Atlas of important habitat for key fish species of the Scotian Shelf, Canada

Tracy Horsman and Nancy Shackell

Oceans, Habitat and Species at Risk Branch
Maritimes Region
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

2009

Canadian Technical Report of
Fisheries and Aquatic Sciences 2835

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 2835

2009

Atlas of important habitat for key fish species of the Scotian Shelf, Canada

by

Tracy Horsman[1] and Nancy Shackell[2]

Fisheries and Oceans Canada
Maritimes Region
Bedford Institute of Oceanography
Dartmouth, Nova Scotia
B2Y 4A2

[1] Oceans and Coastal Management Division, Bedford Institute of Oceanography
PO Box 1006, Dartmouth, Nova Scotia, B2Y 4A2 Canada. Email: tracy.horsman@dfo-mpo.gc.ca

[2] Ecosystem Research Division, Bedford Institute of Oceanography
PO Box 1006, Dartmouth, Nova Scotia, B2Y 4A2 Canada. Email: nancy.shackell@dfo-mpo.gc.ca

Cat. No. Fs 97-6/2835E ISSN 0706-6457

Correct citation for this publication:

Horsman, T.L. and Shackell, N.L. 2009. Atlas of important habitat for key fish species of the Scotian Shelf, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2835: viii + 82 p.

Table of Contents

List of Figures

List of Tables

Abstract

Habitat information is critical to the process of protecting any species. On the Scotian Shelf, several fish species have been identified as key and influential components of the ecosystem. We evaluated important habitat for many of these key species by assessing the persistence of relatively high observed biomass in space and time using summer research trawl survey data. We propose that in general areas persistently ranked high are important habitat for these species.

Résumé

L'information sur l'habitat est un élément crucial du processus de protection de toute espèce. Plusieurs espèces marines présentes sur le plateau néo-écossais sont considérées comme étant des composantes essentielles et influentes de l'écosystème. Nous avons cerné l'habitat important d'un bon nombre de ces espèces importantes en évaluant la persistance, dans le temps et dans l'espace, des biomasses relativement hautes observées dans le relevé scientifique au chalut effectué l'été. Nous proposons que de façon générale les zones où la biomasse des espèces susmentionnées est considérée comme étant élevée de façon persistante soient considérées comme un habitat important pour ces espèces.

This page was left blank intentionally.

1.0 Introduction

In 1997, Canada's Oceans Act was passed to provide a statutory framework for a national oceans management strategy based on the principles of sustainable development, integrated management and the precautionary approach. There are several pilot projects for integrated ocean management across Canada that are developing plans to manage the multiple human activities occurring in the marine environment and to achieve precautionary conservation goals and a framework for sustainable ocean use and development. As part of a broad and detailed process, members of the Stakeholder Advisory Council for the Eastern Scotian Shelf Integrated Management (ESSIM) area developed a set of objectives under their identified goal for "Healthy Ecosystems". These strategic objectives are based both on ecological process and species. The species-based conservation objectives broadly stated, are to ensure that key species are not "perturbed by human activities to the point where [they] are unable to fulfill their role within the ecosystem" (DFO 2007a). Of course, habitat information is critical to the process of protecting any species. On the Scotian Shelf, several fish species have been identified as key and influential components of the ecosystem, based on ecosystem modelling (Bundy 2005). This atlas was prepared by the Oceans and Coastal Management Division to provide contemporary regional information on the areas of importance during the summer for key species on the Scotian Shelf, Canada.

1.1 How is important habitat defined?

There is a vast amount of information on the life history and habitat requirements of Atlantic Canada fish species (e.g Simon and Comeau 1994; Breeze *et al.* 2002; Scott and Scott 1988; Mahon *et al.* 1998). The problem is the information can be overly general, not spatially explicit or cannot be applied on a regional scale. Conservation biologists will often test for "density-dependent geographic distribution" which means that animals expand their range when their densities increase, as has been observed in many taxa (Gaston and Blackburn 2000). This is related to the theory that animals will occupy habitat that maximizes their fitness ---if there are too many animals in an optimal habitat, the resources per individual decline, so some animals will benefit by moving to marginal habitat (Fretwell and Lucas, 1970, MacCall 1990).

In Atlantic Canada, there has been considerable effort to identify important habitat for marine fish by testing whether fish expanded their range when the population expanded (e.g. Myers and Stokes 1989; Marshall and Frank 1994; Swain and Sinclair 1994; Swain and Morin 1996; Frank and Fisher 2004, Shackell *et al.* 2005). The results varied across studies—not all species conformed to expectations but important insight was gained. Animals will not expand their range when their population increases if:

1) population abundance does not vary (no expansion will be detected);
2) the preferred habitat is unsaturated;
3) the species requires a specific but limited type of habitat;
4) habitat selection changes over time or with age;
5) fishing was concentrated on high-density areas which were not replenished fast enough. That means that areas occupied by severely depleted species may not reflect the historical array of important habitat.

We based our approach on the factors listed above. We adopted a method which would be independent of changes in abundance. As well, we divided the summer time series into fishery management eras in order to detect whether a high-density area had been abandoned due to a severe population decline as a result of directed fishing. In effect, we adopted a simple and practical approach that assumes that summer is a time of rapid growth and feeding, and that summer habitat is important to a species if it is found there consistently in higher concentrations.

In the Atlantic Canada region, there are a variety of related initiatives contributing to the development of integrated management that will find these maps useful. However, the maps should be interpreted in the context of the status of the population (also included). For example, we recommend a precautionary approach that assumes the existence of low-mixing populations that can be differentially affected by fishing. For species at risk, only those maps derived before significant population declines should be used to identify high-density areas. Such areas would represent those with the potential to support higher densities as well as the historical array of subpopulations (Shackell *et al.* 2005).

2.0 Methodology:

2.1 Key Species

The identification of "ecologically significant species and community properties" (DFO 2006) and conservation objectives for large ocean management areas (LOMAs), such as the eastern Scotian Shelf, (DFO 2007b) was a requirement in support of Ocean Action Plan Phase 1 (DFO 2005). Ecologically significant species (ESS) and community properties were categorized under four types: 1) species with a potentially controlling influence on the ecosystem structure or function, such as species with significant trophodynamic roles (e.g. influential predators, forage species); 2) structure providing species; 3) aggregate ecosystem properties above the species level; and 4) species which could pose a particular threat to the ecosystem (e.g. invasive species) (DFO 2006). We focused our effort on the identification of important habitat for species that are regularly observed in scientific trawl surveys and that were identified as type 1 (i.e., influential predators and forage species) in the Maritimes region. We also include species that were identified as "depleted" based on their status from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on guidance for the establishment of conservation priorities within LOMAs (DFO 2007b). In our region some "depleted" species, such as Spotted and Northern Wolffish, may currently be at the limit of their natural range and their status is debatable. Nonetheless, they were included in the "depleted" category to maintain consistency with the COSEWIC designation. The species evaluated in this report are identified in Table 1 by both their common and scientific names, and by grouping (i.e. ESS, depleted, etc). The COSEWIC listing status is indicated in parantheses next to the common name for depleted species. Nine additional species that are dominant (i.e., occur in > 10% of all trawl sets) in the summer research vessel trawl surveys have also been included (Table 2).

Table 1. Ecologically significant and depleted (or rare) species of the Scotian Shelf Large Ocean Management Area (LOMA).

Scientific Name	Common Name	Group
Mallotus villosus	Capelin	ESS – Type 1, Forage Species
Clupea harengus	Herring	ESS – Type 1, Forage Species
Scomber scrombus	Mackerel	ESS – Type 1, Forage Species
Ammodytes dubius	Sandlance	ESS – Type 1, Forage Species
Illex illecebrosus	Shortfin Squid	ESS – Type 1, Forage Species
Glyptocephalus cynoglossus	Witch Flounder	ESS – Type 1, Forage Species[1]
Merluccius bilinearis	Silver Hake	ESS – Type 1, Influential Predator

[1] While this species was identified as a forage species, there is conflicting information about its role as a forage species based on information available from stomach analyses in the region (J. Simon, pers. comm.). Nonetheless, this species meets our criteria as a dominant species in the region.

Hippoglossoides platessoides	American Plaice	ESS – Type 1, Influential Predator
Gadus morhua	Atlantic Cod (special concern)	ESS – Type 1, Influential Predator & Depleted Species
Melanogrammus aeglefinus	Haddock	ESS – Type 1, Influential Predator
Hippoglossus hippoglossus	Atlantic Halibut	ESS – Type 1, Influential Predator
Myoxocephalus octodecemspinosus	Longhorn Sculpin	ESS – Type 1, Influential Predator
Pollachius virens	Pollock	ESS – Type 1, Influential Predator
Urophycis chuss	Red Hake	ESS – Type 1, Influential Predator
Sebastes spp.	Redfish	ESS – Type 1, Influential Predator
Malacoraja senta	Smooth Skate	ESS – Type 1, Influential Predator
Squalus acanthias	Dogfish	ESS – Type 1, Influential Predator
Urophycis tenuis	White Hake	ESS – Type 1, Influential Predator
Leucoraja ocellata	Winter Skate (threatened / special concern)	ESS – Type 1, Influential Predator & Depleted Species
Brosme brosme	Cusk (threatened)	Depleted Species
Anarhichas denticulatus	Northern Wolffish (threatened)	Depleted Species
Anarhichas minor	Spotted Wolffish (threatened)	Depleted Species
Anarhichas lupus	Atlantic Wolffish (special concern)	Depleted Species

Table 2. Additional Dominant Species Observed in Summer Trawl Surveys

Scientific Name	Common Name
Triglops murrayi	Mustache Sculpin
Amblyraja radiata	Thorny Skate
Limanda ferruginea	Yellowtail Flounder
Lophius americanus	Monkfish
Hemitripterus americanus	Sea Raven / Sea Sculpin
Zoarces americanus	Ocean Pout
Pseudopleuronectes americanus	Blackback / Winter Flounder
Argentina silus	Atlantic Argentine
Phycis chesteri	Longfin Hake

2.2 Identifying Important Habitat

We asked whether there were areas of consistently high(er) biomass despite changes in ecological/environmental characteristics and fishery management influences. We used ArcGIS® software for the analyses and display.

2.2.1 Summer Research Vessel Survey

Since 1970, the Department of Fisheries and Oceans (DFO) has conducted a summer research vessel (RV) survey on the Scotian Shelf in Atlantic Canada to assess the distribution and abundance of both commercial and non-commercial species. The survey uses a stratified random sampling design. Forty-eight strata are defined by geographic location and uniform depth (Figure 1). Samples (sets) are allocated to each stratum in proportion to its area. Each set consists of the deployment of a standard, Western IIA bottom trawl with a 19 mm codend liner. The surveys used a #36 Yankee bottom trawl from 1970 to 1981 and a Western IIA trawl since 1982. The trawl is towed at a constant speed of 3.5 knots for approximately 30 minutes. The total swept area of one set is 0.0404 km^2. The survey is conducted around the clock, randomly within strata and among years during the month of July (Simon and Comeau, 1994). In the early 1970s, several sets were taken in the Gulf of St. Lawrence, outside of the main domain.

The survey data were not corrected for differences in catchability among species. However, invertebrates were not routinely measured, and if they were (e.g. lobster), their catchability is considered to be less than that of finfish (J. Simon, DFO, pers. comm.). In addition, earlier in the time series, Red Hake was sometimes misidentified. As well, there was earlier confusion in differentiating little and Winter Skates. In both cases, the magnitude of misidentification cannot be quantified.

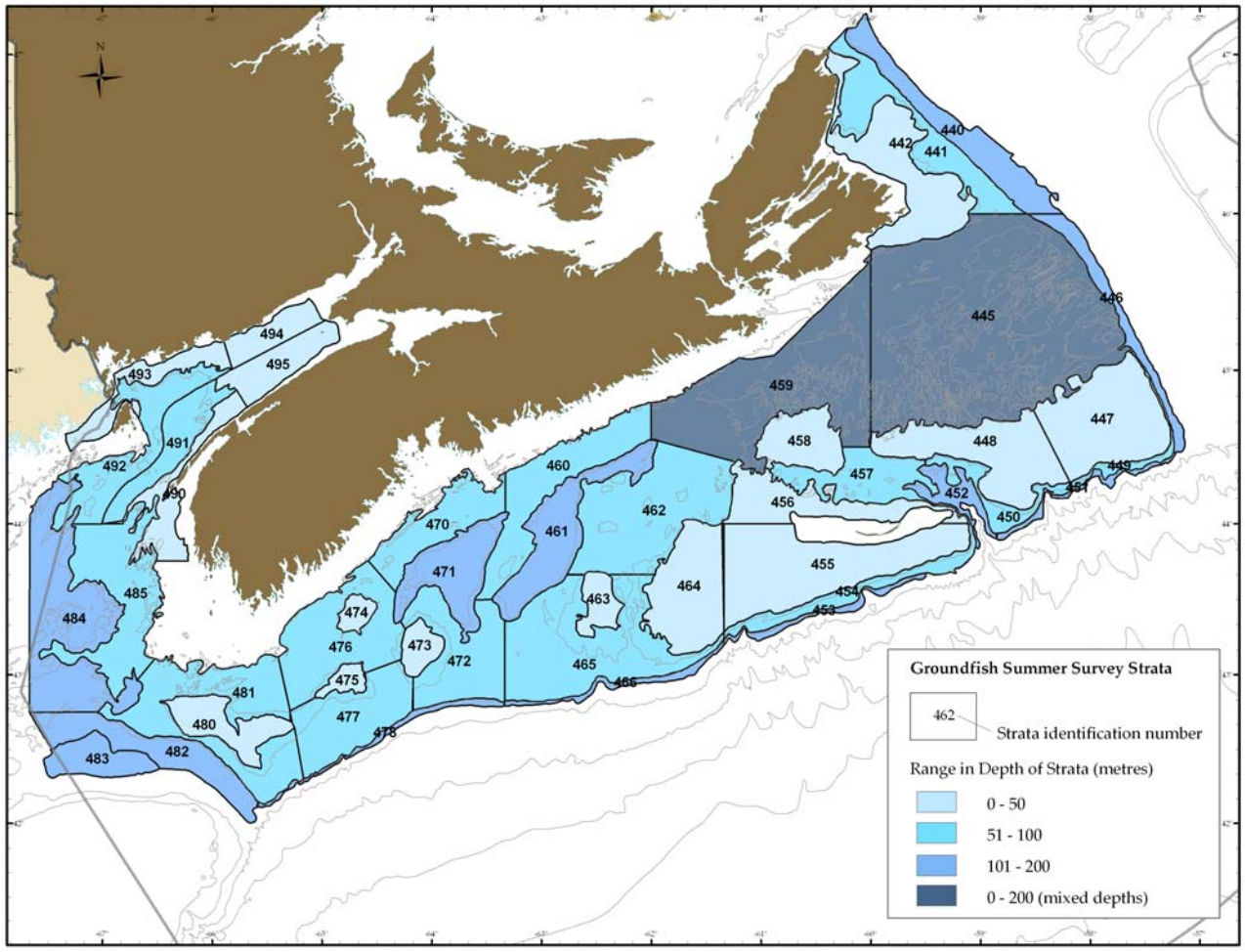


Figure 1. Map of research vessel (RV) survey strata in the Maritimes Region.

2.2.2 Definition of Time Blocks

Our first step was to divide the time series into 4 periods, roughly corresponding to fishery management eras. Note that the divisions are similar to the 5-year time blocks used by Simon and Comeau 1994. The eras are:

1. 1970-77- represents a period when foreign fleets were active in Canadian waters;
2. 1978-85: Establishment of the 200 mile limit, (Exclusive Economic Zone) and subsequent recovery of domestic stocks before domestic fishery was fully engaged;
3. 1986-93: domestic fleets increased fishing pressure, combined with colder waters on the eastern Scotian shelf, decline in growth rate and collapse of some fish stocks;
4. 1994-2006: collapse and non-recovery of several groundfish species on the eastern Scotian shelf.

2.2.3 Interpolation Method of Spatial Data

For each species in our study the observed weight per tow, hereafter referred to as biomass, including null values, were interpolated across the sampled area using the inverse distance weighting (IDW) technique in ArcGIS®. This method was applied for each of the four time blocks. For the interpolation we used a fixed search radius of 0.15 degrees (equivalent to approximately 14-15 kilometres for our study area) with an output cell size of 0.026177 degrees. The interpolation was optimized by the software (ArcGIS® Spatial Analyst, ESRI) for the spatial distribution of the data. The results of these interpolations are displayed as Maps 1 to 4 for each species in Section 3. The following map (Figure 2) shows the trawl survey locations for the years from 1970 to 2006, inclusive, and is provided only to assist the reader in visualizing the extent of the interpolation window relative to the available data.

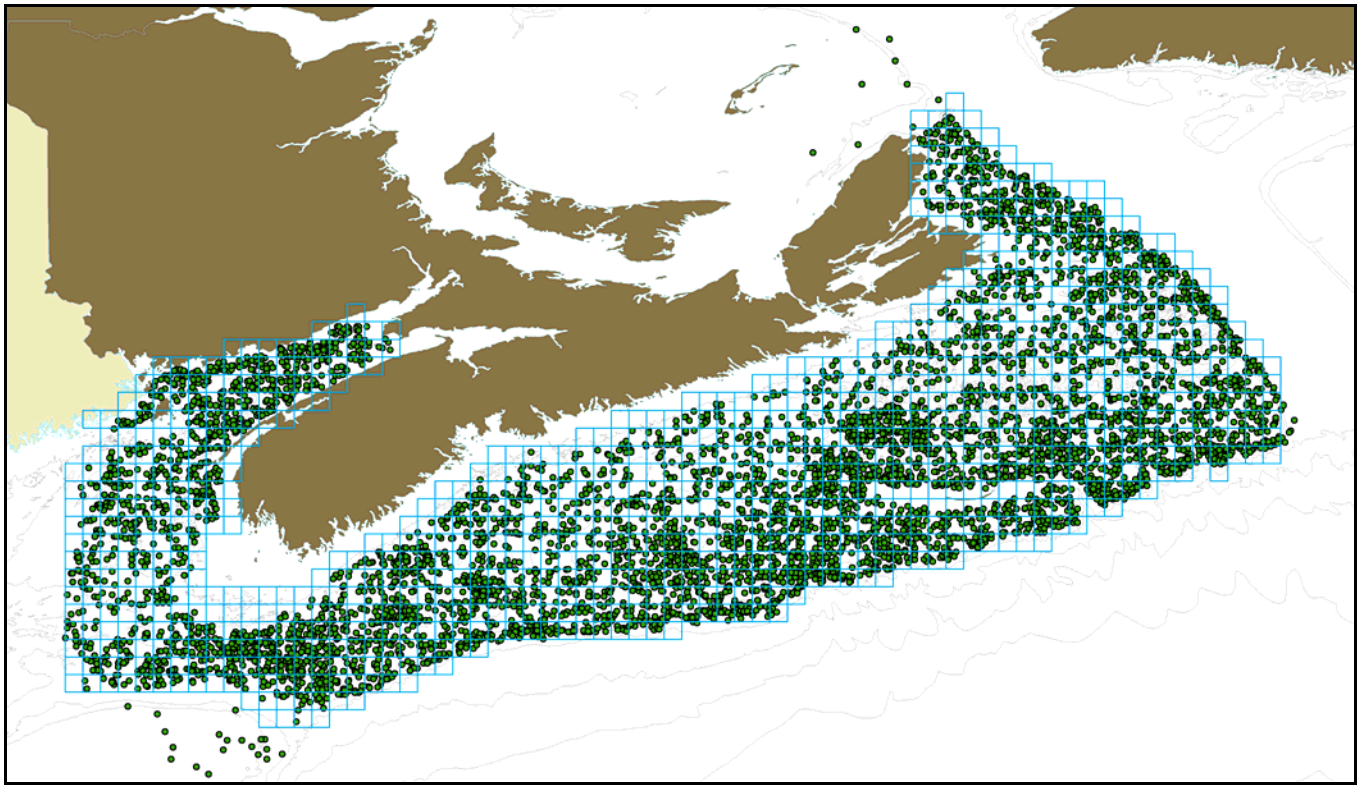


Figure 2. Map shows a 0.15 degree grid cell (blue squares) relative to the location of the trawl sets during the period from 1970 to 2006 (inclusive).

IDW is an interpolation technique that fits the source data accurately and preserves local anomalies in the interpolation grid. In contrast, Kriging techniques assume the source data have regionalized errors of

estimation and generalize the data to minimize estimation variance. Kriging tends to eliminate local anomalies from the interpolation grid to portray a more general trend for the data. For this exercise, we decided to use the technique that would preserve local anomalies where they are observed.

2.2.4 Mapping Procedure for the Identification of Important Habitat

We evaluated important habitat for each of the key species by assessing the persistence of relatively high observed biomass in space over the entire time period of the data. Relative biomass in each time period was assessed by classifying the interpolated distribution into 10 quantile breaks, where for example the 10^{th} class break represents the top 10% of areas where the species is observed. This method allows us to ignore population trends and simply determine, regardless of population status, where the areas of highest biomass are located. We propose that in general areas persistently ranked high are important habitat for these species. These areas were determined by using simple spatial algebra to combine the four time blocks for each species. Precedence for this type of analysis to identify important or critical habitat can be found in Keith (2005).

For each species, our procedure was as follows:

1. **Extracted data:** Data for each of the key species were extracted from the Summer RV Survey data (1970-2006), including null values.
2. **Interpolated data:** From this, Inverse Distance Weighted (IDW) interpolations of the observed weight for each species were created for four periods representing different fishery management regimes (1970-1977, 1978-1985, 1986-1993, 1994-2006) (Figure 3). Parameters for the IDW interpolation were as described in Section 2.2.3.
3. **Classified interpolated data into deciles:** Each of four maps for was classified into 10 percentile classes using the "Quantile breaks" ArcGIS® tool. Zero and null values were excluded from the classification. Note: The quantile breaks tool defines the breaks by area (i.e., of the total area where a species is observed).
4. **Assigned ranks:** The maps where then reclassified (ranked) with a value of 1 through 10; where 1 represents the observations in the 1^{st} decile ($1\text{-}10^{th}$ percentile), 2 represents the 2^{nd} decile (11^{th}-20^{th} percentile), and so on up to 10 which represents areas with the 91^{st}-100^{th} ranked observations (Table 3) based on interpolation of the observed weight per tow.
5. **Summed ranks over time:** The four resulting ranked maps were added together to create a picture of the continuity of the area as important habitat for the species. So for example if an area had a score of 10 in each time block, the final score would be 40 (10+10+10+10 = 40) and reflect that a relative high biomass of that species had always been found in the area.

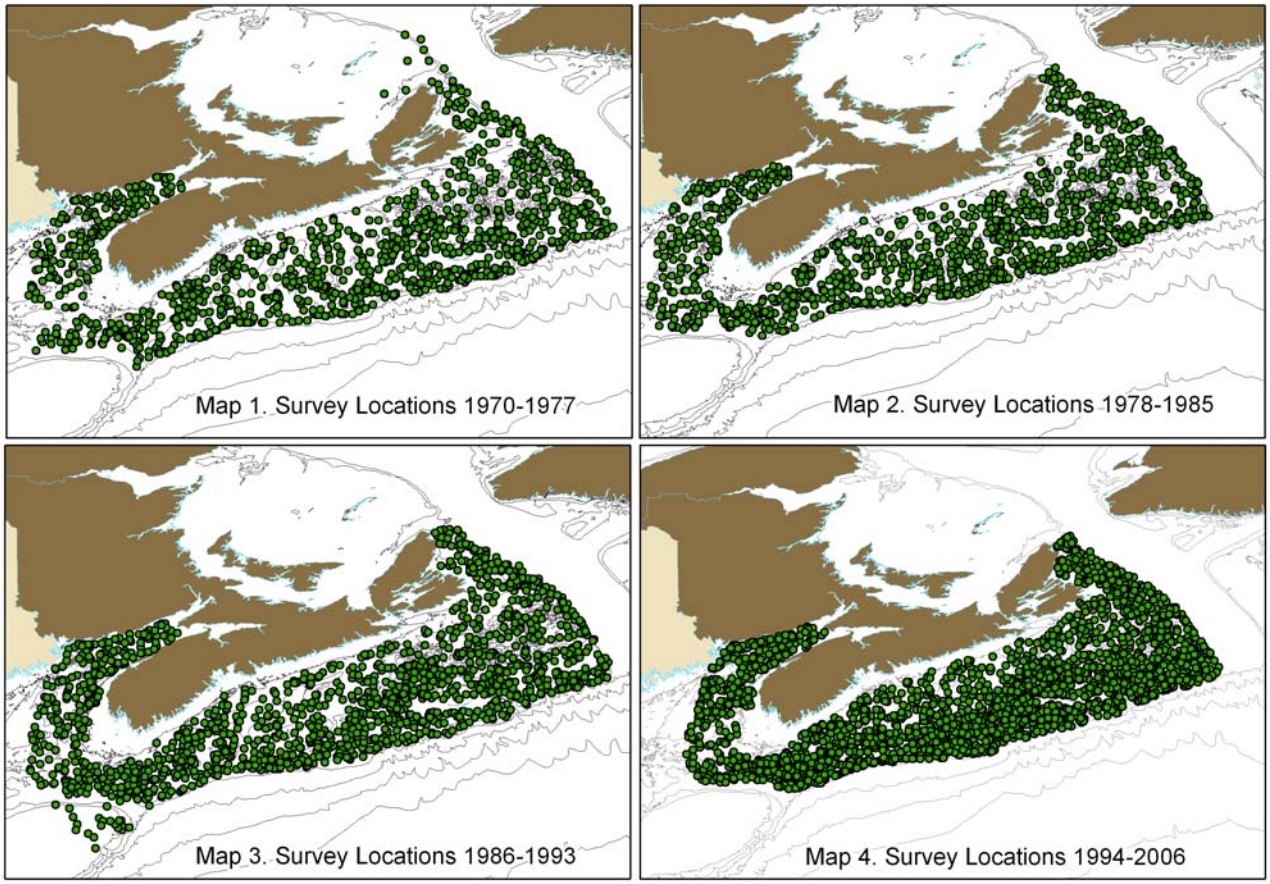


Figure 3. Map shows trawl set locations in the four time periods evaluated. Data for observed weight from these trawls were used in the interpolation of the observed weight for each species.

Table 3. Quantile Break Scores

Percentile	Score
<=10th	1
11-20th	2
21-30th	3
31-40th	4
41-50th	5
51-60th	6
61-70th	7
71-80th	8
81-90th	9
91-100th	10

Note that in each period the quantile break scores reflect the relative spatial distribution of biomass and not the absolute. This allows the reader to identify the areas where the species is consistently sampled regardless of absolute biomass. To assess the population status, the maps are accompanied by the temporal trend in biomass and abundance for each species.

2.3 Trends in the Trawl Survey Catch for Key Species

The stratified mean number per tow (abundance) and mean weight per tow (biomass) are shown on each species page as "Figure 1. Population Trends". Note that each y-axis is scaled to the data. Stratified estimates were extracted from the DFO Virtual Data Centre (http://marvdc.bio.dfo.ca/pls/vdc/mwmfdweb.splash).

2.4 Larval Fish Distributions

For comparison with the distribution of adult fish, when possible, we have included maps (Map 6 for each species) that indicate the distribution of larval fish from the SSIP data collected by DFO. For these maps the average number of individuals observed in a standardized volume is plotted. From these point data a fixed kernel density estimate was calculated using Hawth's Tools (Beyer 2008), a freely available software extension for ArcGIS® (http://www.spatialecology.com/htools/index.php). Subsequently the tool was used to plot contours that identify the percentage of the observed data, in our case 80% and 95% of the total number of individual larval fish.

2.4.1 Scotian Shelf Ichthyoplankton Programme (SSIP)

The data used in this study were collected on the Scotian Shelf from 1978 to 1982 as part of the SSIP. Only larval stage data from the original SSIP data set were used in our analyses. The SSIP was designed to collect temporal and spatial information about fish eggs and larvae on the Scotian Shelf. The survey used a standard sampling design on a transect grid. An oblique Bongo tow with a 333-mm-mesh net was typically deployed for around 30 min. The total volume filtered was measured by flowmeters attached to the Bongo net at tow depths that ranged from 23 to 247 m, averaging 112 m. The ranges of sampling depth were comparable across months. Samples stored in 5% formalin were identified and catalogued at the Huntsman Marine Laboratory, St. Andrew's, New Brunswick, Canada. Additional information on the SSIP survey design can be found in O'Boyle *et al.* (1984).

2.4.2 Mapping Procedure for Larval Fish

Larval fish from the SSIP data were mapped by sampling locations aggregating the sampling location to one eighth of a degree or 7.5 arc minutes of latitude and longitude. If SSIP data were available for the species of interest, we used a kernel density mapping tool to plot the 80% and 95% contours of total

observed abundance for the species. Hawth's Tools, which is an extension for ArcGIS® software, (http://www.spatialecology.com/htools/index.php) was used to perform this analysis.

3.0 Results – Important Habitat and Population Trends

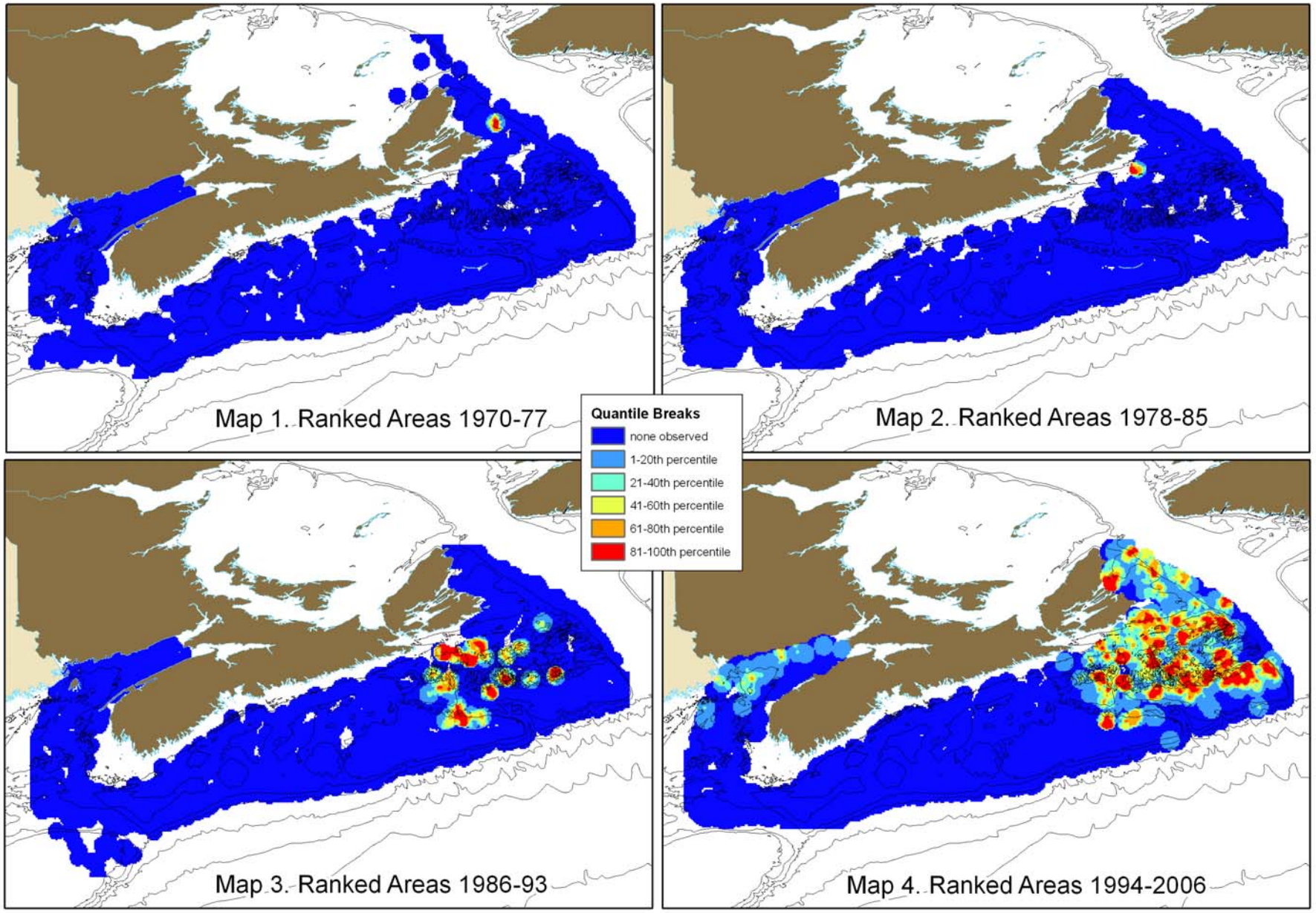
The following information describes how the maps of species distributions should be interpreted.

In each of the four time periods (Maps 1 to 4 for each species), areas where sampling occurred but where the species was not observed (within the search radius of the interpolation) are displayed in dark blue, whereas areas with no colour were not sampled (or within the search radius of the interpolation).

