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Supplement

Tables S1–S6 shows an overview of the responses in 6 organism groups when exposed to a type of light source and the physical properties of ALAN.

Table S1. Key findings about the effects of ALAN for the organism group of plants.

#	Type of light source	Key findings	Ref.
1	FL	An altered foliage was reported in White clover (*Trifolium repens*) and red clover (*Trifolium pratense*) when they were exposed to FL with a PPFD of 0.6 - 1 µmol m−2 s−1 (at plant height) at night.	[59]
2	ALAN (dir.)	An early flowering, and the growth of longer stems, was reported in Whorled tickseeds (*Coreopsis verticillata*) and large-flowered tickseeds (*Coreopsis grandiflora*) when they were exposed to ALAN with a PPFD of 0.05 - 2.0 µmol m−2 s−1 (approximately 3.7 – 180 lx HPS, CFL).	[60]
3	Two different LEDs	Complex and cascading effects on grasslands were found when they were exposed to two variations of LED light at night: amber LEDs (near monochromatic, λp = 588 nm) and b) cool white LEDs (CCT 6000 K). For both treatments, legume cover decreased. It decreased by 19% when it was exposed to amber LEDs and by 12% when it was exposed to cool white LEDs. No significant effect from a) or b) was detected on grasses or non-leguminous forbs; 16% of the herbivore community increased and 10% of herbivores and predators increased. No significant effects were reported on the cover of grasses or non-leguminous forbs when they were exposed to a) and b). The production of flower heads and inflorescence decreased with the presence of herbivores in *L. pedunculatus* when exposed to a) and b) at night; No significant effect was reported on inflorescence in the presence of predators; There was a decrease of 29% in carbon to nitrogen ratio when exposed to a) or b); There was a decrease of 17% in the abundance of pea aphids (*A. pisum*) when exposed to a), while no significant effect was reported when exposed to b); There was a decreased abundance of 55% of grey field slugs (*Deroceras reticulatum*) when exposed to b) in the presence of a visual predator.	[61]
4	ALAN (dir.)	The dense cover of epicuticular wax crystals was reported on the leaves of yellow poplars (*L. tulipifera L.*) when they were exposed to ALAN with a varied PAR irradiance (PPFD) that included a) 1 µmol m−2 s−1, b) 3 µmol m−2 s−1, c) 50 µmol m−2 s−1. A gradual reduction of guard cells was observed when plants were exposed to a gradual increase of PPFD. The exposure to (a) reduced guard cells by 22%, by 30% when exposed to (b), and by 44% when exposed to (c); When exposed to ALAN there was a reduction of stomatal in aperture and width; There was a gradual decrease in stomatal aperture by 22% when exposed to (a), by 30% when exposed to (b), and by 44% when exposed to (c); Stomatal width decreased when exposed to (a) by 29%, (b) by 58%, and (c) by 72%; Shrinkage of abaxial leaf surface was demonstrated when exposed to (c); Stomatal density increased by 48% when exposed to (a), by 18% when exposed to (b), and when exposed to (c) by 40%; Stomatal size was reduced by 26% when exposed to (a), by 48% when exposed to (b), and by 63% when exposed to (c); Leaves with abnormal development of chloroplast; When exposed to ALAN at dusk, endogenous abscisic acid was reduced by 63% when exposed to (a), by 78 % when exposed to (b), and by 94% when exposed to (c).	[62]
5	ALAN (dir.)	An early budburst was reported in Sycamore maples (*Acer pseudoplatanus*), European beeches (*Fagus sylvatica*), English oaks (*Quercus robur*), and European ash trees (*Fraxinus excelsior*) when they were exposed to ALAN (using night-time satellite images).	[63]
6	ALAN (dir.)	An increased flowering process was observed in tussock bellflowers (*Campanula carpatica Jacq.*), large-flowered tickseeds (*C. grandiflora*), garden petunias (*Petunia x hybrida*), and black-eyed susans (*Rudbeckia hirta L.*) when they were exposed to ALAN.	[64]
7	ALAN (dir.)	Parts of the plants of Traganum moquinii exposed directly to the artificial light show a significant decrease in the production of flowers, compared to the parts in plants in shade, and to the plants more distant from artificial lights. In consequence, plants exposed more directly to artificial light have a lower potential for seed reproduction. The spectrum of	[65]

		artificial light also affects the plants, and light between 600 and 700 nm primarily affects the reproductive cycle of the Traganum moquinii species.	
8	ALAN (dir.)	A delay in the flowering state of short day plants and the promotion of flowering in long day plants were observed when they were exposed to ALAN with ca. 10 lx.	[66]
9	LEDs	Lotus pedunculatus and herbivore pea aphid (*Acyrthosiphon pisum*) were exposed to two variations of LED light: a) cool white LEDs (CCT 6000 K) with an illuminance of 10 lx ; b) amber LEDs (near monochromatic λp = 588 nm) with an illuminance of 10 lx. The presence of aphids suppressed the density of flower heads over the course of the year; both a) and b) light treatments decreased the flower density when compared to flowers kept in darkness.	[67]
10	HPS and LEDs	Exposure to white light with a broad SPD such as cool white LED light (CCT >5000 K) with a luminous flux of 5000 lm, and HPS (CCT ca. 2000 K) with a luminous flux of 5300 lm, resulted in the disrupted pollen transport of nocturnal pollinators, an increase in pollination, increased seed count in the disrupted pollen transport of nocturnal pollinators, and an increase in pollination of white campion wildflowers *(Silene latifolia*). The following variations were defined as a) HPS with a continuous duration, b) HPS switched off at midnight, c) LEDs with a continuous duration, and d) LEDs switched off at midnight. Illuminances varied between 0.1 lx and 100 lx depending on the distance to the source.	[68]
11	LEDs	LEDs with an illuminance of 180 lx, a broad SPD (400-750 nm), and a CCT = 6500 K were observed to increase the leaf litter decomposition in Chinese wingnut (*P. stenoptera*). The increase of leaf litter decomposition led to a decreased lignin content in leaf litter, which changed the fungal community composition and structure, and increased microbial biomass.	[69]
12	LEDs	LEDs with a broad SPD (400-750 nm), and a CCT = 6500 K were observed to decrease the lignin content of plant leaf litter by 12% in Chinese wingnut (*P. stenoptera*) involving cadmium (Cd) polluted conditions in aquatic ecosystems; they also altered the fungal community structure.	[70]
13	ALAN (dir.)	ALAN with an illuminance of 7 – 12 lx caused an alteration to the plant's toughness of smooth brom (*Bromus inermis Leyss*).	[71]
14	ALAN (dir.)	When exposed to ALAN, there was an alteration and delay of leaf colouring at the tree crown observed in staghorn sumac shrubs (*Rhus typina L.*) and sycamore maples (*A. pseudoplatanus L.*).	[72]
15	LEDs	Velvet grass (*Holcus lanatus*), sweet vernal grass (*Anthoxanthum. odoratum*), and colonial bentgrass (*Aliciella tenuis*) were observed to have varied responses when exposed to LEDs with different illuminance levels, SPD, and durations: cool white LEDs (6000 K) with a) an illuminance of approximately 30 lx from dusk to dawn; b) approximately 14.6 lx from dusk to dawn; c) approximately 14.4 lux between 24h – 04h; and d) amber LEDs (near monochromatic SPD with λp = 588 nm) with an illuminance level of approximately 18.3 lx from dusk to dawn. When velvet grass (*H. lanatus*) and sweet vernal grass (*A. odoratum*) were exposed to amber LED with (d), their constant cover (frequency) increased. When colonial bentgrass (*A. tenuis*) was exposed to amber LED with (d) its cover (frequency) decreased. When colonial bentgrass (*A. tenuis*) was exposed to b), cool white LED, approximately 14.6 lx, its biomass was lowered. Also, a lowered biomass in colonial bentgrass (*A. tenuis*) was reported when it was exposed to amber LEDs with (d). When sweet vernal grass (*A. odoratum*) was exposed to amber LEDs with (d) there was a significant increase in its biomass. When velvet grass (*H. lanatus*) was exposed to cool white LEDs with (a) and amber LEDs with (d), an increase in biomass was observed.	[73]
16	ALAN (dir.)	European horse-chestnut (*Aesculus hippocastanum*) trees exposed to road lighting had bigger leaves and less signs of senescence in autumn; ALAN appeared to extend the larval activity of horse-chestnut leaf miner (*Cameraria ohridella*) in the winter months.	[74]
17	LEDs	There was no direct effects on plant height; however, 34.6% of the leaves of Brassicales (*Brassica nigra Linnaeus*), Fabale pea seedlings (*Pisum sativum Linnaeuss*), and tomato plants (*Solanum lycopersicum*) were reportedly damaged by insects attracted to the illuminated leaves when these plants were exposed to neutral white LEDs (CCT 4200 K) with an illuminance ranging from about 67 - 105 lx at night.	[75]
18	ALAN (dir.)	ALAN was reported to alter the end of the vegetative season in the leaves of London planetrees (*Platanus x acerifolia*) during autumn.	[76]
19	LEDs	Cool white LEDs (6500 K) with an illuminance of approximately 180 lx, a broad SPD (400-750 nm), and a CCT = 6500 K, increased the decomposition of leaf litter from the Chinese	[77]

		wingnut (*Pterocaya stenoptera*), decreased dry mass, reduced the toxicity of silver nanoparticles (AgNP – commonly contained in commercial products that are used daily, which then end up in freshwater ecosystems), and increased the microbial biodiversity (a significant abundance of fungi was reported compared to the bacterial community).

Table S2. Key findings about the effects of ALAN for the organism group of arthropods: insects, and spiders.

