Estimating the Distribution and Impact of Ghost Nets in the Gulf of Carpentaria

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15 July 2010

Milestone Report to the Northern Gulf Resource Management Group

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Funding for this work has been provided by the Northern Gulf Resource Management Group's GhostNets Australia (formerly Carpentaria Ghost Nets Programme) through a DEWHA (Caring for our Country) grant; and through the CSIRO Wealth from Oceans Flagship.

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Because the contents of this report comprise information to be submitted for publication in an international scientific journal, we respectfully request that the contents of this report not be released until such time as the manuscript has been accepted for publication.

Summary Report for the Northern Gulf Resource Management Group's GhostNets Australia Programme (formerly the Carpentaria Ghost Nets Programme)

Project Update and Summary

Rationale

Lost, abandoned or discarded fishing gear is a serious externality from commercial fisheries, as this gear continues to fish unattended causing mortality to species that can be threatened or commercially valuable. This is particularly true for net-based gear that continues to fish until nets wash ashore or otherwise decompose, which has been estimated to be 5 years on average. These 'ghost nets' impact not only local fisheries, but also result in by-catch of threatened and protected marine species. Many of these nets are washed up on northern Australia beaches, entangling numerous marine species including turtles and dugong which are important for cultural reasons and are protected by the EPBC act due to concerns about their population persistence.

Progress to Date and Outputs

To date, we have submitted and had accepted for publication a journal article entitled "Tackling 'ghost nets': Local solutions to a global issue in northern Australia". The expected publication date is August 2010, and the article is being published by Ecology, Management and Restoration.

Our current working efforts have been to summarize existing Carpentaria Ghost Net Programme (CGNP) data that have previously been collated. The goal of this work is to analyse data such that it is suitable for publication in a scientific journal of international standing. To date, we have prepared a draft article for publication in which we combine 1) existing CGNP data from ghost nets including ensnared wildlife with 2) existing Northern Prawn Trawl fisheries data to estimate turtles captured at sea within the Gulf of Carpentaria and 3) an oceanographic particle tracking model in which we back project likely pathways for particles (nets) that have arrived in the Gulf and been noted from beach clean up surveys. While this publication is beyond the initial expectation of the project, it provides a unique opportunity and a novel means of combining multiple long term datasets in a new way to estimate the biodiversity impacts of ghost nets within the Gulf of Carpentaria. Hence, the value far exceeds what could be done with one isolated dataset.

Concurrently, we are working on Milestone 3: a cluster analysis to provide assignment of ghost nets to useful categories. This work is on target or ahead of schedule, as preliminary analyses of net clusters has already been performed for the nets found in The Net Kit.

In summary, project targets are being met, outputs have been successful, we have achieved the desired goals, communication remains open amongst team members, and we are excited about the continued opportunities of this work.

Acknowledgements

We acknowledge the following community ranger groups, as without their engagement, this work would not be possible: Anindilyakwa Land Council, Badu Aboriginal Shire Council, Carpentaria Land Council, Dhimurru Aboriginal Corporation, Hammond Island Council, Injinoo Aboriginal Shire Council, Kaurareg Aboriginal Corporation, Kowanyama Aboriginal Shire Council, Laynhapuy Homelands Resource Centre, Mabunji Aboriginal Resources Association, Mapoon Aboriginal Shire Council, Marthakal Homelands, Napranum Aboriginal Shire Council, Numbulwar Homelands, Pormpuraaw Aboriginal Shire Council, Torres Strait Regional Authority and the Yugal Mangi Rangers. We also thank Jane Dermer, Gary Luchi and Lisa Hamblin for their efforts in the Ghost Nets Programme. Thanks also to Gary Fry for providing a complied version of the trawl data for the GOC region, including data from a variety of sources; and to AFMA, FRDC, AIMS and the Northern Prawn Fishery operators for supporting the collection and compilation of that data.

This report completes Milestone agreement #2 between the Northern Gulf Resources Management Group and CSIRO.

Attachments: Appendix 1

Appendix 1.

ESTIMATING THE DISTRIBUTION AND IMPACT OF ABANDONED FISHING GEAR

KEYWORDS: biodiversity impact, ghost net, marine debris, net swept area, threatened species

ABSTRACT

Lost, abandoned or discarded fishing gear from commercial fisheries is a serious environmental concern. This gear continues to fish unattended for years or even decades, causing mortality to species that may be threatened or commercially valuable. In order to assess this threat or ameliorate its impact on marine species, we need to understand the spatial distribution of the abandoned fishing gear. We used an oceanographic model that includes both wind and current forcing to track the paths of nets. Using this model we took a dataset of approximately 5,400 fishing nets that had been recovered along the northern coast of the Australian continent, and estimated the likely paths these nets followed to their stranding location. By aggregating these potential paths across many simulations over the whole dataset on stranded fishing gear, we were able to build a distribution of the fishing effort by this gear across the Timor, Arafura and Coral Seas. We found that estimated effort varied from almost nil at the southernmost point of the Gulf of Carpentaria to >600 encounter paths at a grid scale of 1 km along the northernmost tip of the continent near the Torres Strait. Combining this distribution of fishing effort with species distributions, we were able to estimate the relative impact of the ghost nets on different threatened species in the northern Australian region to estimate the potential biodiversity impact.

INTRODUCTION

Human activity is responsible for a major decline in global biodiversity, with widespread impacts across ecosystems and taxa. As the global human population has grown, pollution has been increasingly implicated in impacting biodiversity at local, landscape and global scales. For example, with where the Mississippi River spills into the ocean is known as the ‘dead zone’ due to hypoxia where sediment filled water meets the ocean. In the 1970s, the pesticide application (in particular, DDT; dichlorodiphenyl trichloroethane) resulted in egg thinning and was associated with widespread declines in bird populations. Even with DDT restrictions in place for the last several decades, impacts from this terrestrial fertilizer persist: substantial quantities of the pesticide continue to be released from our oceans (Stemmler and Lammel 2009). And indeed, along with the recent oil spills in the Gulf of Mexico (1979, 2010) each are each timely examples of pollution that has been shown to and is predicted to have long lasting and far reaching impacts on terrestrial, coastal and marine biodiversity.

