Instrumental Light Measurement Techniques for Biological studies

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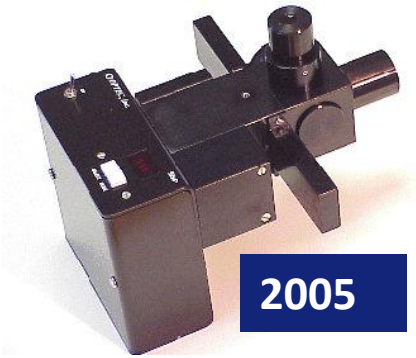
Objective

1992

1999+

2000


2004


2005


2004 - 2010


2010 - 2015

Sky Quality Camera

2015

Assess nine different commercial instruments/techniques for measuring light against a range of criteria pertinent to field biology

Presentation Outline

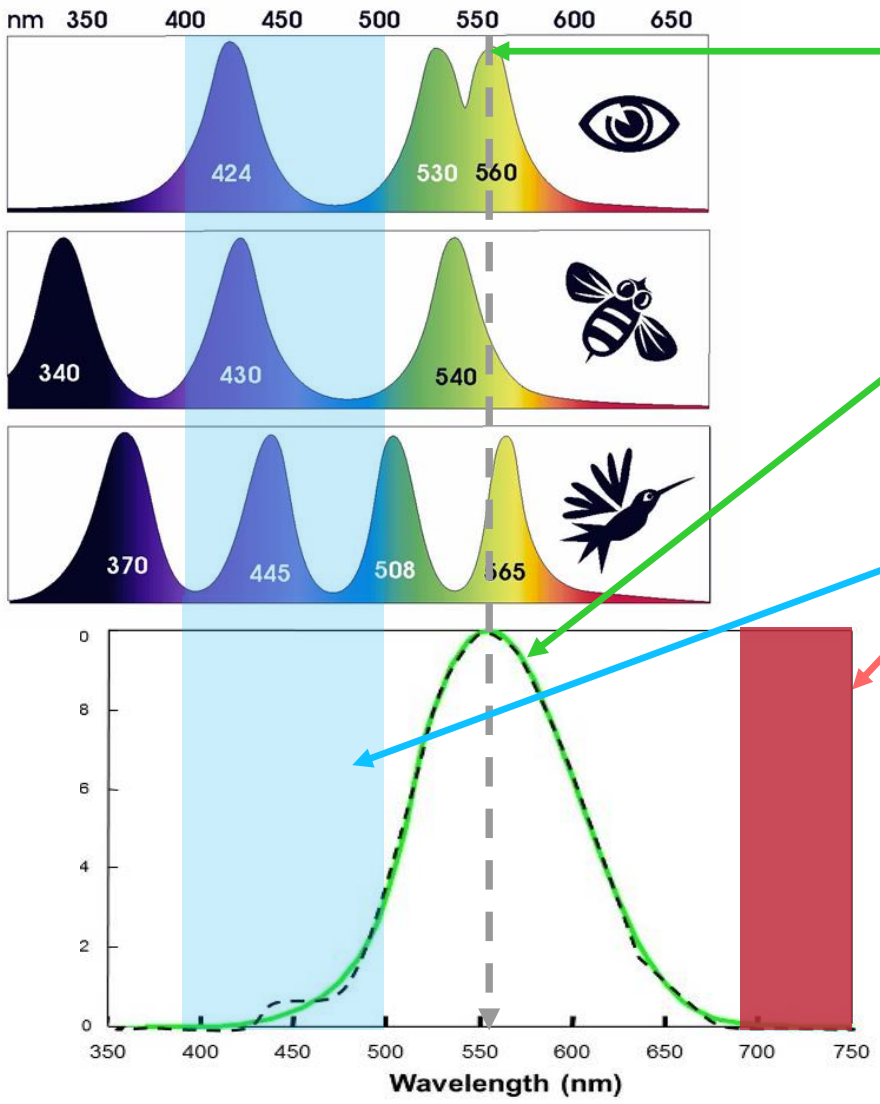
Outline:

