Flight activity of wood- and bark-boring insects at New Zealand ports

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Appendix A: Site information and collection of meteorological variables

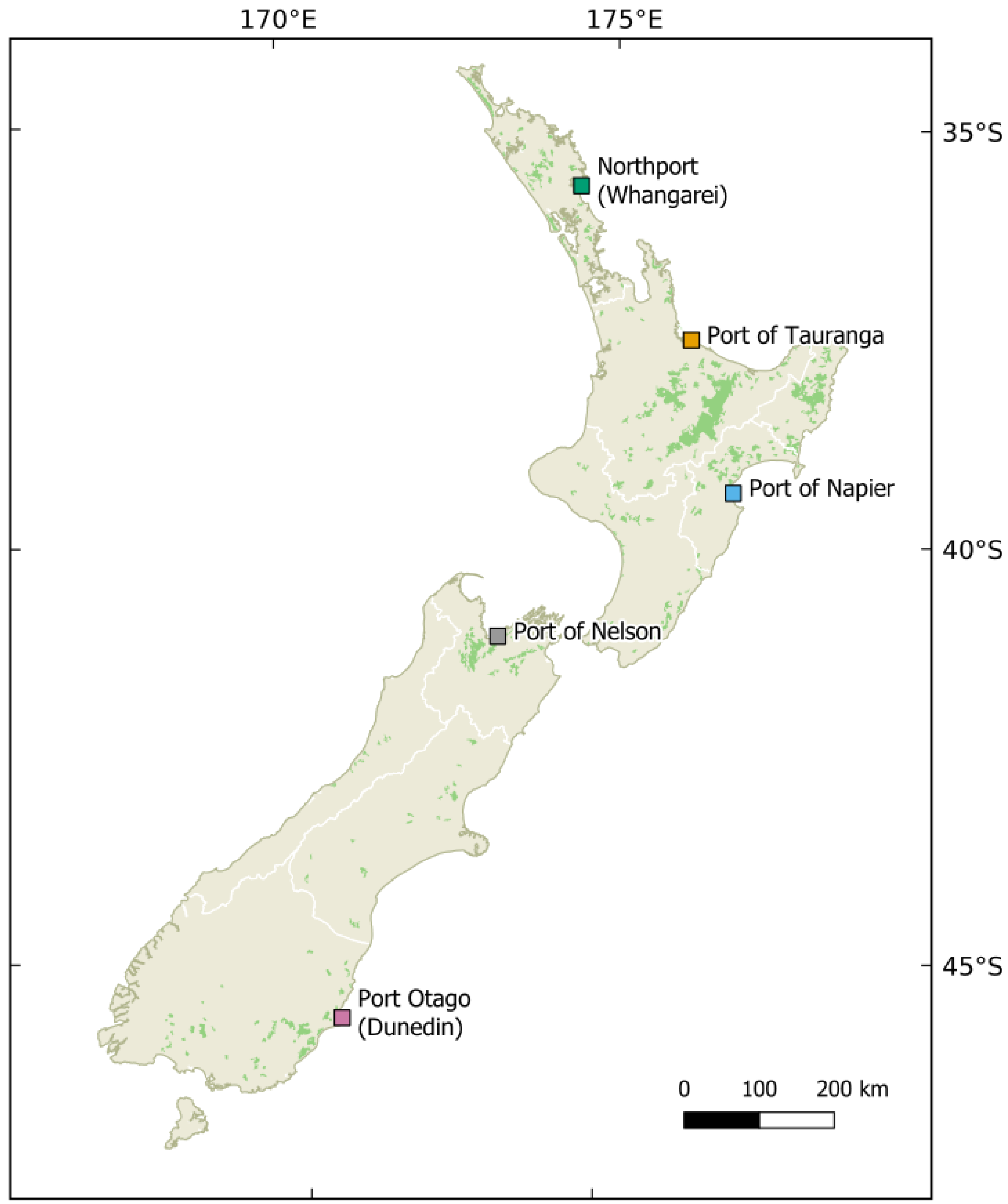

Figure A1: Map of Aotearoa/New Zealand showing the location of participating port cities.


A: Whangarei, Northport
Legend
Google Earth
B: Tauranga, Port of Tauranga
Legend
Google Earth


C: Napier (Port of Napier)
Legend
N
400 m
Google Earth
D: Nelson, Port Nelson
Legend
N
100 m
Google Earth

Figure A2: Location of individual flight intercept traps at each port. A. Whangarei (Northport), B. Tauranga (Port of Tauranga), C. Napier (Port of Napier), D. Nelson (Port Nelson), E. Dunedin (Port Otago).

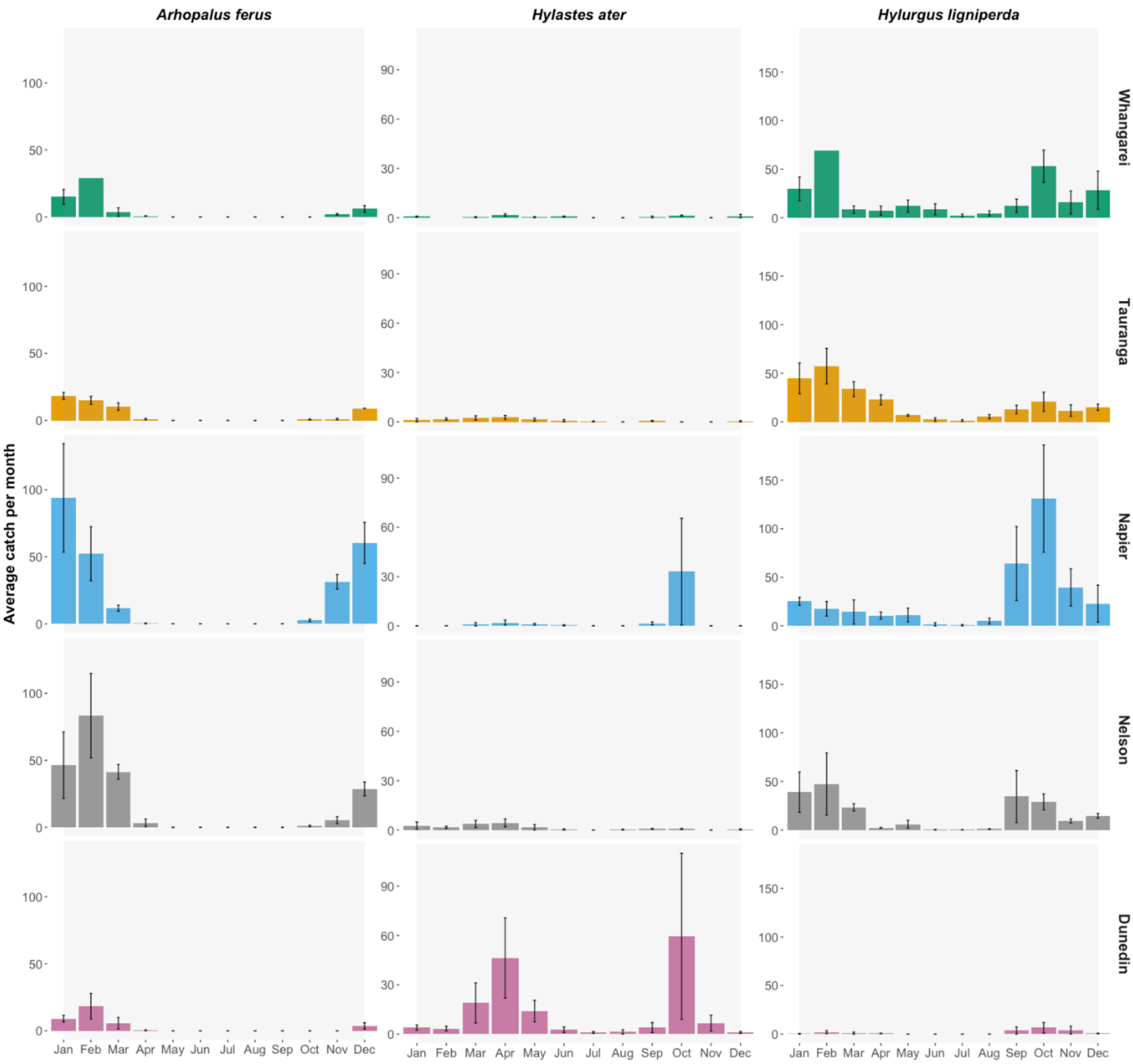

Figure A3: Average catch per month with 95% confidence intervals for the three most commonly trapped beetle species, *A. ferus, Hylastes ater* and *Hylurgus ligniperda*, by port.

