

### Supplementary Material

#### **Who lives in the open sea? Distribution and densities of surfacing marine megafauna in three subregions of the South Pacific (New Caledonia, Wallis and Futuna, and French Polynesia)**

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SUPPLEMENT MATERIAL

Supplementary table S1. On-effort sightings in number of encounter (and number of individuals) of marine mammals collected during the three surveys in the western and central South Pacific Ocean. Shaded cells represent new description of the species for the surveyed block and # when the species was previously mentioned in the area by the literature but not identified during the REMMOA surveys (Borsa 2006; Doremus *et al.* 2010; Gannier 2000; Gannier 2002; Gannier 2009; Gannier and West 2005; Garrigue and Poupon 2013; Miller 2023; Reeves *et al.* 1999) \*unpublished stranding.

Taxonomic group	Species	New Caledonia	Wallis and Futuna	French Polynesia						Total
				Australis	Society	Tuamotu-Gambier			Marquesas	
						Gambier	South of Tuamotu	North of Tuamotu		
<b>Physeteridae</b>	Sperm whale, <i>Physeter macrocephalus</i>	17 (37)	1 (2)	6 (17)	#			1 (2)	3 (4)	28 (62)
<b>Kogiidae</b>	Pygmy/dwarf sperm whale, <i>Kogia</i> spp	19 (26)	8 (14)	2 (3)	1 (1)			4 (5)	17 (28)	51 (77)
<b>Ziphiidae</b>	Cuvier's beaked whale, <i>Ziphius cavirostris</i>	16 (26)	#	6 (11)	4 (7)	2 (2)	2 (2)	6 (11)	5 (9)	44 (74)
	Blainville's beaked whale, <i>Mesoplodon densirostris</i>	#	*	3 (9)	1 (4)				#	4 (13)
	Longman's beaked whale, <i>Indopacetus pacificus</i>	7 (28)	6 (21)							13 (49)
	Mesoplodon spp.	8 (20)	4 (7)		2 (3)	2 (4)	2 (4)	1 (2)	3 (5)	21 (45)
	Beaked whale undetermined	8 (12)	2 (2)	4 (7)	2 (2)	1 (2)	1 (2)	2 (3)	8 (12)	28 (41)
<b>Large Globicephalinae</b>	Short finned pilot whale, <i>Globicephala macrorhynchus</i>	32 (206)	3 (18)	off effort	1 (13)	#	1 (25)	2 (13)	12 (80)	51 (355)
	False killer whale, <i>Pseudorca crassidens</i>	5 (14)	3 (6)		#		#		1 (20)	9 (40)
	<i>Globicephala/Pseudorca</i>	10 (31)	6 (8)	2 (4)	2 (26)	2 (9)	2 (9)	6 (38)	7 (153)	35 (269)
	Killer whale, <i>Orcinus orca</i>	#	1 (4)		#			1 (2)	1 (1)	3 (7)
<b>Risso's dolphin,</b>	Grampus griseus	10 (74)	10 (54)		5 (65)	3 (30)	3 (30)	4 (33)	6 (52)	41 (314)
<b>Small Globicephalinae</b>	Melon-headed whale, <i>Peponocephala electra</i>	3 (490)	2 (300)		#			2 (130)	2 (250)	9 (1170)
	Melon-headed whale or Dwarf killer whales <i>Feresa attenuata</i>	1 (15)	5 (262)		1 (50)	1 (15)	1 (15)	2 (30)		10 (372)
<b>Large Delphininae</b>	Common bottlenose dolphin, <i>Tursiops truncatus</i>	9 (61)	10 (119)		1 (5)	off effort	3 (14)	4 (12)	5 (52)	32 (263)
	<i>Tursiops</i> spp	22 (219)	1 (15)							23 (234)
	Fraser's dolphin, <i>Lagenodelphis hosei</i>	3 (174)			#	off effort			#	3 (174)
	Rough-toothed dolphin, <i>Steno bredanensis</i>	#	1 (2)	#	1 (12)	#	1 (10)		3 (13)	6 (37)
	Large Delphininae undetermined	8 (28)	1 (20)	2 (5)	6 (24)	4 (8)	4 (8)	3 (17)	11 (69)	35 (171)
<b>Small Delphininae</b>	Spinner dolphin, <i>Stenella longirostris</i>	2 (150)			off effort		#		#	2 (150)
	Pantropical spotted dolphin, <i>S. attenuata</i>	2 (61)	6 (113)		#				off effort	8 (174)

	<i>Stenella spp./Delphinus spp.</i>	18 (196)	20 (223)		3 (27)	3 (36)	3 (36)	3 (56)	11 (109)	59 (677)
	Omura's whale, <i>Balaenoptera omurai</i>	3 (3)								3 (3)
	Fin whale, <i>Balaenoptera physalus</i>	1 (1)								1 (1)
<b>Balaenopteridae</b>	Humpback whale, <i>Megaptera novaeangliae</i>	1 (1)	#	#	#	#	#	#	#	1 (1)
	Antarctic Minke whale, <i>Balaenoptera bonaerensis</i>	1 (1)								1 (1)
	<i>Balaenopteridae</i> undetermined	5 (10)	2 (3)							7 (13)
	Delphinidae undetermined	4 (57)	4 (75)			1 (2)	1 (2)	3 (42)	7 (75)	22 (258)
<b>Undetermined</b>	Small cetacean undetermined	2 (7)		1 (1)	2 (4)	1 (3)	1 (3)		1 (7)	8 (27)
	Medium cetacean undetermined	8 (18)		2 (2)	4 (24)	2 (5)	2 (5)	2 (13)	2 (6)	21 (69)
	Large cetacean undetermined	2 (3)								2 (3)
<b>Dugongidae</b>	Dugong, <i>Dugong dugon</i>	21 (25)								21 (25)
	<b>Total</b>	248 (1994)	96 (1268)	28 (59)	36 (267)	27 (165)	27 (165)	46 (409)	105 (945)	602 (5169)

Supplementary table S2. On-effort sightings of seabirds in number of encounter (and number of individuals) collected during the three surveys in the South Pacific Ocean.

