Australia's National Science Agency

Ghost nets in the Gulf of Carpentaria, Australia, 2004-2020

Quantifying abandoned, lost and derelict fishing gear (ALDFG) across northern Australia

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Important disclaimer

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Acknowledgments

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Executive summary

Home to numerous Indigenous communities, Australia's northernmost regions are considered some of the most remote environments in the world (Halpern et al., 2008). Until recent decades, most of what washed ashore in these remote communities was comprised of natural materials. However, there have been growing concerns about the increasing quantities of plastic waste, including lost fishing gear washing ashore in northern Australia.

The Gulf of Carpentaria (GoC) survey area represents 3350 km, or approximately ten percent of the Australian coastline. The Gulf is home to numerous threatened and endangered species, however, many of which occur in the shallow waters there. The movement through the GoC of abandoned, lost and derelict fishing gear (ALDFG) or 'ghost nets' exacts a substantial toll on coastal and marine wildlife, ensnaring marine turtles, as well as dugong, crocodiles, sawfish, hammerhead sharks, sea snakes, and thousands of invertebrates.

The purpose of this project was to bring together information from multiple aerial surveys that have taken place across the Gulf of Carpentaria since 2004. The goal was to compare ghost nets observed from multiple aerial helicopter surveys that have taken place across the region in the last two decades. We used the information from these surveys to understand whether coastal, stranded nets appeared to be increasing, decreasing or remaining consistent in numbers and location, based on aerial survey data. In this report we include:

(i) A summary description of where surveys took place between 2004 and 2020;

(ii) An analysis of existing data in which we highlighted hotspots of derelict fishing nets;

(iii) A discussion of whether net numbers, density and distribution appeared consistent between years;

(iv) A discussion of potential options for reducing gear lost at sea;

(v) Identification of opportunities for net interdictions where feasible, considering cost, safety, and other relevant considerations.

Highlights

- Hotspots for net accumulation in the Gulf of Carpentaria occur along the Cape York Peninsula and within the territory gulfs that occur south of the Gove Peninsula;
- Despite management efforts, the numbers of ghost nets along shorelines in the Gulf of Carpentaria appear to have increased across the region;
- Ghost nets recorded by aerial surveys are an underestimate of the true number of nets present along the coastlines, because aerial surveys are less likely to detect smaller fragments of net, nets buried under sand or those that may be obscured by vegetation;
- Information about on-ground, local clean-up efforts would be useful to contextualise this information.

Part I Surveying ghost gear in the Gulf of Carpentaria, Northern Australia, 2004 - 2020.

Ghost gear in Northern Australia

In the last decade, the social and political awareness of the 'ghost gear' issue has grown substantially, both locally and internationally. Domestically, the Indigenous Ranger Program across northern Australia has evolved and grown, enabling more Indigenous people to remain culturally connected to their land and sea country through meaningful employment. Across northern Australia, Indigenous ranger groups continue to remove nets on their country, demonstrating the success of the initial GhostNets Australia (GNA) program supported by the Australian Government. GhostNets Australia, initiated in 2004, has operated under the principle of 'saltwater people working together'. The organisation has worked closely with communities across the region, and across the country, bringing together stakeholders.

Numerous projects targeting ghost net removal have been operational since the early 2000's with support of the Australian Government. Thousands of nets have been recorded and removed by local ranger groups within this remote region, yielding multiple benefits including new livelihood skills, converting ghost nets to artwork (with associated domestic and international recognition), and improved mental health and well-being (Gunn et al., 2010). Collectively, as of 2015, nearly 15,000 ghost nets have been removed from the region. The net removal program has extended beyond Ranger groups working in the Gulf of Carpentaria to include the Torres Strait, the western part of the Northern Territory Coast, and parts of the Kimberly coastline in Western Australia.

In recognition of the issue, there is now a multi-stakeholder alliance of fishing industry, private sector, multinational corporations, non-government organizations, academics and governments, called the Global Ghost Gear Initiative (GGGI), which is focused on solving the problem of derelict fishing gear worldwide. Both CSIRO and GhostNets Australia were founding members of this alliance and have been instrumental in engagement and scientific endeavours which inform the GGGI.

CSIRO began working with GNA in 2009, helping to analyse data collected by the ranger teams as part of their management efforts on country. In 2020, CSIRO was involved in supporting an aerial (re)survey of the coastline across Northern Australia. In affiliation with World Animal Protection and James Cook University, CSIRO supported surveys aiming to look at changes in the number of ghost nets along the shoreline. Surveys to date have taken place across the top end of Australia, with the initial surveys having taken place in the Gulf of Carpentaria.

1 Ghost gear surveys

1.1 Description of surveys

To achieve the project goals, we compiled data from coastal aerial surveys across the northern Australian region. Helicopter surveys took place in November 2004, December 2017, September 2019 and February 2020. In this report we prioritised aerial surveys for data comparability between the four years of aerial (helicopter) survey to meet the goals of the project. The survey area represents approximately 2,367 km of Australian coastline in the Gulf of Carpentaria, from Peak Point/Punsand and Horn Island in Cape York, Queensland, to Gove in the Northern Territory (excluding 119 km of coastline in the deltas of the Embley and Mission rivers near Weipa), 218 km around Mornington and Derham Islands (Figure 1). That said, the entire survey area was not covered by each aerial survey. Furthermore, the methods employed were not consistent across each of the four aerial surveys (see further description below). However, after quality assurance/quality control efforts, we employed the best available approaches, given the data at hand, to enable us to make predictions for estimated ghost net densities for areas that were unsurveyed.

1.1.1 Aerial surveys

Aerial surveys were conducted by individual spotters in a helicopter. Provided a similar route is flown by the helicopter, from a similar height, the data collected from aerial surveys is comparable between years. Ghost nets recorded by aerial surveys are best considered an underestimate of the true number of nets present along the coastlines, as aerial surveys are less likely to detect smaller fragments of net, nets buried under sand or those that may be obscured by or hidden in vegetation.

Four aerial surveys were conducted between 2004 and 2020. The presence of ghost nets in these surveys was recorded in addition to the primary purpose of the survey, where ghost nets were not the focus of the survey.

In 2004, an aerial seagrass survey of the intertidal coastlines of the Gulf of Carpentaria was conducted by the Department of Primary Industries and Fisheries of the Northern Territory, CRC Reef Research Centre and Biodiversity and Conservation, NT Department of Infrastructure, Planning and Environment (Roelofs et al., 2005). Following this, helicopter surveys of mangrove dieback in 2017 and 2019 were conducted through James Cook University as part of the Australian Government's National Environmental Science Programme (NESP): Northern Australia Environmental Resources Research Priorities (Duke et al., 2017). Finally, an additional survey was conducted in 2020, funded by a private individual (Mr Rupert Imhoff) which aimed to survey ghost nets from south of Aurukun to Punsand Bay. In this 2020 survey, Professor Duke from James Cook University also participated to record information on coastal mangroves within the region surveyed.

Table 1. Summary of information for the four aerial surveys conducted in northern Australia 2004 – 2020, inclusive.

Dates	Organised by / participants	Nature of survey	Survey location
13-20 Nov 2004	Anthony Roelofs, Rob Coles, Neil Smit	Seagrass survey	Gulf of Carpentaria: Van Diemen Gulf to Castlereagh Bay, Northern Territory, and from Gove to Horn Island, Queensland
1-11 December 2017	Norm Duke and Rob Coles	Mangrove (GoC NESP 2017) and ghost gear surveys	Gulf of Carpentaria: Numburindi, Northern Territory along coastline to Aurukun, Queensland, Including Wellesley Islands.
11-23 September 2019	Norm Duke, Jock Mackenzie, Apanie Wood	Mangrove and ghost gear surveys	Gulf of Carpentaria: Numburindi, Northern Territory along coastline to Weipa, Queensland
28 February -1 March 2020	Norm Duke, Rupert Imhoff, Nicole McLachlan	Ghost gear and mangrove surveys	Gulf of Carpentaria: Punsand Bay to south of Aurukun, Queensland

1.1.2 On-ground surveys

Between 2004 and 2009, Indigenous rangers from communities across the northern Gulf region participated in Caring for Country activities including but not limited to recording information on and removing ghost nets from country. During this period, several ranger groups worked with GhostNets Australia on activities around ghost net removal as well as recording of information on nets found. More than 19 ranger groups were engaged in ghost nets work on country across the Gulf of Carpentaria. During the five-year period, 6035 nets were recorded and removed across approximately 1500 km of coastline, with the highest numbers being removed from Mapoon (n=1,105), Dhimurru (n=828) and Napranum (n=791) (Heathcote et al., 2011). In 2010 alone, approximately 2600 nets were removed (GhostNets Australia, 2010). During this time, rangers were also trained in electronic data recording, in addition to ghost net removal (Heathcote et al, 2013). On-ground activities, including surveys and net removal programs are important to ground-truth aerial surveys, which may miss nets that are buried or hidden from the view among vegetation.

1.2 2004 aerial survey (seagrass survey)

An aerial helicopter survey of the intertidal habitats between Van Diemen Gulf and Castlereagh Bay, Northern Territory was conducted between 13 and 17 November 2004 and from Gove to the Torres Strait between 17 and 20 November 2004. Dates for the survey were selected based on suitable low tides, to allow the best visible observation of seagrass (and, opportunistically, for coastal ghost nets). The purpose of this initial survey was to survey seagrass. However, in the course of seagrass surveys, observers recorded and reported ghost nets. Note, however, the survey methodology used differed in 2004 than that utilised in subsequent survey efforts.

Regarding ghost gear, the 2004 seagrass report “A survey of intertidal seagrass from Van Diemen Gulf to Castlereagh Bay, Northern Territory, and from Gove to Horn Island, Queensland” (Roelofs et al., 2005) states:

> *“The distribution of discarded fishing gear was clumped with most occurring in two locations – the north western Gulf and just to the north of Aurukun. The majority of discarded fishing gear sighted was net pieces (1 – 10 metres in length), not intact fishing gear. Much of the net was partially buried and many net pieces would not be visible from a helicopter because of this. Only stranded net would be observed during a seagrass survey*.”

Dates of surveys:

- 17 November 2004. Gove to Borroloola.
- 18 November 2004. Borroloola to Karumba.
- 19 November 2004. Karumba to Weipa.
- 20 November 2004. Weipa to Horn Island.

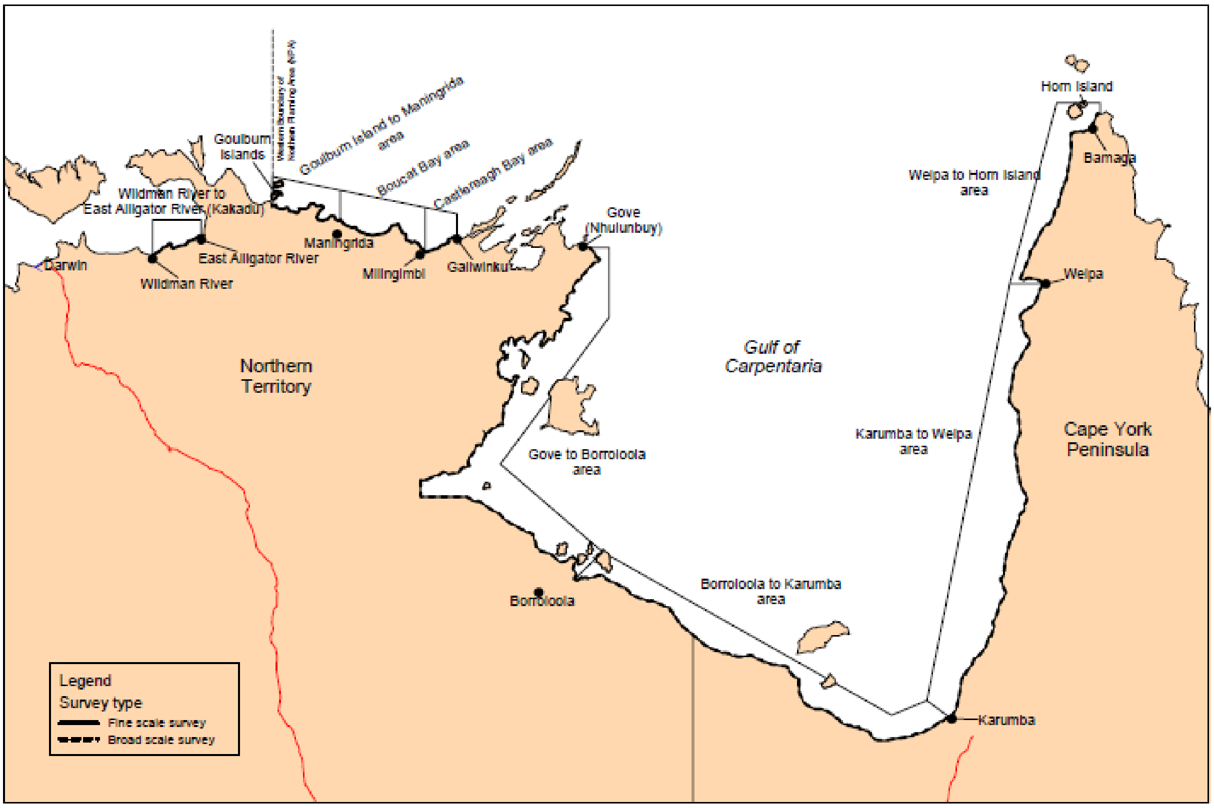

Figure 1. Map of study area from 2004 initial (seagrass-focused) helicopter survey. Note that subsequent surveys have taken place in some areas outside of this initial survey. Analyses and associated report are based upon all available information.

