U.S. Fish and Wildlife Service

Recovery rates of stocked and wild Chinook salmon in Lake Michigan, 2011-2015

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March 2017

Results are from fish tagged and recovered through the cooperative Great Lakes Mass Marking Program

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Recovery rates of stocked and wild Chinook salmon in Lake Michigan, 2011-2015

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Summary of Revisions and New Results

The first version of this report was distributed to the Lake Michigan Technical Committee (LMTC) and discussed at the LMTC meeting on July 26, 2016. This revised report corrects errors and responds to several additional analyses requested by the LMTC. Specifically:

A) IN DNR noted, some of their stream return data may have been coded as being from bio techs during the open water season, and if so they should be removed from the analyses.

- Some stream fish recovered in both Indiana and Michigan were coded as open water fish, and were removed.
- **These changes necessitated re-running all analyses and resulted in changes to every figure reported in this document. Please disregard the first draft of this report.**
- Notably, these changes resulted in even stronger evidence for higher survival of Wisconsin-stocked fish. 14 of the 17 tag lots with the highest survival index were stocked in Wisconsin waters.

B) Several LMTC members requested the breakdown of the origin of hatchery fish in their jurisdictional fisheries during April-August and September, with the prediction that Lake Huron fish would have a greater contribution to the fishery during the earlier season.

- Breaking down CPUE by season provided evidence that:
    - Lake Huron stocked fish leave Lake Michigan in fall, likely because they return to Lake Huron to spawn.
    - The portion of the Lake Michigan fishery comprised of wild fish declines from 65% in April-August to 47% in September (average from 2014-2015). This may suggest that a portion of wild fish captured in Lake Michigan originated in Lake Huron, or may reflect higher overall CPUE in Wisconsin, where stocked fish outnumber wild fish, during September.
    - Wisconsin-stocked fish were the highest proportion of stocked fish caught in each jurisdiction during April-August.
    - Wild fish dominate the catch in Michigan waters during September (86%), suggesting that the Michigan coast is a source for wild recruitment, and/or Michigan-stocked fish have poor returns.

Details on Revisions and New Results

Data processing revision: Stream fish coded as head hunter recoveries

A total of 39 CWT Chinook salmon were recovered by biotechs during 2013, 2014 and 2015 in October from stream sites (13 from IN DNR and 26 from MI DNR). These fish were included in the initial analysis of Chinook salmon recoveries, but should not have been, as they are not from the open-water fishery and thus are not a result of the angler effort included in the calculations of CPUE and Survival Index. The figures contained in this revised report reflect the removal of these stream recoveries from the analysis. While 39 recoveries may not seem like a lot, due to low sampling and angling effort during

October, these recoveries produced disproportionately large month-specific CPUE values. **Since the CPUE and Survival Index results were based on averaging the month-specific CPUE values, the October recoveries had a disproportionately large effect on some of the results. Therefore, all figures in this revised report have changed.**

Data processing revision: Removal of all October recoveries

After removing the 39 stream-recovered Chinook salmon from the analysis, it became apparent that the only state with any open-water recoveries in October was Wisconsin. We elected to remove these fish from the analysis as well. Fish caught in October tend to be staging for spawning, and thus tend to be stocked in the area of recapture. To include fish from Wisconsin during October when fish from Michigan, Indiana and Illinois waters were not sampled would potentially bias the CPUE of the Fishery results in favor of Wisconsin-stocked fish, and against wild fish, which tend to be more abundant on the Michigan shoreline. Similarly, the inclusion of such fish could also bias survival estimates, as fish from other waters were not sampled during a time when one might expect high recoveries of fish stocked in certain locations.

New Results: Chinook salmon CPUE by recovery location

This section provides information on where Chinook salmon CPUE is greatest in Lake Michigan and on overall patterns in CPUE over time. Overall CPUE was highest in April-August 2014, then declined to a relatively constant among from September 2014 through September 2015. Percent composition of CPUE was largely similar from April-August 2014 through April-August 2015. In September of 2015, however, CPUE in Wisconsin comprised a much large percentage of total CPUE (81%) than it had in the prior three periods (37-53%). Sampling effort was relatively consistent among years, and it is not clear why CPUE was so low in Michigan and Indiana, and so high in Wisconsin, during September of 2015.

Revised Results: CPUE of Chinook salmon in Lake Michigan over all dates

Removal of the fall stream fish slightly changed some percentages, but the overall figures and message are the same.

New Results: CPUE of Chinook salmon in Lake Michigan split by season: April – August vs. September

Percent of CPUE by origin during April – August mirrored the overall lake-wide patterns across all dates, likely because this time period is the majority of the sampling season. Relative to April-August, there were reductions in the contributions of Lake Huron stocked fish (9% vs. 4%) in September. **This supports prior results showing that Lake Huron stocked fish return to Lake Huron during spawning.** The percentage of wild fish in the Lake Michigan fishery also declined in September (65% vs. 47%), which may indicate that a portion of the wild fish captured in Lake Michigan originated in Lake Huron, but also reflects that overall CPUE was greater in Wisconsin during September of 2015. The contribution of Wisconsin-stocked fish increased in September relative to April – August (15 vs.

39%), which is consistent with greater survival of Wisconsin-stocked fish and with greater angler CPUE (fish per hour) on the Wisconsin shoreline as shown by Clark et al. *in review*.

Revised Results: CPUE of Chinook salmon by jurisdiction over all dates

The figure for fish recovered in Indiana changed substantially, with Indiana-stocked fish representing a much lower proportion of the catch in Indiana waters (19% in the old report vs. 3% in the revised report). This was due to the removal of stream-recovered fish from Indiana in October. There was also a small but noticeable change to catch in Michigan waters, with Wisconsin-stocked fish rising from 7 to 11% and Michigan stocked fish falling from 11 to 7%, such that Wisconsin-stocked fish were the largest proportion of the Michigan fishery of any of the stocked fish. This was driven by the removal of the stream-recovered fish from October in Michigan, and is more consistent with data on Chinook salmon movement and survival. **With these revisions, Wisconsin-stocked fish were the highest proportion of stocked fish caught in each jurisdiction's fishery, at least when CPUEs were pooled across all dates.** Minor changes were noted in the pie charts for fish recovered in the waters of the other states, but there were no other major differences.

New Results: CPUE of Chinook salmon by jurisdiction, April-August vs. September

Contributions to the jurisdictional fisheries were relatively similar during April-August, as would be expected from a well-mixed population of Chinook salmon. During September, the Michigan and Wisconsin fisheries stood in stark contrast. The September Wisconsin fishery was comprised mostly of stocked fish (74% stocked, 26% wild,), especially fish stocked in Wisconsin (60%). By contrast, the September Michigan fishery was dominated by wild fish (86%), with only 8% attributable to Michigan-stocked fish. Indiana was also comprised mostly of wild fish (64%) in September. No data were collected from Illinois waters in September. **These results support the notion that much of the wild Chinook salmon recruitment in Lake Michigan occurs in tributaries on the eastern shoreline of the lake, and are consistent with the data on survival of stocked Chinook salmon detailed in other sections of this report.**

Revised Results: Where are Chinook salmon stocked in Lake Michigan by each state caught?

The figure for Indiana-stocked fish recovered across all dates changed substantially in the revised version due to the removal of the stream-recovered fish from October, with % recovered in Indiana dropping from 64% to 15%, and recoveries in other states increasing. The figure for Michigan-stocked fish also changed due to removal of stream-caught fish, with percent recovered in Michigan waters dropping from 69 to 54%.

New Results: Where are Chinook salmon stocked in Lake Michigan by each state caught during April – August vs. September?

The figures from the April – August period are all consistent with a substantially mixed population of Chinook salmon during this time period. September recoveries from 2013-2014 generally show that stocked fish move back to the region of stocking to spawn, with $\geq$ 80% of fish stocked in Indiana, Michigan and Wisconsin recovered in the state of stocking during September. This pattern was less

apparent for Illinois-stocked fish, where more fish were recovered in neighboring Indiana (46%) than in Illinois (22%) during September. Data were only available from Illinois during 2013, as there was no Illinois sampling in September of 2014 or 2015. Notably, Indiana had the second-highest recoveries, following the state of stocking, for both Wisconsin- and Michigan-stocked fish during September.

In September of 2015, Wisconsin comprised over 80% of the Lake Michigan CPUE, compared to 37 to 53% during the rest of 2014 and 2014. Thus, CPUE was very low in Indiana, Michigan and Illinois during September 2015. As a result of much greater overall CPUE, most fish caught in September of 2015 were caught in Wisconsin regardless of stocking origin.

Revised Results: Chinook salmon survival

The very high survival index of MM3- and IND-stocked fish from the 2011 year class were driven by the now-removed October stream recoveries, although those fish still had relatively high survival. **However, Wisconsin statistical districts now have the highest and second highest survival index for stocked Chinook salmon in all there year classes. Moreover, 14 of the 17 tag lots with the highest survival index were stocked in Wisconsin waters.** The revised survival index data strongly suggest higher survival of Wisconsin-stocked Chinook salmon relative to fish stocked elsewhere in Lake Michigan. Based on the revised survival index numbers, the summary map on Page 20 has also changed slightly. The “Low to Average” category has been replaced by an “Average” category containing ILL, MM7 and MM8, with MM4 moved to the “Boom or Bust” category.

Full Revised Report

1) Rationale

The Lake Michigan Committee is considering lake-wide Chinook salmon stocking reductions due to the predator:prey ratio exceeding the 0.1 benchmark in two of the past three years. Several states have requested from the USFWS information on the lake-wide recoveries of Chinook salmon stocked in their waters. To meet these requests, USFWS set up an analytical framework for correcting Chinook salmon catch for sampling effort and targeted angling effort. The new approach offers refined information on Chinook salmon survival from different tag lots and stocking locations, and enables the production of summary statistics that address some common questions posed by anglers and other stakeholders to the state agencies. This report serves to share lake-wide and state-specific data on effort-corrected Chinook salmon catch with all state partners involved in the Great Lakes Mass Marking Program.

2) Methods

We used the recoveries of Chinook salmon from all ports in Lake Michigan, corrected for sampling effort, angler effort, and number of fish stocked, as a metric for assessing contribution to the fishery, recovery rate, and post-stocking survival. We used recoveries from the open-water fishery collected by USFWS and state agency biotechs (a.k.a. headhunters), because their sampling protocol was the most consistent and reliable of all sources available in terms of documenting sampling effort.

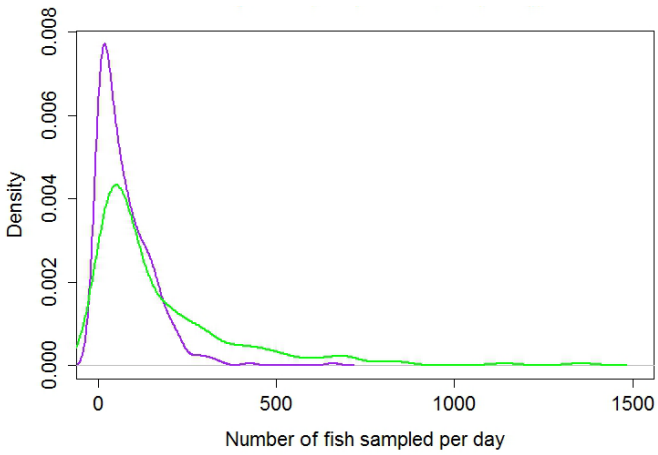


Fig. 1: Density of the number of fish sampled per day from sport+charter fishers combined (purple) and from tournaments (green) in Lake Michigan, 2013-2015 .

