DOCUMENT: BYC-11-INF-A

Definition of guidelines to reduce the impact of lost and abandoned Fish Aggregating Devices (FADs) on Sea Turtles

Moreno G.[1], Escalle L.[2], Lopez J.[3] Lynch J.[4], Scutt Phillips J.[2], Royer S.J.[4], Aires-da-Silva A.[3], Swimmer Y.[5], Hampton J.[2], Restrepo V[1]. and Murua H.[1]

IATTC Working group on bycatch – 11th meeting 10-11 May 2022

Objectives

1. **State of the art**: This objective will review the known and unknowns of dFAD structure impact on marine turtles' habitat and populations.

2. **Modelling FAD trajectories:** this objective will simulate virtual FAD trajectories arriving at essential habitats for turtles with special focus on leatherback turtle and Hawaiian Islands.

3. **Evaluating options to reduce dFAD impact and definition of best practices guidelines**: Based on previous work and discussions with key purse seine fleets in expert workshops.

4. **Outreach** to fishers, scientists and managers.

Recommendations

That the 11th Meeting of the Bycatch Working Group NOTES document BYC-11-INF-A, on the Pacific-wide project to define best practice guidelines and conservation recommendations to reduce the impact of FAD structure on sea turtles´ populations and habitat in the Pacific Ocean.

Document: BYC-11-05

Modeling drifting Fish Aggregating Devices (dFADs) trajectories arriving at essential habitats for sea turtles in the Pacific Ocean

Escalle L.[1], Scutt Phillips J.[1], Moreno G.[2], Lopez J.[3], Lynch J.[4], Murua H.[2], Aires-da-Silva A.[3], Royer S.J.[4], Hampton J.[1], Swimmer Y.[5], Wallace, B.[6], Corniuk R.[3], Mcwhirter A.[3], Restrepo V.[2]

[1]The Pacific Community (SPC)

[2]International Seafood Sustainability Foundation (ISSF)

[3]Inter-American Tropical Tuna Commission (IATTC)

[4]Hawai'i Pacific University (HPU)

[5]NOAA Fisheries, Pacific Islands Fisheries Science Center

[6]Ecolibrium, Inc, Boulder, CO, United States

Modelling FAD trajectories arriving at essential habitats for sea turtles

Part 2 of Pacific Islands Regional Office (PIRO) - NOAA project (2020-2022), which aims at defining guidelines and conservation recommendations to reduce the impact of lost and abandoned FADs on sea turtles in the Pacific Ocean

See more in Moreno *et al.* 2022. BYC-11-INF-A, IATTC Bycatch Working Group, 11th meeting.

OBJECTIVE:

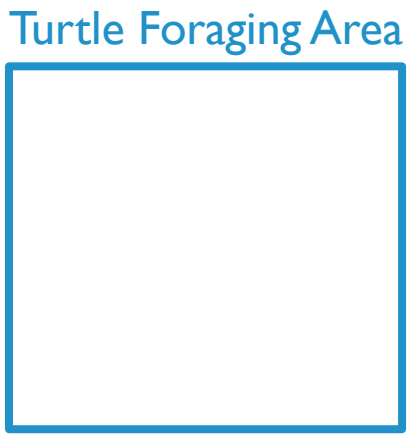
Explore and quantify the potential connectivity between:

- Zones of habitat importance in sea turtle life history (oceanic habitat and nesting areas) in the Pacific Ocean, mostly focused on leatherbacks

- Equatorial zones, where dFADs are known to drift and be deployed

Passive drift simulation

- **Limited availability of observed FAD trajectory data**
- **Use knowledge of ocean currents to predict the pathways of passively drifting objects**
- **Virtual ‘particles’ are moved around by current velocity forcings, across depths corresponding to FAD drift profile**
- **Seed particles randomly across areas of interest and repeatedly through time**

