# New connections across marine ecosystems facilitated by spread and accumulation of floating anthropogenic debris

Partner

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*James Carlton – Williams College*

*Luca Centurioni and Verena Hormann - Scripps Institution of Oceanography*

*Fiona Chong - University of Hull, UK*

*Mary Crowley - Ocean Voyages Institute*

*Cathryn Clarke Murray and Cynthia Wright - Fisheries and Oceans Canada*

*Rebecca R. Helm - Georgetown University*

*Andrey Shcherbina - University of Washington*

**FloatEco**

**GOSEA**

**ADRIFT**

## Instrument deployment


## … and inspection



## VOLUNTEERS & PARTNERS

The Swim
Algalita Marine Research
The Ocean Cleanup
eXXpedition
SEA
Greenpeace
Polynesian Voyaging Society
Figure 8 Voyage
Rick Pelton S/V Anais
Ray McCormack S/V Firefly
Erden Eruc
Jim Linderman S/V Lyric
Russ Johnson S/V Blue Moon
Other Transpac and Pacific Cup boats
and many others

## Debris tagging with OVI GPS trackers







## … and sample collection


Photo: Ocean Voyages Institute

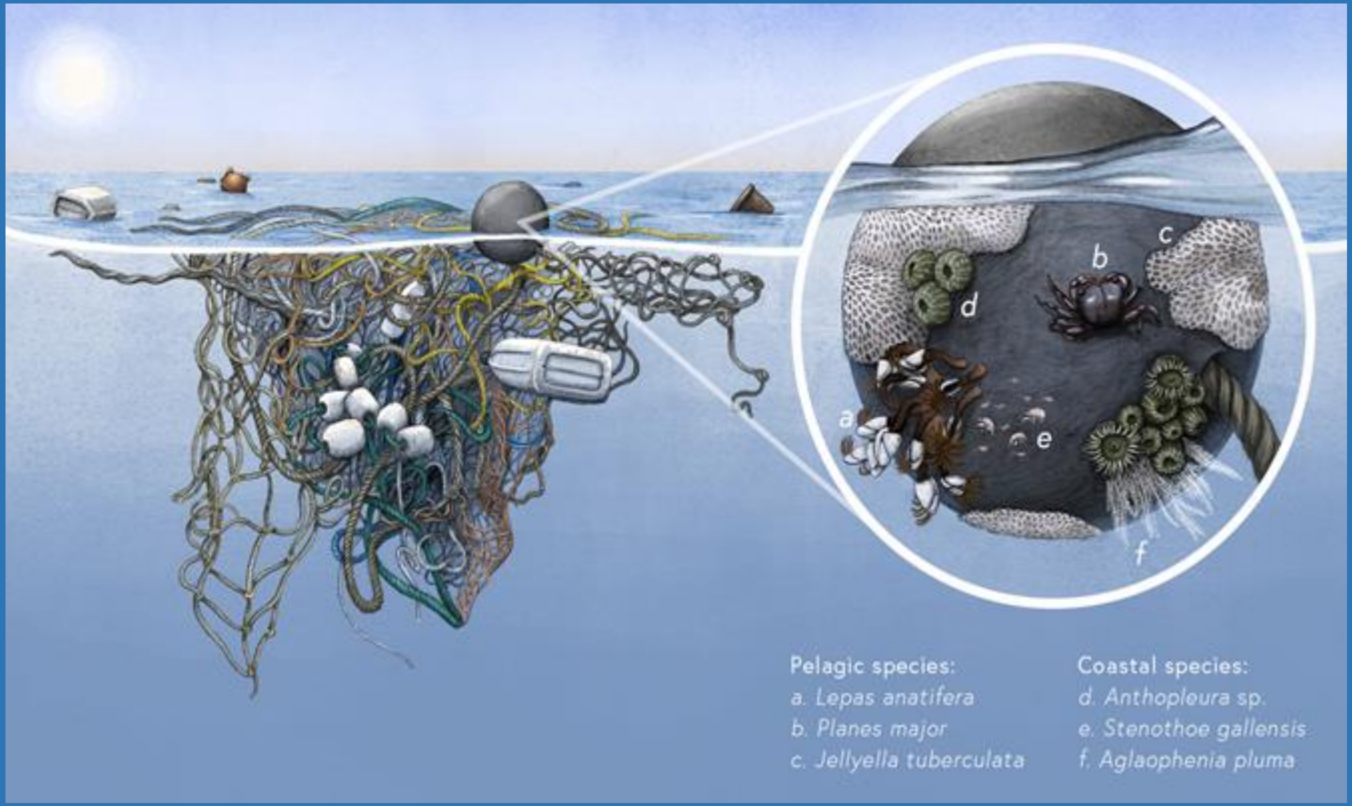

# Neopelagic ecosystem

FloatEco

**Key finding:** coastal species established and reproducing in the North Pacific garbage patch, a pelagic ocean area located northeast of Hawaii.

Coastal taxa found on 73% of pelagic debris.

37 coastal species, primarily bryozoans, crustaceans, and cnidarians (hydroids and sea anemones).



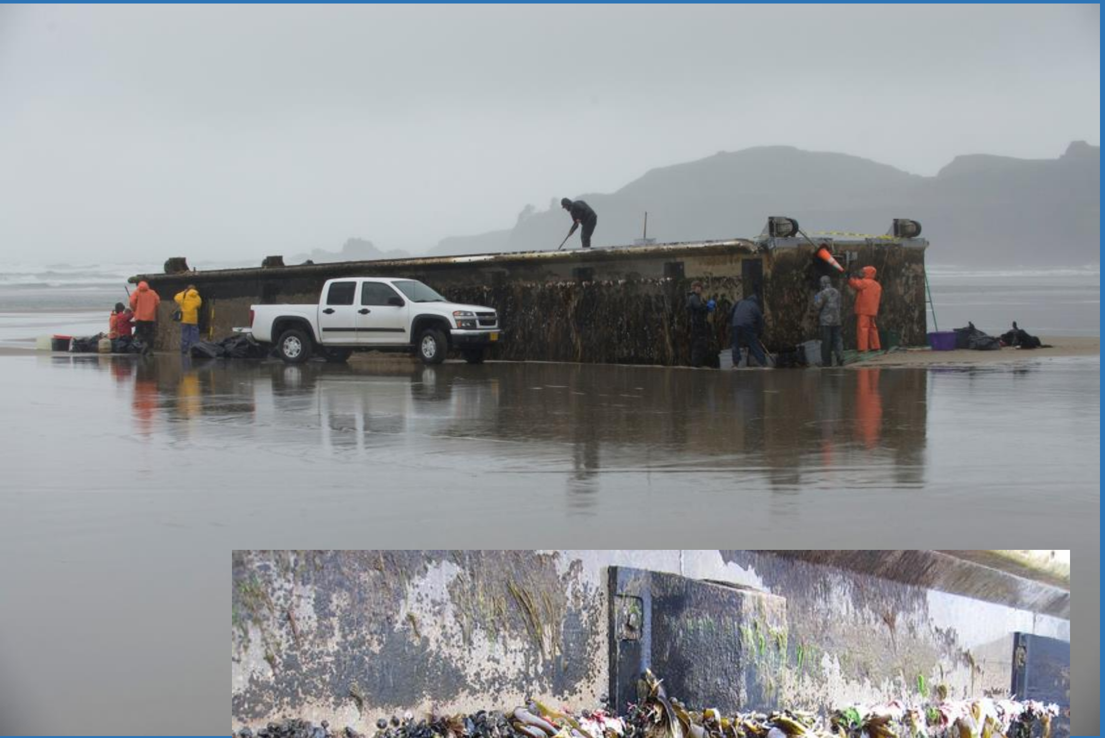

***What led us to this discovery?***

Haram et al., Nature Comm., 2021

## March 11, 2011 tsunami in Japan

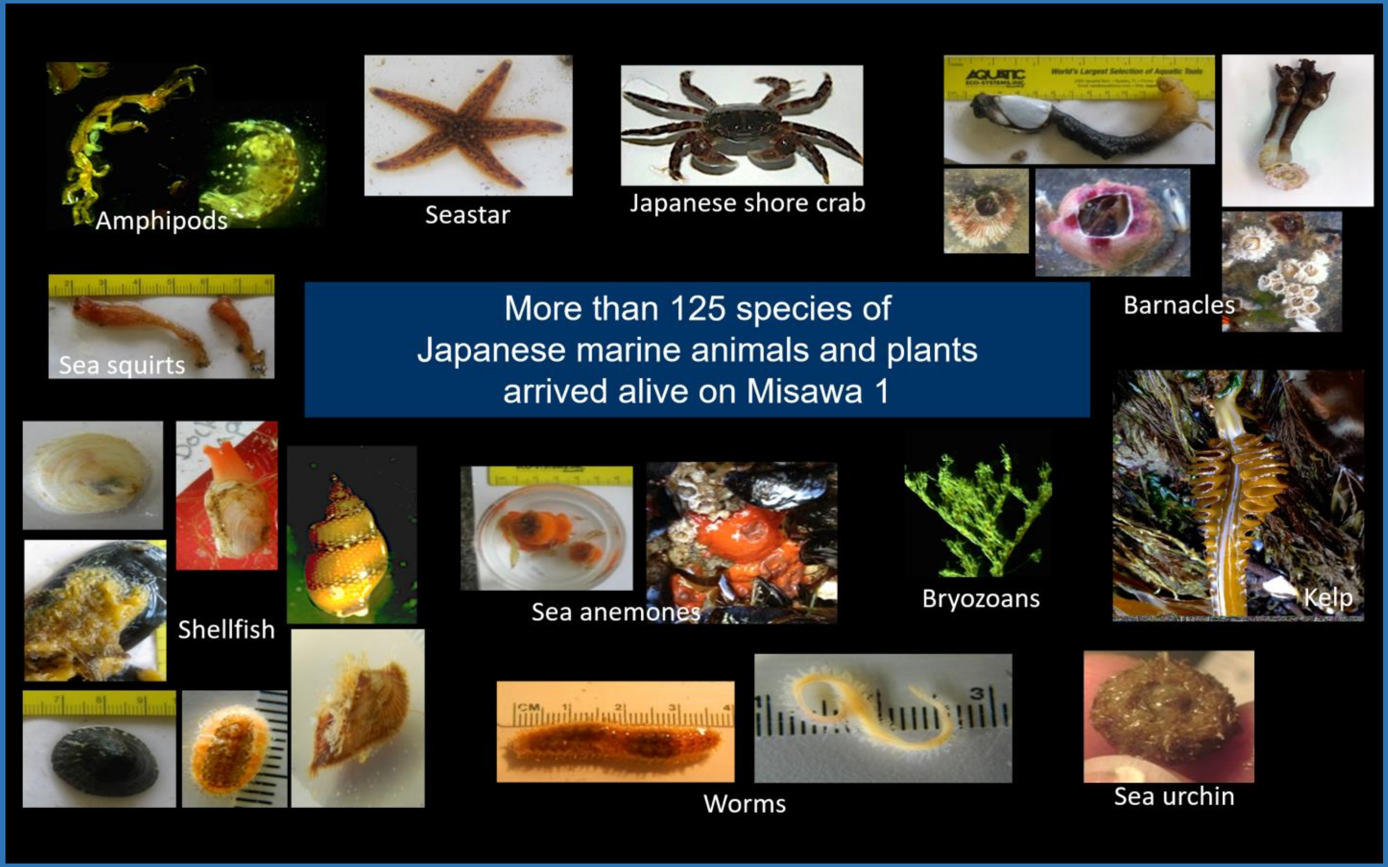

Tsunami destoyed > 100,000 homes and generated
> 1.5 million tons of floating debris (equivalent of a full year North Pacific budget of general debris) which drifted across the ocean.

## Tsunami debris arrival in North America and survival of coastal species



June 6, 2012: One of four 20-meter docks, released by tsunami from Misawa Harbor, arrived on Agate Beach, Oregon, USA.

Biologists inspected the dock and documented more than hundred live Japanese coastal species, some known as potential invaders.



ADRIFT

**Assessing the Debris-Related Impacts From the Tsunami (2014-2017)**

Project funded by Ministry of the Environment of Japan

Coordinated by PICES

*Project Research Team*


Fisheries & Oceans Canada
NOAA
National Institute Environmental Studies, Japan
Ehime University
Kagoshima University
Kobe University
Kyushu University
Japan Meteorological Agency
Japan Agency for Marine-Earth Science Technology
National Institute for Land and Infrastructure Management
Tohoku University
Fisheries Research Agency, Japan
Oregon State University
Moss Landing Marine Laboratory
Smithsonian Environmental Research Center
University of British Columbia
University of Hawaii at Manoa
Williams College and Mystic Seaport

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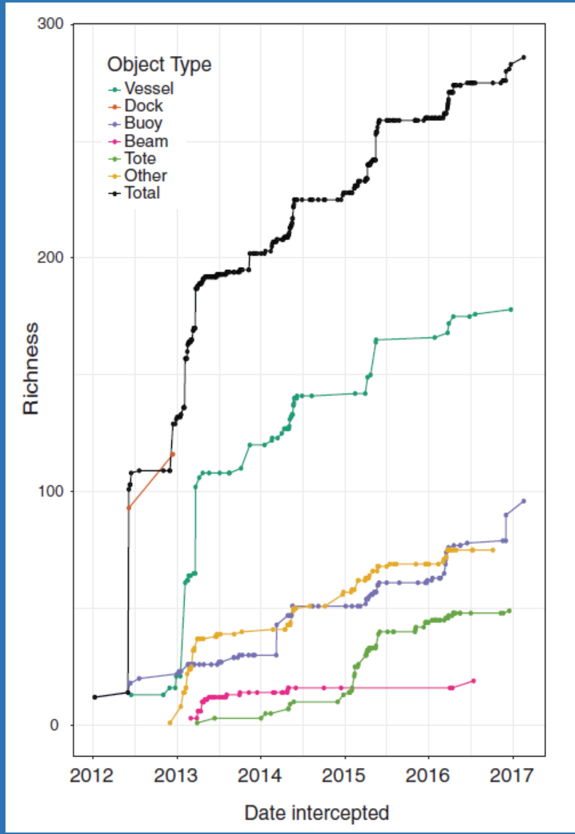
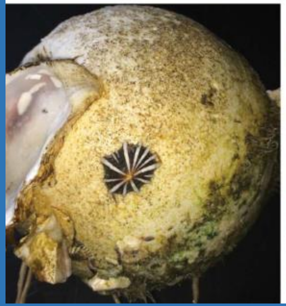
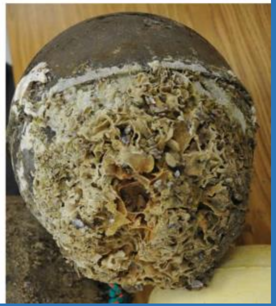





As of 2021, when the last verified-to-date JTMD arrived, 390 living Japanese species of invertebrates, fish, and seaweed (algae) were documented arriving in North America and the Hawaiian Islands on tsunami debris.

