of some of the larger net manufacturing companies are provided below:

Memphis Net and Twine Co.
P.O. Box 8331
Memphis, Tennessee 38108

Nylon Net Company
P.O. Box 592
Memphis Tennessee 38101

Atlantic and Gulf Fishing Supply Corp.
591 S. W. 8th Street
Miami, Florida 33130

Champlin Net Co.
P.O. Box 788
401 Front Street
Jonesville, Louisiana 71343

Marinovich Trawl Company
P.O. Box 294
Biloxi, Mississippi 39533

The following are average 1983 prices for various types of nets, and should be used only as a guide for estimating equipment costs. Price catalogs can be obtained from most of the larger net manufacturing companies and should be consulted when ordering netting equipment and supplies.

Category	Description	Price
Seine	Length - 15 m (50 ft) Depth - 1.2 m (4 ft) Nylon, 6 mm (1/4 in) bar mesh (complete with leads and floats)	$ 80.00
Dip Net	Heavy duty, steel frame (30 x 45 cm) and handle with a 6 mm (1/4 in) bar mesh net	$ 22.00
Trawl	5 m (16 ft) headrope (equipped with doors, cork and lead lines)	$ 300.00
Gill Net	Length - 15 m (50 ft) Depth - 2 m (6 ft) Monofilament with 51 mm (2 in) bar mesh; lead and float lines	$ 28.00
Experimental Gill Net	Monofilament with 6 sections 1.8 m (6 ft) deep and each 7.6 m (25 ft) long, using 13, 25, 38, 51, 76, and 102 mm (1/2, 1, 1 1/2, 2, 3, and 4 in) bar mesh	$ 120.00
Trammel Net	Length - 30 m (100 ft) Depth - 1.2 m (4 ft) Monofilament with 76 mm (3 in) bar mesh (with 8 in bar mesh outer wall) and lead and float lines.	$ 70.00
Hoop Net	Seven 1.3 m (4 ft) diameter hoops, covered with 38 mm (1 1/2 in) bar mesh, and treated with a commercial preservative	$ 110.00

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ANALYSIS OF FISHERY DATA

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INTRODUCTION

Fishery biologists are responsible for evaluation and enhancement of a wide range of fishery resources. Typically, a limited amount of information is available on which to base decisions, as fish populations rarely can be completely enumerated. In addition, most management decisions have both biological and socio-economic implications. For these reasons, a biologist's recommendations should be supported by appropriate sampling programs and statistical analyses. A statistician should be consulted before sampling begins to insure that the sampling program will satisfy study objectives.

Selection of a sampling method depends on the objectives of the study, sampling conditions, species to be collected, efficiency of the method, and availability of manpower and equipment. By outlining the advantages and limitations of each sampling method, the chapters in this manual will assist in the decisions to be made by biologists and fisheries students. In this chapter, we attempt to outline some general considerations pertaining to the quantitative and statistical aspects of sampling and analysis.

The first consideration in the selection of a sampling method is the objective of the study. Ideally, this would be the only factor determining the method to be used; i.e., which is the best sampling method for the job? For a study with a clearly defined target species of a specific size, the decision may be fairly easy. However, we will consider a study with broader objectives, such as a baseline study or general monitoring program.

The two most likely questions to be asked of a baseline study are:

1) What species are present in the sampling area, and what is their relative abundance?

2) Have there been changes in the fish community, above those that occur naturally with season, or will the data base provide sufficient information to detect future changes?

The first question is difficult to answer because no gear is likely to catch all species of all sizes in proportion to their absolute abundance. Every sampling method is somewhat selective, although the degree of selectivity varies with gear type. Perhaps the least selective are toxicants and explosives, but because both require some degree of expertise and considerable manpower for proper application they may be inappropriate in some instances. It seems likely, however, that one of those two methods would be preferred for obtaining the most representative sample of a fish community.

Unfortunately, the sampling method best suited to answer the first question is not necessarily best suited to answer the second. How does an investigator demonstrate that a change has occurred? If a change has occurred, could it be due to normal seasonal or annual variation? To answer this question, the biologist must estimate the range of normal fluctuations, or know what is occurring outside the areas being investigated. If the change cannot be attributed to normal variation or was unique to the area in question, then a good case can be made that a change has occurred.

A statistical test of hypothesis can be used to answer the second question, and this test will require a measure of the natural or intrinsic variability of parameters of interest. A parameter is defined as an unknown quantity that we wish to estimate, such as total standing crop, relative abundance, or the change in abundance after alteration of a stream. The variability of the sample data indicates the degree of confidence we can place in parameter estimates. Repeated sampling to estimate this variation is rarely practical when sampling with fish toxicants or explosives, and a simpler, quicker, and cheaper method of sampling may be preferable. Alternatively, the use of toxicants could be supplemented with another less labor-intensive method.

Inferences may be made about a single species of a specific size or the entire fish community; this species or community may be referred to (in a statistical sense) as the target "population". The biologist must recognize the limitations of possible sampling techniques and match the gear to the target "population", or restrict inferences to a target "population" which can be sampled with the available gear. For a baseline study, many species must be sampled and data from several gears may be needed to draw correct inferences about the status of the target "population".

An essential part of developing a study design is to determine the smallest sample size that will enable study objectives to be met. Selection of appropriate sample sizes for classical designs such as simple random sampling or stratified random sampling are discussed by Snedecor and Cochran (1967), Green (1979), and Raj (1968); this approach is illustrated by Summers et al. (1983). A more difficult question to address is "what constitutes an adequate sample for a baseline study?", where information of varying precision is obtained for many species. If stratified random sampling will be used and total sampling effort is fixed, effort might be allocated among areas based on the size of each area (stratum) or the variability of preliminary estimates or historical data from each area (Snedecor and Cochran 1967). Obviously, the question cannot be answered fully without knowing what may be asked of the baseline data. However, several considerations may be examined to establish some minimal guidelines.

Bias is a consistent tendency of the data to over- or underestimate the parameter of interest. A likely source of bias in fisheries data would be the failure to sample randomly. Sampling at randomly selected locations is most practical with less labor-intensive methods such as electrofishing, netting, or seining. Samples obtained with toxicants are not collected at randomly selected sites, but typically are obtained from "representative" pooled areas or sections with sluggish flows (see chapter on fish toxicants). A reasonable compromise when sampling with toxicants would be to determine the number of stream sections which could be sampled effectively then randomly select one or more sites from this group. Inferences about parameters such as total standing crop would apply only to similar stream sections.

Some sources of variation, such as seasons or areas, can be accounted for when developing an experimental design. Sources of variation generally are termed "treatments" when the variation is to be tested statistically, or "blocks" when the source of variation is simply to be accounted for as a recognized source of variation. The remaining variation is termed sampling error or unexplained variation, and is important for statistical tests of hypotheses. In order to estimate sampling error, it is necessary to take replicate samples; i.e., samples taken at nearly identical sites and at virtually the same time. This is not practical with some of the more labor-intensive methods, but often is required to evaluate differences between treatments.

To estimate seasonal variation in parameters of interest, sampling may be done over a wide range of environmental conditions. The investigator must consider seasonal changes in habitat and faunal characteristics at selected sampling sites when choosing a sampling technique. Expected changes in characteristics affecting gear efficiency, such as turbidity and flow, should be considered at the initiation of a study.

In summary, two factors must be considered in developing a study design if statistical analyses are anticipated. First, minimize bias by clearly defining the target "population" and selecting the most appropriate sampling techniques. Second, sufficient numbers of replicate samples should be taken to measure variation attributable to areas, seasons, or other recognized sources of variation pertinent to the study. This may require many applications of the sampling technique, so the method must be efficient.

