A GEOSPATIAL ANALYSIS OF MYSTIC AQUARIUM'S MARINE ANIMAL STRANDING DATA

By

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Abstract

Mystic Aquarium's Marine Mammal and Sea Turtle Stranding Program has been responding to distressed marine animals in Connecticut and Rhode Island for over 35 years. Since 1975, the Aquarium has responded to more than 1,290 stranded marine mammals and sea turtles. As required by NOAA, each recorded stranding has an associated Level A data form which contains the details of the stranding event, including specific information on the animal, its condition and the exact location of the event. This detailed information is very valuable, and can be mapped in programs such as ArcMap and shared through online databases like OBIS-SEAMAP and SeaTurtle.Org for visual representation and analysis. Interactive maps of the coordinates and details of these stranding events can be used to detect spatial and temporal trends in marine animal strandings, and can also improve efficiency in responding to future events by targeting education and outreach efforts based on historic observations of species, location and seasonality. Mystic Aquarium's stranding data was mapped using both ArcMap and OBIS-SEAMAP, to look for spatial and temporal patterns in marine mammal and sea turtle strandings. The maps produced will be used to target resources and educational efforts to identified stranding hot spots, and also used as educational displays outside Mystic's Seal Rescue Clinic. Adding data to OBIS-SEA map will add to the growing global database and allow researchers to observe trends on a larger scale.

Acknowledgements

I would like to thank my Master's Project and academic advisor Dr. Andrew Read for his support of this project, as well as my academic career at Duke over the last two years. This project would not have been possible without the continued assistance and encouragement of Mystic Aquarium, especially the stranding department staff, Janelle Schuh and Walter 'Skip' Graf, as well as Melissa Wands, the stranding intern, and numerous volunteers that assisted in answering questions and double checking data against archived records. Many thanks also to Dr. Matthew Godfrey of the North Carolina Wildlife Resource Commission for sharing his knowledge of marine turtle strandings. I am grateful for my friends and family for their support, both technical and emotional, throughout this project, and for Zach and his superb knowledge of Excel formulas, which often saved the day.

Introduction

Mystic Aquarium's Marine Mammal and Sea Turtle Stranding Department has been responding to distressed marine animals in Connecticut, Rhode Island and Fisher's Island, New York since 1975. Primary financial support for Mystic Aquarium's stranding response and rehabilitation comes from the federal Marine Mammal Rescue Assistance Act of 2000, by way of the John H. Prescott Marine Mammal Rescue Assistance Grant Program (NOAA Fisheries, 2012b). The program also relies on support from fundraisers, private monetary and in-kind donations (J.Schuh, personal communication, February 2013).

The stranding program is managed by two full time staff members, and is supported by one to two unpaid interns at a time. The program also relies heavily volunteers. Over 30 in-house volunteers and over 300 first responders (field volunteers) provide 3,500-4,500 hours per year, which is crucial to the smooth daily operation of the program (J. Schuh, personal communication, March 2013). The Aquarium responds to strandings over 1,000 miles of coastline in Connecticut, Rhode Island, and Fisher's Island, New York, so volunteers are often crucial to assess the condition of animals reported by the public before a rescue can be attempted. When a member of the public reports a stranded marine mammal or sea turtle to the Aquarium's 24-hour stranding hotline, the staff decides whether they will respond immediately or delegate a trained first responder volunteer to further investigate the situation first.

If stranding staff or volunteer responds to a live or dead stranded marine mammal, they must complete a Level A data form, as required by NOAA. This form contains the details of the stranding event, including specific information on the animal and its condition, observed human interaction (entanglement, gunshot wounds) and the exact location of the event using GPS coordinates (NOAA Fisheries, 2013b). This form is reported back to the regional stranding coordinator, and the data is also recorded in the stranding department's Microsoft Access database for record keeping.

A number of publications have reported on the use of GIS software to analyze spatial and temporal trends in marine animal strandings. Mapping stranding data gives the user a visual representation of trends observed and the data can be filtered to focus on details such as a species or particular time range. For example, David Harris and Sat Gupta (2006) used GIS to analyze hooded and harp seal strandings in the Gulf of Maine, and their analysis identified seasonal trends in strandings that were consistent with observed onshore seal sightings.

Stephanie Norman and colleagues discuss the applications of GIS to unusual mortality events, which can encompass many animals over a long period of time. They emphasizes the use of spatial analysis to investigate time–space clustering of disease and mortality events, including "mapping of strandings to demonstrate disease and mortality events, surveillance and monitoring of diseases, disease cluster detection, identification of environmental predictors of disease in wildlife populations, risk assessments, and modeling the spread and impact of disease (Norman et al. 2011)."

As GIS software becomes more accessible and user-friendly, it may encourage additional researchers and stranding facilities to utilize this method of data analysis. By developing maps that look at a wide range of marine animal stranding or mass mortality events, scientists can gain a better understanding of causes and effects of strandings, as well as how diseases spread among individuals and populations.

A growing resource for compiling and sharing marine animal data is OBIS-SEAMAP - a spatially and temporally interactive online database for marine protected species. Hosted by the Marine Geospatial Ecology Lab at Duke University, this 10-year old repository is made possible by contributions from data providers around the world – researchers, public and private aquaria, government agencies, and non-profit conservation groups, and includes sighting, survey, tagging and stranding data for marine mammals, sea turtles and sea birds (Marine Geospatial Ecology Lab, 2011). Currently, the OBIS-SEAMAP database holds over 3 million records for 368 species from more than 500 providers and is still growing (OBIS-SEAMAP, 2013). A variety of analytical tools are found on OBIS-SEAMAP, including the ability to browse records by species or submitting organization, and to view records graphically.

In 2012, the Virginia Aquarium uploaded Level A data collected from marine mammal strandings between 1988 and 2008 to OBIS-SEAMAP. This dataset encompassed 1,588 individual stranding events, from 33 different species, including cetaceans, pinnipeds and sirenians (Virginia Aquarium Stranding Response Program, 2012). The only other stranding data set on the east coast of the United States included in OBIS-SEAMAP is from the Bahamas Marine Mammal Research Organization, which contributed 89 marine mammal stranding events from 1944 through 2005 (Bahamas Marine Mammal Research Organization, 2006). However, Level A data has been collected from all stranding response organizations along the east coast, and these data could and should be added to this growing online database.

Another useful online data repository is SeaTurtle.Org, a non-profit online database, with the goal of "organizing the world's sea turtle information and making it universally accessible and useful" (SeaTurtle.Org). Using the Sea Turtle Rehabilitation and Necropsy Database (STRAND), the states of North and South Carolina, Georgia and Florida report their stranding data, which is publically available. This database allows stranding data to be summarized by species, month, year, county and beach. Strandings are also plotted using Google maps, with links back to details of the event (Sea Turtle Rescue and Necropsy Database, 2013).

Objective

Due to the high volume of stranding data collected since 1975, Mystic Aquarium requested that the data be mapped using geographic information systems (GIS). Maps of Mystic Aquarium's stranding data were created using ArcMap and data were uploaded to OBIS-SEAMAP to examine spatial and temporal patterns. The maps produced will be used to target resources and educational efforts to identified stranding hot spots, and also used as educational displays outside Mystic's Seal Rescue Clinic. Maps and quantitative data describing the number and timing of strandings will allow Mystic Aquarium to recruit and train volunteers in high-volume areas. Other potential first responder organizations, such as lifeguards or local police departments can be educated on the species commonly seen in their areas to assist in proper reporting and response to strandings. By adding the data to online databases such as OBIS-SEAMAP and SeaTurtle.Org, researchers and other stranding organizations can achieve a more comprehensive view of marine animal strandings along the east coast.

In addition, by sharing their stranding data, Mystic Aquarium may also encourage other stranding response organizations to share their Level A data and thus improve collaborate efforts among facilities. This is especially important for facilities that work within the same geographical range of migratory species. These data also support researchers and government employees who utilize stranding information to advocate for marine animals' protection, such as relocation of shipping lanes and fishing gear regulations.

Materials and Methods

The data being utilized in this project were collected by Mystic Aquarium stranding staff or volunteers as each stranding event occurred, and are stored in two Microsoft Access databases. For this analysis, I focused on strandings that occurred from 1990 – 2011, as data were more consistently recorded from 1990 onwards, and 2011 was the last full year of data collection before the analysis began. The Aquarium specifically requested maps displaying: (1) all Connecticut pinniped strandings; (2) all Rhode Island pinniped strandings; (3) marine turtle strandings for both states; (4) cetacean strandings for both states, and (5) an overview of all marine mammals versus marine turtle strandings for both states.

For the purposes of my analysis, therefore, the data being utilized were organized into a new Excel database, including only the relative details: species, date of stranding, latitude and longitude, county and state of stranding, and whether the animal was found alive or dead. Data such as the name of responders, morphometric measurements, and responder comments were deleted from these spreadsheets. GPS coordinates were converted into decimal degrees using the Excel function 'Convert_Decimal'.

I obtained base maps of Connecticut and Rhode Island from the respective state websites. I added additional layers to display county lines and major hydrological features such as rivers, which can also be stranding sites if animals become disoriented or follow prey up from the ocean or Long Island Sound. I uploaded the coordinates of each stranding into ArcMap 10.1 using the 'Add X Y data' tool.

I also analyzed strandings as density per county, based on distance of shoreline. I obtained the total length of shoreline using the Northeastern United States County Boundary Line, which was published in 2006 by the State of Connecticut, Department of Environmental Protection (Connecticut Environmental Conditions Online, 2006). I calculated stranding density by dividing the length of shoreline for each county by the total number of pinnipeds, turtle and cetacean strandings in that county, for the 1990-2000 range, and 2001-2011 range

Following the work of Harris and Gupta (2006) I plotted stranding latitudes against day of the year, to look for seasonal trends. This was done for ice seals - harp seal, *Pagophilus groenlandicus,* and hooded seal, *Cystophora cristata*, all pinnipeds, all cetaceans, odontocetes (toothed whales), mysticetes (baleen whales), and all marine turtles. To convert dates into Julian dates (day of year), I used the excel formula =(reference)-DATE(YEAR(reference),1,0). Julian dates were plotted against the stranding latitude in a simple scatter plot.

I submitted stranding data to be uploaded into OBIS-SEAMAP by sending copies of all Excel spreadsheets to Connie Kot, Research Associate in the Marine Geospatial Ecology Lab.

