Artificial light at night alters locomotory activity and diet in the sea urchin *Paracentrotus lividus*

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UNIVERSITÀ DI PISA

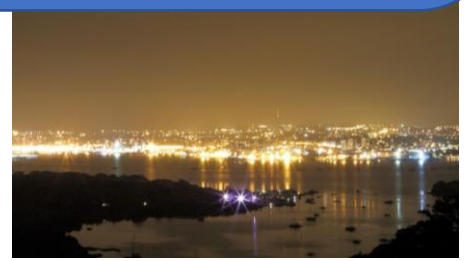
DIPARTIMENTO di BIOLOGIA

Artificial Light At Night (ALAN)

alteration of ambient light levels *(Cinzano et al. 2001)*

direct light emissions (outdoor lighting sources: 10 lux - 100 lux)

Skyglow (brightening of the night sky by artificial light reflected by water, dust and gas molecules: 0.2 lux - 0.5 lux)



RESEARCH ARTICLE

ENVIRONMENTAL PROTECTION

The new world atlas of artificial night sky brightness

10.1126/sciadv.1600377

Fabio Falchi,[1]* Pierantonio Cinzano,[1] Dan Duriscoe,[2] Christopher C. M. Kyba,[3,4] Christopher D. Elvidge,[5] Kimberly Baugh,[6] Boris A. Portnov,[7] Nataliya A. Rybnikova,[7] Riccardo Furgoni[1,8]

ALAN affects 83% of the population and **45%** of the **world coastlines**

Ecological light pollution

alteration of natural light-dark cycles in ecosystems *(Longcore et al. 2004)*

Impacts on marine habitats

Impacts on a **variety of habitats at all levels of biological organization**

nature ecology & evolution

ARTICLES

https://doi.org/10.1038/s41559-020-01322-x

A meta-analysis of biological impacts of artificial light at night

Dirk Sanders[1,2], Enric Frago[3,4], Rachel Kehoe[2], Christophe Patterson[2] and Kevin J. Gaston[1]

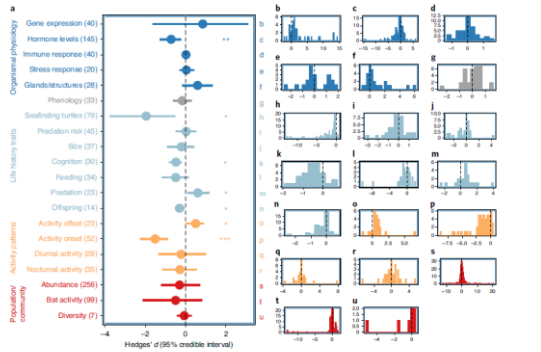
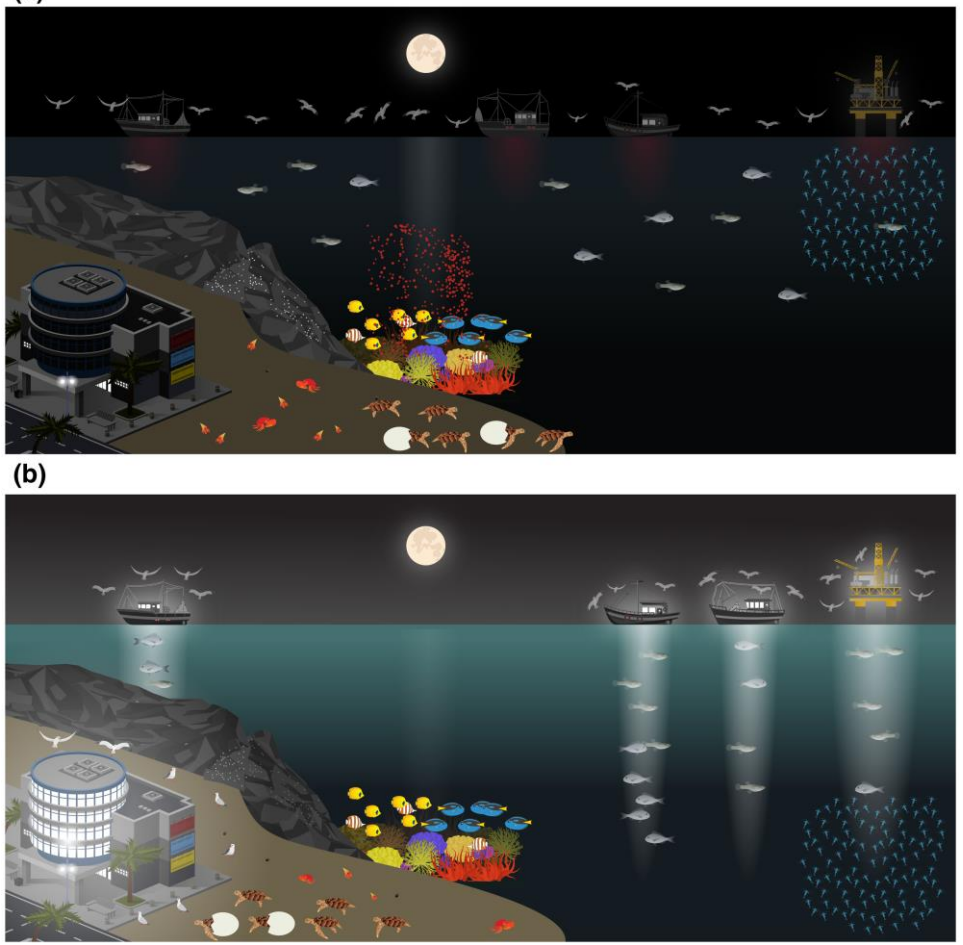


