Importance of visibility improvements for safety in automotive lighting

Michael J. Flannagan
University of Michigan
Transportation Research Institute

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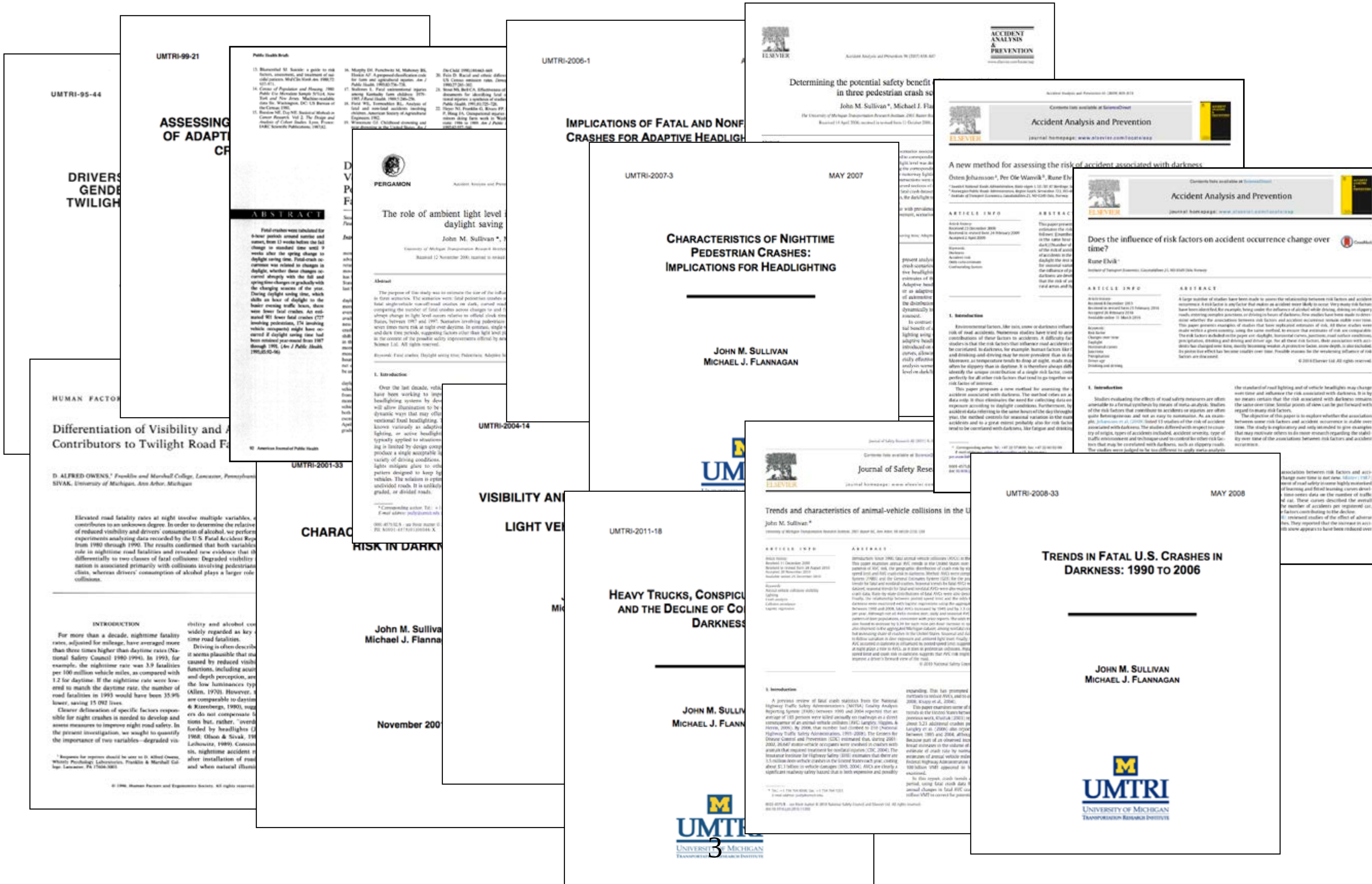
UMTRI

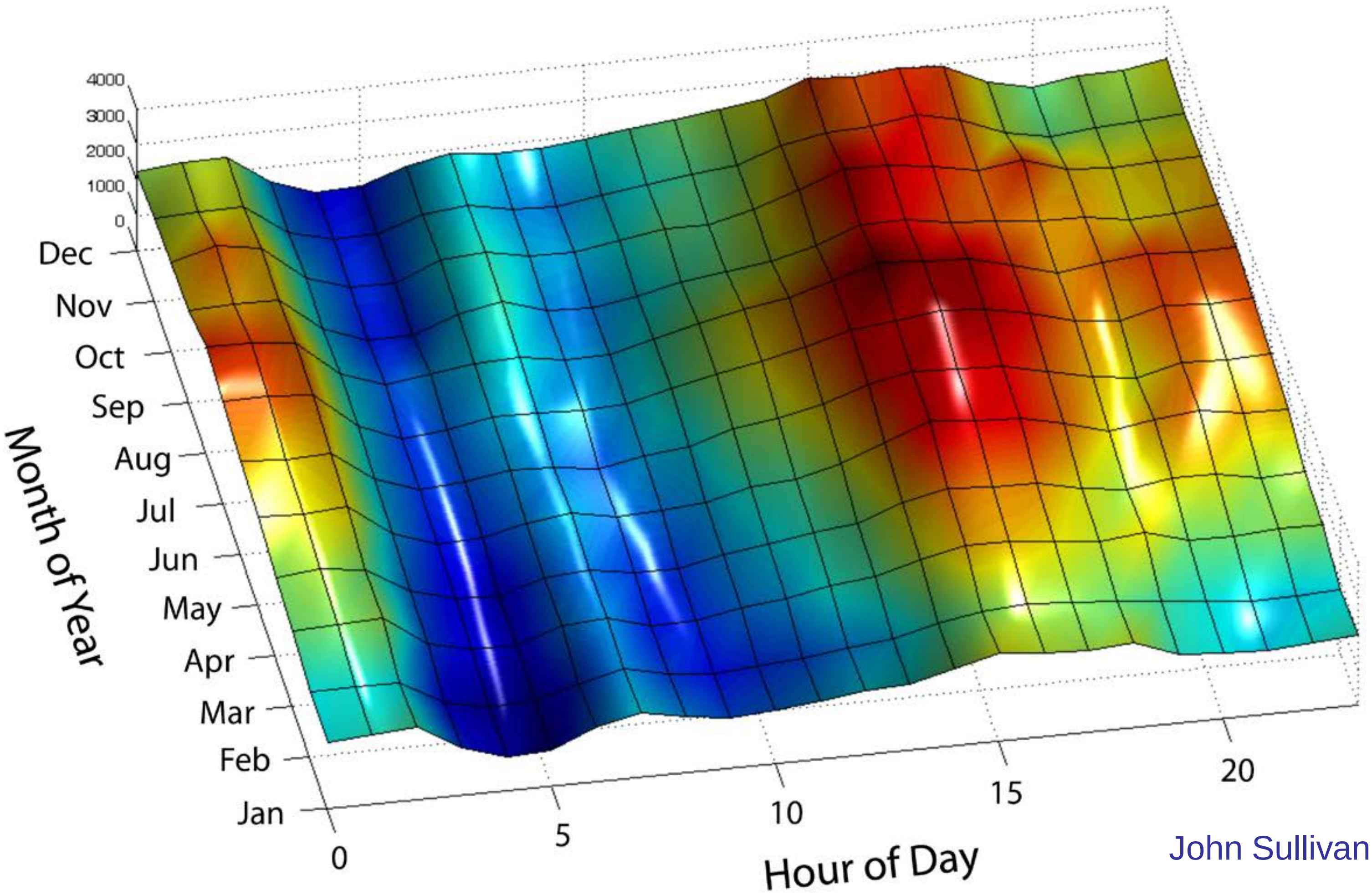
Approaches to understanding headlighting effectiveness

- Driver vision and human factors
  - Visual detection limits in darkness
  - Eye movements while driving
  - Decision making with risk
- Analysis of crash data
  - Crash rates night/day?
  - But, night/day also involves differences in traffic volume, alcohol, fatigue, etc.
  - Two approaches that can help:
    - Seasonal variations in light/dark
    - Transitions with daylight saving time (DST)

Studies using seasonal light changes or DST to isolate effects of darkness on crashes over the past 25 years

