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Pennsylvania Department of Environmental Protection
Policy Office
Rachel Carson State Office Building
P.O. Box 2063
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Re: 2016 Draft Pennsylvania Integrated Water Quality Monitoring and Assessment Report
46 Pa. Bull. 4264-65 (July 30, 2016)

To Whom It May Concern:

On behalf of Citizens for Pennsylvania's Future (PennFuture) and its members, I submit these comments on the "2016 Draft Pennsylvania Integrated Water Quality Monitoring and Assessment Report" (2016 Draft IR) prepared by the Pennsylvania Department of Environmental Protection (Department or DEP). The 2016 Draft IR combines two biennial submissions to the U.S. Environmental Protection Agency (EPA): the "Section 305(b) Report" on water quality required by Section 305(b) of the federal Clean Water Act, 33 U.S.C. § 1315(b), and the "303(d) List" of impaired waters required by Section 303(d) of the Clean Water Act, *id.* § 1313(d). Pennsylvania's draft 303(d) List is also the combination of "Category 5" and "Category 5alt" in the 2016 Draft IR.[1]

PennFuture is a public interest membership organization dedicated to leading the transition to a clean energy economy in Pennsylvania and beyond. PennFuture strives to protect our air, water and land, and to empower citizens to build sustainable communities for future generations. One focus of PennFuture's work is to improve and protect water resources and water quality across Pennsylvania through public outreach and education, advocacy, and

[1] The 2016 Draft IR states that "Category 5 *constitutes the Section 303(d) list* EPA will approve or disapprove under the Clean Water Act," and that the impaired waters listed in Category 5alt "*remain on the 303(d) list* until water quality standards are achieved or a TMDL is developed." (2016 Draft IR, p. 5) (emphasis added). These statements imply that all of the segments and associated impaired uses, sources, and causes listed in Category 5alt also continue to appear on the Category 5 list, but that does not appear to be the case. For example, the first segment listed in Category 5alt, Deer Run (HUC 02040105), does not appear at all on the Category 5 list. Similarly, the nutrient impairments listed in Category 5alt for Wissahickon Creek (HUC 02040203) do not appear on the Category 5 list. Either all of the segments listed in Category 5alt should also be listed in Category 5, or the final Integrated Report should state: "The combination of Category 5 and Category 5alt constitutes the Section 303(d) list EPA will approve or disapprove under the Clean Water Act."

litigation. In previous reporting cycles, PennFuture has submitted monitoring data or comments to the Department for consideration in preparing its draft and final Integrated Report. PennFuture also has a long history of involvement in efforts to improve water quality in the Susquehanna River, including advocacy that helped spur the installation of cooling towers at the Brunner Island Steam Electric Generating Station in York County.

1. The Department should add the Susquehanna River from the Adam T. Bower Memorial Dam to the Holtwood Dam to the 303(d) List because of impairments to protected water uses and failure to attain Pennsylvania's general narrative water quality criterion.

A. Background

At the turn of the Millennium, the Susquehanna River had a thriving smallmouth bass population. In 2005, *Bassmaster* magazine listed the Susquehanna as one of the country's top five bass fisheries.

Beginning in 2005, however, unprecedented numbers of dead and diseased "young of the year" (YOY) bass were found in the river system, particularly in the Lower Susquehanna below the confluence of the North and West Branches of the river. The YOY classes in most subsequent years were considerably below historical average. As a result, "recruitment" into the ranks of adult (one year of age and older) smallmouth bass plummeted. In an effort to stem the decline in the smallmouth bass population, in 2010, the Pennsylvania Fish and Boat Commission (PFBC) instituted a ban on harvesting bass from the inflatable Adam T. Bower Memorial Dam in Sunbury to the Holtwood Dam near the village of Holtwood. Further, in late 2011, PFBC imposed a "closed season" restriction for bass that prohibits targeting or attempting to catch bass during the spring spawning period. Despite these restrictions, today, the Susquehanna's smallmouth bass population remains significantly below its pre-2005 level.

In August 2011, PFBC, joined by PennFuture, Chesapeake Bay Foundation, American Rivers, and the Pennsylvania Chapter of Trout Unlimited, submitted data to the Department in support of a request to include 98 miles of the Lower Susquehanna River, from the Adam T. Bower Memorial Dam to the Holtwood Dam, on its 2012 draft of the 303(d) List. Specifically, the organizations argued that data demonstrating an elevated incidence of disease and significant decline in population among the river's smallmouth bass showed that the river's designated Aquatic Life use of Warm Water Fishes and the designated Recreation use of Fishing were impaired.

The Department's 2012 draft Integrated Report did not include this requested impairment listing. To the contrary, the Department proposed to include most of the Lower Susquehanna River in Category 2 (waters where some, but not all, designated uses are met). PennFuture joined many other groups and individuals, including PFBC and 22 retired Department professionals, in submitting comments calling for the Department instead to place the 98-mile segment of the Lower Susquehanna on the 303(d) List of impaired waters (i.e., to switch it from Category 2 to Category 5). Those comments focused on impairments to the river's designated Aquatic Life use of Warm Water Fishes (WWF), *see* 25 Pa. Code §§ 93.3 (Table 1), 93.4(a)

(Table 2), 93.9m, 93.9*o*, and designated Recreation use of Fishing, *see id*. §§ 93.3 (Table 1), 93.4(a) (Table 2), resulting from the well-documented increases in the incidence of disease and mortality among YOY smallmouth bass in the river beginning in 2005, and related declines in the river's population of adult smallmouth bass.

The Department denied these requests on the grounds that it lacked sufficient information to make assessment determinations for the river's Aquatic Life and Recreation Uses. Specifically, the Department asserted that the available data did not suggest what was causing the increased incidence of disease and the decline in population among the smallmouth bass in the river. Consistent with that determination, for both the Aquatic Life and Recreation designated uses, DEP's final 2012 Integrated Report included portions of the Lower Susquehanna River (HUC 0205301, 0205305, 0205306) in Category 3 – "Waters for which there is insufficient information to determine if designated uses are met."[2] In May 2013, EPA Region III approved the Department's decision to place the Lower Susquehanna River in Category 3 rather than Category 5 (i.e., its decision *not* to include the Lower Susquehanna River on the 303(d) List of impaired waters).

The issue of the proper reporting category for the Lower Susquehanna River was dormant during the 2014 reporting cycle because intensive studies intended to inform the assessment and listing decisions were ongoing. In its comments on Pennsylvania's draft 2014 Integrated Report, EPA lauded the Department's contribution to those ongoing studies, and stated that it understood that "PADEP is still awaiting analytical result of some samples and has not had time to fully evaluate all available Susquehanna River Study data." EPA further indicated that it "anticipate[d] the aquatic life use of the Susquehanna River will be fully assessed for the 2016 IR [Integrated Report]." (2014 Integrated Report, App. I, p. 2, Comment 3). The Department's response, which referred to EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS), stated: "The DEP anticipates assessing the aquatic life use of the Susquehanna River for the 2016 Integrated Report. To aid in this effort, the DEP intends to employ the EPA CADDIS process beginning in the fall of 2014." (2014 Integrated Report, App. I, p. 2, Response to Comment 3).