Fig. 2 | Effect sizes for the measures from the main categories. a, Effect sizes (Hedges' *d*) with post-mean and 95% credible intervals based on results from MCMCglmm for each variable from the five main categories (organismal physiology, phenology, life history traits, activity patterns and population/community). The numbers in brackets indicate the sample size and the asterisks the significance level for the pMCMC statistic, with *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$). **b**–**u**, Histograms showing the distribution of the effect sizes for each of the categories shown in **a**, with the black dashed line indicating the zero *x*-axis intercept, the range of the effect size values on the *x* axis and frequency on the *y* axis.

(a)

(b)



GCB REVIEW

Global Change Biology WILEY

Impacts of artificial light at night in marine ecosystems—A review

Laura F. B. Marangoni[1] | Thomas Davies[2] | Tim Smyth[3] | Airam Rodríguez[4,5,6] | Mark Hamann[7] | Cristian Duarte[8] | Kellie Pendoley[9] | Jørgen Berge[10,11,12] | Elena Maggi[13] | Oren Levy[14,15]

FIGURE 2 (a) Different marine environments not affected by Artificial Light Pollution at Night (ALAN), and (b) marine environments under the potential impacts of ALAN *(source: Marangoni et al. 2022)*

Ecological light pollution

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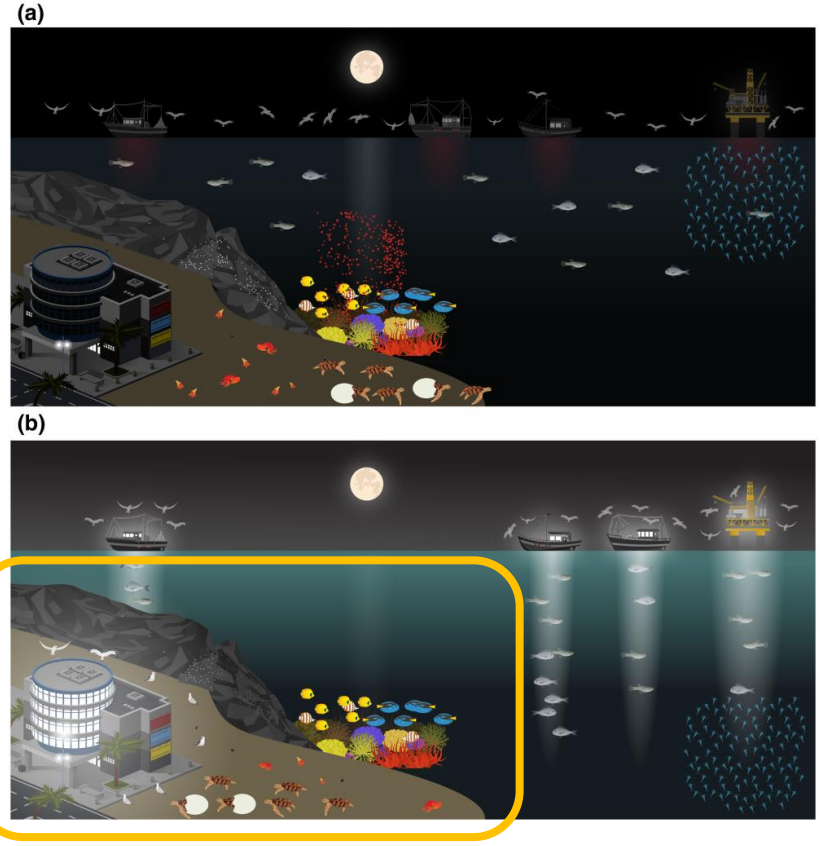


Impacts on coastal habitats

foraging behavior and locomotion

(Luarte et al. 2016, Bauer et al. 2022)

orientation

(Bourgeois et al. 2009, Berry et al. 2013, Rivas et al. 2015, Dimitriadis et al. 2018)

disruption/loss of circadian rhythm

(Duarte et al. 2019, Pulgar et al. 2019)

alteration of trophic and community structure and interactions

(Davies et al. 2015, Bolton et al., 2017, Underwood et al. 2017, Maggi et al. 2018, 2019, 2019b, Garratt et al. 2019)

ALAN and sea urchins

Why sea urchins?

