Fishery Data Series No. 96-41

Observations of Fish Attraction Devices in Hidden and Harding Lakes, Alaska.

by
Tim Viavant

November 1996

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 96-41

OBSERVATIONS OF FISH ATTRACTION DEVICES IN HIDDEN AND HARDING LAKES, ALASKA.

by

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ABSTRACT

Three replicates of mid-water, floating fish attraction devices (FADs) were placed into Harding Lake, a 1,000 ha interior Alaskan lake stocked with; Arctic char *Salvelinus alpinus*, lake trout *Salvelinus namaycush*, Arctic grayling *Thymallus arcticus*, and rainbow trout *Oncorhynchus mykiss*, and containing natural stocks of burbot *Lota lota*, least cisco *Coregonus sardinella*, and northern pike *Esox lucius*. Replicates of benthic brush pile FADs were placed at three sites in Hidden Lake, a 7.2 ha interior Alaskan lake stocked with rainbow trout, Arctic grayling, and Arctic char. Three equivalent control sites were established and marked in each lake. Timed counts of fish in a defined zone around the FADs and controls were made in random order three times for each site during early, middle, and late summer. Counts were made by two divers stationed at defined points 2.5 m away from opposite corners of the FADs. Almost no fish were observed in Harding Lake at either the FADs or at the control sites. Fish were observed and counted in Hidden Lake during mid-summer and fall, but numbers observed were not significantly different between FADs and control sites.

Key words: fish attraction device, underwater observation, timed counts, stocked fish, rainbow trout *Oncorhynchus mykiss*, Arctic char *Salvelinus alpinus*, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, least cisco *Coregonus sardinella*, northern pike *Esox lucius*.

INTRODUCTION

Many lakes in interior Alaska are stocked annually in an effort to provide additional and different angling opportunity, and to divert angling pressure from wild stock fisheries. A number of the smaller of these lakes were formed by gravel extraction, and thus have limited shoreline development and lack areas of natural cover. Because of the morphology of such lakes, there tend to be few areas where angling success is particularly good, such as shoals or adjacent to natural weed beds. Hidden Lake is such a lake, formed as a result of gravel extraction, located just off the Richardson Highway 25 km south of Fairbanks. The lake has a surface area of 6.4 ha and a maximum depth of 4.8 m (Figure 1). The lake is stocked with Arctic grayling *Thymallus arcticus*, Arctic char *Salvelinus alpinus*, and rainbow trout *Oncorhynchus mykiss*. The lake bottom is very uniform, and consists of silt-covered gravel substrates.

Harding Lake is a relatively large (1,000 ha), natural lake located just off the Richardson Highway 69 km south of Fairbanks. The lake is stocked with Arctic grayling, Arctic char, rainbow trout and lake trout *Salvelinus namaycush*, and contains natural stocks of burbot *Lota lota*, least cisco *Coregonus sardinella*, and northern pike *Esox lucius*. Harding Lake supports a recreational fishery that has averaged an estimated 4,000 angler days between 1985 and 1994 (Mills 1986 - 1994, Howe et al. 1995). Harding Lake is the largest natural lake in interior Alaska that is stocked by the Alaska Department of Fish and Game (ADF&G). Relative to the other large, natural lakes that are stocked by ADF&G (Quartz and Birch lakes), Harding Lake is larger, relatively deep, has limited amounts of littoral zone, and contains little bottom relief or aquatic vegetation. (Figure 2). Angling success at Harding Lake is substantially lower than at the other large lakes stocked by ADF&G (Table 1). Birch and Quartz lakes contain areas such as drop-offs, shoals, and weed beds that anglers have found to result in good fishing success, but Harding Lake has few such areas.

Because both Hidden and Harding lakes lack areas of natural cover, there are no areas where fish might be likely to congregate. The fisheries in these stocked lakes are managed to maximize angler catch rates (benefit) from a given stocking density (cost). If fish could be attracted to or concentrated around certain areas, it is possible that catch rates could be increased for a given