Results

Figure 1 displays that, although pinnipeds strandings occurred year-round, they were concentrated in the first half of the year, with a median stranding Julian date of 101 (April 10 or 11), and day 90 (March 30 or 31) was the most common date for a stranding to occur. When separated out in Figure 2, ice seal (harp and hooded seal) strandings were more concentrated, with a median stranding date of 79 (March 19 or 20) and day 76 (March 16 or 17) as the most common. Ninety five percent of ice seal strandings happen before day 152 (May 31 or June 1), whereas only 79% of the total seal strandings occurred before day 152.

The median day of sea turtle strandings was 233 (August 20 or 21) and with the exception of 3 dead carcasses found earlier in the year, Figure 3 displays that sea turtle strandings occurred predominantly in the second half of the year. Cetacean strandings, as displayed in Figure 4, occurred throughout the year, with a median stranding date of 162 (June 10 or 11). A noticeable trend was observed for mysticetes: humpback whale, *Megaptera novaeangliae*, fin whale, *Balaenoptera physalus*, minke whale, *Balaenoptera acutorostrata*, blue whale, *Balaenoptera musculus* and North Atlantic right whale, *Eubalaena glacialis*. With the exception of one stranding in March, baleen whale strandings, shown in Figure 5 occurred from May through December, with a median day of 198 (July 16 or 17). Figure 6 shows that odontocetes such as harbor porpoises (*Phocoena phocoena*), common dolphins (*Delphinus* spp.), and pilot whales (*Globicephala* spp.), strandings occurred over all seasons, with a median day of 154 (June 2 or 3).

Several changes in the number of strandings were observed when comparing the entire 1990-2000 and 2011-2011 data sets. A 52% increase was seen in the number of pinniped strandings, from 267 to 408, but the number of sea turtle strandings decreased from 125 data to 117, a 6% decrease. The number of cetacean strandings more than doubled from 64 to 139, a 117% increase. The change in locations of pinniped, sea turtle and cetacean strandings from 1990-2000 to 2001-2011 are displayed in Figures 7,8, and 9respectively.

At a local level, changes were seen for many counties. As shown on Figure 10, increases were seen in the number of pinniped strandings for all coastal counties, except for New Haven county. The number of sea turtle strandings increased for New London, Middlesex, and New Haven counties, decreased in Washington and Fairfield counties, and remained the same in Providence county. Changes could not be calculated for Bristol and Kent counties because the 1990-2000 data sets had no sea turtle strandings, but increases were seen for strandings in 2001-2011. Cetacean strandings decreased in Providence county, did not change in New Haven and Middlesex counties, and increased in all other coastal counties. The highest percent increases in cetacean strandings were seen in Fairfield, Washington and Newport counties.

Between 1990-2011, the density of pinnipeds strandings was highest in Washington at 0.844 strandings per kilometer of shoreline (an average of 0.040 strandings per kilometer per year), Newport county was second at 0.686 seals per kilometer, and New London was third highest at 0.312 strandings per kilometer of shoreline. Sea turtle strandings were highest in Washington county at 0.352 strandings per kilometer (for an average of 0.017 strandings per kilometer per year), then Newport county at 0.291 strandings per kilometer and New London county at 0.042 strandings per kilometer. Cetacean stranding density was highest in Newport county at 0.359 strandings per kilometer of coastline (for an average of 0.017 strandings per kilometer per year), followed by Washington county with 0.228 strandings per kilometer, and Kent county with 0.087 strandings per kilometer.

Discussion

Many of the trends seen in stranding data presented here can be attributed, at least in part, to the natural history of the species involved. Adult harp and hooded seals give birth on the ice in late winter and early spring in Canada and northern Maine. Harris and Gupta found that ice-breeding seals generally strand farther north in the Gulf of Maine in the early winter, farther south in the late winter, and farther north again in the spring. They also note that individual ice seals show substantial variability in their movements based on age and species. For instance, juvenile ice seals are believed to range more widely than do adults (Harris & Gupta, 2006). This connects well to stranding observations in southern New England – the harp and hooded seals seen by Mystic Aquarium are commonly pups that have been weaned from their mothers and are learning how to forage on their own.

In contrast to harp and hooded seals, harbor (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) have residential populations in southern New England, and their strandings typically occur later in the year than harp and hooded seals. Additionally, population changes are being translated into changes in strandings. Specifically, Massachusetts' grey seal population is experiencing significant growth. According to the 2012 NMFS Western North Atlantic Stock Assessment, in the mid-1980s, a small number of grey seals, including pupping females, were observed on several remote islands along the Maine coast and in Nantucket-Vineyard Sound, Massachusetts. As the stock assessment notes, the grey seal population has continued to grow over time, and in the late 1990s, a year-round breeding population of several hundred grey seals was seen on outer Cape Cod and Muskeget Island, Massachusetts. In 2011, a maximum count of 15,756 was obtained in southeastern Massachusetts coastal waters (NOAA Fisheries, 2012e). This population trend is reflected in Mystic Aquarium's data: from 1990-2000 there were 18 grey seal strandings; from 2001-2011, there were 89 grey seal strandings – a 394% increase.

In contrast, harbor seal strandings in Mystic Aquarium's response range decreased from 109 strandings to 100, an 8.3% decrease. The 2012 NMFS Western North Atlantic Stock Assessment details that harbor seal pup production declined on Sable Island, Canada from 600 in 1989 to less than a dozen in 2002. A decline in the number of juveniles and adults did not occur immediately, but a decline was observed in these age classes as a result of the reduced number of pups recruiting into the older age classes. NMFS lists possible reasons for this decline including increased use of the island by grey seals and increased predation by sharks (NOAA Fisheries, 2012d). This trend is also being seen in the Cape Cod population of harbor seals, as the grey seal population continues to increase.

Sea turtles are poikilothermic reptiles that require relatively warm water temperatures. Hard-shelled sea turtles are found in tropical to temperate waters throughout the world, including the western Atlantic Ocean. A clear trend in sea turtle strandings can be seen as the turtles move from south to north in summer, in correlation to rising water temperatures. Sarah Milton and Peter Lutz note that as water temperatures drop in the fall and winter, “Sea turtles, with the exception of leatherbacks, trapped in cold waters (below 8-10C) may become lethargic and buoyant, floating at the surface. This condition is known as cold stunning. Sea turtles that overwinter in inshore waters are most susceptible to cold-stunning because temperatures changes are most rapid in shallow waters, especially in semi-enclosed areas such as lagoons. As temperatures drop below 5-6C, death rates become significant, because the animals can no longer swim or dive, become vulnerable to predators, and may wash up onshore, where they are exposed to even colder temperatures” (2003). These turtles can successfully be rehabilitated by gradually rewarming their core temperature, and is often highly successful, depending on the initial condition that the turtle is found in. For cold-stunned turtles at New England Aquarium in the 1999-2000 season, successful rehabilitation ranged from 66% in green turtles (*Chelonia mydas*), to 100% in loggerheads (*Caretta caretta*) (Milton & Lutz, 2003).

Similarly, the seasonal trend in baleen whale strandings is consistent with the whales’ seasonal migrations. “For many mysticetes, long migrations occur between calving grounds in warmer water and foraging areas in colder polar or high-latitude temperate waters” (Stevick, McConnell & Hammond, 2002). For example, “In the western North Atlantic ocean, humpback whales feed during spring, summer, and fall over a range that encompasses the eastern coast of the United States (including the Gulf of Maine), the Gulf of St. Lawrence, Newfoundland/ Labrador, and western Greenland. In winter, whales from the Gulf of Maine mate and calve primarily in the West Indies” (NOAA Fisheries, 2013a). Stevick, McConnell and Hammond note that changes observed in the distribution of humpback, fin, right and sei whales off the northeastern US coast were associated with a relative abundance of copepods, herring and sand eels in the region (2002). This may help to explain annual fluctuations, where Mystic saw years with no baleen whale strandings, like 2003, while 2004 saw a high of 6 baleen whale strandings.

Conversely, toothed whales do not make as extreme seasonal migrations as the baleen whales, so strandings in southern New England are seen year round. For example, the long-finned pilot whale has an antitropical distribution, with the population primarily located in the Southern Ocean and North Atlantic (Martin, A.R. & R.R. Reeves, 2002). In the Northern Hemisphere, their range includes the U.S. east coast and Gulf of St. Lawrence. In contrast to the south-north migration of humpback whales, the pilot whale migration pattern is longitudinal - in the winter and spring, pilot whales are more commonly found in offshore oceanic waters or on the continental slope (Martin, A.R. & R.R. Reeves, 2002). With warmer water temperatures in the summer and autumn months, long-finned pilot whales generally follow their preferred prey items farther inshore and on to the continental shelf (Martin, A.R. & R.R. Reeves, 2002). The harbor porpoise, although smaller than other toothed whales is "the only small cetacean with an exclusively northern temperate/subarctic range" (Martin, A.R. & R.R. Reeves, 2002). There are 10 stocks of harbor porpoises in U.S. Waters, including the Gulf of Maine-Bay of Fundy population, and are commonly found in bays, estuaries, harbors, and fjords less than 200 meters deep, which could also contribute to their high levels of reporting (NOAA Fisheries, 2012a).

Pyenson (2011) discusses the significant role that cetacean strandings play in relation to knowledge of species' richness and abundance. He concluded that, for stranding data collected for shorelines over 2,000 km, death assemblages (dead strandings) provided a richer picture of species richness than surveys of live cetaceans (Pyenson 2011). Mystic Aquarium responds to strandings along the entire length of the shorelines of Connecticut and Rhode Island, roughly 1,600 km in length. Thus, if the present data is combined with that of other neighboring areas, the data set may provide a more accurate picture of species richness of sea turtles and marine mammals than coastal surveys in this area of New England.

Pyenson (2011) also discusses how stranding records can represent unusual occurrences of rarely seen pelagic species, such as beaked whales. According to the Mystic's Microsoft Access database, in the 1990s, the Aquarium responded to and necropsied two rare beaked whales – Blainville's beaked whale, *Mesoplodon densirostris*, and Gervais' beaked whale, *Mesoplodon europaeus*,. These necropsies provided valuable insight into species that Marine Mammals Ashore classifies as "rare, including historical records" – Blainville's - and "every 1-5 years" – Gervais' (Geraci & Loundsbury, 2005).