One of the major factors affecting biodiversity is pollution in the marine environment, with human activities impacting nearly all marine ecosystems (Glover and Smith 2003). Impacts in marine systems are highly heterogeneous and may include coral bleaching (Hughes et al. 2003), plastic ingestion by seabirds (van Franeker 1985; Ryan et al. 1988) and turtles (Mrosovsky et al., 2009; Derraik 2002), as well as less apparent impacts on benthic worms, mussels, krill and other organisms. Medium to high impacts are nearly globally distributed, with climate change, fishing activities and pollution as the main anthropogenic drivers (Halpern et al. 2007; 2008). The global marine debris problem has become increasingly well known and publicized, with estimates of a 'garbage patch' in the Pacific that has in excess of 334,000 pieces of plastic per square kilometre in some areas (Moore et al. 2001). Marine debris is potentially the most pervasive type of pollution in the marine zone, with an estimated total of rubbish items entering the marine environment estimated at 30 million tons annually from the United States alone (O'Hara et al. 1988 as cited in Derraik 2003).

While we know there are tremendous quantities of rubbish in our oceans (Thompson et al. 2010), far less is known about where the debris occurs, what species it interacts with and what the direct impacts are of those interactions. Much of our knowledge of marine pollution comes from coastal clean ups and where debris arrives on land. We have typically used the more common and easier to get beach clean up data to infer the much rarer at-sea distribution of marine pollution due to expense and sheer vastness of evaluating debris in the marine environment that may require use of aircraft (sensu Pichel et al. 2007) or at-sea observers positioned on vessels (sensu Barnes and Milner 2004) to sample a small fraction of the total area. However, recent advances in oceanographic modelling afford new opportunities for analysis.

Here, we take a risk-based approach to estimate the biodiversity impact of one type of marine debris in Australia. We look at ghost nets (abandoned, lost or derelict fishing gear) which comprise a small proportion (~ 5%) of the total marine debris in Australia. In spite of this, ghost nets likely exert a disproportionate impact on biodiversity because fishing nets are designed to ensnare and kill. We first estimate the at sea distribution of ghost nets based upon where they occur on shore. We then estimate the marine species that are most likely to be affected by derelict nets based upon their distribution. Finally, we combine the species distribution and likely encounter rate to evaluate the risk to biodiversity from this marine debris threat.

METHODOLOGY

Net data

5,491 records of ghost nets were collected from beaches around the Gulf of Carpentaria Coast by indigenous rangers between August 2005 and November 2009. Each net record gives the survey area where the net drifted ashore, and also the date it was found. Further details of nets were identified when possible using the WWF Net Kit (Hamilton et al. 2004). The Net size was recorded as one of three coarse size classes: small, medium or large (based on the amount of people it would take to lift it). A more precise net length was also recorded where possible. Any animals caught in the net were recorded along with their life-status (alive or dead). The spatial density of nets and the unsurveyed areas are illustrated in Figure 1.

True net length were recorded in 93% (N=5104) of the observations. However a number of records were considered inaccurate based on the tendency for large nets of the same size being repeatedly being observed at some sites as well as evidence of excessive rounding of net lengths being applied. Because of the issues of absent net lengths and a lack of confidence in some net lengths we considered three approaches to calculating fishing effort by drifting nets in later analysis: 1) ignoring the size of individual nets, and treating all nets as equivalent in size; 2) using net lengths where available, and for nets where only a size class was available allocating sizes using a parametric bootstrap within that size class; 3) fitting a log-normal distribution to the net lengths within an area and randomly drawing the sizes of nets for that area from that from the distribution. A log-normal distribution was chosen because net lengths must be greater than zero but tend to have a long tailed distribution. The differences between the effort distribution using the measurements from rangers and the other two methods are shown in Appendix A.

A further 673 records of the spatial distribution of ghost-net density were collected during helicopter flights conducted as part of sea grass surveys between November 13 and 17, 2004. Lengths of nets could not be estimated using this method and only the position and counts of nets observed were recorded. These data were collected for the entire Gulf of Carpentaria coast but excluded the coasts of islands (Figure 1). This data set gave further confidence in the use of the ranger-collected data as there was good agreement between the densities of distribution of nets observed in each data set. The helicopter survey also provided net records in areas of coastline that were not surveyed by rangers.

Generating an at-sea distribution for nets

We used a simulation model, driven by the modelled and observed ocean currents, to create a large number of potential paths of ghost nets. In the model drifting particles are released on a regular grid spanning the area 115 to 152° E and -16 to 10°S on a daily basis. Each release is at a random location within one of the 4 by 4° grid cells. The region of releases includes the Arafura, Timor and Banda Seas and was chosen so as to be representative of the possible origin of ghost nets which drift ashore in the GOC. The simulation model records where the drifting particles are located throughout the year of release and the subsequent year on a daily time step. Particles were released daily from 1996 to 2007. Particles are lost from the array if they drift outside 110 to 156 longitude, or 8 to -20° latitude.

We recorded the track of any drifting particle that came within 25 km of each of the observed nets, as recorded in the ranger data (Figure 1a). We choose a buffer of 25 km as the oceanographic model is not accurate in close proximity to the shore, due to effects of shallow bathymetry. This method gave a set of potential paths for each observed net which the net could have taken to wash up at that site. In order to create a spatial distribution of fishing effort for the nets, we first gridded the entire region into 0.1 degree latitude by 0.1 degree longitude cells. For each cell we recorded the number of days each net in our database of potential individual net tracks was expected to be in a given cell. We weighted this count by multiplying by the predicted size of the net in one of three ways, either ignoring the size of the net (i.e. all observations multiplied by 1), multiplying by the recorded length with bootstrapping for missing lengths, or by drawing a length at random from the fitted lognormal distributions.

We determined what constituted an adequate sample-size of simulated particle tracks by examining the change in the at-sea distribution predicted for nets from a site as additional particle tracks were added to the data set of potential paths. We recorded the number of new grid cells that were included in the spatial distribution as additional potential paths were added to the data set. When these plots reached an asymptote, we assumed that all likely pathways for nets to arrive at a site had been sampled and were included in the data set (Figure 2). We evaluated the sample size of our simulated tracks using this method for four locations around the Gulf of Carpentaria, including sites with high and low net density. In total 48,180 particles were released.

