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Comparison of Creel Survey Data to Traditional Sampling Techniques in Pit-Lake Fisheries of Muhlenberg County, Kentucky

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COMPARISON OF CREEL SURVEY DATA TO TRADITIONAL SAMPLING TECHNIQUES IN PIT-LAKE FISHERIES OF MUHLENBERG COUNTY, KENTUCKY

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COMPARISON OF CREEL SURVEY DATA TO TRADITIONAL SAMPLING TECHNIQUES IN PIT-LAKE FISHERIES OF MUHLENBERG COUNTY, KENTUCKY

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Derek L. Rupert May 2012 37 Pages

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Populations of largemouth bass, *Micropterus salmoides,* and bluegill, *Lepomis macrochirus,* were evaluated from five pit-lakes in Muhlenberg County, Kentucky, to determine if accurate proportional stock density (PSD) data can be obtained from a mandatory creel survey. It was hypothesized that the proportion of stock-to-quality (300-400mm) and quality (+400mm) largemouth bass from four years (2007-2010) of creel survey data would be statistically similar to those generated through on-site sampling in 2011. Fish were collected via a combination of gill netting, seining, hook-and-line fishing, and boat-mounted electro-fishing. In two of the pit-lakes, the sampling-generated length frequency data was not significantly different from the creel survey data (Pump $G_{adj[1]}$=0.03, P=0.8629, Goose $G_{adj[1]}$=0.76, P=0.3850). There were significant differences between creel and sampling data for the other pit-lakes (Big Reno $G_{adj[1]}$=5.74 P=0.0166, Airstrip $G_{adj[1]}$=14.3 P=0.0002, Lime $G_{adj[1]}$=9.81 P=0.0017). At least one of the lakes likely demonstrated significances because of low sample size (Airstrip and/or Lime). Changes in population structure due to modified harvest regulations may be responsible for the significant differences (Big Reno and Lime). Population structures were verified with relative weight, length-at-age, and an assessment of five years of largemouth bass and bluegill PSD data. It appears that creel survey

data does accurately reflect that of simple sampling techniques and can help guide management decisions.

INTRODUCTION

The goal of small impoundment fisheries management has shifted between two major paradigms, both of which are based on the desires of anglers. The elder paradigm, maximum sustained yield (MSY), aims to produce the maximum biomass of fish (Kohler and Hubert 1999). The main goal is to produce the greatest amount of fish flesh to be harvested as a food resource. Early work by Swingle (1950) explains that the predator-prey relationship in small ponds occurs across a continuum of weight-based ratios, with some community structures being obviously more advantageous than others in terms of harvestable biomass, or MSY. During the 1970's, fisheries management underwent a paradigm shift, and transitioned from MSY to optimal sustained yield (OSY). Optimal sustained yield attempts to increase the number high-quality fish, with less attention given to biomass yield. Often with OSY management, a fishery may have a population of very large target species (e.g. largemouth bass), but at the expense of prey species (Anderson 1976; Gablehouse 1984b; Boxrucker 1987; Guy and Willis 1990).

Proportional Stock Density

In the 1970's, Anderson developed a tool to allow managers to assess pond fish populations through simple sampling techniques (Anderson 1976, 1978). Anderson (1976) introduced the Proportional Stock Density (PSD) index, which provides the data that managers need to assess small impoundment population structures. Based on the PSD values, managers can implement regulations that may lead to an increase in the abundance of high quality fish, the current goal of fisheries management under the OSY paradigm (Kohler and Hubert 1999).

Proportional stock density examines population structure based on fish length frequencies. The use of PSD is most often associated with fish populations in small bodies of water where it was developed and has been applied with success (Anderson 1976, 1978; Anderson and Gutreuter 1983; Weiss-Glanz and Stanley 1984; Ebbers 1987). By understanding PSD, managers can regulate predator harvest, which will manipulate fish populations to fit the needs of their angling constituency. PSD is an effective and popular tool to manage largemouth bass, bluegill, crappie, perch, and walleye fisheries in small impoundments across the midwestern and southeastern U.S. (Novinger and Dillard 1978; Guy and Willis 1990; Willis et al. 1993).

PSD is calculated by comparing the number of fish above a "quality" size to the number of fish above a "stock" size (Figure 1). Although there are multiple definitions for these lengths, most relate stock length to the size at which the

$$\text{PSD} = \frac{\text{Number of fish} > \text{quality length}}{\text{Number of fish} > \text{stock length}} \times 100$$

species become sexually mature and quality length to the minimum size that anglers prefer to catch. Gablehouse (1984a) later defines, for many fish species, quality lengths as 40% world record length and stock as 20% world record length. Gablehouse (1984a) adds larger specific size classes (preferred, memorable, and trophy) based on percent of world record length in order to refine this index for fisheries managed for very large fish. He also modified PSD to produce Relative Stock Density (RSD), which can use these new size class definitions to replace quality length. Relative stock density is identical to PSD when it is written as $RSD_{quality}$. Although there have been many attempts to modify PSD, the basic formula devised by Anderson (1976) remains the standard method used in fisheries management (northern pike, *Esox lucius*, Pierce et al. 2003; bluegill, Schultz and Haines 2005; new terminology for PSD, Guy et al. 2006; shovelnose sturgeon, *Scaphirhynchus platorynchus*, Shuman et al. 2007; channel catfish, *Ictalurus punctatus,* Michaletz 2009).

The largemouth bass, *Micropterus salmoides,* and bluegill, *Lepomis macrochirus,* stock lengths are 203 and 76mm respectively, with quality lengths of 305 and 153 mm, respectively (Anderson 1978; Gablehouse 1984a). The PSD of largemouth bass and bluegill occur in an inverse relationship (Anderson 1978; Guy and Willis 1990; Figure 2). I will refer to this largemouth bass PSD and bluegill PSD relationship as the $PSD_{bass:bluegill}$. When largemouth bass (the predator) population structure shifts, bluegill (the prey) population structure will experience an inverse shift (Anderson 1978; Guy and Willis 1990). Yearly calculation of $PSD_{bass:bluegill}$ allows managers to assess the current population structure and examine long term trends (Anderson 1976). Proportional stock density works best in warm-water ponds and lakes where largemouth bass and bluegill (or similar prey species) are the only species present, but it also works in lakes with more species if largemouth bass remain the dominant predator.

The usefulness of PSD may be reduced in impoundments above a particular size (Carline et al. 1984). These authors suggest a 15ha breaking point (major reduction in the slope of the relationship) in the $PSD_{bass:bluegill}$ relationship. Carline et al. (1984) suggest that in larger lakes bluegill PSD may no longer respond to changes in the PSD of largemouth bass. Others suggest that this size criterion may be too conservative, as Gablehouse (1984c) and Willis and Guy (1990) observed a 34ha impoundment and 55ha lake, respectively, that followed the $PSD_{bass:bluegill}$ relationship. It is currently unclear what surface area size(s) will cause a breakdown of the $PSD_{bass:bluegill}$ relationship. This project has the potential to further elucidate the $PSD_{bass:bluegill}$ relationship breaking point, as the study lakes are of similar sizes (25, 11, 10, 9, and 6 ha) as the previously mentioned studies.