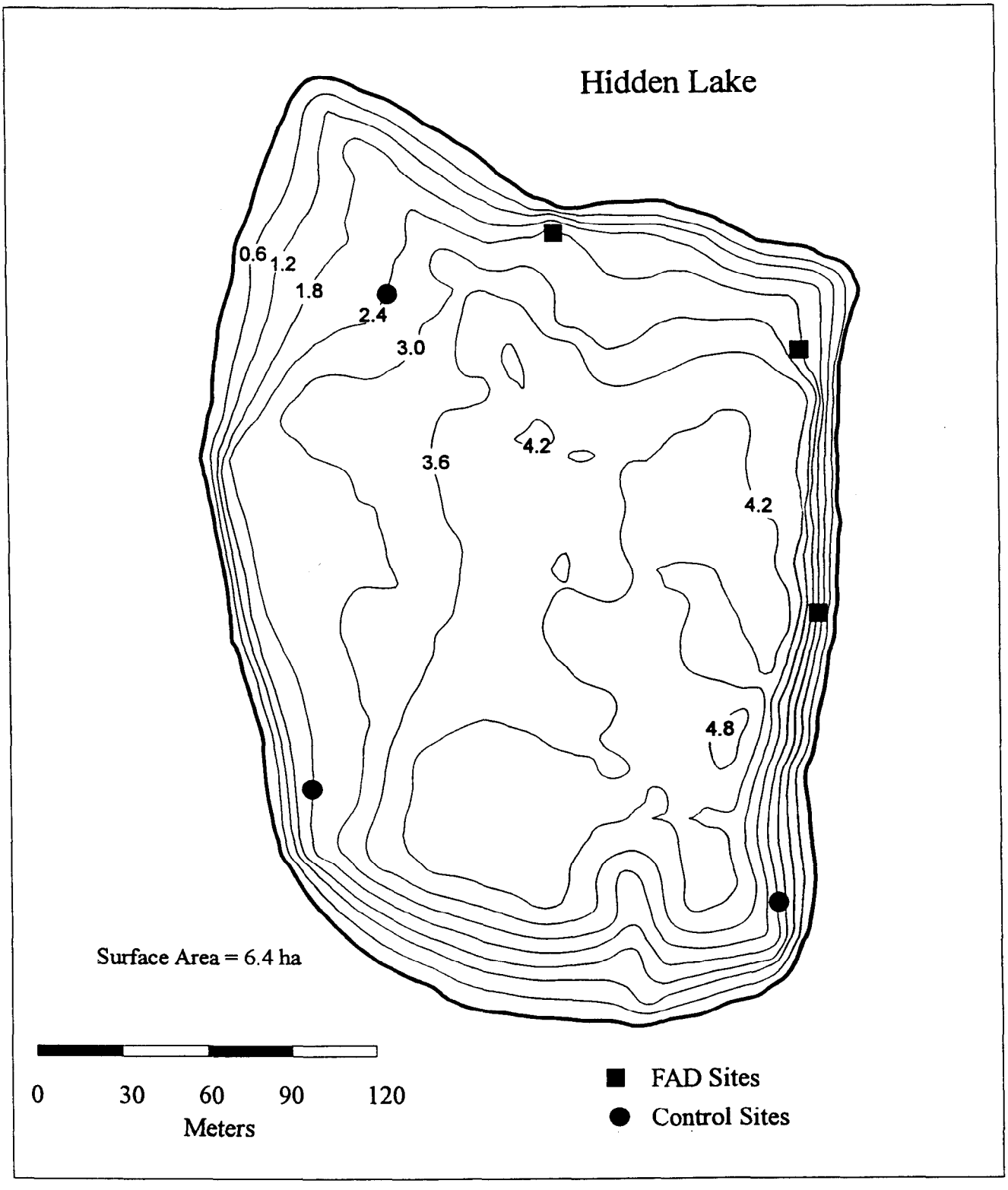

Figure 1.-Map of Hidden Lake, Alaska, showing locations of FADs and control sites.