2.1) Sampling effort: Recoveries were sampled from sport anglers, charter anglers, and at tournaments. Sampling effort was measured as the number of regular sampling days (defined as non-tournament days where sport and/or charter anglers were sampled) plus 2.6 times the number of tournament days. The 2.6 multiplier for tournament days is needed because tournaments produce 2.6 times more fish per day (84.7 vs. 32.7, geometric means) as a non-tournament day. The multiplier would have been 2.3 based on arithmetic means (167.3 vs. 71.3), but due to right-tailed (log-normal) distributions for fish-per-day from both types of effort (Fig.1), we decided geometric means were more appropriate. Note: in 2012, interview source (i.e., sport, charter, and tournament) was not regularly recorded, so the total number of days was used without any modifiers in 2012. We assumed that sampling effort was independent of angler effort, which seems reasonable because biotechs were distributed lake-wide and without regard for angling effort, aside from when tournaments were targeted.

2.2) Angler effort: Angler effort was estimated as the total number of hours fished from boats and charters targeting trout and salmon. Angler effort was specific to each statistical district and month (April – October) and was estimated from creel surveys by the WI, MI, IN and IL DNRs. Angler effort was not measured from some months/years, and in those cases we assumed the average value of effort from that month/statistical district from other years.

2.3) Computation of the recovery rate metrics: Two metrics were used in this analysis: (a) catch per unit effort to examine the contribution of stocked and wild fish to the fishery, and (b) a survival index to assess survival of fish stocked from different locations.

(a) Catch Per Unit Effort: To examine contribution of stocked and wild fish to the fishery, we calculated a catch per unit effort equal to the average of the month- and district-specific number of recoveries, per sampling day, per 1,000 angler hours, for each tag code collected during the 2012-2015 recovery years. For recovery years 2014-2015, unclipped fish were assumed to be of wild origin and were treated as a separate 'wild' tag code. Unclipped fish from 2012 and 2013 could not be assumed to be wild because many Chinook salmon from the 2010 year class and prior did not receive a fin clip, and were likely still a part of the Chinook salmon population in 2012 and 2013. Fish of all ages were included in this calculation so that the CPUE of wild fish, whose ages were not known, could be computed. The number of fish stocked was not included in calculating CPUE in order to provide an overall an indicator of contribution to the fishery for stocked fish from each tag code and jurisdiction, and for wild fish. Average CPUE was calculated as:

$$(1) \qquad Average\ CPUE_{kz} = \left(\frac{\sum_{i=0}^{n} x_{ijk}/d_{ij}/(0.001\times h_{ij})}{n_{ij}}\right)$$

where x_{ijk} is the number of Chinook salmon recovered in month i (April – October) in statistical district j from tag code k; d_{ij} is the number of sample days in month i and statistical district j; h_{ij} is the number of targeted angler hours in month i and statistical district j; and n_{ij} is the number of month/statistical district combinations from which there was non-zero sampling effort. Average CPUEs were calculated for each tag code (k) across recovery regions (z) including all recoveries, lake-specific recoveries (i.e., recoveries in Lake Michigan and Lake Huron), and jurisdiction-specific recoveries (i.e., recoveries in Wisconsin, Illinois, Indiana, and Michigan waters).

We then calculated the percent of Chinook salmon CPUE attributable to six different origins m (fish stocked by each state in Lake Michigan [4 origins], fish stocked in Lake Huron, and wild fish) in Lake Michigan and in state-specific waters as:

$$(2) \qquad \%\ of\ Chinook\ salmon\ CPUE_z = \frac{\sum_k Average\ CPUE_{mz}}{\sum_k Average\ CPUE_z}$$

where z is the recovery region of interest (e.g., Lake Michigan or state-specific recoveries), Σ_k Average $CPUE_{jz}$ is the sum of the Average CPUE value of all tag codes k attributable to origin m and recovered in recovery region z, and Σ_k Average $CPUE_z$ is the sum of the Average CPUE value of all tag codes recovered in recovery region z.

(b) Survival Index: To estimate Chinook salmon survival, we calculated the average month- and district-specific CPUE per 100,000 fish stocked for each tag code. Only fish recovered at Ages 2 or 3 were included in developing the survival index because the majority (85.8%) of Chinook salmon are recovered at Ages 2 or 3, when they are likely fully recruited to the fishery. Age 1 fish are not fully vulnerable to angling due to their smaller size, and including recoveries at Age 1 could bias survival estimates if there are differences in size at stocking or growth of Age 1 fish stocked in different locations. As a result of using fish recovered at Age 2 or 3 in our survival index, only tag lots from the 2010-2013 year classes were examined.

Only survival of Chinook salmon stocked in Lake Michigan were evaluated in this report. Lake Huron recoveries were predominantly from Chinook salmon stocked in Lake Huron and from wild fish.

Survival index was calculated as:

$$(3) \qquad Survival\ index = \ Average\ Lake\ Michigan\ CPUE_{k,\ Age\ 2\&3} \div \left(\frac{y_k}{100{,}000}\right)$$

where the Average CPUE of fish recovered in Lake Michigan from tag code *k* at Ages 2 and 3 was calculated as in equation (1), and y_k is the number of recoverable tags stocked with tag code *k*.

Step-by-step computations performed on month- and district-specific angler effort and sampling effort were as follows:

Average CPUE (equation 1)

1) Determined the number of recoveries from each CWT lot from each statistical district from each month of collection (April – October from each of the two recovery years).

2) Divided the month- and district-specific recoveries by the month- and district-specific number of sampling days (sampling days = sport fishery days + 2.6*tournament days).

3) Divided the quotients from step 2 by the month- and district-specific number of targeted angler hours divided by 1,000 (i.e., number of recoveries per 1,000 angler hours).

4) Average the month- and district-specific quotients from step 3 to produce the average number of recoveries per sampling day per 1,000 angler hours for each CWT and for wild fish. For examining contribution to fisheries, we stopped after this step and looked at the percentage composition by origin (equation 2).

Survival Index (equation 3)

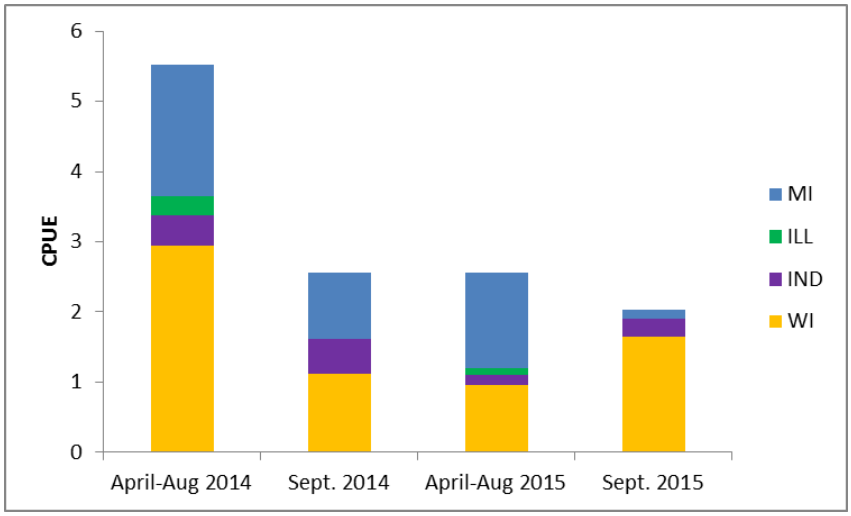
5) For estimates of Chinook salmon survival, we repeated steps 1 through 4 above for fish recovered at Ages 2 and 3 only. Then we divided the averages from step 4 by the number of fish stocked in each tag lot, divided by 100,000 (i.e., number of recoveries per 100,000 fish stocked).

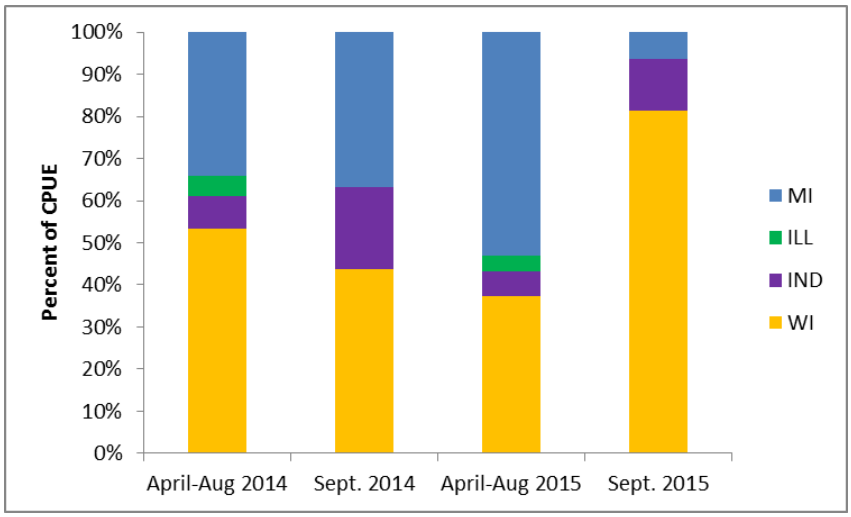
Note: Our Average CPUE values reflect biotech sampling only, and are not up-scaled based on total harvest estimates. Thus, the units of these two metrics are not consistent with the fish-per-hour CPUE data computed annually by state agencies from creel surveys.

3) Results – Chinook salmon CPUE by recovery location

This section provides information on where Chinook salmon CPUE is greatest in Lake Michigan and on overall patterns in CPUE over time. The analysis was limited to 2014 and 2015 to allow for wild fish to contribute to the overall CPUE. No data were collected from Illinois waters during September 2014-2015. Overall CPUE was highest in April-August 2014, then declined to a relatively constant among from September 2014 through September 2015. Percent composition of CPUE was largely similar from April-August 2014 through April-August 2015. In September of 2015, however, CPUE in Wisconsin comprised a much large percentage of total CPUE (81%) than it had in the prior three periods (37-53%). Sampling effort was relatively consistent among years, and it is not clear why CPUE was so low in Michigan and Indiana during September of 2015.

Figure 2: CPUE of Chinook salmon in Lake Michigan by recovery location over four periods from April-August 2014 through September 2015. The two panels show the same data in terms of absolute numbers (top panel) and percentages (bottom panel).

