Marine robotic developments toward the monitoring of exploited fish stocks

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Stock assessment and biodiversity are influenced by the behavior of individuals within local populations

Migration

Feeding

Reproduction

→ Temporal Dimension (Days/Seasons) → Life’s adaptation to cycles → Bias on perceived stocks metrics and biodiversity

Kronfeld-Schor and Dayan, 2003. ¡Ann. Rev. Ecol. Syst. 34: 153-181

Major Research Lines

1-Characterization of behavioral and physiological rhythms and the molecular mechanisms that control their temporal expression (*laboratory experiments*)

2-Characterization of changes in communities composition and biodiversity due to the spatiotemporal modulation of behavior of species (*field sampling*)

3-Implementation of new monitoring technologies to track behavior and its effects on ecosystems (*both laboratory and field*).

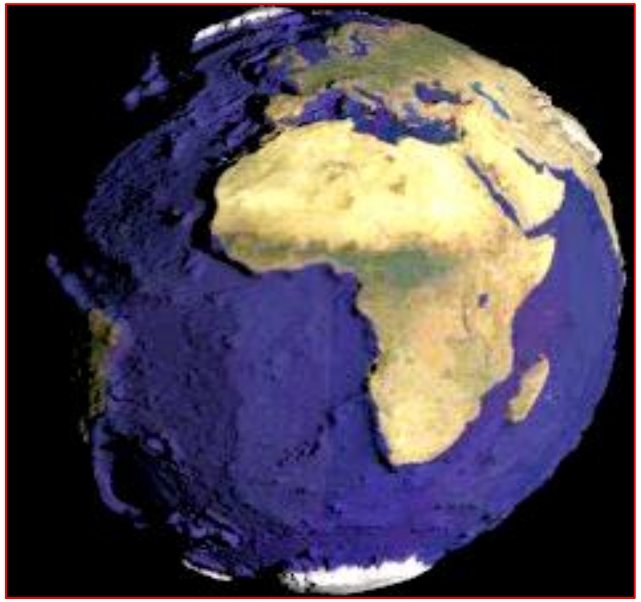
Biological clock controls behavior and physiology in relation to geophysical cycles

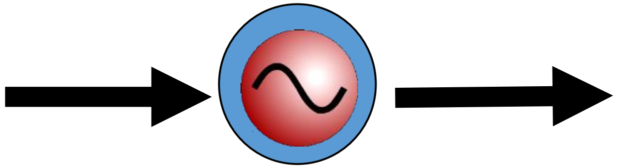
The Circadian system

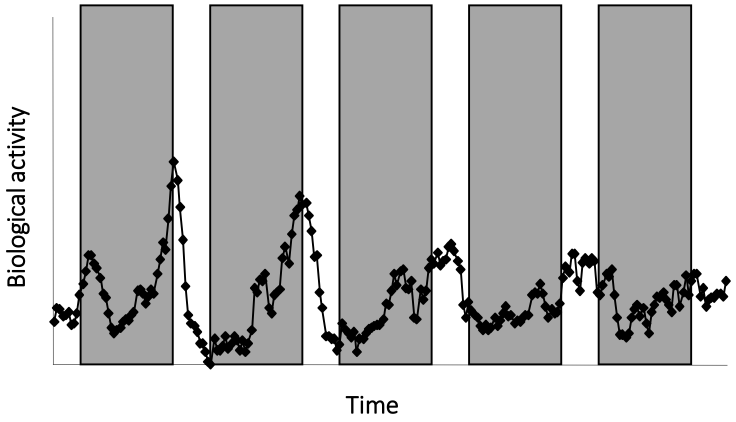
Sensorial organs

Biological clock

The biological rhythm



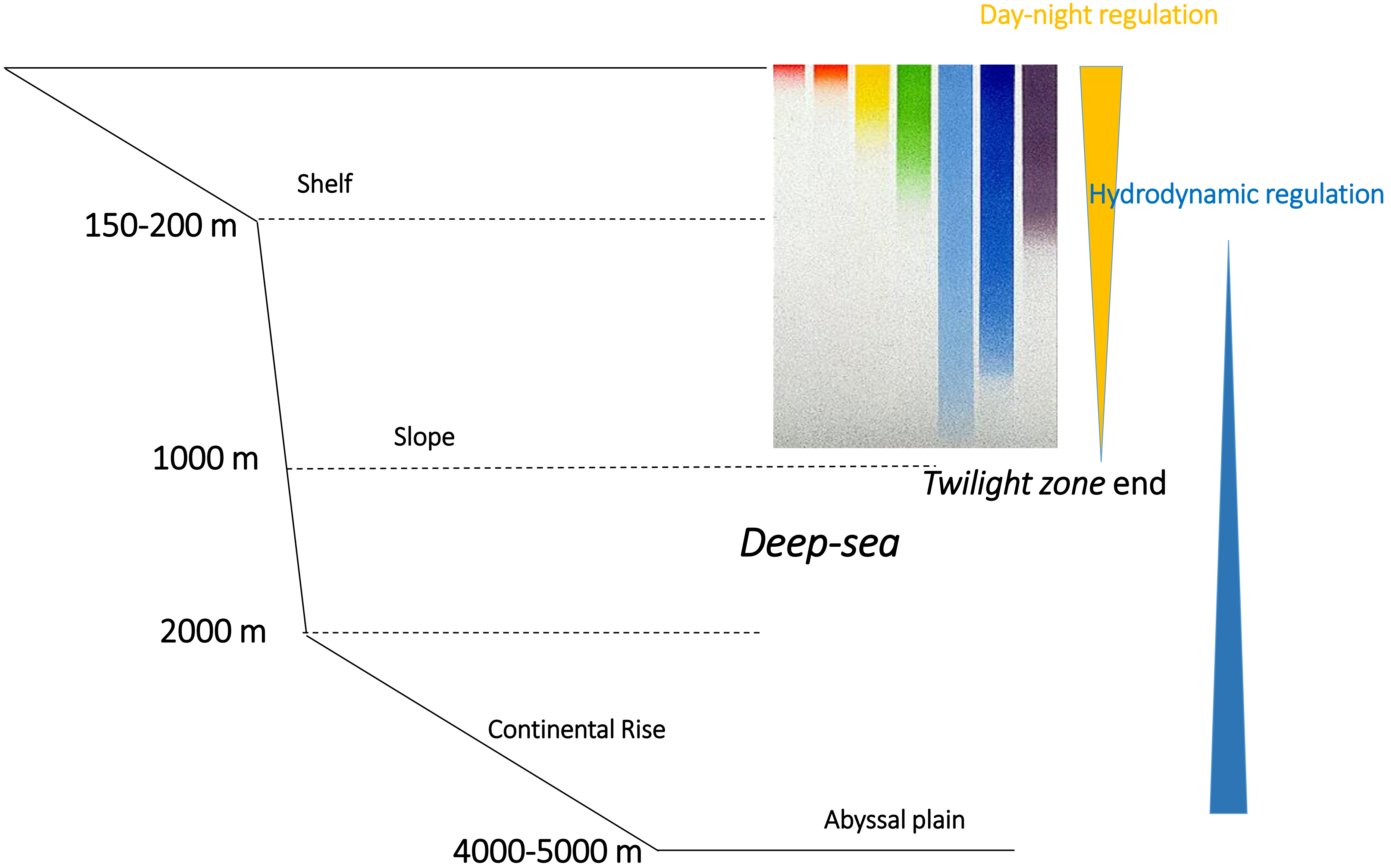




Chronobiology

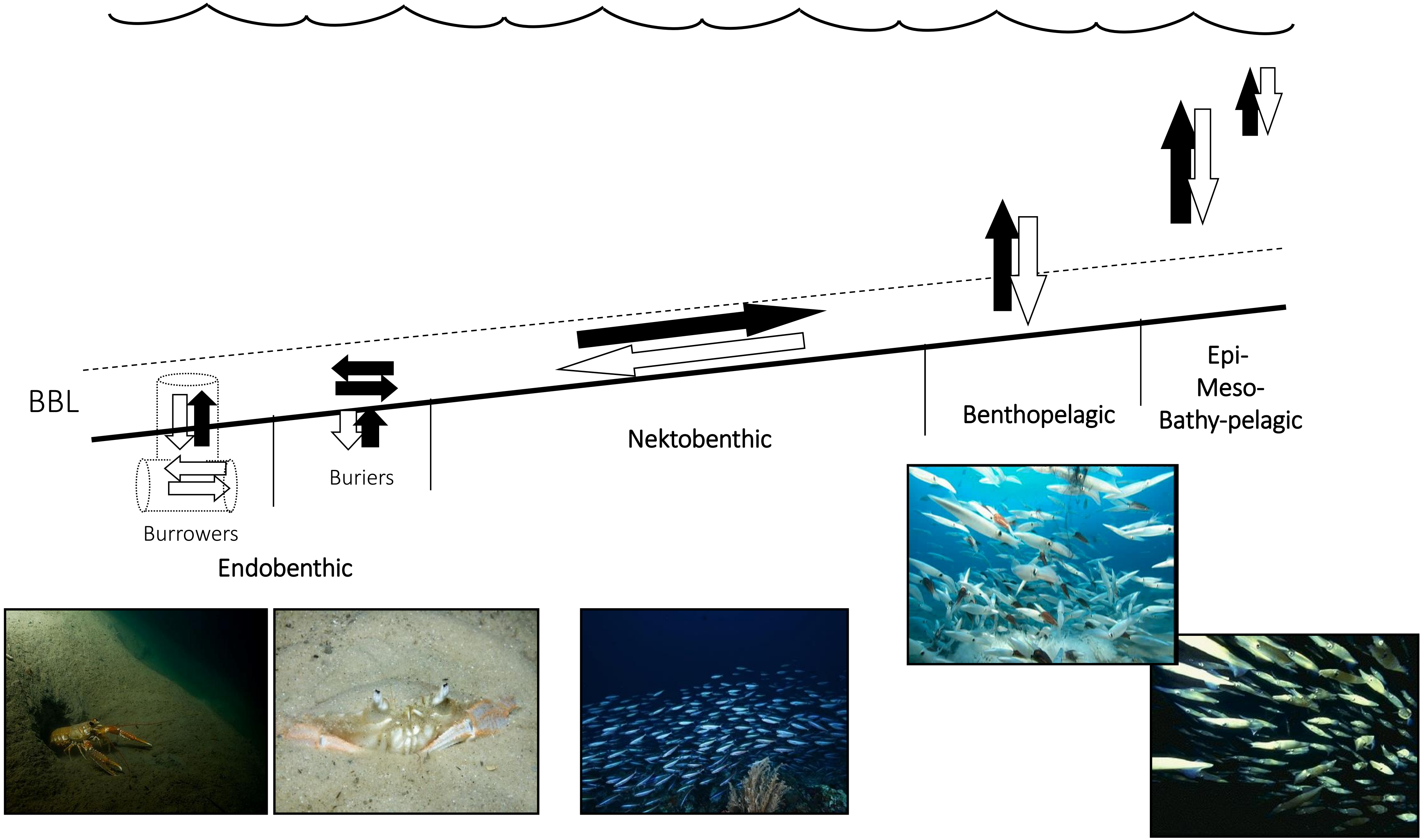
Tosini and Aguzzi . 2005. Elsevier, Amsterdam. Pp. 165-174

Day-night and tidal cycles regulate displacement rhythms into continental margin areas



Herring 2003. Oxford University Press, NY
Aguzzi et al. 2011. Front. Biosci. 16: 131-150

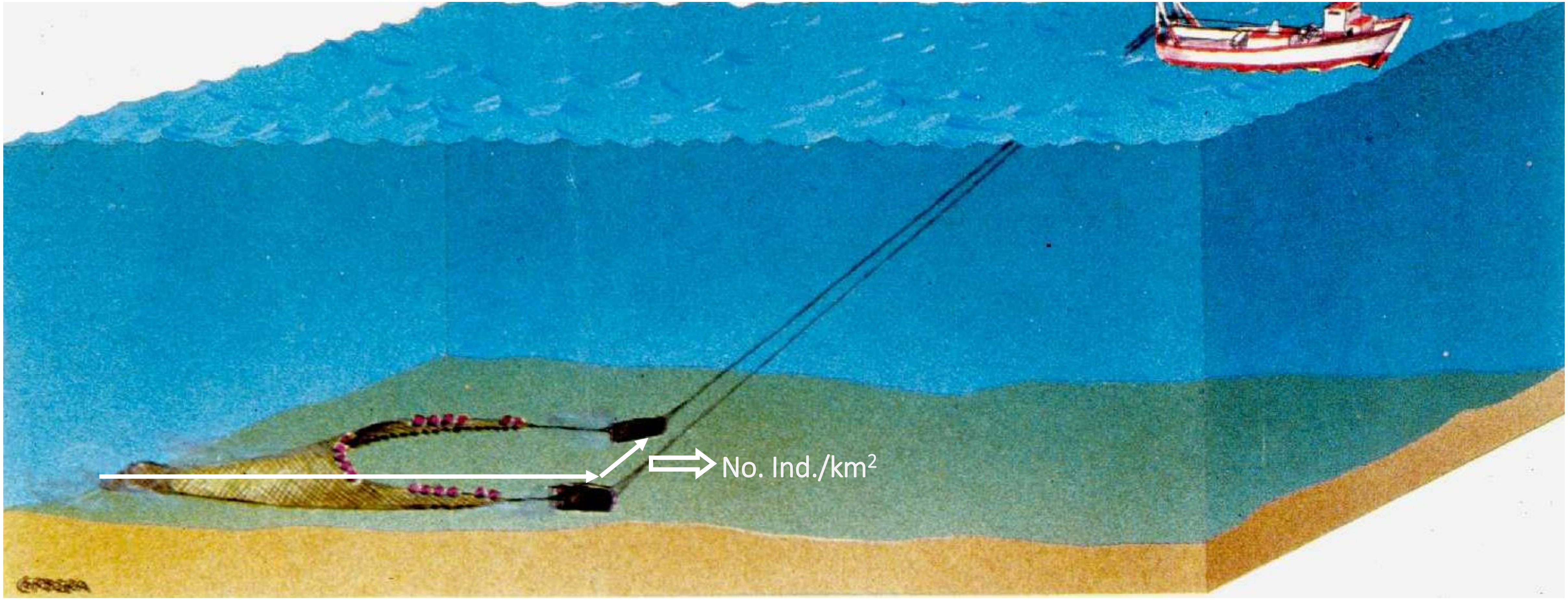
Different types of massive displacements into the 3-D marine environment



Aguzzi and Company, 2010. Adv. Mar. Biol. 58: 155-225

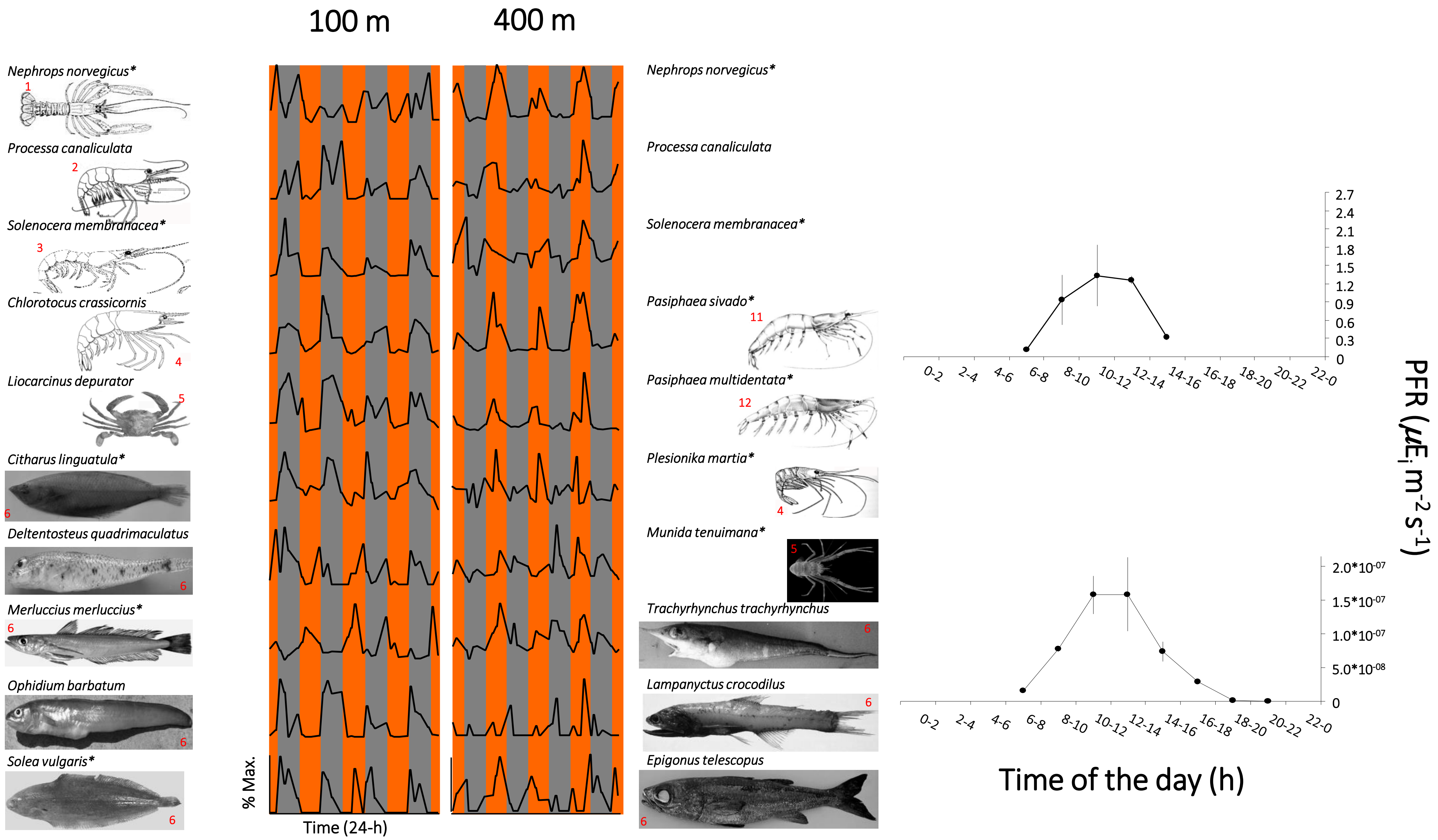
Siebel and Drazen 2007. Phil. Trans. R. Soc. B 362: 2061-2078

Trawling is a traditional system of sampling for population/stock and biodiversity assessments



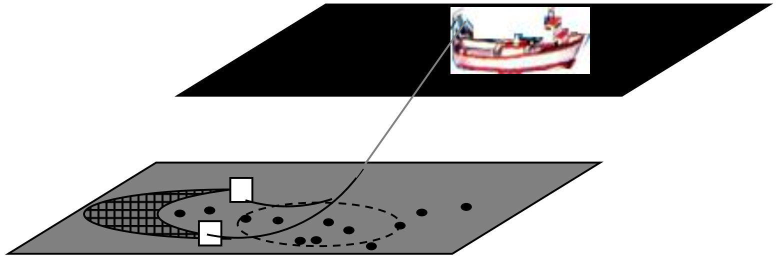
BUT the rhythmic behavior of species generates a diel variability in catches

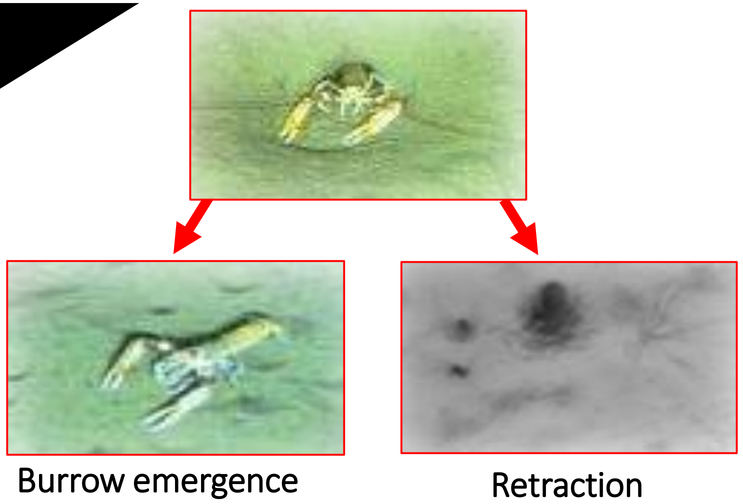
Different "catchability" patterns in species as proxy of their rhythmic behavior

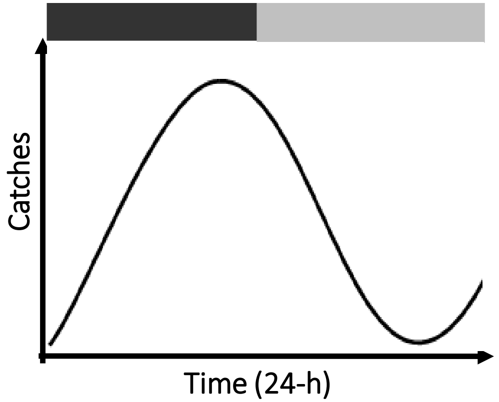


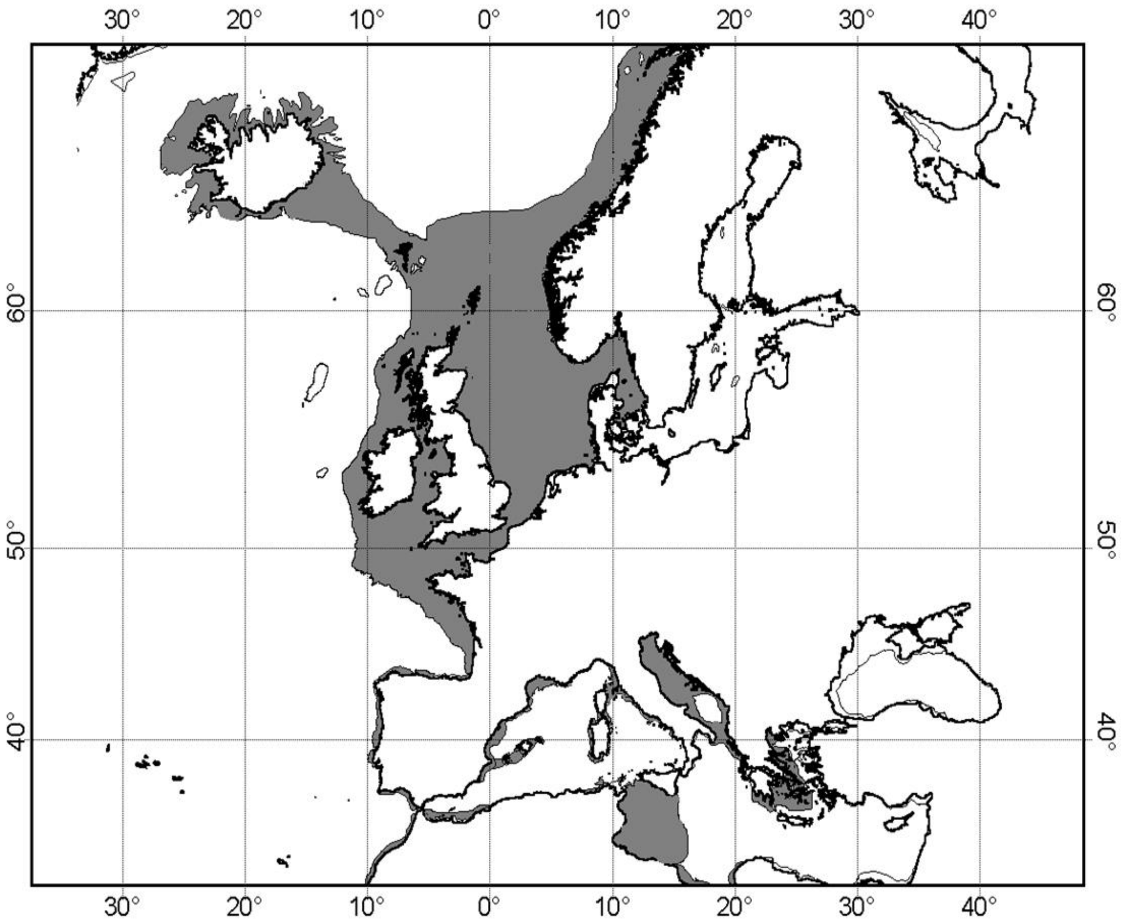
1. Aguzzi et al. 2003. MEPS 258:201-211
2. Aguzzi et al. 2008. Crustaceana 81:1301-1316
3. Aguzzi et al. 2008. Crustaceana 81:1301-1316
4. Aguzzi et al. 2007. J. Zool. 273:340–349
5. Aguzzi et al. 2008. Mar. Ecol. 30:93-105
6. NERIT Project Unpub. Res.

The Norway lobster as a model for behavioral studies



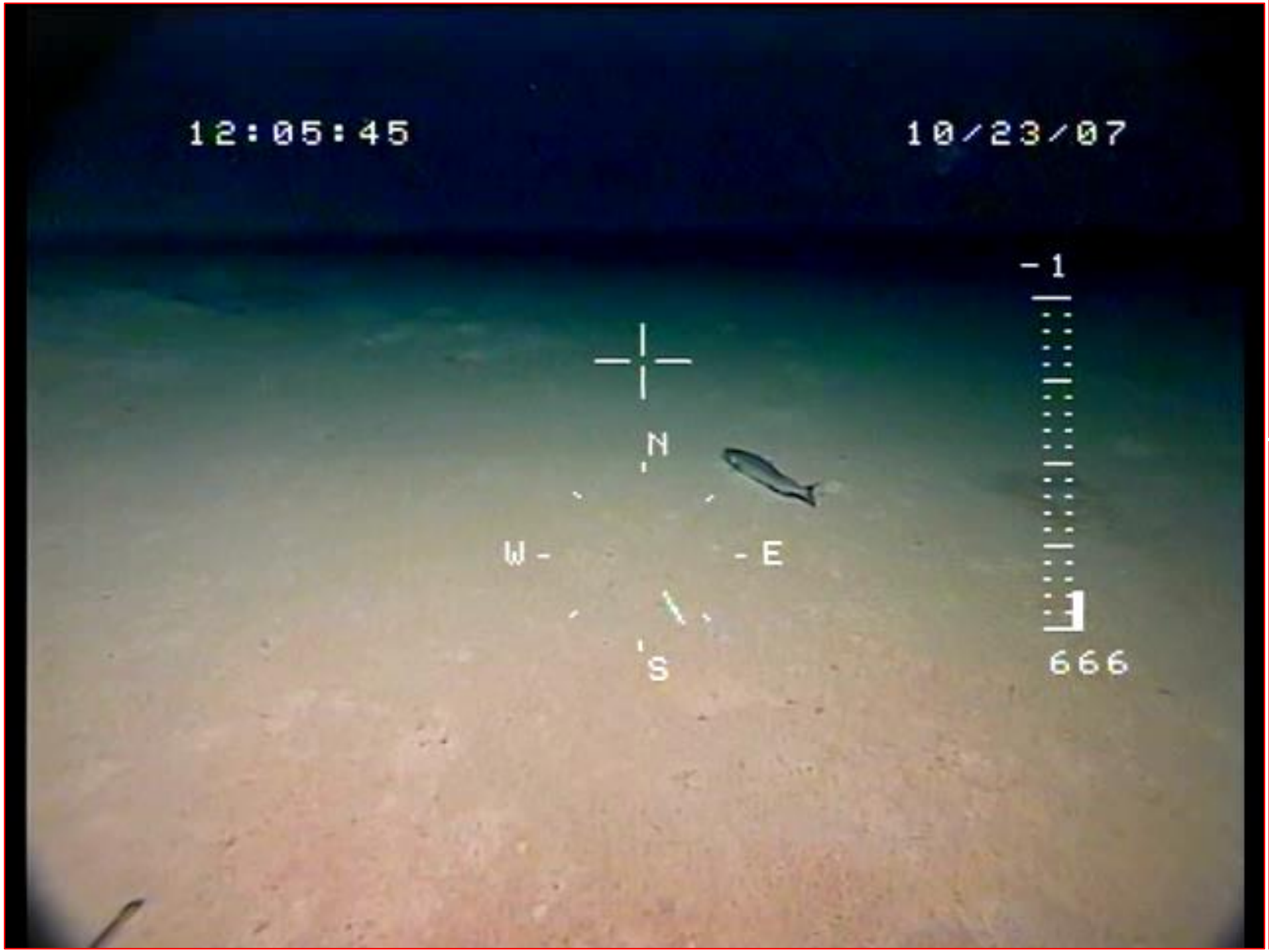


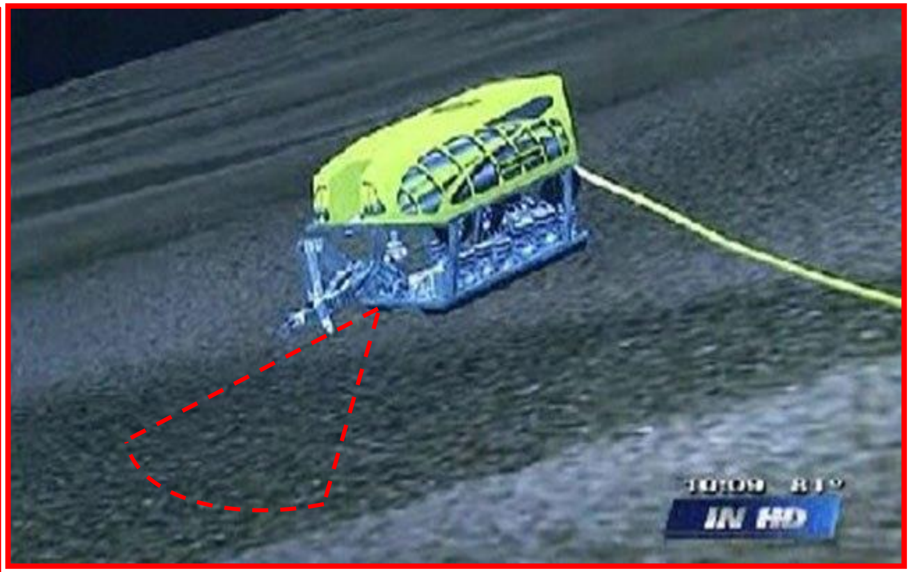


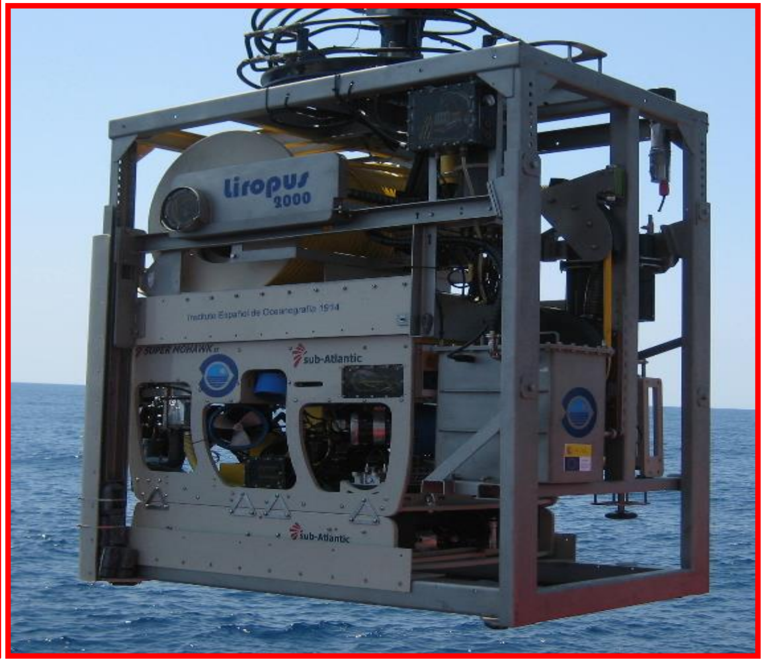


Aguzzi et al. 2004. Biogeog. 25: 81-92

An example of burrow-emergence behavior in the field (by ROV, 700 m depth off Barcelona)

