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Evaluation of dFAD construction materials in the WCPO

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Executive Summary

Drifting Fish Aggregating Devices (dFADs) are widely used in the WCPO purse seine fishery, and have the potential to lead to ecosystems impacts such as ghost fishing, tuna school fragmentation, marine pollution and damage to coral reef or coastal areas. To mitigate these impacts, through CMM 2017-01 the WCPFC encourages the use of biodegradable and non-entangling dFAD materials. This paper reviewed the materials used to construct dFADs, as recorded by observers over the last 8 years. DFAD design was divided into i) the raft itself, including some components to ensure buoyancy and often covered by old nets or sacking to reduce detection by other vessels and ii) submerged appendages. For these two parts of dFADs, the use of natural (e.g. bamboos, trees, branches, natural debris, coconut fronds, planks, pallets, timbers) and artificial (e.g. floats, metal or plastic drums, pipes, cords, ropes, sacks, bags) materials was investigated.

Over the period 2011 to 2018, less than 2% of dFADs were made of completely natural materials and between 20–35% of dFADs investigated annually (observers record during deployment, fishing, servicing or visiting a dFAD) were made of completely artificial materials. No temporal trend in material use was detected. All fleets primarily used rafts that were either i) completely artificial or ii) a mix of artificial and natural materials, with artificial submerged appendages, to construct their dFADs. Fleets using rafts with mostly natural materials (although only in 8–14% of their dFADs) were Indonesia, Philippines, and Solomon Islands, using bamboo, planks or logs in the raft, with either no appendages or artificial appendages. However, even for those fleets, the occurrence of natural rafts remained occasional, with the majority of their rafts made of floats. Some specific dFAD designs include: i) bamboo rafts used by EU Spain, Ecuador and El Salvador; and ii) Philippines design drum rafts. Appendages were, however, almost always artificial, with a combination of cord, net, sacking or sheeting and weights.

The presence of nets used as appendages on dFADs was specifically investigated as an indication of the entangling potential of dFADs. Less than 12% of the dFADs had no netting, with no trend over time. However, the analysis detected a slight increase in the use of nets in both appendages and rafts over time. Philippines (42%), Tuvalu (31%) and Indonesia (26%) were fleets using the least netting within their dFADs construction.

Overall, natural and non-entangling dFAD materials appear seldom used in the WCPO. Non-entangling dFAD designs are well known and biodegradable dFAD designs are currently on trial at sea in other oceans (see Appendices for review of non-entangling and biodegradable dFADs). However, appropriateness of these dFAD designs (e.g. cost, material availability and effectiveness) for the WCPO still needs to be investigated.

We invite WCPFC-SC14 to:

- Note the materials currently used in dFADs in the region. In particular, the limited use of non-entangling and biodegradable materials, as well as the variability among fleets.
- Note the review of biodegradable materials and non-entangling dFAD designs from research projects in other oceans.
- Consider potential research activities and at-sea trials of biodegradable and non-entangling design options in the WCPO and provide corresponding advice to the FAD Management Options Intersessional Working Group.

Introduction

Drifting Fish Aggregating Devices (dFADs) are widely used in tropical tuna purse seine fisheries to enhance the probability of catching tuna. However, several adverse effects can result, such as relatively high catches of juvenile tuna, bycatch species, and ecosystem impacts (Balderson and Martin, 2015; Filmalter et al., 2013; Leroy et al., 2013).

DFADs consist of two parts: i) the raft itself, including components to ensure buoyancy (e.g. buoys, floats, drums, pipes), and which is often covered by old nets or sacking to limit detection by other vessels or to act as a shadow to attract fish; and ii) submerged appendages to increase drag, reducing drifting speed and increasing its attractive power. DFADs have been commonly constructed with non-natural materials that are cheap and readily available, for instance old buoys or drums and fishing nets. However, these artificial materials degrade slowly and contribute to marine pollution unless the dFAD is retrieved. In addition, the presence of nets to cover the raft can lead to turtle entanglements, while underwater netting appendages can lead to both shark and turtle entanglements, which can continue when the dFAD is lost, through ghost fishing (Filmalter et al., 2013; Pilling et al., 2017).

To mitigate these impacts of dFADs on the marine ecosystem, the use of biodegradable and non-entangling dFADs (as defined in Pilling et al. (2017)) has been investigated worldwide (e.g. Lopez et al., 2016; Moreno et al., 2016). In the Western and Central Pacific Ocean (WCPO), while no specific trials have been implemented, the WCPFC encourages the use of non-entangling designs and biodegradable materials in the construction of dFADs (WCPFC, 2017). This year the Commission will also consider the adoption of measures for the implementation of non-entangling and/or biodegradable materials on dFADs (paragraph 22; WCPFC, 2017).

In this paper, we present the current materials used in dFAD construction based on records made by observers since 2011, with a focus on natural vs artificial materials and the presence of nets (i.e. entangling or non-entangling dFADs). First, patterns of natural and artificial material use in dFAD construction are examined over time and across fleets. Then, a more detailed examination of the different materials used for the raft and submerged appendages is presented.

Patterns of natural and artificial materials used

Since 2011 observers have recorded, when possible, the materials of any dFADs encountered at sea, including during deployment, fishing, servicing or visiting a dFAD. Materials considered as “natural” include bamboos, trees, branches, natural debris, coconut fronds, planks, pallets, timbers. Any other material was classified here as artificial. We note that cords, ropes, sacks and bags could be of natural origin, but were assumed within this analysis to be artificial unless otherwise specified by the observer.

