STATE OF WASHINGTON December 2001

Underwater Methods for Sampling the Distribution and Abundance of Smallmouth Bass in Lake Washington and Lake Union

Warmwater Fish Enhancement

by Karl W. Mueller, Don P. Rothaus and Kurt L. Fresh

Washington Department of
FISH AND WILDLIFE
Fish Program
Fish Management Division,
Warmwater Fish Enhancement Program
Point Whitney Shellfish Laboratory
Science Division, Ecological Investigations

WDFW 770

Technical Report # FPT01-17

UNDERWATER METHODS FOR SAMPLING THE DISTRIBUTION AND ABUNDANCE OF SMALLMOUTH BASS IN LAKE WASHINGTON AND LAKE UNION

by

Karl W. Mueller
Washington Department of Fish and Wildlife
Warmwater Fish Enhancement Program
P.O. Box 1100
La Conner, Washington 98257

Don P. Rothaus
Washington Department of Fish and Wildlife
Point Whitney Shellfish Laboratory
1000 Point Whitney Road
Brinnon, Washington 98320

and

Kurt L. Fresh
Washington Department of Fish and Wildlife
Ecological Investigations
600 Capitol Way North
Olympia, Washington 98501

December 2001

ACKNOWLEDGMENTS

We thank Mark Carr, Chris Waldbillig, Michael Ulrich, Pete Verhey, Bob Sizemore, and Hwa Kim of WDFW for technical assistance in the field. Additional technical support was provided by Crayton Fenn of Innerspace Exploration Team, Mill Creek, Washington. Chris Waldbillig prepared the map of Lake Washington and Lake Union. Chad Jackson and Steve Jackson of WDFW provided thoughtful reviews of the original draft of the manuscript. Lauren Munday, Walt Cooper, Everett Latch, Rick Goldsmith, Darrel Pruett, and Peggy Ushakoff (all WDFW) proved indispensable when preparing and printing the final report. Major funding for this project was made possible by grants from the City of Seattle and King County Department of Natural Resources, with additional support from WDFW's Warmwater Fish Enhancement Program.

> *"The training of fisheries personnel in the future will increasingly include underwater techniques and their application to fisheries methods. Technological advances in the design and manufacture of diving gear and visual monitoring devices have reduced the costs and increased the safety and accessibility of this equipment. A modern fisheries organization can now afford underwater methods and should incorporate them into its program."*
>
> Gene S. Helfman (1983)

ABSTRACT

Direct underwater observations were used to characterize habitat use and to quantify abundance of smallmouth bass in the littoral zones of Lake Washington and Lake Union during the spring and summer of 2000 and 2001. We evaluated monthly changes in density, size structure, size-specific selection of natural vs. artificial structure, and nest-site characteristics of smallmouth bass at several locations. Integrating diver observations, side-scan sonar imagery, global positioning system (GPS) data, and geographic information systems (GIS) should provide maps of smallmouth bass distribution and abundance that will benefit resource managers and anglers alike.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Lake Washington and neighboring Lake Union support one of the premiere smallmouth bass (*Micropterus dolomieu*) fisheries in Washington State. In fact, Lake Washington is fast becoming nationally recognized as a tournament destination (Ledeboer 2000; Marcantonio 2000). The lakes, which are connected via Union Bay and the Montlake Cut, lie in the heart of the greater Seattle metropolitan area (Figure 1). Nearshore development in Lake Washington is mostly comprised of urban residential lakefront properties, whereas the shoreline of Lake Union is used primarily for commercial purposes. Stationary and floating docks are widespread and reported to harbor piscine predators forming a gauntlet for migratory juvenile salmonids (Larry Fisher, Washington Department of Fish and Wildlife, personal communication). However, few published studies of the lakes' smallmouth bass resources exist, especially those concerning the impact of smallmouth bass on resident fish (Fayram and Sibley 2000). Although researchers from the University of Washington, U.S. Fish and Wildlife Service, and Muckleshoot Indian Tribe have begun studying the role of smallmouth bass in the watershed, published information on smallmouth bass habitat use or spatial and temporal overlaps with threatened native species such as chinook salmon (*Oncorhynchus tshawytscha*) are lacking. To rectify this, the Washington Department of Fish and Wildlife (WDFW) conducted a study of the distribution and habitat use of smallmouth bass in the littoral zones of Lake Washington and Lake Union during the spring and summer of 2000 and 2001.

Figure 1. View of Lake Union and Montlake Cut area north of downtown Seattle, Washington (photo by Karl W. Mueller).

Traditional lake fishery investigations utilize an assortment of potentially harmful or lethal gear types (e.g., electrofishing boats or gillnets) to assess fish distribution and abundance. Direct observation while scuba diving or snorkeling provides a non-destructive alternative to traditional exploitative methods (Mullner et al. 1998). Furthermore, direct observation by divers allows real time recording of individual or group movement, behavior, and habitat associations (Figure 2). When combined with spatial analysis tools such as geographic information systems (GIS), differential global positioning system (GPS) data, and side-scan sonar imaging of the bottom, observations made by divers can be used to generate three-dimensional maps of their subject's habitat use. WDFW researchers combined multiple layers of information from these technologies to explore smallmouth bass selection of natural (e.g., boulders or submersed woody debris) vs. artificial structure (e.g., docks and pilings) and to assess the spatial and temporal overlap between smallmouth bass and juvenile chinook salmon in Lake Washington and Lake Union. This report summarizes the underwater methods used by WDFW personnel during spring and summer 2000 and 2001. Examples of the information gathered are provided to show the utility of this methodology in studying the ecology and fishery of smallmouth bass in Lake Washington and Lake Union. A rigorous analysis and discussion of the original study objectives will be reported under separate cover.

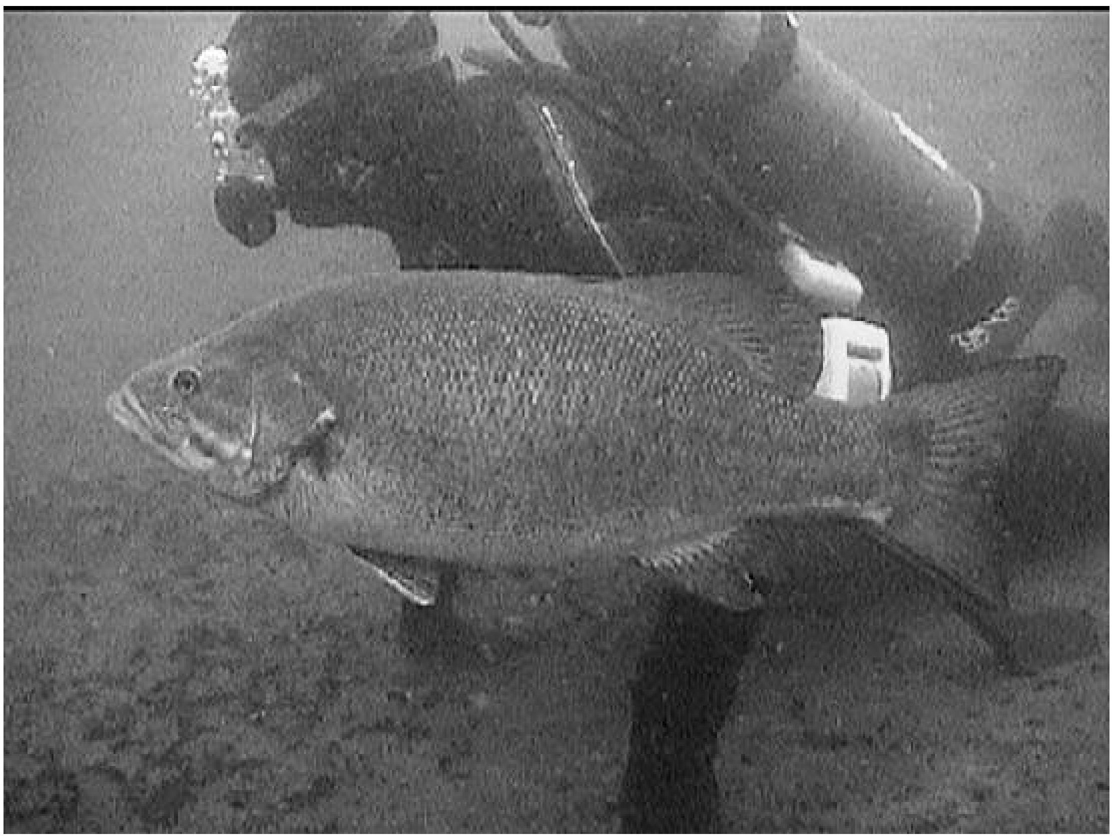


Figure 2. Smallmouth bass swimming near a WDFW diver off Webster Point, Lake Washington during fall 2000. Divers's bubbles had little effect on smallmouth bass behavior (photo by Don P. Rothaus).

MATERIALS AND METHODS

The study was conducted from May 9 to August 25, 2000 and from May 23 to August 9, 2001. Dive operations were carried out over 3 – 4 consecutive days each month of the study period. Smallmouth bass distribution and abundance were investigated at several (n = 13) 1,000 ft sections of shoreline around Lake Washington and Lake Union (Table 1, Figure 3). These sites were historically used by WDFW as beach seining locations for the study of outmigrating juvenile chinook salmon, but also included areas that partially overlapped, or were located within, waterfront park boundaries (i.e., undeveloped shoreline) or other possible salmonid migration routes. In this way, we hoped to assess the temporal and spatial overlap between smallmouth bass and juvenile chinook salmon, and the impact of shoreline development (e.g., docks and pilings) on smallmouth bass distribution and abundance.

