Chapter 2: Warmwater Fish in Small Standing Waters

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2.1 INTRODUCTION

2.1.1 Definition of Water Body

This chapter describes standardized sampling techniques for routine monitoring and population assessment of warmwater sport and prey fishes in small standing water bodies. Although water temperature regulates growth, survival, and reproduction of fishes, there are no specific criteria that define a warmwater fish community. Dodds (2002) noted that warmwater fish communities tend to be dominated by sunfishes, temperate basses, and catfishes. Perches and pikes are common to coolwater fish communities, and trouts and salmons are characteristic of coldwater fish communities. For this chapter, we focus on species that prefer water temperatures greater than 15°C. Coolwater fishes that are important in small natural lakes or impoundments and not incorporated in other chapters are also included.

As with warmwater fish, there is also no stringent definition of a small standing water body. Small standing waters generally contain less complex habitats and fish communities than large standing waters. For this chapter, an area of 200 ha was selected as the maximum surface area for small standing waters, but surface-area designations may vary regionally. Other than a strict definition based on surface area, the manageability of less complex fish communities in small water bodies along with differences in their physical and limnological characteristics, as described below, help separate them from larger water bodies.

On a broad scale, there are four generic types of small standing water bodies: impoundments (ponds), natural lakes, excavated pits, and dugouts. An impoundment is created by damming a perennial, intermittent, or ephemeral stream in a watershed. A natural lake is a depression in the landscape that gathers water, either by seepage, runoff, direct precipitation, or a combination of sources. An excavated pit results from groundwater seepage into an excavated site that was mined for gravel, sand, rock, or fill for construction. A dugout (referred to as a tank in the Southwest) is created by collection of surface water or well water in an excavated site built for the purpose of watering livestock.

The limnetic zone is absent or restricted by shallow depths in most small impoundments, small natural lakes, and dugouts. In contrast, the littoral zone is typically narrow in excavated pits because of steep-sloping banks. These physical differences, in combination with variations in nutrient loading, trophic state, and water-level fluctuations affect recruitment patterns of fishes and resulting population dynamics among small standing water bodies.

Physical characteristics of water bodies (e.g., surface area, water volume, stratification patterns, and inflow and outflow rates) affect the composition, distribution, and behavior of fishes and, hence, influence the efficiency and selectivity of fish sampling techniques. Several differences exist in physical characteristics between small and large standing water bodies. Water temperatures during summer are generally warmer in small waters than in nearby larger waters. The ratio of littoral surface area to limnetic surface area is substantially greater in some small standing water bodies compared to large standing waters. Aquatic vegetation is typically more prevalent in small ponds and can profoundly affect water quality and fish composition, abundance, and distribution. The influence of the shoreline interface also is greater in small water bodies because of their smaller size.

2.1.2 Targeted Fish Assemblages

The warmwater fish assemblages in small standing water bodies of North America typically contain fishes from some combination of the following taxa: sunfishes, catfishes, perches, pikes, temperate basses, cichlids, herrings, carps, and minnows. The sampling protocols described in this chapter are directed at largemouth bass, smallmouth bass, bluegills, redear sunfish, redbreast sunfish, green sunfish, black crappies, white crappies, gizzard shad, threadfin shad, channel catfish, black bullheads, white bass, white perch, yellow bass, hybrid striped bass, northern pike, chain pickerel, walleyes, yellow perch, fathead minnow, golden shiners, red shiners, and cichlids.

2.1.3 Standard Gears

Gears were selected based on an objective of easily comparing indices of population structure and abundance (e.g., presence, length structure, condition, growth, and catch per unit effort [CPUE]) along spatial and temporal gradients in which fish communities are assessed. Given this objective, we identify four gear types for sampling fishes in small, warmwater lentic systems: (1) boat electrofisher, (2) bag seine, (3) sinking experimental gill net, and (4) modified-fyke net. Using all four gears in a single water body may be unnecessary, especially when the species composition is known and it does not include species targeted by a particular gear.

Electrofishing and seining are active capture techniques (Hayes et al. 1996; Reynolds 1996), whereas gill and fyke netting are passive capture techniques (Hubert 1996). Thus, capture of fishes with an electrofisher and seine depends more on biologists' skill in the field. In contrast, capture of fishes with correctly-deployed gill and fyke nets depends more on fish movement and the ability of the nets to retain fish once they are caught. For passive gears, active fishes are more readily caught than are sedentary and cover-oriented fishes, although some cover-seeking species, such as crappies, are vulnerable to capture in fyke nets because of a "brush-pile" effect (i.e., they are attracted to the nets because of the cover provided).

