Automated stereocameras to assess populations and movement in a pelagic forage fish

Matthew Baker[1-3], TS Smeltz[3], Kresimir Williams[1], Casey Greufe[2], Gary Greene[4], John Aschoff[4], Heather Lopes[2], Megan Ewing[2], Jonathan Chapman[2], Julia Glassy, [2] Eva Hasegawa[2], Kathleen Cieri[2], Rick Towler[1]

[1] NOAA Alaska Fisheries Science Center, Seattle, WA, USA
[2] University of Washington, Friday Harbor Laboratories, San Juan Islands, WA USA
[3] Alaska Pacific University, Anchorage, AK, USA
[34] Moss Landing Laboratories, California State University

PICES Annual Science Meeting 2024 – Honolulu, HI USA
S-III – Advanced tools to monitor, observe, and assess small pelagic fish populations in support of ecosystem based fisheries management and maintaining ecosystem services

Forage Fishes

Integral part of marine food webs in ecosystems of the North Pacific

Significant knowledge gaps related to status, life histories

Pacific herring, Clupea pallasii

Sandlance, Ammodytes sp.

Capelin, Mallotus villosus

Eulachon, Thaleichthys pacificus

Forage Fishes

Monitoring is complicated…

- populations difficult to sample
- large fluctuations in abundance
- prone to density-dependent and environmentally-driven range shifts

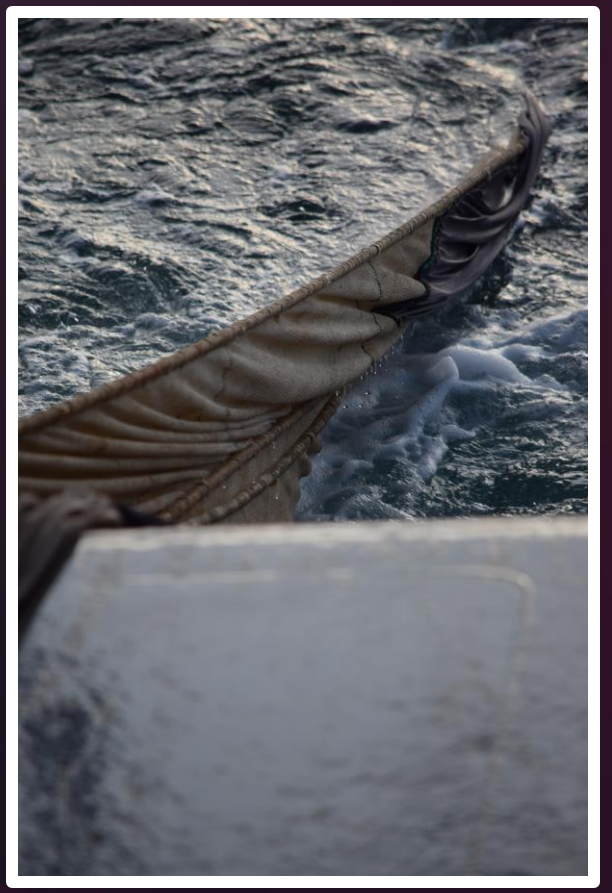
Pacific herring, Clupea pallasii

Sandlance, Ammodytes sp.

Capelin, Mallotus villosus

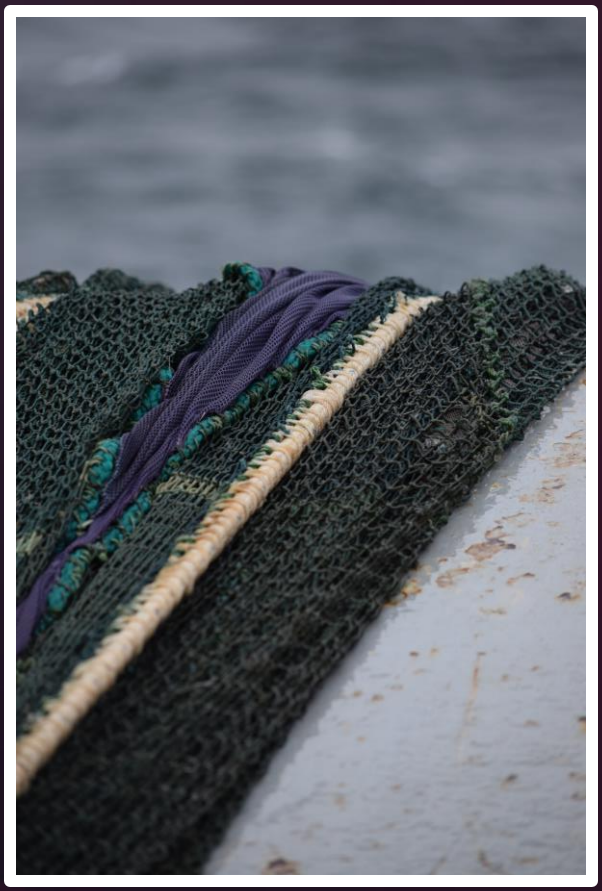
Eulachon, Thaleichthys pacificus

Data Poor



Non-target species – few fisheries for forage spp. in Northeast Pacific
Limited stock assessments

Sampling



Challenges to effective sampling…

- habitat constraints (limits to availability)
- gear constraints (issues related to selectivity)

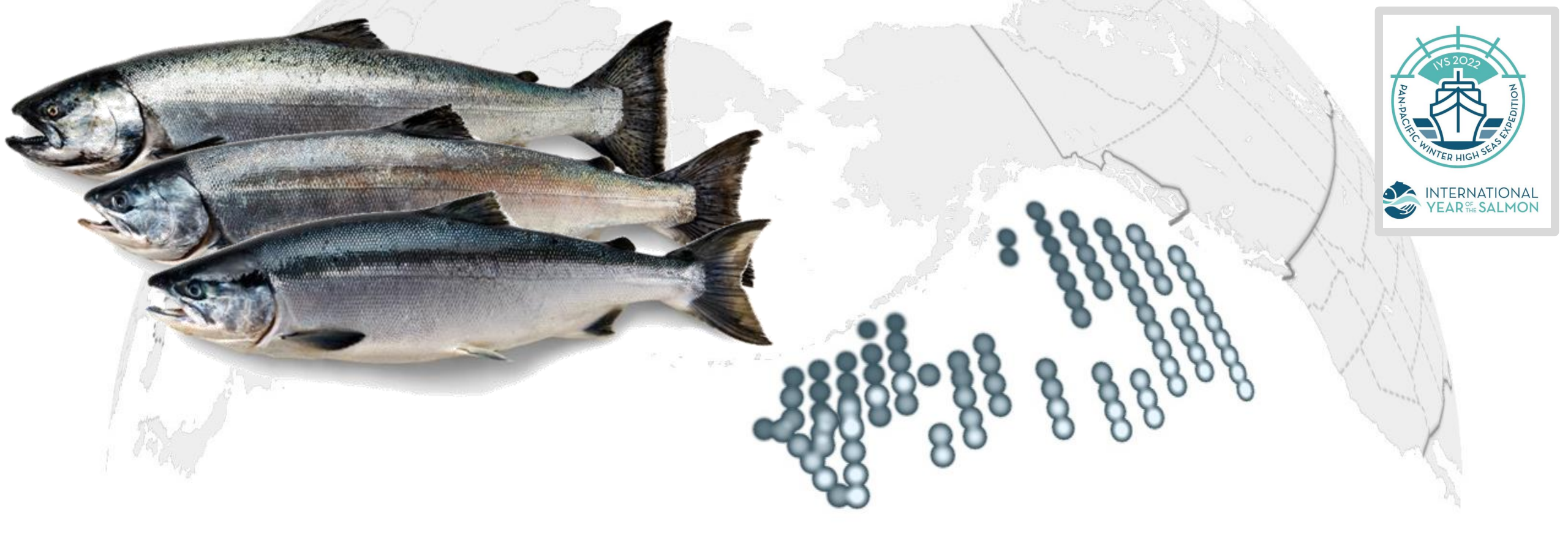
Monitoring requires creative approaches to sampling and assessment

In most traditional fishery surveys… gear used and habitats surveyed not optimized for forage species.

Standardized surveys lack gear and protocols to quantitatively evaluate forage fish.

IYS 2022
PAN-PACIFIC WINTER HIGH SEAS EXPEDITION
INTERNATIONAL YEAR OF THE SALMON

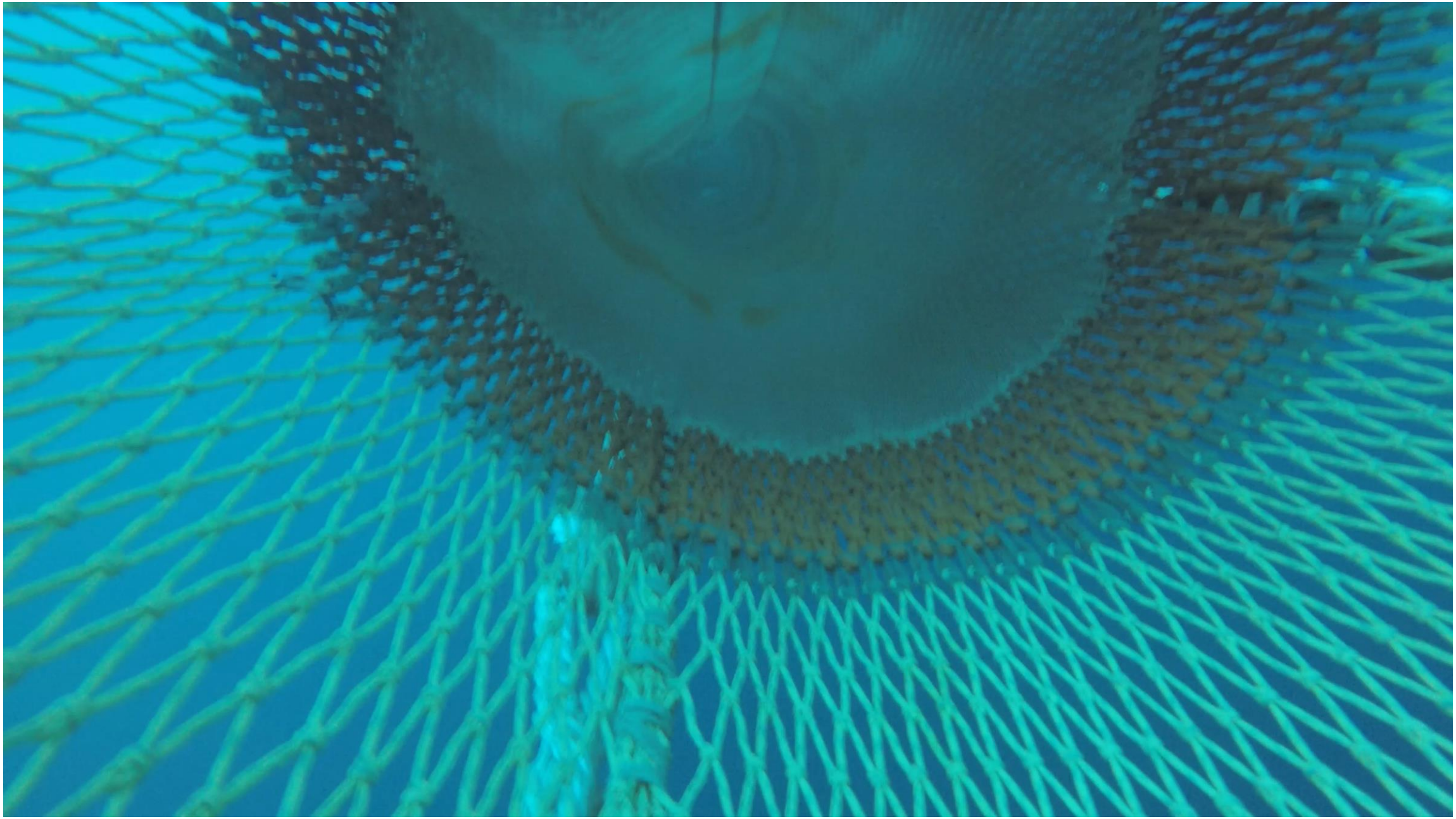
Targeted surveys are expensive and rare.



The 2022 Pan-Pacific Winter High Seas Expedition

The largest ever pan-Pacific expedition to study the winter ecology of salmon in the North

IYS 2022
PAN-PACIFIC WINTER HIGH SEAS EXPEDITION
INTERNATIONAL YEAR OF THE SALMON



Pelagic Trawls

small pelagic fishes are challenging

- (sufficiently motile to avoid fine-mesh trawls, small enough to pass thru mesh in standard trawls)

Recapture nets

Marinovich trawls fitted with small-mesh recapture nets designed to quantify fish escapement thru trawl mesh panels

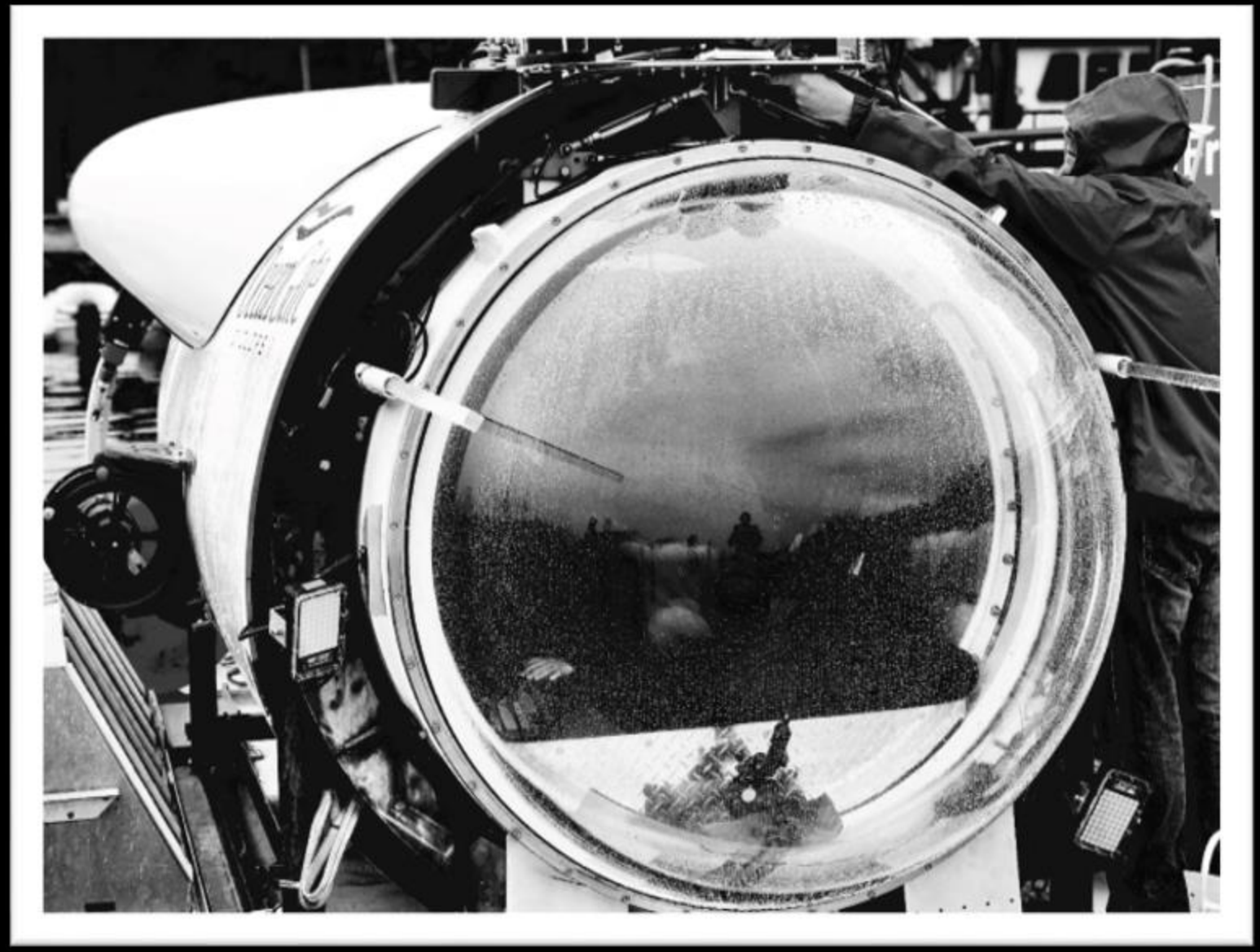
Trawl Modification

mod-1 Marinovich

- pelagic herring trawl with fine-mesh cod-end liner used in baseline acoustic-trawl survey
- further modified adding a small-mesh section to reduce escapement
- further use of recapture nets in acoustic-trawl surveys confirmed increased retention and reduced size selectivity

Another Way…

Another Way…



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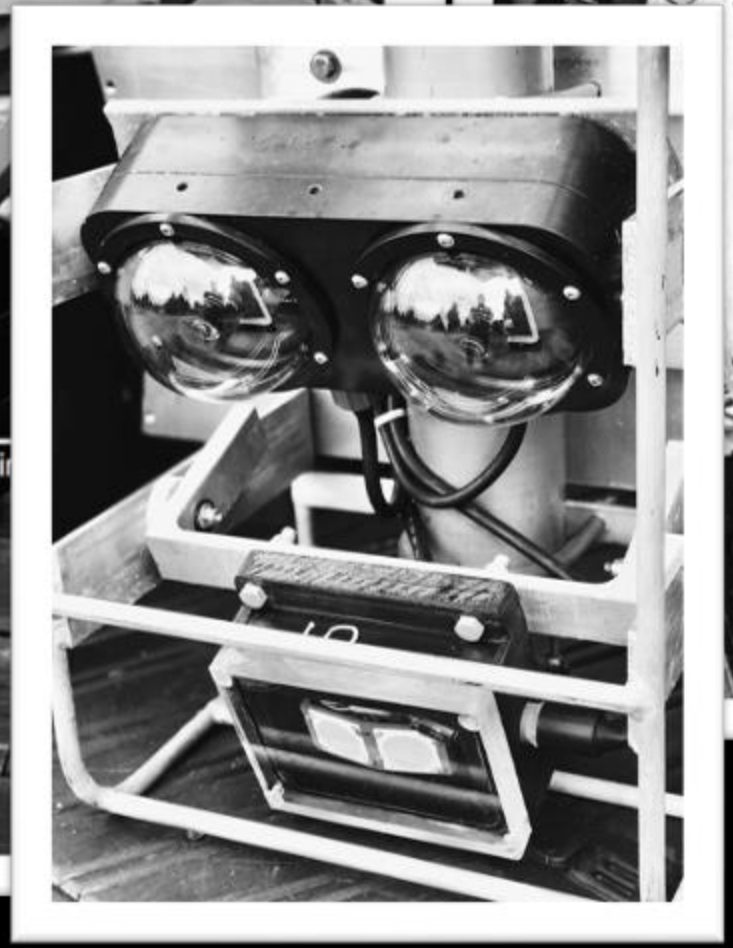

