Supplementary Figures:

Seasonal variation in UVA light drives hormonal and behavioral changes in a marine annelid via a ciliary opsin

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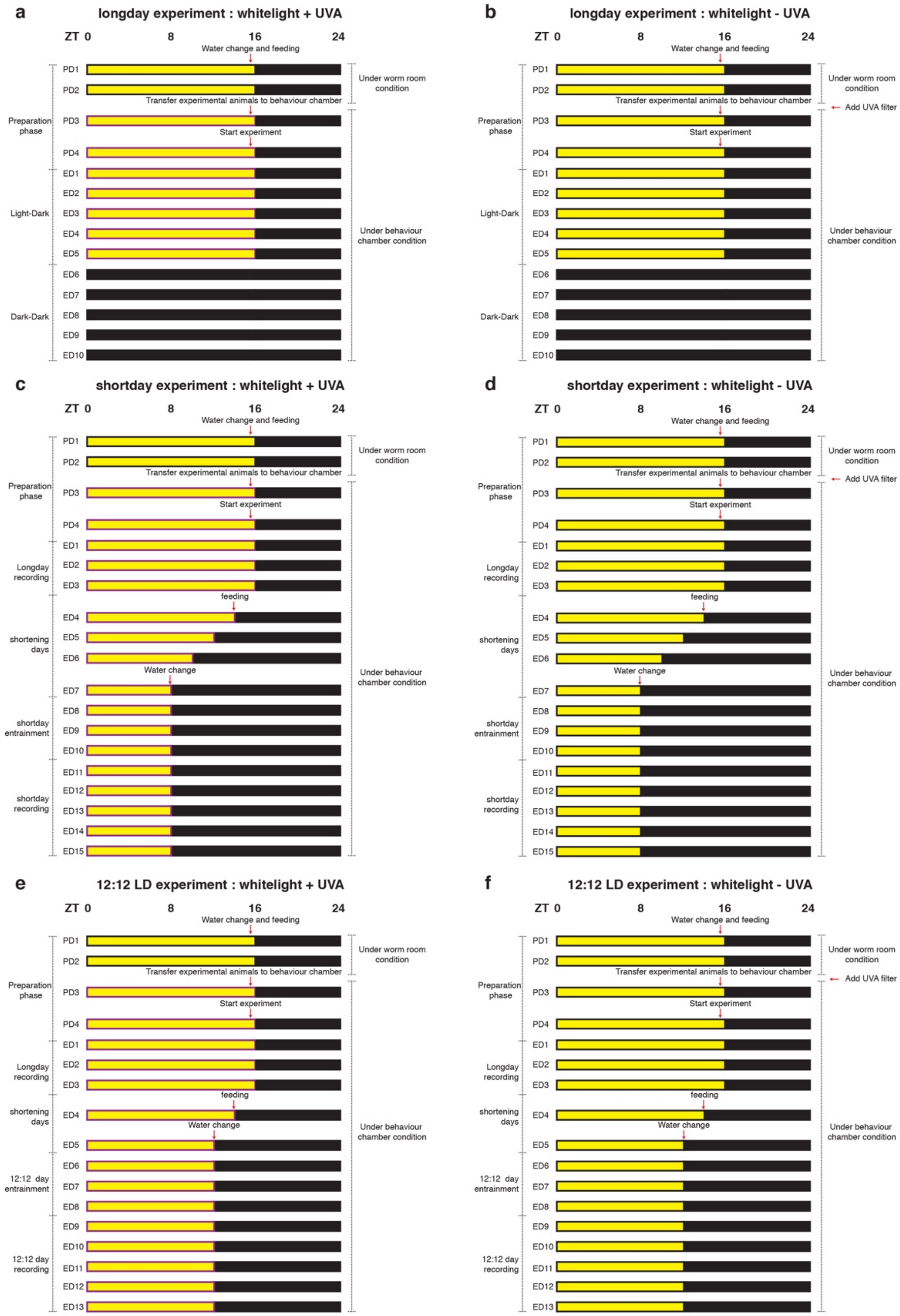
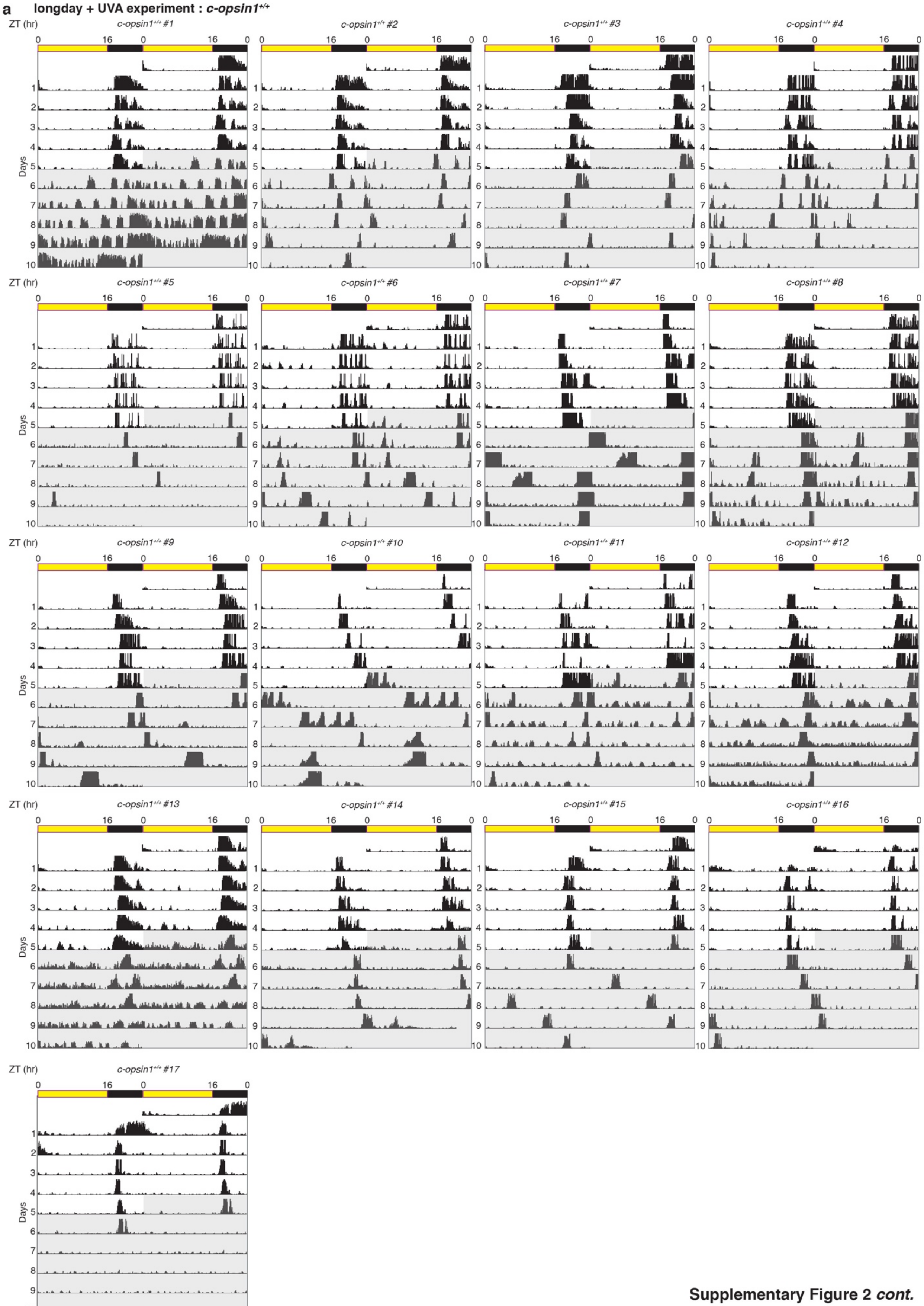


Supplementary Figure 1

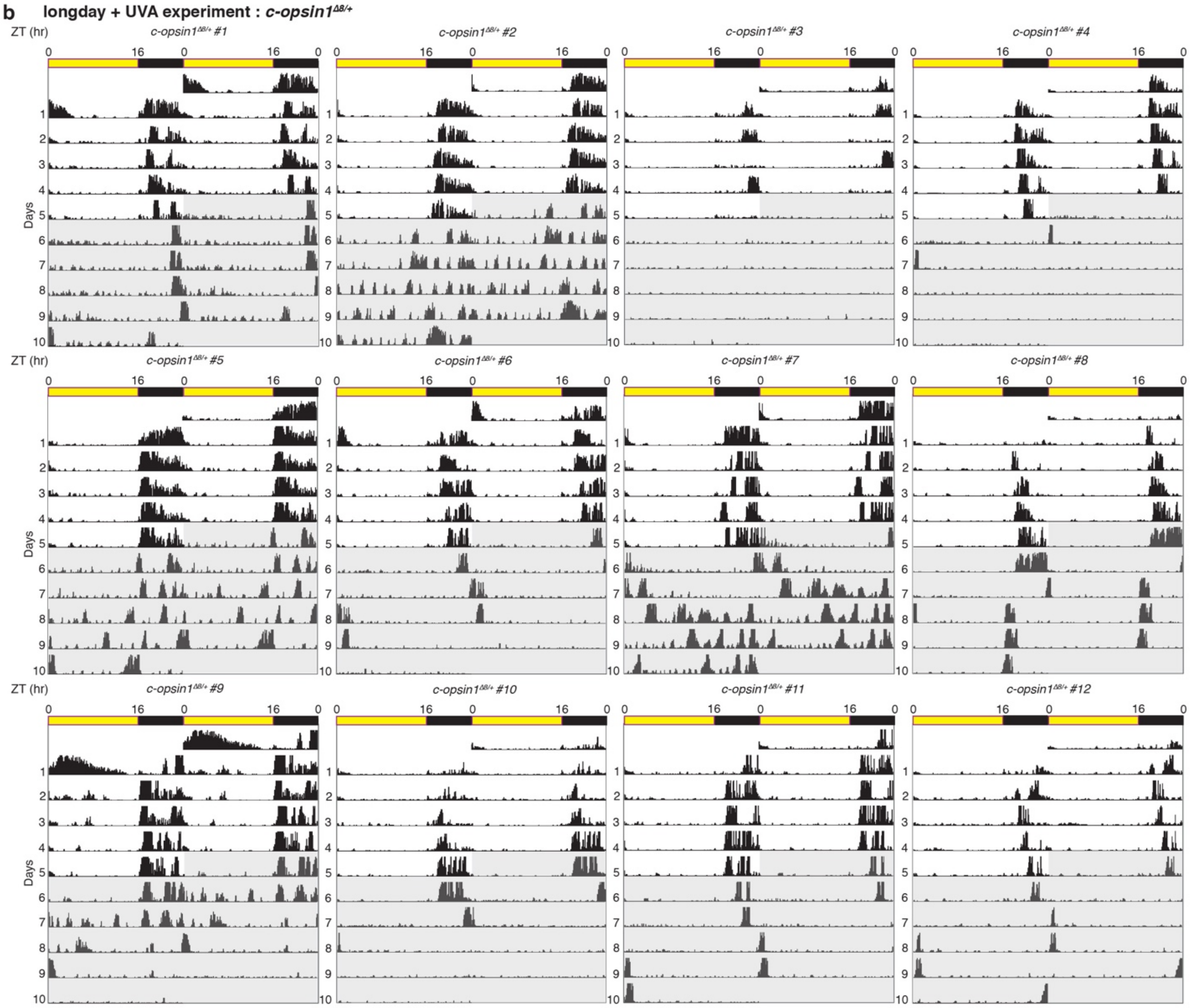
SupplFig. 1. Temporal schematic of illumination for long day and short day experiments. (**a,b**) longday (16:8 LD) experiment entrained under "white" light including UVA (a) and "white" light with filter-reduced UVA (B). (**c-f**) short day (**c,d-** LD8:16) and equal daylength (**e,f-** LD12:12**)** experiments. As worms are normally grown at LD 16:8, shorter daylength are achieved by gradually decreasing daylength from longday. The gradual decrease is performed to avoid confounding the worms' circalunar entrainment. PD – Preparation day, ED – Experimental day. For light spectra: Extended Data Fig.4.