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Table A1. City, port, site ID, sampling duration, and geographic location for each trap. Site ID's noted with " – D" were disestablished during the trial and replaced by a new location due to operational changes at the port.

City	Port Company	Site ID	Sampling Start	Sampling End	Longitude	Latitude
Nelson	Port Nelson	NPORT1	Jul-13	Sep-16	173.2761	-41.2618
Nelson	Port Nelson	NPORT2 - D	Jul-13	Jan-16	173.2769	-41.2643
Nelson	Port Nelson	NPORT3 - D	Jul-13	May-16	173.2765	-41.2626
Nelson	Port Nelson	NPORT2	Jan-16	Sep-16	173.2774	-41.2617
Nelson	Port Nelson	NPORT3	May-16	Sep-16	173.2765	-41.2626
Whangarei	Northport	NORTH PORT ST1	Aug-13	Sep-16	174.4830	-35.8340
Whangarei	Northport	NORTH PORT ST2	Aug-13	Sep-16	174.4857	-35.8410
Whangarei	Northport	NORTH PORT ST3	Aug-13	Sep-16	174.4853	-35.8396
Napier	Port of Napier	NAPIER_3	Jul-13	Sep-16	176.9228	-39.4744
Napier	Port of Napier	NAPIER_1	Jul-13	Sep-16	176.9115	-39.4764
Napier	Port of Napier	NAPIER_2	Jul-13	Sep-16	176.9197	-39.4788
Dunedin	Port Otago	PORT OTAGO ST1	Nov-13	Sep-16	170.6294	-45.8183
Dunedin	Port Otago	PORT OTAGO ST2	Nov-13	Sep-16	170.6283	-45.8175
Dunedin	Port Otago	PORT OTAGO ST3	Nov-13	Sep-16	170.6283	-45.8182
Tauranga	Port of Tauranga	TAURANGA_1	Jul-13	Sep-16	176.1851	-37.6535
Tauranga	Port of Tauranga	TAURANGA_2	Jul-13	Sep-16	176.1841	-37.6617
Tauranga	Port of Tauranga	TAURANGA_3	Jul-13	Sep-16	176.1839	-37.6641

Appendix B: Generalized additive models (GAMs) of the effects of season, weather, and volume on flight activity of forest insects

Seasonal effects

Catch per 100 trap day data were analysed using separate Poisson GAMs for each species that included two fixed-effect terms; a *port effect* and a *season effect* (weeks of the year; Week*)*. The port effect allows for variation in flight activity between ports, whereas weeks of the year represents a seasonal trend, where the variable 'Week' is assigned an appropriate value between 1 and 52. These models also included an interaction term for 'Port' and 'Week' to account for the differences in the way that counts varied over time in relation to different ports. A first-autoregressive covariance structure within each port was used to account for independence due to repeated measures of catches over time.

GAMs including a first-autoregressive covariance structure were fitted by penalised quasi-likelihood using R-mgcv (S.N. Wood 2018). A GAM is a nonparametric extension of generalized linear models (GLMs). It models the mean of the response in terms of a sum of smooth terms of the explanatory variables instead of using only parametric relationship. The use of smooth functions adds much flexibility for the modelling of non-linear relationships between the explanatory variables and the dependent variable. GAMs based on penalised regression splines proposed by S.N. Wood (2000); (S.N.. Wood 2004; S.N. Wood 2006) were used in our analysis. In Wood's approach, GAMs were represented as penalised generalized linear models, where each smooth term was represented using an appropriate set of basis functions and the model was estimated by penalised regression methods. The estimate of the smooth function of predictor variables, F-statistics and approximate p-values for the smoothers were therefore represented. To assess collinearity, variance inflation factors (VIF) were applied and a cut-off value of 3 was used to remove collinearity variables, as recommended by Zuur et al. (2013). The VIF for export volume indicated that it was collinear with the 'port' variable, hence export volume was dropped from the model. In all cases, cyclic cubic regression splines were used. Penalties were based on the second-order derivatives and the automatic smoothing parameter selection was obtained through minimization of the unbiased risk estimator (UBRE) (Wood, 2006). Graphical tools such as Pearson residual plots were used to test for model validation. Auto-correlation plots were used to assess temporal autocorrelation. Over-dispersion was detected, and the standard errors were corrected using a quasi-Poisson model.

Table B1 GAMs for seasonal flight-activity of *A. ferus, Hylastes ater* and *Hylurgus ligniperda*. GAMs have a parametric component and a smoothing part, hence the distinction between parametric coefficients and the smoothing terms. s( ) = smooth term for a continuous variable, *SE* = standard error of the estimate, *t* = *t-statistic*, *P* = *P*-value, *edf* = estimated degrees of freedom, *F* = *F-statistic* and Week = weeks of the year. Significant values are denoted with P <0.05 = *, P <0.01 = **, P <0.001 = ***.

Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Arhopalus ferus				
Intercept	-0.85	0.71	-1.19	0.233
Port : Tauranga	0.67	0.82	0.81	0.414
Port : Napier	0.87	0.90	0.96	0.335
Port : Nelson	1.06	0.85	1.25	0.211
Port : Dunedin	-0.50	1.09	-0.46	0.645
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Week) : Whangarei		3.72	7.76	< 0.001 ***
s(Week) : Tauranga		3.79	7.92	< 0.001 ***
s(Week) : Napier		4.84	31.38	< 0.001 ***
s(Week) : Nelson		4.72	29.08	< 0.001 ***
s(Week) : Dunedin		3.68	6.95	< 0.001 ***
Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Hylastes ater				
Intercept	-0.09	0.30	-0.31	0.755
Port : Tauranga	-0.19	0.45	-0.44	0.660
Port : Napier	-0.47	0.50	-0.94	0.344
Port : Nelson	0.25	0.40	0.63	0.527
Port : Dunedin	1.78	0.34	5.24	< 0.001 ***
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Week) : Whangarei		1.32	0.33	0.117
s(Week) : Tauranga		2.06	1.12	< 0.01 **
s(Week) : Napier		4.67	2.18	< 0.01 **
s(Week) : Nelson		2.42	1.71	< 0.001 ***
s(Week) : Dunedin		7.15	20.94	< 0.001 ***

[a] Models have a Poisson error structure, and include a first-autoregressive covariance structure, and the standard errors are corrected using the quasi-Poisson model.

Table B1 (continued).

Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Hylurgus ligniperda				
Intercept	2.91	0.14	20.79	< 0.001 ***
Port : Tauranga	-0.21	0.20	-1.06	0.289
Port : Napier	-0.16	0.22	-0.70	0.480
Port : Nelson	-0.44	0.23	-1.86	0.062
Port : Dunedin	-2.40	0.42	-5.66	< 0.001 ***
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Week) : Whangarei		5.03	4.37	< 0.001 ***
s(Week) : Tauranga		4.54	6.07	< 0.001 ***
s(Week) : Napier		6.48	17.69	< 0.001 ***
s(Week) : Nelson		5.36	5.72	< 0.001 ***
s(Week) : Dunedin		1.24	0.31	0.12

[a] Models have a Poisson error structure, and include a first-autoregressive covariance structure, and the standard errors are corrected using the quasi-Poisson model.

