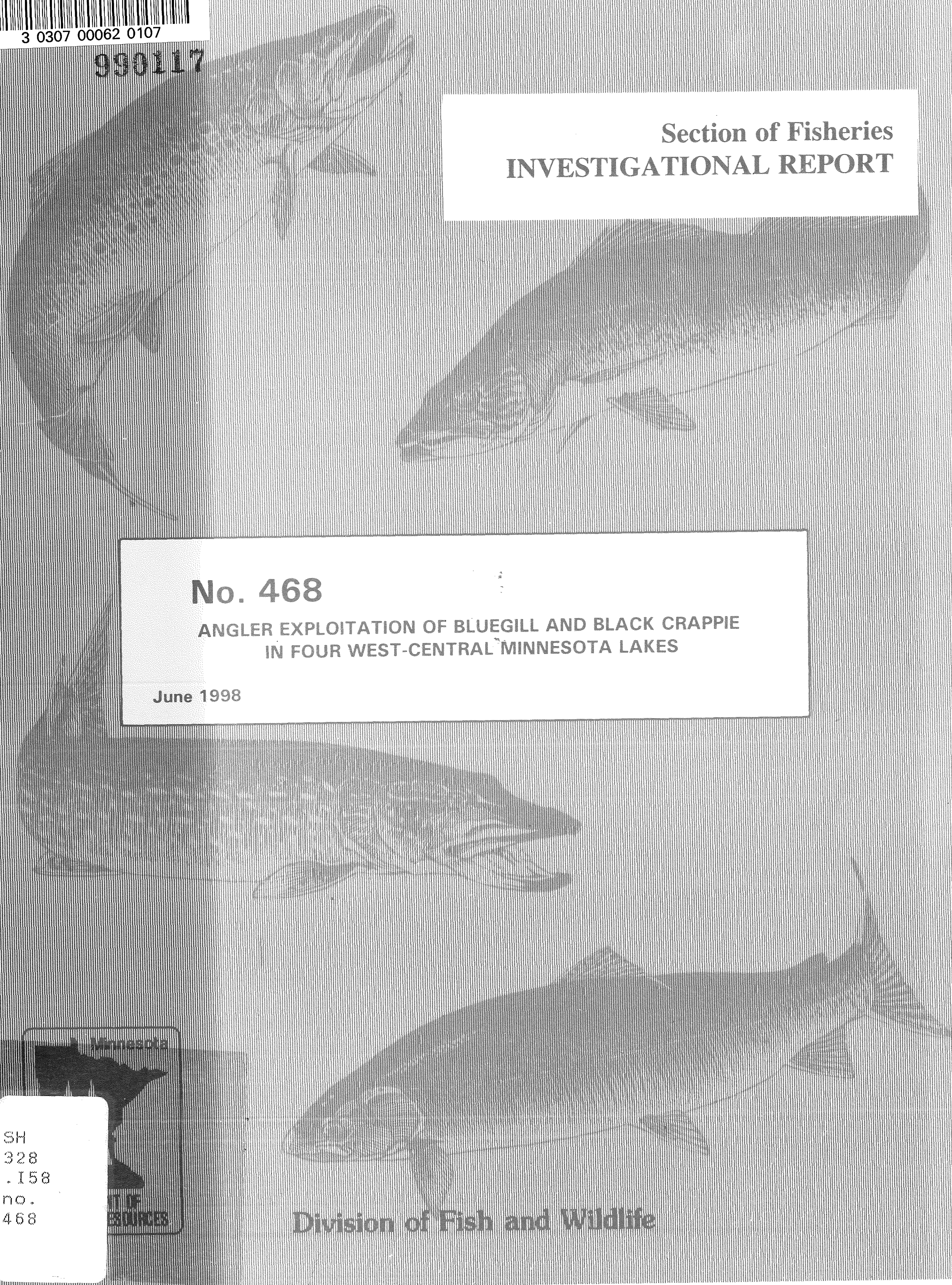

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ANGLER EXPLOITATION OF BLUEGILL AND BLACK CRAPPIE IN FOUR WEST-CENTRAL MINNESOTA LAKES

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Angler Exploitation of Bluegill and Black Crappie in Four West-Central Minnesota Lakes[1]

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Abstract. We examined angler rates of exploitation of bluegill *Lepomis macrochirus* and black crappie *Pomoxis nigromaculatus* in lakes Andrew, Le Homme Dieu, Maple, and Victoria in Douglas County, Minnesota. Bluegill ≥ 150 mm and black crappie ≥ 180 mm caught with trap nets in September and October 1993-1995 were tagged with individually numbered t-bar anchor tags. Exploitation was estimated through voluntary tag returns, and total mortality was estimated by the rate of decline in reporting of fish tagged in 1993. Tag returns were encouraged through a public information campaign and a modest reward program. Reporting rate was estimated to be 69%. Rates of exploitation of bluegill varied among lakes and years and ranged from 8% on Lake Le Homme Dieu in 1994 to 32% on Maple Lake in 1996. Rates of exploitation of black crappie were consistent across years in Lake Le Homme Dieu (26%) and Maple Lake (28%), increased from 9% in 1994 to 34% in 1996 on Lake Andrew, and declined from 33% in 1994 to 7% in 1996 on Lake Victoria. Average total annual mortality in the four lakes was 75% for bluegill and 59% for black crappie. Exploitation appeared to negatively affect the size structure of bluegill and black crappie in these lakes.

Introduction

Minnesota anglers are generally satisfied with the numbers of bluegill *Lepomis macrochirus* and black crappie *Pomoxis nigromaculatus* caught, but are often disappointed in the size structure of their catch (Minnesota Fishing Roundtable 1990; 1991; Leitch and Baltezore 1987). There is evidence that their concerns have merit. Statewide trends indicate that bluegill populations have increased while average size has decreased over the past 40 years (MN DNR, unpublished data). Numbers of trophy-sized bluegill and mean weights of all bluegill entered in a northwestern Minnesota fishing contest declined dramatically from 1970 through 1987 (Olson and Cunningham 1989). Mean weights of

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black crappie entered in the contest also declined steadily from 1950-1987. Little information is available in Minnesota for black crappie population trends because they are poorly sampled by standard lake surveys (McInerny et al. 1993).

Attempts to improve bluegill size structures in Minnesota lakes have generally focused on fish community manipulations. Goeman et al. (1990) stocked yellow perch *Perca flavescens* and walleye *Stizostedion vitreum* in four lakes, and Goeman and Spencer (1992) tried intensive removal of small northern pike *Esox lucius* and stocking of yellow perch and large northern pike. Neither study resulted in improvement of bluegill size structures or growth rates. Efforts to reduce bluegill population density, either directly with fish toxicants (Davis 1979) or indirectly through macrophyte removal (Cross et al. 1992; Olson et al. 1998), have shown some success. The benefits are, however, often short-lived, and the initial cost can be substantial. None of these efforts directly addressed angler exploitation as a factor.

Bluegill can be very vulnerable to angling. Brown and Ball (1943) reported that 24% of legal-sized (> 150 mm) bluegill were removed from Third Sister Lake, Michigan, during the first month of the new fishery. In Mid Lake, Wisconsin, another newly opened bluegill fishery, anglers harvested 13% of the bluegill > 150 mm within the first three days and 35% by the end of the third month (Goedde and Coble 1981). After this initial exploitation, Mid Lake's bluegill population resembled that of a nearby lake which had been continuously open to angling. Rates of exploitation in excess of 25% are also common in established bluegill fisheries, and combined with consistent recruitment tends to produce and maintain poor bluegill size structures (Coble 1988). Despite this information, regulations designed to reduce bluegill harvest are very rare.

Crappie populations are also vulnerable to angling. Rates of exploitation of black crappie were as high as 50% in Escanaba Lake, Wisconsin, (Kempinger et al. 1975) and 35% in Sugarloaf Lake, Michigan (Cooper and Latta 1954). Unlike bluegill, restrictive crappie regulations have been tried in the midwest and southern United States and have often succeeded (Colvin 1991; Webb and Ott 1991). Best results occur when growth is fast and natural mortality is low (Allen and Miranda 1995).

Information on bluegill and black crappie exploitation and mortality is scarce for north-temperate lakes and non-existent for Minnesota lakes. Therefore, the goal of this project was to quantify bluegill and black crappie harvest, exploitation, and growth in four west-central Minnesota lakes. This information should be useful in developing regulations designed to produce larger panfish in Minnesota.

Study Area

We selected four lakes in the Alexandria area of Douglas County in west-central Minnesota. Douglas County has a resident population of 29,000. It is also a popular tourist and resort area, which effectively doubles the population during the summer months. The study lakes were lakes Andrew, Le Homme Dieu, Maple, and Victoria (Table 1). Each lake had previous data, either from creel survey or lake survey, suggesting popular

Table 1. Physical characteristics of lakes Andrew, Le Homme Dieu (LHD), Maple, and Victoria.

	Andrew	LHD	Maple	Victoria
Area (ha)	383	706	338	170
Littoral area	134	310	190	50
Max depth(m)	25	26	22	18
Lake class	27	22	25	25

panfish fisheries. All lakes are managed for walleye with frequent stocking of fry or fingerlings. Historically, they have also received stockings of northern pike and various centrarchid species. In Minnesota's lake classification system (Schupp 1992), the lakes were in Classes 22, 25, and 27. These classes are limnologically similar and have been grouped together in other analyses (MN DNR 1996). Fish populations in these classes are characterized by walleye, northern pike, bluegill, and yellow bullhead *Ameirus natalis*. Physical characteristics of the lakes are found in Table 1.

Lake Andrew has a history of producing large bluegill and black crappie (Larson 1961a). The shoreline is moderately developed, with a single public access and two resorts. The most prominent feature of Lake Andrew is an expansive area of bulrush *Scirpus* spp. Lake Le Homme Dieu is located adjacent to the city limits of Alexandria. The entire shoreline is developed with homes, and it has two public accesses and a resort. Two small shallow bays are posted as spawning areas and closed to angling from ice-out to 30 June. Lake Le Homme Dieu is part of a chain of lakes, with navigable connections to lakes Geneva and Carlos (Figure 1). Lake Victoria is in the same chain of lakes, with navigable connections to lakes Geneva and Jessie. Lake Victoria lies partially within the city limits of Alexandria, is moderately developed with homes, and has one public access and two resorts. It is long and narrow, with sharp drop-offs and limited littoral area. Maple Lake is also moderately developed and has two resorts and two public accesses. With the exception of a large bay at the southwest end of the lake, Maple Lake has limited areas of submergent and emergent vegetation in its littoral zone.

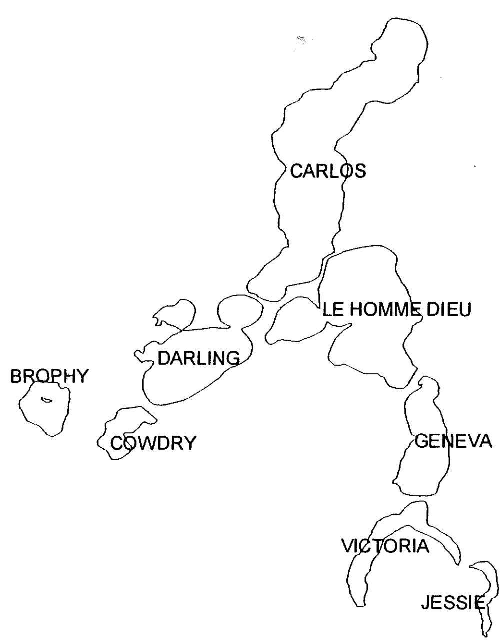


Figure 1. Locations of lakes Le Homme Dieu and Victoria in the Alexandria chain of lakes.

Methods

Bluegill and black crappie were captured with double frame, 19 mm bar mesh trap nets in September and October 1993-1995. Water temperatures during netting generally ranged between 15 and 5° C. We tagged bluegill ≥ 150 mm and black crappie ≥ 180 mm because these were sizes considered minimally acceptable to anglers. The fish were tagged with individually numbered Hallprint[2] TBF-1 fine anchor t-bar tags inserted with a Dennison[1] fine-fabric gun diagonally forward and laterally through the pterygiophores of the spinous dorsal fin. Tagging quotas were set at 4 bluegill and 2 black crappie per littoral (< 4.6 m deep) hectare for each lake. Fish that appeared stressed by the netting were not tagged. Tagged fish were released away from trap nets to discourage immediate recapture. Netting to supplement insufficient samples of black crappie tagged during fall sampling was conducted from 28 April to 6 May 1994 at lakes Le Homme Dieu and Victoria and 25-30 April 1995 on Lake Victoria.

An experiment was conducted to determine tag retention and mortality rates. Eight large (> 200 mm) bluegill were tagged and released into a 0.2 ha holding pond in October 1992. In May 1993, 40 black crappie (mean length 210 mm) and 49 bluegill (mean length 162 mm) were measured, tagged, given a lower caudal fin clip, and released into the same pond. Thirteen untagged black crappie and 54 untagged bluegill were also released to determine differential mortality between tagged and untagged fish. Dead fish were retrieved daily for one month following release and weekly after that. Dead fish were examined for tag loss and measured. In September and October 1993, the pond was trap netted to recover tagged and untagged fish. An additional experiment was conducted during normal tagging operations. Subsamples of bluegill tagged in 1993 on Lakes Andrew and Victoria and black crappie tagged in 1994 on Lake Victoria were double tagged.

Emigration of fish from lakes Le Homme Dieu and Victoria was monitored through tag returns from other lakes. The proportion of all tag returns which came from other than the source lake was considered the emigration rate.

A public information campaign was used to encourage returns of tags from anglers. Signs explaining the project, with boxes containing postage-paid tag return envelopes, were placed at public accesses. The tag return envelopes were also distributed to local bait shops and resorts. Press releases and interviews with local media were also used to increase awareness. Each angler returning tag information was sent a letter describing the project and encouraging them to report all tagged fish caught. A local sportsmen's club donated fishing jigs to be given to each angler who returned tag information, and a raffle for t-shirts and other small prizes was held at the end of each year.