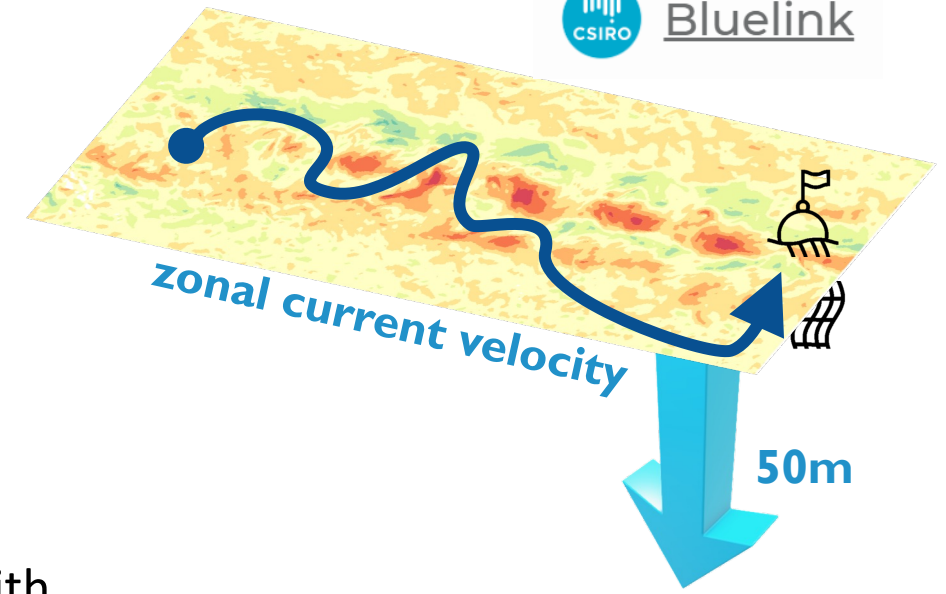


Zone of interest

Pacific Community
Communauté du Pacifique

Lagrangian Simulation Overview

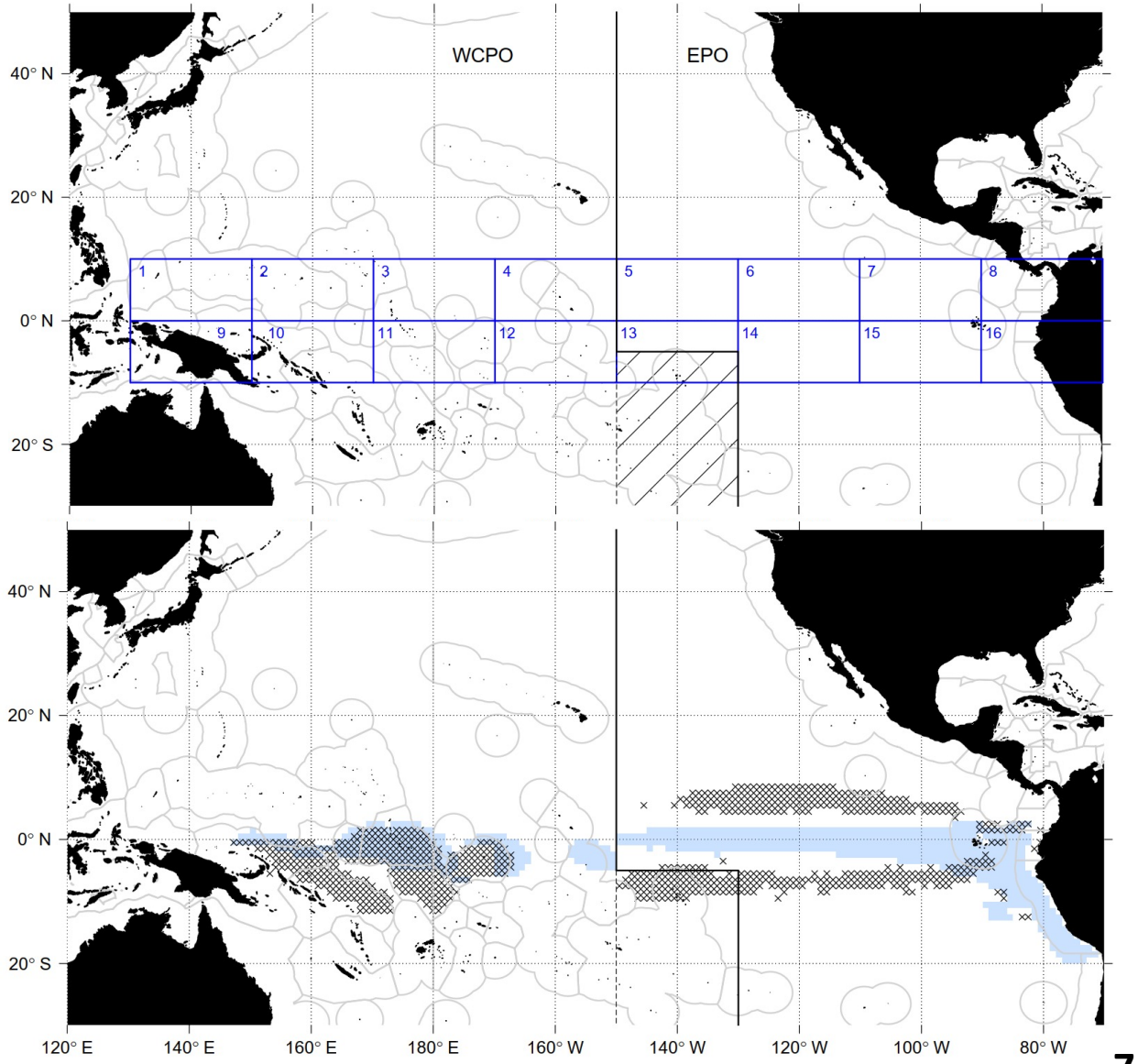
CSIRO Bluelink



- Ocean circulation model: **Bluelink Reanalysis physical ocean data** Current **velocity flow fields at 1/10°, daily** resolution
- Mean **velocity integrated across top 50m** of water column
- Domain bounded by **120°E to 70°W, and 50°N to 30°S**
- Virtual FAD particles (**vFADs**) advected using a **6-hour time-step,** with positions **saved at weekly intervals**
- New **FAD seeding at weekly intervals** during deployment periods
- Drift-trajectories simulated for further two years after final deployment

Origin Zones (EZ and FZ)

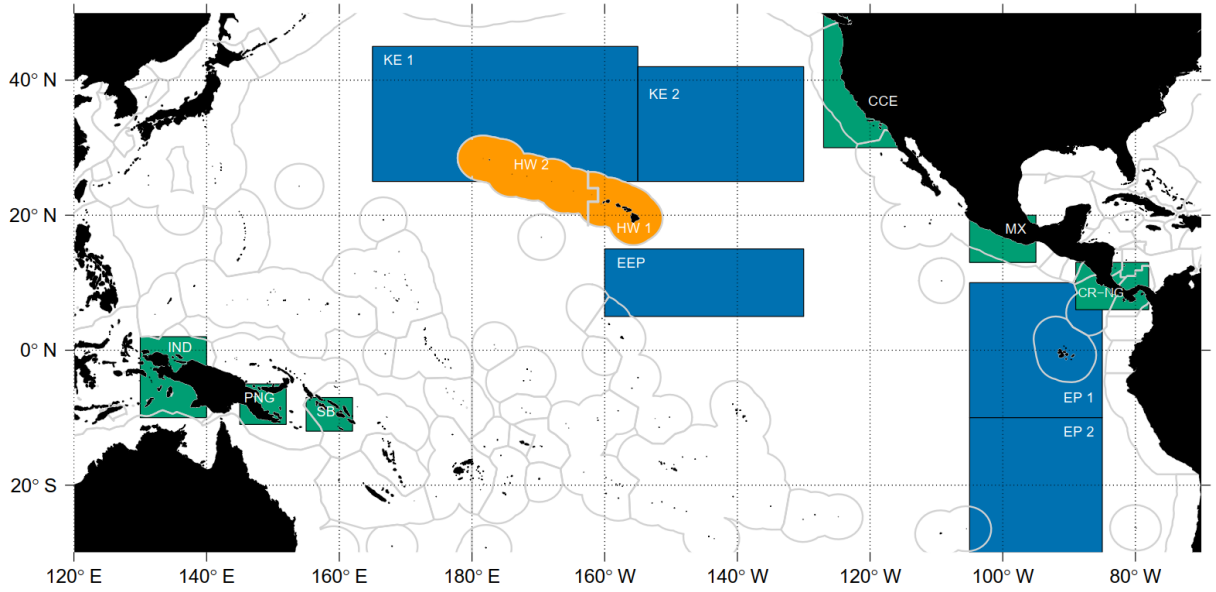
- Based on area of **tropical tuna fishing ground**
- Divided into **WCPO and EPO** origin zones
- Zoning into **16 equatorial deployment areas**, spread across both convention areas **(EZs)**
- Alternatively, zones of dense, **observed FAD operations (FZs)**, divided into deployment (depl) and density hotspots (dens)



