COMPARISON OF ELECTROFISHING AND SCUBA DIVING TECHNIQUES TO SAMPLE BLACK BASS

by

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FEBRUARY 2002

ACKNOWLEDGMENTS

I thank Pete Verhey, Tom Buroker, and Brian Berna for their invaluable assistance in the field. Except for the water quality data, the King County Department of Natural Resources, Water and Land Resource Division, Seattle, Washington, supplied the information in Table 1. Jack Tipping, Dave Willis, Phil Bettoli, and Scott Bonar provided thoughtful reviews of the original draft of the manuscript. This project was funded by the Warmwater Fish Enhancement Program of the Washington Department of Fish and Wildlife.

ABSTRACT

Electrofishing can potentially hurt or kill early life stages of fish or fish listed under the Endangered Species Act, is not effective in water of extreme (low or high) conductivity, and when performed at night, can be intrusive to people in residential areas. A non-destructive and less intrusive alternative to nighttime electrofishing is daytime scuba diving. Using a widely accepted length-categorization system to assess fish stocks, I compared the relative efficiency of nighttime electrofishing and daytime scuba diving at estimating the abundance and size structure of black bass in three western Washington lakes. Catch per unit effort and length-frequency distributions of largemouth bass *Micropterus salmoides* and smallmouth bass *M. dolomieu* gathered by scuba divers compared favorably with those of electrofishers. In some cases, scuba diving may be preferable to electrofishing because of its low impact on the resource and because it is less labor intensive. Provided the water clarity is sufficient, daytime scuba diving operations can be conducted under all water quality conditions with few concerns from shoreline property owners.

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INTRODUCTION

Traditional freshwater fishery investigations utilize an assortment of potentially harmful or lethal gear types to examine species composition, distribution, and abundance. The Washington Department of Fish and Wildlife (WDFW) uses electrofishing boats, gill nets, and fyke nets when conducting standardized stock assessment surveys in lentic environments. The gear types are used in combination to capture the greatest number and widest variety of fishes in most lakes or ponds and to offset gear-related biases (Bonar and Hubert 2002). Direct current (DC) electrofishing is the most effective of the three gear types, especially when sampling largemouth bass *Micropterus salmoides* (Divens et al. 1998) and smallmouth bass *M. dolomieu* (Beamesderfer and Rieman 1988). However, even the careful electrofisher can inadvertently harm or kill early life stages of fish (Muth and Ruppert 1997) while rarely injuring adult fish (Bardygula-Nonn et al. 1995).

A non-destructive alternative to traditional sampling methods is direct observation while scuba diving or snorkeling (Helfman 1983). Diving techniques are commonplace in lotic fish studies throughout the Pacific Northwest (e.g., Slaney and Martin 1987, Roni and Fayram 2000), but not in the region's lentic environments, despite the utility of diving in lakes being demonstrated elsewhere (e.g., Hall and Werner 1977, Graham 1992). Therefore, the purpose of this study was to examine the use of scuba diving to sample fish in Pacific Northwest lakes, with the emphasis on comparing this technique to electrofishing, the most common method of sampling black bass in western Washington. The objectives were 1) evaluate the relationship between electrofishing and scuba diving catch per unit effort, and 2) test whether length-frequencies were different among fish collected while electrofishing and those observed scuba diving.

STUDY SITES

Three lakes were selected to examine the differences between electrofishing and scuba diving when sampling largemouth bass and smallmouth bass in western Washington (Table 1). These were Angle Lake, located within the city limits of SeaTac (47 25'30"N, 122 17'32"W), Pine Lake, located just outside the City of Issaquah (47 35'15"N, 122 02'42"W), and Lake Meridian, located within the city limits of Kent (47 21'30"N, 122 08'43"W). All lakes were of similar size and trophic status and located within King County, the most populous region of Washington. Their morphometries were simple with relatively uniform habitat characteristics. The water clarity of each was high and the coverage of submersed and floating aquatic vegetation was low and nearly identical among lakes. Furthermore, all lakes were subject to high levels of development as indicated by the number of docks per 100 m shoreline and their proximity to urban centers. Finally, the lakes were selected as much for their reputed quality bass angling opportunities (Johansen 1999) as for their physiochemical and cultural similarities.

