Network Analysis of the Hawai‘i-based Longline Fishery

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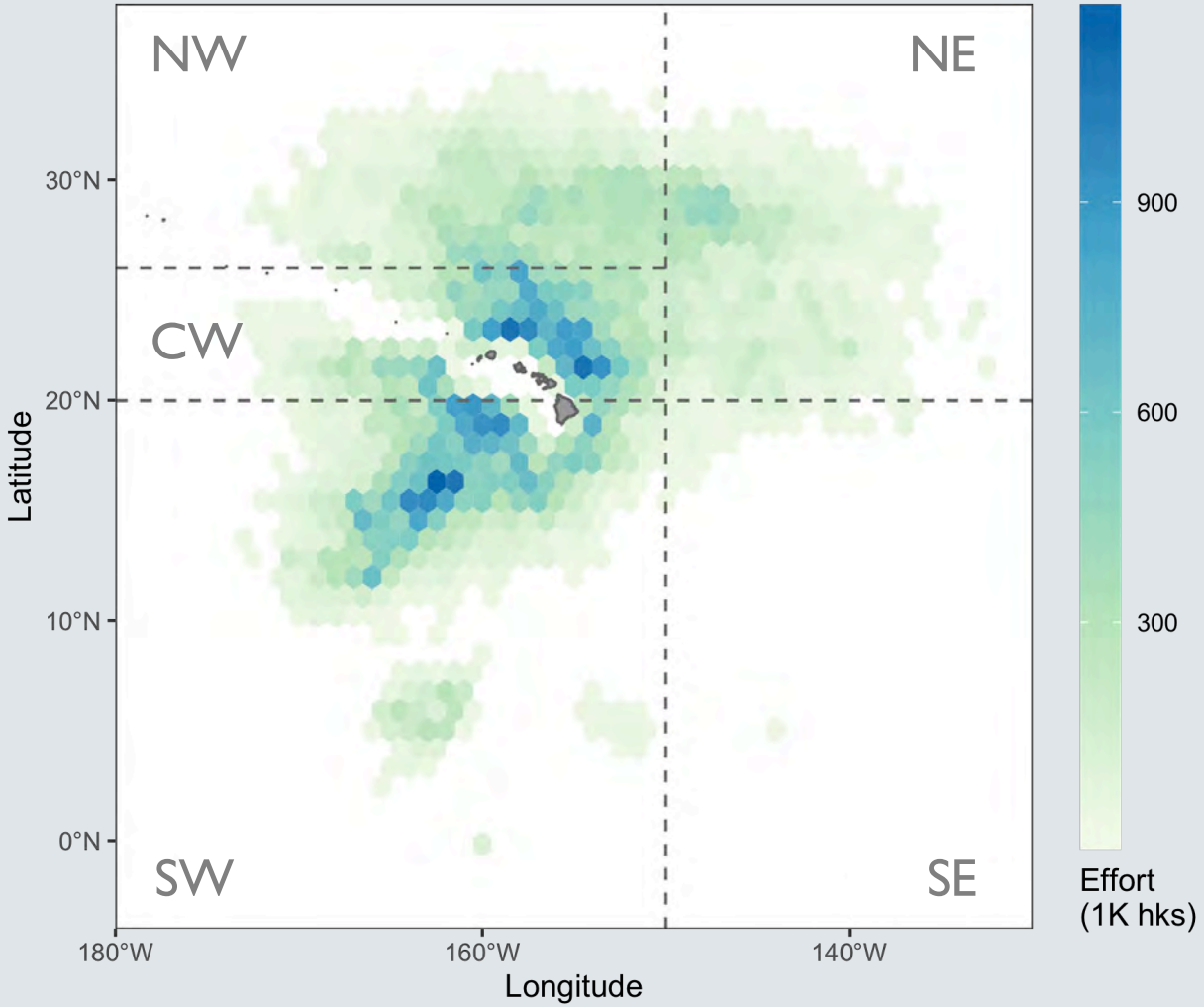
Hawai‘i Deep-Set Longline Fishery

Targets bigeye tuna but retains and sells other species

8th largest by value in the US

Footprint of 15 million km^2

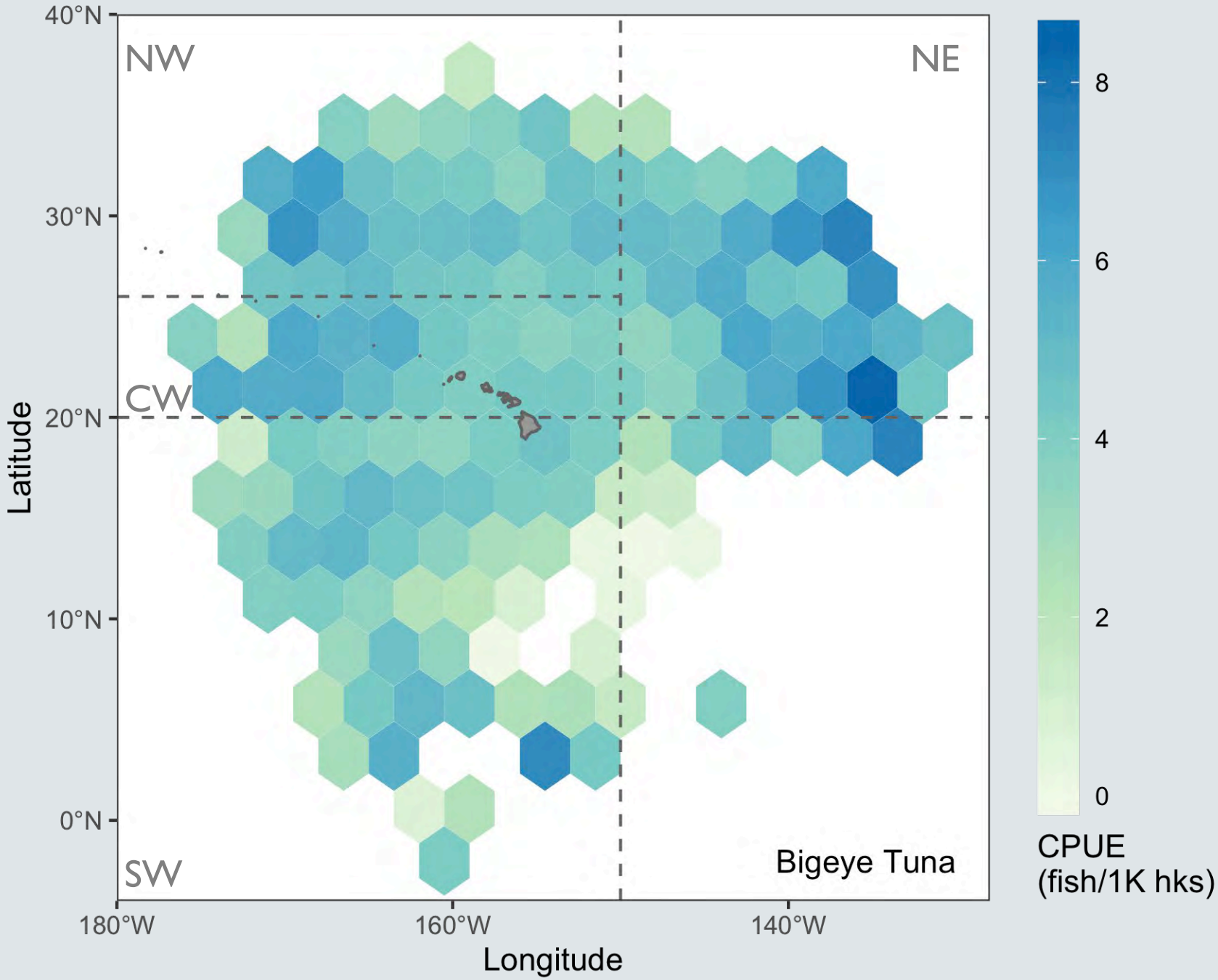
Spatial shift of the fishery towards the NORTH EAST



