Considering the Great Blue Heron as an Indicator Species for Organochlorine Contamination in the Willamette River, Oregon

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HC 441: Willamette River Health
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June 3, 2004

Since the 1940's, The Willamette River has become a sink for products and wastes of modern industry. Many tributaries and parts of the main stem of the Willamette are contaminated with persistent, bio-accumulative toxins (PBTs). Some of the most harmful and toxic are organochlorine pesticides, Polychlorinated biphenyls (PCBs) and Polychlorinated dibenzo-p-dioxins/furans (PCDD/F's). Studies have linked persistent toxins to various health and reproductive problems in birds (Hoffman et al 2000, Wiemeyer 1996, Blus 1996, Elliott et al. 2003, Henny et al. 2000, Broughton et al 2003, Harris et al 2003). Some contaminants, such as DDT, have been widely studied, but there are many contaminants that warrant concern in the Willamette basin and need to be monitored.

The Great Blue Heron (*Ardea herodias*) has been shown to be a good bio-indicator species for PBTs in the Pacific Northwest, particularly in studies done in British Columbia coast (Elliot et al 2003 and Harris et al 2003). Indicator species can be used to measure contamination of watersheds and to monitor ecosystem health. In a study on Great Blue Heron (GBH) contaminants on the coast of British Columbia, it is stated that, "Great Blue Herons have been used to monitor environmental contamination by chlorinated hydrocarbons" (Harris et al 2003). By analyzing current contamination levels in the Willamette and studies done on contamination levels in piscivorous birds, this paper will explore the potential of the GBH as an indicator species in the Willamette River.

The range of the Great Blue Heron extends from southern Canada to Mexico, and in winters extends to northern South America. The Willamette has essential feeding, breeding and nesting habitat for the Heron. For example, 24 of 31 heron rookeries studied along the Willamette River in Oregon were located within 100m of known feeding areas. Since juvenile and adult heron's main food source is fish, including brown bullhead, carp, crappie, suckers, chub, warmouth bass, trout, shiner perch and shad, the link between fish contamination and bio-accumulated levels of contamination in GBH should be indicative of river health (Thomas and Anthony 1999). This is important because in the Willamette fish have been shown to exceed consumption guidelines for human health in some contaminants, indicating a potential threat to wildlife that subsists mainly on fish (ibid). Harris agrees that the "strong linear regression between prey fish and heron egg contaminant levels suggests that local dietary uptake was an important rate of exposure for Herons" (2003).

Great Blue Herons also have a high trophic feeding level, near or at the top of marine/aquatic food chain, maintain annual nesting spots and have a wide distribution (Elliot et al 2001, Thomas and Anthony 1999). Herons often forage in back eddies and still waters where persistent contaminants are at their highest concentration levels, because of the settled nature of particles (Harris 2003). Thus, The GBH should be a good candidate for bio-indication of Willamette River PBTs. Still, with the data available there are some problems using the GBH as an indicator species on the Willamette. This concerns the sensitivity of GBH to contaminants and current contamination levels. In order to assess GBH utility as an indicator in the Willamette it is necessary to examine the sources of these pollutants, current condition of the Willamette, and their known effects on birds. This paper will focus mainly on a comparison of a study done on the Willamette (Thomas and Anthony 1999) with studies done on the coast of British Columbia (Harris et al 2003 and Elliot et al 2001) as well as data from other pertinent studies on contaminants in piscivorous birds.

Organochlorine Pesticides

Organochlorine pesticides were first released into the environment, and consequently the surface waters in the late 1940’s and 1950s (Wiemeyer 1996). Today, some 11,000 organochlorines are bought and sold on the world market (Thornton 99). Chlorine is a highly reactive element, and when chlorinated organic compounds are created there are byproducts, many of which are more toxic than what is purposefully produced (299). Many organochlorine pesticides have hormone-like effects, consequently causing disruption in the endocrine system. Some have attracted a lot of attention because of their immense toxicity at low doses, or critical development stages, while others, still extremely harmful, have often been ignored in studies. When looking for an indicator species it is important to recognize and consider the large holes in the research data concerning piscivorous birds and the effects on these species of individual chemicals and mixtures of contaminants in the environment and prey.

