A short-lived FAD in the Pacific: Implications and Adaptations in the Move to Biodegradable Fish Aggregating Devices

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Summary

A transition to the widespread use of biodegradable fish aggregating devices in the Pacific ocean will reduce marine pollution through earlier breakdown of drifting FAD components and reduced stranding and beaching. However, there may also be negative impacts to some fishing fleets through a premature loss of still operational FADs drifting within the equatorial purse seine fishing ground, and these impacts may vary spatially in response to ocean circulation and FAD deployment strategies.

Here, we outline results from a passive drift simulation study using estimated FAD deployments and ocean currents from a basin-scale physical ocean circulation model, to quantify the potential reduction in both FADs lost outside of the equatorial fishing ground and those that will prematurely breakdown, under different bio-FAD lifetime scenarios.

Results indicate that implementing a one-year physical degradation threshold for FADs yields the most substantial reduction in FADs exiting equatorial fishing grounds in the Western and Central Pacific Ocean. However, this benefit is offset by a 2–4x increase in the number of FADs degrading while still being potentially fishable, limiting their effectiveness for some deployment regions.

Our work highlights the need to potentially balance the environmental mitigation strategies that bio-FADs offer with the functional utility of FADs and their deployment locations. It further emphasizes considerations related to FAD maintenance, the potential for premature loss of operational units, and the possibility of compensatory responses by fishing fleets—specifically, increased deployment rates—to maintain catch efficiency.

Introduction

Drifting fish aggregating devices (FADs) are a dominant fishing method in tropical tuna fisheries, with annual deployments in the Pacific Ocean reaching up to 65,000 (Escalle et al., 2021; Lopez et al., 2024). The widespread use of FADs has raised ecological concerns, including bycatch of vulnerable species, increased capture of juvenile tuna, and their contribution to marine pollution when lost or abandoned (Escalle et al., 2023; Lezama-Ochoa et al., 2017; Scutt Phillips et al., 2017). Many FADs drift out of operational areas and strand in sensitive coastal regions, notably in the Pacific, prompting efforts to develop more environmentally responsible alternatives (Escalle et al., 2023; Escalle, L., Muller, B., Scutt Phillips, J., Brouwer, S., Pilling, G., 2019; Mourot et al., 2023).

In response, several Regional Fisheries Management Organisations (RFMOs) have endorsed or mandated a shift to biodegradable FADs (bio-FADs), which are designed to disintegrate more quickly and reduce long-term marine debris (Murua et al., 2023). Full transition deadlines vary by organization, with the IATTC, IOTC, and ICCAT aiming for complete adoption by 2030, 2029, and 2028, respectively (IATTC C-23-04; IOTC Res 24/02; ICCAT Rec 24-01). While bio-FADs would ideally meet the functional needs of fishing operations for up to around a one year lifetime (Moreno et al., 2016), they are inherently shorter-lived than conventional FADs, the components of which can persist in the ocean for up to eight years (Mourot et al., 2023). Understanding both the operational and physical lifetimes of bio-FADs is critical for evaluating their ecological and economic implications.

Despite improved satellite tracking, there are significant data gaps in FAD behaviour after they exit fishing grounds. Drift simulations suggest spatial and seasonal variability in FAD loss patterns, with known stranding hotspots in areas like French Polynesia and Papua New Guinea (Escalle et al., 2019, 2023; Scutt Phillips et al., 2019). Premature degradation of bio-FADs may also reduce FAD availability within operational zones, potentially prompting increased deployments to maintain catch rates and undermining sustainability. Given variable fleet behaviour and jurisdictional overlap (Lopez et al., 2024), assessing bio-FAD effectiveness requires spatially explicit modelling. To that end, this paper details a simulation study that uses high-resolution Lagrangian simulations to examine FAD drift trajectories and quantify changes in loss patterns, addressing how bio-FAD adoption may reshape the distribution and fate of FADs in the equatorial Pacific.

Methods

Drift simulations of fish aggregating devices (FADs) were conducted using the Parcels Lagrangian modelling framework (Delandmeter & van Sebille, 2019) and ocean current data from the Bluelink Reanalysis 2020 model (Chamberlain et al., 2021). The simulations used surface to 50 m depth current velocities at a 1/10° spatial resolution across the Pacific Ocean (120°E–90°W, 50°N–30°S), reflecting the typical depth of FAD tails (Escalle et al., 2023; Lopez et al., 2024). Only physical ocean currents were used to drive FAD drift, excluding additional forces such as windage or Stokes drift, in order to focus on broad-scale drift patterns rather than nearshore dynamics or beaching events.