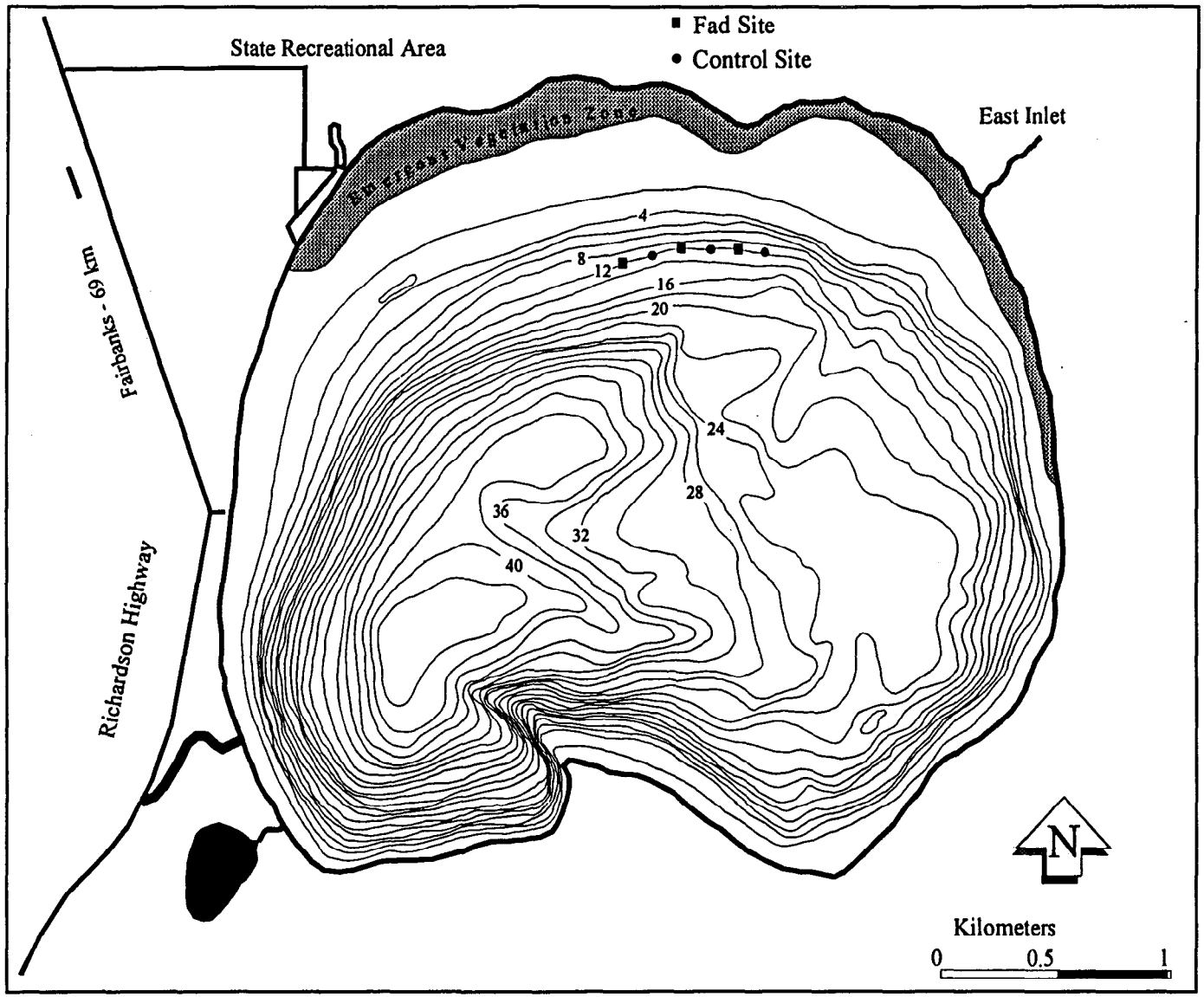

Figure 2.-Map of Harding Lake, Alaska, showing locations of FADs and control sites.

stocking density, or maintained at current levels given a lowered stocking density. It is possible that stocking densities could be reduced while maintaining catch rates, thus freeing up stocked fish for other fisheries.

A number of studies in the past 60 years have shown that many species of warm-water fish show attraction to, and congregate around, various kinds of artificial structure (often referred to as fish attraction devices, or FADs) in fresh water (Prince and Maughan 1979, Prince et al. 1985, Stone 1985, Moring et al. 1989, Stone et al. 1991, Walters et. al. 1991, Bassett 1994, Moring and Nicholson 1994). Artificial structures in fresh water have also been shown to increase angler success in the area around the structures (Pierce 1967, Petit 1972, Wilber 1978, Paxton and Stevenson 1979, Wege and Anderson 1979, Aadland 1982, Johnson and Lynch 1992). Nearly all studies of fish attraction to FADs in fresh water have involved warm-water species such as centrarchids, percids, cyprinids, and ictalurids. While these studies have shown fish attraction to FADs, there has been very little study of attraction to FADs by cold water species such as salmonids. A study to investigate attraction to FADs by stocked salmonids in a man-made lake in interior Alaska (Viavant 1995) failed to show any attraction by stocked rainbow trout *O. mykiss* and coho salmon *O. kisutch.* Because the previous study only involved one lake, only investigated attraction to FADs at one depth, and only during mid-summer, this study was undertaken to further investigate salmonid attraction to FADs of different types at different depths, during other times of the open water season, and in other lakes than the previous study.

Table 1.-Estimated angler use, catch and average catch per day for large stocked lakes in interior Alaska during 1994[a].

Lake	Total Anglers	Total Angler-Days	Total Catch	Average Catch/Day
Birch	5,270	9,880	29,110	2.95
Quartz	7,962	14,031	34,887	2.49
Chena	1,847	2,828	12,825	4.53
Harding	2,381	4,913	6,702	1.36

[a] Data from Howe et al. 1995.

The objectives of this project were to:

1. test the hypothesis that fish were not significantly attracted to mid-water Fish Attraction Devices in Harding Lake in mid-July, mid-September, and late May such that a difference of 35% in the number of fish counted could be detected with probabilities of Type I and Type II errors, being 0.10 and 0.20, respectively; and
2. to test the hypothesis that fish were not significantly attracted to benthic Fish Attraction Devices in Hidden Lake in mid-July, mid-September, and late May such that a difference of 35% in the number of fish counted could be detected with probabilities of Type I and Type II errors, being 0.10 and 0.20, respectively.

METHODS

HARDING LAKE

Mid-water FADs were constructed of woven polyethylene fabric laced around a PVC pipe frame. The FADs were two dimensional, 2.5 m wide by 6 m long. Three of these FADs were suspended horizontally at 6 m below the surface. FADs were anchored at the four corners with ropes and equipped with floatation so that the FADs were held horizontally parallel to the water surface. Three control sites were marked with a single buoy suspended at 6 m deep from an anchor. FADs and controls were placed 100 m apart in a single transect, with FADs and controls in alternating positions (Figure 2). The first position in this transect was randomly assigned to be either a FAD or control site, and FADs and controls were alternated along the transect for the remaining five positions. Sampling sites were selected to avoid the areas in Harding Lake that receive the most recreational boating use, thereby reducing problems with boaters, jet skiers, and water skiers using the marker bouys as slalom gates; and potential safety problems involving boaters and divers in the water. The transect followed approximately along the 12 m depth contour. Harding Lake has very uniform substrates, and there is no reason to suspect that fish would be any more or less likely to be present or absent in any area of the lake. Water temperatures were measured by data loggers located at 2 m deep, 4 m deep, and at 10 m deep (lake bottom) from 1 June to 30 August of 1995. Water temperatures were also measured during observations at the depth of the FADs. The FADs were placed in Harding Lake six weeks prior to the first observations in order to allow fish to acclimate to the presence of new structure.

HIDDEN LAKE

Three benthic FADs consisting of 2 m x 2 m x 1 m tall brush-filled log frames were anchored to the bottom at randomly selected locations in 2.5 m deep water. Six sites were selected randomly around the edge of Hidden Lake, and FADs and control sites were randomly assigned to each location (Figure 1). Control sites were marked with a single buoy suspended at 1 m from the lake bottom. Water temperatures were measured by data loggers located at the surface, at 1 m deep, and at 2 m (lake bottom) from 25 May to 25 August of 1995. Water temperatures were also measured during observations at the depth of the FADs. The FADs were placed into Hidden Lake six weeks prior to the first observations to allow fish to acclimate to the presence of new structure.