a longday + UVA experiment : *c-opsin1+/+*

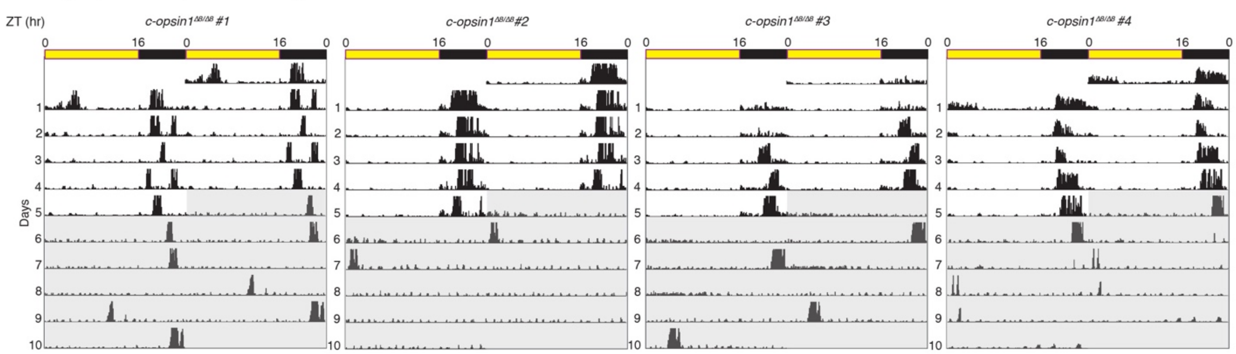


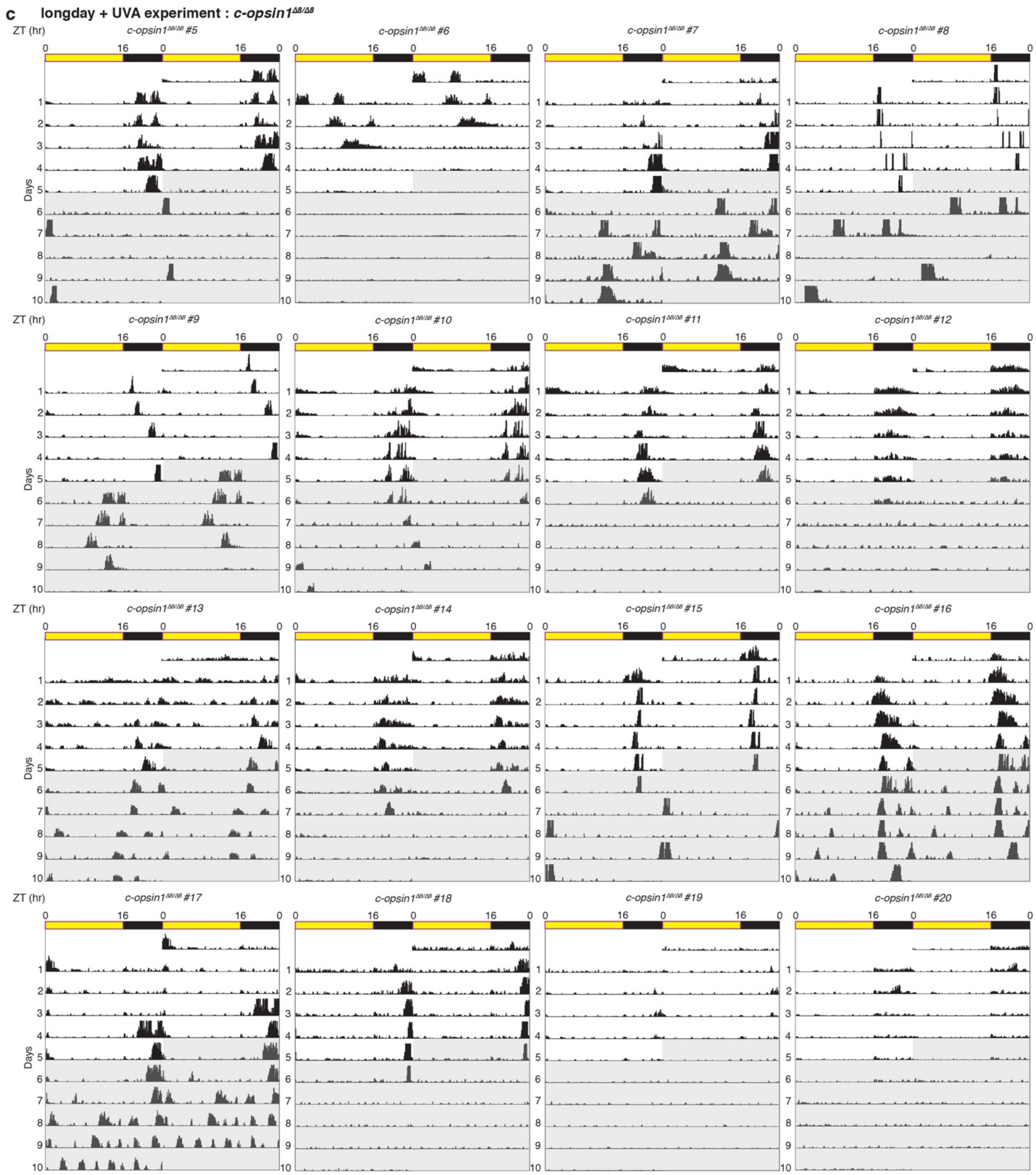
Supplementary Figure 2 *cont.*
Page 1

b **longday + UVA experiment : *c-opsin1*$^{\Delta 8/+}$**



c **longday + UVA experiment : *c-opsin1*$^{\Delta 8/\Delta 8}$**

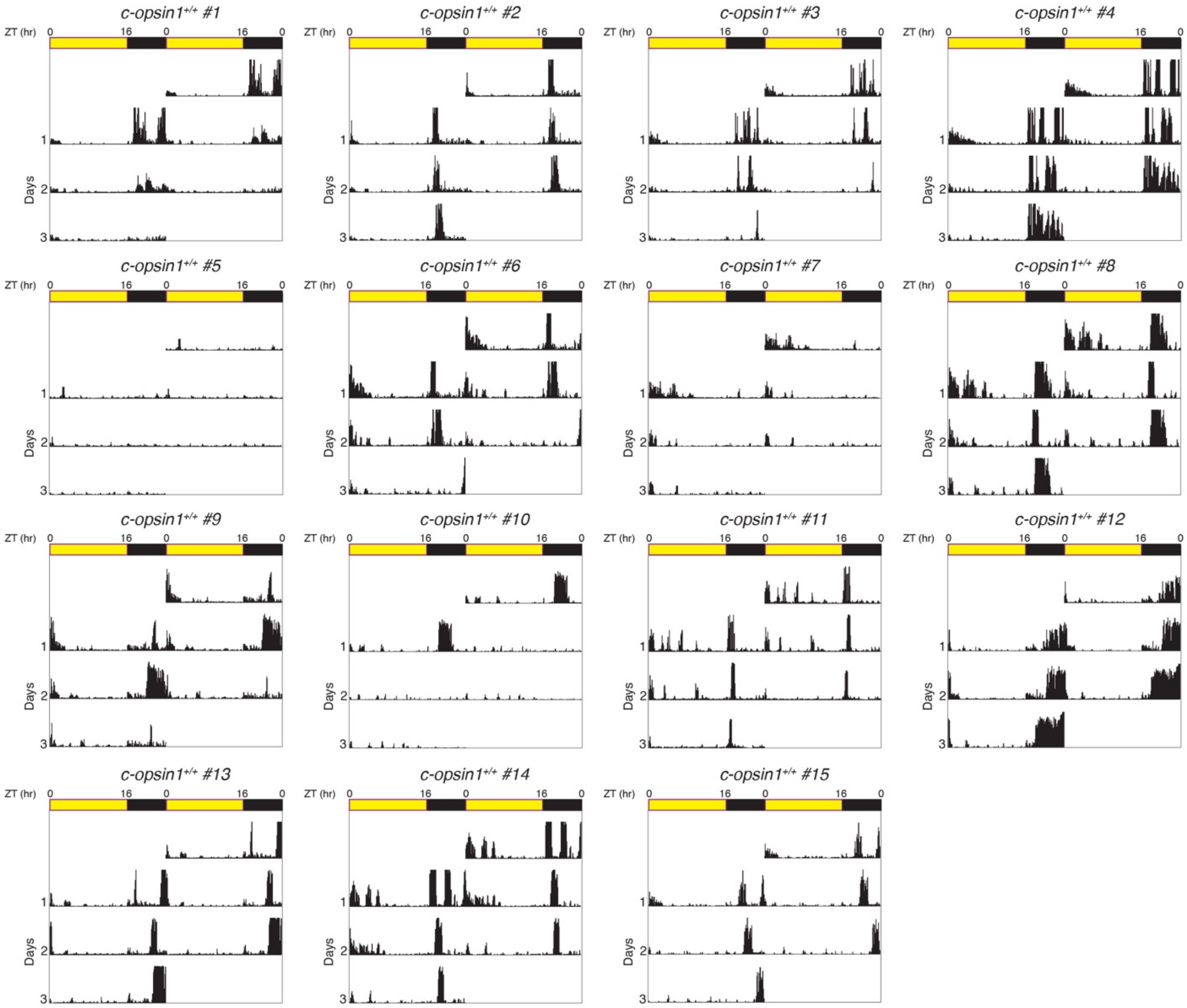




Supplementary Figure 2
Page 3

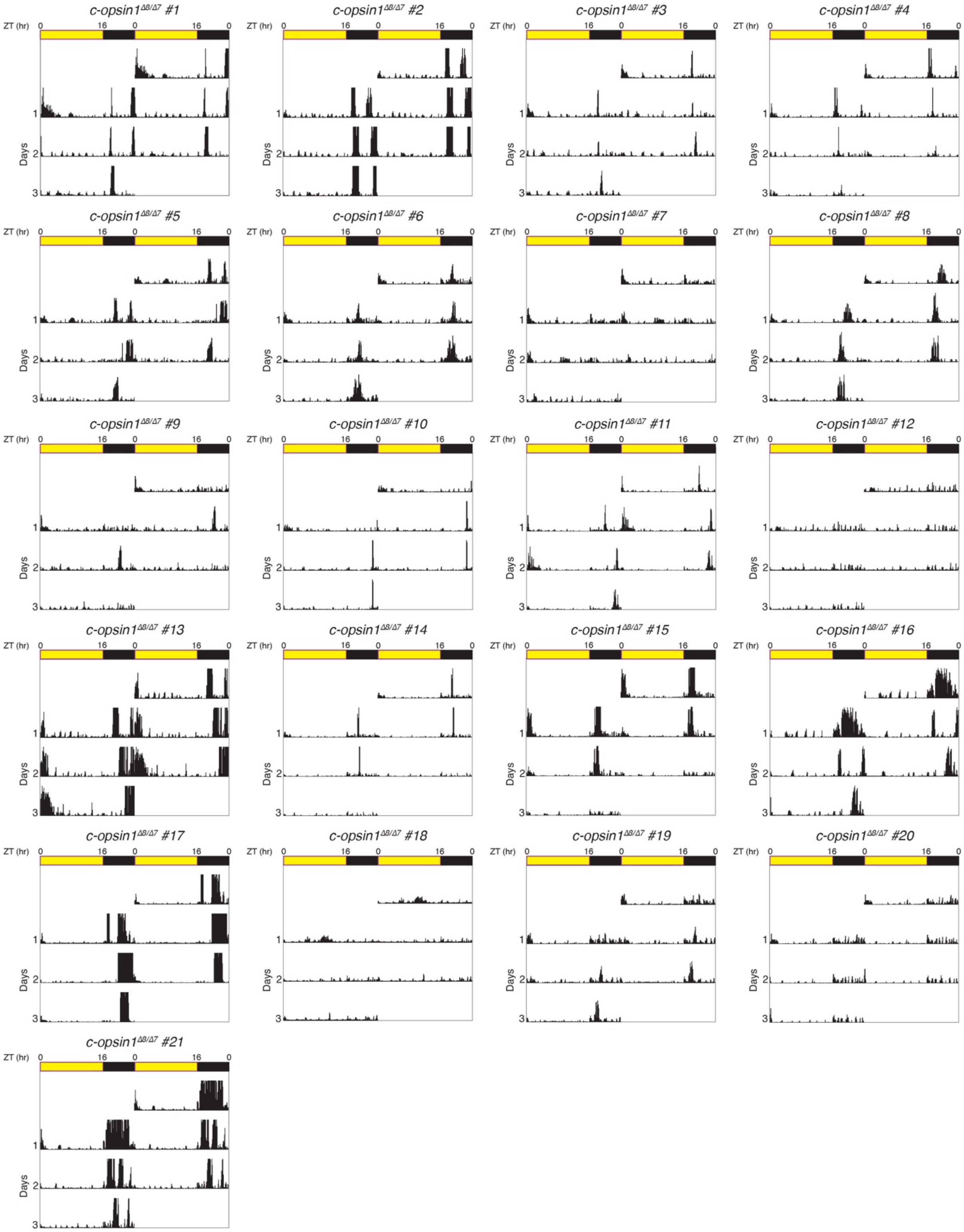
SupplFig. 2. Individual actograms of *c-opsin1*$^{\Delta 8}$ homozygous, heterozygous and wildtype siblings under long day, including strong UVA. Individual double-plotted actograms. 5 days of LD followed by 5 days of DD (shaded). Genotypes as indicated. Y-axis: days.