Interpreting PSD is fundamental to small impoundment management because $PSD_{bass:bluegill}$ provides managers with the status of the predator/prey relationship. Through predator harvest, managers can adjust the length frequency distributions of these species to meet the wishes of their fishing constituency. As largemouth bass are the top predator in these fisheries, any changes to the largemouth bass population will affect the prey species. Bluegill growth and PSD are both positively correlated with the density of largemouth bass (Boxrucker 1987; Guy and Willis 1990) and largemouth bass density is negatively correlated with largemouth bass PSD (Gablehouse 1984b; Boxrucker 1987, Guy and Willis 1990; Saffel et al. 1990). This suggests that bluegill populations change in response to changes in largemouth populations. This is why managers typically use largemouth bass harvest rates to manipulate population size structures of largemouth bass and bluegill (Otis et al. 1990).

Fisheries that exhibit a low largemouth bass PSD (≈10) and a high bluegill PSD (≈90) are dominated by numerous, small largemouth bass and few, large bluegill (Figure 2a). This condition has been termed "panfish option" as the fishery will provide excellent panfish fishing. This may also be referred to as "bass crowded," as the largemouth bass population is dominated by many small individuals. Managers should implement a no-harvest regulation on largemouth bass if they wish to retain the panfish option condition. Conversely, in lakes with a high largemouth bass PSD (≈90) and a low bluegill PSD (≈10), the fishery will be dominated by few very large largemouth bass and numerous small bluegill (Figure 2b). This condition would be achieved through a liberal harvest of small largemouth bass and protection of large largemouth bass. Because harvesting small largemouth bass may not appeal to anglers, it may be necessary for managers to remove many of the small largemouth bass needed to achieve a "trophy bass" condition. Removing small or recruit-sized largemouth bass frees up resources that they would normally sequester. Presumably, these extra resources allow the remaining largemouth bass to grow faster. Flinkinger et al. (1999), propose a yearly harvest of 75 largemouth bass 200-300mm and twelve 300-380mm per hectare per year, to reach a trophy bass condition. It is very important that large largemouth bass be released, as they take many years to reach a "memorable" size. For example, it takes eight years for a largemouth bass to reach 500mm+ in Kentucky (Gablehouse 1984a; Beamesderfer and North 1995).

If the PSD for both species is between 40 and 60, there will be a moderate abundance and size of both largemouth bass and bluegill. This condition is referred to as "optimal," as there are sufficient numbers of quality-sized fish of both species (Figure 2c). Managers must allow a moderate harvest of largemouth bass to maintain this condition. Flinkinger et al. (1999) proposes the harvest of 75 largemouth bass 200-300mm per hectare per year for the optimal condition.

Research has documented that other prey species, e.g., crappie, *Pomoxis* spp., and yellow perch, *Perca flavescens*, respond similarly to bluegill in the $PSD_{bass:bluegill}$ relationship (Gablehouse 1984b; Boxrucker 1987; Guy and Willis 1990). This means that a crappie fishery can be managed through largemouth bass harvest regulations, where the two coexist. An average crappie fishery is the product of a small impoundment with a management plan that is set up to provide an optimal condition. Large crappie are more common in ponds that are managed for a panfish condition (Gablehouse 1984b). Similar to bluegill, crappie in lakes managed for a trophy largemouth bass condition may be numerous, but most will be too small for harvest (Gablehouse 1984b).

Angler Data

Effective management of small impoundment fisheries requires continuous fish population monitoring and regulation manipulation, this is referred to as active management. Fisheries managers often use costly, time consuming, and labor-intensive techniques (e.g. electro-fishing, gillnetting, etc.) to assess fish populations. The use of angler diaries and volunteer surveys has been recommended as an easy way to obtain and an inexpensive means to collect fish population data (Weiss-Glanz and Stanley 1984; Green et al. 1986; Willis and Hartmann 1986; Prentice et al. 1993). Accurately assessing fish communities is the cornerstone of small impoundment management and any accurate method of data collection has the opportunity to be extremely helpful in making management decisions (Swingle 1950). This project aims to explore the use of creel survey data collected from the pit lake fisheries of Wendell Ford Regional Training Center (WFRTC), with the expectation of providing accurate data for active management of these fisheries. Specifically, I hypothesized that creel survey data will be statistically similar to field sampling data.

Additional Assessment Tools

Willis et al. (1993) suggest that PSD be used in conjunction with other fisheries techniques. They propose that length frequency indices (e.g. PSD) should be used in conjunction with a condition factor, growth assessment, or community assessment, etc., to provide a reliable assessment of a fishery. I will use relative weight, length-at-age, and assemblage assessments to validate the PSD findings.

Relative weight index (W_r) is a condition factor index that compares a fish's actual weight to an optimal species-specific weight at length (Wedge and Anderson 1978; Anderson and Neumann 1996). This is a measure of robustness, and an indirect measure of growth and condition. A population with a mean W_r of approximately 1.0 has average plumpness and growth. A population exhibiting a W_r <1.0 contains thin, slow-growing fish with limited food resources. A population with a mean W_r >1.0, contains above-average fish plumpness and fast growth, but resources may be underutilized (Wedge and Anderson 1978; Anderson and Neumann 1996).

The species present and the overall community assemblage can greatly affect a fishery. A lake with only largemouth bass and bluegill (or similar prey species) is often thought of as the best assemblage, as anglers desire both species and management is simple (Flickinger et al. 1999). Channel catfish and crappie are often stocked in small impoundments to provide alternative sport-fishing opportunities. Crappie populations have a tendency to stunt and overpopulate (Flickinger et al. 1999). Gizzard shad, *Dorosoma cepedianum,* can be advantageous in lakes managed for trophy bass, but they can have adverse effects on all other management strategies, such as the trophy panfish management (Flickinger et al. 1999). Additional predator species may have deleterious effects on largemouth bass fisheries. Flathead catfish, *Pylodictis olivaris,* have been documented to change largemouth bass and bluegill population structures (Balsman and Smith 2010).

Length-at-age (L_{age}) is an assessment technique that examines the mean length of a species age class (Beamesderfer and North 1995). Simply put, a five-year-old fish in a population of fast growing fish will be longer than if it was from a population of slow growing fish. The age of fish is determined by examining otoliths (Devries and Frie 1996). Length-at-age information is useful in gauging the growth of fish across multiple populations.

STUDY SITE

The Wendell H. Ford Regional Training Center (WFRTC, the training center) is a 4,450ha National Guard training center located in Muhlenberg County, Kentucky. The training center property has had a long history of coal mining. "Pit lakes" scatter the training center, ranging from <0.1 to 25 ha. Some of these lakes now provide recreational fisheries to National Guard soldiers, veterans, and employees.

Pit lakes are products of open-pit mining; the remnant earthen voids left from subsurface coal removal. The historic mining process that led to the WFRTC lakes began by removing the overburden, which is the material that lies atop a seam of coal. The coal was then extracted resulting in a deep depression or "pit." These pits were then abandoned, presumably because they were expensive to restore. The pits filled with water because they sat below the water table and/or due to surface runoff (Castro and Moore 2000).