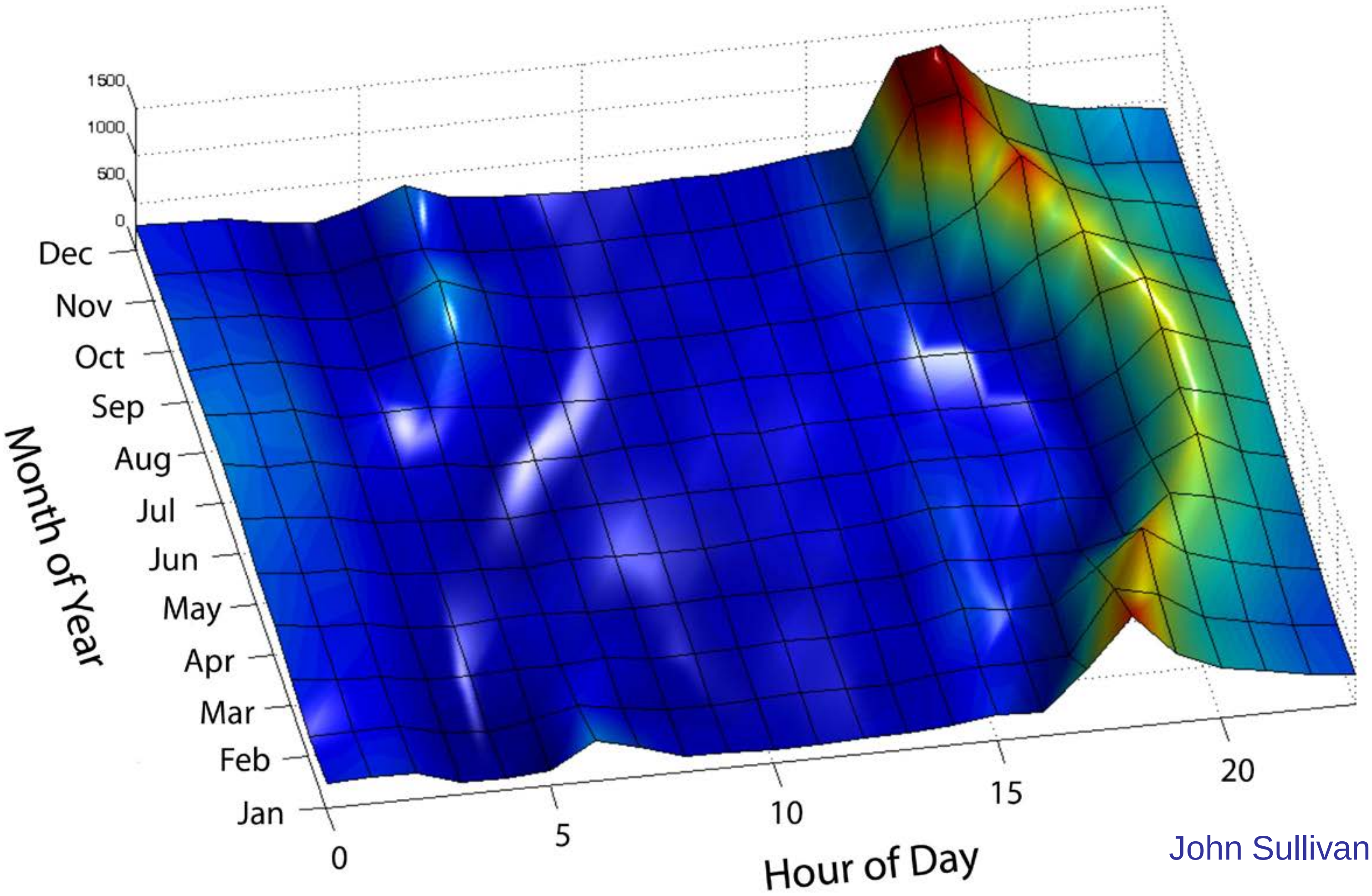


Vehicle occupant deaths FARS, 1987-2003



John Sullivan, UMTRI

Pedestrian deaths
FARS, 1987-2003



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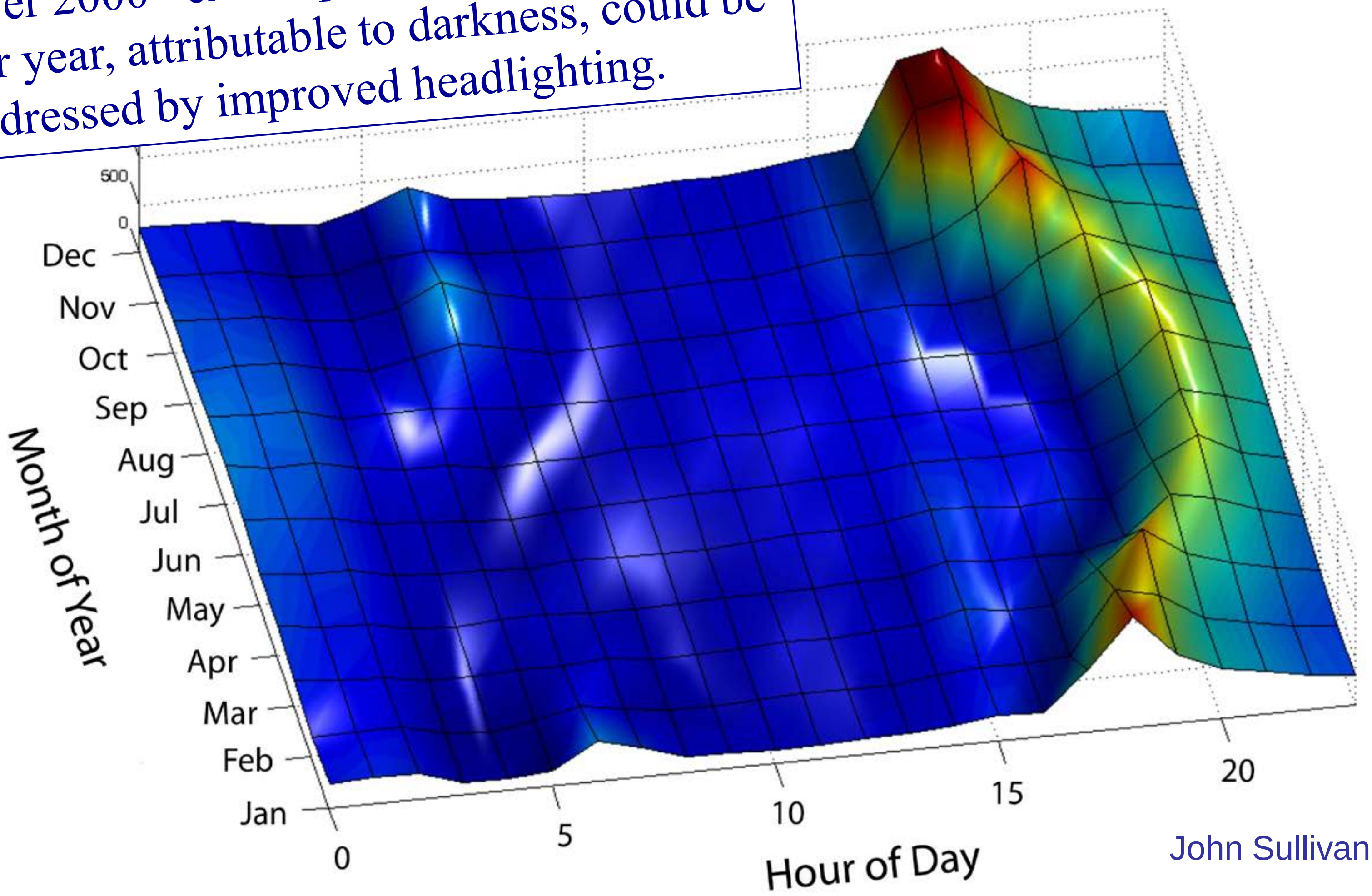
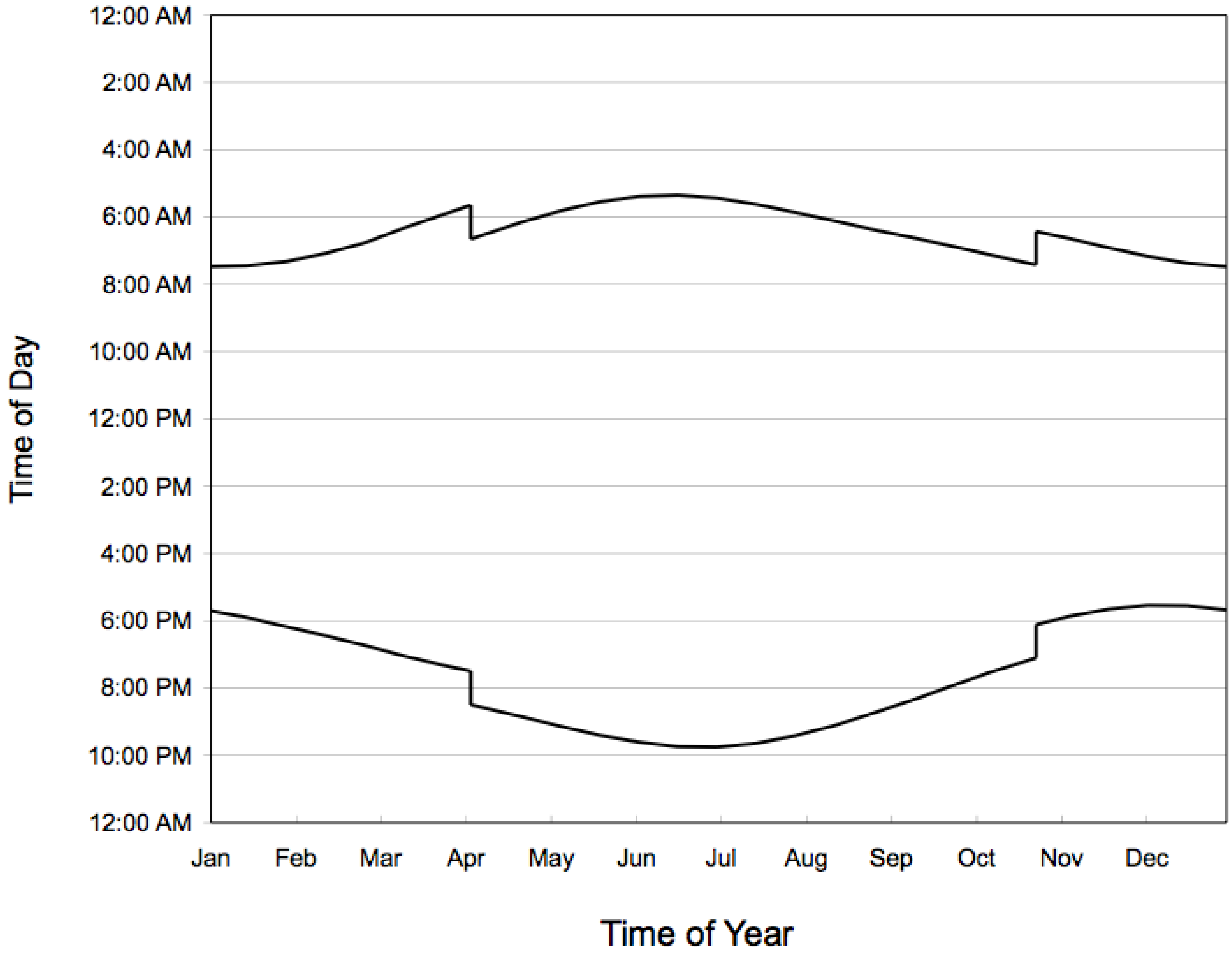
Pedestrian deaths
FARS, 1987-2003

Over 2000 “extra” pedestrian deaths per year, attributable to darkness, could be addressed by improved headlighting.



John Sullivan, UMTRI



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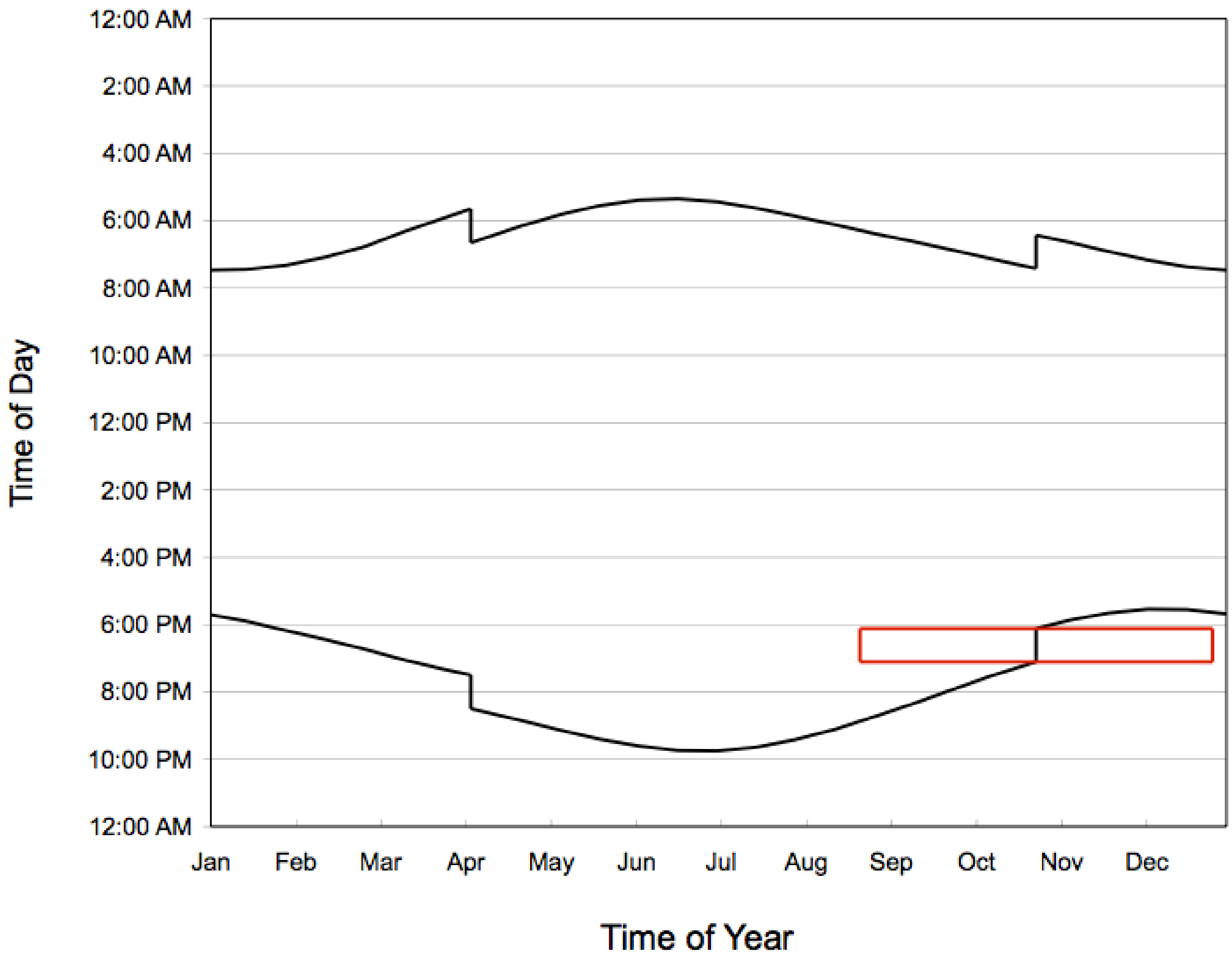