Table 1. Location of dive transects used to examine the distribution and abundance of smallmouth bass in Lake Washington and Lake Union during spring and summer 2000 and 2001. Numbers in parentheses can be used to cross-reference table with Figure 3.

Study Site	Water body	Location	Year(s) surveyed	Mapped using side-scan sonar?
St. Edward State Park (1)	Lake Washington	47.728593 N 122.26322 W	2000	Yes
Holmes Point (2)	Lake Washington	47.722193 N 122.261582 W	2000	Yes
Warren Magnuson Park (3A, 3B)	Lake Washington	47.672943 N 122.251175 W	2001	No
Webster Point (4)	Lake Washington	47.647783 N 122.277590 W	2000, 2001	Yes
Madison (5)	Lake Washington	47.622236 N 122.281596 W	2000	Yes
Seward Park, Bailey Peninsula (6)	Lake Washington	47.559137 N 122.248029 W	2001	No
Taylor Creek (7)	Lake Washington	47.512877 N 122.248503 W	2000, 2001	Yes
Bryn Mawr (8)	Lake Washington	47.504327 N 122.225704 W	2000	Yes
Coleman Point (9)	Lake Washington	47.516904 N 122.209641 W	2000, 2001	Yes
Caulkins Point, Mercer Island (10)	Lake Washington	47.594369 N 122.240881 W	2001	No
Faben Point, Mercer Island (11)	Lake Washington	47.593722 N 122.252146 W	2000	Yes
University of Washington (12)	Montlake Cut	47.648434 N 122.310732 W	2001	No
Gas Works Park (13)	Lake Union	47.644411 N 122.335875 W	2001	No
Waterway #3 (14)	Lake Union	47.626835 N 122.338231 W	2001	No

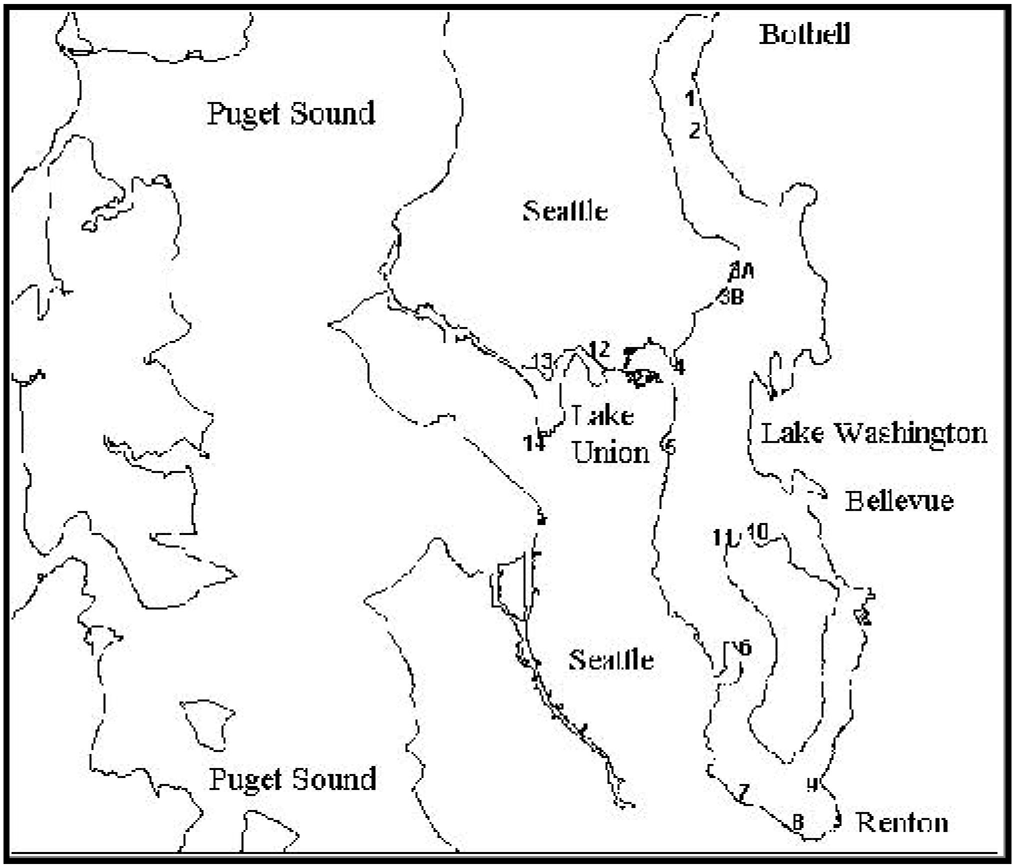


Figure 3. Map of Lake Washington and Lake Union showing study locations (numerals).

Prior to starting 2000 dive operations, eight study locations were mapped using side-scan sonar technology (Table 1). A 5 ft, 600 khz towfish with 246 ft maximum range was towed behind a 24 ft aluminum workboat (Innerspace Exploration Team, Mill Creek, Washington) following the 30 ft isobath at a speed of ~ 2.5 knots. The towfish scanned the bottom from the vessel shoreward with readings processed using Marine Sonic® software. The resulting imagery revealed several submerged structures and features (Figure 4), both natural and artificial, at each sample location that were 'ground truthed' by divers during subsequent dives.

Standardized transects were performed by two divers (Figure 5) along three depth ranges [shallow (4 – 6 ft), middle (10 – 14 ft), and deep (18 – 22 ft)] at each sample location during morning (0900 – 1130) or afternoon (1330 – 1600). Divers entered the water and descended a downline attached to a buoy that marked the beginning of the deepest transect line (Figure 6). Underwater visibility (lateral distance) was determined by one diver who selected an object at the limit of his vision then measured the distance from the downline to that object using a water-proof measuring tape. This distance was assumed to be the same for all transects within a sample location and essentially became the width of each transect for smallmouth bass density estimate purposes. Surface tenders then positioned a 19 ft support vessel (Figure 7) over the divers' bubbles to obtain the start point using a portable, onboard GPS unit (Figure 8). The GPS antenna was secured to a boom extending beyond the bow of the support vessel. This enabled the surface tender to more accurately position the antenna over divers' bubbles (Figure 9).

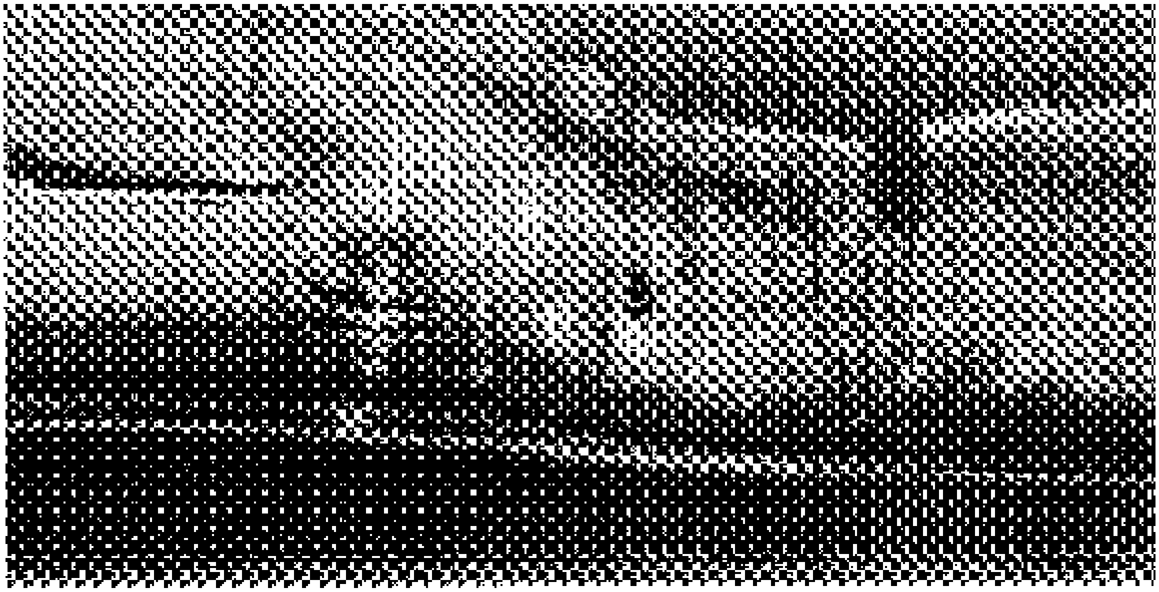


Figure 4. Side-scan sonar image showing submerged structure (natural and artificial) in littoral zone of Lake Washington. The white border starting at the upper right quadrant of the image marks the shoreline. Note the large log and woody debris at left. The white dots and vertical black streaks are dock pilings and shadows cast by the side-scan sonar. The narrow, dark shadow extending from the shoreline into the lake is from a boat at the surface tied to a dock. An inset bulkhead is visible at the top center (photo by Crayton Fenn, Innerspace Exploration Team).