Although many characteristics of pit lakes are also shared with small impoundments, ponds, and natural lakes, it is important to differentiate how these basins are distinctive. Pit lakes are not built with the intention of recreational use, rather they are remnants of industrial mining. Many pit lakes have steep, nearly vertical, edges with limited littoral area, and vary greatly in terms of surface area. Pit lakes often suffer from a variety of water quality issues, namely, low pH (<3), high specific conductivity, and high heavy metal concentrations (Lewis and Peters, 1959; Riley, 1960; McCullough, 2008).

Five WFRTC pit-lakes were evaluated: Big Reno, Airstrip, Goose, Pump, and Lime (Table 1). These lakes are among the largest and most popular for anglers at the training center. They range in surface area from 6ha (Lime) to 25ha (Big Reno) and maximum depths from 5m (Goose) to 15m (Big Reno and Airstrip).

The five study pit-lakes do not appear to exhibit the water quality issues that occur in many pit lakes. The low pH that is often associated with coal pit lakes is not a problem, with a pH across all the depths and study lakes ranging from 6.2 – 8.9 (March through October). The WFRTC Biologists do apply lime ($CaCO_3$) to the most popular fishing lakes, which could be buffering the pH. All of our study lakes contained summertime anoxic (<1mg/l O_2) chemoclines. Big Reno and Airstrip contained an anoxic chemocline at 4m and 9m, respectively, during all sampling events from March to October. These anoxic zones likely persist all year long in these deep lakes (each 15m total depth). This means that the fish are limited to the upper strata of oxygenate water, limiting the total available habitat within these lakes. Goose, Pump, and Lime do have a summer anoxic zone, but turnover in the spring and fall successfully cycles oxygen to the depths (Unpublished data).

The WFRTC lakes have been haphazardly stocked throughout the years with a variety of fish species (B. Morris WFRTC Environmental Division, personal communication). Common local sport species, namely, largemouth bass, bluegill, and black crappie, *P. nigromaculatus,* are found in several WFRTC lakes. These three species are the most sought after fish by WFRTC anglers, and thus the management objectives revolve around improving their quality (e.g. size and robustness) and quantity. Other species known to inhabit the WFRTC's waters include, redear sunfish, *L. microlophus*, channel catfish, *Ictalurus punctatus*, gizzard shad ,*Dorosoma cepedianum*, spotted gar, *Lepisosteus oculatus*, and white crappie, *P. annularis*. The WFRTC biologists stock hatchery-reared black crappie into some of the more popular lakes, with the hopes of supplementing the wild populations. They have also introduced sport fish such as walleye, *Stizostedion vitreum,* and hybrid striped bass, *Morone chrysops* x *M. saxatilis* (B. Morris WFRTC Environmental Division, personal communication). Flooding may have also washed in various species, as some of these lakes are within close proximity to streams and other lakes. There is a limited stocking history for these lakes and this study will provide the first quantitative assessment of their fish species assemblages.

The WFRTC currently uses the fish harvest regulations that are offered by the Kentucky Department of Fish and Wildlife Resources, with two exceptions. In early spring of 2008, a no-harvest regulation was implemented on Big Reno pit-lake, as the WFRTC biologists noticed that over harvest was causing a decrease in angler catch rates. The other exception is a 9-inch minimum size limit on crappie in all of the study lakes.

METHODS

Fish Sampling

Field sampling in 2011 consisted of a combination of gill netting, seining, and hook-and-line sampling, completed between August and September 2011. This field sampling regime was chosen to provide effective capture of a broad diversity of species and negate the bias associated with each individual technique. Four experimental gillnets (38m x 1.5m) were used. Each gillnet was constructed from five panels, each with a progressively larger mesh size (13mm to 50mm). Four gillnets were set overnight (≈16:00 to ≈8:00) for one night per pit-lake (four net nights). Hook-and-line sampling was performed after gillnetting was completed. Two anglers used simple fishing tackle for at least three hours per lake, attempting to capture as many fish as possible. Six seine (1.2m x 6m, 5mm mesh) hauls where completed over the gravel boat ramps of each pit lake.

Big Reno was part of a larger sampling effort to evaluate crappie population dynamics. This more extensive sampling regime included 28 additional net-nights, set during April to June 2011 and one electro-fishing event in May 2011.

All fish were identified to species and measured for weight and total length. The sampling, handling, and harvesting were performed under Western Kentucky University's Institutional Animal Care and Use Committee approval (see attached approval notification).

Largemouth bass, bluegill, and crappie were harvested and the otoliths removed for age determination. Individual growth rings (annuli) of the otolith represent one year of growth. The age is determined by counting the number of annuli from the nucleus (center or kernel) to the outer edge. A high-quality dissecting microscope (Leica Microsystems S6 E) with a moveable light source provided detailed viewing of each otolith. Otoliths from older fish and from those with vague growth rings were sectioned into halves (transverse section) and polished to expose the nucleus (Devries and Frie 1996).

The relative weight (W_r) was calculated for all largemouth bass and bluegill. The W_r of largemouth bass and bluegill was evaluated using standard weight (W_s) equations derived by Henson (1991) and Hillman (1982), respectively. Both W_s equations were recommended by Kohler and Hubert (1999).

Creel Survey

Creel survey data from the past four years (2007 to 2010) were obtained from the WFRTC biologists. This data is from a mandatory creel survey that is conducted by the WFRTC biologists. The WFRTC is a secure facility and all anglers must check in and out at a guard station. As anglers depart from the training center, they are required to complete the creel survey. The creel survey gathers data such as lake visited, target fish species, number and length (within 2-inch size classes) of fish caught, and number of fish kept (harvest). Conveniently, the 8-10in and 10-12in size class intervals of the survey correspond closely with largemouth bass PSD stock and quality length groups (200mm and 300mm, respectively).

Statistical Analysis

The G-test of independence was used to determine if a difference exists between the proportion of catch in the creel survey data (2007-2010) and the sampling data 2011 (Sokal and Rohlf 1981). The creel survey data was categorical, was not independent between each year, and individual fish may have been sampled more than once. Each year's largemouth bass length frequency data was partitioned into two size categories, stock-to-quality (200-300mm) and quality (>301mm), which correspond with largemouth bass stock and quality lengths. Fish <200mm were dropped from this analysis, as they are not used in PSD calculations. The range (high and low) and mean for the proportion of fish within each category across the four years of creel data was determined. The field sampling data was set as the expected values as this is the type of data fisheries managers traditionally collect to calculate PSD. The observed values were set as the closest datum point (high, mean, or low) from the four years of creel data. The null hypothesis states that the distribution of the fish in the two categories does not differ between creel survey and field sampling data. The standard scientific confidence level of 95% (α=0.05) was used. There was one "0" fish catch value and it was changed to very small number (0.01), to perform a natural log function used in the G-test. A William's correction was used to adjust the G-values to be more conservative for the low numbers of fish in the field sampling data. A chi-squared (X^2) distribution was used to evaluate the G-values for significance (Sokal and Rohlf 1981).

Comparison between the $PSD_{bass:bluegill}$ values derived from the field sampling (2011) and each creel survey year (2007-2010) may also help gauge the accuracy of the creel survey. If all five years of data form a logical trend or clump together then it is evidence that the creel survey data is accurate. If the data vary widely or does not form a trend then it is evidence that the creel survey data is not accurate.