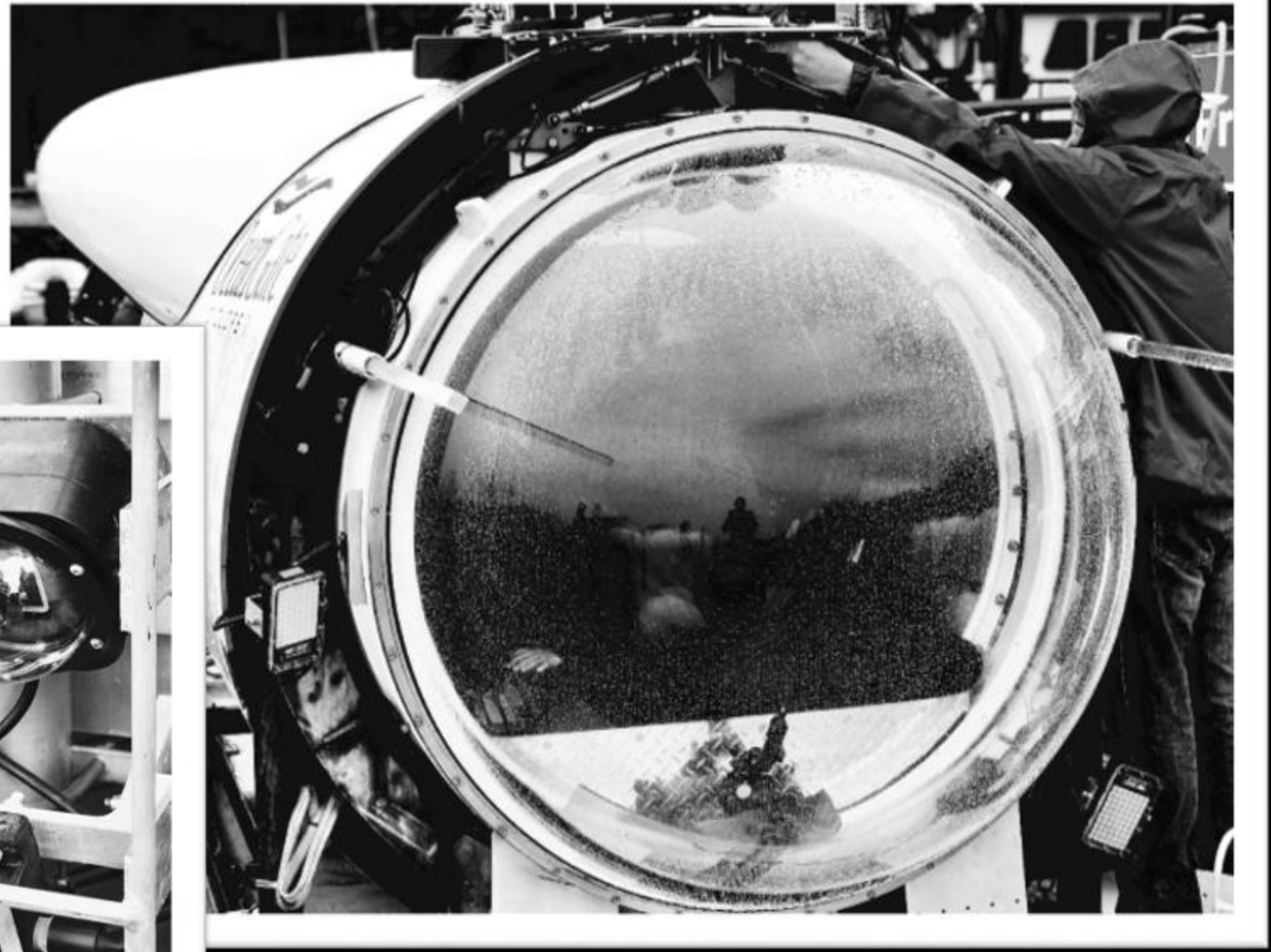

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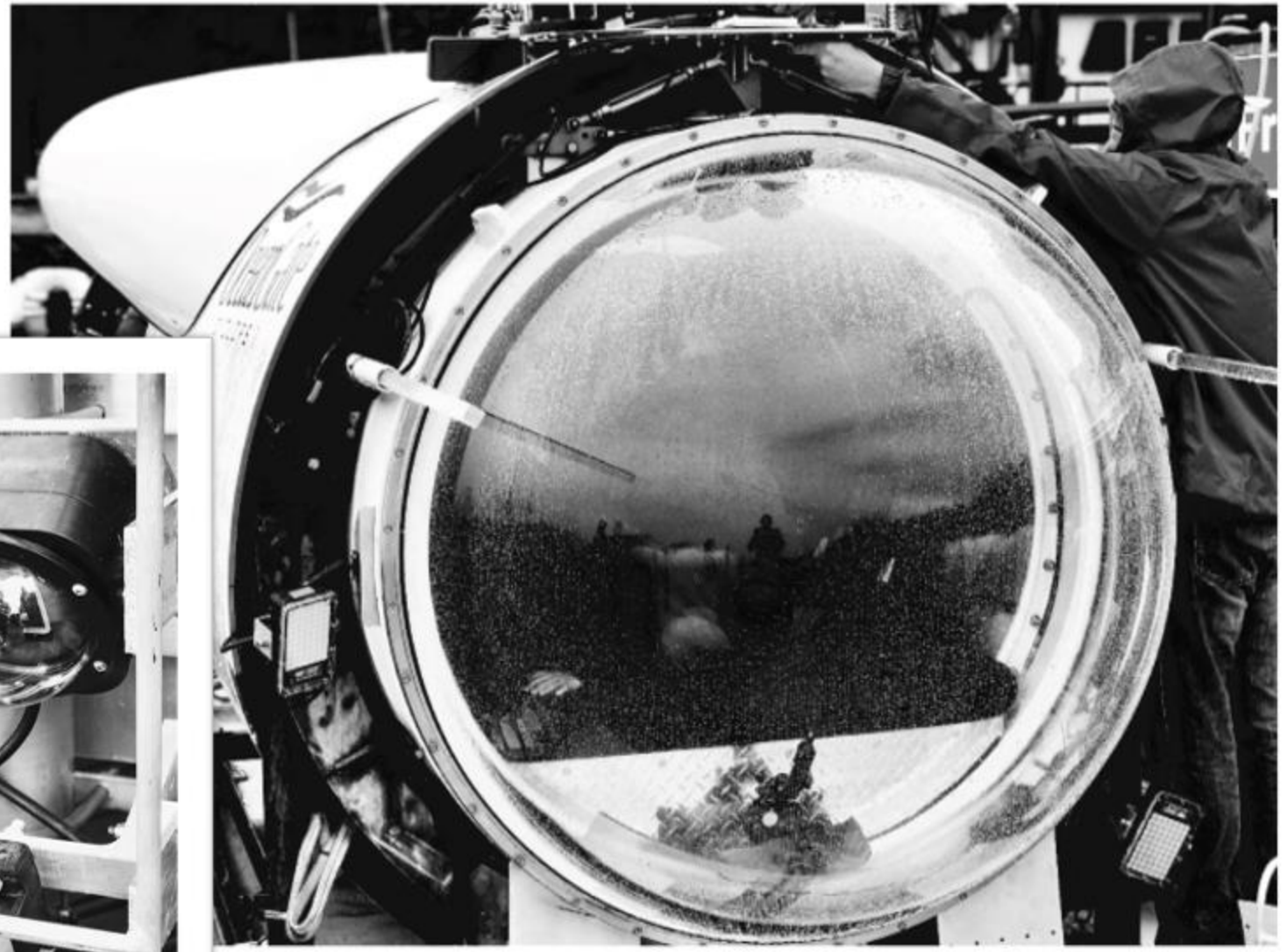
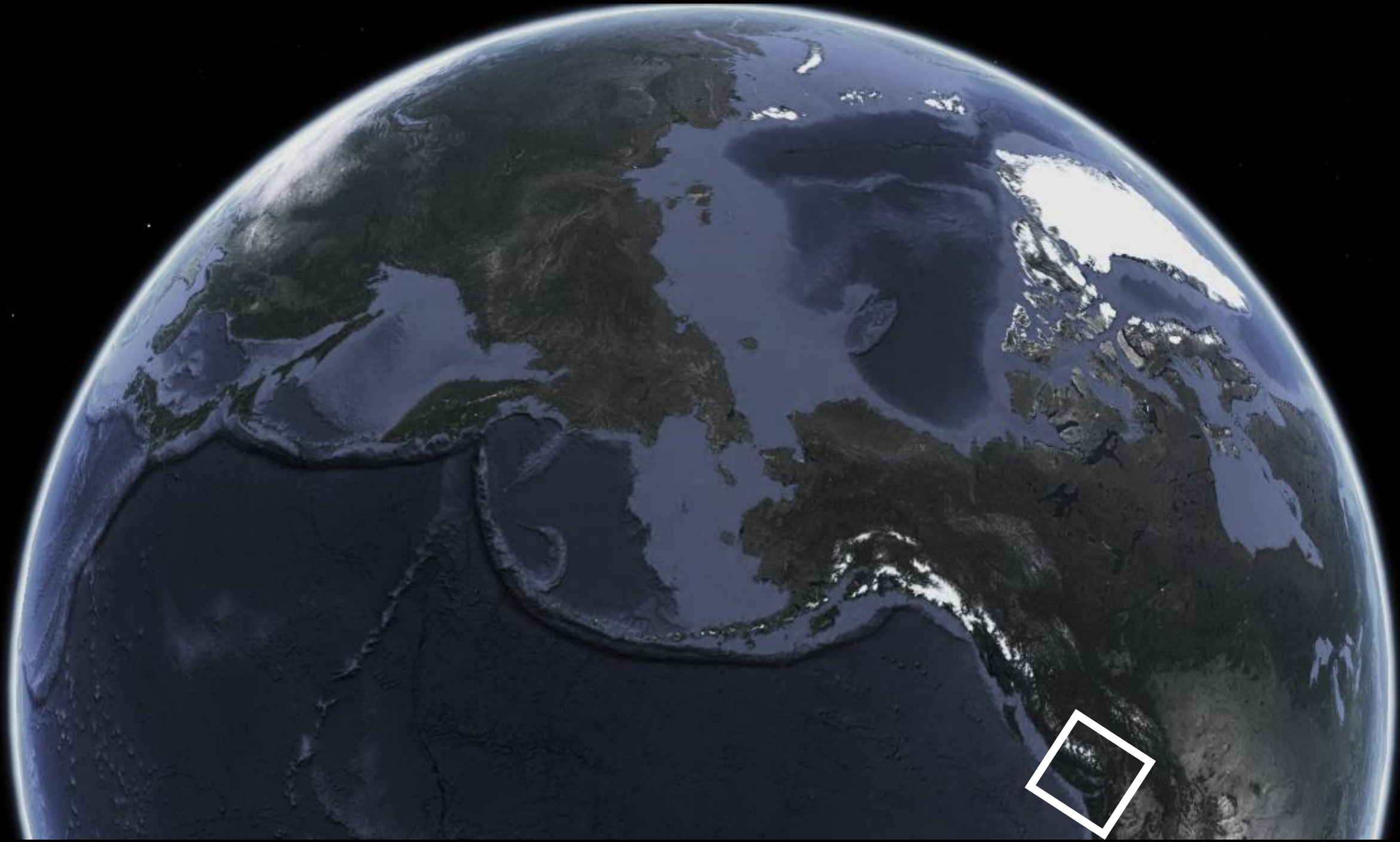
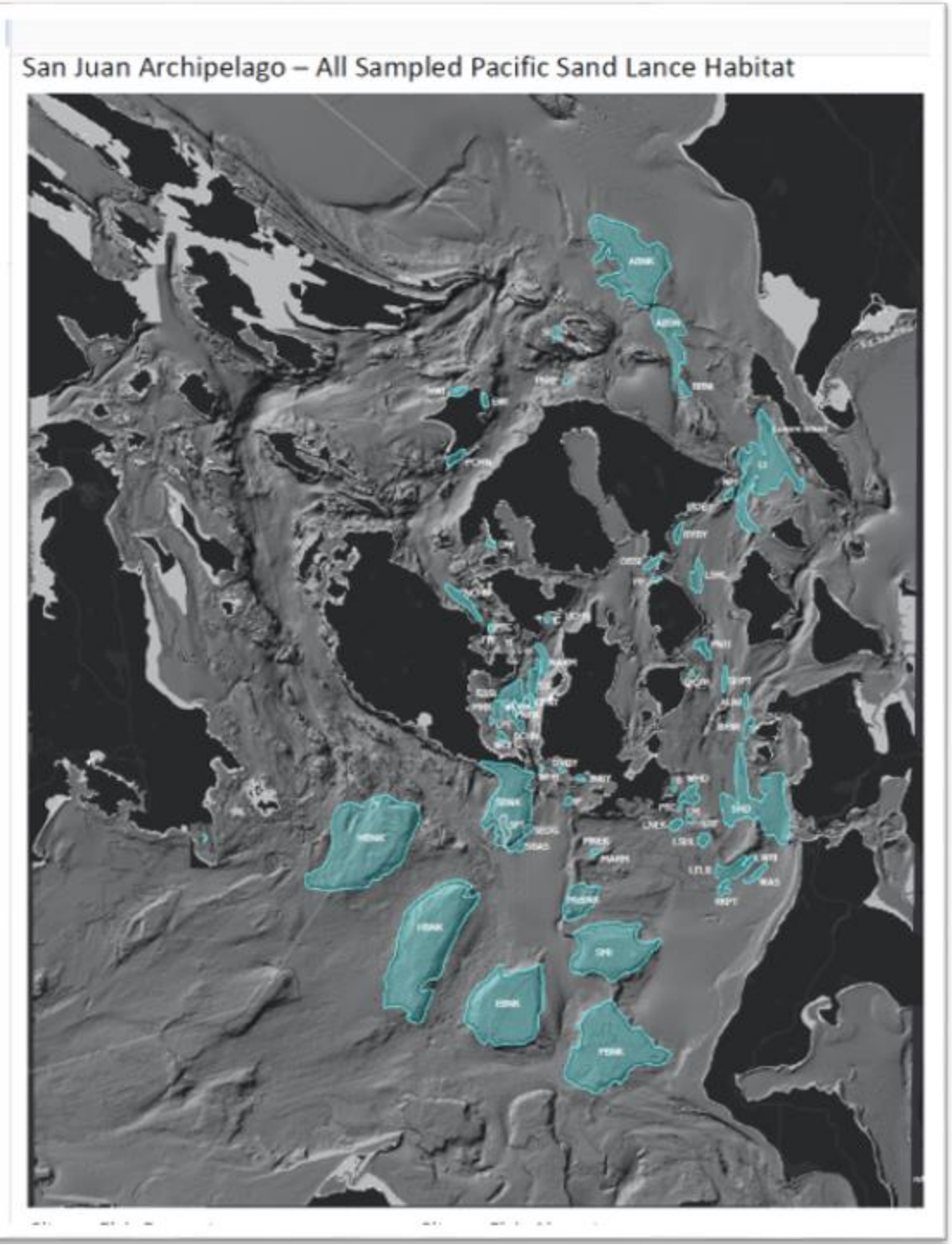


Sand lance (*Ammodytes spp.)* are small planktivorous fishes

Integral to Northern Hemisphere pelagic ecosystems




North Pacific
Vancouver
Salish Sea
San Juan Islands
Victoria
San Juan Islands
Seattle



Contents lists available at ScienceDirect

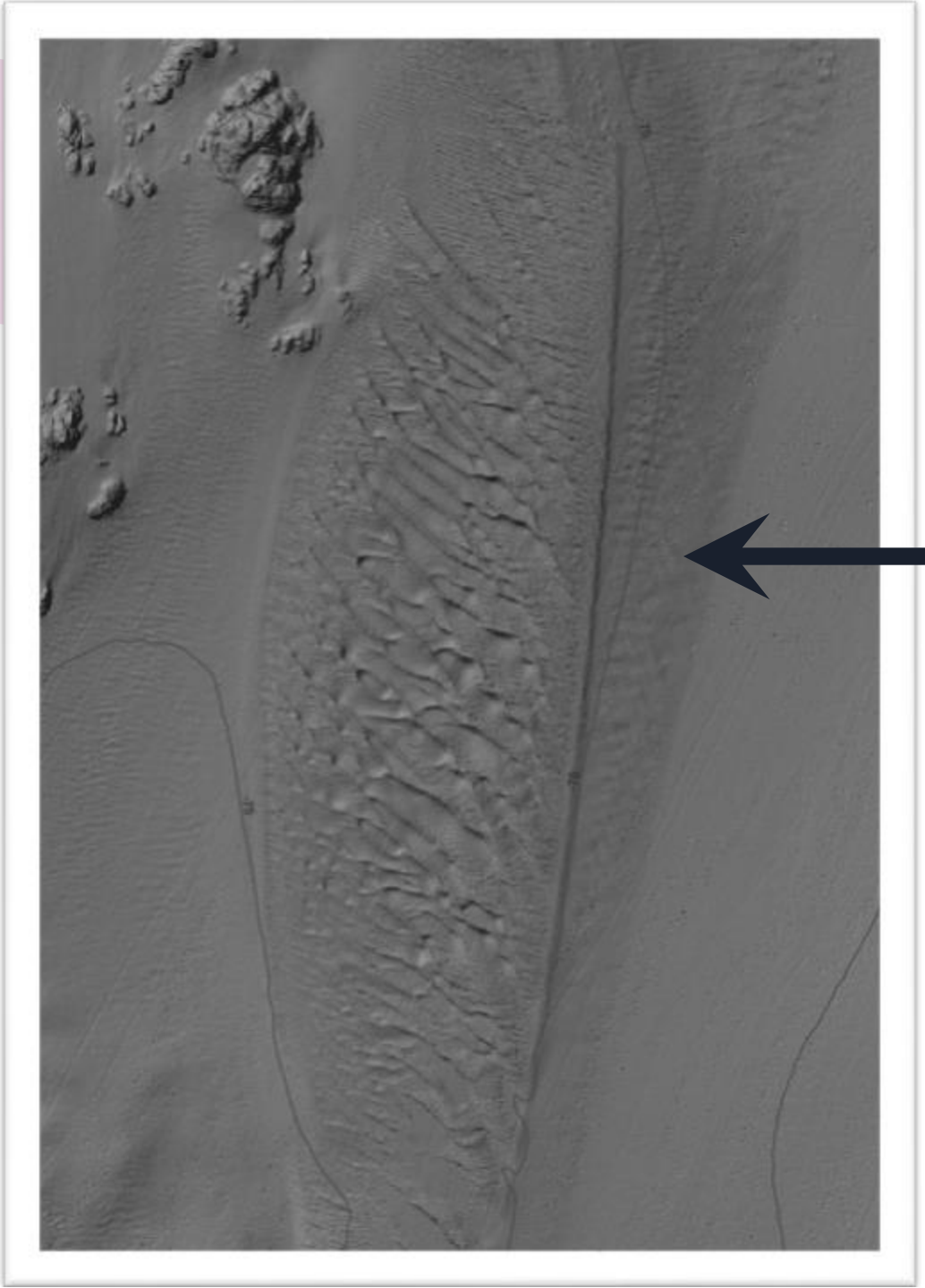
Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