#	Type of light source	Key findings	Ref.
1	HPS	When rustic shoulder-knot moths (*Apamea sordens*) at the larval stage were exposed to HPS with an illuminance of 7 - 12 lx at night, there was a decrease in body mass gain, and altered performance and development. Their larval weight decreased by 43% indicating lower larval fitness.	[71]
2	FL	FL with a broad SPD ranging at about 250 – 3000 nm at night on the top of a railing for a footbridge across a canal, was demonstrated to affect the density of nocturnal orb-web spiders (*Larinioides scloptearius*) at illuminated locations (0.0 – 17.7 individuals/m2). A higher density of spiders was reported in comparison to unlit locations (0.0 -4.7 individuals/m2). Seasonal changes were observed to affect spider density in these locations as there was a significant increase in autumn. The insect density and capture rate of spiders were higher in illuminated locations. Also, the webs in illuminated locations entangled more prey compared to unlit locations.	[78]
3	ALAN (dir.)	The attraction of camel spiders (*Solifugae*) to light sources was demonstrated when they were exposed to ALAN with a luminous flux of 750 lm at dusk.	[79]
4	ALAN (ind.)	ALAN proximate to littoral zones was shown to attract large-sized buzzer midges (*Chironomus plumosus*), the small-sized *Tanypus punctipennis* and *Procladius spp.*	[80]
5	ALAN (ind.)	During the period between 1985–2015, a decline in moth population affecting 481 moth species was highly correlated with urban illuminated areas.	[81]
6	HPS	The attraction of moth families was reported when they were exposed to HPS with a luminous flux = 96 lm, CCT = 2000 K. A street lighting matrix (lighting layout) showed varied attractions of moths to mid and corner luminaires in a lighting matrix with HPS (CCT 2000 K) with a luminous flux of 96 lm. Moths were caught at corner luminaires, to a lower amount at wing luminaires and with much lower proportion at luminaires positioned in the middle of the matrix indicating a barrier effect. No sexual differences in the attraction rate nor in the attraction radius of male and female moths was demonstrated.	[82]
7	FL	FL with a broad spectral output and with λp = 405 nm and 617 nm were observed to attract arthropods at night. FL with λp = 617 nm caused the least amount of moth attraction.	[83]
8	ALAN	ALAN was demonstrated to impact the macro-moth population after multiple years of night-time exposure to ALAN with a varied SPD (white, green, and red). A higher decline in population was observed when moths were exposed to ALAN with a broad SPD (white) and green wavelengths. Little to no decline was reported when moths were exposed to ALAN with longer wavelengths (red).	[84]
9	ALAN (dir.)	ALAN with an illuminance of 10 – 12 lx decreased the density and diversity in tetragnathid spider families, decreased the size of emerging aquatic insects (riparian emergent insects) and increased the size of terrestrial arthropods.	[85]
10	ALAN	An attraction and aggregation of arthropods from riparian ecosystems was observed in	[86]

	(dir.)	illuminated areas at night.	
11	ALAN (dir.)	ALAN at illuminated river bridges altered the food chain of insects and insectivorous predators such as birds and peregrine falcons.	[87]
12	HPS and HPM	HPS and HPM light sources rich in ultraviolet (UV) wavelengths were observed to alter insect flight activity. A greater attraction was reported for HPM compared to HPS. A lower attraction was reported in HPM with ultraviolet (UV) absorbing filters. The study suggests the use of filters or UV absorbing glass to reduce the invisible light emission in order to potentially reduce the attraction of insects at night.	[88]
13	LEDs and HPM	Exposure to LEDs and HPM in urban and peri-urban environments was observed to attract insects including *Diptera*, *Hemiptera*, *Hymenoptera*, and *Lepidoptera*.	[89]
14	LEDs and FL	Numbers of flying terrestrial insects were attracted to FL and LED light sources in correlation to the CCT values, which were ranging from (2700 K to 3510 K).	[90]
15	HPS and LEDs	A higher amount of flying insects including *Diptera*, *Trichoptera*, *Coleoptera*, *Hymenoptera*, *Hemiptera*, *Ephemeroptera*, *Psocidae*, *Lepidoptera*, *Neuroptera*, *Thysanoptera*, *Aranae*, *Plecoptera*, *Isoptera*, *Othoptera*, and *Blattodea* were attracted to LEDs compared to HPS. The CCT of LEDs had no significant effect on invertebrate attraction. All lights had a broad SPD: HPS had a CCT of ca. 2000 K and LEDs had varied CCTs (2700 K, 3000 K, 3500 K, 4000 K).	[91]
16	CMH, HPM, LPS, and LEDs	The highest level of attraction occurred when insects were exposed to HPM compared to LPS, CMH, and LEDs. LEDs attracted significantly less individual insects compared to the other light sources. The difference between LPS and CMH was reported as insignificant.	[92]
17	CMH, HPS, and LEDs	The highest attraction of arthropods including *Diptera*, *Lepidoptera*, *Erebidae*, *Chironomidae*, *Coleoptera*, *Noctuidae*, and *Psychodiodae* occurred when they were exposed to CMH compared to HPS and LEDs.	[93]
18	CMH, HPS, and LEDs	The attraction of aquatic and terrestrial insects to the horizontally polarised light reflected from black and white illuminated surfaces occurred when aquatic and terrestrial insects were exposed to CMH, HPS, and LEDs at night. Phototaxis was measured to be of higher relevance than the degree of polarization for most of the tested insects.	[94]
19	LEDs	The street illumination from LEDs on a bridge, reflected on the road surface attracted terrestrial and aquatic insects. (Mayflies typically lay eggs on the surface of the water. Instead, their eggs were laid on illuminated human-made structures.) A high degree of horizontally polarised light, reflected from illuminated surfaces can resemble the surface of water. This was shown to alter oviposition which may lead to reproductive failure in aquatic and terrestrial arthropods near aquatic habitats including mayflies (*E. virgo*).	[95]
20	LEDs	LEDs with different SPDs (warm/neutral white, green and red) with an illuminance of 10 lx were used to study avoidance in arthropods (*Operophtera brumata*) when they were exposed to ALAN. Green showed the highest avoidance, white the second highest, and red the lowest avoidance of the light treatments. All treatments had higher avoidance than no ALAN. A higher number of mated female arthropods were observed on top of non illuminated tree trunks.	[96]
21	FL	A lower propensity to fly towards light was observed in urban moths commonly accustomed to illuminated locations at night. A relative attraction to FL was reported in moths from darker locations.	[97]
22	LEDs	Cool white LEDs (CCT 5700 K) with a luminous flux of 1000 lm induced the avoidance of illuminated areas as an anti-predator behaviour in the cricket-like insects tree weta (*Hemideina thoracica*) and cave weta (*Rhaphidophoridae*).	[98]

23	LEDs	Warm white LEDs (CCT 2700 K) with a luminous flux of 55 lm resulted in a reduced light avoidance behaviour in urban spiderlings and an altered web building choice of location for urban and rural populations of spiders (*Steatoda triangulosa*).	[99]
24	ALAN (ind.)	ALAN with an illuminance of 0.1 – 5 lx decreased aphid abundance by 45.5%, increased plant biomass, and altered the parasitism rate; Higher illuminance levels were considered to potentially increase a plant's biomass by increasing the photosynthetic rate of the plant, however, the effect of night-time illumination may vary from one plant species to another. Parasitoids were reported to attack aphids when exposed to ALAN with an illuminance of 1 lx and 20 lx, which may indicate that active parasitoids depend on photoperiods. Parasitism rate of *Aphidius megourae* increased by 10 % with an illuminance of 0.1 – 5 lx, while the parasitism rate of *Aphidius ervi* and *Lysiphlebus fabarum* responded significantly to night-time illumination. The overall parasitism rate declined when aphids were exposed to low or high illuminance levels.	[100]
25	LEDs	When exposed at night to cool white LEDs with an illuminance of 20 lux and a broad SPD, the nocturnal juvenile Australian garden orb-web spider (*Eriophora biapicata*) displayed an altered web site selection, as well as changes in foraging behaviour and prey capture success. An increase in prey availability and changes in the preference of foraging sites were observed in Australian garden orb-web spider (*E. biapicata*). Of 51 spiders, 48 (94%) constructed their web on the illuminated location. The rate of small prey capture was significantly higher in the illuminated location when compared with the dark location. Medium and large prey were only captured in illuminated sites, although only two large prey were caught overall.	[101]
26	HPS	A set of HPS streetlights (CCT 2000 K), with a maximum illuminance of 50 lx, an average illuminance of 10 lx between two post-lamps, and a minimum illuminance of 1 lx, were demonstrated to increase the abundance and diversity of insects to terrestrial predators compared to unlit controls. Also, the nutritional flux of aquatic webs to terrestrial food webs were altered at the lit site. An increased catch of insects occurred at the illuminated site (an approximate of 60 insects per hour) compared to the un-illuminated site (0 to 1 insects were caught per hour). The most abundant orders were sawflies, wasps, bees, and ants (*Coleoptera*, *Hymenoptera*, and *Diptera*). At the illuminated site 539 moths (*Lepidoptera*) were caught while only 2 were caught at the un-illuminated site. At the illuminated site 80 spiders (*Araneae*) were captured, however, they were six times more abundant at the nonilluminated site.	[102]
27	LEDs and HPM	No effect on insect biomass was reported for insects that were exposed to HPM or LED emission. However, an altered biomass was observed which was affected by the percentage of moonlight illuminance.	[103]
28	LEDs	The night-time exposure to LEDs with different SPDs (λp = 361, 450, 500, 600, 626, and 660 nm) was studied in parasitoid wasp *Aphidius ervi* and its host, the pea aphid (*Acyrthosiphon pisum*). The different wavelengths had no observed effect on the parasitoids probability of walking, and activity depended on the sex of individuals. When tested, males parasitoid wasps (*A. ervi*) were more active than females under all monochromatic wavelength spectra.	[104]
29	HPS	Spider Pachygnatha clercki (*Tetragnathidae*) and three long-legged harvestmen species Opiliones (*Rilaena triangularis* in spring, *Nelima sempronii* and *Phalangium opilio* in summer), were some of the species affected by a HPS streetlight setup (CCT 2000 K) with an illuminance of 1 lx (between two rows of luminaires), 10 lx (between two adjacent luminaires), and 50 lx (maximum) compared to un-illuminated controls. Exposure to HPS increased the density of aquatic and terrestrial prey which altered the diet of riparian secondary consumers.	[105]
30	LEDs	Three different night-time experiments demonstrated altered predator species flashes, a visual signal in fireflies *Photinus pyralis* and *Photuris versicolor*, when they were exposed to	[106]