Figure 5. All underwater transects were performed by two WDFW divers at study locations on Lake Washington and Lake Union during spring and summer 2000 and 2001 (photo by Don P. Rothaus).

Figure 6. WDFW divers prepare to descend the downline attached to a float marking the start of the deep transect off Caulkins Point, Mercer Island, Lake Washington. An identical float was placed 1,000 ft. away to mark the end of the transect (photo by Don P. Rothaus).

Figure 7. WDFW support vessel and surface tender (foreground) on Lake Union (photo by Karl W. Mueller).

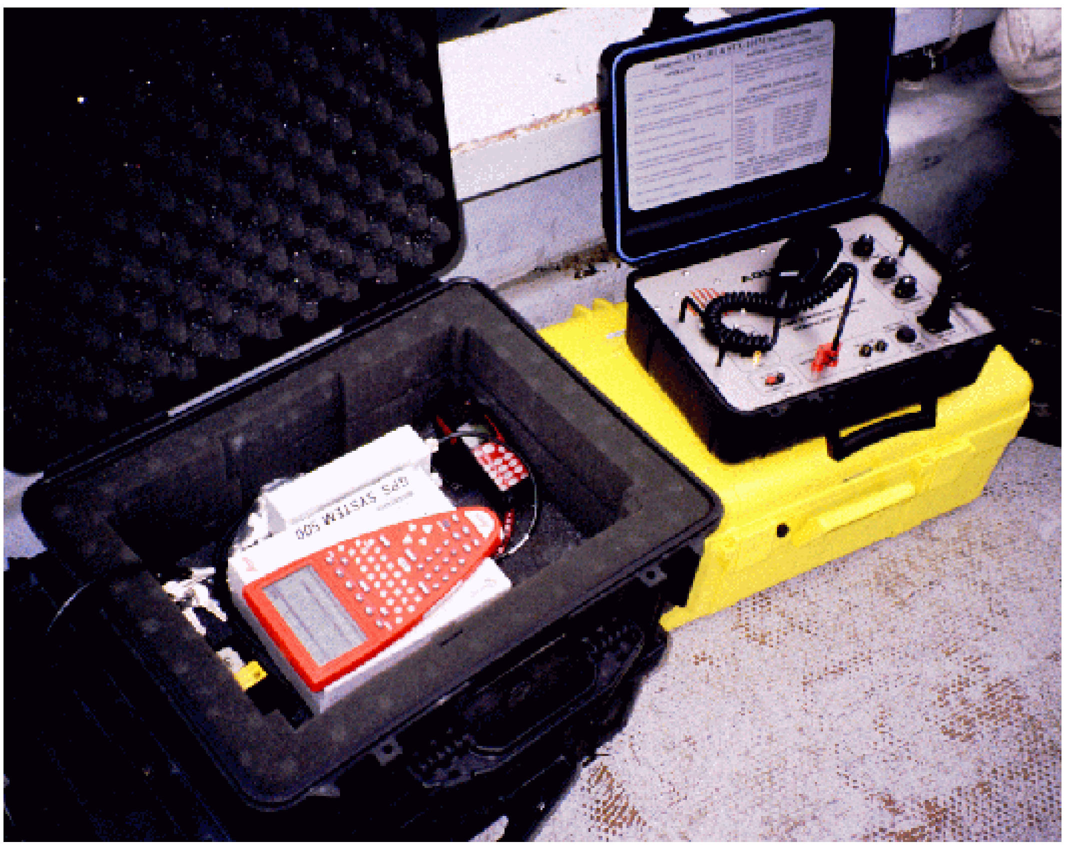


Figure 8. GPS (left) and diver communication surface unit (right) used in WDFW dive operations at Lake Washington and Lake Union during spring and summer 2000 and 2001 (photo by Karl W. Mueller).

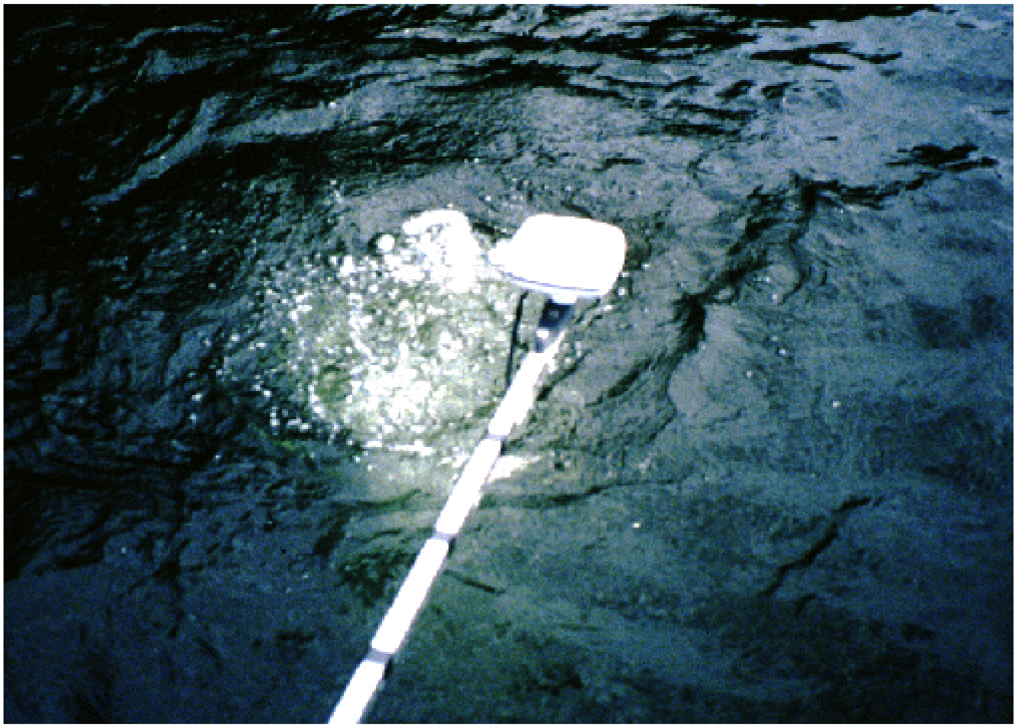


Figure 9. The start and end points of each transect, and all observation points in between, were located by positioning a GPS antenna over the exhaust bubbles of WDFW divers stationary on the bottom (photo by Karl W. Mueller).

Divers swam side-by-side, maintained a relatively constant rate of forward motion, and used the depth contour bounds to guide them along a given transect. In areas of flat or low slope bottoms it was often necessary to use a compass bearing in conjunction with the depth bounds so that the transect stayed generally parallel to shore (Figure 10). The support vessel shadowed the divers along each transect, holding a position slightly behind to avoid possible fish disturbance. The support vessel was equipped with an electric outboard motor capable of maneuvering 360E (Figure 11). The electric motor was also used to eliminate any possible noise disturbance associated with a standard gasoline outboard motor.

Divers were in constant verbal communication with each other and the surface tenders using a wireless, voice activated communication system (Figure 12, 13). When smallmouth bass or submerged structure were encountered alone or collectively, the divers stopped, hailed the support vessel to obtain their position using the GPS unit, and gave a brief description of their observations (Figure 14). Diver observations were recorded topside by a surface tender (Figure 15) and included a visual estimation of fish size [small (< 10" total length or TL), medium (10 – 15" TL), and large (> 15" TL) relative to the 18" length of a hand-held underwater slate (Figure 16)], behavior (swimming, sheltering, guarding nest, etc.), and position relative to structure or substrate. Furthermore, the surface tender recorded bottom depth (ft), structure (woody debris, vegetation, rip-rap, dock, etc.) and substrate classifications (mud, sand, gravel, etc.) (Figure 17), and when present, the number of young-of-year smallmouth bass (Figure 18) as indicated by the divers. To insure independence of fish counts between transects, divers recognized individual fish and groups of fish by scars or fin anomalies, size, and relative position within the transect (Figure 19). The latter was used to discern whether or not fish migrated between depth contours. In all cases, divers conferred with each other to make sure fish were counted only once.

