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Mechanical Suppression of Northern Pike *Esox lucius* Populations in Small Arizona Reservoirs

Fisheries Research Report 01-10

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Mechanical Suppression of Northern Pike *Esox lucius* Populations in Small Arizona Reservoirs

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Executive Summary

- Introduced populations of northern pike *Esox lucius* have provided angling opportunities in the western United States. However, the northern pike is a voracious piscivore and its large size, high fecundity, and broad physiological tolerance make it capable of drastically altering ecosystems it invades.
- Illegal stockings of northern pike in Arizona have necessitated investigating a variety of management strategies necessary for the removal of nuisance populations to protect valuable trout populations and potential impacts to other species.
- Chemical and mechanical control methods have been used throughout the United States to control nuisance northern pike populations. Chemical control can be more effective than mechanical control for complete removal, but can be controversial in some areas.
- Mechanical control is generally less effective than chemical control, but may be needed in some areas where chemical control cannot be used. Typically mechanical control has not worked well in large lakes and reservoirs in the United States to control northern pike populations.
- Mechanical control, by overfishing, is one cause of the collapse of northern pike fisheries in the huge Dnieper Reservoirs of the Ukraine.
- United States and Ukrainian scientists collaborated to test a variety of mechanical methods; used in the Dnieper River Reservoirs, Ukraine and the United States; in small Arizona lakes to evaluate whether they could be used for northern pike population suppression. These methods included gill netting, trap netting, trap netting with barriers, boat electrofishing, and angling with incentives.

- We tested techniques in Fool Hollow Lake and Rainbow Lake, Arizona in 2006 and 2007. Parker Canyon Lake was dropped from the study because northern pike populations had already crashed.
- Mechanical techniques were used to remove 50% of the northern pike population in Rainbow Lake and 80% of the population in Fool Hollow Lake. These percentages may be somewhat overestimated because of the inability to correct for potential violations of the equal catchability assumption for abundance estimates. Northern pike abundance was estimated through mark-recapture data input into a Jolly-Seber (POPAN) open-population model on program MARK.
- Capture techniques were compared on a catch per personnel hour divided by the northern pike abundance at time of capture. Gill nets and trap nets with barriers were the most effective methods, best used in spawning coves in early spring after ice-out. Gill netting during the day was preferred for capturing northern pike only, because gill net by-catch (of black bass and bullhead) was significantly higher at night.
- Boat electrofishing efficiency increased when the waters warmed in the summer, and individual northern pike caught using this method were generally smaller and younger than those captured by net.
- Our angler incentive program did not result in many removed northern pike. Our estimates of northern pike removed calculated from the angler incentive program were considerably different than estimates of northern pike removed calculated from AZGFD creel data, which indicates angler removal might be quite high. More research will need to be conducted to ascertain the effectiveness of public angling for northern pike control.

- Mechanical suppression of northern pike was possible in our study. However, for it to be effective, it must be continued over time, much like mowing of a lawn. For lakes similar in size and fish community to those we studied, control efforts could take place over a 14-day period, say once every other year, following spring ice melt when water temperatures approximate 14°C in the spawning areas, and before catchable trout are stocked. Fourteen days of work for two people once per every two years will consist 14 person- days per year. Assuming a $200 USD cost per day, control efforts for waterbody similar to those we studied should cost $2800 USD per year.

Introduction

Introduced populations of northern pike *Esox lucius* have provided angling opportunities in the western United States (McMahon and Bennett 1996). However, the northern pike is a voracious piscivore and its large size, high fecundity, and broad physiological tolerance make it capable of drastically altering ecosystems it invades (Marchetti et al. 2004). Indeed, predation by northern pike has been shown to significantly alter fish community structure and put native fishes at a higher extinction risk (He and Kitchell 1990, Findlay et al. 2000). Predation by northern pike is viewed as a significant threat to native stocks of salmonids in Washington, British Columbia, and California (McMahon and Bennett 1996, California Department of Fish and Game [CDFG] 2003).

Both chemical and mechanical control methods have been used to attempt to control nuisance northern pike populations (Lee 2002; CDFG 2003; Martin 2005; Jolley et al. 2008; Monroe and Hedrick 2008). Chemical control has effectively removed northern pike populations, but can be controversial in populated areas (Lee 2002).

In North America, effectiveness of mechanical control of northern pike has been mixed. Mechanical suppression of northern pike in small water bodies has resulted in positive responses in other game fish species (Jolley et al. 2008). Despite attempts to mechanically eradicate or control northern pike in 1631 ha Lake Davis, California, a large population of northern pike remained and threatened the popular rainbow trout *Oncorhynchus mykiss* fishery (Lee 2002; CDFG 2003) until the northern pike were finally removed by rotenone in 2007 (CDFG 2008). The 2003 assessment of the CDFG mechanical removal plan concluded that control efforts did not stop the growth of the northern pike population or reduce the threat to rainbow trout. The assessment concluded that the rapid growth rates, earlier maturation, and higher fecundity of northern pike when at low densities, compensated for the level of mechanical removal achieved by the plan (CDFG 2003). In the Yampa and Green Rivers of the Western United States, sustained mechanical removal has successfully reduced northern pike abundance (Martin 2005; Monroe and Hedrick 2008).

Mechanical removal has resulted in substantial reductions in northern pike populations overseas, where commercial gear and intense effort is used. Commercial and recreational overfishing resulted in northern pike harvest declines from 0.2 kg/ha to about 0.05 kg/ha in large (41-225 thousand ha) reservoirs of the Dnieper River system, Ukraine in the 1990's following disintegration of the USSR (Dnieper reservoirs report, 1956-2008; Ukraine Institute of Fisheries data).

Testing additional gear types under intense effort, such as those used in the Ukraine, in small water bodies might provide more chances for success. Here we evaluated use of both Ukrainian and United States methods to mechanically remove introduced northern pike from Rainbow and Fool Hollow lakes in northern Arizona (both less than 70 ha at full capacity). The goals of our research were (1) to compare the effectiveness of commonly used Ukrainian and North American methods to capture northern pike, (2) to test the efficiency of these techniques for removing different Northern pike size classes, (3) to identify times and locations where northern pike can best be captured and (4) to investigate the feasibility of removing a large percentage of northern pike from small Arizona water bodies.

Methods

Study sites. -- Rainbow Lake is a shallow, eutrophic impoundment, created in 1903 (Meyer et al. 2006) and located in the town of Lakeside at 2,060 m elevation

(FIGURE 1). Its surface area was 47 ha. Its maximum depth was 4.6 m with a mean depth of 2.3 m. Naturally propagating warm water species included largemouth bass *Micropterus salmoides*, channel catfish *Ictalurus punctatus*), black bullhead *Ictalurus melas*, bluegill *Lepomis macrochirus* and green sunfish *Lepomis cyanellus*. The Arizona Game and Fish Department (AZGFD) reported that the northern pike was illegally stocked in the lake in the late 1990s (K. Meyer, AZGFD personal communication).

