Title: Reconciling Walleye Catch Differences from Multiple Fishery Independent Gill Net Surveys in Lake Erie

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Abstract

Fishery independent gill net surveys provide valuable demographic information for population assessment and resource management, but relative to net construction, the effects of ancillary species, and environmental variables on focal species catch rates are poorly understood. In response, we conducted comparative deployments with three unique, inter-agency, survey gill nets used to assess walleye (*Sander vitreus*) in Lake Erie. We used an information-theoretic approach with Akaike's second-order information criterion (AIC_c) to evaluate linear mixed models of walleye catch as a function of net type (multifilament and two types of monofilament netting), mesh size (categorical), Secchi depth, temperature, water depth, catch of ancillary species, and interactions among selected variables. The model with the greatest weight of evidence showed that walleye catches were positively associated with potential prey, and intra-guild predators, and negatively associated with water depth and temperature. In addition, the multifilament net had higher average walleye catches than either of the two monofilament nets. Results from this study both help inform decisions about proposed gear changes to stock assessment surveys in Lake Erie, and advance our understanding of how multispecies associations explain variation in gill net catches.

Keywords: Lake Erie; Walleye; Inter-jurisdictional Fisheries; Gear Comparison

1. Introduction

For fishery independent population assessments, gill nets provide a highly selective method to capture a particular size range of fish. Gill net size selectivity is well understood on both empirical and theoretical grounds, and the size of the mesh opening relative to the morphology of the fish (e.g., girth, potential for mouth entanglement, and presence of body protrusions such as scales and spines) primarily determines the expected size distribution of the catch (Hamley, 1975; Hansen et al., 1997; Millar and Fryer, 1999). The magnitude of the catch is dependent on many other factors including net characteristics (e.g., monofilament versus multifilament material), hang ratio, environmental conditions (e.g., turbidity, illuminance), catch of ancillary species (i.e., by-catch), and local abundance of fish, which is typically the factor about which we wish to draw inferences (Hamley, 1975). While net characteristics and environmental effects have been the subject of a handful of investigations (reviewed by Hamley, 1975), less attention has been paid to interactions with ancillary species (Jester, 1977; Olin et al., 2004), and the comparative influences of all these factors on the catch rate of focal species is poorly understood.

The lack of understanding of the myriad of factors that can influence gill net catch is particularly important for walleye (*Sander vitreus*) fishery management in Lake Erie, where the spatial segregation of different types of gill nets, obsolescence of one net type, and relatively high catches of ancillary species complicates inter-jurisdictional efforts to assess the stock with fishery independent data. Net type differences among jurisdictions exist because of historical factors with each management agency, and they persist out of concern for altering long time-series of data. One survey conducted in U.S. waters uses a net constructed with (now) obsolete multifilament netting, and it has been dependent upon a diminishing stock of spare netting. Thus, there is an urgent need to define how the multifilament net performs relative to commercially available monofilament nets to support a necessary gear change (Vandergoot et al., 2011). Despite some evidence that multifilament netting is more visible to fish and has lower catch efficiency (Cui et al., 1991; Henderson and Nepszy, 1992), our anecdotal observations suggest the opposite, because multifilament ensnares spines, scales and other body protrusions more efficiently than monofilament. Further, a second net type used in Canadian waters of Lake Erie is constructed of relatively thin diameter monofilament, and in contrast again with the literature (Hamley, 1975; Yokota et al., 2001) we questioned whether this net catches larger walleye less efficiently because the strands of monofilament break more easily allowing fish to escape. Finally, there is a dearth of information on the effects of ancillary species catches on focal species. Although Olin et al. (2004) observed reduced catch rates as total catch increased through time, our qualitative observations from several decades of Lake Erie gill net surveys suggested a positive correlation between ancillary species and walleye catches. This situation highlights that our understanding of focal species population dynamics might be conditioned on the population variability of ancillary species.

