Waterfowl and Waterbird Abundance and Utilization of Aquatic Off-Channel Habitats in the Chehalis Floodplain

25 April 2017

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EXECUTIVE SUMMARY

Introduction

We conducted waterfowl and waterbird observational surveys as part of a larger collaboration informing the Chehalis Basin Programmatic Environmental Impact Statement (PEIS) in response to evaluating flood reduction alternatives on the upper reaches of the Chehalis River. The Chehalis floodplain is the focus of annual transect-based aerial breeding waterfowl surveys, but those surveys are insufficient to characterize waterfowl assemblages and habitat utilization across key portions of their annual cycles. Hence, this report documents waterfowl studies conducted during 2015-2016 expressly to fulfill this need. In particular, these studies:

1. Quantified waterfowl and waterbird utilization of and abundance associated with Chehalis floodplain aquatic off-channel habitats;
2. Derived estimates of waterfowl abundance, across temporal and spatial gradients, throughout the floodplain; and
3. Documented waterfowl production within floodplain aquatic off-channel habitats.

Methods

Waterfowl and waterbird spatial distributions and abundance estimates were derived through aerial surveys. Four aerial surveys were conducted during the 2015 and 2016 breeding seasons, the 2015 fall migration, and the 2016 spring migration. The aerial surveys were comprised of thirty-nine 400-m wide north/south-oriented transects evenly spaced 1.9 km apart. All waterfowl/waterbirds and water features within the transect strips were documented and georeferenced by pairing the time of observation with the flight path log.

Ground surveys at 36 study sites assessed waterfowl utilization and production within aquatic off-channel habitats. When conditions allowed, optic-assisted visual surveys were conducted remotely from land. When water levels or dense vegetation impeded remote observations, visual surveys were conducted from kayaks. Observers attempted to identify the species, sex, and count of all waterfowl and waterbirds encountered within each study site.

The utilization of and abundance in off-channel habitats was modeled using observational data of dominant species collected during ground surveys along with the proportion of land cover types at each study site. Production estimates were derived by applying species-specific recruitment rates to our floodplain-wide population estimates.

Results and Conclusions

We documented the presence of 32 waterfowl/waterbird species. Mallard, Ring-necked duck, Canada goose, and Trumpeter swan were the most abundant and widely distributed species in their respective tribes. Bufflehead and American coot were, respectively, the most abundant sea duck and waterbird observed, but Hooded merganser and Great blue heron were the most widely distributed sea duck and waterbird, respectively.

Species richness was highest (≥16) at five sites: the WDFW Wenzel Slough, WDFW 306, Vetter, WDFW Hoxit 1, and Lantbruk. These sites tended to be dominated by herbaceous wetlands, had limited surface flow, and were in close proximity to pastures and agricultural fields. Sites close enough to the Chehalis mainstem to have substantial surface flow through them during high water events, such as Centralia Discovery and Chapman, had low species richness and use.

Modeling, expressly used to minimize temporal confounds resulting from the sampling approach, revealed that surface-feeding ducks were the most abundant tribe while sea ducks were the least abundant. Most species experienced marked increases in abundance during the fall and spring migratory periods, as well as reduced abundances during mid-winter. Of the species recorded between November and April, Green-winged teal, Ring-necked duck, and Hooded merganser had the least variable numbers.

More species were positively associated with herbaceous wetlands than woody wetlands or open water habitat; however, numerous species were positively associated with woody wetlands and open water habitat. This varied habitat association clearly illustrates the need for heterogeneity in wetland habitats. Although its distribution is severely limited throughout the floodplain, wet prairie had far greater use than any other habitat type, specifically by surface-feeding ducks during the spring migration.

Brood rearing of Mallard, Wood duck, Canada goose, Cinnamon teal, Blue-winged teal, Hooded merganser, Common merganser, and Pied-billed grebe were documented during production surveys. Mallard and Wood duck observations were frequent enough to enable the establishment of recruitment rates. Mallard females produced 1.73 ± 0.49 offspring each while Wood duck females produced 1.67 ± 0.36 each. Using these recruitment rates and our 2016 breeding period floodplain estimates, we estimated floodplain production to be 763 (SD = 218) Mallard offspring and 137 (SD = 43) Wood duck offspring.

Next Steps

Disproportionately high use of wet prairie by surface-feeding duck species was clearly established during this study. Future studies should expand the understanding of this pattern to determine whether restoration efforts should preferentially address these habitats. Additionally, the use of mainstem rivers as well as agricultural and pasture habitats within the floodplain should be documented. Mainstem rivers and their immediate peripheral habitats are known to be used by several sea duck species and may be used by surface-feeding and diving ducks. Agricultural and pasture habitats are also known to be heavily used by geese, swans, and surface-feeding ducks, but the extent to which they are used in the Chehalis Basin has not been detailed. Due to persistent, poor weather, aerial surveys were not as frequent as originally anticipated, so an additional season (October – April) of aerial surveys would produce a more robust understanding of temporal and spatial abundance trends within the floodplain.

REPORT

Introduction

The Chehalis River, southwest Washington State, drains 6,889 km^2 (2,660 mi^2), making it the largest watershed fully within the state. The mainstem Chehalis River originates in the Willapa Hills and empties into the eastern portion of Grays Harbor, 201 km (125 miles) from its origin. The Chehalis Basin is unique in western Washington reaching into three ecoregions: the Willapa Hills, the Cascade Mountains, and the southern slope of the Olympic Mountains (**Figure 1**) (The William D. Ruckelshaus Center 2012).

Remote land cover data from 2011 indicates that agriculture, mainly pastureland, is the most frequent (36%) cover type within the Chehalis floodplain; other important cover types include wetlands (24%), developed lands (13%), forested lands (10%), and open water (6%) (Homer et al. 2015). With limited glacial/snowmelt input, the Chehalis system is rain-dominated, with most rainfall occurring between October and mid-March. Mean annual precipitation ranges from 250-355 cm (100-140 in) in the Willapa Hills headwaters and the southern slope of the Olympic Mountains to 114 cm (45 in) near Centralia (NOAA 1985, Prism Climate Group 2016). Floodplain inundation often accompanies the seasonal pulse of rainfall. In unaltered riverine systems, these periods of inundation and the movement of water throughout the floodplain may be the most important factor controlling aquatic, biotic adaptations (Bayley 1995).

Exceptional rainfall events in 2007 and 2009 caused substantial flooding throughout the basin; the 2007 event alone cost the 140,000 residents of the basin over $900 million worth of damages and led to the closure of Interstate Highway-5 for four days. These inundation events, along with others that occurred in the 15 years prior, prompted efforts to explore flood reduction alternatives. In 2011, Washington State Legislature mandated a formal investigation of flood reduction alternatives. These alternatives are currently being assessed through a Programmatic Environmental Impact Statement (PEIS).

As the largest floodplain entirely within western Washington, the Chehalis floodplain, along with the adjacent estuarine environment of Grays Harbor, are well known as important overwintering and migratory stopover points for diverse avifauna. Numerous waterfowl and waterbird species utilize various Chehalis floodplain habitats throughout the yearly cycle. Although landscape utilization varies amongst these species, all are affected by processes driven by recurrent riverine inundation. In healthy systems, inundation-dependent ecosystem processes result in: increased invertebrate abundance and diversity, the distribution of seeds and unharvested grains, and the dispersal of fish into otherwise disconnected off-channel aquatic habitats (Fredrickson 1988, Bayley 1995). These processes sustain feeding opportunities for waterfowl and waterbirds (Fredrickson 1988, Ringelman 1988, Bayley 1995, Heitmeyer 2006). Furthermore, following a flood event, the continual downstream procession and retraction of the littoral zone offers new, shallowly flooded areas for feeding. These shallowly flooded areas may be utilized by multiple waterfowl and waterbird taxa, but in particular, can provide exceptional foraging conditions for surface-feeding ducks (tribe Anatini) (Fredrickson and Reid 1988, Moss et al. 2009).

To effectively develop the PEIS, information on waterfowl and waterbird utilization of the Chehalis floodplain was an important need. The Chehalis floodplain is the focus of annual transect-based breeding waterfowl aerial surveys, but those surveys are insufficient to characterize waterfowl assemblages and habitat utilization across key portions of the annual cycle. Hence, this report documents waterfowl studies conducted in 2015 and 2016 expressly to fulfill this need. In particular, these studies:

1. Quantified waterfowl and waterbird use of and abundance associated with Chehalis floodplain aquatic off-channel habitats;
2. Derived estimates of waterfowl abundance, across temporal and spatial gradients, throughout the floodplain; and
3. Documented waterfowl production within floodplain aquatic off-channel habitats.

We used three distinct study approaches to achieve these goals. During the migratory and wintering periods, we employed ground surveys (hereafter primary ground survey) to quantify waterfowl and waterbird utilization and abundance. We conducted multiple aerial helicopter transect surveys (hereafter aerial surveys) to estimate waterfowl populations during the 2015 fall migration, 2016 spring migration, and during the breeding periods of 2015 and 2016. Lastly, we documented waterfowl production via additional ground surveys during the breeding/ brood-rearing period of 2016 (hereafter brood ground survey).

Methods

Survey Area and Site Selection

Our study area encompassed virtually the entire Chehalis River floodplain (**Figure 1**). We defined the floodplain as that area within the limit of the FEMA-designated 100-year flood plus an additional 100-meter buffer.

Figure 1. Study area, river segments, and floodplain extent of the Chehalis River floodplain.

The Washington Department of Fish and Wildlife (WDFW) Habitat Program delineated aquatic off-channel habitats within the Chehalis floodplain remotely using 2011 and 2013 National Agriculture Imagery Program (NAIP) aerial imagery (USDA 2013). All aquatic habitats spatially separated from the mainstem of the Chehalis River – excluding manure lagoons – were considered off-channel habitats regardless of their origin. Sites dominated by a single waterbody (i.e. pond) were delineated by that waterbody's shoreline; sites not dominated by a single waterbody were delineated to encompass all continuous wetlands. This effort identified 332 distinctive off-channel aquatic habitats within the floodplain. For ease of description, WDFW mapping also stratified the floodplain into 10 segments delineated by major tributaries (**Figure 1**) (**Appendix 1, 2, 3**).

We selected 36 off-channel sites for the primary and brood ground surveys from the off-channel habitat pool (**Appendix 1, 2, 3**). Most sites (22) were on publicly owned parcels, the remainder (14) were privately owned. Selection of off-channel sites on public land was favored because landowner permission was not required for access. Most private landowner relations had been established prior to the start of the waterfowl and waterbird surveys through ongoing WDFW Habitat Program studies. The lesser number of privately owned sites selected were based on landowner willingness to allow access. Our survey footprints included a 50-meter buffer around selected site boundaries to enable the inclusion of waterfowl and waterbirds near shorelines.

Primary Ground Survey

We conducted the primary ground survey throughout the Chehalis floodplain from November 2015 through May 2016. This timeframe allowed for observations during part of the fall migration, the mid-winter period, the spring migration period, and a portion of the breeding season. Primary ground survey sites were distributed throughout 8 of the 10 river segments; surveys were not conducted in the Newaukum River to South Fork Chehalis River segment or upstream of Elk Creek; 35 of the 36 sites were downstream of the Newaukum River (**Appendix 1, 2, 3**). Sites were visited on a rotational basis, with 2 to 13 sites visited daily.

We made observations from land enabling an unobstructed view of aquatic habitats (i.e. clear of vision-obstructing elements, dense vegetation, etc.). Spotting scopes (20-60 × 80) and binoculars (8 × 42) were used to identify and count all waterfowl and waterbirds. We made observations by flushing birds when selected areas precluded optic-assisted direct observation. We used a hybrid method of spot then flush when the habitat was partially observable or if birds were partially observable in dense cover (i.e. tall grass). This method allowed for the collection of sex ratios and ensured virtually all birds in dense cover were counted. We used kayaks under conditions and at locations precluding land-based observations. We estimated and recorded the percentage of the site effectively surveyed (typically 100%) at the end of each site visit.

We recorded waterfowl locations using Garmin GPSMAP 64 GPS units in the WGS-84 datum. Locations were recorded to indicate the center of flocks of like species using a common habitat type. Wherever possible, we marked the geographic location where birds were observed. When directly recording locations was not possible, we calculated the location of observed birds by marking the location we made the observation from; we then recorded the distance and bearing to the observed birds using, respectively, a rangefinder (Leupold RX-650) and electronic compass (Garmin GPSMAP 64 GPS). Observer location and the distance/direction to the birds was then used to plot bird observation locations in ArcGIS. All waterfowl and waterbirds observed within a 50-meter buffer of delineated sites were recorded. If we were unsure whether birds were within 50 meters of site boundaries, the observation and location were recorded, GIS was then used to remove data records of observations outside of the 50-meter buffers. Due to the difficulty of accurate remote identification, Lesser scaup (*Aythya affinis)* and Greater scaup *(A. marila*) were classified into one "Scaup" species category.

Aerial Surveys

Aerial surveys, conducted by helicopter, covered the entirety of the Chehalis floodplain, from the headwaters to the mouth at Grays Harbor (**Figure 2**). We scheduled aerial surveys for the 2015 and 2016 breeding seasons, and monthly during the 2015 fall migration, 2015-2016 mid-winter period, and the 2016 spring migration. February and April 2016 surveys were shortened to exclude areas upstream of Meskill, in the South Fork Chehalis River to Elk Creek river segment. These transects were removed because they were designed to fit the narrow geography of the valley and had they been retained, it would not have been possible to cover the entire survey area within one day during shorter winter days. Aerial surveys comprised of thirty-nine 400-m wide north/south-oriented transects evenly spaced 1.9 km apart.

