Linking plastics, seabirds, and zooplankton to estimate exposure and impact in North Pacific food webs

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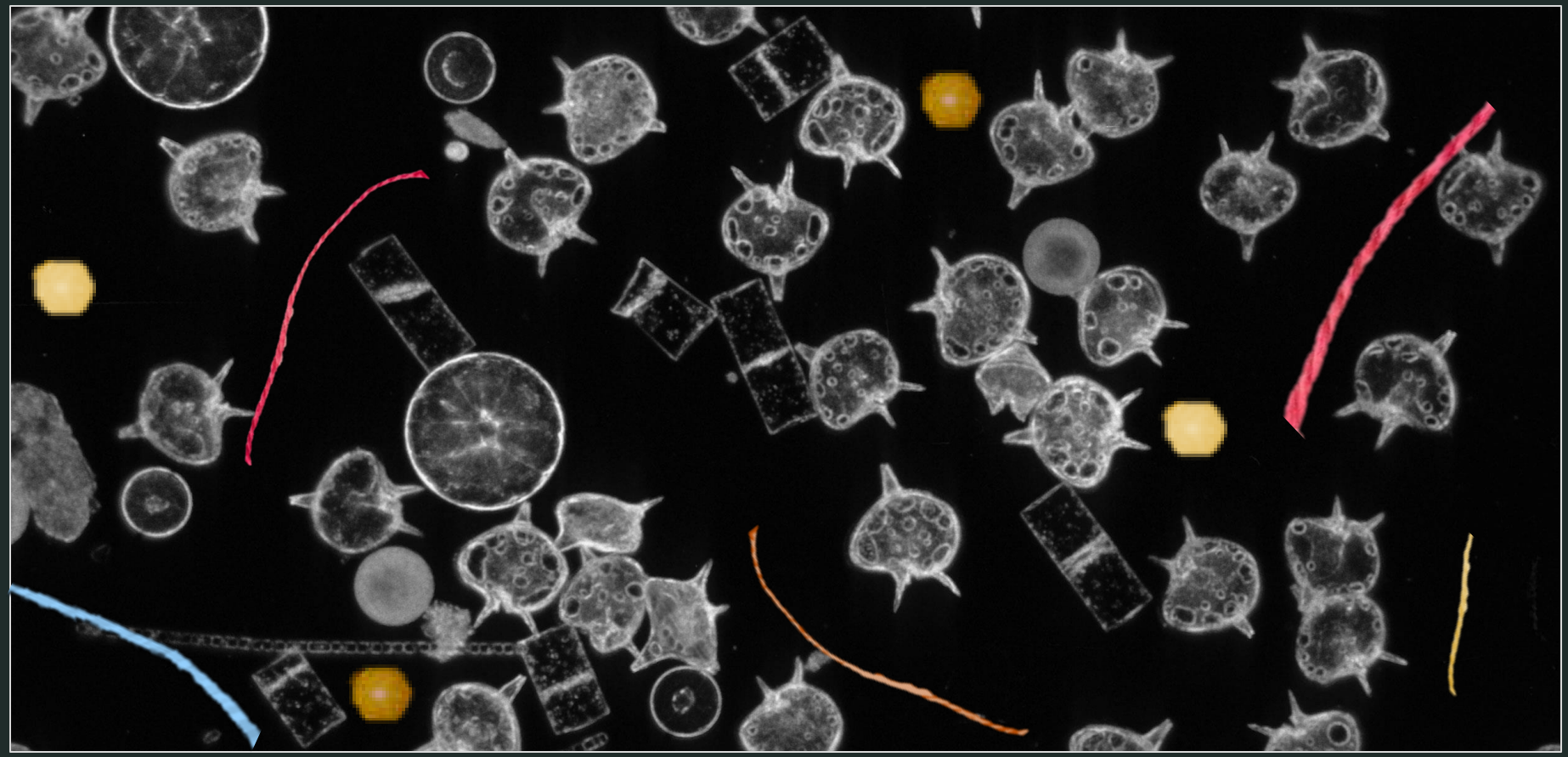
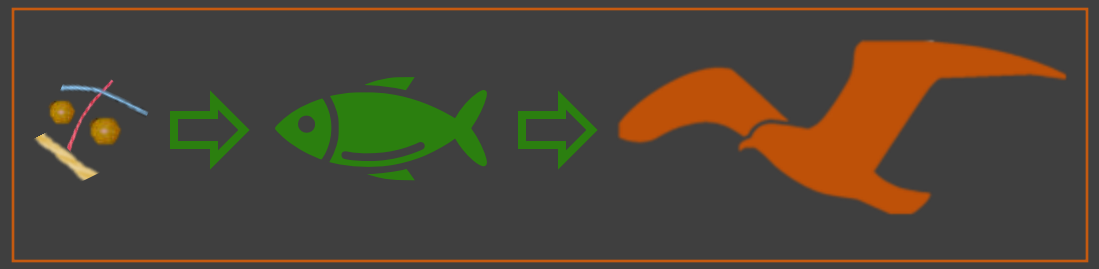


Marine plastics in the north Pacific are increasing, and present many ecological challenges.

In marine foodwebs, plastic may be directly or indirectly ingested by consumers in marine food webs.



海ではプラスチック廃棄物が増加しており、海洋動物が直接または間接的に食べている可能性がある。

Photo credit: Susanne Kuehn

Some seabird guilds are especially known to ingest plastics, which is observed in the stomach contents of bycatch specimens or beach carcasses, or via colony studies.

海鳥の中にはプラスチックを食べる種もいますが、そのことは海鳥の胃の中にプラスチックが見つかったり、海鳥の食事に関する研究でプラスチックが見つかったりしていることからわかっています。

Small surface planktivores

Storm-petrels
Phalaropes

Diving planktivores

Auklets

Large surface foragers

Northern Fulmar
Albatross
Kittiwakes

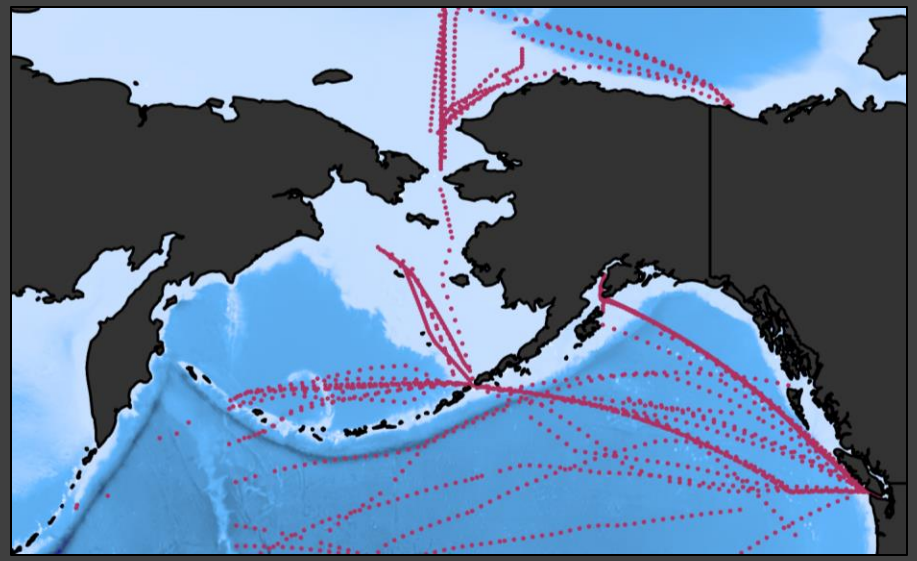
Photo credit: Susanne Kuehn

Combining two long-term, high-quality data sources that provide at-sea data on plastics, zooplankton, and seabird distribution patterns in the North Pacific.

この疑問に答えるために、私たちは2つの有名なデータセットを組み合わせました

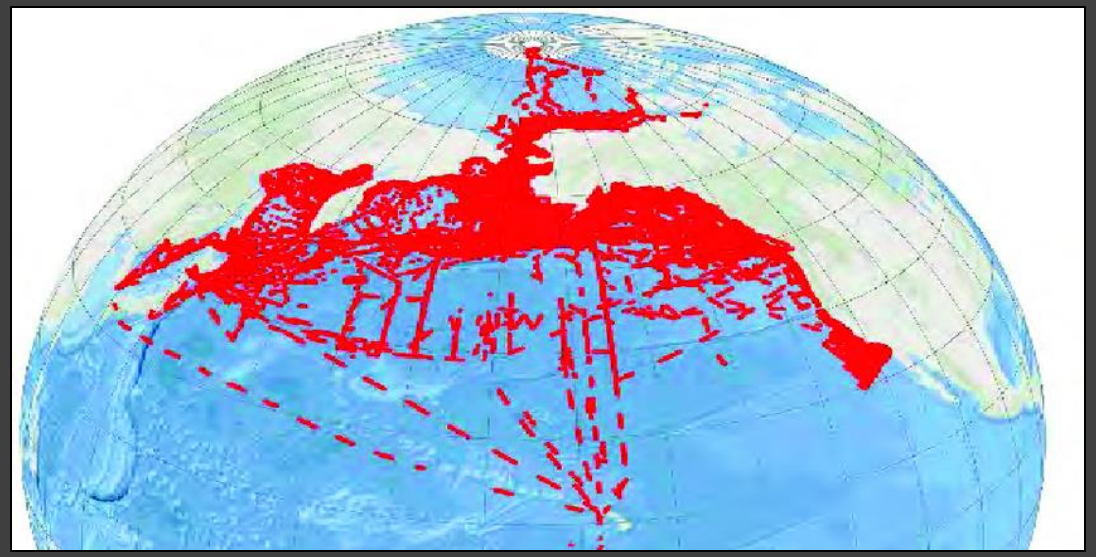
Plankton surveys from Continuous Planton Recorder Survey

Marine Biological Association



Seabird sightings from North Pacific Pelagic Seabird Database

USGS science for a changing world



Watanuki, Yutaka, et al. "Spatial ecology of marine top predators in the North Pacific: Tools for integrating across datasets and identifying high use areas." PICES Scientific Report 50 (2016): I-55.

Continuous Planktorn Recorder Survey: the CPR program has collected long-term zooplankton data in the Pacific since 2000. Since 2016, plastics entrained in the recorder have been quantified to a coarse level.