Our objective was to determine if gill net catch rates of walleye in Lake Erie were related to net material, mesh size, other species, and environmental factors. Here, we report on four seasons of field investigations in Lake Erie in which we deployed all three net types simultaneously for comparative analysis of abiotic and biotic variables on the catch rate of walleye. This model system illustrates both practical and fundamental issues for understanding catchability of fish in gill nets that cannot be resolved in the existing literature. We used an information-theoretic approach (Burnham and Anderson, 2002) to evaluate candidate linear mixed models of walleye catch and quantify the relative importance of key variables. We also followed management agency protocols for deployment and mesh size configuration so that the results can inform immediate practical decisions about gear differences that face Lake Erie fishery managers.

2. Materials and Methods

2.1 Net Descriptions and Field Sampling Approach

Each of the three survey nets had a unique combination of mesh sizes, and the order of the panels was randomized at a previous time (the inception of each agency's survey). Multifilament nets were 1300 feet long (396 m) by 6 feet deep (1.8 m) with 13 100-foot long (30.5 m) panels with mesh sizes from 2 to 5 inches (51 to 127 mm, stretch measure) in 0.25-inch increments (6 mm), with a twine diameter of 0.37 mm, and a hang ratio of 0.5. The New Monofilament nets (termed so because they are intended to replace the Multifilament net; Vandergoot et al. 2011) were 1200 feet long (366 m) by 6 feet deep (1.8 m) with 12 100-foot long (30.5 m) panels with mesh sizes from 1.5 to 7 inches (38 to 178 mm) in 0.5-inch increments (12 mm), with a hang ratio of 0.5, and graded twine diameter. The diameters of the New

Monofilament twine were 0.20 mm for 1.5 inch (38 mm) mesh, 0.28 mm for meshes 2 to 5 inches (51 to 127 mm), and 0.33 mm mesh sizes > 5.5 inches (140 to 178 mm). The Partnership nets (termed so because it is fished cooperatively with commercial fishing industry in Ontario, Canada) were 1250 feet long (381 m) by 6 feet deep (1.8 m) with 25 50-foot long (15.2 m) panels with mesh sizes from 1.25 to 6 inches (32 to 152 mm), with a hang ratio of 0.5, and twine diameter of 0.23 mm. The number of panels for each mesh size varied: one panel each of 1.25 (32 mm), 1.5 (38 mm), and 1.75 (44 mm) inch mesh; two panels each of 2 (51 mm), 2.25 (57 mm), 2.5 (64 mm), 2.75 (70 mm), 3 (76 mm), 3.5 (89 mm), 4 (102 mm), 4.5 (114 mm), 5 (127 mm), 5.5 (140 mm), and 6 (152 mm) inch mesh.

From 2010 through 2013 during fall (September through November), all three nets were deployed overnight in a single gang at a random subset of sites (n=48) that have been historically sampled in Ohio and Ontario waters of Lake Erie to monitor walleye populations (Figure 1). Exceptions occurred in 2010 and 2011, when no sites in Canadian waters were sampled and in 2012 when sites (n=9) in Canadian waters were only sampled with Multifilament and Partnership nets. Sites were distributed throughout Ohio, USA, and Ontario, Canada, jurisdictions of the western and central basins of Lake Erie. The order of nets in the gang was randomized at each site, and each net was separated by an anchor and distance of ~60 m. According to established management agency protocols, nets were suspended from the surface by buoys with the headline at a depth of 6 feet (1.8 m). Buoys were attached between each net junction and on the ends of each net. Each gang of nets was deployed after noon during daylight and fished overnight. Water quality measurements (temperature, Secchi depth and dissolved oxygen) were recorded for each site on the deployment day. Captured fish were sorted by net type and mesh size, identified, measured (total length), and weighed.

2.2 Data Analysis

We treated walleye as the focal species and examined catch as a linear function of net type (Multifilament, New Monofilament, and Partnership), water clarity (indexed by Secchi depth, continuous variable), and catch of ancillary species of selected groups (as covariates). We also included surface water temperature as a covariate based upon association with walleye catches in two previous analyses (Berger et al., 2012; Pandit et al., 2013). We did not examine dissolved oxygen effects because all of the surface water samples in our data were normoxic.

