The History of Turtle-Flambeau Flowage Walleye: Maintaining a Sustainable Fishery Through a No-minimum Length Limit

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Introduction

Wisconsin is home to one of the most popular recreational sport fisheries in the United States (Ditton et al. 2002), and walleye are Wisconsin anglers' most targeted species (Weigel 2008). Length limit restrictions are the primary tool fisheries managers have to structure walleye harvest in Wisconsin. However, evaluating the effectiveness of walleye length limits can be challenging since they have had a propensity to be changed rather frequently (especially when considering the life history of walleye, longevity ≈ 10-15+ years) as new information becomes available or new policy is implemented.

The Turtle-Flambeau Flowage (hereafter, TFF) is one of Northern Wisconsin's premier walleye fisheries, and has been managed with a no-minimum length restriction on walleye since 1958. The TFF has an extensive walleye monitoring history in addition to the consistency in length restriction. As a result, the TFF walleye population and its management provide a good example of, and a rare opportunity to assess, a walleye fishery managed consistently under a no-minimum length limit.

The TFF was created in 1926 after a dam was placed just downstream of the confluence of the Turtle and Flambeau rivers. The TFF is a roughly 13,545 acre (approx. 14,300 acres including Trude Lake), mesotrophic system that is characterized by aquatic habitat (e.g. low water clarity, an abundance of rock spawning substrate and little vegetation) and fish community dynamics (e.g. low panfish and largemouth bass abundances, yellow perch forage base) that favor sustenance of walleye dominance. The walleye population is monitored frequently in order to track population health and structure. More specifically, the adult portion of the population is assessed in alternate years during early-spring netting surveys, and juveniles are monitored every year during fall recruitment surveys.

Since the first comprehensive fisheries survey of the TFF in 1975 (Lealos and Bever 1982), the walleye fishery appears to have remained strong and relatively stable. The walleye population continues to be characterized by "above average densities, slow growth, and an adequate size structure" (Roth no date). Thus, the TFF walleye population continues to meet the objectives identified in the 2007 Fishery Management Plan. Socially, TFF stakeholders have indicated a preference for a walleye population characterized by relatively high numbers of fish with an emphasis on numbers over size (Roth and Neuswanger 2007). Biologically, the population exhibits consistent characteristics of a sustainable fishery through time. In this document we provide a summation of past survey findings, along with a discussion on ecological relationships (e.g. habitat characteristics and fish community dynamics) occurring within the TFF that affect walleye, to provide a foundation of information going forward demonstrating that the no-minimum regulation has been, and can continue to be, sustainable.

Habitat – As It Relates to Walleye

Water Quality - Productivity

Roth and Neuswanger (2007) reported average TFF alkalinity (buffering capacity) to be 30 parts per million, total phosphorous to be 23 parts per billion, and chlorophyll *a* (measure of microscopic algae abundance) to be 3 parts per billion. Based on these characteristics, along with a Trophic State Index value of 43, the TFF is best classified as being moderately productive (i.e. mesotrophic; Roth and Neuswanger 2007).

Water Clarity

Water clarity in the TFF is considered to be moderately stained, which is a result of tannins released from decayed organic materials throughout the Flowage's contributing watersheds (encompassing some 600+ square miles; Daulton 2010). Although water clarity (measured as Sechhi depth) can vary among seasons and location on the TFF (some natural lake basins contain slightly clearer water), it typically averages between 5 and 6 feet (Eslinger et al. 2014). Lester et al. (2004) found that optimum water clarity for walleye was 2 meters or roughly 6.6 feet. Therefore, the TFF's water clarity conditions are favorable for walleye.

Aquatic Vegetation

Aquatic vegetation is rather limited in the TFF, and is typically limited to shallow, backwater areas at depths less than six feet. Currently, the TFF does not contain any non-native submergent aquatic plants, and purple loosestrife is the only known non-native emergent plant species present. Limited aquatic vegetation in the TFF is favorable for walleyes over other fish species. Prey species, which are also potential competitors and predators, have few areas to escape walleye predation. As a result, walleyes can more efficiently forage, subsequently leading to relatively-low numbers of panfishes and other potential competitors and predators. Roving predator species such as walleye (that typically forage by swimming through the water column), struggle when foraging in dense vegetation. In contrast, elevated concentrations of aquatic vegetation have been found to favor sunfishes (Hinch and Collins 1993), largemouth bass (Moxley and Langford 1982, Durocher et al. 1984, and Smith and Orth 1990, studies cited by Engel 1995), and ambush predators such as northern pike. Changes to the aquatic plant community, most notably through the introduction of an invasive such as Eurasian water milfoil, could ultimately lead to fish community changes that are undesirable (e.g. declines in walleye abundances, increases in pike and largemouth bass abundances).

Spawning Substrates

Preferred walleye spawning habitat consists of shallow, wind-swept shoreline areas consisting of gravel and cobble substrates containing clean, interstitial spaces for eggs to settle, promoting incubation and providing protection from predation (Niemuth et al. 1972). Rocky habitats are one of the most prevalent shoreline habitat types in the TFF. This characteristic is likely due to the fact that underlying soil sediments are typically comprised of rocky outcroppings. An examination of the National Resources Conservation Service (NRCS) online soil survey shows predominant soil types around the TFF being characterized as "stony" or "very stony". As a result, rock and gravel substrates are abundant, and walleyes utilize many of these areas for spawning. The fact that walleyes spawn in numerous areas throughout the Flowage increases their chances of consistent, successful reproduction (whereas a single, large spawning aggregation leaves an entire year's reproductive success vulnerable to the same localized environmental conditions and greater attraction to predators).

Wood

Thousands of acres of forested lands were flooded during creation of the TFF. Over the past decades the TFF's habitats continue to evolve. Standing trees that once scattered the watery landscape have since decayed and most are no longer evident. Log jams, that once allowed anglers a standing platform to vertically jig, are no longer present. Although most of these easily recognizable wood features have disappeared to the naked eye, a large portion of them likely remains beneath the water's surface. When examining the age of submerged white pines in an Ontario Lake, Guyette and Cole (1999) found that it took an average of 443 years for a living tree to completely decompose underwater. Although most of the wood in the TFF likely consisted of second-growth hardwood species (not virgin white pine), it's still a safe assumption that much of the originally-flooded timber is still contributing (as fish/invertebrate habitat or as a source of carbon) to the Flowage's aquatic ecosystem. In addition to the flooded timber that remains from the TFF's creation, 400+ log fish cribs have been added to supplement natural wood attrition. Additionally, a tornado in 2010 swept across the Flowage, depositing wood into the water, and creating a number of so-called "tree-drops" along some of the shoreline areas. When considering these facts, it is easily apparent that the TFF still contains a relatively-high abundance of wood, especially when compared with other waters.

Walleye Population Estimates, Creel, and Harvest Statistics

Historically, TFF adult walleye population estimates have ranged between densities of 4.0 and 7.9 adults per acre (Table 1). In comparison, adult walleye density estimates from all lakes classified as "NR" and "C-NR" (considered to have the strongest walleye populations in Wisconsin's Ceded Territory) average 4.2 per acre (Tom Cichosz, WDNR, unpublished data).

The DNR's primary goal for the TFF fishery is to retain walleye as the dominant fish species, and maintain relatively high adult densities (as indicated in the TFF fishery management plan; see excerpt below; Roth and Neuswanger 2007).

"**Objective 1.1:** 4 to 8 adult walleye per acre in spring population estimates
(Adult walleye are defined by DNR as all fish over 15 inches long and all smaller fish for which gender can be determined.)"

The TFF has been surveyed five times since 1975 in which comprehensive surveys (includes estimation of adult walleye abundance along with angler catch and harvest statistics) have been conducted (1975, 1989, 1992, 1997, 2009). The following tables and figures summarize and compare key statistics from those surveys.

Table 1. Summary of adult walleye abundance, density, male to female ratio, and proportion of the population represented in respective inch classes (%) within the TFF.

Year	Adult PE	Density (No./ac.)	M:F Ratio[A]	0 - 11.9	12.0 - 14.9	15.0 - 19.9	20.0+
1975[B]	112,535	7.9	7.7	12,646 (11%)	49,645 (44%)	46,104 (41%)	4,140 (4%)
1989	72,967	5.4	2.8	7,589 (10%)	28,659 (39%)	34,792 (48%)	1,927 (3%)
1992	57,697	4.3	4.9	3,694 (6%)	24,507 (42%)	25,559 (44%)	3,935 (7%)
1997	54,758	4.0	7.4	14,582 (27%)	23,930 (44%)	14,911 (27%)	1,347 (2%)
2009	54,208	4.1	7.7	5,016 (9%)	30,605 (56%)	16,727 (31%)	1,860 (3%)

[A] derived from observations during spring netting and shocking surveys; 1989 value includes only netting sample
[B] includes TFF and Trude lakes

Table 2. Walleye harvest (estimated angler harvest and actual tribal harvest) and exploitation of walleye within the TFF.

Year	Estimated Harvest	Angler Harvest	Tribal Harvest	Angler Exploitation	Tribal Exploitation	Total Exploitation
1975[A]	35,525	35,525	0	0.210[B]	0.000	0.210[B]
1989	32,422	32,422	0	0.171	0.000	0.171
1992	26,334	24,187	2,147	0.064	0.035	0.099
1997	35,318	33,146	2,172	0.200	0.040	0.239
2009	13,959[C]	12,167[C]	1,792	0.080	0.033	0.113

[A] includes TFF and Trude lakes
[B] exploitation value = estimated harvest/total spring population estimate; differs from methods used for other exploitation values
[C] values are assumed underestimates of what actually occurred due to creel survey methodology (bus route) during the 2009 creel survey

Table 3. Estimated angling effort, walleye catch and harvest statistics from angler creel surveys within the TFF.