CPUE

1994 - 2018

OBSERVER DATA

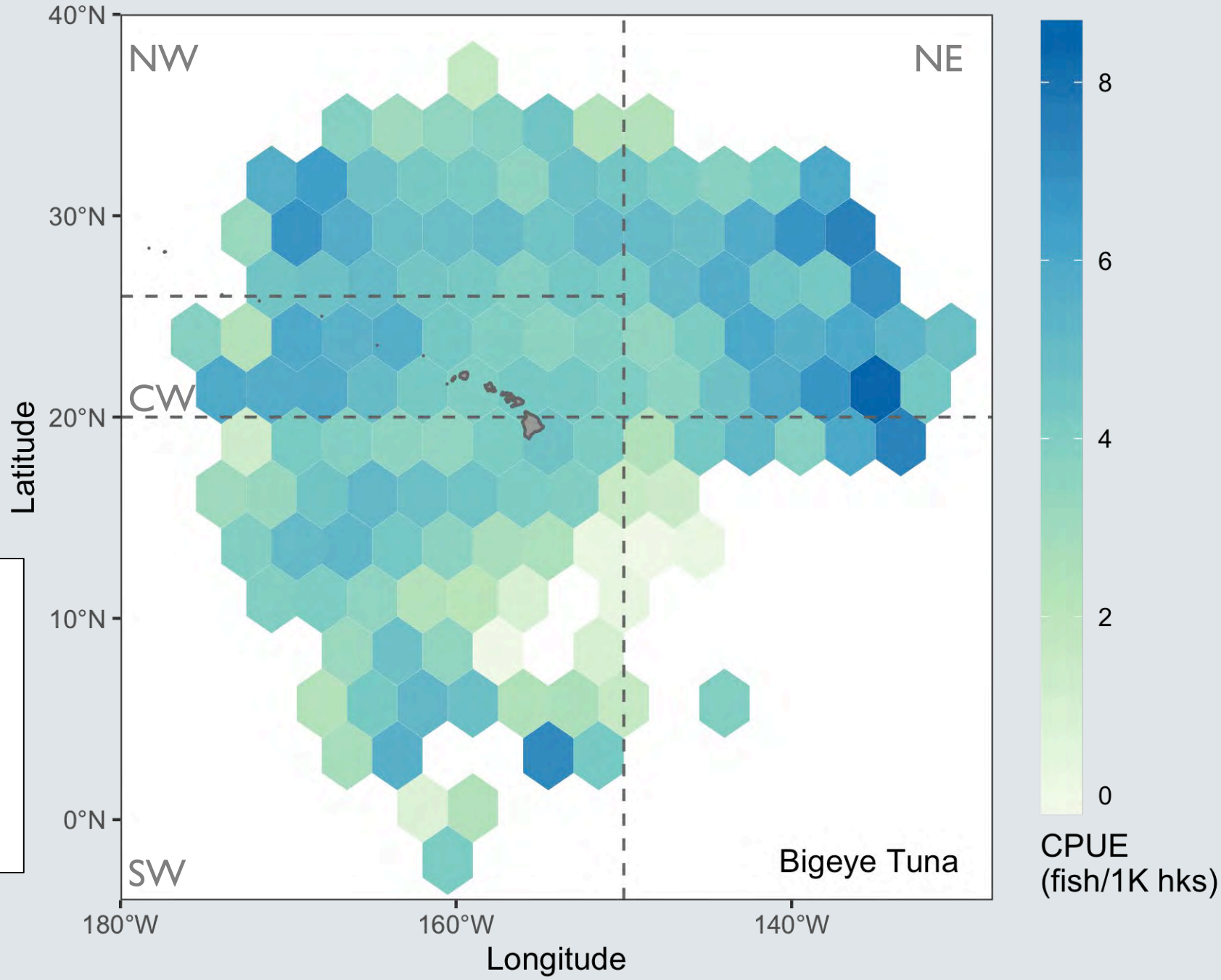


CPUE

1994-2018

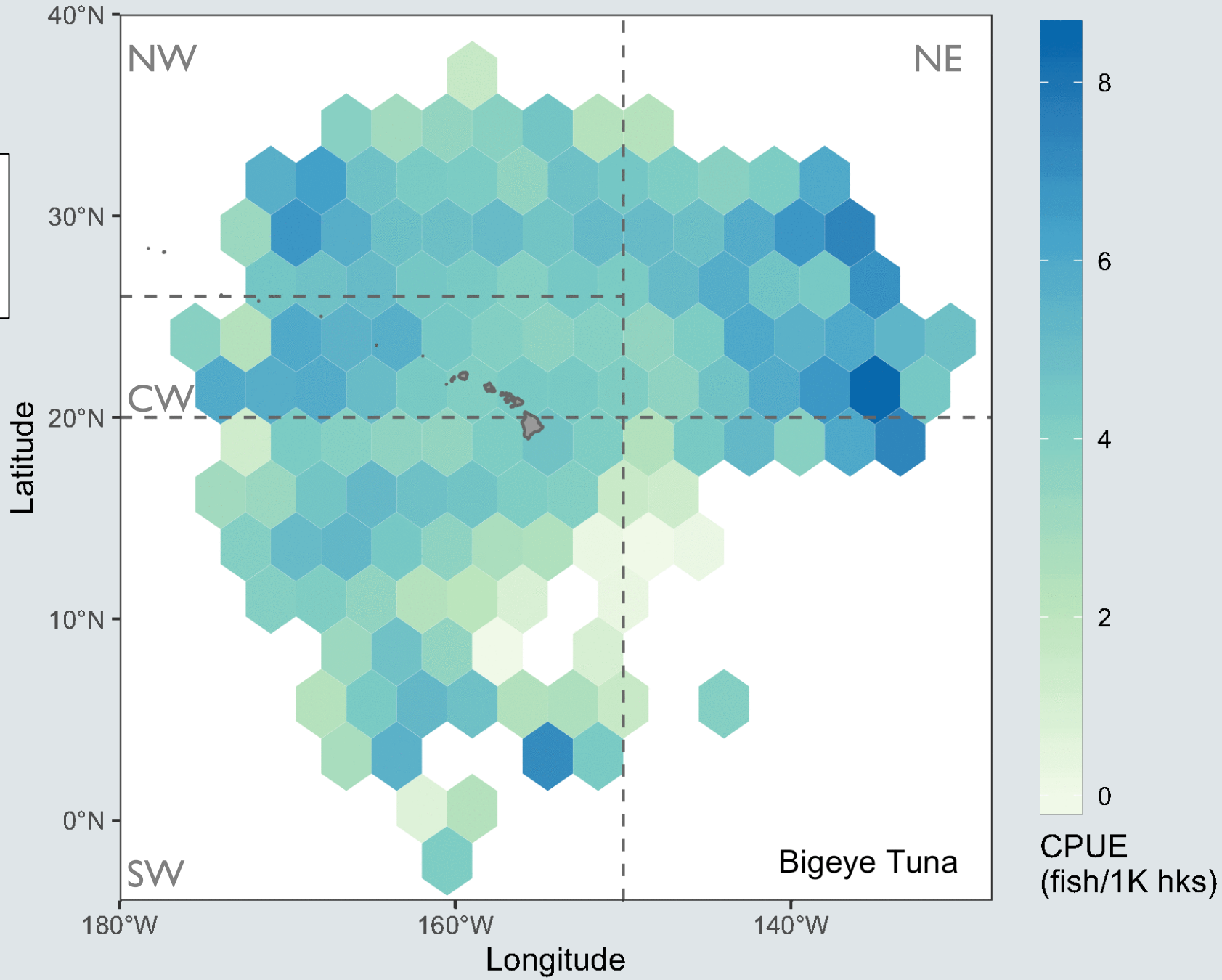
OBSERVER DATA

BIGEYE HAS RELATIVELY EVEN DISTRIBUTION OF CPUE ACROSS THE OF THE FISHERY

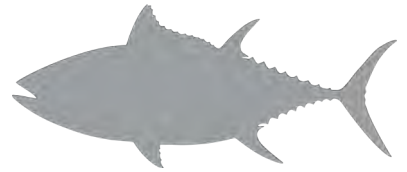


THE SAME IS NOT TRUE FOR OTHER SPECIES

DISTINCT SPATIAL PATTERNS IN CPUE



Management Challenges

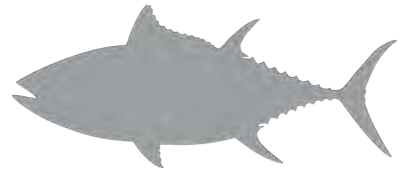


BIGEYE is the only managed species being fished and ANNUAL QUOTAS are set by RFMOs

Fishery experiences CLOSURES due to PROTECTED SPECIES INTERACTIONS

Can understanding species associations and NETWORKS in FISHERIES DEPENDENT catch data inform EBFM?

Management Challenges



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Co-occurrence and Network Analysis

- **Co-occurrence**
  - Pairwise
  - Greater or less than random chance
- **Clustering**
  - Optimal modality
  - Possible because networks are small
- **Networks**
  - Undirected
  - Positive and non-random
- **Centrality measures**
  - Degree
  - Closeness
  - Betweenness