Pacific Community
Communauté du Pacifique

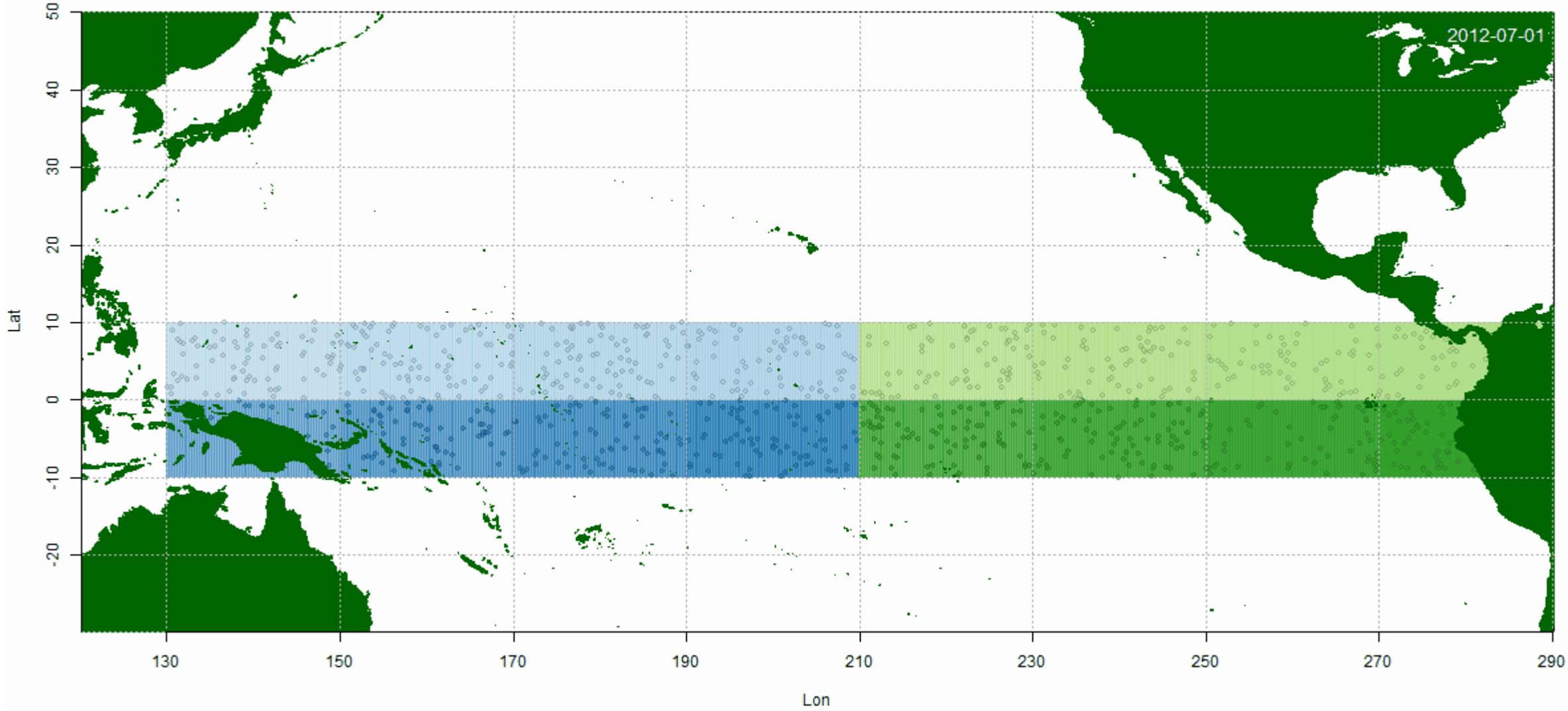
Sea Turtle Habitat Zones (TZ)

- Based on areas discussed and identified during the first part of the project
- Divided into **large oceanic or coastal sea turtle habitat zones**
- Turtle habitat zones include HI EEZ, large oceanic foraging zones, and offshore areas of continental/archipelagic nesting sites



Pacific Community
Communauté du Pacifique

FAD seeding in the equatorial region (animation: example of one-year seeding)