October 2025 Nome-Dutch Harbor CPR deployme
on Canadian Coast Guard vessel Wilfred Laurier

	midpoint_dat	latitude	longitude	Plastic	Plastic.Total.	Plastic.stran	Plastic.stran	Plastic.stran	Plastic.stran	Plastic.stran	Plastic.stran	Plastic.stran	Plastic.fragm	Plastic.fragm	Plastic.fragm	Plastic.fragm
1	##########	46.172	227.683	0	0	0	0	0	0	0	0	0	0	0	0	0
2	##########	46.648	227.012	0	0	0	0	0	0	0	0	0	0	0	0	0
3	##########	47.072	226.26	0.001	3	1	2	0	0	0	0	0	0	0	0	0
4	##########	47.49	225.495	0.001	2	0	0	2	0	0	0	0	0	0	0	0
5	##########	47.903	224.718	0	0	0	0	0	0	0	0	0	0	0	0	0
6	##########	48.312	223.928	0.001	1	0	0	0	1	0	0	0	0	0	0	0
7	##########	48.715	223.127	0	0	0	0	0	0	0	0	0	0	0	0	0
8	##########	49.112	222.312	0	0	0	0	0	0	0	0	0	0	0	0	0
9	##########	49.503	221.483	0	0	0	0	0	0	0	0	0	0	0	0	0
10	##########	49.888	220.642	0	0	0	0	0	0	0	0	0	0	0	0	0
11	##########	50.267	219.787	0	0	0	0	0	0	0	0	0	0	0	0	0
12	##########	50.64	218.92	0	0	0	0	0	0	0	0	0	0	0	0	0
13	##########	51.007	218.037	0	0	0	0	0	0	0	0	0	0	0	0	0
14	##########	51.25	217.445	0.001	2	0	0	1	1	0	0	0	0	0	0	0
15	##########	51.615	216.55	0	0	0	0	0	0	0	0	0	0	0	0	0
16	##########	51.907	215.582	0	0	0	0	0	0	0	0	0	0	0	0	0
17	##########	52.192	214.602	0	0	0	0	0	0	0	0	0	0	0	0	0
18	##########	52.42	213.593	0	0	0	0	0	0	0	0	0	0	0	0	0
19	##########	52.625	212.552	0	0	0	0	0	0	0	0	0	0	0	0	0
20	##########	52.795	211.512	0	0	0	0	0	0	0	0	0	0	0	0	0
21	##########	52.927	210.43	0	0	0	0	0	0	0	0	0	0	0	0	0
22	##########	53.05	209.34	0	0	0	0	0	0	0	0	0	0	0	0	0
23	##########	53.163	208.247	0	0	0	0	0	0	0	0	0	0	0	0	0
24	##########	53.267	207.147	0	0	0	0	0	0	0	0	0	0	0	0	0
25	##########	53.358	206.04	0	0	0	0	0	0	0	0	0	0	0	0	0
26	##########	53.442	204.932	0	0	0	0	0	0	0	0	0	0	0	0	0
27	##########	53.505	204.248	0.001	75	35	1	17	6	0	0	6	0	0	0	0
28	##########	53.648	203.152	0	0	0	0	0	0	0	0	0	0	0	0	0

Our study questions:

- ✓ Where are the plastics in the north Pacific, and how are densities changing over time?
- ✓ What is known about plastics in high latitude habitats in the Bering, Chukchi, and Beaufort?
- ✓ How are marine plastics overlapping with seabirds that are known to ingest plastic?
- ✗ How do we quantify risk in plastic-seabird overlaps?

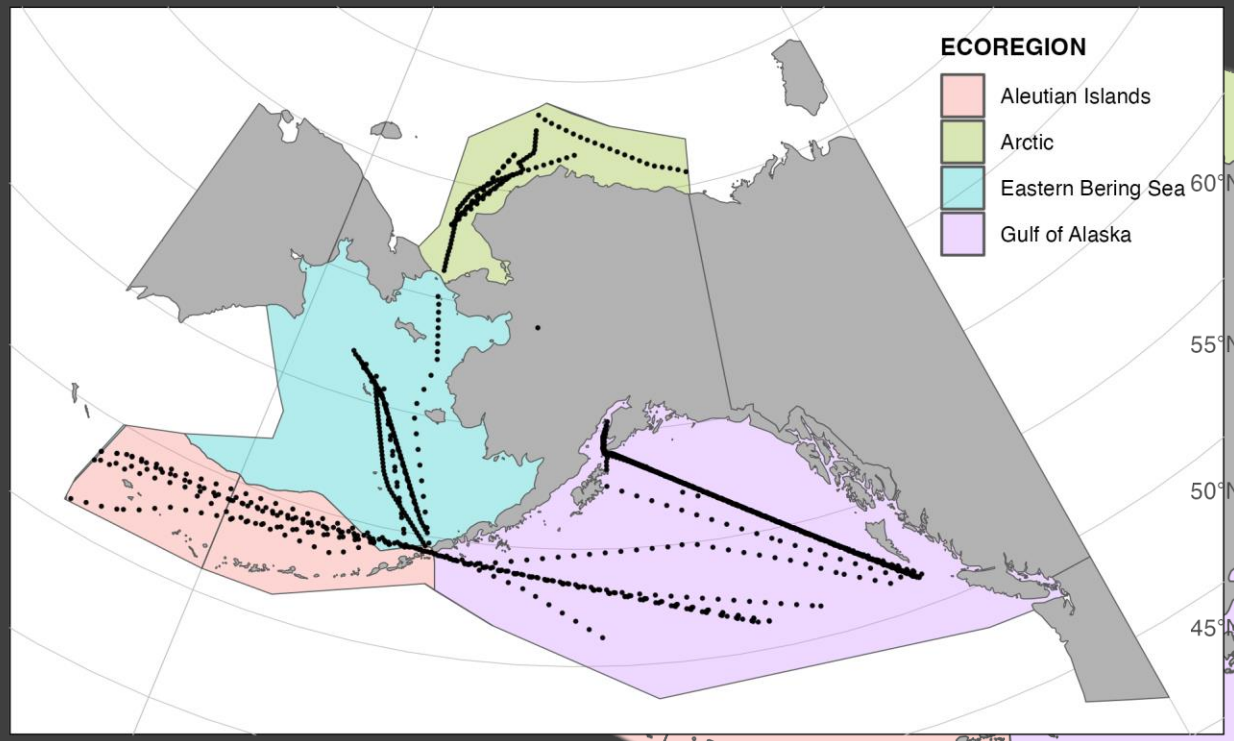
私たちの研究の課題は、北太平洋でプラスチックが増加しているかどうか、また、これらのプラスチックがそれを食べる可能性のある海鳥とどのように重なっているかを問うことです。

In North Bering and Arctic seas, plastic may be entrained and frozen in ice, then released during thaw

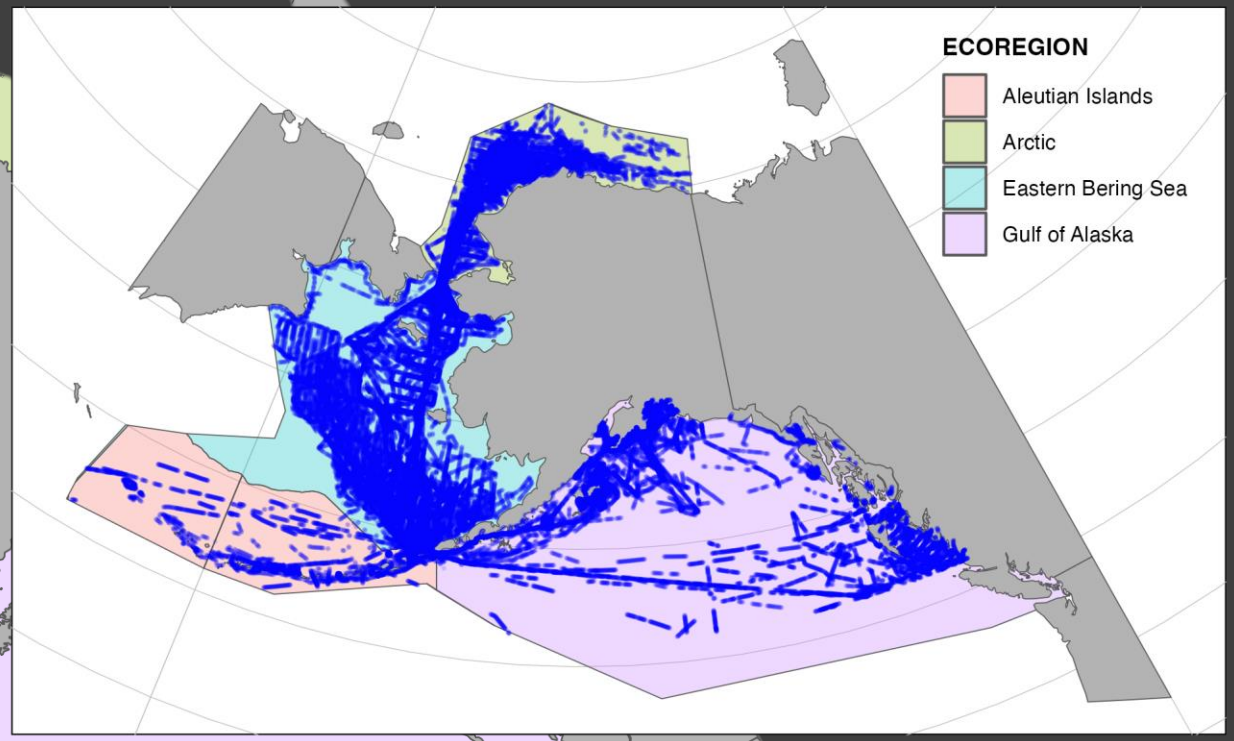
Photo credit: phys.org

Methods: We focused on 4 ecoregions in the North Pacific, for the months May-Sept.
私たちは5月から9月にかけて北太平洋の4つの生態地域に焦点を当てました。

Continuous Plankton Recorder Effort: 2016-2023



Seabird Survey Coverage Effort: 2001-2021



RESULTS

1A: Are marine plastics detected in CPR changing over time?

Answer: Yes, though mostly an Aleutian and GoA signal

CPRデータでは、プラスチックは1016年から2023年にかけて増加しており、そのほとんどはアラスカ湾とアリューシャン列島で発生している。

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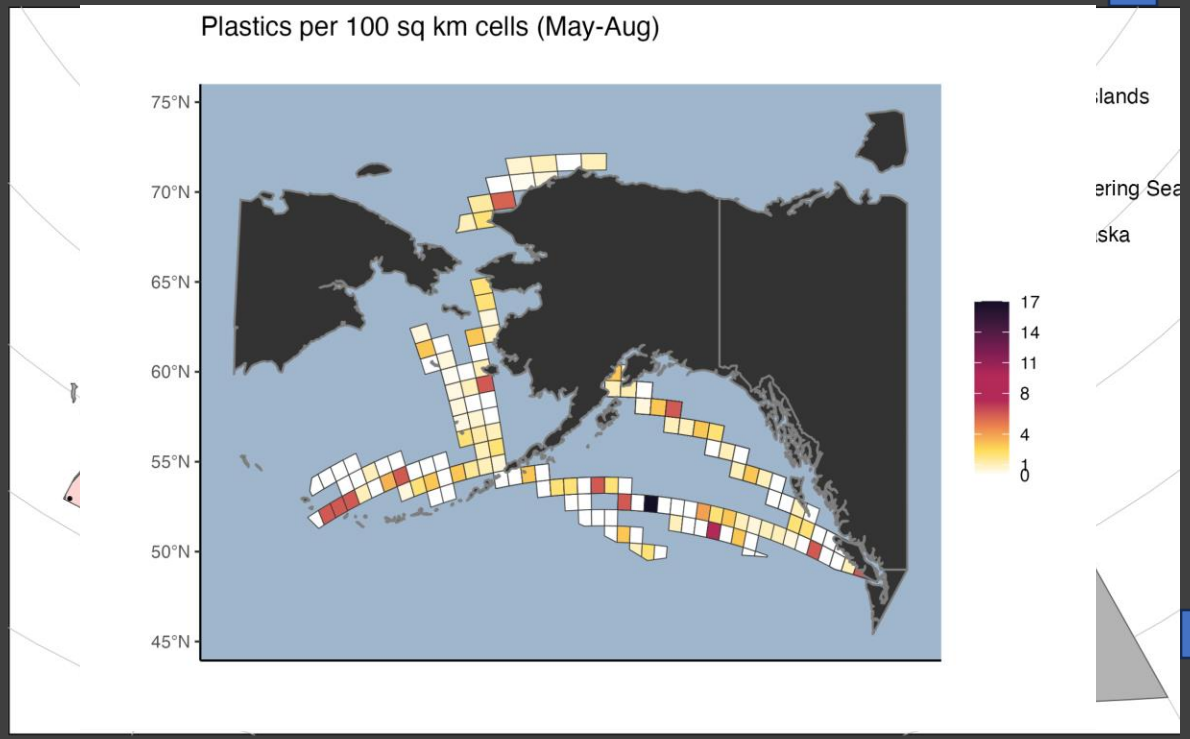

OVERALL?

