ASSESSING RELATIONSHIPS BETWEEN ANGLING EFFORT AND LARVAL TREMATODES IN SMALL BLUEGILL

by

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I wanted to determine if catch-and-release angling increased larval trematodes in small (50-160 mm) bluegill (*Lepomis macrochirus*). I used angling effort as a proxy for amount of catch-and-release angling. I assumed bluegill assessed, due to their size and age, experienced catch-and-release events. I assessed larval trematode intensity, black spot (*Crassiphiala bulboglossa*) and white grub (*Posthodiplostomum minimum centrarchi*), in 750 bluegill. The first objective was to quantify the association between angling effort and reservoir area. Angling effort and reservoir area were positively correlated. The second objective was to determine if angling effort, reservoir area, bluegill age, and total length affect larval trematode intensity. I hypothesized that angling effort would positively affect larval trematode intensities, allowing larval trematode intensity to be an index of angling effort. Reservoir area, bluegill age, and total length were influential on larval trematode intensity; reservoir area and total length were negatively correlated, and bluegill age was positively correlated with larval trematode intensity, whereas angling effort was both negatively and positively correlated with larval trematode intensity. The third objective was to determine if angling effort, reservoir area, bluegill age, total length, and larval trematode intensity affect condition of bluegill. I

hypothesized that increased angling effort and increased larval trematode intensity, and associated stressors from both variables, would decrease condition of fish. Reservoir area, total length, and larval trematode intensity were influential on condition factors, and angling effort and bluegill age were partially influential; reservoir area, bluegill age, and larval trematode intensity were positively correlated with three condition factors (viscerosomatic and hepatosomatic indices, and Fulton's condition factor), whereas the angling effort and total length were positively and negatively correlated with condition factors. Overall, the effects of catch-and-release angling activities provide limited support for the hypotheses I put forth, indicating that larval trematode intensity is not a viable indicator of angling effort.

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CHAPTER 1. INTRODUCTION

Catch-and-release events are typically enacted through regulations with a conservation-minded approach to management with a number of studies documenting positive effects in response to catch-and-release management for numerous fish species in a wide range of environments (Wydoski 1977; Reiss et al. 2003; Arlinghaus et al. 2007; Brownscombe et al. 2016; Rahel 2016). Intense angling effort can cause a direct decline in fish populations through harvest (Hartley and Moring 1995; Post et al. 2002; Edwards et al. 2004; Lewin et al. 2006; Arlinghaus et al. 2016; Sheaves et al. 2016) and an indirect decline through discard mortality (Cowx 1998; Post et al. 2002; Cambray 2003; Coleman et al. 2004; Cooke and Cowx 2004, 2006; Lewin et al. 2006; Danylchuk et al. 2011; Strehlow et al. 2012; Arlinghaus et al. 2016). In addition to the lethal effects of angling, fish captured and released by anglers are often subjected to sublethal stressors (a negative factor impacting an organisms' health) that alter physiology, which have the potential to alter fish behavior and ultimately reproductive fitness (Barton & Iwama 1991; Chopin and Arimoto 1995; Wendelaar Bonga 1997; Chrousos 1998; Cooke et al 2002a, 2002b; Cooke & Suski 2005; Rapp 2009). Increased amounts of hooking, fighting, and handling leads to increased stress on fish, which ultimately compromises potential immune system responses, allowing the fish to become more susceptible to infestation by diseases and parasites (Landsberg et al. 1998; Khan 1999; Lafferty and Kuris 1999; Hoffman 1999; Lafferty and Kuris 2004; Marcogliese 2004; Hill 2008; Pracheil and Muzzall 2009, 2010; Bauer 2010; Wisenden et al. 2012; Chapman et al. 2015). A positive relationship between stress caused by catch-and-release events and

parasite intensity has been documented, with a direct increase in parasite intensity due to elevated levels of stress (Wedemeyer and Goodyear 1984; Landsberg et al. 1998; Hoffman 1999; Lafferty and Kuris 1999; Altman and Byers 2014). Parasite intensity (Bakker et al. 1997), especially larval trematode intensity, has previously been used to infer the amount of stress affecting individual fish (Hunter and Hunter 1938; Lemly and Esch 1984a, 1984b; Wilson et al. 1996; Fischer and Kelso 1998, 1990; Bennett et al. 2003; Pietrock and Marcogliese 2003; Steinauer and Font 2003; Koprivnikar et al. 2006; Altman and Byers 2014).

The purpose of this study was to measure the relationship, if any, that existed between angling effort in the Salt Valley watershed and the sublethal stress from catch-and-release indicated by infestation of larval trematodes in small bluegill. Bluegill was selected based on the availability in all of the study areas and their popularity among catch-and-release anglers in the Salt Valley reservoirs. Martin (2013) indicated that bluegill are among the top 5% of species caught within the Salt Valley Reservoir. Small bluegill, defined as ranging from 80-mm to 130-mm are more likely to be caught and released by anglers due to their small size, compared to bluegill that are over 130-mm where the probability of harvest by anglers increases (Chizinski et al. 2014). In this study, I assumed that catch-and-release stress would be directly related to effort and then tested this assumption. I developed a study that tested how angling effort (hours; how many people were fishing at that particular hour), reservoir area (hectares), bluegill age, and bluegill total length (mm) affected larval trematode intensity in small bluegill. I also tested how angling effort, reservoir area, bluegill age, bluegill total length (mm), and larval trematode intensity impacted bluegill condition.

My hypothesis for the relationship of angling effort and larval trematodes was ultimately based on the catch equation (Ricker 1975; Peterman and Steer 1981; Yodzis 1994):

$$C = q\, f\, N,$$

where C is catch, referring to catch-and-release and harvest; where q is the catchability, the fraction of the stock which is caught by a defined unit of the fishing effort (Ricker 1975); where f is the effort; and N is the abundance. Larval trematode intensity could be used as a natural tag (Marcogliese 2005) to designate the subset of fish that were caught, released, and survived (CRL) then the proportion of a representative sample with larval trematodes should indicate CRL/N and it should be proportional to effort if q was assumed constant.

ANGLING EFFORT

Recreational angling activities are increasing in popularity on a global scale, as new fishing methods develop and anglers' avidity increase (Cowx 2002; Cooke and Suski 2005; Arlinghaus et al. 2007; Arlinghaus and Cooke 2009; Danylchuk et al. 2011; FAO 2012; Arlinghaus et al. 2016). In 2002, the Illinois Department of Natural Resources documented that 84% of anglers participated in catch-and-release activities within state waters (Ditton 2002). Recreational angling has the opportunity to affect millions of people due to the multitude of fish species available, the increase in accessibility of newly available gear and equipment, regulations, catch-and-release fisheries, "free fishing" opportunities, economic importance, as well as diverse social needs (Arlinghaus et al., 2002a; Post et al. 2002; Radonski 2002; Lewin et al. 2006 Cowx 2015; Arlinghaus

et al. 2016; Cooke et al. 2016). Global estimates indicate the number of recreational anglers ranges from 220 million (World Bank 2012; Arlinghaus et al. 2016) to 700 million (Cooke and Cowx 2004; Arlinghaus et al. 2016). Fishery managers work to promote recreational angling among their respective fishing communities by adopting programs to facilitate conservation and sustainable fisheries (Bate 2001; Siemer and Knuth 2001; Policansky 2002; Reiss et al. 2003; Cowx et al. 2010; Danylchuk et al. 2011; Salmi and Ratamaki 2011; Arlinghaus et al. 2016). Currently, as more dependable data are available, statistics indicate that countries average 11% angler participation in catch-and-release events (Arlinghaus et al. 2015a; Arlinghaus et al. 2016).

The origins of catch-and-release events date back to 1954 in the Great Smokey Mountains National Park, where the first areas were designated primarily for recreational angling through their "fishing-for-fun" program (Barnhart 1989). The term "catch-and-release" was adopted in 1964 due to the release of fish caught by successful anglers (Barnhart 1989; Radonski 2002). Historically, the term "catch-and-release" was defined as the "process of capturing fish by using hook and line, mostly assisted by rods and reels, and then releasing live fish back to the waters where they were captured, presumably to survive unharmed" (Arlinghaus et al. 2007). Today, catch-and-release activities are used as a management tool in regulations to help improve unsustainable, exploited fish populations (Nelson 2002) and the definitions used to define the term "catch-and-release" have become increasingly diverse in the management industry (Salmi and Ratamaki 2011; Ferter et al. 2016).

However, many studies have conversely demonstrated that fish have experienced a number of negative effects associated from elevated levels of angling effort (Barnhart

1989; Lafferty and Kuris 1999; Nelson 2002; Post et al. 2002; Coleman et al. 2004; Cooke and Cowx 2004, 2006; Cooke and Suski 2005; Thomas et al. 2005; Lewin et al. 2006; Danylchuk et al. 2011; Strehlow et al. 2012; Maggs et al. 2015; Arlinghaus et al. 2016; Sheaves et al. 2016). First, the increase in recreational angling activities can intensify boat traffic, which produces increased pollutant loads (e.g. oil, gas, fishing line, human trash and waste) that can impair water quality and degrade the protective mucus layer in fish (Khan 1990; Seriani et al 2015). Furthermore, waves created by an increase in boat traffic contribute to environmental and habitat degradation through erosion (Khan 1990; Adams et al. 1993; Turner et al. 1999; Cowx 2002; McPhee et al. 2002; Cooke and Cowx 2004; Thomas et al. 2005; Dudgeon et al. 2006; Lewin et al. 2006; Uphoff et al 2011; Arlinghaus et al. 2015b), as well as increasing the frequency of boat strikes with fish (McPhee et al. 2002) and noise pollution (Lewin et al. 2006). Experimental studies have shown fish can suffer from noise-induced stress and hearing loss (Scholik and Yan, 2002; Lewin et al. 2006; Graham and Cooke 2008; Popper and Hastings 2009; Picciulin et al. 2010; Slabbekoorn et al. 2010; Jacobsen et al. 2014) as well as other species-specific behavioral and physiological responses in conjunction with an increase in ambient sound levels (Kenyon et al., 1998; Lewin et al. 2006; Wysocki et al., 2006; Graham and Cooke 2008; Jacobsen et al. 2014).

Second, increased development surrounding waterbodies and subsequent increases in angling effort along shorelines increases anthropogenic stressors that can lead to potentially larger effects implicating environmental declines on broader spatial scales including ecosystem-level damages, such as increases in runoff volume and intensity, erosion, sedimentation, temperature, and contaminant and nutrient loads

(Pearce 1991; Adams et al. 1993; Auster et al. 1996; Landsberg et al. 1998; Thrush et al. 1998; Lafferty and Kuris 1999; Turner et al. 1999; Boreman 2000; Thomas et al. 2005; Uphoff et al. 2011; Martin and Lutterschmidt 2013; Lutterschmidt et al. 2016; Buck and Lutterschmidt 2017). For example, the results of Uphoff et al. (2011) demonstrated that increases in impervious surfaces, such as paved roads and parking lots, attendant to the transformation of rural lands into urban environments in the Chesapeake Bay sub-estuaries, produced a significant decline in bottom-water fish habitat, thus affecting the quantity and quality of fish species and reproductive success. Other studies focused on how renovations to reservoirs or the land around a waterbody had a negative influence on ecosystem-level effects by changing parasite communities (Izyumoya 1987; Morley 2007) and removing a complete populations of littoral snails (*Gastropoda* spp.) due to increased anthropogenic sediments (McIntyre et al. 2005).

Third, intense angling effort can cause a direct decline in fish populations through harvest (Hartley and Moring 1995; Post et al. 2002; Edwards et al. 2004; Lewin et al. 2006; Arlinghaus et al. 2016; Sheaves et al. 2016) and indirectly through discard mortality (Cowx 1998; Post et al. 2002; Cambray 2003; Coleman et al. 2004; Cooke and Cowx 2004, 2006; Lewin et al. 2006; Danylchuk et al. 2011; Strehlow et al. 2012; Arlinghaus et al. 2016). Directed recreational landings annually contribute nearly 12 % of the harvest of exploited fish populations on a global level (Cooke and Cowx 2004; Cooke and Cowx 2006). In some developed fisheries, mortality associated with recreational harvest approaches, or exceeds the losses generated by commercial fisheries (e.g. Atlantic Striped Bass, ASMFC 2013, 2016) (Cooke and Cowx 2006; Danylchuk et al. 2011; Cooke et al. 2013). Further amplifying the effects of losses associated with recreational

harvest, shore-based recreational angling effort focuses on inshore, shallow areas that act as juvenile nursery habitat for many early life-history stages of key gamefish and forage fish species (Coble 1988; McPhee et al. 2002). Cumulative losses to early life stages and juvenile stages, will eventually affect year-class strength, and adult recruitment if mortality rates from directed harvest or incidental mortality are high.

Fourth, beyond instant release mortality, catch-and-release fishing practices, known to be one of the most physically stressful actions for fish (Booth et al. 1995; Meka and McCormick 2005), can alter behavior, physiology, and fitness in fish and entire populations (Chopin and Arimoto 1995; Brobbel et al. 1996; Cooke et al. 2002a, 2002b; Cooke and Cowx 2004, 2006; Cooke and Suski 2005; Arlinghaus et al. 2007; Coggins et al. 2007; Cooke and Schramm 2007; Siepker et al. 2007; Richard et al. 2013; Johnston et al. 2015; Arlinghaus et al. 2016). Research of sublethal and physiological effects from catch-and-release events have been assessed in both laboratory-controlled settings and in field environments (Anderson 1998; Bettoli and Osborne 1998; Campbell et al. 2009; Cooke and Philipp 2004; Cooke and Schramm 2007; Siepker et al. 2007; Skomal 2007). A study by Kieffer et al. (1995) conducted on the effects of catch-and-release activities on nesting male smallmouth bass (*Micropterus dolomieu*) found that increased exhaustion due to increased angling duration negatively impacted reproductive success, reducing fitness. Additionally, several studies have identified post-release survival (Marnell and Hunsaker 1970; Warner 1976; Schaefer 1989; Hubbard and Miranda 1991; Bendock and Alexandersdottir 1993) and mortality rates (Muoneke and Childress 1994; Chopin and Arimoto 1995; Bartholomew and Bohnsack 2005) for various fish species. The post-release mortality of members of the Centrachidae family have been found to

range from 0% to 95% (Wydoski 1977; Beggs et al. 1980; Muoneke and Childress 1994; Lindsay et al. 2004; Bartholomew & Bohnsack 2005; Lewin et al. 2006; Arlinghaus et al. 2007; Rapp 2009) depending on equipment used, hooking location, handling time, as well as environmental conditions (Muoneke and Childress 1994; Chopin and Arimoto 1995; Bartholomew and Bohnsack 2005; Cooke and Suski 2005; Lewin et al. 2006; Arlinghaus et al. 2007). Bettoli and Osborne (1998) found a linear relationship between mortality rates and air temperature, surface water temperature, and handling time for Atlantic striped bass (*Morone saxatilis*) in Tims Ford Reservoir, Tennessee. Likewise, Lukacovic and Uphoff (2002) concluded seasonal impacts of Fall and Summer influenced the hooking mortality rates of striped bass (12% and 36%, respectively in the Chesapeake Bay).

In addition to the lethal effects of angling, fish captured and released by anglers are often subjected to sublethal stressors (a negative factor impacting an organisms' health) that alter physiology, which have the potential to alter fish behavior and ultimately reproductive fitness (Barton & Iwama 1991; Chopin and Arimoto 1995; Wendelaar Bonga 1997; Chrousos 1998; Cooke et al 2002a, 2002b; Cooke & Suski 2005; Rapp 2009). Historically, stress was defined as "the sum of all physiological effects by which an animal attempts to maintain or re-establish a normal metabolism in the face of a physical or chemical force" (Selye 1950). More recently, the definition of stress has been expanded as the response caused by abiotic or biotic stressors in the environment that affects the normal homeostasis of an individual, implying "that stress may operate at any level of biological organization, ranging from a unit cell to ecosystem" (Brett 1958; Wedemeyer 1970; Esch et al. 1975). Examples of stress-induced functions are increased

cardiac output, increased blood pressure, and increased gill diffusing capacity to regulate additional oxygen needs (Suski et al. 2007). The responses to stressors that occur have been either identified as primary responses, secondary responses, or tertiary responses (Wedemeyer and McLeay 1981; Barton 2002; Barton et al. 2002; Cooke et al 2002a; Suski et al. 2003a, 2003b; Cooke and Suski 2005; Rapp 2009).

Primary responses alter the initial neuroendocrine processes (Barton et al 2002). The neuroendocrine processes cause immediate changes in catecholamines from chromaffin tissues and subsequently release of corticosteroids with cortisol representing the most commonly measured. Secondary responses cause hormonal and non-hormonal effects at the blood and tissue level, such as metabolism, respiration, acid-base status, immune function, and cellular reactions, and can emerge quickly (Wedemeyer and McLeay 1981; Barton et al. 2002; Portz et al. 2006; Rapp 2009). Tertiary stress response involves changes in biological functions in the affected organisms as a result of secondary physiological changes; tertiary responses may include altered growth, reduced condition, reduced ability to resist disease, changes in metabolic scope for activity, changes in behavior, and ultimately survival (Barton 2002; Barton et al. 2002; Cooke et al 2002a; Suski et al. 2003a, 2003b; Cooke and Suski 2005; Portz et al. 2006; Rapp 2009).

The extent of sublethal changes in fish from catch-and-release events is determined by the magnitude and duration of the angling event, air exposure, water temperature, equipment used by anglers, and the life stage of fish encountered (Wydoski 1977; Gustaveson et al. 1991; Muoneke and Childress 1994; Barton 2002; Barton et al. 2002; Cooke et al. 2002a; Suski et al. 2003a, 2003b; Cooke and Philipp 2004; Lafferty

and Kuris 2004; Cooke and Suski 2005; Arlinghaus et al. 2007; Cooke and Schramm 2007; Rapp 2009; Arlinghaus et al. 2016). Therefore, catch-and-release events can affect foraging patterns, locomotion, speed, habitat usage, osmoregulatory balance, energy stores, metabolic wastes, tissue damage, hormonal and cardiovascular disturbances, parental care abilities, gamete quality and quantity, mate selection, reproduction, and additional fitness measurements (Barton 2002; Barton et al. 2002; Cooke et al 2002a; Suski et al. 2003a, 2003b; Lafferty and Kuris 2004; Cooke and Suski 2005; Arlinghaus et al. 2007; Cooke and Schramm 2007; Rapp 2009; Arlinghaus et al. 2016). For example, increased fight and handling time lead rainbow trout (*Oncorhynchus mykiss*) to experience increases in plasma cortisol and lactate (Meka and McCormick 2005). The affects have a wide variation among fish species, some species are less tolerant of stress and considered more "delicate" than other species, such as herring and shad species (*Alosa* spp.).

In addition to increasing the direct physiological responses to catch-and-release activities, angling effort can influence the prevalence of larval trematode infection. Increased amounts of hooking, fighting, and handling leads to increased stress on fish, which ultimately compromises potential immune system responses, allowing the fish to become more susceptible to infestation by diseases and parasites (Landsberg et al. 1998; Khan 1999; Lafferty and Kuris 1999; Hoffman 1999; Lafferty and Kuris 2004; Marcogliese 2004; Hill 2008; Pracheil and Muzzall 2009, 2010; Bauer 2010; Wisenden et al. 2012; Chapman et al. 2015). Interactions between fish and parasites are extremely common and fish can be infected by numerous parasites (Hoffman 1999). Parasites affect their hosts in various ways (Poulin and Thomas 1999; Barber et al. 2000; Poulin 2006;

Lafferty 2008; Lafferty et al. 2008; Seppänen et al 2009; Wisenden et al. 2012; Largue and Poulin 2015) and have numerous facets to their life cycle (the number and type of intermediate hosts, a direct or indirect penetration of their hosts, etc.) that vary according to parasite stage and species-specific factors. Beyond parasitic factors, other variables can affect the severity of response to parasite infection, such as age (Balbuena et al. 2000; King and Cone 2009; Pracheil and Muzzall 2009; Skovgaard et al 2009; Behrmann-Godel 2013). Age was found to influence the parasite species that infect bluegill (*Lepomis macrochirus*), based on the diet and habitat usage between juvenile and adult stages (Pracheil 2006; Wisenden et al. 2012). Beyond impairing individual physiological performance (Lutterschidt et al. 2007; Buck and Lutterschmidt 2017), parasites can negatively affect fish by altering population dynamics (growth, recruitment, and mortality), thereby affecting the overall quality of a fishery (Esch et al. 1975; Lafferty and Kuris 1999; Barber et al. 2000; Lafferty and Kuris 2004; Poulin 2006; Lafferty 2008; Lafferty et al. 2008; Wisenden et al. 2012; Largue and Poulin 2015). A positive relationship between stress caused by catch-and-release events and parasite intensity has been documented, with a direct increase in parasite intensity due to elevated levels of stress (Wedemeyer and Goodyear 1984; Landsberg et al. 1998; Hoffman 1999; Lafferty and Kuris 1999; Altman and Byers 2014). Parasite intensity (Bakker et al. 1997), especially larval trematode intensity, has previously been used to infer the amount of stress affecting individual fish (Hunter and Hunter 1938; Lemly and Esch 1984a, 1984b; Wilson et al. 1996; Fischer and Kelso 1998, 1990; Bennett et al. 2003; Pietrock and Marcogliese 2003; Steinauer and Font 2003; Koprivnikar et al. 2006; Altman and Byers 2014). Therefore, larval trematode intensity could be used to assess the amount of stress

affecting the fish, while using the amount of catch-and-release angling activities as the stressor for increased larval trematode intensity.

STUDY LARVAL TREMATODES

Larval trematodes black spot (*Crassiphiala bulboglossa*), yellow grub (*Clinostomunm marginatum*), and white grub (*Posthodiplostomum minimum centrarchi*) are classified as endoparasites (Hoffman 1958; Olsen 1962). These species of trematodes were selected for this study due to their visibility to anglers and regularity of occurrence (prevalence and intensity) among bluegill (Avault Jr. and Smitherman 1965; Hoffman 1999; Lane et al. 2015; Buck and Lutterschmidt 2017). Larval trematodes are long-lived (Spall and Summerfelt 1970; Hoffman 1999; Pracheil 2006) and can infect their intermediate hosts directly (penetration by cercariae stage of larval trematode) or indirectly (infected by another intermediate host), affecting bluegill primarily in the littoral zone. Freshwater mollusks (aquatic snails) that reside in the littoral zone with bluegill are a common intermediate host to larval trematodes and are a common prey item for bluegill. Fish, including bluegill, often act as another intermediate host, with waterfowl serving as the final host completing the parasite life cycle (Hoffman 1999; Lane et al. 2015).

Larval trematodes can be visible to the naked eye. Black spot forms a “black spot” in the skin, fins, or in the muscle of numerous fish species by the metacercarial stage of the larval trematode. The larval trematode itself is not actually black; the fish will react to the trematode infection by pigmenting the infection site (Davis 1967; Berra et al. 1978; Wisenden et al. 2012). An angler can observe these “black spots” in the skin

and fins or in the muscle fibers of the fillet when filleting the fish. Black spot can cause the infected fish to lose stored fat or energy which decreases the fishes chance of survival during winter months, increasing overwinter mortality rate (Lemly and Esch 1984b; Pracheil and Muzzall 2010; Wisenden et al. 2012), as well as fish condition (Lemly and Esch 1984b; Lane and Morris 2000; Wisenden et al. 2012). White grub can be observed in the viscera (liver and kidney) of the fish. A heavy infection may be noticeable to anglers, but a histological examination is needed to identify white grub intensity. White grub is known to vary with sex (Spall and Summerfelt 1970) and age in sunfish (*Lepomis* spp; Spall and Summerfelt 1970; Wisenden et al. 2012). Yellow grub is known to be "complex" (requiring both blue heron and aquatic snails to complete their life cycle; Hoffman 1979). Yellow grub can survive the winter since they do not noticeably affect the fish and can live for several years within fish (Fischthal 1949; Hoffman 1956). Yellow grub can be observed embedded in the muscle fibers of the fillet or under the skin due to their large size and color. Redear sunfish (*Lepomis microlophus*) are known to actually disturb the yellow grub populations (Ledford and Kelly 2006; Smith 2000, 2011) which can influence the yellow grub intensity present.

STUDY FISH

A common sport fish, bluegill, was selected based on the availability in all of the study areas and their popularity among catch-and-release anglers in the Salt Valley reservoirs, as well as their life cycle. Martin (2013) indicated that bluegill are among the top 5% of species caught in several of the Salt Valley reservoirs. The native range for this species covers much of the USA, southeastern Canada and northeastern Mexico (Pfieger

1997). Bluegill is a benthopelagic, freshwater species that is found in thousands of impoundments, ranging in size from small farm ponds (0.5-1.5 hectares) to large lakes (400 > hectares) (Pfieger 1997). The literature and research regarding bluegill and its population dynamics (recruitment, growth, and mortality) are widespread, from habitat selection (Fish and Savitz 1983; Werner and Hall 1988; Knights et al. 1995; Paukert 2001; Weimer 2004; Gosch et al. 2006; Pracheil and Muzzall 2009, 2010), to movement (Pfieger 1997; Paukert 2001; Paukert et al. 2004), to forage habits (Werner 1967; Werner and Hall 1988; Osenberg et al. 1992; Weimer 2004; Pracheil and Muzzall 2009, 2010; Stahr and Shoup 2016).

Based on the population dynamics and associated littoral habitat usage of bluegill, small bluegill were collected and evaluated for this study. Small bluegill, ranged from 80-mm to 130-mm, were selected over larger bluegill (>130-mm) due to the probability of anglers catching-and-releasing small bluegill being greater than anglers catch-and-releasing larger bluegill (Chizinski et al. 2014), as well as, the amount of amount of time small bluegill spend foraging in the littoral zone (McDaniel and Bailey 1974; Cone and Anderson 1977; Hanek and Fernando 1978a, 1978b; Mittelbach 1981; Bailey 1984; Weimer 2004; Gosch et al. 2006; Pracheil 2006; Pracheil and Muzzall 2009, 2010), where they are most susceptible to larval trematode infection. Bluegill habitat selection depends on a variety of biotic (sex, prey, size, and competition) and abiotic (diel periods, seasonal factors, water quality factors, and habitat structure) factors (Paukert et al. 2004; Pflieger 1997; Spotte 2007). Bluegill can be found mostly along the shoreline and shallows during the morning and evening hours, and in deeper water or in water shaded by overhanging vegetation during mid-day especially during warmer months (Pflieger

1997; Spotte 2007). Small bluegill spend a majority of their time foraging in the littoral zone (Werner 1967; Werner and Hall 1988; Osenberg et al. 1992; Gosch et al. 2006; Pracheil and Muzzall 2009; 2010; Stahr and Shoup 2016), and are more abundant in the littoral zone than larger adult bluegill, making it easier to collect small bluegill. Due to the abundance of small bluegill, larval trematodes have a higher transmission rate (rate at which susceptible hosts are infected) among small bluegill (Begon et al. 2002). An infection involving a few larval trematodes may have a limited effect on the fish's health, but a larger infection of larval trematodes, can seriously compromise health or lead to death (Klak, 1940; Grizzle and Goldsby 1996; Hoffman 1999; Lutterschmidt et al. 2007; Bullard and Overstreet 2008; Lafferty 2008; Pracheil and Muzzall 2010; Wisenden et al. 2012; Lagrue and Poulin 2015; Lane et al. 2015; Buck and Lutterschmidt 2017; Schaaf et al. 2017). For example, Krull (1934) observed fish with the metacercariae of *Uvulifer ambloplitis* which produced an impressive nervous response in fish, within 2 to 4 days fish that were heavily infected died (Hoffman 1956). In addition, studies revealed fish with higher parasite infestation rates had significant weight loss (Hunter and Hunter 1938; Hoffman 1956; Wisenden et al. 2012) affecting body condition (Lemly and Esch 1984b; Wisenden et al. 2012; Lagrue and Poulin 2015). Studies by Ferguson (1943) and Hoffman (1950) have also revealed that once a fish is infected with larval trematodes they do not develop an immunity to the larval trematodes, fish will continue to be infected by larval trematodes (Hoffman 1956). Furthermore, parasites are able to manipulate the behavior of intermediate hosts causing a potential increase in exposure to predators (Poulin and Thomas 1999; Barber et al. 2000; Moore 2002; Lafferty 2008; Poulin 2006; Lafferty et al. 2008; Wisenden et al. 2012).

GOALS

My study examined how the size of a reservoir area (hectares), the amount of angling effort (hours) present, bluegill age, and total length (mm) affected larval trematode intensity (black spot, yellow grub, and white grub) per bluegill; and how reservoir area, angling effort, bluegill age, total length, and larval trematode intensity affected condition in small bluegill. I refined the main research topic into three questions,

(1) Does the size of a reservoir (area) covary with the amount of angling effort (effort representing the act of catch-and-release angling activities)?

(2) How does the size of a reservoir, the amount of angling effort, bluegill age, and total length (mm) affect the larval trematode intensity (black spot, white grub, and yellow grub) in small bluegill?

(3) How does the size of a reservoir, angling effort, bluegill age, total length (mm), and the larval trematode intensity (black spot, white grub, and yellow grub) per fish affect condition of small bluegill?

The first objective was to quantify the association between angling effort and reservoir area. I hypothesized that as reservoir size (area) increases, angling effort (hours) should positively increase (Figure 1) because more fishable area is available to anglers. Based on this hypothesis, I approached my second question regarding how the two main variables, reservoir area and angling effort, as well as bluegill age and total length (mm) of bluegill affect the larval trematode intensity (black spot, white grub, and yellow grub) present. I hypothesized that angling effort would positively affect larval trematode intensity, allowing larval trematode intensity to be an index of angling effort (Figure 2).

Finally, I hypothesized that increased angling effort and increased larval trematode intensity, and associated stressors from both variables, would decrease condition of fish (Figure 3).

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CHAPTER 2. METHODS

STUDY AREAS

The study areas were located within the Salt Valley Watershed and are referred to hereafter as the Salt Valley Reservoirs (Figure 4). Salt Creek, a main tributary for the Platte River, is the main drainage area for the Salt Valley watershed, draining a 4,247 square kilometer (km^2) area located around Lincoln in the southeastern part of Nebraska. Salt Creek was altered in the early 1900's to create flood-control measures, several dams, levees, channels, and reservoirs within the watershed. There are more than twenty Salt Valley Reservoirs that range in size from 5 to 728 hectares (ha) and can be found in both urban and rural lands. Surface area (hectares) for each study area reservoir of the Salt Valley watershed were acquired from the Lower Platte South Natural Resources District (LPSNRD; 2014) and Nebraska Game and Parks Commission (NGPC; 2014). Fifteen of the Salt Valley Reservoirs were selected for this study. The selected reservoirs were located in both rural and urban areas, ranging in size from small (11 hectares) to large (728 hectares). One reservoir in particular, Holmes Lake, is defined as an urban reservoir, located within the city limits of Lincoln, NE.