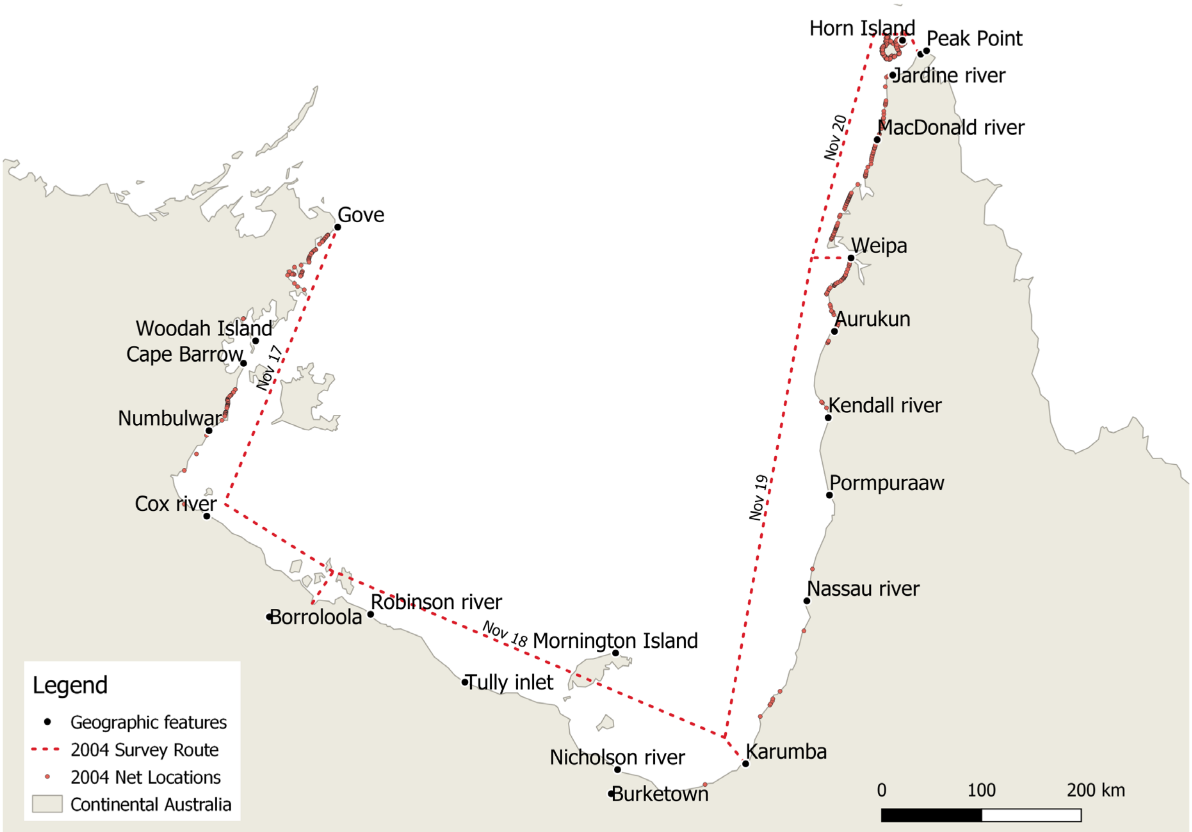

Figure 2. Locations of ghost nets observed in the 2004 aerial surveys.

1.3 2017 aerial survey (ghost gear and mangrove)

Between late 2015 and early 2016, extensive areas of mangrove tidal wetland vegetation died back along 1000 km of the shoreline of Australia's remote Gulf of Carpentaria (see (Duke et al., 2017)). The 2017 ghost gear and mangrove dieback aerial helicopter surveys across the Gulf of Carpentaria began at Weipa, Queensland on 1 December 2017, following the coastline to Numburindi, Northern Territory. Surveys were completed on 11 December 2017. Surveying both ghost gear and mangroves, these surveys were conducted in a finer-scale manner than the 2004 seagrass surveys, covering shorter distances per day and taking high resolution imagery along the way.

As part of the survey methodology, high resolution video footage was taken of the entire coastal survey, in a consistent manner. This footage was then scanned to identify and count ghost nets. While the purpose of the survey was primarily to assess mangrove dieback, the technology employed supported the recording of ghost nets in a reliable, consistent manner.

Dates of surveys with associated survey areas:

- 1st December 2017. Weipa to Pormpurraw.
- 2nd December 2017. Around Pormpurraw to Nassau river.
- 4th December 2017. Pormpurraw to Kurumba.

- 5th December 2017. Kurumba to Burketown.
- 6th December 2017. Burketown to Tully inlet.
- 7th December 2017. Around Mornington Island.
- 8th December 2017. Tully inlet to Borroloola.
- 9th December 2017. Borroloola to Cox River.
- 10th December 2017. Cox river to Numbulwar.
- 11th December 2017. Numbulwar to above Woodah Island.

Figure 3. Location of ghost nets in the 2017 surveys.

1.4 2019 helicopter survey (ghost gear and mangroves)

As a follow up to the 2017 aerial survey, the same method was employed to evaluate mangrove dieback (enabling the documentation of ghost nets) across the region in 2019. These aerial surveys began at Weipa, Queensland, and followed the coastline to Numburindi, Northern Territory between 11 and 23 September 2019. Again, as part of the survey methodology, high resolution video footage was taken of the entire coastal survey, in a consistent manner. This footage was then scanned to identify and count ghost nets.

Dates of surveys with associated survey areas:

- 12 September 2019. Weipa to Kendall River.
- 13 September 2019. Kendall River to Nassau River.
- 14 September 2019. Nassau River to Karumba.
- 15 September 2019. No survey.
- 16 September 2019. Karumba to Nicholson River.
- 17 September 2019. Nicholson River (Qld) to Robinson River (NT).
- 18 September 2019. Robinson River to Cox River.
- 19 September 2019. No survey.
- 20 September 2019. Cox River to Numbulwar.
- 21 September 2019. Numbulwar to Cape Barrow

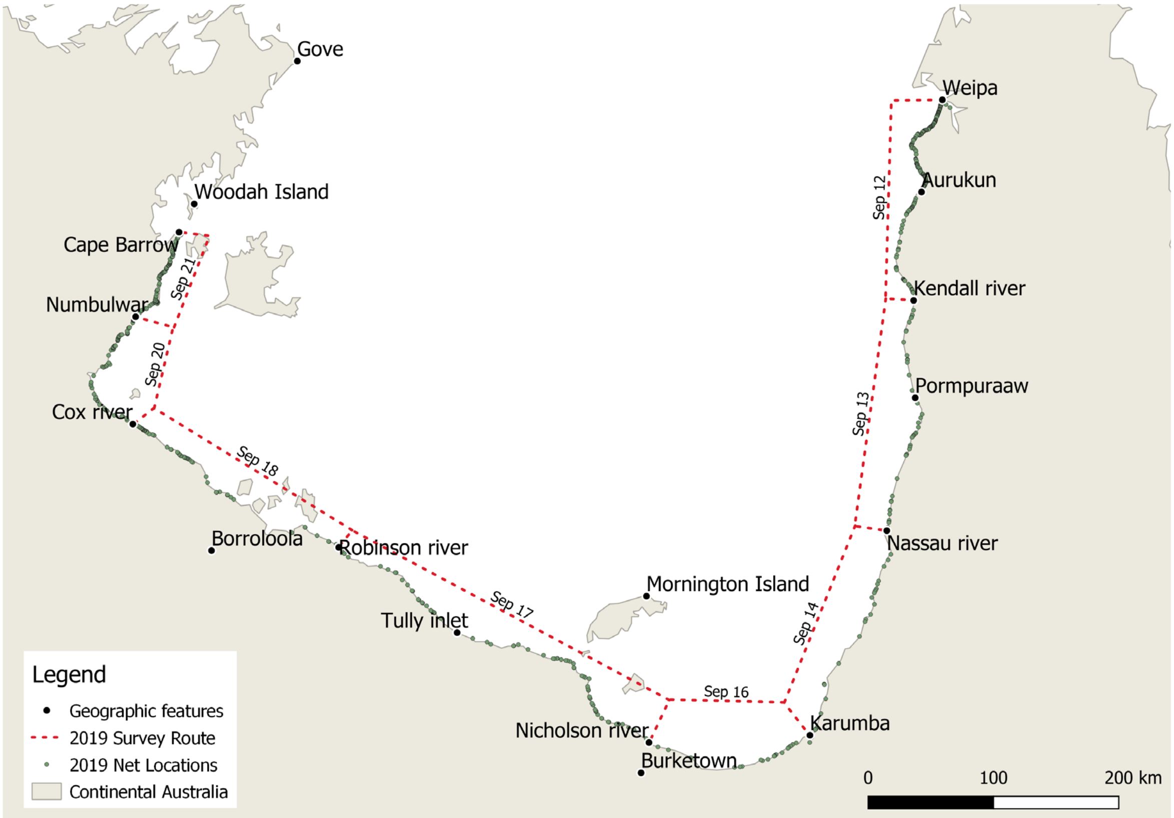

Figure 4. Location of ghost nets in the 2019 surveys.

1.5 2020 helicopter survey (ghost gear and mangroves)

Ghost gear and mangrove dieback helicopter surveys of the Queensland coastline between Peak Point (-10.7072°, 142.4391°) and south of Aurukun (-13.4871°, 141.5666°) were conducted between 28 February and 1 March 2020, inclusive, by Dr. Norman Duke (James Cook University), Rupert Imhoff and Nicole McLachlan (Southern Cross University). In this aerial survey, qualitative information including approximate ghost net locations was provided to the CSIRO team (see Appendix A., Figure 5, Figure 6, and Figure 7). Two observers or spotters recorded estimated net numbers, based on 'zones' or regions where numbers of nets were recorded. We do not have imagery access from the survey which was conducted in 2020.