BY REGION?

RESULTS

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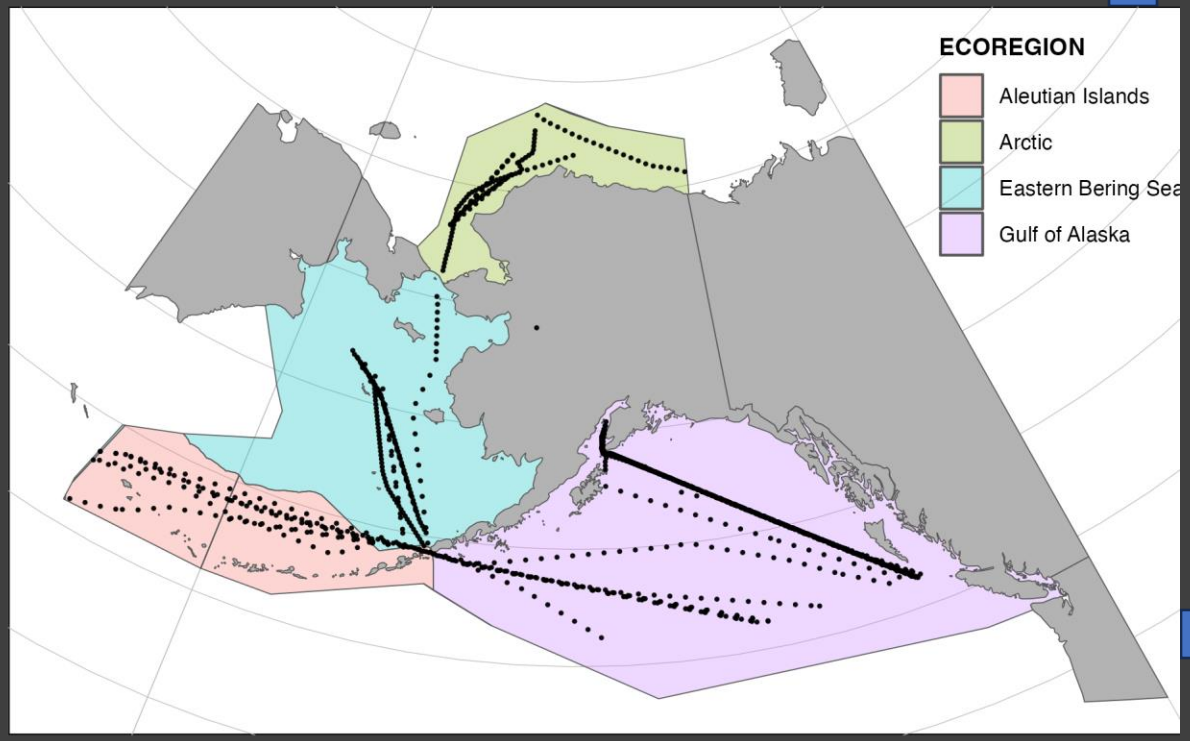
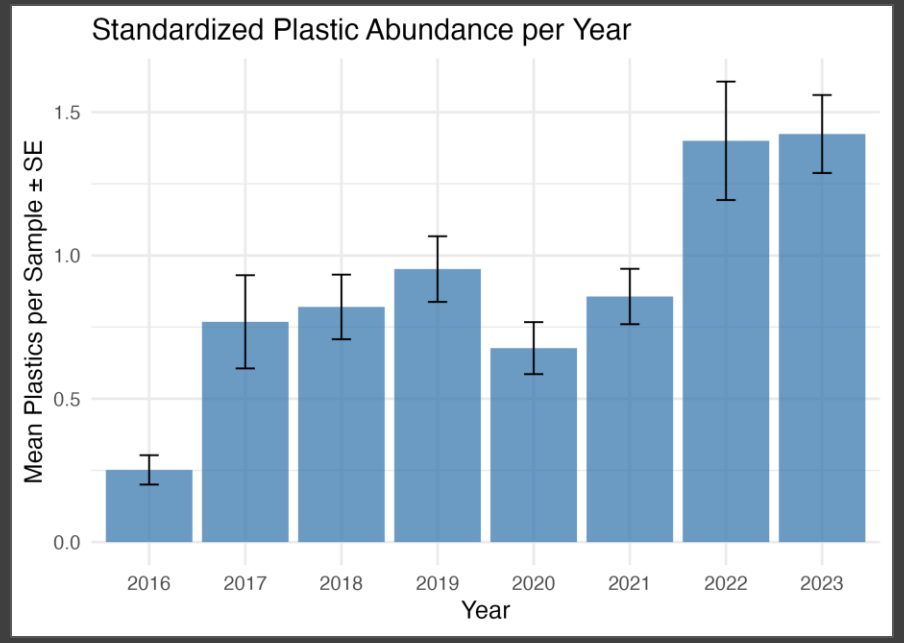
CPRデータでは、プラスチックは1016年から2023年にかけて増加しており、そのほとんどはアラスカ湾とアリューシャン列島で発生している。

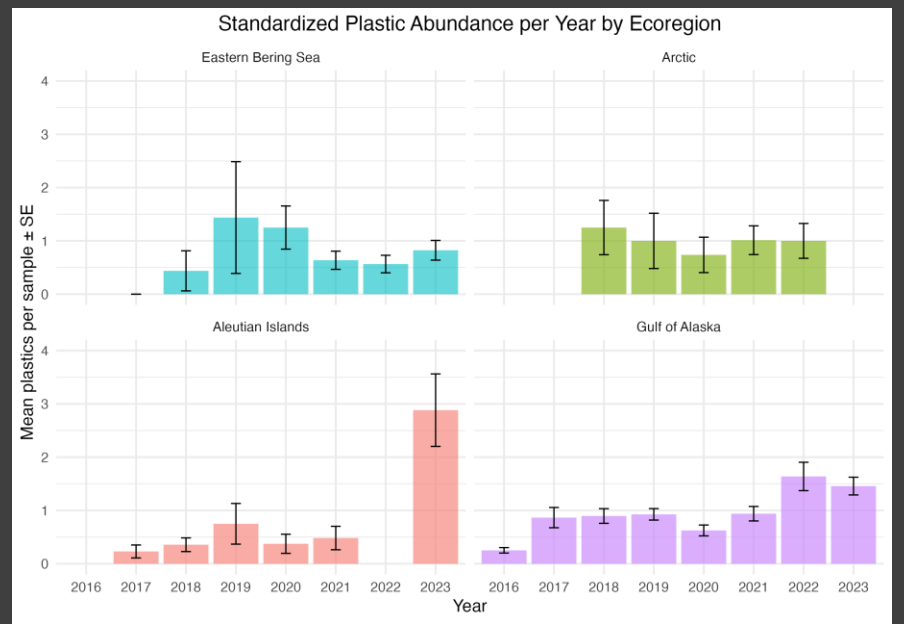
Increasing over time

Continuous Plankton Recorder Effort: 2016-2023

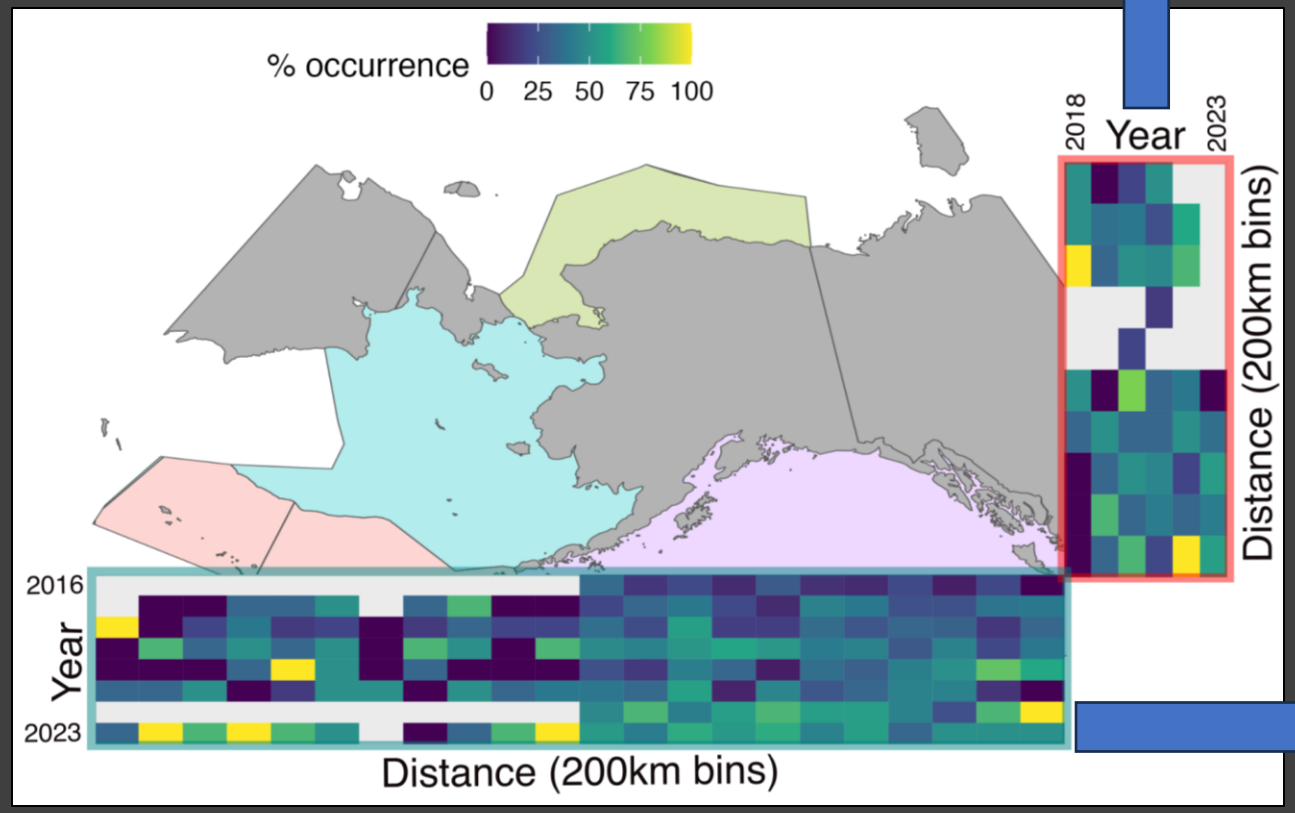


Mostly Aleutians and GoA signal





1B: Are marine plastics detected in CPR becoming more widespread?



Have plastics increased North-South?