		night-time illumination. For Experiment 1, an illuminated location with white LED floodlights (CCT not given) mounted at 0.3 m heightreported that 189% of individual fireflies *P. pyralis* and *P. versicolor* were found in illuminated areas at night. The number of found species varies for the prey species, and the number of individuals increased over the course of the evening. For experiment 2, LED floodlights were mounted at 3 m height with an illuminance of about 57.4 lx that operated from 21h30 – 23h30. Unlit locations reached an illuminance of about 0.03 lx. When exposed to LEDs, female fireflies *P. pyralis* and *P. versicolor* never flashed, whereas 11 females tethered in unlit areas flashed at least once. For experiment 3, male fireflies did not flash near female fireflies when they were exposed to one LED at the center of a mesocosm, at a height of 2.5 m, and with an illuminance of about 0.01 lx and increasing at about 174 lx. Although there was no significant effect based on the presence of a predator, and no significant interaction between predator presence and light pollution - LEDs significantly decreased the number of predator species flashes in *P. pyralis* and *P. versicolor*.	
31	LEDs	The night-time exposure to cool white LEDs (CCT 5900 K) with varied illuminances levels of 0, 1, 10, and 100 lx resulted in increased mating behaviour and less engaged females, while males reared and mounted females more often under 100 lx in the crepuscular and nocturnal Australian black field cricket (*Teleogryllus commodus*).	[107]
32	LEDs	When Black field crickets (*Teleogryllus commodus*) were exposed to cool white LEDs (CCT 5900 K) with a varied illuminance of 1, 10, and 100 lx at night, there was altered function of their immune system, measured with haemocyte concentration, lytic activity, and phenoloxidase activity. LEDs incited negative effects on haemocytes, while the effects on lytic activity and phenoloxidase activity were more complex or largely unaffected by LEDs.	[108]
33	LEDs	Cool white LEDs (CCT 5900 K) and varied illuminance levels of 0, 1, 10, and 100 lx were shown to affect the fecundity and survival rate in the Black-bellied fruit fly (*Drosophila melanogaster*). The oviposition rate decreased and female flies were reported to lay less eggs when they were exposed to a gradual increase of illuminance levels (1 – 100 lx).	[109]
34	LEDs	LED light (CCT not reported) with an illuminance of 20 lx was observed to affect the development of orb-weaving spiders (*Eriophora biapicata*). When they were exposed to ALAN, there was accelerated development with orb spiders maturing significantly earlier, compared to spiders that had no ALAN exposure. Orb-weaving spiders growing under ALAN were smaller in size, with an increase in mortality, and there was a reduced number of eggs produced by females, affecting reproductive success and survival.	[110]
35	LEDs	The night-time exposure to green LEDs (near monochromatic $\lambda p = 520$ nm) for varied periods of time (2, 4, 6, 8, and 10 hours) resulted in altered development stages for northern armyworm moths (*Mythimna separata*). Long exposure to LEDs prolonged the egg period, decreased the hatch rate when exposed to 6, 8 and 10 h, shortened the developmental period of larvae when exposed to 4 and 10 h, increased the larval survival rate when exposed to 10 h, decreased fecundity per female when exposed to 8 and 10 h, and decreased the oviposition quantity per day when exposed to 6, 8, and 10 h, pre-oviposition periods were also prolonged when exposed to 10 h, and oviposition periods were lengthened when exposed to 2, 6, and 8 h. However, no significant differences in pupae rate were reported.	[111]
36	ALAN (dir.)	A significantly high abundance of spiders and beetles was observed to remain under ALAN. The taxa attracted to ALAN included Lycosidae: *Trochosa ruricola*; Tetragnathidae: *Pachygnatha degeeri*; Linyphiidae: *Dicymbium nigrum*, *Centromerita bicolor*, and Oedothorax spp, - *Oedothorax retuses* and *Oedothorax fuscus* combined and three beetle taxa (Carabidae: *Pterostichus niger*; Pselaphidae: *Rybaxis longicornis*; Ptiliidae: *Acrotrichis spp.*)	[112]
37	HPS	The attraction of non-biting midges (*Chironomidae*), crane-flies (*Tipulidae*), dragonflies and damselflies (*Odonata*), mayflies (*Ephemeroptera*), and mosquitoes and blackflies (*Culicomorpha*) occurred proximate to a river when it was illuminated with warm white	[113]

		HPS (CCT 2000 K) with a luminous flux of 5600 lm.	
38	FL	FL operating at sunset (at 18h30) that emitted light upwards to illuminate higher building levels, resulted in the attraction of nocturnal insects such as *Paederus fuscipes*.	[114]
39	FL	The Wellington tree weta (*Hemideina crassidens*) did not present a changed preference in fruit choice when exposed to cool white FL (CCT 4100 K) and with λp = 350, 450, 530, 570, and 700 nm. When exposed to FL the wetas showed a preference for naturally coloured bright blue fruits over fruits dyed dull red. FL did not affect the selection of fruits at night.	[115]
40	FL and LEDs	A reduced activity pattern was observed in ground beetles (*Pterostichus melanarius*) when they were exposed to FL and LED emission at night. LEDs rich in long wavelengths were reported to have the least disruption to their movement and speed compared to FL with a broad SPD (320 – 780 nm).	[116]
41	LEDs	Cool white LEDs (CCT 6000 K) with a luminous flux of 4000 lm, were placed facing downstream to guide female egg-laying mayflies (*Ephoron virgo*) towards the water (i.e. underneath the bridge) to prevent the mass deaths of mayflies on the road surface of illuminated river bridges. The study demonstrated that the management of artificial lighting can aid the survival of mass swarming mayflies.	[117]
42	LEDs	Garden lamps with cool white LEDs (CCT 7250 K) attracted invertebrates, which included 126 ground beetles, two species *Calathus melanocephalus* and *Pseudoophonus rufipes*, which may alter the nocturnal activity pattern of invertebrates. One single garden lamp attracted 101 invertebrates while four garden lamps attracted 540 invertebrates. The study reported an active nocturnal behaviour in *Chrysopa nigricorni*, 75% of *C. nigricorni* were active at night and 8% of *C. nigricorni* were active in the day, while with Beetle species (*Thamnatophilus sp.*) 48% were observed to be active at night near the garden lamps. Nocturnal carabid species decreased their activity during the night under LEDs.	[118]
43	LEDs	A lower abundance of isopods (*Tylos spinylosus*) was observed in illuminated areas at night when they were exposed to cold white LEDs (CCT 5000 K) with an illuminance of 120 lx, with a gradual decrease to 3 lx towards low tide, compared to the non illuminated locations where the abundance of isopods was higher with a peak of abundance at 02h30. Under illuminated conditions at night, locomotor activity during the day decreased (activity from 06h00 - 08h00 was decreased, and during 09h00 - 20h00 was drastically slowed), which inhibited the circadian rhythm of coastal nocturnal species such as *T. spinylosus*.	[119]

Table S3. Key findings about the effects of ALAN for the organism group of fish.

#	Type of light source	Key findings	Ref.
1	CMH	CMH with an irradiance between of 13.0 – 15.3 Wm–2 (5 m distance) and 0.02 - 0.10 Wm–2 (50 m distance from the light) resulted in the attraction and aggregation of fish including sand lances (*Ammodyteshexapterus sp.*), three-spined sticklebacks (*Gasterosteus aculeatus*), Pacific herrings (*Clupea pallasi*), great sculpins (*Myoxocephalus polyacanthoscephalus*), and soft sculpins (*Psychrolutes sigalutes*).	[120]
2	ALAN (dir.)	When European eels (*Anguilla anguilla*) were exposed to luminous fluxes of about 60 lm (bright light source) and about 3 lm (dim light source), they exhibited avoidance to ALAN. The avoidance behavior increased with lights that	[121]

		were directed upstream.	
3	ALAN (ind.)	When European eels (*A. anguilla)* were exposed to ALAN they displayed avoidance to illuminated waters.	[122]
4	LEDs	LEDs with a different SPD (white, blue 480 nm, and yellow 550 nm) (CCT not mentioned for white) and low (1 Hz) and high (30 Hz) flicker frequency, were used to investigate the ALAN response of American eels (*A. rostrata*). Blue light at a high flicker frequency showed the greatest ALAN avoidance effect. The study proposes the use of artificial light to guide eels into safe waters.	[123]
5	ALAN (dir.)	An avoidance of illuminated waters was reported for vendace fish (*Coregonus albula*) when light sources were submerged at 30 m depth in the water.	[124]
6	ALAN (ind.)	When *B. boops* were exposed to ALAN, they displayed altered nocturnal emergence, which forced them to drift away from illuminated waters towards shaded locations to avoid predators.	[125]
7	CMH	Night-time illuminated waters exposed to CMH with an illuminance of 14 lx (upstream) was linked to altered behaviour and migratory timing in Atlantic salmon (*Salmo salar*) smolts that were leaving their natal stream.	[126]
8	CMH	When Atlantic salmon (*S. salar*) were exposed to CMH with fitted filter sheets and a range of illuminance levels (6.1, 11.3, 12.9, 20.0, 22.7, and 49 lx) at night, there was a late initiation of fry dispersal.	[127]
9	CMH	A delayed dispersal timing (by 1.4 – 2.2 days) and disrupted diel pattern behaviours were observed in Atlantic salmon (*S. salar*) when they were exposed at night to CMH with illuminances of 1, 2, 4, and 8 lx.	[128]
10	LEDs	Exposure to warm white LEDs at night with an illuminance of about 13 lx, was observed to alter fish predatory behaviour, their habitat use, and sessile invertebrate prey assemblages. It also decreased fish abundance.	[129]
11	CMH, HPS, TH	An altered predator-prey interaction was reported for predator juvenile rudd (*Scardinius erythropthalmis*) and prey (*Daphnia pulex x pulicaria*) when they were exposed to three different light sources that included: TH, HPS, and CMH. a) An increase in the reaction distance and swimming speed was observed in juvenile rudd under THs at night compared to the night-time exposure of HPS. b) Increased reaction distance and swimming speed was noted in juvenile rudd under CMH at night compared to the night-time exposure of TH and HPS. c) A greater evasiveness was observed in *D. pulex x pulicaria* under THs and HPS compared to CMH and no exposure to ALAN.	[130]
12	FL	When European perch (*Perca fluviatilis*) were exposed to FL with an illuminance of 100 lx and a CCT of 6000 K, the suppression of melatonin levels was observed.	[131]
13	ALAN (dir.)	When waters were exposed to an illuminance of 1 lx at night there was an observed decrease in melatonin production in the European perch (*P. fluviatilis*). Cortisol levels did not differ between exposure to 0 lx and 1 lx.	[132]
14	LEDs	An altered production of melatonin was reported for perches (*P. fluviatilis*) when they were exposed to blue LEDs with short-narrow-band wavelengths with an illuminance of 0.15 lx. Exposure to blue LEDs at 0.15 lx were the least	[133]