Year	Effort (hrs/ac)	% WE Effort	Angler Bag	Estimated Catch	Specific Catch Rate	Estimated Harvest	Mean Length
1975[A]	15.7	NA	5	NA	NA	35,525	14.6[B]
1989	14.2	NA	5	49,838	3.1[B]	32,422	13.9[B]
1992	15.8	58	3	50,849	3.4	24,187	14.5
1997	14.9	63	3	85,230	1.8	33,146	13.6
2009	9.9[C]	52	3	19,910[C]	3.9	12,167[C]	14.0

Effort: Iron Co. Avg = 13.8 hrs/ac; Ceded Territory Avg = 33.6 hrs/ac
[A] includes TFF and Trude lakes
[B] open water portion of the creel survey only
[C] values are assumed underestimates of what actually occurred due to creel survey methodology (bus route) during the 2009 creel survey

Population Estimates and Abundances

Due to a variety of nuances (e.g. differing protocols, biologists, agreements, acreages used, etc.) walleye population estimate methods have varied slightly over the years. Although we couldn't go back and simply recalculate all the estimates, we adjusted where we could to make the estimates most comparable. Appendix A provides explanations for each respective year to clearly identify the methodology used to derive the estimates in Table 1.

It appears that the TFF adult walleye density and abundances have decreased from levels documented in 1975 (Table 1). However, densities of TFF walleye are still comparable to northern Wisconsin's strongest walleye fisheries. Additionally, adult walleye abundances can fluctuate substantially from year to year depending on contributing year-class strength in even the best walleye fisheries. Nate et al. (2011) reported that adult walleye density estimates varied "erratically" for the majority of years collected in Escanaba Lake (WI), Oneida Lake (NY), and Lake Erie. They attributed the large variation in adult density/abundance to the relative strength of a year-class recruiting into the adult population (intermittent strong year-classes drove adult densities up and down) (Nate et al. 2011). This oscillating walleye year-class strength phenomenon occurs in the TFF (Figure 5), and is elaborated on in the "Walleye Recruitment, Habitat and Fish Community Impacts" section. With oscillating walleye year-class strength driving variability in walleye abundance in a system the size of the TFF, it's possible to have abundances fluctuate by tens of thousands of fish within a single year's time. For example, a strong walleye year-class that has just recruited into the adult population (fish are maturing/spawning for the first time) can have a great impact on the overall number of adults present when compared with a poor year-class. None-the-less, the numbers suggest that adult walleye abundances have decreased somewhat over the past several decades. In an analysis of TFF fisheries surveys between 1975 and 1997, fisheries biologist, Jeff Roth, concluded that increased pressure and harvest on the walleye fishery along with an increase in gamefish diversity would make it unlikely that the Flowage would support exceptionally high walleye densities in the future (Roth no date). Although we agree with this conclusion, we expect that walleye densities in the TFF will remain relatively strong (due largely to habitat and fish community characteristics that are advantageous to walleye), and that walleye will continue to be the dominant species in the fishery.

Walleye stocking has been a seldomly used management tool in the TFF. Walleye stockings occurred during the late 1930s, early 1940s, early to mid-1950s, early 1980s, and early 1990s (Appendix B). These stockings were most likely associated with "plant-back" events from hatchery spawning operations where TFF broodstock were used as an egg source for stocking other waters (no longer occurs within the TFF). Due to the high levels of natural walleye recruitment that typically occurs, walleye stocking remains an unnecessary practice in the TFF. Unwarranted stockings could have detrimental effects on the reproductive fitness and genetic integrity of TFF walleye; potentially jeopardizing the sustainability of the fishery.

Angler Harvest and Creel Statistics

The TFF has supported an estimated annual walleye harvest between 13,959 and 35,525 fish (Table 2). On average, roughly 2 walleyes per acre are harvested from the TFF annually (range: 1.1 – 2.6 over the five creel surveys). This average is for all walleye, juveniles and adults. Our walleye population estimates presented in Table 1 are for the adult population only. This is an important distinction, because in the TFF, the juvenile portion of the total walleye population may very well be equal to, or greater than, the adult portion depending upon year-class strength. For reference, in Escanaba Lake (Vilas County, WI), roughly 8 walleyes per acre were harvested annually between 1946 and 2003 (range: <1 – 20) (Sass, unpublished data). Although Escanaba Lake (293 acres) is much smaller than the TFF, it contains a very similar fish community where walleyes have been dominant for many years.

Table 3 highlights angler statistics collected during creel surveys conducted on the TFF. From these surveys, an estimated 52-63% of the total fishing pressure is directed at walleye. Typically, May is the month with the greatest fishing pressure and walleye harvest on the TFF. This is likely due to the time of year coinciding with walleye spawning which results in increased opportunities for aggressive, post-spawn fish. Specific catch rates, represented as the number of hours it takes to catch a walleye by an angler targeting walleye, has ranged between 1.8 and 3.9 hours (average 3.0 hours) on the TFF. The average specific catch rate for walleyes within northern Wisconsin's best walleye fisheries (those classified as "NR" or "C-NR") is 4.3 hours of angling effort to catch a walleye (obtained from creel survey data between 1990 and 2013). Total angling effort, measured as the number of hours of fishing pressure per acre of surface water, has ranged between 9.9 and 15.7 hours per acre on the TFF. These values are less than half of the angling pressure experienced on the average Ceded Territory lake (33.6 hours per acre; obtained from creel survey data between 1990 and 2013). From their 1975 report, Lealos and Bever (1982) reported that fishing pressure on the TFF "can be considered light by national, statewide, and regional standards." The 1989-90 survey report concluded that "For a lake of its size the flowage receives little fishing pressure." (DNR treaty assessment lake survey report). To this day, fishing pressure remains relatively low on the TFF.

Recently, interviews were conducted with longtime TFF fishing guides (Don Pemble – over 50 years fishing the TFF, and Mike Sabec ≈ 45 years fishing the TFF) to document their perspective of the walleye fishery. In general, their perspectives are that walleye numbers in the TFF remain strong (no significant change over the years), although size structure of the population may be slightly smaller than in the past. This information is another useful tool to monitor the fishery.

Tribal Harvest

Tribal spear harvest has occurred on the TFF since 1985 (Appendix C). Between 1985 and 2014, the average tribal spear harvest of walleyes from the TFF has been 2,673 fish. All spear-harvested fish are counted, and a sub-sample is measured and examined for gender. On average, approximately 87% of harvested walleyes per year are male (n = 27, range 68 – 96%, standard deviation = 7%), 6% are female (n = 27, range 1 – 15%, standard deviation = 4%), and 7% are of unknown gender (n = 27, range 1 – 27%, standard deviation = 7%). Sex ratios of spear-harvested walleyes have remained consistent over time, providing more substantiating evidence that the TFF walleye population remains healthy and relatively stable. These statistics also suggest that the current amount of harvest (from anglers and tribal spearers combined) is sustainable. Tribal walleye harvest from the TFF represents 11% (on average) of the total annual Ceded Territory harvest (Wisconsin portion; Appendix C). Historic angler bag limits for TFF walleye, set after the conclusion of tribal spear harvest, are shown in Appendix D.

Population Size Structure

The TFF walleye population size structure has remained similar over the past four decades (although there may have been a slight decline). Strong recruitment of young fish, a healthy proportion of moderately-sized fish (13 – 17 inches), and relatively low numbers of large fish (20+ inches) typifies the walleye population structure within most years. During the 1975 survey, Lealos and Bever (1982) reported that "The bulk of the walleyes sampled in spring were 11.0 – 17.0 inches." The 1989 survey found that the average size of marked male and female walleyes was 14.2 and 17.3 inches, respectively (DNR treaty assessment lake survey report). Mean lengths of angler-caught walleye observed from the five creel surveys have all been similar, ranging between 13.6 and 14.6 inches (Table 2). Average lengths of spear-harvested walleye in the TFF have also remained relatively similar since the first harvest occurred in 1985. The respective average lengths of spear-harvested male, female, unknown sex, and all walleye combined is: 14.2 (n = 27, range 13.1 – 15.5 inches, standard deviation = 0.7 inches), 17.4 (n = 27, range 15.6 – 19.6 inches, standard deviation = 1.1 inches), 14.5 (n = 27, range 12.6 – 17.5 inches, standard deviation = 1.4 inches), and 14.5 (n = 29, range 13.3 – 16.7 inches, standard deviation = 0.8 inches) inches.

It appears that there has been a slight decline in the proportion of adult walleye within the 15.0 – 19.9 inch class in the TFF since what was documented in the late '70s and '80s (Table 1). This decline in size structure was also something that biologist, Jeff Roth (no date), concluded in his TFF analysis. Roth (no date) suggested that the decline may have been the result of weak year-classes, high exploitation, or a combination of the two. From the data presented in this document, we conclude that the apparent decline in size structure may be the result of strong year-classes recruiting to the adult population (i.e. if a strong year-class of relatively young, smaller fish recruits to a fishery/population the proportion of fish below 15 inches will be larger, and therefore subsequent inch-class proportions will most likely be smaller), slow growth, and potentially higher exploitation on the 15.0 – 19.9 inch-class. Although walleye exploitation in the TFF does not appear to be overly high (see "Mortality and Exploitation" section below), Rypel et al. (In press) found that the effects of exploitation were most evident on the production rates of older, larger walleye. This might explain the decrease in the relative proportion of 15.0 – 19.9 inch walleyes in the TFF. Walleye greater than 20 inches in length have always been relatively rare in the TFF, with proportions of the entire adult population having ranged between 2-7% (Table 1). Elaboration on why TFF walleye size structure may be relatively smaller than historically, and the reasoning for few fish over 20 inches, is discussed in the upcoming "Growth" section.

