Significant underreporting of bycatch and ecosystem impacts in tuna purse seine fisheries

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While it is well known that purse seine fleets capture more juvenile tuna and more bycatch species when setting their nets around drifting Fish Aggregating Devices (dFADs), the broader ecosystem impacts caused by dFADs are not well quantified. Some research into the bycatch rates associated with tuna purse seine fishing has aimed to quantify the direct bycatch of animals that is noted by observers aboard vessels, but many feel that those estimations do not provide the full story of purse seine fleets impacts upon non-tuna species and their habitats. This is because what an observer records aboard a fishing vessel that is actively fishing does not capture the entanglement, pollution and direct habitat damage caused by drifting FADs. Ultimately, quantifying the bycatch captured within a purse seine net when it is hauled onboard only deals with a potentially small proportion of the real damage actually caused by drifting FADs, and the survivorship of animals discarded overboard as bycatch has only been lightly assessed for a few of the species that face these impacts.

Through this paper we wish to express and explain our concern around how promoting purse seine fleets as incurring minimal ecosystem impacts is not necessarily correct, and that a broader ecosystem approach to such assessments, as well as to the management of these fisheries and their drifting FADs, is urgently necessary. In the meantime, estimations and claims around bycatch levels, which focuses only on animals hauled aboard purse seine vessels, threaten to misinform fisheries managers and ethical consumers alike. Until a more holistic and accurate quantification of the true ecosystem impacts caused by drifting FADs is available, the precautionary approach should be applied as required under the FAO Code of Conduct for Responsible Fisheries[1].

Not all negative interactions between the ocean ecosystem and purse seine fishing gear occur when a net is set and hauled. We will further outline ghost fishing impacts later in this paper, but it's worth noting here that many animals (typically unseen by observers/data collectors) that escape the active net when being deployed or retrieved can be mortally damaged in the process of their escape. Animals that later die because of interacting with fishing vessels and/or fishing gears need to be considered in suitable estimates of the ecosystem impacts resulting from these fleets activities. The movements of such large, technology advanced and fast-moving modern purse seine vessels during day and nighttime hours also poses a threat to some animals such as whales, for which mitigation measures imposed upon the trade shipping industry may be overdue for application to large and fast-moving fishing vessels. Through the rest of this paper, we will describe our concerns covering some of the more broadly known and studied bycatch impacts and the charismatic species for which such impacts have been assessed.

[1] Article 6.5 of the FAO Code of Conduct for Responsible Fisheries: "*States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment.*" https://www.fao.org/3/v9878e/v9878e.pdf

Silky sharks

Silky shark entanglements have been reported by industry and scientists alike for over a decade now in the IOTC[2,3],as well in other RFMOs.[4] One scientific publication in particular by Filmalter *et al*.[5], highlighted the ghost fishing impacts that tuna purse seine fleets drifting FADs are having on silky sharks. Drifting FAD entanglement mortality estimates for silky sharks in this paper were between five and ten times more than the bycatch rates being recorded aboard fishing purse seine vessels. This represented numbers up to 960,000 silky sharks being mortally entangled by drifting FADs each year in the Indian Ocean alone. To provide more perspective, that would mean 110 individuals of this threatened species being mortally entangled by a dFAD every hour of every day in the Indian Ocean alone. To make matters worse for this species, early juvenile silky sharks are more impacted by drifting FAD fishing than adults. These juvenile deaths compromise stock reproduction in a similar way to how drifting FADs compromise that of overfished Indian Ocean yellowfin and bigeye tuna stocks drifting FADs by creating catch proportions which are over 95% juvenile tunas[6]. Such research results emphasize the need to appropriately consider the broader ecosystem impacts of drifting FADs, beyond the bycatch estimates currently submitted from purse seine vessels.