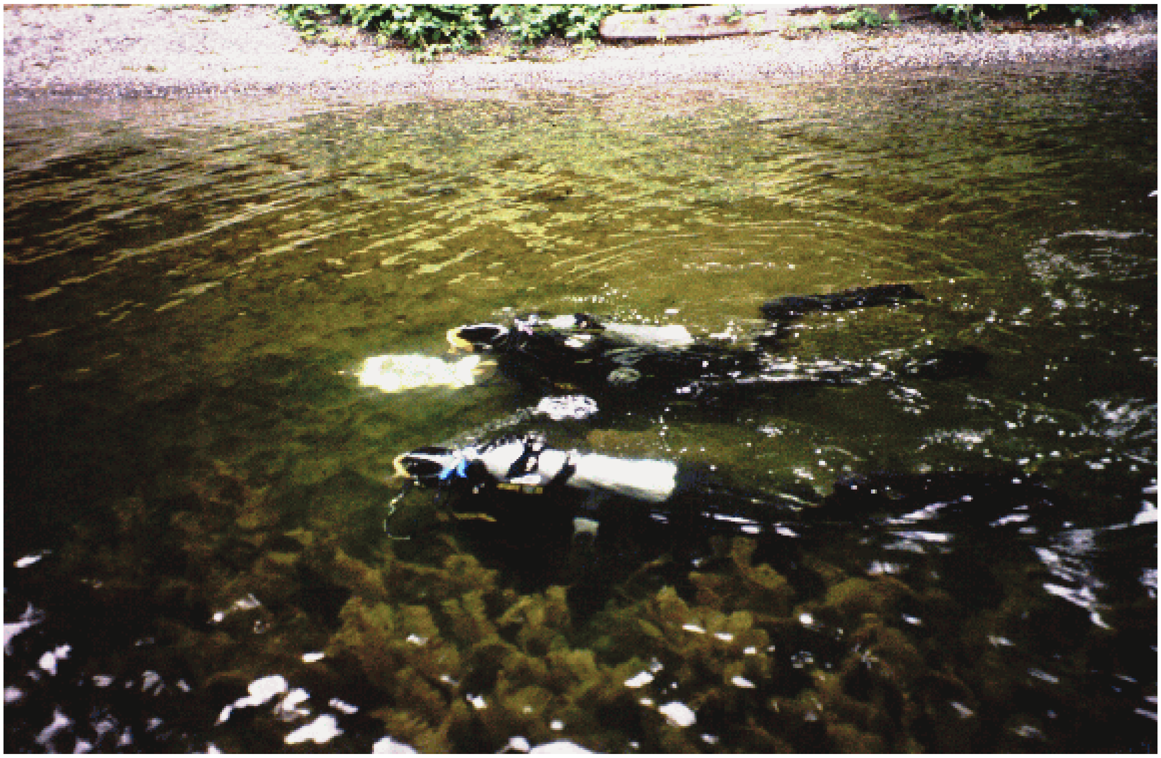


Figure 10. WDFW divers swimming along the shallow transect parallel to shore at Seward Park (Bailey Peninsula), Lake Washington (photo by Karl W. Mueller).

Figure 11. WDFW surface tender positioning support vessel and GPS antenna over divers' exhaust bubbles during the deep transect off Seward Park (Bailey Peninsula), Lake Washington (photo by Karl W. Mueller).

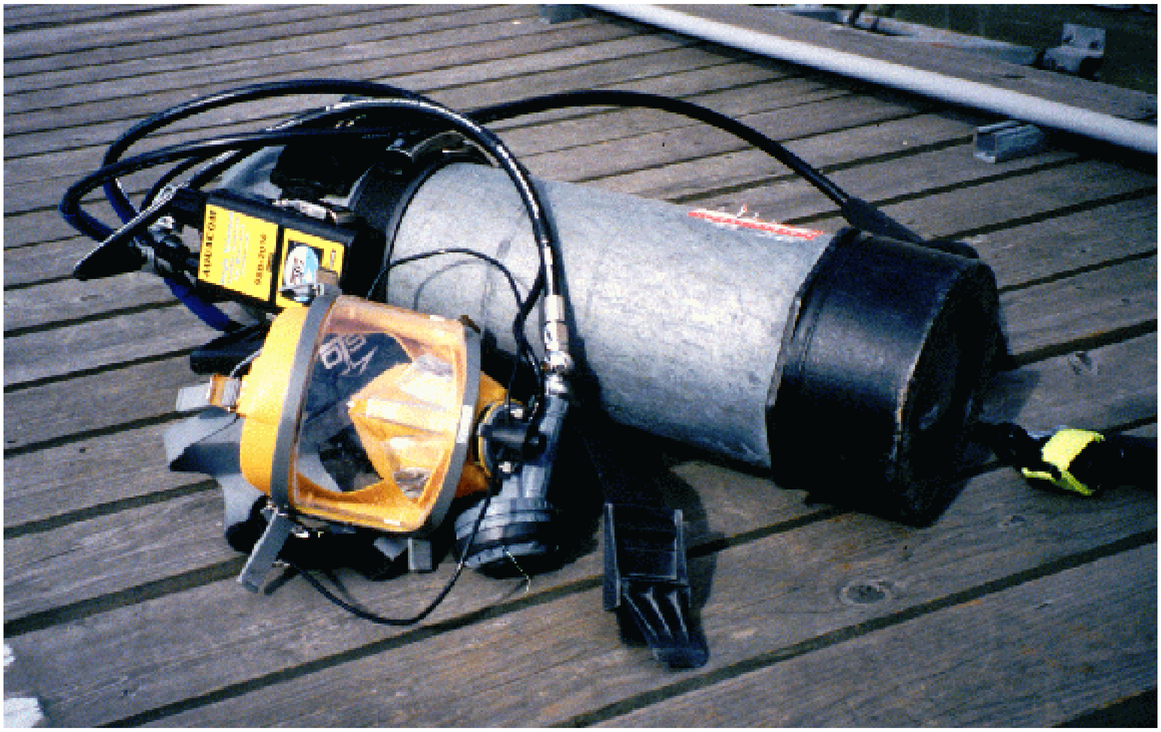


Figure 12. Full face mask underwater communication system used in dive operations at Lake Washington and Lake Union during spring and summer 2000 and 2001 (photo by Karl W. Mueller).

Figure 13. Full face mask underwater communication system allowed WDFW divers to speak to each other or directly with topside surface tenders to relay their observations of smallmouth bass presence, abundance, habitat association, and behavior (photo by Karl W. Mueller).

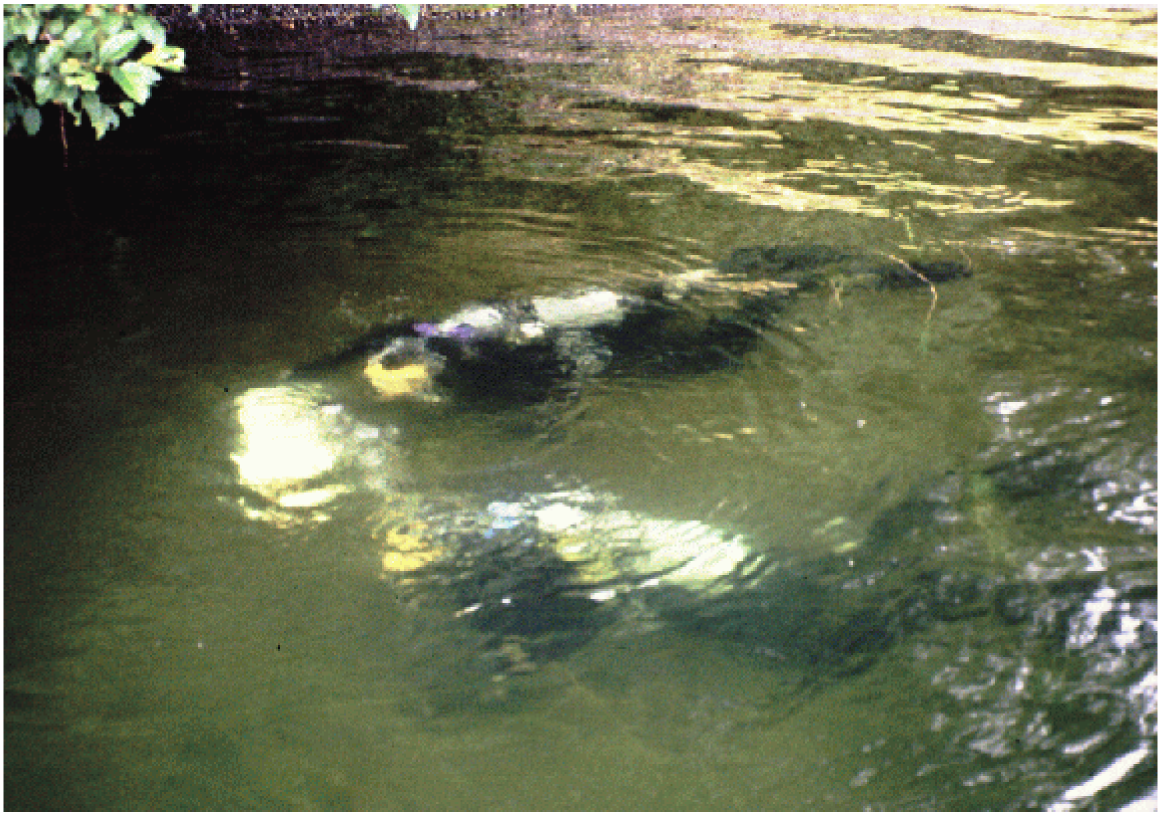


Figure 14. WDFW divers pause along the shallow transect off Seward Park (Bailey Peninsula), Lake Washington to relay observations to topside surface tender (photo by Karl W. Mueller).