The rate at which anglers reported tagged fish caught was estimated using tagged fish seen by the creel clerk. The creel clerk did not collect tags observed in the angler's catch. The percentage of tags observed by the clerk and subsequently returned voluntarily was the estimated reporting rate. This method likely yielded an optimistic reporting rate because contact by the clerk undoubtedly raised awareness of the project.

Exploitation rates were calculated from voluntary tag returns. Number of tagged fish was adjusted for tag loss and emigration, and tag returns were adjusted to compensate for non-reporting. Chi-square tests were used to determine if exploitation differed among size groups. The year was divided into eight seasons to determine seasonal exploitation patterns (Table 2).

Recaptures of tagged fish by anglers were used to estimate populations by the adjusted Peterson method (Ricker 1975). Estimated harvest was used for catch and tag returns adjusted for non-reporting were used for recaptures in the formula. Confidence

[2]Use of trade names does not imply endorsement of products.

Table 2. Seasons for study years 1994 - 1996.

Season	1994	1995	1996
Fall open-water (FOW)*		10/1 - 11/1/94	10/1-11/1/95
Early winter (EW)	12/4/93 - 1/23/94	12/10/94 - 1/20/95	12/10/95-1/19/96
Late winter (LW)	1/24 - 2/20	1/21 - 2/19	1/20 - 2/18
Late winter panfish (LWP)	2/21 - 4/5	2/20 - 3/22	2/19 - 4/15
Early open-water panfish (EOP)	4/16 - 5/13	4/20 - 5/12	Not creeled
Early Summer (ES)	5/14 - 7/4	5/13 - 7/4	5/11 - 7/4
Late Summer (LS)	7/5 - 9/5	7/5 - 9/4	7/5 - 9/2
Post Labor Day (PLD)*	9/6 - 9/30	9/5 - 9/30	9/3 -10/31

* Indicates seasons without creel surveys

intervals (95%) were calculated by treating recaptures as a Poisson variable. Estimated harvests were adjusted to account for growth by the tagged portion of the population and recruitment of young fish to tagging size. Bluegill harvests were adjusted for the proportion of bluegill ≥ 150 mm and black crappie harvests for the proportion ≥ 180 mm in the angling for most seasons. During the late open-water walleye season, bluegill harvests were adjusted for the proportion ≥ 170 mm in Lakes Andrew and Victoria and ≥ 160 mm in Lake Le Homme Dieu and Maple Lake; black crappie harvests were adjusted for the proportion ≥ 230 mm in all lakes.

Roving, incomplete trip creel surveys were conducted on each lake from formation of safe ice in early December 1993 through Labor Day 1996. Creels were not conducted from the day after Labor Day through November due to low angling effort. This period was divided into two seasons, fall open-water, when newly tagged fish were available for harvest, and post-Labor Day, when only fish tagged the previous fall were available. The creel surveys were stratified by season, time period, and day type. The creel year covered six seasons, three for ice fishing and three during open water (Table 2). Early winter was from ice formation through mid-January, and late winter was from mid-January through the close of predator fish angling in mid-February. This distinction was made because previous creel experience indicated that the species targeted by anglers began to change in mid-January. During the late winter panfish and early open-water panfish seasons, panfish were the only legal fish for anglers as per statewide Minnesota regulations. The summer was also divided into two seasons, again because angler behavior in terms of species targeted has historically been different during early and late summer.

The angling day was considered to be 12 hours during the winter. The sampling day was from 0700 to 1900 during the early and late winter periods and 0800 to 2000 during the late winter panfish period. The sampling day was divided into three periods of 4 hours each. The angling day was only 8 hours (1300 to 2100) in the early open-water panfish period because the limited length of this season did not allow one clerk to adequately sample both mornings and afternoons. We chose to sample afternoons due to previously observed patterns of angler use. The angling day was 16 hours (0600 to 2200) during the summer seasons. The sampling day was divided into four periods of 4 hours each. Day type during all seasons was separated into weekdays and weekend/holiday days.

One clerk, working 40 hours per week, covered each lake and period with equal effort. Four hours were sampled on each of two lakes per day. To reduce travel time, lakes Le Homme Dieu and Victoria were sampled on the same day, as were lakes Andrew and Maple.

In the winter, instantaneous counts were made of occupied fish houses and open ice anglers. The clerk differentiated between angling and northern pike spearing houses so spearing pressure and harvest could be calculated separately. During the open-water seasons, two instantaneous counts were made of angling boats and shore anglers during sampling on each lake. Angling pressure was calculated by version 2 of the MN DNR Gencreel program. Effort targeting bluegill and black crappie was estimated by multiplying total effort for each season by the proportion of interviews in that season where bluegill or black crappie were the species sought.

Anglers answered questions on time spent fishing, species sought, total catch, and harvest. Harvested fish were measured individually, and scales and weights were taken from a representative portion of each species harvested. Weights were used to develop a length-weight equation for each species by lake. The equations were similar among lakes, therefore, measurements were combined and a single equation for each species was developed for all lakes. Bluegill and black crappie were examined for tags or scars that could indicate potential tag loss. Harvest and release rates and total harvest were calculated for each season using version 2 of the MN DNR Gencreel program.

The number of bluegill and black crappie harvested per angler per trip was calculated from completed trip interviews. Since parties did not separate fish by angler, we assigned catch equally among the party. For example, if a party of three anglers harvested 25 bluegill, one angler was assigned a catch of 9 bluegill and two anglers were assigned a catch of 8 bluegill. We also examined the potential effects of reduced daily bag limits on harvest by truncating the number of fish per angler. Anglers who caught more than the "new" daily bag limit were assumed to have caught only the new bag limit.

Growth rates were determined from scales collected from angler-caught fish. Scales were also taken from bluegill during regularly scheduled fisheries management lake surveys conducted in 1995 on lakes Andrew and Maple and in 1996 on lakes Le Homme Dieu and Victoria. Additional black crappie scales were taken on Maple Lake during fall trap netting in 1996. Length-at-age was back-calculated using Disbcal (Frie 1982) with scale intercepts of 20 mm for bluegill and 35 mm for black crappie (Carlander 1982). Growth of tagged fish recaptured at least one full growing season after tagging was compared to the average annual growth increment for their age with the paired sample t-test. Growth of bluegill was compared to lake class medians derived by Tomcko and Pierce (1997).

Mortality rates were estimated by estimating the decline in angler CPUE during the study period of the fish tagged in the fall of 1993. Voluntary tag returns for the year adjusted for non-reporting (catch) were divided by the total annual amount of angling effort. The CPUE's this generated were transformed by natural log, yielding a line similar to the descending limb of a catch curve (Ricker 1975). The slope of this regression line was the estimate of instantaneous total mortality (Z) for each species in each lake. Total annual mortality (A) was calculated as ($A = 1\text{-}e^{-Z}$). Exploitation (μ) calculated from adjusted voluntary tag returns was subtracted from A, yielding an estimate of natural mortality (ν). Since we used tagged fish to estimate mortality rates, differential growth rates among lakes led to mortality estimates for different age ranges. Bluegill mortality rates were estimated for ages 5-8 in Lake Andrew, 5-9 in Lake Victoria, 6-9 in Lake Le Homme Dieu, and 6-8 in Maple Lake. Black crappie mortality rates were estimated for ages 3-7 in Lake Andrew, 3-8 in Lake Victoria, and 3-6 in Lake Le Homme Dieu and Maple Lake.

Linear regression models were used to determine the relationship between harvest and exploitation. Harvest in number of fish per ha was the dependent variable, and adjusted exploitation rate was the independent variable. Models were developed for both species using all lakes together, for individual lakes, and for combinations of lakes. Models were also developed to determine the relationship between angling effort directed at bluegill and exploitation rate.

We used chi-square tests to determine if exploitation was related to size of fish at tagging. Twenty-five mm length groups were used for bluegill and 50 mm groups were used for black crappie. The exception was for black crappie under 200 mm since only fish ≥ 180 mm were tagged.

Results

Growth

Bluegill growth rates varied among lakes (Table 3). Growth was very slow in lakes Le Homme Dieu and Maple, where bluegill did not reach 150 mm until after age 6 and 200 mm until age 9 or 10. Bluegill in these lakes were also below the median for their lake class until approximately age 8 (Tomcko and Pierce 1997). Growth was faster in lakes Andrew and Victoria. Lake Andrew bluegill exceeded Class 27 medians by age 4, reached minimum tagging size of 150 mm by age 5 and 200 mm by age 7. Bluegill in Lake Victoria reached 146 mm and the Class 25 median by age 5. Growth slowed after age 5, and 200 mm was not approached until age 8.

Black crappie growth also differed among lakes (Table 3). In Lake Andrew,

Table 3. Mean back-calculated length at age of bluegill and black crappie from lakes Andrew, Le Homme Dieu, Maple, and Victoria. Samples are from winter and summer creel surveys 1994 - 1996 and from lake surveys on lakes Andrew and Maple in 1995 and lakes Le Homme Dieu and Victoria in 1996. Numbers of fish are in parenthesis. Lake class median back-calculated length at age is also included for bluegill (Tomcko and Pierce 1997).

Lake	1	2	3	4	5	6	7	8	9	10	11
					Bluegill						
Andrew	35 (212)	56 (212)	83 (212)	119 (212)	155 (195)	182 (118)	200 (51)	213 (14)	233 (2)	258 (1)	
LeHDieu	32 (101)	45 (101)	63 (101)	90 (101)	121 (101)	148 (94)	168 (79)	179 (39)	189 (8)	204 (1)	212 (1)
Maple	33 (164)	48 (164)	66 (164)	88 (164)	115 (160)	141 (144)	161 (92)	176 (21)	200 (4)	264 (1)	267 (1)
Victoria	34 (99)	56 (99)	85 (99)	119 (99)	149 (91)	171 (83)	186 (64)	196 (38)	213 (8)	216 (1)	
Class 22	40	64	89	118	148	162	176	185	194	199	185
Class 25	41	68	96	125	146	163	170	180	179	185	189
Class 27	40	64	90	120	147	161	176	189	198	204	211
					Black Crappie						
Andrew	59 (66)	118 (66)	194 (65)	245 (63)	278 (48)	302 (33)	321 (12)	331 (3)			
LeHDieu	59 (85)	106 (85)	172 (83)	228 (69)	259 (23)	278 (6)	300 (1)				
Maple	60 (298)	114 (272)	174 (145)	215 (80)	257 (53)	287 (11)	301 (4)				
Victoria	63 (117)	120 (117)	182 (92)	222 (81)	246 (75)	267 (63)	286 (30)	298 (10)	305 (3)		

growth was fast at all ages, and fish reached 300 mm at age 6. Growth slowed considerably after age 3 in Lake Victoria, so 300 mm was not approached until age 8. Growth in lakes Le Homme Dieu and Maple was slow at early ages, but accelerated after age 3. Consequently, 300 mm was reached at age 7.

Tagging appeared to have some effect on growth. The majority of recaptured bluegill came from lakes Andrew and Le Homme Dieu. There was no significant difference in growth of tagged bluegill in Lake Le Homme Dieu, but tagged bluegill grew significantly slower than average in Lake Andrew ($P = 0.0159$) and for all four lakes combined ($P = 0.0111$). Most recaptured black crappie came from lakes Andrew and Maple, and there was no significant difference in growth for either of these lakes or all four lakes combined. The magnitude of the differences was generally small, ranging from +17 mm to -14 mm for black crappie and +14 mm to -11 mm for bluegill. It is unlikely that growth of either species was affected to the point of biasing the exploitation results.

Tag Retention and Mortality

The pond experiment showed similar mortality between tagged (35%) and untagged (46%) bluegill and a tag retention rate of 97%. Thirty-four dead bluegill, 16 of which had been tagged, were recovered during the first month in the pond. Eleven bluegill were found dead during the second month following tagging; four of these had been tagged. None of the recovered dead bluegill had lost a tag. Fall trap netting in the pond recovered 27 bluegill (17 tagged, 1 lost tag, and 9 untagged) released the previous May. Four bluegill tagged in the fall of 1992 were also recaptured with no tag loss.

It is difficult to say whether tagging caused mortality of black crappie because few (13) "control" fish existed. Ten of the 53 black crappie released were recovered during the first month in the pond. All found dead had been tagged, but one had lost its tag. No dead black crappie were observed after the first month of monitoring. Fall trap netting caught 15 black crappie (14 tagged, 1 untagged). Since 25% of the black crappie released in the pond were untagged, we would expect that about four untagged fish should have been recaptured. Therefore, mortality of the untagged fish was at least as high as tagged fish. Black crappie tag retention was 96%.

Ten bluegill which had been double-tagged were reported caught by anglers, and all had retained both tags. Five of six double-tagged black crappie reported by anglers retained both tags. This yields a 93% tag retention rate for both species combined. Since this was the lowest retention rate, it was used to adjust number of tagged fish for tag loss throughout this report.

Emigration

Emigration of tagged fish from lakes Le Homme Dieu and Victoria was common. Twenty-six percent of tag returns from bluegill tagged in Lake Le Homme Dieu in 1993 came from other lakes (Table 4; Figure 1). This declined to 4% and 6% in 1994 and 1995, leading to a significant difference among years ($P < 0.001$). Returns of Lake Le Homme Dieu black crappie tags from non-source lakes were also highest (11%) in 1993. No tags from black crappie tagged in 1994 came from other lakes, while 8% of those tagged in 1995 did. The difference among years was not significant for black crappie.