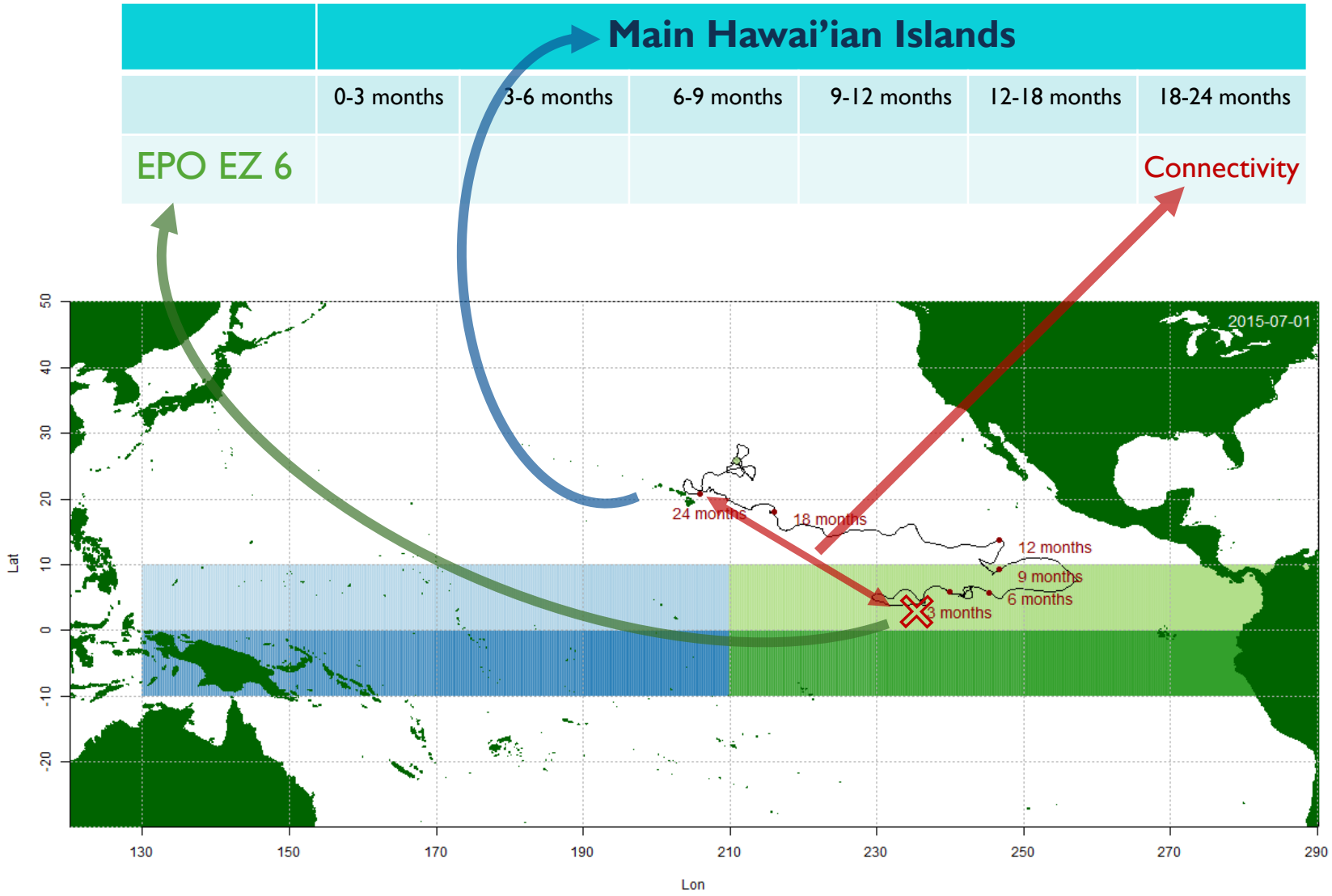
Pacific Community
Communauté du Pacifique

Quantifying Connectivity

- Connectivity based on tracking vFADs between zones
- Structured on each vFAD relative time and deployment/arrival zone
- Combine for all vFADs:

- released in an origin zone
- arriving in a destination zone
- having drifted for a certain time