The use of natural materials in dFAD construction did not vary over the last 8 years. Most dFADs recorded had a raft with a mix of natural and artificial materials, for instance bamboos or planks reinforced by some buoys to enhance buoyancy; and artificial appendages (33–47% of FADs, Figure 1). This is followed by completely artificial dFADs: the raft and appendages being made of artificial materials (20–35%). Less than 8% of dFADs had a natural raft with some artificial appendages. Finally less than 2% of the dFADs were completely natural (Figure 1), mostly due to the raft being natural with no submerged appendages.

Floating objects found at sea are sometimes used by fishers, as they aggregate tunas, and are recorded by observers as logs. These could include natural objects, potentially modified by fishers (e.g. using floats, bamboo and/or nets) or anthropomorphic debris found at sea. In these instances, the observer recorded that 50–63% of the logs were natural, and up to 80% of logs had additional artificial appendages (Figure 2).

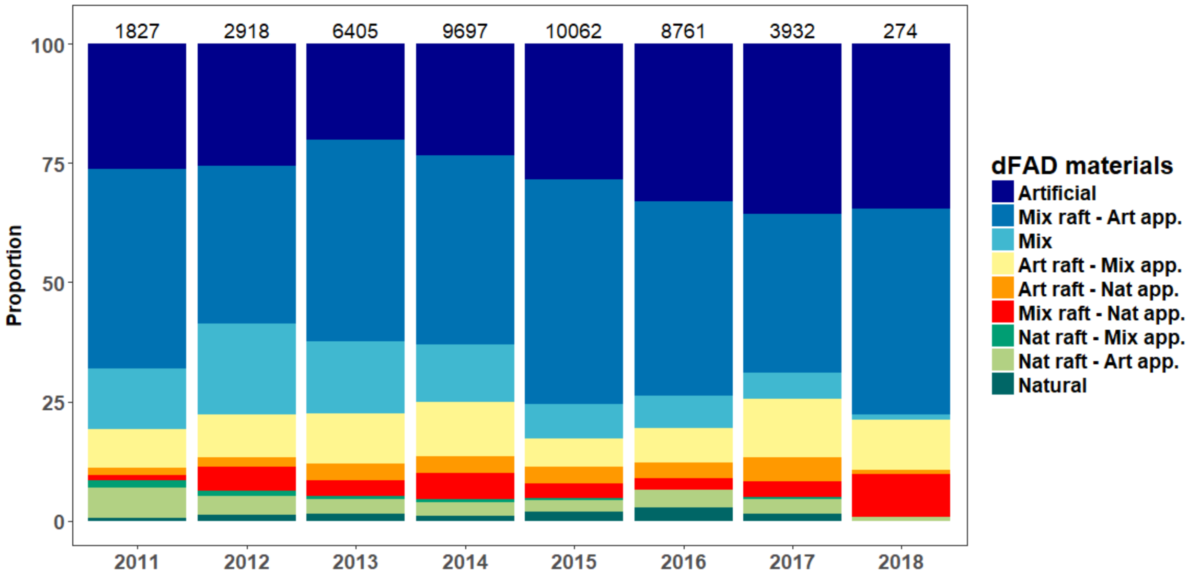

Figure 1. Proportion of dFADs per year constructed with natural (Nat), artificial (Art) or a mix of both materials in the design of the raft or the appendages (app.), as recorded by observers. Numbers on the top of the figure correspond to the number of dFADs with information on materials per year.

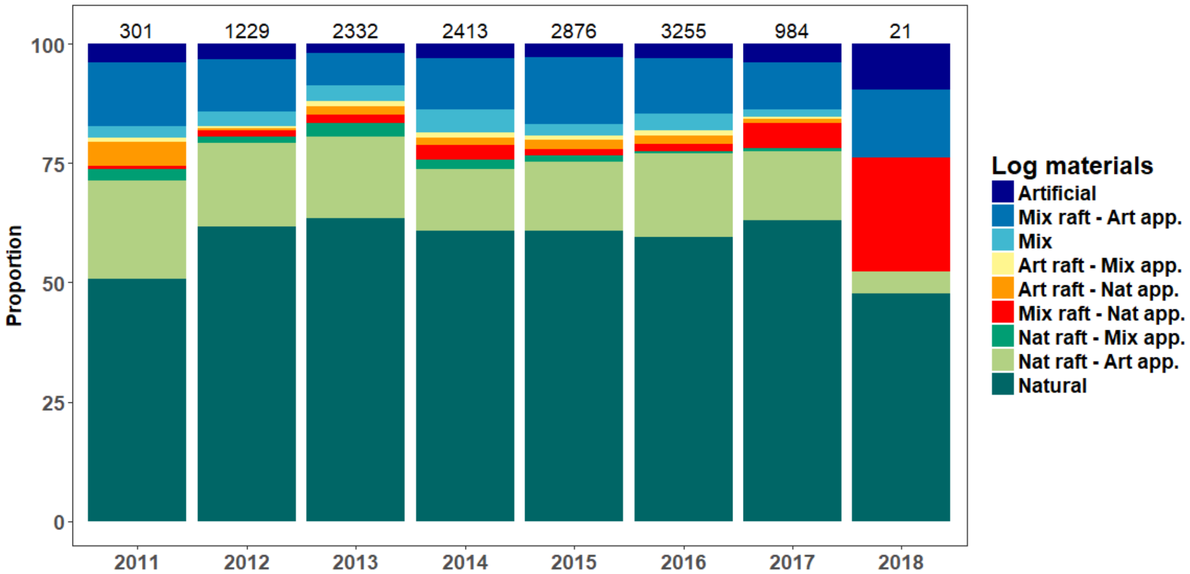

Figure 2. Proportion of logs per year constructed with natural (Nat), artificial (Art) or a mix of both materials in the design of the raft or the appendages (app.), as recorded by observers. Numbers on the top of the figure correspond to the number of logs with information on materials per year.