Fool Hollow Lake was constructed in 1957 to provide water-oriented outdoor recreation. It is located in Showlow, Arizona at an elevation of 1,910 m. The lake's surface area was 61 ha, with a mean depth of 7.0 m (FIGURE 2). Fool Hollow Lake contained self-sustaining populations of largemouth bass, smallmouth bass *Micropterus dolomieui*, green sunfish, walleye *Sander vitreus*, common carp *Cyprinus carpio* and black crappie *Pomoxis nigromaculatus*. The AZGFD stocked both lakes with catchable-sized (27-30 cm) rainbow trout *Oncorhynchus mykiss* throughout the spring and summer.

Parker Canyon Lake in southern Arizona was also considered for the study. However, after several unsuccessful northern pike sampling trips and information from the AZGFD that northern pike populations had crashed in the lake, we discontinued it from consideration.

Study Design.-- Our study was conducted during two seasons (January-July 2006; March-July 2007) in Rainbow Lake and one season (November 2006 to July 2007) in Fool Hollow Lake. Removal techniques were selected based on a literature review of both North American and Eurasian studies of northern pike and a survey of Ukrainian and United States experts on northern pike biology for possible unreported capture techniques. Northern pike are often susceptible to capture during their spawning period. To identify the spawning period in the two lakes, we analyzed the number of northern pike captured in potential spawning areas in 2007 by the day of sampling and examined the development stage of generative organs of captured fish. To evaluate differences in the age and size composition of northern pike catch among gear types, we collected scales and otholiths for growth measurements (Schreck and Moyle 1990); obtained standard and total length; determined sex and degree of fertility; and noted health of each fish captured.

We tested five mechanical removal techniques that were selected jointly by researchers at the USGS Arizona Cooperative Fish and Wildlife Research Unit; Zaporizhzha State University and Institute of Fisheries, Ukraine; and the AZGFD. The five methods were sinking gill nets, trap nets, trap nets set in shallow areas with barrier nets, electrofishing and angling with incentives. Except for the trap net used with barrier nets, each gear type was used throughout the season. For electrofishing, a 5-m aluminum flat-hulled boat with a Coffelt VVP-15 electrofishing unit set to 8 to 10 amp pulsed DC current between 100 to 200 volts was used. Sinking experimental gillnets were 45.7–m in length and consisted of six 7.6-m panels containing bar-measure meshes of 13, 19, 25, 32, 38 and 51 mm. We used trap nets with the following dimensions: 1.5 m x 1.5 m x 1.5 m crib; 3.7 m wings; 22.9 m x 1.5 m leader; 19-mm bar mesh netting (FIGURE 3). These were set in combination with barrier nets to capture northern pike on their way to spawning area, a common method used by fishers to maximize northern pike catches in the Ukraine. Barrier nets were used to channel northern pike into the trap net (FIGURE 4)

Each lake was divided into four sections for sampling (FIGURES 1 and 2). Each gear was used concurrently in different sections of each lake to reduce interference. For the day's work, one gear type (e.g. electrofishing, gill nets, or trap nets) was randomly assigned to a section. For electrofishing, the entire section was sampled twice in a 24-h period, once at night (20:00-21:00 hrs) and once during the day (11:00-12:00 hrs). For netting, all sections were subdivided into stations. If a section was chosen to be gill or trap netted, a random numbers table was used to determine the station where the net would be set. Gill nets were set perpendicular to the shoreline during the day from 7:00-20:00 hrs and at night from 20:00-7:00 hrs the next day. The trap net combined with barrier nets had to be set in spawning coves, so thus could not be placed in random locations. Their locations were chosen in accordance to northern pike spawning habitat requirements (Cassellman and Lewis 1996) and data obtained in the first year of study.

For all methods, catch per unit effort (CPUE) was measured in personnel-hours, in a similar manner to Bonar et al. (1993). For active techniques, CPUE was calculated by multiplying the time a crew fished by the number of people in the crew. For passive techniques, CPUE was calculated as the time required to check a trap multiplied by the number of people required to check it. Catch per unit effort was divided by the northern pike population size at that time to provide a measure of gear efficiency which allowed us to compare all data from both lakes at any period of time (i.e., CPUE at time *i*/abundance at time *i* = efficiency at time *i*).

Mark-recapture estimates of abundance were conducted in Rainbow Lake from January 5, 2006 to March 25, 2006, and in Fool Hollow Lake from November 5, 2006 to May 8, 2007. We estimated abundance of northern pike on each sampling date using a Jolly-Seber (POPAN) open-population model on program MARK (Cooch and White 2006). On each of *K* sampling occasions, fish were captured. All unmarked fish, of all sizes, were tagged with plastic individually-numbered tags (Floy Tag Incorporated, Seattle, Washington) inserted posterior and ventral to the dorsal fin

(Pierce and Tomcko 1993) and released at the area where the nets were set previously or in the middle of lake after electrofishing. Previously marked fish had their tag numbers read and were again released. It was assumed that unmarked fish in the population had the same probability of capture as marked fish in the population, i.e., that newly captured unmarked fish were a random sample of all unmarked animals in the population. Using different capture techniques reduced bias in abundance estimates of northern pike in other studies (Pierce 1997). Therefore, we hoped that the variety of gear types we used in our study would minimize bias in our population estimates as well.

For our angler incentive program, we placed signs around each lake to encourage anglers to capture northern pike. The signs stated that anglers who caught a tagged northern pike could remove the tag and return it to the authors with information about date, gear type, length and weight of tagged fish for a $10 USD reward. Previous research shows that tag reporting levels in similar reward programs approximate 50% (Finn and Loomis 2001; Denson et al. 2002; Schmalz et al. 2004). Therefore, we assumed a similar tag reporting rate of 50%, and to estimate the number of tagged fish caught, we multiplied reported tags by 2. Next, we used the method of Schmalz et al (2004) to calculate total catch. The ratio of tagged to untagged fish in each lake was applied to the reported tags to extrapolate the approximate northern pike total catch in each lake.

Results

Using all methods, we caught 648 pike from Rainbow Lake, of which 221 were released and 427 were removed. In Fool Hollow Lake we caught 94 fish, of which 27 were released and 67 removed (TABLE 1).

Age analysis (n = 30) and length frequency analysis revealed the majority of all pike caught in Rainbow Lake in 2006 were from the 2003 year class (length 451 to 500 mm), and in 2007 the majority were from the 2005 year class (length 300-351 mm; TABLE 2) Sex ratio in the catch was 1 female to 3 males. In Rainbow Lake all adult pike had well developed generative organs in concordance with the time of year. In total we caught 25 % juvenile and 75% adult pike, of which 36.3 % of the adults were female and 63.7% were male. Peak of northern pike spawning, which included northern pike aggregating in shallow coves, occurred in Rainbow and Fool Hollow Lake from March 8-13, 2007 and March 11-20, 2007, respectively.

In Fool Hollow Lake the few fish captured for scale analysis (n = 12) ranged from 400 mm SL (460 mm TL) mm to 1000 mm SL (1130 mm TL), and were all age 5. The sex ratio of these fish was 25.4% male and 74.6% female. All fish appeared healthy. During and one month before spawning, 26 (57%) of female pike in Fool Hollow Lake had undeveloped gonads; 14 (30%) were in the 3rd stage of the developmental cycle and not ready to spawn, 5 (11%) were in the 5th stage, and one (2%) was in the 6th stage. (Henderson 1962).