Family	Species/species category	New Caledonia	Wallis and Futuna	French Polynesia						Total
				Austral	Society	Tuamotu-Gambier			Marquesas	
Gambier	South of Tuamotu	North of Tuamotu								
<i>Laridae</i>	Grey/Blue noddies, <i>Anous albivittus</i> , <i>A. ceruleus</i>	-	-	-	-	-	-	-	85 (153)	85 (153)
	Other noddies <i>Anous</i> spp	387 (1 769)	274 (1 256)	103 (511)	260 (1 177)	117 (627)	258 (1408)	851 (7593)	457 (2896)	2 707 (17 237)
	White terns, <i>Gygis</i> spp	171 (254)	799 (1394)	861 (1217)	959 (1 950)	747 (1 177)	1 937 (3 008)	1777 (2 970)	1600 (2 932)	8 851 (14 902)
	Silver gull, <i>Larus novaehollandiae</i>	10 (63)	-	-	-	-	-	-	-	10 (63)
	'Brown' terns, <i>Onychoprion</i> spp	769 (3 372)	553 (3 034)	13 (48)	300 (1431)	8 (8)	96 (173)	258 (978)	725 (2 510)	2 722 (11 554)
	'Grey' terns	349 (1 785)	15 (25)	1 (1)	20 (25)	3 (4)	25 (28)	70 (99)	35 (77)	518 (2 044)
<i>Phaethontidae</i>	White-tailed tropicbird, <i>Phaethon lepturus</i>	133 (146)	329 (376)	55 (57)	243 (266)	19 (19)	5 (6)	36 (36)	315 (334)	1135 (1240)
	Red-tailed tropicbird, <i>Phaethon rubricauda</i>	21 (21)	25 (26)	51 (59)	12 (12)	26 (35)	19 (20)	15 (16)	34 (34)	203 (223)
	<i>Phaethon</i> spp.	118 (144)	18 (32)	79 (82)	16 (16)	5 (5)	15 (16)	25 (28)	20 (21)	296 (344)
<i>Hydrobatidae</i> / <i>Oceanitidae</i>	Storm-petrels	15 (15)	1 (1)	-	4 (4)	-	2 (2)	-	68 (73)	90 (95)
<i>Procellariidae</i>	'Grey' petrels, <i>Pterodroma</i> spp	789 (1014)	32 (34)	9 (11)	33 (38)	5 (5)	6 (7)	25 (25)	24 (25)	923 (1 159)

	'Brown' petrels	510 (950)	25 (68)	38 (45)	257 (382)	33 (44)	67 (105)	266 (322)	224 (336)	1 420 (2 252)
	Tahiti petrel, <i>Pseudobulweria rostrata</i>		-	-	6 (6)	-	3 (3)	3 (3)	3 (3)	15 (15)
	Shearwaters <i>Puffinus spp. / Ardeanna spp</i>	3 203 (11 037)	261 (534)	1 (1)	22 (32)	41 (44)	3 (3)	46 (51)	69 (75)	3 646 (11 777)
	Procellariidae undetermined	-	1 (3)	3 (4)	26 (115)	8 (20)	4 (4)	9 (9)	12 (13)	63 (168)
<i>Fregatidae</i>	Lesser frigatebird, <i>Fregata ariel</i>	2 (2)	-	-	-	-	-	9 (9)	14 (14)	25 (25)
	Great frigatebird, <i>Fregata minor</i>	2 (6)	1 (1)	-	-	2 (2)	5 (5)	3 (3)	27 (38)	40 (55)
	<i>Fregata</i> spp	43 (49)	12 (18)	8 (8)	10 (11)	12 (18)	43 (109)	63 (151)	120 (146)	311 (510)
<i>Sulidae</i>	Masked booby, <i>Sula dactylatra</i>	32 (53)	2 (2)	-	5 (7)	3 (7)	1 (1)	2 (2)	17 (17)	62 (89)
	Brown booby, <i>Sula leucogaster</i>	92 (190)	22 (110)	1 (2)	9 (10)	-	6 (9)	31 (71)	22 (28)	183 (420)
	Red-footed booby, <i>Sula sula</i>	269 (666)	369 (1 188)	2 (2)	474 (1298)	132 (516)	305 (1 246)	569 (2 998)	301 (764)	2 421 (8 678)
	<i>Sula</i> spp	66 (127)	13 (65)		14 (71)		2 (2)	4 (4)	17 (38)	116 (307)
<b>Total</b>		6 981 (21 663)	2 752 (8 167)	1 225 (2 048)	2 670 (6 851)	1161 (2 531)	2802 (6 155)	4062 (15 368)	4 189 (10 527)	25 842 (73 310)

Supplementary table S3. Potential species of seabirds by taxonomic groups.