Network Analysis

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Network Analysis

Co-occurrence

- pairwise
- greater or less than random chance

Clustering

- optimal modality
- use networks are small
- non-random

Centrality measures

- closeness
- betweenness

All years individually and aggregate

For top 46 species

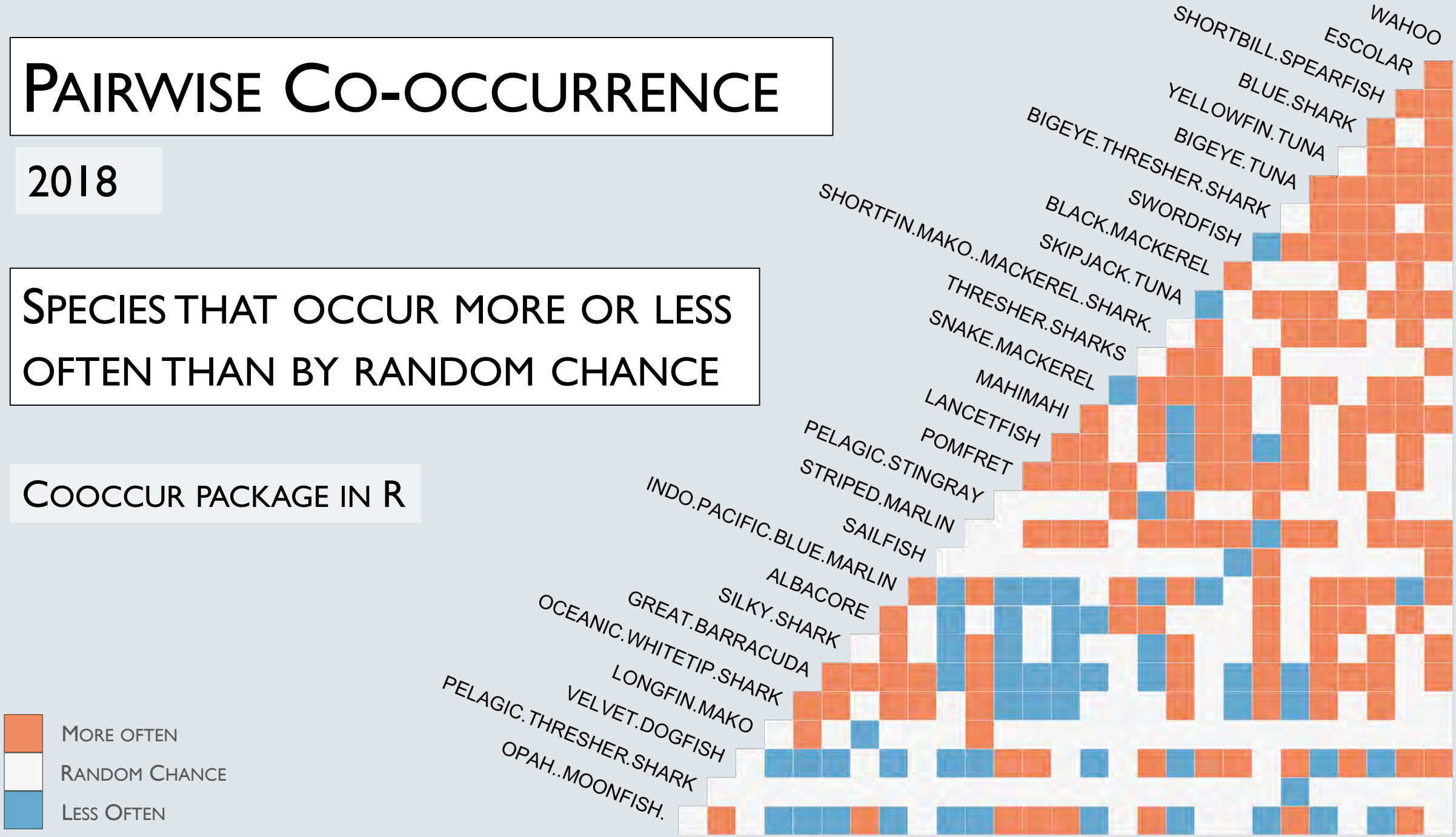
over Four spatial regions

Pairwise Co-occurrence

2018

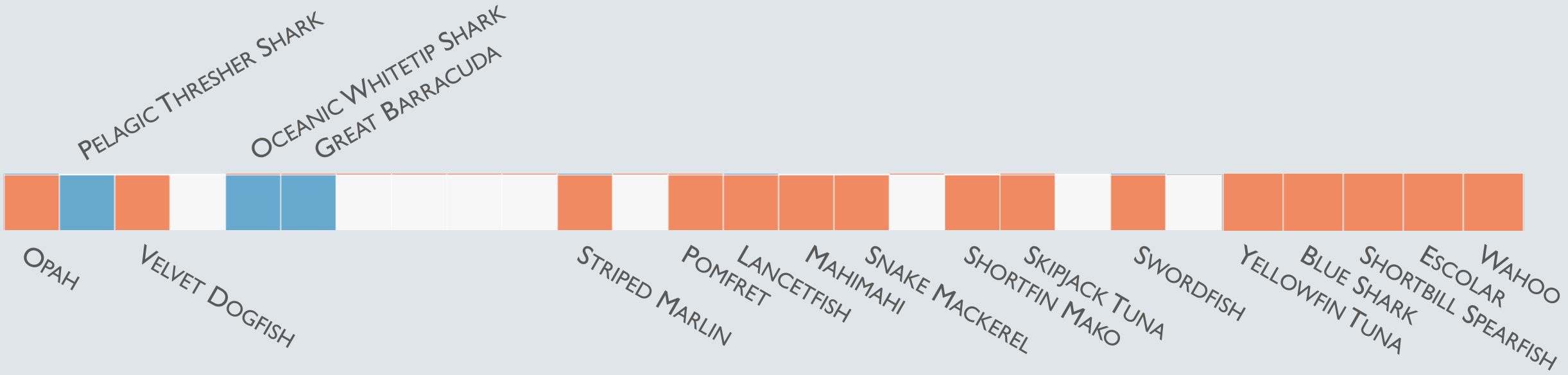
Species that occur more or less often than by random chance

