Written Testimony of Carys L. Mitchelmore, Ph.D.
To the House Environmental and Transportation Committee
Regarding HB 229: Pesticides – Use of Chlorpyrifos - Prohibition

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Chairman Barve, Vice Chairman Stein and members of the Committee, I would like to take this opportunity to thank you for considering my written testimony outlining the state of the science on the impact of chlorpyrifos to aquatic organisms. My name is Dr. Carys Mitchelmore. I am a Professor at the University of Maryland Center for Environmental Science (UMCES), Chesapeake Biological Laboratory. My field of study is in environmental health and aquatic toxicology and includes research into the fate and effects of chemical contaminants on organisms. Today I am representing my personal views as a researcher in the field of environmental health and as a local citizen of the Chesapeake Bay watershed. My views do not reflect the Institution where I work. I will specifically focus on the weight of evidence in the scientific literature relating to the toxicity of the pesticide chlorpyrifos on

From my synthesis of the current literature I have two main summary findings to highlight:

1. Chlorpyrifos is widespread in streams and rivers, including in Maryland waterways.
2. Chlorpyrifos is present in aquatic environments at concentrations that may cause harm to a variety of aquatic organisms and also negatively impact various ecosystem services.

Chlorpyrifos has been in use since 1965 as a broad-spectrum chlorinated organophosphate insecticide and is used in agriculture (e.g. on grain, cotton, fruit, nut and vegetable crops), used on farm animals, domestic dwellings and on lawns and ornamental plants. It is effective by direct contact, ingestion and inhalation. This insecticide works by interfering with the enzyme cholinesterase that is essential for the proper working of the nervous system. Specifically, it inhibits the breakdown of the neurotransmitter, acetylcholine, resulting in overstimulation of the nerve cells causing neurotoxicity and ultimately death (Karanth and Pope 2000, USDHSS 1997). Although it can also interact with other enzymes in the body too and impair an organisms normal function as outlined below (Karanth and Pope 2000).

Although this pesticide should not be applied directly to water, chlorpyrifos has been measured in aquatic ecosystems in a number of studies and has been ranked third on the 2006 Chesapeake Bay "Toxics of Concern" list having been detected in 90% of all environmental samples analyzed (Chesapeake Bay Program 2006). This may be due to agricultural runoff, leaching, atmospheric transport, spray drift and improper disposal. The presence of chlorpyrifos in aquatic systems exposes aquatic organisms that may accumulate it, potentially resulting in a number of toxicological impacts. **Indeed over 40% of the samples analyzed in the Chesapeake Bay were at concentrations that exceeded toxicity thresholds indicating potential impacts** (Chesapeake Bay Program 2006).

Chlorpyrifos is highly effective at controlling insects, however, many studies have shown that it is also very highly toxic to other organisms, such as, fish and aquatic insects as normal functioning and activity of acetylcholine is essential for normal behavior and muscular function. USEPA 1989, 2017, Barron and Woodburn 1995, Deb and Das 2013). **Exposing fish to low environmentally relevant concentrations of chlorpyrifos has been shown to cause acute toxicity (death)** through inhibition of cholinesterase activity (NYSEDC 1986). For example, acute toxicity concentrations are at low part per billion concentrations in a number of fish (i.e. 96-hour LC50's; the lethal concentration that kills 50% of the population), such as, rainbow trout (3-7ppb) and bluegill sunfish (2-3ppb)(Deb and Das 2013). **Therefore, chlorpyrifos has been classified as very highly toxic to fish. There are many similar fish species in the streams and rivers of the Chesapeake Bay that may also be similarly affected at these low concentrations**. Acute toxicity (i.e. 48-hour LC50s) for aquatic invertebrates has been seen at even lower concentrations of chlorpyrifos, for example, 0.5 and 1.7 ppb for Korean shrimp and *Daphnia* sp. respectively (Tomlin 2006). Losing important invertebrate species can have drastic effects to the trophic food web as the prey

base is lost and also may impact important ecosystem services, such as nutrient recycling and leaf litter breakdown. Furthermore, the toxicity of chlorpyrifos has been shown to increase with other co-stressors, including those relevant to climate change, such as, increasing temperatures (Schimmel et al. 1983). This is very important for Chesapeake Bay organisms as they are exposed to these chemicals and also experiencing increased water temperatures due to climate change. In addition, **chlorpyrifos can impact the fish directly due to its toxicity but also indirectly by reducing the amount of invertebrate prey that the fish rely on for food.**