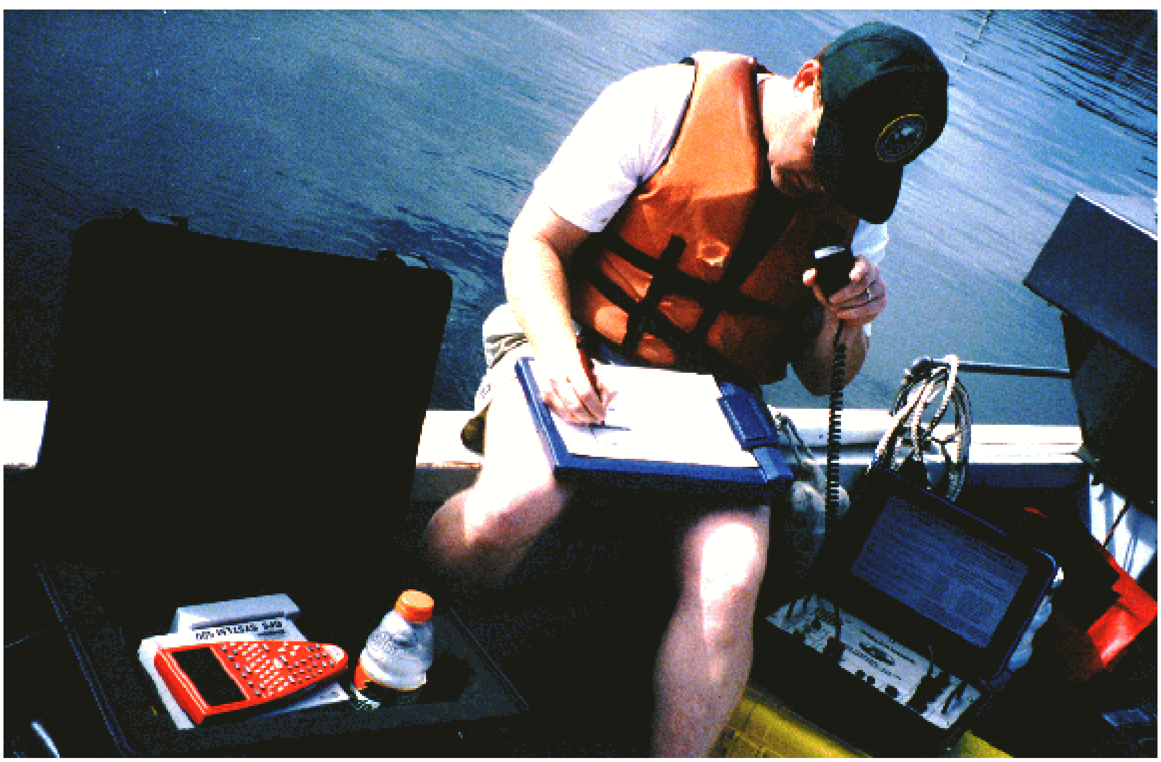


Figure 15. Topside WDFW surface tender communicating with submerged divers while recording their observations off Gas Works Park, Lake Union (photo by Karl W. Mueller).

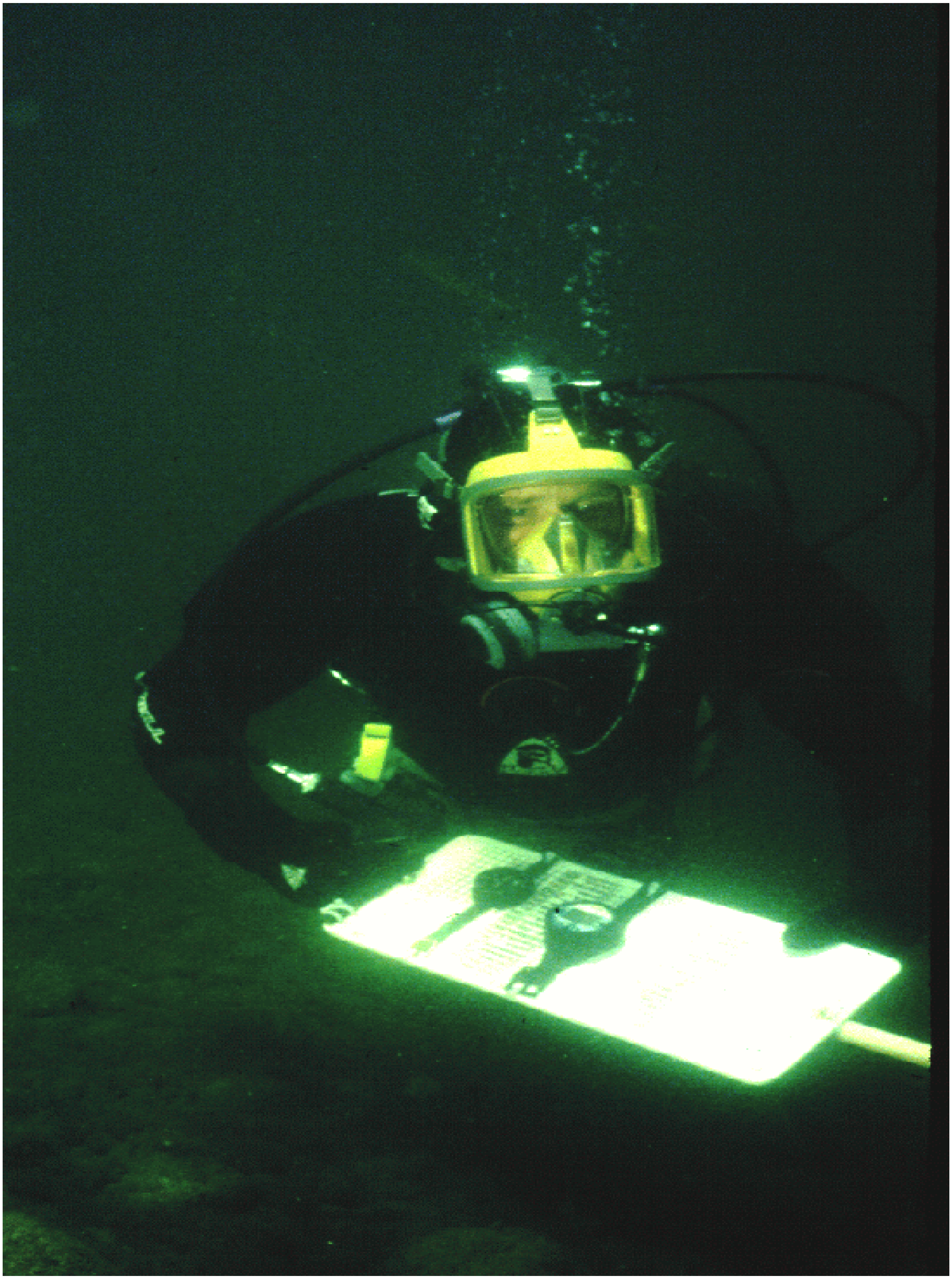


Figure 16. WDFW divers monitored depth and time, navigated, and visually estimated the size of smallmouth bass encountered during transects using a hand-held underwater slate (photo by Don P. Rathaus).

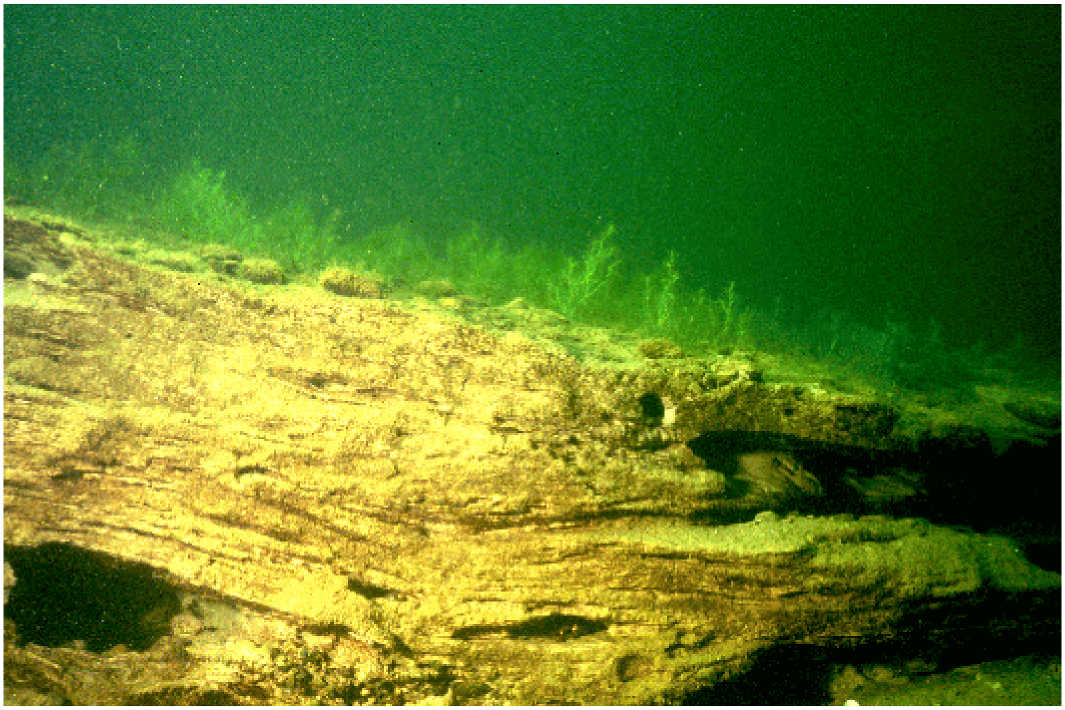


Figure 17. Direct observation by WDFW divers allowed classification of structure, aquatic vegetation, and substrate type(s) at study locations. Pictured here is the wall above the dredge channel at Webster Point, Lake Washington (photo by Don P. Rothaus).