PREPARATION OF DATA FOR COMPUTERS

Most studies, particularly those involving large data bases, are facilitated by using computers. This is especially true when statistical analyses are anticipated. Computer output provides the researcher with legible, well-organized records of catch, summary statistics, and graphics. The biologist should be aware of what steps are required to enter data into a computing system, what information may eventually be required, and in what form. The following discussion outlines some principles and conventions involved in preparing data for computer analysis.

The first step is to decide what constitutes a "record", which is the smallest set of useful information, or it can be thought of as the variables to be entered on one line of a computer code sheet or on a computer card. A record may contain all information from a single sample or only the information for a single fish. A record usually consists of no more than 80 columns of numbers or letters, a convention followed in this discussion. These 80 columns are called the record length. The description of the information contained on a record (the variable names, their size, the columns they occupy and the number of digits to the right of the decimal point) is called the record format. It is advantageous to develop this format before field sampling begins so that data can be keypunched or entered at a computer terminal without transcription to computer code sheets. Field data sheets need not resemble computer sheets but should, in general, follow the record format which will be used.

The following suggestions may aid in designing an appropriate record format:

1) The most important decision is to determine the lowest level of biological data which will be required for analysis. The computer can easily combine records to provide needed summary values, but cannot subdivide records that were combined before data entry. For example, records that contain information on individual fish would be required to evaluate growth rates. If necessary, the computer can sum these individual records to obtain total numbers or weight for each species and each sample. A good guideline is to determine if data from the proposed record format would be sufficient to complete the proposed analysis should the original field data be lost. If some important information is missing, then the computer record is incomplete.

2) If space permits, include both environmental and biological data on the record. If this is not possible, include a variable in each record type which uniquely identifies each sample. This will allow the computer to merge environmental and biological data for each sample; for example, to analyze the relationship between temperature, dissolved oxygen, and catch rates.

3) If data for all species are included on a single record, the columns in which data are entered can be used to identify the species (Figure 1). If each record contains information for only one species (Figure 2), include a variable (SPEC) which identifies the species. If SPEC is entered as a numeric value, it is a good practice to instruct the computer to translate numbers into names with a programming statement of the form:

```
IF SPECIES=3 THEN NAME='BLUEGILL'
```

This will enhance the readability of computer output.

4) Variables which may have the same value for several records should be entered first on the record. For example, MONTH, DAY, and

PROJECT________ SAMPLER________ GEAR TYPE________ PAGE________

	MON/DAY/YR	AREA	STN	TEMP	D.O.	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16	SP17	SP18	SP20	RT
1																									1
2																									1
3																									1
4																									1
5																									1
6																									1
7																									1
8																									1
9																									1
10																									1
11																									1
12																									1
13																									1
14																									1
15																									1

Figure 1. A code sheet designed for up to 999 individuals for each of up to 20 species for a single study.

	SAMP ID	AREA	STA.	MON	DAY	YR	TIME	GEAR	DUR	D.O.	AIR TEMP.	WATER TEMP.	PH	TURB	...	RT
							:		min	mg/l	°C	°C		JTU		
1																2

PAGE ______ OF ______

SAMPLER ____________

OBSERVATIONS ____________

	SAMP ID	SPEC.	SEX	5- 9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	00-04	05-09	10-14	15-19	RT
1																											3
2																											3
3																											3
4																											3
5																											3
6																											3
7																											3
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11																											3
12																											3
13																											3
14																											3
15																											3

Figure 2. Net catches split into two records, one with environmental data and one with catches by species in size classes.

YEAR of capture might have the same value for many records if one record is used per fish. If computer cards will be keypunched from the data, such sections may be easily duplicated on successive cards.

5) One important distinction to be made in recording data is the difference between data that are "missing" and those that have a value of zero. If the net was lost or the sample was not taken, those catches should be represented as missing values. Some computer systems distinguish blank columns, indicating a missing value, from those with a zero entered. Other computing systems interpret both blanks and zeros as a zero value. The biologist should check with computing facility personnel to determine how missing values are handled. Missing values also may be represented by "impossible" values (e.g., -1 for dissolved oxygen), and this should be documented so that anyone using the data will be aware of the convention.

6) It is not necessary to make conversions (e.g., feet to meters) before data are entered. It is important to record data from all samples in the same units. Otherwise, the record must include both the value and the units in which the measurement was made to enable the computer to convert all values of a variable to a common scale.

7) Record formats in Figures 1-2 employ a fixed set of columns for each variable. This is not required for all computer systems but may aid in data entry and validation. Statistical packages generally support free-format data entry, where adjacent variables are separated by one or more blank spaces. Missing values might be represented by a period (.) or by "impossible" values in free-format data entry.

8) When records are designed using fixed columns for each variable, a value typically is "right-justified" within its field. If the value does not fill the columns available, the left-most columns are blank.

9) The computer can be instructed to insert a decimal point after a particular column (see columns for air temperature in Figure 2). In this case, the position of a value within a field is fixed by the computer-placed decimal. This usually can be overridden if a decimal point is included in the entered value.

10) The number of columns for each variable should be based on the largest value expected for that variable and the number of significant digits to the right of the decimal point. Some variables (e.g., sex) can be entered as numeric (0 or 1) or alphabetic (M or F). Some computing systems do not handle alphabetic characters as easily as numeric values, so check to determine which format is best. Alphabetic characters are recommended whenever possible to eliminate the need to "translate" computer output.

The following examples illustrate some of the above recommendations.

The record format in Figure 1 could be used when detailed biological information is not required. With 3 columns per species, this record format will accommodate up to 999 individuals for 20 species. The number of columns allowed also could vary, with three or more columns for abundant species, and fewer columns for less abundant species.

Figure 2 demonstrates a record format where greater biological detail is required and environmental and biological data are recorded separately. By including sample id (SAMP ID) as a common variable, environmental and biological data can be merged for analysis. Column 80 contains a variable denoting record type (RT) which can be used to differentiate between record formats, if data of the two types are not stored separately. The biological records will accommodate up to 999 individuals from 23 length classes, and a variable is included to denote species (SPEC). If fishes from a wider size range will be caught, two or more records will be required for each species. Samples collected with toxicants typically are recorded as numbers and weight for each size class, and more than one record would be needed for each species. If individual lengths, weights, tag numbers, etc. are required, each record will contain information for perhaps one to three fish. In this case, it will be particularly important to maintain separate files for environmental and biological data to avoid repeating descriptive information about a sample on hundreds of records.

DATA ANALYSIS

Introduction

We have focused on statistical techniques applicable to an important subset of objectives, i.e., detecting changes in abundance among locations and sampling periods. Usually we restrict the discussion to analysis of catch data for a single species, because we consider multivariate analyses beyond the scope of this chapter.

Some biologists will not have the necessary resources and training required for some of the analyses that may apply. Therefore, they will require statistical support personnel. We will suggest some approaches that may aid in data analyses and help the researcher recognize problems that will require additional assistance. Moreover, we will suggest the type of data required and its preparation for analysis. A useful set of guidelines for reporting research results is given by Tacha et al. (1982).

In the following sections, frequent reference is made to "probability distribution" or to particular distributions such as the normal, Poisson, or negative binomial. The reason for considering various probability distributions is that some analyses require that we assume sample data are approximately normally distributed. In many if not most cases, the data are not and that problem is emphasized in this chapter.