		suppressive compared to red LEDs (long-narrow band wavelengths) with an illuminance of 0.62 lx, and green LEDs (mid-narrow band wavelengths) with an illuminance of 2.2 lx.	
15	FL and LEDs	Low light intensities of FL and LEDs with a broad SPD were observed to disturb the melatonin rhythms in roaches (*Rutilus rutilus*) at very low intensities and at different wavelengths. Therefore, light pollution in urban waters has the potential to impact the biological rhythms in fish. However, the mRNA expression of gonadotropins was not affected by ALAN during the period of the experiments. Thus, the suspected implications of ALAN on the reproduction of roaches could not be substantiated.	[134]
16	ALAN (ind.)	When exposed to ALAN, there was an observed suppression in the secretion of melatonin in golden rabbitfish (*Siganus guttatus*). The moon's brightness was considered to alter melatonin levels at night as well.	[135]
17	ALAN (ind.)	When exposed to ALAN, Zebrafish (*Danio rerio*) were reported to develop ovarian tumour, lose circadian rhythmicity, and have lower concentrations of melatonin in the brain, retina, ovary, and serum. The long term exposure of one year increased the expression of NF-KB, a cellular transformer of tumour genesis which formed thecoma (benign ovarian neoplasms) and granulosa cell tumours (a type of ovarian cancer) when exposed to ALAN.	[136]
18	CMH	When exposed at night to CMH with an illuminance of 8 lx, there was an observed lowering in the cortisol rate of Atlantic salmon (*S. salar*). This was linked to changes in their dispersal across the water.	[137]
19	HPS	When juvenile bonefish (*Albula vulpes*) were exposed at night to HPS with an illuminance of 48 – 80 lx at the water's surface, their blood glucose concentrations were elevated (a stress indicator).	[138]
20	LEDs	The reduction of thyroid hormone levels and changes in settlement were reported in larvae surgeonfish (*Acanthurus triostegus*) when they were exposed at night to cool white LEDs (CCT 6500 K),with an illuminance of 20 to 25 lx. A preference for darker habitats at night was observed. Researchers also found there was a reduction in thyroid hormone levels during metamorphosis, faster growth, more rapid swimming behaviour, higher susceptibility to predation, and a higher mortality rate. The visual cue response was not considered altered when exposed to LEDs.	[139]
21	FL	When larval fish Nile tilapia (*Oreochromis niloticus*) were exposed to FL with a broad SPD (400 – 750 nm) located at 1m above the water surface for a photoperiod of 8 h at 100 lx or 2500 lx and a photoperiod of 24 h at 100 lx or 2500 lx, they were observed to have low larval growth and feed conversion efficiency. The combined effects of a varied photoperiod and illuminance resulted in altered growth rhythms. The study suggests light intensity can potentially change growth during the larval stage.	[140]
22	CMH and LEDs	When Atlantic salmon (*S. salar*) were exposed to various LEDs there was an increase in their growth and body weight, and an increase in their swimming activity, which may reduce the incidence of sexual maturation. Three LEDs were kept at maximal output (100%, irradiance 38 μmol s-1 m-2), and 4 LEDs were dimmed to 75% (irradiance 3.3 μmol s-1 m-2), 50% (irradiance 2.3 μmol s-1 m-2),	[141]

		25% (irradiance 1.13 μmol s-1 m-2), and 1% (irradiance 0.06 μmol s-1 m-2), and CMH (with an irradiance of 4.5 μmol s-1 m-2). These light sources were observed to potentially alter the physiological and behavioural responses in Atlantic salmon (*S. salar*).	
23	LEDs	No difference in the amount of fry yields was reported for adult guppies (*Poecilia reticulata*) when they were exposed continuously to LEDs with different SPDs at night. This included three monochromatic LEDs with λp = 645, 525, and 480 nm, and one white LED (CCT not mentioned) with a broad SPD (440–660 nm).	[142]
24	CMH and LEDs	The distant presence of CMH in relation to two types of LEDs (an LED characterised by short wavelengths with λp = 450 – 499.5 nm and another LED with a broad SPD with λp = 460 nm and 553 nm) was observed to maintain melatonin levels irrespective of intensities. No significant difference was reported in the mean weight, length, and growth rate of Atlantic salmon (S. salar).	[143]
25	ALAN (ind.)	When exposed to ALAN, Atlantic salmon (*S. salar*) were observed to have no significant effect on their growth rate. However, there was an accelerated oocyte reabsorption, which may alter their basic pattern of growth.	[144]
26	HPS	The blood concentration of sex steroids (17β-estradiol; 11-ketotestosterone) as well as the mRNA expression of gonadotropins (luteinizing hormone, and follicle stimulating hormone) were reduced in roaches (*Rutilus rutilus*) and Eurasian perches (*P. fluviatilis*) when they were exposed at night to HPS (CCT 2000 K) with an illuminance of 13 – 16.5 lx at the water's surface and 6.8 – 8.5 lx 50 cm below the water surface.	[145]
27	ALAN (dir.)	*Girella laevifrons* fish exposed to ALAN with an illuminance of 78 lx were observed to have an increase in activity and oxygen consumption.	[146]
28	LEDs	A decreased hatching and reproductive rate was observed in clownfish (*Amphiprion ocellary*) when they were exposed at night to cool white LEDs (CCT 5000 K) with an illuminance of 26 lx (at the water's surface).	[147]

Table S4. Key findings about the effects of ALAN for the organism group of amphibians.

#	Type of light source	Key findings	Ref.
1	ALAN (dir.)	ALAN with an illuminance of 14.7 lx altered the preference of leaf litter in frogs and salamanders. When exposed to ALAN, Jefferson salamanders (*Ambystoma jeffersonianum*) and blue-spotted salamanders (*Ambystoma laterale*) both displayed a preference for coniferous litter over deciduous litter.	[148]
2	ALAN (ind.)	The passage of bullfrogs (*Lithobates catesbeianus*) from their typical habitats to urban areas was reported to be affected by ALAN and spatial and temporal factors.	[149]
3	ALAN (ind.)	ALAN may alter the passage of amphibians in typically visited landscapes and from land to aquatic environments. A decline in amphibian populations was shown to be caused by road-kills. Most anuran road-kills were observed concentrated in locations along the road section. The mortality rate in amphibians was influenced by ALAN, waterbody distance, managed wood,	[150]

		silviculture, and grassland.	
4	LEDs	When northern green frogs (*Rana clamitans melanota*) were exposed to white LEDs with an illuminance of 52 to 120 lx, males were observed to have altered vocalisation calls. There was also a reduced occurrence of male calls and a reduction in the calls detected by females.	[151]
5	HPS	HPS with an illuminance of 60 lx induced an earlier calling behaviour in frogs. Lesser swimming frogs (*Pseudis minuta*) had an altered activity peak when they were proximate to illuminated areas. In settings without illumination, amphibians showed longer varied vocalisations (a sign of calling behaviour in males) with the exception of Sanborn's treefrogs (*Dendropsophus sanborni*) and Hensel's swamp frogs (*Pseudopaludicola falcipes*) which exhibited a longer vocalisation during calling seasons.	[152]
6	ALAN (ind.)	When *Hyla chrysosceli* were exposed to ALAN, this resulted in an altered detection and consumption of prey.	[153]
7	ALAN (dir.)	Very low illuminance has been observed to impact frog behavior. A 5-minute exposure to ALAN was observed to increase the orientation towards prey and attempts to capture prey in *Hyla squirella*. No attempt to capture prey occurred in *H. squirella* when they were exposed to complete darkness, but at the illuminance of 0.001 lx, all squirrel tree frogs oriented towards prey and attempted to capture prey. Orientation towards prey was reported in 50% of squirrel tree frogs when they were exposed to very low illuminance of 0.00006 lx which is less than starlight.	[154]
8	LEDs	Common toads (*Bufo bufo*) displayed increased activity when they were continuously exposed at night to near monochromatic LED light (λp = 590 nm) with an illuminance of 0.01 (dark control), 0.1 lx, 5 lx, and 20 lx.	[155]
9	LEDs	Exposure at night to cool white LED light (CCT 6000 – 6500 K) and varied illuminances of 0.01 (dark control), 0.1 lx, and 5 lx was observed to alter the mate selection and reproductive success of male toads (*B. bufo*).	[156]
10	LEDs	Exposure to neutral white LEDs (CCT ca. 4000 K) with an illuminance of 3 lx and 16 lx resulted in the reduced growth of juvenile toads and a lack of retreat to leaf litter. Post-metamorphic growth was reduced by 15% in juvenile American toads (*Anaxyrus americanus*).	[157]
11	FL	Yungas red-belly male toads (*Melanophryniscus rubiventris*) exposed to FL at an illuminance of 30 lx showed an immune response that caused high production levels of neutrophil proportions and altered ratios between neutrophils to lymphocytes.	[158]
12	ALAN (ind.)	When eastern gray treefrogs (*Hyla versicolor*) were exposed to ALAN, there was an unaltered mate choice behaviour reported in females.	[159]

Table S5. Key findings about the effects of ALAN for the organism group of reptiles.

#	Type of light source	Key findings	Ref.
1	ALAN (ind.)	Satellite imagery data from 1992 - 2012 reveals the spatial extent of ALAN across Southeast Asia and South Asia, areas that also have a high richness of terrestrial and freshwater mammals, birds, reptiles and amphibians. For the group of reptiles, geckos were shown in areas such as Southeast Asia and South Asia where ALAN has increased in the past years.	[160]

2	ALAN (dir.)	15 reptile species that include Lace monitor (*Varanus varanus*), red bellied black snake (*Pseudechis porphyriacus*), and common blue tongue (*Tiliqua scincoides*) were attracted to ALAN.	[161]
3	ALAN (dir.)	Changes in the predatory behaviour was reported in 34% of Moorish wall geckos (*Tarentola mauritanica*). ALAN is reported as an opportunistic circumstance for geckos to catch easy prey.	[162]
4	ALAN (dir.)	Marine turtles including *Caretta caretta L.*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, *Natator depressus* and *Dermochelys coriacea* were attracted to ALAN.	[163]
5	ALAN (dir.)	ALAN was shown to deviate the nocturnal trajectories of the marine turtle *Natator depressus*.	[164]
6	LEDs	Deviated nocturnal trajectories were observed in loggerhead sea turtles (*Caretta caretta L.*) when they were exposed at night to LEDs with a broad SPD.	[165]
7	ALAN (dir.)	ALAN with a SPD rich in ultraviolet and short-wavelengths disturbed the hatching behaviour and altered the trajectories in land of green turtles (*Chelonia mydas*).	[166]
8	HPS, MH, LPS, and LEDs	Varied organism groups including arachnids, insects, reptiles, birds, and mammals were significantly stimulated by light sources with a broad SPD and short wavelengths, which include HPS, MH, LPS, and LEDs. The highest visual range sensitivities in reptiles were presented when exposed to MH, followed by HPS and LEDs. LPS was reported as the light source that induced the least detectable sensitivities in reptiles.	[167]

Table S5. Key findings about the effects of ALAN for the organism group of birds.