Virtual FADs were seeded weekly across 10 years (2007–2016) in grid cells representing the top 10% of observed deployment densities within both the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC) areas. Deployment locations were based on observer and tracking data from 2016–2020 (Escalle et al., 2023; Lopez et al., 2024). Particle drift was simulated with a fourth-order Runge-Kutta advection scheme and results were archived weekly. Seasonal and annual drift patterns were captured by aggregating outputs by relative drift time, rather than by calendar year.

To evaluate the consequences of biodegradable FAD adoption, simulations incorporated different physical lifetime scenarios: 4, 9, and 12 months, compared to a two-year “status quo” representing conventional FADs (Escalle et al., 2023; G. Moreno, pers. comm.). Operational lifetime was defined by FAD retention within the equatorial fishing zone (10°N–10°S), which we subdivided into 16 spatial boxes covering the key fishing ground for purse seine. FADs were considered lost once they exited this zone before physically degrading. Analyses focused on changes in the density of lost FADs, identification of primary pathways of loss out of the equatorial zone, and the relative reduction of operational FADs due to premature degradation under each scenario.

Results

Under the status quo scenario, FADs drift widely across the Pacific, with highest densities between 10°S and 10°N, especially west of 180° and around 155°E in the WCPO. Drift-time until FADs exit the fishing zone varied by deployment region, with longer operational durations in parts of the eastern EPO and southern WCPO, and shorter durations in northeastern WCPO and southeastern EPO regions (Figure 1). FADs deployed near the equator remained operational for around 9 to 10 months on average. Some seasonal differences were evident, particularly in the northern EPO, where drift durations varied by up to four months depending on the quarter of deployment.

Reducing physical lifetimes to one year or less substantially confines FAD drift to the equatorial fishing grounds. When assuming only four months of drift, nearly all FADs remain within 10°N–10°S, indicating that very short physical lifetimes will significantly limit dispersal and loss of FADs outside of the equatorial fishing ground and reduce the presence and stranding of FADs in more peripheral areas.

Reductions in physical lifetime had a clear impact on both the quantity and spatial origin of lost FADs. A one-year physical lifetime reduced overall FAD loss from the equatorial fishing grounds by 16.1%, with the majority of reductions occurring in the WCPO (Figure 2). However, shorter lifetimes increased the premature loss of FADs still within the fishing zone by 224% to 956% compared to the status quo. When examining by the deployment origin of FADs regionally, the greatest reductions in operational FADs due to shorter lifetimes were observed for deployments in Central America, the Gilbert Islands, the Solomon Islands, and the central Pacific (Figure 3). Median operational losses were 14% and 16% for WCPO and EPO deployments, respectively, under a one-year physical lifetime scenario.