In addition to learning about species abundance, Norman et. al. (2011) emphasize that "Increased effort to examine live- and dead-stranded marine mammals has helped to improve our knowledge of mortality rates and causes, allowing a better understanding of population threats and stressors, as well as our ability to determine when a stranding situation is "unusual" as seen in strandings involving *Toxoplasma gondii*, *Cryptococcus gattii*, and morbilliviruses." Norman goes on to discuss how, "understanding and investigating marine mammal unusual mortality events is important because these events can serve as indicators of ocean health, giving insight into larger environmental issues, which may have implications for human health and animal welfare." Research done on these diseases in stranded animals can translate to a better understanding of the disease and treatments in humans, and further emphasizes the importance of investigating strandings.

It can be a challenge to locate stranded animals or their carcass, especially for organizations that rely on public reporting. Harris and Gupta (2006) noted that their Gulf of Maine study used the most extensive and consistently maintained database available of harp and hooded seal stranding locations, but it is likely not a comprehensive account of all strandings. "It is, none the less, opportunistic rather than the result of a transect analysis, and is thus open to reporting bias (i.e., the impact of factors that influence whether or not an ice seal onshore is seen, reported to a stranding organization, observed by that organization, and deemed stranded)." The authors assume that people are more likely to recreate on public rather public rather than private land, and their finding that proximity to public land is a predictor of high stranding density is consistent with a reporting bias. Their conclusion is important because it implies that there more ice-breeding seals strand on the Gulf of Maine coast than are reported, and the same could be true for Connecticut and Rhode Island, that strandings are occurring on beaches and marshes that are not accessible or frequented by the public, and are subsequently going unreported.

To test Harris and Gupta's hypothesis that stranding reports are more likely to occur on public beaches, I examined the stranding data collected by Mystic Aquarium. Connecticut's 2012 Annual Report for the US EPA Beach Grant reports 73 public beaches and state parks (Connecticut Department of Public Health, 2013) and the Rhode Island Department of Health 2011 Beach Report lists 72 for the state (Rhode Island Department of Health, 2011). Most of Rhode Island's beaches occur in Washington and Newport counties, which is where 72.7% of pinniped strandings, 85.1% of sea turtle strandings and 86.7% of cetacean strandings occur.

In North Carolina, patrols of organized volunteers monitor known sea turtle nesting beaches from May through August to check for adult turtles laying nests, as well as the hatchlings' emergence. These data are reported to volunteer managers, and eventually to the Wildlife Resource Commission, where they are entered into the state database on SeaTurtle.Org (M. Godfrey, personal communication, March 2013). In winter months, cold-stunned turtles strand in high numbers in areas like Cape Lookout National Seashores and Hatteras Island. Park rangers and trained volunteers perform daily patrols of these common stranding areas when water temperatures drop below 12C, which is very likely linked to the high number of strandings reported and taken to rehabilitation (M. Godfrey, personal communication, March 2013). Connecticut and Rhode Island do not experience the same volume of cold-stunned sea turtles as North Carolina, or Cape Cod, Massachusetts, due to the geographic and oceanic conditions that drive weakened turtles into these areas, so this volunteer patrol effort has not been enacted. Between 1990 and 2011, Mystic responded to a total of 16 sea turtles between the months of November and February, with a high season of four cold stunned sea turtles in 1999. This is a vast contrast from North Carolina's 144 cold stunned turtles in the 2012-2013 winter, (Sea Turtle Rescue and Necropsy Database, 2013) and Cape Cod's 242 (New England Aquarium, 2013) for the 2012-2013 winter.

Even if all beaches had equal visitation, public education may lead to increased reporting of strandings over time. Connecticut and Rhode Island have high influx of out of state tourists in the summer months, so these beach-goers may not recognize the signs of a distressed animal, or may not know how or choose not to report a carcass. It is possible that the Aquarium's increased outreach and education on reporting may have contributed to the increases seen in numbers of strandings recorded from 2001-2011, especially reflected in the number of offshore reports of dead marine turtles and cetaceans, as shown in Figures 8 and 9.

According to the US Census Bureau, the United States coastal population grew by 40 million people between 1960 and 2008 - an 84.3% increase, while for the same time, non-coastal population only grew by 64.3% (US Census Bureau, 2012a). In 2010, 52% of the US population lived in a coastal county (counties with at least 15% of their land either in a coastal watershed or in a coastal cataloging unit). Nearly half (23%) of this population resides on the Atlantic coast (U.S. Census Bureau, 2012b). The number of housing units in Rhode Island increased 5.4%

from 2000-2010, and housing units in Connecticut increased 7.4% for the same period (U.S. Census Bureau, 2012c). As these trends of increasing population and development continue, there is an increased chance of humans interacting with marine animals that consider the coastline and coastal waters their home. This increasing coastal population is an important factor consider when looking to the future of marine animal stranding response and public education.

Conclusion

The maps and data gained from this analysis can be used by Mystic Aquarium to focus resources, such as volunteer recruitment and training courses, in areas that see high densities of strandings. Training can also be targeted towards other potential responding agencies, such as law enforcement, life guards or park rangers, to assist in more consistent and timely reporting of strandings.

In the future, it is recommended that the Stranding department continue to collect and record data in a consistent form, for the ease of updating maps. Before records are archived, it is also recommended that the data be checked for accuracy, which will prevent future delays in research and mapping. The maps can easily be updated using ARC GIS software, and charts can be updated simply by adding updated information into the Excel spreadsheets.

The Aquarium is encouraged to share these results at conferences such as the Northeast Regional Stranding Network conference, or with neighboring responding facilities. By sharing results and encouraging other facilities to contribute their data to OBIS-SEAMAP, larger and long-term trends can be observed regarding marine mammal and sea turtle strandings on the east coast. Mystic is also encouraged to utilize the online database at SeaTurtle.Org to report strandings, as well as healthy sightings of turtles in Connecticut and Rhode Island.

Figure 1: Pinniped stranding latitudes plotted against day of year

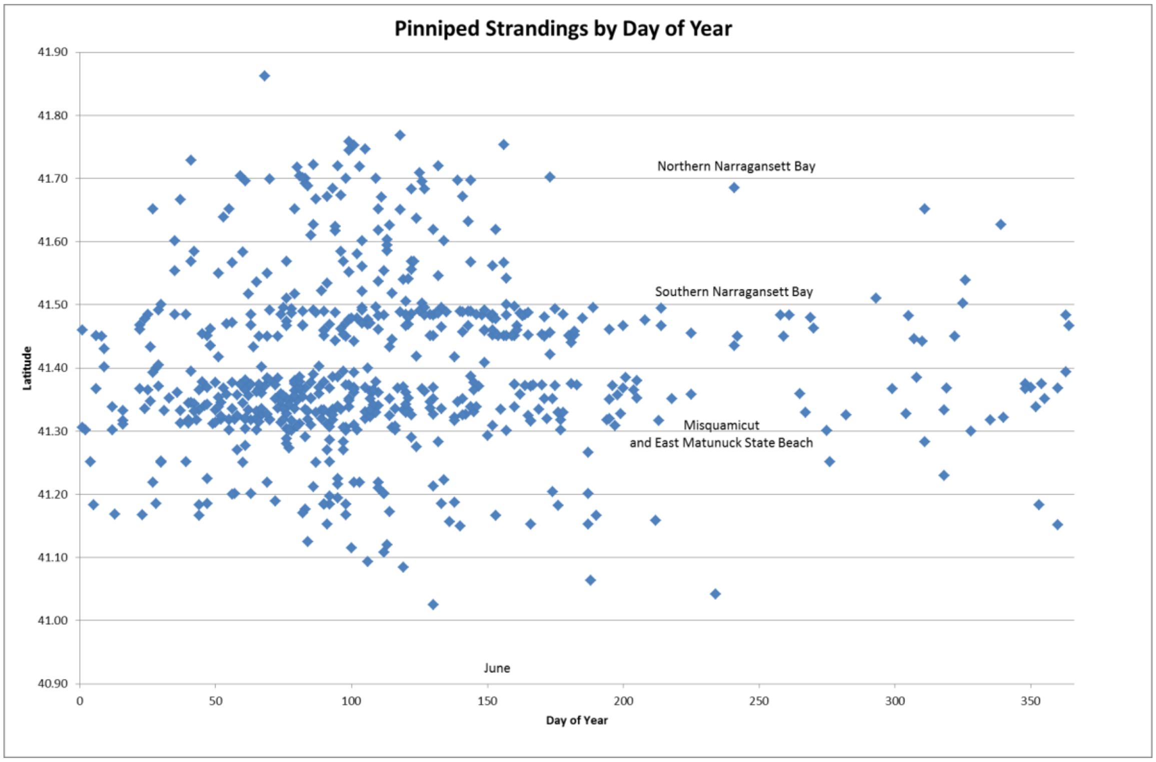


Figure 2: Ice seal (harp and hooded) stranding latitudes plotted against day of year

