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The global network of ports supporting high seas fishing

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ABSTRACT

Fisheries in waters beyond national jurisdiction ("high seas") are difficult to monitor and manage. Their regulation for sustainability requires critical information on how fishing effort is distributed across fishing and landing areas, including possible border effects at the exclusive economic zone (EEZ) limits. We infer the global network linking harbors supporting fishing vessels to fishing areas in high seas from automatic identification system tracking data in 2014, observing a modular structure, with vessels departing from a given harbor fishing mostly in a single province. The top 16% of these harbors support 84% of fishing effort in high seas, with harbors in low-and middle-income countries ranked among the top supporters. Fishing effort concentrates along narrow strips attached to the boundaries of EEZs with productive fisheries, identifying a free-riding behavior that jeopardizes efforts by nations to sustainably manage their fisheries, perpetuating the tragedy of the commons affecting global fishery resources.





Fig. 2 Global fishing network composed of ports and high seas fishing provinces. Provinces (represented with different colors) of strongly connected locations are identified with Infomap. Ports are depicted as circles with colors identified with the provinces they support. The 14 fishing provinces are North Eastern Pacific (NEP), Northern Central Pacific (NCP), Southern Central Pacific (SCP), Eastern Pacific (EP), Southern Pacific (SP), Southern Atlantic (SA), Northern Seas (NS), Northern Atlantic (NA), Central Atlantic (CA), South Eastern Atlantic (SEA), South Western Indian (SWI), Northern Indian (NI), South Eastern Indian (SEI), and North Western Pacific (NWP). Gray traces represent the trajectories of the vessels

Fig. 1 Fishing effort in the high seas.

(A) Fishing effort, as total days of fishing activity in 2014, at each grid cell (of size 0.5° lat × 0.5° lon) in the high seas. Red contours delimit the areas including the grid cells with the top 10% fishing effort. (B to E) Zooms on the regions enclosed by the dashed lines in (A), where high fishing effort concentrates along the outer edge of productive EEZs. (F) Number of cells for each observed fishing effort value classified according to the distance d to the closest shore. (G) Fraction of the global fishing effort in the high seas observed at a distance d to the closest shore; bars represent the fraction along bands of 50-km width.



connecting ports and fishing locations.



Fig. 3 Distribution of high seas fishing effort among provinces and harbors. Central panel: Effort (vertical axis) of the top 10 harbors in each province, which are depicted in the horizontal plane. Label numbers correspond to their global rank according to **(A)**. **(A)** Fraction of effort

supported by the top 10 harbors. **(B)** Ranking plot of the fraction of the global fishing effort supported by each harbor. **(C)** Bipartite network linking the top 10 harbors used by vessels operating in the high seas and the fishing provinces they exploit therein. Links connect the ports with the hotspots visited immediately before and after the detected presence of each vessel in each port, and their widths are proportional to the estimated fishing efforts in the hotspots before and after the presence in ports.

NEP ONCP OSCROEP OSP OSA ONS ONA OCA OSEA OSWATONI OSEI ONWP

Fig. 4 Distribution of fishing effort in high seas among the countries supporting it. (A) Area plot depicting the fraction of the global fishing effort supported by each of the 88 countries with at least one harbor supporting fishing effort at the high seas, specifying the acronyms of the top 20 nations (ES: Spain, PE: Peru, PF: French Polynesia, JP: Japan, ZA: South Africa, FJ: Fiji, ID: Indonesia, CL: Chile, KI: Kiribati, UY: Uruguay, CV: Cape Verde, PT: Portugal, FK: Falkland Islands, EC: Ecuador, NA: Namibia, NO: Norway, US: United States, MH: Marshall Islands, PA: Panama, AS: American Samoa). (B) Network between the top 10 countries (left) and fishing provinces (right). Each link groups the effort of the harbors located in each country, and the width is proportional to the fishing effort. (C) Geographical distribution of the links between the top 10 countries [colored in dark gray and ranked according to (A)] and the 14 fishing provinces in the high seas (represented by colored dots). Lines link countries to the fishing provinces, with their thickness being proportional to the fishing efforts associated with each link.

CONCLUSIONS

- The fishing effort is heterogeneously distributed in igh seas, with narrow strips of ocean highly overused near the borders of productive EEZs, signaling free-riding behavior.
- The fishing effort is also highly organized around 14 provinces identified through community detection methods that use vessels trajectories as inputs.
- We have uncovered the global network of harbors that support fishing on the 14 provinces.
- Together these results provide guidance for the correct global management of oceanic fishing resources.