Cooccur package in R



Pairwise Co-occurrence

2018



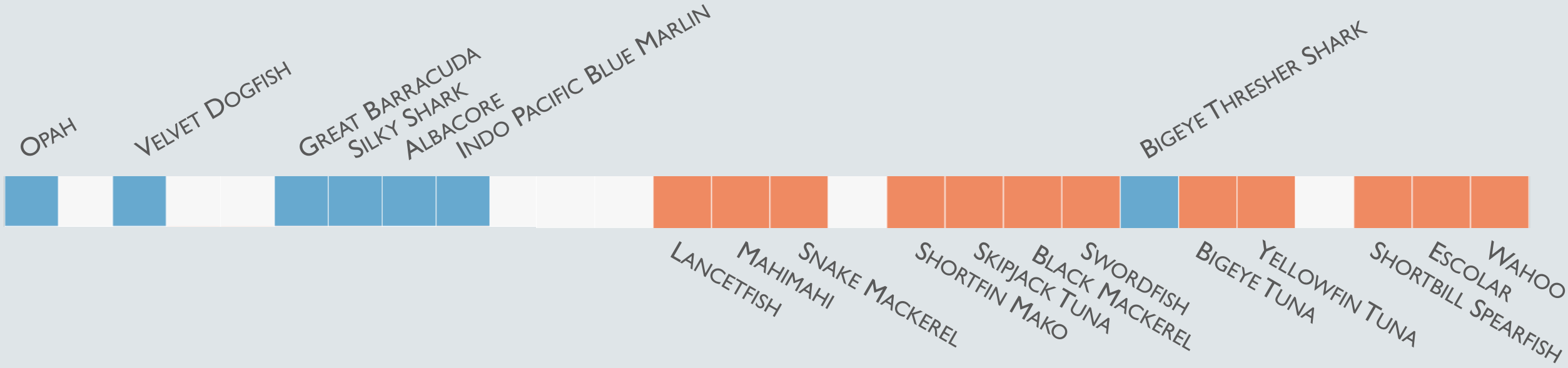
More often

Random Chance

Less Often

Pairwise Co-occurrence

2018



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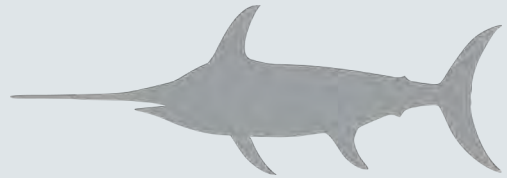
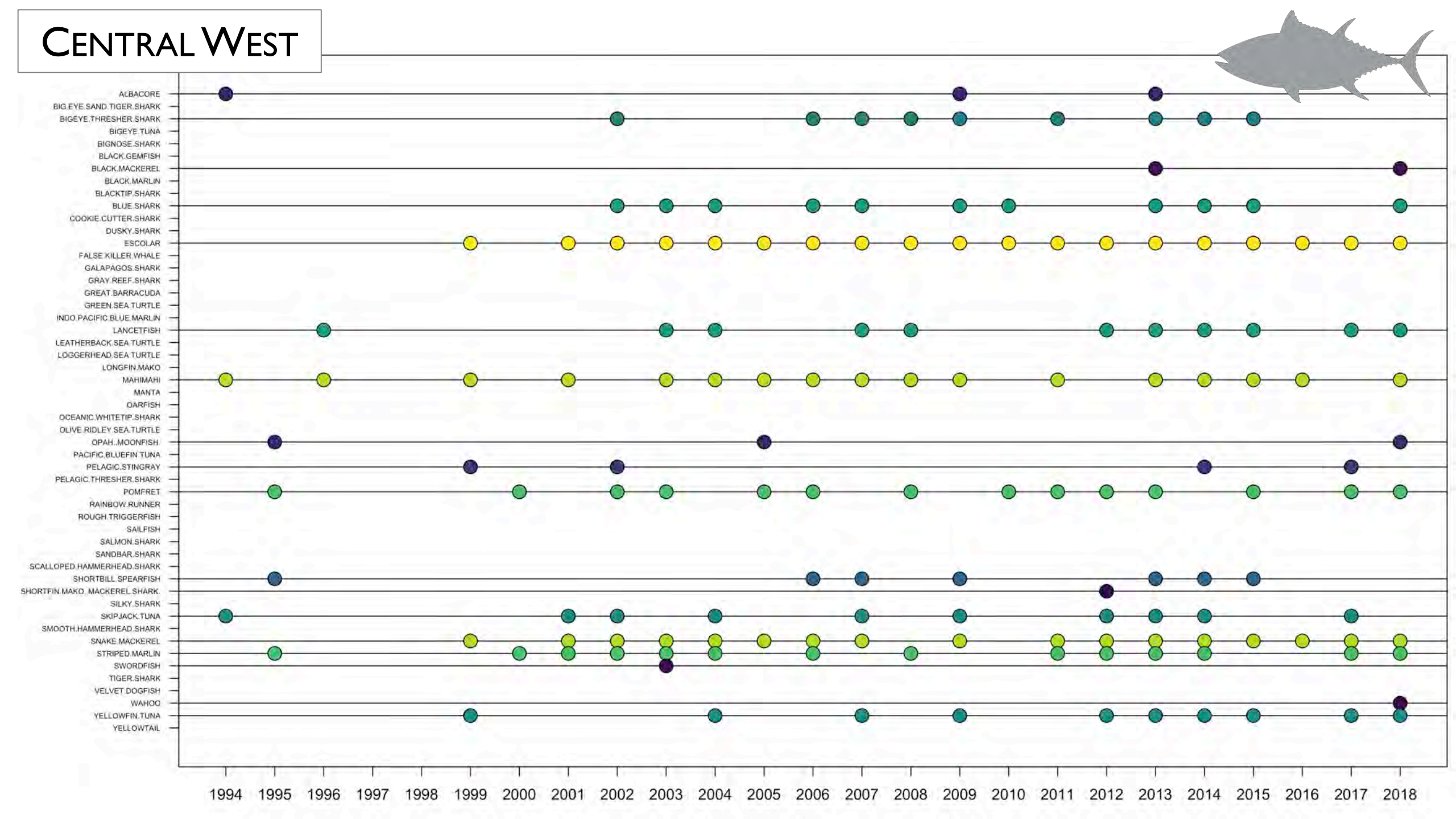