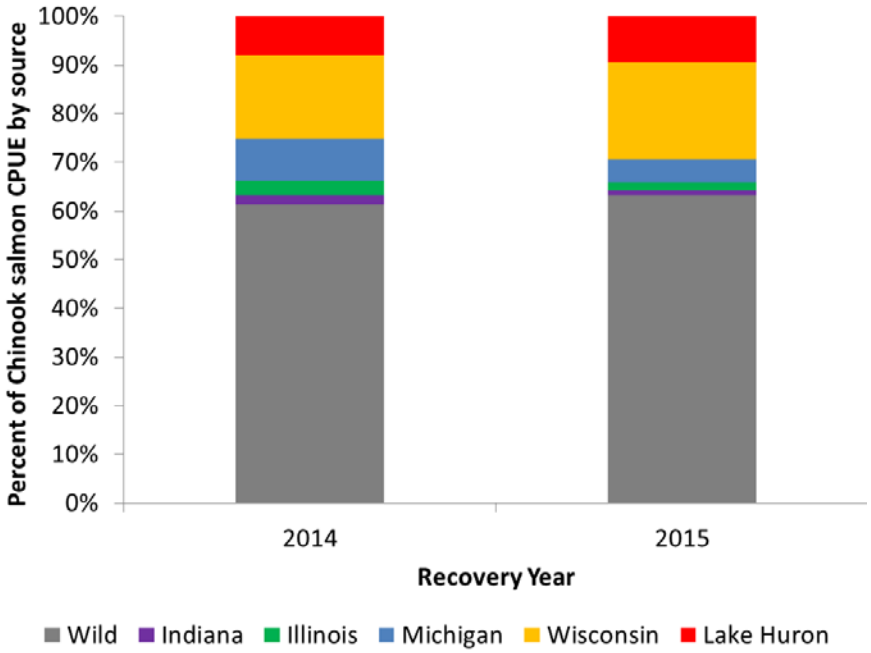


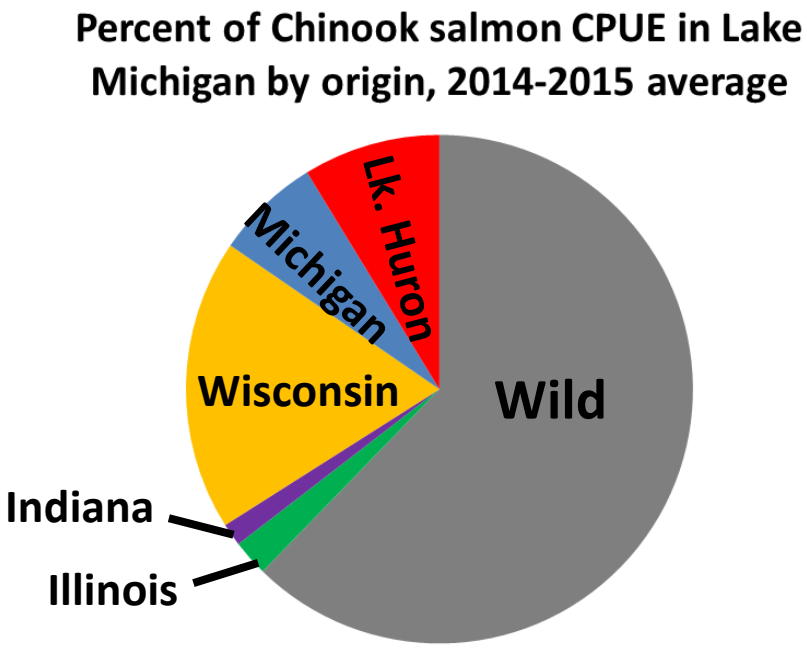


4) Results – Contributions of Chinook Salmon to the Lake Michigan Fishery by Origin

This section answers the question "What Chinook salmon do Lake Michigan anglers catch?" The average origin-specific contributions to the Lake Michigan fishery from 2014 and 2015 (Fig. 2, bottom panel, April – September recoveries) are as follows: 62% wild, 19% Wisconsin-stocked, 7% Michigan-stocked, 9% stocked in Lake Huron, 1% Indiana-stocked, and 2% Illinois-stocked.

Figure 3: Percent of total Chinook salmon CPUE (relative abundance) in Lake Michigan by origin, 2014 – 2015, pooled April – September recoveries. The percent of Chinook salmon CPUE by origin (Lake Michigan-stocked fish by state, Lake Huron stocked fish, or wild fish) was fairly consistent from 2014 through 2015 (top panel) and can be summarized by looking at the pooled 2014-2015 average (bottom panel). Fish of all ages, recovered from April – September, are included. Stocked fish are various colors according to stocking location; wild fish are gray. Note: CPUEs are not corrected for number of fish stocked. Thus, these figures represent the composition of the fishery and the relative abundance from each source (the intended purpose) and should not be interpreted as patterns in survival.



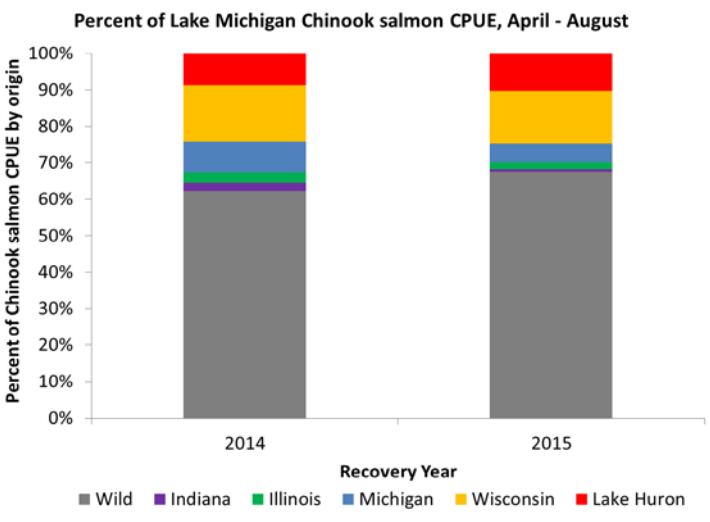


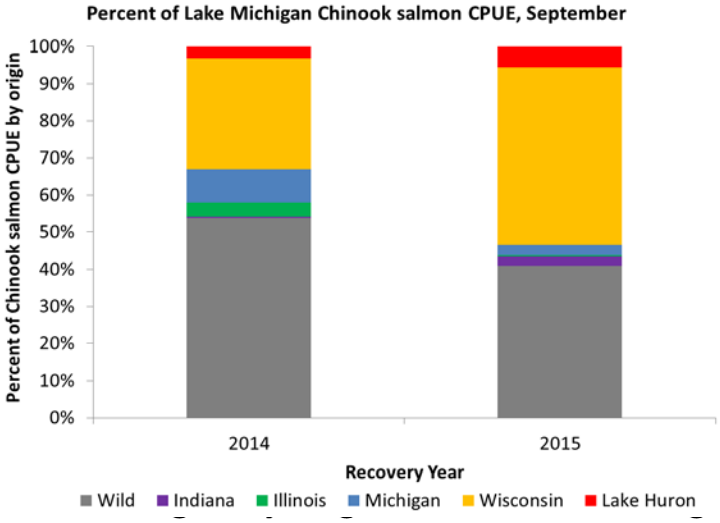
Contributions of Chinook Salmon to the Lake Michigan Fishery by Origin During Feeding (April –August) and Spawning (September) Seasons

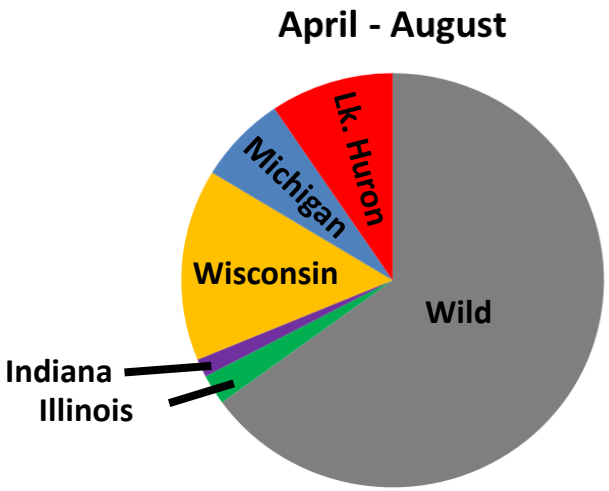
Percent of CPUE by origin during April – August mirrored the overall lake-wide patterns on the prior page. Relative to April-August, there were reductions in the contributions of Lake Huron stocked fish (9% vs. 4%) in September. This supports prior results showing that Lake Huron stocked fish return to Lake Huron during spawning. The percentage of wild fish in the Lake Michigan fishery also declined in September (65% vs. 47%), which may indicate that a portion of the wild fish captured in Lake Michigan originated in Lake Huron, or reflect that overall CPUE was greater in Wisconsin during September of 2015**.** There is evidence to support both of these hypotheses. In 2014, CPUE was similarly allocated among states between April-August and September (Fig. 2, lower panel), yet % wild dropped from 62% in April-August to 54% in September, consistent with some portion of Lake Michigan wild fish being of Lake Huron origin. In 2015, the drop in % wild from April-August (68%) and September (41%) was amplified, likely because of the high percentage of overall CPUE occurring in Wisconsin, where wild recruitment is thought to be lower, during September 2015.

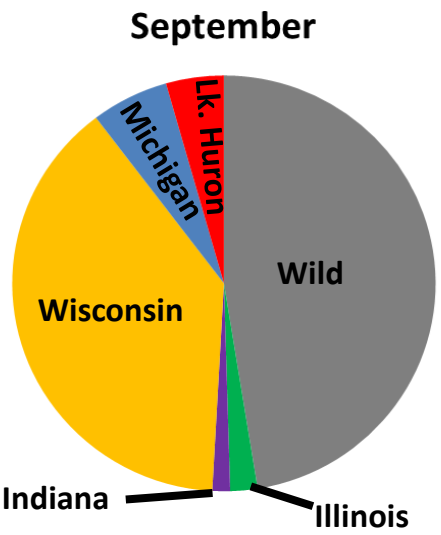
The contribution of Wisconsin-stocked fish increased in September relative to April – August (15 vs. 39%), which is consistent with greater survival of Wisconsin-stocked fish and with greater angler CPUE (fish per hour) on the Wisconsin shoreline as shown by Clark et al. *in review* and by Figure 2, lower panel.

Figure 4: Percent of Chinook salmon CPUE in Lake Michigan by origin, 2014 – 2015, pooled April – August (left panels) vs. September recoveries (right panels). Values with each month range were fairly consistent from 2014 through 2015 (top panels) and are summarized in the pooled 2014-2015 averages (bottom panels). Stocked fish are various colors according to stocking location; wild fish are gray. Note: CPUEs are not corrected for number of fish stocked. Thus, these figures represent the composition of the fishery (the intended purpose) and should not be interpreted as patterns in survival.





