Boat Scarring Effects on Submerged Aquatic Vegetation in Virginia
(Year 1)

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by

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EXECUTIVE SUMMARY

Submerged Aquatic Vegetation (SAV) in Chesapeake Bay has received significant attention in recent decades due to increasing understanding of the importance of these habitats for ecological functions, including fisheries habitat. Yet, SAV in many regions of the bay are at some of the lowest levels of abundance in recorded history. This has led state management agencies to adopt numerous policies and regulations to protect and restore these valuable communities. The Chesapeake Bay 2000 Agreement highlights SAV by recommitting to the goal of protecting and restoring 114,000 acres, revising existing restoration goals and strategies by 2002, and implementing a strategy to protect and restore SAV by 2002 (Chesapeake Executive Council, 2000). In addition to addressing water quality issues, which are considered the major cause of SAV changes in distribution and abundance, there is increasing concern regarding how direct human impacts such as dredging and boating are affecting SAV.

Aerial photography taken annually for monitoring SAV populations baywide has shown evidence of one form of human-induced damage--boat scarring. We therefore more closely examined photographs taken between 1987 and 2000 to evaluate this disturbance. Scarred sites were identified and assessed for key characteristics including intensity, orientation to shoreline, and scar curvature at each site. In addition Virginia Marine Resources Commission (VMRC) enforcement personnel were surveyed for qualitative information on the occurrence of recreational and commercial fishing activities in Virginia's waters in the vicinity of SAV beds.

Aerial photographic analysis revealed 47 sites that had been scarred for at least one year, with 21 and 26 sites noted for the eastern and western shores, respectively. Scars along the eastern shore were clustered in the Tangier Island area, while along the western shore they were located from Mobjack Bay to Poquoson Flats. No scars were visible in grass beds between New Point Comfort and Smith Point on the western shore, or from Nandua Creek to Old Plantation Creek on the eastern shore. While many sites had scars noted in 5

years or fewer (49%), 11 sites (23%) had scars in 10 or more years, with 9 of these sites (82%) located on the western shore.

Scar attributes differed between eastern and western sites, with eastern shore scars being curved and randomly oriented. These eastern regions were reported by the VMRC bottom use survey to be heavily scraped. Scars on the western shore were generally associated with points of land, oriented perpendicular to shore and in straight lines, and were in regions of frequent haul seining as well as recreational use and scraping.

This data suggests that scars on the eastern shore are consistent with observed boat tracks of crab scraping. Scars on the western shore are more consistent with observed haul seining activity. While recreational boats can also create scars in these areas, the lack of scars in recreationally important areas (that are not seined or scraped) minimizes the probability that these boats are a primary cause of the scarring observed in this study.

INTRODUCTION

Over the past 30 years, research has demonstrated that submerged aquatic vegetation (SAV) habitats provide several critical functions to the Chesapeake Bay ecosystem. These functions include primary production, shoreline protection (by baffling wave energy), enhancing water quality, and providing foraging and nursery areas for a wide variety of benthic animals and recreationally and commercially important fish and shellfish. More recently, emphasis has been placed on the value of SAV as a critical nursery for the blue crab.

However, after the dramatic decline of SAV in Chesapeake Bay in the early 1970s due to declining water quality (Orth and Moore, 1983), the need for the protection and restoration of these habitats has become more important to government agencies. Many factors threaten SAV, including poor water quality and physical disturbance by human activities. The areas that have survived since the 1970s are generally found in regions where water quality has remained good; therefore physical disturbance by human activities can be a significant source of impact. Since 1987, various government agencies adopted policies and laws to help restore and protect SAV from damage (Orth, et al., in press).

Because SAV in Chesapeake Bay are found in shallow waters generally less than two meters deep, they are very susceptible to physical impacts, from both natural as well as human induced causes. Direct human-induced physical damages to SAV beds generally include recreational boat propeller scarring, commercial boat propeller scarring, anchor damage, haul seining, crab scraping, shading from docks and marinas, and dredging (Zieman, 1976; Short and Wyllie-Escheverria, 1996; Goldsborough, 1997; Francour et al. 1999; Stephan et al. 2000). Propeller scarring is the most obvious source of damage, as these scars are easily visible in aerial photography (**Figure 1**). Propeller scarring has been of significant concern throughout the world. In Florida the high degree of boating activity and the shallow nature of many of Florida's bays combine to make propeller scarring an important resource management issue (Sargent et al., 1995; Dawes et al., 1997).

Beds of SAV throughout Chesapeake Bay are monitored every year with vertical aerial photography (Orth et al., 2000). Each year, these photographs have revealed the presence of narrow scars coursing through beds in certain locations. These scars can be directly attributed to some type of boating activity impacting the grass bed. This two-year study was undertaken for the Commonwealth of Virginia to assess management strategies. The objectives of the first year of this study were twofold:

1. Identify the magnitude of boating impacts on Virginia SAV beds, which consist of two species, eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*).
2. Identify major human uses of specific grass beds to assist in the management and protection of these areas.

The second year of this study will focus primarily on estimating recovery rates of SAV in the scarred sites.

METHODS

Aerial photography:

The primary data source for assessing boat scars on Virginia grass beds was through examination of black and white aerial photography collected as part of an annual baywide SAV mapping effort (Orth et al. 2000). SAV in Chesapeake Bay has been mapped since 1978 and serves managers, researchers and the public of Maryland and Virginia as the prime source of information concerning the distribution and abundance of Chesapeake Bay SAV.

For the baywide mapping effort, over 1800 black and white photographs of Chesapeake Bay were taken at an altitude of approximately 12,000 feet each year since 1984 (excluding 1988), producing 1:24,000 scale prints. For this project, we limited examination of boat scars to Virginia's western shore from Smith Point southward including the James River and the eastern shore from Fisherman's Island north to the Maryland/Virginia state line, including the mid-bay islands but excluding the Virginia Coastal Bays. Multiple individual assessments of each photograph were made using a 6X wide field magnifier and a light table.

Scars were identified as thin white or dark lines running through the darker background of the grass bed (**Figure 1**). Previous field examinations have confirmed that such photographic signatures are in fact propeller scars and are often as narrow as 0.5 m (approximately 2 feet).

Photographs from 1987 through 2000 (excluding 1988) were examined for presence of scars. A scarred site was defined as areas with three or more scars bounded by the extent of scarring over all scarred years. Areas were categorized into multiple sites if the scarring was interrupted by a major channel or river. In this first year's study, we did not discriminate between sites which were newly scarred (within a year of the photograph) and sites in which older scars (over one year old) were still visible. In both cases, the site was categorized as scarred. In 1987, only the western shore photography was examined due to poor quality of eastern shore photography.

Several attributes of each scarred site were recorded from each photograph in order to qualitatively describe the scarring at each site and to assess the most likely causes of scarring:

1. *Scar intensity*: Following the intensity rating scale used by Sargent et. al (1995) **(Figure 2)**, scars were rated as "light" (area with < 5% scarring), "moderate" (5-20% of area scarred), or "severe" (>20% of area scarred) over the entire site.
2. *Presence of "point scars"*: Scars associated with a point of land protruding from the shoreline.
3. *Orientation*: Scars were classified as randomly oriented, perpendicular to shore, parallel to shore, or as in the case of offshore/open water scarred areas, not applicable. Randomly oriented scars are haphazard in direction, having no particular directional relationship with the shoreline; perpendicular and parallel scars are relative to the shoreline.
4. *Curvature*: Scars were classified as either straight, curved, or a combination of the two.
5. *Presence of boats*: Boats that appeared to be actively haul seining were recorded. This included boats in scarred as well as unscarred areas.
6. *Presence of pens*: Any visible fish holding pens in scarred or unscarred areas were recorded.
7. *Miscellaneous attributes*:
    a. *Length of shoreline affected by scarring*: dial calipers were used to measure the distance of affected shoreline in millimeters to the nearest 0.05 mm on the photograph (1.2 meters scaled). When scarring was noted offshore, the longest straight-line extent was measured.
    b. *Shoreline Type*: Affected shorelines were categorized as either "marsh or undeveloped" or "developed" shorelines.
    c. *Piers*: Scars originating from or leading to a public or private pier.
    d. *Marinas*: Scars originating from or leading to a marina facility**.**

e. *Boat ramps*: Scars originating from or leading to a boat ramp**.**
f. *Navigational channels*: Scars associated with boaters cutting through shallow areas of channels or adjacent areas.
g. *Bar/open water*: Scars associated with an offshore bar, or scars not associated with a particular shoreline.

All scar information (including locations) was transferred into a geographic information system and analyzed using ArcView®.

VMRC Survey:

In order to evaluate the types of activities occurring at these scarred sites, maps of 1999 SAV distribution (Orth et al., 2000) were distributed to the Law Enforcement Division of Virginia Marine Resource Commission (VMRC) with instructions for the officers to delineate areas of frequent recreational boating, crab scraping, or haul seine areas (or combinations of these categories) based on their recent observations in the field. We excluded crab potting from the survey because we assumed this activity was ubiquitous. The delineated areas were digitized into a geographic information system using ArcView® and analyzed as qualitative data with the scar information.

RESULTS

Throughout the 13 years of photographs analyzed, there were 47 vegetated sites in which scarring was evident (**Figure 3**). Twenty-one of these sites are located along the eastern shore, where scars were clustered primarily in the grassbeds of Tangier and Smith Islands, but also at Great Fox Island and between Halfmoon Island south to Nandua Creek. No scars were visible between Nandua Creek and Old Plantation Creek. On the western shore (26 sites), scars were noted primarily circling Mobjack Bay, the lower York River, Poquoson River and Poquoson Flats, and Back River. No scars were visible in grassbeds between New Point Comfort and Smith Point, nor were any scars visible in the lower James River.

In each year (except 1987, in which only the western shore was analyzed), there were over 16 vegetated sites that had scars, with some years having up to 33 sites with scars (**Figure 4**). The highest number of sites with scars occurred in 1990, 1992, and 1994, with 33, 31, and 31 sites respectively. Nearly half (49%) of the sites were scarred between 1 and 5 years and another 23% of the sites had scars present for 10 or more of the 13 years analyzed (**Figure 5**). Of the 11 high-frequency scarred sites (10 or more years), 9 were located on the western shore (**Figure 6**).

The eastern shore and western shore consistently differed in many attributes other than the frequency of scarring (**Table 1**). Most sites which had scars closely associated with points of land were located on the western shore (**Figure 7**). The western shore also primarily had scars oriented perpendicular to shore (**Figure 8A**) and in straight lines (**Figure 9**). Although many sites had those characteristics on the eastern shore, many more eastern shore sites had curving scars oriented randomly across the site and were also darker than the western shore sites (**Figure 8B, Figure 9**). Both eastern and western shores had some scars oriented parallel to shore (**Figure 8C**).

Of the most frequently scarred sites (10 or more years), each of the following sites primarily had scars that were in straight lines, oriented perpendicular to shore, and were associated with a point of land. Each of these sites was located on the western shore.

- Pepper Creek (**Figure 10**): 11 years with primarily light intensity scarring.
- Minter Point (**Figure 11**): 12 years with light and moderate intensity scarring.
- Ware Neck Point (**Figure 12**): 12 years with light and moderate intensity scarring.
- Bush Point (**Figure 13**): 12 years with primarily light intensity scarring.
- Guinea Marsh (**Figure 14**): 12 years with light and moderate intensity scarring.
- Goodwin Island- Northern Shore (**Figure 15**): 12 years with light and moderate intensity scarring.
- Brown's Bay (**Figure 1**): 13 years with light and moderate intensity scarring
- Allen's Island (**Figure 16**): 13 years with light and moderate intensity scarring.
- Plum Tree Island (**Figure 17**): 13 years. This site also had scars oriented randomly relative to the shoreline.

The remaining two frequently scarred sites (10 or more years) were located on the eastern shore, where each site had both straight and curved scars that were oriented in random directions:

- South Point Marsh (**Figure 18**): 10 years with light and moderate scarring.
- Near Goose Island (**Figure 19**): 11 years with light and moderate intensity scarring. Severe scarring was visible in 1990 and 1998.

Severe intensity scarring (>20% of the bed scarred) was relatively rare (found only in some years at the North Goose Island and Gaines Point sites). Most sites had a combination of light and moderate intensity scarring, with no apparent temporal trends, except for Poquoson Flats, which was lightly scarred prior to 1997 and moderately scarred after 1997.

A number of sites had scars that appeared to be associated with navigational channels (e.g. Back River), marinas, or ramps. While we also observed some scarred sites had scars near piers, we saw few scars actually coming from a pier.

VMRC Bottom use Survey

Results of the VMRC Enforcement Official survey are shown in **Figure 20A, 20B, and 20C**. The results show that the Tangier, Smith, and Great Fox Islands are heavily used by crab scrapers, as is a portion of the eastern shore of Pocomoke Sound. In the center of Pocomoke Sound, and further north, haul seining is more prevalent. Further south along the shore towards Cape Charles, recreational activity seems to be more dominant.

Along Mobjack Bay, Goodwin Islands, and Poquoson flats, the grassbeds appear to be consistently used by multiple groups, including crab scrapers, haul seiners, and recreational boaters (**Figures 20A, 20B, and 20C**). While crab scraping has been a traditional method of harvesting crabs in the Tangier area, and although quantitative data is lacking, this type of crab harvesting does not appear to have been common on the western shore until recently (personal observations).

DISCUSSION

Aerial photographic analysis shows that similar to other states such as Florida (Sargent et al. 1995), propeller scarring is a source of continuous damage to Virginia's SAV beds. Both shores of the Chesapeake have been affected by propeller scarring since at least 1987, with most sites scarred for multiple years. In general, there were more sites with scars in the first half of the 1990s than in the latter half of the decade. In addition, there does not appear to be a major change in intensity of scarring within each site over the past 13 years (except perhaps at Plum Tree Island, in which scarring has increased from light intensity to moderate intensity after 1997). The overall spatial distribution of sites also does not seem to change over the past 13 years. This suggests that the causes of these scars have been relatively stable during this time period.

Vessels can potentially create propeller scars for several reasons, for which there are many photographic examples. First, navigational error may cause boats to run upon shallow water unexpectedly (as observed with some scarred sites associated with navigational channels or sand bars). Boats may force their way through shallow water in order to enter or leave a marina, public or private pier, or boat ramp facility. Also, boats may scar grassbeds as they power their way towards deeper water as an ebbing tide reduces water depth. Scars might also be formed as a boat pulls an object such as a net or scrape in very shallow water.