In the Willamette valley, agricultural use and industrial production of organochlorine pesticides has contributed to the presence of residues in Willamette River water and sediment. The most well known organochlorine, DDT, was banned 25 years ago but it is still one of the most common pesticides measured in sediments and fish tissue in the Willamette River (Wentz 1998). Banned organochlorine pesticides still found in the Willamette watershed include DDT, Chlordane and Dieldrin. Concentrations of DDT, Chlordane and Dieldrin exceeded EPA limits at 10 out of 47 sites along the Willamette when measured in 1998 (ibid). Suggested reasons why they are still found in large concentrations in some areas and in wildlife tissue are exposure from past legal use and slow degradation, illegal use, local legal use of non-banned pesticides that contain isomers of compounds such as DDT, and high exposure of migrating birds in Latin American countries where organochlorines are not banned (ibid).

DDT, for example, has a 2000-day soil half life, and a very high tendency to bind to soil particles, a measure of persistence in the environment (Extoxnet 2004). DDT consists of several compounds that may be changed or broken down in the environment into the forms of DDE or DDD, so its effects are felt many years after application. Besides persistence from past use, point source industrial pollution of these toxins is also present on the Willamette. For example, the Port of Portland terminal was found to have DDT/ DDE in riverbed sediments adjacent to the terminal in the late 1980's (River Watch 1992). Elf Atochem in Portland is currently cleaning up DDT contamination from past chemical production (OECR 2000).

Heptachlor, consisting of 10% Chlordane, is used in transformers to kill fire ants, although it is banned for all other uses. Heptachlor travel easily in wind, sticks to soil sediment and builds up in fish and mammal fatty tissue. In rats, heptachlor exposure reduced litter size, shortened life, caused liver, adrenal and nervous system disorders, and in high dosages, caused death. (ATSDR 1995) Sources in the Willamette could be from localized contaminated industrial sites, unused stockpiles or atmospheric deposition (OECR 2000).

After the most potent, bio-accumulating toxins were banned, a new class of chlorine compounds was produced. These chemicals were touted as less toxic because of their shorter half-lives, yet they are still relatively persistent and bio-accumulative. These include carcinogens, endocrine disruptors and toxins that caused reproductive harm in lab studies (Thornton 15, 59, 156). These secondary chlorine pesticides, insecticides and herbicides are widely used today in Oregon agriculture and in homes.

One of the most common is known by the trade name Atrazine. In a Willamette River Basin Water Quality Study conducted from 1992 to 1994, Atrazine was detected in 90% of samples and at maximum detection was 2.7 *m*g/L, very close to the lifetime health advisory drinking water standard of 3. 5 *m*g/L. In Oregon, 40, 000 tons of Atrazine is used yearly (Extoxnet 2004). Endosulfan is another secondary chlorinated compound used in Oregon as an insecticide. It was sprayed on 33,000 acres of cropland in 1987 as an insecticide, and is in continued use today. Streams near sprayed areas can become contaminated by surface runoff, as it usually binds to sediment particles and builds up in the fatty tissue of fish and other wildlife (Extoxnet 2004). Numerous studies have found Endosulfan to be acutely toxic to fish. Endodulfan is present in tests of portions of the Willamette river (US Army Corp of Engineers, 1999).

The implication of this discussion of organochlorine pesticides in the Willamette River is that it is necessary to take into consideration the bio-accumulative effect of these pollutants in GBH from fish consumption. It is apparent that a problem exists, and thus an indicator species is necessary for continued monitoring of river health. There are various recorded health problems in birds associated with organochlorine exposure, which may indicate high levels of contamination. Although cross-species comparisons of health effects are limited because of differences in sensitivity, at various magnitudes there are similar general effects across species, especially in fish eating birds. Main concerns in birds have focused on eggshell thinning and reduced reproductive success. The amounts that are associated with these effects will be discussed and compared with the amount found in GBH eggs in the Willamette River study.