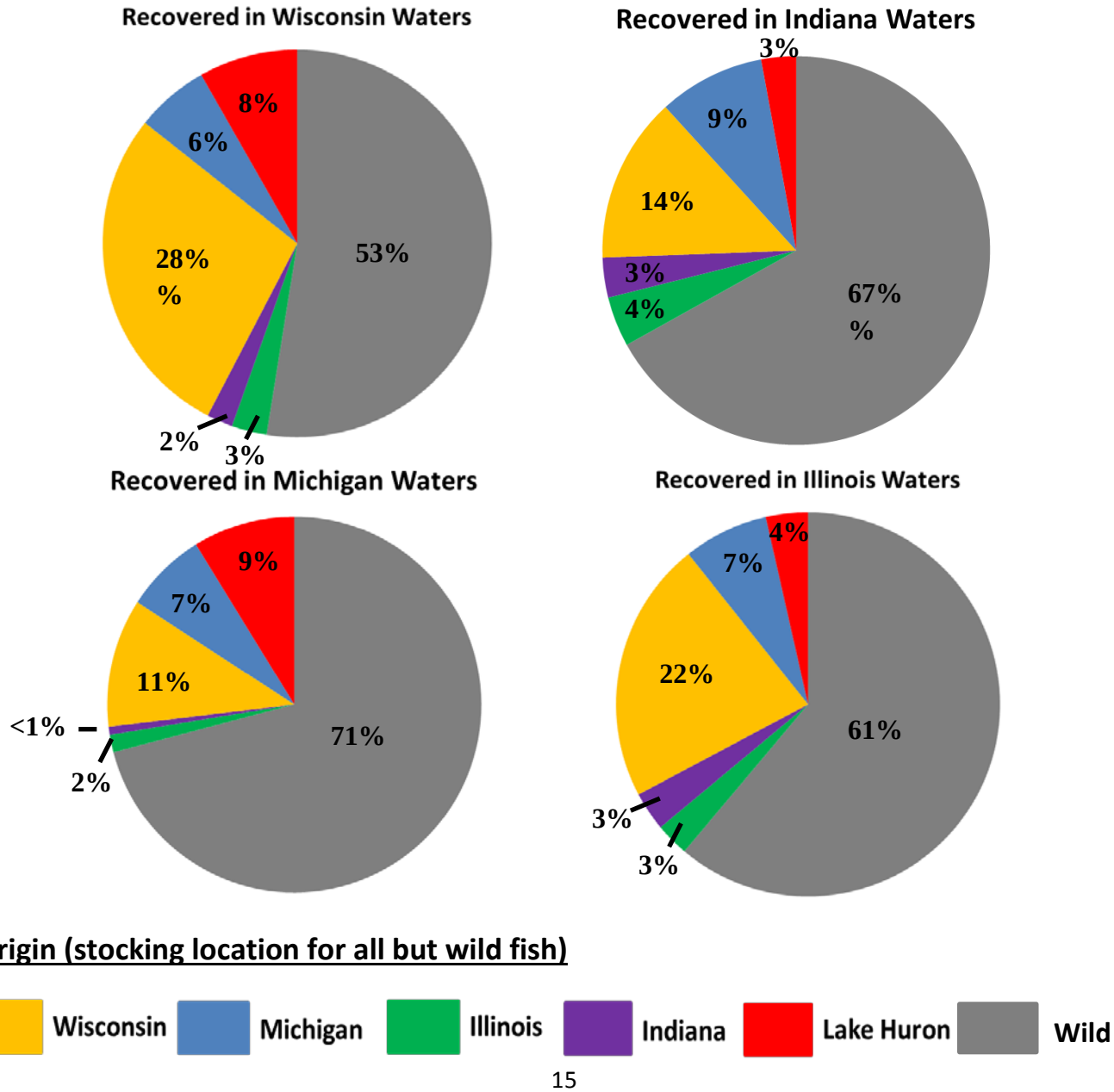




5) Results – Contributions of Chinook Salmon to each Jurisdiction's fishery by Origin

This section answers the question "What Chinook salmon do anglers in each state catch?" Pie charts show the proportion of fish from each origin recovered in the waters of each state.

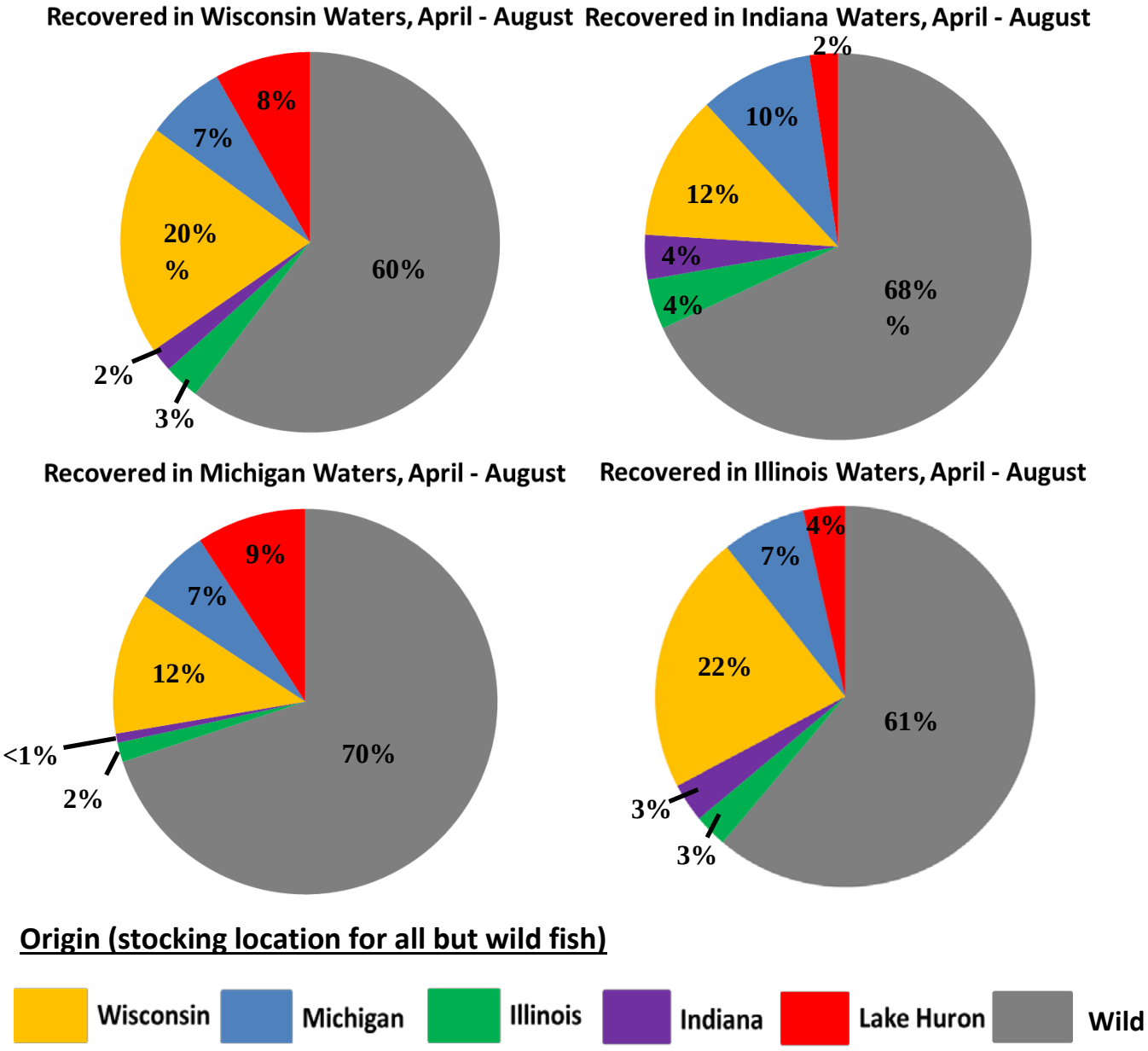
Figure 5: Percent of Chinook salmon CPUE recovered in Lake Michigan waters of each state by origin, 2014 – 2015. The percent of Chinook salmon CPUE by origin (Lake Michigan-stocked fish by state, Lake Huron stocked fish, or wild fish) is shown as the pooled 2014-2015 average. Stocked fish are various colors according to stocking location; wild fish are gray. Fish of all ages are included. Note: CPUEs are not corrected for number of fish stocked. Thus, these figures represent the composition of each state's fishery (the intended purpose) and should not be interpreted as patterns in survival. Numbers may not add to 100% due to rounding.



Contributions of Chinook Salmon to Each Jurisdiction's Fishery by Origin During the Feeding Season (April –August)

Contributions to the jurisdictional fisheries were relatively similar during April-August, as would be expected from a well-mixed population of Chinook salmon.

Figure 6: Percent of Chinook salmon CPUE recovered in Lake Michigan waters of each state by origin, 2014 – 2015, during April-August. The percent of Chinook salmon CPUE by origin (Lake Michigan-stocked fish by state, Lake Huron stocked fish, or wild fish) is shown as the pooled 2014-2015 average. Stocked fish are various colors according to stocking location; wild fish are gray. Fish of all ages are included

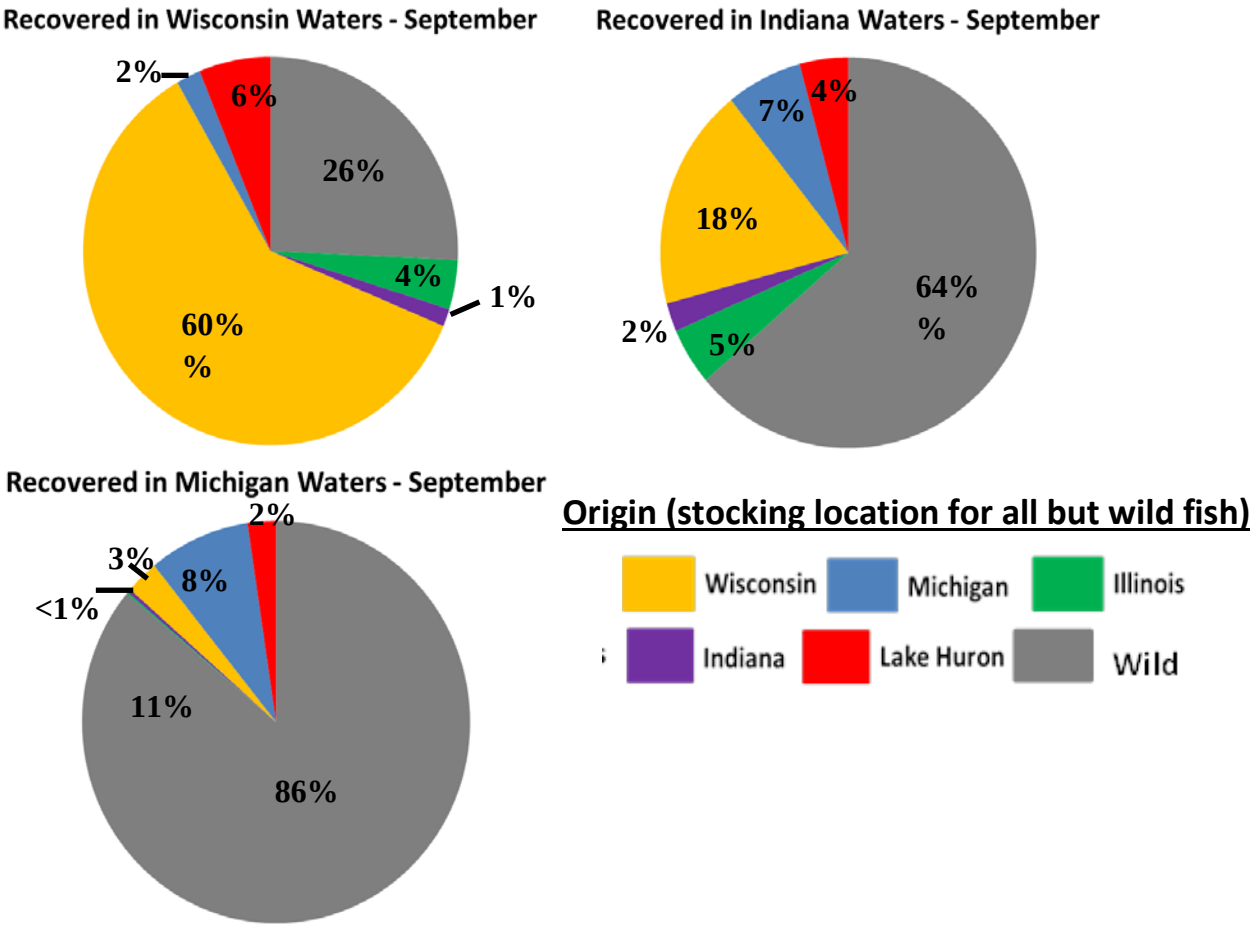


Contributions of Chinook Salmon to Each Jurisdiction's Fishery by Origin During the Spawning Season (September)*

*Note – there was no sampling in Illinois during September of 2014 or 2015, and thus there is no figure because percent wild could not be calculated prior to 2014.