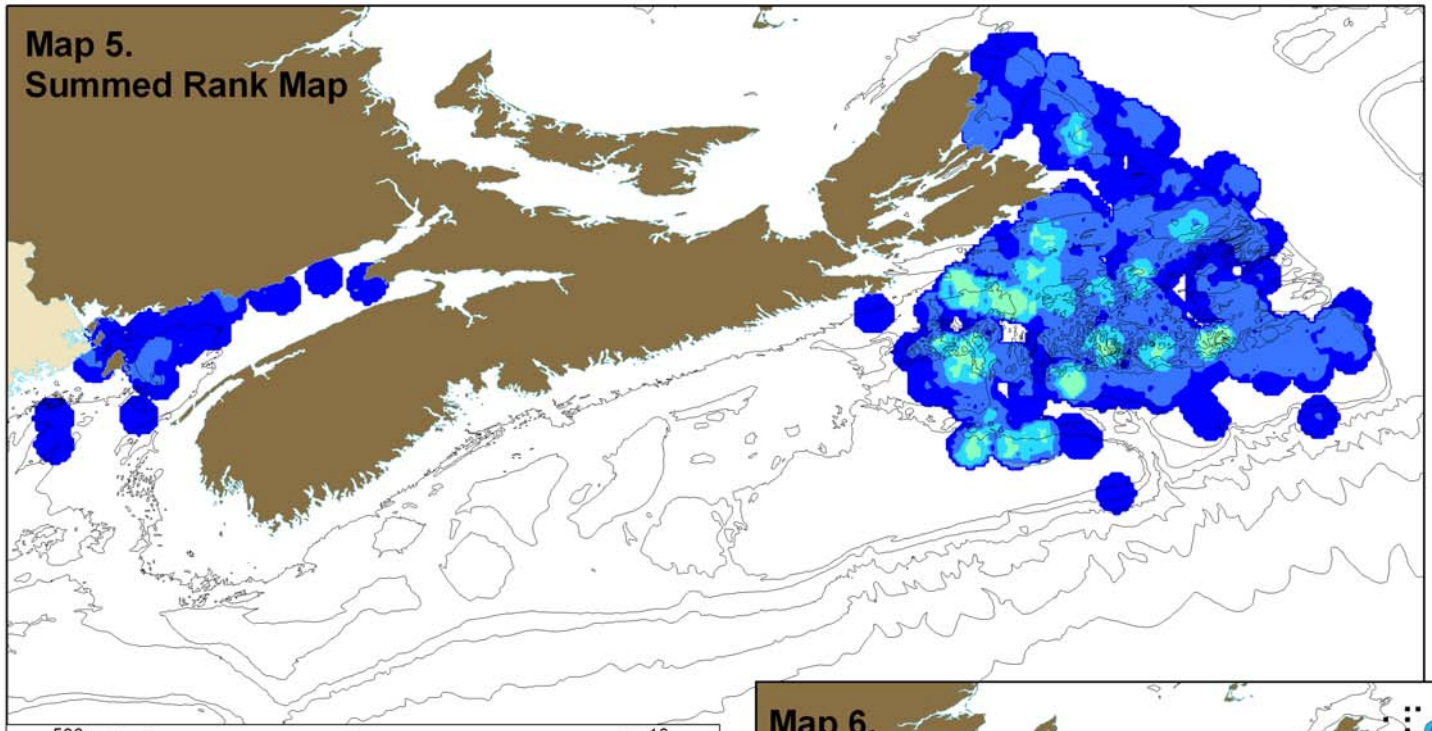
On the summed rank maps (Map 5 for each species) only areas where the species was observed appear. On these maps areas where the species was rarely observed are indicated in dark blue. Areas in dark orange to red on these maps are areas where the species has been observed in large amounts (biomass) in each of the four time periods.

3.1 Forage Species

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for the these species identified as important forage species for the Scotian Shelf: Capelin *(Mallotus villosus);* Herring *(Clupea harengus);* Mackerel *(Scomber scrombus)*; Sandlance *(Ammodytes dubius);* Northern Shortfin Squid *(Illex illecebrosus)*; Witch Flounder (*Glyptocephalus cynoglossus).*



Capelin (*Mallotus villosus*)



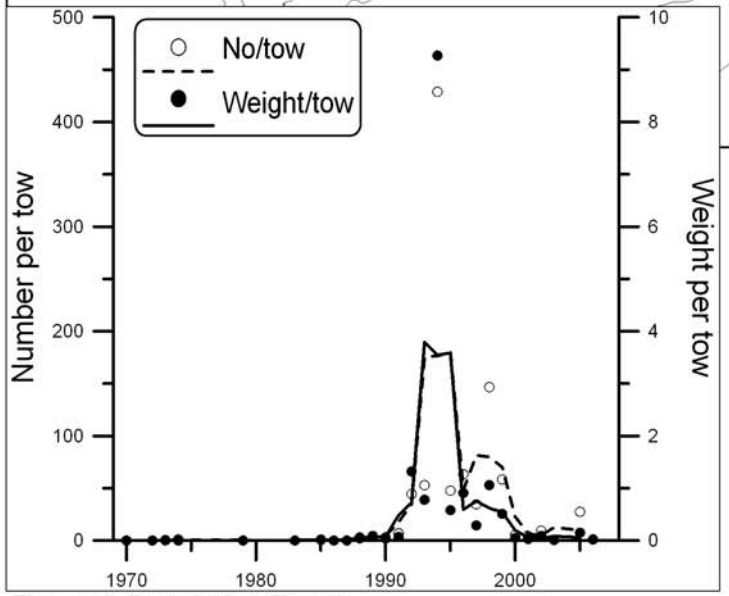
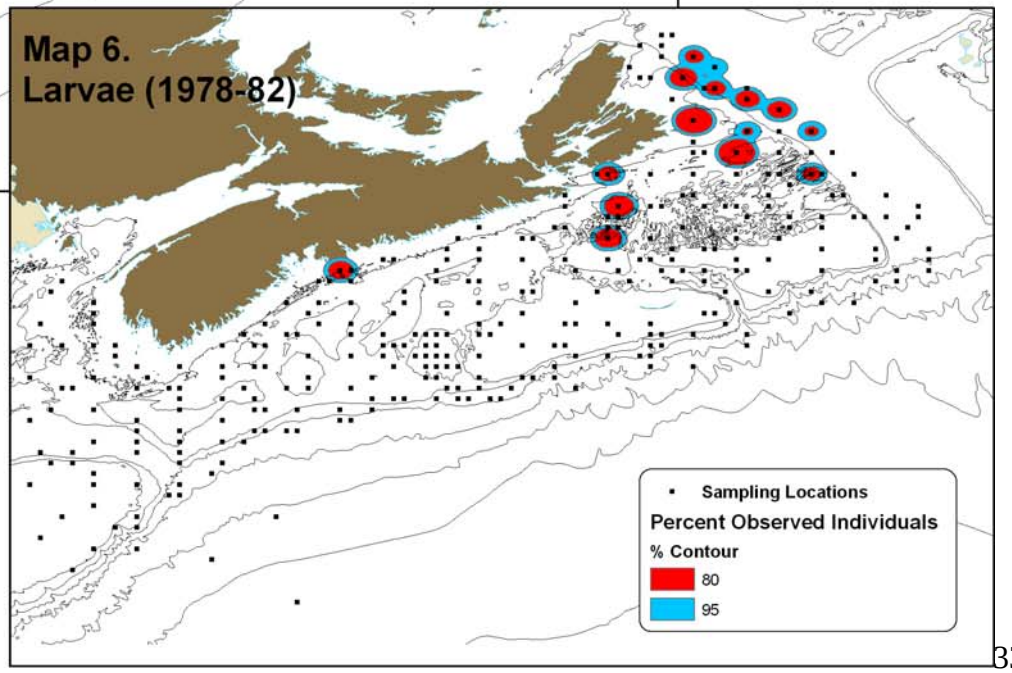
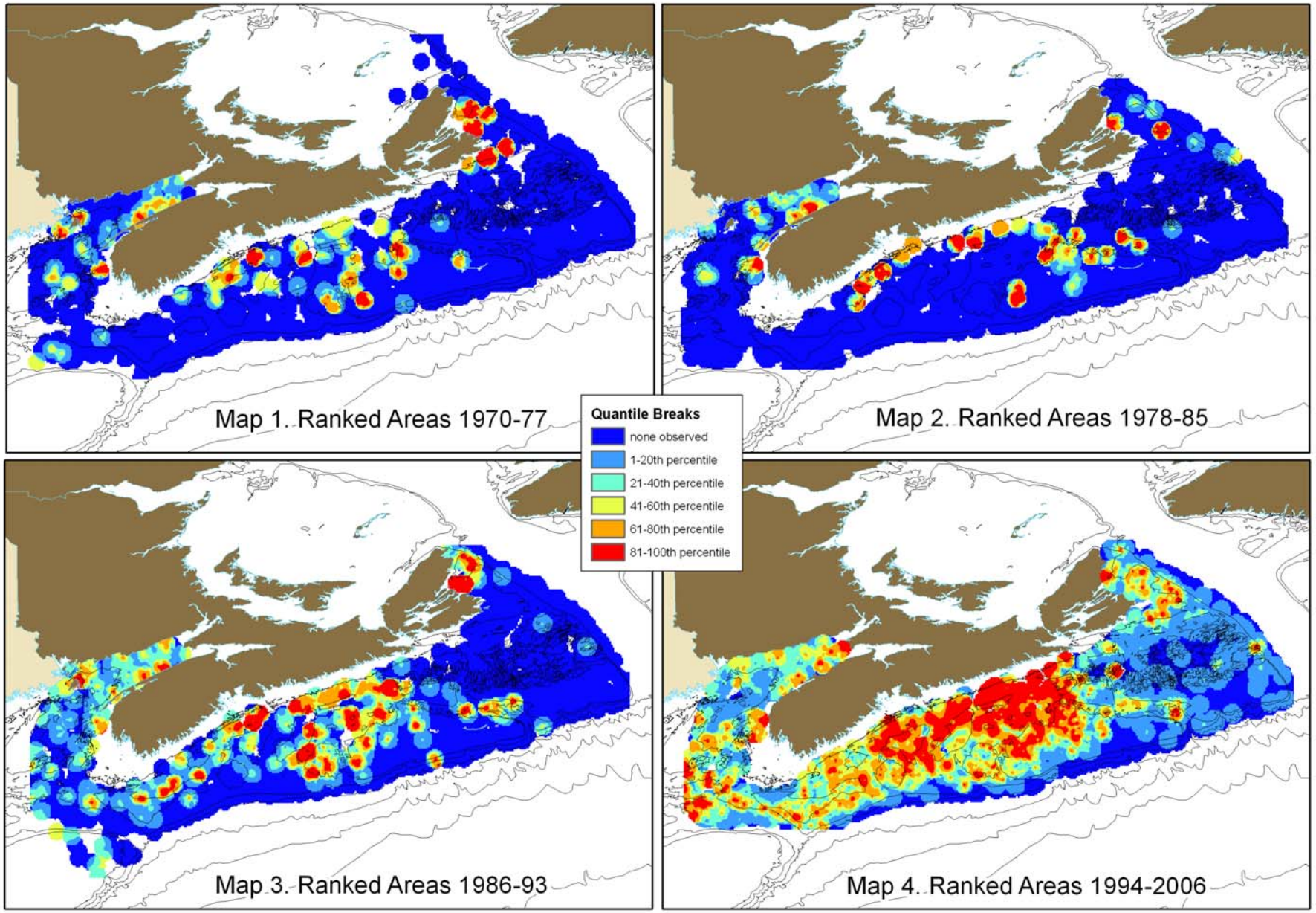
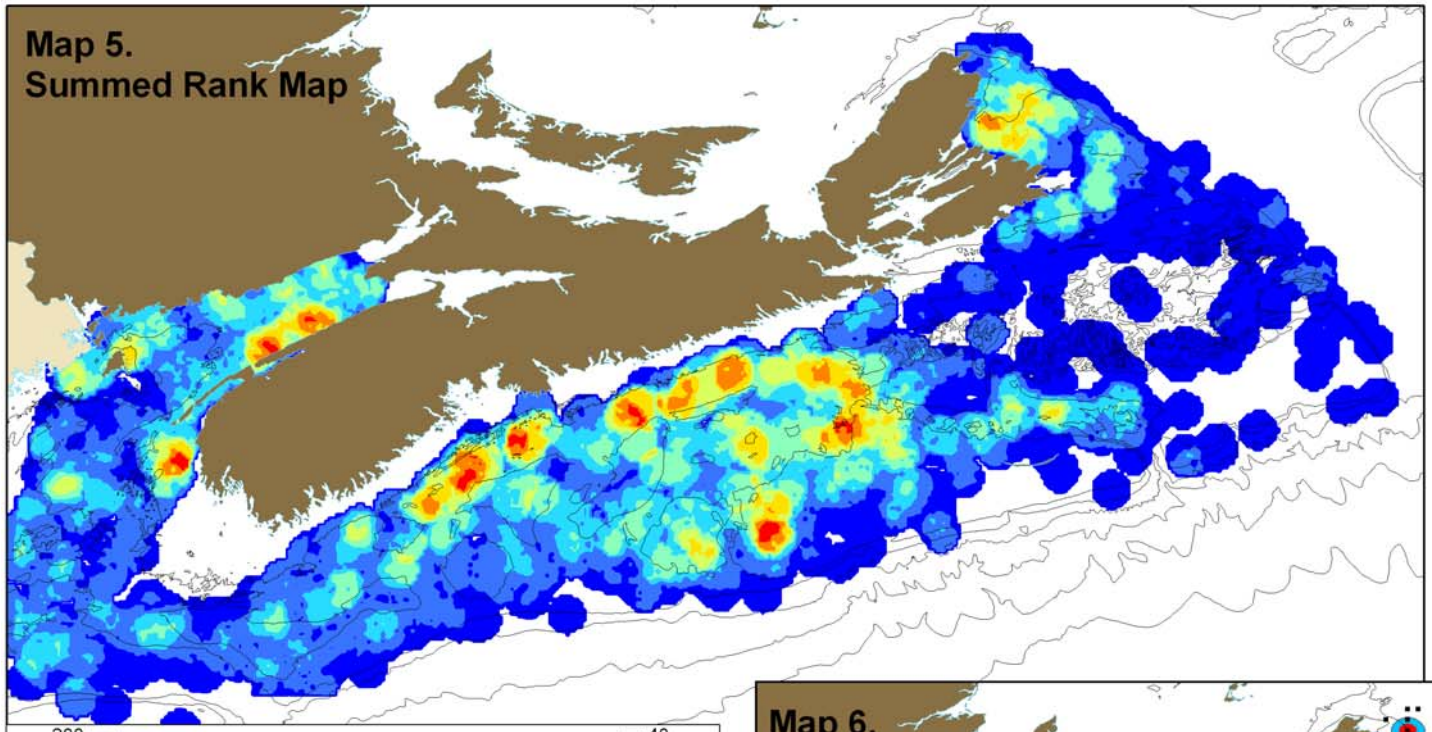


Figure 1. Population Trend





Herring (*Clupea harengus*)



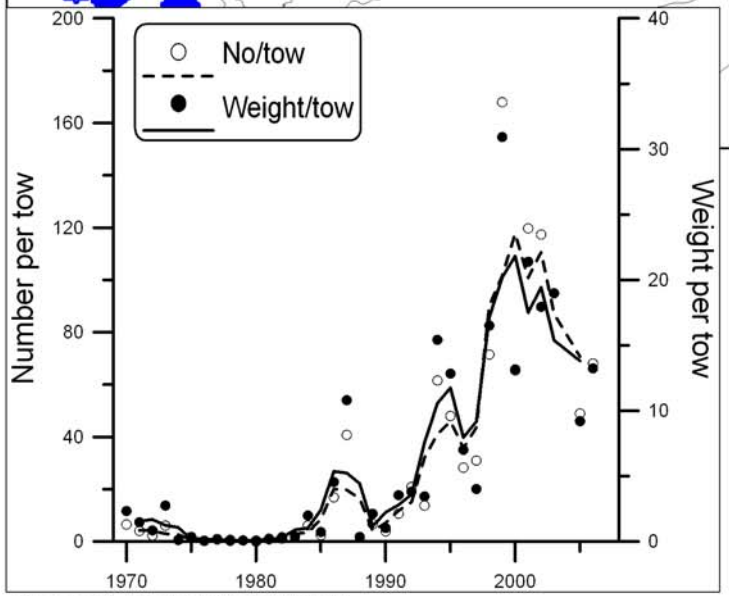
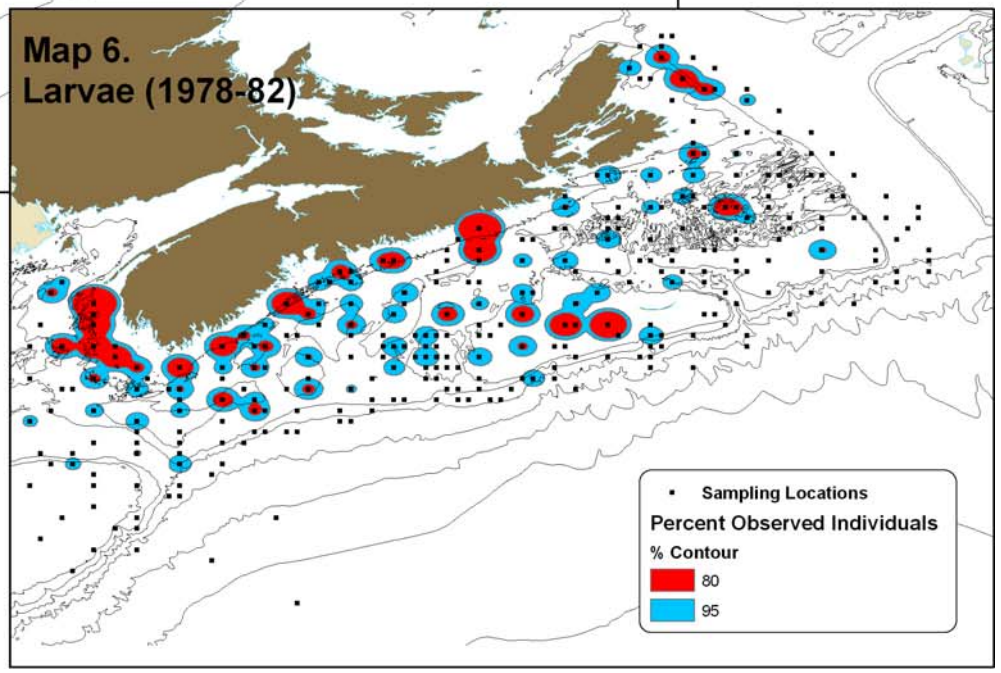
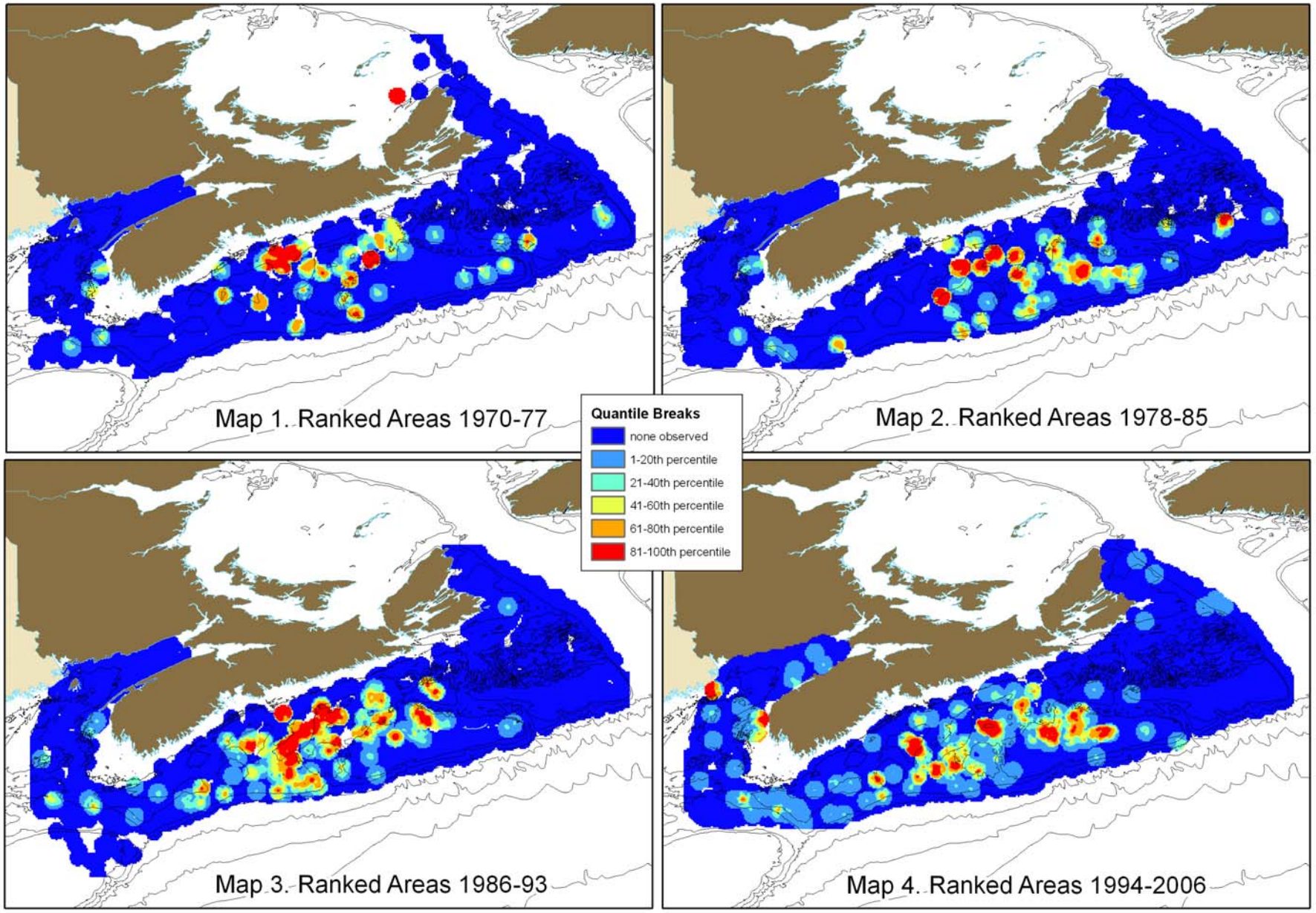
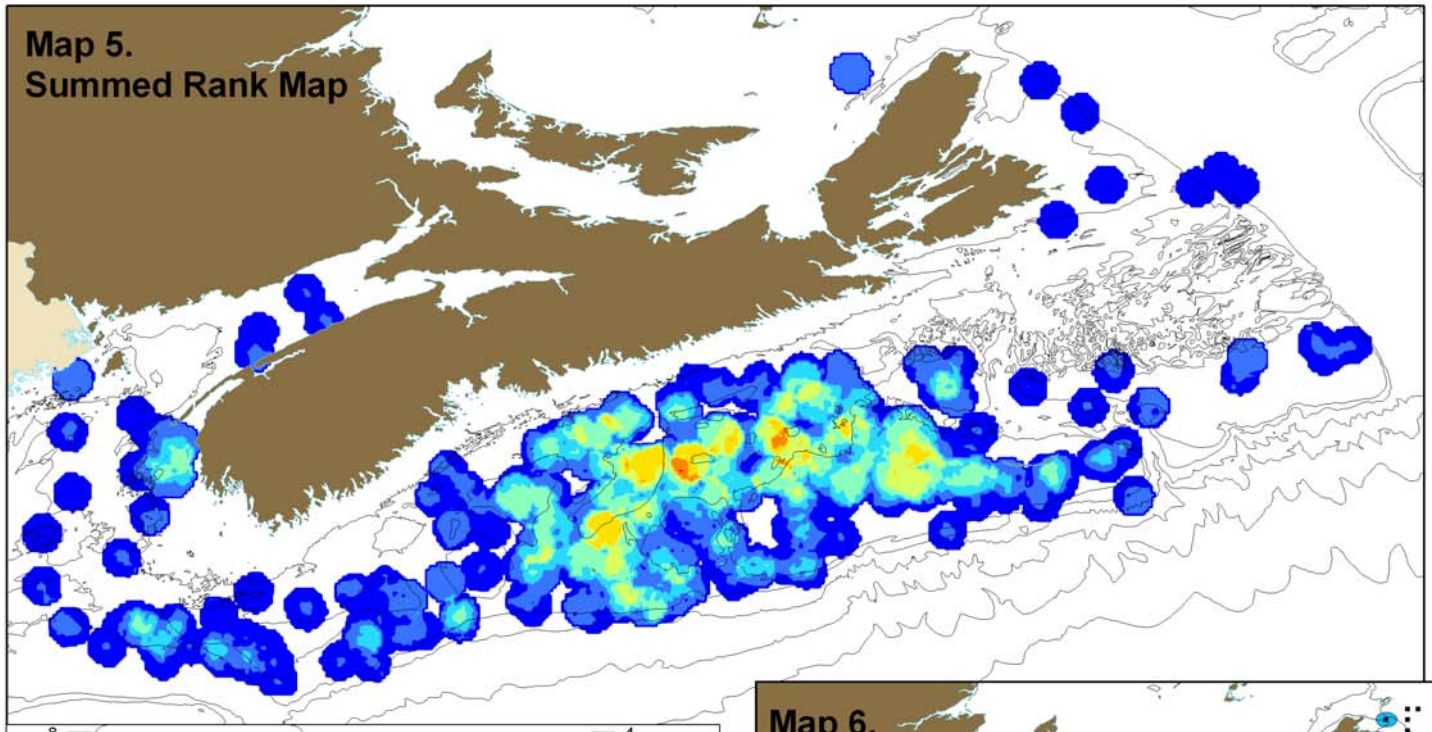


Figure 1. Population Trend





Mackerel (*Scomber scombrus*)



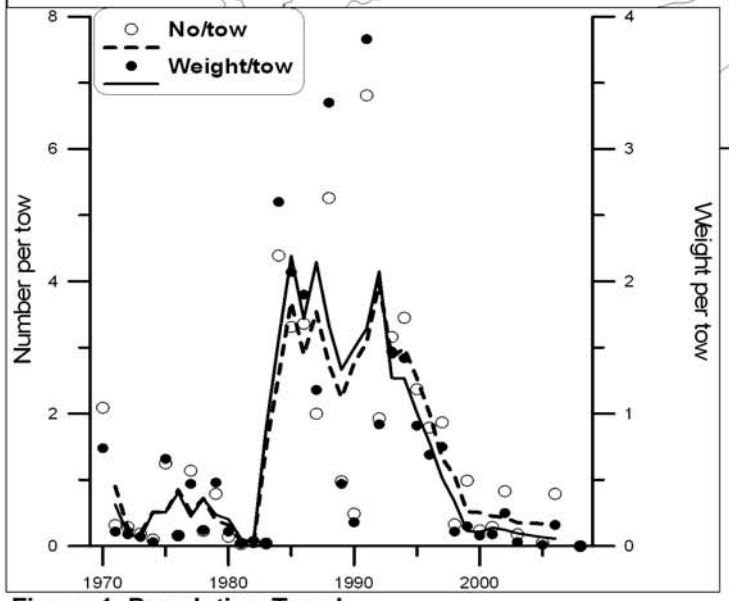
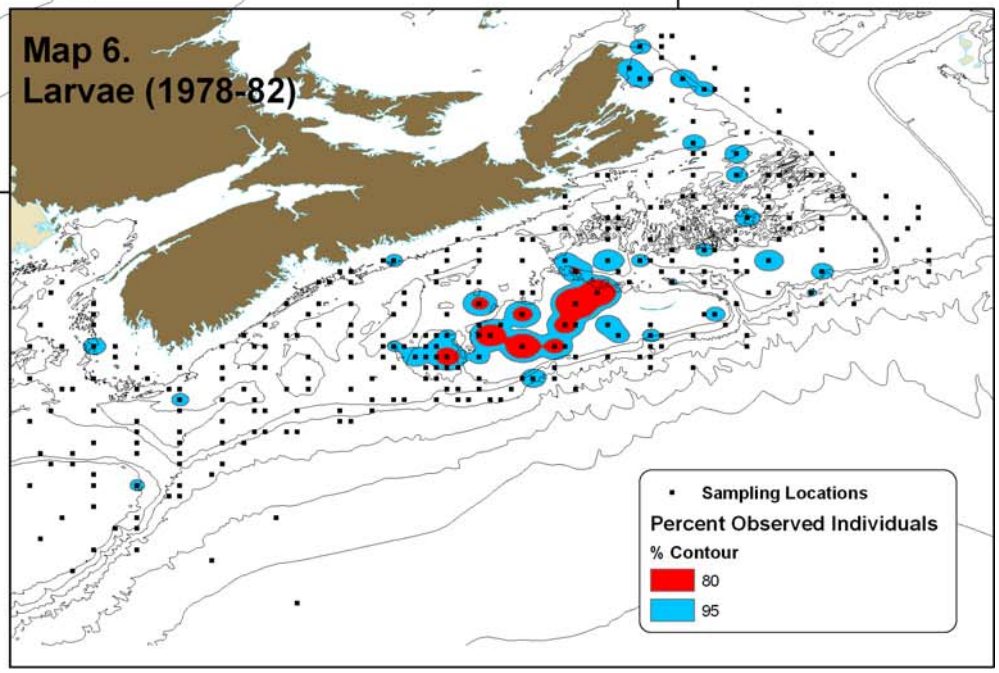
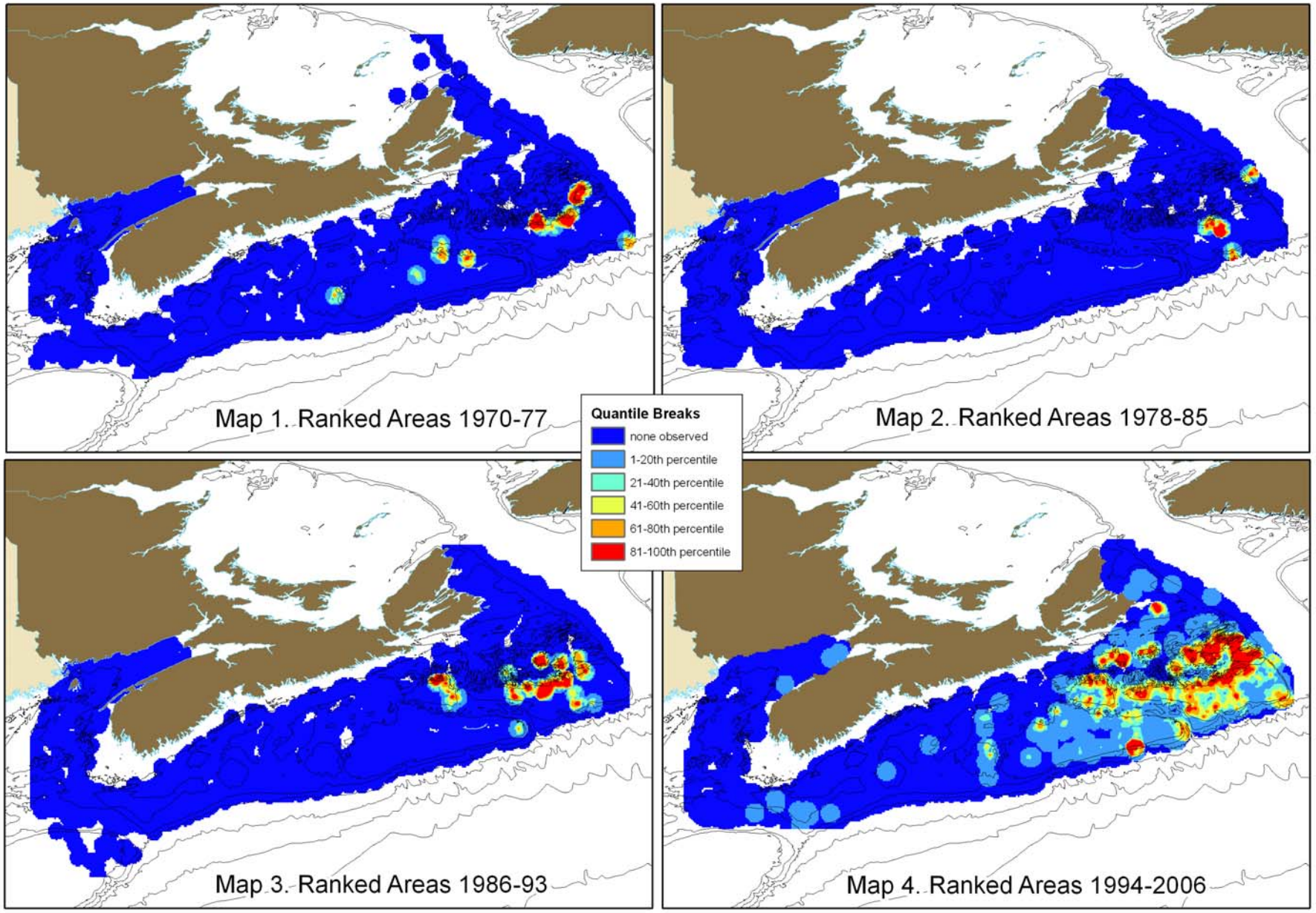


Figure 1. Population Trend





Sandlance(*Ammodytes dubius*)