A probability distribution is a curve that represents the likelihood that particular values occur. Values from a normal

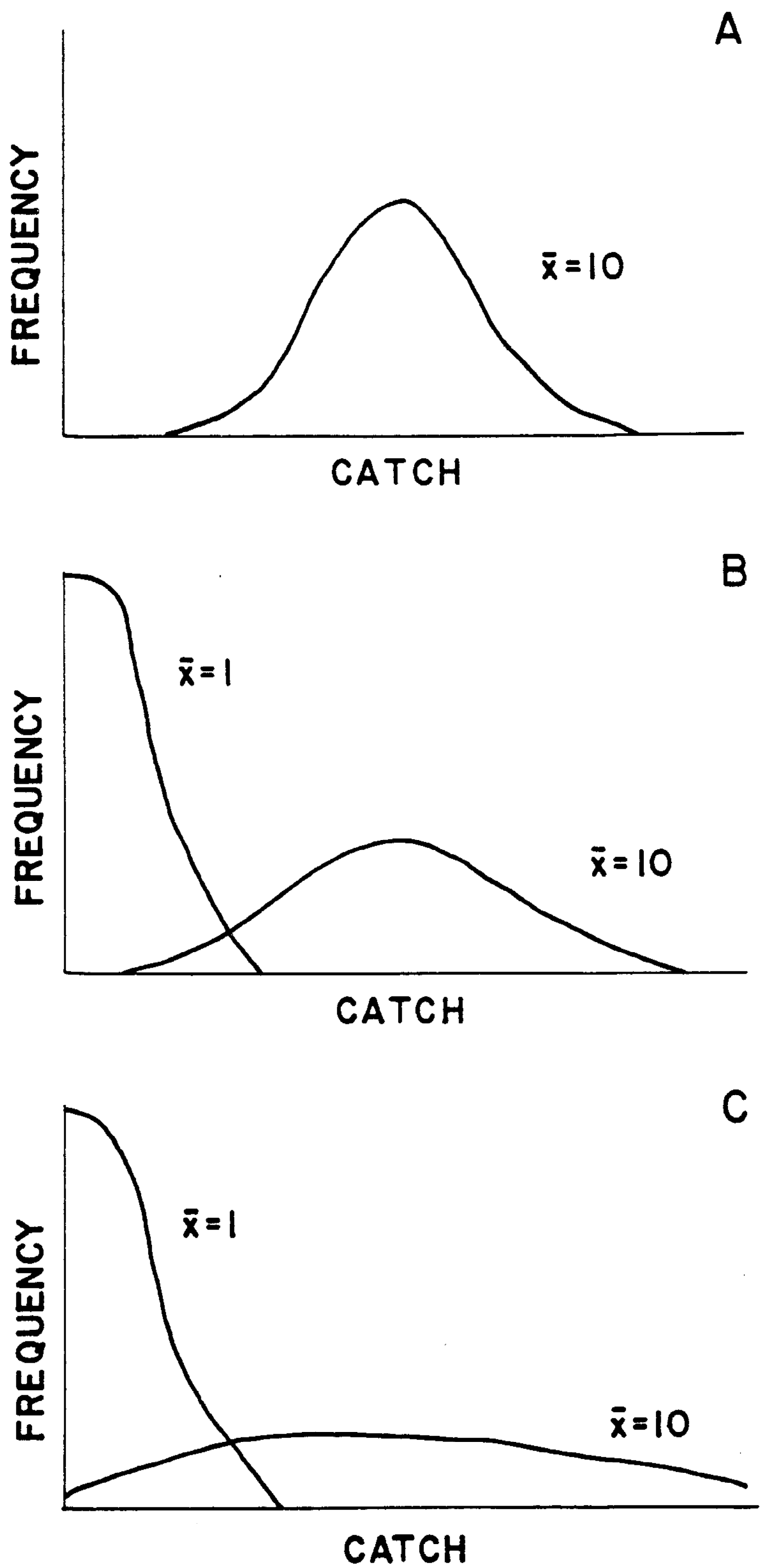

Figure 3. A = normal distribution, B = Poisson distribution, and C = binomial distribution.

distribution are most likely to occur near the mean, so the normal distribution peaks at the mean (Figure 3A). Length data for a single cohort, when plotted as a length frequency distribution, usually are assumed to approximate a normal distribution. Other distributions have somewhat different shapes. For example, the Poisson distribution would be shifted toward zero if very low values were common (Figure 3B). If the mean of the Poisson distribution were large, it would be similar to a normal distribution. The same is true of the negative binomial distribution, but its shape is influenced by a second parameter in addition to the mean (Figure 3C).

The distribution of a set of catch data reflects the interaction between the location and movement of fishes through an area and the ability of the gear to sample them. Catch data usually conform to one of two probability distributions. If fish are not randomly dispersed but tend to be aggregated or clumped, catch data approximate a negative binomial distribution (Elliot 1979). If fish are located randomly throughout the area to be sampled, catch data probably conform to a Poisson distribution (Elliot 1979). For example, if black crappie (Pomoxis nigromaculatus) were dispersed randomly throughout a river, catch data would approximate a Poisson distribution. And, if average catch per unit of effort exceeded 10 to 20 black crappie, the Poisson distribution would be similar to a normal distribution. However, because catch data often contain many catches of, or near, zero, transformation usually is required before the data approximate a normal distribution.

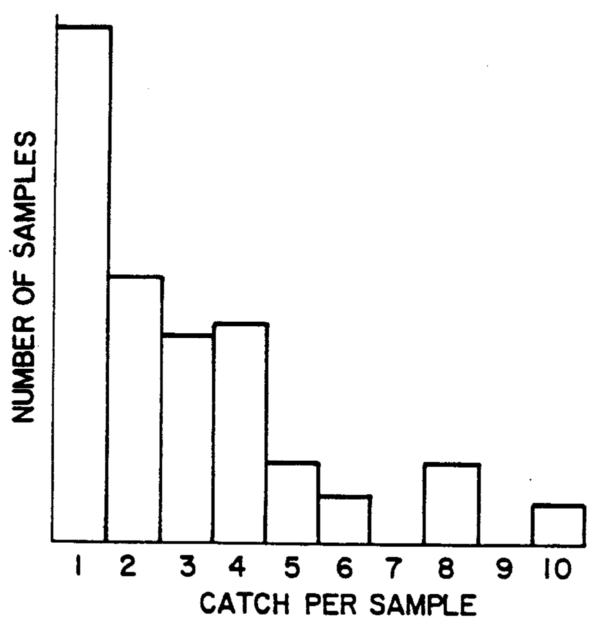

Figure 4. Gill net catches from a population where individuals were aggregated in time or space.

A frequency histogram can be used to examine the distribution of a set of catch data. The gill net catches depicted in Figure 4 might represent samples from a clumped fish population, where high catches were obtained only for those samples where the net was set near an aggregation of fish. These catches do not approximate a sample from a normal distribution, but might represent a negative binomial distribution. Passive sampling techniques such as netting will be more likely to produce highly skewed catch distributions than will active techniques such as electrofishing.

If the number of samples collected is too small to arrange the catches into a frequency histogram, the relationship between the sample mean($\bar{x}$) and variance(s^2) may indicate the underlying distribution of sample catches (Elliot 1979). Typically the variance will be much larger than the mean ($s^2 >> \bar{x}$), and catches will approximate a negative binomial distribution (Elliot 1979). The sample mean and variance should be approximately equal ($s^2 = \bar{x}$) if catches are assumed to approximate a Poisson distribution (Elliot 1979).

Selection of a statistical test - There are two broad classes of statistical techniques used to analyze catch data. Parametric tests include the t-test and analysis of variance (ANOVA). Nonparametric tests include the Chi-square, Kolmogorov-Smirnov, and Mann-Whitney U-test. Statisticians have not agreed on how to characterize the differences between parametric and nonparametric tests (Conover 1971), but in general, parametric tests require more stringent assumptions about the distributions from which sample data are collected. Nonparametric tests also are called distribution-free tests, because they are not dependent on a given distribution, but can be used to analyze data from a wide range of distributions (Sokal and Rohlf 1981).