#	Type of light source	Key findings	Ref.
1	ALAN (ind.)	The nest-building behaviour (height choice of the nest) was altered in urban great tits (*P. major*). Nests were built at higher locations, and thinner nests were built in cavities when proximate to night-time illumination, which is probably due to avoidance of predators and light pollution.	[168]
2	ALAN (ind.)	An earlier onset for breeding and offspring fledgings was observed in urban areas with noise, light pollution, temperature, and humidity, compared to great tits (*P. major*) that bred in forests. Although attempts were made to control the temperature, humidity, light, and noise, the differences persisted, which led to inconclusive results. The study results imply that forest and city bird populations may be shaped by other environmental factors that were not considered in the study.	[169]
3	LEDs	This study reported varied responses in great tits (*P. major*) and pied flycatchers	[170]

		(*Ficedula hypoleuca*) when they were exposed to LED light with an illuminance of 8.2 lx and with varied SPDs (white, green, red). The two year experiment showed an early egg-laying behaviour in great tits (*P. major*) for the first year for white and green light when compared to individuals kept in the dark. However, no such effect was observed in the second year. For pied flycatchers (*F. hypoleuca*), no effect was reported in the laying of eggs for both years when exposed to ALAN. In both great tits and pied flycatchers, ALAN presented no effect on their clutch size. However, in the first year of the study, great tits were observed laying larger clutches away from the location where ALAN was present. ALAN caused no effect on the probability of brood failure, the number of chicks fledged, and the breeding densities of great tits and pied flycatchers.	
4	ALAN (ind.)	When exposed to ALAN, urban tawny owls (*Strix alvoc*) showed an early onset in their breeding behaviour compared to rural birds.	[171]
5	ALAN (dir.)	Urban blackbirds (*T. merula*) were observed to have an advanced reproductive maturity of 19 days earlier compared to rural birds. Urban birds in the business district presented an earlier onset of the day. At an intermediate level of urbanisation, no significant difference in onset of the day was reported for blackbirds (*T. merula*) in rural forests and urban parks.	[172]
6	ALAN (dir.)	Exposure to ALAN was observed to cause an early onset of gonadal development and an early onset of hormonal secretion in urban blackbirds (*T. merula*).	[173]
7	LEDs	Different stages of gonadal growth were activated for male great tits (*P. major*) when exposed to warm white LED light with varied illuminance of 0.5, 1.5, and 5 lx at night. The study reported an increased development of germ cells at 0.5 lx. Also, males exposed to 0.5 lx and 1.5 lx showed transcript levels related to steroid synthesis, spermatogenesis, and a slight growth of the testes size. Males exposed to 5 lx presented significantly larger testes compared to males exposed to lower illumination. The study suggests that a photoperiodic response was induced in male great tits (P. major) at night when exposed to low levels of LEDs.	[174]
8	LEDs	An altered sexual selection process was noted in wild great tits (*P. major*) mates, which can potentially affect the parentage of great tits offspring when exposed to LED light with an illuminance of 8.2 lx and different SPDs (white, green, red). Few young broods reported an increased extra pair copulation when exposed to white and red LED light with distance from the nearest sources. No effects were reported related to the distance to the nearest light source when exposed to green LED lights.	[175]
9	ALAN (dir.)	Low levels of estradiol were reported in female and male scrub-jays (*Aphelocoma coerulescens*) when they were exposed to ALAN with an illuminance of 3.2 lx.	[176]
10	LEDs	When great tits (*P. major*) were exposed to warm white LED light with varied illuminances of 0.05 lx, 0.15 lx, 0.5 lx and 1.5 lx at night, the onset of their activity was significantly advanced. The activity offset was delayed and melatonin levels were decreased at midnight. Night-time activity increased and melatonin levels measured at midnight decreased with higher intensities.	[177]
11	FL	Zebra finches (*Taeniopugia guttata*) showed an increased cell proliferation in their ventricular zone, a decrease of neural densities in two distinct areas of the brain significant in areas essential for visual perception, associative learning, audition,	[178]

		and vocal communication in birds, and suppressed melatonin production under FL with a broad SPD and illuminances of 0.5, 1.5, and 5 lx, which is suggested to increase body mass as well (except for the exposure of 5 lx). Melatonin levels were significantly lowered at all illuminances. However it was significantly lowered for illuminances of 0.5 and 5 lx.	
12	FL	Higher locomotor activity was reported in urban birds when they were exposed to FL at night with an illuminance of 0.53 – 8 lx and a broad SPD, compared to rural birds (no ALAN exposure, 0 lx). Urban birds showed an early onset of locomotor activity before luminaires started to operate and stayed active thirty minutes more compared to rural birds, which started their activity after luminaires started operating and remained quiet after the lights went off. Suppressed melatonin levels were observed in urban birds compared to rural birds. Also, ALAN was reported to induce lower species diversity and the species richness of intestinal microbiota in birds, which may result in weight loss, digestive dysfunction, and immuno-deficiency in Eurasian tree sparrows.	[179]
13	ALAN (dir.)	Birds during long nocturnal migration flights may stop-over at illuminated locations, which may increase the density of migrating birds in areas illuminated at night, but may decrease within a few kilometres of the operating source of light at night. The attraction of birds towards illuminated locations may include a potential impact on the selection process of forest stop-over and habitats in migrating birds.	[180]
14	ALAN (ind.)	The attraction of nocturnal migratory birds to light polluted locations may alter the perception of orientation and navigation cues, which can potentially lead to destination shifts and changes in flying routes.	[181]
15	CMH	Nocturnally migrating birds were observed to have significant attraction and disorientation when exposed to CMH (red, green, blue) and MH with opaque filters. Both exposures were observed during overcast conditions (cloudy with more than 50% cloud cover and clear with at most 50% cloud cover), and moonlight (less than or equal to half moon and more than half moon) at night. The exposure to white and red MH was noted to highly disturb and attract birds. Under blue MH birds followed a seasonally migratory direction. Under green MH birds were less oriented than in blue MH, however, birds were less attracted and disturbed in comparison to red and white light.	[182]
16	ALAN (ind.)	Disorientation has been observed in nocturnally migrating birds,. Birds may be attracted to illuminated locations at night. During these nocturnal flights, disorientation might lead to looped migrations which may have a larger effect in the number of attracted birds and may raise the mortality rate in juvenile birds, as young birds undertake their first migratory flights at night during autumn.	[183]
17	CMH, HPS, and LEDs	When exposed to CMH, HPS, and LEDs at night, approximately 230 migrating birds were grounded, including short-tailed shearwaters (*Ardenna tenuirostris*). Also, the study suggested that the attraction and disorientation occurred during night flights. MH was observed to attract the highest number of birds, as it is a source rich in short-wavelengths. However, the study suggests that the attraction of birds is a wavelength dependent response.	[184]
18	ALAN (dir.)	The upward emission of ALAN has been observed to cause collisions of nocturnally migrating birds against man-made structures which can result in the	[185]

		death of birds, and for those that are injured, potentially put them at risk of predation. Birds, which produced nocturnal flight calls during migration flights, collided more often with buildings as a response to positive phototaxis towards ALAN, compared to birds that did not produce such communication calls. About 69,000 collisions involving 93 species from 15 families of birds were reported.	
19	ALAN (ind.)	ALAN was reported to cause the death of about 6,000 nocturnally migrating birds for spring, and about 11,800 birds for the fall season. These deaths involved 121 species.	[186]
20	ALAN (indir.) and moonlight	This study investigated the number of birds influenced by ALAN and moonlight. The vast majority of birds were found grounded during low moonlight visibility (with less than 20% of the moon's face illuminated or above the horizon and at sea level during sunset and sunrise). Bird species influenced by ALAN included Flying Leach's storm-petrel (*Oceanodroma leucorhoa*), European storm-petrel (*Hydrobates pelagicus*), and Manx shearwater (*Puffinus puffinus*).	[187]
21	ALAN (ind.)	ALAN was observed to attract and disorientate short-tailed shearwaters (*Ardenna tenuirostris*), with a 39% fatality rate.	[188]
22	ALAN (ind.)	298 species of migratory birds such as Basra reed warbler (*Acrocephalus griseldis*) and the Sakhalin leaf warbler (*Phylloscopus borealoides*) were exposed to light polluted locations except for the golden crowned sparrow (*Zonotrichia atricapilla*). The study observed that birds were exposed to ALAN during migration and in non-breeding ranges.	[189]
23	ALAN (ind.)	Nocturnally migrating birds were observed to be exposed to light polluted locations when flying at higher altitudes. ALAN in urban areas was reported to affect. Flight altitudes in migrating birds were reported higher (vertical distribution of flying/migrating birds) when flying over bright locations when compared to darker areas (non-urban locations) at night. However, the study indicates that the flying ranges depend on site and seasonality.	[190]
24	ALAN (ind.)	Fallout behaviour at night was observed when a large number of birds were grounded during migration. Fallout is a result of weather conditions and light pollution which can induce disorientation during night flights, and/or attract birds towards illuminated areas, leading to potential collisions, and predation, and may prevent birds becoming airborne again. The study observed that a considerable number of fallouts involving grounded Hutton's shearwater fledglings (*Puffinus huttoni*) coincided with the new moon. 0.1 – 0.3 % of annual fledglings was recorded each year for a period of 8 years. However, fallouts were not observed to occur in direct correlation to the extent of light pollution on land. The occurrence of fallout suggests that a negative impact results from exposure to high illuminance levels, as most of the light sources were HPS and LEDs.	[191]
25	ALAN (dir.)	A consistent spatial pattern of fallout was reported in Newell's shearwaters (*Puffins newelli*) when they were exposed to illuminated areas on land at night. However, the study suggests ALAN is not exclusively limited to land, and that it may also adversely impact birds in flight at sea which could affect large populations of fledglings near coastlines.	[192]
26	ALAN (ind.)	Nighttime exposure to ALAN has been shown to significantly decrease the overall efficacy of nocturnal insectivorous neotropical migrating birds.	[193]

27	LEDs	Blackbirds (*Turdus merula*), long tailed tits (*Aegithalos caudatus*), gold crests (*Regulus regulus*), willow warblers (*Phylloscopus trochilus*), and great tits (*Parus major*) were exposed to LEDs with an illuminance of 8.2 lx and with different SPDs (white, green, red). There was a significant difference in bird activity in dark locations when compared to the activity of birds in locations exposed to green and red LED light. However, the study suggests that the results remain inconclusive for birds as it is unclear what may have caused the change in the number of active birds at night at illuminated transects.	[194]
28	LEDs	Great tits (*P. major*) were exposed to white LED light with an illuminance of 1.6 lx at the bottom of their nests. An early onset of activity was observed, specifically during the waking up time. Also, birds were observed being active at night, which was observed to reduce their sleep time by 5%. Female great tits spent a significant portion of the night time awake under ALAN.	[195]
29	LEDs	Great tits (*P. major*) were exposed to white LED lights at night with an illuminance of 1.6 lx at the bottom of their nests. Females were observed to fall asleep later and they woke up earlier, which significantly reduced their resting portion. The frequency of their sleep bouts decreased, while the length of their sleep bouts remained the same. Female chicks showed altered sleeping patterns at night, which increased their begging and interrupted the sleeping portion of the night.	[196]
30	LEDs	The total daily activity of male urban great tits (*P. major*) did not differ when the birds were exposed to LED lights with different SPDs (white and green) and an illuminance of 1.5 lx. Both light treatments showed a higher level of daily energy expenditure and a preference for roosting behaviour. However, forest birds were considered more active when they were exposed to white light. No conclusive results were reported on the plasma levels of oxalic acid (a biomarker of sleep deprivation).	[197]
31	LEDs	Great tits (*P. major*) feeding offspring while exposed to LED light with an illuminance of 7.6 lx showed lower daily energy expenditure compared to birds in the dark. However, the study revealed an increase in food availability in the illuminated transects where lower daily energy expenditure was reported which may have mediated this result.	[198]
32	LEDs	An advanced onset of activity during the morning and an advanced activity during the night was reported for captive blue tits (*C. caeruleus*) when they were exposed to LED light with different SPDs (white, green, red) and an illuminance of 5 lx. An advanced onset (more than 2 h and 1 h) was observed with white and green light, respectively, when compared to the birds with no ALAN exposure.	[199]
33	ALAN (ind.)	European robins (*Erthiacus rubecula*), European blackbirds (*T. merula*), European wrens (*Troglodytes troglodytes*), great tits (*P. major*), and blue tits (*C. caeruleus*) were observed to be active at night when exposed to ALAN. European robins (*E. rubecula*) and European wrens (*T. troglodytes*) extended their night-time activity, which led to a premature start of activity before sunrise 03h30 – 04h00. In various occasions, European robins (*E. rubecula*) started earlier at 00h30, and European blackbirds (*T. merula*) started earlier at 04h00 and 05h00, while great tits (*P. major*) and blue tits (*C. caeruleus*) did also to some extent. European robins (*E. rubecula*), also showed an active behaviour at night, but most of their activity occurred during the day.	[200]