It was not possible to identify types of potential damage other than propeller scarring using the aerial photography in this study; damage such as shearing of leaves, shearing of seeds or flowers, burial of leaves, or the effects of temporary increases in turbidity (Stephan et al. 2000) are not discernable in the SAV photographic signature. It is possible that some of the darker shaded scars may be areas where leaves have been sheared off, or areas where algae has collected, but no ground measurements were made to confirm this hypothesis or determine whether those other forms of sub-lethal damage have occurred. In Maryland, studies have shown that haul seine nets in fresher water SAV beds did not alter SAV height, density or species composition (Sadzinski et al. 1996). Haul seine net experiments in Australia have found only small impacts on *Zostera capricorni* shoot and leaf density and leaf length, but only in the winter. During the summer's growth season, these impacts were not evident (Otway and Macbeth, 1999). However, these experiments tested effects of the nets, and not whether the boats pulling the nets damaged the beds. Also, no such experimentation has been conducted in the saline regions of the bay in eelgrass (*Z. marina* L.) and widgeon grass (*R. maritima*) beds.

Eelgrass beds may be relatively resistant to significant net damage such as shearing of leaves, since the plants' growing structures lie below the sediment surface. Therefore this species is primarily vulnerable to sediment excavations, either from propellers or other forms of sediment excavation such as dredging. For example, in Chincoteague Bay, clam dredging by modified oyster dredges (in Virginia) and hydraulic dredges (in Maryland) have severely damaged existing grass beds by creating large scars that can take over three years to recover (Moore and Orth 1997, Orth et al. 1998, Orth et al., submitted). However, monospecific widgeon grass beds may be more susceptible to both shearing of leaves and excavation as they have shallower root structures. During the reproductive period, reproductive shoots are usually longer than vegetative shoots (Kantrud, 1991), making it easier for these leaves to be cut off or pulled out of the sediment. Widgeon grass beds also tend to be in shallower water than eelgrass, further endangering widgeon grass from propeller damage.

In Chesapeake Bay, Moore and Orth (1982) examined propeller scars near Mobjack Bay and found that widgeon grass colonized into the scar faster than eelgrass. They estimated at least two years are needed for widgeon grass to fully recolonize a scar, while eelgrass likely required longer than two years. However, this study followed a single scar over only one growing season, and did not evaluate effects of multiple scarring events on the bed overall, or over several years. The long-term, large spatial scale effects of boat scarring on the distribution and abundance of Virginia SAV have not been investigated. Given the results of the Moore and Orth study, it is possible that in areas of persistent SAV that undergo repeated scarring, there may be a shift in species dominance from a eelgrass-dominated bed to a widgeon grass-dominated bed. Also, it is possible that dense boat scarring may reduce the stability of the surrounding bed over time, as scars may make beds more susceptible to erosion because of decreased ability to bind sediments together coupled with the decreased wave and current attenuation that extensive grassbeds provide. **Figures 1, 14, 15 and 19** show areas within heavily scarred regions in which the adjacent grass appears to have been eroded away.

It is also important to note that this study did not discriminate between new scarring and existing scarring. Therefore, a site for which scars were visible for several years may not necessarily have been repeatedly scarred each year. Instead, it may have been scarred only one year and not fully recovered for several more years. The second year of this study will analyze specific sites in detail over several years and should provide information on repeated scarring and recovery rates.

Possible Causes:

Identifying the exact cause of scarring at a particular site is difficult, because direct evidence of scarring as it is taking place is extremely rare. Such evidence would require direct photography or observation of a boat moving through a grass bed, with immediate sampling of the grass along the exact track, a task that has not been attempted. A few aerial photographs exist of boats kicking up a sediment plume behind them (**Figure 21A, Figure 22A**), however no one has immediately sampled a scar along that exact track. As a result, the photographic analysis from this study does not allow the identification of the precise cause of a particular scar. Such determinations are mostly correlative with survey information, anecdotal information, and logical assumptions.

The VMRC bottom use survey allows a generalized understanding of some potential causes of scarring in each location, although it is not spatially precise, as it is dependent upon the recent judgement of officers who may remember general areas in which they have observed certain activities, but who are not at each site everyday to witness which activities occur. As a result, the boundaries of survey regions include a fairly large amount of survey error, and as a result, conclusions based on the survey data must be weighed accordingly. This information similarly is based on witnessed bottom use from the past few years during recent memory rather than the thirteen-year span of this study. However, using this survey together with basic understanding of how boats are used in each activity can yield valuable insights.

For example, on the eastern shore, a majority of the sites occurred within areas delineated by the VMRC survey as frequent crab scraping areas (**Table 1**). Scars within these sites were oriented in all directions (often randomly) and were often curved in shape. These scars are similar in orientation and curvature to sediment plumes visible in aerial photographs of active crab scraping (**Figures 21A and 22A**). Nonetheless, it is important to note that in some photographs showing active crab scraping, we often did not find scars in subsequent years' photography along the exact boat track (**Figures 21B and 22B**). However, scars are abundant within the regions in which scraping has been photographed or observed in the bottom use survey (**Figure 20**). This suggests that during scraping, scarring of the bottom is relatively rare, with any scars formed caused by propellers in shallower water and not by the scrape itself. If the actual scrape commonly created scars, it would be reasonable to assume that much more of the bottom would be scarred, resulting in higher intensity of scarring at more sites and in deeper waters, particularly given the high level of crab scraping occurring on the eastern shore. It remains unknown whether the crab scrape creates other, non-lethal damages to grassbeds such as reduced flowering or production, particularly in widgeon grass beds that are shallow and susceptible to being pulled out. Given that according to the survey a relatively low amount of recreational activity occurs in the area, and that haul seine activity on the eastern shore is primarily in areas outside the grassbeds, boats that are crab scraping are a likely cause of existing scarring in this region.

On the western shore, a majority of the sites contained scars in straight lines (23 of 26 sites), oriented perpendicular to shore (21 sites), with nearly half (11 sites) associated with points of land (**Table 1**). The VMRC survey describes these regions as heavily used by haul seiners, crab scrapers, and recreational boaters combined; therefore, the survey does not attribute a particular activity as a major cause of scars in this region. Each site may have scars caused by any or all of these activities. However, most of the scars associated with points of land appear in areas we have witnessed haul seining occurring (e.g. Plum Tree Island, Brown's Bay, Guinea Marsh, Goodwin Island). These boats may scar the beds while attempting to pull a net, or by forcing their way to deeper water after pursing the net. **Figure 23** is a low-level photograph taken at an altitude of 1000 ft, showing a site in the York River in which haul seining was observed a few weeks before the photograph. These scars look similar to perpendicular scars in grassbeds. The scars on the western shore are not similar in orientation and curvature to the heavily scraped eastern shore scars (**Table 1**), making it less likely that extensive crab scraping is a primary cause of western shore scarring. If these scars were created during haul seine activities, it is likely that the propellers created the scar rather than the nets, for the same reasons described above for crab scrapes.

Recreational boats may also cause boat scars at these sites, primarily in the heavily fished western shore locations. However, anecdotal observations show that recreational boaters attempting to fish in the grassbeds tend to drift or motor through the bed slowly, tilting the outboard or I/O engines to avoid damaging their propellers. Accidental groundings are usually limited to deeper sections of the bed where the bottom shoals quickly. These deeper water areas should then show scars appearing only towards the deeper edges of the beds. This is visible in some areas, yet most scars on the western shore are in shallower waters and continue directly to shore. These scars are also adjacent to undeveloped land without sandy beaches or other obvious recreational destinations. Although recreational boats can create scars such as those observed near Ocean City in the coastal bays of Maryland (**Figure 24**, M. Naylor personal communication), we do not see scarring in frequent recreational areas of Virginia such as New Point Comfort (**Figure 25**), or along the eastern shore between Nandua Creek and Old Plantation Creek.

Boats that are potting for crabs are potential causes of some of the scarring observed. Crab pots are often oriented in lines parallel to shore (personal observation) and there are some sites on both the eastern and western shores that have scars oriented parallel to shore (**Figure 8C**). However, scarring is restricted to only certain locations in Virginia, while we believe potting to be ubiquitous throughout Virginia (personal observation, as potting was not part of the VMRC survey). Therefore, we believe that potting is not a primary cause of boat scarring.

Conclusions:

The impact of boat propellers on Virginia grass beds is large enough to be clearly visible on aerial photography, with some sites consistently scarred during most of the years surveyed. The second year's study will investigate heavily scarred areas to identify recovery rates, species compositions, and other potential changes to the bed that are attributable to propeller scarring. Although the actual amount of grass removed during the formation of these scars is small relative to the total amount of grass in the bed, protection of even small amounts of grass is becoming more important, particularly given the recent interest in restoration projects and in avoiding net losses of SAV from non-water quality impacts. The causes of this scarring appear to be varied, as there are some differences in bed utilization between the eastern and western shores. Scars on the eastern shore appear more closely related to crab scraping, while scars on the western shore appear more closely related to haul seining. While recreational boats can create scars as well, the lack of scars in recreationally important areas minimizes the probability that these boats are a primary cause of scarring. Regardless of which activities primarily cause scars, it is important to note that water depth is the critical factor and that any boat, when in shallow enough water, is capable of causing damage.

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TABLE 1: Numbers of sites with scars having the measured physical attributes. The scars were separated into western and eastern shores. The numbers of sites located within areas of the VMRC bottom use survey are also shown. (HS= Haul Seine areas, CS = Crab Scrape areas, Rec = Recreational use areas).

	Attribute		Tot. # Sites	Sites in HS	Sites in CS	Sites in Rec
Western Shore (26 sites)	Point scars		11	11	9	11
	Curvature	Straight	26	23	21	23
		Curved	2	1	1	1
	Orientation	Perpend.	21	20	17	20
		Parallel	4	4	4	4
		Random	4	3	3	3
Eastern Shore (21 sites)	Point scars		1	0	1	0
	Curvature	Straight	18	0	15	2
		Curved	21	0	18	2
	Orientation	Perpend.	4	0	4	0
		Parallel	9	0	9	1
		Random	17	0	14	3

FIGURES

Figure 1) 1:24,000 scale aerial photograph of Brown's Bay, 1992. SAV are the darker areas of the photographs. Arrows point to sand bars and propeller scars.

Figure 2) Diagrammatic representation of the intensity scale from Sargent *et al.* (1995) used to rate scarred sites in this study.

Figure 3) Map of scarred sites in Virginia (1987-2000)

Figure 4) Number of sites scarred each year on the eastern and western shores between 1987 and 2000.

Figure 5) Frequency of scarring at all sites between 1987 and 2000.

Figure 6) Locations of sites scarred at various frequencies between 1987 and 2000.

Figure 7) Map of scarred sites that contain scars associated with points of land, i.e. scars pointing to or from a point of land.

Figure 8) A) Map of scarred sites that contain scars oriented perpendicular to shore. B) Sites that contain scars oriented randomly relative to the shoreline. C) Sites that contain scars oriented parallel to the shoreline.

Figure 9) Map of scarred sites that contain scars that are in straight lines, curved in shape, or both.

Figure 10) 1:24,000 scale aerial photograph of Pepper Creek in 1992.

Figure 11) 1:24,000 scale aerial photograph of Minter Point in 1992.

Figure 12) 1:24,000 scale aerial photograph of the southern tip of Ware Neck Point in 2000. Scars are visible heading towards the point of land.

Figure 13) 1:24,000 scale aerial photograph of Bush Point in 1992.

Figure 14) 1:24,000 scale aerial photograph of Guinea Marsh in 1990.

Figure 15) 1:24,000 scale aerial photograph of the northern shore of Goodwin Island in 1992.

Figure 16) 1:24,000 scale aerial photograph of the north shore of the York River, west of Allen's Island.

Figure 17) 1:24,000 scale aerial photograph of Plum Tree Island in 1998.

Figure 18) 1:24,000 scale aerial photograph of South Point Marsh (north of Tangier Island) in 1990.

Figure 19) 1:24,000 scale aerial photograph of the area near Goose Island (north of Tangier Island) in 1992 showing curved scars.

Figure 20) Map of the Bottom Use Survey from VMRC enforcement officials showing areas of A) frequent haul seining, B) crab scraping, and C) recreational use.

Figure 21) 1:24,000 scale aerial photograph of an area near Finney's Island on the eastern shore (North of Pungateague Creek), showing A) crab scraping occurring in a grass bed in 1996, with associated sediment plumes, and B) the same region in 1997 showing no scars along those boat tracks.

Figure 22) 1:24,000 scale aerial photograph of an area near Webb Island on the eastern shore showing A) crab scraping occurring in a grass bed in 1997, with associated sediment plumes, and B) the same region in 1998 showing no scars along those boat tracks.

Figure 23) 1:2,000 scale aerial photograph of an area west of Wormley Creek in the York River taken in 2001 showing propeller scars running through unvegetated areas. Eelgrass restoration transplants are visible at the edge of the shoal. This area has been repeatedly observed to be haul seined.

Figure 24) 1:2000 scale aerial photograph in Sinepuxent Bay, Ocean City, Maryland. Scars near small boat channels are visible, as are scars from a personal watercraft rental vendor. On the bottom of the photograph is a restaurant frequented by small boats which power through the grass bed as well as anchor within the bed. At each place, the area is nearly devoid of vegetation. (photograph courtesy Maryland Department of Natural Resources).

Figure 25) 1:24000 scale aerial photograph of New Point Comfort in 1998.

