Duncan Dam Project Water Use Plan

Lower Duncan River Mosquito Monitoring and Management Plan Development

Implementation Year 6

Reference: DDMMON-9

Lower Duncan River Mosquito Monitoring and Management

Plan Development – Year 6

Study Period: 2015 – 2016

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Prepared for BC Hydro

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Executive Summary:

Under the Duncan Dam Water Use Plan (WUP), an evidence-based empirical model has been developed to predict how operation of the Duncan Dam will influence production of nuisance mosquitoes on the Duncan-Lardeau floodplain. The predictive model is called the Nuisance Mosquito Performance Measure calculator (NMPM calculator), and a detailed description and the rationale for its development can be found in the report Lower Duncan River Mosquito Monitoring and Management Plan Development - Implementation Year 6 (Jackson et al., 2015).

To improve and test performance of the NMPM calculator, additional larval count data were collected from the floodplain in 2016. These new data were collected with two purposes. First, they were used to test how well the model predicts larval productivity, using conventional model validation methods. Second, some of these new data were collected earlier in the season than in previous sampling years to capture early season levels of larval production, which are typically very high. So in addition to model testing, the new data were also used to adjust model parameter values for better model performance.

Results from the model validation procedure indicate that the NMPM calculator provides accurate, unbiased estimates of larval productivity. The NMPM calculator's predictions are generated using the average of predictions from two distinct statistical sub-models, one that uses temporally-rich data collected from six different years (DDM sub-model) and another that uses spatially-rich data from six different classes of dominant vegetation that occur on the floodplain (vegetation sub-model). Model validation was conducted separately for each of these two sub-models. The DDM sub-model performed unusually well in that the model predictions fit a test data set better than the model fit the data that were used to parameterize the model (training set). The vegetation sub-model did not fit the test data as well as the training set, which is more typical. But test results suggest this disparity is reduced by updating the model parameter values with the new data. Overall, results of model validation indicate that the NMPM calculator provides realistic, unbiased predictions of larval production.

The Duncan-Lardeau floodplain has four ecologically distinct genera of mosquitoes. Previously the NMPM calculator predicted productivity only for *Aedes*, the genus that is by far most abundant and produces the greatest nuisance. The model has now been updated with parameter values for each of the four genera, offering a more complete ecological picture of productivity.

NMPM calculator predictions indicate that the main driver of larval productivity is seasonal egg hatching rates controlled by mosquito biology (phenology), such that the vast majority of *Aedes* larvae are produced in May and June. Despite model assumptions that tie dam discharge to availability of larval habitat, the model does not predict that dam operations substantially influence this seasonal dynamic. For *Aedes*, the seasonal effect appears to wash out effects of discharge on habitat availability. Other factors that influence larval productivity include average air temperature and precipitation during the 10 day period of larval development and vegetation. Areas dominated by grass are particularly productive for *Aedes*, which are adapted to hatch during spring floods.

The NMPM calculator is informed by counts of different larval species sampled extensively across both space and time (Executive Summary Table 1). It also accounts for important ecological factors that determine productivity of larval mosquitoes. Results of model validation indicate that the model gives useful estimates of larval productivity. Further data collection is not recommended (beyond any previously committed for future high flow events).

Executive Summary Table 1: DDMMON #9 - Status of objectives, management questions, and hypotheses after Year 7 (2015-2016).

Objective	Year 7 (2015-2016) Status	Progress/Impediments WRT answering Management Question(s)
Refine the nuisance mosquito performance measure originally designed for the DDM WUP by improving the resolution of the flow-habitat flooding relationship and increasing the understanding of mosquito production drivers and migration in the lower Duncan River floodplain	**Complete**	Modelling work completed by Dr. Phelan. Migration not relevant to NMPM design for DDM WUP.
Provide meaningful recommendations towards improving the effectiveness of the current mosquito abatement program	**Complete**	The model identifies areas that are likely productive habitat for nuisance mosquitoes.
Provide meaningful recommendations towards identifying and addressing the potential threat of WNv	**Complete**	Very few WNv vector mosquitoes were discovered throughout the entire study, and the threat is low.

Management Hypothesis	Year 7 (2015-2016) Status	Progress/Impediments WRT answering Management Question(s)
Nuisance mosquito productivity is correlated to environmental and stochastic factors, such as precipitation and temperature, and to the frequency and amplitude of flooding.	**Accepted**	Multiple regression analysis accounts for the relationship between environmental variables and larval productivity.
Existing nuisance and WNv mosquito management programs on the Lower Duncan River can be improved through increased understanding of drivers of mosquito productivity.	**Accepted**	Model can identify important wetted areas for nuisance mosquito habitats.

Management Question(s)	Year 7 (2015-2016) Status	Progress/Impediments WRT answering Management Question(s)
How may discharges from the Duncan Dam affect production of *Aedes* mosquitoes through inundation of Low Bench areas in the Lower Duncan and Lardeau floodplains from May to September?	**Complete**	Model predicts a relationship between Dam discharge and mosquito production.

Do groundwater variations in different areas at different dam discharge rates relate to flooding regimes, vegetation types and mosquito production?	**Unknown, but not relevant**	Model speaks to wetted areas. Links between discharge, vegetation, and mosquito abundances are discussed.
Is the current Nuisance Mosquito Performance Measure effective at predicting the potential production of late outbreaks of nuisance mosquitoes related to Duncan Dam operations?	**Complete**	Yes. NMPM has been updated to include early, mid-, and late-season nuisance mosquito outbreaks.
Can we more accurately predict when outbreaks of nuisance mosquitoes are most likely to occur given particular environmental and climatic conditions?	**Complete**	Environmental and climatic data can be entered into model to predict where and when nuisance mosquitoes will hatch under different environmental scenarios.
What can the current mosquito abatement program (managed by the Regional District of Central Kootenay, RDCK) do to improve its effectiveness based on the information collected in this program?	**Complete**	Prioritize treatment of low lying grass areas as these are the most productive habitat for nuisance mosquitoes. Plan the timing of treatments using thresholds to target specific species. Include mosquito identification in the program to enable focused treatment of target species, and to eliminate unnecessary treatments. Use species ecology and larval monitoring to ensure treatment applications are conducted at the optimal time to result in maximum effectiveness.
Is the operation of the Duncan Dam linked to production of high competence WNv vector mosquitoes?	**Complete**	Low numbers of *Culex tarsalis* can be found in the floodplain in high water years, but this is not linked to Dam operations. There is very low risk of West Nile virus outbreaks.

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1.0 Introduction:

Project Rationale:

The Duncan Dam facility became fully operational in 1967. The dam is a storage reservoir for a drainage basin of 2,400 km^2 and the largest inflows occur in May and June as a result of snowmelt. The highest levels of precipitation are seen from July to October, or later. The dam is operated under the terms of the Columbia River Treaty and the Water Use Plan, which dictate reservoir storage requirements throughout the year to manage downstream flooding and power requirements for environmental and social values (BC Hydro 2005). The 45 km long Duncan Reservoir is contained by a 40 m high earth-fill dam wall and holds 1,727 million m^3 of storage with an average drawdown of 30 m. Due to the restrictions of the Water Use Plan (WUP), it is unusual for large volumes of water to be discharged from the dam between May and mid-July. Thus, there was uncertainty as to the degree of influence that discharges from the dam may have on mosquito production annually (Jackson *et al.* 2002). Downstream of the dam is the confluence with the unregulated Lardeau River, which can contribute to flooding of the Lower Duncan River and Meadow Creek floodplain during May and June. Fluctuation in Kootenay Lake levels may also have an impact on mosquito production along the shores and in other areas of the floodplain.

The Duncan Dam WUP Consultative Committee was particularly interested in the effect that dam operations had on nuisance mosquito production in the Lower Duncan River floodplain. The WUP was approved with significant operational constraints to downstream flooding, which were assumed to minimise mosquito production. A monitoring program was recommended to test this assumption and provide recommendations for improved mosquito controls.

In addition to monitoring, advances in computer technology and analytical tools now allow for the development of sophisticated models to predict species distributions based on environmental variables. Data collected in the field can both inform the predictive model and help to test its performance. Understanding mosquito distribution and abundance at the landscape level, and the underlying factors that affect mosquito presence, is an essential tool in developing appropriate mosquito management strategies, whether for vectors or nuisance mosquitoes.

The term 'nuisance mosquito' is broadly defined as mosquito species that are known to emerge in large numbers and are aggressive human biters, but are generally not known vectors of human disease. The two major species that fall into this category on this floodplain are *Aedes sticticus* and *Aedes vexans*. Species from the other, less abundant genera found on the floodplain are not considered nuisance species.

Summary of Previous Work:

Data collected between 2009 and 2014 are summarized in the annual report, Lower Duncan River Mosquito Monitoring and Management Plan Development - Implementation Year 6 (Jackson et al., 2015). Previous studies have shown a strong trend between vegetation type and species identity (Jackson et al., 2015). For example, *Aedes vexans* is most commonly found in grassland vegetation types, while *Aedes sticticus* is closely associated with cottonwoods (Jackson et al., 2015). Temporal differences between species have also emerged as important trends in the data, with some, such as *Aedes vexans*, appearing early in the season, and others, such as *Culiseta minnesotae*, emerging later on

(Jackson et al., 2015). In addition to vegetation type and seasonal variation, other factors can interact to affect mosquito distribution and this variation needs to be taken into account in the analysis. A numerical model (the NMPM), based on the extensive dataset from six years of data collection, was devised in 2015 to allow for predictions of mosquito abundance depending on environmental conditions and to help inform management decisions. It was subsequently identified that early summer mosquito production was under-represented in the analysis and was recommended for assessment in 2016. This report integrates the 2016 data collection and provides an updated version of the NMPM tool.

The Model:

The Nuisance Mosquito Performance Measure (NMPM) is based on statistical associations between levels of environmental variables and larval abundance of nuisance species at different times. These statistical associations were used within a Geographic Information System (GIS), in conjunction with a hydraulic model, to predict how mosquito production will respond to various dam discharge scenarios. The NMPM is generated using a custom software tool developed within the R environment for statistical computing and graphics. Levels of variables for different environmental and discharge scenarios are entered into the software tool and indices of mosquito production are generated. These predictions are informed by statistical associations between observed abundance of mosquito larvae and the various environmental factors relevant to production of larval mosquitoes, as well as availability of water for mosquito hatching habitats resulting from Hydro operations.

The NMPM is formulated on data that were collected from the Duncan-Lardeau floodplain between 2009 and 2016. These data are reported in the annual reports from 2009-2012 and a detailed outline of the materials and methodology used to build the NMPM can be found in the 2015 annual report, Duncan Dam Water Use Plan (Jackson et al., 2015). This 2016 report contains the results of a revised and expanded statistical analysis of larval abundance data, validation of the NMPM using data collected in 2016, and post-hoc model predictions that use historical dam discharge and environmental data from previous years.

2.0 Materials and Methodology

Larval Sampling:

The NMPM was developed and parameterized using data specific to the production of larval mosquitoes in the Duncan-Lardeau floodplain. To effectively test the model, larvae were sampled similarly to previous years, except that in 2016 larvae were also sampled earlier in the year. Sampling measured both abundance of larval mosquitoes and levels of environmental variables known to influence mosquito production. Data were collected during the season of mosquito production (spring through late summer 2016). Mosquito sampling consisted primarily of systematically collecting, counting and identifying larval mosquitoes to species. Larvae were captured with a 500mL long handled dip sampler, using a standard dipping method described in the Municipal Mosquito Control Guidelines (Ellis 2004). Each sample consisted of ten dips pooled from a single site.

Data were collected in two distinct sampling regimes; 1) regular samples from long-term study sites and 2) less frequent but more spatially-intensive sampling across classes of dominant vegetation on the floodplain.

1) Regular samples from long-term study sites: The first larval sampling regime was carried out over a total of nine weeks in 2016, with two sampling weeks occurring in May, three in June, one in July and three in August. The aim of this sampling was to continue to capture the relationship between the productivity of larval habitats through time. Larval counts were collected from 13 fixed locations on the floodplain. Figure 1 shows these 13 sites labeled 1 through 13 with the prefix DDM (Duncan Dam).

2) Less frequent but more spatially-intensive sampling across classes of dominant vegetation on the floodplain. Six classes of dominant vegetation have been identified for the floodplain, and in 2014 larval abundance was measured in each of these six classes to capture across-vegetation variation in larval productivity (Jackson et al., 2015). In 2016 further sampling across the six vegetation classes was conducted three times, involving ninety sites across the floodplain. Sampling events occurred on May 10th and 11th, July 13th and 14th and August 16th and 17th. For each sampling event, 15 samples were collected from within each vegetation class (three events x six vegetation classes x 15 samples = 270 samples total). Sampling locations are shown in

Figure 2.

For both sampling regimes, larvae in each sample were counted and collected for later identification to species level. Late-instar larvae were immediately preserved in alcohol for identification. Early instars cannot immediately be identified to species so these were kept alive and reared into adult mosquitoes for easier identification. During this rearing process a proportion of larvae typically die. For this reason field counts of unidentified larvae were often substantially larger than laboratory counts identified larvae. Both types of counts are reported in the Results, and the predictive model uses the total field counts to adjust taxon-specific estimates of larval abundance.

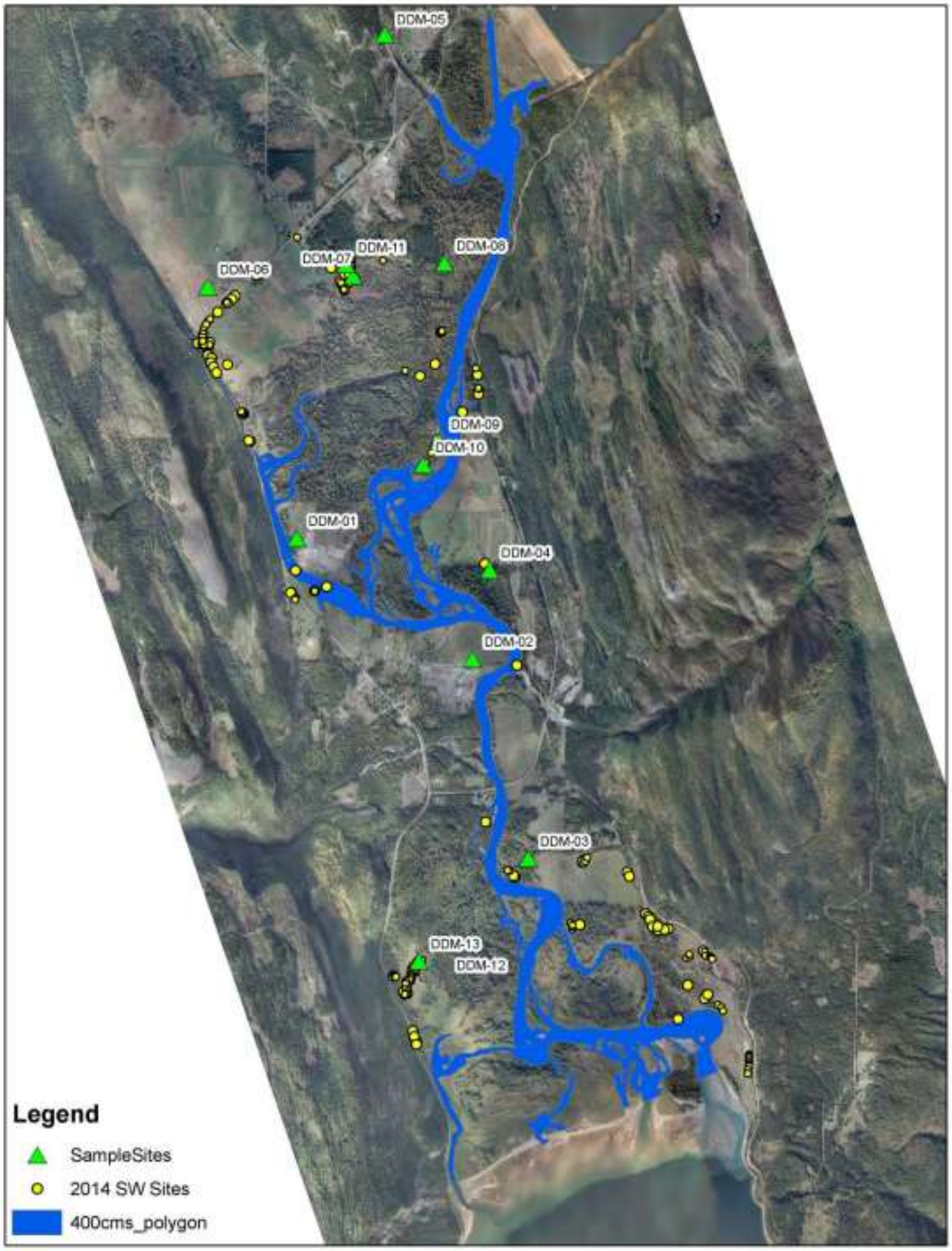


Figure 1: Predicted inundated area under the highest discharge scenario (400 m^3/s) from the 2D hydraulic model and the locations of the 13 long-term sampling sites.

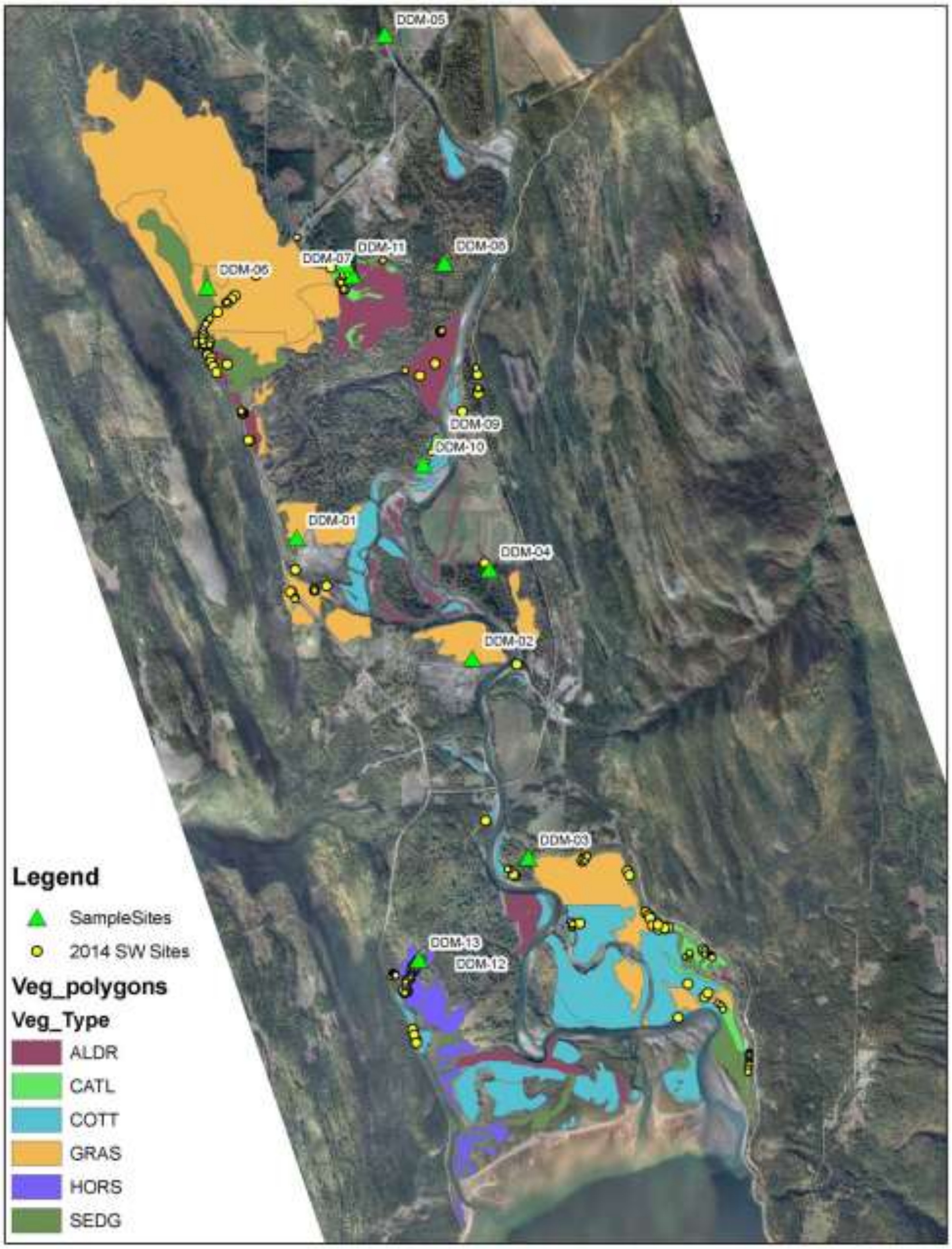


Figure 2: Vegetation polygons and sampling sites for the 2014 and 2016 spatially-intensive larval sampling across the six dominant vegetation classes. Locations of sites are clustered due to availability of larval habitat. ALDR = alder, CATL = cattail, COTT = cottonwood, GRAS = grass, HORS = horsetail, and SEDG = sedge. No GPS site coordinates were collected in 2016 but samples were collected in the vicinity of the 2014 sites. GPS coordinates can be found in the Duncan Dam Water Use Plan: Lower Duncan River Mosquito Monitoring and Management Plan Development, Implementation Year 6, DDMMON#9 (Jackson et al., 2015).