The bulk of dFADs deployed by fleet are made of i) completely artificial materials or ii) a mixed artificial/natural raft with artificial appendages (Figure 3). Some differences were detected for EU Spain, Ecuador and El Salvador, that use a dFAD design quite different from other fleets. DFADs deployed by these three fleets were dominated by a mixed artificial/natural raft with artificial appendages (47–88% of their dFADs). Fleets using the highest proportion of natural materials are Indonesia, Philippines, and Solomon Islands, but that proportion remains minor (8–14% of their dFADs) (Figure 3). Regarding logs, patterns did not vary between fleets, and hence reflect the general pattern described previously (Figure 2 and 4). However, some fleets had no information on log materials recorded by observers, presumably as they performed very few log sets (EU Spain, Ecuador, New Zealand, El Salvador and Tuvalu).

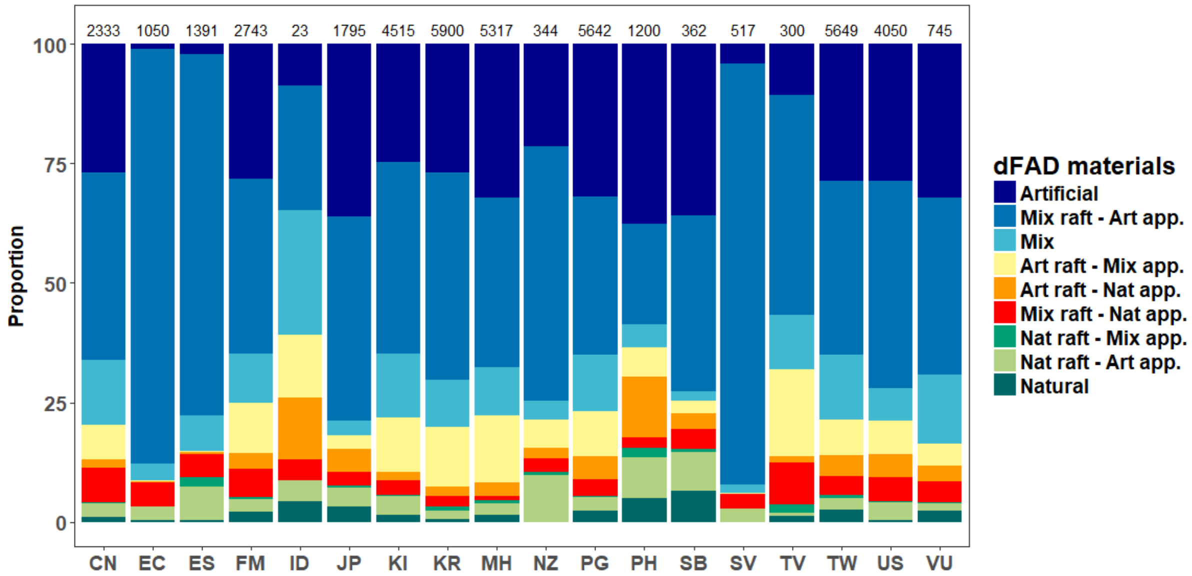

Figure 3. Proportion of natural (Nat), artificial (Art) or a mix of both materials in the design of the raft or the appendages (app.) of dFADs per fleet, as recorded by observers (2011–2018). Numbers on the top of the figure correspond to the number of dFADs with information on materials per fleet.

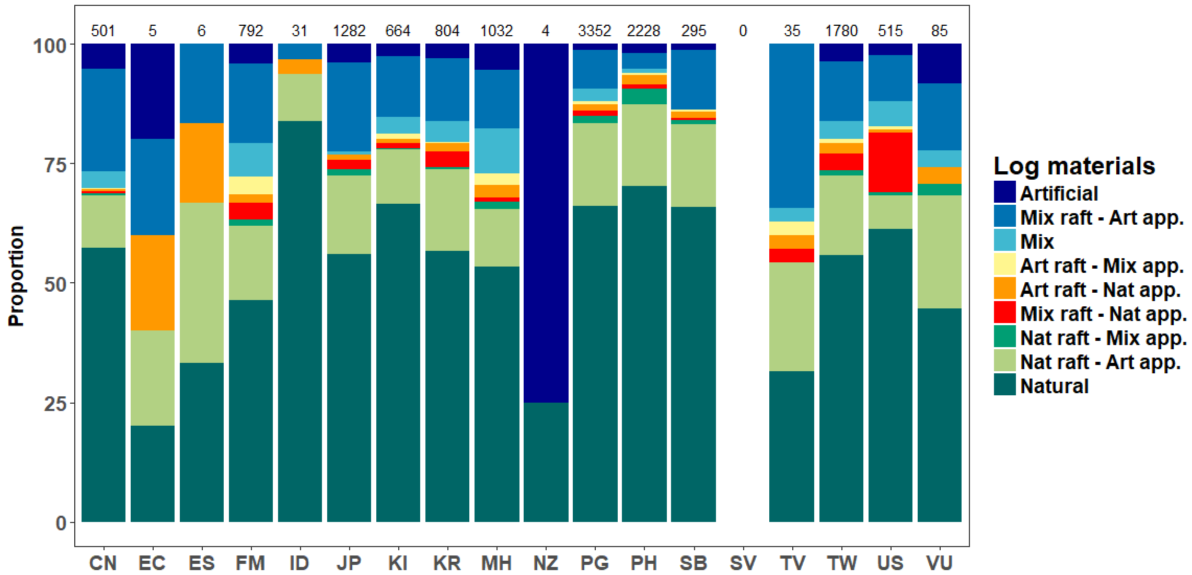

Figure 4. Proportion of natural (Nat), artificial (Art) or a mix of both materials in the design of the raft or the appendages (app.) of logs per fleet, as recorded by observers (2011–2018). Numbers on the top of the figure correspond to the number of logs with information on materials per fleet.