Figure 1: Brown's Bay, 1992

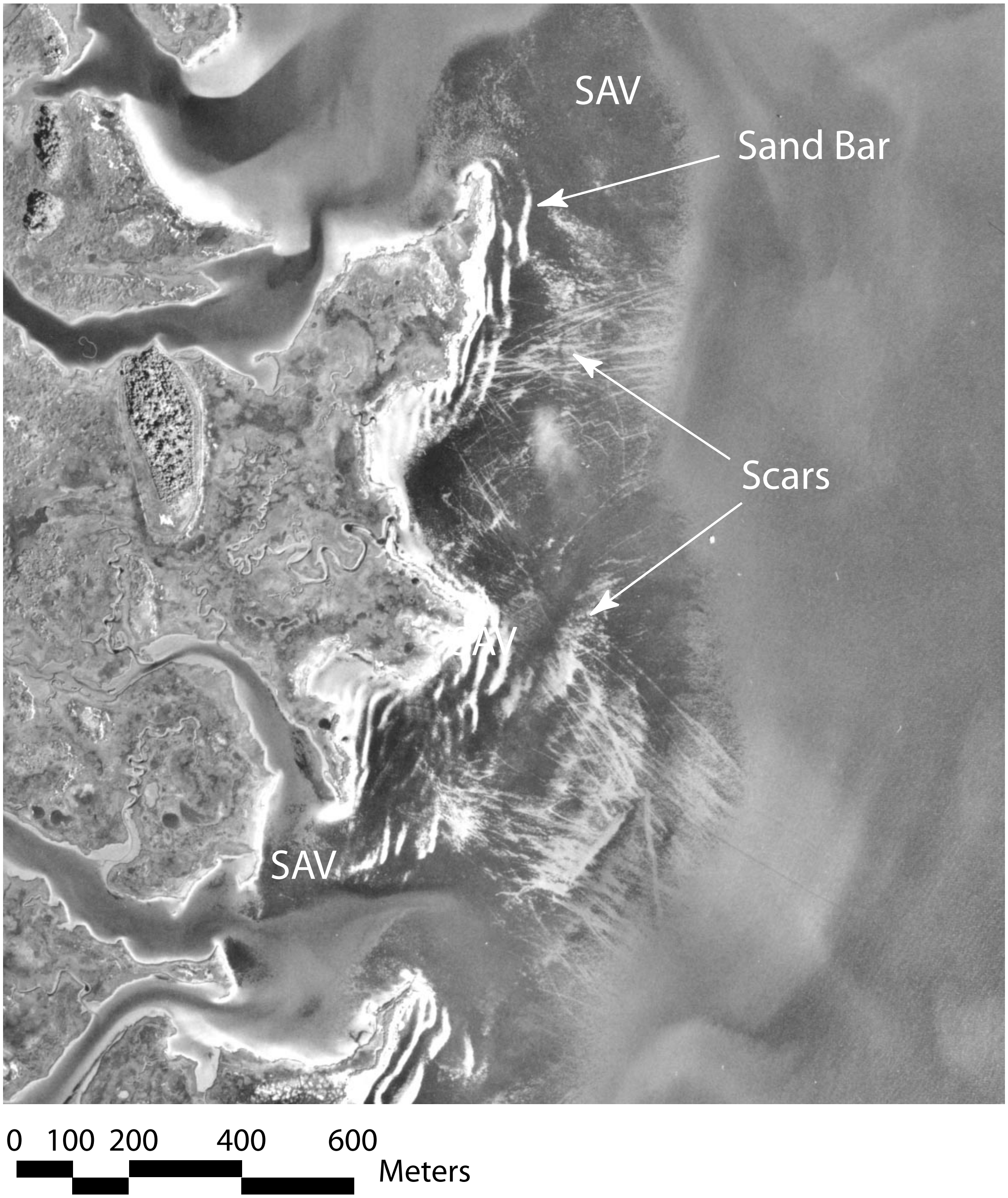


Figure 2: Scar Intensity Scale (from Sargent et al. 1995)

Light Scarring

Moderate Scarring

Severe Scarring

Figure 3: Boat Scars 1987-2000

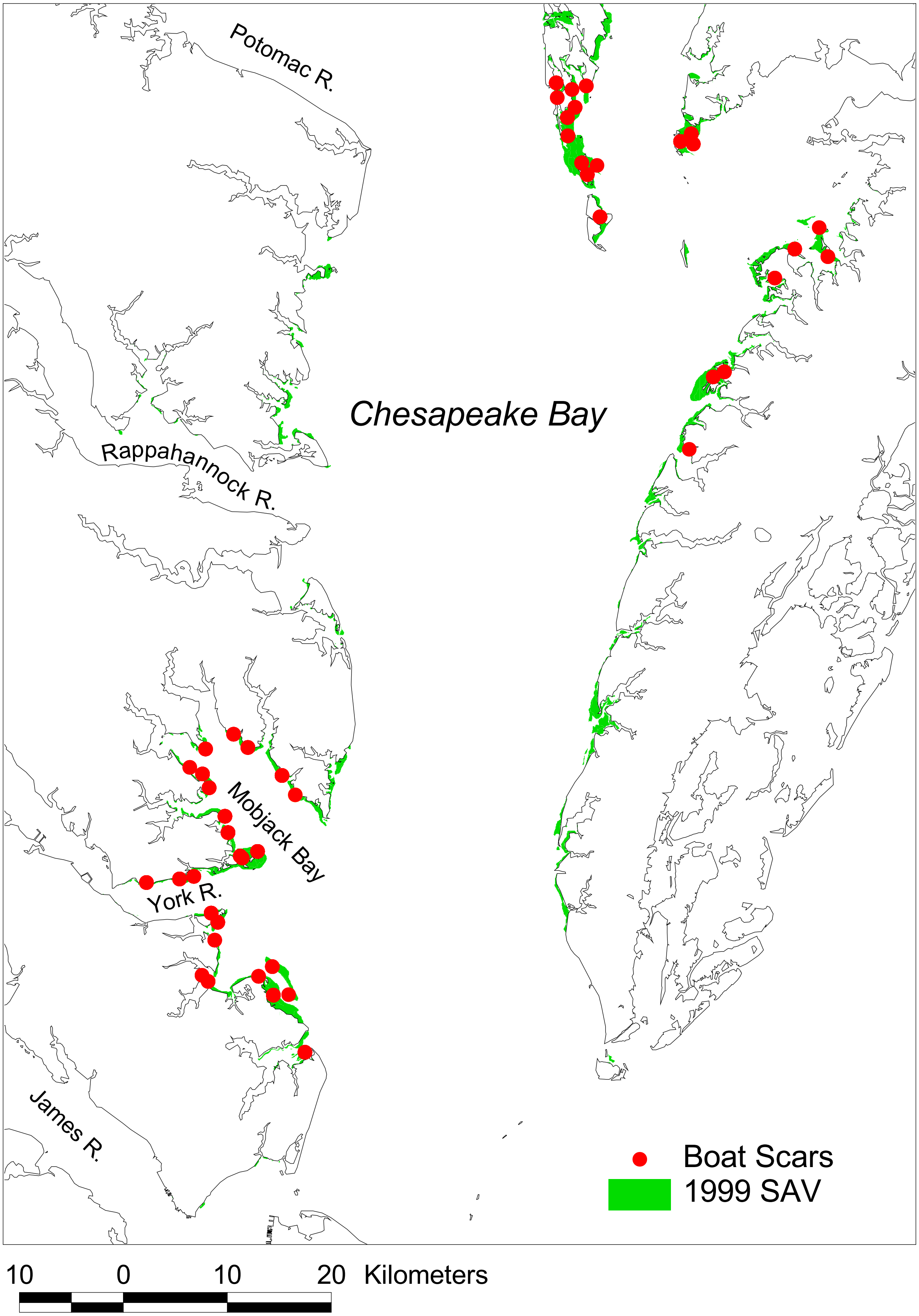


Figure 4: Number of Scarred Sites (1987-2000)