Bluestem Lake

Bluestem Lake located 4 km southwest of Lincoln, Nebraska near Sprague, Nebraska in Lancaster County surrounded by rural lands. Bluestem is a Nebraska State Recreation Area and has a surface area of 132 ha. The fish species present at Bluestem are bluegill, channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), white

crappie (*Pomoxis annularis*) and black crappie (*Pomoxis nigromaculatus*), flathead catfish (*Pylodictis olivaris*), largemouth bass (*Micropterus salmoides*), and walleye (*Sander vitreus*). Fishing regulations for Bluestem follow Nebraska's statewide fishing regulations.

Branched Oak Lake

Branched Oak Lake is the largest of the Salt Valley Reservoirs with a surface area of 728 ha. Branched Oak is located 21 km northwest of Lincoln, Nebraska near Malcolm, Nebraska in Lancaster County surrounded by rural lands. The fish species at Branched Oak are blue catfish (*Ictalurus furcatus*), bluegill, channel catfish, common carp, black and white crappie, flathead catfish, largemouth bass, hybrid striped bass (*Morone chrysops x saxatilis*), walleye, and white perch (*Morone americana*). Fishing regulations for Branched Oak follow Nebraska's statewide fishing regulations, except for walleye which have a daily bag limit of one, 254-mm or longer; crappie which have a 254-mm minimum length limit; and hybrid striped bass and flathead catfish which are catch-and-release only.

Conestoga Lake

Conestoga Lake located 15 km west of Lincoln, Nebraska near Denton, Nebraska in Lancaster County surrounded by rural lands. Conestoga is a Nebraska State Recreation Area and has a surface area of 93 ha. The fish species present at Conestoga are bluegill, channel catfish, black and white crappie, flathead catfish, freshwater drum (*Aplodinotus*

grunniens), largemouth bass, and walleye. Fishing regulations for Conestoga follow Nebraska's statewide fishing regulations.

Cottontail Lake

Cottontail Lake located about 20 km southwest of Lincoln, Nebraska, north of Martell, Nebraska in Lancaster County surrounded by rural lands. Conestoga is operated by the Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 12 ha. In 2006, the LPSNRD improved Cottontail by deepening the reservoir to increase water quality and enhanced the fishery by stocking. The fish species present at Cottontail are bluegill, channel catfish, and largemouth Bass. Fishing regulations for Cottontail follow Nebraska's statewide fishing regulations, except for largemouth bass which have a 533-mm minimum length limit.

Holmes Lake

Holmes Lake located within the city of Lincoln, Nebraska in Lancaster County and a flood-control reservoir surrounded by an urban setting. The lake was built in 1962 by the U.S. Army Corp of Engineers and originally 50 ha, but in 2001, surface area of Holmes Lake was decreased to 44 ha (NDEQ 2003). Nebraska Game and Parks mapped Holmes Lake surface area at 40 ha. The loss of 9 ha in 48 years is due to excessive sediment loading that is taking place throughout the reservoir. The City of Lincoln owns Holmes Lake and had the lake renovated during 2004–2005. The fish species present at Holmes Lake are bluegill, channel catfish, largemouth bass, rainbow trout (stocked during spring and fall seasons), and walleye. Fishing regulations for Holmes Lake follow

Nebraska's statewide fishing regulations, except for largemouth bass which are catch-and-release only; panfish have a daily bag limit of 10; channel catfish have a daily bag limit of 3; rainbow trout have a daily bag limit of 8 when available. In addition, regulations indicate no live bait can be used or possessed and only electric or non-powered boats are allowed at Holmes.

Meadowlark Lake

Meadowlark Lake located 30 km northwest of Lincoln, Nebraska near Agnew, Nebraska in Steward County surrounded by rural lands. Meadowlark, a flood-control reservoir, is owned and operated by Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 22 ha. In 2006, Meadowlark was renovated, drained, and fish habitat improvements were made. The fish species present at Meadowlark are bluegill, channel catfish, black and white crappie, and largemouth bass. The fishing regulations at Meadowlark follow Nebraska's statewide fishing regulations, except for largemouth bass which have a 533-mm minimum length limit. In addition, regulations indicate no live baitfish can be used or possessed at Meadowlark.

Merganser Lake

Merganser Lake located 28 km southwest of Lincoln, Nebraska near Kramer, Nebraska in Lancaster County surrounded by rural lands. Merganser, a flood-control reservoir, is owned and operated by Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 17 ha. The fish species present at Merganser Reservoir are bluegill, channel catfish, and largemouth bass. The fishing regulations for

Merganser follow Nebraska's statewide fishing regulations, except for largemouth bass which has a 533-mm minimum length limit.

Olive Creek Lake

Olive Creek Lake located 30 km southwest of Lincoln, Nebraska near Kramer, Nebraska in Lancaster County surrounded by rural lands. Olive Creek is a State Recreation Area and has a surface area of 71 ha. The fish species present at Olive Creek are bluegill, channel catfish, and largemouth bass. The fishing regulations at Olive Creek follow Nebraska's statewide fishing regulations, except for largemouth bass which have a 533-mm minimum length limit. In addition, regulations indicate no live baitfish can be used or possessed at Olive Creek.

Pawnee Lake

Pawnee Lake is the second largest reservoir of the Salt Valley Reservoirs with a surface area of 300 ha. Pawnee located 15 km west of Lincoln, Nebraska near Emerald, Nebraska in Lancaster County surrounded by rural lands and is designated as a State Recreation Area. The fish species present at Pawnee are bluegill, channel catfish, common carp, black and white crappie, flathead catfish, freshwater drum, largemouth bass, sauger (*Sander canadensis*), walleye, white bass (*Morone chrysops*), and white perch. The fishing regulations at Pawnee follow Nebraska's statewide fishing regulations.

Red Cedar Lake

Red Cedar Lake located 40 km northwest of Lincoln, Nebraska near Valparaiso, Nebraska in Saunders County surrounded by rural lands. Red Cedar is owned and operated by Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 20 ha. The fish species present at Red Cedar are bluegill, channel catfish, flathead catfish, and largemouth bass. The fishing regulations at Red Cedar follow Nebraska's statewide fishing regulations.

Stagecoach Lake

Stagecoach Lake located 25 km south of Lincoln, Nebraska near Hickman, Nebraska in Lancaster County surrounded by rural lands. Stagecoach, a flood-control reservoir, is a State Recreation Area and has a surface area of 79 ha. Stagecoach was renovated in the early 1990's to remove the overabundant populations of common carp and gizzard shad (*Dorosoma cepedianum*). The fish species present at Stagecoach are bluegill, channel catfish, common carp, black and white crappie, largemouth bass, hybrid striped bass, and walleye. The fishing regulations at Stagecoach follow Nebraska's statewide fishing regulations, except largemouth bass have a 533-mm minimum length limit; and hybrid striped bass have a daily bag limit of 3, with no more than one fish being 457-mm or greater.

Timber Point Lake

Timber Point Lake located 43 km northwest of Lincoln, Nebraska near Brainard, Nebraska in Butler County surrounded by rural lands. Timber Point, a flood-control

reservoir, is owned and operated by Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 29 ha. A renovation of Timber Point was completed in 2005. The fish species present at Timber Point consists of bluegill, channel catfish, largemouth bass, and muskellunge (*Esox masquinongy*). The fishing regulations at Stagecoach follow Nebraska's statewide fishing regulations, except largemouth bass have a 533-mm minimum length limit.

Wagon Train Lake

Wagon Train Lake located 23 km south of Lincoln, Nebraska near Hickman, Nebraska in Lancaster County surrounded by rural lands. Wagon Train, a flood-control reservoir, is a State Recreation Area and has a surface area of 127 ha. The reservoir was built in 1963 by the U.S. Army Corp of Engineers (NDEQ 2002). The fish species present at Wagon Train are bluegill, channel catfish, largemouth bass, muskellunge, redear sunfish, hybrid striped bass, and walleye. The fishing regulations at Wagon Train follow Nebraska's statewide fishing regulations, except largemouth bass have a 533-mm minimum length limit; hybrid striped bass have a daily bag limit of 3, with no more than one fish being 457-mm or greater.

Wildwood Lake

Wildwood Lake is located 26 km from Lincoln, Nebraska near Agnew, Nebraska in Lancaster County, Nebraska surrounded by rural lands. Wildwood, a flood control reservoir, is owned and operated by Lower Platte South Natural Resources District (LPSNRD) and has a surface area of 42 ha. Wildwood was originally built in 1978 by the

Lower Platte South Natural Resources District (LPSNRD) and USDA – Natural Resources Conservation Service. A restoration project of Wildwood Reservoir was completed in 2003. In 2005, a substantial fish kill occurred due to a massive rain event that caused the aquatic plant community to die off and the reservoir to become muddy. Therefore, additional fishing regulations were put into place to help reestablish the fish community. The fish species present at Wildwood are bluegill, channel catfish, flathead catfish, black and white crappie, largemouth bass, and walleye. The fishing regulations at Wildwood follow Nebraska's statewide fishing regulations, except all Largemouth bass have a 533-mm minimum length limit; and all channel and flathead catfish are catch and release only. In addition, regulations indicate no live baitfish can be used or possessed at Wildwood.

Yankee Hill Lake

Yankee Hill Lake is 13 km southwest of Lincoln, Nebraska near Denton, Nebraska in Lancaster County surrounded by rural lands. Yankee Hill is a Wildlife Management Area and has a surface area of 84 km. Yankee Hill Lake was renovated in 2007 and restocked. The fish species present at Yankee Hill are bluegill, channel catfish, largemouth bass, and walleye. The fishing regulations at Yankee Hill follow Nebraska's statewide fishing regulations, except all largemouth bass have a 533-mm minimum length limit. In addition, regulations indicate no live baitfish can be used or possessed at Yankee Hill.

ANGLING EFFORT

Anglers (angling effort) were counted onsite during 2010. Counts consisted of recording angling effort activities (how many people were fishing at that particular hour). Angler effort was observed and recorded using the bus-route method described by Chizinski et al. (2011) and Martin (2013). The bus-route method is designed to enable one to conduct pressure-counts at numerous sites over a geographical area within a predetermined sampling period (Pollock et al. 1994). The 'route' is defined as a "loop" with designated times and stops (Pollock et al. 1994). The bus-route survey was conducted twice during six sample periods (weekday-early [00:00 – 08:00], weekday-mid [08:00 – 16:00], weekday-late [16:00 – 00:00], weekend-early [00:00 – 08:00], weekend-mid [08:00 – 16:00], and weekend-late [16:00 – 00:00]) for a total of twelve angler effort counts per month per study reservoir; each sample date was randomly selected, as was the start direction, start time, and beginning location of the bus-route survey (Chizinski et al. 2011; Martin 2013). The previously mentioned study areas were included in the bus-route survey involving 19 of the Salt Valley Reservoirs during 2010.

FISH COLLECTION

Field collections of the study fish occurred during the first two weeks of October, 2010. At each sampling site, temperature, conductivity, turbidity, dissolved oxygen (DO), and pH, were recorded (Appendix A). Laboratory assessments of size, age, larval trematodes identification and presence, and condition parameters were completed from October 2010 through January 2011. Bluegill were collected from 15 Salt Valley Reservoirs, using standard boat-mounted electrofishing gear with pulsed DC and

maintaining 3.5 – 4-amps (Appendix B; Reynolds 1996). Electrofishing was conducted in the littoral zones on each study area to primarily collect small bluegill (80-mm – 130-mm), as the location that bluegill are collected from in a water body can influence size and age of fish collected (Mittelbach 1981; Crowder and Cooper 1982; Werner and Hall 1988; Osenberg et al. 1992; Willis and Murphy 1996; Walton et al. 1997; Weimer 2004; Pracheil and Muzzall 2009). I collected 100 bluegill from each study area to identify trends in length frequency (Appendixes C – Q) to assess the population and age-groups. All 100 bluegill collected were measured, recorded, and put into a holding tank filled with circulating water. I randomly selected 50 out of the 100 fish captured for laboratory (age and length; Appendixes R and S) and larval trematode (black spot [internal and external] and white grub; Appendixes T – W) assessments. The 50 randomly selected bluegill were euthanized with an overdose of MS-222 and individually tagged.

LABORATORY ASSESSMENTS

Age Verification

In addition to the external and internal visual examination of each bluegill, otoliths were removed for each fish to estimate and standardize age. Standard collection methods were used for the removal of sagittal otoliths from individual bluegill collected at each study area (Secor et al. 1991). Whole otoliths were submersed in water to clarify annuli. Two readers, both graduate students, independently examined the otoliths and assigned ages. For any disagreements of ages between readers, a concert reading (Buckmeier et al. 2002; Kowalewski et al. 2012) of the otolith by both readers occurred and an agreed age was assigned to the otolith. The individual readers correctly agreed on

76% of otolith ages. Out of the 24% were readers disagreed on age, 14% were between ages 0 and 1; 8% were between ages 1 and 2; and 2% were between ages 2 and 3. Aging of bluegill allowed for grouping during data analysis and verified that younger (smaller) bluegill were used.

Parasitological Examinations

Individual bluegill were placed in a warm water bath to thaw the fish prior to examination to remove skin and organs. Standard length (SL) and total length (TL) measurements to the nearest 1-mm, weight to the nearest 1-g, and a visible health assessment were made for each fish. The visible health assessment of each individual bluegill was categorized as good (G), fair (F), or poor (P), to quantify noticeable health concerns (malnourished, sores, etc), abnormalities, or ectoparasites (Barber et al. 2000; Roberts and Janovy 2000). Good visible health assessments indicated no visible health concerns or issues, a fair visible health assessment indicated a minor concern or issue with the fish's health (limited amount of parasite infections, or limited abnormalities or lesions observed), and a poor visible health assessment indicated multiple concerns or issues with the fish's health (greater intensities of parasite infections, or numerous abnormalities or lesions observed).

After preliminary observations, a detailed analysis of individual skin tissue was conducted to count the individual larval trematodes in the outer skin (black spot and yellow grub). The species and location of each larval trematode was recorded on the visible health assessment data sheet. During the evaluation process, any larval trematodes (Barber et al. 2000; Roberts and Janovy 2000) that were observed in the skin or fins of

the bluegill were identified. In addition to recording the species and location of trematodes in skin tissue, similar data were recorded for larval trematodes in the muscle fibers (fillet) of the bluegill (Hoffman 1999). Because black spot infection could occur externally, as well as internally; black spot was divided into two categories for assessments, internal black spot and external black spot; since anglers may not observe or worry about external black spots in the skin or fins of the fish, or may be more concerned of the presence of internal black spot in the fillet of the fish.

Next, internal organs (stomach, pyloric ceca, intestines, gall bladder, liver, spleen, kidneys, heart, and gonads) were removed from each fish and weighed for each bluegill. Weighing of internal organs involved rinsing the organs and dabbing them dry. After the removal of the viscera, the body cavity was observed for larval trematodes. The number and species of each larval trematode observed in the viscera and body cavity were recorded. The liver was removed from the viscera and weighed. The number and species of each larval trematode observed in the liver were recorded. In cases of extreme larval trematode (white grub) infection, a small portion of the dry liver was sectioned and the number of larval trematodes were counted; the sectioned piece was weighed separately (sections weighed exactly 0.1-g) and the larval trematode count was extrapolated to the total weight of the liver. The gonads were examined to identify gender (male, female, or unknown).

DATA ANALYSIS

Angler Effort

I focused on angling effort from April 2010 through October 2010 for this study. Angling effort during the winter season is comparatively less than angling effort in spring, summer, and fall seasons throughout the Salt Valley Reservoirs (*see* Chizinski et al. 2011 and Martin 2013). Total angling effort (total effort per reservoir for April – October), mean monthly effort (the mean monthly effort per reservoir), and the standard error were calculated for each reservoir. Similarly, effort per hectare was calculated and analyzed for each location.

Prevalence of Larval Trematodes

Prevalence (Bush et al. 1997; Roberts and Janovy 2000) of larval trematodes is defined as a percentage of bluegill infected with one or more larval trematodes (black spot [internal and external], white grub, or yellow grub) from the entire sample collected within each study reservoir and for bluegill age (age 0, age 1, age 2, and age 3). Larval trematode prevalence was calculated for each species of larval trematode assessed using:

$$PrevP = (NumPB / NumTB) \times 100,$$

where *PrevP* is the percentage of bluegill in a sample infected with one or more larval trematodes; where *NumPB* is the number of bluegill that have one or more larval trematodes; and where *NumTB* is the total number of bluegill collected in the sample per bluegill age per study area reservoir. The prevalence is used to express the percentage of

fish infected with larval trematodes (black spot [internal and external], white grub, and yellow grub) per the subsampled bluegill selected from each study area reservoir.

Larval Trematode Intensity and Intensity Mean

The larval trematode intensity is the actual number of larval trematodes of a particular species (black spot [internal and external], white grub, or yellow grub) counted for each individual bluegill sampled from each study reservoir (Bush et al. 1997; Roberts and Janovy 2000; Pracheil 2006). The larval trematode intensity mean was calculated for bluegill per reservoir using:

$$MI = NumPS / NumTPS,$$

where *MI* is the intensity mean of one particular species of larval trematode (black spot [internal and external], yellow grub, or white grub) per bluegill age per study reservoir; where *NumPS* is the total number of one particular species of larval trematode (black spot [internal and external], white grub, or yellow grub) found within the sampled bluegill per study reservoir; and where *NumTPS* is the total number of bluegill collected within each study area reservoir. The intensity mean is used to express larval trematode intensity of infected individuals and were calculated per bluegill age per study area reservoir. Intensity estimates were used to assess the relationship between larval trematode intensity (internal black spot, external black spot, and white grub) and condition of fish.

Condition Indices

I used multiple condition factors to assess condition of bluegill due to the fact that angling effort and larval trematodes can affect bluegill physically and physiologically

differently. The condition factors viscerosomatic (VSI) and hepatosomatic (HSI) indices assess physiological processes which are influenced by stressors from catch-and-release angling activities present. Fulton's condition factor assesses overall condition using growth variables which are influenced by the amount of catch-and-release angling activities present. I go into further detail on calculating the condition factors below.

I used a viscerosomatic indice (VSI), to provide an indication of physiological condition, calculated by:

$$VSI = (W_{Viscera}/W_{TBW}) \times 100,$$

where the viscera weight ($W_{Viscera}$) is divided by the total body weight (W_{TBW}) and multiplied by a constant (Goede and Barton 1990). Viscerosomatic indice mean and standard error (SE) are calculated per bluegill age per study reservoir. The data were normally distributed to meet the assumptions of the statistical analyses performed.

I used a hepatosomatic indice (HSI), as a condition to define the relative energy reserves per bluegill, calculated by:

$$HSI = (W_{Liver}/W_{TBW}) \times 100,$$

where the liver weight (W_{Liver}) is divided by the total body weight (W_{TBW}) and multiplied by a constant (Goede and Barton 1990). Hepatosomatic indice was calculated per bluegill per study reservoir. A mean and standard error (SE) are estimated per bluegill age per study area reservoir. The data were normally distributed to meet the assumptions of the statistical analyses performed.

I used Fulton's condition factor (K; Barton et al. 1991; Blackwell et al. 2000; Neff and Cargnelli 2004) to measure the overall condition of fish, which assesses the somatic

growth due to nutrition that influences body weight mass and length. Fulton's condition factor is calculated by:

$$K = (W/L^3) \times 100{,}000,$$

where weight (*W*; grams) is divided by the cube of length (*L*; millimeters) and multiplied by a constant. Fulton's condition factor (K) was calculated using total length (TL) for each fish and indicated as K_{TL} during analyses. Fulton's (K_{TL}) mean and standard error (SE) are pooled per bluegill age per reservoir. The data were normally distributed to meet the assumptions of the statistical analyses performed.

Statistical Analyses

A non-parametric Spearman rank correlation was used to quantify the association between angling effort (hours) and reservoir area (hectares) present based on the apparent non-normality of the data upon visual inspection. An analysis of variance (ANOVA) model:

$$I = A\ f\ a\ TL,$$

was used to evaluate the differences in means among the model variables (Miller 2013) on the larval trematode intensity (*I*; internal black spot, external black spot, and white grub) per bluegill, where *A* is reservoir area; where *f* is angler effort; where *a* is bluegill age; and where *TL* is total length (mm) per bluegill . Finally, an ANOVA model:

$$c = A\ f\ I\ a\ TL,$$

was used to examine the differences in means among the model variables (Miller 2013) on the condition of bluegill, where *c* is the condition factor; where *A* is the reservoir area; where *f* is angler effort; *I* is the larval trematode intensity per bluegill; where *a* is bluegill

age; and where *TL* is total length (mm) per bluegill. I used condition factors Fulton's (K_{TL}), hepatosomatic (HSI) and viscerosomatic (VSI) indices as metrics of individual condition of bluegill. Condition metrics and larval trematode intensities were adjusted using a log transformation plus allowing for normal distribution of the data. Residuals were observed for any patterns. Analysis of variance tests were run on full models per larval trematode using all independent variables. If any of the independent variables were not significant in the full model, they were removed from the model and a reduced model was run with only the significant variables present. Furthermore, to make all the model variables in both the ANOVA tests visibly comparable to one another, due to differences in scale of the coefficients between variables, reservoir area, angling effort, bluegill age, total length (mm), and larval trematode intensity, I used a formula to adjust the scale of coefficients (Green 1979):

(coefficient*maximum value) – (coefficient*minimum value),

where the coefficient is the ANOVA estimate per model variable; where the maximum and minimum values refer to the model variable maximum and minimum values (reservoir area, angling effort, bluegill age, total length, and larval trematode intensity). This allows someone to visibly observe the impact of each of the model variables on a similar scale. Finally, statistical significance was set at $\alpha = 0.05$ for all correlations and ANOVA tests.

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CHAPTER 3. RESULTS

STUDY FISH

A total of 100 bluegill were collected and total length (TL) measured per reservoir to identify trends in length frequency to assess the population and age-groups. A subsample of 50 small bluegill were dissected per study reservoir and ranged from 60 mm to 160 mm. Median total length (± SE) of dissected bluegill was 103.5 mm (2.4) in Bluestem; 91.0 mm (2.9) in Branched Oak; 86.5 mm (3.6) in Conestoga; 98.5 mm (1.4) in Cottontail; 109.5 mm (3.4) in Holmes; 90.0 (1.2) in Meadowlark; 88.0 mm (4.5) in Merganser; 88.5 mm (3.7) in Olive Creek; 98.5 mm (2.9) in Pawnee; 124.5 mm (2.4) in Red Cedar; 110.0 mm (2.3) in Stagecoach; 90.5 mm (2.4) in Timber Point; 96.5 (3.4) in Wagon Train; 87.0 mm (1.2) in Wildwood; and 111.5 mm (4.1) in Yankee Hill. Weight and total lengths of each bluegill were plotted, indicating length was a cubed function of weight (Figure 5). Ages of dissected bluegill ranged from 0 to 3, with the mean age being age 1 among all reservoirs. Bluegill ages ranged from age 0 to age 2 in Bluestem; age 0 to age 2 in Branched Oak; age 0 to age 2 in Conestoga; age 0 to age 2 in Cottontail; age 0 to age 3 in Holmes; age 0 to age 2 in Meadowlark; age 0 to age 3 in Merganser; age 0 to age 3 in Olive Creek; age 0 to age 2 in Pawnee; age 1 to age 2 in Red Cedar; age 0 to age 2 in Stagecoach; age 1 to age 2 in Timber Point; age 1 to age 2 in Wagon Train; age 0 to age 2 in Wildwood; and age 0 to age 3 in Yankee Hill. Plotting bluegill age by total length (mm) indicated a positive relationship ($R^2 = 0.5761$; N = 750; $P < 0.0001$; Figure 6).

ANGLING EFFORT

Total angling effort calculated for April through October, 2010 ranged from 1,582 hours (Red Cedar Lake) to 69,184 hours (Holmes Lake) per the 15 Salt Valley reservoirs. Mean monthly angling effort ranged from 226 hours per month (Red Cedar Lake) to 9,883 hours per month (Holmes Lake; Table 1). Angler effort per hectare ranged from 46 hours per hectare to 1,708 hours per hectare. Bluestem Lake had the least angler effort per hectare (46 hours per hectare), although it is the third largest reservoir among the study reservoirs. Holmes Lake had the greatest angler effort per hectare (1,708.25 hours/ha) even though it's the fifth smallest reservoir among the study reservoirs. A plot of reservoir area versus total angling effort for the 15 reservoirs shows both Holmes Lake and Branched Oak Lake as outliers (Figure 7).

PREVALENCE OF LARVAL TREMATODES

Bluestem reservoir had the least prevalence of internal black spot in bluegill (26%; Table 2). Meadowlark, Timber Point, and Yankee Hill reservoirs had the greatest prevalence of internal black spot in bluegill (100%). The prevalence of external black spot was least in Bluestem reservoir (0%) and greatest in Meadowlark reservoir (90%). Compared to ages 0, 1, and 3 bluegill; age 2 bluegill had the greatest majority of internal (73%) and external (60%) black spot among the 15 Salt Valley reservoirs. White grub infected 100% of bluegill in 14 of the 15 sampled Salt Valley reservoirs, only Merganser Lake, had 94% white grub prevalence. Yellow grub had zero prevalence in all 15 reservoirs. When assessing prevalence of black spot (internal and external) and white grub for the 15 reservoirs by reservoir area (smallest to largest; hectares), I noticed a

trend (pattern) in prevalence estimates, only with the larval trematode black spot (internal and external; Figure 8).

LARVAL TREMATODE INTENSITY MEAN

Intensity mean was calculated per bluegill age per Salt Valley Reservoir (Table 3). Timber Point Lake ($\bar{x}$ = 8; N = 50; SE = 1.19) had the greatest external black spot intensity mean for all bluegill collected per reservoir. When considering age, a majority of the greatest external black spot intensity mean of in bluegill occurred at age 1 (35%) compared to ages 0 (14%), 2 (29%), and 3 (21%). Timber Point Lake ($\bar{x}$ = 51.38; N = 50; SE = 5.71) had the greatest internal black spot intensity mean for all bluegill collected per reservoir. Age 2 bluegill (40%) had the greatest internal black spot intensity mean of bluegill compared to ages 0 (0%), 1 (33%), and 3 (27%). Merganser Lake had the greatest white grub intensity mean ($\bar{x}$ = 1,584; N = 50; SE = 254.34); with one bluegill calculated to contain 8,876 white grub trematodes. Results indicated that age 2 bluegill had the greatest intensity mean (73%) of white grub compared to ages 0 (0%), 1 (0%), and 3 (27%). Only four reservoirs had age 3 bluegill; all four reservoirs had greater intensity means in age 3 than age 2 bluegill. The infection rates of white grub evidently increase by age, although in both Branched Oak and Conestoga Lakes, age 0 bluegill have higher intensity means than age 1 bluegill. Yellow grub had a zero intensity mean in all 15 reservoirs. When assessing intensity means of internal black spot, external black spot, and white grub for the 15 reservoirs by reservoir area (hectares), I noticed a trend (pattern) in intensity mean estimates, only with the larval trematode black spot (internal and external; Figure 9). Furthermore, a positive relationship (r2 = 0.71; N = 750; $P <$

0.0001) exists between internal black spot and external black spot intensity for the 750 bluegill assessed (Figure 10); further assessments continue to use both internal and external black spot categories since anglers may not observe or worry about external black spots in the skin or fins of the fish, or may be more concerned of the presence of internal black spot in the fillet of the fish.

CONDITION INDICES

Condition factors were calculated per bluegill age per Salt Valley reservoir (Table 4). Viscerosomatic (VSI) and hepatosomatic (HSI) indice means are presented per bluegill age per reservoir; both indices show no correlation with age. Cottontail had the least mean VSI ($\bar{x}$ = 5.32; N = 50; SE = 0.17); Merganser had the greatest mean VSI ($\bar{x}$ = 14.60; N = 50; SE = 1.61). Stagecoach had the least mean HSI ($\bar{x}$ = 0.92; N = 50; SE = 0.04); Merganser had the greatest mean HSI ($\bar{x}$ = 4.56; N = 50; SE = 0.46). Fulton's condition factor (K_{TL}; total length is a cubed function of weight [Figure 5]) evidently increases by age except in Bluestem Lake between ages 0 and 1, Stagecoach Lake between ages 0 and 1, and Yankee Hill Lake between ages 2 and 3. Cottontail bluegill had the least mean Fulton's condition score ($\bar{x}$ = 1.65; N = 50; SE = 0.02); Pawnee Lake bluegill had the greatest mean Fulton's condition score ($\bar{x}$ = 1.96; N = 50; SE = 0.03).

STATISTICAL ANALYSIS

As reservoirs increase in size, generally angling effort increases as well, except for Holmes Lake (urban reservoir) which had the greatest angling effort compared to its

size. Reservoir area and angling effort per Salt Valley reservoirs were found to be positively correlated (r = 0.679; N = 15; *P* = 0.005; Table 5). However, the relationship is not perfect due to outliers based on effort and area (Figure 7). When the outlier, Holmes Lake, was removed from the correlation, due to Holmes being an urbanized system and centrally located within the city limits of Lincoln, the correlation positively became stronger (r = 0.802; N = 15; *P* = 0.0006), respectively. Furthermore, running a linear regression, without Holmes Lake, indicated a positive relationship between angling effort and reservoir area (r^2 = 0.32; N = 14; *P* = 0.03), respectively. Nonetheless, all 15 Salt Valley reservoirs were included in all statistical assessments. Reservoir area, angling effort, bluegill age, and total length (mm) per bluegill were used throughout all statistical assessments in order to evaluate their influences and effects on larval trematode intensity and condition of bluegill; acknowledging that there is still a moderate correlation between reservoir area and angling effort, as well as positive relationship between internal and external black spot.

Larval trematode intensity was influenced by reservoir area (hectares), angling effort (hectares), bluegill age or total length (mm) of bluegill in most all the ANOVA models run; however, the r-square values for the models ranged from 0.32 to 0.40, respectively, indicating that the ANOVA models did not explain a lot of the variation that effort, area, age, and length had on larval trematode intensity. The full ANOVA model for internal black spot intensity indicated that only reservoir area (r^2 = 0.33; df = 4; *P* < 0.0001), bluegill age (r^2 = 0.33; df = 4; *P* < 0.0001), and total length (r^2 = 0.33; df = 4; *P* < 0.0001) were associated with internal black spot intensity, angling effort was not associated (r^2 = 0.33; df = 4; *P* = 0.77; Table 6). The reduced ANOVA model for internal

black spot showed that reservoir area ($r^2 = 0.33$; df = 3; $P < 0.0001$), bluegill age ($r^2 = 0.33$; df = 3; $P < 0.0001$), and total length ($r^2 = 0.33$; df = 3; $P < 0.0001$) were still associated with internal black spot intensity (Table 6). The full ANOVA model for external black spot explained that all main model variables, angling effort ($r^2 = 0.32$; df = 4; $P < 0.0001$), reservoir area ($r^2 = 0.32$; df = 4; $P < 0.0001$), bluegill age ($r^2 = 0.32$; df = 4; $P < 0.0001$), and total length ($r^2 = 0.32$; df = 4; $P = 0.0005$) were associated with external black spot intensity (Table 7). The full ANOVA model for white grub showed that all main model variables, angling effort ($r^2 = 0.40$; df = 4; $P < 0.0001$), reservoir area ($r^2 = 0.40$; df = 4; $P < 0.0001$), bluegill age ($r^2 = 0.40$; df = 4; $P < 0.0001$), and total length ($r^2 = 0.40$; df = 4; $P = 0.01$) were associated with white grub intensity (Table 8).