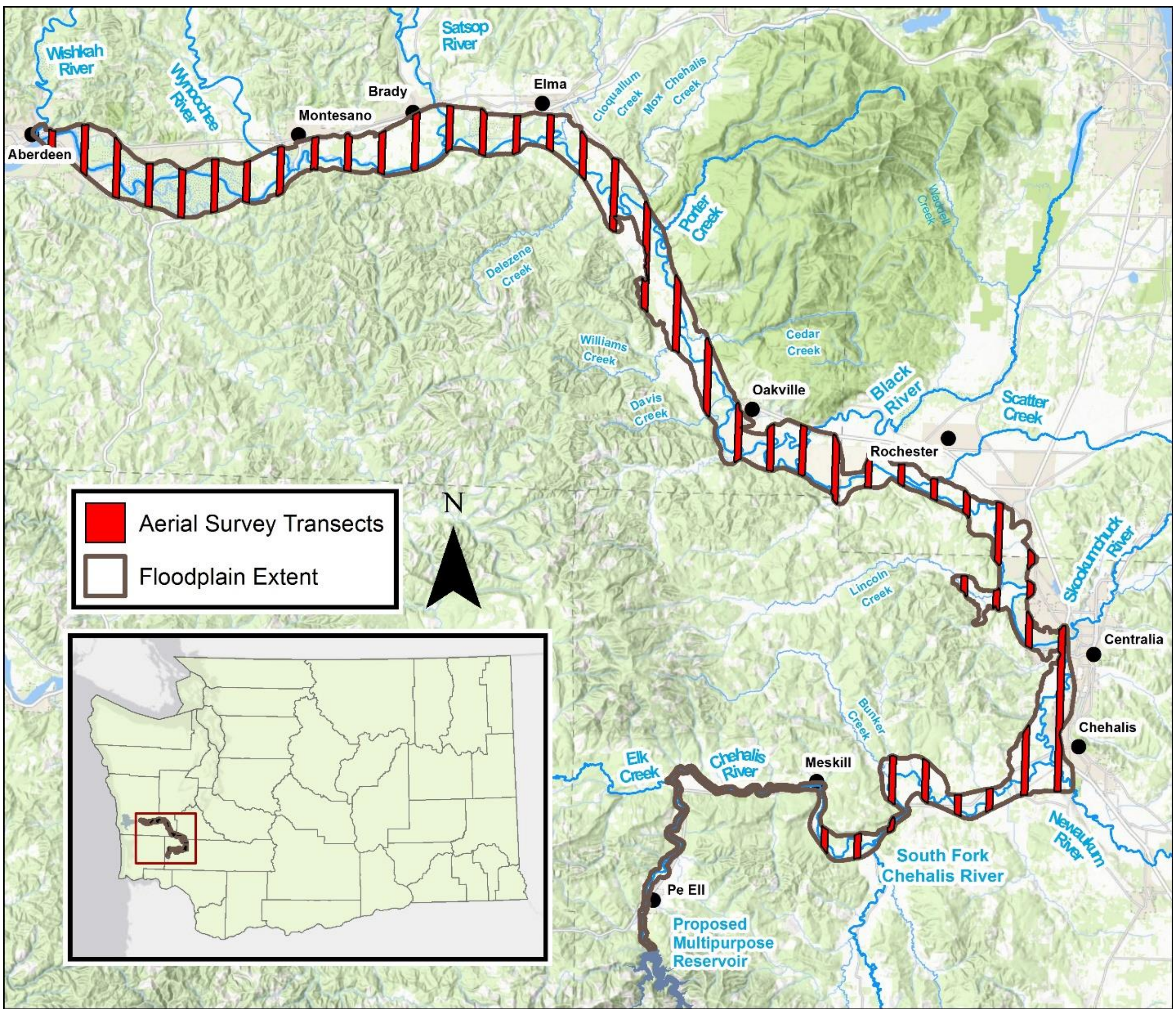

Figure 2. Transect study strips surveyed during the four aerial waterfowl surveys.

All waterfowl (count, species, sex when possible) and water features within the transect strips were documented via oral dictation. As needed, circling over waterfowl concentrations was conducted to guarantee accurate identification and counts. We georeferenced all waterfowl and water features by pairing the observation time with the flight path log.

Brood Ground Survey

We conducted brood ground surveys at the same 36 sites used for the primary ground survey (**Appendix 1, 2, 3**). Two brood surveys were conducted at each site during late May and June 2016. Consecutive site visits were at least nine days apart and no more than 20 days apart; the majority of consecutive visits were 13 days apart. Observations were made using the same methods as the primary ground survey. Female association and brood plumage was used to identify brood species. Brood age was determined using the methods outlined by Gollop and Marshall (1954). We used a Canon EOS 5DS-R digital camera equipped with a Cannon EF 100-400mm f/4.5-5.6 IS II USM lens to photograph broods in order to assist with brood aging. Locations were recorded using the same methods as the primary ground survey.

Land Cover Classification

We used GIS to classify land cover at the 36 study sites surveyed by the primary and brood ground surveys. Land cover was classified as either: open water, non-agricultural upland, forested wetland, emergent wetland, agriculture, wet prairie, shrub-scrub wetland, or unconsolidated vegetated riverine.

National Land Cover data (Homer et al. 2015) was used to verify land cover types but was too coarse to use alone. Land cover boundaries were largely established using NAIP 2013 imagery in natural color (USDA 2013). When land cover contrasts were known, but not apparent in natural color imagery, near-infrared bands within the NAIP 2013 imagery were used. Water levels were drawn to reflect levels during the late mid-winter period; this was aided by navigating real-world shorelines and recording the track with a GPS. Once produced, land cover maps were verified using ground truthing.

We used land cover maps to calculate total and land cover areas within each site. Using the calculated site areas, the number of site visits, and the estimated percent of site observed per visit, we calculated the total surveyed area of each site and land cover type.

Analytical Methods

Abundance and Habitat Use Modeling

A zero-inflated Poisson mixed model using the sites as a random effect was fit to counts of each species or tribe separately. A seasonal trend across all sites, and site-level percent open water, percent herbaceous wetland, and percent woody wetland entered the model as fixed explanatory variables, offset by the area surveyed at every visit to a site. The woody wetland variable summed the proportion of forested and shrub-scrub wetland land classes; the herbaceous wetland variable summed the proportion of emergent wetland and wet prairie land classes. Waterfowl tribe abundance consisted of all present individuals belonging to a given tribe, and was not constrained to the dominant species with observations numerous enough to enable species-level modeling. We categorized waterfowl species into tribes as defined by Livezey (1997).

For any given species/tribe, data consisted of counts, including zero, from all visits to sites in which the species/tribe was observed at least once during the study period. The zero-inflation nuisance parameter ψ controlled for sampling variation in detecting presence at any occupied site on any given visit. To reflect seasonality, we used the cosine curve:

$$\mu_{jt} = A\,cos(2\pi f t + \Phi)$$

Where μ_{jt}, the mean count for the j^{th} site at time *t,* oscillate between *A* (> 0) and *–A*, the amplitude of seasonal variation, and Φ is phase, or the origin on the time axis. Frequency (f) represents predetermined number of migration cycles in the survey period and was fixed in the model for every species while amplitude and phase were being estimated in the model.

We used Markov chain Monte Carlo (MCMC) simulations to estimate parameters of the model constructed in JAGS 4.1 (Plummer 2003) with flat (non-informative) priors on all hyper-parameters. Four chains initiated at random starting values were run for 5,500 iterations. We discarded the first 1,000 iterations as burn in and retained every 15th draw for a total of 1,200 independent draws from the target distribution. Trace plots, $\hat{R} < 1.1$ criteria, and effective sample sizes for parameters of interest were used to evaluate model convergence to the posterior and lack of autocorrelation in the MCMC output (Gelman and Rubin 1992).

Proportion Female

We analyzed the proportion of females in each sexually dimorphic species as the mean proportion observed by month. For Bufflehead only, because of the similar appearances of females and juvenile-males the reported "proportion female" should be interpreted as proportion not-adult male. Site-day observations that contained any amount of unknown sex were not included in the analysis. Daily proportions were then determined by summing the remaining site-day observations. Monthly mean female proportion and accompanying standard error were calculated using the daily proportions with R 3.2.5 software (R Core Team 2016).

Floodplain Population Estimates

We calculated floodplain population estimates and their associated standard errors from the count results of our four aerial surveys using standard protocol (CWS/USFWS 1987). During the surveys our counts were recorded for each species by transect. Transect species densities were derived by dividing the transect count by transect area. Transect area was determined through ArcGIS using the bounds of our standard transect width and floodplain boundaries. Mean transect densities were multiplied by the floodplain area to estimate floodplain abundance. Reported standard error is the square root of the product of inter-transect variance and the square of the floodplain area.

Production Estimates

We derived species production estimates from the product of the recruitment rate and number of indicated breeding pairs (as inferred by male presence) from our 2016 breeding period aerial survey (Dzubin 1969, Cowardin and Johnson 1979, Cowardin and Blohm 1992). Thick vegetation greatly reduced observable site area during the production survey. Data collected at sites where less than 50% of the site was observable were censored from recruitment rate and production estimate calculations to lessen possible measurement error.

To establish recruitment rates(R), we first calculated the brood:pair ratio (I) $(I = number\ of\ broods/number\ of\ pairs)$. Pair counts were totaled from the last visit to each site during the primary ground survey; brood counts were totaled from both site visits during the brood ground survey. Broods that appeared to be recounts during the second site visit were censored from the data. Broods were considered recounts within the same study site if: (1) they matched the previous observed species; (2) brood size was equivalent to or less than the previously observed brood; (3) observed brood age was consistent with established age class progression (Gollop and Marshall 1954). Mean brood size (B) was also required to calculate the recruitment rate. The recruitment rate was computed with the general equation of $R = I \times B$. This equation is a modification of that used by Cowardin & Johnson (1979) where $R = (I \times B)/2$, and R is the recruitment rate of young females fledged per hen. The divisor of two was removed from our equation to calculate the recruitment of both males and females. Ultimately, our reported species production estimates were calculated as means by bootstrapping the above equations in R 3.2.5. This accounted for standard error associated with mean brood size and floodplain population estimates. Standard deviation was also calculated in R from the results of the bootstrapping effort (R Core Team 2016).

RESULTS

Primary Ground Survey

Not all 36 sites were immediately available for observation at the beginning of the primary ground survey in early November 2015. By 1 December 2015, 28 of the 36 sites had been visited at least once. Five additional sites became available during December 2015. The remaining three sites were added to the survey during the first week of February 2016. We completed ground observations in eight of the ten river segments at the 36 sites with 482 site visits (**Table 1**).

Table 1. Off-channel aquatic sites and area surveyed per river segment during the primary ground survey of the Chehalis floodplain.

River Segment	Sites	Site Visits	Total Area Surveyed (km^2)
Highway 101 Bridge to Wynoochee River	2	28	4.42
Wynoochee River to Satsop River	6	71	12.22
Satsop River to Porter Creek	10	138	19.49
Porter Creek to Black River	8	109	12.29
Black River to Scatter Creek	4	57	9.56
Scatter Creek to Skookumchuck River	1	14	0.79
Skookumchuck River to Newaukum River	4	56	6.22
Newaukum River to S.F. Chehalis River	0	0	0.00
S.F. Chehalis River to Elk Creek	1	9	1.07
Elk Creek to Proposed Reservoir Site	0	0	0.00
Proposed Reservoir Site	0	0	0.00
Total	**36**	**482**	**66.06**

We identified a total of 22 waterfowl species in five tribes; ten surface-feeding ducks (tribe Anatini), three diving ducks (tribe Aythyini), six sea ducks (tribe Mergini), two geese (tribe Anserini), and one swan (tribe Cygnini) (**Table 2**) (**Appendix 4**). We also documented the presence of ten non-waterfowl species, discussed collectively as waterbirds.

Table 2. Number of sites encountered and summary counts of waterfowl/waterbird species observed in the Chehalis floodplain during the primary ground survey.

Species	Sites Observed	Total	Species	Sites Observed	Total
Surface-feeding Ducks	**34**	**12,199**	**Sea Ducks**	**31**	**809**
Mallard	34	5,260	Bufflehead	19	323
Green-winged teal	16	3,327	Hooded merganser	23	202
American wigeon	21	2,603	Common goldeneye	10	164
Northern pintail	8	636	Common merganser	13	117
Wood duck	20	167	Red-breasted merganser	1	2
Northern shoveler	9	158	Surf scoter	1	1
Cinnamon teal	8	31			
Gadwall	2	10	**Waterbirds**	**32**	**1,724**
Eurasian wigeon	1	5			
Blue-winged teal	1	2	American coot	8	977
			Double-crested cormorant	20	368
Diving Ducks	**29**	**2,893**	Pied-billed grebe	25	250
			Great blue heron	26	121
Ring-necked duck	27	2,717	Green heron	2	3
Scaup [a]	7	174	Great egret	1	1
Canvasback	1	2	Common loon	1	1
			Red-throated loon	1	1
Geese	**23**	**2,134**	Horned grebe	1	1
			Western grebe	1	1
Canada goose	23	1,868			
Cackling goose	4	266			
Swans	**8**	**80**			
Trumpeter swan	8	80			

[a] Scaup: *Aythya affinis/ marila*

Species richness was highest (≥16) at five sites: the WDFW Wenzel Slough, WDFW 306, Vetter, WDFW Hoxit 1, and Lantbruk sites (**Appendix 5**). Mallards, Ring-necked ducks, Hooded merganser, Trumpeter swan, and Canada geese were the most widely distributed species, that is observed at the most sites, for their respective tribes.