In both lakes, northern pike abundance declined consistently over time as mechanical removal methods were being applied (FIGURE 5). Abundance estimates for northern pike in Rainbow Lake were calculated from 15 separate marking events. During the marking period 189 northern pike were marked and released and 87 were recaptured. The estimated number of northern pike in Rainbow Lake at the start of our study (January 2006) was 462 fish (9.8 fish/ha). Biomass of northern pike in Rainbow Lake was 6.6 kg/ha. Abundance estimates at Fool Hollow Lake were calculated from 22 marking events. Only 25 northern pike were marked, and 20 were recaptured. The estimated number of northern pike in Fool Hollow Lake at the start of our study was 85 fish (1.4 fish/ha). Biomass of northern pike in Fool Hollow Lake was 3.0 kg/ha.

We were able to capture about 50 percent of the population of northern pike measured at the start of the study in Rainbow Lake, and about 80 percent of the northern pike in Fool Hollow Lake using mechanical methods. Most fish were caught in the spring (e.g. FIGURE 6). Efficiency of various gear (catch per personnel hour divided by abundance at a particular time was different (TABLE 3) During both years of research, the most effective method was gill netting and trap netting with barriers in early spring during the northern pike spawning period (TABLE 3). Following this period efficiency of gill nets decreased (April-June) and then increased slightly in July. We captured no northern pike at night by electrofishing. Therefore, daytime electrofishing results are those reported. Efficacy of daytime electrofishing increased sequentially from March to July. Average total length, standard length and weight of caught fishes also differed by gear type (FIGURE 7) Northern pike caught in trap nets with barriers were larger than those captured in gill nets (Rainbow Lake), and electrofishing catches. ($P < 0.05$)

Catch per unit effort in standard trap nets was substantially lower than catch in trap net sets with barriers (TABLE 3). However, trap net sets with barriers were only effective in early spring when northern pike were spawning. Following spawning, the quantity of fish caught by this method decreased significantly. Additionally, overgrowth of this large trap by aquatic macrophytes started following spawning, making net retrieval difficult. Thus we removed this type of gear from our reservoirs following the spawning period.

Electrofishing caught smaller (age 0 to age 2) northern pike than the other gear types (FIGURE 7). Electrofishing efficiency at Rainbow Lake was highest in the summer, because of the higher proportion of young-of-year in the population later in the season, and because of a decrease in lake water level in the summer of 2007, which allowed electrofishing to be used more effectively over a larger area of the lake. Except for summer 2007, electrofishing was less effective than other gears for capturing adult northern pike, because these fish tended to live in offshore areas, inaccessible to electrofishing.

Catches of northern pike from day sets of gill nets were not significantly different ($P < 0.05$) than overnight sets (TABLE 3). Therefore, CPUE of day and night sets was combined for the analysis. Also, there were no differences in mean standard length, mean total length and mean weight of northern pike caught at day and at night ($P < 0.05$). However, by-catch of fish besides northern pike, mainly largemouth bass and black bullheads, was much higher for night sets than day sets (TABLE 4). The 32 mm-bar mesh size in the gill nets caught the most northern pike ($P < 0.05$; nonparametric Wilcoxon test) by number (FIGURE 8) and weight (FIGURE 9). There was no difference in the number, length, or weight of caught fishes between the 19 and 25 mesh sizes; nor was their a difference in these parameters between the 38 and 51 mm mesh sizes. The mean standard length of northern pike caught by the 32 mm-bar mesh size and above was larger than 400 mm (FIGURE 10), an important consideration when removing northern pike that would be able to consume newly-stocked catchable-sized trout.

Gill netting was most effective in early spring (TABLE 3). In Rainbow Lake, northern pike catch was highest in area 1 (the spawning area) in March. Following March, catch was evenly distributed across areas and the frequency of fish caught per net declined. In Fool Hollow Lake we caught northern pike in the winter only in area 2 near the dam, while at other times, most northern pike were caught in area 1.

Few fish were reported by anglers in our angler incentive program. We received 8 tags from northern pike caught by anglers, 6 of them from Rainbow Lake and 2 from Fool Hollow Lake. Assuming a 50% reporting rate, this means that 12 tagged fishes were captured in Rainbow Lake and 4 in Fool Hollow Lake. In Rainbow Lake, the ratio of tagged to untagged fish in the population was 1:2.4. Therefore, using this ratio, we calculated the total number of fish caught by anglers to be 30 in 2007. In Fool Hollow Lake, the ratio of tagged to untagged fish was 1:2.3. Therefore, we calculated the total number of fish caught by anglers in Fool Hollow Lake to be 14 in 2007.

Discussion

It is possible to depress populations of fish in a wide variety of water bodies using mechanical control. Otherwise, there would be no need to manage harvest of fish stocks in large reservoirs and oceans. The pertinent question when designing a mechanical fish control program is not whether it is possible to mechanically suppress the fish (it is), but whether the suppression is economically feasible given the available resources, and it achieves the desired results (e.g. reestablishment of native fish populations or valuable sport fisheries). In large North American lakes such as Lake Davis, California, where complete eradication is desired, mechanical suppression may not be economically feasible and piscicide treatment a better choice (CDFG 2003). In smaller North American lakes and ponds, such as Rainbow Lake and Fool Hollow Lake, Arizona, mechanical suppression of a top predator such as northern pike may be economically feasible. In larger systems where labor costs are low and desire for freshwater fish as food is high, such as on the Dnieper system of the Ukraine, mechanical suppression may also occur. Mechanical suppression may also be feasible where management agencies decide the costs to apply sustained pressure over time might be acceptable, and piscicide is not an option, such as in the case as preventing the extinction of a threatened or endangered species (e.g. upper Colorado River system).

Our study suggests that mechanical methods can be used feasibly to remove a large proportion of northern pike from small Arizona lakes. We used two people on most capture surveys, and if trapping occurs in the spring, especially during spawning season, effectiveness is maximized. These results may be supported by findings in Parker Canyon Lake, Arizona, where following multiple years of gill net removals, northern pike catch rates declined to 0 (Mitchell, D. AZGFD, Unpublished Data). However, because this lake was at the extreme southern range of northern pike distribution, temperature or other water quality factors may have influenced the population as well.

While our techniques were successful in capturing many northern pike, we may have overestimated the proportion of fish removed during our study. Pierce (1997) found that by using multiple-capture techniques involving only trap net sets in Minnesota lakes during early spring following ice-out, abundance estimates averaged 39% less than using a Petersen estimate with two gear types conducted over a longer period of time. These resulted because of violation of the equal catchability assumption of abundance estimation, a very sensitive assumption (Pierce 1997). Although we used many gear types, the majority of our fish were captured using one gear type and method - gill nets fished in the early spring - potentially biasing our population estimates low. In addition most of the fish we captured were over 300 mm in length, potentially further violating the equal catchability assumption for fish under 300 mm. Our probable overestimation of the total percentage of northern pike removed from the lake did not affect our evaluation of the relative effectiveness of the different techniques.