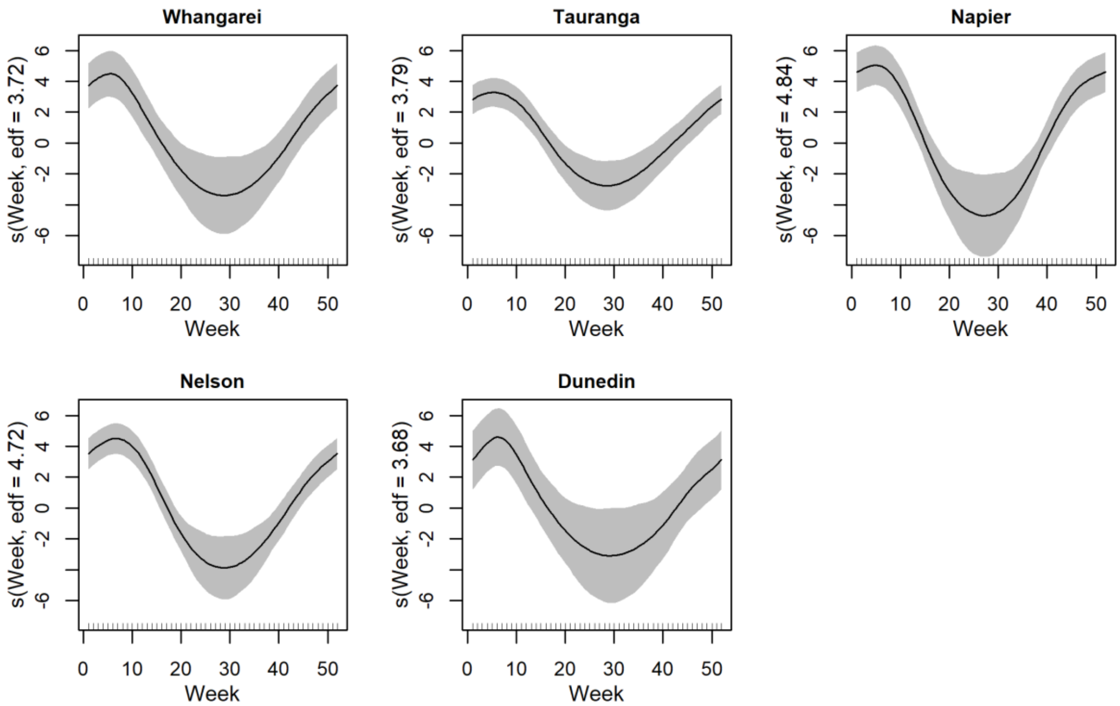

Figure B1: Fitted functions for weeks of the year (1 to 52) by port for the flight activity data of *A. ferus* using the quasi-Poisson GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf=x.xx), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

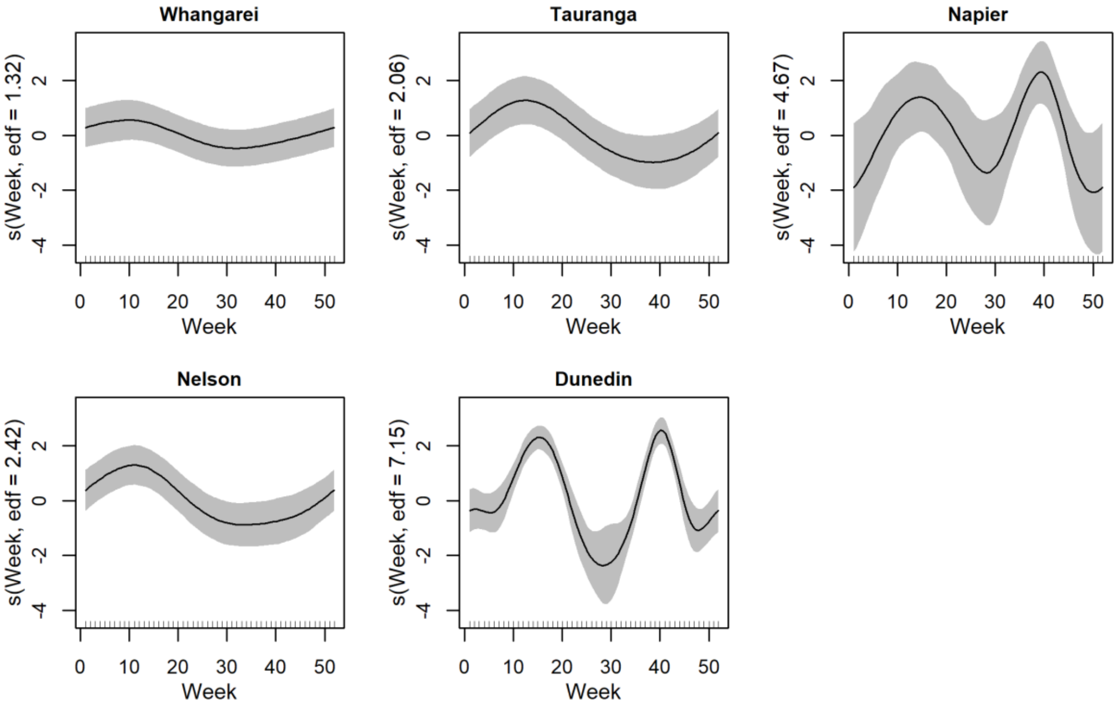

Figure B2: Fitted functions for week of the year by port for the flight activity data of *Hylastes ater* using the quasi-Poisson GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf=x.xx), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect.The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

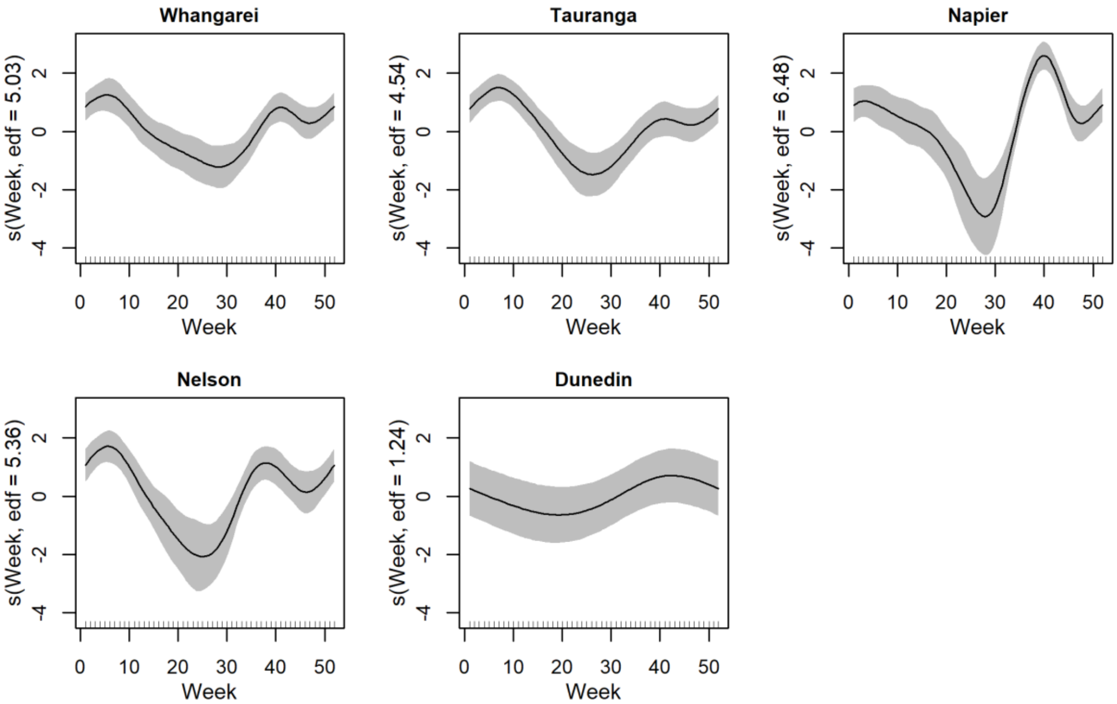

Figure B3: Fitted functions for week of the year by port for the flight activity data of *Hylurgus ligniperda* using the quasi-Poisson GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf=x.xx), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

Effect of meteorology on flight activity

Individual GAM models were fitted for each meteorological variable and for each species as per the following methods. Daily trap catch was transformed into catch per 100 trap day data and summed across each port at weekly intervals between 10 July 2013 and 28 September 2016. Transformation of daily catch data into units of catch per 100 trap days permits communication of low catch rates that would otherwise be expressed as small fractions of an individual over particular time periods. As an example of this transformation, if you were to establish 100 traps and then you checked these traps on a daily basis then the total observed catch on any given day amongst those traps would reflect the catch per 100 trap days.

Maximum temperature (°C)

The Gaussian additive models including a first-autoregressive covariance structure fitted by restricted maximum likelihood estimation (REML) was used to analyze the impact of maximum temperature on the logarithmic transformed average catch per 100 trap days of *A. ferus* and *Hylastes ater* (Generalised Additive Models (GAMs); R-mgcv). Cubic regression spline with shrinkage of dimension 4 with 2^{nd} order difference penalty was used, while smoothing parameters were chosen automatically through the minimization of the Generalised Cross Validation (GCV) score. The effects of maximum temperature on catches per 100 trap days of *Hylurgus ligniperda* were assessed using a Poisson error structure including a first-autoregressive covariance structure within each port and an observation-level random intercept. The Poisson GAM was again fitted by penalised quasi-likelihood using cubic regression spline with shrinkage with basis dimensions equal to 4 together with a second order penalty, and the smoothing parameters being selected automatically through minimization of the UBRE score. For Gaussian additive models, standard graphs such as residuals versus fitted values, a QQ-plot or histogram of the residuals, and residuals versus each explanatory variable were used to verify model validation. For a Poisson GAM, model checks and validation carried out as described above (*Impact of season on flight activity of A. ferus, Hylastes ater* and *Hylurgus ligniperda)*. In all cases, GAM models comprised port, average maximum temperature (daily for *Hylastes ater* and *Hylurgus ligniperda* and evening for *A. ferus*) and their interaction, and significance of the main effects was assessed using likelihood-ratio tests and model selection was based on the AIC.