- Briefly define the 7 criteria used to assess each instrument
- Technique assessment
  - Satellite photography
  - Aerial photography
  - SQM
  - Luxmeter
  - Spectroradiometer
  - Luminance meter
  - Stellar photometer
  - CCD All Sky Camera
  - CCD digital camera and fish eye lens

Assessment Criteria

- **Detect light equally across the entire spectrum**
- Detect very low light levels, e.g. sky glow
- Resolve individual point sources of light
- Instrument must be ruggardized and field ready
- Detect and quantify light on the horizon as well as overhead
- Quantify light precisely and accurately
- Cost effective

Spectral detection range



- Human vision peak most sensitive to green and yellow light
- Commercial light monitoring instruments calibrated to the sensitivity of human eye (CIE curve)
- HOWEVER Visibility into the blue violet UV range is common in insects, birds, fish and marine turtles. Many reptiles hunt in the IR
- Commercial instruments have little or no sensitivity in the biologically active 400 – 500 nm or 700+ nm range
- The sensitivity of the ideal instrument for biological studies will be equally weighted across the entire spectrum from 300nm to 700nm

Assessment Criteria

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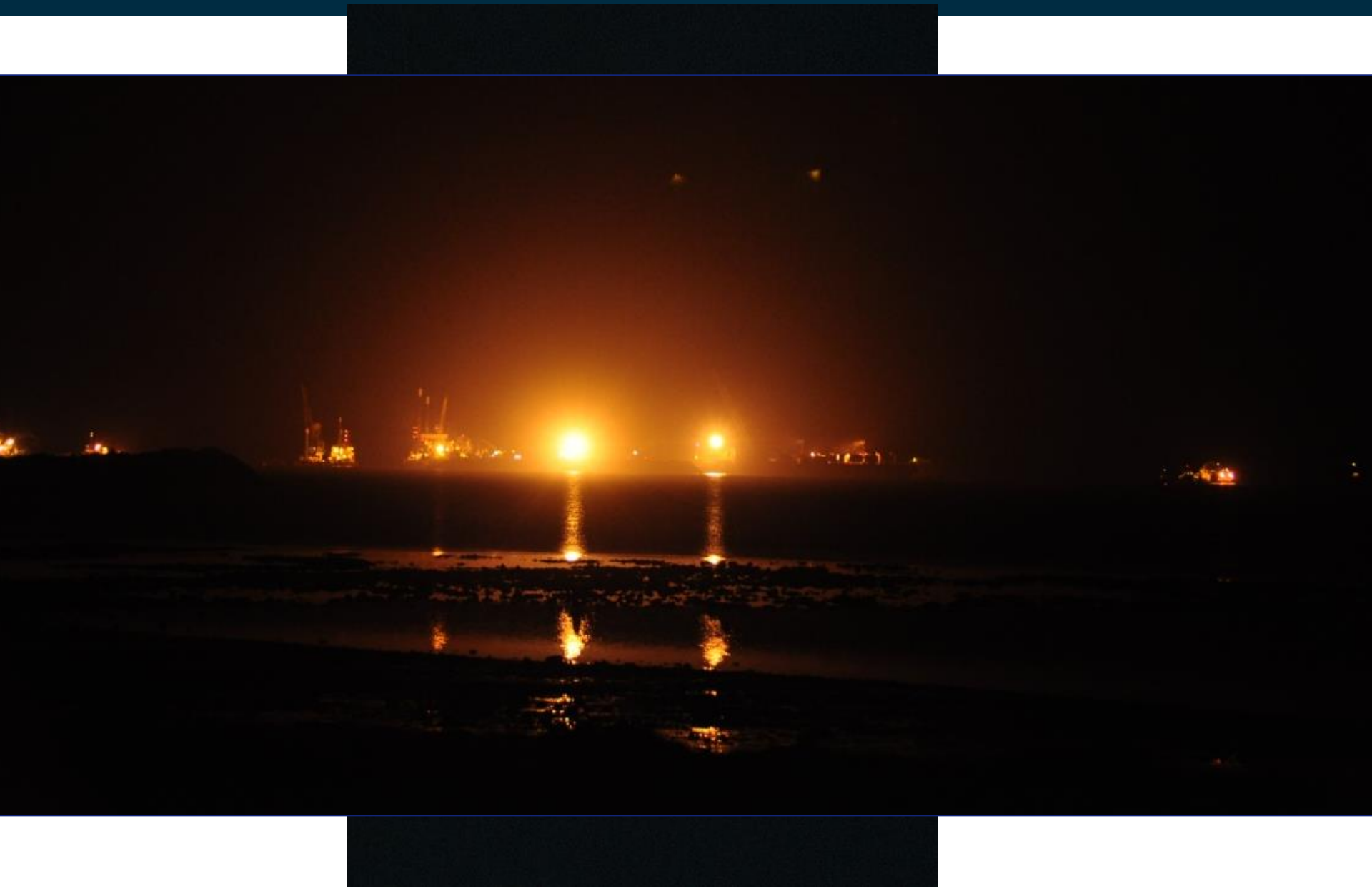
- Detect very low light levels, e.g. sky glow
- Resolve individual point sources of light
- Instrument must be ruggardized and field ready
- Detect and quantify light on the horizon as well as overhead
- Quantify light precisely and accurately
- Cost effective