The key assumption in our analysis was that the same local population of fish was available to all three nets at any particular site. Because site and inter-annual variability were expected but not of primary interest, we constructed a site by year category (n=48 categories) that was included in the model as a random effect.

Overall catches in each net type were not directly comparable because of non-matching mesh sizes, so we included only the seven mesh sizes common to all three net types: 2 to 5 inches (51 to 127 mm) in 0.5-inch increments (13 mm). For the Partnership net, data from each pair of 50 foot (15.2 m) panels was treated as an equivalent 100 foot (30.5 m) panel, to support the assumption of equal fishing power between net types (Millar and Fryer, 1999; Millar and Holst, 1997). Further, each mesh size typically has right-skewed monotonic size selectivity, and catches vary between meshes due to the size structure of the local population of fish available to the gear (Hamley, 1975; Vandergoot et al., 2011). We did not presume to know the size-distribution of the local population, so we included mesh size as a categorical factor. To understand the effect of the interaction between size-selectivity and local population size-structure on catches, we compared length distributions of walleye between each net type for each mesh size using Kolomogorov-Smirnov (K-S) tests with a Bonferroni correction for multiple comparisons (experiment-wise α=0.05).

The catch of ancillary species was historically comprised of two main species groups: Clupeidae (primarily Gizzard Shad *Dorosoma cepedianum*, and some Alewife *Alosa pseudoharengus*), and Moronidae (primarily White Bass *Morone chrysops*, and some White Perch *M. americana*). Other species numerically accounted for less than 3% of the total catch. Therefore, we constructed covariates for each main group (Clupeids and Moronids) to separate effects of potential prey (Clupeids) from intra-guild predator species (Moronids) that potentially school with walleye.

Finally, nets sampled a fixed vertical span of the water column (1.8 m) that represented a variable proportion of total depth from 6.4 to 23 m, which suggested that nets may have disproportionately sampled shallower sites at a higher rate because nets blocked a greater proportion of the available water column. Depth was not explicitly part of the sampling design, so we included depth as a covariate in the model. In initial model runs, we observed correlation between the intercept and depth, temperature and Secchi depth. This was corrected by centering depth, temperature and Secchi depth.

Despite high catches overall, initial exploration of the data revealed that sample size limited our ability to examine all possible interactions among variables. Therefore, we included only interaction terms that addressed specific plausible questions. First, the relationship between mesh size and twine diameter varied among mesh sizes and between net types, so we determined if this pattern affected catches of walleye at larger mesh sizes where the mesh size–twine diameter relationship was most disparate by including the interaction between net type and mesh size. Next, the effect of net type might vary with water clarity, so we included an interaction between Secchi depth and net type. Next, walleye catch is inversely related to water clarity (Pandit et al. 2013), so we included the interaction between temperature and Secchi depth. Finally, catches of ancillary species likely vary with net type, so we included interactions between net type and each ancillary species group.

In total, we examined 12 variables (7 main effects, plus 5 interactions) in a linear, mixed-effects model with one random effect (site-by-year) and 512 candidate models that represented all possible combinations of main effects and interactions. Counts of walleye and ancillary species were square-root transformed prior to analysis. We evaluated models using Akaike's second order information criterion (AIC_c) and Akaike weights (ω) as the criterion for selection of the best model (Burnham and Anderson, 2002). In the best model, correlation between effects was evaluated for evidence of collinearity, and parameters were compared to determine which factors had the most influence on walleye catches. Confidence intervals were constructed to compare mean walleye catch between net types and selected levels of covariates. Linear mixed models were fit in R (R Core Team, 2015) using the *lme4* package (Bates et al. 2015). For model-comparison purposes, linear mixed-effects models were estimated via maximum likelihood through Laplace approximation of the marginal likelihood function. Once a best-performing model was identified, we used restricted maximum likelihood (REML) to estimate parameters and confidence intervals for the model, which is a more robust estimation approach for estimating variance components in mixed-effects models but which is not appropriate for conducting model comparisons involving variation in fixed-effect components. Fit of the best performing model was assessed using conditional and marginal R^2 and was calculated using the *MuMIn* package in R (Barton 2015).