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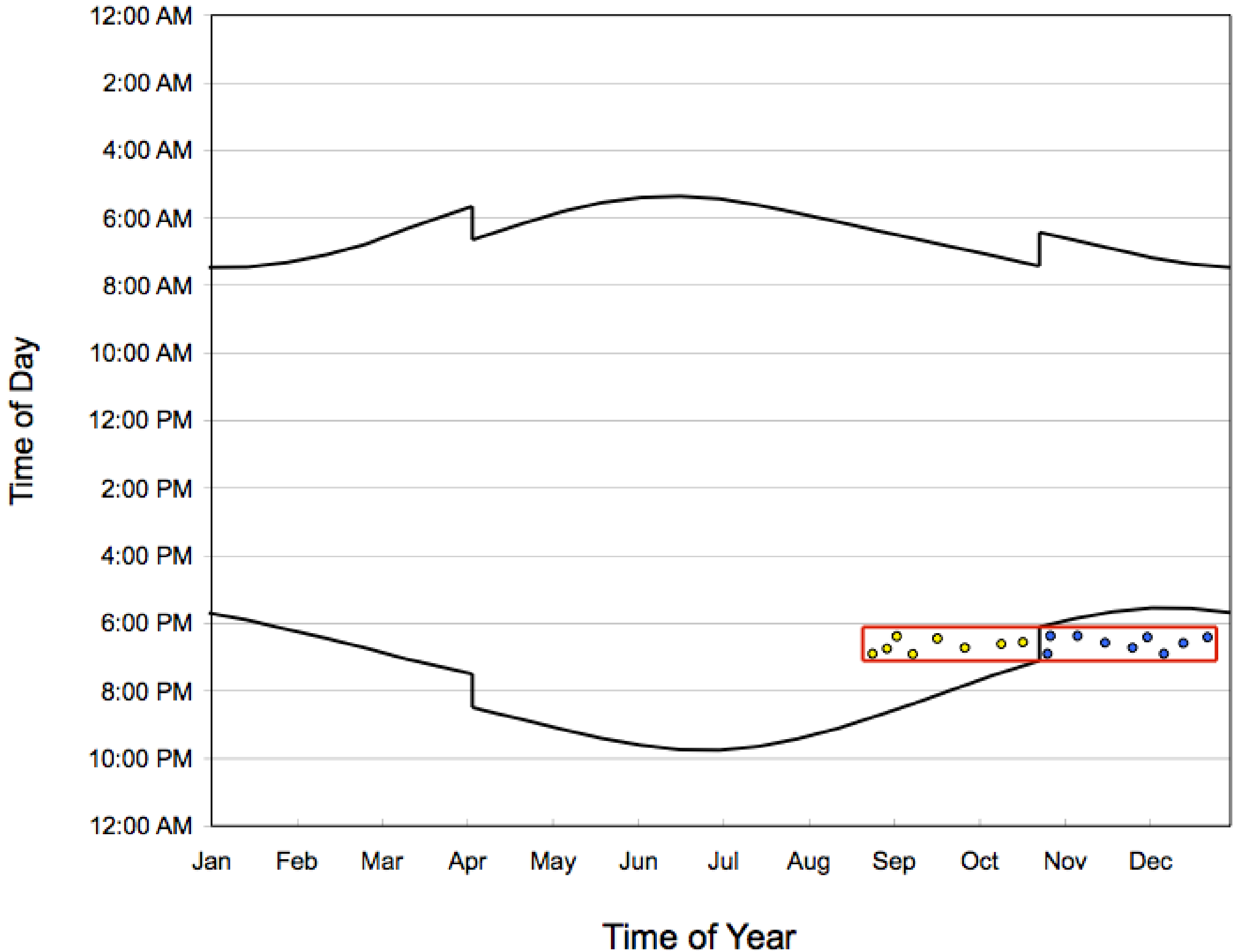
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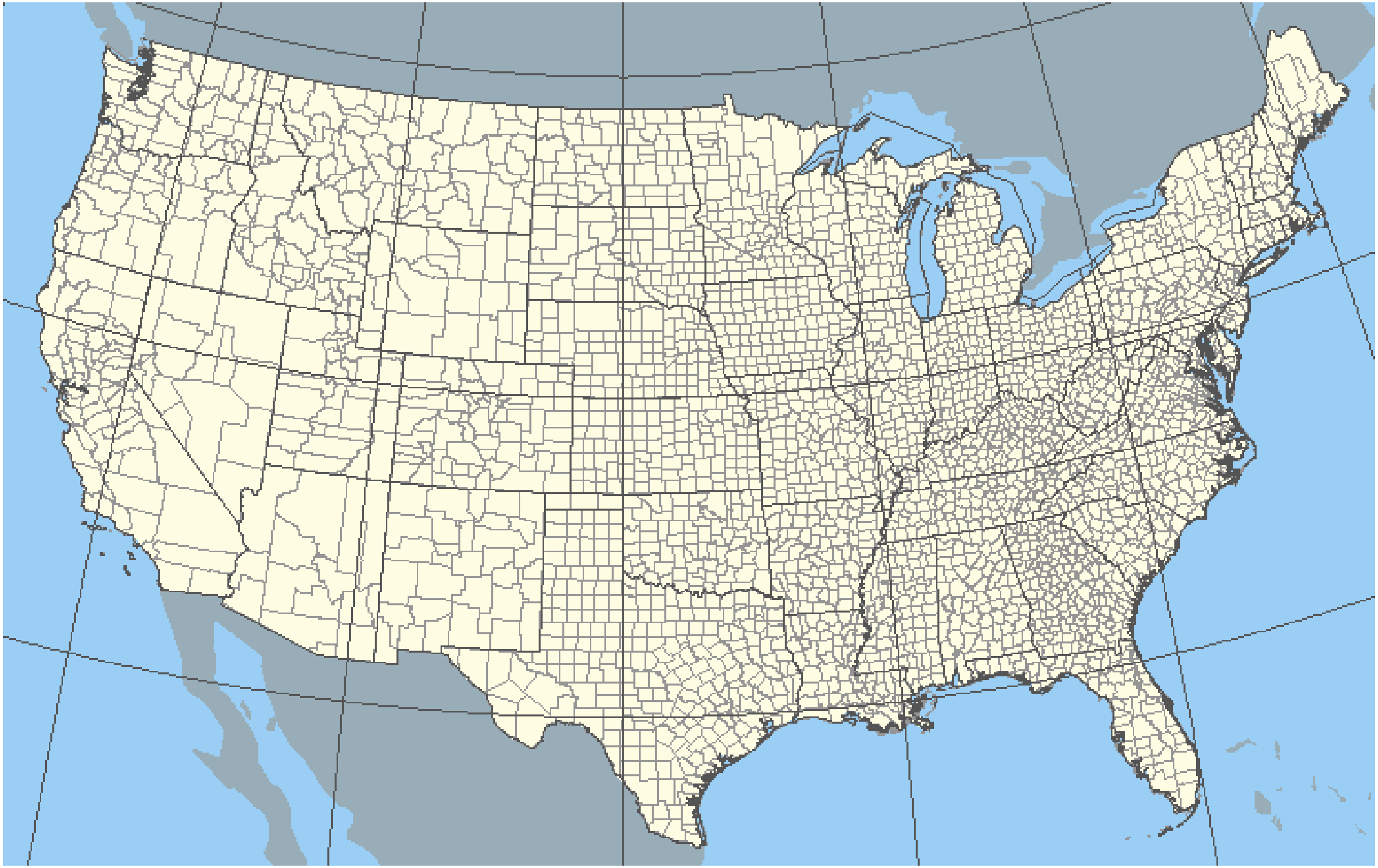
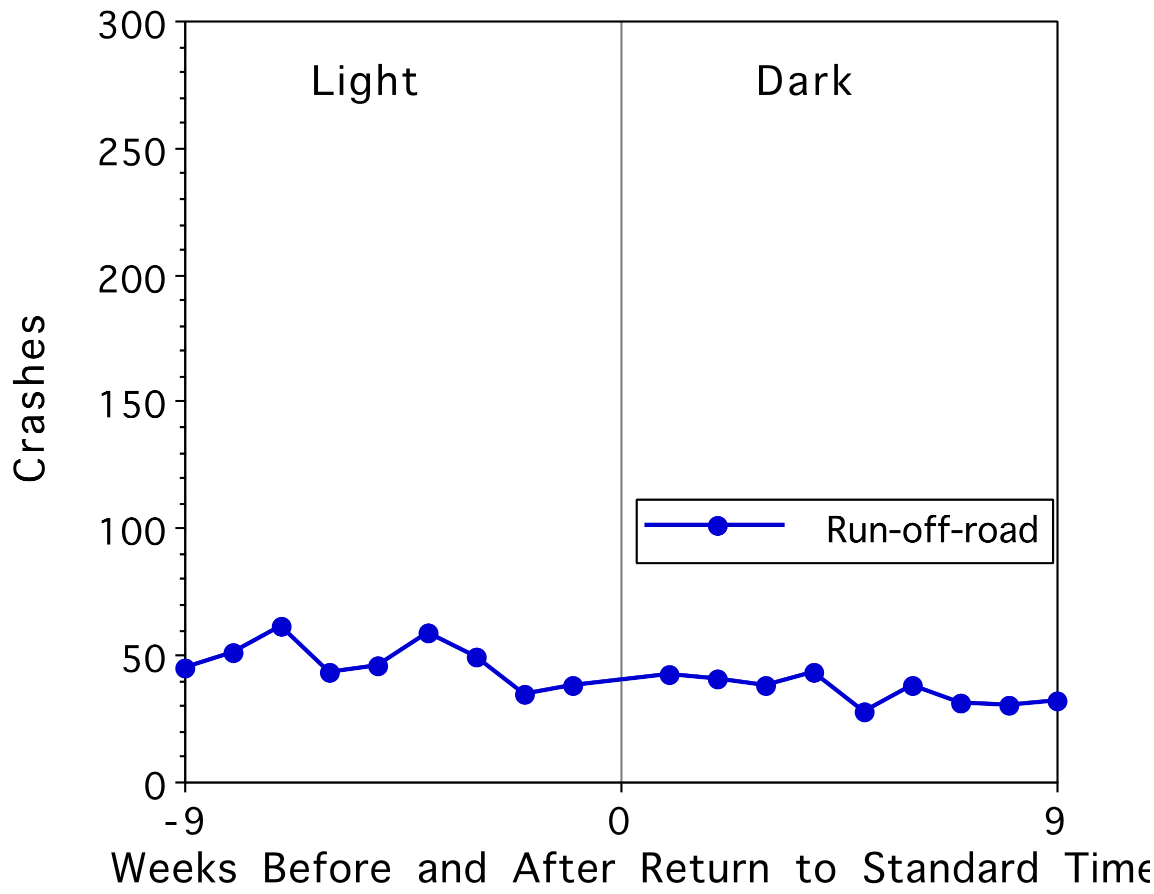
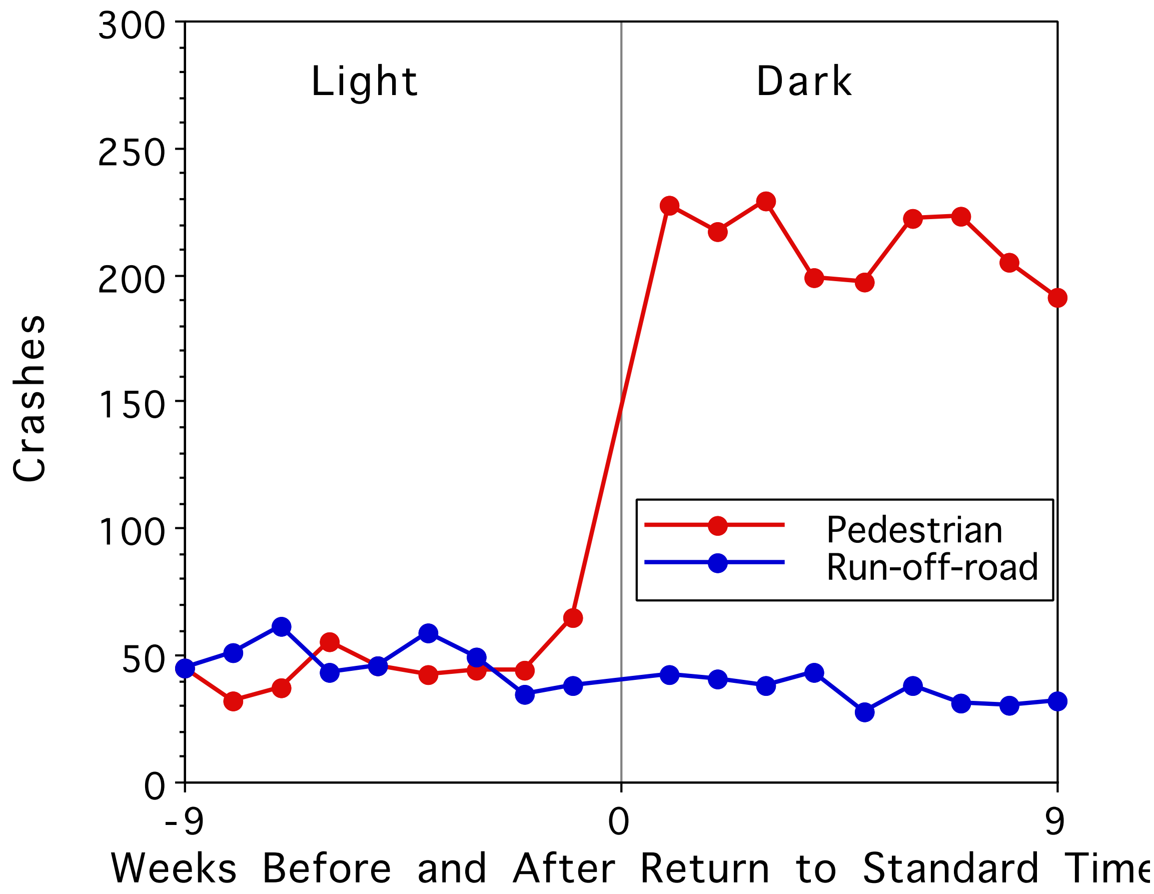


Crash counts around fall PM return to standard time



Crash counts around fall PM return to standard time (UMTRI-99-21)