There was a strong contrast between fish recovered in Wisconsin vs. Michigan waters during September. The September Wisconsin fishery was comprised mostly of stocked fish, particularly fish stocked in Wisconsin (60%), with wild fish only comprising 26% of the fishery. By contrast, the September Michigan fishery was overwhelmingly comprised of wild fish (86%), with only 8% attributable to Michigan-stocked fish. Indiana was also comprised mostly of wild fish (64%) in September. These data support the notion that most wild recruits in Lake Michigan originate from the eastern shoreline of the lake, and are consistent with the data on survival of stocked Chinook salmon detailed in other sections of this report.

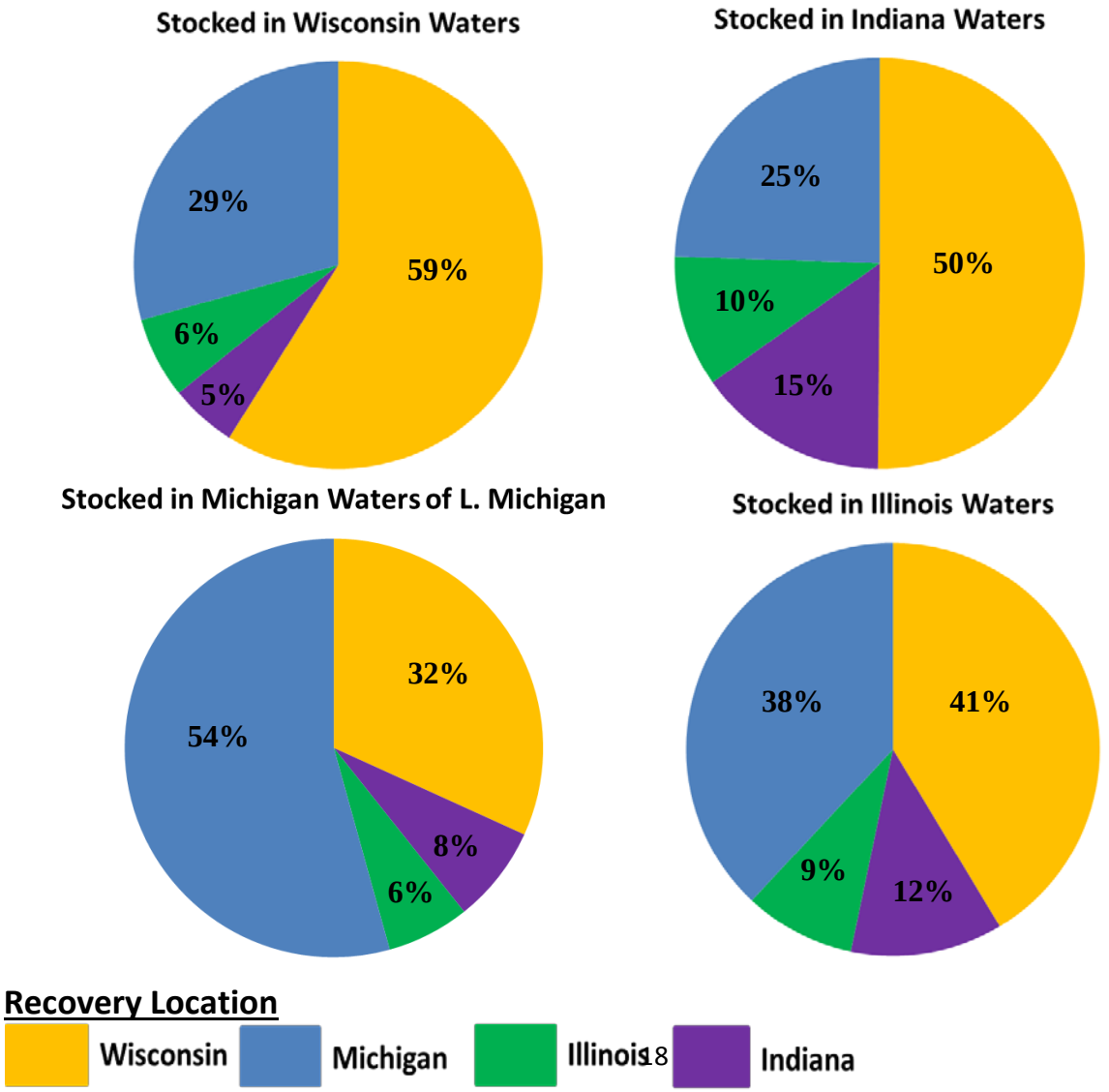
Figure 7: Percent of Chinook salmon CPUE recovered in Lake Michigan waters of each state by origin, 2014 – 2015, during September. The percent of Chinook salmon CPUE by origin (Lake Michigan-stocked fish by state, Lake Huron stocked fish, or wild fish) is shown as the pooled 2014-2015 average. Stocked fish are various colors according to stocking location; wild fish are gray. Fish of all ages are included.



6) Results – Fate of Chinook salmon stocked by each jurisdiction

This section answers the question "Where are Chinook salmon stocked by each state caught?" Pie charts show the proportion of fish recovered in each jurisdiction from fish stocked into Lake Michigan by each state. Only Age 2 and 3 fish were included to avoid possible bias in recoveries of Age 1 fish related to size. Note that there was no recovery effort in Illinois in 2014 and 2015 after August, which may drive down the % of Illinois fish recovered in Illinois waters given evidence from elsewhere that stocked fish tend to return to their stocking location after August.

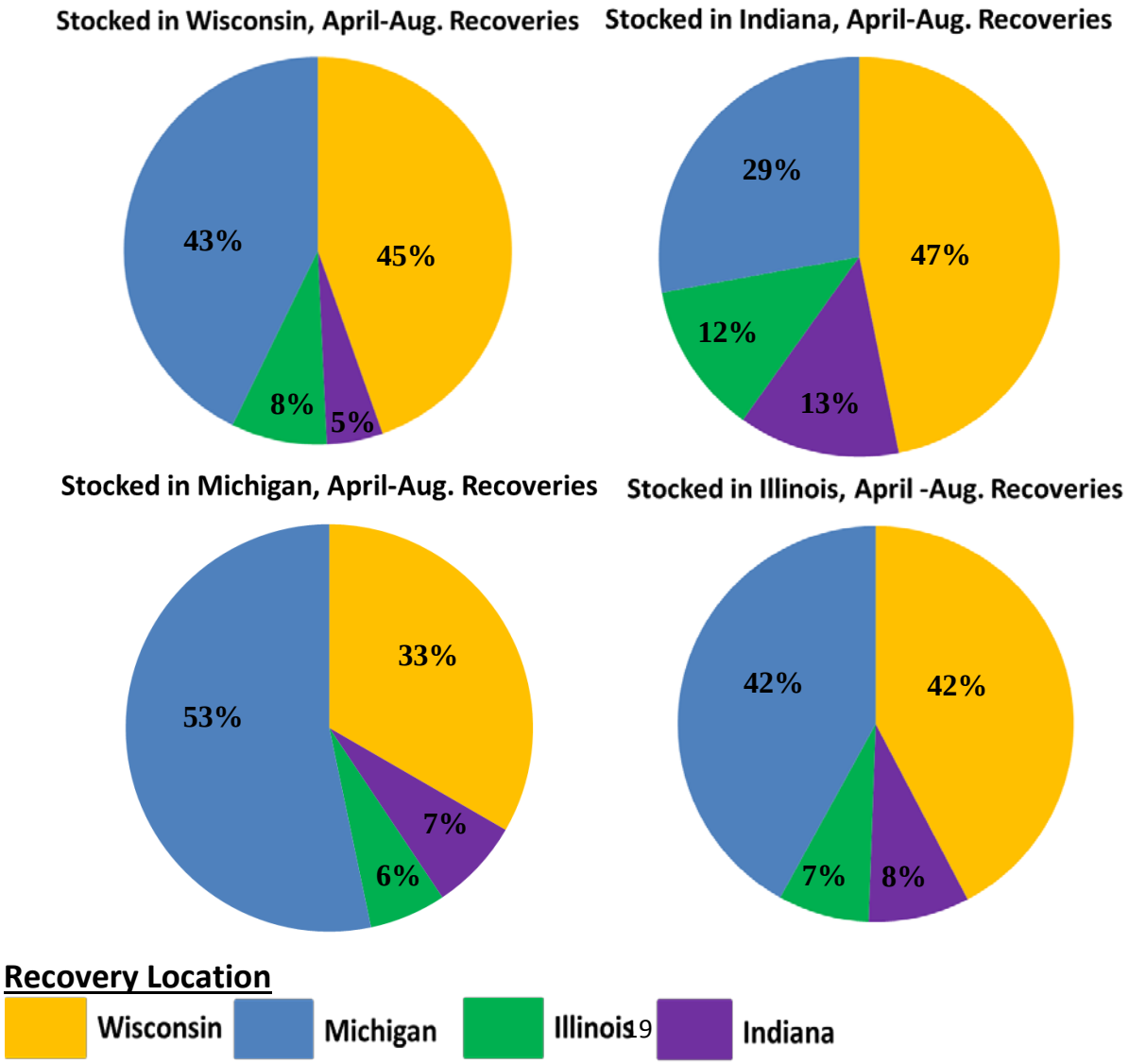
Figure 8: Recovery location proportions of Chinook salmon stocked into Lake Michigan by Illinois, Indiana, Michigan and Wisconsin, all sampling dates pooled. Chinook salmon CPUEs were compiled for fish stocked by each state into Lake Michigan. Pie charts show the proportional breakdown of where those fish were recovered, averaged across 2013-2015 recoveries. Only Age 2 and 3 fish were included. Note: CPUEs are not corrected for number of fish stocked. Thus, these figures should not be interpreted as patterns in survival. Numbers may not add to 100% due to rounding.



Fate of Chinook salmon stocked by each jurisdiction, recovered during April – August

This section answers the question "Where are Chinook salmon stocked in Lake Michigan by each state caught during April – August?" Only Age 2 and 3 fish were included to avoid possible bias in recoveries of Age 1 fish related to size. These figures were similar to the averages from all dates on the previous page for all states except Wisconsin – stocked fish, which were recovered more in Michigan and less in Wisconsin during the April-August period. All figures are consistent with a mixed population of Chinook salmon during April-August.