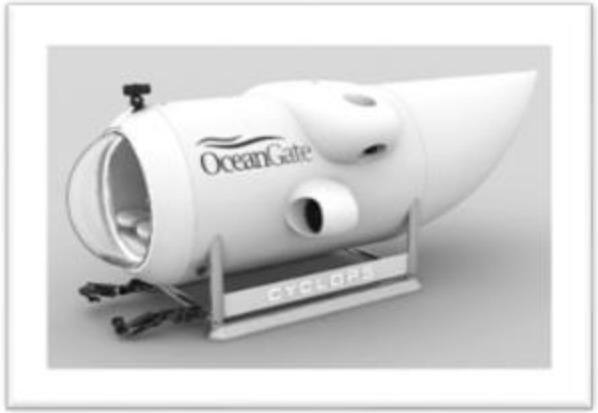
Atlas of pacific sand lance (*Ammodytes personatus*) benthic habitat – Application of multibeam acoustics and directed sampling to identify viable subtidal substrates

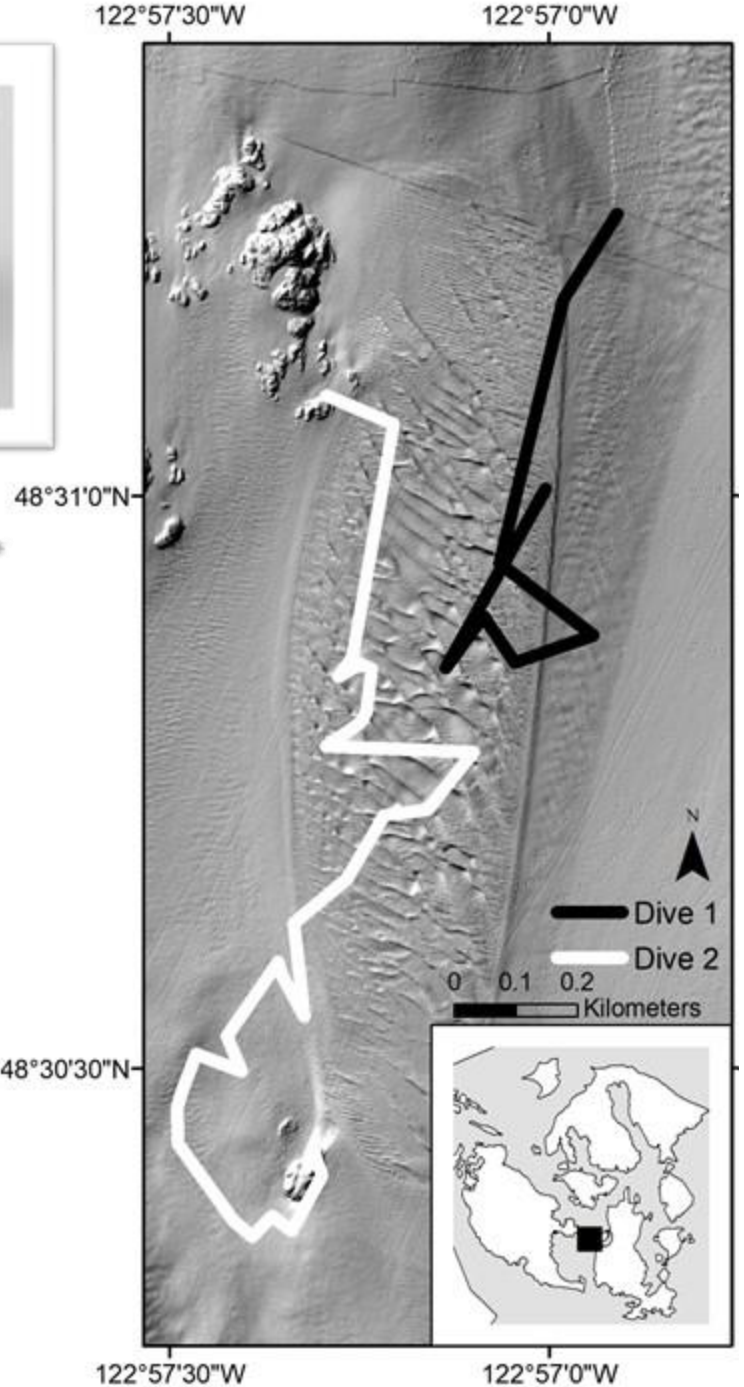
Matthew R. Baker [a,b,*], H. Gary Greene [c,d], John Aschoff [d], Elisa Aitoro [b], Eileen Bates [b], Donovan Hesselroth [b], Katie Johnson [b], Benjamin Mather [b], Nancy Sealover [b]

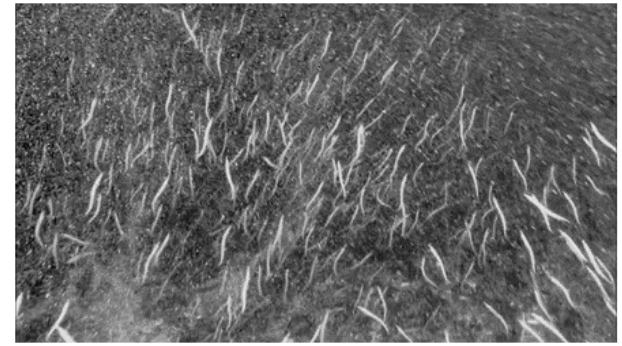
Fish associated with particular benthic habitats (rockfishes, sandeels, sandlances) may be particularly difficult to assess thru standard survey methodologies

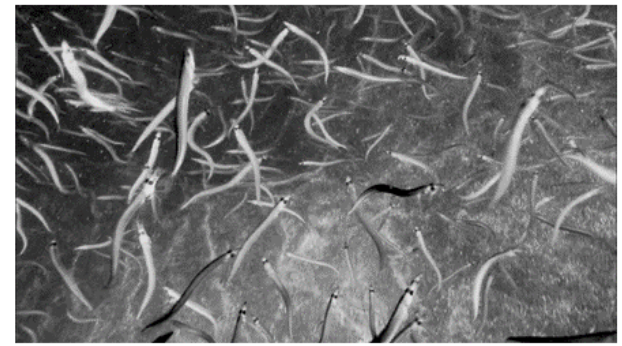


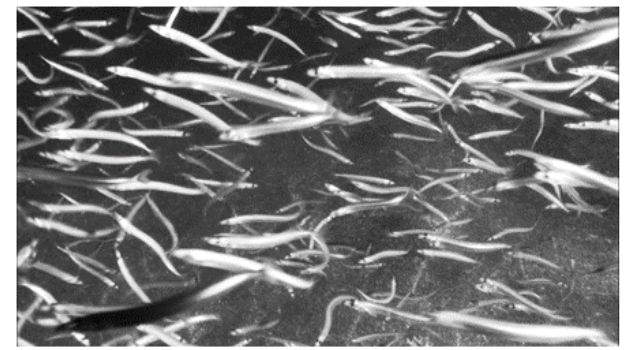

San Juan Islands

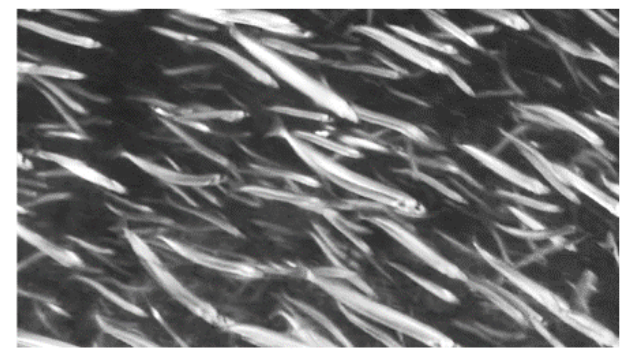

OceanGate
CYCLOPS

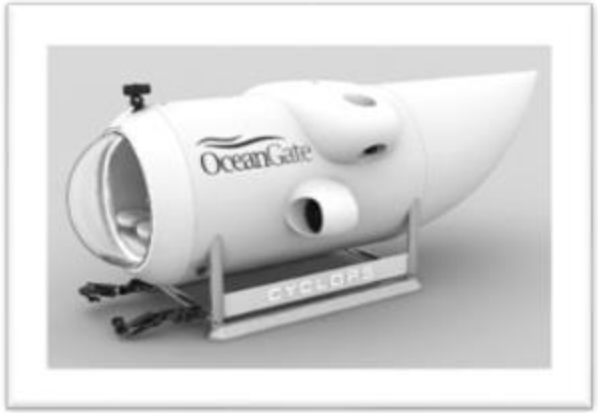

122°57'30"W
122°57'0"W
48°31'0"N
48°30'30"N
N
Dive 1
Dive 2
0 0.1 0.2
Kilometers

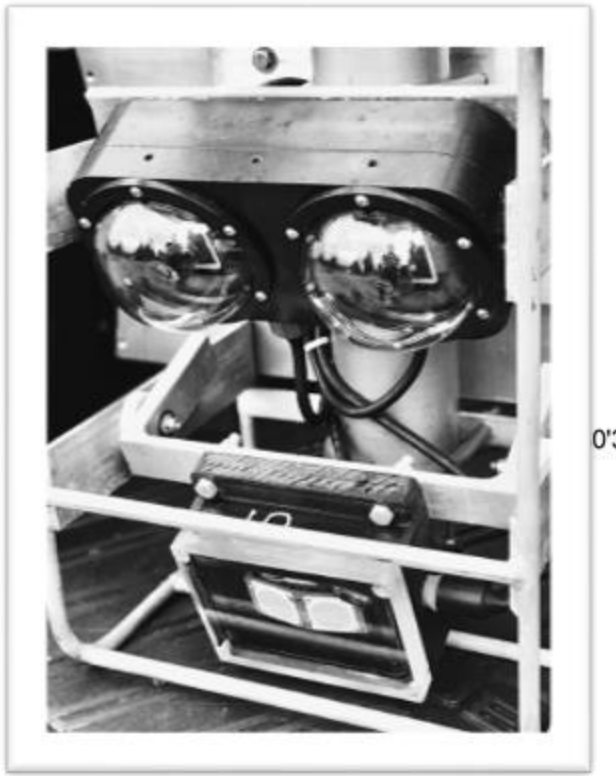


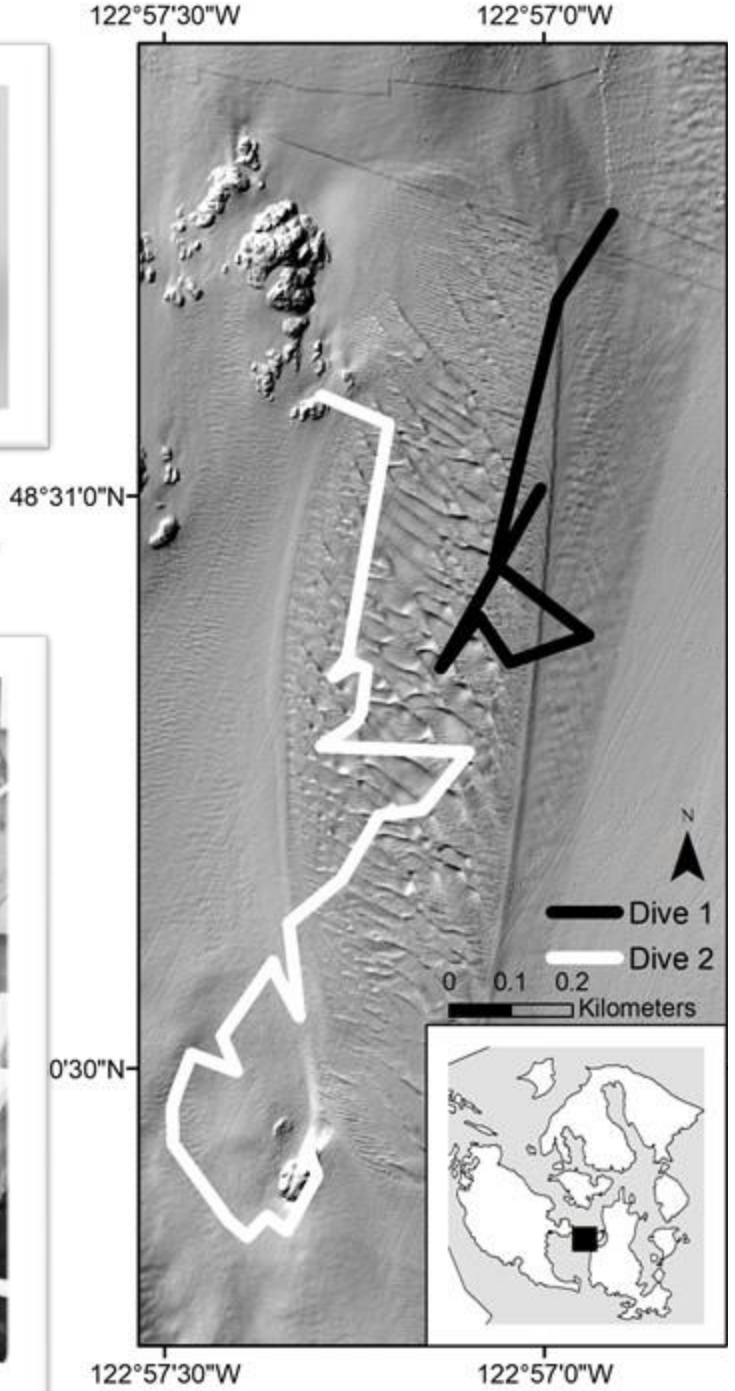








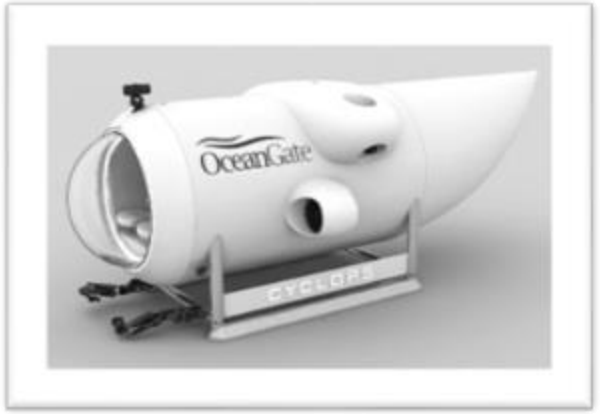


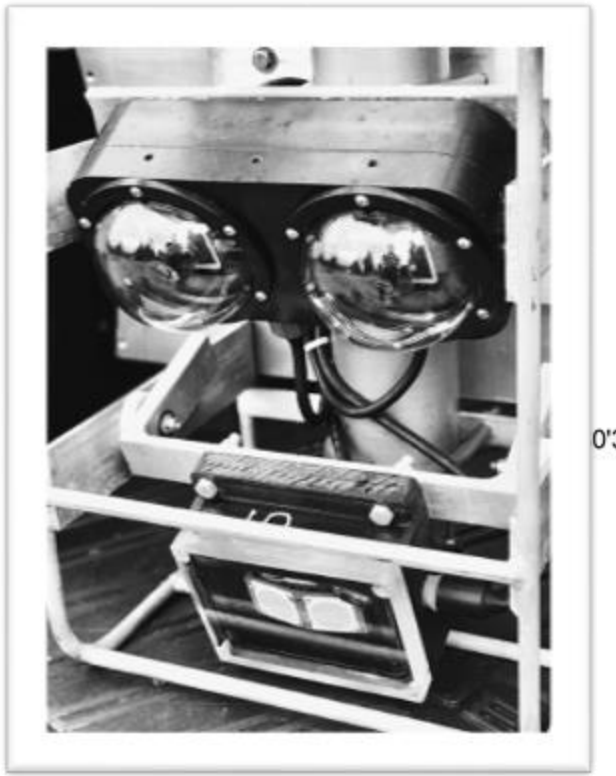


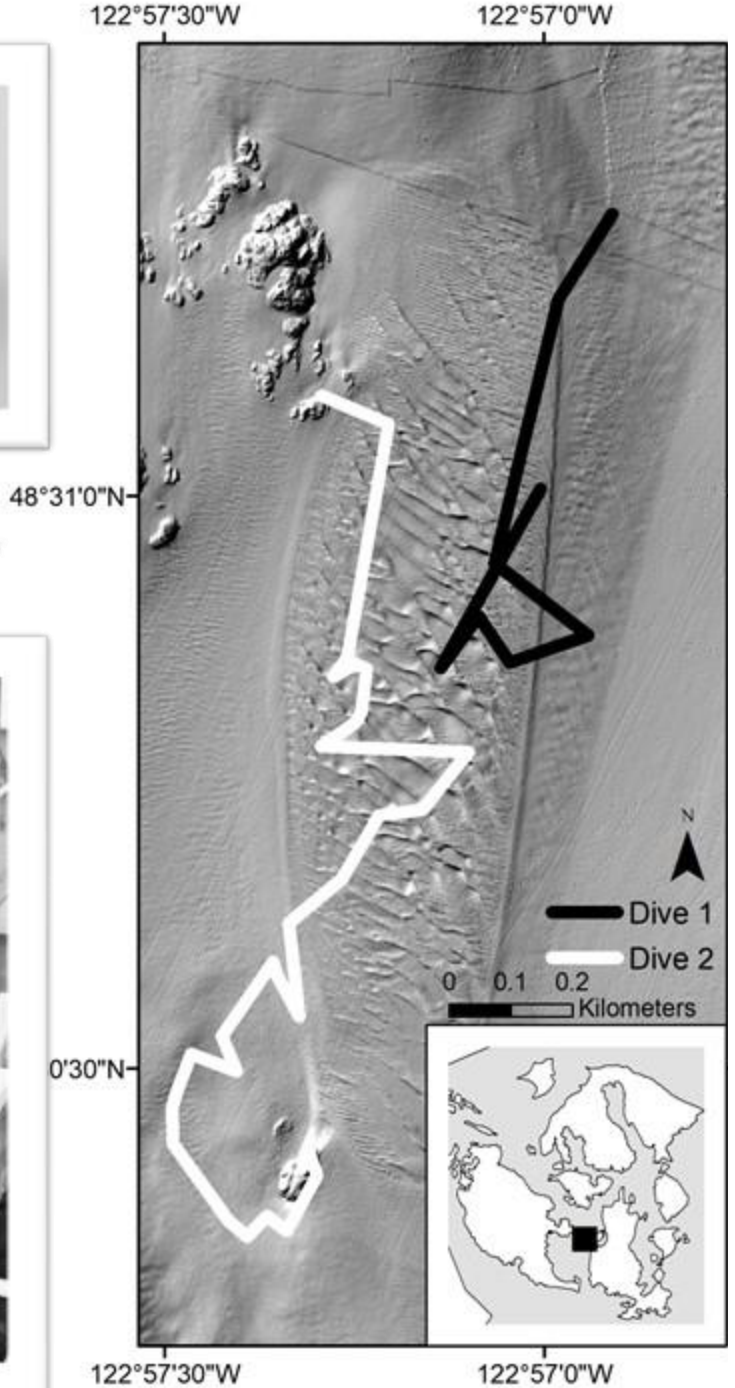
Stereocamera System....