The reduced ANOVA model for the larval trematode, internal black spot indicates that bluegill age had the greatest influence on internal black spot intensity, followed by total length; reservoir area had the least influence on the internal black spot intensity (Figure 11). Reservoir area and total length affected the internal black spot intensity negatively, while bluegill age had a positive effect (Figure 11). The full ANOVA model for the larval trematode, external black spot, specified that bluegill age had the greatest influence on external black spot intensity, followed by total length then reservoir area; angling effort had the least influence on the external black spot intensity (Figure 12). The model variables, angling effort, reservoir area, and total length, effected external black spot intensity negatively; bluegill age effected external black spot intensity positively (Figure 12). The full ANOVA model for the larval trematode, white grub, showed that bluegill age had the greatest influence on white grub intensity, followed by total length then angling effort; reservoir area had the least influence on white grub intensity (Figure

13). The model variables, angling effort and bluegill age, affected white grub intensity positively, while reservoir area and total length affected white grub intensity negatively (Figure 13). The best ANOVA models for assessing which model variables significantly influence larval trematode intensity are the reduced model for internal black spot, the full model for external black spot, and the full model for white grub (Figure 14).

Condition factors (viscerosomatic and hepatosomatic indices, and Fulton's condition) found to be associated related with larval trematode intensity (internal black spot, external black spot, and white grub) per bluegill, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm), depending on the condition factor used as the continuous dependent variable in the ANOVA models. The r-square values for each of the ANOVA models for all condition factors ranged from 0.04 to 0.69, respectively; the low r-square values (0.04 – 0.17) indicate that the ANOVA models for condition factors, VSI and HSI, did not explain a lot of the variation that effort, area, age, length, and larval trematode intensity per bluegill had on condition of bluegill. The ANOVA models using K_{TL} have r-square values that ranged from 0.68 to 0.69, and are considered respectable for ecological data and explain an adequate amount of the variation in the models. Residuals for each model were inspected for any patterns. The ANOVA models for viscerosomatic indice (VSI) varied slightly by larval trematode (internal black spot, external black spot, and white grub). The full ANOVA model for VSI with internal black spot indicated an association among internal black spot intensity ($r^2 = 0.07$; df = 5; $P < 0.0001$), reservoir area ($r^2 = 0.07$; df = 5; $P < 0.0001$), and total length ($r^2 = 0.07$; df = 5; $P = 0.01$) variables; angling effort ($r^2 = 0.07$; df = 5; $P = 0.35$) and bluegill age ($r^2 = 0.07$; df = 5; $P = 0.22$) was not associated with VSI (Table 9). The

reduced model for VSI with internal black spot indicated that variables, internal black spot intensity ($r^2 = 0.07$; df = 3; $P < 0.0001$), reservoir area ($r^2 = 0.07$; df = 3; $P < 0.0001$), and total length ($r^2 = 0.07$; df = 3; $P = 0.003$), were associated with VSI (Table 9). The full ANOVA model for VSI with external black spot explained that external black spot intensity ($r^2 = 0.04$; df = 5; $P = 0.0088$), reservoir area ($r^2 = 0.04$; df = 5; $P = 0.0026$), bluegill age ($r^2 = 0.04$; df = 5; $P = 0.01$), and total length ($r^2 = 0.04$; df = 5; $P = 0.0011$), were the only variables associated with VSI; angling effort ($r^2 = 0.04$; df = 5; $P = 0.64$) was not associated with VSI (Table 10). The reduced model for VSI with external black spot indicated that variables, external black spot intensity ($r^2 = 0.04$; df = 4; $P = 0.0059$), reservoir area ($r^2 = 0.04$; df = 4; $P = 0.0025$), bluegill age ($r^2 = 0.04$; df = 4; $P = 0.0103$), and total length ($r^2 = 0.04$; df = 4; $P = 0.0007$), were associated with VSI (Table 10). The final ANOVA model for VSI with white grub, revealed that variables, white grub intensity ($r^2 = 0.14$; df = 5; $P < 0.0001$), angling effort ($r^2 = 0.14$; df = 5 ; $P = 0.0014$), reservoir area ($r^2 = 0.14$; df = 5; $P < 0.0001$), and total length ($r^2 = 0.14$; df = 5; $P = 0.0033$), were significant; bluegill age ($r^2 = 0.14$; df = 5; $P = 0.28$) was not associated with VSI (Table 11). The reduced model for VSI with white grub indicates that variables, white grub intensity ($r^2 = 0.14$; df = 4; $P < 0.0001$), angling effort ($r^2 = 0.14$; df = 4; $P = 0.0024$), reservoir area ($r^2 = 0.14$; df = 4; $P < 0.0001$), and total length ($r^2 = 0.14$; df = 4; $P < 0.0001$) were associated with VSI (Table 11).

The ANOVA models for hepatosomatic indice (HSI) differed based on the larval trematode used in the assessment. The full ANOVA model for HSI with internal black spot indicated that model variables, internal black spot intensity ($r^2 = 0.1$; df = 5; $P < 0.0001$), reservoir area ($r^2 = 0.1$; df = 5; $P = 0.0003$), and total length ($r^2 = 0.1$; df = 5; $P <$

0.0001), were associated with HSI (Table 12). The model variables, angling effort (r^2 = 0.1; df = 5; P = 0.11) and bluegill age (r^2 = 0.1; df = 5; P = 0.31) were not significant in the full model for HSI. The reduced model for HSI with internal black spot indicated variables, internal black spot intensity (r^2 = 0.1; df = 3; $P < 0.0001$), reservoir area (r^2 = 0.1; df = 3; P = 0.0004), and total length (r^2 = 0.1; df = 3; $P < 0.0001$), were associated with HSI (Table 12). The full ANOVA model for HSI with external black spot indicated that model variables, external black spot intensity (r^2 = 0.06; df = 5; P = 0.0069), reservoir area (r^2 = 0.06; df = 5; P = 0.0183), bluegill age (r^2 = 0.06; df = 5; P = 0.01), and total length (r^2 = 0.06; df = 5; $P < 0.0001$), were associated with HSI (Table 13). Only model variable angling effort (r^2 = 0.06; df = 5; P = 0.27) was not significant in the full model. The reduced model for HSI with external black spot indicated model variables, external black spot (r^2 = 0.06; df = 4; P = 0.0031), reservoir area (r^2 = 0.06; df = 4; P = 0.0347), bluegill age (r^2 = 0.06; df = 4; P = 0.0058), and total length (r^2 = 0.06; df = 4; $P < 0.0001$), were all associated with HSI (Table 13). The final ANOVA model for HSI with white grub, revealed that the model variables, white grub intensity (r^2 = 0.17; df = 5; $P < 0.0001$), angling effort (r^2 = 0.17; df = 5; $P < 0.0001$), reservoir area (r^2 = 0.17; df = 5; P = 0.0004), and total length (r^2 = 0.17; df = 5; $P < 0.0001$) were associated with HSI (Table 14). Only the model variable bluegill age (r^2 = 0.17; df = 5; P = 0.24) was not significant in the full model with HSI. The reduced model for HSI with white grub indicated variables, white grub intensity (r^2 = 0.17; df = 4; $P < 0.0001$), angling effort (r^2 = 0.17; df = 4; P = 0.0001), reservoir area (r^2 = 0.17; df = 4; P = 0.0007), and total length (r^2 = 0.17; df = 4; $P < 0.0001$), were all associated with HSI (Table 14).

The ANOVA models for Fulton's condition factor (K_{TL}) were the same for all larval trematodes. The ANOVA model for K_{TL} with internal black spot indicated that all variables, internal black spot intensity ($r^2 = 0.68$; df = 5; $P < 0.0001$), angling effort ($r^2 = 0.68$; df = 5; $P < 0.0001$), reservoir area ($r^2 = 0.68$; df = 5; $P < 0.0001$), bluegill age ($r^2 = 0.68$; df = 5; $P < 0.0001$), and total length ($r^2 = 0.68$; df = 5; $P < 0.0001$), were associated with K_{TL} (Table 15). The ANOVA model for K_{TL} with external black spot showed that all variables, external black spot intensity ($r^2 = 0.69$; df = 5; $P < 0.0001$), angling effort ($r^2 = 0.69$; df = 5; $P < 0.0001$), reservoir area ($r^2 = 0.69$; df = 5; $P < 0.0001$), bluegill age ($r^2 = 0.69$; df = 5; $P < 0.0001$), and total length ($r^2 = 0.69$; df = 5; $P < 0.0001$), were associated with K_{TL} (Table 16). The final ANOVA model for K_{TL} with white grub, explained that all variables, white grub intensity ($r^2 = 0.69$; df = 5; $P < 0.0001$), angling effort ($r^2 = 0.69$; df = 5; $P < 0.0001$), reservoir area ($r^2 = 0.69$; df = 5; $P < 0.0001$), bluegill age ($r^2 = 0.69$; df = 5; $P < 0.0001$), and total length ($r^2 = 0.69$; df = 5; $P < 0.0001$), were associated with K_{TL} (Table 17).

The reduced ANOVA models for viscerosomatic indice (VSI) with the larval trematodes (black spot [internal and external] and white grub), showed that all model variables were highly variable (Figure 15). The VSI model with internal black spot, showed that internal black spot intensity had the greatest influence on VSI condition, followed by reservoir area; total length had the least influence on VSI. The VSI model with external black spot showed total length had the greatest influence on VSI, followed by bluegill age, the external black spot intensity; reservoir area had the least influence on VSI. The final VSI model with white grub, indicated that white grub intensity had the greatest influence on VSI, followed by total length, then reservoir area; angling effort had

the least influence on VSI. Model variables, larval trematode intensity, reservoir area, and total length, were present in all three VSI models; angling effort was only present in the white grub model, and bluegill age was only present in the external black spot model. Larval trematode intensity, reservoir area, and bluegill age all positively affected VSI; angling effort and total length negatively affected VSI condition in fish. The reduced ANOVA models for hepatosomatic indice (HSI) with the larval trematodes (black spot [internal and external] and white grub) showed that all model variables were highly variable on HSI condition (Figure 16). The internal black spot model indicated that internal black spot intensity had the greatest influence on HSI, followed by total length; reservoir area had the least influence on HSI. The external black spot model showed that total length had the greatest influence on HSI, followed by bluegill age, then angling effort; reservoir area had the least influence on HSI. The white grub model indicated that white grub intensity had the greatest influence on HSI, followed by total length, then reservoir area; angling effort had the least influence on HSI. Model variables, larval trematode intensity, reservoir area, and total length, were present in all three models; bluegill age was only present in the external black spot model, and angling effort was only present in the white grub model. Larval trematode intensity, reservoir area, and bluegill age all positively affected HSI; angling effort and total length negatively affected HSI. The full ANOVA models for Fulton's condition factor (K_{TL}) with the larval trematodes (black spot [internal and external] and white grub) showed that bluegill age had the greatest influence on K_{TL} condition (Figure 17). Angling effort, reservoir area, and total length varied among how influential they were on $K_{TL,}$ but all model variables did positively influence K_{TL} condition in all models. The best ANOVA models for each

condition factor per larval trematode indicated that Fulton's condition factor had higher r-square values, ranging from 0.68 to 0.69, than condition factors, VSI and HSI; and that the larval trematode, white grub, provided higher r-squares values, than black spot (internal and external; Figure 18).

CHAPTER 4. DISCUSSION

Overall, the effects of catch-and-release angling activities provide limited support for the hypotheses I put forth, further indicating that larval trematode intensity is not a viable indicator of angling effort. The model between white grub intensity and angling effort does provide some limited support for my hypothesis. Furthermore, angling effort decreases condition of bluegill when associated with the condition factors, viscerosomatic and hepatosomatic indices, although the correlation is weak. However, my results do suggest that a potential relationship of dependence exists between larval trematodes and small bluegill in the reservoirs of the Salt Valley Watershed; bluegill population estimates would be needed to assess if the relationship was density- or frequency-dependent. Although I acknowledge that all statistical tests preformed in this study were significant, the models explained little of the variation found among the independent variables.

Firstly, I hypnotized that angling effort would increase with reservoir area. A relatively strong, positive correlation does exist between angling effort (hours) and reservoir area (hectares) in the Salt Valley watershed, indicating that as surface area of a reservoir increases the more angling effort is likely to occur. However, the relationship between angling effort and reservoir area was not perfect. Looking at the relationship, I removed the one urban reservoir, Holmes Lake, from the correlation, due to its centralized location within the city limits of Lincoln; Holmes Lake had an enlarged angling effort for the size of reservoir. The correlation between angling effort and reservoir area became stronger and more significant without Holmes Lake, respectively.

The relationship between the variables also indicated a substantial linear improvement. Furthermore, I looked into the outlier, Branched Oak Lake, which due to its large size had relatively low angling effort. Removing both Branched Oak and Holmes Lake, from the correlation created a similar, positive result. The correlation was stronger, but not as strong if I only removed the urban reservoir. Ultimately, I continued to use all fifteen reservoirs in further assessments to observe whether reservoir area or angling effort had the greatest influence on larval trematode intensity and condition of bluegill. Overall, the correlation and regression models with variables, angling effort and reservoir area, provided a majority of the explanation for each of the models variation, but there seems to be additional variables that affect the relationship between angling effort and reservoir area that were not taken into consideration in this study. This study was part of a larger study that focused on assessing how angler behavior influenced angling effort on reservoirs throughout the Salt Valley watershed; see Martin (2013) for additional variables that could influence the amount of angling effort on the Salt Valley reservoirs.

Secondly, I hypothesized that angling effort would positively affect larval trematode intensity, allowing larval trematode intensity to be an index of angling effort. The conclusive finding discovered when assessing the relationships between larval trematode intensity (black spot and white grub) and the independent variables, angling effort (hours), reservoir area (hectares), bluegill age, and total length, is that bluegill age, total length, and reservoir area have the greatest influence on larval trematode intensity in small bluegill; angling effort had the least influence on larval trematode intensity. Bluegill age has a positive relationship with larval trematode intensity; this relationship makes ecological sense, as bluegill age increases the accumulation of larval trematodes

increase due to the fact that fish do not develop immunity against larval trematodes. Reservoir area has a negative relationship with larval trematode intensity; the relationship between area and larval trematode intensity also makes ecological sense. As reservoir area increases in size, the encounter rates between fish and larval trematodes decreases. The smaller the reservoir the greater the opportunity larval trematodes have to encounter bluegill, perhaps indicating that relationship of dependence exists between larval trematodes and small bluegill in the reservoirs of the Salt Valley Watershed; bluegill population estimates are needed to assess if the relationship is density- or frequency-dependent. Total length of bluegill has a negative relationship with larval trematode intensity; this relationship also makes ecological sense. As fish increase in size (length), they are not as accessible to predators, allowing larger-sized fish to leave the protection of the littoral zone and venture out into deeper water to forage for additional resources. Consequently, when larger-sized (length) fish spend less time in the littoral zone where they are most susceptible to larval trematode infection, the intensity rates of larval trematodes decrease. Angling effort is highly variable, and not consistent enough to make a final conclusion. Angling effort was either not present in the models, had a negative influence, or had a positive influence on larval trematode intensity based on what larval trematode was acting as the dependent variable in my assessments. The negative effect angling effort had on external black spot intensity could be a result of angling effort decreasing fish density, either through discard mortality or harvest; the less fish present, the less fish encounter larval trematodes. The positive effect angling effort had on white grub intensity could be a result of increased catch-and-release angling activities increasing the stress fish experience allowing fish to become more susceptible to white

grub. The relationship between white grub and angling effort provides limited support for my hypothesis; both white grub and angling effort (catch-and-release) and the stress involved with both variables impacts the physiological processes occurring within the fish. Overall, all the models tested were significant, the models explained little of the variation in larval trematode intensity, indicating that larval trematode intensity is not a viable indicator of angling effort. Inserting additional variables into the models may help increase explanatory power; further research could provide insight into whether a predator-prey dynamic, or a food-web dynamic, or an environmental factor influences larval trematode intensities more than angling effort.

Thirdly, I hypothesized that increased angling effort and increased larval trematode intensity, and associated stressors from both variables, would decrease condition of bluegill. The ANOVA results revealed when assessing the relationships between condition factors (viscerosomatic [VSI] and hepatosomatic [HSI] indices and Fulton's condition) and the independent variables, angling effort (hours), reservoir area (hectares), bluegill age, total length (mm), and larval trematode intensity (black spot [internal and external] and white grub) per bluegill, that the models are variable in results based on the larval trematode (independent variable) and the condition factor (dependent variable) being assessed. The results, although inconsistent, make sense due to the fact that each condition factor calculates condition of bluegill differently and that each larval trematode affects bluegill differently. Overall, the positive effect reservoir area had on all the condition factors in all the models for each larval trematode made ecological sense. The larger the reservoir area, the more fish can disperse, and the interspecific competition for resources decreases. The positive effect larval trematode intensity had on all condition

factors in all the models may be slightly misleading; perhaps showing the increased weight due to increased larval trematode intensities, as well as swelling and edema of the organs causing greater condition values. Bluegill age is variable and is either not present in final models, or when present has a positive relationship with condition factors; as bluegill age increases, condition increases. This positive relationship makes sense as fish age they become mature, which is positively related to condition (variety of factors may influence when fish reach maturity [Morgan and Colbourne, 1999]); bluegills are estimated to reach maturity at 1 year of age (Belk 1995). The effect of total length of bluegill was variable and confounding due to the fact that Fulton's condition uses length to predict K, but condition factors, VSI and HSI indices are truly independent of length. Total length had a negative relationship with condition, VSI and HSI indices; indicating that larger-size (length) fish have poorer condition, possibly due physiological processes being affected by recruitment processes. The positive effect total length had on Fulton's condition factor may be misleading due to the relationship between Fulton's condition (overall growth) and fish size (length). The negative effect of angling effort on condition factors VSI and HSI indicates a greater amount of angling effort decreases condition values, perhaps due to the increased stress bluegill experience from stressors that catch-and-release angling activities can cause, which negatively affect physiological processes, such as absorption, digestion, fitness, and energy reserves. The positive effect angling effort on Fulton's condition value indicates greater amounts of angling effort increases condition values, perhaps due to the increased amounts of catch-and-release mortality, which decreases fish density and leads to less interspecific competition for resources providing more opportunities for somatic growth due to nutrition. I acknowledge that I

did not take into consideration during assessments that empty and full stomachs can decrease and increase condition values, respectively. Furthermore, pollutants (urban and agricultural) can affect liver size, possibly increasing condition factors VSI and HSI. Finally, I did not include larval trematode weight into condition assessments, which can influence condition factor values; condition values can be inflated when the weight of parasites are included in the total mass of the fish (Lagure and Poulin 2015). Although I acknowledge that all statistical tests performed were significant, little variation was explained among the independent variables; Fulton's condition factor models do provide a reasonable amount of explanation within the models. Overall, study results indicate that angling effort does convincingly affect condition like I hypothesized, but varies depending on the condition factor being assessed. Adding supplementary variables into the models may help increase explanatory power; further research could provide insight into whether a predator-prey dynamic, or a food-web dynamic, or an environmental factor influences condition of bluegill more than angling effort.

Several findings support the possible existence of a dependence relationship between small bluegill and black spot, but there were possible limitations within this study. Larval trematodes can have a multifaceted life cycle, they are also known to seasonally fluctuate in intensity, and can be influenced by environmental factors. The life cycle of larval trematodes and intermediate hosts were not taken into account for this study. There are studies that indicate that parasite transmission rates (infection rates of susceptible hosts) and direct or indirect life cycles play a role in infection rates of parasites in hosts, especially when angling effort is present (Wood and Lafferty 2015). Though other studies indicate parasite transmission is not affected and is resilient to

angling effort (Johnson et al. 2011; Wood and Lafferty 2015). Intermediate hosts of larval trematodes, like aquatic snails, were also not assessed for presence-absence in each of the Salt Valley reservoirs used for this study. Population estimates of aquatic snails could help unravel the dependence relationship observed between small bluegill, black spot, and area. Furthermore, seasonal effects on larval trematode intensities are known to exist (Wood and Lafferty 2015; Schade et al. 2016). Finally, environmental factors can influence intensities. For example, Izyumova (1987) found that parasite communities will change after a period in reservoirs that have been renovated or newly developed; and that parasite communities differ between naturally developed lakes and man-made reservoirs (Marcogliese 2005). Parasite intensities in fish can also vary depending on water quality (Cone et al. 1993). I did not take into account the age of each Salt Valley reservoir used in my study; the functional age of reservoirs (Miranda and Krogman 2015; Pegg et al. 2015) can change littoral development where larval trematodes primarily reside. The Salt Valley reservoirs have been renovated over different time periods, and the age of the reservoir could influence the prevalence and intensity of larval trematodes; reservoir age could be one explanation for the trends (pattern) observed in black spot (internal and external) that I observed in the Salt Valley reservoirs used for this study (Figures 8 and 9; reservoir age data were not available to assess this relationship at the time). The presence-absence of intermediate hosts of larval trematodes can further influence larval trematode intensities; aquatic snail populations can be depleted by increased sediment loads (McIntyre et al. 2005), as well as other fish populations, such as freshwater drum and redear sunfish, which are known to feed heavily on aquatic (littoral) snails (Ledford and Kelly 2006; Strayer 1999; Smith 2000, 2011). Habitat changes along the shoreline

and in the littoral zone can also affect the presence of a blue heron (*Ardea* spp.) population, known to be a definitive host of larval trematodes.

I examined three different larval trematodes, black spot (internal and external), white grub, and yellow grub, and saw different responses between two of the larval trematodes (black spot [internal and external] and white grub). Yellow grub were not present in any of the bluegill examined. Acknowledging that yellow grub requires two intermediate hosts to complete its life cycle, a presence-absence study may need to occur to examine if the aquatic snail or blue heron species needed to complete the yellow grub life cycle are present. Based on research as mentioned previously, I do not believe larval trematode life cycles affected my study; a direct life cycle caused by penetration of larval trematodes or indirect life cycle caused by another intermediate host should not influence larval trematode intensities. Seasonal variability that can occur with larval trematode intensity may have affected my study even though I collected bluegill at the time when the larval trematode intensity is thought to be greatest before succumbing to overwinter mortality. Likewise, the date in which bluegill collections took place (October 2010) could have influenced the size and condition of bluegill collected; bluegill could have started building reserves for overwintering due to the drop in temperatures. Bluegill are known to inhabit different zones (littoral or limnetic) based on time of day, feeding habitats, age, and cover. Despite this concern, the number of bluegill I collected still provided enough variability in the data to test my hypotheses. Finally, the amount of area covered while electrofishing varied by each collection event. Although my collection times varied between reservoirs, I do not believe this affected my study due to the fact that I randomized my selection of small bluegill for laboratory examinations, though the

littoral zones in each reservoir may be at different stage in development based on the functional age of the reservoir, as previously mentioned.

In conclusion, my study results suggest that a relatively strong, positive correlation exists between angling effort (hours) and area (hectares). Other studies have demonstrated that as reservoir surface area increases the opportunity for angling effort increases, and that parasite intensity and density varied depending on the parasite's life cycle and the host being targeted (fished; Wood et al. 2010; Wood and Lafferty 2015); parasites can affect fish physically and physiologically differently, angling can target hosts of parasites creating a bottle-neck (Wood et al. 2010; Wood and Lafferty 2015), and angling effort can influence stress levels and density of fish populations differently. The response parasites have to angling effort can be complex and vary by species, location, and age (Wood and Lafferty 2015). By increasing angling effort, the population density of fish is directly affected, therefore affecting the parasite intensity (Wood et al. 2010; Wood and Lafferty 2015). By reducing the numbers of hosts for parasites, parasite populations could disappear or increase in parasite intensity within the remaining fish. The presence of a density-dependent relationship can affect condition of fish as well (Shin et al. 2005). In addition, angling primarily is known to target larger fish within a population (Wood et al. 2010; Chizinski et al. 2014; Wood and Lafferty 2015). Those older fish are known to possibly carry a greater concentration of parasites (Wood et al. 2010; Wood and Lafferty 2015), which my study indicates (bluegill age positively effects larval trematode intensity). Further, it has been noted that fish density increases when no angling effort is present, which in return increases parasite intensity (Wood and Lafferty

2015). My study results further support this research, indicating that when angling effort is low, bluegill experience increased black spot (external) intensity.

My study results provide further insight as to how area affects larval trematode intensity in bluegill. Area HAD a negative association with larval trematode intensity of black spot (internal and external) and white grub in bluegill. Therefore, as the area of a reservoir increased in size, the presence of black spot decreased among the bluegill population. This result strongly suggests a relationship of dependence between larval trematodes and small bluegill in the reservoirs of the Salt Valley Watershed; bluegill population estimates of the Salt Valley reservoirs are needed to assess if the relationship was density- or frequency-dependent. A recent study by Buck and Lutterschmidt (2017) looking at parasite intensity and host density found that host density negatively affected parasite intensity, which is also what my study results indicate. As reservoir area increases, larval trematode intensity decreases in small bluegill due to the fact fish have more area to disperse and the encounter rates decrease between larval trematodes and bluegill.

Catch-and-release angling is a popular recreational activity in the Salt Valley region and as more people become involved, the public and fishery managers need to be aware of the effect increased angling effort has on the health and condition of fish populations. The results from this study will help fishery managers recognize the ramifications that angling effort, reservoir area, bluegill age, and total length per bluegill can have on the larval trematode intensities, as well as how all those variables plus larval trematode intensity affect condition of bluegill in the Salt Valley watershed, especially for small bluegill. The relationship between angling effort and larval trematode intensity

may vary among the larval trematode being assessed, as well as be influenced by additional variables that were not included in this study but mentioned throughout the discussion, such as reservoir age, snail and blue heron populations, littoral zone development, and additional fish populations present. Nevertheless, understanding the relationship between angling effort and larval trematodes, as well as the stress from both variables, can help fishery managers set angling regulations, create educational campaigns for anglers, and affect population dynamics (stocking) for each waterbody.

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TABLES AND FIGURES

Table 1. Mean monthly angling effort (hours) from April 2010 through October 2010 and surface area (hectares) for 15 Salt Valley reservoirs.

Reservoir	Effort (SE)	Area
Bluestem Lake	882 (222)	131.9
Branched Oak Lake	5835 (1119)	728.4
Conestoga Lake	4254 (859)	93.1
Cottontail Lake	483 (54)	11.7
Holmes Lake	9883 (1721)	40.5
Meadowlark Lake	694 (254)	22.3
Merganser Lake	319 (91)	16.6
Olive Creek Lake	2542 (563)	70.8
Pawnee Lake	5738 (1236)	299.5
Red Cedar Lake	226 (78)	20.2
Stagecoach Lake	4244 (1518)	78.9
Timber Point Lake	858 (193)	11.3
Wagon Train Lake	7782 (1722)	127.5
Wildwood Lake	3639 (803)	41.7
Yankee Hill Lake	2681 (504)	84.2

Table 2. Sample size (N) and prevalence (%) of black spot (internal and external), prevalence of white grub, and prevalence of yellow grub per age group of bluegill in 15 Salt Valley reservoirs. The dash symbol (-) indicates that no bluegill were collected.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub	Yellow Grub
Bluestem Lake	0	4	0	0	100	0
	1	22	32	0	100	0
	2	24	25	0	100	0
	3	0	-	-	-	-
Branched Oak Lake	0	7	43	0	100	0
	1	28	46	7	100	0
	2	15	100	40	100	0
	3	0	-	-	-	-
Conestoga Lake	0	20	25	0	100	0
	1	11	0	0	100	0
	2	19	79	42	100	0
	3	0	-	-	-	-
Cottontail Lake	0	16	94	69	100	0
	1	21	95	67	100	0
	2	13	92	77	100	0
	3	0	-	-	-	-
Holmes Lake	0	5	80	40	100	0
	1	19	89	42	100	0
	2	22	100	55	100	0
	3	4	100	50	100	0

Table 2. Continued.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub	Yellow Grub
Meadowlark Lake	0	6	100	67	100	0
	1	33	100	91	100	0
	2	11	100	100	100	0
	3	0	-	-	-	-
Merganser Lake	0	10	80	30	70	0
	1	19	100	26	100	0
	2	20	100	85	100	0
	3	1	100	100	100	0
Olive Creek Lake	0	7	57	57	100	0
	1	23	96	65	100	0
	2	19	100	74	100	0
	3	1	100	100	100	0
Pawnee Lake	0	4	0	0	100	0
	1	23	48	0	100	0
	2	23	48	4	100	0
	3	0	-	-	-	-
Red Cedar Lake	0	0	-	-	-	-
	1	16	63	31	100	0
	2	34	47	21	100	0
	3	0	-	-	-	-
Stagecoach Lake	0	1	0	0	100	0
	1	29	55	0	100	0
	2	20	40	5	100	0
	3	0	-	-	-	-

Table 2. Continued.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub	Yellow Grub
Timber Point Lake	0	0	-	-	-	-
	1	27	100	96	100	0
	2	23	100	78	100	0
	3	0	-	-	-	-
Wagon Train Lake	0	0	-	-	-	-
	1	33	97	27	100	0
	2	17	100	71	100	0
	3	0	-	-	-	-
Wildwood Lake	0	6	50	33	100	0
	1	35	66	26	100	0
	2	9	100	44	100	0
	3	0	-	-	-	-
Yankee Hill Lake	0	1	100	0	100	0
	1	22	100	68	100	0
	2	26	100	65	100	0
	3	1	100	100	100	0

Table 3. Sample size (N), intensity mean with standard error (±SE), and the maximum number of larval trematode per internal black spot, external black spot, and white grub per age group of bluegill in 15 Salt Valley reservoirs. A dash symbol (-) indicates that no bluegill were collected.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub
Bluestem Lake	0	4	0	0	6.5 ± 2.10 (11)
	1	22	0.4 ± 0.14 (2)	0	16.2 ± 4.81 (81)
	2	24	0.3 ± 0.13 (2)	0	19.2 ± 4.25 (76)
	3	0	-	-	-
Branched Oak Lake	0	7	0.4 ± 0.20 (1)	-	108.3 ± 29.40 (228)
	1	28	1.5 ± 0.50 (9)	0.1 ± 0.10 (2)	81.6 ± 8.18 (174)
	2	15	4.9 ± 0.61 (10)	0.7 ± 0.27 (3)	301.7 ± 70.73 (835)
	3	0	-	-	-
Conestoga Lake	0	20	0.4 ± 0.15 (2)	0	20.9 ± 4.06 (61)
	1	11	0	0	6.2 ± 0.88 (11)
	2	19	15.0 ± 6.22 (91)	4.1 ± 2.12 (31)	66.8 ± 7.45 (131)
	3	0	-	-	-

Table 3. Continued.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub
Cottontail Lake	0	16	5.6 ± 1.01 (12)	3.5 ± 0.94 (10)	17.7 ± 1.93 (42)
	1	21	37.2 ± 11.07 (159)	3.2 ± 1.09 (43)	98.1 ± 131.91 (402)
	2	13	28.5 ± 7.78 (74)	3.2 ± 1.09 (12)	186.4 ± 55.46 (702)
	3	0	-	-	-
Holmes Lake	0	5	3.2 ± 1.07 (6)	1.2 ± 0.80 (4)	39.8 ± 6.89 (65)
	1	19	7.0 ± 1.61 (27)	1.3 ± 0.48 (6)	83.4 ± 13.56 (218)
	2	22	13.6 ± 1.89 (35)	1.7 ± 0.44 (6)	493.8 ± 91.55 (2150)
	3	4	33.8 ± 5.74 (49)	3.0 ± 1.91 (8)	1151.8 ± 176.61 (1498)
Meadowlark Lake	0	6	16.5 ± 2.60 (29)	1.8 ± 0.79 (5)	33.5 ± 6.80 (65)
	1	33	39.8 ± 4.59 (136)	9.8 ± 1.89 (44)	88.6 ± 16.49 (348)
	2	11	24.6 ± 3.02 (44)	5.0 ± 1.26 (15)	190.3 ± 44.93 (531)
	3	0	-	-	-
Merganser Lake	0	10	1.4 ± 0.34 (3)	0.4 ± 0.22 (2)	142.2 ± 40.98 (408)
	1	19	23.7 ± 6.45 (86)	1.1 ± 0.53 (7)	991.6 ± 152.63 (2786)
	2	20	25.8 ± 9.22 (148)	3.0 ± 0.90 (14)	2680.4 ± 471.65 (8876)
	3	1	148.0 ± 0 (148)	7.0 ± 0 (7)	5370.0 ± 0 (5370)

Table 3. Continued.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub
Olive Creek Lake	0	7	4.3 ± 2.57 (19)	3.7 ± 2.46 (18)	182.9 ± 25.87 (267)
	1	23	4.9 ± 0.70 (12)	2.0 ± 0.54 (10)	332.7 ± 31.29 (603)
	2	19	19.5 ± 2.62 (42)	2.4 ± 0.51 (8)	1504.9 ± 119.99 (2889)
	3	1	40.0 ± 0 (40)	1.0 ± 0 (1)	3312.0 ± 0 (3312)
Pawnee Lake	0	4	0	0	16.5 ± 3.75 (26)
	1	23	1.2 ± 0.39 (7)	0	35.8 ± 3.51 (69)
	2	23	1.2 ± 0.32 (5)	0.04 ± 0.04 (1)	185.1 ± 32.36 (570)
	3	0	-	-	-
Red Cedar Lake	0	0	-	-	-
	1	16	1.0 ± 0.27 (4)	0.5 ± 0.22 (3)	39.3 ± 5.45 (83)
	2	34	1.7 ± 0.48 (13)	0.2 ± 0.07 (1)	118.4 ± 19.83 (505)
	3	0	-	-	-
Stagecoach Lake	0	1	0	0	34.0 ± 0 (34)
	1	29	1.7 ± 0.41 (8)	0	102.7 ± 20.07 (535)
	2	20	0.8 ± 0.29 (4)	0.1 ± 0.05 (1)	325.1 ± 52.81 (1030)
	3	0	-	-	-

Table 3. Continued.