Table 1. Some physiochemical and cultural characteristics of three lakes used to examine differences between electrofishing and scuba diving when sampling black bass in western Washington during early summer and fall 2000.

Lake	Surface area (ha)	Shoreline length (km)	Max/mean depth (m)	Specific conductance (FS/cm)	Secchi depth (m)	Trophic status	Aquatic plant coverage[a] (%)	# docks/100 m shoreline
Angle	41.3	3.54	15.8/7.6	57	7.3	Oligotrophic	< 25	3.1
Pine	34.8	3.93	11.9/6.1	66	5.3	Oligotrophic	< 25	2.9
Meridian	60.7	4.02	27.4/12.5	96	4.8	Oligotrophic	< 25	2.6

[a] Excluding emergent vegetation.

METHODS

In 2000, WDFW conducted standardized stock assessment surveys of each lake using a 4.9-m Smith-Root 5.0 GPP electrofishing boat. Angle Lake, Pine Lake, and Lake Meridian were surveyed by a three-person team on June 5–7, September 5–7, and September 11–15, respectively. All electrofishing occurred during evening hours. Sampling locations in each lake were selected by dividing the shoreline into several (up to 11) consecutively numbered sections of 400 m each (determined visually from a map). Nighttime (2000–0200 hours) electrofishing occurred along six of these sections, or over 50% of the available shoreline in each lake. The electrofishing boat was maneuvered through the shallows (depth < 5 m), adjacent to the shoreline, taking about 30 min to cover the 400-m shoreline distance of each sample section. The electrofishing unit was set to 350–400 V and 6 A using pulsed DC (60–120 Hz), and engaged intermittently (to avoid "herding" fish) for a total of 10 min in each section. All fish captured were identified to species, measured to the nearest mm (total length, TL), and released near their point of capture. Fish sample processing time ranged from 15 to 90 min for each section. Water quality data, including secchi depth (m), were collected midday near the deepest part of each lake on June 7, September 6 and September 11 at Angle Lake, Pine Lake, and Lake Meridian, respectively.

Daylight (1000–1600 hours) diving operations were conducted on June 15, October 4, and October 5, 2000 at Angle Lake, Lake Meridian, and Pine Lake, respectively. Up to four weeks elapsed between electrofishing and scuba diving surveys to ensure that all displaced black bass returned to their home sites (Ridgway and Shuter 1996). Modified strip transects (Eberhardt 1978), similar to those described by Hall and Werner (1977), were conducted by two divers along the six 400-m shoreline sections previously electrofished in each lake. Divers swam side-by-side for 20 min using depth contour bounds (1.2–4.6 m) to guide them along the transect. In areas where the bottom was low grade or flat, an underwater compass bearing was used in conjunction with the depth bounds to ensure that the transect stayed generally parallel to shore. Divers maintained a relatively constant rate of forward motion and easily covered the 400-m shoreline distance of each sample section in 20 min. All fish observed were identified to species and total lengths of black bass were estimated visually by comparing the animals to reference marks spaced 5 mm apart along one edge of a hand-held underwater slate. The accuracy of underwater length estimates was confirmed by comparing the markings on the slate with structural relief that black bass rested on or passed by (Mueller 1995). This practice was repeated until divers could discern between size classes from distances up to 5 m away. To ensure independence of fish counts within each transect, divers recognized individual fish and groups of fish by size, scars or fin anomalies, and relative position within the transect. Divers conferred with each other using hand signals to make sure fish were counted only once (*sensu* Eberhardt 1978). Divers recorded their observations separately on underwater slates and upon returning to the surface, relayed their data to a surface tender/recorder aboard a 4.9-m support vessel. About 30 min was required to complete the entire process for each sample section.