Detect and quantify very low light levels

Assessment Criteria

- Detect light equally across the entire spectrum
- Detect very low light levels, e.g. sky glow
- Resolve individual point sources or grouped light
- Instrument must be ruggardized and field ready
- Detect and quantify light on the horizon as well as overhead
- Quantify light precisely and accurately
- Cost effective

Resolve individual light sources



Assessment Criteria

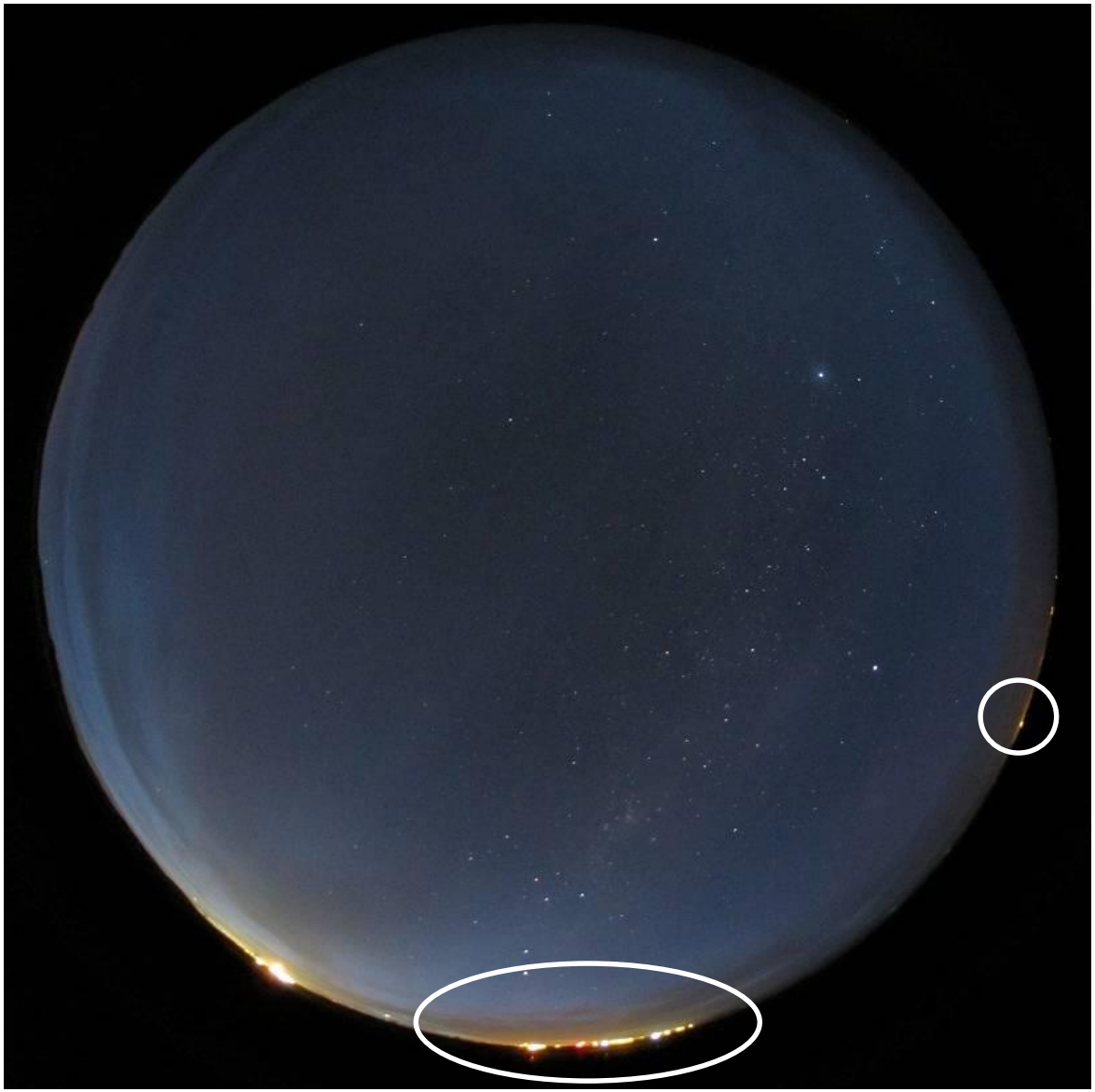
- Detect light equally across the entire spectrum
- Detect very low light levels, e.g. sky glow
- Resolve individual point sources of light
- Instrument must be ruggardized and field ready
- Detect and quantify light on the horizon as well as overhead
- Quantify light precisely and accurately
- Cost effective