Dates of surveys with associated survey areas:

28 February 2020. Weipa to MacDonald River.

29 February 2020. MacDonald River to Punsand, Cape York.

1 March 2020. Weipa to Aurukun.

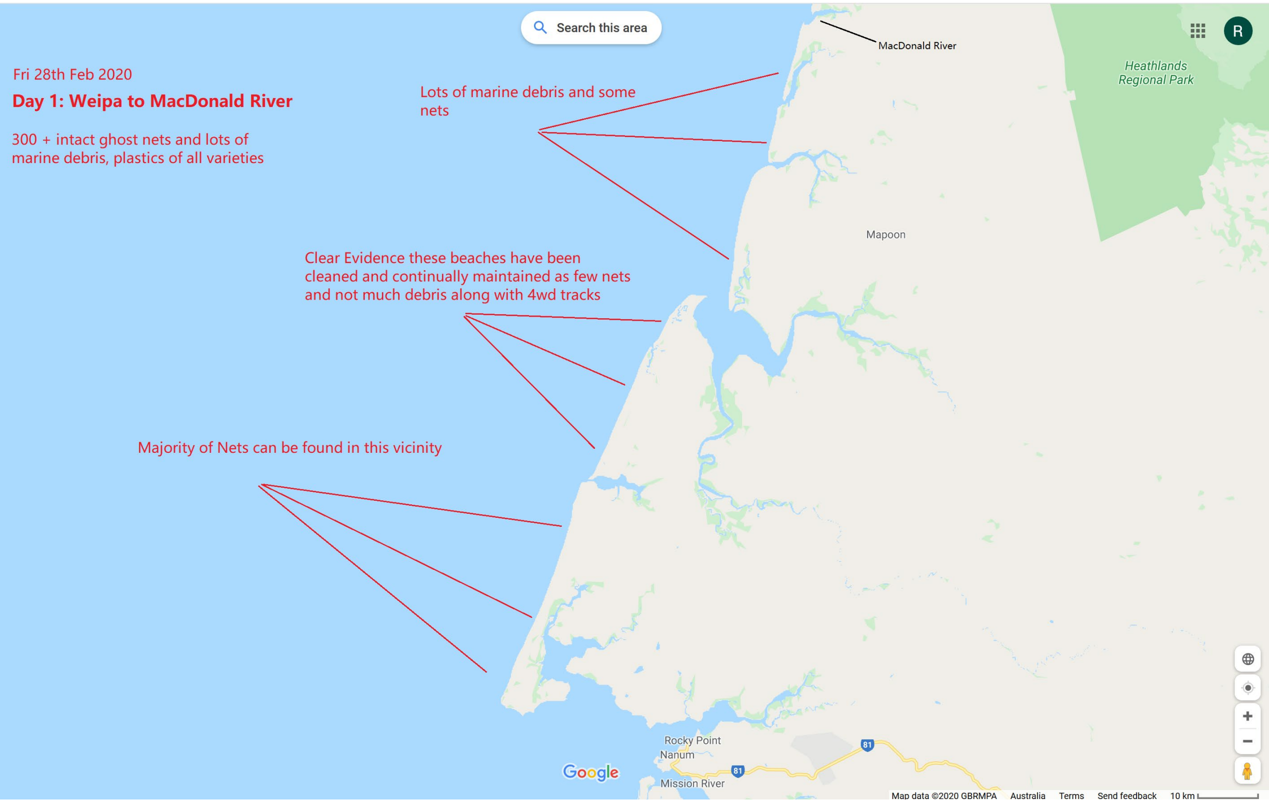

Figure 5. First provided map showing Day 1 survey (28 February 2020) from Weipa to MacDonald River, Queensland, Australia on Friday 28 February 2020. More than 300 intact ghost nets were counted, and a high abundance of other marine debris was reported (See Appendix A.).

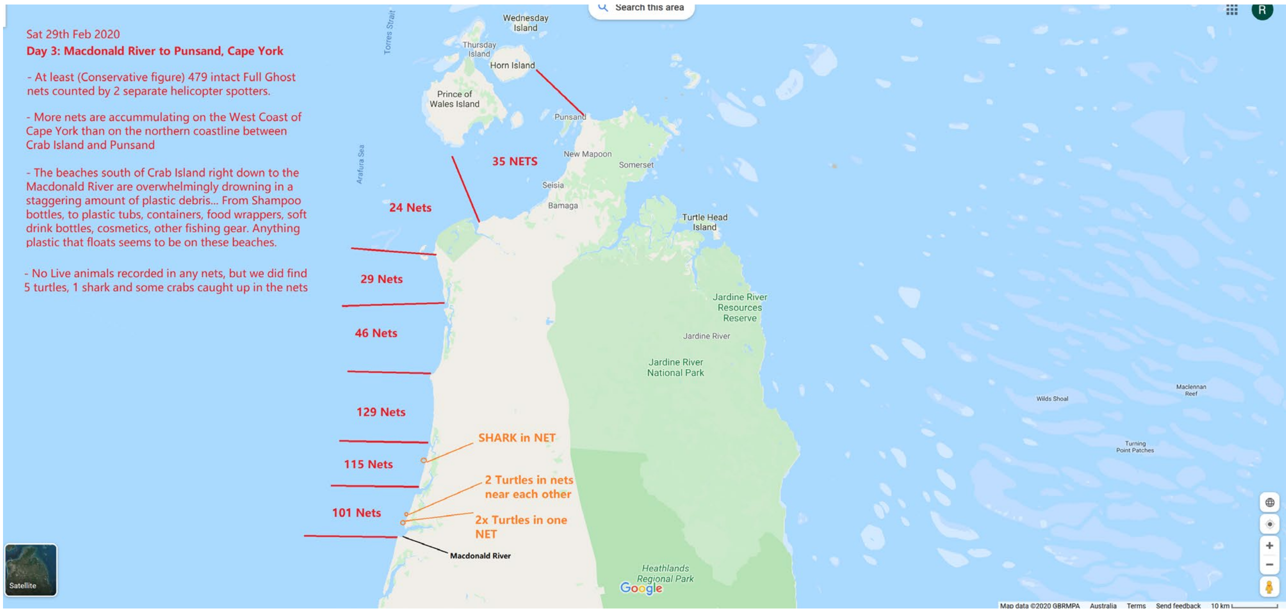

Figure 6. Map provided showing survey from MacDonald River to Peak Point, Punsand Bay, Cape York on Saturday 29 February 2020. More than 479 intact ghost nets were counted, and a high abundance of other marine debris was reported. Carcasses of five sea turtles, a shark and crabs were observed in the nets. Net numbers are estimated from visual observations from two spotters, with net numbers in 'zones' or regions provided.

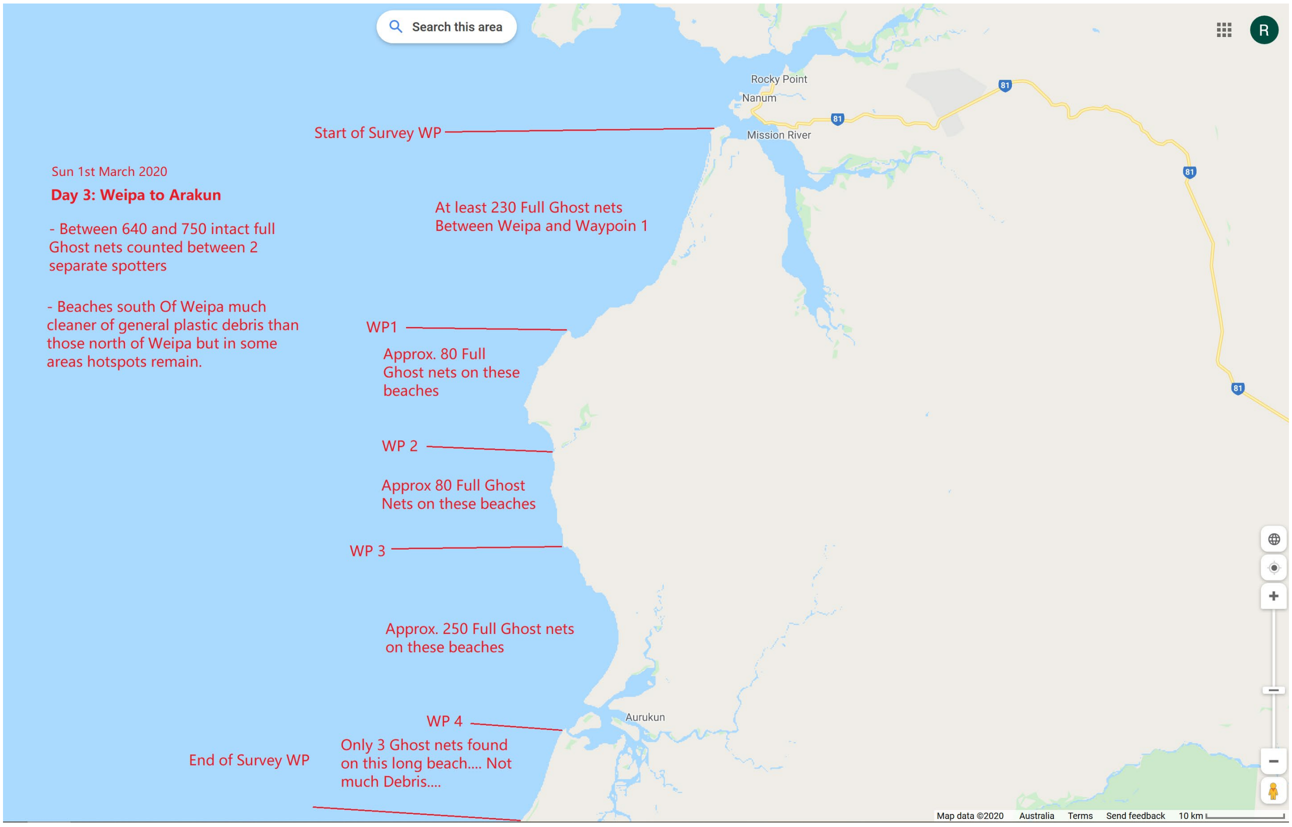

Figure 7. Map provided showing Day 3 survey (1 March 2020) from Weipa to Aurukun. Spotters estimated between 640 and 750 intact ghost nets were observed.

Part II An analysis to identify ghost gear hotspots and changes through time in the Gulf of Carpentaria, Northern Australia.

2 Methodological approach

2.1 Locations

Surveys took place across the Gulf of Carpentaria during 2004, 2017, 2019 and 2020. However, data collection approaches, survey times of year, and effort (number of observers x time spent per survey area) was not entirely consistent among surveys. Given one of the key goals of the project was to identify if ghost nets density has changed in space and time, and that some survey areas were not observed during all four of the survey periods, some locations were excluded from analyses (e.g. those areas that were only surveyed once). These locations include Wellesley Islands (surveyed in 2017 only), regional Northern Territory north of Isle Woodah (surveyed 2004 only) and Prince of Wales Island/Horn Island and surrounding islands (surveyed 2004 only). Locations that were not surveyed were also not included in this report and associated analyses. This includes most of the islands in the Gulf of Carpentaria (except where specifically mentioned as included), including larger islands such as Groote Eylandt. We also excluded the three Badu Island nets counted during the 2004 survey. Furthermore, precise locations of nets observed were not reported consistently across all surveys (see Section 2.2.1 below).

2.2 Analysis approach

We calculated coastline distances using QGIS version 3.18.0. This was a first step required to ensure geographic distances were consistent among survey years. Statistical analysis was conducted using a Generalized Additive Model (GAM) with the “mgcv” package (Wood, 2019) in R version 3.5.1 (R Core Team, 2018). This approach performs hypothesis testing and allows models to be compared to be fitted to the same data using the same smoothing parameter selection function (Wood 2019).

2.2.1 Generating GPS locations for ghost nets sighted in 2020 surveys

Whereas for other survey years geolocation data was available, only qualitative data (descriptive data) was provided for the 2020 aerial surveys. Hence, we did not have specific geolocation information for each ghost net observed in the 2020 helicopter survey. Though locations provided were imprecise, 1,422 nets were recorded in the 2020 survey (see Figure 5, Figure 6, and Figure 7, Appendix A.). There were 300 nets recorded on day one, 479 nets recorded on day two and 643 nets recorded on day three. Hence, we divided the survey routes into 15 survey ‘legs’ between major geographic features noted in the survey notes. To remedy the unknown GPS locations of the nets, we generated GPS net location points based on survey data and placed them randomly within a 0.005^{o} (approximately 1 km width) buffer of the surveyed coastline between Peak Point/Punsand and south of Aurukun (excluding Ducie, Mission and Embley rivers), following the distances in Table 2 (Figure 8).

Table 2. Start and end points of survey legs conducted in Queensland in 2020.