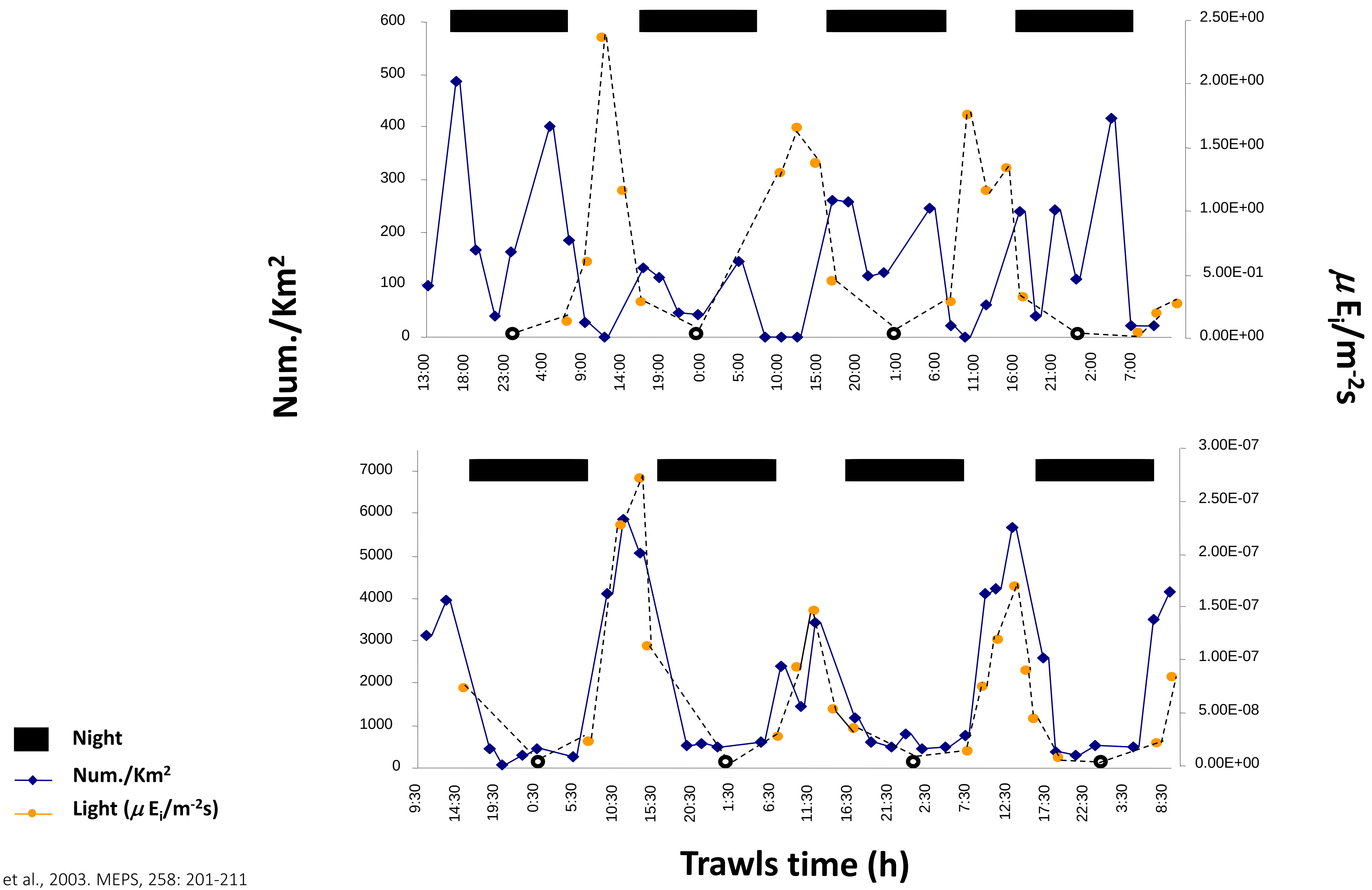






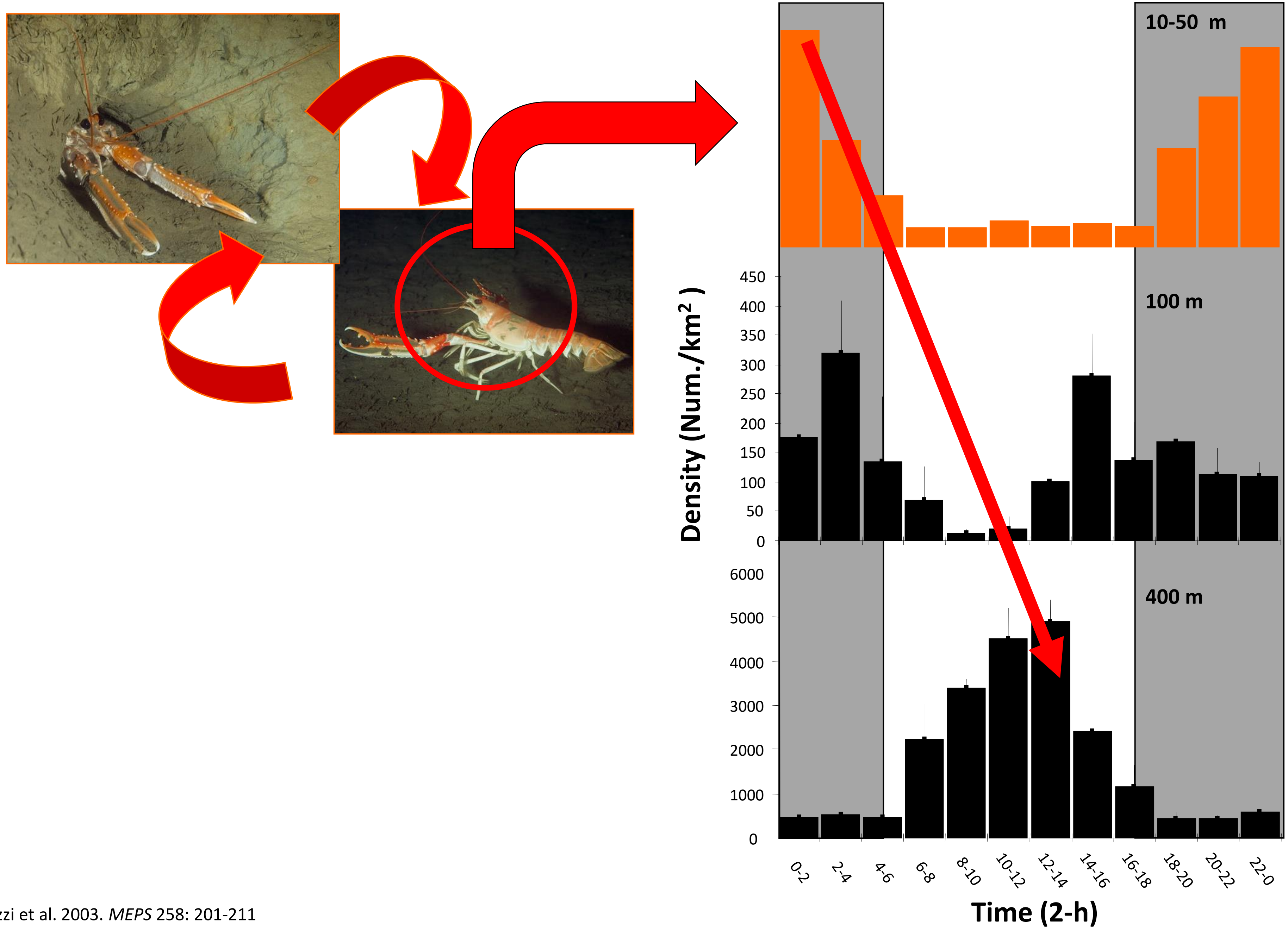
Sardà F., Aguzzi J. 2012. Rev. Fish Biol. Fisher. 22: 409-422

Catch rhythmicity and light cycle in October, 100 and 400 m



Aguzzi et al., 2003. MEPS, 258: 201-211

Behavioral rhythms in burrow emergence affect the stock assessment

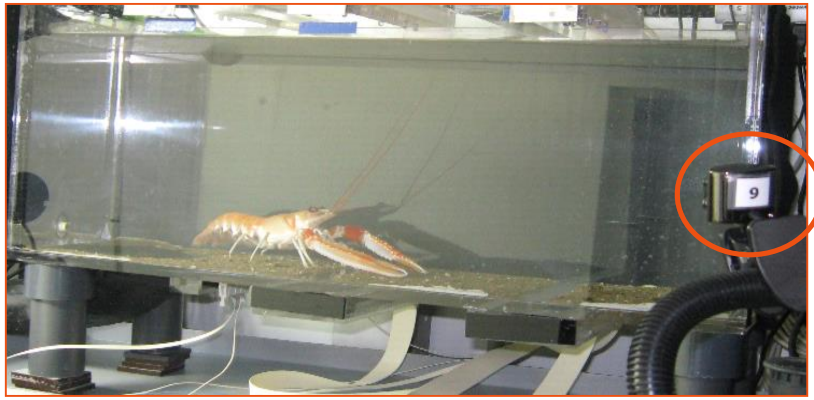


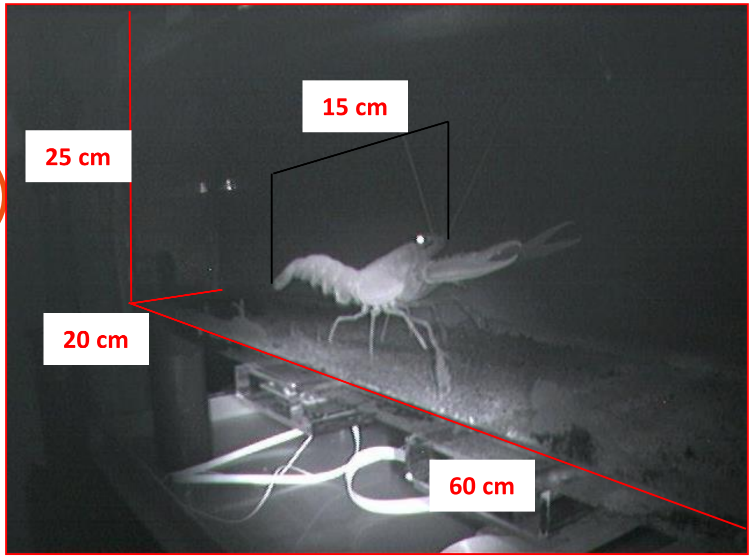
Naylor E. 1988. *Symp. Zool. Soc. Lond.* 59: 177-199.

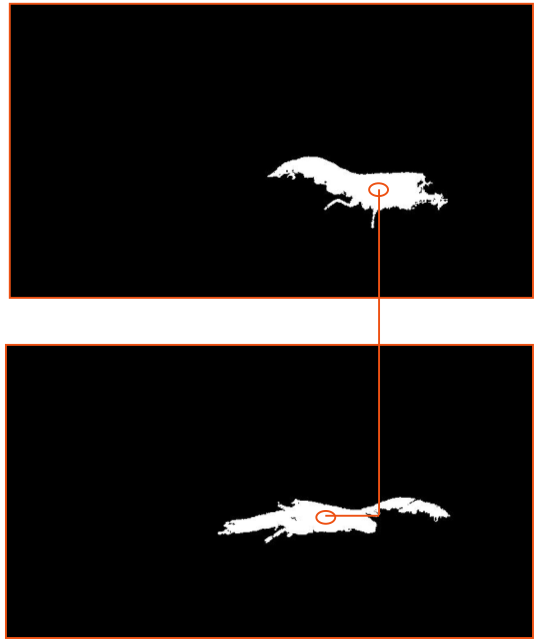
Aguzzi et al. 2003. *MEPS* 258: 201-211

Nephrops as good animal model for laboratory testing

Video-tracking technology to deliver more ethological information





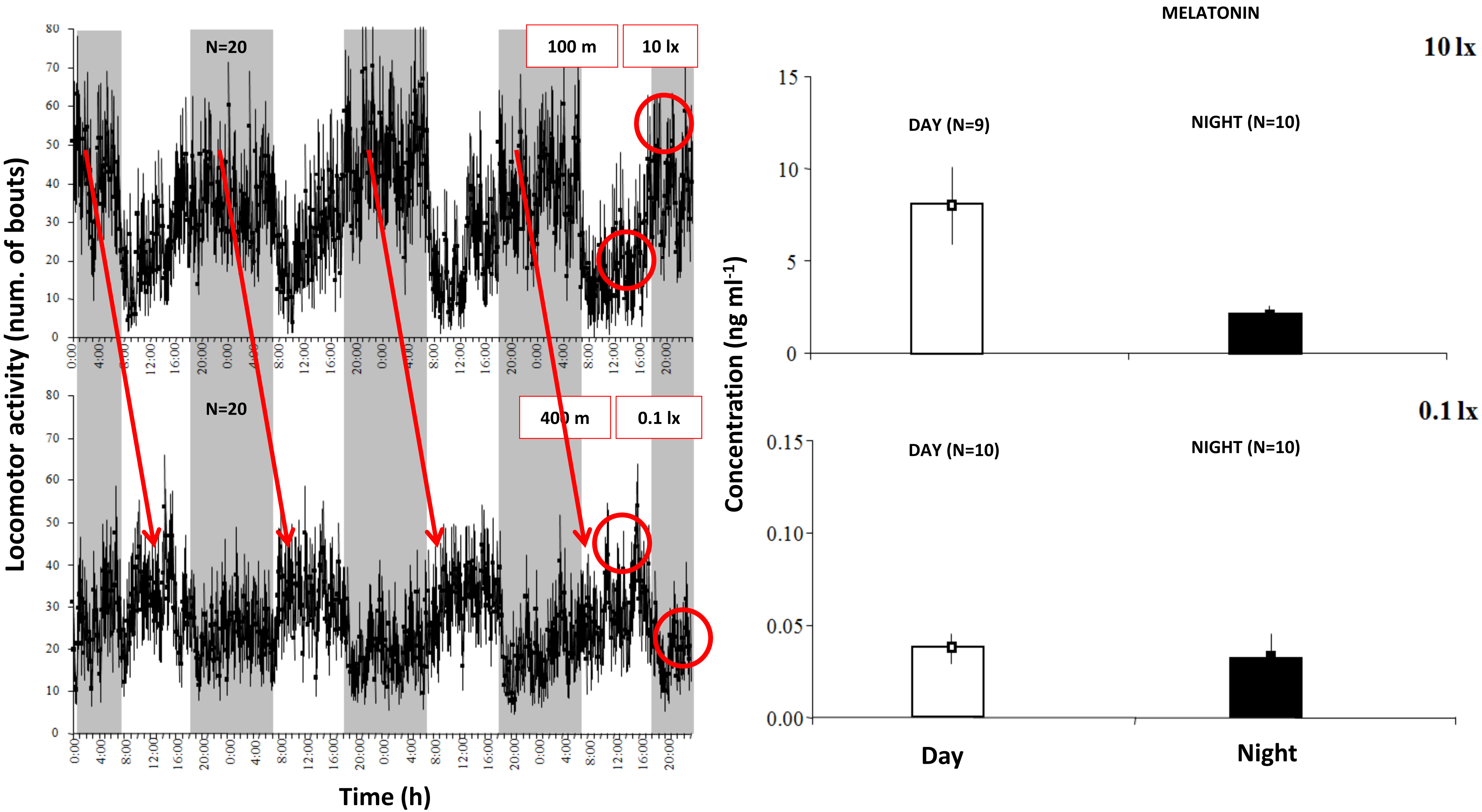


1-Role of blue monochromatic light (480 nm): test with different Intensities as proxy for depth

2-RoI of melatonin: time-lapse extraction from hemolymph and fluctuation assessment by mass spectrometry

Aguzzi et al. 2009. Scientia Marina 73(4): 773-783

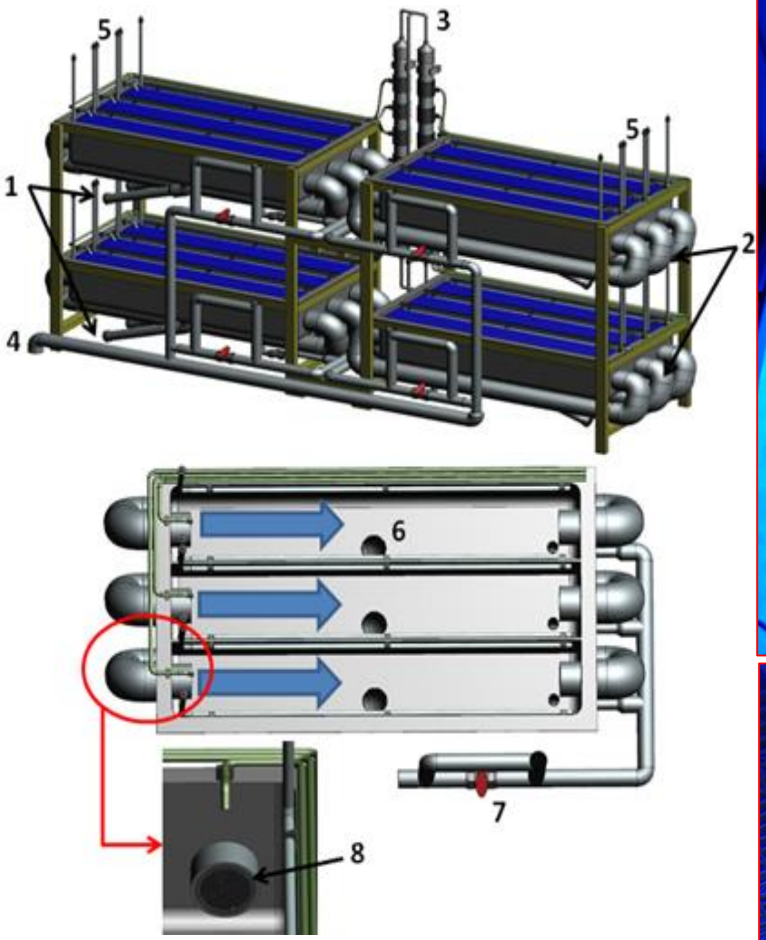
Monochromatic blue light intensity reduction evokes a time-shift in burrow emergence in the field through sampling/catches at different depths

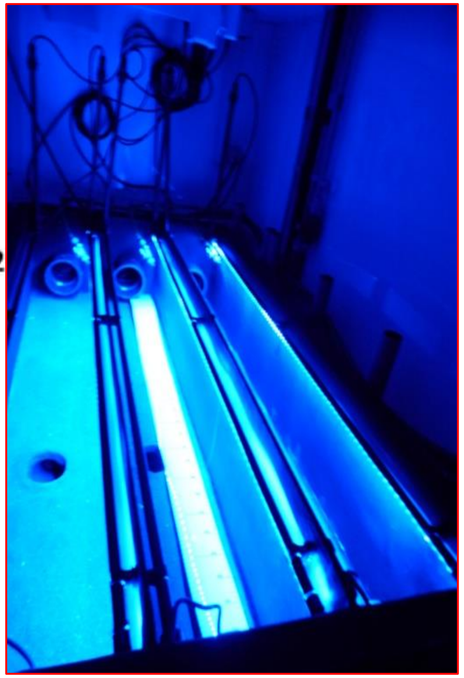


Aguzzi et al. 2009. Deep-Sea Res. I 56: 1894-1905

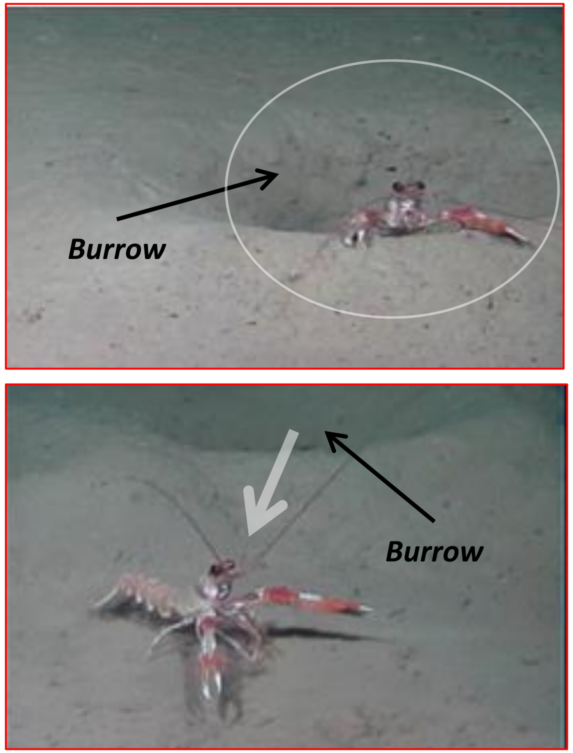
Aguzzi et al. 2009. Sci. Mar. 73: 773-783

Video-tracking technology applied to mini-flumes: testing for conflicting entraining cycles





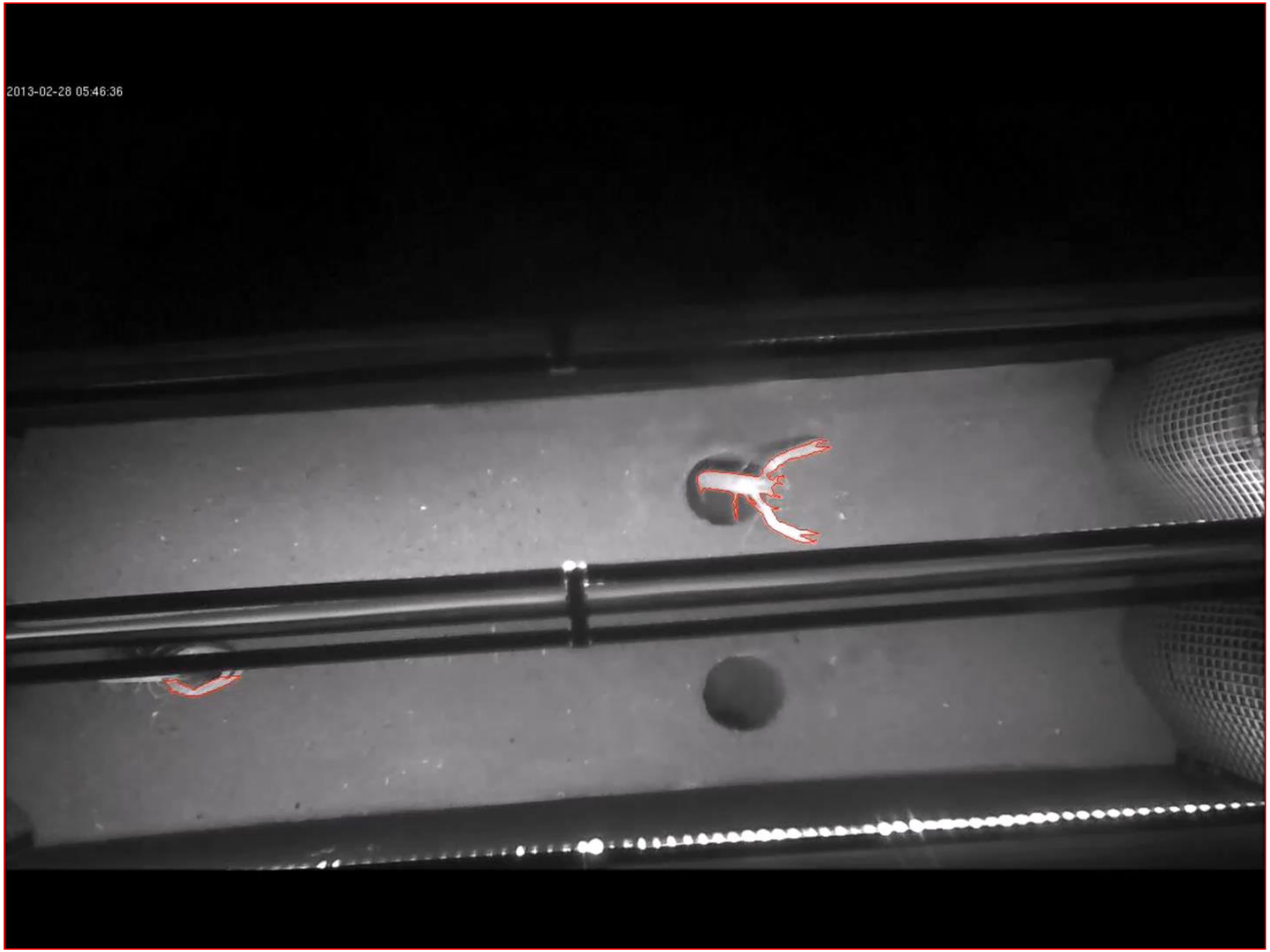
FIELD



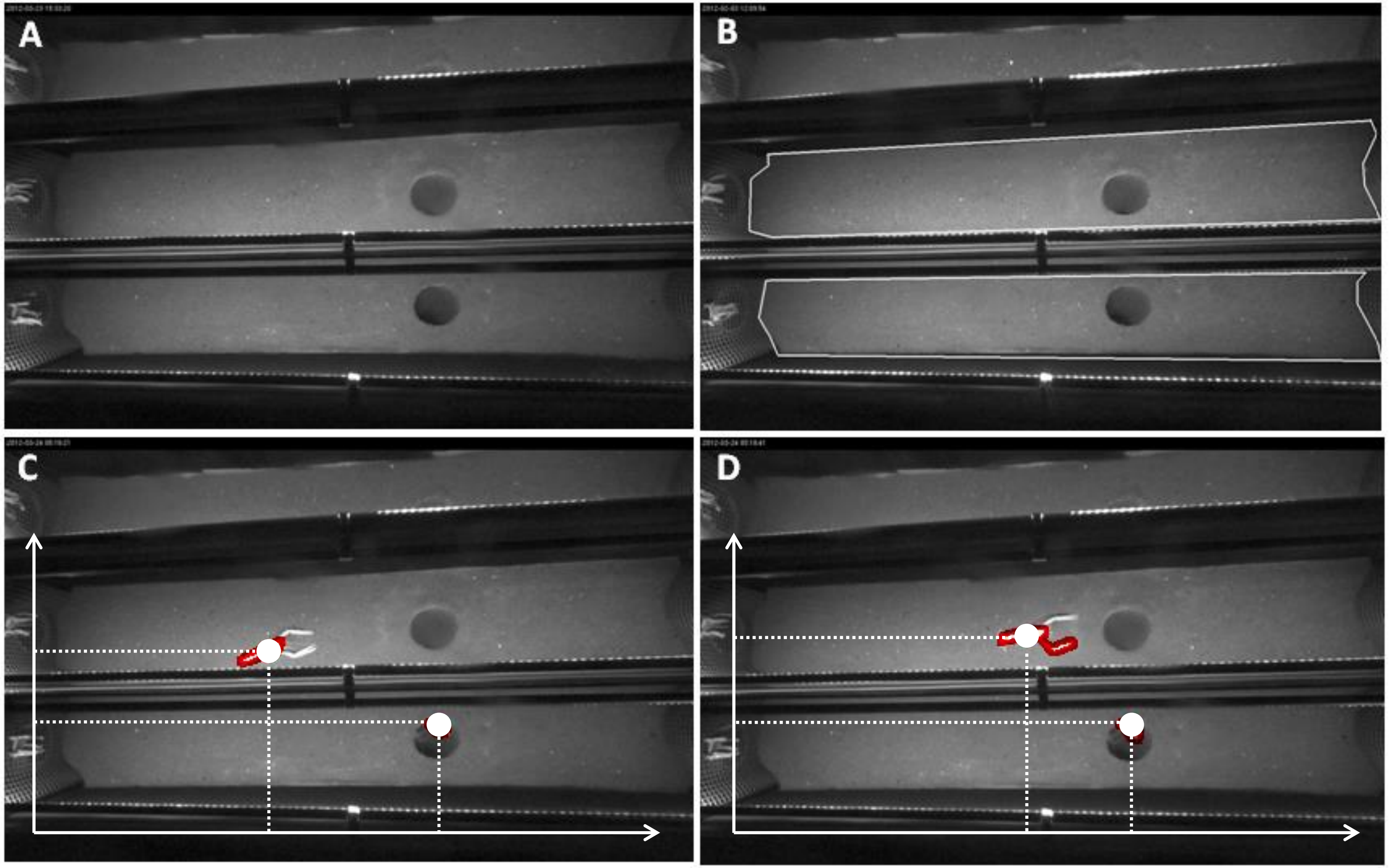
LABORATORY

Sbragaglia, Aguzzi et. al. 2013. JEMBE. 446 177-185

Automated video imaging on time-lapse images (5 s)



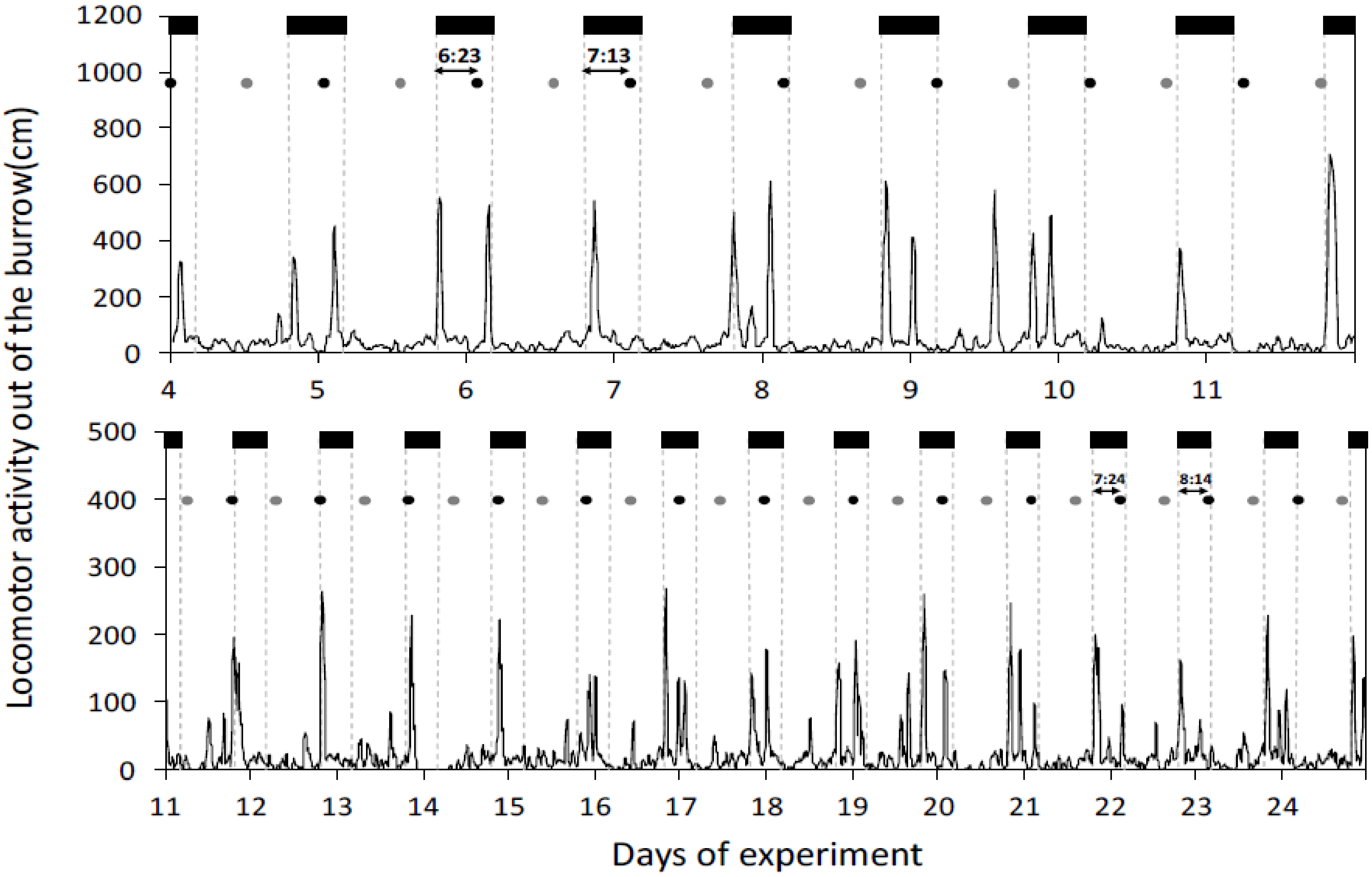
Real-time image processing routine



A. Background picture
B. Regions Of Interest
C. Detection at time n
D. Detection at time n + 1

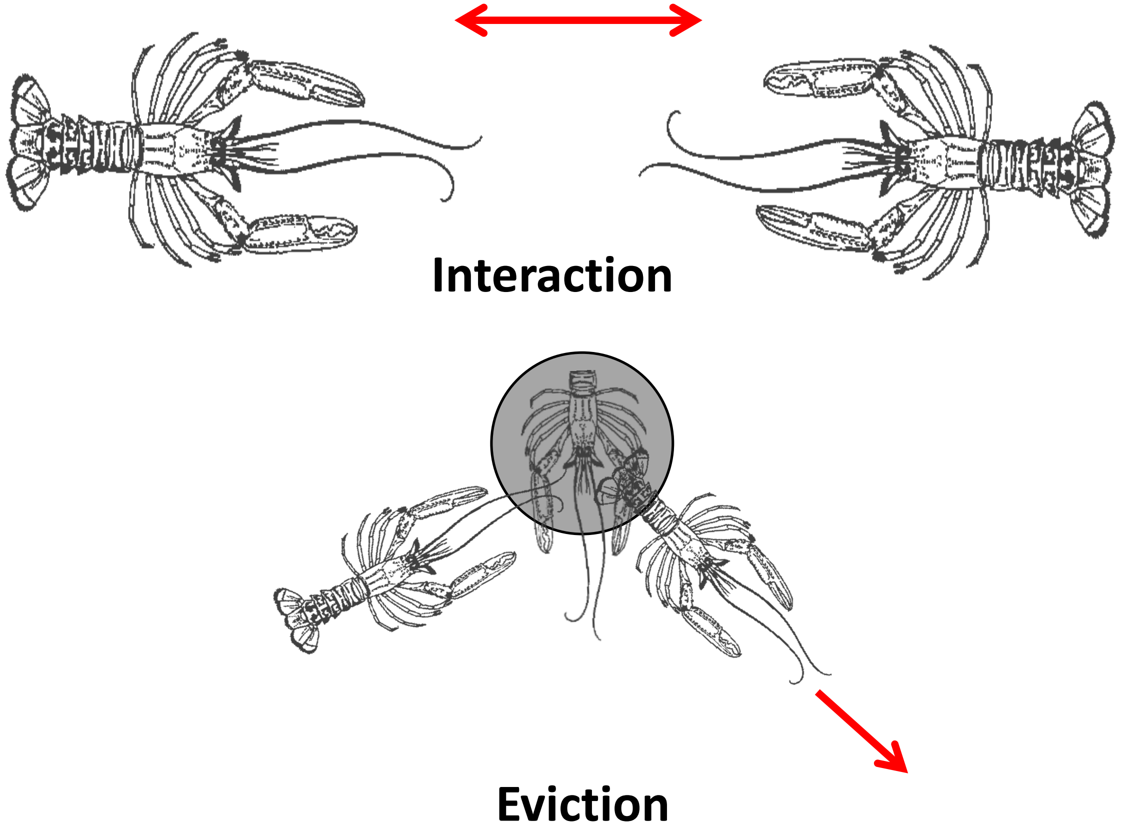
García, Aguzzi J. et al. 2019. J. Visual. Exp. (JoVE). In Press.