Chameleon3 machine vision cameras
- single-board ARM (Acorn RISC Machine)
- system-on-chip computer (ODroid XU4)
- custom circuit for power and timing control

Cameras mounted in aluminum housing (Sexton Inc.)
- Domed viewports used to allow wide view angles and minimize radial distortion caused by light refraction
- Strobe unit consisted of two Bridgelux LED arrays powered by a TaskLED driver, producing 1300 lumens at 10.4 W
- System powered with 24 V 10 Ah NiMH battery pack
- Images collected every 5 seconds







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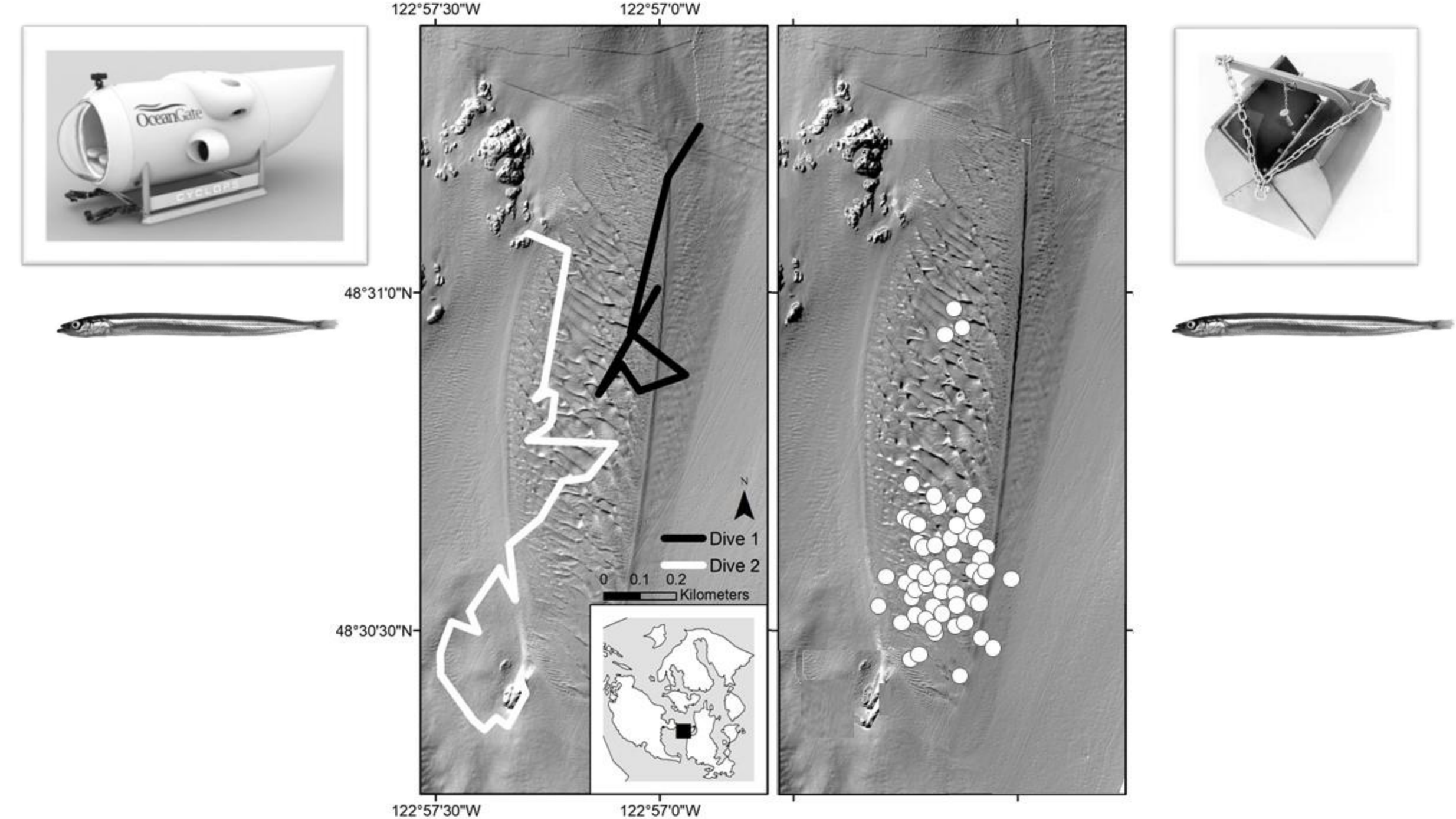
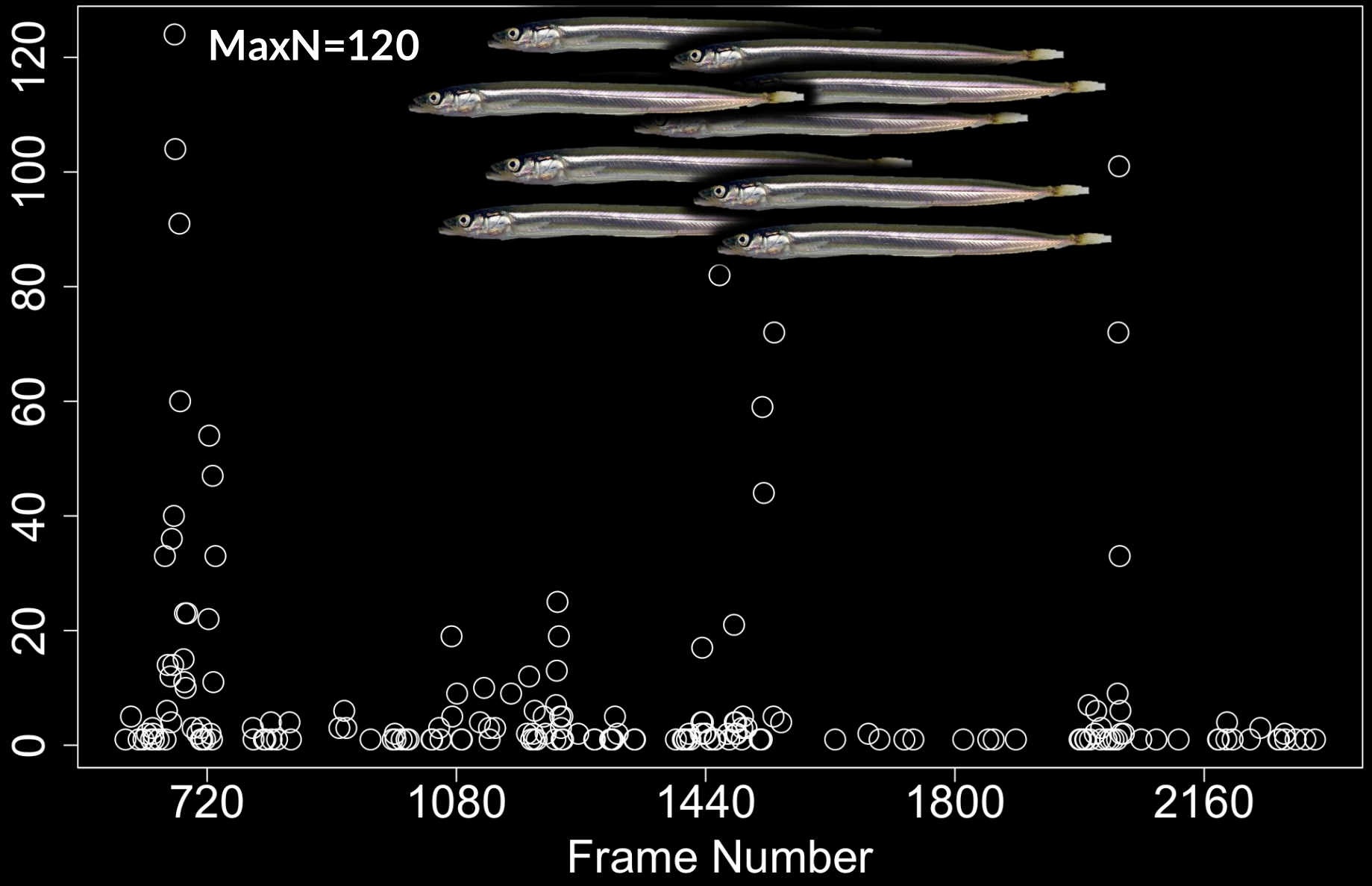
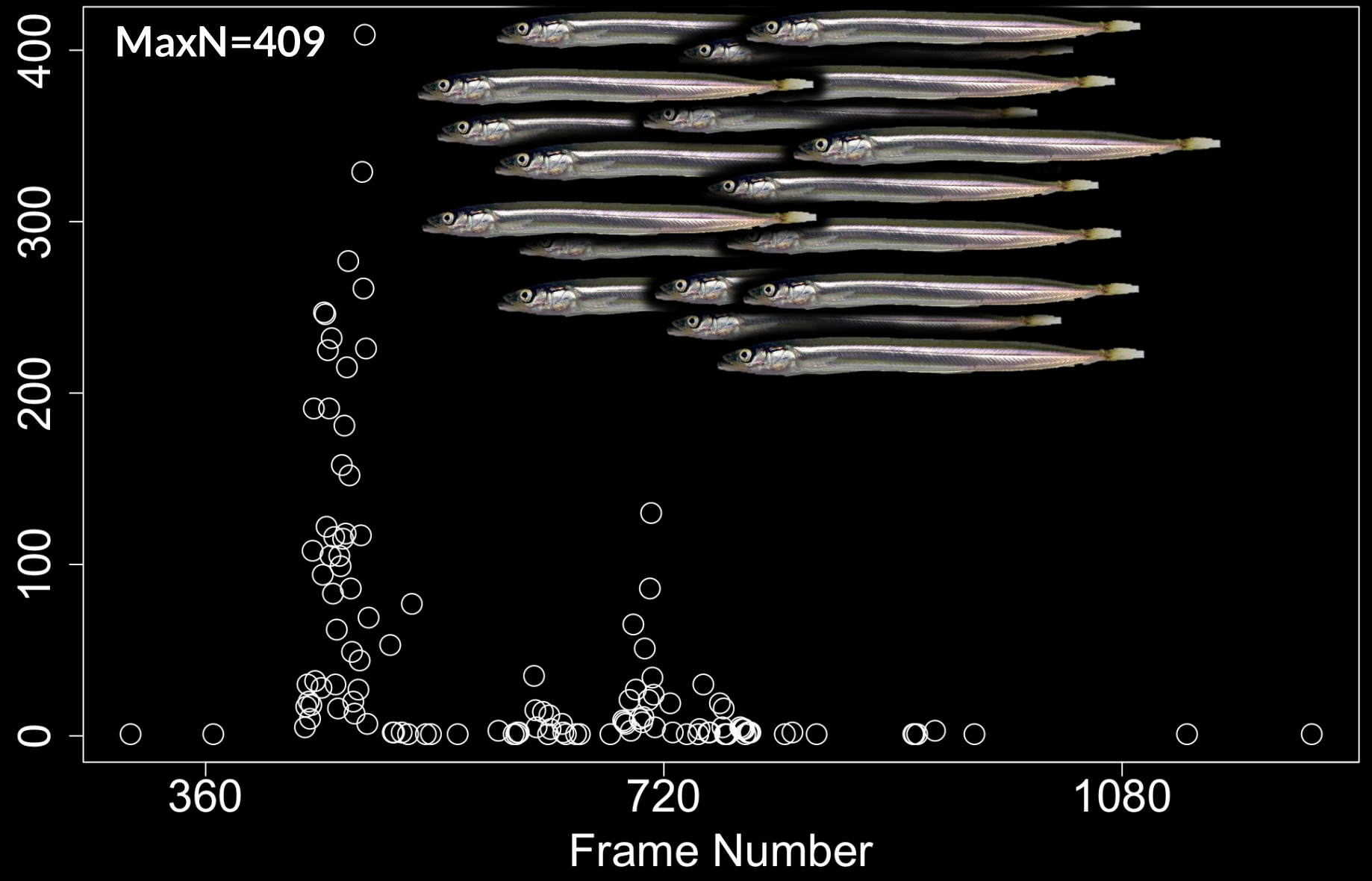
CYCLOPS

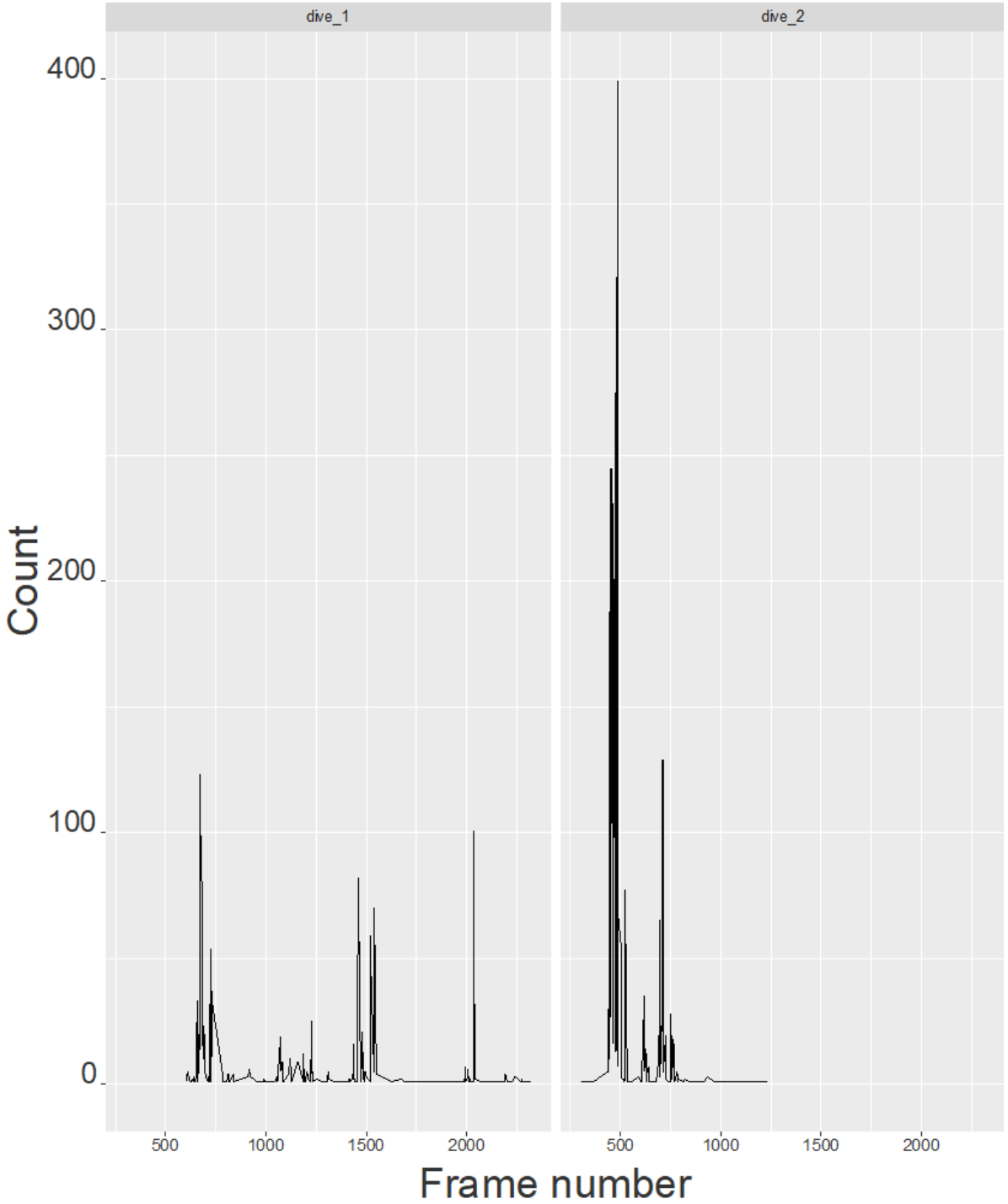

122°57'30"W
122°57'0"W
48°31'0"N
48°30'30"N
N
Dive 1
Dive 2
0 0.1 0.2
Kilometers

Dive 1


MaxN=120
0
20
40
60
80
100
120
720
1080
1440
1800
2160
Frame Number

Dive 2

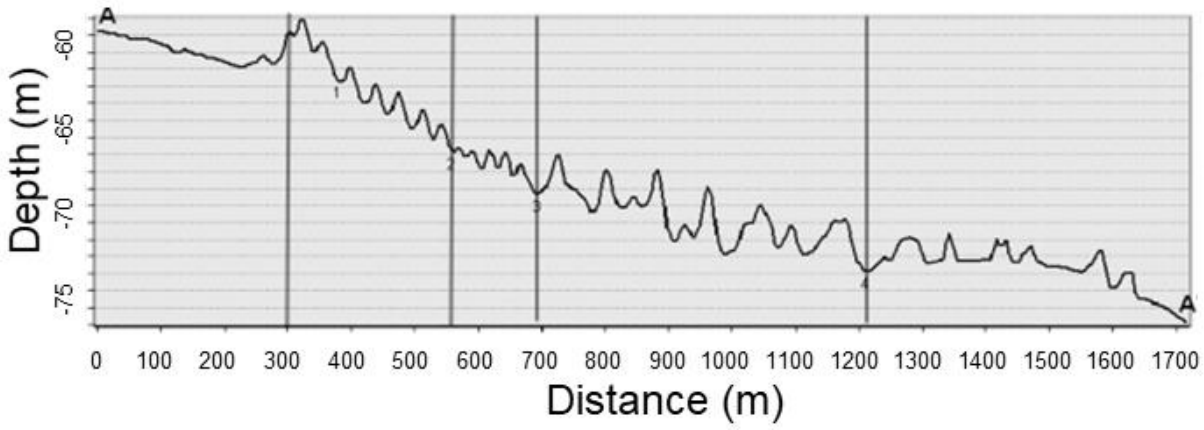




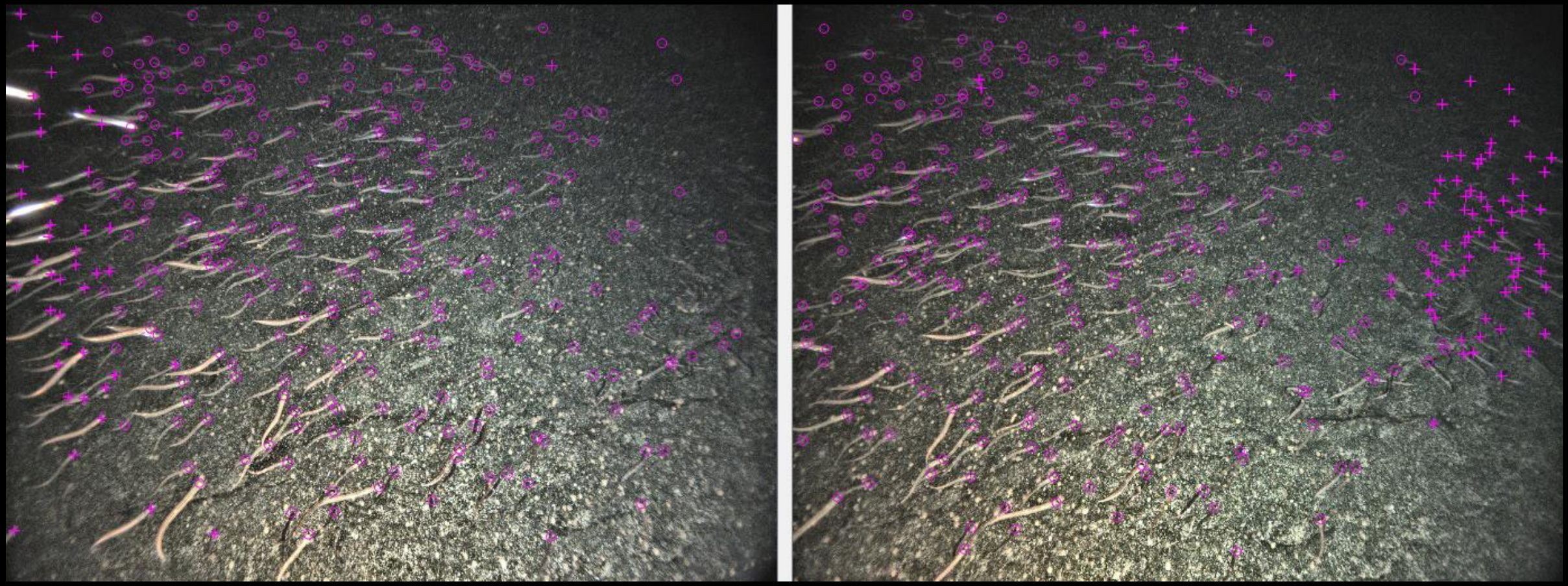
Abundance

SEBASTES open-source software

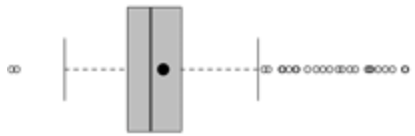
Dive 1 – 1691 observed, MaxN = 124
Dive 2 – 6148 observed, MaxN = 409

