Summary of Activities

Date: November, 2016

To: Ian Kitch
Manitoba Sustainable Development

From: Holly Urban, Brock Koutecky & Megan Paterson - Swan Valley Sport Fishing Enhancement Technical Staff
Contact: svsfe@mymts.net

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

---

Location: Beaver Lake, Duck Mountain Provincial Park, 14U 373176 5740308

Background Info: Beaver Lake has been a project lake for SVSFE and Manitoba Sustainable Development – Fisheries Branch since the 80s and has a long management history with limited success regarding different fish species introductions. Historically, Beaver Lake had been solely a northern pike fishery. In 1982, a decision was made to stock 200,000 walleye fry. By 1987, because of limited walleye success, the Beaver Lake Reclamations Project was initiated and all rough fish were removed through chemical reclamation. The lake was then managed as a trout fishery through the 90s and 2000s, primarily stocked with rainbow trout, followed by splake introductions in the 2000s to address the raising perch populations. Following a decline angling quality and low catchments of trout in SVSFE's 2010/11 trout assessments, a new management plan was initialized when lake managers decided to stock adult walleye and closely monitor success.

Since 2011, SVSFE, Fisheries Branch and partners have stocked adult walleye on a annual basis via the "Beautiful Lake Walleye Transfer"(Table) and initiated a protected slot regulation (45-70cm) with lower limits (2) on the lake in 2014, after high angling quality & pressure was exhibited on the walleye fishery. In addition to Beautiful Lake walleye, mature walleye from North Steeprock Lake were transferred on Oct 22, 2013 in efforts to enhance the number of mature walleye within the population. Unfortunately only two walleye were captured during that time. We refer to them as Waldo (FL of 503mm) and Wilma (FL of 630).

Beaver Lake Walleye Stocking		
Year	Stocking	Average Size
2011	548	345
2012	90	276
2013	882	175
2014	737	244
2015	865	322
2016	1916	170
Total: 5,038		

Figure: average walleye transferred from Beautiful Lake in 2011

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

In 2013 it was recognized that Beaver Lake lacked suitable walleye spawning habitat and therefore funds were acquired from Recreational Fisheries Conservation Partnership Program (RFCPP) to create two artificial spawning shoals to facilitate successful walleye recruitment. The support from partners to undertake this project far exceeded expectations and enhanced 1050m^2 of habitat in the winter of 2014. Unfortunately the rock which was delivered to Beaver Lake for the shoal creation consisted of a much higher percentage of large rock than anticipated, resulting in two rock structures (spawning shoals) not ideal for egg deposition and survival. SVSFE tried to remain optimistic during monitoring, but lack of recruitment success and literature support the need for future "tweaking" by adding smaller diameter rock to the shoals.



Since 2012, SVSFE has been monitoring walleye populations, spawning, survival, growth rates, stock response, natural recruitment success and angling quality through various projects. The primary objectives were to 1) evaluate stocking success and 2) evaluate the level of natural recruitment. The data would help support the management objective of creating a small, semi-remote, self-sustaining walleye fishery that would require little to no supplemental stocking in the long term.

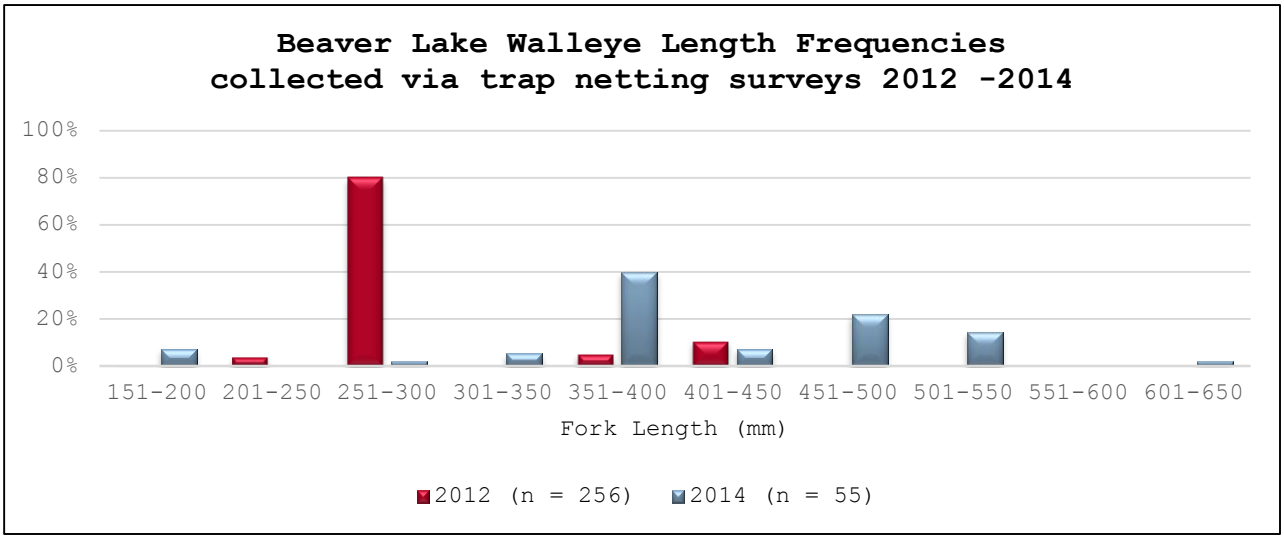
In 2012, SVSFE initiated a condensed version of the End of Spring Trap Netting (ESTN) program which was referred to as "Mission Walleye". The program was developed to quantify the survival of walleye transferred from Beautiful Lake. Results indicated high survival of walleye from the 2011 planting, with 80% of the walleye measuring between 250-301 mm. Only 16% of the larger fish >300mm which were the "average sized" stocked in 2011 were observed. Seining results indicated a variety of forage but zero walleye recruitment, which was expected (See Prj 11-035 Integrated Fisheries Assessment #2).