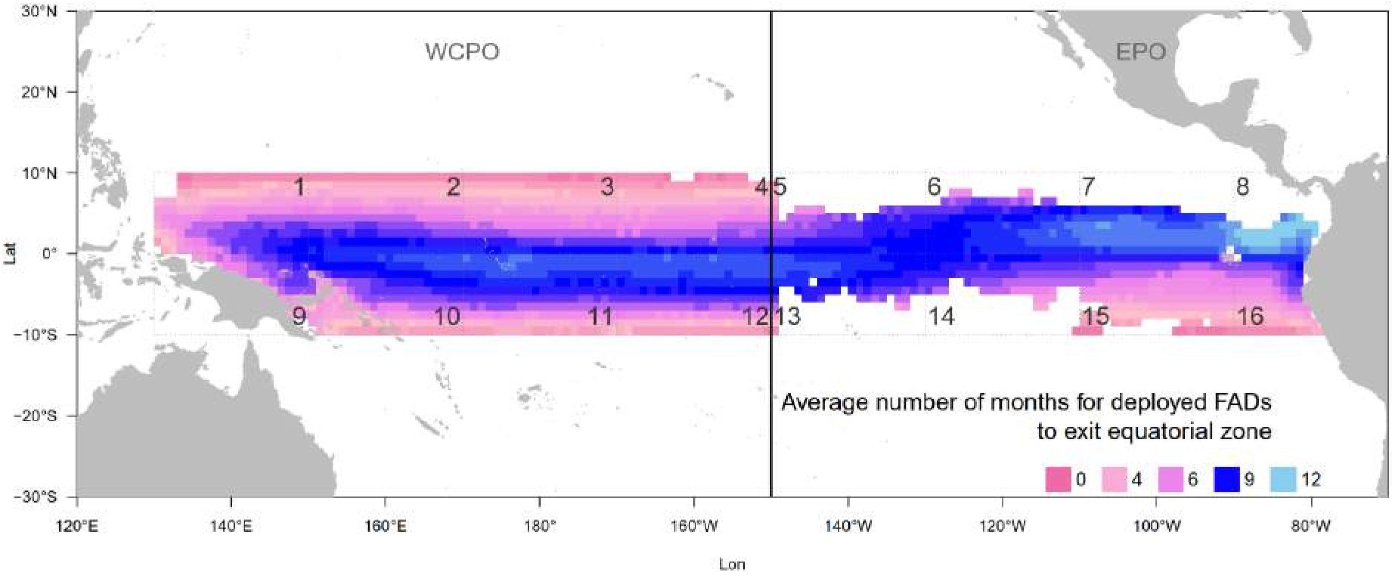

Figure 1. *Average time for simulated FADs to leave the equatorial fishing zone, across all time-periods and shown by one-degree cell of deployment*