Deep tidal flows can affect BUT DO NOT ALTER burrow emergence: Animals emerge always at night time (shelf conditions)

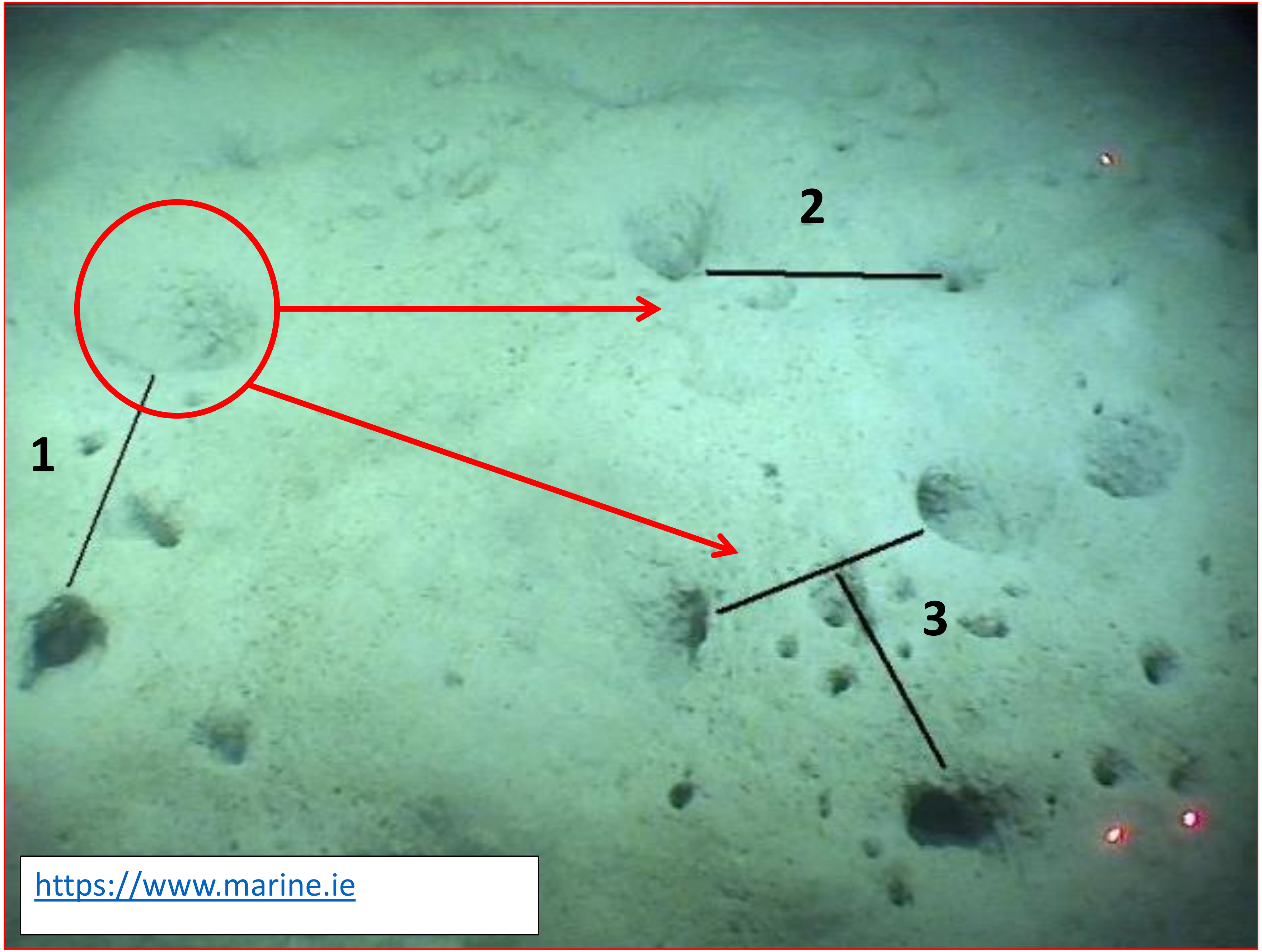


Sbragaglia, Aguzzi et. al. 2013. JEMBE. 446 177-185

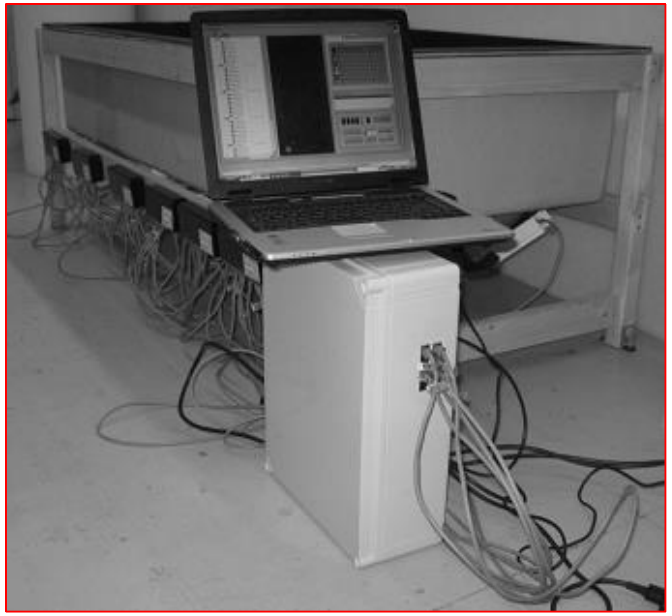
Territoriality over burrows: the hypothesis of the "dominant"

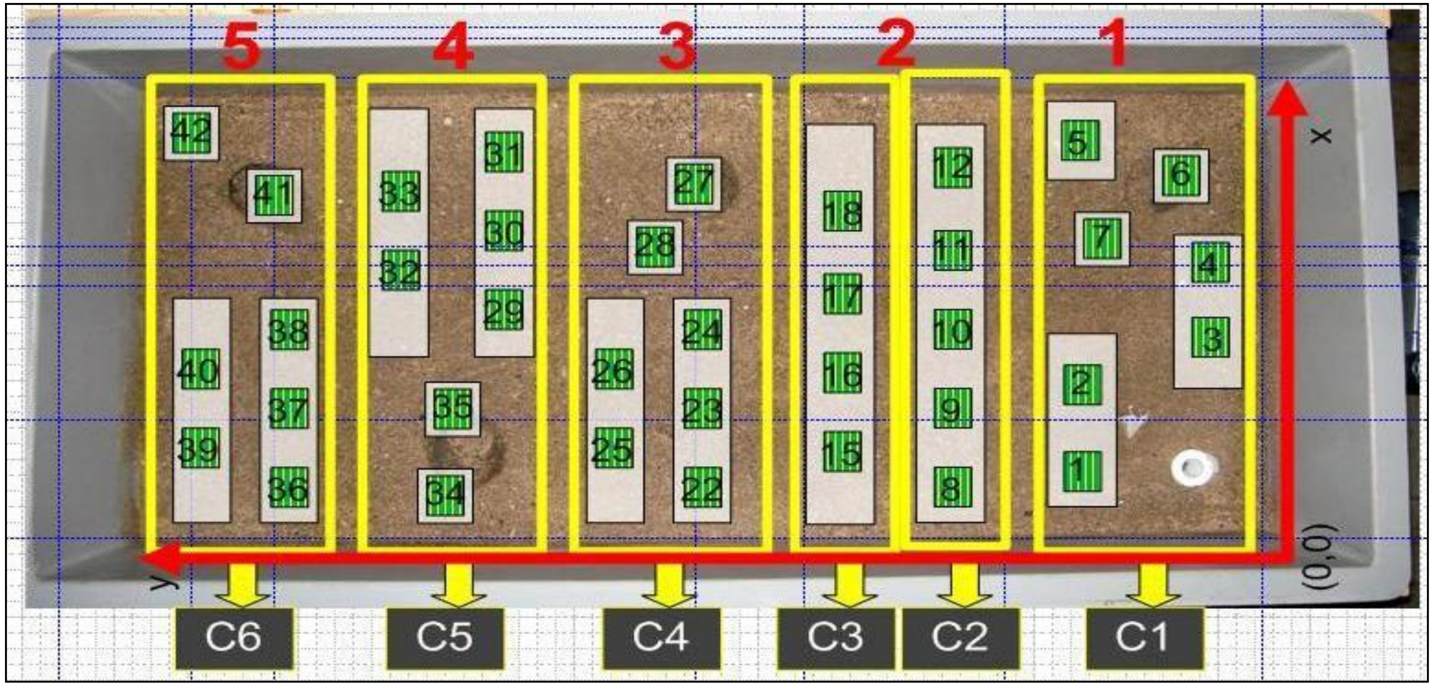


Field burrow high-density assets recreated in mesocosm experiments

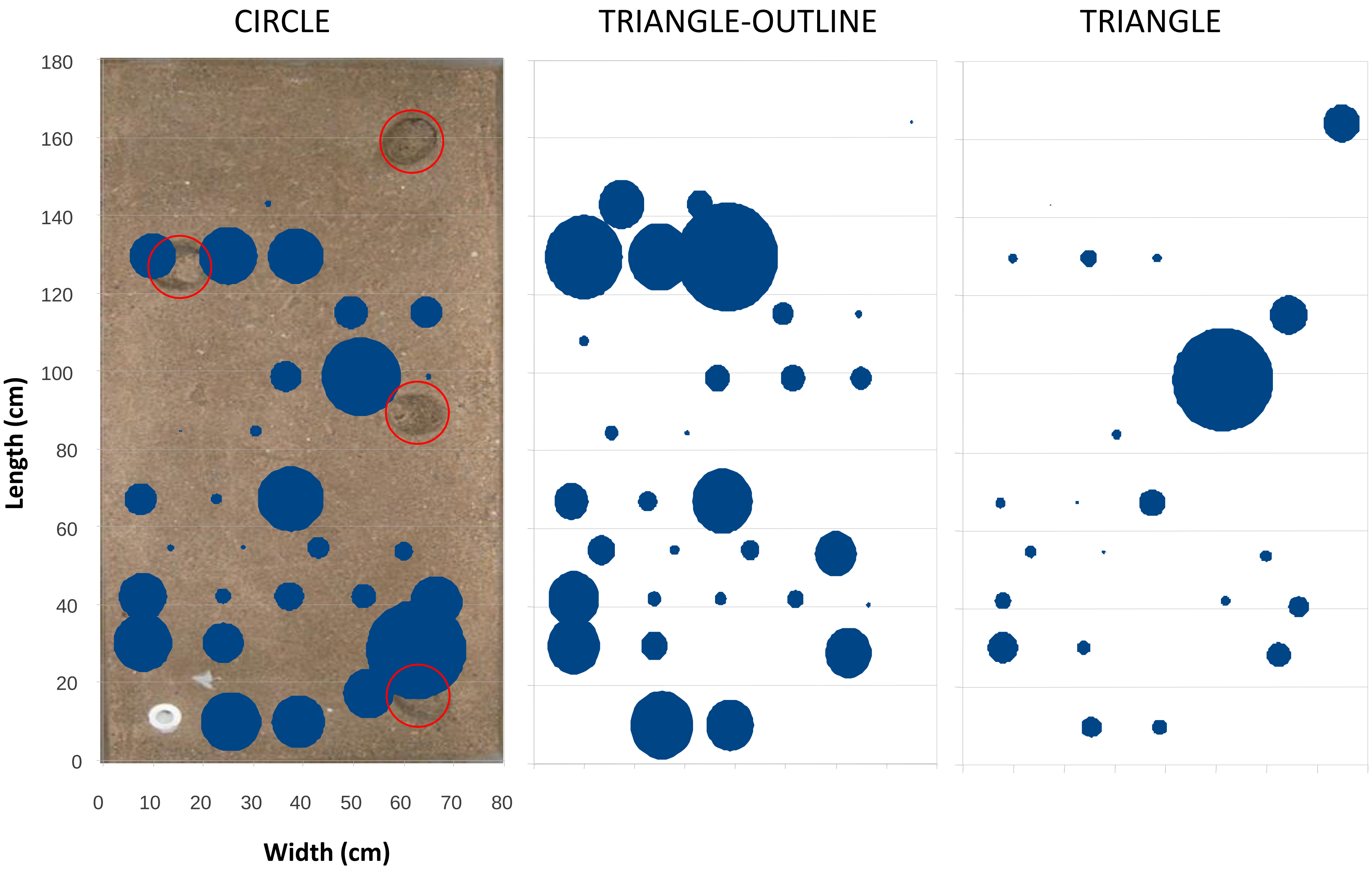


Social interactions as modulators of burrow emergence/catch availability





Animals display a differential spatial occupation in relation to burrows, as result of their social aggressive interactions

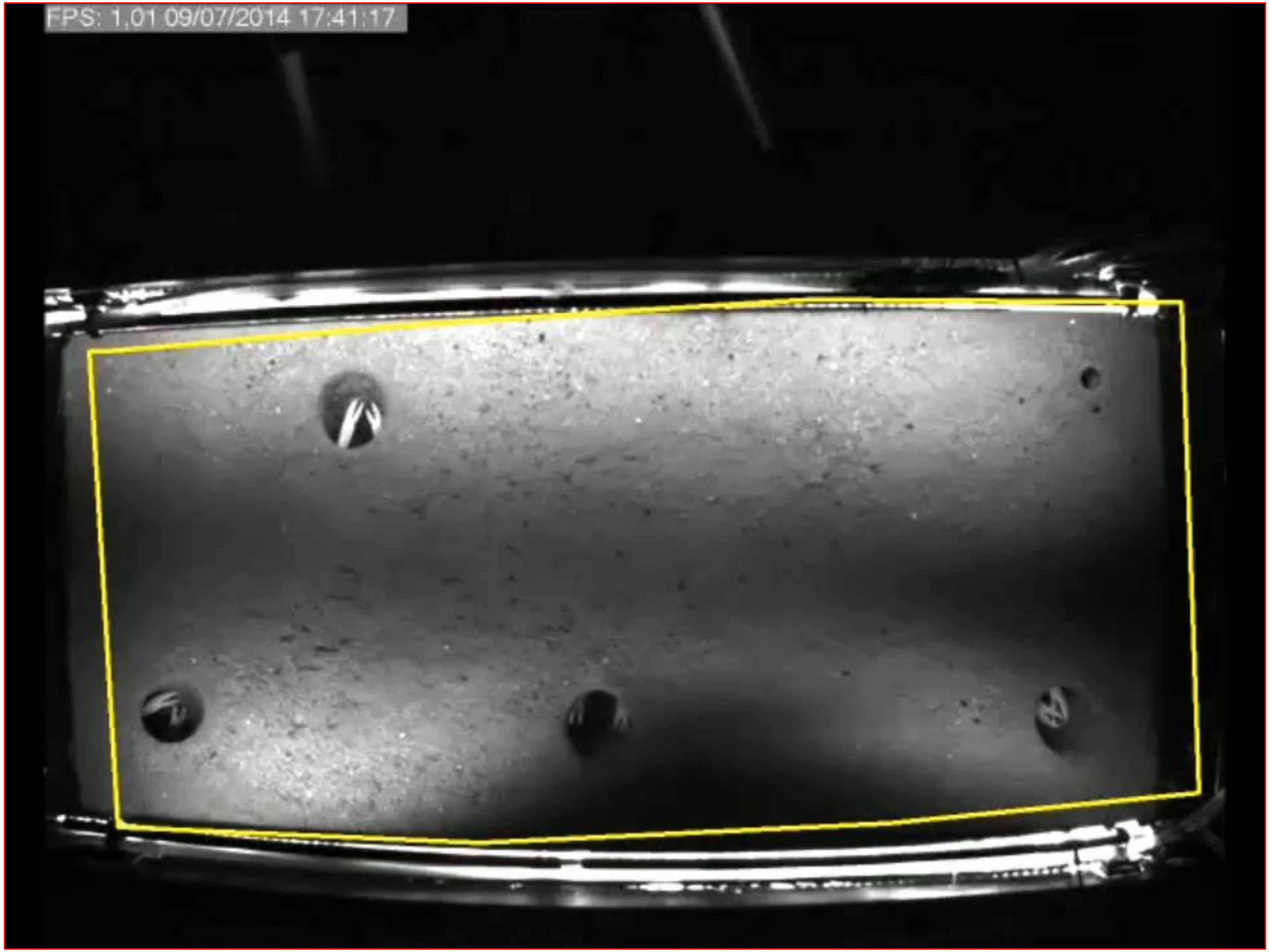


Aguzzi et al., 2011. Sensors-Basel 11: 9532-9548


Circle
Holed Circle
Triangle
Holed Triangle
FPS: 1,00 12/02/2014 23:21:18

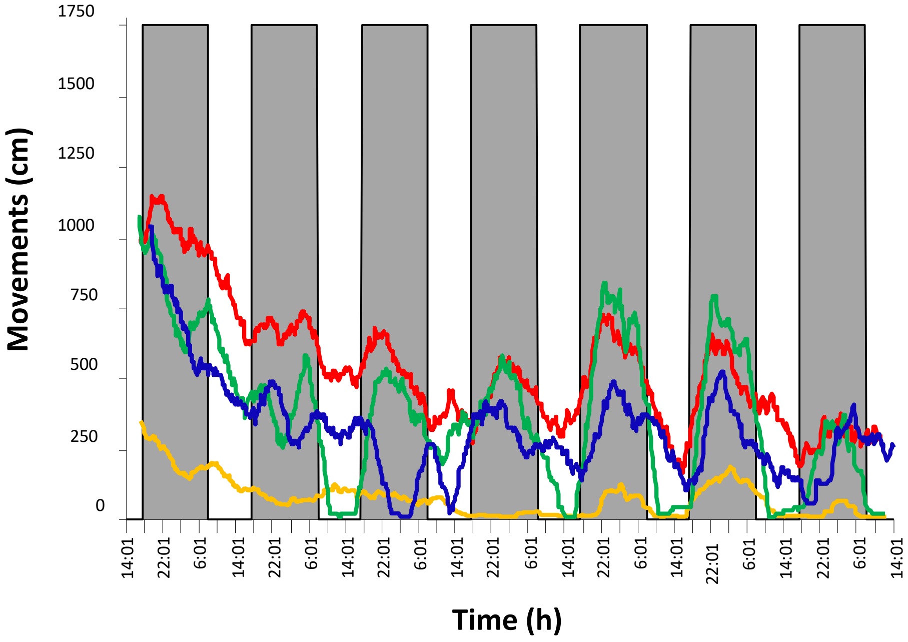
Time-lapse (5 s) image acquisition under day (blue) and night (IR) conditions

Video-tracking technology to monitor a group of individuals



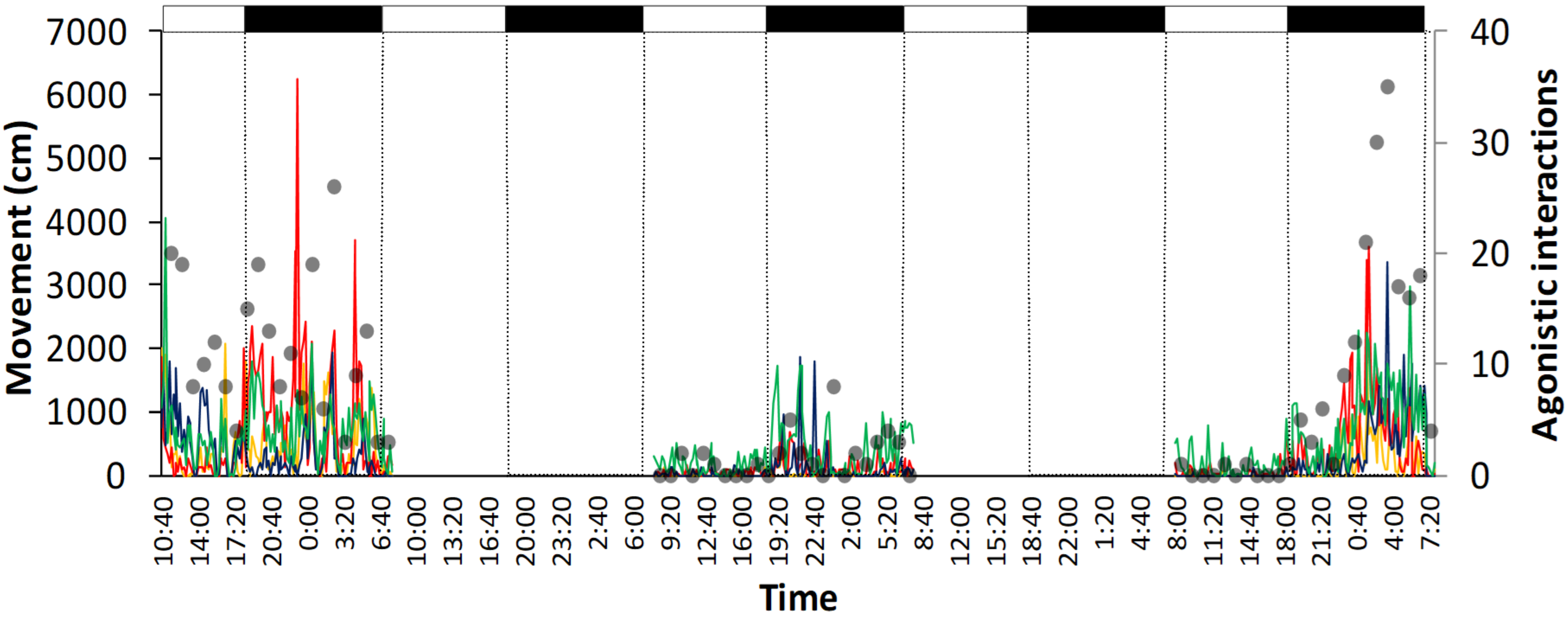
Sbragaglia, Aguzzi et al., 2018. J. Exp. Biol. 220: 4624-4633

Tracking outputs



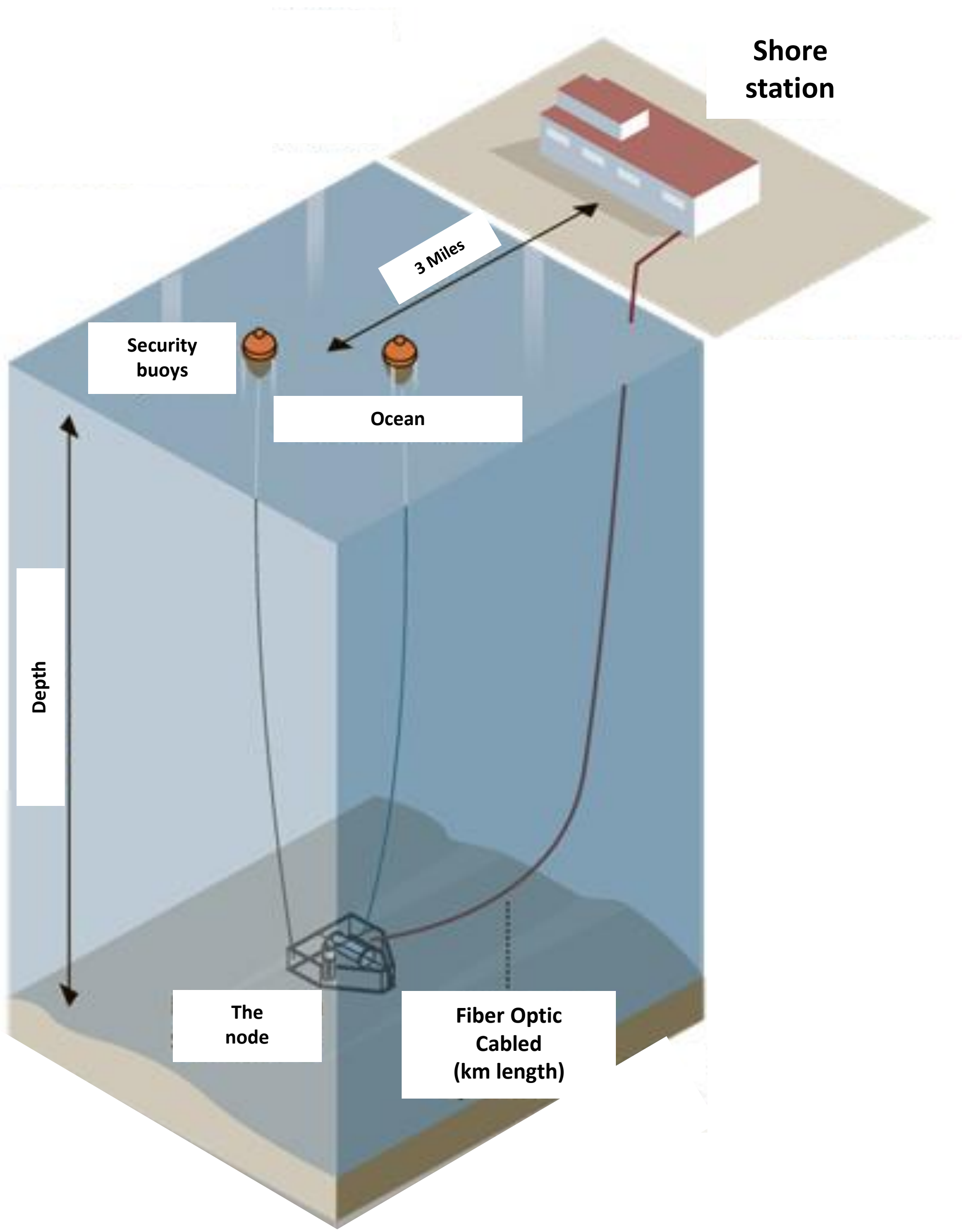
Sbragaglia, Aguzzi et al., 2018. J. Exp. Biol. 220: 4624-4633

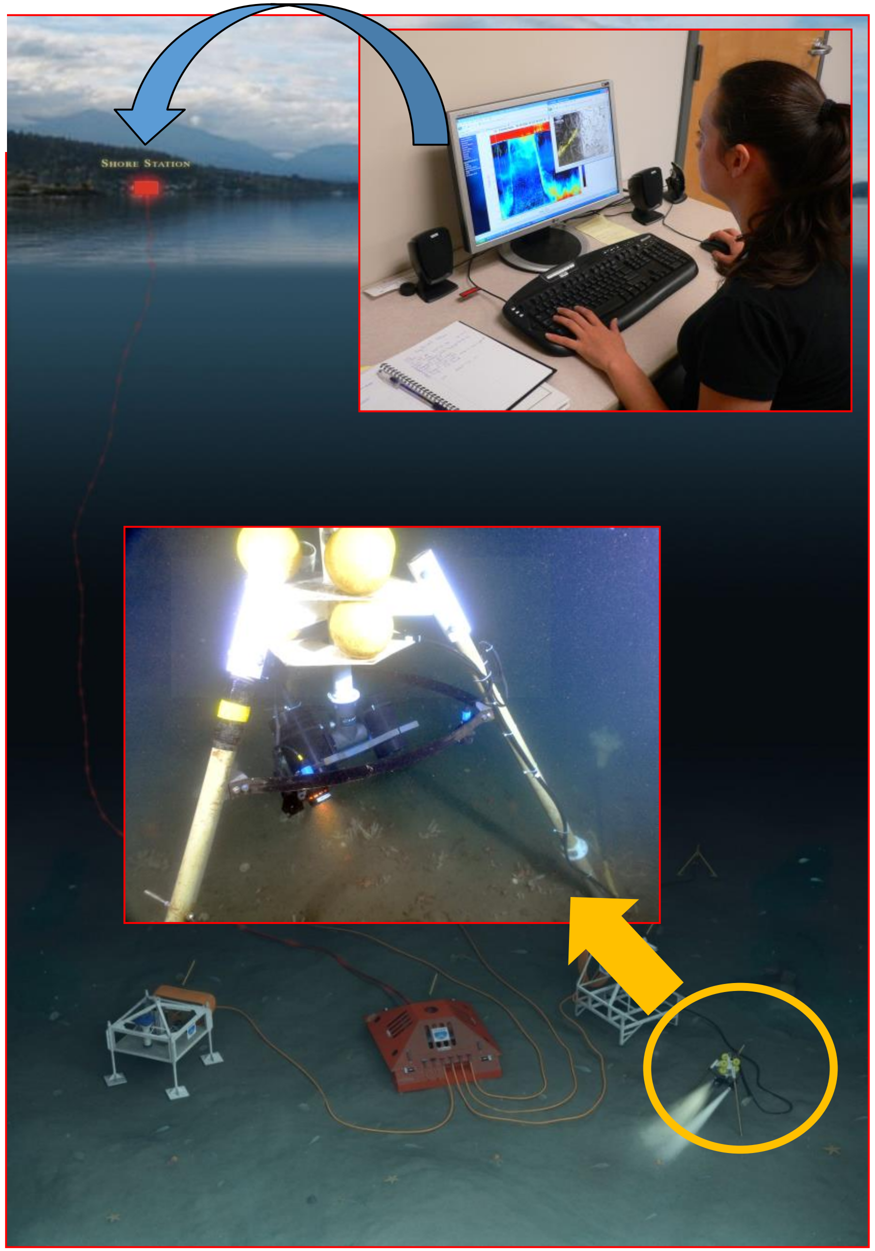
Locomotor activity out of the burrow and agonistic interactions of 4 lobsters (different coloured lines) at day 1, 3, and 5. The grey circles are the number of agonistic interactions