Our results suggest that unlike a chemical renovation to remove nuisance northern pike, a sustained effort is needed for mechanical control. We did not entirely remove all northern pike, and populations could rebuild if mechanical control is not continued. Mechanical control of fish can be compared to mowing a lawn. Biomass will be controlled with continued effort, but in the absence of such effort, biomass will increase, sometimes rapidly.

Our study agreed with others that found that gill netting was a highly efficient method for capturing northern pike (Flinders and Bonar 2008; References in Bonar et al. 2009). Broughton and Fisher (1981), compared gill nets, seine nets, and angling, and found gill nets were the most effective by the number of fishes caught to the number of personnel hours. Several chapters in Bonar et al. (2009) recommend gill nets as a method of choice for capturing northern pike.

Our study demonstrates that gill netting efficiency for northern pike can be maximized using specific techniques. Using the nets to capture northern pike when they concentrate during the spawning season can be very effective. Northern pike distribution in Rainbow Lake in spring was in accordance with the spawning period. A few days before and during spawning, northern pike concentrated in the shallow zone of area 1 (FIGURE 1). Immediately after spawning (when females of reproductive stage 5 disappeared from catches) the total efficiency of gill nets in area 1 decreased. In April, total catch of pike in this area was three times lower than in March and gradually decreased, as it did in other parts of lake. This indicates the northern pike distributed throughout the lake following spawning, in accordance with its biology as an ambush predator. Therefore, biologists interested in maximizing catch should concentrate on these early spring spawning assemblages.

An additional reason to concentrate gill net fishing in early spring is to reduce the effect on stocked trout, which are usually stocked beginning in April. Before the spring stockings, we captured no trout in gill nets. Following stocking we averaged 1.04 fish per hour of gill netting.

A variety of gill net mesh sizes will capture a wide distribution of northern pike lengths. The most effective mesh size for capturing northern pike in Rainbow and Fool Hollow lake was a 32 mm bar (FIGURE 6). Furthermore, because the largest northern pike were caught in nets with mesh sizes of 38-51 mm, we suggest the most preferable mesh sizes will be a combination of 32- 51 mm bars for lakes with a similar size structure of northern pike. Using mesh of this size and above would allow the culling of larger northern pike that would have the most immediate impact on stocked trout.

The difference in efficiency of day and night gill nets sets for northern pike was not statistically significant (0.5 CPUE/AB at day and 0.2 CPUE/AB at night) and length-weight characteristics between the two catches were similar. However, night catches contained a high number of by-catch of other species, especially bullhead, making the process of net handling very difficult. If control efforts are designed for both northern pike and other species, this would be positive; however, if efforts are designed for northern pike alone, netting should be focused during the day. An important exception to this timing suggestion would be net sets at spawning periods. Implementation of both day and night net sets at the entry to spawning areas would increase the effectiveness of removing fish during the short spawning period and would help close the spawning areas to northern pike both day and night

Generally, catchability of northern pike in gill nets was higher than in trap nets, but there are several advantages for also using trap nets in combination with barrier net crowders to capture northern pike. Trap nets with barrier net crowders can control accessibility to spawning areas, a small amount of time is needed to handle these nets, there is less mortality of by-caught fish in trap/barrier crowders than in gill nets and the largest northern pike were captured in the trap-barrier combination (Average SL 476.5 mm). Therefore, it might be advantageous to use these nets in combination with gill nets.

Electrofishing with our typical boat unit was less effective for control, possibly because of high noisiness which led to the fear reaction of adult northern pike a long time before the fish could be affected by electric field. Also, electrofishing was gear intensive and logistically more difficult that deploying gill or trap nets. Future research could consider Ukrainian electrofishing methods for northern pike. In Ukrainian reservoirs, poachers use electrofishing to capture northern pike illegally (Authors personal experience as Ukrainian fisheries police). Most of the illegal electrofishing equipment uses current up to 2000 volts which stuns or kills the fishes. This equipment has been installed on small boats with electric engines and uses batteries to reduce noisiness.

The results we obtained by our angler incentive program were considerably different that those obtained by a creel survey conducted by the AZGFD. Our angler incentive program calculations revealed that anglers caught 30 northern pike (during February – June 2007) in Rainbow Lake and 14 northern pike in Fool Hollow Lake (during February – June 2007) A creel survey conducted by the AZGFD during the same time period suggests angling was a highly effective method. Arizona Game and Fish Department data shows that in 2006 Anglers caught 722 (SE163) and removed

271 (SE 85) northern pike from Rainbow Lake, while in 2007 they removed 126 (SE 68). In 2006, anglers removed 85 (SE 37) fish from Fool Hollow Lake (K. Meyer, AZGFD, Unpublished Data). Information about anglers' effort and catch distribution was obtained by AZGFD annual creel surveys, using the protocol of AZGFD (Bryan et al. 2004). Such a difference in data could be attributed to several factors: (1) a low return of tags for rewards in the angler incentive program, considerably under the assumed 50% rate, thus affecting the final harvest estimate; (2) an overestimate in the capture rate in the creel survey – the creel survey estimate is higher that the population estimate of northern pike captured by a variety of methods or (3) a combination of the two. Angling is a low cost method of control, but we cannot ascertain its effectiveness from our study. More work needs to be conducted to determine which estimate is closer to the actual number removed by anglers.

According to the AZGFD only about 4% of anglers prefer fishing for northern pike (Meyer et al. 2006). Northern pike are usually by-catch, obtained when anglers are trying to catch other predators such as bass or walleye. We found anglers did not show a lot of interest in the angler incentive program when this study was started, due to the low amount of tags returned and acts of vandalism such as the removal of information brochures and stands from the side of lake. Minimal effort to improving of angler's awareness level by publications and placement of additional information signs around the lake could be made without substantial financial expenditures and thereby angling could be a promising additional method for northern pike removal considering its low cost and the high intensity of angler activity in this area.

During our research we observed factors that might improve the effectiveness of anglers for controlling northern pike. Most anglers who tried to catch northern pike used small lures up to 10 cm long, which were effective for other species. As fish grow they tend to broaden the size range of prey items they ingest and eat larger prey for higher efficiency (Blaxter and Jones 1967; Houde and Schekter 1980; Schmitt and Holbrook 1984; Werner and Gilliam 1984; Blaxter 1986; Miller et al. 1988; Osenberg et al. 1988; Mark et al. 1989). The optimal prey size of northern pike is between 0.33 and 0.50 of their length (Scott and Crossman 1973). Therefore, the average length of northern pike caught by anglers should be about 30 cm long or less, which we observed during the study. In Rainbow Lake, targeting this size of northern pike to improve trout survival is less efficient because these pike cannot eat stocked catchable trout. Larger lures may select for the larger fish. Other factors that decease the catchability of lures is low water clarity and the high level of other available foods in the lakes, such as a high trout density, when angler activity is highest (May-June).