2013 was limited to recruitment surveys via seining. This year marked the only successful recruitment over the past five years. At that time it was estimated that the lake had a moderate population of walleye over 450 mm as walleye transferred from Beautiful Lake in 2011 were averaged 345 mm at the time of stocking, therefore the handful of mature walleye did exceptionally well. "The fact that young of the year walleye were found … is truly encouraging". Remarkably, 2013 displayed the highest angling quality of all years, displayed through recapture submissions. (See FEF Project 12-042 Evaluating The Success of Walleye Recruitment)

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Following the shoal creation, SVSFE replicated the "Mission Walleye" trap netting program in 2014 with the addition of a full spawn assessment on the shoals (Figure). Population estimates calculated 571 individuals with minimal signs of recently stocked walleye (882 in 2013). These numbers were much lower then anticipated indicating low survival of fingerlings. It was encouraging, that 39% of walleye were found within the protected slot of 450 – 700mm suggesting a growing, mature and now protected population. Walleye also displayed significant levels of growth (average of 44mm and 202g per year).



Again, no signs of recruitment and no indication that walleye were utilizing the reef during spawning periods. Interestingly, in 2014 the lake experienced a large increase in water levels (raising levels up 70cm) due to a beaver dam blow out on one of the connected tributaries. Rising waters levels may have contributed to poor recruitment but this "blowout" then made once unsuitable and inaccessible creek habitat, suitable and available to fish. SVSFE found white suckers to be utilizing the creek for spawning along with other forage species. Suggestions following 2014 assessments were to continue natural recruitment success surveys as the walleye continually mature. It was also determined that there is a need for more information on angling pressure, quality, and harvest (See Integrated Walleye Enhancement Project FEF Project 13-063).

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Annual recruitment surveys between 2012-2014 were reserved to beach seining. When it comes to Beaver Lake, there is limited beach areas and really only one "seinable" location. Other sites have been surveyed but woody debris, soft substrate and steep drop-offs made seining very difficult. Also with the creation of the shoals, the one seinable site now contained various boulders/cobble.

Therefore in 2015, as a attempt to fish an un-seinable area and further understand if natural recruitment was occurring, one fine mesh trap net was set for a duration of 21 hours. Results were again negative and the method deemed unsuccessful for collecting age 0+ walleye where larger walleye are present. A very significant catchment (n=63) of 2+, or 3+ walleye were captured instead. These fish were from previous sub-adult stocking in 2013 and 2014. This confirmed fair survival of recently stocked walleye. Unfortunately, only one walleye was of larger size (>450mm) which raised some concerns. As we know, one trap net is not representative, and further investigates were necessary.

From there, SVSFE introduced a new method of collection to Beaver Lake. In early September, 2015, Eastern Regional Biologist, Ken Kansas suggested creating a replicable fish inventory survey while at the same time assessing natural recruitment in Beaver Lake. This method utilizes a Smith-Root electrofishing boat and consisted of electrofishing five transects for approximately 500 seconds (Figure). Every fish (small and large bodied) was collected for non-lethal sample. Walleye were measured and rough fish/forage were strictly counted. The five random transects chosen were designed to exhibit a full habitat representation. Unfortunately, no YOY walleye were discovered. In terms of adult/sub-adult walleye a total of 38 fish were captured equating to a CPUE of 52.76 fish per hour shocking. Of these fish, the mean length was 294 mm, and only one fish was in the designated protected slot at 480 mm. In terms of forage, it appeared that Beaver Lake was extremely healthy with a perch CPUE of 952 fish/hour shocking. Many age classes of white sucker and yellow perch were discovered, along with presence of longnose dace and fathead minnows.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

For the second consecutive year, SVSFE was unsuccessful in finding natural recruitment in Beaver Lake. It was hypothesized that the reasoning behind this was lack of a mature walleye due to high angling mortality. Through methods of trap netting and electrofishing in 2015, SVSFE captured a total of 102 adult walleye and only 2% of these fish were deemed protected under current regulations. Suggestions were to continue to stock adult (larger) walleye through the Beautiful Lake Walleye Transfer, monitor fishing quality through voluntary creel surveys, and continue low effort recruitment assessments for the next few years.(See FWEF Project 15-036 IFAMM).