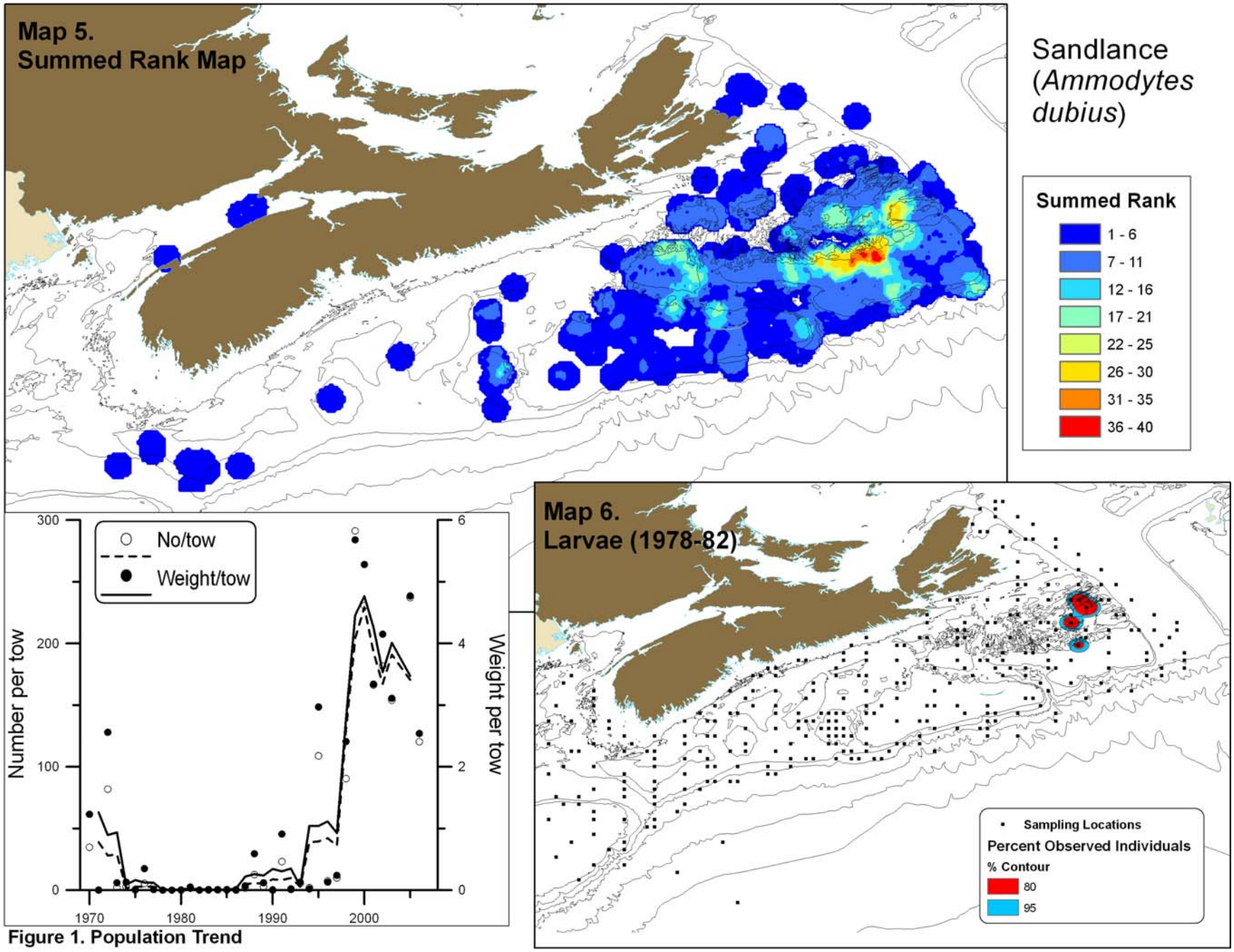
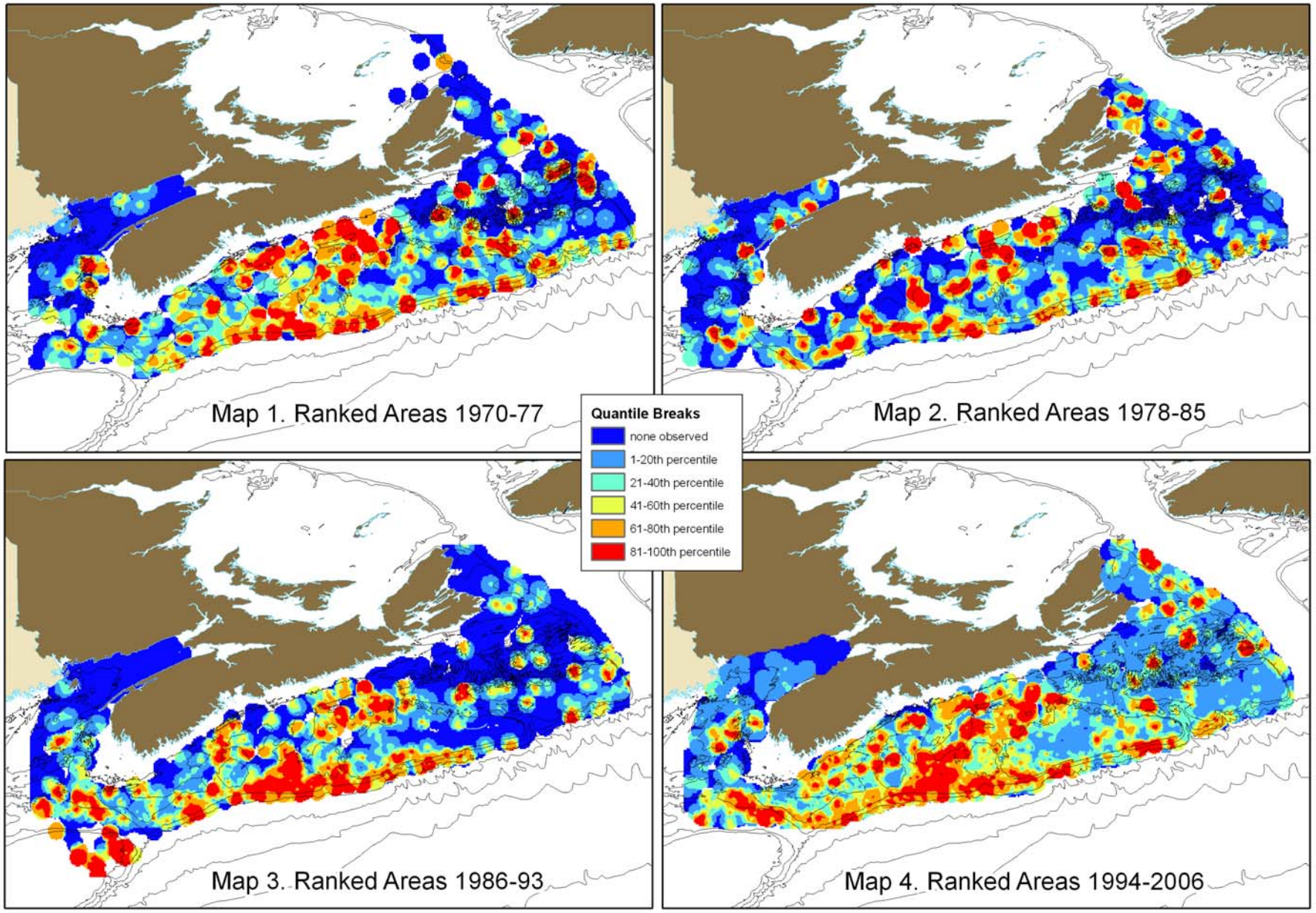


Figure 1. Population Trend



Northern Shortfin Squid (*Illex illecebrosus*)

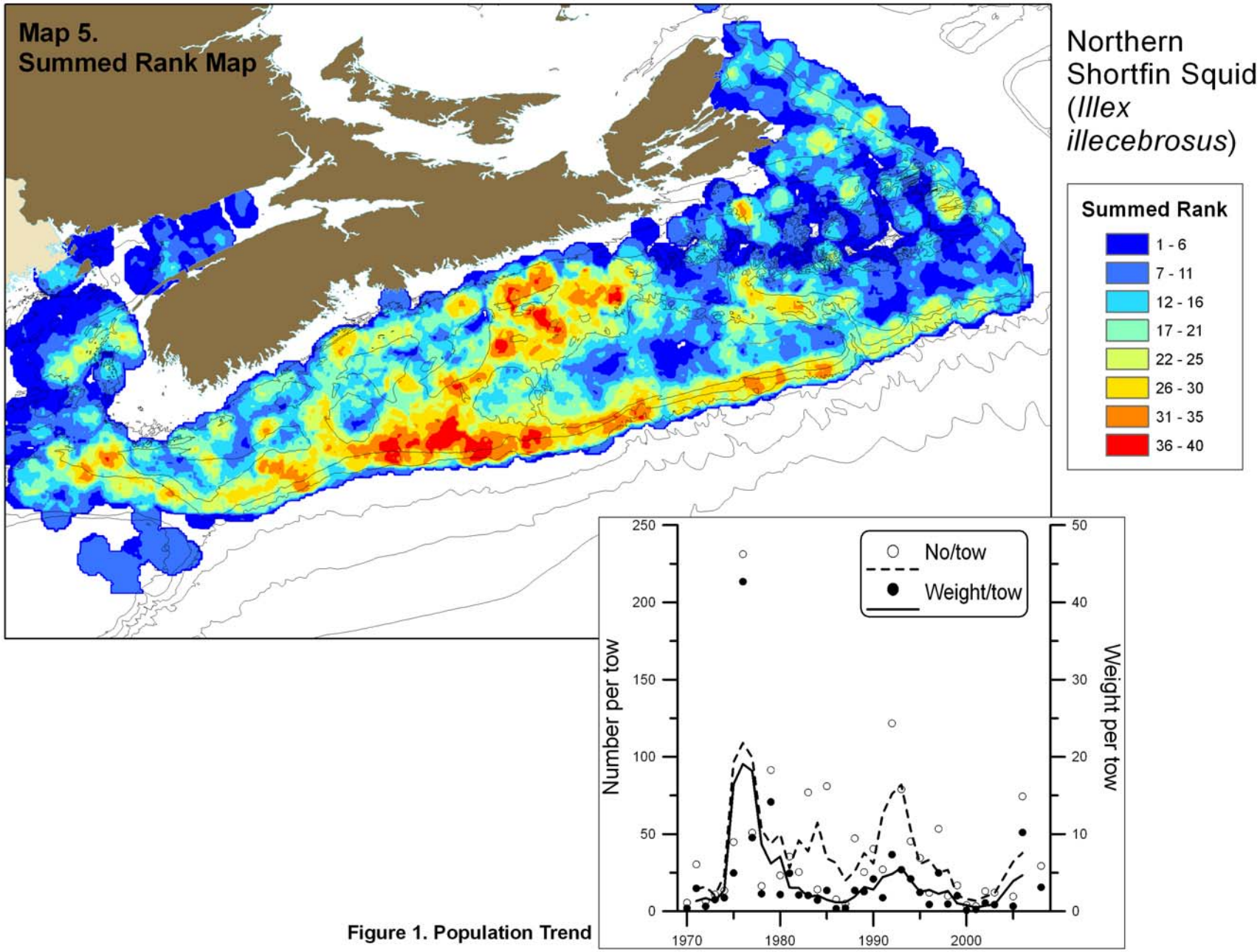
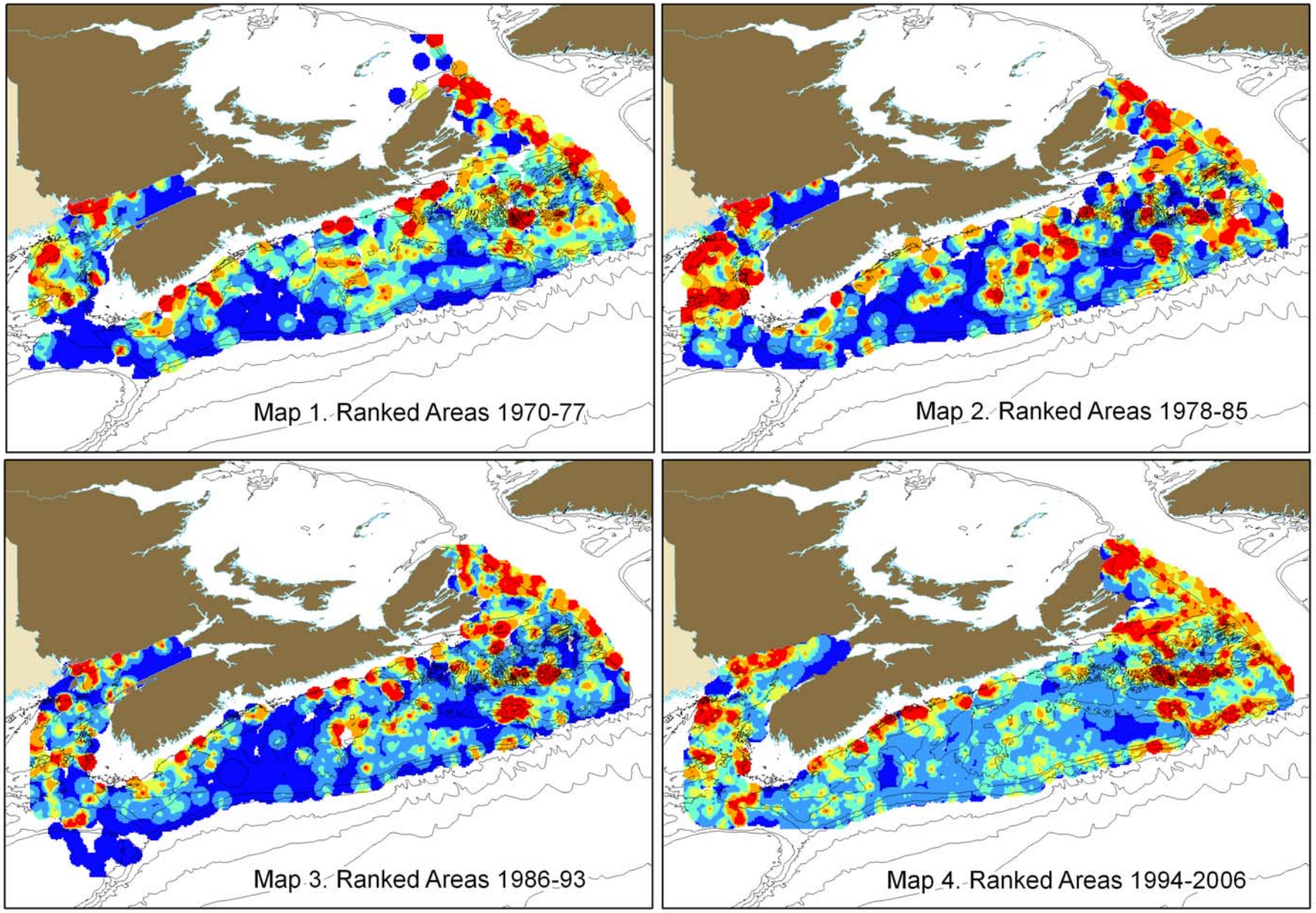
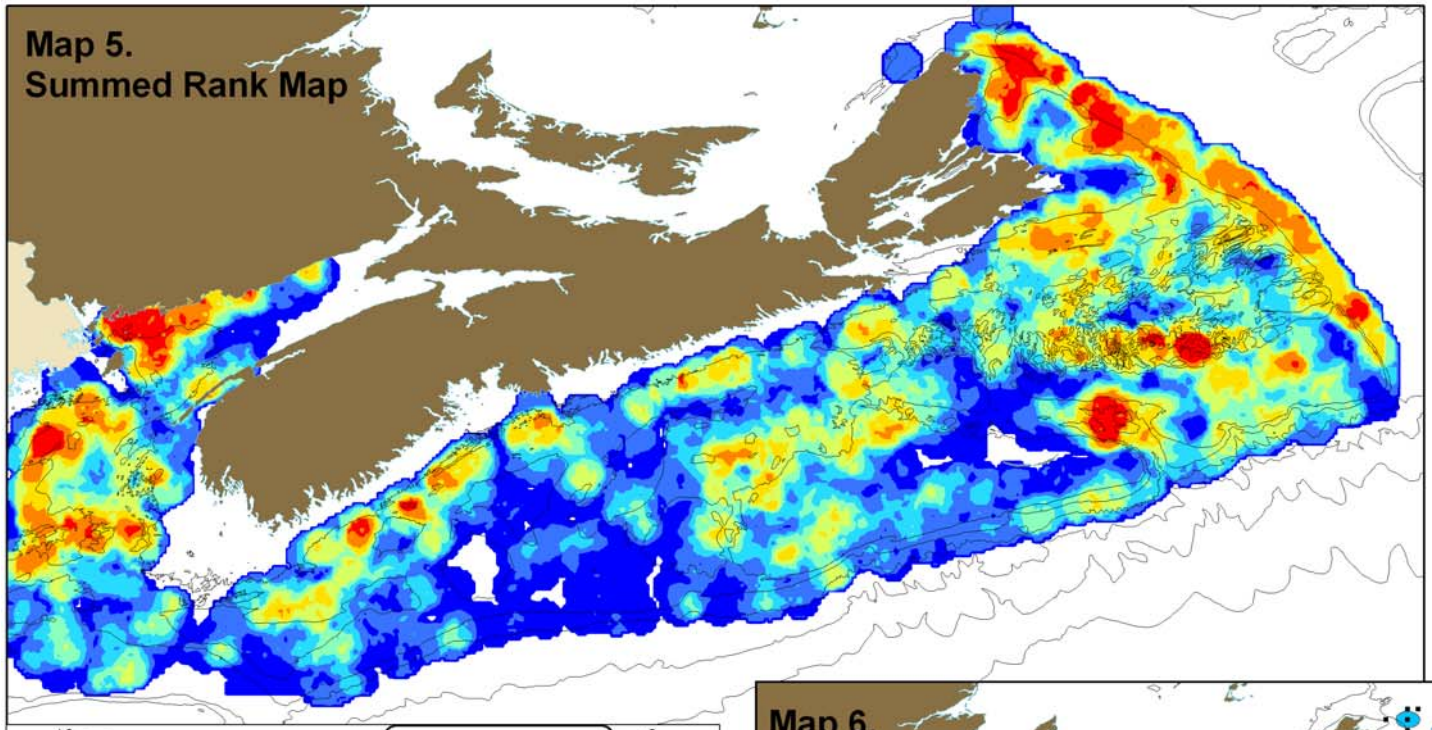


Figure 1. Population Trend



Witch Flounder (*Glyptocephalus cynoglossus*)



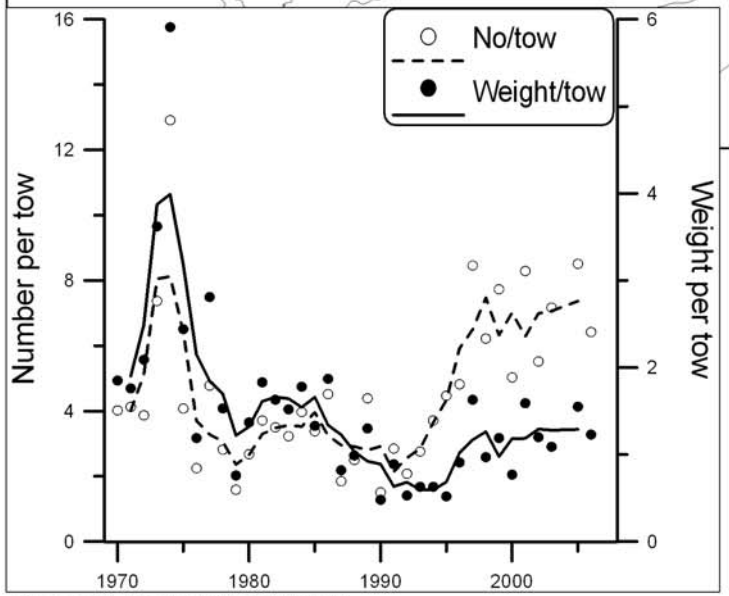
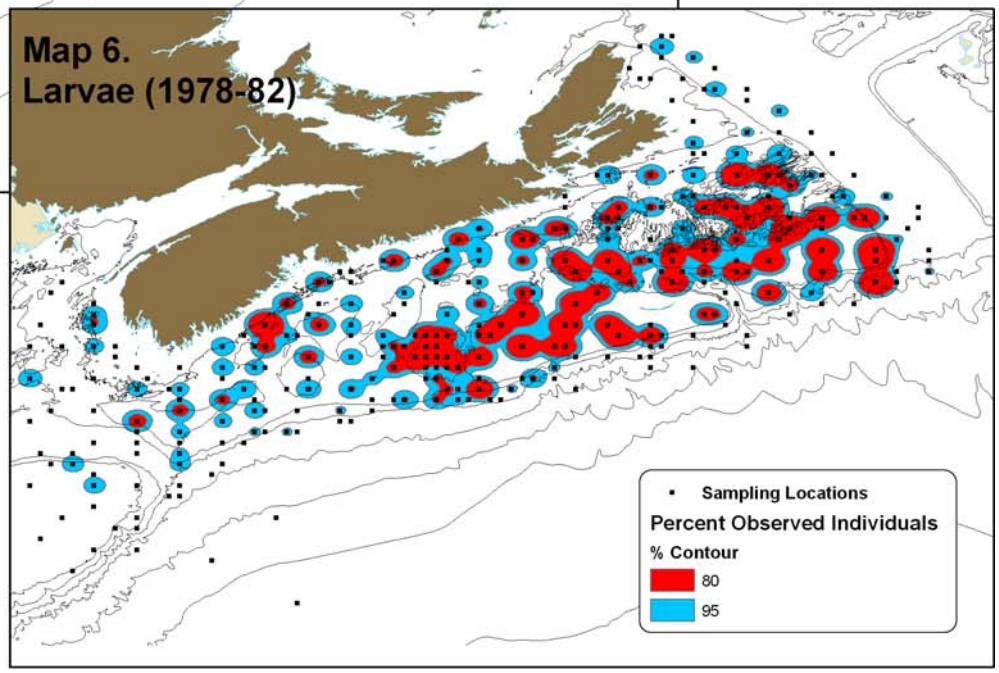


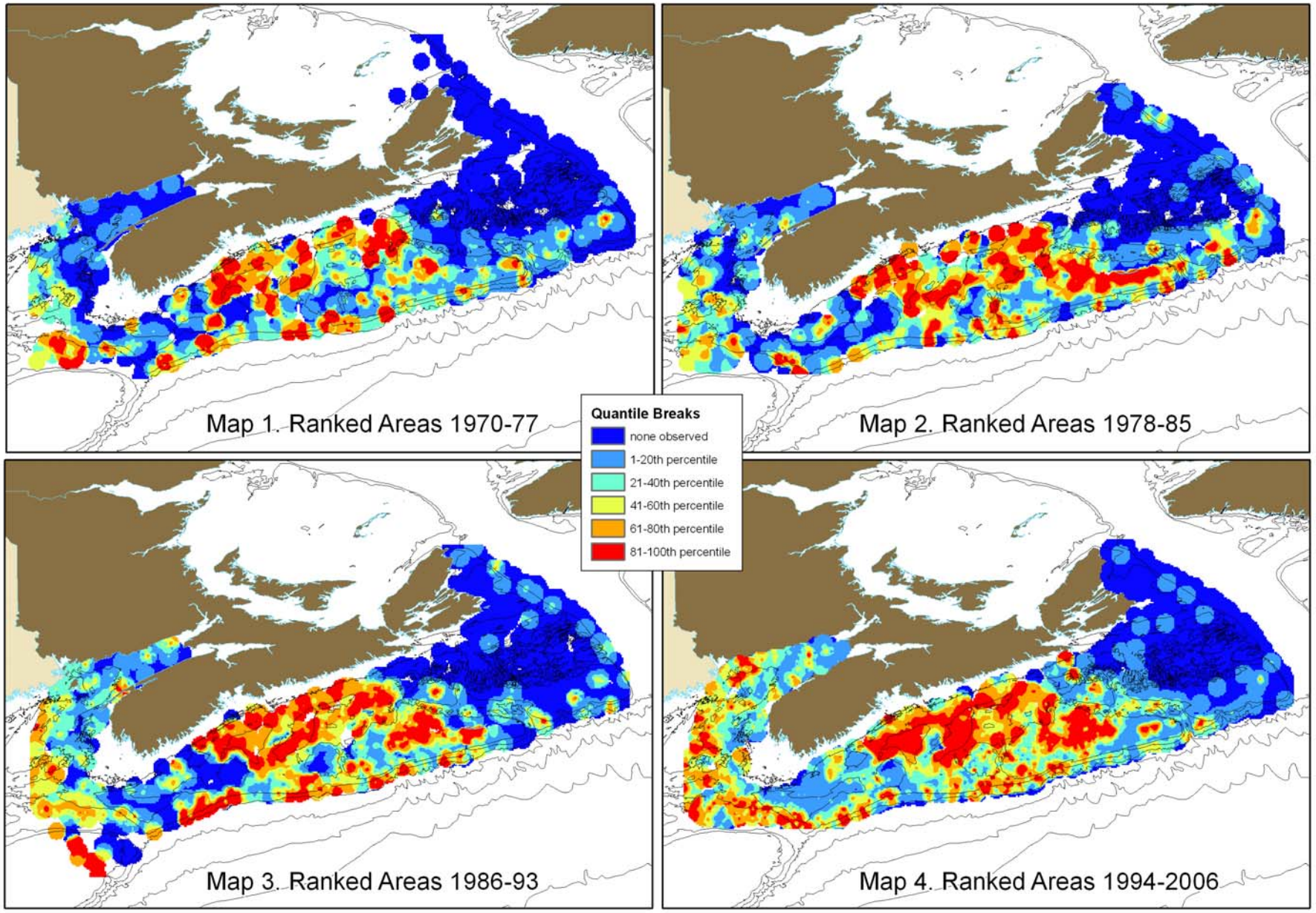
Figure 1. Population Trend



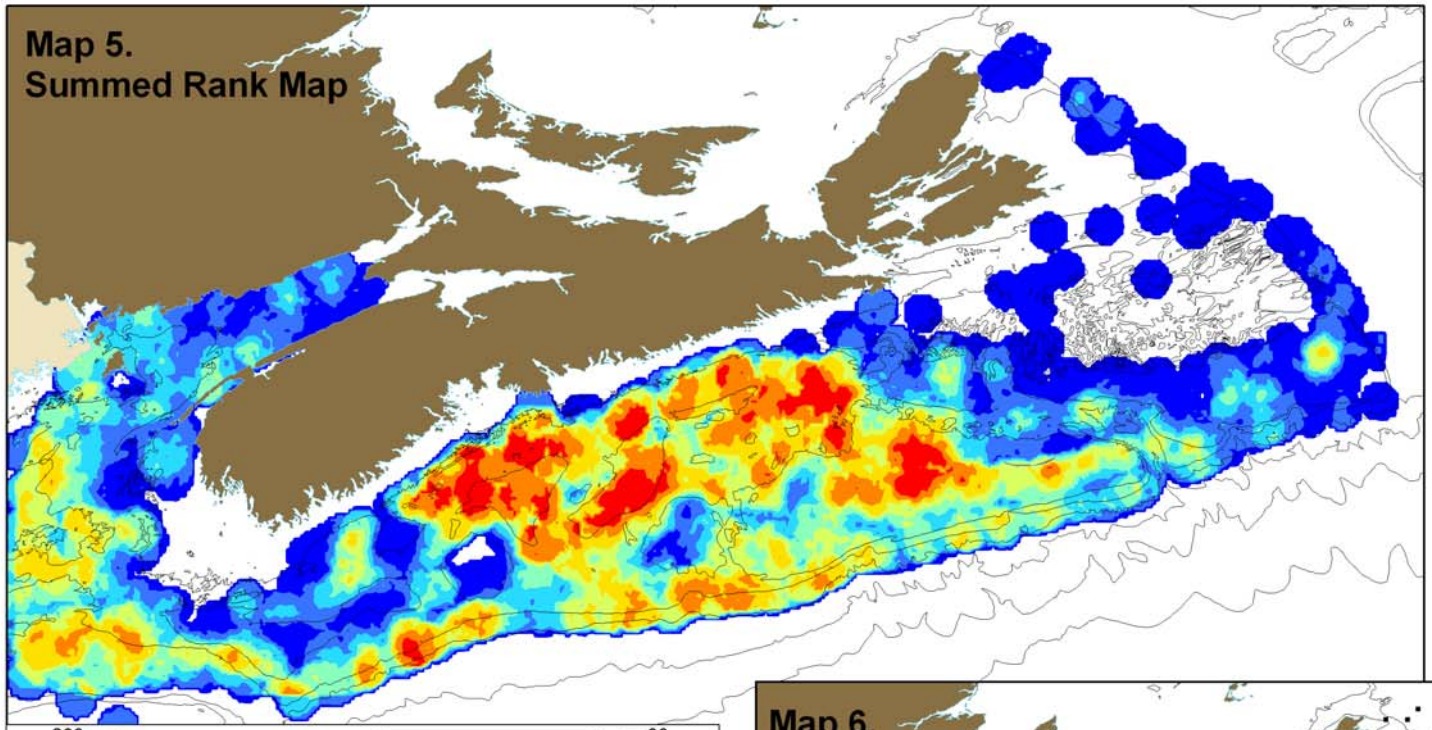
This page was left blank intentionally.

3.2 Influential Predators

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for the these species identified as influential predators for the Scotian Shelf: Silver Hake (*Merluccius bilinearis*); American Plaice (*Hippoglossoides platessoides*); Atlantic Cod (*Gadus morhua*); Haddock (*Melanogrammus aeglefinus*); Atlantic Halibut (*Hippoglossus hippoglossus*); Longhorn Sculpin (*Myoxocephalus octodecemspinosus*); Pollock (*Pollachius virens*); Red Hake (*Urophycis chuss*); Redfish (*Sebastes* spp.); Smooth Skate (*Malacoraja senta*); Spiny Dogfish (*Squalus acanthias*); White Hake (*Urophycis tenuis*); Winter Skate (*Leucoraja ocellata*).



Silver Hake (*Merluccius bilinearis*)



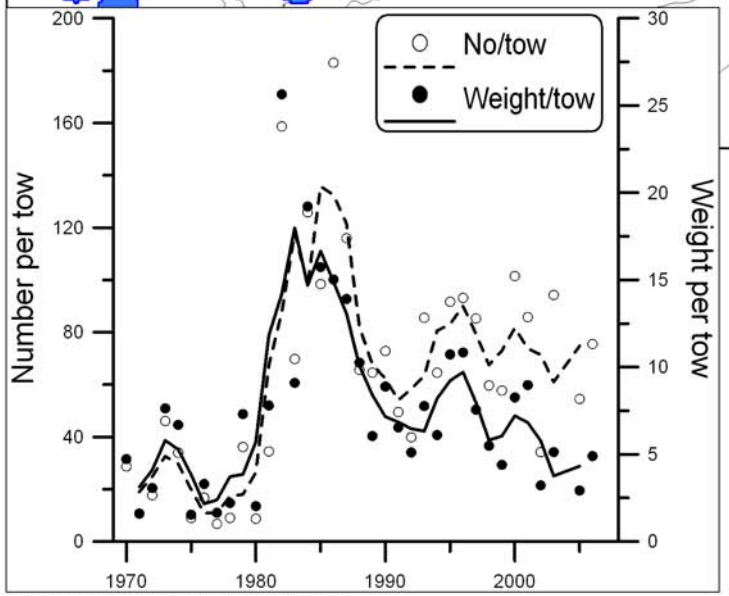
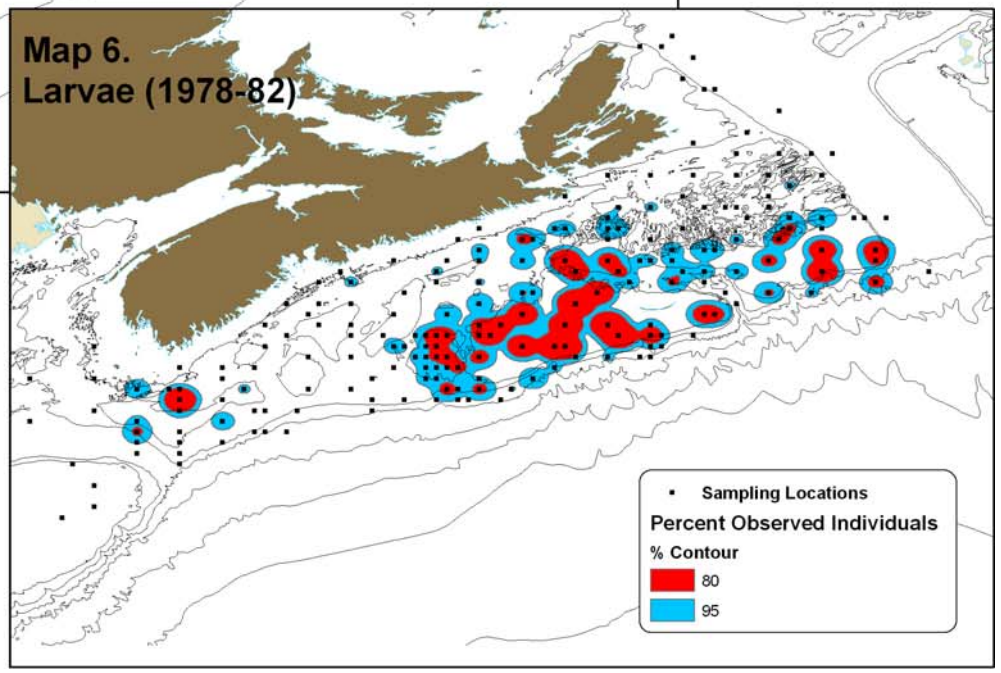
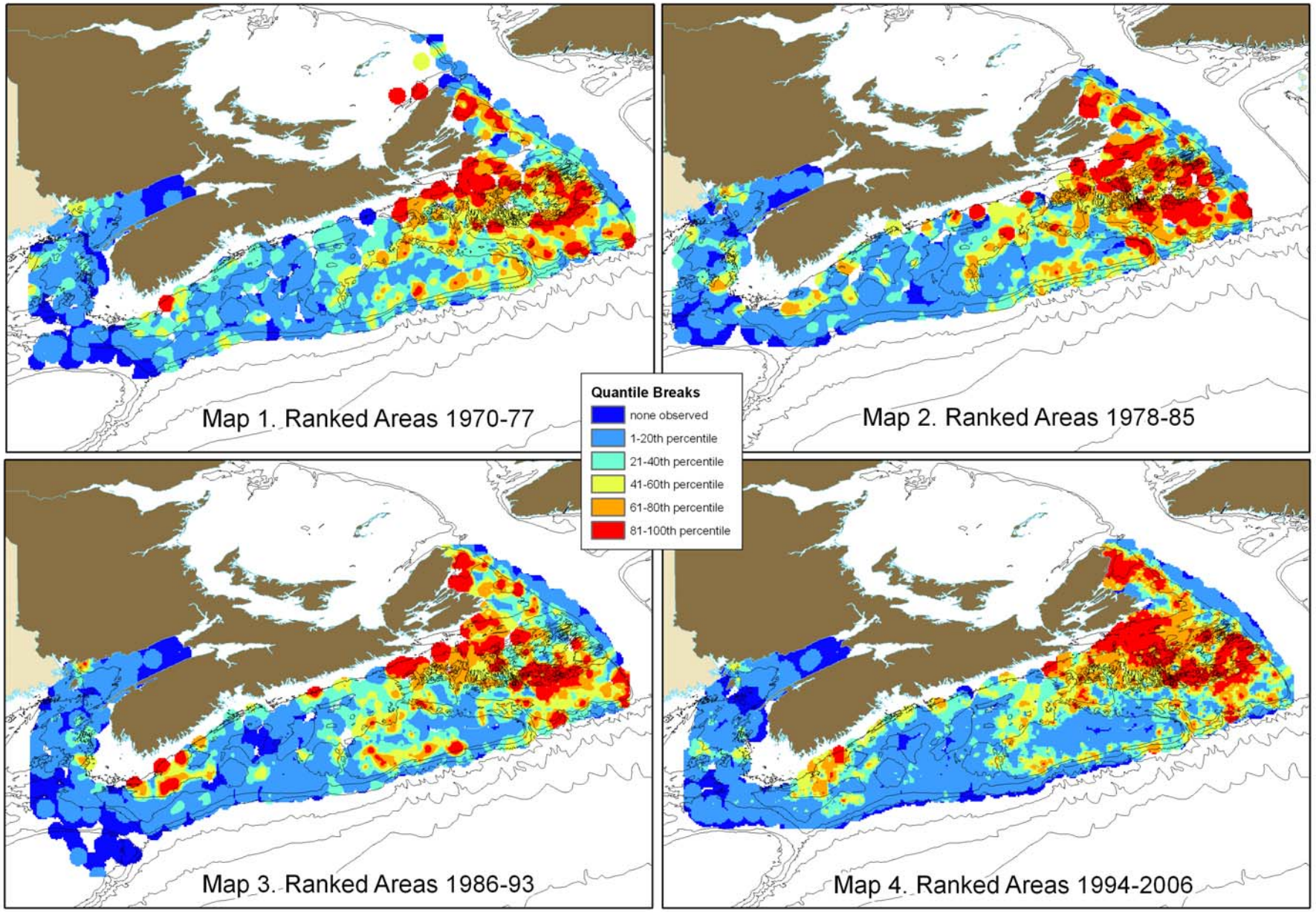
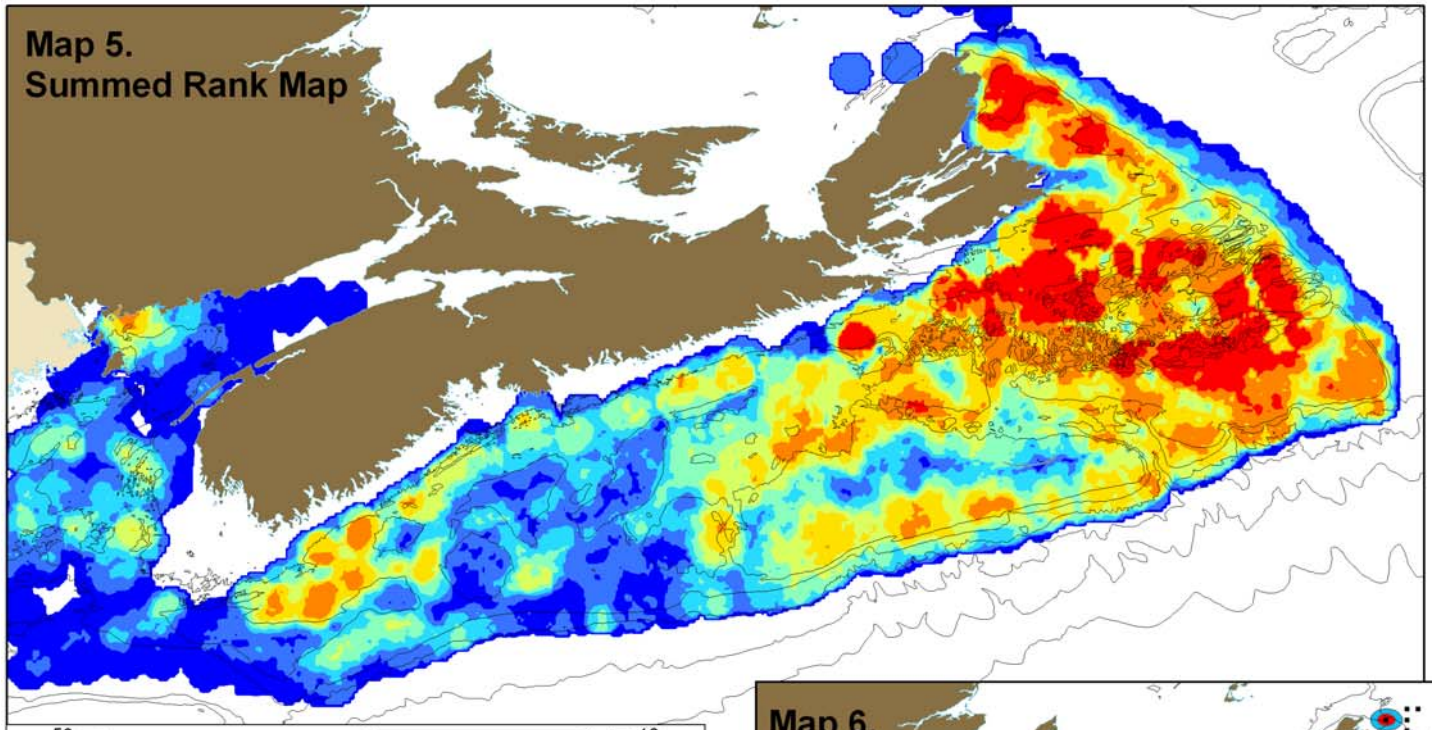