OBSERVATIONS

Fish counts were made using a method modified from Davis and Anderson (1989) and Graham (1992). Divers were stationed at marked points 2.5 m from opposite corners of each artificial structure or control site. Five counts were made (one count each minute) over 5 min. Counts began 10 min after both divers were at rest near marked stations to allow fish to acclimate to the observers presence. Previous studies of fish attraction to FADs have found that bluegill *Lepomis macrochirus* acclimated to divers presence within 3 min after the divers became stationary (Graham 1992), and that largemouth bass *Micropterus salmoides* (Prince and Maughan 1979) and rainbow trout and coho salmon (Viavant 1995) allowed swimming divers to approach to within distances of less than 2 m before exhibiting any fright response or moving away.

Fish were counted if they were within a defined area around the structures bounded by a 90 degree wedge, the sides of which paralleled the sides of the artificial structures and the apex of

which was located at the marked station where the observer was located (Figure 3). The one-minute totals from each diver were summed for each of the five 1 min totals, and the highest of the five summed totals was used as the number of fish present at the FAD for that count.

Counts were made in random order among the six sites at each lake three different times over a two day period during mid-July (mid-summer) and early October (fall) of 1995, and in late May (spring) of 1996. The counts were made in a new random order for each of the three counts made during each month. Divers submerged adjacent to the tender approximately 30 to 40 m away from the structures and approached from underwater to minimize the possibility of the tender or the divers entering the water disturbing fish in the vicinity of the structures. Observations at both lakes during the spring counting period were terminated after two rounds of counting instead of conducting a full three rounds, since no fish had been observed at the FADs at either lake during the first two rounds of counting.

DATA ANALYSIS

For the mid-summer and fall data from Hidden Lake, the highest summed counts of fish observed for each 5 min counting period at each site were ranked for each period (mid-summer and fall), and differences between FAD and control numbers were examined using the Mann-Whitney test (Zar 1984). No statistical tests were done for the counts from Harding Lake, since only one fish was observed. No tests were done on the data from the spring observations at Hidden Lake either, since no fish were observed.

RESULTS AND DISCUSSION

HARDING LAKE

Only one fish (a burbot) was seen during the observations of the FADs and controls at Harding Lake. This fish was observed underneath one of the FADs during the mid-summer counting period. No other fish were observed during any of the counting periods, either around the FADs or controls, or during the time divers were moving from site to site, or back and forth between the sites and the tender. Because no fish were observed at either the FAD or control sites, the null hypothesis of objective number one is not rejected, since the data provide no basis for rejecting the null hypothesis.

The results from Harding Lake, while contradicting most previous studies of fish attraction to FADs, are consistent with the findings of the previous study of FADs at Chena Lake (Viavant 1995). Harding Lake is much larger and deeper than Chena Lake, contains some fish species that are absent in Chena Lake (lake trout, burbot, northern pike, and least cisco), and lacks one species that is present in Chena Lake (coho salmon).

Underwater visibility in Harding Lake was approximately 6 m during all of the counting periods (mid-summer, fall, and spring), and would not have affected either the ability of observers to see fish, or of fish to visually locate the FADs. Water temperatures at Harding Lake at the depth of the FADs were 12.5 °C during the mid-summer observations, 8.5 °C during the fall observations, and 5.5 °C during the spring observations. During the mid-summer observations, the FADs were just at the thermocline (Figure 4). Although observations of the FADs in Harding Lake were made through a fairly broad range of temperatures, it is not possible to draw conclusions about