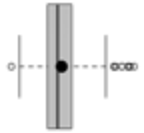


Fish Counts

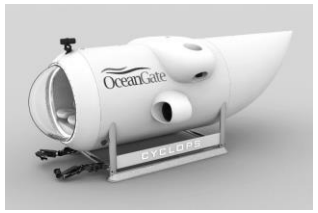


Fish Measurements

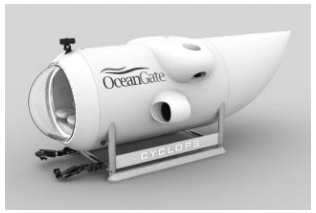




dive 1



dive 2



Van Veen grab

Number of Fish

60
40
20
0

150
100
50
0

150
100
50
0

0 10 20 30

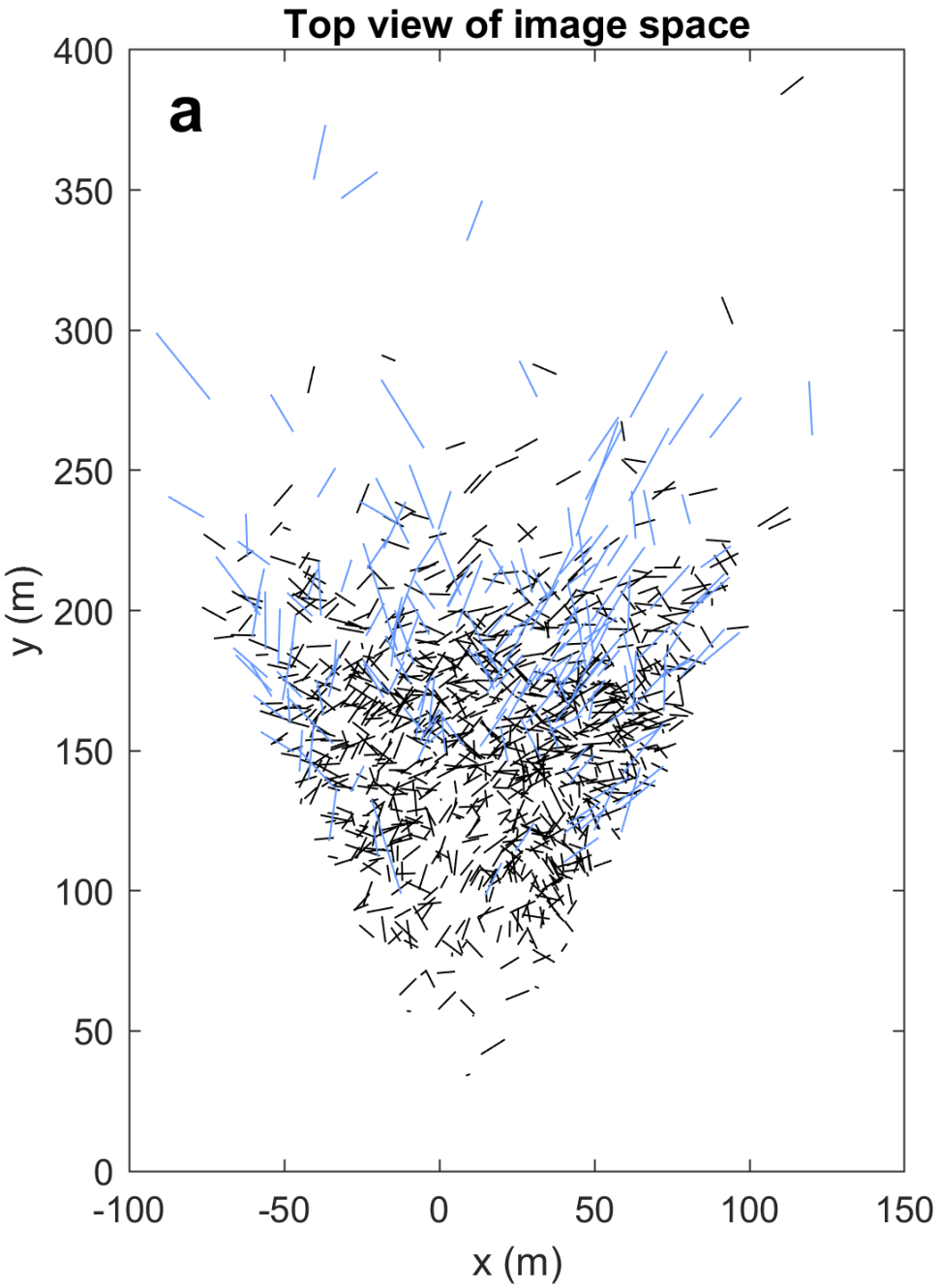
0 10 20 30

0 10 20 30

length (cm)

Lengths estimated using SEBASTES not significantly different from specimens measured in lab.

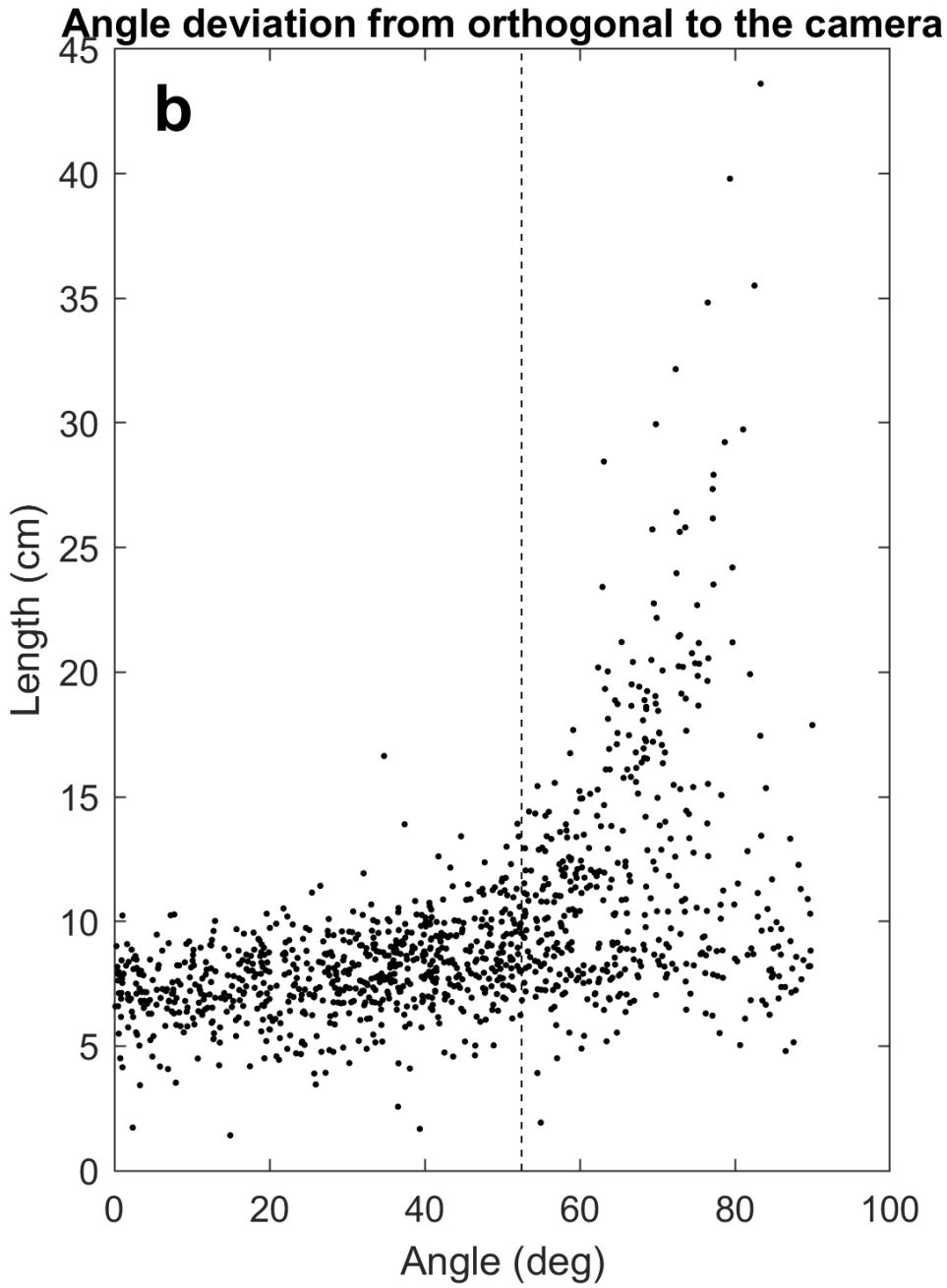
stereocamera= higher variance



Measurement error for fish lengths…
I. Distance from camera

Extreme values (lengths beyond observed measurements in captured specimens) occurred at…

- greatest distances from the camera (extreme y-axis values)
- periphery of the image space (extreme x-axis values)

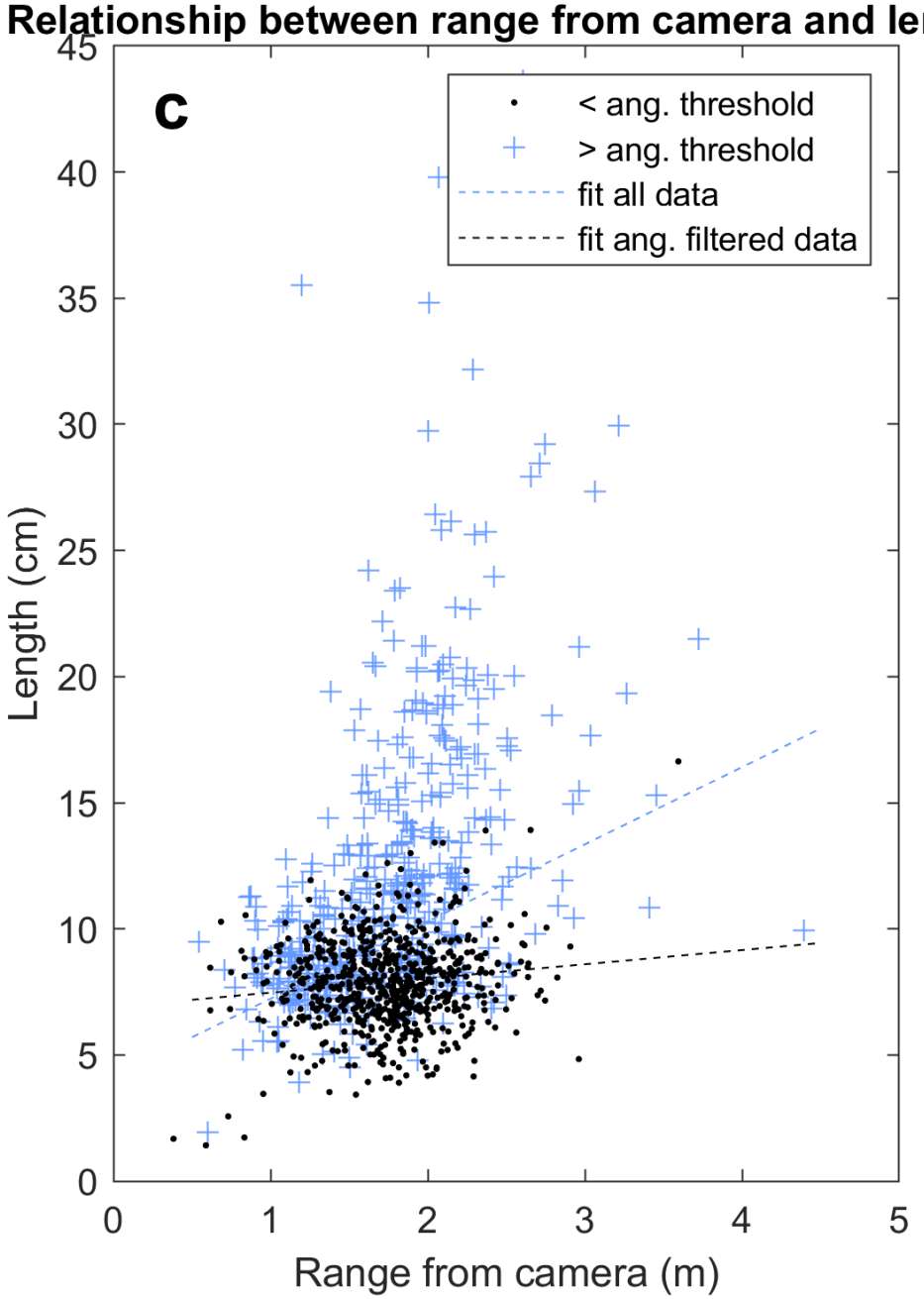


Measurement error for fish lengths…
II. Fish Angle (deviation from orthogonal)

Extreme values (lengths beyond observed measurements in captured specimens) occurred…

- fish > 50◦ from orthogonal to the camera.

Regression analysis identified a breakpoint at 50◦.



Solution

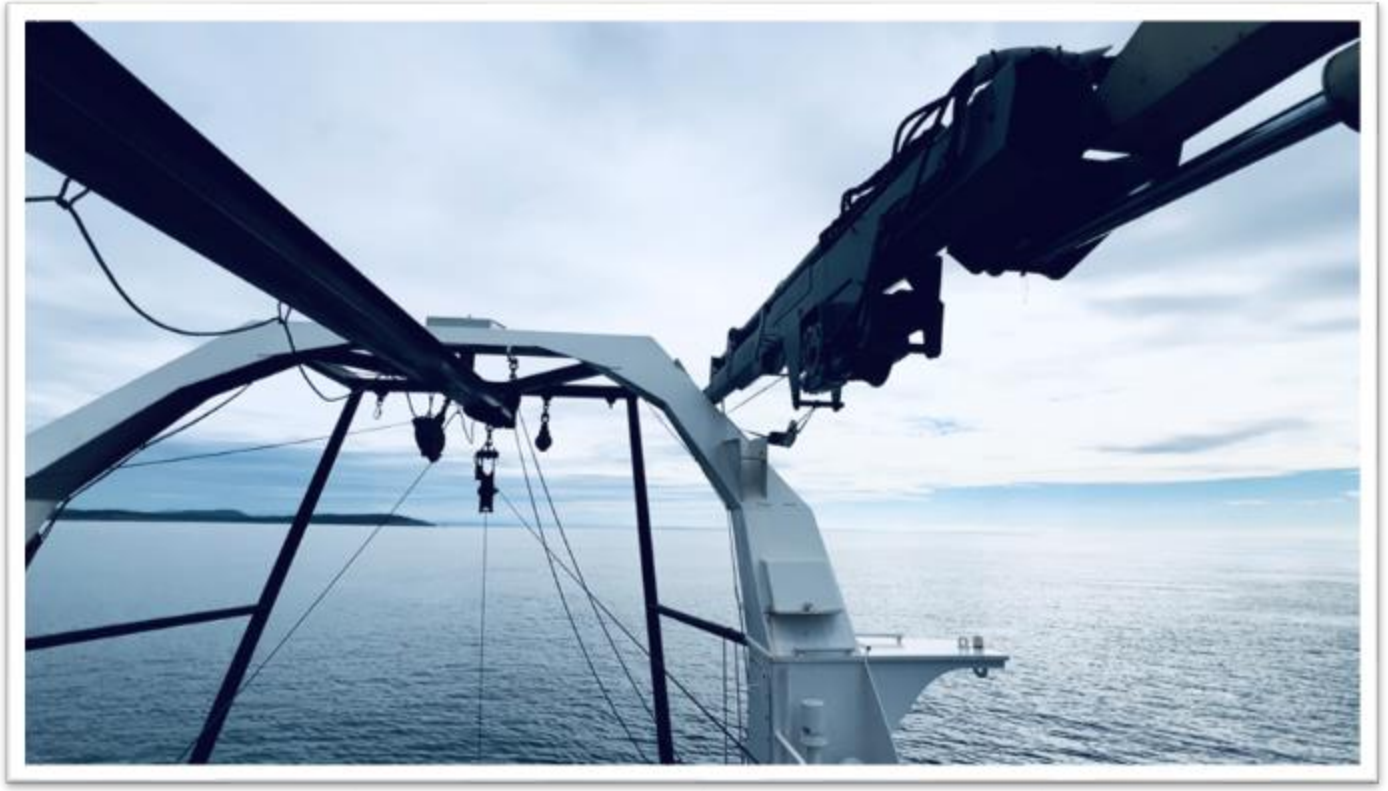
Removal of fish > 50◦ from orthogonal removed…

- extreme values for length measurement

Measurement error (variation in length) reduced by order of magnitude

Submersible observations…

- insight to physical conditions and habitat
- confirmed wavefield morphologies previously identified thru multibeam acoustics
- insight to abundance and behavioral attributes
- insight to light penetration, relevant to diurnal cues and diel vertical migration



Quantitative analysis of stereocamera data…

- fish abundance and length distribution
- insight to presence, abundance, and movement
- insight to applications and constraints to observation-based sampling methods

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Full length article

Use of manned submersible and autonomous stereo-camera array to assess forage fish and associated subtidal habitat

Matthew R. Baker [a,b,*], Kresimir Williams [a], H.G. Greene [c,d], Casey Greufe [b], Heather Lopes [b], John Aschoff [d], Rick Towler [a]

ICES Journal of Marine Science, 2023, 0, 1–15
DOI: 10.1093/icesjms/fsad106
Original Article