3. Results

Total catch of walleye in common mesh sizes summed across sites and years was highest for Multifilament nets (n=3464), followed by Partnership nets (n=2068) and New Monofilament nets (n=2038). Overall catch rates (total walleye from all nets per site) varied over two-fold among years with the highest average catch rate in 2010 (mean = 189 per site [s.e. = 54]), second highest in 2011 (mean = 129 per site [s.e. = 76]), and lowest in 2012 (mean = 73 per site [s.e. = 75]) and 2013 (mean = 77 per site [s.e. = 39]). Fewer fish were captured in Canadian (n=1697) than U.S. (n=5873) waters. Fewer sites were sampled in Canadian (n=21) than U.S. (n=39) waters, and in 2012 the New Monofilament net was not fished at 9 sites in Canadian waters.

Jurisdictional differences in temperature and depth were observed in some years. Surface water temperature ranged from 7.3 to 22.7° C (mean = 13.5°, s.e. = 4.1) across all samples, and was significantly warmer in Canadian than US waters by 6.6 and 5.9 degrees, respectively in 2012 (t-value = 4.35, p-value < 0.001) and 2013 (t-value = 3.56, p-value = 0.004). Site depth ranged from 6.4 to 23 m (mean = 12 m, s.d. = 4.4) across all years, and in 2012, average site depth was 8 m deeper in Canadian samples (t-value = 4.36, p-value <0.001). Secchi depth ranged from 0.2 to 3.3 m (mean = 1.5 m, s.e. = 0.75), but did not differ between jurisdictions (t-value = 1.86, d.f.= 43, p = 0.07). Temperature and depth were not correlated, but Secchi depth was weakly, positively correlated to temperature and depth ($r = 0.29$ and 0.27, respectively; p-values < 0.0001). Walleye length distributions only differed between New Monofilament and Partnership nets for the 3.5 inch (89 mm) mesh size based on K-S test results (Table 1). Therefore, catches were not corrected for differences in mesh selectivity among net configurations.

All of the top ten models shared four effects: catch of Clupeids, net type, mesh size, and depth (Table 2). The top three models that accounted for 52% of the total weight of evidence (ω) and had delta-AIC_c values < 3.0 also included Secchi depth, catch of Moronids, and an interaction between Moronids and net type (Table 2). Overall, models with interaction terms had low weights of evidence (≤ 8%). Interactions between Moronid or Clupeid catch and net type were present in 4 of the top ten models (Table 2), and in each case, walleye catch in the Partnership net type increased with ancillary species catch at a lower rate than the other net types. Based on weight of evidence ratios, the top ranked model was 2.3 and 3.9 times more likely than the second or third ranked models to be the correct model given that the correct model is in the list of candidates (Table 2). Thus, the top ranked model was selected for evaluation of parameters and means.

The best model included Moronids, Clupeids, mesh size, net type, water depth, and temperature. The conditional R^2 (fixed and random effects) for the best-performing model was 0.48, whereas the marginal R^2 (fixed effects only) was 0.26. Multifilament nets caught more walleye than the New Monofilament (mean difference = 1.0 fish) or Partnership nets (mean difference = 1.4 fish; Table 3, Figure 2). Both temperature and depth were inversely associated with walleye catch (Table 3). Both ancillary species groups were positively associated with walleye catch, and the effect of Clupeid catch was slightly higher than and uncorrelated with (r = -0.03) Moronid catch (Table 3, Figure 2). Effects of depth, temperature, and ancillary species catch were small relative to net type effects. For example, the difference between the Multifilament and Partnership nets was equivalent to either 3.3 m change in depth, 5 degrees change in temperature, or 25 ancillary species (Table 3, Figure 2). Mesh size effects were relatively large, with peaks at 3.0 and 5.0 inch mesh sizes (Table 3). Individual mesh sizes were moderately and positively correlated (r = 0.39 to 0.51), but only weakly correlated to other effects ($r < |0.2|$).