Polychlorinated Dibenzo-p-dioxins/furans

Dioxins and furans are a family of related chlorinated compounds with extreme toxicity, low solubility in water, and a preference for maintaining humus and lipid phases (Bonn 1997). There are many congeners, with some more toxic than others. The most toxic are 2, 3, 7, 8-TCDD/F and are usually the ones commonly referred to as dioxin and furan respectively. The EPA placed a total maximum daily load (TMDL) listing for dioxin in the Willamette in 1991 because of a high amounts of dioxin found in fish tissue, that listing continues today (ibid). In the Willamette, the highest concentrations of dioxins and furans were found in industrial or urban areas where waste inputs were likely. A US Geological Survey study found that concentrations in the Willamette are high enough to be associated with increased risk to sensitive wildlife (Bonn 1997).

The highest amounts of dioxin-like compounds are given off in the chlorine pulp bleaching process common in pulp mills, in cement kilns, in steel mills, in wood treated with pentachlorophenol (PCP), in waste incinerators, and in municipal waste water sludge (Thornton 263, 320). There are many chemicals that contain dioxins that are still in use today. Oregon is third in the nation for amount of PCP release, a chemical used to protect timber from rot that gives off various types of dioxins as byproducts. (Extoxnet 2004) According to the EPA, 100 pesticides are identified as having dioxin as a byproduct (Thornton 298). An example of their source is a chemical company in Portland; Rone-Poulence manufactured pesticides until the late 1980's including 30 chlorinated ones. Their site was contaminated with dioxins and chlorinated phenols (River Watch 1992). In 1991, McCormick and Baxter wood treatment facility left Portland with $15 million worth of cleanup because of dioxin contamination (ibid). There are many pulp mills in Oregon that use chlorine-bleaching methods (OECR 2000, Bonn 1997, River Watch 1992). These include Willamette Industries in Albany, Weyerhaeuser in Springfield, Boise Cascade in St. Helens, James River Corporation in Halsey, Pope and Talbot in Portland and Smurfit in Oregon City (Manufacturers Register 1996).

On average a pulp mill using elemental chlorine bleaching processes releases 50 tons of organochlorines each day (Thornton 319). EPA Cluster rules for paper and pulp mills were passed in 1998 and have limited the most polluting form of bleaching that uses elemental chlorine. The alternative method of chlorine dioxide bleaching still creates dioxins. In 1997 half of the worlds production of bleached pulp was from chlorine dioxide (Thornton 321). If all bleaching were switched over to chlorine dioxide, an 80%

reduction in organochlorine production would occur, but bleaching would still be one of the largest contributors of dioxin to the environment. Thus the problem remains significant (Thornton 323). In Oregon most pulp mills switched in the early 1990's to chlorine dioxide methods. Sludge formed from paper mill waste is also a problem, reportedly releasing PCB's, dioxins and furans into the environment along with other PBT's (Thornton 320).

The large presence of dioxins and furans in the Willamette is a cause for concern, especially because of the levels found in fish. It is necessary to continue to monitor these contaminants through an indicator species that subsists on fish. It appears that the GBH would again serve as a likely indicator species for dioxin and furan contamination on the Willamette because of its place in the food chain. The main disorders in birds contaminated with dioxins and furans include embryotoxicity, birth defects and decrease in clutch size (Hoffman 1996).The levels at which these are apparent will be discussed later and compared to the levels of dioxins in GBH of the Willamette River.