The primary taxonomic groups included mollusks, polychaete worms, hydroids, bryozoans, and crustaceans.

Carlton et al., 2017

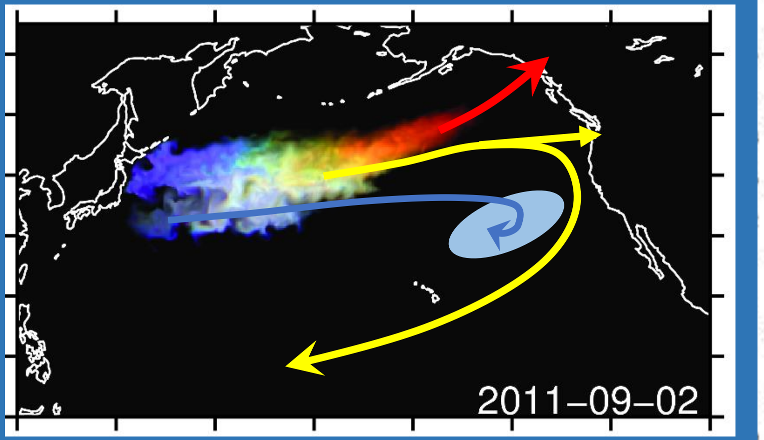
*Continuous surprise:*

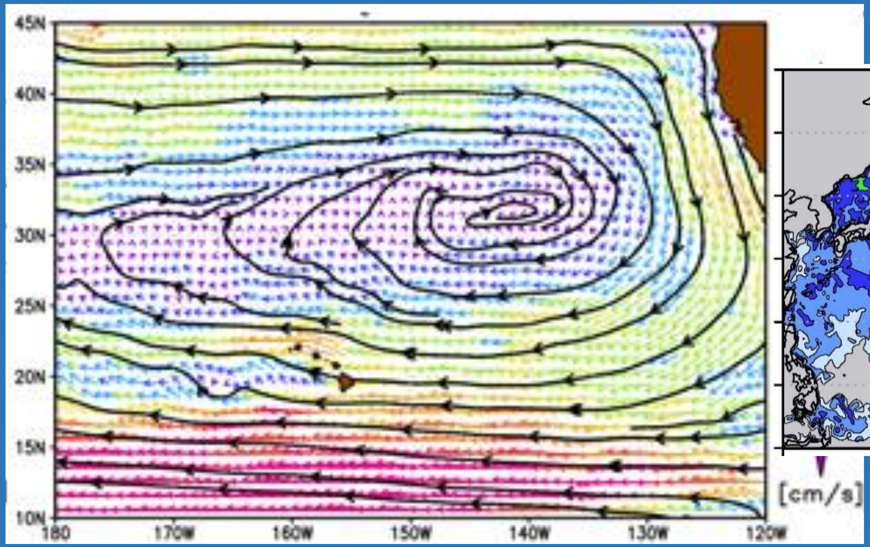
**While tsunami debris was degrading and its numbers in the ocean and on the North American and Hawaiian shorelines were decreasing, Japanese coastal species were still arriving, often on "fresh" debris, and often the specimen were too young to be relevant to the 2011 tsunami.**

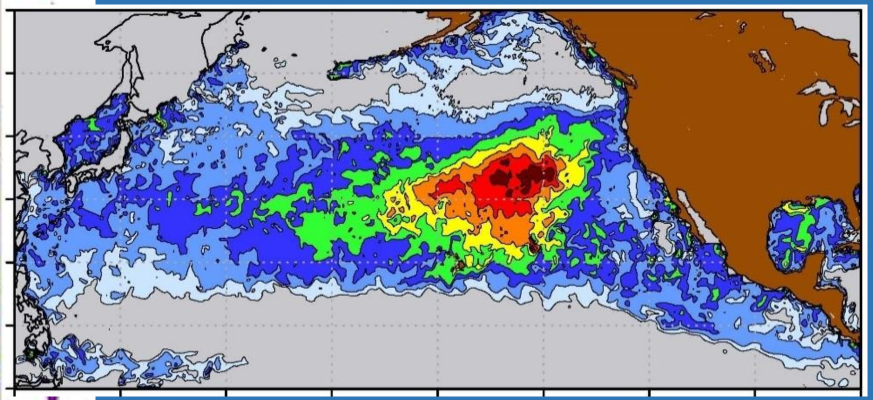
**This led to hypothesis:**
**Coastal species established and are reproducing in the pelagic ocean.**

**The North Pacific garbage patch was identified as the most likely habitat.**

Garbage patch in drifter streamlines



Garbage patch in model simulations

Pathways of tsunami debris of different geometry

*NASA Physical Oceanography, NASA Biodiversity and Ecological Forecasting & NASA Citizen Science Programs*

Partner

# FloatEco and GOSEA projects

**2017-2022**

**Floating Ocean Ecosystems**

https://www.floateco.org/

James Carlton
Luca Centurioni
Verena Hormann
Cathryn Murray
Gregory Ruiz
Andrey Shcherbina
Cynthia Wright

Nikolai Maximenko
Mary Crowley
Jan Hafner
Linsey Haram

**2021-2023**

**Global Ocean Surface Ecosystem Alliance**

https://goseascience.org/

Lauren Biermann
Rebecca R. Helm
Justin Stopa
Davida Streett
Chela Zabin

**Multidisciplinary cutting edge science**

+

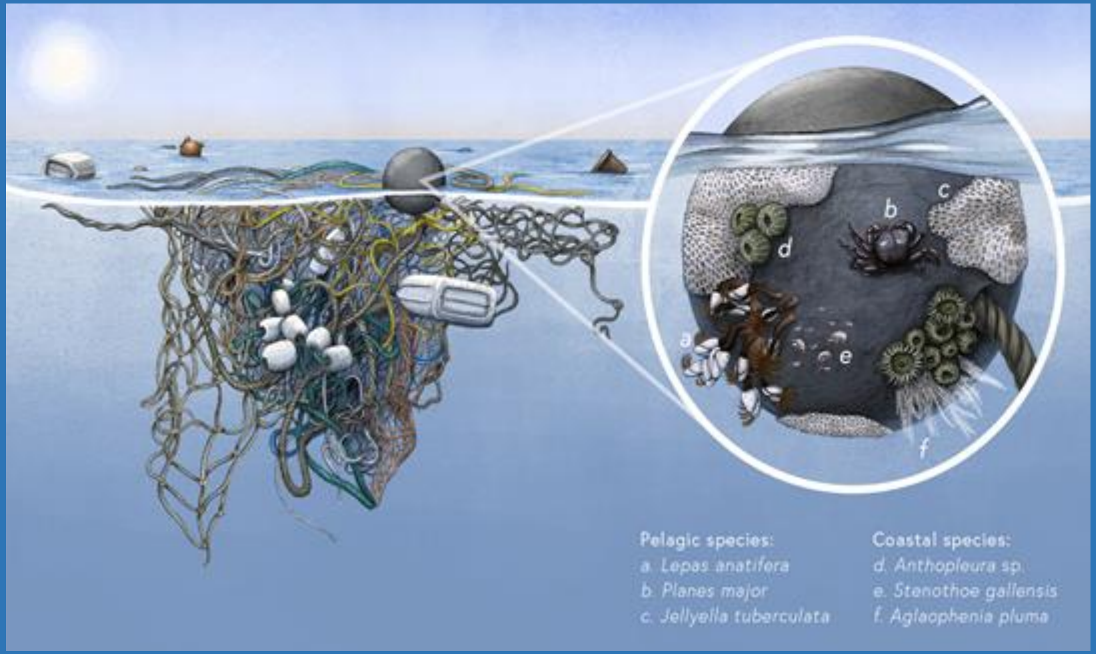
**Unique opportunities provided by citizen scientists**

**marine debris, pelagic ecosystem, ocean transport and phenomena, synergy of in situ reports, satellite observations and modeling**

# Every floating object creates an "oasis" of life

- **Microbial communities**
- **Fouling species**
- **Semi-mobile species (crabs, worms, amphipods, etc.)**
- **Fish**
- **Neuston**

BTW, this is well known to fishermen using FADs (fish aggregating devices)




Haram et al., Nature Comm., 2021

FloatEco

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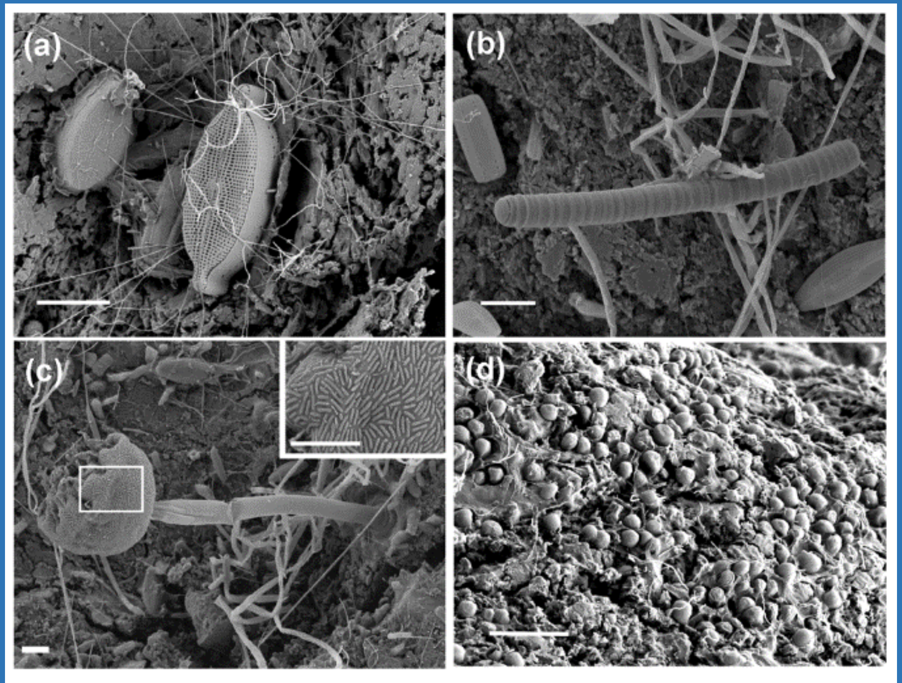
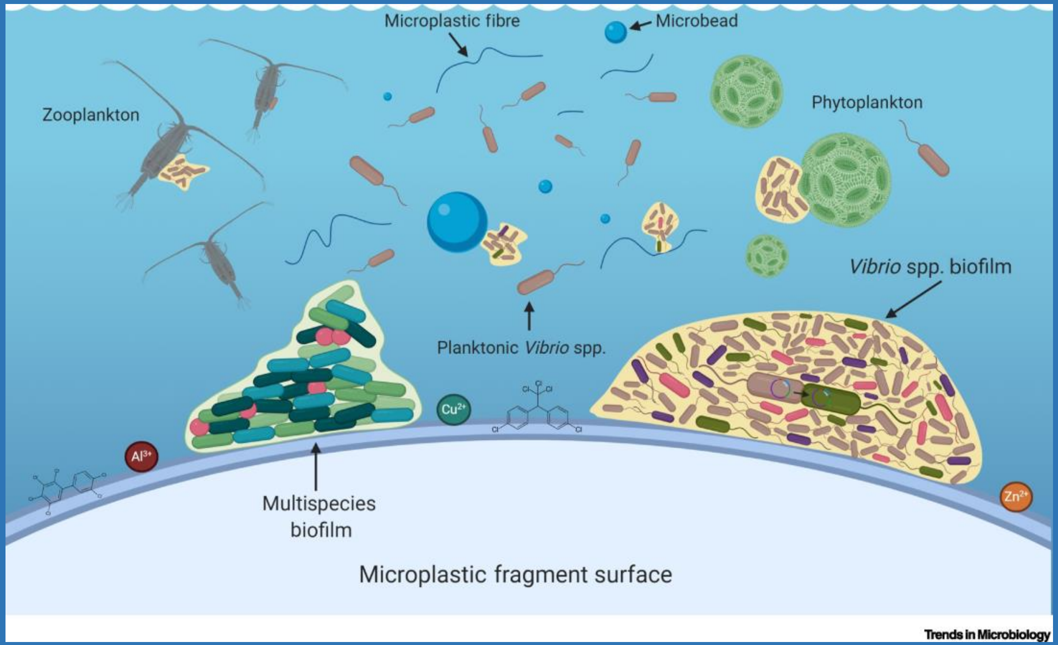



Microbial communities on plastic samples from the Subtropical North Atlantic (from Zettler et al, 2013)




Summary of the Potential Microbe–Microplastic Interactions (from Bowley et al, 2021)

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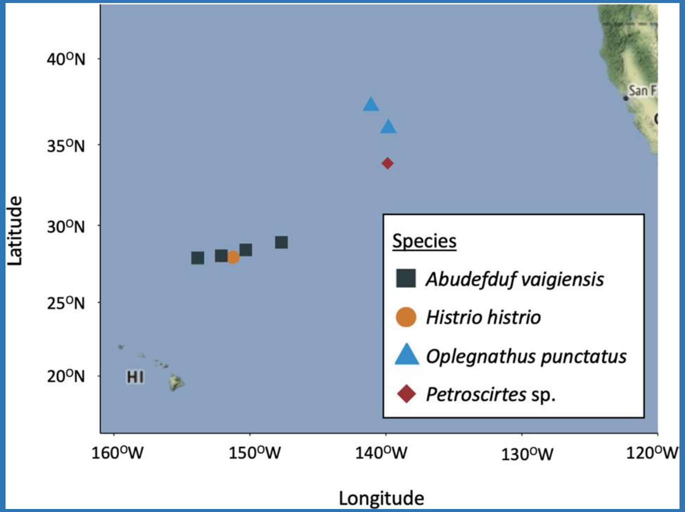