To select a statistical test, the biologist must examine the hypothesis to be tested and whether the data are likely to meet the assumptions upon which the test is based. Nonparametric tests are available for designs which have been analyzed traditionally with t-tests or one- and two-way ANOVA. Complex experiments typically are analyzed with parametric tests. For example, if the effect of three factors was considered in a single experiment (e.g., time, location, and sampling gear), a factorial ANOVA could be used. A nonparametric alternative to the factorial ANOVA exists, although it has not been widely used to date. An extension of the Kruskal-Wallis test can be applied to a balanced factorial design, wherein observed catches would be replaced by ranks and the traditional ANOVA algorithms would be used to obtain rank sums of squares for each main effect (factor) and interaction (Scheirer et al. 1976). The technique is straightforward and "combines the computational efficiency and versatility of the analysis of variance with the less demanding assumptions of a rank test for the analysis of data derived from a completely randomized factorial design" (Scheirer et al. 1976). When either a parametric or nonparametric test can be used, there is considerable disagreement about which is preferable for analysis of biological data (Gooch 1977, Green 1979). Classical statistics texts provide little guidance for analyzing fisheries data that violate the assumptions of parametric tests.

Thus, we need to know:

(1) why the assumptions of parametric tests are violated,

(2) how severe can violations be without jeopardizing results of the test, and

(3) what to do about data that violate the assumptions.

For example, assume that catch data have been collected from four stations and we want to know if catch differs significantly among stations. The one-way ANOVA usually would be used as the statistical test. However, when sample means and variances are calculated, we find strong evidence that the sample variance is much larger for stations where mean catch is much greater. This lack of homogeneity among variances violates one of the assumptions of the ANOVA test. Our alternatives are to appropriately transform the data and use ANOVA, or use an equivalent nonparametric test.

Biologists should recognize that the type and severity of the violation will determine which approach should be used. The appropriate statistical test should be selected on a case-by-case basis.

Nonparametric tests - Gooch (1977) considered parametric and nonparametric statistical tests for analysis of gill net data, and argued strongly for using nonparametric statistics. He suggested that many series of gill net catch data follow a negative binomial distribution and could be transformed for parametric analyses. However, he concluded that no specific transformation is appropriate for all gill net catch data, and recommended the use of nonparametric tests. Specifically, Gooch (1977) suggested that the Mann-Whitney and Kruskal-Wallis tests are the best methods available for analyzing such data.

One basis for choosing a particular test is its power, that is, its ability to detect differences when they exist (or as statisticians may say: reject a false null hypothesis). When the assumptions required for a parametric model are violated, nonparametric tests generally are more powerful, and they perform nearly as well as their parametric counterparts when conditions for the parametric test are met (Elliot 1979). Elliot (1979) suggested that nonparametric tests are particularly suitable for small samples from clumped populations. However, Pirie and Hubert (1977) argue that nonparametric tests are useful for a much broader range of problems, easy to use, valid, and perform well in most situations. They also demonstrated the danger of using parametric statistics without checking to determine if the assumptions of the test were met.

Parametric tests - Alternatively, Green (1979) emphasized that random sampling and transformation of data, if necessary, can alleviate many of the potential problems with biological data. Glass et al. (1972) stated that assumptions of ANOVA models typically are violated, but stressed that the important question is whether these violations seriously affect the validity of probability statements. They reviewed studies which examine the consequences of two commonly violated assumptions of ANOVA: non-normality and heterogeneity of variances among groups. They concluded that probability statements from ANOVA are valid in most circumstances, unless sample sizes differ among groups. Based on their review, the following recommendations should help insure the validity of ANOVA results:

(1) sampling must be random,

(2) sample sizes should be equal in each group, and

(3) samples should be as large as possible.

Glass et al. (1972) reported that acceptable results were obtained from one-way ANOVA designs having 2 to 5 groups and as few as 5 observations per group. These sample sizes might serve as a guideline for application of their results.

As a rule, we believe transformed catch data can be analyzed appropriately with parametric statistics. If the mean catch per unit of effort is very low or the number of observations is small, (i.e., less than 5 per group), nonparametric tests probably are preferable. Moreover, if sample sizes are small <u>and</u> differ among groups, nonparametric tests should be used.

Transformations

When samples were taken at different times or locations (termed treatments), we anticipate that mean catch varied with time or location. To test such a hypothesis using a parametric statistical test, we assume the data are normally distributed around a mean and that the variance is the same for all treatments. Although these assumptions typically will be violated by catch data, parametric tests such as t-test or ANOVA are robust to violations of these assumptions, and often are satisfactory even when the assumptions are not met. However, it is often possible to reduce the violations by an appropriate transformation of the data. Our objective is to insure that the data approximate the probability distribution required by the statistical test. In addition, transformation usually serves to eliminate the relationship between sample means and variances (Snedecor and Cochran 1967, Elliot 1979).

Suppose we are interested in comparing catch of chain pickerel (<u>Esox niger</u>) from four streams. We collect five 1-hour electrofishing samples from each stream and assume that factors other than location (e.g., weather) do not vary during the time the 20 samples are taken. Our objective is to test for differences in catch among locations with a one-way ANOVA. To do so, the data must meet the assumption that sample variances and means are independent. However, when means and variances are estimated, there appears to be a direct relationship between sample means and variances (Example 1).

Three approaches for determining if a transformation is needed are:

(1) Taylor's power law,

(2) Bartlett's test,

(3) inspection of means and variances.

Taylor's power law (Taylor 1961) assumes a nonlinear relationship between mean and variance for most field data. By fitting a model to estimated means and variances, the appropriate transformation can be determined. Details of the technique are provided in Elliot (1979) or Green (1979). Another formal approach is Bartlett's test for significant heterogeneity among variance estimates (Snedecor and Cochran 1967), which is illustrated in Example 1. The third approach (inspection of means and variances) is most likely to be used in practice. For example, Reynolds and Simpson (1978) demonstrated a clear relationship between sample means and variances of seining data by plotting means and variances.

Taylor's method can be used to select an appropriate transformation, while Bartlett's test indicates only whether a transformation is needed. Appropriate transformations for catch data include square root, logarithmic, or exact negative binomial transformation. If parametric statistical tests will be used, we recommend the logarithmic transformation of catch data (equivalent results are obtained with either natural or base 10 logarithms). The log(catch+1) transformation is used if any catches equal zero because the logarithm of zero is undefined. Green (1979) stated that most field collection data should be log transformed. Elliot (1979) noted that a more precise transformation can be obtained from Taylor's power law, but the log transformation is easy to apply and usually corrects heterogeneity of variances among groups.

After transformation, the data should be more normally distributed and the variances should be approximately independent of the means. This can be illustrated by plotting means and variances for the transformed data (Reynolds and Simpson 1978, Elliot 1979).

Example 1. Electrofishing yielded the following catch data for chain pickerel in four streams. Inspection of sample means and variances and results of Bartlett's test suggest that the data should be transformed before analysis with parametric tests.

Stream	Catch					Sample Mean	Sample Variance (S_i^2)
1	2	0	0	2	0	0.8	1.2
2	5	1	0	14	2	4.4	32.3
3	0	1	0	0	2	0.6	0.8
4	11	4	1	0	15	6.2	42.7

Note that sample means and variances appear to be correlated. As a formal check, we use Bartlett's test:

a = 4 sample variances (S_i^2)

f = 4 degrees of freedom (number of samples per stream - 1)

Stream	S_i^2	$\log_{10}(S_i^2)$
1	1.2	0.079
2	32.3	1.509
3	0.8	-0.097
4	42.7	1.630
Total	77.0	3.121

$\bar{S}^2 = \frac{77.0}{4} = 19.25$

$\log_{10}(\bar{S}^2) = 1.284$

$M = 2.3026\ f[a \log_{10}(\bar{S}^2) - \Sigma \log_{10}(S_i^2)] = 2.306(4)[4(1.284)-3.121]$
$= 18.59$

$C = 1 + \frac{a+1}{3af} = 1 + \frac{4+1}{3(4)4} = 1.104$

Compare $\frac{M}{C} = 18.59/1.104 = 16.84$
with χ^2 (a-1 , 0.95) = 7.81

Because 16.84 > 7.81, we reject H_0 and conclude that variances differ significantly among streams.