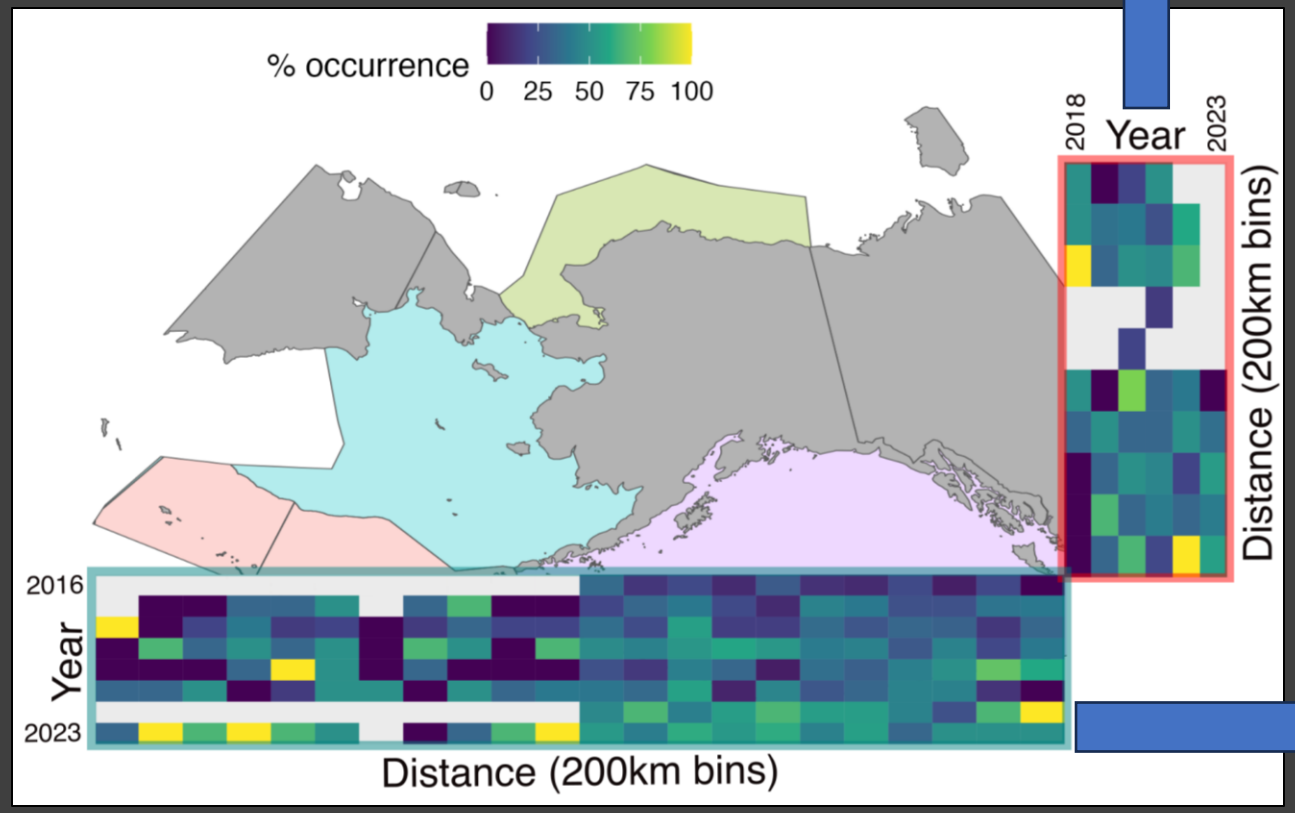
Have plastics increased East-West?

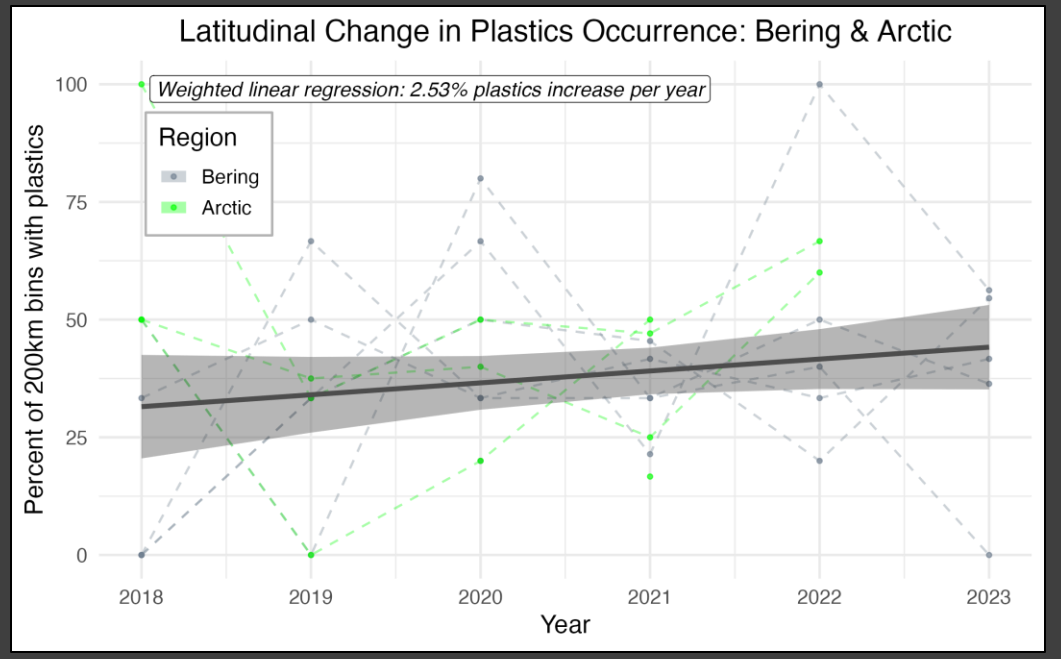
RESULTS

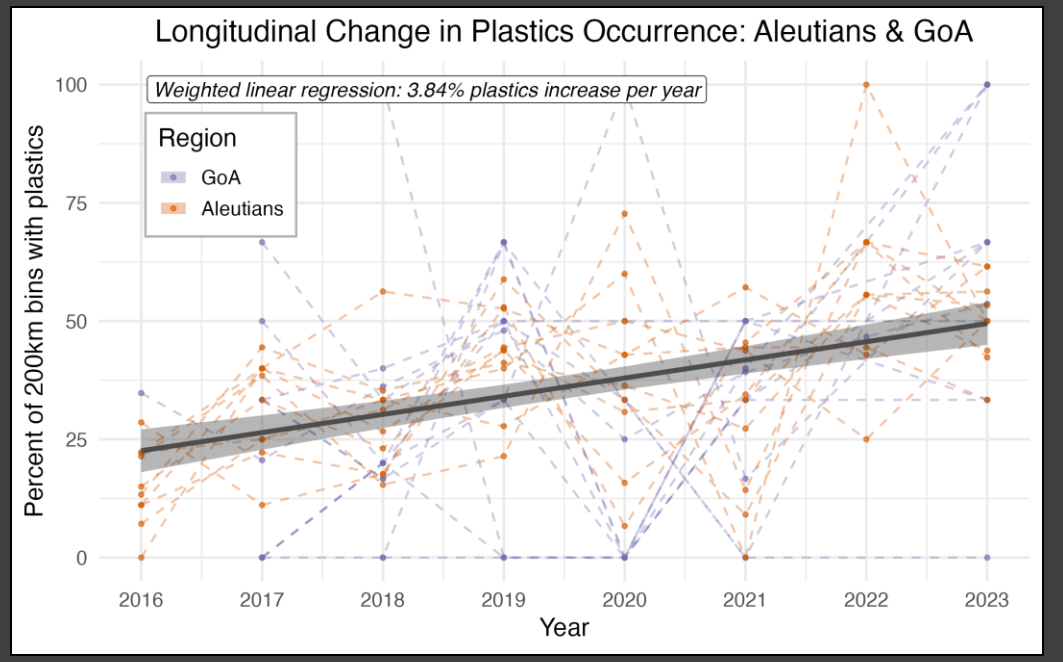
1B: Are marine plastics detected in CPR becoming more widespread?

Answer: Yes, Frequency of Occurrence is increasing, mostly along East-West GoA and Aleutians gradient.

CPRデータでは、プラスチックの存在は東西と南北の勾配で増加した。





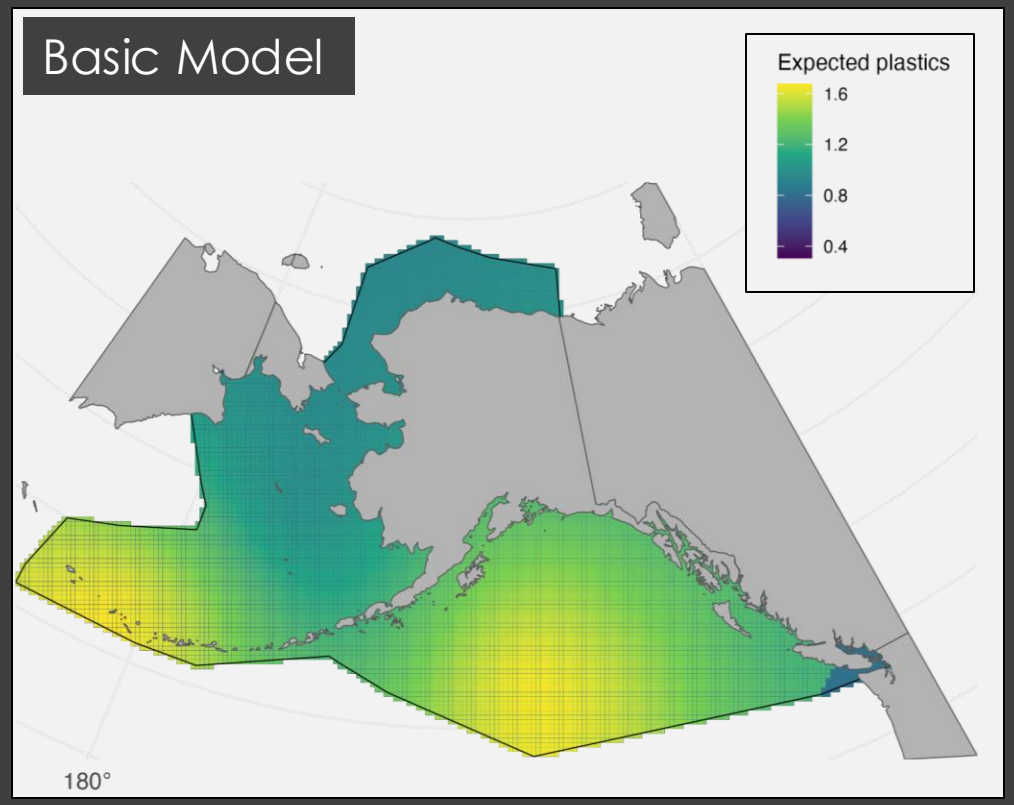


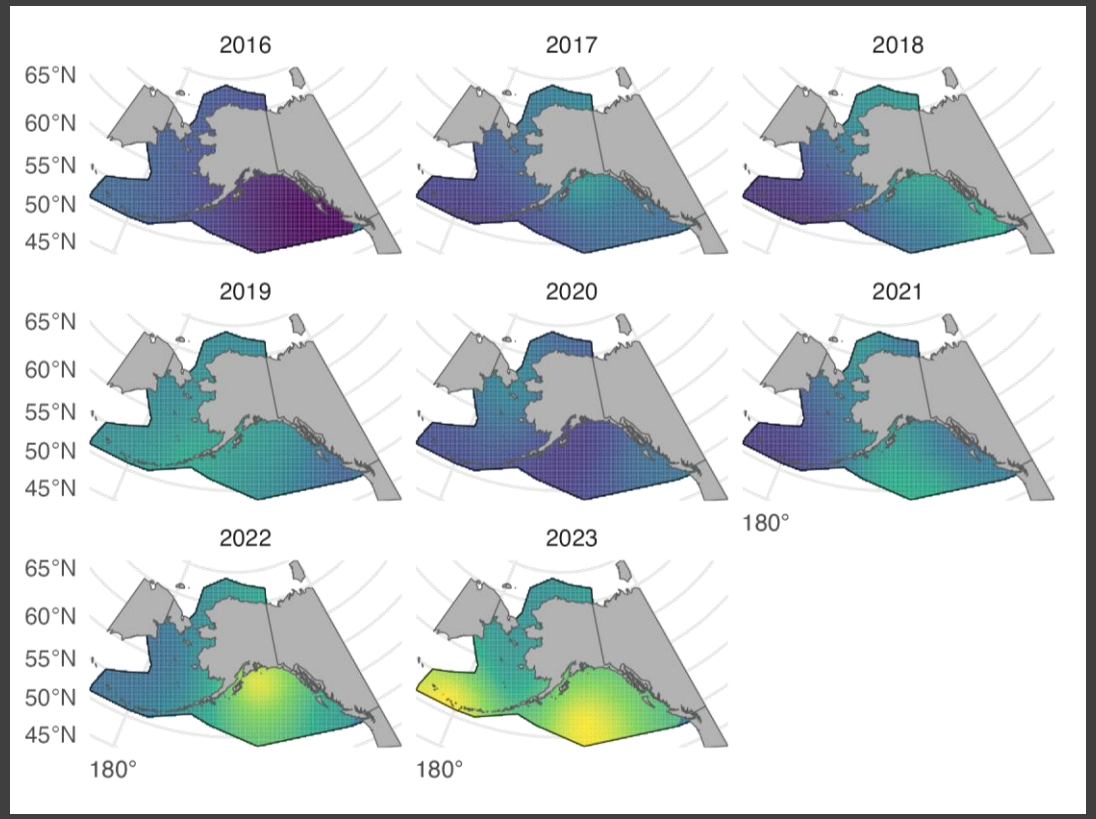
RESULTS

1C: Can we use CPR plastics data to make a basic spatial map to align with bird distributions?