Emigration of tagged fish from Lake Victoria was very apparent in 1996. Sixteen of the 44 bluegill tags (36%) and 10 of 11 black crappie tags (92%) reported in 1996 were harvested from lakes other than Victoria, primarily Lake Jessie (Table 4; Figure 1). Numbers were substantially lower for the 1993 and 1994 taggings, so there was a significant difference among years ($P < 0.0001$).

These numbers represent the best available estimates of emigration of tagged fish from lakes Le Homme Dieu and Victoria. Therefore, when we calculated exploitation rates, the number of fish tagged in any given year was reduced by the proportion which

Table 4. Tag returns from bluegill and black crappie tagged in lakes Le Homme Dieu (LHD), Victoria (VIC), and from other lakes in the Alexandria chain of lakes.

Source Lake	Tag Year	LHD	Brophy	Carlos	Darling	Geneva	Jessie	Victoria	%non-source
					Bluegill				
LHD	1993	51	0	1	0	16	0	1	26%
LHD	1994	158	0	2	0	5	0	0	4%
LHD	1995	130	1	4	0	3	0	0	6%
LHD	All	339	1	7	0	24	0	1	9%
VIC	1993	0	0	0	0	0	3	42	7%
VIC	1994	0	0	0	0	0	2	60	3%
VIC	1995	0	0	0	0	1	15	28	36%
VIC	All	0	0	0	0	1	20	130	14%
					Black Crappie				
LHD	1993	24	0	1	0	2	0	0	11%
LHD	1994	30	0	0	0	0	0	0	0%
LHD	1995	72	0	0	2	4	0	0	8%
LHD	All	126	0	1	2	6	0	0	7%
VIC	1993	0	0	0	0	0	1	34	3%
VIC	1994	0	0	0	0	0	5	23	18%
VIC	1995	1	0	0	0	2	8	1	92%
VIC	All	1	0	0	0	2	14	58	23%

moved into other lakes by year (Table 4). Since no tags from fish tagged in Lakes Andrew or Maple were reported from other lakes, emigration was considered to be zero.

Reporting Rate

Too few tags were observed by the clerk to make meaningful estimates of reporting rate for individual lakes, so the lakes were pooled for this analysis. There were minor differences among years and between species in the proportion of tags observed by the clerk which were subsequently reported. In the 1994 creel survey, 28 of 38 (74%) tags were reported, 10 of 16 (63%) in 1995, and 9 of 14 (64%) in 1996. A chi-square test indicated these differences were not significant ($P > 0.05$). Although black crappie tags were returned at a slightly higher rate (23 of 30, 77%) than bluegill tags (24 of 38, 63%), the difference was also not significant. Therefore, all years and both species were pooled to yield a reporting rate of 69% (47 of 68 reported) which we used for both species for the entire study. Since contact by the clerk undoubtedly raised awareness of the project, this must be considered a maximum reporting rate.

Bluegill

Lake Andrew - At least 477 bluegill were tagged each year (Table 5). The mean length and size structure of tagged bluegill increased each year (Figure 2). The modal length group of tagged bluegill increased from 160 mm in 1993 to 180 mm in 1995. By 1995, over 60% of bluegill tagged were 180 mm or longer, and 20% were 200 mm or longer. This appeared to be the result of a strong, fast growing 1989 year class.

Bluegill exploitation, harvest, and targeted effort showed similar yearly patterns. Rate of exploitation was around 25% in both 1994 and 1995 but dropped to 9% in 1996 due to a low rate for fish < 200 mm (Table 6). Harvest was about 30 fish/ha and mean length was 175 mm in 1994 and 1995, but in 1996

Table 5. Numbers of bluegill tagged in relation to tagging quotas, and minimum, maximum, and mean length with standard error of tagged fish in lakes Andrew, Le Homme Dieu, Maple, and Victoria, fall 1993 and 1994.

	Andrew			Le Homme Dieu		
	1993	1994	1995	1993	1994	1995
Quota	536	536	536	1,240	1,240	1,240
Number	612	477	540	1,113	1,373	1,221
% Quota	114	89	101	90	111	99
Minimum	150	150	150	150	150	150
Maximum	246	227	239	228	208	215
Mean	174	176	185	169	167	170
SE	0.7	0.7	0.8	0.3	0.3	0.4
	Maple			Victoria		
	1993	1994	1995	1993	1994	1995
Quota	758	758	758	200	200	200
Number	85	102	385	232	283	339
% Quota	11	13	51	116	142	170
Minimum	150	150	150	150	150	150
Maximum	201	216	197	216	233	228
Mean	161	159	162	174	169	168
SE	1.0	1.1	0.5	0.9	0.8	0.7

harvest dropped to 12 fish/ha while mean length increased to 190 mm (Table 7). The percent of total effort directed toward bluegill also fell in 1996 (Table 8). The summer seasons dominated tag returns (Table 9) and harvest. Harvest rates, however, were generally higher in the winter seasons (Table 10), but very low effort limited the number harvested.

Lake Le Homme Dieu - Numbers and mean lengths of bluegill tagged were similar among years (Table 5). There was little change in the length distribution of tagged fish, but bluegill ≥ 180 mm comprised 25% of fish tagged in 1995 compared to about 15% in 1993 and 1994 (Figure 2). This was also due to growth of the 1989 year class. Very few bluegill ≥ 200 mm were tagged in any year.

Bluegill exploitation and harvest increased each year of the study. Exploitation increased from 7% in 1994 to 16% in 1996 (Table 6), and harvest rose from 20/ha in 1994 to 50/ha in 1996 (Table 7). Mean length of a harvested bluegill was also highest in 1996. Effort directed at bluegill was also highest in 1996, increasing from 19% of total effort in 1994-1995 to 33% in 1996 (Table 8). Winter angling was a large component of the Lake Le Homme Dieu bluegill fishery, providing 45%, 22%, and 60% of total harvest in 1994, 1995, and 1996, respectively. Harvest was highest in the late winter panfish season in 1994 and 1996. Nearly one-half of the tag returns in those years were from that period (Table 9). The season was unusually long in 1996 because ice cover remained until mid-April, and 44% of the 1996 bluegill harvest occurred during this season. Harvest rates were generally similar between winter and open-water anglers (Table 10).

Maple Lake - Very few bluegill were tagged in 1993 and 1994 (Table 5). Considerably more were tagged in 1995 because the 1989 year class finally reached tagging size (150 mm). Mean length of tagged bluegill was consistently small (159-162 mm), and the 150

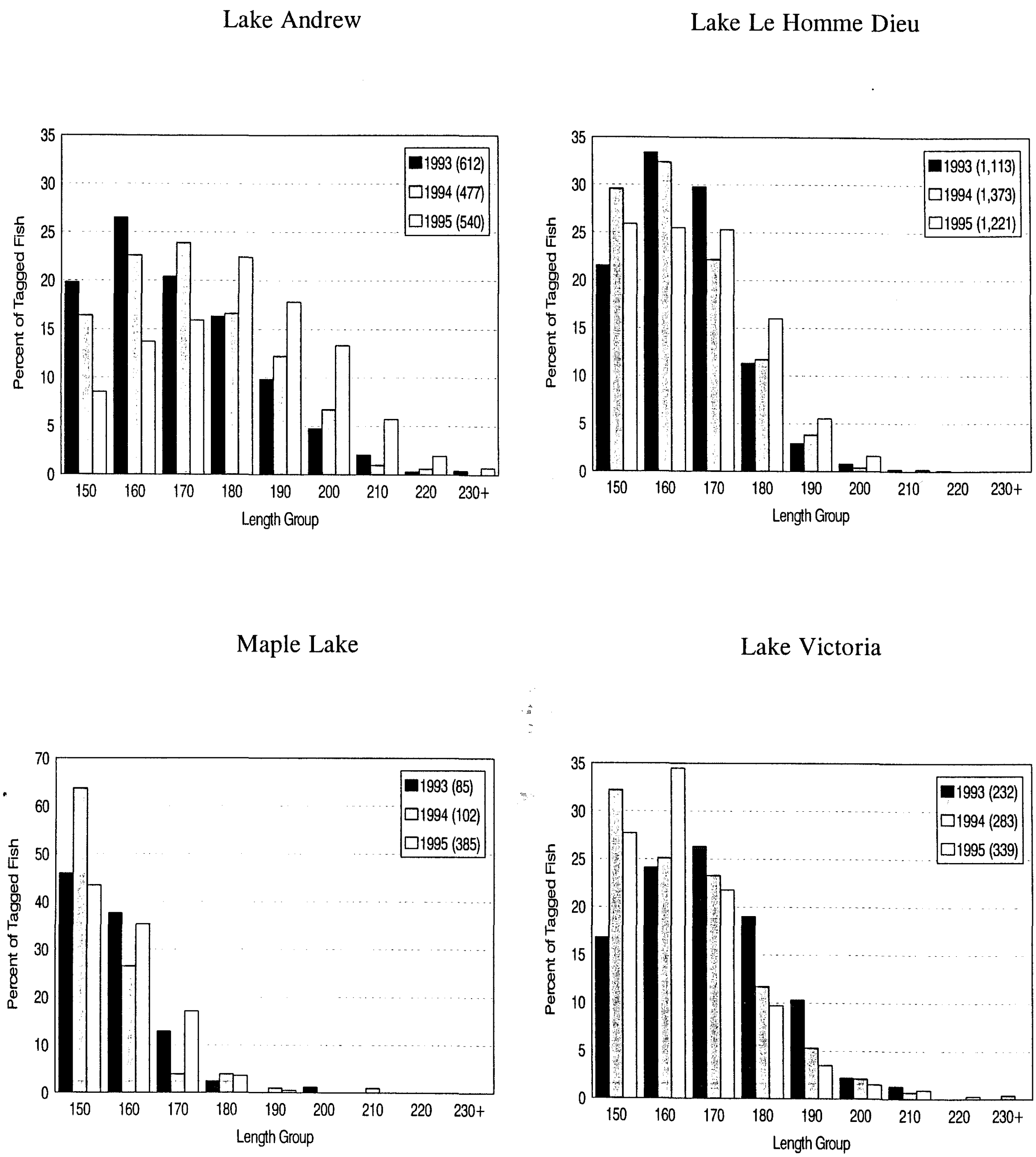


Figure 2. Length distributions of tagged bluegill by 10 mm length group (ie 170 indicates fish 170-179 mm) from lakes Andrew, Le Homme Dieu, Maple, and Victoria, 1993-1995. Number of fish tagged each year is shown in the legend.

Table 6. Adjusted rates of exploitation of bluegill by length group (mm) on lakes Andrew, Le Homme Dieu, Maple, and Victoria. Number of fish tagged was adjusted for tagging mortality and emigration. Number of tags returned was adjusted for non-reporting.

Group	Tag	Ret	μ	Tag	Ret	μ	Tag	Ret	μ	Tag	Ret	μ
						Andrew						
	1994			1995			1996			All years combined		
150-174	327	83	25.4	225	74	32.9	153	7	4.6	735	164	22.3
175-199	201	57	28.4	181	46	25.4	240	23	9.6	622	126	20.3
200-224	39	13	33.3	35	10	28.6	103	20	19.4	177	43	24.3
225+	4	0	-	2	0	-	6	1	16.7	12	1	8.3
All	571	153	26.8	443	130	29.3	502	51	10.2	1,546	334	21.6
						Le Homme Dieu						
	1994			1995			1996			All years combined		
150-174	539	36	6.7	906	104	11.5	675	83	12.3	2,120	223	10.5
175-199	199	23	11.6	312	61	19.6	367	101	27.5	878	185	21.1
200-224	7	0	-	4	0	-	20	4	20.0	31	4	12.9
225+	1	0	-	0		-	0		-	1	0	0.0
All	745	59	7.9	1,218	165	13.5	1,062	188	17.7	3,025	412	13.6
						Maple						
	1994			1995			1996			All years combined		
150-174	75	13	17.3	86	17	19.8	321	100	31.2	482	130	27.0
175-199	4	0	-	7	0	-	37	14	37.8	48	14	29.2
200-224	1	1	100	1	0	-	0		-	2	1	50.0
225+	0		-	0		-	0		-	0		-
All	80	14	17.5	94	17	18.1	358	114	31.8	532	145	27.3
						Victoria						
	1994			1995			1996			All years combined		
150-174	113	29	25.7	172	48	27.9	145	25	17.2	430	102	23.7
175-199	80	29	36.3	77	23	29.9	43	14	32.6	200	66	33.3
200-224	7	0	-	7	6	85.7	5	0	-	19	6	31.6
225+	0		-	1	0	-	1	0	-	2	0	0.0
All	200	52	29.0	257	77	30.0	194	39	20.0	651	174	26.7

mm length group was the mode in each year of tagging (Figure 2). Only one fish in 1993 and one in 1994 exceeded 200 mm, and the 190 mm length group was also rare.

Bluegill harvest and exploitation followed a similar pattern. In 1994 and 1995, harvest was 11/ha (Table 7) and rate of exploitation was 17% (Table 6). In 1996, harvest more than doubled (25/ha), rate of exploitation increased to 29%, and bluegill anglers accounted for 17% of total effort (Table 8). The majority of tag returns in 1996 came from the late winter panfish season (Table 9). Despite low angling effort (Table 8), 38% of the harvest occurred in this season due to a harvest rate by bluegill anglers of over 7/hr (Table 10).

Lake Victoria - At least 230 bluegill were tagged each year (Table 5). Mean length and size distribution of tagged bluegill were largest in 1993 (Figure 2), but recruitment of the 1989 year class led to modal length groups of 150 and 160 mm in 1994 and 1995. Large bluegill did occur in Lake Victoria; fish ≥ 200 mm comprised about 4% of tagged bluegill each year.

Rate of exploitation (26%) (Table 6) and harvest (65/ha) (Table 7) were similar in 1994 and 1995. In 1996, however, harvest was considerably lower (19/ha) and rate of exploitation also fell to 18%. The early summer season was responsible for most of the decline; estimated harvest was only 720 bluegill in 1996

Table 7. Estimated harvest (SE) and mean length of the observed harvest of bluegill by creel survey season and for the entire creel year from lakes Andrew, Le Homme Dieu, Maple, and Victoria.