Nearly 60 individuals from five agencies, two academic institutions, and the Susquehanna River Basin Commission participated in the CADDIS process in 2014-2015, which culminated in December 2015 with the Department's release of a peer-reviewed report titled "Causal Analysis of the Smallmouth Bass decline in the Susquehanna and Juniata Rivers" (CADDIS Report). The focus of the inquiry, referred to as the "case," was defined as the decrease in the abundance of smallmouth bass in the Lower Susquehanna and Lower Juniata Rivers from 2005 through the present as a result of poor recruitment into the adult smallmouth bass population. (CADDIS Report, p. 7). "The CADDIS process identified two candidate causes as Likely for the decline in recruitment of YOY SMB [smallmouth bass] into the adult population:" 1) endocrine disrupting compounds (EDCs) and herbicides; and 2) pathogens and parasites, in the presence of other stressors. (CADDIS Report, pp. 7, 9).

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[2] Specifically, the Department added to Category 3: 40.6 miles of the Susquehanna River for both the Aquatic Life and Recreation uses in Hydrologic Unit Code (HUC) 0205301; 31.6 miles for Aquatic Life and 22.9 miles for Recreation in HUC 0205305; and 56.8 miles for Aquatic Life and 41.4 miles for Recreation in HUC 0205306.

B. Continuations and changes concerning the listings for the Lower Susquehanna River in the 2016 Draft IR

i. Aquatic Life Use

The Department's 2014 response to EPA, quoted above, implied that a central purpose of engaging in the CADDIS process would be to inform an assessment of the Aquatic Life use of the Susquehanna River during the current, 2016 reporting cycle. Having now completed the CADDIS process, however, the Department is singing a different tune. Specifically, the 2016 Draft IR states:

> The CADDIS process was a stepwise scientific process to identify the most probable stressors affecting one species (SMB). CADDIS was not a decision to assess the protected Uses of the Susquehanna River for the Federal Clean Water Act Section 303(d). Although CADDIS utilized the same data the Department collected for water quality assessments, it is important to note that the CADDIS process analyzed these data using different methods than how the Department is required to assess protected uses.

(2016 Draft IR, p. 33). The 2016 Draft IR goes to emphasize that while the CADDIS Report eliminated some potential causes and played an important role in focusing future research and data collection on others, it did not establish any "definitive link" or "scientifically defensible link" between any particular class of stressors and the observed conditions of the Susquehanna's smallmouth bass population. (2016 Draft IR, pp. 36-37). As in 2012 and 2014, the Department concludes that "[m]ore data are needed on these topics." (*Id*., p. 37).

The 2016 Draft IR also explains that the Department is developing a large river aquatic life use assessment protocol that "will be made available for public comment in advance of the 2018 Integrated Report." (2016 Draft IR, p. 37). The Department hedges, however, on whether this nascent large rivers protocol will actually be available for application during the 2018 reporting cycle, stating only that "once finalized," the new protocol "should be completed in time to make accurate aquatic life use assessment in the Susquehanna River system as part of the next Integrated Report." (2016 Draft IR, p. 37). The Draft 2016 IR does not address the related issue of whether sufficient data satisfying the requirements of the forthcoming protocol will be available by 2018 to allow the Department to apply the new protocol in making Aquatic Life use assessments.

Overall, "the Department acknowledges the [smallmouth bass] disease and population decline as being potentially related to water quality issues," but declines to make assessments of the river's aquatic life use during 2016 because of:

- the attainment of numeric water quality criteria in the river study areas;
- the need to "develop appropriate biological assessment methods that look at whole biological communities" in order to provide "more rigorous analyses" that are "needed to correctly assess the aquatic life use;"
- the apparent lack of a strong correlation between the concentration of emerging

contaminants (higher in tributaries) and the prevalence of disease in YOY bass (higher in the mainstem of the river);[3] and

- uncertainty about what concentrations of emerging contaminant might cause immunosuppression in bass.

(2016 Draft IR, p. 38) As a result, with respect to the Aquatic Life use, the 2016 Draft IR proposes to leave unchanged the listing of three segments of the Lower Susquehanna River in Category 3 (unassessed/insufficient information).[4] See footnote 2, above.

ii. Recreation Use

The Draft 2016 Integrated Report does propose substantial changes in the listings pertaining to the Lower Susquehanna River's Recreation use, but those changes are unrelated to the observed disease and population impacts on the smallmouth bass. Based on water monitoring for fecal coliform bacteria in the Lower Susquehanna basin completed before 2015, the Department is proposing to:

- remove the Recreation use listings for the three segments of the Lower Susquehanna River from Category 3;
- newly list three segments of the lower Susquehanna totaling slightly more than four miles in Category 5 for having a Recreation use impairment;
- newly list more than 60 miles of the Susquehanna River in Category 2 as attaining the Recreation use; and
- newly list dozens of segments of tributaries to the Lower Susquehanna River in Category 5 for having a Recreation use impairment.

The Department's assessment of the Recreation use, however, is entirely "based on observed levels of fecal coliform bacteria. If the bacteria levels are considered unsafe for water contact sports such as swimming, the water is considered impaired." (2016 Draft IR, p. 33). The 2016 Draft IR briefly discusses the previously-existing Fish Consumption impairment listings for the Susquehanna, which extend from the confluence of the North and West Branches to the border with Maryland.[5] (*Id*., pp. 33-34). Otherwise, however, the draft report does not discuss

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[3] This assertion appears to be at odds with the discussion of the "Spatial co-occurrence" in Section 13.2.1 of the 2015 CADDIS Report. If it is based on more recent monitoring data, the Department should make that data available to the public on its "Susquehanna River Study Updates" web page. Moreover, the Department should explain how it accounted for the other factors that might affect the level of disease.

[4] It also proposes to add to Category 3 a listing for the Aquatic Life use for a 38.9 miles segment of the Lower Juniata River (HUC 0205304) from Port Royal to the confluence with the Susquehanna River.

[5] These listings, which are based on the concentration of polychlorinated biphenyls (PCBs) in tissue samples collected from channel catfish, are discussed in greater detail below. As noted in that discussion, although Pennsylvania has a category of designated water uses that is labeled "Recreation and Fish Consumption" in one section of its water quality standards regulations, *see* 25 Pa. Code § 93.3 (Table 1), and simply "Recreation" in the next section, *see id*. § 93.4(a) (Table 2), the state's water quality standards do not include a separate designated use of "Fish Consumption." Instead, fish consumption is one aspect of the designated use of "Fishing," which is defined as: "Use of the water for the legal taking of fish. For recreation *or consumption*." *Id*. § 93.3 (Table 1) (emphasis added).

the Recreation use of Fishing, 25 Pa. Code §§ 93.3 (Table 1), 93.4(a) (Table 2), and does not suggest that the Department evaluated possible impairment of the Fishing use of the Lower Susquehanna River by the observed impacts on the smallmouth bass population and resulting restrictions adopted by PFBC.

