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# Update on Wetland Buffers: The State of the Science

## Final Report

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# Update on Wetland Buffers: The State of the Science

## Final Report

October 2013

*by;*

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# Acknowledgements

This update would not have been possible without the help of all those who participated in the original 2005 synthesis. The 2005 synthesis provided an easy format to follow in updating the science and this helped focus our efforts in our search for more recent studies. I also wish to thank all the reviewers of this update within the Washington State Department of Ecology, Washington Department of Fish and Wildlife, and wetland scientists and regulators outside these agencies. Their efforts have made this a much better and coherent document.

NOTE: We are using an alternate format for scientific citations in this report. Instead of citing the authors and the date, each reference is assigned a number based on its position in the alphabetic list of references at the end of this document. This is the format used by scientific journals such as *Science, Nature,* and the *Proceedings of the National Academy of Science.* This format is easier to read when a statement is supported by multiple citations, and it reduces the length of the text.

# 1.0 Introduction

In 2005 the Washington State Department of Ecology (Ecology) published a synthesis of scientific information available on freshwater wetlands, their functions, and their management (81). The purpose of the synthesis was to provide local governments in the state with the best available science (BAS) when managing their wetland resources. Using BAS in making decisions was mandated by the 1995 amendment to the Growth Management Act (Revised Code of Washington (RCW) 36.70A.172[1]).

Our scientific knowledge is continually increasing and changing and we recognized that the synthesis would need periodic updates. Much of the information presented is still valid, but research in the last decade has provided new data to expand and clarify many of the conclusions made in the original synthesis. This is especially true for the information on the role of buffers in protecting wetland functions.

Buffers are vegetated areas adjacent to aquatic resources that can, through various physical, chemical, and/or biological processes, reduce impacts to these resources from adjacent land uses. Buffers also provide some of the terrestrial habitats necessary for wetland-dependent species that require both aquatic and terrestrial habitats.

Several jurisdictions, including Island County and San Juan County, have developed their own syntheses of scientific research based on some of the more recent information on buffers. These syntheses focused on the wetlands found within their jurisdiction and the information may be limited relative to other areas in the state. Ecology is expanding on these efforts. The goal is to provide updated information on wetland buffers that can be applied statewide. The objective is to synthesize the information on buffers that was published between 2003 and the winter of 2012. We focus on wetland buffers, since buffers are one of the most common elements of wetland regulations in Critical Area Ordinances (CAO's), and they are consistently the part of a CAO of most interest and concern to the public. Limited resources prevent us from expanding our review and update to other issues at this time.

This update revisits the conclusions and key points concerning wetland buffers made in the 2005 synthesis. Each conclusion is reviewed with respect to any new information that was published between 2003 and 2012, or information in earlier studies that we may have missed and that has come to our attention. If the conclusion is still valid, new references supporting it are noted. If the conclusion needs to be expanded or modified, then revised conclusions are presented based on the new information. In reviewing the recent information we also found that some of the studies address issues that were not commonly discussed in the past. New conclusions that can be made from this information are presented as updates of old conclusions in the appropriate sections.

This synthesis DOES NOT contain agency recommendations or suggestions for implementing programs to protect or manage wetlands using buffers. Its purpose is to identify the sources of information reviewed and relied upon by Ecology in the process of updating our guidance on wetland buffers as required in state law (HB1113). Any recommendations documented here are those that have been described in the literature. They are included here only as part of the synthesis of existing scientific information. Agency recommendations that stem from this synthesis will be provided as supplements to the Appendices in Ecology publication #05-06-008, Wetlands in Washington State, Volume 2: Guidance for Protecting and Managing Wetlands.

## 2.0 Approach Used to Synthesize the Literature for the Update

As the amount of scientific information grows exponentially, scientists are developing tools to help synthesize this information. This update was conducted using the guidelines for scientific syntheses described by Pullin and Stewart (61). The guidelines involve a six-step process that includes:

- Formulating questions that need to be answered by the synthesis
- Defining and implementing a strategy for searching the literature
- Cataloguing and prioritizing the importance of articles based on the questions in #1
- Reading and extracting key information relevant to the questions
- Synthesizing the information by identifying connections among topics
- Peer review of synthesis

### 2.1 Questions that need to be answered by the synthesis:

The questions posed for this synthesis are:

- Are the conclusions and key points regarding wetland buffers made in the 2005 synthesis still valid?
- If not, what new conclusions can be made from the recent research about how buffers protect wetland functions?

> The scope of the literature review on buffers is the same as described in Sections 1.2 and 1.3 of our original synthesis in 2005 (81). We focus our review on information relevant to the effectiveness of buffers at protecting the functions of freshwater wetlands in Washington State.

### 2.2 Strategy for searching literature

We began by starting a project file to hold paper copies of all the studies found in the search. If we printed an article from a digital file, we also saved the digital version.

Initially, we reviewed and compiled articles referenced in more recent syntheses done for Island County (http://www.islandcounty.net/planning/criticalareas/BestAvailableSciencePhaseII.pdf.pdf ) and San Juan County (http://www.co.san-juan.wa.us/cao/BAS_Synthesis.aspx). We flagged all articles whose title or summaries met our search criteria (see bulleted list below) and that were published after 2002. We obtained copies of these articles from web searches, and if the entire article was not available, we printed and filed copies of the abstract.

In addition, Ecology maintains a library of more than 5000 scientific articles related to wetlands that has been updated weekly since 1992. The original database used to store bibliographic information was RefBase® but all entries were moved to Endnote® when we switched to a Windows 7® platform. Ecology subscribed to ISI's Current Contents ® which provided a weekly list of the table of contents of over 150 journals in the ecological and biological sciences. Articles of interest to the program were requested from the authors and added to the library and database when received. For this synthesis we searched our database for articles published after 2002 using the same keywords listed below. The abstracts of these selected articles were read, and if the data presented were relevant to the questions being asked in this synthesis, a copy of the article was placed in the project file.

Next, we searched Google Scholar ® using "buffers" as a keyword, followed by each of the following terms separately:

- Wetland
- Amphibians
- Mammals + wetland
- Birds + wetland
- Fish + wetland
- Names for each species of amphibians found in Washington as listed in Leonard and others (46).
- Wetland + water quality
- Wetland + flood reduction
- Wetland + hydrologic functions
- Wetland + functions

Titles that appeared potentially useful were accessed on the web, and if the abstract indicated the data were relevant to the questions, a copy of the article or abstract was placed in the project file.

Finally, we searched for articles of interest that were cited in those found during the basic search.

We reviewed over 300 abstracts and obtained 144 published articles for the project file.

## 2.3 Cataloguing and prioritizing the importance of articles

All of the articles and reports in the project file were read and the important information each contained was highlighted in the document. Articles were sorted based on the following topics:

- Amphibians
- Birds
- Mammals
- Reptiles
- Fish
- Water Quality
- Policy and Regulation

In the 2005 synthesis we concluded that buffers do little to protect the hydrologic functions of wetlands (storing water and reducing the velocity of flows within the wetland itself). No articles were found in this search to suggest this conclusion needs to be changed so we did not include this topic in the sorting.

Within each topic, articles were further sorted based on the location of the research (Northwest, U.S. outside of the Pacific Northwest, elsewhere) and whether the research discussed landscape issues or site scale issues.

During the initial screening, each article was categorized by its importance and relevance to the synthesis as A (highest priority for inclusion in the synthesis), B (moderate priority), and C (lowest priority). Highest priority was assigned to publications that described original research in the Pacific Northwest and that met the highest standards for "Best Available Science" as outlined in WAC 365-195-900 through 925. We assigned a lower priority (B) to publications that dealt with buffers in general or research done outside the Pacific Northwest, and (C) to those that did not undergo peer review. By peer review we mean articles that have been published in peer reviewed journals or documents that were reviewed by outside experts and that describe the review process in the document. We made a special effort to obtain copies of articles in Category A.

## 2.4 Reading and extracting key information

We read all articles in Categories A and B, and some in Category C. As each article was read, the keywords originally assigned to the article were checked and modified as needed. Notes and keywords were written directly on a copy of each article and it was then filed by topic and sub-topic. If an article addressed more than one topic we made an additional copy for each topic. We incorporated relevant information from each article directly in the text of this synthesis as it was being written, using the notes made on the paper copy.

## 2.5 Synthesis of information

The 2005 synthesis contained numerous conclusions and key points made from the literature review. Conclusions were in the beginning of each section and key points at the end. For this synthesis we treated each of conclusion and key point made as a separate item to update. Our objective was to determine if the new information in the recent scientific studies was consistent with the older studies. If conclusions and key points were not consistent, they were modified based on the more recent information compiled.