DATA ANALYSIS

The relative abundance of black bass in each lake was evaluated by calculating catch per unit effort (CPUE, number of stock length fish/hour) by gear type and species. The minimum stock length of a species refers to the minimum size fish with recreational value and is based on 20-26% of the world record length for that species. For largemouth bass, the minimum stock length is 200 mm TL, for smallmouth bass, 180 mm TL (Gabelhouse 1984). When possible, 80% confidence intervals were determined for mean CPUE by gear type and species for descriptive purposes only. Mean CPUE data that met assumptions of normality as determined by Wilk-Shapiro test ($0.10 < P < 0.50$) were compared using a two-sample *t* test. Data that were not normally distributed (Wilk-Shapiro test, $P < 0.05$), and that also failed $\log_{10}+1$ transformation, were compared using the nonparametric Mann-Whitney *U* test (Zar 1984).

The size structures of black bass populations in each lake were evaluated by constructing length-frequency distributions by gear type type and species. Size classes followed the length-categorization system proposed by Gabelhouse (1984) and reviewed by Anderson and Neumann (1996). Thus, largemouth bass and smallmouth bass were placed into one of six length categories that varied by species (Table 2): substock length (SUB), stock to quality length (S-Q), quality to preferred length (Q-P), preferred to memorable length (P-M), memorable to trophy length (M-T), and trophy length (TRO). Although young-of-year were counted, only fish estimated to be at least one year old ($ 130 mm TL) were used to construct length-frequency distributions. When possible, length-frequency distributions were compared using the Kolmogorov-Smirnov *D* test (Zar 1984). All computations were run using Statistix® analytical software (Analytical Software, Tallahassee, Florida).

Table 2. Length categories of fish used to construct length-frequency distributions of black bass sampled from three western Washington lakes during early summer and fall 2000. SUB = substock length (excluding young-of-year), S-Q = stock to quality length, Q-P = quality to preferred length, P-M = preferred to memorable length, M-T = memorable to trophy length, and TRO = trophy length. Measurements are total lengths (mm) for each category (Gablehouse 1984; but see also Anderson and Neumann 1996).

	Length category					
Species	**SUB**	**S-Q**	**Q-P**	**P-M**	**M-T**	**TRO**
Largemouth bass	130 - 199	200 - 299	300 - 379	300 - 379	510 - 629	$ 630
Smallmouth bass	130 - 179	180 - 279	280 - 349	350 - 429	430 - 509	$ 510

RESULTS

CATCH PER UNIT EFFORT

There was no significant difference between mean CPUE of electrofishing (2.97 ± 1.70 fish/hr) and scuba diving (3.00 ± 1.40 fish/hr) for stock length largemouth bass at Angle Lake (U = 21, P = 0.69), where a total of 13.5 worker-hours was spent electrofishing and nine worker-hours were spent scuba diving. Similarly, there was no significant difference between mean CPUE of electrofishing (11.60 ± 6.14 fish/hr) and scuba diving (11.50 ± 4.37 fish/hr) for stock length largemouth bass at Pine Lake (t = 0.02, DF = 10, P = 0.98), nor was there a significant difference between mean CPUE of electrofishing (0.91 ± 1.17 fish/hr) and scuba diving (0.50 ± 0.64 fish/hr) for stock length smallmouth bass (U = 18.5, P = 0.99). Thirty-six worker-hours were spent electrofishing Pine Lake, whereas nine worker-hours were spent scuba diving. Finally, there was no significant difference between mean CPUE of electrofishing (14.50 ± 5.25 fish/hr) and scuba diving (9.50 ± 3.20 fish/hr) for stock length largemouth bass at Lake Meridian (t = 1.04, DF = 10, P = 0.32), nor was there a significant difference between mean CPUE of electrofishing (3.89 ± 2.50 fish/hr) and scuba diving (1.50 ± 0.86 fish/hr) for stock length smallmouth bass (U = 22.5, P = 0.52). Here, 22.5 worker-hours were spent electrofishing, whereas nine worker-hours were spent scuba diving.