Event	Dark	Light	Total	Dark/Light Ratio	% Crashes in Darkness
Motor Vehicle in Transport	1454	1091	2545	**1.33**	57.1%
Pedestrian	1147	277	1424	**4.14**	80.5%
Overturn	174	239	413	0.73	42.1%
Tree	168	170	338	0.99	49.7%
Pedalcycle	77	86	163	0.90	47.2%
Utility Pole	45	58	103	0.78	43.7%
Ditch	43	51	94	0.84	45.7%
Guardrail	46	44	90	1.05	51.1%
Motor Vehicle in Transport in Other Roadway	36	40	76	0.90	47.4%
Culvert	27	37	64	0.73	42.2%
Curb	25	34	59	0.74	42.4%
Embankment - Material Type Unknown	26	32	58	0.81	44.8%
Parked Motor Vehicle	38	18	56	**2.11**	67.9%
Other Fixed Object	30	25	55	1.20	54.5%
Railway Train	35	18	53	**1.94**	66.0%
Embankment – Earth	23	22	45	1.05	51.1%
Highway/Traffic Sign Post	19	22	41	0.86	46.3%
Fence	20	20	40	1.00	50.0%
Fell from Vehicle	14	20	34	0.70	41.2%
Other Post, Other Pole, or Other Support	13	18	31	0.72	41.9%
Concrete Traffic Barrier	16	14	30	1.14	53.3%
Animal	23	5	28	**4.60**	82.1%
Bridge Pier or Abutment	11	11	22	1.00	50.0%
Bridge Rail	9	11	20	0.82	45.0%
Wall	7	11	18	0.64	38.9%
Other Non-Collision	5	12	17	0.42	29.4%
Other Type Non-Motorist	8	7	15	1.14	53.3%
Embankment - Rock, Stone, or Concrete	6	7	13	0.86	46.2%
Other Object(not fixed)	5	6	11	0.83	45.5%
Boulder	5	4	9	1.25	55.6%
Building	3	4	7	0.75	42.9%
Bridge Parapet End	2	4	6	0.50	33.3%
Fire Hydrant	1	3	4	0.33	25.0%
Immersion	2	2	4	1.00	50.0%
Pavement Surface Irregularity (1993 only)	1	3	4	0.33	25.0%
Luminary/Light Support		3	3	-	-
Other Longitudinal Barrier Type		3	3	-	-
Shrubbery	1	2	3	-	-
Impact Attenuator/Crash Cushion	1	1	2	-	-
Thrown or Falling Object	2		2	-	-
Transport Device Used as Equipment (Since 1993)	2		2	-	-
Unknown		2	2	-	-
Injured in Vehicle		1	1	-	-
Grand Total	1454	1091	6008	1.46	59.4%

Dark/light ratios in DST data from UMTRI-2001-33

Significant effects of light by first harmful event, FARS 1987-1997 (UMTRI-2001-33)

Event	Dark	Light	D/L ratio
Motor vehicle in transport	1454	1091	1.33
Pedestrian	1147	277	4.14
Overturn	174	239	0.73
Parked motor vehicle	38	18	2.11
Railway train	35	18	1.94
Animal	23	5	4.60

A selected event without a significant dark/light effect

Event	Dark	Light	D/L ratio
Tree	168	170	0.99

Psychological consequences of the effects of darkness by crash type

- Darkness has very different effects by crash type. For fatal crashes, darkness increases risk by factors of:

Pedestrian	4.14
Two-vehicle	1.33
Road departure	0.99

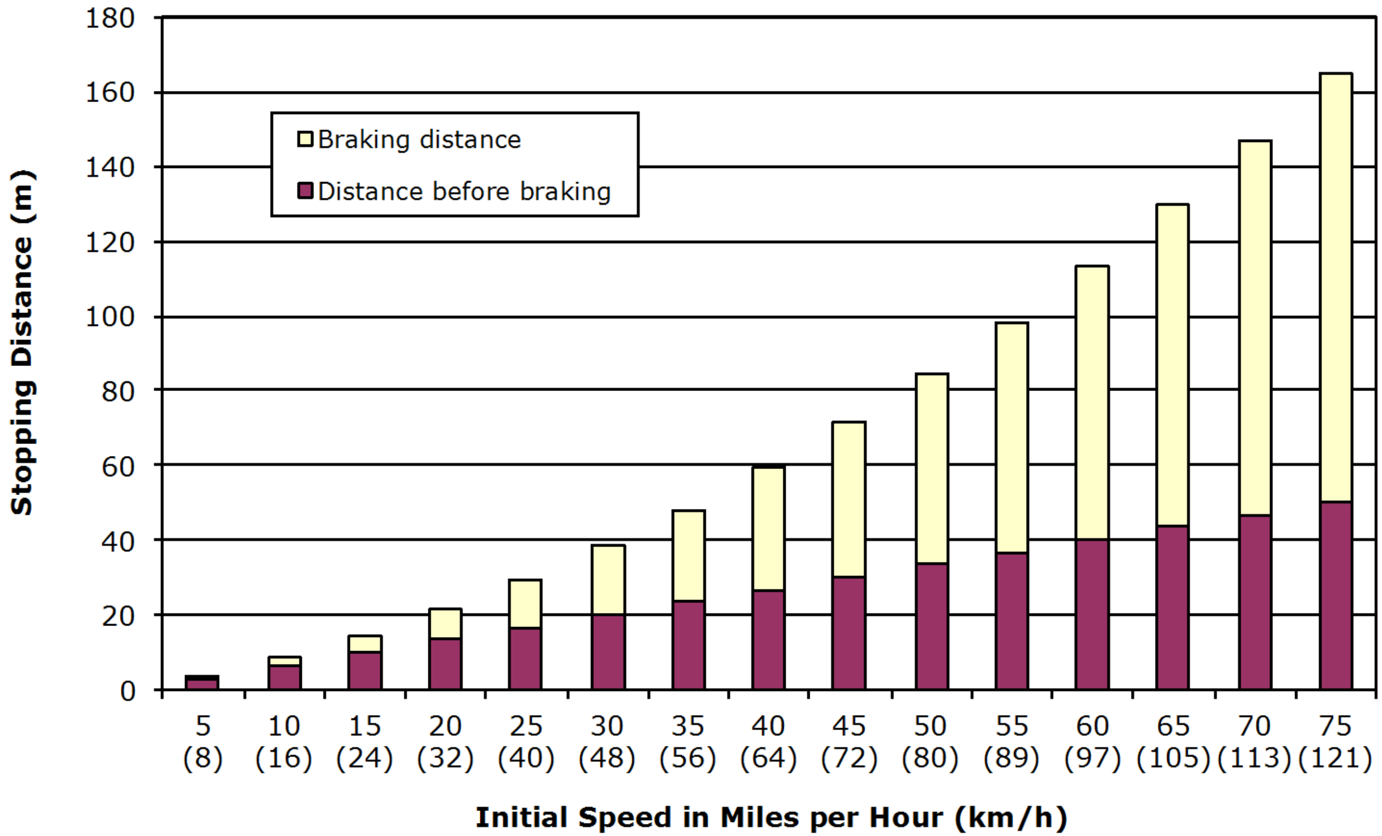
- Staying on the road is a task that drivers do continuously, but encounters with pedestrians are rare.
- Drivers' impressions of headlamp effectiveness are probably dominated by the fact that headlamps are adequate for seeing the road, and they may not realize how poorly headlamps work for pedestrian visibility.
- Leibowitz and Owens (1977) called this "selective visual degradation"

The selective degradation hypothesis: ambient vision and focal vision

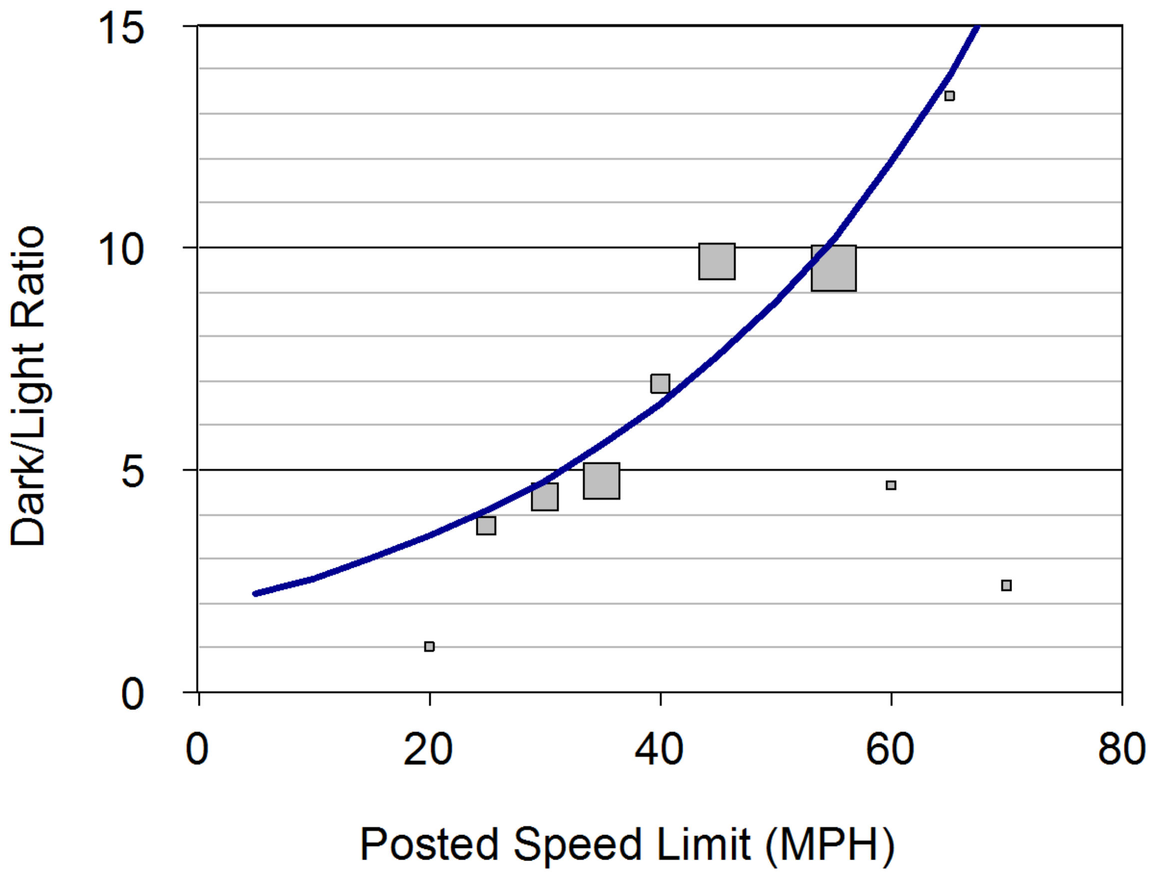
Since the major tasks of driving [dynamic spatial orientation, staying on the road] are relatively unimpaired by reduced illumination, the driver does not anticipate and is not prepared to deal with stimuli for which the focal system suffers a selective deficit [such as pedestrians]. In effect, the driver is unjustifiably reassured by the high performance level of the dynamic spatial orientation system and is unaware of a loss in focal visual abilities. Since the visual deficit is only partial and of consequence only for low-probability stimuli, the driver is unaware of the loss of function and does not take the necessary precautions.

(Leibowitz & Owens, 1977)

Stopping distance (and therefore required seeing distance) by speed



Dark/Light pedestrian risk by speed



Sullivan & Flannagan, 2007

Potential crash reductions by various lighting innovations (US, annual)

	Potential reductions		
	Fatal crashes	Fatal and injury crashes	Ratio All / fatal
Motorway lighting	768	1344	1.75
Curve lighting	128	280	2.19
Cornering lighting	24	1059	44.13

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An opportunity

Sullivan & Flannagan, 2007

The Importance of Glare in Headlighting

- It is what drivers notice most
- Is glare bad?
  - How bad?
  - In what way?
- Does glare cause crashes?
  - Glare is seldom cited as a cause of crashes (< 1%)
  - What can be inferred from crash data?