a **longday + UVA : *c-opsin1*$^{+/+}$**



Supplementary Figure 3 *cont.*

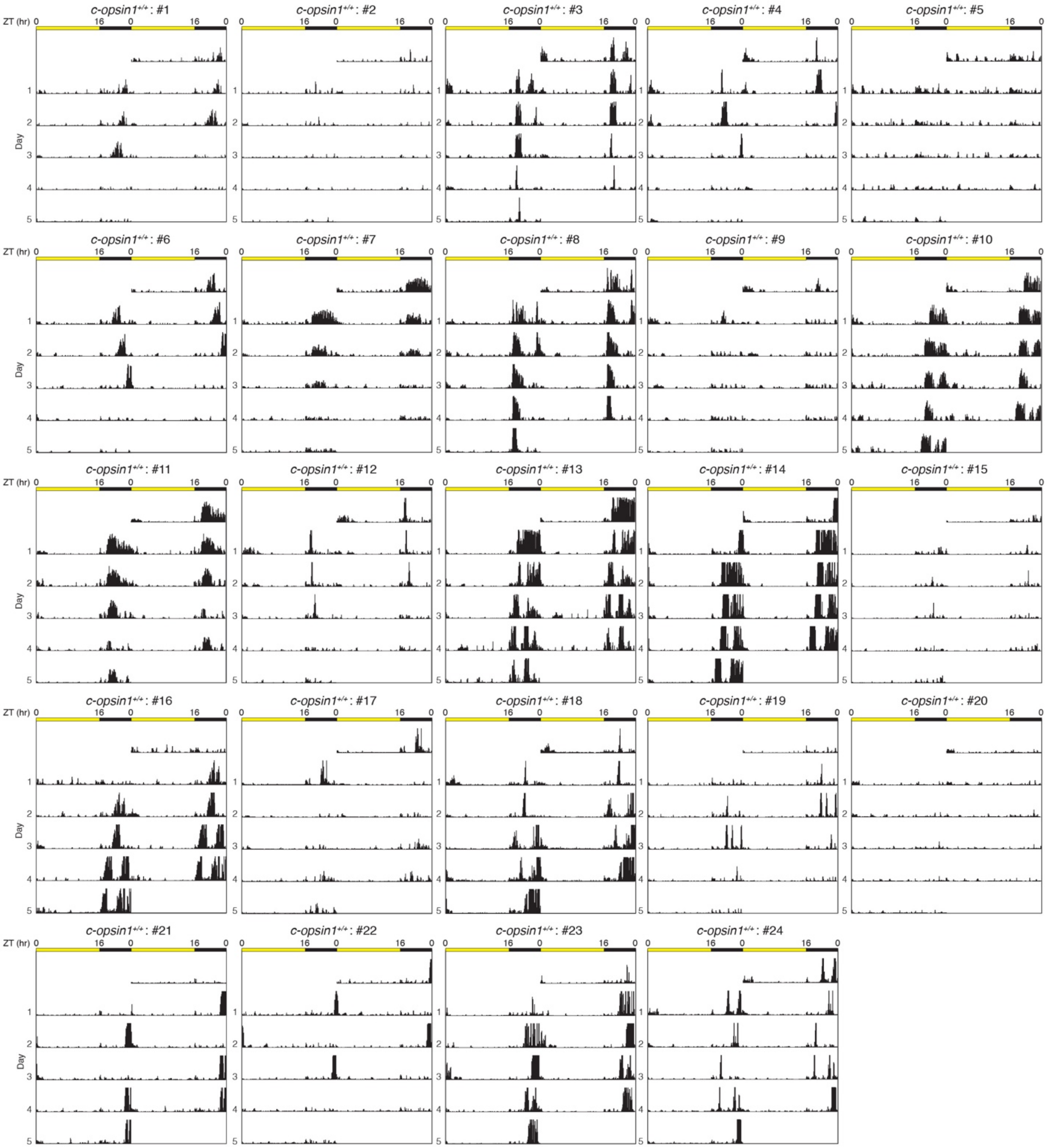
b longday + UVA : *c-opsin1*$^{Δ8/Δ7}$



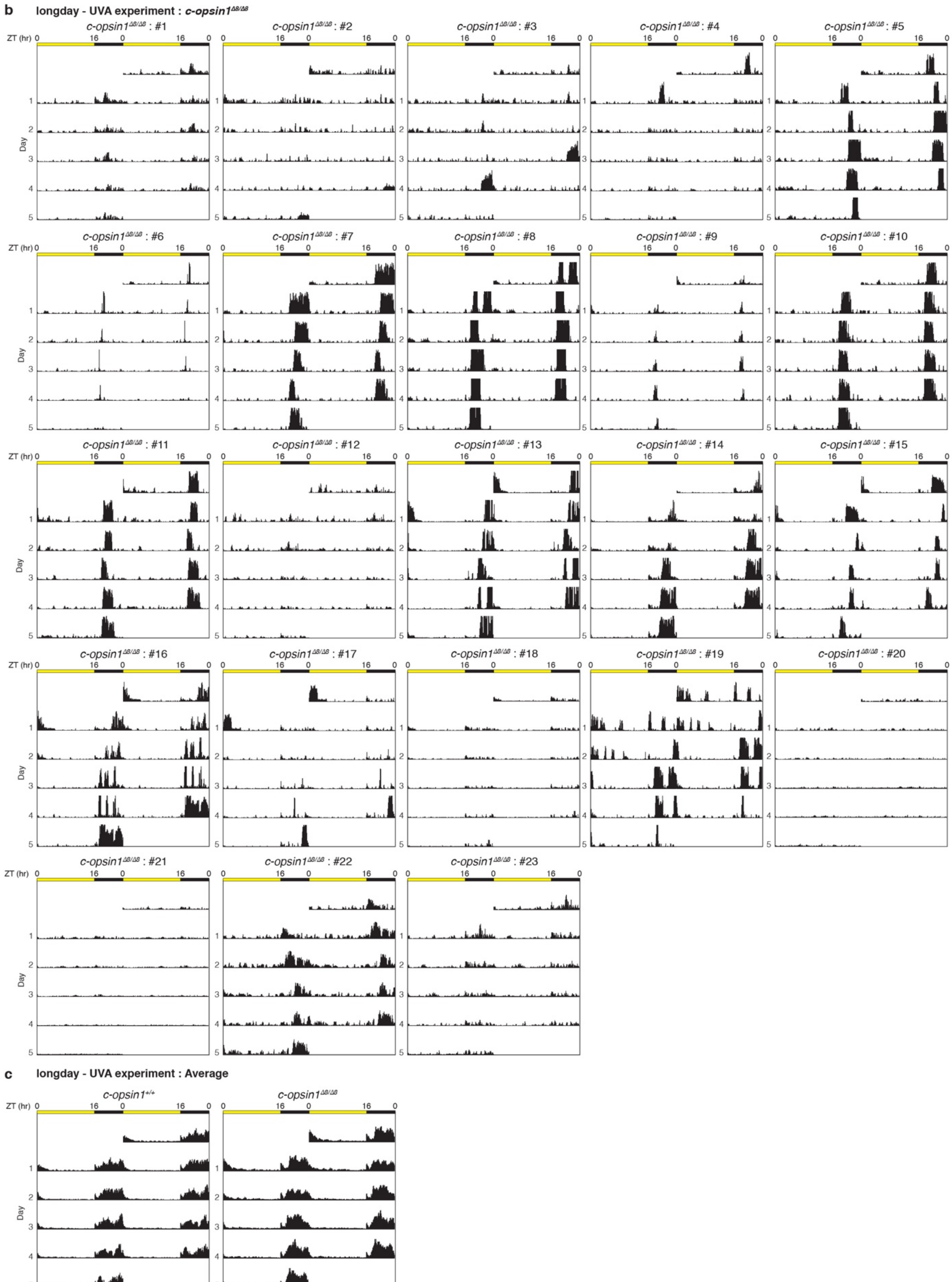
Supplementary Figure 3 *cont.*
Page 2

SupplFig.3. Individual actograms of *c-opsin1*$^{Δ8/Δ7}$ transheterozygous and wildtype under longday, including strong UVA. 3 days of LD. Individual double-plotted actograms plot of *c- opsin1*$^{+/+}$ (**A**) and *c-opsin1*$^{Δ8/Δ7}$ (**B**). Genotypes as indicated. Y-axis: days.