3.0 Results

Larval Sampling Results:

Data collected at the Duncan Dam sites in 2016 were consistent with past years of data that were collected. Larval sampling over five years (2009-2014) has shown that there is a strong correlation between vegetation type and species identity (Jackson et al. 2015). Furthermore, *Aedes vexans* – the most abundant species by far, has been consistently found in high numbers in grassland vegetation types during the early season after the spring freshet (Jackson et al. 2015). The higher productivity of grasslands in the early season is shown in Figure 3. As shown in Table 1 and Table 2 (also Appendix 2.), larval samples collected during 2016 are consistent with previous studies. 1289 *Aedes vexans* were collected from all vegetation sites on May 10-11 2016. 899 of the *Ae. vexans* were collected from the fifteen grassland vegetation sites, with the rest being found between the five other vegetation classes Figure 4. Vegetation sampling on July 13-14 and August 16-17 found very few *Aedes vexans* Table 2. The predominant species in both July and August was *Anopheles freeborni* with large numbers of *Aedes sticticus* and *Culex* species also being collected in August Figure 4.

Table 1: Summary of Larval Sample Identification from the 13 DDM Sites in 2016. A full summary of the data can be found in Appendix 2.

Date	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinerus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
06-May-16	709	362	0	0	11	7	1	300	0	5	3	0	2	0	0	6	17
20-May-16	375	207	0	6	0	0	0	168	0	0	1	0	22	0	2	1	7
01-Jun-16	191	166	2	43	0	0	0	103	0	0	0	0	1	0	0	0	18
10-Jun-16	196	36	5	12	0	0	0	3	0	0	0	0	2	0	0	0	14
22-Jun-16	64	21	0	7	0	0	0	1	0	0	0	1	7	1	0	4	0
02-Jul-16	24	14	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Aug-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Aug-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-Aug-16	20	7	0	3	0	0	0	0	1	1	2	0	0	0	0	0	0
Total	**1579**	**813**	**7**	**85**	**11**	**7**	**1**	**575**	**1**	**6**	**6**	**1**	**34**	**1**	**2**	**11**	**56**

Table 2: Summary of Larval Identification of Vegetation Samples collected three times in May, July and August 2016. A full summary of the data can be found in Appendix 2.

Date	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes campestris*	*Aedes canadensis*	*Aedes cinereus*	*Aedes impiger*	*Aedes implicatus*	*Aedes sticticus*	*Aedes punctor*	*Aedes vexans*	*Aedes pullatus*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Anopheles punctipennis*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culiseta incidens*	*Culiseta mortisans*	*Culex tarsalis*	*Culex territans*	*Culex spp.*	Unidentifiable mosquito
May	6686	1532	9	5	1	6	0	13	44	1	1289	2	2	0	6	0	8	13	0	2	2	23	43	1	51
July	1051	315	0	0	0	0	0	0	0	0	1	0	7	6	149	2	3	1	0	0	1	68	73	0	7
August	2019	468	5	0	0	62	1	1	93	0	81	0	5	4	110	0	4	3	6	13	0	57	4	4	15
Total	**9756**	**2315**	**14**	**5**	**1**	**68**	**1**	**14**	**137**	**1**	**1371**	**2**	**14**	**10**	**265**	**2**	**15**	**17**	**6**	**15**	**3**	**148**	**120**	**5**	**73**

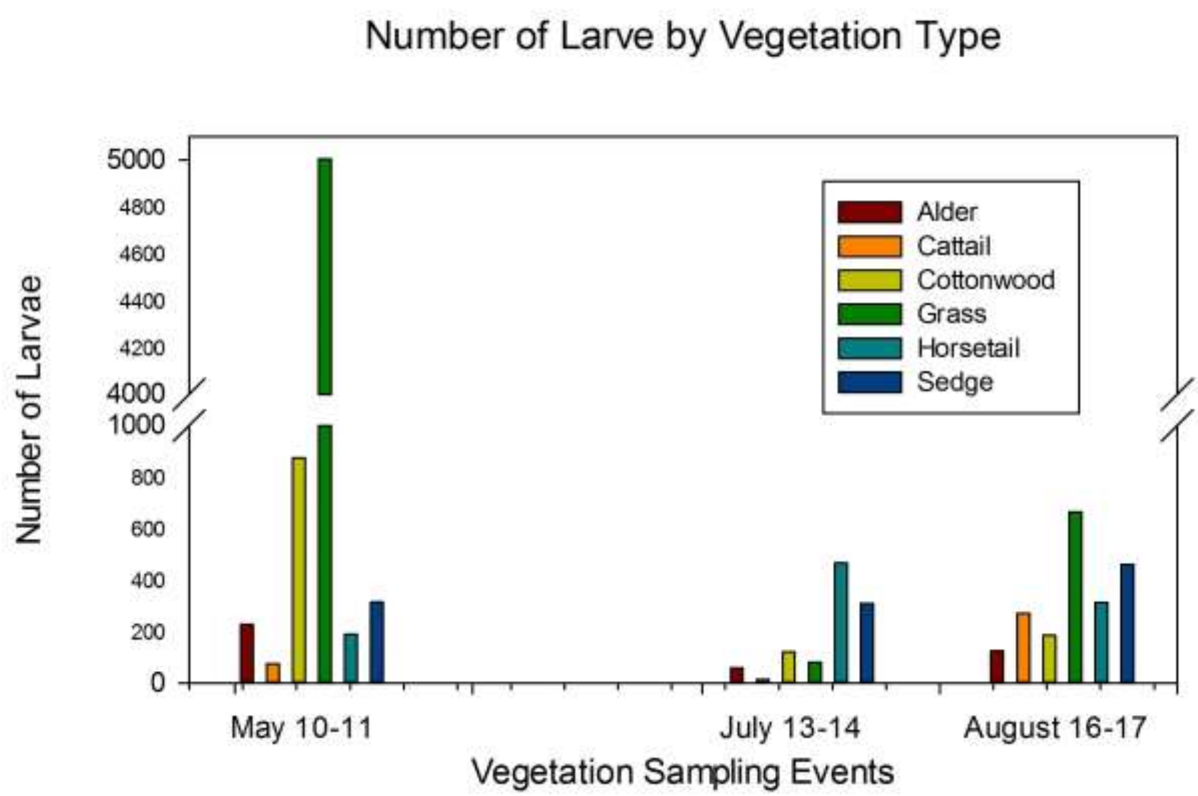


Figure 3: Total Number of Larvae Sampled during the three sampling events in 2016 illustrated by Vegetation Class.

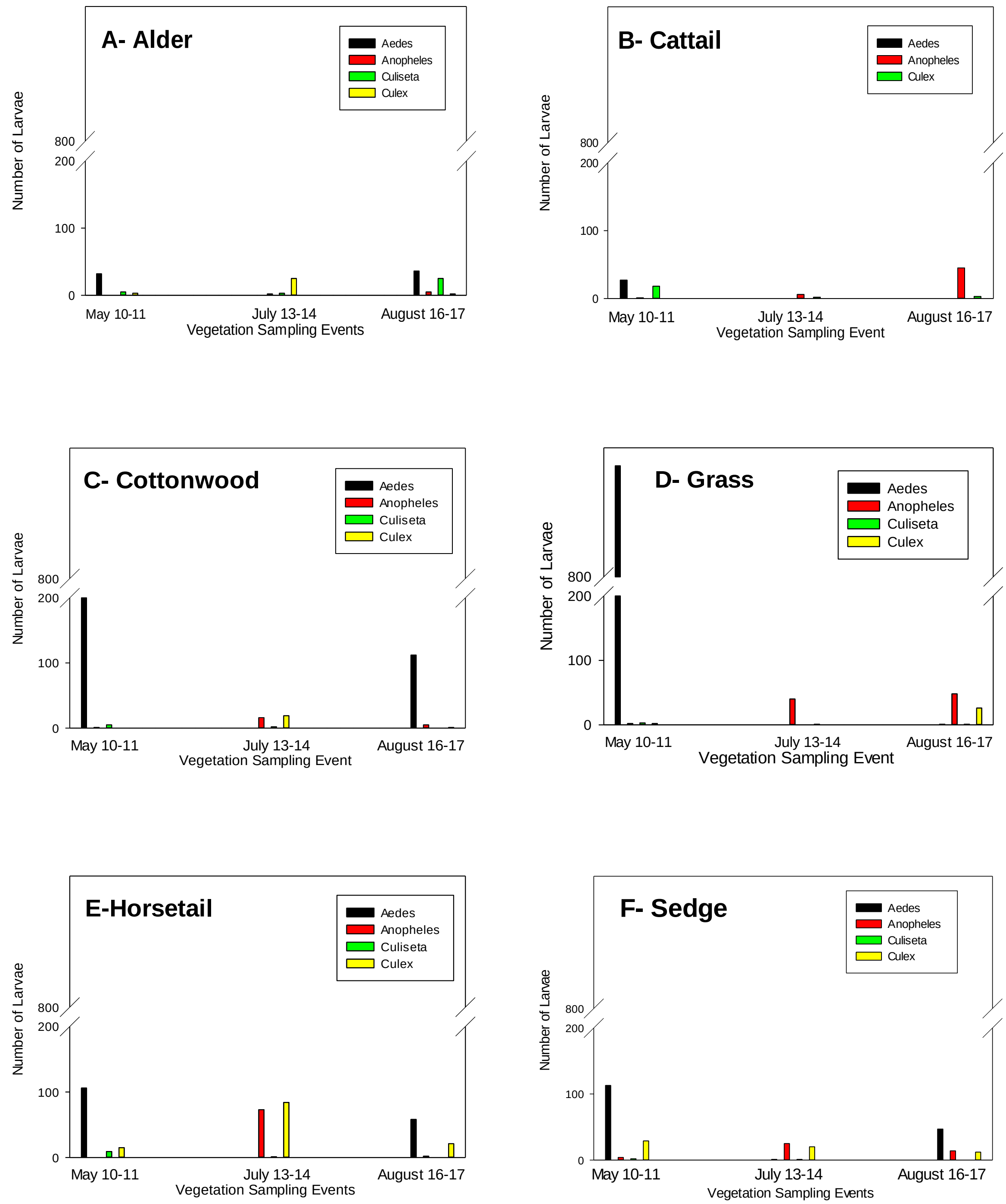


Figure 4: Numbers of identified larvae by genus for each of the three vegetation sampling events in 2016. Each panel A through F shows a different dominant vegetation class: A – Alder, B - Cattail, C – Cottonwood, D – Grass, E – Horsetail, F – Sedge.

Results of Model Validation:

As outlined above, larval count data have been collected using two distinct sampling regimes. The first regime involved repeated sampling of larvae from the same 13 fixed sites during the mosquito seasons over 6 years (the DDM sites). The second regime sampled larvae widely from 6 areas that each had distinct classifications of dominant vegetation in 2014 and 2016 (Veg sites). Differences between these two sampling protocols required separate statistical analyses for each of them. The major methods of each of these analyses are outlined in the method section of the report, Lower Duncan River Mosquito Monitoring and Management Plan Development - Implementation Year 6 (Jackson et al., 2015). The DDM site model data called for a generalized linear mixed regression model (a multi-level model) and the vegetation site data used a simpler generalized linear regression model. In the NMPM calculator, the average of the predictions from each of these two statistical sub-models is used to predict larval productivity.

Further sampling was conducted in 2016 for both the DDM and vegetation regimes to 1) better inform the model's predictions and 2) to enable model validation, or testing of model performance. Mosquito larval count data are highly variable and typically follow a negative binomial frequency distribution so there tend to be many counts of very small values (0s, 1s, etc.) relatively few intermediate values (e.g. 25), and occasional-but-important very high values (e.g. hundreds or even thousands of larvae in a sample). This property requires specialized statistical methods that demand substantial sample sizes. For this reason, the 2016 samples were invaluable for assessing model performance, particularly with respect to the vegetation sampling regime, which had only occurred previously in one year (2014).

Performance of the predictive statistical components of the NMPM calculator was assessed, for both the DDM site and vegetation regression models. For each one, the model is used to predict larval counts by generating and comparing predictions from two data sets; 1) the training set and 2) a test set. The training set is simply the original data that were used to parameterize the model (the data upon which the statistics were carried out). The test set is the new data from 2016, which were not used to develop model parameters (at least not prior to the validation process). The differences between the model's predicted values and the observed values indicate how well the model is working for each set of data (goodness-of-it). Table 3 shows such differences using the statistic Root Mean Square Error (RSME).

Table 3: Goodness-of-fit estimates for each of the DDM and vegetation site regression sub-models. Table rows show results for DDM and vegetation models. The average of predictions from these two sub-models is used to estimate larval productivity in the NMPM calculator. Lower RMSE values indicate better fit. RMSE All is a model parameterized using the entire pooled data set for all years. RMSE Training shows performance of the model predicting the data it was parameterized (trained) with. RMSE Test shows how well the model fit the new set of data from 2016. % diff is the percent difference between Training and Test RMSE. Percent change is the percent change in RMSE going from Training to Test.

Model	RMSE All	RMSE Training	RMSE Test	% diff	% change
DDM sites	233.33	279.22	39.12	151	-86
Veg sites	24.43	17.83	23.04	25	29

In general, RMSE values are expected to be lower for training data than for testing data. However, Table 3 shows that our DDM site sub-model showed a decrease in goodness-of-fit between the training and testing data sets (pre-2016 data to 2016 data). This likely results from the infrequent occurrence of very high count data – there happened to be some extremely high values in the pre-2016 and relatively fewer such values in 2016. This higher level of variation in the training data set results in a relatively high RMSE Training value. The lower RMSE Test value shows that the DDM model is performing well in predicting larval occurrence for the Test data set. Finding an 86% better fit for the test set indicates that the model is providing accurate predictions.

The RMSE values for the vegetation sub-model are more typical of model validation results in that RMSE increased from the Training set to the Test set. RMSE increased by 25%. This shows that the model was 25% worse at predicting data in the new 2016 context than for 2014. However, the RMSE All is close in value to RMSE Test. This suggests that the training model's performance with the test set is about the same as the All-years model's predictions on its own data.

These validation results show that both the DDM site and vegetation site sub-models performed well. The average of predictions from these two sub-models is used to estimate larval productivity in the NMPM calculator. The DDM site sub-model performed exceptionally well in that the test set fit the data substantially better than the training set. And the vegetation site model showed a moderate but acceptable level of over-fitting of the Training set, which will be mitigated by re-parameterization using data from all years. The NMPM model performance is therefore near optimal with respect to the variance-bias trade-off, and will not be improved substantially by gathering more sample data in the future.

Model predictions:

Since the 2015 annual report was submitted (Jackson et al., 2015), the NMPM calculator has been adjusted to address issues with how model coefficients were being implemented within the GIS framework. This adjustment included an update of model parameters so that they are now informed by all the available data, including from 2016. The new implementation properly accounts for environmental factors, mosquito phenology, and levels of dam discharge. Additionally, model parameters were calculated for estimating larval productivity of each of the four mosquito genera (rather than just for *Aedes*), as well as all species considered together.

For purposes of analysis, the season of mosquito larval production has been divided into three periods: early, mid, and late seasons. The early season corresponds to the period of May 1 to June 28, the mid-season from June 29 to August 7, and the late season from August 8 to September 16.

Figure 5 displays 2014 environmental and discharge data along with post-hoc NMPM predictions for *Aedes* mosquitoes, as well as all species pooled. See Appendix 1 for similar graphs of 2009, 2010, and 2011, and 2012. These results show that biological seasonal differences in larval production (phenology) are the dominant factor driving larval production. In general, the NMPM model predicts very high productivity of *Aedes* mosquitoes for the early mosquito season, with comparatively negligible production of this genus for the mid and late seasons. When all species are considered together, predicted levels of early season productivity of *Aedes* are followed by increased mid to late-season productivity in other genera.

Figure 6 displays 2014 weather and discharge data with post-hoc NMPM predictions for the three less-abundant genera of mosquitoes, *Anopheles, Culex, and Culiseta*. These three genera account for much of the larval productivity in the mid and late seasons (38% of mid-season and 85% of late season).

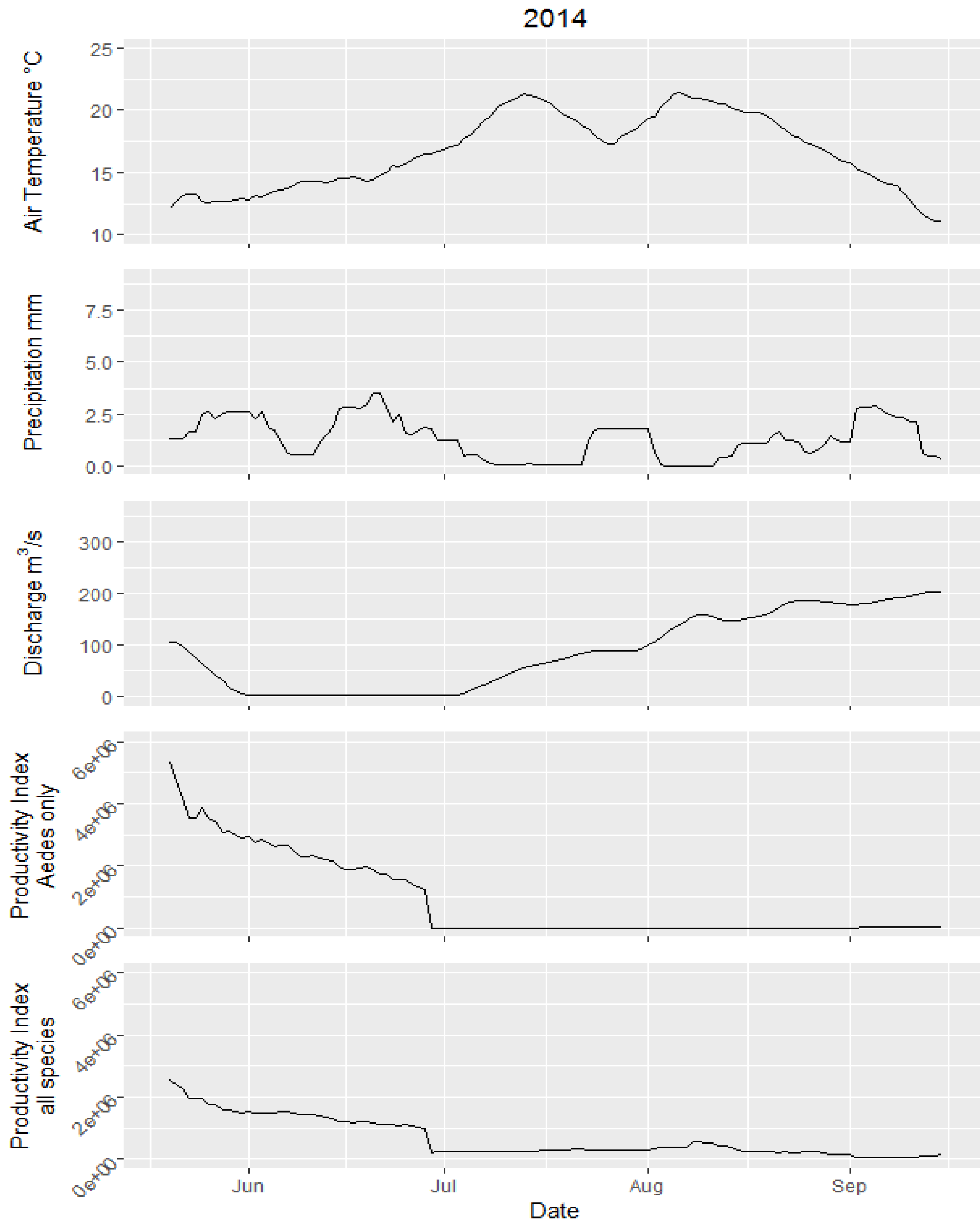


Figure 5: 2014 Levels of environmental factors and discharge of the Duncan Dam, along with predicted levels of total larval productivity for 1) *Aedes* only and 2) all species pooled. For the *Aedes* only model, predicted productivity of the mid and late seasons are non-zero but negligible relative to the early season. Modelling all species as a single group has the effect of reducing predicted early season productivity and raising predicted mid and late season productivity. k = 0.2 (see Table 4 of the annual report, Lower Duncan River Mosquito Monitoring and Management Plan Development – Implementation Year 6 (Jackson et al., 2015)).