Leg	Number of nets	Start Location	Longitude	Latitude	End location	Longitude	Latitude
1	35	Peak point	142.4391	-10.7072	Jardine river	142.4391	-10.7072
2	24	Jardine river	142.2112	-10.9221	Crab island	142.2112	-10.9221
3	29	Crab island	142.1301	-10.9858	Northern peninsula	142.1301	-10.9858
4	46	Northern peninsula	142.1531	-11.0842	Vrilya point	142.1531	-11.0842
5	129	Vrilya point	142.1166	-11.2248	Cotterell Creek	142.1166	-11.2248
6	115	Cotterell Creek	142.1201	-11.3669	Doughboy river	142.1201	-11.3669
7	101	Doughboy river	142.0949	-11.4591	Macdonald river	142.0949	-11.4591
8	40	Macdonald river	142.0635	-11.5341	Cullen point	142.0635	-11.5341
9	10	Cullen point	141.9102	-11.9501	Mapoon	141.9102	-11.9501
10	250	Mapoon	141.7994	-12.0618	Weipa	141.7994	-12.0618
11	230	Weipa	141.8169	-12.6528	Boyd point	141.8169	-12.6528
12	80	Boyd point	141.6314	-12.8968	Norman creek	141.6314	-12.8968
13	80	Norman creek	141.6147	-13.0477	Waypoint 3	141.6147	-13.0477
14	250	Waypoint 3	141.6311	-13.1605	Aurukun	141.6311	-13.1605
15	3	Aurukun	141.6346	-13.3619	End 2020	141.6346	-13.3619

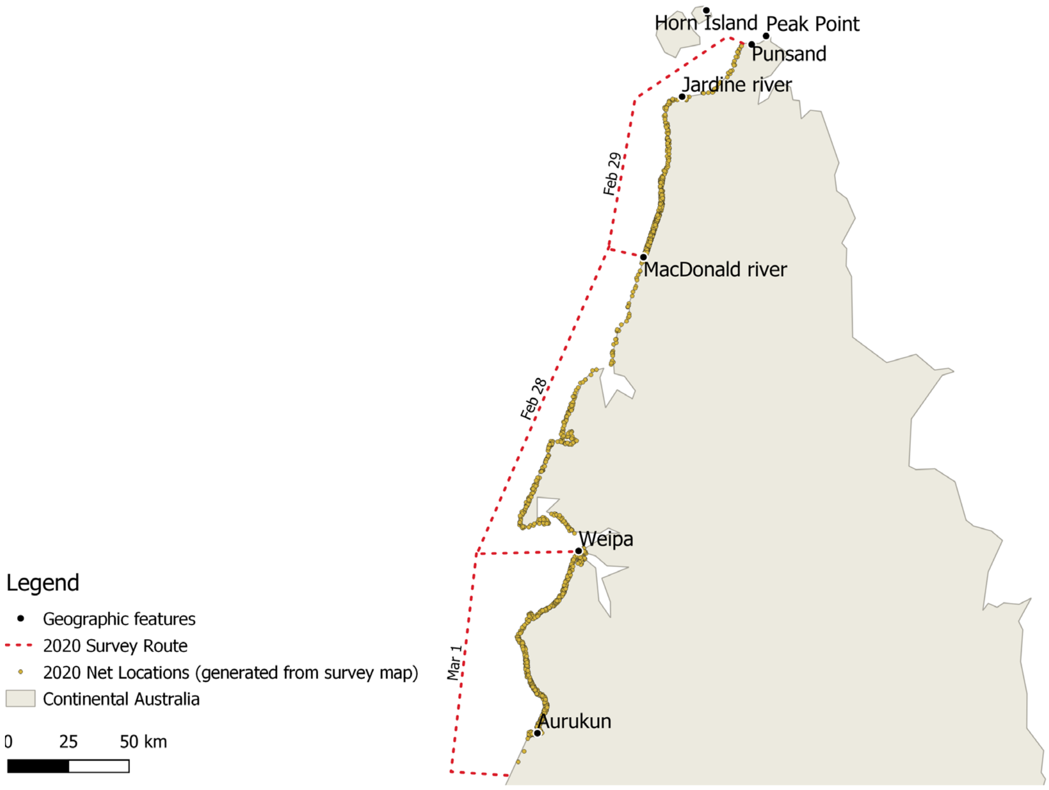

Figure 8. Predicted net locations from 2020 surveys. Using the survey maps in Figure 5, Figure 6, and Figure 7, we generated GPS datapoints within a 0.005 degree buffer of the Queensland coastline surveyed during 2020.

2.2.2 Grid map of the Gulf of Carpentaria

To monitor changes in beached ghost net density across the Gulf of Carpentaria, we divided the GoC region to 1º x 1º grid cells. While coarser in scale, this allowed us to amalgamate data collected over multiple years from each of the four helicopter surveys. Each 1º x 1º grid cell represents an area of approximately 111x111 km (sensu Wilcox et al. 2013, Figure 9 below). Due to tortuosity of the coastline, the actual length of coastline within each 1º grid cell varies (see Table 3 for values).

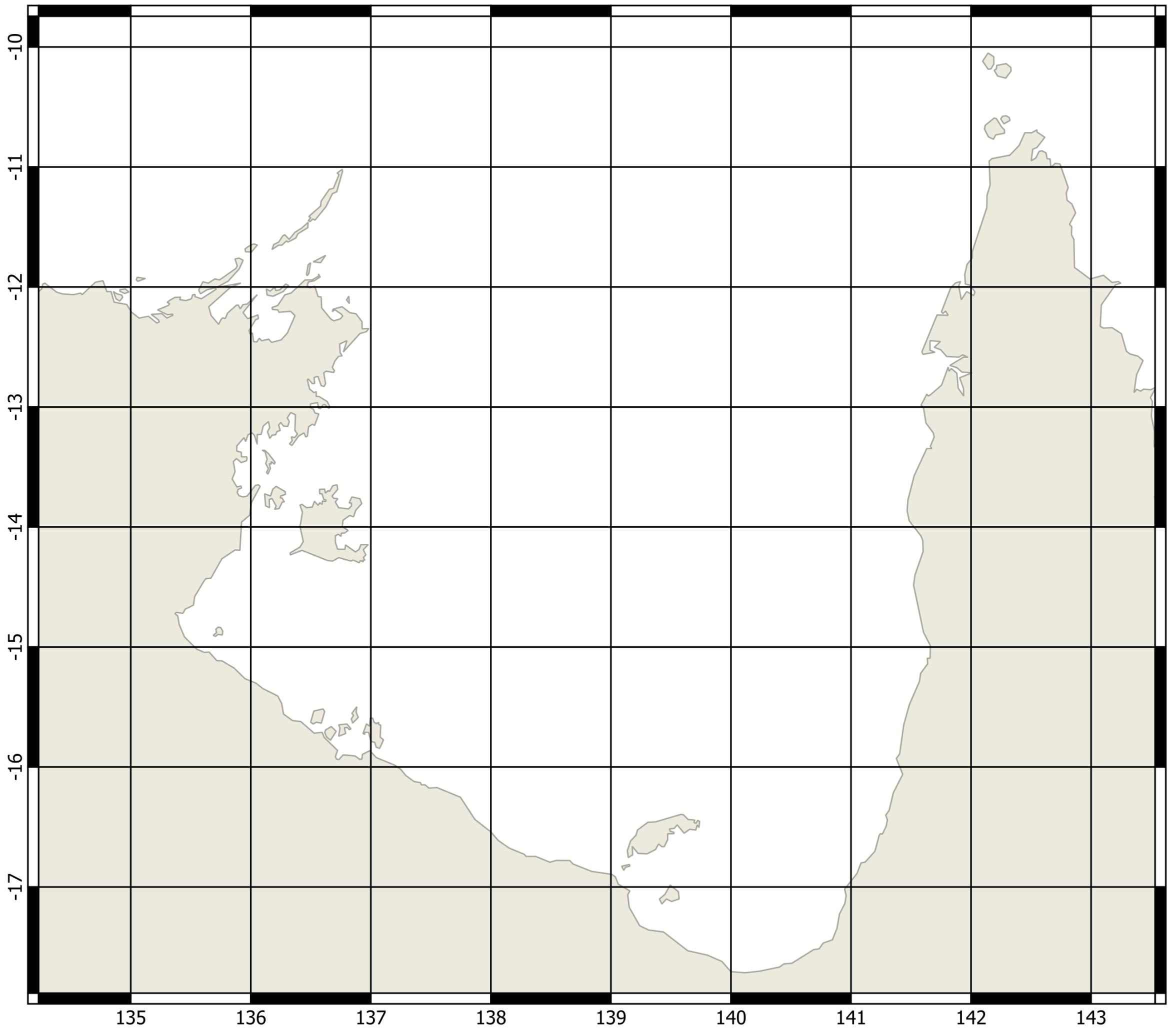

Figure 9. 1º grid cell applied over the gulf of Carpentaria.

After determining the length of coastline in each grid cell, we plotted a colour-coded grid map of the count of nets recorded in each grid cell in each year the grid was surveyed (Figure 10). However, these values are not adjusted for the length of the coastline nor the survey effort (the distance of coastline flown during a survey day per year). To determine the density of beached ghost nets per grid cell, we divided the net count per grid cell by the length of coastline per grid cell (Figure 11). Note that the values depicted in Figure 10 and Figure 11 are *not* adjusted for survey effort.

Table 3. The length of the coastline and major geographic features (towns, points and river mouths) in each of the 20 surveyed 1° grid cells. We also include the survey years and any relevant notes (columns 3 and 4, respectively).

Grid cell	Survey coast length	Geographic features	Survey Years	Notes
-11, 142	52	Horn island, Peak point/Punsand, Jardine river (QLD)	2004, 2020	Measured coastline from Peak Point/Punsand. Prince of Wales Island 59 km; Horn island 25 km.
-12, 141	88	Cullen point (QLD)	2004, 2020	
-12, 142	39	Vrilya point, Cotterell creek, Doughboy river, MacDonald river (QLD)	2004, 2020	
-13, 136	206	Gove (NT)	2004	Coastline not measured beyond Gove.
-13, 141	137	Weipa, Mapoon, Boyd point (QLD)	2004, 2017, 2019, 2020	
-14, 135	39	Cape Barrow (NT)	2004, 2017, 2019	Northern part of inlet 210km. Woodah Island, northern Groote Eylandt not surveyed (NT).
-14, 136	135	Walker river (NT)	2004, 2017, 2019	
-14, 141	125	Aurukun, Norman creek, southern end of 2020 survey (QLD)	2004, 2017, 2019, 2020	
-15, 135	151	Numbulwar (NT)	2004, 2017, 2019	
-15, 141	188	Kendall river, Pormpuraaw (QLD)	2004, 2017, 2019	
-16, 135	62	Cox river (NT)	2004, 2017, 2019	
-16, 136	360	Roper gulf coast and islands (NT)	2004, 2017, 2019	Roper gulf coast 192km (north of Borroloola), West Island, Centre Island, North Island and Vanderlin Island (together 168 km).
-16, 137	79	Coast and part of Vanderlin Island (NT)	2004, 2017, 2019	part Vanderlin Island (NT) and 28 coast.
-16, 141	121	Nassau river (QLD)	2004, 2017, 2019	
-17, 137	97	Robinson river, Norther Territory side of state border (NT)	2004, 2017, 2019	

-17, 138	119	Tully inlet, Queensland side of state border (QLD)	2004, 2017, 2019	
-17, 139	255	Mornington Island, Forsyth Island and coast (QLD)	2004, 2017, 2019	Mornington Island (218 km), Forsyth island (21 km) and 16 km of coastline.
-17, 141	123	Staaten river, Gilbert river, Dinah Island nature refuge (QLD)	2004, 2017, 2019	
-18, 139	138	Nicholson river (QLD)	2004, 2017, 2019	
-18, 140	151	Karumba (QLD)	2004, 2017, 2019	

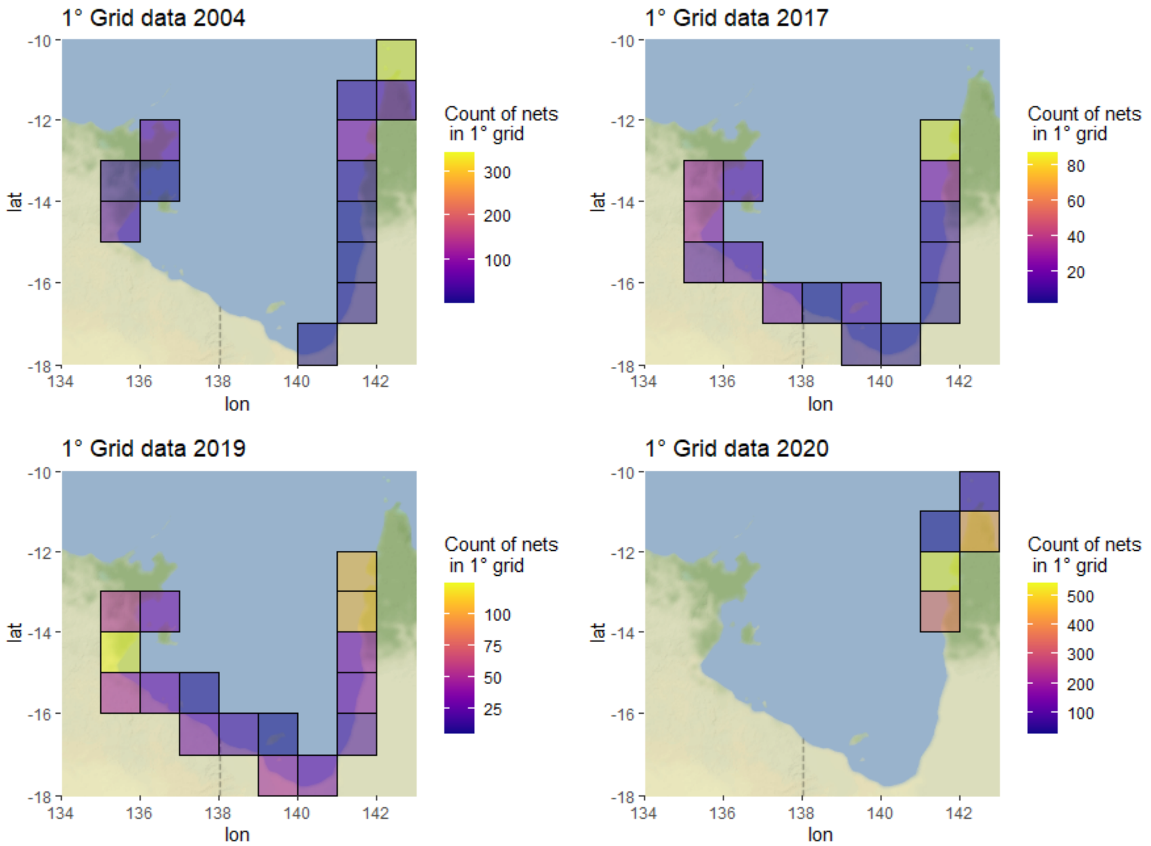

Figure 10. Raw number of nets counted per grid cell. The mapped density of nets per grid cell is not adjusted for the length of coastline per grid cell, nor for survey effort.