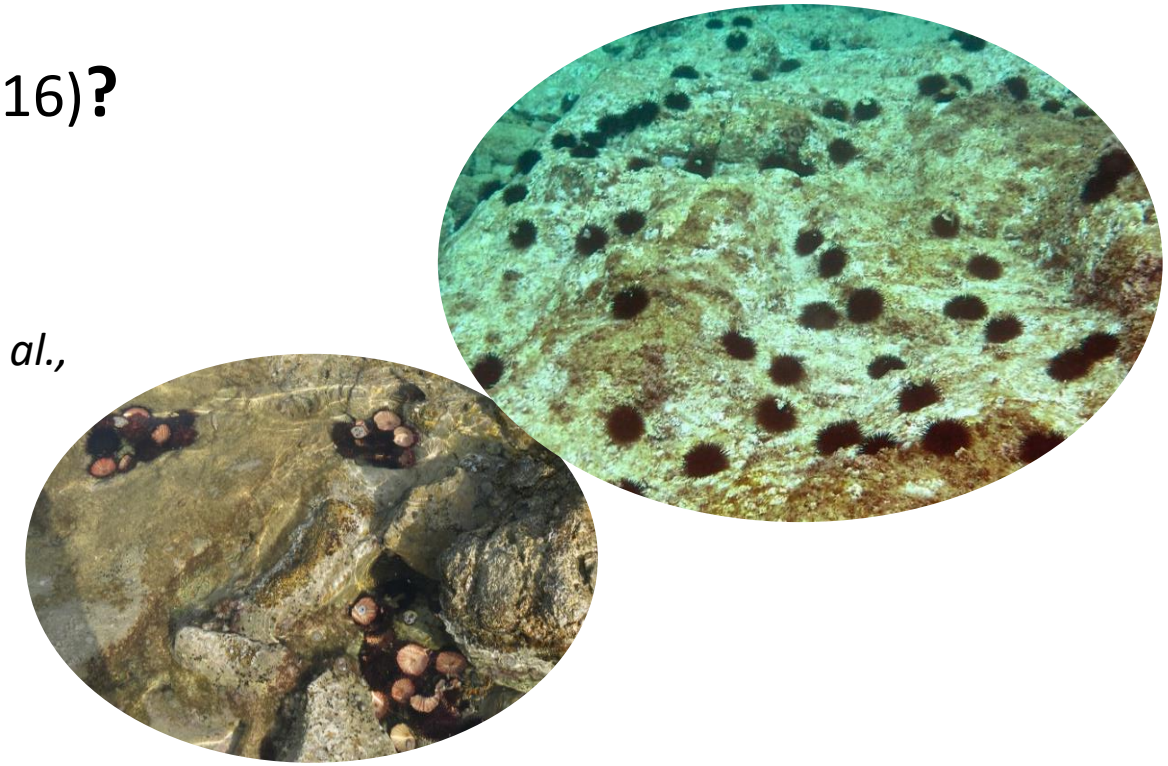
Key taxonomic group for the ecology and economy of coastal habitats, showing **nocturnal activity** and **photic behaviors**

(Yoshida, 1984, Boudouresque et al. 2013, Lawrence 2013)

Why *Paracentrotus lividus* (Lamarck, 1816)?

Predominant **grazer** shaping benthic Mediterranean ecosystems *(Benedetti Cecchi et al., 1995; Barnes et al., 2002)*

High **commercial value** of its gonads *(Cirino et al., 2017)*



ALAN and *P. lividus*

stress

nocturnal locomotory behavior and **diet**

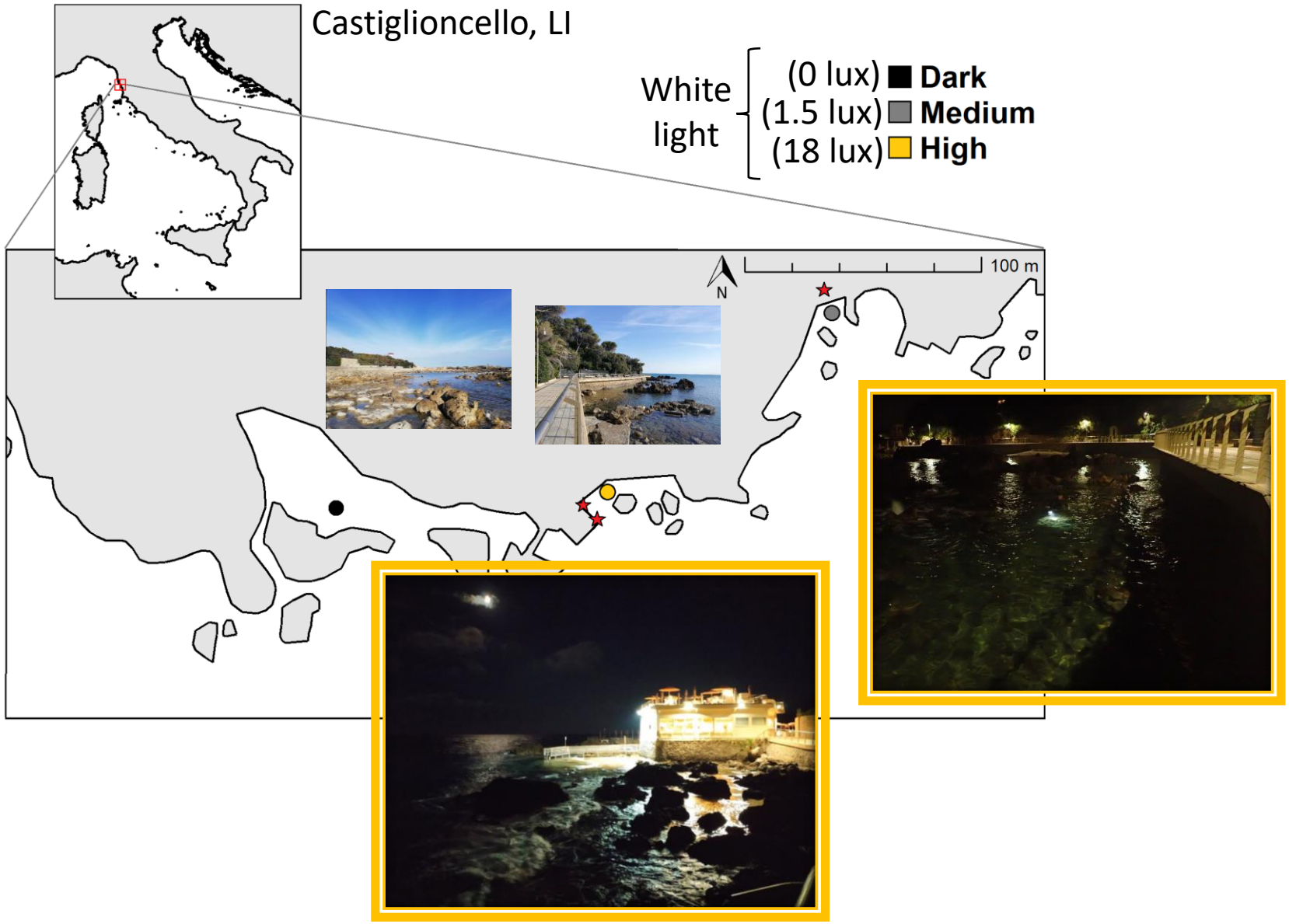
1 **move away** from the light source
change in **locomotory performance** (speed, latency and sinuosity) at increasing light intensity

