Analysis of marine fishing using vessels trajectories: global structure, suspicious behavior and emergent pathways

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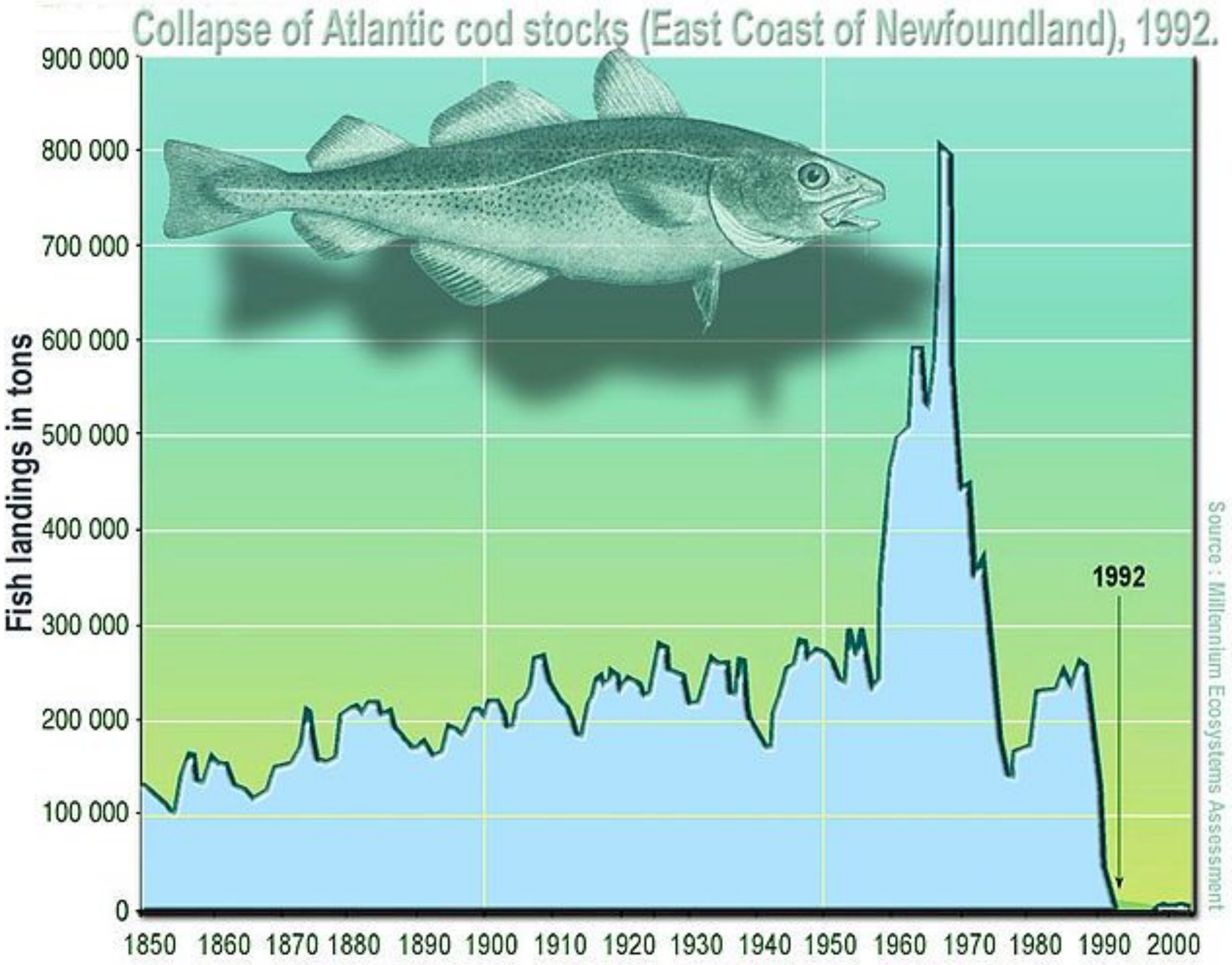
IFISC