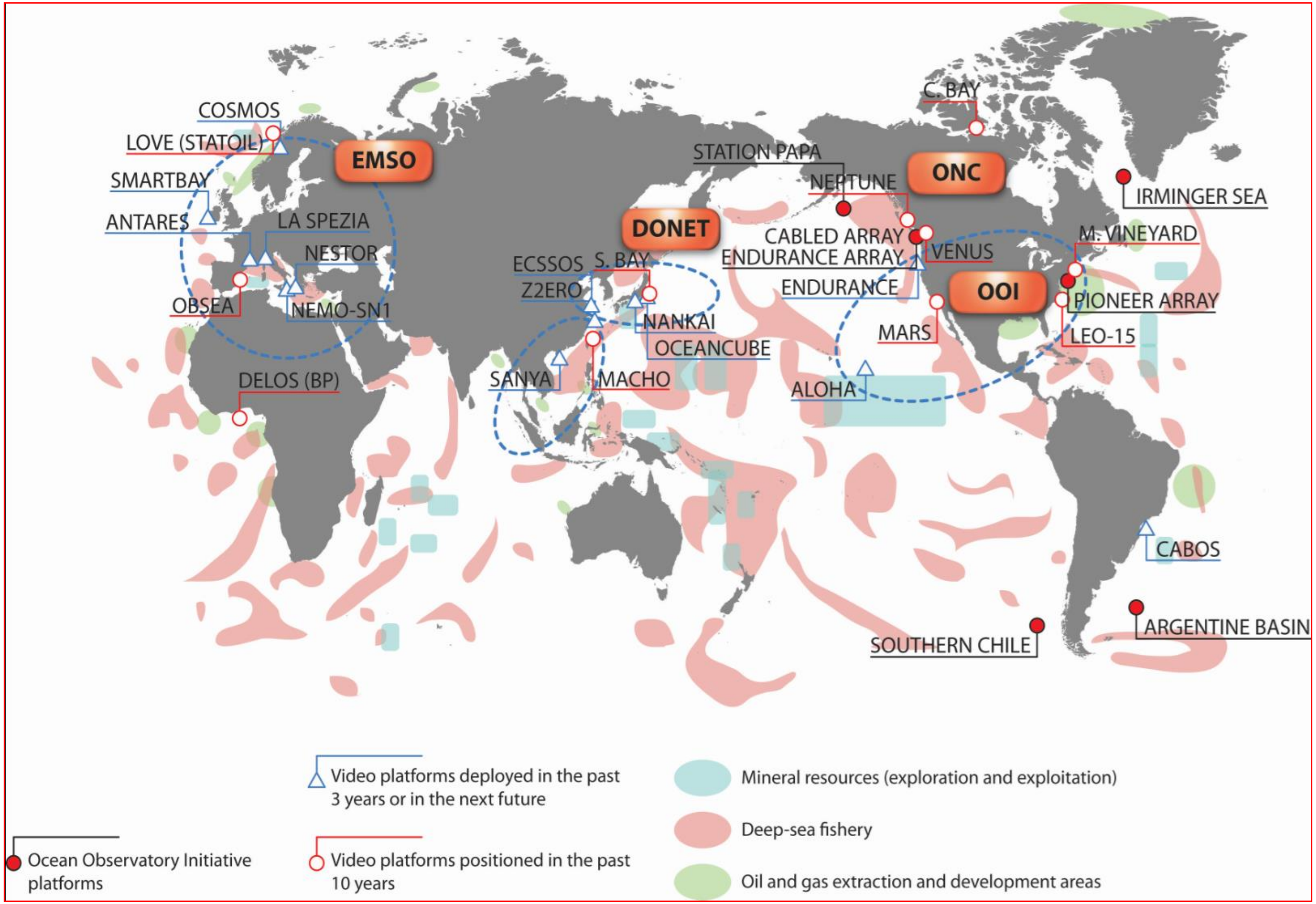
Sbragaglia, Aguzzi et al., 2018. J. Exp. Biol. 220: 4624-4633

Cabled observatories as a new generation of platforms for ecological monitoring





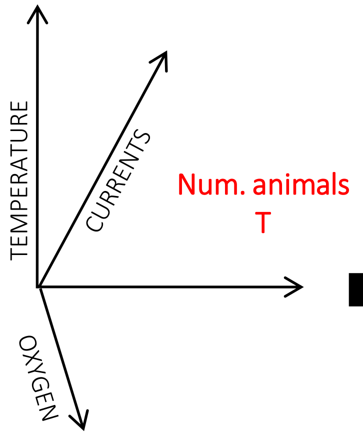
Major networks in impacted areas worldwide

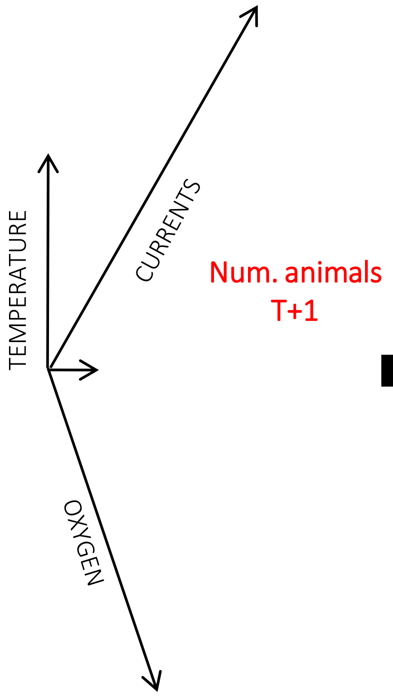


Danovaro, Aguzzi et al. 2017. Science 355: 452-454

Temporally extensive multiparametric data banks

In situ definition of the Hutchinson Niche (1957)



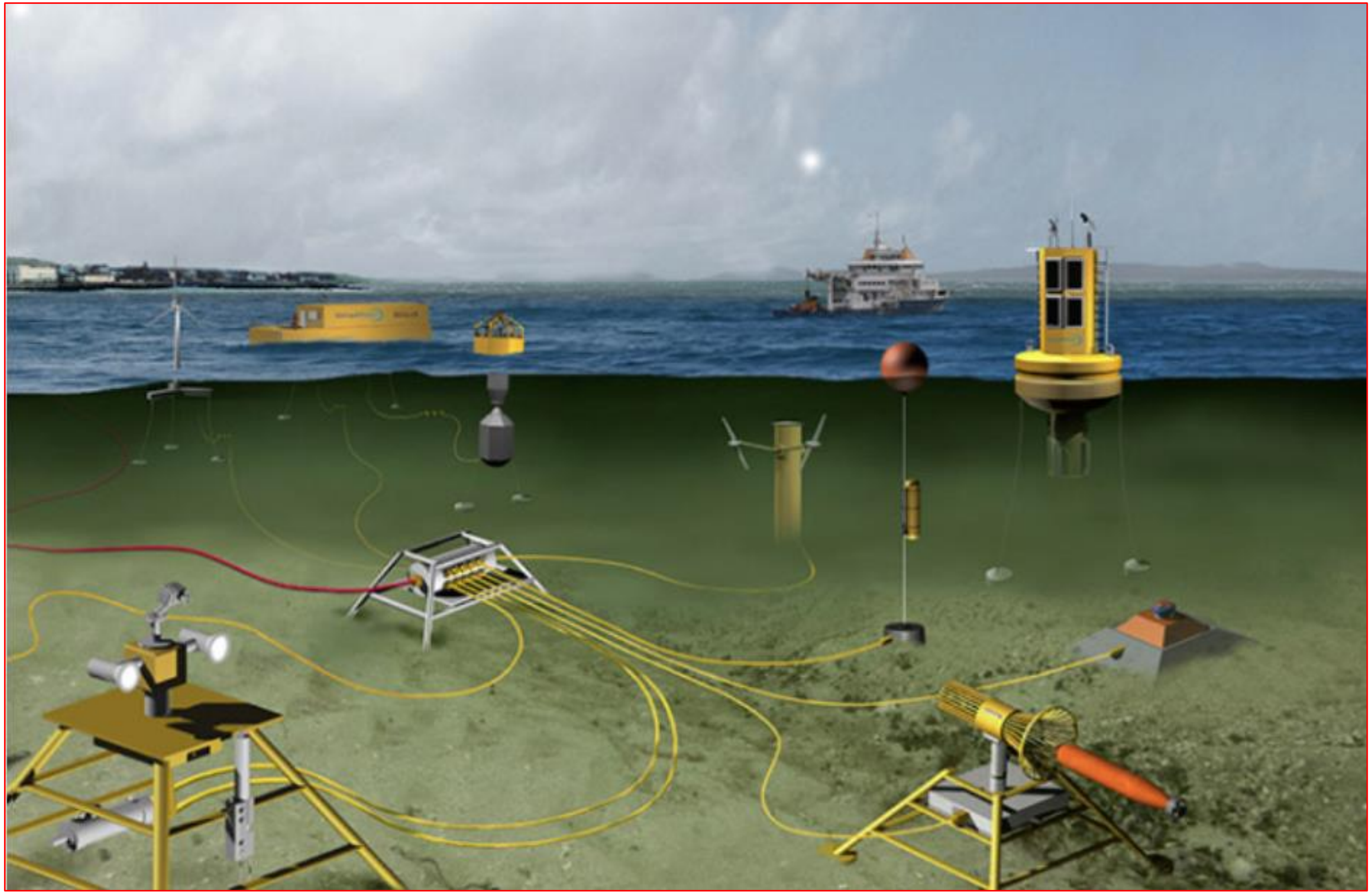


Cause-effect relationship between the environmental control and the species response (and the effects on "perceived community composition")

Advantage: Getting closer to the analitic power of land and coastal ecology
Disadvantage: Too local data-por ecological representation power

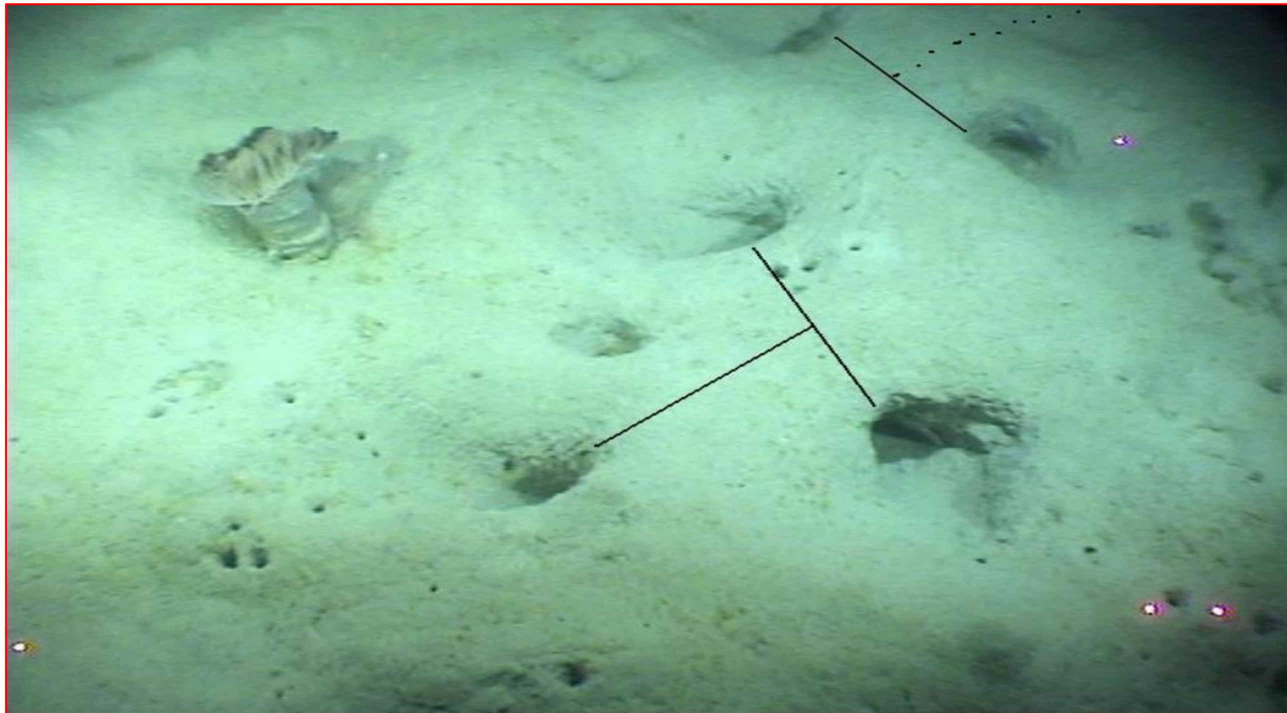
Aguzzi et al. 2015. Rev. Fish Bio. Fisher.

Cabled observatories sustaining a science of services: for the production of ancillary data for stock assessment



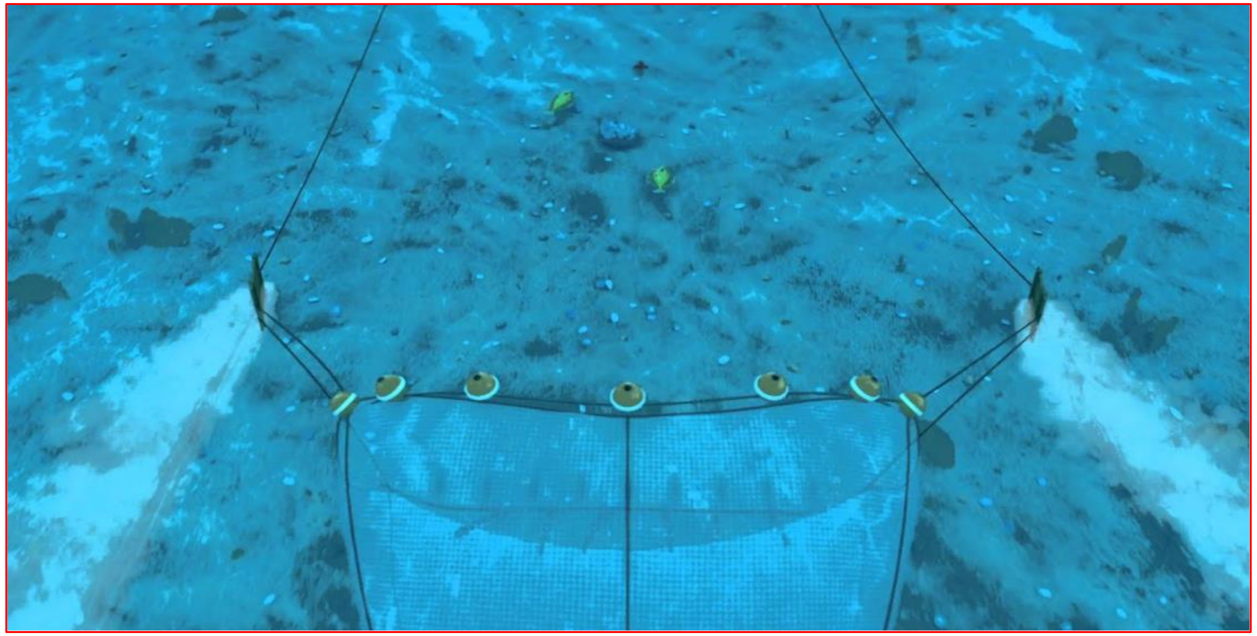
Norway lobster (*Nephrops norvegicus*) population dynamics from automated video-monitoring at SmartBay cabled underwater observatory (SmartLobster). European Multidisciplinary Seafloor and water column Observations (EMSO)-LINK Trans National Access (TNA). 2019-2021. PI: J. Aguzzi

Stock assessment tools for *Nephrops norvegicus* (UWTV)



Collect data and information needed to validate or improve the assumptions made in the UWTV assessment methodology

The ecological tuning of the stock assessment equation ”1 burrow-1 animal”



Burrow persistence: death / **opportunistic occupation** (other species)

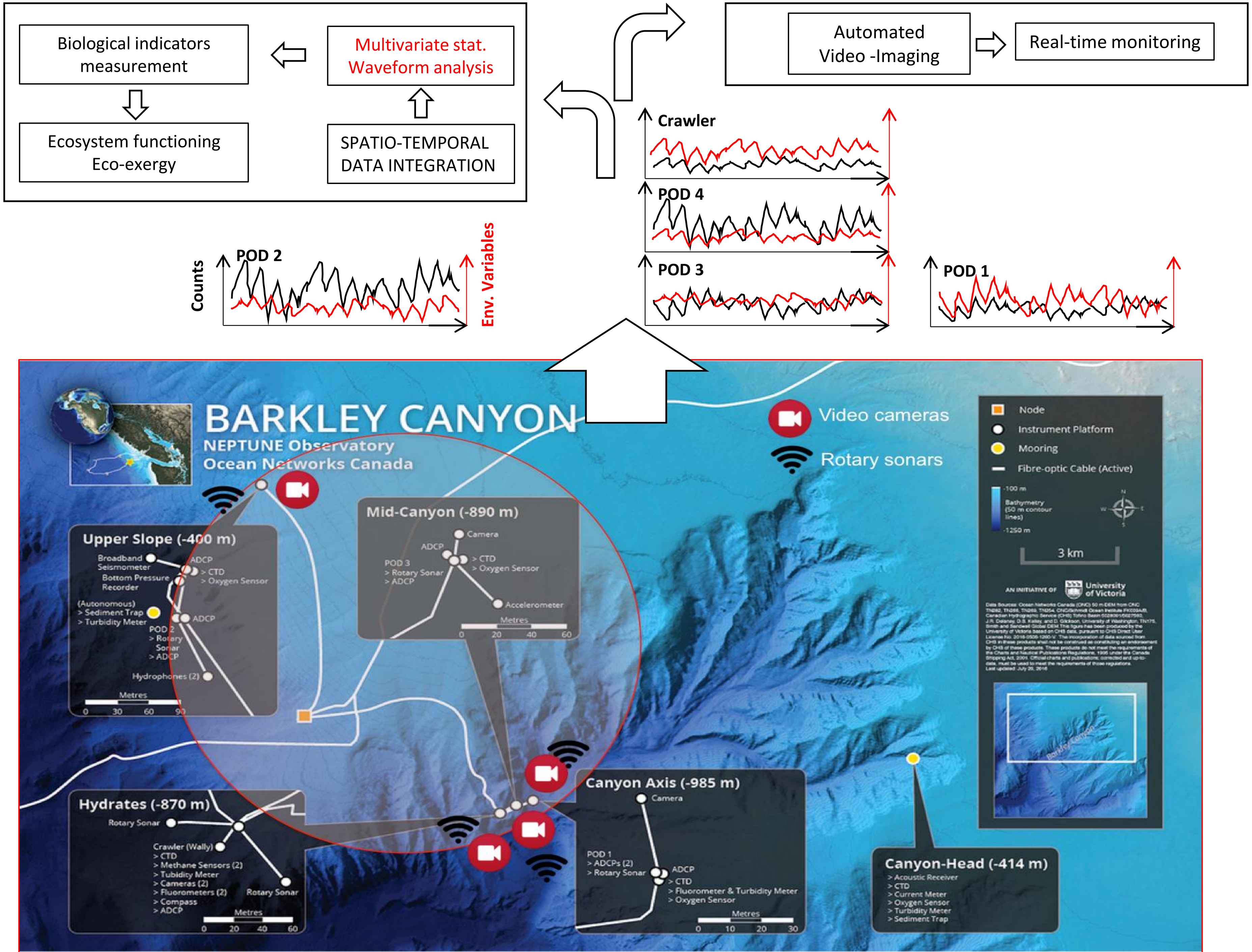
Emergence patterns: **Rhythms variation** at different time scales (tidal, day and seasons)

Emergence duration: **hunger state** (predation-scavenging) / interspecific interactions (territoriality)

Emergence suppression: environmental noise (?) / **predators presence**

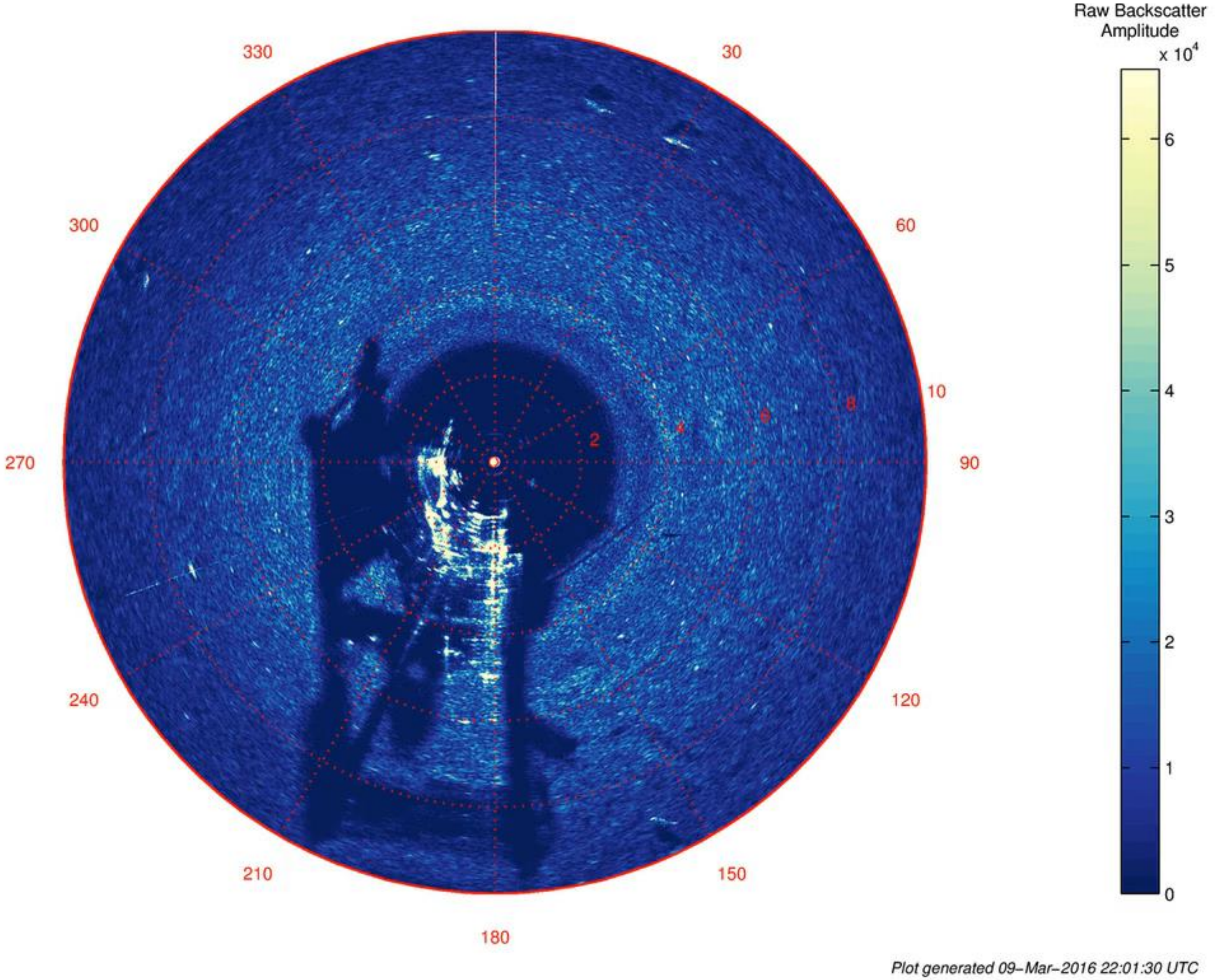
An example of video-monitoring of the Norway lobster

ONC platforms (400-2500 m depth) also produce ancillary data for the stock assessment of sablefish (*Anoplopoma fimbria*)

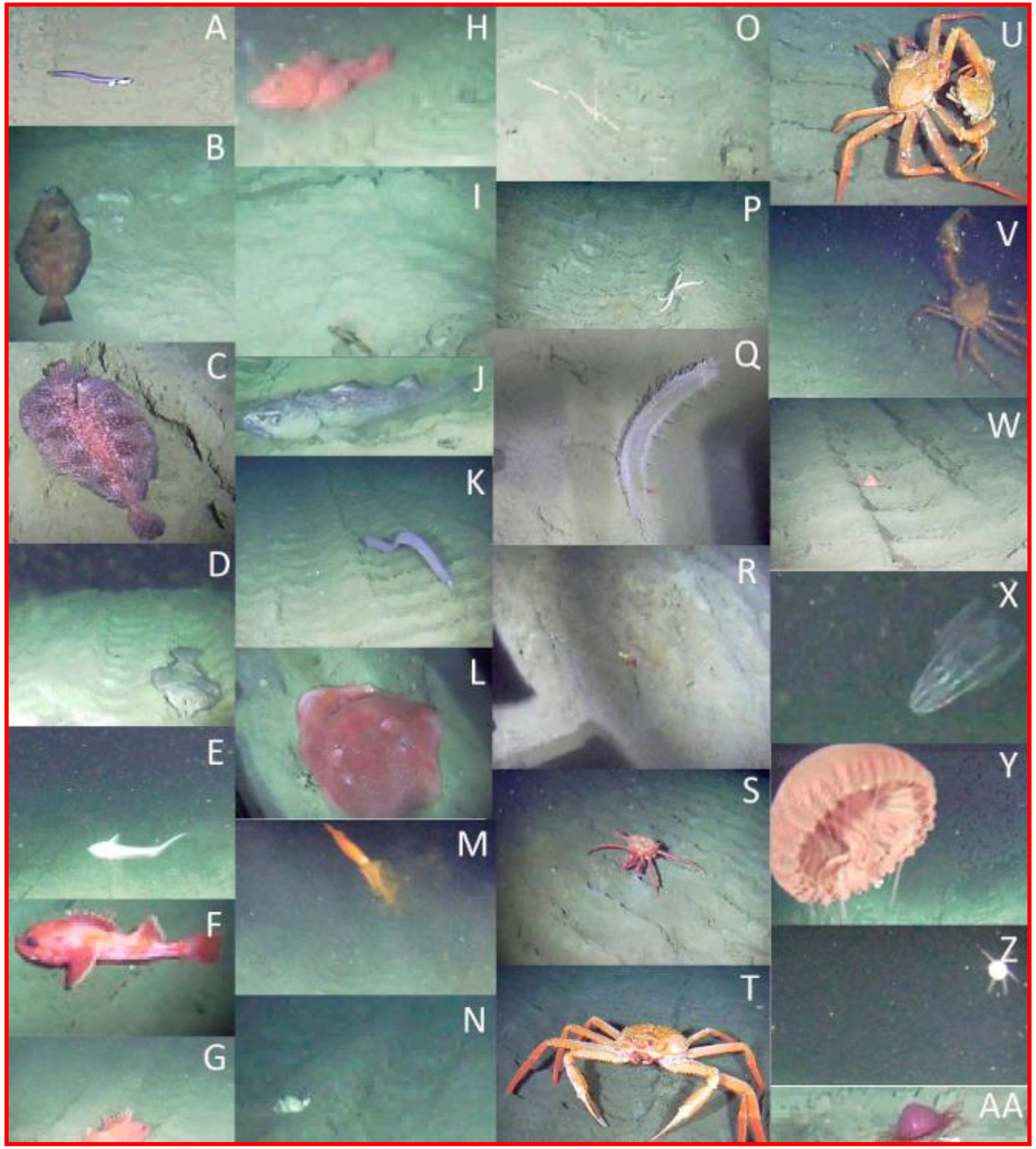

Biological indicators measurement
Multivariate stat. Waveform analysis
Ecosystem functioning Eco-exergy
SPATIO-TEMPORAL DATA INTEGRATION
Automated Video -Imaging
Real-time monitoring
Crawler
POD 4
POD 3
POD 2
POD 1
Counts
Env. Variables
BARKLEY CANYON
NEPTUNE Observatory
Ocean Networks Canada
Video cameras
Rotary sonars
Node
Instrument Platform
Mooring
Fibre-optic Cable (Active)
3 km
Upper Slope (-400 m)
Broadband Seismometer
Bottom Pressure Recorder
(Autonomous)
> Sediment Trap
> Turbidity Meter
ADCP
> CTD
> Oxygen Sensor
ADCP
POD 2
> Rotary Sonar
> ADCP
Hydrophones (2)
Metres
0 30 60 90
Mid-Canyon (-890 m)
Camera
ADCP
POD 3
> Rotary Sonar
> ADCP
> CTD
> Oxygen Sensor
Accelerometer
Metres
0 20 40 60
Hydrates (-870 m)
Rotary Sonar
Crawler (Wally)
> CTD
> Methane Sensors (2)
> Tubidity Meter
> Cameras (2)
> Fluorometers (2)
> Compass
> ADCP
Rotary Sonar
Metres
0 20 40 60
Canyon Axis (-985 m)
Camera
POD 1
> ADCPs (2)
> Rotary Sonar
ADCP
> CTD
> Fluorometer & Turbidity Meter
> Oxygen Sensor
Metres
0 10 20 30
Canyon-Head (-414 m)
> Acoustic Receiver
> CTD
> Current Meter
> Oxygen Sensor
> Turbidity Meter
> Sediment Trap

An example of HD image monitoring on sablefish with a cabled observatory

An example of rotary-sonar (acoustic imaging) monitoring of sablefish and other megafauna



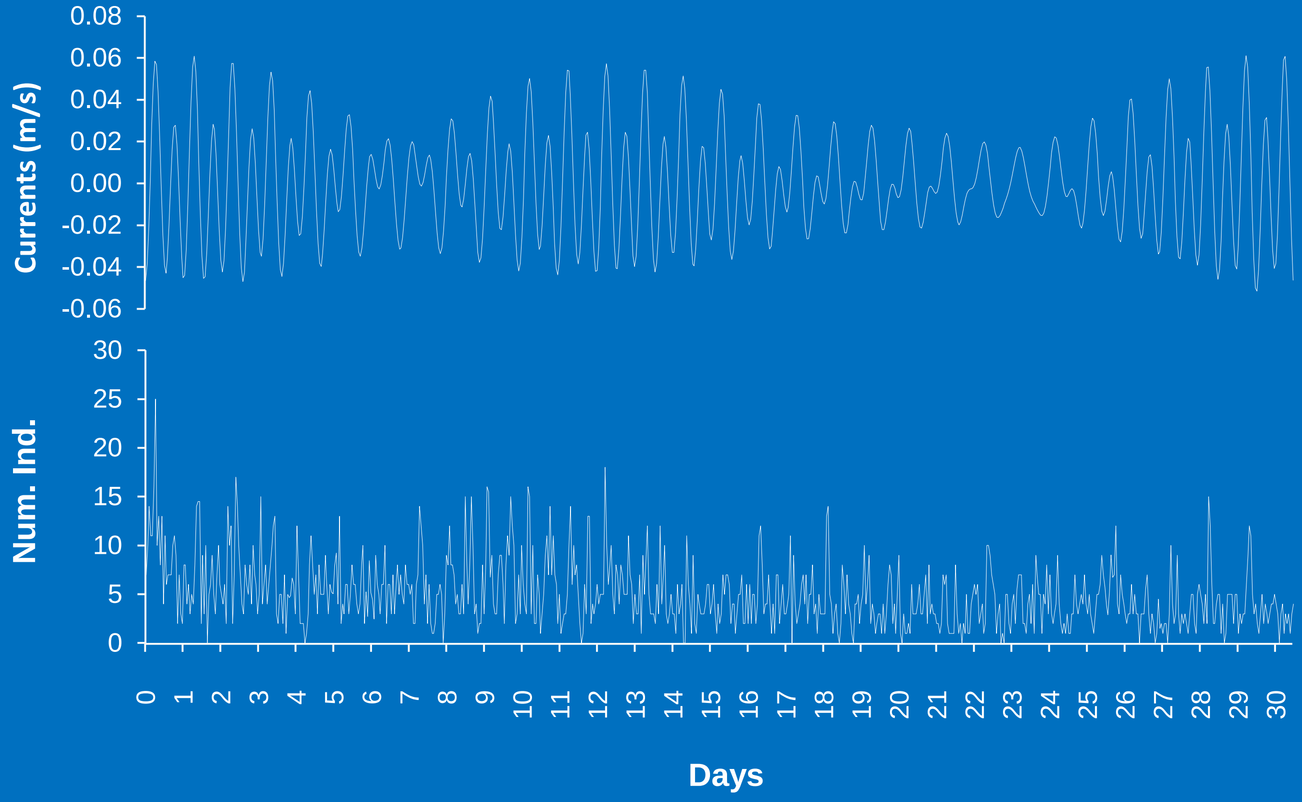
The production of reliable richness data sustains ecosystem-based fishery management approaches