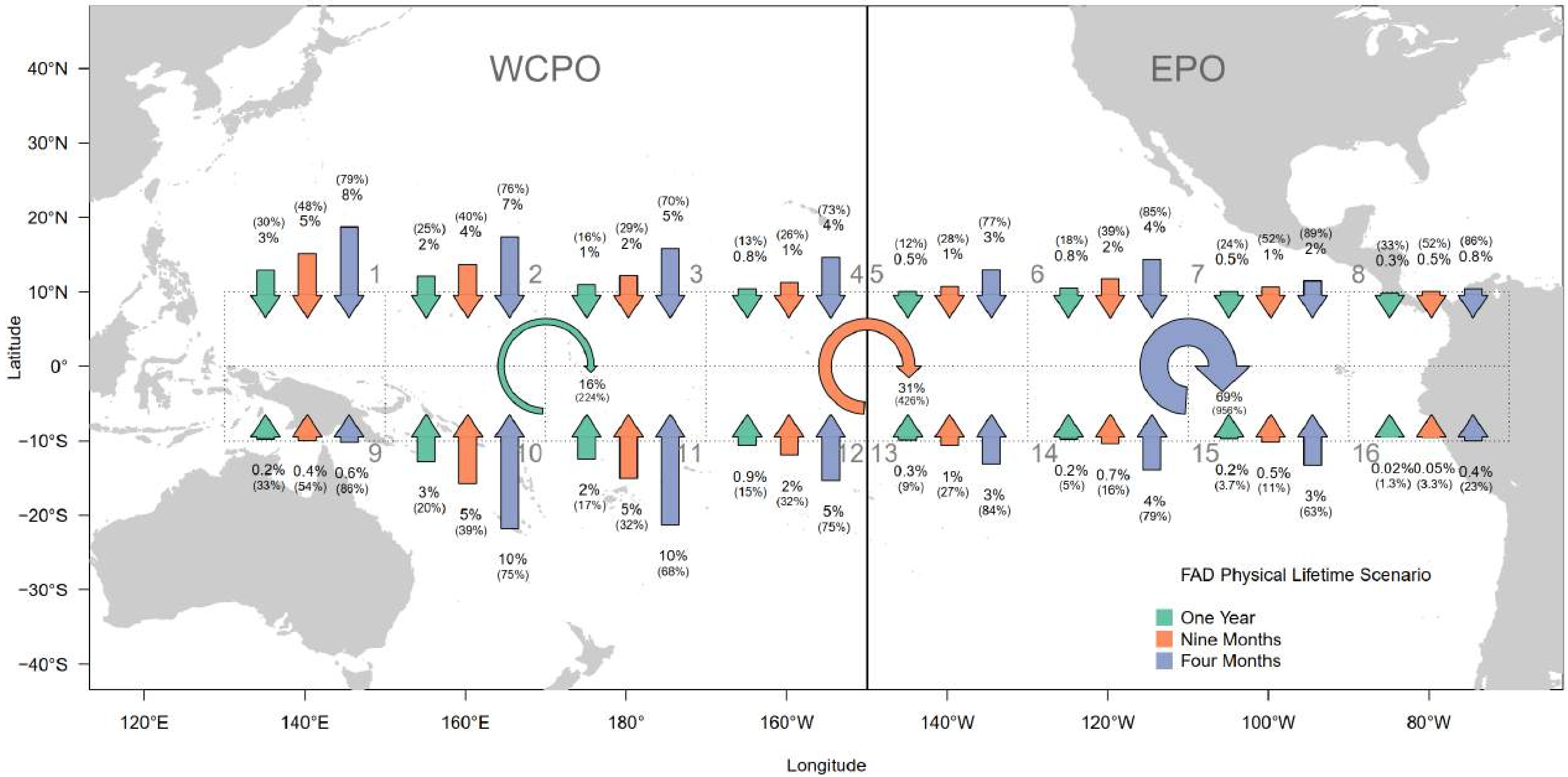

Figure 2. *Changes in FAD loss from each equatorial fishing zone compared to the two-year lifetime status quo (arrows), under differing bio-FAD lifetime scenarios. The absolute reduction in percentage FAD loss (from Figure 3) is shown for each zone, with the relative decrease given in parentheses. Within the equatorial area, the relative increase in FADs reaching the end of their physical lifetime while still retained in the fishing zone is indicated (circular arrows).*