PennFuture takes no position on the 2016 Draft IR's newly-proposed listing of four miles of the Lower Susquehanna River as having a Recreation use impairment based on the sampling data for bacteria, which PennFuture has not reviewed. For the reasons explained below, those proposed listings do not go far enough, in either geographic extent or the basis for the identified Recreation use impairment. No portion of the Lower Susquehanna River should be listed in Category 2 as attaining the Recreation use. To the contrary, the Department should include the entire Lower Susquehanna River, from the Adam T. Bower Memorial Dam to the Holtwood Dam, on the 303(d) List of impaired waters in Category 5 of the final 2016 Integrated Report.

C. Rationale for additional impairment listings

i. Data and methodology

EPA's regulations require states to "assemble and evaluate all existing and readily available water quality-related data and information to develop" the 303 (d) List, 40 C.F.R. § 130.7(b)(5), including data pertaining to "waters for which water quality problems have been reported by local, state, or federal agencies; members of the public; or academic institutions." *Id*. § 130.7(b)(5)(iii). EPA's "2006 IR Guidance"[6] explains that among the data sought by states should be data concerning "observed effects" (2006 IR Guidance, p. 30), a concept the guidance's glossary explains as follows:

> Direct manifestations of an undesirable effect on waterbody conditions. For example, fish kills, fish lesions, depressed populations of certain aquatic species**,** and bioassessment scores are observed effects indicating changes in aquatic communities. . . . Major algal blooms, undesirable taste and odor in raw and finished drinking water, and increased incidences of gastroenteritis and other waterborne diseases among swimmers are also observed effects. Depending on a state's *water quality standards* and specific waterbody conditions, *observed effects* may form the basis of an impairment decision. For example, depending on the magnitude and cause of a fish kill, this observed effect may or may not result in an assessment of "impaired."

(*Id*., p. 53) (italics in original, underscoring added).

When it comes to "depressed populations of certain aquatic species," readily available data unmistakably show that the population of the Lower Susquehanna River's signature sport fish, the smallmouth bass, is severely depressed from the levels that prevailed just over a decade

[6] U.S. EPA, *Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act* (July 29, 2005) (available at https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf).

ago. Attached to these comments are data and graphs PennFuture obtained from PFBC that show the results of PFBC's smallmouth bass electrofishing surveys in the Susquehanna River between Sunbury and York Haven during the period 1990 through 2015. PFBC's graphs of the data, and its comparison of the median values of the measures of "catch per unit effort" (CPUE) for both adult and YOY smallmouth bass for the "pre-2005" and "post-2005" (2005-2015) periods,[7] leave no doubt that significant population declines have occurred. While there is expected fluctuation year-to-year, most of the annual figures for both YOY and adult smallmouth bass during the 2005-2015 period are below the overall long-term median CPUE values. For YOY smallmouth bass, the 2005-2015 median CPUE (1.9 fish/50m) is less than one-quarter of the pre-2005 median (8.7 fish/50m). The difference for adults is similarly startling, with the 2005-2015 median CPUE (29.2 fish/h) at roughly one-quarter the pre-2005 level (117.8 fish/h).

For both adult and YOY smallmouth bass, the differences between the pre-2005 and 2005-2015 periods are statistically significant. PennFuture used an on-line calculator to apply the firmly established, nonparametric Wilcoxon-Mann-Whitney test (also known as the Mann-Whitney U- test)[8] to the electrofishing survey data obtained from PFBC. As shown in the calculation summaries attached to this letter, for both the adult and YOY sampling, using a one-tailed null hypothesis, the U-value is significant at the 0.01 (one percent) significance level.[9] Thus, for both adult and YOU smallmouth bass in the Lower Susquehanna, one may say with at least 99% confidence that the populations in the 2005-2015 period are lower than they were before 2005.

By itself, this documented, statistically significant "observed effect" on the river's smallmouth bass population is sufficient for the Department to list the Lower Susquehanna's Aquatic Life and Recreation uses as impaired from the Bower Memorial Dam to the Holtwood Dam. As discussed below, there is additional, readily available information, including the 2015 CADDIS report, that provides further support for listing the river's protected uses as impaired. But without more, the population data collected using standardized electrofishing methods and analyzed using established statistical methods are sufficient to warrant a listing of the river as impaired. That is to say, methodically counting smallmouth bass and methodically analyzing the resulting population survey data satisfy the requirements of 40 C.F.R. § 130.7(b)(5)(i) & (ii) (requiring state to submit to EPA a description of the methodology and the data and information used to develop the 303(d) List). PFBC's electrofishing survey protocol and elementary statistics are the only methodologies needed to support listing the Lower Susquehanna as impaired.

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[7] PennFuture confirmed that PFBC used the onset of the disease outbreak in the summer of 2005 as the dividing line between what it labels the "pre-2005" and "post-2005" periods, so the "post-2005" data includes the data for the electrofishing surveys conducted in September of 2005.

[8] On August 18, 2016, the Independent Regulatory Review Commission approved revisions to Pennsylvania's remining regulations that employ the Wilcoxon-Mann-Whitney test as one method for determining whether there is a statistically significant difference between baseline and post-remining pollutant loads. *See* 45 Pa. Bull. 5920 (Oct. 3, 2015) (proposed rulemaking).

[9] Applying a one-tailed student's t-test to the same data similarly shows a statistically significant difference between the means of the two data sets at the 0.01 significance level. See attached calculation summaries.

The fact that the Department has not finalized its biological index methodology for large rivers does not mean that it is prohibited from listing the Aquatic Life use of such rivers as impaired. Both EPA's 2006 "IR Guidance"[10] and the Department's exiting biological indices for wadeable streams recognize that it is appropriate to take into account impacts on fish populations in assessing the aquatic life use of surface waters. Moreover, so long as the methodology applied in making a listing decision is scientifically defensible and accurately reflects the relevant water quality standard(s), it need not have been formally adopted by the state or circulated for public comment in advance of the preparation of the draft Integrated Report and 303(d) List. Thus, for example, when EPA recently proposed to add 61 stream segments to West Virginia's 2014 303(d) List, it applied a peer-reviewed genus-level methodology known by the acronym GLIMPSS despite the facts that West Virginia had not proposed using that particular methodology, and indeed viewed itself as prohibited from doing so by state law. *See* 81 Fed. Reg. 35350 (June 2, 2016).

ii. Pollutants/likely causes

The fact that the Department cannot definitively identify which pollutant(s) is causing or contributing to the smallmouth bass population decline also provides no basis to omit the Lower Susquehanna from the 303(d) List. As in previous reports, "Source Unknown" and "Cause Unknown" are ubiquitous on the 2016 Draft IR's Category 5 list. The 2016 Draft IR indicates that "Source Unknown" applies to 11,268 miles of stream impairment listings, ranking first among the impairment source categories, and "Cause Unknown" ranks seventh among the causes at 1,187 miles, all for Aquatic Life use impairments. An additional 66 miles of streams have "Unknown Toxicity" listed as the cause of an Aquatic Life use impairment. (2016 Draft IR, pp. 45-46 (Tables 3 & 4)) EPA listed as "Unknown" the "Source" of the impairment of all 61 segments it recently proposed to add to West Virginia's 2014 303(d) List. *See* EPA, Enclosure 3, EPA proposed waters to add to West Virginia's 2014 Section 303(d) List (May 11, 2016). EPA explained that "[b]ecause the addition of these waters is proposed based upon a direct measure of the aquatic community and no stressor identification analysis has been performed, the pollutant or pollutants causing the proposed impairments is unknown at this time. EPA, Enclosure 2, EPA's List Development Process (May 11, 2016), p. 4. *See also* EPA, Enclosure 1, Review of West Virginia's 2014 Section 303(d) List and Decision Rationale (May 11, 2016), p. 10 (providing similar explanation for approval of portions of West Virginia's 303(d) List listing source of biological impairment as unknown, notwithstanding 40 C.F.R. § 130.7(b)(6), where West Virginia "anticipates that the cause of biological impairments will be determined during TMDL development.").[11]

Population data of the kind submitted by PFBC likewise constitutes "a direct measure of the aquatic community" that reveals impacts with multiple potential causes or contributing factors. Thus, the inability to definitively specify, at this time, the pollutant(s) causing or

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[10] U.S. EPA, *Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act* (July 29, 2005) (available at https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf).