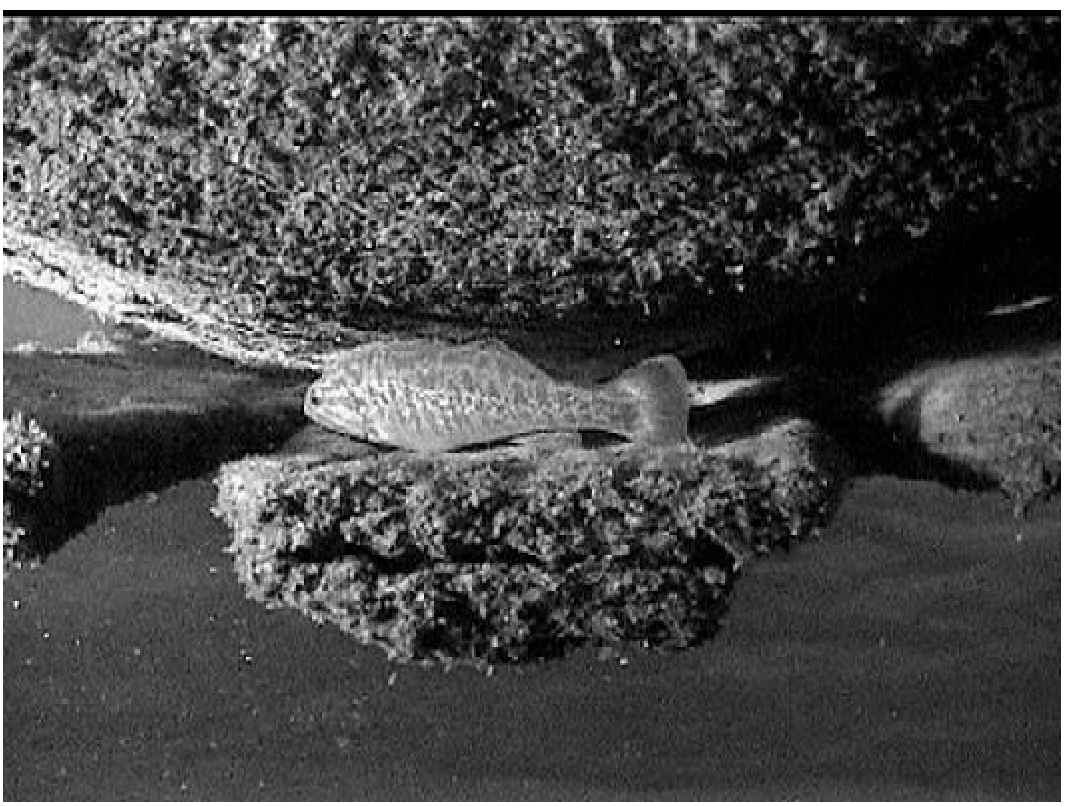


Figure 18. Juvenile smallmouth bass seeking refuge inside bark of submerged cut-log off Taylor Creek, Lake Washington (photo by Don P. Rothaus).

Figure 19. Smallmouth bass hovering over the fine substrate off Webster Point, Lake Washington. Note the split anal fin. WDFW divers were able to recognize individual fish using anomalies such as this to insure independence between fish counts (photo by Don P. Rathaus).

The transect was complete when divers encountered the downline from a second buoy that was 1,000 ft from the first buoy (as determined by laser rangefinder) marking the end point of the deep transect line. At this point, divers verbally called out the transect-end water temperature (E F) as shown on their diving consoles, then swam directly inshore to a point within the middle depth range. This then became the start point of the middle transect which was completed after swimming along the middle depth range in the opposite direction and inshore from the first (deep) transect line. The third and shallowest transect was directly inshore of the other two, the divers following the same direction as the deep transect line.

In 2001, we modified our sampling approach to include six additional dive sites (Table 1), day vs. night sampling, and shallow vs. deep sampling. Diel differences in smallmouth bass activity, distribution and abundance were examined by performing dive transects at two locations (Coleman and Webster Points) during the morning (0900 – 1130), afternoon (1330 – 1600), and night (0030 – 0300). Changes in the vertical distribution and abundance of smallmouth bass were examined by including two additional isobaths (~50 ft and < 4 ft) at two locations (Coleman Point and Taylor Creek). The shallow transects were completed while snorkeling at the surface. The results of these efforts will also be reported under separate cover.

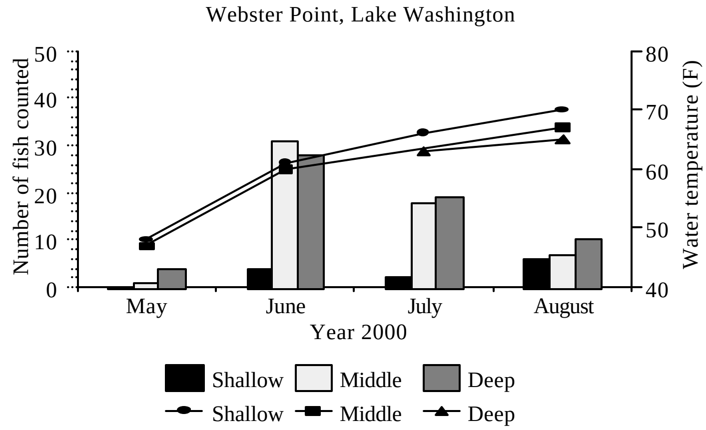
To remain within the scope of a methods report, only selected results from three locations surveyed in 2000 will be discussed. The dive site at Webster Point (Table 1) was located in the upper half of Lake Washington, just north of the Evergreen Point Floating Bridge, along the west shore. A stationary, navigational aid, located about halfway along the deeper transects, marked the point and the northern margin of an offshore, dredged channel. The shoreline was comprised of private, lakefront properties. There were a total of eight docks within the 1,000-ft (linear distance) study area. The other two dive sites were located in the south half of Lake Washington. The first was located along the southeast shore, near the base of Coleman Point (Table 1), and overlapped the northern boundary of Gene Coulon Park. Outside the park boundary, the shoreline was comprised of private, lakefront properties. A total of seven docks were located within this area. The third dive site was located at the mouth of Taylor Creek (Table 1), which discharges into the south end of the lake. This 1,000-ft stretch of shoreline was characterized by higher density residential use and contained 23 docks.

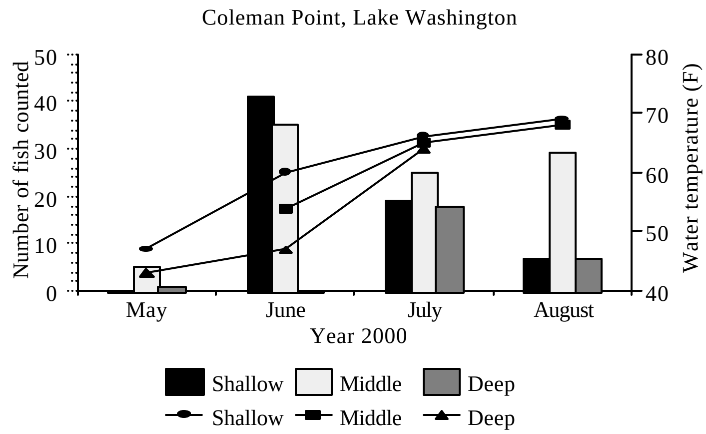
SELECTED RESULTS

In May 2000, few, if any, smallmouth bass were observed by divers when water temperatures were below 50EF. Peak smallmouth bass abundance occurred in June at all study sites when water temperatures exceeded 50EF (Figure 20). Some variation in abundance between depths and locations was observed. For example, in June and July, few smallmouth bass were observed in the shallows at Webster Point, whereas considerable numbers were observed at Coleman Point. No smallmouth bass were observed along the deep transect of Coleman Point during June whereas more than 10 smallmouth bass each were observed along the deep transects of Webster Point and Taylor Creek during the same period. The predator was not observed along the deep transect at Coleman Point until July, when water temperatures exceeded 60EF (Figure 20). Thus, cool water temperatures (< 50EF) may partially explain the absence of smallmouth bass in deep water during June (Jackson et al. 2001). The lowest smallmouth bass counts occurred at Taylor Creek, the most developed of the three sites (> 2 docks/100 ft shoreline compared to < 1 dock/100 ft shoreline at Webster and Coleman Points). Taylor Creek was also the site of least variation in counts between depths from June to August.

Except for the shallow transect at Webster Point, smallmouth bass abundance generally decreased from June to August at all depths and sites (Figure 20). The decline of small fish through summer accounts for much of this trend. The number of medium fish decreased at Webster Point, fluctuated at Coleman Point, and remained static at Taylor Creek from June to August. The number of large fish observed on-site during the same period never exceeded 10. Large fish abundance fluctuated at Webster Point, remained static at Coleman Point, and increased at Taylor Creek through summer (Figures 21 – 23). As expected, proportional smallmouth bass association with docks was higher at Taylor Creek, the most developed section, compared to Webster and Coleman Points. However, docks did not necessarily congregate fish. If this were not the case, proportionally more smallmouth bass would have been associated with docks at Webster and Coleman Points, the sites with higher fish counts. Irrespective of location, small fish tended to be more closely associated with docks than larger conspecifics (Figures 21 – 23).