The sample of fish captured by a single gear often is not an accurate representation of a fish population (e.g., length structure) or assemblage (e.g., relative species composition; Murphy and Willis 1996). That is, a given sample typically does not consist of the same proportions of lengths or species present within a water body. This bias in sampling is known as "gear selectivity" and is described below.

Capture rates of fishes (indexed with CPUE) with a boat electrofisher, gill net, or fyke net often peak during spring and again during autumn (Pope and Willis 1996). Similarly, catchability of different-sized individuals is typically not constant within or among fishing gears, reflecting seasonal and diel rhythms in fish movements and behavior, along with differences in habitats that hold fish of varying size. Electrofishing, for example, is size-selective. Reynolds and Simpson (1978) demonstrated that electrofishing efficiency increased as a function of total length for largemouth bass (although a curvilinear relationship likely exists when including large [greater than 45 cm] largemouth bass in this assessment), whereas electrofishing efficiency was greater for bluegills between 8 and 15 cm compared with those less than 8 cm or greater than 15 cm. Thus, length structure is slightly overestimated for largemouth bass and underestimated for bluegills. Further, differences in length structure between daytime and nighttime catches were noted for samples of bluegills, largemouth bass, smallmouth bass, saugers, and gizzard shad (Gilliland 1987; Paragamian 1989; Malvestuto and Sonski 1990; Van Zee et al. 1996; Dumont and Dennis 1997), illustrating that time of day can affect sample structure. As examples of differences in length structure of samples among gears, smallmouth bass captured with a boat electrofisher were generally shorter than smallmouth bass captured with fyke nets (Milewski and Willis 1991) and bluegills captured with a boat electrofisher were generally shorter than bluegills captured with hook-and-line (i.e., creel survey; Santucci and Wahl 1991). These differences in length structure likely lead to similar biases for assessment of age structure. A more thorough review of the effects of gear type on size structure of a fish sample is provided by Neumann and Allen (2007).

A beach seine is most effective for the capture of fish that reside near shore (Hayes et al. 1996) and its efficiency is greater for species residing in the middle of the water column than for demersal species (Lyons 1986). Factors such as fish swimming speed and size, substrate composition, and presence of obstructions in the water column (e.g., aquatic vegetation and woody debris) can also affect seining effectiveness. Incorporation of a bag into the beach seine improves capture efficiency because fish are unable to swim under or over the seine once inside the bag (von Brandt 1984).

Experimental gill nets, which include several graduated mesh sizes, are often used to sample broad length ranges of species. The use of experimental gill nets does not ensure that the length structure of the sampled fish is representative of the true length structure of the fish population because mesh-size selectivity and efficiency influence catch rates of various sized fish. Mesh-size selectivity influences the length range of fish effectively caught within a particular mesh size, and primarily depends on fish length and shape, mesh size and hanging ratio, and method of fishing (Hamley 1975). Fish are usually captured in gill nets by being gilled (head of fish penetrates through mesh and a strand of the net slips behind fish's operculum) or wedged (fish swim part-way through mesh, but mid-body is too large to fit through mesh), which depend on fish size (Hamley 1975; Hubert 1996). Size selectivity of gill nets is further exacerbated when larger fish become entangled by mouth parts in smaller meshes of the net (Hansen et al. 1997). Mesh efficiency is a phenomenon whereby fish with girths appropriate for a large mesh are more readily captured than fish with girths appropriate for a smaller mesh because (1) there is less material in larger mesh, likely making the net more difficult to detect, (2) larger fish travel greater distances, increasing odds of encountering a net, and (3) larger fish swim with greater momentum, increasing the odds of wedging when encountering a net (Rudstam et al. 1984). Mesh efficiency is affected by net material, twine diameter and color, and method of fishing (Hamley 1975).

Fyke nets are most effective for capturing species that tend to move along shorelines (Hubert 1996) and their efficiency in capturing fish is likely related to differences in mobility among species and age-groups. For example, fyke net efficiency increases for older age-groups of walleyes during autumn, but is constant for age-groups of mature walleyes during spring (Forney 1961). Catch rates of crappies that represent the population structure generally are greatest in fyke nets during autumn (Hamley and Howley 1985; Boxrucker and Ploskey 1989) and catches are biased toward larger sizes of sunfish (Laarman and Ryckman 1982), especially during spring (Schultz and Haines 2005). Vulnerability of large bluegills to capture in fyke nets declines from spring through early autumn (Cross et al. 1995) perhaps because larger bluegills inhabit deeper, open water after spawning (Paukert and Willis 2002).