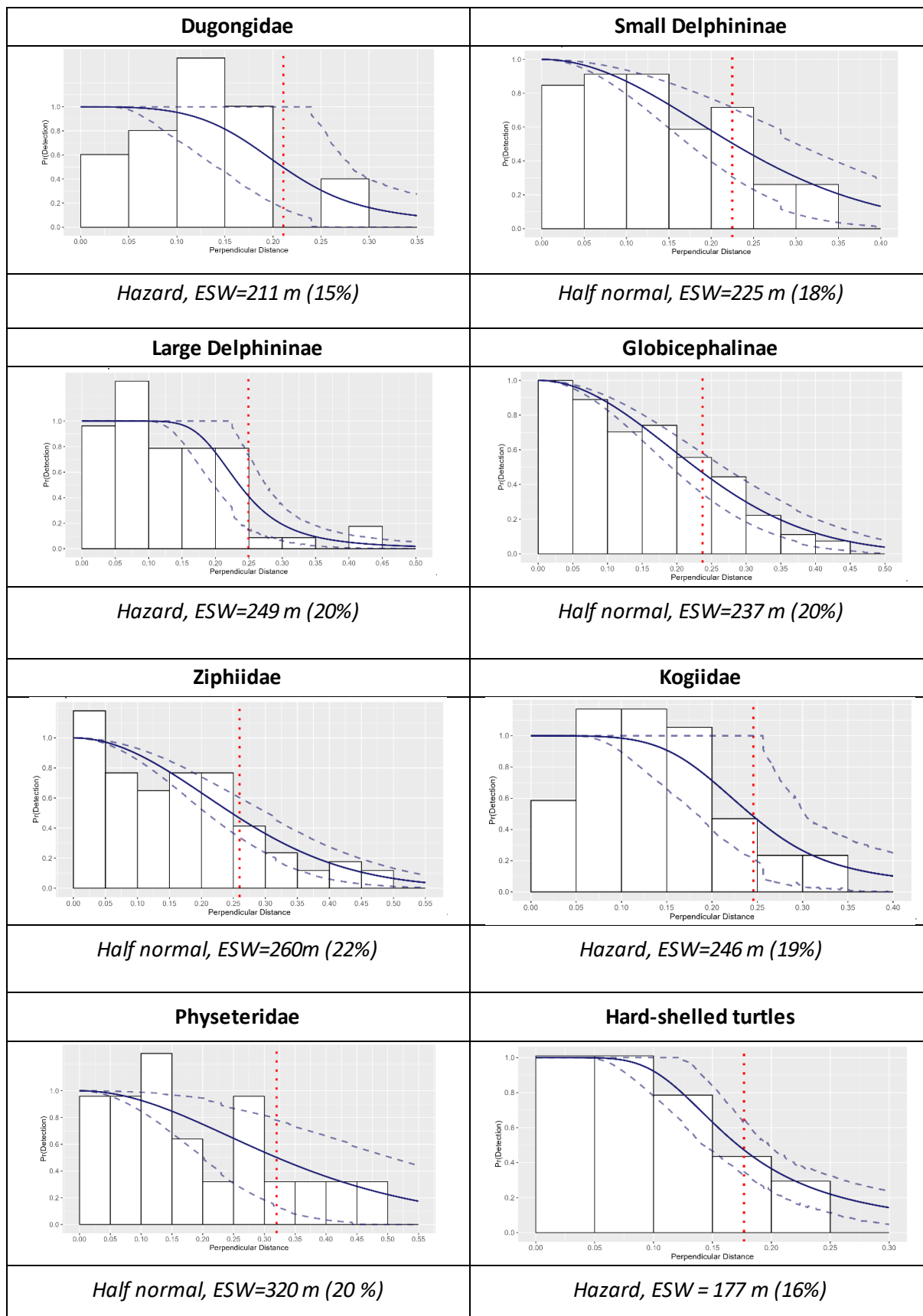
Order	Family	Species or category	Potential species
CHARADRIIFORMES	Laridae	Grey/Blue noddy	<i>Anous albivittus</i> , <i>A. ceruleus</i>
		Noddy sp.	<i>Anous minutus</i> , <i>A. stolidus</i> , <i>A. tenuirostris</i>
		White tern	<i>Gygis alba</i>
		Silver gull	<i>Larus novaehollandiae</i>
		'Brown' tern sp.	<i>Onychoprion anaethetus</i> , <i>O. fuscatus</i> , <i>O. lunatus</i>
		'Grey' tern sp.	<i>Sterna dougallii</i> , <i>S. sumatrana</i> , <i>S. hirundo</i> , <i>Sternula nereis</i> , , <i>Onychoprion lunatus</i> , <i>Thalasseus bergii</i>
PHAETHONTIFORMES	Phaethontidae	White-tailed tropicbird	<i>Phaethon lepturus</i>
		Red-tailed tropicbird	<i>Phaethon rubricauda</i>
		Tropicbird sp.	<i>Phaethon lepturus</i> , <i>P. rubricauda</i>
PROCELLARIIFORMES	Hydrobatidae / Oceanitidae	Storm-petrel sp.	<i>Fregetta grallaria</i> , <i>F. lineata</i> , <i>Fregetta tropica</i> , <i>Nesofregetta fuliginosa</i> , <i>Oceanites oceanicus</i> , <i>Pelagodroma marina</i>
	Procellariidae	"Grey" petrel sp.	<i>Pterodroma brevipes</i> , , <i>P. leucoptera</i> , , <i>P. nigripennis</i> , <i>P. ultima</i>
		"Brown" petrel sp.	<i>Pterodroma alba</i> , <i>P. neglecta</i> , <i>P. heraldica</i> , <i>P. Iherminieri</i> , <i>Pseudobulweria rostrata</i> , <i>Ardenna pacifica</i> , <i>Puffinus nativitatis</i> , <i>Bulweria bulwerii</i> , <i>A. tenuirostris</i> , <i>A. Bulleri</i>
		Tahiti petrel	<i>Pseudobulweria rostrata</i>