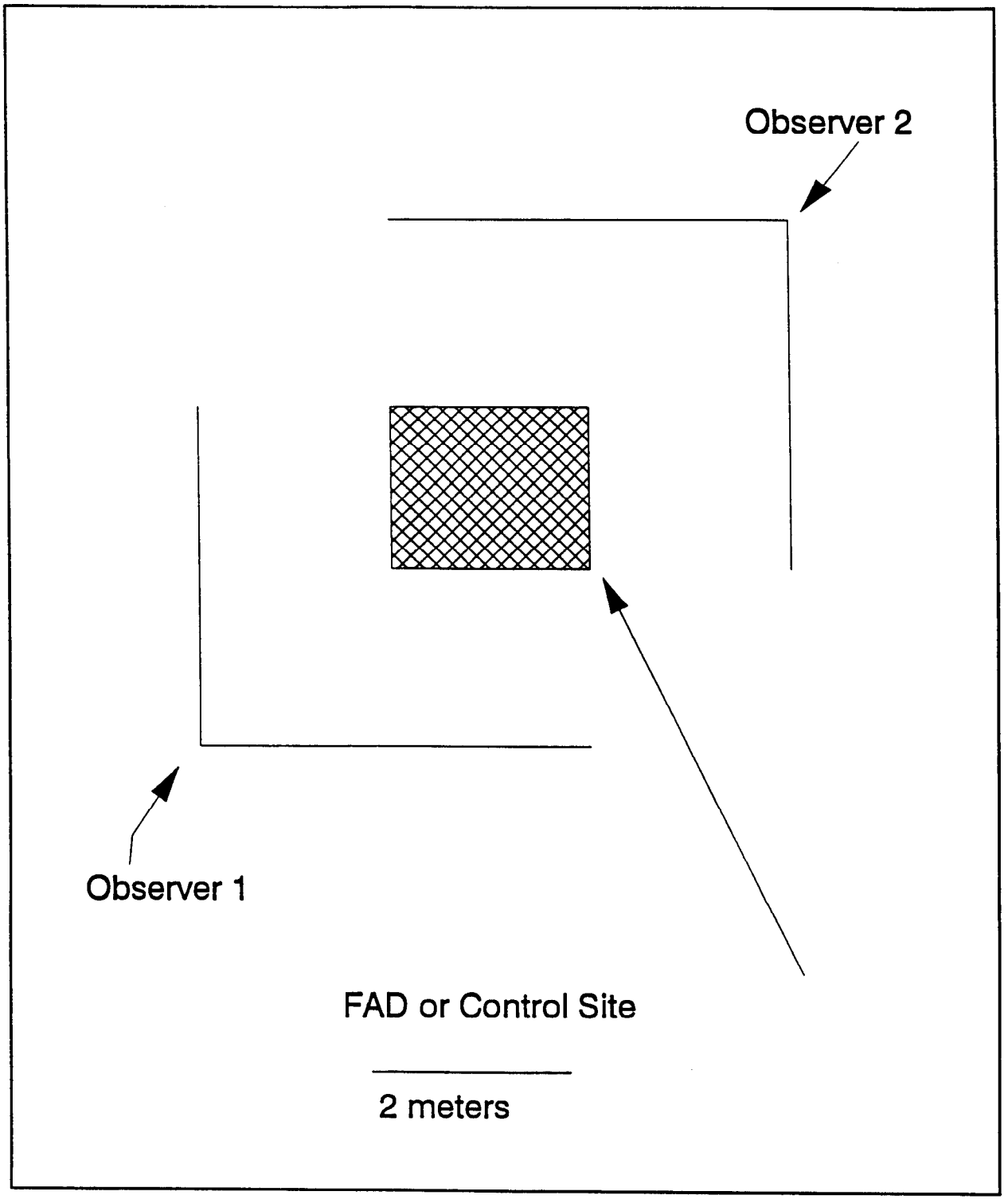

Figure 3.-Diagram showing spatial limits of observation area around each FAD or control site.

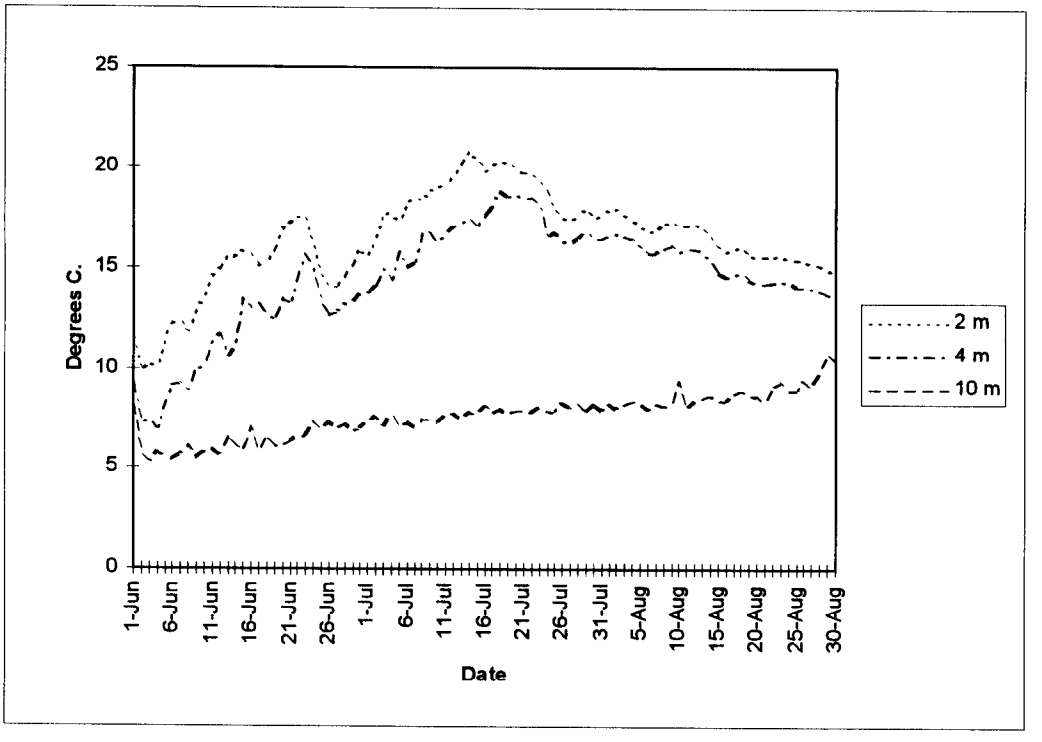

Figure 4.-Water temperatures around FAD and control sites at Harding Lake, Alaska, 1995.

the role of water temperature in attracting fish to the FADs in Harding Lake, since no fish were observed.

The FADs at Harding Lake were substantially different in nature from those used in the Chena Lakes study, and were specifically designed to create overhead cover. Arctic char have been observed in past years congregating beneath floating docks in Harding Lake, perhaps because of the overhead cover these docks provided. Although population estimates have not been done at Harding Lake for any species, the lake was stocked with 11,500 catchable and 412,000 subcatchable Arctic char, 184,000 fingerling and 19,500 catchable rainbow trout, and 1,426,000 Arctic grayling fry between 1991 and 1995.