a **longday - UVA experiment : *c-opsin1*$^{+/+}$**

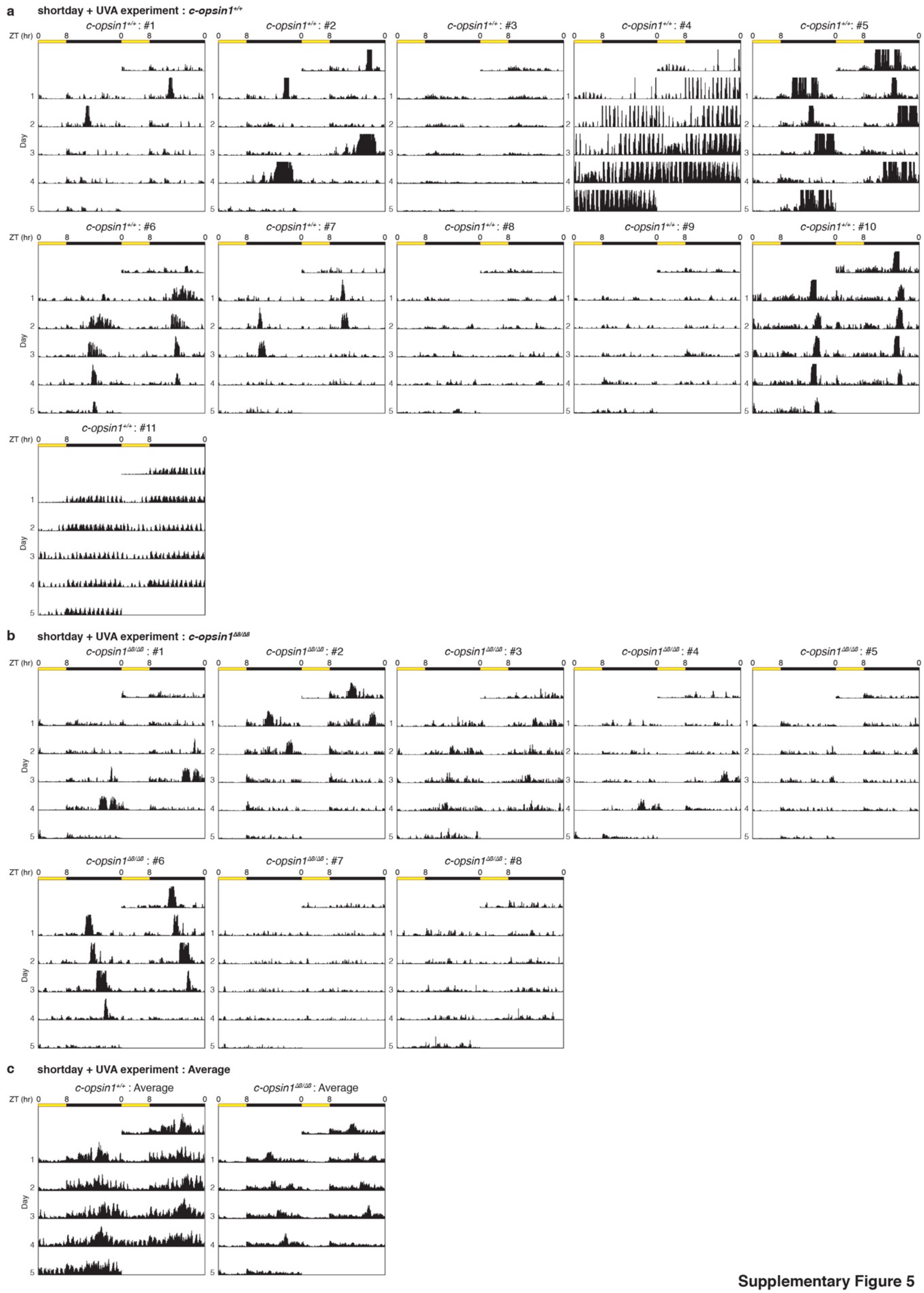


Supplementary Figure 4 *cont.*



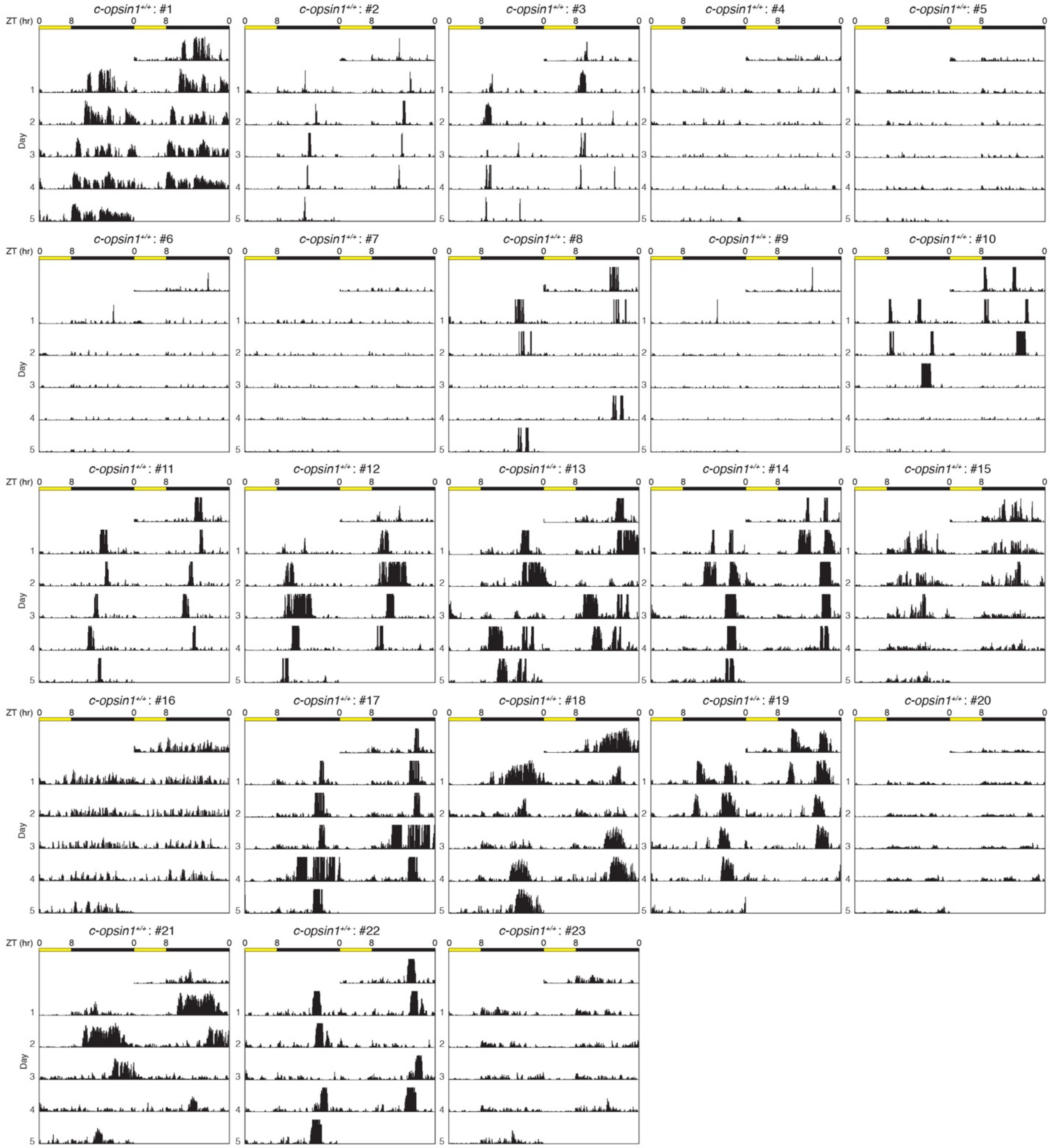
Supplementary Figure 4
Page. 2

SupplFig.4. Individual double-plotted actograms of *c-opsin1*$^{\Delta 8}$ and corresponding wt under long day, with filter-reduced UVA. 5 days of LD. Genotypes as indicated. Y-axis: days.