34	ALAN (ind.)	This study evaluates the activity rhythms of urban adult male European blackbirds (*T. merula*) during two periods that include earlier in the night (10h00 – 00h30) and later in the night (00h30 – 3h00). The advancement of onset and daily activity was observed in urban birds compared to birds in rural locations. Also, an earlier onset of activity was reported in birds located within the business district that were exposed to high levels of ALAN late at night. However, the night time exposure to ALAN was not considered to influence the end of daily activity.	[201]
35	ALAN (ind.)	Active nocturnal behaviour was exhibited during the breeding season and after sunset that continued until early in the morning. The active hunting behaviour of Eleonora's falcons (*Falco eleonorae*) was also reported to occur during nights with little moonlight or overcast conditions. ALAN was observed to increase the capture of nocturnal migrant species such as members of the genera *Sylvia* and *Acrocephalus*.	[202]
36	ALAN (dir.)	The night-time behaviour of the common swift (*Apus apus*) was studied in four locations with four different illuminance levels (0.005 lx, 0.83 lx, 3.85 lx, and 120 lx). No activity was observed during sunset at 0.005 lx. The highest level of night-time activity was registered at 120 lx. Morning activity started earlier in colonies exposed to 0.005 lx, 0.83 lx, and 3.85 lx.	[203]
37	LEDs	An advanced onset of activity was observed in great tits (*P. major*) when they were exposed to the light emitted from white LEDs with varied illuminances (0.15, 0.5, 1.5 and 5 lx), rather than a phase shift of their internal circadian clock.	[204]
38	ALAN (ind.)	When exposed to ALAN, an earlier seasonal timing was reported in great tits (*P. major*), blue tits (*C. caenleun*), common chaffinches (*Fringilla coelebs*), and European blackbirds (*Turdus merula*), which may cue changes in behavioural patterns of activity such as dawn and dusk singing, and rest. Birds were seen to wake up earlier and they showed extended activity patterns during the night-time such as foraging, which continued throughout the night. The length of sleep in birds was shortened.	[205]
39	LEDs	A prolonged activity and extended foraging period were observed in great tits (*P. major*) when they were exposed to white LEDs with an illuminance level of 10 lx.	[206]
40	ALAN (ind.)	Altered foraging behaviour was observed in mockingbirds (*Mimus polyglottos*) that were located in areas with high levels of illuminance such as parking lots. With increased illuminance, mocking birds were observed to feed their nestlings later into the night.	[207]
41	ALAN (ind.)	An altered timing and distribution of foraging opportunities were reported in redshanks (*Tringa totanus*) when they were exposed to ALAN. Their night-time foraging activity was influenced by the moon phase on clear nights. During the new moon, redshanks were seen to spend less time foraging than during the full moon.	[208]
42	ALAN (ind.)	This study investigated the interaction and foraging behaviour of bats and nighthawks (*Chordeiles minor*) attracted by an illuminated obelisk. The illuminated obelisk was considered to attract insects, and as a consequence, also attract potential predators such as bats and nighthawks. Nighthawks were observed foraging at a higher location compared to bats.	[209]
43	ALAN	Altered foraging activity was observed in urban blackbirds (*T. merula*) at locations	[210]

	(dir.)	with different illuminance levels: urban centers (0.36 – 44 lx), parks (0.12 – 0.15 lx), and forest (0.07 lx). Longer foraging periods were reported in areas with higher illuminance, such as urban centers, in comparison to darker areas such as parks and forests. An extended foraging behaviour was most pronounced during March, when days were shorter, and decreased considerably by mid-April. The body condition of blackbirds (*T. merula*) did not differ with the presence of ALAN.	
44	ALAN (dir.)	An altered timing of singing was reported in European robins (*Erithacus rubecula*), blackbirds (*T. merula*), great tits (*P. major*), and blue tits (*C. caenleun*), with a significant impact on European robins (*E. rubecula*) when they were exposed to ALAN with an illuminance of 4 lx at the center of each site. The light source had a luminous flux of 8850 lm, a CCT of 2900 K, and a broad SPD.	[211]
45	HPS	The reproductive behaviour and communication of singing birds were hindered in chaffinches (*Fringilla coelebs*), blue tits (*C. caenleun)*, great tits (*P. major*), blackbirds (*T. merula*), and robins (*E. rubecula*) when they were exposed to HPS with an illuminance of 100 lx. For instance, female birds laid their eggs earlier, and males started their dawn songs earlier before morning, which may modify pairing success.	[212]
46	ALAN (ind.)	An earlier dawn singing with no additional effects of ALAN was observed in robins (*E. rubecula*) and blackbirds (*T. merula*). Singing birds that include great tits (P. major), blue tits (*C. caeruleus*), and chaffinches (*F. coelebs*) had similar onsets of dawn song relative to sunrise across the season and similar effects of an earlier dawn singing when they were exposed to ALAN in five peri-urban forest sites with street lighting during their breeding season.	[213]
47	ALAN (ind.)	An onset of dawn chorus behaviour was observed in American robins (*Turdus migratorius*) for two years when they were exposed to ALAN. Whereas, the onset of dawn chorus occurred during true night in breeding.	[214]
48	ALAN (ind.)	An onset of dawn chorus behaviour was observed in American robins (*T. migratorius*) in a two year experiment where American robins were exposed to ALAN. The onset of dawn chorus occurred during true night in breeding.	[215]
49	LEDs	An earlier daily onset of dawn singing was observed in 14 species of birds in eight dark forest edges that were illuminated with LED light with different SPDs (white, green, red) with an illuminance level of 7.4 lx. No other effect was observed, such as an earlier daily onset of dawn singing among the 14 species of birds.	[216]
50	ALAN (dir.)	No impact was reported in the dawn singing behaviour of rufous-collared sparrows (*Zonotrichia capensis*) when they were exposed to ALAN with an illuminance of 0.7 - 9.4 lx.	[217]
51	ALAN (ind.)	The exposure to environmental factors such as noise and light pollution were observed not to affect the timing of dawn songs for male house wrens (*Troglodytes aedon*). However, social factors were seen to influence the timing of dawn songs in male house wrens (*T. aedon*). Earlier singing was noted in male house wrens (*T. aedon*) that were building nests during the nesting stag compared to male house wrens that were in incubation or the nestling stage. Male house wrens sung earlier in the presence of numerous neighboring male birds. During the building stage, unpaired male birds showed a late onset singing compared to paired males.	[218]
52	ALAN	No effect on calling activity was observed in wood pigeons (*Columba palumbus*)	[219]

	(ind.)	when they were exposed to ALAN.	
53	LEDs	Great tits (*P. major*) exposed at night to white LED lights with an illuminance of 1.6 lx and 3 lx (inside of the nesting box) during the month of December (winter) and February (pre-breeding season) had a decreased duration of sleep (~ 40 min) with an early onset of sleep (~24 minutes). Birds were observed leaving their nest 18 minutes earlier. Sleep was delayed at 3 lx compared to birds that were exposed to 1.6 lx.	[220]
54	ALAN (ind.)	Male and female great tits (*P. major*) exposed to ALAN showed increased oxalate levels (a component seen in sleep loss) in male nestlings. However, the study suggests it is difficult to predict the correlation between sleep loss and increased oxalate levels in developing nestlings..	[221]
55	LEDs	Silvereyes (*Zosterops lateralis*) were studied using LED light with different SPDs (white, blue 470 nm, green 510 nm, yellow 580 nm and orange 620 nm). Their sleep onset time was determined by the end of chirping. The results showed that white, orange, and yellow light significantly delayed sleep onset while blue and green light showed only a slight interference. The higher the irradiance level (0.01, 0.02, 0.03 W/m^2), the longer the sleep onset was postponed.	[222]
56	ALAN (ind.)	ALAN is considered to alter the patterns of resting behaviour in female great tits (*P. major*) during the night, which varied between females. Female birds spent 93.3% of the night in a resting position. The variation of pattern resting behaviour was not affected or linked to urban environmental factors such as temperature, atmospheric humidity, ALAN, or nocturnal noise.	[223]
57	LEDs	Great tits (*P. major*) and blue tits (*C. caeruleus*) both had their sleep affected by white LED light with an illuminance of 3 lx, with great tits showing more pronounced effects in comparison to blue tits. Great tits showed a loss of 50 mins of sleep, while blue tits only reported an altered evening latency, sleep bout length and frequency. Both great and blue tits presented an increased sleep bout length, decreased bout frequency, and an altered pattern in falling asleep.	[224]
58	LEDs	An active night-time behaviour and a gradual decrease of oxalic acid concentrations (indicating sleep deprivation) were reported in great tits (*P. major*) when they were exposed to white LED light with an illuminance of 8.2 lx.	[225]
59	LEDs	No effect on the night-time sleep behaviour was observed in free-living great tits (*P. major*) when they were exposed to white LED light with an illuminance of 1.6 lx. However, the birds were living in cavities, which may shield to some extent, the ALAN treatments.	[226]
60	ALAN (dir.)	An altered nest selection was observed in urban black birds (*T. merula*), indicating a preference for illuminated nests at night as predators avoided the nests. The avoided predators included tawny owls (S. aluco), rodents, martens (*Martes spec*), and possibly also racoons (*Procyon lotor*). A correlation was also made between ALAN and advanced laying dates (by almost a week) when birds transitioned from nest sites in darkness to nest sites exposed to an illuminance of 1 lx.	[227]
61	ALAN (dir.)	ALAN and noise pollution was reported to influence the density of birds and their inter-seasonal stability, while food sources available were also considered to impact the species richness and density of birds. About 64 species of birds were observed to be affected by ALAN and noise pollution. The most numerous bird	[228]