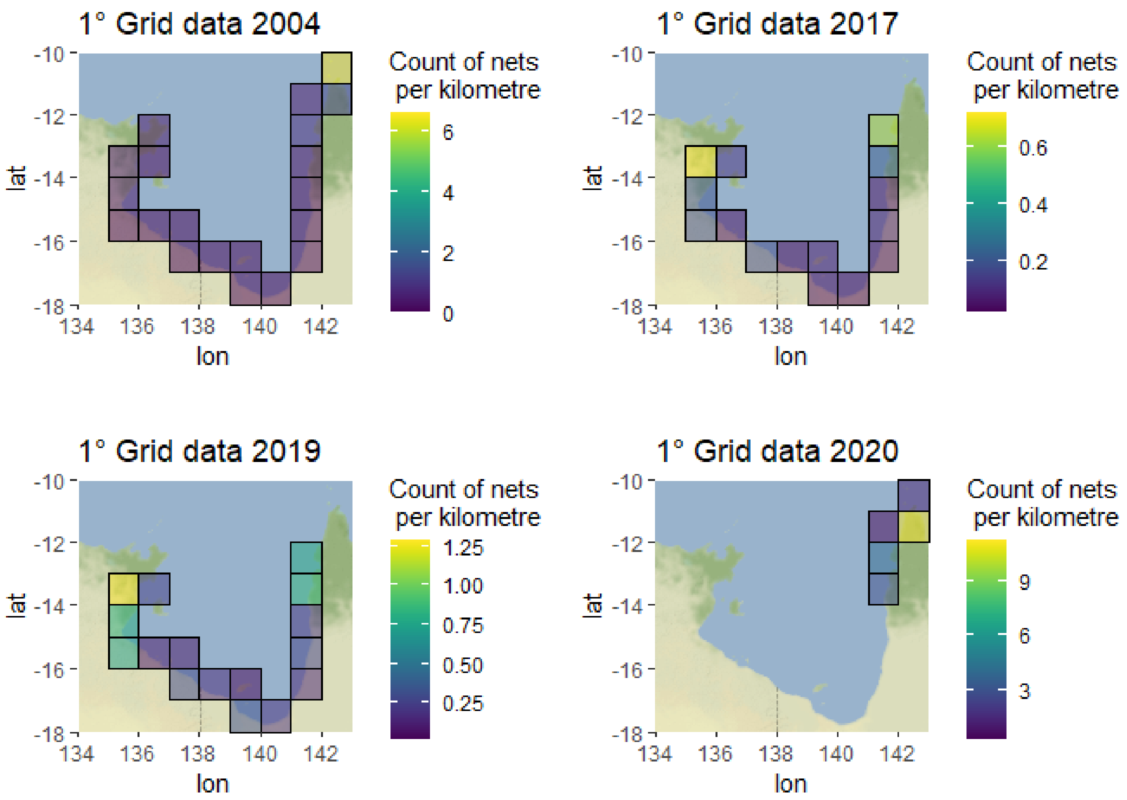

Figure 11. Nets standardised per kilometre of coastline observed within each survey year. This means the number of nets per grid cell has been adjusted for the length of coastline per grid cell, including zeros. The mapped nets per kilometre in each grid cell has not been adjusted for survey effort.

Not surprisingly, the number of nets recorded per kilometre of coastline varied between survey year. When nets per kilometre are mapped with a regular colour scale showing a range of 0-12 nets between years, it shows that the number is <1 net per kilometre for most regions, except for the northern extents of the Gulf of Carpentaria, including the vast inlet surrounding the Isle of Woodah in the Northern Territory and the Cape York Peninsula, Queensland (Figure 12). However, these maps do not account for survey effort, which was much higher in the 2020 survey and may be influencing this result.

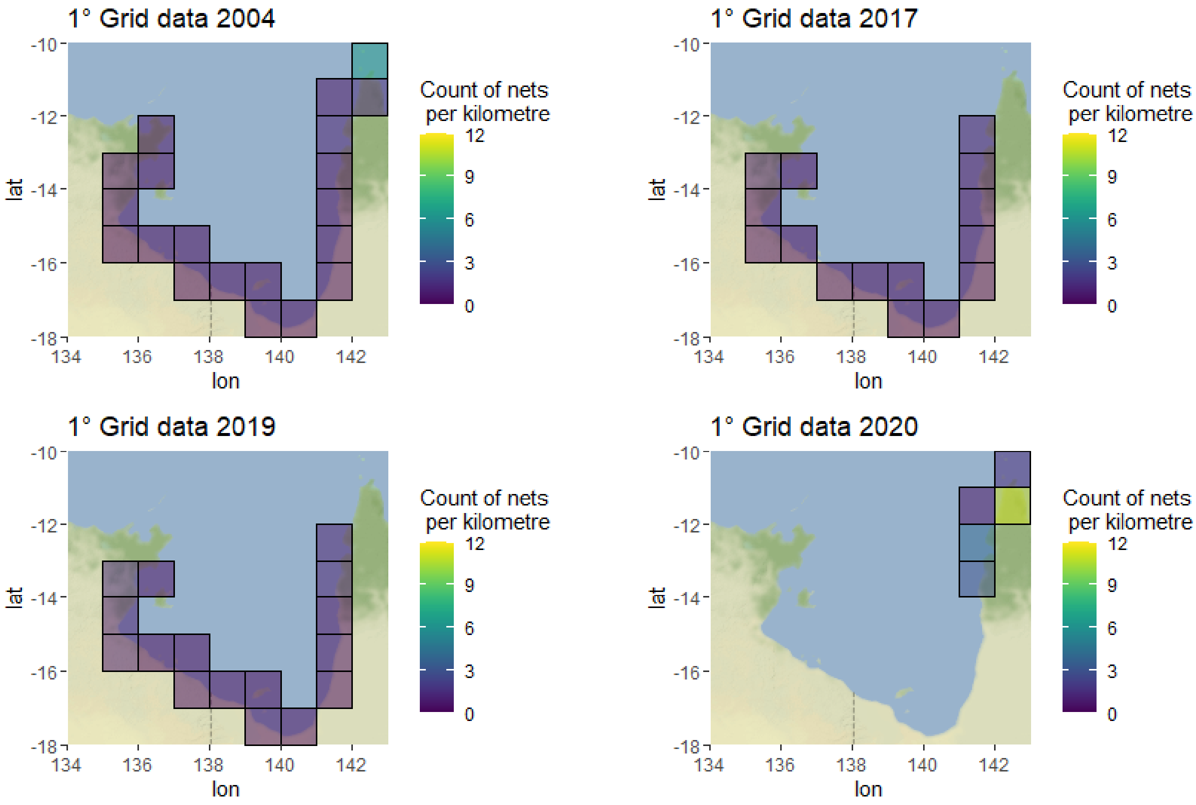

Figure 12. Nets standardised per kilometre of coastline observed between survey years. This means the number of nets per grid cell has been adjusted for the length of coastline within each grid cell, including zeros, with a fixed legend scale. This differs from Figure 11, in which the colour scale varies each survey year to show variation within survey year. The mapped nets per kilometre in each grid cell has not been adjusted for survey effort.

2.2.3 Survey effort

Survey effort was applied at the most appropriate scale based on the information available. We then summarized the data to survey effort based on the number of coastal kilometres surveyed over each helicopter day (Table 4). Ideally, the number of survey flight hours would provide more accurate survey effort, but this information was not available across all surveys. As noted previously, we used QGIS (a free and open source Geographic Information Systems platform) and the ESRI "Coastlines" package to quantify the coastline length across the Gulf of Carpentaria (ESRI (Environmental Systems Research Institute) is an international supplier of GIS software).

Table 4. Survey effort (kilometres of coastline surveyed per day of aerial surveys) during 2004, 2017, 2019 and 2020 helicopter surveys.

Survey year	Date	Start	End	Nets Reported	Coastline Surveyed (km)	Notes
2004	17 Nov	Gove	Borroloola	125	878	Measured coastline to/from Roper Gulf rather than the inland Borroloola township.
2004	18 Nov	Borroloola	Karumba	1	593	Measured coastline to/from Roper Gulf rather than the inland Borroloola township.
2004	19 Nov	Karumba	Weipa	83	524	Excluded Embley river delta.
2004	20 Nov	Weipa	Horn island	123	372	Excluded Mission river delta.
2004	20 Nov	Horn island	Horn island	338	84	Coastline measurement Horn Island and Prince of Wales Island. Nets were on Horn Island, Prince of Wales Island, Wednesday Island, Friday Island and Goode Island.
2017	1 Dec	Weipa	Pormpurraw	120	288	
2017	2 Dec	Pormpurraw	Nassau river	8	123	
2017	4 Dec	Nassau river	Kurumba	3	197	
2017	5 Dec	Karumba	Nicholson river	3	145	
2017	6 Dec	Nicholson river	Tully inlet	7	202	
2017	7 Dec	Mornington island	Mornington island	12	218	
2017	8 Dec	Tully inlet	Borroloola	18	182	
2017	9 Dec	Borroloola	Cox river	21	209	
2017	10 Dec	Cox river	Numbulwar	17	130	
2017	11 Dec	Numbulwar	North of Woodah Island	56	232	
2019	12 Sep	Weipa	Kendall river	241	204	
2019	13 Sep	Kendall river	Nassau river	40	207	
2019	14 Sep	Nassau river	Kurumba	25	197	
2019	16 Sep	Kurumba	Nicholson river	22	145	
2019	17 Sep	Nicholson river	Robinson river	83	327	
2019	18 Sep	Robinson river	Cox river	23	231	
2019	20 Sep	Cox river	Numbulwar	140	130	
2019	21 Sep	Numbulwar	Cape Barrow	127	91	
2020	28 Feb	Weipa	MacDonald river	300	260	
2020	29 Feb	MacDonald river	Punsand/ Peak Point	479	113	
2020	1 Mar	Weipa	past Aurukun	643	122	

2.2.4 Scaling survey effort to 1° grid cells

To standardise survey effort, we used general additive models (GAM)s with a Tweedie distribution (R package "mgcv" (Wood, 2019)), selected due to the commonality of zero counts in the data. As part of the data validation process, we also visually validated data, ensuring zero values were included into each surveyed grid cell where no nets were detected in a survey year. GAMs were used to assess the relationship between the number of nets per grid cell, the grid cell location, the length of the coastline, year of survey, survey effort (1 / number of kilometres of coastline surveyed per day), the latitude of survey grid cell (1°) and longitude of survey grid cell (1°), examining both additive (+) and interactive (x) relationships. Akaike Information Criterion (AIC) was used to choose the GAM that best fit the data and comparing these to the null model. Using AIC, the best model is that which has the lowest AIC, though models which differ by a value less than 2 may be considered equivalent (Burnham & Anderson, 2002) (see Table 5).

Table 5. Comparison of general additive models (GAMs) that examine the relationship between number of counted nets and survey effort parameters for each 1° grid cell. Model 4 (bold) is the best model, based on AIC. Tested models that did not converge are not included in this table.