RESULTS

Fish Sampling

Each of the sampling techniques (electro-fishing, gillnets, seines, and hook-and-line) provided unique data. Gillnets and seining tended to catch a relatively high diversity of species, while electro-fishing and hook-and-line caught a high number of target game species (largemouth bass, crappie, and bluegill). The number of fish species in each community varies between lakes, from 12 species

(Big Reno) to five species (Airstrip and Lime). All the study lakes contained a core group of four species: largemouth bass, bluegill, black crappie (none were captured in Lime Lake, but they are known to occur there), and mosquito fish, *Gambusia affinis* (Table 2). Big Reno holds the highest number of species, including the core group and eight additional species; warmouth, *L. gulosus*, redear sunfish, gizzard shad, common carp, spotted gar, channel catfish, yellow bullhead, *Ameiurus natalis*, and brook silversides, *Labidesthes sicculus*. Goose Lake contained four species in addition to the core group including, redear sunfish, warmouth, yellow bullhead, and blue catfish, *Ictalurus furcatus*. Pump contained the core group, plus warmouth, and channel catfish. Airstrip and Lime each contained one addition to the core group, redear sunfish and warmouth, respectively (Table 2).

The fish sampling in 2011 captured 107 largemouth bass and 62 bluegills (excluding juveniles from seine hauls). This is an average of 21 largemouth bass/lake and 12 bluegill/lake.

The median W_r of largemouth bass and bluegill varied between 75 - 80% for each pit lake, with one exception (Figure 3). Bluegill in Big Reno pit-lake exhibited median W_r of about 110%.

Creel Survey

The number of fish recorded by anglers varied greatly among the lakes. Big Reno had the greatest average number of largemouth bass caught per year (3004 largemouth bass/year). Lime had the fewest (142 largemouth bass/year) (Table 1). The creel surveys also provided data that gauged the amount of largemouth bass and bluegill harvested (Table 1). This data does not detail the size of the fish harvested, only the number of individuals. In 2007, Big Reno had a significant harvest of 30 largemouth bass/ha, then a regulation change stopped all largemouth bass harvest for the following four years. Goose, Pump, and Lime all had a relatively low largemouth bass harvest rate of approximately four largemouth bass/ha. The bluegill harvest rate was highest in Airstrip, with an average of 34 bluegill/ha. Bluegill harvest was moderate in Big Reno, Goose, and Pump (average 13 bluegill/ha), and low in Lime (1 bluegill/ha).

Creel Survey - Sampling Comparisons

The proportion of largemouth bass within stock and quality size categories was not significantly different between creel survey data and field sampling data in Goose ($G_{adj[1]}$=0.76, P=0.385) and Pump ($G_{adj[1]}$=0.03, P=0.863). The proportion of largemouth bass within stock and quality size categories was significantly different between creel survey data and field sampling data in Big Reno ($G_{adj[1]}$=5.74, P=0.017), Airstrip ($G_{adj[1]}$=14.3, P=<0.001), and Lime ($G_{adj[1]}$=9.81, P=0.002) (Table 4).

Visual Examination of $PSD_{bass:bluegill}$

The $PSD_{bass:bluegill}$ values across all five years of data were grouped tightly in Airstrip, Goose, and Pump (Figure 6). This implies that creel data is accurate. Big Reno's $PSD_{bass:bluegill}$ values progressed in a tight linear trend. This trend is unique to Big Reno and is likely the result of changes in harvest regulations. Evaluation of the $PSD_{bass:bluegill}$ in Lime Lake was hindered by insufficient data. Only three data points were available for Lime Lake, as no bluegill were reported for two years of creel survey data. These three $PSD_{bass:bluegill}$ points did not tightly cluster (Figure 6).

DISCUSSION

Creel Data for Use in PSD Assessment

Two out of five lakes had statistically similar creel and field sampling data (Goose and Pump). This provides support that creel survey data can be used to accurately assess fish populations in some cases. The statistical analysis used here, assumes that the population structure is stable. Both of these lakes have been part of the WFRTC for many years and have had consistent harvest regulations. As a result, these two lakes appear to have stable largemouth bass and bluegill populations.

There was a significant difference between creel survey and field sampling data in Big Reno, Airstrip, and Lime. These differences were likely due to low sample sizes and shifts in largemouth bass length frequencies due to changes in regulations. First, low numbers of largemouth bass caught during the field sampling may have led to high type I error for Airstrip Lake. If just one quality largemouth bass was caught in Airstrip the results would not have been significant ($G_{adj[1]}=2.44$ $P=0.118$). In fact, there were four largemouth bass (out of 19 total) within 25mm of being of quality size. Secondly, if the population structure is in fluctuation, the data will then differ among all years. This appears to be what is happening in Big Reno.

Big Reno has had an increasing proportion of larger fish since 2007, when largemouth bass harvest was closed (Figure 5). This trend may explain why there was a significant difference detected with Big Reno data. Lime appears to have suffered from both low sample size and regulation changes. Lime is a recent WFRTC acquisition and is likely still adjusting to their specific management regulations. Reported largemouth bass catch has declined from 275 in 2007 to 18 in 2010, the lowest catch numbers among these lakes.

There were relatively tight groupings of $PSD_{bass:bluegill}$ in all lakes, excluding Lime. This examination supports the conclusion that creel survey data provides an accurate means to assess fish populations in Kentucky pit lakes. In Lime, the lack of bluegill catch hampered evaluation of PSD. In the other four lakes, the field sampling derived $PSD_{bass:bluegill}$ were slightly outside the creel survey derived value clusters (Figure 6). The tight grouping of $PSD_{bass:bluegill}$ within each site supports the hypothesis that creel survey data and field sampling are not different.

My analysis demonstrates that the creel data reflects the population structure similarly to simple sampling techniques within Kentucky pit lakes. It is possible that the creel surveys provide a more accurate representation than my field sampling techniques. This creel survey data is easier and less expensive to collect than field sampling data and represents the population accurately for PSD analysis (Prentice et al. 1993). The field sampling in 2011 was laborious and expensive, requiring two workers, over 20 net nights of gillnetting, 30 seine hauls, 100's man-hours, and costly equipment. Calculating PSD from creel survey data takes just a few hours. Creel survey data, when combined with relative weight and length-at-age, can describe the status of the fishery, or can be used alone to document the trends in fish population structures that occur across multiple years. Tracking PSD trends is very useful to a fisheries manager wishing to manipulate the fishery in the future.

It is necessary to point out a few possible inconsistencies with parts of the data set. The creel survey combined all the 0-150mm bluegill within one category. This could pose a problem because PSD uses a 75mm minimum for stock-sized bluegill. However, anglers do not catch enough sub-75mm bluegills to severely alter our results. Also, during the electro-fishing event on Big Reno the largemouth bass may have not been sampled completely randomly. There were 23 largemouth bass chosen from a collection within the electro-fishing boats livewell. At the time, largemouth bass where selected for age and growth analysis and not a population assessment. Again, I do not think this poses a problem as the other sampling techniques supplemented Big Reno’s largemouth bass data.