In addition to gear selectivity, there are numerous advantages and disadvantages of active and passive collection methods. The cost and maintenance of a boat electrofisher is expensive compared to gill nets and seines. Nets have short life expectancy and are easily damaged when tangled with structure such as woody debris and from animals such as muskrats eating holes in fyke nets. Damaged nets must be replaced or repaired to maintain sampling effectiveness. Fish mortality is substantial for some passive sampling techniques, especially gill nets set for long durations or during warm seasons. Passive collection methods typically provide greater flexibility in daily work schedules than active sampling techniques because passive gears (e.g., nets) often can be left unattended while fishing.

2.2 BOAT ELECTROFISHER

2.2.1 Targeted Fishes

The fishes targeted with a boat electrofisher include largemouth bass, smallmouth bass, bluegills, redear sunfish, redbreast sunfish, green sunfish, gizzard shad, threadfin shad, and cichlids (e.g., Mayan cichlid and tenguayaca).

2.2.2 Specifications

Applying electricity to water can be dangerous to humans. However, several precautions reduce the hazards associated with electrofishing. Sturdy railing around the bow helps the individual in front of the boat to maintain their balance while netting fish. Safety switches should be operated by both the netter and boat driver to prevent accidents. All crew members should wear U.S. Coast Guard-approved personal flotation devices, rubber boots, and electrician gloves (minimum rating greater than or equal to generator capacity), and be trained in principles of electrofishing, cardiopulmonary resuscitation (CPR), and first aid. See Reynolds (1996) for additional safety guidelines.

An overview of specifications of the standard electrofishing boat is presented here, with additional detail in Table A.1. The electrofisher components (generator, control unit, and necessary wiring and safety switches) should be mounted in a flat-bottom aluminum boat (often used as the cathode) of sufficient size to safely transport equipment and crew (Figure 2.1). Twin booms should support the anode, consisting of a spider or ring array attached at the end of each boom. The recommended distance between centers of the two anode arrays is 1.9–2.0 m and recommended distance from front of boat to center of each array is 2.4–2.5 m. Suggested dimensions for each spider or ring array is a 91.4 cm diameter with

Figure 2.1 Boat electrofishing to capture warmwater fish in standing waters.

six stainless-steel dropper cables (diameter of each cable is 4.8–6.4 mm; submersible length of cables is 0.91 m) that are spaced evenly around the perimeter of the array. The generator-powered electrofisher should be capable of producing a pulsed-DC waveform with ability to regulate applied power.

2.2.3 Operation/Deployment

Electrofishing should be concentrated along the shoreline. If the entire shoreline is not sampled, randomly selected shoreline segments are recommended (see Brown and Austen [1996] and Guy and Brown [2007] for more detailed discussion of experimental design). Generally, continuous power (i.e., pedal down) should be used while fishing; power should only be switched off when safety is a concern or when the switch cannot be controlled.

Use a pulsed-DC (60 Hz) waveform with a 10–20% duty cycle and adjust applied power (by manipulating amperage and voltage) for water conductivity so that power transferred to fish is between 2,750 and 3,250 W (Chapter 14). Through time, the portions of the electrodes that create the in-water electric field (i.e., droppers and forward section of boat hull) become anodized; periodic cleaning of the electrodes is necessary to maintain consistency of the electric field through time. Fish injuries increase with increasing magnitude of the voltage differential generated across the fish (i.e., head-to-tail voltage; Snyder 2003); thus, a minimal power selection within the desired range reduces the probability of fish injury.

For CPUE (number per hour of electrofishing) comparisons, fish are dipped by two netters, unless fish density is so low that one netter can easily net all fish. Dip nets should have 6.4-mm mesh and be 30 cm deep, with a 2.4- to 3.1-m fiberglass handle. All stunned fish should be netted without size or species favoritism.

After measurements (total length and weight for each individual) are recorded, fish should be released in an area (e.g., near middle of the sampled segment) that minimizes their potential movement into areas that have yet to be sampled. If this is not feasible or if there is concern about small sample size for length-structure assessment, then captured fish should be marked (e.g., fin punch) before release or held in a live pen until sampling is completed.

2.2.4 Time of Sampling

Electrofishing should be conducted at night (during the period 30 min after sunset to 30 min before sunrise) as this time typically produces greater CPUE (Bennett and Brown 1969; Paragamian 1989; Malvestuto and Sonski 1990; Sanders 1992), resulting in larger sample sizes for length and age structure and condition indices. However, CPUE can be similar between day and night in waters with low visibility (Secchi depth < 1 m). For logistical reasons, daytime electrofishing may be used in turbid waters. Sampling during spring (water temperature warming and between 15°C and 23°C) generally provides the greatest CPUE for most of the target species; thus, electrofishing should be conducted in spring for most warm, small, standing waters. More precise sampling times, which can vary depending on differential periods of vulnerability among regions and species, are at the discretion of the sampler. For example, species in centrarchid-dominated fish communities are often sampled later in spring than those in esocid- and percid-dominated communities because spawning times and habitat use differ, with subsequent differences in vulnerability to the fishing gear. In addition, electrofishing during autumn for age-0 fish, such as walleyes (Serns 1982), provides a reasonable index of yearly reproduction.