It is worth noting that there are strong environmental drivers in this region. The monsoonal cycle dominates the weather in the region, with monsoon season is generally considered to be from October to May but is highly variable. This period is characterised by high rainfall and strong winds predominantly from the North West. Either side of the monsoon period there is patchy rain Sept-Nov and April-May where wind direction is more variable. The shallow depth of the gulf together with high tidal energy in the region means that wind and tidally driven mixing are important processes in the system (Forbes 1984; Wolanski and Ridd 1990). Within the gulf there are two distinct regions, a shallow (15 - 20 m) turbid zone and the deeper (20 – 70 m) central waters, separated by a boundary current (Wolanski and Ridd 1990).

Estimating the interaction between nets and threatened species

The ranger data on nets includes records on the species caught in the nets and their condition. There were 5 species of turtles recorded, along with 5 other taxa recorded to varying taxonomic levels (Table 1). More than 80% of the animals recorded in the nets were marine turtles (Table 1). Based on this information, we concentrated on evaluating the expected interactions between nets and marine turtles. We chose to take a risk-based approach in this analysis, evaluating the extent and distribution of interactions by overlaying the at-sea distribution of the nets with that for the turtle species.

There is only sparse data on the distribution of marine turtles in the GOC area. While most of the nesting sites are known and there are data on the number of individuals nesting at each location (see http://www.environment.gov.au/coasts/species/turtles/), the distribution of nesting sites is not representative of the at sea distribution of the turtles. There are some data from satellite tagging programs which give information on the distribution of turtles in the region (Kennett et al. 2004; Whiting et al. 2007) however, these tagging studies only cover a small subset of the species and breeding sites and thus would not be expected to give a clear picture of the turtles' at-sea distribution. The best data set in the region is based on research and commercial trawl data taken in the GOC and along the northern coast of the Australian continent, largely as part of the prawn trawl fishery operating in the region. We were able to obtain records for 178,056 trawls conducted between 21/11/1990 and 05/03/2009 (Figure 3). These records included information on the starting location of the trawl, size of the net and duration of the trawl, along with the number of turtles caught. The area swept (km^2) was calculated based on the net size and duration of trawls to give a grid of effort. Catch per Unit effort could then be calculated by area swept/number of turtles caught. Turtles were identified to species where possible, with remaining records listed as unidentified. We used these data to estimate the spatial distribution of the turtles in the GOC region. In doing this we assume that turtle excluder devices, which reduce the catch of turtles, came in simultaneously throughout the fleet and thus while they reduce the catch they do not bias the spatial distribution of encounters.

RESULTS

Particles entering the GOC tended to follow two different paths. During the monsoon season, particles came in from the western side of the gulf (Figure 4, inset upper left). During the non-monsoon season particles entered the GOC from the east, through the Torres Strait (Figure 4, inset upper right). The resulting pattern is a large concentration of particles distributed on a north westerly axis from the upper eastern coast of Cape York stretching into the Arafura Sea (Figure 4). This concentration stretches south following the coast of the GOC and extends up the western shore of the Gulf.

Based on this dataset of potential tracks and using the sizes of nets reported by the rangers from each site, the estimated ghost net fishing effort per area is concentrated along the northeast shore of the GOC and to a lesser extent along the northwestern shore (Figure 5). The seasonal differences in the number of tracks that reach the coast suggest that most of the nets washing ashore come during the monsoon season (Figure 5a & b). The monsoonal pattern (Figure 4, upper left inset) is visible several months after the beginning of the monsoon period in November (Figure 5b). The Non-monsoon pattern is visible starting in July and strengthening into the early monsoon period (Figure 5a &d). Comparing the expected at-sea distribution of the nets with the distribution of fishing effort, which takes into account the size and abundance of nets, there is a strong concentration of effort in the near-shore region of the northern gulf, and significantly less fishing effort in the central and south (Figure 4, Figure 5a &b).

Summarizing the expected distribution of ghost net fishing effort on an annual basis over the dataset of simulated tracks, there is a very similar pattern over the six years included in the analysis (Figure 6). On an annual basis the monsoonal pattern dominates the non-monsoon pattern, as the majority of tracks intersecting the coast come across from the Arafura Sea to the northwest (Figure 6). Comparing patterns in 2004 and 2008 in particular with 2000 through 2003 there is important variation in the penetration of high densities of drifting nets south into the gulf (Figure 6a, b, &c vs. d &f). This variation coincides with increased effort in the open waters in the central gulf, as is particularly apparent in 2000 (Figure 6a). There is also substantial variation in the concentration of the pattern of drift on the northwest axis toward the Arafura Sea. In some years fishing effort is concentrated along a narrow band, as in 2001, while in others it is more widely distributed and includes a significant contribution from the non-monsoonal pattern as in 2000 (Figure 6b, Figure 6a).

We estimated the distribution of marine turtles overall, and by species, in the GOC using data from commercial prawn trawls and research surveys in the region (Figure

7, Figure 8). Turtle density was most concentrated in the shallow regions along the western and southwestern coasts of the GOC, and in coastal region in the northeast (Figure 7). The density of the trawl data varies substantially, with fairly sparse coverage particularly in the central region of the gulf, and thus our estimates of turtle catch rates in this region are significantly more uncertain (Figure 3). However, there are regions, such as in the extreme south of the gulf, where there is reasonable coverage and low catch rates (Figure 3). Based on this it is likely that the estimated low densities of turtles in the south, and along the southeast coastal margin represent real patterns (Figure 7).

Combining the distribution of turtles estimated from the trawl data, with the observed captures of turtles in ghost nets it is clear that entanglement of turtles in ghost nets generally occurs in areas where turtle density would be expected to be high (Figure 7). In addition, not all areas of high turtle density have relatively high entanglement rates, particularly in the southern gulf (Figure 7). Combining the areas of high expected ghost net fishing effort (Figure 5a & b) and the areas of high turtle density (Figure 7), one would expect entanglements to be relatively common along the northern coastal margins of the gulf, exactly where they appear (Figure 7). This pattern suggests that entanglements are roughly proportional to the rate of turtle-net encounters. Examining the pattern on a species by species basis we can evaluate whether entanglements appear to be proportional to encounters for each species, or whether there are particular species for which the pattern does not hold (Figure 8). Again, on a species by species basis turtles appear to be caught in areas of high ghost net density (Figures 4, 8). Moreover, there doesn't appear to be an elevated level of catch for any species in the southwestern gulf where a number of these species feed and densities appear to be relatively high (Figure 8).