Ten smallmouth bass nests were observed during summer 2000 (Table 2). The median depth of all nests was 5 ft. The mean and range were 6.3 and 4 – 12 ft, respectively. The substrate at nest sites was primarily gravel. Of the five locations where smallmouth bass nesting was observed, Coleman Point had the highest concentration of nests (n = 5). Nest-site fidelity is common in smallmouth bass (Ridgway et al. 1991a), which might explain the higher abundance of fish observed here in the shallows during June and July compared to the other sites (Figure 20). Large fish occupied three nests whereas medium fish occupied seven nests. Differences in developmental and nesting stages were apparent (Table 2). Large fish guarded nests with hatched embryos or swim-up fry. Of the seven medium fish observed, six guarded empty nests or nests with eggs. The exception was guarding a nest with swim-up fry. These findings are consistent with previous research demonstrating that large male smallmouth bass precede smaller males in establishing nest sites and receiving eggs (Ridgway et al. 1991b).





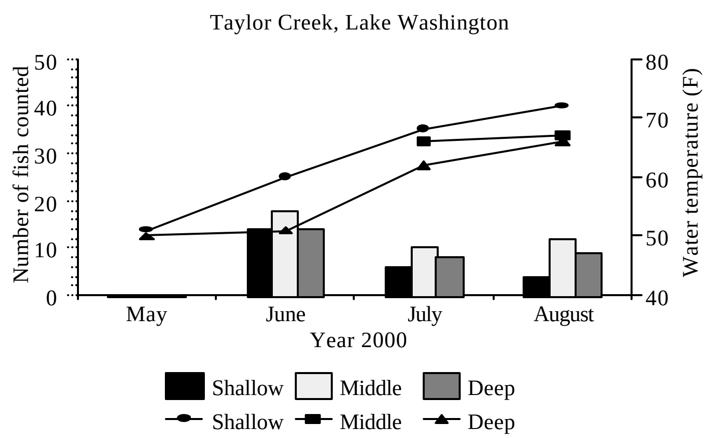


Figure 20. Relationship between spring and summer smallmouth bass abundance, transect depth (bars), and water temperature (lines) at three locations (north to south) on Lake Washington. Shallow = 4-6 ft, middle = 10-14 ft, and deep = 18-22 ft.

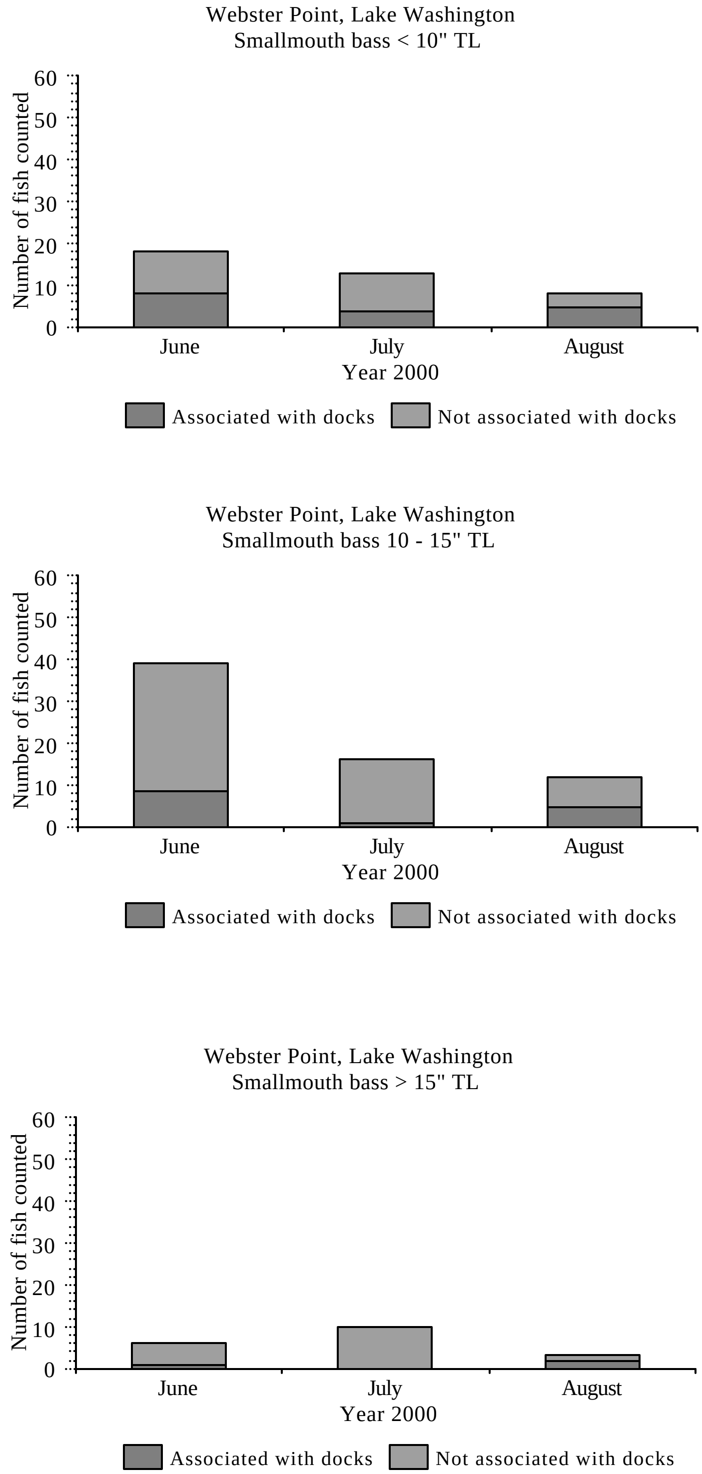


Figure 21. Relationship between abundance of smallmouth bass (small, medium, and large) and habitat (associated with docks, not associated with docks) at Webster Point, Lake Washington during summer 2000.

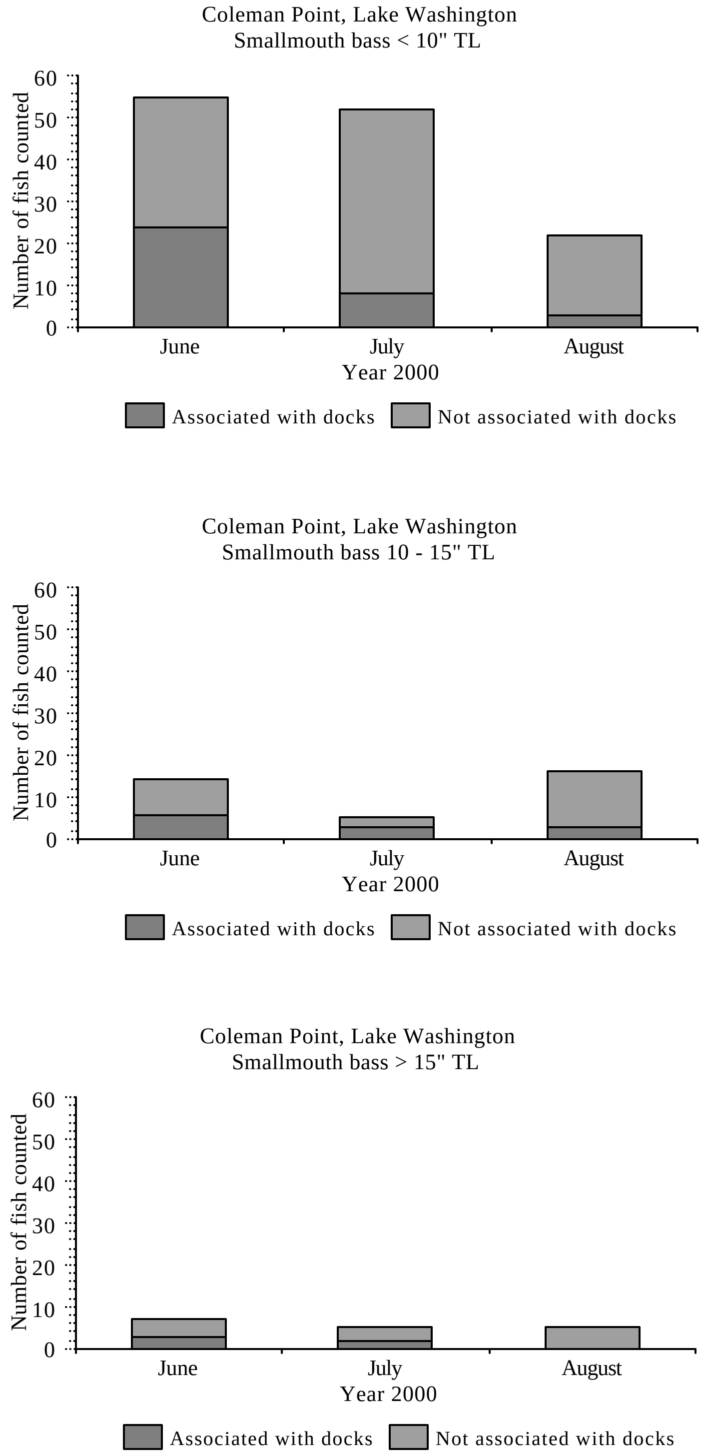


Figure 22. Relationship between abundance of smallmouth bass (small, medium, and large) and habitat (associated with docks, not assoicated with docks) at Coleman Point, Lake Washington during summer 2000.