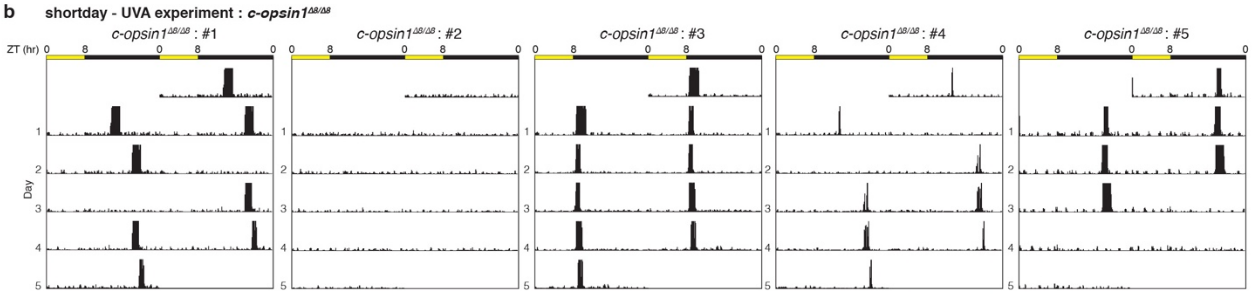


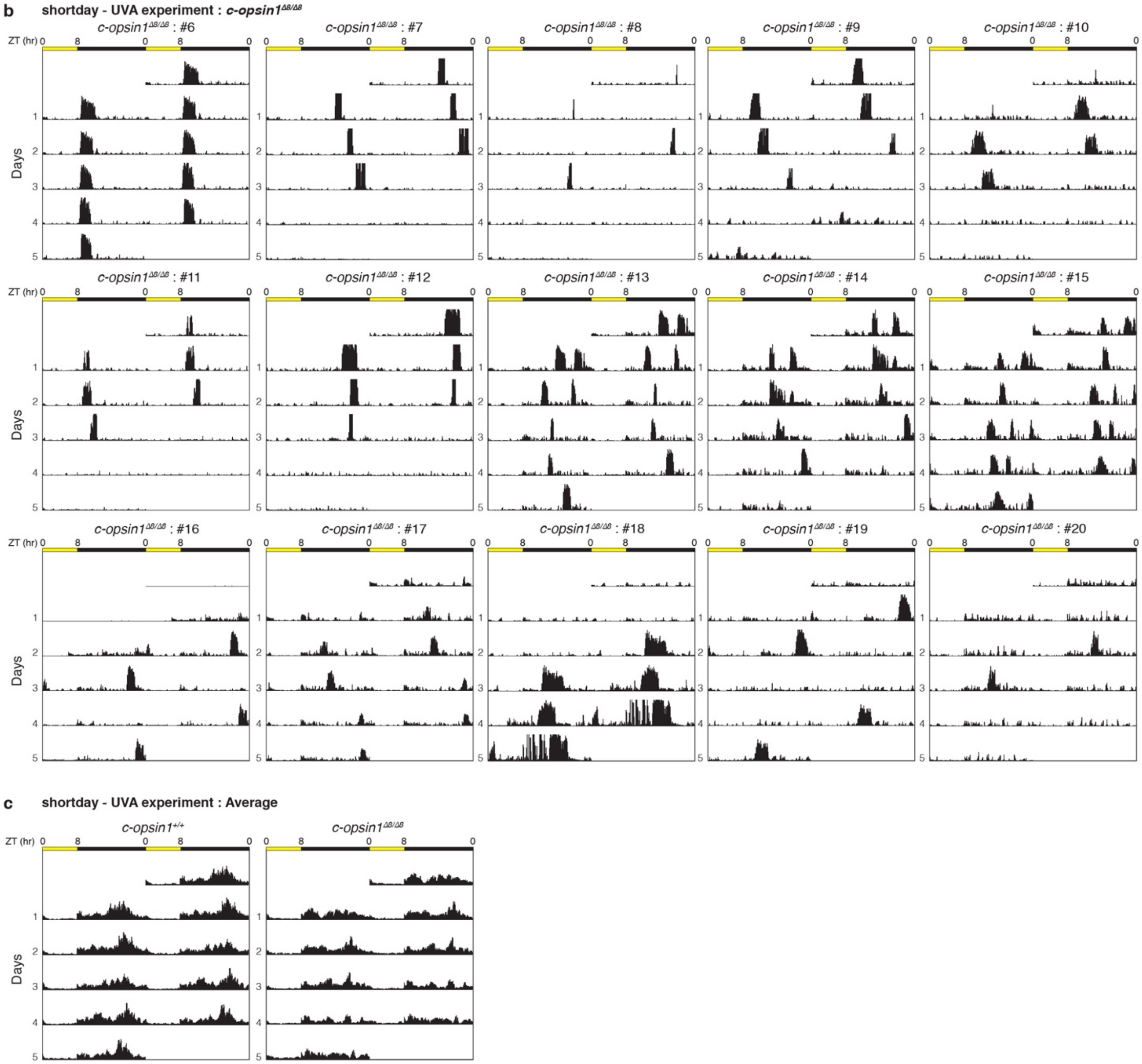
SupplFig.5. Individual double-plotted actograms of *c-opsin1*$^{\Delta 8}$ and corresponding wt under short day, including strong UVA. 5 days of LD. Genotypes as indicated. Y-axis: days.

a **shortday - UVA experiment : *c-opsin1*$^{+/+}$**



b **shortday - UVA experiment : *c-opsin1*$^{\Delta 8/\Delta 8}$**





Supplementary Figure 6
Page. 2

SupplFig.6. Individual double-plotted actograms of *c-opsin1*$^{\Delta 8}$ and corresponding wt under shortday, with filter-reduced UVA. 5 days of LD. Genotypes as indicated. Y-axis: days.

Longday experiment - 16:8LD

Comparison	One-way ANOVA (Sidak's multiple correction test)	Significant?	Summary	Adjusted P-value
c-opsin1$^{+/+}$ LD+UVA vs LD-UVA	*c-opsin1*$^{+/+}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(0-8hrs)	No	ns	0.9837
	c-opsin1$^{+/+}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(8-16hrs)	No	ns	0.9998
	c-opsin1$^{+/+}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(16-24hrs)	Yes	****	<0.0001
c-opsin1$^{-/-}$ LD+UVA vs LD-UVA	*c-opsin1*$^{-/-}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-8hrs)	No	ns	>0.9999
	c-opsin1$^{-/-}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(8-16hrs)	No	ns	0.9957
	c-opsin1$^{-/-}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(16-24hrs)	No	ns	0.9761
LD+UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(0-8hrs)	No	ns	0.9898
	c-opsin1$^{+/+}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(8-16hrs)	No	ns	0.9616
	c-opsin1$^{+/+}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(16-24hrs)	Yes	****	<0.0001
LD-UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD-UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-8hrs)	No	ns	0.9111
	c-opsin1$^{+/+}$ LD-UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(8-16hrs)	No	ns	0.9859
	c-opsin1$^{+/+}$ LD-UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(16-24hrs)	No	ns	0.2644

Shortday experiment – 8:16LD

Comparison	One-way ANOVA (Sidak's multiple correction test)	Significant?	Summary	Adjusted P-value
c-opsin1$^{+/+}$ SD+UVA vs SD-UVA	*c-opsin1*$^{+/+}$ SD+UVA(0-8hrs) vs. *c-opsin1*$^{+/+}$ SD-UVA(0-8hrs)	No	ns	0.7789
	c-opsin1$^{+/+}$ SD+UVA(8-16hrs) vs. *c-opsin1*$^{+/+}$ SD-UVA(8-16hrs)	No	ns	0.9328
	c-opsin1$^{+/+}$ SD+UVA(16-24hrs) vs. *c-opsin1*$^{+/+}$ SD-UVA(16-24hrs)	No	ns	0.9863
c-opsin1$^{-/-}$ SD+UVA vs SD-UVA	*c-opsin1*$^{-/-}$ SD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(0-8hrs)	No	ns	0.9989
	c-opsin1$^{-/-}$ SD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(8-16hrs)	No	ns	0.1658
	c-opsin1$^{-/-}$ SD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(16-24hrs)	No	ns	0.2459
SD+UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ SD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ SD+UVA(0-8hrs)	No	ns	0.8137
	c-opsin1$^{+/+}$ SD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ SD+UVA(8-16hrs)	No	ns	0.3913
	c-opsin1$^{+/+}$ SD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ SD+UVA(16-24hrs)	No	ns	0.0525
SD-UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ SD-UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(0-8hrs)	No	ns	>0.9999
	c-opsin1$^{+/+}$ SD-UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(8-16hrs)	No	ns	>0.9999
	c-opsin1$^{+/+}$ SD-UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ SD-UVA(16-24hrs)	No	ns	0.0603

Equinox experiment – 16:8LD

Comparison	One-way ANOVA (Sidak's multiple correction test)	Significant?	Summary	Adjusted P-value
c-opsin1$^{+/+}$ LD+UVA vs LD-UVA	*c-opsin1*$^{+/+}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(0-8hrs)	No	ns	0.9981
	c-opsin1$^{+/+}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(8-16hrs)	No	ns	>0.9999
	c-opsin1$^{+/+}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(16-24hrs)	Yes	**	0.0056
c-opsin1$^{-/-}$ LD+UVA vs LD-UVA	*c-opsin1*$^{-/-}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-8hrs)	No	ns	0.8926
	c-opsin1$^{-/-}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(8-16hrs)	No	ns	0.9927
	c-opsin1$^{-/-}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(16-24hrs)	No	ns	0.3264
LD+UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD+UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(0-8hrs)	No	ns	0.9969
	c-opsin1$^{+/+}$ LD+UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(8-16hrs)	No	ns	>0.9999
	c-opsin1$^{+/+}$ LD+UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(16-24hrs)	Yes	**	0.0045
LD-UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD-UVA(0-8hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-8hrs)	No	ns	0.9647
	c-opsin1$^{+/+}$ LD-UVA(8-16hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(8-16hrs)	No	ns	>0.9999
	c-opsin1$^{+/+}$ LD-UVA(16-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(16-24hrs)	No	ns	0.3128