Reservoir	Age	N	Internal Black Spot	External Black Spot	White Grub
Timber Point Lake	0	0	-	-	-
	1	27	35.6±3.77 (92)	8.2±1.20 (22)	38.3±3.93 (89)
	2	23	69.9±10.45 (217)	7.9±2.20 (45)	344.9±26.89 (576)
	3	0	-	-	-
Wagontrain Lake	0	0	-	-	-
	1	33	12.6±1.50 (30)	0.7±0.27 (6)	255.2±26.93 (882)
	2	17	18.3±4.67 (82)	2.5±0.86 (13)	1424.4±184.74 (2772)
	3	0	-	-	-
Wildwood Lake	0	6	1.7±0.92 (5)	1.2±0.83 (5)	41.7±3.58 (53)
	1	35	1.8±0.44 (12)	0.3±0.10 (2)	139.2±10.53 (206)
	2	9	48.3±26.69 (257)	1.7±1.19 (11)	177.7±36.69 (318)
	3	0	-	-	-
Yankee Hill Lake	0	1	16.0±0 (16)	0	121.0±0 (121)
	1	22	24.1±3.81 (75)	3.6±1.27 (24)	258.8±21.70 (435)
	2	26	35.6±8.44 (159)	5.2±1.65 (34)	526.6±47.14 (938)
	3	1	192.0±0 (192)	24.0±0 (24)	1056.0±0 (1056)

Table 4. Sample size (N), mean, standard error (±SE), and the maximum for condition factors, Fulton's Condition Factor (K_{TL}), hepatosomatic (HSI), and viscerosomatic (VSI) per age group of bluegill in 15 Salt Valley reservoirs. A dash symbol (-) indicates no bluegill were present.

Reservoir	Age	N	Fulton's Condition Factor (K_{TL})	Hepatosomatic Index	Viscerosomatic Index
Bluestem Lake	0	4	1.9 ± 0.01 (1.9)	2.2 ± 0.1 (2.2)	7.3 ± 0.2 (7.9)
	1	22	1.7 ± 0.02 (1.9)	1.5 ± 0.1 (2.2)	7.4 ± 0.5 (13.3)
	2	24	1.8 ± 0.02 (2.0)	0.9 ± 0 (1.3)	5.4 ± 0.2 (7.2)
	3	0	-	-	-
Branched Oak Lake	0	7	1.7 ± 0.02 (1.8)	3.4 ± 0.4 (5.0)	10.0 ± 1.2 (13.3)
	1	28	1.8 ± 0.03 (2.3)	2.9 ± 0.3 (5.9)	12.4 ± 1.1 (21.2)
	2	15	1.9 ± 0.03 (2.1)	1.1 ± 0.1 (1.9)	6.1 ± 0.5 (12.8)
	3	0	-	-	-
Conestoga Lake	0	20	1.7 ± 0.04 (2.2)	2.6 ± 0.1 (3.7)	7.9 ± 0.2 (10.7)
	1	11	1.8 ± 0.05 (2.0)	1.7 ± 0.1 (2.0)	6.1 ± 0.2 (8.0)
	2	19	2.0 ± 0.02 (2.1)	0.7 ± 0 (1.0)	5.9 ± 0.2 (7.7)
	3	0	-	-	-
Cottontail Lake	0	16	1.6 ± 0.02 (1.7)	1.4 ± 0.1 (1.8)	5.0 ± 0.2 (6.0)
	1	21	1.6 ± 0.02 (1.8)	1.0 ± 0.1 (2.0)	4.8 ± 0.2 (6.8)
	2	13	1.8 ± 0.03 (2.0)	1.0 ± 0.1 (1.5)	6.4 ± 0.3 (8.4)
	3	0	-	-	-

Table 4. Continued.

Reservoir	Age	N	Fulton's Condition Factor (K_{TL})	Hepatosomatic Index	Viscerosomatic Index
Holmes Lake	0	5	1.6 ± 0.07 (1.9)	3.3 ± 0.3 (4.1)	8.6 ± 0.6 (10.8)
	1	19	1.7 ± 0.02 (1.9)	1.5 ± 0.1 (2.8)	6.3 ± 0.4 (9.9)
	2	22	1.9 ± 0.03 (2.2)	1.1 ± 0.1 (1.6)	6.9 ± 0.4 (14.4)
	3	4	2.1 ± 0.04 (2.2)	0.8 ± 0.1 (0.9)	5.9 ± 0.2 (6.3)
Meadowlark Lake	0	6	1.6 ± 0.04 (1.7)	3.0 ± 0.2 (3.6)	10.40.9 (13.3)
	1	33	1.8 ± 0.02 (2.0)	1.8 ± 0.1 (3.2)	8.90.4 (13.8)
	2	11	1.9 ± 0.02 (2.0)	1.4 ± 0.1 (2.0)	7.10.2 (8.2)
	3	0	-	-	-
Merganser Lake	0	10	1.6 ± 0.04 (1.8)	7.0 ± 1.0 (14.7)	24.3 ± 4.3 (55.9)
	1	19	1.7 ± 0.04 (2.1)	5.8 ± 0.8 (14.6)	17.7 ± 2.7 (45.7)
	2	20	1.9 ± 0.02 (2.0)	2.3 ± 0.2 (4.7)	7.2 ± 0.3 (9.5)
	3	1	2.0 ± 0 (2.0)	2.7 ± 0 (2.7)	7.8 ± 0 (7.8)
Olive Creek Lake	0	7	1.6 ± 0.03 (1.7)	3.3 ± 0.4 (4.8)	9.1 ± 0.9 (11.5)
	1	23	1.6 ± 0.03 (1.8)	2.6 ± 0.1 (4.6)	11.6 ± 0.6 (17.9)
	2	19	1.9 ± 0.05 (2.2)	1.8 ± 0.1 (3.2)	9.4 ± 0.7 (18.3)
	3	1	1.9 ± 0 (1.9)	1.0 ± 0 (1.0)	5.3 ± 0 (5.3)

Table 4. Continued.

Reservoir	Age	N	Fulton's Condition Factor (K_{TL})	Hepatosomatic Index	Viscerosomatic Index
Pawnee Lake	0	4	1.8 ± 0.03 (1.8)	3.2 ± 0.4 (3.8)	8.5 ± 0.3 (9.0)
	1	23	1.9 ± 0.03 (2.2)	1.9 ± 0.1 (3.0)	9.4 ± 0.8 (16.7)
	2	23	2.1 ± 0.03 (2.4)	1.0 ± 0 (1.7)	6.4 ± 0.2 (9.4)
	3	0	-	-	-
Red Cedar Lake	0	0	-	-	-
	1	16	1.7 ± 0.03 (2.0)	1.2 ± 0.1 (2.1)	6.3 ± 0.6 (10.6)
	2	34	1.8 ± 0.02 (2.1)	0.8 ± 0 (1.6)	5.7 ± 0.3 (12.2)
	3	0	-	-	-
Stagecoach Lake	0	1	2.2 ± 0 (2.2)	0.4 ± 0 (0.4)	1.4 ± 0 (1.4)
	1	29	1.8 ± 0.02 (2.1)	1.0 ± 0.1 (1.8)	6.6 ± 0.3 (11.8)
	2	20	2.0 ± 0.04 (2.5)	0.8 ± 0.1 (1.3)	6.3 ± 0.2 (8.4)
	3	0	-	-	-
Timber Point Lake	0	0	-	-	-
	1	27	1.6 ± 0.03 (2.0)	2.8 ± 0.2 (4.5)	10.1 ± 0.5 (14.9)
	2	23	1.8 ± 0.03 (2.1)	1.3 ± 0.1 (2.7)	7.1 ± 0.4 (11.9)
	3	0	-	-	-

Table 4. Continued.

Reservoir	Age	N	Fulton's Condition Factor (K_{TL})	Hepatosomatic Index	Viscerosomatic Index
Wagon Train Lake	0	0	-	-	-
	1	33	1.8 ± 0.02 (2.2)	1.7 ± 0.1 (3.3)	8.0 ± 0.3 (11.1)
	2	17	2.0 ± 0.03 (2.2)	1.4 ± 0.1 (1.9)	7.7 ± 0.2 (9.1)
	3	0	-	-	-
Wildwood Lake	0	6	1.7 ± 0.07 (2.0)	2.6 ± 0.2 (3.5)	7.5 ± 0.8 (10.1)
	1	35	1.7 ± 0.02 (2.1)	2.2 ± 0.1 (5.0)	8.1 ± 0.5 (16.7)
	2	9	1.7 ± 0.04 (1.9)	2.2 ± 0.3 (4.0)	10.0 ± 2.3 (26.7)
	3	0	-	-	-
Yankee Hill Lake	0	1	1.3 ± 0 (1.3)	9.4 ± 0 (9.4)	21.9 ± 0 (21.9)
	1	22	1.8 ± 0.04 (2.1)	2.7 ± 0.7 (11.8)	11.9 ± 2.5 (47.1)
	2	26	2.0 ± 0.03 (2.4)	1.3 ± 0.1 (3.2)	8.1 ± 0.9 (23.7)
	3	1	1.9 ± 0 (1.9)	1.1 ± 0 (1.1)	6.5 ± 0 (6.5)

Table 5. Spearman correlation statistics with reservoir area (hectares) and angling effort (hours). Bold numbers indicate a significant association. Alpha (α) is 0.05.

	Statistics	Effort	Area
Area	r	**0.67857**	1
	P	**0.0054**	
	N	**15**	
Effort	r	1	**0.67857**
	P		**0.0054**
	N		**15**

Table 6. The full and reduced models of analysis of variance (ANOVA) for internal black spot intensity by angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**Internal Black Spot Intensity = Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	479.59	119.90	91.65	<0.0001	
Error	745	974.58	1.31			
Total	749	1454.17				
r^2 = 0.330						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.50	0.22	6.78	<0.0001	1.07	1.93
Effort	-6.53E-07	2.28E-06	-0.29	0.77	-5.12E-06	3.82E-06
Area	-2.13E-03	2.57E-04	-8.29	<0.0001	-2.64E-03	-1.63E-03
Age	1.34E+00	9.55E-02	14.01	<0.0001	1.15E+00	1.53E+00
Length (TL)	-0.01	2.87E-03	-4.69	<0.0001	-0.02	-0.01
Reduced Model	**Internal Black Spot Intensity = Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	3	479.48	159.83	122.33	<0.0001	
Error	746	974.69	1.31			
Total	749	1454.17				
r^2 = 0.330						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.50	0.22	6.78	<0.0001	1.07	1.93
Area	-2.16E-03	2.36E-04	-9.15	<0.0001	-2.62E-03	-1.70E-03
Age	1.34	0.10	14.12	<0.0001	1.15	1.53
Length (TL)	-0.01	2.83E-03	-4.81	<0.0001	-0.02	-0.01

Table 7. The full model of analysis of variance (ANOVA) for external black spot intensity by angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**External Black Spot Intensity = Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	198.60	49.65	87.01	<0.0001	
Error	745	425.09	0.57			
Total	749	623.69				
r2 = 0.318						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	0.58	0.15	3.98	<0.0001	0.30	0.87
Effort	-7.80E-06	1.50E-06	-5.19	<0.0001	-1.08E-05	-4.85E-06
Area	-9.89E-04	1.70E-04	-5.83	<0.0001	-1.32E-03	-6.56E-04
Age	0.79	0.06	12.58	<0.0001	0.67	0.92
Length (TL)	-0.01	1.89E-03	-3.48	0.0005	-0.01	-2.87E-03

Table 8. The full model of analysis of variance (ANOVA) for white grub intensity by angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed. Alpha (α) is 0.05.

Full Model	**White Grub Intensity = Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	748.28	187.07	123.86	<.0001	
Error	745	1125.23	1.51			
Total	749	1873.51				
r2 = 0.399						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	3.17	0.24	13.32	<0.0001	2.70	3.63
Effort	1.54E-05	2.45E-06	6.27	<0.0001	1.05E-05	2.02E-05
Area	-1.16E-03	2.76E-04	-4.22	<0.0001	-1.71E-03	-6.22E-04
Age	1.58	0.10	15.42	<0.0001	1.38	1.78
Length (TL)	-0.01	3.08E-03	-2.5	0.01	-0.01	-1.65E-03

Table 9. The full and reduced models of analysis of variance (ANOVA) for condition factor viscerosomatic indice (VSI) by internal black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**VSI = Internal Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	7.45	1.49	11.08	<0.0001	
Error	744	100.08	0.13			
Total	749	107.53				
r^2 = 0.069						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.23	0.07	30.48	<0.0001	2.08	2.37
Larval Trematode Intensity	0.06	0.01	5.29	<0.0001	0.04	0.09
Effort	-6.85E-07	7.30E-07	-0.94	0.35	-2.12E-06	7.48E-07
Area	3.43E-04	8.61E-05	3.99	<0.0001	1.74E-04	5.12E-04
Age	4.22E-02	3.44E-02	1.23	0.22	-2.54E-02	1.10E-01
Length (TL)	-2.56E-03	9.33E-04	-2.75	0.01	-4.40E-03	-7.33E-04
Reduced Model	**VSI = Internal Black Spot Intensity Area Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	3	7.10	2.37	17.59	<0.0001	
Error	746	100.43	0.13			
Total	749	107.53				
r^2 = 0.066						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.18	0.06	34.33	<0.0001	2.05	2.30
Larval Trematode Intensity	0.07	0.01	6.64	<0.0001	0.05	0.09
Area	3.34E-04	7.84E-05	4.26	<0.0001	1.80E-04	4.88E-04
Length (TL)	-1.81E-03	6.15E-04	-2.94	0.0033	-3.02E-03	-6.03E-04

Table 10. The full and reduced models of analysis of variance (ANOVA) for condition factor viscerosomatic indice (VSI) by external black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**VSI = External Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	4.64	0.93	6.71	<.0001	
Error	744	102.89	0.14			
Total	749	107.53				
r^2 = 0.043						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.29	0.07	31.55	<0.0001	2.15	2.44
Larval Trematode Intensity	0.05	0.02	2.63	0.0088	0.01	0.08
Effort	-3.56E-07	7.50E-07	-0.47	0.64	-1.84E-06	1.12E-06
Area	2.58E-04	8.54E-05	3.02	0.0026	9.00E-05	4.25E-04
Age	8.78E-02	3.42E-02	2.57	0.01	2.07E-02	1.55E-01
Length (TL)	-3.09E-03	9.40E-04	-3.29	0.0011	-4.93E-03	-1.24E-03
Reduced Model	**VSI = External Black Spot Intensity Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	4.61	1.15	8.34	<0.0001	
Error	745	102.92	0.14			
Total	749	107.53				
r^2 = 0.043						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.29	0.07	31.58	<0.0001	2.15	2.44
Larval Trematode Intensity	0.05	0.02	2.76	0.0059	0.01	0.08
Area	2.44E-04	8.03E-05	3.04	0.0025	8.64E-05	4.02E-04
Age	8.79E-02	3.42E-02	2.57	0.0103	2.08E-02	1.55E-01
Length (TL)	-3.15E-03	9.30E-04	-3.39	0.0007	-4.98E-03	-1.32E-03

Table 11. The full and reduced models of analysis of variance (ANOVA) for condition factor viscerosomatic indice (VSI) by white grub intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**VSI = White Grub Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	15.48	3.10	25.03	<.0001	
Error	744	92.05	0.12			
Total	749	107.53				
r^2 = 0.144						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.00	0.08	26.38	<0.0001	1.85	2.15
Larval Trematode Intensity	0.10	0.01	9.76	<0.0001	0.08	0.12
Effort	-2.30E-06	7.20E-07	-3.2	0.0014	-3.71E-06	-8.87E-07
Area	3.30E-04	8.00E-05	4.13	<0.0001	1.73E-04	4.87E-04
Age	-3.67E-02	3.37E-02	-1.09	0.28	-1.03E-01	2.96E-02
Length (TL)	-2.61E-03	8.86E-04	-2.95	0.0033	-4.35E-03	-8.74E-04
Reduced Model	**VSI = White Grub Intensity Effort Area Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	15.34	3.83	30.98	<.0001	
Error	745	92.20	0.12			
Total	749	107.53				
r^2 = 0.143						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	2.04	0.06	32.64	<0.0001	1.92	2.17
Larval Trematode Intensity	0.10	0.01	10.6	<0.0001	0.08	0.11
Effort	-2.15E-06	7.10E-07	-3.04	0.0024	-3.53E-06	-7.62E-07
Area	3.17E-04	7.90E-05	4.01	<0.0001	1.61E-04	4.72E-04
Length (TL)	-3.29E-03	6.28E-04	-5.24	<0.0001	-4.52E-03	-2.06E-03

Table 12. The full and reduced models of analysis of variance (ANOVA) for condition factor hepatosomatic indice (HSI) by internal black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**HSI = Internal Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	10.95	2.19	16.07	<0.0001	
Error	744	101.36	0.14			
Total	749	112.31				
r^2 = 0.097						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.22	0.07	16.52	<0.0001	1.07	1.36
Larval Trematode Intensity	0.07	0.01	6.27	<0.0001	0.05	0.10
Effort	-1.18E-06	7.30E-07	-1.61	0.11	-2.62E-06	2.62E-07
Area	3.14E-04	8.67E-05	3.62	0.0003	1.44E-04	4.84E-04
Age	3.55E-02	3.47E-02	1.02	0.31	-3.25E-02	1.04E-01
Length (TL)	-4.09E-03	9.39E-04	-4.36	<0.0001	-5.93E-03	-2.25E-03
Reduced Model	**HSI = Internal Black Spot Intensity Area Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	3	10.41	3.47	25.41	<0.0001	
Error	746	101.89	0.14			
Total	749	112.31				
r^2 = 0.093						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.17	0.06	18.3	<0.0001	1.05	1.30
Larval Trematode Intensity	0.08	0.01	7.67	<0.0001	0.06	0.10
Area	2.80E-04	7.89E-05	3.55	0.0004	1.25E-04	4.35E-04
Length (TL)	-3.54E-03	6.20E-04	-5.71	<0.0001	-4.75E-03	-2.32E-03

Table 13. The full and reduced models of analysis of variance (ANOVA) for condition factor hepatosomatic indice (HSI) by external black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**HSI = External Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	6.63	1.33	9.33	<.0001	
Error	744	105.68	0.14			
Total	749	112.31				
r^2 = 0.059						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.30	0.07	17.61	<0.0001	1.15	1.44
Larval Trematode Intensity	0.05	0.02	2.71	0.0069	0.01	0.09
Effort	-8.42E-07	7.60E-07	-1.1	0.27	-2.34E-06	6.57E-07
Area	2.05E-04	8.66E-05	2.36	0.0183	3.47E-05	3.75E-04
Age	9.55E-02	3.47E-02	2.75	0.01	2.74E-02	1.64E-01
Length (TL)	-4.76E-03	9.53E-04	-5	<0.0001	-6.63E-03	-2.89E-03
Reduced Model	**HSI = External Black Spot Intensity Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	6.46	1.61	11.36	<0.0001	
Error	745	105.85	0.14			
Total	749	112.31				
r^2 = 0.057						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.29	0.07	17.58	<0.0001	1.15	1.44
Larval Trematode Intensity	0.05	0.02	2.97	0.0031	0.02	0.09
Area	1.72E-04	8.15E-05	2.12	0.0347	1.24E-05	3.32E-04
Age	9.58E-02	3.47E-02	2.76	0.0058	2.78E-02	1.64E-01
Length (TL)	-4.91E-03	9.44E-04	-5.2	<0.0001	-6.76E-03	-3.06E-03

Table 14. The full and reduced models of analysis of variance (ANOVA) for condition factor hepatosomatic indice (HSI) by white grub intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**HSI = White Grub Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	19.27	3.85	30.82	<0.0001	
Error	744	93.04	0.13			
Total	749	112.31				
r^2 = 0.172						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	0.98	0.08	12.84	<0.0001	0.83	1.13
Larval Trematode Intensity	0.11	0.01	10.46	<0.0001	0.09	0.13
Effort	-2.92E-06	7.20E-07	-4.04	<0.0001	-4.34E-06	-1.50E-06
Area	2.84E-04	8.04E-05	3.53	0.0004	1.26E-04	4.42E-04
Age	-3.98E-02	3.39E-02	-1.17	0.24	-1.06E-01	2.68E-02
Length (TL)	-4.24E-03	8.90E-04	-4.76	<0.0001	-5.99E-03	-2.49E-03
Reduced Model	**HSI = White Grub Intensity Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	4	19.10	4.77	38.16	<0.0001	
Error	745	93.21	0.13			
Total	749	112.31				
r^2 = 0.170						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	1.03	0.06	16.32	<0.0001	0.90	1.15
Larval Trematode Intensity	0.10	0.01	11.35	<0.0001	0.09	0.12
Effort	-2.76E-06	7.10E-07	-3.89	0.0001	-4.15E-06	-1.37E-06
Area	2.69E-04	7.94E-05	3.39	0.0007	1.13E-04	4.25E-04
Length (TL)	-4.98E-03	6.31E-04	-7.88	<0.0001	-6.22E-03	-3.74E-03

Table 15. The full model of analysis of variance (ANOVA) for Fulton's condition factor (K_{TL}) by internal black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

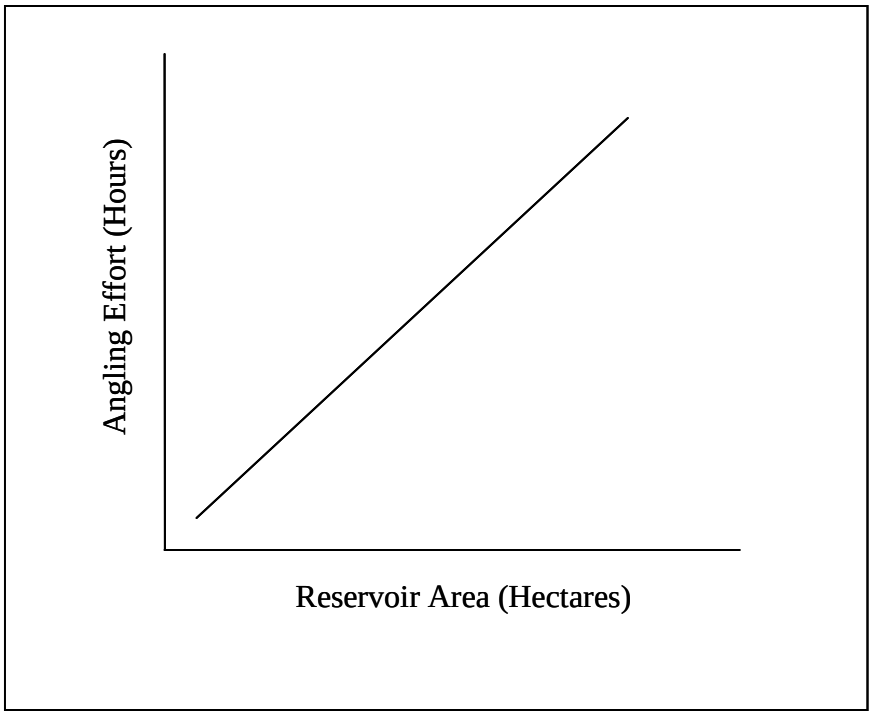
Full Model	**K = Internal Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	2.06	0.41	317.70	<0.0001	
Error	744	0.97	0.00			
Total	749	3.03				
r^2 = 0.681						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	0.88	0.01	121.86	<0.0001	0.86	0.89
Larval Trematode Intensity	0.01	1.15E-03	5.11	<0.0001	3.64E-03	0.01
Effort	4.51E-07	7.00E-08	6.28	<0.0001	3.10E-07	5.92E-07
Area	6.86E-05	8.47E-06	8.11	<0.0001	5.20E-05	8.52E-05
Age	5.46E-02	3.38E-03	16.14	<0.0001	4.80E-02	6.13E-02
Length (TL)	4.85E-04	9.17E-05	5.29	<0.0001	3.05E-04	6.65E-04

Table 16. The full model of analysis of variance (ANOVA) for Fulton's condition factor (K_{TL}) by external black spot intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**K = External Black Spot Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	2.09	0.42	327.69	<0.0001	
Error	744	0.95	0.00			
Total	749	3.03				
r^2 = 0.688						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	0.88	0.01	125.9	<0.0001	0.86	0.89
Larval Trematode Intensity	0.01	1.73E-03	6.53	<0.0001	7.90E-03	0.01
Effort	5.35E-07	7.00E-08	7.41	<0.0001	3.93E-07	6.77E-07
Area	6.72E-05	8.19E-06	8.2	<0.0001	5.11E-05	8.33E-05
Age	5.36E-02	3.28E-03	16.33	<0.0001	4.71E-02	6.00E-02
Length (TL)	4.80E-04	9.02E-05	5.33	<0.0001	3.03E-04	6.57E-04

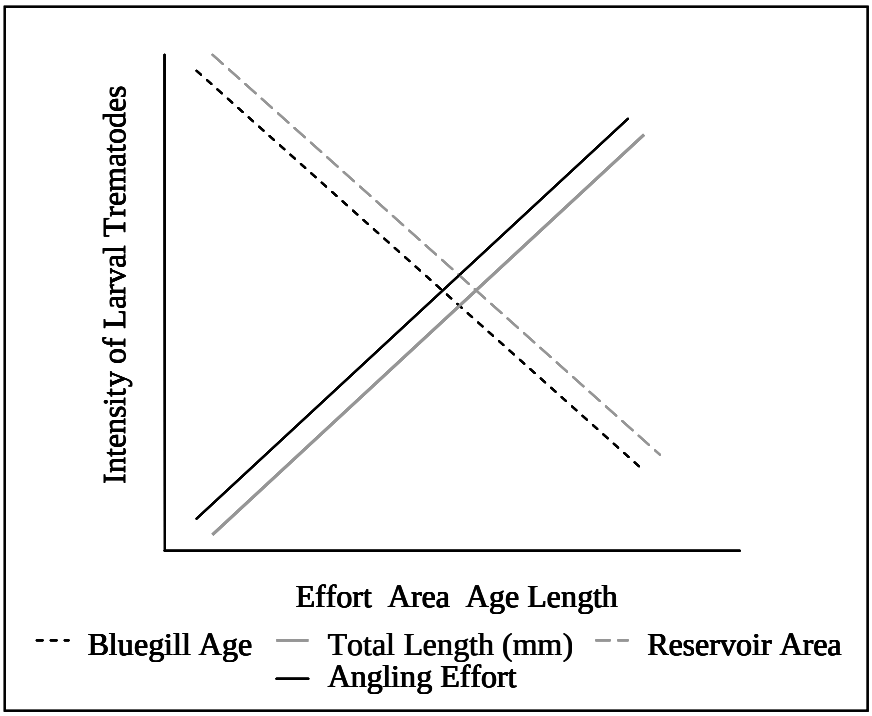
Table 17. The full model of analysis of variance (ANOVA) for Fulton's condition factor (K_{TL}) white grub intensity, angling effort (hours), surface area (hectares), bluegill age, and total length (mm) for 15 Salt Valley reservoirs surveyed (N = 750). Alpha (α) is 0.05.