General Assumptions

Whenever catch data are compared among groups or treatments, samples from each group are assumed to be collected at random (that is, every possible sample has an equal chance of selection), and samples collected from different locations or times are assumed to be independent. These assumptions are required for either parametric or nonparametric tests. Consider 3 streams which will be sampled annually for several years. The two factors we want to evaluate are stream and year. The first assumption means that replicate samples (samples from stream i, and in year j) must be taken at randomly selected locations, and collection of one sample should not affect the results of any other sample. If, for example, samples at upstream sites affect subsequent downstream samples, samples might be taken at randomly selected locations in a non-random order (starting with the most downstream site and moving upstream). If sampling at short time intervals (e.g., weekly), carefully evaluate the potential for samples not being independent. As Green (1979) noted, lack of independence among samples cannot be accounted for by transforming the data; it must be prevented by random sampling. Additional information about parametric (Snedecor and Cochran 1967, Cochran and Cox 1957, Green 1979, Kleinbaum and Kupper 1978) or nonparametric tests (Elliot 1979, Conover 1971, Gooch 1977) should be obtained whenever the study design differs from the examples given below.

Biologists should recognize that biological assumptions also are made whenever results of a statistical test are interpreted. This is particularly true when analyzing data from field research, where a multitude of factors can influence the outcome of a study. Gooch (1977) noted that gill net catches are affected by any factor that influences fish movement, such as spawning activity, water temperature, barometric pressure, light, food supply, predation, underwater topography, and sources of inflow. Differences in catches may be due to differences in behavior, weather, etc. Replication provides an estimate of natural variation when uncontrollable external factors are (approximately) constant. Random site selection helps preclude systematic biases introduced when potential sampling sites are selected to represent areas of interest. Another potential source of error results from gear size selectivity. For example, differences in gill net catch between two areas may be the result of a difference in size distribution rather than abundance (Gooch 1977).

EXAMPLES

The purpose of this section is to discuss techniques for analyzing catch data. We concentrate on simple study designs and the techniques should apply to most gear types considered in the preceding chapters. These examples are intended to help others develop an experimental design, evaluate assumptions of the test, test hypotheses, and interpret results. We recognize that use of specific examples limits the generality of the discussion, but we do so for clarity; references are indicated where computational details, theoretical background, and generality are required.

Confidence Limits on the Mean Catch

Because fishes are difficult to sample intensively, a single estimate of relative abundance provides minimal information about a community. Catch rates may fluctuate considerably from sample to sample without the population or community fluctuating at all. One measure of the uncertainty about a mean catch rate is a confidence interval. When upper and lower bounds for a 95% confidence interval are given, we interpret the confidence interval as follows: the probability of this interval covering the mean is 0.95 (Sokal and Rohlf 1981).

By presenting a confidence interval or standard error ($s/\sqrt{n}$) for mean catch, we provide information about the precision of study results. A mean catch of 2 chain pickerel per hour of electrofishing has little meaning if the confidence interval includes 0 and 50. Confidence intervals usually are constructed using a t-distribution because sample size is small (less than 30). If the data appear to be normally distributed or the sample size is larger than 30, confidence intervals are calculated without transforming the data. In Example 2, catch data are transformed before confidence limits are estimated (Elliot 1979). Confidence limits derived in this way are asymmetrical and wider than traditional confidence limits, but the technique is conservative and probably more reasonable for catch data.

Example 2. Catch data from gill net sampling were summarized to obtain mean catch and a 95% confidence interval about the mean catch of gizzard shad (<u>Dorosoma cepedianum</u>). The untransformed catches from the n=7 samples are 0, 0, 6, 1, 0, 1, 23. The estimated mean and variance ($\bar{x}$ = 4.429, s^2 = 71.619) suggest that a transformation is needed because s^2 greatly exceeds $\bar{x}$ ($s^2 \gg \bar{x}$). Because several catches were 0, the log(x+1) transformation was used. The estimated mean and variance ($\bar{x}$ = 0.404, s^2 = 0.276) of the transformed data were used to construct a 95% confidence interval:

$$\bar{x} \pm t, \; s/\sqrt{n}, \text{ where } t_{(n-1 = 6,\ 0.05)} = 2.447$$

$$= 0.404 \pm 2.447 \sqrt{0.276/7} = 0.404 \pm 0.486 = -0.082 \text{ to } 0.890$$

To convert the confidence limits back to report untransformed catch rates, take antilogs then subtract 1 (Elliot 1979):

$$\text{mean} = 10^{0.404} - 1 = 2.535 - 1 = 1.535$$
$$\text{lower bound} = 10^{-0.082} - 1 = 0.828 - 1 = < 0$$
$$\text{upper bound} = 10^{0.890} - 1 = 7.762 - 1 = 6.762$$

So the 95% confidence interval is

$$0 > \bar{x} > 6.76.$$

Note that (1) confidence limits obtained from log-transformed data are not symmetric around the mean, and (2) the antilog of the mean transformed catch (1.535) will be less than the arithmetic mean of the untransformed data (4.429).

*(If no catches equal 0, the $\log_{10}(x)$ transformation is used. To convert confidence limits back to report untransformed catch rates, simply take antilogs (Elliot 1979)).

Evaluating Differences in Catch by Location or Time

When the purpose of a study is to evaluate differences in catch, analysis of variance probably can be used. Despite recognized problems with non-normality of catch data and heterogeneity of error variances, transformation of the data (when necessary), coupled with the robustness of the technique, should insure valid results. For readers unfamiliar with ANOVA, see any of the following for a detailed presentation (Snedecor and Cochran 1967, Cochran and Cox 1957, Kleinbaum and Kupper 1978, Underwood 1981).

Following an example in Elliot (1979), assume we want to evaluate the abundance of largemouth bass (<u>Micropterus salmoides</u>) in four coastal rivers. We use an electrofishing boat to sample the four rivers, with all sampling conducted in a relatively short interval. Each river is divided into 1000-m segments and five randomly selected segments per river are electrofished. The catch data from this experiment are analyzed using a one-way ANOVA (Example 3). Notice that the data were transformed before the analysis because our preliminary check of means and variances showed evidence of heterogeneity. If we had been comparing only two rivers, a t-test could have been used to compare the log-transformed catches from each river.