Figure 1. Population Trend





American Plaice (*Hippoglossoides platessoides*)



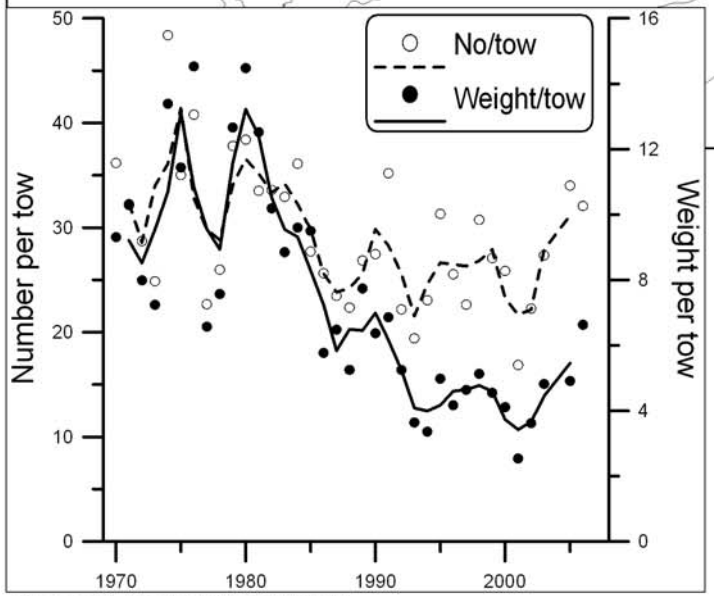
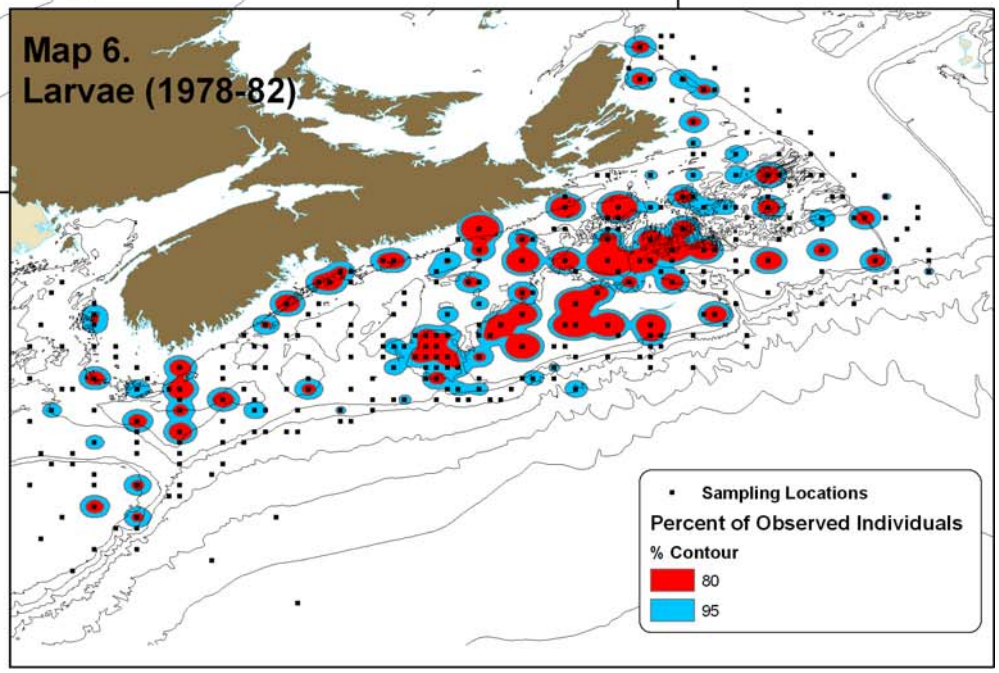
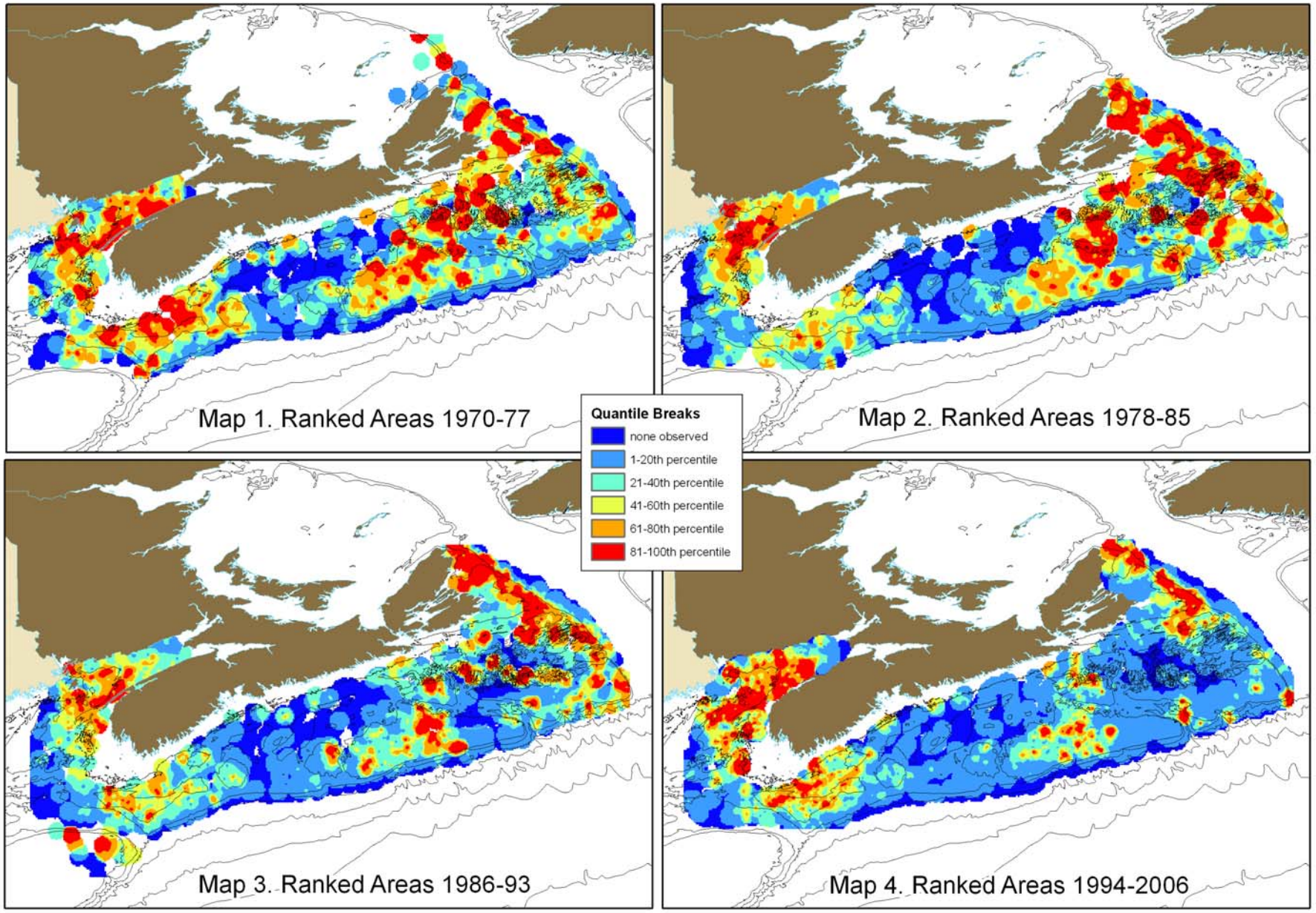


Figure 1. Population Trend





Atlantic Cod (*Gadus morhua*)

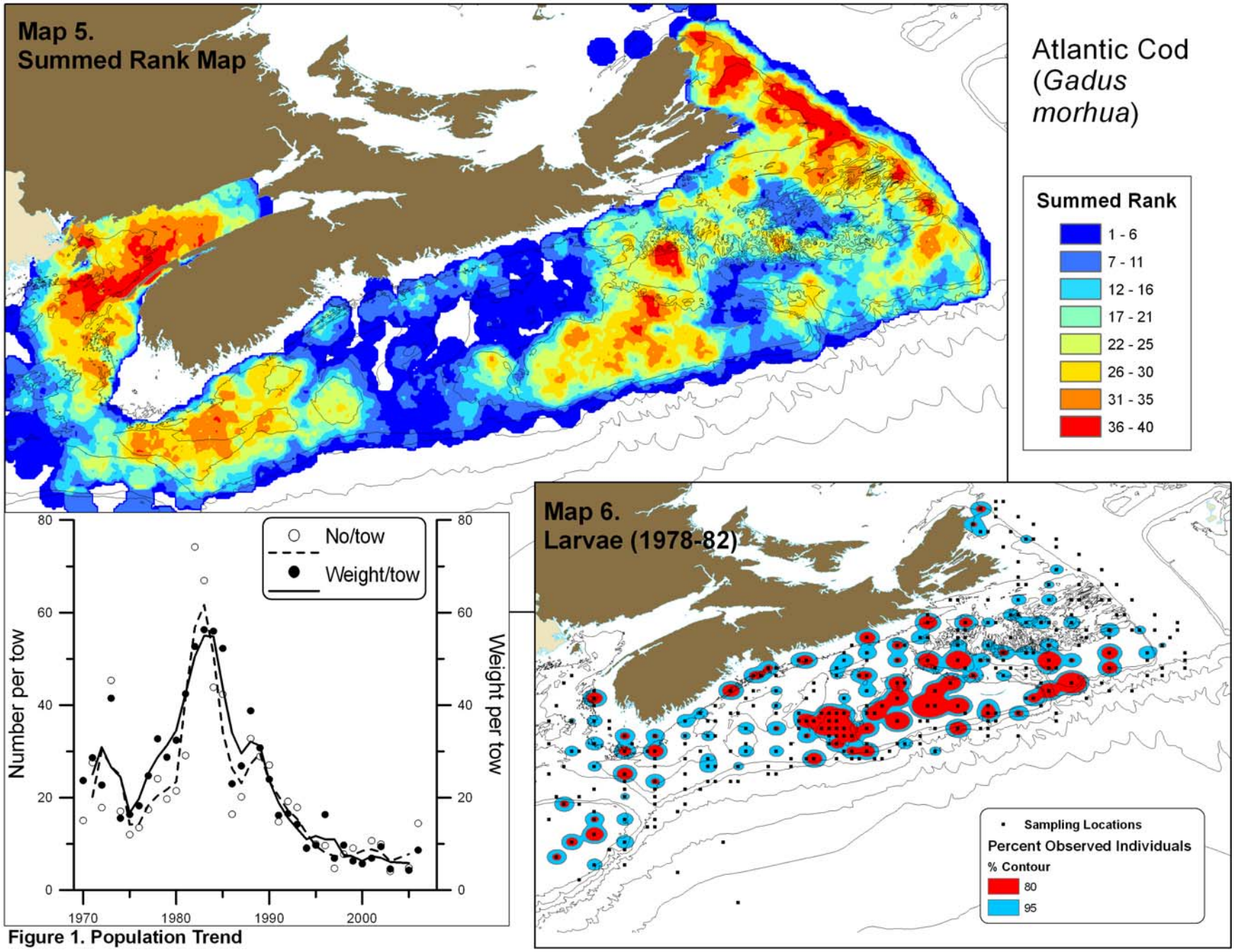
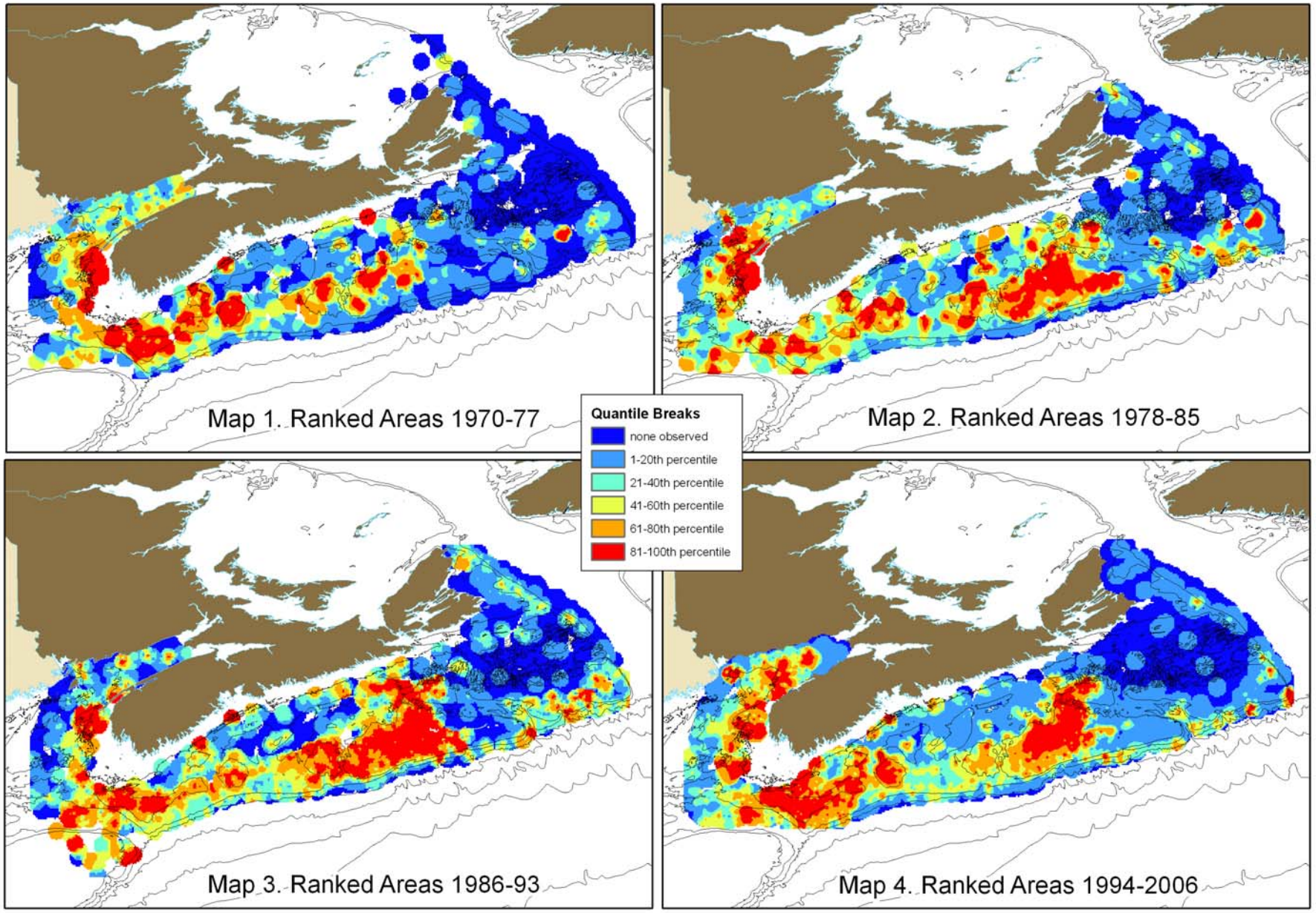
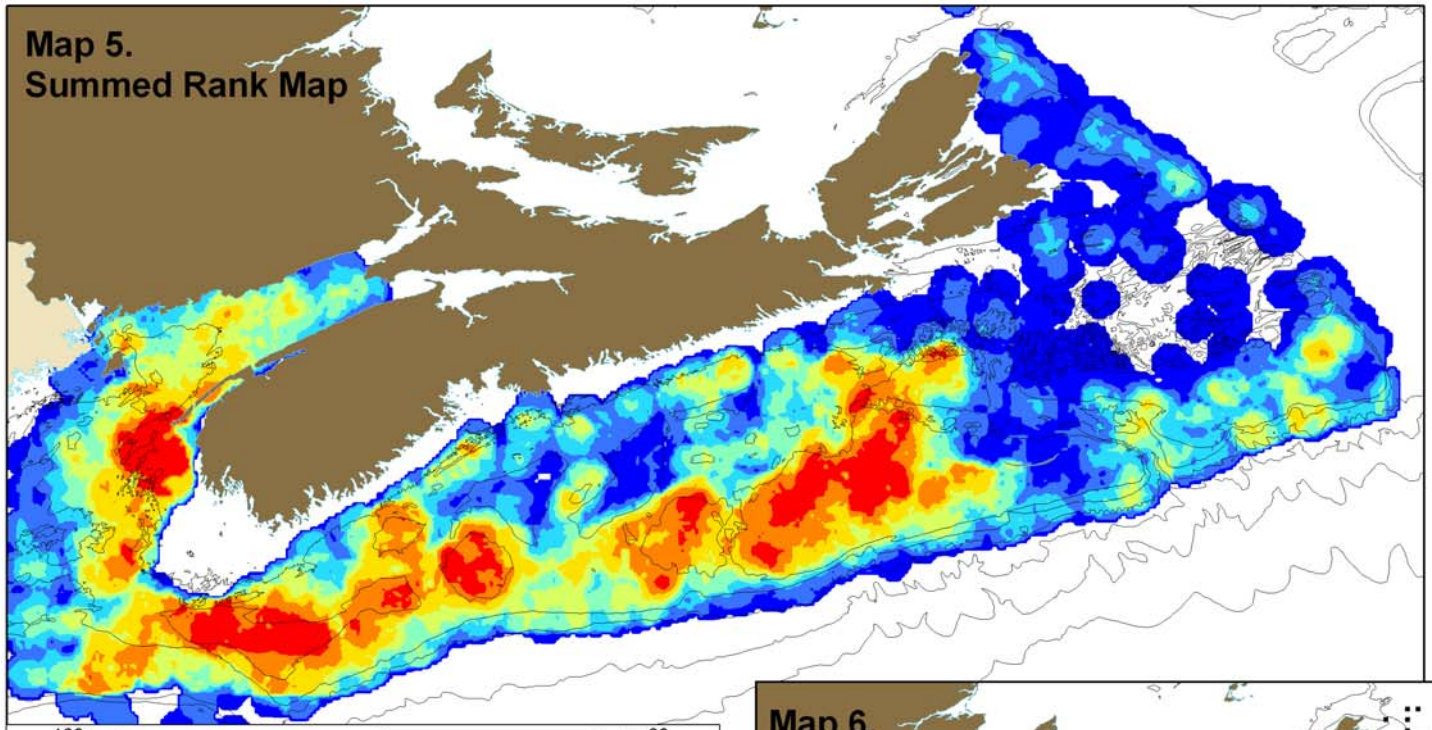
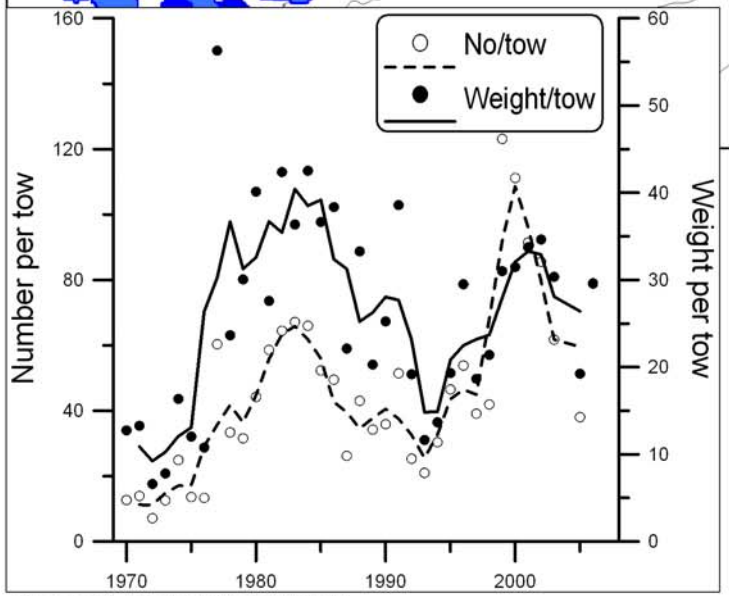


Figure 1. Population Trend



Haddock (*Melanogrammus aeglefinus*)





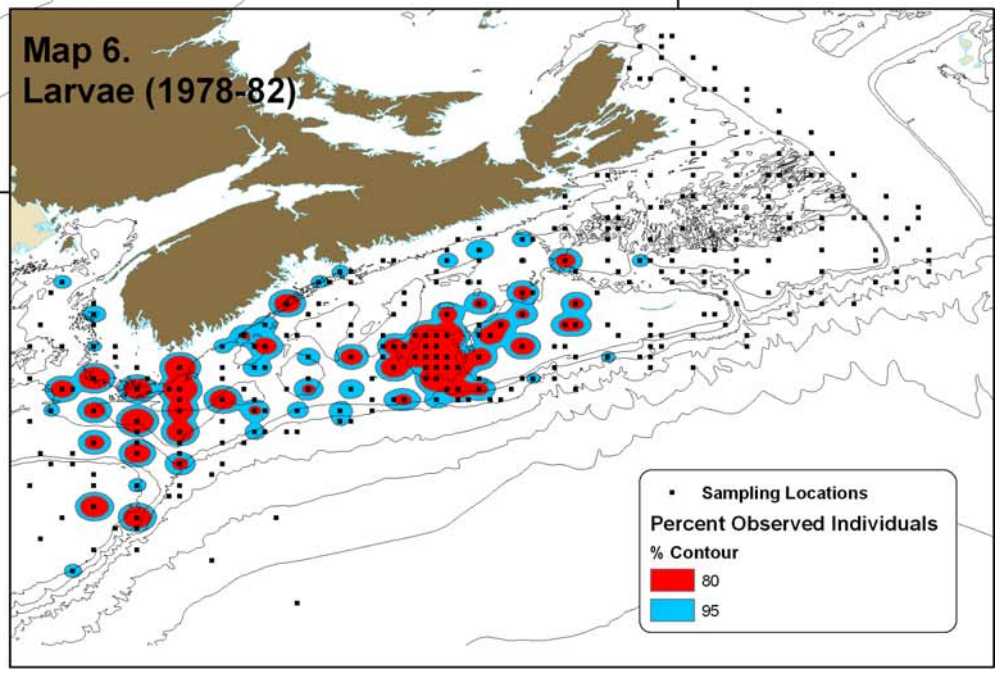
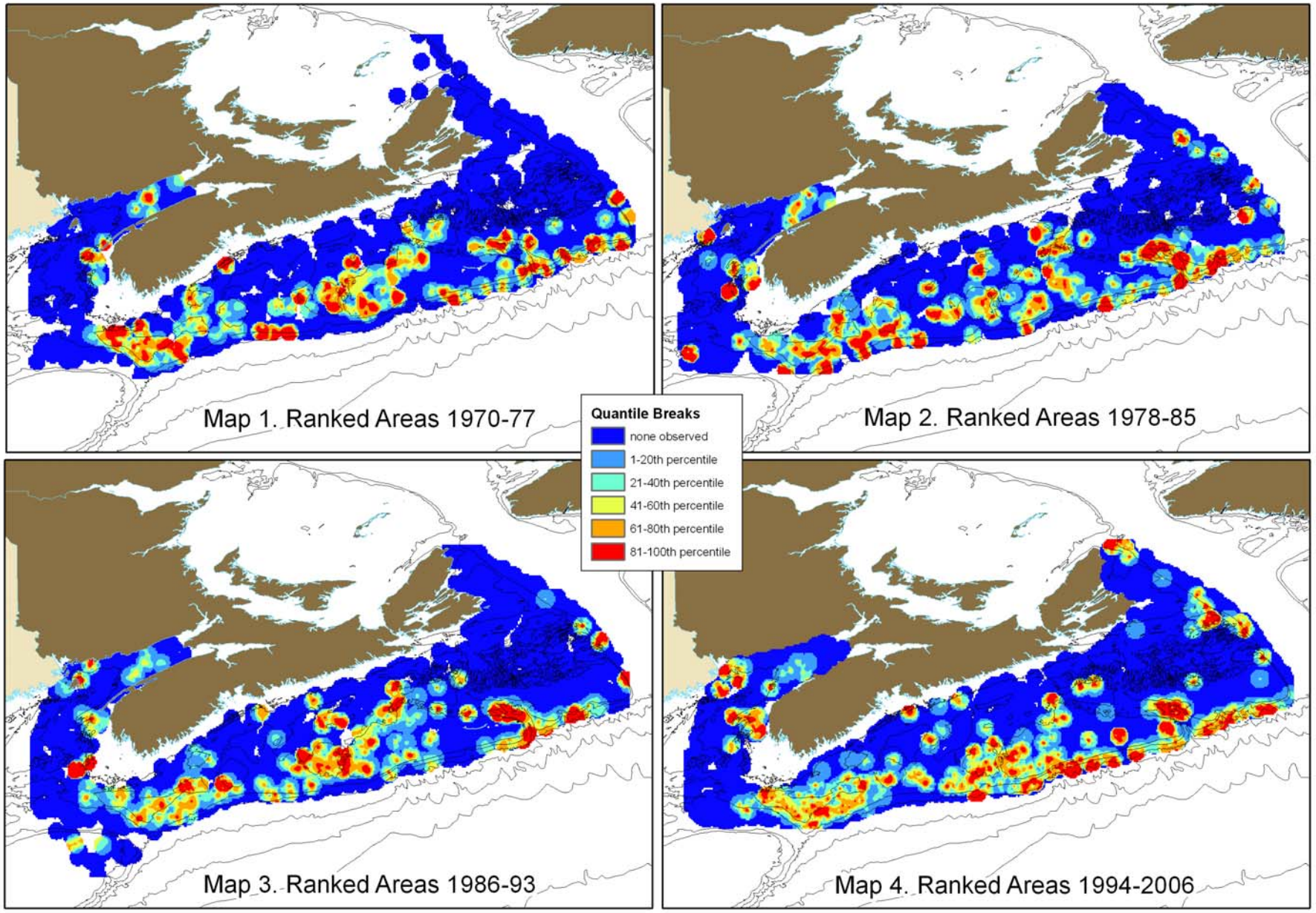


Figure 1. Population Trend



Halibut (*Hippoglossus hippoglossus*)