CENTRAL WEST



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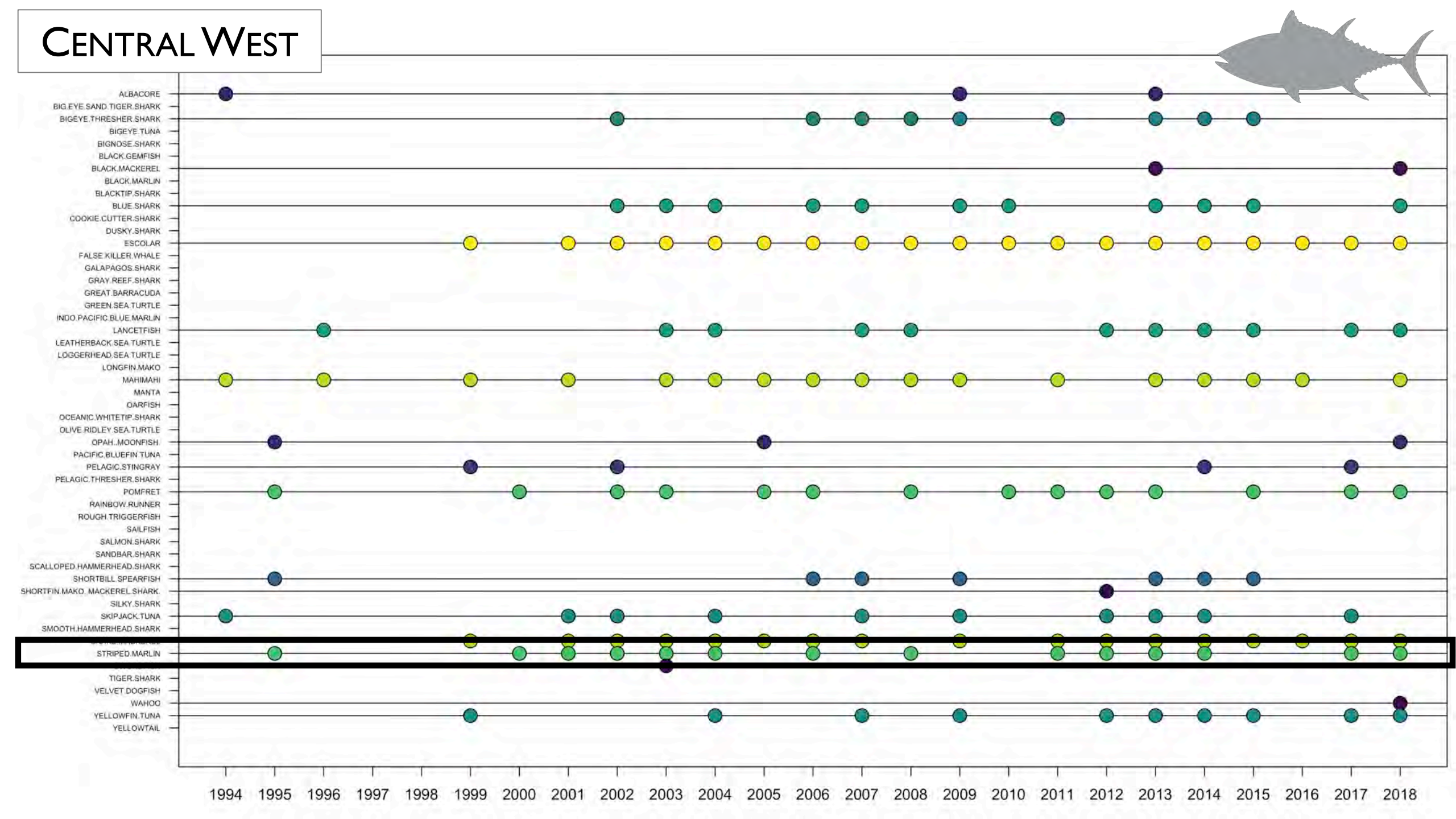
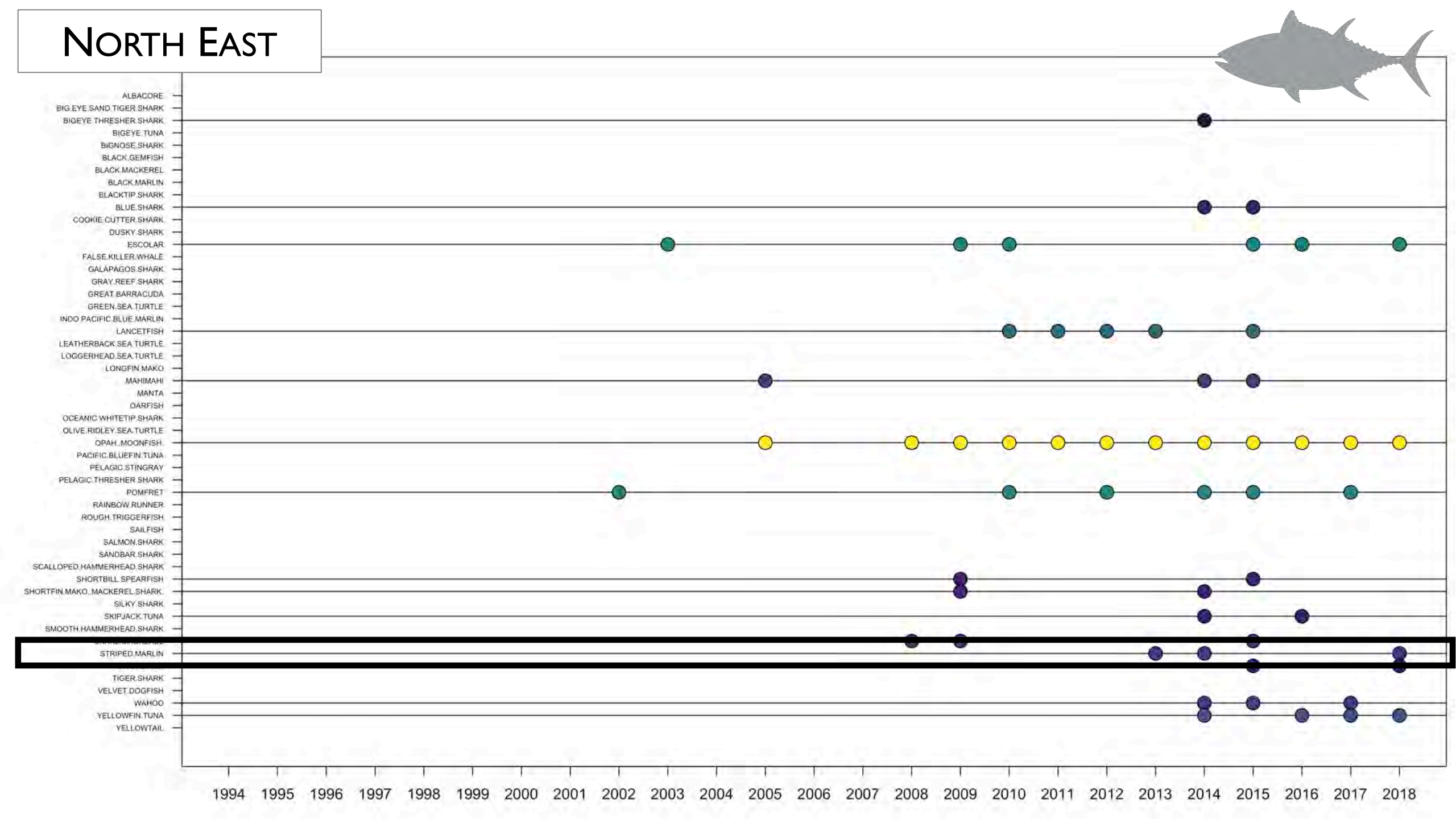