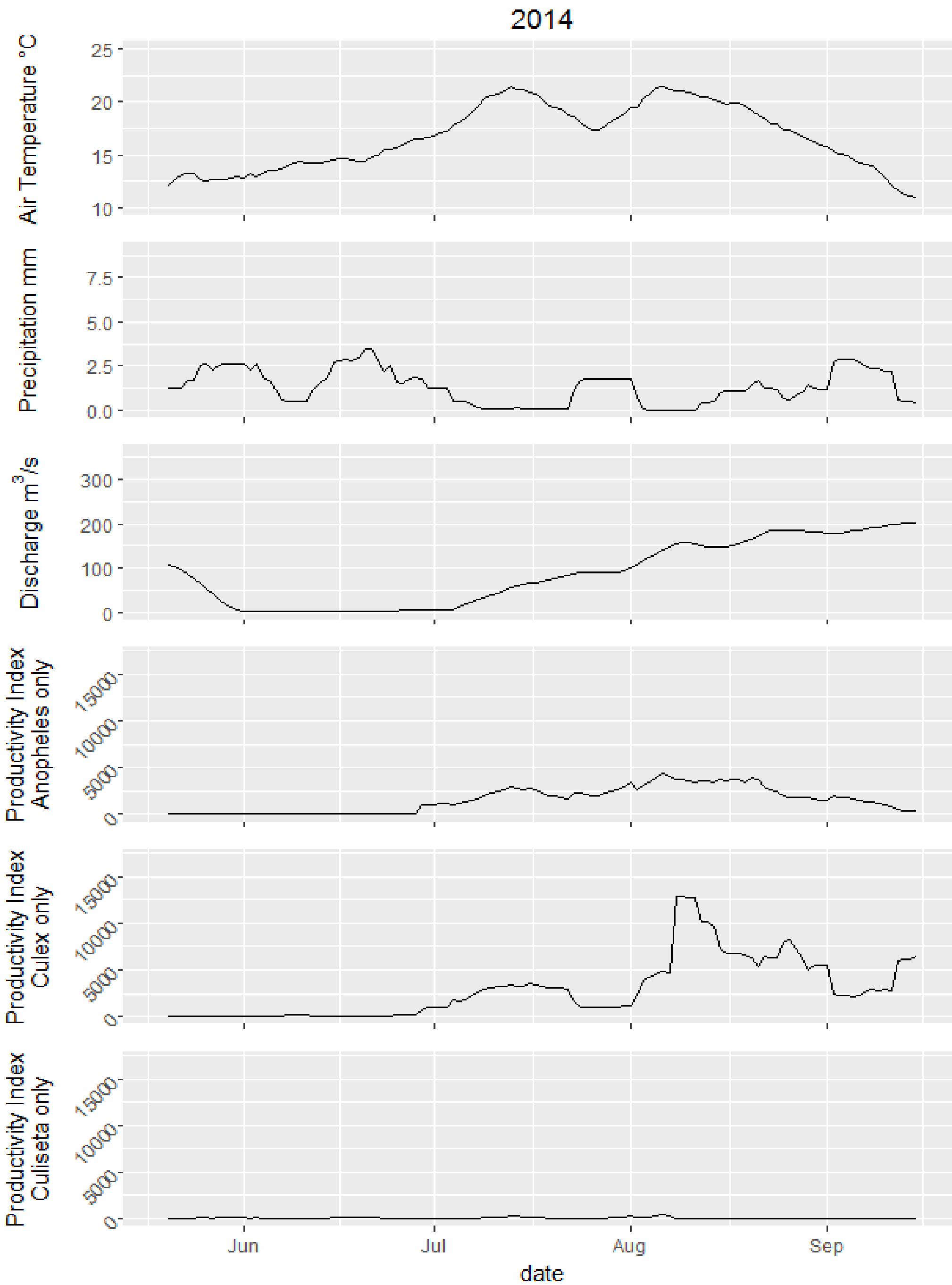
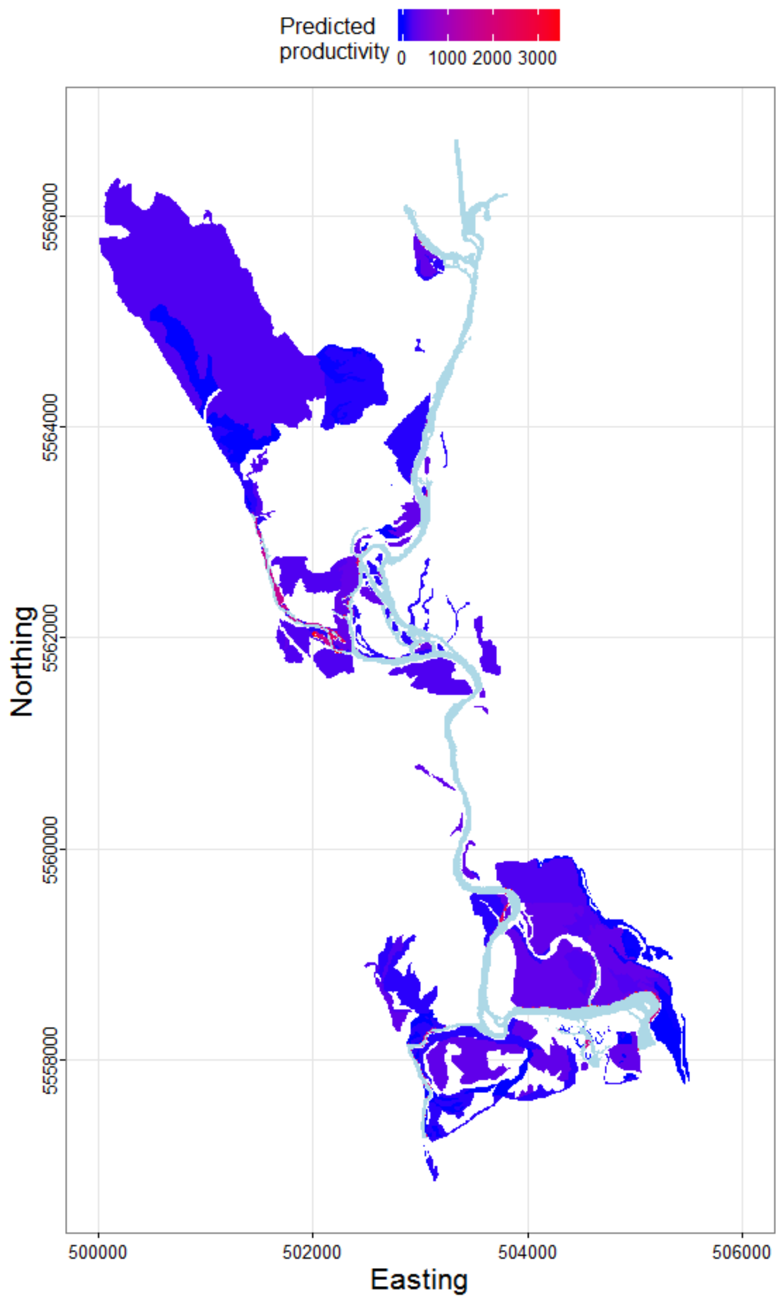


Figure 6: 2014 Levels of environmental factors and discharge of the Duncan Dam, along with predicted levels of total larval productivity for three genera of mosquitoes 1) *Anopheles* only, 2) *Culex* only, and 3) *Culiseta* only. *k* = 0.2 (see Table 4 of the annual report, Lower Duncan River Mosquito Monitoring and Management Plan Development – Implementation Year 6 (Jackson et al., 2015)). Note that the scale of predicted larval productivity on this figure is far lower than the preceding figure (Figure 5).

Figure 7 through Figure 11 are maps of predicted *Aedes* larval production among six classes of dominant vegetation. Each of the first three maps represents a different level of dam discharge for the early season (75, 200, and 300 m^3/s respectively). Colour differences among these maps show where early season discharge level is expected to influence larval productivity. Using the same colour scale, the maps in Figure 10 and Figure 11 show *Aedes* larval production for the late season at discharges of 75 and 200 m^3/s. Predicted *Aedes* larval production for the late period is negligible relative to the early season and the different discharge levels are indistinguishable.

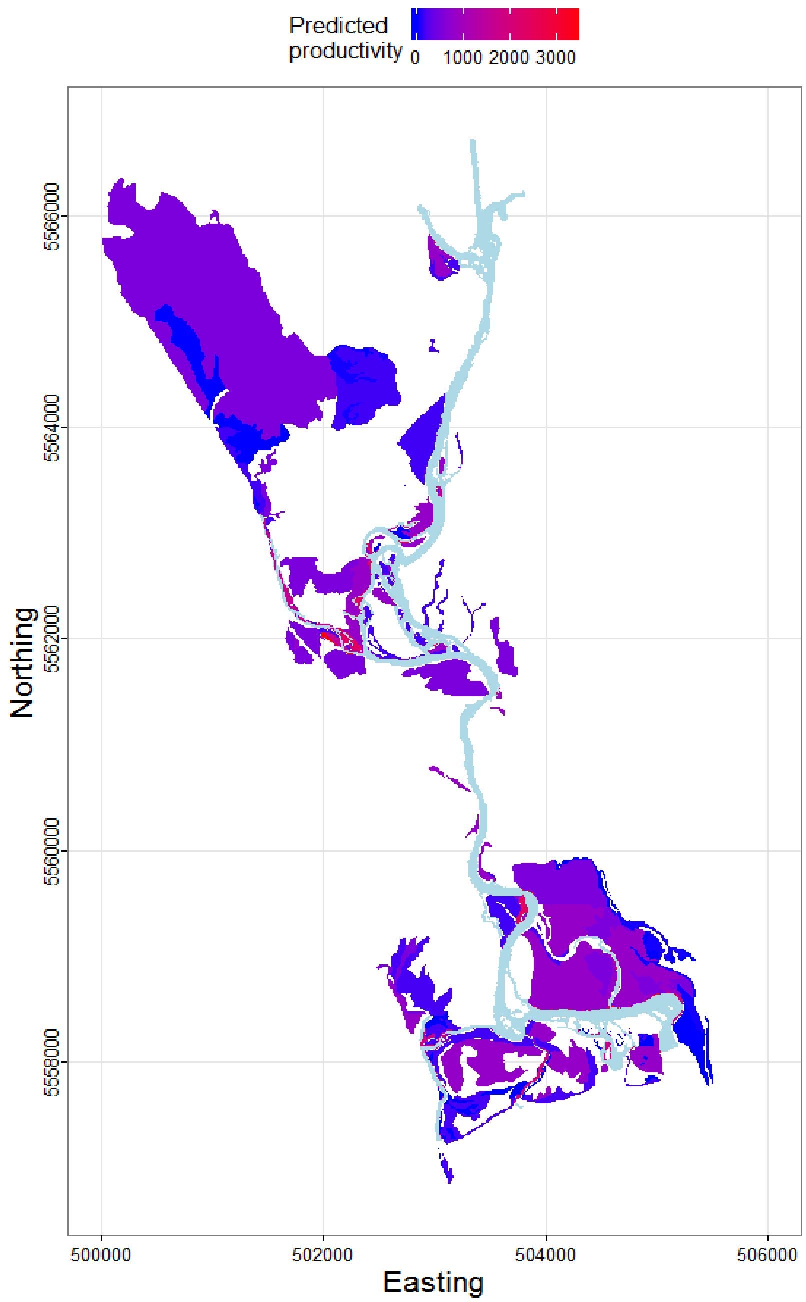
Figures 12 through 16 are maps with the same environmental input levels as

Figure 7 through Figure 11, but they were produced using NMPM predictions for all species pooled. The early season colours are less intense than the *Aedes* maps, reflecting lower predicted larval productivity.



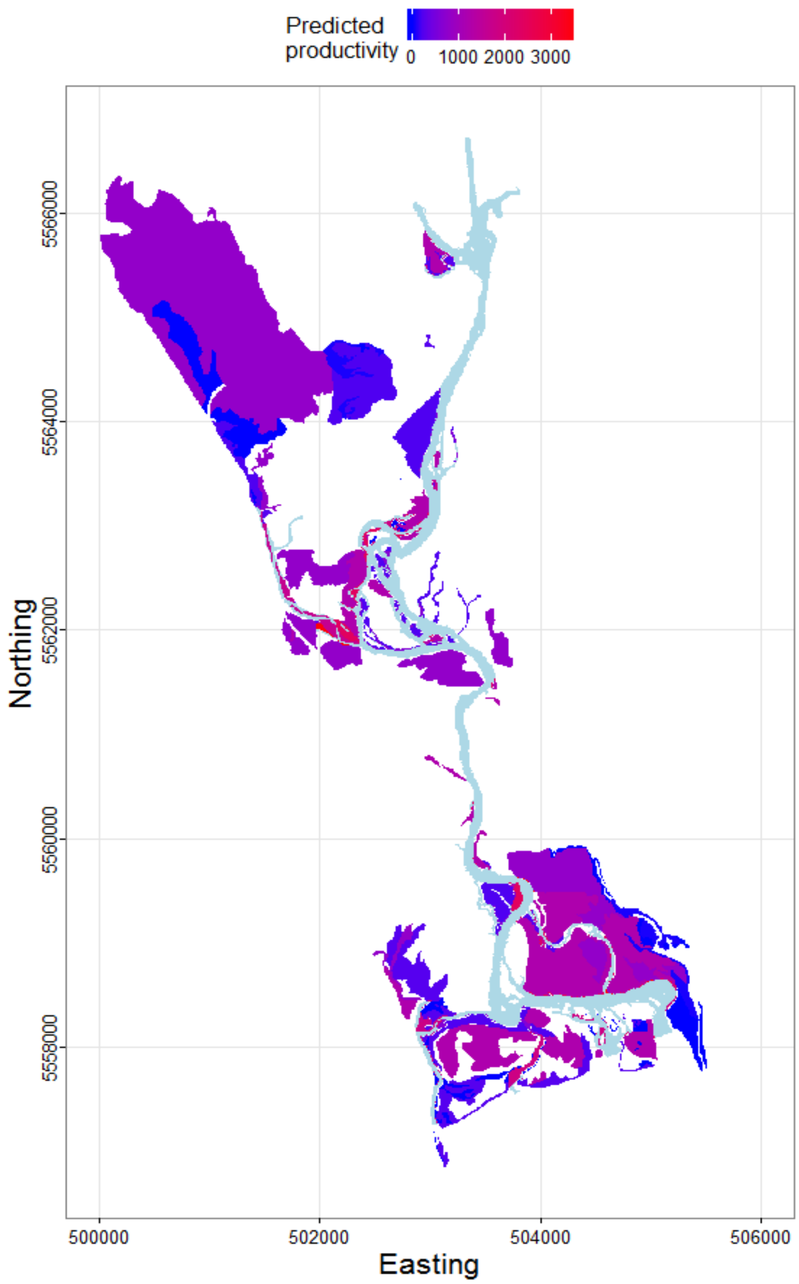
Early Season Dam Discharge level 75 m^3/s

Figure 7: Heat map showing relative predicted productivity of potential habitat for larval *Aedes* mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 75; season = early; air temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812.



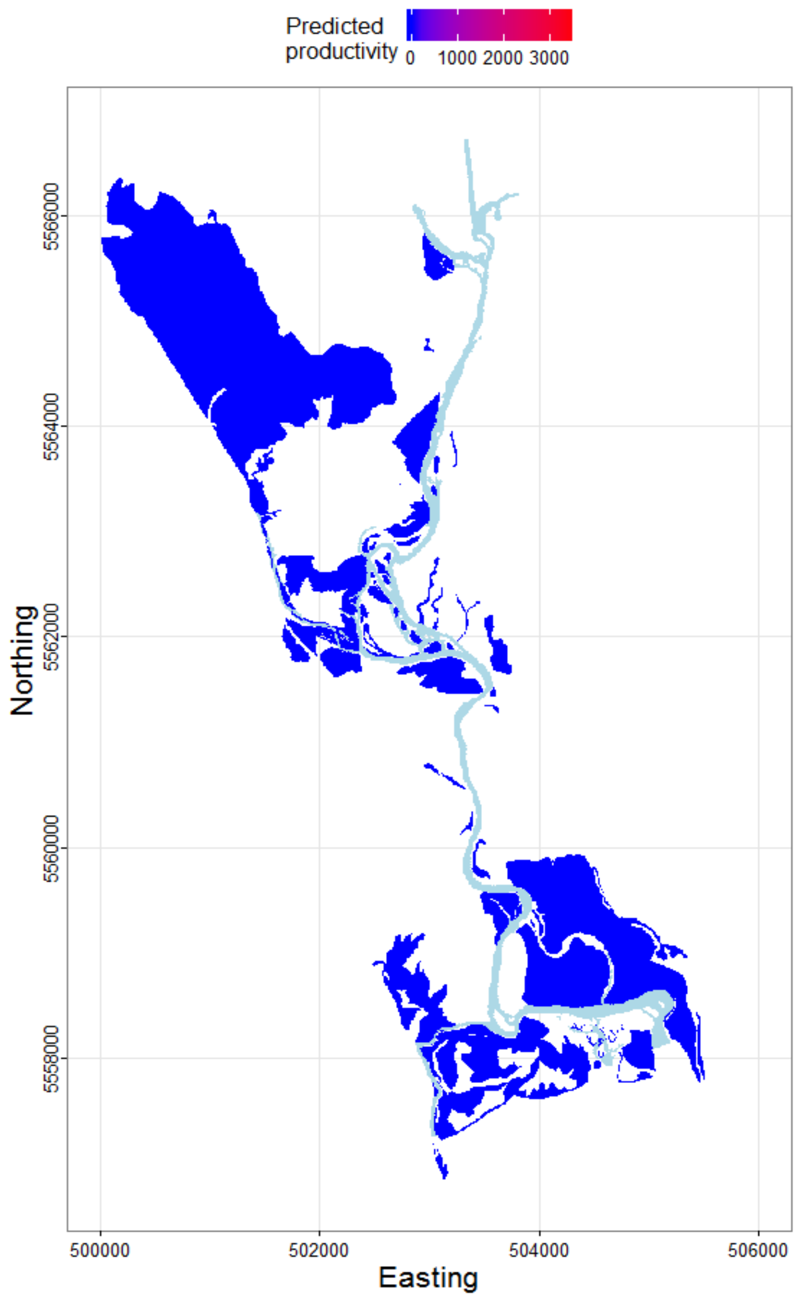
Early Season Dam Discharge Level 200 m^3/s

Figure 8: Heat map showing relative predicted productivity of potential habitat for larval *Aedes* mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 200; season = early; air temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812



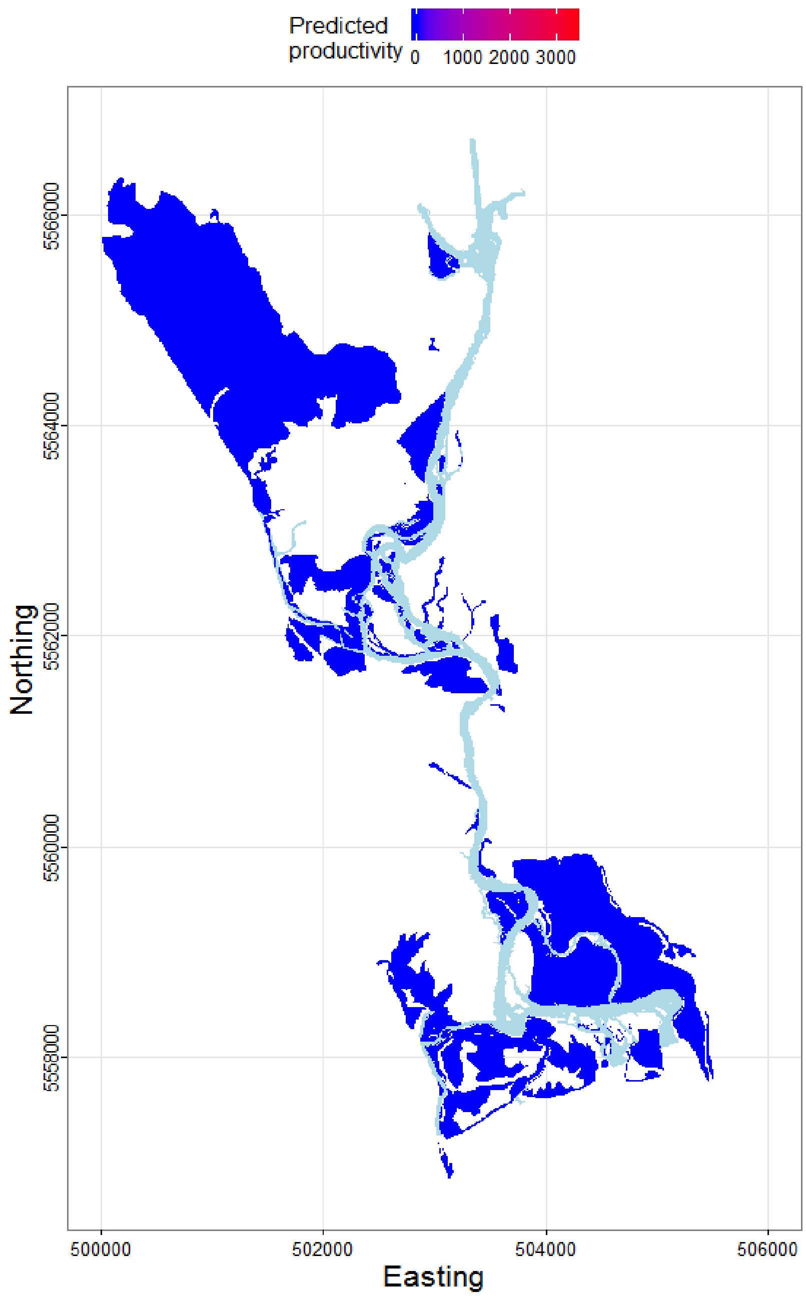
Early Season Dam Discharge Level 300 m³/s