	1994			1995			1996		
Season	Number	kg	Length	Number	kg	Length	Number	kg	Length
				Lake Andrew					
EW	371 (240)	45 (29)	176 (2)	1,420 (540)	205 (158)	183 (2)	95 (106)	16 (8)	192 (-)
LW	88 (70)	1 (9)	174 (4)	524 (209)	59 (47)	174 (2)	0	0	
LWP	0	0		163 (114)	20 (19)	180 (2)	598 (408)	107 (-)	194 (8)
EOP	0	0		27 (27)	4 (4)	188 (28)	Not creeled		
ES	2,776 (1,194)	386 (268)	179 (1)	499 (346)	52 (70)	174 (3)	72 (73)	15 (16)	206 (-)
LS	7,901 (2,784)	1,093 (658)	181 (1)	10,249 (2,884)	1,190 (802)	173 (1)	3,934 (2,663)	630 (701)	189 (3)
All	11,136 (3,040)	1,534 (711)	175 (2)	12,882 (2,950)	1,581 (864)	174 (2)	4,512 (2,697)	738 (708)	190 (2)
Per ha	29.1	4.01		33.6	4.13		11.8	1.93	
				Lake Le Homme Dieu					
EW	125 (84)	12 (8)	167 (3)	1,243 (638)	139 (132)	180 (2)	4,704 (2,510)	591 (-)	179 (2)
LW	770 (278)	74 (27)	168 (1)	961 (384)	100 (83)	171 (1)	899 (542)	120 (-)	176 (1)
LWP	5,462 (853)	498 (77)	165 (1)	1,876 (916)	195 (156)	171 (1)	15,716 (5,760)	1,932 (1,471)	176 (1)
EOP	288 (202)	31 (23)	175 (2)	0	0		Not creeled		
ES	5,189 (1,965)	587 (344)	172 (1)	4,870 (2,384)	521 (422)	172 (2)	5,191 (2,627)	702 (515)	181 (2)
LS	2,280 (848)	266 (195)	172 (2)	9,778 (3,530)	1,090 (640)	171 (1)	8,841 (4,201)	1,231 (1,163)	182 (1)
All	14,113 (2,331)	1,468 (405)	170 (1)	18,728 (4,415)	2,044 (802)	172 (1)	35,481 (8,060)	4,594 (1,969)	178 (1)
Per ha	20.0	2.08		26.5	2.90		50.3	6.51	
				Maple Lake					
EW	563 (357)	36 (21)	151 (2)	233 (183)	17 (15)	150 (2)	0	0	
LW	0	0		0	0		432 (282)	41 (35)	165 (2)
LWP	153 (81)	14 (7)	159 (2)	0	0		3,202 (1,320)	311 (249)	165 (1)
EOP	0	0		0	0		Not creeled		
ES	1,017 (466)	91 (60)	156 (3)	736 (285)	73 (67)	167 (2)	1,815 (1,388)	181 (298)	166 (2)
LS	2,021 (788)	177 (115)	159 (1)	2,850 (1,213)	277 (224)	164 (2)	3,166 (1,369)	328 (285)	167 (1)
All	3,754 (984)	319 (131)	156 (2)	3,793 (1,170)	368 (182)	164 (2)	8,501 (2,289)	849 (389)	166 (1)
Per ha	11.1	0.94		11.2	1.09		25.2	2.51	
				Lake Victoria					
EW	325 (237)	38 (28)	175 (2)	91 (108)	14 (15)	190 (4)	0	0	
LW	641 (248)	95 (38)	185 (2)	102 (45)	16 (11)	189 (5)	0	0	
LWP	356 (241)	42 (27)	176 (2)	311 (326)	48 (59)	191 (3)	497 (372)	67 (53)	180 (5)
EOP	56 (62)	7 (7)	182 (3)	0	0		Not creeled		
ES	4,779 (1,174)	651 (275)	179 (1)	5,871 (571)	680 (353)	173 (1)	683 (284)	92 (97)	180 (2)
LS	4,663 (1,508)	637 (396)	181 (1)	4,591 (1,304)	588 (330)	179 (1)	1,969 (735)	264 (207)	180 (1)
All	10,820 (1,974)	1,470 (485)	181 (1)	11,052 (2,392)	1,355 (493)	176 (1)	3,186 (870)	428 (235)	180 (2)
Per ha	63.6	8.65		65.0	7.97		18.7	2.52	

Table 8. Estimated angling effort (SE) by creel season (see Table 2) and the entire creel year on Lakes Andrew, Le Homme Dieu, Maple, and Victoria. Also included are the hours and percent of total effort for anglers who indicated they were seeking bluegill (BLG) or black crappie (BLC).

Season	Andrew 1994		Andrew 1995		Andrew 1996		Le Homme Dieu 1994		Le Homme Dieu 1995		Le Homme Dieu 1996	
EW	662	(422)	2,500	(458)	731	(352)	4,097	(1,531)	13,262	(3,503)	11,209	(3,484)
LW	167	(111)	937	(343)	168	(168)	861	(270)	3,956	(1,351)	1,260	(425)
LWP	21	(6)	1,071	(730)	439	(265)	2,745	(1,315)	901	(356)	3,909	(1,145)
EOP	0		788	(511)	NA		2,418	(1,163)	703	(465)	NA	
ES	12,763	(2,164)	10,477	(1,755)	10,756	(1,969)	15,590	(3,775)	16,063	(2,363)	11,616	(1,763)
LS	13,819	(1,745)	15,138	(2,310)	9,429	(1,897)	12,542	(1,936)	16,448	(3,166)	9,391	(1,435)
Total	27,432	(2,814)	30,911	(3,088)	21,532	(2,775)	38,253	(4,847)	51,333	(5,481)	37,385	(4,336)
Hr/Ha	71.6		80.7		56.2		54.2		72.7		53.0	
BLG	6,888	(25%)	9,505	(31%)	3,040	(14%)	7,262	(19%)	9,522	(19%)	12,291	(33%)
BLC	2,949	(11%)	2,443	(8%)	940	(4%)	6,107	(16%)	4,198	(8%)	3,656	(10%)

Season	Maple 1994		Maple 1995		Maple 1996		Victoria 1994		Victoria 1995		Victoria 1996	
EW	1,365	(804)	1,895	(599)	1,365	(626)	1,284	(323)	1,790	(553)	3,095	(1,148)
LW	112	(122)	362	(109)	123	(74)	1,006	(816)	786	(182)	360	(148)
LWP	741	(475)	0		502	(156)	1,908	(1,188)	644	(281)	877	(493)
EOP	140	(61)	208	(94)	NA		832	(319)	543	(308)	NA	
ES	10,058	(1,556)	9,777	(1,205)	9,689	(1,915)	15,092	(2,127)	10,040	(1,691)	9,240	(1,642)
LS	8,157	(1,236)	10,796	(1,452)	6,397	(1,135)	11,015	(1,724)	6,992	(1,120)	5,419	(691)
Total	20,573	(2,257)	23,039	(1,986)	18,076	(2,319)	31,137	(3,192)	20,795	(2,151)	18,991	(2,181)
Hr/Ha	60.9		68.2		53.5		183.2		122.3		111.7	
BLG	2,079	(10%)	1,463	(6%)	3,013	(17%)	10,564	(34%)	8,855	(43%)	4,674	(25%)
BLC	2,831	(14%)	1,615	(7%)	228	(1%)	7,972	(26%)	3,199	(15%)	1,926	(10%)

Table 9. Voluntary tag returns by creel survey season during creel years 1994-1996 and minimum exploitation rates based on voluntary tag returns for bluegill from lakes Andrew, Le Homme Dieu, Maple, and Victoria.

Bluegill

	Andrew			Le Homme Dieu			Maple			Victoria		
	94	95	96	94	95	96	94	95	96	94	95	96
FOW	0	0	0	0	12	1	0	0	0	0	0	0
EW	4	14	9	0	2	9	1	0	1	1	7	0
LW	0	5	0	4	5	14	0	0	1	6	1	2
LWP	0	3	4	19	9	60	2	0	35	2	3	6
EOP	0	0	0	0	2	0	0	0	0	0	0	0
ES	33	19	6	8	18	19	4	10	19	13	13	2
LS	68	49	14	10	66	20	3	2	22	18	29	17
PLD	0	1	3	0	0	7	0	0	1	1	0	0
Expl.	17.1	18.9	6.7	3.7	8.2	10.6	11.6	11.8	20.8	17.2	18.4	8.0

Black crappie

	Andrew			Le Homme Dieu			Maple			Victoria		
	94	95	96	94	95	96	94	95	96	94	95	96
FOW	0	0	0	0	10	3	0	0	0	0	0	0
EW	2	1	0	0	2	6	4	5	2	0	1	0
LW	0	0	0	0	3	0	0	0	0	0	0	0
LWP	0	5	2	1	3	17	23	2	26	0	3	0
EOP	0	0	0	3	0	7	0	1	0	0	0	0
ES	9	0	4	7	3	11	12	2	12	13	2	1
LS	7	3	18	4	5	16	7	6	6	10	11	0
PLD	0	0	0	4	0	12	0	1	0	0	0	0
Expl.	6.0	14.8	23.1	14.3	16.1	15.6	18.2	18.5	24.5	20.2	11.9	0.8

compared to 5,000 in 1994 and 1995 (Table 9). Bluegill catch rates in Lake Victoria differed from the other three lakes. Harvest rate by bluegill anglers never exceeded 2/hr (Table 10). Despite the relatively low success, bluegill anglers accounted for a higher proportion of total effort in Lake Victoria, ranging from 43% in 1995 to 25% in 1996 (Table 8).

Black Crappie

Lake Andrew - Over 300 black crappie were tagged in 1993, but numbers were considerably lower in following years (Table 11). The 1989 year class dominated throughout the study. Therefore, the modal length group increased from 260 mm in 1993 to 300 mm in 1995 (Figure 3). Very large black crappie were also present in Lake Andrew; fish ≥ 340 mm comprised over 5% of tagged black crappie in 1994 and 1995.

Rates of exploitation increased each year of the study from 9% in 1994 to 32% in 1996 (Table 12). In 1996, 75% of tag returns occurred during the late summer season (Table 9). Harvest was consistently low (1.6-2.2/ha), but mean length increased each year to 309 mm in 1996 (Table 13). Contrary to increased rates of exploitation, the proportion of effort directed toward black crappie declined each year from 11% in 1994 to 4% in 1996 (Table 8). Black crappie angling was primarily confined to the summer seasons, and harvest rates > 0.5/hr were common (Table 14).

Lake Le Homme Dieu - Only 37 black crappie were tagged in the fall of 1993, so spring netting was conducted in 1994. Fall netting was somewhat more successful in 1994

Table 10. Harvest and release rates expressed as fish per angler hour (SE) by creel survey season for anglers seeking bluegill on lakes Andrew, Le Homme Dieu, Maple, and Victoria. NA indicates no anglers sought bluegill in that season; (-) indicates insufficient interviews to calculate a standard error.

	1994				1995				1996			
Season	Harvest		Release		Harvest		Release		Harvest		Release	
Lake Andrew												
EW	5.647	(0.222)	8.235	(0.320)	2.211	(1.036)	1.108	(0.540)	1.075	(-)	0.922	(-)
LW	3.429	(0.112)	7.347	(1.295)	2.366	(0.326)	2.184	(0.071)	NA			
LWP	NA		NA		0.263	(0.231)	1.699	(1.320)	2.488	(1.259)	1.791	(0.740)
EOP	NA		NA		0.571	(-)	0.000	(-)	Not Creeled			
ES	1.299	(0.352)	1.516	(0.403)	0.136	(0.124)	0.333	(0.152)	0.000	(0.000)	0.275	(0.174)
LS	1.388	(0.398)	1.575	(0.338)	1.229	(0.235)	0.995	(0.165)	1.504	(0.691)	1.095	(0.305)
Lake Le Homme Dieu												
EW	1.424	(0.359)	2.644	(0.844)	0.967	(0.185)	3.147	(0.567)	1.347	(0.610)	1.785	(0.500)
LW	2.525	(0.333)	7.639	(1.377)	0.932	(0.208)	3.523	(1.239)	1.907	(0.816)	3.982	(1.071)
LWP	2.503	(0.118)	5.431	(0.206)	2.851	(0.624)	9.210	(2.346)	4.205	(0.791)	6.655	(0.936)
EOP	0.691	(0.000)	0.922	(0.000)	NA		NA		Not creeled			
ES	2.248	(0.730)	4.960	(0.564)	3.108	(0.133)	3.738	(0.956)	2.019	(0.722)	4.338	(1.330)
LS	1.033	(0.492)	4.443	(0.546)	2.714	(0.743)	2.151	(0.615)	2.752	(1.122)	3.060	(0.453)
Maple Lake												
EW	1.261	(0.123)	0.505	(0.051)	1.687	(1.988)	0.843	(0.526)	NA		NA	
LW	NA		NA		0.000	(0.000)	0.000	(0.000)	5.288	(-)	4.461	(-)
LWP	1.055	(0.458)	0.264	(0.131)	NA		NA		7.197	(2.591)	10.301	(1.937)
EOP	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	Not creeled			
ES	1.462	(1.062)	2.911	(0.297)	0.935	(0.502)	1.447	(0.760)	1.435	(0.759)	2.777	(1.213)
LS	0.894	(0.241)	3.942	(1.642)	1.184	(0.304)	2.969	(0.847)	2.248	(1.192)	4.882	(1.257)
Lake Victoria												
EW	1.979	(0.328)	1.263	(0.193)	0.359	(0.338)	0.518	(0.480)	0.000	(-)	0.000	(-)
LW	1.665	(0.271)	2.325	(0.677)	0.294	(0.228)	0.862	(0.545)	0.000	(-)	6.000	(-)
LWP	0.947	(0.308)	0.434	(0.105)	1.149	(1.264)	0.843	(0.874)	0.972	(0.510)	1.467	(0.698)
EOP	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	Not creeled			
ES	0.791	(0.135)	0.933	(0.187)	1.187	(0.314)	1.084	(0.231)	0.273	(0.110)	1.040	(0.394)
LS	0.891	(0.285)	1.885	(0.375)	0.778	(0.147)	1.498	(0.487)	1.192	(0.702)	2.745	(1.175)

Table 11. Numbers of black crappie tagged in relation to tagging quotas, and minimum, maximum, and mean length with standard error of tagged fish in lakes Andrew, Le Homme Dieu, Maple, and Victoria, fall 1993 and 1994. Fish tagged in Le Homme Dieu and Victoria in 1993 includes fish tagged in the spring of 1994. Fish tagged in Victoria in 1994 includes fish tagged in the spring of 1995.