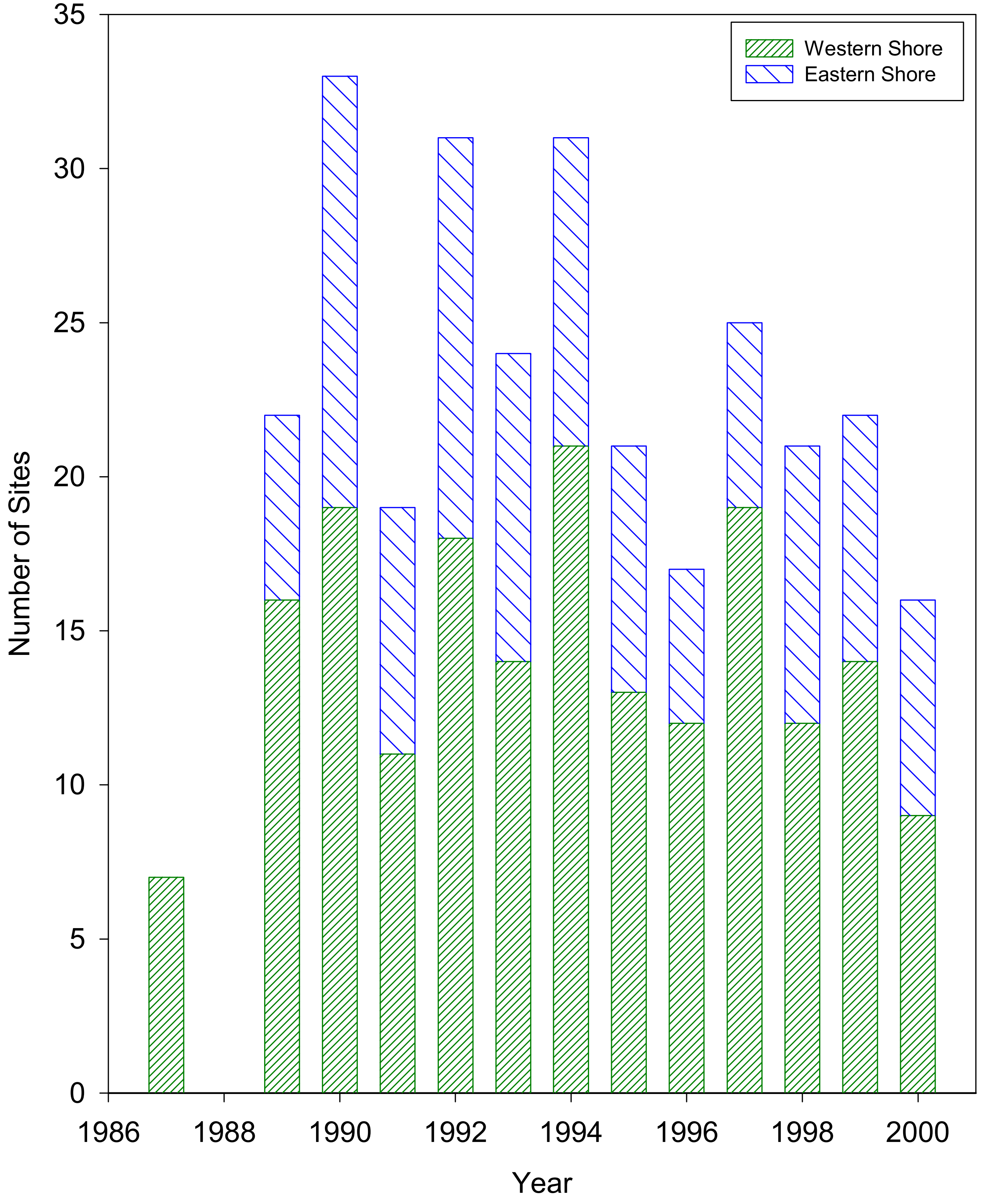


Figure 5: Number of Years Scarred

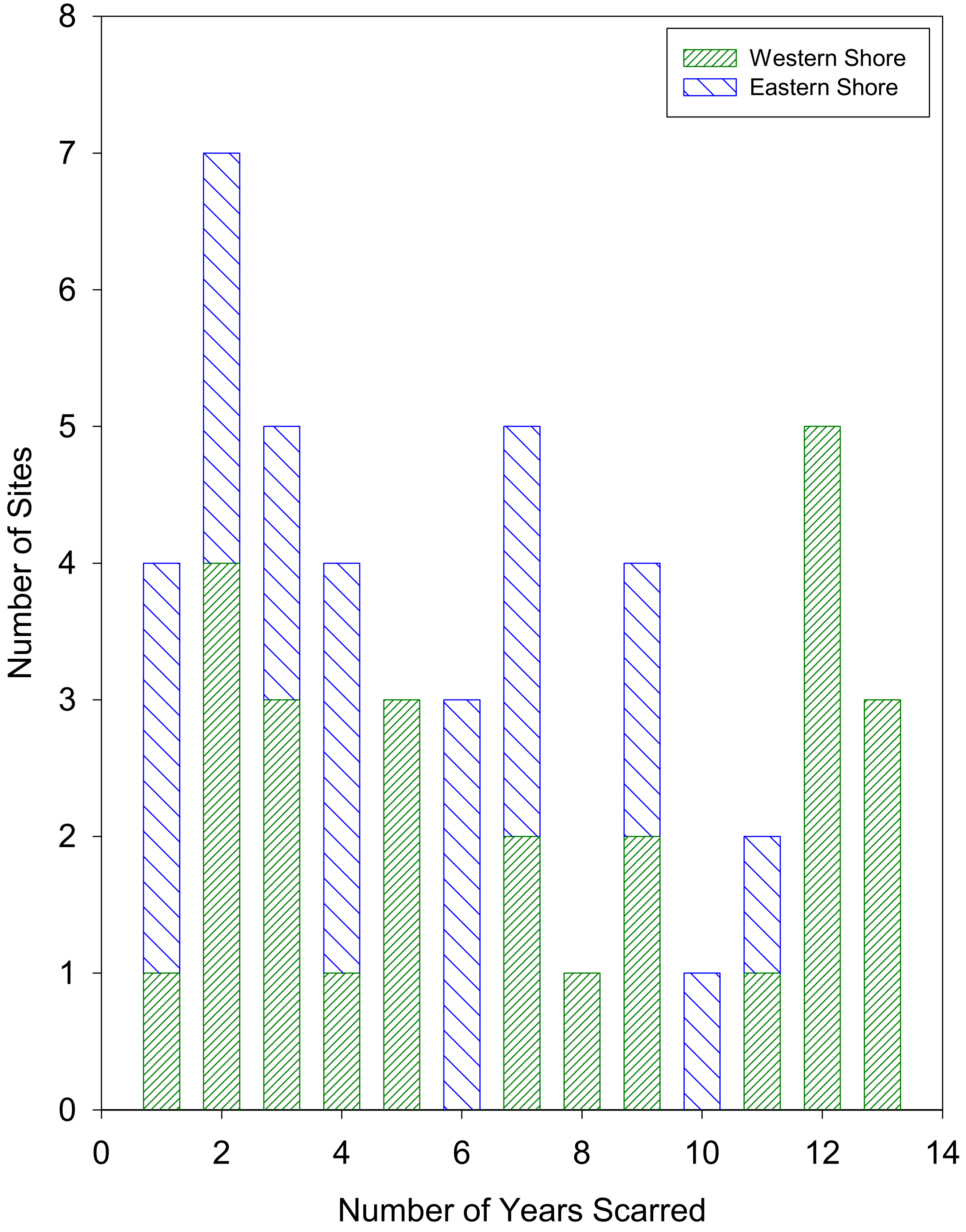


Figure 6: Frequency of Scarring

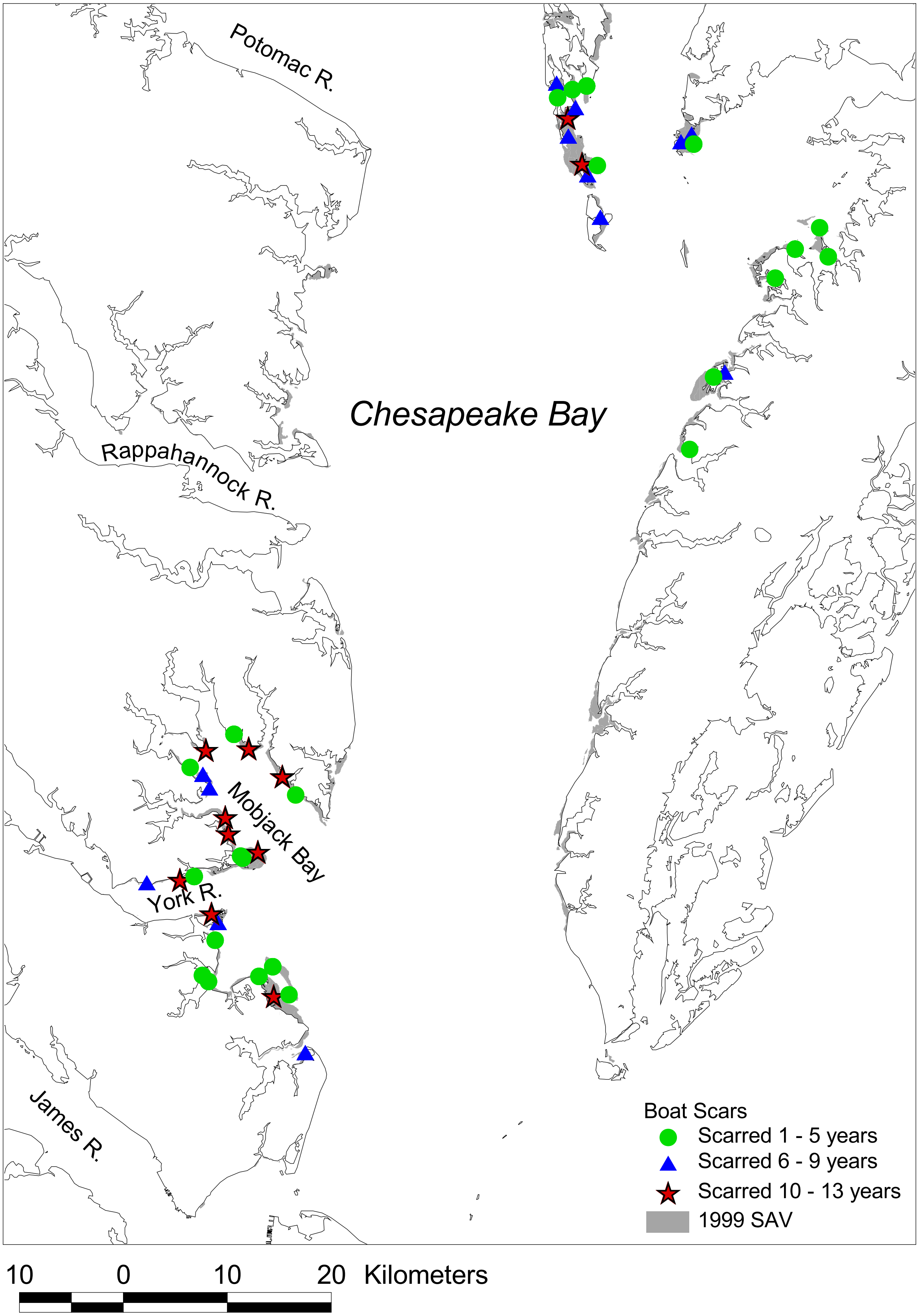


Figure 7: Sites with Scars Associated with Points of Land

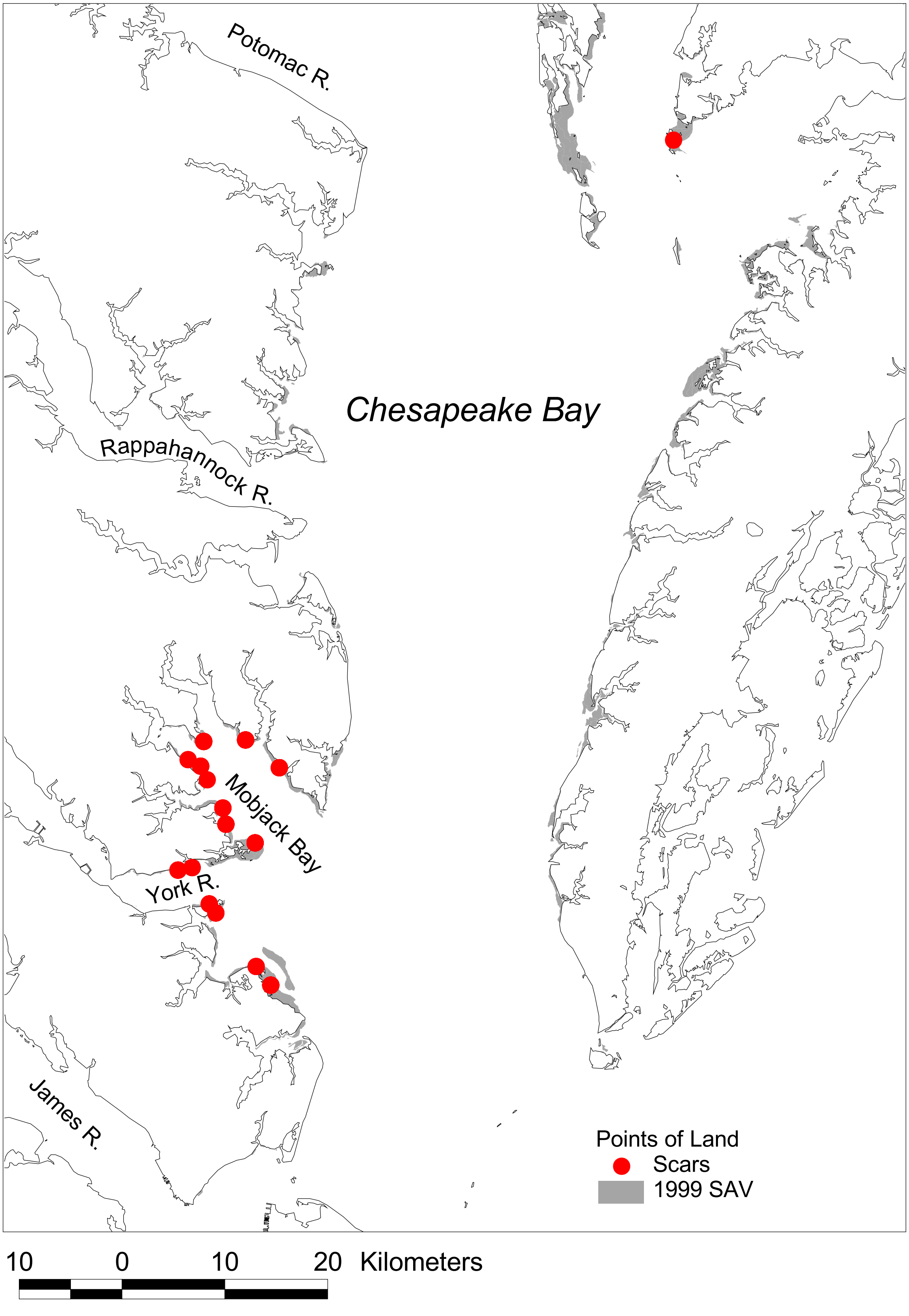


Figure 8A: Sites with Scars Oriented Perpendicular Relative to Shore

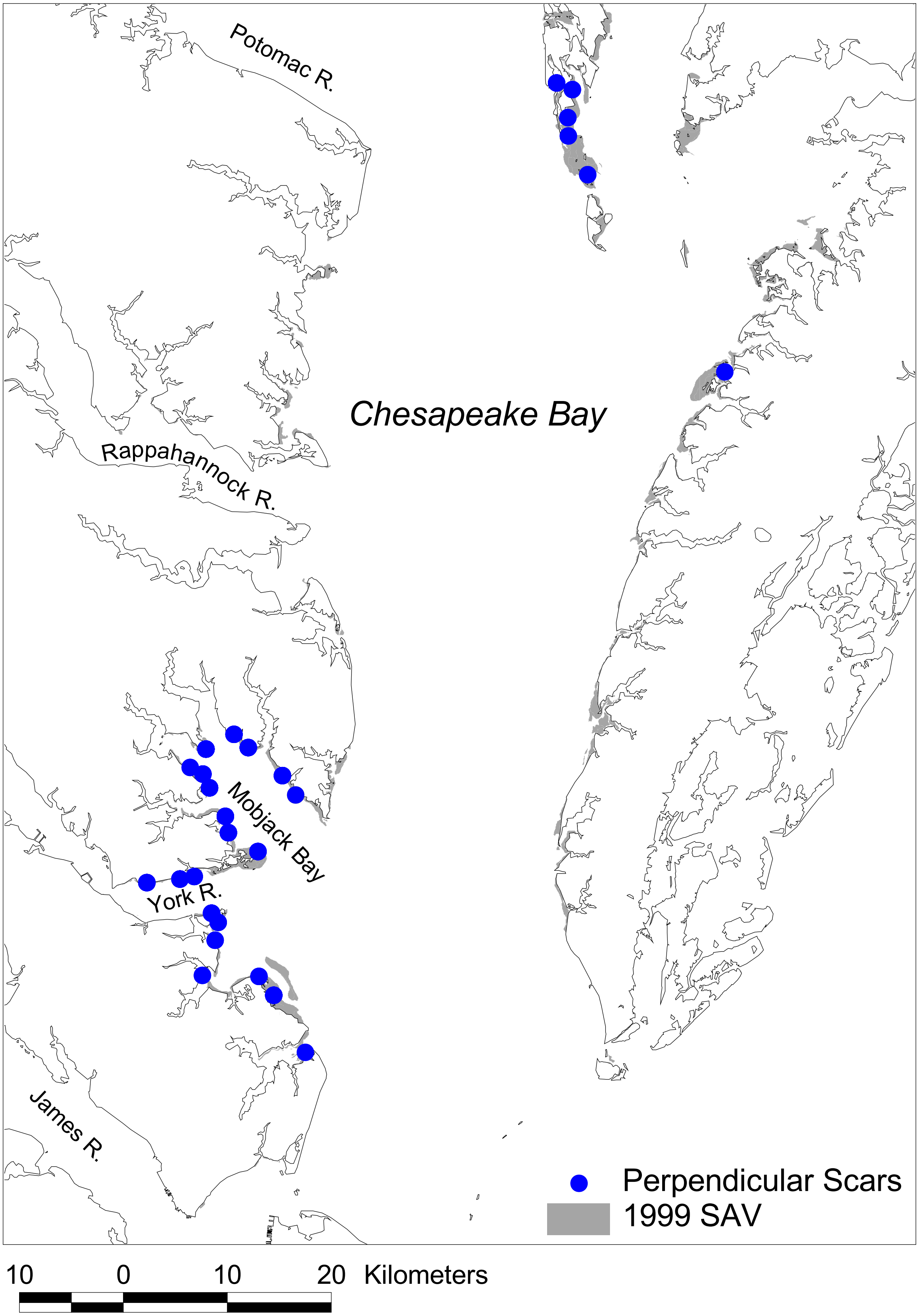