During one month (March 2007) of fishing on Rainbow lake with total effort 84 nets days (8 hours on each) 171 pike were caught, consisting of about 45% of all adult pike in reservoir. Totally 100 hours of personnel work were spent on setting and handling of nets. Considering that that only half of net panels caught most of the adult pike, it is possible to predict that by the using nets with bar mesh size of 32 -51 mm, efficiency of fishing could be improved 50 percent. Likewise installation of nets only at day or only at night probably decreased efficiency of the effort, particular during the short spawning period. Net sets of 24 hours at the mouth of the spawning area may improve efficiency of fishing effort.

During our research we could not set all our nets in one area because we were testing them in different areas of the lake. However, catch distribution definitely showed a high concentration of northern pike in area 1, where the most optimal sites for spawning were located. Thereby during control efforts, installation of all nets in this area in one line or perpendicular to wings of trap net (if one will be used) as it is often applied in Ukrainian reservoirs will likely lead to the highest efficiency of gill netting

Further pressure on larger northern pike may lead to an increasing of young-of-year density. But fishes up to 400 mm in length could not eat stocked trout (Meyer et al. 2006) and regular removal of adult pike may allow a decrease in density of northern pike in Rainbow Lake to acceptably low levels. In addition, any further impairment of the environment for northern pike, such as increasing numbers of predators, or reducing water levels at specific times of the year would have further effects.

From our study, some recommendations can be identified. For Rainbow Lake we recommend installation of 10 gill nets (length, 25 m; depth, 2 m bar mesh size 32-51 mm) for 14 days once every two years at spring after ice melt or when spring water temperature approximates 14°C in the spawning zone (area 1). This should hold the density of the northern pike which are able to prey on catchable trout at a low level. The AZGFD determined the break-even point of mechanical removal as $5,200 USD (approximately 26 person-days) annually. Fourteen days of work for two people once per every two years will consist 14 person- days per year, which equals $2800 per year. Lost of stocked trout would be minimal at these times because the activities will be conducted before trout are stocked into the reservoir.

Our data suggest mechanical suppression of northern pike in small Arizona lakes is possible if the goal is to reduce impacts to catchable-sized trout. To apply results from this research into other reservoirs, we suggest.

1. Estimating length-at-age and abundance of northern pike population;
2. Estimating time and area of spawning;

3. Estimating optimal location to install trap and gill nets; Construction of gears, choosing of optimal mesh size based on the biological characteristics of the population; matching the dimensions of the nets to the depth and width of the spawning area;

4. Installing trap nets 2 weeks before estimated time of spawning (Trap nets should be checked once per 2-3 days);

5. Gill netting with two gill nets sets at day and at night in the spawning area during the entire spawning period.

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TABLE 1. Total catch of northern pike from Rainbow and Fool Hollow Lakes, Arizona, January 2006 - July 2007.

	Rainbow Lake				Fool Hollow Lake	
	2006		2007		2007	
	Caught and Released	Caught and Removed	Caught and Released	Caught and Removed	Caught and Released	Caught and Removed
Gill Net	206	60		297	27	47
Trap Net	4	1				
Trap Net with Barriers				11		5
Day Electrofishing	11			28		1
Angling with Incentives				30		14
Total	221	61		366	27	67

TABLE 2. Lengths-weights-at-age of northern pike from Rainbow Lake, Arizona, December 2006 -July 2007.

Age	1	2	3	4	5	6	7	8
Number of fish	34	138	16	53	40	39	6	10
Mean standard length (mm)	223	301	365	426	515	595	688	766
SE	7	2	3	4	4	4	7	7
Mean weight (g)	106	223	436	722	1305	1917	2817	3801
SE	11	6	246	22	45	62	170	252

TABLE 3. Efficiency of different gears for northern pike removing from Rainbow (RL) and Fool Hollow (FHL) Lakes, Arizona by month. Efficiency presented in fish per personnel hours (CPE) and fish per personnel hours divided by northern pike abundance size at that time (CPE/A). Gear included gill netting (GN), trap netting (TP), trap netting with barriers (TPB), day electrofishing (DEF) and angling with incentives (AI).

Lake	Month	Year	GN		TP		TPB		DEF		AI	
			CPE	CPE/A	CPE	CPE/A	CPE	CPE/A	CPE	CPE/A	CPE	CPE/A
RL	Jan	2006	2.19	0.47								
	Feb		2.99	0.65	0.30	0.05			0.75	0.16		
	Mar		3.62	0.79	0.50	0.10			1.00	0.22	0.50	0.15
	Apr		2.82	0.64	0.10	0.03			0.50	0.11		
	May											
	Jun		2.08	0.51					0	0		
	Jul								0.75	0.18		
	Total		**2.82**	**0.63**	**0.29**	**0.06**			**0.68**	**0.20**	**0.50**	**0.15**
	Jan	2007										
	Feb											
	Mar		2.20	0.57			1.0	0.29	1.00	0.20		
	Apr		1.10	0.32			1.5	0.43	1.33	0.51		
	May		1.50	0.47			0	0	0.50	0.23		
	Jun		0.80	0.28					1.50	0.72		
	Jul		1.30	0.48					1.50	0.80		
	Total		**1.68**	**0.57**			**1.1**	**0.30**	**1.17**	**0.50**		
FHL	Nov	2006	0.20	0.20								
	Dec		0.60	0.80								
	Jan	2007										
	Feb		0.80	1.16					0	0		
	Mar		0.80	1.74			0.8	1.50	0	0		
	Apr		0.21	1.00					0.5	2.3		
	May		0.30	0.17					0	0	0.75	1.2
	Jun											
	Jul											
	Total		**0.62**	**1.36**			**0.8**	**1.5**	**0.13**	**0.6**	**0.75**	**1.2**

TABLE 4- Bycatch of fishes (fish per personnel hour ± standard error) in experimental gill nets in Rainbow Lake, Arizona, Jan-July, 2007. Total effort is reported in personnel hours.

Set type	**Total effort**	**Rainbow trout**	**Largemouth bass**	**Black bullhead**
overnight	336	1.037 ± 0.09	0.03 +0.004	2.94+0.237
day	1080	0.15 +0.03	0.003±0.001	0.11±0.086