Details on the materials used in dFAD construction

Where natural materials are used in the construction of dFADs' rafts (see Figure 3), they include bamboo, logs (trunk, branches or other natural debris) and planks (including pallets, timbers or spools). Logs were most commonly used when some natural material is used, followed by bamboo (Figure 5). Some fleets use specific designs (Figure 5 and 7) with a high dominance of i) bamboo (EU Spain, New Zealand, El Salvador) or ii) bamboo and planks (Ecuador) for the raft, but no natural materials used in the submerged appendages (Figure 6). For the rest of the fleets, natural appendages were rarely used, but when present in appendages, included branches and coconut fronds. Note that when dFADs were recorded to be completely natural it was mostly due to the raft being natural with no submerged appendages.

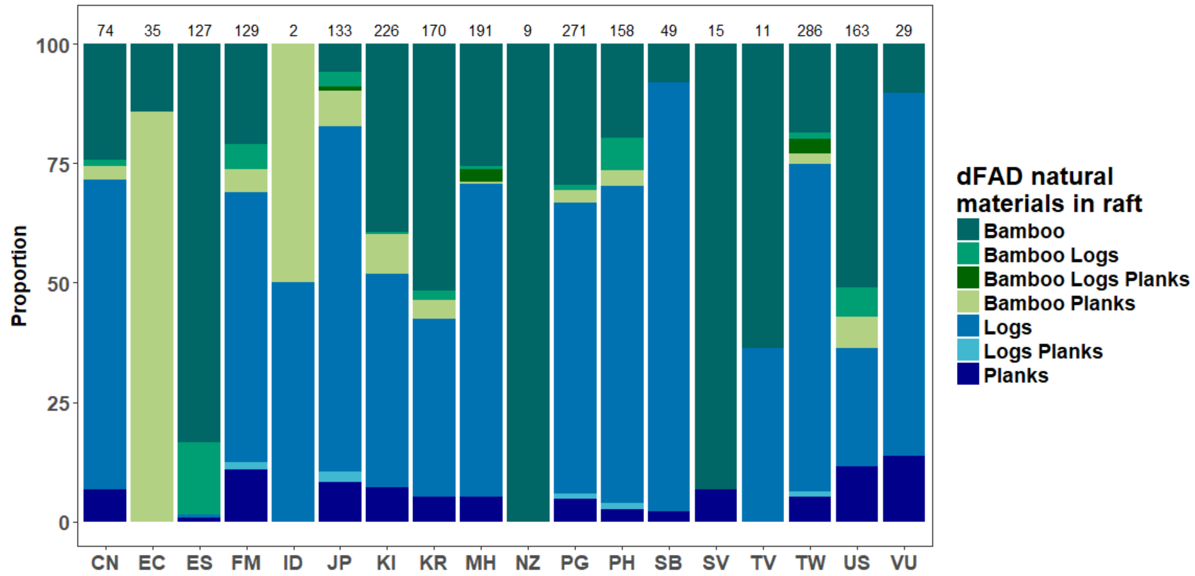

Figure 5. Natural materials used in the dFAD rafts, as recorded by observers (2011–2018). Numbers on the top of the figure correspond to the number of dFADs with natural materials in their raft.

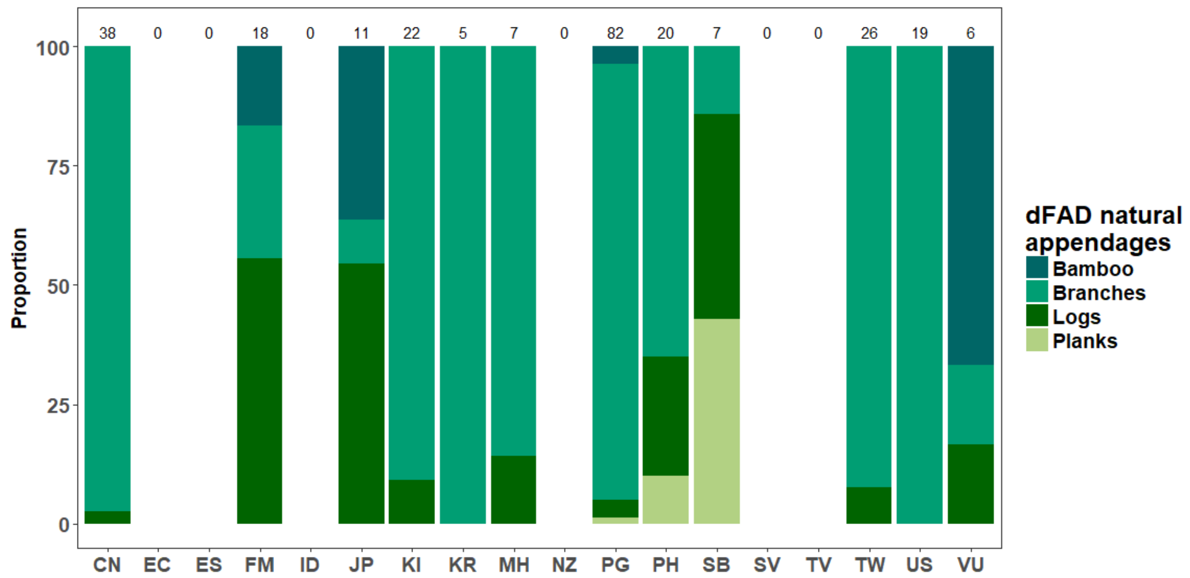

Figure 6. Natural materials (branches include coconut fronds; planks include pallets and timbers) used as dFAD appendages, as recorded by observers (2011–2018). Numbers on the top of the figure correspond to the number of dFADs with natural appendages.