Seasonal Abundance Modeling

Seasonal abundance models were developed for five surface-feeding ducks: Mallard, Green-winged teal, American wigeon, Northern pintail, Wood duck; four sea ducks: Hooded merganser, Common merganser, Bufflehead, Common goldeneye; two diving ducks: Ring-necked duck, Scaup; one goose: Canada goose; and three waterbird species: American coot, Double-crested cormorant, Pied-billed grebe.

Except diving ducks, all tribes showed a marked mid-winter decrease in abundance; peak abundance occurred during the fall and spring migration periods (mid-November and early to mid-March, respectively) for all tribes modeled (**Figure 3**). Surface-feeding ducks and sea ducks were, respectively, the most abundant and least abundant tribes using off-channel habitats during the study. Geese were more abundant than diving ducks throughout much of the study period except the mid-winter period (from mid-December to mid-February) and during April.

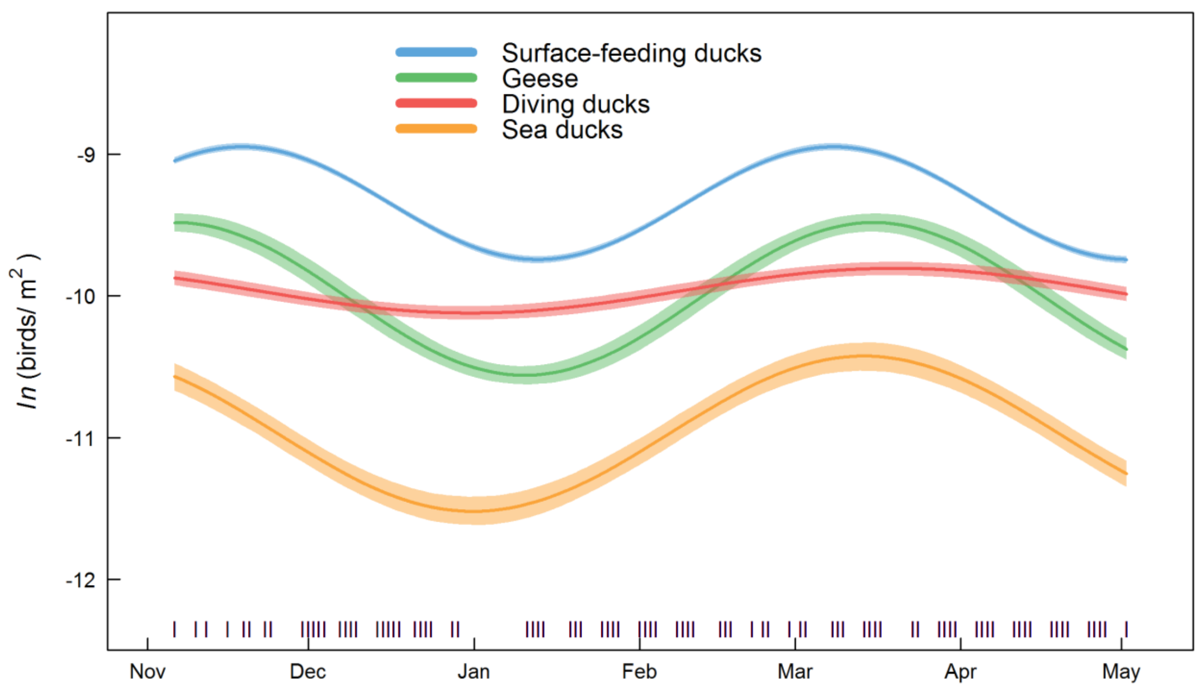

Figure 3. Modeled abundance of surface-feeding ducks (tribe Anatini), geese (tribe Anserini), diving ducks (tribe Aythyini), and sea ducks (tribe Mergini) in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Five surface-feeding duck species had enough observations to enable modeling. Mid-winter decreases in abundance were observed for each of these surface-feeding duck species (**Figure 4**). Mallards were the most abundant species for most of the study period; during the mid-winter period and throughout April, Green-winged teal experienced densities similar to Mallards but had the least seasonal variation among surface-feeding duck species compared. Mallards, American wigeon, and Northern pintail all peaked during late November to early December and in early March. Wood ducks were not observed within off-channel habitats between 2 December 2015 and 10 February 2016. When they were present, Wood duck densities were highest in mid-November and early to mid-April.

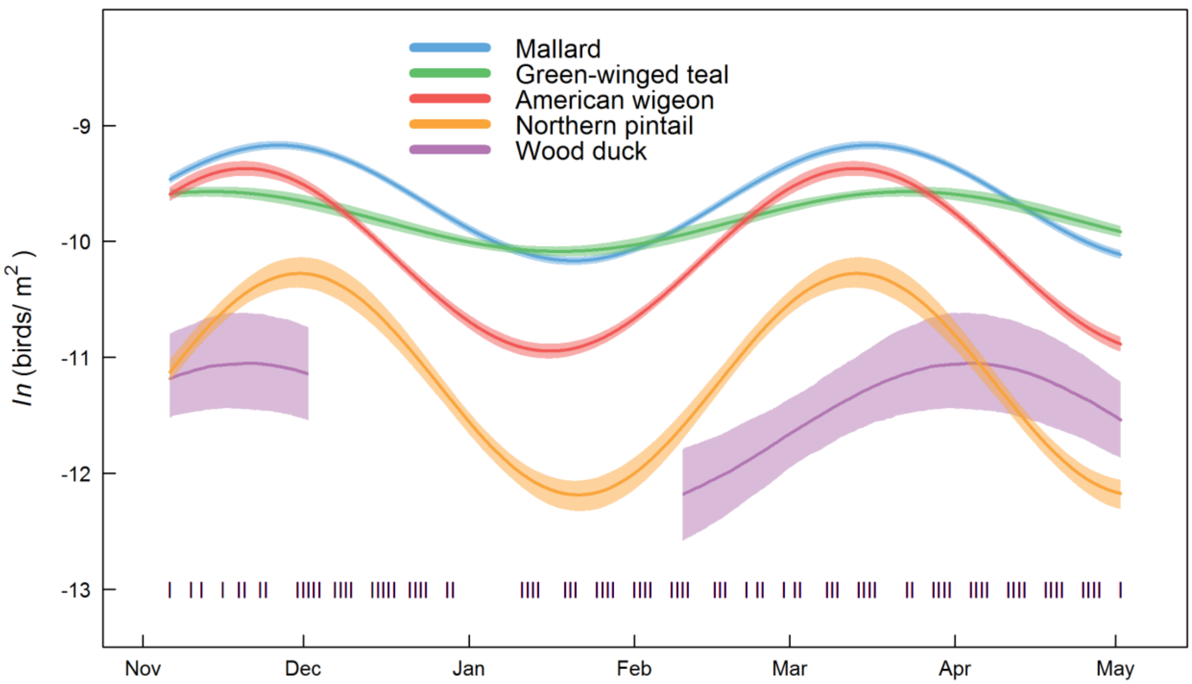

Figure 4. Modeled abundance of dominant surface-feeding duck species (tribe Anatini) in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Two diving duck taxa had enough observations to enable modeling. Among those, Ring-necked duck densities remained relatively stable and at a high level throughout the study period. Mid-winter abundance of Ring-necked ducks was approximately equivalent to that of Mallards and Green-winged teal (**Figure 5**). Scaup abundance showed a seasonal oscillation similar to surface-feeding ducks, but was relatively low.

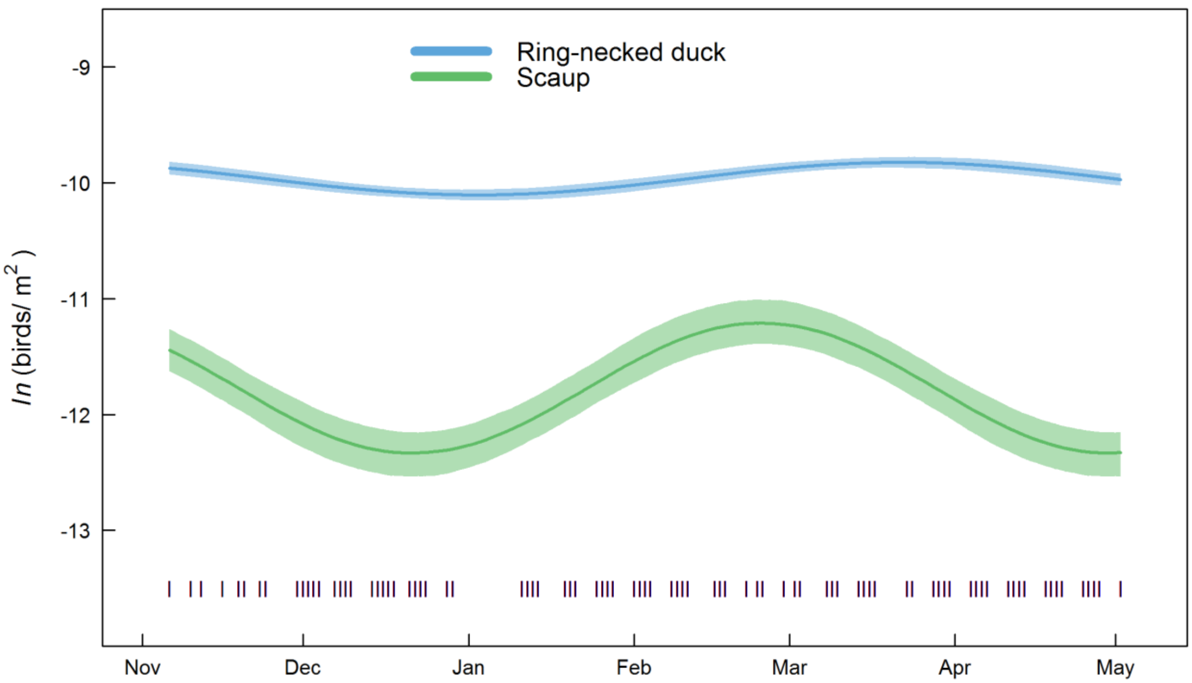

Figure 5. Modeled abundance of dominant diving duck species (tribe Aythyini) in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Four sea duck species had sufficient observations to enable modeling. These four sea ducks were among the least abundant of the common waterfowl species. Although they exhibited a slight mid-winter lull, Hooded merganser densities were overall the highest and least variable among the sea ducks (**Figure 6**). The remaining three species all had fall and late winter/early spring peaks slightly time shifted from each other. For example, the early calendar year peak for Common merganser was late February, whereas for Bufflehead and Common goldeneye, it was mid-to-late March.

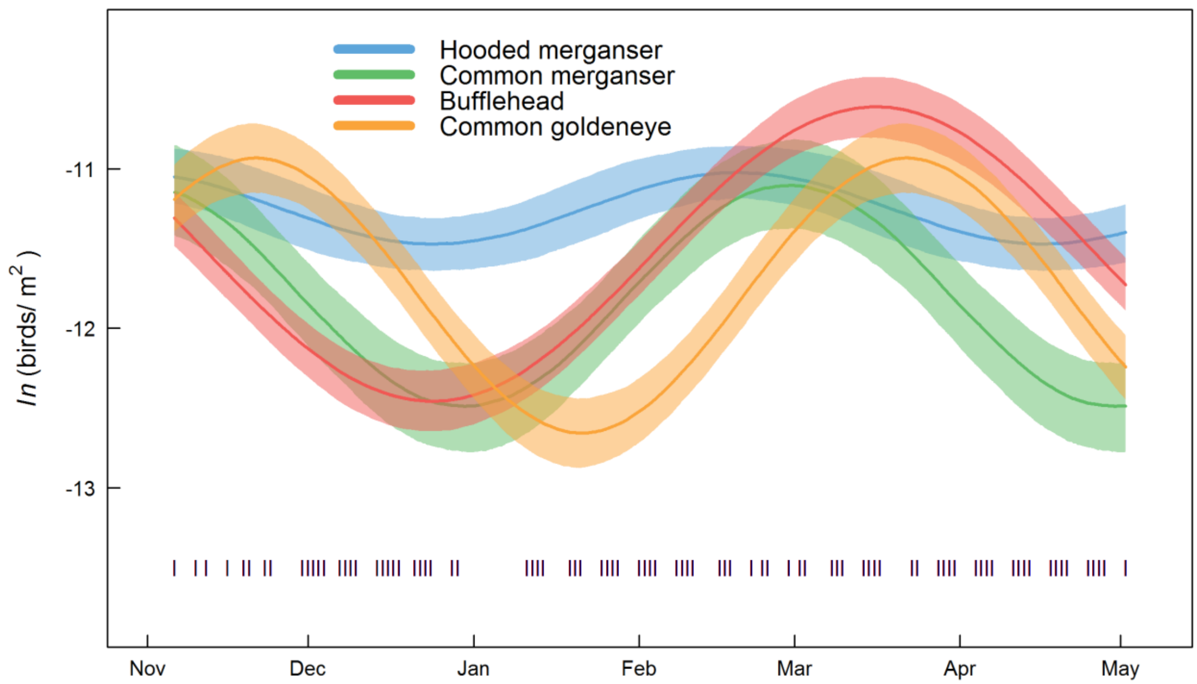

Figure 6. Modeled abundance of dominant sea duck species (tribe Mergini) in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Only one goose species, Canada goose, had sufficient observations to allow modeling. Canada goose abundance within off-channel habitats was lowest at the beginning of January; it peaked in early November and around early March (**Figure 7**).