Figure 9: Heat map showing relative predicted productivity of potential habitat for larval *Aedes* mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 300; season = early; air Temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812



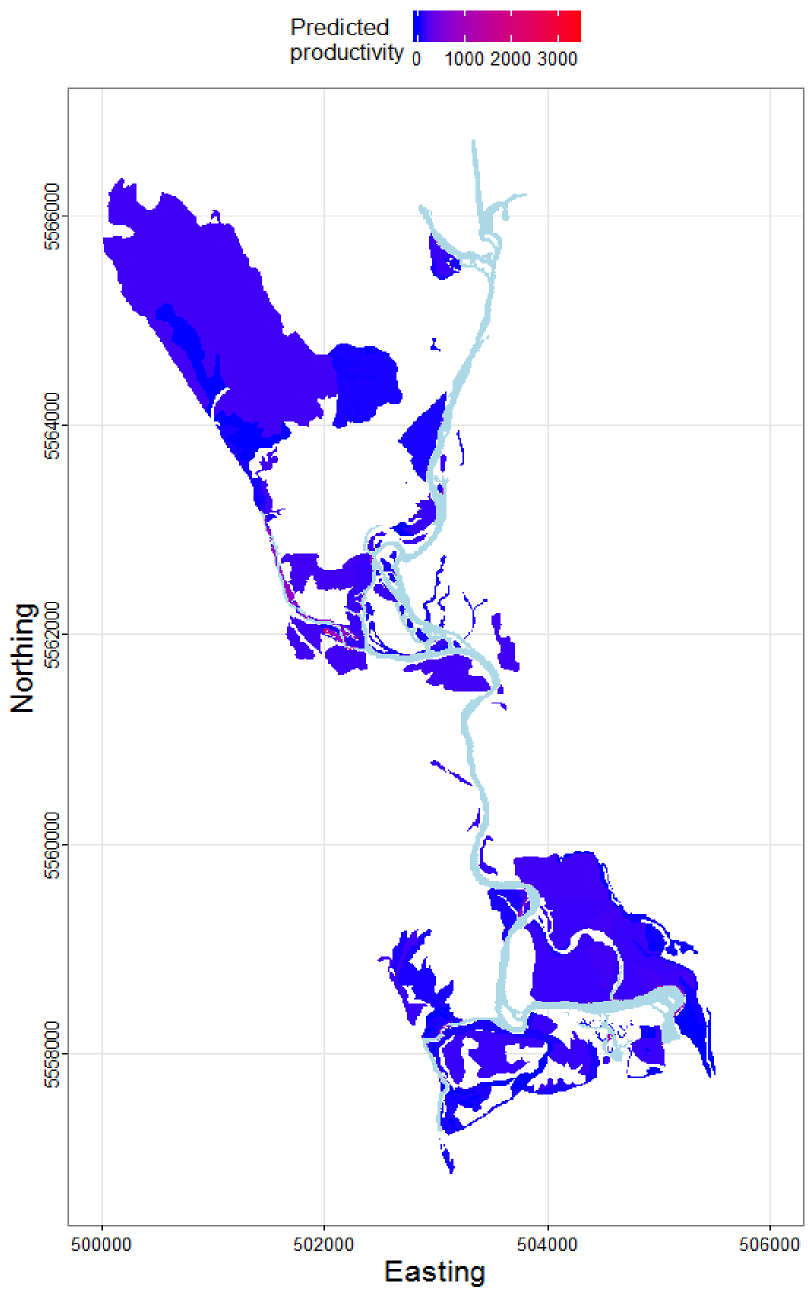
Late Season Dam Discharge Level 75 m³/s

Figure 10: Heat map showing relative predicted productivity of potential habitat for larval *Aedes* mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 75; season = late; air Temperature = 16.61; precipitation = 1.05; adj = 0.7; fthresh = 2.953



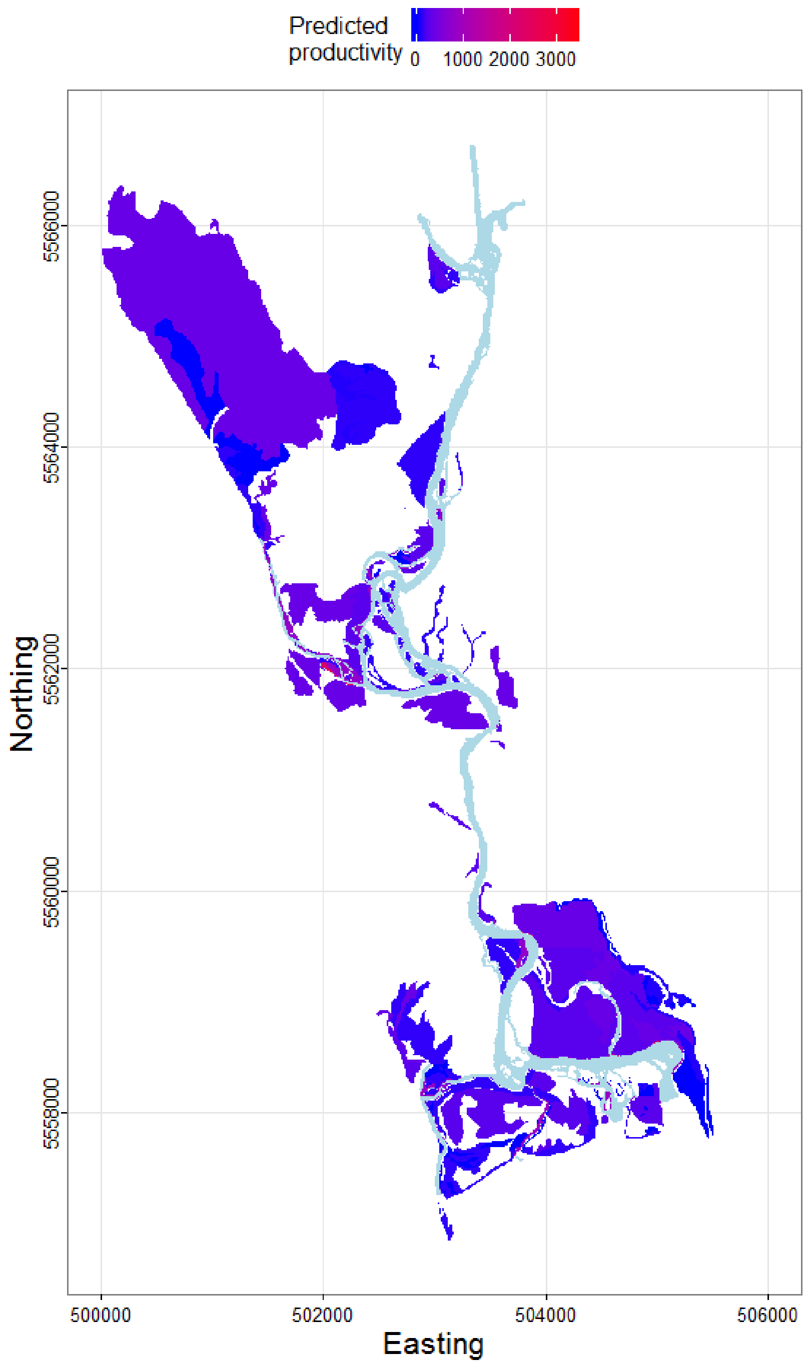
Late Season Dam Discharge Level 300 m^3/s

Figure 11: Heat map showing relative predicted productivity of potential habitat for larval *Aedes* mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 300; season = late; air Temperature = 16.61; precipitation = 1.05; adj = 0.7; fthresh = 2.953.



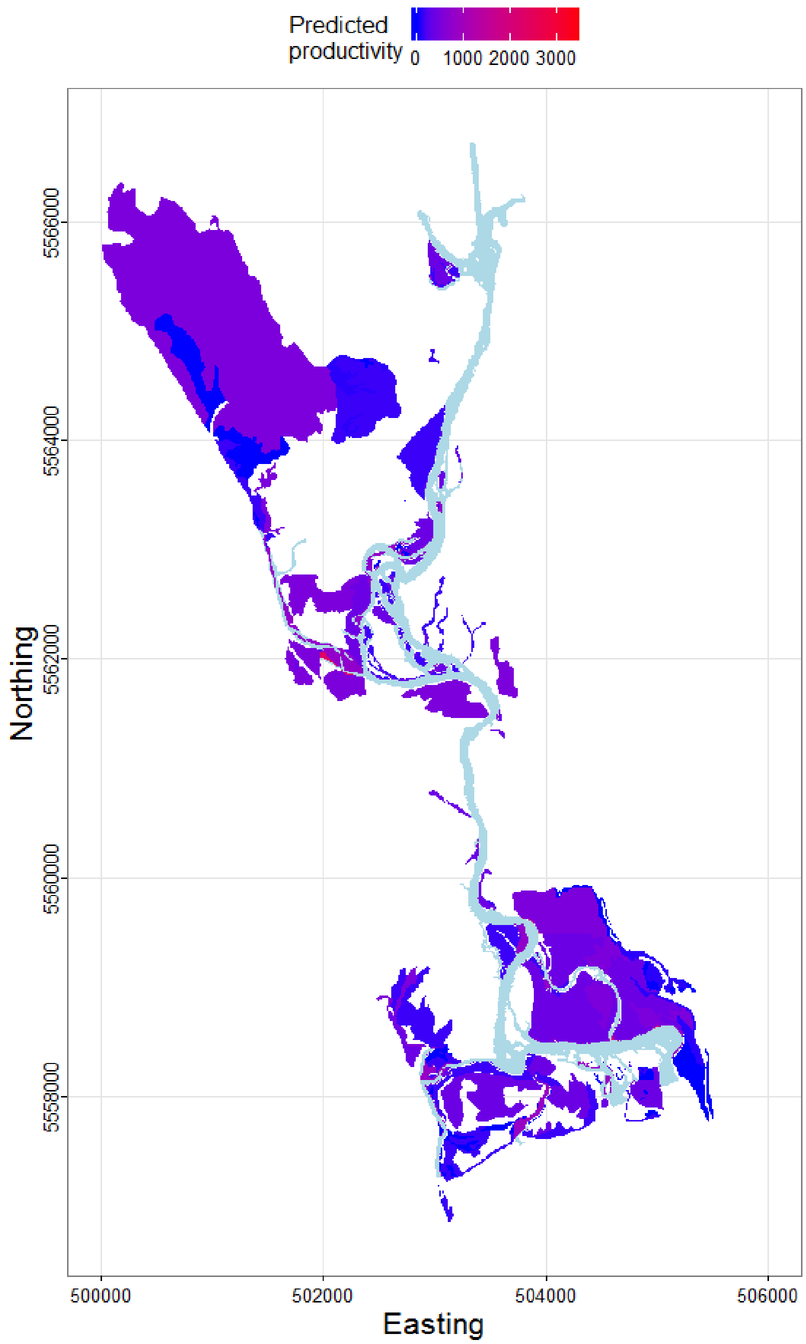
Early Season Dam Discharge Level 75 m^3/s

Figure 12: Heat map showing relative predicted productivity of potential habitat for all larval mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 75; season = early; air Temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812.



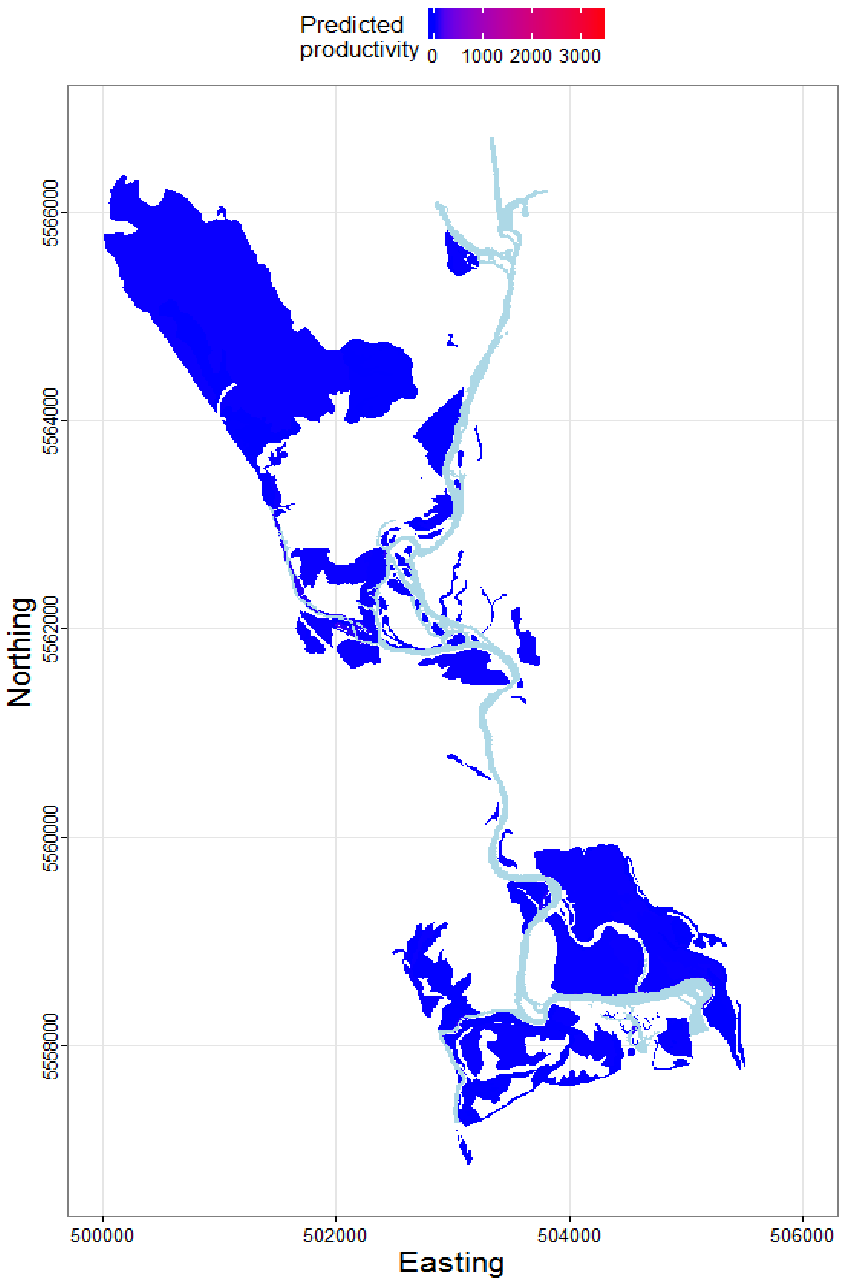
Early Season Dam Discharge Level 200 m^3/s

Figure 13: Heat map showing relative predicted productivity of potential habitat for all larval mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 200; season = early; air Temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812.



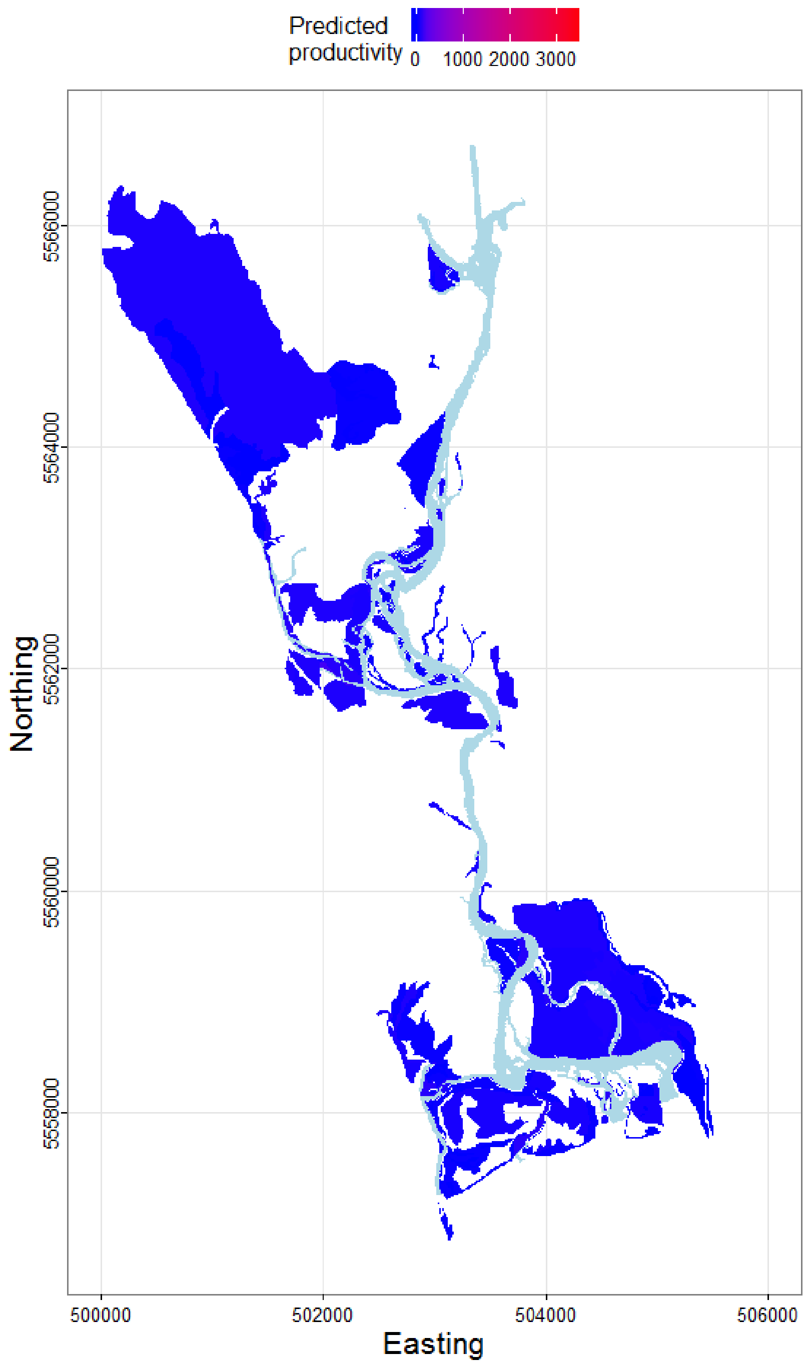
Early Season Dam Discharge Level 300 m³/s

Figure 14: Heat map showing relative predicted productivity of potential habitat for all larval mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 300; season = early; air Temperature = 12.00; precipitation = 2.09; adj = 0.7; fthresh = 2.812.



Late Season Dam Discharge Level 75 m³/s

Figure 15: Heat map showing relative predicted productivity of potential habitat for all larval mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 75; season = late; air temperature = 16.61; precipitation = 1.05; adj = 0.7; fthresh = 2.953.



Late Season Dam Discharge Level 300 m³/s

Figure 16: Heat map showing relative predicted productivity of potential habitat for all larval mosquitoes. Coloured areas correspond to six distinct classes of dominant vegetation classes. Parameter input levels: discharge = 300; season = late; air Temperature = 16.61; precipitation = 1.05; adj = 0.7; fthresh = 2.953.

4.0 Discussions and Conclusions

Summary of Results:

Results of the NMPM calculator demonstrate the following:

- Time of year (early, mid, late season) most strongly affects productivity of different species of mosquito larvae.
- There are strong relationships between occurrence of different mosquito species and dominant vegetation.
- Air temperature and precipitation have an important effect on the numbers of larvae.

Statistical relationships (regression coefficients) were used within a GIS framework to estimate total productivity for the floodplain. Predicted productivities of aquatic larval mosquito habitat were summed up across all the various vegetation types, during different times of season, under specified weather conditions.

Importantly, the NMPM calculator assumes that availability of larval mosquito habitat is determined by the recent level of discharge from the Duncan Dam. That is, if all other factors are held equal, the model assumes that mosquito productivity is determined by dam discharge because it provides water for larval mosquito habitat.

Environmental scenarios that use historical data show that predicted larval productivity is primarily determined by mosquito phenology (biologically driven seasonal differences in mosquito occurrence). Figure 5 shows that predicted production of *Aedes* larvae drops precipitously from the early to the mid period, and remains relatively low through the late period. This seasonal dynamic consistently dominates the predictions despite the model assumption that larval habitat availability increases with the level of dam discharge over the season (see results of sensitivity analysis in Appendix 3). These results suggest that dam discharge is not a major predictor of *Aedes* larval productivity.