Full Model	**K = White Grub Intensity Effort Area Age Length**					
ANOVA	df	SS	MS	F	Significance F	
Model	5	2.10	0.42	332.96	<0.0001	
Error	744	0.94	0.00			
Total	749	3.03				
r^2 = 0.691						
	Estimate	SE	t Value	P	Lower 95%	Upper 95%
Intercept	0.86	0.01	112.69	<0.0001	0.85	0.88
Larval Trematode Intensity	0.01	1.06E-03	7.16	<0.0001	5.50E-03	0.01
Effort	3.31E-07	7.00E-08	4.57	<0.0001	1.89E-07	4.73E-07
Area	6.48E-05	8.06E-06	8.04	<0.0001	4.90E-05	8.07E-05
Age	5.05E-02	3.40E-03	14.85	<0.0001	4.39E-02	5.72E-02
Length (TL)	4.64E-04	8.93E-05	5.2	<0.0001	2.89E-04	6.40E-04



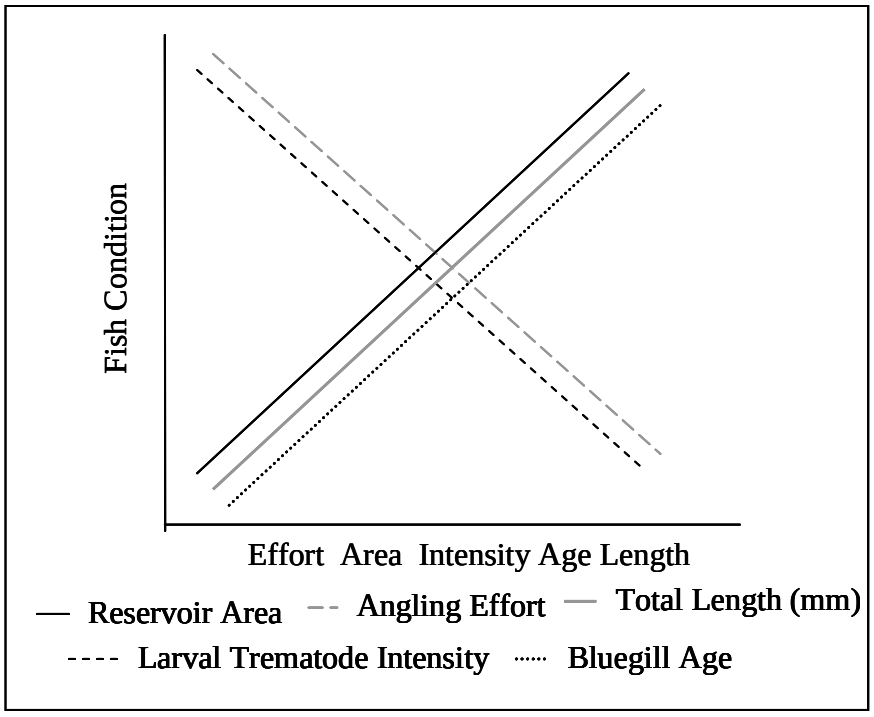
Hypothesis 1: Reservoir area (hectares) increases, angling effort (hours) should positively increase.

Figure 1. A conceptual model illustrating the research hypothesis that represents the theoretical cause and effect between the size of a reservoir area and the amount of angling effort present at that reservoir.



Hypothesis 2: Angling effort (hours) and total length (mm) would have a positive effect on larval trematode (black spot, white grub, and yellow grub) intensities in small bluegill. Bluegill age and reservoir area (hectares) would have a negative effect on larval trematode intensities in small bluegill.

Figure 2. A conceptual model illustrating the research hypothesis that represents the theoretical cause and effect relationship that could occur between the area of a reservoir, the amount of angling effort, bluegill age, and total length (mm) affect the intensity of larval trematodes in small bluegill.



Hypothesis 3: Reservoir area (hectares), total length (mm), and bluegill age would have a positive effect on larval trematode (black spot, white grub, and yellow grub) intensities in small bluegill. Angling effort (hours) and prevalence of larval trematodes per a reservoir would have a negative effect on condition of small bluegill.

Figure 3. A conceptual model illustrating the research hypothesis that represents the theoretical cause and effect relationship that could occur between the area of a reservoir, the amount of angling effort, total length (mm), age, and larval trematode intensity per bluegill affect the condition of small bluegill.

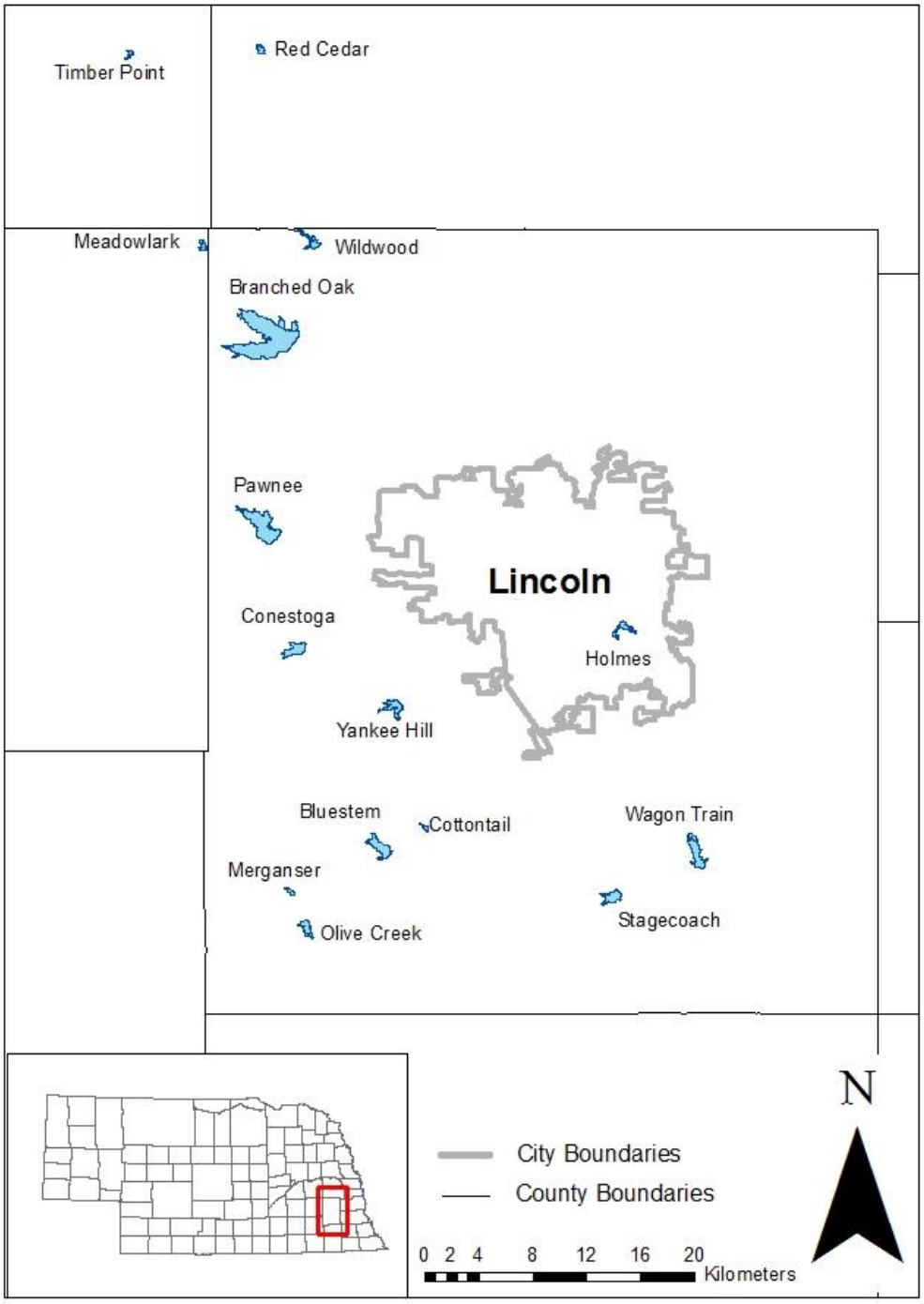


Figure 4. Map of Salt Valley watershed showing the 15 reservoirs selected as study areas for sampling bluegill and angling effort.

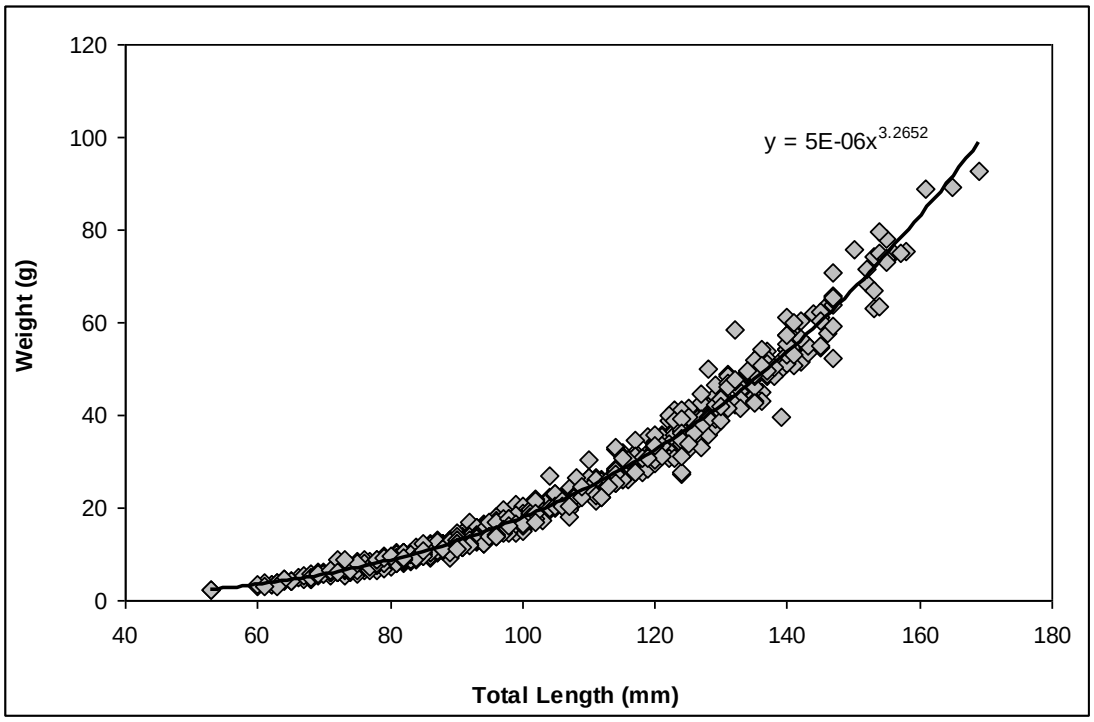


Figure 5. Plot indicating total length (mm) versus weight (g) of the 750 bluegill collected from the 15 Salt Valley reservoirs in October 2010.

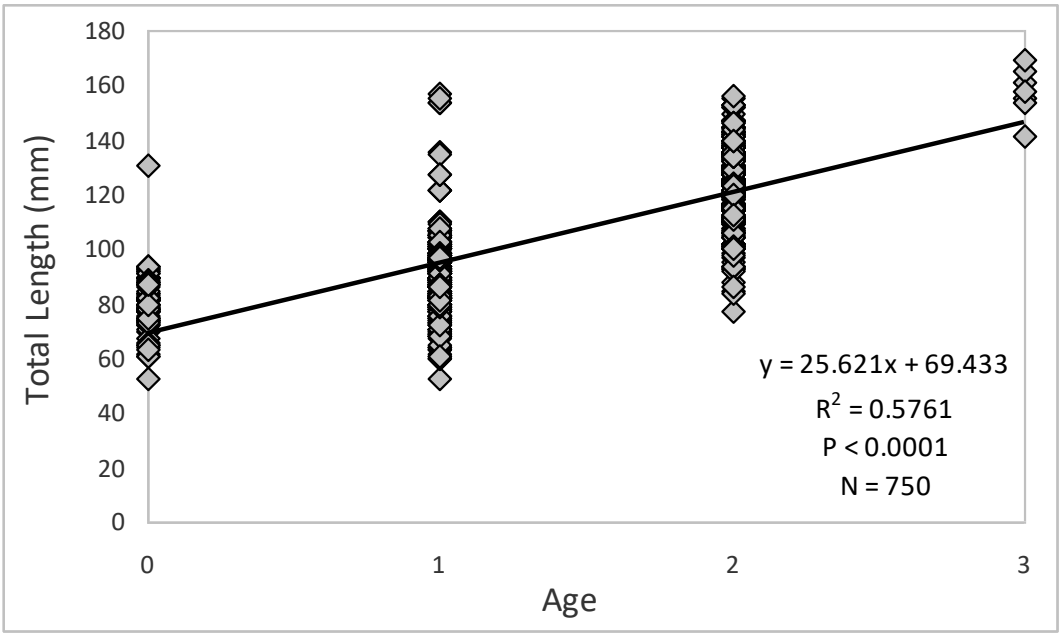


Figure 6. Plot indicating bluegill age versus total length (mm) of the 750 bluegill collected from the 15 Salt Valley reservoirs in October 2010.

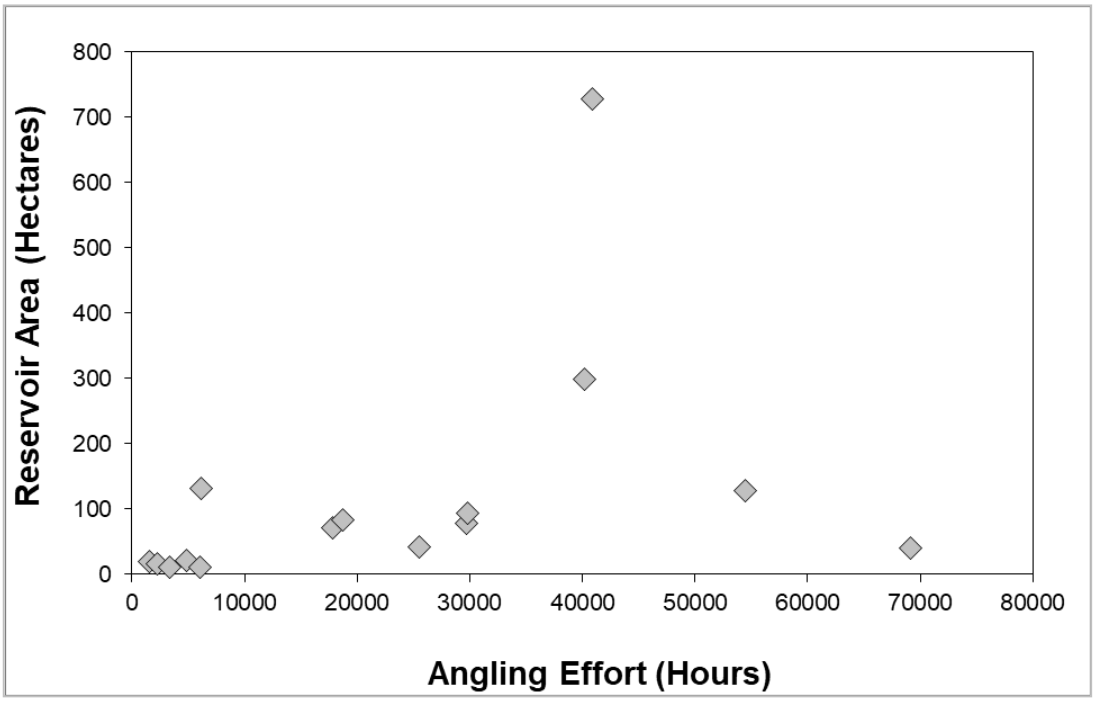


Figure 7. Plot indicating reservoir area (hectares) of the 15 Salt Valley reservoirs versus the calculated angling effort (hours) collected from April to October, 2010.

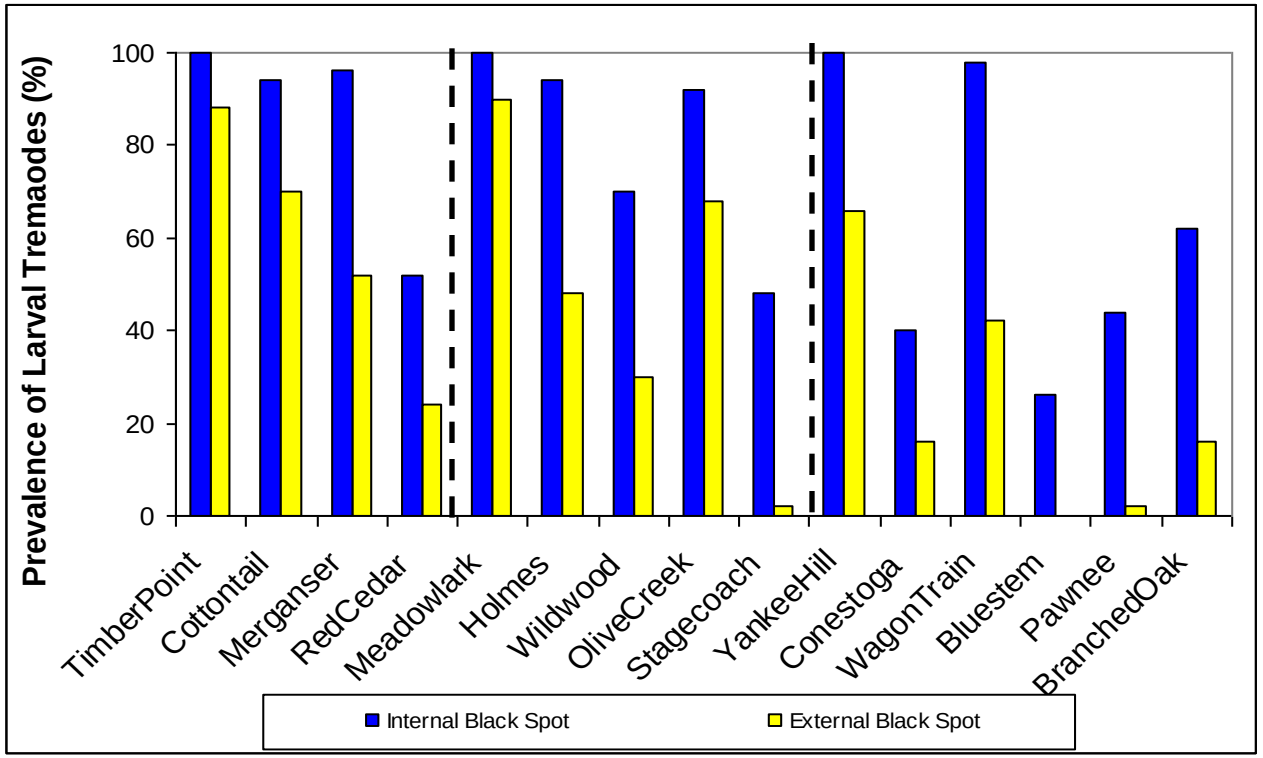


Figure 8. Prevalence of internal black spot (blue bars) and external black spot (yellow bars) of the 750 bluegill sampled from the 15 Salt Valley reservoirs arranged by size (hectares), smallest to largest. Black dashed lines indicate trends in prevalence estimates. No pattern observed with white grub prevalence estimates.

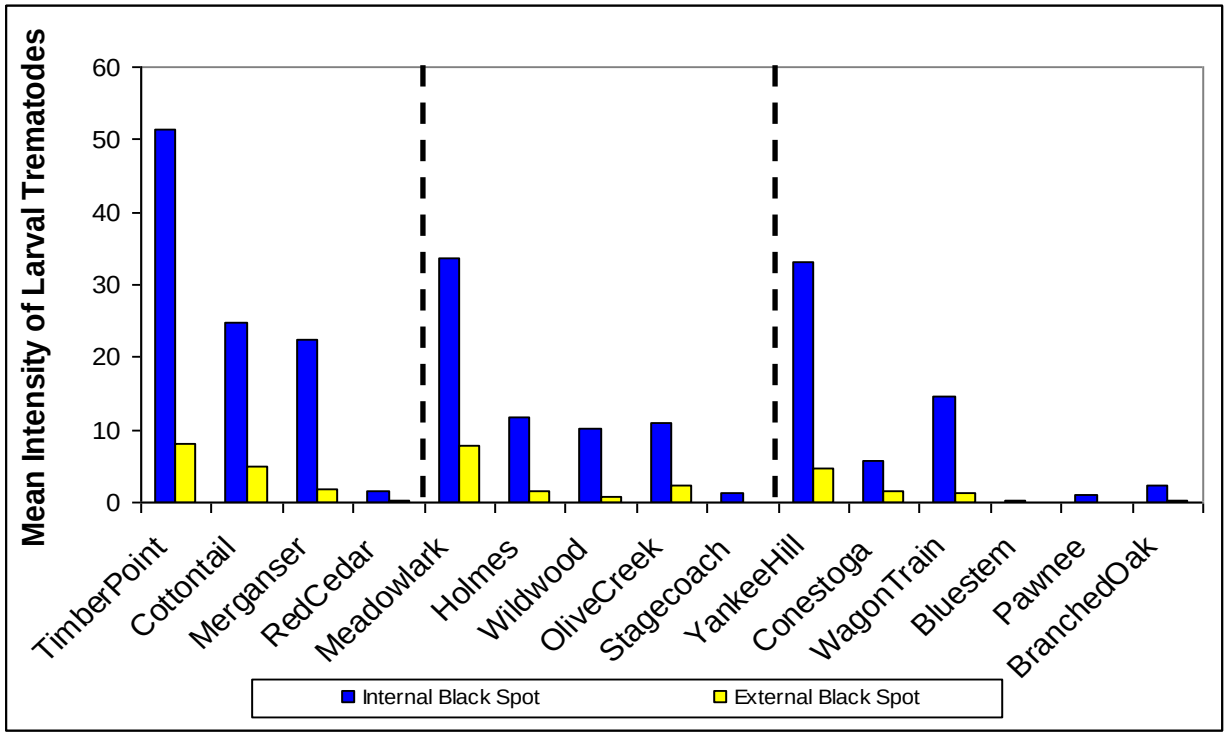


Figure 9. Intensity means for internal black spot (blue bars) and external black spot (yellow bars) of the 750 bluegill sampled from the 15 Salt Valley Reservoirs arranged by size (hectares), smallest to largest. Black dashed lines indicate trends in intensity mean estimates. No pattern observed with white grub intensity mean estimates.

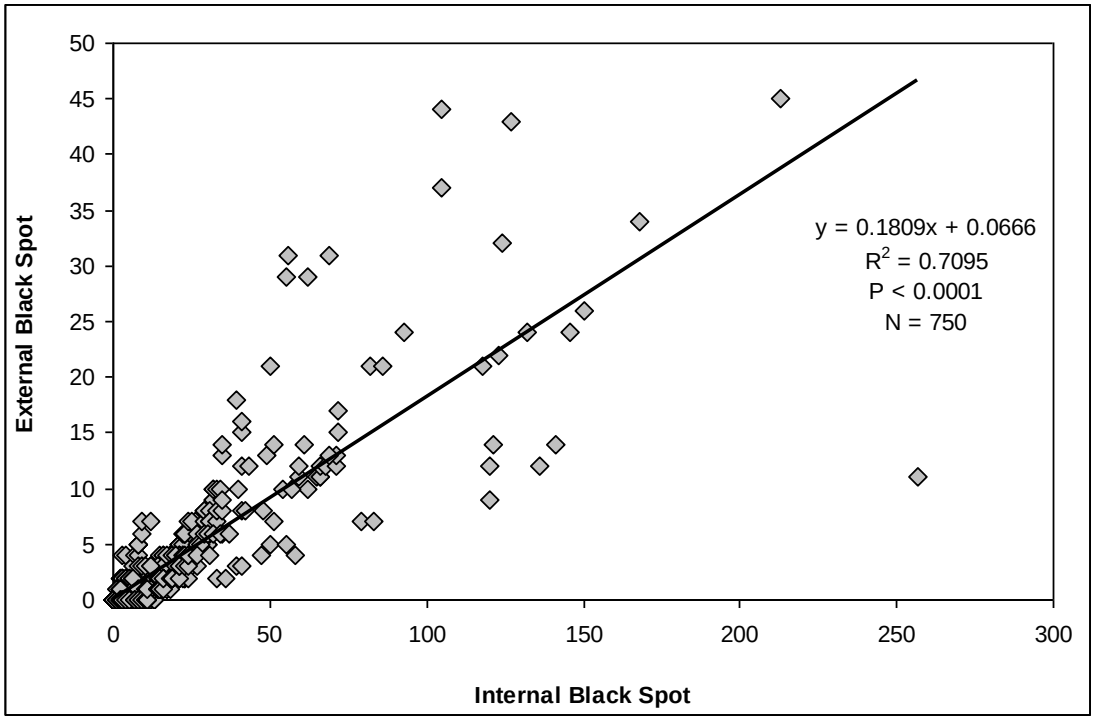


Figure 10. Plot indicating the relationship between internal black spot and external black spot.

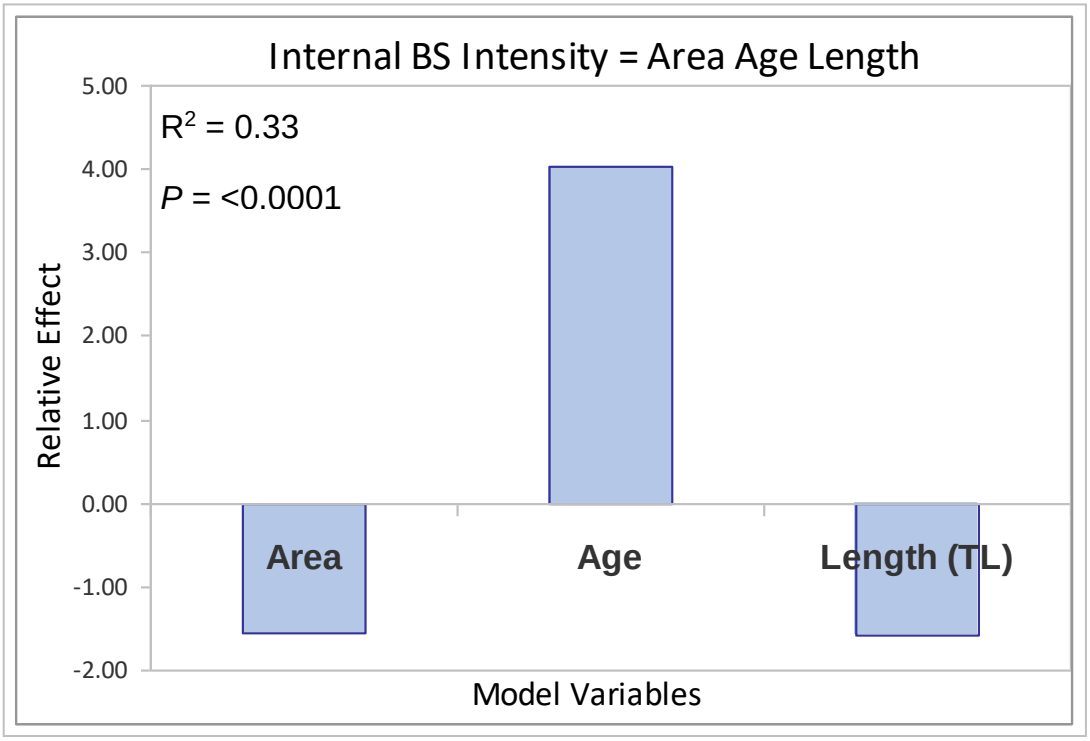


Figure 11. The reduced analysis of variance (ANOVA) model for the intensity of internal black spot and the model variables, reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect of each model variable was adjusted for visual comparison.

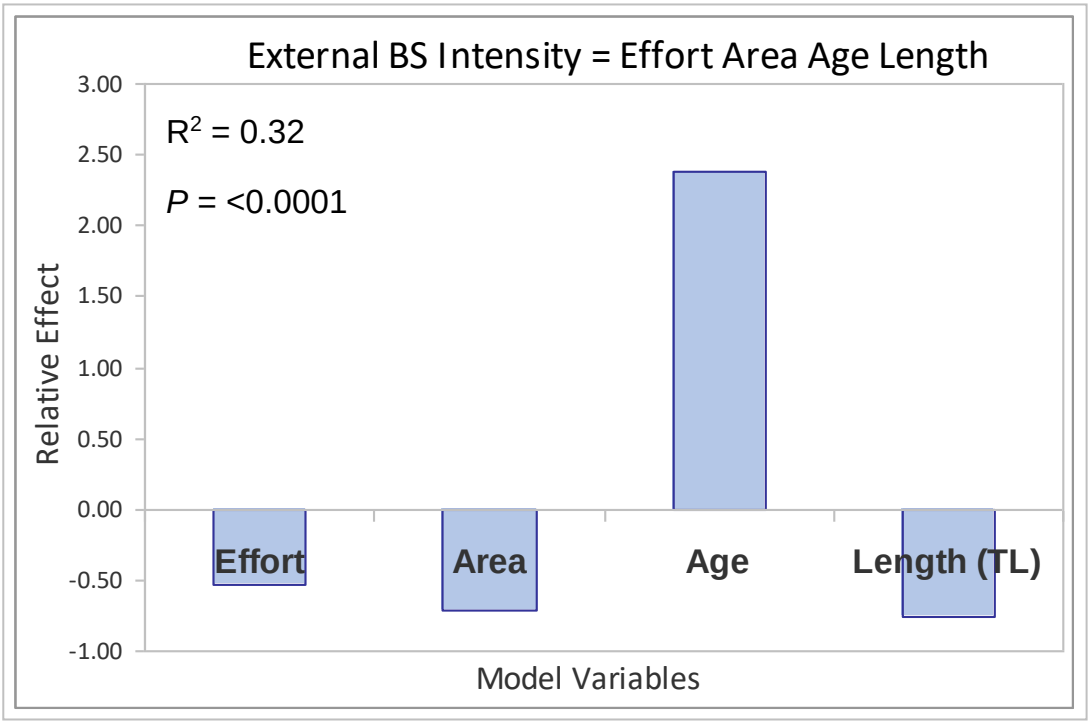


Figure 12. The full analysis of variance (ANOVA) model for the intensity of external black spot and the model variables, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect for each model variable was adjusted for visual comparison.