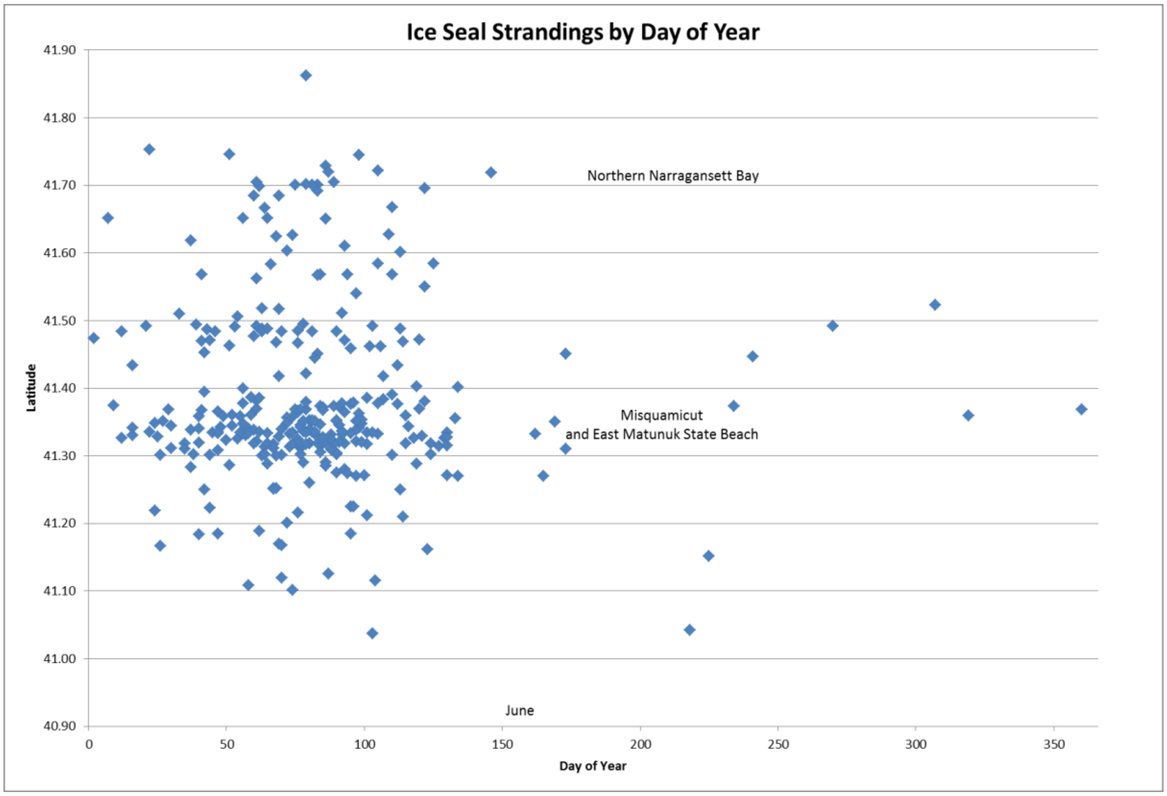


Figure 3: Marine Turtle stranding latitudes plotted against day of year

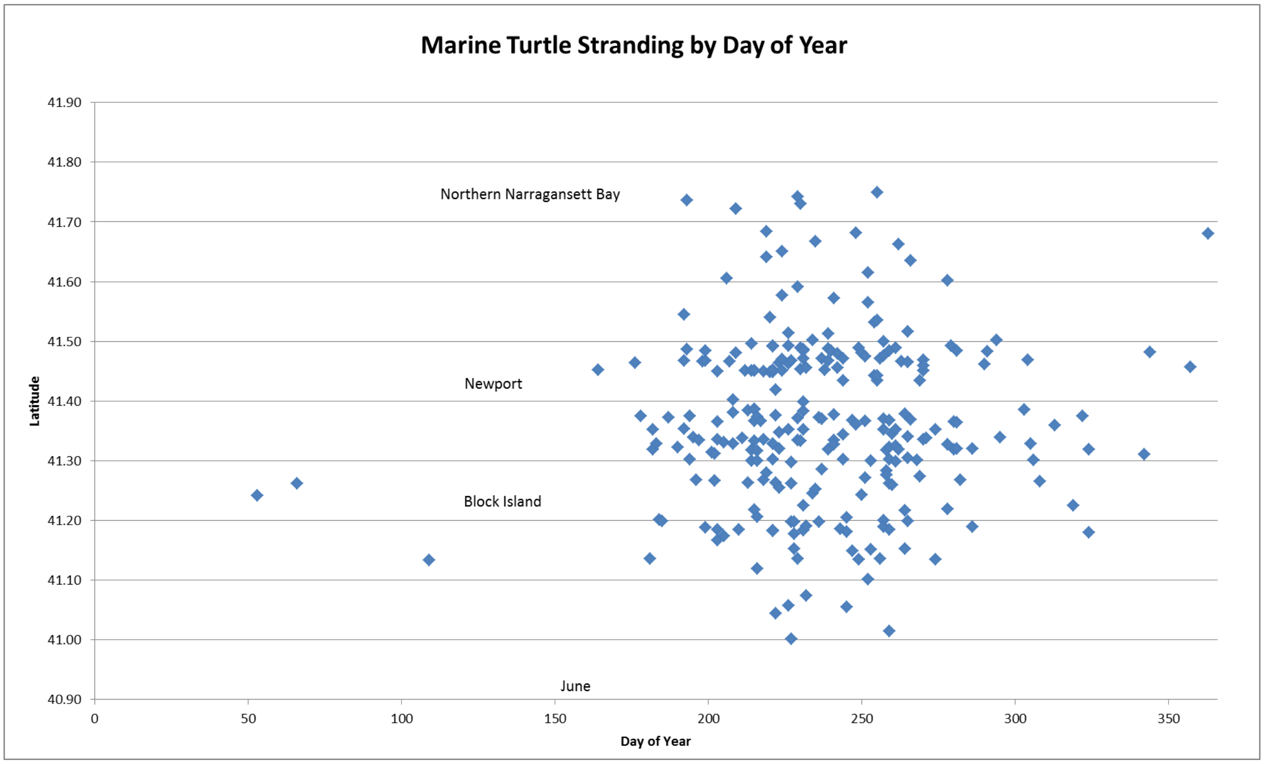


Figure 4: Cetacean stranding latitudes plotted against day of year

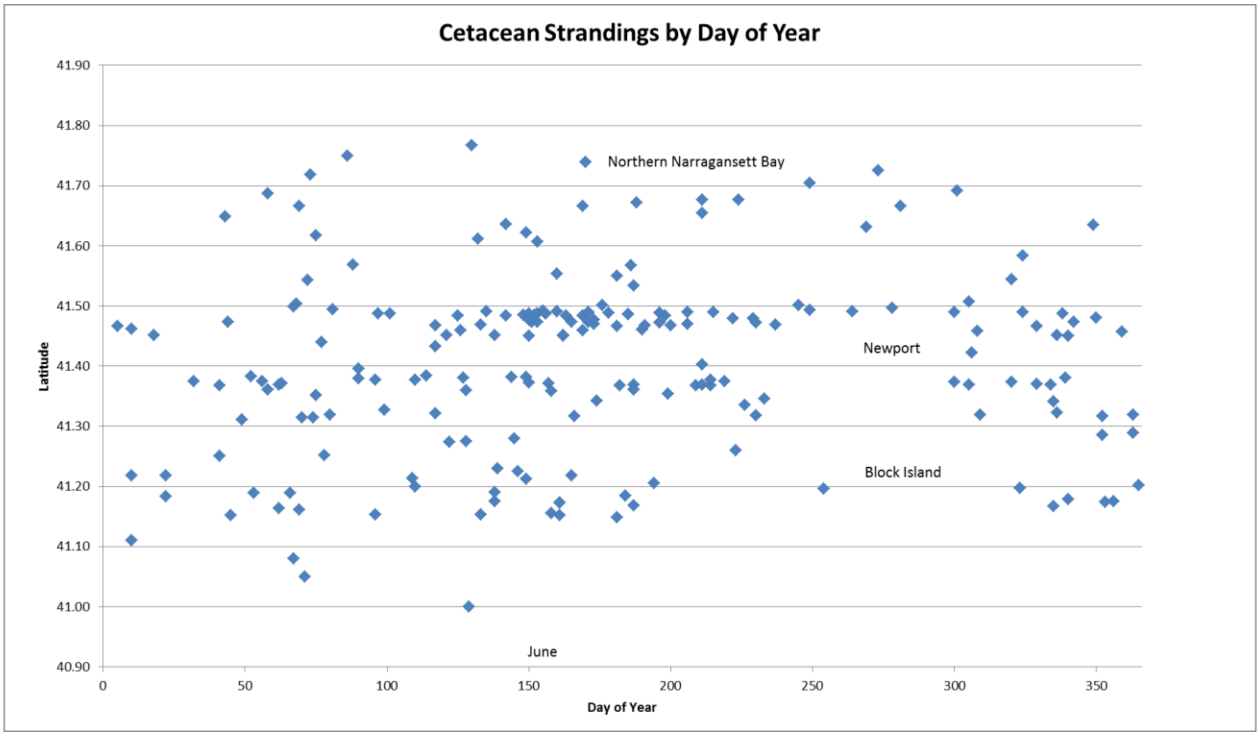


Figure 5: Mysticete (baleen whale) stranding latitudes plotted against day of year

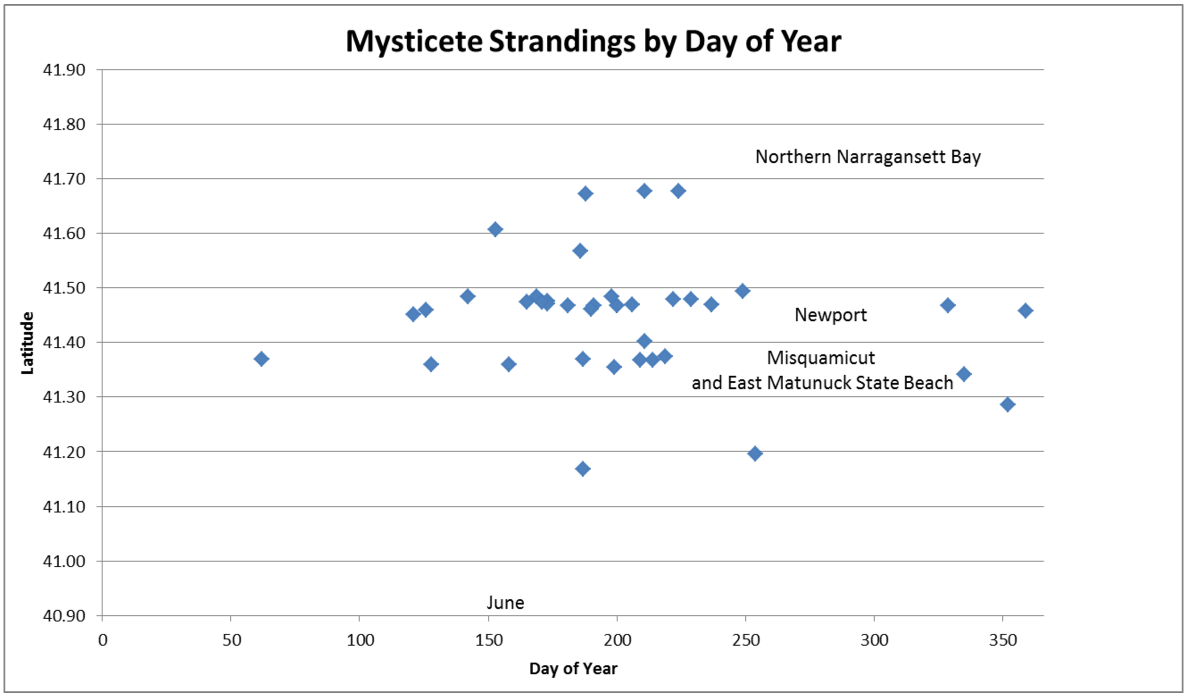


Figure 6: Odontocete (toothed whale) stranding latitudes plotted against day of year