The NMPM calculator can be parameterized to predict larval productivity for all four genera of larvae, as well as mean productivity of all species considered together (Figure 5 and Figure 6). Post-hoc predicted dynamics of each genus is qualitatively distinct (note that the larval index scales differ dramatically between productivity graphs on Figure 5 and Figure 6). These distinct dynamics among genera uphold the expectation that the different genera are ecologically unique. Much of the predicted pattern for all-species, however, appears to follow the *Aedes* dynamic (Figure 5). This is because most of larval counts in the pooled species data were *Aedes*. Thus, the all-species model provides estimates that ignore a substantial amount of the ecological information available from the data and are heavily biased toward *Aedes*. Thus when considering larval dynamics, it is most informative to consider the individual contributions of each genus.

Conclusions:

There are four ecologically distinct genera of mosquitoes found on the floodplain, *Aedes, Anopheles, Culex*, and *Culiseta*. *Aedes* mosquitoes are by far the dominant group of mosquitoes on the Duncan-Lardeau floodplain, and they have been identified as a nuisance. Time of season is the dominant factor determining productivity of *Aedes* mosquitoes, with the vast majority of *Aedes* larvae being produced in the early season. Larval productivity is also influenced by dominant vegetation, air temperature and precipitation. Dam discharge at current levels does not appear to play an important role in the dynamics of larval *Aedes*.

The NMPM calculator has been updated and re-parametrized to include mosquito abundance data collected in 2016. These new data enabled testing of the vegetation sub-model and provided larval count data for an earlier time of season than in previous sampling years. There are now sufficient data to inform the predictive model and no further sampling is required. Results of model validation indicate that the NMPM calculator provides accurate, unbiased predictions of larval productivity.

5.0 References

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Jackson, MJ, Bull, J, and Phelan, C. 2002. The influence of the Duncan Dam on the Mosquito Populations of the Lower Duncan Floodplain. 2002 Final Report. Submitted to BC Hydro.

Jackson, MJ, Evelyn, MJ, McMahon, TJS, and Sheppard, J. 2009. Lower Duncan River Mosquito Monitoring and Management Plan Development. Implementation Year 1. Reference: DDMMON#9. Study Period: 2009

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Jackson, MJ and McMahon, TJS. 2011. Mosquito abatement program recommendations: enhancing the control of nuisance mosquito larvae in the Duncan floodplain. Submitted to BC Hydro April 7, 2011.

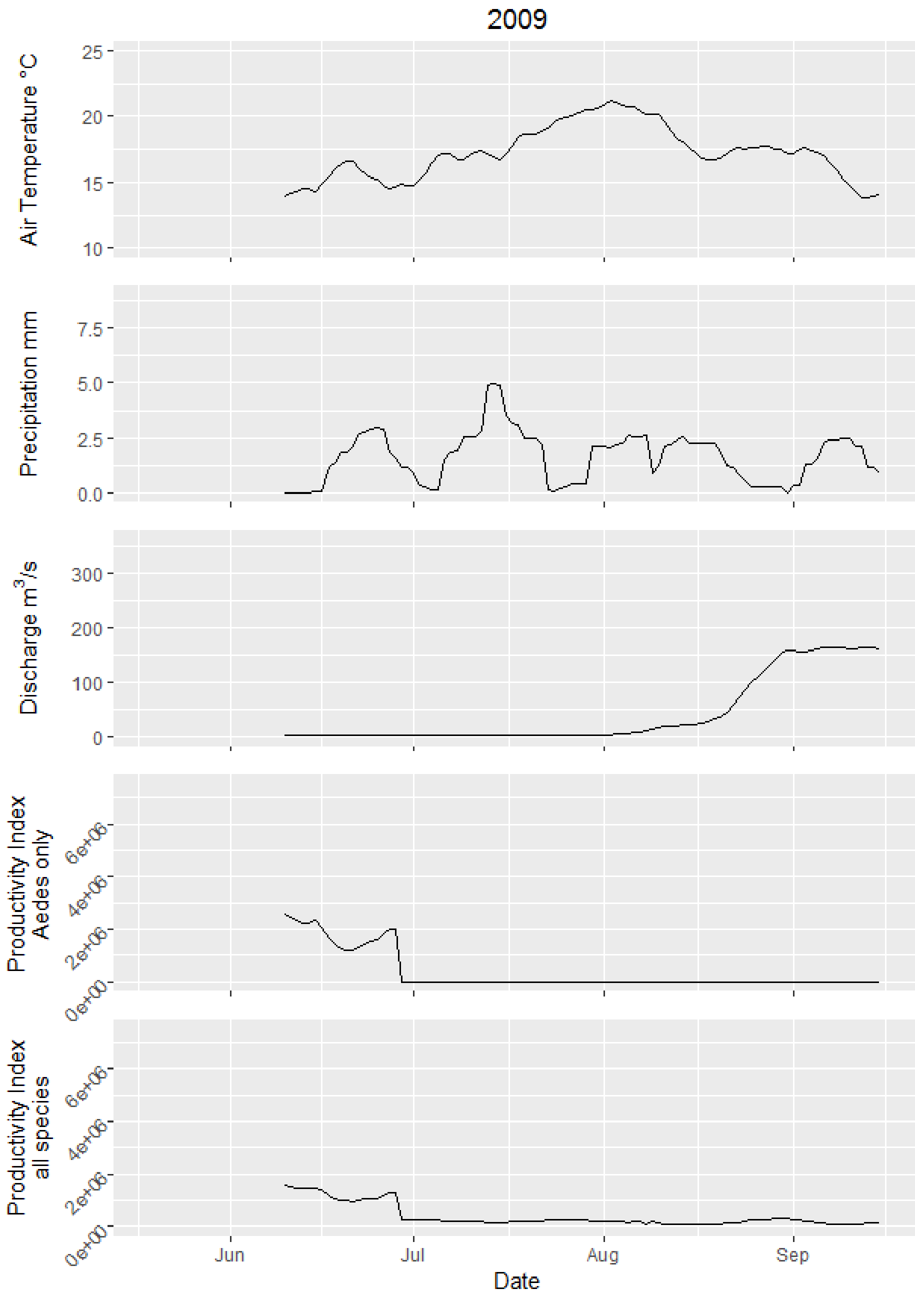
Jackson, MJ, McMahon, TJS, and Sheppard, J. 2011. Lower Duncan River Mosquito Monitoring and Management Plan Development. Implementation Year 3. Reference: DDMMON#9. Study Period: 2011

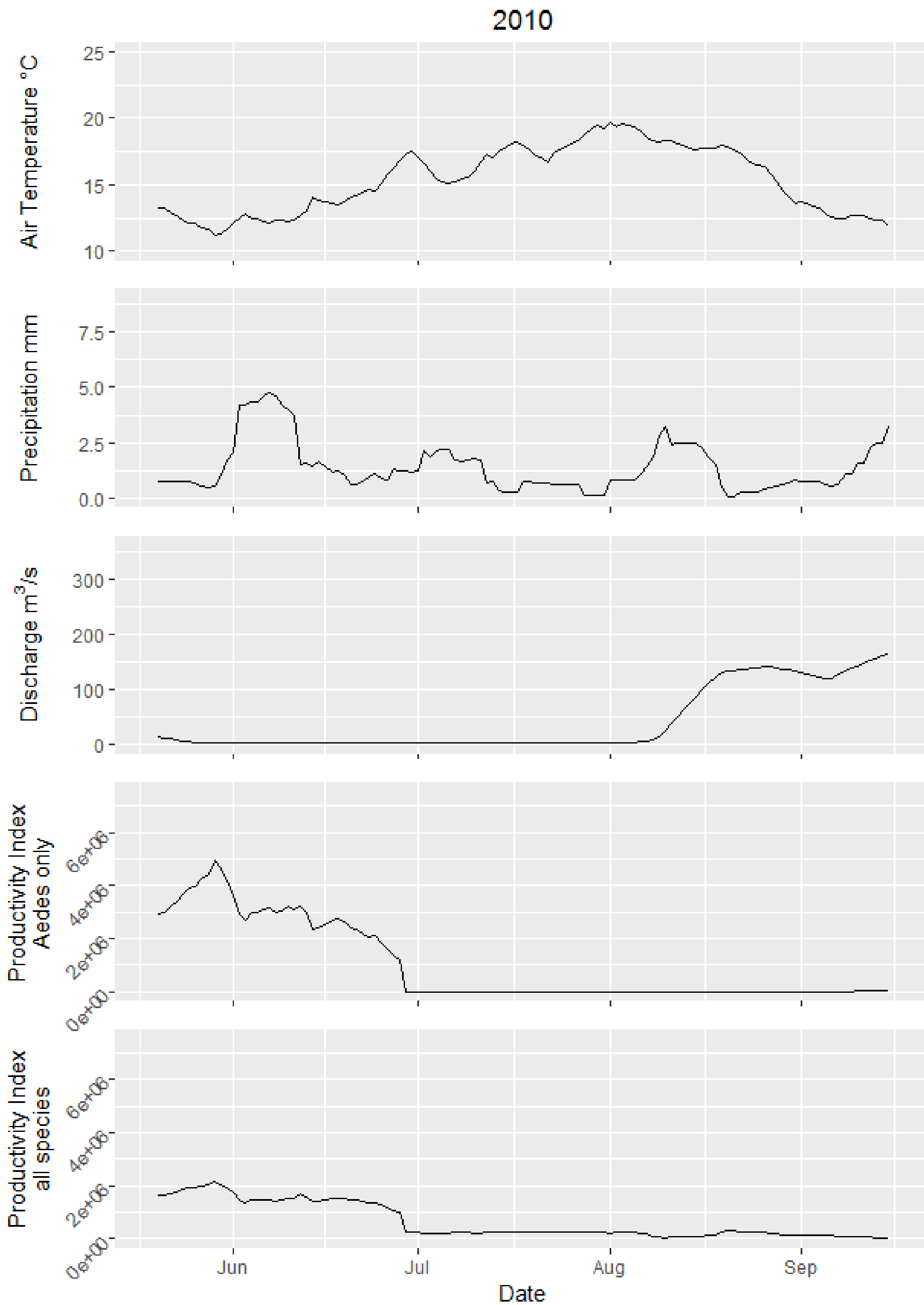
Jackson, MJ, McMahon, TJS, Thielman, A., Herbison, B., Rodman, S., Howay, T., and Phelan, C. 2012. Lower Duncan River Mosquito Monitoring and Management Plan Development. Implementation Year 4. Reference DDMMON#9. Study Period: 2012.

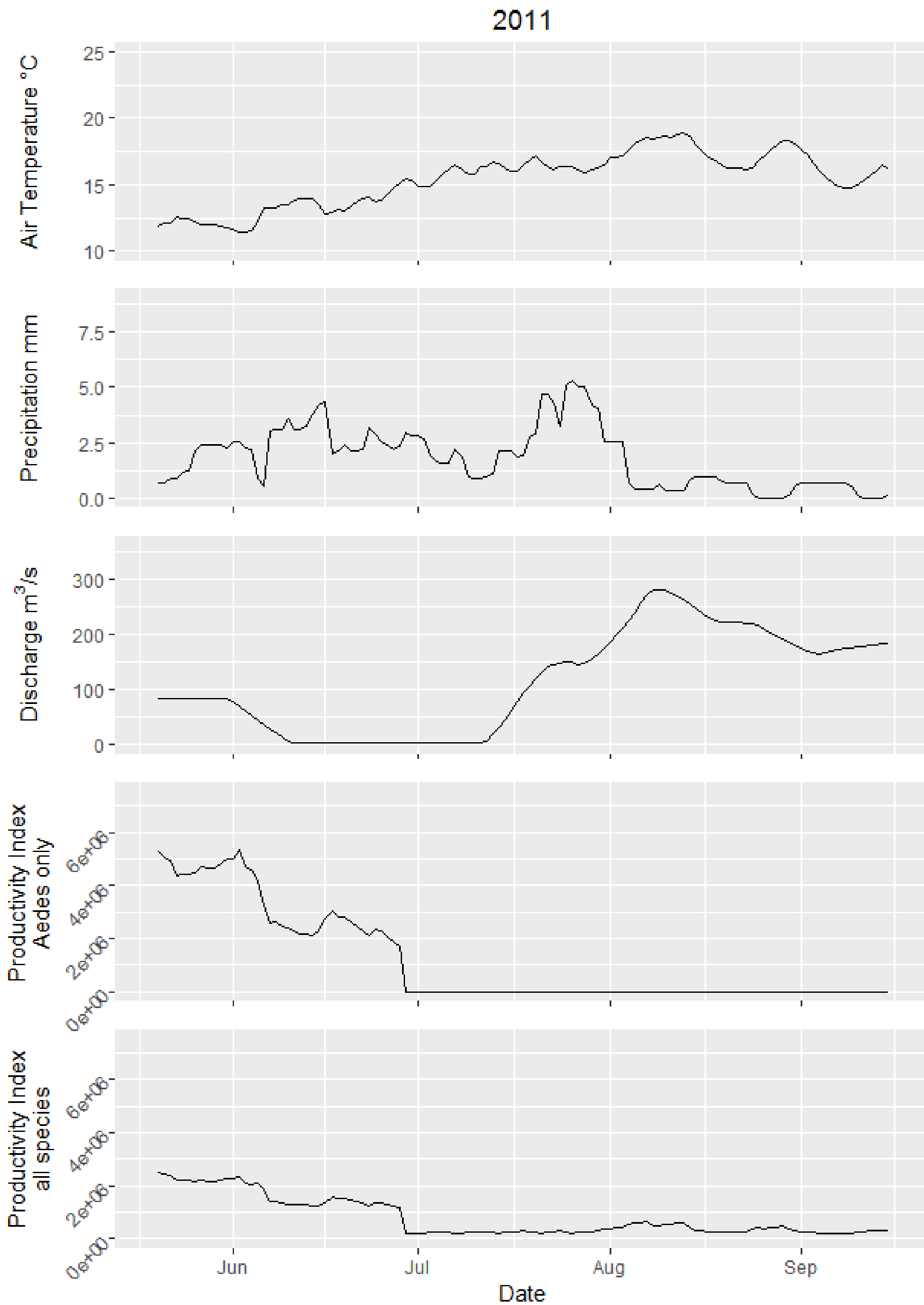
Jackson, MJ, Phelan, C, Scholefield, J, McMahon, TJS, and Munshaw, R. 2015. Lower Duncan River Mosquito Monitoring and Management Plan Development. Implementation Year 6. Reference DDMMON#9. Study Period: 2014-2015.

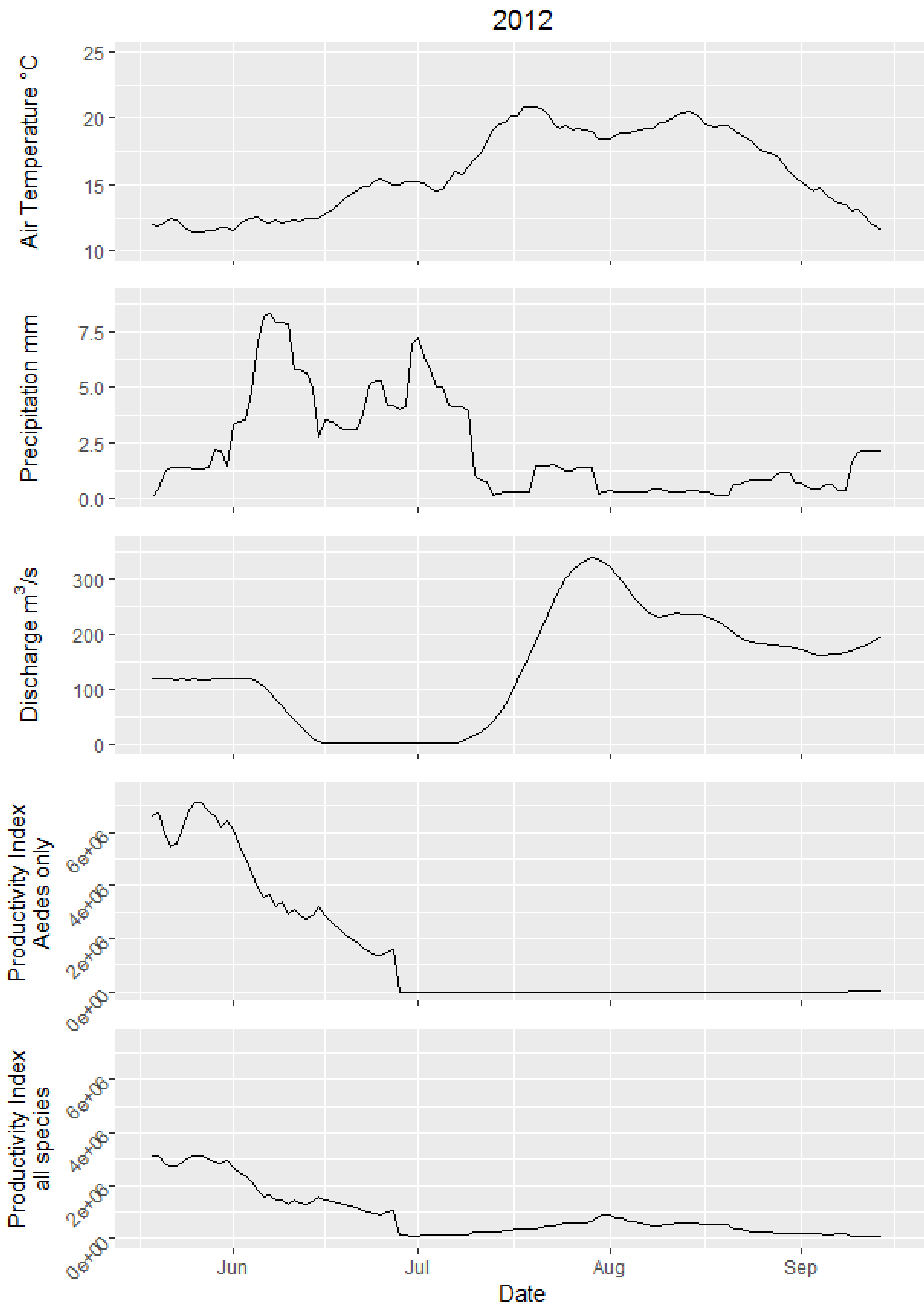
Appendix 1.

Post hoc predictions of seasonal total larval productivity for preceding years. Predictions are based on levels of environmental factors, including air temperature, precipitation, as well as dam discharge.




2010
Air Temperature °C
25
20
15
10
Precipitation mm
7.5
5.0
2.5
0.0
Discharge m3/s
300
200
100
0
Productivity Index
Aedes only
6e+06
4e+06
2e+06
0e+00
Productivity Index
all species
6e+06
4e+06
2e+06
0e+00
Jun
Jul
Aug
Sep
Date


2011
Air Temperature °C
25
20
15
10
Precipitation mm
7.5
5.0
2.5
0.0
Discharge m³/s
300
200
100
0
Productivity Index
Aedes only
6e+06
4e+06
2e+06
0e+00
Productivity Index
all species
6e+06
4e+06
2e+06
0e+00
Jun
Jul
Aug
Sep
Date


2012
Air Temperature °C
25
20
15
10
Precipitation mm
7.5
5.0
2.5
0.0
Discharge m³/s
300
200
100
0
Productivity Index
Aedes only
6e+06
4e+06
2e+06
0e+00
Productivity Index
all species
6e+06
4e+06
2e+06
0e+00
Jun
Jul
Aug
Sep
Date

Appendix 2.

Table A1. Larval Identification of samples collected at the 13 DDM sites on nine sampling days between May and August 2016.