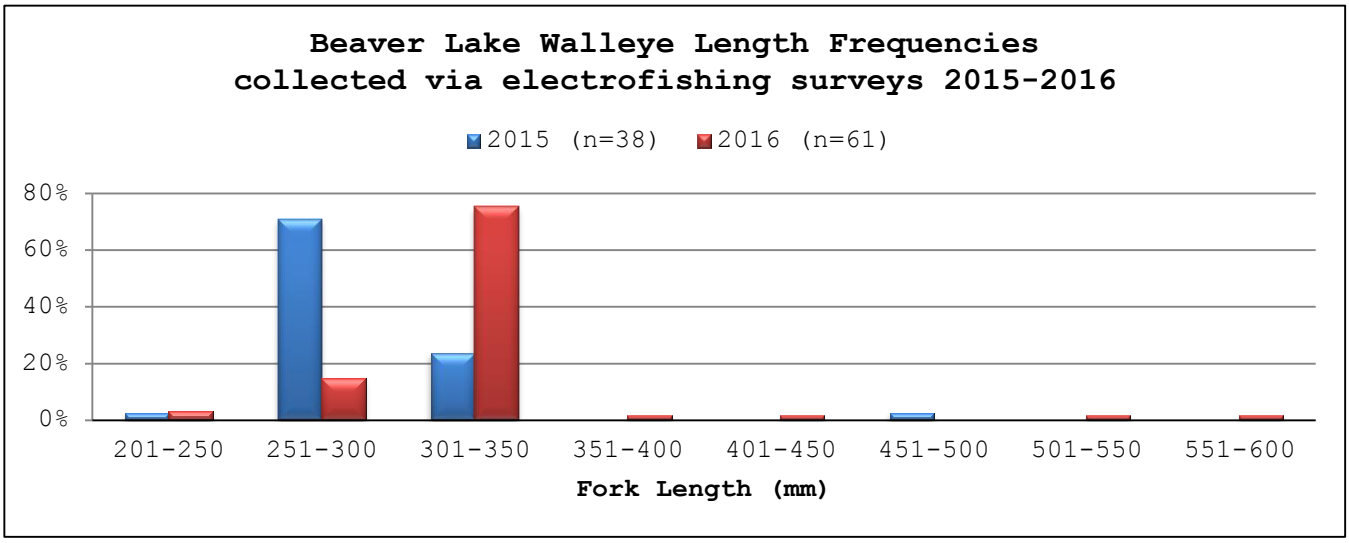
Figure: Beaver Lake Electrofishing Sites (2015, 2016)

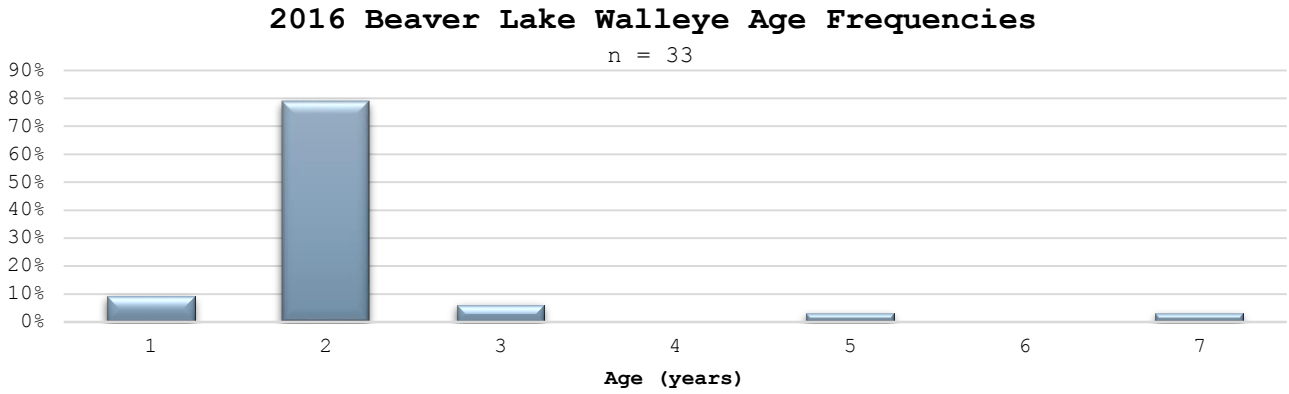
2016 Electrofishing Results: On the evening of September 13th, 2016, SVSFE was capable of replicating 2015 electrofishing surveys on Beaver Lake in efforts monitor walleye abundance and recruitment. Again, walleye and white suckers were measured, and forage (YLPR and darters) were counted. Unfortunately, no YOY walleye were located. It is important to state that water conditions during the last transect (#5) of the night presented unfavourable conditions for electrofishing which may have caused a source of error. Electrofishing catch rates are highly dependent on water temperature, water clarity, and weather (Ward, 2014).

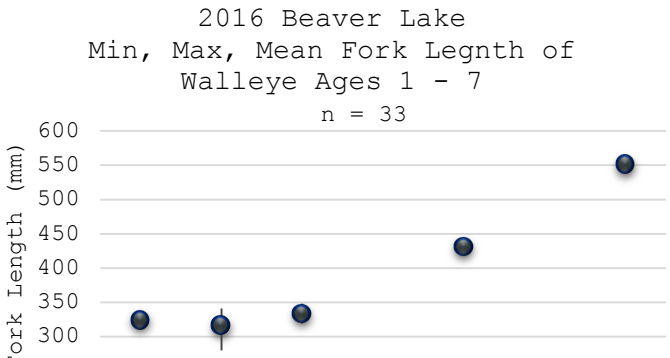
In terms of adult/sub-adult walleye a total of 61 were captured equating to a CPUE of 77.9 fish per hour shocking, up significantly from 2015. Of these fish, the mean length was 325mm, and only two fish were in the designated protected slot(541mm, 551mm). Again, results indicating high catches of recently stocked walleye but no significant sign of larger walleye. Population estimate (Chapman-Peterson Model) indicated 511 walleye (pre-2016 stocking) with a 95% confidence that the true number lies between 69 and 954. Comparative figures from 2015 and 2016 can be viewed on the following page.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment







	1	2	3	4	5	6	7
Min	312	280	319		431		551
Max	336	341	348		431		551
Mean	324.3	316.2	333.5		431		551

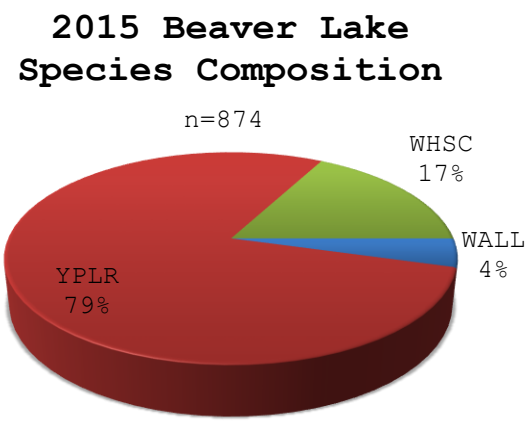
During past walleye transfers, not all fish stocked in Beaver Lake were tagged. This practice was initiated to decrease handling and stress to the fish. In order to further validate successful plantings, age structures were collected from walleye which were not previously sampled or tagged (n=33). Results indicated age 2 as a strong year class. These fish could be yoys or 1+ walleye from 2014 or 2015 transfers, respectively. The oldest walleye was aged at seven and well within the protected slot.

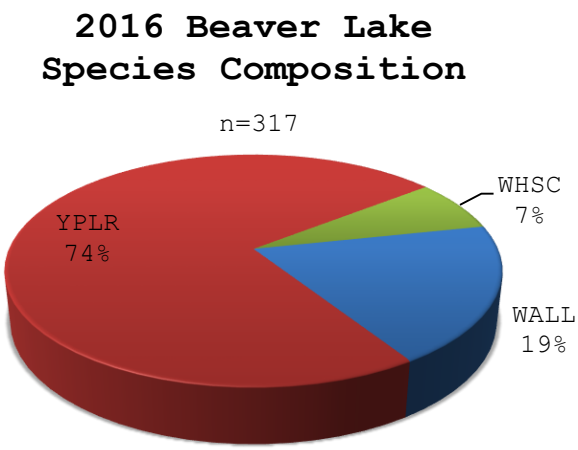
Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Fish CPUE (fish/hour)		
	2015	**2016**
WALL	52.8	77.9
WHSC	208.3	29.4
YLPR	952.4	297.4
FORAGE	5.6	2.7

While total catches were down from the 2015 levels, the species composition remained fairly consistent with a slight shift in walleye and white sucker compositions. The CPUE of forage both in yellow perch and minnows is down considerably. The diversity of minnow species has also shifted from 4-6 different species found between 2012-2015, to one (johnny darters) collected in 2016. One should not too many conclusions from this as evaluations of diversity was comparing all methods of collection over the years, where 2016 was limited to electrofishing only, but is worth noting.





Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Discussion: At current, SVSFE has a very large database on Beaver Lake collected through various surveys including, 2010-2011 stocked trout assessments, 2011-2016 sub-adult/adult walleye stocking records, spring trap netting for 2012 & 2014, 2014 spawn assessments, 2012-2015 seine catches, 2015 trap-netting (fine-mesh to evaluate recruitment), 2015 & 2016 electrofishing, along with voluntary creel information from anglers. Through various monitoring and stocking we are that much closer to understanding the lake's dynamics to further develop long term plans. After further analysis of the fish community in Beaver Lake there are some trends worth discussion.

The 2012 & 2014 trap netting programs suggested a high stocking success of initial stocking, with reasonable growth and a population estimate of 571 individuals. With regards to 2015 and 2016 electrofishing SVSFE found very similar results with high success in the recent (2014 & 2015) stocked walleye and a population estimate of approximately 511 walleye. Interestingly, both two year studies found low numbers of fish with length frequencies >450mm (protected slot frequency), following five years of annual advanced fingerling and sub-adult/adult walleye stocking. In regards to natural recruitment, success is far from ideal but is partially expected after evaluating the circumstances faced. Recruitment is the most variable and most influential vital rate for many fish populations (Ricker 1975). Again, the only recruitment was seen two years (2013) after introductions, indicating survival of mature fish. 2013 also displayed the highest return in recaps indicating high angling pressure prior regulation changes.

Source of error is always a consideration when looking for trends. It was hypothesized that recent electrofishing surveys may not be targeting/locating larger walleye which are actually present. Samplings methods have varied over the years and all methods have limiting factors and bias to selectivity. It worth stating that electrofishing targets fish within littoral areas at a certain point in time, where trap netting targets fish in the littoral area of a particular site for 22-24 hours of a day. In contrast, electrofishing is not selective to fish size as is trap netting, which also a passive method relying on fish to swim into the net. Both methods have limiting factors therefore a combination of sampling methods over time will compliment each other and provide the most accurate evaluation of the fish community.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Discussion cont'd: There are many limiting factors which can contribute to slow establishment of a walleye population and walleye recruitment. These include:

1) Angling Pressure. When walleye were first introduced to Beaver lake, the limits fell under the Duck Mountain regulation which is a limit of four walleye with only one exceeding 55 cm. SVSFE aimed to offer an alternate walleye fishery in the Ducks where anglers could "catch their dinner" and take pressure off other walleye lakes. What wasn't expected was the instant angling success from introducing sub-adult fish and the pressure received within the first two years. MNDNR (2016) states, "not only are more anglers spending more time at their sport, they also are better educated in their fishing techniques and better outfitted". In 2014, a regulation change was imposed with a limit of two walleye with all fish between 45-75 cm to be released. This regulation change may have been three years too late, compromising the initial stocking success of larger walleye.