The figures below (1, 2, and 3) depict length frequency histograms of walleyes captured during 1992, 1997, and 2009 by means of population assessments (early-spring netting and electrofishing surveys), tribal spear harvest, and recreational angling harvest (both observed by creel clerks). Special attention is given to the proportion of fish observed under and over 14 inches. The size distribution of walleyes sampled during population assessments, as well as those harvested by tribal spearers and recreational anglers match closely with one another (especially if we accounted for only mature fish sampled in our population surveys). This gives us confidence that population assessments are providing accurate depictions of the adult walleye stock. Early-spring netting surveys will be continued in alternate years to monitor walleye size structure and relative abundance.

The Turtle-Flambeau Flowage Fishery Management Plan identifies the following objective regarding walleye size structure (Roth and Neuswanger 2007):

"**Objective 1.2:** Of all walleye 10 inches and longer captured by fyke netting in early spring, 30-50% should be 15 inches or longer (PSD = 30-50%)."

In years with extensive walleye population monitoring (represented in the "A" panels below), we found proportional stock density (PSD) values of 36% (1992), 28% (1997), and 28% (2009); these values were obtained from spring netting and shocking surveys. In addition, other recent adult walleye index surveys (netting efforts only) have found PSD values of 36% (2006), 57% (2011), and 33% (2013). Respective PSD values of spear and angler-harvested fish (represented in the "B" and "C" panels below, respectively) were 25% and 34% in 1992, 24% and 19% in 1997, and 24% and 28% in 2009.

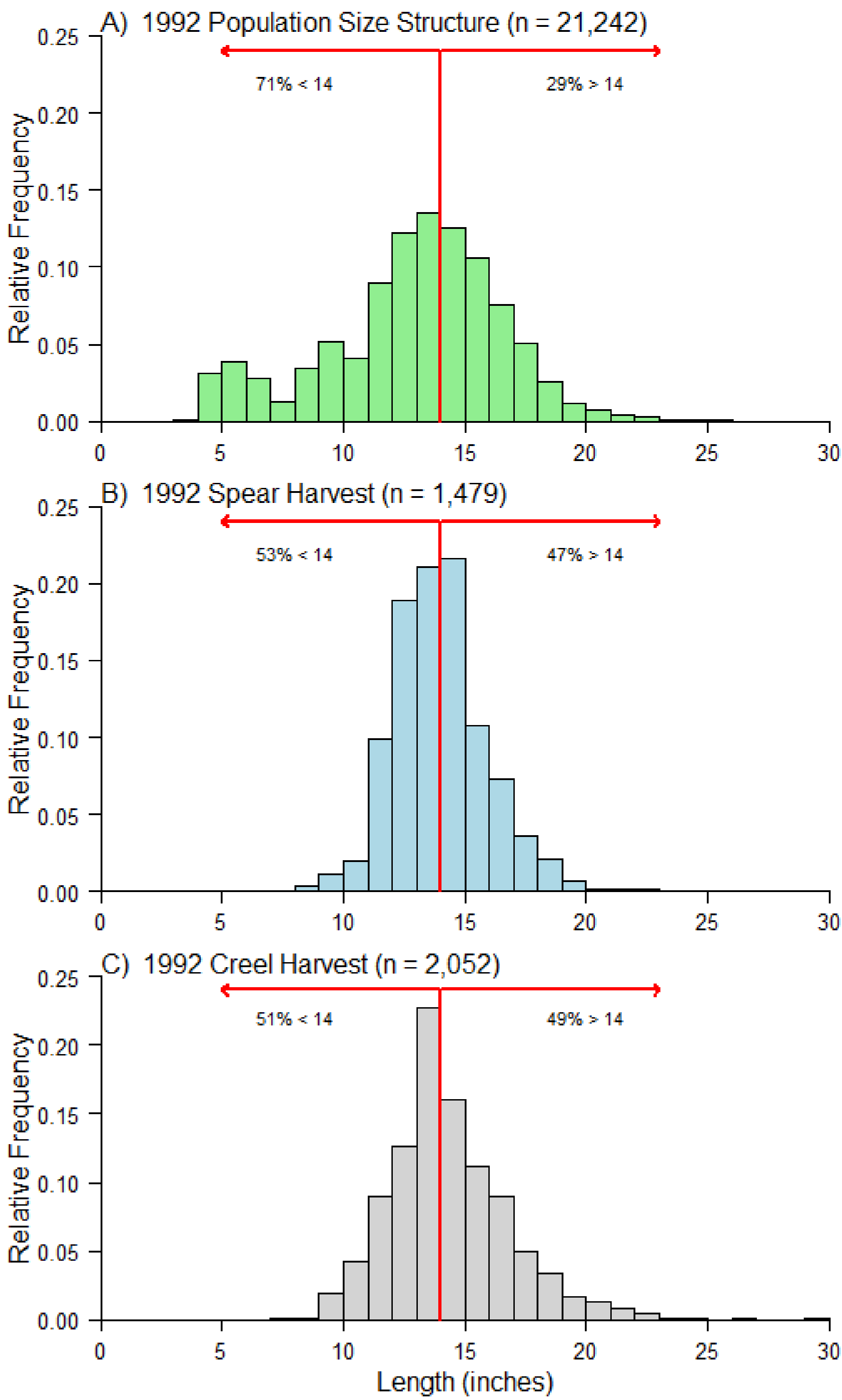

Figure 1. Walleye population size structure from spring netting and electrofishing surveys (A), spear harvest (B), and angler harvest (C) observed in 1992.

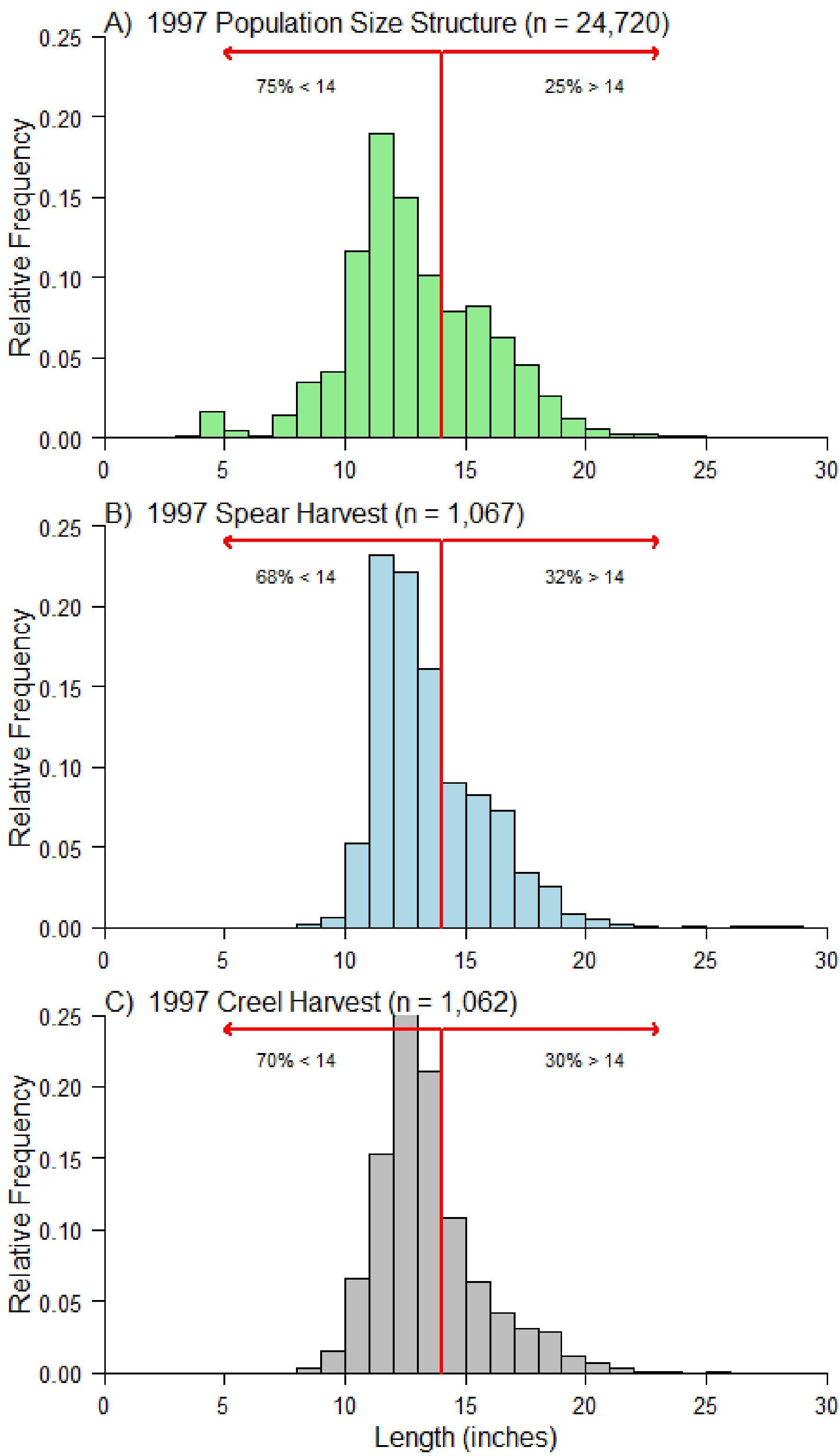

Figure 2. Walleye population size structure from spring netting and electrofishing surveys (A), spear harvest (B), and angler harvest (C) observed in 1997.