Polychlorinated Biphenyls

PCB is the family name of over 200 compounds that were originally used as coolants and lubricants in electrical transformers. Although banned in 1976, 3.4 billion pounds of PCBs had already been produced worldwide. The ban didn't monitor the PCBs already in use (OECR 2000). PCBs act in a similar way to dioxins and are extremely persistent. In the Willamette River PCB contamination of water could stem from PCBs still in use in Oregon utilities, or release of contaminated oils into sediment and water. The largest utilities in the state are Pacific Gas and Electric, PacifiCorp, Eugene Water and Electric Board, and Bonneville Power Administration (Wentz 1998). As of 2000, each of these still had PCB-laced equipment in service, although all are attempting to phase out and dispose of this equipment, especially those with higher than 50ppm (OECR 2000). Other smaller utilities and industrial facilities also have PCBs in use. PCB-contaminated oil spills have been reported on the Willamette since PCBs were banned. For example, Simpson Timber in West Linn spilled contaminated oil along the Willamette that contributed PCBs to soil. PGE had numerous PCB hotspots on its property in the 1980s and early 1990s, and the river sediment level of PCB contamination at this site was very high (River Watch 1992).

The Department of Environmental Quality (DEQ) has found PCBs in fish samples in the Willamette (ODEQ 1998). The human health screening level of PCBs in fish above which they are unfit for human consumption is 0.02 parts per million (ppm). In fish in the Willamette River near Portland the levels are around 0.02-0.04 ppm on average. This is a cause for concern. The manifold sources of PCBs and their continued occurrence in the environment are an indication that continued monitoring of levels in wildlife is needed. As a fish eater, the GBH is suggested as a bio-indicator species for PCBs monitoring. PCB contamination in birds is associated with altered embryonic growth, birth defects and neurological disorders (Hoffman 1996). The specific effects on birds at various concentrations will be compared to the levels found in GBH in the Willamette.

Case Studies

Organochlorine presence in the Willamette River is a cause for concern. The next step is to consider what contaminant levels are in GBH in the Willamette River basin as compared to other areas, as well as what levels of contamination are critical. Thomas and Anthony collected eggs and prey from six colonies of GBH in the Willamette and Columbia Basin in 1994 and 1995 and tested for OC pesticides, PCBs, dioxins, eggshell thickness, reproductive success and clutch size. Of the 25 OCs analyzed, Dieldrin, Chlordane, DDE, DDT and total PCBs were all above detection limits (1999). Dioxin was also above detection limits at all sites at all times measured. This study will be compared to two studies that used GBHs as an indicator species, both concerning permanent population of GBH on the coast of British Columbia (Harris et al 2001 and Elliot et al 2003). In cases where the data from these two studies don’t compare or overlap, such as with OC pesticides, supplemental studies from other areas are used.

OC Pesticides

In a review of DDE studies on birds it was found that in the wild a 246 ppm of DDE in the brains of GBH was lethal (Blus et al 1996). DDE is the form of DDT associated with reproductive failure because of its ability to act as a hormone mimic in the endocrine system (Blus 1996). Elevated concentrations of DDE in Black Crowned Night Herons and Bald Eagle eggs from the Columbia River are associated with reduced reproductive success (Thomas and Anthony 1999) Productivity of American Kestrels in the Columbia basin was reduced when eggs contained greater than 1.5 ppm of heptachlor epoxide (the metabolized form of heptachlor in vertebrates). The nests with the highest levels of heptachlor epoxide in eggs had the greatest rate of reproductive failure (Wiemeyer 1996).

The eggs collected from Ross Island, one of two sites on the Willamette near Portland, had the highest mean concentration of all OCs. This site was 10 miles downstream from a pulp mill. In 1994**,** the levels of DDT were 26 ppb. Molalla, the other site along the Willamette, had higher levels of DDT (34 ppb) than all other sites on the Willamette and Columbia and more DDT than its toxic equivalent of breakdown component (DDE)--signifying a recent exposure. The DDE concentrations at Molalla (795 parts per billion, ppb) were similar to those at Ross Island (1,616 ppb) and both exceeded the concentrations found in eggs on the Willamette in a 1975 study. These are much lower than the lethal dosage of 246 ppm.