2) Stocking Rate – "Adjusting stocking levels up and down are necessary. The goals of these manipulations is to find the appropriate stocking levels that increase or maintain healthy walleye populations. Simply put, stocking a lot of small fish does not guarantee catching a lot of big fish" (MNDNR, 2016). Stocking frequency also influences stocking success. "Walleye stocked or hatched one year (called a year class) will eat much of the food needed by the next year class. This phenomenon is called year class suppression" (MNDNR, 2016). With Beaver Lake being a lake of only 20.5 hectares and only 6.9 hectares of that being littoral area, improper stocking rates could limit resources and cause high levels of intra-specfic competition. The initial planting of walleye appeared to proliferate, which was foreseeable. They were the top predators with unlimited forage for the taking. The average stocking rate between 2011-2015 was 624 walleye stocked annually. Some stocking years displayed fair survival where others, specifically the 2013 planting of 882 walleye showed low survival. These fish were too small for anglers to harvest them prior to the 2014 trap netting assessment, therefore illustrating high mortality or density-dependent limitations. Many challenges could of caused this decline in survival including, stress during transfer, size of stock, competition or year class suppression. The degree of success/failure of the most recent stocking, in 2016 of 1916 walleye should be closely monitored. This could compare survival of smaller walleye (170mm) at different rates, with different handling practices during transfer (2013 yoy walleye were fin clipped versus no marking of 2016 yoy walleye). In hindsight, following data analysis, concluding estimated populations of ~500 from two different surveys, stocking at this rate may be ineffective. Time will only tell.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

3) Lake suitability – Scott and Crossman 1973 state, "walleye are tolerant of a wide range of environmental conditions but are generally most abundant in moderate-to-large lacustrine (> 100 ha)". Where Hartman 2009 states, "Suitable lakes are usually ≥ 400 ha, with large littoral zones. Adult walleye prefer shallow areas over rock and gravel shoals, and occur at depths from 1 to 15 m. Habitat requirements for juvenile walleye are similar to those of the adults once they leave the shallows". Several models have been developed to predict probability of successful introductions. Bennett and McArthur 1990, found that four physical variables - area, maximum depth, pH, and date the impoundment was formed - were significant in determining stocking success. Ellison and Franzin 1992, found, "Factors that governed the success of walleye plantings were food availability, temperature, weather, and predation.

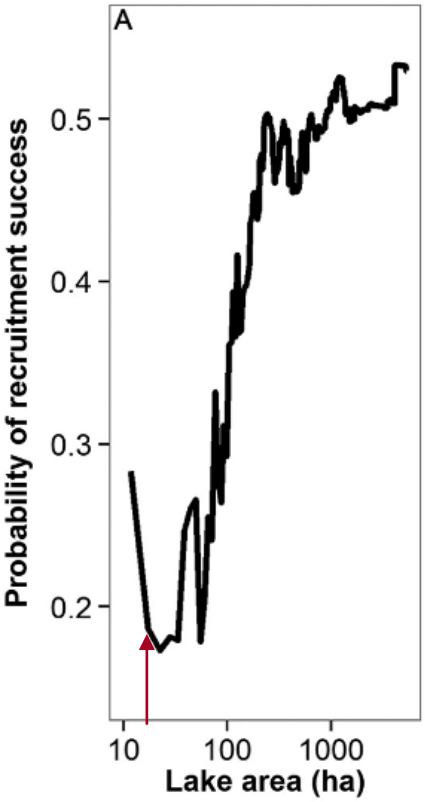
Walleye being tolerant to environmental condition provides some confidence but available space in Beaver Lake may pose challenges. Space is a basic condition that any living organism requires to survive. Space will limit the carry capacity of the populations, available habitat for fish development and the number of fish available for harvest. Again, interestingly, regardless of adult/sub-adult stocking, population estimates remained very similar over the four year period. Perhaps, this is the carrying capacity of Beaver Lake.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

4) Limiting factors on recruitment – As acknowledged previously, spawning habitat is limited in Beaver Lake. Another factor under review is conditions which effect recruitment. Most recently, Hansen et al 2015, developed a final model which classified recruitment success based on lake surface area, water temperature degree-days, shoreline development factor, and conductivity. The model classified walleye recruitment with 81% accuracy using a random forest model. Recruitment of walleye is affected by a large number of biotic and abiotic factors (Baccante and Colby 1996). Lake surface area was the most important predictor of walleye recruitment in the final model. SVSFE, compared parameters to this classification model to further understand potential for success of recruitment in Beaver Lake.

Lake Size - on average, the probability of successful walleye recruitment increased with increasing lake size and plateaued around 50% for lakes greater than approximately 225 ha.