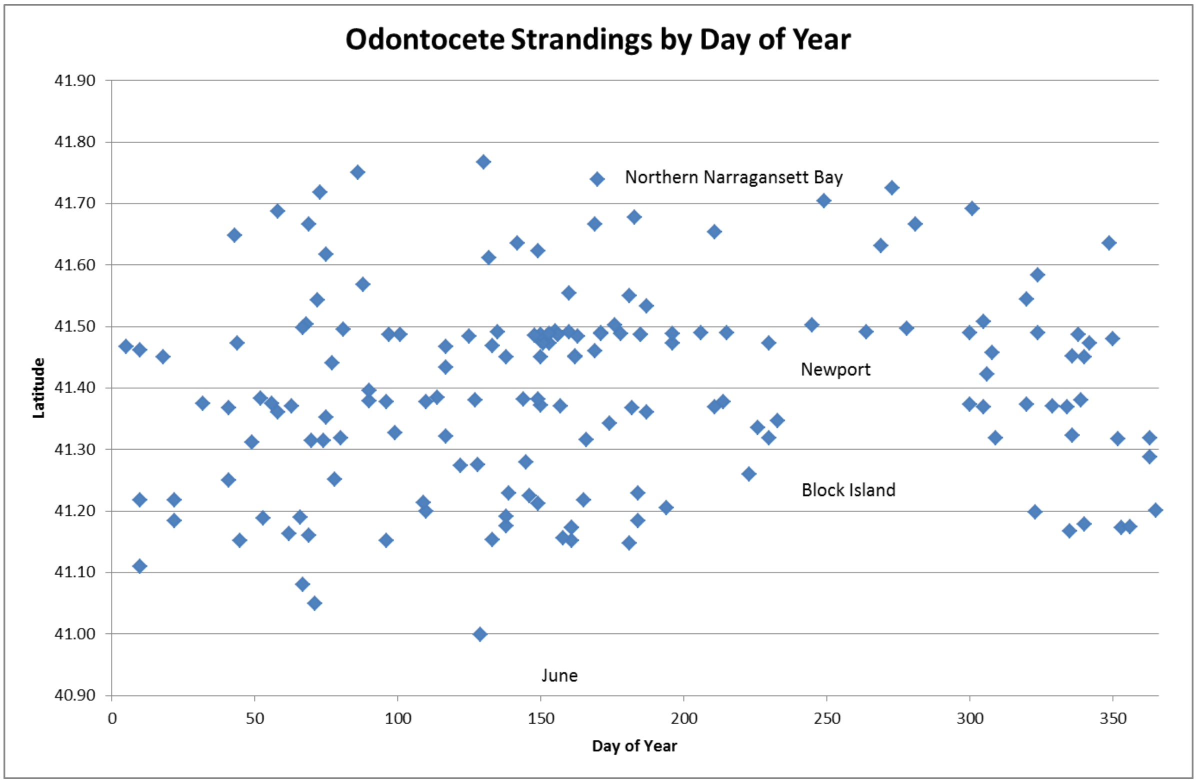


Figure 7: Change in location of pinniped strandings, comparing 1990-2000 strandings against 2001-2011 stranding locations.

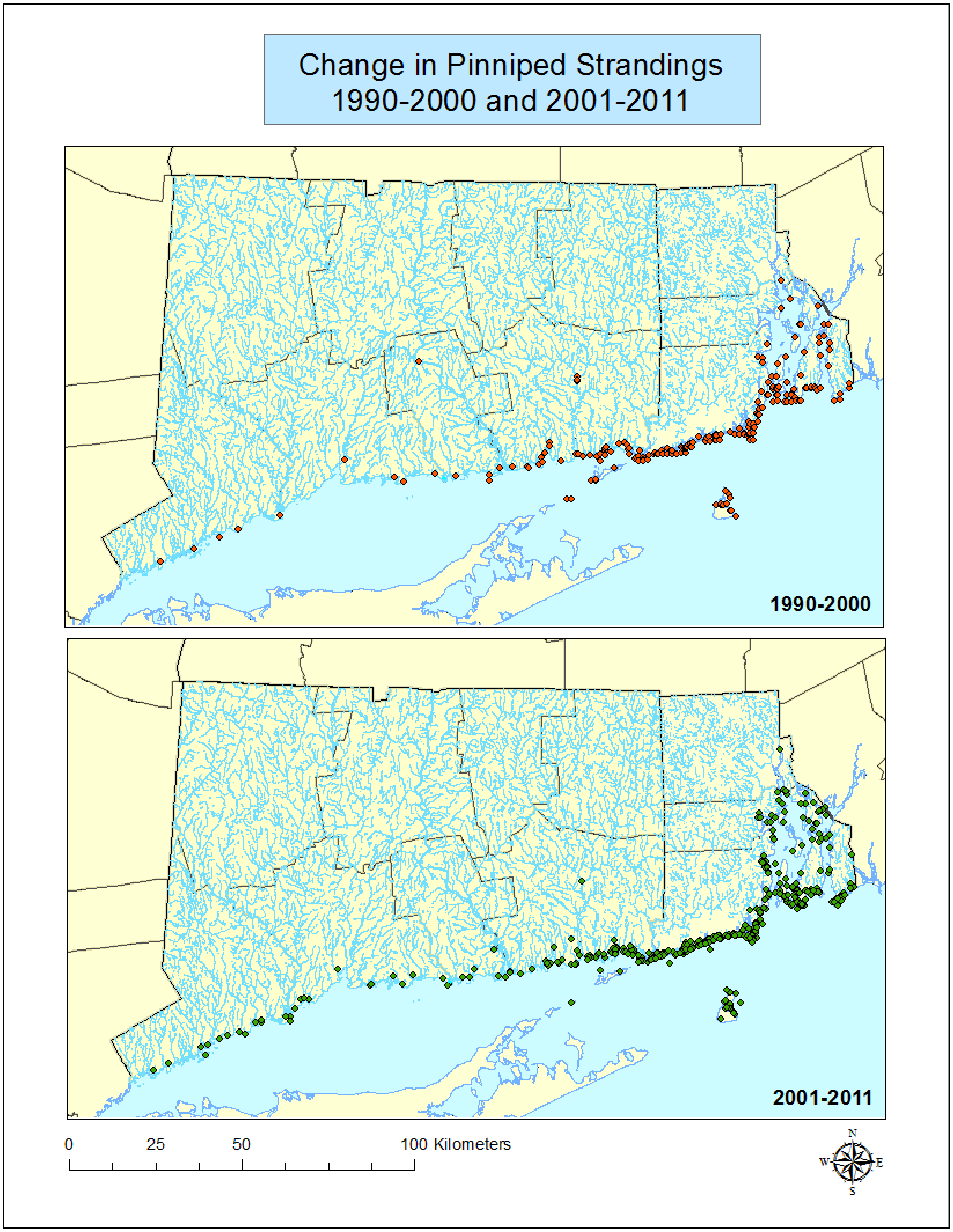


Figure 8: Change in location of marine turtle strandings, comparing 1990-2000 strandings against 2001-2011 stranding locations.

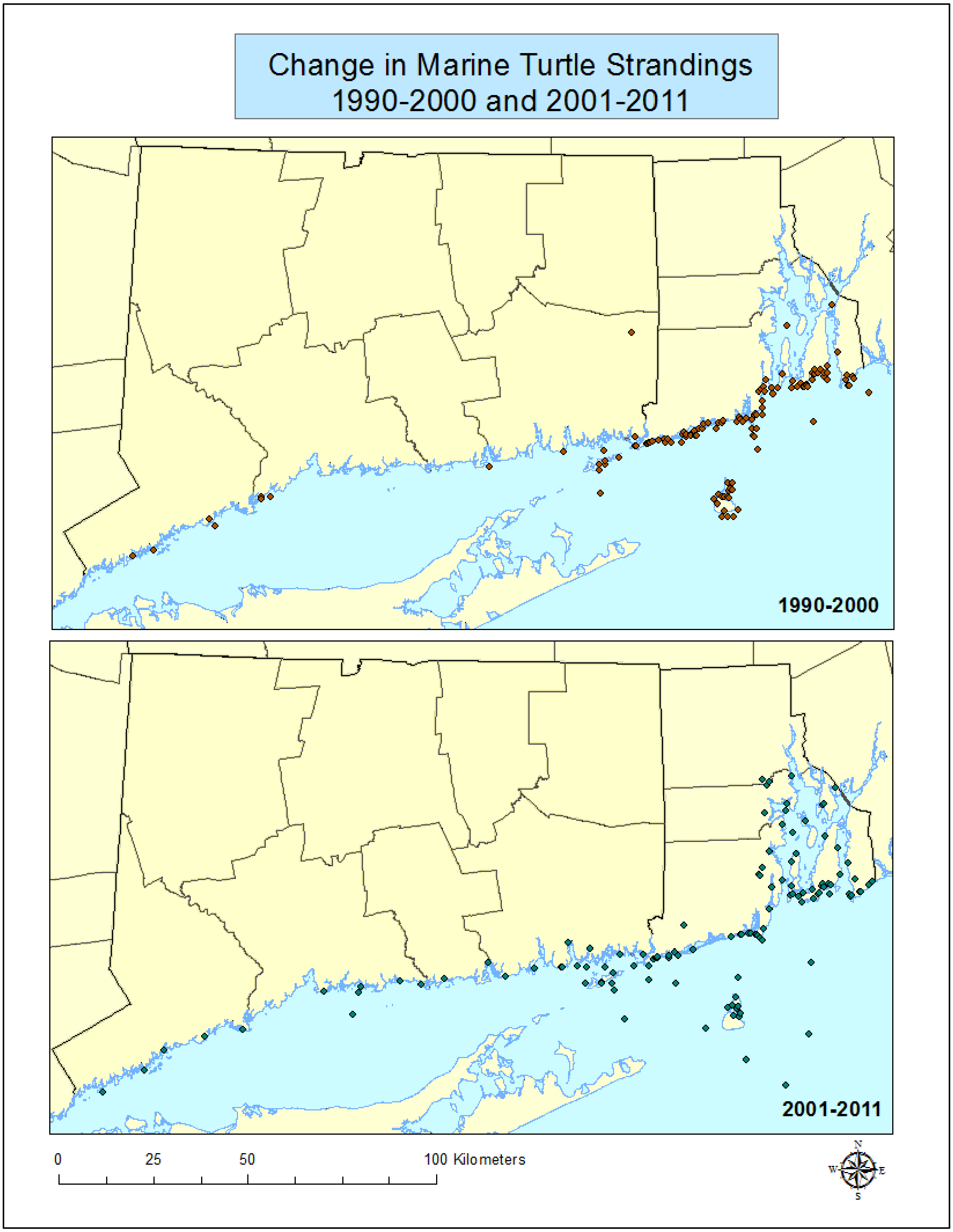


Figure 9: Change in location of cetacean strandings, comparing 1990-2000 strandings against 2001-2011 stranding locations.