ICES CIEM

Diel vertical migration in Pacific sand lance (*Ammodytes personatus*)—a pelagic forage fish associated with benthic substrates

Matthew R. Baker[1,2,3,4,*], T. S. Smeltz[3], Kresimir Williams[4], Casey Greufe[2], Megan Ewing[2], Jonathan Chapman[2], Julia Glassy[2], Eva Hasegawa[2], Kathleen P. Cieri[2], Sofia Matson[2], and Rick Towler[4]

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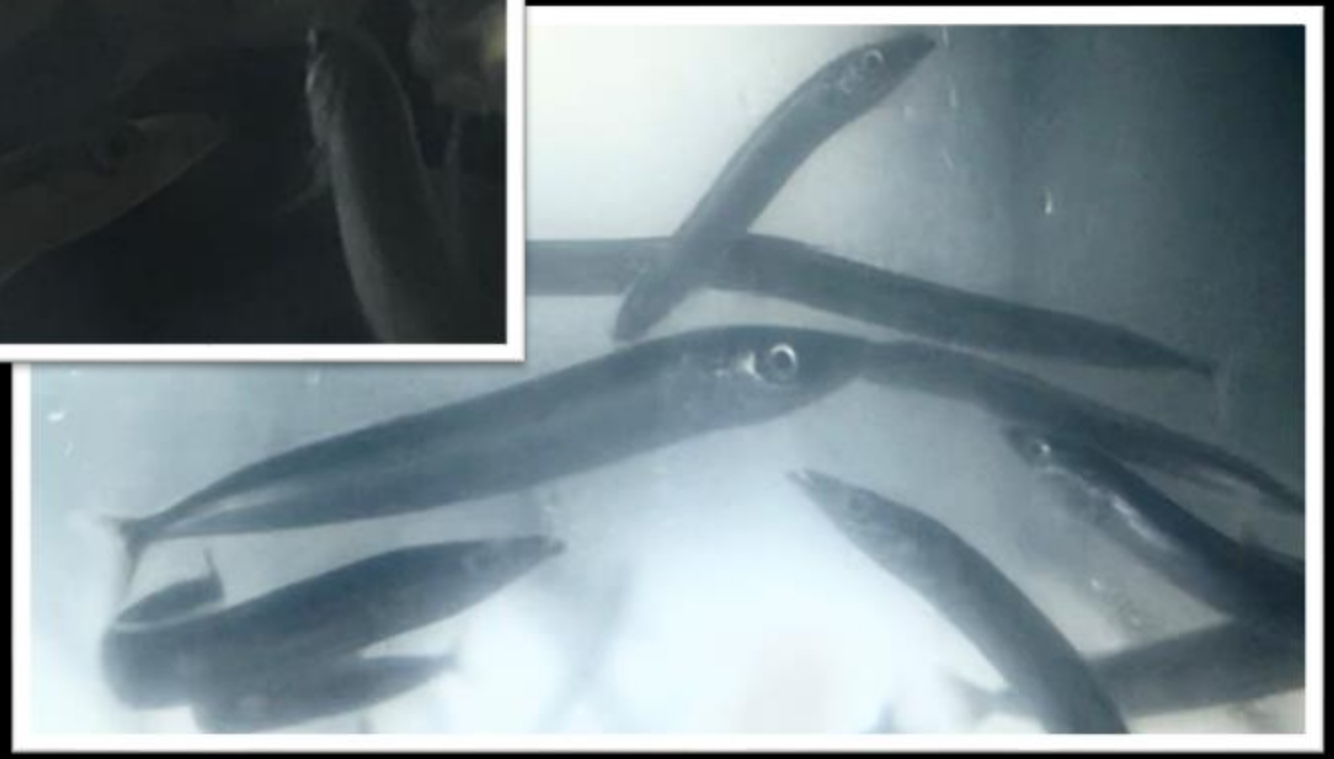
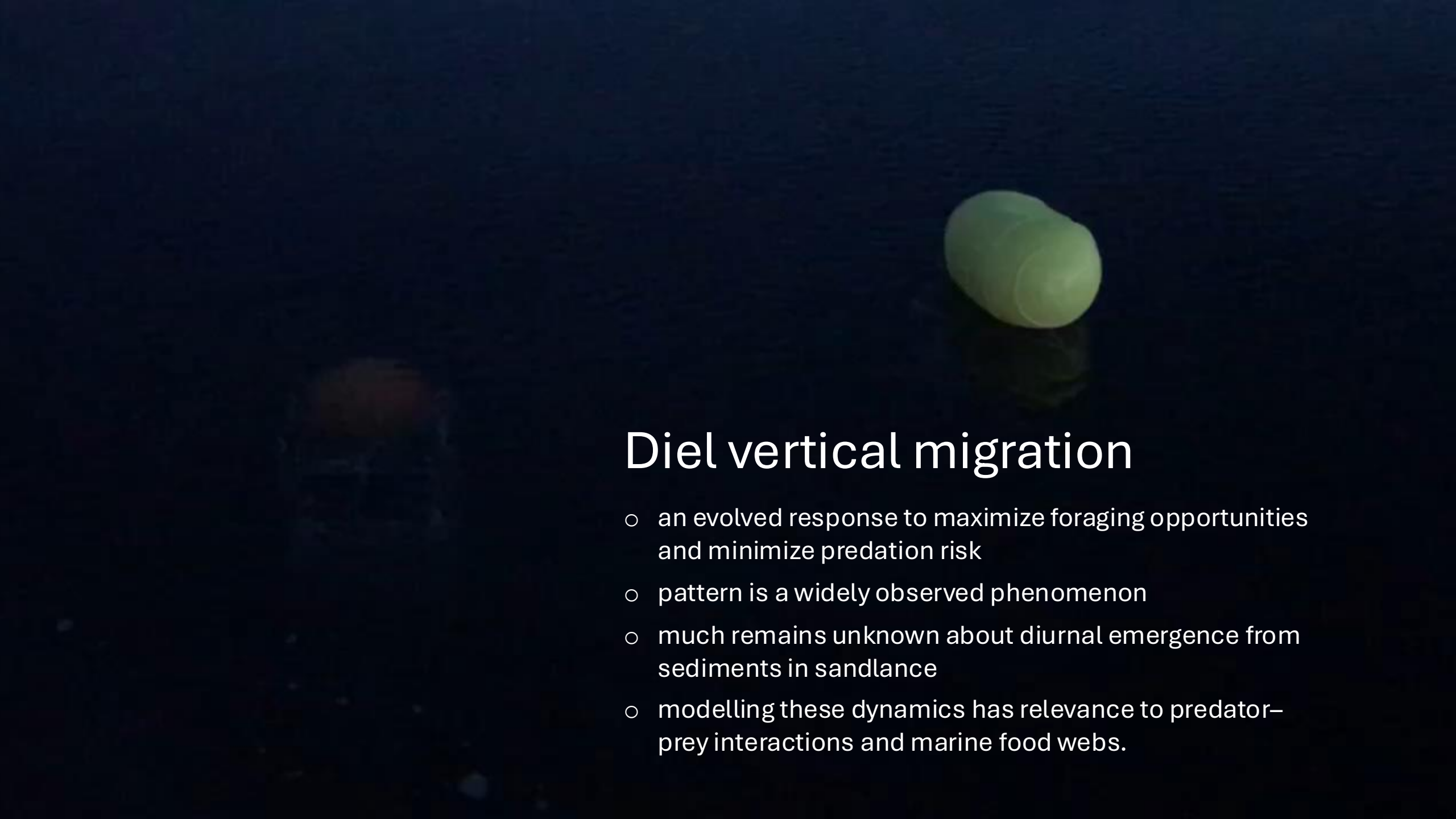
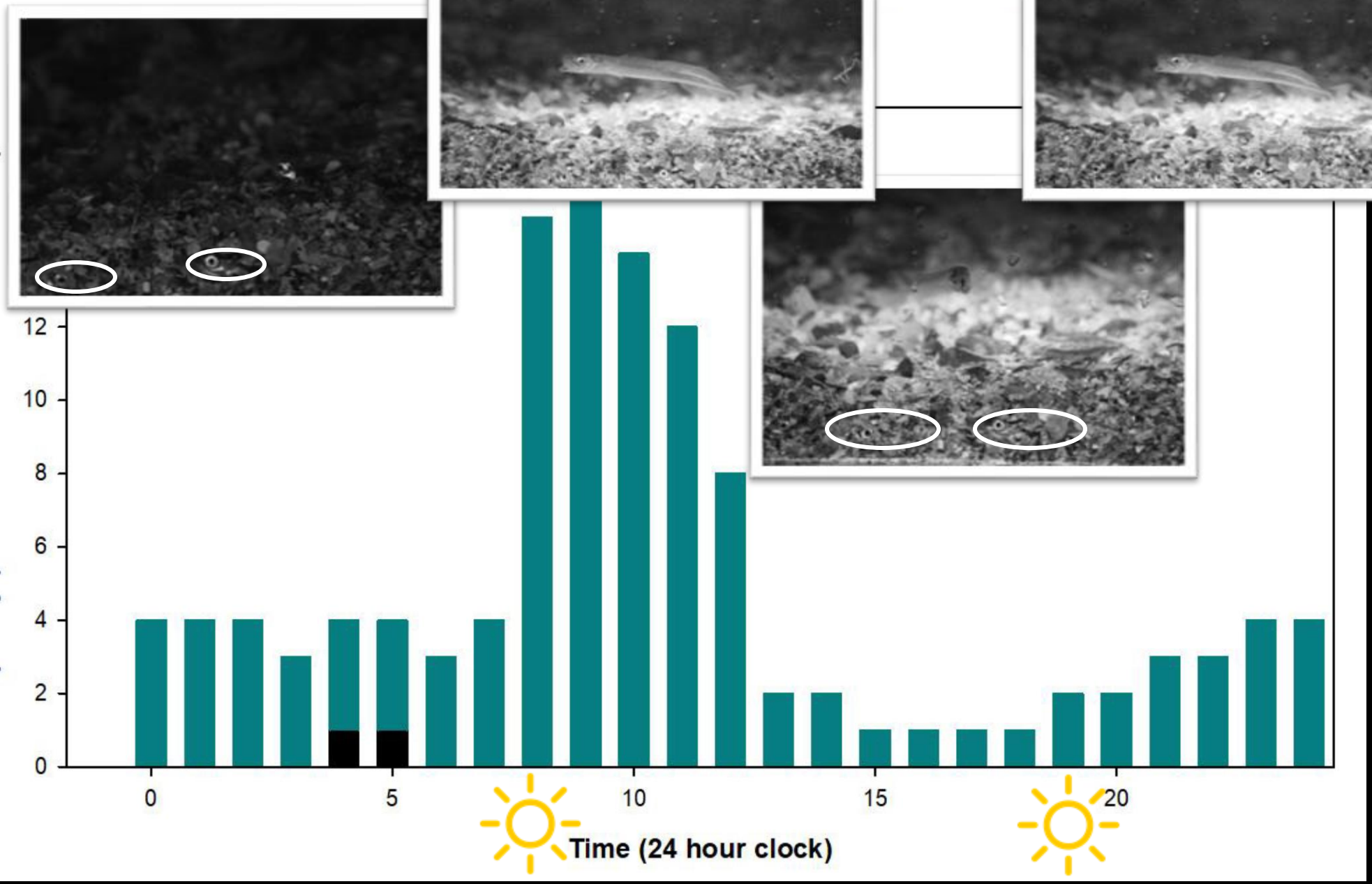


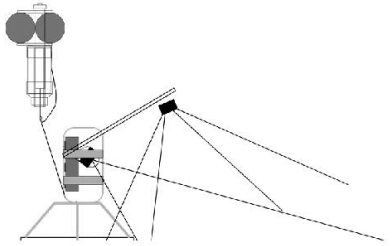


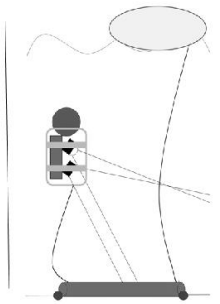
Diel vertical migration

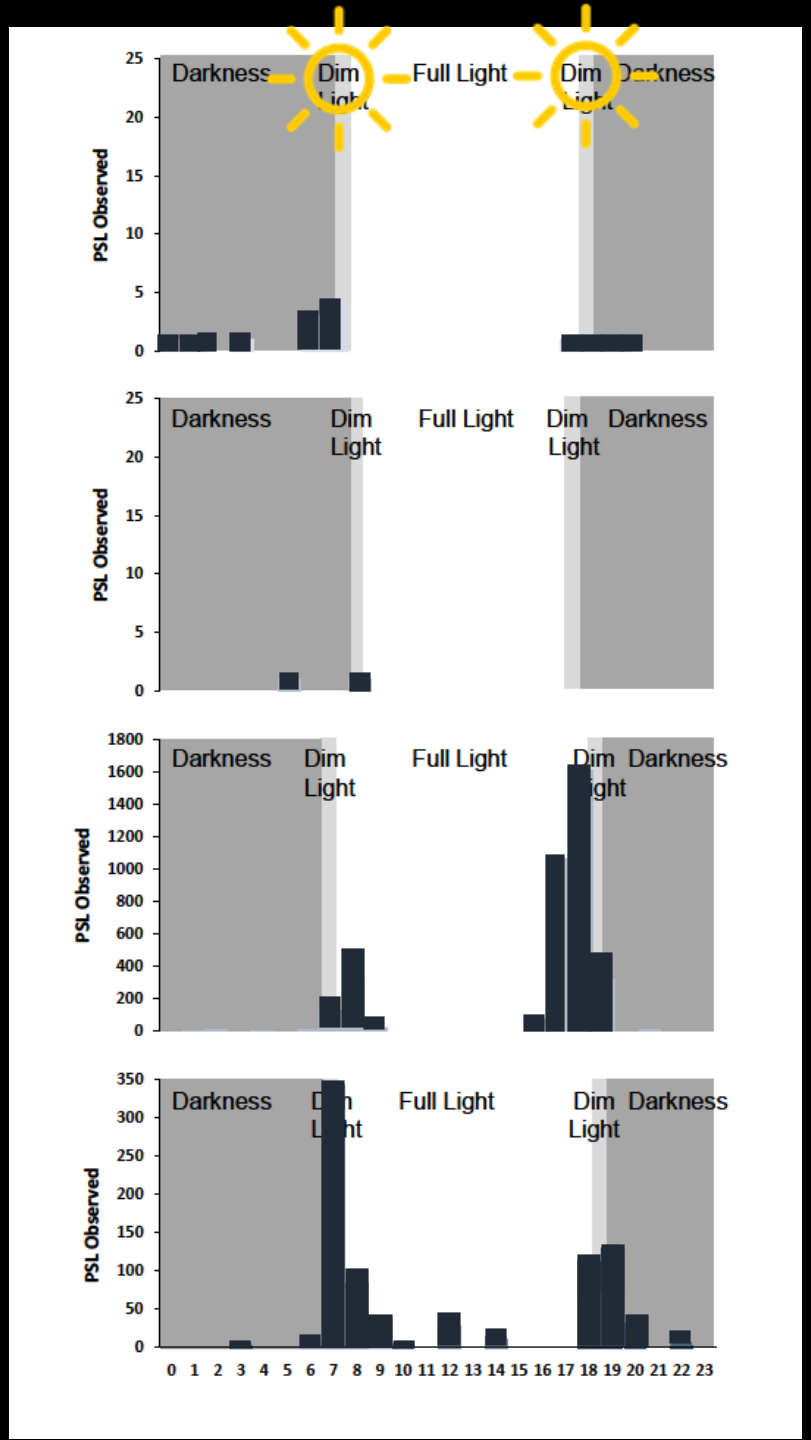
- an evolved response to maximize foraging opportunities and minimize predation risk
- pattern is a widely observed phenomenon
- much remains unknown about diurnal emergence from sediments in sandlance
- modelling these dynamics has relevance to predator–prey interactions and marine food webs.

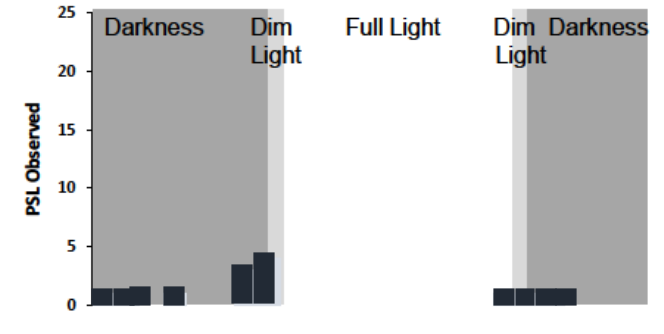

Frequency (number of PSL in water column)
0
2
4
6
8
10
12
0
5
10
15
20
Time (24 hour clock)

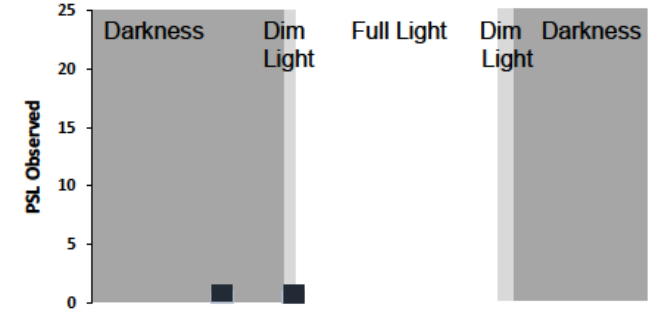

107

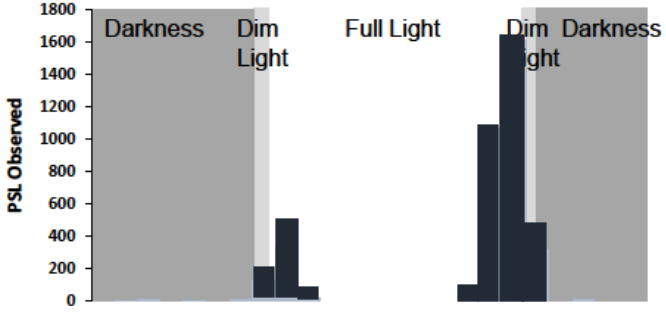


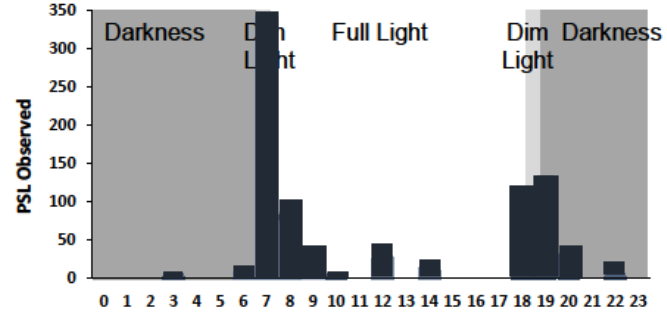



Darkness
Dim Light
Full Light
Dim Light
Darkness
PSL Observed
0
5
10
15
20
25
Darkness
Dim Light
Full Light
Dim Light
Darkness
PSL Observed
0
5
10
15
20
25
Darkness
Dim Light
Full Light
Dim Light
Darkness
PSL Observed
0
200
400
600
800
1000
1200
1400
1600
1800
Darkness
Full Light
Dim Light
Darkness
PSL Observed
0
50
100
150
200
250
300
350
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