Coding of “trafficway” in crash data (U.S. FARS and GES)

0 Non-trafficway area
1 Two-way, not divided
2 Two-way, divided, unprotected (painted > 1.2 m) median
3 Two-way, divided, positive median barrier
4 One-way trafficway
5 Two-way, not divided, with a continuous left-turn lane
6 Entrance/exit ramp

8 Not reported
9 Unknown

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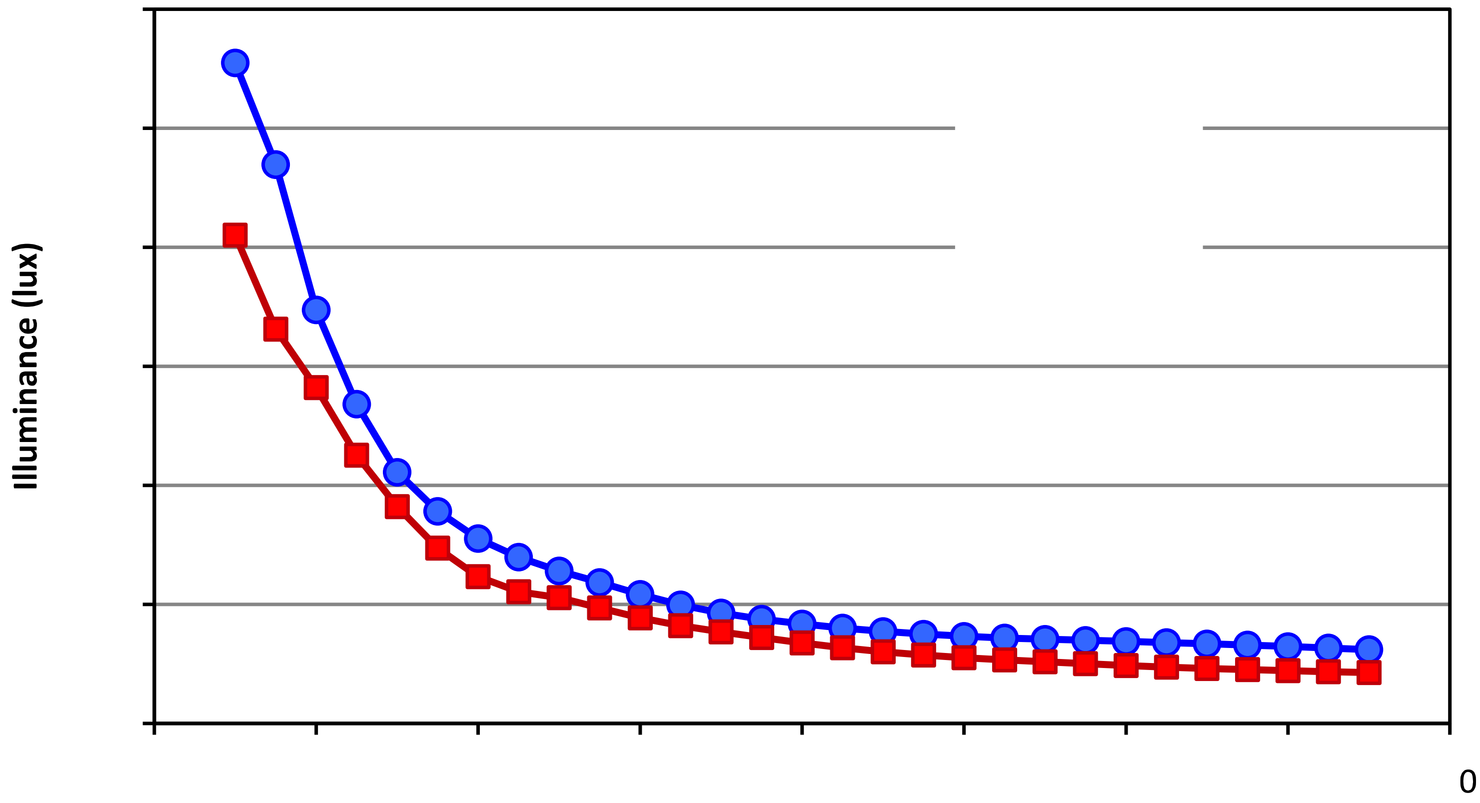
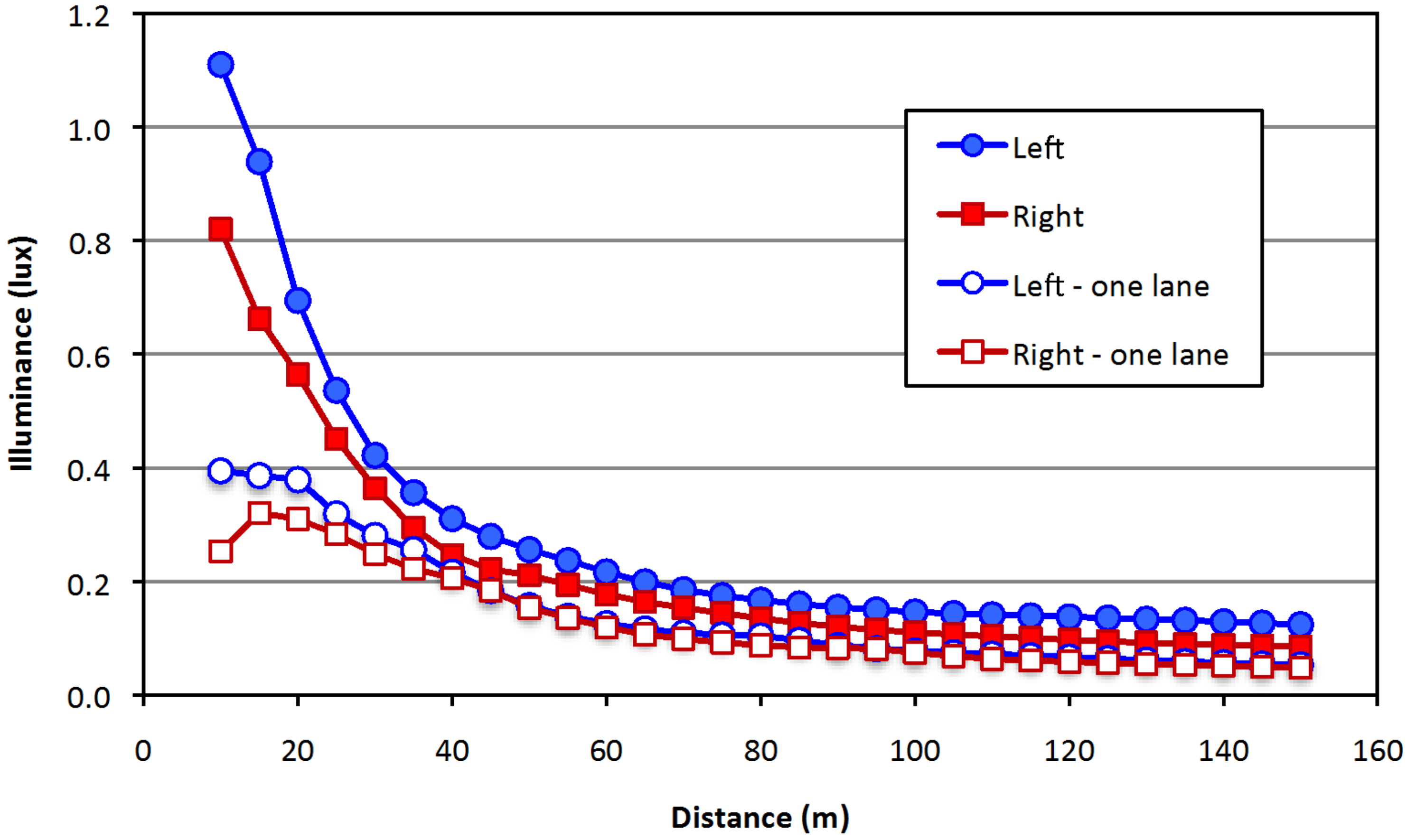
How does lane separation affect photometry (and glare)?

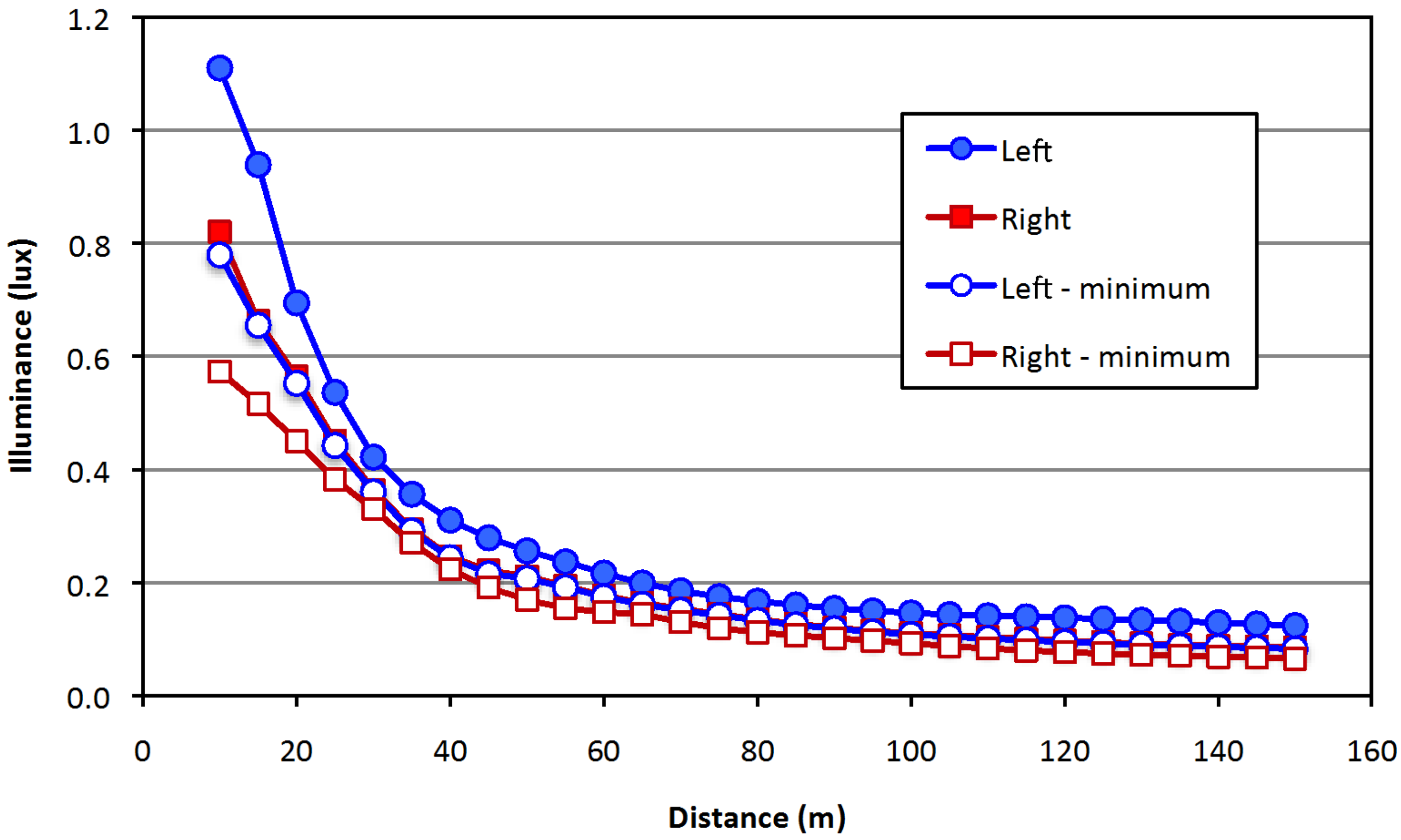
Glare from lamps of approaching car, median U.S. beam pattern



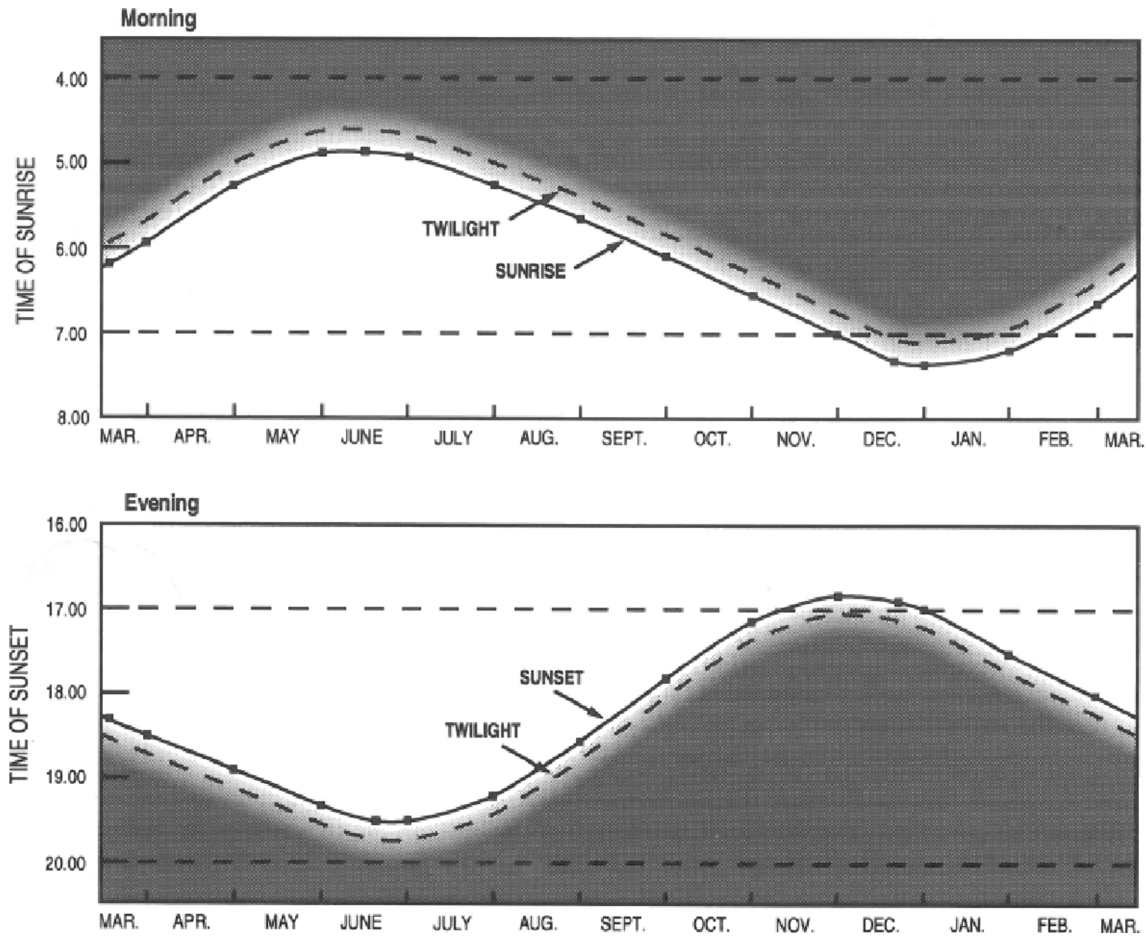
Glare from lamps of approaching car, lateral separation by one lane