Artificial materials used in the dFAD rafts are mostly floats, dominating dFAD construction for most fleets (Figure 7). However, some specific designs can be identified for some fleets. The Philippines fleet for instance used drums. El Salvador and Ecuador used pipes in 30% of their rafts containing artificial materials, and EU Spain used nets, cords or sacking in 20% of their rafts with artificial materials, where the nets, cords or sacking are likely used to reinforce or cover their bamboo rafts (Figures 5 and 7).

Finally, the types of artificial materials used in dFAD appendages are highly variable between and among fleets (Figure 8), but are mostly a combination of i) cord, net and weights; ii) net, sacking or sheeting and weight; iii) cord, net, sacking or sheeting and weigh; or iv) cord and net.

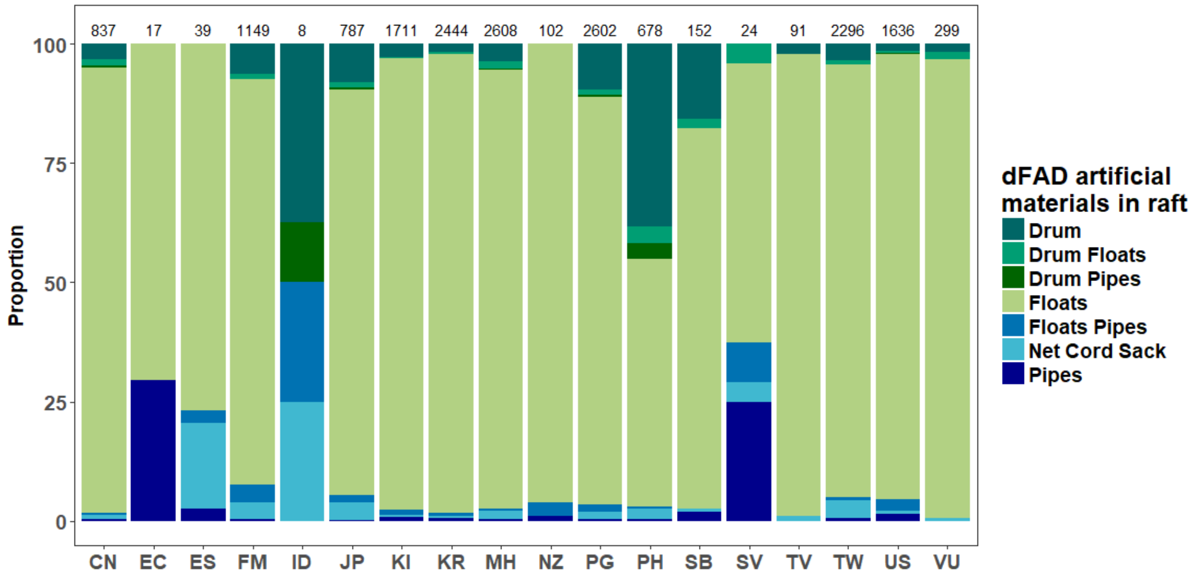

Figure 7. Artificial materials used in the dFAD rafts, as recorded by observers (2011–2018). Numbers on the top of the figure correspond to the number of dFADs with artificial materials in their rafts.

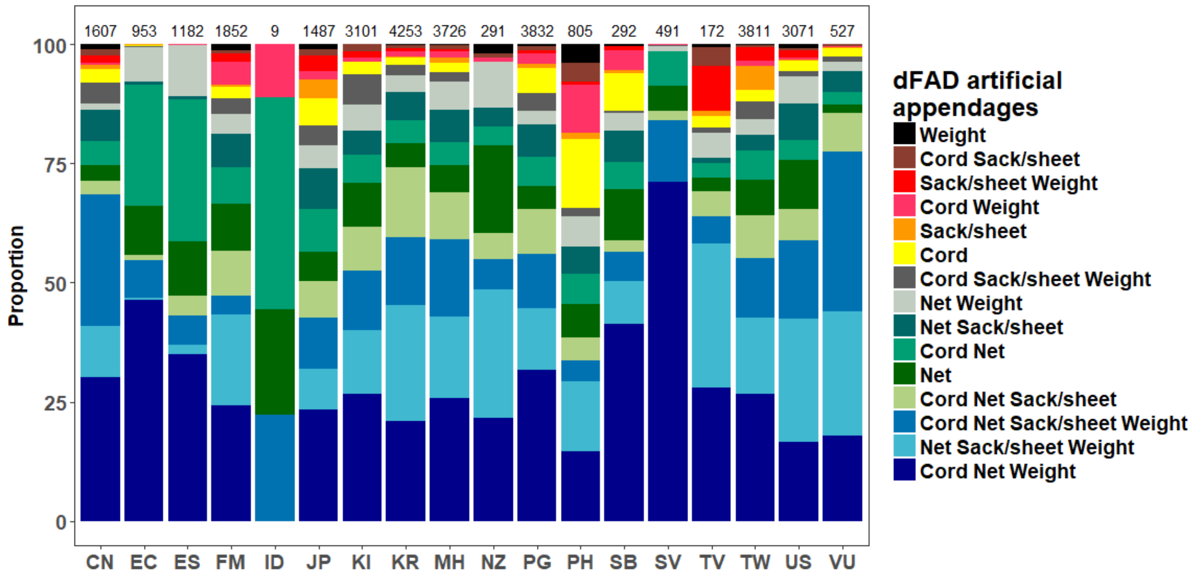

Figure 8. Artificial materials used as dFAD appendages, as recorded by observers (2011–2018). Numbers on the top of the figure corresponds to the number of dFADs with artificial appendages.