4. Discussion

Our results are somewhat contrary to previous investigations that showed monofilament nets caught more walleye than multifilament nets (Collins, 1979; Gray et al., 2005; Henderson and Nepszy, 1992; Hylen and Jakobsen, 1979; Washington, 1973). In these studies, higher visibility of multifilament netting apparently resulted in gear avoidance (Cui et al., 1991; Jester, 1977). Twine color, depth, and turbidity (as it relates to the light intensity around the gear) can affect the depth at which fish react to a net, but multifilament netting has a lower illuminance threshold for fish reaction than monofilament (Cui et al., 1991). Most other studies deployed nets in daytime or in clear water (e.g., in Lake Huron where moonlight was shown to have an effect; Collins, 1979). Our nighttime deployments in turbid waters (mean Secchi depth = 1.5 m), and the lack of a Secchi depth effect in the best model supports a conclusion that visibility of the netting (under these conditions) was negligible. Previous results from Lake Erie in which the visibility of netting would have been higher (mean Secchi depth range = 2.2. to 5.2 m) demonstrated that walleye catches were greater in monofilament than multifilament nets

(Henderson and Nepszy, 1992); therefore, lack of contrast in our Secchi depth conditions limited our ability to fully evaluate an interaction between net type and Secchi depth. Vulnerability to suspended net configurations may differ from nets fished on bottom (Henderson and Nepszy 1992) due to the effects of surface turbulence on light transmission or net movement. Differences between results may also relate to some temporal influence; Sep-Oct vs May-June and a contrast in species composition that included few Clupeids during the 1989-1990 study (Henderson and Nepszy, 1992). Under a broader range of conditions from more extensive survey data, others have demonstrated that walleye catches in Lake Erie are negatively correlated with water transparency (Berger et al., 2012; Pandit et al., 2013), and positively correlated with temperature at low water transparency (Pandit et al., 2013). In our data, inferences are complicated by small but significant positive correlations between Secchi depth and water depth and temperature (i.e., sites with higher transparency tended to be deeper and warmer). In part, this effect is a result of deeper and warmer Canadian samples, which were collected at earlier times during the sampling season. In the spring and summer, walleye undergo eastward migration that is associated with seasonal warming trends and changes in forage distribution (Wang et al., 2007). The western return migration to shallower habitats during autumn coincides with declining water temperatures. Our analysis was consistent with Walleye behavior, indicating negative associations between walleye catch and depth and temperature.

Assuming the visibility of each net type was similar, other mechanisms that cause higher catches in Multifilament nets require additional investigation. Our qualitative observations suggest that Multifilament nets ensnare spines, scales and other body protrusions more efficiently than Monofilament nets. We considered categorizing individual fish according to how they were captured (Hamley, 1975), but initial trials indicated that a large proportion of walleye were simultaneously wedged, ensnared, or entangled. Short-term deployments might reduce the probability that a fish would be captured by multiple mechanisms, but this was beyond the scope of our study.

The perception that thinner monofilament in Partnership Nets might lead to lower catches via breakage (especially for larger fish) was not supported by our analysis. We did not find differences between monofilament net types, nor between mesh sizes within net types. If the twine diameter effect is present, the magnitude is small relative to other factors based upon the net type - mesh size interaction in four of the top 10 candidate models. Our findings are similar to a previous study that examined monofilament diameter (Gray et al., 2005), but contradicts two other studies (conducted on rainbow trout, *Oncorhynchus mykiss*, and common sole, *Solea solea*; <250 mm) that found higher catch efficiency of thinner monofilament (Grati et al., 2015; Yokota et al., 2001). In studies that observed significant effects of monofilament diameter on catch, diameters examined only overlapped with Partnership Nets (<0.31 mm; both studies) and mesh sizes did not overlap (<52 mm; Yokota et al. 2001). Lower average catch rates in Partnership Nets indicated that results of Yokota et al. (2001) and Grati et al. (2015) should not be extrapolated to monofilament diameter and mesh size combinations that we studied.