## 2.6 . Peer Review

A preliminary draft was reviewed by habitat biologists from the Washington Department of Fish and Wildlife and by wetland scientists at the Department of Ecology. Their comments were incorporated into a draft that went out for a more general review. This latter draft was sent to over 900 subscribers of Ecology's wetlands list serve for comment and review. Subscribers to the list serve include wetland scientists, consultants and regulators. The final draft incorporates the comments received through October 2013 from these outside reviewers. All the comments and our responses to them will be published in a separate document, and will be available on our web site after January 2014: http://www.ecy.wa.gov/programs/sea/wetlands/bas/index.html.

# 3.0 Update on the Conclusions and Key Points from the 2005 Synthesis

| |
|---|
| We include all the conclusions and key points regarding buffers from the 2005 synthesis in italics. These are copied, unedited, from the original text. |

### 3.1 General conclusions in the introduction to section 5.5 (section on buffers)

Conclusion - *Page 5-23: The majority of research on buffers tends to focus on the processes that buffers provide to filter sediment or take up nutrients (i.e., their influence on water quality). Far fewer studies look at the influence of a buffer's physical characteristics on attenuating surface water flow rates, except as it relates to water quality. The long-term effectiveness of buffers in providing such mechanical and biological processes is not well documented in the literature and may represent a critical need for future research.*

> Update: This conclusion is still valid. We were unable to find any new research documenting how buffers can attenuate surface water flow rates in the context of reducing the intensity of stormwater flows and potential flooding in a wetland. Some reports discuss the increased infiltration that occurs in vegetated buffers (35, 90), but these studies are focused on the higher rates of nutrient removal that occur when polluted waters enter vegetated buffers.
>
> There is, however, one logical inference that can be made on how buffers protect the hydrologic functions of certain types of wetlands. Depressional wetlands, especially those with no outlet, reduce storm flows by storing water and releasing it more slowly than the surrounding uplands (9, 40). The amount of stormwater a wetland can store will be reduced if the surface flows coming into the wetland contain sediment and fill the depression. A vegetated buffer can trap sediments before they reach the wetland (35, 55, 95), and thus protect its storage capacity. This inference, however, has not been validated with any studies.

Conclusion - *Page 5-23: The literature on buffers related to wildlife is, in general, less focused. Most studies document the needs of a particular species or guild relative to distances for breeding or other life-history needs within a radius from aquatic habitats.*

> Update: Studies that document the needs of particular species or guilds continue to be published. However, there have also been recent attempts to document and model the abundance and extinction rates of amphibian populations relative to specific buffer widths (e.g. 5, 29).

Conclusion - *Page 5-23: There is substantial literature on the implications of habitat fragmentation and connectivity, some of it related specifically to agricultural practices, forestry practices, or the impacts of urbanization. This literature does not specifically address the role of buffers in providing connectivity between wetlands and other parts of the* *landscape. It does, however, unequivocally support maintaining connectivity between wetlands in order to maintain viable populations of species that are closely associated with wetlands.*

Update: The relationships between buffer width, habitat fragmentation, and connectivity are increasingly being studied, especially as it relates to birds and amphibians. Buffer widths are one of the variables that are analyzed in studies that look at several landscape factors together to explain population dynamics and abundances of wetland-dependent species (e.g., 54, 68, 69, 74, 83, 94). The new information takes a closer look at the relationships between buffers, corridors and fragmentation. These studies are reviewed in the sections discussing wildlife, specifically birds and amphibians.

Conclusion - *Page 5-23: Older research studied the tolerance limits of wetland wildlife for disturbance—how closely a disturbance can approach animals before they are flushed from wetlands—with particular emphasis on waterfowl. These studies tend to be older than 1990 and focus on the prairie pothole region of North America. Where the findings are germane and where they have not been superseded by more recent work, they are included.*

Update: A number of new articles have been published on the flushing distances for wetland birds in different parts of the world (6, 22, 41, 93) to supplement past research. In addition, one study (15) documents the impact of disturbance from a major highway on populations of frogs in wetlands at different distances from the road.

### 3.2 The role of buffers in protecting water quality

Conclusions: Page – 5-27. *Buffers protect the water quality of wetlands through four basic mechanisms:*

- *They remove sediment (and attached pollutants) from surface water flowing across the buffer.*
- *They biologically treat surface and shallow groundwater through plant uptake or by biological conversion of nutrients and bacteria into less harmful forms*
- *They bind dissolved pollutants by adsorption onto clay and humus particles in the soil*
- *They help maintain the water temperatures in the wetland through shading and blocking wind.*

Update: Recent research indicates that buffers protect water quality through several additional mechanisms:

- They remove pollutants from groundwater flows through interaction of the soils and deep-rooted plants (36, 49, 60, 63, 90).
- They infiltrate polluted surface waters and slow the flow so pollutants can be removed more effectively (8, 60).

- They may lose their effectiveness if they are subject to very high levels of pollutants. If they become saturated with sediment and phosphorus they can no longer trap these pollutants (56).

> Some of the studies on the effectiveness of buffers at protecting water quality cited in the original synthesis (81) and in this update were done in the buffers of streams and rivers (commonly called the riparian zone). The ecological attributes by which buffers protect water quality do not depend on whether the buffer is adjacent to a stream or a wetland. The original synthesis (81) describes these ecological attributes that are common to buffers of riparian areas and wetlands in more detail (Section 5.5).

<u>Key point #1</u>: Page 5-38. *The use of buffers to protect and maintain water quality in wetlands (removing sediments, nutrients, and toxicants) is best accomplished by ensuring sheet flow across a well-vegetated buffer with a flat slope (less than 5%).*

Update: Recent research suggests that the effectiveness of a buffer is also based on factors other than sheet flow, vegetation, and slope.

- Buffer width and slope are only two of the six factors found to be important (8). The other four are soil infiltration, surface roughness (partially caused by vegetation), slope length, and adjacent land use practices.
- Mayer and others (49) analyzed 45 published studies on nitrogen removal in buffers and concluded that there was a broad range of results in effectiveness when only buffer width and vegetation were considered. Their analysis suggests that soil type, subsurface water regime (e.g. soil saturation, groundwater flow paths) and subsurface biogeochemistry (the supply of organic carbon and inputs of nitrate) are also important factors.
- A review of the literature on the removal of phosphorus in buffers (36) found that the interactions between groundwater and surface water are important for the biogeochemical processes governing phosphorus dynamics in buffers. The different paths by which water moves through the buffer determine where and how phosphorus compounds meet and interact with the minerals and how phosphorus attached to sediments is trapped.

<u>Key point #2</u>: Page 5-38. *Significant reductions in some pollutants, especially coarse sediments and the pollutants adhered to them, can be accomplished in a relatively narrow buffer of 16 to 66 feet (5 to 20 m), but removal of fine sediments requires substantially wider buffers of 66 to 328 feet (20 to 100 m).*

Update: Owen and others (55) confirmed the original conclusion that fine sediments are not effectively removed in narrow buffers. Most of the recent research however, has focused on refining the factors that have caused the large variations in the earlier measurement of the efficiency of a buffer at trapping sediments.

- Yuan and others (95), in a review of literature on vegetated buffers in agricultural areas, concluded that the efficiency in trapping sediments depended on vegetation type, the density and spacing of plants, the size of sediment particles, the slope gradient and length, and flow convergence, as well as the buffer width.
- Site-specific factors (vegetation density and spacing, initial soil water content, saturated hydraulic conductivity, and sediment characteristics) are so important in determining the effectiveness of a buffer that simple designs that do not account for these factors can fail to perform their protective functions (60).
- Only a small fraction of the total buffer area (9%-18%) in four sites measured actually was in contact with surface runoff which may result in reducing the trapping efficiency from 41%-99% to an actual 15%-43% (13).

Key point #3 – Page 5-38. *Removal of dissolved nutrients requires long retention times (dense vegetation and/or very low slope) and, more importantly, contact with fine roots in the upper soil profile (i.e., soils that are permeable and not compacted). Distances for dissolved nutrient removal are quite variable, ranging in the literature from approximately 16 to 131 feet (5 to 40 m).*

Update: More recent research has focused on identifying the specific environmental processes that remove nutrients in buffers and in modeling the removal of nutrients by buffers at a watershed scale. Again, the research shows that the processes are more complicated than initially reported, and they are very site specific (14). Also there are differences in the processes that remove nitrogen from those that remove phosphorus (25, 36, 49). During certain times of the year a buffer might release phosphorus rather than trapping it, especially if it has been receiving excessive amounts (87, and a review in 36).

Most of the studies that have been done in the last three decades focus on the efficiency with which a buffer removes pollutants. These studies do not address the potential impacts of the pollutants that escape the buffer into the wetland. We only found one study (38) that monitored water quality in wetlands relative to the amount of forest present in the surrounding landscape. The levels of sediment, nitrogen, and phosphorus in 73 wetlands in Ontario, Canada were analyzed statistically relative to the amount of forest to a distance of 5000m from the wetland. When these data were analyzed, Houlahan and Findlay (38) found that the level of nitrogen and phosphorus in wetlands was negatively correlated (i.e., concentrations of the pollutants in the wetlands increased as the amount of forest decreased) with forest cover up to a distance of 2250 m. The levels of phosphorus attached to the sediments coming into wetlands was negatively correlated (using multiple linear regression models) with forest cover up to a distance of 4000m from the wetland.