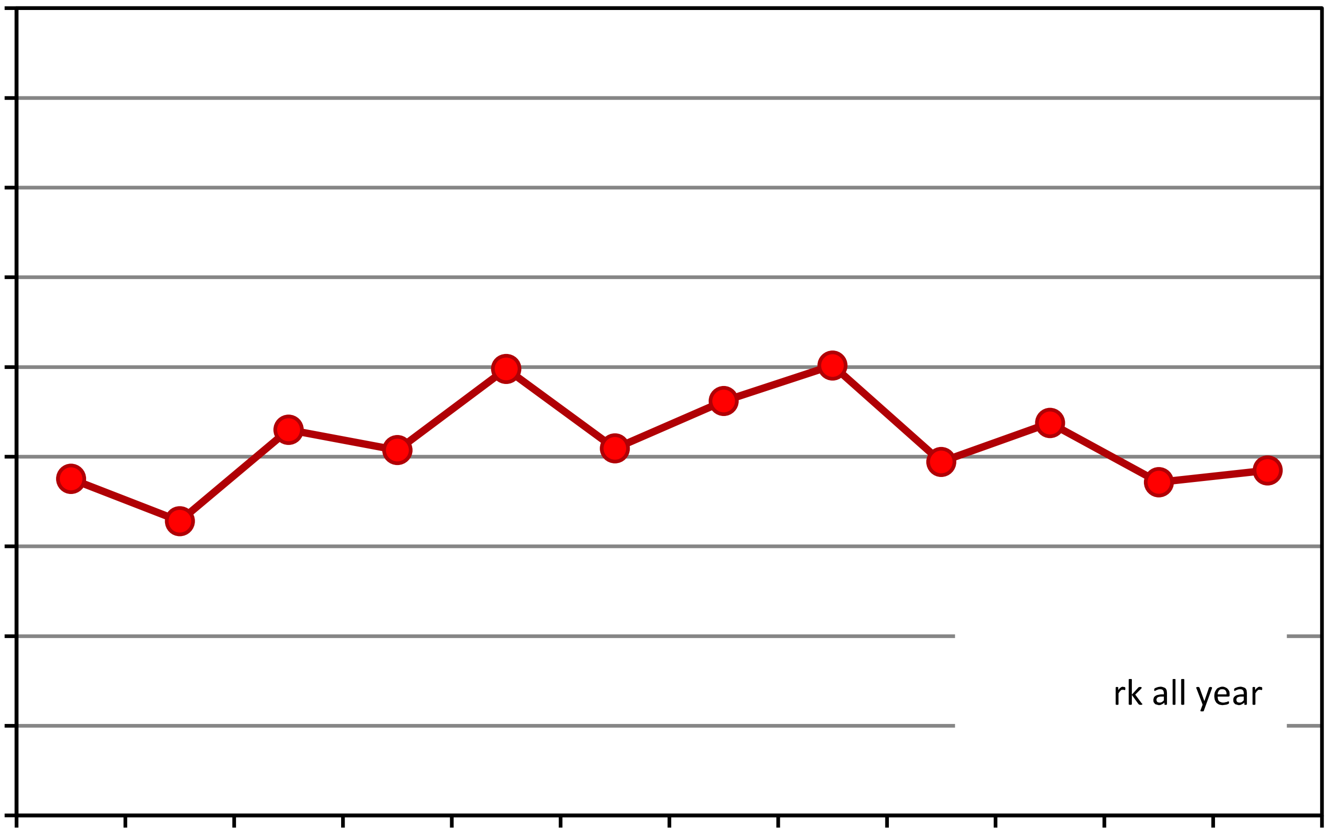
Glare from lamps of approaching car, minimum lateral separation (1.2 m)



“Twilight Zones” average for continental U.S. (4:00-7:00 and 17:00-20:00)

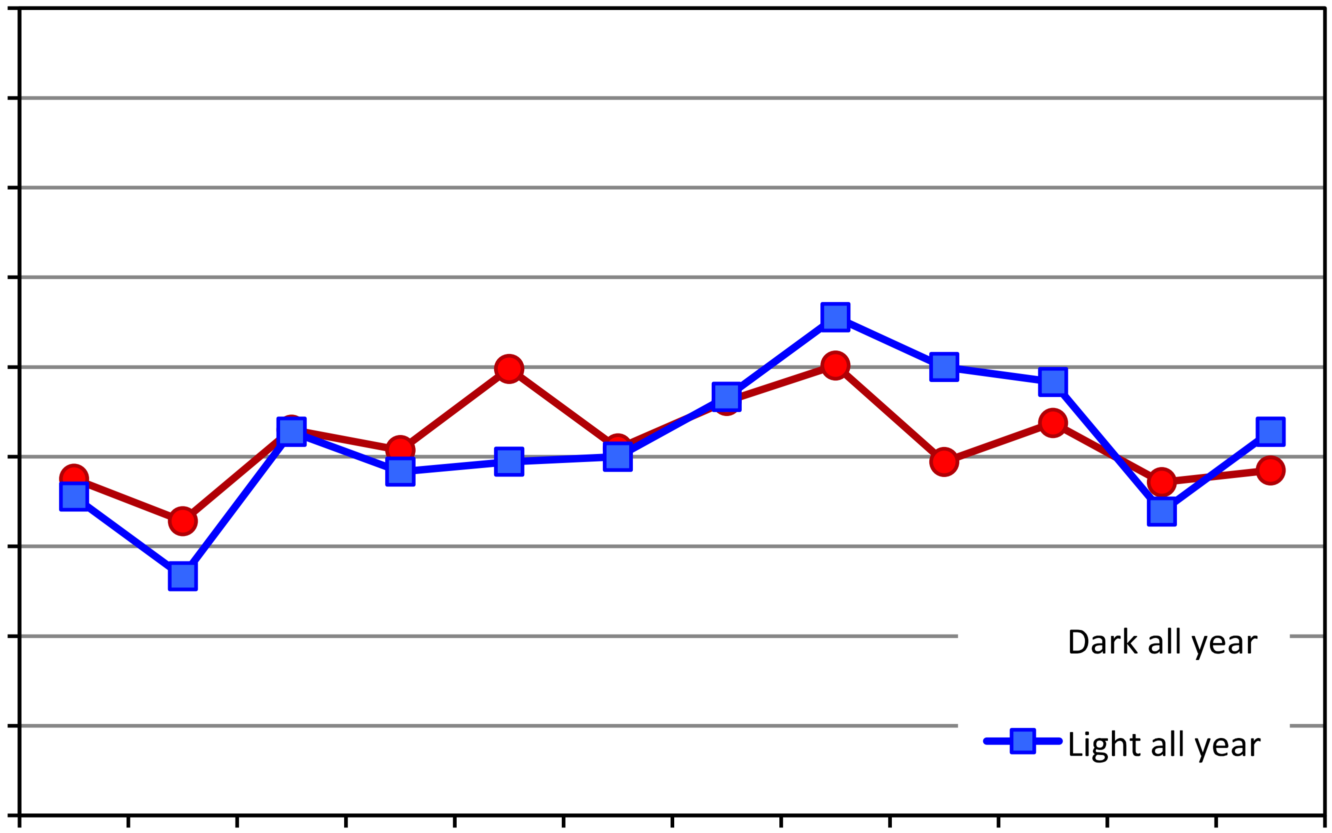


Pedestrian fatal crashes by time of year – times of day that are dark all year



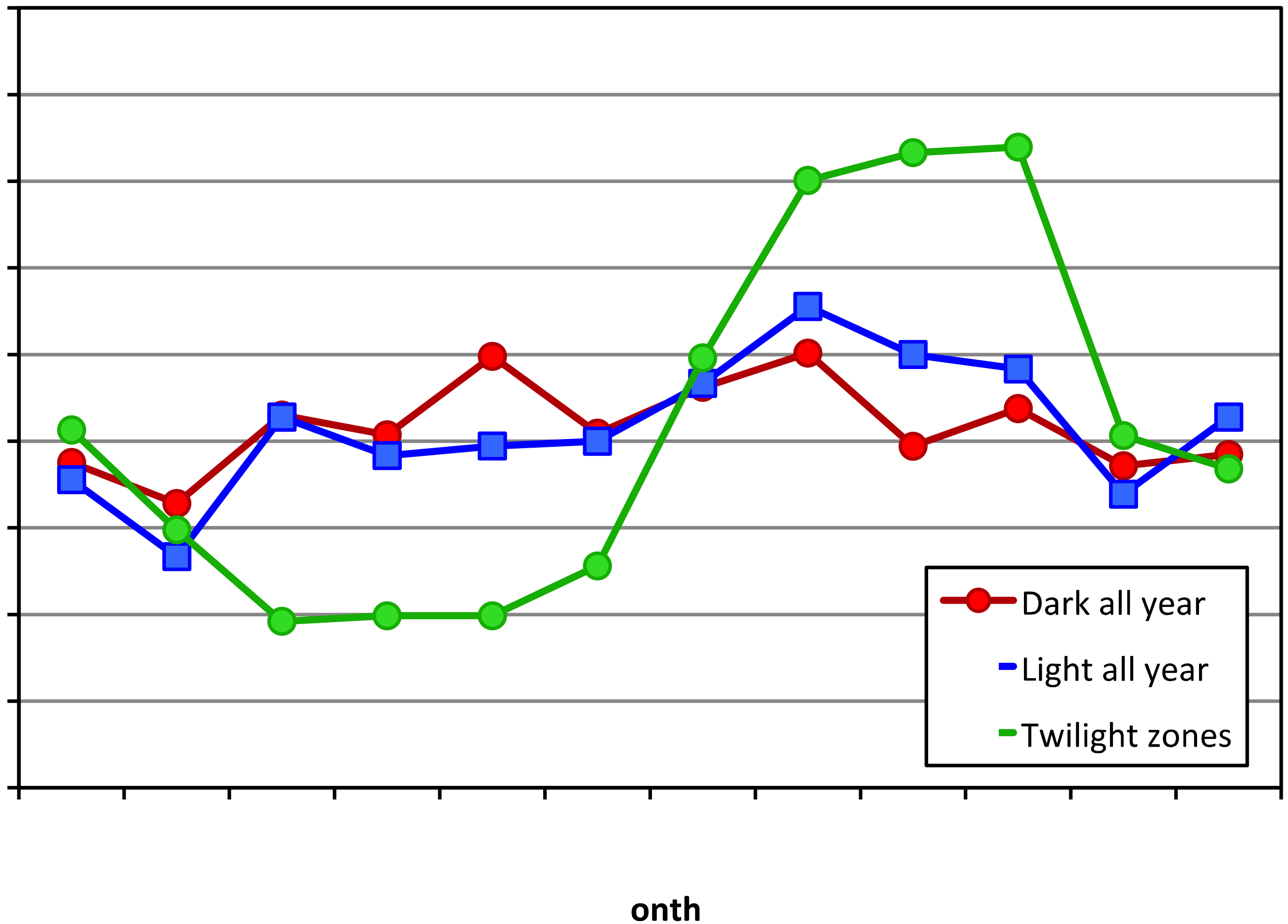
U.S. FARS, 2011

Pedestrian fatal crashes by time of year – times of day that are dark or light all year



U.S. FARS, 2011

Pedestrian fatal crashes by time of year – times of day that are dark, light, or vary