Based on the assumption that encounters between ghost nets and turtles are a good proxy for the expected impact of the nets, i.e. that entanglement is proportional to encounters, we estimated the relative risk to turtles in each 100 km by 100 km block in the gulf (Figure 9). The predicted areas of risk generally correspond to areas where entanglements are observed. This would be expected if our model of encounters is correct and if nets are likely to wash onto nearby beaches. Importantly though, some of the highest areas of risk are in regions further offshore in the gulf where there are no local observations. In particular, nets sweeping down the east coast of the gulf encounter high concentrations of turtles as they are driven westward in the southern gulf by the persistent gyre in that region (Figures 6, 9).

DISCUSSION

The ghost nets issue and their potential impact on biodiversity is a cumbersome problem (Kaiser 2010), though clearly one that is possible to resolve. With recent technological and analytical advances, predicting the impact of ghost nets on biodiversity becomes relatively straightforward. Impacts appear to be driven by encounters, and encounter rates are readily predictable based upon a species at-sea distribution and the distribution of nets in the marine environment.

It is worth noting that turtles are known to occur in the southern part of the Gulf (Kennett et al. 2004), yet no entanglements were observed there. Habitat usage by turtles surely impacts their probability of encountering derelict nets and while the lack of observations in the southern Gulf could be in part due to low densities of observers in the region (thus reduced records could be infrequent) it is also possible that carcasses may be scavenged or decompose prior to observation (decomposition experiments may provide useful information here). It is also reasonable to consider that some proportion of nets in the northern region have actually followed the gyre and/or are from the southern region and we may simply be unaware. Alternatively, nets may take a long time to travel from the south to the northern coast and thus scavengers may have removed turtles or they may have fallen out nets by the time they get there. Overall, our data suggest that turtle distribution and behavior does not drive entanglement, and that the distribution of nets is the driver.

Furthermore, given that the Gulf is only 30m deep in most areas (Wolanski and Ridd 1990); many nets will sample a significant portion of the water column. Hence, whether a turtle is on the bottom or up in the water column may not make much difference in the overall frequency of entanglement. However, it is also possible that turtles may feed in the southern area of the Gulf at a time when nets are seldom present due to seasonality and currents. Importantly, the data presented are a map of actual encounters, not a map of expected or predicted reporting of entanglements.

If we assume that nets are released uniformly throughout the year out into the marine environment, then the distributions we calculated indicate not only the path of the nets but also the seasonality and overall timing of arrival. While net release may to be clumped both spatially and temporally based upon seasonal fisheries and their associated practices (Brown et al. 2005, Macfadyen et al. 2009), we simply have no data available at this time to address potential seasonal differences in net loss rates and timing. Such data would be welcome as it could allow us to improve models, particularly with respect to coupling seasonal foraging and movement patterns of marine wildlife and their likely encounter rates with derelict fishing gear. In additional to net encounter being affected by seasonal fishing practices, nets may also arrive onshore and subsequently be washed out to sea during storms (C. Limpus, pers. comm.), to continue ghost fishing and having additional opportunities to encounter and ensnare marine wildlife.

In comparing upon two independently collected threats datasets (nets as surveyed by rangers and those detected through aerial helicopter surveys), we find that the data compiled are relatively accurate, and they enable us to begin to consider the proportion of turtle species distribution that is threatened by nets not only in the GOC, but in wider geographic regions. Doing so enables us to have a broader sense or scale of what proportion of a particular species distribution, and thus, a population, is at risk of net encounter because in essence, the fraction of a species range impacted by ghost nets serves as a proxy for population risk.

This work demonstrates the value of combining long term datasets and those that have historically been collected for different purposes. The 20 years of trawl data and the extensive dataset resulting from the effort of cleaning up ghost nets within the GOC region, together with broad scale oceanographic observations, enables us to address important questions about impacts to biodiversity that would otherwise be tricky if not impossible to address. Improving our knowledge of species foraging, migrating and general at-sea distributions will improve our ability to estimate species and population level impacts due to ghost net and other marine debris encounters at larger spatial scales.

Presently, we know far less about our oceans than we do about our terrestrial environments (including what is known about lunar landscapes). However, as global models improve, it will be increasingly possible to do analyses such as these at global scales. Typically, global models operate at scale of 1-2 degrees, and, accordingly, have not been able to account for eddies and smaller scale gyre influences. However, ongoing efforts are in place to downscale models and to add empirical data at scales of 1-10km grid sizes. Accumulating additional at-sea data and matching drift patterns at such scales will allow us to more comprehensively explore sparse at-sea data survey data. This is critical because ship surveys are prohibitive due to the vast expanse and the associated cost of surveying the world's oceans, and biodiversity impacts due to ghost nets and other marine debris, while poorly understood, are presumably high (Derraik 2002; Halpern et al. 2007, 2008; Pruter 1987). Finally, while we have not yet explored our data yet to analyse the potential sources of ghost nets washing up on Australia's northern shores, this is clearly another application of the tools we have developed and is an important next step. We must first identify the sources to ameliorate the impacts of ghost nets.