2.2.5 Computation of Effort

Data should be recorded separately for each sampled segment of shoreline. Effort should be transformed to a per-hour basis (e.g., 600 s ≈ 0.17 h) of power-on (pedal-down) time, as measured by the electrofisher timer. Thus, CPUE might be the mean number of redear sunfish captured per hour of electrofishing. Recording distance sampled (actual distance the boat moves) for each segment is encouraged for future computation of effort based on segment length.

The amount of sampling needed depends on survey objectives and the desired precision of CPUE estimates, which dictates the level of change that can be detected (Brown and Austen 1996; Quist et al. 2006; Guy and Brown 2007). The minimum amount of effort in small water bodies should be three shoreline segments, which is the minimum number required to calculate a variance for mean CPUE. Each segment should consist of approximately 600 s of power-on time, or 0.33 of the shoreline distance in water bodies in which the entire shoreline is sampled with less than 30 min of pedal-down time.

These guidelines do not address recommended sample sizes for estimation of length structure, age structure, or body condition (e.g., Gilliland 1987; Vokoun et al. 2001; Miranda 2007). The number of fish sampled varies depending on CPUE and total effort. If additional fish are needed for indices of length structure, age structure, or body condition, then sampling of more segments is encouraged, even if it is necessary to re-sample areas (i.e., a second lap around the water); however, data gathered during this re-sampling should not be included in CPUE estimations because catch rates would likely be diminished during resampling. Also, recaptured fish (marked with a fin punch) should not be double-counted.

2.3 BAG SEINE

2.3.1 Targeted Fishes

The fishes targeted with a bag seine include fathead minnow, golden shiners, red shiners, and age-0 fishes. Bag seines are used by managers of small standing waters to assess reproduction of largemouth bass and bluegills, the prey base for largemouth bass, and potential invasion by undesired fishes. Swingle (1956) provided a method to assess overall balance of pond fish communities by interpretation of seine catches (see Flickinger et al. [1999] for a summary of the method).

2.3.2 Specifications

The standard seine is 9.1 × 1.8 m, with a 29.5-kg leadcore bottom line and sponge floats evenly spaced on the float core top line (Table A.5). A bag (1.8 × 1.8 × 1.8 m) is incorporated in the center of the seine; thus, the seine contains 3.65-m wings on each side of the bag. Recommended mesh for the entire seine is 6.4-mm Delta. Seine brails can be polyvinyl-chloride tubing or wood, should be sturdy enough to pull the net, and should measure 1.8–2.5 m in length.

2.3.3 Operation/Deployment

Deployment is achieved by fully extending the seine perpendicular from the shore and then pivoting around the entry (anchor) point; that is, the seine covers an area equal to a 0.25 circle with a radius of 9.1 m (known as a quarter haul or quarter arc). The seine should be moved as quickly as possible through the water, being careful to keep the leadline in constant contact with the bottom and the floatline on the surface. If the seine is frequently snagged during sampling, then that sample should be abandoned because it is unknown if and how many fish may have escaped. Areas with a steeply sloping shoreline (such as the dam on a pond) and excessive debris or snags should be avoided. Randomly selected sites (i.e., sites are randomly selected for each sampling date) are recommended (see Brown and Austen [1996] and Guy and Brown [2007] for more detailed discussion on experimental design). The addition of extra sampling sites, randomly selected, is encouraged in the event that one or more randomly selected sites are unsuitable for seining (e.g., contains many snags).

2.3.4 Time of Sampling

For safety reasons, seining should be conducted during daylight. Seining should occur during late summer (before water temperature begins cooling for autumn) as this is the period when many age-0 sport fishes have grown to a size where they are vulnerable to capture with a seine. More precise sampling times are at the discretion of the sampler. Sampling times may vary among geographic regions and species, depending on differential periods of vulnerability.

2.3.5 Computation of Effort

Data should be recorded separately for each haul. Effort is calculated on a per-haul basis. Thus, CPUE might be the mean number of age-0 largemouth bass collected per quarter-arc seine haul.

The amount of sampling needed depends on survey objectives and the desired precision of CPUE estimates (see 2.2.5). The minimum amount of effort in small water bodies is three seine hauls, which is the minimum number required to calculate a variance for mean CPUE. However, additional seine hauls are preferred because fish catches for a given species are frequently zero in individual hauls.