2 change in **stable isotope** (C and N) signature of **stomach** content and **muscle** at increasing light intensity **(WORK IN PROGRESS!)**

1 Methods: nocturnal locomotory behavior

Summer 2021

5 nights
absence of the moon
clear sky
calm sea



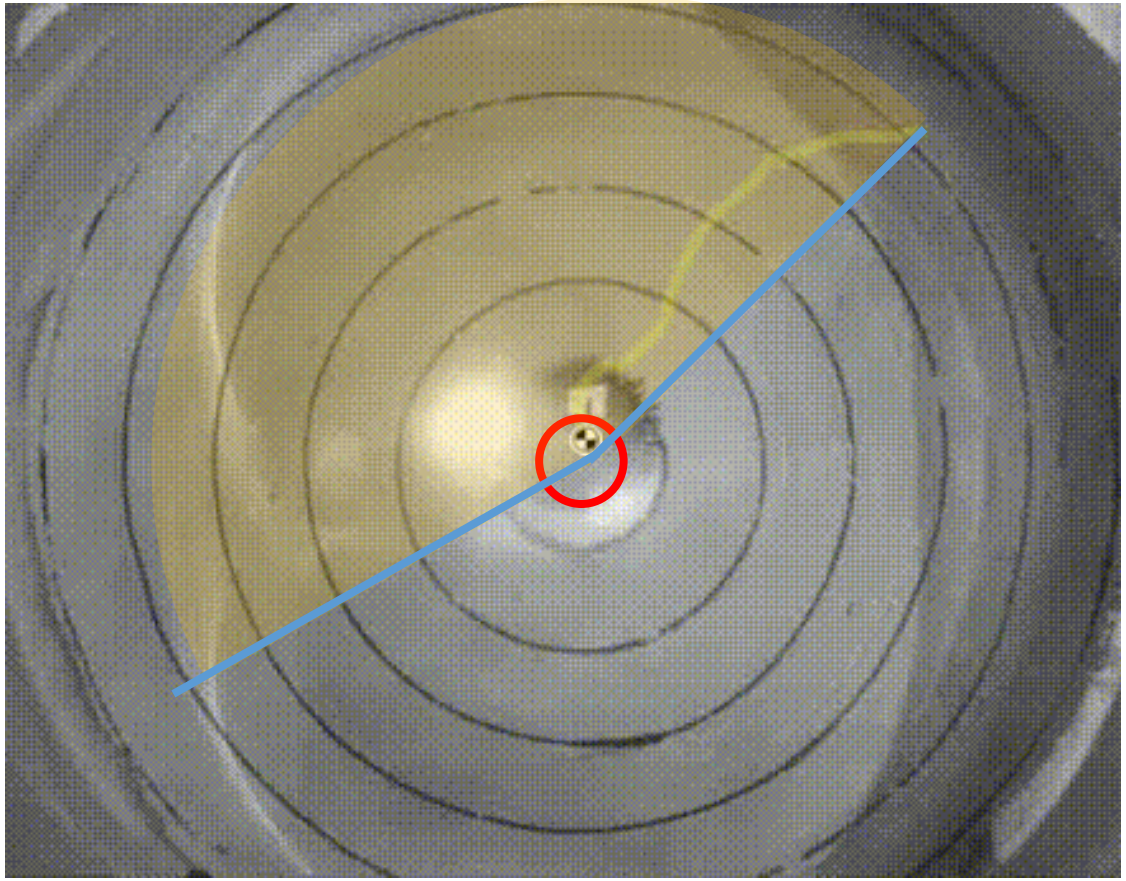
Dark: 57 individuals
Medium: 69 individuals
High: 69 individuals