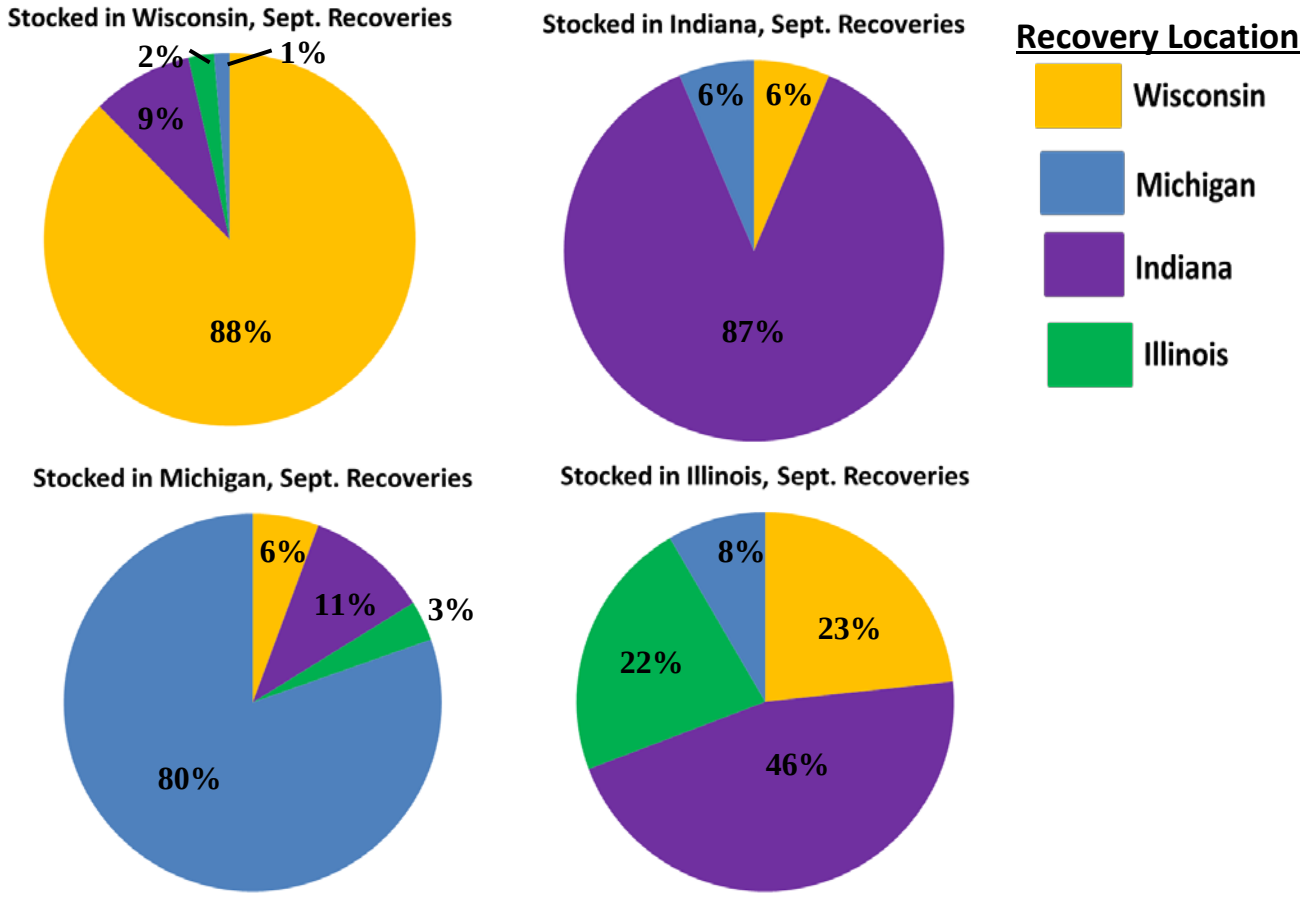
Figure 9: Recovery location proportions of Chinook salmon stocked into Lake Michigan by Illinois, Indiana, Michigan and Wisconsin, during April – August. Chinook salmon CPUEs were compiled for fish stocked by each state into Lake Michigan. Pie charts show the proportional breakdown of where those fish were recovered, averaged across 2013-2015 recoveries. Only Age 2 and 3 fish were included. Note: CPUEs are not corrected for number of fish stocked. Thus, these figures should not be interpreted as patterns in survival. Numbers may not add to 100% due to rounding.



Fate of Chinook salmon stocked by each jurisdiction, recovered during September

This section answers the question "Where are Chinook salmon stocked in Lake Michigan by each state caught during September?" Only Age 2 and 3 fish were included to avoid possible bias in recoveries of Age 1 fish related to size. Only recoveries from 2013-2014 are used in these figures. In 2015, CPUE was very low in Indiana (5 CWT Chinook salmon recovered) and Michigan (15 fish) waters relative to Wisconsin (121 fish). As a result of much greater overall CPUE, most hatchery fish caught in September of 2015 were caught in Wisconsin regardless of stocking origin. Patterns from 2013-2014 recoveries are consistent with past data showing that stocked fish move back to the region of stocking to spawn. This pattern was less apparent for Illinois-stocked fish, where more fish were recovered in neighboring Indiana (46%) than in Illinois (22%) during September. Interestingly, Indiana was the second highest September recovery location for fish stocked in Wisconsin, Michigan and Illinois. Note: there was no sampling effort in Illinois during 2014 or 2015, so only 2013 data are used in the figure for fish stocked in Illinois.

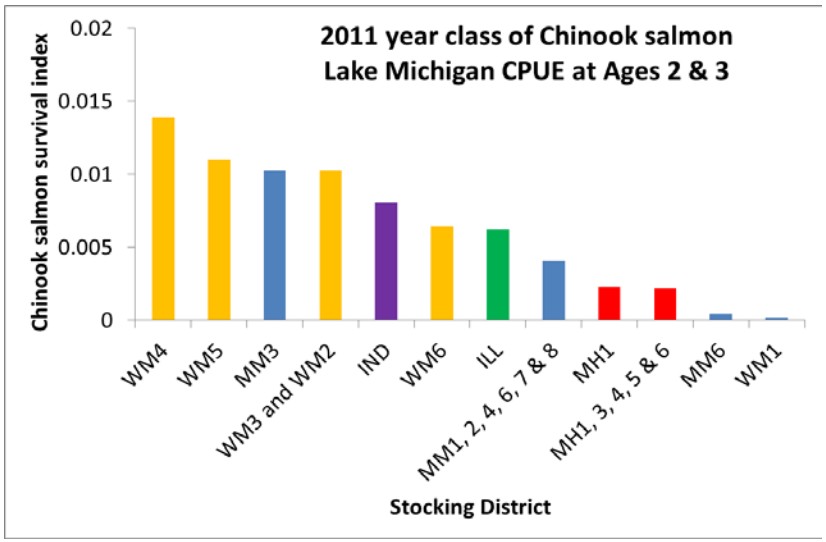
Figure 10: Recovery location proportions of Chinook salmon stocked into Lake Michigan by Illinois, Indiana, Michigan and Wisconsin, during September. Chinook salmon CPUEs were compiled for fish stocked by each state into Lake Michigan. Pie charts show the proportional breakdown of where those fish were recovered, averaged across 2013-2014 recoveries. Only Age 2 and 3 fish were included. These figures should not be interpreted as patterns in survival. Numbers may not add to 100% due to rounding

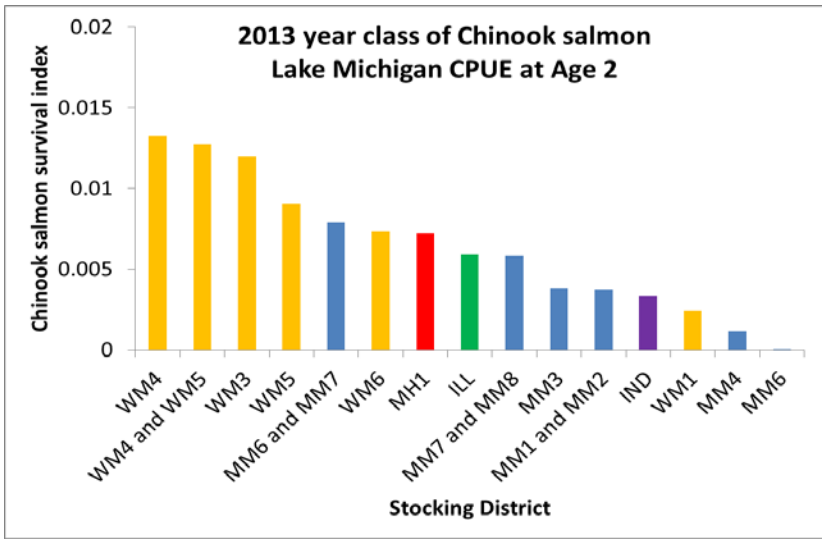


7) Results – Chinook salmon survival index for Lake Michigan recoveries

- Post-release survival of Chinook salmon varied by year class, especially for fish stocked in MM3 (Medusa Creek), MM4 (Grand Traverse Bay), WM3 (Strawberry Creek), and Indiana. Fish of 2011 year class stocked in MM3 and IND had very high survival, but the 2012 year class in Indiana and 2013 year class in Indiana and Medusa Creek had poor survival. For WM3 the 2011 and 2013 year classes had very high survival but the 2012 year class had low survival. Chinook salmon stocked in MM4 had good returns from the 2012 year class and poor returns from the 2013 year class.
- Wisconsin districts WM4, WM5, and to a lesser extent WM6, had consistently high survival across all year classes.
- Wisconsin statistical districts had the highest and second highest survival index for stocked Chinook salmon in all there year classes. Moreover, 14 of the 17 tag lots with the highest survival index were stocked in Wisconsin waters.
- Fish stocked in WM1, WM2, MM1 and MM2 (Green Bay) as well as MM6 (Little Manistee River) had consistently low survival.

Figure 11: Chinook salmon survival index by year class from each stocking district. Units on y-axis are the average month- and district-specific CPUE / 100,000 fish stocked.





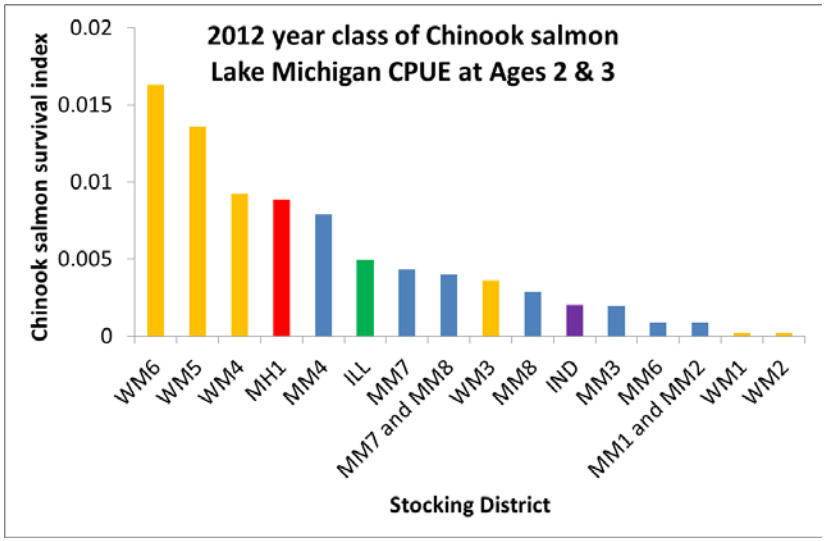


Figure 12: Survival Index of Chinook salmon in Lake Michigan waters at ages 2 & 3 for each tag lot, organized by jurisdiction. Recoveries are the average month- and district-specific average recoveries per sampling day per 1000 targeted angler hours, per 100,000 fish stocked. Tag lots are in descending order of survival index within each jurisdiction.