- Connectivity matrices and particle density plots



Pacific Community
Communauté du Pacifique

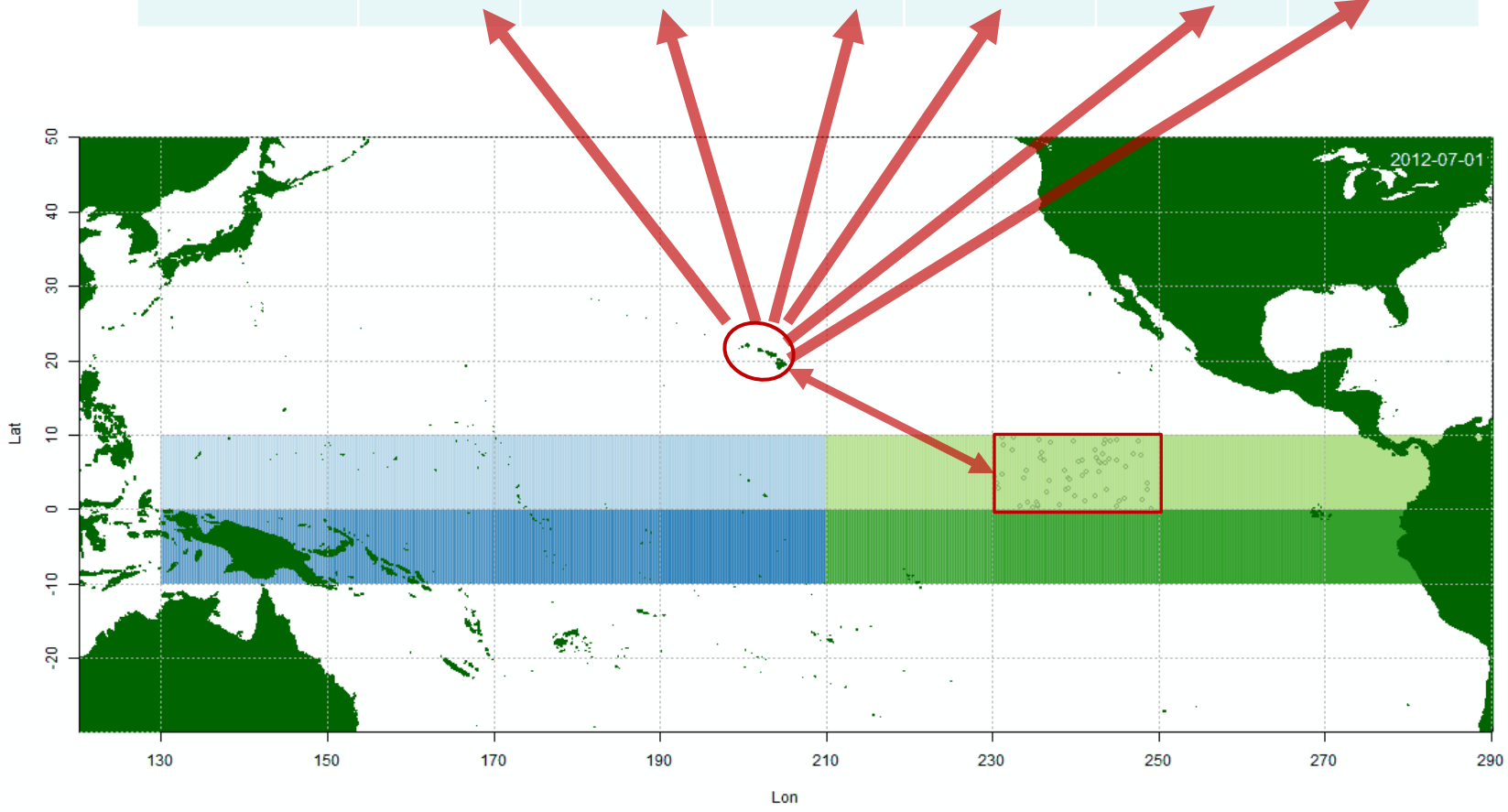
Quantifying Connectivity

- Connectivity based on tracking vFADs between zones
- Structured on each vFAD relative time and deployment/arrival zone
- Combine for all vFADs:

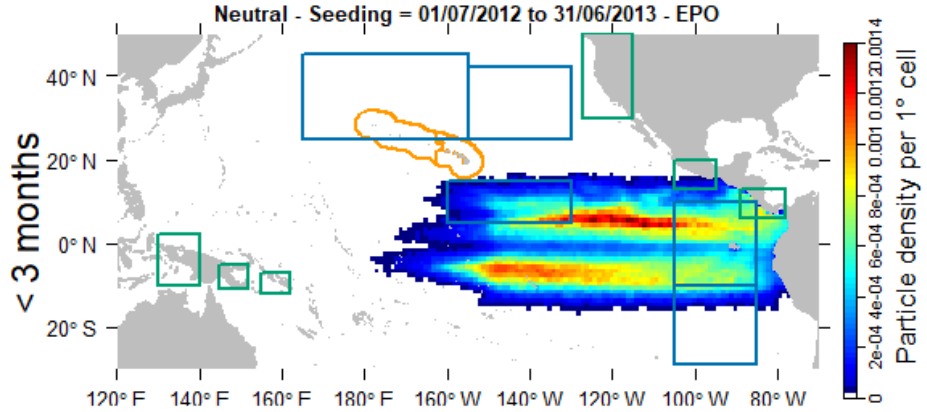
- released in an origin zone
- arriving in a destination zone
- having drifted for a certain time

- Connectivity matrices and particle density plots

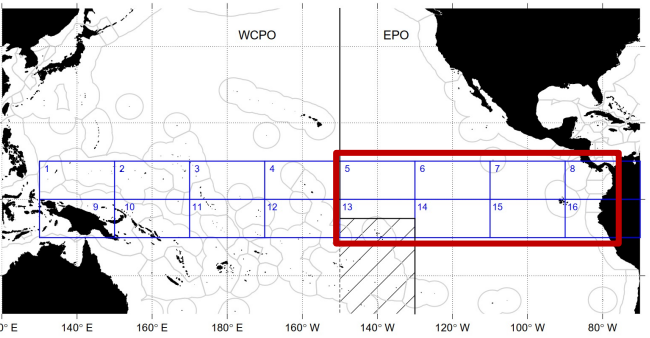
	Main Hawai'ian Islands					
	0-3 months	3-6 months	6-9 months	9-12 months	12-18 months	18-24 months
EPO EZ 6	0%	0%	0%	0.1%	1.3%	2.8%



Connectivity of vFADs between Equatorial Zones and Turtle habitat Zones - Spatial probability density



Seeding area



Connectivity of vFADs between Equatorial Zones and Turtle habitat Zones

Neutral - Seeding = 01/07/2012 to 31/06/2013

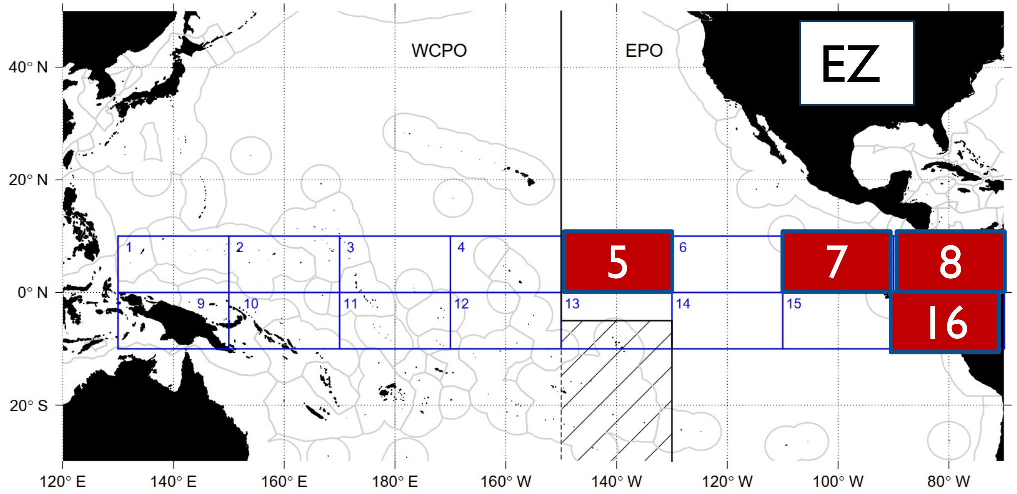
TZ	Other							KE 1							KE 2						
Months	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
EZ 5	50.5	63.5	72	74.7	71.7	66.2	58.8	0	0	0	0.2	1.6	4	5.6	0	0	0.1	0.8	4.2	8.8	16.4
6	76.8	73.6	74.1	74.2	73.7	72.6	68	0	0	0	0	0.3	1	1.9	0	0	0.2	0.7	3.4	7	13
7	53.9	61.3	62.8	64.4	70.7	74.9	75.7	0	0	0	0	0	0.2	0.6	0	0	0	0	0.3	1.4	4.2
8	39.7	46	52.6	58.1	68.3	74.7	78.6	0	0	0	0	0	0	0.1	0	0	0	0	0	0.3	0.9
EPO 13	98.6	98.7	98.1	97.4	97.1	96.5	95	0	0	0	0	0	0.1	0.3	0	0	0	0	0.1	0.2	0.5
14	98.2	98.8	98.9	99	98.9	98.7	98.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0.1	0.4
15	63.4	80.6	90	95.2	98.1	98.5	98.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
16	16.6	17.5	26.6	40.9	69.9	83.2	87.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1