[11] These documents concerning EPA's pending partial disapproval of West Virginias's 2014 303(d) List are available at: https://www.epa.gov/tmdl/impaired-waters-and-tmdls-region-3.

contributing to the decline in the Lower Susquehanna's smallmouth bass population is not a bar to listing that portion of the river as having its Aquatic Life and Recreation uses impaired.

There is more here, however, than just population data; the fact is, we *do* have well-informed ideas about the pollutants to target. A stressor analysis has been performed using EPA's CADDIS methodology, which identified classes of pollutants – EDCs and herbicides – as "Likely Causes" of the observed effects on the Susquehanna's smallmouth bass population. If "Unknown Cause" is sufficient to support the listing of nearly 2,000 miles of streams as impaired, "Likely Cause" more than suffices.

iii. Impacts observed principally in one species

The fact that the impacts at issue (population decline, elevated incidence of disease, intersex fish, black splotches) have been observed principally in one species – smallmouth bass – likewise does not preclude the Department from listing the Lower Susquehanna River as impaired. This is true with respect to four relevant water quality standards: 1) the Aquatic Life use of Warm Water Fishes; 2) the Recreation use of Fishing; 3) the pre-2005 Existing Use of an abundant and healthy smallmouth bass fishery; and 4) the general narrative water quality criterion codified at 25 Pa. Code § 93.6(a). Indeed, as explained below, Pennsylvania recently listed the entire Lower Susquehanna River as impaired based on a mere consumption advisory applicable to a subset of a single species.

a) Aquatic Life/Warm Water Fishes Use

The designated Aquatic Life use of Warm Water Fishes (WWF) is defined as "[m]aintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat." 25 Pa. Code § 93.3 (Table 1). The Department suggests that biological assessment methods must "look at whole biological communities," and further states that "[p]reliminary qualitative and semi-quantitative analysis of macroinvertebrate and fish community data do not suggest there are major issues occurring to aquatic life" in the Susquehanna. (2016 Draft IR, p. 38) But given the importance of the smallmouth bass to the Susquehanna's aquatic biological community, the large, dramatic drop in its population is, without more, a "major issue."

In short, all species "count," but they do not all count the same. As noted above, EPA's 2006 IR Guidance recognizes that "depressed populations of certain aquatic species" may constitute the kind of "observed effect" that "may form the basis of an impairment decision." (2006 IR Guidance, p. 53) The "weight" given to an impact on any particular species in a listing decision must depend on both the severity of the impact and the importance of the species to the water use (or other water quality standard) at issue. Here, the severe and precipitous impact on a predominant, signature species so substantially affects the aquatic biological community that, by itself, it warrants listing the river's Aquatic Life use as impaired.

b) Recreation/Fishing Use

This reasoning applies with even greater force to the river's designated use of Fishing, to which the centrality of the smallmouth bass population cannot be gainsaid. Some anglers have always fished the Susquehanna for other species, and many continue to fish the river for smallmouth bass. The depressed population of smallmouth bass, however, has both directly and indirectly (through the fishing restrictions described above necessitated by the population decline) diminished the river's signature fishing experience.

The designated use of Fishing (F) is one of four specific water uses[12] in the category labeled "Recreation and Fish Consumption" in one section of Pennsylvania's water quality standards regulations, *see* 25 Pa. Code § 93.3(Table 1), and simply "Recreation" in the next section of those regulations, *see* 25 Pa. Code § 93.4(a) (Table 2). Despite the fact that the Department repeatedly speaks of a "Fish Consumption" use, *e.g.*, 2016 Draft IR, pp. 5-6, there is no separate designated water use of "Fish Consumption" in Pennsylvania's approved water quality standards. Rather, fish consumption is one aspect of the statewide designated use of Fishing (F), which is defined as: "Use of the water for the legal taking of fish. For recreation *or consumption*." *Id.* § 93.3 (Table 1) (emphasis added). *See also id.* § 93.4(a) (Table 2) (listing "Fishing" among the four water uses in the "Recreation" category that are applicable to all surface waters).

In 2014, the Department listed the entire mainstem of the Susquehanna River from the confluence of the West and North Branches at Northumberland to the state border with Maryland as having an impaired use of "Fish Consumption," which, as shown immediately above, is in reality one dimension of the statewide designated use of Fishing. This listing was based on the analysis tissue samples of fish taken from the river for polychlorinated biphenyls (PCBs), which in turn had prompted the Department, together with PFBC and the Pennsylvania Department of Health, to issue an advisory suggesting that the consumption of channel catfish over 20 inches in length taken from the mainstem of the river be limited to one meal per month.

So, in 2014 the Department listed the entire Lower Susquehanna as impaired based on sampling that resulted in a mere advisory to limit the consumption of a subset of one particular species – channel catfish over 20 inches long – to no more than one meal per month. It would seem to follow that the enforceable prohibition against harvesting (and thus consuming) so much as a single bass from the Bower Memorial Dam to the Holtwood Dam causes even greater impairment to the fish consumption dimension of the designated use of Fishing. In short, if the mere advisory not to eat more than one meal per month of certain channel catfish is enough to warrant listing entire mainstem of the Susquehanna River as having an impaired "Recreation and Fish Consumption" use, then the prohibition against any harvest of bass from most of that same section is more than enough to support a similar impairment listing.

[12] The other three are Boating (B), Water Contact Sports (WC), and Esthetics (E). *See* 25 Pa. Code §§ 93.3 (Table 1), 93.4(a) (Table 2).

c) Antidegradation Program/Existing Use

Pennsylvania's water quality standards include an antidegradation program, 25 Pa. Code §§ 93.4a-93.4d, one provision of which states that "[e]xisting instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." *Id*. § 93.4a(b). "Existing uses" are defined as "[t]hose uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." *Id*. § 93.1. After November 28, 1975, and certainly from the early 1990s through 2004, the Lower Susquehanna River had an existing use of propagation and maintenance of a thriving, world-class smallmouth bass fishery. That "existing use" (as defined in the quoted regulation) no longer exists in fact, which is to say that the Lower Susquehanna fails to attain the antidegradation water quality standard requiring that existing water uses be "maintained and protected." *Id*. § 93.4a(b). By itself, the documented impairment of this existing use is sufficient to warrant the inclusion of the Lower Susquehanna on the 303(d) List.

d) General Narrative Water Quality Criterion

Another of Pennsylvania's water quality standards is the general narrative water quality criterion codified at 25 Pa. Code § 93.6(a), which states that "[w]ater may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life." By the plain language of § 93.6(a), the Department does not have to be able to definitively specify the substance(s) having the harmful or inimical effect in order to find that this general criterion is not being attained.