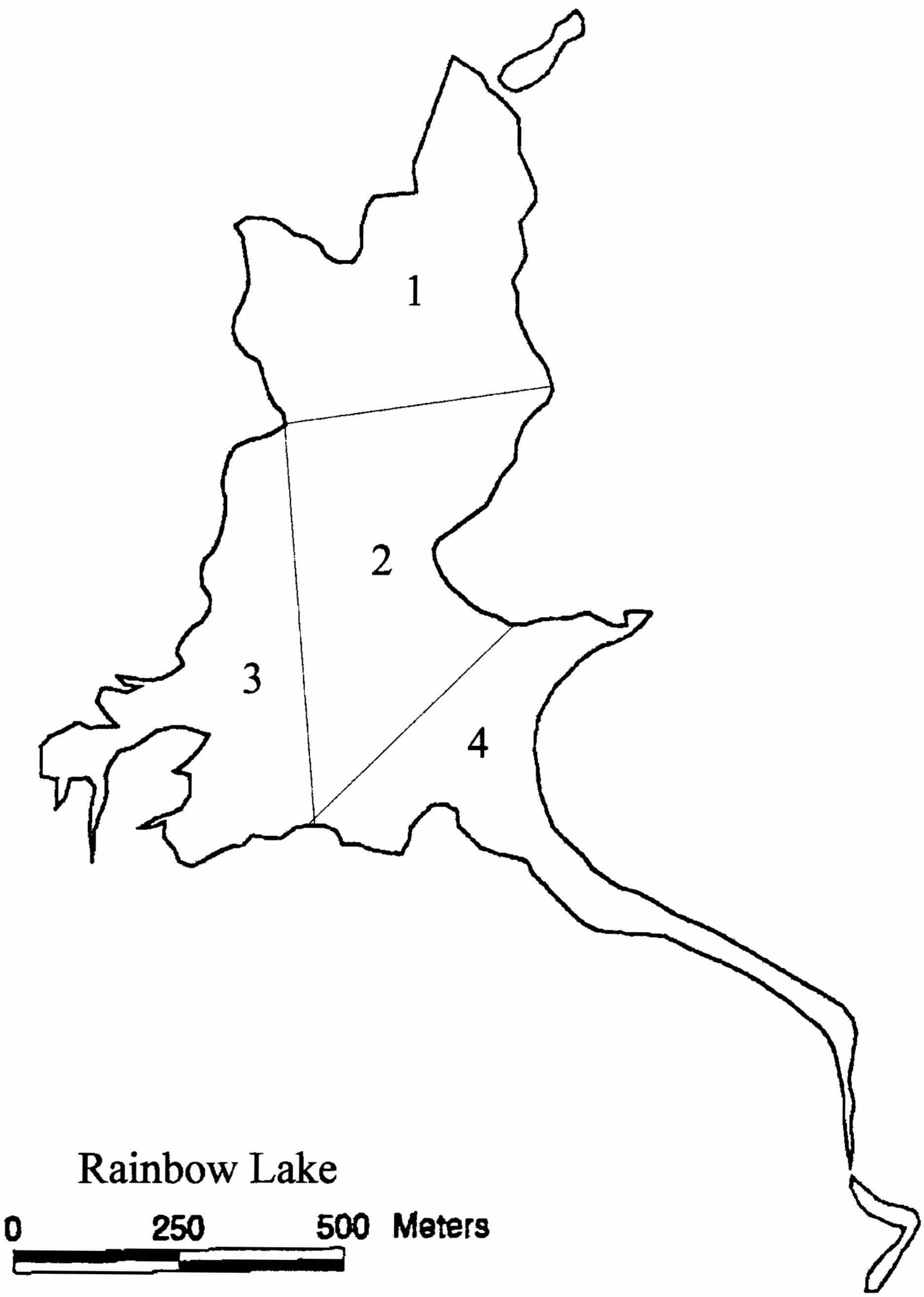

FIGURE 1. Map of Rainbow Lake, Arizona, with study areas.

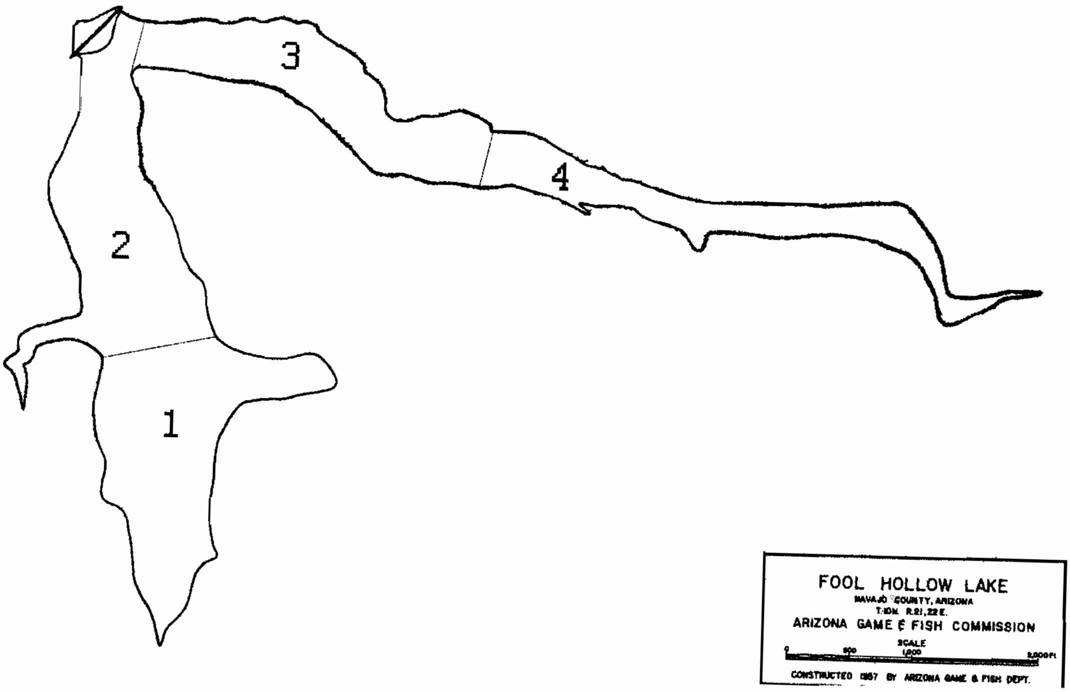

FIGURE 2. Map of Fool Hollow Lake with study areas.

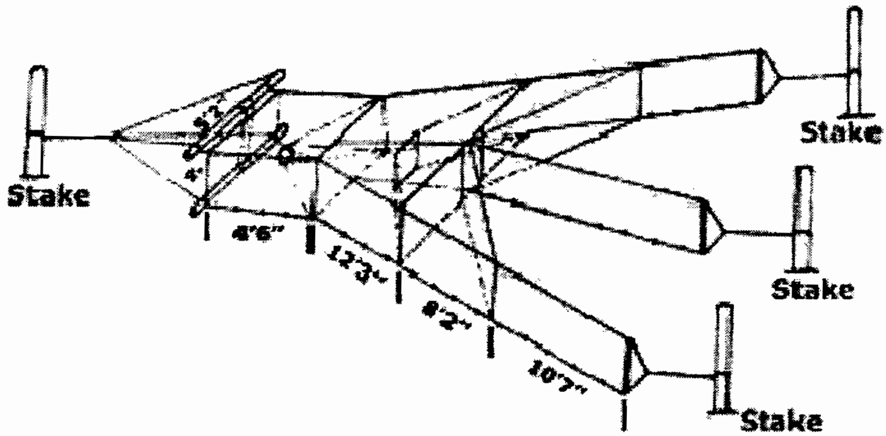

FIGURE 3. Trap net used in Arizona study lakes to remove northern pike.

FIGURE 4. Ukrainian trap net and barrier method to capture northern pike. 1- trap net, 2-barrier nets, 3-gill nets, arrows – northern pike movement.