Rugged and field ready

Assessment Criteria

- Detect light equally across the entire spectrum
- Detect very low light levels, e.g. sky glow
- Resolve individual point sources of light
- Instrument must be ruggardized and field ready
- Detect and quantify light on the horizon and over large distances
- Quantify light precisely and accurately
- Cost effective

Detect and quantify horizon light



Assessment Criteria

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- Quantify light precisely and accurately
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Quantify light precisely and accurately

Growing expectation from environmental regulators for environmental practitioners to;

- Precisely and accurately quantify ALAN
- Monitor changes in ALAN
  - over time,
  - over different geographical scales, and
  - under various atmospheric condition
- Apply statistical bounds around ALAN data

Assessment Criteria

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- Detect very low light levels, e.g. sky glow
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- Quantify light precisely and accurately
- Cost effective

Cost effective

- We monitor multiple locations in one night, requires multiple instruments (+ spares)
- Data collection limited by logistics, site operations and remote locations
- Field time limited by client budgets

Assessment

- Since 1991 we have tested a range of different instrumental techniques to quantify **biologically meaningful** light.
- I will provide a brief assessment of commonly used techniques for measuring ALAN and assess them against my field biology criteria

Satellite photography

Benefits:

- Useful for large scale studies
- Great for monitoring temporal changes

Limitations:

- Doesn't provide a ground based view of the horizon and sky
- Cant quantify that light that is visible from the ground
- Cannot resolve small point sources of light

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Measure light on the horizon	Quantitative data	Cost effective
✓	✗	✗	✗	✓	✗	✓	✓

Aerial photography

- Benefits
  - Resolve individual light sources
  - Quantify the ALAN
  - Provides a permanent georeferenced record
- Limitations
  - Cannot measure sky glow
  - Doesn't show horizon visibility
  - **Subject to weather - cost**