Doya, Aguzzi et al. 2017. PLoS I, 12: e0176917

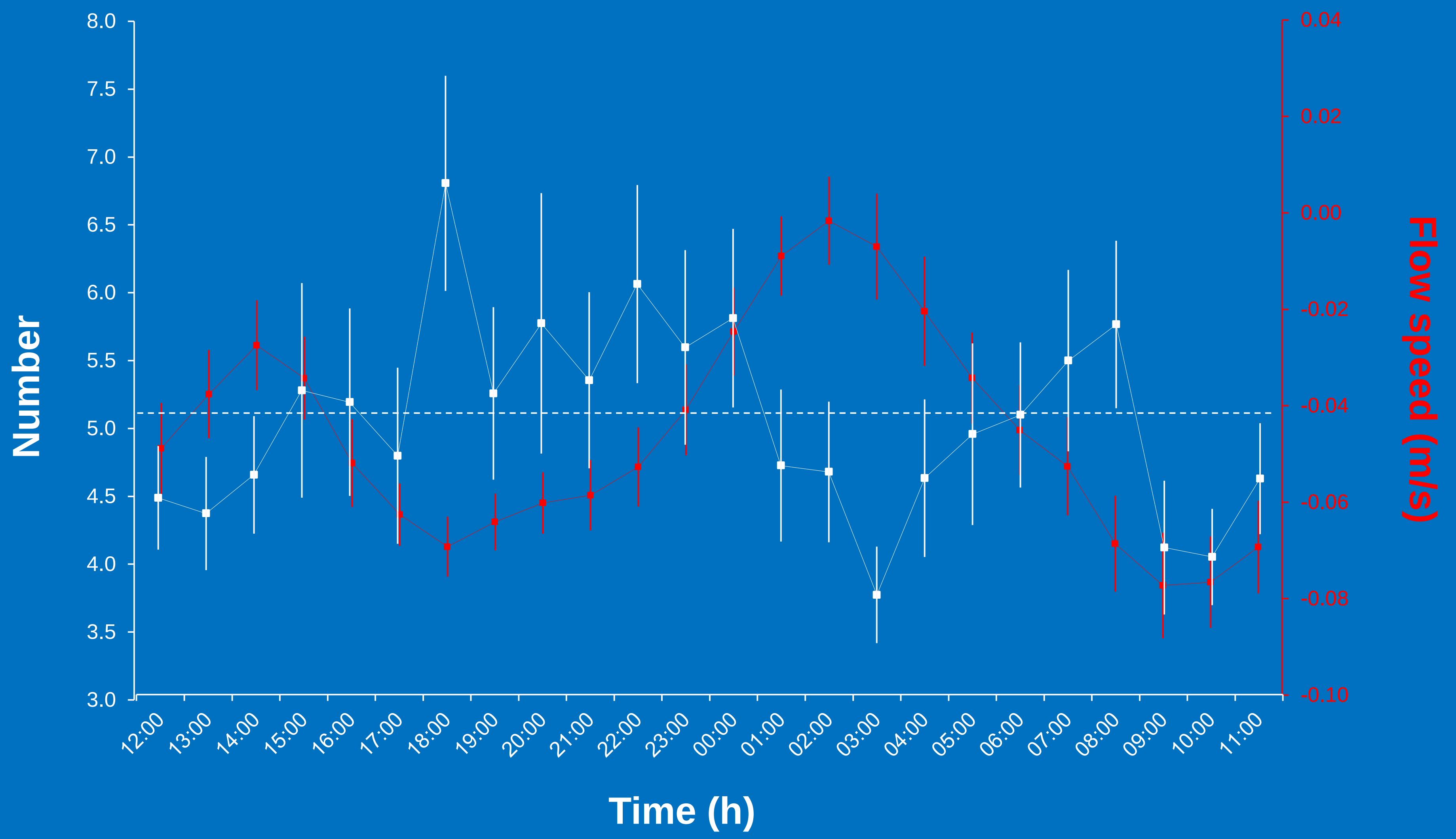
Time-lapse image monitoring to evaluate the impact of behavioral rhythms on demographic indices

[1-month time-lapse photography at 30 min]

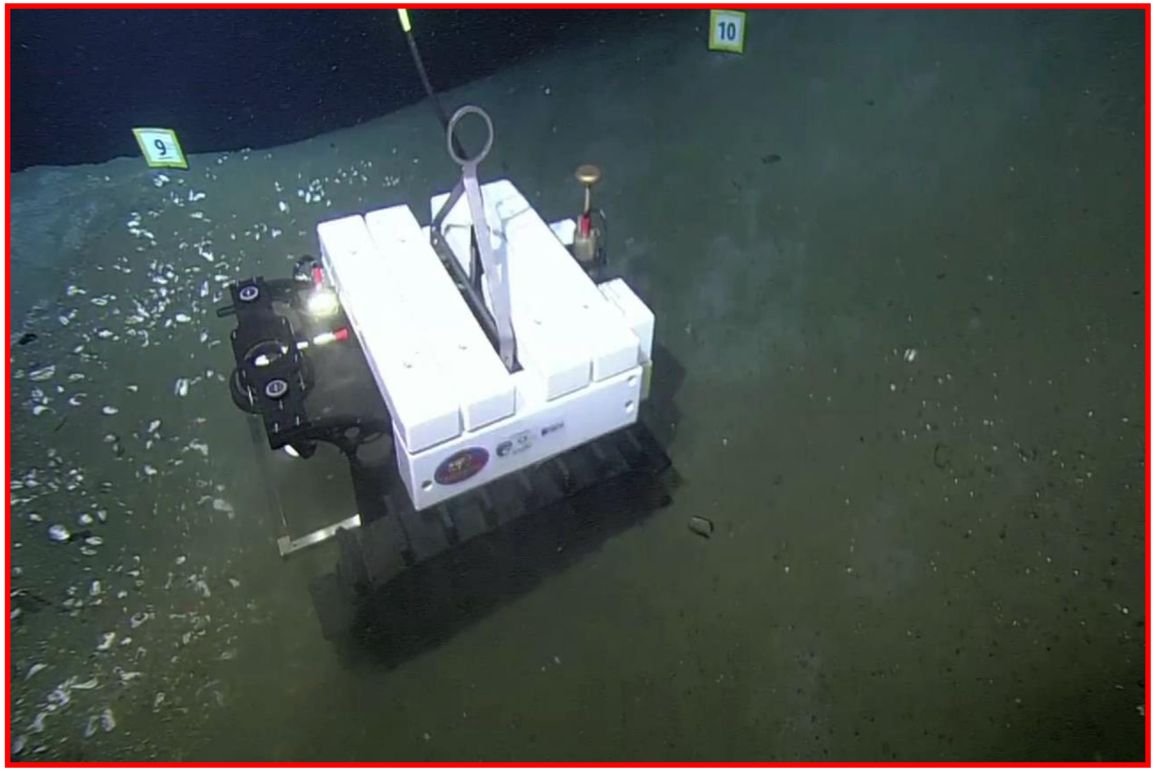


Doya, Aguzzi et al. 2013. J. Mar. Syst. 130: 69-78

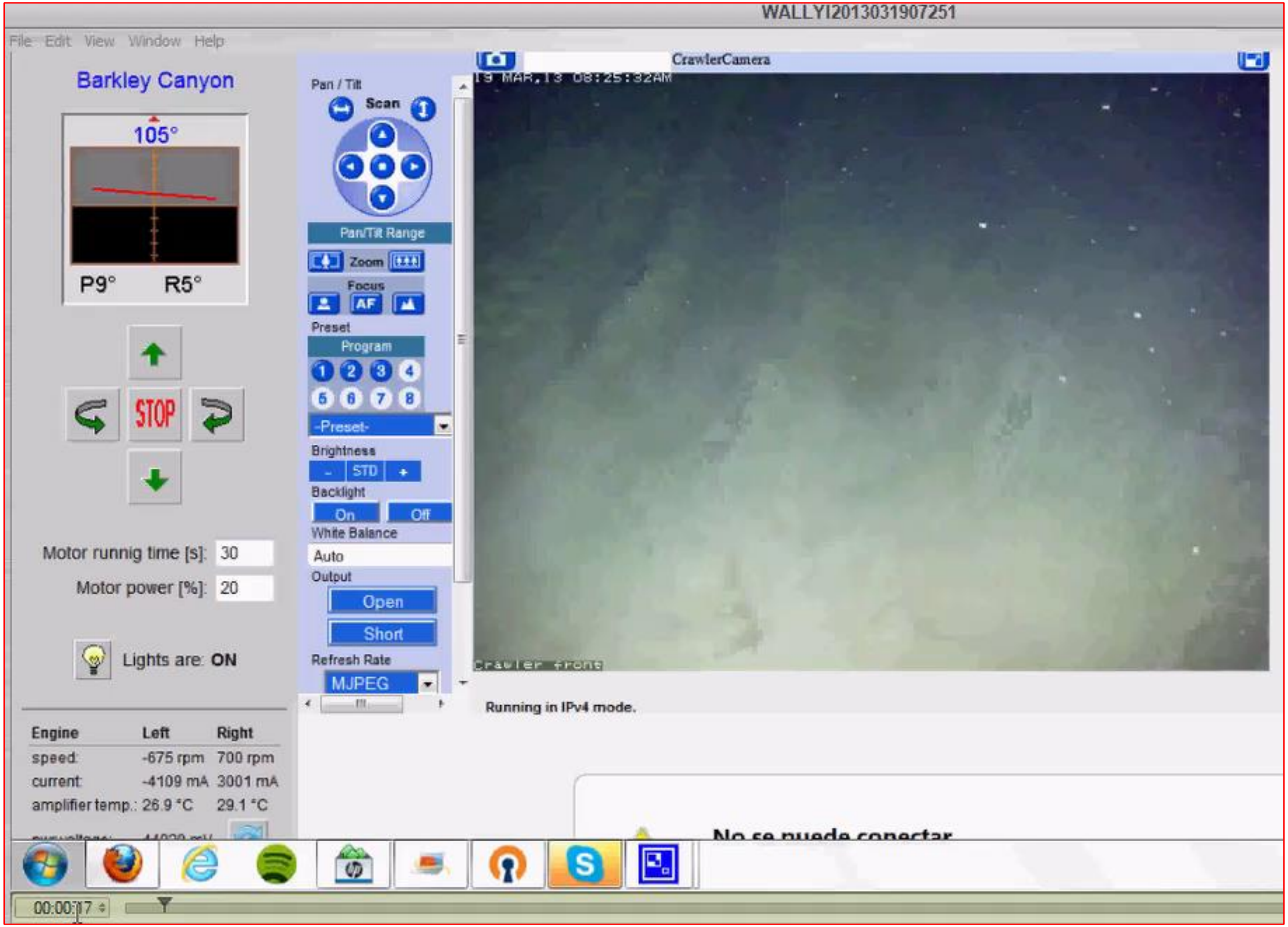
Local counts are affected by internal tides since animals use flows to perform a low-energy budget dispersal



The expansion of monitoring radius to obtain more ecologically-representative data: Crawlers

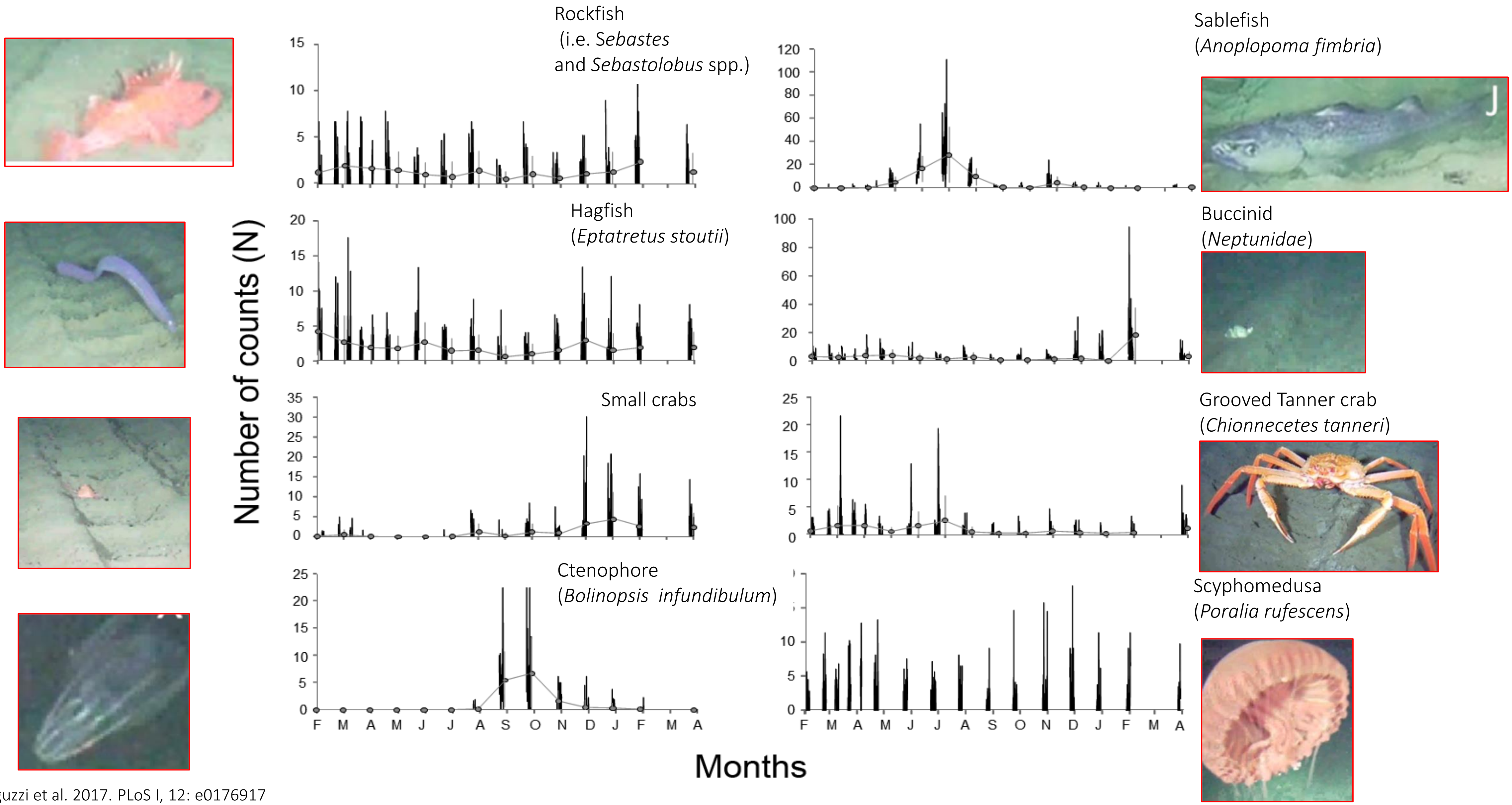


Web applications for driving form anywhere



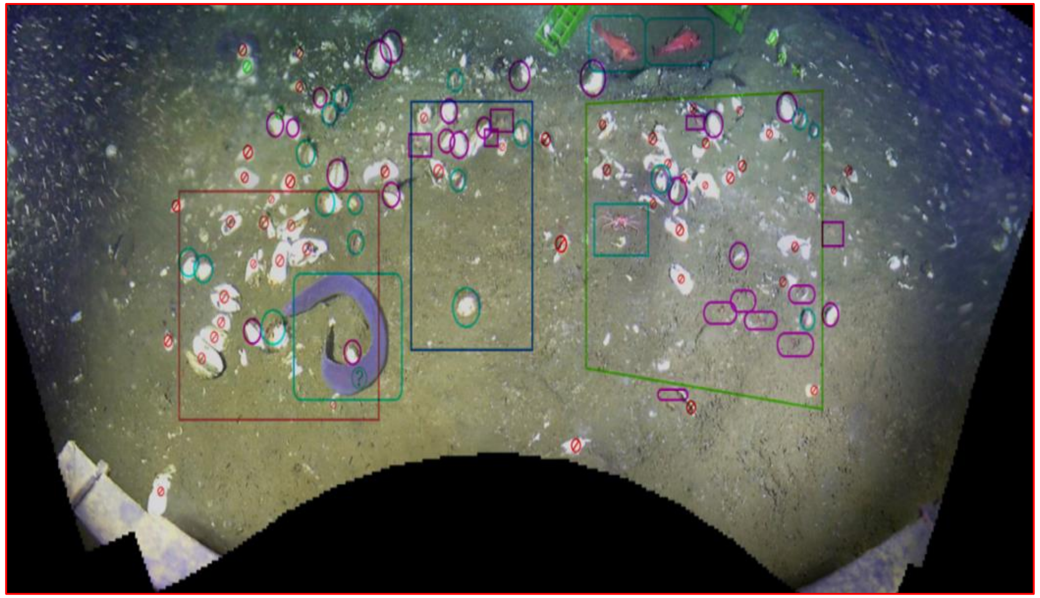
Visual counts time series

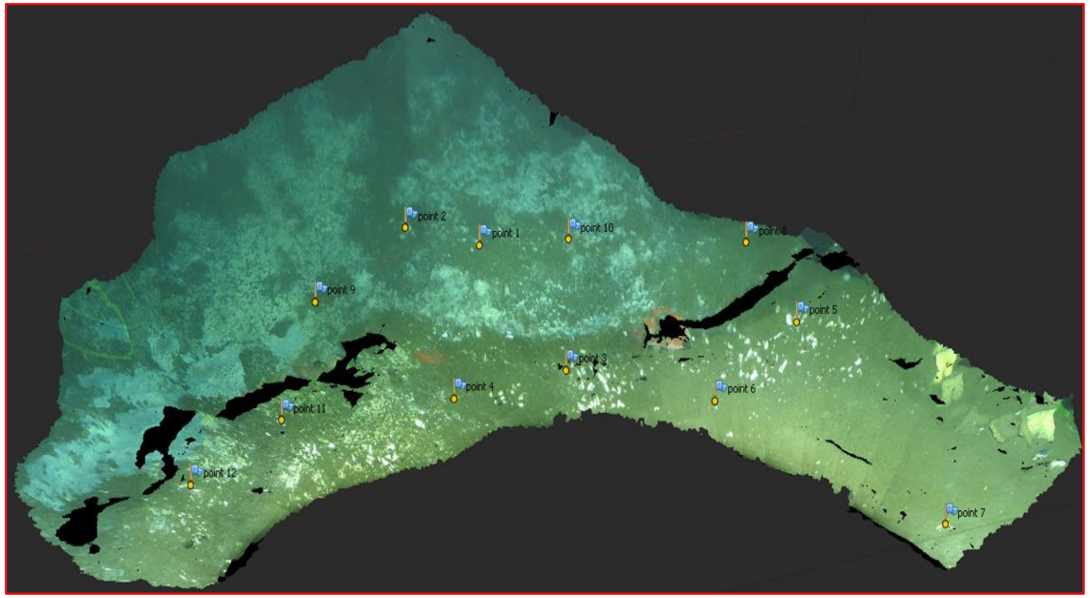
[14th February 2013 to 14th April 2014]

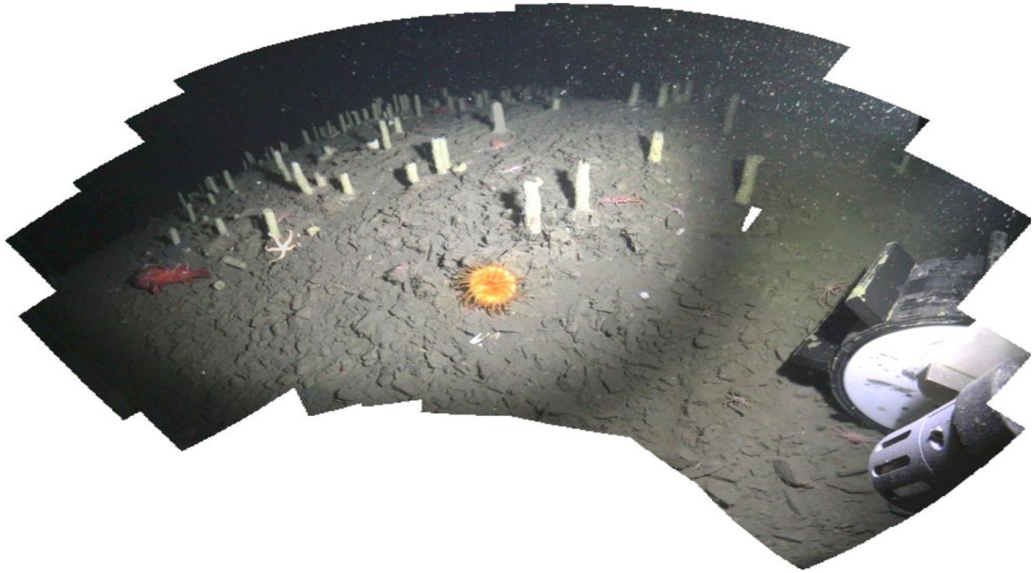


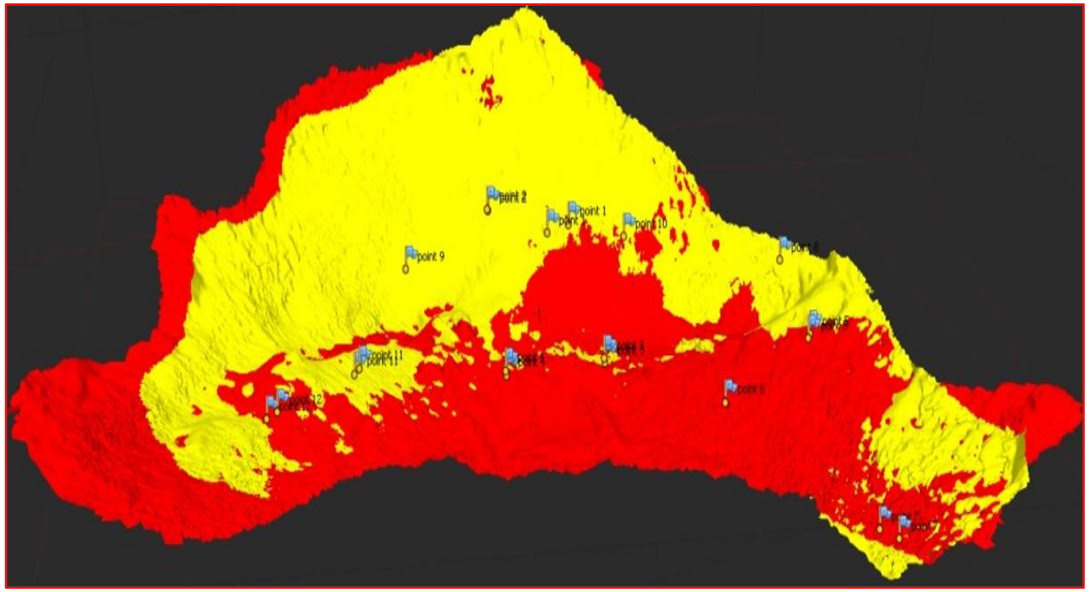
Doya, Aguzzi et al. 2017. PLoS I, 12: e0176917

An example of photo-mosaics



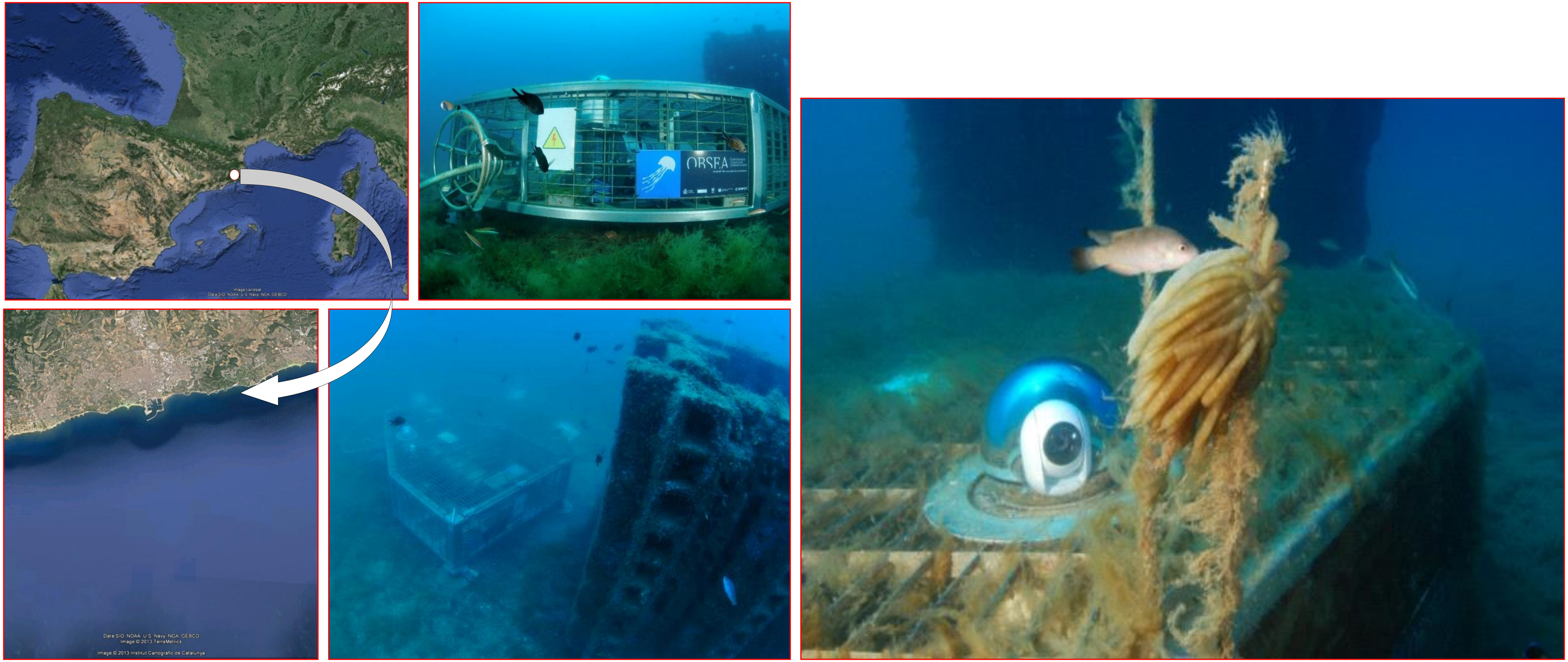






Aguzzi et al. 2019. Frontiers in Ecology and the Environment. Accepted

The Western Mediterranean OBSEA platform (20 m) as testing sites for new technologies and monitoring protocols



Aguzzi et al. 2011. Sensors 11: 5850-5872

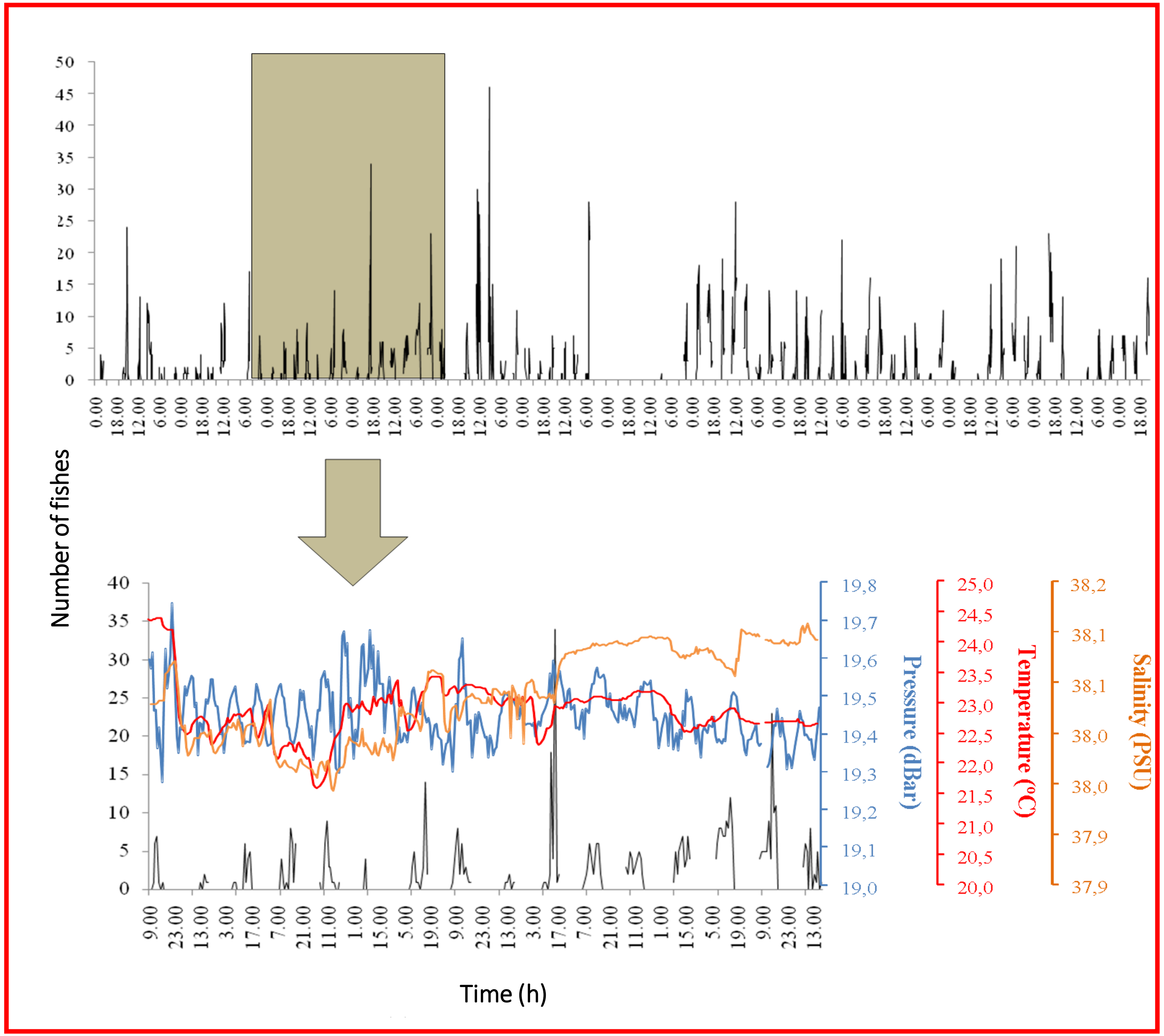
Rotary HD camera allowing different field of views into a MPA surrounded by artificial reefs

Examples of time-lapse imaging carried out for monitoring (left) and automated tracking/classification (right)

Development of automated video-imaging routines

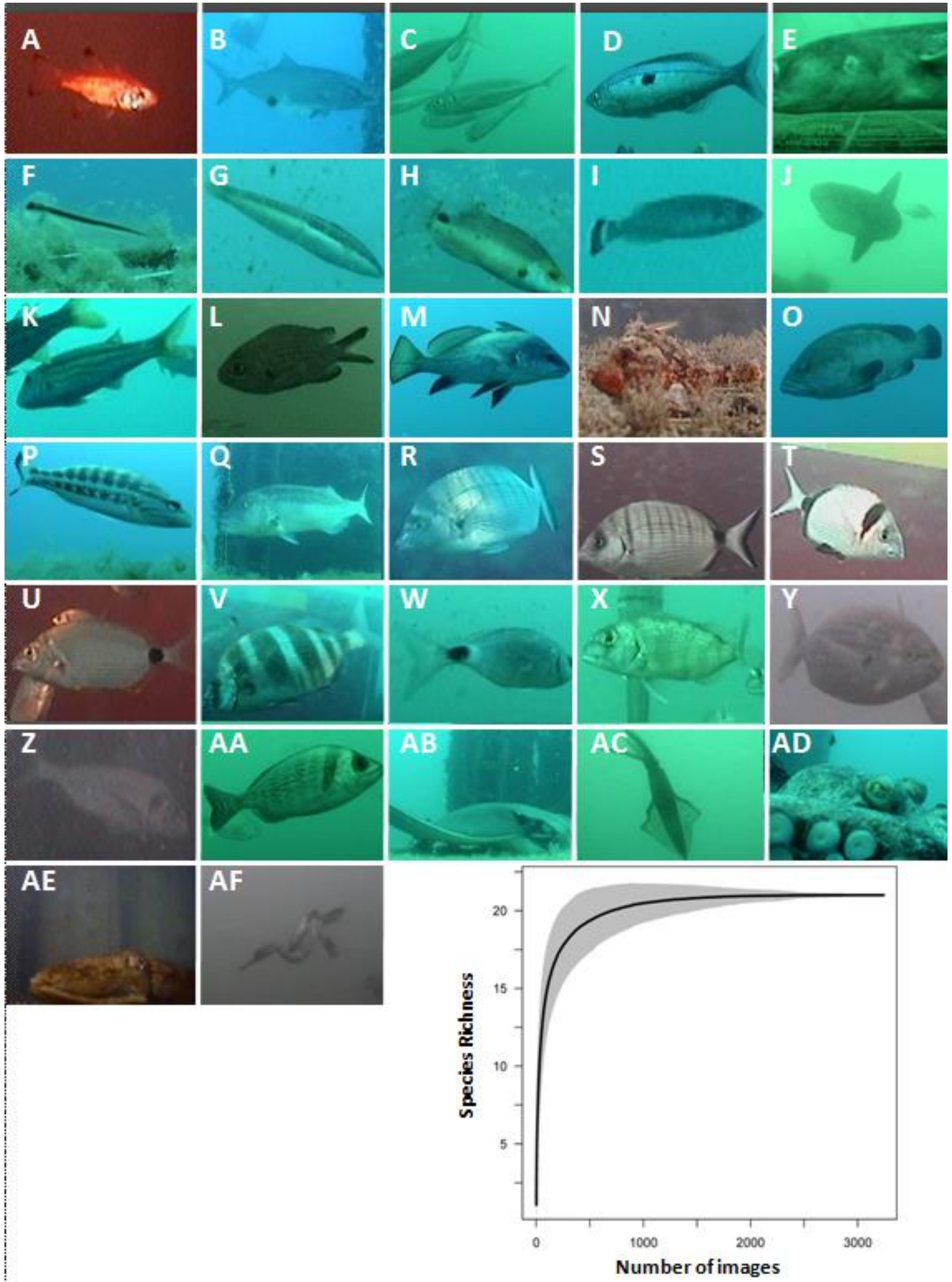
Marini, Aguzzi et al., 2018. Sci. Rep. 8: 13748

Development of multiparametric data banks for multivariate statistic applications



Aguzzi et al. 2011. Sensors 11: 5850-5872

Richness estimation and monitoring effort efficiency



FISHES

Apogonidae: *Apogon imberbis* (A); Carangidae: *Seriola dumerili* (B); *Trachurus* sp. (C); Centracanthidae: *Spicara maena* (D); Congridae: *Conger conger* (E); Gobiidae: *Gobius vittatus* (F); Labridae: *Coris julis* (G); *Symphodus mediterraneus* (H); *Symphodus melanocercus* (I); Molidae: *Mola mola* (J); Mullidae: *Mullus surmuletus* (K); Pomacentridae: *Chromis chromis* (L); Sciaenidae: *Sciaena umbra* (M); Scorpaenidae: *Scorpaena* sp. (N); Serranidae: *Epinephelus marginatus* (O); *Serranus cabrilla* (P); Sparidae: *Dentex dentex* (Q); *Diplodus puntazzo* (R); *Diplodus sargus* (S); *Diplodus vulgaris* (T); *Diplodus annularis* (U); *Diplodus cervinus* (V); *Oblada melanura* (W); *Pagellus erythrinus* (X); *Sarpa salpa* (Y); *Sparus aurata* (Z); *Spondyliosoma cantharus* (AA); Myliobatidae: *Myliobatis aquila* (AB).