Answer: Yes, but many regions are coarsely interpolated and using other data sources can improve this

このデータを用いて、プラスチックの分布に関する基本的な空間マップを作成しました。ただし、これにはさらなる作業が必要です。





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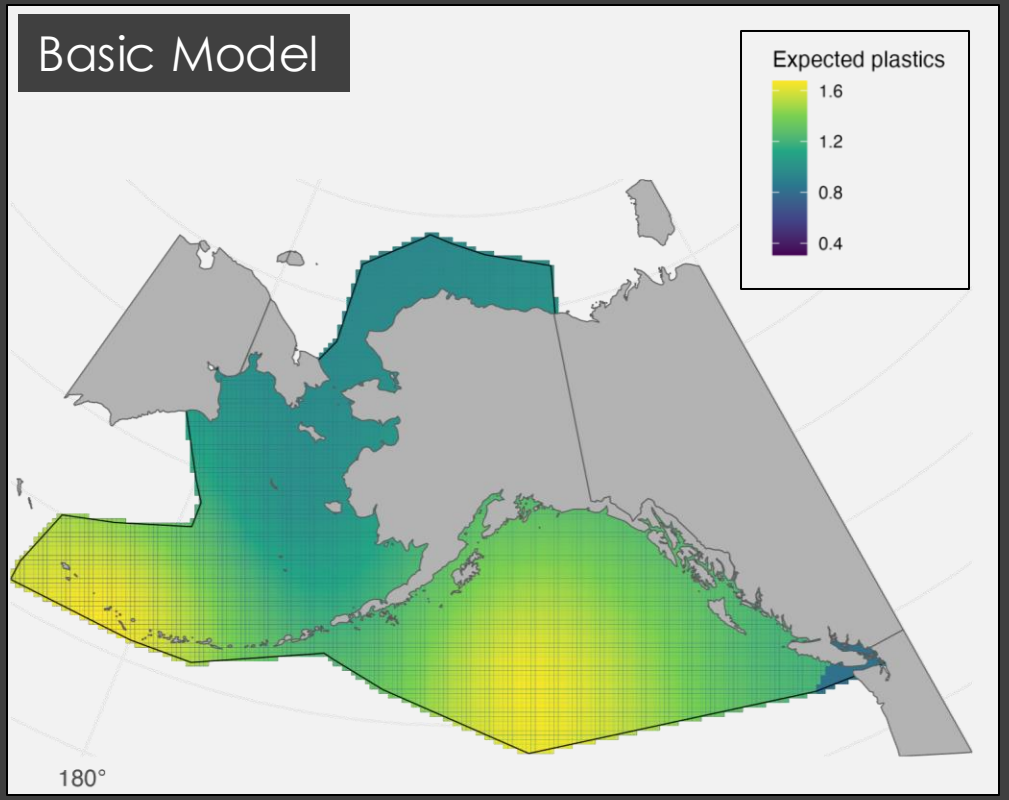
Basic Model

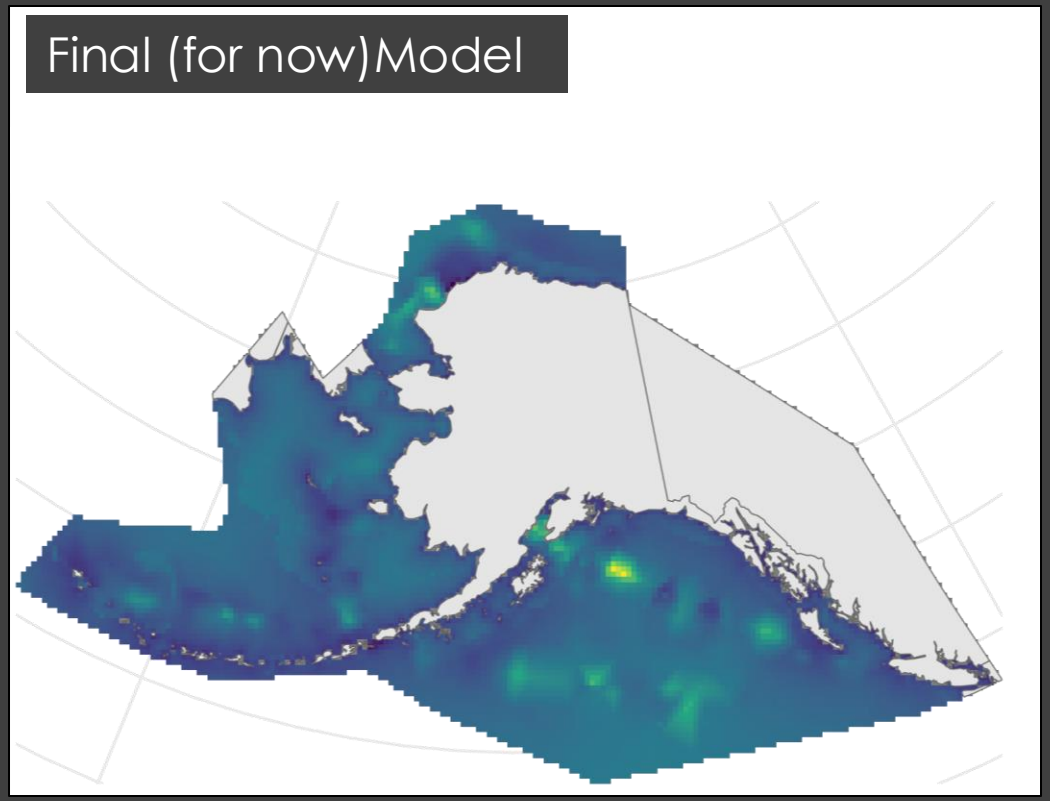


Parameters

- R: sdmTMB
- Hurdle model
- Anisotropic
- SP term: Random Walk or IID

- Covariates
- Distance_land
- Depth
- Spatial varying effects

Final (for now)Model



RESULTS

Part 2: Overlay bird and plastics distributions to identify regions of greatest exposure

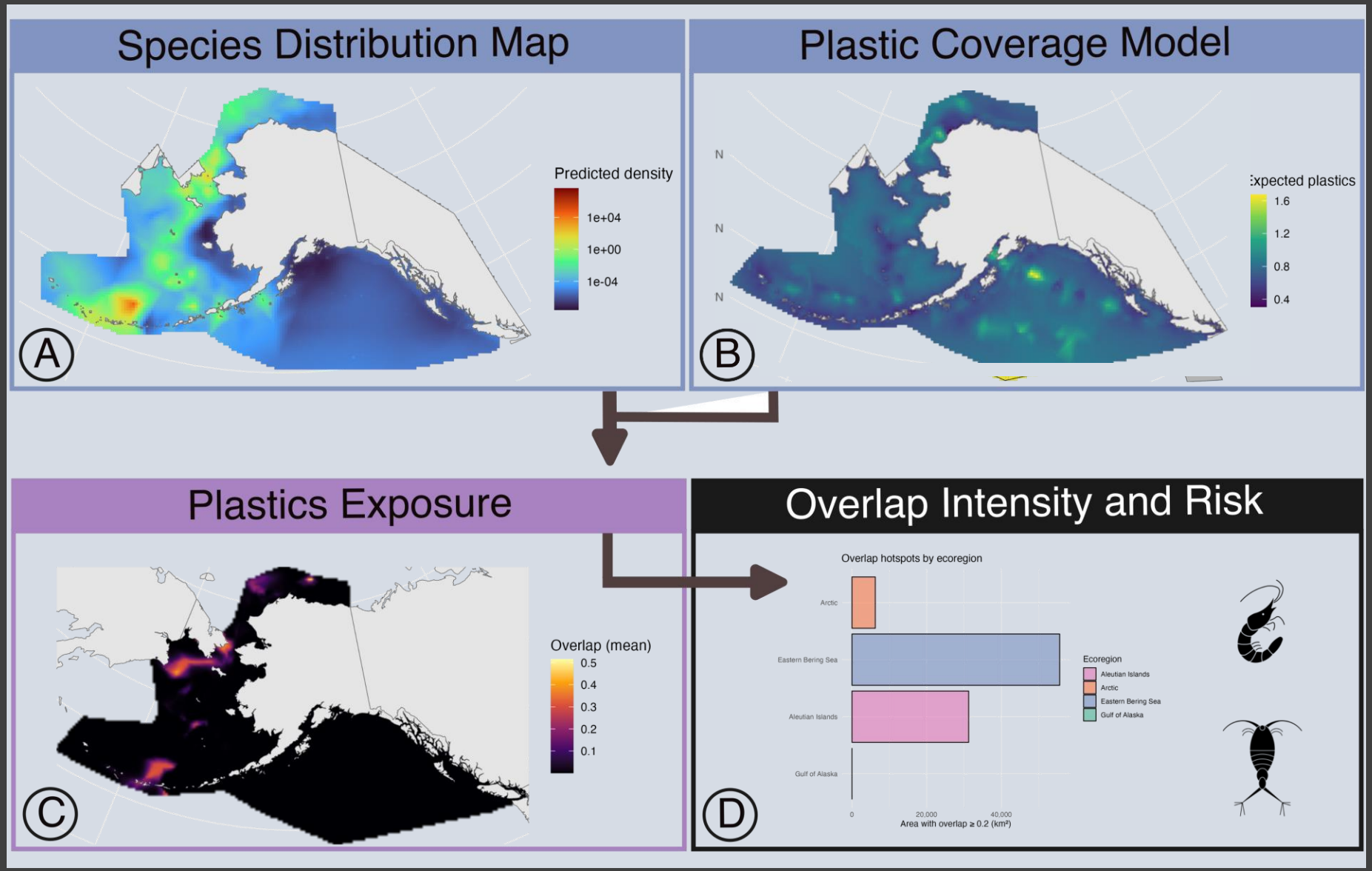
これらは、プラスチックと鳥を一致させるために使用する手順です。

A) Species Distribution Models for plastic-consuming seabirds

B) Plastics Distribution model

C) Spatial and Temporal overlap between seabird and plastics

D) Extract overlap and interpret risk



Models and Analysis

これが私たちが使用した統計モデルのタイプです。

- Used 2016-2023 CPR data
- Used 2000 to 2021 seabird data, as more data was useful for creating spatiotemporal Species Distribution Models.