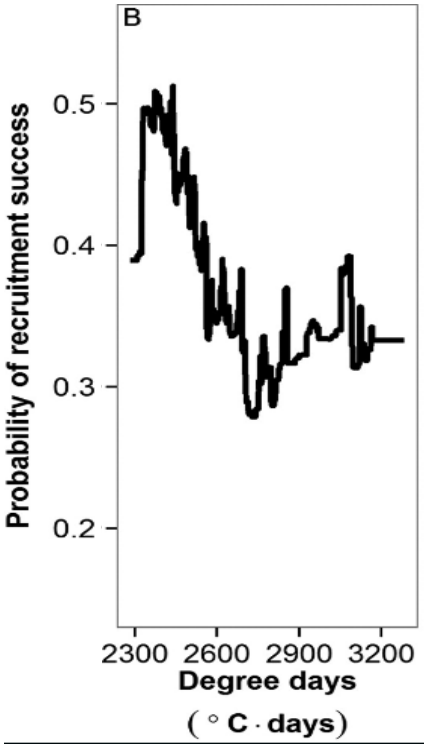
Beaver Lake possesses a surface area of 20.5 ha. This falls very low in the probability of recruitment success at approximately 0.16. Lake area influences the availability of critical habitat (Johnson et al. 1977; Jackson et al. 2001) and influences fish production (Ryder 1965) and walleye yield (Lester et al. 2004). Lake area also affects the diversity of prey species (Barbour and Brown 1974; Tonn and Magnuson 1982; Rahel 1986). Lower availability of alternative prey in small lakes could reduce recruitment success because of increased predation on age-0 walleye by piscivores, including cannibalism by adult walleye (Forney 1976; Rudstam et al. 1996). Furthermore, larval walleye rely on sufficient pelagic zooplankton resources when they switch from endogenous to exogenous feeding (Li and Mathias 1982; McDonnell and Roth 2014), and lower zooplankton density and richness in small lakes (Patalas 1971) as well as lower volume of pelagic habitat (Vadeboncoeur et al. 2008) could decrease the foraging success and survival of larval walleye during this critical period.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

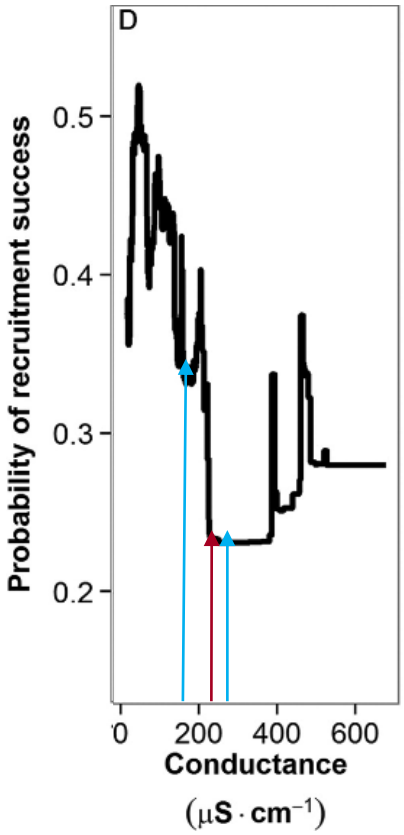
Water Temperature Degree-Days – walleye recruitment was also influenced by DD_5; on average, recruitment was more likely in lakes with lower DD_5 than in lakes with higher DD_5. The effect of DD_5 varied with lake size; in fact, the effect of DD_5 was only evident in small lakes (e.g., 100 ha) where recruitment was most likely when DD_5 were low. (DD_5; base temperature 5 °C, a measure of cumulative annual thermal energy; Chezik et al. 2014)

Our escarpment lakes would provide lower degree days but unfortunately at this time, this parameter is unknown. This is something SVSFE could compile with the installation of a temp logger and further analysis or through reference to online simulation models if available. Low degree-days in a smaller lake would increase the probability of success.



Conductivity – the relationship between conductivity (a proxy for productivity) and recruitment was hump-shaped, with the highest probability of recruitment in lakes where conductivity was approximately 50 $\mu S \cdot cm^{-1}$ and declining probability of recruitment either above or below this value.

Conductivity at Beaver Lake was found to range between 176 – 275 with an average conductance of 224 µS-cm. This again falls low on probability of recruitment at approximately 0.23



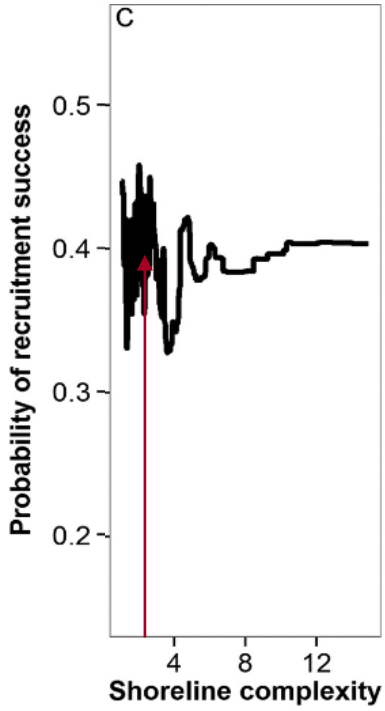
Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