Research by Hutchingson *et al*.[7] determined that silky sharks also represent the largest component of elasmobranch catch taken by tropical tuna purse seine fisheries. They used satellite tags to assess post release mortality of silky sharks released after capture by a purse seine vessel, with more than 85% of those sharks later dying as a result of the stress and damage caused by their capture and release experience. Another concerning result of that study was that the shark interactions recorded by the scientists of this study while aboard the vessel, were markedly higher than those recorded by the independent fishery observer and the vessel officers. High catch rates of juvenile silky sharks have also been recorded for purse seine fleets using drifting FADs in all other oceans, while a study by Poisson *et al*.[8] also demonstrate post release survival rates below 20%. There has been growing contention between conservationists and the purse seine industry over these worrying statistics for many years now but, with stock declines ongoing, the urgency of ensuring the purse seine industry addresses these issues in time grown each year.

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[2] Amandè MJ, Chassot E, Chavance P, Pianet, R. 2008. Silky shark Carcharhinus falciformis bycatch in the French tuna purse-seine fishery of the Indian Ocean. IOTC- 2008-WPEB-16, *Indian Ocean Tuna Commission*

[3] Amandè MJ, Ariz J, Chassot E, Delgado de Molina A and others. 2010. Bycatch of the European purse seine tuna shery in the Atlantic Ocean for the 2003−2007 period. *Aquatic Living Resources* 23:353−362

[4] Román-Verdesoto MH, Orozco-Zoller M. 2005. Bycatches of sharks in the tuna purse-seine fishery of the eastern Pacific Ocean reported by observers of the Inter-Ameri- can Tropical Tuna Commission, 1993−2004. *IATTC*

[5] Filmalter JD, Capello M, Deneubourg JL, Cowley PD, Dagorn L. 2013. Looking Behind the Curtain: quantifying massive shark mortality in fish aggregating devices. *Frontiers in Ecology and the Environment*. 11(6): 291-296.

[6] Rattle J. 2021. Sustainability of yellowfin tuna (Thunnus albacares) fisheries in the Indian Ocean, with a special focus on juvenile catches. *For Global Tuna Alliance.*

[7] Hutchingson MR, Itano DG, Muir JA, Holland KN. 2015. Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery. *Marine Ecology Progress Series*. 521:143-154.

[8] Poisson F, Filmalter JD, Vernet A-L, Dagorn L. 2014. Mortality rate of silky sharks (Carcharhinus falciformis) caught in the tropical tuna purse seine fishery in the Indian Ocean. *Canadian Journal of Fisheries and Aquatic Sciences*. 71(6):795−798

Figure 1 – Photo by Fabien Forget of two sharks entangled in a drifting FAD (left) and another likely juvenile silky shark entangled in netting below a drifting FAD (right) (©Fadio/IRD/Ifremer/mtaquet)
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Turtles

The highest contribution of bycatch animals in research conducted in the Eastern Indian Ocean during 2002 was from 30 marine turtles, of which 18 were entangled by the three abandoned European drifting FADs encountered during that study[9]. One net set that produced zero tuna catch lead to the capture of 25 non-tuna species. The three abandoned European drifting FADs had 18 animals entangled in their structures including 15 turtles and a shark.

Figure 2 – Turtle entangled within a so-called "eco-FAD" (© Fabien Forget)
PHOTO CREDIT: COPYRIGHT ISSF/FABIAN FORGET

[9] Chanrachkij I, Loog-on. 2007. Preliminary Report on Ghost Fishing Phenomena by Drifting FADs in Eastern Indian Ocean. IOTC-2007-WPEB-INF06.

Research indicates that sea turtle entanglements increase larger mesh sizes in fishing nets[10]. However, evidence also suggests that damaged fishing nets, irrespective of mesh size, pose a potential entanglement threat to sea turtles[11]. Although nets are typically omitted from "non-entangling" drifting fish aggregating devices (dFADs)[12], it is important to note that shade cloth and other meshed materials are susceptible to damage. This can lead to openings in the cloth, causing the structure to pose a risk of entanglement to sea turtles.

Cetaceans

Research by Chanrachkij and Loog-on[13] in the eastern Indian Ocean assessed catches from 17 purse seine sets around drifting FADs, as well as three drifting FADs that seem to have been abandoned by European purse seine vessels but were not set upon. Across that relatively small sample size they noted 103 bycatch animals spanning 13 species. Within this study they recorded 7 entangled porpoises within 6 drifting FADs, which were already too badly decomposed to enable measurement and further assessment. This study highlights not only that cetaceans are victims of ghost fishing by drifting FADs, but also that ghost fishing is a wasteful form of fishery associated mortality that does not result in the trade or consumption of animals that die because of entanglement within drifting FADs. Furthermore, dead animals entangled in the netting beneath drifting FADs entice other animals to feed and risk becoming entangled themselves in a self-perpetuating cycle of wasteful mortality that includes endangered, threatened, and protected marine species.