Available information on the effect of ancillary species on focal species catch rates provides an indirect and equivocal view on the variability of focal species catches. In an Australian ecosystem, Gray et al. (2005) reduced catches of non-target species by altering net characteristics without affecting catch rates of focal species, which suggests that catch rates of focal and non-target species varied independently. By comparison, in a study of Finnish lakes, accumulation of fish in a gill net (quantified as the proportion of occupied meshes) substantially and negatively affected catchability through time (Hansen et al., 1998; Olin et al., 2004). Because nets saturated faster during day, Olin et al., (2004) concluded that nets became more visible as catch accumulated, and that avoidance increased with net visibility. This implied a possible negative relationship between ancillary and focal species catch rate that agrees with experimental observations of fish reactions to gill nets under different lighting levels (Cui et al., 1991). The positive linear association between walleye and ancillary species indicated that saturation effects were not present within the range of catches that we observed. Dark conditions during our gill net deployments may in part explain a lack of saturation, but we expect that longer set times would be needed to observe potential saturation effects. Further, baiting gill nets increases encounter rates (Kallayil et al., 2003) and catch rates in commercial fisheries (Dartay and Duman, 2014; Engas et al., 2000). For research studies that use multiple mesh sizes (e.g., this study), the accumulation of ancillary species might attract larger focal species similar to baiting. For two uncorrelated species groups (potential prey and intra-guild predators), we found additive positive effects on walleye catches. We speculate that a more general behavioral response, perhaps attraction to vibrations of struggling fish in nets, rather than a response to bait, might explain the association between walleye catch and catch of other species. Alternatively, walleye may not be attracted to other species, so correlated catches might result from similar net encounter rates or shared habitat preferences of multiple species.

Gill net data are often considered only for one species, yet gill net catches in most systems represent an assemblage of multiple species. Whereas others have examined only abiotic variables (Berger et al., 2012; Pandit et al., 2013), our analysis emphasizes the importance of evaluating associations between species (or species groups) to account for variation in walleye catch. Better understanding of these associations would greatly aid the interpretation of fishery independent gill net data on Lake Erie walleye and on exploited fishes in other ecosystems, particularly if a focal species is attracted to other captured species as we hypothesized. Further, spatial-jurisdictional differences in walleye catch between Multifilament and Partnership nets that were observed in previous analyses (Berger et al., 2012; Pandit et al., 2013) are complicated by comparing total catches from an idiosyncratic mismatch of mesh sizes. Based on comparative sampling (this study), all three net types used in Lake Erie were remarkably similar in terms of average catch and length distribution of walleye. This indicates that inter-calibration of net types could be accomplished using common mesh sizes, although inferences would be limited to an observed range of environmental conditions (i.e., Secchi depths < 3.3 m). Increases in water clarity (e.g., Barbiero and Tuchman, 2004) that affect the visibility of gill nets would potentially alter effects we found. Finally, our results indicated that conversion from Multifilament to New Monofilament nets must account for a reduced number of walleye in the catch. Due to lower catch rates in monofilament nets, more sampling effort may be needed to achieve minimum required sample sizes for estimation of length and age distributions (Gerritsen and McGrath, 2007; Miranda, 2007; Stewart et al., 2014).

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Table 1. Mean length (and sample size) of walleye from three gill net types and seven mesh sizes.

Mesh (inches)	Multifilament	New Monofilament	Partnership
2	380 (n=119)	368 (n=63)	362 (n=83)
2.5	412 (n=346)	405 (n=244)	402 (n=225)
3	437 (n=407)	432 (n=348)	435 (n=301)
3.5	471 (n=292)	477* (n=337)	466* (n=332)
4	503 (n=302)	503 (n=263)	514 (n=237)
4.5	530 (n=198)	538 (n=191)	541 (n=179)
5	557 (n=196)	569 (n=213)	574 (n=132)

*K-S test of walleye length distributions between the New Monofilament and Partnership nets indicated significant differences in length distributions at an $\alpha=0.05$ with a Bonferonni correction.