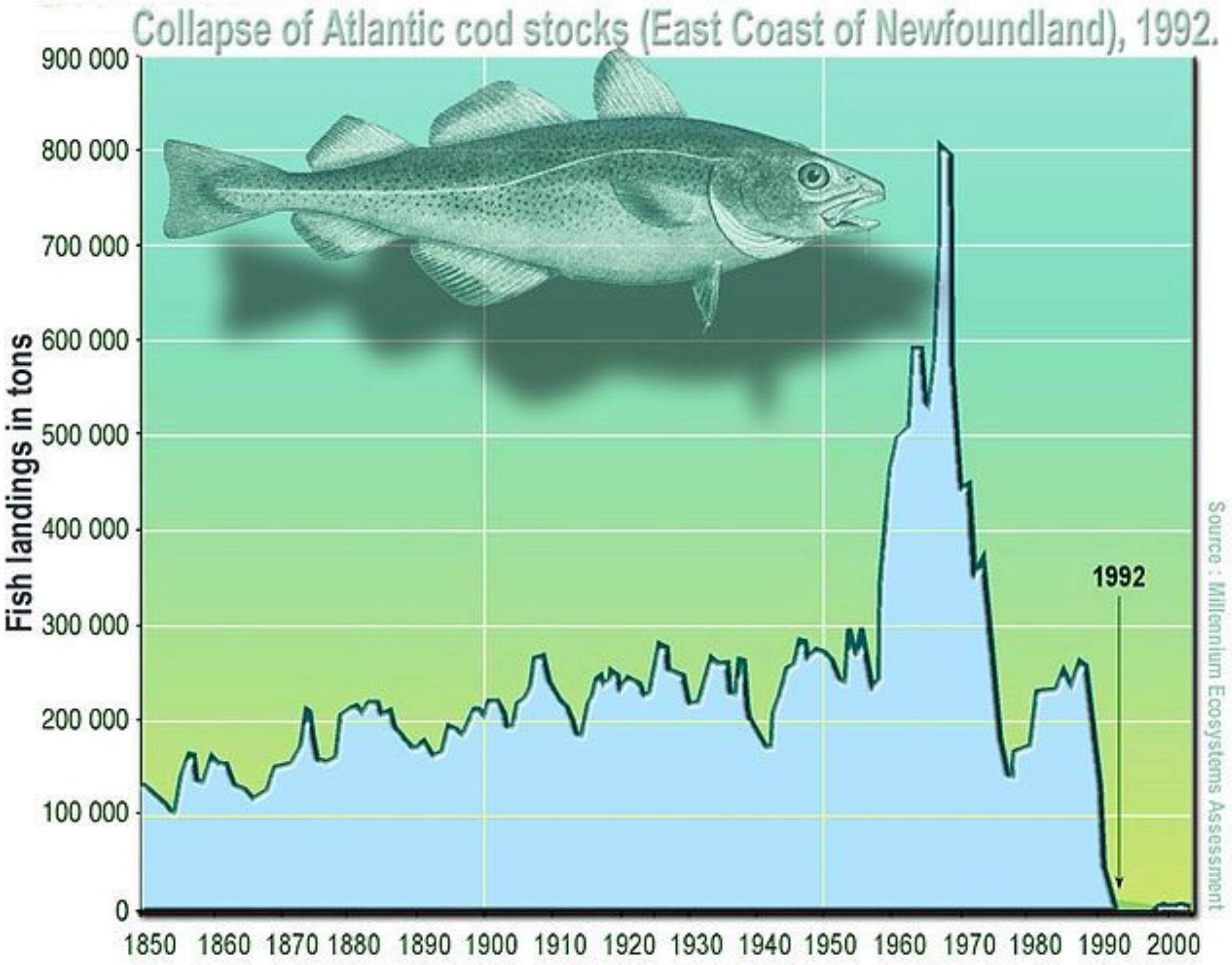
AGENCIA ESTATAL DE INVESTIGACIÓN

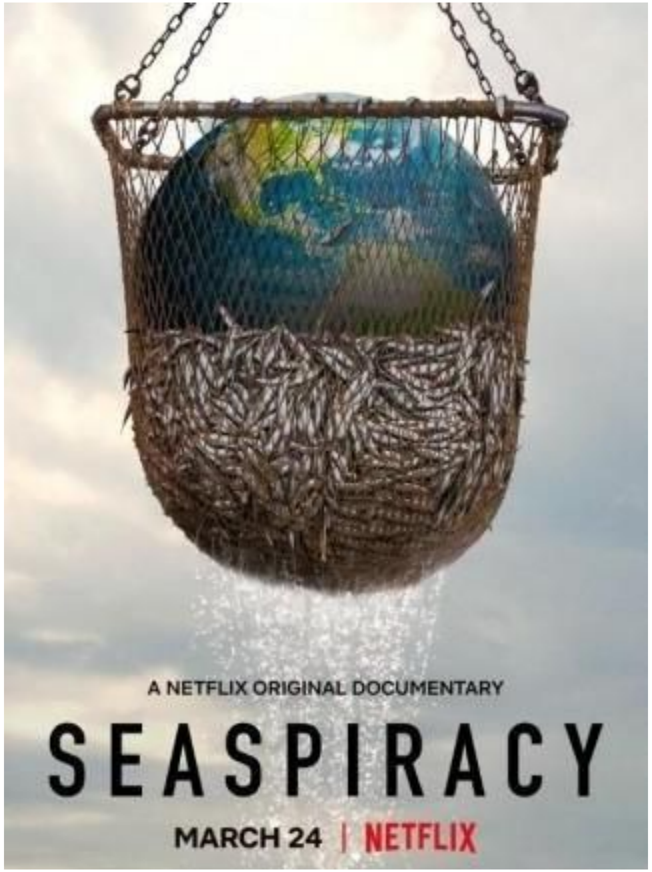
EXCELENCIA MARÍA DE MAEZTU 2023 - 2027

IFISC, Palma, 22nd May 2024

Fishing: overexploitation of resources




Collapse of Atlantic cod stocks (East Coast of Newfoundland), 1992.
Fish landings in tons
900 000
800 000
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
1992
Source : Millennium Ecosystems Assessment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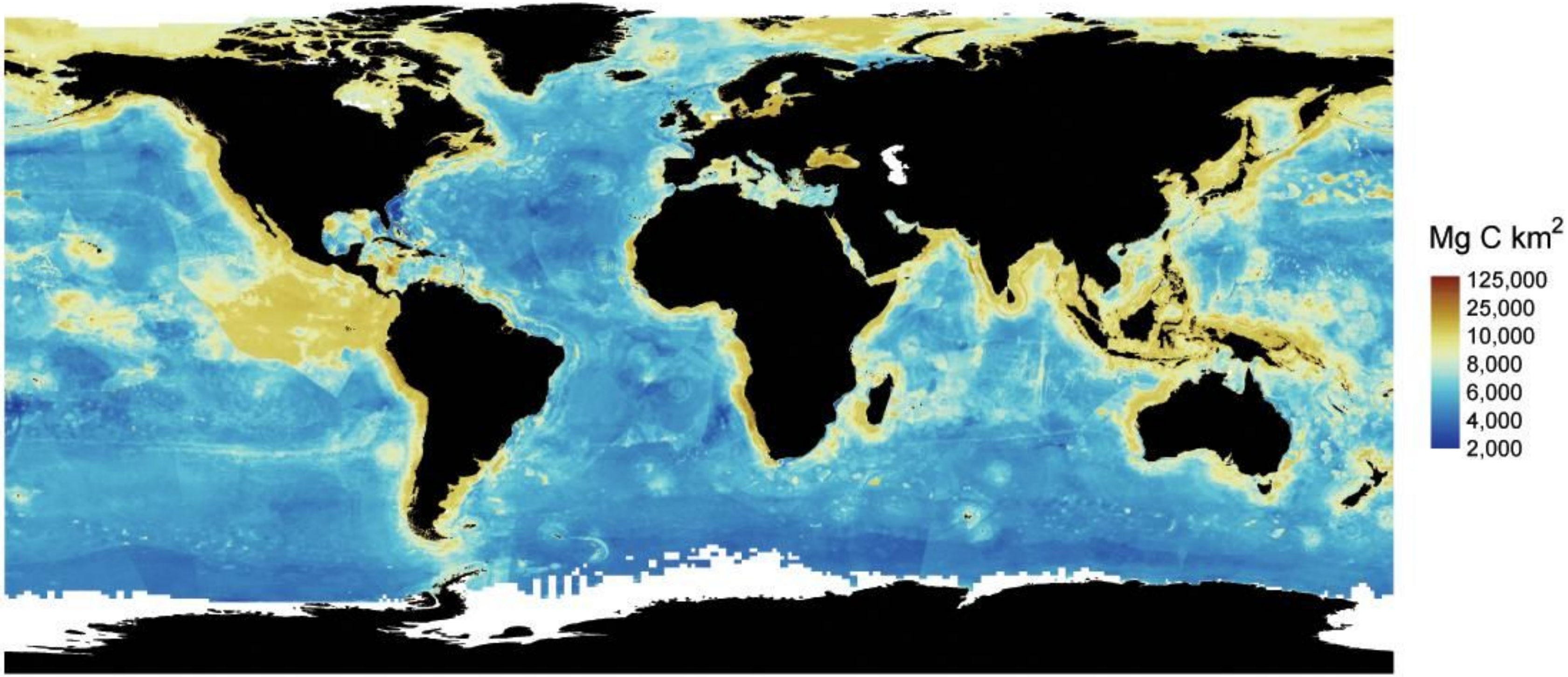
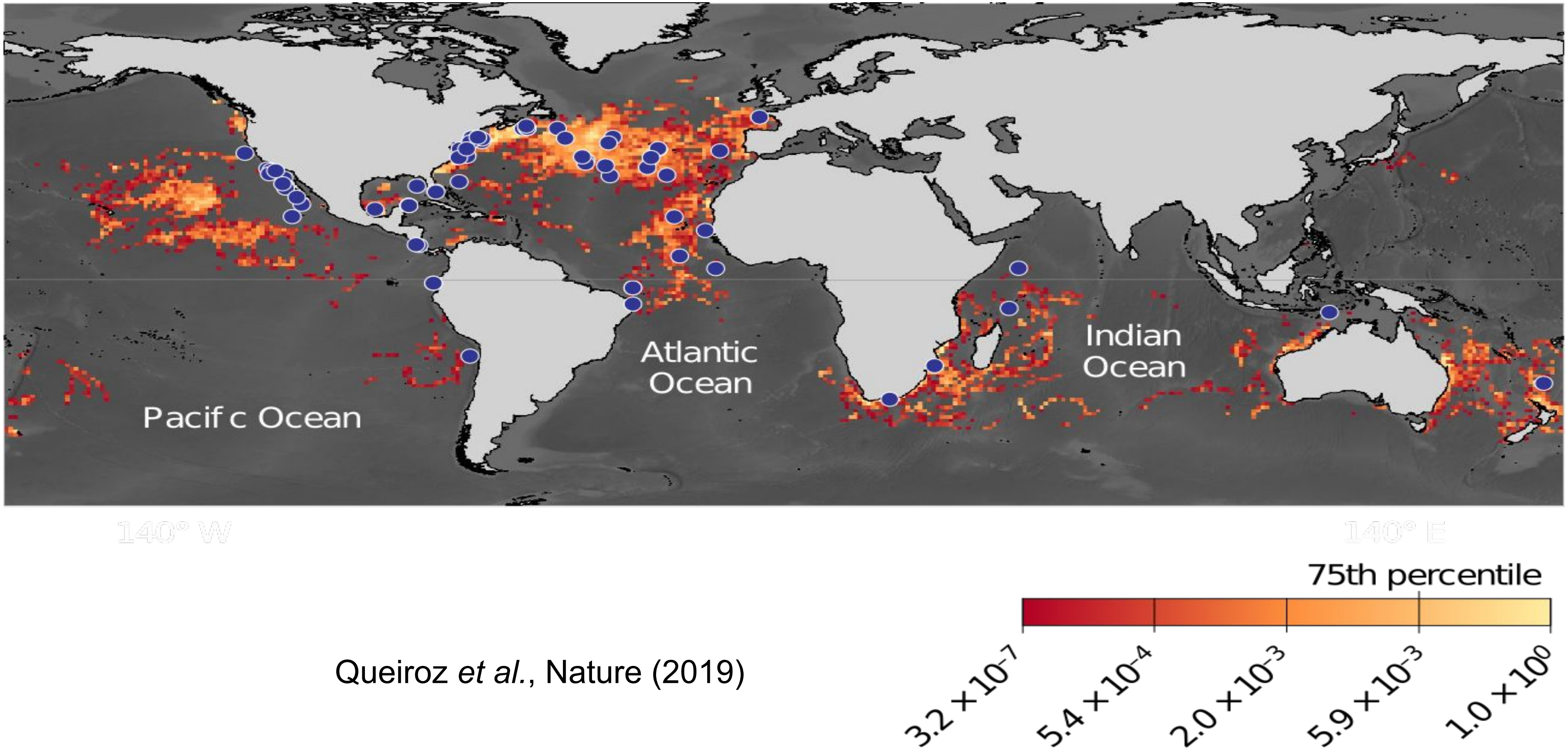
1) Carbon reservoirs in sediments (trawling gear)



Atwood *et al.*, Front. Mar. Sci. (2020)
Sala *et al.*, Nature (2021)

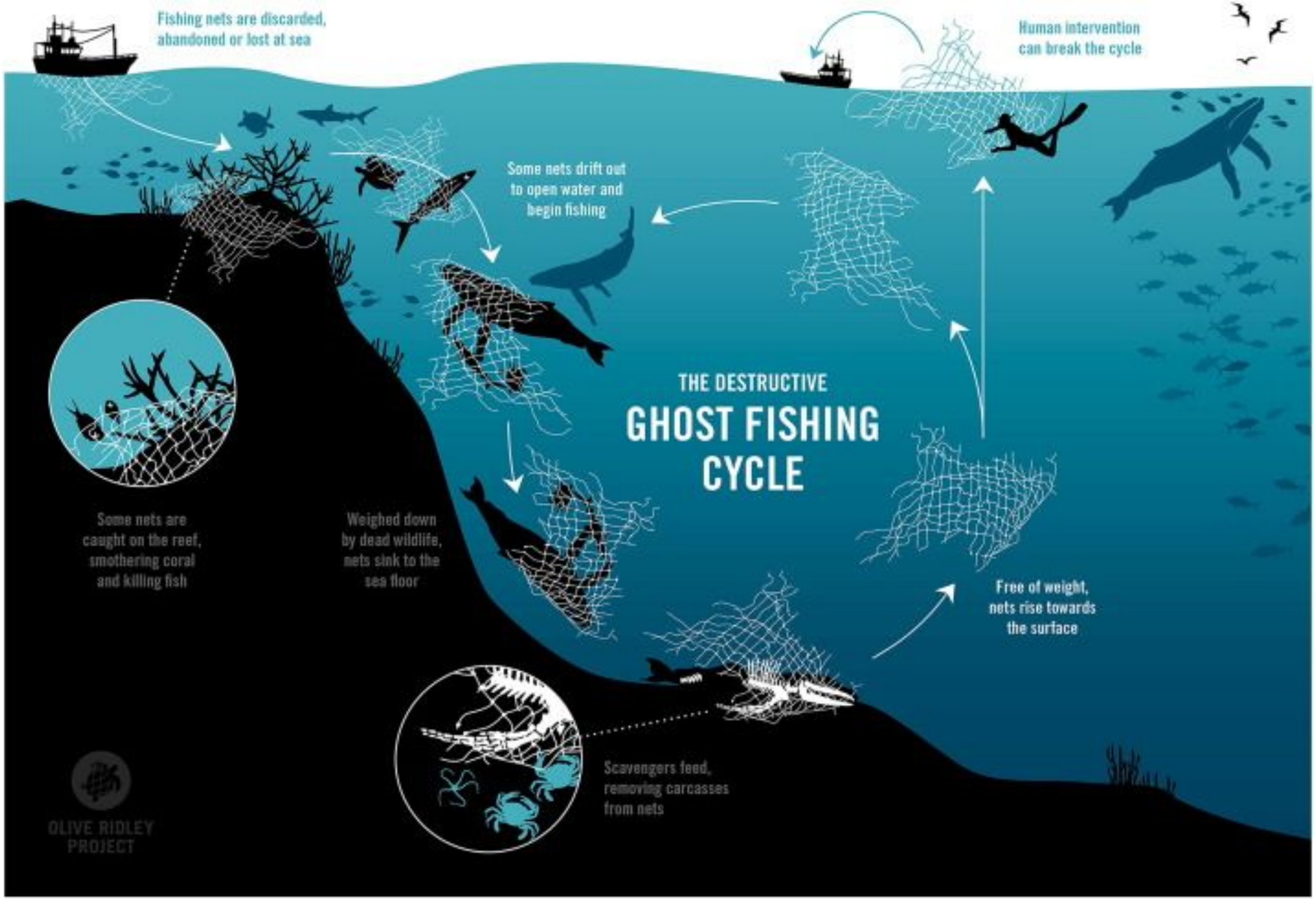
2) Bycatch

Overlap with sharks:

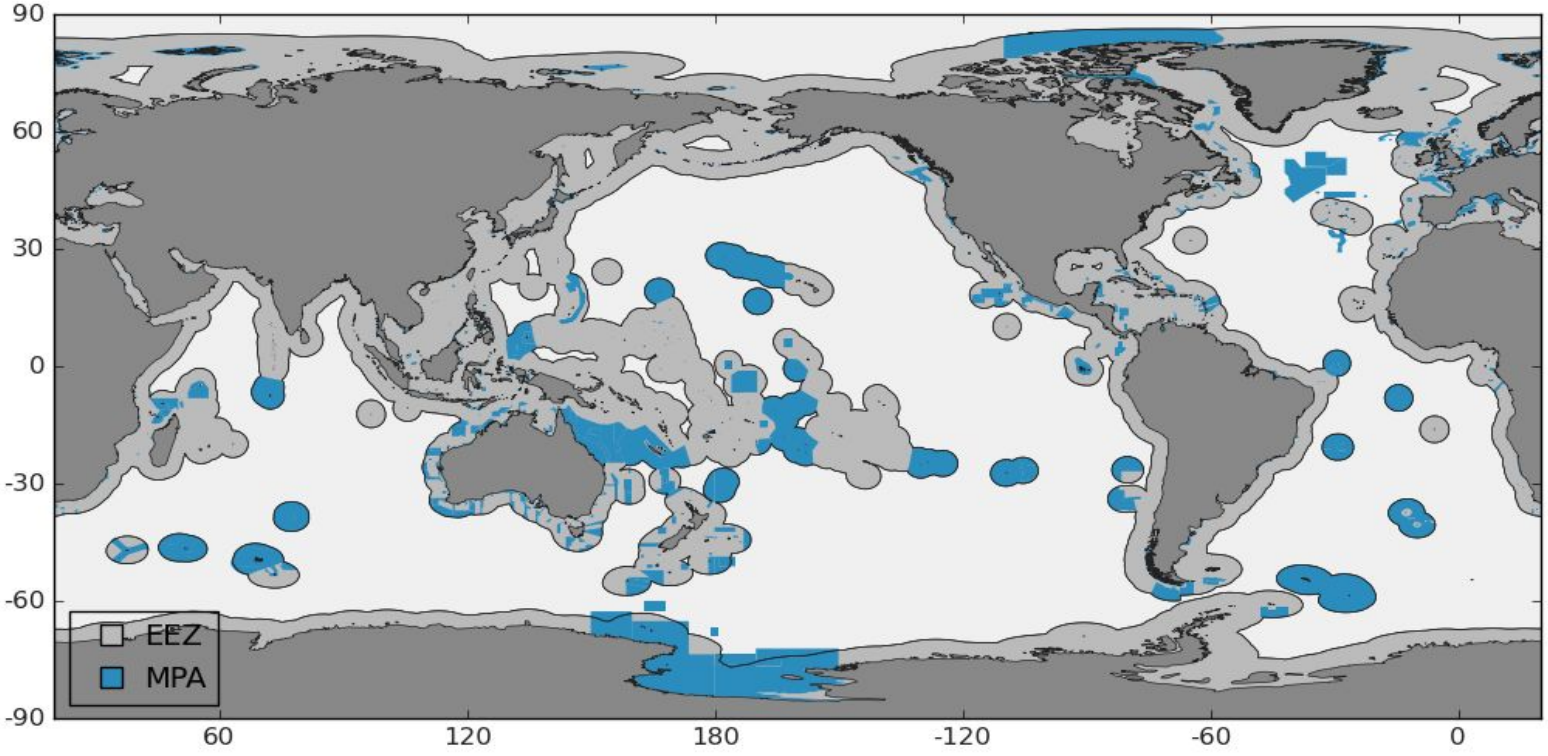


Queiroz *et al.*, Nature (2019)