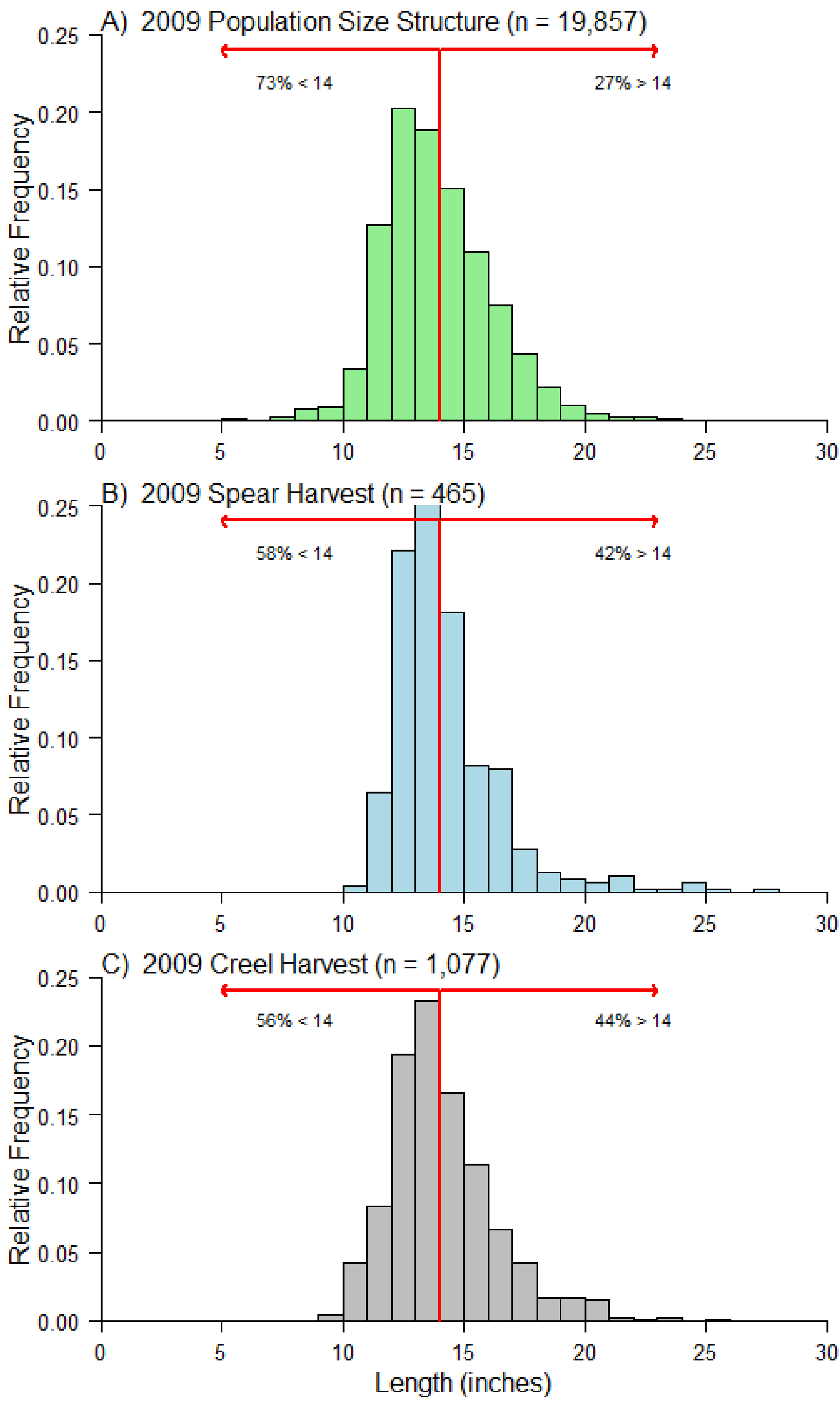

Figure 3. Walleye population size structure from spring netting and electrofishing surveys (A), spear harvest (B), and angler harvest (C) observed in 2009.

Growth

Walleyes in the TFF have always been characterized as being relatively slow growing. In their 1982 report, Lealos and Bever reported walleye growth to be "considerably slower" when compared with the northern Wisconsin average (Lealos and Bever 1982). The 1989 treaty survey assessment report states, "The walleye population is relatively high density with slow growth rates." (DNR treaty assessment lake survey report). TFF walleyes were exempted from the 15-inch statewide limit in 1990 (retaining the no-minimum regulation) based on slow growth (Roth no date). Figure 4 (below) depicts mean length at age growth estimates compared with northern Wisconsin averages. Von Bertalanffy growth analyses (from ageing data collected between 1989 and 2009) show that the average male and female walleye in the TFF would reach maximum sizes of about 20.7, and 28.1 inches, respectively.

Slow walleye growth in the TFF is most likely due to the fact that yellow perch are their primary forage. Yellow perch are relatively low in caloric value (when compared with other minnow species for example), and slow growth of walleyes is a common characteristic in other walleye – yellow perch systems. In an analysis of 23 New York waters where the walleye-perch predator-prey relationship is predominant, Rudstam et al. (1996) found that when walleye are abundant, growth is slow.

The primary reasons that 20+ inch fish are rare in the TFF are 1. the population exhibits slow growth, and 2. the population is proportionally dominated by males (M:F ratio found in Table 1; a characteristic found in most healthy walleye fisheries).

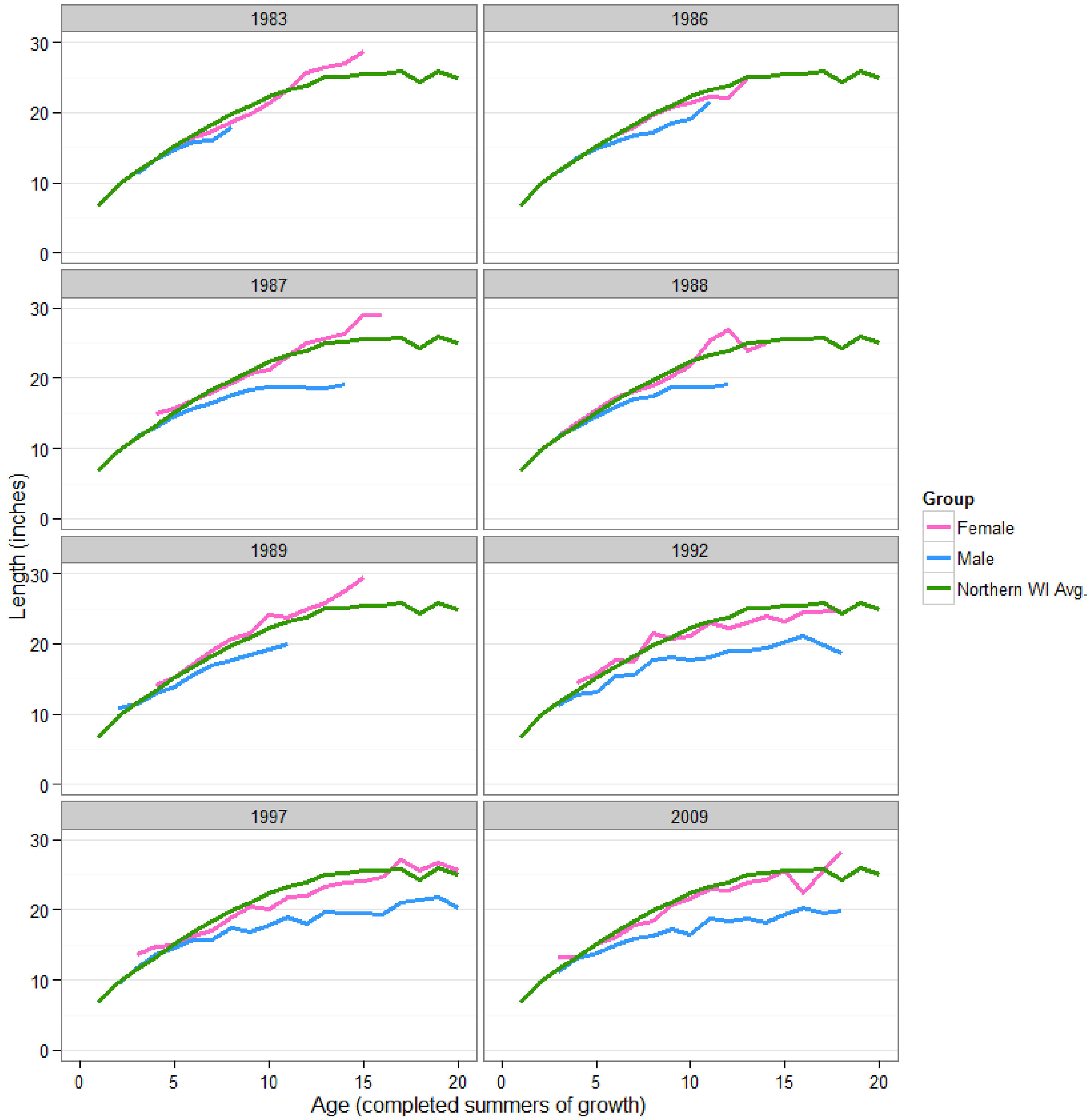

Figure 4. Mean length at age estimates of TFF male and female walleyes compared with Northern Wisconsin averages.