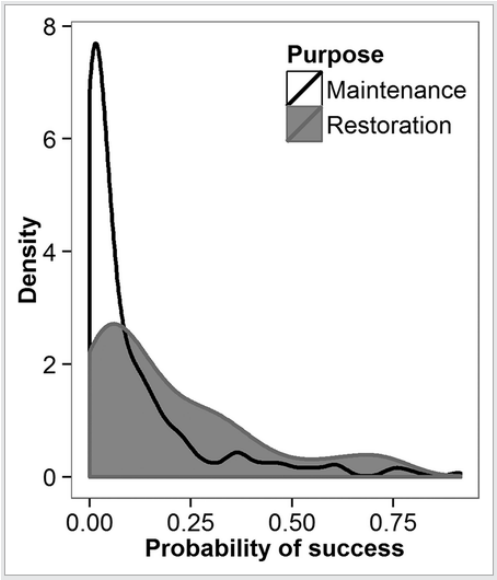
Shoreline Development Factor (SDF)- Walleye recruitment was predicted more accurately when SDF was included in the model, although the effect of SDF on recruitment was relatively flat when averaged across all values of other variables (Fig. 3), indicating that the effect of SDF on recruitment success depends on the value of other predictors. Shoreline development factor (a measure of shoreline complexity) was calculated using ArcGIS and the following formula:

Ratio of shoreline length to that expected if lake were a perfect circle (shoreline length/2 × (π × area)$^{0.5}$) (Wetzel 2001)

The estimated calculation of SDF for Beaver Lake is 2.4. This equates to a probability of recruitment success at 0.4



Hansen stated the prediction model found "probability of recruitment to be low (<0.25) in the majority of systems nominated for stocking under the Wisconsin Walleye Stocking Initiative (WWSI)" and that "lakes proposed for restoration stocking were twice as likely to be predicted by our model to produce successful walleye recruitment as those proposed for maintenance stocking" (Figure below).



Through utilizing the model develop by Hansen et. al. and basic review of three known parameters, Beaver Lake was found to have a low probability of recruitment success at a scale of 0.26. The predictors utilized in this model may explain limiting factors causing poor recruitment. At this time, the establishment of this walleye fishery is "too early in the game" to develop any extensive conclusions. SVSFE has seen recent recruitment in neighboring lakes which would also fall low on the probability scale. Verrall Lake (41 ha) located in the Ducks displayed signs of recruitment and East Goose (15 ha) in the Roblin area where walleye were illegally introduced have also suggested recruitment is possible in smaller waterbodies. Whether these lakes are able to sustain populations over time under fishing pressure is unknown.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Recommendations: At this point, very similar trends year after year are apparent; low natural recruitment, little creel data, and lack of larger fish in the system. This opens up discussions on the next step for Beaver Lake. Managers and SVSFE need to review the facts and understand the unknowns pertaining to the walleye fishery in Beaver Lake. Listed are suggestions to consider for future advancement of this fishery;

1) Continue to "further enhance" spawning habitat. In Minnesota, stocking is a useful tool for some purposes; one where walleye are introduced to lakes that have been "rehabilitated" (that is, where the previous fish were deemed undesirable and removed). Where habitat is suitable, these introductions often establish self-sustaining fisheries (MNDNR 2016). As stated previously, the rock supplied for the shoal creations was far from ideal. For this reason, SVSFE has proposed to add gravel to these structures in 2017/18, therefore representing the artificial shoal which was initially anticipated back in 2013. As discussed amongst SVSFE techs, directors, and regional fisheries staff a layer of smaller diameter clean rock atop the reef should show greater levels of walleye utilization. In terms of additional spawning habitat for both walleye and forage, it was discovered that the inflowing tributary from Cluff Lake provides beautiful clean substrate when flow is ideal. The small portion of habitat should remain accessible to fish. The <100m section of creek provides excellent habitat for spawning of several species and by managing one beaver dam at the mouth of the lake will allow passage during critical spawning periods.

2) Continue stocking of advanced walleye fingerlings or larger walleye from Beautiful Lake. Prior to stocking mangers should develop stocking rates which will facilitate higher survival and predicted angling pressure. Alternate stocking years should also be considered to avoid year class suppression. If natural recruitment remains non-existent, fry and/or fingerling stocking rates to promote a "put and take" fishery should be established. If long term stocking is the suitable management practice, the rate fingerling stocking should remain in the range of 600 fingerlings semi-annually. If road access over time influences size of fish stocked (ATV access only due to poor road conditions) fry stocking of 10,000 alternate years should be considered.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

3) Collect information on angler pressure and quality. This can be collected via voluntary creel surveys and with the use of traffic counters. If permitted by Park's, SVSFE could promote a real "in-your-face" style voluntary creel submission box at the boat launch of Beaver Lake. More creel information on harvest and fishing quality would prove to be invaluable in terms of the next step for Beaver Lake management. Traffic counters could be incorporated to indicate the number of visitors who frequent Beaver Lake during all seasons and provide insight on the pressure this semi-remote lake receives.

4) Continue utilizing efficient and economical methods - recruitment surveys following "further enhancement" of the Beaver Lake spawning shoals should be of top priority. This can be conducted through a short electrofishing session which involves a couple hours, one night a year. With regards to a representation of the present fish community, it is suggested to replicate the "Mission Walleye" trap netting program from 2012/2014 in the near future to re-evaluate fish populations and stocking effectiveness. This protocol involves one week of surveys and is easily replicated.