		Shearwater sp.	<i>Ardenna pacifica</i> , <i>A. tenuirostris</i> , <i>A. bulleri</i> , <i>Puffinus bailloni</i> , <i>P. myrtae</i> , <i>P. nativitatis</i> , <i>P.</i> <i>tenuirostris</i> , <i>P. lherminieri</i> , <i>P. newelli</i>
		Other procellariids	all species of 'Grey,' 'Brown' petrels, Tahiti petrel and shearwaters sp.
SULIFORMES	Fregatidae	Lesser frigatebird	<i>Fregata ariel</i>
		Great frigatebird	<i>Fregata minor</i>
		Frigatebird sp.	<i>Fregata ariel</i> , <i>F. minor</i>
	Sulidae	Masked booby	<i>Sula dactylatra</i>
		Brown booby	<i>Sula leucogaster</i>
		Red-footed booby	<i>Sula sula</i>
		Booby sp.	<i>Sula dactylatra</i> , <i>S. leucogaster</i> , <i>S. sula</i>

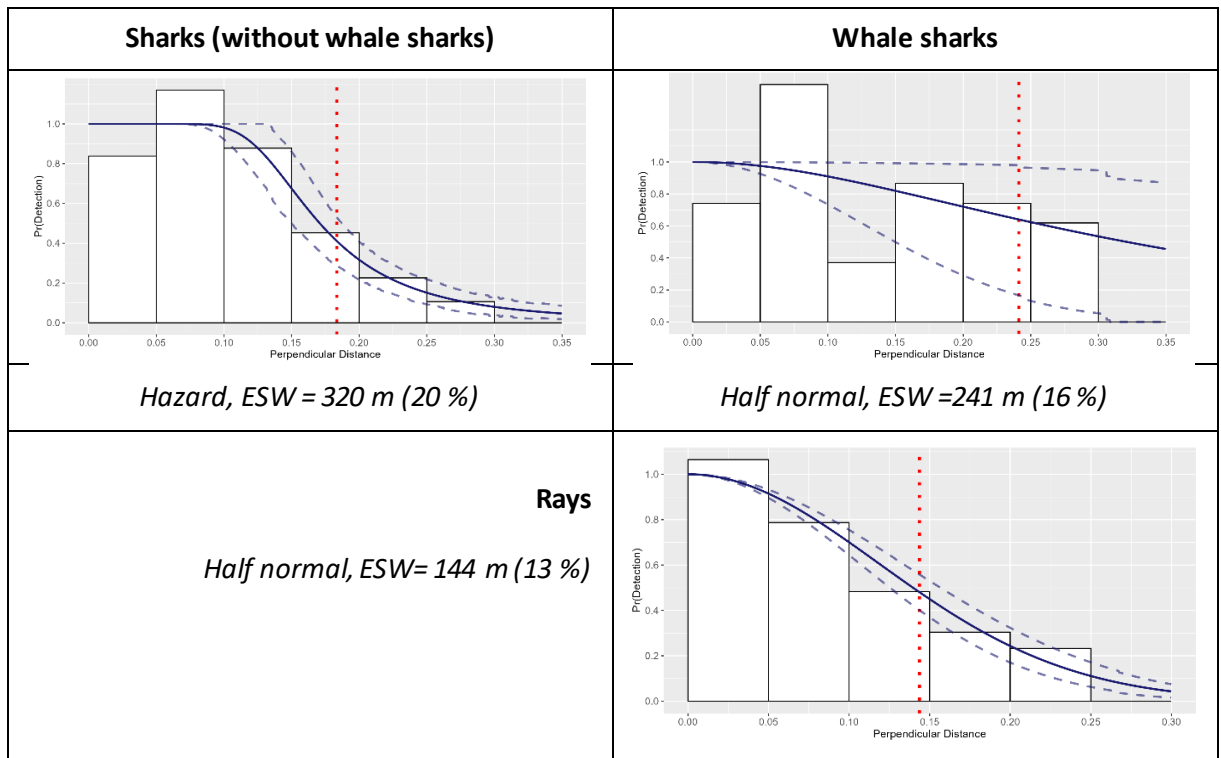
Supplementary table S4. On-effort sightings of sea turtles and Elasmobranchs in number of encounter (and number of individuals) collected during the three surveys in the South Pacific Ocean.

		New Caledonia	Wallis and Futuna	French Polynesia					Marquesas	Total
				Austra l	Societ y	Tuamotu-Gambier				
						Gambie r	South of Tuamot u	North of Tuamot u		
Turtle	Hard-shelled sea turtle: potentially loggerhead sea turtle ( <i>Caretta caretta</i> ), hawksbill sea turtle ( <i>Eretmochelys imbricata</i> ), green sea turtle ( <i>Chelonia mydas</i> ), or Pacific ridley turtle ( <i>Lepidochelys olivacea</i> )	185 (200)	33 (45)	4 (4)	6 (6)	1 (1)	1 (1)	13 (13)	3 (3)	257 (284)
	Leatherback turtle, <i>Dermochelys coriacea</i>	1 (1)	1 (1)		1 (1)					3 (3)
<b>Elasmobranchs</b>										
Shark	Whale shark, <i>Rhincodon typus</i>	12 (12)	20 (20)	3 (3)	4 (4)	1 (1)	1 (1)	6 (6)	1 (1)	47 (47)
	Great white sharks, <i>Carcharodon carcharias</i>	2 (2)								2 (2)
	Hammerhead sharks, <i>Sphyrna</i> spp	37 (37)			2 (2)	2 (2)	2 (2)		6 (12)	47 (53)
	Oceanic whitetip sharks, <i>Carcharhinus longimanus</i>	15 (15)	1 (5)		1 (1)			1 (1)	3 (3)	21 (25)
	Tiger sharks, <i>Galeocerdo cuvier</i>	5 (5)	1 (1)							6 (6)
	Sharks undetermined	76 (129)	14 (17)	3 (8)	18 (28)	8 (12)	8 (12)	61 (70)	7 (7)	198 (286)
	Devil rays, <i>Mobula</i> spp.	24 (30)	7 (8)	3 (5)		5 (7)	5 (7)		6 (7)	47 (59)
	Manta ray, <i>Mobula</i> spp.	28 (36)	3 (4)	7 (7)	14 (17)	3 (3)	3 (3)	6 (7)	81 (99)	143 (174)
	Spotted Eagle Ray, <i>Aetobatus narinari</i>	80 (108)	7 (7)			2 (2)	2 (2)	3 (3)		92 (120)
	Stingray undetermined, <i>Dasyatis</i> sp.	35 (53)	6 (7)							41 (60)
Ray undetermined.	32 (41)			8 (10)	2 (5)	2 (5)	11 (12)	4 (4)	58 (73)	
<b>Total Elasmobranchs</b>		<b>346 (468)</b>	<b>59 (69)</b>	<b>16 (23)</b>	<b>47 (62)</b>	<b>23 (32)</b>	<b>23 (32)</b>	<b>88 (99)</b>	<b>108 (133)</b>	<b>702 (905)</b>