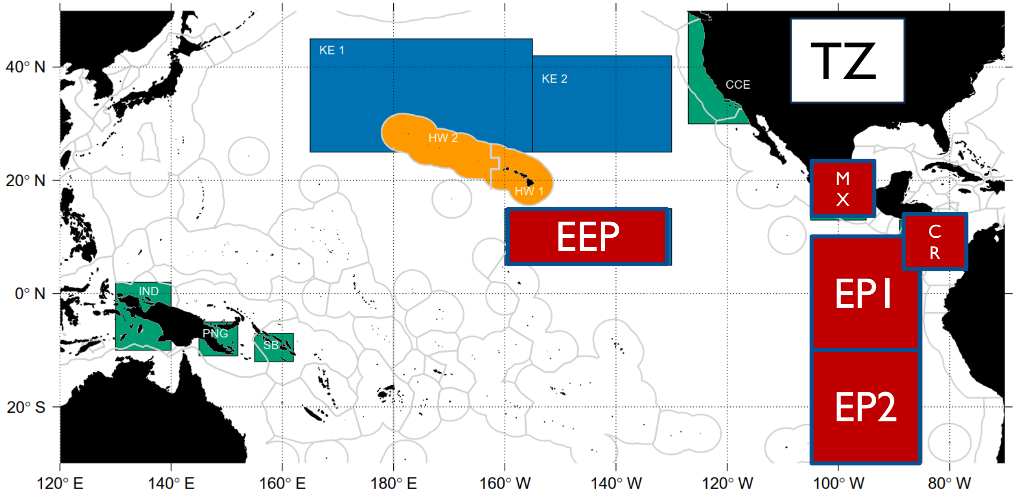
TZ	CCE							IND							PNG						
Months	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
EZ 5	0	0	0	0	0	0	0	0	0	0.2	0.2	0.1	0.2	0.3	0	0	0.1	0.1	0.1	0.2	0.2
6	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPO 13	0	0	0	0	0	0	0	0	0	0.4	0.6	0.6	0.8	1.1	0	0	0.2	0.3	0.6	0.7	1.1
14	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1	0.2
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TZ	SB							EEP							MX						
Months	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
EZ 5	0	0	0.2	0.2	0.1	0.1	0.2	49.3	29.6	14	7	2.3	1	0.4	0	0.2	0.5	1	1.4	1.8	1.1
6	0	0	0	0.1	0.1	0.1	0.1	11	12.5	9.8	7.1	3.5	1.8	1	0.6	1.4	1.4	2.3	3.6	3.8	3.2
7	0	0	0	0	0	0	0	0.4	2.2	4.1	4.2	3.6	2.4	1.5	3.5	5.6	6.2	6.7	6.9	6.6	6
8	0	0	0	0	0	0	0	0	0.3	1	1.4	2.5	2.4	1.6	1.3	6.6	10.9	12.1	9.5	7.9	7.1
EPO 13	0	0	0.5	0.8	0.9	1	1.2	1.3	1.2	0.6	0.4	0.2	0.1	0.2	0	0	0	0	0.1	0.1	0
14	0	0	0	0.1	0.1	0.2	0.3	0.4	0.6	0.5	0.3	0.2	0.1	0	0	0	0	0.1	0.1	0.1	0.1
15	0	0	0	0	0	0	0	0	0.1	0.2	0.2	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.1
16	0	0	0	0	0	0	0	0	0	0.1	0.3	0.3	0.1	0.1	0	0	0.1	0.3	0.4	0.4	0.2

TZ	CR-NG							EP 1							EP 2						
Months	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
EZ 5	0	0	0.2	0.4	0.5	0.4	0.2	0.1	3.6	5.1	4	3.6	2	1	0	0	0	0	0	0.1	0.1
6	0	0.6	1	1.5	1.5	1	0.7	11.5	11.7	12.5	11.4	8	4.9	3.1	0	0.1	0.1	0	0.2	0.4	0.4
7	4.5	4.4	3.6	3.5	2.7	1.9	1.4	37.6	25.9	22.9	20.4	13.5	8.9	5.9	0.1	0.6	0.4	0.5	1	1.1	0.8
8	24.4	16.2	9.6	5.9	3	2.3	1.9	34.6	29.2	22.7	19	13.7	9.5	6.8	0	1.7	3.3	3.4	2.7	2.1	1.4
EPO 13	0	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.1	0.1	0	0	0	0	0	0	0	0
14	0	0	0	0	0.1	0	0	1.4	0.5	0.5	0.4	0.3	0.2	0.1	0	0.1	0	0	0	0	0
15	0.1	0.1	0.1	0.1	0.1	0	0	16.4	2	0.6	0.5	0.3	0.2	0.1	20	17.2	9.1	4	1.2	0.9	1
16	0.4	0.4	0.3	0.2	0.2	0.1	0.1	53.9	22.1	6.8	2.6	1.1	0.8	0.4	29	60	66	55.6	28.1	15.2	11.3