Update on the information on nitrogen (N) removal:

- Removal of nitrogen in the groundwater flowing through a buffer does not appear to be related to buffer width, while removal of nitrogen from surface water was only partly related to the width of the buffer (49). The reduction of nitrate in groundwater flowing through a buffer has been attributed to denitrification, uptake by vegetation as function of its density, and immobilization by micro-organisms (review in 63).

- Plant uptake and microbial immobilization represent only a temporary storage since the nitrate will be released on death of the organisms (63).
- Measurable rates of denitrification occur only if there is organic matter in the soil and anoxic conditions (49, 63). Denitrification generally does not occur in surface waters because they are oxygenated. In addition to anoxic conditions and organic matter, the rates of denitrification are controlled by variability in nitrate concentrations in the groundwater (13 references cited in the review by 63) and the flow path of groundwater (49).
- The relative removal of nitrate in a buffer is reduced as the concentration of nitrate in the incoming water is increased. Data collected in 14 sites across Europe found that the rate of nitrate removal dropped to 0% when the concentration of nitrate was above 20 mg/l (75).
- Modeling nitrate removal at a watershed scale supports the view that in some cases a buffer width of less than 20m (66ft) is sufficient for nitrate removal. This conclusion, however, does not hold if the soils in the buffer are coarse grained or nitrate transport occurs mainly through groundwater seeps that are fed by infiltration within the watershed (90). Baker and others (2) have also found that buffer width does not adequately quantify the effects of buffers on nutrient dynamics at a watershed scale. They analyzed 503 watersheds in the Chesapeake Bay drainage and found that variables based on the flow path through the buffer and how the buffer functions provided greater detail and flexibility in understanding nitrogen dynamics than just the width.

Update on the information on Phosphorus (P) removal:

- Phosphorus in runoff coming into a buffer can be removed by sorption onto soil particles, sedimentation of phosphorus bound to other particles, and through uptake by plants. These processes however, may not be linked so it is difficult to predict how well a buffer will remove phosphorus (35, 36). A review of the research done regarding phosphorus (36) found that the effectiveness of a buffer depends on many different factors including:
    - Soil type (sorbents, redox state, pH)
    - The degree of saturation of phosphorus on soil particles.
    - The slope and width of the buffer.
    - The types of plants present and how they are managed.
    - The amount of land in the surrounding landscape that is the source of the phosphorus.

- The ratio of the buffer area to the area of the source of the phosphorus.
- The flow path of surface and groundwater and its interaction with iron, aluminum oxides, or other minerals that bind dissolved phosphorus.

- Most of the phosphorus coming into a buffer is bound to sediments. Removal of phosphorus is closely linked to the effectiveness of a buffer at trapping sediments (8, 35, 36, 55).
- The capacity for phosphorus removal is finite and a buffer may become saturated so that it no longer removes phosphorus. This is especially true for dissolved phosphorus that relies on binding to minerals in the soil. Once all binding sites are full, the dissolved phosphorus will flow through the buffer. (35, 90).
- Buffers may release stored phosphorus under certain conditions. This can result in pulses of much higher phosphorus concentrations (8, 36 , 87) to the wetland. If the soils in a buffer are saturated with phosphorus, changes in temperature, pH, and volume of the flows coming through the buffer can cause a release of phosphorus (87, 90).

<u>Key point # 4</u>: Page 5-38. *The literature is consistent in finding that it takes a proportionally larger buffer to remove significantly more pollutants because coarse sediments and the pollutants associated with them drop out in the initial (outer) portions of a buffer. It takes a longer time for settling, filtering, and contact with biologically active root zones to remove fine particles and dissolved nutrients.*

Update: The recent research and reviews confirm this conclusion (13, 49, 76, 95). In general, the removal of pollutants relative to the width of the buffer follows a mathematical curve that is exponential with fractional exponents (Figure 1). The figure also shows that the relationship between the effectiveness of a buffer and its width is not statistically very strong. Many data points lie far away from the actual curve. This provides a graphical representation of the conclusion that buffer width is only one of several variables that determine the efficiency of the buffer at removing nitrogen.

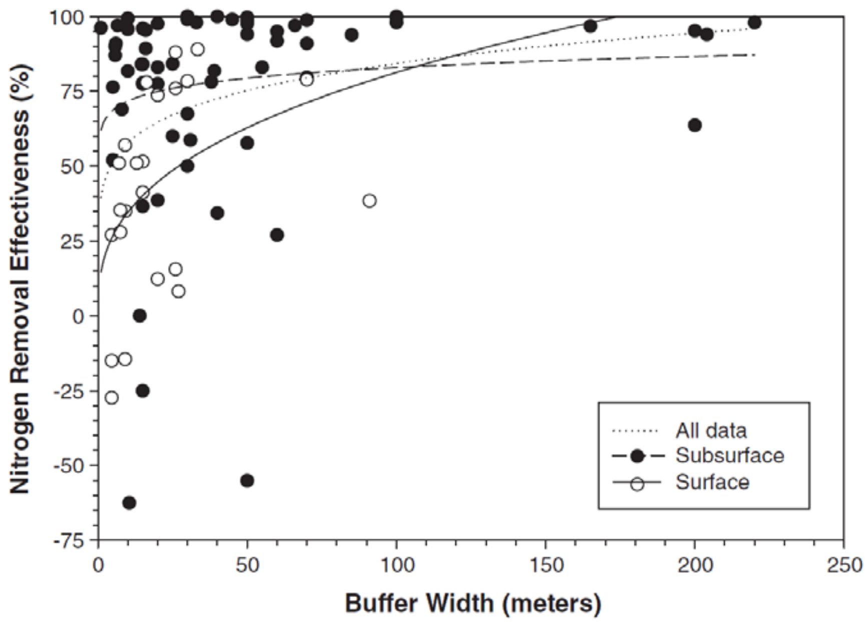



Figure 1: An example of the removal of nitrogen as a function of the width of the buffer based on data published for 89 individual measurements (figure is from 49).

Another meta-analysis by Zhang and others (96) analyzed the data from 73 published papers on the effectiveness of buffers at removing pollutants. Their conclusions were that width alone explains only part of the effectiveness of a buffer at removing pollutants. Width alone as a variable explains only:

- 37% of the effectiveness at removing sediments,
- 60% of the effectiveness at removing pesticides,
- 44% of the effectiveness at removing nitrogen compounds,
- 35% of the effectiveness at removing phosphorus compounds.

The other environmental variables that were analyzed were slope, drainage category of soil, and type of vegetation (trees, grasses, trees + grasses). Of these four additional variables, only three were significantly correlated with removing pollutants. The soil drainage type did not show a significant effect on the efficacy of removal.

Both the Mayer (49) and Zhang (96) studies have fit mathematical curves (called models) to the data showing how effectiveness at removal increases with increasing buffer width (the lines in Figure 1 above). These models however, do not provide much useful information for establishing standards for removing pollutants based on width alone. The variability in the data makes it difficult to assume that a specific width will provide adequate protection. For example six of the 89 measurements (7%) show a release of nitrogen (rather than removal) for buffers widths up to 50 m (~160ft). A buffer of 20 m (66ft) can remove 30% of the nitrogen in one case and 75% in another.

Statisticians calculate a number called $R^2$ that provides an estimate of how much the data vary relative to the mathematical line they calculate. It is an estimate of the fraction of the variability in the data can be explained by the model. An $R^2$ of 1 means all points lie on the line and there is a perfect fit between the line and the data. An $R^2$ of 0 means the data do not fit the proposed mathematical line. In Figure 1 shown above (from 49) the $R^2$ for all data was 0.09 and 0.21 if only the nitrogen removal along the surface was considered. This indicates that a buffer width chosen using the line will match the removal effectiveness (numbers on vertical axis) only 21% of the time. For example, the model shows that a buffer width of 50 meters (164 ft) will remove about 60% of the nitrogen coming through in surface water. However, the low value for the $R^2$ indicates that this will be true only 21% of the time.

Similar graphs in Zhang and others (96) had $R^2$ values of 0.37 for the removal of sediment vs. width; $R^2$ = 0.44 for the removal of nitrogen; $R^2$ = 0.60 for the removal of pesticides and 0.35 for the removal of phosphorus. Scientists, however, usually consider a line is a good fit to the data if the $R^2$ value is at least 0.7 or higher. From a management perspective, an $R^2$ of 0.7 indicates that a proposed buffer width that falls on the line will provide the level of protection modeled 70% of the time.

Key point #5: Page 5-38. *The role of buffers in protecting the microclimate of streams is well documented and may be applicable to wetlands, but no specific data on buffers and wetland microclimate maintenance were found.*

Update: We were unable to find any new information on how vegetated buffers may protect the microclimate of wetlands. This function is acknowledged as probable (50), but we have not found any field data to support this assumption.