2.4 GILL NET

2.4.1 Targeted Fishes

The fishes targeted with experimental gill nets include bullheads, chain pickerels, channel catfish, rock bass, white bass, white perch, yellow bass, hybrid striped bass, and cichlids (e.g., tilapia). Other fishes frequently encountered in gill nets include walleyes, yellow perch, and northern pike.

2.4.2 Specifications

The standard sinking gill net is 24.8 m long and 1.8 m deep with a 0.5 hanging ratio (Table A.3). The net is made of eight 3.1-m panels of 19 to 64 mm in 6–7 mm increments bar mesh. Panel order is 38, 57, 25, 44, 19, 64, 32, 51 mm (a quasi-random order) to minimize capture bias based on direction of fish movements upon encountering the net (Rudstam et al. 1984; Hansen et al. 1997). Mesh material is clear monofilament with 0.28 mm diameter for 19-, 25- and 32-mm mesh, 0.33 mm diameter for 38-, 44-, and 51-mm mesh, and 0.40 mm diameter for 57- and 64-mm mesh. Solid foam-core top line and lead-core bottom line minimize net tangling, making it easier to deploy and retrieve the net.

This net is referred to as the standard "core-mesh" gill net, and is the standard adopted in this book for systems in which benthic gill netting is used. The standard core-mesh net should be used for reporting standardized CPUE and length composition of species for comparison of fish samples among waters or within a water through time. If data are needed for smaller or larger fish than targeted with these mesh sizes, additional gill nets with different mesh sizes can be fished independently (i.e., separate nets). Data from these additional nets should be recorded and analyzed separately from data collected with the core-mesh gill net.

2.4.3 Operation/Deployment

Deployment and retrieval of gill nets should follow the procedure described by Hubert (1996). Each net should be set in water 1.8 to 5 m deep, perpendicular to shore on the bottom (i.e., bottom set). The net should not extend into an area of anoxic hypolimnetic water. The net-end that is set closest to shore should be randomly determined for each net set. In larger waters, two or three standard core nets can be joined together (attach the end of the 38-mm mesh panel on one net to the end of the 51-mm mesh panel of the other net) to create a larger net and reduce the likelihood of zero catches for individual nets. Randomly selected sites (i.e., sites are randomly selected for each sampling date) are recommended (see Brown and Austen [1996] and Guy and Brown [2007] for more detailed discussion of experimental design).

2.4.4 Time of Sampling

Gill nets should be set during late afternoon and retrieved the following morning so that the sampling period encompasses both crepuscular periods. Sampling should occur during spring to maximize catch rates. For logistical reasons, sampling can occur during the same sampling trip for electrofishing and fyke netting. If catch data are to be compared with larger waters, then sampling must occur during autumn when water temperatures drop below 20°C. However, data collected during different seasons (e.g., spring and autumn) should not be compiled into a single standardized data set (see Pope and Willis [1996] for discussion of seasonal influences on fishery data).

In water bodies with species of special concern or in instances when fish mortality from sampling is unacceptable, extended (i.e., overnight) sets are inappropriate. In these cases, gill nets can be set and retrieved within 2 h. After measurements are recorded, fish should be released in an area that minimizes their potential encounter with other gill-net sets. If this is not feasible, captured fish should be held in live pens until sampling has been completed.

2.4.5 Computation of Effort

Data are recorded separately for each gill net, and each net is identified as a standard core-mesh gill net or an add-on-mesh (with mesh sizes and order identified) gill net. There is much value in recording data separately by mesh size within each net. Catch of standard core-mesh nets that are joined together for larger waters are divided by the number of nets joined together to standardize CPUE estimates. Effort is calculated on a per-net-night basis, with separation of standard core-mesh nets and add-on-mesh nets. Thus, CPUE might be the number of channel catfish caught per net night in a 24.4-m standard core-mesh gill net. When 2-h sets are used, effort is calculated on a 2-h set; however, results from 2-h sets are not directly comparable with results from overnight sets and should not be converted to a common unit of effort simply by adjusting for set duration. Nets that were physically disturbed by humans, animals, or weather in a manner that altered their effectiveness should be excluded from the calculation of CPUE.

The amount of sampling needed depends on survey objectives and the desired precision of CPUE estimates (see 2.2.5). The minimum amount of effort in small water bodies is three nets (three different sites each sampled one night; not one site sampled three consecutive nights), which is the minimum number required to calculate a variance for mean CPUE. However, additional net sets are preferred because fish catches for a given species are frequently zero in individual nets.