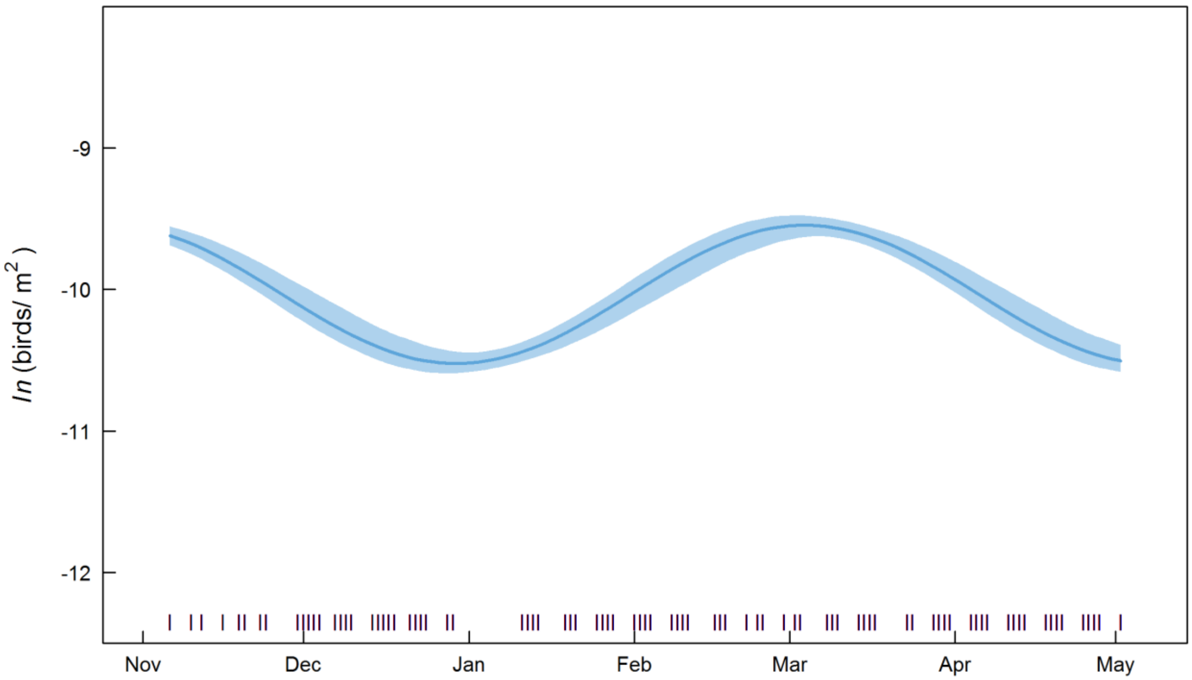

Figure 7. Modeled abundance of Canada geese (*Branta canadensis)* in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Three waterbird species (American coot, Double-crested cormorant, and Pied-billed grebe) had sufficient observation to allow abundance modeling. American coot displayed an abundance pattern similar to most waterfowl species with a mid-winter lull and an increase during the fall and spring migration periods (**Figure 8**). In contrast, Double-crested cormorant and Pied-billed grebe both had their highest densities just prior to the mid-winter period. Their densities progressively decreased from mid-winter through spring, though they remained present throughout the entire survey period.

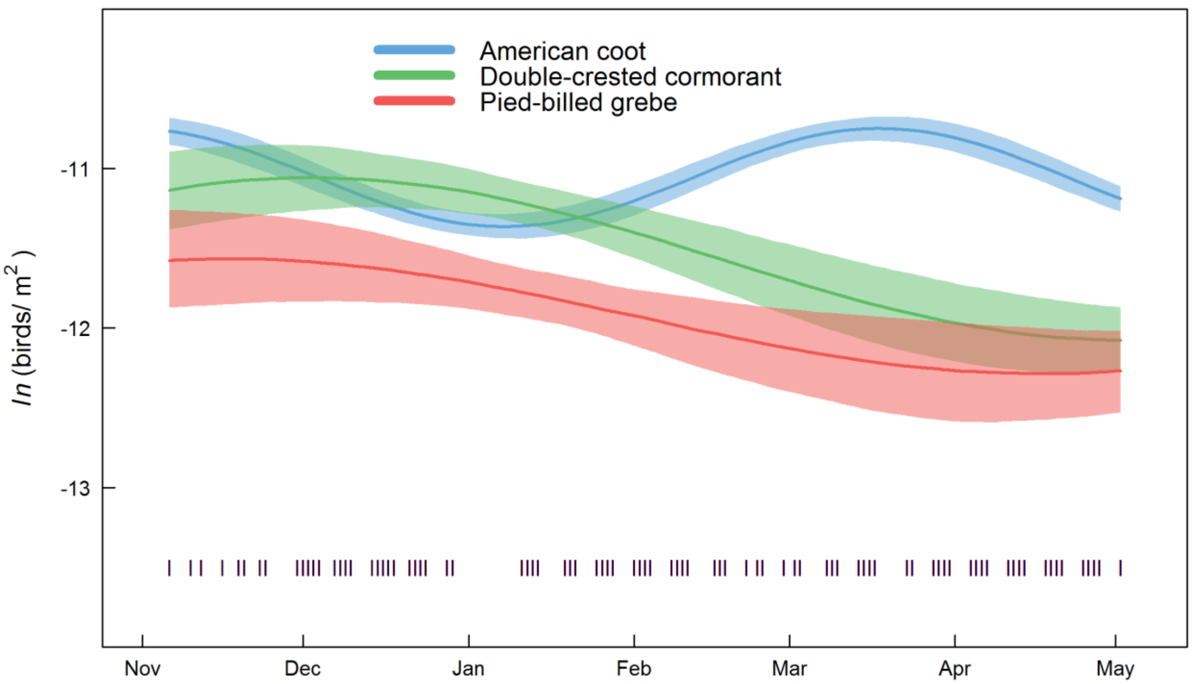

Figure 8. Modeled abundance of American coot (*Fulica americana*), Double-crested cormorant (*Phalacrocorax auritus*), and Pied-billed grebe (*Podilymbus podiceps*) in off-channel habitats of the Chehalis floodplain during the primary ground survey conducted during the 2015-2016 winter and migratory periods. The narrow, darker lines indicate estimated mean natural log density; the lighter edges encompassing of the darker lines display 90% credible intervals on the natural log scale. Bottom tick marks indicate the days for each survey.

Habitat Regression Modeling

We conducted habitat regression modeling analyses on six surface-feeding ducks: Mallard, Green-winged teal, American wigeon, Northern pintail, Wood duck, and Northern shoveler; two diving ducks: Ring-necked duck, and Scaup; four sea ducks: Bufflehead, Hooded merganser, Common goldeneye, and Common merganser; one goose: Canada goose; 1 swan: Trumpeter swan; and three waterbirds: American coot, Double-crested cormorant, and Pied-billed grebe.

Open Water

Mallard densities decreased as the extent of open water within our study sites increased (**Table 3**). The 90% confidence intervals for American wigeon, Green-winged teal, Northern pintail, and Northern shoveler all encompassed zero, indicating a strong pattern could not be inferred; nonetheless, except for Wood duck, uniformly negative means of the density relationship with open water imply a similar pattern for all these species. Wood duck was the only surface-feeding duck species to exhibit a significant positive relationship with open water.

Table 3. Sample size (n), mean, standard deviation (SD), and 90% credible interval regression results of dominant species densities and their use of off-channel habitats with various proportions of open water in the Chehalis floodplain.

Open Water											
Species	**n**	**Mean**	**SD**	**5.0%**	**95.0%**	**Species**	**n**	**Mean**	**SD**	**5.0%**	**95.0%**
Surface-feeding Ducks						**Diving Ducks**					
Mallard**	264	-3.1	1.2	-5.0	-1.1	Ring-necked duck	171	-2.0	2.0	-5.3	1.2
Green-winged teal	68	-1.9	2.8	-6.3	2.7	Scaup*	26	6.3	3.3	1.1	11.7
American wigeon	83	-2.3	1.9	-5.4	0.7						
Northern pintail	28	-3.8	3.5	-9.5	1.4	**Swans**					
Wood duck*	50	2.8	1.7	0.1	5.6						
Northern shoveler	19	-3.4	2.8	-7.7	0.9	Trumpeter swan	13	5.5	3.7	-0.1	11.2
Sea Ducks						**Waterbirds**					
Bufflehead	79	-0.5	1.4	-2.8	1.8	American coot	47	2.1	5.1	-5.3	10.1
Hooded merganser	72	-0.5	1.4	-2.8	1.7	D.c. cormorant	117	2.0	1.9	-1.1	5.0
Common goldeneye	36	3.1	3.2	-2.0	8.1	Pied-billed grebe**	114	3.0	1.0	1.5	4.7
Common merganser*	37	3.7	2.1	0.4	7.3						
Geese											
Canada goose	107	-1.0	1.8	-4.0	1.9						

*significant at $P<0.1$; **significant at $P<0.05$

Increasing densities of Scaup, Common merganser, Common goldeneye, Trumpeter swan, Double-crested cormorant, and Pied-billed grebe were associated with greater open water coverage. Ring-necked duck densities suggested a negative association.

Woody Wetlands

Green-winged teal and American wigeon densities diminished as the proportion of woody wetlands in our study sites increased; whereas Wood duck densities exhibited a positive relationship (**Table 4**). No clear association with woody wetlands was apparent for Mallard, Northern pintail, and Northern shoveler.

Table 4. Sample size (n), mean, standard deviation (SD), and 90% credible interval regression results of dominant species densities and their use of off-channel habitats with various proportions of woody wetlands in the Chehalis floodplain.

Woody Wetlands											
Species	**n**	**Mean**	**SD**	**5.0%**	**95.0%**	**Species**	**n**	**Mean**	**SD**	**5.0%**	**95.0%**
Surface-feeding Ducks						**Diving Ducks**					
Mallard	264	-0.9	0.9	-2.4	0.5	Ring-necked duck	171	-0.7	1.3	-2.9	1.5
Green-winged teal*	68	-2.5	1.4	-4.7	-0.2	Scaup	26	1.8	8.3	-11.6	14.6
American wigeon*	83	-2.5	1.4	-4.9	-0.2						
Northern pintail	28	-4.3	6.7	-15.2	6.4	**Swans**					
Wood duck**	50	1.7	0.8	0.5	3.0						
Northern shoveler	19	-3.4	4.7	-11.3	4.4	Trumpeter swan	13	-3.6	3.0	-8.5	1.3
Sea Ducks						**Waterbirds**					
Bufflehead	79	-0.7	1.4	-3.0	1.6	American coot	47	-7.3	10.9	-24.4	10.4
Hooded merganser	72	0.7	0.9	-0.8	2.1	D.c. cormorant	117	-0.9	0.9	-2.3	0.6
Common goldeneye	36	-4.6	3.2	-10.0	0.5	Pied-billed grebe	114	-1.3	1.0	-2.8	0.3
Common merganser	37	-2.7	1.8	-5.8	0.1						
Geese											
Canada goose	107	-0.9	1.4	-3.2	1.2						

*significant at P<0.1; **significant at P<0.05

Positive associations with diving ducks, sea ducks, geese, swans, and waterbirds were not found. However, densities of Common goldeneye, Common merganser, Trumpeter swan, and Pied-billed grebe suggested a negative pattern.

Herbaceous Wetlands

As the expanse of herbaceous wetlands within our study sites increased, we observed higher densities of five of the six species of surface-feeding ducks: namely Mallard, Green-winged teal, American wigeon, Northern pintail, and Northern shoveler (**Table 5**). In contrast, Wood duck densities were depressed where herbaceous wetlands were more prevalent.

Table 5. Sample size (n), mean, standard deviation (SD), and 90% credible interval regression results of dominant species densities and their use of off-channel habitats with various proportions of herbaceous wetlands in the Chehalis floodplain.

Herbaceous Wetlands											
Species	**n**	**Mean**	**SD**	**5.0%**	**95.0%**	**Species**	**n**	**Mean**	**SD**	**5.0%**	**95.0%**
Surface-feeding Ducks						**Diving Ducks**					
Mallard*	264	1.2	0.8	0.0	2.5	Ring-necked duck	171	1.3	1.0	-0.3	2.9
Green-winged teal**	68	2.3	1.1	0.6	4.0	Scaup	26	-3.2	3.2	-8.3	1.9
American wigeon*	83	1.8	1.0	0.0	3.4						
Northern pintail**	28	3.4	1.5	0.9	5.9	**Swans**					
Wood duck**	50	-1.7	0.9	-3.3	-0.3						
Northern shoveler	19	2.6	1.8	-0.3	5.5	Trumpeter swan	13	-1.7	2.6	-5.7	2.4
Sea Ducks						**Waterbirds**					
Bufflehead	79	-0.8	0.8	-2.2	0.6	American coot	47	-2.0	3.4	-7.7	3.4
Hooded merganser	72	-1.0	0.8	-2.2	0.3	D.c. cormorant**	117	-4.0	2.0	-7.3	-0.7
Common goldeneye	36	-2.3	1.6	-4.9	0.2	Pied-billed grebe**	114	-1.8	0.7	-3.0	-0.6
Common merganser	37	-2.5	1.9	-5.6	0.6						
Geese											
Canada goose	107	0.5	1.0	-1.0	2.2						

*significant at $P<0.1$; **significant at $P<0.05$

Ring-necked ducks were the only non-dabbler to suggest higher densities in areas with greater herbaceous wetland coverage. The densities of Common goldeneye, Common merganser, Double-crested cormorant, and Pied-billed grebe decreased with greater coverage of herbaceous wetland.