The focus of current research is still on the role buffers play in protecting the microclimate of streams. However, we judge that this information has a limited applicability to wetlands. The shading and attenuation of wind by trees in the buffer will only extend a short distance from the edge. Thus, the microclimate in the center of larger depressional wetlands will be dependent on other factors. Forested buffers on streams can have a larger impact on microclimate because streams are narrow and linear, and the ratio of edge to total area is much larger. In addition, the research on buffers, streams, and microclimates has focused on forested buffers. Many wetlands in eastern Washington do not have forested buffers, and this work would not be applicable in any case.

## 3. 3 The role of buffers in protecting wildlife habitat

Conclusions on how buffers function: bulleted list on Page 5-38. *Wetland buffers are essential to maintaining viable wildlife habitat because they perform three overlapping functions:*

- *Buffers can provide an ecologically rich and diverse transition zone between aquatic and terrestrial habitats. This includes necessary terrestrial habitats for many wildlife species that use and/or need wetlands but also need terrestrial habitats to meet critical life requirements.*

Update: Some ecologists are now calling buffers that provide critical life requirements for wetland dependent species "core habitats" rather than buffers (10, 79, 80, 82). The distinction is related to the idea that the buffer is not reducing (buffering) impacts to the functions provided by a wetland. Rather, wetlands in proximity to adjacent upland habitat provide a critical function. The combination of the two habitat types is essential to a suite of species that would be absent from either habitat alone. These core habitats are essential to a number of wetland-dependent species, including amphibians (80). Inadequate quantity or quality of core habitat will increase the probability of local amphibian population extinction (77). In addition, some scientists suggest that the core habitat itself requires a buffer to protect its habitat functions from outside disturbances (80).

- *Buffers can screen wetland habitat from the disturbances of adjacent human development.*

  Update: This conclusion is often made (42, 50), but there is little new research to provide additional documentation. Noise from an adjacent highway has been hypothesized as one factor that reduces the species richness and abundance of frog populations in wetlands with smaller buffers (15).

- *Buffers may provide connectivity between otherwise isolated habitat areas.*

  Update: Recent research is emphasizing that relatively undisturbed uplands between wetlands are important for maintaining the populations of many wetland-dependent species (3, 5, 66, 69, 77). A narrow undisturbed buffer can provide the first stage of a connection between wetlands, or it alone can provide that connection if wetlands are close together. A buffer, however, that is not part of a system of connected upland and wetland habitats may not provide adequate protection for populations of amphibians (5).

<u>Conclusion</u>: Page 5-38. *In regard to wildlife, most of the scientific research is not directly focused on the effectiveness of buffers for maintaining individuals or populations of species that use wetlands. Some of the research simply documents use of upland habitats adjacent to wetlands by wildlife to meet their life-history needs. For example, a substantial body of research identifies the distances that amphibians may be found away from a wetland edge. However, the implications to amphibian populations of providing buffers that are smaller than those identified ranges are not well documented.*

Update: The effects of buffers, their width and structure, on wildlife populations are being increasingly studied. In the last decade there have been numerous studies assessing the impact of buffer widths on populations of amphibians (5, 15, 29, 86) and wetland-associated birds (12, 27, 28, 33, 48, 52, 58, 83, 84). These will be discussed in more detail in the sections on amphibians and birds.

<u>Conclusion:</u> Page 5-41. *One consideration not found for this synthesis was the implication of the condition of the upland buffer relative to its provision of wildlife habitat. In several studies on the use of upland buffers by native species, the study identified that the buffer was upland forest. However, no studies were reviewed for this synthesis that compared wildlife*

*use of mature forested buffers with buffers composed of meadow, shrubland, harvest forest, or younger forests. Some research has identified the importance of intact forest habitat to wetland-related species (Azous and Horner 2001, Richter 1997), but a comparison study was not found for this synthesis.*

*Generally, wildlife species have varying needs for different types of adjacent habitat for different life needs, such as breeding, foraging, and resting (Brown 1985). This makes it difficult to prescribe one particular type of habitat as best for wildlife. Habitat is very species specific. However, as a general rule, most researchers have recommended that buffers be maintained or restored to a forested condition if only for the screening function they provide. (Obviously, this has little relevance to the shrub-steppe ecoregion in Eastern Washington, where trees are rarely found.)*

> Update: More recent research confirms that preferences for the type of vegetation in a buffer are very species specific.
>
> For example, among species of amphibians found in Washington State, the western toad (*Bufo boreas*) prefers uplands that are forested (51) and specifically open forest over forests with closed canopies (4). On the other hand, the Woodhouse toad (*Bufo woodhousii*) and the northern leopard frog (*Rana pipiens*) prefer open landscapes dominated by natural grasses (51). The Columbia spotted frog (*Rana luteiventris*) found in Oregon prefers agricultural areas and shrub/clearcut (24).
>
> Another study (69) using radio tags found that spotted salamanders (*Ambystoma maculatum*) will actively seek a forested buffer for migration when part of the buffer is grassland. Salamanders moved from water to upland habitat only along the side of the wetland that was forested. If salamanders came across grasslands as they moved from a wetland, they often returned to the wetland. Another study of this species found that the strength of the grassland as a barrier can depend on weather conditions. Spotted salamanders did move into grasslands when it rained and the grasses were wet (89).
>
> The presence of a forested buffer was also found to be an insignificant factor in the distribution of many bird species. Smith and Chow-Fraser (83) found that the presence of a forested buffer surrounding a wetland in Ontario Canada was not an important factor in predicting the distribution of generalist, wetland-dependent, or synanthropic species in wetlands. (Synanthropic bird species are those that have adapted to living in developed and residential areas).

<u>Key point #1</u>: Page 5-49. *There is no simple, general answer for what constitutes an effective buffer width for wildlife considerations. The width of the buffer is dependent upon the species in question and its life-history needs, whether the goal is to maintain connectivity of habitats across a landscape, or whether one is simply trying to screen wildlife from human interactions.*

> Update: The recent research is showing that the answer for what constitutes an effective buffer is even more complex than summarized in Key point #1. Studies and models are beginning to address the impact of different buffer widths on populations.

These studies address the question: what is the probability of extinction for a population of a wetland-dependent species at different buffer widths?

For example, Figure 2 graphs the probability of extinction over time for the wood frog (*Rana sylvatica*) and the spotted salamander (*Ambystoma maculatum*) for different buffer widths (29, 51). The spotted salamander has a low probability of extinction as long as the buffer is wider than 20m. The wood frog on the other hand, has a 10% chance of extinction even with a buffer that is 1000m wide.

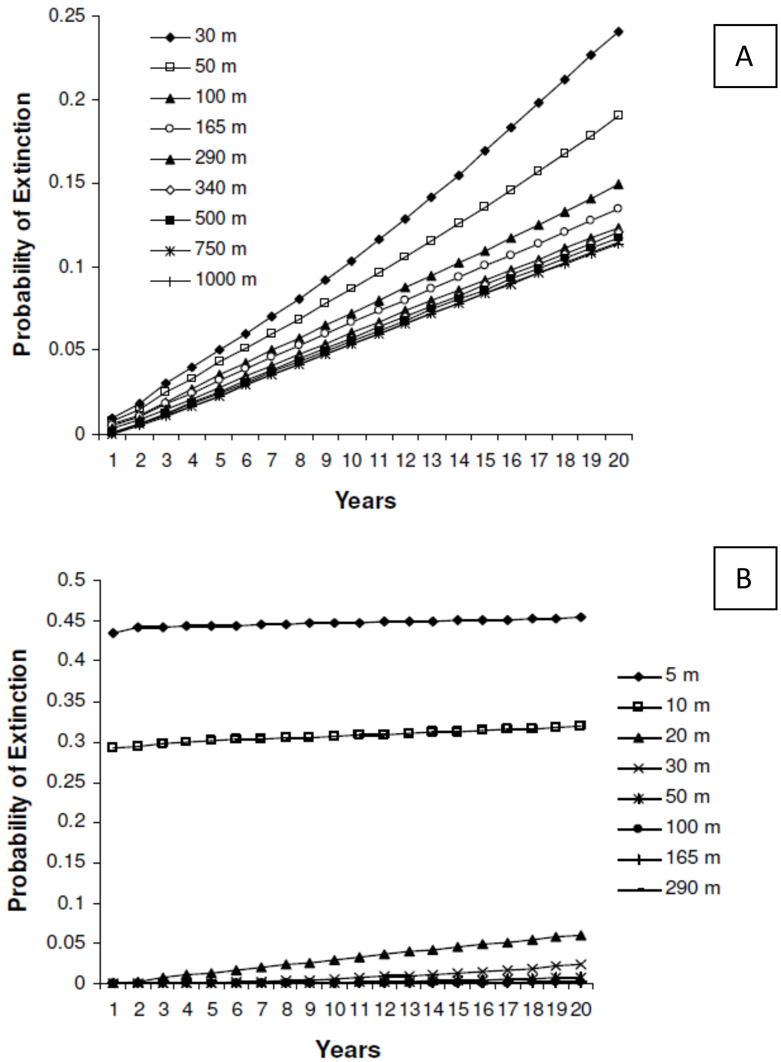



Figure 2: Results of model simulation predicting the probability of extinction of (A) wood frog populations and (B) populations of spotted salamanders as a function of the width of the terrestrial core habitat (buffer) [from 51].