3) Entanglement with fishing gear



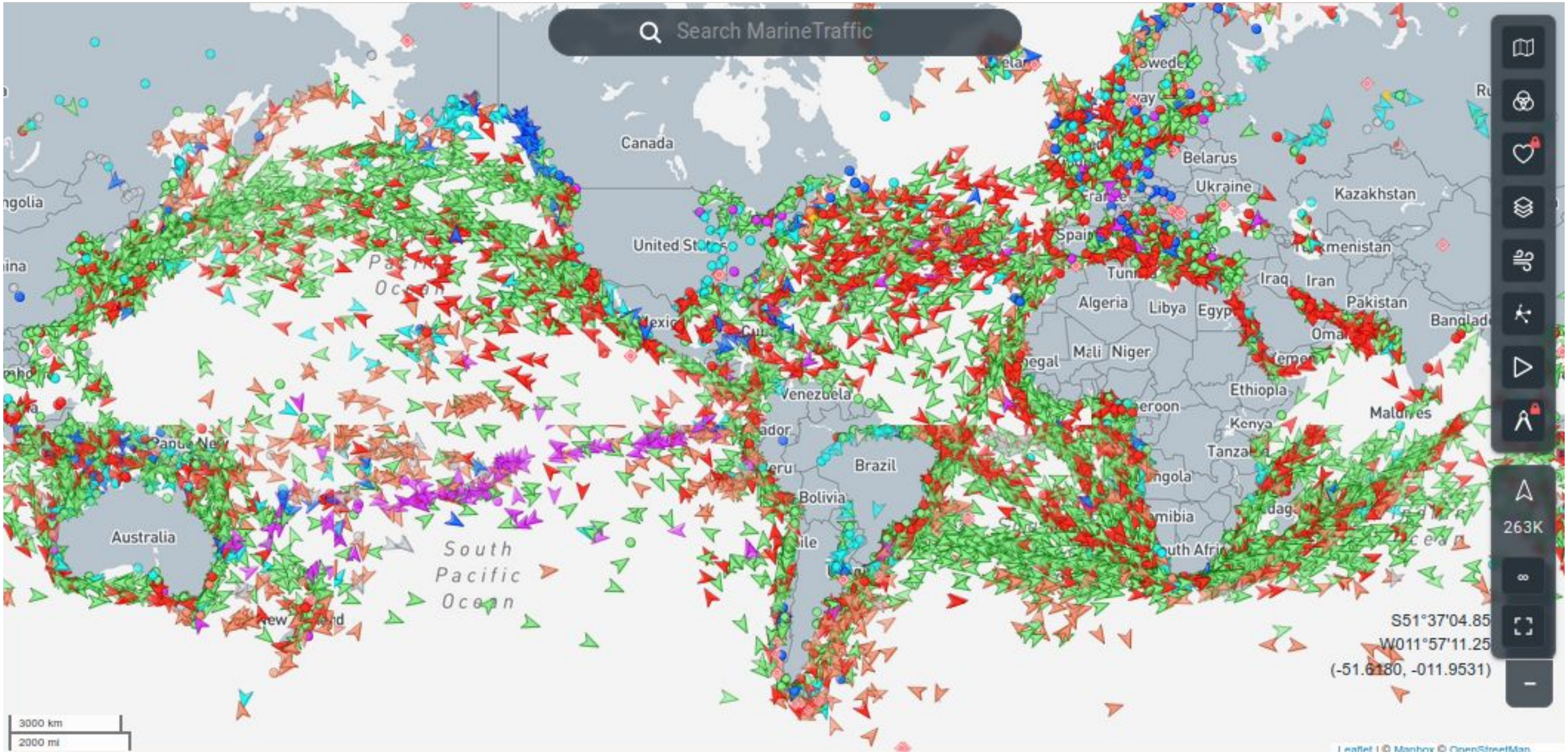
Stelfox *et al.*, Mar. Pol. Bull. (2016)



MPA: Marine Protected Areas (8% of area)
EEZ: Exclusive Economic Zones, national jurisdiction (9% covered by MPA)
High seas: international jurisdiction, 1% covered by MPA

Automatic Identification System (AIS)

MarineTraffic



Our dataset:

- AIS data from fishing vessels in 2014 (+ other categories in 2020, 2021 & 2022)
- L = 250 M locations from N = 112 K vessels

  Sample of the data:

FishingHighSeas / Data / Trajectories / **1000524664.csv**

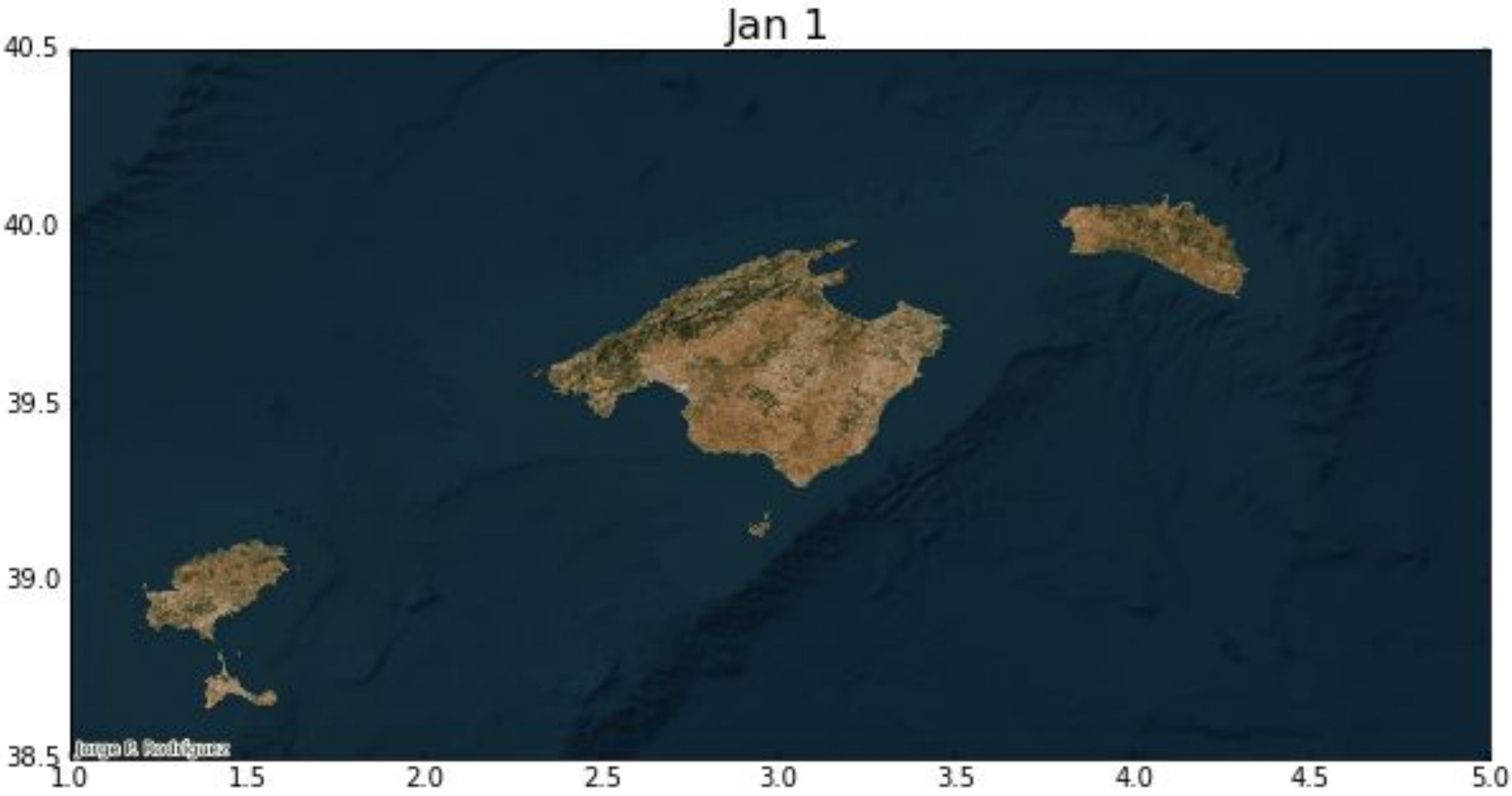
jorgeprodriguezg add data files

Preview | Code | Blame 38 lines (38 loc) · 1.44 KB

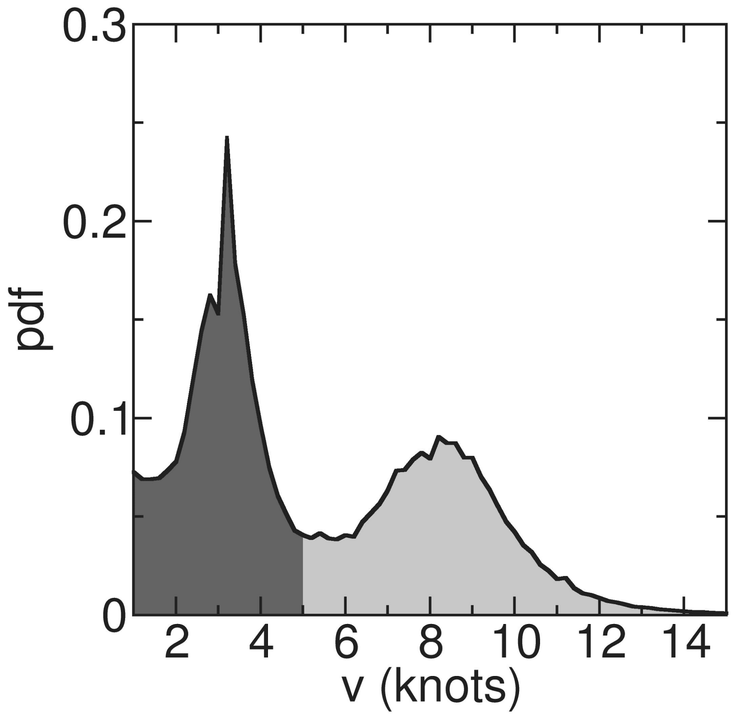
Search this file

1	lat	long	time	speed
2	21.97278	113.397	16202.6638889	0.0
3	22.0216	113.4018	16208.8666667	6.5
4	22.0128	113.4072	16208.8701389	6.7
5	21.988020000000002	113.3945	16208.8819444	6.3

Available in https://github.com/jorgeprodriguezg/FishingHighSeas


Jan 1
40.5
40.0
39.5
39.0
38.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Jorge P. Rodríguez