Non-entangling dFADs

The proportion of dFADs with some nets used in the raft or the appendages was investigated, as an indication of low-entangling/non-entangling dFADs. Less than 12% of observed dFADs had no nets, with no temporal trend detected. Most dFADs have at least some nets as appendages (60–90%), with a slight increase in the use of nets in both appendages and raft over time (Figure 9). Philippines, Tuvalu and Indonesia used the least netting with 42%, 31% and 26% of their dFADs observed to have none (Figure 10). El Salvador, Ecuador and New Zealand tended to use nets as appendages, being found less frequently in the raft.

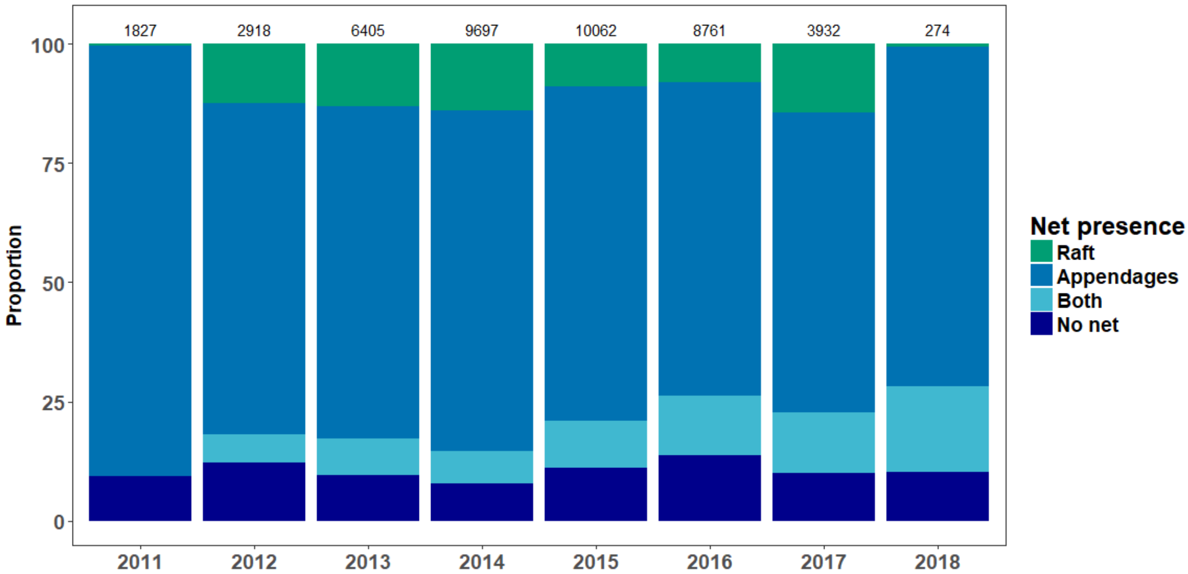

Figure 9. The use of nets in raft and appendages of dFADs, as recorded by observers per year. Numbers on the top of the figure correspond to the number of dFADs per year.

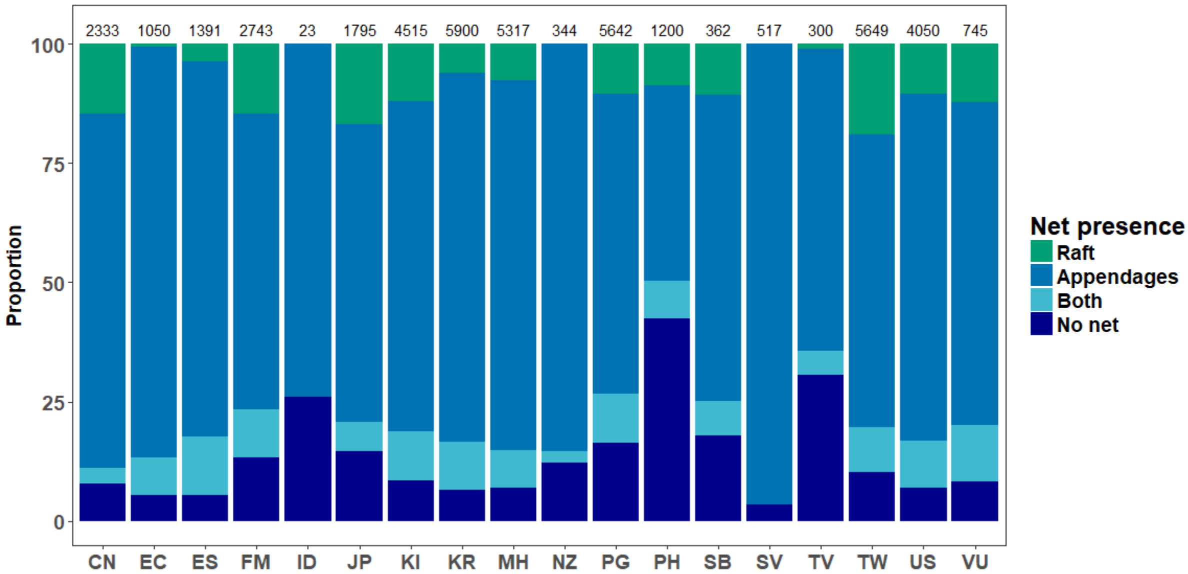

Figure 10. The use of nets in raft and appendages of dFADs, as recorded by observers per fleet (2011–2018). Numbers on the top of the figure correspond to the number of dFADs per fleet.