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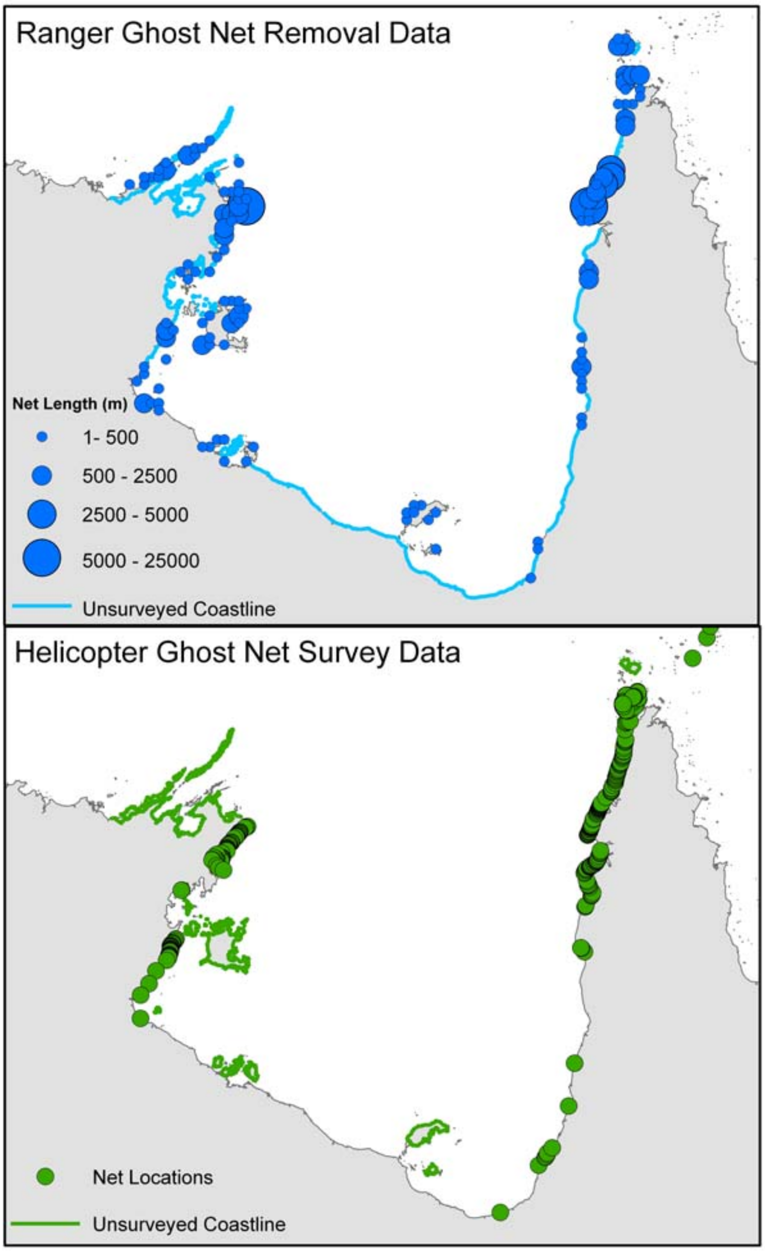

Figure 1. Locations of ghost nets along the shores of the Gulf of Carpentaria as detected by a) ranger groups during beach surveys and removal activities and b) helicopter surveys.

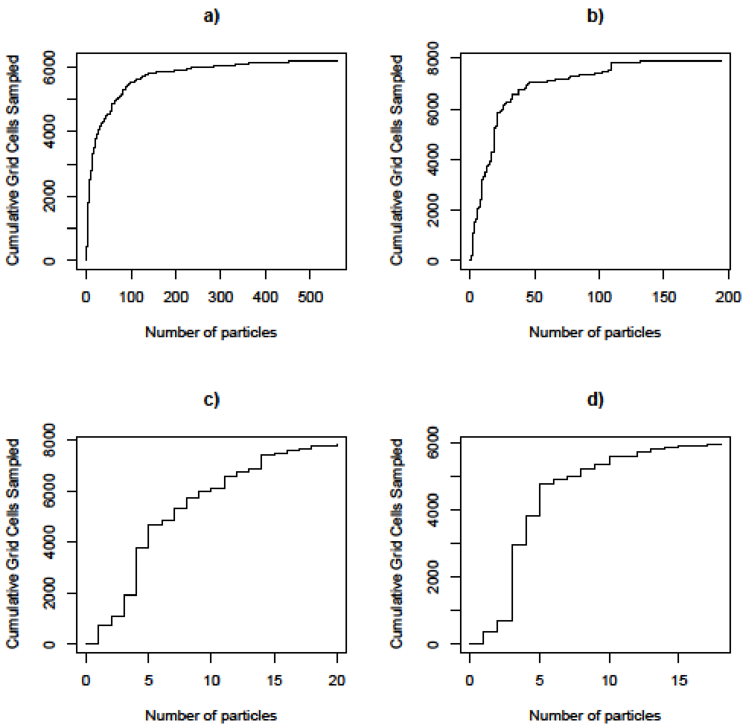

Figure 2. a) Northwest coast of GOC, b) Northeast coast of GOC, c) Southwest coast of GOC, d) Southeast coast of GOC

Figure 3. Locations for the starting points for prawn fishery trawls (grey dots) and incidental turtles caught by the fishery (1990-2009). [Figure itself not presented. We await permission to show these data, even in a restricted-release report].