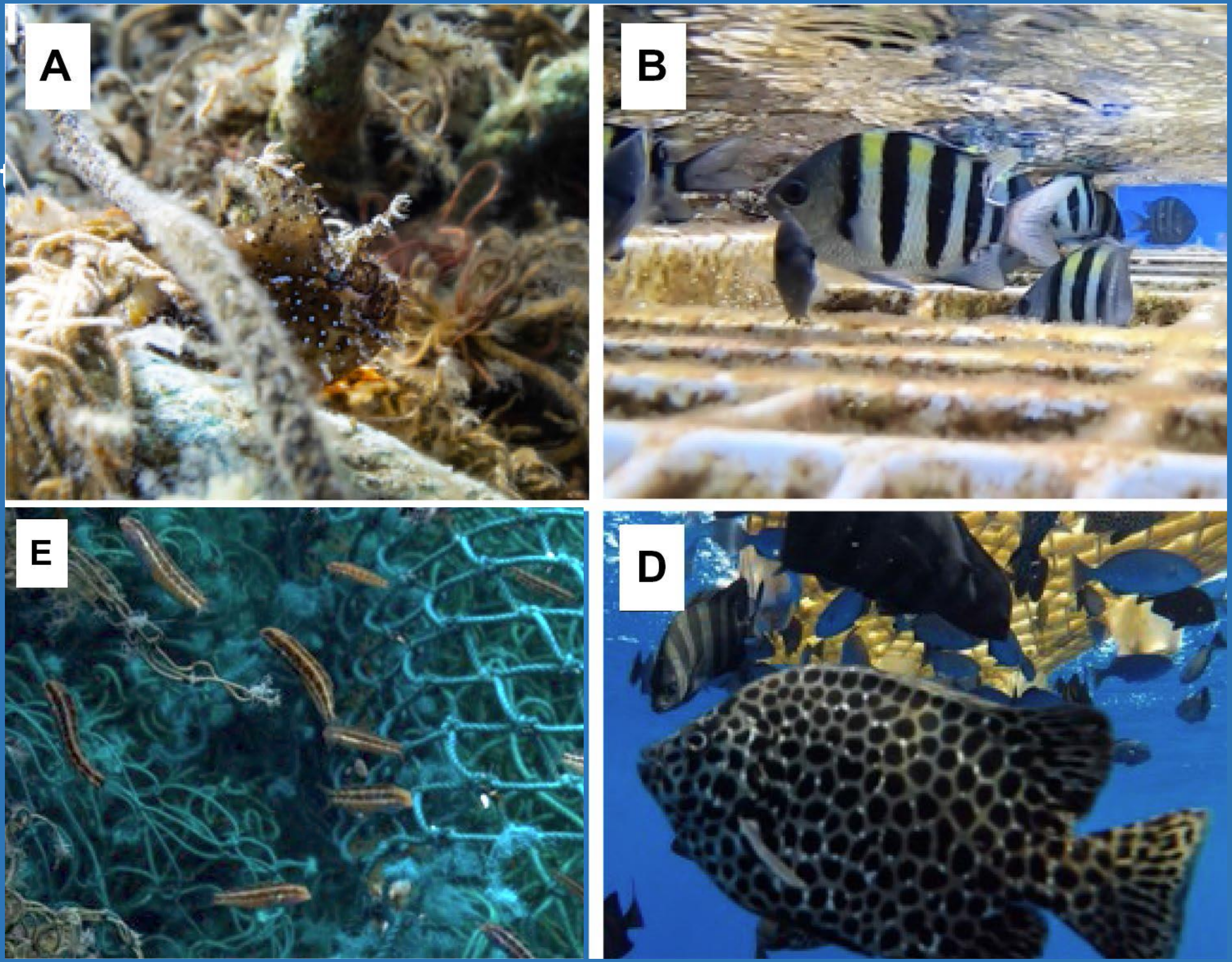


Western Pacific fish recently detected east of Hawaii:
**a** Sargassum fish, *Histrio histrio*
**b** The Indo-Pacific sergeant, *Abudefduf vaigiensis*,
**d** the spotted knifejaw, *Oplegnathus punctatus*
**e** the blenny *Petroscirtes* spp.

From Benadon et al., 2024

FloatEco

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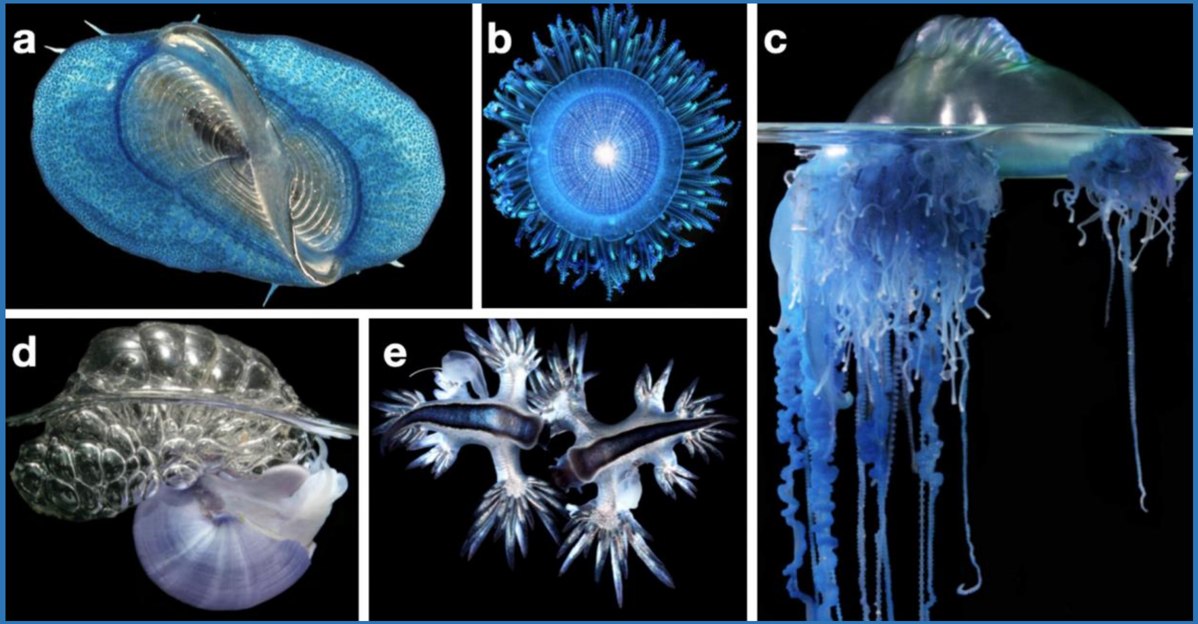
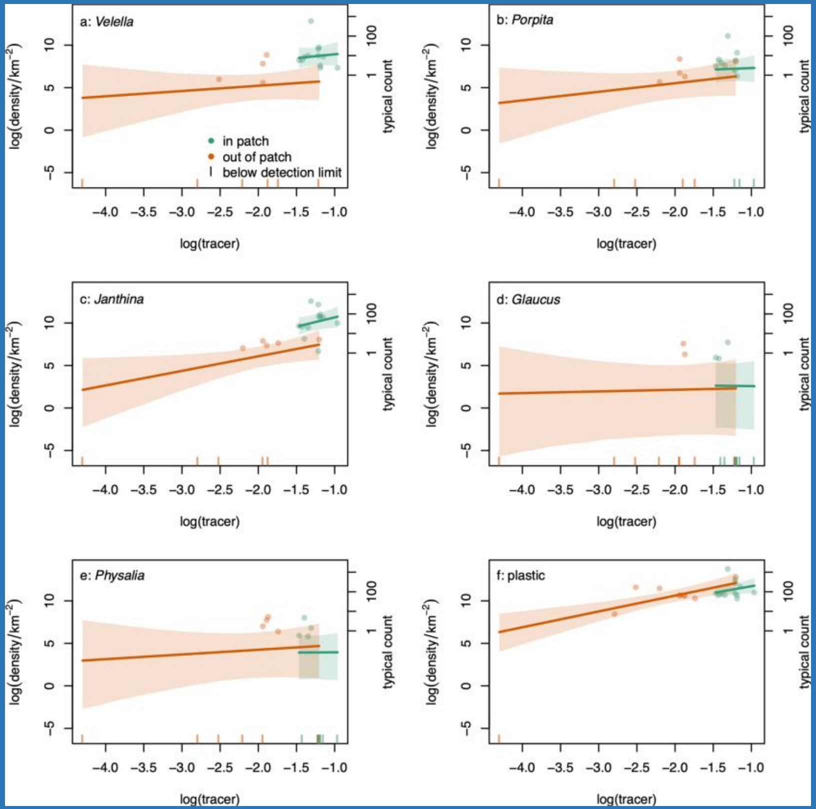



(a) by-the-wind sailor *Velella* sp.
(b) blue button *Porpita* sp.
(c) Portuguese man-o-war *Physalia* sp.
(d) violet snail *Janthina* sp.
(e) blue sea dragons *Glaucus* sp.




From Chong et al., 2023

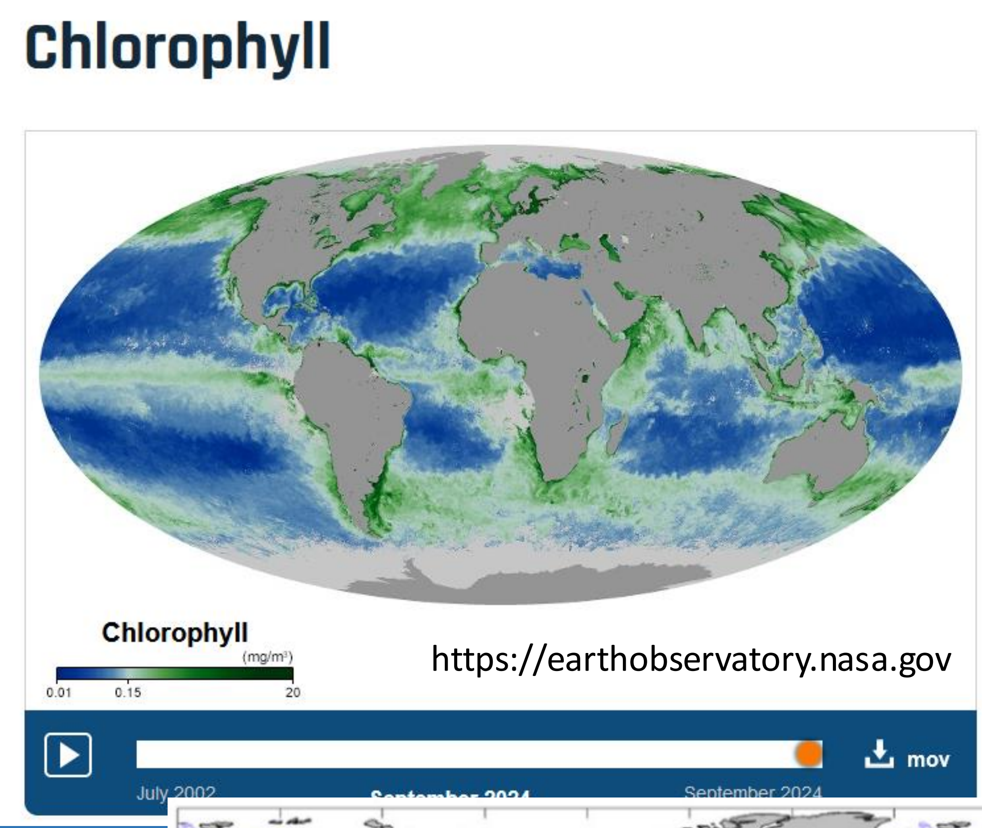
Positive correlation was found in trawl samples collected in the North Pacific garbage patch between microplastics and neustons.