TZ	HW 1							HW2						
Months	3	6	9	12	18	24	30	3	6	9	12	18	24	30
EZ 5	0	0	0.6	1.9	5.8	8.7	9.3	0.1	2.9	7	9.5	8.4	6.7	6.2
6	0	0	0	0.1	1.3	2.8	3.8	0	0	0.9	2.5	4.5	4.6	4.6
7	0	0	0	0	0.1	0.6	1.4	0	0	0	0.2	1.2	1.9	2.4
8	0	0	0	0	0	0.1	0.4	0	0	0	0	0.2	0.6	1
EPO 13	0	0	0	0	0.1	0.2	0.5	0	0	0.1	0.2	0.2	0.2	0.3
14	0	0	0	0	0	0.1	0.2	0	0	0	0.1	0.1	0.2	0.2
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
16	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1





Key results

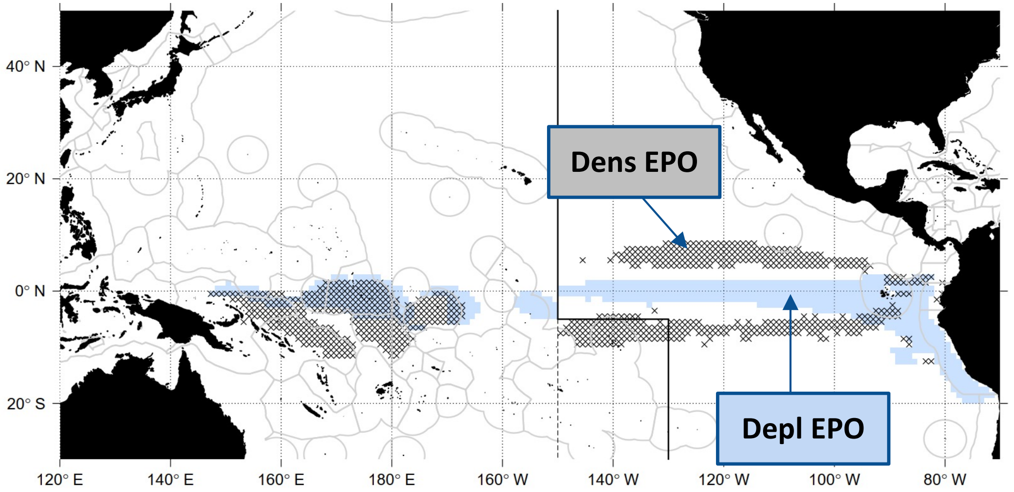
Connectivity of vFADs between FAD operational Zones and Turtle habitat Zones

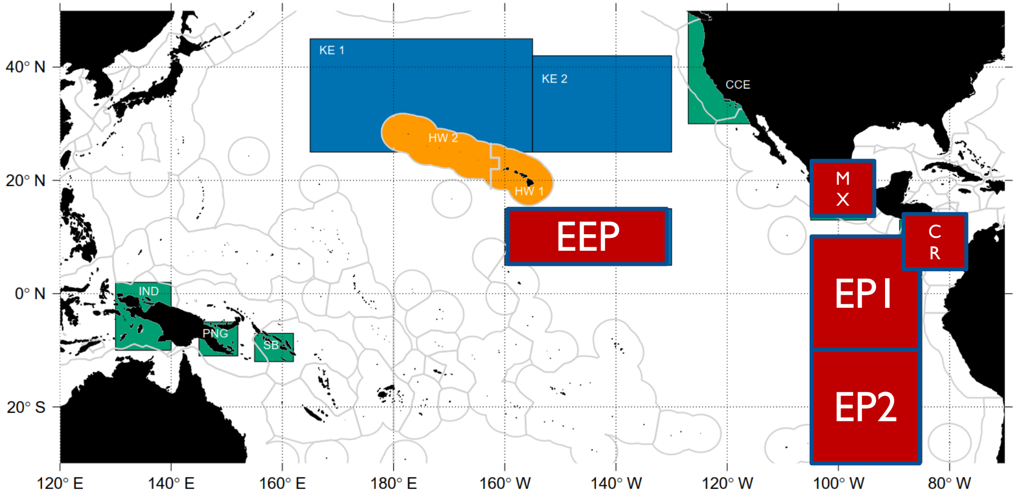
Neutral - Seeding = 01/07/2012 to 31/06/2013

TZ	Other							KE 1							KE 2							CCE							IND						
Months / FZ	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
Depl WCPO	94.2	87.6	86.7	87.3	87.1	85.8	84.8	0	0	0	0	0.3	1	2.4	0	0	0	0	0.2	0.6	0.6	0	0	0	0	0	0	0	1.4	4	5.1	4.9	4.4	4.1	4.1
Dens WCPO	92.2	86.5	86.2	86.8	86.8	85.9	86.4	0	0	0	0	0.1	0.5	1.3	0	0	0	0	0.1	0.2	0.2	0	0	0	0	0	0	0	1.6	4.4	5.1	4.8	4.8	4.6	4.1
Depl EPO	59.9	66.4	71.8	76.9	84.4	87.2	86.1	0	0	0	0	0.1	0.4	0.9	0	0	0	0	0.4	1.2	3	0	0	0	0	0	0	0	0	0	0.1	0.2	0.1	0.2	0.3
Dens EPO	74.7	79.4	82.5	84.1	85.8	86.2	84.9	0	0	0	0	0.2	0.4	0.6	0	0	0.1	0.2	1.3	2.7	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1