In addition to acute toxicity, various sublethal effects of exposure to chlorpyrifos at low, environmentally-relevant concentrations have also been demonstrated that ultimately may impact the growth, survival and reproductive success of aquatic organisms (TOXNET 1986, Sunanda et al. 2016). Multiple mechanisms of effect include, damage to DNA (Ali 2008, Ismail et al. 2018), liver problems (Muttappa et al. 2015), blood cell changes (Ismail et al. 2018, Sunanda et al. 2016), oxidative stress and alterations in protective antioxidant mechanisms (Goel et al. 2005), neurobehavioral and neurochemical changes (Slotkin et al., 2005). Studies in larval and embryonic fish show problems with development, their body shape and form, and behavior, including alterations in swimming (Levin et al. 2003, 2004, Richendrfer et al. 2012). Exposures of juvenile common carp demonstrated an array of irregular and erratic swimming movements, in addition to body form changes and deformities (Halappa and David, 2009). **Chlorpyrifos causes permanent neurotoxic effects also at low concentrations** (Sledge et al. 2011). There is also evidence that **chlorpyrifos may be an endocrine disruptor in fish** and interfere with steroid hormone (e.g. cortisol) production at low parts per billion concentrations, which are responsible for normal homeostatic mechanisms and immune function (Oruc 2010).

In December, 2017, the National Marine Fisheries Service (NMFS) in their biological opinion report concluded that three pesticides, including chlorpyrifos, were likely to significantly impact the survival of salmon species (genus *Oncorhynchus*), many of which are already endangered species of fish. **We have similar fish species as these in the Chesapeake Bay that may also be impacted, for example the freshwater Brook trout (genus *Salvelinus* or Char) and Rainbow trout**. Rainbow trout belong to the genera *Oncorhynchus* as do Pacific Salmon. This report, highlighted that chlorpyrifos is affecting 38 species of endangered fish (NMFS 2017). Bioaccumulation of chlorpyrifos in the tissues of aquatic organisms, including fish, has been observed with values ranging from 58 to 5100 (i.e. accumulations up to 5100 times more concentrated in the tissues than levels of the chemical in water; Ahmad et al. 2000, Banu et al. 2001, Racke 1992). Indeed, **the NMFS report also stated that chlorpyrifos negatively impacts the orcas that eat the pesticide-contaminated salmon. The Chesapeake Bay also has a number of higher trophic level organisms (including humans) that could also eat pesticide-contaminated fish and so there may also be food-web implications.**

In summary, there are a number of studies demonstrating that chlorpyrifos is present in the Chesapeake Bay at concentrations that may be detrimental to a number of important species in the Bay. This includes aquatic invertebrates that perform essential ecosystem services and are important food sources for recreationally, commercially and ecologically important fish species. Studies have also shown significant impacts, including endocrine disruption, behavioral and genetic integrity changes in fish and other vertebrate species at these environmental concentrations and warrants concern and further investigation. If you would like a further explanation or copies of the listed references please contact me.

References:

Ahmad, I. Hamid, T. Fatima, M. Chand, H.S. Jain, S.K. Athar, M. and Raisuddin, S. 2000. Induction of hepatic antioxidants in freshwater catfish (*Channa punctatus Bloch*) is a biomarker of paper mill effluent exposure. Biochim. Biophys. Acta 1523: 37-48.

Ali, D., Nagpure, N.S., Kumar, S., Kumar, R., Kushwaha, B. and W.S. Lakra. 2008. Assessment of genotoxic and mutagenic effects of chlorpyrifos in freshwater fish *Channa punctatus (Bloch*) using micronucleus (MN) assay and alkaline single-cell gel electrophoresis. Food and Chemical Toxicology : an International Journal Published for the British Industrial Biological Research Association, 47(3):650-656.

Banu, B.S. Danadevi, K. Rahman, M.F. Ahuja,Y.R. and Kaiser, J. 2001. Genotoxic effect of monocrotophos to sentinel species using comet assay. Food Chem. Toxicol. 39: 361–366.

Barron M.G. and Woodburn K.B. 1995. Ecotoxicology of chlorpyrifos. Reviews of Environmental Contamination and Toxicology

1995, 144, 1-93.

Chesapeake Bay Program. 2006. Prioritized Chesapeake Bay Organic Toxics of Concern Method and Assessment. Toxics Subcommittee of the Chesapeake Bay Program. Annapolis, MD, August 2006. TOC01.2

Deb, N. and Das, S. 2013. Chlorpyrifos Toxicity in Fish: A Review. Current World Environment, 8, 1, 77-84.

Goel, A. Danni, V. and Dhawan, D.K. 2005. Protective effects of zinc on lipid peroxidation Antioxidant enzymes and hepatic histoarchitecture in chlorpyrifos-induced toxicity. Chemico-Biological Interactions, 156:131–140.

Halappa, R., and M. David. 2009. Behavioural Responses of the Freshwater Fish, *Cyprinus carpio* (Linnaeus) Following Sublethal Exposure to Chlorpyrifos. Turkish J. of Fisheries and Aquatic Sciences, 9, 233-238.