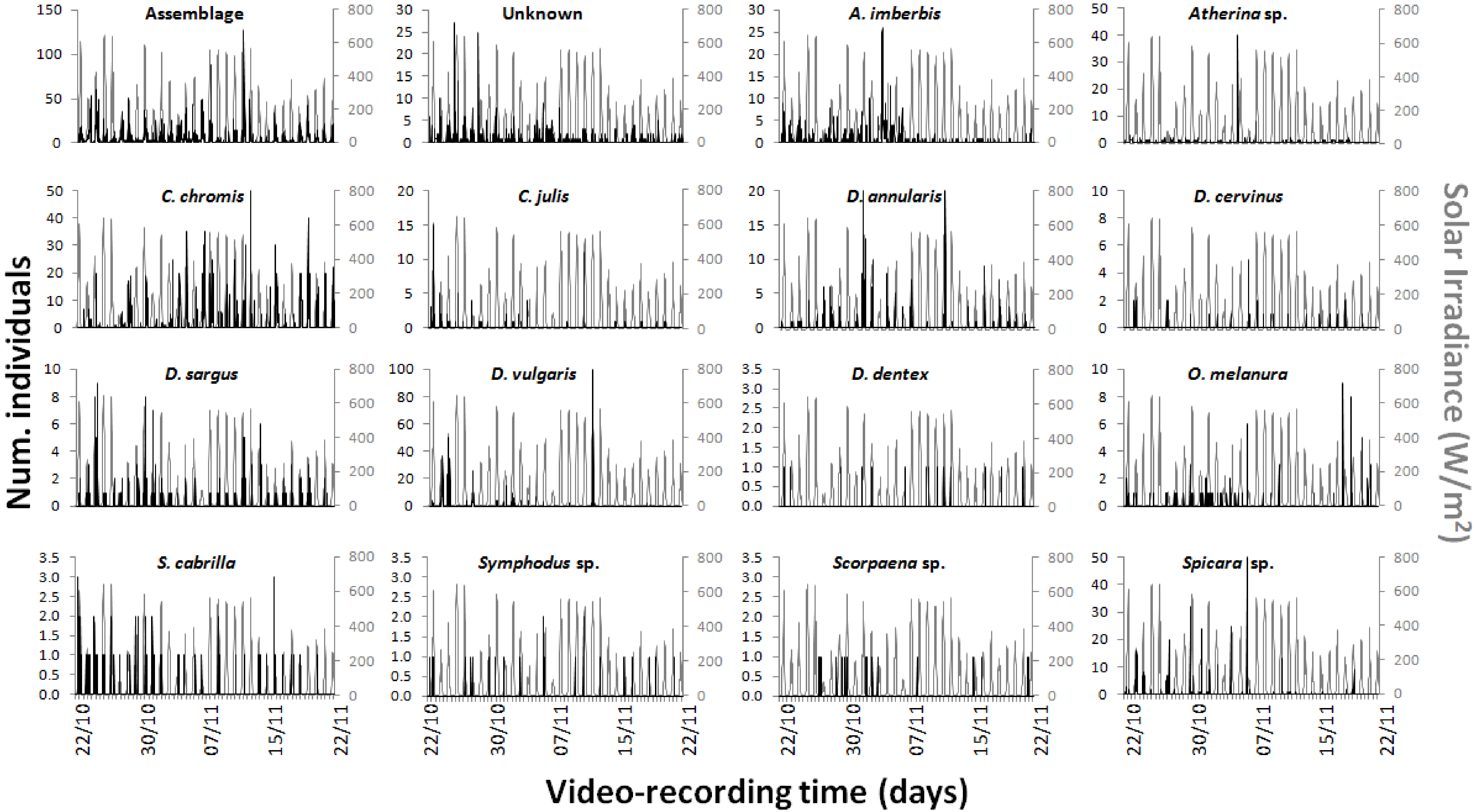
OTHER OCCASIONALLY RECORDED SPECIES

Loligo vulgaris (AC); *Octopus vulgaris* (AD); *Sepia officinalis* (AE); *Phalacrocorax aristotelis* (AF).

Aguzzi et al., 2015. Rev. Fish. Biol. Fisher. 25: 463-483

Day-night continuous monitoring

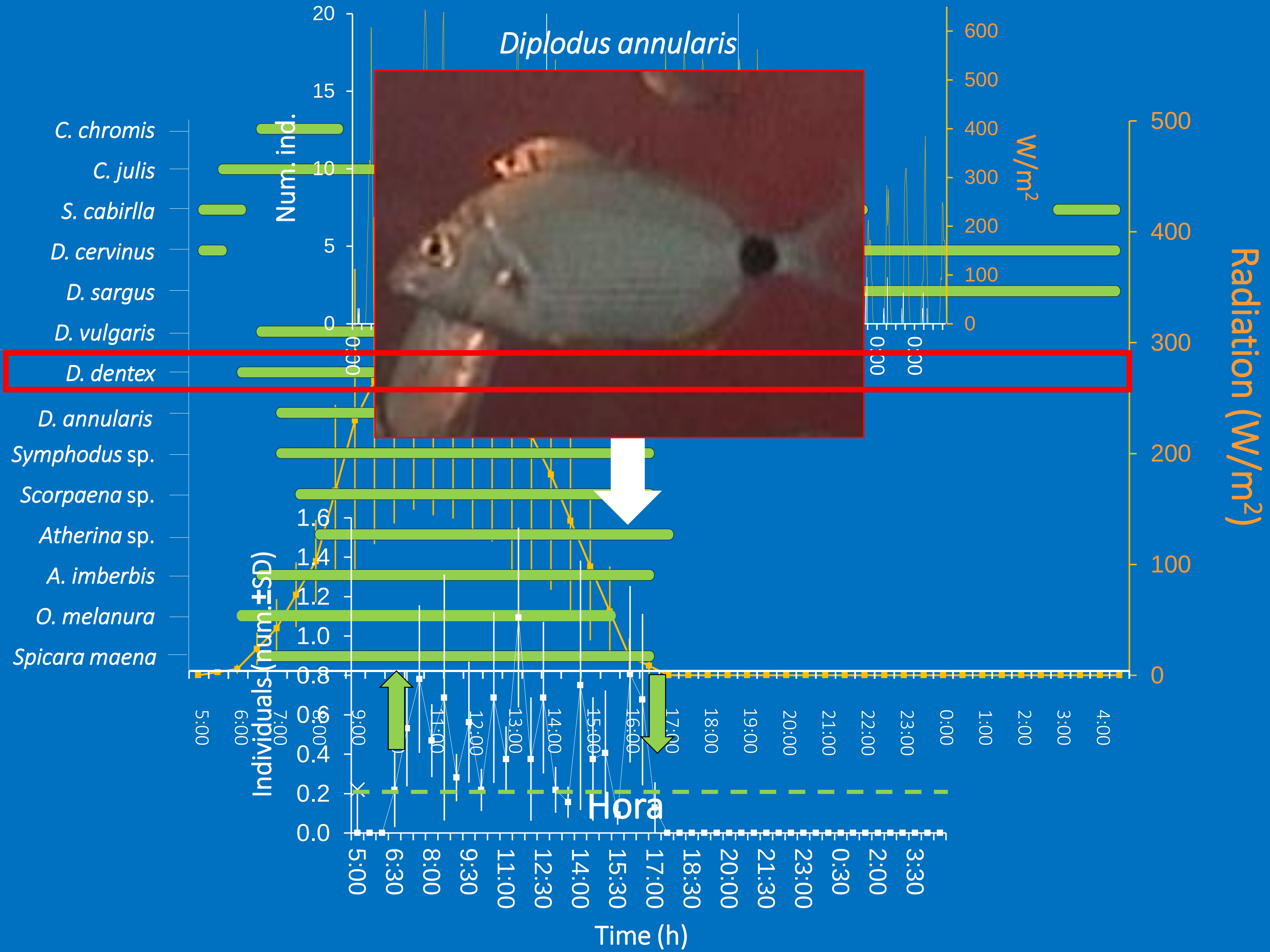
[1-month time-lapse photography at 30 min]



Aguzzi et al. 2013. MEPS 486: 223-236

Light driven rhythms

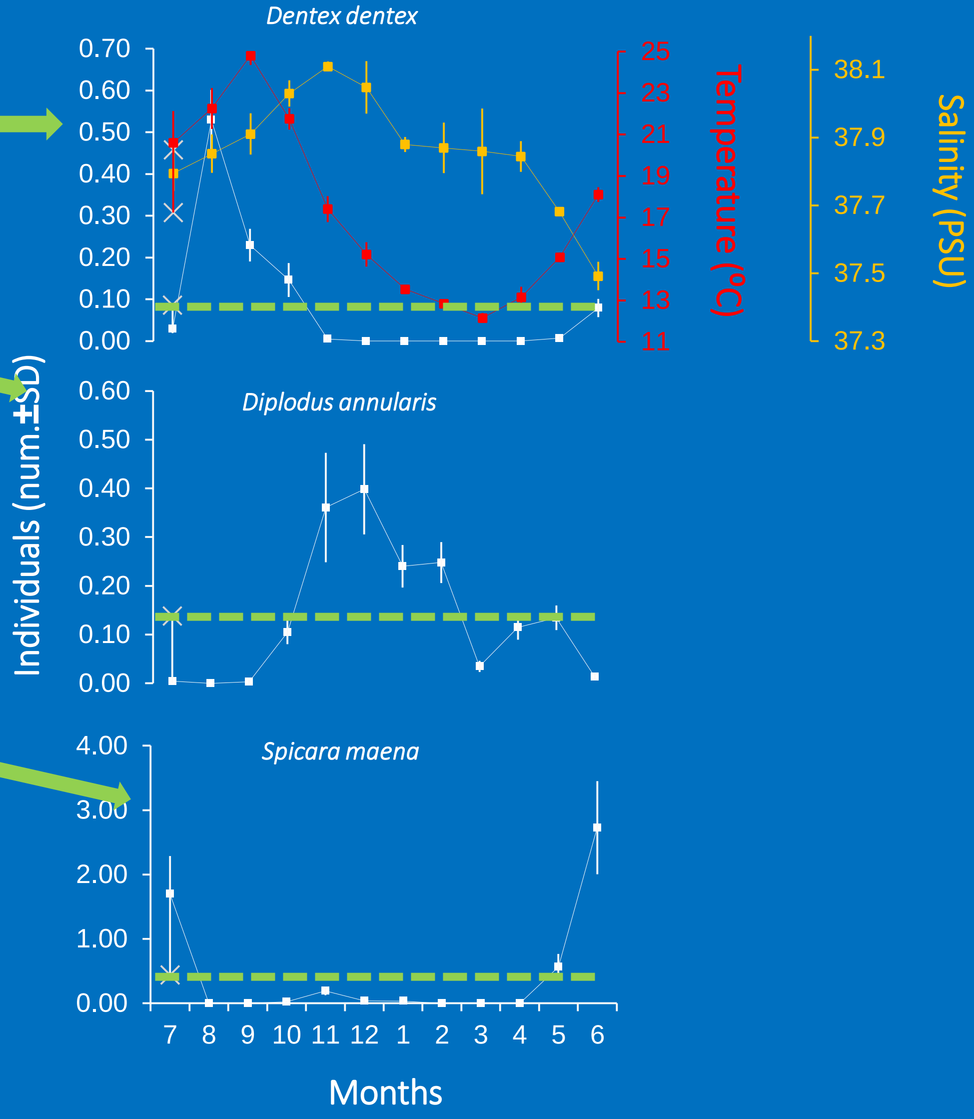
[1-month time-lapse photography at 30 min]



Aguzzi et al. 2013. MEPS. 486: 223-236

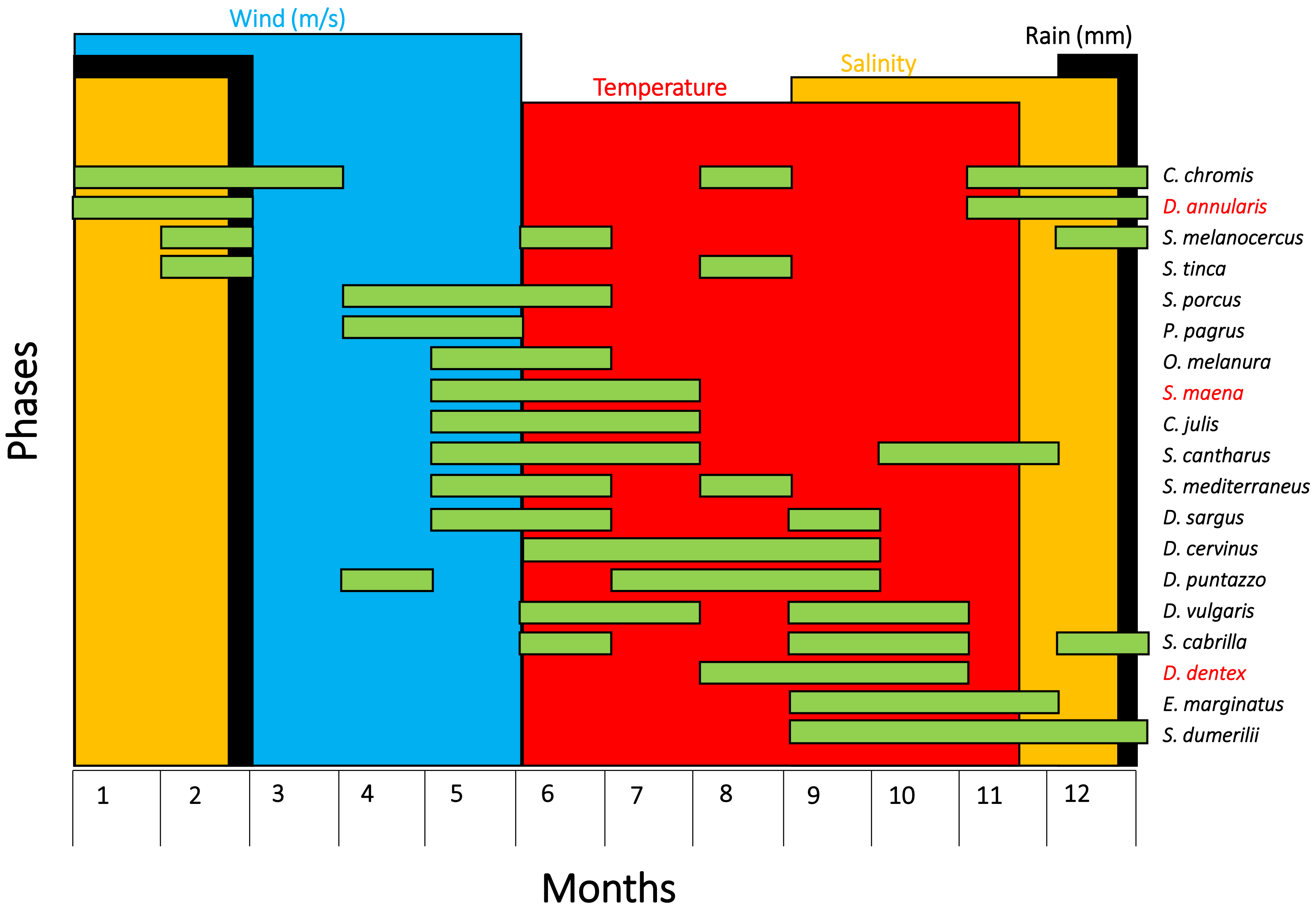
Seasonal monitoring for environmental drivers

[e.g. 12 months time-lapse photography plus oceanographic measurements at 1-h freq.]



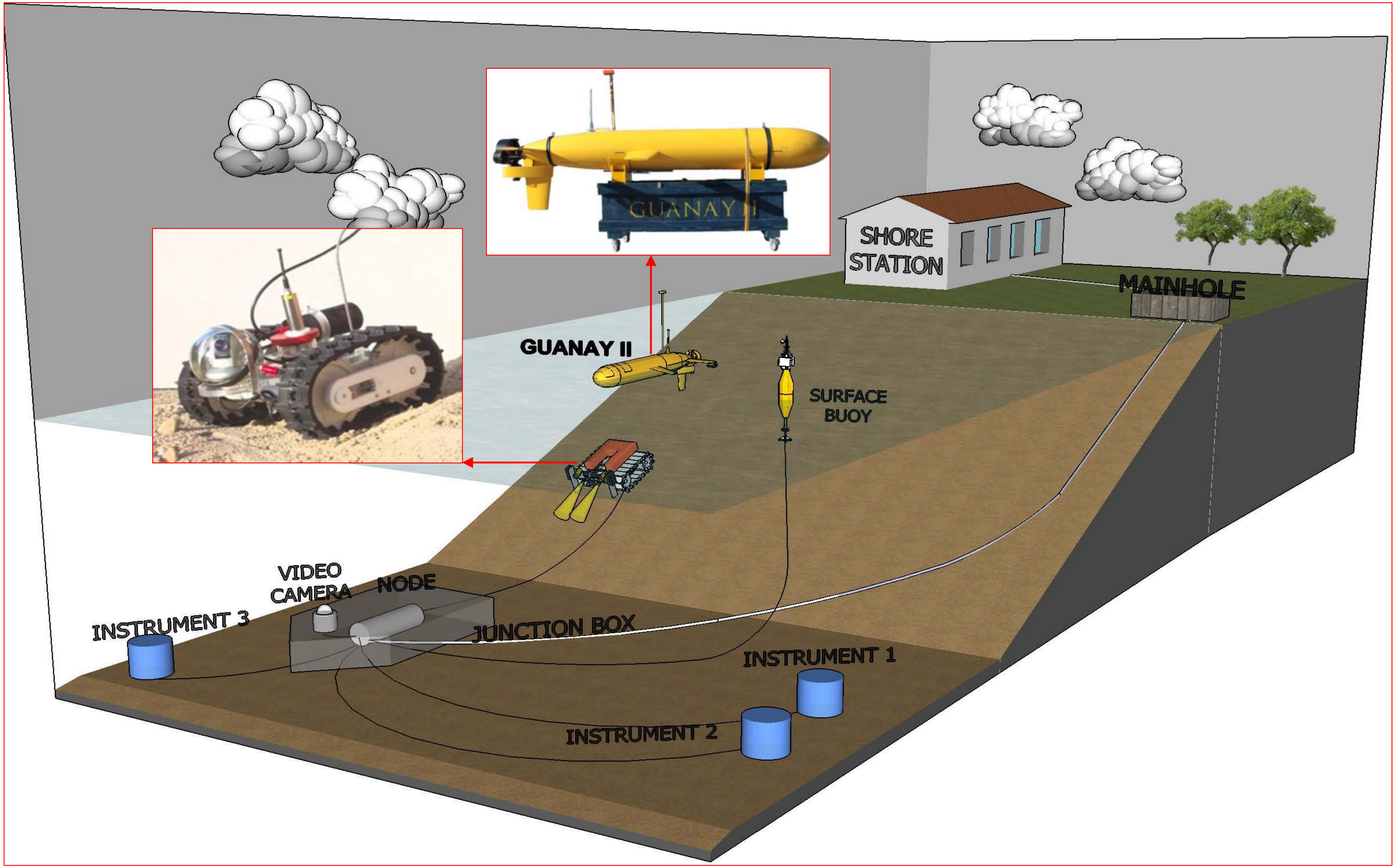
Condal, Aguzzi et al. 2012. Mar. Biol. 159: 2809-2817

Integrated analysis of visual count patterns



Aguzzi et al. 2015. Rev. Fish Biol. Fisher. 25: 463-483

The creation of a local network of platforms



RESBIO Spanish National Research Project (TEC2017-87861-R); 2018-2021. *PIs:* J. del Rio; J. Aguzzi

The deep-water testing of new tracking technologies


ICES Journal of Marine Science

ICES CIEM

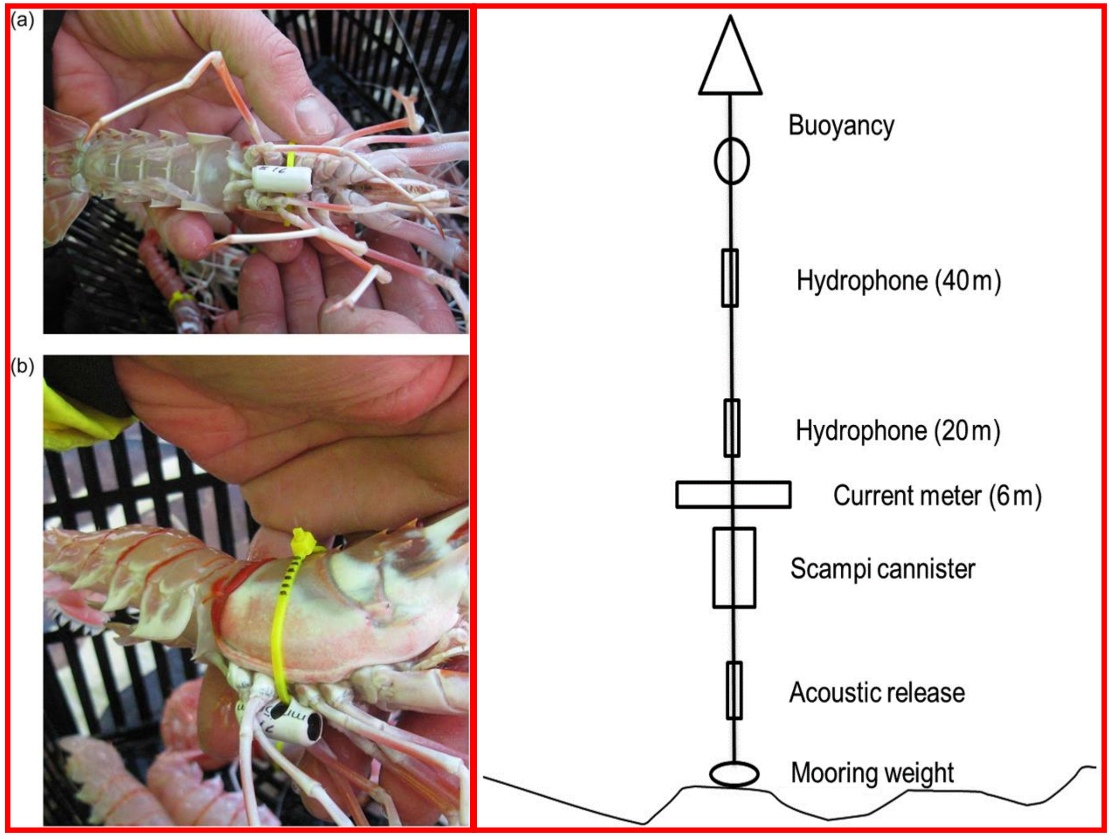
ICES Journal of Marine Science (2015), 72(Supplement 1), i199–i210. doi:10.1093/icesjms/fsu244

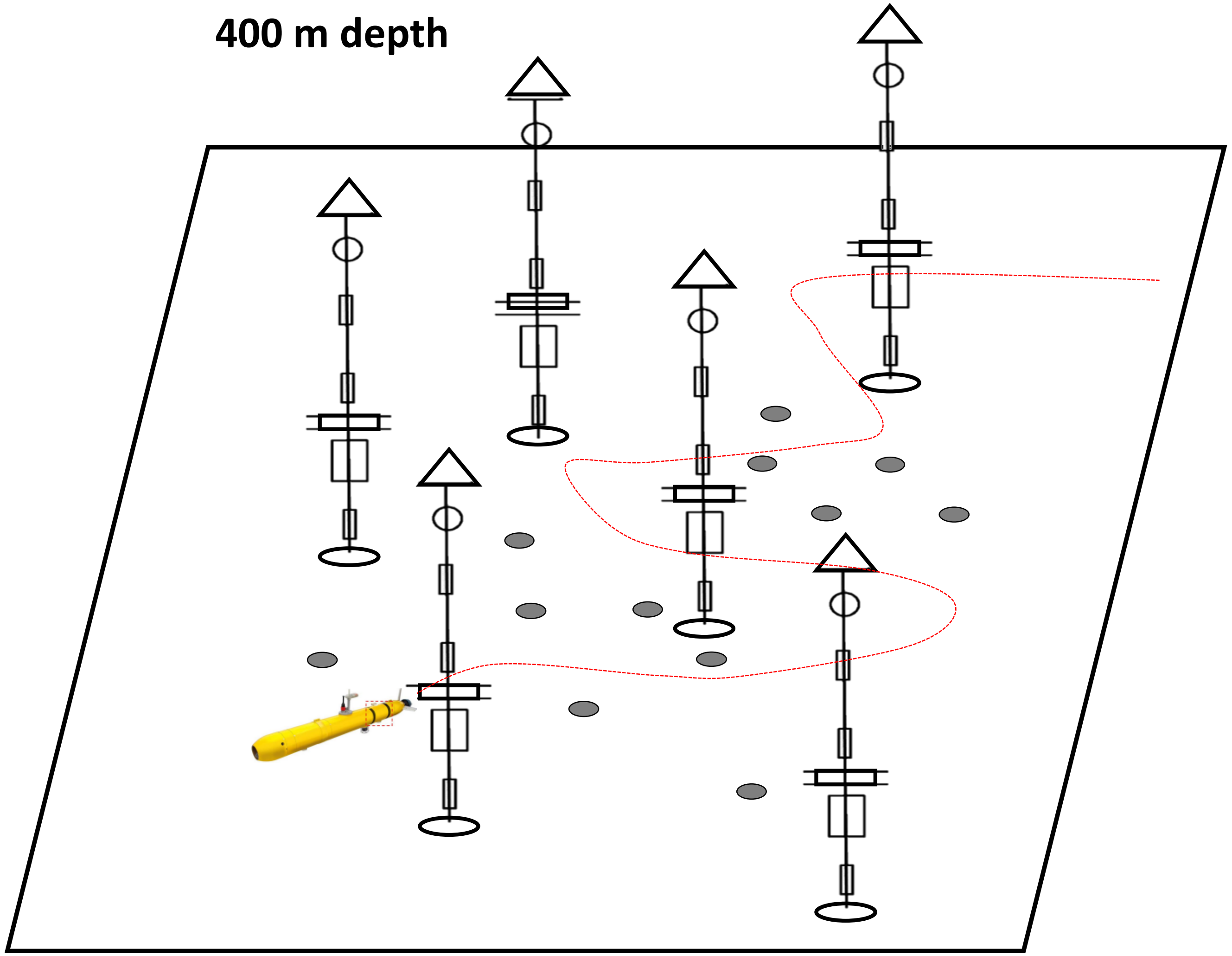
Contribution to the Supplement: '*Lobsters in a Changing Climate*'