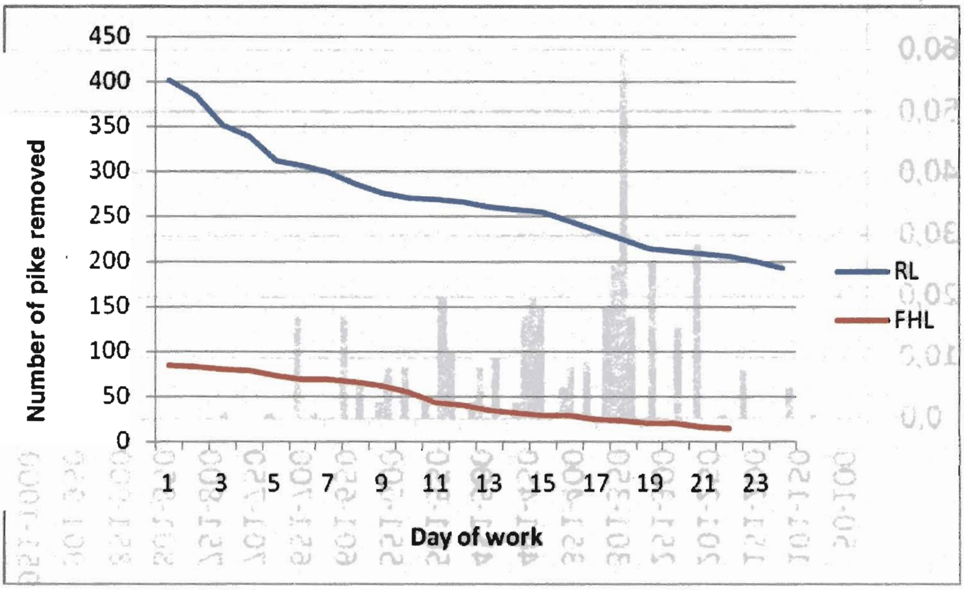

FIGURE 5. Decline in northern pike over time in Rainbow (RL) and Fool Hollow (FHL) Lakes, Arizona, 2007.

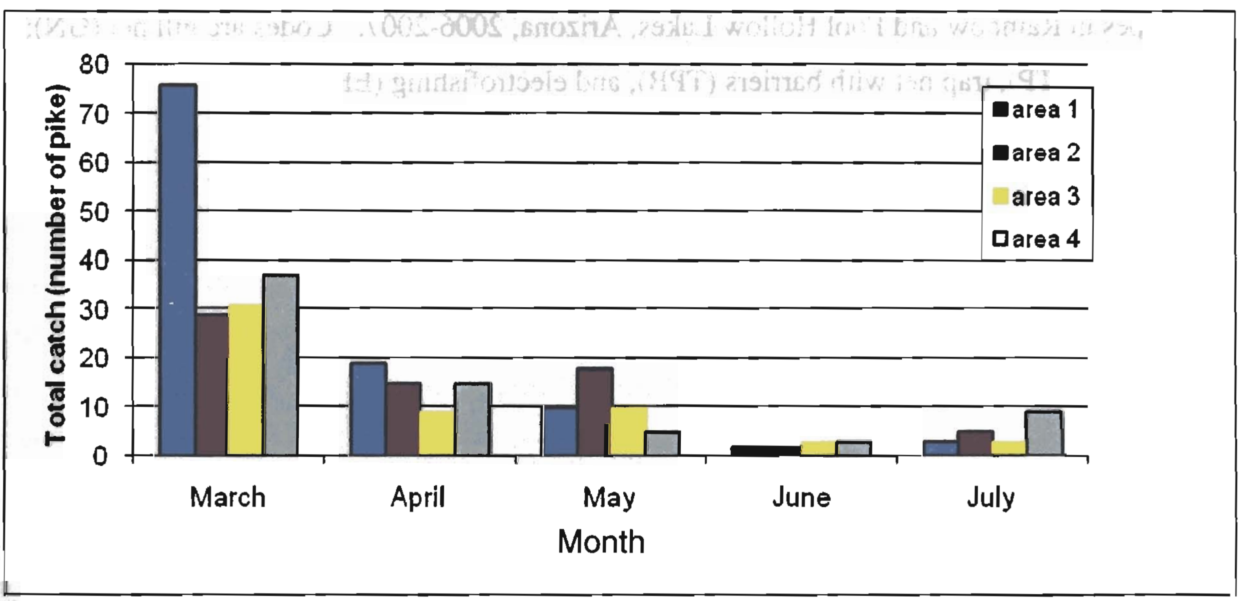

FIGURE 6. Catch of northern pike by month and area in Rainbow Lake, Arizona, 2007.

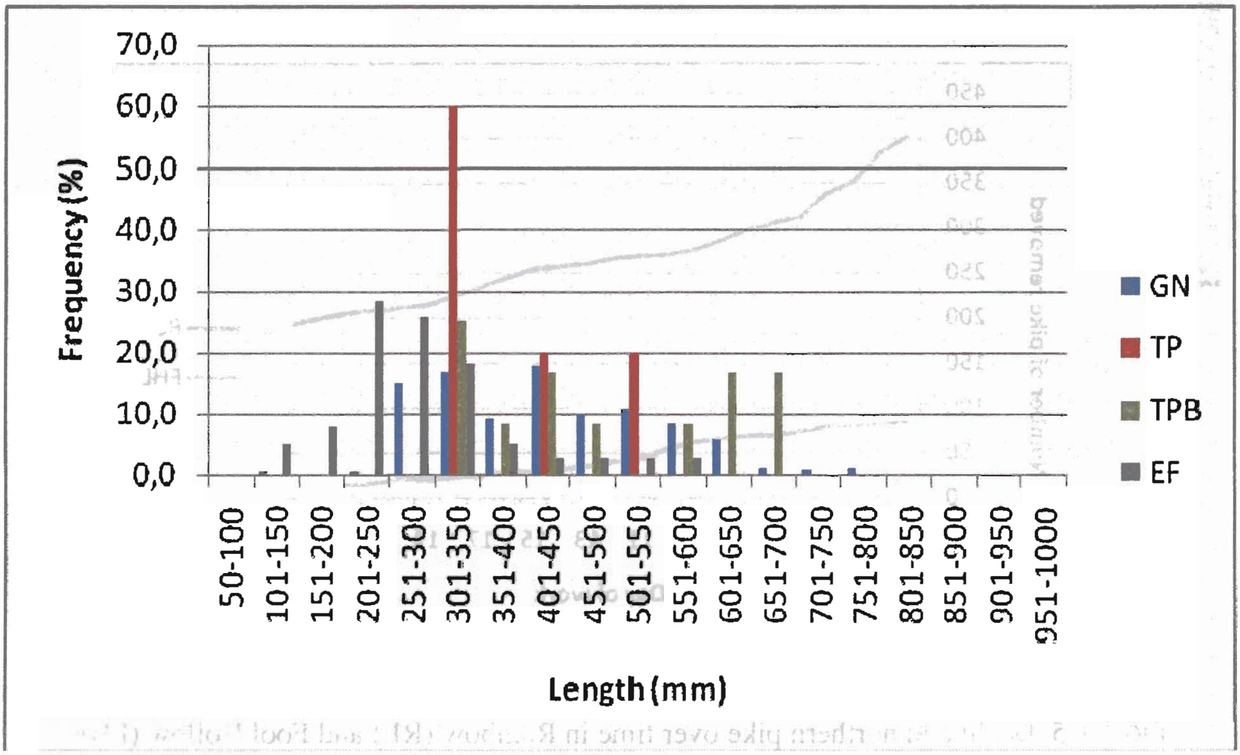

FIGURE 7. Length frequency distributions of northern pike captured by the various gear types in Rainbow and Fool Hollow Lakes, Arizona, 2006-2007. Codes are gill net (GN); trap net (TP), trap net with barriers (TPB), and electrofishing (EF).