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-05-06	DDM-01	216	112			2			110									
2016-05-06	DDM-02	160	35			8			27									
2016-05-06	DDM-03	0	0															
2016-05-06	DDM-04	1	2											2				
2016-05-06	DDM-05	33	22			1	7		10									4
2016-05-06	DDM-06	19	21						19									2
2016-05-06	DDM-07	52	30						30									
2016-05-06	DDM-08	30	15						9								6	
2016-05-06	DDM-09	24	11						2		5	3						1
2016-05-06	DDM-10	0	0															
2016-05-06	DDM-11	8	1						1									
2016-05-06	DDM-12	142	103					1	82									10
2016-05-06	DDM-13	24	10						10									
Total		**709**	**362**	**0**	**0**	**11**	**7**	**1**	**300**	**0**	**5**	**3**	**0**	**2**	**0**	**0**	**6**	**17**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-05-20	DDM-01	43	15		1				12							2		
2016-05-20	DDM-02	205	145						145									
2016-05-20	DDM-03	17	3											3				
2016-05-20	DDM-04	17	18		1									16				1
2016-05-20	DDM-05	14	4						3									1
2016-05-20	DDM-06	0	0															
2016-05-20	DDM-07	38	4						3									1
2016-05-20	DDM-08	2	2											1			1	
2016-05-20	DDM-09	5	1									1						
2016-05-20	DDM-10	0	0															
2016-05-20	DDM-11	5	3						3									
2016-05-20	DDM-12	22	10		4				2									4
2016-05-20	DDM-13	7	2											2				
Total		**375**	**207**	**0**	**6**	**0**	**0**	**0**	**168**	**0**	**0**	**1**	**0**	**22**	**0**	**2**	**1**	**7**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-06-01	DDM-01	2	2						1					1				
2016-06-01	DDM-02	DRY	DRY															
2016-06-01	DDM-03	2	2	1					1									
2016-06-01	DDM-04	0	0															
2016-06-01	DDM-05	48	20	1	13				6									
2016-06-01	DDM-06	134	141		29				95									17
2016-06-01	DDM-07	0	0															
2016-06-01	DDM-08	2	0															
2016-06-01	DDM-09	0	0															
2016-06-01	DDM-10	0	0															
2016-06-01	DDM-11	0	0															
2016-06-01	DDM-12	2	1		1													1
2016-06-01	DDM-13	1	0															
Total		**191**	**166**	**2**	**43**	**0**	**0**	**0**	**103**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**18**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-06-10	DDM-01	141	5		2													3
2016-06-10	DDM-02	DRY	DRY															
2016-06-10	DDM-03	0	0															
2016-06-10	DDM-04	0	0															
2016-06-10	DDM-05	6																
2016-06-10	DDM-06	36	29	5	10				3									11
2016-06-10	DDM-07	0	0															
2016-06-10	DDM-08	0	0															
2016-06-10	DDM-09	0	0															
2016-06-10	DDM-10	0	0															
2016-06-10	DDM-11	0	0															
2016-06-10	DDM-12	4	0															
2016-06-10	DDM-13	9	2											2				
Total		**196**	**36**	**5**	**12**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**14**

2016-06-22	DDM-01	DRY	DRY																
2016-06-22	DDM-02	DRY	DRY																
2016-06-22	DDM-03	0	0																
2016-06-22	DDM-04	1	2									1				1			
2016-06-22	DDM-05	20	7		7														
2016-06-22	DDM-06	15	1													1			
2016-06-22	DDM-07	0	0																
2016-06-22	DDM-08	2																	
2016-06-22	DDM-09	DRY	DRY																
2016-06-22	DDM-10	DRY	DRY																
2016-06-22	DDM-11	0	0																
2016-06-22	DDM-12	25	11						1				7	1		2			
2016-06-22	DDM-13	1																	
Total		**64**	**21**	**0**	**7**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**7**	**1**	**0**	**4**	**0**	**0**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-07-02	DDM-01	DRY	DRY															
2016-07-02	DDM-02	DRY	DRY															
2016-07-02	DDM-03	DRY	DRY															
2016-07-02	DDM-04	0	0															
2016-07-02	DDM-05	19	14		14													
2016-07-02	DDM-06	0	0															
2016-07-02	DDM-07	5	0															
2016-07-02	DDM-08	DRY	DRY															
2016-07-02	DDM-09	0	0															
2016-07-02	DDM-10	0	0															
2016-07-02	DDM-11	0	0															
2016-07-02	DDM-12	DRY	DRY															
2016-07-02	DDM-13	DRY	DRY															
Total		**24**	**14**	**0**	**14**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2016-08-02	DDM-01	DRY	DRY															
2016-08-02	DDM-02	DRY	DRY															
2016-08-02	DDM-03	DRY	DRY															
2016-08-02	DDM-04	DRY	DRY															
2016-08-02	DDM-05	DRY	DRY															
2016-08-02	DDM-06	DRY	DRY															
2016-08-02	DDM-07	DRY	DRY															
2016-08-02	DDM-08	DRY	DRY															
2016-08-02	DDM-09	DRY	DRY															
2016-08-02	DDM-10	DRY	DRY															
2016-08-02	DDM-11	DRY	DRY															
2016-08-02	DDM-12	DRY	DRY															
2016-08-02	DDM-13	DRY	DRY															
Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2016-08-13	DDM-01	DRY	DRY															
2016-08-13	DDM-02	DRY	DRY															
2016-08-13	DDM-03	DRY	DRY															
2016-08-13	DDM-04	DRY	DRY															
2016-08-13	DDM-05	DRY	DRY															
2016-08-13	DDM-06	DRY	DRY															
2016-08-13	DDM-07	DRY	DRY															
2016-08-13	DDM-08	DRY	DRY															
2016-08-13	DDM-09	DRY	DRY															
2016-08-13	DDM-10	DRY	DRY															
2016-08-13	DDM-11	DRY	DRY															
2016-08-13	DDM-12	DRY	DRY															
2016-08-13	DDM-13	DRY	DRY															
Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes cinereus*	*Aedes implicatus*	*Aedes intrudans*	*Aedes punctor*	*Aedes Vexans*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culex pipiens*	*Culex territans*	Unidentifiable Mosquito
2016-08-31	DDM-01	DRY	DRY															
2016-08-31	DDM-02	DRY	DRY															
2016-08-31	DDM-03	DRY	DRY															
2016-08-31	DDM-04	4	2								1	1						
2016-08-31	DDM-05	DRY	DRY															
2016-08-31	DDM-06	DRY	DRY															
2016-08-31	DDM-07	DRY	DRY															
2016-08-31	DDM-08	14	4		3					1								
2016-08-31	DDM-09	2	1									1						
2016-08-31	DDM-10	0	0															
2016-08-31	DDM-11	DRY	DRY															
2016-08-31	DDM-12	DRY	DRY															
2016-08-31	DDM-13	DRY	DRY															
Total		**20**	**7**	**0**	**3**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**

Table A2. Larval Identification of Vegetation Sites sampled in May, July and August 2016.

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes campestris*	*Aedes canadensis*	*Aedes cinereus*	*Aedes impiger*	*Aedes implicatus*	*Aedes sticticus*	*Aedes punctor*	*Aedes vexans*	*Aedes pullatus*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Anopheles punctipennis*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culiseta incidens*	*Culiseta mortisans*	*Culex tarsalis*	*Culex territans*	*Culex spp.*	Unidentifiable mosquito
2016-05-10	ALDR-01	80	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-02	25	4	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-03	28	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-04	9	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-05	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-06	8	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-07	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-08	4	7	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2016-05-10	ALDR-09	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
2016-05-10	ALDR-10	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	ALDR-11	17	6	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	1
2016-05-10	ALDR-12	22	13	0	0	0	1	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	1	0	5
2016-05-10	ALDR-13	10	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2	0	0
2016-05-11	ALDR-14	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	ALDR-15	9	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-01	12	8	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-05-11	CATL-02	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-03	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-05-11	CATL-05	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-07	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-11	6	7	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-12	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1	0
2016-05-11	CATL-13	4	7	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	CATL-14	16	10	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	6	0	0
2016-05-11	CATL-15	11	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0
2016-05-09	COTT-01	2	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-05-10	COTT-02	43	30	2	0	0	0	0	0	1	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-05-09	COTT-03	7	5	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-09	COTT-04	85	27	3	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2016-05-10	COTT-05	207	65	0	0	0	0	0	0	36	0	20	0	0	0	0	0	1	2	0	0	0	0	0	0	6
2016-05-10	COTT-06	84	24	0	5	0	0	0	0	3	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	COTT-07	39	10	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	6
2016-05-10	COTT-08	227	22	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	COTT-10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-05-10	COTT-11	6	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-09	COTT-12	168	36	0	0	0	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	COTT-14	4	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	1
2016-05-10	COTT-15	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-01	14	6	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-02	8	6	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-03	8	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-04	9	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-05	17	5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2016-05-10	GRAS-06	6	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	GRAS-07	11	3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1
2016-05-10	GRAS-08	235	194	0	0	0	0	0	8	0	0	184	0	0	0	0	0	2	0	0	0	0	0	0	0	0
2016-05-10	GRAS-09	22	8	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2016-05-11	GRAS-10	312	112	0	0	1	0	0	0	0	0	108	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2016-05-11	GRAS-11	195	43	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2016-05-10	GRAS-12	334	74	0	0	0	0	0	1	0	0	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-12	GRAS-13	1875	192	0	0	0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2016-05-12	GRAS-14	183	135	0	0	0	0	0	0	0	0	134	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2016-05-12	GRAS-15	1777	121	0	0	0	0	0	1	0	0	117	0	0	0	0	0	0	0	0	0	0	0	1	0	2
2016-05-11	HORS-02	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	HORS-03	4	4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-05-11	HORS-04	3	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	HORS-07	3	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2016-05-11	HORS-08	3	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	HORS-09	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2016-05-11	HORS-11	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	HORS-12	4	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	HORS-13	41	36	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	5	0	0	0	0	8	0	0
2016-05-11	HORS-14	66	57	0	0	0	0	0	0	0	0	47	0	0	0	0	0	1	1	0	0	0	0	7	0	1
2016-05-11	HORS-15	60	33	0	0	0	2	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2016-05-11	SEDG-01	19	13	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	10	0	0	0
2016-05-11	SEDG-02	9	6	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	SEDG-03	12	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0
2016-05-11	SEDG-04	18	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	0	0
2016-05-11	SEDG-05	14	10	0	0	0	1	0	0	0	0	8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2016-05-11	SEDG-06	12	5	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-11	SEDG-07	50	33	0	0	0	1	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2016-05-11	SEDG-08	34	38	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2016-05-10	SEDG-10	15	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	SEDG-11	16	6	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2016-05-10	SEDG-12	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	SEDG-13	27	6	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-05-10	SEDG-14	14	5	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	2
2016-05-10	SEDG-15	65	10	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		**6686**	**1532**	**9**	**5**	**1**	**6**	**0**	**13**	**44**	**1**	**1289**	**2**	**2**	**0**	**6**	**0**	**8**	**13**	**0**	**2**	**2**	**23**	**43**	**1**	**51**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes campestris*	*Aedes canadensis*	*Aedes cinereus*	*Aedes impiger*	*Aedes implicatus*	*Aedes sticticus*	*Aedes punctor*	*Aedes vexans*	*Aedes pullatus*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Anopheles punctipennis*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culiseta incidens*	*Culiseta mortisans*	*Culex tarsalis*	*Culex territans*	*Culex spp.*	Unidentifiable mosquito
2016-07-14	ALDR-04	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	ALDR-05	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2016-07-14	ALDR-07	11	10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	9	0	0	0
2016-07-14	ALDR-10	31	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	12	0	0
2016-07-14	ALDR-11	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
2016-07-14	ALDR-12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	ALDR-14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	ALDR-15	3	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-01	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-03	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	CATL-04	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-05	4	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
2016-07-13	CATL-06	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-07	2	3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0
2016-07-13	CATL-08	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-09	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	CATL-13	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-07-13	COTT-02	58	14	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	5	0	0
2016-07-13	COTT-03	23	6	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0
2016-07-13	COTT-04	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	COTT-05	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	COTT-07	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	0	0
2016-07-13	COTT-08	10	10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	0	1
2016-07-13	COTT-11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	COTT-15	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-02	4	4	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-03	20	8	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-04	15	8	0	0	0	0	0	0	0	0	0	0	1	0	7	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-05	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-06	4	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
2016-07-13	GRAS-10	23	17	0	0	0	0	0	0	0	0	0	0	1	0	16	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-11	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-13	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	GRAS-14	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	HORS-01	16	15	0	0	0	0	0	0	0	0	0	0	1	0	9	0	0	0	0	0	0	5	0	0	0
2016-07-13	HORS-02	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	HORS-03	46	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
2016-07-13	HORS-04	124	33	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	13	0	0	0
2016-07-13	HORS-05	100	40	0	0	0	0	0	0	0	0	0	0	0	1	13	0	0	0	0	0	0	25	1	0	0
2016-07-14	HORS-07	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
2016-07-14	HORS-08	5	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
2016-07-14	HORS-09	33	7	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0
2016-07-14	HORS-10	41	9	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	3	0	0	0
2016-07-14	HORS-11	57	8	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	2	1	0	0
2016-07-14	HORS-12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	HORS-13	11	24	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	16	0	0
2016-07-14	HORS-14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	HORS-15	6	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	SEDG-01	30	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2016-07-13	SEDG-02	91	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0
2016-07-13	SEDG-03	24	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	1
2016-07-13	SEDG-04	37	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
2016-07-13	SEDG-05	22	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
2016-07-13	SEDG-07	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	SEDG-08	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	SEDG-10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-13	SEDG-11	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-07-14	SEDG-12	18	4	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0
2016-07-14	SEDG-13	10	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
2016-07-14	SEDG-14	16	9	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	1	0	0	0	0
2016-07-14	SEDG-15	16	10	0	0	0	0	0	0	0	0	0	0	1	0	9	0	0	0	0	0	0	0	0	0	0
Total		**1051**	**315**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**7**	**6**	**149**	**2**	**3**	**1**	**0**	**0**	**1**	**68**	**73**	**0**	**7**

Date	Site ID	Total Larvae Collected	Total Larvae Identified	*Aedes spp.*	*Aedes campestris*	*Aedes canadensis*	*Aedes cinereus*	*Aedes impiger*	*Aedes implicatus*	*Aedes sticticus*	*Aedes punctor*	*Aedes vexans*	*Aedes pullatus*	*Anopheles spp.*	*Anopheles earlei*	*Anopheles freeborni*	*Anopheles punctipennis*	*Culiseta spp.*	*Culiseta alaskaensis*	*Culiseta impatiens*	*Culiseta incidens*	*Culiseta mortisans*	*Culex tarsalis*	*Culex territans*	*Culex spp.*	Unidentifiable mosquito
2016-08-17	ALDR-03	7	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
2016-08-17	ALDR-04	8	4	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0
2016-08-17	ALDR-05	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	ALDR-06	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	ALDR-10	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	ALDR-11	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	ALDR-13	26	33	2	0	0	9	0	0	0	0	5	0	0	0	0	0	3	0	6	7	0	0	0	0	1
2016-08-17	ALDR-14	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-17	ALDR-15	45	27	0	0	0	17	0	1	0	0	0	0	0	0	0	0	1	2	0	6	0	0	0	0	0
2016-08-17	CATL-01	1	6	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	1	1	0	0
2016-08-17	CATL-02	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-03	54	4	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-04	11	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-05	50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2016-08-17	CATL-07	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-08	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-09	5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-10	8	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-11	62	3	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-12	16	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
2016-08-16	CATL-13	0	9	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	1
2016-08-17	CATL-14	32	8	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
2016-08-17	CATL-15	13	11	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-01	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-02	5	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-03	70	59	0	0	0	6	0	0	41	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2016-08-16	COTT-04	28	20	0	0	0	4	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-05	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	COTT-07	27	19	0	0	0	3	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	COTT-08	3	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0
2016-08-17	COTT-09	4	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	COTT-12	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	COTT-13	21	14	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	COTT-14	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	COTT-15	7	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-01	68	5	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0	0	1
2016-08-16	GRAS-02	27	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-08-16	GRAS-03	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-04	4	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-05	10	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-06	6	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-07	7	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-08	64	6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0	0	0
2016-08-16	GRAS-09	44	14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	9	0	4	0
2016-08-16	GRAS-10	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-11	57	12	0	0	0	0	0	0	0	0	0	0	3	0	9	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-12	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2016-08-16	GRAS-13	216	15	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	1	0	0	0	3	0	0	1
2016-08-16	GRAS-14	107	10	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	3	0	0	0
2016-08-16	GRAS-15	18	5	0	0	0	1	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-01	33	15	0	0	0	4	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2016-08-16	HORS-02	21	2	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-03	42	18	0	0	0	1	0	0	3	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-04	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-05	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2016-08-16	HORS-07	15	5	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2016-08-16	HORS-08	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-09	12	6	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	HORS-10	27	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	HORS-11	18	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1
2016-08-17	HORS-12	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2016-08-17	HORS-13	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-17	HORS-14	55	15	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	13	0	0	0
2016-08-17	HORS-15	50	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1
2016-08-16	SEDG-01	15	4	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-02	10	5	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-03	17	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-04	38	23	0	0	0	0	0	0	15	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-05	17	9	0	0	0	1	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2016-08-16	SEDG-06	11	4	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-07	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-08	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016-08-16	SEDG-09	38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2016-08-16	SEDG-10	79	5	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
2016-08-16	SEDG-11	60	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
2016-08-17	SEDG-12	27	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
2016-08-17	SEDG-13	53	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
2016-08-17	SEDG-14	55	10	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0	1	0	0	1
2016-08-17	SEDG-15	35	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Total		**2019**	**468**	**5**	**0**	**0**	**62**	**1**	**1**	**93**	**0**	**81**	**0**	**5**	**4**	**110**	**0**	**4**	**3**	**6**	**13**	**0**	**57**	**4**	**4**	**15**

Appendix 3.

Results of a sensitivity analysis of the NMPM calculator parameterized with *Aedes* data from all sampling years up to and including 2016.

Effect of Dam Discharge Level

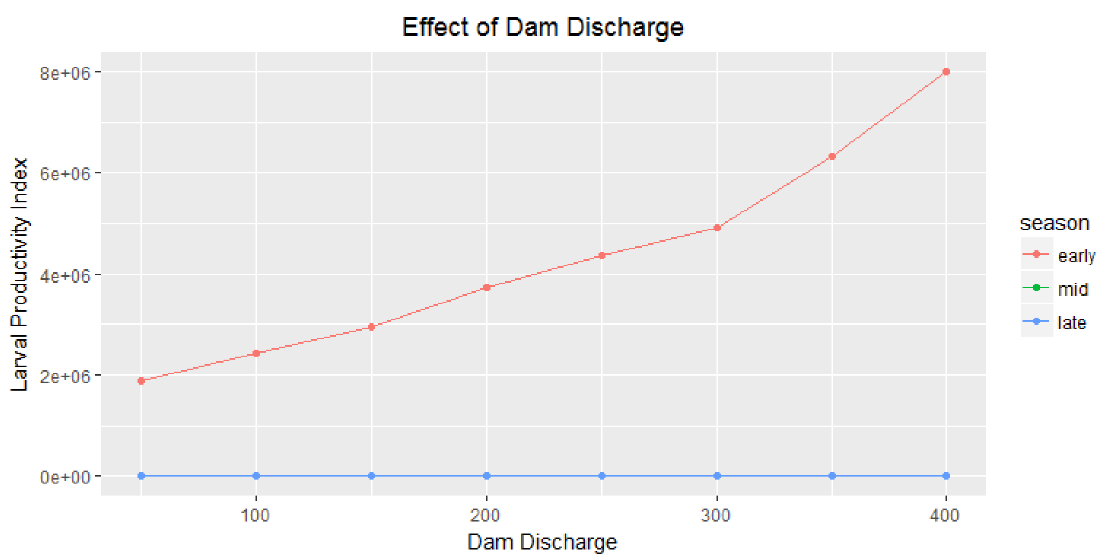


Figure 1. adj = 0.2008, fthresh = 3, for temperature and precipitation seasonal averages were used. This figure confirms that, all else being equal, larval productivity increases with dam discharge, which was a major assumption of how habitat availability was modelled. Predicted mid and late season productivity are so low compared to predicted early season productivity that they appear to both be zero in this figure.

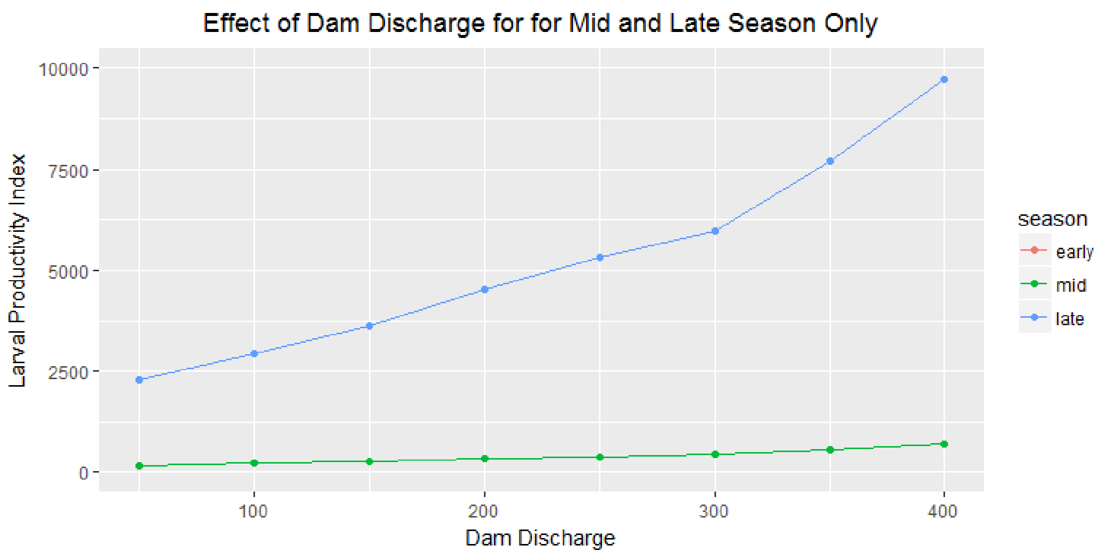


Figure 2. adj = 0.2008, fthresh = 3, for temperature and precipitation seasonal averages were used. In contrast to the preceding figure, this figure shows predicted mid and late season productivity on a scale that shows their responses to discharge level. Early season productivity is beyond the scale shown here.