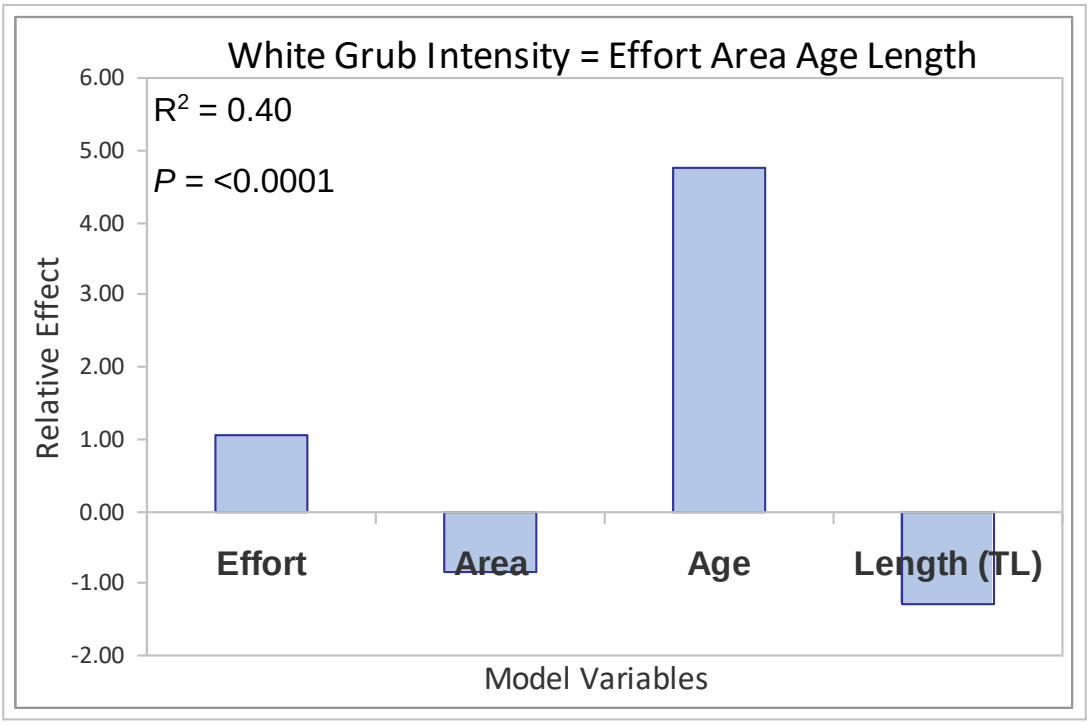


Figure 13. The full analysis of variance (ANOVA) model for the intensity of white grub and the model variables, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect for each model variable was adjusted for visual comparison.

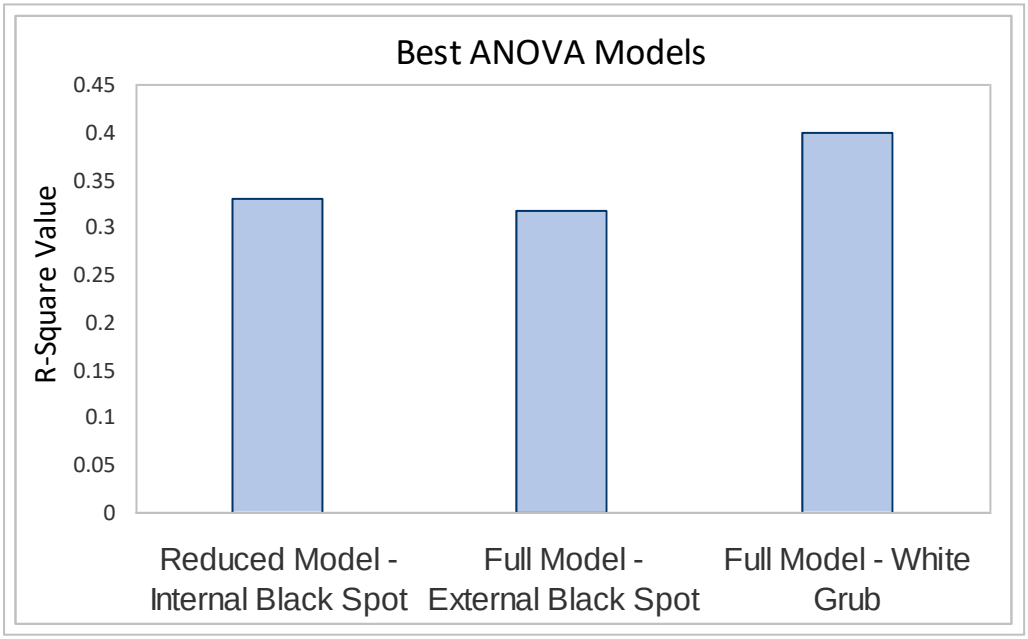


Figure 14. The r-squares from the best ANOVA models (reduced and full models) for each larval trematode, black spot (internal and external) and white grub. Statistical significance was set at $\alpha = 0.05$ for each model.

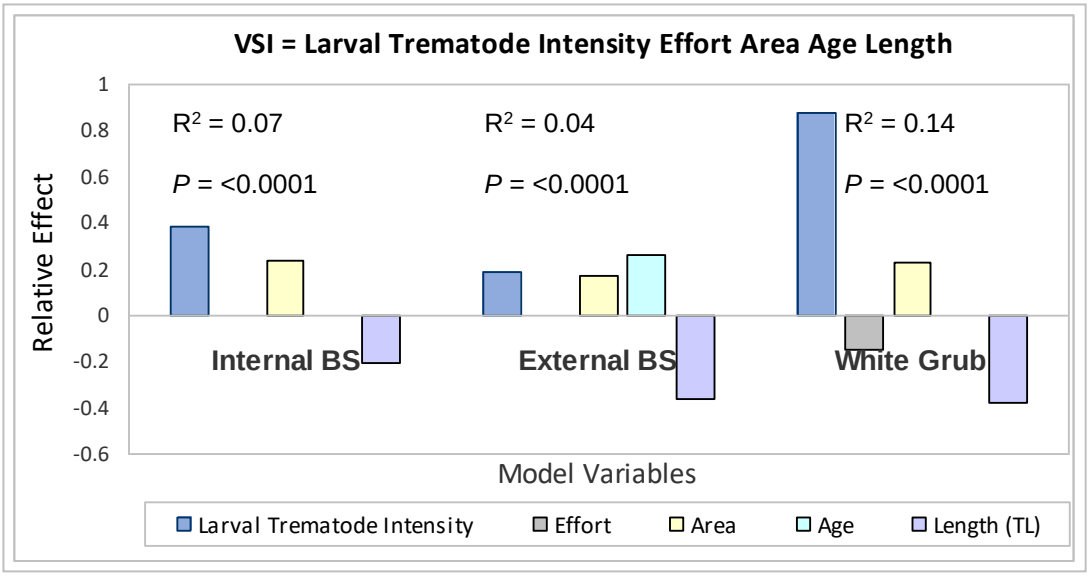


Figure 15. The reduced ANOVA models for the condition factor, viscerosomatic indice (VSI), for each larval trematode (internal black spot, internal black spot, and white grub) with the model variables, larval trematode intensity, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect for each model variable was adjusted for visual comparison. Statistical significance was set at $\alpha = 0.05$.

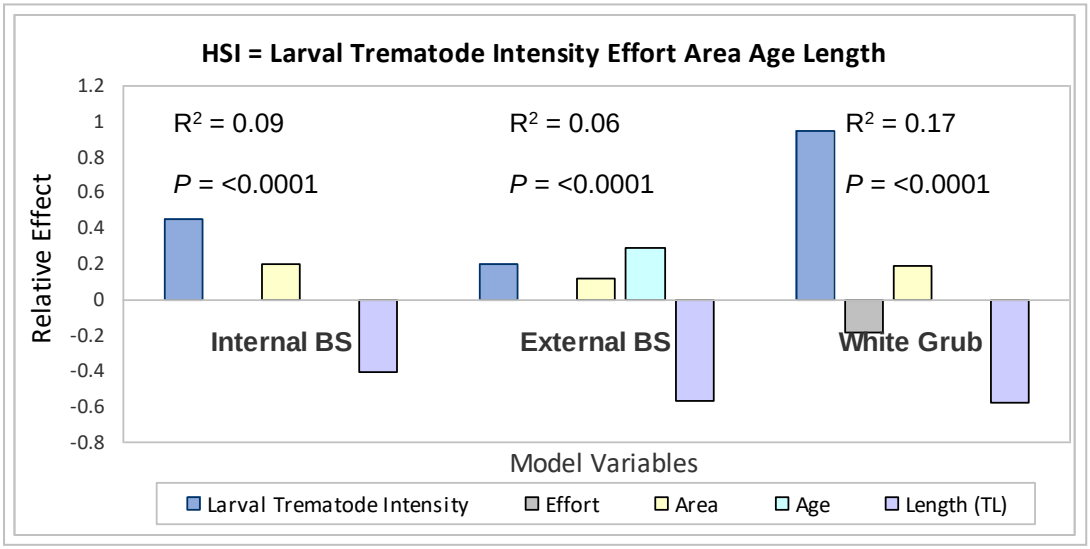


Figure 16. The reduced ANOVA models for the condition factor, hepatosomatic indice (HSI), for each larval trematode (internal black spot, internal black spot, and white grub) with the model variables, larval trematode intensity, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect for each model variable was adjusted for visual comparison. Statistical significance was set at $\alpha = 0.05$.

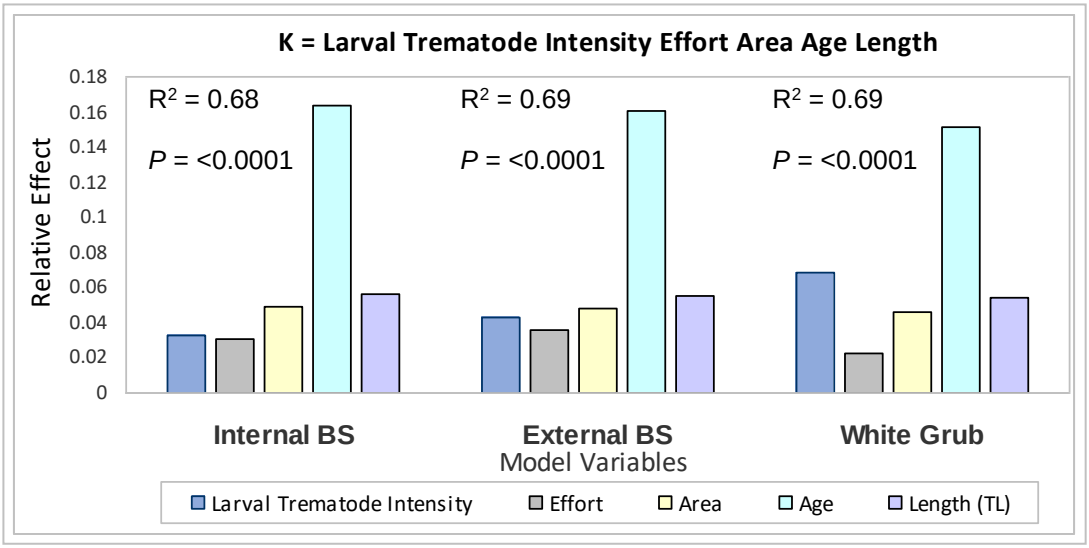


Figure 17. The full ANOVA models for the condition factor, Fulton's condition (K_{TL}), for each larval trematode (internal black spot, internal black spot, and white grub) with the model variables, larval trematode intensity, angling effort (hours), reservoir area (hectares), bluegill age, and total length (mm) (N = 750). The relative effect for each model variable was adjusted for visual comparison. Statistical significance was set at $\alpha = 0.05$.

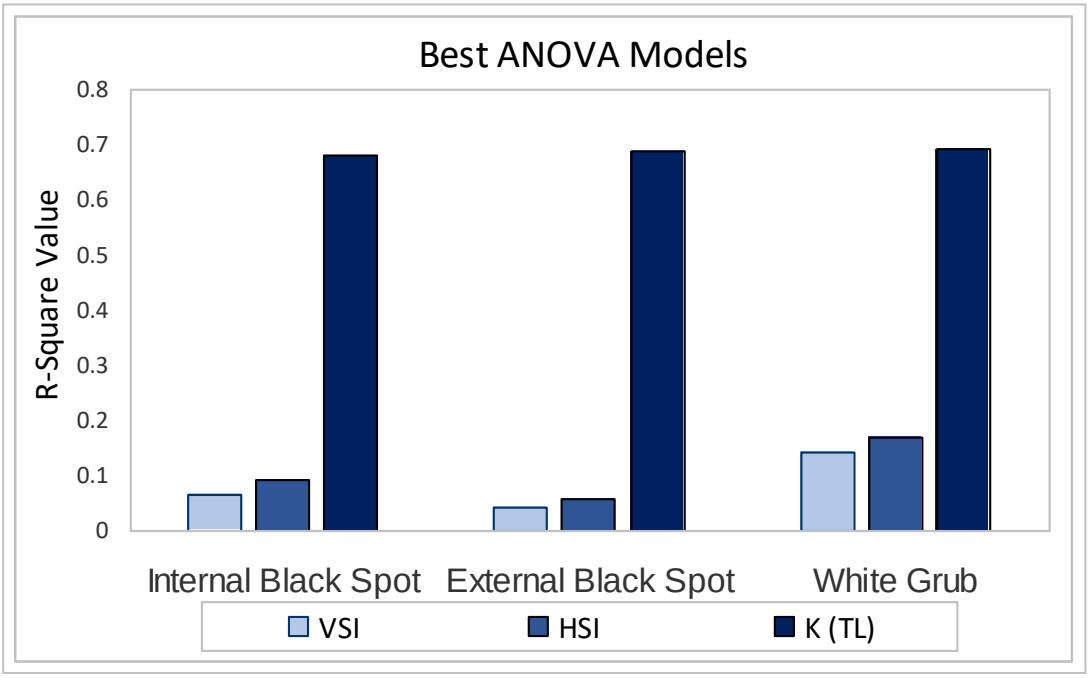


Figure 18. The r-squares from the best ANOVA models (reduced and full models) for each condition factor, viscerosomatic indice (VSI), hepatosomatic indice (HSI), and Fulton's condition (K_{TL}), for each larval trematode, internal black spot, external black spot, and white grub. Statistical significance was set at $\alpha = 0.05$ for each model.

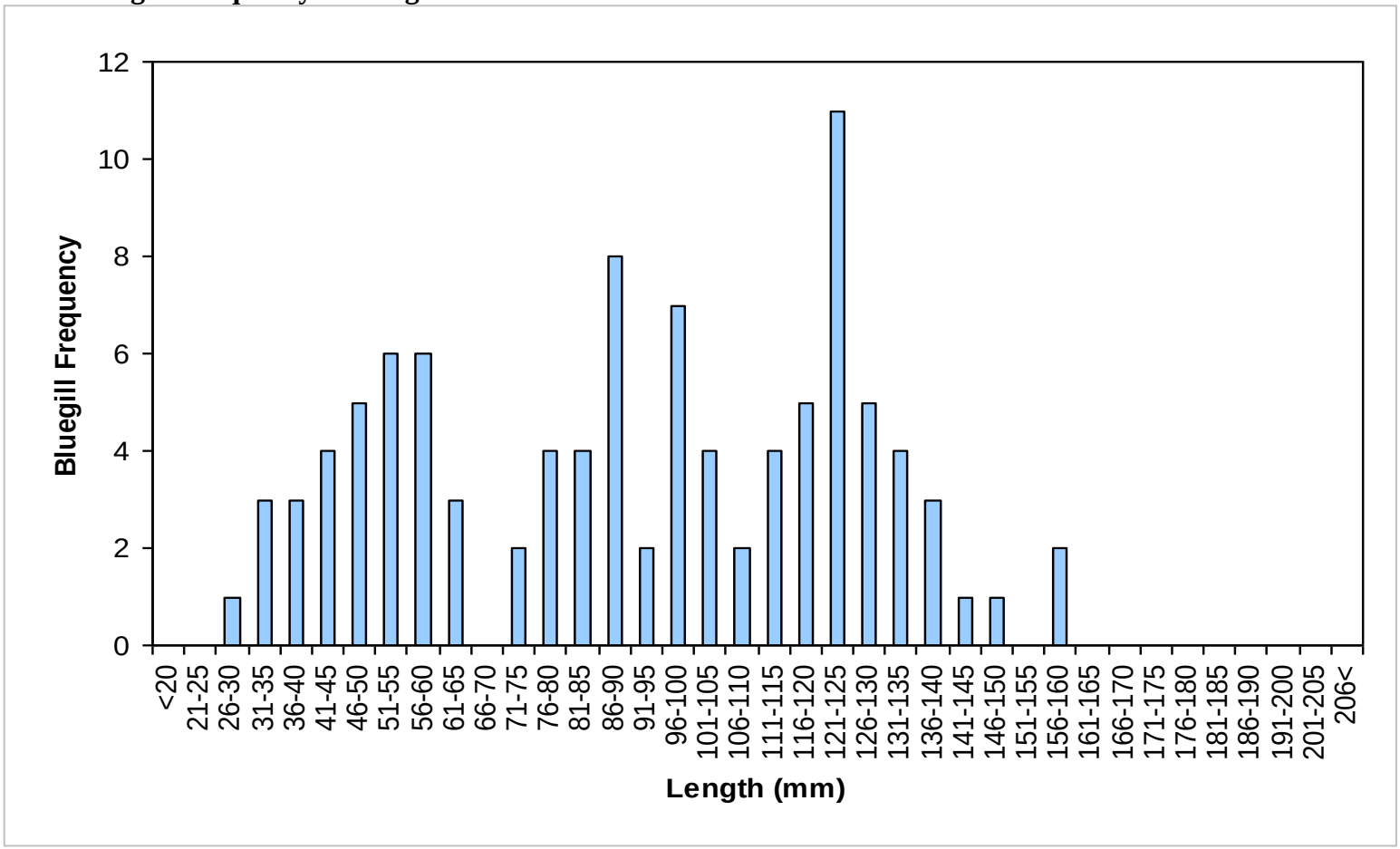
Appendix A. Water quality data collected at each Salt Valley Reservoir.

Reservoir	Date	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (mmohl/L)	Turbidity (NTU)	pH
Bluestem Lake	10/5/2010	16.1	13.26	353	26	7.66
Branched Oak Lake	10/4/2010	17.86	10.46	380	12.1	8.818
Conestoga Lake	10/4/2010	17.89	11.01	441	18.8	8.32
Cottontail Lake	10/5/2010	16	9.8	303	29.5	7.66
Holmes Lake	10/6/2010	16.39	8.69	338	3.36	7.69
Meadowlark Lake	10/1/2010	20.2	11.31	366	15.1	6.76
Merganser Lake	10/5/2010	16.48	10.51	157	15.6	7.32
Olive Creek Lake	10/5/2010	16.95	8.21	266	6.29	7.55
Pawnee Lake	10/4/2010	17.68	12.37	354	17.1	8.310
Red Cedar Lake	10/1/2010	18.88	10.25	242	23.6	7.19
Stagecoach Lake	10/5/2010	17.32	10.83	394	10.9	7.21
Timber Point Lake	10/1/2010	19.56	11.91	440	9.55	6.52
Wagon Train Lake	10/6/2010	17.13	9.56	346	7.78	7.25
Wildwood Lake	10/1/2010	19.36	7.41	307	10.87	7.63
Yankee Hill Lake	10/4/2010	17.43	8.52	411	15.2	7.4

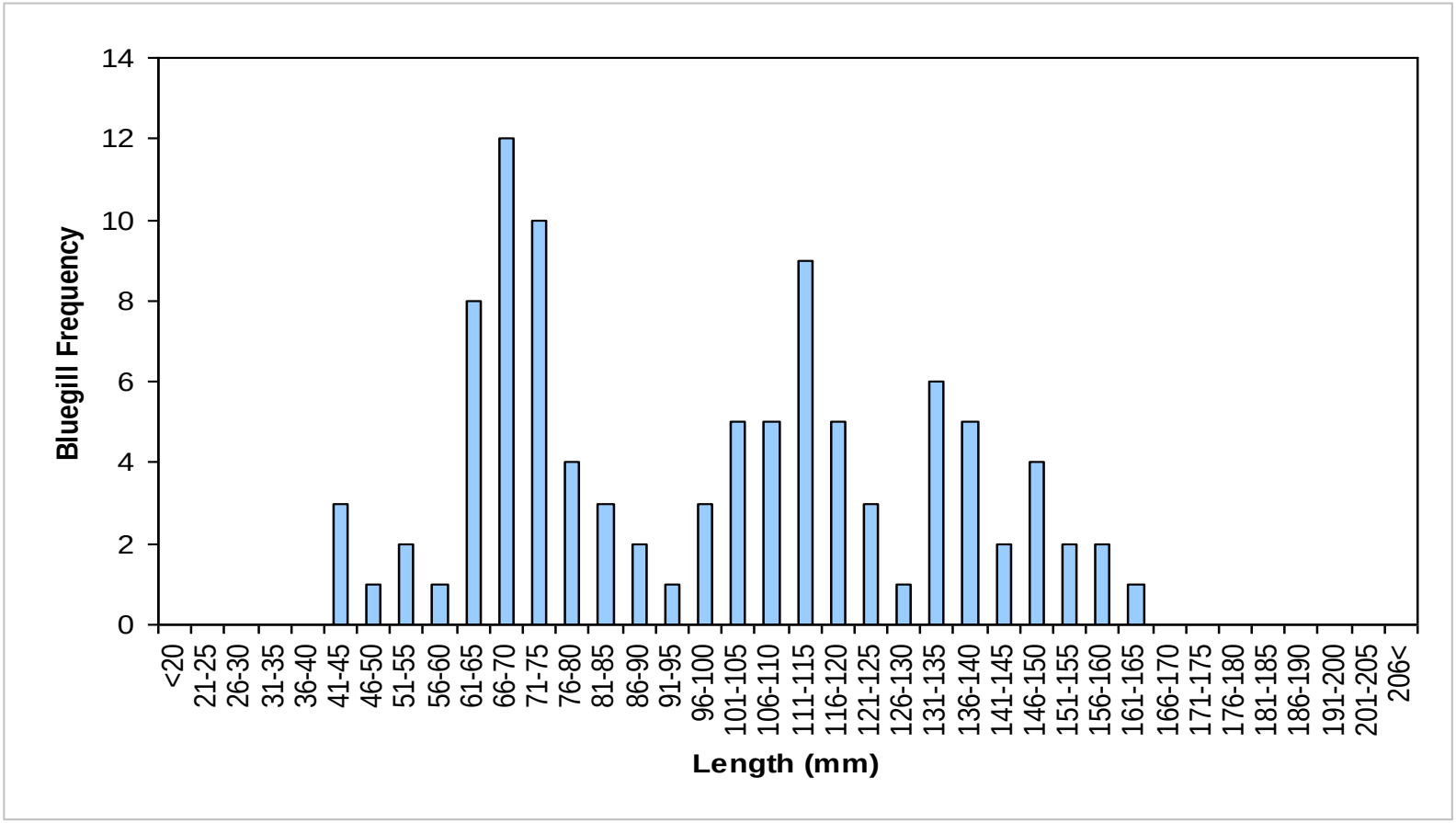
Appendix B. Fish collection times using standard boat-mounted electrofishing equipment.

Reservoir	Date	Electrofishing Start Time	Electrofishing Stop Time	Hours : Minutes
Bluestem Lake	10/5/2010	8:35	9:25	0:50
Branched Oak Lake	10/4/2010	8:25	9:05	0:40
Conestoga Lake	10/4/2010	12:55	13:50	0:55
Cottontail Lake	10/5/2010	10:15	10:45	0:30
Holmes Lake	10/6/2010	8:23	9:30	1:07
Meadowlark Lake	10/1/2010	14:27	14:50	0:23
Merganser Lake	10/5/2010	11:40	12:15	0:35
Olive Creek Lake	10/5/2010	12:57	13:17	0:20
Pawnee Lake	10/4/2010	10:10	11:35	1:25
Red Cedar Lake	10/1/2010	10:42	12:00	1:18
Stagecoach Lake	10/5/2010	14:20	15:55	1:35
Timber Point Lake	10/1/2010	12:56	13:28	0:32
Wagon Train Lake	10/6/2010	10:40	11:20	0:40
Wildwood Lake	10/1/2010	8:31	9:46	1:15
Yankee Hill Lake	10/4/2010	12:36	15:30	2:54

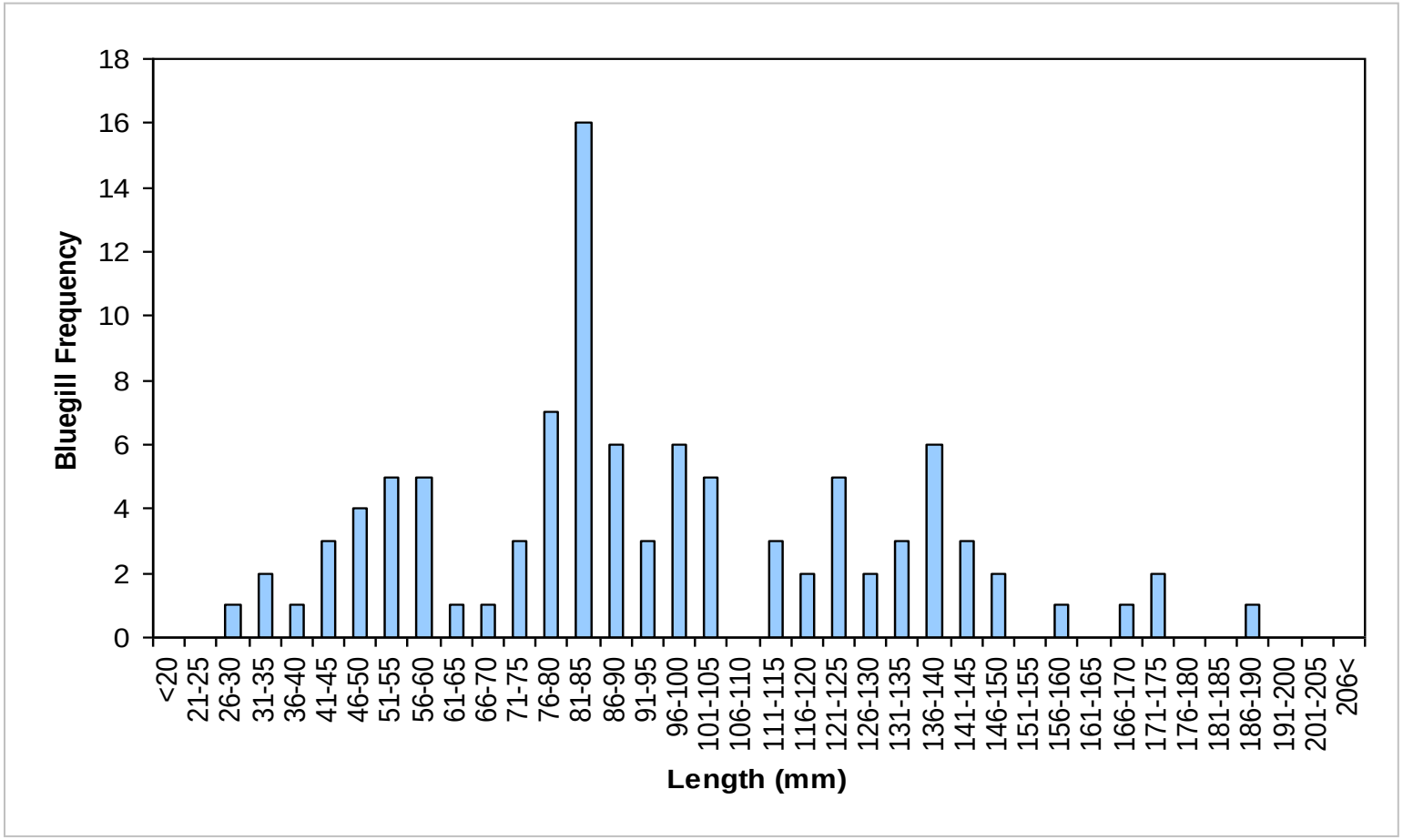
Appendix C. Lengths frequency of bluegill selected in Bluestem Lake.



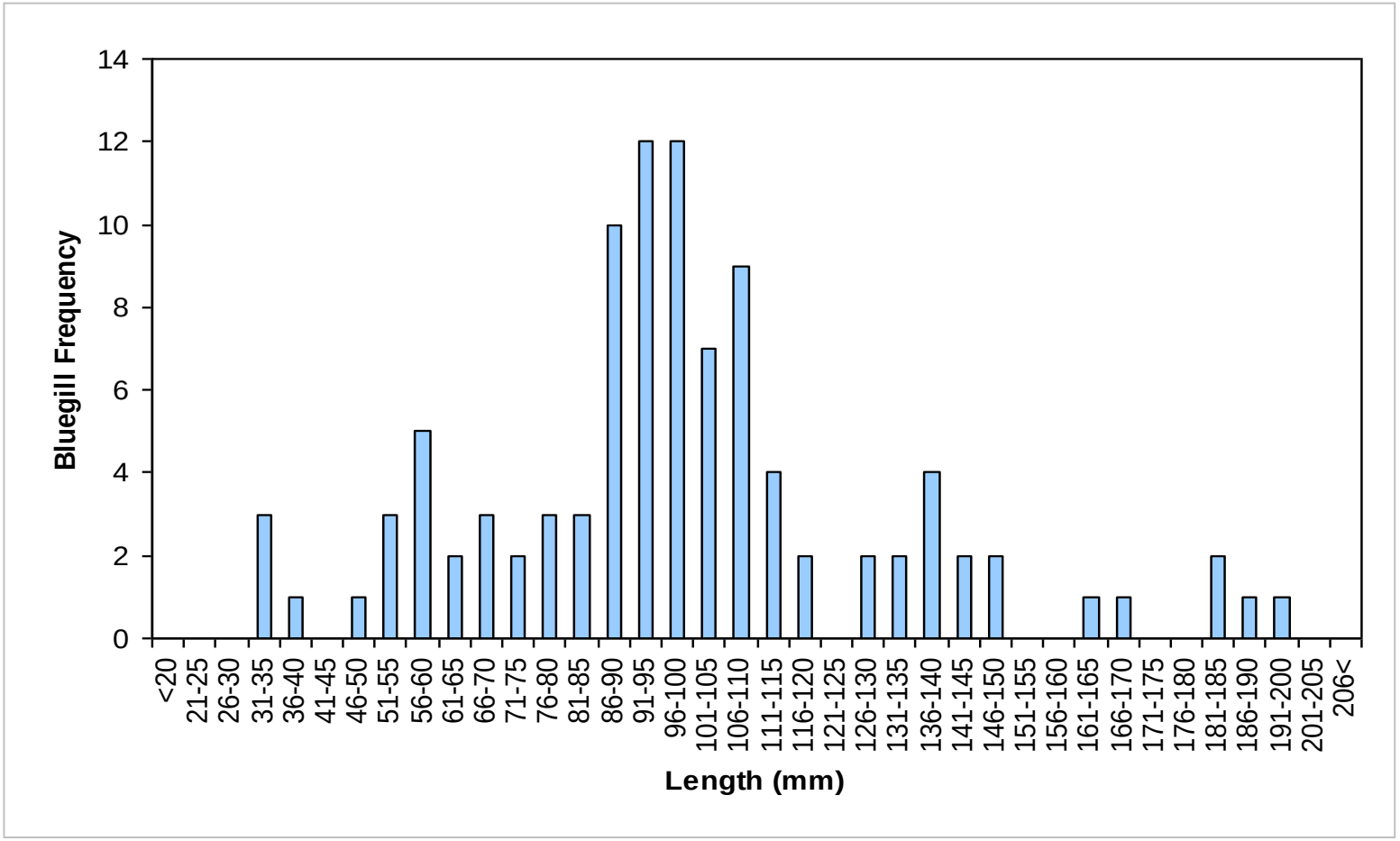
Appendix D. Lengths frequency of bluegill selected in Branched Oak Lake.