Aerial Survey

The 2015 breeding waterfowl aerial survey was flown on 27 April 2015; one fall migration survey was flown on 15 October 2015. An aerial survey was attempted on 9 November 2015 but could not be completed due to fog and decreased visibility. Once a month aerial surveys were scheduled for December, January, February, and March; persistent, poor weather conditions prevented aerial surveys during December, January, and March. One aerial survey was completed on 23 February 2016. The 2016 breeding waterfowl aerial survey was flown on 28 April 2016.

Species richness was greatest during the 23 February 2016 survey when 15 species were counted; 12 species were observed on 27 April 2015, 11 on 15 October 2015, and 10 on 28 April 2016.

For most species, floodplain population estimates ($\widehat{N}$) were highest during the early spring flight on 23 February 2016 (**Table 6**). Wood duck ($\widehat{N}$ = 571 ± 188), Gadwall ($\widehat{N}$ **=** 526 ± 206), Blue-winged teal ($\widehat{N}$ = 807 ± 444), and Cinnamon teal ($\widehat{N}$ = 202 ± 188) abundance was highest during the early fall flight on 15 October 2015; Northern shoveler ($\widehat{N}$ = 195 ± 94) abundance was greatest during the 2015 breeding period flight on 27 April 2015.

Table 6. Species richness (SR), population estimates ($\hat{N}$), and associated standard error (SE) of dominant species encountered during multiple aerial helicopter transect surveys of the Chehalis floodplain.

	Breeding 2015 27 April 2015			Early Fall 15 October 2015			Early Spring 23 February 2016			Breeding 2016 28 April 2016		
Species	**SR**	$\hat{N}$	**SE**	**SR**	$\hat{N}$	**SE**	**SR**	$\hat{N}$	**SE**	**SR**	$\hat{N}$	**SE**
Surface-feeding Ducks	**7**	**1546**	**294**	**8**	**5815**	**1275**	**7**	**32827**	**8834**	**6**	**1199**	**274**
Mallard		887	161		1874	538		13253	2589		868	221
American wigeon		127	60		280	172		11723	4900		24	25
Green-winged teal		0	0		1333	638		5421	3677		73	47
Northern pintail		0	0		39	40		1771	1051		0	0
Wood duck		122	38		571	188		103	71		166	49
Northern shoveler		195	94		0	0		49	40		0	0
Gadwall		49	31		526	206		0	0		39	24
Blue-winged teal		63	38		807	444		10	10		0	0
Cinnamon teal		78	53		202	188		0	0		29	22
Unclassified teal		5	5		44	26		15	15		0	0
Diving Ducks	**1**	**93**	**38**	**1**	**54**	**41**	**2**	**2868**	**661**	**1**	**122**	**66**
Ring-necked duck		93	38		54	41		2834	662		122	66
Scaup		0	0		0	0		34	23		0	0
Sea Ducks	**3**	**268**	**125**	**0**	**0**	**0**	**4**	**1574**	**396**	**2**	**185**	**84**
Common merganser		215	123		0	0		895	397		176	84
Bufflehead		29	16		0	0		546	231		0	0
Hooded merganser		0	0		0	0		74	43		0	0
Goldeneye		24	25		0	0		59	48		10	10
Unclassified duck		5	5		44	26		15	15		0	0
Total Ducks	**11**	**1911**	**251**	**9**	**5913**	**1026**	**13**	**37284**	**6788**	**9**	**1507**	**258**
Canada goose		624	321		782	455		11516	6470		731	626

Breeding Period Aerial Surveys 2015 & 2016

Floodplain population estimates ($\widehat{N}$) were lowest during the 2015 and 2016 breeding period flights on 27 April 2015 and 28 April 2016 (**Table 6**). Estimates were slightly lower during the 2016 breeding period flight for all species present except Green-winged teal, Wood duck, Ring-necked duck, and Canada goose. Total duck estimates were lower in 2016 ($\widehat{N}_{2016}$ = 1507 ± 258) than 2015 ($\widehat{N}_{2015}$ = 1911 ± 251).

Surface-feeding ducks were the dominant waterfowl tribe observed during breeding period aerial surveys. Mallard ($\widehat{N}_{2015}$ = 887 ± 161, $\widehat{N}_{2016}$ = 868 ± 221), American wigeon ($\widehat{N}_{2015}$ = 127 ± 60, $\widehat{N}_{2016}$ = 24 ± 25), Wood duck ($\widehat{N}_{2015}$ = 122 ± 38, $\widehat{N}_{2016}$ = 166 ± 49), Gadwall ($\widehat{N}_{2015}$ = 49 ± 31, $\widehat{N}_{2016}$ = 39 ± 24), and Cinnamon teal ($\widehat{N}_{2015}$ = 78 ± 53, $\widehat{N}_{2016}$ = 29 ± 22) were observed both years. Northern shoveler ($\widehat{N}_{2015}$ = 195 ± 94) and Blue-winged teal ($\widehat{N}_{2015}$ = 63 ± 38) were observed in 2015, but not 2016; Green-winged teal ($\widehat{N}_{2016}$ = 73 ± 47) were only observed in 2016. Northern pintail were not observed during either the 2015 or 2016 breeding period flights. Except for Wood ducks, surface-feeding ducks were largely absent downstream of the Wynoochee River – where tidal fluctuation is greatest. Mallards were present in 62% (n = 24) of the 39 transects surveyed; they were not present in the six furthest downstream transects. Wood ducks were observed in 49% (n = 19) of the 39 transects and were distributed throughout most of the floodplain; their highest densities were observed upstream of the Newaukum River. The remaining surface-feeding duck species concentrated in habitats near Brady to the Black River and between the Skookumchuck and Newaukum Rivers.

Ring-necked ducks were the only diving duck observed during the breeding period flights; population estimates for 2016 ($\widehat{N}_{2016}$ = 122 ± 66) were slightly higher than 2015 ($\widehat{N}_{2015}$ = 93 ± 38). They were only found upstream of the Satsop River during the breeding period flights.

Breeding period population estimates were higher for Common merganser ($\widehat{N}_{2015}$ = 215 ± 123, $\widehat{N}_{2016}$ = 176 ± 84) than any other sea duck species. Most were observed on the mainstem of the Chehalis River upstream of the Black River. Goldeneye ($\widehat{N}_{2015}$ = 24 ± 25, $\widehat{N}_{2016}$ = 10 ± 10) were scarce in the floodplain during breeding period surveys; Bufflehead were scarce during the 2015 survey ($\widehat{N}_{2015}$ = 29 ± 16) and not observed during the 2016 survey. Hooded mergansers were not observed during either breeding period aerial survey, even though they were observed concurrently and into the summer during 2016 ground surveys.

Canada goose population estimates were 624 ± 321 in 2015 and 731 ± 626 in 2016; although estimates were slightly higher in 2016 their distribution throughout the floodplain was much greater in 2015. In 2015, Canada geese were observed in 49% (n = 19) of the 39 transects, but only 15% (n = 6) of the 39 transects in 2016. Canada geese were distributed widely throughout the floodplain in 2015 with most downstream of the Black River; in 2016 most were observed in a single field complex just south of Elma.

Early Fall 2015 Aerial Survey

We estimated 5913 ± 1026 ducks were present in the Chehalis floodplain during our aerial survey on 15 October 2015 (**Table 6**). At that time, the vast majority (96%) of the waterfowl population was comprised of surface-feeding ducks.

Wood duck ($\widehat{N}$ = 571 ± 188), gadwall ($\widehat{N}$ = 526 ± 206), blue-winged teal ($\widehat{N}$ = 807 ± 444), and cinnamon teal ($\widehat{N}$ = 202 ± 188) were most abundant during the aerial survey on 15 October 2015. Mallard ($\widehat{N}$ = 1874 ± 538), American wigeon ($\widehat{N}$ = 280 ± 172), Green-winged teal ($\widehat{N}$ = 1333 ± 638), and Northern pintail ($\widehat{N}$ = 39 ± 40) were also observed during the October survey. Mallards were distributed widely throughout the floodplain, including areas downstream of the Wynoochee River. Wood ducks were also broadly distributed throughout the floodplain, but were encountered most frequently upstream of Scatter Creek. The remaining surface-feeding duck species generally occupied the floodplain between the Wynoochee and Black Rivers.

During the October aerial survey, the Chehalis floodplain appeared to be void of sea ducks and largely void of diving ducks. Ring-necked ducks ($\widehat{N}$ = 54 ± 41) were the only diving duck present, though their abundance was very low.

Canada goose ($\widehat{N}$ = 782 ± 455) abundance was slightly higher during the survey in October 2015 than it was during the previous breeding period. Concentrations were found in the Wishkah River to Wynoochee River, Satsop River to Porter Creek, and Skookumchuck to Newaukum River segments.

Early Spring 2016 Aerial Survey

Total duck abundance ($\widehat{N}$ = 37284 ± 6788) was highest during the early spring survey on 23 February 2016 (**Table 6**). Several surface-feeding duck species also peaked in abundance during this time, they included: Mallard ($\widehat{N}$ = 13253 ± 2589), American wigeon ($\widehat{N}$ = 11723 ± 4900), Green-winged teal ($\widehat{N}$ = 5421 ± 3677), and Northern pintail ($\widehat{N}$ = 1771 ± 1051). Additionally, Wood duck ($\widehat{N}$ = 103 ± 71), Northern shoveler ($\widehat{N}$ = 49 ± 40), and Blue-winged teal ($\widehat{N}$ = 10 ± 10) were observed during the survey. Mallards were widely distributed throughout the floodplain in 77% (n = 30) of the 39 transects; the largest concentrations were found between the Wynoochee River and Porter Creek and immediately upstream of the Newaukum River. Northern pintail and Green-winged teal exhibited similar distributions, most occurred between the Satsop River and Scatter Creek and immediately upstream of the Newaukum River. American wigeon were observed in 41% (n = 16) of the 39 transect, the highest concentrations occurred in flooded fields near Porter Creek, between the Black and Skookumchuck River, and immediately upstream of the Newaukum River.

Early spring was the only time Scaup ($\widehat{N}$ = 34 ± 23) were observed in the floodplain during an aerial survey, they were only found downstream of Porter Creek. Ring-necked duck ($\widehat{N}$ = 2834 ± 662) abundance was highest during the early spring survey. Ring-necked ducks were widely distributed upstream of the Satsop River in 74% (n = 20) of the 27 transects. Downstream of the Satsop River, Ring-necked ducks were found in just 25% (n = 3) of the 12 transects.

Population estimates for Common merganser ($\widehat{N}$ = 895 ± 397), Bufflehead ($\widehat{N}$ = 546 ± 231), Hooded merganser ($\widehat{N}$ = 74 ± 43), and Goldeneye ($\widehat{N}$ = 59 ± 48) were also the highest during the early spring survey. Common merganser distribution above the Satsop River was sparse, we located them in just 19% (n = 5) of the 27 transects; downstream of the Satsop River they were much more common, we found them in 67% (n = 8) of the 12 transects. Bufflehead, Hooded merganser, and Goldeneye were found at low concentrations; these species did not follow an evident spatial pattern.

Canada geese were found in flocks throughout the length of the floodplain. Specifically, large concentrations were located in fields between Porter Creek and Black River, and immediately upstream of the Newaukum River. Our counts led us to estimate that 11516 ± 6470 Canada geese were present in the floodplain at the time of our survey on 23 February 2016, the largest Canada goose estimate of the four aerial surveys.

Proportion Female

During our study (November 2015 – April 2016) female proportions were negatively biased for Mallard ($\widehat{P}_{\text{female}}$ = 0.44 ± 0.02), American wigeon ($\widehat{P}_{\text{female}}$ = 0.44 ± 0.03), Northern pintail ($\widehat{P}_{\text{female}}$ = 0.45 ± 0.06), and Wood duck ($\widehat{P}_{\text{female}}$ = 0.37 ± 0.04) (**Table 7**). Green-winged teal ($\widehat{P}_{\text{female}}$ = 0.54 ± 0.04) were the only surface-feeding duck species to display ratios positively biased towards females. Mallard females accounted for approximately one-half of our observations during December ($\widehat{P}_{\text{female}}$ = 0.47 ± 0.04), January ($\widehat{P}_{\text{female}}$ = 0.50 ± 0.03), February ($\widehat{P}_{\text{female}}$ = 0.49 ± 0.01), and March ($\widehat{P}_{\text{female}}$ = 0.49 ± 0.01). Female Mallards were in the minority during November ($\widehat{P}_{\text{female}}$ = 0.27 ± 0.10) and April ($\widehat{P}_{\text{female}}$ = 0.36 ± 0.03). Green-winged teal and American wigeon were encountered in large flocks during the spring migration; this resulted in increased unknown sex observations, which reduced the number of observation records available for sex proportion analysis. The proportion of female Green-winged teal was not substantially skewed towards either direction, although it slightly favored females during most months. American wigeon sex ratios were essentially equal during November ($\widehat{P}_{\text{female}}$ = 0.50 ± 0.00), December ($\widehat{P}_{\text{female}}$ = 0.48 ± 0.12), and April ($\widehat{P}_{\text{female}}$ = 0.50 ± 0.03); females were outnumbered by males during January ($\widehat{P}_{\text{female}}$ = 0.41 ± 0.11), February ($\widehat{P}_{\text{female}}$ = 0.42 ± 0.05), and March ($\widehat{P}_{\text{female}}$ = 0.40 ± 0.06). Female Wood ducks were outnumbered by males every month the species was present.