Original Article

Scampi (*Metanephrops challengeri*) emergence patterns and catchability

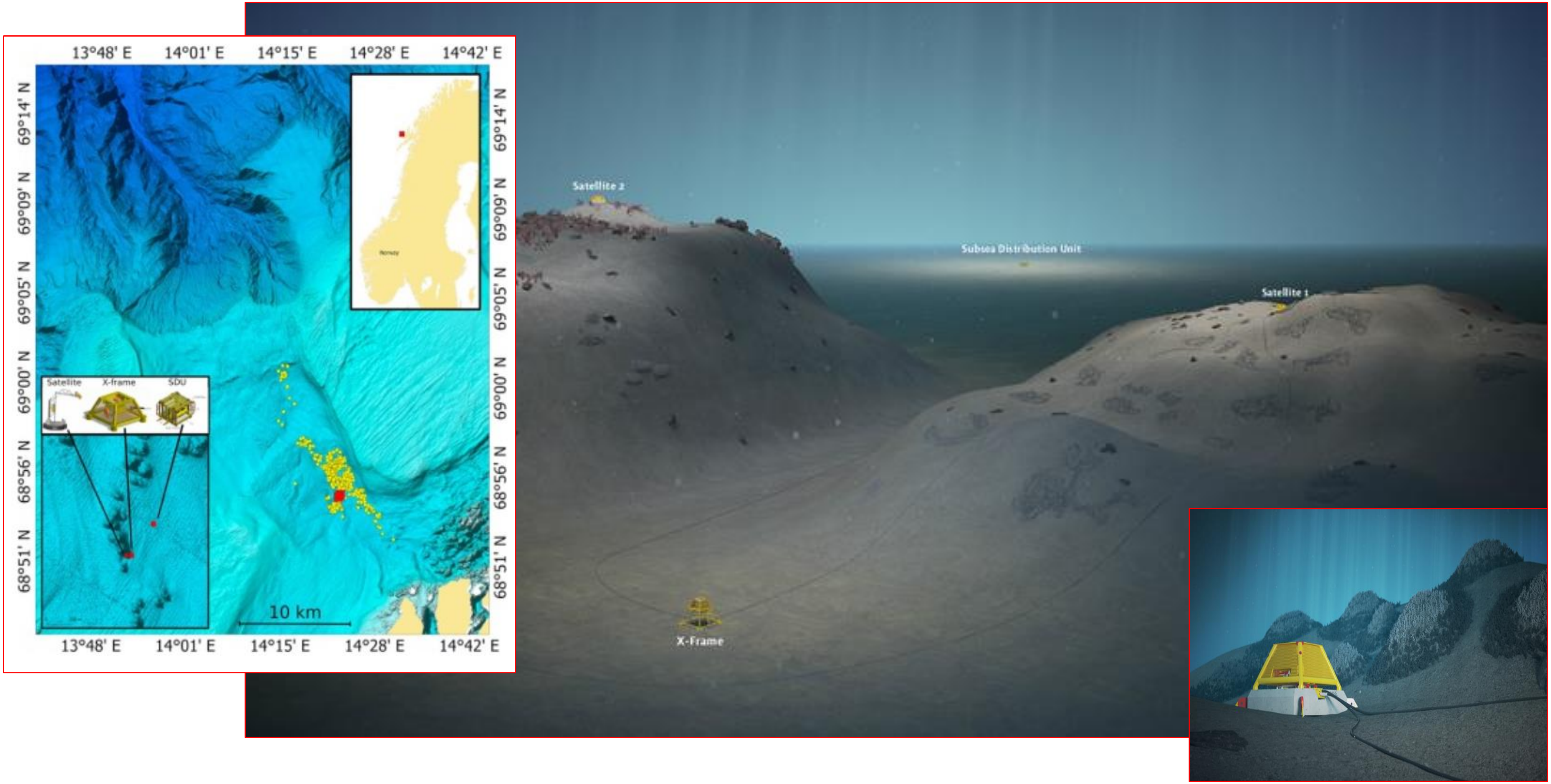
Ian D. Tuck[1,2*], Darren M. Parsons[1], Bruce W. Hartill[1], and Stephen M. Chiswell[3]



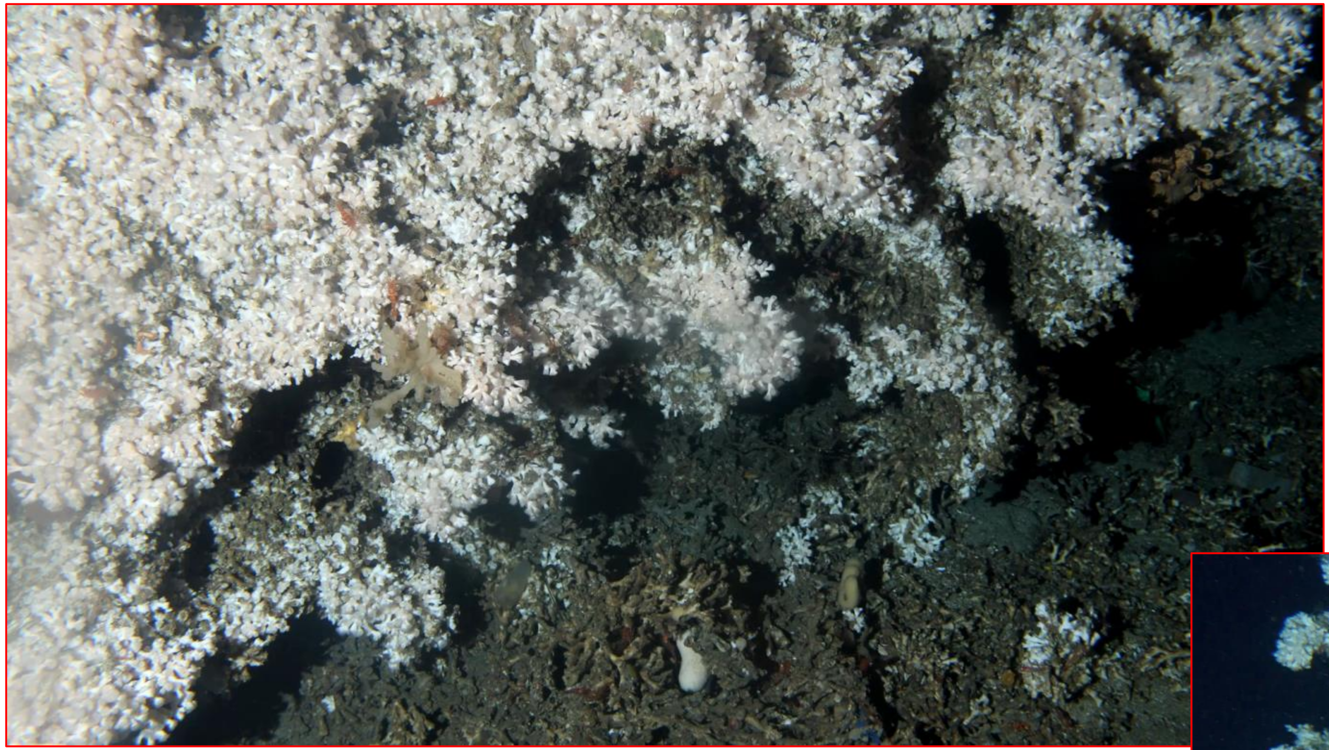


RESNEP Spanish National Research Project (CTM2017-82991-C2-1-R). 2018-2021. IP: J. Navarrro, J.B. Company

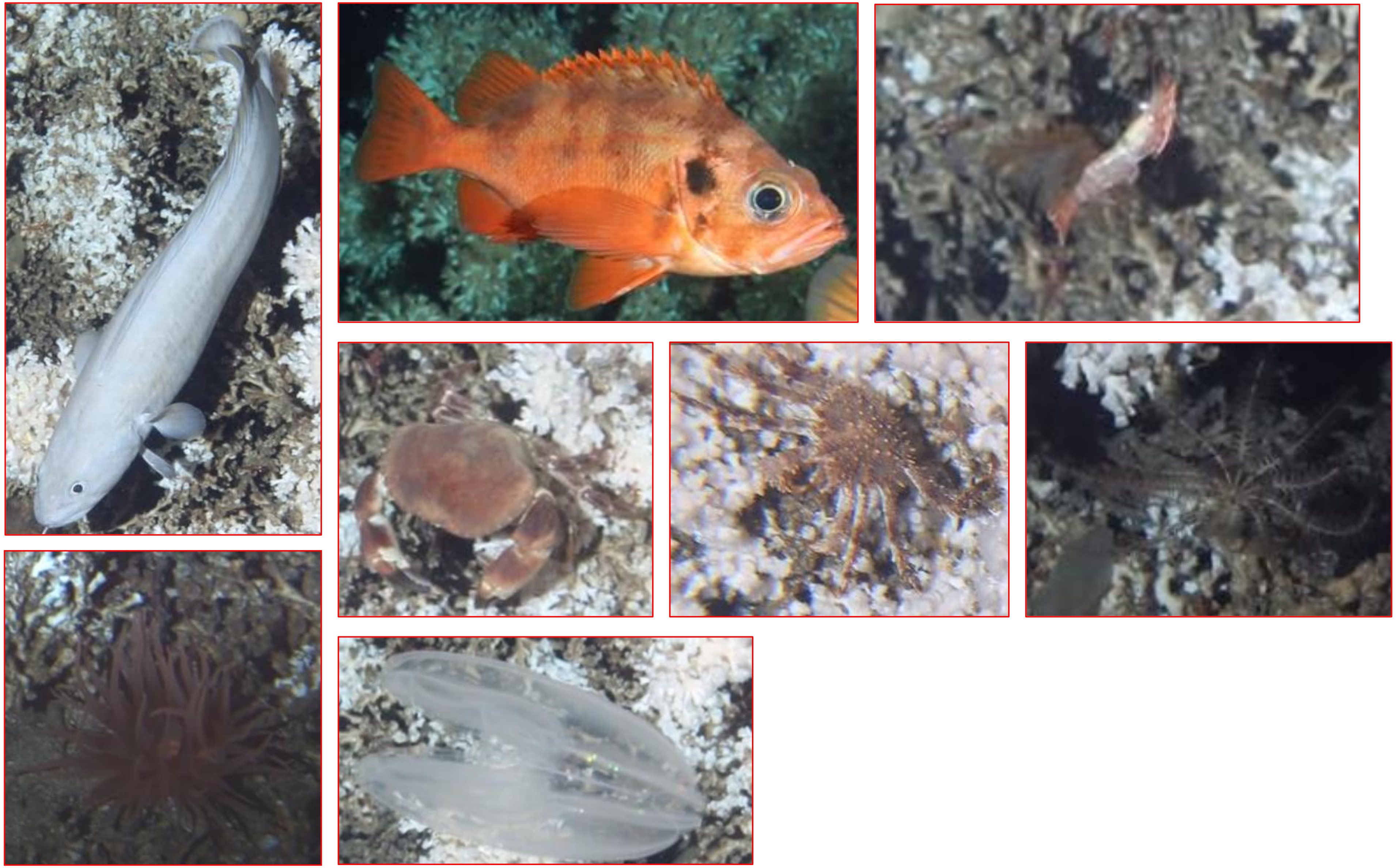
Cold water coral nursery areas monitoring: Lovoten-Verlag (LoVe) observatory (250-1000 m depth)



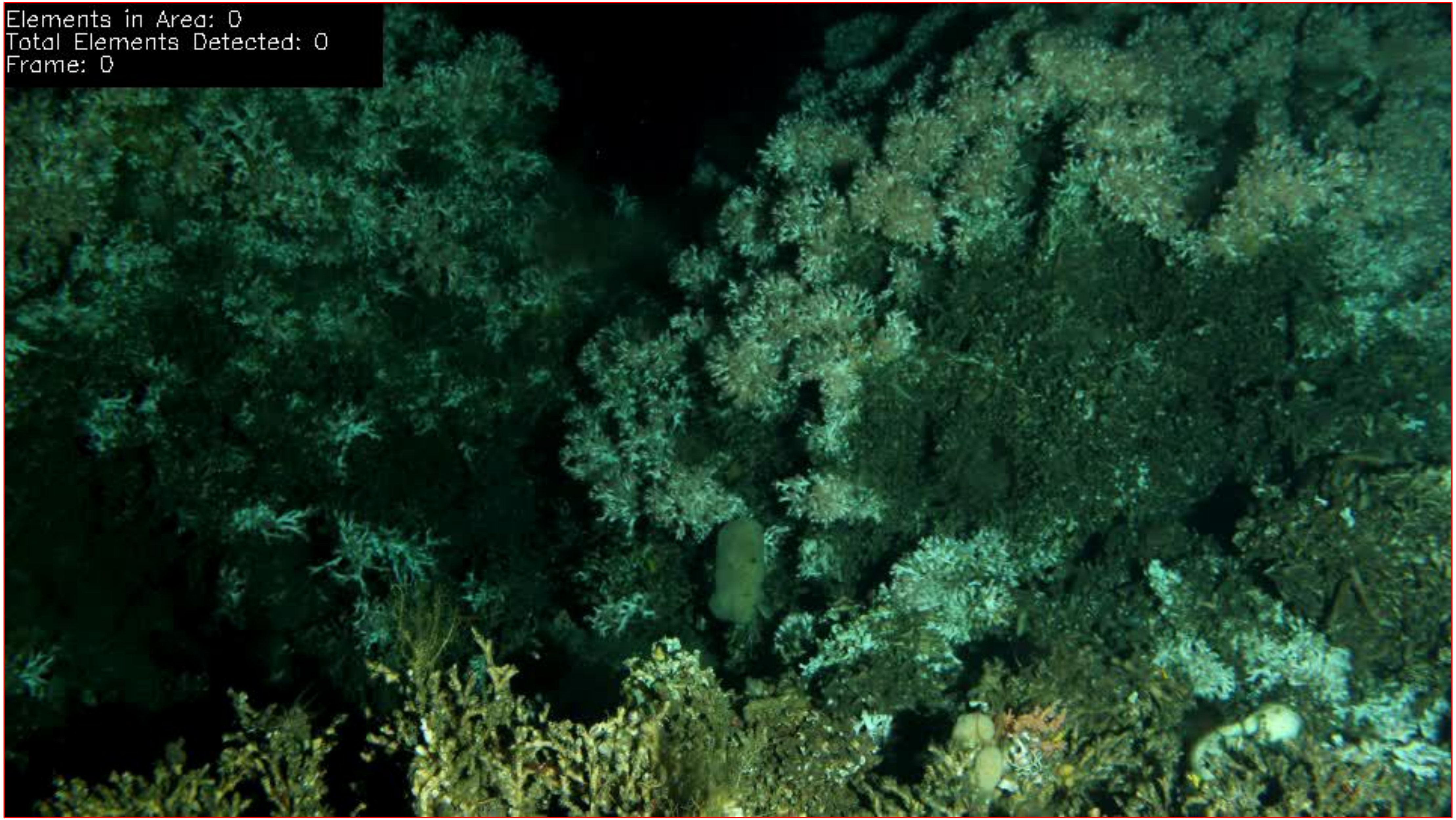
Several cabled nodes and different fields of view



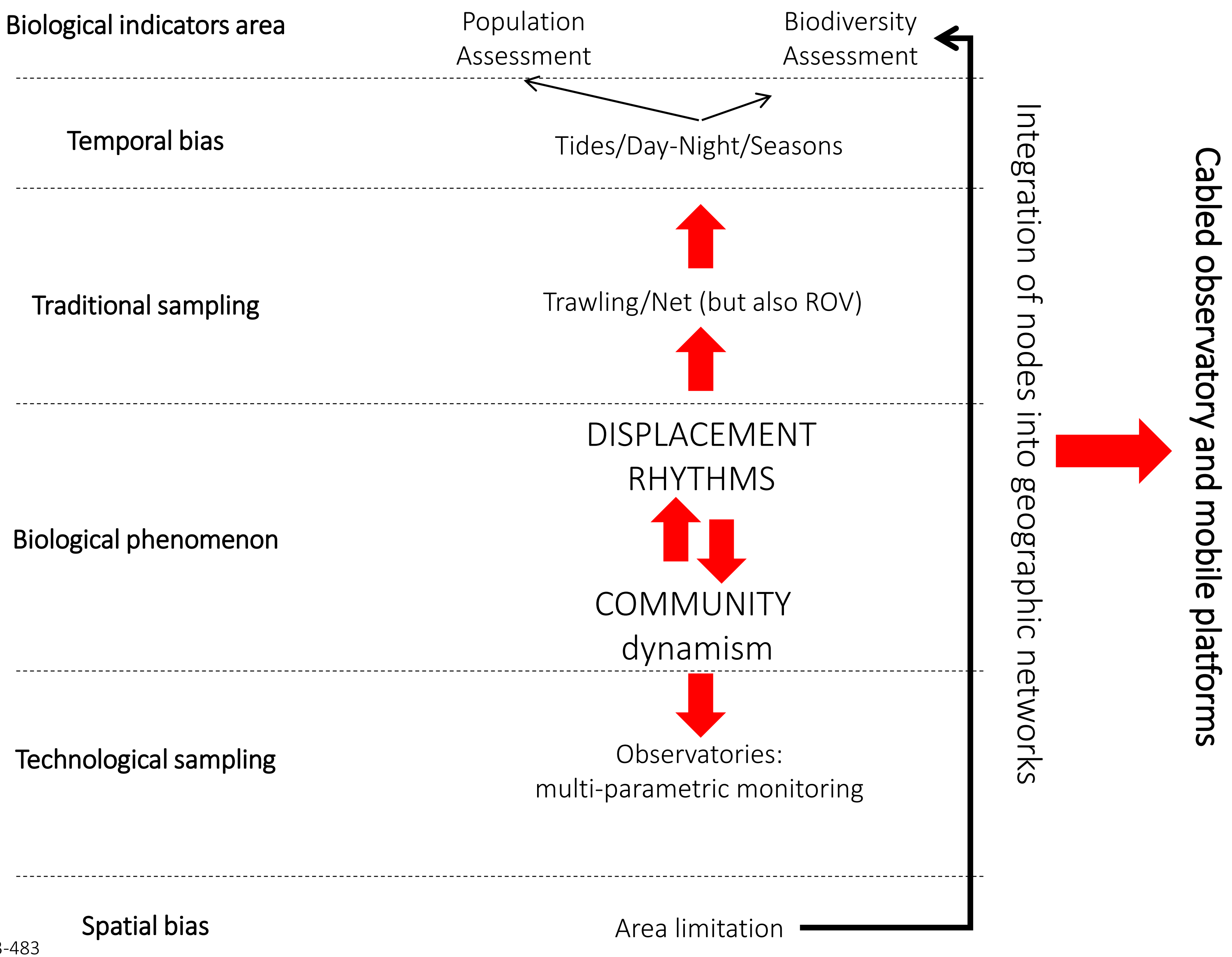
Richness



Automated processing for fish count (Rockfish, *Sebastes* sp.)

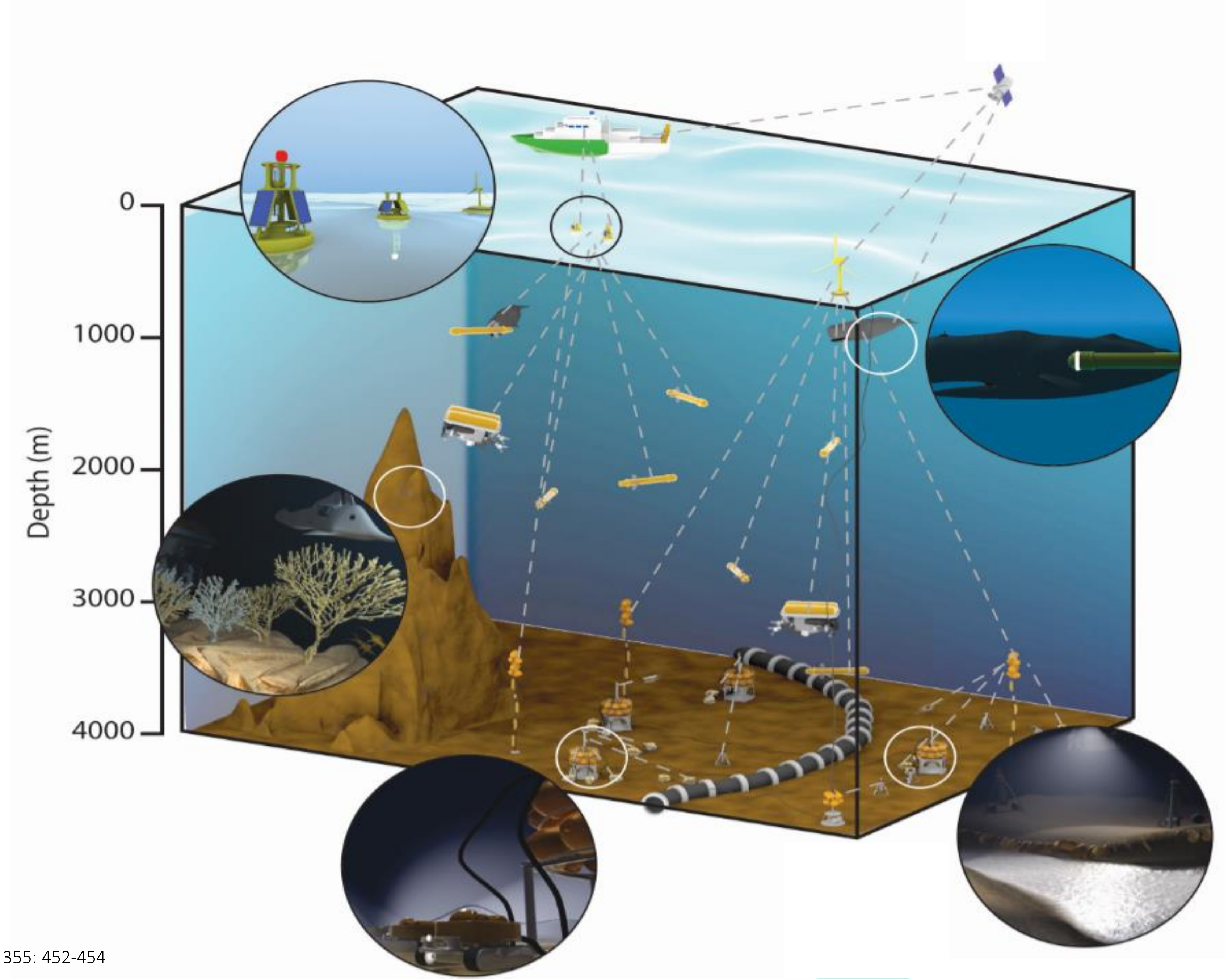


Future development directions



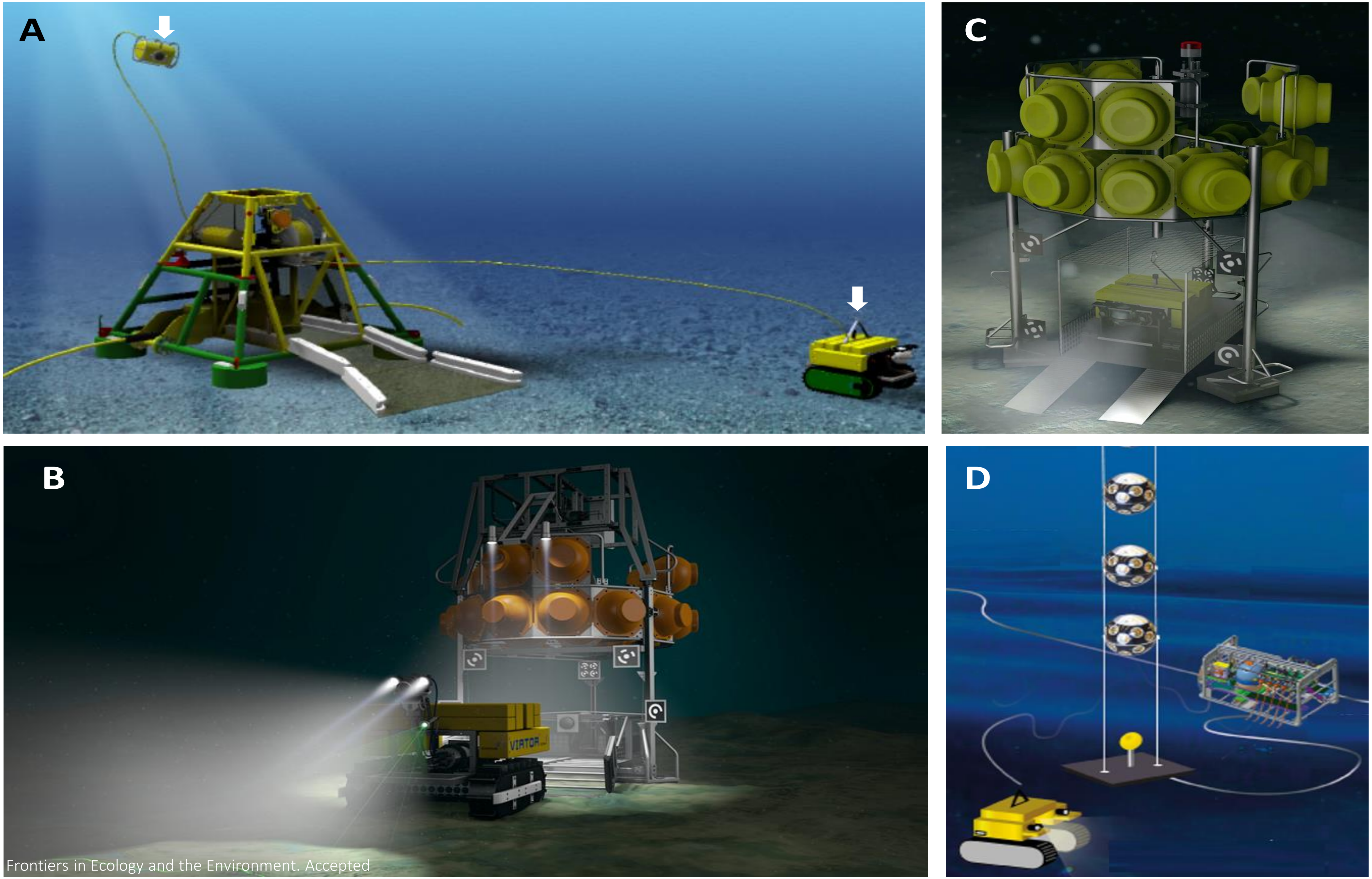
Aguzzi et al. 2015. Rev. Fish Biol. Fisher. 25: 463-483

Networks of cabled fixed and mobile platforms as in situ “robotized marine laboratories”



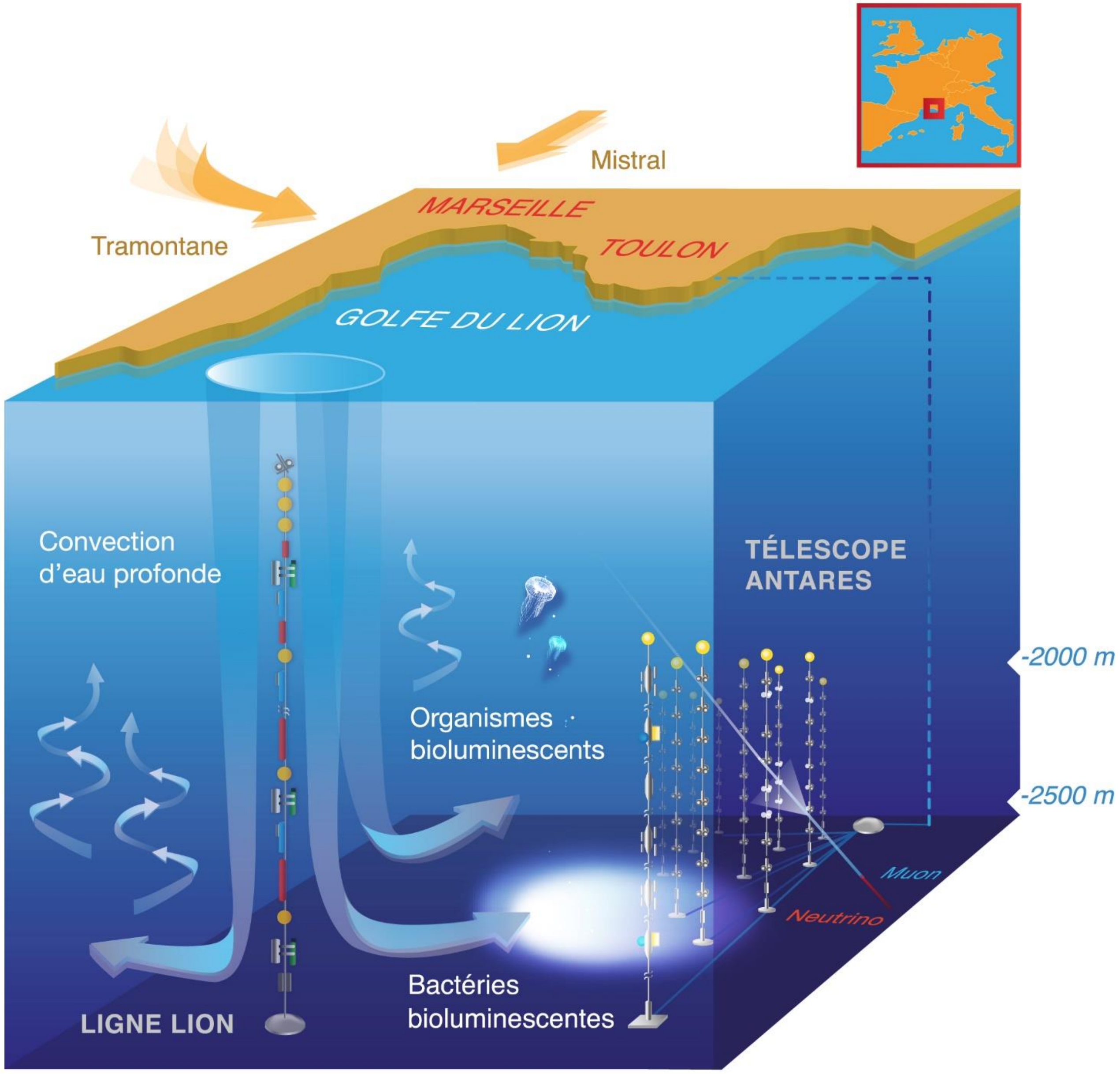
Danovaro, Aguzzi et al. 2017. Science, 355: 452-454

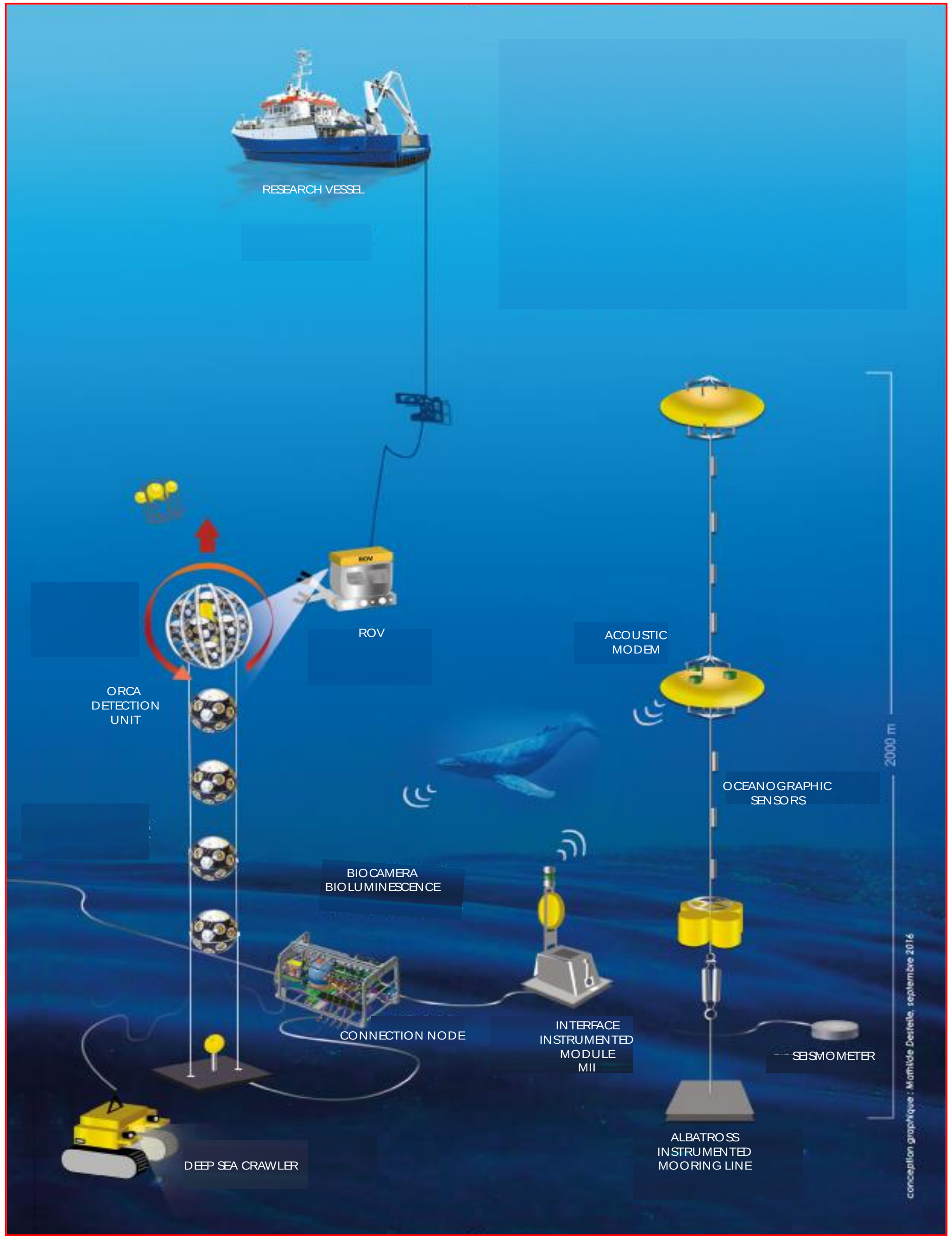
Examples of docking development for semi-autonomous (tethered) mobile platforms