GOSEA

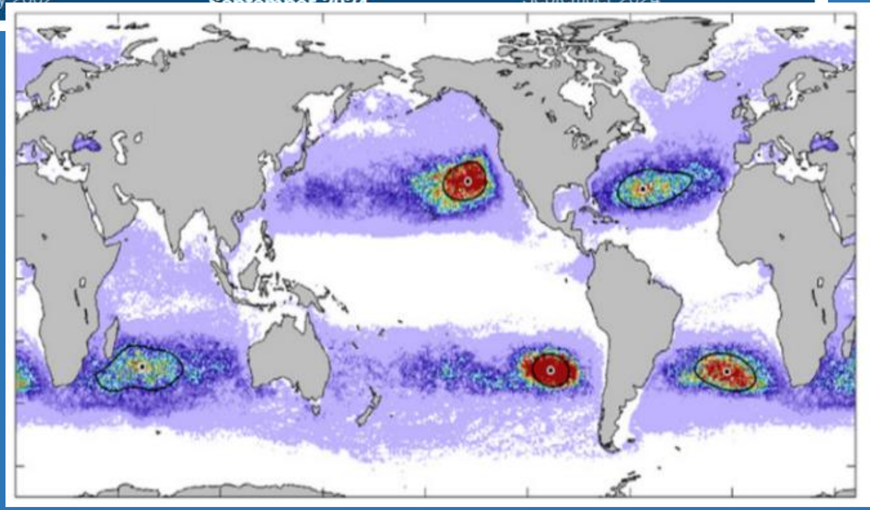
# Every floating object creates an “oasis” of life

- Microbial communities
- Fouling species
- Semi-mobile species (crabs, worms, amphipods, etc.)
- Fish
- Neuston

**Debris services:**
- A substrate
- A shelter
- Source of Dissolved Organic Carbon



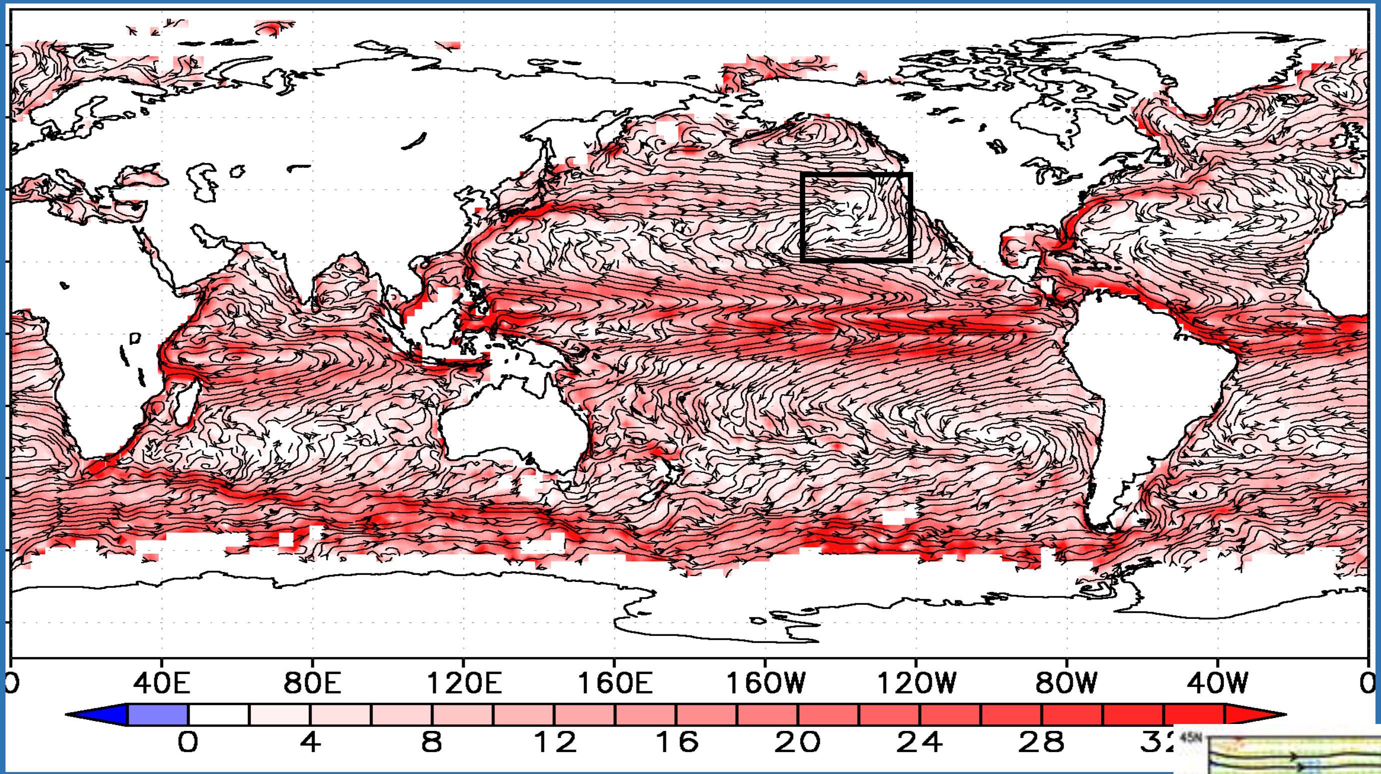

Romera-Castillo et al. 2018: Dissolved organic carbon leaching from plastics stimulates microbial activity in the ocean, Nature Comm.



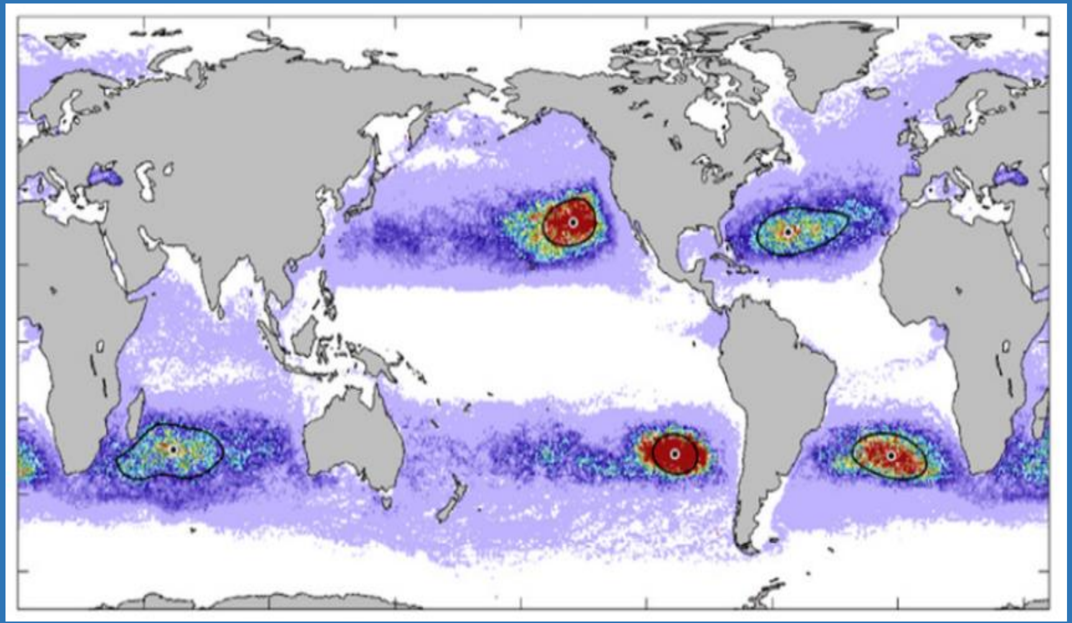
**Ocean dynamics aggregates floating marine debris in the areas of low nutrients where plastic can become an important source of DOC**

# Dynamic of the garbage patches

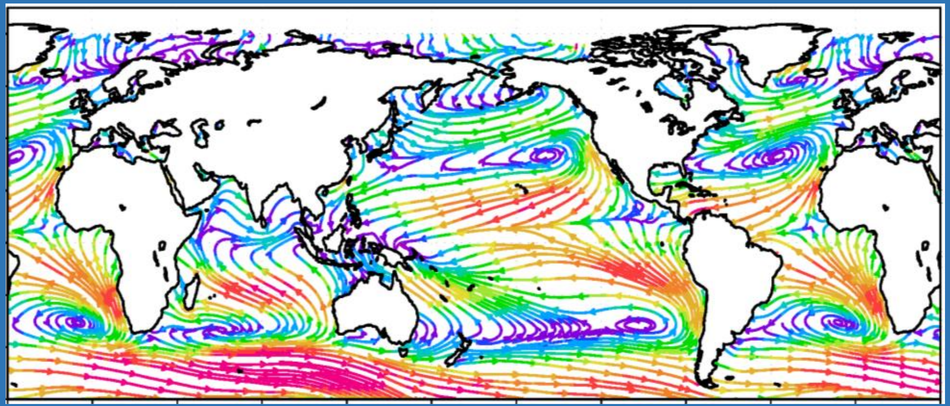
mean surface currents from drifters

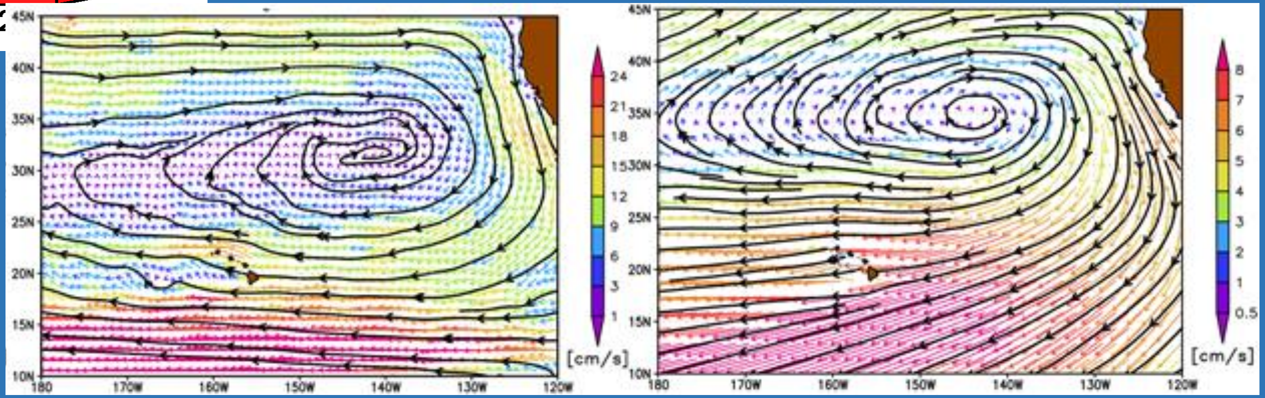



garbage patches in drifter-based model



mean surface wind from satellites



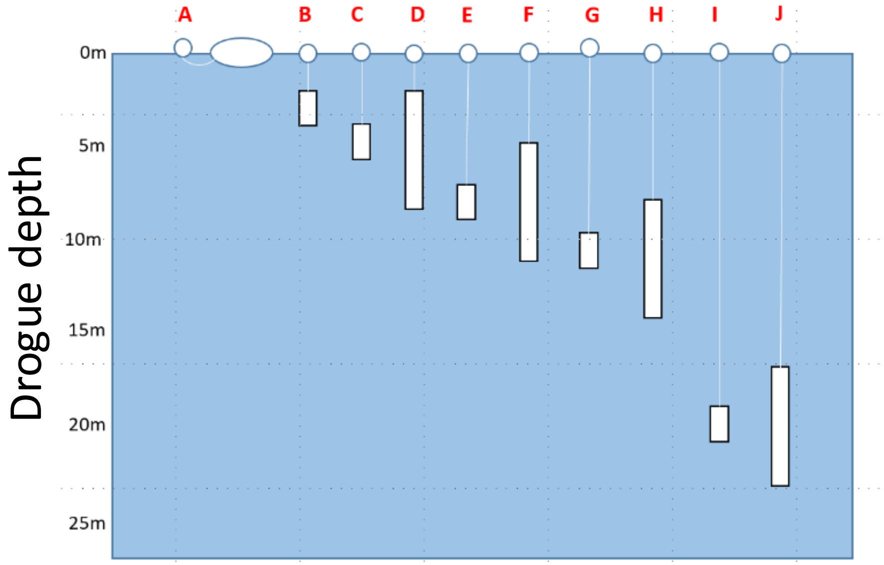



mean currents

mean wind

# Lagrangian instruments

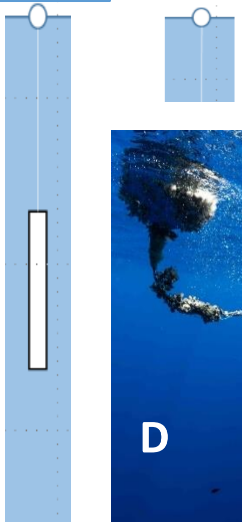
FloatEco 2018 cluster

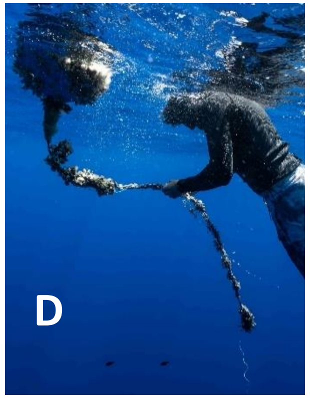



Global Drifter Program (GDP)

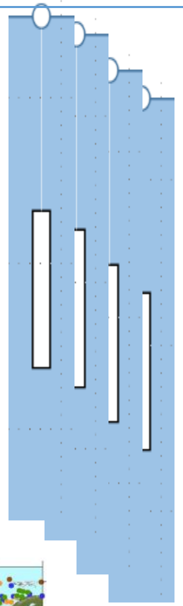
drogued at 15m

undrogued



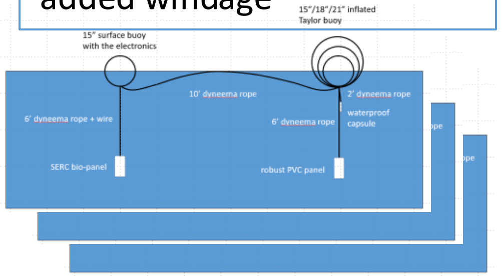


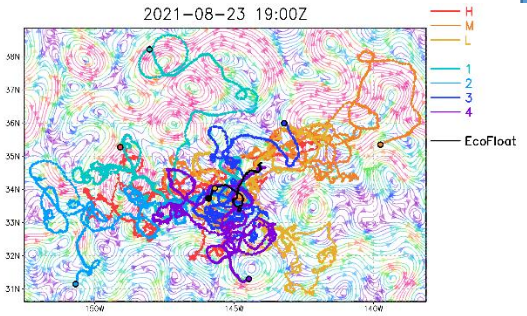

4 standard GDP drifters



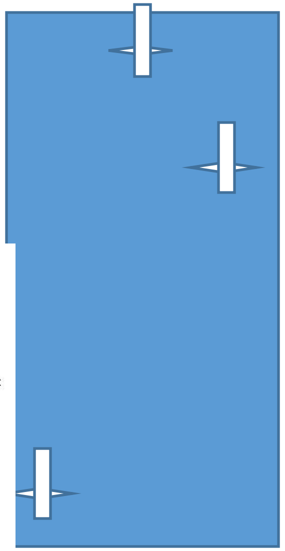
FloatEco 2020 cluster

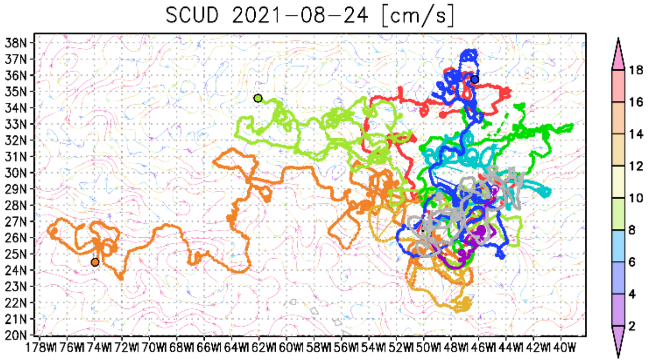
3 undrogued drifters with added windage



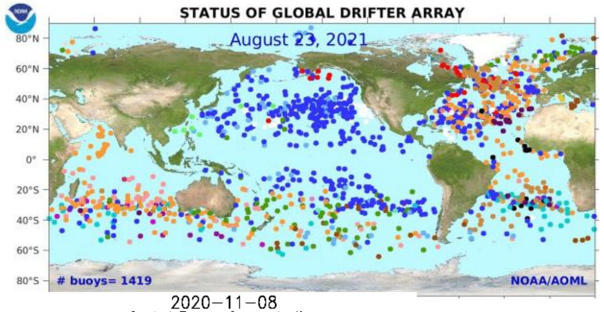



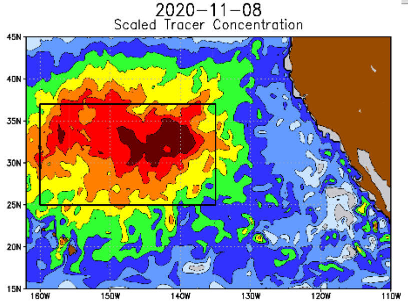

Mixed-layer float (EcoFloat)