		species that were impacted included great tits (*P. major*), magpies (*Pica pica*), blackbirds (*T. merula*), blue tits (*Cyanistes caeruleus*), rooks (*Corvus frugilegus*), fieldfares (*Turdus pilaris*), and house sparrows (*Passer domesticus*).	
62	ALAN (ind.)	In urban birds, the combined 24h exposure to ALAN and noise pollution, specifically noise, decreased the daytime activity of male great tits (*P. major*), while ALAN was considered to have no effect on their daytime activity. The combined exposure to ALAN and noise increased the night-time activity in urban birds, compared to forest birds. No significant interaction of ALAN and noise was observed. ALAN significantly influenced the onset of activity for urban and forest birds.	[229]
63	CMH	Mixed-species flocks of birds that included wood-warblers (*Parulidae*), tyrant fly-catchers (*Tyrannidae*), and mimids (*Mimidae*) were observed to forage on insects attracted to the emission of CMH at night.	[230]
64	ALAN (dir.)	European blackbirds (*T. merula*) exposed to an illuminance of 0.17 lux (range 0.07 – 61.7 lux) were shown to have lower levels of testosterone in female birds. Female blackbirds showed clear seasonally adapted levels of estrone, which increased in February and March, and then declined until May. In females, levels of estrone were reported to decrease with increasing lamp densities, while no effect was reported to influence male estrone concentrations.	[231]
65	LEDs	When nestling great tits (*P. major*) were exposed to white LED light with an illuminance of 3 lx (at the bottom of the nest) there was no increase in body mass. There was also no effect on their oxidative status. Whereas, great tits (*P. major*) from non-illuminated locations were observed to have a gradual body mass gain and no effect on oxidative status.	[232]
66	LEDs	When female great tits (*P. major*) were exposed to LED light with an illuminance of 7.6 lx and with varied a SPD (white, green, red) they laid their eggs earlier when compared to female birds, which were exposed to no ALAN. Female great tits (*P. major*) exposed to green and white light, laid eggs earlier than the female great tits exposed to darkness at night. While birds exposed to red light laid their eggs earlier, this was not as significantly earlier as the female birds exposed to white and green light. During spring, when temperatures were recorded to be low, an advanced egg laying date was seen in females exposed to LED light when compared to those exposed to no ALAN.	[233]
67	LEDs	An elevated corticosterone hormone was reported for great tits (P. major) when the bird's nests were illuminated with cold white LED light (CCT > 6000 K) with an illuminance of 1 lx at the nest height.	[234]
68	LEDs	This study exposed Zebra finches (*Taeniopygia guttata*) to warm and cool white LED lights (CCT 3000 K and 5000 K) with an illuminance of 0.3 lx. Higher rates of night time activity were observed in individuals that were exposed to 5000 K light compared to 3000 K light and no ALAN. Birds in the 5000 K treatment group also had increased corticosterone levels compared to those that were exposed to 3000 K and no ALAN, but there were no changes in their body condition or food intake. Individuals that were active during the night did not consequently decrease daytime activity.	[235]
69	ALAN	Urban and rural tree sparrows (*Passer montanus*) were compared when they were	[236]

	(dir.)	exposed to ALAN with illuminance of 12.5 lx to analyse their levels of luteinizing hormone, testosterone, and estradiol when exposed to night-time illumination. Urban tree sparrows were observed to have an earlier increase of luteinizing hormone, a lower peak in the secretion of luteinizing hormone, and lowered levels of testosterone and estradiol compared to rural birds that were exposed to lower levels of night-time illumination, while rural birds presented a higher peak in luteinizing hormone.	
70	FL	Captive Australian budgerigars (*Melopsittacus undulatus*) were exposed to FL with an illuminance of 200 lx, a CCT of 4000 K, and different durations of exposures at night (30, 60, and 90 minutes). The study showed a gradual increase of body mass over a period of 3 months for all durations of exposures compared to no exposure. Increased duration of exposure to ALAN resulted in decreased egg production (by 85% at 30 min and 92% at 60 min). Birds exposed to 90 min of ALAN did not present an onset of egg production and showed reduced hatchability (from 61 – 41%). Additionally, disease severity increased with a duration of exposure which may increase susceptibility to infections.	[237]
71	LEDs	Great tits (*P. major*) were exposed to white LED light with an illuminance of 1.6 lx and 3 lx (inside their nesting box) during the winter period (Nov. – Feb. 2010 - 2015). This did not alter their exploration behaviour. The exploration behavior was not associated with the roosting behaviour in nest boxes illuminated at night. However, the percentage of birds that roosted in illuminated nest boxes at night decreased to 71%. No conclusive evidence was found for ALAN as an environmental component that may induce personality dependent effects on the sleep patterns in birds. Sleep behaviour in slow and fast explorers was observed to be equally disrupted by ALAN.	[238]
72	ALAN (ind.)	The arrival of various birds was associated with ALAN, temperature, rainfall, and urban land cover. However, no effect was observed on the timing of their foraging behaviour or their arrival to these locations in winter when the birds were exposed to ALAN.	[239]
73	ALAN (dir.)	ALAN and noise pollution were observed to alter the nest attendance and weight gain of Scopoli's shearwaters (*Calonectris diomedea*). The birds gained less weight during nights with higher levels of moonlight regardless of light and noise pollution.	[240]
74	FL	When Australian budegerigars (*Melopsittacus undulatus*) were exposed to FL with an illuminance of 200 lx, a CCT = 4000K for 60 minutes, there was a significant increase in their body mass, and food and water intake, as well as a decrease in their reproductive behaviour, plus an increase in stress responses compared to individuals kept in darkness.	[241]
75	ALAN (dir.)	When wild tree sparrows (*Passer montanus*) were exposed to ALAN with varied illuminances of 0, 85, 150, 300 lx, they were observed to have an accelerated reproductive endocrine activation of the hypothalamic-pituitary-gonadal axis. Key proteins (TSH-b, Dio2, and GnRH-I), which express the reproductive endocrine activation in the hypothalamus, were significantly higher at an illuminance of 85 lx. Meanwhile, tree sparrows (*P. montanus*) exposed to 150 and 300 lx were observed to have a reduction in the peak expression of their pituitary hormone and estradiol levels, but there was no delay in the timing of these peaks compared to birds that were exposed to dark settings.	[242]

76	ALAN (dir.)	When female and male king quails (*Excalfactoria chinensis*) were exposed to ALAN with an illuminance of 0.3 lx, they were observed to have an increase in innate immune activity (increased bacterial activity) at different developmental stages.	[243]

Table S6. Key findings about the effects of ALAN for the organism group of non-human mammals: bats, primates, rodents, marsupials

#	Type of light source	Key findings	Ref.
1	HPS	Lesser horseshoe bats (*Rhinolophus hipposideros*) were observed to have a delayed commuting behaviour and altered flying trajectories, which negatively limited the selection of flying routes when they were exposed to HPS at night.	[24]
2	ALAN (indir.)	Mammals are potentially threatened by the expansion of ALAN in North American, European, and East-Asian cities increasing towards South American, South-East Asian, and sub-Saharan African cities. The regions with high mammal species richness showed a 354 % increase in the extent of light pollution. Bats were particularly affected by the increase and extent of ALAN.	[160]
3	ALAN (dir.)	No effect was reported on the nocturnal activity and behaviour of common wombats (*Vombatus ursinus*) when they were exposed to ALAN. The study observed 956 mammals detected at night out of 1086 species, which included wombats (622; 57%) and kangaroos (228; 22%) which made up 79% of the total detected species.	[161]
4	LEDs	This study investigated the activity of bats when they were exposed to LED light with different SPDs (white, green, red) with an illuminance of 8.2 lx. Bat activity was significantly increased when they were exposed to green light in comparison to red lights and no ALAN.	[194]
5	LEDs	Tammar wallabies (*Macropus eugenii*) were exposed to two different LED lights: a) cool white LED (CCT 5000 K) with an irradiance of 2.8 W/m², and b) amber LED (CCT 1700 K) with an irradiance of 2.0 W/m². A reduction of melatonin production was observed in wallabies exposed to cool white light compared to the amber light.	[244]
6	ALAN	About 4,000 species of mammals were found exposed to ALAN in less than 10% of their habitat range during the years 1992 – 2012. In addition, North America, Europe, and Japan are geographic areas that are experiencing an increase in ALAN. The study observed about 4,000 mammal species have experienced changes in ALAN within their habitat range.	[245]
7	ALAN	The presence of bat species at night that included *Pipistrellus nathusii* and *Pipistrellus pygmaeus*, was investigated when they were exposed to ALAN with a monochromatic SPD (green λp = 520 nm). The presence of both bat species increased by more than 50% when ALAN was operating, in comparison to no ALAN.	[246]

8	ALAN	A large-scale survey on the calls made by bats at two different locations showed that the type of operating light sources at night and the density of operating luminaires were not associated with an increase in bat activity at night. The study demonstrated that the most abundant active species at night was *Pipistellus spp.* However, bat activity at night and calls made by lesser noctules (*Nyctalus leisleri*) were significantly linked to the density of luminaires and the type of operating light sources.	[247]
9	ALAN	Noctules (*Nyctalus noctula*), an insectivorous bat, were observed foraging close to aquatic and vegetative areas, and illuminated locations at night. They showed no preference or avoidance while commuting in forests at night when they were exposed to ALAN. However, the study suggests that their foraging locations might be influenced by the presence of ALAN.	[248]
10	LEDs	When lesser horseshoe (*Rhinolophus hipposideros*) and *Myotis spp.* bats were exposed to cool white LED light with an illuminance of 3.6 lx, they were observed to display repulsion away from the light during flight and their activity was reduced.	[249]
11	HPS	When Sowell's short-tailed bats (*Carollia sowelli*) were exposed to HPS with an illuminance of 4.5 lx they had a repulsive response, less explorative flight trajectories, and a reduced harvest action of fruits.	[250]
12	ALAN	Pond bats (*Myotis dasycneme*) showed altered flight paths when they were exposed to ALAN with an illuminance of 30 lx.	[251]
13	HPS, LEDs, induction lamps	A restricted use of flying routes was considered to potentially disrupt the foraging activity of individual lesser horseshoe bats *(Rhinolophus hipposideros*) when exposed to HPS (referred as orange), neutral white LEDs (referred as white), and two induction lamps with narrowband wavelengths rich in mid and long wavelengths (referred as greed and red). All light sources, which were placed on hedgerows, were reported to reduce the activity of lesser horseshoe bats (*R. hipposideros*) during night flights. Also, lesser horseshoe bats (*R. hipposideros*) changed their flight paths to the dark side of the hedgerows, as a rapid adaptation, that allowed them to reach their foraging sites. Other species concisdered in the experiment were Myotis spp., which were observed avoiding HPS, LEDs, and the induction lamps rich in mid wavelengths. While *Pipistrellus spp.* was observed more active under PS, LEDs, and the induction lamps rich in mid wavelengths in comparison to nights exposed to no ALAN. *Nyctalus* or *Eptesicus spp.* presented no effect under ALAN. The study suggests the preservation of dark corridors as responses may vary among bat species.	[252]
14	ALAN	When Kuhl's pipistrelles (*Pipistrellus kuhlii*) and Botta's serotine bats (*Eptesicus bottae*) were exposed to ALAN with an illuminance of 12 lx they were both observed to have faster flight behaviour and a lower flying altitude.	[253]
15	FL	Suppressed melatonin levels were observed in female Japanese monkeys (*Macaca fuscata fuscata*) when they were exposed to FLs with illuminances of 10 – 30 lx. Whereas, the lower exposure of 2 – 5 lx did not suppress melatonin levels.	[254]