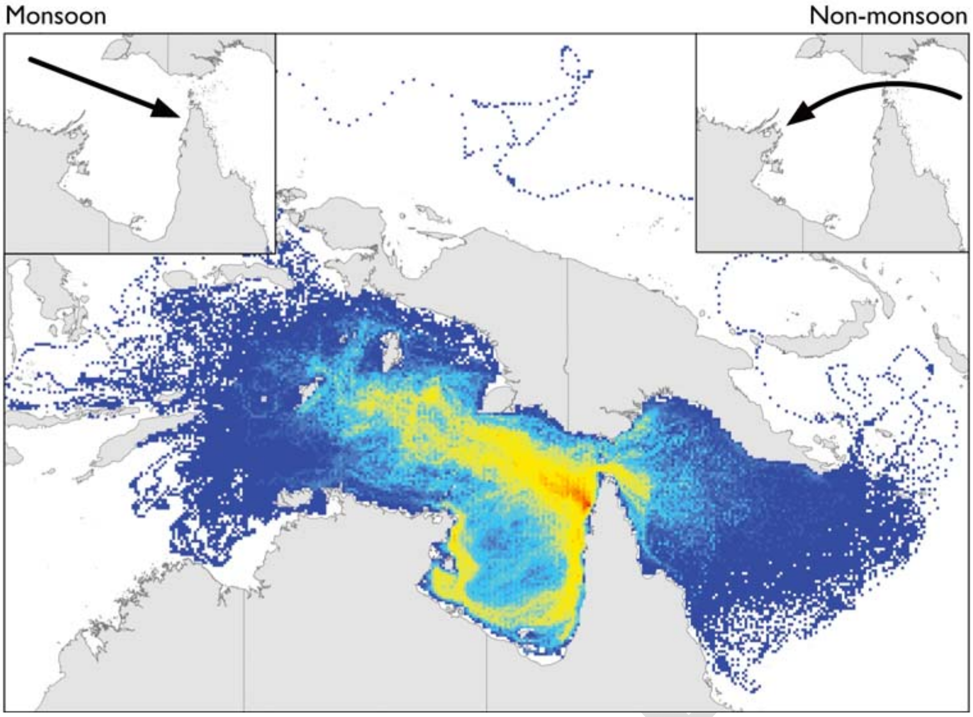

Figure 4. Potential tracks of ghost nets. Tracks are based on daily releases of particles from 1996 through 2008 on a regular grid extending from 115 to 152° E and -16 to 10°S. Released particles are individually tracked until they move outside the grid or age more than two years. Insets show the prevailing movement pattern of particles entering the GOC during the monsoon (November - April) and non-monsoon (April - November) seasons.

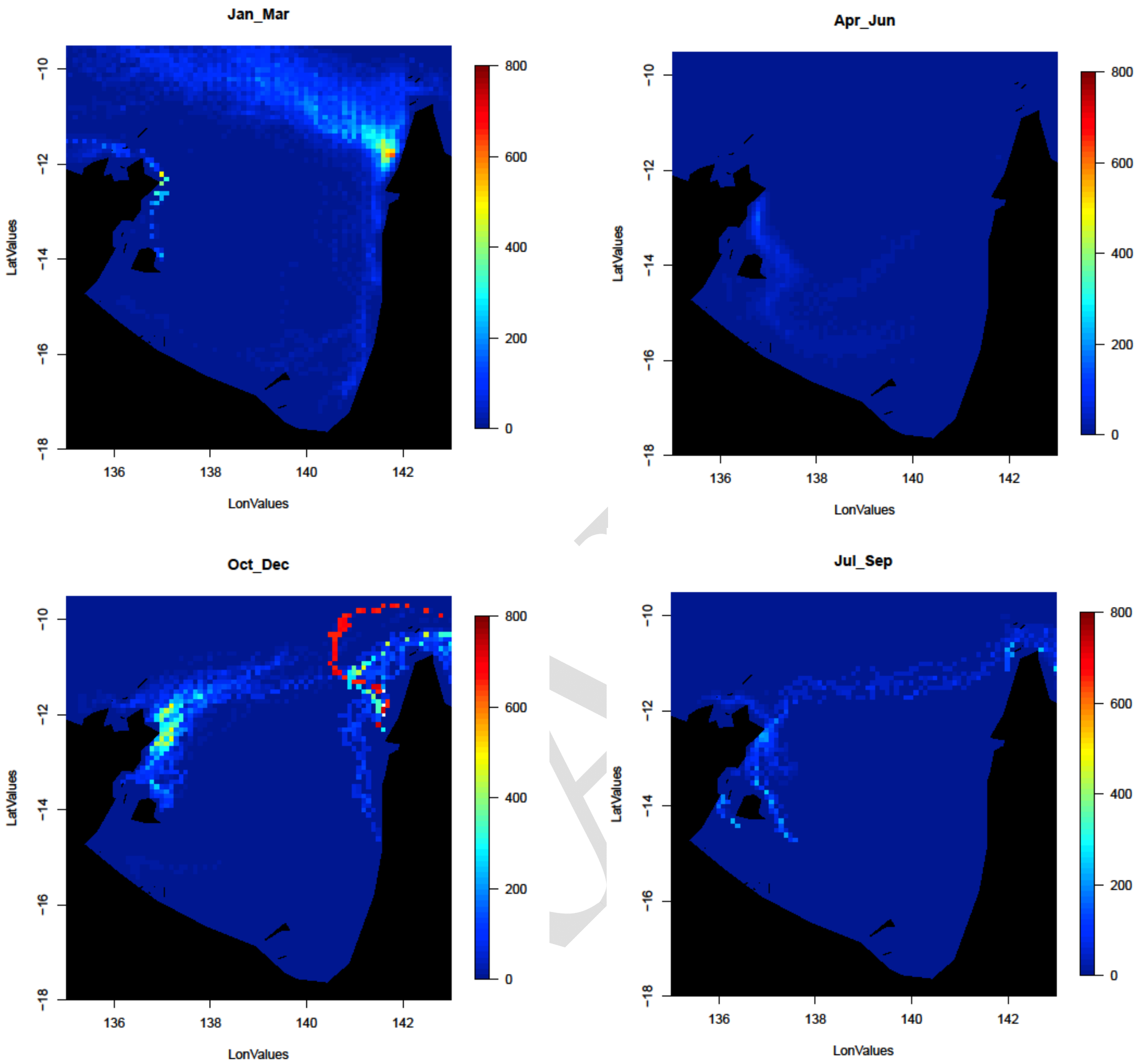

Figure 5. Ghost net fishing effort by season from 1996 to 2008.