Effect of *k* value

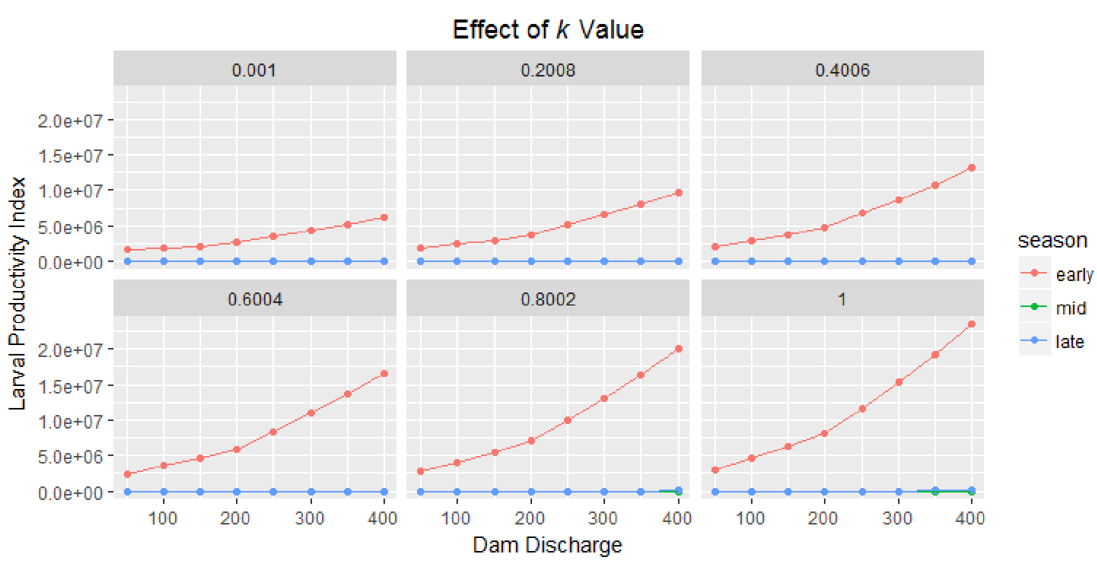


Figure 3. Each panel shows the effect of a different level of *k*, ranging from 0.001 to 1.

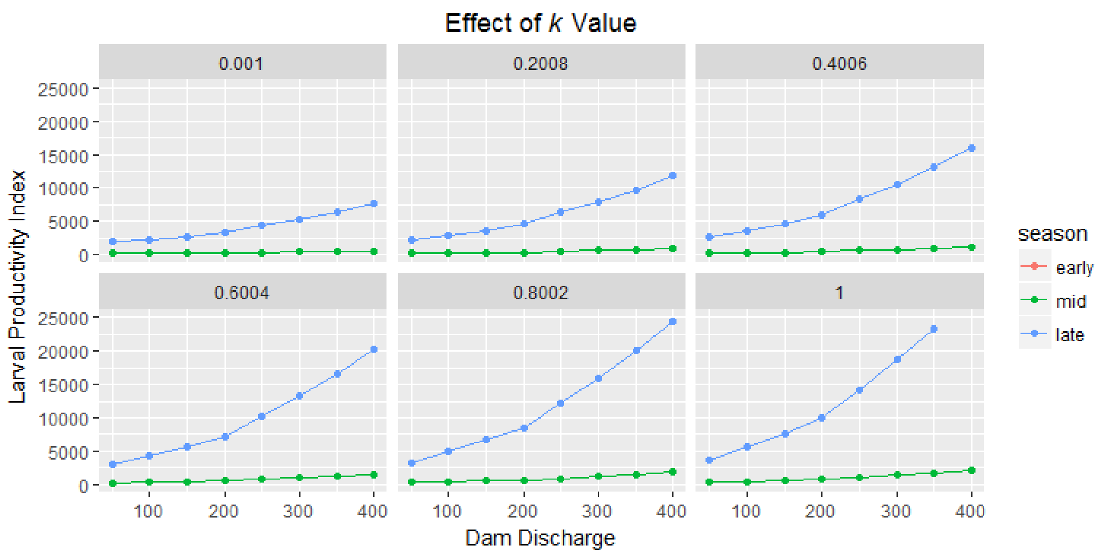


Figure 4. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Each panel shows the effect of a different level of *k*, ranging from 0.001 to 1.

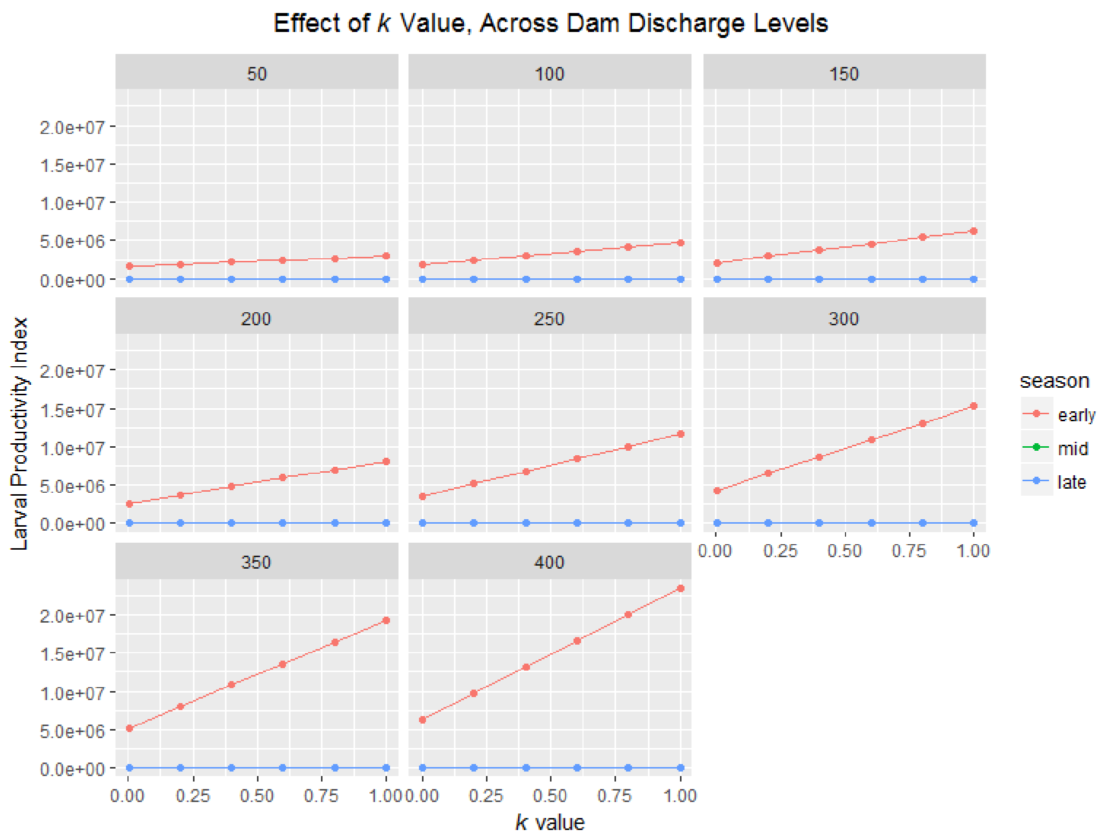


Figure 5. Each panel shows the effect of a different level of dam discharge, ranging from 50 to 400 m^3/s. This figure confirms that *k* has a simple linear effect on predicted larval productivity.

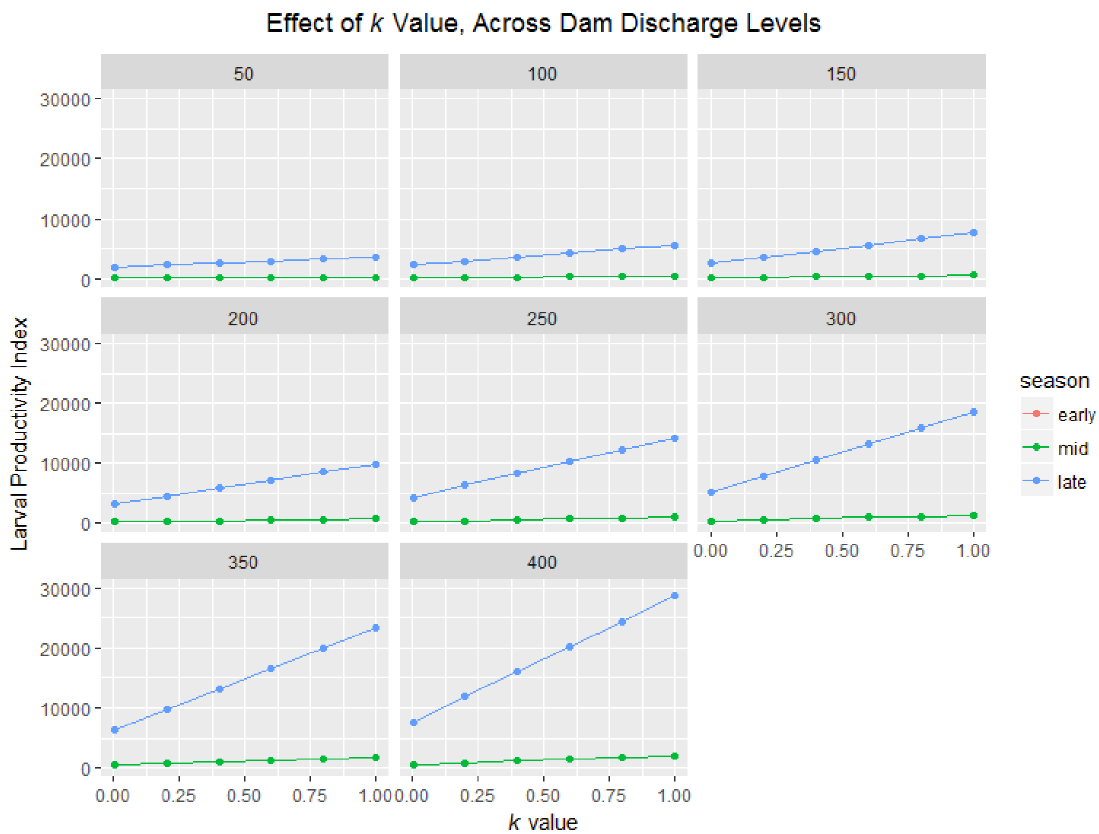


Figure 6. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Each panel shows the effect of a different level of dam discharge, ranging from 50 to 400 m^3/s. This figure confirms that *k* has a simple linear effect on predicted larval productivity.

Effect of fthresh Value

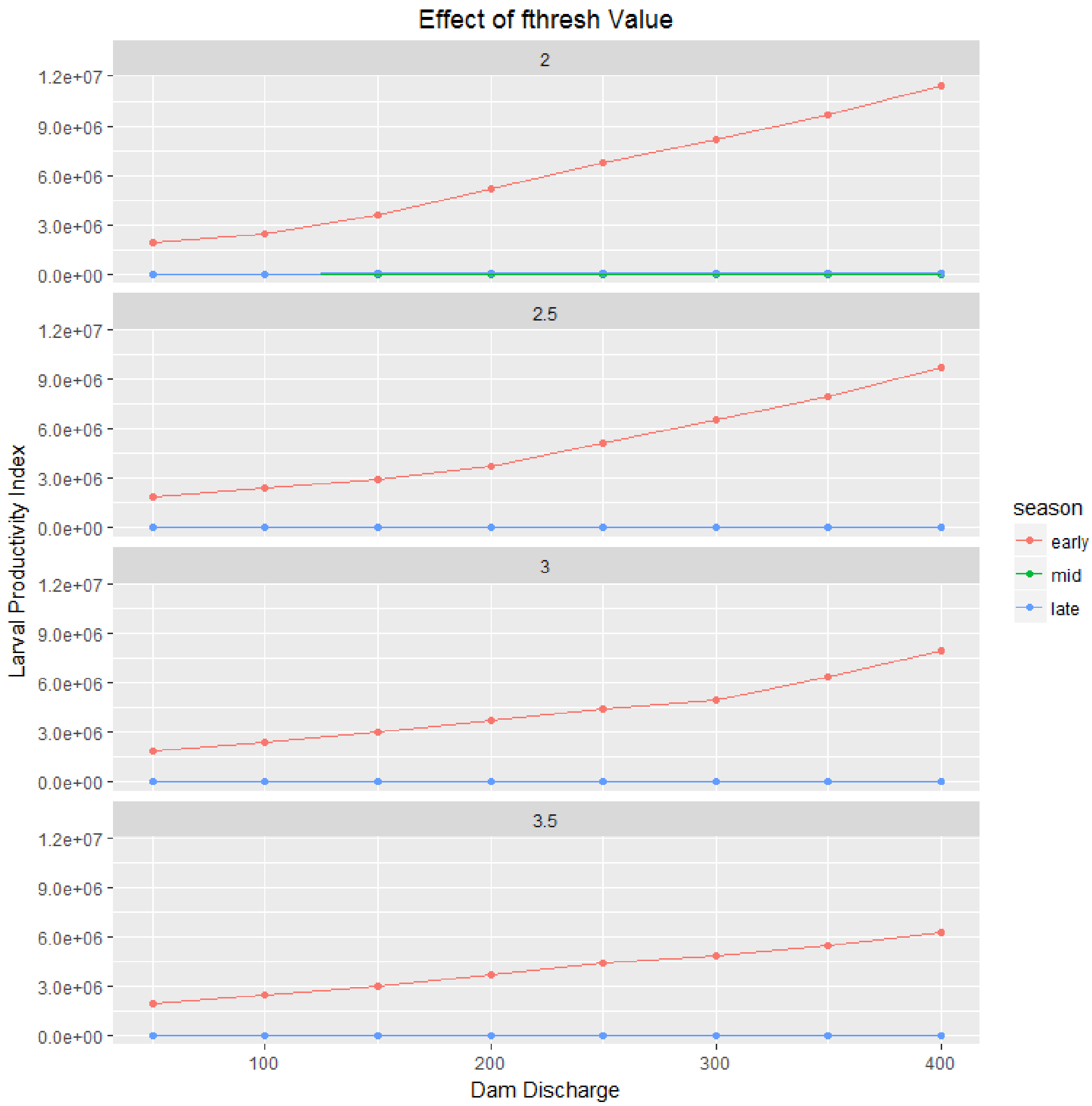


Figure 7. Predicted larval productivity with increasing fthresh values. As expected, fthresh level corresponds to an increase in larval productivity when fthresh is exceeded by the level of the Lower Duncan at higher levels of dam discharge. Note that such elevated levels of larval productivity are only temporary because the fthresh value is dynamically updated so that it increases to the highest level achieved in a season.

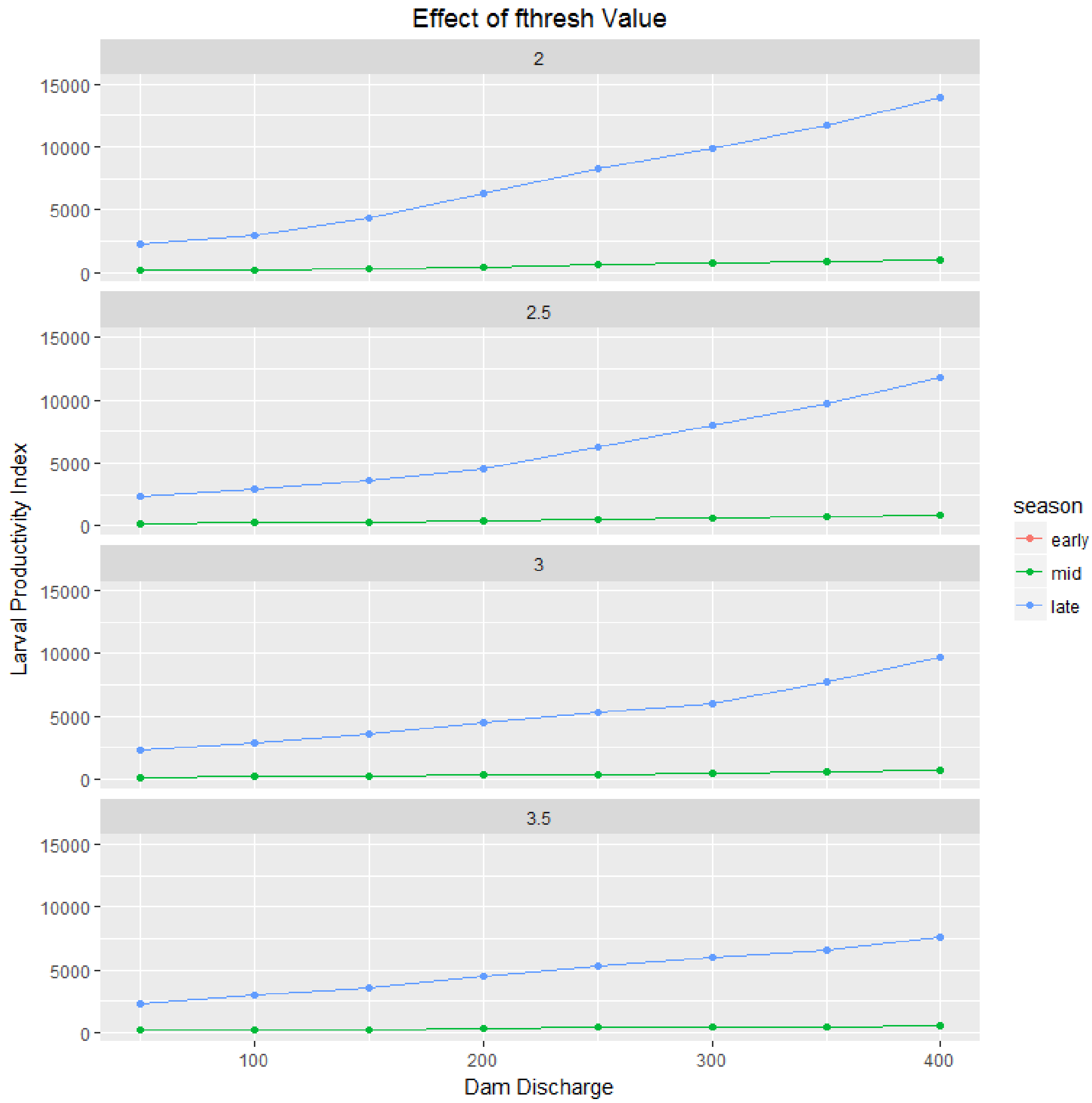


Figure 8. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Predicted larval productivity with increasing fthresh values. As expected, fthresh level corresponds to an increase in larval productivity when fthresh is exceeded by the level of the Lower Duncan at higher levels of dam discharge. Note that such elevated levels of larval productivity are only temporary because the fthresh value is dynamically updated so that it increases to the highest level achieved in a season.

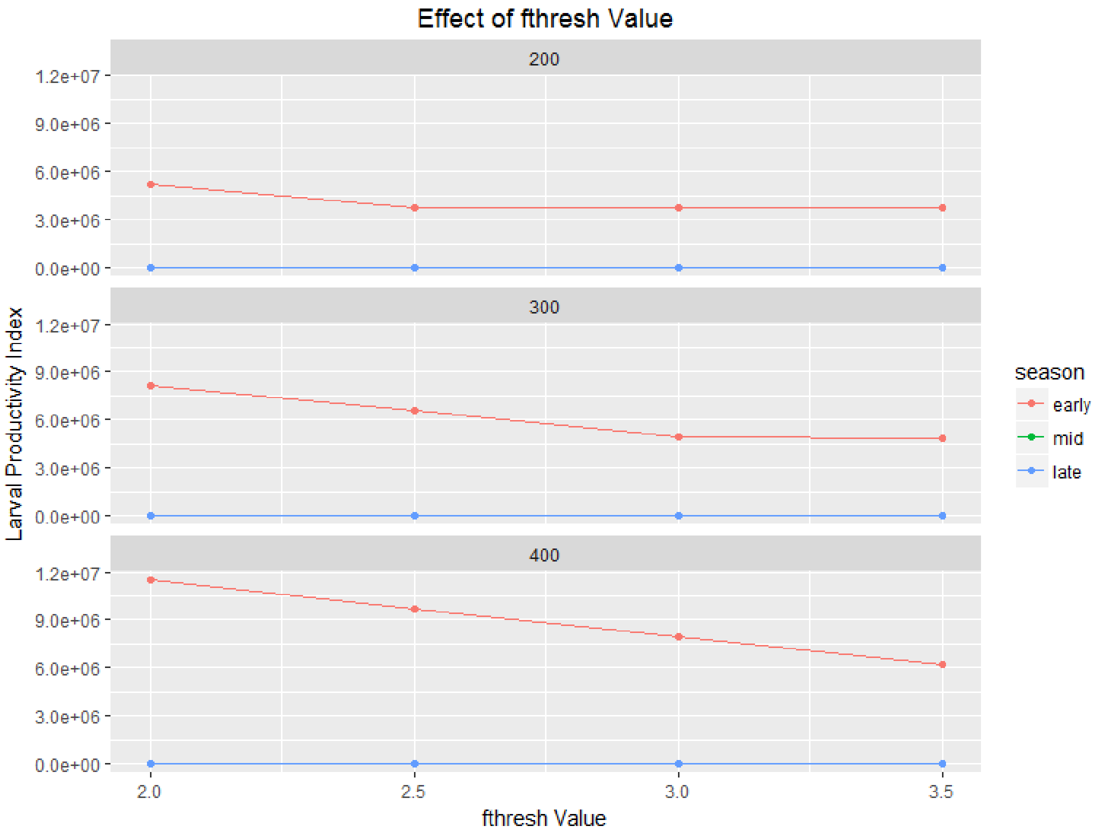


Figure 9. Predicted larval productivity with increasing fthresh values. fthresh level corresponds to an increase in larval productivity when fthresh is exceeded by the level of the Lower Duncan at higher levels of dam discharge. These figures illustrate that the effect of fthresh on predicted larval productivity is contingent on the level of dam discharge because fthresh comes into play when the level of the Lower Duncan river exceeds fthresh. Note that in a historical or hypothetical seasonal simulation over the course of a season, such increased levels of productivity are expected to be temporary because the fthresh value is dynamically updated so that it increases to the highest level achieved in a season.