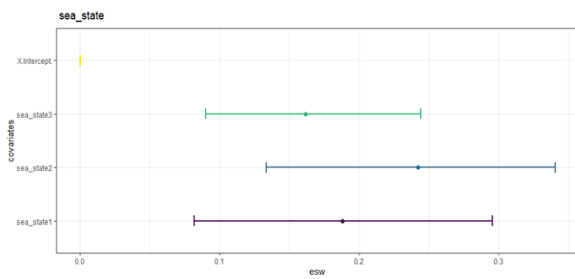


Supplementary figure S1. Detection function per species or group and its confidence interval (x-axis in km), model selected and corresponding effective width strip (ESW red dot line) with its associated coefficient of variation.

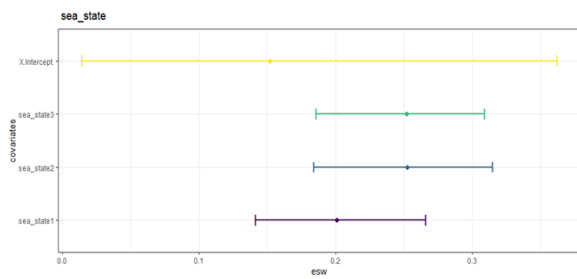


Supplementary figure S1 (continued)

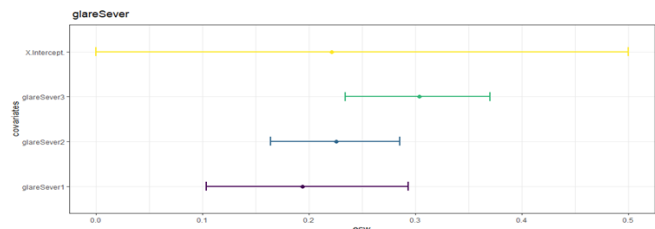
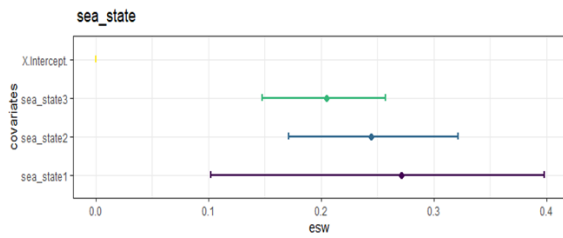
**Kogiidae**



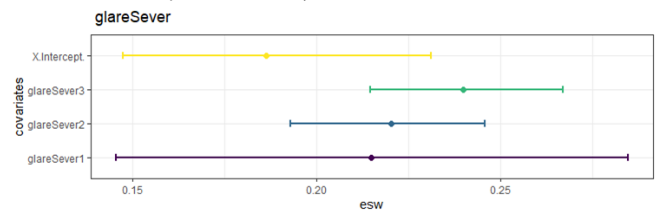
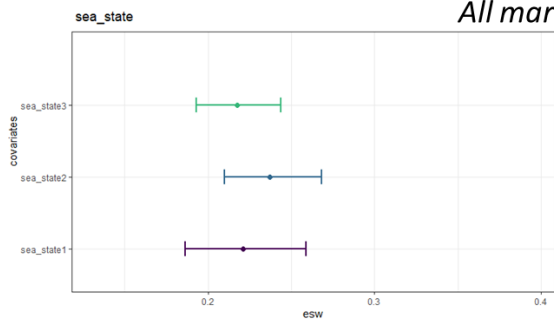
**Globicephalinae**