<u>Key point #2</u>: page 5-49. *The majority of wildlife species in Washington use wetland habitats for some portion of their life-history needs. Many species that are closely associated with wetlands (those that depend upon wetlands for breeding, brood-raising, or feeding) depend upon surrounding upland habitats as well for some life-history stages.*

Update: The need for appropriate upland habitat has been well documented for amphibians and continues to be a focus of recent research (10, 11, 17, 21, 29, 37, 51, 70, 77, 86). Wetland-dependent birds are another wildlife group that continues to be a focus (22,28, 33, 48, 72, 83, 93). In addition the research has also expanded to include invertebrates such as dragonflies (7) and biting midges (Chironomids) (43).

Key point #3: Page 5-49. *Many terrestrial species that are dependent upon wetlands have broad-ranging habitats, some over 3,280 feet (1,000m) from the source wetland. Although this might be expected for large mammals such as deer or black bears, it is also true for smaller species, such as salamanders and other amphibians.*

Update: Numerous studies document the habitat zones and needs for individual wetland-dependent amphibians and birds. This research documents the movement of wetland-dependent species into the surrounding uplands. Increasingly, studies are also documenting the impact of types of buffer, their width, and other characteristics of the surrounding landscape on populations. These studies have collected data on species richness and abundance as well as presence/absence. Below is a summary of recent results sorted by the major taxa.

Amphibians and Reptiles:

Semlitsch (79) summarized the results from studies of core habitat for 32 species of amphibians and 33 species of reptiles in over 100 articles. The type and structure of the appropriate core habitat will differ among species, but in general, all core habitats are relatively undisturbed. Semlitsch's results (Table 1) show that the minimum distance required for buffer/core habitat ranges between 117m and 205m for amphibians and reptiles.

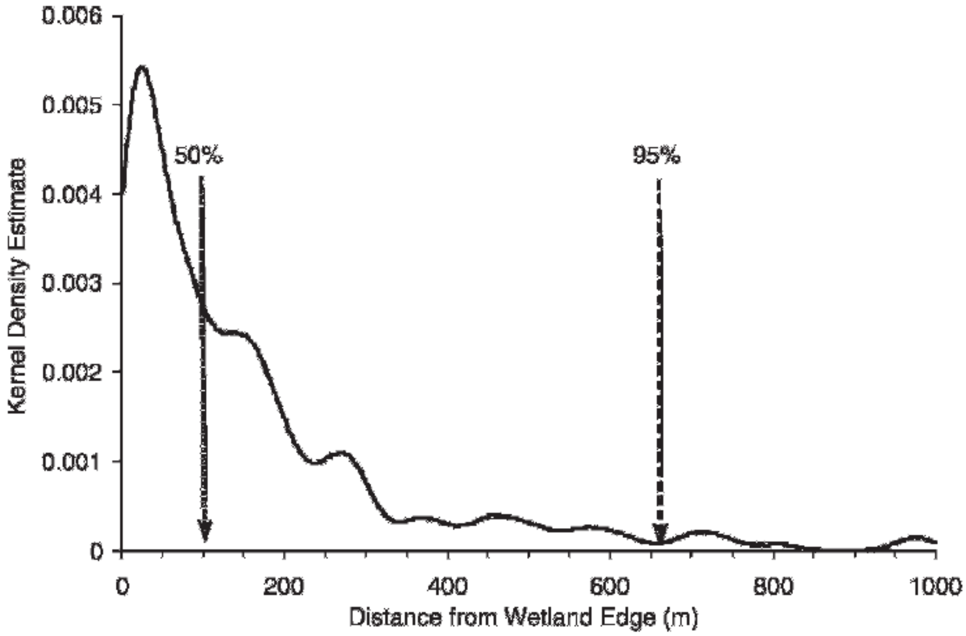
Table 1: Mean minimum and maximum core habitat (uplands) for amphibians and reptiles.* (copied from 79; We assume the last line represents the overall average, but this is not clear in the original review)

| *Group* | *Mean minimum (m)* | *Mean maximum (m)* |
|---|---|---|
| Frogs | 205 | 368 |
| Salamanders | 117 | 218 |
| Amphibians | 159 | 290 |
| Snakes | 168 | 304 |
| Turtles | 123 | 287 |
| Reptiles | 127 | 289 |
| Herpetofauna | 142 | 289 |

**Values represent mean linear radii extending outward from the edge of aquatic habitats compiled from summary data in Appendices 1 and 2.*

Rittenhouse and Semlitsch (70) analyzed the data from 13 studies that tracked 404 individual amphibians. They used these data to develop a mathematical model that plots the distribution of all these animals as a distance from the wetland edge. The model shows that one-half of the animals were found beyond 93 m (about 300 ft) (Figure 3) even though the peak of the distribution occurred at 30m (100 ft).

Figure 3: The density of amphibians as a function of distance from the wetland edge. Arrows represent the distance at which 50% and 95% of the populations were modeled (copied from 70).




One study (15) monitored the distribution and abundance of seven species of frogs as a function of the distance from a major highway in 34 wetlands in a rural section of Ontario, Canada. The distance of the wetlands from the highway ranged between 68m-3262m (223ft – 10,700ft). The wetlands were at least 500 m apart with mixed buffers of forest and fields. Lower abundances were measured in wetlands closest to the highway for all seven species. In addition, lower abundances were found for four of the seven species if the buffers were less than 250m (820 ft). The other three species had a relatively linear response in abundance out to the maximum distance of over 3000m (~10,000ft). This means that impacts on amphibian abundances were still being observed in the wetlands that were farthest from the highway.

The reviews cited above incorporate data on species found in Washington as well those that are not. Thus, the summaries they provide may not be exactly representative of what the amphibians in Washington's wetlands actually need as upland habitat. We were unable to find much information for the first synthesis on the upland habitat needs of amphibians specific to Washington. Research during the last decade however, has improved our knowledge. Table 2 summarizes the information on upland habitat use by amphibians found in Washington State. The research on a species may not have been done in Washington State, but we assume that the habitat needs for an individual species will not change significantly within its natural geographic range. Furthermore, the data summarized in Table 2 indicate that the habitat requirements of species found in Washington fall within the range found for species that have been studies more intensely.

Table 2: List of amphibian species found in Washington State. The second column summarizes the information on upland habitat use that was found in the literature search. The list of species found in Washington State is from the on-line field guide provided by the Burke Museum at the University of Washington. http://www.burkemuseum.org/herpetology/amphibians (accessed February 4, 2013).

| Amphibian species Found in Washington | Information on buffer widths, population dynamics and landscape factors outside of wetland | Reference |
|---|---|---|
| *Taricha granulosa*, Rough-skinned newt | Occurrence best predicted by amount of forest cover within 1km of wetland | 57 |
| *Ambystoma gracile*, Northwestern salamander | 200m of a forested upland buffer is home range for most | 68 |
| *Ambystoma macrodactylum*, Long-toed salamander | Presence is highest in wetlands surrounded by 500m of forest<br>Preferred dispersing through forested areas rather than agricultural or shrub areas | 51<br>24 |
| *Ambystoma tigrinum*, Tiger salamander | Presence was best predicted by other landscape factors rather than forest cover within 1000m | 51 |
| *Dicamptodon copei,* Cope's giant salamander | *No information* | |
| *Dicamptodon tenebrosus*, Coastal giant salamander | *No information* | |
| *Ensatina eschscholtzii*, Ensatina | Populations did not decline over 10 years with forested buffers as small as 14m<br>20% of trapped animals within 0-20m; 40% in a buffer zone of 20-30m, and 40% in buffer zone of 30-40m (40m was maximum distance of sampling) | 30<br>88 |
| *Plethodon dunni*, Dunn's salamander | 80% of trapped animals found within a buffer of 10m, remaining found within 40m (40m was maximum distance of sampling) | 88 |
| *Plethodon larselli*, Larch Mountain salamander | *No information* | |
| *Plethodon vandykei*, Van Dyke salamander | *No information* | |
| *Plethodon vehiculum*, Western red-backed salamander | Populations did not decline over 10 years with buffers as small as 14m<br>30% of captures in buffer zone 0-10m; 70% captures equally distributed to 40m (maximum distance of sampling) | 30<br>88 |
| *Rhyacotriton cascadae*, Cascade torrent salamander | *No information* | |
| *Rhyacotriton kezeri*, Columbia torrent salamander | 70% of trapped animals within 0-10m buffer; the remaining 30% equally distributed out to 40m (maximum distance of sampling) | 88 |
| *Rhyacotriton olympicus*, Olympic torrent salamander | *No information* | |
| *Rana pipiens*, Leopard frog | Presence was best predicted by both grasslands within | 51 |