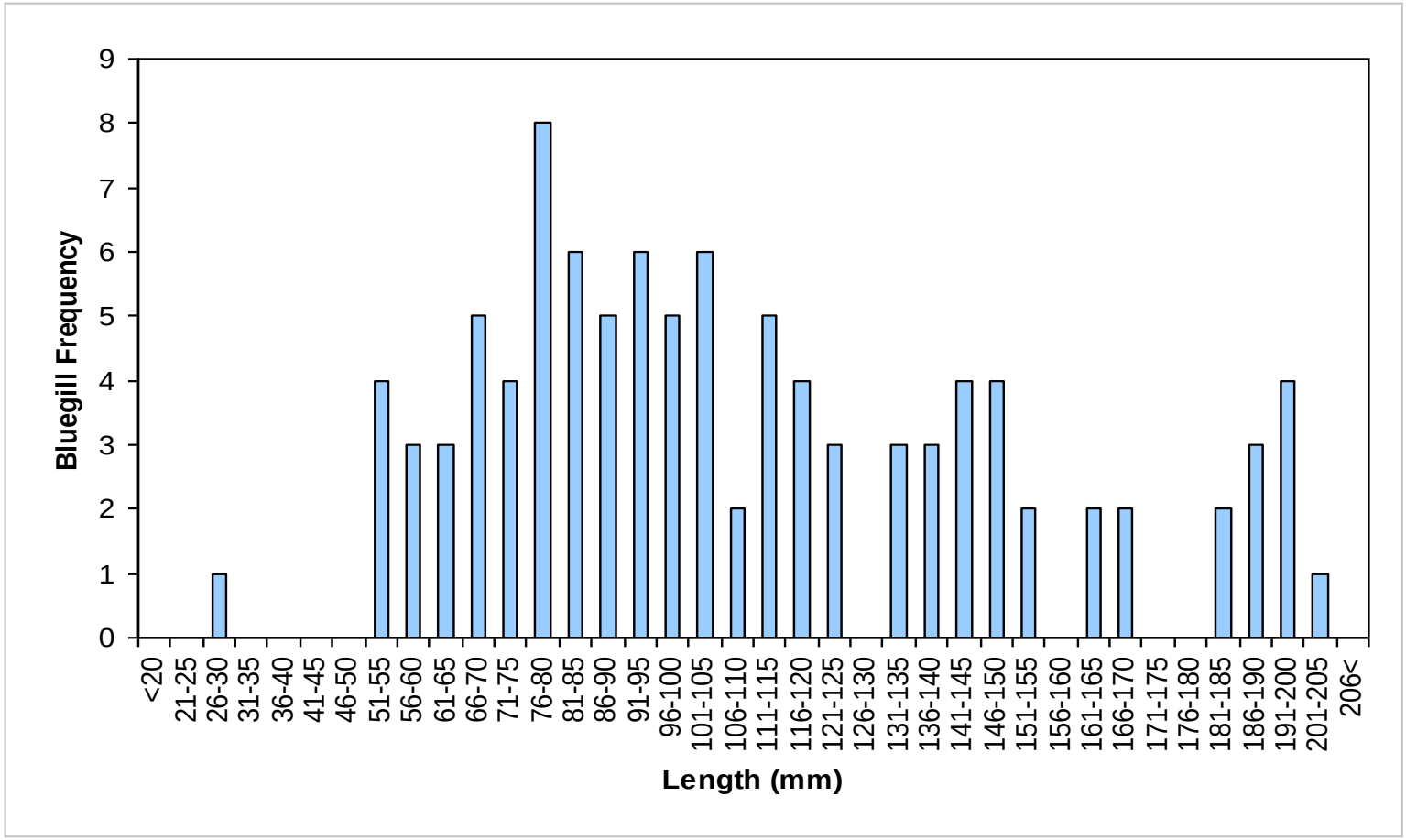
Appendix E. Lengths frequency of bluegill selected in Conestoga Lake.



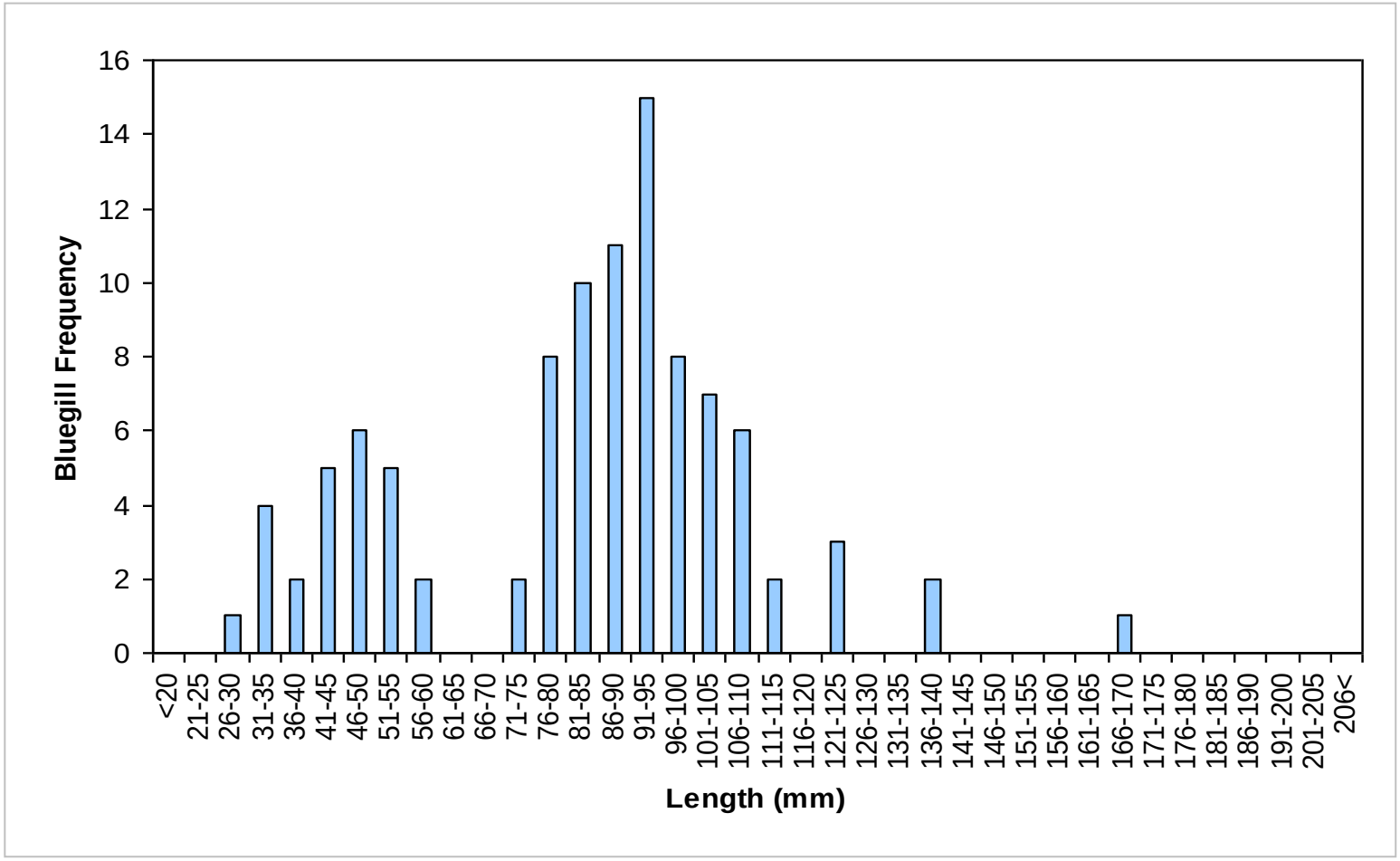
Appendix F. Lengths frequency of bluegill selected in Cottontail Lake.



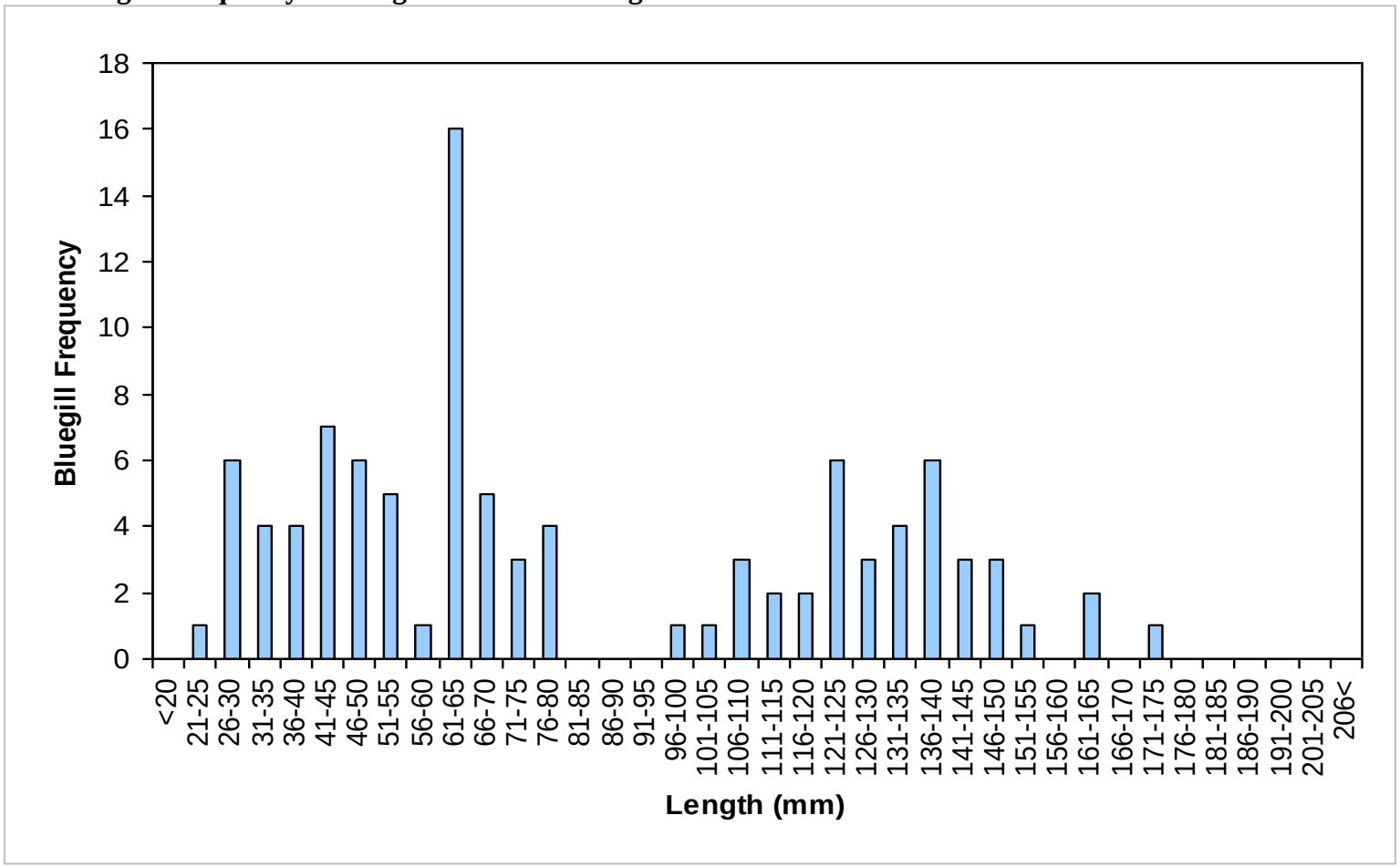
Appendix G. Lengths frequency of bluegill selected in Holmes Lake.



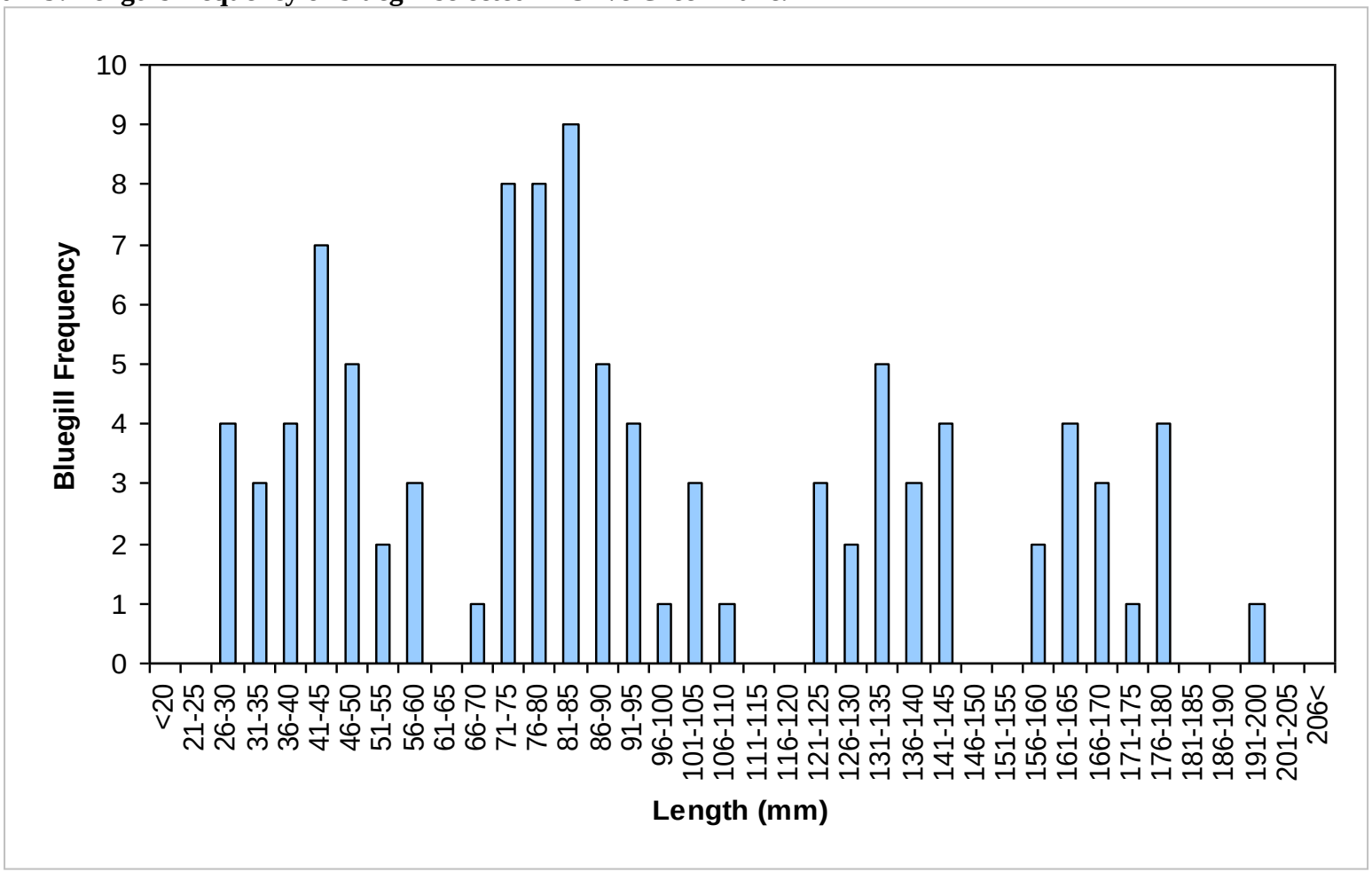
Appendix H. Lengths frequency of bluegill selected in Meadowlark Lake.



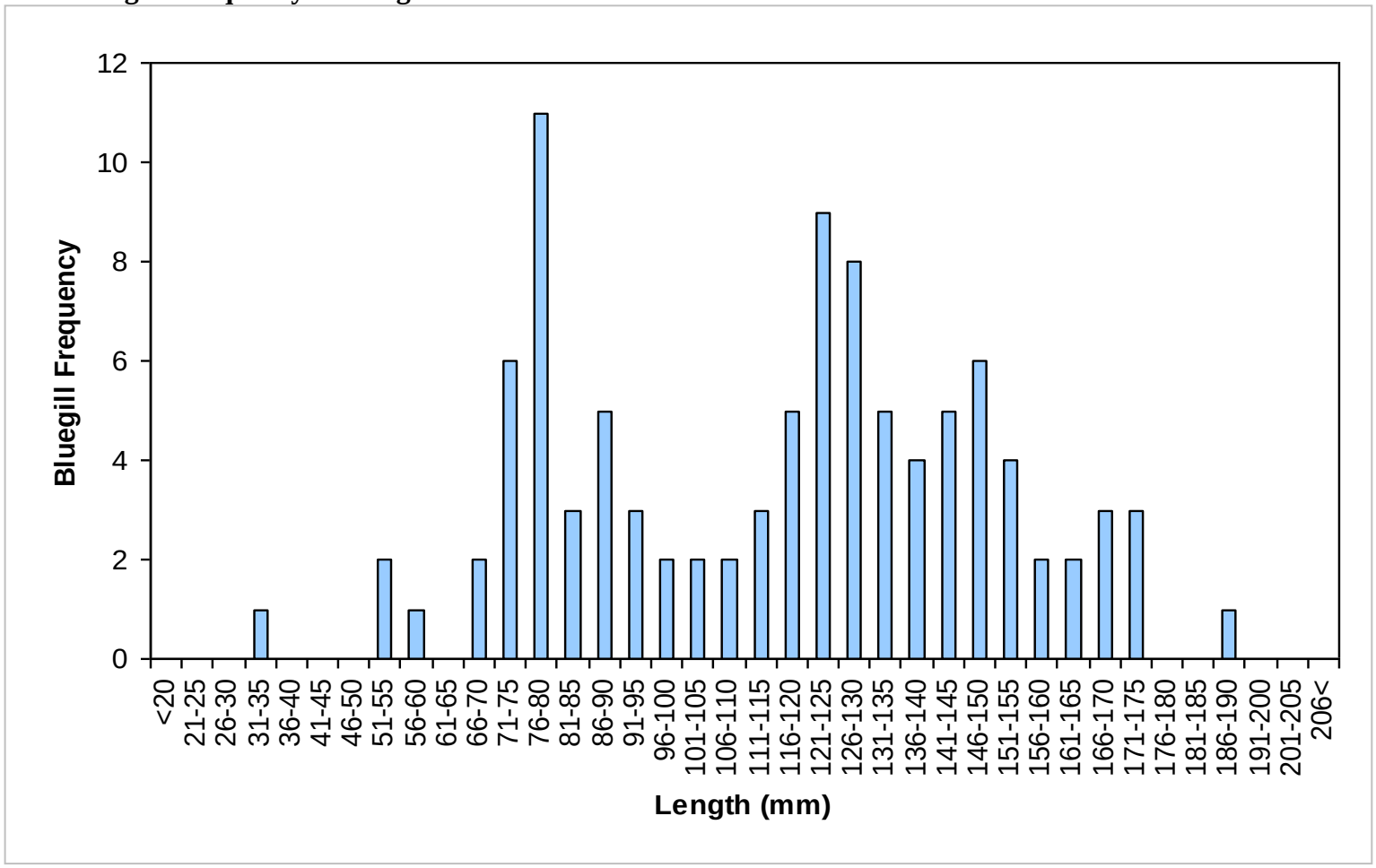
Appendix I. Lengths frequency of bluegill selected in Merganser Lake.



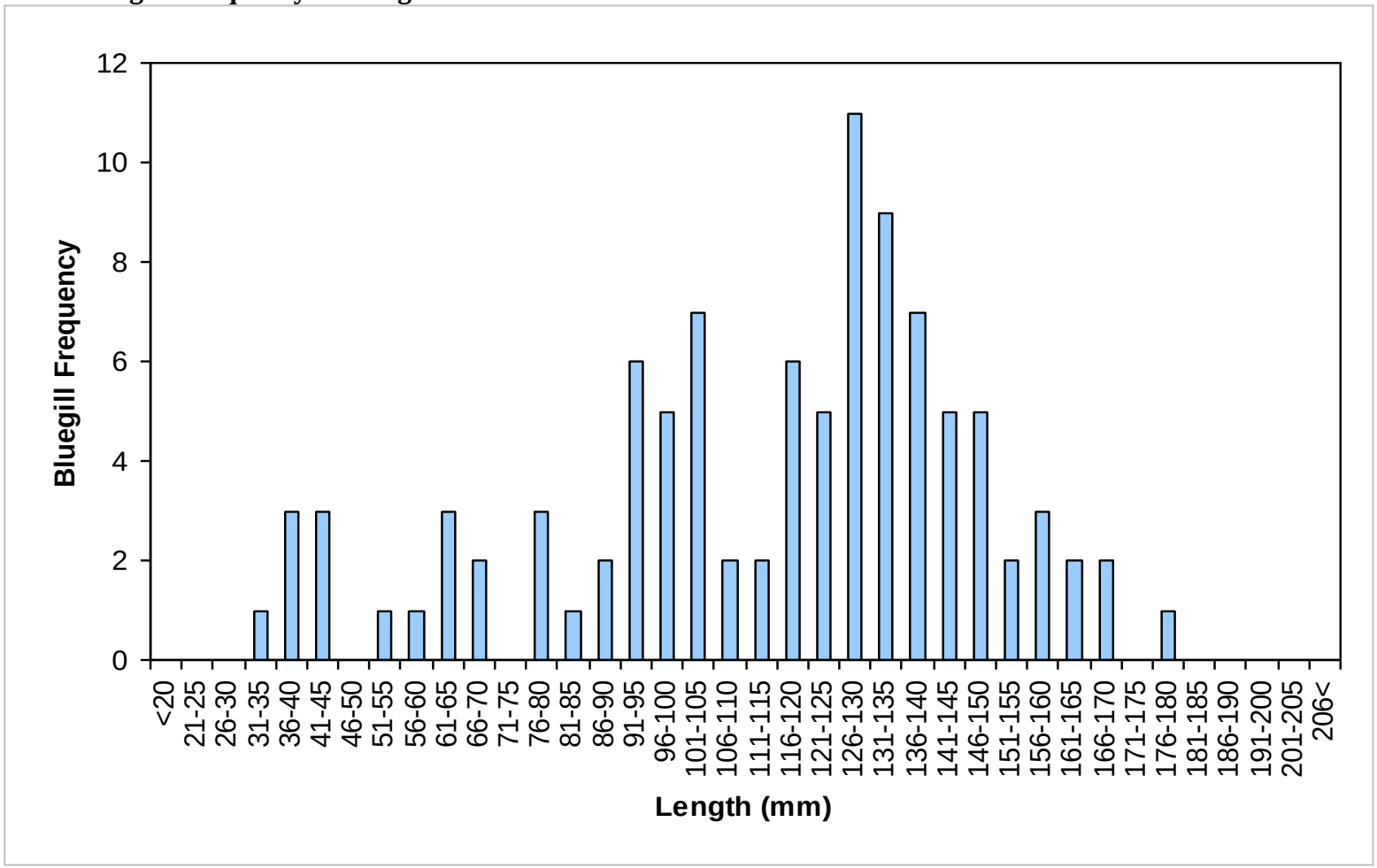
Appendix J. Lengths frequency of bluegill selected in Olive Creek Lake.



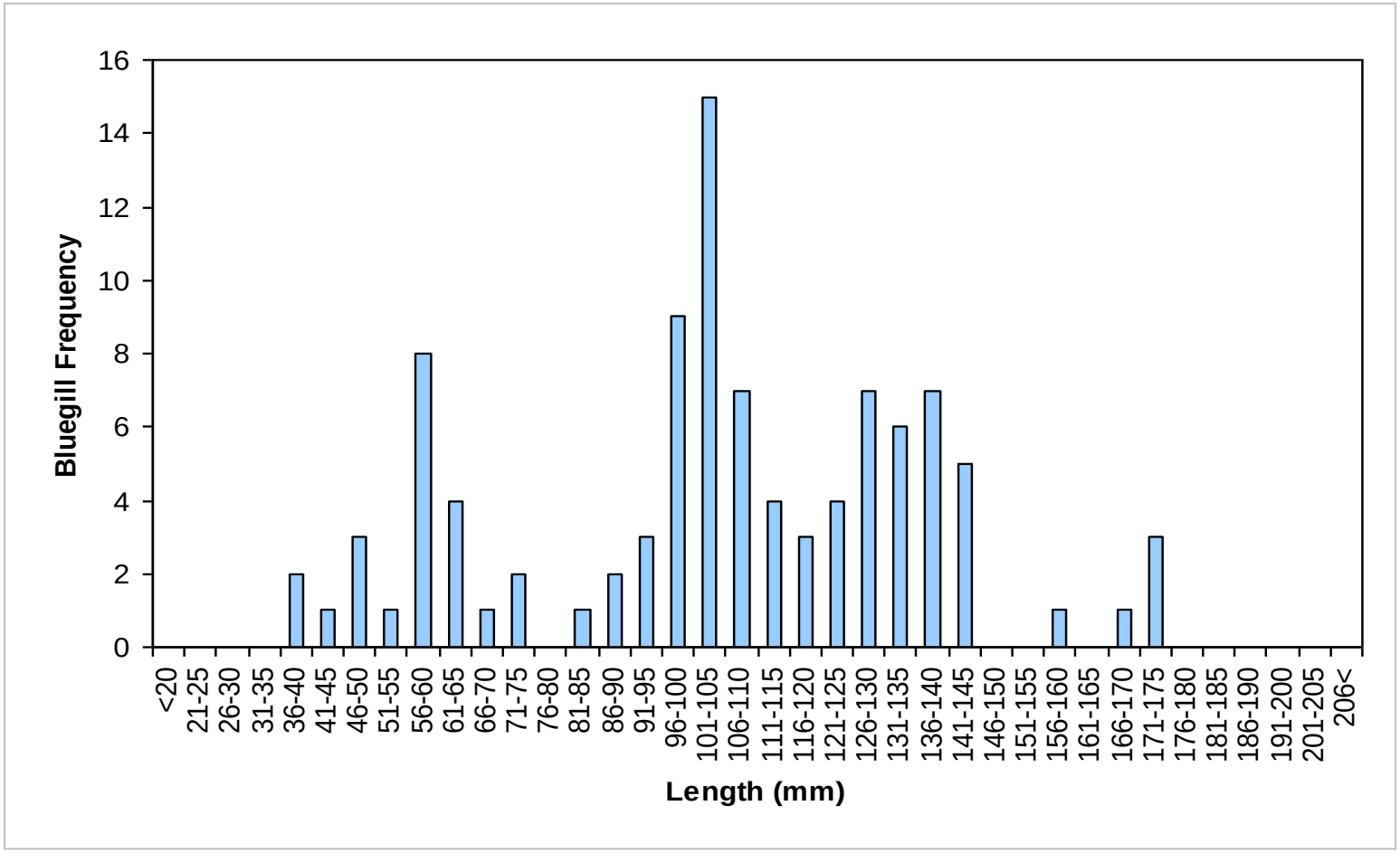
Appendix K. Lengths frequency of bluegill selected in Pawnee Lake.



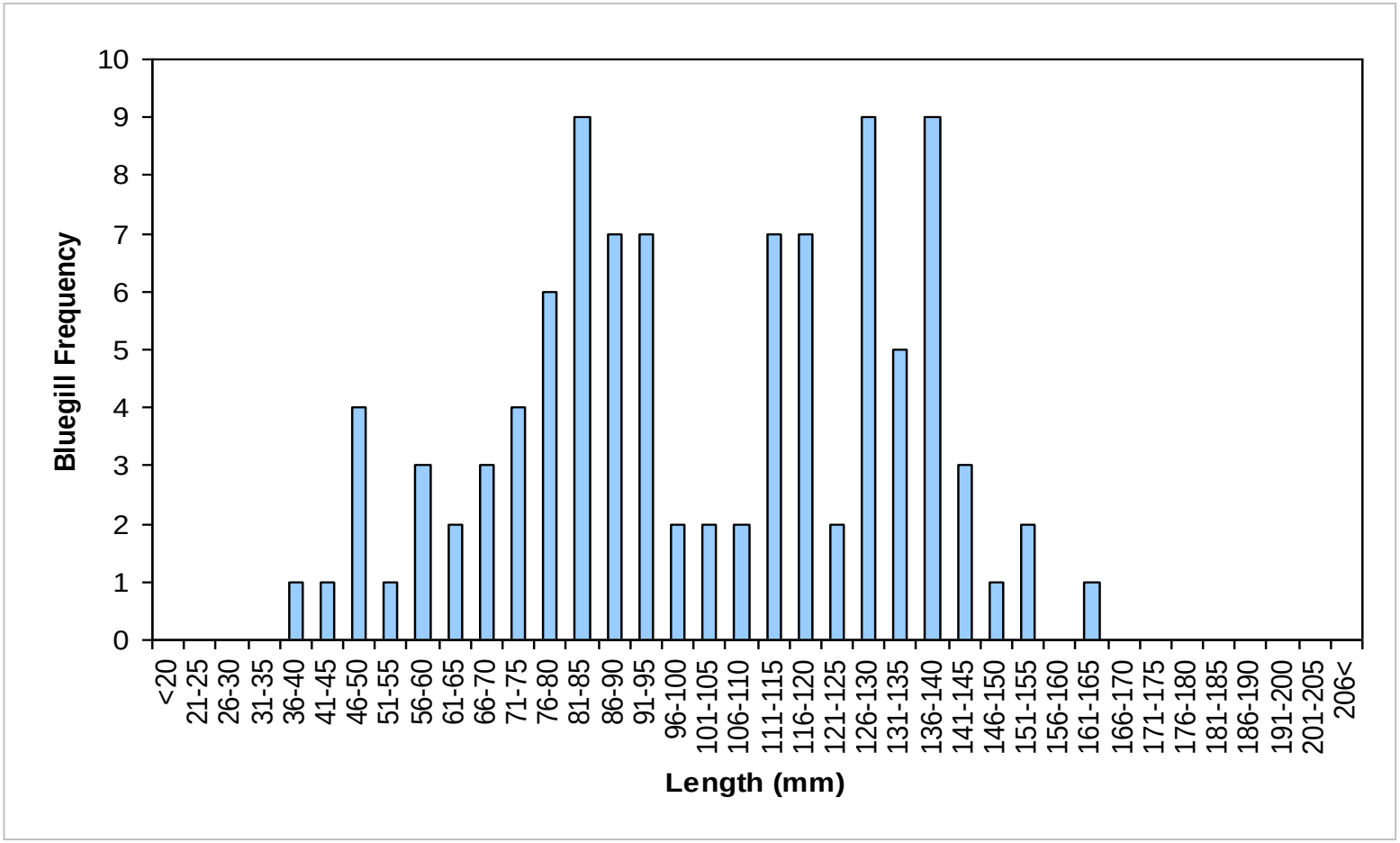
Appendix L. Lengths frequency of bluegill selected in Red Cedar Lake.