Model	Model parameters	AIC
0) Null model	Number of nets ~ 1, offset = effort.	548.8
1) Addition only model	Number of nets ~ Grid cell + Coastline length + Year + 1° latitude * 1° longitude, offset = effort.	498.7
2) Interaction between year and location	Number of nets ~ Grid cell + Coastline length + Year * 1° latitude * 1° longitude, offset = effort.	486.5
3) Interaction between coastline length and year	Number of nets ~ Grid cell + Coastline length * Year + 1° latitude * 1° longitude, offset = effort.	494.9
4) Interaction between coastline length, year and location	**Number of nets ~ Grid cell + Coastline length * Year * 1° latitude * 1° longitude, offset = effort.**	**484.0**
5) Interaction between coastline length and location	Number of nets ~ Grid cell + Year + Coastline length * 1° latitude * 1° longitude, offset = effort.	498.5
6) Interaction between grid cell and coastline length	Number of nets ~ Grid cell * Coastline length + Year + 1° latitude * 1° longitude, offset = effort.	499.3
7) Interaction between grid cell and coastline length, year and location	Number of nets ~ Grid cell * Coastline length + Year * 1° latitude * 1° longitude, offset = effort.	486.9

The model that best described the relationship between the number of nets, the coastline length, year of survey, survey effort (1 / number of kilometres of coastline surveyed per day), latitude of survey grid cell (1^o) and longitude of survey grid cell (1^o), was Model 4 (in bold, Table 5). This model shows that the density of nets per grid cells is most strongly driven by the interaction between survey year interacting with location (as represented by latitude and longitude).

2.2.5 Survey effort-adjusted net densities in 1^o grid cells

Using the Model 4 (see section above (2.2.4), we predicted the number of nets for each grid cell, for each year, in a scenario where survey effort remained consistent. We performed this prediction based on the median survey effort of 205 km of coastline surveyed per day. The output of this survey effort-adjusted ghost net density is shown in Figure 13.

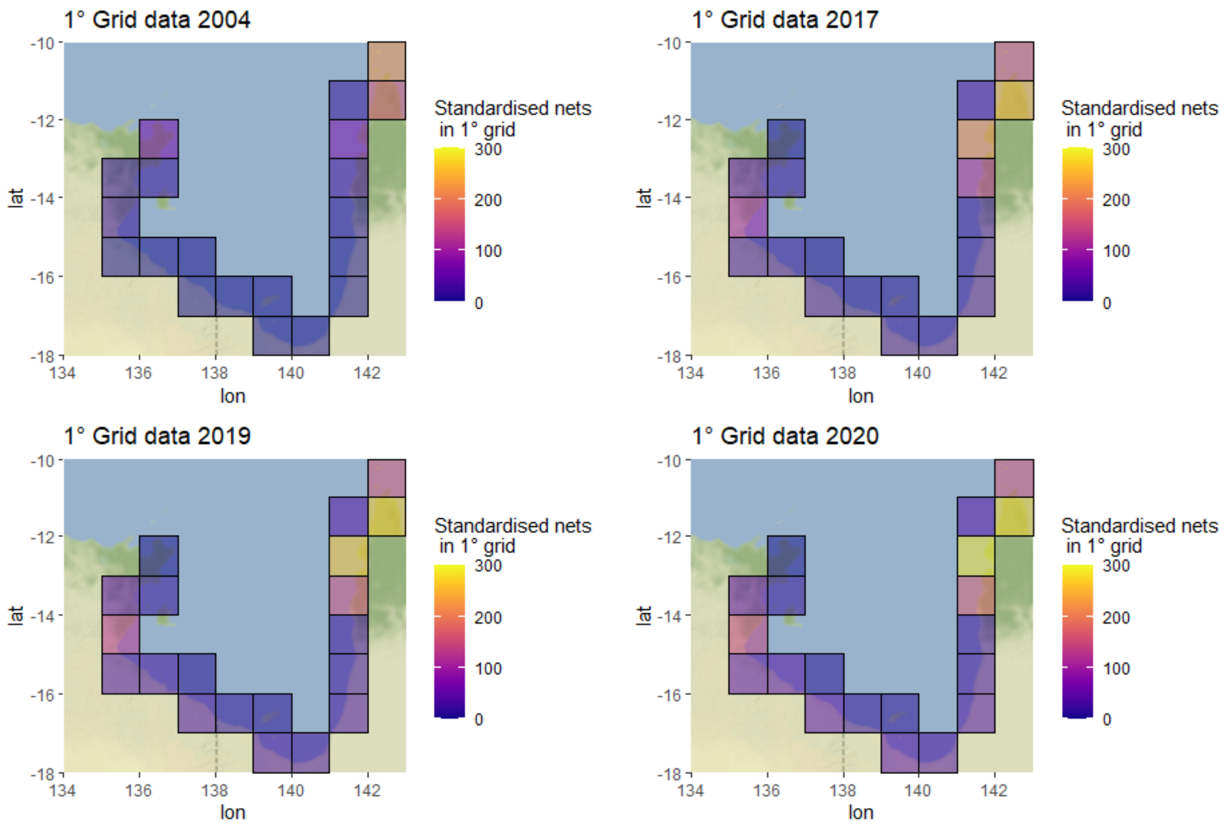

Figure 13. Effort-standardised number of nets predicted to occur per 1^0 grid cell. The mapped density of nets per grid cell is not adjusted for the length of coastline per grid cell.

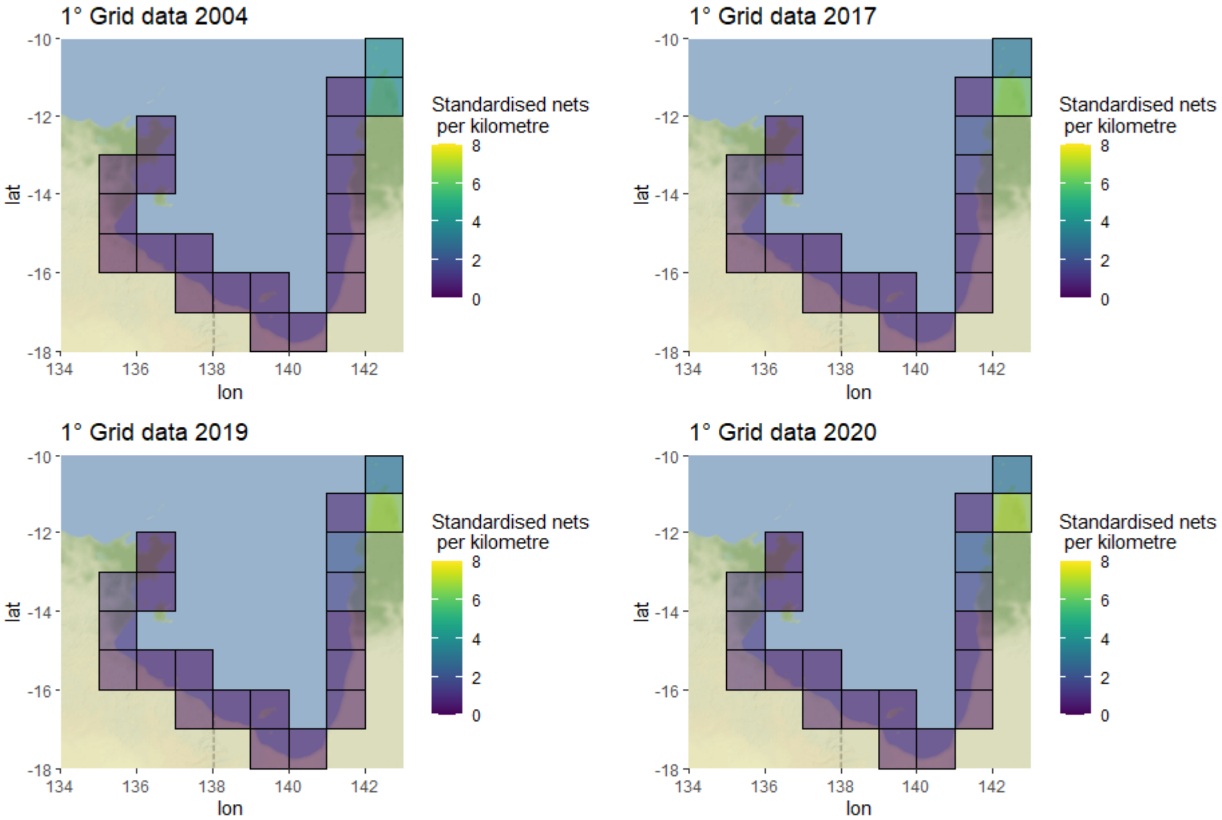

Figure 14. The number of nets predicted to occur per kilometre in each grid cell for 2004, 2017, 2019 and 2020.

3 Findings and their interpretations

In the section below we present and discuss the ghost net density results in in the Gulf of Carpentaria region, based on aerial helicopter surveys conducted in 2004, 2017, 2019 and 2020. In regions or grid cells where fewer surveys were conducted, the predictions of ghost net densities and changes through time will be less reliable than in those regions that were surveyed in each of the four survey periods.

Overall, because of the bathymetry, geography, monsoonal seasonality and influence of wind, waves, and currents, the Gulf of Carpentaria acts as an accumulation area, or sink, for ghost nets and other anthropogenic debris. While previous studies have noted the high density of ghost nets in the region (see Wilcox et al. 2012, Gunn et al. 2010, Kiessling 2002), it is worth noting that if the loss of fishing nets is not abated, the issue of net and other debris will continue within the region. This is a high biodiversity value, with six of the seven threatened marine turtle species occurring here, with substantial proportions of the remaining global populations for some species (Limpus and Fien 2009, Biddle and Limpus 2011). The gulf's shallow waters are extensive, with seagrass and mangrove-reliant communities. Land and sea management here is complicated due to its remoteness.

3.1 Ghost net hotspots

Based on the four helicopter surveys, the highest number of nets per kilometre is predicted to occur in the northern Cape York Peninsula of Queensland, including the coastline passing Vrilya point, Cotterell creek, Doughboy river, MacDonald river (QLD). Another hotspot occurs south of the Gove Peninsula. These findings reflect hotspots identified in the 2004-2009 Summary report by GhostNets Australia, which reported that hotspots were predominantly found in the north-eastern and north-western corners of the Gulf (Heathcote et al., 2011). The southern portion of the Gulf of Carpentaria, near the Queensland/Northern territory border, was predicted to contain the fewest nets (Table 6).

Table 6. Predicted ghost nets per kilometre of coastline in surveyed regions of the Gulf of Carpentaria, standardised for aerial survey effort. This hotspot table is sorted by descending number of nets for the most recent year of survey, 2020.

Grid cell	2004	2017	2019	2020	Geographic features
-12, 142	4.2	6.5	6.9	7.1	Vrilya point, Cotterell creek, Doughboy river, MacDonald river (QLD)
-11, 142	4.3	3.3	3.1	3.1	Horn island, Peak point/Punsand, Jardine river (QLD)
-13, 141	0.5	1.6	1.9	2.1	Weipa, Mapoon, Boyd point (QLD)
-14, 141	0.2	1	1.2	1.4	Aurukun, Norman creek, southern end of 2020 survey (QLD)
-14, 135	0.3	0.9	1.1	1.2	Cape Barrow (NT)
-15, 135	0.1	0.6	0.8	0.9	Numbulwar (NT)
-16, 135	0	0.3	0.5	0.6	Cox river (NT)
-12, 141	0.2	0.3	0.4	0.4	Cullen point (QLD)
-17, 137	0	0.1	0.3	0.4	Robinson river, Norther Territory side of state border (NT)
-17, 141	0	0.1	0.2	0.3	Staaten river, Gilbert river, Dinah island nature refuge (QLD)
-18, 139	0	0.1	0.2	0.3	Nicholson river (QLD)
-16, 141	0	0.1	0.2	0.2	Nassau river (QLD)
-18, 140	0	0.1	0.1	0.2	Karumba (QLD)
-14, 136	0.1	0.1	0.1	0.1	Walker river (NT)
-15, 141	0	0.1	0.1	0.1	Kendall river, Pormpuraaw (QLD)
-16, 136	0	0	0.1	0.1	Roper gulf coast and islands (NT)
-16, 137	0	0	0.1	0.1	Coast and part of Vanderlin island (NT)
-17, 138	0	0	0.1	0.1	Tully inlet, Queensland side of state border (QLD)
-13, 136	0.3	0	0	0	Gove (NT)
-17, 139	0	0	0	0	Mornington Island, Forsyth island and coast (QLD)

3.2 Ghost gear changes through time

The number of ghost nets in most locations (85% or 17 of 20) increased from 2004 until 2020 surveys. The density of beached ghost nets in three grid cells appear to be decreasing. Notably, ghost net accumulation in some regions is more rapid than in others. This may be a 'real' phenomenon or may reflect clean-up activities or changes in fishing locations. It may also reflect a change in operation of the types of fishing boats that have high rates of gear becoming derelict and generating ghost nets. Information on net types that are stranded would help us to answer this question.