Example 3. We want to test for differences in relative abundance of largemouth bass among four rivers using a one-way ANOVA. The catch data are as follows:

River	Catch	Mean	Variance
1	0, 5, 23, 1, 6	7.0	86.5
2	63, 41, 55, 84, 6	49.8	841.7
3	21, 22, 39, 2, 55	27.8	402.7
4	113, 81, 36, 69, 154	90.6	2015.3

Notice that variances are much larger than means ($s^2 >> \bar{x}$) and sample means and variances appear to be correlated. These two observations suggest that a logarithmic transformation is needed. Using natural logarithms (either log(e) or log(10) can be used), the transformed data are:

River	log (Catch + 1)					Mean	Variance	Total
1	0.000	1.792	3.178	0.693	1.946	1.522	1.500	7.609
2	4.159	3.738	4.025	4.443	1.946	3.662	0.985	18.310
3	3.091	3.135	3.689	1.099	4.025	3.008	1.291	15.040
4	4.736	4.407	3.611	4.248	5.043	4.409	0.293	22.045
								63.004

Notice that the correlation between mean and variance is no longer apparent. The model sums of squares are calculated as:

Correction factor (CF) = (Grand Total)^2/20 = 63.004^2/20 = 198.4752008
Treatment SS = 1/5 [7.609^2 + ... + 22.045^2] - CF = 221.0673212 - CF
Total SS = 0.000^2 + 1.792^2 + ...+ 4.248^2 + 5.043^2 - CF = 237.34350 - CF
Error SS = Total SS - Model SS

The grand total (63.004) is the sum of all transformed observations. It is simpler just to add the row totals (63.004 = 7.609 + 18.310 + 15.040 + 22.045). The significance of differences among rivers is tested by constructing the ANOVA table:

Analysis of variance table.

Source	df	Sums of squares	Mean square	F
Treatment(rivers)	3	22.59212	7.53071	7.40
Error	16	16.27618	1.01726	
Total	19	38.86830		

We compare the calculated F value with the $F_{(3, 16, 0.05)}$ value from a table of F values. Because $7.40 > F_{(3, 16)} = 3.24$, we reject the null hypothesis. We conclude that there is significant evidence that catch is not equivalent among rivers.

Consider the assumptions made in comparing catch data from four rivers. First we assume that our sampling interval was short enough so that catch was not affected by changes through time. The last samples should not be taken at the onset of winter weather if other samples were taken in late fall. We must subjectively determine if factors affecting electrofishing efficiency (e.g., depth, specific conductance and turbidity) are similar in the four rivers. Ideally the four largemouth bass populations include fish of similar lengths, because vulnerability to electrofishing changes with length (Reynolds and Simpson 1978). Length frequencies might also be compared between rivers. If all populations contain largemouth bass of similar sizes, we can say with greater certainty that differences in catch were due to differences in abundance. Significant differences in catches should be attributable to differences in abundance and not to extraneous factors associated with the sampling effort.

A nonparametric alternative to one-way ANOVA is the Kruskal-Wallis test. Consider an example where common carp (Cyprinus carpio) are electrofished for 5 months. The null hypothesis is that the catch rates were the same for the 5 monthly sampling periods. The alternative hypothesis is that the catch was higher in one month than in one or more of the others. In Example 4, we illustrate how to deal with small and unequal sample sizes using a nonparametric test.

Example 4. We want to evaluate monthly differences in catch of common carp at a tailwater sampling station using the Kruskal-Wallis nonparametric test. The data are as follows:

	Month				
	Aug	Sep	Oct	Nov	Dec
Catches	7	10	15	8	8
	20	19	1	14	5
	6				

The raw catch data are converted to ranks. There are N = 11 observations, so ranks run from 1 for the lowest catch to 11 for the highest catch. The tied values are given the average rank (e.g., two catch values of 8 are 5th and 6th lowest, so each is ranked 5.5).

	Month				
	Aug	Sep	Oct	Nov	Dec
Ranked	4	7	9	5.5	5.5
Catches	11	10	1	8	2
	3				
R_i:	18	17	10	13.5	7.5
n_i:	3	2	2	2	2

($\Sigma n_i = N = 11$)

where: R_i is the total of ranks in each month

n_i is the sample size in each category

$$K = \left[\frac{12}{N(N+1)} \Sigma(R_i^2/n_i)\right] - 3(N+1) = \left[\frac{1}{11} 421.75\right] - 36 = 2.34$$

The computed K value, 2.34, is compared to a χ^2 of 9.488 with 4 degrees of freedom. Because $2.34 < 9.488$, we cannot reject the null hypothesis. We find no evidence to conclude that catch at our sampling station varies significantly among months. The computational details and underlying theory are provided in Conover (1971).

When a second factor may influence catch, a two-way ANOVA can be used to obtain more precise results. For example, assume that we want to compare the relative abundance of white bass (Morone chrysops) from three rivers during a spawning run. We believe that the week when a sample is collected may also influence results. We sample each river once per week for 5 weeks so that we can separate the effect of time and location (Example 5).

Example 5. Relative abundance of white bass is compared among three rivers using a two-way ANOVA. Samples are collected weekly for 5 weeks and each value represents catch/hour of electrofishing.

	Week				
River	1	2	3	4	5
1	19.1	23.4	29.5	23.4	16.6
2	50.1	166.1	223.9	58.9	64.6
3	123.0	407.4	398.1	229.1	251.2

As recommended, we log transform the data before doing the analysis:

River	Week 1	2	3	4	5	Totals
1	2.950	3.153	3.384	3.153	2.809	15.449
2	3.914	5.113	5.411	4.076	4.168	22.682
3	4.812	6.010	5.987	5.434	5.526	27.769
Totals	11.676	14.276	14.782	12.663	12.503	65.900

CF = $65.900^2/15$ = 289.520667

River SS = $1/5\ [15.499^2 + 22.682^2 + 27.769^2] - CF$

Week SS = $1/3\ [11.676^2 + \ldots + 12.503^2] - CF$

Total SS = $2.950^2 + 3.153^2 + \ldots + 5.434^2 + 5.526^2 - CF$

The ANOVA table will be:

Source	d.f.	SS	MS	F
River	2	15.33175	7.665875	83.46
Week	4	2.25175		
Error	8	0.73482	0.091853	
Total	14	18.31832		

The calculated F value (83.46) can be compared against $F_{(2, 8, 0.05)}$ = 4.46. Because 83.46 > 4.46 we reject the null hypothesis and conclude that differences between rivers were significant.

Note that in Example 5 we have assumed that there is no interaction between time and location. That would mean that the relationship between rivers would be similar from week to week. Specifically, we are using a randomized block design, which is a special type of two-way ANOVA. It is used whenever one factor is of particular interest (river) and the other factor (week) is used to reduce overall variation. The difference in location is more easily seen if not confounded by temporal effects. A better approach would be to take several samples for each location-time combination. This approach is demonstrated with the following example.

Assume we want to compare golden shiner (Notemigonus crysoleucas) abundance among three streams. In addition, we want to determine if abundance declines markedly during winter months as predatory fishes deplete the prey base. In Example 6, we attempt to evaluate time and location using a two-way ANOVA. To replicate our sampling, we seine three randomly selected sections of each stream in summer and winter.

(We will refer to each stream/season combination as a cell). The replicates (observations in each cell) give us an estimate of the natural variation in catch when neither factor changes.

Example 6. Relative abundance of golden shiner is compared among streams and seasons using two-way ANOVA. Three seine samples are taken on each of 3 streams during summer and winter and catch data are given below:

STREAM	Season: Summer	Season: Winter
1	16, 8, 3	0, 7, 2
2	0, 21, 15	1, 0, 7
3	11, 9, 3	2, 0, 0

We transform the data (using $\log_e (X+1)$ because some catches were 0) and analyze these transformed data:

STREAM	Season: Summer	Season: Winter
1	2.833, 2.197, 1.386	0.000, 2.079, 1.099
2	0.000, 3.091, 2.773	0.693, 0.000, 2.079
3	2.485, 2.303, 1.386	1.099, 0.000, 0.000

The next step is to construct a table of cell totals, cell means, totals by season and stream, and the grand total.