Figure 8B: Sites with Scars Oriented Randomly Relative to Shore

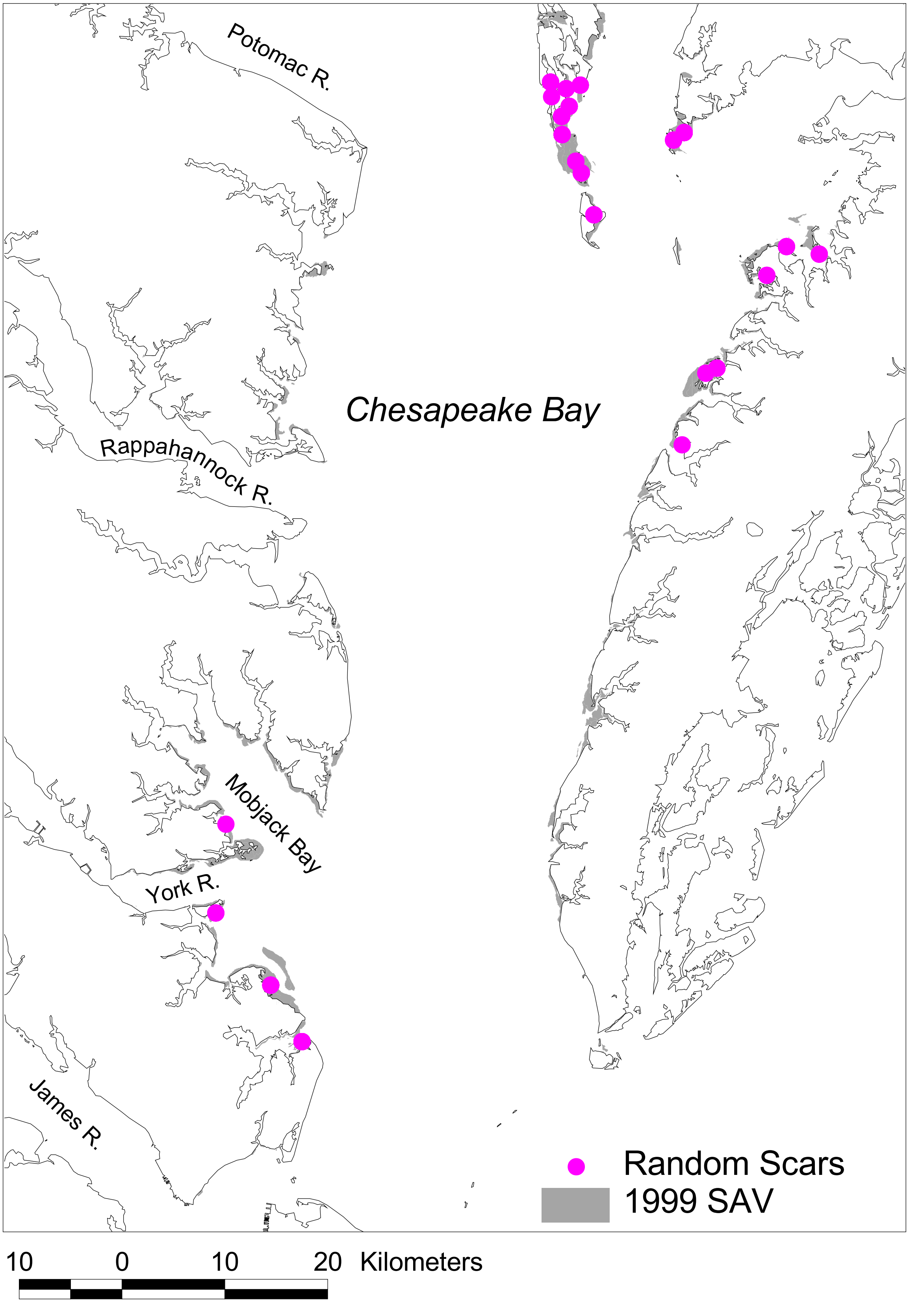


Figure 8C: Sites with Scars Oriented Parallel Relative to Shore

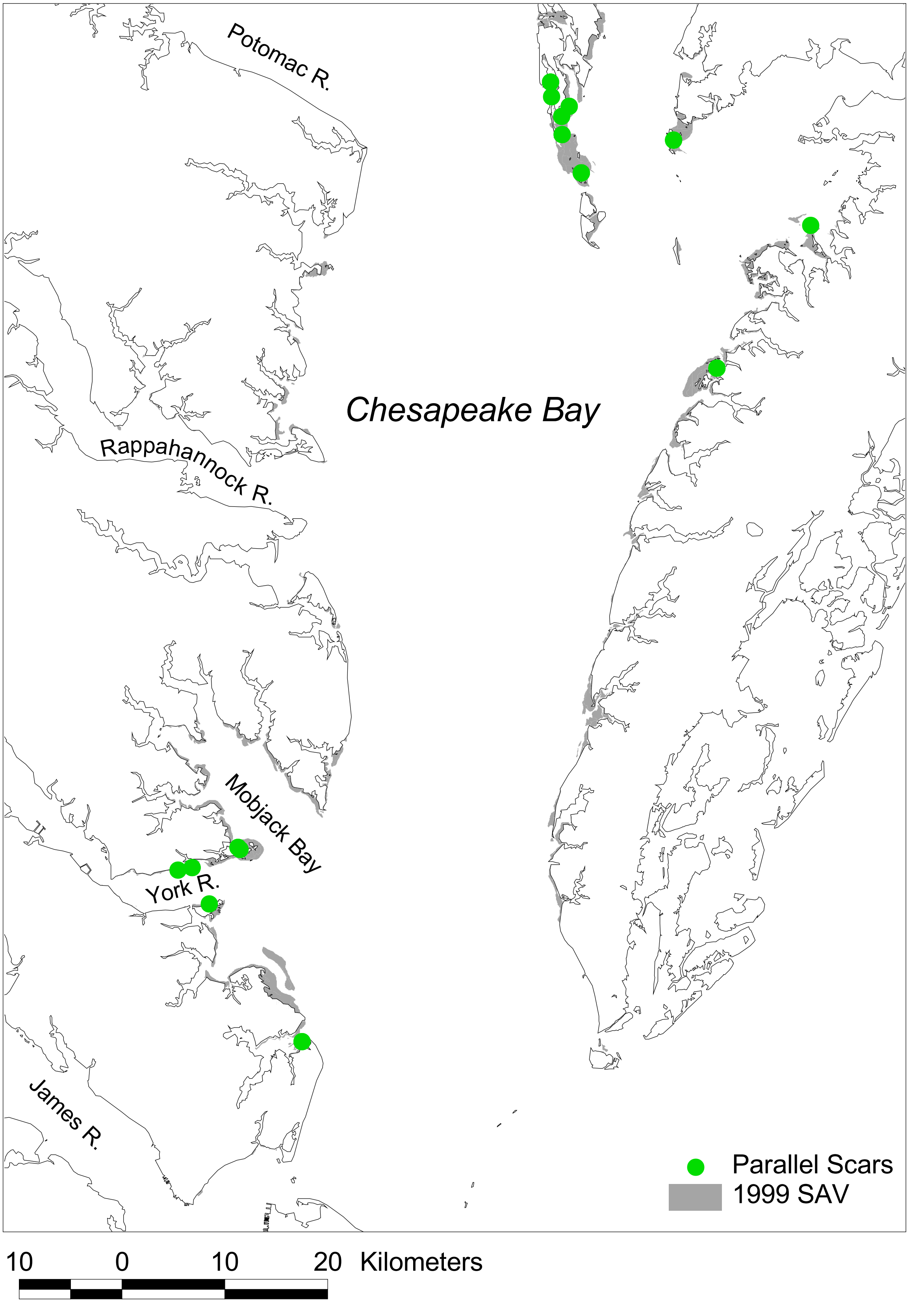


Figure 9: Scar Curvature

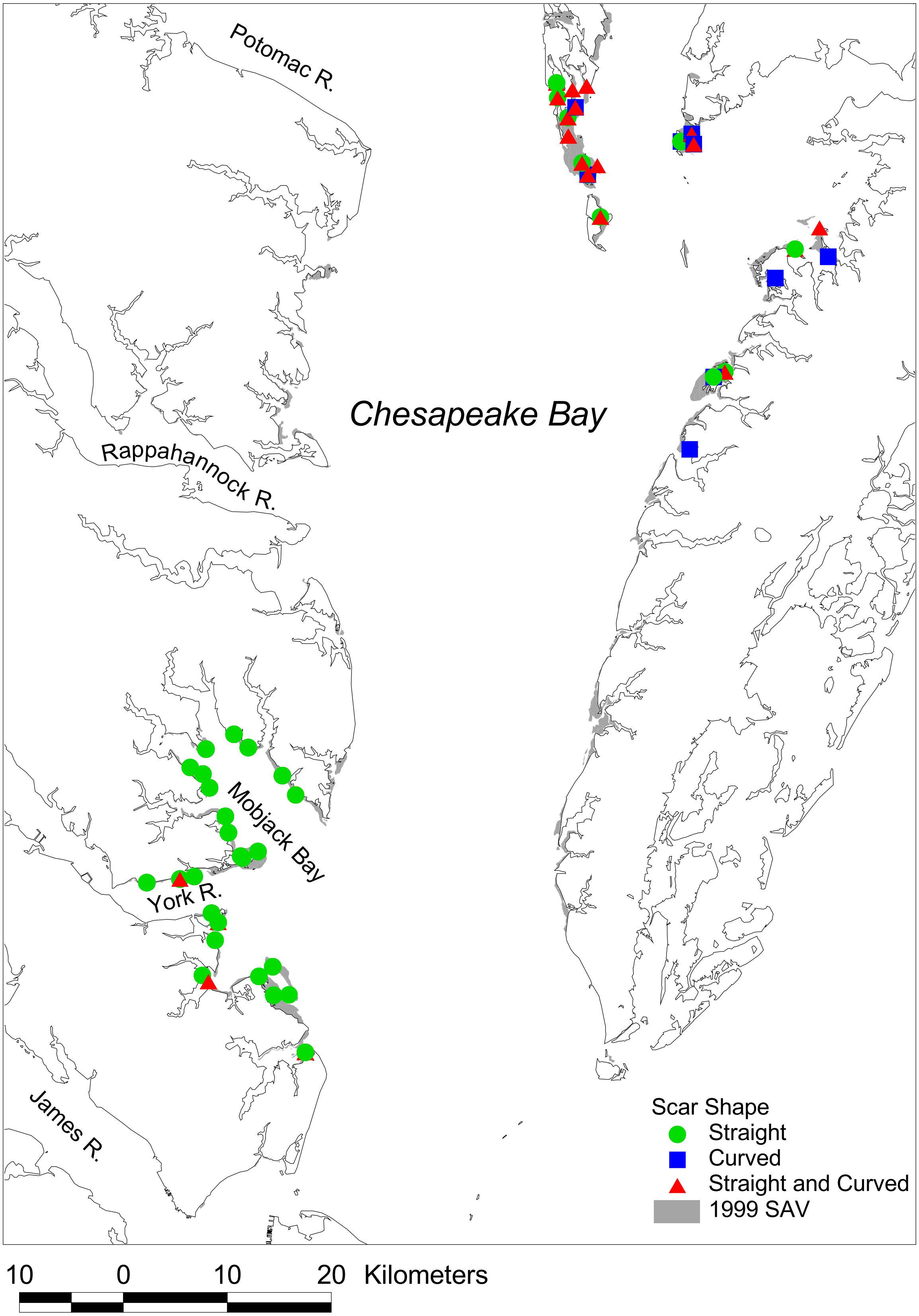


Figure 10: Pepper Creek, 1992

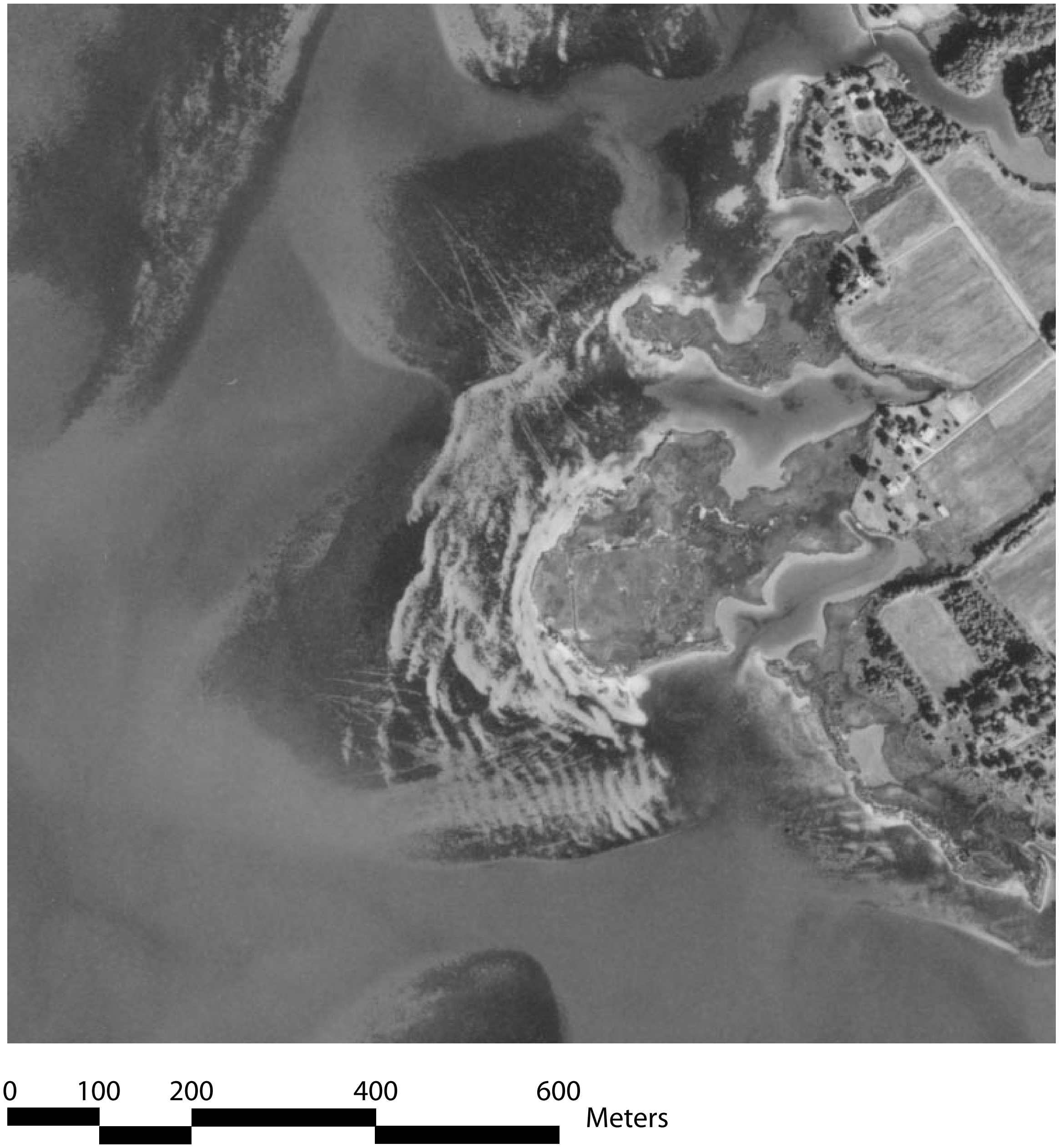


Figure 11: Minter Point, 1992

Figure 12: Tip of Ware Neck Point, 2000