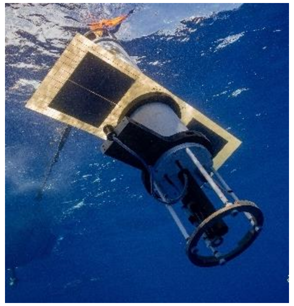



SCUD model



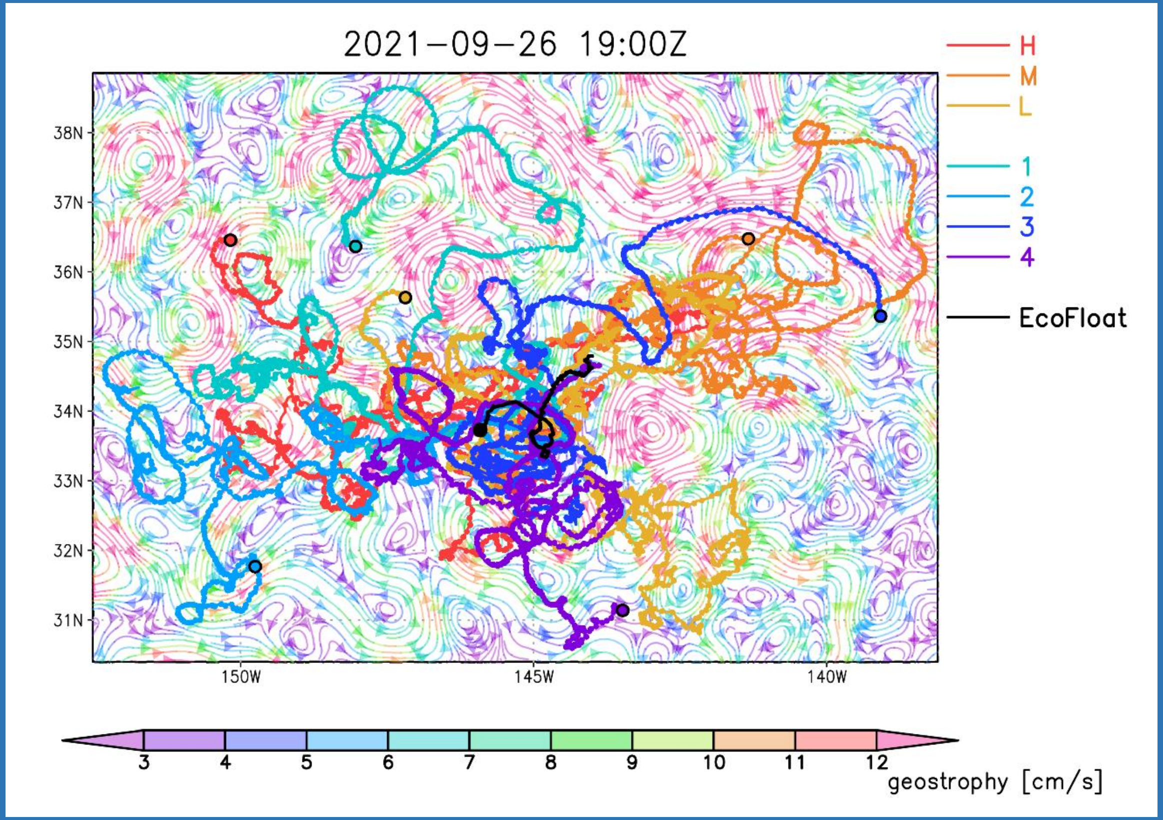




OVI GPS trackers attached to debris



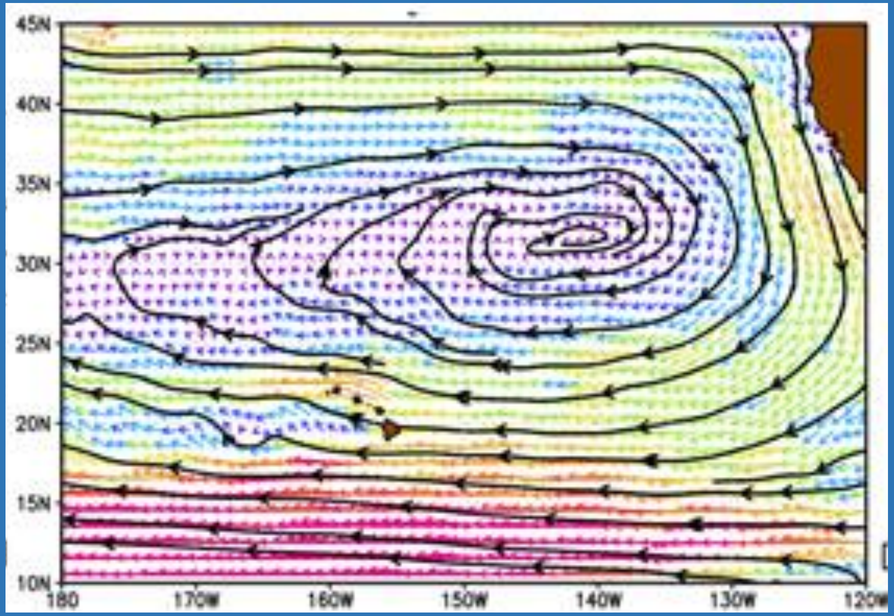
FloatEco

# Drift model



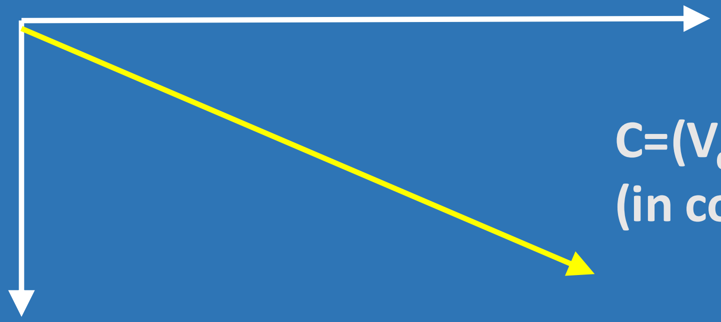

Actual drifter trajectories

## Mean currents




Simple model: $V_{drifter} = V_{geostrophy} + C \cdot V_{wind}$

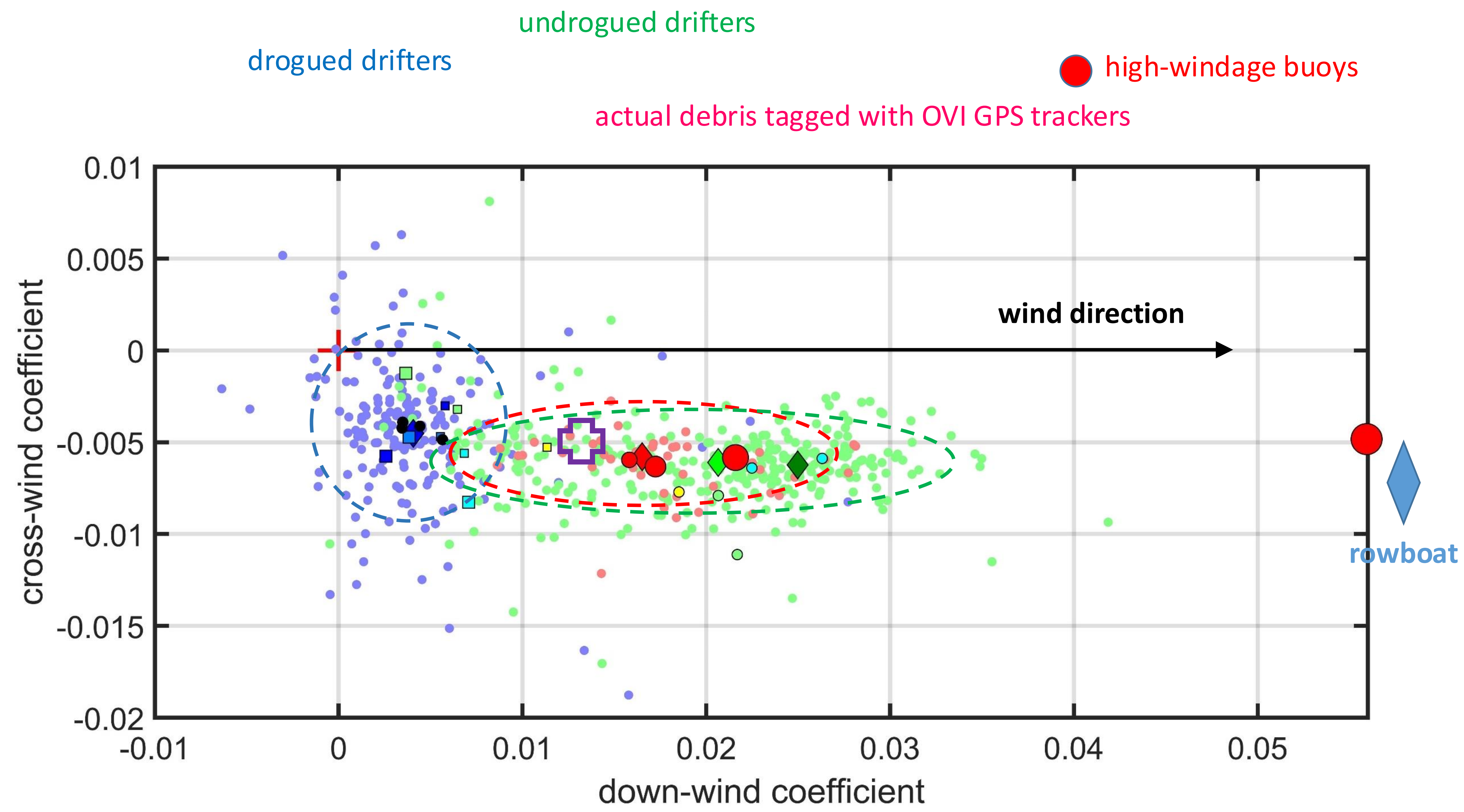
Complex coefficient



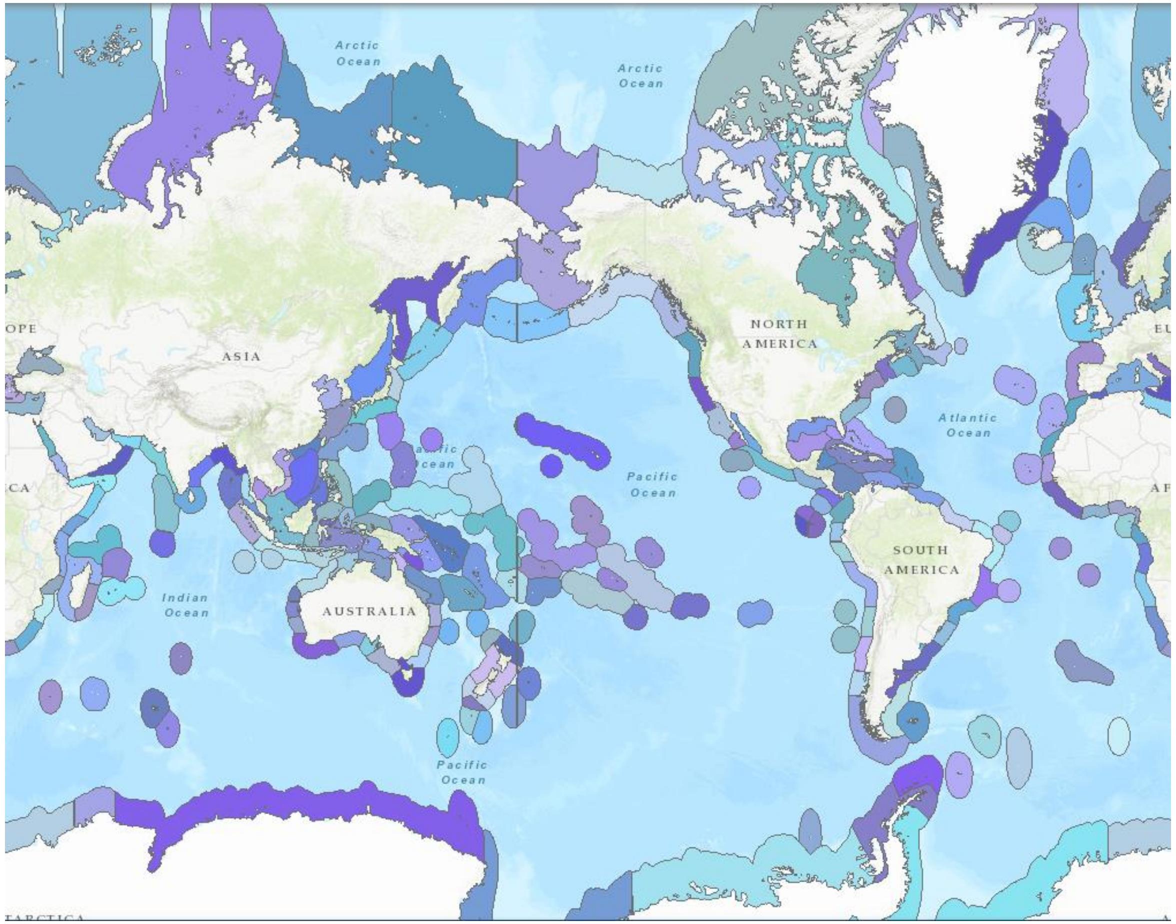
wind direction

$C = (V_{drifter} - V_{geostrophy}) / V_{wind}$
(in complex notation)