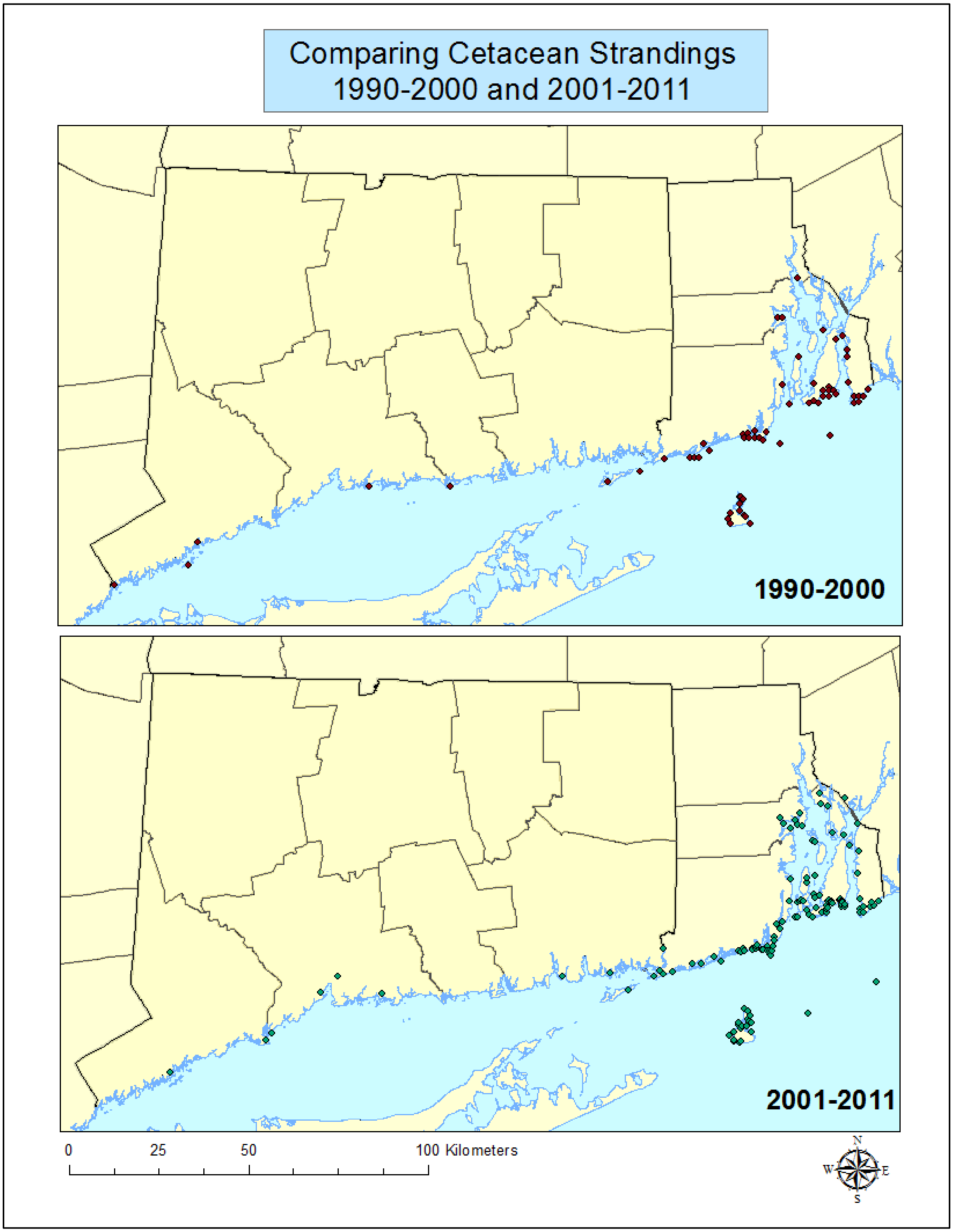
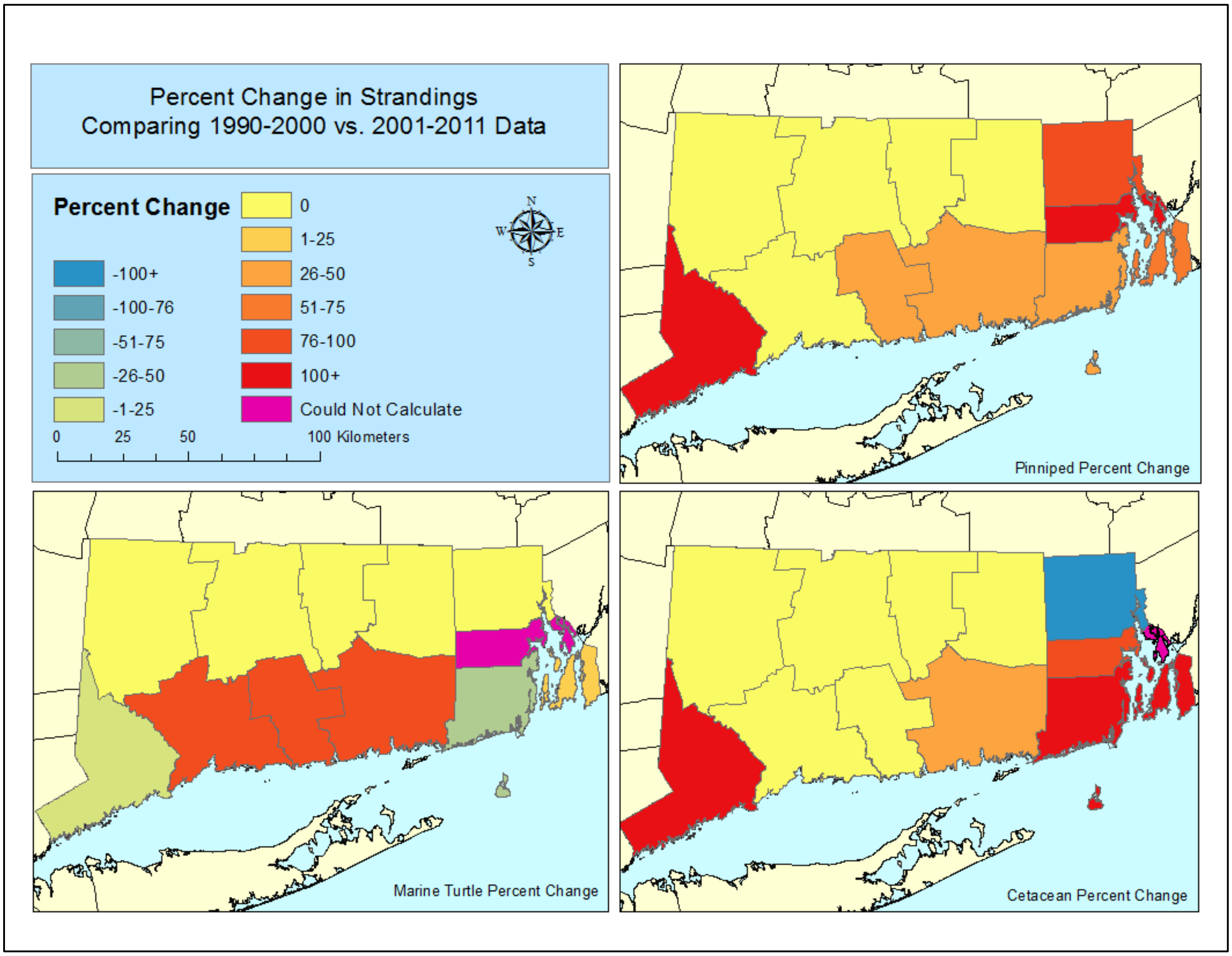


Figure 10: Comparing the change in stranding density by county, comparing 1990-2000 data against 2001-2011 data.