There have been substantial changes in fisheries management practices in recent years by our Indonesian neighbours that have resulted in a reduction of total fishing vessels within the Arafura and surrounding seas. However, while there has been a prohibition of purse seine and trawl nets, there has been a concordant increase in gill nets (AFMA, pers. comm.). Hence, it is possible that the number of nets lots may not have changed substantially, though further investigation into the *types* of nets washing ashore in the Gulf of Carpentaria could prove meaningful. Overall, we were surprised that given the many years of on-ground clean-up activities in which ghost nets have been removed within the Gulf of Carpentaria, an overall increase in the number of nets was detected from 2004 through 2020.

Table 7. Changes through time of standardised and predicted ghost nets per grid cell in the Gulf of Carpentaria.

Grid cell	Geographic features	2004	2017	2019	2020	Increasing or decreasing	Change
-11, 142	Horn island, Peak point/Punsand, Jardine river (QLD)	222.9	170.6	163.7	160.4	Decreasing	-62.5
-12, 141	Cullen point (QLD)	17.2	30.5	33.3	34.8	Increasing	17.6
-12, 142	Vrilya point, Cotterell creek, Doughboy river, MacDonald river (QLD)	163.5	251.6	268.8	277.9	Increasing	114.4
-13, 136	Gove (NT)	63.9	1.6	0.9	0.7	Decreasing	-63.2
-13, 141	Weipa, Mapoon, Boyd point (QLD)	66.9	219.9	264.1	289.4	Increasing	222.5
-14, 135	Cape Barrow (NT)	13.2	36.8	43.1	46.7	Increasing	33.5
-14, 136	Walker river (NT)	18.5	16	15.6	15.5	Decreasing	-3
-14, 141	Aurukun, Norman creek, southern end of 2020 survey (QLD)	25.2	119.6	151.9	171.2	Increasing	146
-15, 135	Numbulwar (NT)	17.7	95.1	123.2	140.2	Increasing	122.5
-15, 141	Kendall river, Pormpuraaw (QLD)	7.1	16.8	19.1	20.4	Increasing	13.3
-16, 135	Cox river (NT)	0.6	17.9	30	38.9	Increasing	38.3
-16, 136	Roper gulf coast and islands (NT)	0.2	13.3	25.5	35.4	Increasing	35.2
-16, 137	Coast and part of Vanderlin island (NT)	0.1	3	5.1	6.7	Increasing	6.6
-16, 141	Nassau river (QLD)	1.3	14.2	20.4	24.5	Increasing	23.2
-17, 137	Robinson river, Norther Territory side of state border (NT)	0.1	13.5	28.2	40.7	Increasing	40.6
-17, 138	Tully inlet, Queensland side of state border (QLD)	0.1	5.5	10.7	15	Increasing	14.9
-17, 139	Mornington Island, Forsyth island and coast (QLD)	1.1	6.3	8.3	9.6	Increasing	8.5
-17, 141	Staaten river, Gilbert river, Dinah island nature refuge (QLD)	1.1	16.8	25.4	31.2	Increasing	30.1
-18, 139	Nicholson river (QLD)	0.2	13.3	26.5	37.4	Increasing	37.2
-18, 140	Karumba (QLD)	0.6	13.9	22.4	28.3	Increasing	27.7

3.2.1 Queensland changes through time

The number of beached ghost nets increased in all but one grid cell between 2004 and 2020 for Queensland sites (Figure 15). The sharpest increase occurred at the grid cells containing Weipa, Mapoon, Boyd point (QLD) (-13, 141) and Vrilya point, Cotterell creek, Doughboy river, MacDonald river (QLD) (-12, 142), which gained 225.5 and 114.4 nets respectively between 2004 and 2020. This increase is despite clean-up efforts in the area, noted by Rupert during the 2020 northern Queensland survey. This suggests that despite clean-up efforts, beached ghost nets may be increasing in this area. Information about on-ground, local clean-up efforts would be useful to contextualise this information.

The northern neighbouring grid cell (-11, 142), containing Horn island, Peak point/Punsand, Jardine river (QLD), likewise demonstrated high numbers of beached nets during 2004, standardised at 222.9 nets. However, this grid cell (-11, 142), was the only location in Queensland where the number of beached nets appeared to have decreased over time, with a reduction to 160.4 nets/km in 2020 (Table 7). The reason for decrease in nets is not known, though it may be due to local clean-up efforts, an artefact of the surveys that were conducted (for example, this grid cell contains several islands, and we only have information on which islands were included in the survey during 2004) or it could be associated with greater detectability due to mangrove dieback. It is possible that this predicted decrease is an artefact of the survey or analysis methods, as this northern point was surveyed in only two years (2004 and 2020), meaning that the data is less robust than other regions. We urge caution against overinterpretation of this finding.

One interesting observation is the sharp increase in nets at the southern Queensland latitudes. The 2004 surveys revealed very few nets in these regions, but later (2017, 2019) surveys showed nets accumulating in this southern region. From this data alone, and without more specific information on clean-up effort in the region, we do not know whether all southern regions are rapidly accumulating ghost nets or whether it reflects less clean up occurring than other sections of the Queensland coastline, given its sparse population.

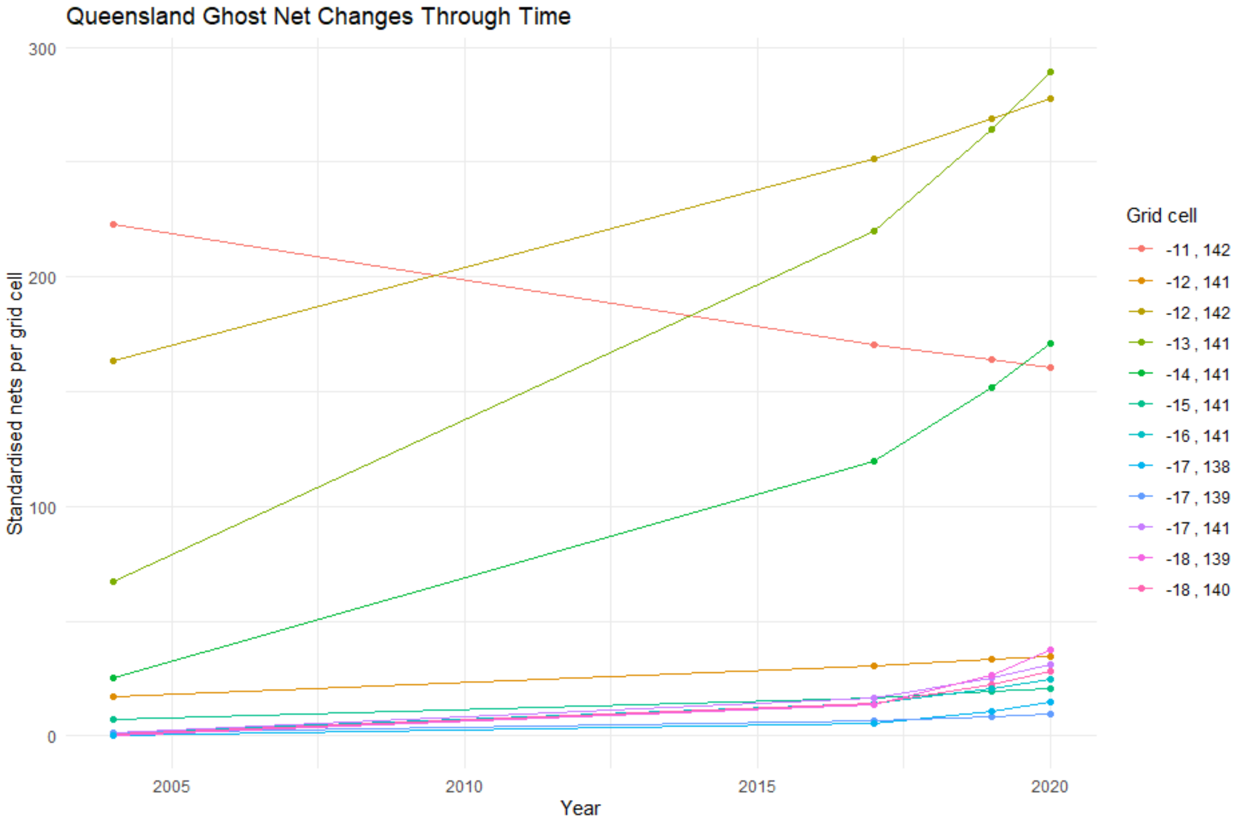

Figure 15. Changes in net numbers through time in each grid cell across Queensland.

3.2.2 Northern Territory changes through time

Across the Northern Territory, the change in the number of ghost nets through time was not as dramatic as for Queensland (Figure 16), except for two grid cells. The sharpest increase in predicted net density in the Northern Territory occurs on the coast and among the grid cell containing Numbulwar (-15, 135), which experienced a nine-fold increase in nets. The remaining regions within the Northern Territory showed a gradual increase (two showed a gradual decrease) in ghost nets between 2004 and 2020. The sharpest decrease occurred in the grid cell containing the Gove peninsula (-13, 136), however this grid cell was only surveyed once in 2004 and therefore the expected decrease is based on modelled variables rather than real observations of a decrease, so we urge caution in over-interpreting this finding. Other sites within the Northern Territory were fairly consistent in numbers of nets observed across the 16 years of aerial surveys (Figure 16).

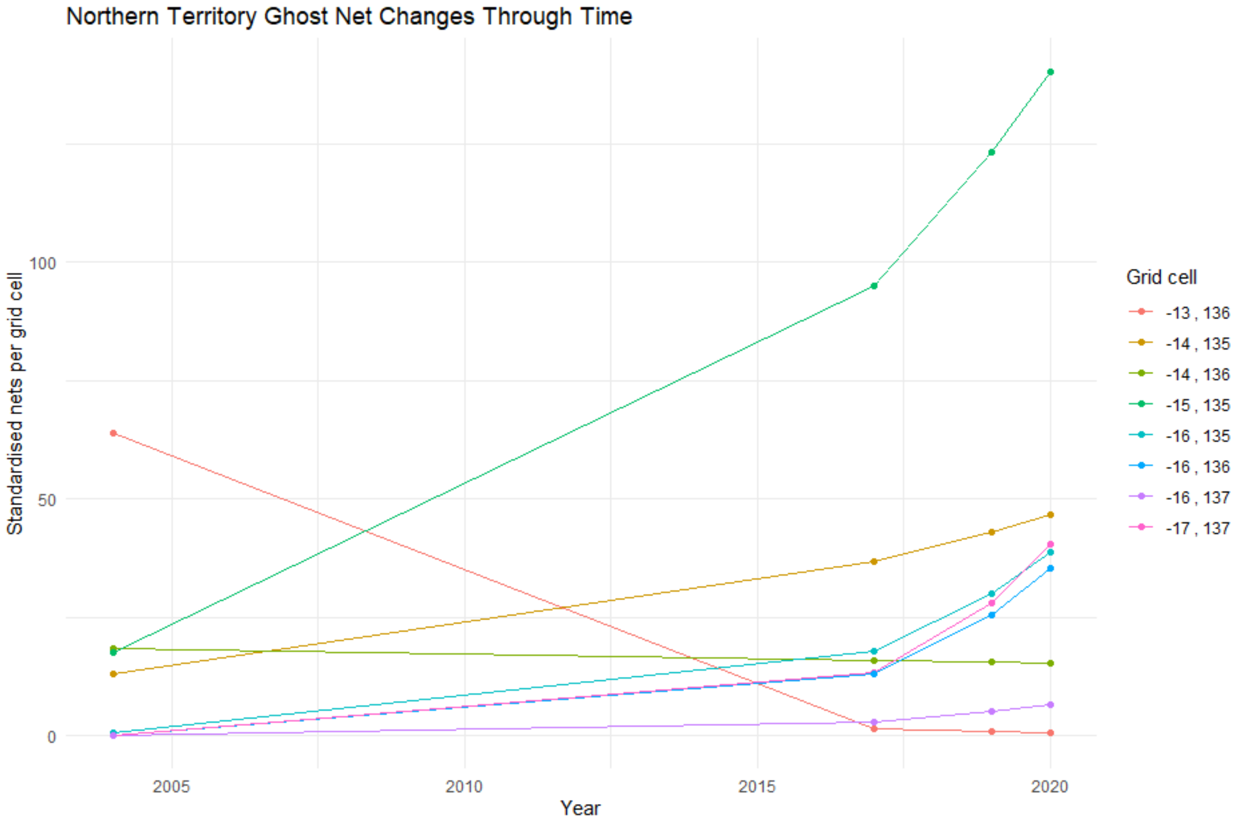

Figure 16. Changes in net numbers through time in each grid cell in Northern Territory.