5) Re-evaluate management objectives. A change in objectives could proceed all of the above suggestions and be a stand alone approach. But with investments in habitat improvements and walleye stocking it would be valuable to further understand the effects from management practices implemented. Therefore, findings can support future practices elsewhere. As it stands now, walleye were initially introduced with the intensions of creating a semi-remote **self-sustaining** walleye fishery which would require, limited to no supplemental stocking long term. To date approximately $58,000 (through local, provincial and federal funding) has been invested in Beaver since 2010. Not to mention the cost of reclamation in 1987 and fish stocking costs from the province. To continue with this objective after investments only make sense. It is hard to walk away when efforts are only half completed. If efforts through habitat enhancement & future stocking can not reach this objective due to uncontrollable limiting factors (ie. lake size), managers may consider changing targets to facilitating a "put and take" or "maintenance stocking" walleye fishery. The downfall to this type of management is the requirement of long term stocking but when successful, benefits will pay off considerably.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Literature Cited:

Baccante, D.A. and P.J. Colby. 1996. Harvest, density and reproductive characteristics of North American walleye populations. Ann. Zool. Fennici 33:601-615

Barbour, C.D., and Brown,J.H.1974.Fishspeciesdiversityinlakes.Am.Nat.108: 473–489. doi:10.1086/282927.

Bennett, D.H. and T.J. McArthur. 1990. Predicting success of walleye stocking programs in the United Stated and Canada. Fisheries 15(4): 19-23

Chezik, K.A., Lester, N.P., and Venturelli, P.A. 2014. Fish growth and degreedays I: Selecting a base temperature for a within-population study. Can. J. Fish. Aquat. Sci. 71(1): 47–55. doi:10.1139/cjfas-2013-0295.

Ellison, D.G. and W.G. Franzin. 1992. Overview of the symposium on walleye stockd and stocking. North American Journal of Fisheries Man. 12:271-275

Forney,J.L.1976.Year-classformation in the walleye (Stizostedion vitreum vitreum) population of Oneida Lake, New York, 1966–73. J. Fish. Res. Board Can. 33(4): 783–792. doi:10.1139/f76-096.

Hansen, G.J.A, S. R. Carpenter, J. W. Gaeta, J.M. Hennessy, J.V. Zanden. 2015. Predicting walleye recruitment as a tool for prioritizing management actions. Wisconsin Department of Natural Resources. Canadian Journal of Fisheries and Aquatic Sciences, 2015, 72(5): 661-672 http://www.nrcresearchpress.com/doi/full/10.1139/cjfas-2014-0513#.WD55nIWcHIV

Hartman, G.F. 2009. A Biological Synopsis of Walleye (Sander vitreus). Fisheries and Oceans Canada Science Branch, Pacific Region

Jackson, D.A., Peres-Neto, P.R., and Olden, J.D. 2001. What controls who is where in freshwater fish communities: the roles of biotic, abiotic, and spatial factors. Can. J. Fish. Aquat. Sci. 58(1): 157–170. doi:10.1139/f00-239.

Johnson, M.G., Leach, J.H., Minns, C.K., and Olver, C.H. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye (Stizostedion vitreum vitreum), northern pike (Esox lucius), lake trout (Salvelinus namaycush), and smallmouth bass (Micropterus dolomieui). J. Fish. Res. Board Can. 34(10): 1592–1601. doi:10.1139/f77-224.

Lester, N.P., Dextrase, A.J., Kushneriuk, R.S., Rawson, M.R., and Ryan, P.A. 2004.Light and temperature: key factors affecting walleye abundance and production. Trans. Am. Fish. Soc. 133(3): 588–605. doi:10.1577/T02-111.1.

Li, S., and Mathias, J.A. 1982. Causes of high mortality among cultured larval walleyes. Trans. Am. Fish. Soc. 111(6): 710–721. doi:10.1577/1548-8659(1982) 111<710:COHMAC>2.0.CO;2.

McDonnell and Roth 2014

MNDNR. 2016. Walleye management. Minnesota Department of Natural Resources. http://www.dnr.state.mn.us/fish/walleye/management.html. Sourced November 29, 2016

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fish Res. Board Can. Bull. 184 966 pp.

Summary of Activities

Subject: 2016 Beaver Lake – Walleye stocking success & recruitment

Literature Cited:

Patalas, K. 1971. Crustacean plankton communities in forty-five lakes in the experimental lakes area, northwestern Ontario. J.Fish.Res.Board Can.28(2): 231–244. doi:10.1139/f71-034.

Rahel, F.J. 1986. Biogeographic influences on fish species composition of northern Wisconsin lakes with applications for lake acidification studies. Can. J. Fish. Aquat. Sci. 43(1): 124–134. doi:10.1139/f86-013.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Ottawa.

Tonn and Magnuson 1982

Rudstam, L.G., Green, D.M., Forney, J.L., Stang, D.L., and Evans, J.T. 1996. Evidence of interactions between walleye and yellow perch in New York state lakes. Ann. Zool. Fenn. 33: 443–449.

Vadeboncoeur, Y., Peterson, G., Vander Zanden, M.J., and Kalff, J. 2008. Benthic algal production across lake size gradients: interactions among morphometry, nutrients, and light. Ecology, 89(9): 2542–2552. doi:10.1890/07-1058.1. PMID:18831175. et al. 2008

Ward M. & T. Stevens. 2014. Large Lake Sampling Program Assessment Report for Leech Lake 2014 (Completion Report). Walker Area Fisheries Office. Minnesota Department of Natural Resources Division of Fisheries and Wildlife http://files.dnr.state.mn.us/areas/fisheries/walker/2014_llr_leech.pdf

Wetzel, R.G. 2001. Limnology: Lake and river ecosystems. 3rd ed. Academic Press, San Diego, Calif.