FloatEco

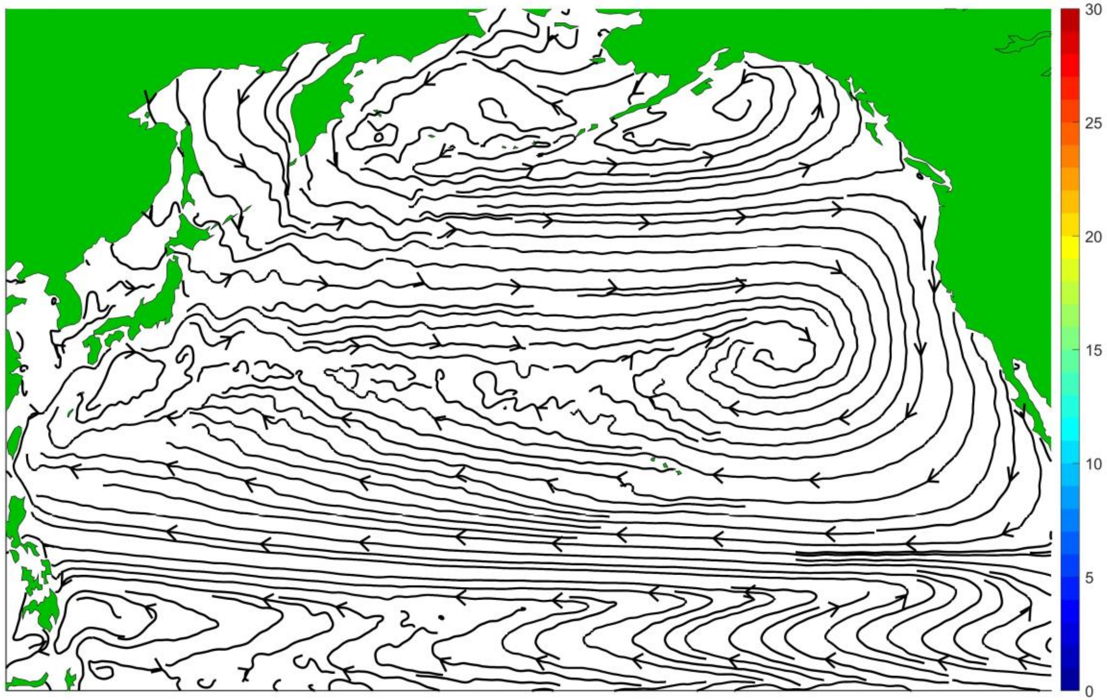



*Wind coefficients for a variety of instruments, tagged debris and boats of opportunity*



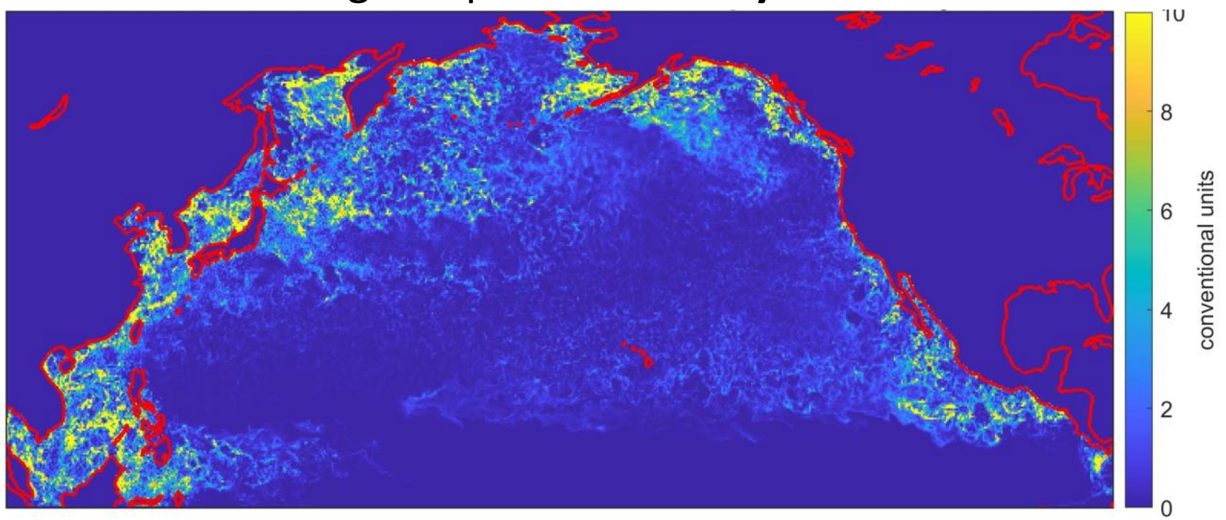

https://databasin.org

Important factors of successful dispersal:
- Pathways of floating substrate.
- Durability of substrate
- Environmental parameters, food, predators along the path
- Climate at destination.



Saturated model solutions with constant coastal sources

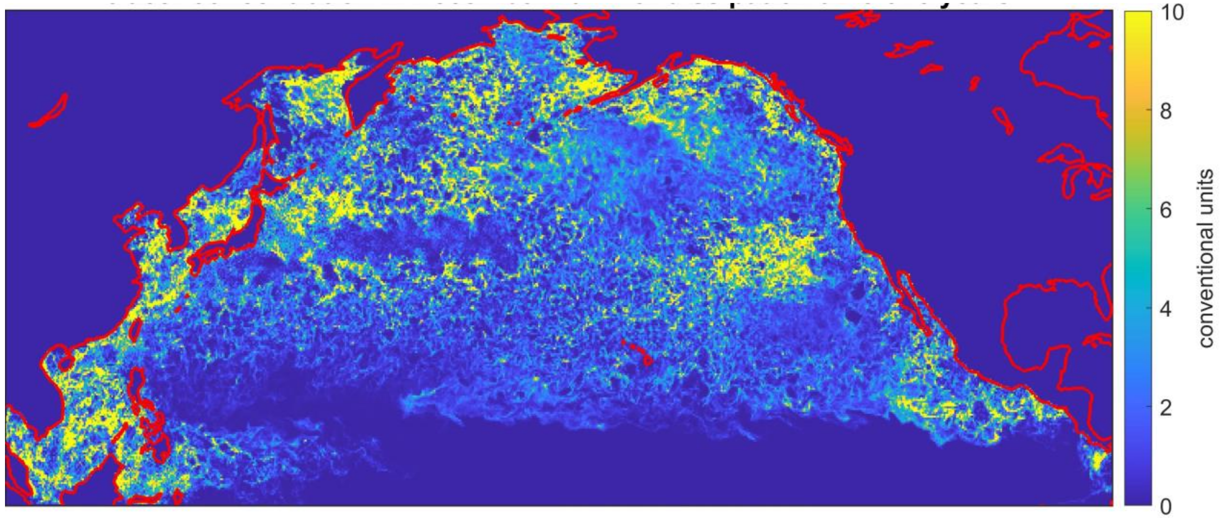
e-folding dissipation time: **1 year**



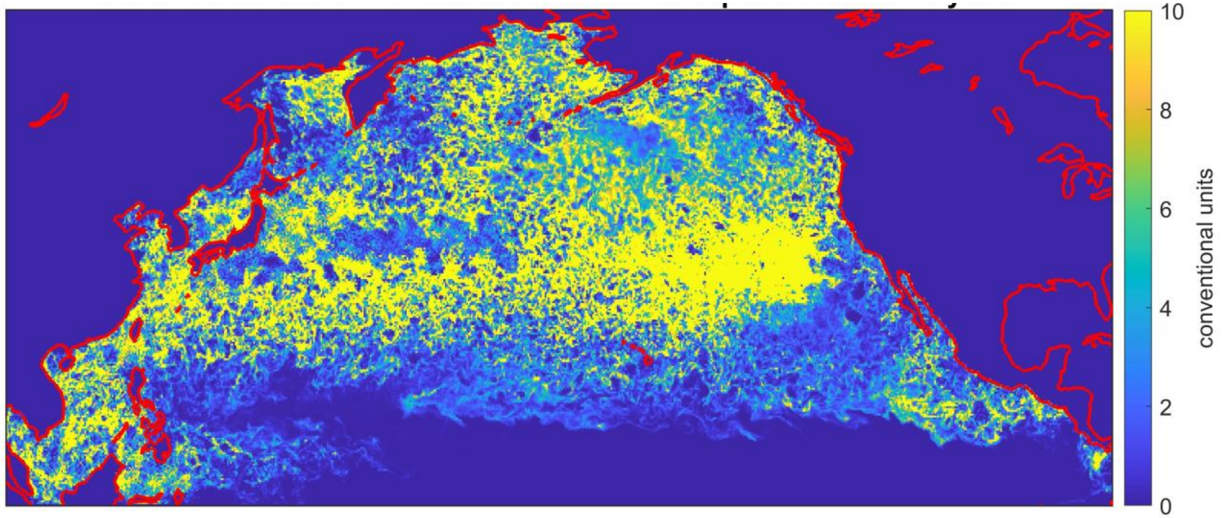

**Important factors of successful dispersal:**

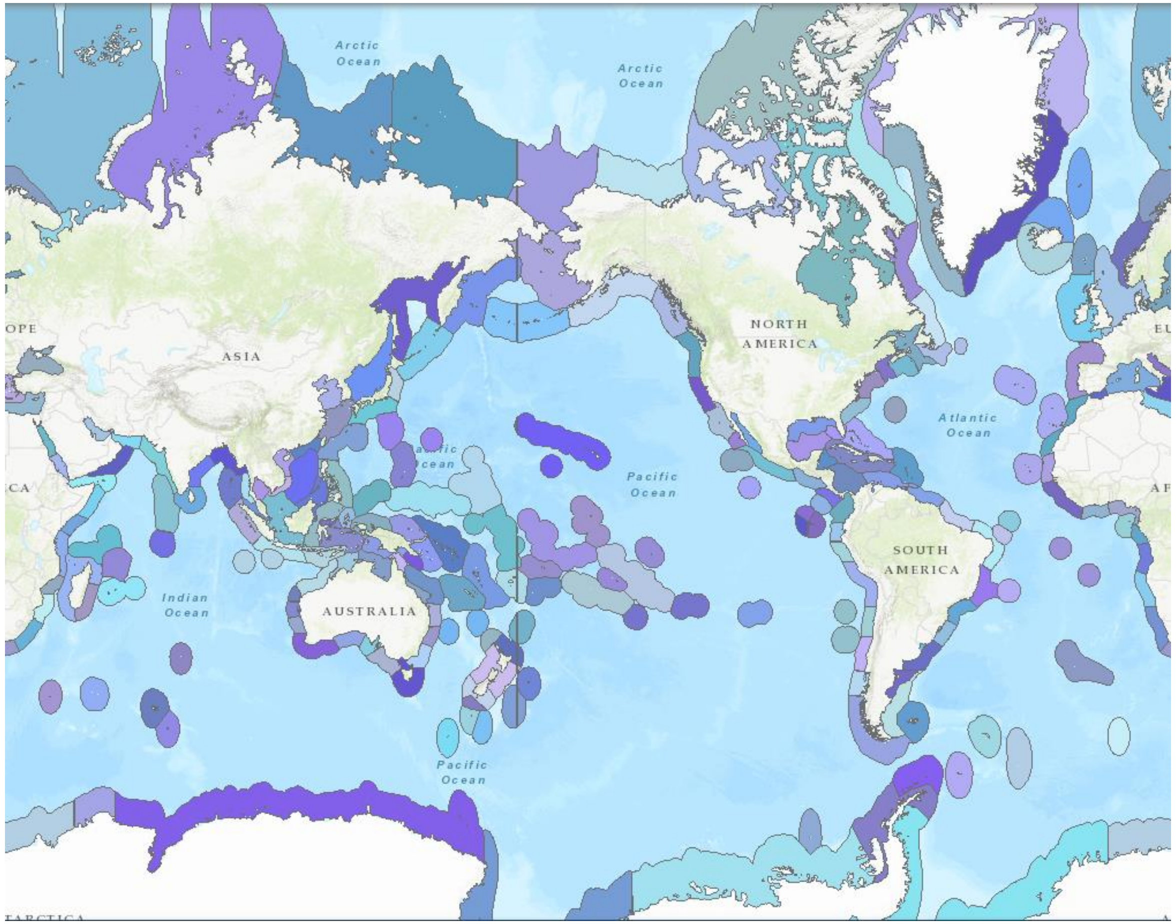
- **Pathways of floating substrate.**
- **Durability of substrate**
- **Environmental parameters, food, predators along the path**
- **Climate at destination.**

e-folding dissipation time: **3 years**




e-folding dissipation time: **20 years**






https://databasin.org

Let’s broaden our view to discuss a general concept of long-range dispersal of coastal species.