[10] Wilcox, C., Heathcote, G., Goldberg, J., Gunn, R., Peel, D. and Hardesty, B.D. 2015. Understanding the sources and effects of abandoned, lost, and discarded fishing gear on marine turtles in northern Australia. *Conservation biology*, *29*(1):198-206.
[11] Stelfox, M., Bulling, M. and Sweet, M. 2019. Untangling the origin of ghost gear within the Maldivian archipelago and its impact on olive ridley (Lepidochelys olivacea) populations. *Endangered Species Research*, 40:309-320.
[12] Escalle, L., Mourot, J., Hamer, P., Hare, S.R., Phillip Jr, N.B. and Pilling, G.M. 2023. Towards non-entangling and biodegradable drifting fish aggregating devices–Baselines and transition in the world's largest tuna purse seine fishery. *Marine Policy*, 149:105500.
[13] Chanrachkij I, Loog-on. 2007. Preliminary Report on Ghost Fishing Phenomena by Drifting FADs in Eastern Indian Ocean. IOTC-2007-WPEB-INF06.

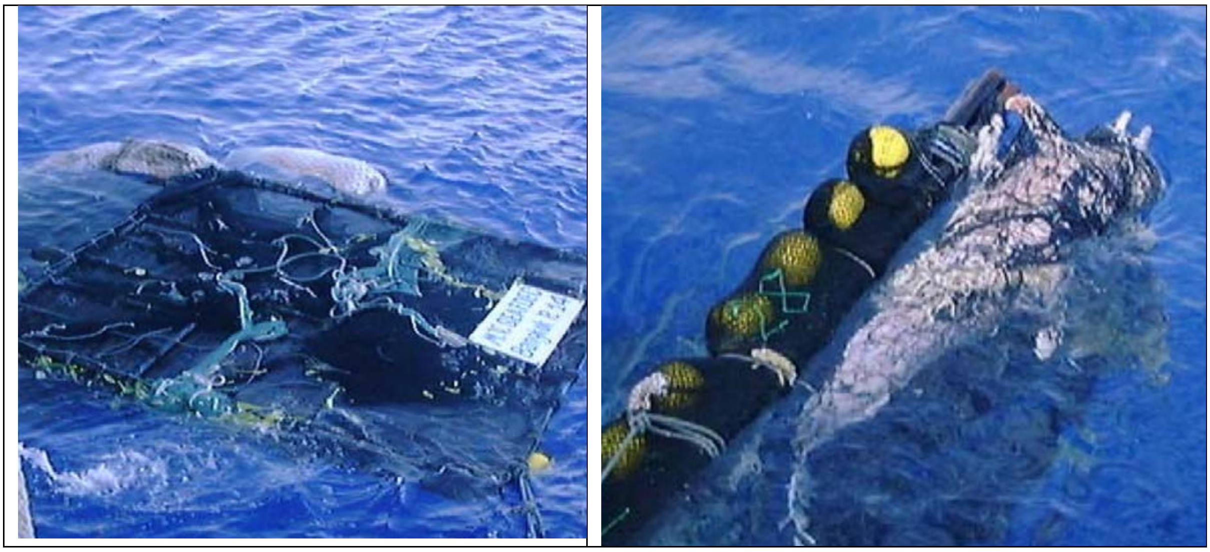

Figure 3 – Photographs of porpoises, turtles and a shark entangled in drifting FADs from Chanrachkij and Loog-on, 2003[10]

Habitat damage

As a passive fishing gear, the fate of drifting FADs lost or abandoned at sea cannot be controlled. This means that they can, and regularly do, drift into prohibited areas, such as protected areas or exclusive economic zones where they are not legalized, and into critical habitats. Some estimates in the Indian Ocean [14] find that 10% of drifting FADs deployed beach along coastlines. However, others have found the number of FADs beaching on critical habitats to be as high as 30% in some seasons[15]. This research aligns with estimates from the Pacific Ocean which went on to find that 92% of these beaching events occurred on coral reefs, with an estimated 4-6km^2 damaged by drifting FADs every year in the Pacific Ocean alone[16]. The remaining beaching events were attributed to seagrass meadows, mangroves or sandy beaches.