Ismail, M., Ali, R., Shahid, M., Khan, M.A., Zubair, M., Ali, T and Q. Mahmood Khan. 2018. Genotoxic and hematological effects of chlorpyrifos exposure on freshwater fish *Labeo rohita*. Drug Chem. Toxicol., 41, 1, 22-26.

Karanth, S. and Pope, C. 2000. Carbosylesterase and A-Esterase Activities during Maturation and Aging: Relationship to the Toxicity of Chlorpyrifos and Parathion in Rats. *Toxicol. Sci.*, 58, 282-289.

Levin, E.D. Swain, H.A. Donerly, S. and Linney, E. 2004. Developmental chlorpyrifos effects on hatchling zebrafish swimming behaviour. Neurotoxicology and Teratology 26: 719–723.

Levin, E. Crysthansis, E. Yacisin, K. and Linney, E. 2003. Chlorpyrifos exposure of developing zebrafish: Effects on survival and long-term effects on response latency and spatial discrimination. Neurotoxicology and Teratology 25: 51– 57.

Muttappa K., Reddy, H.R.V., Padmanabha, A., Shridhar Bhatt, Prabhudeva, K.N., Basavaraju, Y., Gangadhar Gowda, Rajanna, K.B. and N. Chethan. 2015. Chlorpyrifos induced histological changes in the liver of Tilapia (*Oreochromis mossambicus*). International Journal of Recent Scientific Research, Vol. 6, Issue 8, pp. 5819 – 5823.

NYSEDC, 1986. New York State Department of Environmental Conservation. Draft Environmental Impact Statement on Amendments to 6 NYCRR Part 326 Relating to the restriction of the pesticides aldrin, chlordane, chlorpyrifos, dieldrin and heptachlor. Division of Lands and Forests. Bureau of Pesticides. Albany, NY. 1986 (Feb.).

NMFS (2017). National Marine fisheries Service. Biological Opinion on the Environmental Protection Agency's Registration of Pesticides containing Chlorpyrifos, Diazinon, and Malathion, FPR 2017-9241. Washington D.C., December 29, 2017. http://doi.org/10.7289/V5CJ8BQM.

Oruç, E.O. 2010. Oxidative stress, steroid hormone concentrations and acetylcholinesterase activity in *Oreochromis niloticus* exposed to chlorpyrifos. Pesticide Biochemistry and Physiology, 96:160-166.

Racke, K. D. Environmental Fate of Chlorpyrifos. *Rev. Environ. Contam. Toxicol.* 1993, 131, 1-150.

Richendrfer, H. Pelkowski, S.D. Colwill, R.M. and Créton, R. 2012. Developmental sub-chronic exposure to chlorpyrifos reduces anxiety related behavior in zebrafish larvae. Neurotoxicology and Teratology 34: 458–465.

Schimmel, S.C. et al. 1983 (Jan.-Feb.). Acute toxicity, bioconcentration, and persistence of AC 222, 705, Benthiocarb, Chlorpyrifos, Fenvalerate, Methyl Parathion, and Permethrin in the estuarine environment. In Journal of Agricultural and Food Chemistry. The American Chemical Society.

Sledge, D. Yen, J. Morton, T. Dishaw, L. Petro, A. Donerly, S. Linney, E. and Levin, E.D. 2011. Critical duration of exposure for developmental chlorpyrifos-induced neurobehavioral toxicity. Neurotoxicology and Teratology 33: 742–751.

Slotkin, T.A. Olivier, C.A. and Seidler, F.J. 2005. Critical periods for the role of oxidative stress in the developmental neurotoxicity of chlorpyrifos and terbutaline, alone or in combination. Brain Research Development, 157: 172–180.

Sunanda, M., Chandra Sekhara Rao, J., Neelima, P., Govinda Rao, K. and G. Simhachalam. 2016. Effects of Chlorpyrifos (an Organophosphate Pesticide) in Fish. Int. J. Pharm. Sci. Rev. Res., 9, 1, 59.

USDHSS, 1997. *Toxicological Profile for Chlorpyrifos*; U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Public Health Service: Atlanta.

TOXNET. 1975-1986. National library of medicine's toxicology data network. Hazardous Substances Databank (HSDB). Public Health Service. National Institute of Health, U.S. Department of Health and Human Services. Bethesda, MD: NLM.

USEPA, 1989. *Registration Standard (Second Round Review) for the Registration of Pesticide Products Containing Chlorpyrifos*. U.S. Environmental Protection Agency, Office of Pesticide Programs, U.S. Government Printing Office: Washington, DC.

USEPA, 2006. *Reregistration Eligibility Decision (RED) for Chlorpyrifos*; U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs, U.S. Government Printing Office: Washington, DC.