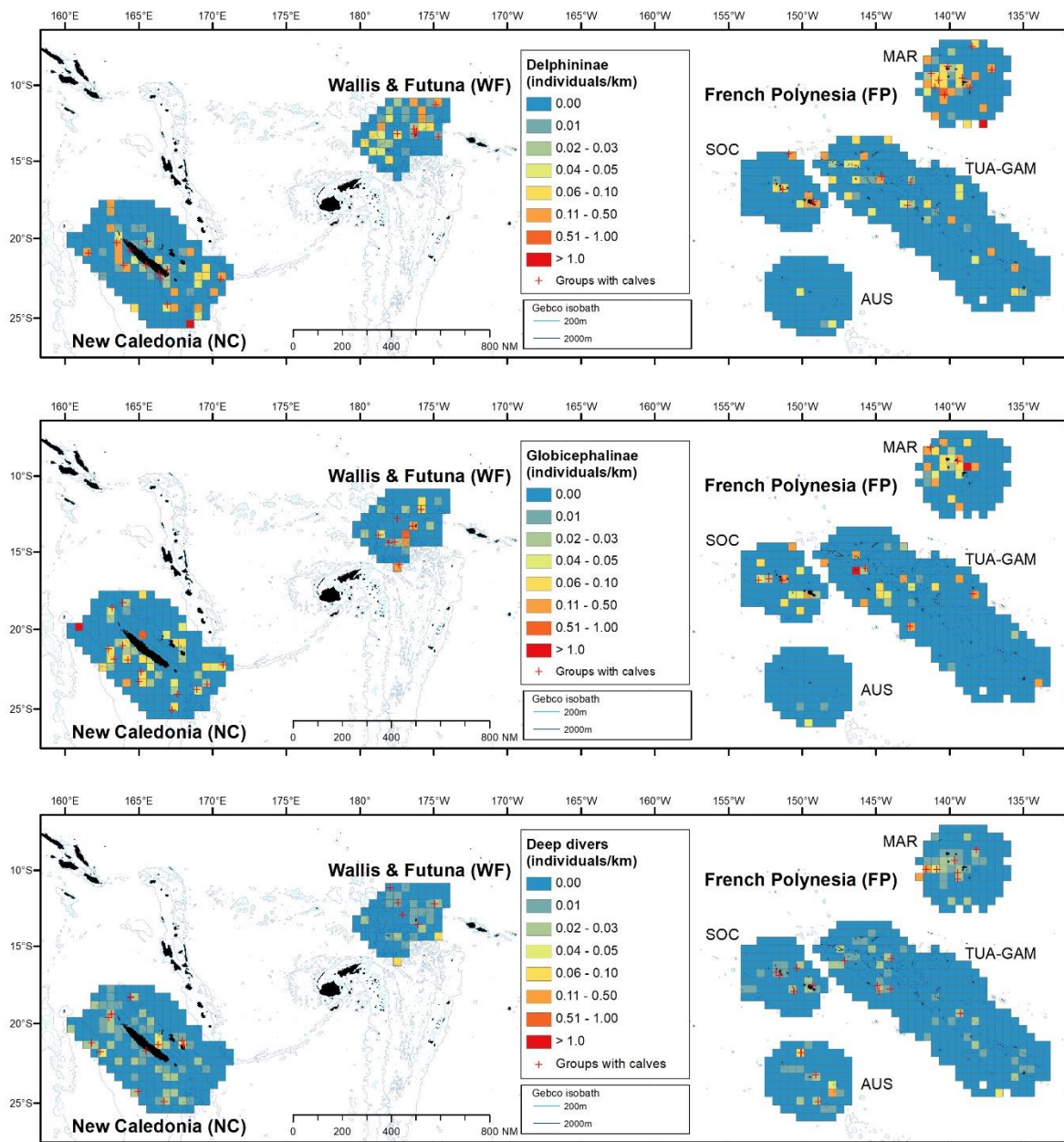
**Ziphiidae**



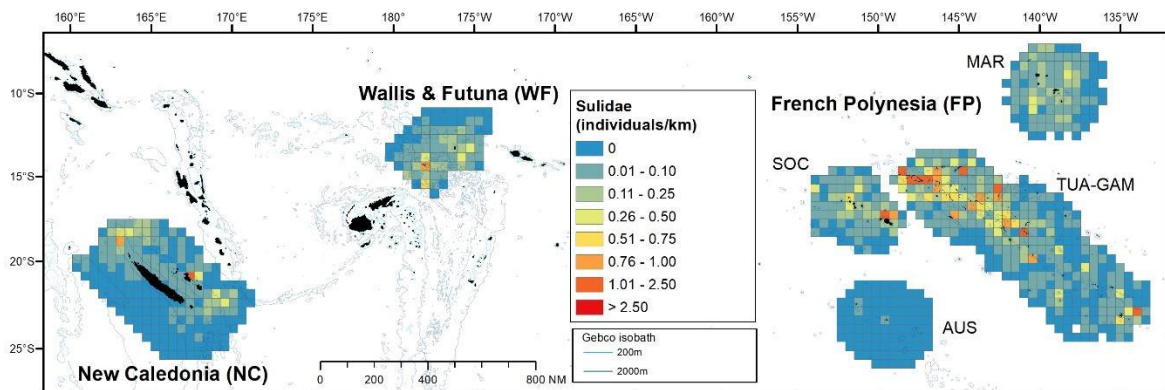
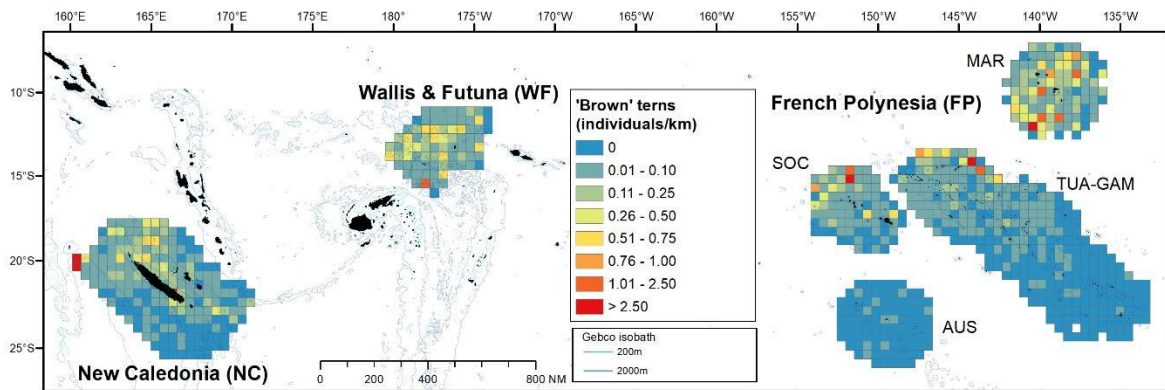
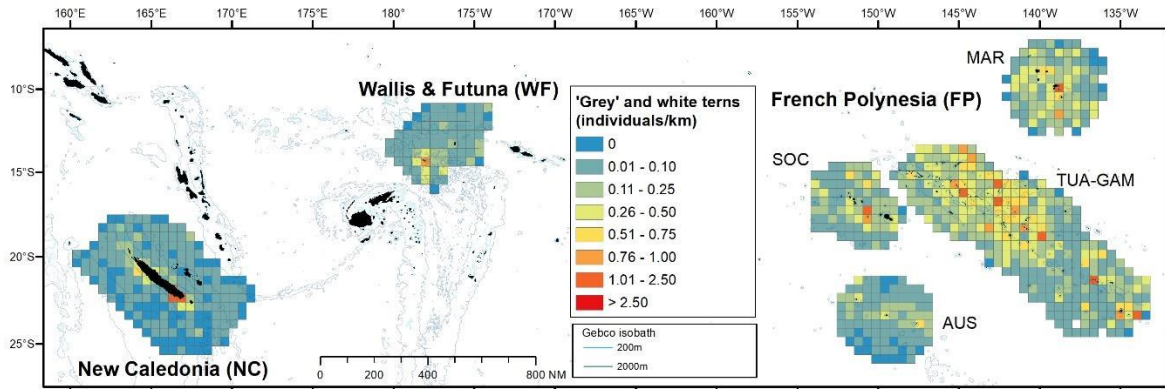
**All marine mammals (truncation=500m)**