Discussion

Results presented in this paper, based on observer records of dFAD materials, showed that very few natural materials are used in the WCPO. No temporal trend was detected, indicating that fleets have been using the same design over the last 8 years. Most fleets use mostly floats, sometimes combined with logs as main materials for the rafts and various artificial appendages. While some fleets used a higher proportion of natural materials within their raft construction, this varied across the dFADs of those fleets, while submerged appendages tended to be from artificial materials.

Most dFADs included the use of nets, with a slight increase in their occurrence in both appendages and raft through time. This dominance of potentially entangling dFADs could have deleterious effects, such as species of special interest (e.g. turtles, sharks) entanglement, which can continue when the dFAD is lost through ghost fishing (Filmalter et al., 2013; Pilling et al., 2017). It should however be noted that the investigation of net use by fleet did not account for mesh size or the dFAD design (i.e. nets rolled up as sausages), which can reduce entanglement (low entanglement design, see Appendix 1). In general, when nets were used it was large size mesh nets (average of 9.8 cm for nets in appendages and 8.3 cm for nets used to cover the raft), which have high entanglement risk. In addition, some materials currently used as appendages or to cover the raft (e.g. cords, sackings) could be of natural origin (Appendix 2), although no details are currently recorded. Additional fields in relevant forms would therefore be necessary to monitor the type of dFAD design and if a given material is artificial or natural.

Overall, natural and non-entangling dFAD materials appear seldom used in the WCPO. Most fleets use floats or drums for the raft, which are not biodegradable (except EU Spain, Ecuador and El Salvador, which use bamboo), as well as artificial appendages including nets. Over the last decade, with the increased use of dFADs, there has also been a growing body of research on biodegradable and non-entangling dFAD designs (Appendices 1 and 2). Non-entangling dFADs are now widely adopted in other oceans (Murua et al., 2016) and trials of biodegradable dFADs have been implemented (e.g. Zudaire, 2017). These trials have mostly focused on finding appropriate submerged appendages, as it is the largest component of dFADs and the one most impacting coral reefs and entangling species of special interest (Moreno et al., 2018). Cotton ropes, with cotton canvas or palm leaves used as "flags" to create more volume (Appendix 2), appear appropriate and are currently tested in real fishing conditions (Moreno et al., 2018; Zudaire, 2017). In addition, bamboo rafts reinforced by some other materials to assure buoyancy (e.g. balsa wood) appear the most promising solution for biodegradable dFAD rafts. Appropriateness of these dFAD designs (e.g. cost, material availability) for the WCPO still needs to be investigated. Nevertheless, the high rate of non-biodegradable and entangling material in use in the dFAD designs within the WCPO suggests that regulation may be required to change these trends.

We invite WCPFC-SC14 to:

- Note the materials currently used in dFADs in the region. In particular, the low use of non-entangling and biodegradable materials, as well as the variability among fleets.
- Note the review of biodegradable materials and non-entangling dFAD designs from research projects in other oceans.

- Consider potential research activities and at-sea trials of biodegradable and non-entangling design options in the WCPO and provide corresponding advice to the FAD Management Options Intersessional Working Group.

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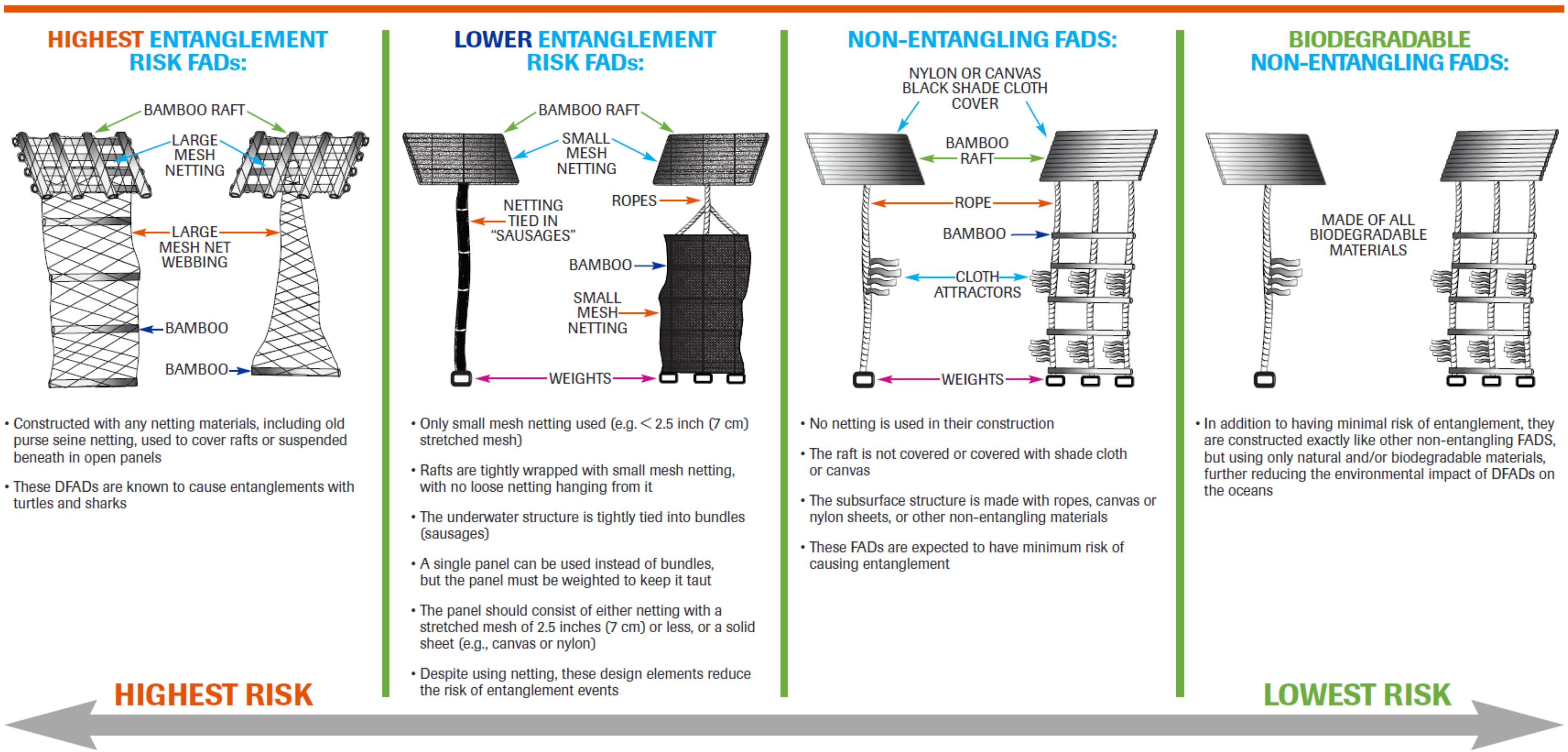
Appendix 1. Examples designs of dFADs with increasing risk of entanglement. Reproduced from ISSF (ISSF, 2015).