| | | |
|---|---|---|
| | 500m and other open areas<br>Highway has a measurable impact on abundance in wetlands that are buffered by over 1000m of mixed forest and open land. Impacts are relatively linear with distance from highway. | 15 |
| *Ascaphus truei*, Coastal tailed frog | Populations declined over 10 years with buffers of either 14m or 30m | 30 |
| *Ascaphus montanus*, Rocky Mountain tailed frog | *No information* | |
| *Bufo boreas*, Western toad | Presence was best predicted by landscape factors rather than forest cover within 1000m<br>Males traveled 581m from wetland, while females traveled 1105-m from wetland; females preferred shrub areas over forested buffers and open forest over closed canopies<br>A buffer of 30.5m (100 ft) did not adequately protect critical upland habitat | 51<br>87<br>23 |
| *Bufo woodhousei*, Woodhouse toad | Presence in wetlands was best predicted by both grasslands within 500m and other open areas | 51 |
| *Rana pretiosa*, Oregon spotted frog | *No information* | |
| *Hyla (Pseudacris) regilla*, Pacific treefrog | *No information* | |
| *Rana cascadae*, Cascades frog | *No information* | |
| *Rana aurora*, Northern red-legged frog | Strongly associated or even limited to forest habitat and may commonly move >1000m in uplands<br>1000m of upland buffer is home range | 31<br>68 |
| *Scaphiopus intermontanus*, Great Basin spadefoot toad | *No information* | |
| *Rana luteiventris*, Columbia spotted frog | Presence was best predicted by landscape factors rather than forest cover within 1000m<br>Preferred moving through agricultural and shrub/clearcut areas rather than forested | 51<br>24 |
| *Rana clamitans*, Green frog (introduced) | Highway has a measurable impact on abundance in wetlands that are buffered by over 1000m of mixed forest and open land. Impacts are relatively linear with distance from highway. | 15 |
| *Rana catesbeiana*, Bullfrog (introduced) | *No information* | |

Information about the requirements of wetland-dependent reptiles in Washington State for buffers or core habitat is relatively sparse. The western pond turtle (*Clemmys marmorata*) is listed in Washington as an endangered species, but its habitat needs are not well documented and it has a very limited distribution in this state. The recovery plan for the pond turtle (65) states that females generally move 20–100m (65–328 ft) into the uplands, but nests have been found as far as 187m (614 ft) from the wetland edge. In California, the turtles moved as far as 500m from their aquatic habitat (64). The information on the painted turtle (*Chrysemis picta*) indicates that the distribution of this species was not influenced by proximity to roads or the amount of forested buffer surrounding the wetland at 30m, 125m, 250m, 500m or 1000m (1). Painted turtles are abundant in wetlands surrounded by a diversity of land uses in the immediate vicinity of the wetland, although their overall distribution is affected by the range of land uses at a landscape scale (71).

Birds

Much of the current research on birds involves riparian buffers along streams and lakes. While we read some of these studies we did not consider them applicable to this synthesis unless they also discussed wetlands. There is enough new research being done on wetland-dependent birds that we judged there was no need to try to extrapolate the information from streams to wetlands.

Recent studies indicate that the protection provided for wetland-dependent birds depends to a large degree on the species involved and on factors other than width, such as the type of vegetation in the buffer, land uses within 500m or 1 km of the wetland, and whether the setting is urban or rural.

Most of the wetland-dependent birds investigated have broad geographic ranges that include Washington State even though the studies were done outside our region. It was not, however, possible to sort out the data in these studies for those species found in Washington, and to summarize the information only for those species found in the state. Much of the recent research has focused on groups of similar birds (guilds and function groups) and it was not possible to separate out species based on their local distribution. Furthermore, the number of bird species involved is much larger than the number of amphibians. For example, McKinney and others (52) found 55 species associated with the wetlands in their study in Rhode Island. Of these, 41 species are also found in Washington (list in reference compared to list in BirdWeb: Seattle Audubon's Guide to the Birds of Washington State, http://birdweb.org/birdweb/ accessed February 6, 2013).

New information relating to the distribution of birds in wetlands and their buffers include:

- Obligate marsh-nesting species preferred rural over urban wetlands; generalist marsh-nesting birds showed no preference; while synanthropic generalist species had higher richness and abundance in urban marshes. The presence of a forested buffer surrounding the marsh in both rural and urban areas, however, was not an important factor in predicting the distribution of any of these bird groups (83).

- Ward and others (92) monitored the abundance and distribution of 12 species of wetland-dependent birds in 196 wetlands over a period of 26 years in the Chicago area. Seven species experienced significant declines, three showed no change, and two had significant increases. These changes were attributed to changes in the structure of the wetlands resulting from increased flows and nutrients caused by development. The percent forest cover or grasslands in a

2km buffer around the wetlands were not significant factors in explaining these changes because the extent of these land uses did not change as a result of development. The development occurred at the expense of agricultural lands.

- Large buffers of woods, grasslands, and other wetlands were a good predictor of abundance for 36 species of wetland-dependent birds [mean width of buffer in wetlands studied = 256m (840 ft) (range 20- 619m)] (53). Mathematical modeling of the data showed a potential benefit for the population as the width of a buffer increased up to 1000m (~3300 ft) for diving and dabbling ducks and up to 2000m (> 1 mile) for birds whose main habitat was the emergent plants in the wetland (53).

- The ecological integrity of a marsh bird community in the Chesapeake Bay area shows a threshold response to development within 500m and 1000m (1640 ft – 3281 ft). The integrity of the bird community was significantly reduced when the amount of urban/suburban development exceeded 14% or the total area within 500m of the wetland, or 25% within 1000m (12). Rooney and others (73) reported similar results where a bird-based index of integrity was best predicted by land used within 500m of wetlands rather than 100m, 300m, 1000m, or greater.

<u>Fish</u>

We did not find any references on the relationship between buffers and fish in wetlands for the initial synthesis in 2005. The studies reviewed addressed the effect of riparian buffers on fish populations in stream and river systems. It is difficult to extrapolate the results of studies in streams to those in wetlands because the habitat provided by streams is quite different from that in wetlands. This lack of information on fish in wetlands continues to this day. We were unable to find any articles on the subject that were written between 2003 and 2012. We did, however, find one study that analyzed the impact of vegetated buffers on fish species in lakes from the Pacific Northwest. This study might provide some useful insights into what might happen in larger, permanently ponded, wetlands.

Francis and Schindler (18) analyzed the food in the guts of fish from 28 lakes in the Pacific Northwest. They found a significant threshold when more than 10% of the lakeshores were developed; where "developed" was defined as shorelines where the vegetated buffers were less than 10m (33ft). The diet of trout and bass in lakes where more than 10% of the shoreline was developed was almost completely aquatic in origin. On the other hand, the diet of these species was over 50% terrestrial in origin in the lakes where less than 10% of the lakeshore was developed. Furthermore, a detailed analysis of the energy balance done in four lakes indicated that trout averaged a 50% greater energy intake in lakes that were not developed (i.e. had vegetated buffers of more than 10m for at least 90% of the lake's circumference).

Mammals

We found little new research on the buffer requirements of wetland-dependent mammals. One article (19) found that mammal diversity and abundance had some positive correlation with 500m and 1000m buffers, but not with 250m buffers. This complements the results from Puget Sound that were cited in the 2005 synthesis, where the highest number of small mammal species was found in wetlands that had a 500m buffer that was at least 60% forested.

Key point #4: page 5-49. *Human access and land uses adjacent to wetlands influence the use and habits of wildlife through noise and light intrusions, as well as elimination or degradation of appropriate upland habitats. Even passive activities, such as bird/nature-watching, have been shown to have effects on roosting and foraging birds.*

Update: The impacts of noise on amphibians and birds have received some attention in the last decade, and a wide variety of responses has been found, again based on differences among species. The overall impact of human land uses adjacent to wetlands has also been studied at a landscape scale. These results indicate that the impacts of such land uses on the richness and abundance of wetland-dependent species may take over two decades to become measurable. Specifically:

- Lengagne (45) found that playing traffic noises to male tree frogs triggered a decrease in calling activity. However, the impacts were decreased when tree frogs were calling in a chorus, probably because the frogs themselves were drowning out the traffic noise. Sun and Narins (85) found a similar response to airplane noise and low-frequency motorcycle noise in three species of frogs, but the noise increased the calling rate in one species.

- Herrera-Montes and Aide (34) found that the species richness of frogs in a wetland with a 100m forested buffer from a highway (noise>60db) was not different from a wetland with a 300m forested buffer (noise<60db). However, they also found that birds with low-frequency songs were absent from sites nearer the highway (at 100m).