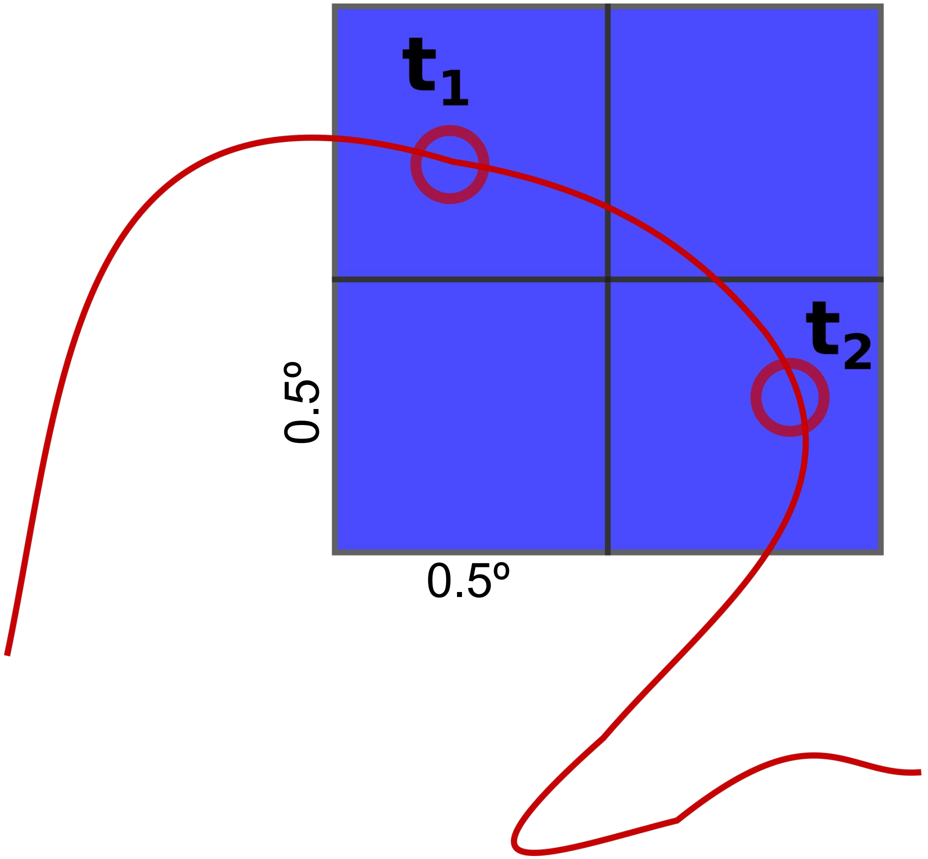
- Fishing effort: **time** spent fishing
- Two motion modes: low speed (fishing), high speed (transit)



Problem: discrete location data (not time spent in a specific area), non-uniform sampling

Fishing effort: **time** spent fishing

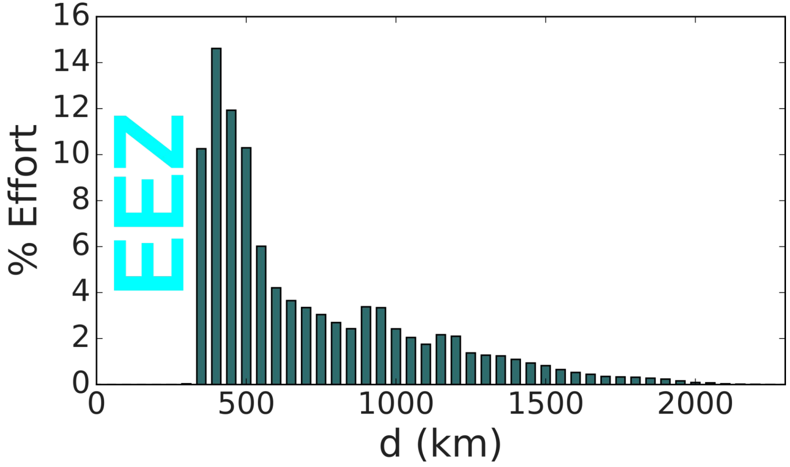
1) Points 1 and 2 in non-transit mode (speed lower than 5 knots)
2) $\Delta t = t_2 - t_1$, $\Delta t < 1$ day
   $d < 2{,}000$ km
3) Effort in each cell: $\Delta t/2$

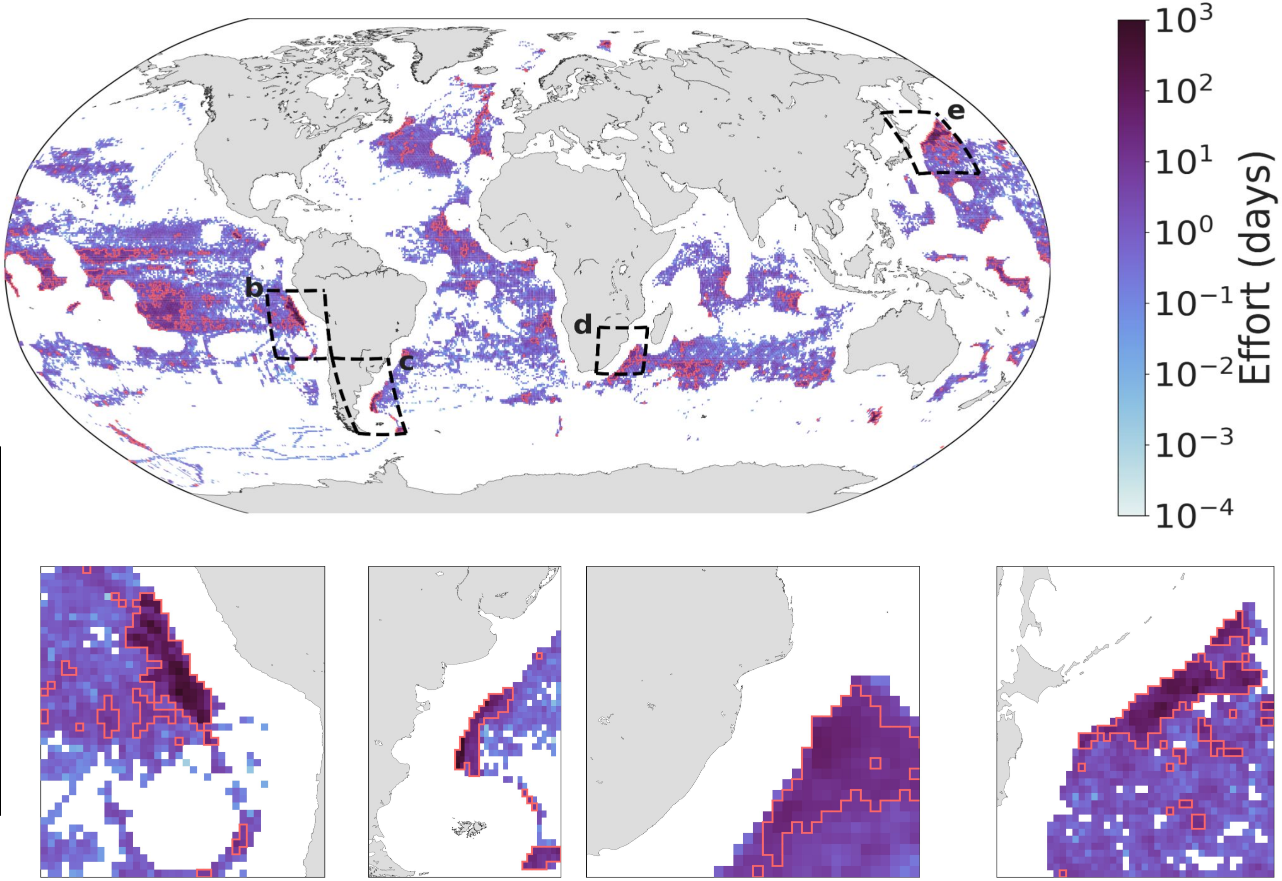


Fishing effort: **time** spent fishing

Our approach works (r^2 = 0.903 with Neural Networks approach)

Highest fishing efforts close to borders of EEZs: **47% in 200 km strip next to EEZ**



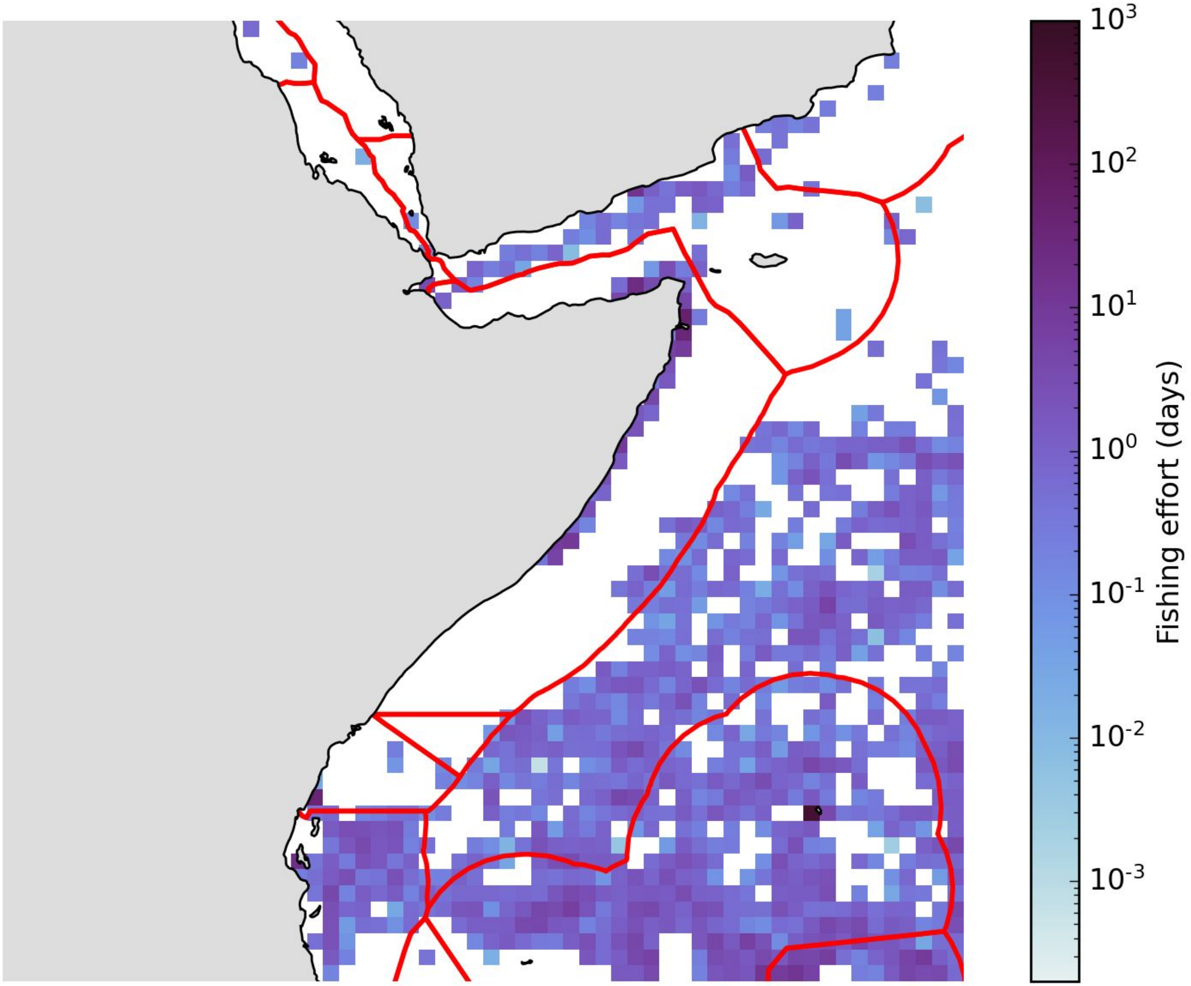


Rodríguez *et al.*, Sci. Adv. (2021)

Top 10% cells

Fishing effort in Somalia (including EEZs and high seas)

Lack of resources, availability of weapons (war)