	Andrew			Le Homme Dieu		
	1993	1994	1995	1993	1994	1995
Quota	268	268	268	620	620	620
Number	302	61	104	133	155	462
% of Quota	113	23	39	21	25	75
Minimum	180	180	184	180	181	181
Maximum	352	346	368	330	303	317
Mean	262	283	289	243	237	222
SE	2.1	5.0	3.6	2.7	1.9	1.1

	Maple			Victoria		
	1993	1994	1995	1993	1994	1995
Quota	379	379	379	100	100	100
Number	253	92	263	114	147	153
% of Quota	67	24	69	114	147	153
Minimum	180	180	180	180	182	180
Maximum	286	298	317	306	315	311
Mean	235	243	225	252	268	220
SE	1.5	3.2	2.0	1.5	2.0	2.4

(155 tagged) due to recruitment of a moderate 1991 year class. A strong 1992 year class led to successful 1995 netting, and 462 fish were tagged (Table 11). Tagged black crappie were consistently smaller than the other lakes with modes of 200 or 220 mm length groups each year (Figure 3). Very few fish ≥ 300 mm were tagged.

Rates of exploitation, harvest, and mean lengths were very consistent among years. Exploitation was 23% or 24% each year (Table 12), harvest ranged from 1.8 to 2.5/ha, and mean length ranged from 232 to 239 mm (Table 13). Directed angling effort was also relatively stable, ranging from 8% in 1995 to 16% in 1994 (Table 8).

Maple Lake - Over 250 black crappie were tagged in 1993 and 1995, but only 92 were tagged in 1994 (Table 11). The 1989 year class provided most of the fish in 1993, while the 1992 year class was responsible for the majority of the fish tagged in 1995. This recruitment pattern caused the modal length group of tagged fish to drop from 240 mm in 1993 and 1994 to 200 mm in 1995 (Figure 3). Large black crappie were very rare, with only 3 fish ≥ 300 mm caught in 1995.

Although rates of exploitation were consistently 25-27% (Table 12), harvest declined from 4.2/ha in 1994 to 0.6/ha in 1996 (Table 13). The low harvest in 1996 was contrary to the 1995 tagging results, which showed an abundant 1992 year class. Anglers apparently did not target these fish because the percentage of angling effort directed toward black crappie declined from 14% in 1994 to 1% in 1996 (Table 8).

Lake Victoria - Fall tagging was unsuccessful in 1993 and 1994, so spring netting of the 1989 year class accounted for

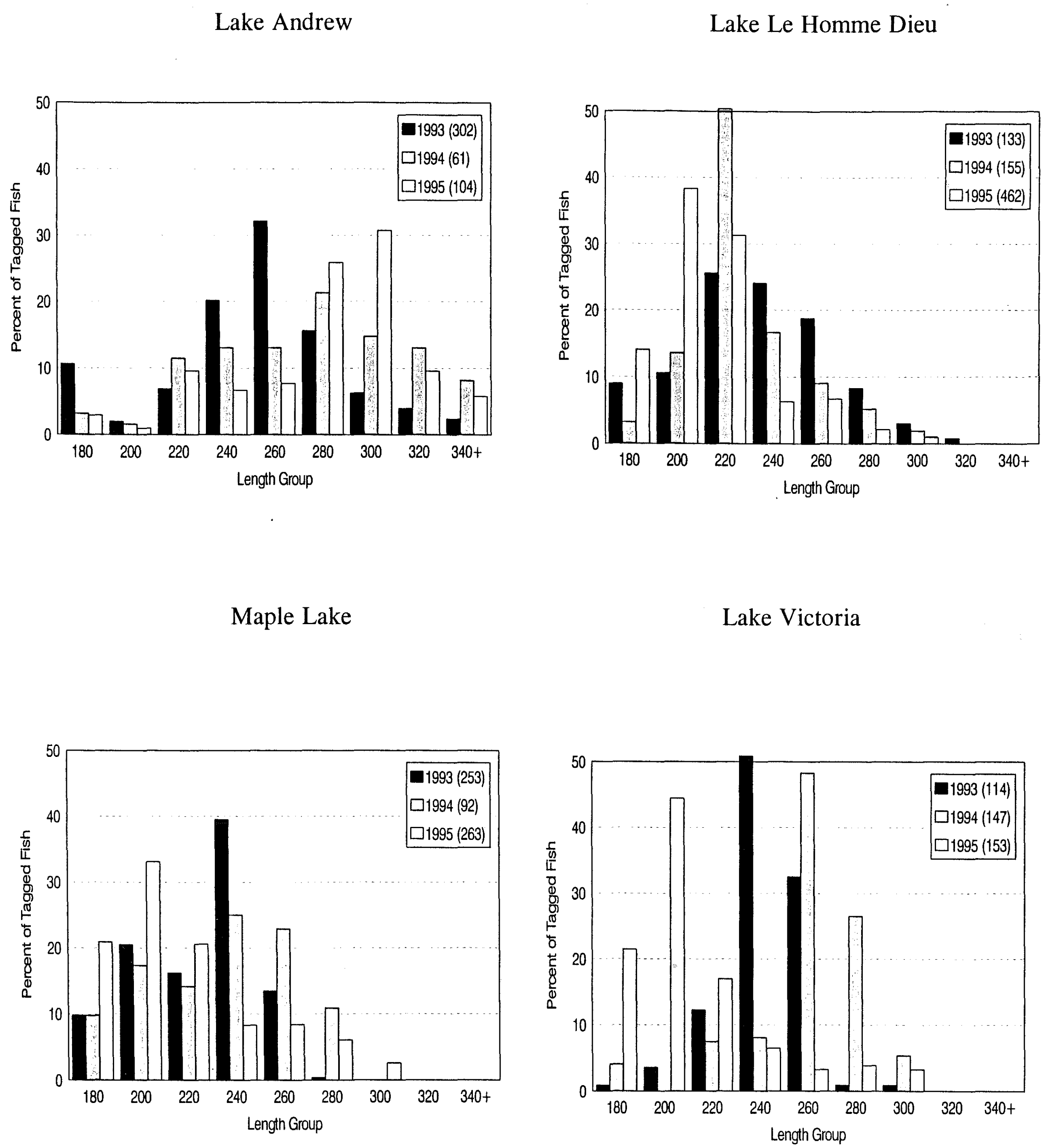


Figure 3. Length distributions of tagged black crappie by 20 mm length group (ie 260 indicates fish from 260-279 mm) from lakes Andrew, Le Homme Dieu, Maple, and Victoria, 1993-1995. Number of fish tagged each year is shown in the legend.

Table 12. Adjusted exploitation rate of black crappie by length group (mm) on lakes Andrew, Le Homme Dieu, Maple, and Victoria. Number of fish tagged was adjusted for tagging mortality and emigration. Number of tags returned was adjusted for non-reporting.

Group	Tag	Ret	μ	Tag	Ret	μ	Tag	Ret	μ	Tag	Ret	μ
						Andrew						
	1994			1995			1996			All years combined		
180-199	30	0	-	2	0	-	3	0	-	35	0	0.0
200-224	7	0	-	1	0	-	2	2	100	10	2	20.0
225-249	53	4	7.5	13	0	-	13	0	-	79	4	5.1
250-274	83	9	10.8	5	1	20.0	6	1	16.7	94	11	11.7
275-299	73	9	12.3	16	7	37.5	29	13	44.8	118	29	24.6
300-324	22	3	13.6	12	4	33.3	33	14	42.4	67	21	31.3
325-349	11	1	9.1	8	0	-	8	3	37.5	27	4	14.8
350+	2	0	-	0	-		3	0	-	5	0	0.0
All	281	26	9.3	57	12	21.1	97	33	34.0	435	71	16.3
						Le Homme Dieu						
	1994			1995			1996			All years combined		
180-199	10	3	30.0	5	0	-	55	10	16.4	70	13	18.6
200-224	20	1	5.3	40	10	25.0	193	52	24.4	253	63	24.9
225-249	34	10	29.4	65	22	33.8	94	29	27.7	193	61	31.6
250-274	30	9	30.0	23	4	19.1	30	3	10.0	83	16	19.3
275-299	12	3	18.2	8	0	-	16	6	31.3	36	9	25.0
300-324	3	1	33.3	3	1	33.3	4	4	100	10	6	60.0
325-349	1	0	-	0		-	0		-	1	0	0.0
350+	0		-	0		-	0		-	0		-
All	110	27	24.5	144	37	25.7	392	104	26.5	646	168	26.0
						Maple						
	1994			1995			1996			All years combined		
180-199	23	0	-	8	0	-	51	9	17.6	82	9	11.0
200-224	56	14	25.0	16	7	43.8	98	22	22.4	170	43	25.3
225-249	81	20	24.7	20	3	15.0	47	14	29.8	148	37	25.0
250-274	74	33	44.6	23	9	39.1	21	9	42.9	118	51	43.2
275-299	1	0	-	18	6	33.0	21	10	47.6	40	16	40.0
300-324	0		-	0		-	7	3	42.9	7	3	42.9
325-350	0		-	0		-	0		-	0		-
350+	0		-	0		-	0		-	0		-
All	235	67	28.5	85	25	29.4	245	67	27.3	565	159	28.1
						Victoria						
	1994			1995			1996			All years combined		
180-199	1	0	-	5	0	-	3	0	-	9	0	0.0
200-224	4	3	75.0	2	0	-	6	0	-	12	3	25.0
225-249	34	9	26.5	8	1	12.5	2	1	50.0	44	11	25.0
250-274	61	22	36.1	47	12	25.5	1	0	-	109	34	31.2
275-299	2	0	-	39	10	25.6	1	0	-	42	10	23.8
300-324	1	0	-	6	1	16.7	1	0	-	8	1	12.5
325-350	0		-	0		-	0		-	0		-
350+	0		-	0		-	0		-	0		-
All	103	34	33.0	107	24	22.4	14	1	7.1	224	59	26.3

[1] Very high emigration rate greatly reduced the number of tagged fish

Table 13. Estimated harvest (SE) and mean length of the observed harvest of black crappie by creel survey season and for the entire creel year from lakes Andrew, Le Homme Dieu, Maple, and Victoria.

Season	1994 Number	1994 kg	1994 Length	1995 Number	1995 kg	1995 Length	1996 Number	1996 kg	1996 Length
Lake Andrew									
EW	21 (13)	10 (8)	293 (53)	47 (26)	20 (15)	296 (21)	0	0	
LW	0	0		0	0		0	0	
LWP	0	0		195 (172)	72 (66)	274 (7)	44 (32)	14 (-)	260 (-)
EOP	0	0		12 (14)	5 (6)	289 (-)	Not creeled		
ES	621 (349)	243 (247)	277 (4)	155 (118)	61 (109)	282 (9)	0		
LS	209 (105)	113 (95)	300 (8)	193 (168)	107 (92)	311 (7)	680 (421)	392 (457)	312 (8)
All	851 (365)	366 (265)	283 (10)	602 (269)	265 (165)	290 (9)	724 (403)	406 (-)	309 (8)
Per ha	2.2	0.96		1.6	0.69		1.8	1.02	
Lake Le Homme Dieu									
EW	0	0		61 (53)	13 (23)	236 (7)	975 (563)	239 (-)	241 (6)
LW	0	0		0	0		27 (17)	5 (-)	224 (-)
LWP	134 (57)	31 (14)	236 (12)	72 (30)	16 (20)	234 (11)	741 (353)	133 (111)	222 (4)
EOP	96 (99)	28 (30)	262 (4)	439 (215)	107 (44)	251 (6)	Not creeled		
ES	854 (583)	179 (243)	234 (5)	449 (428)	102 (94)	239 (8)	17 (18)	4 (4)	239 (-)
LS	185 (125)	58 (72)	256 (10)	337 (356)	70 (82)	222 (18)	40 (39)	4 (5)	186 (-)
All	1,269 (608)	297 (255)	239 (7)	1,358 (689)	308 (209)	238 (10)	1,798	384 (-)	232 (7)
Per ha	1.8	0.42		1.9	0.44		2.5	0.54	
Maple Lake									
EW	88 (27)	25 (27)	251 (8)	49 (59)	18 (22)	275 (-)	0		
LW	0	0		0	0		39 (30)	8 (-)	237 (-)
LWP	862 (167)	214 (42)	245 (2)	0	0		148 (82)	52 (60)	268 (10)
EOP	47 (31)	11 (9)	245 (23)	0	0		Not creeled		
ES	276 (242)	66 (99)	246 (5)	165 (109)	52 (80)	262 (19)	0	0	
LS	160 (105)	45 (48)	249 (7)	824 (376)	218 (198)	244 (7)	0	0	
All	1,432 (315)	361 (122)	246 (6)	1,021 (398)	278 (205)	248 (9)	187 (87)	60 (60)	261 (12)
Per ha	4.2	1.07		3.0	0.82		0.6	0.16	
Lake Victoria									
EW	14 (14)	5 (5)	271 (6)	196 (203)	76 (81)	276 (2)	0	0	
LW	164 (84)	52 (27)	261 (3)	160 (81)	61 (46)	280 (3)	0	0	
LWP	1,013 (275)	330 (88)	260 (2)	174 (118)	66 (39)	277 (2)	233 (162)	106 (-)	292 (9)
EOP	37 (32)	11 (10)	251 (5)	0	0		Not creeled		
ES	1,525 (497)	454 (260)	255 (2)	166 (134)	46 (65)	247 (19)	0	0	
LS	545 (274)	174 (192)	263 (2)	144 (76)	34 (33)	235 (14)	613 (593)	53 (76)	180 (3)
All	3,289 (637)	1,025 (336)	259 (1)	843 (293)	284 (120)	264 (8)	846 (611)	159 (-)	211 (7)
Per ha	19.3	6.03		5.0	1.67		5.0	0.94	

Table 14. Harvest and release rates expressed as fish per angler hour (SE) by creel survey season for anglers seeking black crappie on lakes Andrew, Le Homme Dieu, Maple, and Victoria. NA indicates no anglers sought black crappie during that season; (-) indicates insufficient interviews to calculate a standard error.