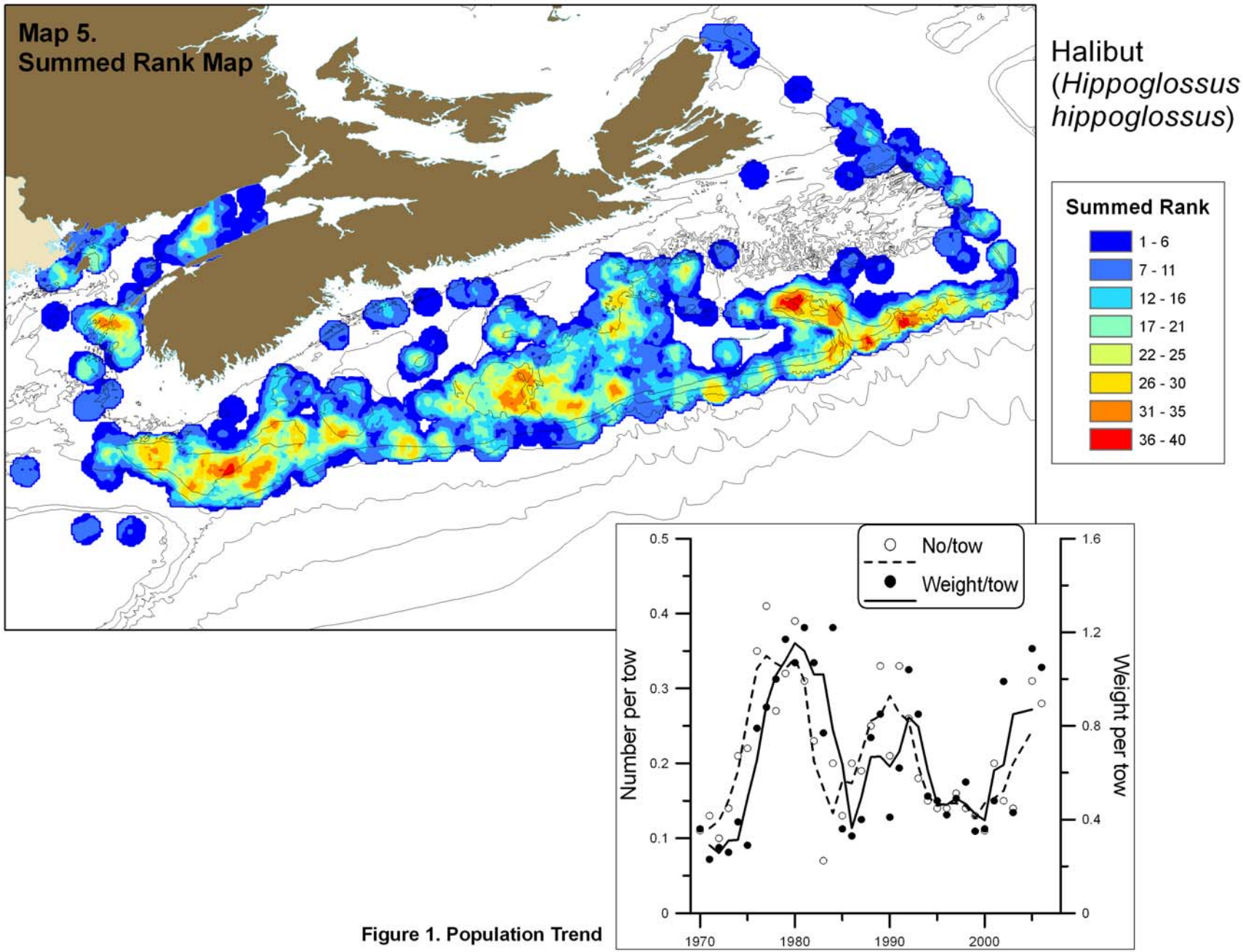
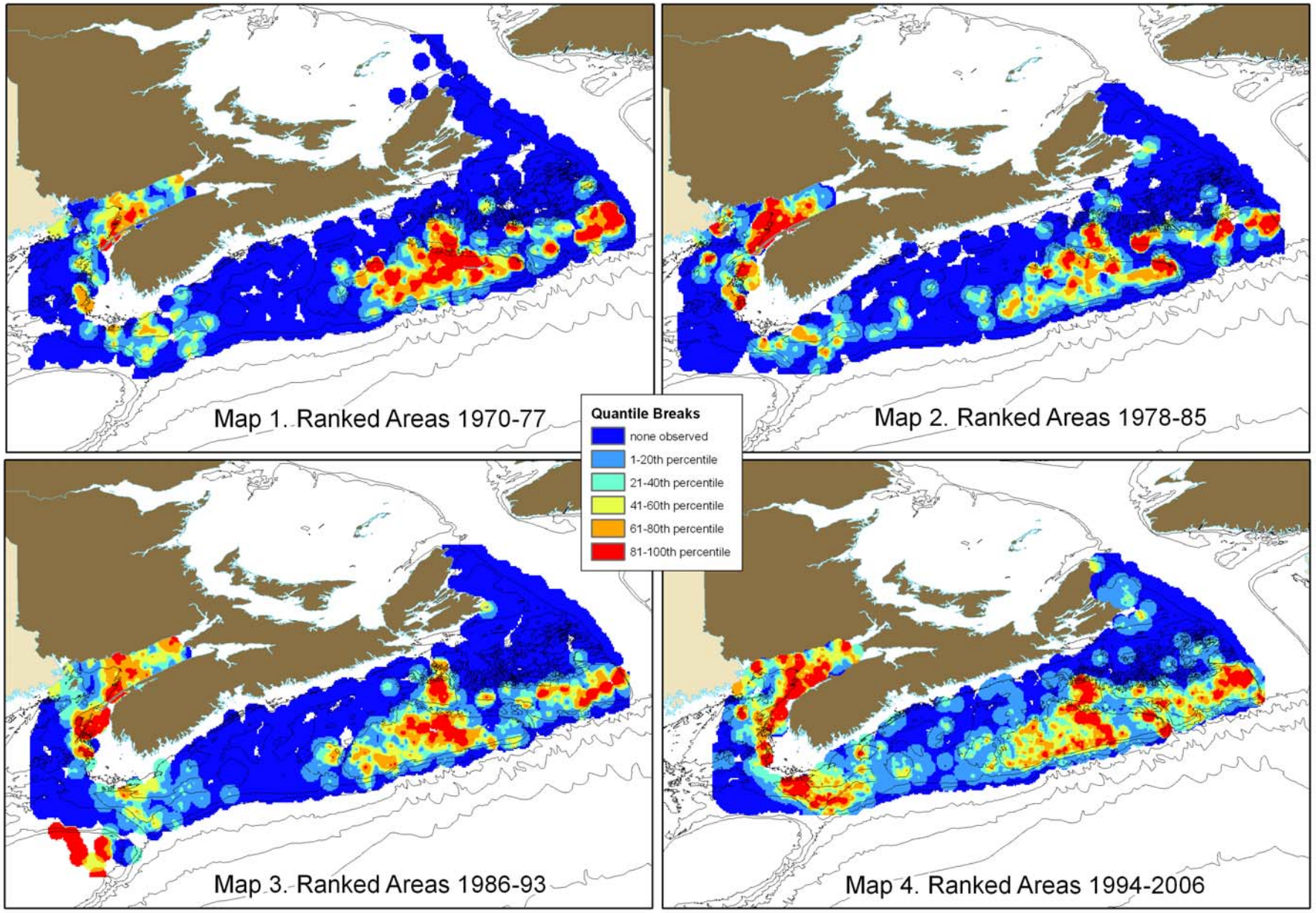
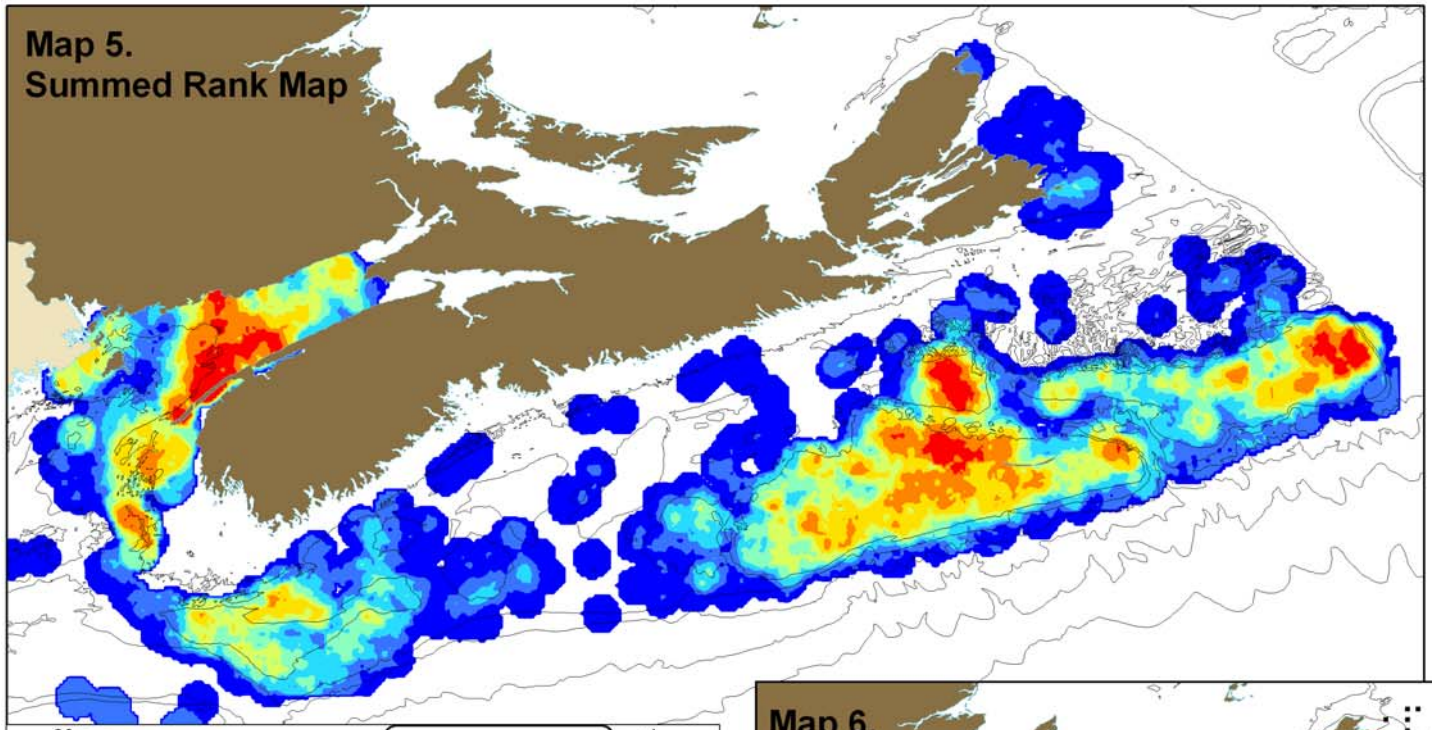


Figure 1. Population Trend



Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)



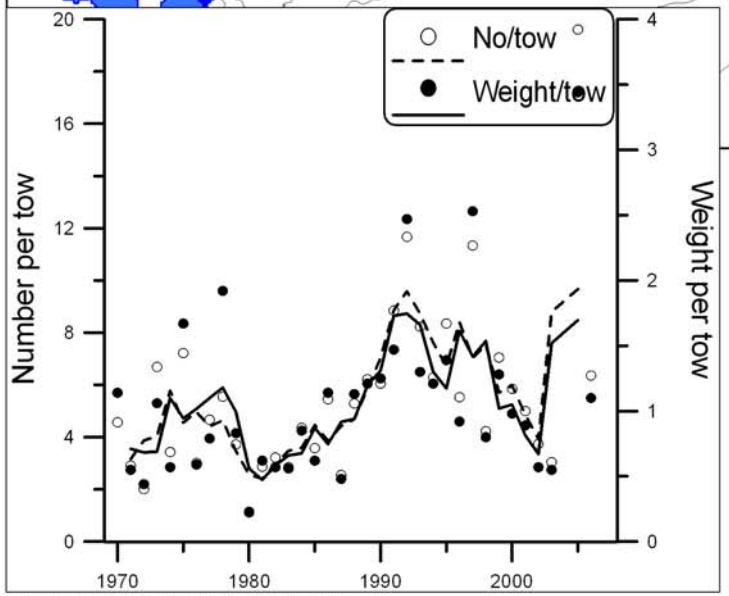
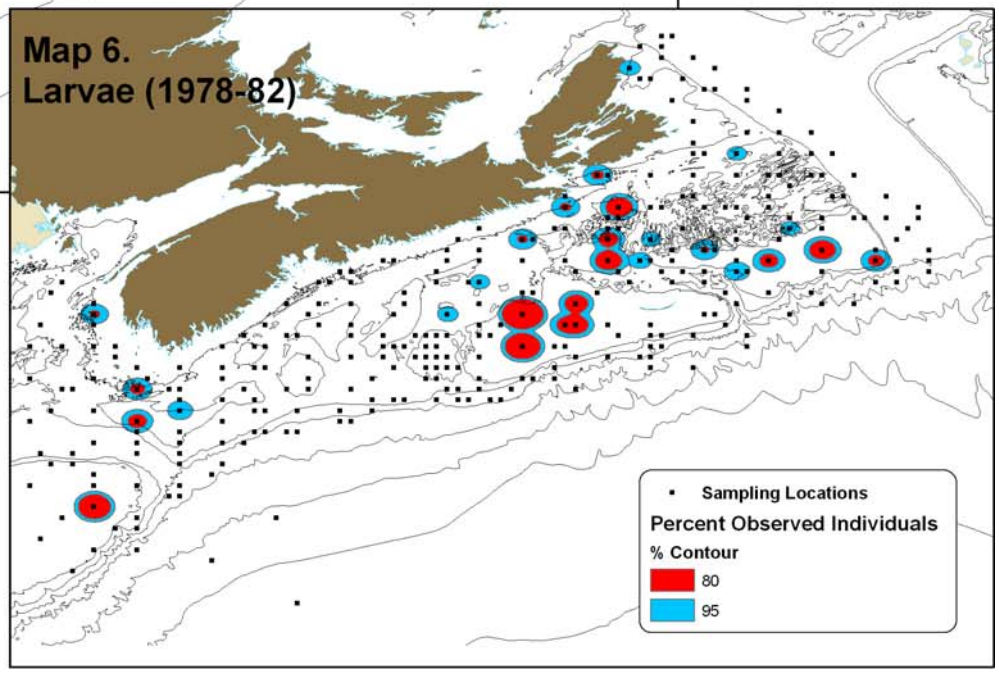
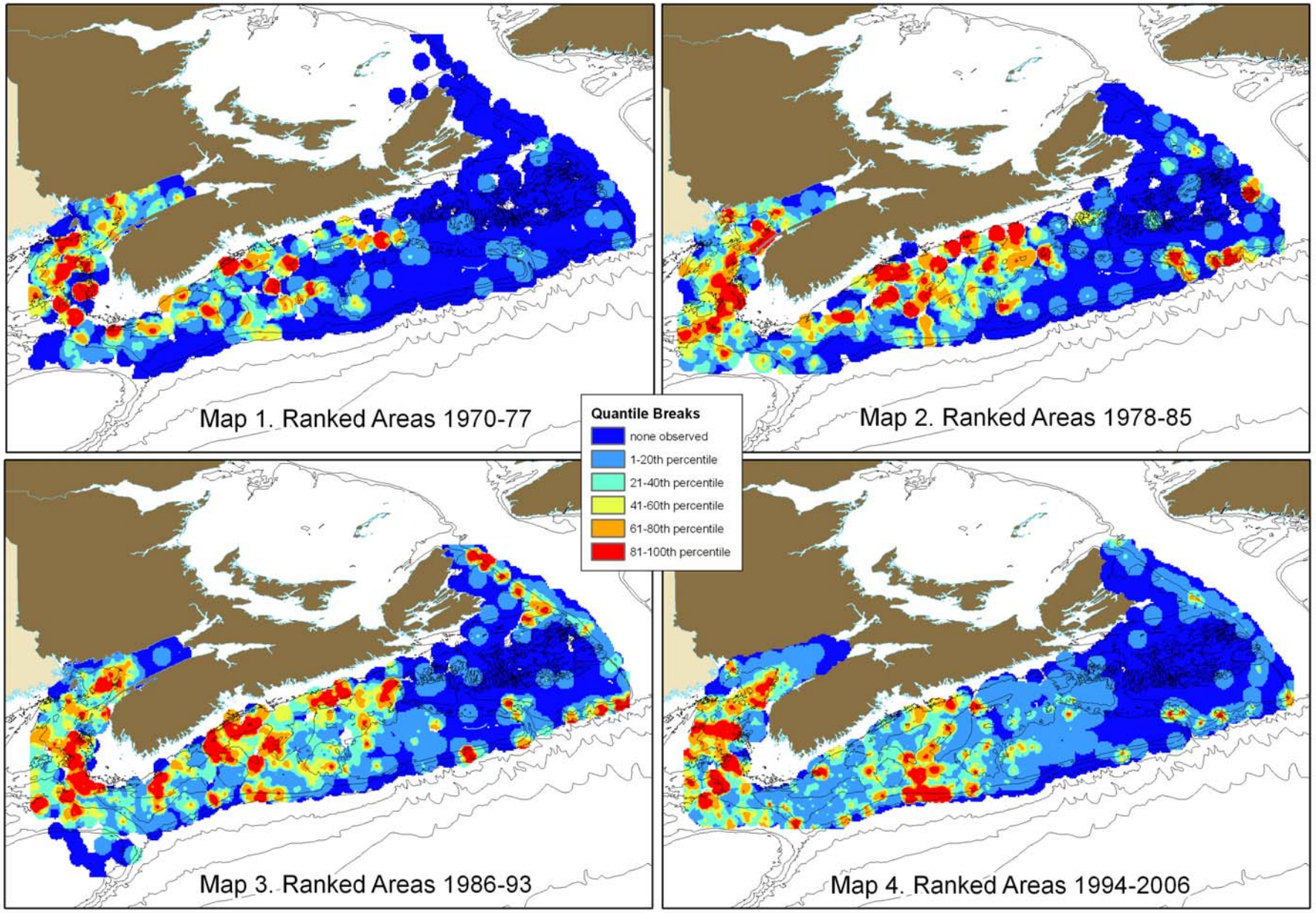


Figure 1. Population Trend





Pollock (*Pollachius virens*)

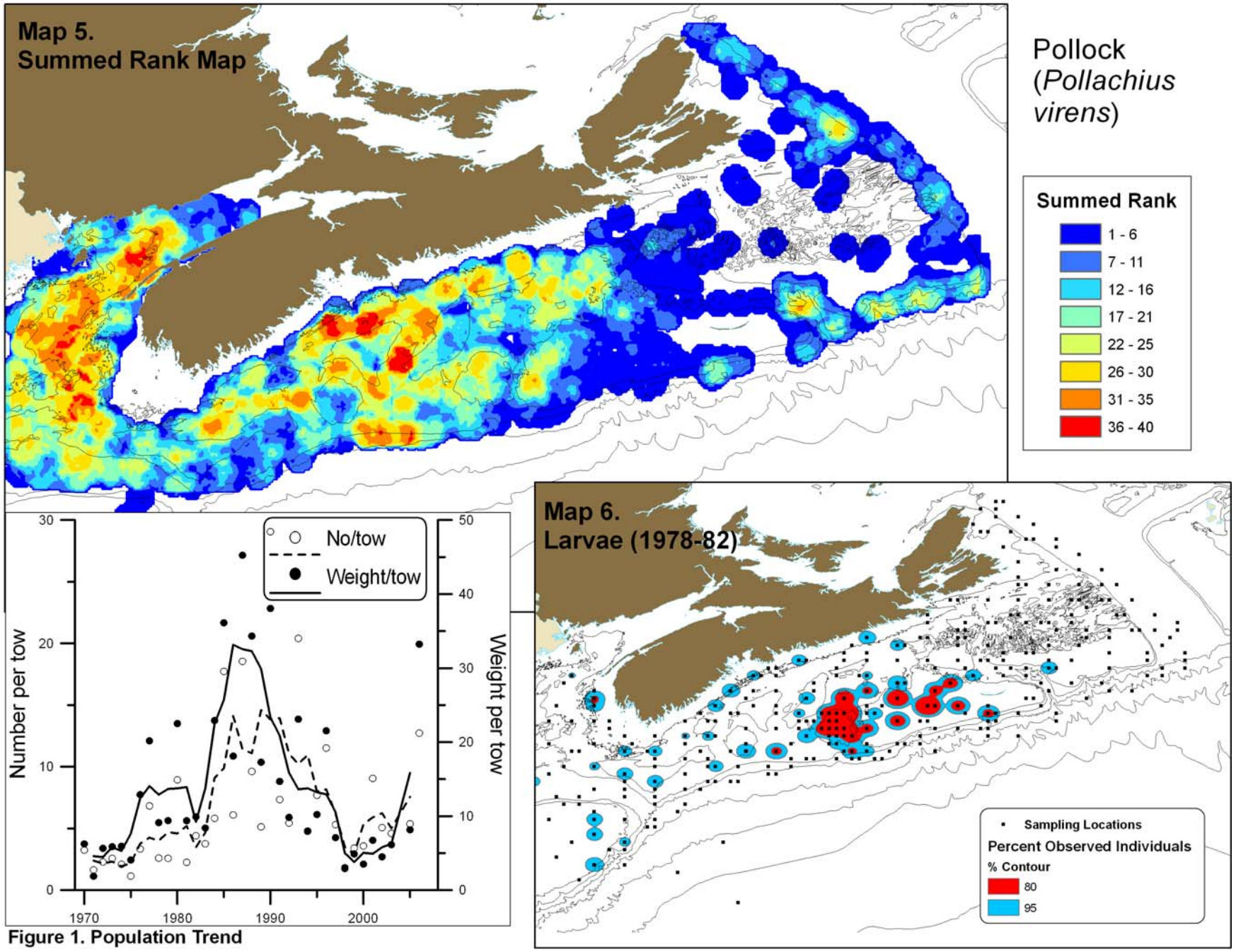
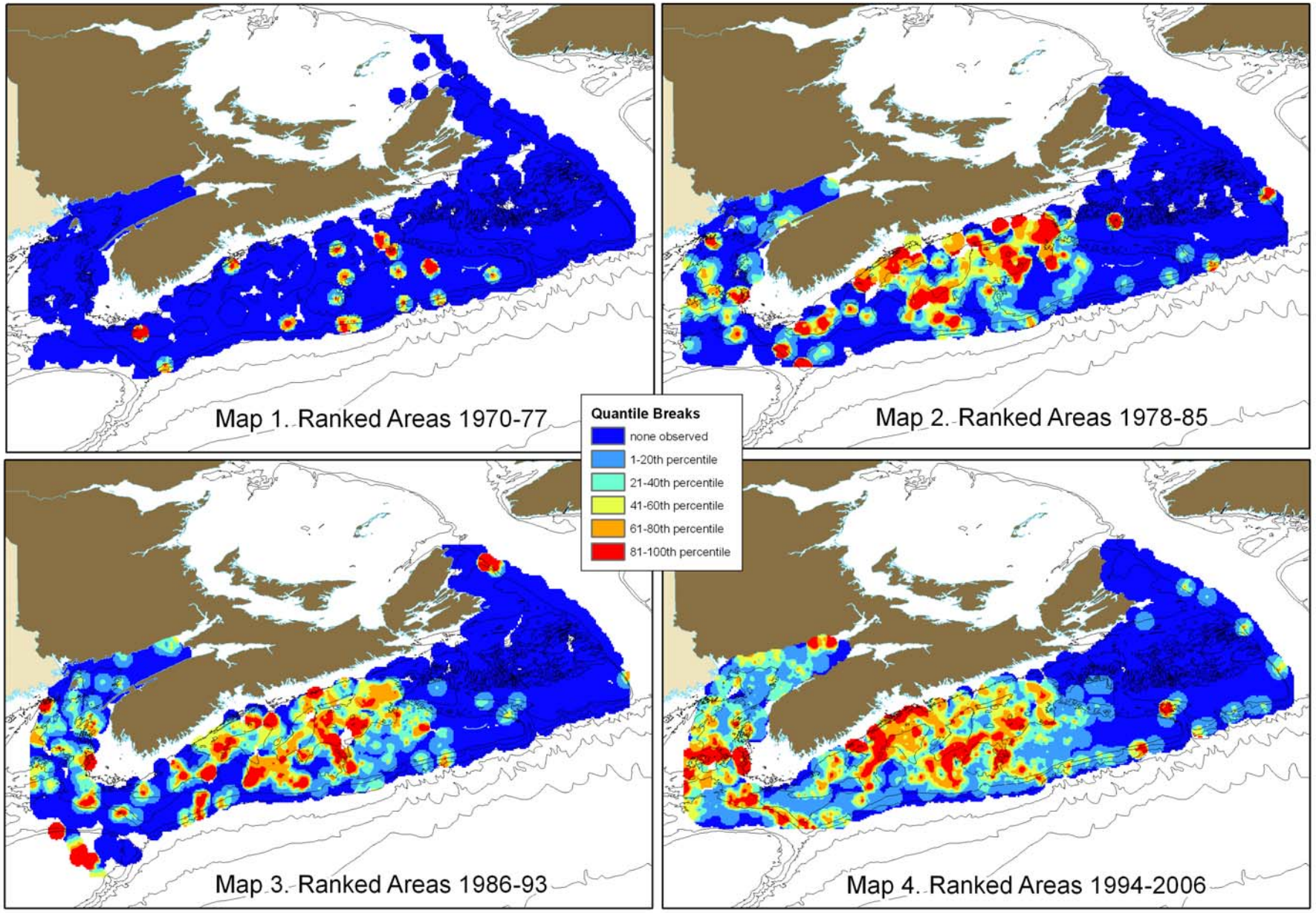
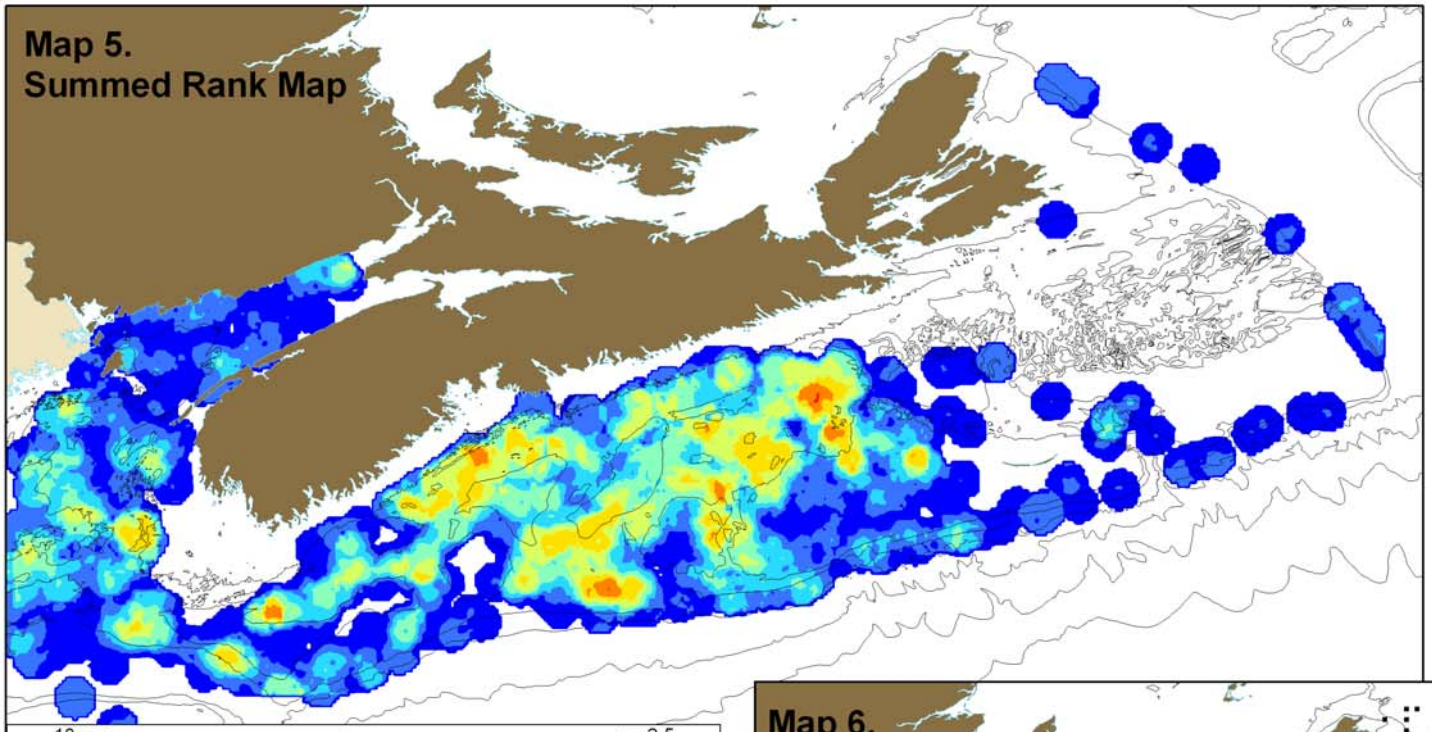


Figure 1. Population Trend



Red Hake (*Urophycis chuss*)



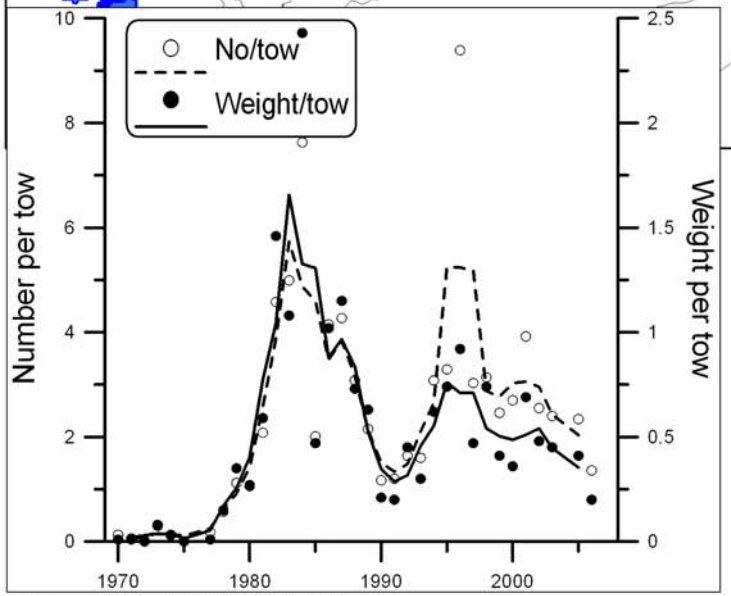
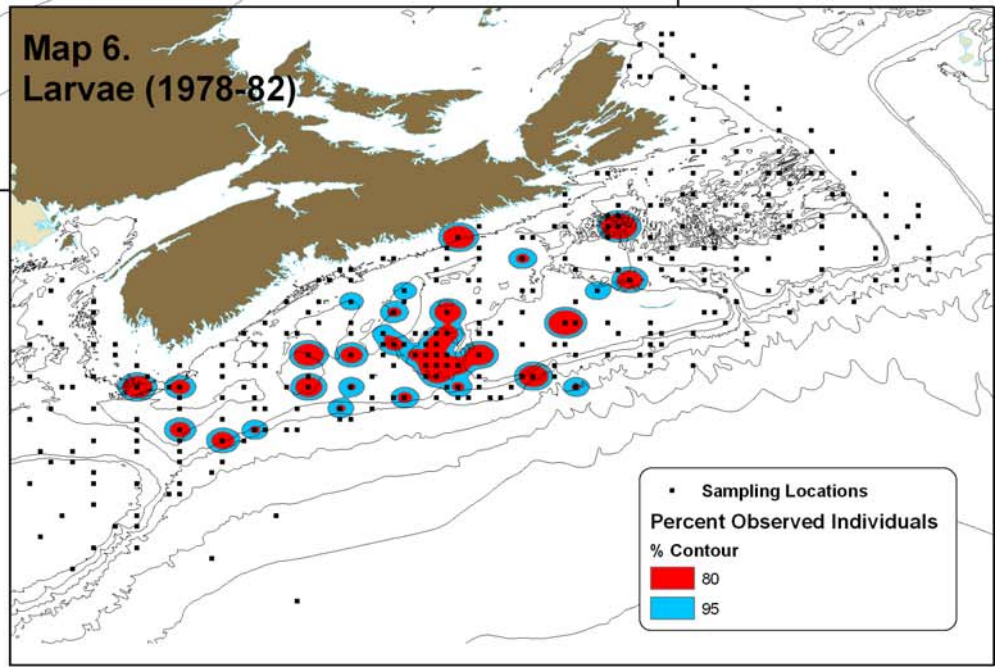
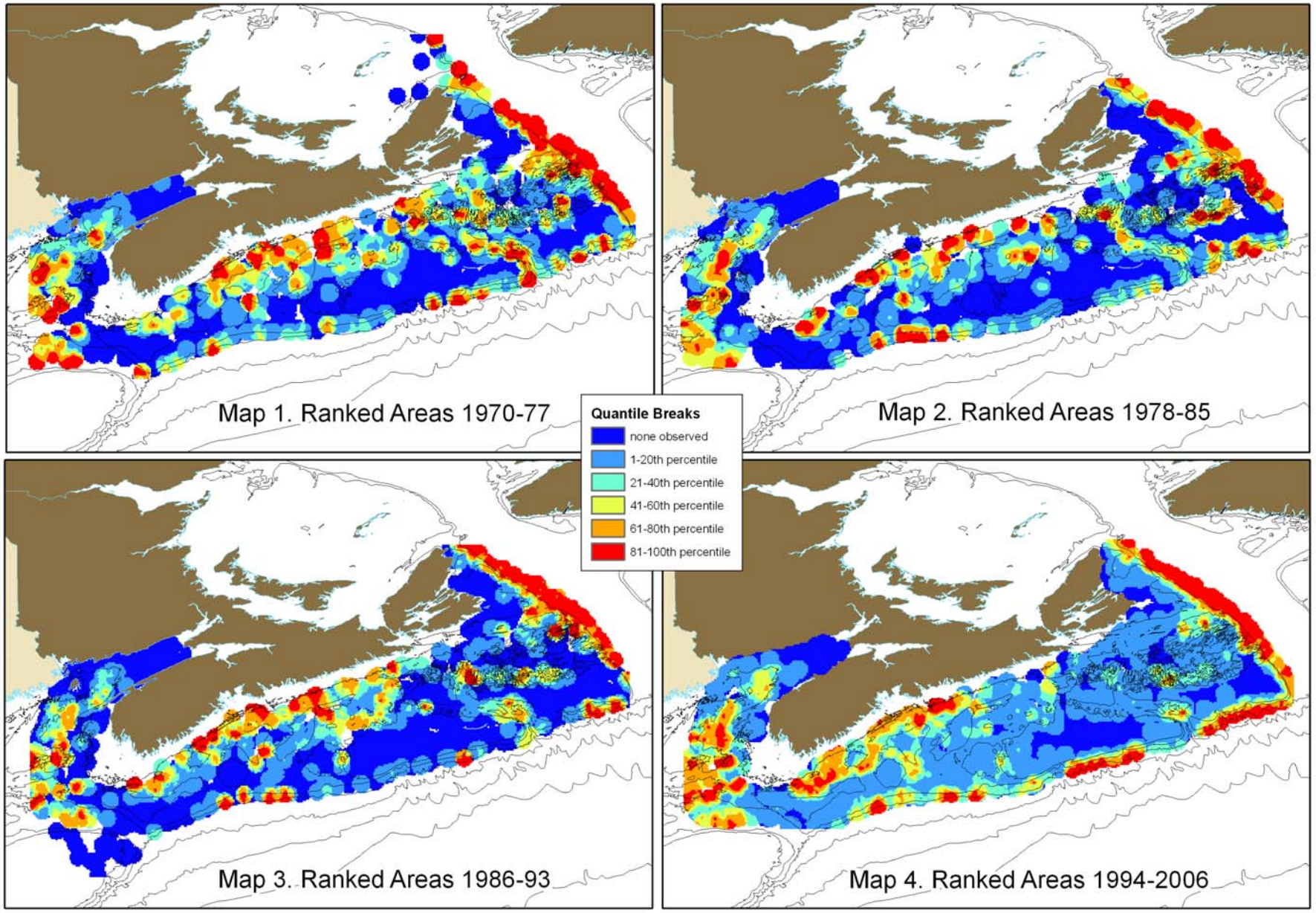


Figure 1. Population Trend





Redfish (*Sebastes spp*)