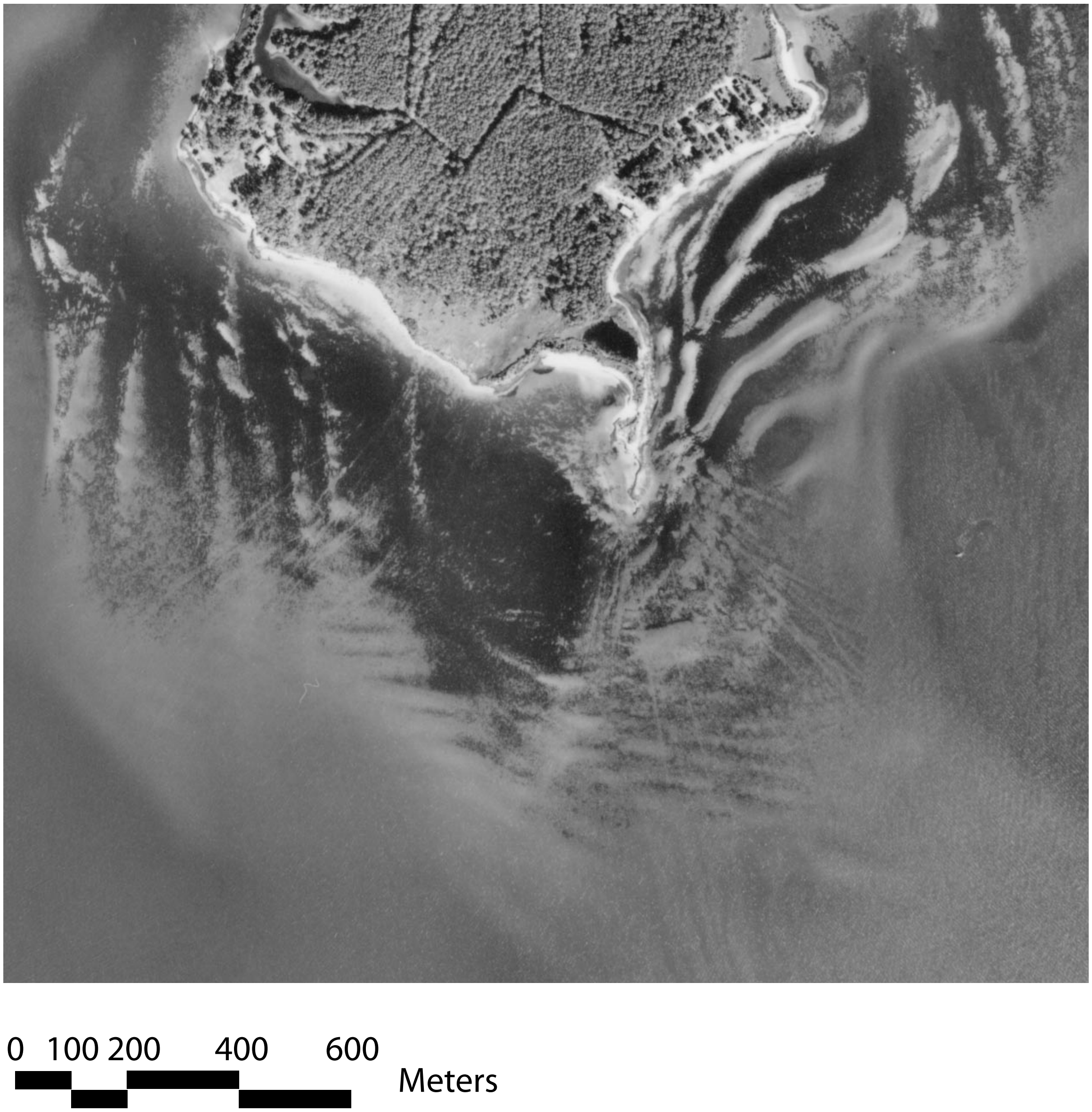


Figure 13: Bush Point, 1992

Figure 14: Guinea Marsh, 1990

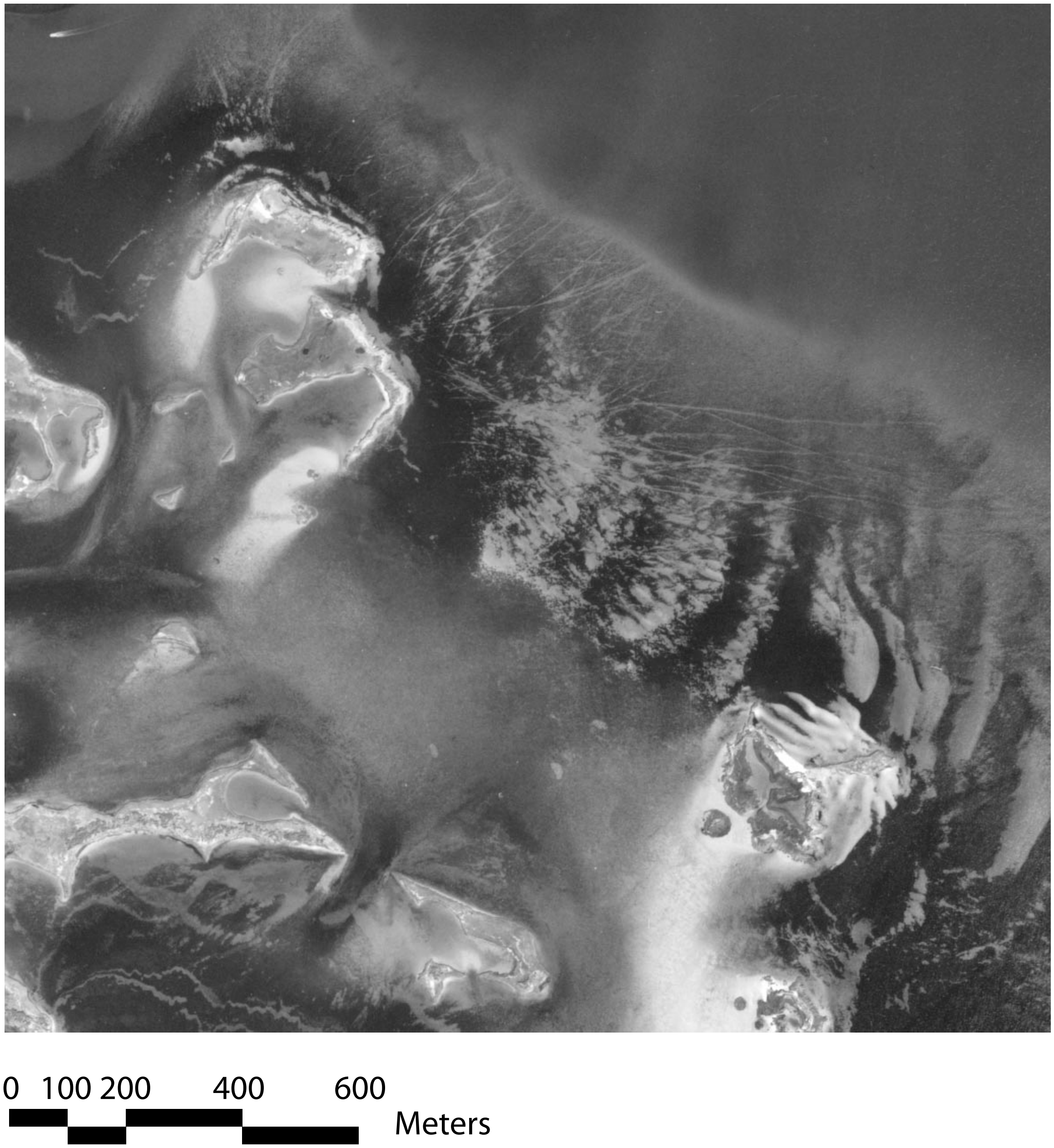


Figure 15: North Shore of Goodwin Island, 1992

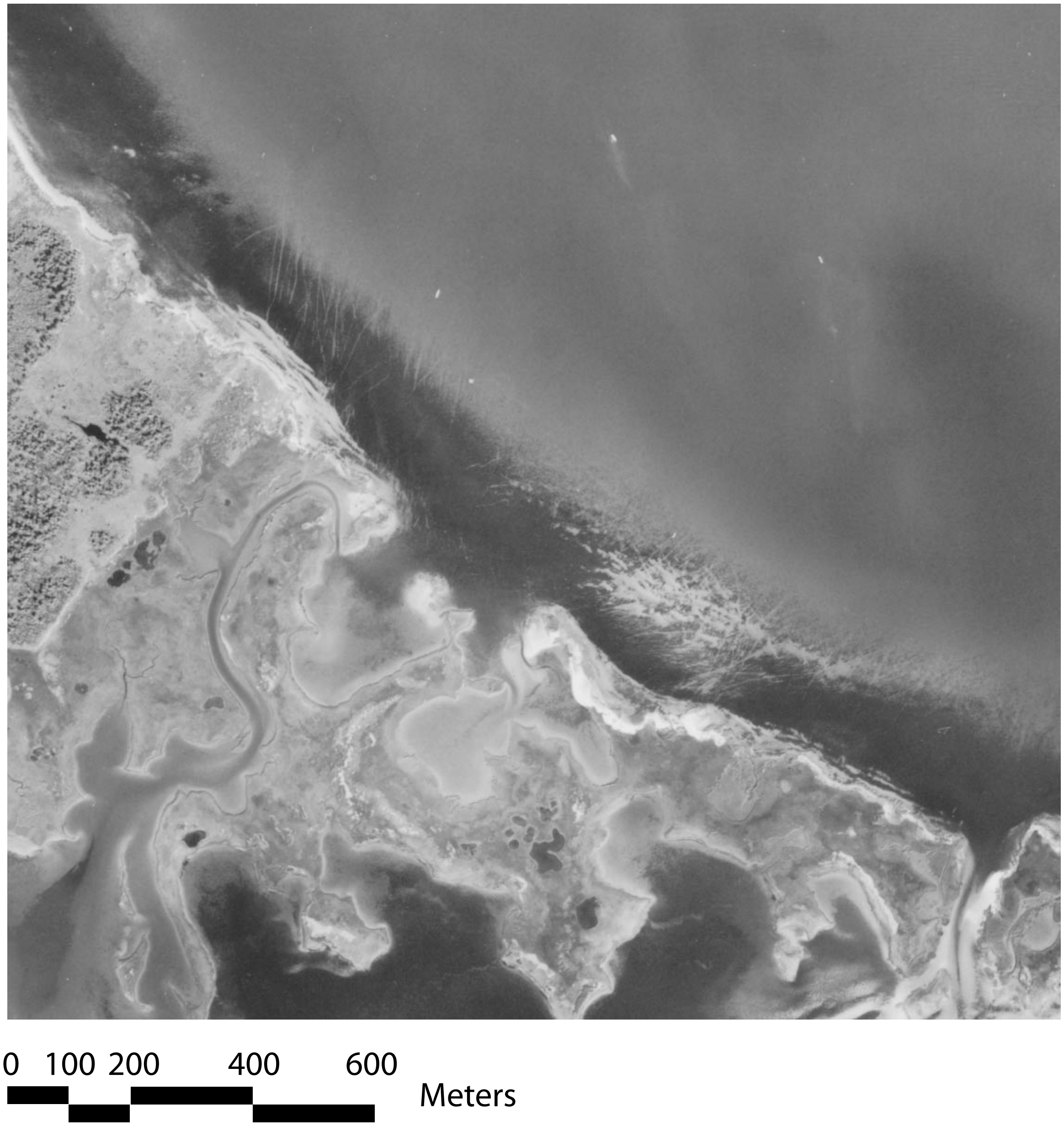


Figure 16: West of Allen's Island, 1997

Figure 17: Plum Tree Island, 1998

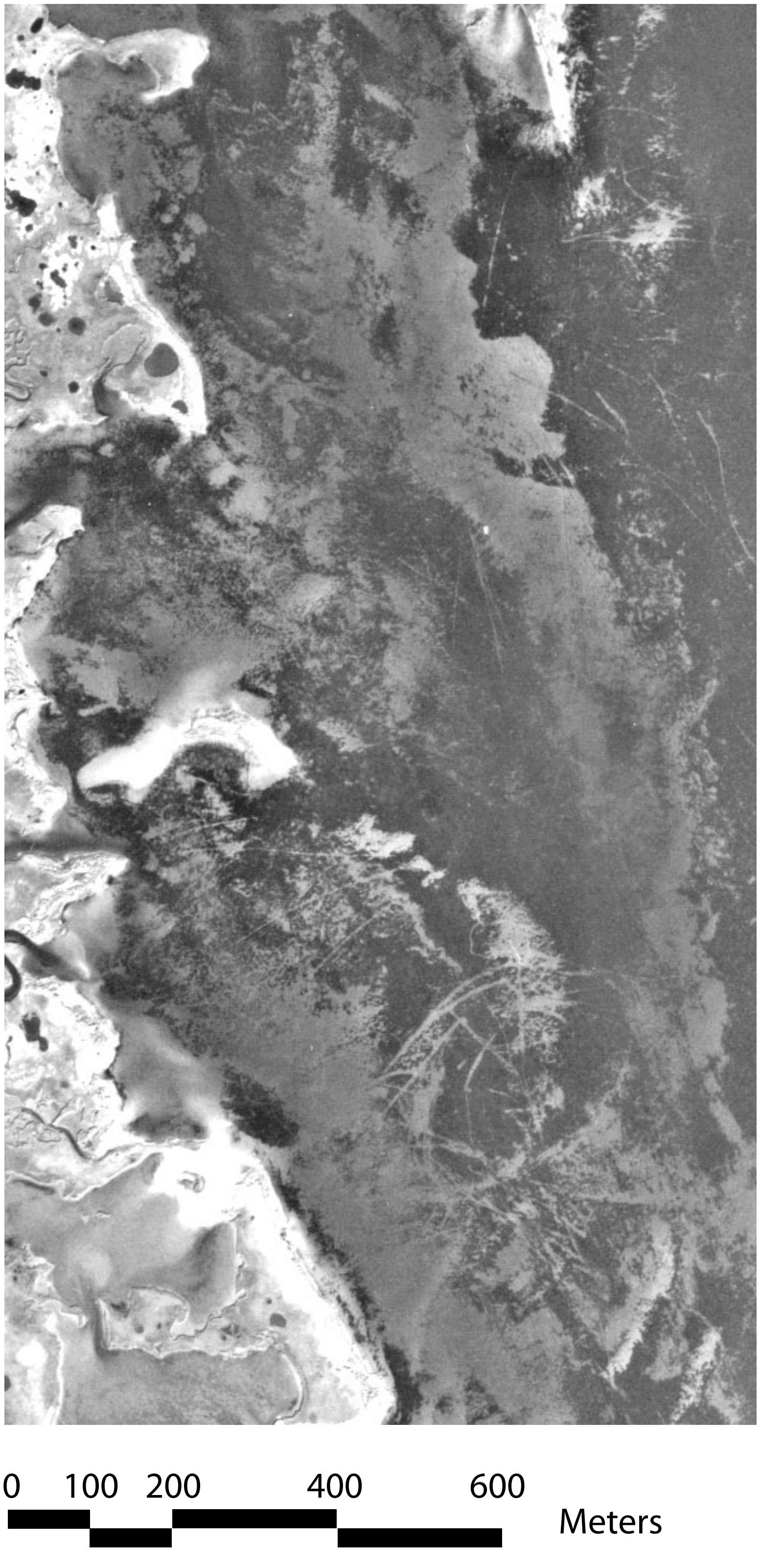


Figure 18: South Point Marsh, 1990

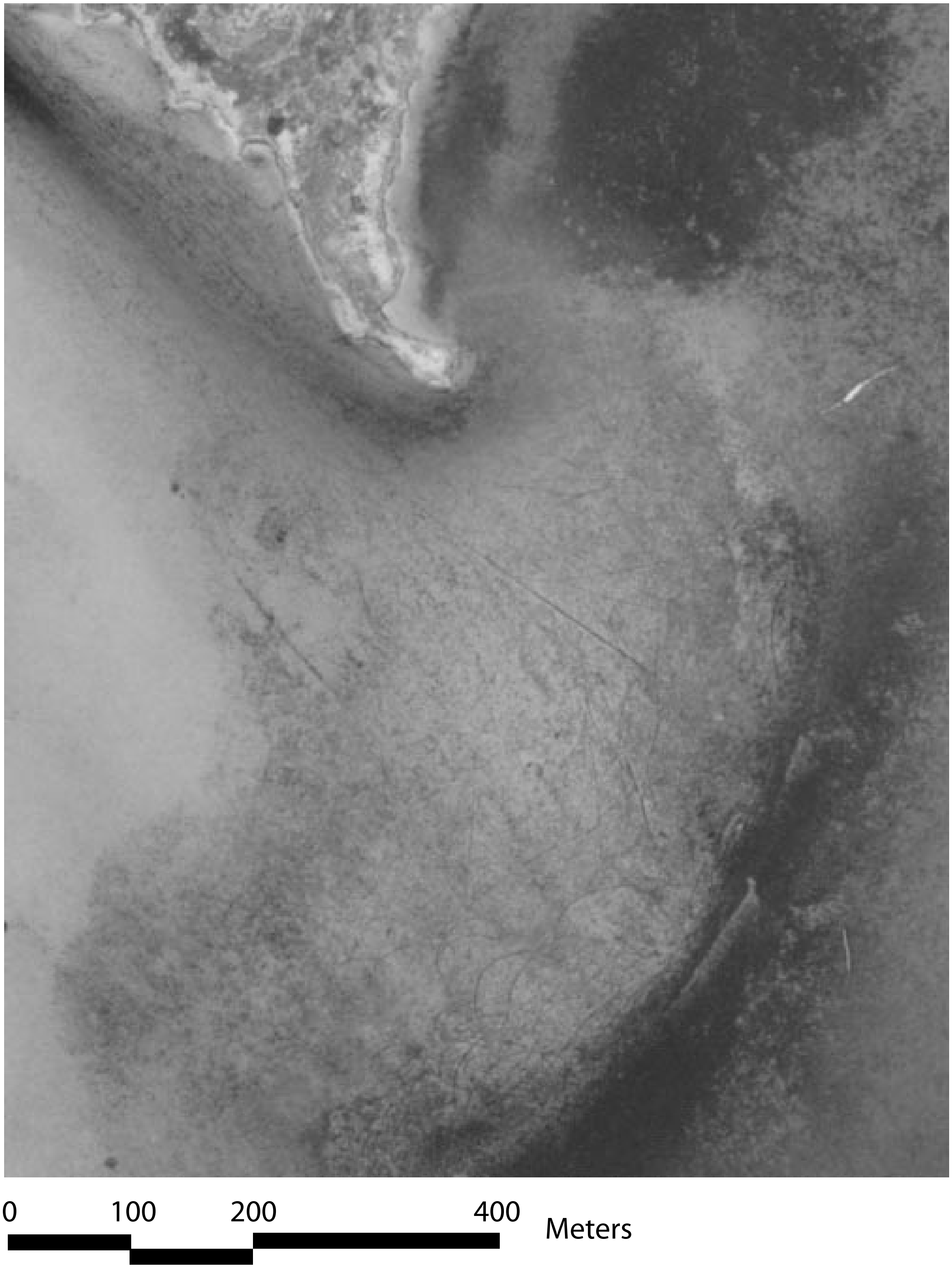