The consistency of the low largemouth bass and bluegill relative weight (median $W_r \approx 0.80$; Figure 4) across the lakes suggests that these fish are not growing at an optimal level (Wege and Anderson 1978; Anderson Neuman 1996). This could be from intra- and interspecies competition, sub-optimal primary production, or various other variables (Blackwell et al. 2000). Regardless of why these fish have a low W_r, it appears that most of the lakes experience this phenomenon. This suggests that the lakes suffer from the same limiting factor, which, if identified, could be remedied to improve the fisheries.

The only lake with high bluegill median relative weight was Big Reno. This high median W_r may be because many of the fish were captured in the spring spawning season, when they develop gonads (Bevier 1988). Gonads recess after spawning and relative weights drop to normal levels. Alternatively, the bluegill in Big Reno may have access to extra resources, which are not available in the other study lakes (e.g. brook silversides).

Big Reno also differs from Airstrip or Lime in that it has twice as many species in the fish assemblage. The relatively high diversity (12 species) in Big Reno did not seem to affect the lakes $PSD_{bass:bluegill}$ (Figure 6). This is likely because largemouth bass remain the major predator species. Spotted gar is another predator present, but are found in low numbers (Table 2) and presumably feed only on very small fish. Channel catfish are a predator but are also present in low numbers and have been suggested to compete with bluegill more than largemouth bass (Swingle 1950). The other eight species, black crappie, warmouth, redear, yellow bullhead, gizzard shad, mosquitofish, and brook silversides, are considered prey species for largemouth bass. If a predator species such as northern pike, *Esox lucius*, bowfin, *Amia calva*, or flathead catfish, *Pylodictus olivaris* were present to compete with largemouth bass, there may have been a significant alteration in the $PSD_{bass:bluegill}$ relationship.

Airstrip, Goose, and Pump bass populations show signs of being in a steady state, i.e., exhibit little fluctuation in length frequencies among years. These lakes are consistently found in the trophy panfish condition. There have been no major changes in the regulations, largemouth bass harvest rates, or any other known factors that would cause these lake's populations to deviate from year to year. This is in contrast with Big Reno and Lime, both of which have seen regulatory changes in recent years.

Airstrip is the most bass crowded; it has the lowest average PSD_{bass} (16), and a high average $PSD_{bluegill}$ (80). Therefore, one would presume that Airstrip would produce trophy panfish and indeed the largest crappie (380mm) and largest bluegill (224mm) sampled in 2011 were captured in Airstrip. Anglers readily harvest Airstrip's large panfish, with a 2007-2010 average of 34 bluegill harvested per hectare, the highest for all the lakes. The bass population in Airstrip is stunted, with Airstrip's largest bass (290mm) shorter than the largest bass from the other lakes and the lowest length-at-age (L_3 = 258mm, L_5 =276, Table 2) among all other lakes.

In Big Reno there was a strong shift in $PSD_{bass:bluegill}$ across the five years of data (Figure 6). One possible reason for this trend is the overharvest of largemouth bass pre-2008 and subsequent recovery due to regulatory change. In 2007 (and most likely pre-2007), the largemouth bass harvest in Big Reno was very high, with anglers taking 30 largemouth bass/ha. The WFRTC rightly implemented a largemouth bass no-harvest regulation in the spring of 2008, which ended the bass over-harvest. The cohort of small fish that remained has grown together and dominated from 2008 to 2011. There should be a large population of large largemouth bass (450mm+) being caught over the next few years (2012 and 2013). Eventually though, this large-sized cohort will diminish and small fish will start to recruit.

In Figure 6, the $PSD_{bass:bluegill}$ relationship in Big Reno conforms to the theoretical inverse relationship between bass and bluegill PSD (Anderson 1976) that guides PSD-based management (Figure 2). This information supports the notion that the $PSD_{bass:bluegill}$ relationship breaking point of surface-area size must be above 25 ha. This is similar to the finding of Gablehouse (1984c) and Willis and Guy (1990), who documented the inverse relationship between bass and bluegill PSD in larger (34 and 55ha) impoundments.

Management Implications

Creel surveys can provide useful data for managers employing active management. Yearly or even seasonally collected data can be easily computed into PSD and regulations adjusted to achieve management goals. The following suggestions are based upon the population assessments from the creel survey (2007-2010) and 2011 field sampling. These recommended harvest rates are estimates and may need to be increased or decreased based on future assessments. In the absence of field sampling data, the mandatory creel survey data will allow managers to track trends and adjust harvest regulations accordingly. All of the suggested management changes require very little extra effort outside of enforcing the new largemouth bass size limits and manually harvesting small largemouth bass if harvest rates are not met.

It is apparent that harvest is important among WFRTC anglers. Thus, Big Reno, Goose, and Pump could be managed for the optimal condition. This will maximize the harvestable amount of fish. This requires increasing their current largemouth bass harvest rate. Flickinger et al. (1999), suggested harvesting 75 largemouth bass per hectare per year within a slot limit of 200-300mm, to maintain an optimal condition fishery. The exact number of fish to be harvested could vary with the WFRTC lakes as they have slower than average growth (mean $W_r \approx 0.80$).

Airstrip Lake has the greatest potential to produce trophy panfish. Implementing a largemouth bass no-harvest regulation would help insure that Airstrip remains in the trophy panfish condition.

Only three years of data could be used in the Lime Lake $PSD_{bass:bluegill}$ plot and these points were scattered. Without precise $PSD_{bass:bluegill}$ data, proposing management suggestions is difficult. Even so, three characteristics of Lime suggest that it would be an excellent candidate for trophy bass management. First, the largest largemouth bass captured during the 2011 sampling was from Lime (442mm), suggesting that this lake already holds large largemouth bass, which are necessary for a trophy bass fishery. Secondly, Lime is small and the high harvest rates of largemouth bass will be easy to achieve. Finally, by informing anglers that Lime is managed for trophy bass may encourage them to fish there and increase the amount of creel survey data collected, allowing for more precise $PSD_{bass:bluegill}$ assessments. To push the population into a trophy bass condition, Flickinger et al. (1999), suggest harvesting 75 largemouth bass within a slot limit of 200-300 mm and 12 largemouth bass within the 300-380mm slot limit per hectare per year. In Lime, a lower harvest rate should be used, as this lake exhibits slow growth as evidenced by low relative weights ($W_r \approx 0.80$).

To refine the data collected through the creel survey, the WFRTC should alter two of the questions in the instrument. Splitting the smallest bluegill length category, 0-6in (0-150mm), into two new categories, 0-3in (0-75mm) and 3-6in (76-150mm), will help increase the $PSD_{bluegill}$ accuracy. Also, adding a trophy bass category to the choices of target species, will help gauge the desire for a large largemouth bass fishery.

The fisheries at the WFRTC already provide excellent recreational opportunities for our National Guard soldiers and veterans, yet room for improvement does exist. Using the creel survey data that is already collected and available, each fishery can be manipulated with harvest regulations to achieve OSY. In particular, management for the trophy bass condition would allow anglers the opportunity to catch very large largemouth bass.

While this project has provided important preliminary information, it has also revealed several interesting areas that should be investigated further. Research could aim to identify the source(s) of the consistently low relative weights of largemouth bass and bluegill or aim to understand and remedy the anoxic dead zones that plague these lakes.