North East


ALBACORE
BIG.EYE.SAND.TIGER.SHARK
BIGEYE.THRESHER.SHARK
BIGEYE.TUNA
BIGNOSE.SHARK
BLACK.GEMFISH
BLACK.MACKEREL
BLACK.MARLIN
BLACKTIP.SHARK
BLUE.SHARK
COOKIE.CUTTER.SHARK
DUSKY.SHARK
ESCOLAR
FALSE.KILLER.WHALE
GALAPAGOS.SHARK
GRAY.REEF.SHARK
GREAT.BARRACUDA
GREEN.SEA.TURTLE
INDO.PACIFIC.BLUE.MARLIN
LANCETFISH
LEATHERBACK.SEA.TURTLE
LOGGERHEAD.SEA.TURTLE
LONGFIN.MAKO
MAHIMAHI
MANTA
OARFISH
OCEANIC.WHITETIP.SHARK
OLIVE.RIDLEY.SEA.TURTLE
OPAH..MOONFISH.
PACIFIC.BLUEFIN.TUNA
PELAGIC.STINGRAY
PELAGIC.THRESHER.SHARK
POMFRET
RAINBOW.RUNNER
ROUGH.TRIGGERFISH
SAILFISH
SALMON.SHARK
SANDBAR.SHARK
SCALLOPED.HAMMERHEAD.SHARK
SHORTBILL.SPEARFISH
SHORTFIN.MAKO..MACKEREL.SHARK.
SILKY.SHARK
SKIPJACK.TUNA
SMOOTH.HAMMERHEAD.SHARK
STRIPED.MARLIN
TIGER.SHARK
VELVET.DOGFISH
WAHOO
YELLOWFIN.TUNA
YELLOWTAIL
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  - degree
  - closeness
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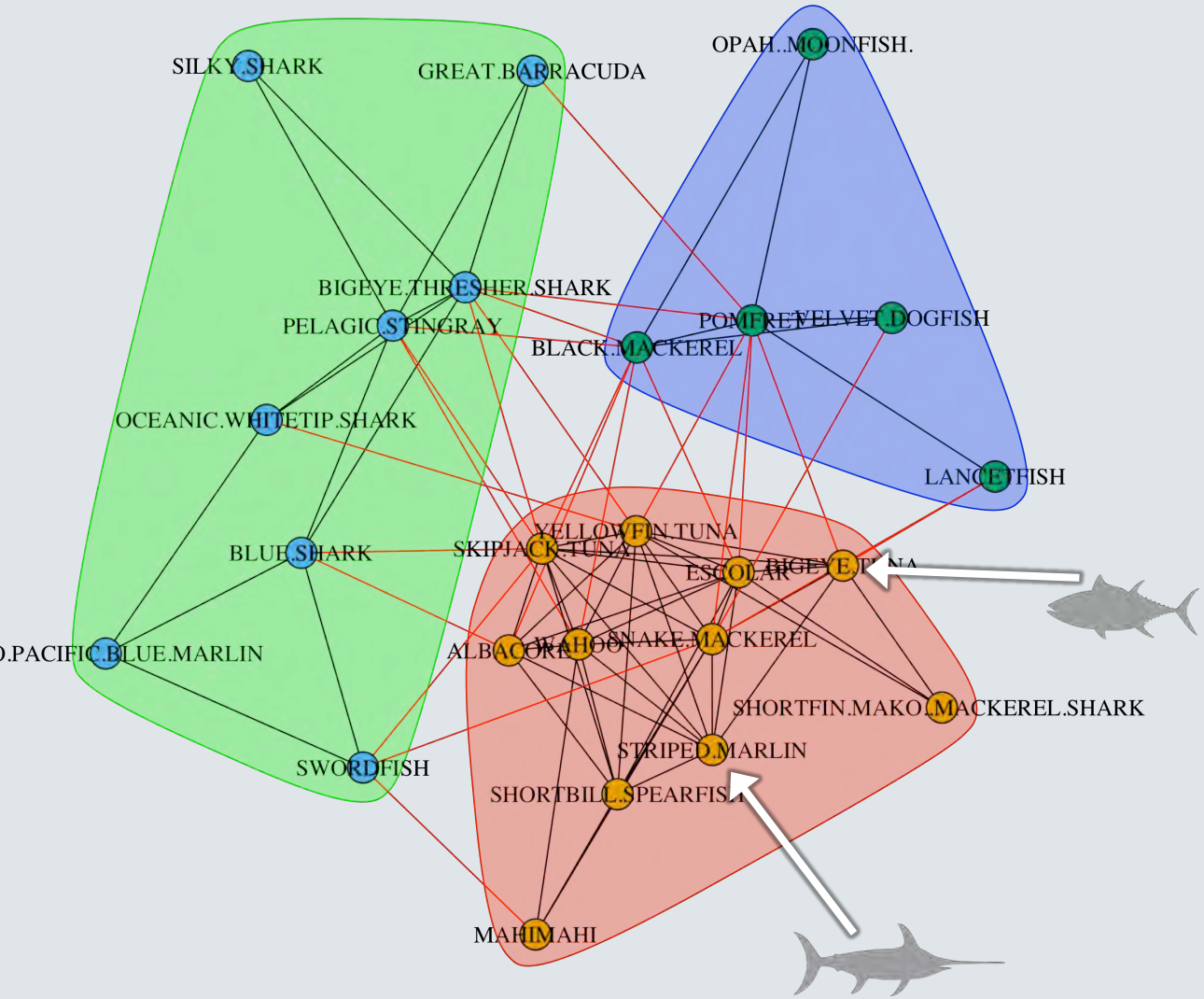
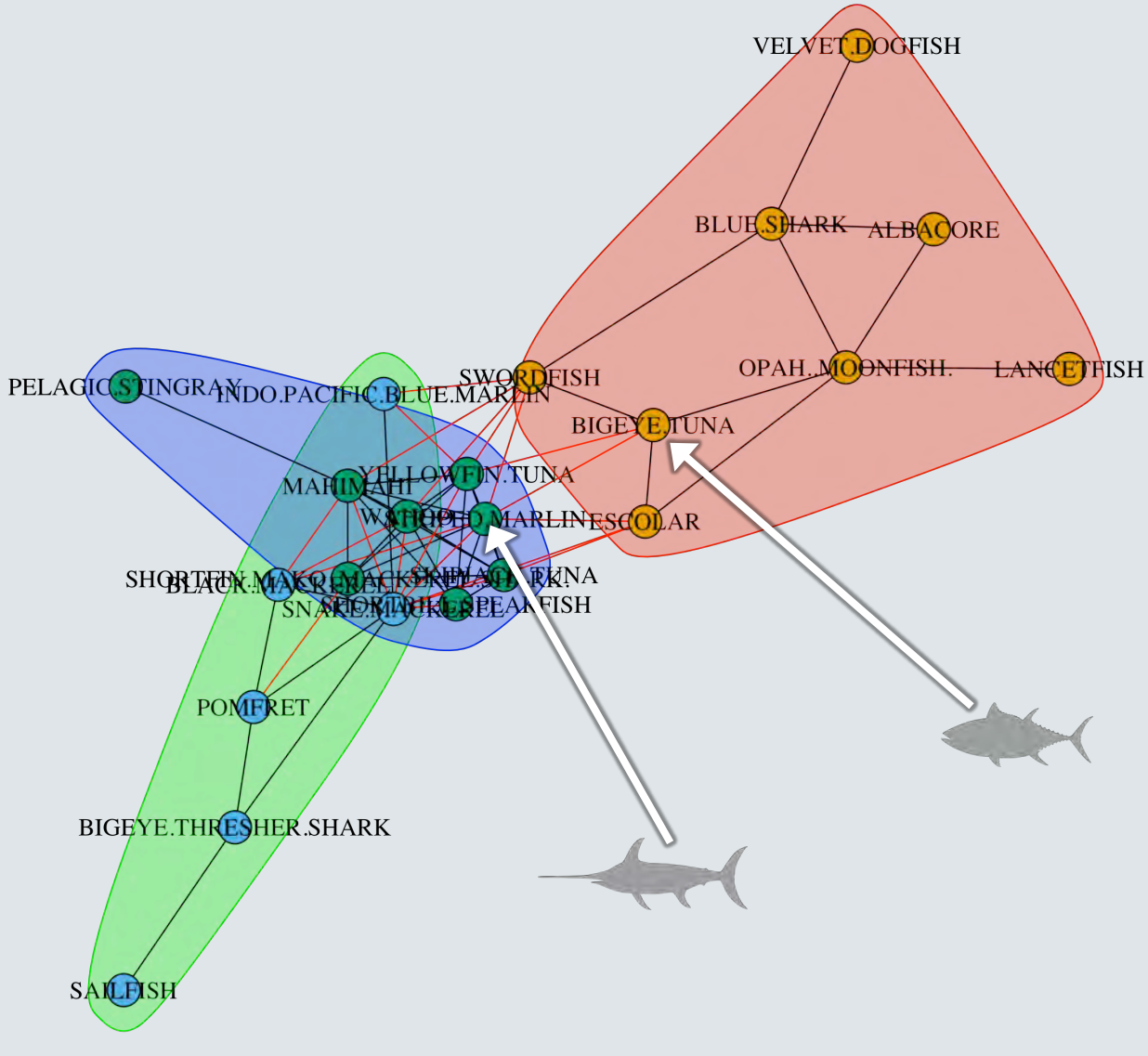