Eggshell thinning is positively correlated with increased amount of DDE residue in eggs. In Black Crowned Night Herons in Colorado and Wyoming, 4 ppm of DDE led to a 9% thinning in shells, whereas a 20% thinning was associated with 54 ppm (Blus et al 1996). Gray Herons in Great Britain with an average of 6 ppm DDE showed 12% thinning (ibid). The GBH was shown to have 20% thinning with an average of 19 ppm (ibid). Eggshell thinning at the Molalla site was 9.8%, while thinning at Ross Island was 14.4%. The Ross Island eggshell thinning is similar to thinning of Heron eggshells (17%) that were broken during incubation in another study, also a 15-20% thinning is associated with indication of long-term decline of species (Thompson and Anthony 1999). The BC site with the most thinning had only 8.6%, with most sites way below that measurement on average (Harris 2001). These data indicate that the GBH may be more sensitive to

DDE levels than other fish-eating birds, and that reproduction at highly polluted sites along the Willamette is being adversely affected.

Dioxins and Furans

Pulp mills are a large source of dioxin congeners. It has been shown in various studies that study populations of fish near bleach pulp mills showed a higher rate of dioxin-like effects than in other areas (Thornton 321). Fish in Canadian rivers where pulp mill effluent was discharged had toxic effects such as deformed jaws and skin, smaller gonads, hormonal changes, impaired reproduction, liver disorders, changes in population structure (Elliot 2003). The EPA defines the highest concentration of dioxin (TCDD) in fish that is unlikely to cause significant effects in avian wildlife as 6 parts per trillion (ppt) and in sediment 21 ppt (Bonn 1997). It has been suggested by Great Lake studies that the background level of 10 ppt of dioxin is typical in birds (Blus et al 1996).

In the Willamette study, TCDD concentration in fish was below guidelines for piscivorous wildlife (6 ppt), but exceeded consumption guidelines for human health (Thompson and Anthony 1999). GBH were also found to have levels way below the suggested background level; at the Ross site it was 4.2 ppt and the Molalla site 3.2 ppt of TCDD (the most toxic congener is being considered). These were below the levels found in the Bald Eagle and in the Double Crested Cormorant in the Columbia basin (Thompson and Anthony 1999). TCDF levels were 1.9 ppt at Ross and <2.0 at Molalla.

Comparatively, a BC site, Crofton, on the Straight of Georgia, was located downstream from a chlorine bleach pulp mill during the late 1980s and early 1990s, after which the mill was closed. Elliot concludes that high levels of dioxins and furans that were found in eggs in select colonies in the study during the 1980s were due to “Pulp and paper mills and PCP- and TeCP treated lumber” (2003). In the 1990s the measured levels of dioxins and furans decreased greatly, mainly because of changes in bleaching technologies and other processes in the pulp industry. The range of TCDD levels in eggs at Crofton during the time that the pulp mill existed was 20-200 ppt; in 1994, a few years after the bleaching stopped, the levels dropped to 4 ppt, very comparable to the Willamette levels mentioned above, and below the background level of 10 ppt suggested by the Great Lake studies. The same is true of the TCDF; it was averaging 2-24 ppt with pulp effluent present and was 2 ppt by 1994, very similar to the Ross Island and Molalla levels.

These results show that the Heron can be used as an indicator at the higher levels considered at the early Canada sites, where health effects at high concentrations were noted. In the Willamette sites, the levels in fish seem important, but do not transfer to significant effects in GBH populations.

Hatching success

Hatching success cannot be correlated with the presence of any one OC, but is affected by dioxins, PCBs and DDE. At the Crofton site Great Blue Heron with residues of 3 ppm of DDE were found to produce 1.7-2.0 active young per nest. Normal recruitment standard for GBH are 1.9 young that must be fledged in order to maintain a stable population**.** Ross had on average 2.0 fledged chicks per successful nests and Molalla, 2.1, which appear to be normal levels. But Molalla had a very high embryo deformity rate in 1994 (40%), as did Ross Island during 1995 (20%). These were deformities associated with PCB and dioxin contamination in birds, such as misshapen heads, crossed bills and club feet These are similar to Great Lake studies that conclude that high levels pf PCBs and dioxins and furans are associated with embryo mortality, edema and deformity in wild piscivorous birds (Harris 2003).