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Table 2. Model selection results for the top ten models of walleye catch (out of 512 candidates), fit by maximum likelihood and ranked by Akaike's second order information criterion, AIC_c, which is a combined measure of goodness of fit and model parsimony. Shown are the number of estimated parameters (*K*), second-order AIC_c values (AIC_c), AIC_c differences (ΔAIC_c), and AIC_c weights (ω) for each model.

Model	***K***	**AIC_c**	**ΔAIC_c**	**ω**
*Moronids+Clupeids+mesh_size+net_type+depth+temperature	15	2789.7	0.0	0.31
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Secchi	16	2791.5	1.8	0.13
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Moronids*net_type	17	2792.3	2.7	0.08
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Clupeids*net_type	17	2792.7	3.1	0.07
Clupeids+mesh_size+net_type+depth+temperature	14	2792.9	3.3	0.06
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Secchi+Secchi*temperature	17	2793.4	3.7	0.05
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Secchi+Moronids*net_type	18	2794.2	4.5	0.03
Moronids+Clupeids+mesh_size+net_type+depth+temperature+Secchi+Clupeids*net_type	18	2794.5	4.9	0.03
Clupeids+mesh_size+net_type+depth+temperature+Secchi	15	2794.6	5.0	0.03
Moronids+Clupeids+mesh_size+net_type+depth	14	2794.6	5.0	0.03

*Selected as best model.

Table 3. Best model parameter estimates*. Whereas selection of the best model was based upon ML and AIC methods, REML was used to generate the estimates provided here. The reference level is specified for the intercept, and the net type and mesh size category values are offsets from the intercept.

Fixed Effects	**Estimate**	**s.e.**
Intercept		
Multifilament (2.0 inch)	1.01	0.14
Net Type		
New Monofilament	-0.23	0.08
Partnership	-0.34	0.08
Ancillary species		
Moronidae	0.012	0.006
Clupeidae	0.013	0.004
Mesh Size (inches)		
2.5	0.83	0.12
3.0	1.30	0.13
3.5	1.16	0.12
4.0	0.97	0.12
4.5	0.52	0.12
5.0	0.55	0.12
Depth (m)	-0.11	0.02
Temperature (C)	-0.07	0.03
Random Effects	**Variance**	**s.d.**
site by year	0.43	0.65
Residual Error	1.004	1.002

*A square root transformation was applied to walleye catch, and depth and temperature were centered in the analysis.