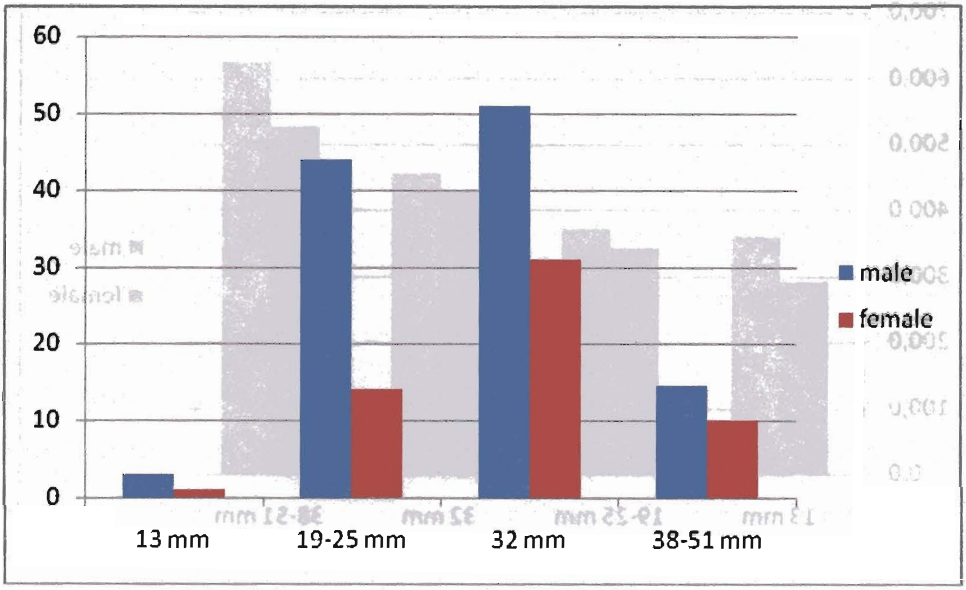

FIGURE 8. The catch distribution by the number of pike caught in gill nets with different mesh size, Fool Hollow and Rainbow Lakes, Arizona 2006-2007.

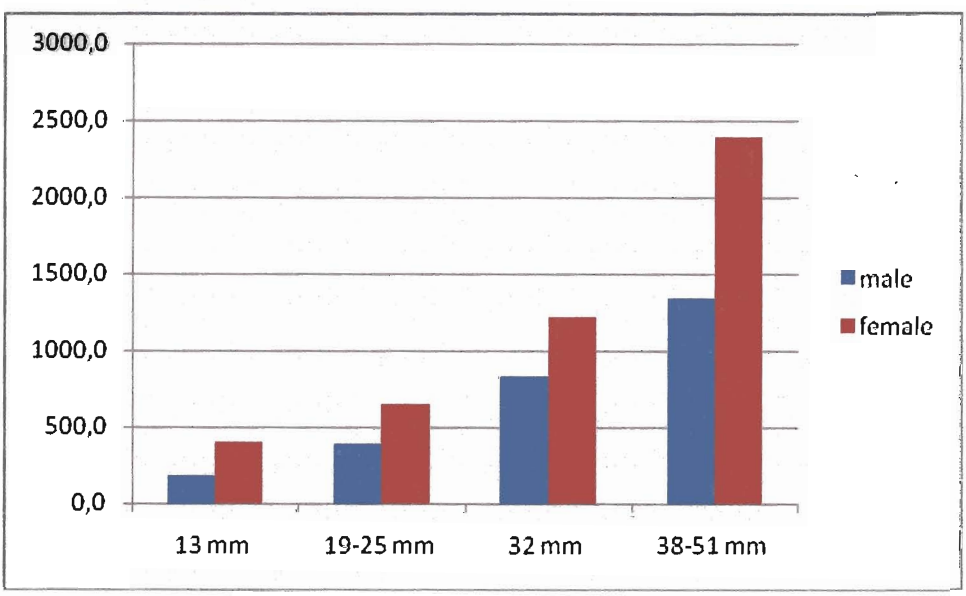

FIGURE 9. The catch distribution by the total weight (g) of pike caught in different gill net mesh sizes, Fool Hollow and Rainbow Lakes, Arizona 2006-2007.

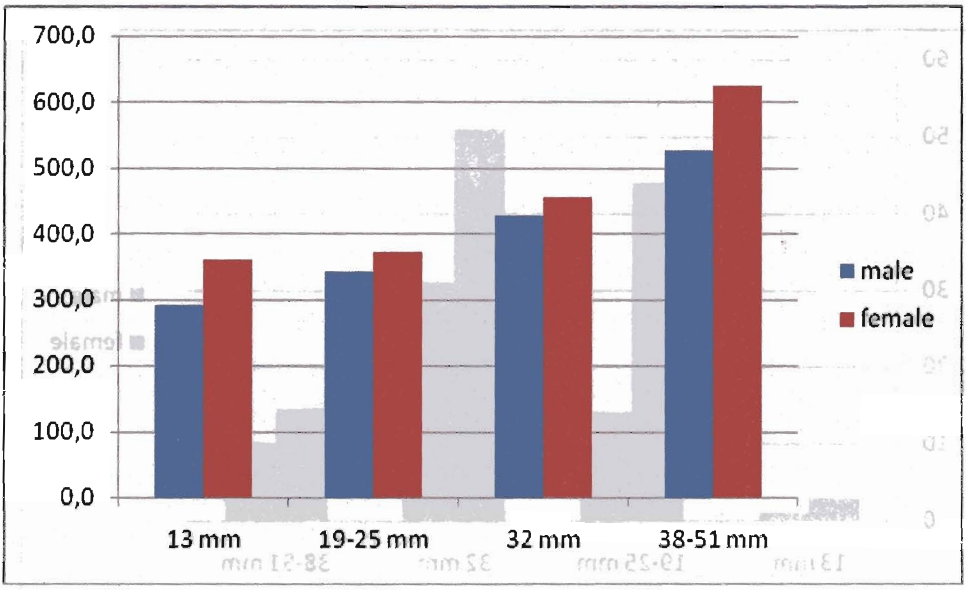

FIGURE 10. The catch distribution by mean standard length (mm) of pike caught in different gill net mesh sizes, Fool Hollow and Rainbow Lakes, Arizona 2006-2007.