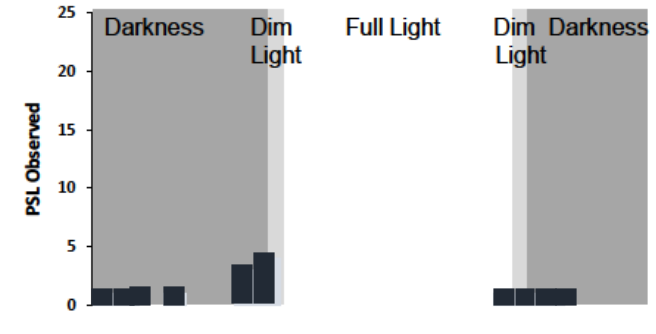


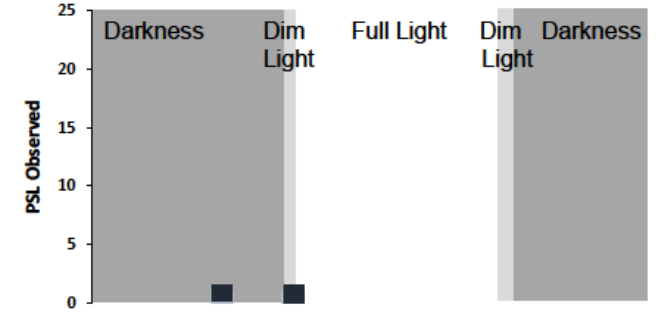


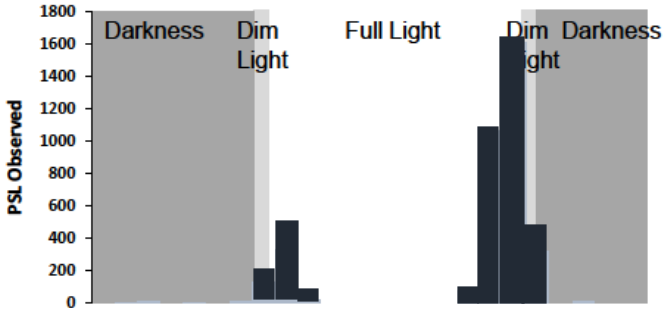


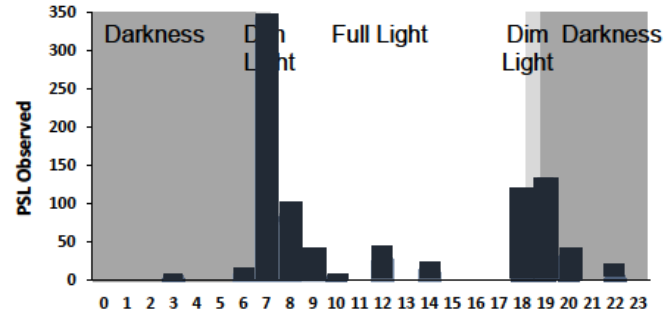


We applied data from autonomous stereo-camera deployments…
(126,720 images at 4 known beach sites, 2018–2020)

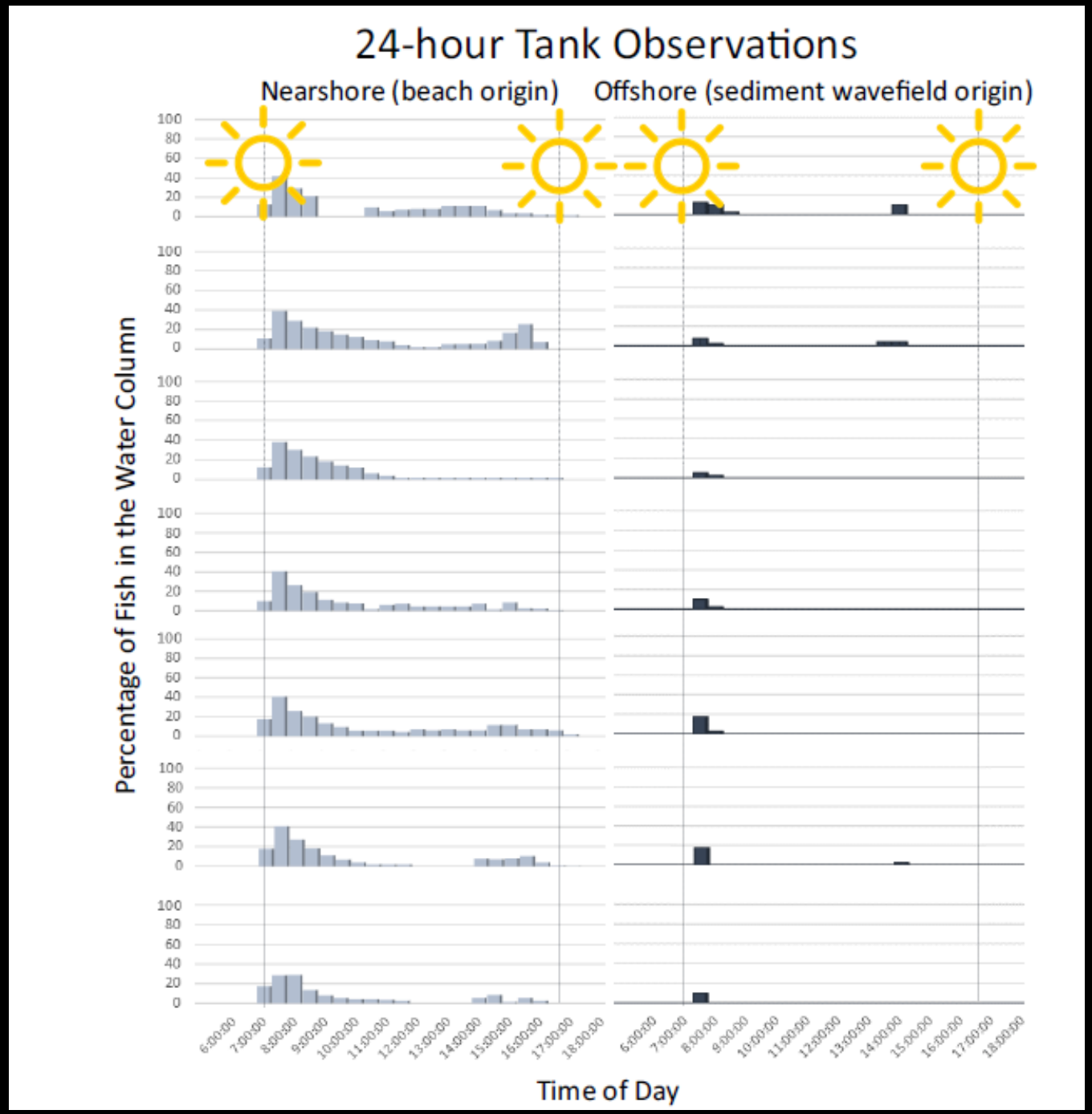






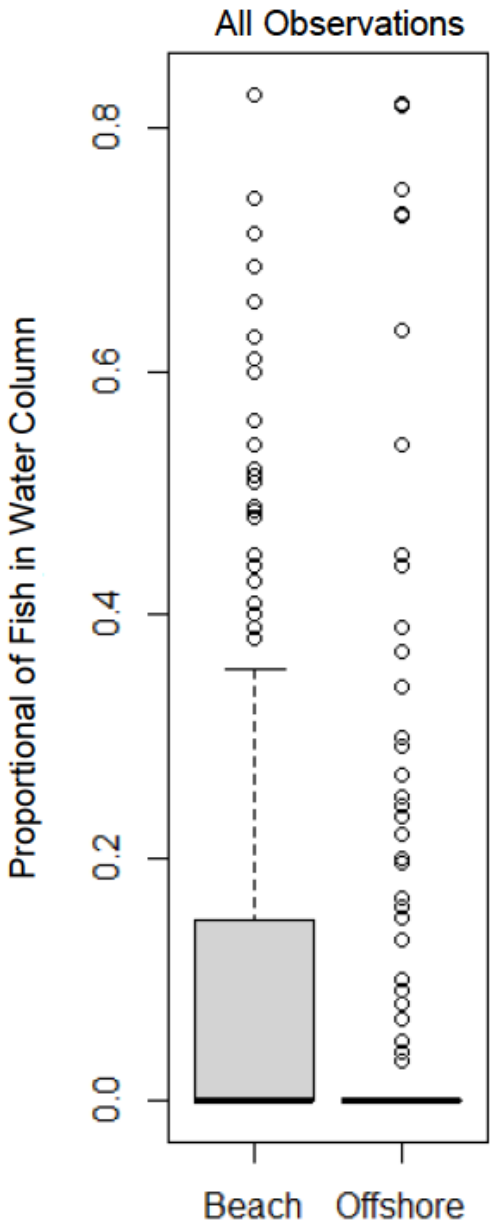


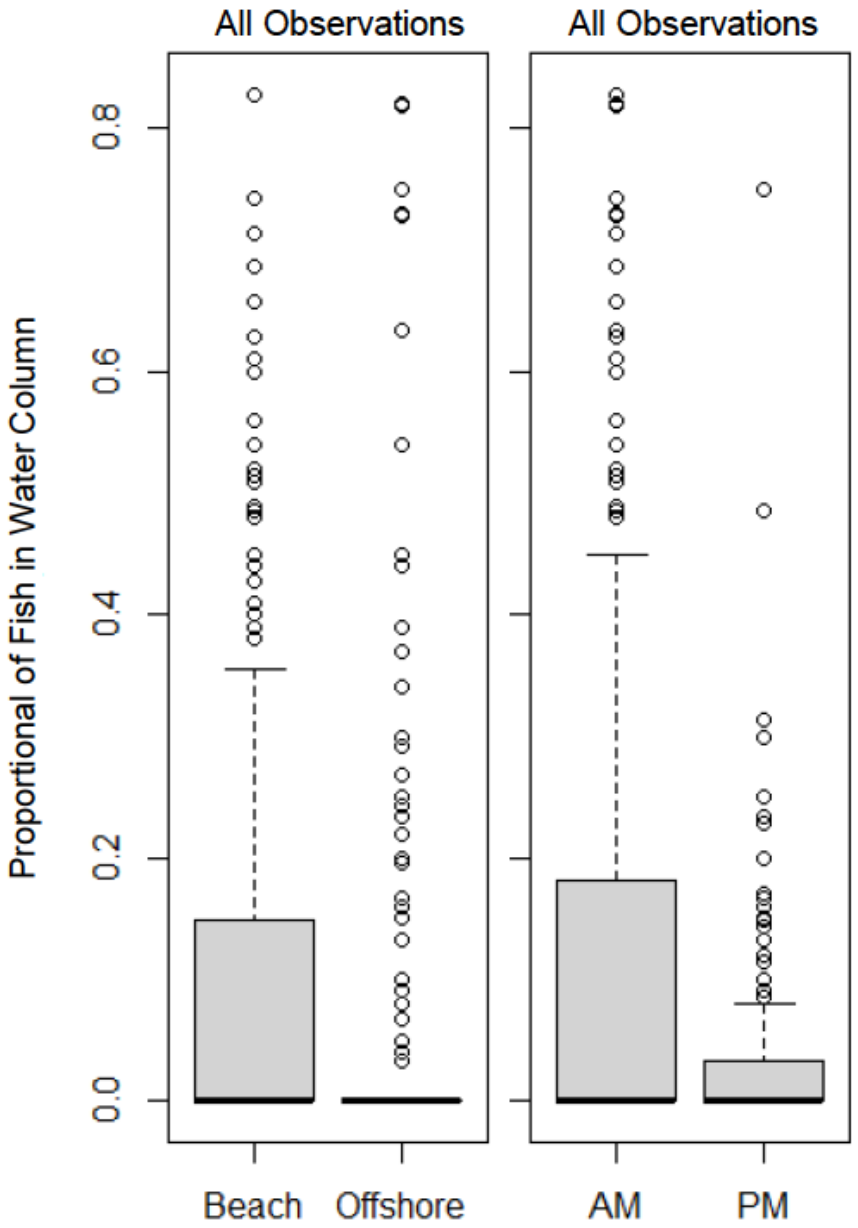
Throughout the 24-h diel cycle, 96% observed in water column were observed within 60 min of dawn (interval = first light to sunrise) or dusk (interval = sunset to last light)

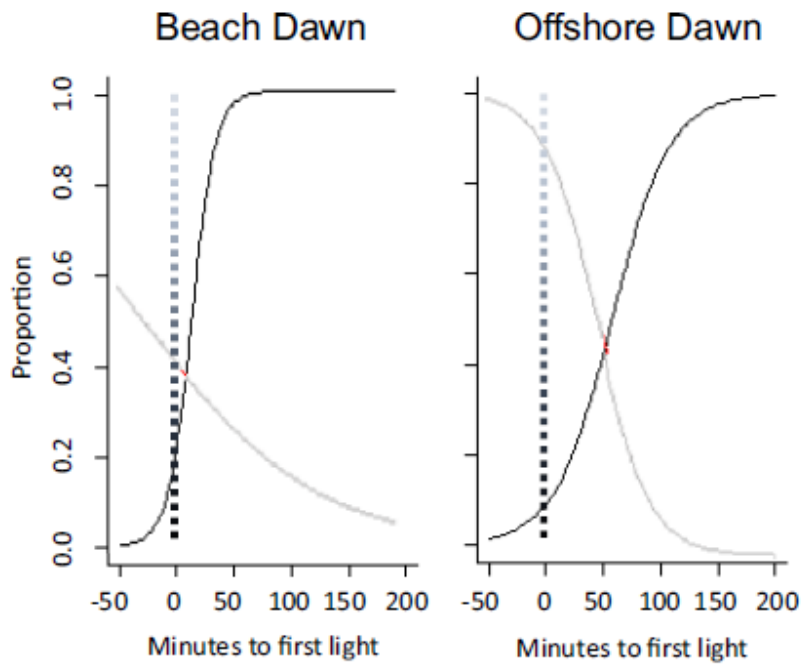


tank observations...

- 24-h intervals (observation days N=10)
- 12-h intervals (observation days N=59)

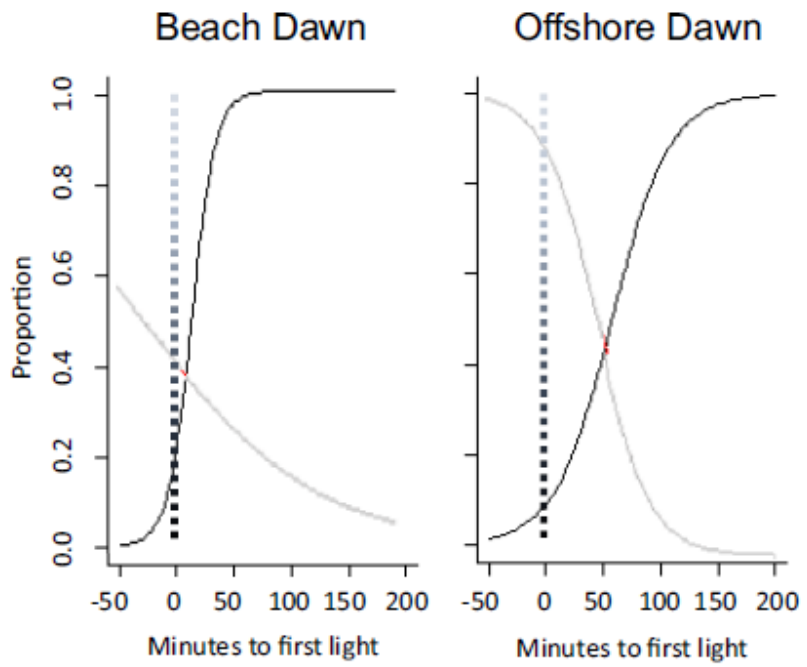

All Observations
Proportional of Fish in Water Column
0.0
0.2
0.4
0.6
0.8
Beach
Offshore

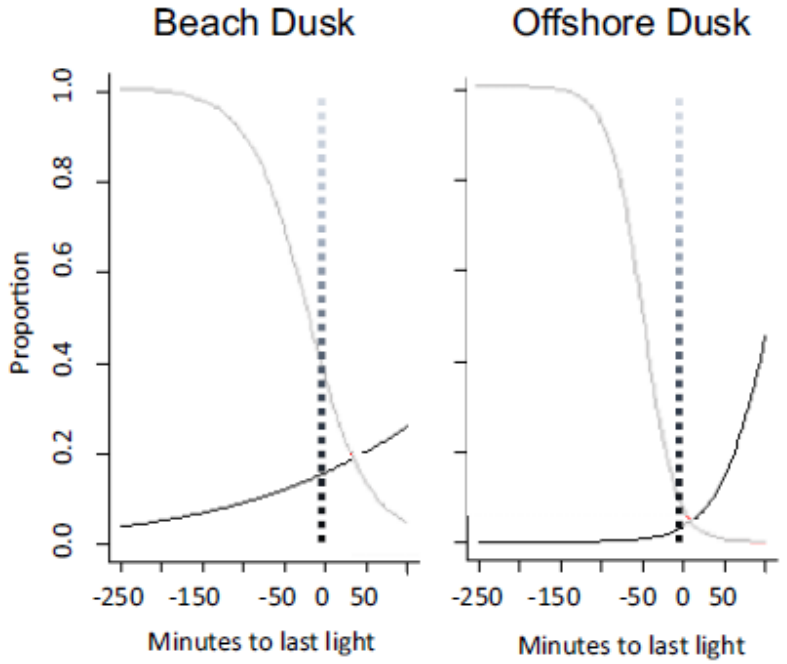

All Observations
All Observations
Proportional of Fish in Water Column
0.0
0.2
0.4
0.6
0.8
Beach
Offshore
AM
PM