16	HPS	When gray mouse lemurs (*Microcebus murinus*) were exposed to HPS their nocturnal emergence, which is an anti-predator response, was delayed. Less time was spent outside of the lemur's refuge. Also, exposure to ALAN was observed to cause a delayed return to their refuge. Moreover, their core temperature was also elevated, which suggests an increase in locomotive activity when the lemur's were exposed to HPS.	[255]
17	ALAN and moonlight	No significant differences were reported in the body mass and daily caloric food intake of female grey mouse lemurs (*M. murinus*) transitioning from short day to long day photoperiods when they were exposed to moonlight and ALAN. However, females that were exposed to ALAN had a higher core temperature and shorter locomotor activity compared to those that were exposed to moonlight. The higher core temperature was present for both photoperiodic exposures that included short days and long days. While the duration of nocturnal active behaviour was on average 66 min shorter in individuals that were exposed to ALAN compared to those lemurs that were exposed to moonlight.	[256]
18	ALAN (dir.)	Djungarian hamsters (*Phodopus sungarus*) exposed to pulses of ALAN with an SPD that was rich in long wavelengths were observed to have an earlier stop of locomotor activity, which eventually led to the suppression of their locomotor activity with a significant decrease in body temperature.	[257]
19	FL and LEDs	Light sources with a broad SPD such as LEDs and FL significantly influenced the period, the strength, and the duration of the active behaviour in mice (*C57BL/6J*). LEDs and FL both reduced the period at which activities occurred.	[258]
20	LEDs	Striped field mice (*Apodemus agrarius*) and bank moles (*Myodes glareolus*) were exposed to warm white LED light (CCT 3000 K) from street lights with an average illuminance of 5.8 lx. Striped field mice showed decreased activity during the daytime when they were exposed to LED light at night. When both species were exposed to white LED light there was a reduced home range overlap, proximity, and activity synchrony of conspecifics (members of the same species).	[259]
21	LEDs	Rodent bank voles (*Myodes glareolus*) exposed to cool white LED light (CCT 7250 K) with an illuminance of 0.8 lx showed an increased activity and an altered use of space during the quarter moon and new moon. No significant effect of ALAN was seen to impact their body mass, or their fecal glucocorticoid metabolites (a metric hormone for circadian disruption and lowered body mass). Male bank voles (*M. glareolus*) showed a greater body mass compared to females. During both the new moon and visible quarter moon, a higher activity was observed for voles that were exposed to ALAN, compared to voles in the dark.	[260]
22	ALAN (dir.)	Male *C57BL/6* mice showed varied responses when they were exposed to ALAN with monochromatic SPD (blue λp = 470 nm and green λp = 530 nm). The blue light was observed to alter their sleep and arousal. Night-time exposure to ALAN caused delayed sleep, increased glucocorticoid (an indicator of induced stress), and behavioural arousal. Mice exposed to the green light brought about rapid sleep. Altered sleep and arousal was seen in mice lacking melanopsin.	[261]

23	ALAN and moonlight	An altered core temperature, the timing and occurrence of estrus, and no significant difference in locomotor activity and urinary 17-ß estradiol (E2) concentration were reported in female grey mouse lemurs (*M. murinus*) that were exposed at night to two types of night-time illumination that included moonlight and ALAN, during the transition of a short day to a long day photoperiod. An early occurrence of estrus (a cycle in female mammals that presents physiological changes induced by reproductive hormones) while in a short day photoperiod was observed in female grey mouse lemurs (*M. murinus*) exposed to LEDs, compared to female grey mouse lemurs (*M. murinus*) that were exposed to moonlight exposure. No significant difference was present in urinary E2 values observed in female grey mouse lemurs that were exposed to moonlight and LEDs.	[262]
24	LEDs	When Wistar rats were exposed to cool white LED light (CCT > 6000K) with an illuminance of 200, they showed a remodeled retina and no sign of death of the outer nuclear layer in the retina, but a noticeable reduction of the outer nuclear layer in the retina. No differences in the number of nucleus, no retinal ganglion cell death, and no damage to the inner structure were detected. However, light sensitive photopigments melanopsin and neuropsin were observed to have a modified location and expression. The study suggests that ALAN does not affect cell survival at this layer, but may induce deep retinal remodelling, which can potentially lead to blindness and circadian rhythm desynchrony.	[263]
25	LEDs	An impaired and delayed healing process was observed in female mice (*C57Bl/6*) that were exposed to white LED light (CCT 5000 K) with an illuminance of 5 lx. The study showed that the night-time period is an essential part of rhythmic cycles necessary for the recovery of wounds in mice.	[264]
26	ALAN and moonlight	Tammar wallabies (*Macropus eugenii*) were exposed to ALAN with a long wavelength SPD (red), broad SPD (white), and no ALAN; as well as three different moon phases (full moon, quarter moon, and new moon) at night. ALAN increased foraging activity and decreased the time allocated to predator avoidance. Predation risk at night can be potentially increased due to the time spent foraging, which reduces the vigilance behaviour necessary to avoid predators. Moon phases had no significant variation in time allocation to behaviour. However, foraging activity increased when the wallabies were exposed to all moon phases under both exposures to ALAN (red, white) in comparison to moon phases with no ALAN. The wallabies were observed to be less vigilant under red ALAN in comparison to no ALAN exposure.	[265]
27	ALAN	Suppressed melatonin levels and a delay of birth were observed in Tammar wallabies (*Macropus eugenii*) that were exposed to ALAN. Individuals living in habitats located within a naval base with ALAN presented lower levels of melatonin when compared to those exposed to no ALAN. Tammar wallabies exposed to ALAN gave birth with a one month delay.	[266]
28	LEDs	Mares (*Equus callabus*) were exposed to monochromatic blue LED light (λp = 468 nm) at different illuminance levels ranging from 0.1, 3, 10, 50, and 100 lx to study their melatonin levels. No significant difference in melatonin was reported when the mares were exposed to 3 lx and below.	[267]

29	ALAN	Siberian hamsters (*Phodopus sungorus*) were exposed to ALAN with illuminance levels = 5 lx to determine if ALAN might alter their circadian clock functions and the molecular mechanisms of their photoperiodic responses. A disrupted short day response in testes mass regression was observed. Also, significantly large testes were seen in Siberian hamsters that were exposed to ALAN compared those that were exposed to 0 lx. The photoperiod and duration of exposure to ALAN was observed to have a significant effect on spermatid nuclei counts in the testes and sperm count in epididymis. The photoperiod had a notable impact on the body mass of Siberian hamsters which was reduced in a short day photoperiod compared to a long day photoperiod. Siberian hamsters exposed to a short day photoperiod and ALAN, were observed to have larger bodies and darker pelage compared to those that were exposed to a short day photoperiod and darkness at night. The photoperiod and duration of ALAN was seen to affect pelage colouration and density. However, no difference in pelage was reported for Siberian hamsters that were exposed to a short day followed by ALAN and a long day exposure. Siberian hamsters exposed to a short day were observed to have a greater pelage density than Siberian hamsters exposed to a long day. However, the pelage density of Siberian hamsters exposed to a short day and ALAN were not significantly different from those that were exposed to a short or long day without ALAN. Siberian hamsters that were exposed to a short day were seen to be less active than those that were exposed to a long day or short day with ALAN. Non-reproductive Siberian hamsters that were exposed to ALAN were observed to have an increase in activity compared to hamsters exposed to a short day. Between light and the dark phase, the locomotor activity of Siberian hamsters was significantly different. Siberian hamsters The photoperiod and exposure to ALAN were considered closely linked with the expression of the circadian clock gene Period1 Per1 and the gene expressions required for photoperiodic responses that include the melatonin receptor Mel-1a, eyes absent 3 Eya3, the thyroid stimulating hormone receptor Tshr, the gonadotropin-releasing hormone GnRH, and the gonadotropin-inhibitory hormone GnIH. An increased in the levels of of Per1 (the circadian clock gene Period1), Mel-1a (melatonin receptor), Eya3 (eyes absent 3), Tshr (the thyroid stimulating hormone receptor), GnRH (the gonadotropin-releasing hormone), and GnIH (the gonadotropin-inhibitory hormone) were detected in Siberian hamsters that were exposed to ALAN compared to those that were exposed to short days.	[268]
30	FL	One male and female potto (*Perodicticus potto*), one female pygmy slow loris (*Nycticebus pygmaeus*), one female aye aye (*Daubentonia madagascarieusis*), a breeding pair of Mohol bushbabies (*Galago moholi*), and one male Mohol bushbaby with a black and rufous elephant shrew (*Rhynchocyn petersi*) were exposed to FL with a SPD rich in long wavelengths and FL with a SPD rich in short wavelengths to demonstrate if active behaviours in Strepsirrhinies primates are affected by FL at night. The active behaviours of Strepsirrhinies primates including social skills, movement, feeding behaviour, self directed, and object examination were significantly reduced when they were exposed to FL with a SPD rich in short wavelengths compared to FL with a SPD rich in long wavelengths. The breeding pair of Mohol bushbabies), the male and female potto, and female pygmy slow loris were observed to be active when exposed to FL with a SPD rich in long wavelengths. The male and female	[269]

		potto, and female pygmy slow loris were seen to spend less time moving when exposed to FL with a SPD rich in short wavelengths compared to the nighttime exposure to FL with a SPD rich in long wavelengths. All mentioned species in this study spent more time examining objects at night when they were exposed to FL with a SPD rich in long wavelengths. Additionally, the female aye aye was observed to have a lowered salivary melatonin concentration when it was exposed to FL rich in short wavelengths compared to when it was exposed to FL with a SPD rich in long wavelengths. The study suggests that the activity increased in all species involved in this study when they were exposed to a SPD rich in long wavelengths.	