Mortality and Exploitation

Table 4 summarizes mortality work (estimated by catch curve analyses from age frequencies) completed on TFF walleyes. Total annual mortality (*A*) estimates from age-4+ male and female walleye (genders combined) were 53% in 1989 and 35% in 2009. For reference, in Escanaba Lake (1967-2007) Nate et al. (2011) found that *A* of age-4+ walleye averaged 50% and ranged from 17 to 76%. Colby et al. (1979) found that *A* ranged from 13-84% for walleye populations in 14 North American lakes and rivers, but was commonly between 40-55%. Due to maturity rates and gear selectivity biases, age-4+ male mortality rates are likely the most accurate in the TFF (100% of male walleye are assumed to be mature by age-4 and therefore vulnerable to fyke netting, whereas 100% maturity of female walleye is likely not reached until several years later). Nonetheless, estimates of *A* for TFF walleye are slightly lower than average when compared with Escanaba Lake, Lake Erie, Oneida Lake, and 14 other lakes and rivers within North America (Nate et al. 2011).

Exploitation (*u*; angling and spearing) of walleye in the TFF has ranged from 9.9-23.9% (16.6% average) during the five Flowage creel surveys (Table 2). In Escanaba Lake (1967 – 2003), *u* averaged 30% (range 9 – 51%; Nate et al. 2011), while exploitation rates from 46 other North American walleye populations had a median *u* rate of 21% with 25^{th} and 75^{th} quartiles of 14 and 25%, respectively (Baccante and Colby 1996 in Nate et al. 2011). When compared with other North American populations, *u* of TFF walleye is also lower than average (similar to mortality). A significant loss in angling quality is expected when *u* rates are higher than 30% (Baccante and Colby 1996 cited in Nate et al. 2011). Annual natural mortality (*v*) of TFF walleye, estimated as the difference between *A* and *u* ($v = A - u$), was 36% in 1989 and 24% in 2009.

In Wisconsin's portion of the Ceded Territory, walleye harvest is managed to prevent annual exploitation (*u* above; from both recreational angling and tribal spearing and netting) from exceeding 35% of the adult population (Schmalz et al. 2011). This level of exploitation is currently deemed sustainable under the assumption that walleye productivity (i.e. recruitment) remains consistent. However, new research on walleye exploitation suggests that a level closer to 20% may be more realistic for sustaining healthy populations and quality fisheries in northern Wisconsin lakes (G. Sass, WDNR, unpublished data). When examining walleye productivity in relation to angler exploitation in Escanaba Lake, Rypel et al. (In press) concluded that the highest sustainable harvest (i.e. maximum sustainable yield) was achieved at an exploitation level of approximately 20%. The adult walleye population (≥ 14 inches) in Mille Lacs Lake, MN, is managed to keep exploitation at, or under, 24% (Deriso 1987, cited by Schmalz et al. 2011).

Table 4. Instantaneous mortality rates (*Z*), total annual survival rates (*S*), and total annual mortality rates (*A*) for male and female walleyes within the TFF.

Year	Gender	Age-Classes	*Z*	*S*	*A*
1983	Male Walleye	3+	0.357	0.700	0.300
1983	Female Walleye	8+	0.400	0.670	0.330
1986	Male Walleye	4+	0.408	0.67	0.330
1986	Female Walleye	5+	0.478	0.62	0.38
1987	Male Walleye	3+	0.343	0.71	0.29
1987	Female Walleye	4+	0.249	0.78	0.22
1989	Genders Combined	4+	0.74	0.468	0.532
2009	Genders Combined	4+	0.431	0.650	0.350
2009	Male Walleye	4+	0.485	0.616	0.384
2009	Female Walleye	4+	0.367	0.693	0.307

In situations where walleye experience sustained levels of high exploitation and/or mortality, common phenomena to observe include: decreased population abundance, increased growth and fecundity (increased gonadal development, i.e. egg production), earlier age at maturity, and highly erratic recruitment (Schmalz et al. 2011). As fish are harvested, food resources per individual increase. This typically results in an improved body condition and increased growth. As a result, fecundity improves, and as long as environmental and biological conditions are favorable, age-0 walleye production is increased. However, if exploitation remains high and adult walleye abundances continue to gradually decline, recruitment success becomes much more erratic and susceptible to failure (due to fewer eggs being deposited and therefore greater vulnerability to mortality). These phenomena were observed in Big Crooked Lake (Vilas County, WI), where adult walleye were subjected to sustained, 35% annual exploitation for 10 consecutive years in an experimental study (Schmalz et al. 2011).

Continued levels of high walleye exploitation have been shown to be unsustainable. In relatively low productivity waters in Alberta, Sullivan (2003) attributed collapses of walleye in some of Alberta's best fisheries to increased fishing pressure and harvest mortality. However, periodic occurrences of relatively-high exploitation followed by low exploitation (which is likely typical in the TFF) is sustainable for walleye populations that have favorable habitat and fish community assemblages (like the TFF). As stated above, exploitation (from angling only) on Escanaba Lake averaged 30% (Nate et al. 2011), however the large variability in the exploitation rate from year to year (range 9-51%), never resulted in a collapse of the walleye population/fishery in this small lake; even after nearly 60 years of no angling restrictions (Escanaba Lake walleye were experimentally managed under a no-minimum length restriction, unlimited bag limit, and no season closure between 1946 and 2003). Both Escanaba and Big Crooked lakes (highlighted above) had relatively high walleye productivity in comparison with other North American walleye populations (Rypel et al. In press). Rypel et al. (In press) theorized that the relatively-high productivity of walleye in Escanaba Lake could be related to the optimal environmental conditions found there (i.e. high availability of preferred habitats, forage base, undeveloped shoreline, etc.).

The TFF, like Escanaba Lake, are rather unique situations where a combination of ecosystem attributes largely favor walleye. As we identified above (in terms of habitat) and below (in terms of fish community dynamics), the TFF appears to contain optimal environmental conditions that have allowed walleye to remain dominant for the better part of a century. In an analysis of walleye productivity in the TFF, WDNR research scientist, Andrew Rypel, concluded that the TFF appears to harbor a "highly productive walleye population" (A. Rypel, WDNR, personal communication). Rypel also went on to say that the TFF may be able to sustain higher rates of walleye exploitation, although he identified that this possibility was based upon too few data points to say it definitively (A. Rypel, personal communication).

Based on walleye exploitation studies, and the variable nature of exploitation (high followed by low, up and down pattern as was demonstrated in Escanaba Lake), we feel that the TFF walleye population can sustain current exploitation levels. Nonetheless, we need to recognize that the average TFF walleye exploitation rate (near 17%) is just under the 20% level that researchers are now suggesting may be more sustainable for northern Wisconsin populations (Rypel et al., In press; G. Sass, unpublished data). The key to sustaining these levels of exploitation, as is the case in any walleye-dominant system, is ensuring that natural walleye recruitment/production remains strong.

Walleye Recruitment, Habitat, and Fish Community Impacts

Fall walleye recruitment surveys have been conducted annually on the TFF since 1984 when the WDNR surveyed six index stations (10 in total, but 4 were in Trude Lake) to assess year class strength. In 1997, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) also began assessing TFF walleye recruitment. The WDNR discontinued the fall survey after 2006 when it was determined that the GLIFWC survey was, itself, sufficient for a reliable assessment. Also of note, during the 1997 fall survey the WDNR index stations resulted in a catch rate approximately four times greater than the total shoreline sample (Roth no date). GLIFWC continues to perform the annual fall recruitment survey on the TFF. Data shown below is from WDNR surveys between 1984 – 1996 and 2004, and GLIFWC surveys between 1997 – 2014 excluding 2004 (reliability was low).

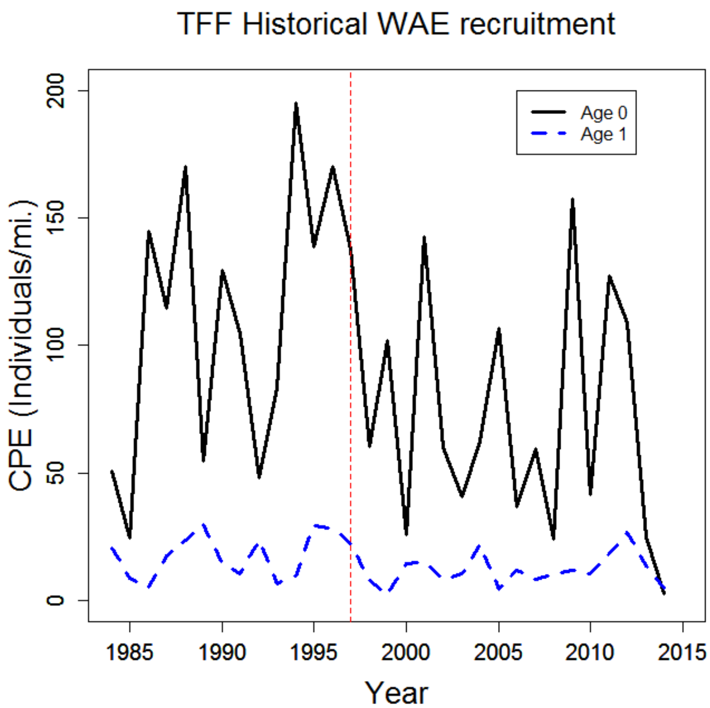

Figure 5. Time series of walleye age-0 and age-1 recruitment on the TFF. The dashed red line denotes the year 1997, which represents the change from DNR to GLIFWC-reported recruitment results (2004 DNR results were used due to low reliability of the GLIFWC survey).

From 1984 – 2014, TFF walleye age-0 and age-1 year-class strength has averaged 88.8 and 14.7 fish per mile, respectively. Catch rates (no./mile) for age-0 and age-1 walleye from lakes classified as "NR" and "C-NR" waters (considered to have the strongest/healthiest walleye populations) have averaged 30.2 and 10.2, respectively (Mark Luehring, GLIFWC inland fisheries biologist, unpublished data).