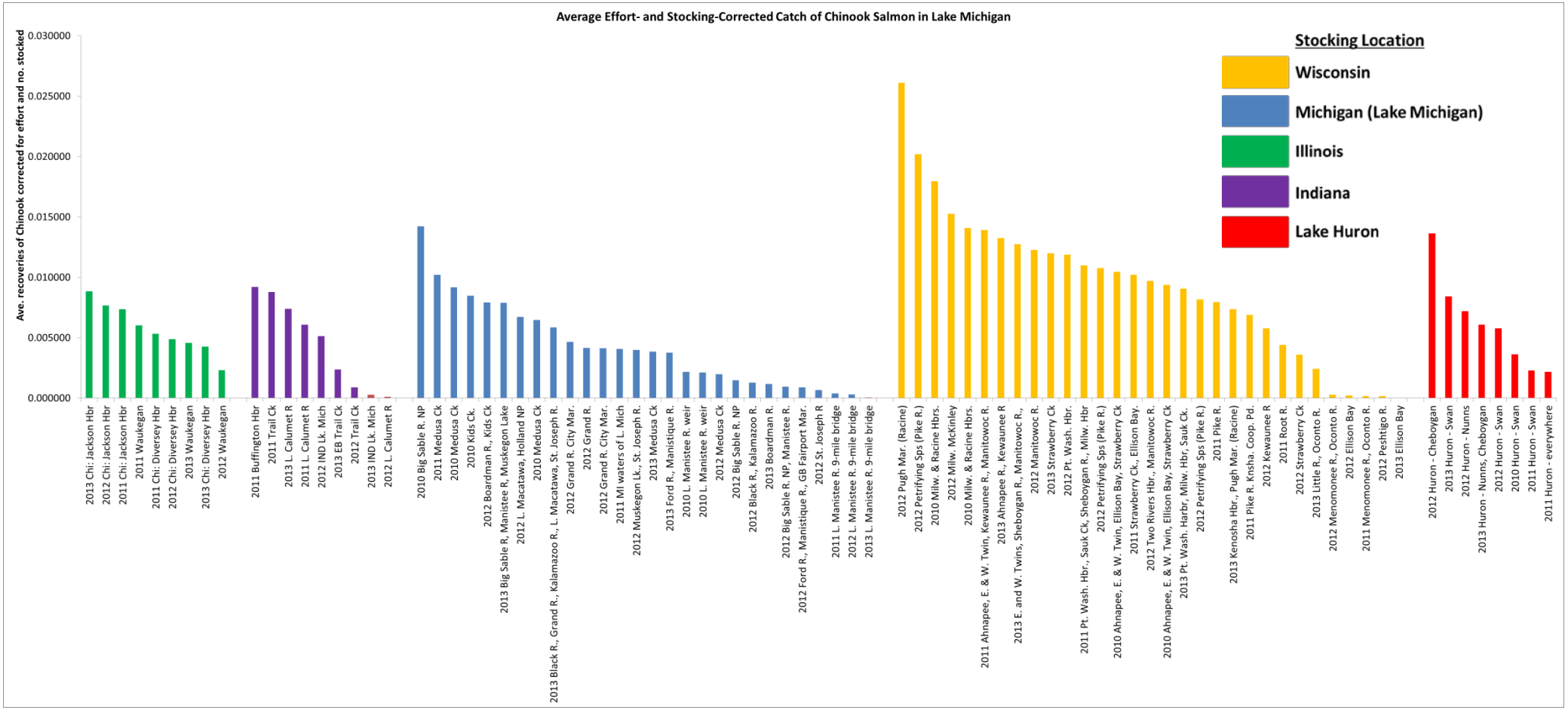
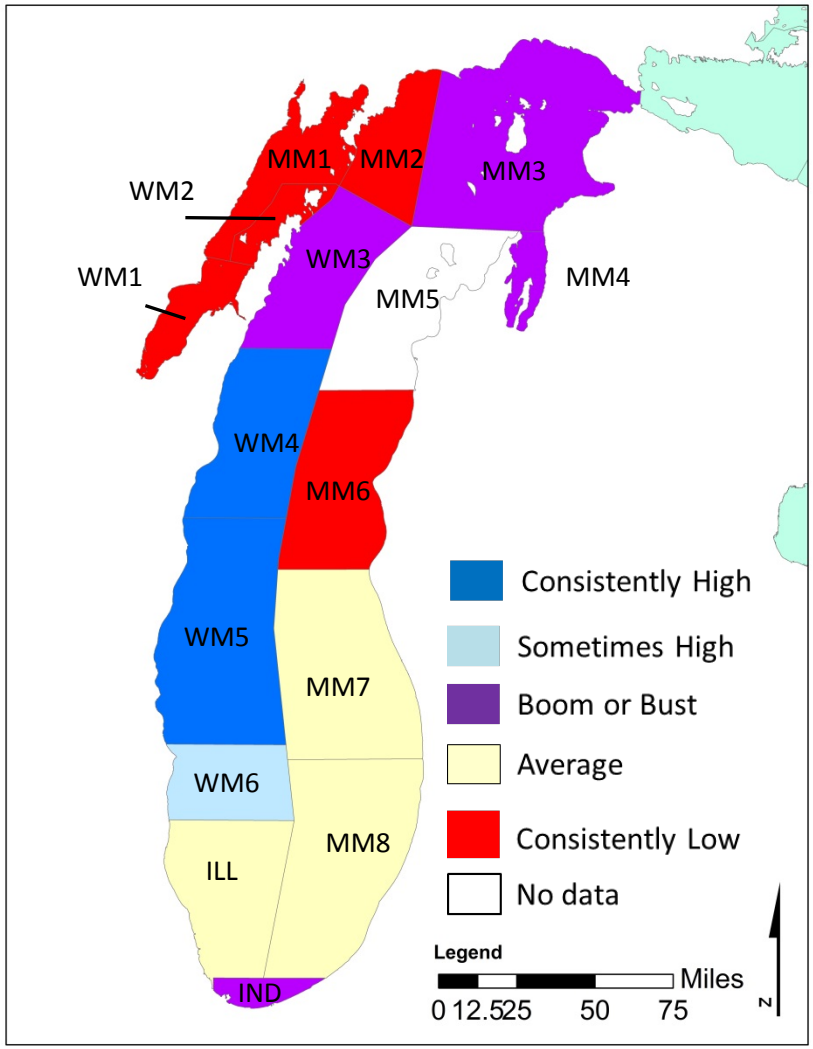


Figure 13: Map summarizing Chinook salmon survival across year classes, paired with Table 1: Specific stocking sites within each stocking district. Summarization categories were based on thresholds apparent in the distribution of survival values across year classes. "Consistently High" was assigned to stocking districts that had a survival index ≥ 0.009 in all three year classes. "Sometimes high" were always ≥ 0.006, and ≥ 0.009 in at least one year class. "Boom or Bust" were either ≥ 0.008 or ≤ 0.004. "Average" ranged from 0.004 to 0.007 in all years. "Consistently Low" were ≤ 0.001 in at least half of the year classes and always ≤ 0.004.



Stat District	Stocking Sites
ILL	Chicago (Diversey and Jackson Harbors), Waukegan
IND	Buffington Harbor, Little Calumet R., Trail Ck., Salt Ck.
MM1	Ford R., LM at Fairport Mar.
MM2	Manistique River
MM3	Medusa Creek
MM4	Boardman R., Kids Ck.
MM5	No stocking
MM6	Big Sable R., Little Manistee R., Manistee R.
MM7	Grand R., Muskegon Lake Outlet
MM8	Black R. Kalamazoo R., Lake Macatawa, St. Joseph R.
WM1	Peshtigo R., Little R., Menominee R., Oconto R.
WM2	Ellison Bay, Gills Rock
WM3	Strawberry Ck.
WM4	Kewaunee R., Ahnapee R., East Twin R., West Twin R., Two Rivers Harbor, Manitowoc R.,
WM5	Milwaukee (McKinley Mar.), Port Washington Hbr., Sauk Ck., Sheboygan R.
WM6	Kenosha Hbr., Pike R., Root R., Pugh Mar.

Table 2: Average survival index of Chinook salmon tag lots stocked in Lakes Michigan and Huron and recovered at ages 2 & 3 in Lake Michigan waters, in descending order of survival index. Survival index values are the average month- and district-specific recoveries per sampling day per 1000 targeted angler hours, per 100,000 fish stocked. Fish from the 2013 year class are listed at the bottom, as these were recovered at Age 2 only. See Table 3 for these same data organized by stocking jurisdiction.

CWT	**Year Class**	**Jurisdiction**	**Sites**	**Survival Index**
2010 – 2012 year classes, age 2 and 3 fish included				
640391	2012	WI	Pugh Mar. (Racine)	0.026101
640243	2012	WI	Petrifying Sps (Pike R.)	0.020199
640133	2010	WI	Milw. & Racine Hbrs.	0.017948
640390	2012	WI	Milw. McKinley	0.015255
640127	2010	MI Michigan	Big Sable R. NP	0.014208
640130	2010	WI	Milw. & Racine Hbrs.	0.014088
640283	2011	WI	Ahnapee, E. & W. Twin, Kewaunee R., Manitowoc R.	0.013900
640407	2012	MI Huron	Huron - Cheboygan	0.013646
640312	2012	WI	Manitowoc R.	0.012278
640325	2012	WI	Pt. Wash. Hbr.	0.011873
640282	2011	WI	Pt. Wash. Hbr., Sauk Ck, Sheboygan R., Milw. Hbr	0.010985
640384	2012	WI	Petrifying Sps (Pike R.)	0.010748
640131	2010	WI	Ahnapee, E. & W. Twin, Ellison Bay, Strawberry Ck	0.010456
640284	2011	MI Michigan	Medusa Ck	0.010214
640281	2011	WI	Strawberry Ck., Ellison Bay.	0.010212
640388	2012	WI	Two Rivers Hbr., Manitowoc R.	0.009689
640132	2010	WI	Ahnapee, E. & W. Twin, Ellison Bay, Strawberry Ck	0.009376
640275	2011	IN	Buffington Hbr	0.009200
590136	2010	MI Michigan	Medusa Ck	0.009177
640274	2011	IN	Trail Ck	0.008794
640126	2010	MI Michigan	Kids Ck.	0.008461
640383	2012	WI	Petrifying Sps (Pike R.)	0.008179
640278	2011	WI	Pike R.	0.007951
640402	2012	MI Michigan	Boardman R., Kids Ck	0.007920
640376	2012	IL	Chi: Jackson Hbr	0.007672
640206	2011	IL	Chi: Jackson Hbr	0.007346