The discussion above shows that the Lower Susquehanna River contains substances – likely including EDCs and herbicides – that have been inimical or harmful to the three protected water uses addressed in the three preceding subsections. Even if the water uses themselves were not impaired, however, it is clear that the river contains some substance(s) that is elevating the incidence of disease among smallmouth bass and depressing the river's smallmouth bass population, and thus that the Lower Susquehanna River contains substances in concentrations or amounts sufficient to be harmful to animal and aquatic life. *See id*. As a result, the Lower Susquehanna fails to satisfy the general narrative criterion stated in § 93.6(a), and that failure to attain an applicable state water quality standard warrants listing this section of the river on the 303(d) List.

2. The Integrated Report should continue to include a trend analysis for Dunkard Creek at monitoring station WQN714.

As in previous reporting cycles, Part C of the 2016 Draft IR ("Surface Water Quality Monitoring and Assessment") ends with a "Trend Analysis for Surface Waters" in Part C.5. (2016 Draft IR, pp. 61-68). One of the monitoring stations included in the Integrated Report's trend analysis in both 2012 and 2014 was Dunkard Creek at Shannopin (WQN714). That monitoring station is omitted from the trend analysis in the 2016 Draft Integrated Report.

In the 2012 and 2014 Integrated Reports, the Dunkard Creek monitoring station was distinguished by having degrading trends for a number of parameters that ran counter to the overall improving trend in water quality seen across Pennsylvania. For example, Pennsylvania's final 2014 Integrated Report stated:

- "Statistically significant trends for TP [total phosphorus] were all negative *with the exception of Dunkard Creek*."

- "Trends for SO4 [sulfate] and TDS [total dissolved solids] were mostly decreasing, *except for Dunkard Creek and Loyalsock Creek*. . . . There were substantial increasing trends for SO4 observed at Dunkard Creek in both time frames."

- "Trends for tested nitrogen species (NO3 [nitrate], NH4 [ammonium], TN [total nitrogen]) were mostly decreasing, but variable across stations. . . . Long term NO3 trends were increasing for the Schuylkill River and West Branch Susquehanna River at Lewisburg. However, the short term trend indicates a decreasing trend. *All statistically significant trends for nitrogen species at Dunkard Creek show moderate to substantial increases*."

(2014 Integrated Report, p. 60) (emphasis added throughout).

In summarizing the trend analysis results, the 2014 Integrated Report singled out the Dunkard Creek monitoring station for bucking the overall trend toward improved water quality:

> The generally decreasing trends in transition metals, poor metals, SO4, nitrogen species, and phosphorus species, combined with increasing trends in ALK [alkalinity] and Hard [hardness] suggest improving chemical water quality conditions based on the sampling conducted in the tested time periods at all the stations analyzed *except the Dunkard Creek station*. Increasing trends in ALK can often be considered water quality improvements because increased ALK means increased acid neutralizing capacity, but elevation of alkalinity much beyond natural levels can have detrimental consequences to water quality, so assessment of the ALK trends depends on the specific context of conditions at each station.
>
> *Trends for many constituents exhibited particularly dramatic increasing trends at the Dunkard Creek station*. Increasing trends at this station were well over 100% for Hard, SO4, NO3, NH4, TN, and TP in one or both time frames. *The Dunkard Creek station also was the only station to show increasing SO4, TP, and TN trends*.

(2014 Integrated Report, pp. 66-67) (emphasis added throughout).

The summary of the trend analysis in the 2012 Integrated Report similarly highlighted Dunkard Creek:

> *Trends for many constituents exhibited particularly dramatic increasing trends at the Dunkard Creek station.* Increasing trends at this station were well over 100% for Hard, Ca, Mg, SO4, TDS, NO3, NH4, TN, and TP in one or both time frames. *The Dunkard Creek station and the Clarion River Station also were the only two stations to show increasing SO4, TP, and TN trends.* These two stations, along with the Youghiogheny River station in the 1991 to 2010 time frame[,] were also the only stations to show increasing TDS trends, *with the increasing TDS trends at Dunkard Creek being particularly dramatic. The Dunkard Creek station was also the only station to show increasing Ca, Mg, NH4, and TP trends.*

(2012 Integrated Report, p. 59) (emphasis added throughout).

The fact that Dunkard Creek has been found in the past to exhibit certain distinctive water quality trends makes it all the more important to keep the Dunkard Creek monitoring station in the trend analysis during the current and future reporting cycles. PennFuture therefore recommends that the Department include monitoring station WQN714 in the trend analysis presented in the final version of the 2016 Integrated Report, and that it continue to include that station in future iterations of the trend analysis.

Thank you for your consideration of these comments. Please feel free to contact me at 717-214-7925 if you have any questions.

Sincerely,

Kurt J. Weist
Senior Attorney

Attachments

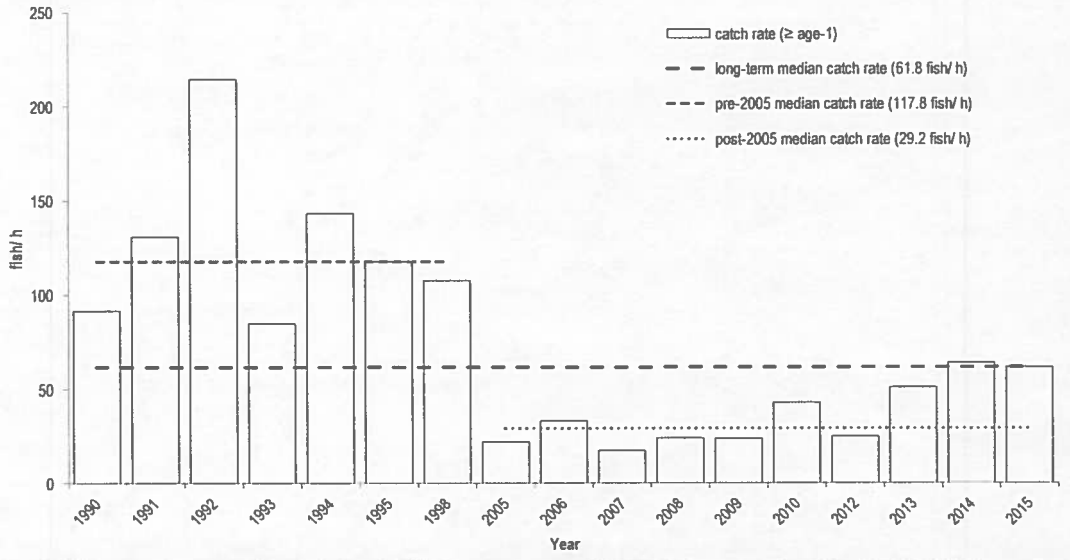
cc: Bill Richardson, EPA Region III (by electronic mail only)