	1994		1995		1996	
Season	Harvest	Release	Harvest	Release	Harvest	Release
			Lake Andrew			
EW	NA	NA	0.000 (-)	0.000 (-)	NA	NA
LW	NA	NA	0.000 (-)	0.000 (-)	NA	NA
LWP	NA	NA	0.428 (0.410)	0.000 (0.000)	0.105 (-)	0.000 (-)
EOP	NA	NA	0.069 (0.061)	0.000 (0.000)	Not creeled	
ES	0.561 (0.289)	0.194 (0.072)	0.323 (0.241)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
LS	0.107 (0.048)	0.000 (0.000)	1.943 (0.878)	0.000 (0.000)	0.825 (0.535)	0.134 (0.047)
			Lake Le Homme Dieu			
EW	NA	NA	0.272 (0.150)	0.000 (0.000)	0.379 (0.610)	0.043 (0.043)
LW	NA	NA	0.000 (0.000)	0.000 (0.000)	0.543 (0.321)	0.000 (0.000)
LWP	0.138 (0.028)	0.023 (0.009)	0.149 (0.033)	0.108 (0.120)	0.442 (0.173)	0.954 (0.873)
EOP	1.115 (0.046)	0.076 (0.068)	0.351 (0.376)	0.193 (0.166)	Not creeled	
ES	0.421 (0.106)	0.248 (0.072)	0.476 (0.237)	0.000 (0.000)	0.016 (0.007)	0.197 (0.079)
LS	0.209 (0.101)	0.000 (0.000)	0.782 (0.252)	0.335 (0.116)	0.000 (0.000)	0.000 (0.000)
			Maple Lake			
EW	0.157 (0.004)	0.000 (0.000)	0.238 (0.146)	0.000 (0.000)	NA	NA
LW	NA	NA	0.000 (0.000)	0.000 (0.000)	NA	NA
LWP	1.244 (0.043)	0.028 (0.005)	NA	NA	0.361 (0.140)	0.948 (0.000)
EOP	0.772 (0.298)	0.385 (0.149)	0.000 (0.000)	0.000 (0.000)	Not creeled	
ES	0.386 (0.183)	0.048 (0.027)	0.278 (0.046)	0.139 (0.066)	0.000 (0.000)	0.000 (0.000)
LS	0.538 (0.299)	0.000 (0.000)	1.051 (0.314)	0.515 (0.430)	0.000 (0.000)	0.000 (0.000)
			Lake Victoria			
EW	0.098 (0.045)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
LW	0.381 (0.062)	0.000 (0.000)	0.265 (0.124)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
LWP	0.658 (0.057)	0.000 (0.000)	0.347 (0.141)	0.115 (0.107)	0.446 (0.108)	0.067 (0.024)
EOP	0.151 (0.158)	0.214 (0.190)	0.000 (0.000)	0.000 (0.000)	Not creeled	
ES	0.357 (0.074)	0.055 (0.034)	0.224 (0.124)	3.074 (2.142)	0.000 (0.000)	0.062 (0.078)
LS	0.258 (0.149)	0.029 (0.026)	0.587 (0.295)	0.591 (0.350)	1.326 (1.007)	0.969 (0.426)

nearly all black crappie tagged in Lake Victoria in the first two study years. Recruitment of the 1992 year class provided fish for the 1995 fall tagging. This recruitment pattern affected the size of tagged fish. Modal length group was 240 mm in 1993, 260 mm in 1994, and 200 mm in 1995 (Figure 3).

Rates of exploitation declined during the study from 28% in 1994 to 7% in 1996 (Table 12). Harvest also fell from 19/ha in 1994 to 5/ha in 1995 and 1996 (Table 13). The 1992 year class should have been available for harvest in 1996, but the only black crappie observed in the 1996 summer creel survey were small fish (mean length = 180 mm) from the 1993 year class.

Mortality Rates

Total annual mortality rates for bluegill ranged from 68% in Maple Lake to 84% in Lake Andrew (Table 15). Subtracting mean exploitation yielded very similar natural mortality rates (60-65%) for lakes Andrew, Le Homme Dieu, and Victoria. Natural mortality was lower (43%) at Maple Lake.

Total annual mortality for black crappie were similar (61-66%) on lakes Le Homme Dieu, Maple, and Victoria, but were lower (48%) on Lake Andrew (Table 15). Subtracting mean exploitation yielded natural mortality rates ranging from 33% on Lake Andrew to 40% on lakes Maple and Victoria.

Population Estimates

Since they were calculated with creel harvest data which had large standard errors, the following population estimates must be considered imprecise. Estimation techniques using only the trap net results were attempted, but too few recaptures in subsequent falls precluded meaningful results.

The Peterson estimates did indicate that lakes Le Homme Dieu and Victoria generally had substantially higher bluegill population densities ≥ 150 mm (200-300/ha) than lakes Andrew and Maple (< 150/ha) (Table 16). Recruitment of the 1989 year class in Maple lake was apparent in the population estimates, which increased from 35-46/ha in 1993 and 1994 to 75/ha in 1996.

Population estimates of black crappie indicated low density populations in all four lakes (Table 16). Estimates in Lake Andrew declined from 24/ha in 1993 to 6/ha in 1995, indicating little recruitment after the 1989 year class. Maple Lake showed a similar pattern, declining from 16/ha in 1993 to 2/ha in 1995. Population estimates were most consistent on

Table 15. Estimated rates of total instantaneous mortality (Z), annual mortality (A), exploitation (μ), and natural mortality (v) for bluegill and black crappie from lakes Andrew, Le Homme Dieu, Maple, and Victoria. The R^2 value represents the fit of the catch curve used to calculate Z.

Lake	Z	A	μ	v
		Bluegill		
Andrew	1.85	0.843	0.190	0.653
LeHomDieu	1.31	0.730	0.118	0.612
Maple	1.14	0.680	0.246	0.434
Victoria	1.61	0.800	0.198	0.602
		Black Crappie		
Andrew	0.66	0.483	0.152	0.331
LeHomDieu	0.94	0.609	0.222	0.387
Maple	1.07	0.657	0.251	0.406
Victoria	0.98	0.625	0.228	0.397

Table 16. Peterson population estimates (95% CI) and densities at time of tagging for bluegill > 150 mm and black crappie > 180 mm in lakes Andrew, Le Homme Dieu (LHD), Maple, and Victoria.

Lake	1993		1994		1995	
			Bluegill			
Andrew	38,986 (33,057-45970)	102/ha	31,820 (26,552-38,134)	83/ha	44,831 (33,821-60898)	117/ha
LHD	224,514 (171,184-294,074)	318/ha	136,381 (115,978-160,375)	193/ha	219,287 (192,436-258,338)	311/ha
Maple	11,917 (6,947-22,452)	35/ha	15,645 (9,703-26,630)	46/ha	25,499 (21,283-31,068)	75/ha
Victoria	38,684 (29,534-52,055)	228/ha	35,254 (27,810-44,693)	207/ha	17,263 (12,504-24,564)	102/ha
			Black Crappie			
Andrew	9,326 (6,370-14,216)	24/ha	2,915 (1,690-5,465)	8/ha	2,132 (1,515-3,100)	6/ha
LHD	5,053 (3,433-7,797)	7/ha	4,219 (3,020-6,107)	6/ha	7,354 (6,064-9,342)	10/ha
Maple	5,371 (4,182-6,899)	16/ha	2,760 (1,840-4,337)	8/ha	758 (617-984)	2/ha
Victoria	6,893 (4,831-10,236)	41/ha	4,457 (2,971-7,003)	26/ha	Insufficient data	

Lake Le Homme Dieu (6-10/ha). This reflected the more consistent black crappie recruitment in Lake Le Homme Dieu, with the 1989, 1991, and 1992 year classes well represented.

Exploitation Relationships

While there was a trend toward increased rates of exploitation with increased bluegill harvest (Figure 4), the regression for all lakes combined was not significant. The regressions for individual lakes were all significant ($P < 0.01$) with high correlations (r > 0.9). This was not unexpected, with only three observations per lake. However, combining the two higher density bluegill lakes (Le Homme Dieu and Victoria) and the two lower density lakes (Andrew and Maple) yielded two significant regressions (both $P = 0.04$) with significantly different slopes ($P < 0.0001$). There were also significant relationships between angling effort directed at bluegill and exploitation (Figure 4). Slopes of the regression lines were steeper in the lower density lakes.

Exploitation was generally not related to bluegill size. In all lakes except Lake Andrew, exploitation was lowest on the 150-174 mm fish (Figure 5). The differences, however, were rather small and chi-square tests showed no differences except in Lake Le Homme Dieu. In Lake Le Homme Dieu, exploitation of the 175-199 mm length group was significantly higher ($\chi^2 = 39.96$; $P < 0.0001$) than the 150-174 mm or 200-224 mm groups. Small sample sizes prevented the use of bluegill > 225 mm in all four lakes and bluegill > 200 mm on Maple Lake.

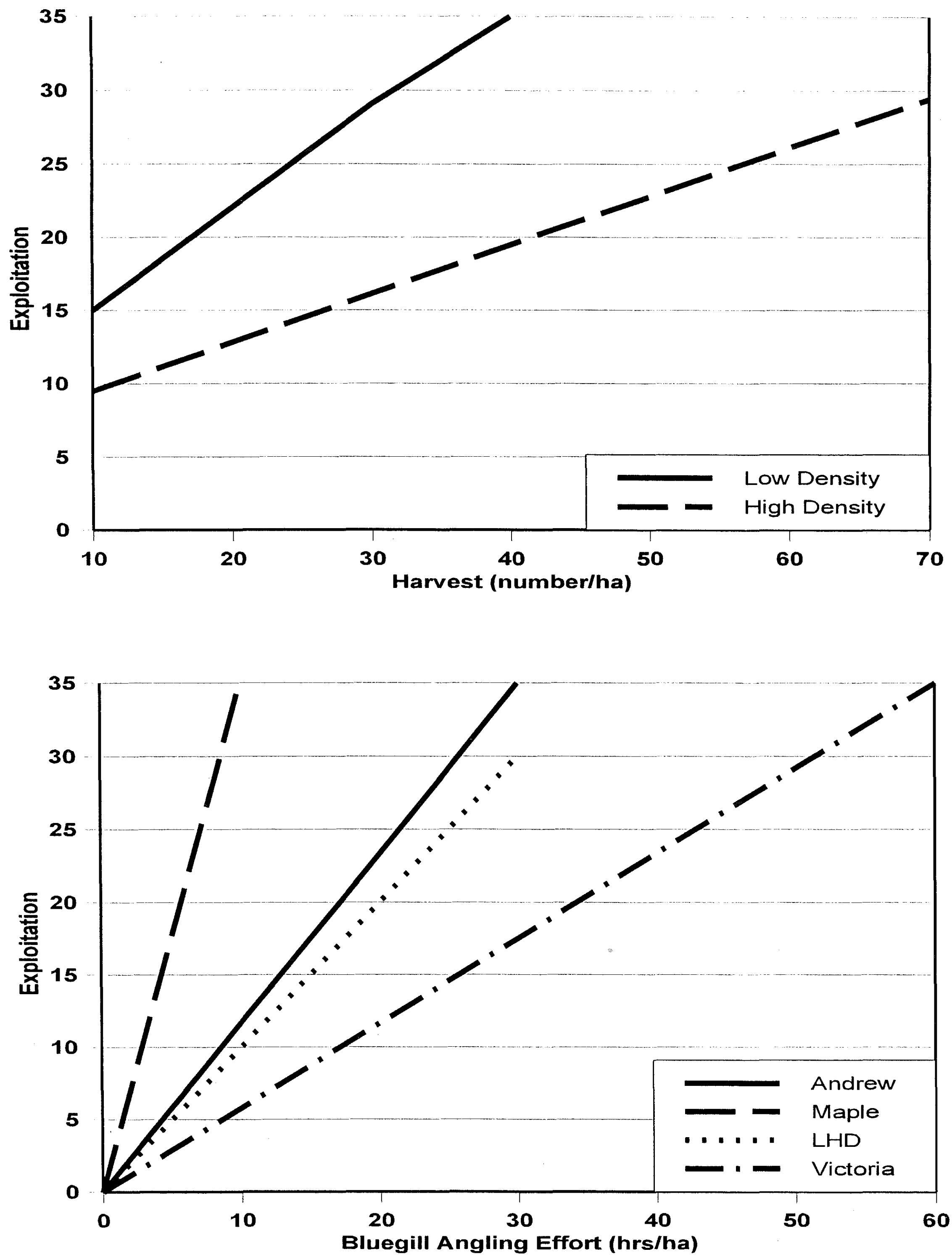
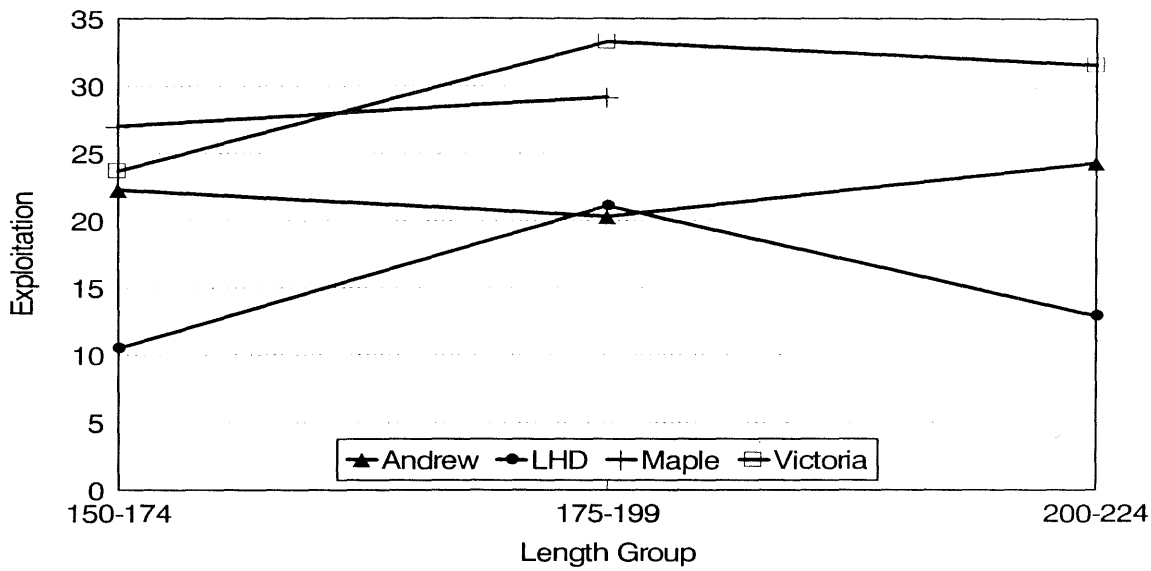