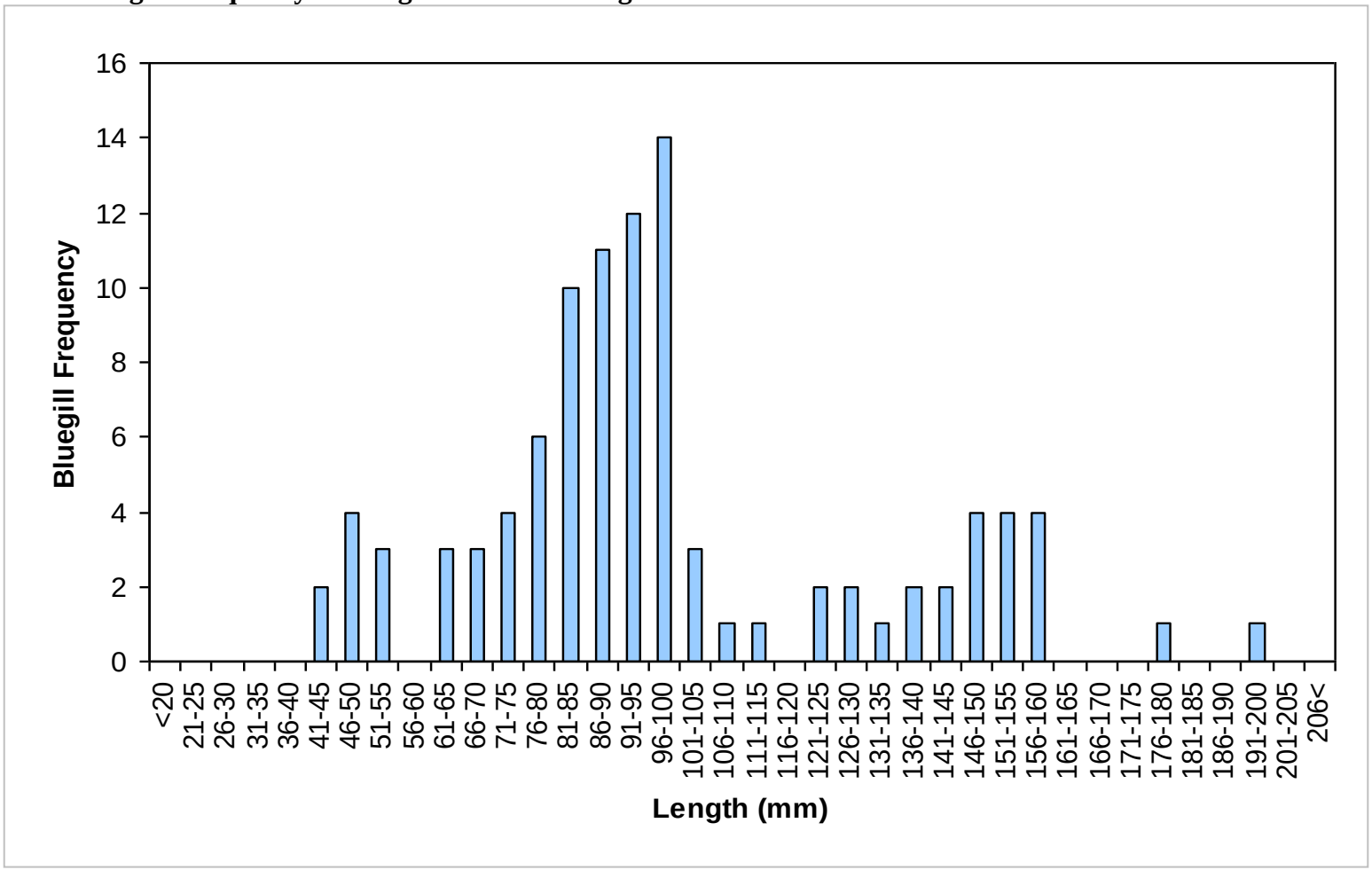
Appendix M. Lengths frequency of bluegill selected in Stagecoach Lake.



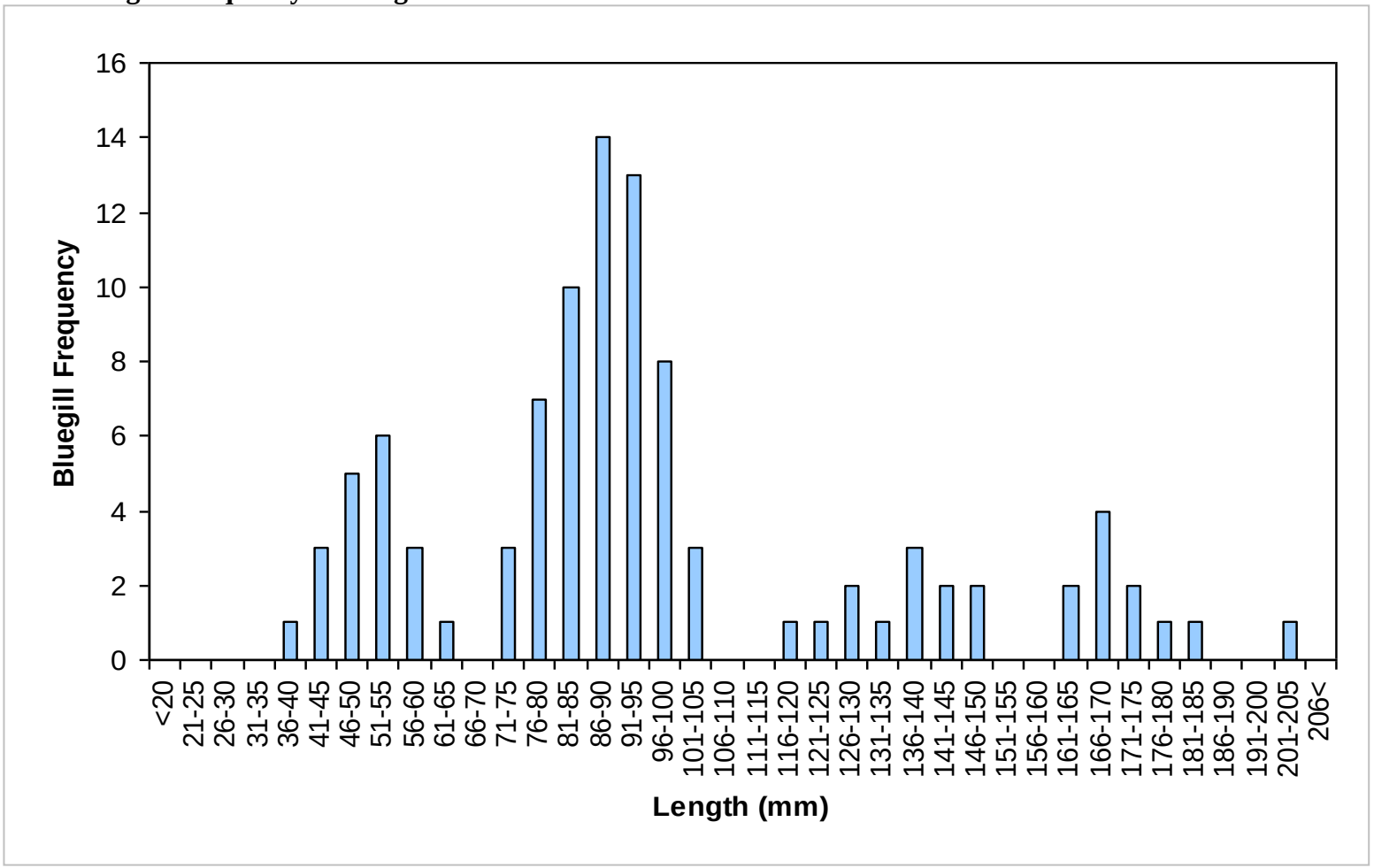
Appendix N. Lengths frequency of bluegill selected in Timber Point Lake.



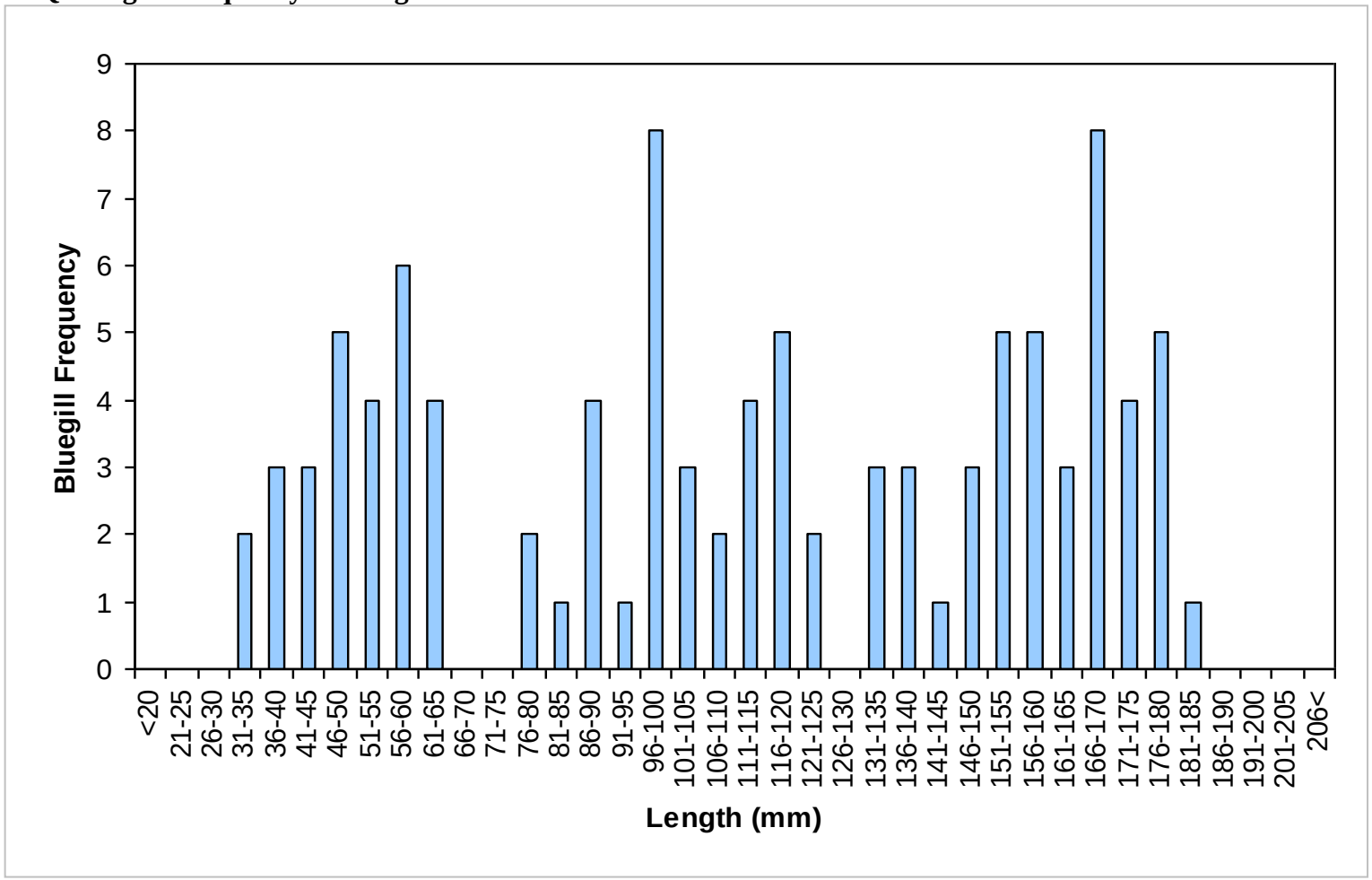
Appendix O. Lengths frequency of bluegill selected in Wagon Train Lake.



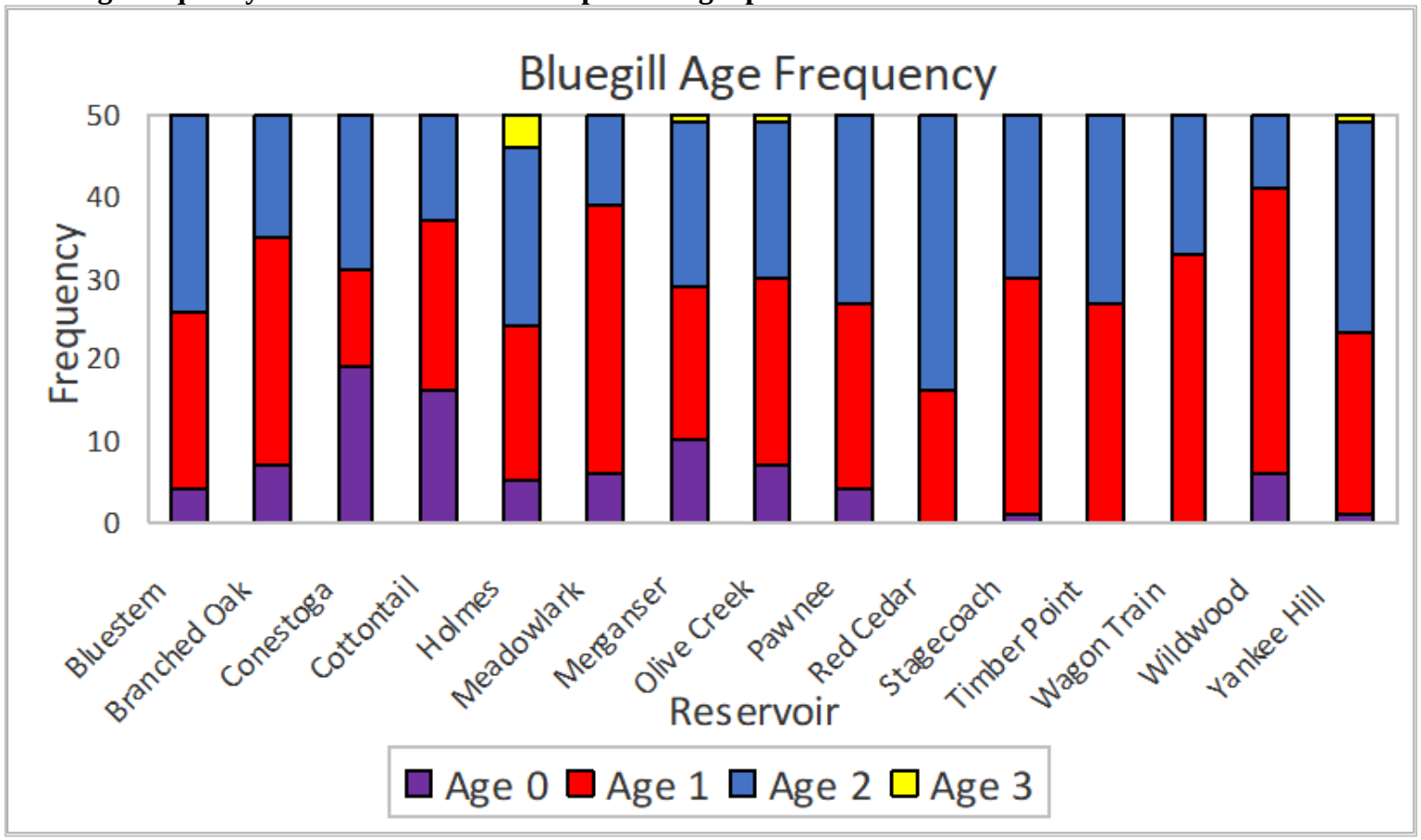
Appendix P. Lengths frequency of bluegill selected in Wildwood Lake.



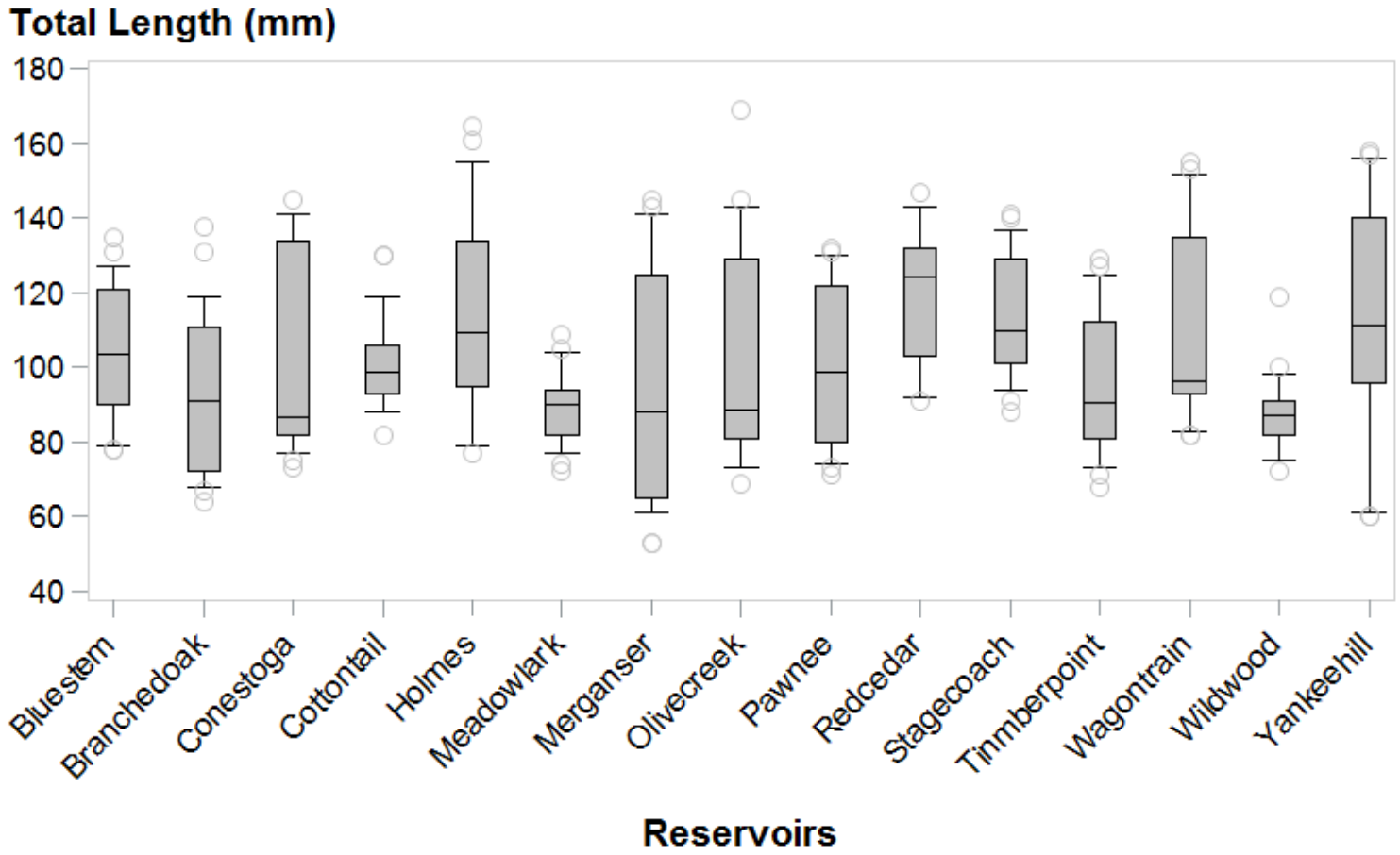
Appendix Q. Lengths frequency of bluegill selected in Yankee Hill Lake.



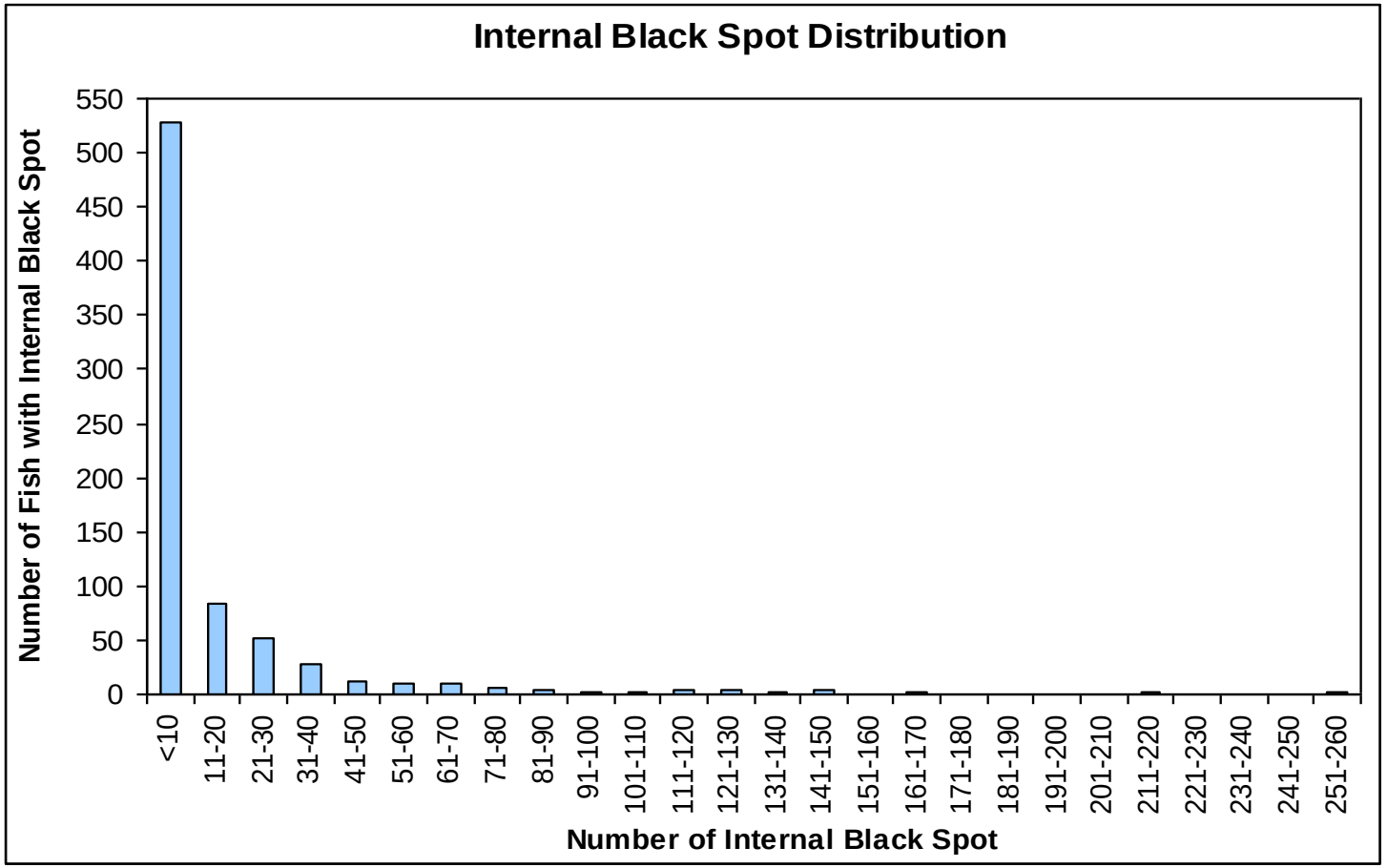
Appendix R. Age frequency estimates for the subsampled bluegill per a reservoir.



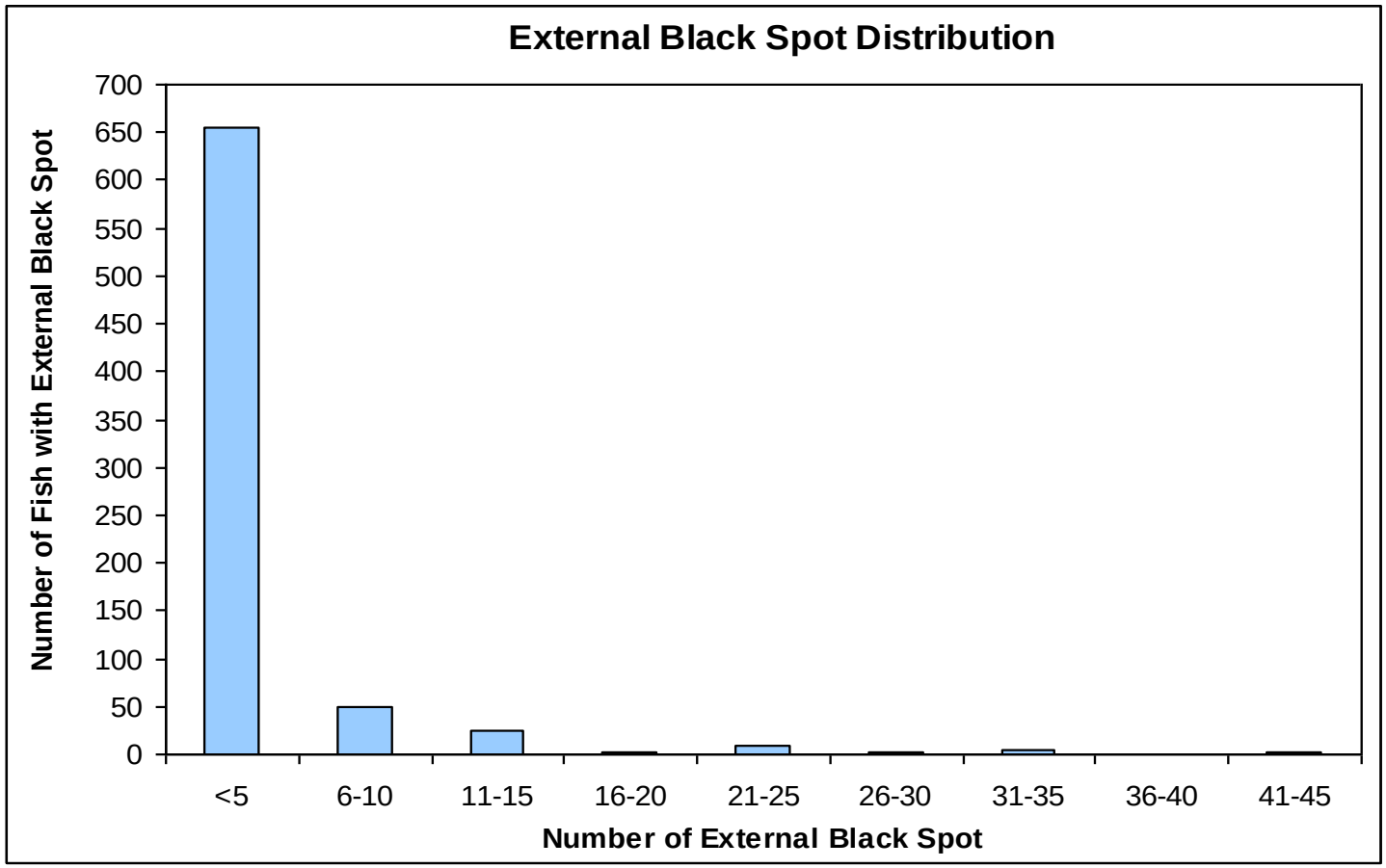
Appendix S. Total length (mm) estimates for the subsampled bluegill per a reservoir.



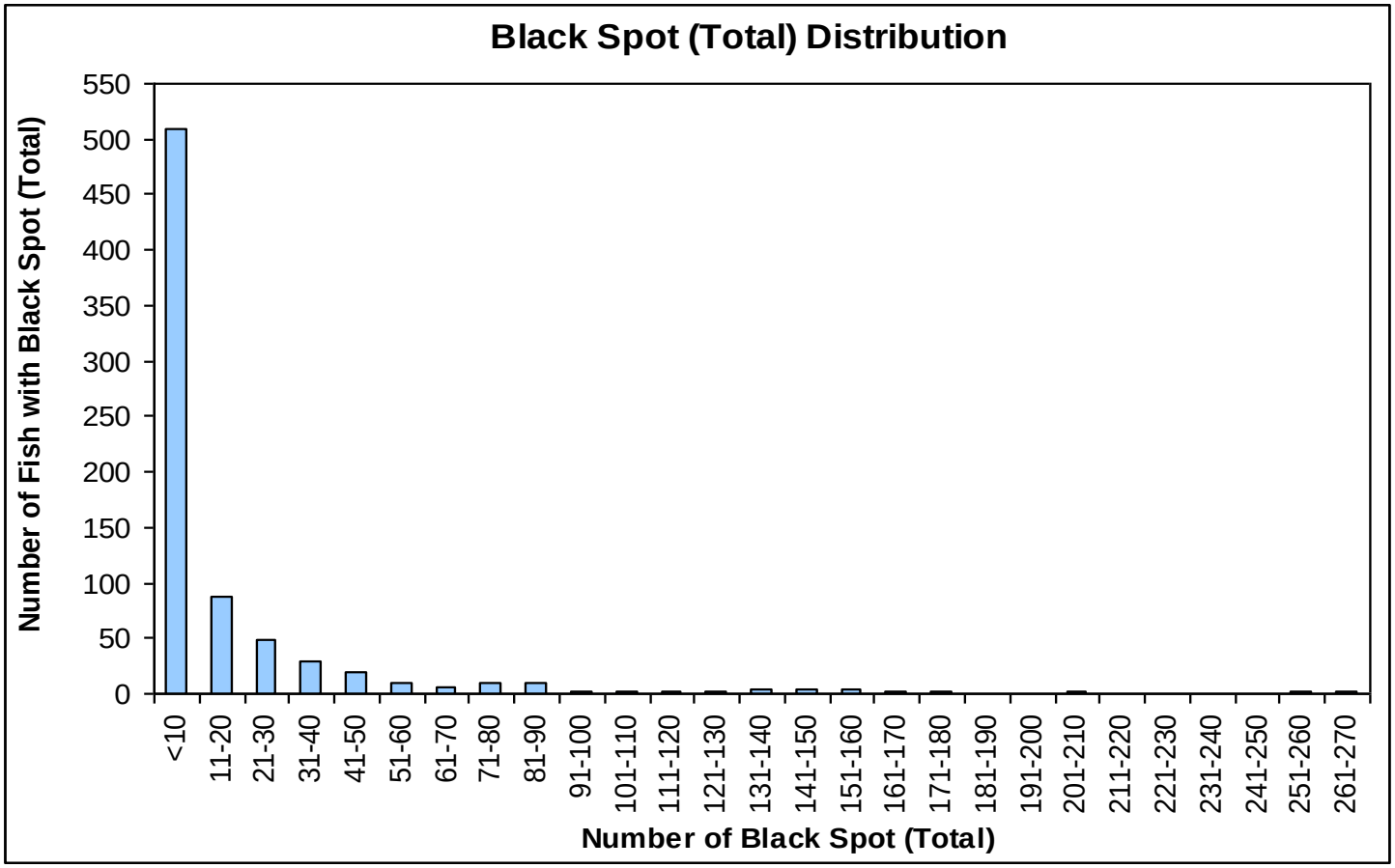
Appendix T. Internal black spot distribution table.



Appendix U. External black spot distribution table.



Appendix V. Total (sum of internal and external black spot) black spot distribution table.



Appendix W. White grub distribution table. Bins starting with an asterisk (*) indicated a break between bins.