Although the past two walleye year-classes have been relatively poor as compared to TFF averages, we expect to see strong year-classes in the near future. Strong TFF walleye year-classes have occurred recently in 2009, 2011, and 2012. Variation in year-class strength (strong and poor year-classes) is a common trait amongst the healthiest walleye populations. Nate et al. (2011) found that recruitment (i.e. year-class strength) was the most variable walleye population characteristic when evaluating Escanaba Lake (small in size), Oneida Lake (moderate in size), and Lake Erie (large in size). As stated in the TFF master plan, "Reproduction has never been a limiting factor and has usually been very high." (Turtle-Flambeau Scenic Waters Area Master Plan 1995). We anticipate that this trend will continue in the TFF as long as large-scale habitat (e.g. dramatic increases in aquatic vegetation) and fish community changes (e.g. exponential increases in panfish and largemouth bass) do not occur.

Water Level Impacts

The following data and figures are taken from work that WDNR Sawyer County fisheries biologist, Max Wolter, completed in 2013 when examining the relationship between the depth of overwinter drawdowns and subsequent age-0 catch rates observed the following fall (Wolter, unpublished). Results from the 2013 analysis pertaining to the TFF were recreated here with permission from Max Wolter.

Between 1984 and 2012, the average overwinter drawdown depth on the TFF was 4.0 feet. Water level drawdown depth shows no consistent pattern or trend, and the minimum and maximum depths over the study period were 1.6 and 7.7 feet, respectively (Figure 6).

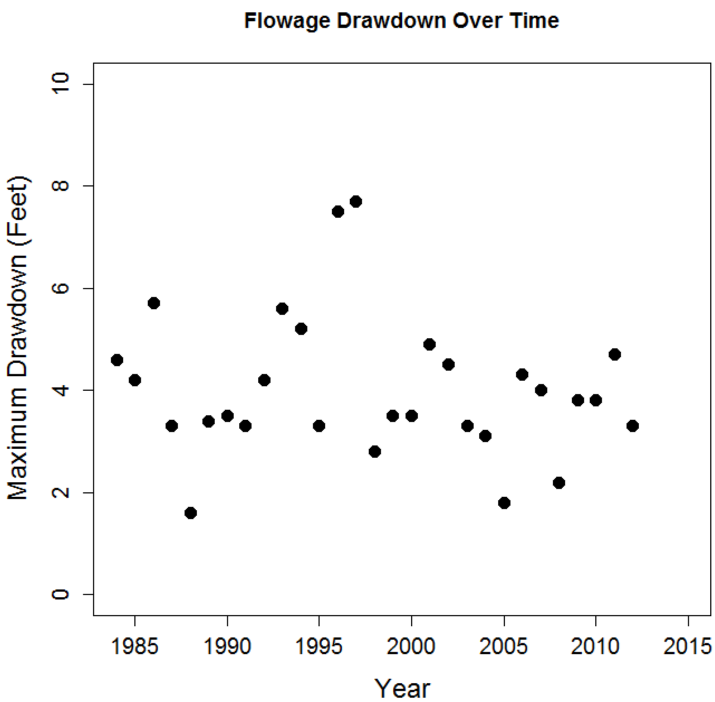

Figure 6. TFF overwinter, maximum water level drawdown depth, 1984 – 2012.

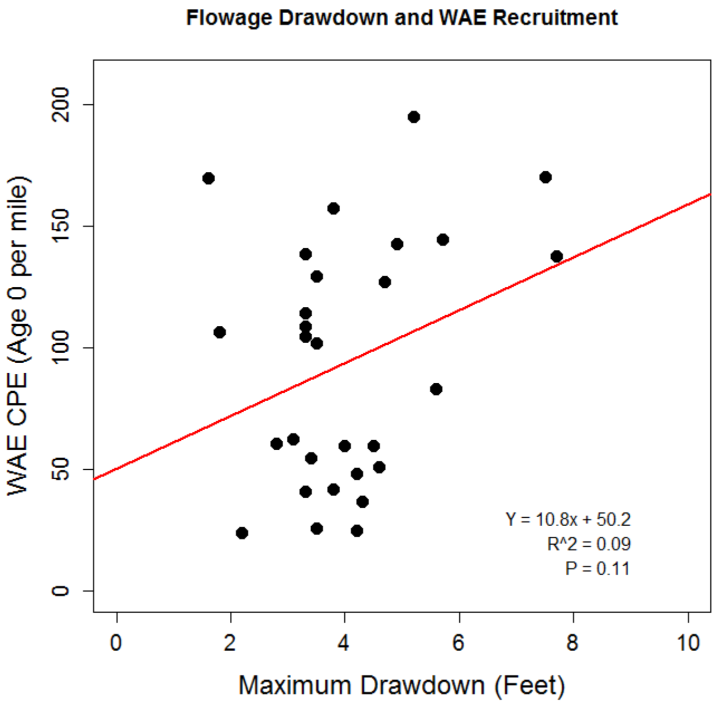

Figure 7. Relationship of age-0 walleye catch rate (no./mile) with overwinter, maximum drawdown level in the TFF.

There is a positive (although statistically insignificant) relationship with TFF age-0 walleye relative abundance and the preceding overwinter, maximum water level drawdown depth (Figure 7). Although many factors influence age-0 year-class strength (not simply drawdown levels), these data suggest that greater overwinter drawdown levels are not a hindrance to walleye year-class strength in the TFF, and may even be beneficial. Water level drawdowns aid in maintaining clean walleye spawning substrates through accelerated decomposition of accumulated organic matter, flushing and/or scouring by water and ice during wave activity and refill.

Spring refill levels have been shown to influence recruitment success of walleye. In an analysis of northern Minnesota lakes (including Rainy Lake), Kallemeyn (1987) found that higher lake levels in the spring significantly correlated with age-0 walleye year-class strength in three of the four lakes studied. Kallemeyn went on to recommend that the water management plan be changed for Rainy Lake, such that lake water levels met, or exceeded, a height close to the upper level of the targeted range in the spring (1987). This would ensure that optimal spawning habitat was accessible to walleyes. In this same study, Kallemeyn (1987) also found that higher lake levels were positively correlated with age-0 yellow perch abundances.

Fish Community Impacts

Walleye are native to the TFF, and they appear to have been a dominant member of the fishery since the late 1930s or early 1940s (Hittle, unpublished manuscript). Relatively-high abundances of walleye are produced through strong, naturally-reproduced year-classes. Stocking has not occurred since 1994 and in years where stocking did occur, it likely contributed little to the population. Abundant walleyes express predatory control on other species, especially young panfishes. This typically results in a quality panfishery; one that is characterized by relatively low numbers but an above average size structure. This exemplifies the panfishery in the TFF (Eslinger et al. 2013, Creel Survey Report 2010, Roth and Neuswanger 2007, 1997-98 DNR Creel Survey Synopsis – unpublished data, Turtle-Flambeau Scenic Waters Area Master Plan 1995, 1992-93 DNR Creel Survey Synopsis – unpublished data, DNR treaty assessment lake survey report, Lealos and Bever 1982).

Panfish numbers and size are good indicators of the relative strength of the walleye population. If TFF walleye numbers remain strong, panfish populations should remain at low abundances but of quality size. However, if walleye numbers begin to falter for a sustained length of time, panfish abundances may increase and their average size will likely decrease. In the following paragraphs, we discuss predominant fish species found within the TFF along with their likely relationship with respect to walleye recruitment.

Yellow Perch

Many of North America's best walleye fisheries (especially those in the northern portions) typically also contain strong yellow perch populations (e.g. Red Lakes, MN (Smith and Pycha 1960), Lake Erie (Parsons 1971), and Oneida Lake, NY (Forney 1974)). The peak of yellow perch spawning follows that of walleye (Herman et al. 1982). As a result, yellow perch fry become a critical source of food for young walleyes as soon as they begin eating fish, which can begin within a couple weeks of hatching. In Escanaba Lake, 71% of age-0 walleyes under 15-mm (0.6 inches) had eaten fish, and an 11-mm (0.4 inch) walleye was found to have eaten a 7-mm (nearly 0.3 inch) perch (Engel et al. 2000). This important predator-prey relationship continues throughout the walleye life-cycle. In an analysis of 23 New York waters, Rudstam et al. (1996) found that high walleye abundances limited perch recruitment through predation, which resulted in accelerated perch growth rates. This phenomenon (low adult perch abundances but a quality size structure, resulting from high rates of walleye predation) has been occurring in the TFF for many years (evident in yellow perch creel statistics below).

Annual age-0 production of yellow perch in the TFF, although unknown, is assumedly high in most years. However, high mortality, primarily through walleye predation (and other predators), most likely limits the number surviving to larger sizes. Two TFF diet studies (conducted in 1989 and 2012), which characterized walleye dietary preferences, found that fish were the primary food type consumed. In the 2012 study, age-0 yellow perch were the predominant fish type found in walleye diets throughout the study period (June – October; Eslinger et al., unpublished). In 1989, fisheries biologist at the time, Dennis Scholl, reported that age-0 yellow perch "seemed to disappear" from walleye diets in the later part of the study (personal communication). Perch were likely no longer readily available, so walleye underwent a dietary shift to more abundant prey, resulting in higher proportions of crayfish observed in diets (Eslinger et al., unpublished). Coincidentally in 1989, age-0 fall walleye recruitment was the lowest it had been on the TFF in four years (and significantly below the long-term average). Management strategies directed at maintaining/enhancing yellow perch spawning success may help to ensure persistence of strong walleye recruitment in the TFF.