- Modeled seabirds in sdmTMB
- Tweedy data distribution using density data, each bird model is separate and optimized, Static habitat covariates: distance to land, depth.
- Random factor: Flying bird data category type (Continuous or Snapshot), and Vessel size.
- No catchability term
- Spatiotemporal ON, used random walk or IID as necessary
- Assessed model convergence using deviance explained and residuals,

Diving planktivores (5 spp.); *copepods, krill, gelatinous (PAAU)*

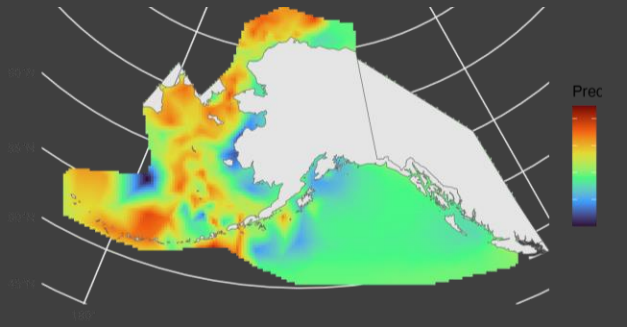
プラスチックを食べる潜水鳥

5% 25% 50% 75% 95%

Ingestion rates from literature

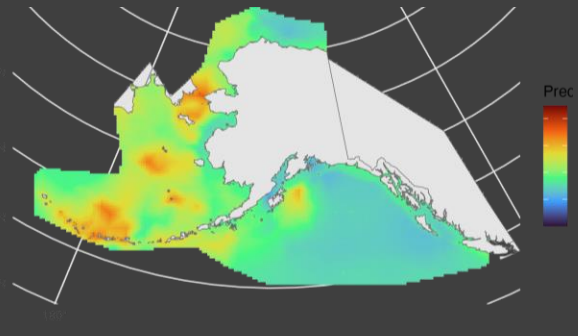
Parakeet Auklet

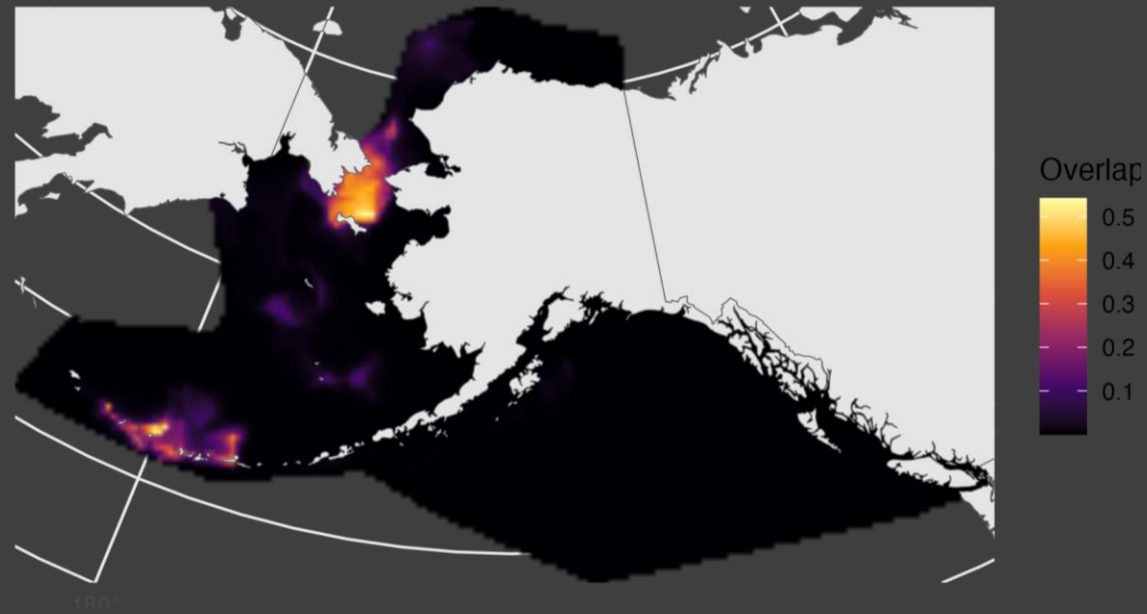
**Uncommon, difficult to model*



Least Auklet

Considered low risk, along with CRAU, WHAU





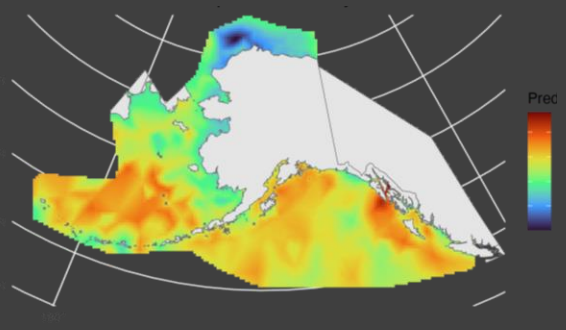
Surface planktivores: *copepods, krill, eggs, icthyoplankton*

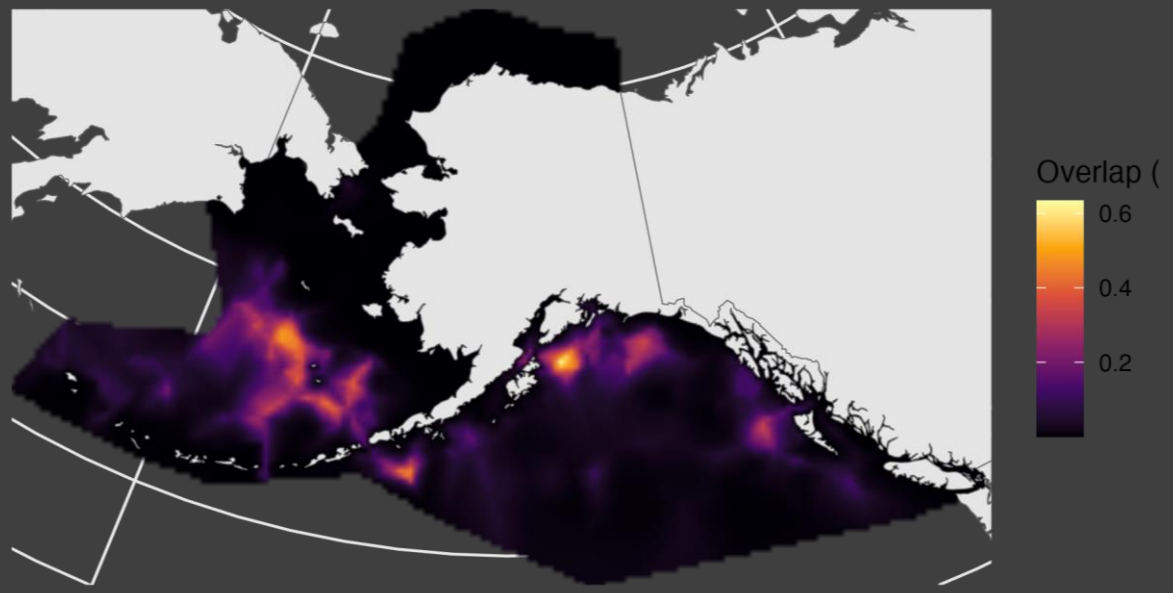
プラスチックを食べる地上の鳥

5% 25% 50% 75% 95%

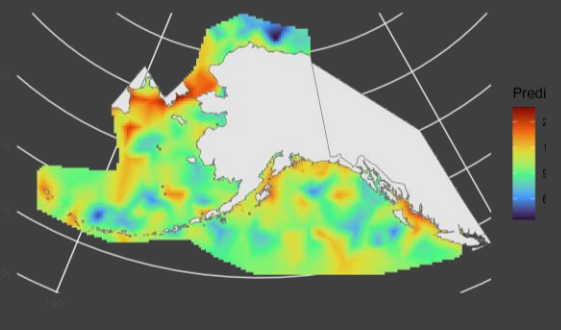
Ingestion rates from literature

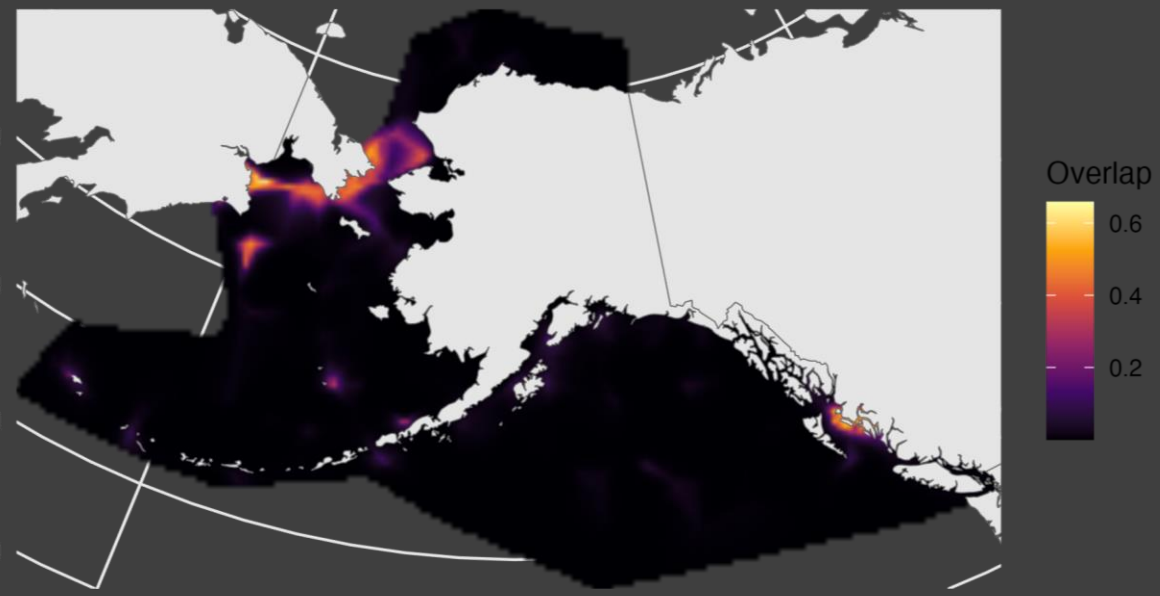
Fork-tailed storm-petrel





Phalarope spp. *(migratory)*





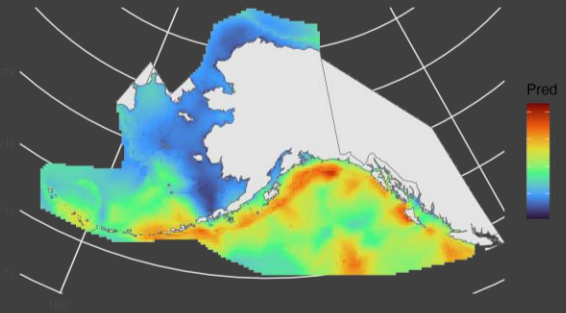
Large omnivores: *squid, fish, bycatch, feed chicks plastic…*