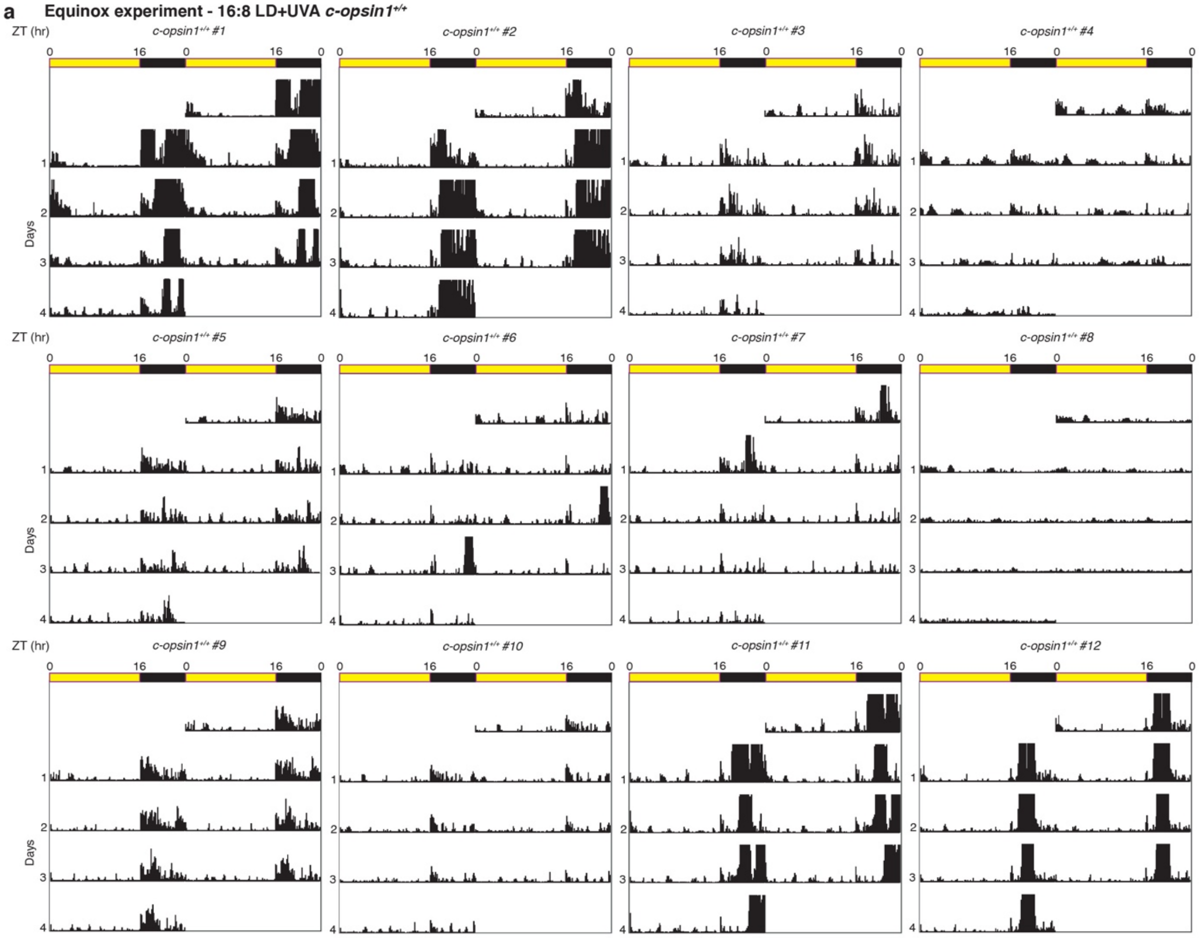
Equinox experiment - 12:12LD

Comparison	One-way ANOVA (Sidak's multiple correction test)	Significant?	Summary	Adjusted P-value
c-opsin1$^{+/+}$ 12:12LD+UVA vs 12:12LD-UVA	*c-opsin1*$^{+/+}$ LD+UVA(0-12hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(0-12hrs)	No	ns	0.9234
	c-opsin1$^{+/+}$ LD+UVA(12-24hrs) vs. *c-opsin1*$^{+/+}$ LD-UVA(12-24hrs)	No	ns	0.0828
c-opsin1$^{-/-}$ 12:12LD+UVA vs 12:12LD-UVA	*c-opsin1*$^{-/-}$ LD+UVA(0-12hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-12hrs)	No	ns	0.9970
	c-opsin1$^{-/-}$ LD+UVA(12-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(12-24hrs)	No	ns	0.5743
12:12LD+UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD+UVA(0-12hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(0-12hrs)	No	ns	0.9975
	c-opsin1$^{+/+}$ LD+UVA(12-24hrs) vs. *c-opsin1*$^{-/-}$ LD+UVA(12-24hrs)	No	ns	0.4974
12:12LD-UVA c-opsin1$^{+/+}$ vs c-opsin1$^{-/-}$	*c-opsin1*$^{+/+}$ LD-UVA(0-12hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(0-12hrs)	No	ns	0.8849
	c-opsin1$^{+/+}$ LD-UVA(12-24hrs) vs. *c-opsin1*$^{-/-}$ LD-UVA(12-24hrs)	No	ns	0.8163

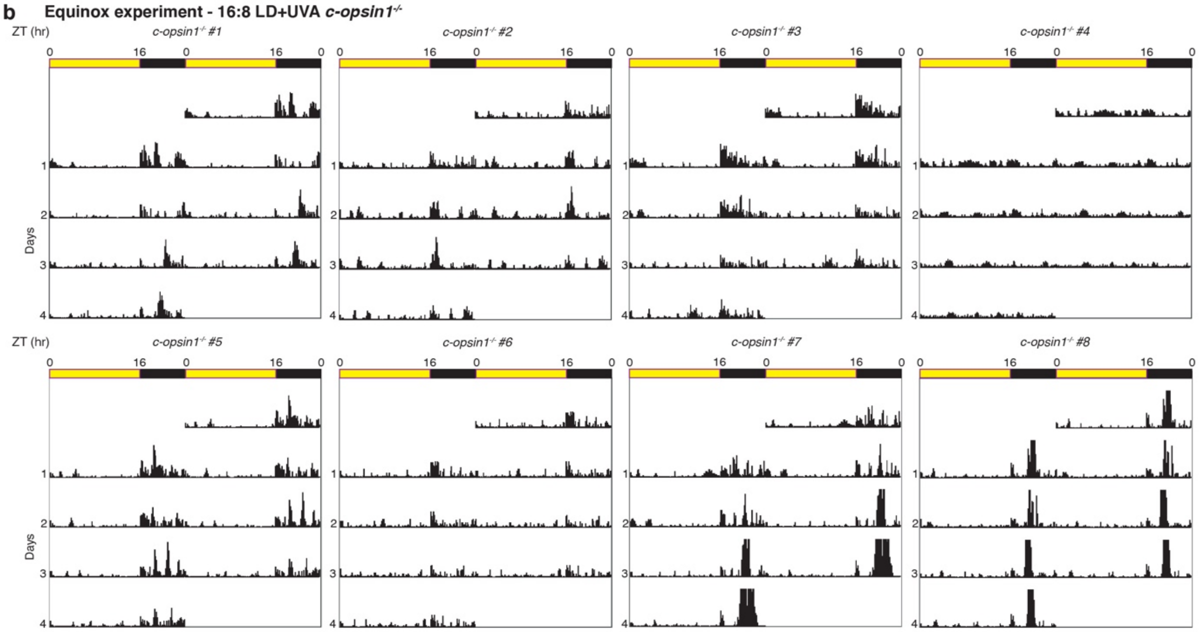
Supplementary Figure 7

SupplFig.7. Statistical analyses and comparisons for different photoperiods, UVA intensities and *c-opsin1* wildtype/mutant.

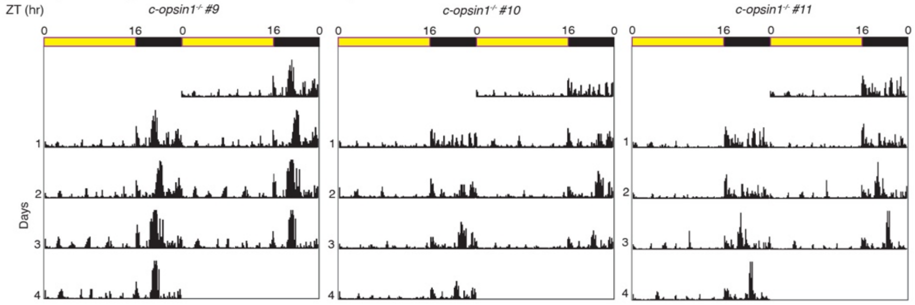
a **Equinox experiment - 16:8 LD+UVA *c-opsin1$^{+/+}$***



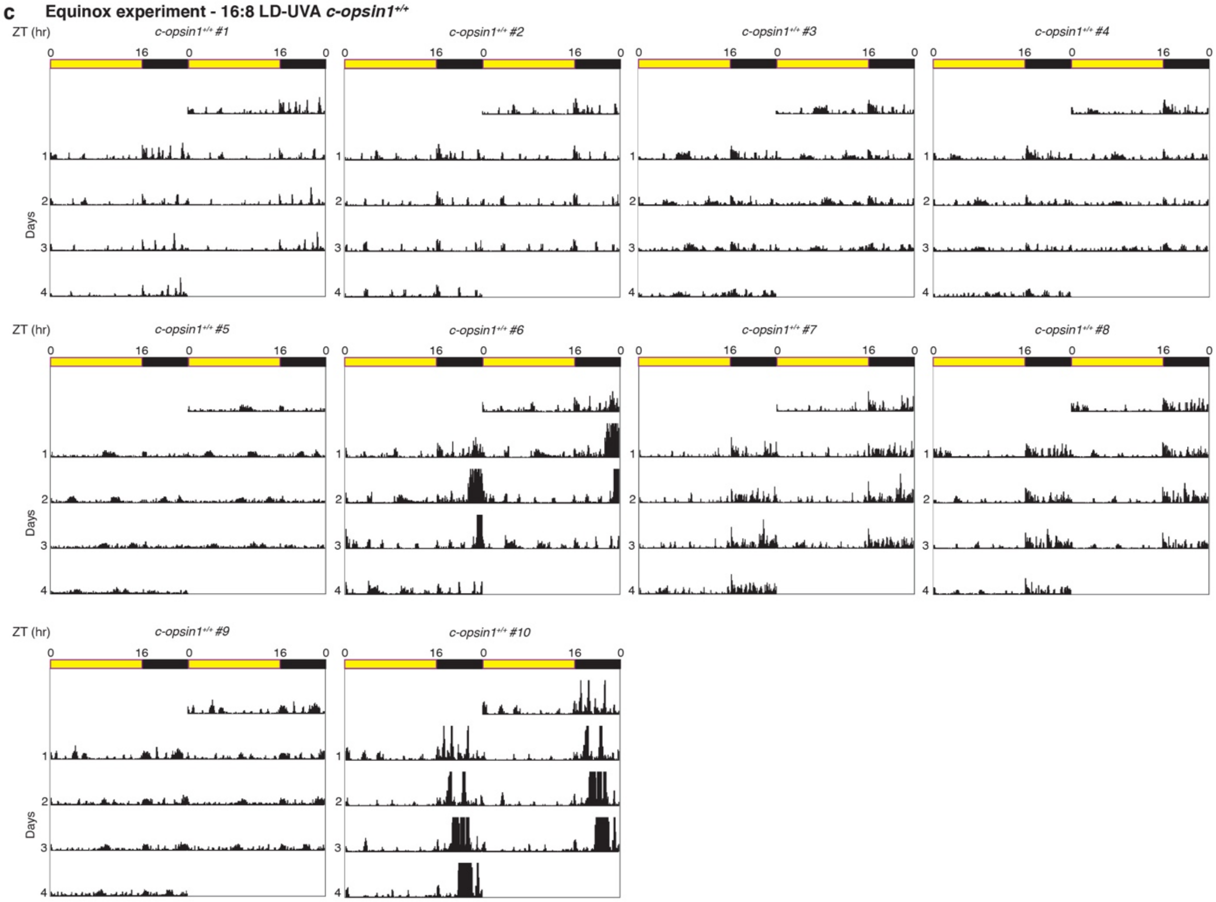
b **Equinox experiment - 16:8 LD+UVA *c-opsin1$^{-/-}$***