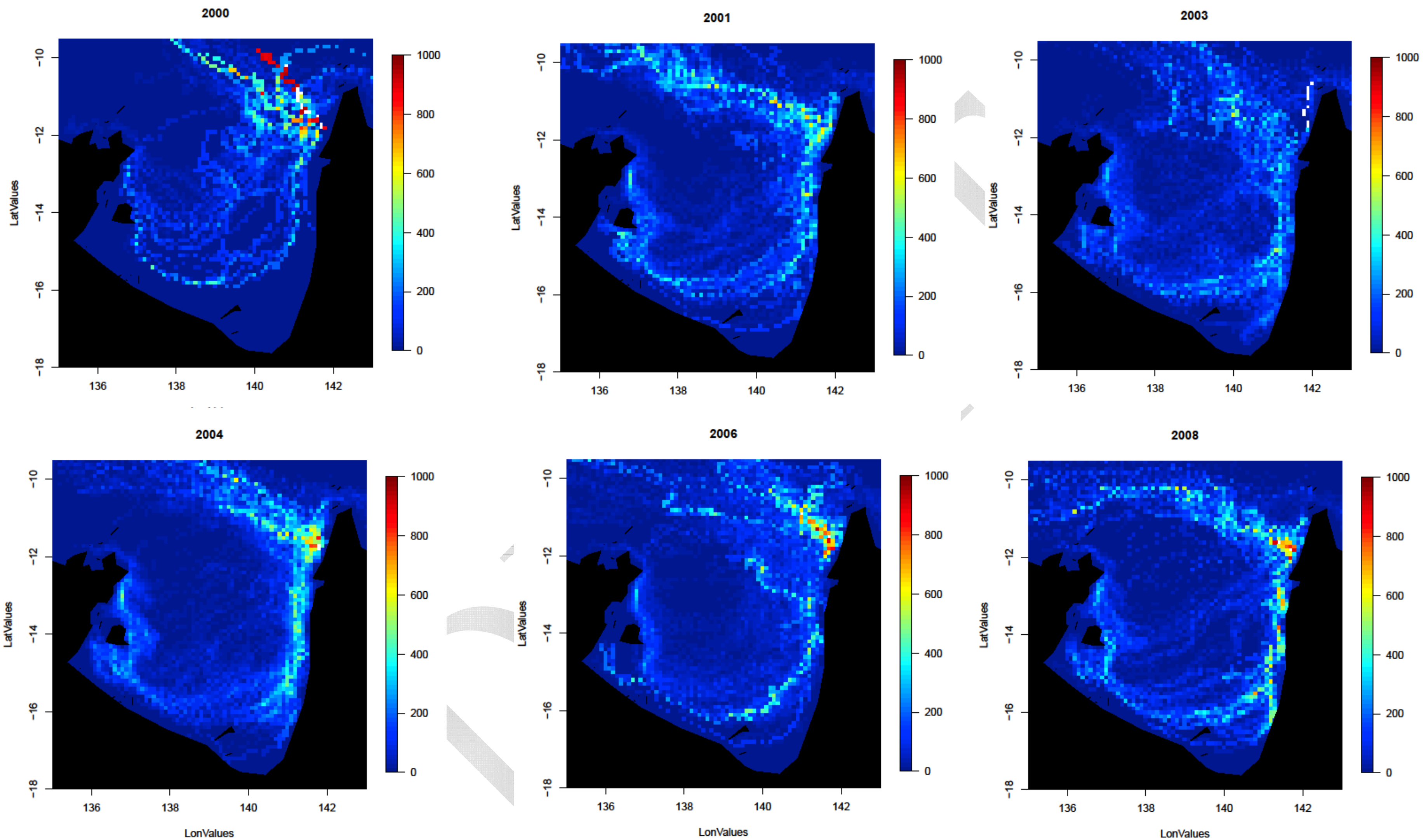

Figure 6. Expected ghost net fishing effort by year from 2000 to 2008. Panels are in chronological order as follows: a) 2000, b) 2001, c) 2003, d) 2004, e) 2006, and f) 2008.

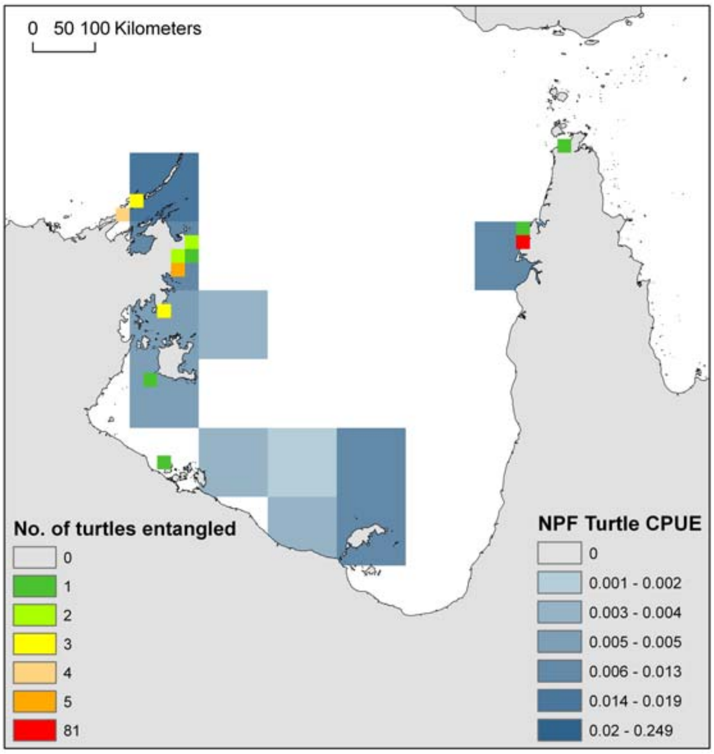

Figure 7. Locations of captures and estimated at-sea distribution of marine turtles reported in ghost nets in the gulf region. The turtle distribution is based on average catch per unit effort in trawls in 100 km by 100 km blocks.