Furthermore, this same study in the Pacific Ocean estimated that approximately 66% of all deployed drifting FADs sink to the sea floor[13]. Due to the inaccessible nature of these habitats, it is harder to estimate the scale and impacts of this but the cumulative impacts of heavy, entangling fishing gears on deep sea benthic habitats is likely to be having significancy consequences for the ocean ecosystem.

All of these habitats are critical for biodiversity and ecosystem resilience to climate change. It is therefore imperative that steps are taken to address these issues and remove drifting FADs from these areas.

Solutions

In February this year at the Sixth Special Session of the IOTC, India's commendable proposal[17] to ban drifting FADs in the Indian Ocean was unsuccessful in its adoption. In the subsequent months, and due to several objections from the European Union and other IOTC CPCs, Indonesia's also commendable

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[14] Maufroy, A., Chassot, E., Joo, R. and Kaplan, D.M. 2015. Large-Scale Examination of Spatio- Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. *PloS One* 10.
[15] Davies, T. K., Curnick, D., Barde, J. and Chassot, E. 2017. Potential environmental impacts caused by beaching of drifting Fish Aggregating Devices and identification of management solutions and uncertainties. *1st joint t-RFMO FAD WG.*
[16] Banks, R. and Zaharia, M. 2020. Characterization of the costs and benefits related to lost and/or abandoned Fish Aggregating Devices in the Western and Central Pacific Ocean. *Report produced by Poseidon Aquatic Resources Management Ltd for The Pew Charitable Trusts.*
[17] https://iotc.org/documents/prohibition-dfads-ind

proposal[18] to impose stricter management measures on drifting FADs failed to be adopted too. We are concerned that the rejection of these two ecologically sound IOTC proposals has resulted in a vacuum of effective and serious conservation and management measures in the Indian Ocean not witnessed in any other tuna RFMOs.

Therefore, and in the absence of a progressive roadmap towards a full ban on harmful dFADs as a way to effectively protect Indian Ocean ecosystems, which could conceivably pass through the future imposition of stricter regulations on dFADs such as were contained in Indonesia's rejected proposal, we currently recommend the following interim solutions to fill the current void: -

The Commission, the industry and scientists should work together to take a more holistic approach to research and bycatch monitoring. By quantifying the broader ecosystem impacts of drifting FADs, steps can be taken to develop more specific measures which address key issues. In the meantime, the Commission should maintain a precautionary approach, which should include mandates on fully biodegradable designs and a FAD closure.

Despite over a decade of research into, and publicity and promotion of, non-entangling and biodegradable drifting FAD designs, they are still not actually being applied on a meaningful scale among purse seine fleets in practice. There is also a prevailing misconception that employing biodegradable fishing nets and components, including those utilized in dFADs, mitigates the issue of ghost fishing[19]. However, research has demonstrated that ghost fishing exerts its most significant impact during the initial phase of gear loss[20,21,22] when the net or gear's geometry enables continued entanglement and trapping of sea turtles. Therefore, the incorporation of biodegradable nets or shade cloth into dFADs may offer limited efficacy in curbing ghost fishing over the short term, precisely when their impact is most pronounced. Instead, biodegradable designs must also be non-entangling and paired with a number of other measures and innovative solutions to curb the negative ecosystem impacts of drifting FADs.

Non-entangling designs are currently outlined under IOTC Resolution 19/02 which prohibits any 'meshed materials'. Unfortunately, ongoing lack of compliance with drifting FAD design regulations has also been consistently evidenced in the Indian Ocean over recent years[23] which raises concerns for the efficacy of drifting FAD measures as a whole.