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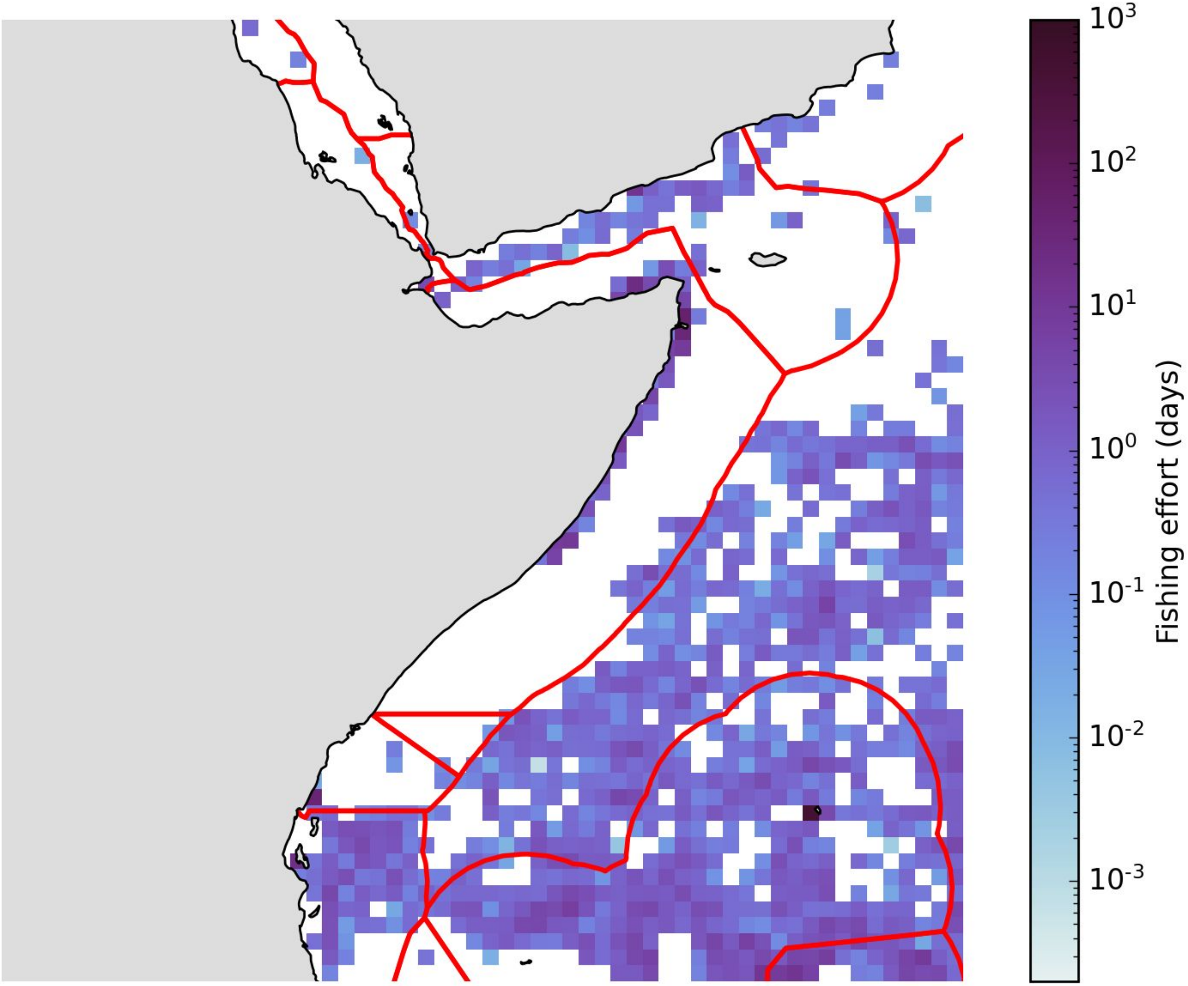


Marine provinces

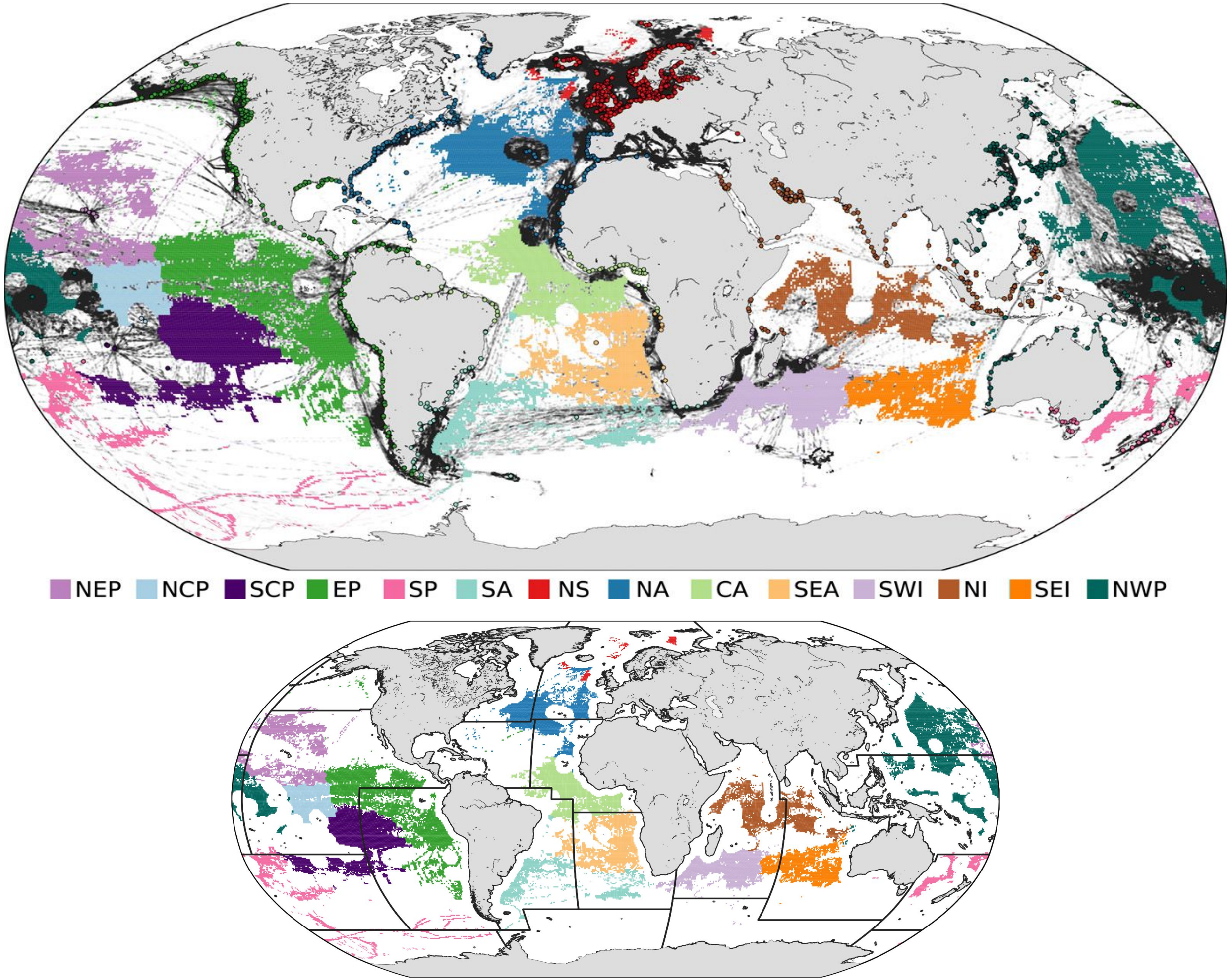
- Follow vessels' trajectories to connect geographical locations (high seas and ports)

- Apply community detection to these connections

- 14 marine provinces

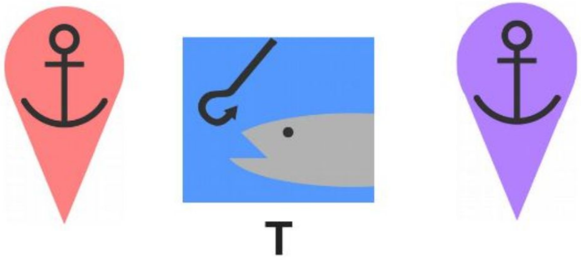
- Differences with FAO zones

- These provinces would be good candidates for new administrative regions

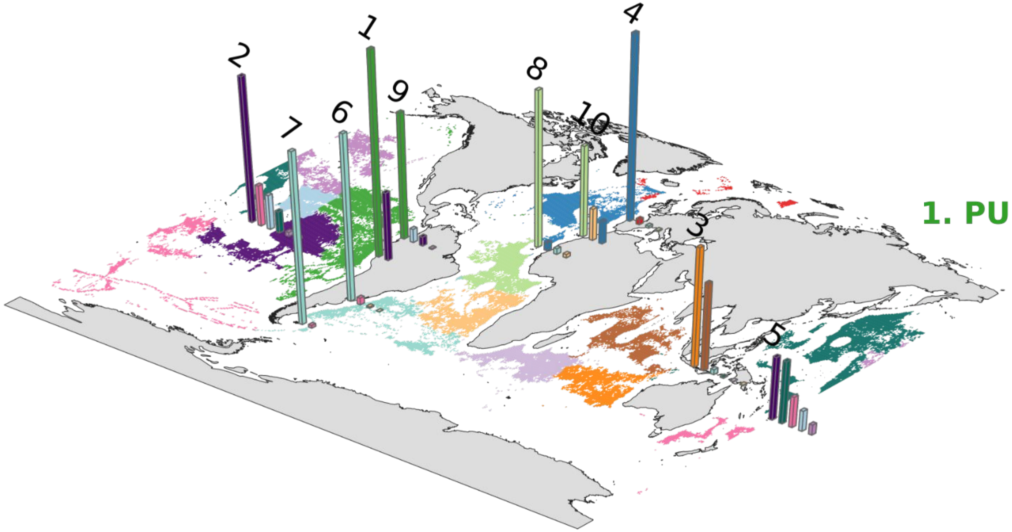


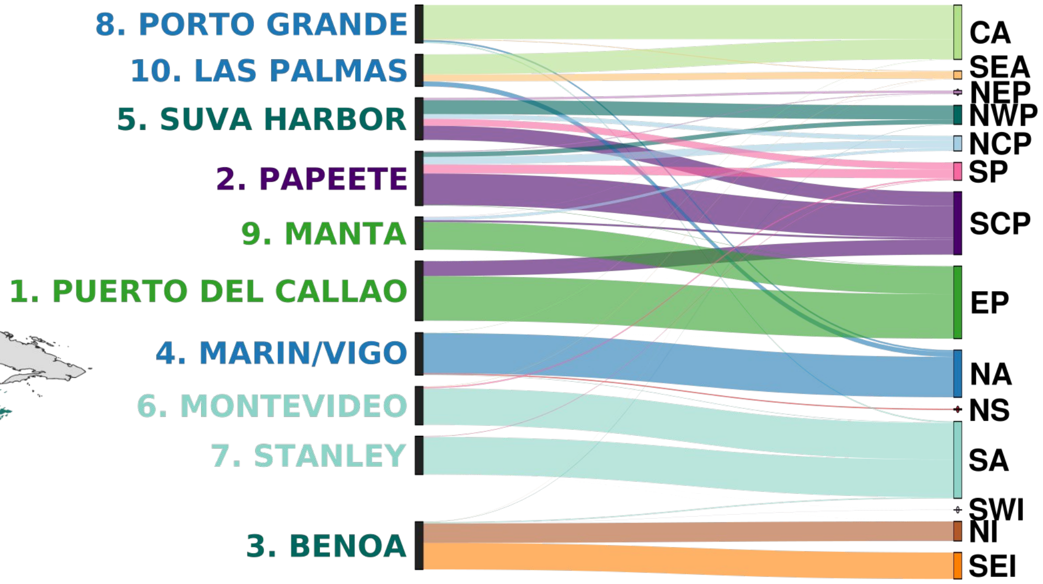
Rodríguez *et al.*, Sci. Adv. (2021)

- Assign effort to **ports** visited before and after fishing
- Extract the top 10 ports with highest fishing effort
- Specialization (except for Central Pacific and Indonesia ports)