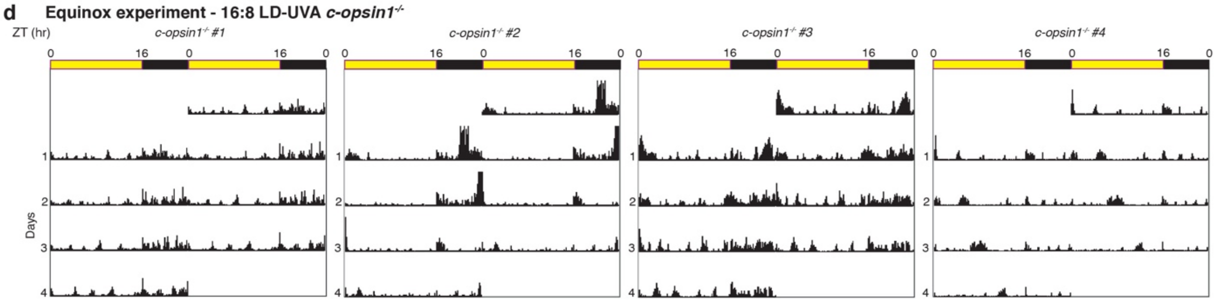
b **Equinox experiment - 16:8 LD+UVA *c-opsin1*$^{-/-}$**

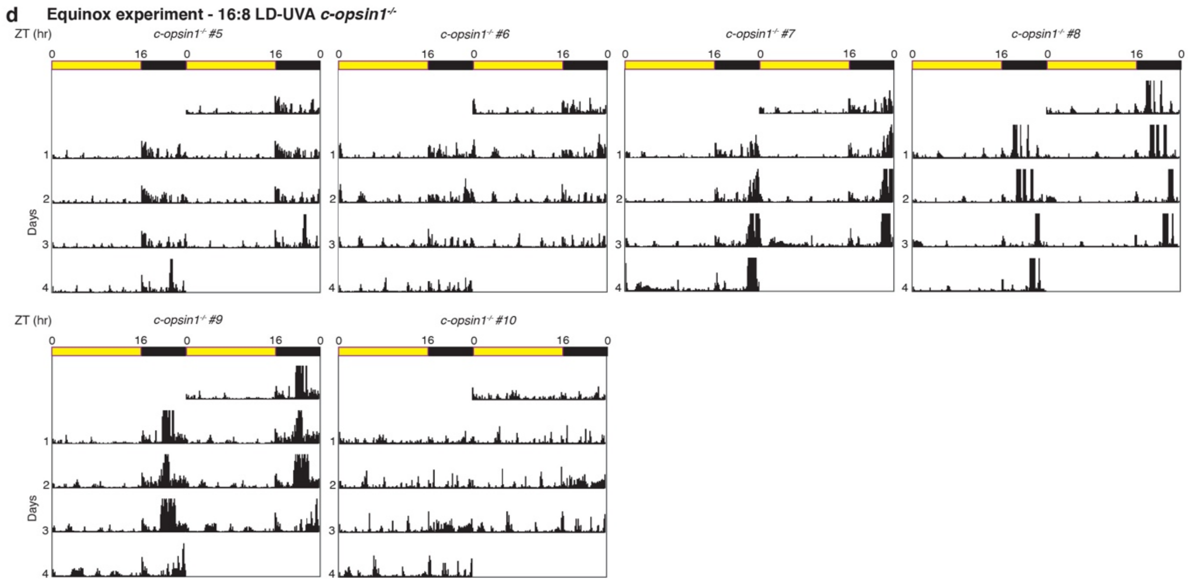


c **Equinox experiment - 16:8 LD-UVA *c-opsin1*$^{+/+}$**



d **Equinox experiment - 16:8 LD-UVA *c-opsin1*$^{-/-}$**

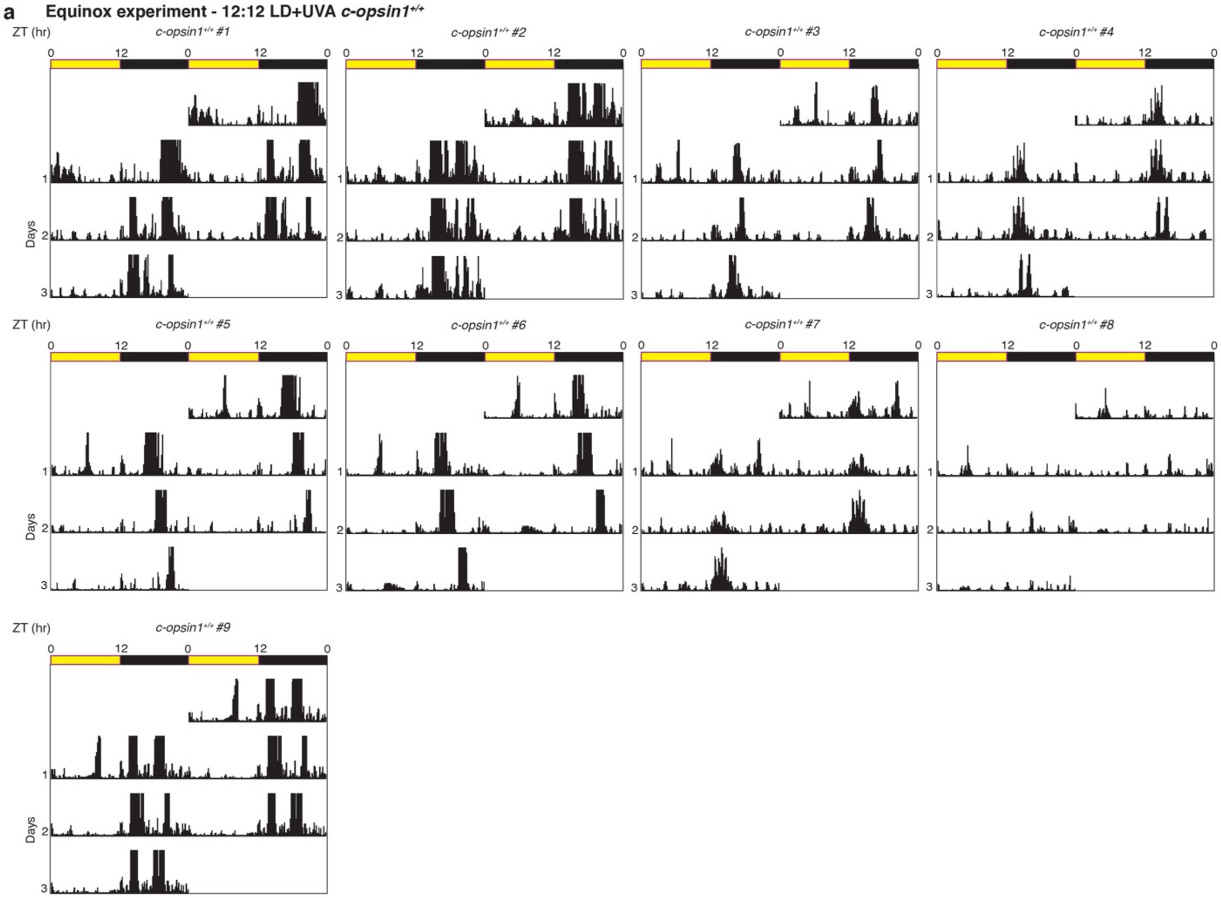




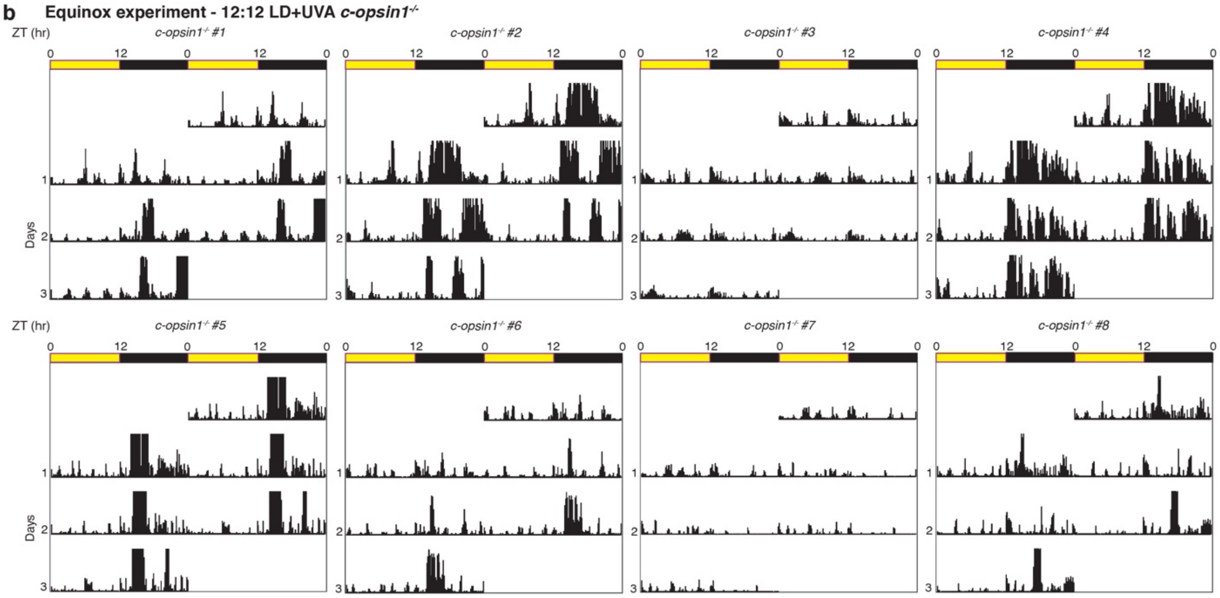
Supplementary Figure 8 *cont.*
Page 3

SupplFig.8. Individual double-plotted actograms of *c-opsin1*$^{\Delta 8}$ and corresponding wt under long day, strong versus filter-reduced UVA. The same worms were subsequently analyzed under LD12:12 (see Suppl.Fig.1e,f and 9), and hence part of the "equinox experiment".