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Appendix

Figure 11: Shoreline in Kilometers, for Rhode Island Counties

County	Shoreline in Kilometers
Providence	51.345
Kent	69.262
Bristol	96.513
Newport	250.613
Washington	377.842

Figure 12: Shoreline in Kilometers for Connecticut Counties

County	Shoreline in Kilometers
Middlesex	92.774
New Haven	257.833
New London	288.003
Fairfield	298.734

Figure 13: Pinniped strandings in the state of Rhode Island, from 1990-2011

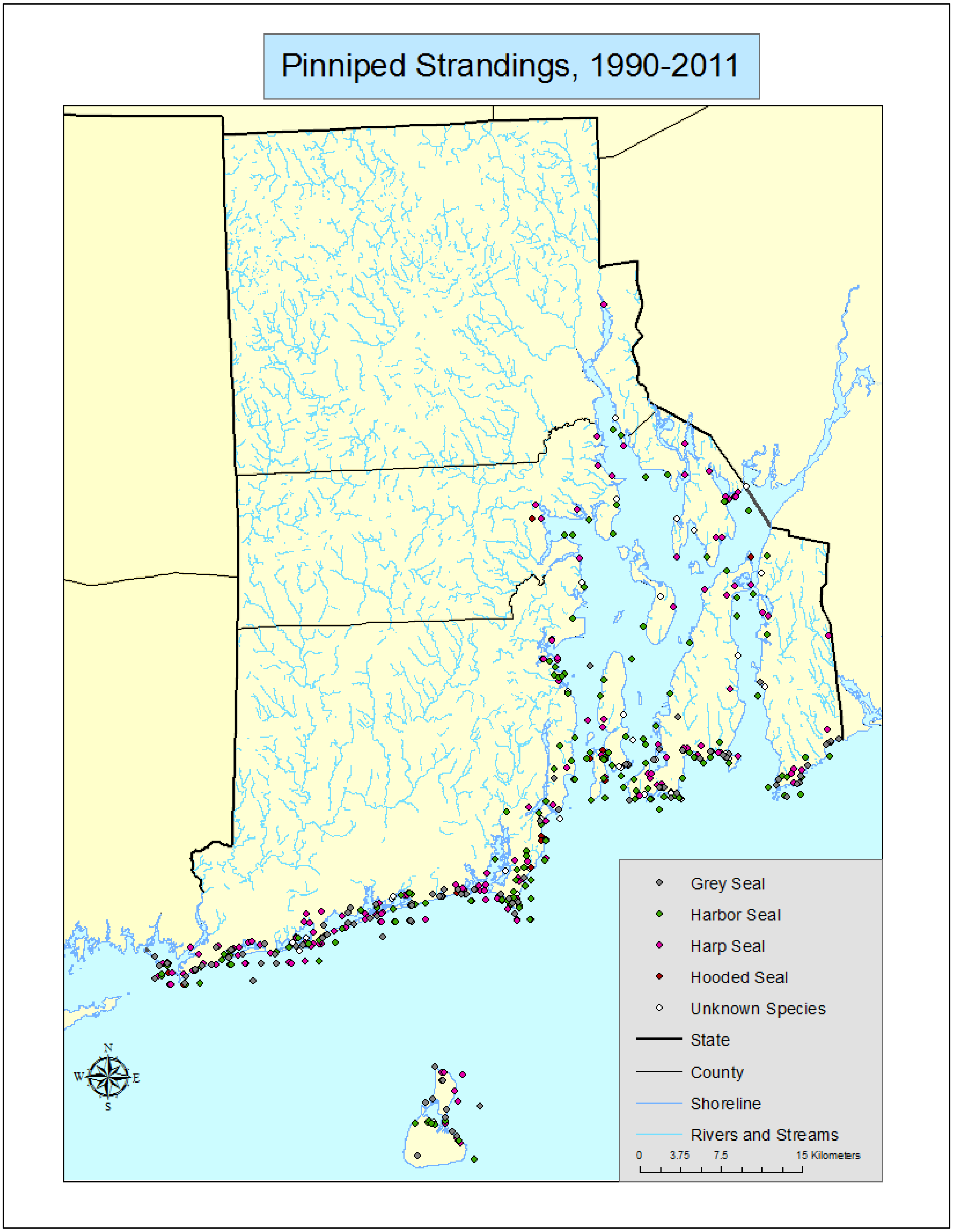

Figure 14: Pinniped strandings in the state of Connecticut and Fisher’s Island, New York, from 1990-2011

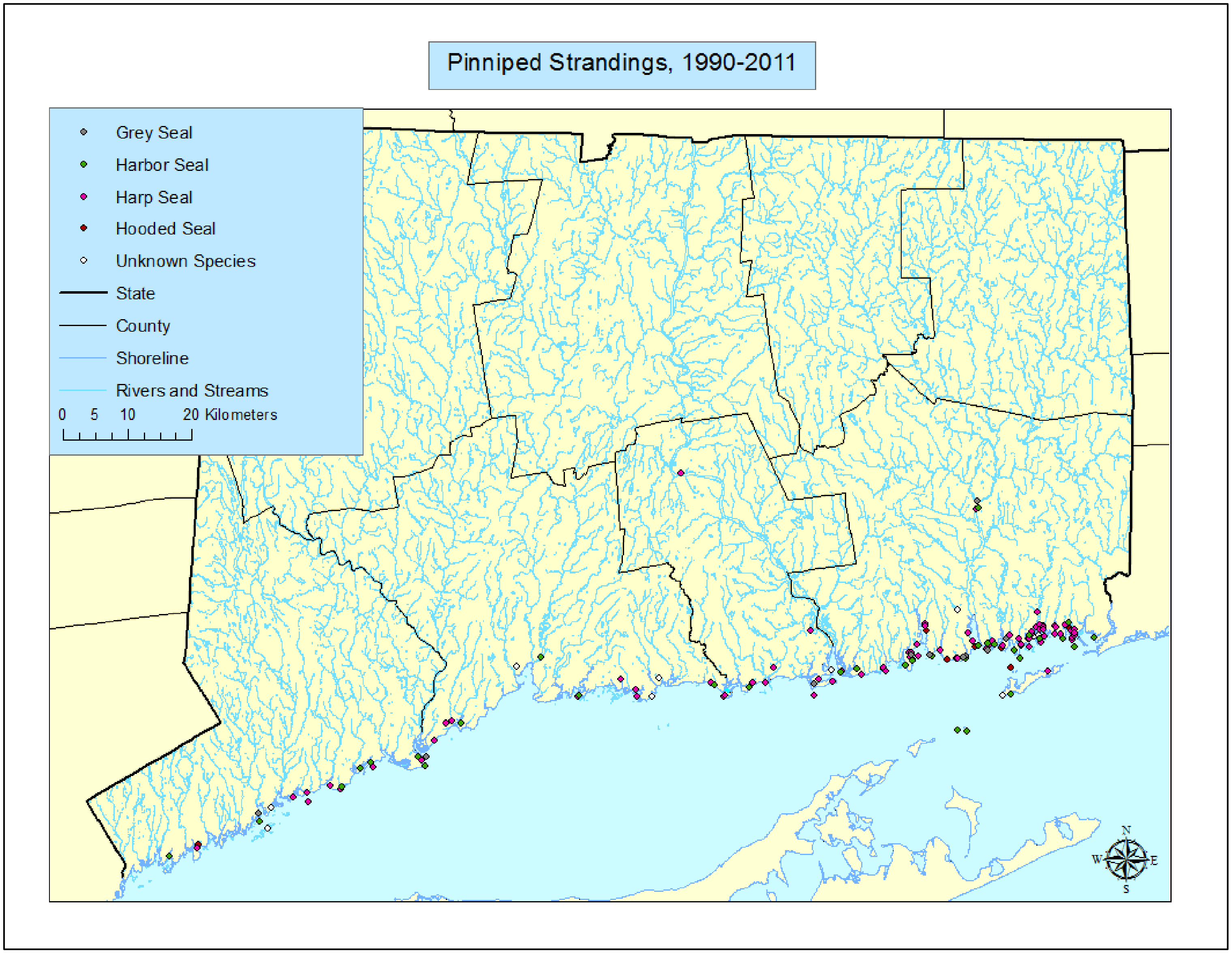

Figure 15: Description of 679 pinniped strandings from 1990-2011

	Total	State		Condition	
Grey	107	CT:	10	Alive:	41
		RI:	97	Dead:	61
		NY:	0	Unknown:	5
Harbor	209	CT:	30	Alive:	39
		RI:	172	Dead:	101
		NY:	7	Unknown:	69
Harp	272	CT:	82	Alive:	128
		RI:	189	Dead:	122
		NY:	1	Unknown:	22
Hooded	33	CT:	8	Alive:	23
		RI:	24	Dead:	8
		NY:	1	Unknown:	2
Unknown Pinniped	58	CT:	9	Alive:	2
		RI:	46	Dead:	39
		NY:	3	Unknown:	17

Figure 16: Pinniped Stranding Density

County	Shoreline in Kilometers	1990-2011 Pinniped Strandings	Strandings Per Kilometer	Average Per Year
Fairfield	298.734	21	0.070	0.003
New Haven	257.833	24	0.093	0.004
Middlesex	92.774	12	0.129	0.006
New London	288.003	90	0.312	0.015

County	Shoreline in Kilometers	1990-2011 Pinniped Strandings	Strandings Per Kilometer	Average Per Year
Providence	51.345	3	0.058	0.003
Kent	69.262	11	0.159	0.008
Bristol	96.513	23	0.238	0.011
Newport	250.613	172	0.686	0.033
Washington	377.842	319	0.844	0.040

Figure 17: Marine turtle strandings in Connecticut, Rhode Island and Fisher's Island, New York, 1990-2011