These results show the contradictions that become evident when trying to attribute certain characteristics to individual toxins. On the one hand, Willamette hatching success dos not seem to be affected and on the other, embryo deformities are high in the same areas. More research is needed to clarify his issue, especially concerning the exact function of each OC in GBHs' reproductive processes and development.

Polychlorinated Biphenyls

It has been shown that heron eggs from urban areas have highest levels of PCB contamination (Harris 2001). In Bald Eagles 8-25 ppm of PCBs in eggs decreased hatching success (Hoffman 1996). PCB concentrations at Ross Island in 1994 exceeded previous measurements on similar species in Western states; one egg from Ross Island measured 0.033 ppm, a number above the level that impaired embryo health in studies done on chickens, yet in this nest, two chicks fledged, showing the reduced sensitivity of GBH to dietary intake of PCBs (Thomas and Anthony 1999).

In another study in BC the levels of OCs in eggs from 23 sites was measured from 1977 through 2000. The PCB levels assessed from the rural colonies were low and comparable to the levels of contamination in the rural areas surveyed by Thomas. The urban areas, on the other hand, had relatively high levels of PCB (1670-1780 ppt, 1991 data) as compared to the Molalla site (425 ppt) and low when compared to the Ross

Island site (3454 ppt). The study found GBH to be relatively insensitive to PCB exposure (Harris 2001).

In this case, it was shown that GBH are less sensitive than other avian species to PCB intake. In the Willamette case, this means that even with high levels that may be dangerous for humans and wildlife, the GBH may still be able to reproduce, and is thus not a good indicator.

Assessing Great Blue Heron as an Indicator Species

It is obvious from the pollutants present in the Willamette river fish, water and sediment, as well as the continued inputs from agriculture and industry of PBTs, that an indicator species is necessary. This indicator species should serve as a sensitive marker of levels of contamination. It cannot be conclusively shown that Great Blue Herons are a good monitor of PBTs in the Willamette River. Some of the data that were collected by Thomas and Anderson are intriguing and show the sensitivity of the herons and their potential as indicator species. For example, eggshell thinning as a possible measurement of DDE seems likely to be a helpful marker of river and wildlife health. The characteristic of annual nesting sites makes this an even more feasible option for continued monitoring. On the other hand, herons are less sensitive to PCBs than other avian species.

The lack of comprehensive studies on the effects of contaminants in the Willamette basin on bird populations, especially GBH, points to the deficiency of information rather than to the failure of the GBH as an indicator species. These shortcomings lead to other possible research directions; I suggest that increased monitoring of contaminants in wildlife tissue in all aspects of the food chain would be a good step. This could be the most helpful way to determine the health of the river and the potential risks to wildlife and even humans. More research on GBH populations along the Willamette River needs to be carried out before levels of contamination can be used as helpful indicators of wildlife health and contamination levels in the water.

Also, an emphasis on PBTs fails to take into account other factors that are affecting the GBH reproductive success. Great Blue Herons are negatively affected by human disturbance, particularly during the early stages of the breeding cycle. Repeated human intrusion into nesting areas often results in nest failure, with abandonment of eggs or chicks. The differences between the Willamette study area and the British Columbia study area are also important in this discussion. In the BC studies, herons were year-round resident that fed on the estuary, an area where many of the contaminants accumulated from a large watershed area. Also in Canada, "besides showing several characteristics suitable for long-term monitoring studies, the BC coastal population is blue-listed meaning it is vulnerable and at risk of local decline and extirpation" (Elliott 2003). The Great Blue Heron are not endangered in the Willamette Valley, and thus are not receiving careful long-term monitoring. Perhaps if this were the case, they would prove to be a better indicator species than they appear at present.

I believe that we need an indicator that correctly represents the need for dialogue and action concerning the PBT concentration in the Willamette River. Even without an indicator species to point out the contamination levels, it is obvious that we need to do something about PBTs in the Willamette. I believe regulations should start form the producing end and eliminate this problem from its source. As we can see from this discussion, these toxins do not easily get cleaned up.

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