Port effort:
T T

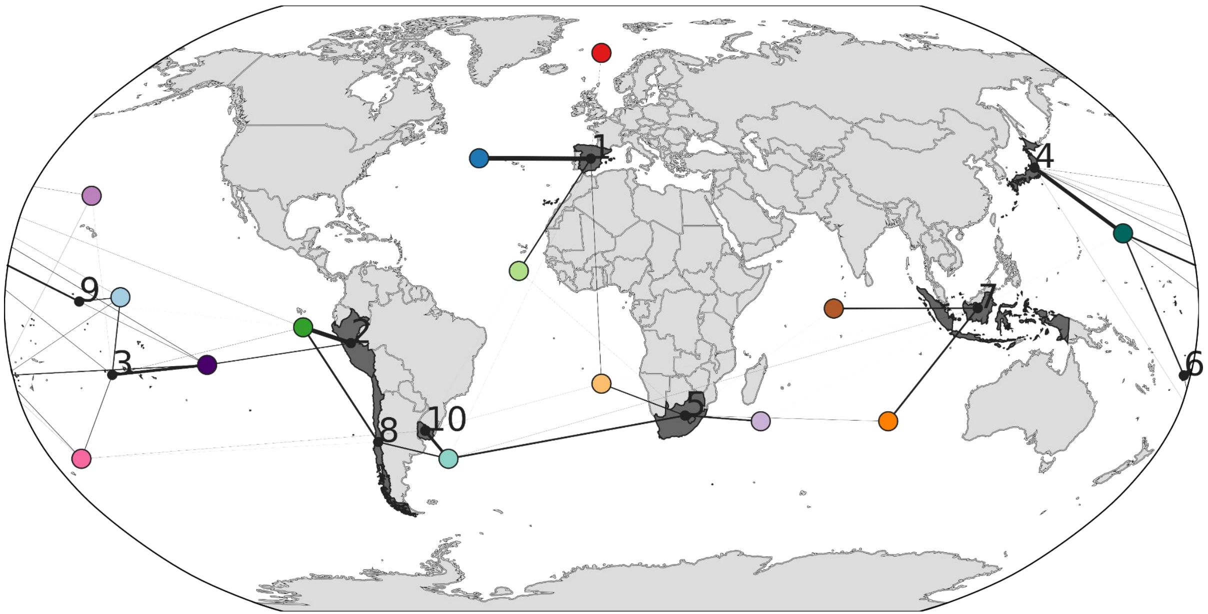


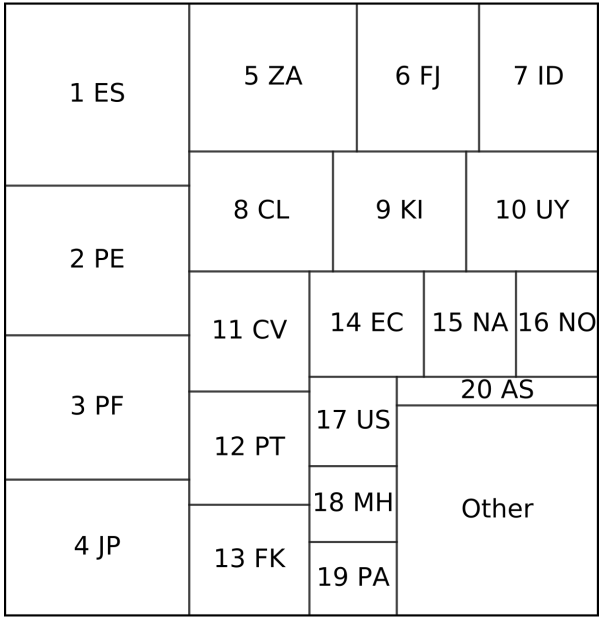


Rodríguez *et al.*, Sci. Adv. (2021)

The global fishing network: countries

- Join the ports by **country**
- Extract the top 10 countries: many low and middle-income countries: opportunity to control and manage (game theory?)





1: Spain, 2: Peru, 3: French Polynesia, 4: Japan, 5: South Africa, 6: Fiji, 7: Indonesia, 8: Chile, 9: Kiribati, 10: Uruguay, 11: Cape Verde, 12: Portugal, 13: Falkland Islands, 14: Ecuador, 15: Namibia, 16: Norway, 17: United States, 18: Marshall Islands, 19: Panama, 20: American Samoa

Rodríguez *et al.*, Sci. Adv. (2021)

- Inter-event statistics for each vessel (no port locations)

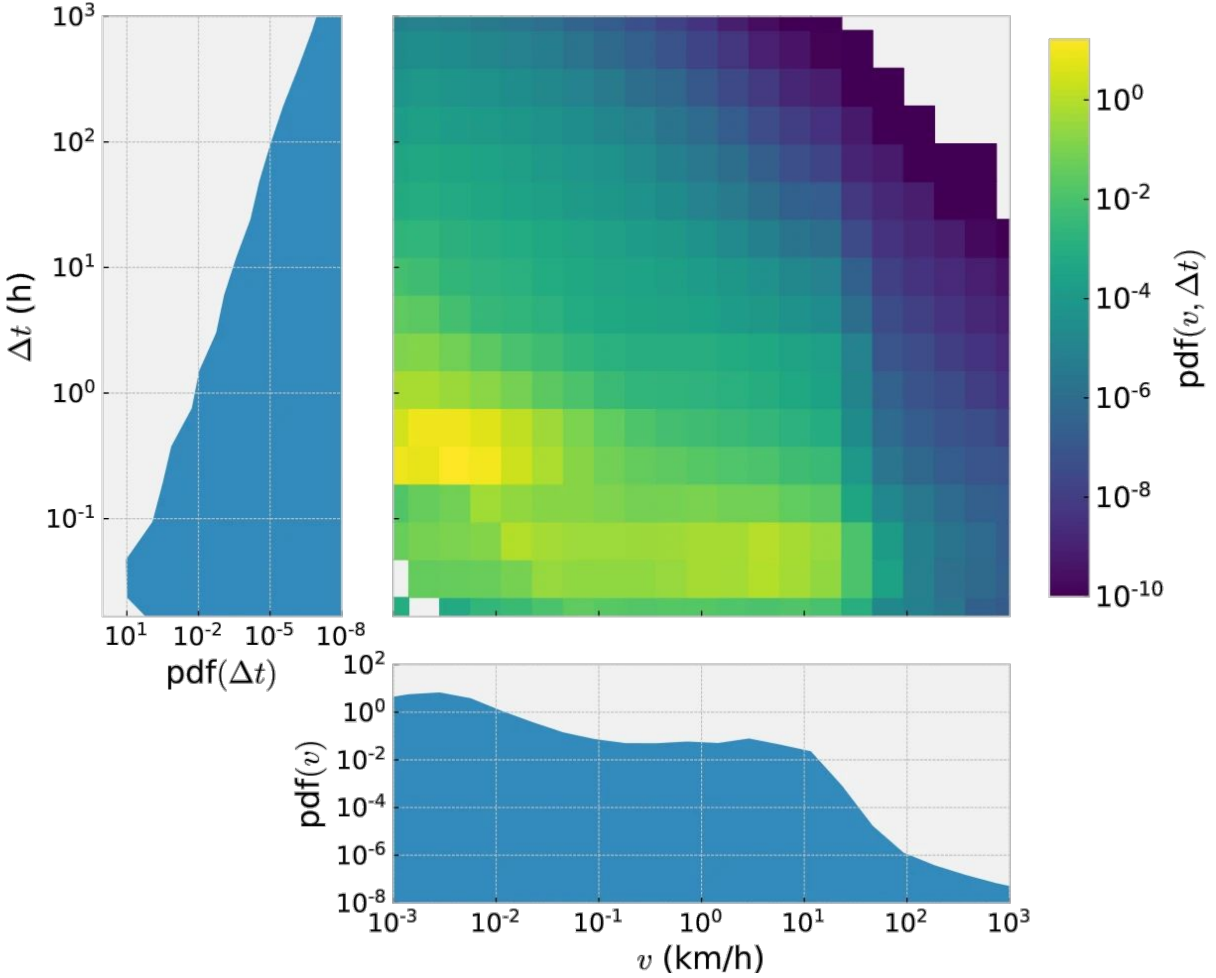
- Large gaps with no data

- Non-feasible speeds

- Focus on cases with Δt > 24 h (silence anomalies)

- 770 K silence anomalies out of 250 M locations

- Maybe the devices were failing. How can we filter these cases?



Rodríguez *et al.*, EPJ Data Sci. (2024)

We need to keep anomalies that cannot be explained by random failure

1) Consider each trajectory with anomalies and cells of 0.5º x 0.5º size, discarding cells with a port (World Port Index)

2) Re-distribute randomly the anomalies in the trajectory

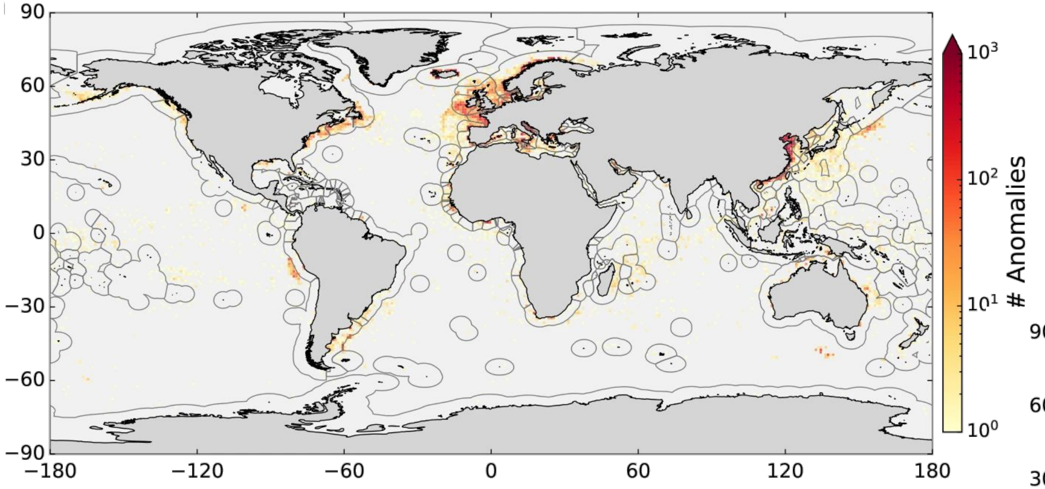
(i.e., probability of anomaly in cell proportional to number of locations)

4) 10^3 realizations for each vessel. Every realization with the number of anomalies higher than the observed in a cell increased *p*-value for that cell

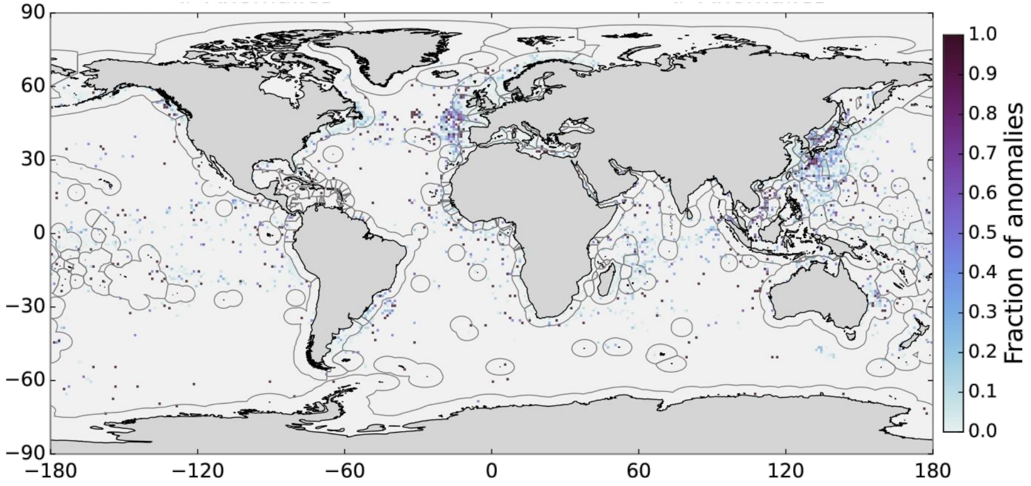
Rodríguez *et al.*, EPJ Data Sci. (2024)

- Select, for each trajectory, anomalies in cells with $p < 0.01$
- 169 K (out of 770 K) remaining anomalies