A drifting FAD closure and increased monitoring systems have been primary areas of contention in the IOTC in recent years, with several member States objecting to the measures under Resolution 23/02. However, these are important steps to protect juvenile tunas, better understand the impacts of drifting FADs, and conserve the broader oceanic biodiversity. The Commission should implement FAD closures and develop a FAD Monitoring System alongside an effective FAD Recovery program that not only collects (rather than abandons) drifting FADs but also proactively removes non-compliant FADs from the ecosystem.

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[18] https://iotc.org/documents/management-dfads-idn-et-al

[19] Murua, H., Zudaire, I., Tolotti, M., Murua, J., Capello, M., Basurko, O.C., Krug, I., Grande, M., Arregui, I., Uranga, J. and Ferarios, J.M., 2023. Lessons learnt from the first large-scale biodegradable FAD research experiment to mitigate drifting FADs impacts on the ecosystem. *Marine Policy*, *148*, p.105394.

[20] Humborstad, O.B., Løkkeborg, S., Hareide, N.R. and Furevik, D.M., 2003. Catches of Greenland halibut (Reinhardtius hippoglossoides) in deepwater ghost-fishing gillnets on the Norwegian continental slope. *Fisheries Research*, *64*(2-3), pp.163-170.

[21] Baeta, F., Costa, M.J. and Cabral, H., 2009. Trammel nets' ghost fishing off the Portuguese central coast. *Fisheries Research*, *98*(1-3), pp.33-39.

[22] Thomas, S.N., Mandhir, S.K., Krishnankutty, H., Baby KA, M. and Ghosh KA, A., 2023. Ghost fishing capacity of lost experimental gillnets: a preliminary study from Indian waters. *Environmental Science and Pollution Research*, *30*(14), pp.40062-40072.

[23] IOTC (2023) Sustained systematic non-compliance of drifting fish aggregating devices (dFADs) with Resolution 19/02 'Procedures on a Fish Aggregating Devices (FADs) Management Plan'. IOTC-2023-CoC20-INF01_Rev1

There are several other innovative solutions which the Commission should consider if they are to address the underreporting of bycatch and mitigate the ecosystem impacts of drifting FAD purse seine fishing. These include:

- Avoiding silky shark hot spots or releasing silky sharks from nets before hauling nets in.
    - Future efforts to reduce the impact of purse seine fishing on silky shark populations should be focused on avoidance or releasing sharks while they are still free swimming [24]. Trials have been done and seem to successfully increase the survival of silky sharks by releasing them from purse seine nets before the net is brought aboard the vessel, with improvements available to also improve the survival of bycaught whale sharks and rays, but these solutions must be actually applied by purse seine fleets outside of research trials in order to mitigate their impacts on a meaningful scale.

- Implement a Polluter Pays mechanism
    - To improve accountability, the Commission should explore introducing a polluter pays principle for drifting FADs which are found to be damaging critical habitats, entangling bycatch species or burdening the coastlines of IOTC member states[25]

- Implement bycatch quotas and/or closed areas with high bycatch
    - To reduce bycatch, the Commission could consider introducing set bycatch quotas for endangered, threatened or protected species. If enough research can be conducted to understand the hotspots of bycatch or deployment areas which are most likely to result in adverse habitat impacts, then closed deployment and FAD setting areas could be established. This could be implemented alongside the observer program, supported by AIS and VMS data, and could help to alleviate some of the bycatch and habitat damage caused by drifting FADs.

- Halt night setting
    - Juvenile individuals, of tuna and other species alike, tend to shelter under floating objects, including drifting FADs overnight, for shelter and protection. By prohibiting night setting on drifting FADs, the juvenile proportion of catch and bycatch could be reduced which would contribute positively to the reproductive potential of these populations.