U.S. FARS, 2011

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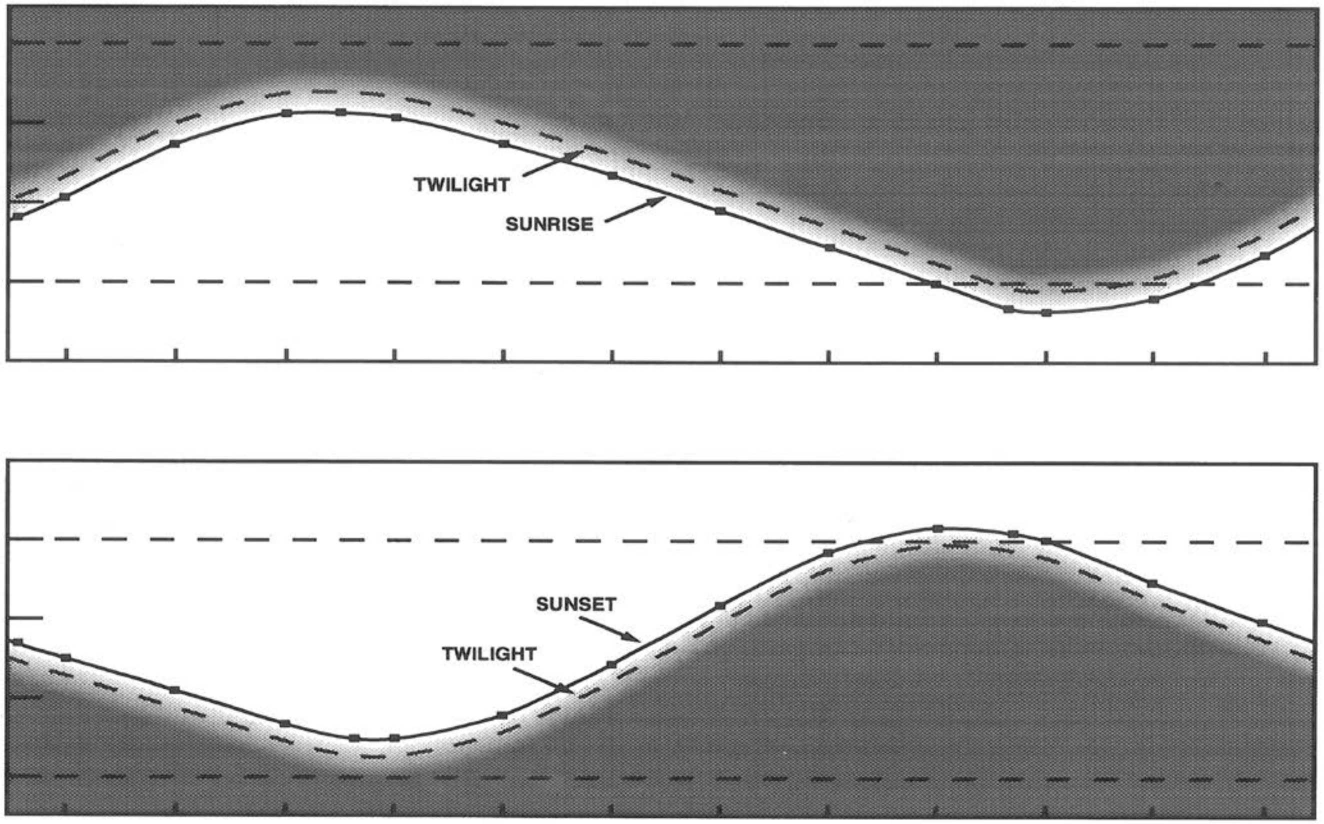

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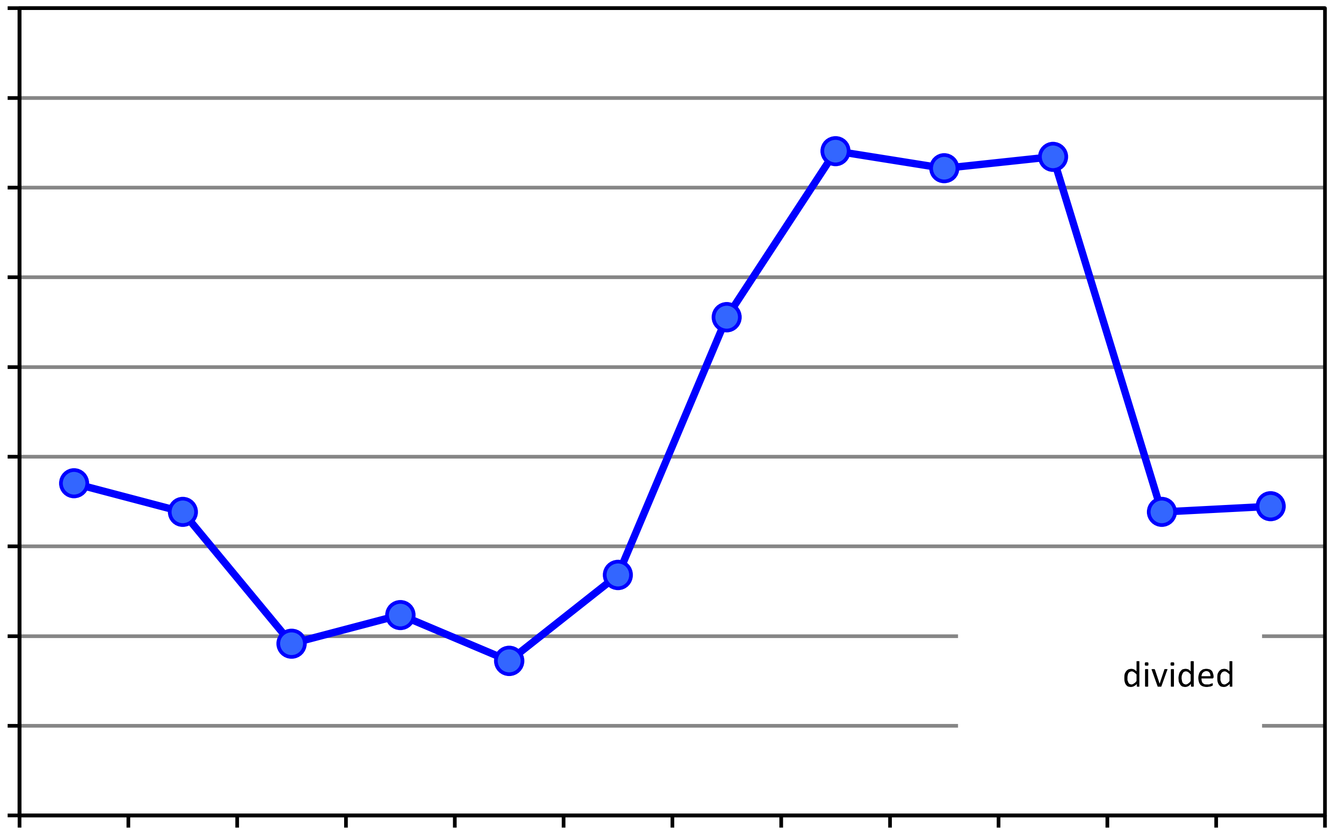
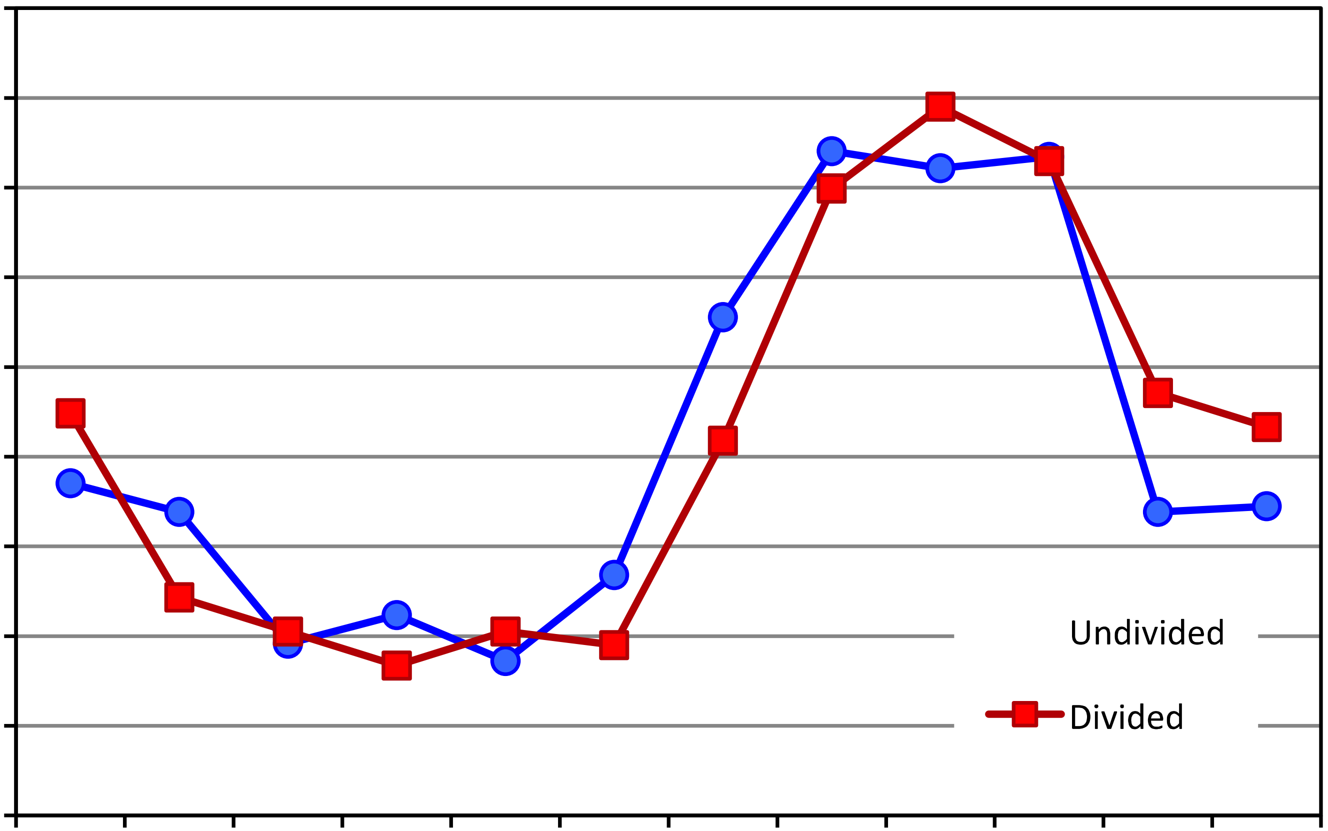
U.S. FARS, 2011

Twilight Zone pedestrian fatal crashes by time of year – undivided roads



U.S. FARS, 2011

Twilight Zone pedestrian fatal crashes by time of year – divided & undivided roads



U.S. FARS, 2011

If drivers hate glare so much, why is it hard to measure effects of glare on safety?

- Two forms of glare:
  - Discomfort
  - Disability

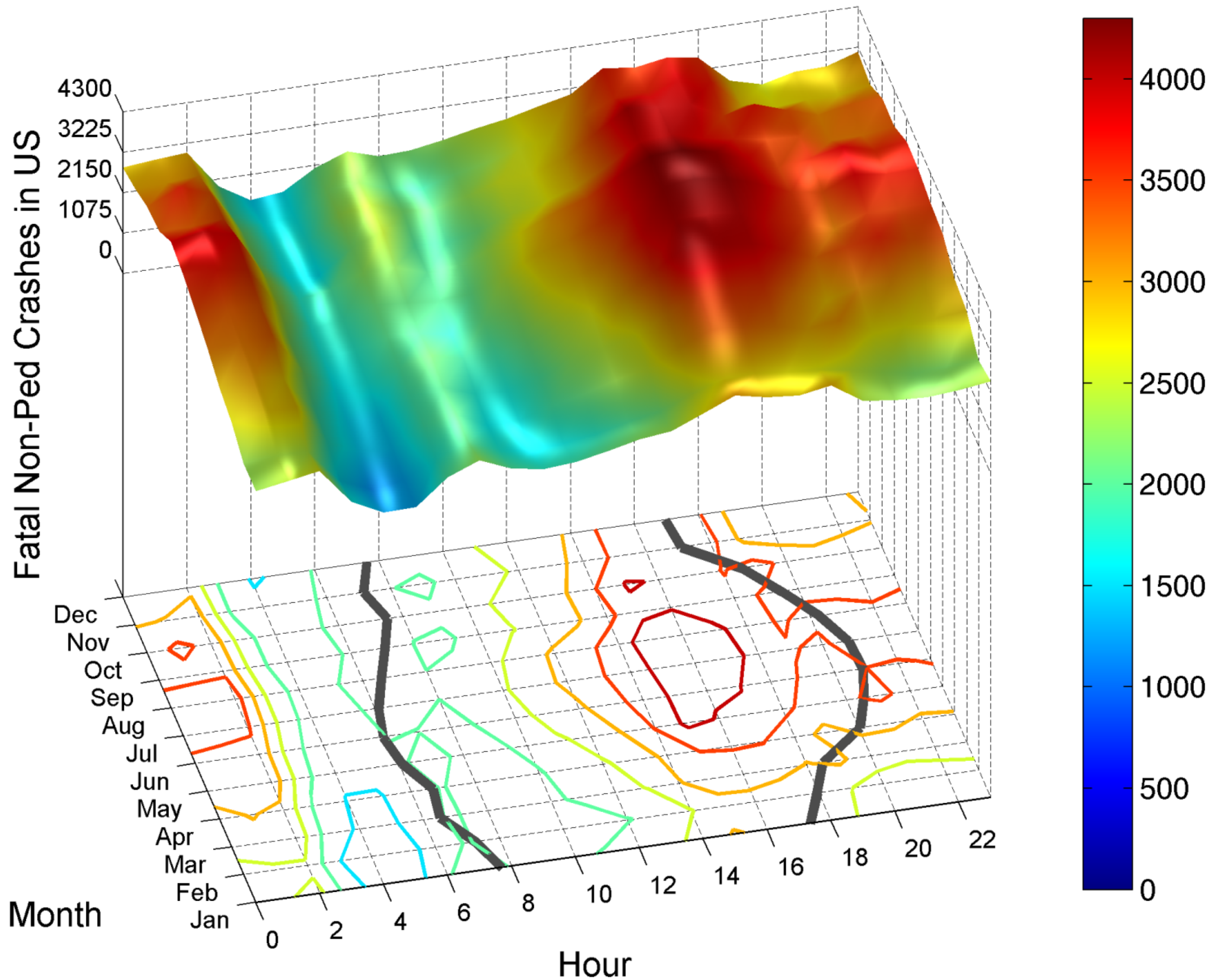
	Disability glare	Discomfort glare
Mechanism	Simple, scattering of light in the eye	Complex, involving memory, perception, and emotion
Affected by	Illumination of the eye	Illumination of the eye, color, source size, duration, etc.
Measured by	Objective visual detection ability	Subjective rating