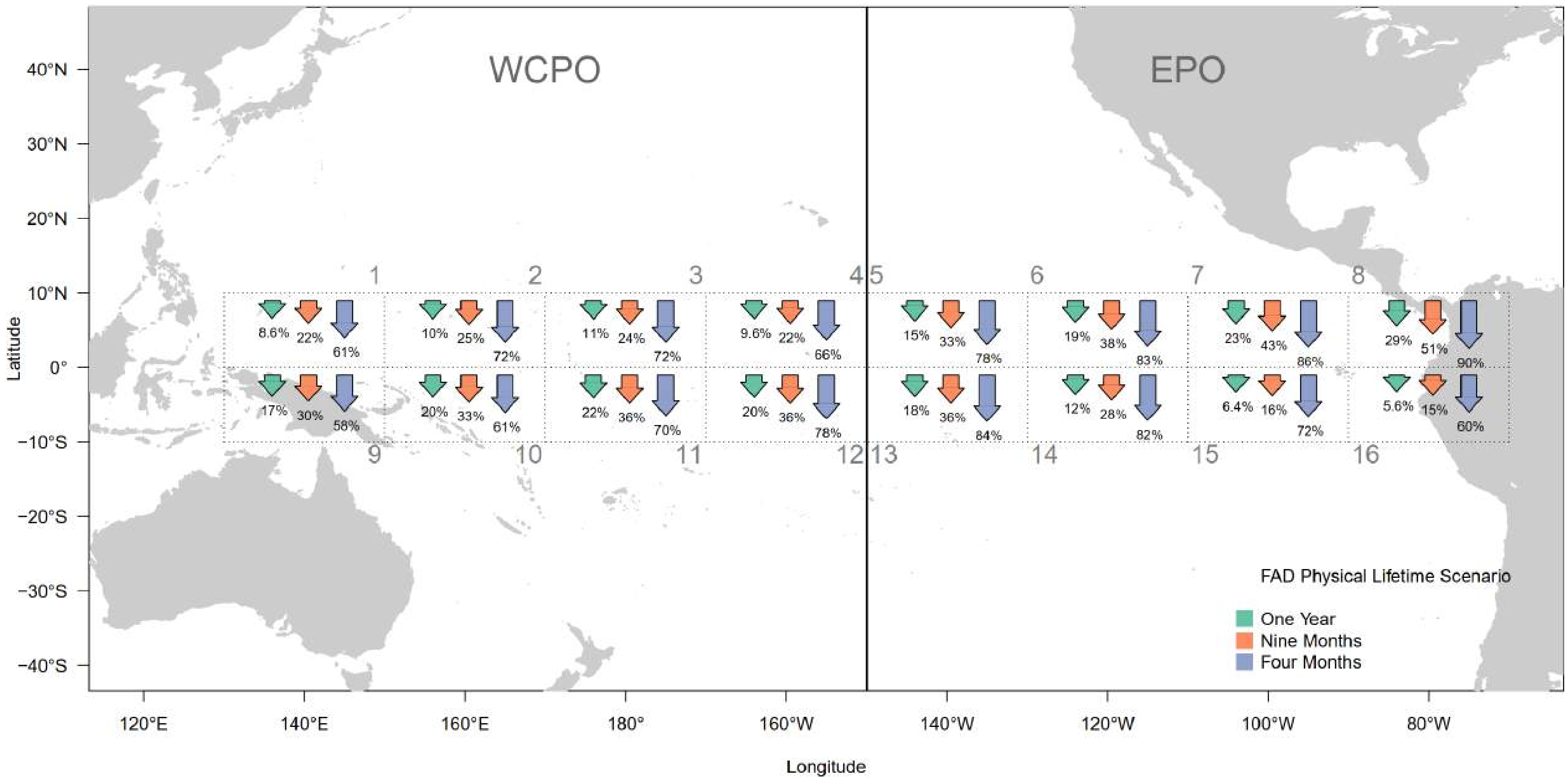

Figure 3. *Relative reduction in operational FADs within the equatorial fishing zone due to shortened physical lifetimes, compared to the status quo scenario, separated by equatorial fishing zone of initial deployment*

Discussion

Our findings show that transitioning to bio-FADs with shorter physical lifespans (9–12 months) could significantly reduce the number of FADs lost outside the equatorial fishing ground, particularly in the WCPO. The strongest reductions were observed in regions such as Palau and the Federated States of Micronesia (Region 1), and the Republic of the Marshall Islands (Region 2), where 25–48% of FADs that would otherwise drift out of bounds are retained or degrade before reaching sensitive areas. Southern WCPO zones (Regions 10–11) showed 17–39% reductions, excluding Papua New Guinea. These patterns align with previous studies of FAD drift dynamics which show consistent FAD leakage southwards or into peripheral EEZs via equatorial and poleward currents. However, in equatorial regions like Tuvalu and PNG where FADs are still within fishing zones at the time of stranding or beaching, the benefits of biodegradability may less immediate or visible (Escalle et al., 2019).

These environmental gains come with trade-offs in operational FAD lifetimes, especially for fleets that rely on extended FAD availability for fishing efficiency. Our simulations suggest that under a one-year bio-FAD physical lifetime, approximately 12,300 FADs would be lost prematurely each year across the Pacific—9,400 in the WCPO and 2,900 in the EPO (Table 1). This includes over 3,300 FADs in Region 11 (Solomon Islands) and 2,100 in Region 12 (Gilbert Islands), where current-driven entrainment can be most intense. Central American fleets may experience 31–52% operational losses, though many already operate mixed strategies and face high natural drift rates (Lopez et al., 2024). Fleets that depend heavily on FADs deployed by others—such as those using drifted IATTC FADs in WCPFC zones—could face substantial challenges under shortened lifespans (Lennert-Cody et al., 2018), especially given RFMO limits on active FADs (IATTC Resolution C-24-01; WCPFC CMM 2023-01).

Strategic responses could include increased deployments, although this risks escalating costs and intensifying environmental impacts such as stranding in vulnerable areas within the fishing ground like Tuvalu and the Solomon Islands. Instead, adaptive solutions—such as collaborative fleet management, enhanced repair and redeployment, or FAD recovery programs already encouraged by three tuna RFMOs—offer more sustainable paths (ISSF, 2023; Zudaire et al., 2018). The ecological upside of using biodegradable materials, which reduce long-term pollution and reef entanglement risks even after partial disintegration, remains substantial (Mourot et al., 2023). However, whether reduced FAD density would alter tuna aggregation behaviour or catchability is still uncertain, with some evidence suggesting possible compensation through larger schools forming around fewer FADs (Dupaix et al., 2024; Nooteboom et al., 2023).

Future work should focus on simulating fishery adaptations using agent-based bio-economic models like Poseidon (Bailey et al., 2019), which can account for variability in fleet strategies, operational needs, and bio-FAD design trade-offs. Investigating how FAD degradation timing, design features (e.g. raft configuration, appendage length), and regional oceanography interact will improve the predictability and management of FAD drift outcomes (Zhang et al., 2024). Enhanced collaboration between fishers, scientists, and managers, alongside improved spatial deployment data (Escalle et al., 2023), will be essential to designing adaptive, low-impact FAD strategies—especially in regions where both operational reliance and environmental risk are high.

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