**Important factors of successful dispersal:**

- **Pathways of floating substrate.**
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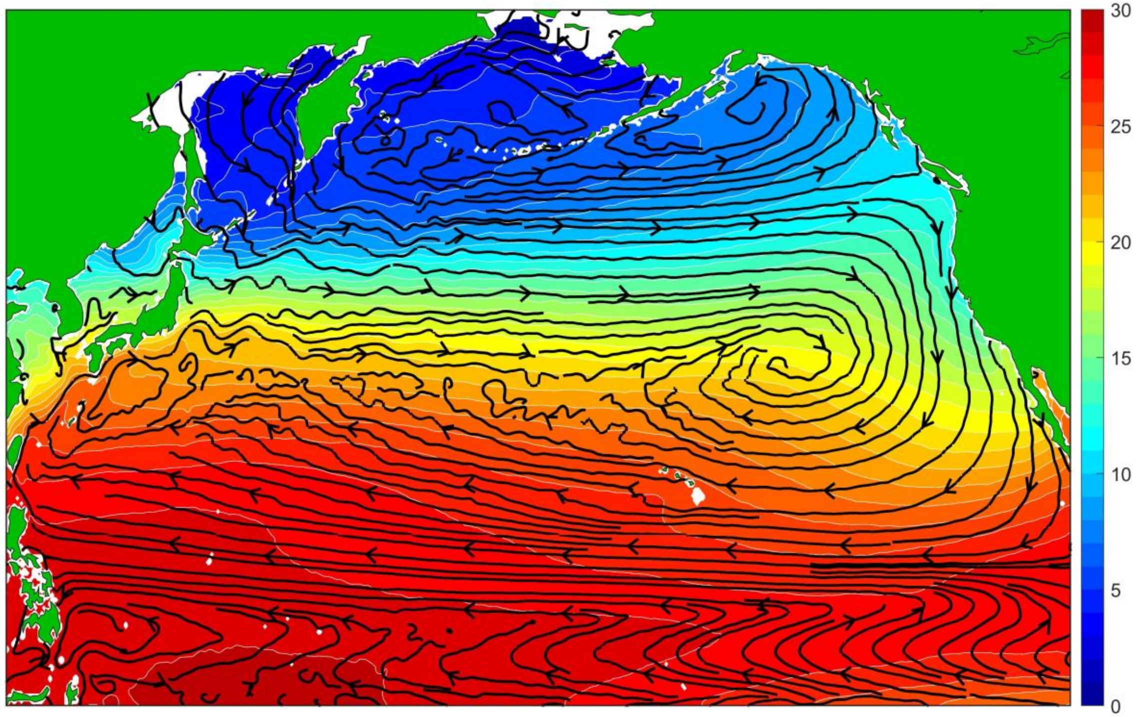
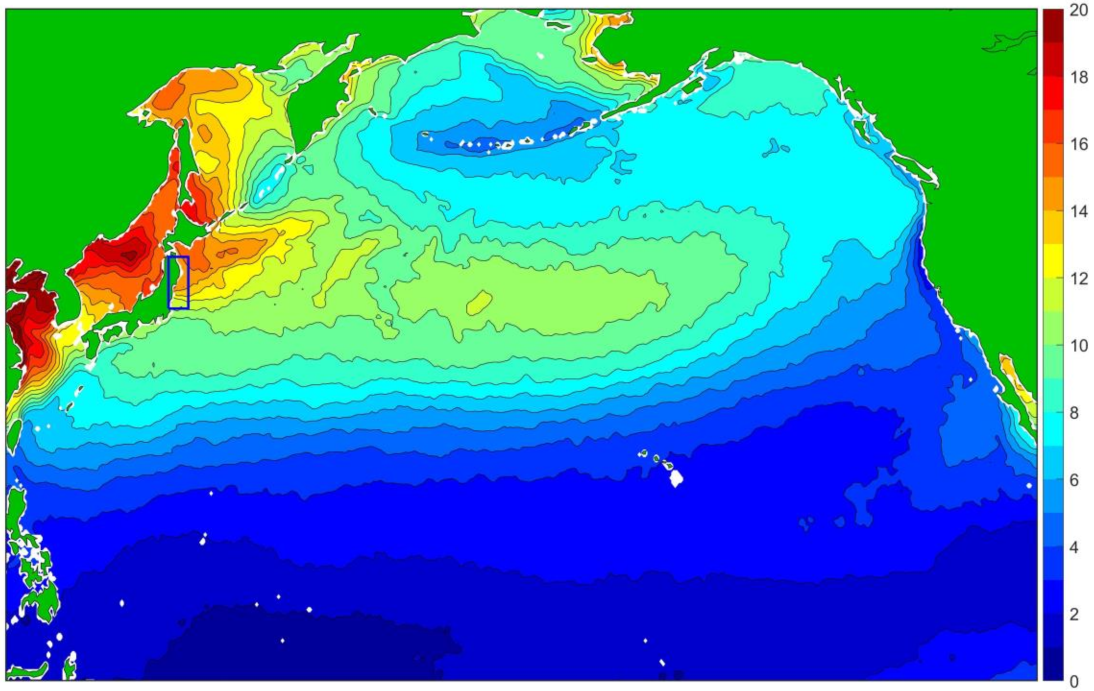
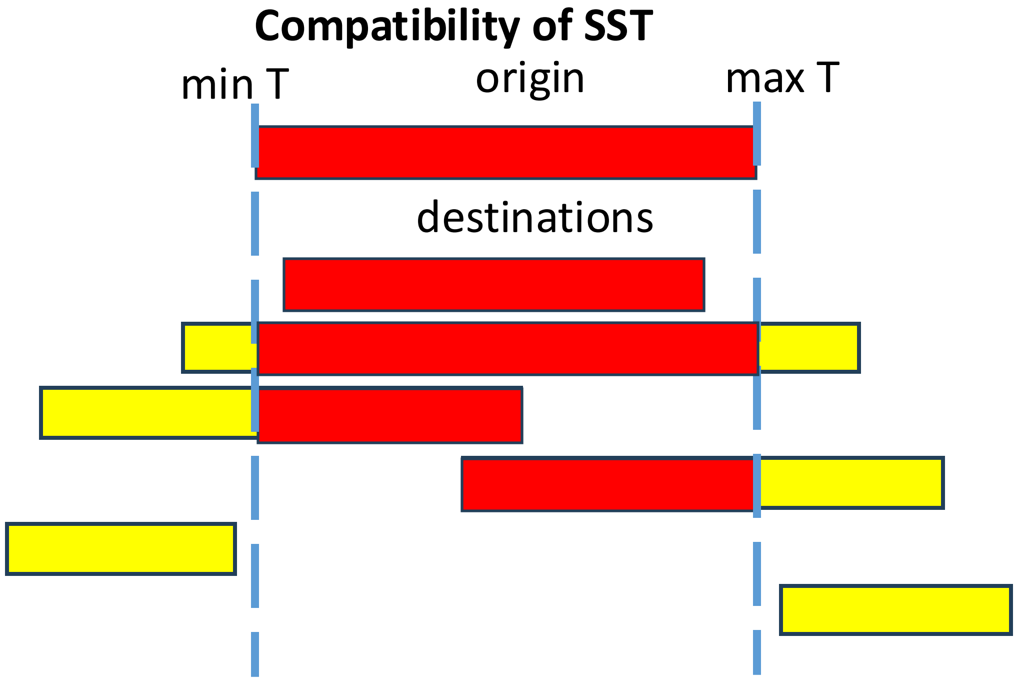
- **Environmental parameters, food, predators along the path**
- **Climate at destination.**

Mean streamlines over mean SST



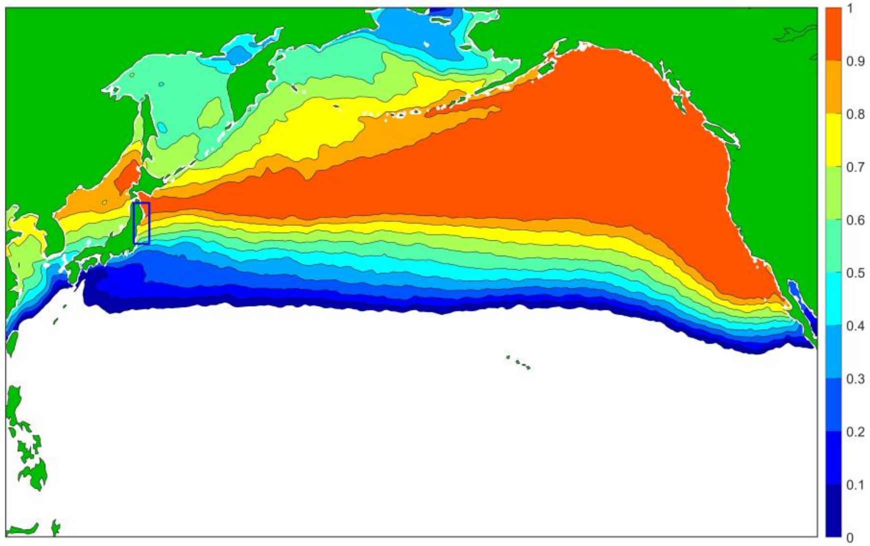


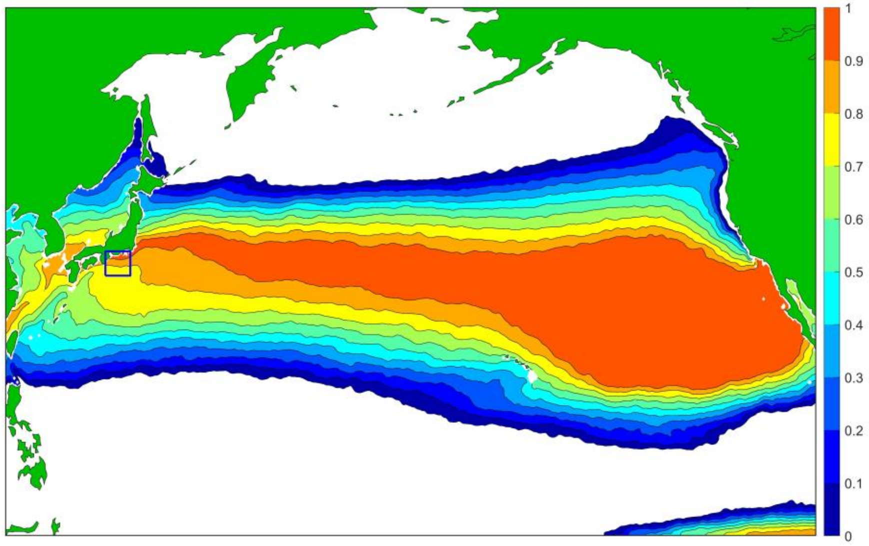

SST range in monthly climatology deg. C



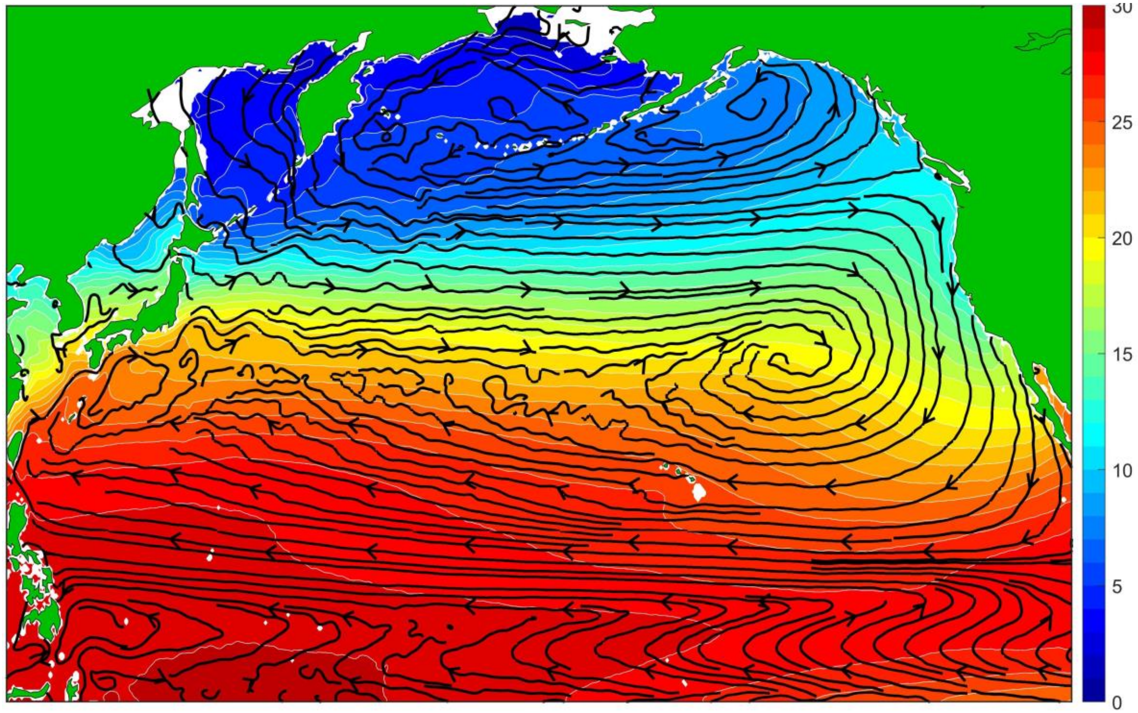

Relative overlap with SST range at the origin.

Coastal area affected by the 2011 tsunami has the greatest variability of SST In the North Pacific. (At least theoretically) Species from that area could survive on the North America west coast anywhere from California to Alaska.