Conclusions

- People overdrive their headlamps. Additional visibility distance, especially at higher speeds, would be beneficial.
- Darkness has very different effects by crash type, greatly increasing the risk for pedestrian crashes, but having little or no effect on road departure crashes.
- Selective effects of darkness by crash type may cause drivers to overestimate the overall effectiveness of headlighting.
- Pedestrian crashes should be used as the main measure for possible benefits of future lamps, or possible differences among current lamps in rating systems.
- Although glare is a severe comfort problem, this approach has not provided evidence for safety effects.

Thank you

Vehicle occupant deaths FARS, 1987-2003



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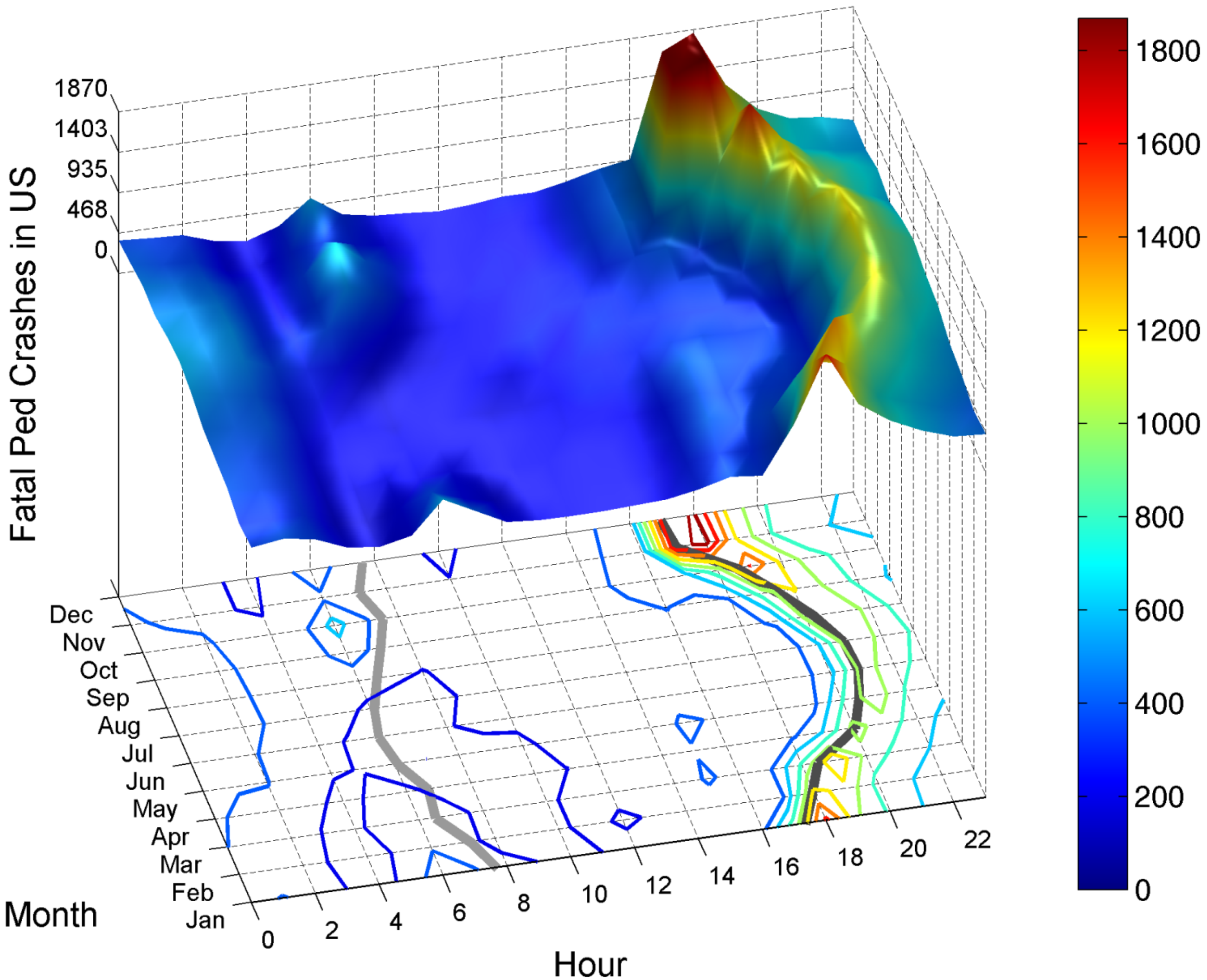
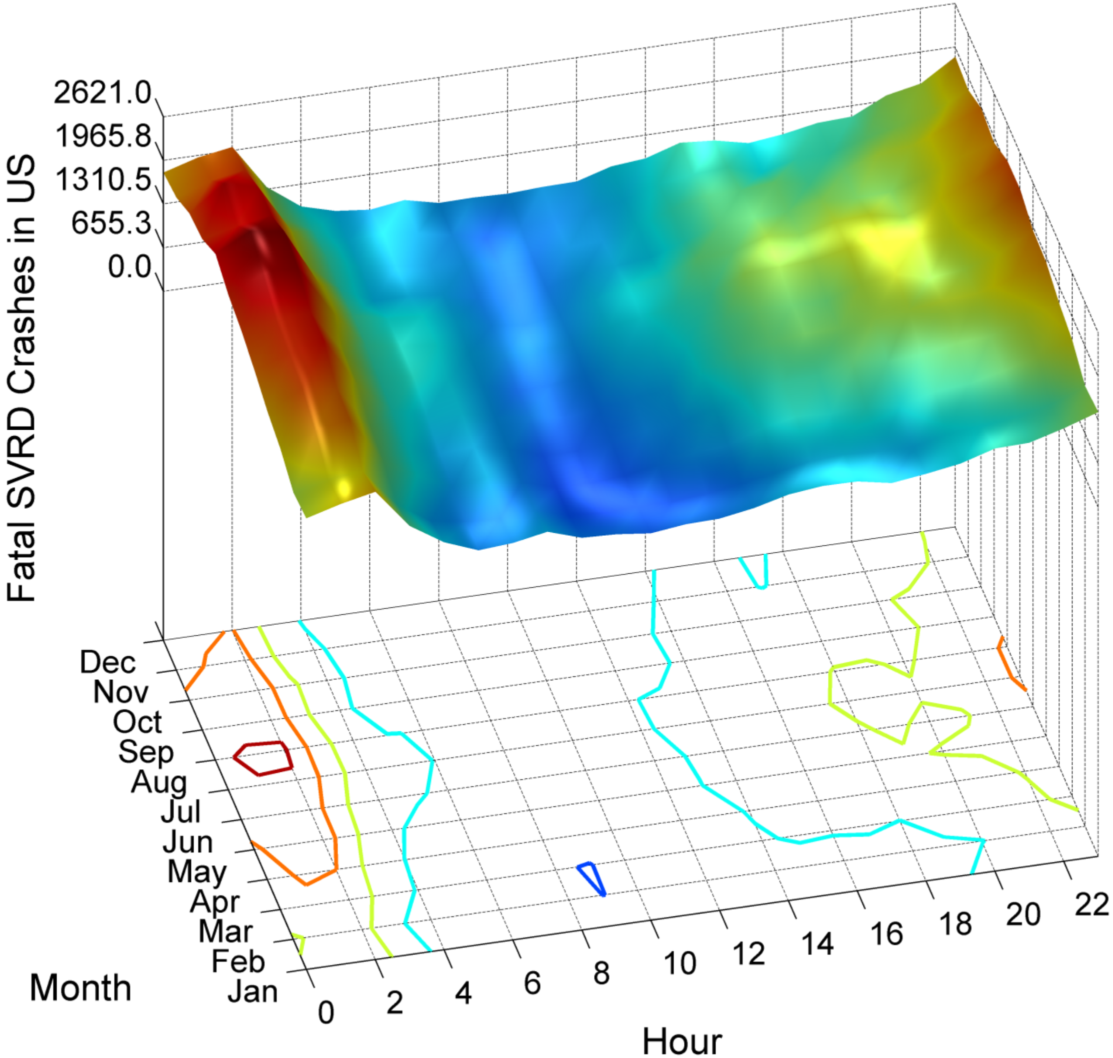


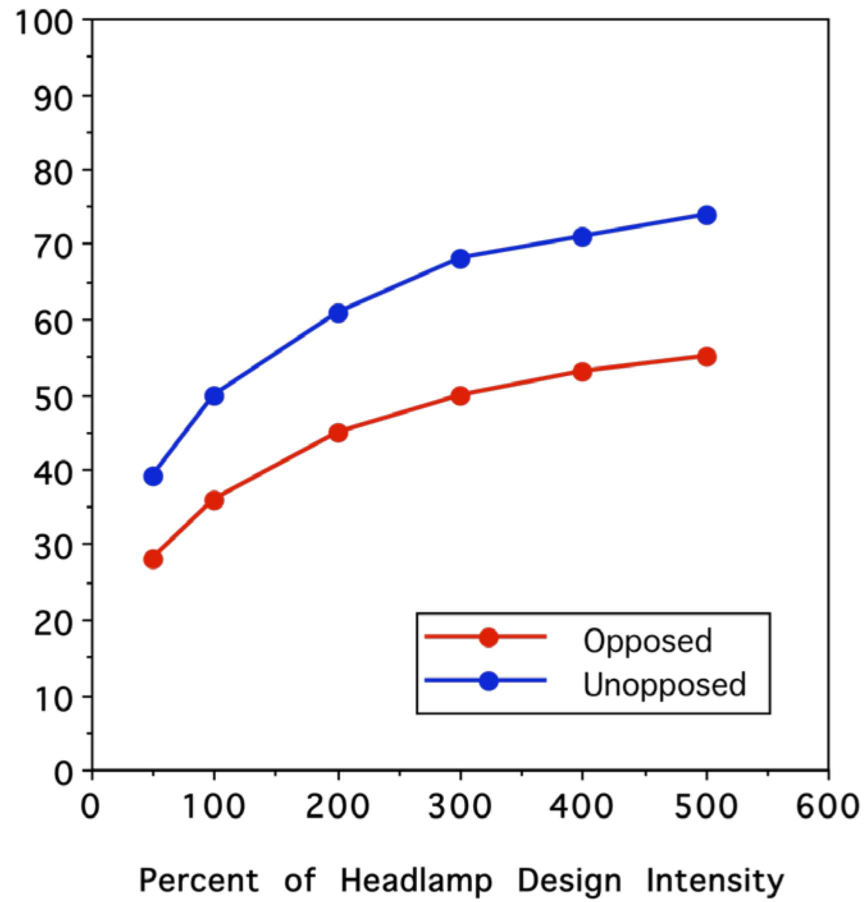
Road departure deaths FARS, 1987-2003



Two effects of glare light

	Objective (disability)	Subjective (discomfort)
Measurement	Decrease in seeing ability	Numerical rating
Mechanism	Scattering in the eye (simple, understood)	The brain??? (complex, not well understood)
Affected by	- lux at the eye - Angle from fixation to glare source	- lux at the eye - Angle from fixation to glare source - source size - color - task demands - etc, etc, etc
Effect on safety	Direct, reduces visibility	Possible indirect?

Percent of encounters with pedestrian visible, simulated (Bhise et al., 1977)



Dark/Light pedestrian risk by road alignment (straight, curved)