ATTACHMENTS

PENNSYLVANIA FISH AND BOAT COMMISSION
ADULT SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

midSusquehanna_adultSMB_CPUE

Year	1990	1991	1992	1993	1994	1995	1998	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015
Type	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach	Reach
Effort (h)	4.75	4.68	4.37	4.08	4.25	4.77	2.95	4.35	4.98	3.4	3.32	5.06	4.92	4.67	4.63	3.12	2.72
Reach-wide CPUE (≥ age-1)	**91.58**	**130.77**	**214.42**	**85.05**	**143.29**	**117.82**	**107.80**	**22.07**	**33.33**	**17.35**	**24.10**	**23.91**	**43.09**	**25.05**	**50.97**	**64.17**	**61.76**
long-term median CPUE (61.8 fish/ h)	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
pre-2005 median CPUE (117.8 fish/ h)	117.82	117.82	117.82	117.82	117.82	117.82	117.82										
post-2005 median CPUE (29.2 fish/ h)								29.19343	29.19343	29.19343	29.19343	29.19343	29.19343	29.19343	29.19343	29.19343	29.19343
long-term median catch rate (61.8 fish/ h)																	
pre-2005 median catch rate (117.8 fish/ h)																	
post-2005 median catch rate (29.2 fish/ h)																	

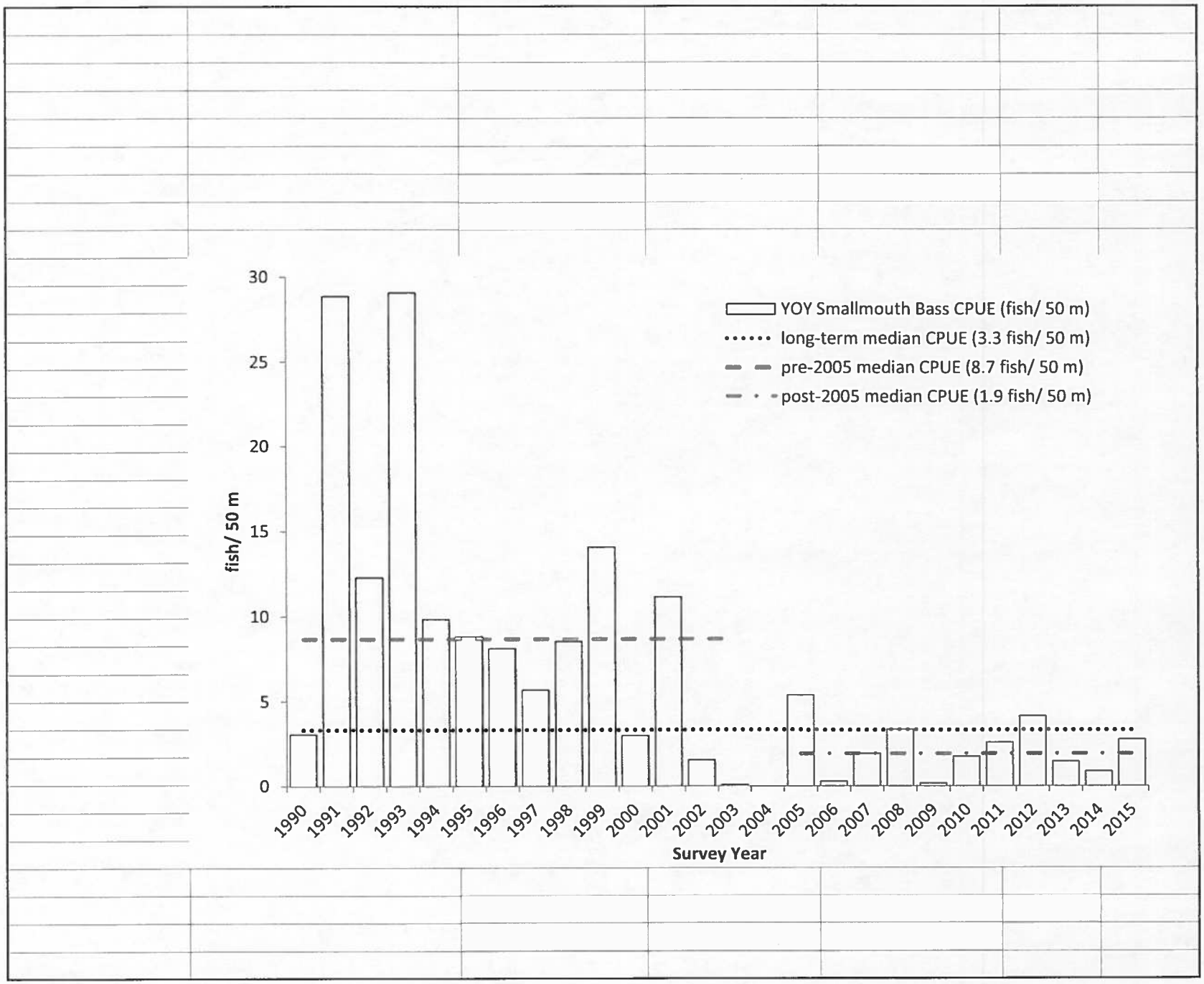


PENNSYLVANIA FISH AND BOAT COMMISSION
YOY SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

midSusquehanna_YOYSMB_CPUE

	middle Susquehanna River	long-term median	pre-2005 median	post-2005 median		
1986		3.3				
1987		3.3				
1988		3.3				
1989		3.3				
1990	3.033333333	3.3	8.7			
1991	28.83333333	3.3	8.7			
1992	12.27777778	3.3	8.7			
1993	29.05555556	3.3	8.7			
1994	9.833333333	3.3	8.7			
1995	8.8	3.3	8.7			
1996	8.1	3.3	8.7			
1997	5.666666667	3.3	8.7			
1998	8.516666667	3.3	8.7			
1999	14.05555556	3.3	8.7			
2000	2.972222222	3.3	8.7			
2001	11.13333333	3.3	8.7			
2002	1.528571429	3.3	8.7			
2003	0.055555556	3.3	8.7			
2004		3.3				
2005	5.333333333	3.3		1.9		
2006	0.263888889	3.3		1.9		
2007	1.87962963	3.3		1.9		
2008	3.317460317	3.3		1.9		
2009	0.15	3.3		1.9		
2010	1.723	3.3		1.9		
2011	2.55	3.3		1.9		
2012	4.1	3.3		1.9		
2013	1.4359	3.3		1.9		
2014	0.86	3.3		1.9		
2015	2.7	3.3		1.9		
MEDIAN	3.3					
pre-2005 median	8.658333333					
post-2005 median	1.87962963					

midSusquehanna_YOYSMB_CPUE



MANN-WHITNEY U-TEST CALCULATION

ADULT SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

Social Science Statistics

Mann-Whitney U Test Calculator

The value of U is 0.

You'll notice below that we have calculated a critical value for U based on alpha level and whether your hypothesis is one or two tailed. We have also calculated a value for *Z* and its associated *p*-value. Results in blue reach significance. Results in red do not.