- The severity of impacts from increasing development on amphibian populations may take several decades to manifest themselves. Lofvenhaft and others (47) measured a time lag of several decades between changes in urban land use and traffic density and the occurrence of amphibians. Gagne and Fahrig (20) found that the relative abundance of four out of five frog species continued to decrease for at least 54 years after residential development occurred.

- In Melbourne, Australia, Hamer and Parris (26) found that the breeding assemblage of frogs was greatly increased if the breeding ponds were surrounded by a high proportion of green open space within 1km. Conversely, there was a strong negative correlation between the number of people living within the 1km circle and the frog populations. They hypothesized that the human preference for tidy ornamental ponds where aquatic plants are often removed as well as shading from tall buildings could be factors for this negative correlation.

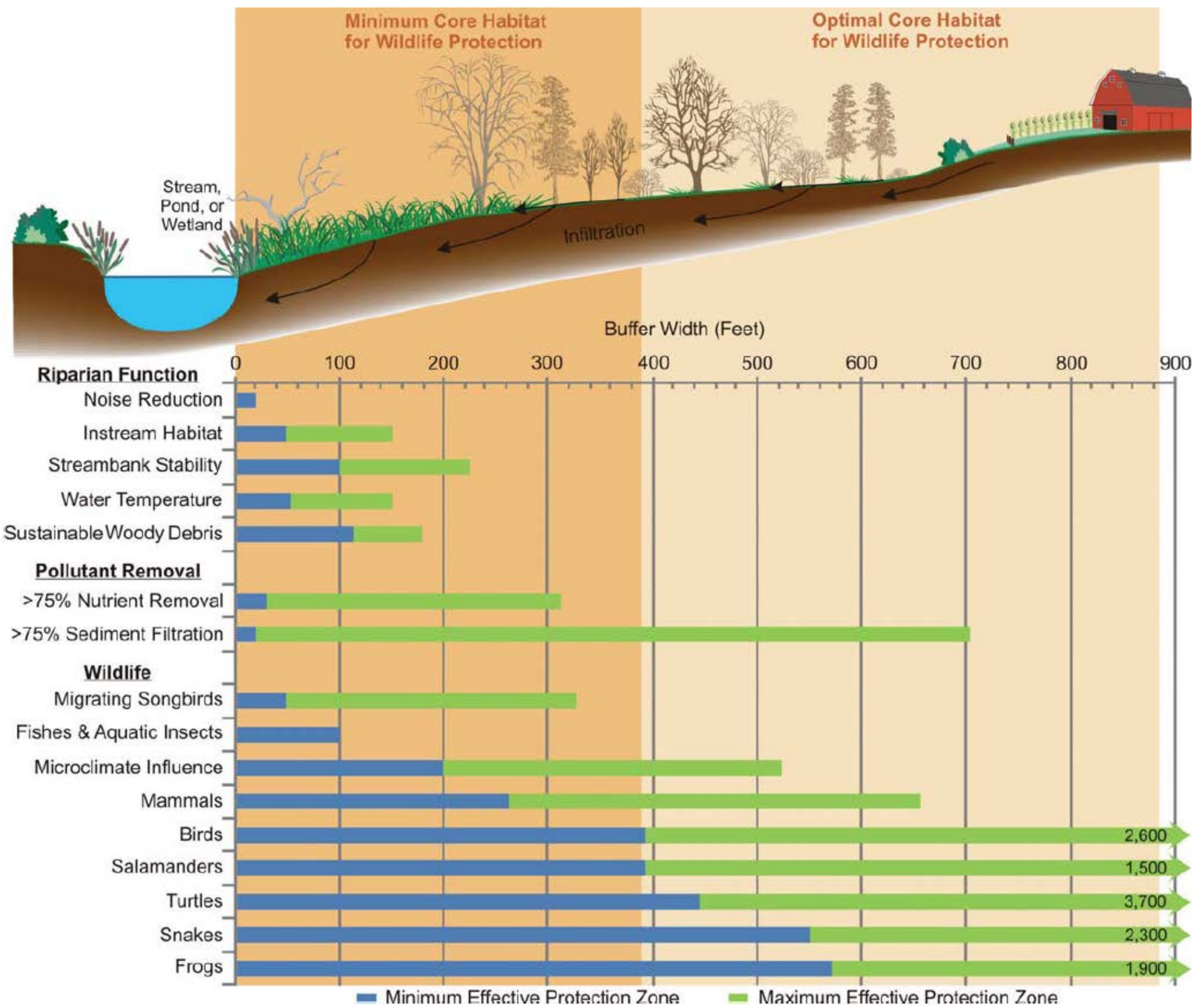
Key point #5: page 5-49. *Synthesis documents that evaluated many studies discussing the protection of habitat provided by wetland buffers generally recommend buffer widths between 50 and 300 feet (15 to 100 m), depending on specific factors. These factors include the quality of the wetland habitat, the species needing protection, the quality of the buffer, and the surrounding land uses*.

Update: Recent synthesis documents provide a more focused approach to buffer widths that is based on the many functions provided by a buffer. In addition, the more recent recommendations specify buffer widths that go beyond 300 ft for many wildlife species. The *Planner's Guide to Wetland Buffers for Local Governments* prepared by the Environmental Law Institute (42) recommends a range of 100–1000ft for wildlife, 30–100ft for sediment removal, 100-180ft for nitrogen removal, and 30-100ft for phosphorus removal.[1] The Southeast Wisconsin Regional Planning Commission (82) recommends a minimum range of 400–580 ft for birds, salamanders, turtles, snakes and frogs (Figure 4) for buffers along streams and wetlands based on the research and synthesis done by Semlitsch and Bodie (79). The synthesis done for Wisconsin states:

> Determining what buffer widths are needed should be based on what functions are desired as well as site conditions. For example, as shown above *(figure 4)*, water temperature protection generally does not require as wide a buffer as provision of habitat for wildlife. Based on the needs of wildlife species found in Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. Hence, the value of large undisturbed parcels along waterways which are part of, and linked to, an environmental corridor system. The minimum effective buffer width distances are based on data reported in the scientific literature and the quality of available habitats within the context of those studies.

[1] This document was peer reviewed by five independent wetland scientists and and by staff from the Environmental Protection Agency. Normallly, scientific journals only require peer review by three scientists.

Figure 4: Recommended widths of buffers to protect aquatic resources (from 81).




The minimum recommended buffers for wetland-dependent species in Wisconsin (82) are shown in Table 3. The table also indicates the number of scientific studies on which the recommendations are based. Three of the 12 frog species, and one species of salamander, found in Wisconsin are also found in Washington State. The recommendations therefore are somewhat applicable to Washington.

Table 3: Minimum and optimum buffers (core habitat) recommended for wetland and riparian wildlife in Wisconsin (from 81). The last column shows the number of studies on which the recommendations are based. [2]

| Wisconsin Species | Mimimum Core Habitat (feet) | Optimum Core Habitat (feet) | Number of Studies |
|---|---|---|---|
| Frogs | 571 | 1,043 | 9 |
| Salamanders | 394 | 705 | 14 |
| Snakes | 551 | 997 | 5 |
| Turtles | 446 | 889 | 27 |
| Birds | 394 | 787 | 45 |
| Mammals | 263 | No data | 11 |
| Fishes and Aquatic Insects | 100 | No data | 11 |
| Mean | 388 | 885 | |

## 3.4. Buffers and Plants

We did not find any references on the relationship between buffers and the plant community in wetlands for the 2005 synthesis. The studies reviewed in that synthesis addressed the impact of increased nutrients on the plant community. Since buffers can reduce the nutrient input into wetlands, they can be considered important for protecting the plant communities sensitive to increased nutrient inputs. Several more-recent studies directly link the width of a buffer to the plant communities found in wetlands. The results show that buffers of at least 70-100m are needed to protect the diversity of the wetland plant community.

- Houlahan and others (39) monitored plant diversity in 58 wetlands in Ontario, Canada and found that forest cover in the buffer was an important predictor of species richness in the wetlands. Statistically significant changes in overall richness were observed when the forest cover was changed to other land uses as far as 250-300m (820ft – 985ft) from the wetland. The richness of the different functional groups of plants in the wetlands (e.g. native, exotic, annual, perennial, forest, open, aquatic), however, did not respond in the same way even though the overall trend was that larger buffers increased richness.

- Rooney and others (73) found that the integrity of the plant community in 45 wetlands in Alberta was best predicted using data on land cover within 100m

[2] This table was adapted from reference 78 by the author of reference 81.

(330ft) rather than other distances ranging up to 3000m (1.9 miles). They used a plant-based index of biological integrity (IBI).

- Ervin (16) found that the presence of a forested buffer of at least 70-100m (230 – 330 ft) was associated with an increase in the quality of wetland vegetation (using a modified plant-based IBI).