Experience from fish observations done at Hidden Lake during this study, and from a previous study (Viavant 1995) do not indicate that rainbow trout or coho salmon tend to avoid divers. Fish of these species that were observed in areas away from FADs or control sites failed to move away from divers until approached to distances of less than two m. Arctic char where not observed in either of these studies, and may be more likely to avoid divers. Because fish were not observed at any location in Harding Lake during this study, it is not possible to draw firm conclusions from the data. The results of this study, however; do not suggest that fish present in Harding Lake, including pelagic species such as least cisco, show attraction to floating, mid-water cover.

HIDDEN LAKE

Fish were observed in small numbers around both the FADs and control sites at Hidden Lake during the mid-summer and fall observation periods (Table 2, Appendix 1). No fish were observed at either FAD or control sites, or at any other location at Hidden Lake during the spring observation period. All fish observed around FAD and control sites during the mid-summer and fall observation periods were Arctic grayling, however, rainbow trout were observed by divers while moving between the sites or from the sites to shore. There were no significant differences ($p > 0.10$) between the numbers of fish observed around the FADs and controls during either the mid-summer or fall counting periods. Because there were no significant differences in the numbers of fish observed between the FAD and control sites, the null hypothesis of objective number two was not rejected, since the data show that fish were not attracted to the FADs.

More fish were observed around the control sites than the FADs during the mid-summer counting period (Table 2). In particular, many more fish were observed around control replicate two during the mid-summer counting period than around any other site. While this was the case during the mid-summer counting period, it was not the case during the fall counting period, when no one site differed much in numbers of fish observed from any other site. It is unclear why more fish were present around control replicate two during the mid-summer observations than around any other site observed. The substrate did not differ from other sites, there were no differences in the amount of aquatic vegetation or other cover, and there were no differences in water temperature or other signs of ground-water input at the site.

Water temperatures at the depth of the FADs at Hidden Lake were 21 °C during the mid-summer observations, 11.5 °C during the fall observations, and 8 °C during the spring observations. The FADs at Hidden Lake were above the thermocline, and water temperatures did not vary greatly with depth, ranging from 20 °C at the lake bottom to 22 °C at the surface during the mid-summer observations (Figure 5).

Table 2.-Fish counts from FAD and control sites at Hidden Lake, Alaska

	Mid Summer Counts		Fall Counts	
Replicate	FAD counts	Control Counts	FAD Counts	Control Counts
1	0	6	0	1
2	5	22	0	1
3	1	0	0	1
1	0	9	1	1
2	3	37	2	2
3	3	0	0	0
1	4	6	1	0
2	5	18	1	2
3	4	0	1	0

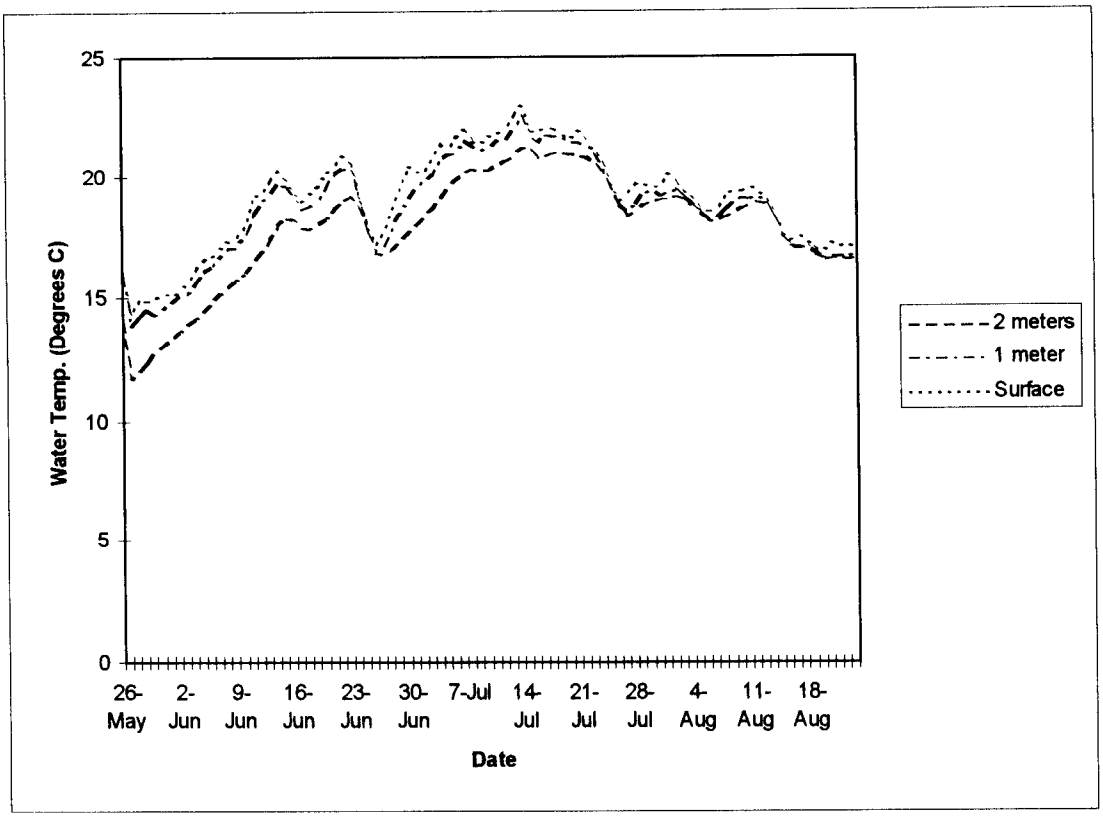

Figure 5.-Water temperatures at the depth of the FADs and controls at Hidden Lake, Alaska, 1995.