LENGTH-FREQUENCY DISTRIBUTION

At Angle Lake, a total of four and eight largemouth bass were sampled while electrofishing and scuba diving, respectively. Of fish captured while electrofishing, one was young-of-year, two were P-M, and one was M-T. Of fish observed scuba diving, two were young-of-year, one was S-Q, three were Q-P, and two were P-M. Small sample sizes precluded analyzing length-frequency distributions of substock length and longer fish.

At Pine Lake, a total of 1,154 and 1,352 largemouth bass were sampled while electrofishing and scuba diving, respectively. Of largemouth bass captured while electrofishing, 1,062 were young-of-year, 80 were SUB, nine were S-Q, two were Q-P, and one was P-M. Of largemouth bass observed while scuba diving, 1,280 were young-of-year, 49 were SUB, 16 were S-Q, four were Q-P, and three were P-M. There was no significant difference between the length-frequency distributions of substock length and longer largemouth bass sampled while electrofishing and scuba diving (D = 0.19, P = 0.11). Regarding smallmouth bass, a total of 119 and 69 fish were sampled while electrofishing and scuba diving, respectively. Of smallmouth bass captured while electrofishing, 101 were young-of-year, 17 were SUB, and one was S-Q. Of smallmouth bass observed while scuba diving, 49 were young-of-year, 19 were SUB, and one was S-Q. There was no significant difference between the length-frequency distributions of substock length and longer smallmouth bass sampled while electrofishing and scuba diving (D = 0.01, P = 0.99).

At Lake Meridian, a total of 227 and 87 largemouth bass were sampled while electrofishing and scuba diving, respectively. Of largemouth bass captured while electrofishing, 197 were young-of-year, 15 were SUB, and 15 were S-Q. Of largemouth bass observed while scuba diving, 63 were young-of-year, five were SUB, 18 were S-Q, and one was Q-P. There was no significant difference between the length-frequency distributions of substock length and longer largemouth bass sampled while electrofishing and scuba diving (D = 0.29, P = 0.21). Regarding smallmouth bass, a total of 121 and eight fish were sampled while electrofishing and scuba diving, respectively. Of smallmouth bass captured while electrofishing, 112 were young-of-year, five were SUB, and four were S-Q. Of smallmouth bass observed while scuba diving, four were young-of-year, one was SUB, and three were S-Q. Small sample sizes precluded analyzing length-frequency distributions of substock length and longer smallmouth bass.

HABITAT USE

Most (83%) of the substock length and longer largemouth bass observed while scuba diving at Angle Lake were under docks, whereas one of two young-of-year was observed in-between docks. At Pine Lake, most (61%) of the largemouth bass (all lengths) observed while scuba diving were under docks. Similarly, most (59%) of the young-of-year smallmouth bass were under docks; however, most (68%) of the substock length and longer smallmouth bass were not under docks. At Lake Meridian, most (92%) of the substock length and longer largemouth bass observed while scuba diving were under docks, whereas 98% of the young-of-year largemouth bass were in-between docks. Finally, all of the substock length and longer smallmouth bass were observed under docks, yet no young-of-year smallmouth bass were observed under docks.

DISCUSSION

Except when sampling Angle Lake and Pine Lake largemouth bass, greater numbers of fish were captured electrofishing compared to the numbers observed scuba diving. This is consistent with comparisons of electrofishing and diving techniques to sample fish from lotic environments (Heggenes et al. 1990; Thurow and Schill 1996; Roni and Fayram 2000). The disparate fish counts observed in this study might be related to changes in the diel activity patterns of black bass. For example, previous studies (Emery 1973; Helfman 1981) have shown that black bass were motile during daylight hours but largely inactive at night, resting on the bottom. Thus, black bass may be more "susceptible" to nighttime electrofishing compared to daytime scuba diving.