This research provides additional evidence that creel survey data can be used to actively manage lakes (Weiss-Glanz and Stanley 1984; Green et al. 1986; Willis and Hartmann 1986; Prentice et al. 1993). Using mandatory creel data is an easy and inexpensive means of data collection for active management of the fisheries at the WFRTC.

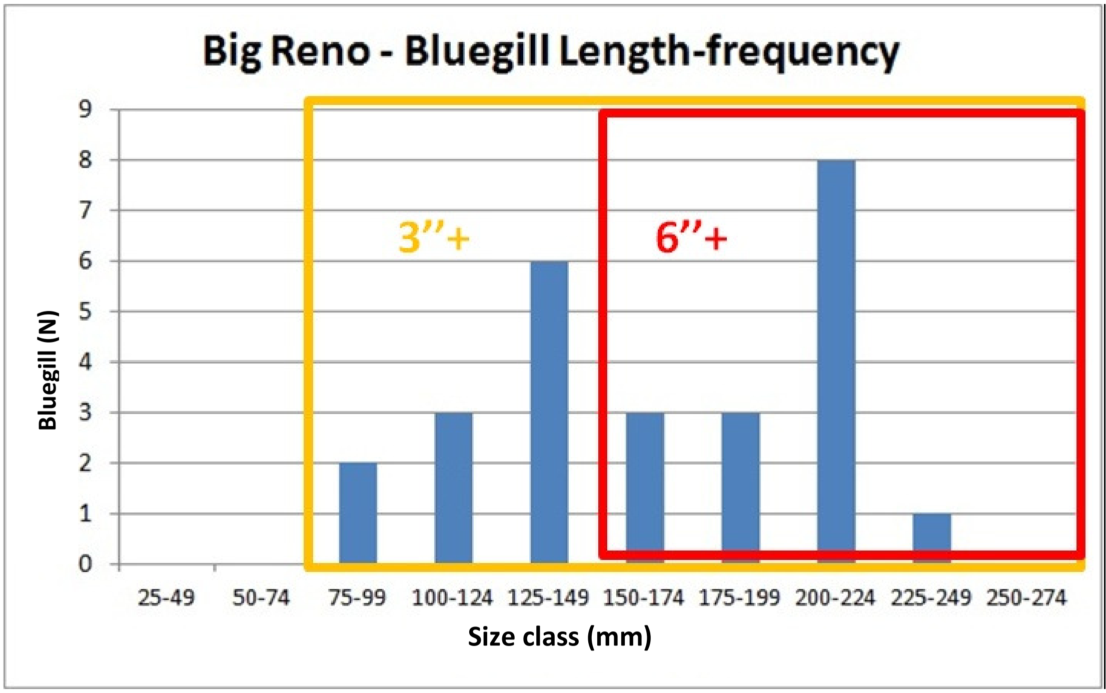

Figure 1: An example length frequency distribution with superimposed stock (orange) and quality lengths (red), used in proportional stock density. This simple method gauges the current size structure of the fish species. Notice that small fish (<75mm) are not included.

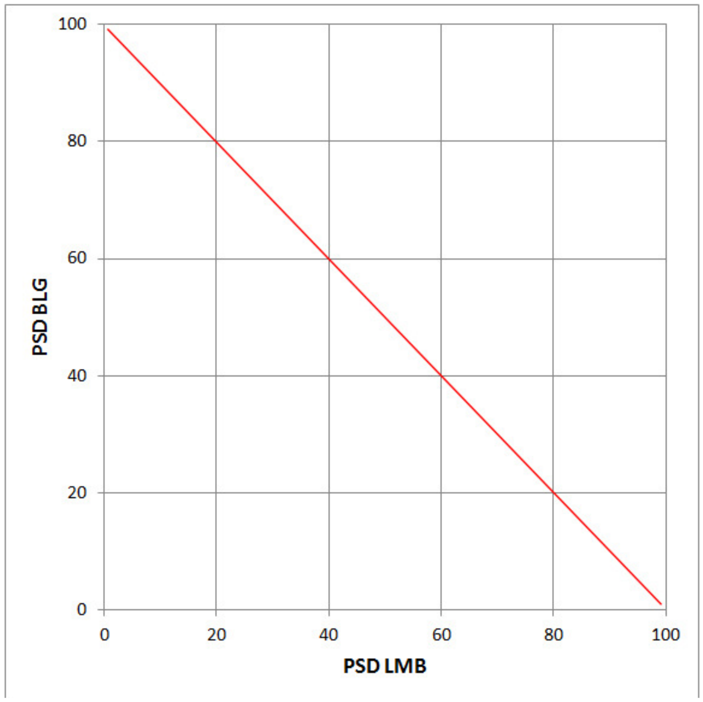

Figure 2: The inverse relationship between the proportional stock density (PSD) of largemouth bass and bluegill. As the proportion of large largemouth bass increases, the proportion of large bluegill will decrease. As the proportion of large largemouth bass decreases, the proportion of large bluegill will increase.

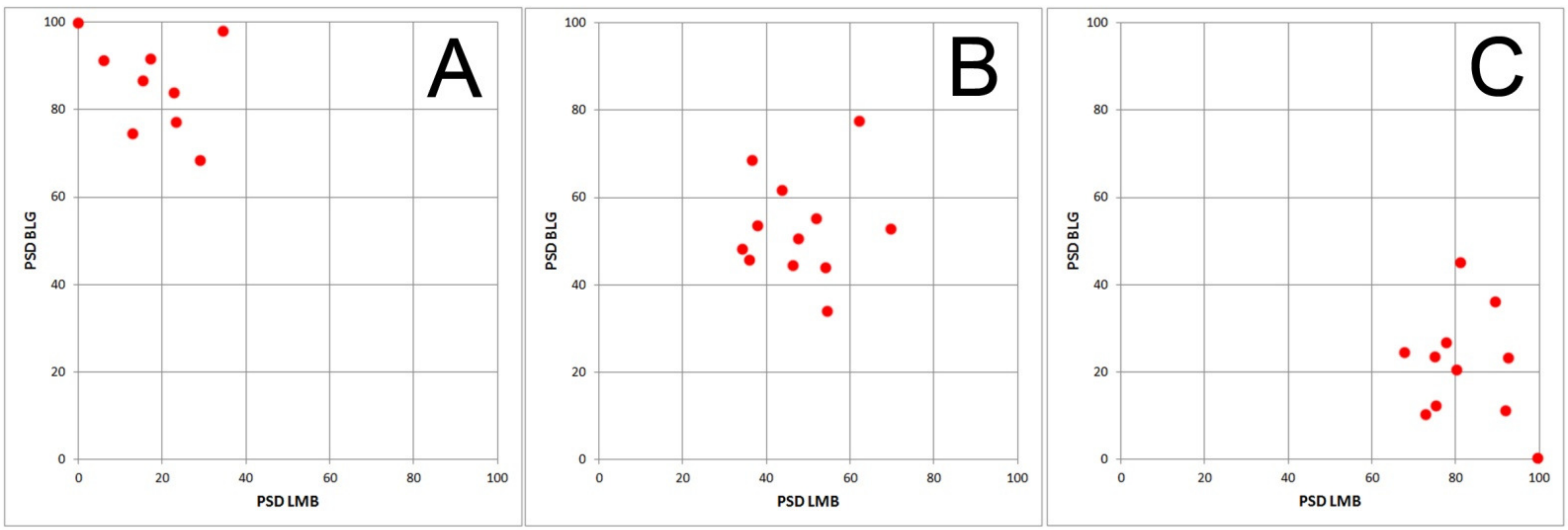

Figure 3: Hypothetical $PSD_{bass:bluegill}$ data from populations in: A) panfish, B) optimal, and C) trophy bass conditions.