It is unclear why Arctic grayling were present (in low numbers) around both control and FAD sites during the mid-summer and fall observation periods, but all fish were completely absent during the spring observations. It is possible that fish were less active or avoided shallow water when temperatures were below a certain level. The apparent lack of fish during the spring was probably not due to proximity to a stocking date, since all fish observed at Hidden Lake around the FADs and control sites were Arctic grayling, and no Arctic grayling have been stocked into Hidden Lake since the fall of 1993.

Although Arctic grayling were the only fish observed around FAD and control sites durint the mid-summer and fall observation periods, rainbow trout and Arctic char were present in the lake during the time those observations were made. Rainbow trout were observed by divers swimming to shore after completing counts at FAD and control sites, and rainbow trout were caught by anglers fishing during the time that observations were being made. Over 1,700 catchable Arctic char were stocked in Hidden Lake in 1993, 900 catchable Arctic char were stocked in Hidden Lake in 1994, and another 900 catchable Arctic char were stocked in Hidden Lake in the fall of 1995 (prior to the fall observations being made at Hidden Lake). It is possible that Arctic char are inclined to avoid divers underwater, although it seems more likely that Arctic char avoid shallow water. The results indicate that Arctic grayling and rainbow trout are not attracted to benthic structure in shallow water at Hidden Lake, and suggest that Arctic char may not utilize shallow water habitats in Hidden Lake.

CONCLUSION

The results from this study show that Arctic grayling and rainbow trout are not attracted to benthic structure in shallow water (2 m deep or less) in Hidden Lake, and there is no reason to suggest that they would behave differently in another similar lake. The results also suggest that stocked Arctic char and other lake resident wild stock species are not attracted to mid-water structure suspended in open water 12 m deep in Harding Lake, and that differing water temperatures and other possible seasonal effects do not appear to influence salmonid attraction to artificial structure at either of these lakes.

These conclusions are based in part on a couple of assumptions. One is that there were fish present in the area of the FADs to have a chance to be attracted. This was clearly the case in Hidden Lake for Arctic grayling and rainbow trout, at least during the mid-summer and fall observation periods. Although the stocking record shows that Arctic char were present in Hidden Lake during the time observations were made, it is possible (and the data suggest it is likely) that Arctic char do not utilize shallow water habitats, at least in Hidden Lake. In Harding Lake, it is less clear that fish were present in densities high enough to give those fish present an opportunity to be attracted to the FADs, and, in fact, the data suggest that there were not. Harding Lake does, however, contain enough fish that if the species present were to show the degree of attraction to FADs shown in the literature by various warm water species, it seems very likely that we would have observed fish around the FADs.

The other assumption implicit in the conclusions is that the fish that were present were not avoiding the divers. There is evidence (cited earlier) that suggests that this was not the case. During the three seasons that I have made dives to observe fish in interior stocked lakes, I have never observed a fish from a distance that fled upon becoming aware of my presence, and I have

approached quite close (within 2 m) to Arctic grayling, burbot, northern pike, rainbow trout, lake trout, and coho salmon.

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LITERATURE CITED

Aadland, L. P. E., 1982. Artificial reefs as a management tool to improve sport fishing in North Dakota reservoirs. Master's thesis. North Dakota State University, Fargo, North Dakota.

Bassett, C. E. 1994. Use and evaluation of fish habitat structures in lakes of the eastern United States by the USDA Forest Service. Bulletin of Marine Science. 55(2 and 3):1137-1148.

Davis, G. E. and T. W. Anderson. 1989. Population estimates of four kelp forest fishes and an evaluation of three in situ assessment techniques. Bulletin of Marine Science. 44:1138-1151.

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

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Johnson, D. L, and W. E. Lynch, Jr. 1992. Panfish use of and angler success at evergreen tree, brush, and stake-bed structures. North American Journal of Fisheries Management. 12:222-229.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1985-1986, Project F-9-18, Volume 27 (RT-2), Juneau.

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

LITERATURE CITED (Continued)

Moring, J. R., M. T. Negus, R. D. McCullough, and S. W. Herke. 1989. Large concentrations of submerged pulpwood logs as fish attraction structures in a reservoir. Bulletin of Marine Science 44:609-615.

Moring, J. R, and P. H. Nicholson. 1994. Evaluation of three types of artificial habitats for fishes in a freshwater pond in Maine, U.S.A.. Bulletin of Marine Science. 55(2 and 3):1149-1159.

Paxton, K. O. and F. Stevenson. 1979. Influence of artificial structures on angler harvest from Killdeer Reservoir, Ohio. Pages 70-76 in Johnson and Stein (1979).

Petit, G. D. 1972. Stake beds as crappie concentrators. Proceedings of the Annual Conference of Southeastern Game and Fish Commissioners 26:401-406.

Pierce, B. E., 1967. Brush shelter studies. West Virginia Department of Natural Resources. Federal Aid in Sport Fish Restoration Project F-10-R-8, Completion Report.