1 Methods: nocturnal locomotory behavior

Time-lapse mode

Infrared camera
(Coolife 1080P, 16MP)

- **latency of locomotion** → 2cm radius
- **sinuosity (S)** → $S = 2[p(((1-c)/(1-c)) + b^2)]^{-}0.5$
  (Benhamou, S. 2004)
- **average speed** (cm/s) → $\frac{L}{t}$ (excluding latency)
- **direction** → **angle**



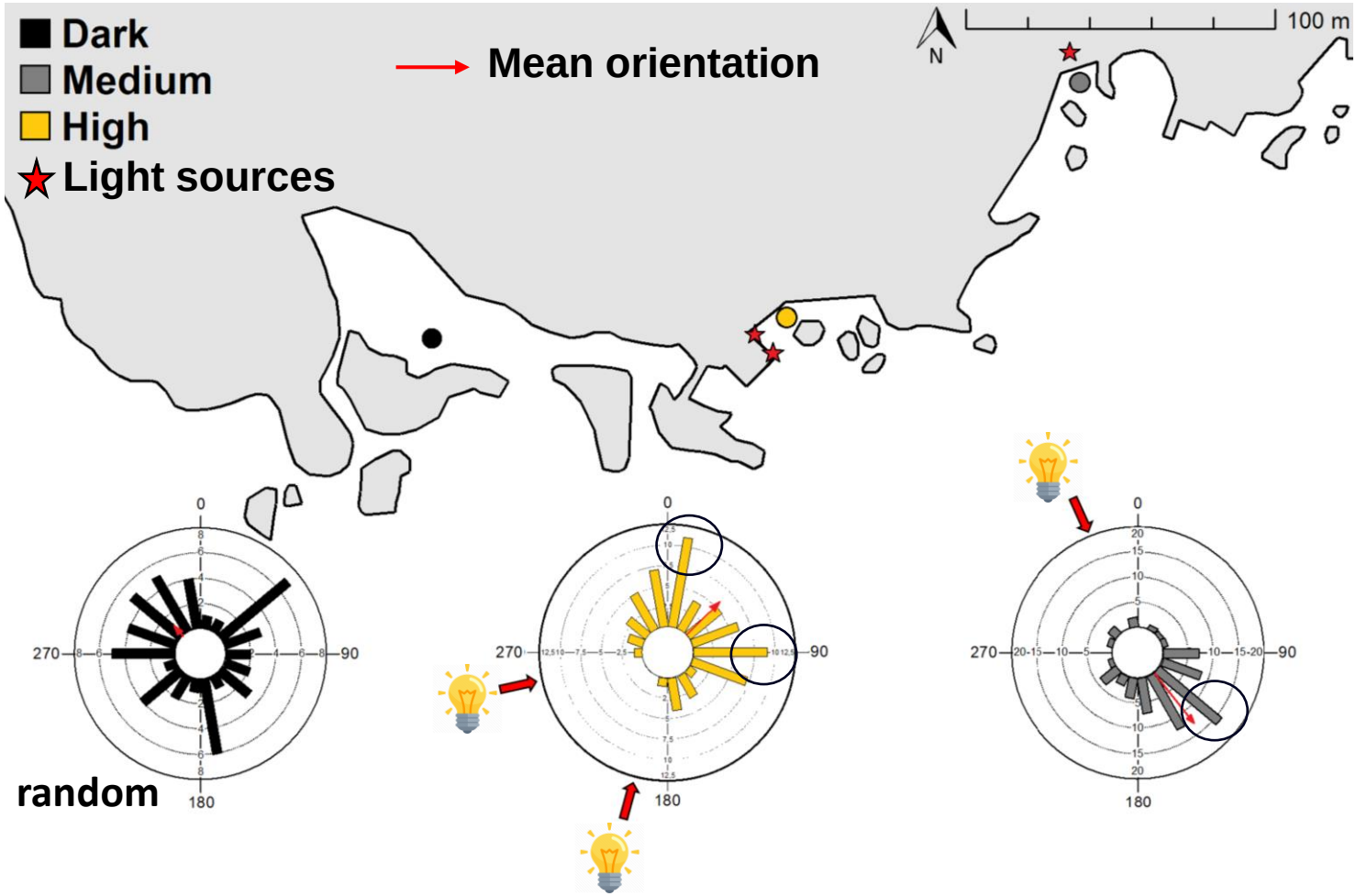
P. lividus in the experimental arena (top view)

1 Results: nocturnal locomotory behavior

DIRECTION

- **Random frequency** pattern only under **dark** conditions

- **Different mean** at changing light conditions



Frequency of the direction of trajectories for *P. lividus*. 0◦, 90◦, 180◦, 270◦ represent North, East, South and West, respectively. Length of thin red arrows is the mean vector (*r*, from 0 to 1; *r* = 1 is represented by an arrow that reaches the edge of the outer circle).