Abundance estimates of smaller fish tend to vary between diving and other sampling methods (Goldstein 1978; Dibble 1991), whereas abundance estimates of larger fish might agree well with each other irrespective of the gear types compared (Slaney and Martin 1987; Richardson 1992). This was apparent when examining the catch rate data from the present study. Within lakes, the homogeneity of electrofishing and scuba diving CPUEs for stock length black bass was striking.

Except for Angle Lake, the length-frequency distributions of largemouth bass and smallmouth bass were skewed toward the smallest size classes with few quality-length and longer fish. This is not unusual for black bass populations in oligotrophic waters, where growth, condition, and standing stock may decrease due to low primary productivity (Ney 1996; Maceina et al. 1996; Maceina and Bayne 2001). The length-frequency distributions from Pine Lake were remarkably similar between gear types and species. Furthermore, the length-frequencies of largemouth bass from Lake Meridian were relatively similar between gear types. As with total fish counts, these findings are consistent with recent comparisons of electrofishing and diving techniques to sample lotic fishes (Thurow and Schill 1996; Roni and Fayram 2000).

Direct observation by divers can provide additional information about habitat use and species composition, among others, that might otherwise go unnoticed using traditional gear types. For example, in the present study, divers found that during daylight hours up to 92% of all largemouth bass and smallmouth bass encountered were directly associated with docks, and that larger fish were more likely to be found under docks than smaller conspecifics. Furthermore, a large (> 600 mm TL) common carp *Cyprinus carpio* was observed by divers in the littoral zone of Angle Lake; however, common carp were not captured during the standardized survey of the lake. Finally, two brown bullhead *Ameiurus nebulosus* were captured back-to-back while electrofishing one section of Angle Lake and all but dismissed by the electrofishers. Yet during the subsequent scuba diving survey, divers observed three nesting pairs of brown bullhead: each pair consisted of one fish resting in a depression underneath a log with the second fish located a short distance (< 2 m) away, out in the open, but oriented toward the first fish. Thus, a complete explanation of the pair observed by the electrofishers with additional life history details that would not have been possible using traditional gear types.

This initial assessment demonstrates that under the right conditions (e.g., clear water with little vegetation), daytime scuba diving compares favorably to nighttime electrofishing when evaluating the relative abundance and size structure of black bass in Pacific Northwest lakes. However, more work is needed to validate correlations between CPUE and length-frequency distributions for the two gear types, especially given the small scale and sample sizes used here. Still, scuba diving is a promising alternative to electrofishing if faced with time constraints, or if injury and mortality to early life stages of fish or fish listed under the Endangered Species Act are concerns. Daytime scuba diving may be preferred over nighttime electrofishing in high-density residential shoreline areas where maneuvering an electrofishing boat through tightly spaced docks is difficult at best, not to mention the disturbance to property owners or added challenge to electrofishers dip-netting stunned fish from under docks and floats. Furthermore, scuba diving might be preferred over electrofishing clear water with extreme conductivity (50 μS/cm > specific conductance > 2000 μS/cm), where the transfer of electric power from the water to the fish is the least efficient (Kolz 1989; Kolz and Reynolds 1989). Although inherent biases exist with any sampling method, and scuba diving is no exception (e.g., loss of precision in measuring length, collection of weight data not possible), at a minimum, it should be used to augment traditional capture methods when developing sampling strategies for lentic environments. Indeed, the most satisfactory results usually come from supplementing the information obtained from one sampling method with that of others (Helfman 1983).

REFERENCES

Anderson, R.O., and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 *in* B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Bardygula-Nonn, L.G., R. Nonn, and J. Savitz. 1995. Influence of pulsed direct current electrofishing mortality and injuries among for centrarchid species. North American Journal of Fisheries Management 15: 799-803.

Bonar, S.A., and W.A. Hubert. 2002. Standard sampling of inland fish: benefits, challenges, and a call for action. Fisheries 27(3): 10-16.