640406	2012	MI Huron	Huron - Nunns	0.007191
640276	2011	WI	Pike R. Knsha. Coop. Pd.	0.006891
590118	2012	MI Michigan	L. Macatawa, Holland NP	0.006722
640128	2010	MI Michigan	Medusa Ck	0.006476
640273	2011	IN	L. Calumet R	0.006065
640205	2011	IL	Waukegan	0.006021
640405	2012	MI Huron	Huron - Swan	0.005764
640382	2012	WI	Kewaunee R	0.005763
640207	2011	IL	Chi: Diversey Hbr	0.005311
640378	2012	IN	IND Lk. Mich	0.005116
640375	2012	IL	Chi: Diversey Hbr	0.004872
640398	2012	MI Michigan	Grand R. City Mar.	0.004640
640277	2011	WI	Root R.	0.004394
640399	2012	MI Michigan	Grand R.	0.004163
640397	2012	MI Michigan	Grand R. City Mar.	0.004115
640288	2011	MI Michigan	MI waters of L. Mich	0.004069
640396	2012	MI Michigan	Muskegon Lk., St. Joseph R.	0.003984
590138	2010	MI Huron	Huron - Swan	0.003607
640389	2012	WI	Strawberry Ck	0.003601
640377	2012	IL	Waukegan	0.002298
640286	2011	MI Huron	Huron - Swan	0.002268
590137	2010	MI Michigan	L. Manistee R. weir	0.002179
640287	2011	MI Huron	Huron - everywhere	0.002161
640129	2010	MI Michigan	L. Manistee R. weir	0.002126
640403	2012	MI Michigan	Medusa Ck	0.001968
640393	2012	MI Michigan	Big Sable R. NP	0.001468
640395	2012	MI Michigan	Black R., Kalamazoo R.	0.001263
640394	2012	MI Michigan	Big Sable R. NP, Manistee R.	0.000929
640380	2012	IN	Trail Ck	0.000883
640392	2012	MI Michigan	Ford R., Manistique R., GB Fairport Mar.	0.000880
640401	2012	MI Michigan	St. Joseph R	0.000676
640285	2011	MI Michigan	L. Manistee R. 9-mile bridge	0.000397
640404	2012	MI Michigan	L. Manistee R. 9-mile bridge	0.000298
640385	2012	WI	Menomonee R., Oconto R.	0.000265
640381	2012	WI	Ellison Bay	0.000217

640280	2011	WI	Menomonee R., Oconto R.	0.000174
640311	2012	WI	Peshtigo R.	0.000153
640379	2012	IN	L. Calumet R	0.000111
2013 Year Class – Age 2 fish only				
640523	2013	WI	Ahnapee R., Kewaunee R	0.013249
640520	2013	WI	E. and W. Twins, Sheboygan R., Manitowoc R.,	0.012729
640522	2013	WI	Strawberry Ck	0.011996
640524	2013	WI	Pt. Wash. Harbr, Milw. Hbr, Sauk Ck.	0.009069
640504	2013	IL	Chi: Jackson Hbr	0.008843
640512	2013	MI Huron	Huron - Swan	0.008409
640509	2013	MI Michigan	Big Sable R, Manistee R, Muskegon Lake	0.007892
640508	2013	IN	L. Calumet R	0.007380
640521	2013	WI	Kenosha Hbr., Pugh Mar. (Racine)	0.007350
640514	2013	MI Huron	Huron - Nunns, Cheboygan	0.006071
640510	2013	MI Michigan	Black R., Grand R., Kalamazoo R., L. Macatawa, St. Joseph R.	0.005841
640505	2013	IL	Waukegan	0.004571
640503	2013	IL	Chi: Diversey Hbr	0.004254
640513	2013	MI Michigan	Medusa Ck	0.003845
640516	2013	MI Michigan	Ford R., Manistique R.	0.003767
640517	2013	WI	Little R., Oconto R.	0.002430
640506	2013	IN	EB Trail Ck	0.002360
640511	2013	MI Michigan	Boardman R.	0.001173
640507	2013	IN	IND Lk. Mich	0.000267
640515	2013	MI Michigan	L. Manistee R. 9-mile bridge	0.000049
640518	2013	WI	Ellison Bay	0.000000

Table 3: Average survival index of Chinook salmon tag lots stocked in Lakes Michigan and Huron and recovered at ages 2 & 3 in Lake Michigan waters, organized by jurisdiction. Survival index values are the average month- and district-specific recoveries per sampling day per 1000 targeted angler hours, per 100,000 fish stocked. Chinook salmon from the 2013 year class were only recovered at Age 2 and are in gray font, but since the CPUE value is an average, the values are comparable between all year classes.

CWT	**Year Class**	**Jurisdiction**	**Sites**	**Ave. CPUE in Lk. Michigan**
Illinois – 2010 to 2013 year classes				
640504	2013	IL	Chi: Jackson Hbr	0.008843
640376	2012	IL	Chi: Jackson Hbr	0.007672
640206	2011	IL	Chi: Jackson Hbr	0.007346
640205	2011	IL	Waukegan	0.006021
640207	2011	IL	Chi: Diversey Hbr	0.005311
640375	2012	IL	Chi: Diversey Hbr	0.004872
640505	2013	IL	Waukegan	0.004571
640503	2013	IL	Chi: Diversey Hbr	0.004254
640377	2012	IL	Waukegan	0.002298
Indiana – 2010 to 2013 year classes				
640275	2011	IN	Buffington Hbr	0.009200
640274	2011	IN	Trail Ck	0.008794
640508	2013	IN	L. Calumet R	0.007380
640273	2011	IN	L. Calumet R	0.006065
640378	2012	IN	IND Lk. Mich	0.005116
640506	2013	IN	EB Trail Ck	0.002360
640380	2012	IN	Trail Ck	0.000883
640507	2013	IN	IND Lk. Mich	0.000267
640379	2012	IN	L. Calumet R	0.000111
Michigan (Lake Michigan Waters) – 2010 to 2013 year classes				
640127	2010	MI Michigan	Big Sable R. NP	0.014208
640284	2011	MI Michigan	Medusa Ck	0.010214
590136	2010	MI Michigan	Medusa Ck	0.009177
640126	2010	MI Michigan	Kids Ck.	0.008461
640402	2012	MI Michigan	Boardman R., Kids Ck	0.007920
640509	2013	MI Michigan	Big Sable R, Manistee R, Muskegon Lake	0.007892

590118	2012	MI Michigan	L. Macatawa, Holland NP	0.006722
640128	2010	MI Michigan	Medusa Ck	0.006476
640510	2013	MI Michigan	Black R., Grand R., Kalamazoo R., L. Macatawa, St. Joseph R.	0.005841
640398	2012	MI Michigan	Grand R. City Mar.	0.004640
640399	2012	MI Michigan	Grand R.	0.004163
640397	2012	MI Michigan	Grand R. City Mar.	0.004115
640288	2011	MI Michigan	MI waters of L. Mich	0.004069
640396	2012	MI Michigan	Muskegon Lk., St. Joseph R.	0.003984
640513	2013	MI Michigan	Medusa Ck	0.003845
640516	2013	MI Michigan	Ford R., Manistique R.	0.003767
590137	2010	MI Michigan	L. Manistee R. weir	0.002179
640129	2010	MI Michigan	L. Manistee R. weir	0.002126
640403	2012	MI Michigan	Medusa Ck	0.001968
640393	2012	MI Michigan	Big Sable R. NP	0.001468
640395	2012	MI Michigan	Black R., Kalamazoo R.	0.001263
640511	2013	MI Michigan	Boardman R.	0.001173
640394	2012	MI Michigan	Big Sable R. NP, Manistee R.	0.000929
640392	2012	MI Michigan	Ford R., Manistique R., GB Fairport Mar.	0.000880
640401	2012	MI Michigan	St. Joseph R	0.000676
640285	2011	MI Michigan	L. Manistee R. 9-mile bridge	0.000397
640404	2012	MI Michigan	L. Manistee R. 9-mile bridge	0.000298
640515	2013	MI Michigan	L. Manistee R. 9-mile bridge	0.000049
Wisconsin – 2010 to 2013 year classes				
640391	2012	WI	Pugh Mar. (Racine)	0.026101
640243	2012	WI	Petrifying Sps (Pike R.)	0.020199
640133	2010	WI	Milw. & Racine Hbrs.	0.017948
640390	2012	WI	Milw. McKinley	0.015255
640130	2010	WI	Milw. & Racine Hbrs.	0.014088
640283	2011	WI	Ahnapee, E. & W. Twin, Kewaunee R., Manitowoc R.	0.013900
640523	2013	WI	Ahnapee R., Kewaunee R	0.013249
640520	2013	WI	E. and W. Twins, Sheboygan R., Manitowoc R.,	0.012729
640312	2012	WI	Manitowoc R.	0.012278
640522	2013	WI	Strawberry Ck	0.011996
640325	2012	WI	Pt. Wash. Hbr.	0.011873
640282	2011	WI	Pt. Wash. Hbr., Sauk Ck, Sheboygan R., Milw. Hbr	0.010985

640384	2012	WI	Petrifying Sps (Pike R.)	0.010748
640131	2010	WI	Ahnapee, E. & W. Twin, Ellison Bay, Strawberry Ck	0.010456
640281	2011	WI	Strawberry Ck., Ellison Bay.	0.010212
640388	2012	WI	Two Rivers Hbr., Manitowoc R.	0.009689
640132	2010	WI	Ahnapee, E. & W. Twin, Ellison Bay, Strawberry Ck	0.009376
640524	2013	WI	Pt. Wash. Harbr, Milw. Hbr, Sauk Ck.	0.009069
640383	2012	WI	Petrifying Sps (Pike R.)	0.008179
640278	2011	WI	Pike R.	0.007951
640521	2013	WI	Kenosha Hbr., Pugh Mar. (Racine)	0.007350
640276	2011	WI	Pike R. Knsha. Coop. Pd.	0.006891
640382	2012	WI	Kewaunee R	0.005763
640277	2011	WI	Root R.	0.004394
640389	2012	WI	Strawberry Ck	0.003601
640517	2013	WI	Little R., Oconto R.	0.002430
640385	2012	WI	Menomonee R., Oconto R.	0.000265
640381	2012	WI	Ellison Bay	0.000217
640280	2011	WI	Menomonee R., Oconto R.	0.000174
640311	2012	WI	Peshtigo R.	0.000153
640518	2013	WI	Ellison Bay	0.000000
Michigan (Lake Huron Waters) – 2010 to 2013 year classes				
640407	2012	MI Huron	Huron - Cheboygan	0.013646
640512	2013	MI Huron	Huron - Swan	0.008409
640406	2012	MI Huron	Huron - Nunns	0.007191
640514	2013	MI Huron	Huron - Nunns, Cheboygan	0.006071
640405	2012	MI Huron	Huron - Swan	0.005764
590138	2010	MI Huron	Huron - Swan	0.003607
640286	2011	MI Huron	Huron - Swan	0.002268
640287	2011	MI Huron	Huron - everywhere	0.002161