Wind speed(m^{-1}/s^{-1})

The effects of average wind speed on catch per 100 trap days of *A. ferus* and *Hylastes ater* were assessed using an additive model with a Poisson error structure including a first-autoregressive covariance structure within each port and an observation-level random intercept, whereas an additive model with Gaussian distribution including a first-autoregressive covariance structure was used to analyze the impact of wind speed on the (transformed) average count per 100 trap days of *Hylurgus ligniperda*. Cubic regression spline with shrinkage of dimension 4 with 2^{nd} order difference penalty was again used for the additive model, while smoothing parameters were chosen automatically through the minimization of the UBRE and GCV score. Model checks and validation carried out as described above (*Impact of season on flight activity of A. ferus, Hylastes ater* and *Hylurgus ligniperda)*. In all cases, the AIC values indicate that the model with one smoother was better than the model with five smoothers (one per port). Each model therefore included only port and average wind speed as main effects. In all cases, significance of the main effects was assessed using likelihood-ratio tests and model selection was based on the AIC.

Average humidity (%)

The effects of average humidity on the (transformed) average count per 100 trap days of *A. ferus*, *Hylastes ater* and *Hylurgus ligniperda* were assessed using an additive model with Gaussian distribution including a first-autoregressive covariance structure within each port. Cubic regression spline with shrinkage of dimension 4 with 2nd order difference penalty was again used for the Gaussian additive model, while smoothing parameters were chosen automatically through the minimization of the GCV score. Each model included port and average humidity as main effects. In all cases, significance of the main effects was assessed using likelihood-ratio tests and model selection was based on the AIC. For all three species, average humidity did not have a significant effect on the flight activity over the entire trapping period ($P > 0.05$; Table B4).

Table B2 Maximum temperature results from the GAMs for the count flight-activity data of *A. ferus, Hylastes ater* and *Hylurgus ligniperda*. GAMs have a parametric component and a smoothing part, hence the distinction between parametric coefficients and the smoothing terms. s( ) = smooth term for a continuous variable, *SE* = standard error of the estimate, *t* = *t-statistic*, *P* = *P*-value, *edf* = estimated degrees of freedom and *F* = *F-statistic* and Temp = Average maximum daily temperature for *Hylastes ater* and *Hylurgus ligniperda* and average evening (8pm to 12 am) maximum temperature for evening flight activity of *A. ferus*. Significant values are denoted with P <0.05 = *, P <0.01 = **, P <0.001 = ***.

Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Arhopalus ferus				
Intercept	0.58	0.27	2.05	< 0.05 *
Port : Tauranga	0.25	0.39	0.65	0.513
Port : Napier	0.78	0.38	2.06	<0.05 *
Port : Nelson	0.77	0.37	2.07	<0.05 *
Port : Dunedin	-0.12	0.38	-0.31	0.754
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Temp) : Whangarei		1.07	1.76	<0.05 *
s(Temp) : Tauranga		0.82	0.93	0.054
s(Temp) : Napier		1.87	5.77	< 0.001 ***
s(Temp) : Nelson		1.77	3.80	< 0.01 **
s(Temp) : Dunedin		1.87	4.15	< 0.001 ***
Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Hylastes ater				
Intercept	0.22	0.11	1.88	0.059
Port : Tauranga	-0.13	0.18	-0.69	0.487
Port : Napier	0.03	0.16	0.23	0.818
Port : Nelson	0.26	0.16	1.59	0.110
Port : Dunedin	1.31	0.17	7.41	< 0.001 ***
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Temp) : Whangarei		0.00	0.00	0.5911
s(Temp) : Tauranga		0.96	2.29	< 0.01 **
s(Temp) : Napier		0.00	0.00	0.647
s(Temp) : Nelson		0.96	1.89	< 0.05 *
s(Temp) : Dunedin		1.32	9.32	< 0.001 ***

[a] Models have a Poisson error structure and include a first-autoregressive covariance structure within each port and an observation-level random intercept.
[b] Models have a Gaussian error structure and include a first-autoregressive covariance structure within each port.

Table B2 (continued).

Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Hylurgus ligniperda				
Intercept	2.05	0.11	18.54	< 0.001 ***
Port : Tauranga	-0.42	0.10	-3.88	<0.001 ***
Port : Napier	0.62	0.04	14.66	< 0.001 ***
Port : Nelson	0.18	0.04	3.86	<0.001 ***
Port : Dunedin	-1.95	0.07	-25.82	< 0.001 ***
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Temp) : Whangarei		1.89	264.78	< 0.001 ***
s(Temp) : Tauranga		1.95	517.21	< 0.001 ***
s(Temp) : Napier		1.89	161.84	< 0.001 ***
s(Temp) : Nelson		1.95	644.15	< 0.001 ***
s(Temp) : Dunedin		1.97	81.72	< 0.001 ***

[a] Models have a Poisson error structure and include a first-autoregressive covariance structure within each port and an observation-level random intercept.
[b] Models have a Gaussian error structure and include a first-autoregressive covariance structure within each port.

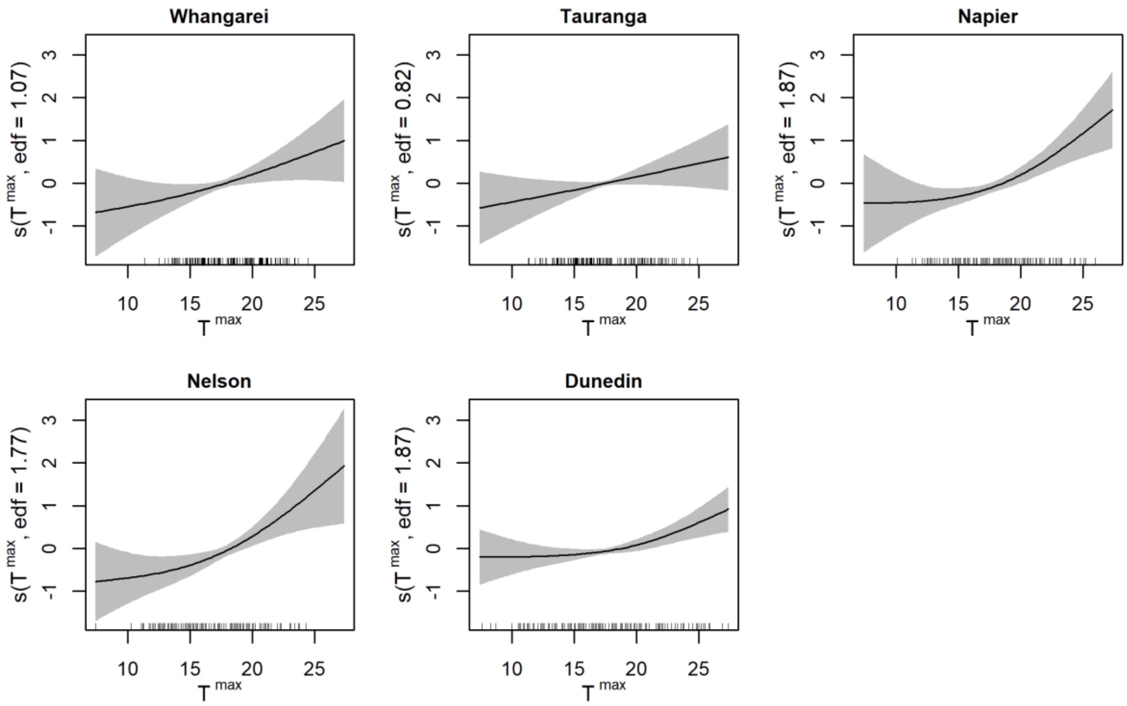

Figure B4: Fitted functions for average maximum evening temperature (T^{max}) by port for the (transformed) average count per 100 trap days data of *A. ferus* using the Gaussian additive models. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(T^{max}, edf=x.xx), where 'T^{max}' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