Ring-necked duck females comprised one-third ($\widehat{P}_{\text{female}}$ = 0.33 ± 0.02) of our observations throughout the study; Scaup females accounted for approximately one-half ($\widehat{P}_{\text{female}}$ = 0.48 ± 0.08) of their species abundance. Female Ring-necked ducks were outnumbered by males every month of our study; especially low proportions of females occurred in November ($\widehat{P}_{\text{female}}$ = 0.17 ± 0.11) and March ($\widehat{P}_{\text{female}}$ = 0.24 ± 0.03). Scaup observations during December ($\widehat{P}_{\text{female}}$ = 0.32 ± 0.16), January ($\widehat{P}_{\text{female}}$ = 0.45 ± 0.04), and February ($\widehat{P}_{\text{female}}$ = 0.25 ± 0.15) revealed relatively low numbers of females; however, female Scaup outnumbered males in March ($\hat{P}_{\mathrm{female}}$ = 0.65 ± 0.15) and April ($\hat{P}_{\mathrm{female}}$ = 0.67 ± 0.33).

In contrast to diving ducks, females (and possibly juvenile, male Bufflehead) dominated our observations for Bufflehead ($\hat{P}_{\mathrm{female}}$ = 0.80 ± 0.04), Hooded merganser ($\hat{P}_{\mathrm{female}}$ = 0.58 ± 0.04), Common goldeneye ($\hat{P}_{\mathrm{female}}$ = 0.68 ± 0.06), and Common merganser ($\hat{P}_{\mathrm{female}}$ = 0.60 ± 0.08). Monthly proportions remained relatively stable with slight month-to-month variability and no evident temporal trends for Bufflehead, Hooded merganser, and Common goldeneye. Common mergansers experienced balanced female proportions during December ($\hat{P}_{\mathrm{female}}$ = 0.51 ± 0.21) and January ($\hat{P}_{\mathrm{female}}$ = 0.48 ± 0.10); females accounted for the majority of our observations as the spring migration progressed during February ($\hat{P}_{\mathrm{female}}$ = 0.57 ± 0.14) and March ($\hat{P}_{\mathrm{female}}$ = 0.72 ± 0.16).

Production Survey and Floodplain Production Estimates

Our production survey of off-channel habitats documented brood rearing for seven waterfowl and one waterbird species: Blue-winged teal, Canada goose, Cinnamon teal, Common merganser, Hooded merganser, Mallard, Wood duck, and Pied-billed grebe (**Table 8**).

We observed Mallard and Wood duck broods frequently enough to calculate recruitment rates and floodplain production estimates for these two species. In off-channel habitats, Mallards recruited 1.73 ± 0.49 offspring per hen, while Wood ducks recruited 1.67 ± 0.36 offspring per hen. Using these recruitment rates and the previously discussed 2016 breeding period floodplain estimates, we estimated floodplain production to be 763 (SD = 218) Mallard offspring and 137 (SD = 43) Wood duck offspring.

Table 7. Monthly mean proportion female ($\hat{P}_{female}$) and associated standard error (SE) for dominant sexually dimorphic species encountered at off-channel habitats in the Chehalis floodplain.

Species	November		December		January		February		March		April		Nov. – April Average	
	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE	$\hat{P}_{female}$	SE
Mallard	0.27	0.10	0.47	0.04	0.50	0.03	0.49	0.01	0.49	0.01	0.36	0.03	0.44	0.02
Green-winged teal	0.52	0.13	0.39	0.20	0.53	0.03	0.58	0.11	0.50	0.01	0.64	0.11	0.54	0.04
American wigeon	0.50	-	0.48	0.12	0.41	0.11	0.42	0.05	0.40	0.06	0.50	0.03	0.44	0.03
Northern pintail	-	-	0.00	-	0.60	0.19	0.41	0.03	0.37	0.10	0.57	0.22	0.45	0.06
Wood duck	0.31	0.19	-	-	-	-	0.21	0.13	0.44	0.07	0.40	0.03	0.37	0.04
Ring-necked duck	0.17	0.11	0.30	0.05	0.42	0.10	0.35	0.04	0.24	0.03	0.42	0.02	0.33	0.02
Scaup	-	-	0.32	0.16	0.45	0.04	0.25	0.15	0.65	0.15	0.67	0.33	0.48	0.08
Bufflehead*	0.78	0.22	0.66	0.14	0.82	0.05	0.88	0.04	0.73	0.11	0.95	0.05	0.80	0.04
Hooded merganser	0.33	0.33	0.66	0.11	0.55	0.12	0.62	0.10	0.50	0.08	0.62	0.08	0.58	0.04
Common goldeneye	0.67	-	0.67	0.33	0.71	0.17	0.67	0.09	0.65	0.10	0.75	0.14	0.68	0.06
Common merganser	-	-	0.51	0.21	0.48	0.10	0.57	0.14	0.72	0.16	-	-	0.60	0.08

* Reported proportions for Bufflehead (*Bucephala albeola*) should be interpreted as proportion not-adult male (female + juvenile male).

Table 8. Brood presence and size of waterfowl/waterbird species observed brood rearing in the Chehalis floodplain. In addition, estimated offspring recruitment rate and production of Mallard (*Anas platyrhynchos*) and Wood duck (*Aix sponsa*).

Species	Sites Brood Present	Broods	Ducklings	Mean Brood Size ± SE	Min. Brood Size	Max. Brood Size	Recruitment Rate ± SE	Production Estimate ± SD
Mallard	13	30	136	4.5 ± 0.6	1	11	1.73 ± 0.49	763 ± 218
Wood duck	9	18	75	4.2 ± 0.4	1	8	1.67 ± 0.36	137 ± 43
Canada goose	2	5	21	4.2 ± 1.0	2	7	-	-
Cinnamon teal	2	2	12	6.0 ± 1.0	5	7	-	-
Hooded merganser	2	3	10	4.3 ± 1.5	1	6	-	-
Blue-winged teal	1	1	9	-	-	-	-	-
Common merganser	1	1	4	-	-	-	-	-
Pied-billed grebe	1	1	5	-	-	-	-	-

DISCUSSION

Waterfowl and waterbirds are present in the Chehalis floodplain year-round, but the region experiences its highest use during waterfowl migration periods. In the spring, the floodplain functions as a staging area where waterfowl – especially surface-feeding ducks and geese – build nutritional reserves on their northward migration.

Floodplain inundation, brought on by winter rainfall events, precedes and coincides with the spring migration period. These inundation events are likely critical in providing the nutritional elements required by migratory waterfowl. In a healthy riverine system, several processes, driven by inundation, function to provide the nutritional requirements: (1) inundation increases invertebrate abundance and diversity; (2) floodwaters distribute seed and unharvested grains throughout the floodplain; (3) fish are dispersed into otherwise disconnected off-channel aquatic habitats; (4) the recession of floodwater provides new, shallowly flooded feeding areas (Fredrickson 1988, Fredrickson and Reid 1988, Ringelman 1988, Bayley 1995). Prolonged periods of inundation (8-10 days) that occur close to the spring migration may be especially beneficial to females. These extended periods of inundation increase feeding opportunities allowing individuals the ability to gain body mass and build internal nutritional reserves. When increased feeding opportunities are available close to and throughout the spring migration, females may be able to transfer their additional nutritional reserves through the migration and to the breeding grounds (Heitmeyer 2006). Although interspecific variation exists, ample nutritional reserves may increase subsequent recruitment via increased nesting attempts, earlier nest initiation, and larger clutch sizes (Devries et al. 2008, Sharp et al. 2013).

Of the 22 waterfowl species observed during the study, four are likely common year-round residents: Mallard, Hooded merganser, Common merganser, and Canada goose. The abundance of these year-round residents increases drastically as their populations are augmented by the arrival of migratory individuals. Three species bred in the floodplain but were absent during the mid-winter period: Wood duck, Cinnamon teal, and Blue-winged teal. Fourteen species were largely absent during the breeding and brood-rearing periods, but should be considered regular occupants during the migratory and mid-winter periods: American wigeon, Green-winged teal, Northern shoveler, Northern pintail, Eurasian wigeon, Gadwall, Ring-necked duck, Scaup, Canvasback, Bufflehead, Common goldeneye, Red-breasted merganser, Trumpeter swan, and Cackling goose. A few of these species may occasionally breed in the floodplain, but those encountered during the 2015 and 2016 breeding period aerial surveys were likely mostly late migrants (Bellrose 1980). The single Surf scoter encountered at an off-channel site was undoubtedly a vagrant and should not be considered as regularly occupying the floodplain.

During the primary ground survey, Mallards and Canada geese were commonly encountered in diverse habitats. Our aerial survey on 23 February 2016 revealed that these generalist species were broadly distributed throughout the floodplain. In contrast, herbaceous wetland specialists such as American wigeon, Green-winged teal, and Northern pintail were found primarily from the Satsop River upstream to immediately above the Newaukum River; flooded pastures, agricultural fields, and off-channel habitats were more common in this portion of the floodplain. Very high concentrations of these species were found immediately upstream of the Newaukum River in inundated fields.

Habitats with high species richness tended to be dominated by herbaceous wetlands, had limited surface flow, and were in close proximity to pastures and agricultural fields. Habitats close enough to the Chehalis mainstem to have substantial surface flow through them during high water events, such as Centralia Discovery and Chapman, had low species richness and use. Canada geese, Mallards, and Wood ducks were observed only once at the Centralia Discovery site during a low-water period; the Chapman site did not produce any observations. Our study sites were identified using summer imagery taken when water levels were lower than what was observed during the primary ground survey (USDA 2013). Mainstem connectivity may have been higher for the Centralia Discovery and Chapman sites than originally anticipated for this study based on summer aerial photographs.

While conducting our primary ground survey, it became apparent that the use of wet prairie habitat by Green-winged teal, American wigeon, Northern pintail, and Northern shoveler was disproportionately high during the spring migration. In the Chehalis Basin, wet prairies occur where well-drained soils are situated above seasonal, high water tables. Historically, indigenous peoples maintained these prairie landscapes through intentional burning during the dry season (Easterly et al. 2005). The current extent of wet prairie habitat has been severely diminished by several factors. Elimination of fire in prairie landscapes has allowed woody vegetation (Oregon ash [*Fraxinus latifolia*], Red-osier dogwood [*Cornus serecea*], etc.) to colonize historic prairies. Agricultural practices have altered ground water levels and transformed prairies into livestock pastures. Furthermore, invasive species, particularly Reed canarygrass (*Phalaris arundinacea*), have outcompeted native flora and turned historically, species-rich prairies into invasive monocultures (Easterly et al. 2005, Noland and Carver 2011).

Wet prairie habitat was present at just two of our 36 study sites. During March and April 2016, these two sites accounted for 91% of the Green-winged teal, 90% of the Northern pintail, 85% of the Northern shoveler, and 72% of the American wigeon observations; all remaining observations were found at the 34 other sites. Comparatively, these two sites accounted for 21% of our Mallard observations during the same interval. This pattern suggests that wet prairie may be the single most important habitat type to spring migrating surface-feeding ducks within the Chehalis floodplain due to its very limited availability and disproportionately high use; determining its true extent across the broader floodplain may be particularly worthwhile. This pattern merits follow-up in subsequent years to determine whether it remains consistent because it has potentially important management implications.

In the Chehalis floodplain, Mallards are the most abundant mid-winter and migratory period resident, and the most prolific breeder. Mallards were found in more habitats and at more sites than any other waterfowl or waterbird species; they utilized emergent wetlands, wet prairies, forested wetlands, agricultural areas, and developed parks. Areas with greater amounts of open water experienced lower Mallard densities, while herbaceous wetlands increased densities. A strong association with woody wetlands was not established, although Mallards were observed utilizing flooded timber, especially, during the latter half of January and into February. Several high water/flood events occurred during January 2016; these events expanded the inundation footprint within the floodplain. With this expansion of inundated area, previously dry, wooded habitat became shallowly flooded. The use of this newly flooded, wooded habitat may be attributable to increased feeding opportunities in previously inaccessible areas (Heitmeyer 2006).

Absence of Mallards during the aerial breeding period surveys in the tidal surge portion of the floodplain may reflect a lack of quality nesting habitat. Mallards primarily build nest bowls near ground level and prefer to nest in uplands immediately adjacent to wetland habitats; the floodplain in the lowest segment of the Chehalis River, downstream of the Wynoochee River, is comprised primarily of low, emergent wetlands subject to tidal inundation. Mallards, and other surface-feeding ducks, who nest in low wetland areas subject to inundation, risk complete nest failure if nests were to be inundated by floodwaters (Wolf 1955, Bellrose 1980, Markham 1982, Slaughter and Hubert 2014).

Overall, Mallards exhibited a relatively balanced sex ratio with females accounting for 44% of our observations. In eastern Washington, Yocom (1949) documented a decrease in the proportion of male Mallards observed after December, from sex ratios during November and December that favored males. He attributed this decrease – at least in part – to a higher hunter harvest of males than females, and possible differential migration/sex-segregated ranges. Sex ratios in the Chehalis floodplain did not exhibit this marked decrease in the abundance of male Mallards after December. Our reported sex ratio favored males in November, but this was based on a relatively small sample size. Mallard sex ratios between December and March remained essentially balanced. We reported a female proportion of 0.36 ± 0.03 during April that was substantially lower than the preceding months. By April, female Mallards had already been observed nesting; it is likely some amount of nesting females were missed, which would underestimate our reported figure. That we may have missed nesting females may be attributed to their cryptic coloration and tendency to nest in upland habitats. The land use shift of nesting Mallard females from wetland to upland habitats may account for the lower sex ratio as female use of our study sites may have decreased (Bellrose 1980).