Figure 19: North of Goose Island

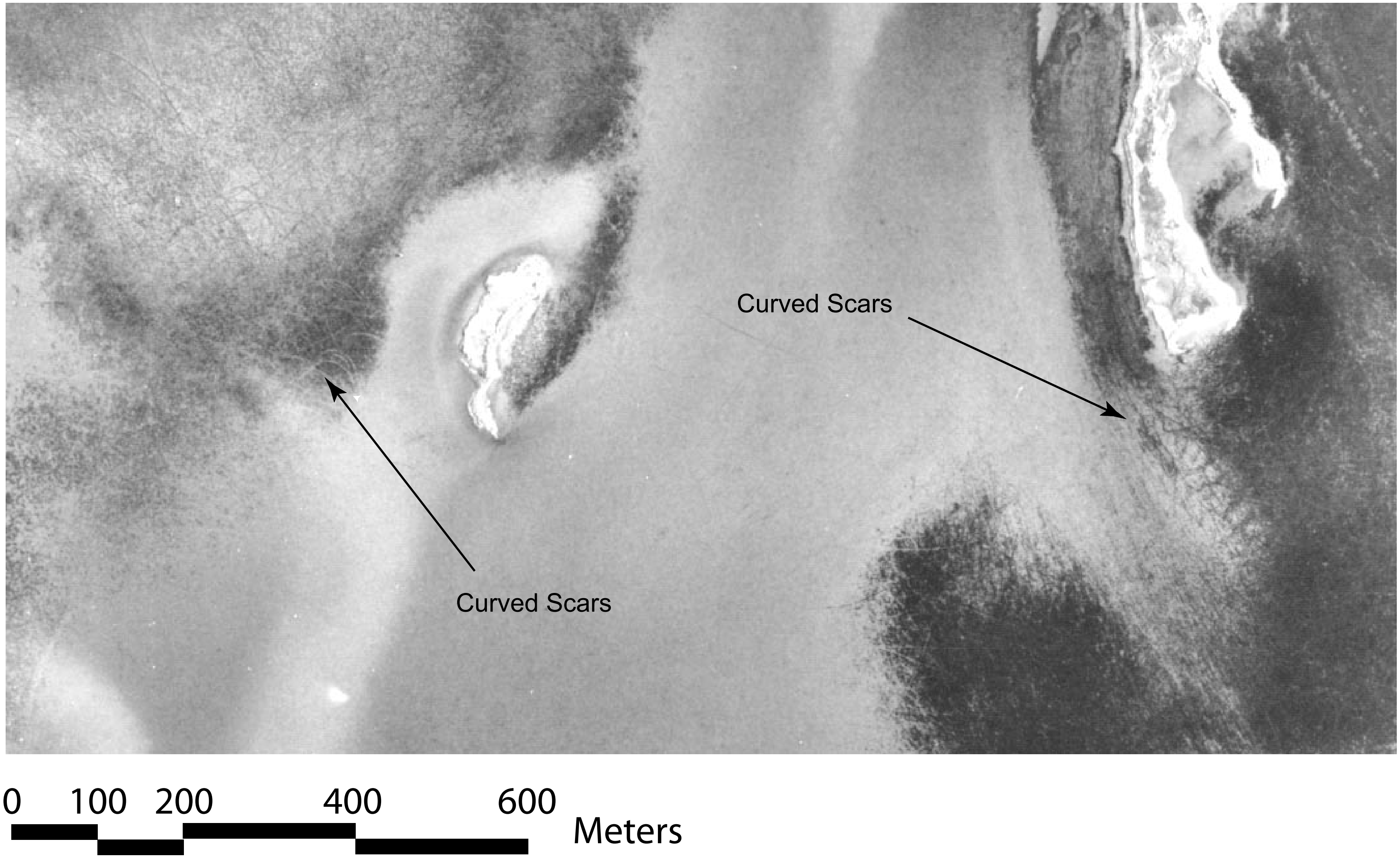


Figure 20A: VMRC Bottom Use Survey-- Crab Scraping

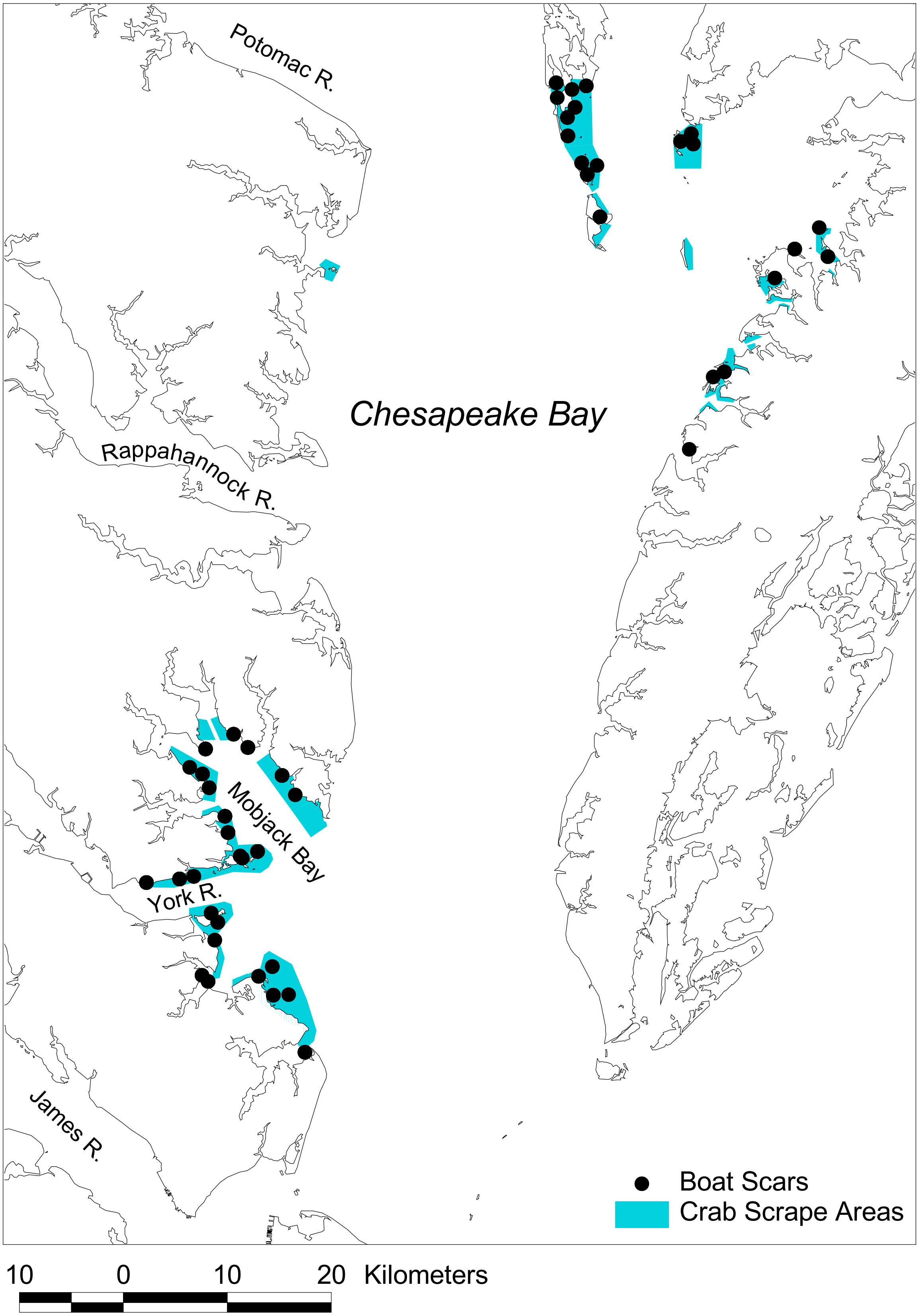


Figure 20B: VMRC Bottom Use Survey-- Haul Seining

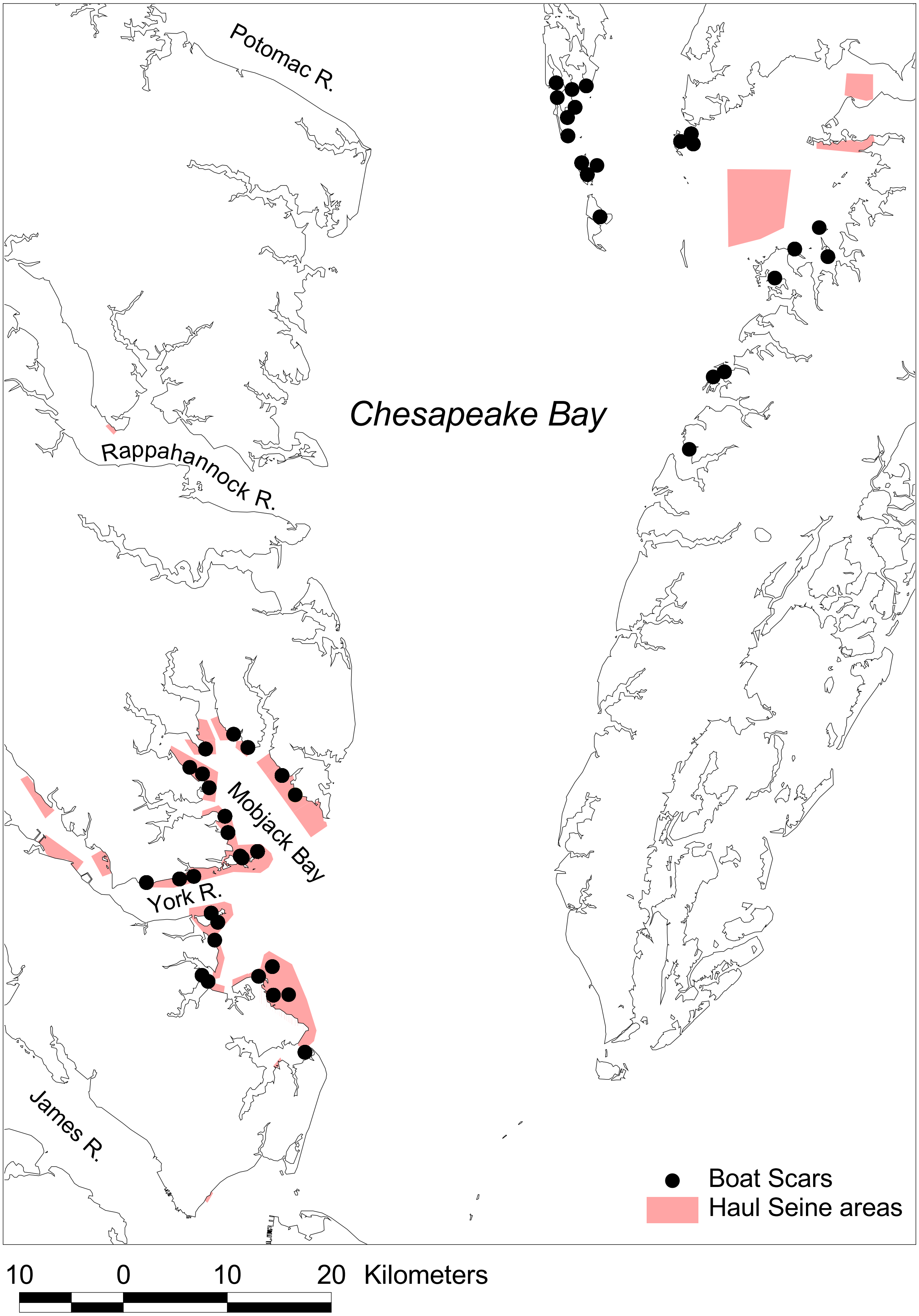


Figure 20C: VMRC Bottom Use Survey-- Recreational

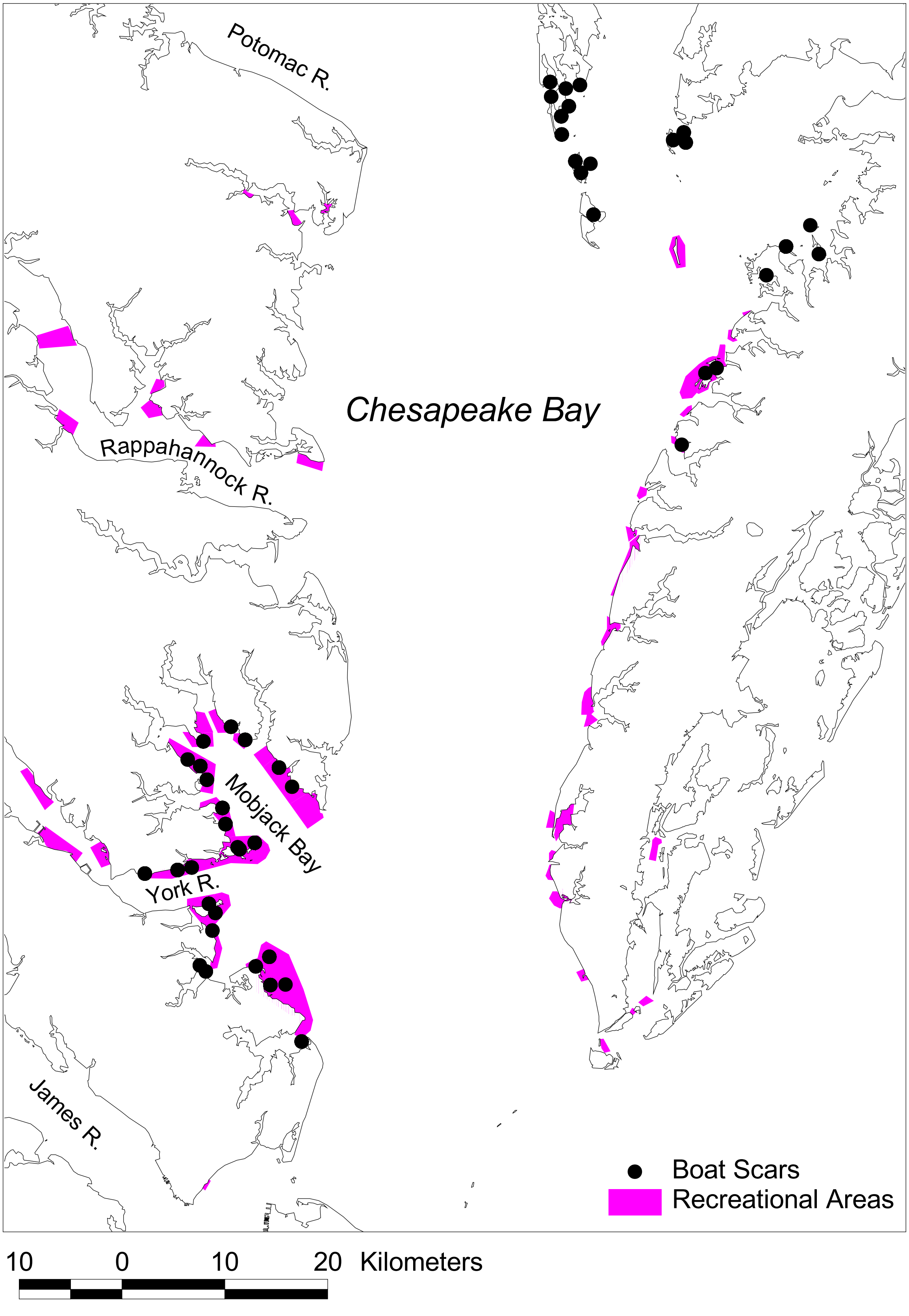


Figure 21A) Finney's Island, 1996

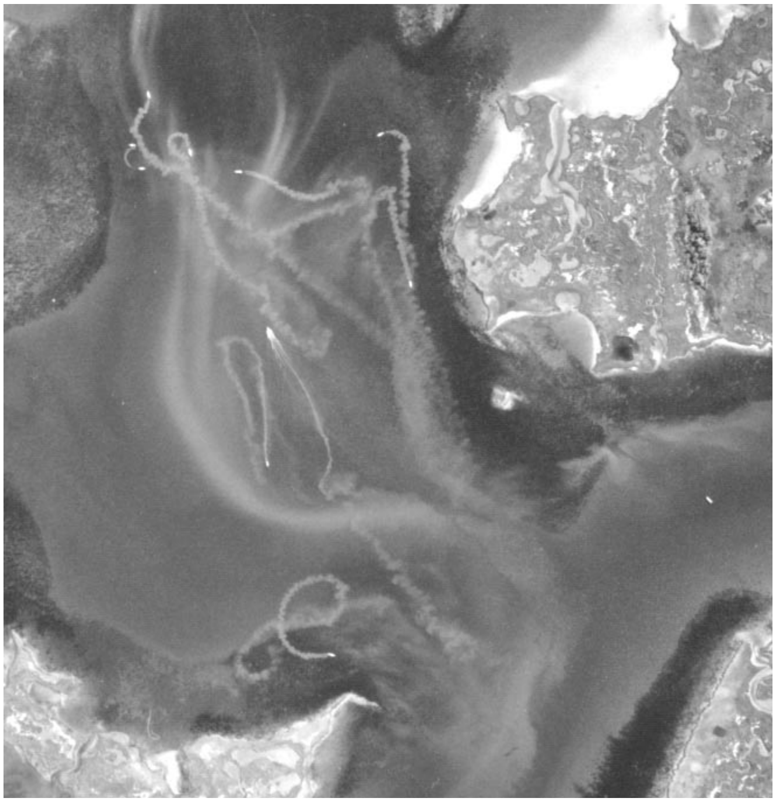