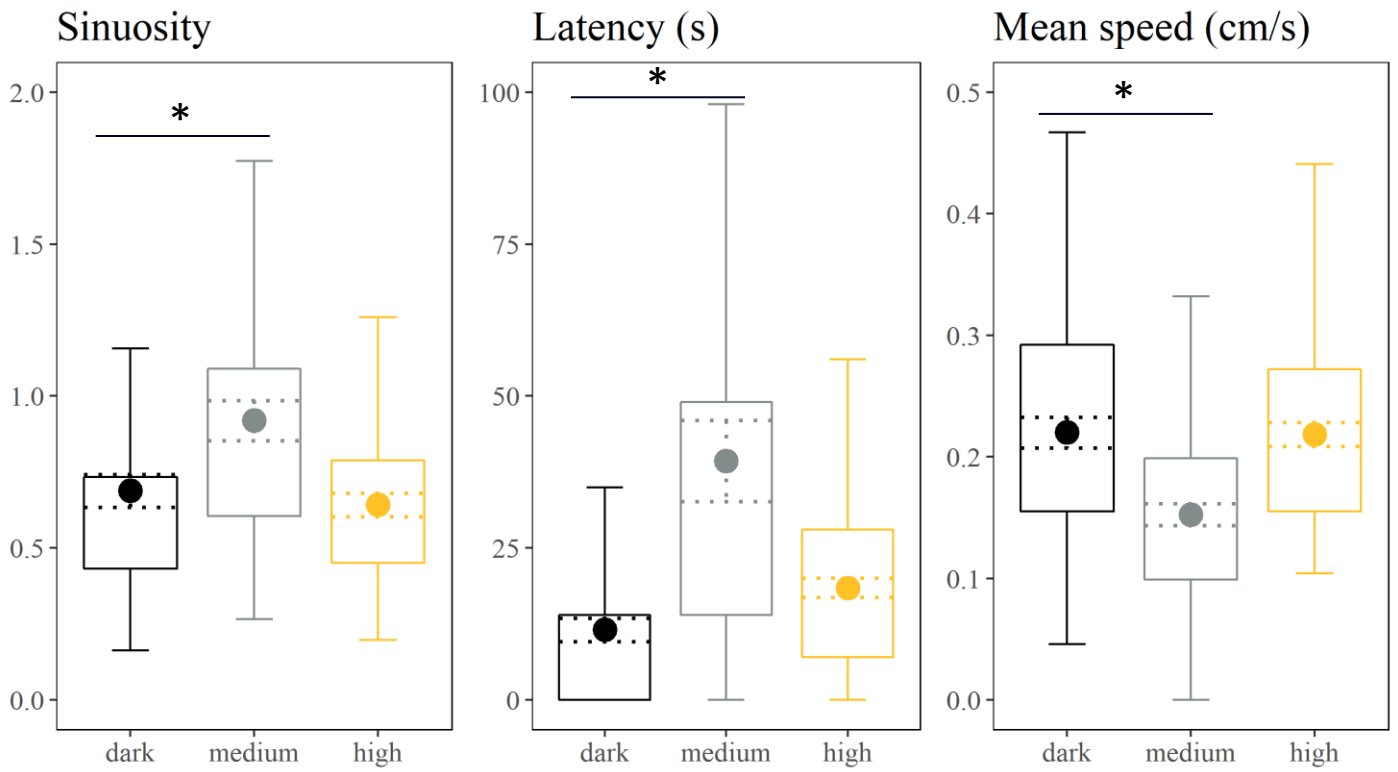
1 Results: nocturnal locomotory behavior

SINUOSITY and LATENCY

- **larger** at **Medium** than at Dark site

MEAN SPEED

- **smaller** at **Medium** than at Dark site



Boxplots representing (**a**) sinuosity, (**b**) latency (s) and (**c**) mean speed (cm/s), for sea urchins in each site, Dark, Medium and High. The big dot with dotted lines represents the mean ± 1SE

1 Discussion: nocturnal locomotory behavior

Hypotheses*:* i) move away from the light source, and **ii)** change in locomotory performance at increasing artificial light intensity

✓ Direction: **sea urchins move away** from the light source **(escape behavior?)**
(*when exposed to two different light sources they chose a preferred path to follow?*)

✓ Medium intensity of ALAN: neither (fast) escape nor exploratory behavior

Future studies:
- different light intensities
- one *vs.* two light sources
- replicated sites
- different spectra

High latency
Low mean speed
High sinuosity

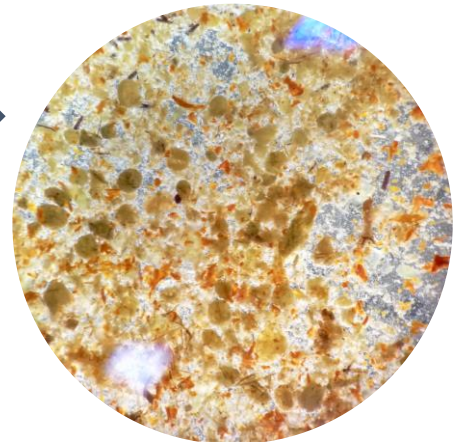
2 Methods: diet

Summer 2021

2 early mornings (after a new moon period)
calm sea

sea urchins (n=5 at each site):