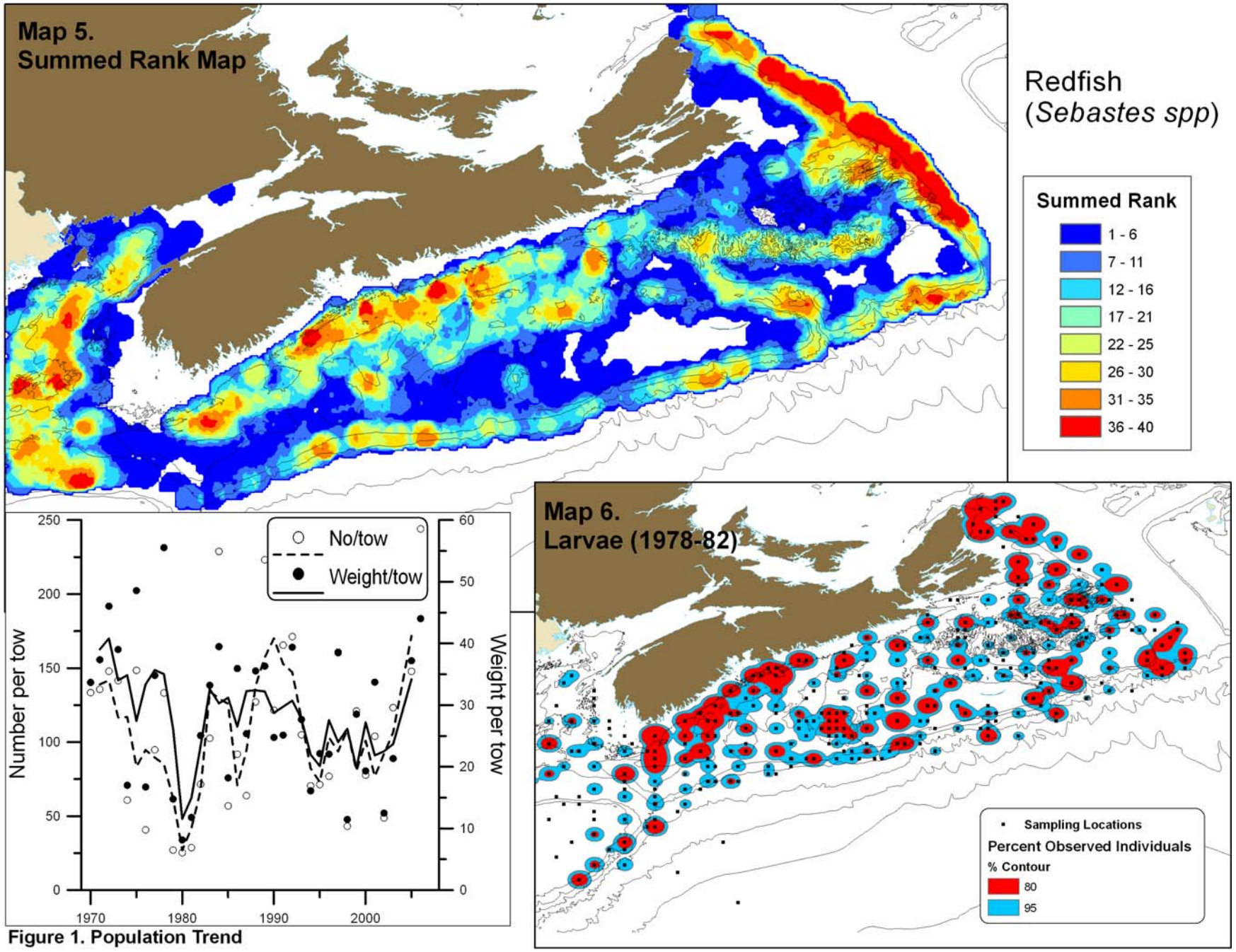
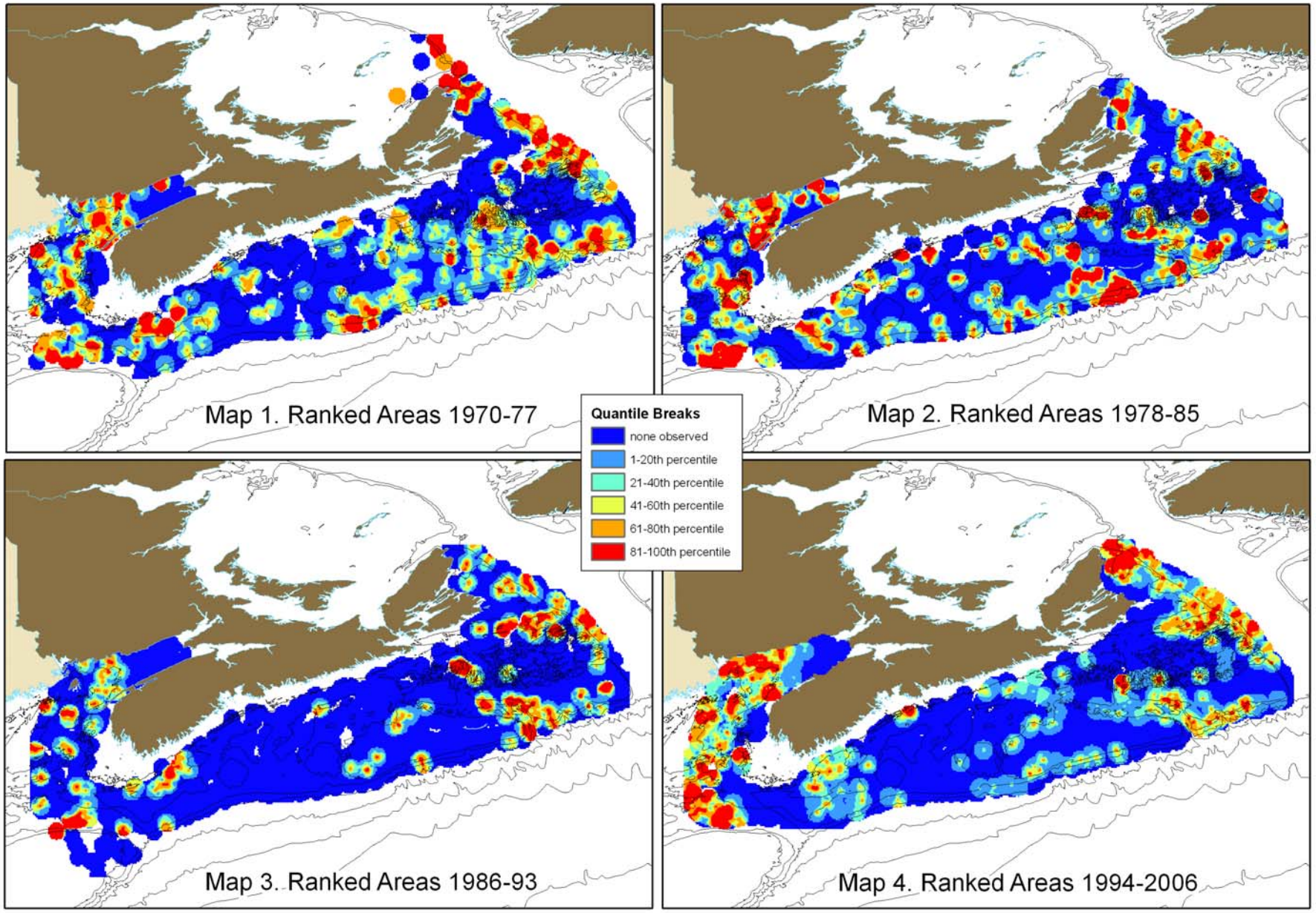
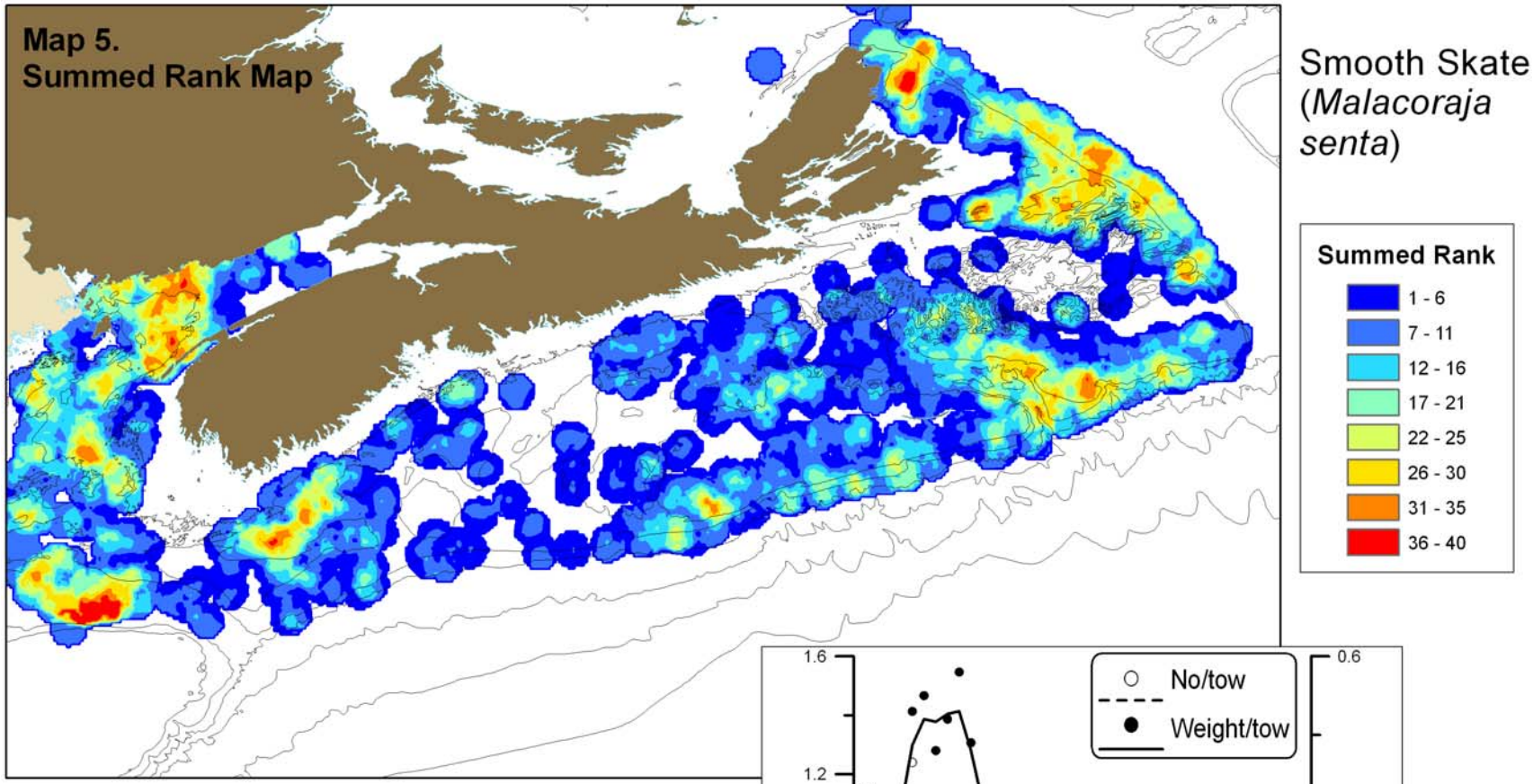


Figure 1. Population Trend



Smooth Skate (*Malacoraja senta*)



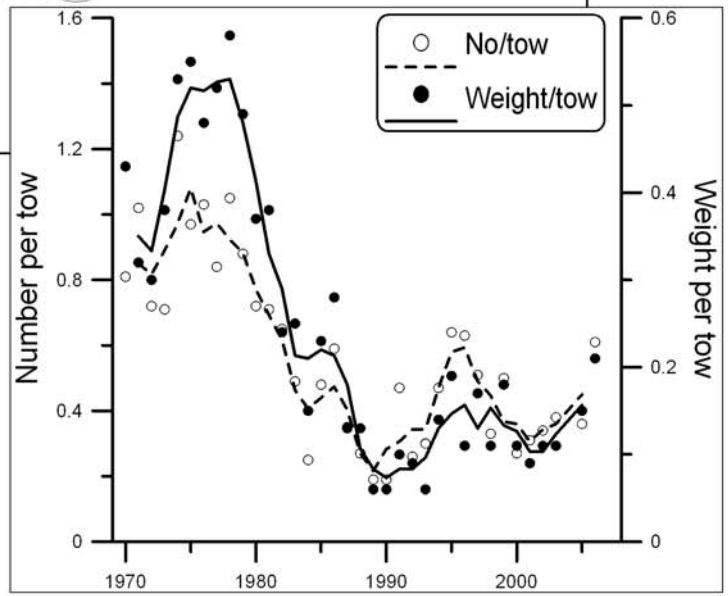
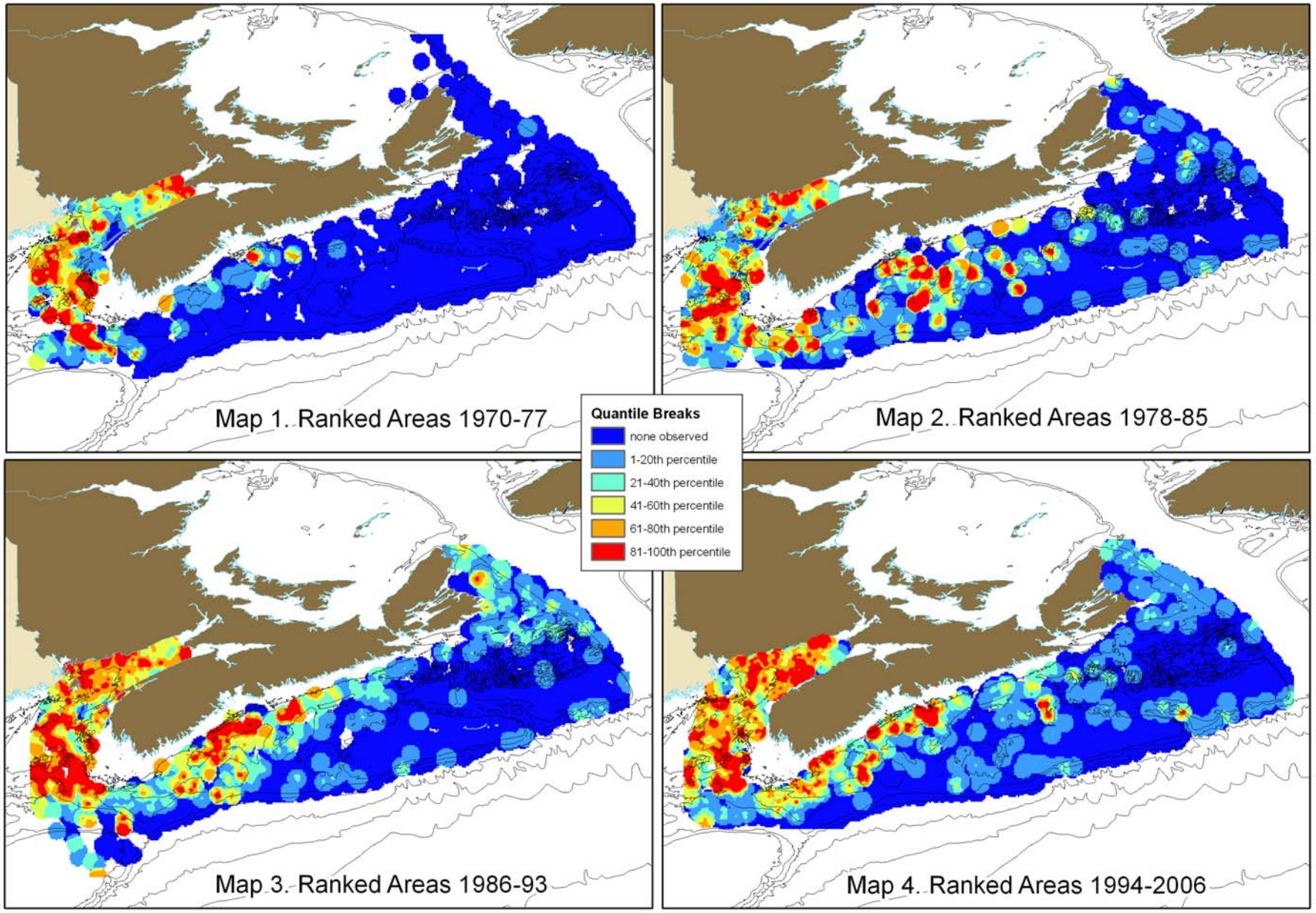


Figure 1. Population Trend



Spiny Dogfish (*Squalus acanthias*)

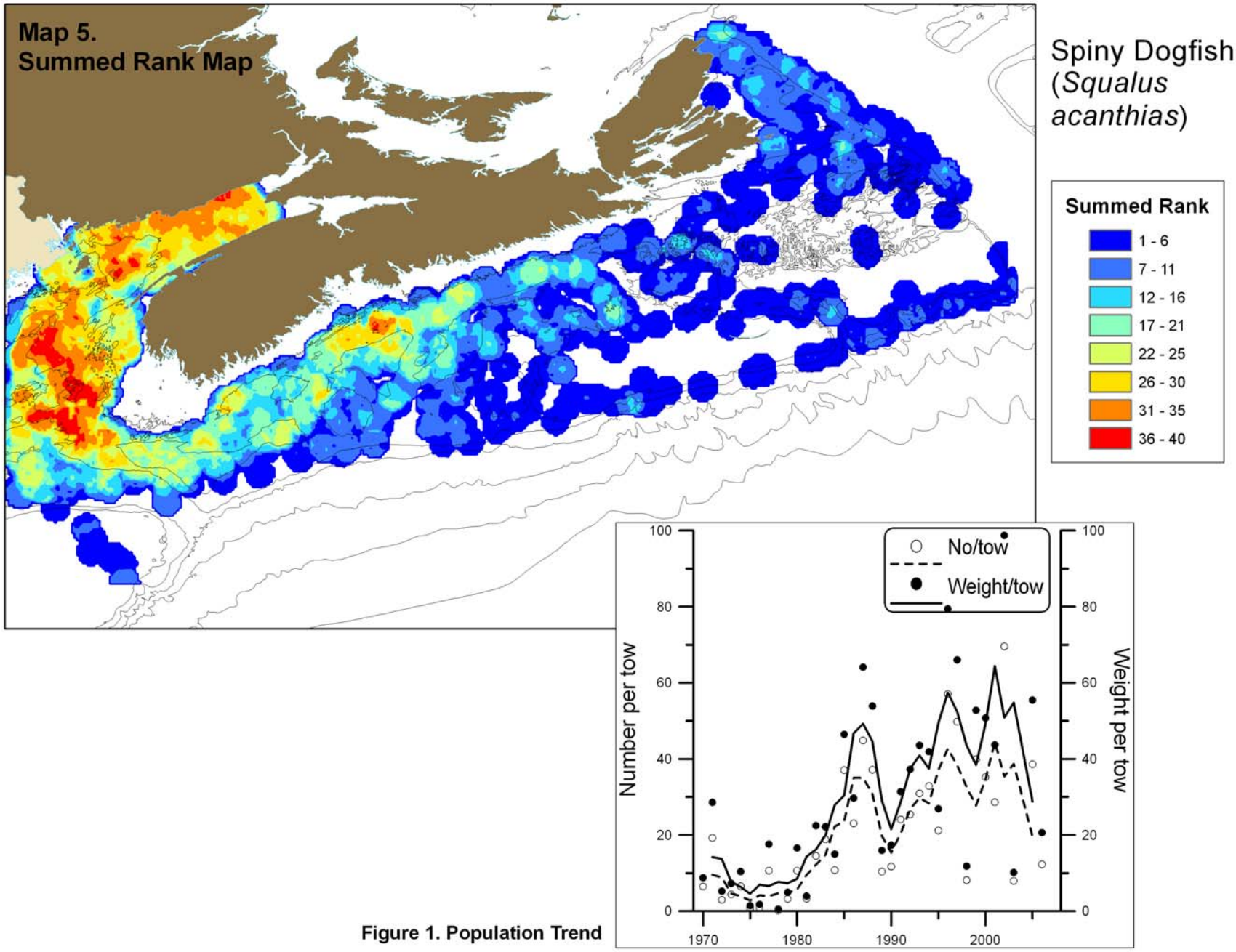
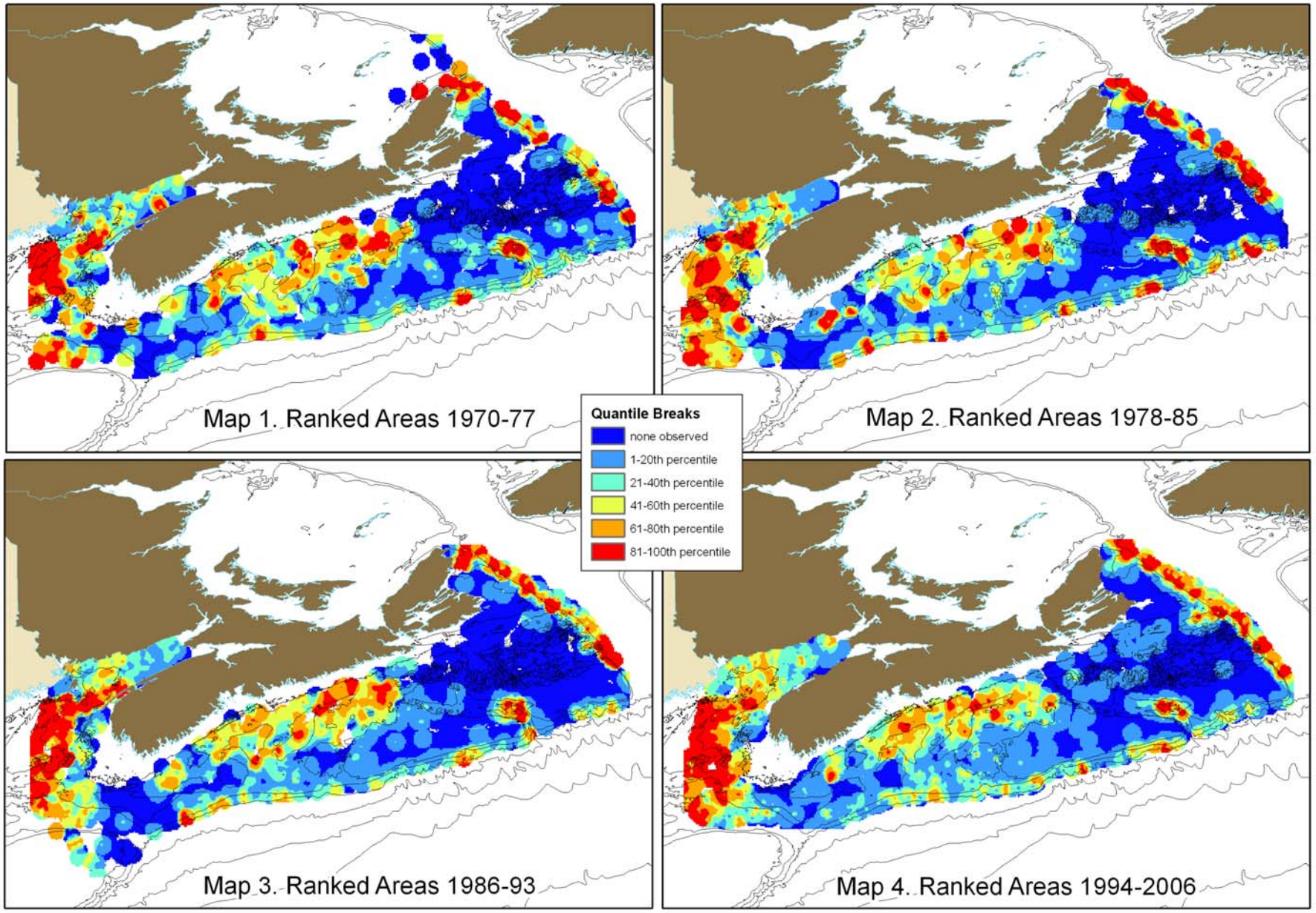
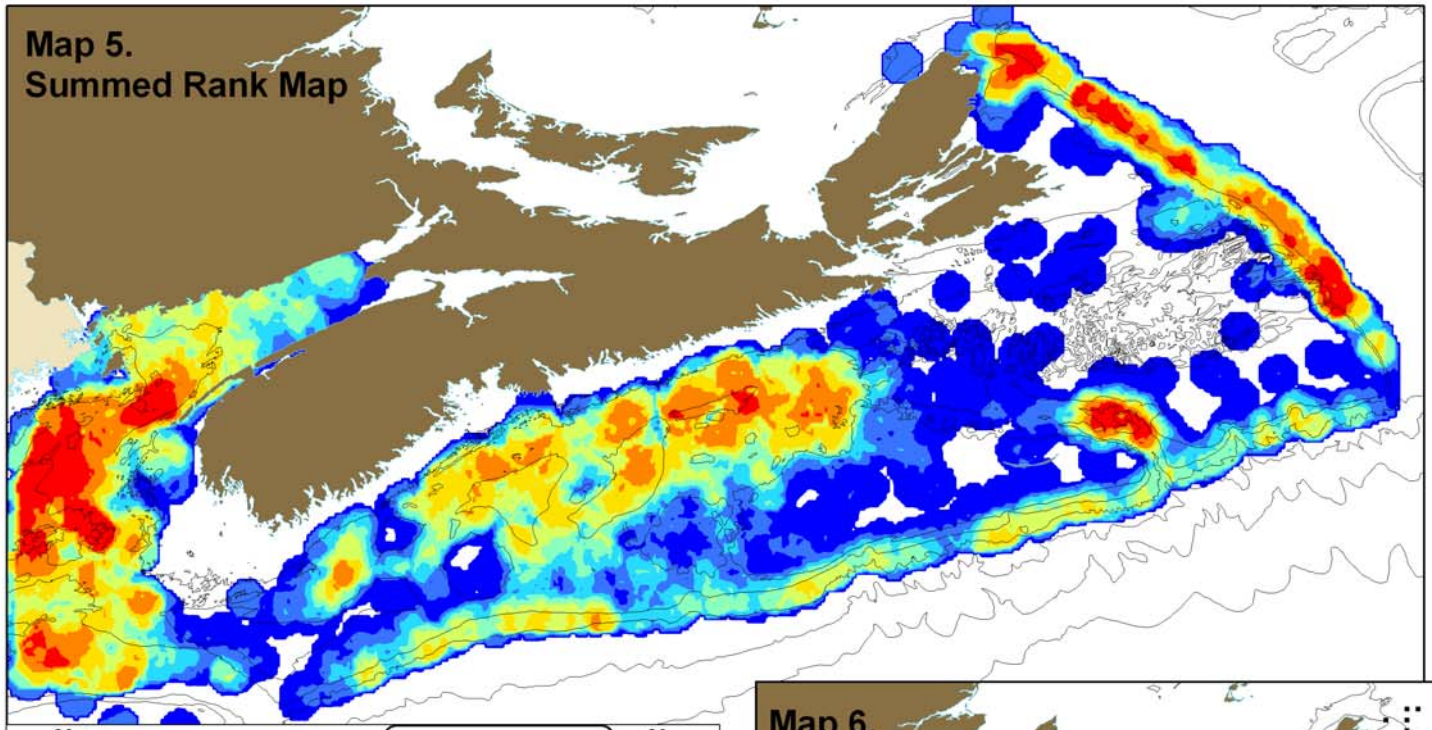


Figure 1. Population Trend



White Hake (*Urophycis tenuis*)



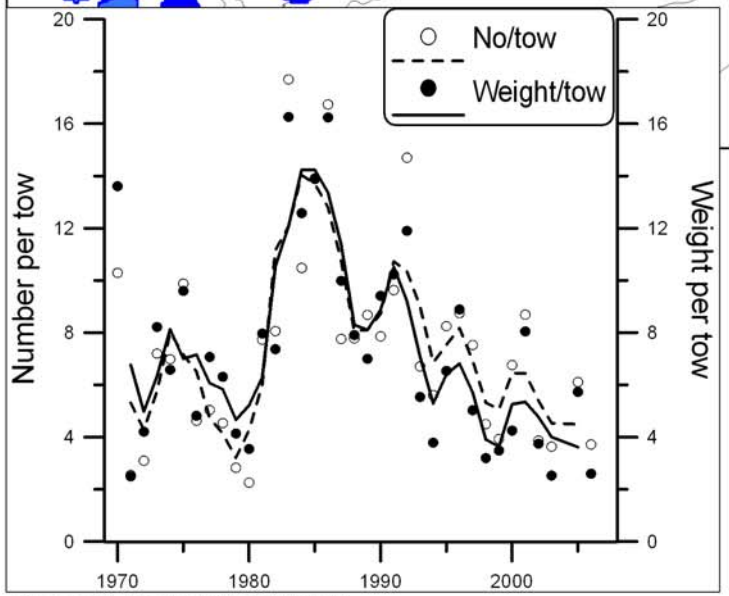
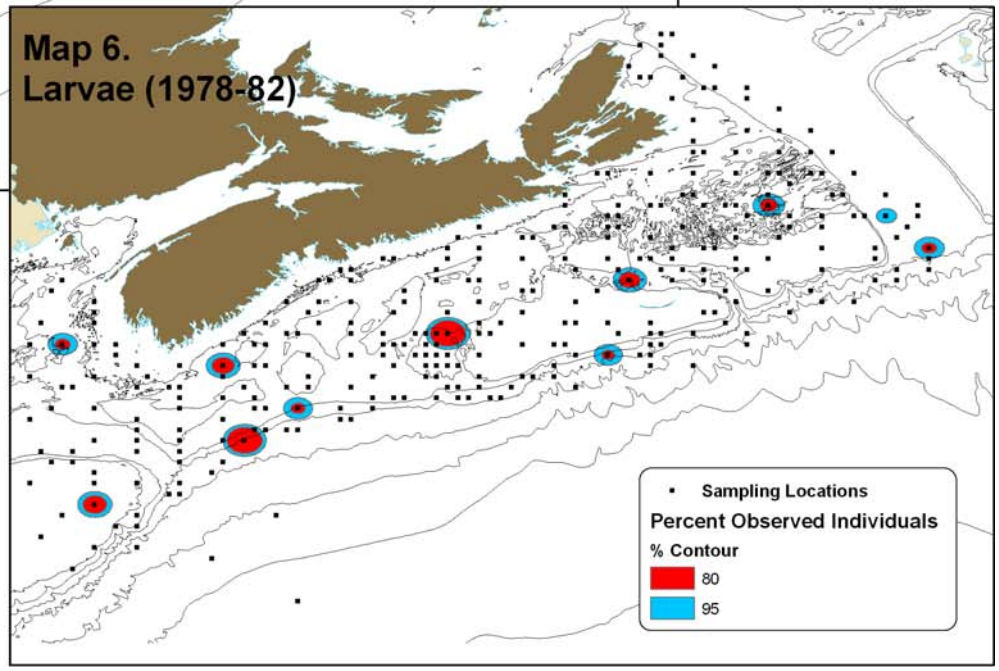
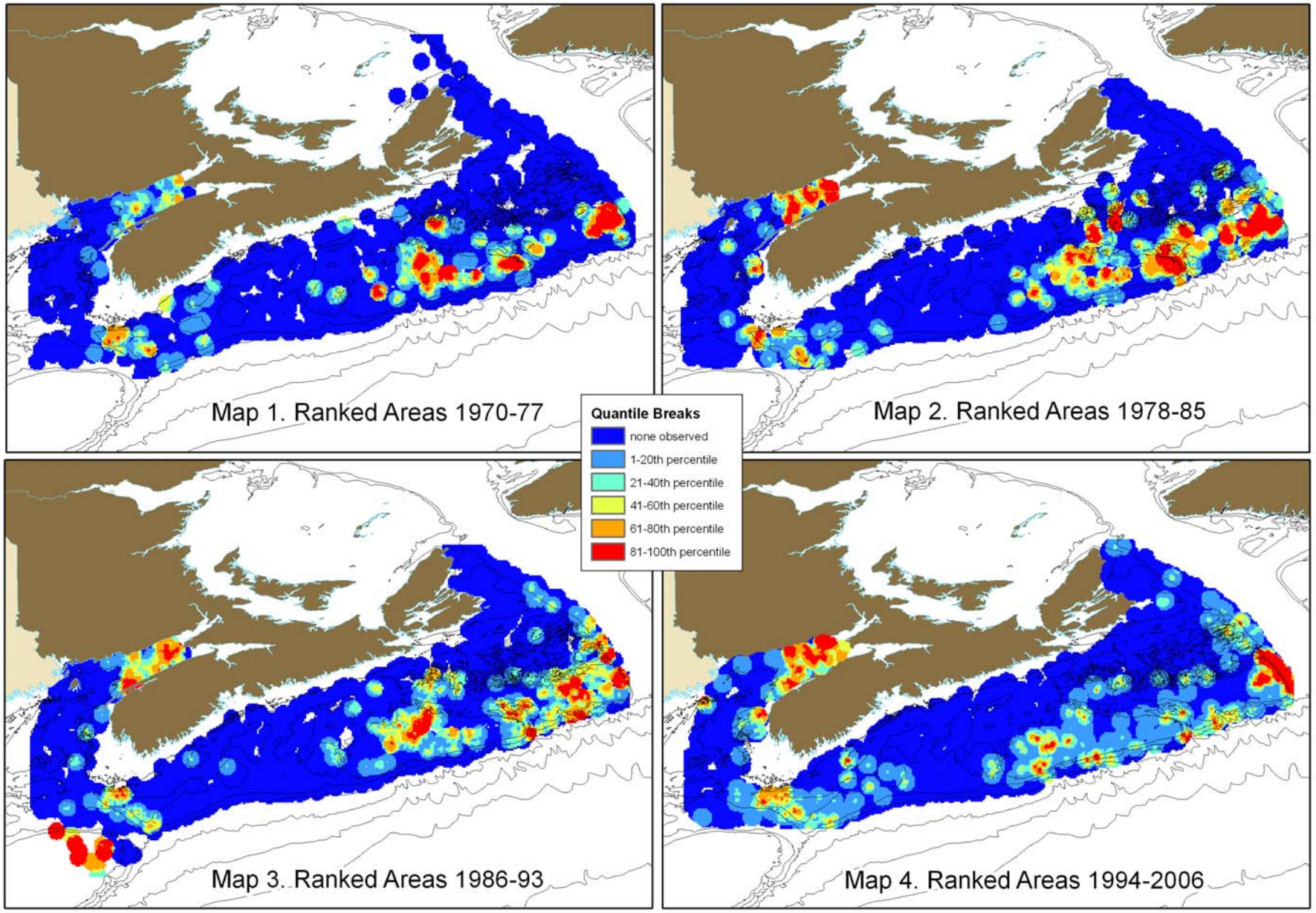


Figure 1. Population Trend





Winter Skate (*Leucoraja ocellata*)