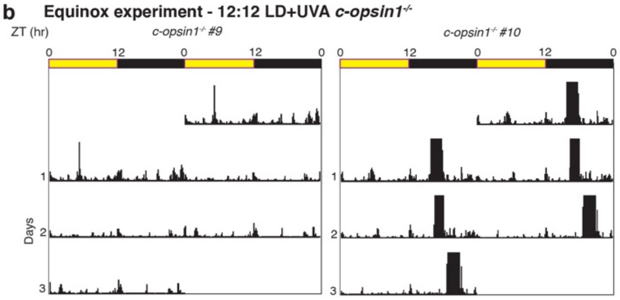
a **Equinox experiment - 12:12 LD+UVA *c-opsin1*$^{+/+}$**



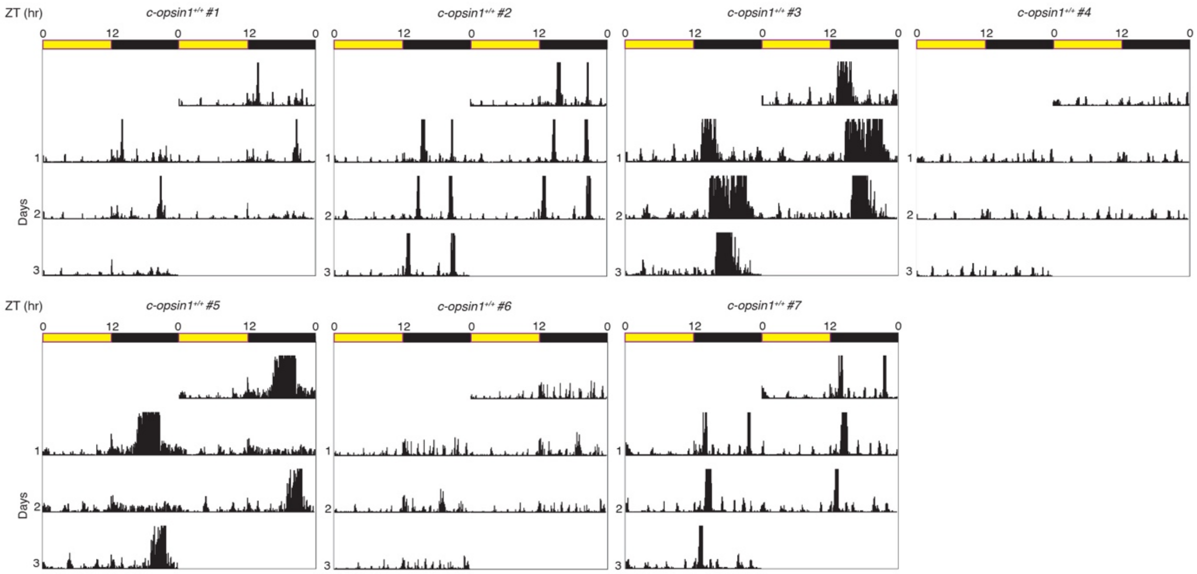
b **Equinox experiment - 12:12 LD+UVA *c-opsin1*$^{-/-}$**



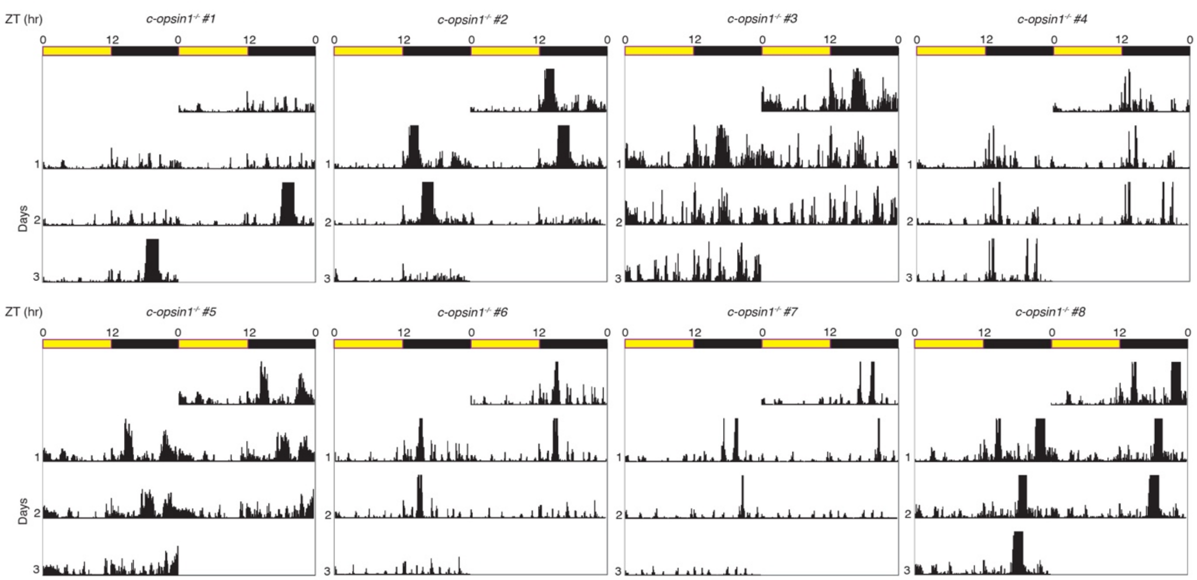
b **Equinox experiment - 12:12 LD+UVA *c-opsin1*$^{-/-}$**



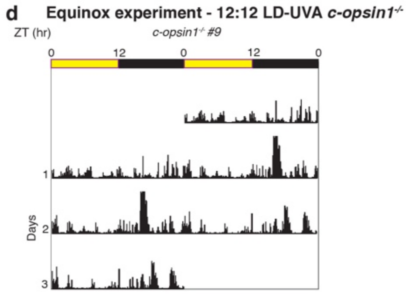
c **Equinox experiment - 12:12 LD-UVA *c-opsin1*$^{+/+}$**



d **Equinox experiment - 12:12 LD-UVA *c-opsin1*$^{-/-}$**



Supplementary Figure 9 *cont.*



Supplementary Figure 9 *cont.*

SupplFig.9. Individual double-plotted actograms of *c-opsin1*$^{\Delta 8}$ and corresponding wt under equinox (LD 12:12), strong versus filter-reduced UVA.

RAMSES-ACC-VIS

Hyperspectral UV-VIS Irradiance Sensor

320..950 nm

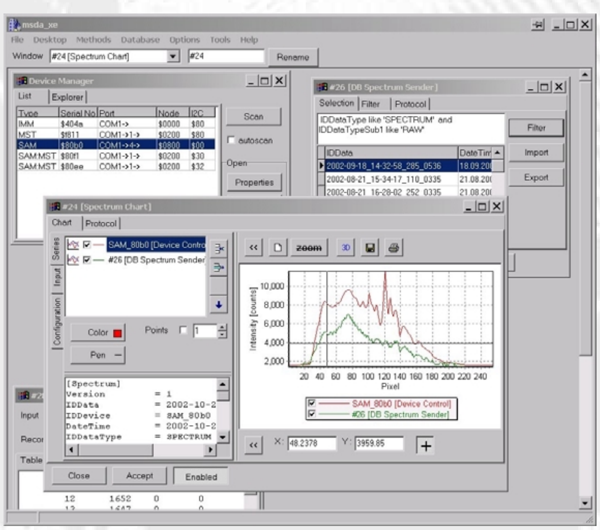
TriOS Optical Sensors

Features:

RAMSES-ACC is a stand-alone highly integrated hyperspectral radiometer for the UV and/or VIS spectral range. Small size and very low power consumption make it suitable for hand-held and autonomous applications. The sensor is part of the **RAMSES radiometer family**, which is especially designed for combining precision hyperspectral light measurements with a maximum of flexibility.

Applications:

- monitoring
- water quality
- field measurements
- satellite data validation
- biology
- photosynthesis
- climatology



Sensors are delivered with our free graphical easy-to-use software for measurement, data display and storage.

TriOS GmbH
Werftweg 15
D-26135 Oldenburg
Germany, info@trios.de
fon +49 (0) 441 - 4 85 98-0
fax +49 (0) 441 - 4 85 98-20

RAMSES-ACC

Features:

- stand-alone hyperspectral radiometer
- low power consumption
- small size
- autorange function
- free Windows-based acquisition and control software

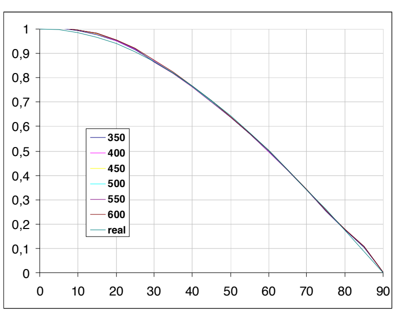
Accessories:

- power supply
- interface for simultaneous operation of up to 4 radiometers
- data logger units
- sensor frames

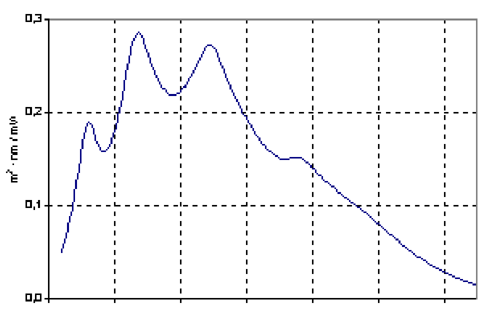
Technical specifications	
	VIS
optical	
wavelength range*	320 – 950 nm
detector type*	channel silicon photodiode array
spectral sampling*	3.3 nm/pixel
spectral accuracy*	0.3 nm
usable channels	190
typical saturation (4ms integration time)	10 W m^{-2} nm^{-1} (at 400nm) 8 W m^{-2} nm^{-1} (at 500nm) 14 W m^{-2} nm^{-1} (at 700nm)
typical NEI (8s integration time)	0.4 μW m^{-2} nm^{-1} (at 400nm) 0.4 μW m^{-2} nm^{-1} (at 500nm) 0.6 μW m^{-2} nm^{-1} (at 700nm)
detection	
collector type	cosine response
accuracy	better then 6 – 10% (depending on spectral range)
electrical	
integration time	4 ms – 8 sec.
telemetry data interface	RS-232
data rate (RS-232)	1,200 – 19,200 baud
power requirements	1.5 – 11 VDC 0.85 W (data acquisition active) 100 mW (interface active) 0.5 mW (stand-by modus)
connector	SUBCONN-Micro 5 pins, male connector
physical	
size	∅ 4.7 cm x 26 cm (without connector)
weight in air	< 1.0 kg (stainless steel/POM housing)
depth rating	300 m
operating temperature	-10 to +50°C

* specifications from Carl ZEISS, Germany

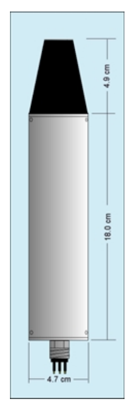
Specifications may change due to technical improvements without notification.



typ. cosine response at different wavelengths



typ. spectral sensitivity of RAMSES-ACC-VIS



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SupplFig.10. Information data sheet of the Ramses hyperspectral radiometers used in the study (TriOS GmbH), new address: TriOS Mess- und Datentechnik GmbH, Buergermeister-Broetje-Str.25, D-26180, Rastede, Germany