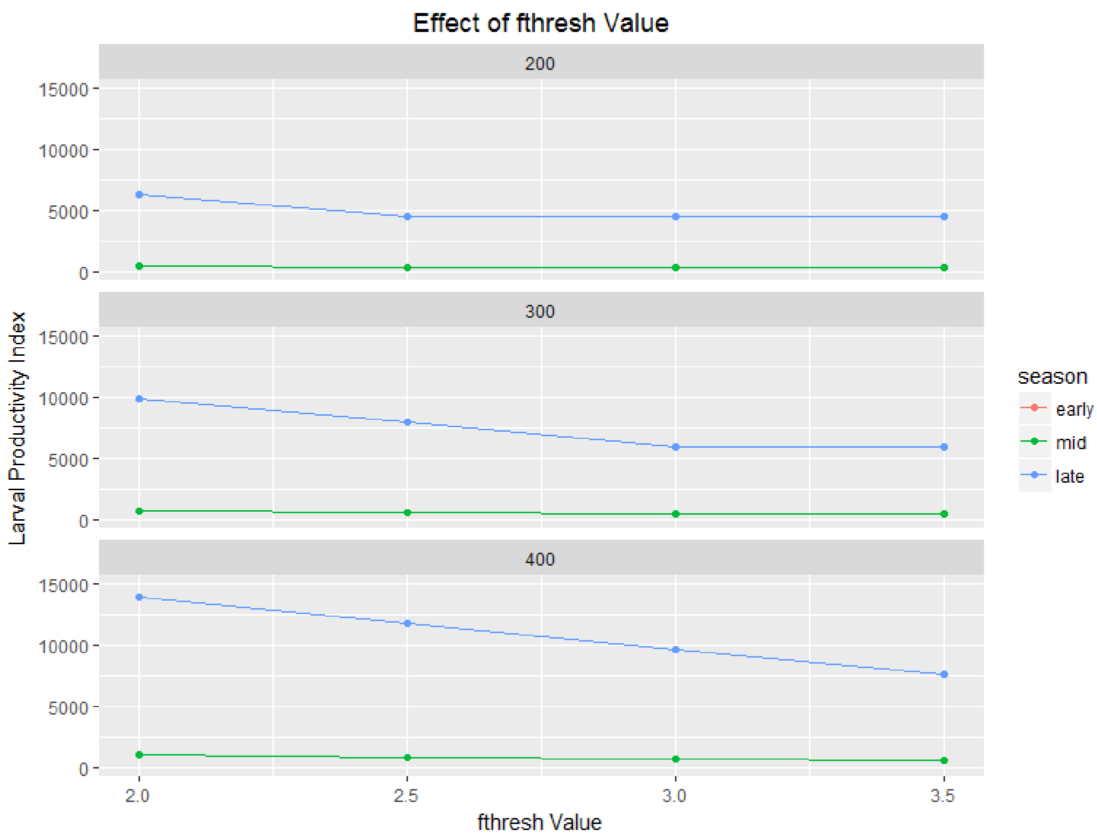


Figure 10. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Predicted larval productivity with increasing fthresh values. fthresh level corresponds to an increase in larval productivity when fthresh is exceeded by the level of the Lower Duncan at higher levels of dam discharge. These figures illustrate that the effect of fthresh on predicted larval productivity is contingent on the level of dam discharge because fthresh comes into play when the level of the Lower Duncan river exceeds fthresh. Note that in a historical or hypothetical seasonal simulation over the course of a season, such increased levels of productivity are expected to be temporary because the fthresh value is dynamically updated so that it increases to the highest level achieved in a season.

Effect Air Temperature

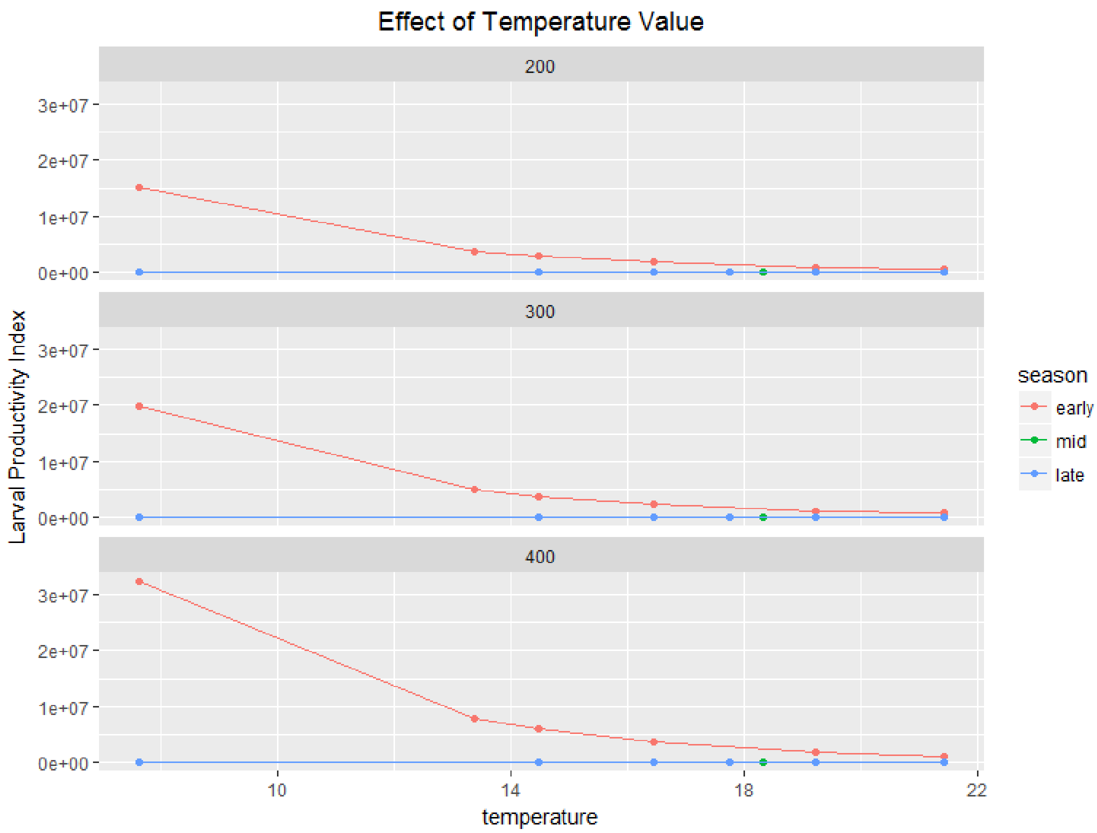


Figure 11. Effect of recent average air temperature (mean temperature for the preceding 10 days). Each panel shows a different level of dam discharge (200, 300, and 400 c^3/s). There is a non-linear effect such that larval productivity (of *Aedes*) is predicted to be lower under higher temperature.

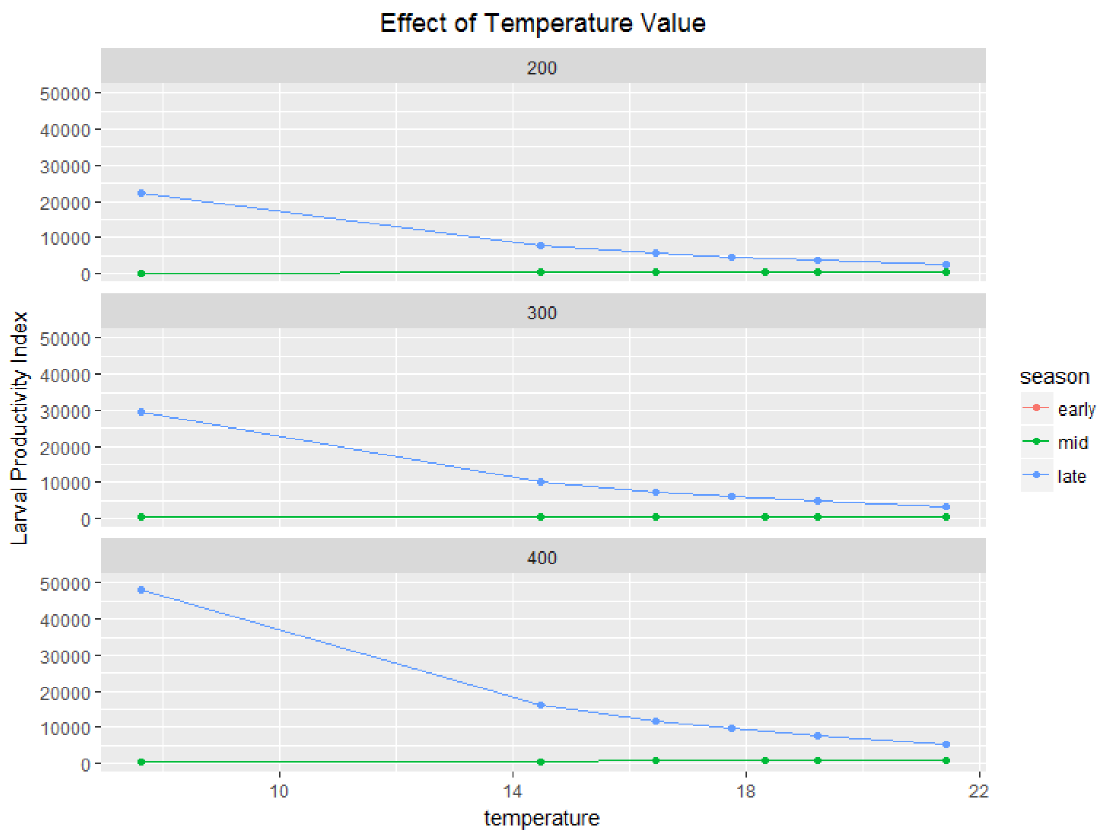


Figure 12. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Effect of recent average air temperature (mean temperature for the preceding 10 days). Each panel shows a different level of dam discharge (200, 300, and 400 c³/s). There is a non-linear effect such that larval productivity (of *Aedes*) is predicted to be lower under higher temperature.

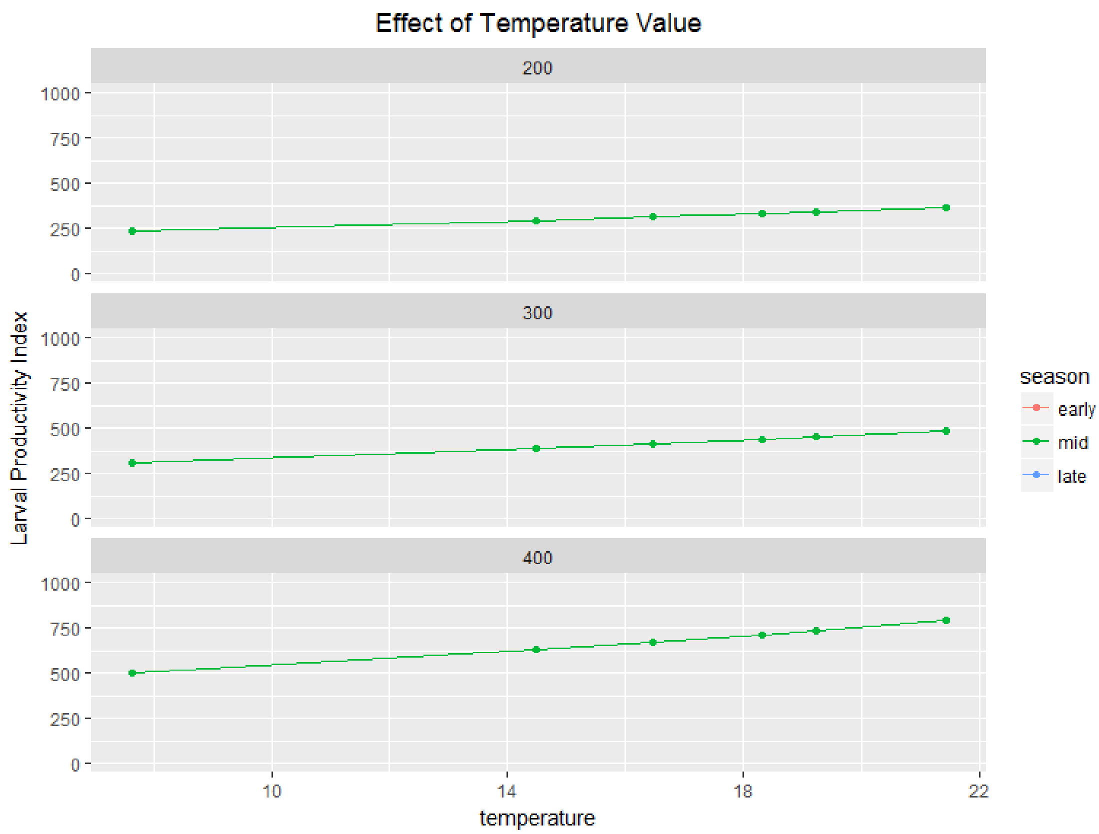


Figure 13. This figure shows the same as the preceding figure, except the scale is reduced to make late season dynamics more visible. Effect of recent average air temperature (mean temperature for the preceding 10 days). Each panel shows a different level of dam discharge (200, 300, and 400 c^3/s). There is a non-linear effect such that larval productivity (of *Aedes*) is predicted to be lower under higher temperature.

Effect of Precipitation

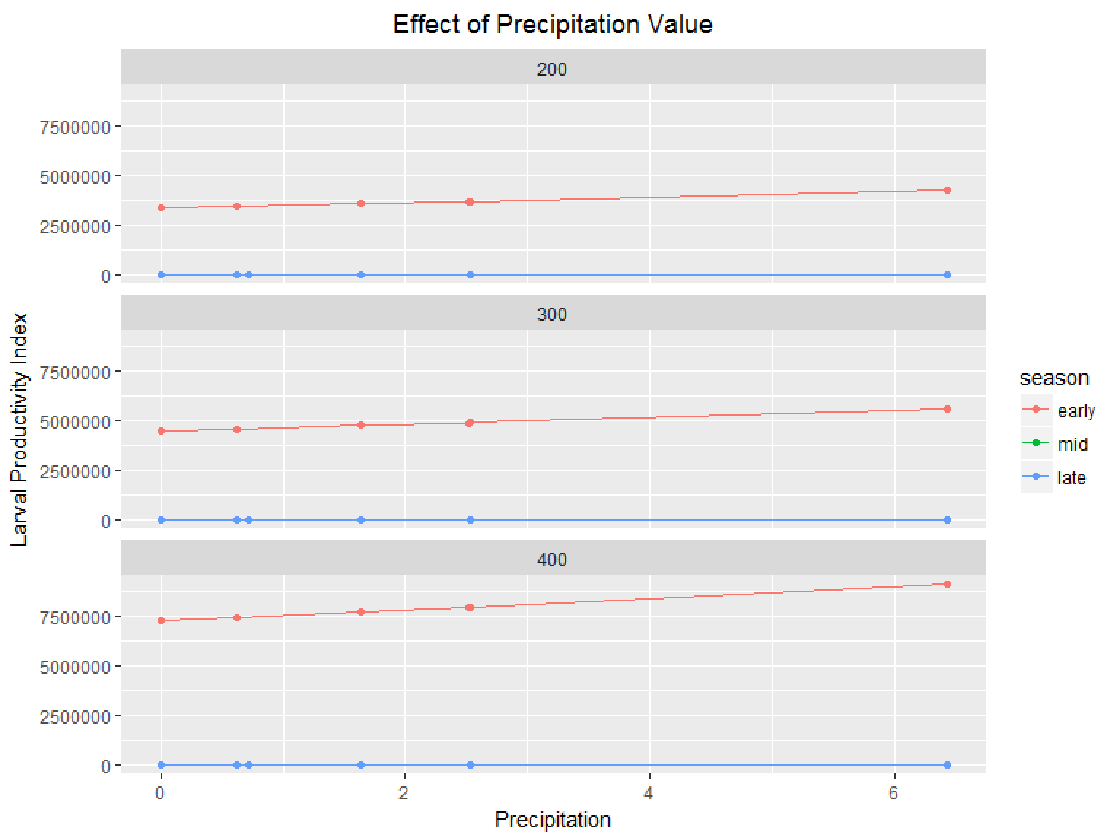


Figure 14. Effect of recent average precipitation (mean for the preceding 10 days). Each panel shows a different level of dam discharge (200, 300, and 400 c^3/s). There is a non-linear effect such that larval productivity (of *Aedes*) is predicted to be lower under higher precipitation.

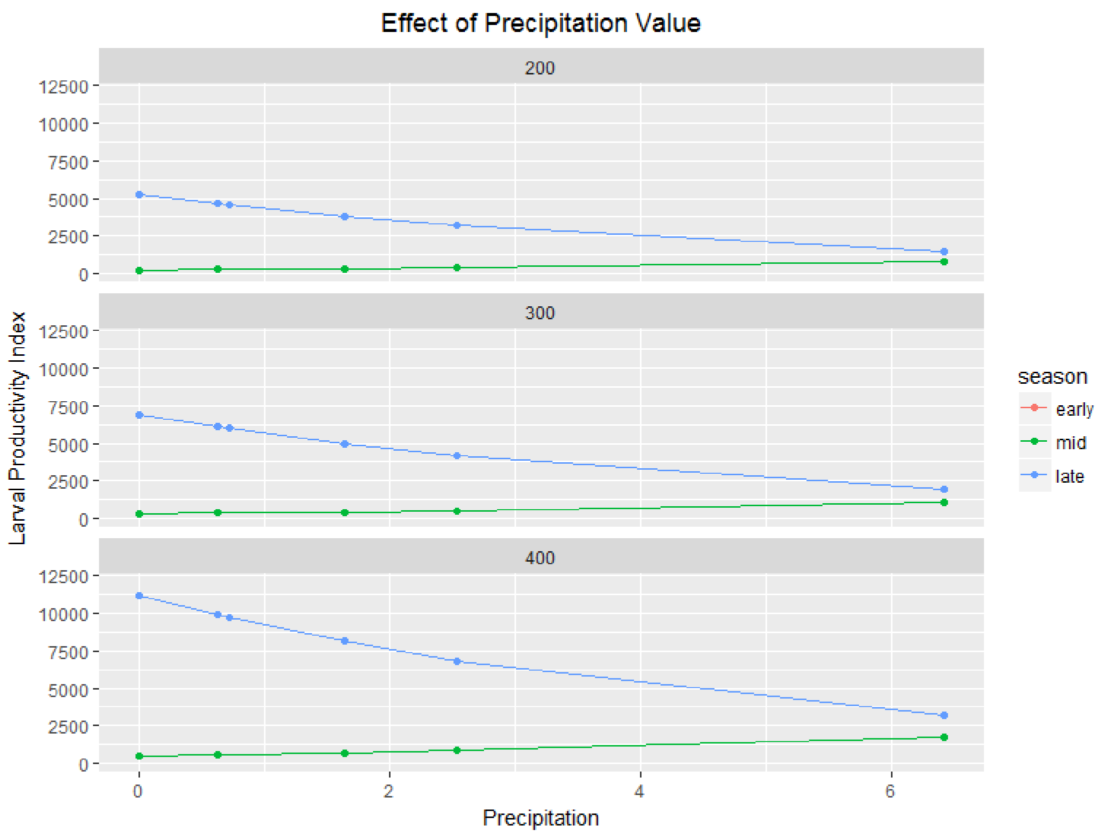


Figure 15. This figure shows the same as the preceding figure, except the scale is reduced to make mid and late season dynamics visible. Effect of recent average precipitation (mean for the preceding 10 days). Each panel shows a different level of dam discharge (200, 300, and 400 c^3/s). There is a non-linear effect such that larval productivity (of *Aedes*) is predicted to be lower under higher precipitation.