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
							

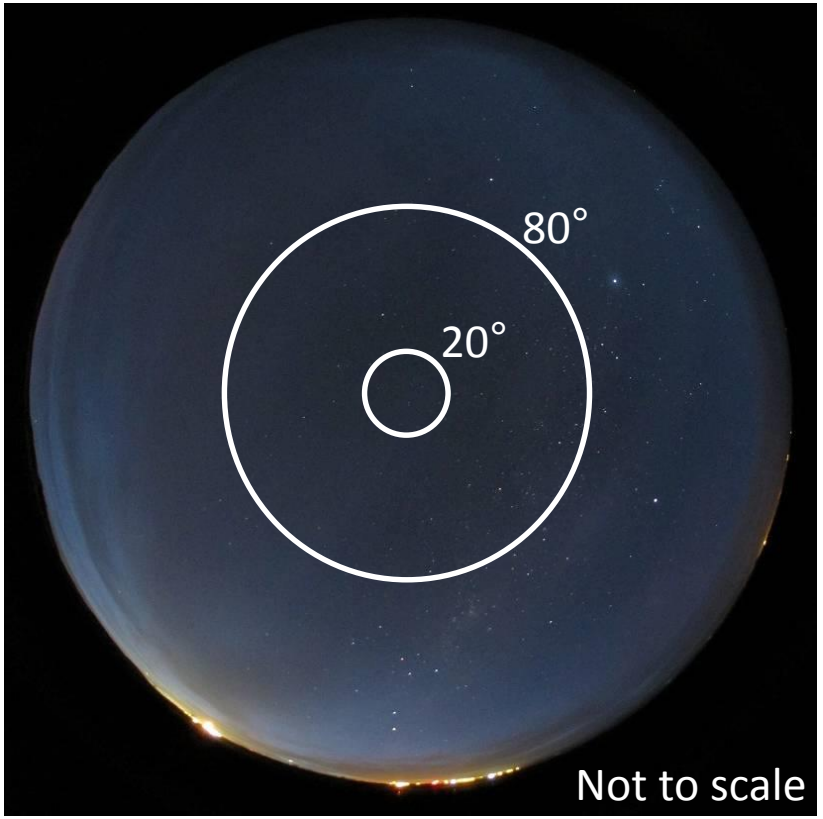
Sky Quality Meter

Benefits

- low cost,
- Field ready
- Quantitative data
- Detects glow

Limitations

- Zenith measurements (20 or 80 FOV)
- Calibrated to the human eye
- Cannot resolve individual light sources
- Cannot measure the critically important horizon light



Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✗	✓	✗	✓	✓	✗	✓	✓

Luxmeter

Benefits

- Quantitative
- Cost effective

Limitations

- Cannot resolve point sources
- Calibrated to human vision
- Cannot measure sky glow
- Limited spatial range, ie meters
- not designed for field biology

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✗	✗	✗	✗	✓	✗	✓	✓

Spectrometer

Benefits

- Can target a specific light source

Limitations

- targeting light over >500m is difficult and impacts precision
- Cannot detect sky glow
- Not field ready, requires laptop to power and operate the spec and to store data
- Quantifies in Lux, calibrated to human eye

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✓	✗	✗	✗	✗	✗	✓	✓

Luminance meter

Benefits

- Precise aiming and measurement of small light sources

Limitations

- Restricted distance (< 1km)
- Not precise at low intensities
- Calibrated to human eye
- Cannot quantify sky glow