Sample 1	Sample 2
91.58	22.07
130.77	33.33
214.42	17.35
85.05	24.10
143.29	23.91
117.82	43.09
107.80	25.05
	50.97
	64.17
	61.76

Significance Level:

- (•) .01
- ( ) .05

1 or 2-tailed hypothesis?:

- (•) One-tailed
- ( ) Two-tailed

The *U*-value is 0. The critical value of *U* at $p < .01$ is 11. Therefore, the result is significant at $p < .01$.

The *Z*-Score is -3.36686. The *p*-value is .00038. The result is significant at $p < .01$.

Note: The approximation to the form of the normal distribution becomes less robust at sample sizes smaller than 10, so caution is appropriate here in making use the Z-value calculation.

Important Note

If you want full details about how the U-value was calculated, including rank order data, descriptive statistics and an explanation of the result, please click the "Calculation Details" button below.

Calculate U | Reset | Calculation Details

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1-1)s_1^2 + (N_2-1)s_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Social Science Statistics

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1-1)s_1^2 + (N_2-1)s_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Mann-Whitney U Test Calculator

The value of *U* is 0.

Explanation of Results

As you can no doubt see, this calculator spits out quite a lot of information. Most of it is self-explanatory, but there are a couple of things worth noting.

First, there is no standard way for the Mann-Whitney *U* test to handle tied ranks, which means if your data has tied ranks, you're going to get a different result for *U* depending on the statistics package you use (for a discussion of some of the issues this raises, see this article, for example).

Second, where the number of scores (i.e., the value of *N*) in each sample is 10 or more, you can assume that your sampling distribution is approximately normal. This means you can use a *Z*-ratio to calculate the value of *p*.

Sample 1	Sample 2	S1 Values	S1 Ranks	S2 Values	S2 Ranks
91.58	22.07	85.05	11	17.35	1
130.77	33.33	91.58	12	22.07	2
214.42	17.35	107.8	13	23.91	3
85.05	24.10	117.82	14	24.1	4
143.29	23.91	130.77	15	25.05	5
117.82	43.09	143.29	16	33.33	6
107.80	25.05	214.42	17	43.09	7
	50.97			50.97	8
	64.17			61.76	9
	61.76			64.17	10

Significance Level:
- (•) 0.01
- ( ) 0.05

1 or 2-tailed hypothesis?:
- (•) One-tailed
- ( ) Two-tailed

Result Details

Sample 1
Sum of ranks: 98
Mean of ranks: 14
Expected sum of ranks: 63
Expected mean of ranks: 9
U-value: 0
Expected *U*-value: 35

Sample 2
Sum of ranks: 55
Mean of ranks: 5.5
Expected sum of ranks: 90
Expected mean of ranks: 9
U-value: 70
Expected *U*-value: 35

Sample 1 & 2 Combined
Sum of ranks: 153
Mean of ranks: 9
Standard Deviation: 10.247

Result 1 - U-value

The *U*-value is 0. The critical value of *U* at $p < .01$ is 11. Therefore, the result is significant at $p < .01$.

Result 2 - Z-ratio

The *Z*-Score is -3.36686. The *p*-value is .00038. The result is significant at $p < .01$.

Note: The approximation to the form of the normal distribution becomes less robust at sample sizes smaller than 10, so caution is appropriate here in making use the Z-value calculation.

Return to Home Reset

MANN-WHITNEY U-TEST CALCULATION

YOY SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

Social Science Statistics

Mann-Whitney U Test Calculator

The value of U is 24.

You'll notice below that we have calculated a critical value for U based on alpha level and whether your hypothesis is one or two tailed. We have also calculated a value for *Z* and its associated *p*-value. Results in blue reach significance. Results in red do not.

Sample 1	Sample 2
3.033	5.333
28.833	0.264
12.278	1.880
29.056	3.317
9.833	0.150
8.800	1.723
8.100	2.550
5.667	4.100
8.517	1.436
14.056	0.860
2.972	2.722
11.133	
1.529	
0.056	

Significance Level:

- (•) .01
- ( ) .05

1 or 2-tailed hypothesis?:

- (•) One-tailed
- ( ) Two-tailed

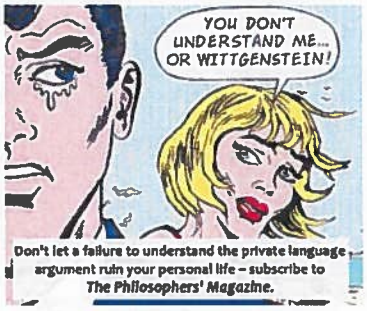
The *U*-value is 24. The critical value of *U* at $p < .01$ is 34. Therefore, the result is significant at $p < .01$.

The *Z*-Score is 2.87411. The *p*-value is .00205. The result is significant at $p < .01$.

Important Note

If you want full details about how the U-value was calculated, including rank order data, descriptive statistics and an explanation of the result, please click the "Calculation Details" button below.

Calculate U | Reset | Calculation Details



Social Science Statistics

Mann-Whitney U Test Calculator

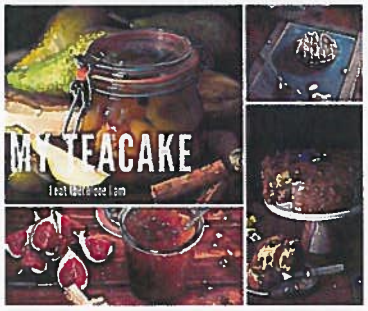
The value of *U* is 24.

Explanation of Results

As you can no doubt see, this calculator spits out quite a lot of information. Most of it is self-explanatory, but there are a couple of things worth noting.

First, there is no standard way for the Mann-Whitney *U* test to handle tied ranks, which means if your data has tied ranks, you're going to get a different result for *U* depending on the statistics package you use (for a discussion of some of the issues this raises, see this article, for example).

Second, where the number of scores (i.e., the value of *N*) in each sample is 10 or more, you can assume that your sampling distribution is approximately normal. This means you can use a *Z*-ratio to calculate the value of *p*.



Sample 1	Sample 2	S1 Values	S1 Ranks	S2 Values	S2 Ranks
3.033	5.333	0.056	1	0.15	2
28.833	0.264	1.529	6	0.264	3
12.278	1.880	2.972	11	0.86	4
29.056	3.317	3.033	12	1.436	5
9.833	0.150	5.667	16	1.723	7
8.800	1.723	8.1	17	1.88	8
8.100	2.550	8.517	18	2.55	9
5.667	4.100	8.8	19	2.722	10
8.517	1.436	9.833	20	3.317	13
14.056	0.860	11.133	21	4.1	14
2.972	2.722	12.278	22	5.333	15
11.133		14.056	23		
1.529		28.833	24		
0.056		29.056	25		

Significance Level:

- (•) 0.01
- ( ) 0.05

1 or 2-tailed hypothesis?:

- (•) One-tailed
- ( ) Two-tailed

Result Details

Sample 1
Sum of ranks: 235
Mean of ranks: 16.79
Expected sum of ranks: 182
Expected mean of ranks: 13
U-value: 24
Expected *U*-value: 77

Sample 2
Sum of ranks: 90
Mean of ranks: 8.18
Expected sum of ranks: 143
Expected mean of ranks: 13
U-value: 130
Expected *U*-value: 77

Sample 1 & 2 Combined
Sum of ranks: 325
Mean of ranks: 13
Standard Deviation: 18.2665

Result 1 - U-value

The *U*-value is 24. The critical value of *U* at $p < .01$ is 34. Therefore, the result is significant at $p < .01$.