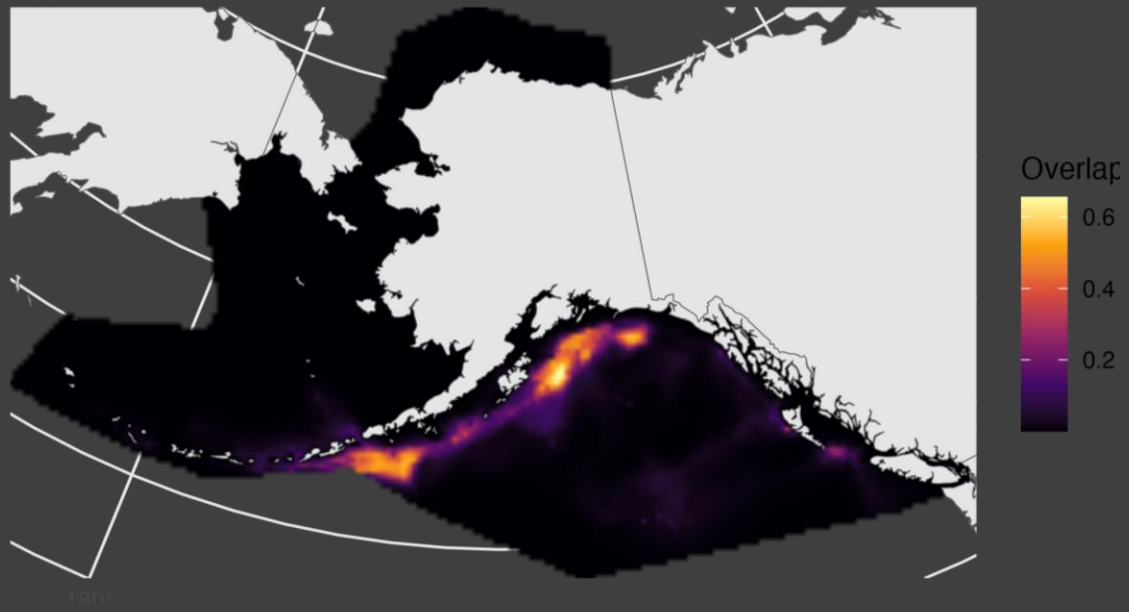
魚やイカを食べる大型鳥類

5% 25% 50% 75% 95%

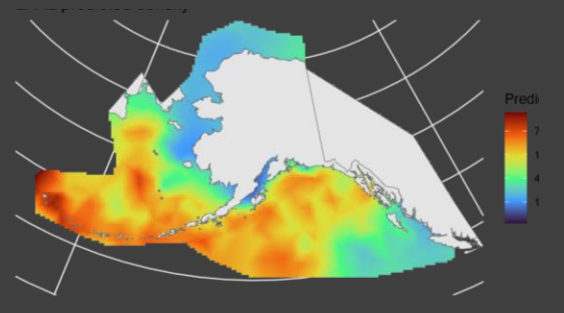
Ingestion rates from literature

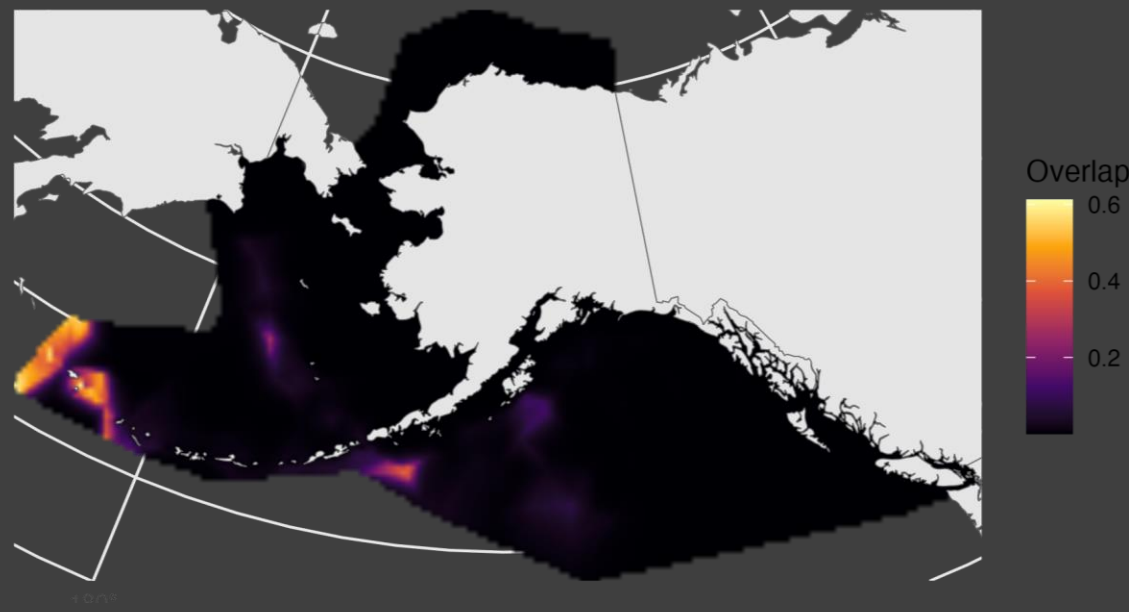
Black-footed albatross





Laysan albatross





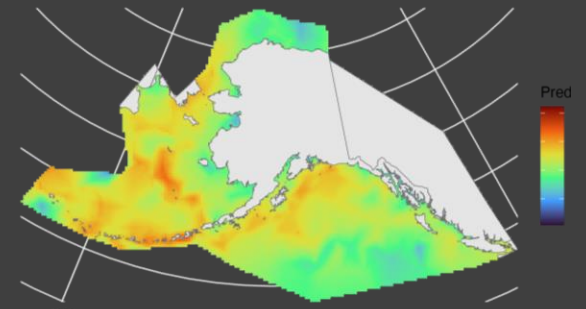
5% 25% 50% 75% 95%

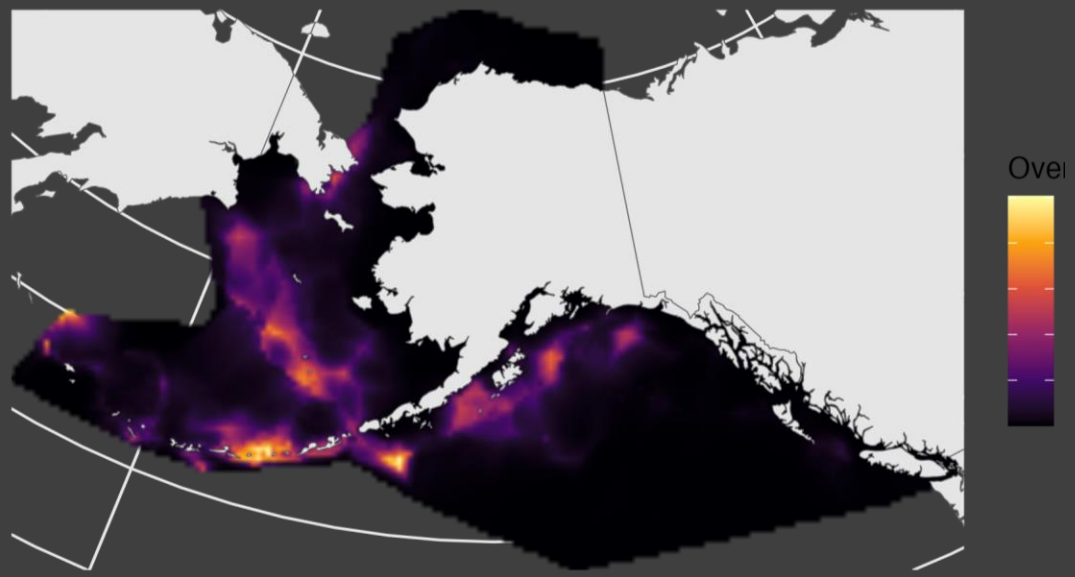
Ingestion rates from literature

Medium-sized omnivores/piscivores: *NOFU are known plastics indicator; both NOFU and BLKI widely distributed.*