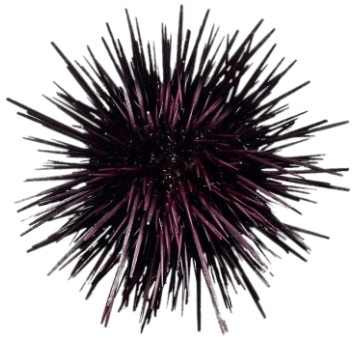
- **stomach content**
- **muscular filaments** of the Aristotle's lantern



Food resources (n=5 at each site for each resource):

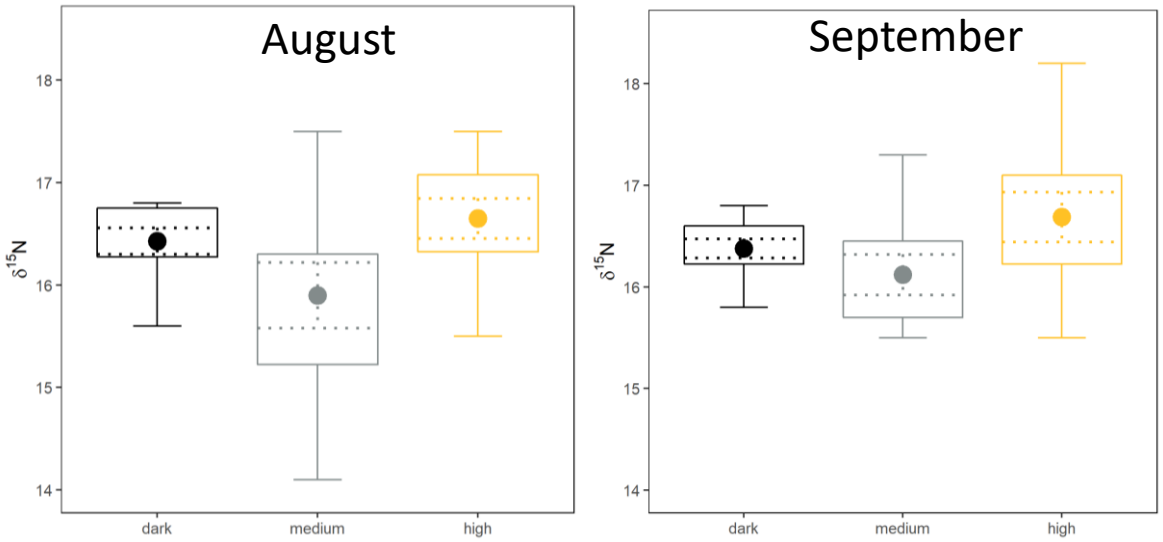
- *Laurencia* spp.
- *Padina pavonica*
- Epilithon
- Epifauna

Stable Isotope Analysis (δ^{13} C and δ^{15} N)