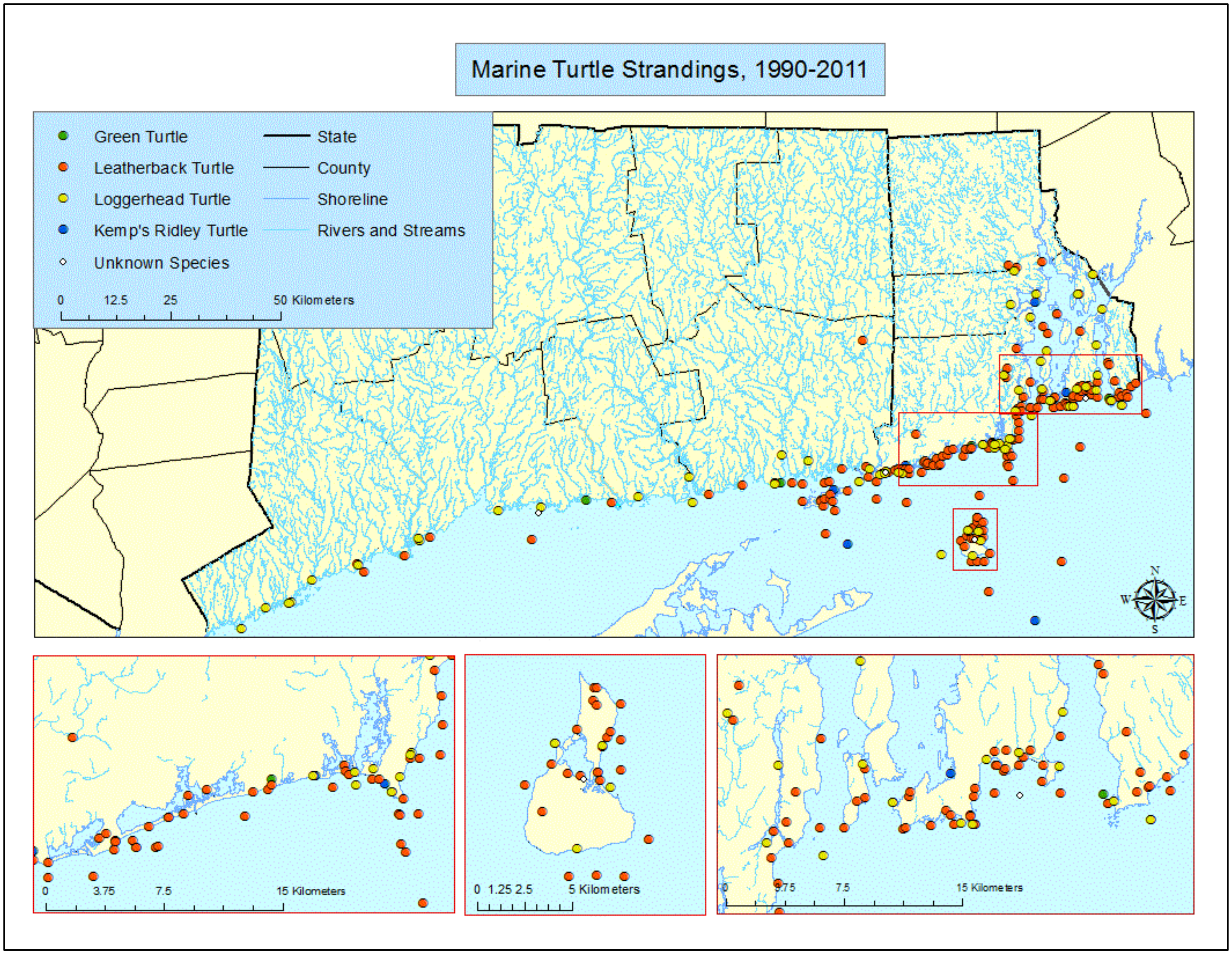

Figure 18: Description of 256 sea turtle strandings seen from 1990-2011

	Total	State		Condition	
Green	4	CT:	2	Alive:	1
		RI:	2	Dead:	3
		NY:	0	Unknown:	0
Kemp's Ridley	9	CT:	0	Alive:	7
		RI:	7	Dead:	2
		NY:	2	Unknown:	0
Leatherback	176	CT:	15	Alive:	9
		RI:	11	Dead:	162
		NY:	150	Unknown:	5
Loggerhead	63	CT:	15	Alive:	3
		RI:	48	Dead:	58
		NY:	0	Unknown:	2
Unknown Turtle	4	CT:	1	Alive:	0
		RI:	3	Dead:	3
		NY:	0	Unknown:	1

Figure 19: Marine Turtle Stranding Density

County	Shoreline in Kilometers	1990-2011 Marine Turtle Strandings	Strandings Per Kilometer	Average Per Year
Fairfield	298.734	9	0.030	0.001
Middlesex	92.774	3	0.032	0.002
New Haven	257.833	9	0.035	0.002
New London	288.003	12	0.042	0.002

County	Shoreline in Kilometers	1990-2011 Marine Turtle Strandings	Strandings Per Kilometer	Average Per Year
Providence	51.345	0	0.000	0.000
Bristol	96.513	1	0.010	0.000
Kent	69.262	2	0.029	0.001
Newport	250.613	73	0.291	0.014
Washington	377.842	133	0.352	0.017

Figure 20: Cetacean Strandings in Connecticut, Rhode Island, and Fisher's Island, New York, 1990-2011

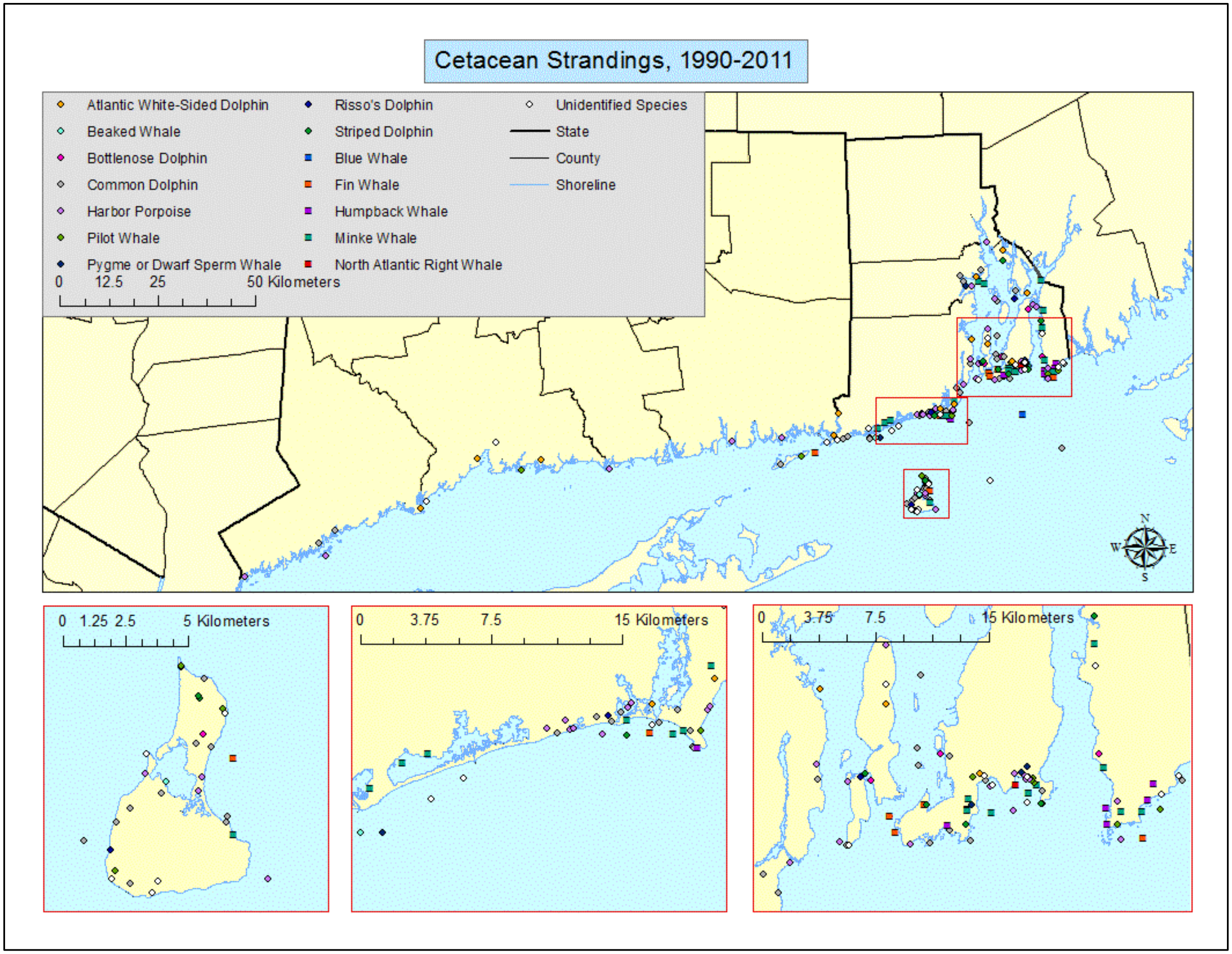

Figure 21: Description of 206 cetacean strandings from 1990-2011

	Total	State		Condition	
Atlantic White Sided Dolphin	14	CT:	3	Alive:	3
		RI:	11	Dead:	11
		NY:	0	Unknown:	0
Blainville's Beaked Whale	1	CT:	0	Alive:	0
		RI:	1	Dead:	1
		NY:	0	Unknown:	0
Blue Whale	1	CT:	0	Alive:	0
		RI:	1	Dead:	1
		NY:	0	Unknown:	0
Bottlenose dolphin	5	CT:	0	Alive:	0
		RI:	5	Dead:	3
		NY:	0	Unknown:	2
Common Dolphin	52	CT:	2	Alive:	10
		RI:	48	Dead:	36
		NY:	2	Unknown:	6
Dwarf Sperm Whale	2	CT:	0	Alive:	1
		RI:	2	Dead:	1
		NY:	0	Unknown:	0
Fin Whale	7	CT:	1	Alive:	2
		RI:	6	Dead:	3
		NY:	0	Unknown:	2
Harbor Porpoise	39	CT:	6	Alive:	5
		RI:	33	Dead:	26
		NY:		Unknown:	8
Humpback Whale	8	CT:	0	Alive:	8
		RI:	8	Dead:	0
		NY:	0	Unknown:	0
Long-finned Pilot Whale	13	CT:	1	Alive:	0
		RI:	11	Dead:	11
		NY:	1	Unknown:	2
Minke Whale	21	CT:	0	Alive:	0
		RI:	21	Dead:	17
		NY:	0	Unknown:	4
Northern Right Whale	1	CT:	0	Alive:	0
		RI:	1	Dead:	0
		NY:	0	Unknown:	1
Pygmy Sperm Whale	3	CT:	0	Alive:	0
		RI:	3	Dead:	3
		NY:	0	Unknown:	0

	Total	State		Condition	
Risso's Dolphin	4	CT: RI: NY:	0 4 0	Alive: Dead: Unknown:	0 2 2
Short-finned Pilot Whale	1	CT: RI: NY:	0 1 0	Alive: Dead: Unknown:	0 1 0
Sowerby's Beaked Whale	1	CT: RI: NY:	0 1 0	Alive: Dead: Unknown:	0 1 0
Striped Dolphin	9	CT: RI: NY:	0 9 0	Alive: Dead: Unknown:	0 6 3
Unidentified Cetacean	24	CT: RI: NY:	3 21 0	Alive: Dead: Unknown:	0 21 3

Figure 22: Cetacean Stranding Density

County	Shoreline in Kilometers	1990-2011 Cetacean Strandings	Strandings Per Kilometer	Average Per Year
Middlesex	92.774	0	0.000	0.000
New London	288.003	4	0.014	0.001
Fairfield	298.734	5	0.017	0.001
New Haven	257.833	7	0.027	0.001

County	Shoreline in Kilometers	1990-2011 Cetacean Strandings	Strandings Per Kilometer	Average Per Year
Providence	51.345	1	0.019	0.001
Bristol	96.513	4	0.041	0.002
Kent	69.262	6	0.087	0.004
Washington	377.842	86	0.228	0.011
Newport	250.613	90	0.359	0.017