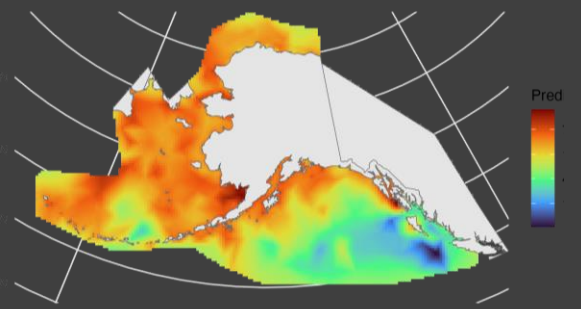
魚類や動物プランクトンを食べる中型の表層鳥類

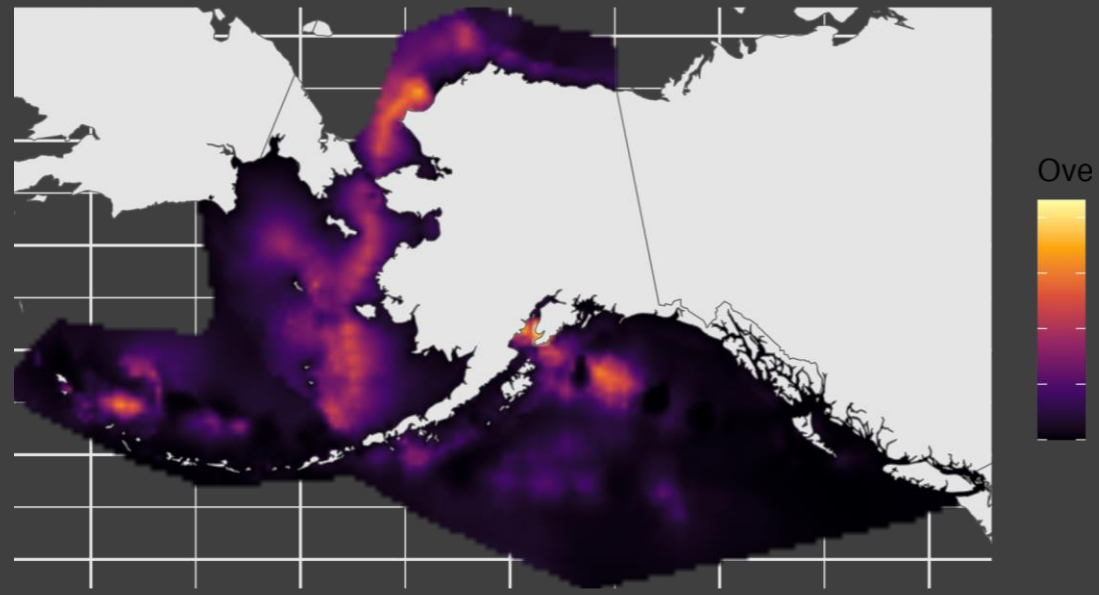
Northern fulmar





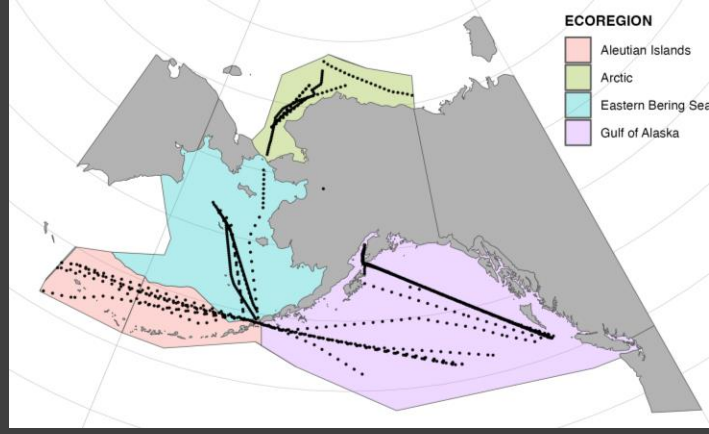
Black-legged kittiwake



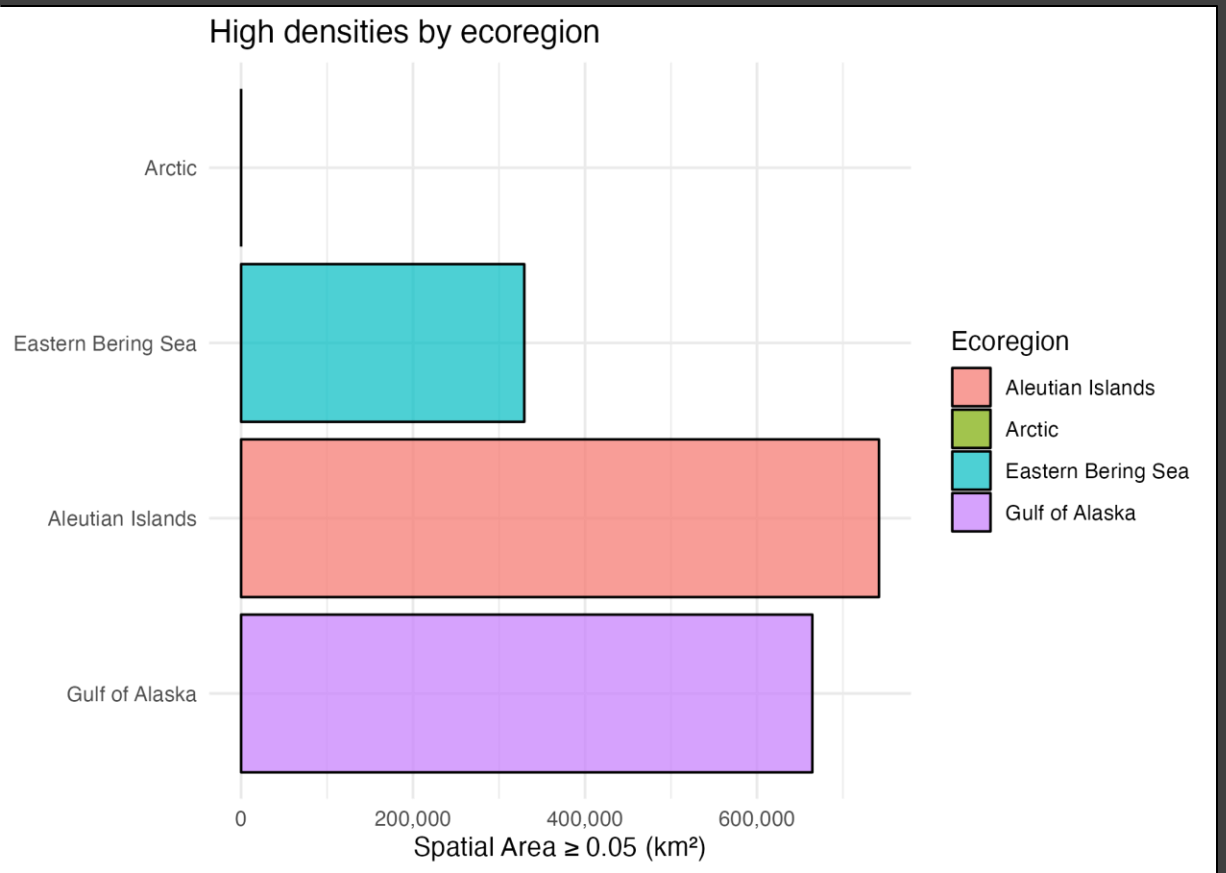


Next Steps

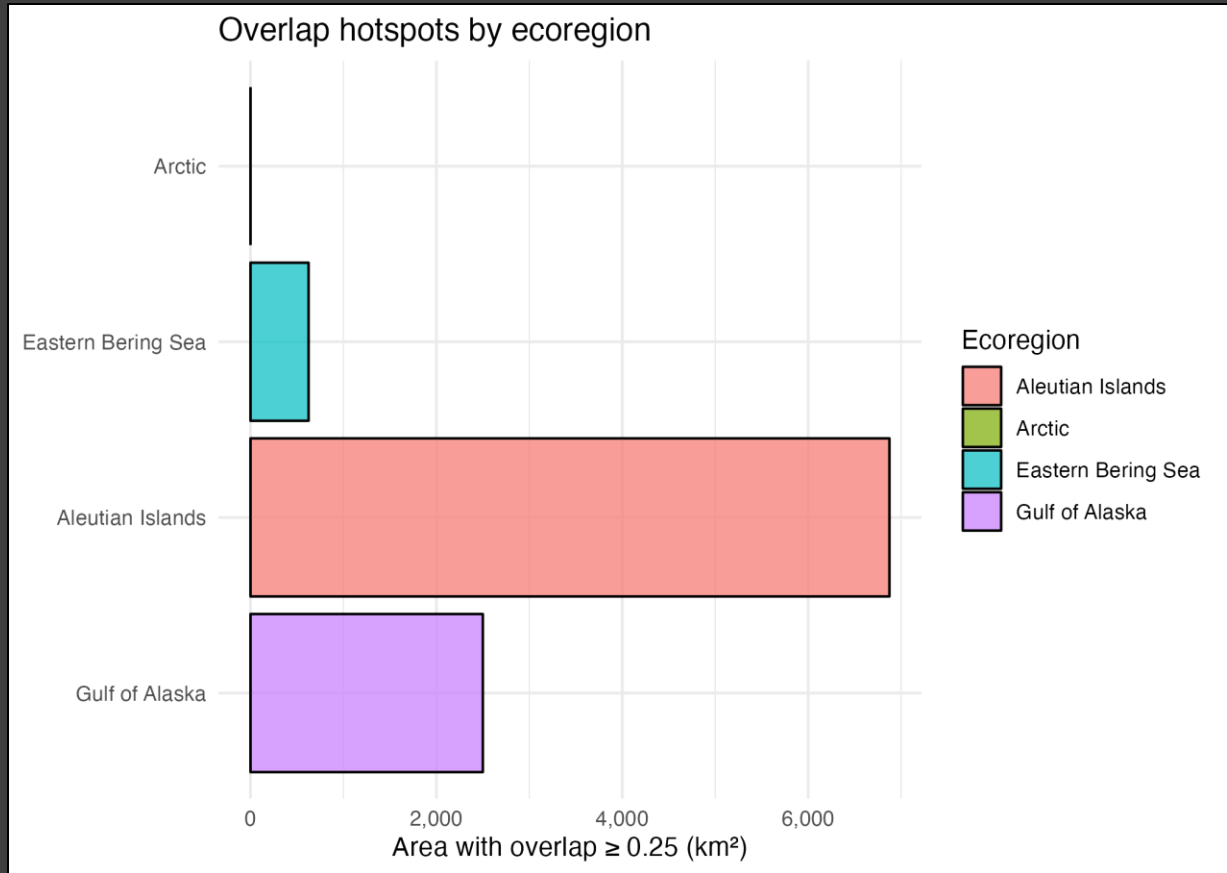
- Summarizing overlap patterns.　パターンを要約する



Where the LAAL high density areas are



Where the LAAL-plastic hotspots are



DISCUSSION

Next Steps

- Summarizing overlap patterns.パターンを要約する

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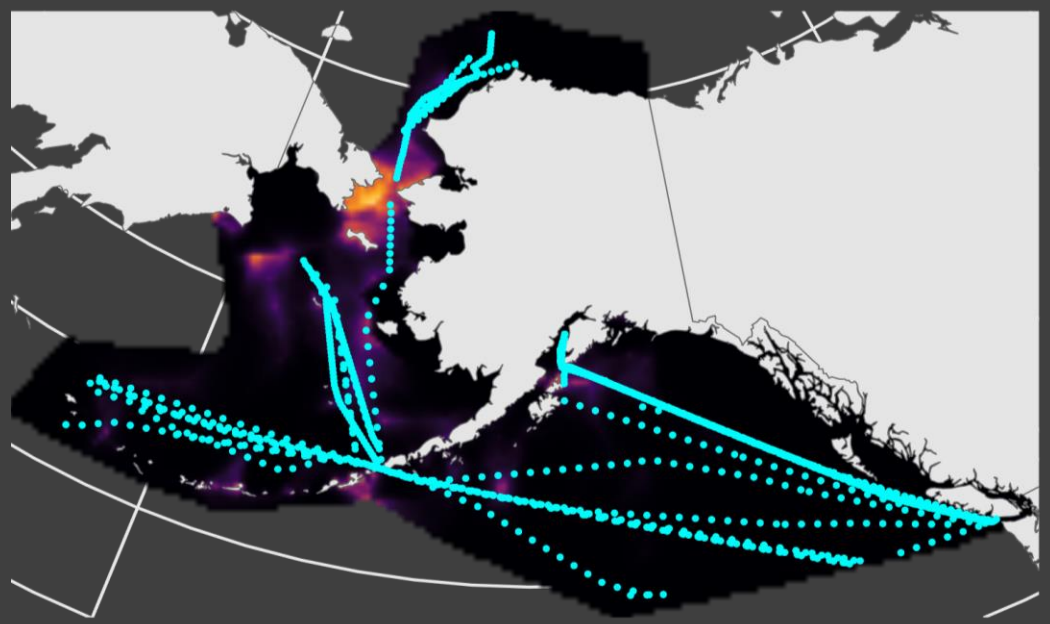

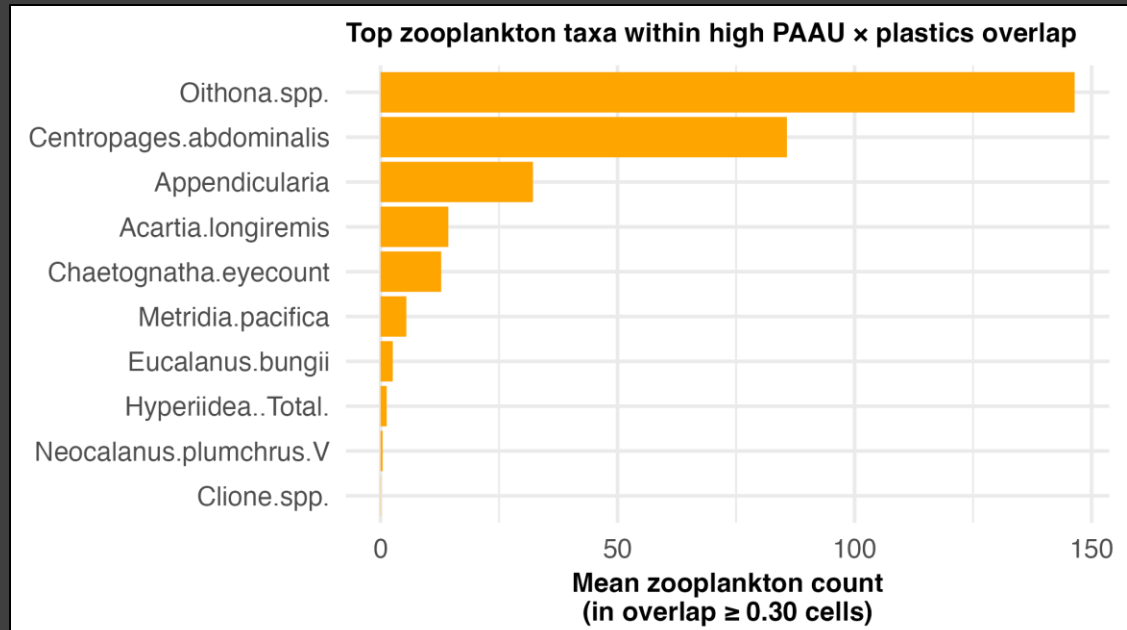

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- ***How to we translate exposure into impact/risk?***
- プラスチックへの曝露をプラスチックの影響やリスクにどのように変換すればよいのでしょうか?

ACKNOWLEDGEMENTS

Thank you! Arigato!

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