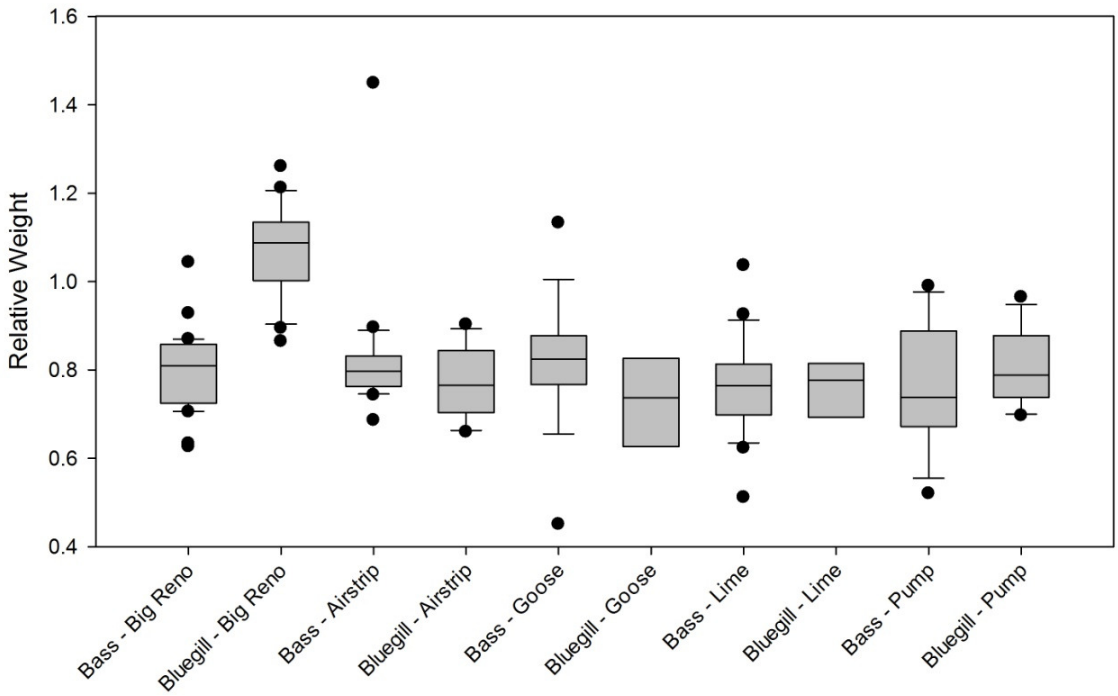

Figure 4: Relative weight of largemouth bass and bluegill from the five pit lakes in Muhlenberg County, KY.

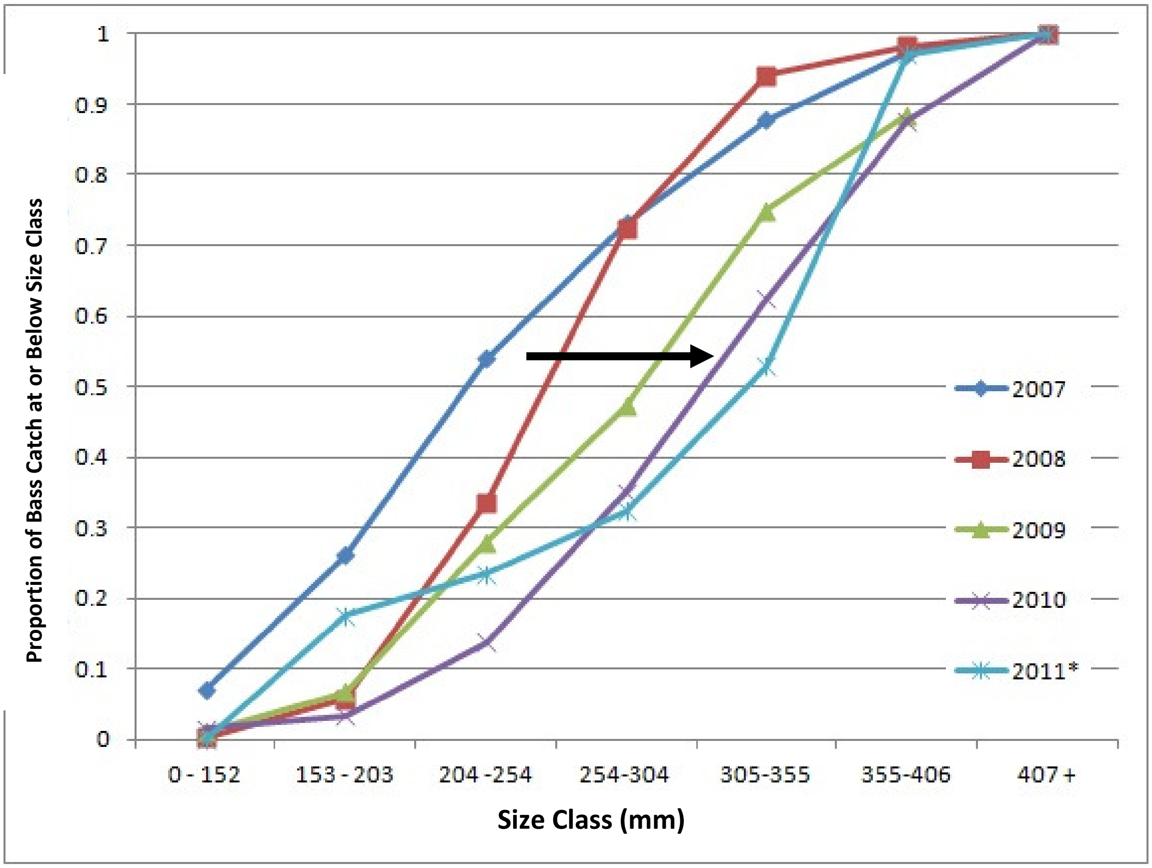

Figure 5: Five years of length frequency data from Big Reno, shown as cumulative proportions of largemouth bass catch. The population has shown a progressive increase in larger largemouth bass, which is likely due to changes in largemouth bass harvest rates in early 2008.