NORTH EAST



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Centrality Measures

Degree centrality

- Number of interactions
- Local

Closeness centrality

- Proximity to all other species
- Global
- How rapidly influences the network

Betweenness centrality

- How many paths go through node
- Influence of species loss on fragmentation

Centrality Measures

Low degree and high closeness means the species has a key role by interacting with important species

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- How rapidly influences the network

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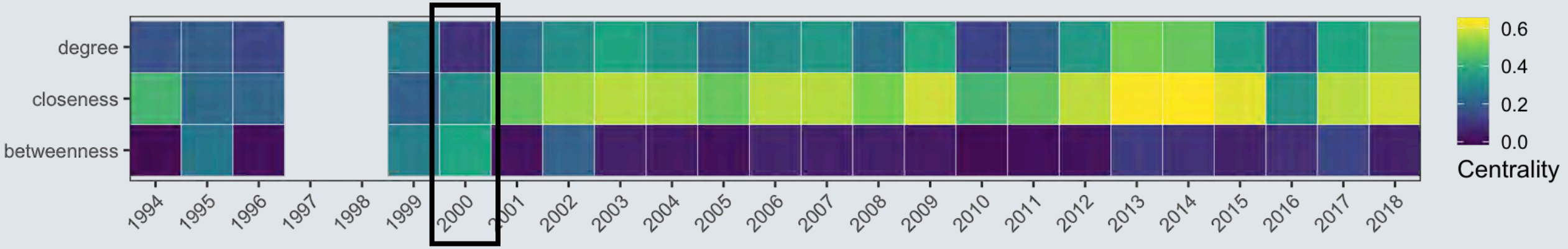
Centrality Measures



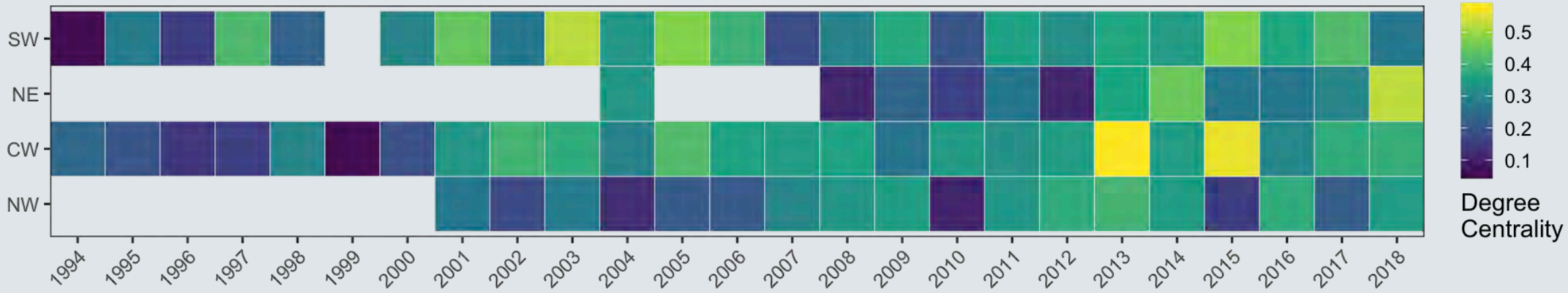
Low degree and high closeness means bigeye has a key role by interacting with important species

Closeness centrality

Global

Low degree and high betweenness means bigeye plays a key role in connecting species that would otherwise not be connected

Degree Centrality



Best to compare centrality measures across networks

C_D Quantifies the immediate influence between nodes

C_D in the South West region is steady while NW and CW regions are increasing

⟹ More complex networks with time in NW and CW

How Can Networks Inform EBFM?

Include environmental variables in the co-occurrence analyses

Better guide fishers where to fish to increase commercially valuable catch and decrease discards

Would love input from you all on the management application of co-occurrence and network analysis!

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THANK YOU!