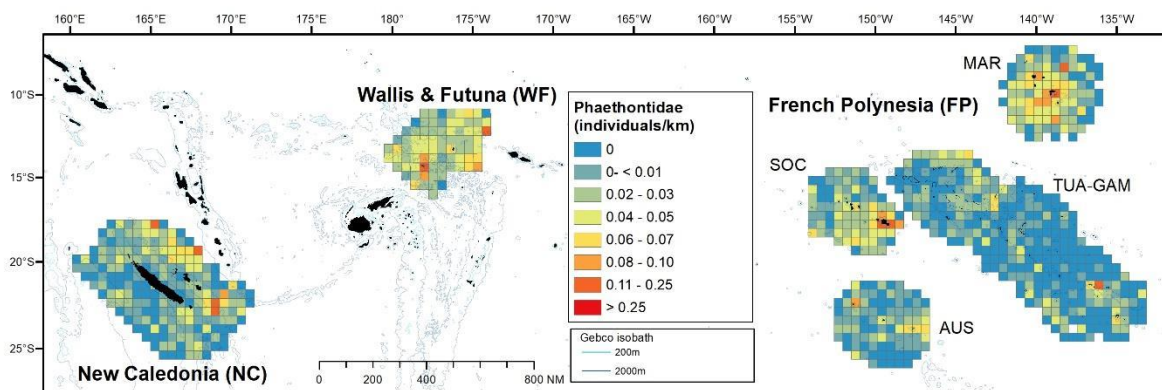
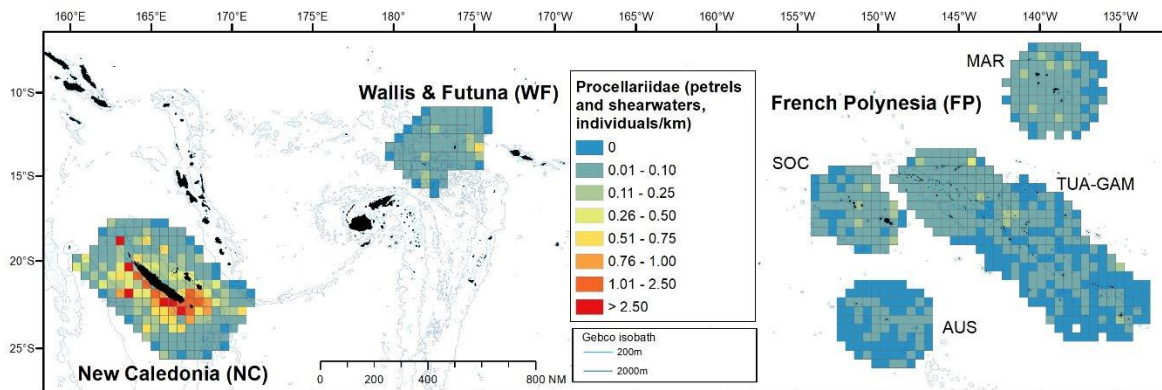
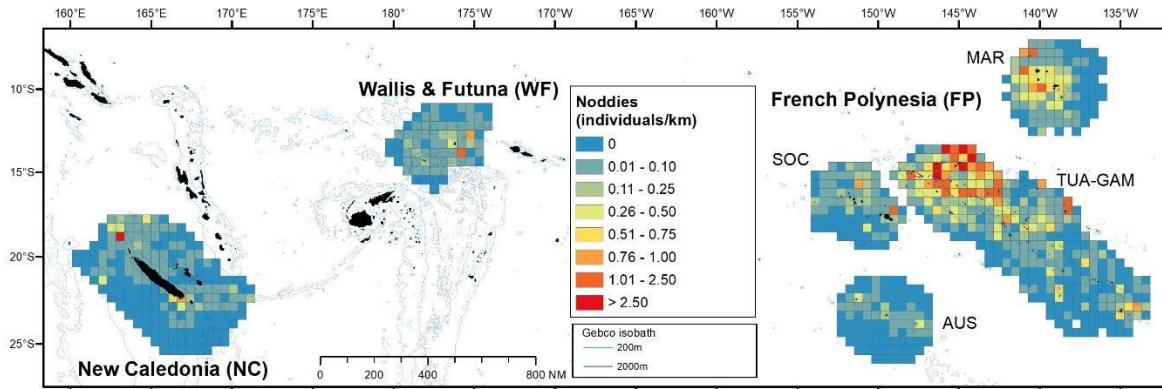
Supplementary figure S2 Confidence interval and the effective strip widths (ESW) including sea state or glare severity as covariate in MCDS, for Kogiidae, Globicephalinae, Ziphiidae and all marine mammal sightings pooled.