Dibble, E.D. 1991. A comparison of diving and rotenone methods for determining relative abundance of fish. Transactions of the American Fisheries Society 120: 663-666.

Divens, M.J., S.A. Bonar, B.D. Bolding, E. Anderson, and P.W. James. 1998. Monitoring warm-water fish populations in north temperate regions: sampling considerations when using proportional stock density. Fisheries Management and Ecology 5: 383-391.

Eberhardt, L.L. 1978. Transect methods for population studies. Journal of Wildlife Management 42: 1-31.

Emery, A.R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. Journal of the Fisheries Research Board of Canada 30: 761-774.

Gabelhouse, D.W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Goldstein, R.M. 1978. Quantitative comparison of seining and underwater observation for stream fishery surveys. The Progressive Fish-Culturist 40: 108-111.

Graham, R.J. 1992. Visually estimating fish density at artificial structures in Lake Anna, Virginia. North American Journal of Fisheries Management 12: 204-212.

Hall, D.J., and E.E. Werner. 1977. Seasonal distribution and abundance of fishes in the littoral zone of a Michigan lake. Transactions of the American Fisheries Society 106: 545-555.

Heggenes, J., C. Brabrand, and S. J. Saltveit. 1990. Comparison of three methods for studies of stream habitat use by young brown trout and Atlantic salmon. Transactions of the American Fisheries Society 119: 101-111.

Helfman, G.S. 1981. Twilight activities and temporal structure in a freshwater fish community. Canadian Journal of Fisheries and Aquatic Sciences 38: 1405-1420.

Helfman, G.S. 1983. Underwater methods. Pages 349–369 in L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques, 1st edition. American Fisheries Society, Bethesda, Maryland.

Johansen R. 1999. Top 10 King County bass holes. Washington-Oregon Game and Fish 1999 (5): 24-26, 52-53.

Kolz, A.L. 1989. A power transfer theory for electrofishing. U.S. Fish and Wildlife Service, Fish and Wildlife Technical Report 22: 1-11.

Kolz, A.L., and J.B. Reynolds. 1989. Determination of power threshold response curves. U.S. Fish and Wildlife Service, Fish and Wildlife Technical Report 22: 15-24.

Maceina, M.J., and D.R. Bayne. 2001. Changes in the black bass community and fishery with oligotrophication in West Point Reservoir, Georgia. North American Journal of Fisheries Management 21: 745-755.

Maceina, M.J., D.R. Bayne, A.S. Hendricks, W.C. Reeves, W.P. Black, and V.J. DiCenzo. 1996. Compatibility between water clarity and quality black bass and crappie fisheries in Alabama. American Fisheries Society Symposium 16: 296-305.

Mueller, K.W. 1995. Size structure of mutton snapper, *Lutjanus analis*, associated with unexploited artificial patch reefs in the central Bahamas. Fishery Bulletin 93: 573-576.

Muth, R.T., and J.B. Ruppert. 1997. Effects of electrofishing fields on captive embryos and larvae of razorback sucker. North American Journal of Fisheries Management 17: 160-166.

Ney, J.J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. American Fisheries Society Symposium 16: 285-295.

Richardson, J. 1992. Drift diving validation. New Zealand Ministry of Agriculture and Fisheries, Freshwater Fisheries Miscellaneous Report # 122, Riccarton, Christchurch.

Ridgway, M.S., and B.J. Shuter. 1996. Effects of displacement on the seasonal movements and home range characteristics of smallmouth bass in Lake Opeongo. North American Journal of Fisheries Management 16: 371-377.

Roni, P., and A. Fayram. 2000. Estimating winter salmonid abundance in small western Washington streams: a comparison of three techniques. North American Journal of Fisheries Management 20: 683-692.

Slaney, P.A., and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. North American Journal of Fisheries Management 7: 117-122.

Thurow, R.F., and D.J. Schill. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second-order Idaho stream. North American Journal of Fisheries Management 16: 314-323.

Zar, J.H. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Englewood Cliffs, New Jersey.