Creel surveys are the best indicator of yellow perch population trends available for the TFF. Specific catch rates (number of hours it takes to catch a fish by anglers targeting them) of yellow perch were 3.4 hours in 1975 (open water creel only; maximum rate – only includes effort where anglers caught fish), 3.1 hours in 1989 (open water creel only), 5.6 hours in 1992, 1.7 hours in 1997, and 2.8 hours in 2009. These catch rates are all indicative of a relatively low density population. The average length of harvested yellow perch in the five respective creel surveys was 9.4, 10.2, 9.7, 9.9, and 9.5 inches; these average lengths are also indicative of relatively low numbers with good growth.

Walleye

Walleye are known to be cannibalistic (eat their own young; documented in the 2012 TFF diet study, Eslinger et al., unpublished) and/or limit themselves through competition for available resources. In fact, they may be one of North America's most cannibalistic freshwater species (evidenced from the following studies). In Escanaba Lake between 1958 and 1996, age-5 and older walleye were the primary factor influencing age-0 recruitment; suggesting higher numbers of adult walleyes resulted in fewer recruits, presumably through cannibalism and/or increased competition (Hansen et al. 1998). This finding compliments results from Oneida Lake, NY (a 51,000+ acre lake where walleye are the most popular sport fish), where low walleye recruitment was most attributed to predation from older, larger walleye (Forney 1976). In another study, Forney concluded that high abundances of young yellow perch likely buffered the rate of cannibalism amongst walleye (Forney 1974).

Even in the healthiest walleye fisheries it is common to see a strong walleye year-class followed by a poor one. Li et al. (1996) found that stocking to supplement natural reproduction resulted in decreases in the abundance of adjacent year-classes. They speculated that increased competition for limited prey resources and cannibalism likely played a role in shaping adjacent, poor year-classes (Li et al. 2011). This phenomenon undoubtedly also occurs between strictly naturally-reproduced year-classes, and likely explains the oscillating pattern in TFF age-0 walleye recruitment (strong year-classes followed by poor ones; Figure 5). This highlights the importance of abundant forage to mitigate competition among young walleyes; exemplifying the importance of young yellow perch in supporting the TFF walleye population.

Largemouth and Smallmouth Bass

There is speculation that largemouth and smallmouth bass may inhibit age-0 walleye recruitment through predation. Published literature suggests largemouth bass are much more likely than smallmouth bass to prey on young walleye (Neuswanger 2009). Two TFF diet studies (previously mentioned) found that smallmouth bass do not significantly prey on young walleye (Eslinger et al., unpublished). In the 1989 and 2012 studies, crayfish accounted for 68.7 and 83.9% of the total prey volume found in smallmouth bass diets, whereas fish accounted for only 11.8 and 11.2%, respectively (Eslinger et al., unpublished). In Big Crooked Lake, Vilas County (another lake that typically contains high abundances of age-0 walleye recruits), no smallmouth bass (sample size = 303) consumed walleye (Frey et al. 2003). In the 2012 TFF diet study, there were zero walleye found in the 113 smallmouth bass stomachs examined (Eslinger et al., unpublished). In an analysis of 208 northern Wisconsin lakes, Fayram et al. (2005) found no significant, negative relationship between walleye and smallmouth bass. Although TFF smallmouth bass abundances are relatively high (discussed below), and they undoubtedly eat an occasional young walleye, smallmouth bass predation is not inhibiting TFF walleye recruitment to any significant extent. Largemouth bass abundances remain at very low levels in the TFF.

TFF smallmouth bass abundances have increased over the past two decades. Catch rates (no./hour) of smallmouth bass were 2.9 in 1989 and have now increased to 33.4 in 2012. This increasing trend is also observed in the TFF creel surveys. Largemouth or smallmouth bass creel statistics were not even reported during the 1975 survey (Lealos and Bever 1982), indicating very low abundances of both species. Specific catch rates (number of hours it takes to catch a fish by anglers targeting them) of smallmouth bass were 5.0 hours in 1989 (open water creel only), 7.7 hours in 1992 and 1997, and 2.2 hours in 2009. Largemouth bass specific catch rates were only reported in 1997 (11.1 hours) and 2009 (12.5 hours). The large increase in TFF smallmouth bass abundances does raise speculation about potential competition between walleye and smallmouth bass. This was one of the reasons the 2012 diet study was conducted (Eslinger et al., unpublished).

In an analysis of interspecific competition between smallmouth bass and walleye in 2012, dietary overlap between the two species was very low (Schoener index value = 0.18; where 0 indicates no overlap and 1 indicates complete overlap (Schoener 1970); Eslinger et al., unpublished). However, in the 1989 study, dietary overlap was relatively high between the two species (Schoener index value = 0.64; Eslinger et al., unpublished). This was largely the result of walleye preying on greater proportions of crayfish during 1989, which is atypical. Most walleye diet studies identify fish as a primary food source and document lower proportions of invertebrates. The 1989 diet study results were likely influenced by poor yellow perch production that year (see yellow perch paragraph above). These results suggest that depending on annual age-0 perch production, competition between walleye and smallmouth bass (and other walleye competitors discussed below) can either be minimal or extensive from year to year. Regardless, a more liberal bass angling regulation for the TFF has been proposed with one intention being to decrease bass abundance (if approved this regulation would be implemented in 2016).

Northern Pike

Many studies have shown that northern pike diets are largely comprised of fish (Johnson 1969), and yellow perch have been found to be a primary forage species (Diana 1979; Soupir et al. 2000, Seaburg and Moyle 1964). In addition, pike have been shown to prey upon walleyes (Lawler 1965). Since young walleye and perch have a similar body shape, pike will likely also prey on walleye if given the opportunity. Of the species discussed here, pike are the only one that spawn prior to walleye. As a result, pike have a distinct advantage when it comes to competition with, and potentially predation upon, young walleyes. In an analysis of 120 northern Wisconsin lakes, Nate et al. (2003) found that in lakes containing high largemouth bass and northern pike densities, the ability of walleye to be self-sustaining (through natural reproduction) was inhibited.

Northern pike abundances appear to have been relatively high in the TFF for quite some time. Pike likely retain the distinction of being the second most common gamefish species documented in the 1997 survey (Roth no date). Density estimates of pike in the TFF were reported at 1.6 per acre in 1975 (Lealos and Bever 1982) and 1.9 per acre in 1997 (Roth no date). In a 2011 early-spring netting survey, pike were captured at a rate of 7.1 per net-lift in targeted net sets (14.3 during the first four days of the survey when pike were closer to the peak of their spawn; Eslinger et al. 2012). In TFF creel surveys, northern pike specific catch rates (number of hours it takes to catch a fish by anglers targeting them) were 5.9 hours in 1975 (open water creel only; maximum rate – only includes effort where anglers caught fish), 1.5 hours in 1989 (open water creel only), 3.2 hours in 1992, 1.8 hours in 1997, and 2.0 hours in 2009. These findings suggest that northern pike are likely the biggest competitor of walleye within the TFF. TFF pike regulations are the most liberal WDNR rule options available (no minimum length limit, daily bag of five fish).

Black Crappie

High abundances of black crappie have also been speculated to limit recruitment of walleye in some northern Wisconsin lakes. However, supportive literature to substantiate this theory is somewhat limited. In Black Lake (8,278 acres and shallow; average and maximum depths of 10 and 16 feet, respectively), NY, Schiavone (1983) suggested that large year-classes of black crappie suppressed walleye recruitment by means of competition for available forage fish (primarily yellow perch) and/or direct predation. However, this study did not conduct diet analyses and conclusions appear to be largely based on relative abundances of walleye (decreased) and black crappie (increased) observed in two years of sampling. Schiavone (1983) also recognized that an increase in aquatic vegetation and sedimentation of shoal areas may have occurred within Black Lake, although there is little discussion of how these changes may have affected the fish community. Keast (1968) investigated black crappie feeding habits in Lake Opinicon, Ontario (2,200 acres in size), and found that fish weren't a significant part of crappie diets until crappie were 161 mm (6.3 inches) or larger. Of the larger crappies (> 160 mm), diets only consisted of about 35% fish (mean of the monthly % volumes; Keast 1968). Crappies are limited to the size of fish they can consume due to their relatively small gape size. Gaeta et al. (in prep) found that when crappies do feed on fish, they typically feed on prey about 13% of their length. They also found that of all prey fish observed in crappie diets, 50% were less than 2 inches in length, regardless of crappie size (Gaeta et al. in prep). Although we acknowledge that black crappies undoubtedly consume some young walleyes, they likely don't predate on them to any significant level unless crappie densities reach very high levels (potentially supporting Schiavone's (1983) conclusions). None-the-less, evidence from the literature and past observations from the TFF lead us to believe that crappies do not significantly predate on small walleyes in the TFF (especially if crappie remain at relatively low abundances, see creel survey statistics below). Although, their preference for smaller perch make crappies another potential competitor of walleye.

Creel surveys provide the best indicator of black crappie population trends available for the TFF. Specific catch rates (number of hours it takes to catch a fish by anglers targeting them) of black crappie were 5.3 hours in 1975 (open water creel only; maximum rate – only includes effort where anglers caught fish), 1.0 hours in 1989 (open water creel only), 2.9 hours in 1992 and 1997, and 2.0 hours in 2009. These catch rates are indicative of a relatively low density population, although black crappie abundances may have increased slightly since the 1975 survey. The average length of harvested black crappie in the five respective creel surveys was 11.0, 11.0, 11.3, 11.1, and 11.3 inches; these average lengths are also indicative of relatively low population density with good growth. It should be noted that a 10-inch minimum size restriction was applied on TFF crappie beginning in 1996 along with a reduced panfish bag limit.