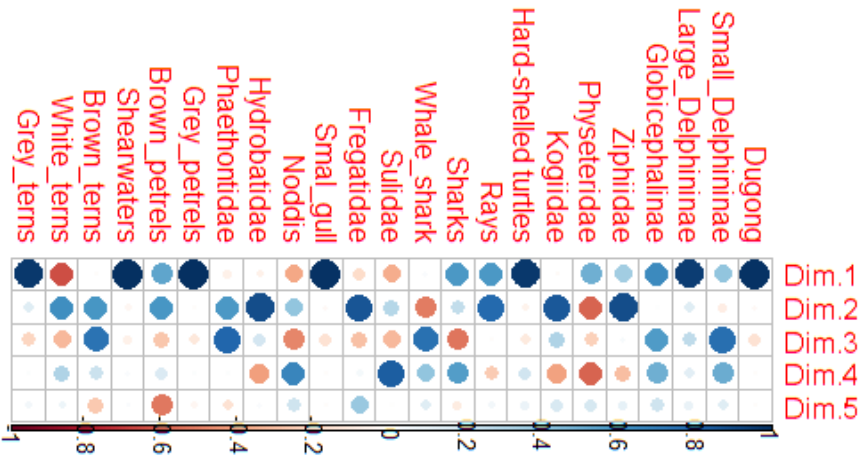
Supplementary figure S3. Spatial distribution of individuals visually counted per kilometre for pooled small and large Delphininae, Globicephalinae and deep divers (Physeteridae, Kogiidae. and Ziphiidae) in the three Pacific's subregions: Wallis and Futuna, New Caledonia and French Polynesia during REMMOA surveys. Each pooled on a 60×60km grid cell. Cells accounting for a minimum effort of 50 km. And groups with juveniles or young individuals (+).



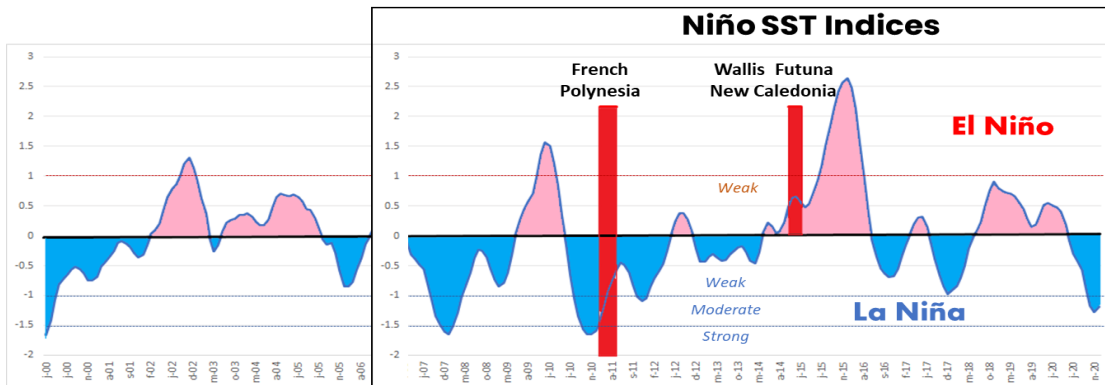
Supplementary figure S4. Spatial distribution of individuals visually counted per kilometre for “grey” terns, “brown” terns, Sulidae, noddies, Procellariidae and Phaethontidae in the three Pacific’s subregions: Wallis and Futuna, New Caledonia and French Polynesia during REMMOA surveys. Each pooled on a 60x60km grid cell. Cells accounting for a minimum effort of 50 km.



Supplementary figure S4. (continued)



Supplementary figure S5. Results of the principal component analysis (PCA) with the correlation plots represent the species that drove each dimension. The larger is the circle, the more important the variable is.



Supplementary figure S6. El Niño Sea surface Temperature index from 2007 to 2020 and period of surveys for French Polynesia, New Caledonia and Wallis and Futuna (ONI values from [psl.noaa.gov/data/correlation/oni.data](https://psl.noaa.gov/data/correlation/oni.data))

Borsa, P. (2006) Marine mammal strandings in the New Caledonia region, Southwest Pacific. *C.R. Biologies* **329**, 277-288.

Doremus, G., Perri, M., Van Canneyt, O., and Ridoux, V. (2010) Echantillonnage visuel des mammifères et oiseaux marins dans la ZEE de Wallis & Futuna sur la campagne FUTUNA. In 'Rapport de campagne de l'Observatoire PELAGIS pour l'Agence des Aires Marines Protégées.' pp. 22 pages)

Gannier, A. (2000) Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. *Aquatic Mammals* **26**, 111-126.

Gannier, A. (2002) Cetaceans of the Marquesas Islands (French Polynesia): distribution and relative abundance as obtained from a small boat dedicated survey. *Aquatic Mammals* **28**, 198–210.

Gannier, A. (2009) Comparison of odontocete populations of the Marquesas and Society Islands (French Polynesia). *Journal of the Marine Biological Association of the United Kingdom* **89**, 931–941.

Gannier, A., and West, K.L. (2005) Distribution of the rough-toothed dolphin (*Steno bredanensis*) around the Windward Islands (French Polynesia). *Pacific Science* **59**, 17-24.

Garrigue, C., and Poupon, M. (2013) 'Guide des mammifères marins de Nouvelle-Calédonie, .' (Nouméa)

Miller, C. (2023) Review of ceatcean diversity, status and threats in the Pacific islands region 2021. . Secretariat of the Pacific Regional Environment Programme, Apia, Samoa.

Reeves, R.R., Leatherwood, S., Stone, G.C., and Eldredge, L.G. (1999) Marine Mammals in the Area Served by the Pacific Regional Environment Program SPREP. PROE, Apia, Samoa.