Unlike other northern areas of similar latitude, the mild, maritime climate of the Chehalis floodplain and northwest coast enables substantial numbers of Green-winged teal to overwinter in the region (Bellrose 1980). Of the surface-feeding ducks, Green-winged teal exhibited the least significant mid-winter decrease of abundance. Wintering of substantial Green-winged teal populations in western Washington agree with the study of Beer (1945) in the Columbia River area just to the south. He reported Green-winged teal were “very abundant the entire study

(September – April)". North of the Chehalis Basin, contemporary aerial surveys of the Puget Sound region regularly encounter Green-winged teal during the mid-winter period (Nysewander et al. 2005, WDFW 2016*a*). Comparatively, in the interior northwest basin, east of the Cascade mountain range, Green-winged teal are typically largely absent after early-December (Bellrose 1980; WDFW 2016*b*, *c*).

Beer (1945) described a process where paired American wigeon migrated prior to unpaired birds, which resulted in sex ratios that favored males during April. We did not observe this pattern; instead, our counts displayed a trend towards an increasing number of females during April. The proportion of female American wigeon was consistently low during January, February, and March, and then the sex ratio evened in April. This may reflect a propensity for females to winter further south, or for southern-wintering males to begin their northward migration before females (Johnsgard and Buss 1956).

Although the overwintering of Wood ducks in southwest Washington has been reported anecdotally, our observations could not confirm this as part of the current pattern within the Chehalis floodplain. An early (1892) preliminary report of birds present in the Grays Harbor region claimed: "A few (Wood ducks) said to winter about the (Grays) harbor" (Lawrence 1892). Beer (1945), when attempting to interpret a lack of mid-winter Wood duck observations in the lower Columbia River region, stated, "The lack of previous observations is not accounted for as this duck is known to be found in this (lower Columbia River) area throughout the year". Collectively, 27 years (1986, 1991 – 2016) of WDFW mid-winter surveys throughout the Chehalis basin result in the trivial total of 19 Wood ducks (unpublished data). Based on these data, we conclude that the Chehalis floodplain does not currently winter significant numbers of Wood ducks, and may become completely void of them during some years. Historically, most Pacific flyway Wood ducks wintered in the Sacramento Valley of California (Bellrose 1980, Heitmeyer et al. 1989, Ball et al. 1989, USFWS:DMBM 2016). Recently, increasing numbers of Wood ducks appear to be wintering throughout western Oregon and in lacustrine/palustrine environments in the southeast Puget Sound region (unpublished data) (USFWS:DMBM 2016). These recent observations may signal a shift of Wood ducks wintering in more northerly areas, which in time, could lead to the increased wintering of Wood ducks in the Chehalis basin.

During the winter, Wood ducks were not observed for a period of over two months (2 December 2015 – 10 February 2016); outside that period, scattered individuals, either in pairs or as lone individuals, were usually found. The largest number of grouped Wood ducks was observed on 13 April 2016, when 4 pairs were displaying courtship behavior at the WDFW Hoxit 3 site. Herbaceous wetlands had low Wood duck densities, but woody wetlands and open water had higher Wood duck densities. The effect of open water on Wood duck densities should be viewed cautiously. The results indicating a positive association with open water may reflect a selection for wooded wetlands, which frequently circumscribe open water habitats in the floodplain. Alternatively, Wood ducks may select wooded habitats adjacent to open water where the open water is a significant attribute of the Wood duck's use of the landscape. Open water habitats without associated wooded wetlands should not be expected to harbor high densities of Wood ducks.

Ring-necked ducks were the most prevalent diving duck in off-channel habitats; they were also the second-most widely distributed and third-most abundant waterfowl species overall. Their abundance remained high and relatively stable during the study. Unlike most species, they did not exhibit a substantial mid-winter decrease. Ring-necked ducks, much like Mallards, occurred in diverse habitats from forested wetlands to flooded agricultural fields. Their densities increased in areas rich in herbaceous wetlands; whereas open water appeared to decrease their densities. The aerial survey on 23 February 2016 also revealed that they occurred much more commonly upstream of the Satsop River. Ring-necked ducks displayed a sex ratio in favor of males; this pattern is consistent with previously reported latitudinal sex segregation in Ring-necked ducks, where males tend to inhabit more northerly areas (Alexander 1983).

Scaup were not identified to species (lesser and greater), but both Scaup species may occur in the floodplain, which would bring the waterfowl species richness total to 23 and the diving duck species total to four. Scaup abundance was relatively low in the Chehalis floodplain, most observations occurred in late February. When Scaup were present, they were primarily found on ponds, not in wetland habitats; and their density increased with the broadening area of open water. Ring-necked ducks were not found at the two sites where Scaup were most abundant (Bowers and Quigg Lakes). The proportion of Scaup females varied during the study; females were outnumbered by males during December, January, and February. Females then outnumbered males during March and April. This could reflect latitudinal sex segregation or differential sex migration, though previous studies have concluded that Scaup do not display these tendencies (Beer 1945) (Alexander 1983).

Collectively, sea ducks were the least abundant ducks in the floodplain. Modeling indicated that Hooded merganser abundance remained relatively stable throughout the study while Bufflehead, Common goldeneye, and Common mergansers experienced pronounced mid-winter decreases and migratory spikes. Our aerial surveys during the 2015 and 2016 breeding periods (late April) suggested that Hooded mergansers were not present in the floodplain; however, in 2016 they were observed throughout April and into May during ground surveys. Their putative absence from the breeding aerial surveys may be a false negative that likely reflects detectability issues induced by their dark coloration, small size, and increased levels of vegetation during the breeding surveys.

Bufflehead and Hooded mergansers occurred in diverse habitats, and modeling revealed that variations in their densities were independent of habitat type. Common goldeneye and Common merganser densities appeared to increase with open water, but woody and herbaceous wetlands decreased their abundance. Bufflehead and Common goldeneye diets are similarly comprised of fish and aquatic invertebrates; however, Common goldeneye may feed in areas where Bufflehead cannot due to their superior diving ability (duration and depth) enabled by the goldeneye's larger body size (Bellrose 1980, Schummer et al. 2008). The ability of Common goldeneye to feed at greater depths than Bufflehead may explain the proportionally greater use of open water habitat by Common goldeneye. The apparent open water habitat selection of Common goldeneye may reflect resource partitioning away from its smaller-bodied congener, Bufflehead. Although body size, and consequently diving ability, may influence the variation in habitat use between Common and Hooded mergansers, it is probable this variation is mostly a result of diet differences. Common mergansers are fish-eating specialists, such a diet would favor open water habitats; Hooded mergansers are dive-feeding generalist consuming variable amounts of fish, amphibians, crayfish, insect larvae, and other aquatic invertebrates, this diet could be satisfied in multiple aquatic habitat types (Bellrose 1980).

Previous studies have described differential migration between the sexes in Common mergansers, which our observations support (Beer 1945, Johnsgard and Buss 1956). During December and January, we found males and females in equal numbers though often in sex-segregated flocks. Males appeared to begin leaving the area during February, by March females accounted for 72% of our observations. The spatial distribution of Common mergansers throughout the floodplain also varied seasonally. Results from our aerial surveys indicated that Common mergansers were located largely on the upper Chehalis River – above the Black River – during the 2015 and 2016 breeding periods. When we surveyed in late February, they were mostly found in the tidal areas of the lower Chehalis River (below the Satsop River). This seasonal distribution pattern may be a result of available food sources. When foraging in tidal river stretches, Common mergansers feed largely on sculpins (Cottidae), pricklebacks (Stichaeidae), gunnels (Pholidae), and flatfish (Bothidae and Pleuronectidae); however, they feed primarily on juvenile salmonids (Salmonidae) in the non-tidal portions of northwest freshwater streams (Wood 1987*a*, *b*).

Canada goose abundance peaked in early March. Prior to peak abundance, Canada goose observations in off-channel habitats were less frequent, but when encountered they occurred at higher densities (larger flocks) than during the peak interval; after the peak interval, Canada geese were observed more frequently but at lower densities. Importantly, due to their substantial use of terrestrial habitats, the model of Canada goose densities in off-channel habitats likely does not reflect their temporal abundance trends within the floodplain as a whole. As a consequence, the maximum abundance of Canada geese within the floodplain may have occurred prior to the beginning of March.

Due to their extensive use of dry and ephemerally flooded agricultural fields, the abundance of Cackling geese and Trumpeter swans is probably also underrepresented in the observations of off-channel habitats. When Cackling geese were observed in off-channel habitats, they were always in association with Canada geese; however, flocks composed solely of Cackling geese were also observed outside of our study sites in agricultural fields. Trumpeter swans were commonly located on moderately-sized bodies of open water with peripheral, emergent vegetation.

Besides the waterfowl species documented in this study, nine White-fronted geese (*Anser albifrons*) and one Snow goose (*Chen caerulescens*) were observed with larger flocks of Canada and Cackling geese in agricultural fields near Brady. These species were not observed at any of our study sites.

American coot was regularly observed in flocks of 50-60 on open bodies of water with peripheral, emergent vegetation such as Hayes Lake, Plummer, and Greenhead East. This tendency to cluster allowed a species with relatively limited site distribution (8 out of 36) to have the highest observed abundance of the non-waterfowl waterbird species. Great blue heron, Pied-billed grebe, and Double-crested cormorant all had high to moderate distribution (26, 25, 20 sites respectively) throughout the floodplain, although their observed local abundances were consistently lower than American coot.

Flying flocks of up to 70 (probably lesser) Sandhill cranes (*Grus canadensis canadensis*) were encountered multiple times within the floodplain during the spring of 2016. We believe the flocks were migrating through the area due to the height and uniform flight direction. We did not observe Sandhill cranes at any of the survey sites or on the ground anywhere within the floodplain.

This study strongly suggested disproportionately high use of wet prairie by some surface-feeding duck species. Future studies should expand the understanding of this occurrence and give restoration preference to these habitats. Additionally, the use of mainstem rivers as well as agricultural and pasture habitats within the floodplain should be documented. Mainstem rivers and their immediate peripheral habitats are used by several sea duck species and may be used by surface-feeding and diving ducks. Agricultural and pasture habitats are used heavily by geese, swans, and surface-feeding ducks, but the extent to which they are used in the Chehalis Basin has not been detailed.

Aerial surveys were not as frequent as originally anticipated, so an additional season (October – April) of aerial surveys would produce a more complete understanding of temporal and spatial abundance trends within the floodplain.

ACKNLOWLEDGEMENTS

This study is grateful to the numerous private landowners who allowed access to their properties. We would also like to thank the various scientific personnel who contributed to the collection of data and helped to guide the study process: Thomas Cyra, Keith Douville, Warren Michaelis, Bryan Murphie, Julie Tyson, and the WDFW Habitat Program's Intensive and Extensive Study field crews. Environmental and biological expertise was provided by Carol Cloen, Don Kraege, Kyle Spragens, and Matt Wilson. Aerial surveys were supported by our flight followers Debbie Moe and Carol Powers; pilots and aircraft were contracted through Hillsboro Aviation Inc. Funding for the study was provided by the Washington State Legislature.