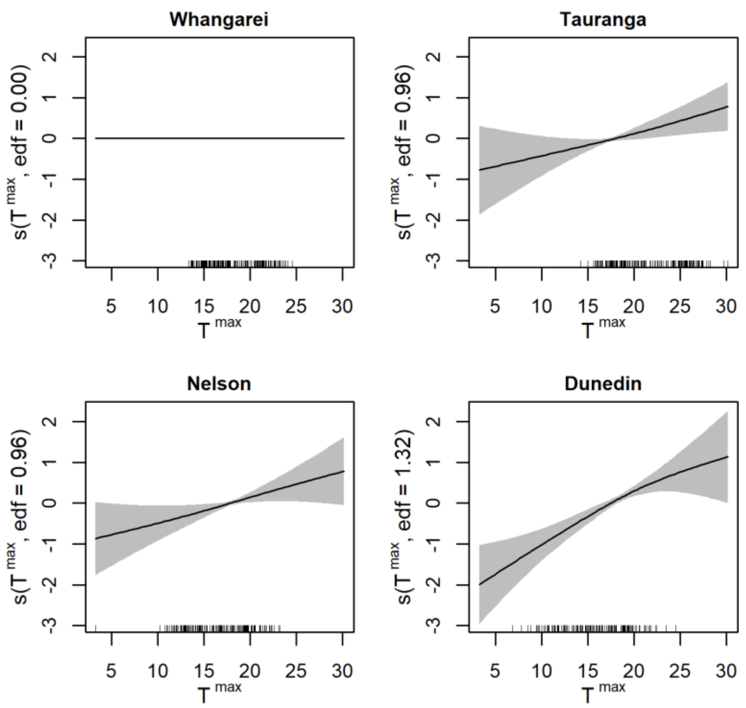

Figure B5: Fitted functions for average maximum temperature by port for the (transformed) average count per 100 trap days data of *Hylastes ater* using the Gaussian additive models. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(T^{max}, edf=x.xx), where 'T^{max}' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

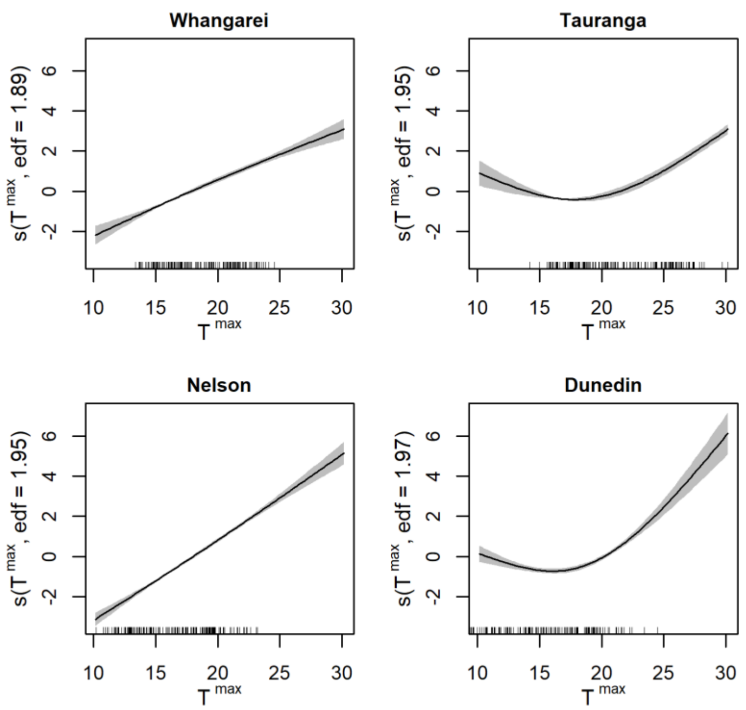

Figure B6: Fitted functions for average maximum temperature by port for the count per 100 trap days data of *Hylurgus ligniperda* using the Poisson GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(T^{max}, edf=x.xx), where 'T^{max}' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

Table B3 Wind speed results from the GAMs for the (transformed) average count/count flight-activity data of *A. ferus, Hylastes ater* and *Hylurgus ligniperda*. GAMs have a parametric component and a smoothing part, hence the distinction between parametric coefficients and the smoothing terms. s( ) = smooth term for a continuous variable, *SE* = standard error of the estimate, *t* = *t-statistic*, *P* = *P*-value, *edf* = estimated degrees of freedom, *F* = *F-statistic* and Wind = Average wind speed (average evening wind speed was used for evening flight activity of *A. ferus)*. Significant values are denoted with P <0.05 = *, P <0.01 = **, P <0.001 = ***.

Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Arhopalus ferus				
Intercept	-1.05	0.27	-3.91	<0.001 ***
Port : Tauranga	-0.03	0.05	-0.58	0.567
Port : Napier	1.84	0.06	29.95	<0.001 ***
Port : Nelson	0.77	0.07	11.42	<0.001 ***
Port : Dunedin	-0.71	0.07	-10.67	<0.001 ***
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Wind)		2.77	32.09	<0.001 ***
Parametric coefficients[a]	*Estimate*	*SE*	*t*	*P*
Hylastes ater				
Intercept	-1.41	0.20	-6.91	< 0.001 ***
Port : Tauranga	0.14	0.12	1.19	0.234
Port : Napier	0.16	016	0.99	0.318
Port : Nelson	0.61	0.12	4.95	<0.001 ***
Port : Dunedin	-0.31	0.28	-1.11	0.267
Approx. significance of smooth terms[a]		*edf*	*F*	*P*
s(Wind)		2.90	23.72	< 0.001 ***
Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Hylurgus ligniperda				
Intercept	1.88	0.25	7.53	< 0.001 ***
Port : Tauranga	0.33	0.35	0.94	0.346
Port : Napier	0.16	0.35	0.47	0.641
Port : Nelson	-0.15	0.34	-0.44	0.660
Port : Dunedin	-1.91	0.60	-3.17	< 0.01 **
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Wind)		0.67	0.56	0.105

[a] Models have a Poisson error structure and include a first-autoregressive covariance structure within each port and an observation-level random intercept.
[b] Models have a Gaussian error structure and include a first-autoregressive covariance structure within each port.

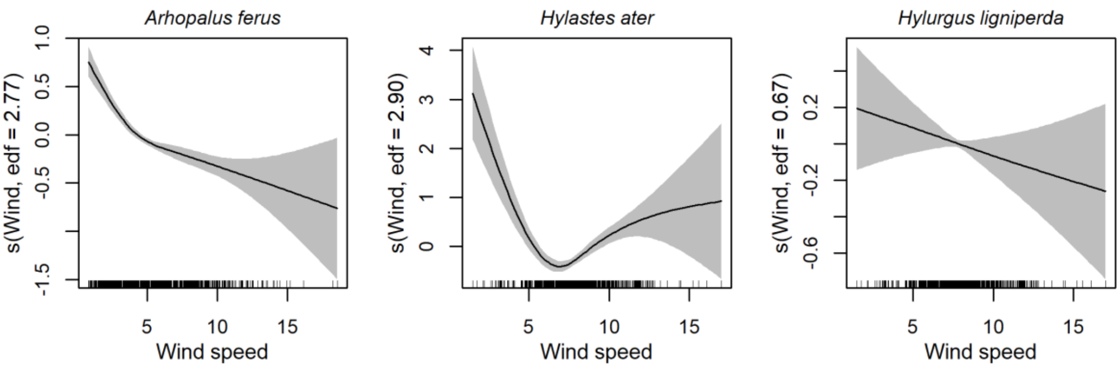

Figure B7: Fitted functions for average wind speed for the count per 100 trap days data of *A. ferus* (left panel), *Hylastes ater* (middle panel) using a Poisson GAM and fitted functions for average wind speed for the (transformed) average count per 100 trap days data *Hylurgus ligniperda* (right panel) using the Gaussian additive models. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Wind, edf=x.xx), where 'Wind' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect.The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

Table B4 Humidity results from the GAMs for the (transformed) average count flight-activity data of *A. ferus, Hylastes ater* and *Hylurgus ligniperda*. GAMs have a parametric component and a smoothing part, hence the distinction between parametric coefficients and the smoothing terms. s( ) = smooth term for a continuous variable, *SE* = standard error of the estimate, *t* = *t-statistic*, *P* = *P*-value, *edf* = estimated degrees of freedom, *F* = *F-statistic* and Humid = Average humidity (average evening humidity was used for evening flight activity of *A. ferus)*. Significant values are denoted with P <0.05 = *, P <0.01 = **, P <0.001 = ***.

Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Arhopalus ferus				
Intercept	0.54	0.38	1.42	0.155
Port : Tauranga	0.32	0.53	0.61	0.545
Port : Napier	0.89	0.53	1.69	0.091
Port : Nelson	0.73	0.52	1.41	0.158
Port : Dunedin	-0.10	0.53	-0.18	0.858
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Humid)		0.00	0.00	0.903
Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Hylastes ater				
Intercept	0.22	0.09	2.35	<0.05 *
Port : Tauranga	0.09	0.13	0.70	0.4839
Port : Napier	0.04	0.13	0.29	0.775
Port : Nelson	0.17	0.13	1.29	0.196
Port : Dunedin	1.15	0.23	4.98	< 0.001 ***
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Humid)		0.00	0.00	0.892
Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Hylurgus ligniperda				
Intercept	1.90	0.25	7.67	< 0.001 ***
Port : Tauranga	0.30	0.34	0.87	0.385
Port : Napier	0.09	034	0.28	0.780
Port : Nelson	-0.16	0.34	-0.48	0.632
Port : Dunedin	-1.79	0.59	-3.02	< 0.01 **
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Humid)		0.00	0.00	0.539

[b] Models have a Gaussian error structure and include a first-autoregressive covariance structure within each port.

Table B5 GAM results for the probability of flight based on presence abundance data for the three most commonly trapped beetle species, *A. ferus, Hylastes ater* and *Hylurgus ligniperda*. GAMs have a parametric component and a smoothing part, hence the distinction between parametric coefficients and the smoothing terms. s( ) = smooth term for a continuous variable, *SE* = standard error of the estimate, *z* = *z*-statistic, *t* = *t-statistic*, *P* = *P*-value, *edf* = estimated degrees of freedom, *Chi-sq* = *Chi Square*-statistic, *F* = *F-statistic* and Week = weeks of the year. Significant values are denoted with P <0.05 = *, P <0.01 = **, P <0.001 = ***.

Parametric coefficients[a]	*Estimate*	*SE*	*z*	*P*
Arhopalus ferus				
Intercept	-5.60	0.58	-9.51	< 0.001 ***
Port : Tauranga	0.63	0.68	0.92	0.355
Port : Napier	0.73	0.73	1.00	0.316
Port : Nelson	0.94	0.73	1.29	0.197
Port : Dunedin	-0.76	0.92	-0.82	0.410
Approx. significance of smooth terms[a]		*edf*	*Chi-sq*	*P*
s(Week) : Whangarei		3.82	10.01	< 0.001 ***
s(Week) : Tauranga		4.17	12.05	< 0.001 ***
s(Week) : Napier		4.79	23.94	< 0.001 ***
s(Week) : Nelson		4.93	28.49	< 0.001 ***
s(Week) : Dunedin		3.64	7.97	< 0.001 ***
Parametric coefficients[a]	*Estimate*	*SE*	*z*	*P*
Hylastes ater				
Intercept	-5.01	0.23	-21.22	< 0.001 ***
Port : Tauranga	-0.01	0.34	-0.04	0.9654
Port : Napier	-1.23	0.64	-1.92	0.0542
Port : Nelson	0.40	0.31	1.31	0.1905
Port : Dunedin	1.68	0.26	6.47	< 0.001 ***
Approx. significance of smooth terms[a]		*edf*	*Chi-sq*	*P*
s(Week) : Whangarei		0.93	0.18	0.192
s(Week) : Tauranga		2.64	2.45	< 0.001 ***
s(Week) : Napier		5.84	4.33	< 0.001 ***
s(Week) : Nelson		3.31	4.04	< 0.001 ***
s(Week) : Dunedin		6.65	13.96	< 0.001 ***

[a] Models have a binomial error structure and include a first-autoregressive covariance structure.
[b] Models have a binomial error structure, and include a first-autoregressive covariance structure, and the standard errors are corrected using the quasi-binomial model.

Table B5 (continued).

Parametric coefficients[b]	*Estimate*	*SE*	*t*	*P*
Hylurgus ligniperda				
Intercept	-2.22	0.09	-24.74	< 0.001 ***
Port : Tauranga	-0.03	0.12	-0.22	0.8214
Port : Napier	-0.28	0.13	-2.05	<0.05 *
Port : Nelson	-0.51	0.16	-3.16	<0.01 **
Port : Dunedin	-2.53	0.28	-8.93	< 0.001 ***
Approx. significance of smooth terms[b]		*edf*	*F*	*P*
s(Week) : Whangarei		5.49	8.79	< 0.001 ***
s(Week) : Tauranga		6.02	15.17	< 0.001 ***
s(Week) : Napier		6.38	8.87	< 0.001 ***
s(Week) : Nelson		6.13	15.82	< 0.001 ***
s(Week) : Dunedin		2.82	1.37	<0.05 **

[a] Models have a binomial error structure and include a first-autoregressive covariance structure.
[b] Models have a binomial error structure, and include a first-autoregressive covariance structure, and the standard errors are corrected using the quasi-binomial model.

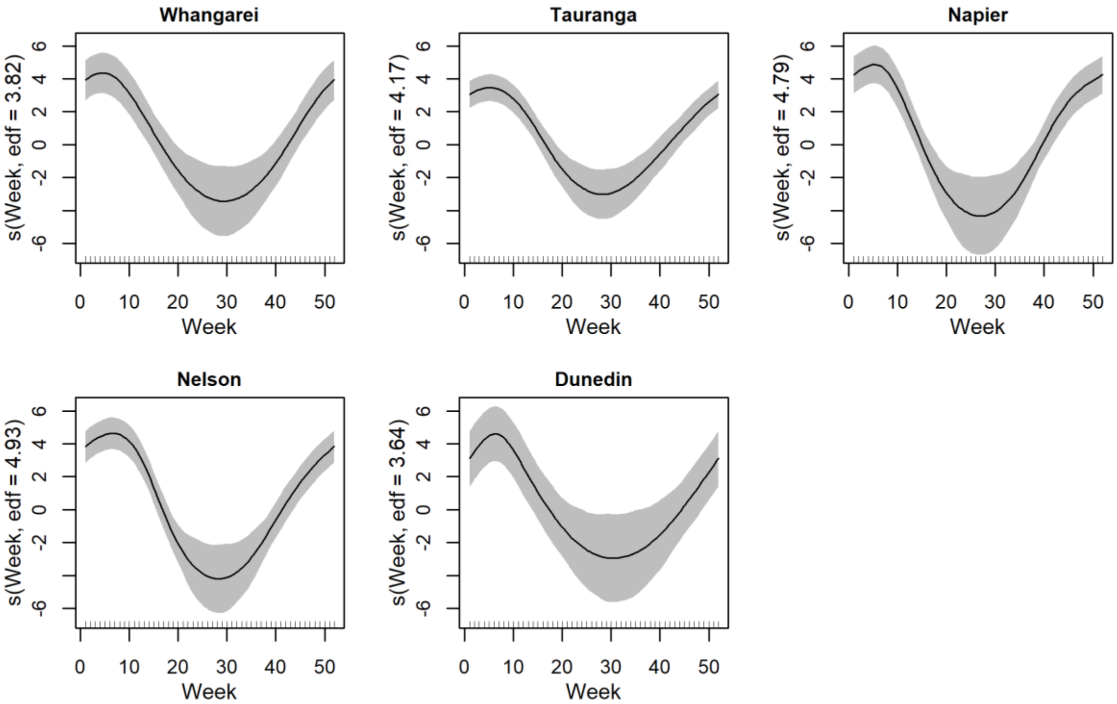

Figure B8: Fitted functions for week of the year by port for the presence abundance data for *A. ferus* using the binomial GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