These guidelines do not address recommended sample sizes for estimation of length and age structure and body condition (e.g., Gilliland 1985; Vokoun et al. 2001). The number of fish sampled varies depending on CPUE and total effort. If additional fish are needed for indices of length structure or condition, then sampling of additional sites is encouraged, even if it is necessary to resample sites or sample additional, subjectively selected sites; however, data gathered from resampled and subjectively selected sites should not be included in CPUE estimations. Also, recaptured fish (e.g., marked with a fin punch) should not be double-counted.

2.5 FYKE NET (TRAP NET)

2.5.1 Targeted Fishes

The fishes targeted with fyke nets include black crappies, white crappies, northern pike, walleyes, and yellow perch. Other fishes frequently encountered in fyke nets include bluegills, redear sunfish, redbreast sunfish, green sunfish, and black bullheads.

2.5.2 Specifications

The standard fyke net is constructed with two rectangular 91 × 183 cm steel frames with center braces that are 61 cm apart with an "in" fyke that tapers from the first frame to the second frame ending in a 10-cm opening, and four 76-cm-diameter hoops spaced 61 cm apart with a mesh funnel attached to first and third hoops (Table A.4). Knotless nylon mesh (13 mm bar) should be used for both the fyke and lead. The lead should be 15–30 m long, 91-cm tall, and hung on a 0.33 ratio. A purse-string closure on the cod end facilitates easy removal of captured fish.

2.5.3 Operation/Deployment

Deployment and retrieval of a fyke net should follow the procedure described by Hubert (1996). Each net should be set in water 1 to 5 m deep, perpendicular to shore (Figure 2.2). The net should not extend into an area of anoxic hypolimnetic water. Randomly selected sites (i.e., sites are randomly selected for each sampling date) are recommended (see Brown and Austen [1996] and Guy and Brown [2007] for more detailed discussion of experimental design).

2.5.4 Time of Sampling

Fyke nets should be set during late afternoon and retrieved the following morning so that the sample period encompasses two crepuscular periods. Sampling should occur during spring (water temperature warming); more precise sampling times are at the discretion of the sampler, and should be determined based on the desired target species. For example, walleyes spawn much earlier in spring (water temperature between 5.5°C and 11.1°C; Colby et al. 1979) than white crappies (water temperature between 16°C and 20°C; Siefert 1968). Thus, CPUE for walleyes is greater in early spring, whereas CPUE for white crappies is greater in middle or late spring.

2.5.5 Computation of Effort

Data should be recorded separately for each fyke net. Effort is calculated on a per-net-night basis. Thus, CPUE might be the mean number of black crappies collected per net-night. Nets that were physically disturbed by humans, animals, or weather in a manner that altered their effectiveness should be excluded from the calculation of CPUE.

The amount of sampling needed depends on survey objectives and the desired preci-