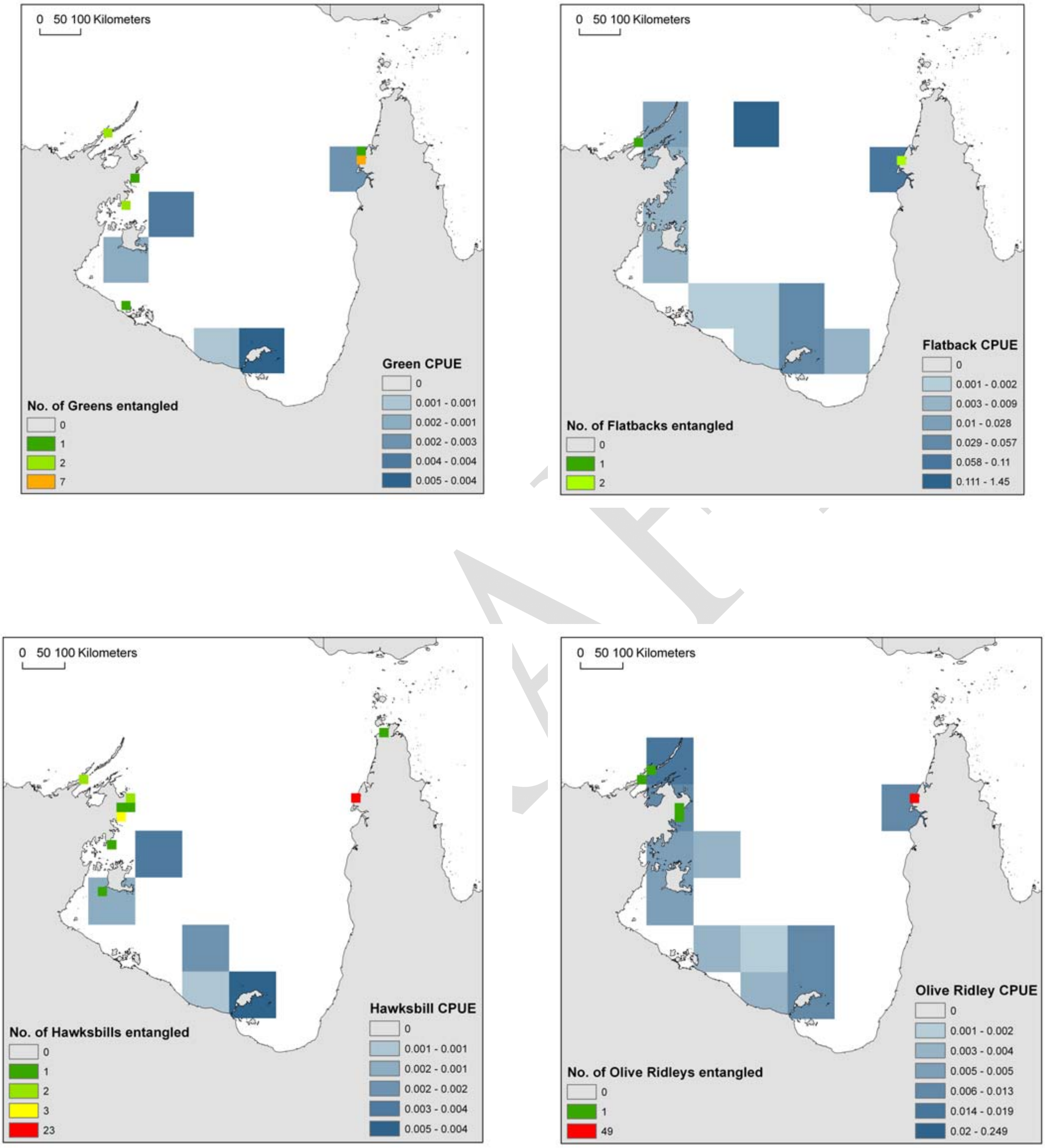

Figure 8. Locations of captures and estimated at-sea distribution of marine turtle species reported in ghost nets in the gulf region. Turtle distributions are based on average catch per unit effort in trawls in 100 km by 100 km blocks.

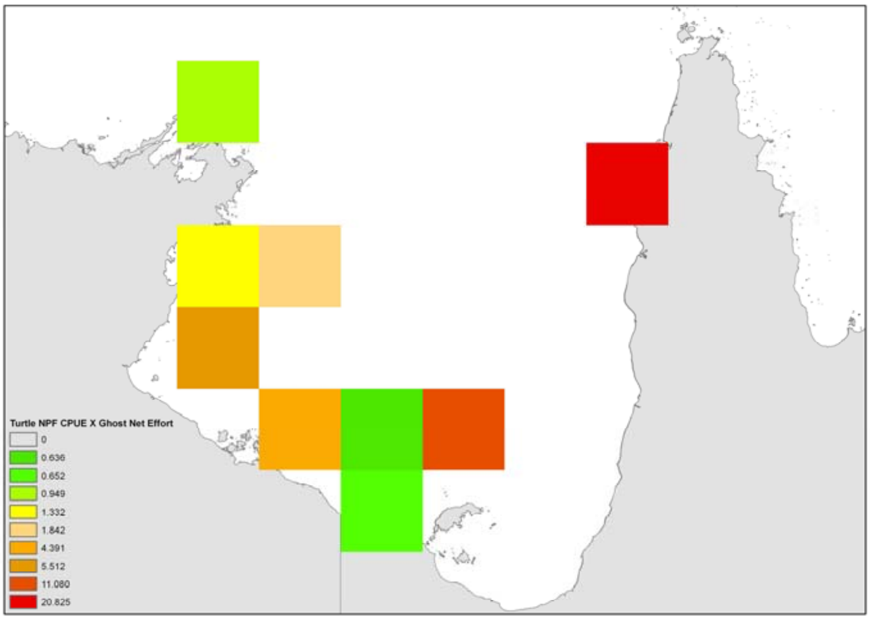

Figure 9. Predicted threat to turtles from lost fishing gear. Threat is based on the probability of encounter between nets, where encounter is predicted as the product of mean turtle density (measured as turtles per unit of trawl effort) and ghost net fishing effort (measured as the mean of the relative number of meters of abandoned fishing gear passing through each cell). Note that the units cannot be interpreted reliably as the actual number of turtles killed, but can be used to assess the expected level of threat in the spatial blocks in the Gulf.

Table 1. Turtle species encountered by a) the Northern Prawn Trawl Fishery in the GOC and b) marine species ensnared by ghost nets as recorded by ranger groups during clean up surveys.

Cheloniidae	Unidentified to species	66
Caretta caretta	Loggerhead	12
Chelonia mydas	Green	10
Eretmochelys imbricata	Hawksbill	6
Lepidochelys olivacea	Olive Ridley	52
Natator depressus	Flatback	105
Total		251

Cheloniidae	Unidentified to species	Not listed
Caretta caretta	Loggerhead	0
Chelonia mydas	Green	14
Eretmochelys imbricata	Hawksbill	35
Lepidochelys olivacea	Olive Ridley	53
Natator depressus	Flatback	3
Dermochelys coriacea	Leatherback	0
	Shark	9
Dugong dugon	Dugong	1
Hydrophiidae family	Sea snake	1
	Crabs	countless
	Fish	12
Total		128

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