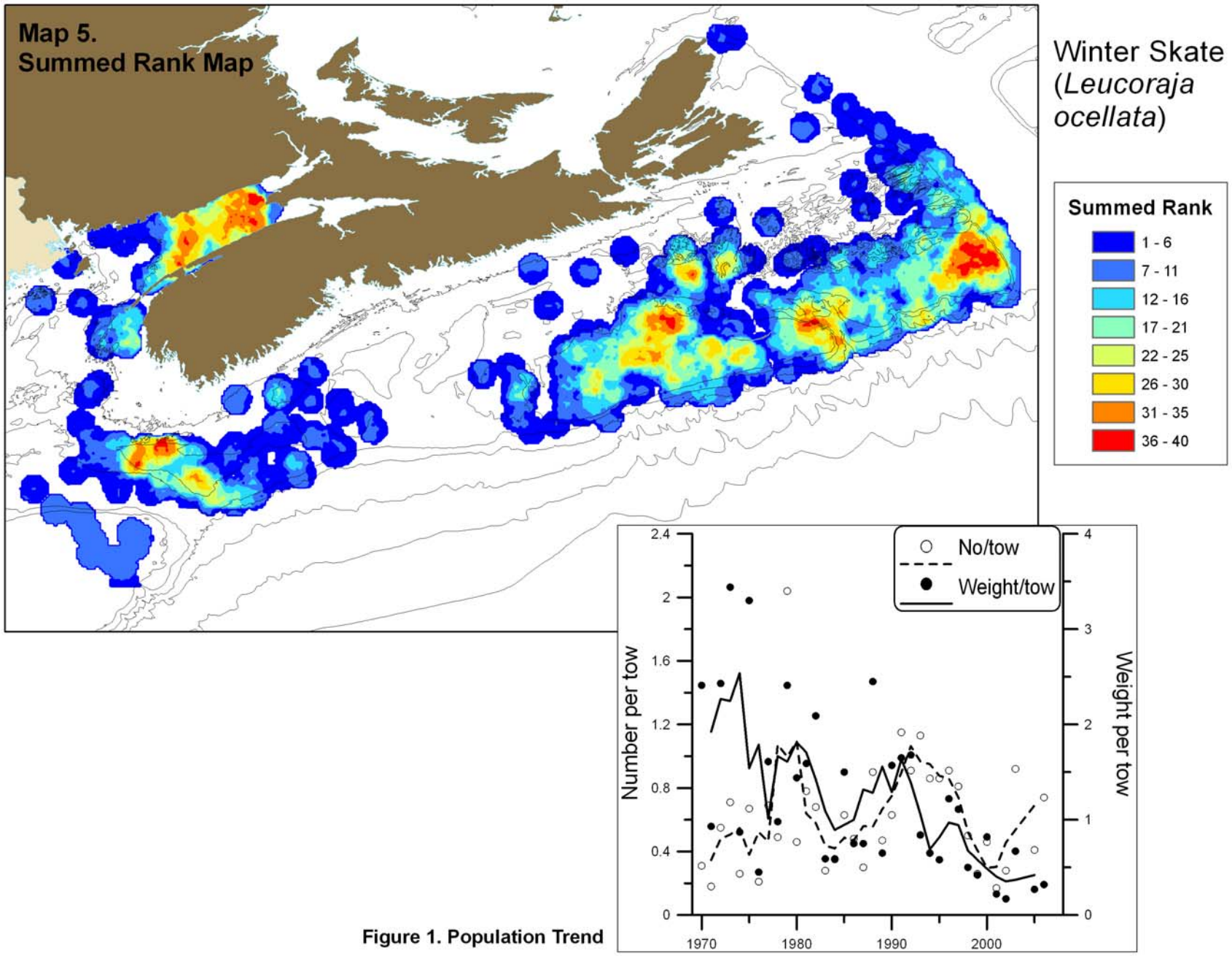
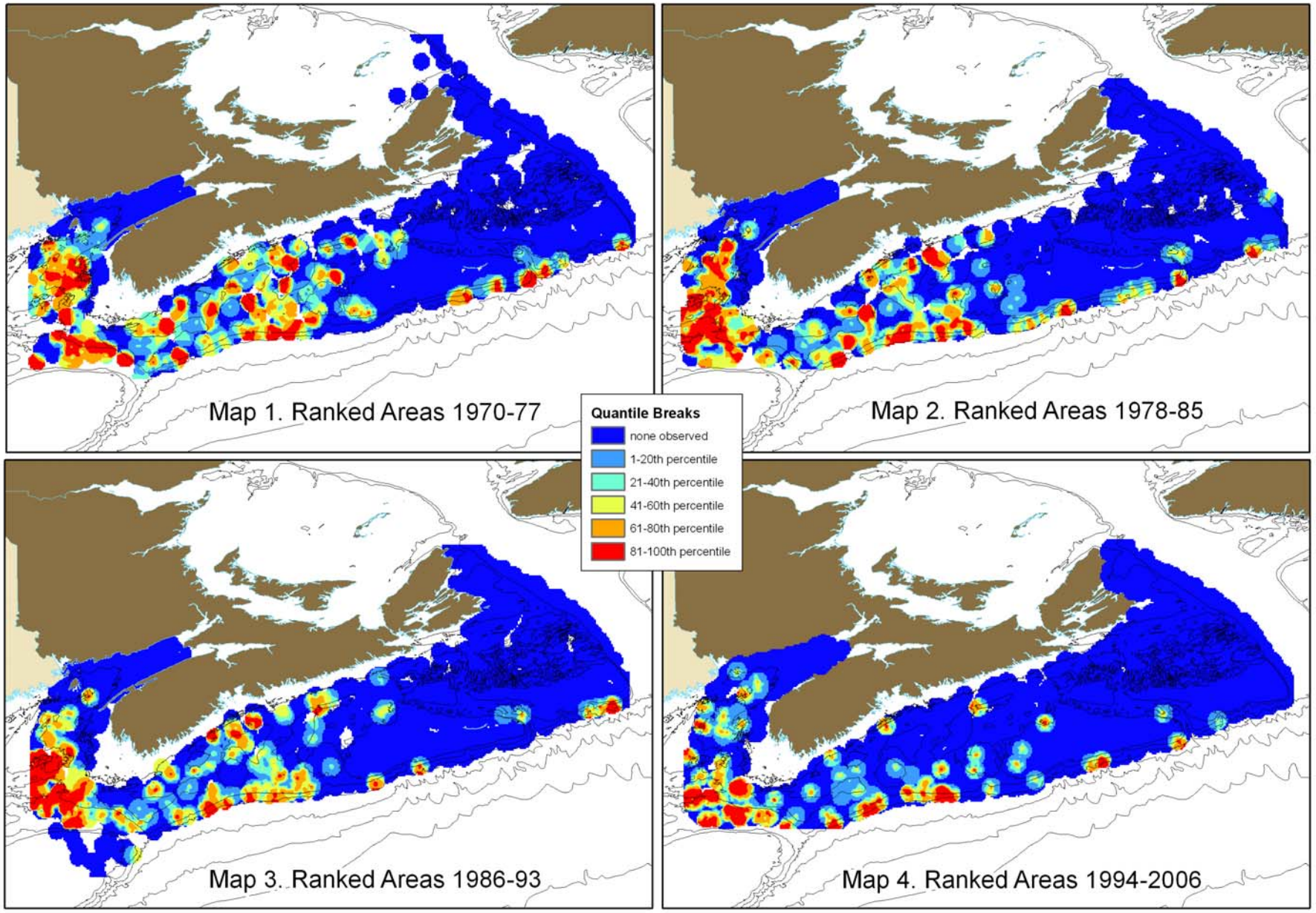


Figure 1. Population Trend

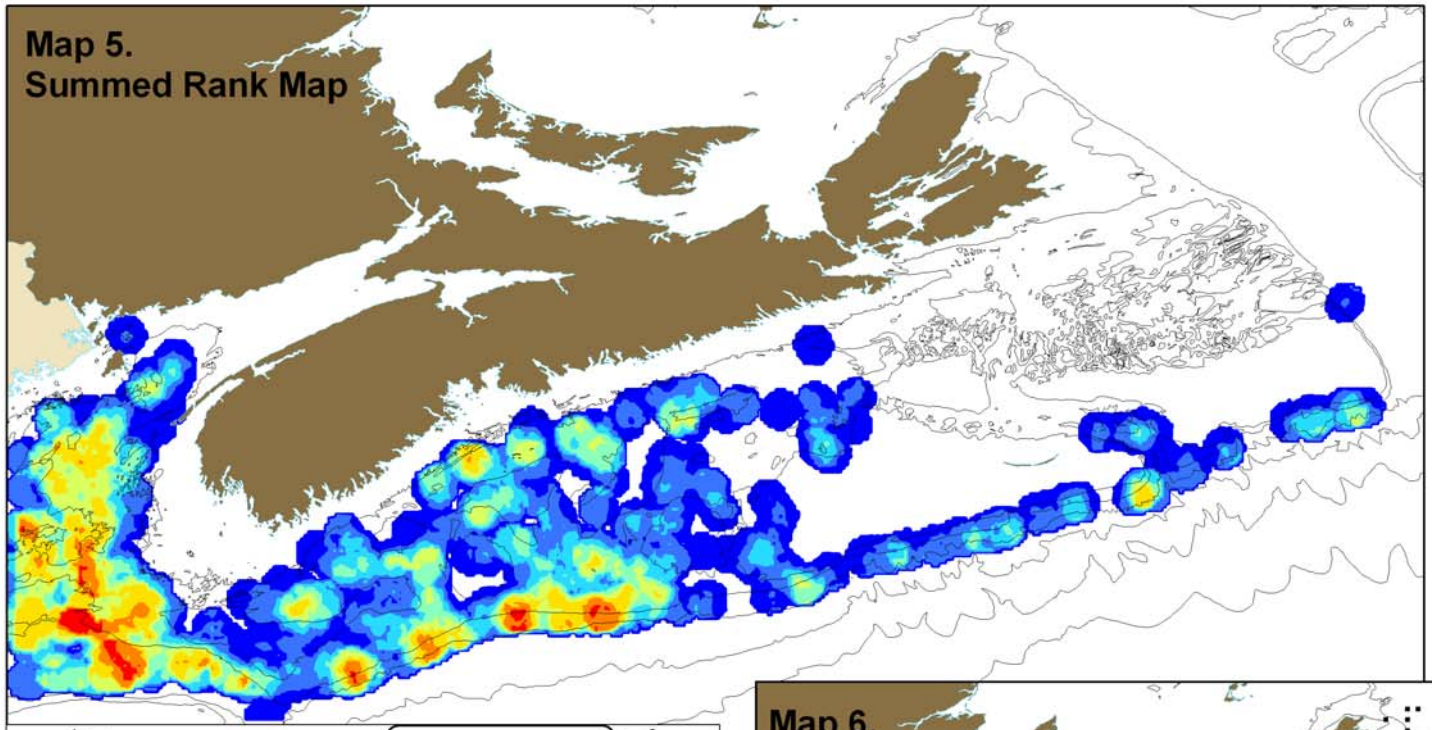
This page was left blank intentionally.

3.3 Depleted or Rare Species

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for these species identified as depleted on the Scotian Shelf: Cusk (*Brosme brosme*); Northern Wolffish*(Anarhichas denticulatus)* Spotted Wolffish (*Anarhichas minor***)**; and Atlantic Wolffish (*Anarhichas lupus*). Both Winter Skate (*Leucoraja ocellata*) and Atlantic Cod (*Gadus morhua*), are identified as depleted but are also influential predators. The maps and population trends for these two species are found in section 3.2 of this report.



Cusk (*Brosme brosme*)



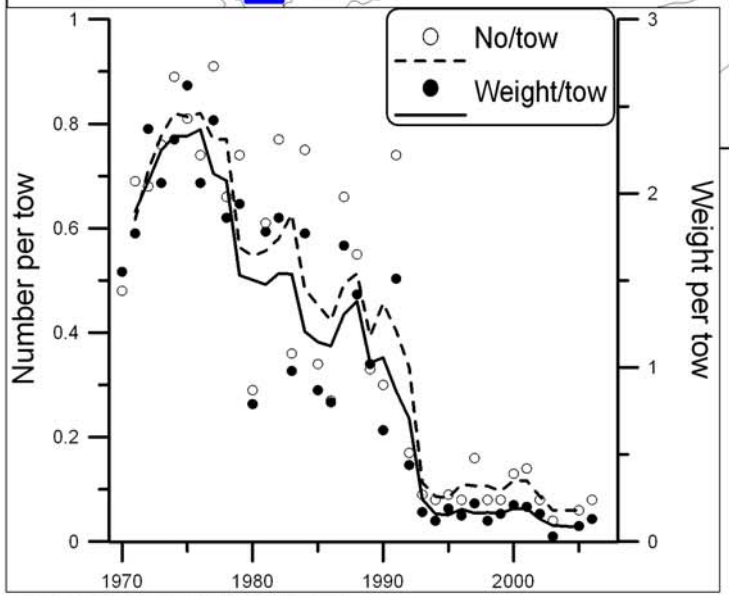
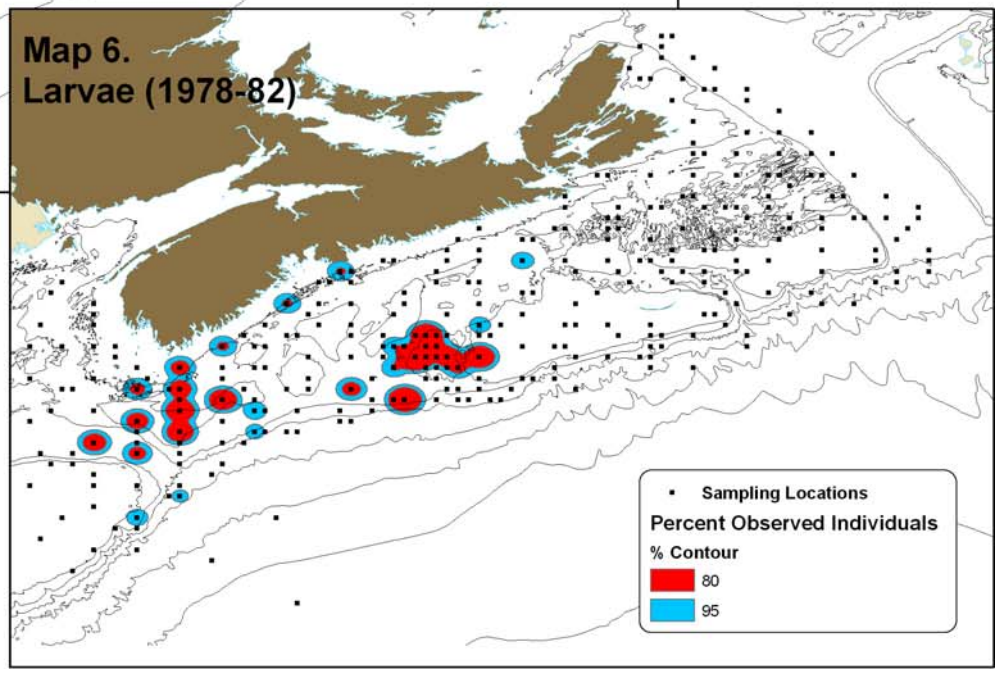
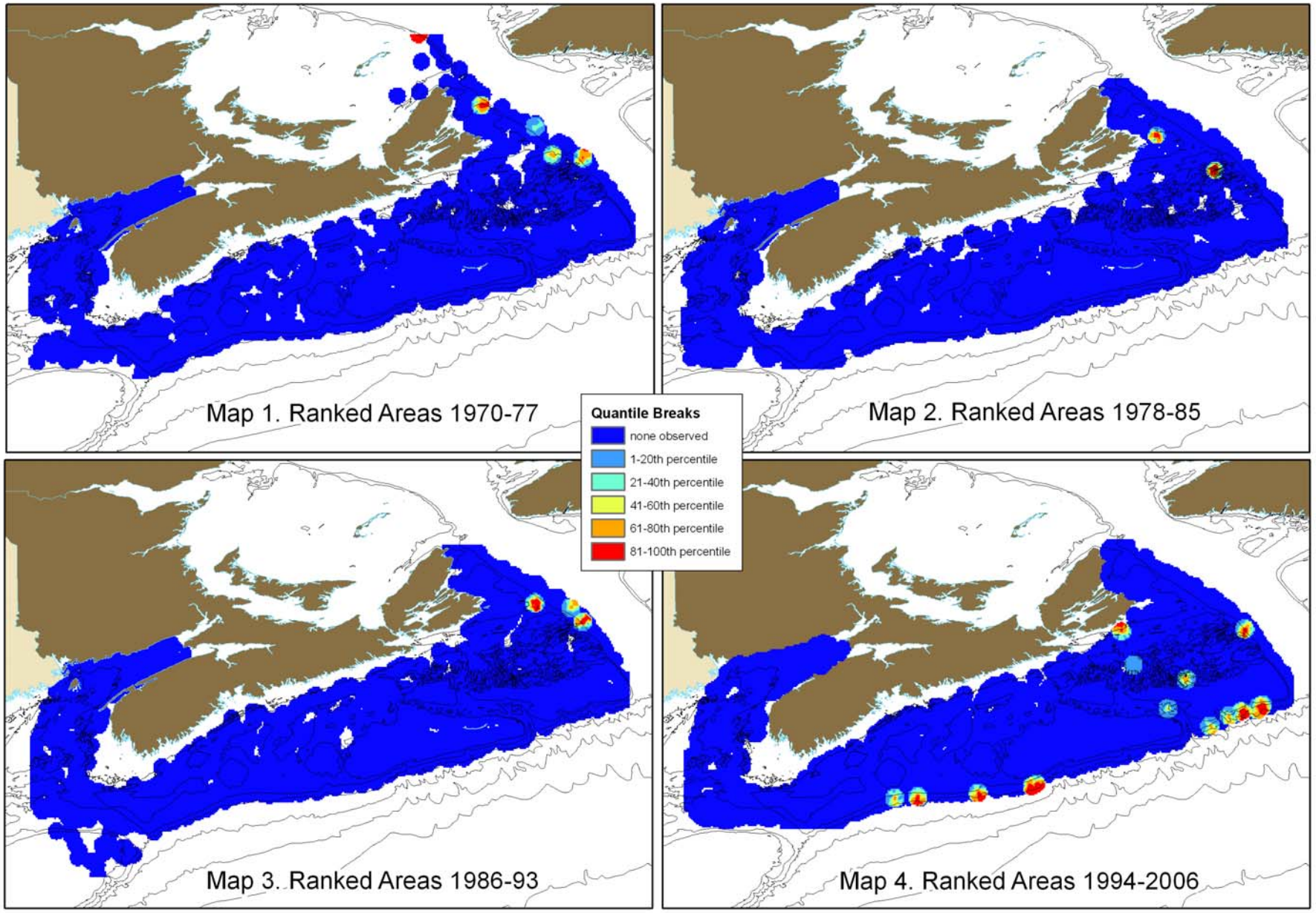


Figure 1. Population Trend





Northern Wolffish (*Anarhicus denticulatus*)

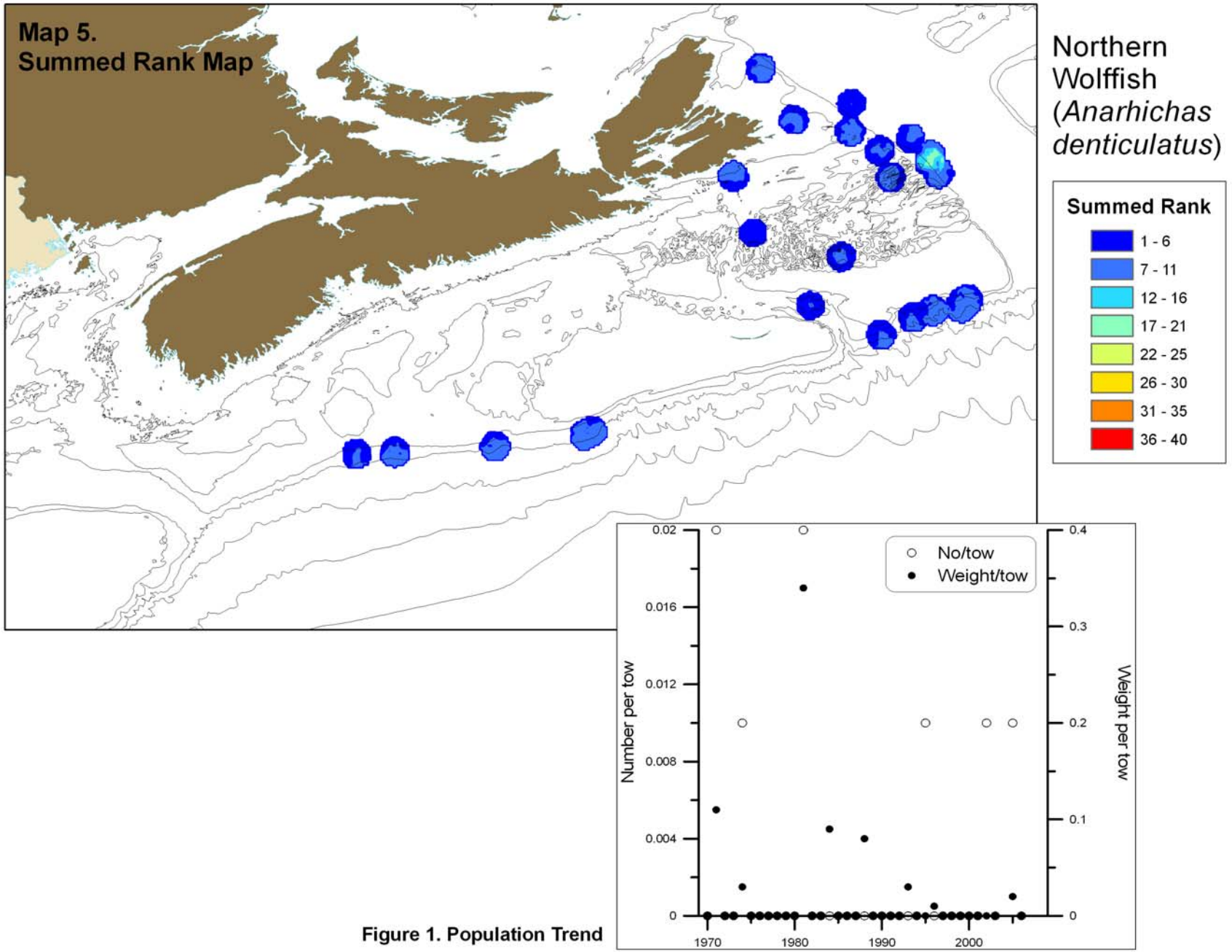
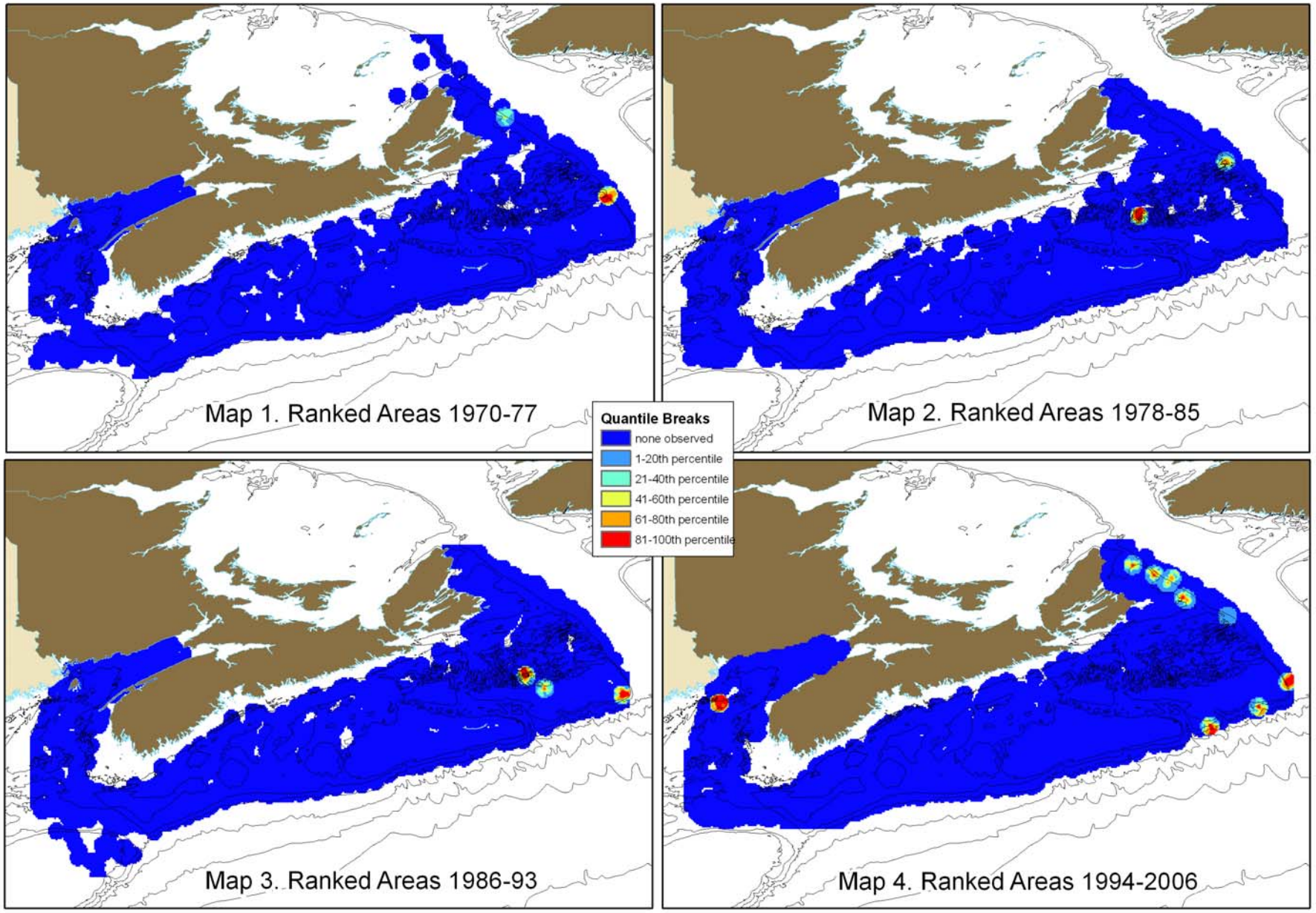


Figure 1. Population Trend



Spotted Wolffish (*Anarhicus minor*)

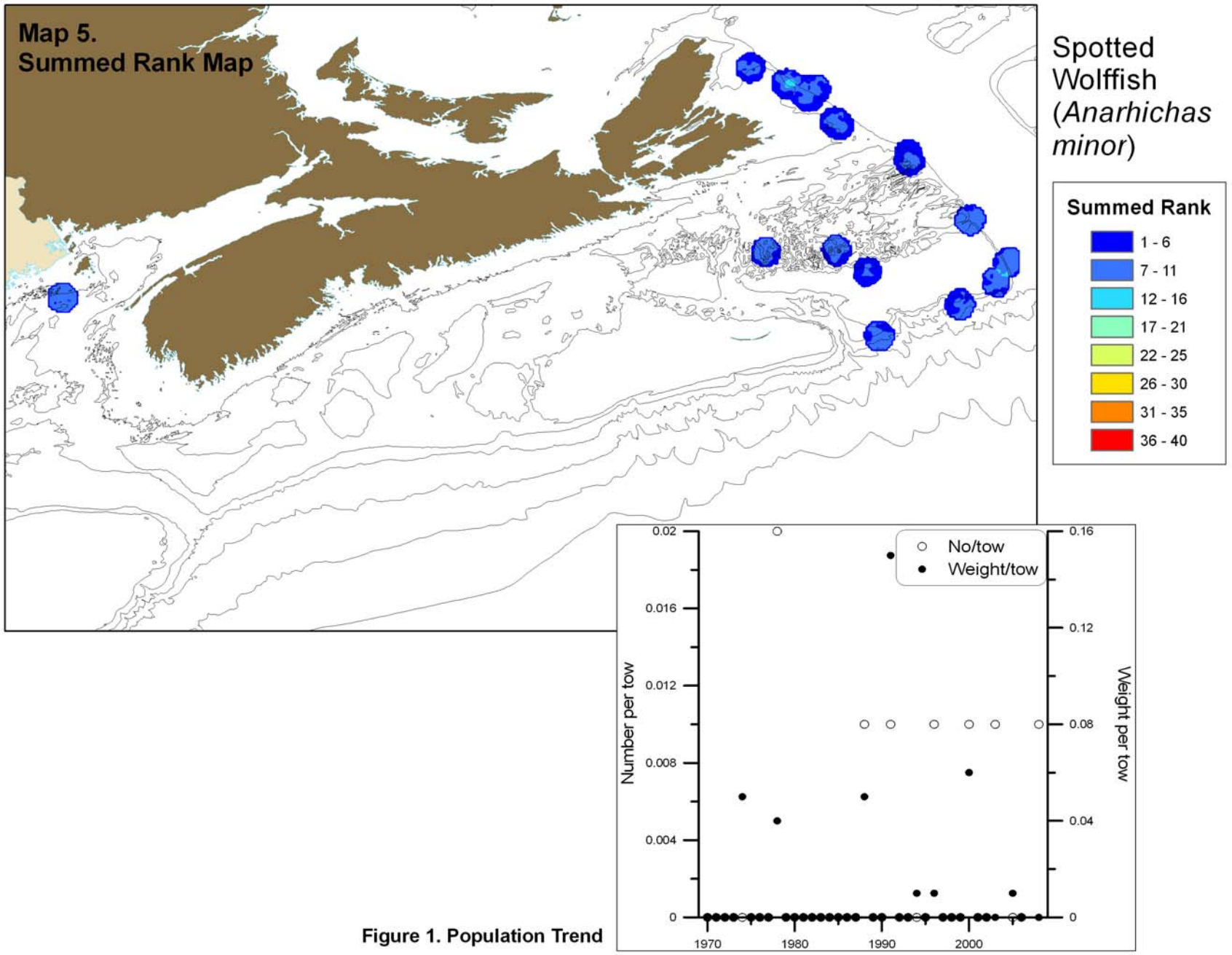
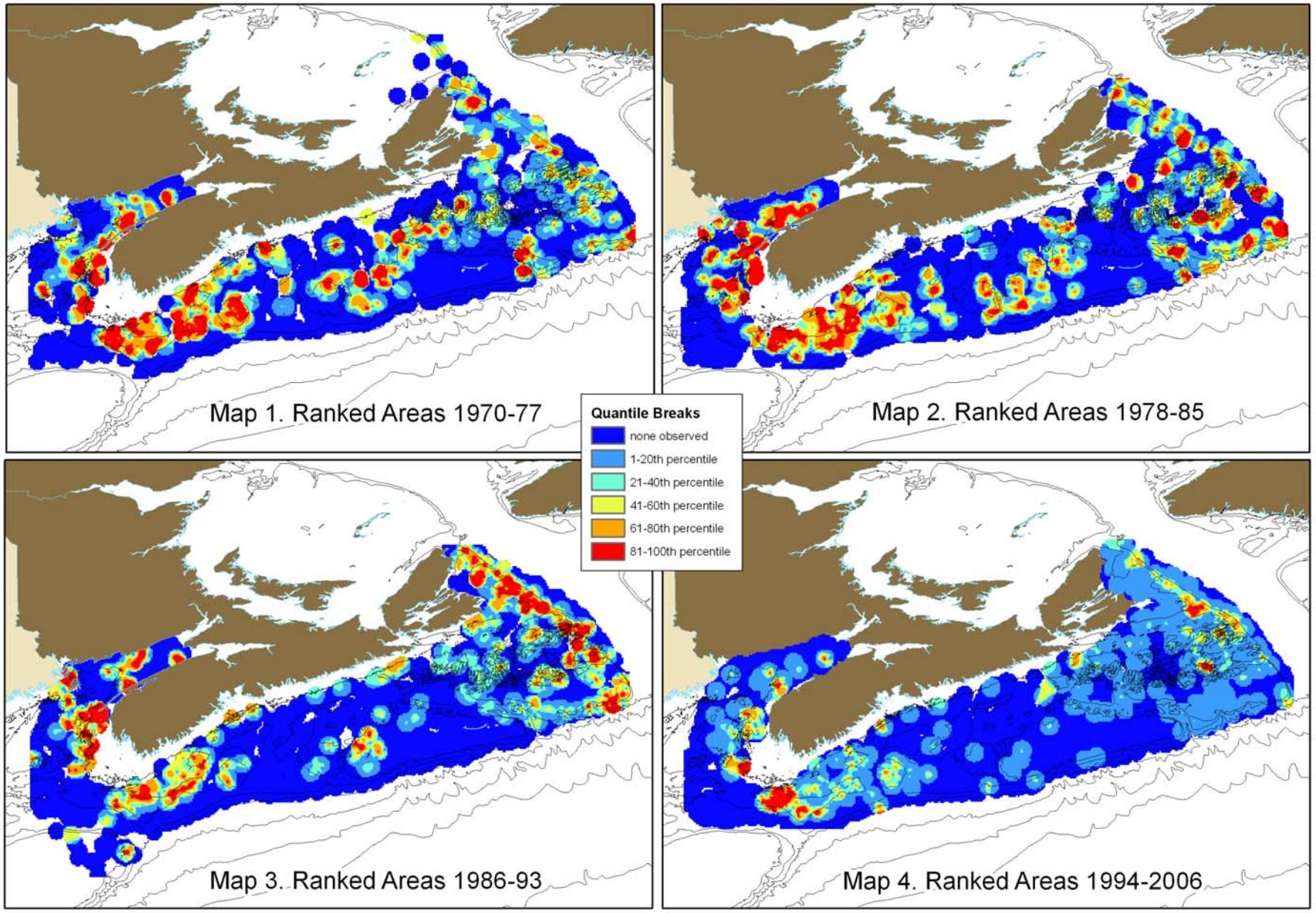
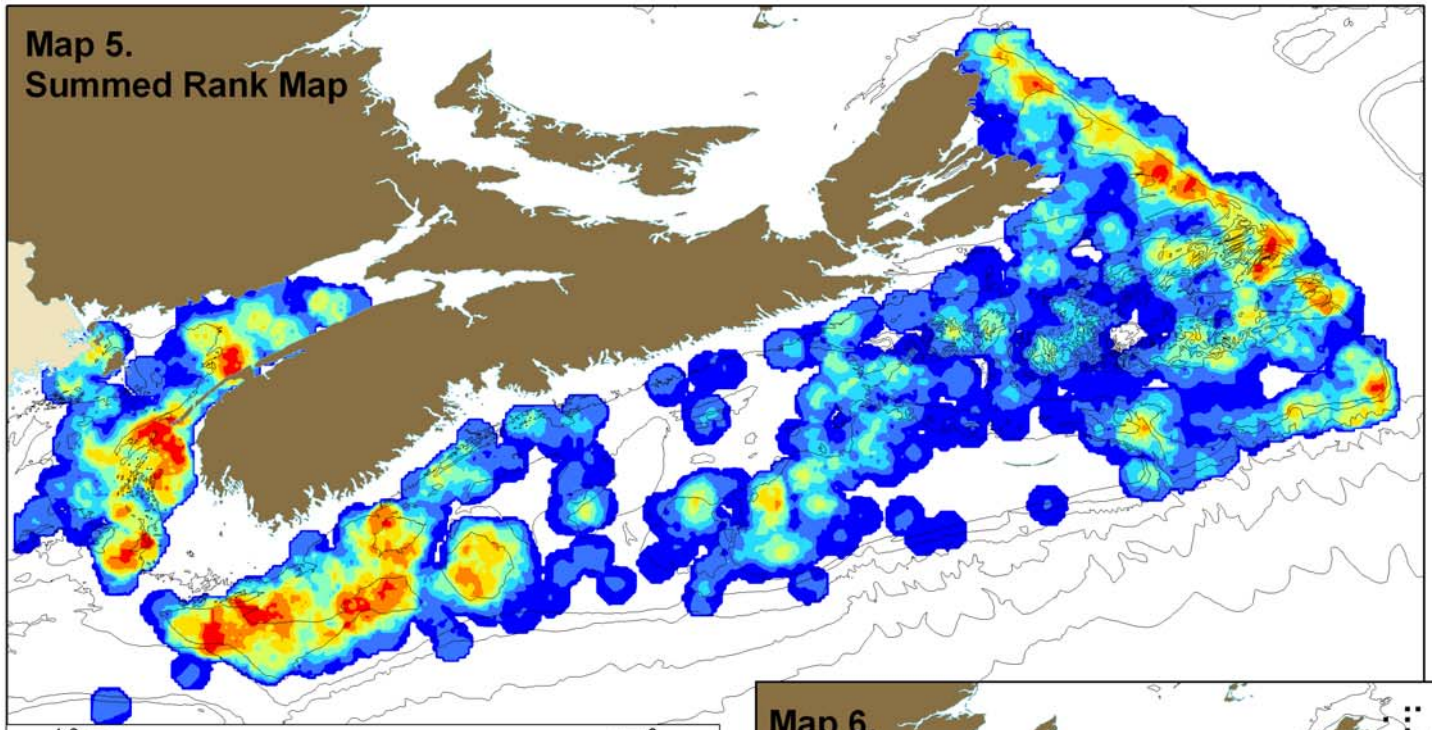