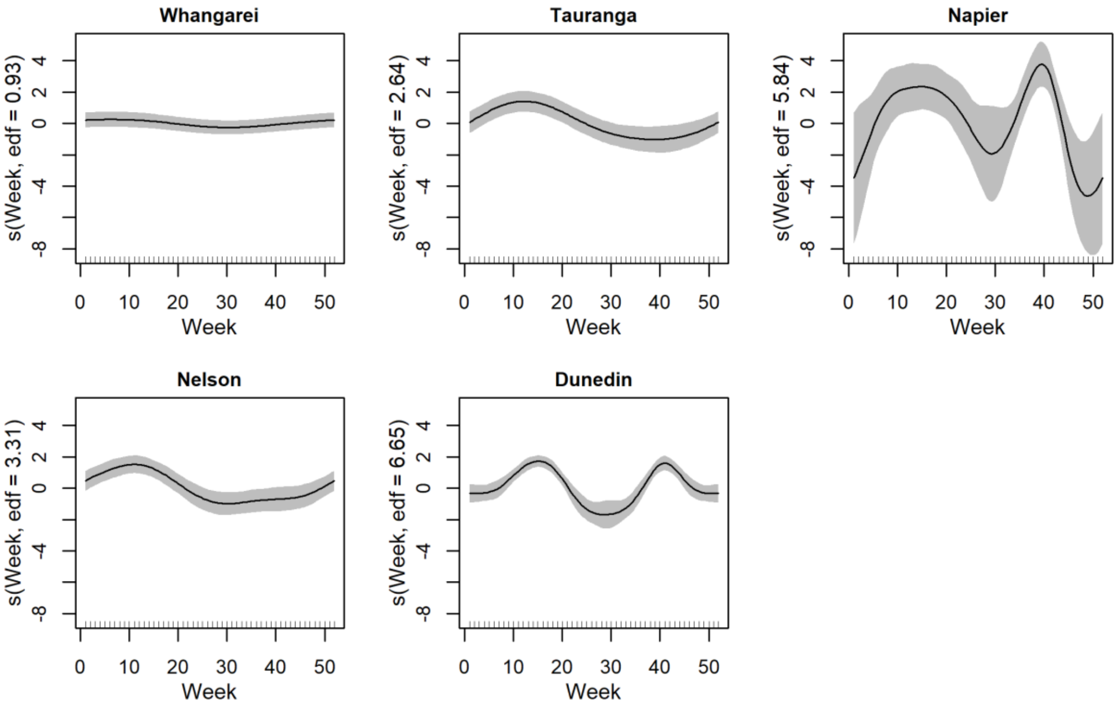

Figure B9: Fitted functions for week of the year by port for the presence abundance data for *Hylastes ater* using the binomial GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf=x.xx), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

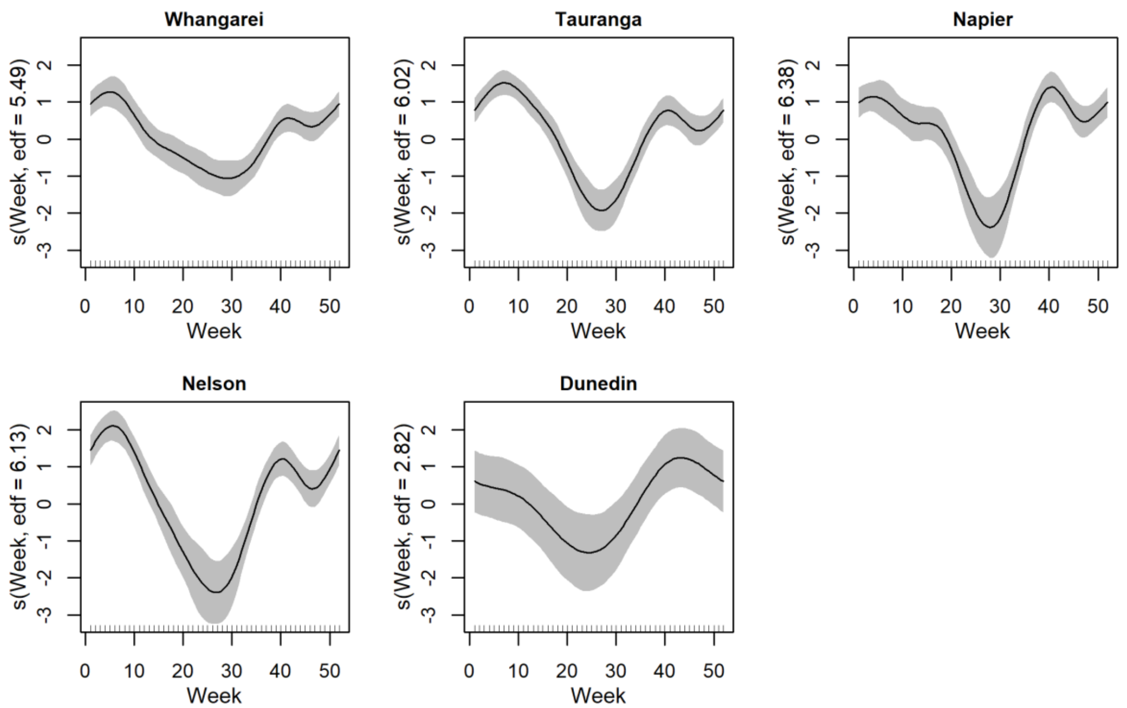

Figure B10: Fitted functions for week of the year by port for the presence abundance data for *Hylurgus ligniperda* using the quasi-binomial GAMs. The shaded region represents twice the pointwise standard errors of the estimated curve. The Y-axis is labelled s(Week, edf=x.xx), where 'Week' is the covariate name and 'edf' is the estimated degrees of freedom of the smooth. edf values >1 indicate a non-linear effect. The rug plots represented at the bottom of each plot show the frequency of the covariates of each smooth.

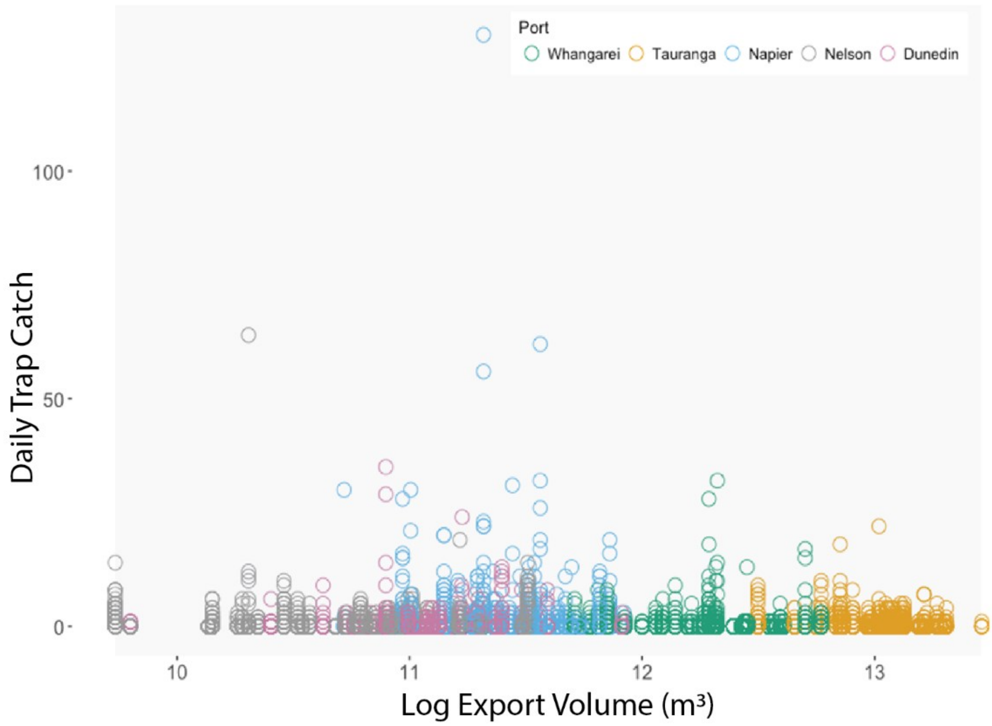

Figure B11: Scatterplot of daily catch versus log-transformed export volume.

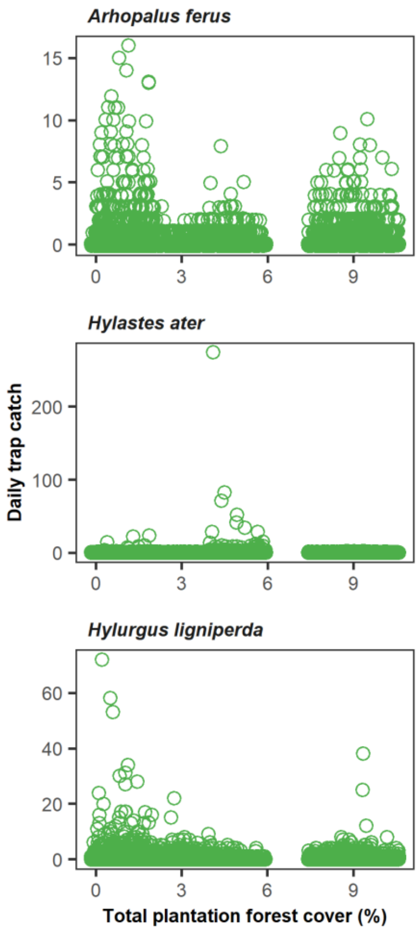

Figure B12: Daily trap catch as a function of total plantation forest cover (%) within a 5 km radius of each port.