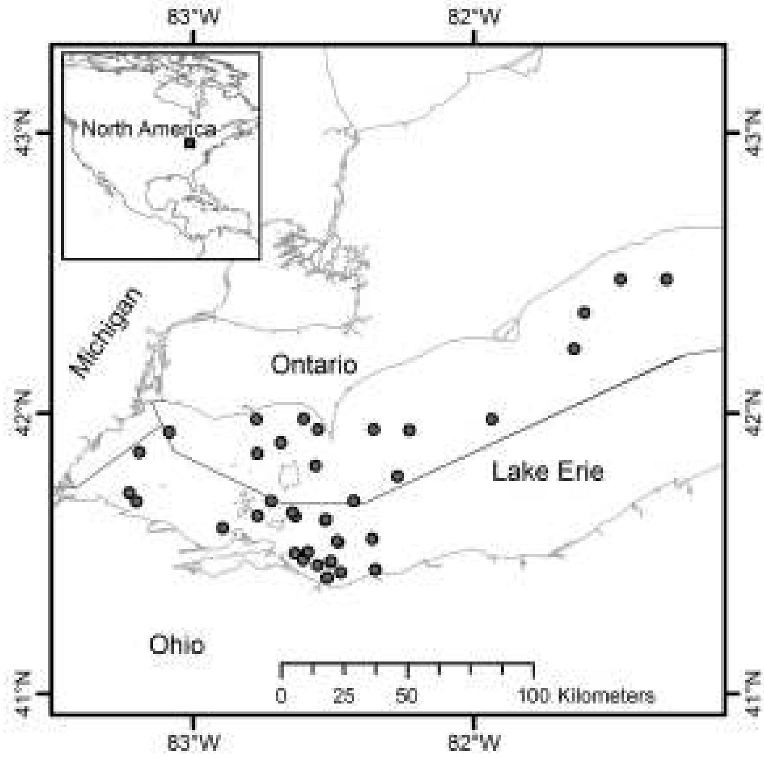

Figure 1. Gill net sampling locations (dots) in Lake Erie showing political jurisdiction boundaries (black lines). The inset map shows the study area location (square) relative to North America.

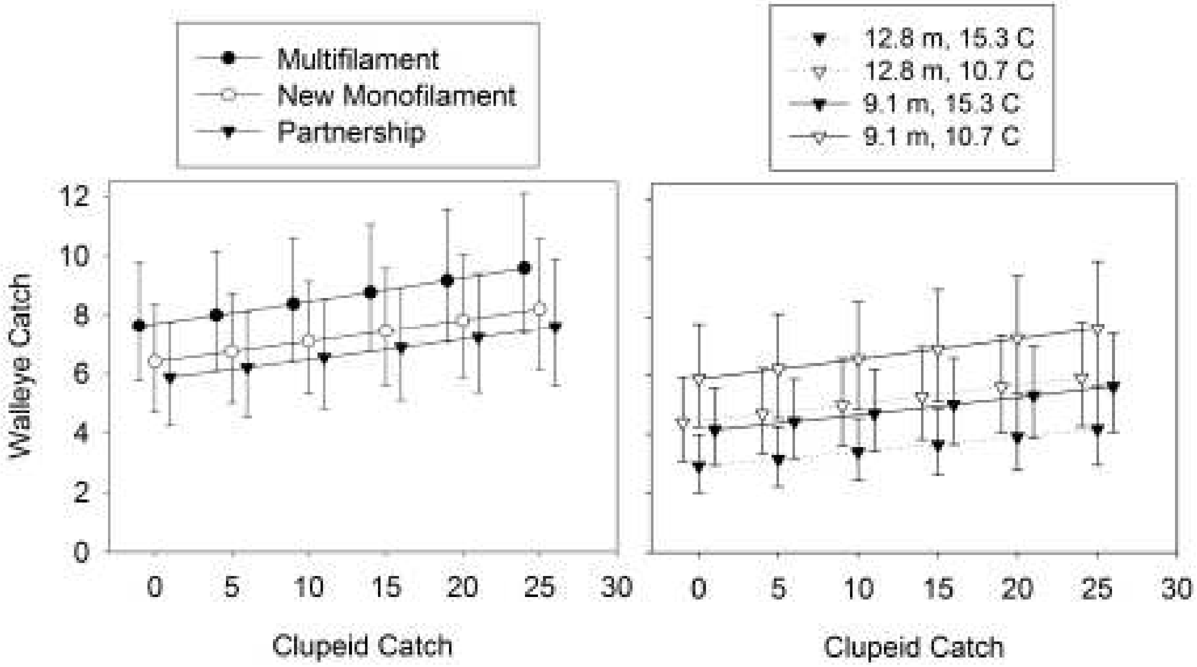

Figure 2. Predicted marginal (least-squares) means (back transformed) of walleye catch for selected levels of Clupeid catch (95% confidence intervals are shown). The values are estimated at the 3.5 inch mesh size, and a fixed Moronid catch of 5. The slopes and range of catches for Clupeids and Moronids were nearly the same; therefore, the patterns would look identical if Moronids were used as the covariate in these plots. The range Clupeid catch in each panel represents 97.5% of the observed values. The left-hand panel compares net types. The right-hand panel compares means for the Partnership net with high and low scenarios for combinations of depth and temperature (indicated in the key). The scenarios were based upon the 1st and 3rd quartiles of observed depth or temperature. Estimates of walleye catch for each selected level of clupeid catch (increments of 5 individuals, x-axis) are offset to reduce symbol overlap.