Considerations and caveats

The hotspot tables and maps produced herein are influenced by a number of factors that are relevant to consider. For instance, ghost net accumulation hotspots are likely influenced by clean-up efforts on other beaches, that may be masking accumulation areas in other parts of the Gulf. This in turn relates to accessibility, location and engagement of local Indigenous ranger groups and their activities, resources, seasonality, and other important points to consider that may affect where and how many ghost nets are observed from aerial surveys.

In addition, it has been noted that mangrove dieback has been a very strong phenomenon across the Gulf of Carpentaria (N. Duke, J. Mackenzie, personal communication). Hence, it may be that the increase in ghost nets recorded across the GoC reflects the increase in detectability of nets, due to lack of vegetation cover. It was beyond the scope of this project to analyse the mangrove data in concert with ghost net data, though adding a simple rank score of mangrove dieback/increased visibility at even the 1^0 x 1^0 scale would provide insights to this potential issue (and would allow the analyses to take the phenomenon into account if indeed it is a mitigating factor affecting net counts).

Finally, there have been a number of major weather events in the last few years within the region, with substantial seasonal storms, including multiple ‘severe’ tropical cyclones. Such weather events have been known to dislodge nets or other items and to move debris substantial distances. It is possible that such weather events have also contributed to the increased detection of ghostnets within the region.

One key consideration that would improve our understanding and interpretation of these results would be to add coastal net clean-up data (including location, effort, seasonality, and net types) to this aerial survey information. Hotspots reflect the arrival of ghost-nets on the beach, minus the offshore transport of ghost nets away from the beach. For the moment, the findings in this report do not include clean-up efforts that may have (likely have) influenced numbers of nets observed (see notes in Appendix A.). Therefore, the hotspots denoted herein may not necessarily reflect solely where the most nets are accumulating. They may also reflect the remoteness, accessibility and on-ground activities taking place within the region. Likewise, those areas where nets are not observed may reflect the intensity of on-ground clean-up efforts, rather than a region that does not or has not accumulated ghost nets.

4 Opportunities and Suggestions

4.1 Improving ghost gear management

In the preceding section, we briefly touched on some of the challenges inherent to interpretation of the data presented, based on the variability in data recording, areas surveyed, time of year, and on ground activities.

We make the following specific recommendations to improve the understanding of sources, movement and distribution of beached ghost nets in the Gulf of Carpentaria:

1) Conduct annual or semi-annual helicopter aerial surveys for ghost nets, with consistent observer effort, meta data recording and data collation;
    a. Specific data to include flight hours per day, number and seating arrangement of observers, type of aircraft, kilometres of coastline surveyed, ambient weather conditions.
    b. If fixed cameras used, ensure metadata associated with image capture/processing is provided.
    c. We suggest or encourage the use of fixed cameras as an independent record and validation of 'spotter' observation data.
    d. Ensure helicopter surveys are conducted at similar times of the year to previous surveys, within weather restrictions and safety limitations.
    e. Align future survey efforts with the best practices and approaches from previous surveys where possible.
2) In concert, add coastal net survey and/or clean-up data (including location, effort, seasonality, and net characteristics) to 'ground truth' or allow one to measure the differences between on-ground and aerial survey efforts. This will facilitate predictions of numbers of ghost nets, hotspots, and other key information desired to improve management efforts and reduce ghost nets, in the absence of complete aerial or on-ground surveys.
3) Seek consistency in data collection, collation and management among aerial surveys and on-ground net removal/clean-up efforts through working closely with Ranger groups.
    a. Specific training within and among data collection groups will ensure consistency in this regard;
    b. Development of training modules and a shared data portal that allows accessibility to appropriate parties would benefit the data collection, maintenance, and analysis opportunities for such efforts.
4) Ensure data are made available for comparison between aerial surveys and on-ground net removal/clean-up efforts.
5) Apply hindcasting models with validation from trackers on actual nets (see Wilcox et al. 2013 for example) to estimate how long and where nets move within and beyond the Gulf of Carpentaria, and to identify potential low cost, safer areas for net retrieval/interdiction.

6) Compare existing mangrove data (collected at the same time as aerial survey data) to evaluate hypothesis that mangrove dieback is contributing to increased net visibility (and hence, higher counts). This will allow improved certainty about whether the estimated number of nets has increased through time or whether this reflects local processes.

4.2 Suggestions for reducing gear losses at sea

With both illegal and legal fishing activities, fishing gear can be abandoned, lost or otherwise discarded. Such gear is called 'Abandoned, lost or otherwise discarded fishing gear' (ALDFG) and is known to comprise a substantial amount of global marine plastic pollution (Derraik, 2002; Richardson et al., 2018). In recent years, attention has increasingly focused on Illegal, Unreported and Unregulated (IUU) fishing. It occurs both on the high seas and within national jurisdictional waters with detrimental consequences for food security, marine ecosystem health and the millions of people who rely on the ocean for their livelihoods.

Within the Gulf of Carpentaria, it is estimated that more than 85% of the nets found there originate from outside of Australia's Exclusive Economic Zone (EEZ), most likely originating from the nearby Arafura Sea (Edyvane and Penny, 2017). With currents and monsoonal winds, nets that are lost or discarded in the Arafura sea can be transported to the neighbouring Gulf of Carpentaria, causing harm to wildlife including threatened turtles, dugong, and other coastal and marine fauna (Gunn et al., 2010; Wilcox et al., 2013).

Fishing gear is lost from vessels for a variety of reasons, including but not limited to stowed gear being washed overboard, gear being lost or abandoned during fishing operations and nets or net repairs being discarded whilst at sea (Richardson et al., 2018). The underpinning reasons for these losses include vessels operating in poor weather (storms or high seas), vessels being inadequately maintained, gear being improperly stored, fishers working in suboptimal conditions and environments (for example, working in marginal habitat due to overcrowding/overcapacity), crew being inadequately trained or being inexperienced, and gear being inadequately marked and/or maintained (Richardson et al., 2018; 2019).

Given that an estimated nearly 6% of all fishing nets, 9% of all traps and 29% of all lines are lost around the world each year (Richardson et al., 2019), reducing fishing gear losses is critically important for social, environmental and economic reasons. To reduce gear losses at sea, there are multiple approaches that can be taken. These may include ensuring constraints on the number of fishing licenses or reducing fishing licenses that are granted and/or increasing enforcement (which would reduce overcrowding/overcapacity issues that result in fishing in marginal habitats) (Macfadyen et al., 2009; Richardson et al., 2018). It may also include the implementation and support of port waste facilities and buyback programs which have been shown to reduce fishers throwing old nets (or fragments of nets) overboard and increase gear recovery rates (Cho, 2009; Richardson et al., 2018; Christie Wilcox et al., 2013)

Furthermore, gear loss (and associated ghost net numbers) is associated with increased fishing effort in Arafura-Timor Sea region (sensu Richardson et al. 2018).

We make the following general suggestions for reducing gear losses at sea and note that these suggestions are general recommendations, without targeting or focusing on any particular government:

1) Support fisheries policies, including legislation to ensure overfishing is minimised and to support sustainable, legal fishing.
2) Support/continue to support gear marking/labelling to identify net ownership and to trace sources and fisheries (and conditions) that are prone to gear being lost at sea; and encourage net marking/labelling by fishers in support of best fishing practices.
3) Support/continue to support bilateral communication and structures with neighbouring countries and Regional Plans of Action (RPOA), in support of combatting IUU fishing and transboundary resource management.
4) Fishers and others on the water to work/continue to work closely with Australian Border Force, Australian Fisheries Management Authority and Australian Defence Force to document nets lost at sea and coordinate net retrieval (see section below).
5) Conduct surveys with fishers in the region to gain increased understanding of changes in fishing practices that may be associated with higher/lower losses of nets during operation.
6) Engage in awareness raising activities with commercial and recreational fishers regarding gear loss impacts, costs and consequences.
7) Facilitate/continue to facilitate regional resources and activities aimed at reducing gear loss (such as buy-back programs, low interest loans for net replacement, port waste facilities, etc.) where able/appropriate.
8) Compare net types washed ashore/removed with interviews from fishers (sensu Richardson et al. 2018; unpublished) to understand whether perceptions from fishers reporting match lost gear observed on coastlines.

4.3 Suggestions for interdicting ghost nets

As previously noted, the Gulf of Carpentaria is a very remote region with high biodiversity value. It is home to nesting grounds for several species of vulnerable turtles as well as dugong, among other species. Hence, opportunities to interdict ghost nets *before* they enter the Gulf, would likely reduce impacts on biodiversity and result in less damage to sensitive coastal ecosystems within the region. It appears that most nets likely enter the Gulf of Carpentaria from the northwest and move along the north-eastern shore in a clockwise direction, based on oceanographic modelling and trackers placed on nets in the region (see Wilcox et al. 2013 for detail).

Therefore, we suggest the following for interdicting derelict nets at sea:

1) Monitoring nets via aerial surveys (such as periodic flyovers by Maritime Border Command during regular operations) or using satellites or drones to ascertain speed and area of movement.
2) Focus aerial survey/monitoring efforts on a reasonably small area in the northeast of the Gulf with a high probability of opportunity for interdicting nets.
3) Attaching transmitters or transponders to floating nets. This can better support safe, more cost-effective net interdiction activities including net retrieval closer to shore, before entering the Gulf (such as near the port town of Weipa). It would provide the further opportunity of

engagement with local fishers (who would likely be provided with devices to attach if/as they came across derelict nets) and increase awareness/best practices.

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Appendix A. Notes from 2020 aerial survey

Notes from survey team (comprised of Rupert Imhoff and Nicole McLachlan):

- We counted at least (Conservative figure) 300 nets between this range
- Hotspot of most nets between Weipa and Pennefather River and again between Pennefather River and Janie Creek
- Also found a lot of marine debris (all sorts of plastics) along these 2 beaches. Much of which had clearly come from Asia as marked on the packaging
- Between Janie Creek and Mapoon, the beaches looked a lot cleaner with fewer nets. 4x4 Tracks were visible indicating indigenous Sea Rangers doing clean-up work along these beaches.
- Beaches again littered with endless debris between the Northern coast of the Ducie River (Mapoon) up to Macdonald River where we stopped survey for the day
- A lot of nets were washing into the mouths of the Ducie, Skardon, Jackson and Macdonald Rivers and catching on mangroves within the first 1km of the of the mouth openings. Mostly catching on the southern banks of these river openings.
- We found no live animals in any of the nets and did not record any dead animals (not that we could see)

Day 2: Saturday 29th February 2020: We started survey at MacDonald River and flew to the tip of Cape York up past Punsand Sand.

- Based on a conservative figure from 2 separate helicopter spotters we counted at least 479 intact Full Ghost nets on this day.
- We found more nets are accumulating on the Western Coastlines (Gulf of Carp) rather than the northern sectors between Seisa and Cape York (Torres Straits).
- The beaches between Macdonald River and Crab Island were overwhelmingly drowning in a staggering amount of plastic debris pollution. Everything from shampoo bottles to food wrappers, soft drink bottles, plastic tubs, containers, other fishing gear and other miscellaneous household waste. You name it, it was there.
- A lot of the debris inspected has signs of being washed in from international nations. Many packaging labels were from Indonesia, Japan and Philippines.
- No Live animals found in any of the nets, but we did record 5 dead turtles, 1 shark and crabs wrapped up in nets

Day 3: Sunday 01st March 2020: We started survey at Weipa and flew South towards Aurukun

- Based on a conservative figure from 2 separate helicopter spotters we counted at least 640-750 intact Full Ghost nets on this day.
- We noted that the beaches south of Weipa were otherwise a lot cleaner of other plastic household debris than those north of Weipa.
- The nets were abundant though. Many buried in the sand showing they had been there for some time.
- The majority of the nets were accumulating on the beaches just north of Aurukun.
- The beaches south of Aurukun were mostly clear of both marine debris and ghost nets; we only found 3 south of Aurukun.

We didn't find any live nor dead animals trapped in ghost nets on this survey. Most of the nets we counted were the smaller green coloured ghost nets and wrapped up around the bases of mangroves or around rocks along the shoreline, but they were apparent and abundant despite the lack of other marine debris.

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