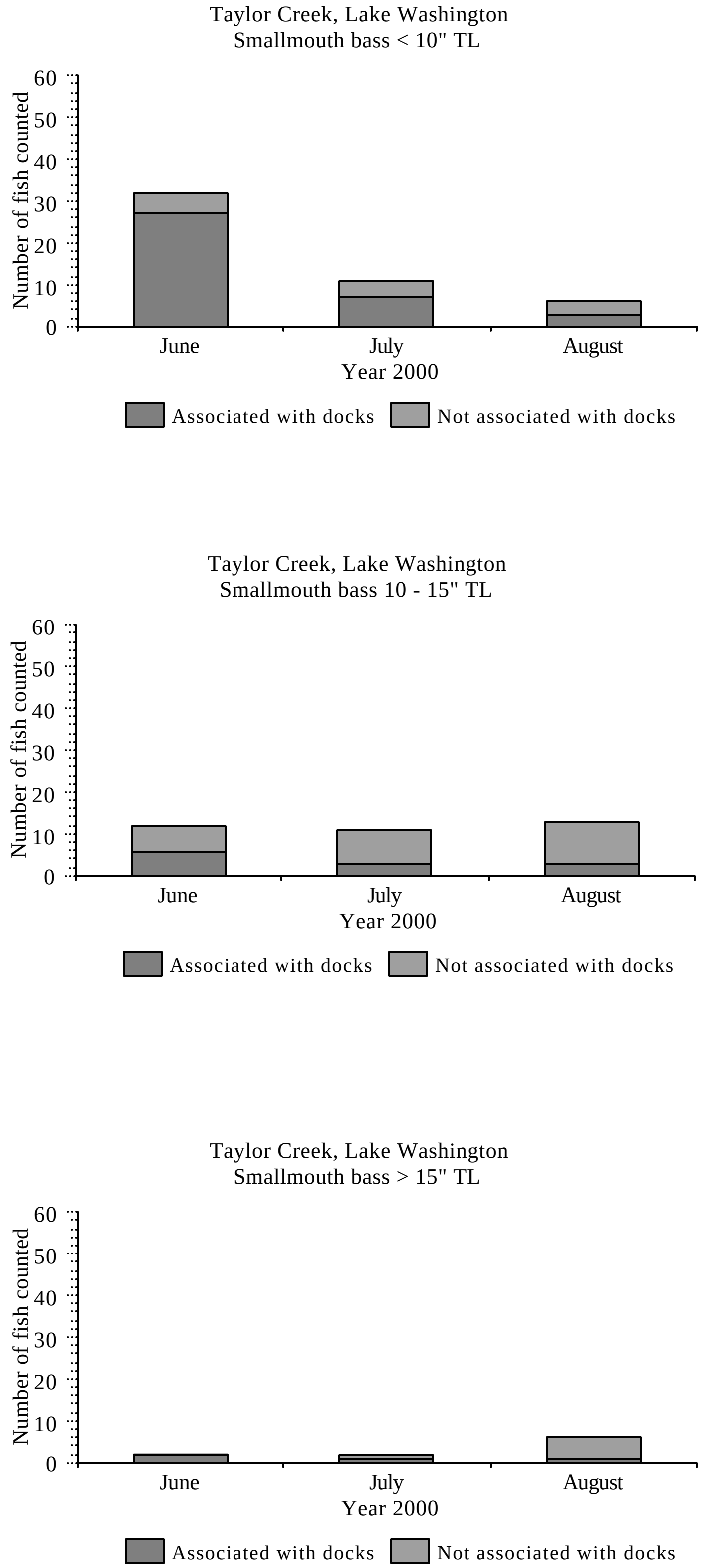


Figure 23. Relationship between abundance of smallmouth bass (small, medium, and large) and habitat (associated with docks, not associated with docks) at Taylor Creek, Lake Washington during summer 2000.

Table 2. Smallmouth bass nesting characteristics at five locations on Lake Washington during summer 2000. Medium = 10-15 in. total length (TL), large >15 in. TL.

Study site (north to south)	Date	Nest depth (ft)	Water temperature (EF)	Size of male guarding nest	Nesting stage
Webster Point	6/22/00	11	60	Medium	Eggs
Madison	6/22/00	5	61	Large	Hatched embryos
Madison	6/22/00	6	61	Medium	Empty
Coleman Point	6/20/00	5	60	Medium	Empty
Coleman Point	6/20/00	5	60	Medium	Eggs
Coleman Point	6/20/00	5	60	Large	Swim-up fry
Coleman Point	7/12/00	5	66	Medium	Swim-up fry
Coleman Point	7/12/00	12	65	Large	Swim-up fry
Taylor Creek	7/12/00	5	68	Medium	Empty
Bryn Mawr	7/12/00	4	68	Medium	Empty

DISCUSSION

Scuba and snorkeling have been used in freshwater fisheries management for decades (Northcote and Wilkie 1963; Reed 1971; Fish Pro 1987; Graham 1992). Direct observation by divers can answer questions concerning the distribution and abundance, seasonal movements and home ranges, microhabitat use, reproduction, and behavior of a variety of species. For example, in Michigan, divers determined the seasonal distribution and abundance of several warmwater species in a bluegill (*Lepomis macrochirus*)-dominated fish community (Hall and Werner 1977). In Arkansas, divers observed tagged black bass (*Micropterus* spp.) to gain knowledge of their territories, home ranges, and the occurrence of multiple spawning by individual fish (Heard and Vogele 1968). In Massachusetts, population estimates for pumpkinseed (*Lepomis gibbosus*) were more reliable and took fewer man-hours to complete when diving compared to electrofishing (Reed 1971). Furthermore, Helfman (1979) examined the diel activity patterns of yellow perch (*Perca flavescens*) while diving in New York.

We used underwater methods to evaluate monthly changes in the density, size structure, size-specific selection of natural vs. artificial structure, and nest-site characteristics of smallmouth bass at several locations around Lake Washington and Lake Union. These preliminary results are examples of the types of information collected while scuba diving that might not be possible using traditional depletion methods. Integrating direct observation, side-scan sonar imagery, GPS, and GIS should provide maps of smallmouth bass distribution and abundance that will benefit resource managers and anglers alike. For example, resource managers with regulatory authority over shoreline development will find this information useful when evaluating new dock construction or placement of submerged structures. Knowing the distribution, habitat preferences, and timing of onshore movements of smallmouth bass should improve the opportunity for anglers to land this prized gamefish, especially given the combined size of Lake Washington and Lake Union.

REFERENCES

Fayram, A.H., and T.H. Sibley. 2000. Impact of predation by smallmouth bass on sockeye salmon in Lake Washington, Washington. North American Journal of Fisheries Management 20: 81-89.

Fish Pro. 1987. Fishery monitoring during restoration of Erie and Campbell Lakes, Skagit County, Washington. Fish Pro, Inc., Port Orchard, WA. 56 p.

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.

Heard, W.R., and L.E. Vogele. 1968. A flag tag for underwater recognition of individual fish by divers. Transactions of the American Fisheries Society 97: 55-57.

Helfman, G.S. 1979. Twilight activities of yellow perch, *Perca flavescens*. Journal of the Fisheries Research Board of Canada 36: 173-179.

Helfman, G.S. 1983. Underwater methods. Pages 349-369 *in* Nielsen, L.A., and D.L. Johnson (eds.), Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Jackson, D.A., P.R. Peres-Neto, and J.D. Olden. 2001. What controls who is where in freshwater fish communities – the roles of biotic, abiotic, and spatial factors. Canadian Journal of Fisheries and Aquatic Science 58: 157-170.

Ledeboer, L. 2000. Washington's spring smallmouths – destined to become the Evergreen State's No. 1 warmwater fish, smallmouth bass are coming up big in a lot of places. Washington-Oregon Game and Fish 2000(5): 17-19.

Marcantonio, M. 2000. Add Lake Washington to list of US's best smallie fisheries. Pages 52 – 56 in May 14 – 18, 2000 issue of Fishing and Hunting News.

Mullner, S.A., W.A. Hubert, and T.A. Wesche. 1998. Snorkeling as an alternative to depletion electrofishing for estimating abundance and length-class frequencies of trout in small streams. North American Journal of Fisheries Management 18: 947-953.

Northcote, T.G., and D.W. Wilkie. 1963. Underwater census of stream fish populations. Transactions of the American Fisheries Society 92: 146-151.

Reed, R.J. 1971. Underwater observations of the population density and behavior of pumpkinseed, *Lepomis gibbosus* (Linnaeus) in Cranberry Pond, Massachusetts. Transactions of the American Fisheries Society 100: 350-353.

Ridgway, M.S., J.A. MacLean, and J.C. MacLeod. 1991a. Nest-site fidelity in a centrarchid fish, the smallmouth bass (*Micropterus dolomieui*). Canadian Journal of Zoology 69: 3103-3105.

Ridgway, M.S., B.J. Shuter, and E.E. Post. 1991b. The relative influence of body size and territorial behavior on nesting asynchrony in male smallmouth bass, *Micropterus dolomieui* (Pisces: Centrarchidae). Journal of Animal Ecology 60: 665-681.