Aguzzi et al. 2019. Frontiers in Ecology and the Environment. Accepted

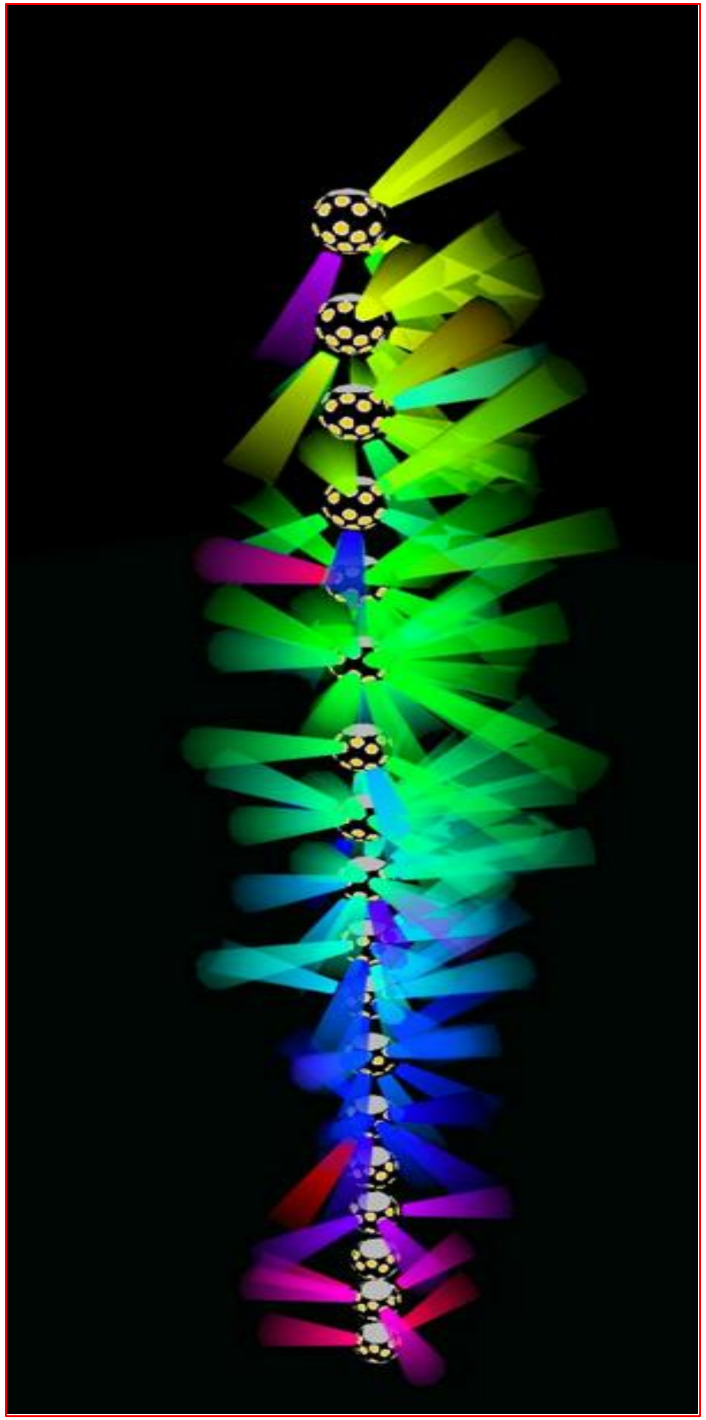
Neutrino telescopes to cover the benthopelagic coupling: the ANTARES case (2500 m, Marseille)





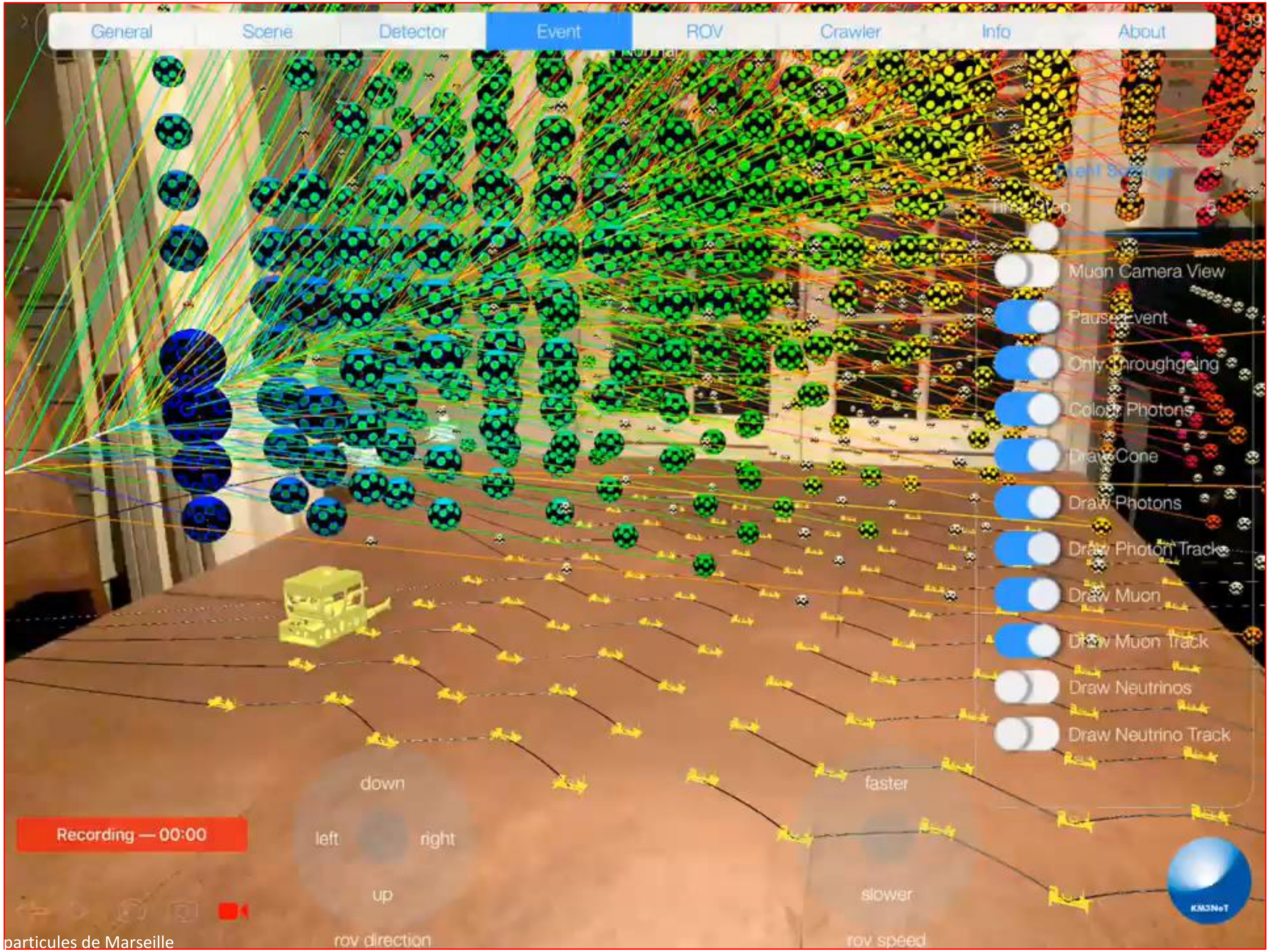
Neutrinos-Mer-Environnement (NUMerENV). Program: CPER/FEDER 2015-2020.
IP: Dr. C. Tamburini, Dr. J. Aguzzi responsible, for crawler monitoring development

Photo-Multiplier Tube (PMTs) towers



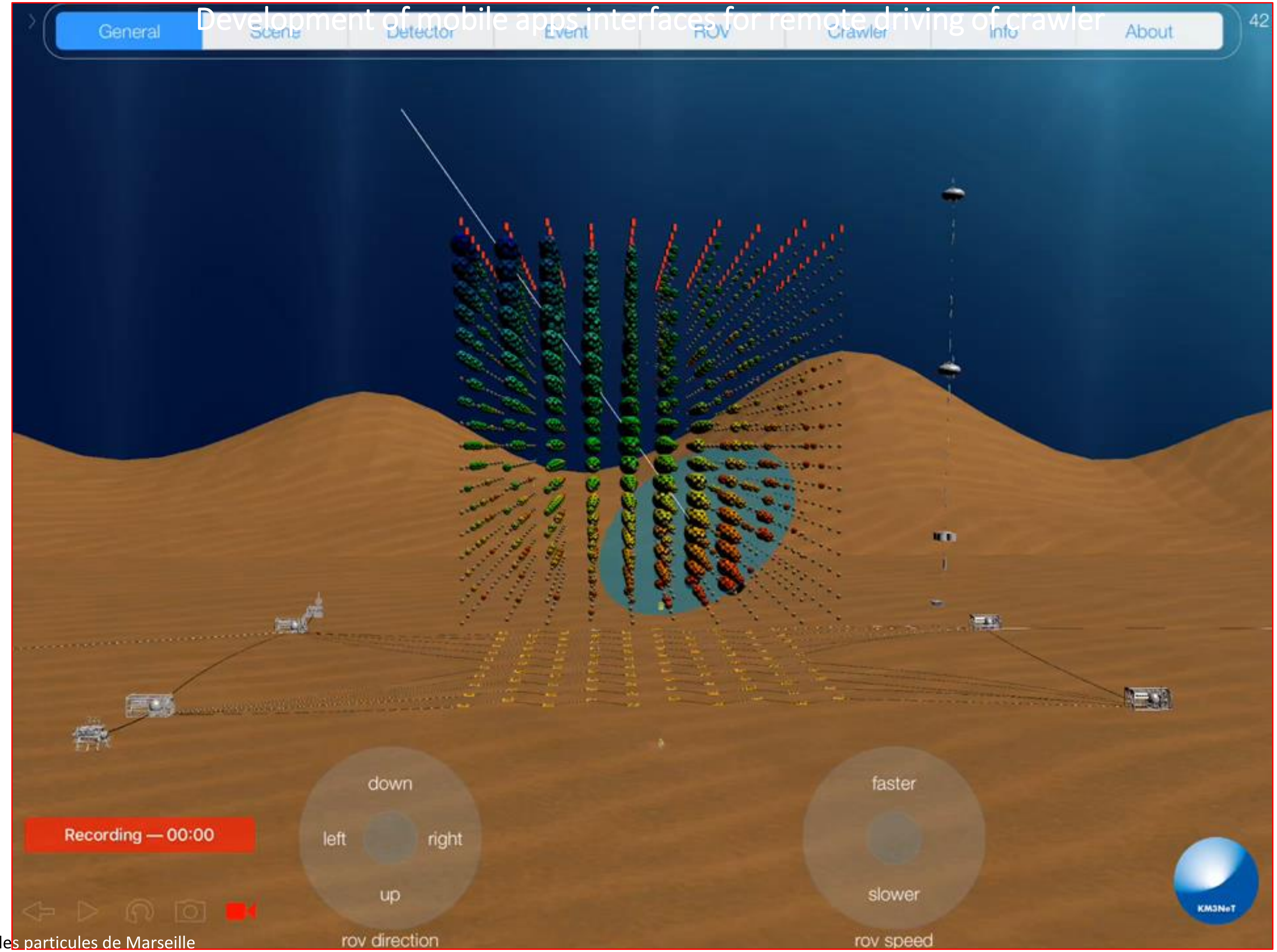
Courtesy of Dr. G. Riccobene (INFN, Catania; km3-NET Italy)

Development of mobile apps interfaces for remote driving of ROVs



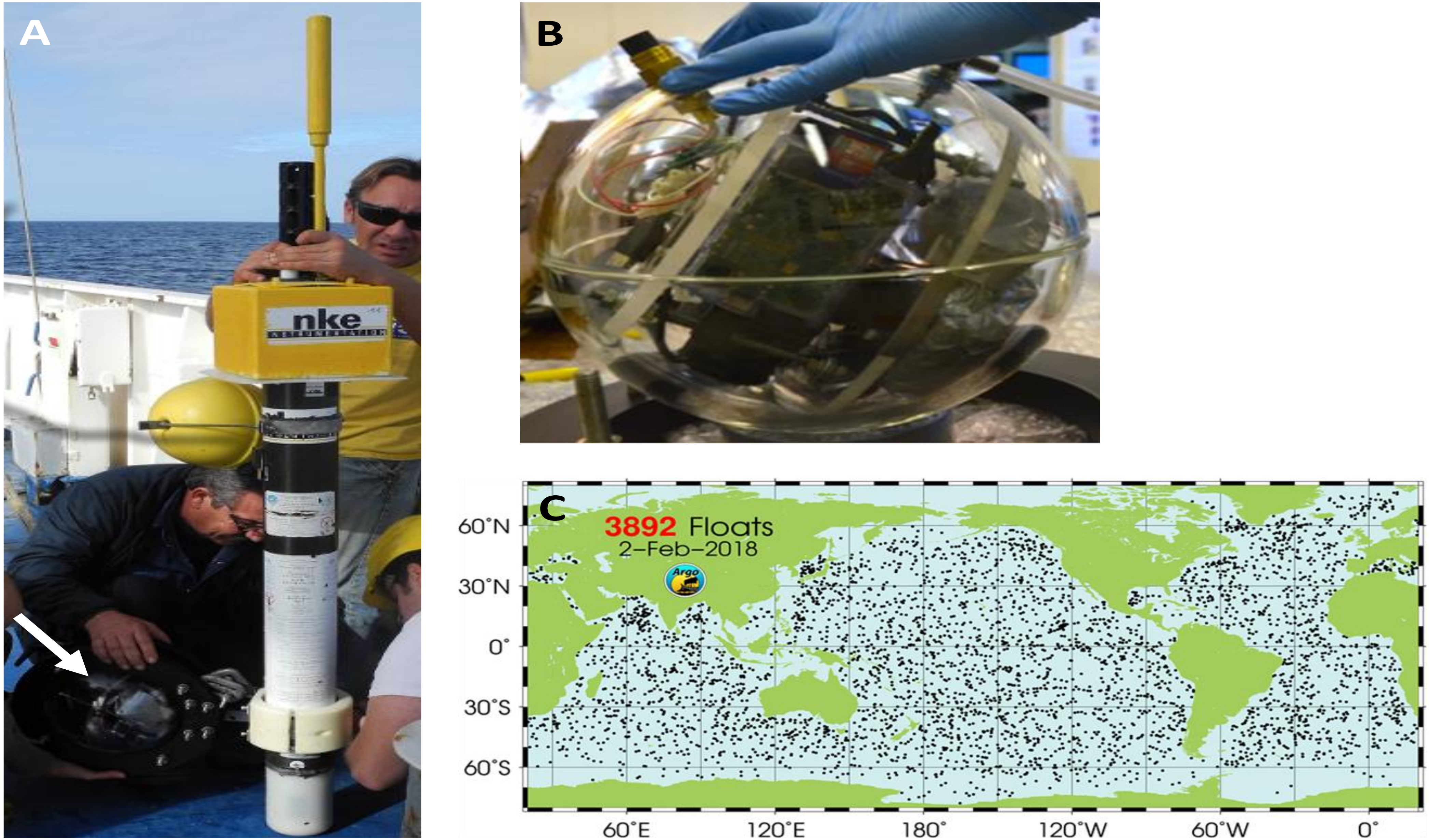
Courtesy of Dr. P. Coyle
CPPM - Centre de physique des particules de Marseille

Development of mobile apps interfaces for remote driving of the crawler



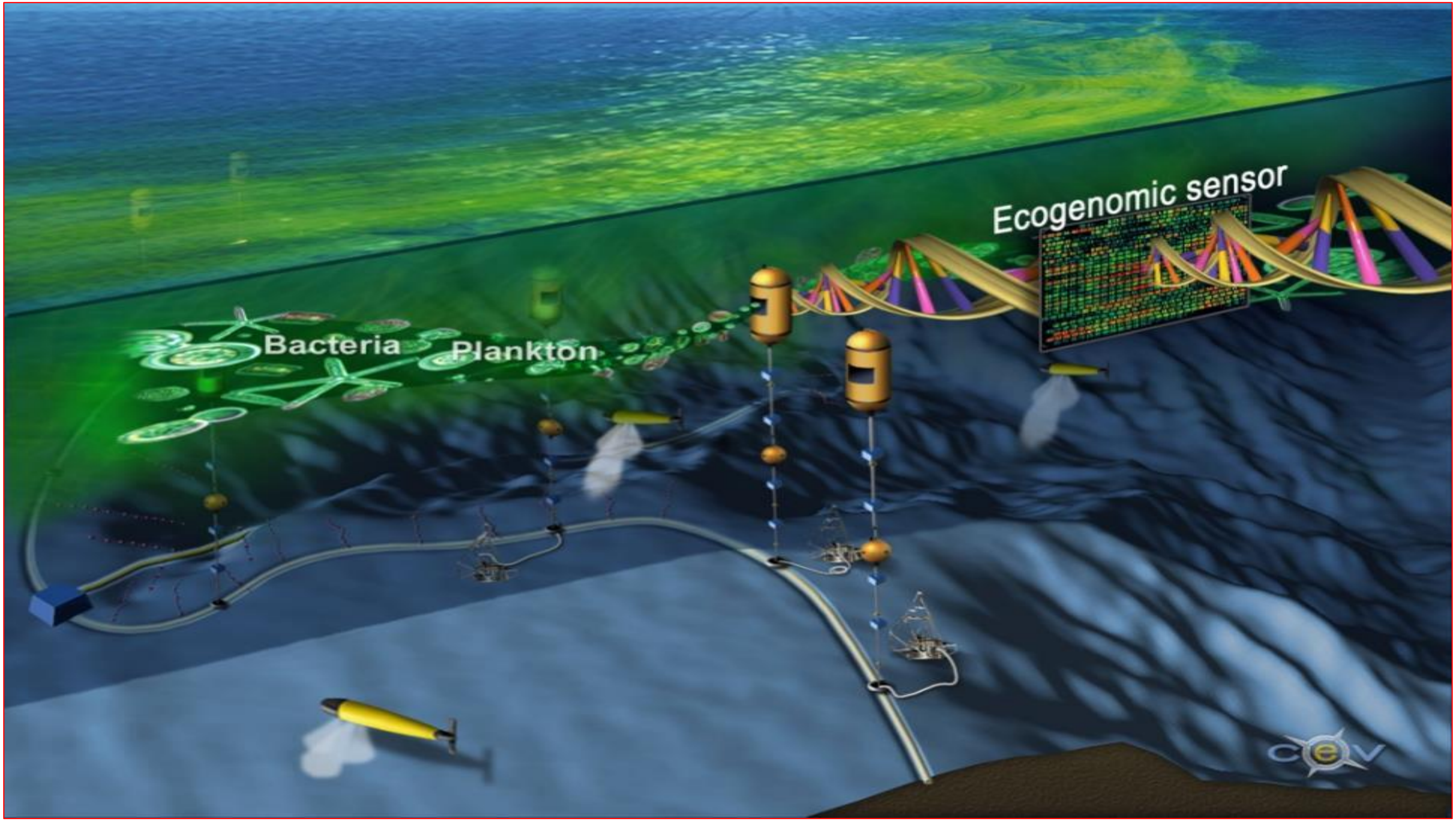
Courtesy of Dr. P. Coyle
CPPM - Centre de physique des particules de Marseille

The growing connection of Eulerian and Lagrangian monitoring assets

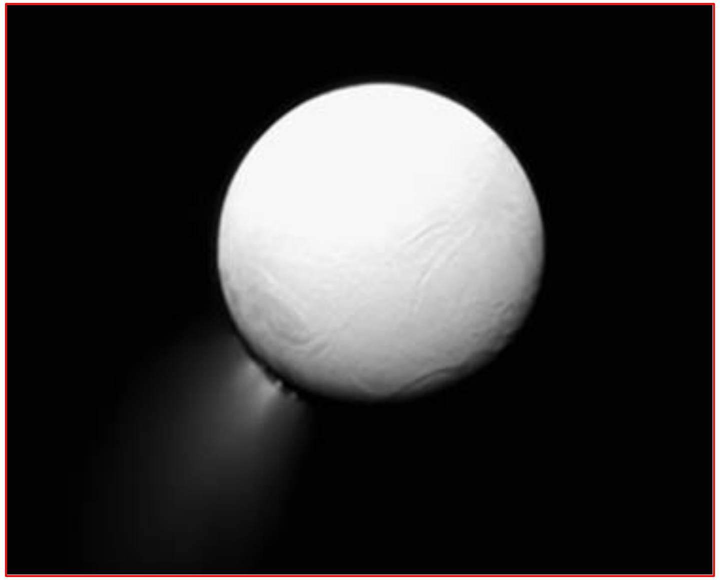


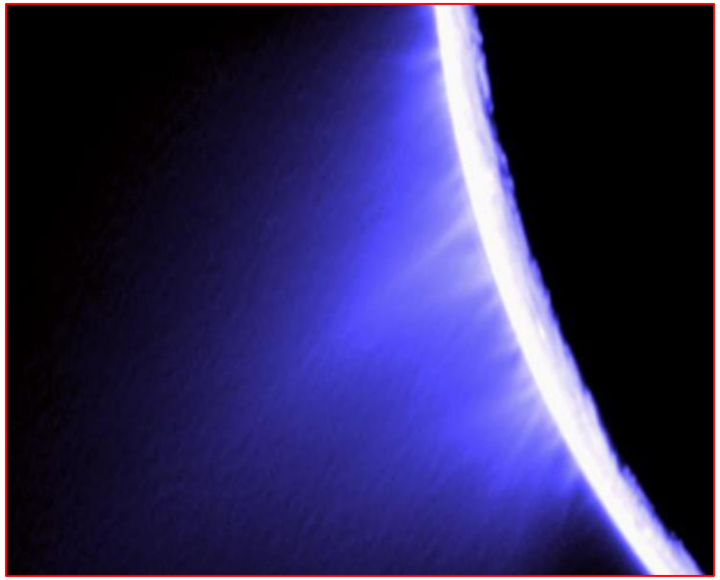
Aguzzi et al. 2019. Frontiers in Ecology and the Environment. Accepted

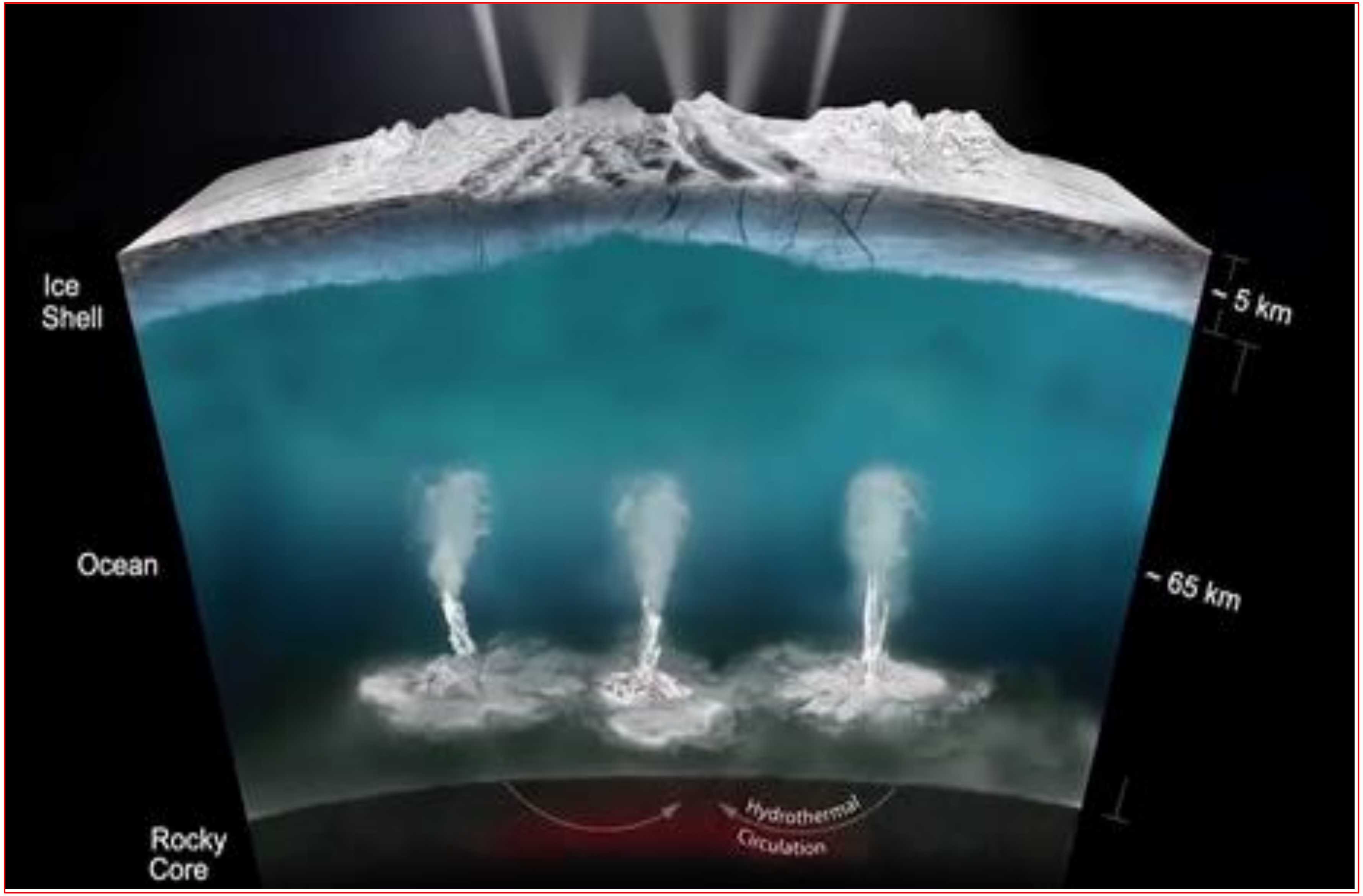
The development of “augmented observatories”: water column monitoring with “omics” technologies

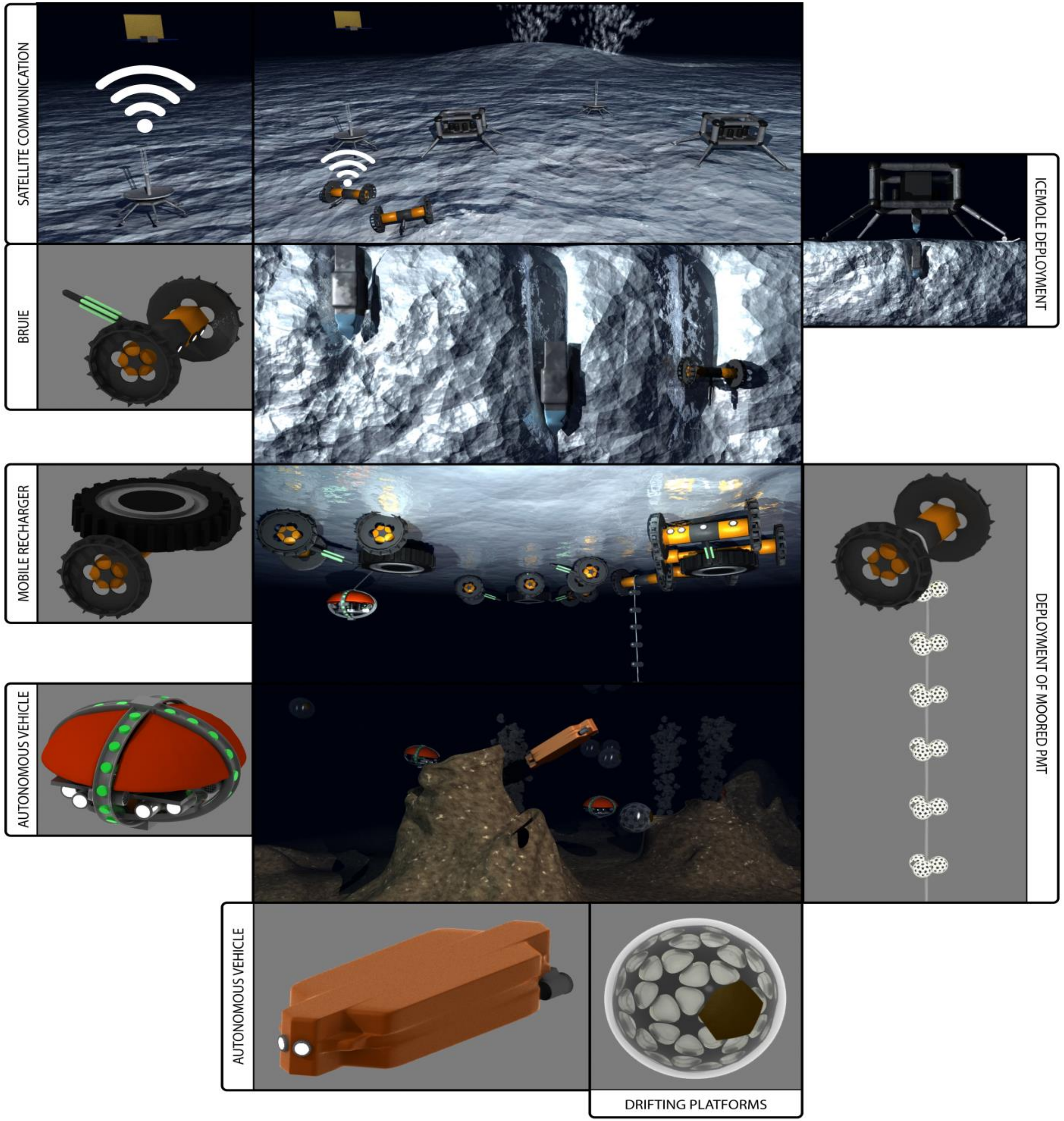


…and finally, form fishery and ecological monitoring to exo-oceans exploration!









Aguzzi et al. 2019. Astrobiology. In Preparation.

Relevant publications

Mirimin L., Desmet S., López Romero D., Fernandez Fernandez S., Miller D., Mynott S., Gonzalez Brincau G., Stefanni S., Berry A., Gaughan P., Aguzzi J. 2020. Don't catch me if you can – Using cabled observatories as multidisciplinary platforms for marine fish community monitoring: a case study combining Underwater Video and environmental DNA (eDNA) data. Sci. Tot. Env. 773: 145351

Aguzzi J., Chatzievangelou D., Company J.B., Thomsen L., Marini S., BonofiglioF., Juanes F., Rountree R., Berry A., Chumbinho R., Lordan C., Doyle J., del Rio J., Navarro J., De Leo F.C., Bahamon N., García J.A., Danovaro R., Francescangeli M., Lopez-Vazquez V., Gaughan P. 2020. Fish-stock assessment using video imagery from worldwide cabled observatory networks. ICES Journal of Marine Science, 77: 2396–2410.

Aguzzi J., Chatzievangelou D., Francescangeli M., Marini S., Bonofiglio F., del Río J., Danovaro R. 2020. The hierarchic treatment of marine ecological information from spatial networks of benthic platforms. Sensors-Basel, 20: 1751.

Aguzzi J., Flexas M., Flögel S., Lo Jacono C., Tagherlini M., Costa C., Fanelli E., Marini S., Bahamon N., martini S., fanelli E., Danovaro R., Stefanni S., Thomsen L., Riccobene G., Hildebandt M., Masmitja I., del Río J., Clark E.B., Branch A., Weiss P., Klesh A.T., Schodlock M. P. 2020. Exo-oceans exploration with deep-sea sensor and platform technologies. Astrobiology, 20: 897-915

Rountree R., Aguzzi J., Marini S., Fanelli E., De Leo.F., Del Rio J., Juanes F. 2020. Towards an optimal design for ecosystem-level ocean observatories. Oceanography and Marine Biology: An annual Review (OMBAR), 58: 79-106.

Aguzzi J., Chatzievangelou D., Marini S., Fanelli E., Danovaro R., Flögel S., Lebris N., Juanes F., De Leo F., Del Rio J., Thomsen L., S., Costa C., Riccobene G., Tamburini C., Lefevre D., Gojak C., Poulain P.M., Favali P., Griffa A., Purser A., Cline D., Edigington D., Navarro J., Stefanni S., Company J.B. 2019. New high-tech interactive and flexible networks for the future monitoring of deep-sea ecosystems. Environmental Science and Technology, 53: 6616-6631.