STREAM	Season				
	Summer		Winter		
	Total	Mean	Total	Mean	TOTAL
1	6.416	2.139	3.178	1.059	9.594
2	5.864	1.955	2.772	0.924	8.636
3	6.174	2.058	1.099	0.366	7.273
Totals	18.454		7.049		25.503

Next, the sums of squares are calculated:

$CF = 25.503^2/18 = 36.1335005$
Stream SS $= 1/6\ [9.594^2 + 8.636^2 + 7.273^2] - CF = 0.4534763333$
Season SS $= 1/9\ [18.454^2 + 7.049^2] - CF = 7.226334722$
Stream x Season SS $= 1/3\ [6.416^2 + 3.178^2 + \ldots + 6.174^2 + 1.099^2]$
$- CF -$ Stream SS $-$ Season SS
$= 44.22043233 - 0.453476333 - 7.226334722 - CF =$
0.407120778

The ANOVA table:

Source	d.f.	SS	MS	F		$F_{.95}$
Stream	2	0.453476333	0.226738166	0.21	<	3.89
Season	1	7.226334722	7.226334722	6.81*	>	4.75
StreamxSeason	2	0.407120778	0.203560389	0.19	<	3.89
Error	12	12.737434670	1.061452889			
Total	17	20.824366503				

We find that differences between streams were nonsignificant while differences between seasons were significant at the 5% level. The interaction between stream and season was nonsignificant, which means that the pattern of catches between summer and winter was similar for all streams.

* denotes a significant effect (α = .05)

Notice that we assumed that the shiner population was found in one of two states - nondepleted summer or depleted winter. If abundance varies in all four seasons, our experimental design will not detect it. Another even more critical assumption was that the observed winter decline in abundance was attributed to predation. This study provides no evidence to support that statement.

To analyze the data, we classify the factors under investigation as fixed or random. A fixed factor is one whose levels (or component groups) are the only relevant levels of interest. A random factor is one whose levels may be regarded as a sample from a large population of levels (Kleinbaum and Kupper 1978). Kleinbaum and Kupper (1978) suggest that random levels need not be selected randomly but should be relatively representative of the larger population of levels of interest. As an example, suppose we wanted to compare catches of white bass from different drainages. If we selected three different drainages to sample and applied our conclusions to all drainages in the southeastern U.S., drainage would be a random factor. If we wanted to compare three specific drainages and not make inferences about drainages in general, we would consider drainage a fixed factor. In our example, if stream and season are fixed factors, we would be in error if our results were considered as representative of streams in general. The distinction between fixed and random factors often is judgemental and may vary from study to study. A study of a few specific locations (not selected at random from a large number) for a few seasons or years would result in locations and years considered as fixed factors. Both factors could be considered random if randomly selected from a large number of possible locations or years.

Note that we have carefully designed experiments which fit the two-way ANOVA design. This type of planning should always be completed before sampling. It is much simpler to fit a sampling scheme into the specific design of a test than to sample and then look for a test that fits the sampling design.

Recognize that a more complicated experiment could arise easily. For example, we might want to evaluate differences between rivers (a fixed factor) and locations within each river. The locations would be a nested random factor (because locations are selected from within the treatments - river) and the analysis of variance would be a nested design. Many studies require unusual sampling designs and should be planned and conducted in close consultation with a statistician.

Recall that in the Kruskal-Wallis nonparametric test (Example 4), we assumed that only time (month) differed among the 5 sets of sample catches. If location is also a factor, use Friedman's test (Conover 1971, Elliot 1979), a nonparametric test that is analogous to the two-way ANOVA or randomized block design. For example, assume that we electroshock four stations on a river during each of eleven months. We are interested in whether the catch of pumpkinseed, Lepomis gibbosus, varies significantly among the four stations (Example 7). Months are equivalent to blocks in the traditional randomized block ANOVA. The null hypothesis is that catch at all stations will be identical, or alternatively, at least one station will tend to yield larger observed catches than other stations. If the rankings stay relatively constant over months, we may conclude that catch is consistently higher at one station. In Example 7, catch at station 1 is consistently highest, and a significant difference in catch was detected. Conover (1971) provides additional details and underlying theory. Keep in mind that the test does not compare among blocks. In our example, we could not test for differences among months, although an ANOVA design would allow months to be tested. We are unable to test for interaction between time and location with Friedman's test. If replicate samples are collected for each station-month combination, the nonparametric test presented by Scheirer et al. (1976) can be used to test individual factors and interactions among factors.

Example 7. Four stations are electrofished during each of 11 months to evaluate differences in catch of pumpkinseed among stations. Each observation is the number caught in one hour of electrofishing:

Month	Station 1	Station 2	Station 3	Station 4
	Catch			
1	38	3	32	2
2	19	5	34	11
3	42	21	11	7
4	40	9	10	13
5	114	32	12	4
6	1	19	18	7
7	30	9	0	0
8	12	2	6	2
9	7	1	3	0
10	8	5	0	5
11	4	3	1	3

The first step in analyzing the data is to convert the observations to ranks. The observations in each row (month) are ranked separately; lowest catch is ranked 1 and highest is ranked 4 (in this case). Ties are accorded the average rank between tied observations:

Month	Station 1	Station 2	Station 3	Station 4	Total
	Ranked Catch				
1	4	2	3	1	
2	3	1	4	2	
3	4	3	2	1	
4	4	1	2	3	
5	4	3	2	1	
6	1	4	3	2	
7	4	3	1.5	1.5	
8	4	1.5	3	1.5	
9	4	2	3	1	
10	4	2.5	1	2.5	
11	4	2.5	1	2.5	
Sum	40.0	25.5	25.5	19.0	110.0

$$S = \Sigma(R_i^2) - \frac{(\Sigma R_i)^2}{n}$$

where R_i = sum of ranks in i^{th} column
n = number of columns
$S = 40.0^2 + 25.5^2 + 25.5^2 + 19.0^2 - (110.0^2/4)$

The divisor in the last term is the number of stations, rather than total sample size. The calculated S value is compared to $\chi^2_{(4-1 = 3\ df)}$; i.e., S = 12.9 and $\chi^2_{(3, 0.95)}$ = 7.815. We reject H_o and conclude that catch differed significantly among stations.

Correcting Catch Data for Uncontrollable Factors

An important technique with which biologists may not be familiar is analysis of covariance. This is particularly useful when a relationship of interest can be affected by an independent variable beyond our control. It is useful since we often have relatively little control over the experimental units we observe in field studies. In most field research, results are affected by weather, water velocity, fishing pressure, and a variety of other complicating factors. We can never absolutely attribute observed results to a specific source but we can minimize this problem through replication, careful use of controls, and collection of pertinent auxiliary information.

As an example, assume a river in our management area recently received a road and boat ramp to improve access to an underutilized 10-km stretch of river. The level of weekly fishing effort was monitored for one month before access was improved to determine if mean fishing effort increased for the same month a year later. Fishing effort appeared to be about the same in both years, but the comparison between years was "unfair" because three times as much rain occurred in the second year and heavy rains reduced fishing effort. We can develop a regression model to predict fishing effort using access (improved, unimproved) and rainfall data. By including rainfall as a covariate, we test for differences in effort as if rainfall had been the same in both years; the covariate removes the differential effect of rainfall.

The necessary calculations to estimate the regression parameters are tedious, but the test is very valuable and can be done easily with most statistical packages. Kleinbaum and Kupper (1978) provided a good description of the technique and how to implement the test using a statistical package.

Evaluating Changes in Species Composition Over Time

One question that should be of general interest is whether the relative abundance of species in a community changes from year to year (Example 8). Alternatively, we could compare several communities in a single year. As an example, assume that rotenone samples have been collected from the same stretch of stream for three years. We want to determine if species composition has changed over time, and an appropriate test is the Chi-Square test (Conover 1971, Elliot 1979). Data are arranged in a contingency table (see Example 8), and the null hypothesis is that the relative abundance of each species remains the same from year to year. If the null hypothesis is rejected, there is significant evidence that species composition has changed over time. The test is designed for data where the expected value of each cell (catch of species i in year j) is relatively large, although Roscoe and Byars (1971) suggested that traditional restrictions on expected values were too confining. They recommended that the average expected frequency ($\bar{E}$ = n/k, where n = total sample size and k = number of cells) should be at least four to six when testing at a significance level of 0.05. In Example 8, the average expected frequency is 1109/(9x3) = 41, which greatly exceeds the recommended guideline.