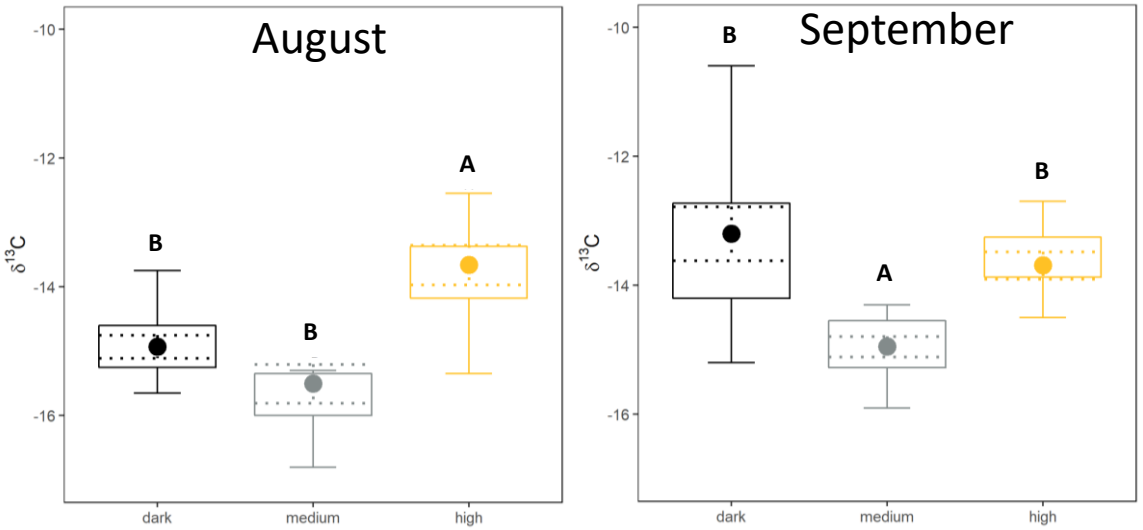


2 Preliminary results

δ^{15} N



δ^{13} C



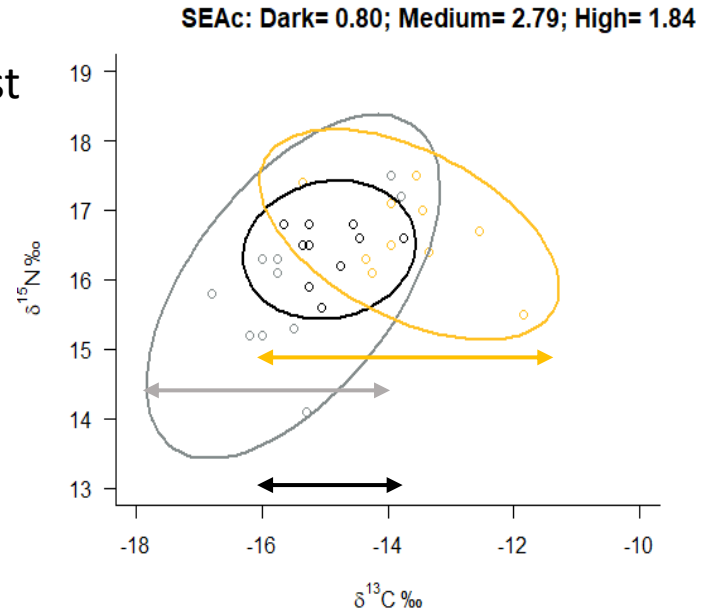
MUSCULAR FILAMENTS (ASSIMILATION)

NO CHANGE IN TROPHIC POSITION

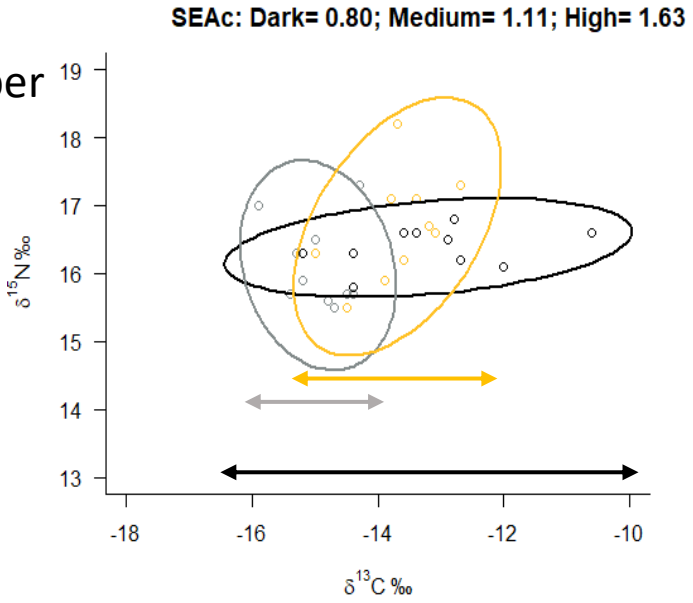
SHIFT IN FOOD RESOURCES

2 Preliminary results

August



September



MUSCULAR FILAMENTS

Dark: larger **temporal change**
in δ^{13} C variability than under lit conditions

change in number
of (assimilated) **resources**

✓Change in resource(s) availability **NO**

✓Change in resource(s) isotopic signature
WORK IN PROGRESS

✓Change in sea urchin behavior

Dark

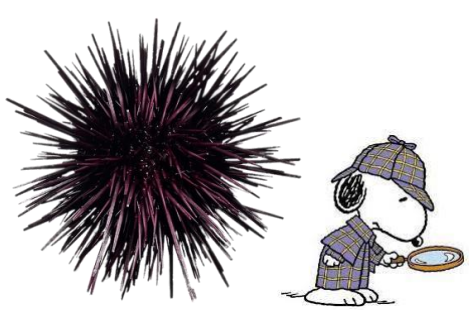
Intermediate light

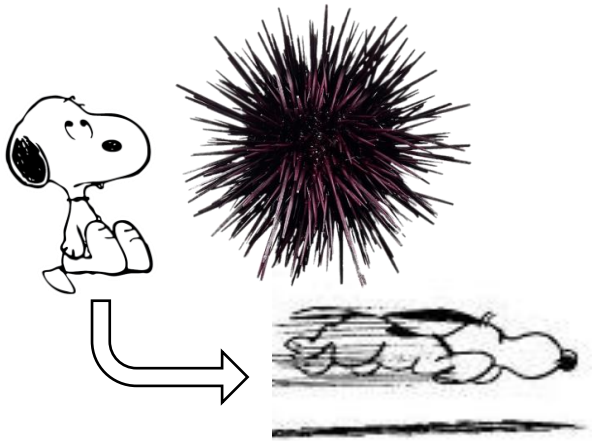
High light

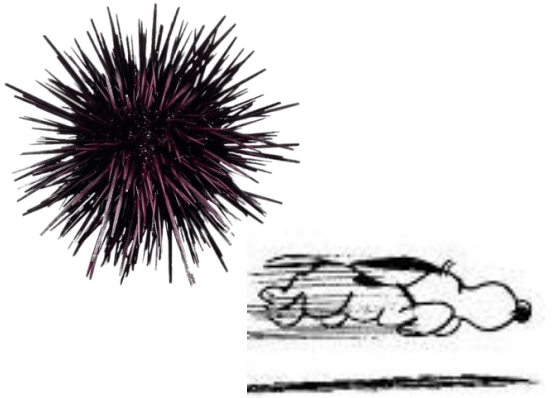
Explore

‘Doubtfully’ escape

Escape!







Shift in food resources?

Loss of temporal variability in the assimilation of resources?

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DIPARTIMENTO di BIOLOGIA

13TH INTERNATIONAL TEMPERATE REEFS SYMPOSIUM
HOBART, UNIVERSITY OF TASMANIA

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