Figure 4. Relationships between bluegill harvest and rate of exploitation in the low density (Andrew and Maple) and high density (Le Homme Dieu and Victoria) bluegill populations, and the relationships between bluegill angling effort and rate of exploitation in the four study lakes.

Bluegill



Black Crappie

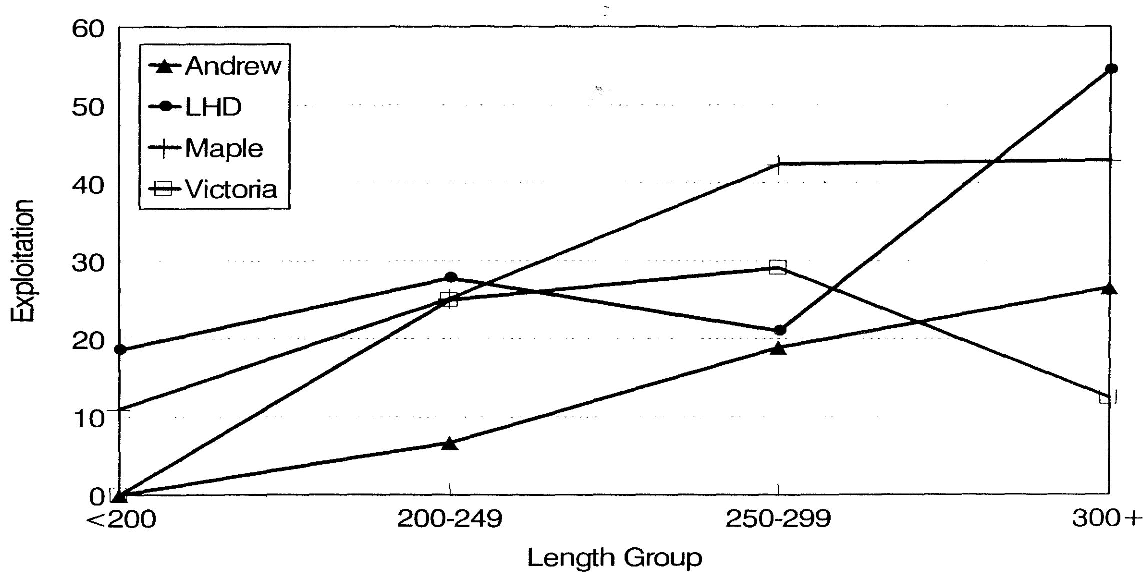


Figure 5. Rate of exploitation by size group for bluegill and black crappie.

There were no relationships between directed angling effort or harvest of black crappie and rate of exploitation. There was little variation in harvest per hectare; only Lake Victoria in 1994 had harvest > 5/ha. Similarly, there was little variation in exploitation rate with 8 of the 12 observations between 20 and 28%.

The trend was for increased rate of exploitation with increased size of black crappie. There were differences in exploitation of different sizes of black crappie in all lakes except Le Homme Dieu (Figure 5). In lakes Andrew (χ^2 = 22.26; P=0.0011) and Maple (χ^2 = 15.60; P=0.0337), exploitation increased as length group increased. In Lake Victoria, there was a significant difference among size groups (χ^2 = 21.64; P<0.0001), but highest exploitation was found for the 250-299 mm group. Highest exploitation in Lake Le Homme Dieu was on the 300+ mm length group, but this group had a small sample size (N = 10), Very small sample sizes prevented the use of black crappie > 325 mm in the chi-square tests in all lakes except Andrew.

Fish Per Angler

Because the creel survey encountered few completed trips in any given year, data from all three years were combined to determine the number of fish harvested per angler. For anglers seeking bluegill, the mean number of fish per angler was three on Lake Victoria, five on lakes Andrew and Maple, and eight on Lake Le Homme Dieu. Among bluegill anglers who harvested at least one bluegill, at least 20% on each lake kept more than 10, and this figure reached 39% on Lake Le Homme Dieu (Figure 6). On Lake Victoria, only 2% harvested more than 20 bluegill per trip, but this figure was 12-14% on the other three lakes.

Reducing the bluegill daily bag limit to 20 per day would only have reduced harvest by about 10% on lakes Andrew, Le Homme Dieu, and Maple, and less than 2% on Lake Victoria. A 10 per day limit would reduce harvest only 15% on Lake Victoria and about 35% on the other lakes. To reduce harvest by over 50%, a daily bag limit of 5 per day would be necessary. However, this would only reduce harvest by 42% on Lake Victoria.

For anglers seeking black crappie, the mean number of fish per angler was three on Maple Lake, but less than one on the other three lakes. Of those who caught at least one black crappie, nearly 30% of anglers on Maple Lake harvested more than 10, but Lake Victoria was the only other lake where any anglers harvested more than 8 black crappie per trip (Figure 5).

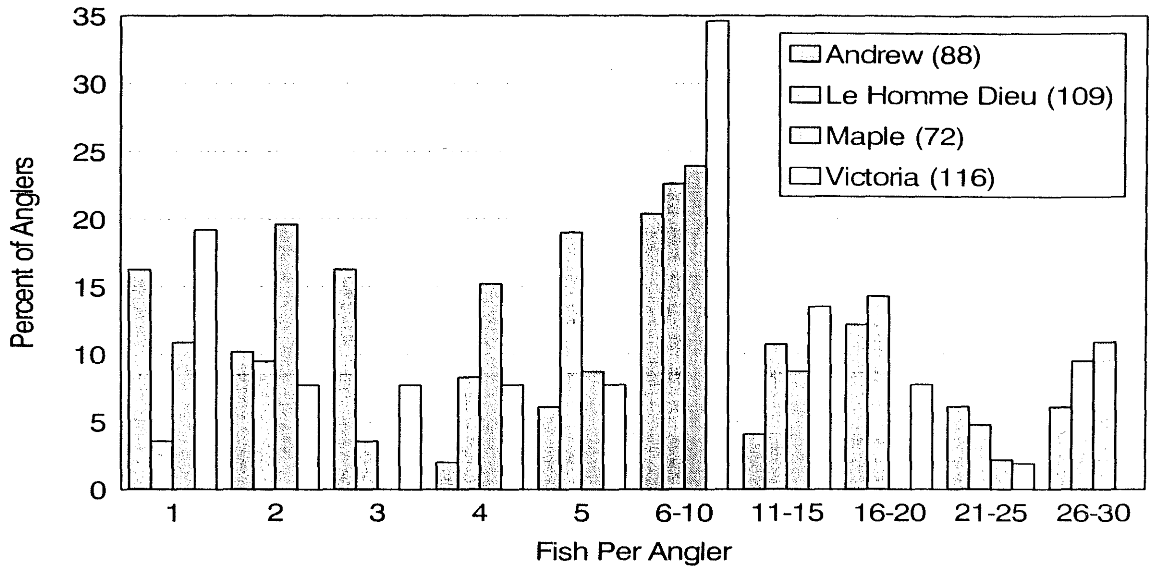
Reduction of the black crappie limit to 10 per day (from 15) would reduce harvest by 18% on Maple Lake and 3% on Lake Victoria. Our data indicate no change would occur on lakes Andrew or Le Homme Dieu because no interviews showed anglers harvesting more than 10 black crappie. Even a reduction to 5 per day would reduce harvest only about 10% on these two lakes. A reduction to 5 would decrease harvest 20% on Lake Victoria and 45% on Maple Lake.

Discussion

Exploitation appeared to affect the size structure of bluegill on the four study lakes. Different growth rates and recruitment patterns, however, caused the ultimate effect to vary among lakes. Lake Andrew bluegill experienced some of the highest exploitation rates in the study, but still had the best size structure of the four lakes due to faster growth. However, the current size structure in Lake Andrew is considerably smaller relative to historical records. A creel survey conducted in the summer of 1955 (Larson 1961a) showed 40% of the harvested bluegill were 225 mm or larger. Only 1% measured during the creel survey in this study were as large. Exploitation appears to limit the trophy bluegill potential in Lake Andrew.

Substantial exploitation of bluegill also occurred on Lake Victoria, but growth rates were slower than in Lake Andrew. Although 200+ mm fish did exist, and two bluegill > 225 mm were tagged, the density of large

Bluegill



Black Crappie

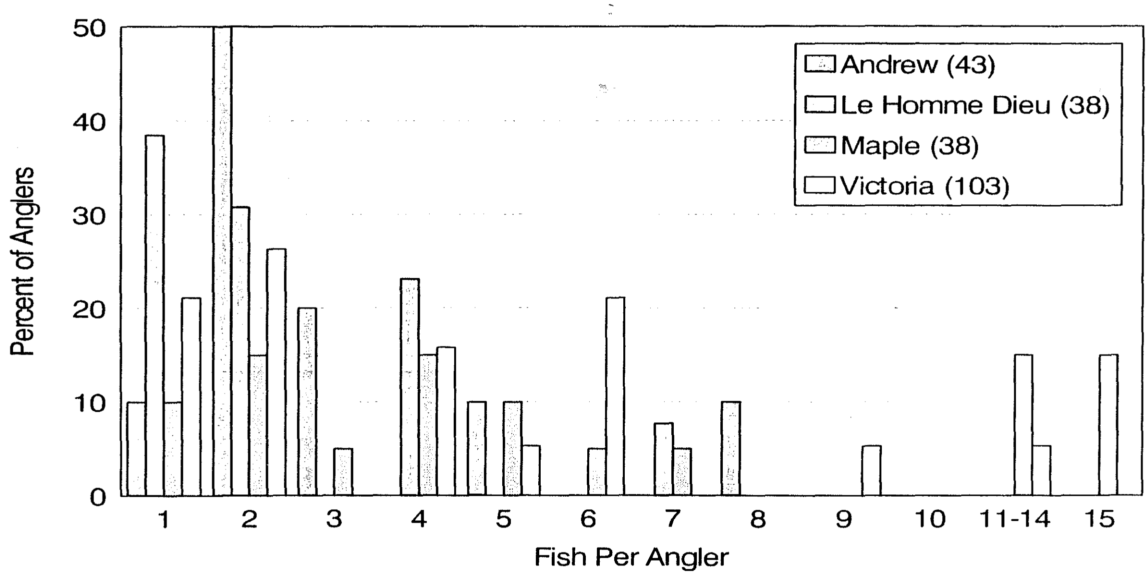


Figure 6. Numbers of bluegill or black crappie per angler for anglers seeking that species and harvesting at least one fish.

bluegill was much lower. Reducing the rate of exploitation would likely improve the bluegill size structure on Lake Victoria, but frequent emigration to Lake Jessie may reduce the benefits if Lake Victoria was the only lake in the chain managed for large bluegill.

When the strong 1989 year class of bluegill reached harvestable size in lakes Le Homme Dieu and Maple in 1996, anglers quickly responded. Bluegill harvest from both lakes doubled due primarily to the late winter panfish season. Exploitation increased from 17% to 29% on Maple Lake and from 12% to 16% on Lake Le Homme Dieu. A similar scenario occurred on Manistee Lake, Michigan (Laarman 1980). Prior to recruitment of the 1973 year class, angling effort was 15 and 35 hrs/ha in 1976 and 1977 while exploitation was only 10%. In 1978, however, angling effort climbed to 59 hrs/ha and rate of exploitation increased to 31% in 1978 as the 1973 year class recruited to the fishery. The lower exploitation from Lake Le Homme Dieu allowed few bluegill to reach 200 mm despite poor growth, but such fish were nearly nonexistent in Maple Lake. Consistent with bluegill population simulations conducted by Beard et al. (1997), the response by anglers and slow growth rates will likely maintain the poor size structure on both lakes.