Table B6. Estimated probability of flight of *Arhopalus ferus, Hylastes ater* and *Hylurgus ligniperda* by port using the GAM approach to model data from the 3 years of sampling.

Arhopalus ferus						*Hylastes ater*						*Hylurgus ligniperda*					
Week	**Whangarei**	**Tauranga**	**Napier**	**Nelson**	**Dunedin**	**Week**	**Whangarei**	**Tauranga**	**Napier**	**Nelson**	**Dunedin**	**Week**	**Whangarei**	**Tauranga**	**Napier**	**Nelson**	**Dunedin**
1	0.16	0.13	0.35	0.3	0.04	1	0.01	0.01	0	0.02	0.02	1	0.22	0.19	0.18	0.21	0.02
2	0.19	0.15	0.4	0.35	0.06	2	0.01	0.01	0	0.02	0.03	2	0.24	0.21	0.19	0.26	0.01
3	0.21	0.16	0.44	0.4	0.08	3	0.01	0.01	0	0.02	0.03	3	0.26	0.24	0.2	0.29	0.01
4	0.22	0.18	0.48	0.44	0.11	4	0.01	0.01	0	0.02	0.03	4	0.27	0.27	0.2	0.33	0.01
5	0.22	0.18	0.5	0.47	0.13	5	0.01	0.01	0	0.03	0.03	5	0.28	0.3	0.2	0.34	0.01
6	0.21	0.18	0.49	0.49	0.15	6	0.01	0.02	0	0.03	0.03	6	0.27	0.32	0.19	0.35	0.01
7	0.18	0.17	0.45	0.49	0.14	7	0.01	0.02	0.01	0.03	0.03	7	0.26	0.32	0.18	0.33	0.01
8	0.15	0.15	0.38	0.47	0.12	8	0.01	0.02	0.01	0.04	0.04	8	0.23	0.32	0.16	0.3	0.01
9	0.11	0.13	0.28	0.43	0.09	9	0.01	0.02	0.01	0.04	0.06	9	0.2	0.3	0.15	0.25	0.01
10	0.08	0.1	0.18	0.37	0.06	10	0.01	0.02	0.01	0.04	0.07	10	0.17	0.28	0.13	0.2	0.01
11	0.05	0.08	0.11	0.29	0.04	11	0.01	0.03	0.02	0.04	0.1	11	0.14	0.26	0.12	0.16	0.01
12	0.03	0.05	0.06	0.21	0.02	12	0.01	0.03	0.02	0.04	0.12	12	0.12	0.23	0.11	0.12	0.01
13	0.02	0.04	0.03	0.13	0.01	13	0.01	0.03	0.02	0.04	0.14	13	0.11	0.21	0.11	0.1	0.01
14	0.01	0.02	0.01	0.07	0.01	14	0.01	0.02	0.02	0.04	0.16	14	0.09	0.18	0.11	0.07	0.01
15	0.01	0.01	0.01	0.04	0	15	0.01	0.02	0.02	0.03	0.17	15	0.09	0.16	0.11	0.06	0.01
16	0	0.01	0	0.02	0	16	0.01	0.02	0.02	0.03	0.16	16	0.08	0.13	0.11	0.05	0
17	0	0.01	0	0.01	0	17	0.01	0.02	0.02	0.02	0.15	17	0.07	0.11	0.1	0.04	0
18	0	0	0	0	0	18	0.01	0.02	0.02	0.02	0.12	18	0.07	0.09	0.09	0.03	0
19	0	0	0	0	0	19	0.01	0.02	0.01	0.02	0.09	19	0.07	0.07	0.07	0.02	0
20	0	0	0	0	0	20	0.01	0.01	0.01	0.01	0.06	20	0.06	0.05	0.06	0.02	0
21	0	0	0	0	0	21	0.01	0.01	0.01	0.01	0.04	21	0.06	0.04	0.04	0.01	0
22	0	0	0	0	0	22	0.01	0.01	0.01	0.01	0.03	22	0.05	0.03	0.03	0.01	0
23	0	0	0	0	0	23	0.01	0.01	0	0.01	0.02	23	0.05	0.02	0.02	0.01	0
24	0	0	0	0	0	24	0.01	0.01	0	0.01	0.01	24	0.05	0.02	0.01	0.01	0
25	0	0	0	0	0	25	0.01	0.01	0	0.01	0.01	25	0.04	0.02	0.01	0.01	0
26	0	0	0	0	0	26	0.01	0.01	0	0	0.01	26	0.04	0.02	0.01	0.01	0
27	0	0	0	0	0	27	0.01	0	0	0	0.01	27	0.04	0.01	0.01	0.01	0
28	0	0	0	0	0	28	0.01	0	0	0	0.01	28	0.04	0.02	0.01	0.01	0
29	0	0	0	0	0	29	0.01	0	0	0	0.01	29	0.04	0.02	0.01	0.01	0
30	0	0	0	0	0	30	0.01	0	0	0	0.01	30	0.04	0.02	0.01	0.01	0
31	0	0	0	0	0	31	0.01	0	0	0	0.01	31	0.04	0.02	0.01	0.01	0
32	0	0	0	0	0	32	0.01	0	0	0	0.01	32	0.04	0.03	0.02	0.02	0.01
33	0	0	0	0	0	33	0.01	0	0	0	0.01	33	0.04	0.04	0.03	0.03	0.01
34	0	0	0	0	0	34	0.01	0	0	0	0.01	34	0.05	0.06	0.05	0.04	0.01
35	0	0	0	0	0	35	0.01	0	0.01	0	0.02	35	0.06	0.08	0.07	0.06	0.01
36	0	0	0	0	0	36	0.01	0	0.01	0	0.03	36	0.07	0.1	0.11	0.08	0.01
37	0	0	0	0	0	37	0.01	0	0.03	0	0.05	37	0.09	0.12	0.15	0.11	0.02
38	0	0	0	0	0	38	0.01	0	0.05	0	0.07	38	0.11	0.15	0.19	0.14	0.02
39	0	0	0.01	0	0	39	0.01	0	0.07	0	0.11	39	0.13	0.17	0.22	0.16	0.02
40	0	0	0.01	0.01	0	40	0.01	0	0.07	0	0.14	40	0.15	0.18	0.25	0.18	0.02
41	0	0.01	0.02	0.01	0	41	0.01	0	0.05	0	0.15	41	0.16	0.19	0.25	0.17	0.03
42	0	0.01	0.03	0.01	0	42	0.01	0	0.02	0.01	0.14	42	0.16	0.18	0.23	0.16	0.03

43	0	0.01	0.04	0.02	0	43	0.01	0	0	0.01	0.11	43	0.15	0.16	0.2	0.14	0.03
44	0.01	0.01	0.07	0.03	0	44	0.01	0	0	0.01	0.08	44	0.14	0.14	0.16	0.11	0.03
45	0.01	0.02	0.1	0.05	0	45	0.01	0	0	0.01	0.06	45	0.14	0.13	0.14	0.1	0.03
46	0.02	0.03	0.13	0.07	0	46	0.01	0	0	0.01	0.04	46	0.13	0.12	0.12	0.09	0.03
47	0.03	0.04	0.17	0.09	0	47	0.01	0	0	0.01	0.03	47	0.13	0.12	0.11	0.09	0.02
48	0.05	0.05	0.2	0.12	0.01	48	0.01	0	0	0.01	0.03	48	0.14	0.12	0.12	0.1	0.02
49	0.07	0.07	0.24	0.16	0.01	49	0.01	0	0	0.01	0.03	49	0.15	0.13	0.13	0.11	0.02
50	0.1	0.09	0.27	0.21	0.02	50	0.01	0.01	0	0.01	0.02	50	0.17	0.14	0.14	0.14	0.02
51	0.13	0.11	0.31	0.25	0.02	51	0.01	0.01	0	0.01	0.02	51	0.19	0.16	0.16	0.17	0.02
52	0.16	0.13	0.35	0.3	0.04	52	0.01	0.01	0	0.02	0.02	52	0.22	0.19	0.18	0.21	0.02

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