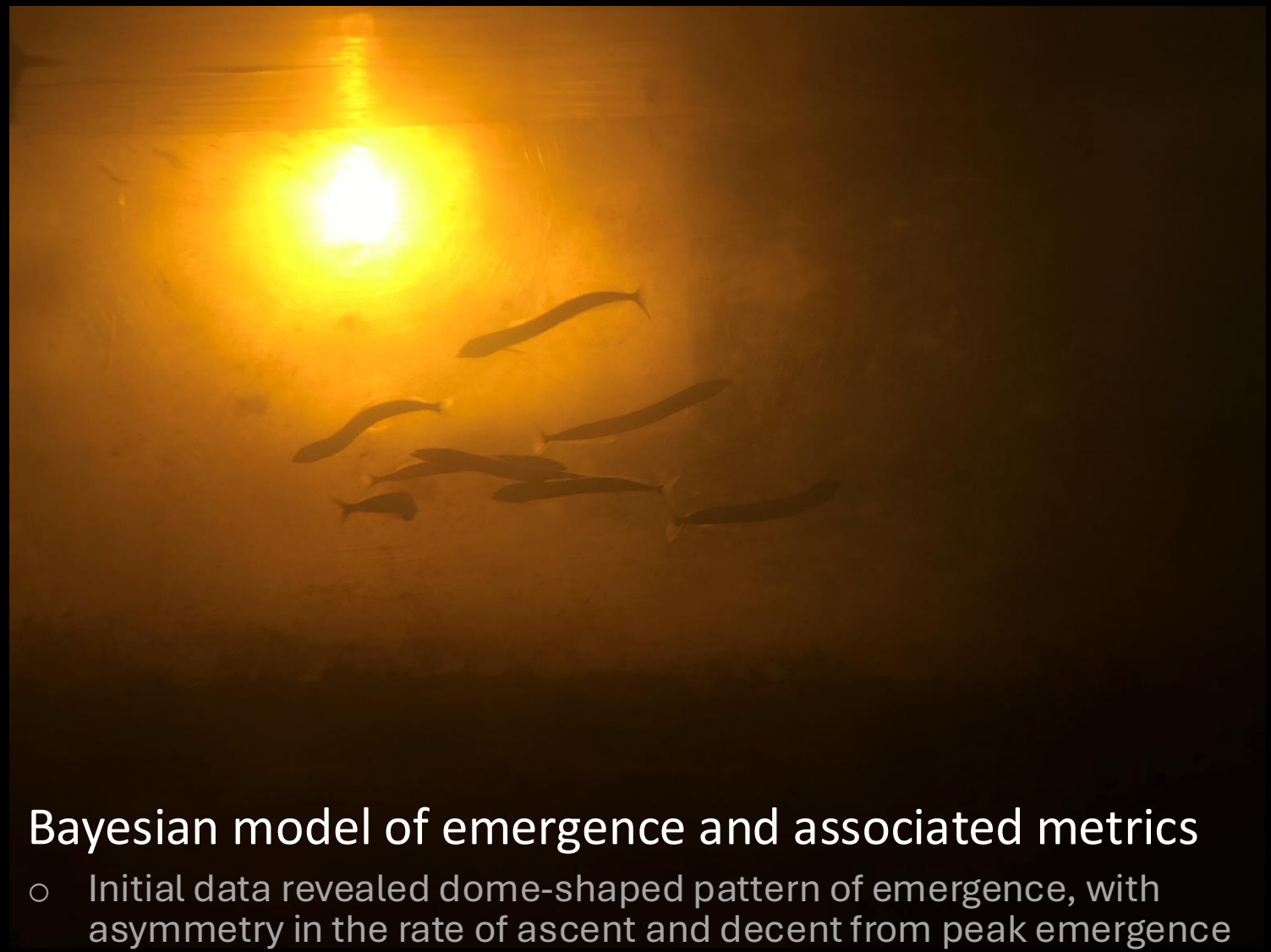


Bayesian model of emergence and associated metrics

- Initial data revealed dome-shaped pattern of emergence, with asymmetry in the rate of ascent and decent from peak emergence

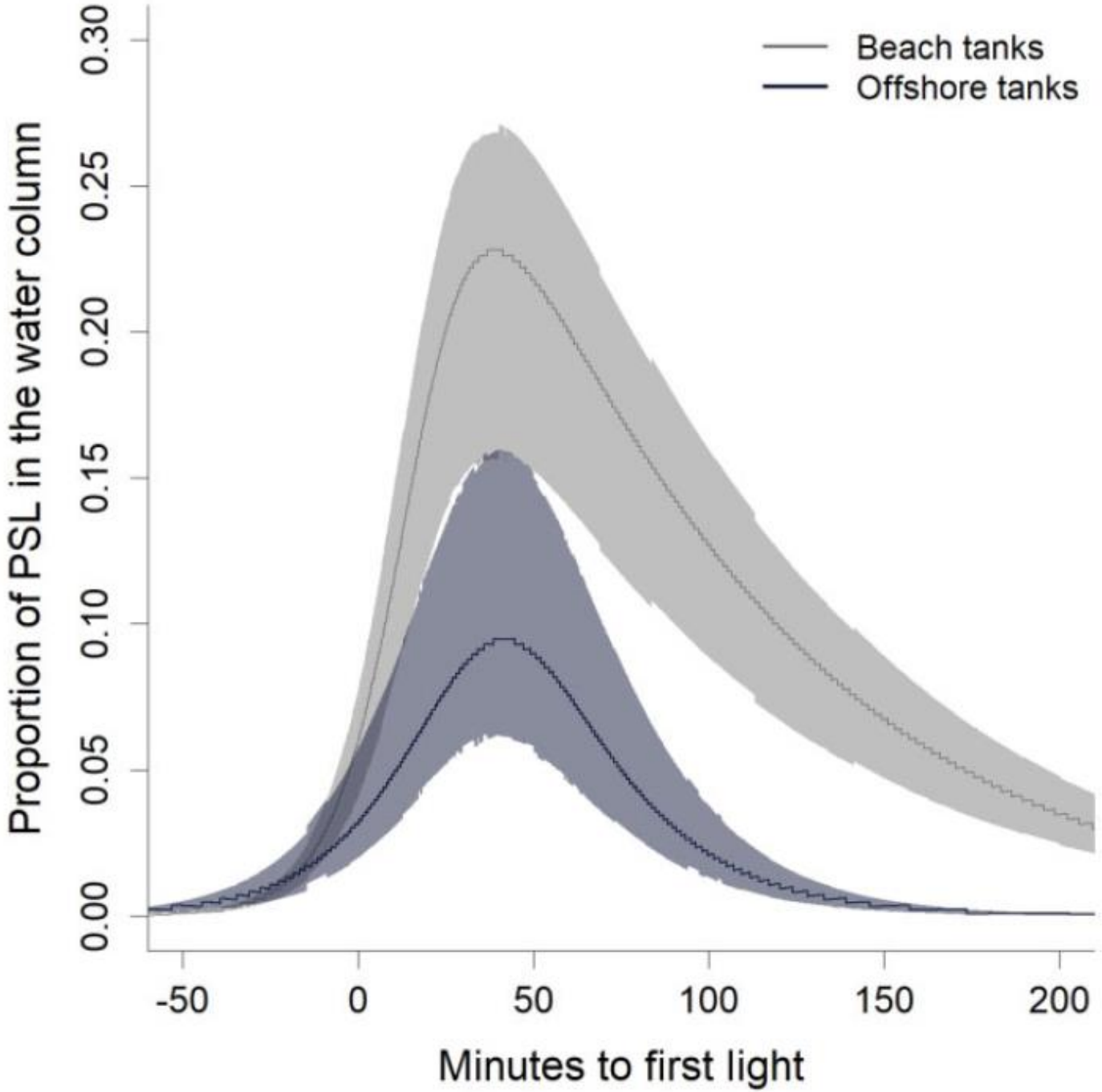






Bayesian model of emergence and associated metrics

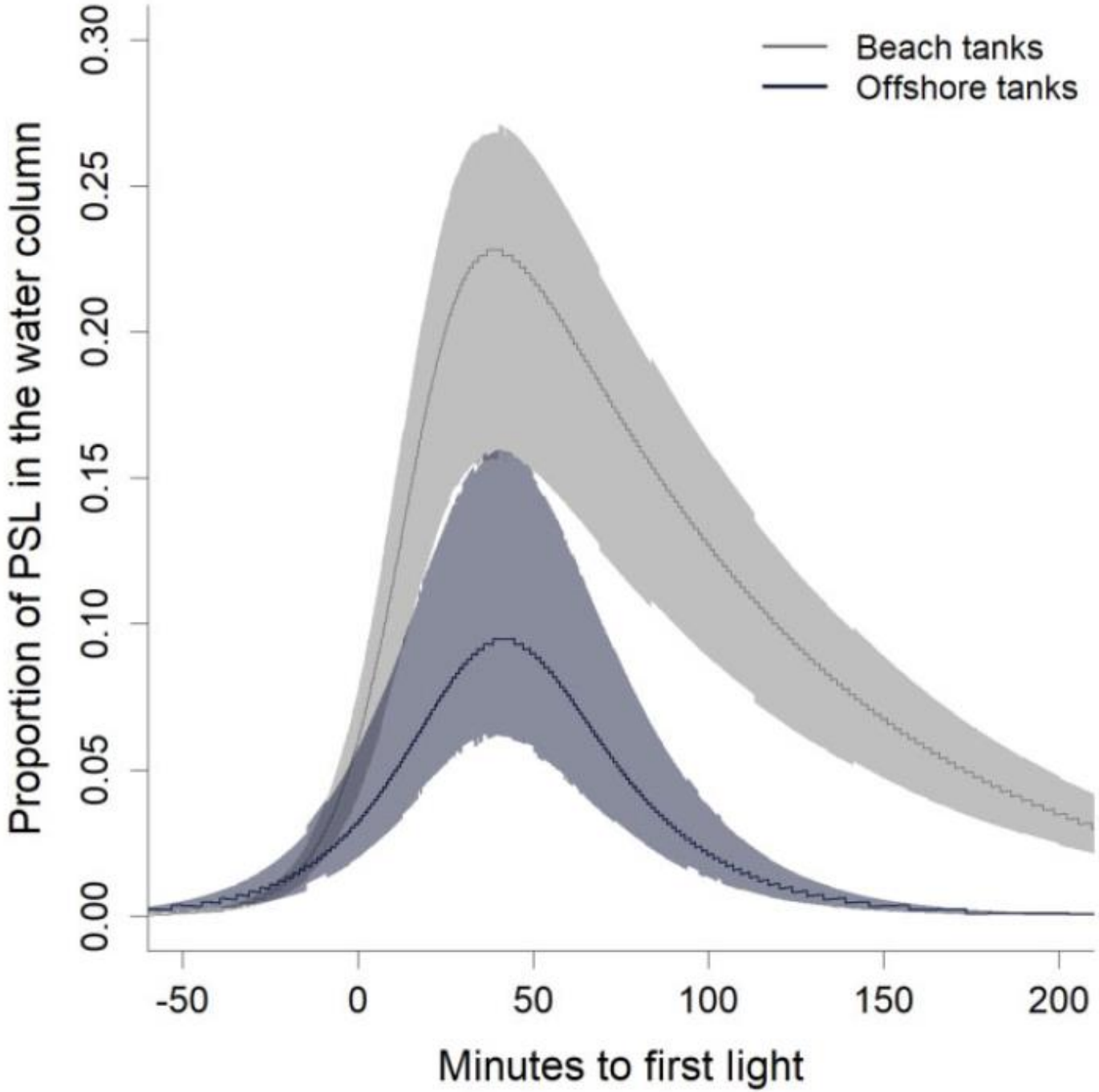
- Initial data revealed dome-shaped pattern of emergence, with asymmetry in the rate of ascent and decent from peak emergence
- To evaluate potential asymmetry, we modelled p_t as the product of two logistic curves (each oriented in opposite directions)



Bayesian model of emergence and associated metrics

To interpret the shape of the curve, we calculated 4 derived parameters:

- timing and magnitude of peak emergence were calculated by constructing a curve from each MCMC sample of the shape parameters to identify the value (p_{max}) and location (t_{max}) of the peak.



Bayesian model of emergence and associated metrics

To interpret the shape of the curve, we calculated 4 derived parameters:

- timing and magnitude of peak emergence were calculated by constructing a curve from each MCMC sample of the shape parameters to identify the value (p_{max}) and location (t_{max}) of the peak.
- amount of time before/after t_{max} when 50% of p_{max} fish were observed in the water column were used to estimate rate of ascent/descent.

Light Thresholds

Results provide evidence that…

- proximate cue is light intensity
- emergence (am) delayed until sufficient level of light
- settlement (pm) occurs when light falls below same threshold

Model Interpretation

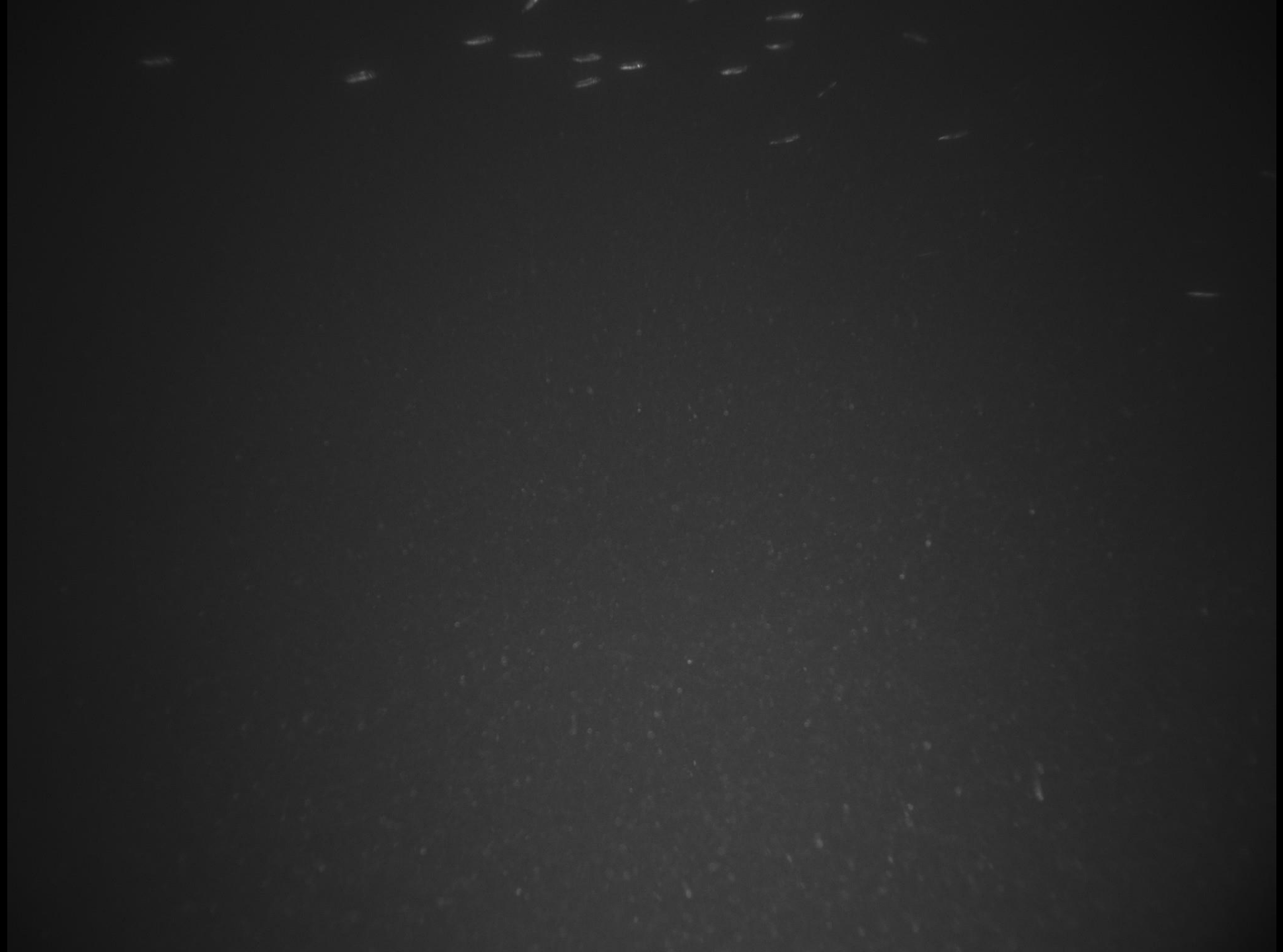
We theorized diel emergence would be asymmetrical.

We based this on assumptions:

- threshold of minimum light necessary to enable foraging
- more nuanced trade-offs between foraging efficiency and predation risk within the daylight photoperiod

What questions can we answer with stereo camera images?

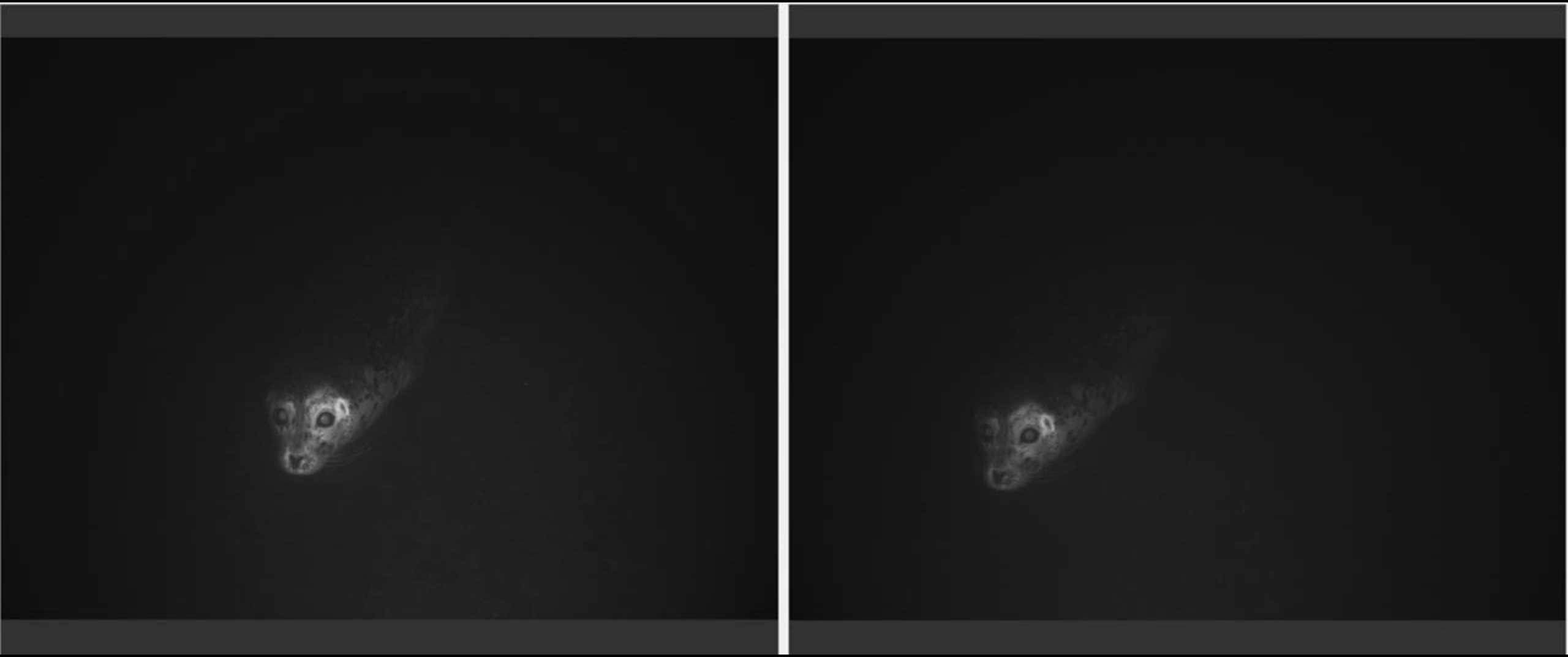
- Schooling



What questions can we answer with stereo camera images?

- Schooling

- Presence of predators



Conclusions

Direct observations (submersibles) invaluable for groundtruthing assumptions (light, currents, emergence)

Automated systems robust approach to estimate:

- abundance
- length distributions
- schooling dynamics, movement, and positioning
- areas otherwise inaccessible

Acknowledgements

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