Result 2 - Z-ratio

The *Z*-Score is 2.87411. The *p*-value is .00205. The result is significant at $p < .01$.

Return to Home | Reset

STUDENT'S t-TEST CALCULATION

ADULT SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1-1)s_1^2 + (N_2-1)s_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Social Science Statistics

T-Test Calculator for 2 Independent Means

Success!

Explanation of results

The output of this calculator is pretty straightforward. The values of *t* and *p* appear at the bottom of the page. If the text is blue, your result is significant; if it's red, it's not. The only thing that might catch you out is the way that we've rounded the data. The data you see in front of you, apart from the *t* and *p* values at the page bottom, has been rounded to 2 significant figures. However, we did not round when actualy calculating the values of *t* and *p*. This means if you try to calculate these values on the basis of the summary data provided here, you're likely going to end up with a different, less accurate, result. This is especially the case if you're dealing with numbers that are fractions of 1.

Treatment 1 (*X*)	*Diff* (*X* - *M*)	*Sq. Diff* $(X - M)^2$
91.58	-35.67	1272.15
130.77	3.52	12.41
214.42	87.17	7599.11
85.05	-42.20	1780.60
143.29	16.04	257.37
117.82	-9.43	88.87
107.80	-19.45	378.19
	M: 127.25	SS: 11388.70

Treatment 2 (*X*)	*Diff* (*X* - *M*)	*Sq. Diff* $(X - M)^2$
22.07	-14.51	210.54
33.33	-3.25	10.56
17.35	-19.23	369.79
24.10	-12.48	155.75
23.91	-12.67	160.53
43.09	6.51	42.38
25.05	-11.53	132.94
50.97	14.39	207.07
64.17	27.59	761.21
61.76	25.18	634.03
	M: 36.58	SS: 2684.81

Significance Level:

- (•) .01
- ( ) .05
- ( ) .10

One-tailed or two-tailed hypothesis?:

- (•) One-tailed
- ( ) Two-tailed

Difference Scores Calculations

Treatment 1

N_1: 7
$df_1 = N - 1 = 7 - 1 = 6$
M_1: 127.25
SS_1: 11388.7
$s^2_1 = SS_1/(N - 1) = 11388.7/(7-1) = 1898.12$

Treatment 2

N_2: 10
$df_2 = N - 1 = 10 - 1 = 9$
M_2: 36.58
SS_2: 2684.81
$s^2_2 = SS_2/(N - 1) = 2684.81/(10-1) = 298.31$

T-value Calculation

$s^2_p = ((df_1/(df_1 + df_2)) * s^2_1) + ((df_2/(df_2 + df_2)) * s^2_2) = ((6/15) * 1898.12) + ((9/15) * 298.31) = 938.23$

$s^2_{M_1} = s^2_p/N_1 = 938.23/7 = 134.03$
$s^2_{M_2} = s^2_p/N_2 = 938.23/10 = 93.82$

$t = (M_1 - M_2)/\sqrt{(s^2_{M_1} + s^2_{M_2})} = 90.67/\sqrt{227.86} = 6.01$

The t-value is 6.00647. The p-value is .000012. The result is significant at $p < .01$.

Note: If you wish to calculate the effect size, this calculator will do the job.

Calculate T and P Values | Reset

STUDENT'S t-TEST CALCULATION

YOY SMALLMOUTH BASS ELECTROFISHING DATA (CPUE)
SUNBURY TO YORK HAVEN
1990-2015

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1-1)s_1^2 + (N_2-1)s_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Social Science Statistics

T-Test Calculator for 2 Independent Means

Success!

Explanation of results

The output of this calculator is pretty straightforward. The values of *t* and *p* appear at the bottom of the page. If the text is blue, your result is significant; if it's red, it's not. The only thing that might catch you out is the way that we've rounded the data. The data you see in front of you, apart from the *t* and *p* values at the page bottom, has been rounded to 2 significant figures. However, we did not round when actually calculating the values of *t* and *p*. This means if you try to calculate these values on the basis of the summary data provided here, you're likely going to end up with a different, less accurate, result. This is especially the case if you're dealing with numbers that are fractions of 1.

Treatment 1 (*X*)	*Diff* (*X* - *M*)	*Sq. Diff* (*X* - *M*)^2
3.033	-7.24	52.46
28.833	18.56	344.36
12.276	2.00	4.01
29.056	18.78	352.69
9.833	-0.44	0.20
8.800	-1.48	2.18
8.100	-2.18	4.73
5.667	-4.61	21.24
8.517	-1.76	3.09
14.056	3.78	14.29
2.972	-7.30	53.35
11.133	0.86	0.73
1.529	-8.75	76.51
0.056	-10.22	104.45
	M: 10.28	SS: 1034.30

Treatment 2 (*X*)	*Diff* (*X* - *M*)	*Sq. Diff* (*X* - *M*)^2
5.333	3.12	9.74
0.264	-1.95	3.80
1.980	-0.33	0.11
3.317	1.10	1.22
0.150	-2.06	4.25
1.723	-0.49	0.24
2.550	0.34	0.11
4.100	1.89	3.56
1.436	-0.78	0.60
0.860	-1.35	1.83
2.722	0.51	0.26
	M: 2.21	SS: 25.73

Significance Level:

- (•) .01
- ( ) .05
- ( ) .10

One-tailed or two-tailed hypothesis?:

- (•) One-tailed
- ( ) Two-tailed

Difference Scores Calculations

Treatment 1

N_1: 14
$df_1 = N - 1 = 14 - 1 = 13$
M_1: 10.28
SS_1: 1034.3
$s^2_1 = SS_1/(N - 1) = 1034.3/(14-1) = 79.56$

Treatment 2

N_2: 11
$df_2 = N - 1 = 11 - 1 = 10$
M_2: 2.21
SS_2: 25.73
$s^2_2 = SS_2/(N - 1) = 25.73/(11-1) = 2.57$

T-value Calculation

$s^2_p = ((df_1/(df_1 + df_2)) * s^2_1) + ((df_2/(df_2 + df_2)) * s^2_2) = ((13/23) * 79.56) + ((10/23) *$

2.57) = 46.09

$s^2_{M_1} = s^2_p/N_1 = 46.09/14 = 329$
$s^2_{M_2} = s^2_p/N_2 = 46.09/11 = 419$

$t = (M_1 - M_2)/\sqrt{(s^2_{M_1} + s^2_{M_2})} = 8.06/\sqrt{7.48} = 2.95$

The *t*-value is 2.94801. The *p*-value is .003609. The result is significant at $p < .01$.

Note: If you wish to calculate the effect size, this calculator will do the job.

Calculate T and P Values | Reset