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✓	✗	✓	✗	✓	✓	✓	✓

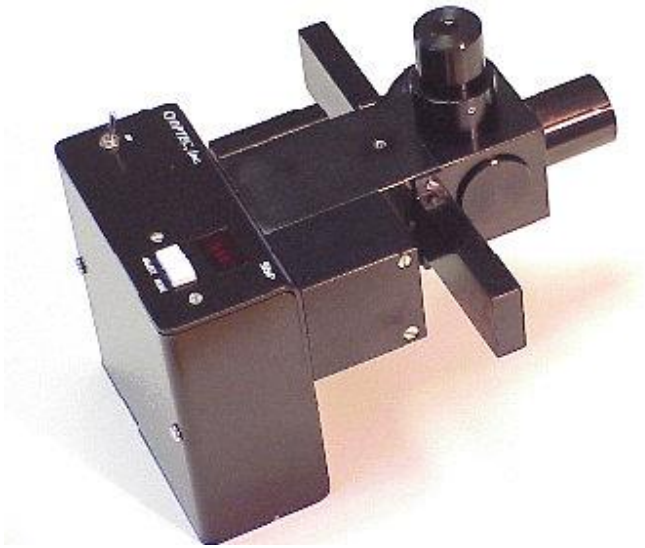
Stellar photometer

Benefits

- Can quantify light over a large distance
- Can detect sky glow
- Partially field ready, requires battery power

Limitations

- expensive
- Data precision and accuracy affected by temperature and detector noise and voltage fluctuations
- Couldn't quantify horizon light consistently



Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✓	✓	✓	✗	✗	✗	✓	✗

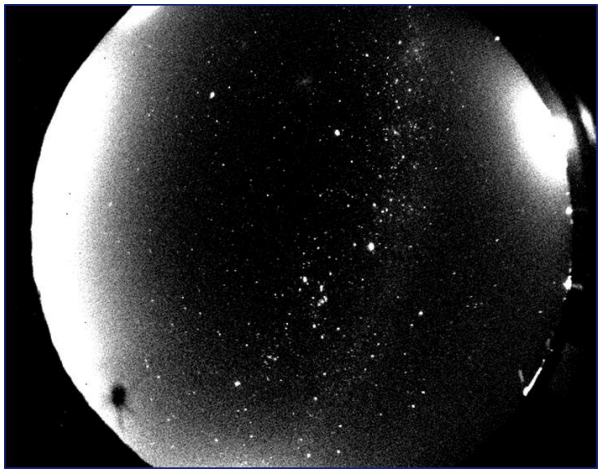
CCD SBIG All Sky Camera

Benefits

- Resolve point sources
- Detect sky glow
- Raw images can be converted into quantitative data
- Quantifies light on the horizon

Limitations

- Shape of CCD attenuates image – loss of ~40% of the horizon
- Not field ready, required batteries, computers and weatherproof housing to be built
- Couldn't separate parts of the spectrum without adding filters



Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✗	✓	✓	✗	✗	✗ ✓	✓	✗

Digital camera + fish eye lens

Benefits

- Robust and field ready
- Relatively cheap
- Quantifies data in the blue, red, green channels of the spectrum
- Measures horizon glow
- Resolves point sources

Limitations

- Costly to get good precision and accuracy

Separate parts of the spectrum	Detect sky glow	Resolve point sources	Precision at different light intensities	Robust and field ready	Quantify light on the horizon	Quantitative data	Cost effective
✓	✓	✓	✓	✓	✓	✓	✗