Prince, E. D., and E. O. Maughan. 1979. Attraction of fishes to artificial tire reefs in Smith Mountain Lake, Virginia. Pages 19-25 in D. L Johnson and R. A. Stein 1979, editors. Response of fish to habitat structure in standing water. North Central Division American Fisheries Society Special Publication 6.

Prince, E. D., E. O. Maughan, and P. Brouha. 1985. Summary and update of the Smith Mountain Lake artificial reef project. Pages 401-430 in F. M. D'itri, Editor. Artificial reefs-marine and freshwater applications. Lewis Publishers, Inc. Chelsea, Michigan.

Stone, R. B. 1985. History of artificial reef use in the United States. Pages 3-11 in F. M. D'itri, Editor. Artificial reefs-marine and freshwater applications. Lewis Publishers, Inc. Chelsea, Michigan.

Stone, R. B., J. M. McGurrin, L. M. Sprague, and W Seaman, Jr. 1991. Artificial habitats of the world: synopsis and major trends. Pages 31-60 in W. Seaman, Jr., and L. M. Sprague, Editors. Artificial habitats for marine and freshwater fisheries. Academic Press, Inc. San Diego, Ca.

Viavant, T. 1995. Fish attraction to artificial structure in Chena Lakes, Alaska. Alaska Department of Fish and Game, Sport Fish Division. Fishery Data Series No. 96-6. 14 pp.

Walters, D. A., W. E. Lynch, Jr., and D. L. Johnson. 1991. How depth and interstice size of artificial structures influence fish attraction. North American Journal of Fisheries Management. 11:311-329.

Wege, G. J. and R. O. Andersen. 1979. Influence of artificial structures on largemouth bass and bluegill in small ponds. Pages 59-69 in D. L Johnson and R. A. Stein 1979, editors. Response of fish to habitat structure in standing water. North Central Division American Fisheries Society Special Publication 6.

Wilbur, R. L., 1978. Two types of fish attractors compared in Lake Tohopekaliga, Florida. Transactions of the American Fisheries Society 107:689-695.

Zar, J. H. 1984. Biostatistical Analysis, Second Ed, Prentice Hall, Inc., Englewood Cliffs, N.J, USA.

APPENDIX A

Appendix A.-Hidden Lake fish counts, summer and fall, 1995.

Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
Summer	1	FAD 1	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		FAD 2	2	2	4	5
			0	0	0	
			2	0	2	
			1	2	3	
			3	2	5	
		FAD 3	0	0	0	1
			0	0	0	
			1	0	1	
			0	1	1	
			0	1	1	
		Control 1	0	3	3	6
			0	3	3	
			3	3	6	
			1	2	3	
			3	1	4	
		Control 2	8	8	16	22
			6	6	12	
			14	8	22	
			9	10	19	
			11	7	18	
		Control 3	0	0	0	0
			0	0	0	

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Appendix A.-Page 2 of 7.

Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			0	0	0	
			0	0	0	
			0	0	0	
	2	FAD 1	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		FAD 2	0	0	0	3
			0	0	0	
			1	0	1	
			2	0	2	
			3	0	3	
		FAD 3	0	0	0	3
			1	0	1	
			2	0	2	
			1	2	3	
			0	2	2	
		Control 1	2	3	5	9
			1	3	4	
			1	4	5	
			2	3	5	
			1	8	9	
		Control 2	8	14	22	37
			11	15	26	
			10	7	17	
			11	10	21	

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Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			15	22	37	
		Control 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
	3	FAD 1	0	0	0	4
			0	0	0	
			2	2	4	
			1	2	3	
			2	1	3	
		FAD 2	1	0	1	5
			1	3	4	
			3	1	4	
			2	2	4	
			3	2	5	
		FAD 3	0	0	0	4
			1	1	2	
			2	2	4	
			2	2	4	
			3	1	4	
		Control 1	2	1	3	6
			0	1	1	
			4	2	6	
			1	1	2	
			4	2	6	
		Control 2	6	10	16	18

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Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			8	4	12	
			10	5	15	
			8	7	15	
			11	7	18	
		Control 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
Fall	1	FAD 1	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		FAD 2	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		FAD 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Control 1	0	0	0	1
			1	0	1	

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Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			0	0	0	
			0	0	0	
			0	0	0	
		Control 2	0	0	0	1
			0	0	0	
			1	0	1	
			0	0	0	
			0	0	0	
		Control 3	0	1	1	1
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
	2	FAD 1	0	0	0	1
			0	0	0	
			0	0	0	
			0	0	0	
			1	0	1	
		FAD 2	0	0	0	2
			0	0	0	
			0	2	2	
			0	0	0	
			0	1	1	
		FAD 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	

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Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			0	0	0	
		Control 1	0	1	1	1
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Control 2	0	0	0	2
			0	0	0	
			0	0	0	
			0	0	0	
			1	1	2	
		Control 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
	3	FAD 1	0	0	0	1
			0	0	0	
			0	0	0	
			0	1	1	
			0	0	0	
		FAD 2	0	0	0	1
			0	0	0	
			0	0	0	
			0	1	1	
			0	0	0	
		FAD 3	0	0	0	1

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Counting Period	Count Number	Location	Observer 1 Count	Observer 2 Count	Combined Count	Maximum Combined Count
			1	0	1	
			0	0	0	
			0	0	0	
			0	0	0	
		Control 1	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Control 2	0	0	0	2
			0	0	0	
			0	0	0	
			1	0	1	
			0	2	2	
		Control 3	0	0	0	0
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	