In addition to Manistee Lake, bluegill exploitation data are available from three other upper midwest lakes of comparable size. Rate of exploitation averaged 37% from 1948-1952 on Sugarloaf Lake, Michigan (Cooper and Latta 1954) and averaged 12% (range 4-24%) from 1955-1970 on Murphy Flowage, Wisconsin (Snow 1978). An average rate of exploitation of 42% (range 34-64%) was found from 1956-1965 on Escanaba Lake, Wisconsin (Kempinger et al. 1975). The bluegill population density was extremely low (2-20 fish/ha) in Escanaba Lake, supporting our finding that exploitation increases faster in low density populations as harvest increases.

Exploitation affected the black crappie size structure in all lakes except Lake Andrew. The black crappie population in Lake Andrew appeared to be of a fairly low density, but the fish grew fast and attained large sizes. Low exploitation in 1994 (9%), combined with relatively low natural mortality (33%), allowed the 1989 year class to reach large sizes. The higher exploitation rates observed in 1995 (21%) and 1996 (32%) were primarily on these large fish. This encouraging pattern allowed a fishery with a high proportion of large black crappie to exist. However, if exploitation were to increase on smaller fish, the quality may be jeopardized.

Lakes Le Homme Dieu and Maple had relatively low density black crappie populations, moderate growth rates, very few large fish, and exploitation rates consistently above 25%. These factors suggest that a minimum size limit may improve the population structure (Allen and Miranda 1995). Based on preliminary information from this study, a 254 mm (10 in) minimum size limit was initiated on Maple Lake in 1997 and will be evaluated through 2005. Despite the similarities between lakes, we did not recommend a similar regulation for Lake Le Homme Dieu for two reasons: 1) migration of fish out of the lake was common and could dilute any beneficial results of a regulation, and 2) connections between Lake Le Homme Dieu and other lakes in the Alexandria chain of lakes are also navigable making enforcement extremely difficult. To be effective, a regulation would need to be instituted on all the lakes in the chain. Black crappie growth in Lake Victoria, located in the same chain of lakes, slowed considerably after age 4, severely limiting the potential effectiveness of a minimum size limit. These differences in growth rates among lakes in the chain suggests that, despite being connected, they behave very differently and a single regulation would be biologically inappropriate.

Data indicated the 254 mm size limit on Maple Lake would protect 49% of the black crappie that were harvested in 1994 and 1995. We found in the bag limit reduction results that a daily bag limit of 5 black crappie would have reduced harvest by approximately the same amount (45%), but felt the minimum size limit to be the better option. A minimum size limit forces the angler to make an immediate decision as to whether or not to violate the law. A five fish bag limit, however, may actually encourage violation of the "sorting" regulation, where anglers keep a small fish until they catch a larger one, whereupon the small fish is released.

The method we used to estimate the effects of reduced bag limits is inherently biased because it fails to consider the relative increase in bluegill or black crappie abundance that may have occurred had the new bag limit been in place (Porch and Fox 1991). If we reduce harvest with a lower bag limit, then the chance of an angler later in the year harvesting fish theoretically increases. An angler who harvested only two fish under the old bag limit would have a better chance of harvesting three or more fish. Therefore, the harvest reductions we calculated must be considered the maximum that could occur.

Information on exploitation of black crappie in the literature is generally limited to southern reservoirs and usually includes white crappie *Pomoxis annularis*. Information is available for the same four upper midwest lakes as bluegill. In Michigan, Manistee Lake had rates of exploitation ranging from 14 to 21% in 1976-1978 (Laarman 1980), and rates of exploitation averaged 35% in Sugarloaf Lake in 1948-1952 (Cooper and Latta 1954). In Wisconsin, rates of exploitation averaged 11% and ranged from 5-22% in Murphy Flowage from 1955-1970 (Snow 1978), and averaged 26% (range 9-50%) in Escanaba Lake (Kempinger et al. 1975). Natural mortality rates were also reported from Manistee Lake (39%) (Laarman 1980) and Murphy Flowage (42%) (Snow 1978). All these rates are similar to our results, suggesting that rates of exploitation of 20-30% or more and natural mortality of 30% to 40% may be common for black crappie in the upper midwest. Since these numbers indicate that harvest restrictions may be beneficial (Allen and Miranda 1995), growth rate becomes the deciding factor. Lakes containing black crappie populations with above average growth should be considered for harvest restrictions if the management objective for the lake is to increase the size of black crappie available to the angler.

The exploitation rates reported in this study must be considered minimum values. Tagging mortality, tag loss, emigration, and non-reporting of tags by anglers could all lead to lower estimates of exploitation than actually occurred. We did not adjust numbers of tagged fish for potential tagging mortality. Mortalities during the pond experiment were common. However, pond fish were handled much more and were placed under considerably more stress than those tagged in the lakes. Larson et al. (1991) estimated that mortality due to tagging black crappie with anchor tags was 2.5% when water temperature was under 13°C but exceeded 30% with warmer temperatures. Water temperatures were generally 5-15°C during our tagging operations. If we applied a mortality rate of 2.5% to the black crappie we tagged, the average exploitation rates of 26.0% on Lake Le Homme Dieu and 28.1% on Maple Lake would have increased to 26.6% and 28.9%, respectively. Therefore, it is unlikely that tagging mortality of this magnitude had a significant effect on our results.

Tag loss can also affect exploitation estimates. Our tag retention estimate of 93% was generally similar to rates found in the literature for anchor tags which ranged from 69-98% for various species (Muoneke 1992; Pierce and Tomcko 1993; Pegg et al. 1996). Larson et al. (1991) reported black crappie tag retention rates from three reservoirs that ranged from 70% to 95%. They suggested that the laterally compressed body shape of black crappie lends itself well to secure lodging of the tag anchor behind the pterygiophores, leading to excellent tag retention. With a similar body shape, this is likely true for bluegill as well. The only bluegill information available was from a drainable pond in Missouri, where the retention rate was 85% (Kruse 1997). We found both species to be easily tagged, and feel confident that retention was very good.

The creel survey provided few observations of tagged fish, so voluntary returns were critical. Zale and Bain (1994) estimated that approximately one-third of anglers return tags altruistically, but the other two-thirds require some inducement. Our reporting rate of 69% was higher than most rates reported in the literature. Most previous studies involving crappie used monetary rewards to encourage returns, compared to our incentives of fishing jigs or t-shirts. A $5 reward yielded reporting rates of 27-44% from Lake Marion, South Carolina (Kraham 1995), and 55-60% from three Georgia reservoirs (Larson et al. 1991). Variable monetary rewards with the opportunity to receive $100 yielded higher crappie tag reporting rates (67-93%) from three Missouri reservoirs (Eder 1990; Colvin 1991). Since our reporting rate involved anglers who had been contacted by the creel clerk, their awareness of the project was undoubtedly raised, potentially inflating our reporting rate. Larson et al. (1991) expressed the same opinion.

Emigration of tagged fish from lakes Le Homme Dieu and Victoria into adjoining lakes was a common phenomenon. Despite not releasing tagged fish near connections to other lakes, our emigration rates were higher than expected. Jacobson (1994) reported that only 6% of walleye tagged in Big Sand Lake, Minnesota, were harvested in adjoining lakes, and walleye are considered much more mobile. Managers need to consider the potential movement of bluegill and black crappie when managing connected lakes.

Creel surveys not covering the entire year underestimate total annual harvest and exploitation (Coble 1988). Creel surveys are common on Minnesota lakes, but the majority of these surveys have been conducted during the open water season, often targeting anglers seeking walleye (Cook et al. 1997). Winter panfish angling can be more successful than open-water. A winter creel bluegill harvest estimate of 12,000 on Lake Minnewaska, Minnesota, was nearly double that of the summer harvest of 6,900 (Kessler 1990). He also reported an estimated winter harvest of 2,700 black crappie, compared to only 600 in the summer. Even these differences likely underestimate the importance of ice angling. Kessler's (1990) and virtually all other Minnesota winter creel surveys ended with the closure of the walleye/northern pike season in mid-February. In our study, the late winter panfish season, which ran from the close of the walleye/northern pike until ice-out in late March or early April, was extremely important. Over 30% of the bluegill tag returns from lakes Le Homme Dieu and Maple came from this season. For black crappie, 14% of Lake Andrew tag returns, 18% of Lake Le Homme Dieu tag returns, and 47% of Maple Lake tag returns came from this season. Since we tagged the fish in the fall, tag returns may have been biased toward the winter seasons, but total harvest showed a similar pattern. The late winter panfish season had the most bluegill harvest in 1994 and 1996 from Lake Le Homme Dieu and in 1996 from Maple Lake, and the most black crappie harvest in 1995 from Lake Andrew and 1994 and 1996 from Maple Lake. Designs for any future creel surveys where panfish are of interest must address this season or the results may be seriously flawed.

While year class strength has been addressed as a factor in angling success for species such as walleye (Parsons et al. 1994), this study indicates that variation in bluegill year class strength can also affect angling. The 1989 year class dominated our bluegill tagging and angler harvest throughout the study on all four lakes. Our best example was the angler response when the 1989 year class was fully recruited to harvestable size on Maple Lake. The year class effect was less apparent for black crappie. Rate of exploitation was consistently above 25% on Maple and Le Homme Dieu despite the presence of only two good year classes. However, the 1989 year class almost entirely supported the black crappie fishery on Lake Andrew during the study period.

Exploitation was higher on large black crappie than small ones, particularly those < 200 mm. Several scenarios could cause this effect. Anglers could have released small black crappie, but release rates by anglers seeking black crappie were usually very low. Furthermore, tag return information from angler released black crappie was not skewed toward small fish. A second possibility is that mortality may have been higher for small tagged black crappie than large ones. This did not appear to be the case because tag returns from fish caught more than one year after tagging, when black crappie which were < 200 mm at tagging had grown into larger size groups, were similar among size groups. Apparently, anglers simply caught very few small black crappie. Whether this was due to angling techniques or behavioral differences between sizes of black crappie is unknown.

Unlike black crappie, there was no trend toward higher exploitation of larger bluegill. While bluegill anglers had very high release rates, these were almost exclusively small fish. Most bluegill caught that were larger than 150 mm were harvested. This even occurred on Lake Andrew, where large bluegill were common and anglers could have selectively harvested larger bluegill. It is possible that the presence of a tag may have persuaded anglers to harvest a bluegill that may otherwise have been released. Although sample size was very small, an examination of the sizes of bluegill kept by angling parties who had kept a tagged bluegill when interviewed indicated no difference in size between the tagged bluegill and other bluegill in their creel.

Anglers have been reported to target large parental male bluegill when they are vulnerable on the spawning beds (Ehlinger 1997). A study on four Missouri reservoirs found 60% of angler tag returns from bluegill during peak spawning in May and June (Kruse 1997). This was not the case on the four lakes in our study. The mean length of harvested bluegill during the early summer period, which includes bluegill spawning, was not higher than the yearly average. Additionally, with the exception of 1994 in Lake Le Homme Dieu and 1995 in Lake Victoria, harvest rates by anglers seeking bluegill were not unusually high in the early summer period. Contrary to the Missouri results (Kruse 1997), we did not find higher exploitation rates on the largest bluegill in the populations. However, creel surveys from the 1950s on lakes Andrew and Maple did show much higher proportions of large bluegill in the creel than we found (Larson 1961a,b). Consistent removal of larger bluegill by angling can cause and perpetuate poor size structure (Coble 1988). Recent studies on bluegill reproductive strategies indicate the situation may be even more complex. Removal of large parental males can cause an overall decline in growth rate within a lake by encouraging parental males to mature at a younger age (Jennings et al. 1997), or by increasing the proportion of cuckolder males in a population (Drake et al. 1997).

The lack of anglers targeting nesting bluegill may also be due to anglers targeting other species. The early summer season was dominated by anglers seeking walleye. Walleye anglers outnumbered bluegill anglers in this season 6.6 to 1 on Maple Lake, 4.6 to 1 on Lake Andrew, 2.0 to 1 on Lake Le Homme Dieu, and 1.1 to 1 on Lake Victoria.

Exploitation is obviously not the only factor affecting bluegill and black crappie populations in these lakes over the years. Fisheries management techniques have likely altered fish community structure in many lakes. For example, in Maple Lake, northern pike stocking and recruitment were encouraged from the 1950s through 1980. The high densities of northern pike maintained by this management strategy were accompanied by a long term decline in yellow perch abundance. We also noted a decline in bluegill growth rates from those observed in the 1950s (Larson 1961b). A similar pattern was observed in Horseshoe Lake, Minnesota, and was attributed to northern pike stocking (Anderson and Schupp 1986).

Anglers' desires for larger bluegill and black crappie are unlikely to decrease, and their complaints about size structure are likely to increase if the trends in panfish populations continue downward. Manipulations of predator populations have failed to improve bluegill size structure (Goeman et al. 1990; Goeman and Spencer 1992), and this study indicated that exploitation did indeed affect size structure of bluegill and black crappie. Fisheries managers and anglers in Minnesota must address panfish exploitation if the size structure of bluegill and black crappie populations are to improve.

Management Recommendations

In lakes with good growth, reducing bluegill exploitation will improve the potential for large bluegill. However, if growth is poor, the cost in potential lost harvest probably outweighs the benefits of reducing exploitation. Managing for large bluegill with reduced exploitation should only be attempted in lakes where growth rates exceed lake class medians (Tomcko and Pierce 1997) and bluegill reach 200 mm prior to age 8.

Managing for reduced black crappie exploitation should improve size structure. Growth rates in our lakes were considerably slower than southern waters where regulations have succeeded. However, natural mortality was lower in this study and maximum age was higher, offsetting the slower growth.

We noted significant movement of bluegill and especially black crappie to connected lakes. While such movement has been considered in the past for species regarded as highly mobile, it should also be considered when managing bluegill and black crappie.

Creel surveys on waters where panfish are of interest should be extended to cover the period from mid-February through ice-out.

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