TZ	PNG							SB							EEP							MX							CR-NG						
Months / FZ	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
Depl WCPO	0.8	1.7	2.4	2.8	2.9	3	2.9	1.6	3.1	3.1	2.9	2.7	2.4	2.1	2	3.5	2.4	1.3	0.5	0.7	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dens WCPO	1.4	2.8	3.4	3.6	3.7	3.9	3.5	4.3	5	4.3	3.8	3.4	3.2	2.8	0.5	1.3	0.9	0.5	0.3	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depl EPO	0	0	0.1	0.1	0.1	0.2	0.3	0	0	0.1	0.2	0.2	0.3	0.4	5.4	5.7	4.2	2.9	1.6	0.8	0.4	0.1	0.4	0.6	0.9	1.3	1.4	1.1	0.5	0.6	0.5	0.5	0.6	0.4	0.2
Dens EPO	0	0	0	0	0	0.1	0.1	0	0	0	0.1	0.1	0.1	0.2	4.9	4.5	3.5	2.8	1.6	1	0.6	0.4	0.9	1.2	1.8	2.2	2.2	2.1	0.8	1	1	1	0.9	0.6	0.5

TZ	EP 1							EP 2							HW 1							HW2						
Months / FZ	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30	3	6	9	12	18	24	30
Depl WCPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.9	1.5	2	0	0	0.2	0.7	1.1	0.8	0.7
Dens WCPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.7	1	0	0	0.1	0.3	0.4	0.4	0.4
Depl EPO	26	10.4	6.6	5.1	3.3	2	1.2	8.1	16.4	15.7	12.3	6.2	3.4	2.7	0	0	0	0.1	0.5	1.1	1.8	0	0	0.3	0.8	1.3	1.3	1.6
Dens EPO	15	9.7	8	6.8	4.6	3	2	4.1	4.4	3.1	2	0.9	0.7	0.6	0	0	0	0.1	0.7	1.2	1.3	0	0.1	0.6	1.2	1.8	1.9	1.9





For FADs deployed in the EPO, the main areas of concern appear to be:

1. **Oceanic leatherback migration and feeding grounds (EP1 and EP2):** dense aggregation of FADs deployed in the EPO over short to moderate drift-durations (0-18 months).

2. **Coastal and oceanic habitats/nesting sites around Mexico, Costa Rica and Panama:** connectivity to the neighboring equatorial zones, mitigated against by the current deployment distribution of FADs in the EPO.

3. **Large, eastern equatorial leatherback turtles foraging:** large numbers of FADs transiting when deployed in the equatorial zones north of the equator, from both the EPO and WCPO.

Take home messages

- **Interaction and connectivity between vFADs and sea turtles reduced under current deployment scenarios**

A northern shift in FAD deployment positions could lead to higher vFADs arrival in many important oceanic sea turtles habitat and the Hawaiian EEZ.

- **Higher vFAD connectivity is detected with oceanic and coastal key turtle habitat located along the equatorial region**

Changes in the lifespan of FADs, through adoption of new designs, such as biodegradable FAD designs, could therefore largely reduce the number of FAD reaching non-equatorial zones, but would likely still reach the important near-by habitat and nesting zones.

- **vFADs released in the EPO exhibited more dense aggregation after long drift time**, with local retention, centered in the southern Pacific Ocean gyre and off the coast of Central America

Recommendations

1. **Given the overlap of FADs with turtles oceanic and coastal habitats, consider no netting materials for FAD construction and eliminate potential entanglement.**

2. **Consider expanding the research and exploration of spatial-management options for FADs, based on the results of the current work; potential connectivity between FADs and sea turtle habitats in the central equatorial Pacific, archipelagic areas of the western warm pool, and the south east Pacific Ocean gyre seems significant for the whole equatorial zone and reduced for known FAD deployment/density hotspots.**

3. **Conduct additional research to better understand the magnitude and effect of at-sea interactions between active or abandoned FADs and at-risk sea turtle populations.**

4. **Support the continuation of the work, using observed and simulated FAD trajectories, to quantify the connectivity, and potential interaction, of FADs and sea turtle habitats assuming that fully non-entangling, without netting, and biodegradable FADs management measures are implemented.**

Questions ?

Acknowledgments

In the EPO, FAD density and deployment hotspots were identified using the IATTC buoy and observer databases. In the WCPO, hotspots of FAD deployments and FAD densities are derived from Escalle *et al.* (2021b), based on the PNA FAD tracking database. Passive drift simulations were run on resources and services from the National Computational Infrastructure (NCI), which is supported by the Australian Government. The authors thank Scott Benson, Maxime Lalire, and Irene Kelly for their participation to the Lagrangian simulation preparatory workshops; their expertise and advice helped design the experiment presented in this report. This project received funding under award NA20NMF4540142 from NOAA Fisheries Pacific Islands Regional Office. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA.

For additional information, send an email to laurianee@spc.int or gmoreno@iss-foundation.org

ISSF INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION

Addressing key research to inform Mobula rays conservation in the Pacific Ocean

Moreno, G.[1], Murua, J.[2], Cronin, M.[3], Murua, H.[1] Ferarios, JM.[2], Lezama, N.[4], Swimmer, Y.[5], Restrepo, V.[1]

U.S. Tropical Tuna Purse seine fleet:
Cape Fisheries, Western Pacific Fisheries, GS Fisheries,
Pacific Princcess Partnership, Da Silva Sea Encounter corp., AACH Holding

AZTI
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

UNIVERSITY OF CALIFORNIA SANTA CRUZ

NOAA FISHERIES

Objectives

1. **Purse seine - Mobula spp interactions and population structure**

2. **Design and testing of a sorting grid for Mobulas and evaluate post-release mortality**

3. **Outreach to fishers, scientists and managers.**

Recommendations

That the 11th Meeting of the Bycatch Working Group NOTES document BYC-11-INF-C, on the project to define best handling practices and conservation recommendations to reduce the impact of purse-seine fishery on Mobula species.