Figure 21B) Finney's Island, 1997

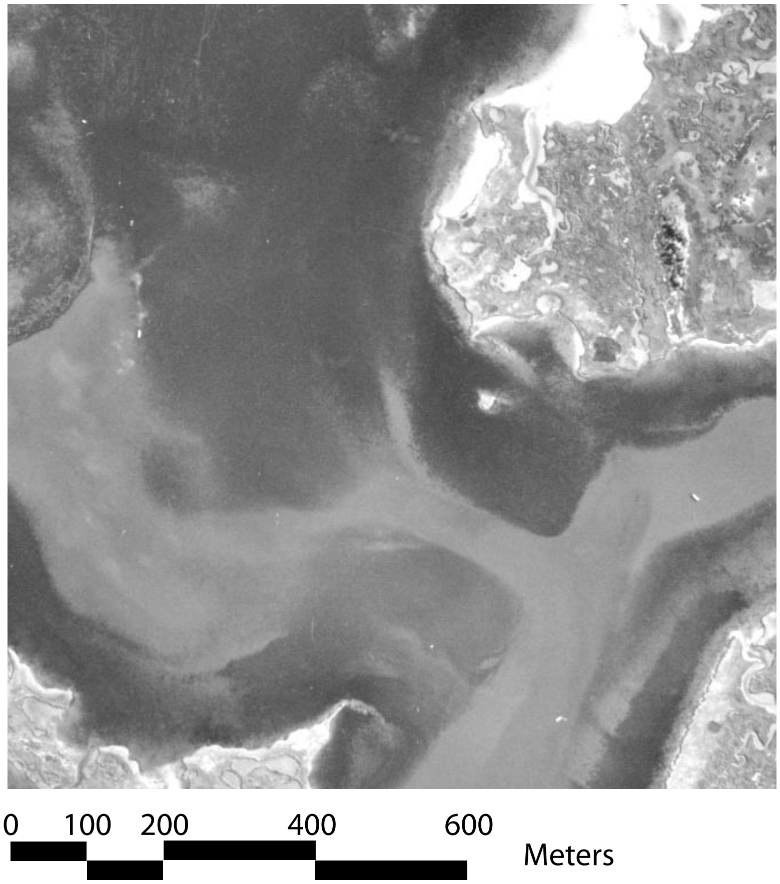
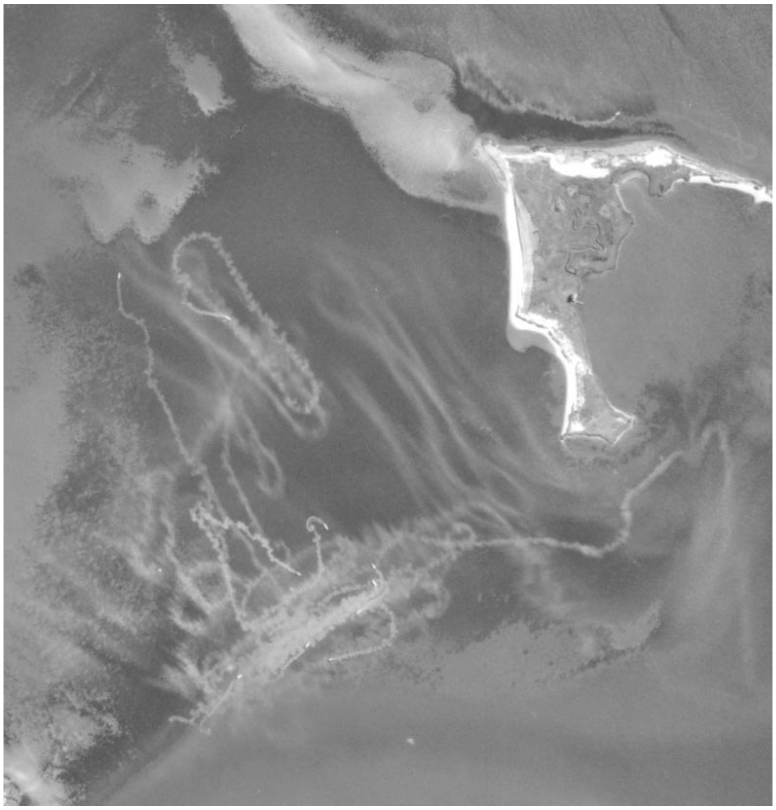


Figure 22 A) Webb Island, 1997



B) Webb Island, 1998

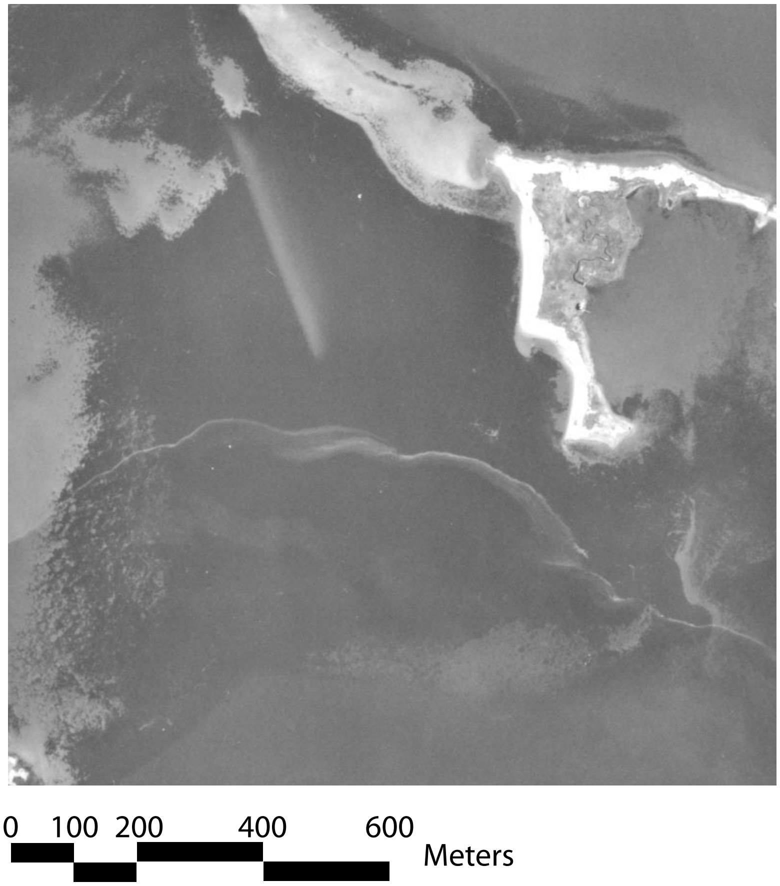


Figure 23: Haul Seine Scars on Southern Shore of York River, 2001

Figure 24: Boat Scarring in Ocean City, Maryland

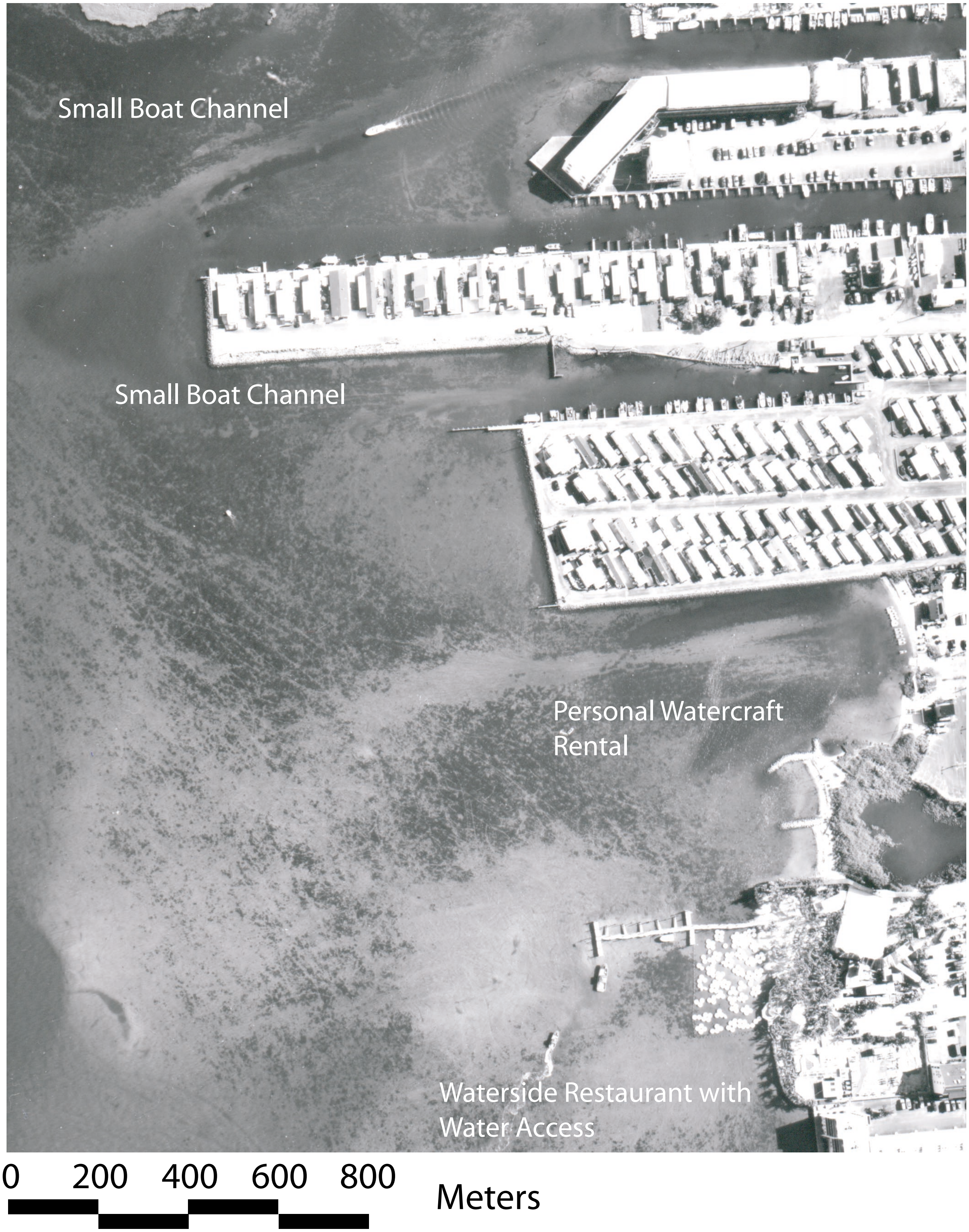


Figure 25: New Point Comfort, 1998