Addendum: The Satellite Industry's Role in Unsustainable Tuna Fisheries

Furthermore, satellite owners such as Iridium, Inmarsat and others should closely examine their important roles as crucial providers of space satellite GPS location services to Spain's Marine Instruments, SatLink and Zunibal, the three principal manufacturers of solar and battery-powered satellite buoys[26]. These buoys are used by the European Union purse seine fishing fleet mainly from Spain and France to attach to unsustainable and ecologically damaging drifting FADs that are made largely of plastic buoys, ropes and nets whilst fishing in the Indian Ocean[27]. Marine Instruments, SatLink and Zunibal floating satellite beacons are constructed with a hard plastic outer shell which, when they break apart, eventually become toxic to the marine environment in the form of large pieces of floating debris (or even micro plastics and nano plastics over a longer timeframe) if not recovered once they become abandoned, discarded or lost at sea, which is common[28]. Plastic satellite beacons

[24] Hutchingson M, Justel-Rubio A, Restrepo V. (2019). At-sea tests of releasing sharks from the net of a tuna purse seiner in the Atlantic Ocean. ICCAT SCRS/2019/029.
[25] Purves, M., Adam, M.S. and Bealey, R., 2021. A polluter pays principle for drifting FADs–how it could be applied?. *2nd IOTC Ad Hoc Working Group on FADs (IOTC, 2021); https://www. iotc. org/documents/polluter-pays-principle-drifting-fads-% E2, 80.*
[26] https://ecohustler.com/technology/iridium-satellites-enabling-overfishing
[27] https://www.marineinstruments.es/products/echo-sounder-satellite-buoy-2/
[28] https://www.nature.com/articles/s41598-020-71444-6

often contain lead and other toxic substances and the dumping of Nickel metal hydride (NiMh) and alkaline batteries at sea is prohibited under European Union law[29]. NiMh batteries contained inside a typical Marine Instruments satellite buoy display the Waste Electrical and Electronic Equipment recycling (WEEE) logo (see Figure 4 below) that calls for the proper disposal of hazardous waste[30] – which is obviously not in the ocean. Once the plastic outer shell is breached by sea water, printed circuit boards and microchips contained in satellite beacons may leach 'forever chemical' persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and dioxins into the marine environment[31] over time[32]. PCBs and dioxins are known to be carcinogenic to humans and wildlife[33]. Taking into consideration our environmental pollution concerns, as well as our concerns on biodiversity loss as presented in the earlier sections of this paper, and in light of Iridium and Inmarsat's public Environment, Social and Governance (ESG) commitments[34,35] as well as their support for the United Nations Sustainable Development Goals (in particular SDG #14 'Life Under Water[36]') we strongly recommend that all satellite owners cancel their contracts with Marine Instruments, SatLink and Zunibal immediately. If this cannot be done for legal reasons, satellite owners should refrain from renewing any existing agreements with these satellite beacon manufacturers that provide the crucial link via space between beacons and their owners, the harmful European Union tuna purse seine fishing industry. Our non-exhaustive list of satellite companies that should cancel all commercial links to the unsustainable and ecologically destructive dFAD satellite beacon industry include[37]; Iridium, Inmarsat, Hispasat, Telenor, Eutelsat, Thuraya, Intellian and Garmin. It is for the reasons outlined in this *addendum* that the public is being asked to call on Iridium to sever links with the manufacturers of destructive dFAD satellite beacons[38].

Figure 4 – Nickel metal hydride (NiMh) batteries recovered from a Marine Instruments drifting FAD satellite beacon in the Indian Ocean displaying the WEEE logo that calls for proper recycling of hazardous waste.
PHOTO CREDIT: COPYRIGHT ALEX HOFFORD

ENDS/

[29] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0066-20131230&rid=1
[30] https://ec.europa.eu/environment/pdf/waste/weee/faq.pdf
[31] https://interestingengineering.com/science/1980s-forever-chemical-pcb-ocean
[32] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5874774/
[33] https://www.atsdr.cdc.gov/csem/polychlorinated-biphenyls/adverse_health.html
[34] https://www.iridium.com/wp-content/uploads/2023/03/Iridium-ESG-Report-2022.pdf
[35] https://www.inmarsat.com/content/dam/inmarsat/corporate/documents/corporate/sustainability/how-we-do-business/Inmarsat%202021%20ESG%20Report.pdf.coredownload.inline.pdf
[36] https://sdgs.un.org/goals/goal14
[37] https://satlink.es/en/solutions/satellite-communications
[38] https://www.change.org/p/iridiumcomm-stop-your-satellites-from-enabling-overfishing