Muskellunge

Muskellunge are at too low of abundance levels in the TFF to have a significant effect on walleye recruitment and abundance. High density walleye and muskellunge populations have been found to co-exist in many northern Wisconsin lakes (Nate et al. 2003, Fayram et al 2005). Fayram et al. (2005) concluded that direct predation or competition does not likely occur (to any significant degree) between the two species. Given evidence from the literature and past observations from the TFF, we have no reason to believe that muskellunge are limiting walleye densities in the TFF.

Lessons Learned From the Chippewa Flowage

The Chippewa Flowage (Chip) is a 15,000+ acre reservoir that is similar in many ways to the TFF (e.g. relative size, complex morphology, fluctuating water levels, fish species present). However, contrary to the TFF, the Chip has experienced sustained poor walleye recruitment for the past six years when compared with long-term averages. Knowledge of the factors that may have attributed to the decline in walleye recruitment success in the Chip is beneficial for walleye management in the TFF. The following information is summarized from conversations with WDNR Sawyer County fisheries biologist, Max Wolter. The Chip walleye population has been managed under a no-minimum length limit since 1984. However, given the struggling walleye recruitment, a minimum length restriction has now been proposed.

Like the TFF, the Chip was historically characterized by an abundant walleye population with above average recruitment, relatively slow growth, and a size structure comprised of by large proportions of small fish. Panfish numbers during that time were relatively low, but the quality was high (in terms of the size of the fish). During the late 1990s and early 2000s the Chip experienced significant changes that likely contributed to the walleye recruitment decline. First, water level operations and precipitation patterns changed significantly. Annual overwinter water level drawdowns in the Chip decreased dramatically in 1998 (and subsequent years) from prior levels (Wolter, unpublished). In addition, northern Wisconsin experienced a number of consecutive years of drought conditions. These two occurrences resulted in more static water levels (less fluctuation) on the Chip during the 2000s. This likely resulted in conditions enabling accelerated aquatic vegetation growth. Secondly, invasive Eurasian water milfoil (EWM) was first documented in the Chip in 1991, and by the early to mid-2000s, EWM reached levels which prompted aquatic plant management actions (Olson and Tyrolt 2008). With the more stable water levels, increased plant growth, and walleye recruitment struggles, populations of centrarchids (i.e. panfish and bass – specifically largemouth) increased dramatically. Now, young walleye in the Chip have an even harder time competing for resources, and escaping predation from, other, more abundant fish species (northern pike abundances also appear to have increased).

The WDNR is currently working with area partners to implement strategies designed to bring walleye dominance back in the Chip (e.g. restrictive walleye harvest regulations, stocking, more dramatic overwinter water drawdowns, etc.), with the hopes that walleye recruitment will rebound and good walleye fishing will again be sustained.

TFF Walleye Management Recommendations

1. Continue to manage walleye under the no-minimum length limit. This regulatory strategy has been in place since 1958. Biologically, and sociologically, there is no apparent need to change the no-minimum length limit at this time. This was also recommended in the TFF fishery management plan (Roth and Neuswanger 2007).
    a. If the walleye population exhibits signs of sustained poor recruitment, consider more restrictive regulations to protect young recruits (i.e. minimum length or harvest slot options).
    b. If high harvest and deteriorating size structure of adult walleye is a concern, additional restrictions (e.g. reduced bag limit) in May could be considered (this was also mentioned in Lealos and Bever 1982). The greatest amount of the annual walleye harvest typically occurs in May. Additionally, if recruitment remains strong, a no-minimum but only 1 fish over length restriction could be used to protect the adult stock (the WDNR currently uses a no-minimum but only 1 fish over regulation to manage many high density walleye populations that are characterized by strong recruitment and slow growth).

2. Continue to monitor the adult (biannually) and juvenile (annually) components of the walleye population, as well as angler and tribal harvest. Continue to gather information from TFF guides.

3. Maintain the current water level regime with an emphasis on ensuring refill during the early-spring walleye spawning period. Maintaining the current water level regime is also identified in the TFF Master Plan (Turtle-Flambeau Scenic Waters Area Master Plan 1995).

4. Continue protection of spawning areas through maintaining established fish refuges and ensuring as little disturbance/degradation as possible of other rocky, gravely shoreline areas.

5. Promote age-0 yellow perch production. Techniques to aid spawning success (e.g. spawning habitat enhancement and/or more restrictive length and bag restrictions) could be considered. Methods to assess age-0 perch production could also be explored.

6. Continue to promote liberalized regulations of northern pike and largemouth bass. Recently, the flexibility has been given to fisheries managers to implement separate length and bag limit restrictions between largemouth and smallmouth bass. Although the proposed TFF bass regulation change (proposed in Fall of 2013, anticipated implementation in Spring of 2016) is designed to decrease bass abundances, a more liberal largemouth bass regulation could additionally be proposed to aid in keeping largemouth abundances low.

Conclusions

The TFF has sustained a walleye-dominant fishery, managed under a no-minimum length regulation, since 1958. The walleye fishery continues to be characterized by an above average density, relatively slow growth, and an acceptable proportion of quality-sized fish. Favorable habitat and fish community dynamics have resulted in strong walleye recruitment and production. Current walleye exploitation levels, through angler and tribal harvest, are at sustainable levels; however, they may be near a level that could sacrifice the quality of the fishery. Emphasis on maintaining healthy habitats (e.g. preventing aquatic invasive species and sedimentation of spawning areas) should be promoted. In addition, promoting a favorable fish community for walleye (e.g. strong yellow perch production and discouragement of largemouth bass and northern pike population increases) should be encouraged.

Acknowledgments

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Appendices

Appendix A. TFF walleye population estimate methodology for respective years in which adult walleye abundance has been estimated.

1975 – Chapman's modification of the Petersen estimator for fish ≥ 10.5 inches within the TFF and Trude Lake combined (14,299 acres). Lealos and Bever (1982) presented an estimate of 165,739 walleyes which represented a total population estimate (all length classes included, regardless of maturity). We chose to include only fish ≥ 10.5 inches because we felt that at that length (and above) most of the fish sampled were mature, which made the estimate most directly comparable to current walleye population estimate methods and is most representative of the adult population.

1989 – Chapman's modification of the Petersen estimator for mature fish and unknowns ≥ 15 inches within the TFF (13,545 acres; not including Trude Lake). The DNR treaty assessment lake survey report presented an estimate of 83,619 walleyes which represented all walleye 9+ inches (regardless of maturity). From the 1989 data, we took only the mature fish and unknowns ≥ 15 inches to calculate the estimate we're reporting, which is directly comparable to current adult walleye population estimate methods.

1992 - Chapman's modification of the Petersen estimator for mature fish and unknowns ≥ 15 inches within the TFF (13,545 acres).

1997 – Chapman's modification of the Petersen estimator for mature fish and unknowns ≥ 15 inches within the TFF (13,545 acres).

2009 – Chapman's modification of the Petersen estimator for mature fish and unknowns ≥ 15 inches within the TFF (13,122 acres).

Appendix B. TFF walleye stocking history.

Year	Number	Size
1938	1,255,755	Fry
1939	1,680,000	Fry
1940	2,980,500	Fry
1941	3,000,000	Fry
1942	5,897,101	Fry
1943	986,000	Fry
1944	1,650,000	Fry
1950	34,815	Fingerling
1952	17,900	Fingerling
1953	17,900	Fingerling
1956	9,100	Fingerling
1980	896,000	Fry
1982	3,779,449	Fry
1983	4,918,176	Fry
1991	4,000,000	Fry
1992	200,000	Fry
1994	200,000	Fry

Appendix C. The declared quota and subsequent TFF tribal spear harvest, percentage of the quota filled, and percentage of the TFF harvest relative to the entire Ceded Territory (WI) tribal harvest total, 1985 – 2014.

Year	Declared Quota	Spearing Harvest	% Quota Filled	% TFF Harvest to Total CT
1985	N.A.	21	N.A.	1
1986	2987	2560	86	37
1987	5974	5741	96	27
1988	6863	6056	88	23
1989	0	0	N.A.	0
1990	5531	5048	91	20
1991	3511	3341	95	15
1992	2276	2147	94	10
1993	3970	3212	81	13
1994	4637	3856	83	15
1995	2540	2488	98	8
1996	3792	3197	84	11
1997	2427	2172	89	9
1998	2676	2262	85	8
1999	3161	2314	73	9
2000	3100	3100	100	10
2001	2441	1063	44	5
2002	2525	1732	69	7
2003	2485	1761	71	6
2004	2538	1847	73	7
2005	2502	1906	76	7
2006	2500	1871	75	7
2007	2500	2470	99	8
2008	2480	1880	76	7
2009	2455	1792	73	6
2010	2655	1665	63	5
2011	4820	4569	95	15
2012	2420	2157	89	7
2013	3531	3132	89	11
2014	2583	2158	84	8
Averages	**3334**	**2673**	**83**	**11**

Appendix D. TFF daily angler bag limits for walleye, 1985 – 2014.

Year	Angler Bag Limit
1985	5
1986	5
1987	5
1988	5
1989	5
1990	3
1991	3
1992	3
1993	2
1994	2
1995	2
1996	2
1997	3
1998	3
1999	3
2000	2
2001	3
2002	3
2003	3
2004	3
2005	3
2006	3
2007	3
2008	3
2009	3
2010	3
2011	2
2012	3
2013	2
2014	3

*Daily walleye bag limits prior to 1985 were 5 (at a minimum).

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