Appendix 2. Review of biodegradable materials explored or tested to be used in the different parts of dFAD construction.

Part of dFADs	Materials currently used	Alternatives	Available information and limits	References
Raft (buoyancy)	Floats, drums, pipes Bamboo Planks, timbers, pallets	**- Bamboo**	- Cheap but loses buoyancy with time due to water seeping inside canes' air chamber. Good when combined with other materials to ensure buoyancy. Recently cut canes have higher lifetime. Natural oils or waxes could be explored to extend lifetime.	(Franco et al., 2009; Moreno et al., 2016)
		- Balsa wood	- Great buoyancy. Ongoing test of raft combining balsa wood and bamboo canes. Availability could not be easy in some regions.	(Moreno et al., 2016, 2018)
		- Coconuts - Containers made of polymers from natural origin - Pine wood	- Potential alternatives suggested.	(Moreno et al., 2016)
Raft cover	Nets Sacks, bags	- **Palm leaves**	- Cheap.	(Franco et al., 2009; Moreno et al., 2018)
		- **Cotton canvas**	- Good alternative; exist in dark colours.	(Moreno et al., 2016)
		- Bambooslats or thin bamboo tied with galvanised wire	- Expansive.	(Franco et al., 2009)
		- Black cotton cloth	- Increase furtiveness (water over it) but is not strong enough.	(Goujon et al., 2012)
Submerged appendages	Nets Cords, ropes	- **Cotton ropes not allowing bio-fouling**	- Without loops. More stable over time compared to ropes allowing biofouling. Similar aggregative patterns were observed for non-biodegradable and biodegradable dFADs (trial of 6 months at sea). On-going tests (EPO, Atlantic Ocean, Western Indian Ocean).	(Moreno et al., 2016, 2017c, 2018)
			- 3 designs were tested offshore Maldives for 1 year: i) twisted cotton; ii) twisted cotton and sisal ropes; and iii) cotton, sisal and linen ropes with loops. Twisted cotton ropes considered more appropriate (can still resist 1 year and ductile), while twisted cotton and sisal ropes were the most	(Moreno et al., 2017b)

		- Cotton ropes with loops allowing bio-fouling (used to grow mussels) - Other vegetal fibre ropes - Coir (coconut husk fibre) - Tencel ropes from Eucalyptus - Sisal, raffia ropes - Vegetal fibre nets (sisal) <7cm mesh rolled	resistant. Need to be tested in real dFADs. Variations in manufacturing processes will affect degradation rates. - Decreased floatability over time, but biofouling could be helpful in the first stages of colonisation. - Designs mixing cotton, sisal, linen, and hem. Degradation rate varies with the fibre and design used, additional at sea trials are necessary. - Tested at anchored FADs in Hawaii. Decompose quickly and low biofouling. Could be appropriate for the appendages but not to bind the raft. - Potential alternatives suggested.	(Moreno et al., 2016, 2017c, 2018) (Lopez et al., 2016) (Moreno et al., 2017a) (Moreno et al., 2016) (Franco et al., 2009) (Franco et al., 2009)
Submerged appendages	Sacks, bags	- **Cotton canvas** - **Palm leaves** - Coco fibre or jute fabric	- Used as “flags” to create more volume and as drift anchors. Fishers preferred thicker cotton canvas. - Can last several months - Too fragile.	(Moreno et al., 2016, 2018) (Franco et al., 2009) (Franco et al., 2009; Moreno et al., 2016)
Weight	Weight	- Stones - Sand - No weight	- Not used by some fishers, who consider that the weight of encrusted animals is enough	(Moreno et al., 2016) (Moreno et al., 2016) (Franco et al., 2009)
Satellite buoy		- Hydrostatic release	- Hydrostatic release before the dFAD sink. The issue of retrieving buoys to limit pollution remains.	(Moreno et al., 2016)