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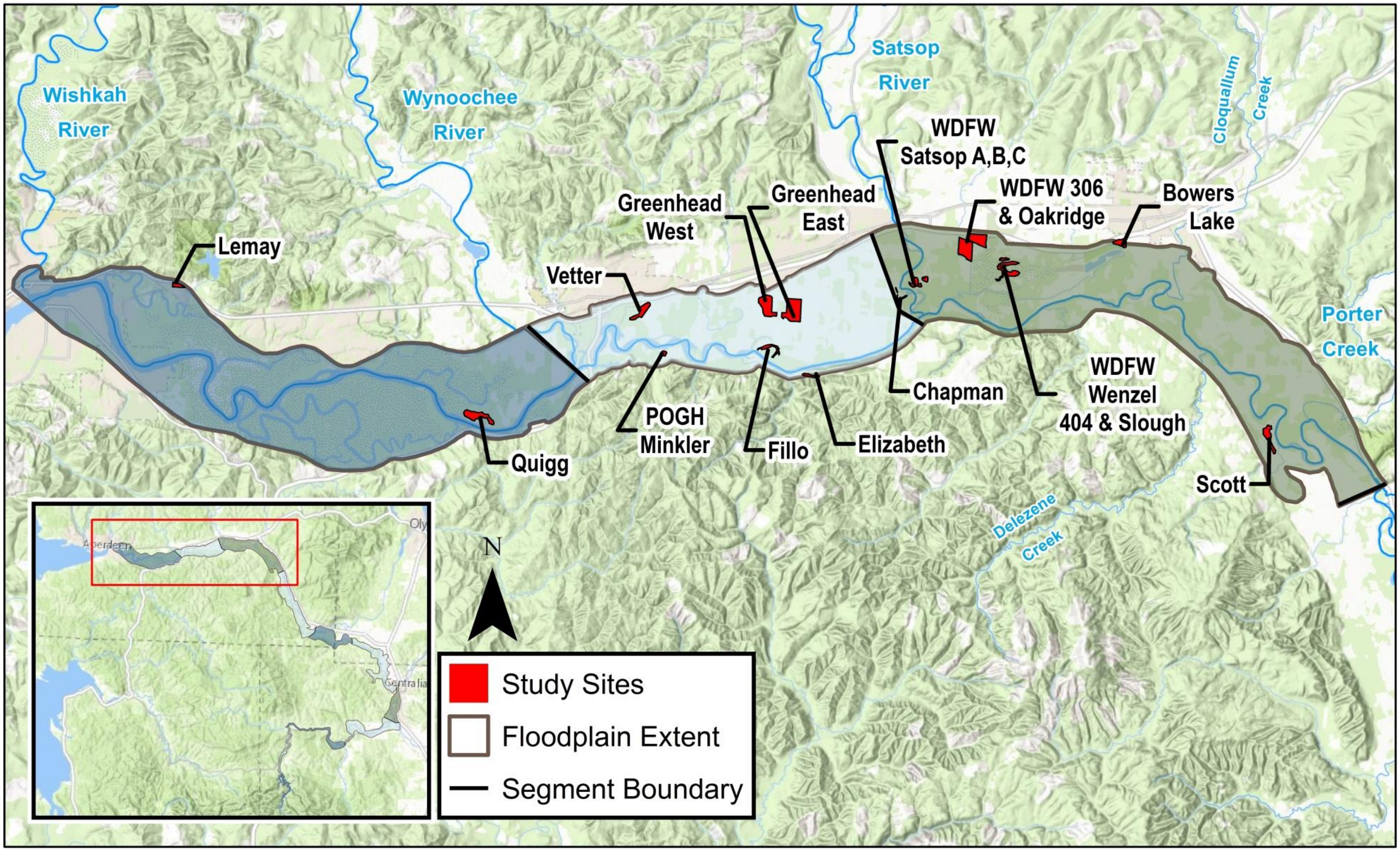
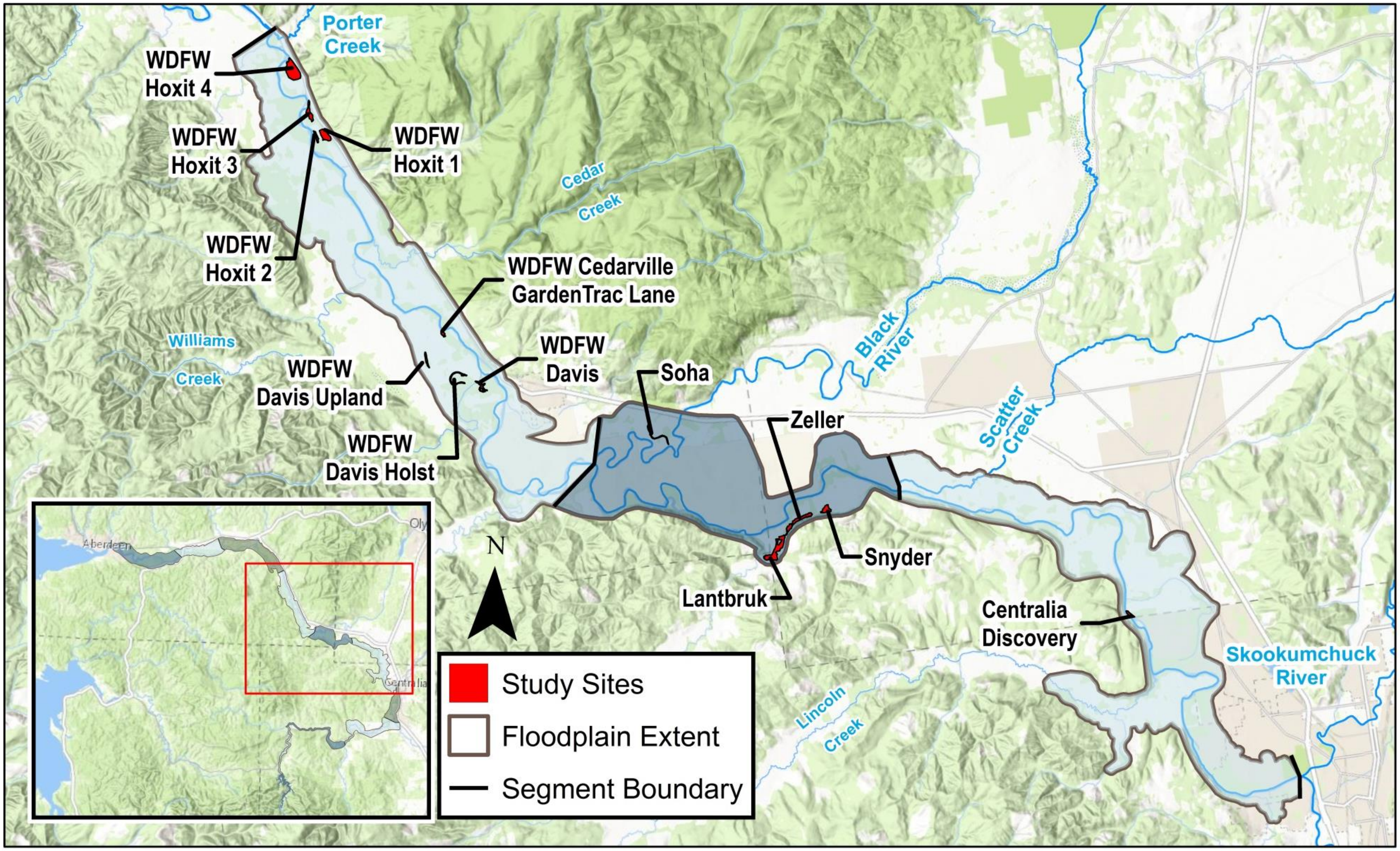
APPENDIX

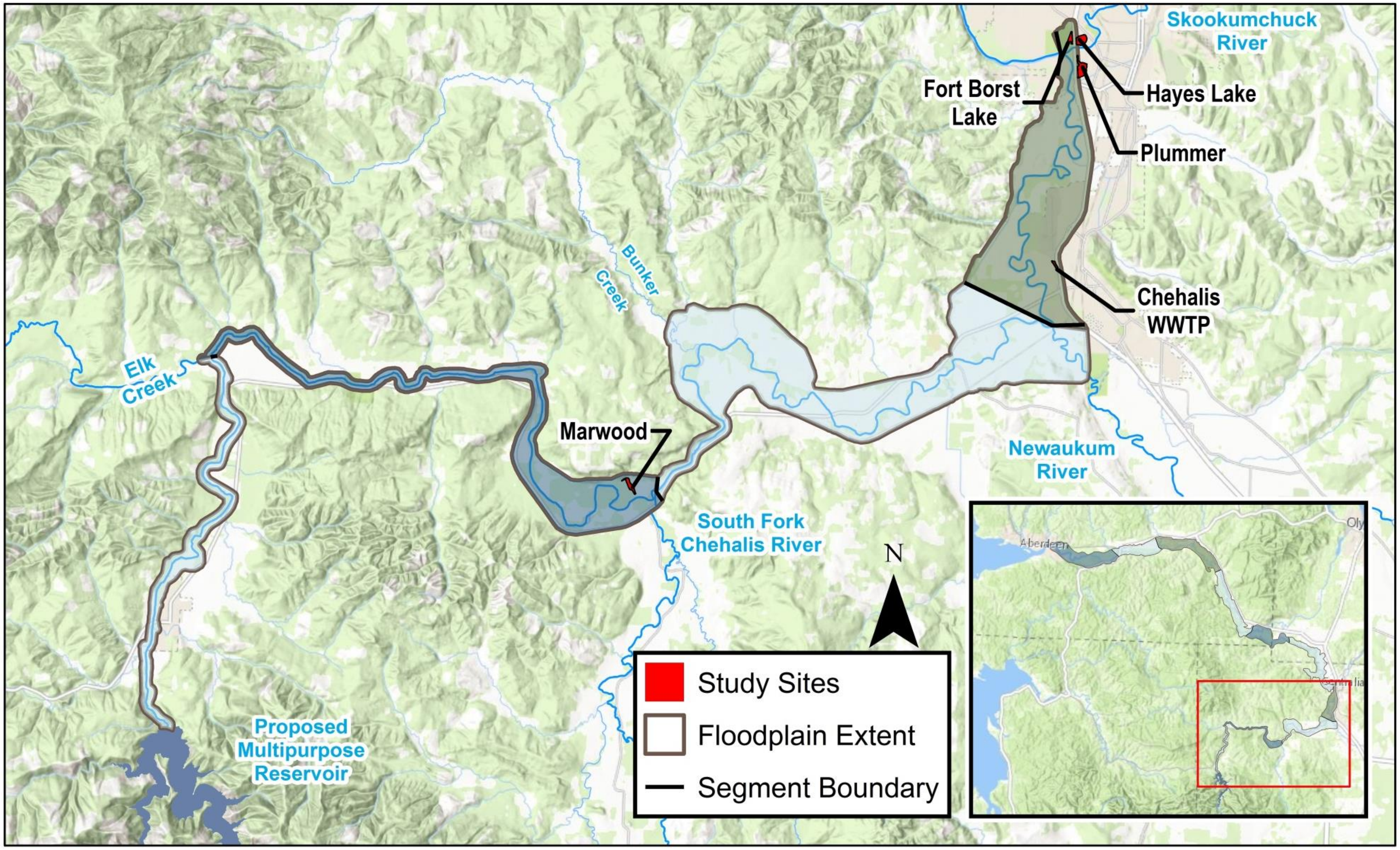
Appendix 1. Lower Chehalis floodplain river segments and study sites for the primary and brood ground surveys.



Appendix 2. Middle Chehalis floodplain river segments and study sites for the primary and brood ground surveys.



Appendix 3. Upper Chehalis floodplain river segments and study sites for the primary and brood ground surveys



Appendix 4. Species documented in this report.

Common Name	Scientific Name
Surface-feeding Ducks	**Tribe Anatini**
Mallard	*Anas platyrhynchos*
Green-winged teal	*Anas carolinensis*
American wigeon	*Anas americana*
Northern pintail	*Anas acuta*
Wood duck	*Aix sponsa*
Northern shoveler	*Anas clypeata*
Cinnamon teal	*Anas cyanoptera*
Gadwall	*Anas strepera*
Eurasian wigeon	*Anas penelope*
Blue-winged teal	*Anas discors*
Diving Ducks	**Tribe Aythyini**
Ring-necked duck	*Aythya collaris*
Lesser scaup	*Aythya affinis*
Greater scaup	*Aythya marila*
Canvasback	*Aythya valisineria*
Sea Ducks	**Tribe Mergini**
Bufflehead	*Bucephala albeola*
Hooded merganser	*Lophodytes cucullatus*
Common goldeneye	*Bucephala clangula*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Surf scoter	*Melanitta perspicillata*
Geese	**Tribe Anserini**
Canada goose	*Branta canadensis*
Cackling goose	*Branta hutchinsii*
Swans	**Tribe Cygnini**
Trumpeter swan	*Cygnus buccinator*

Common Name	Scientific Name
Waterbirds	**Various Taxa**
American coot	*Fulica americana*
Double-crested cormorant	*Phalacrocorax auritus*
Pied-billed grebe	*Podilymbus podiceps*
Great blue heron	*Ardea herodias*
Green heron	*Butorides virescens*
Great egret	*Ardea alba*
Common loon	*Gavia immer*
Red-throated loon	*Gavia stellata*
Horned grebe	*Podiceps auritus*
Western grebe	*Aechmophorus occidentalis*

Appendix 5. Study site species richness during the primary ground survey.

All Sites	Surface-feeding Ducks 10	Diving Ducks 3	Sea Ducks 6	Geese 2	Swans 1	Waterbirds 10	Total 32
WDFW Wenzel Slough	7	1	4	1	1	4	18
WDFW 306	7	2	3	2	1	2	17
Vetter	7	2	3	1	0	3	16
WDFW Hoxit 1	4	2	4	2	1	3	16
Lantbruk	6	2	3	1	0	4	16
Greenhead East	6	1	2	2	1	3	15
Zeller	4	2	4	1	1	3	15
Oakridge	8	1	2	1	0	2	14
WDFW Hoxit 4	5	1	3	1	1	3	14
Plummer	4	1	3	1	0	5	14
Soha	4	1	3	2	0	3	13
Bowers Lake	2	1	2	0	0	7	12
WDFW Davis Upland	3	1	4	1	0	3	12
Greenhead West	5	1	2	1	0	2	11
WDFW Hoxit 3	5	1	2	0	0	3	11
Quigg	3	1	2	1	0	3	10
WDFW Davis	4	1	1	1	0	2	9
WDFW Davis Holst	3	1	1	1	0	3	9
Hayes Lake	1	1	2	0	0	5	9
Fillo	2	1	1	0	1	3	8
Scott	4	1	1	1	0	1	8
WDFW Satsop B	1	1	2	1	1	2	8
WDFW Cedarville	3	1	1	0	0	3	8
Fort Borst Lake	2	1	2	0	0	3	8
Snyder	3	1	1	1	0	1	7
Lemay	3	0	2	1	0	0	6
POGH Minkler	2	1	1	1	0	1	6
Chehalis WWTP	1	2	2	0	0	1	6
WDFW Satsop A	1	0	2	0	0	2	5
WDFW Hoxit 2	1	0	0	1	0	3	5
Elizabeth	3	0	1	0	0	0	4
WDFW Wenzel 404	2	1	0	0	0	1	4
WDFW Satsop C	0	1	1	0	0	1	3
Centralia Discovery	2	0	0	1	0	0	3
Marwood	2	0	0	0	0	1	3
Chapman	0	0	0	0	0	0	0