Example 8. Rotenone samples were collected from the same stream for three years to compare relative abundance of each species in the community over three years. The null hypothesis is: H_o: the proportion of total catch each species comprises does not change from year to year.

Species	Frequency number per rotenone sample by Year 1	 2	 3	Row total
Lepisosteus osseus	31	39	43	113
Anguilla rostrata	118	22	56	196
Dorosoma cepedianum	88	40	47	175
Cyprinus carpio	24	23	27	74
Moxostoma anisurum	39	88	11	138
Ictalurus brunneus	86	17	71	174
I. catus	25	15	18	58
Lepomis auritus	63	28	40	131
L. gibbosus	28	12	10	50
Column totals	502	284	323	1109

These data are put into a contingency table and expected value of each cell (species by year combination) is calculated as:

Row total x Column total/Grand Total = Expected value.

For L. osseus, the expected value is

$$\frac{502(113)}{1109} = 51.2$$

Species	YEAR 1		YEAR 2		YEAR 3	
	OBSERVED	EXPECTED	OBSERVED	EXPECTED	OBSERVED	EXPECTED
L. osseus	31	51.2	39	28.9	43	32.9
A. rostrata	118	88.7	22	50.2	56	57.1
D. cepedianum	88	79.2	40	44.8	47	50.1
C. carpio	24	33.5	23	19.0	27	21.6
M. anisurum	39	62.5	88	35.3	11	40.2
I. brunneus	86	78.8	17	44.6	71	50.7
I. catus	25	26.3	15	14.9	18	16.9
L. auritus	63	59.3	28	33.6	40	38.2
L. gibbosus	28	22.6	12	12.8	10	14.6

$$\chi^2 = \frac{(31-51.2)^2}{51.2} + \frac{(118-88.7)^2}{88.7} + \ldots + \frac{(40-38.2)^2}{38.2} + \frac{(10-14.6)^2}{14.6} = 185.255$$

Compare 185.255 with $\chi^2_{16,0.05} = 7.96$ [16 d.f. = (r-1) x (c-1)] where r = the number of rows and c = the number of columns. Because 185.255 > 7.96, we reject H_0 and conclude that species composition shifts significantly among years.

Evaluating Differences in Length Frequency Distributions

The Kolmogorov-Smirnov test (Conover 1971) can be used to determine if two length frequency distributions differ significantly. Assume that length data for largemouth bass were collected by electrofishing a heavily-fished and lightly-fished oxbow lake to determine if size distributions differed between lakes (Example 9). The null hypothesis for the two-sided test is that the size distributions are equivalent; alternatively, the distributions differ in at least one size interval. If our original reason for sampling was to determine if exploited populations have smaller bass, a one-sided test should be used. Because we usually don't know what we will find when we begin sampling, we illustrate the use of the two-sided test.

To compare more than two length distributions, there are several alternatives. Pairwise comparisons can be made with the Kolmogorov-Smirnov test. The drawback is that when several tests are done at a 95% confidence level, the biologist cannot be 95% confident that all conclusions are correct. In practice, recognize that overall confidence declines as additional tests are done and proceed accordingly. Another alternative is to use a Chi-Square test as we did to compare species composition among years. In a comparison of k length frequency distributions, the null hypothesis is that the proportion of fish in each

Example 9. A Kolmogorov-Smirnov two-sample test is used to compare length-frequency distributions from two largemouth bass populations. Observed lengths were put into 25-mm size intervals:

SIZE	Location A			Location B			
CLASS	number	frequency	cumulative frequency	number	frequency	cumulative frequency	$\lvert S_1(x) - S_2(x)\rvert$
200-224	7	.033	.033	5	.032	.032	.001
225-249	4	.019	.052	6	.039	.071	.019
250-274	13	.062	.114	2	.013	.084	.030
275-299	2	.010	.124	11	.071	.155	.031
300-324	3	.014	.138	16	.103	.258	.120
325-349	17	.081	.219	41	.265	.523	.304
350-374	24	.114	.333	39	.252	.775	.442
375-399	23	.110	.443	6	.039	.814	.371
400-424	30	.143	.586	8	.052	.866	.280
425-449	18	.086	.672	4	.026	.892	.220
450-474	25	.119	.791	3	.019	.911	.120
475-499	14	.067	.858	3	.019	.930	.072
500-524	2	.010	.868	5	.032	.962	.094
525-549	16	.076	.944	1	.006	.968	.024
550-574	9	.043	.987	2	.013	.981	.006
575-599	3	.014	1.001	3	.019	1.000	.000

The test statistic $T = \max \lvert S_1(x) - S_2(x)\rvert = 0.442$. The bars [| |] indicate that the absolute value of the difference between cumulative frequencies is used. The number of largemouth bass in the first sample (n_1) was 210, and 155 in the second sample (n_2). The large-sample approximation to the 95% quantile is:

$$w_{.95} \simeq 1.36 \sqrt{\frac{n_1 + n_2}{n_1\, n_2}} = 1.36 \sqrt{\frac{210 + 155}{210(155)}} = 0.106.$$

Because 0.422 > 0.106, we reject H_0, and conclude that length-frequency distributions from the two populations differed significantly.

size class is the same for all k samples (Conover 1971). Finally, "Smirnov-type" tests are available that are multi-sample analogues to Kolmogorov-Smirnov test for two samples (Conover 1971). A major drawback is that statistical tables are only available for the case where sample sizes are equal from each population. Most length data are not based on a fixed sample size, but this could be incorporated into a study design whenever three or more length distributions are compared.

OTHER APPROACHES

Several equally important techniques have been omitted from this chapter. Among these are correlation and regression analysis and multivariate techniques (cluster analysis, principal components analysis, discriminant analysis, multivariate analysis of variance, canonical correlation and others).

Correlation and regression analysis can be used to evaluate relationships among two or more variables. For example, these techniques can be used to relate environmental variables to estimates of fish abundance and to predict the responses of fish communities to changes in habitat. Draper and Smith (1981) provide an excellent discussion of simple linear, multiple linear, and nonlinear regression analysis. Other useful references on regression analysis are Neter and Wasserman (1974) and Kleinbaum and Kupper (1978). Ricker (1975) discusses several applications of linear regression in fisheries biology, such as using catch curves to estimate survival rates or estimating the relationship between fish length and weight.

Multivariate techniques are well suited to analysis of fisheries data, as fish communities are comprised of many interdependent species. These techniques can be used to summarize data on fish communities, to evaluate patterns of similarity and difference among fish communities, and to relate biological and environmental data (Tonn et al. 1983). For example, univariate tests such as ANOVA can be used for species-by-species comparisons among rivers, while multivariate techniques are used to compare fish communities among rivers. Overviews of multivariate techniques are given by Johnson (1981) and Green (1979). Tonn et al. (1983) use multivariate techniques to define patterns in the fish communities and habitat characteristics of 29 Wisconsin lakes, and this could be a productive approach for analysis of stream fish communities.

CONCLUSIONS

In recent years, quantitative techniques have been used with increasing frequency to evaluate the results of field sampling. The techniques outlined in this chapter should provide a useful set of tools for analyzing catch data. When coupled with an appropriate study design, the use of statistical tests of hypotheses can provide a firm foundation upon which management recommendations can be based.

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