CCD All Sky Cameras

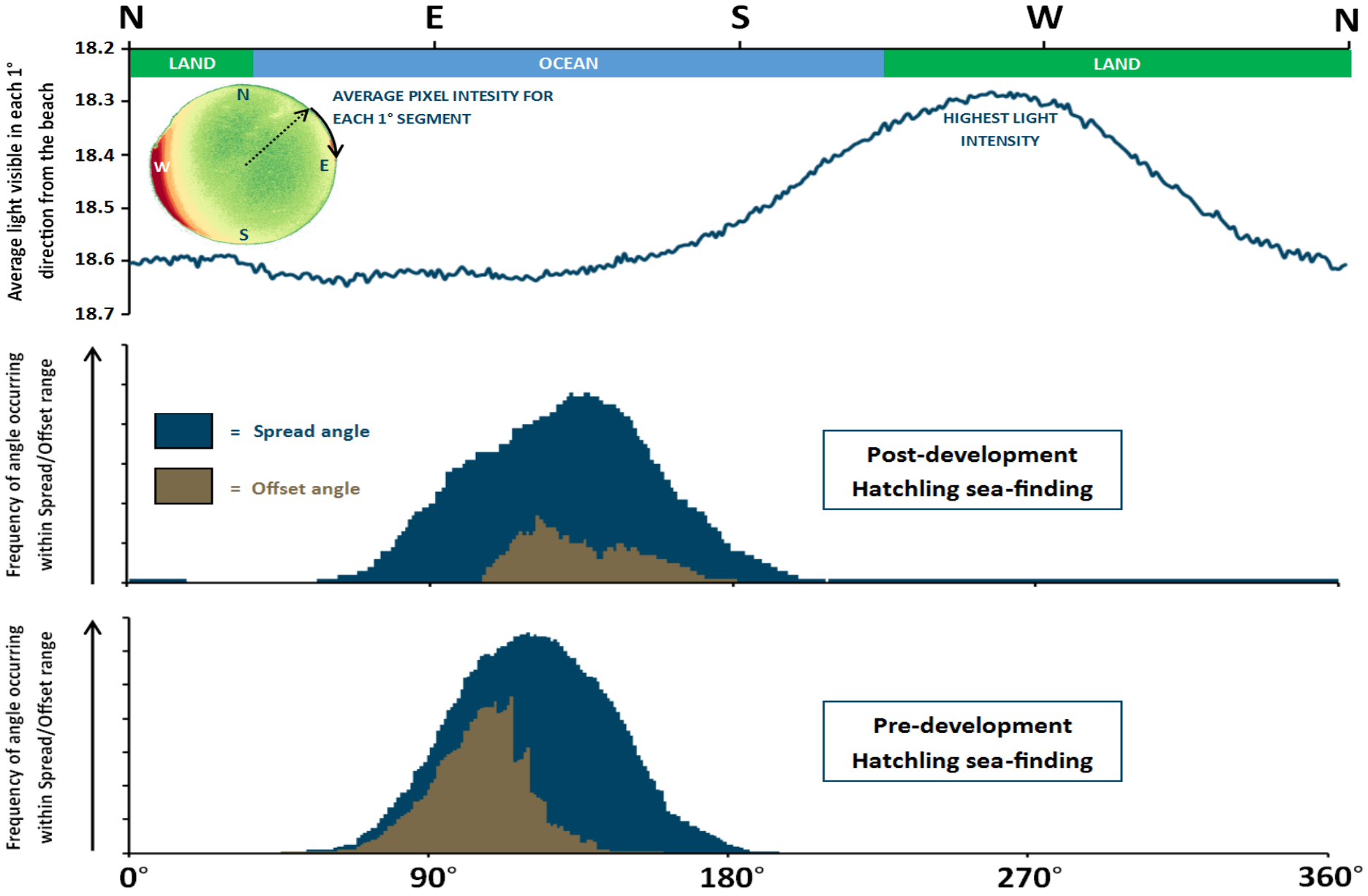
SBIG AllSky

- 2 x SBIG Astronomy Cameras
- Modified to run on external power source
- Data capture - lap top
- Modified by the insertion of a Johnson Blue filter; capture 400 – 500 nm region
- Captures 90% of the sky and 60% of the horizon
- Packs into two crates, needs specialised knowledge and training and 30 minutes to set up and programme

Sky42

- Canon G12 Camera and fish eye lens
- Modified to operate off rechargeable batteries
- Data capture - SD card
- Isolate the blue, green and red regions of the spectrum digitally.
- Captures 100% of the sky and 100% of the horizon
- Packs into hand luggage and takes 1 second to flip the on switch – no special training required

Integration of physical and biological results



Conclusions

- Currently the best instrument for measuring biologically meaningful ALAN is a digital camera with fish eye lens.
- Need to be aware of variability in lens quality and its impact on data precision and accuracy.
- Data processing methods are still being developed and we need to agree on output form and standard units.
- Next step is to trial the Sky Quality Camera and software alongside our Sky42 system

QUESTIONS