***Where do streamlines cross the isotherms?***

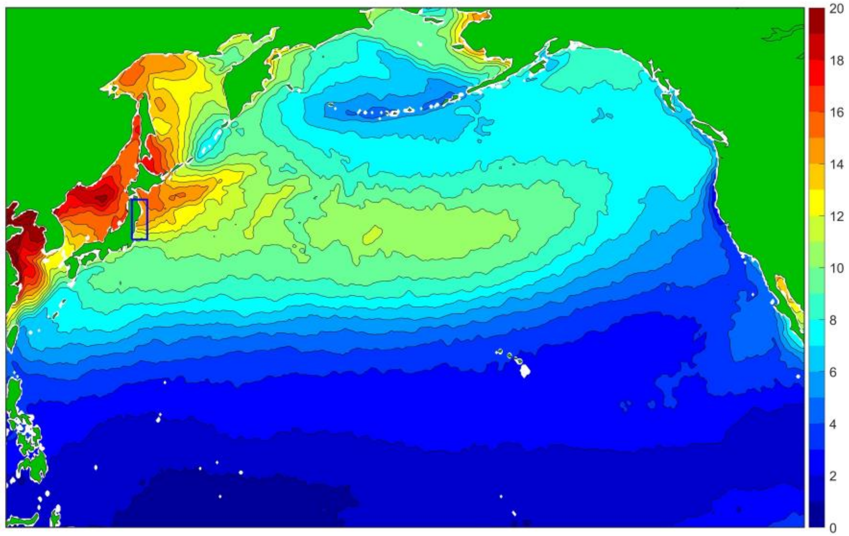


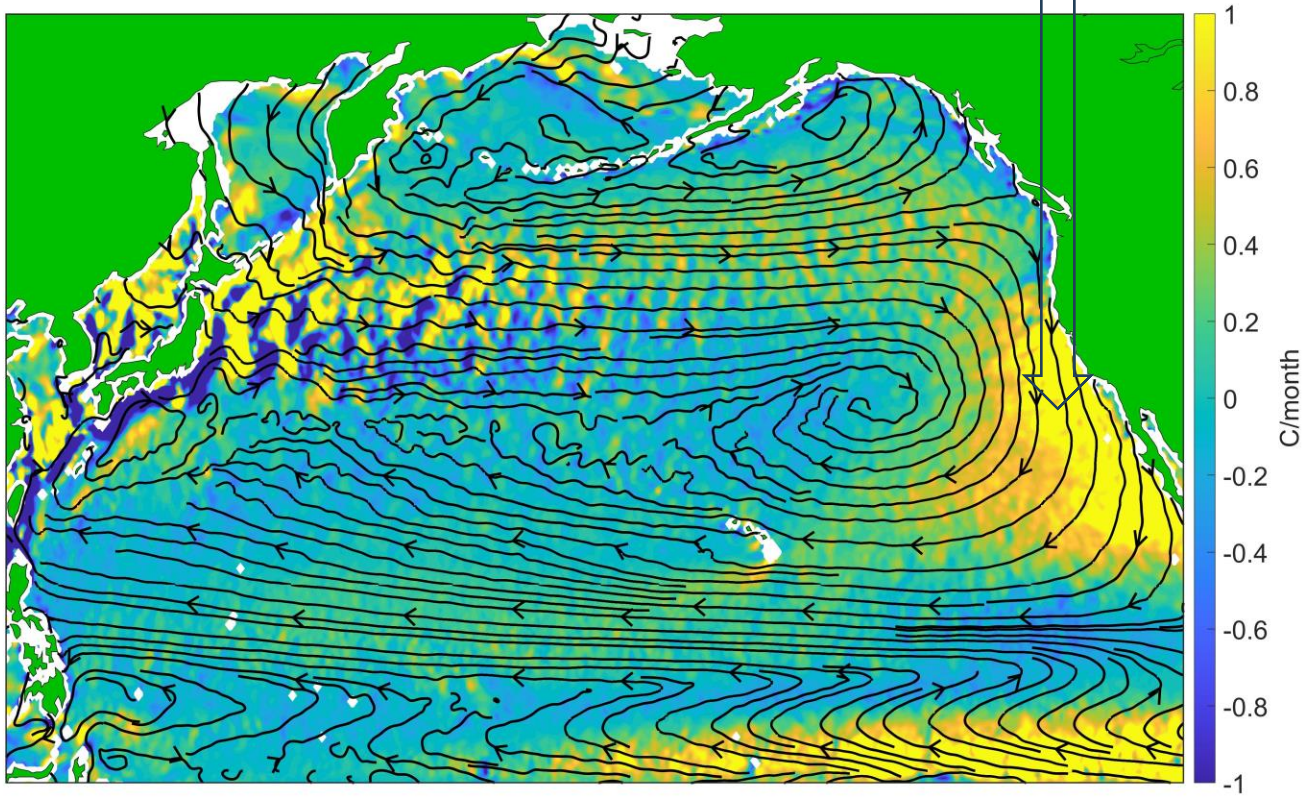

Mean streamlines
over mean SST

May be preventing North American coastal species from dispersing to the garbage patch

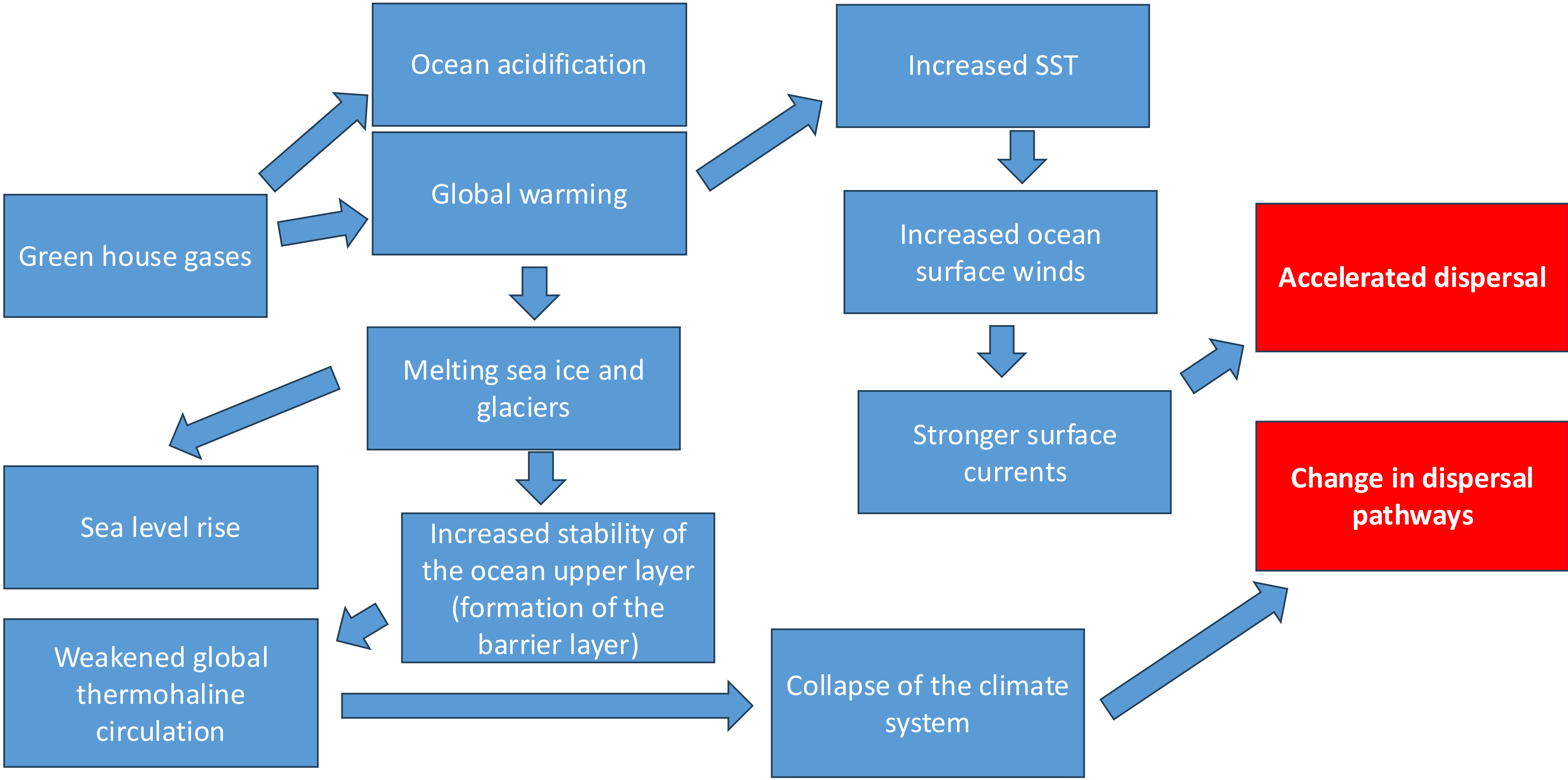
Rate of SST change along the path
dSST/dt=(V·grad)SST

SST range

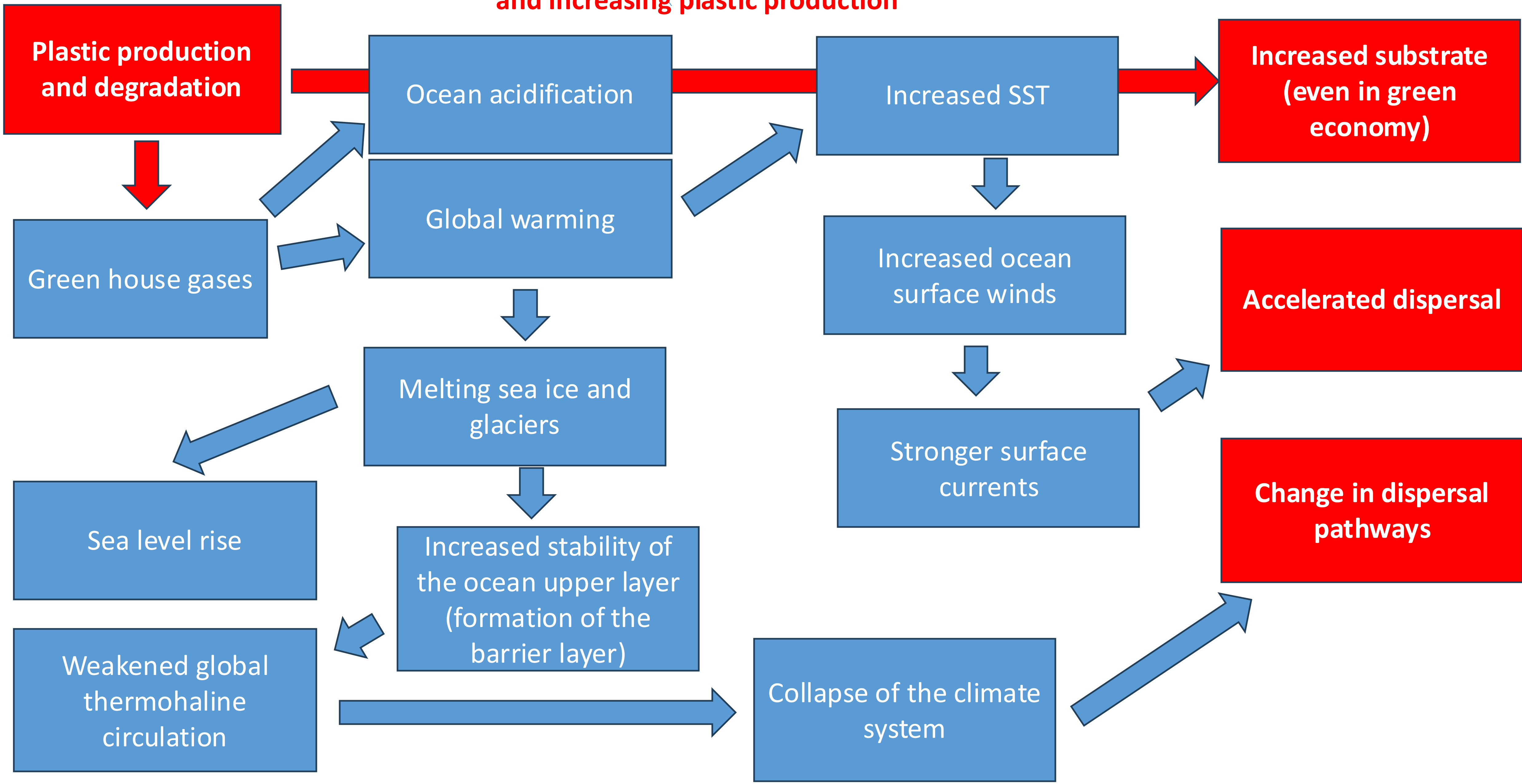


**Potential impacts of climate change on long-range dispersal of species**



**Potential impacts of climate change on long-range dispersal of species and increasing plastic production**



# *Open questions*

- **What happens to invading species after they survive the journey and enter new regions? What does it take to intrude the existing ecosystem?**

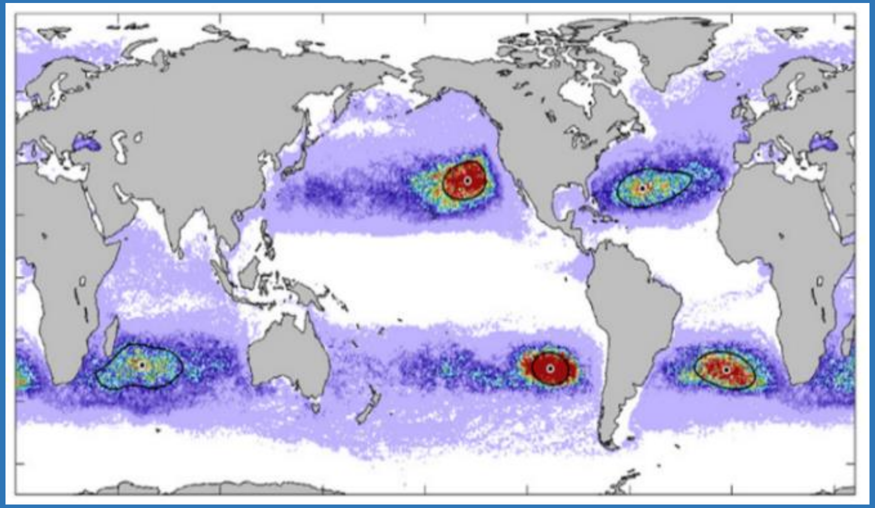
*With the large number of potential invaders found on marine debris in coastal areas of North America and Hawaii, we are not aware of any events of their successful establishment.*

- *It may be a matter of time for the invasion to succeed.*
- *Many invasions may remain undetected by the present monitoring system focusing on commercially important species.*
- *The coastal ecosystems may be resilient to intrusions.*

- The role of the 2011 tsunami: would the neopelagic system form without a massive discharge?

*- So far no North American and Hawaiian coastal species were reported from the garbage patch.*

- *Relatively small FloatEco samples detected at least 7 Japanese species not previously detected on tsunami debris.*
- *Warm water coastal species were detected both in tsunami and in FloatEco samples.*



- What is the status of the ecosystems in other garbage patches?

**Take home notes:**

- Neopelagic ecosystem is forming in the eastern North Pacific.

- Increasing plastic production creates new opportunities for coastal species to disperse over long distances and aggregate in new regions.

- Climate change will likely increase the long-distance dispersal.

*Thank you!*