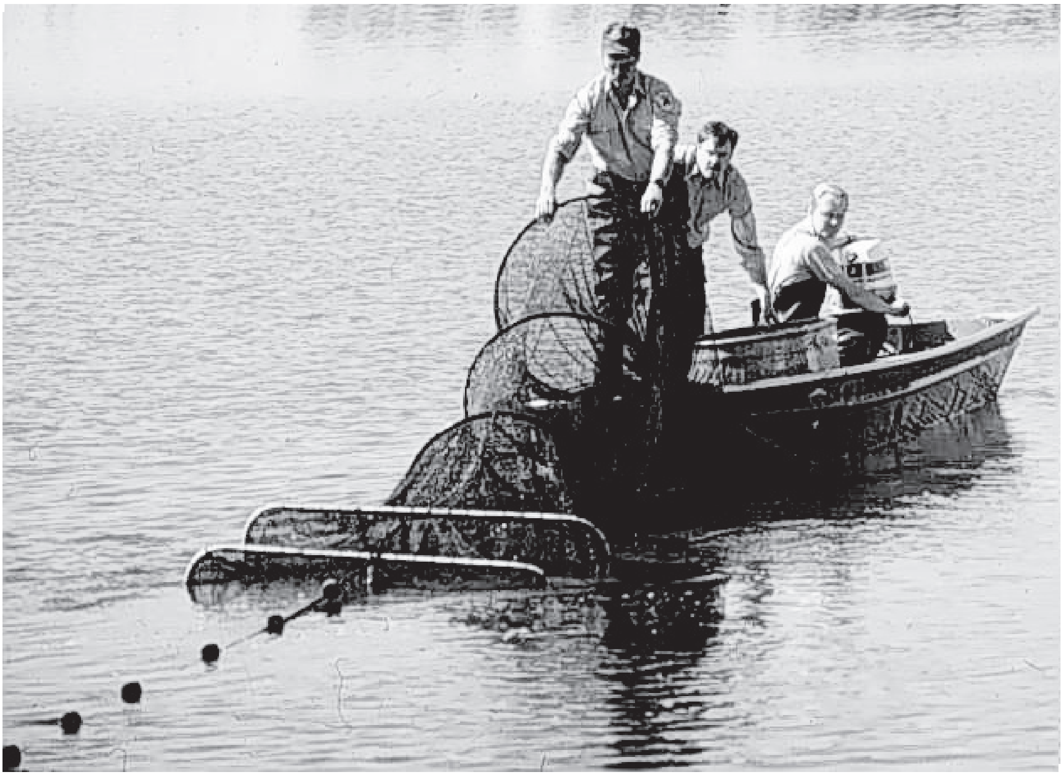

Figure 2.2 Setting a fyke net to capture warmwater fish in standing waters.

sion of CPUE estimates (see 2.2.5). The minimum amount of effort in small water bodies is three nets (three different sites each sampled one night; not one site sampled three consecutive nights), which is the minimum number required to calculate a variance for mean CPUE. However, additional net sets are preferred because fish catches for a given species are frequently zero in individual nets.

These guidelines do not address sample sizes for estimation of length structure, age structure, or body condition (e.g., Gilliland 1985; Vokoun et al. 2001; Miranda 2007). The number of fish sampled varies depending on CPUE and total effort. If additional fish are needed for indices of length structure or body condition, then sampling of additional sites is encouraged, even if it is necessary to re-sample sites or sample additional, subjectively selected sites; however, data gathered from re-sampled and subjectively selected sites should not be included in CPUE estimations. Also, recaptured fish (marked with a fin punch) should not be double-counted.

2.6 FINAL CONSIDERATIONS

2.6.1 Ancillary Data Needs

Water conductivity and applied power should always be reported for electrofishing results. Other desired environmental variables for all sampling gears include water column profiles for temperature, dissolved oxygen and pH, and an estimate of water clarity (e.g., turbidity measured in nephelometric turbidity units or indexed as Secchi disk transparency). Although these variables are not needed to calculate population indices, they are valuable when interpreting results.

2.6.2 Concluding Remarks

Sampling techniques should be standardized, scientifically sound, and reflect the most effective and efficient use of resources. The standard techniques discussed above provide a foundation on which biologists can build monitoring and assessment programs for fish populations and assemblages. These recommendations are meant to facilitate comparisons of fish populations among warmwater and coolwater fishes in small standing water bodies and provide opportunities to assess ecological processes in these systems on a broad geographic scale.

These sampling techniques do not address all of the unique challenges of sampling warmwater fishes in small standing water bodies and are not appropriate for all sampling needs. The primary objective of this chapter is to provide a standardized format for collecting and reporting fish sampling data for small standing water bodies as a foundation for further development of innovative assessments. Thus, the focus is on sampling activities that, based on the best available information, provide the minimum information required for planning and evaluating fishery-management programs. Biologists should strive to achieve these minimum requirements, but should not be constrained by the methods outlined in this chapter. Further, it is hoped that the guidelines presented will stimulate further research for greater understanding of gear selectivity, which ultimately will lead to improved procedures for standardization.

2.7 REFERENCES

Bennett, C. D., and B. E. Brown. 1969. A comparison of fish population sampling techniques on Lake Raymond, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 22:425–444.

Boxrucker, J., and G. Ploskey. 1989. Gear and seasonal biases associated with sampling crappie in Oklahoma. Proceedings of the Annual Meeting of the Southeastern Association of Fish and Wildlife Agencies 42:89–97.

Brown, M. L., and D. J. Austen. 1996. Data management and statistical analysis. Pages 17–62 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Colby, P. J., R. E. McNichol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchell 1818). Food and Agriculture Organization of the United Nations, Synopsis Number 119, Rome.

Cross, T. K., M. C. McInerny, and D. H. Schupp. 1995. Seasonal variation in trap-net catches of bluegill in Minnesota lakes. North American Journal of Fisheries Management 15:382–389.

Dodds, W. K. 2002. Freshwater ecology concepts and environmental applications. Academic Press, San Diego, California.

Dumont, S. C., and J. A. Dennis. 1997. Comparison of day and night electrofishing in Texas reservoirs. North American Journal of Fisheries Management 17:939–946.

Flickinger, S. A., F. J. Bulow, and D. W. Willis. 1999. Small impoundments. Pages 561–587 *in* C. C. Kohler and W. A Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Forney, J. L. 1961. Year-class distribution of walleyes collected by five types of gear. Transactions of the American Fisheries Society 90:308–311.

Gilliland, E. 1987. Evaluation of Oklahoma's standardized electrofishing in calculating population structure indices. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39(1985):277–287.