Number of anomalies



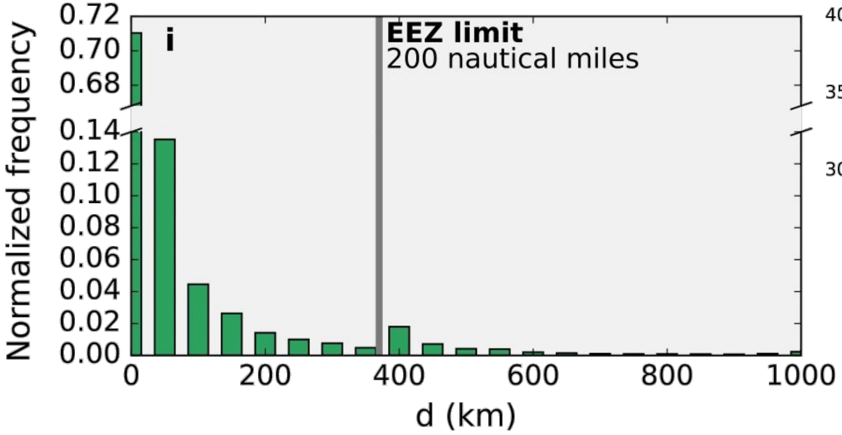
Fraction of anomalies

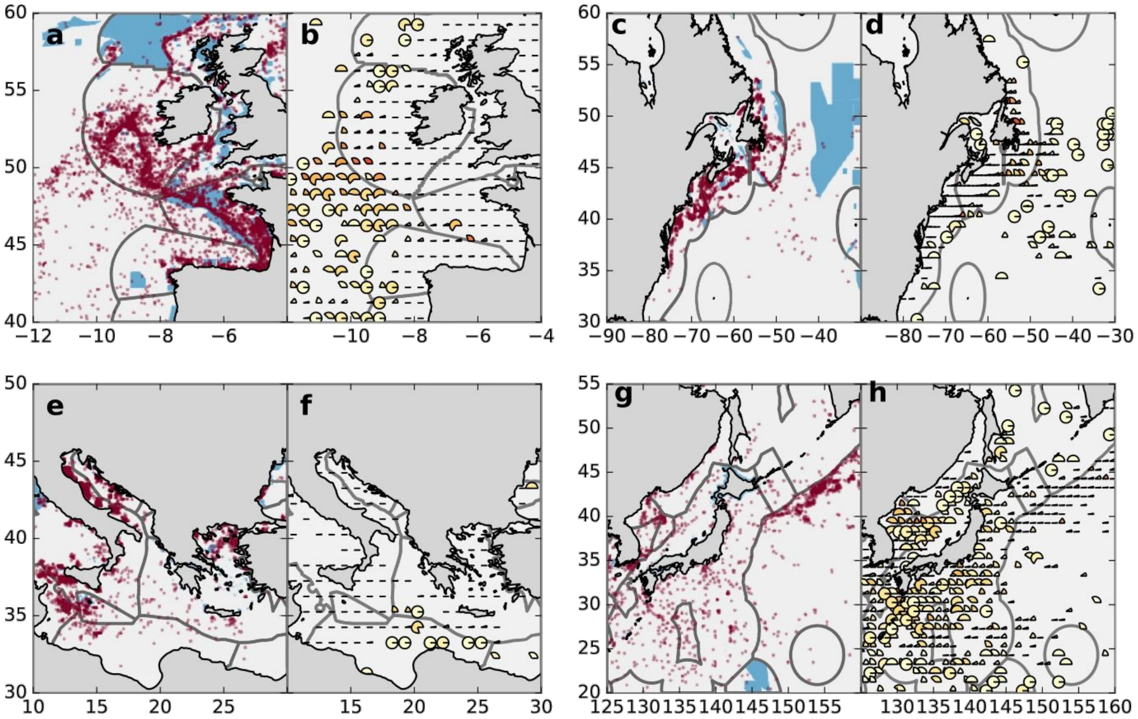


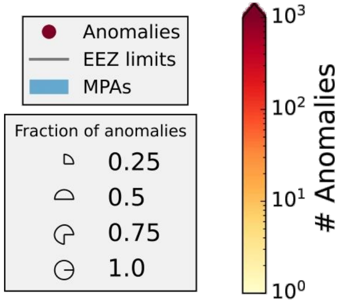
Rodríguez *et al.*, EPJ Data Sci. (2024)

- Most of them close to shore, but interesting increase in border of EEZ

- Specific cases close to Marine Protected Areas and EEZ controversial zones







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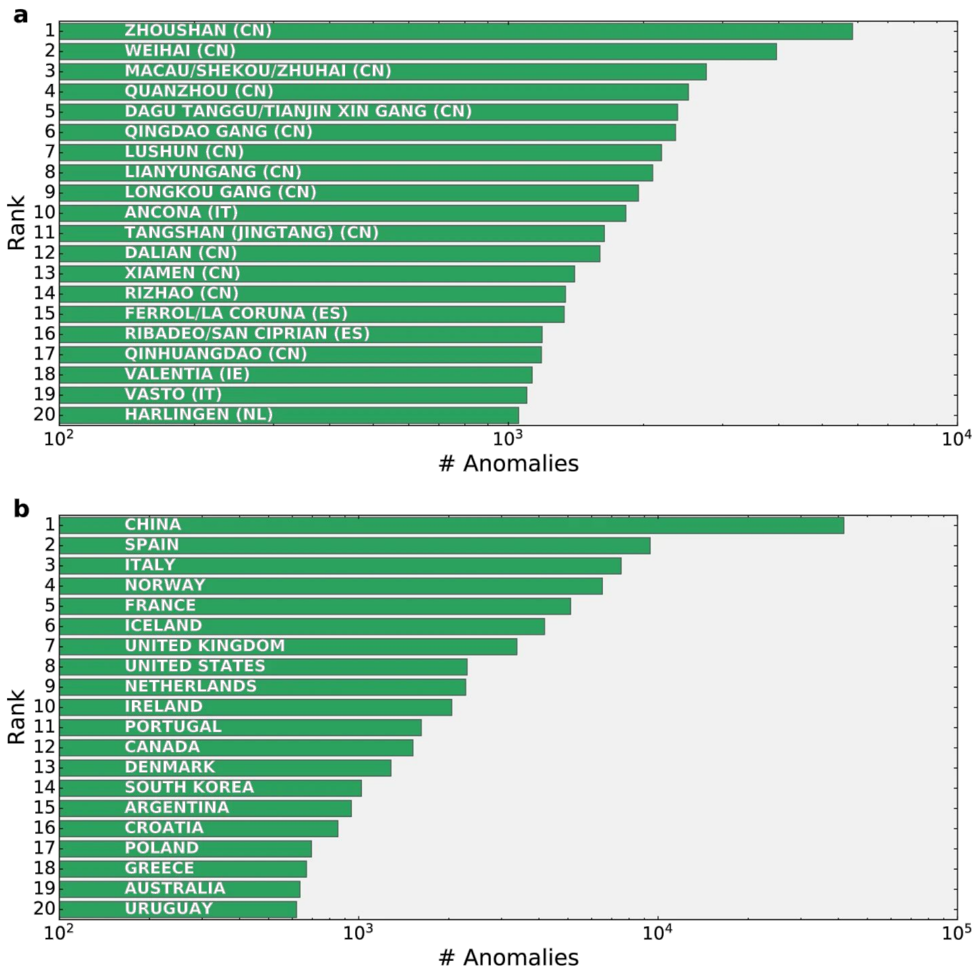
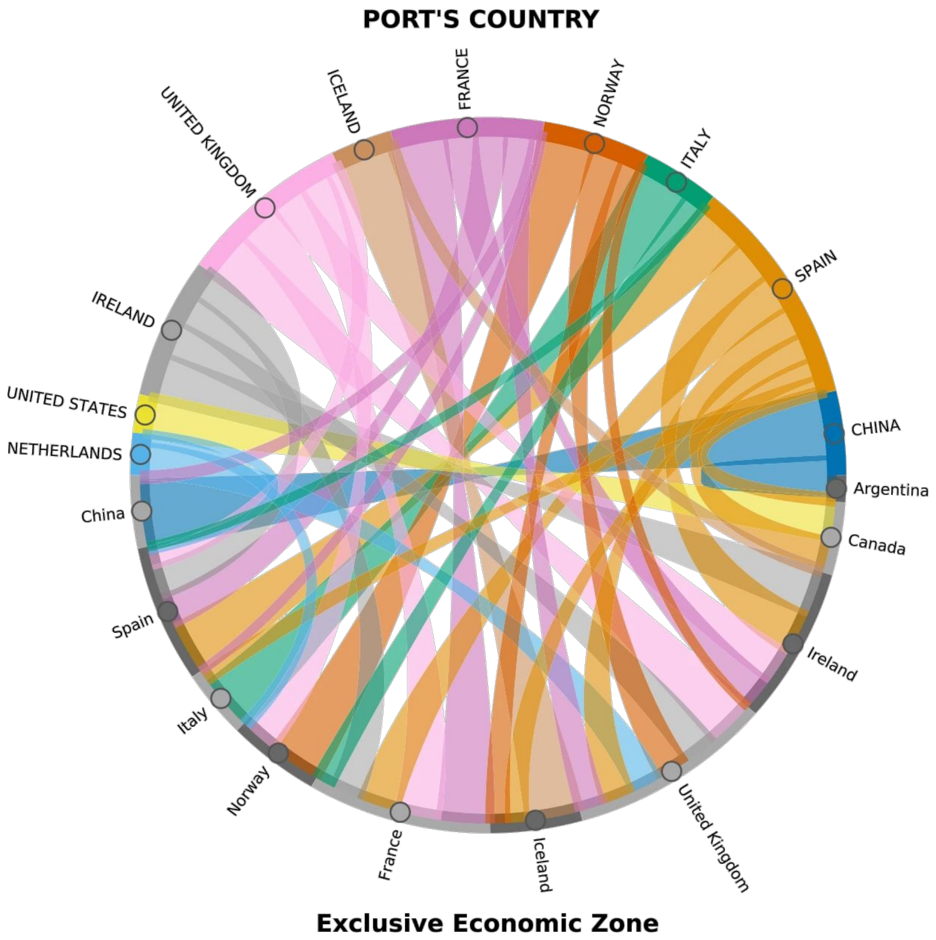
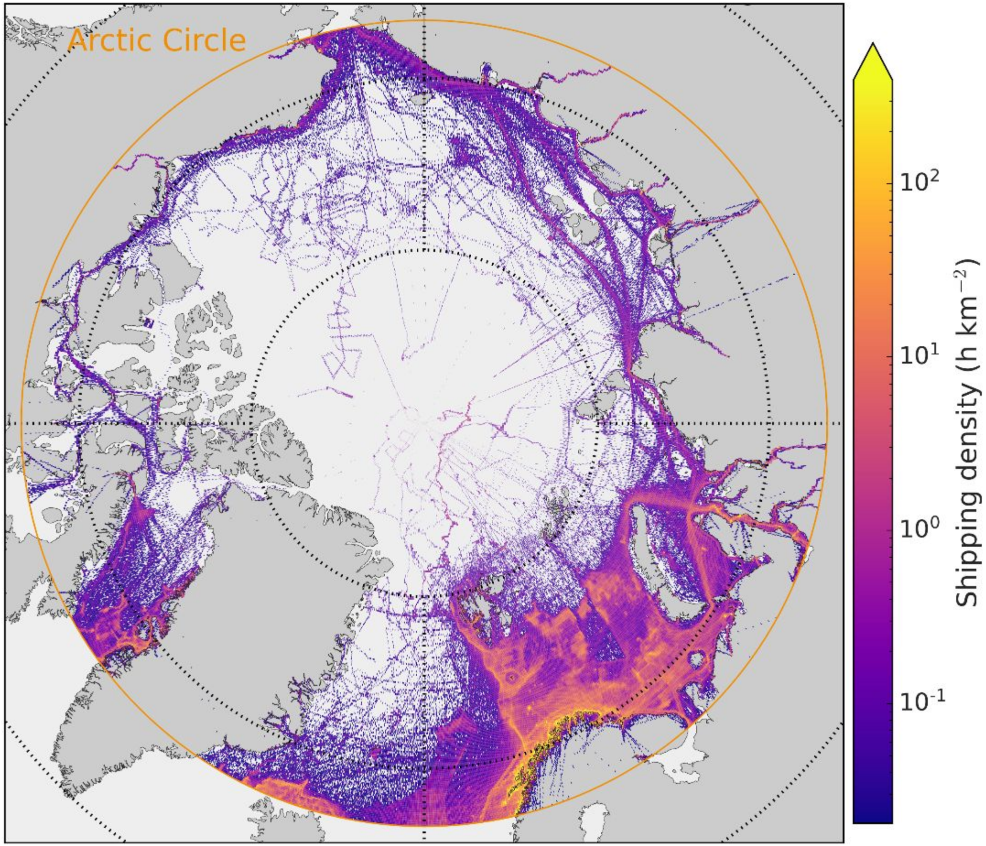
Where did anomalies occur?