### 3.5. Buffer Maintenance and Effectiveness over Time

Key point #1: page 5-51. *Human actions can reduce the effectiveness of buffers in the long term through removal of buffer vegetation, soil compaction, sediment loading, and dumping of garbage.*

Update: We found no new research to support or refute this conclusion. General synthesis documents continue to make similar conclusions (42, 91).

Key point #2: page 5-51. *Buffers may lose their effectiveness to disperse surface flows over time as flows create rills and channels, causing erosion within the buffer.*

Update: Ongoing research supports this conclusion (60, 95). A study in an agricultural environment found that only a small fraction of the total buffer area (9% -18% of the buffer zone) in four sites was actually in contact with surface runoff (13).

Key point #3: page 5-51. *Leaving narrow strips of trees can result in tree loss due to blowdown.*

Update: We found no recent studies on this subject, but we did find one additional study done in 1998 in California. The results indicate that a 30m wide selective cut in a buffer increases the rate of fall in the innermost 15m of uncut buffer by an order of magnitude (65).

Key point #4: page 5-51. *Buffers may become saturated with sediment over time and become less effective at removing pollutants. The literature indicates that this should be considered when determining buffer widths.*

Update: In addition to becoming saturated with sediment, buffers can become saturated with phosphorus. Two reviews (56, 36) conclude that the effectiveness of a buffer at trapping phosphorus can be reduced because the soils become saturated with this pollutant.

# 4.0 Update on Buffer Ranges and Other Characteristics

Key point #1: page 5-51. *Many researchers have recommended using four basic criteria to determine the width of a buffer:*

- *the functions and values of the aquatic resource to be protected by the buffer*
- *the characteristics of the buffer itself and of the watershed contributing to the aquatic resource*
- *the intensity of the adjacent land use (or proposed land use) and the expected impacts that result from that land use*
- *the specific functions that the buffer is supposed to provide, including the targeted species to be managed and an understanding of their habitat needs.*

Update: Recent recommendations on buffers confirm that these basic criteria are still valid (42, 82). In addition, the recent research has focused on identifying the characteristics of the buffer itself that provide the protection of wetland functions (see sections 3 and 4). For water quality these include the soils, the source of water, the infiltration rate, the slope, and the surrounding land uses. For habitat, the research has reinforced the fact that buffer requirements need to be targeted at the species of interest. For example, a forested buffer is optimal for some species but not for others. Fish may need only a 100ft buffer, but some species of amphibians need a 1000ft buffer.

Key point #2: page 5-51. *Protecting wildlife habitat functions of wetlands generally requires larger buffers than protecting water quality functions of wetlands.*

Update: This conclusion is still valid and supported by the more-recent research (see sections 3.2 and 3.3).

Key point #3: page 5-51. *Effective buffer widths should be based on the above factors. They generally should range from:*

- *25 to 75 feet (8 to 23 m) for wetlands with minimal habitat functions and low-intensity land uses adjacent to the wetland*
- *75 to 150 feet (15 to 46 m) for wetlands with moderate habitat functions and moderate or high-intensity land uses adjacent to the wetland*
- *150 to 300+ feet (46 to 92+ m) for wetlands with high habitat functions, regardless of the intensity of the land uses adjacent to the wetland.*

Update: Recent synthesis documents recommend a focused approach to buffer widths that is based on the many functions provided by a buffer. In addition, the more recent recommendations specify buffer widths that are larger than those recommended in the 2005 synthesis. The *Planner's Guide to Wetland Buffers for Local Governments,* prepared by the Environmental Law Institute (42), recommends a range of 100ft–1000ft for wildlife, 30–100ft for sediment removal, 100-180ft for nitrogen removal, and 30-100ft for phosphorus removal.

If prescribed buffers are to be used to adequately protect wetland wildlife, they will probably have to be larger than what is currently used. Based on the needs of wildlife species found in Wisconsin (some of which are also found in Washington State), the minimum buffer width is about 400 ft, and the optimal width for sustaining the majority of wildlife species is about 900 ft (81).

Key point #4: page 5-51. *Fixed-width buffers may not adequately address the issues of habitat fragmentation and population dynamics. Several researchers have recommended a more flexible approach that allows buffer widths to be varied depending on site-specific conditions.*

Update: A request for a more flexible approach is a common theme among recent articles (42, 62, 67, 95). The research reinforces the fact that buffers and fragmentation are only two of many variables that affect the dynamics of wildlife populations. Other factors that have been found to affect the survival of wetland-dependent species are surrounding land use, the structure of the plant community, and the intensity of human disturbance. If buffers are to be used to protect the water quality in wetlands, the factors that need to be considered are slope, soil chemistry, soil structure and the plant community.

# 5.0 Synthesis of New Information on Buffers

The initial questions posed at the beginning of this literature review were:

1. Are the conclusions and key points regarding wetland buffers made in the 2005 synthesis still valid?
2. If not, what new conclusions can be made from the recent research about how buffers protect wetland functions?

In addition, a synthesis should "involve the integration of disparate data with existing concepts and theories to yield new knowledge, insights, and explanations." ( 59). Below we provide our synthesis of the information we presented in the previous chapters. Some conclusions that come out of a synthesis may not have been made previously by others and thus cannot be cited because they provide new knowledge and explanations.

## 5.1 Conclusions on protecting water quality by using buffers (Section 3.2)

The research in the last decade supports the basic conclusion that buffers trap pollutants before they reach a wetland, thus protecting its functions. The recent research has also increased our understanding of the many different factors that control the effectiveness of a buffer at trapping pollutants. These factors include:

- Width
- Slope
- Type of vegetation (herbaceous, shrub, trees)
- Type of pollutant (e.g. nitrogen, phosphorus, sediment, coliform bacteria)
- Geochemical and physical properties of the soil
- Infiltration rates of soils
- Source of pollutants (surface water or groundwater)
- Concentration of pollutants
- Path of surface water through the buffer
- For phosphorus, the amount of phosphorus already trapped by the soil.

All else being equal, wider buffers should be more effective than narrower ones. However, the other site-specific factors listed above can change the effectiveness of wider buffers. For example, a wide buffer where surface runoff has formed a small channel will probably not be as effective as a narrower buffer with no channels. In the latter case, the surface flows carrying pollutants have a chance to diffuse through the vegetation and percolate into the ground. In the former case the pollutants have less opportunity to interact with the processes that trap and transform them.

The approach of using the width of buffers as the only means for protecting water quality in a wetland can be complicated. Different buffers widths may be needed to achieve the same level of protection because other environmental factors are also important.

## 5.2 Conclusions on protecting wetlands as wildlife habitat by using buffers (Section 3.3)

The research in the last decade indicates the habitat needs of wetland-dependent species are highly variable. Protecting wetland-dependent wildlife will probably require a broader, landscape-based approach.

Current research indicates that:

- Some species of amphibians require large areas of relatively undisturbed uplands if their populations are to survive. Models that estimate the extinction rate show that some amphibian populations have a high probability of becoming extinct in a wetland within few decades as buffers are sized using current guidance (100 – 300 ft).

- We found information on the upland habitat needs for 15 of the 27 species of amphibians found in Washington State. These articles do not specify a minimum distance that is required to protect a population, but they show that the species can range 40m (~130ft) to over 1km (0.6 miles) from the edge of a wetland. The type of upland habitat used by species found in Washington are similar to what these species use in other parts of their range. Thus, many of the general conclusions reported in the literature will probably also be valid, even though the research was done on these species in other locations.

- The uplands surrounding a wetland can serve as critical habitat for certain wetland-dependent species. Because this expands the concept of wetland buffer from simply protecting the wetland to protecting species in the uplands, some have suggested using the term core habitat rather than buffer. Many wetland-dependent species will probably not survive unless an adequate amount of core habitat is present.

- Studies on birds as well as amphibians report that core habitat for many species needs to extend between 300m (1000ft) and 1000 m (0.6mi) from the wetland edge. However, we were unable to find information on how much of the wetland edge has to be connected to the core habitat to maintain populations.

- The composition of plants in buffers and core habitats is also an important factor. Some species prefer grasslands while others prefer shrubs and forests.

- Policies and regulations will probably need to protect the upland habitats that are an integral part of their habitat needs.

The current research indicates that a broader approach to protecting wildlife is needed. Buffers alone may not prevent the populations of many species from declining. Wetland policies that rely on only on buffer widths may be ineffective at protecting amphibians or other wetland species that disperse across the landscape. Bauer and others (5) combined an economic cost model with models of amphibian populations and found that in the majority of human-dominated landscapes, some amount of protection for the upland core habitat is necessary for long-term survival of these amphibians. However, in landscapes with less intense land uses, such as low-intensity residential, and a high pond density, wetland buffers may be all that is required (5).

## 5.3 Conclusions on protecting plant biodiversity in wetlands using buffers (Section3.4)

Very little research has been done correlating plant biodiversity in wetland with buffer width. The research that has been done suggest that wetlands may require buffers that are at least 200 ft (60m) to protect sensitive plants.

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