Guy, C. S., and M. L. Brown, editors. 2007. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Hamley, J. M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada 32:1943–1969.

Hamley, J. M., and T. P. Howley. 1985. Factors affecting variability of trap-net catches. Canadian Journal of Fisheries and Aquatic Sciences 42:1079–1087.

Hansen, M. J., C. P. Madenjian, J. H. Selegeby, and T. E. Hesler. 1997. Gillnet selectivity of lake trout *Salvelinus namaycush* in Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 54:2483–2490.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Active capture techniques. Pages 193–220 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hubert, W. A. 1996. Passive capture techniques. Pages 157–192 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Laarman, P. W., and J. R. Ryckman. 1982. Relative size selectivity of trap nets for eight species of fish. North American Journal of Fisheries Management 2:33–37.

Lyons, J. 1986. Capture efficiency of a beach seine for seven freshwater fishes in a north-temperate lake. North American Journal of Fisheries Management 6:288–289.

Malvestuto, S. P., and B. J. Sonski. 1990. Catch rate and stock structure: a comparison of daytime versus nigh-time electric fishing on West Point Reservoir, Georgia, Alabama. Pages 210–218 *in* I. G. Cowx, editor. Developments in electric fishing. Blackwell Scientific Publications, Oxford, UK.

Milewski, C. L., and D. W. Willis. 1991. Smallmouth bass size structure and catch rates in five South Dakota lakes as detected from two sampling gears. The Prairie Naturalist 23:53–60.

Miranda, L. E. 2007. Approximate sample sizes required to estimate length distributions. Transactions of the American Fisheries Society 136:409–415.

Murphy, B. R., and D. W. Willis, editors. 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Neumann, R. M., and M. S. Allen. 2007. Size structure. Pages 375–421 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Paragamian, V. L. 1989. A comparison of day and night electrofishing: size structure and catch per unit effort for smallmouth bass. North American Journal of Fisheries Management 9:500–503.

Paukert, C. P., and D. W. Willis. 2002. Seasonal and diel habitat selection by bluegills in a shallow natural lake. Transactions of the American Fisheries Society 131:1131–1139.

Pope, K. L., and D. W. Willis. 1996. Seasonal influences on freshwater fisheries sampling data. Reviews in Fisheries Science 4:57–73.

Quist, M. C., K. G. Gerow, M.R. Bower, and W. A. Hubert. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the upper Colorado River basin. North American Journal of Fisheries Management 26:1011–1019.

Reynolds, J. B. 1996. Electrofishing. Pages 221–253 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Reynolds, J. B., and D. E. Simpson. 1978. Evaluation of fish sampling methods and rotenone census. Pages 11–24 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, Maryland.

Rudstam, L. G., J. J. Magnuson, and W. M. Tonn. 1984. Size selectivity of passive fishing gear: a correction for encounter probability applied to gill nets. Canadian Journal of Fisheries and Aquatic Sciences 41:1252–1255.

Sanders, R. E. 1992. Day versus night electrofishing catches from near-short waters of the Ohio and Muskingum rivers. Ohio Journal of Science 92:51–59.

Santucci, V. J., and D. H. Wahl. 1991. Use of creel census and electrofishing to assess centrarchid populations. Pages 481–491 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollock, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society Symposium 12, Bethesda, Maryland.

Schultz, R. D., and D. E. Haines. 2005. Comparison of seasonal bluegill catch rates and size distributions obtained from trap nets and electrofishing in a large, heated impoundment. North American Journal of Fisheries Management 25:220–224.

Serns, S. L. 1982. Relationship of walleye fingerling density and electrofishing catch per effort in northern Wisconsin lakes. North American Journal of Fisheries Management 2:38–44.

Siefert, R. E. 1968. Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie. Transactions of the American Fisheries Society 97:252–259.

Snyder, D. E. 2003. Electrofishing and its harmful effects on fish. U.S. Geological Survey, Information and Technology Report USGS/BRD/IRT—2003–0002, Denver.

Swingle, H. S. 1956. Appraisal of methods of fish population study, part 4: determination of balance in farm fish ponds. Transactions of the North American Wildlife Conference 21:298–322.

Van Zee, B. E., D. W. Willis, and C. C. Stone. 1996. Comparison of diel sampling data for sauger collected by electrofishing. Journal of Freshwater Ecology 11:139–143.

Vokoun, J. C., C. F. Rabeni, and J. S. Stanovick. 2001. Sample-size requirements for evaluation population size structure. North American Journal of Fisheries Management 21:660–665.

von Brandt, A. 1984. Fish catching methods of the world, 3rd edition. Fishing News Books Ltd., Farnham, UK.