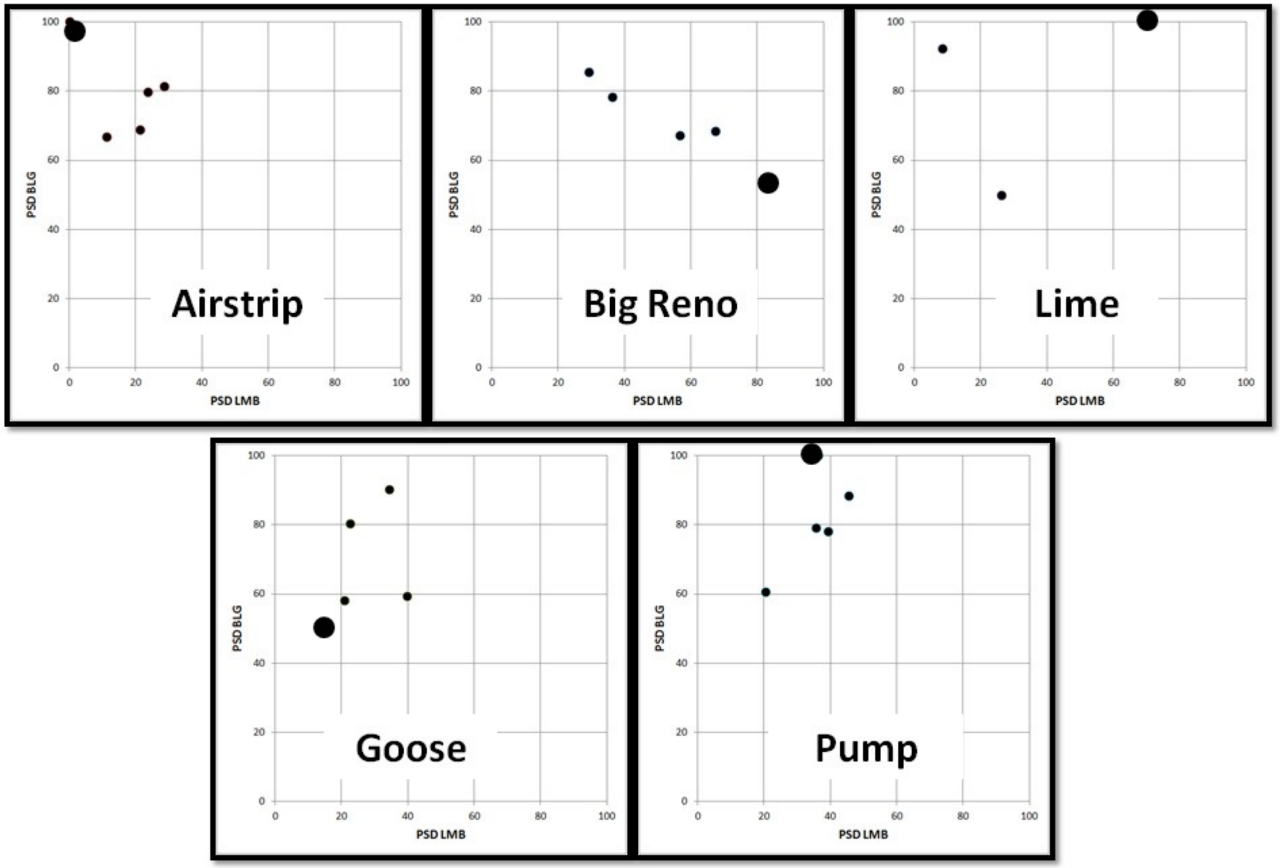

Figure 6: Five years of $PSD_{bass:bluegill}$ data for five WFTRC lakes. Notice that most of the data points fall in the panfish condition range. The small dots represent creel data whereas the large dots represent sampling data.

Table 1: Habitat and Angler Catch Summary.

	Big Reno	Airstrip	Goose	Pump	Lime
Surface Area (ha)	25	11	10	9	6
Max Depth (m)	15	15	5	7	9
Summer Thermocline Depth (m)	4	5	none	none	4
Summer Anoxic ($<1mgO_2/l$) Depth (m)	4	9	2	4	4
2007-2010 Average Total bass catch	3004	866	543	448	142
2007-2010 Mean bass catch/ha	120	79	54	50	24
2007-2010 Mean bluegill catch/ha	9	59	28	35	2
2007-2010 Mean bass harvest/ha	8	2	4	4	4
2007-2010 Mean bluegill harvest/ha	5	34	14	19	0

A summary of selected habitat characteristics and creel survey statistics from five pit-lakes at Wendell Ford Regional Training Center, KY.

Table 2: Field Sampling Summary.

	Big Reno	Airstrip	Goose	Pump	Lime
Total Number of Species	12	5	8	6	5
Largemouth Bass					
Number captured (N)	34	22	17	12	22
Size range (mm)	165-424	169-290	178-395	163-383	162-442
Mean length at Age 3	331	258	269	294	323
Mean length at Age 5	383	276	-	309	-
Mean relative weight	0.8	0.83	0.82	0.76	0.76
PSD (%)	82	0	15	36	70
Bluegill					
Number captured (N)	26	11	8	14	3
Size range (mm)	99-240	188-224	139-182	170-215	179-210
Mean length at Age 3	116	191	145	-	-
Mean length at Age 5	240	196	176	196	-
Mean relative weight	1.07	0.78	0.72	0.81	0.76
PSD (%)	54	100	50	100	100
Crappie					
Number captured (N)	8	5	5	2	0
Size range (mm)	259-350	229-380	165-225	212-305	-
Mean length at Age 3	-	227	223	-	-
Mean length at Age 5	-	275	-	305	-
Mean relative weight	1.01	0.87	1.09	1.04	-
PSD (%)	100	100	83	100	-
Redear					
Number captured	5	2	1	0	0
Size range (mm)	184-238	197-215	212	-	-
Warmouth					
Number captured	3	0	1	2	4
Size range (mm)	181-242	-	176	175-207	151-191
Channel Catfish					
Number captured	3	0	0	1	0
Size range (mm)	530-579	-	-	610	-
Yellow Bullhead					
Number captured	10	0	6	0	0
Size range (mm)	212-340	-	239-329	-	-
Common Carp					
Number captured	1	0	0	0	0
Size range (mm)	615	-	-	-	-
Spotted Gar					
Number captured	11	0	0	0	0
Size range (mm)	424-682	-	-	-	-
Gizzard Shad					
Number captured	79	0	0	0	0
Size range (mm)	331-415	-	-	-	-
Blue Catfish					
Number captured	0	0	1	0	0
Size range (mm)	-	-	380	-	-
Mosquito Fish					
Present	yes	yes	yes	yes	yes
Brook Silverside					
Present	yes	no	no	no	no

A summary of fish species captured during the 2011 sampling of five pit-lakes at Wendell Ford Regional Training Center, KY (excluding the numbers of fish collected through seining).

Table 3: Statistical Output Summary with Correction Factors.

	G	q	G_{adj}	p-value
Big Reno	5.86	1.012	5.74	0.0166
Airstrip	15.17	1.081	14.03	0.0002
Goose	0.806	1.066	0.76	0.385
Pump	0.031	1.051	0.03	0.8629
Lime	10.06	1.026	9.81	0.00174

A summary of the values generated in a G-test of independence, comparing the closest portion of the creel data range (high, mean, or low) to sampling data (G = G-value, q = Williams correction factor, G_{adj} = adjusted G-value). A $X^2_{[0.05]1}$ distribution was used to evaluate significance.

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