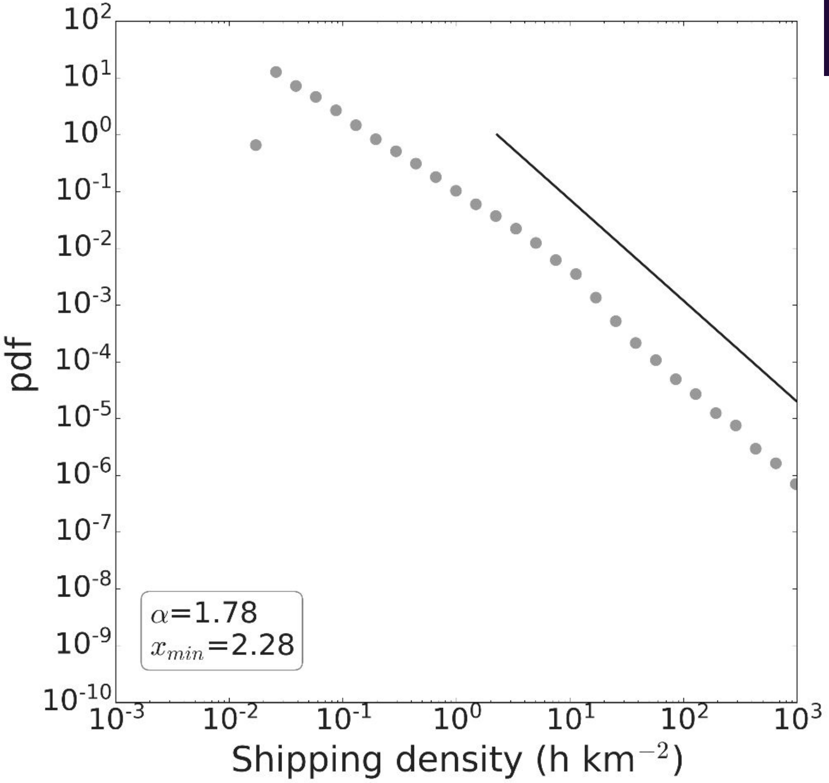




Rodríguez *et al.*, EPJ Data Sci. (2024)

Arctic shipping traffic (2020-2022)





Rodríguez *et al.*, iScience (pre-accepted), arXiv (2024)

Null models of traffic

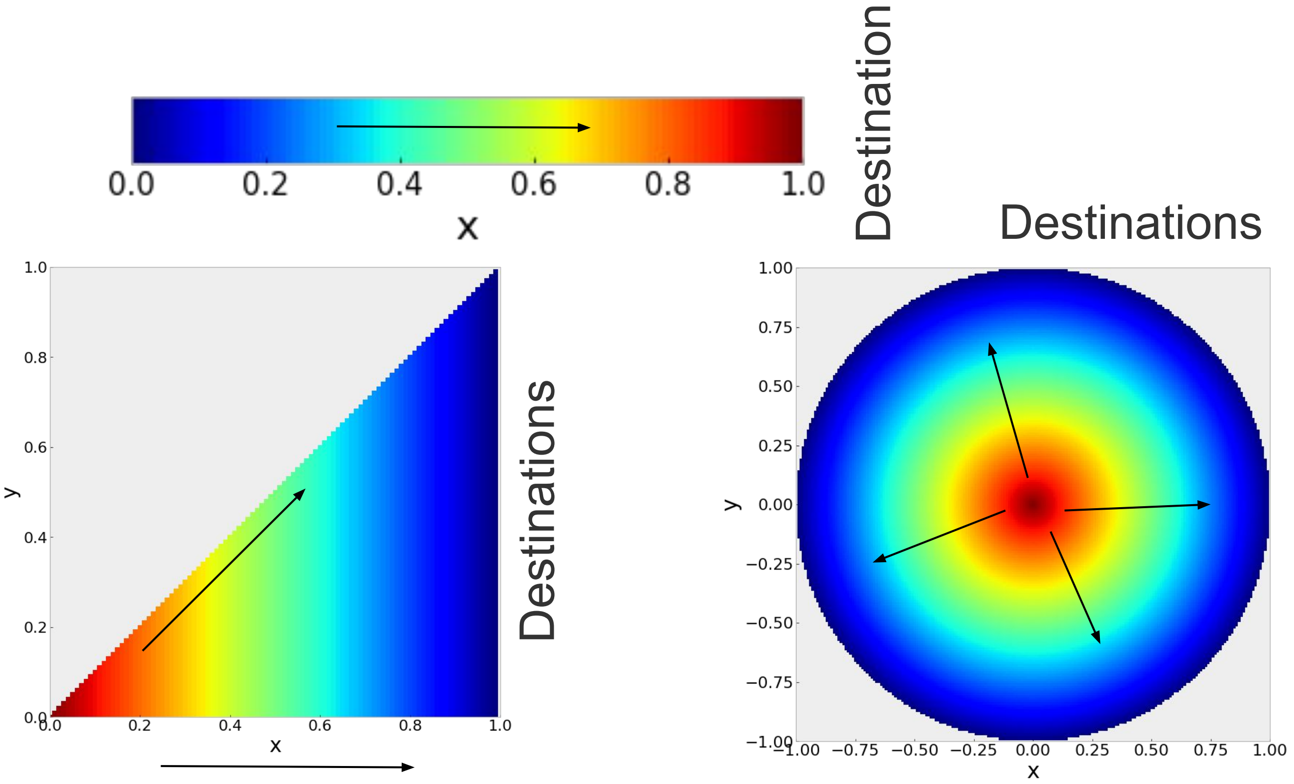
1D transit

Uniform distribution

2D transit

Power-law

$$\mathrm{pdf}(\rho) = K\rho^{-3}$$



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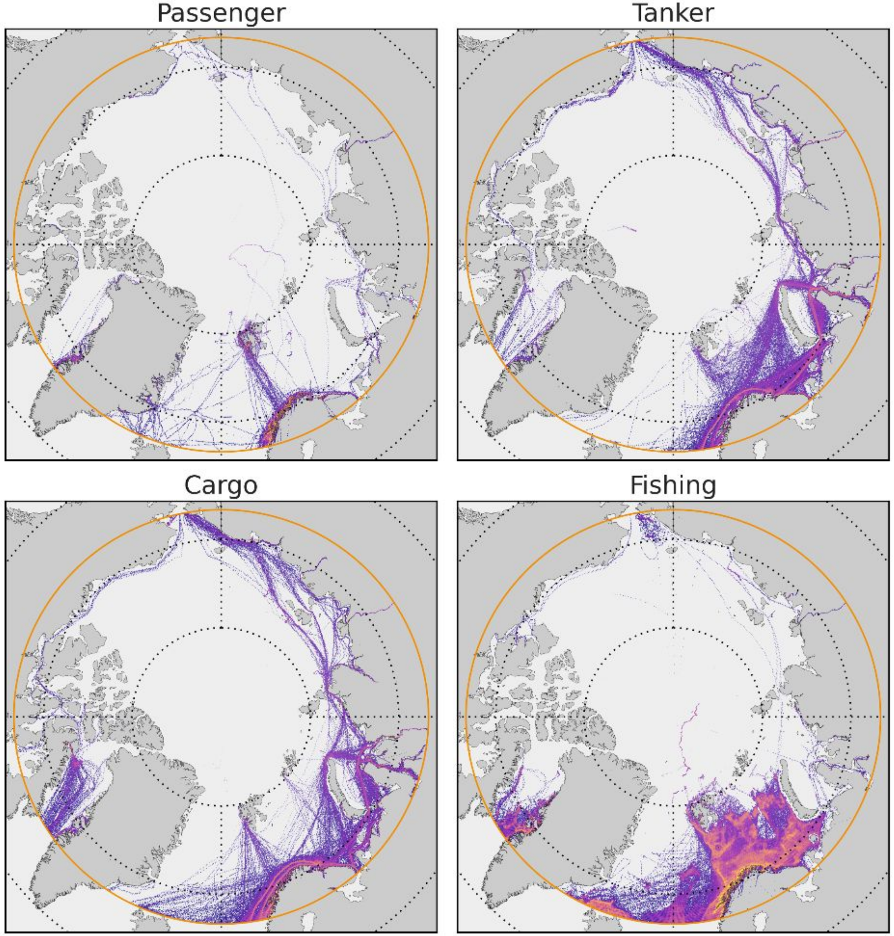

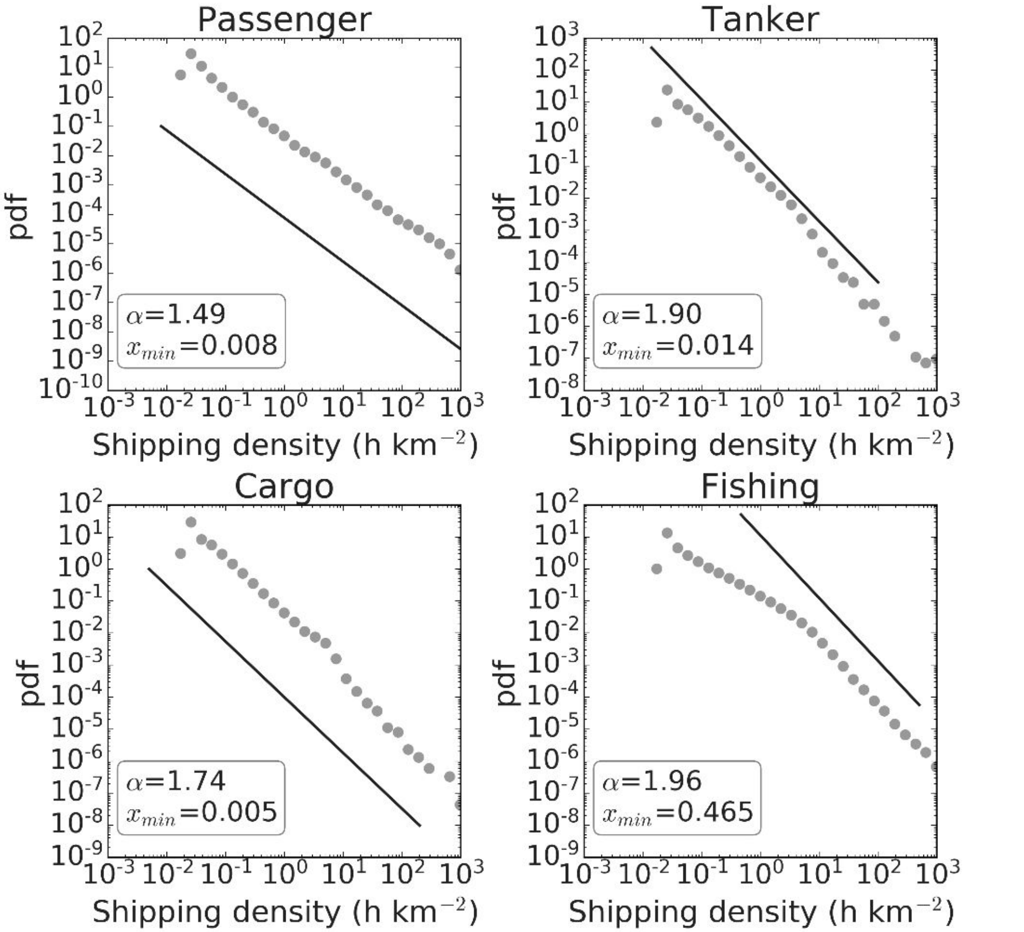

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- In globally connected ecosystems (especially oceans), what happens at the high seas (**free riding**) does not stay at the high seas

- Game theory can be useful to solve less abstract (**real**) problems. How can we convince actors to cooperate for sustainability?

- We can learn from missing/wrong data, illustrating **suspicious behavior**

- Spatial density patterns from transit flows may lead to **power-law** distributions

- **Open data** for sustainability research?

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THANK YOU

Gracias

Gràcies

謝謝

for your attention

Grazie

Danke