Figure 1. Population Trend



Atlantic Wolffish (*Anarhicus lupus*)



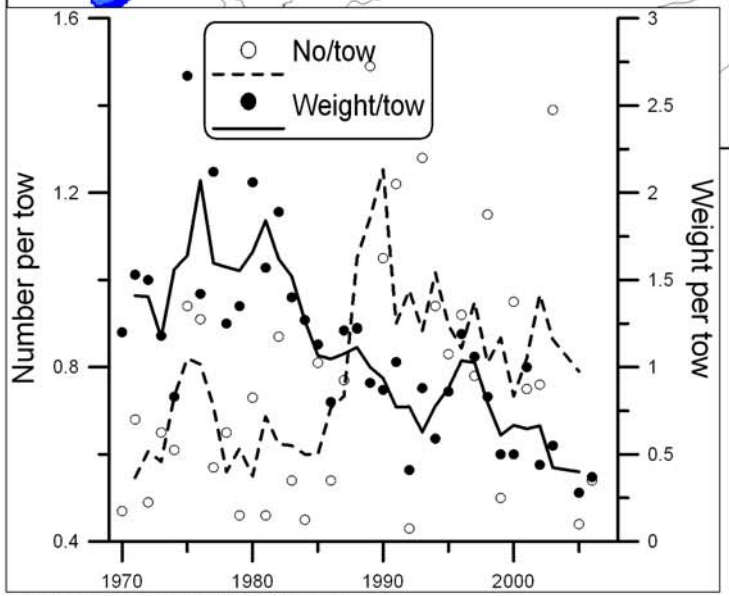
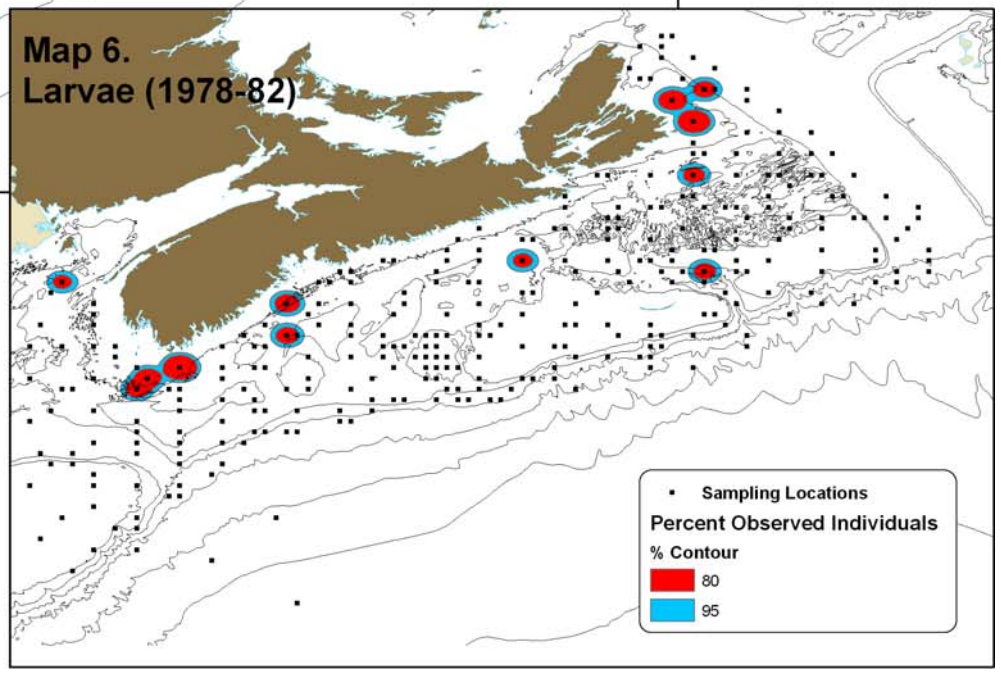


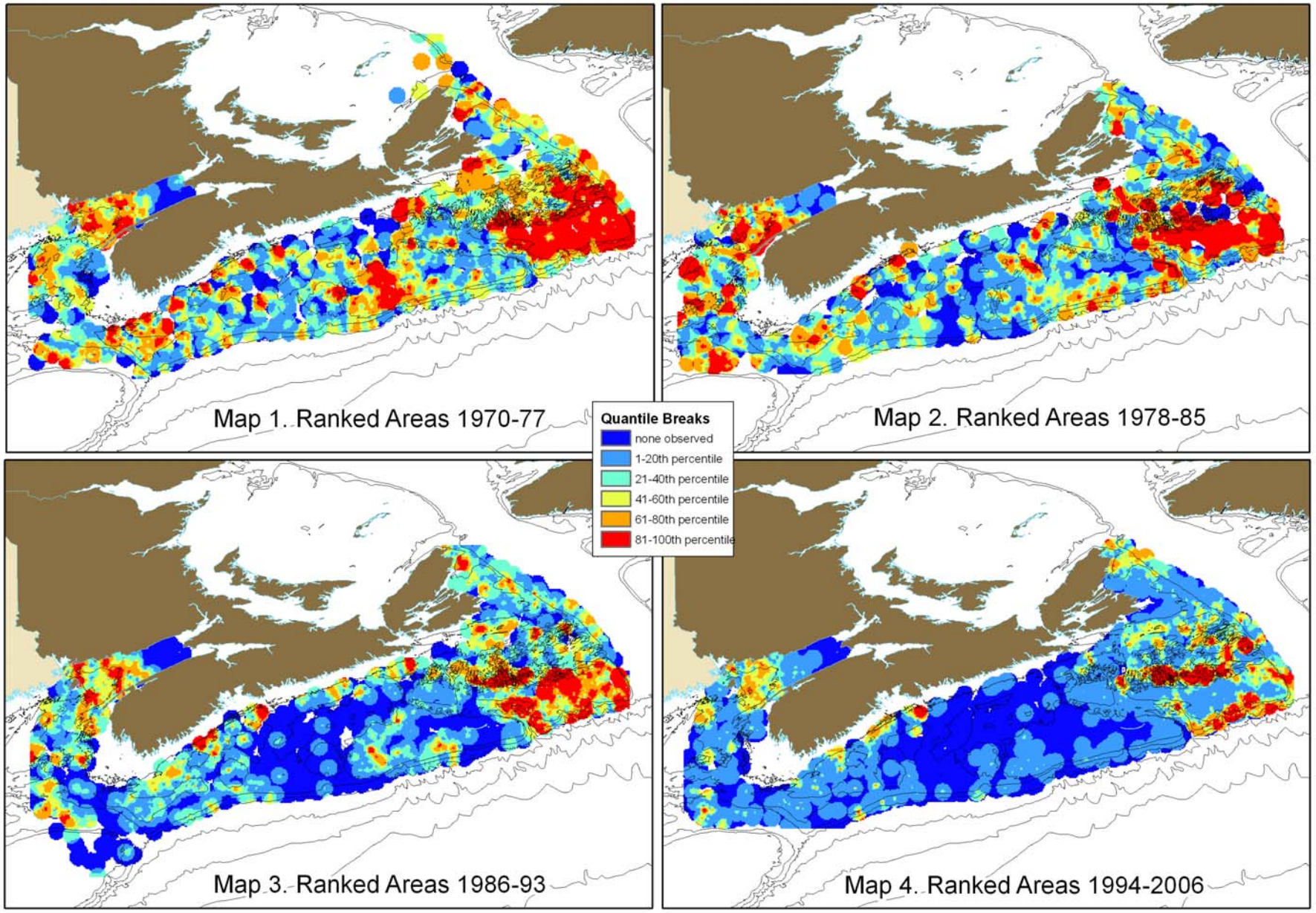
Figure 1. Population Trend



This page was intentionally left blank.

3.4 Other Dominant Species Observed in the Summer Trawl Surveys

The results of our evaluation of areas of persistently high ranking biomass and the population trends can be found on the following pages for species that have been observed to be dominant in the RV surveys (i.e., >10% occurrence in all trawl sets) but that weren't identified as ecologically significant species in any of the existing categories. These nine species are: Moustache/Mailed Sculpin *(Triglops murrayi)*; Thorny Skate (*Amblyraja radiata)*; Yellowtail Flounder *(Limanda ferruginea)*; Monkfish *(Lophius americanus)*; Sea Raven/Sea Sculpin *(Hemitripterus americanus)*; Ocean Pout *(Zoarces americanus)*; Blackback/Winter Flounder *(Pseudopleuronectes americanus)*; Altantic Argentine *(Argentina silus)*; Longfin Hake *(Phycis chesteri).*



Thorny Skate (*Amblyraja radiate*)

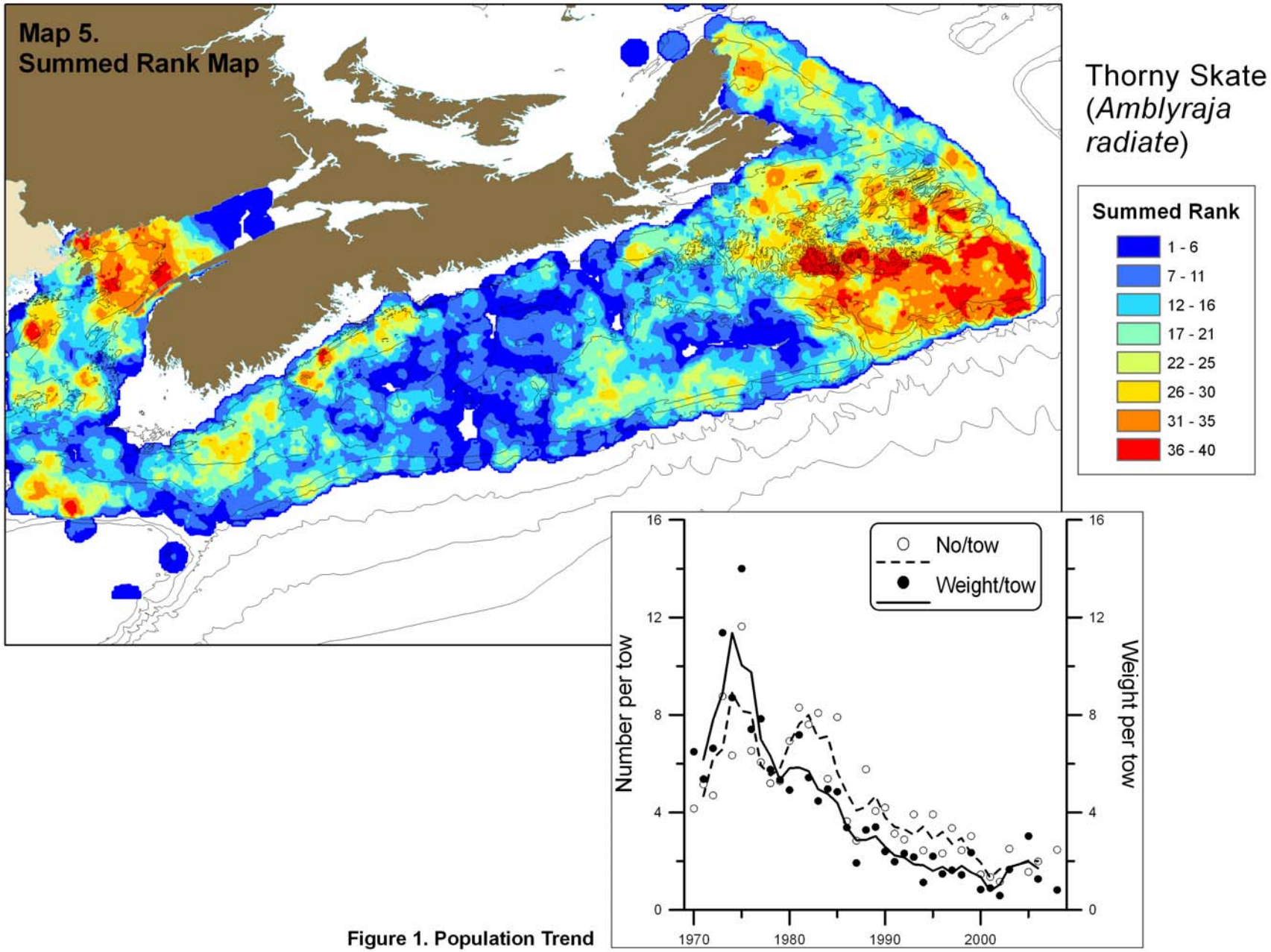
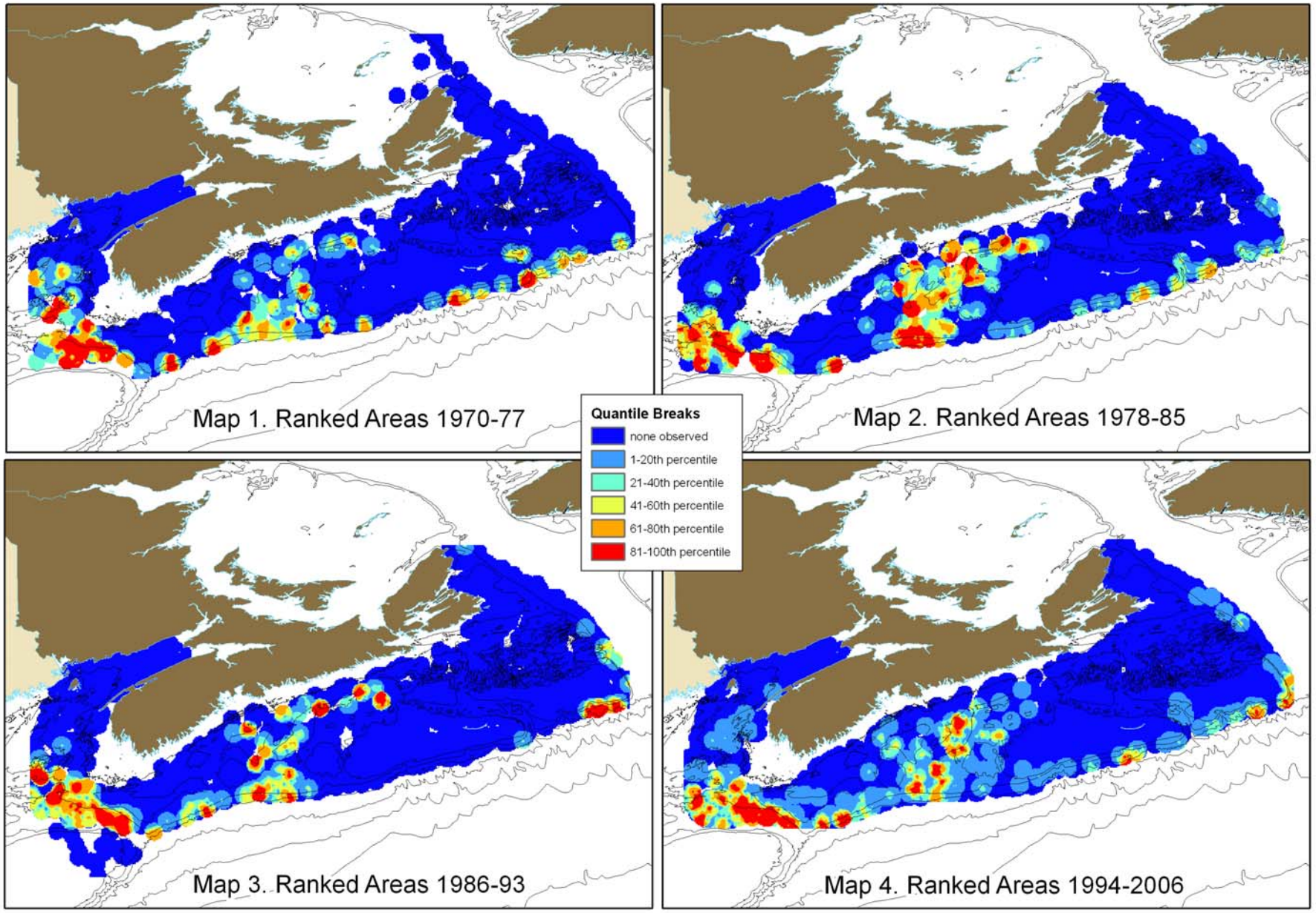
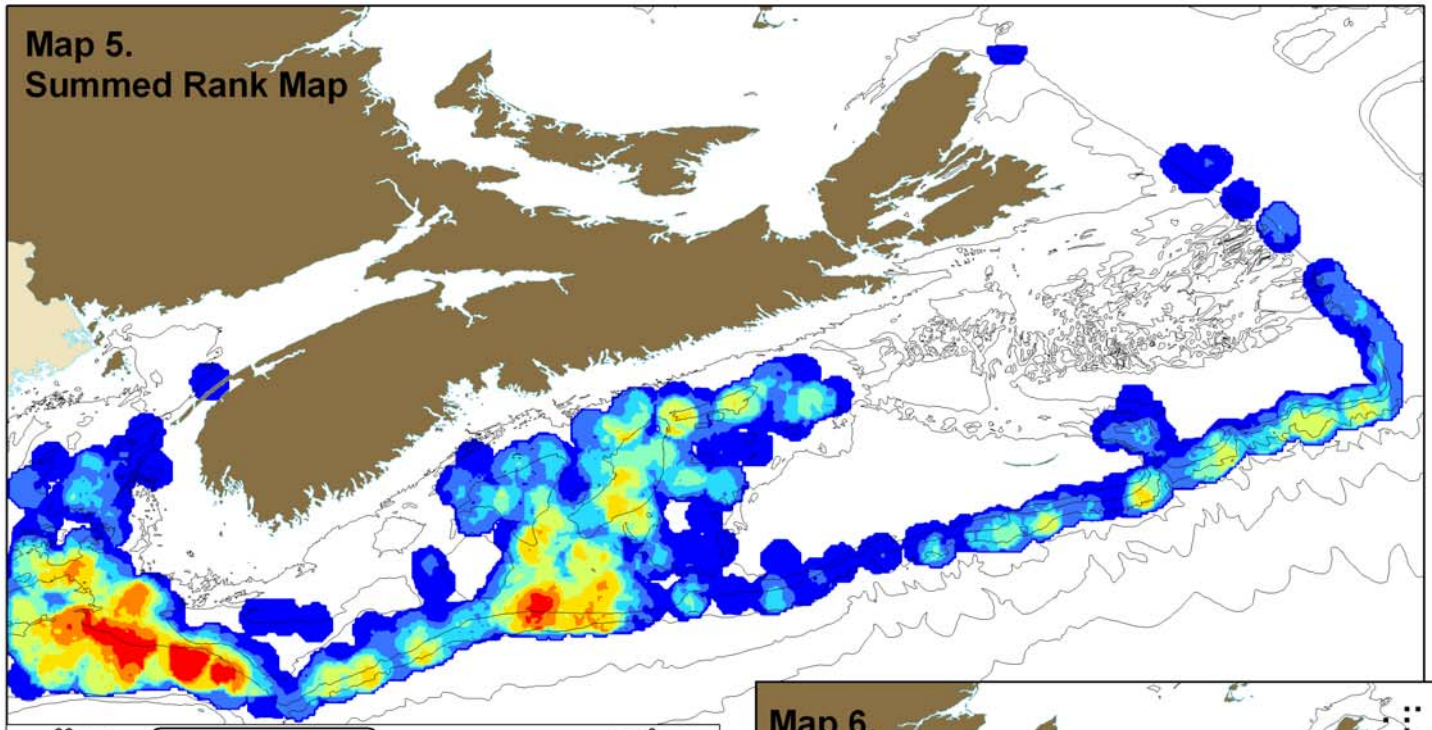


Figure 1. Population Trend



Atlantic argentine (*Argentina silus*)



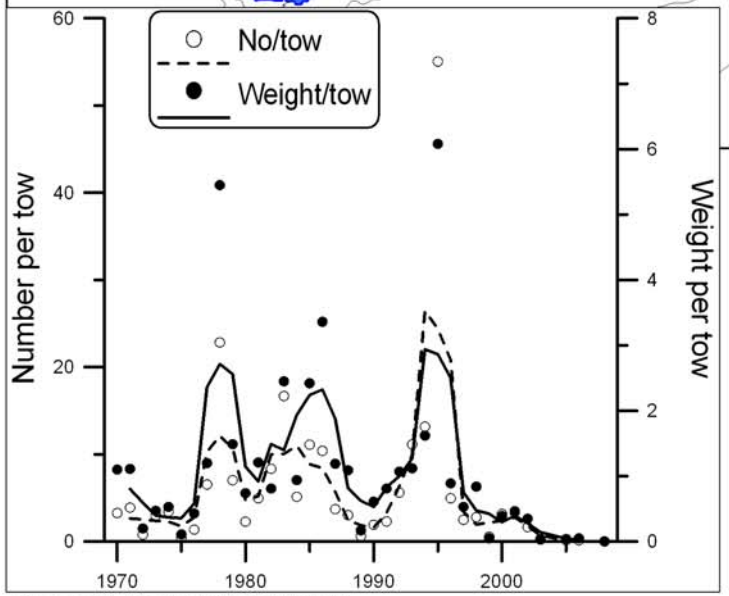
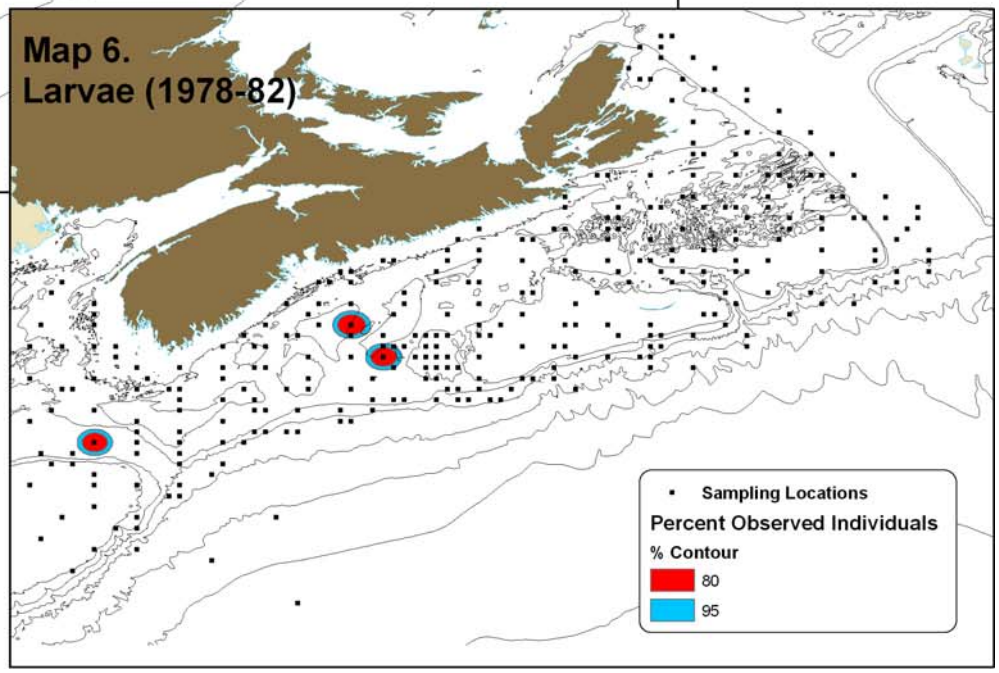
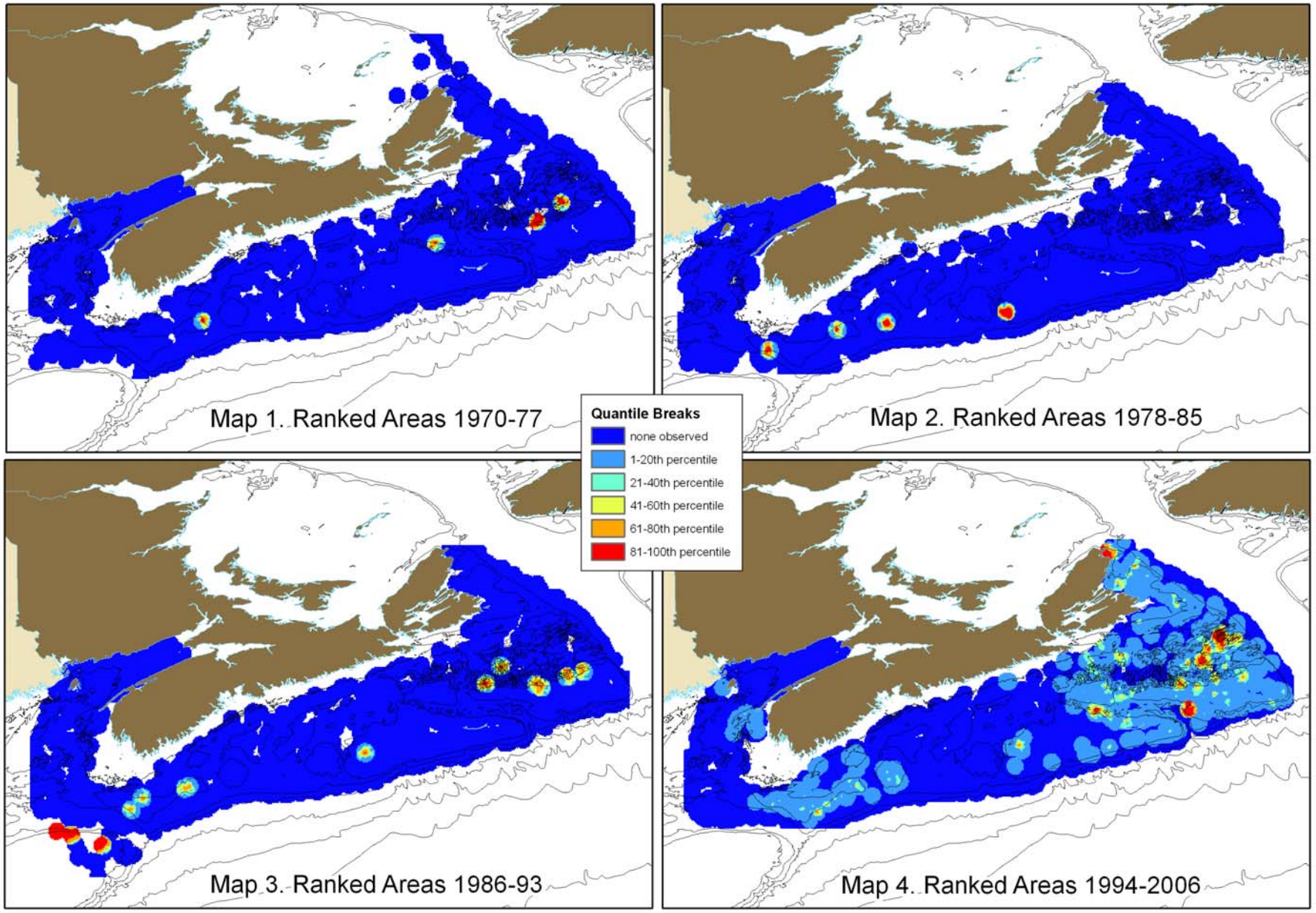
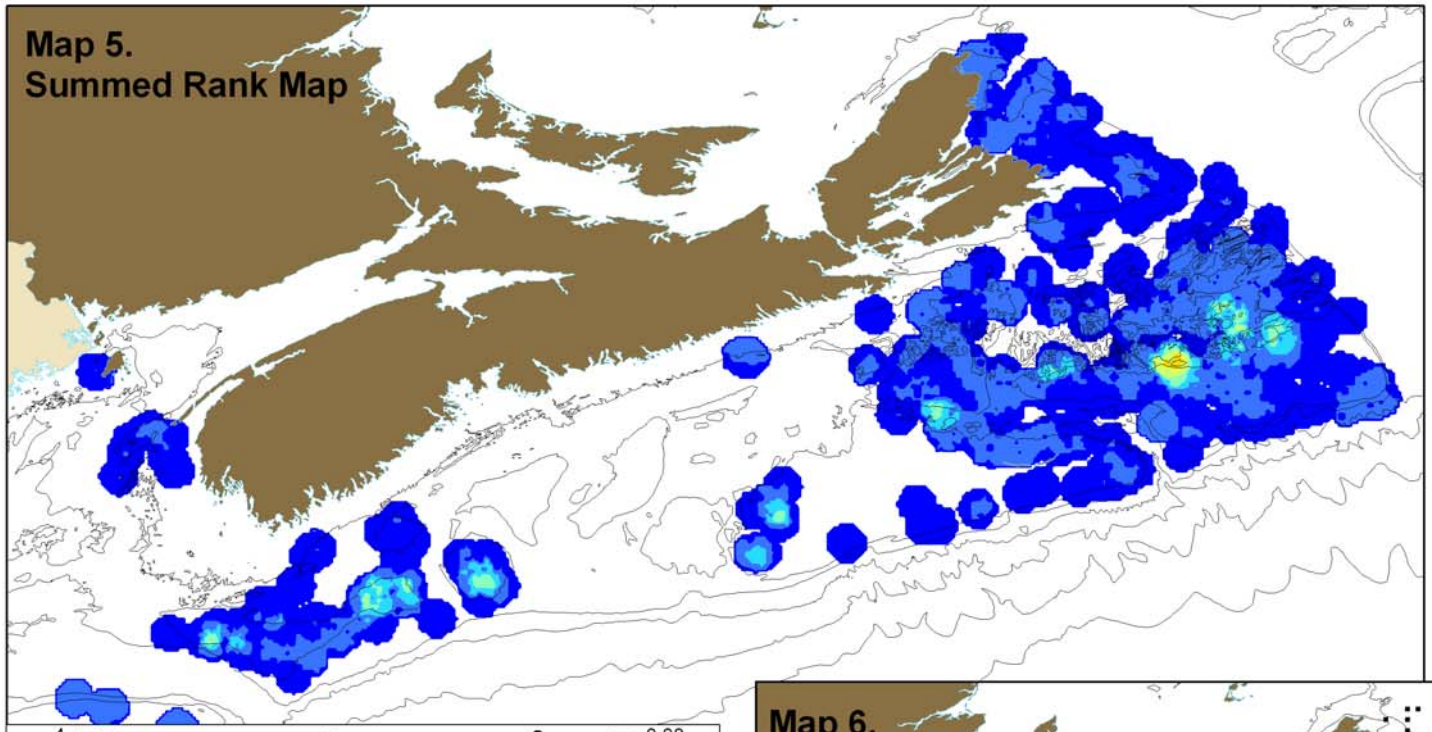


Figure 1. Population Trend





Moustache Sculpin (*Triglops murrayi*)



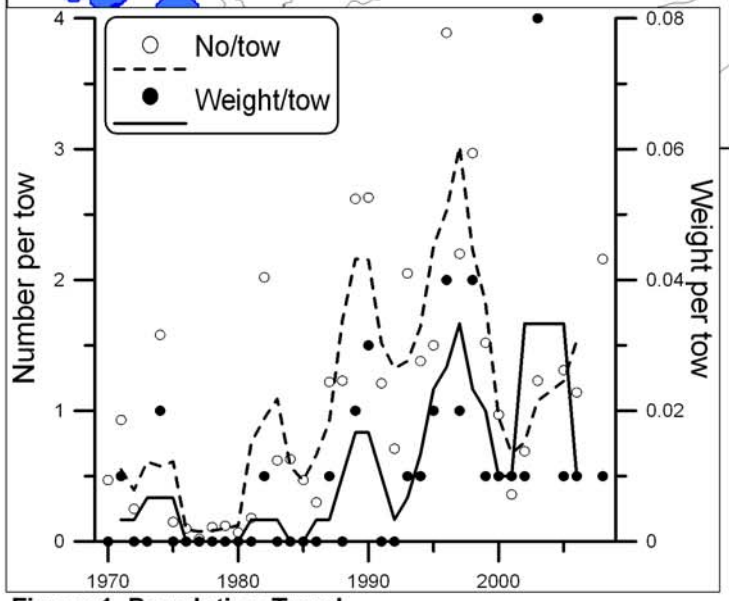
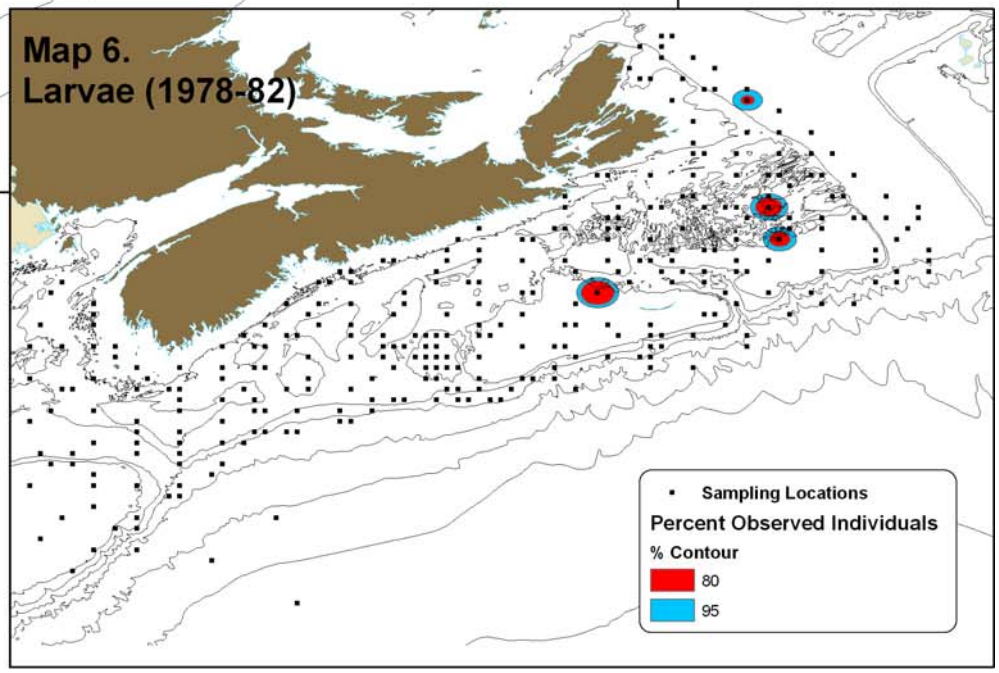
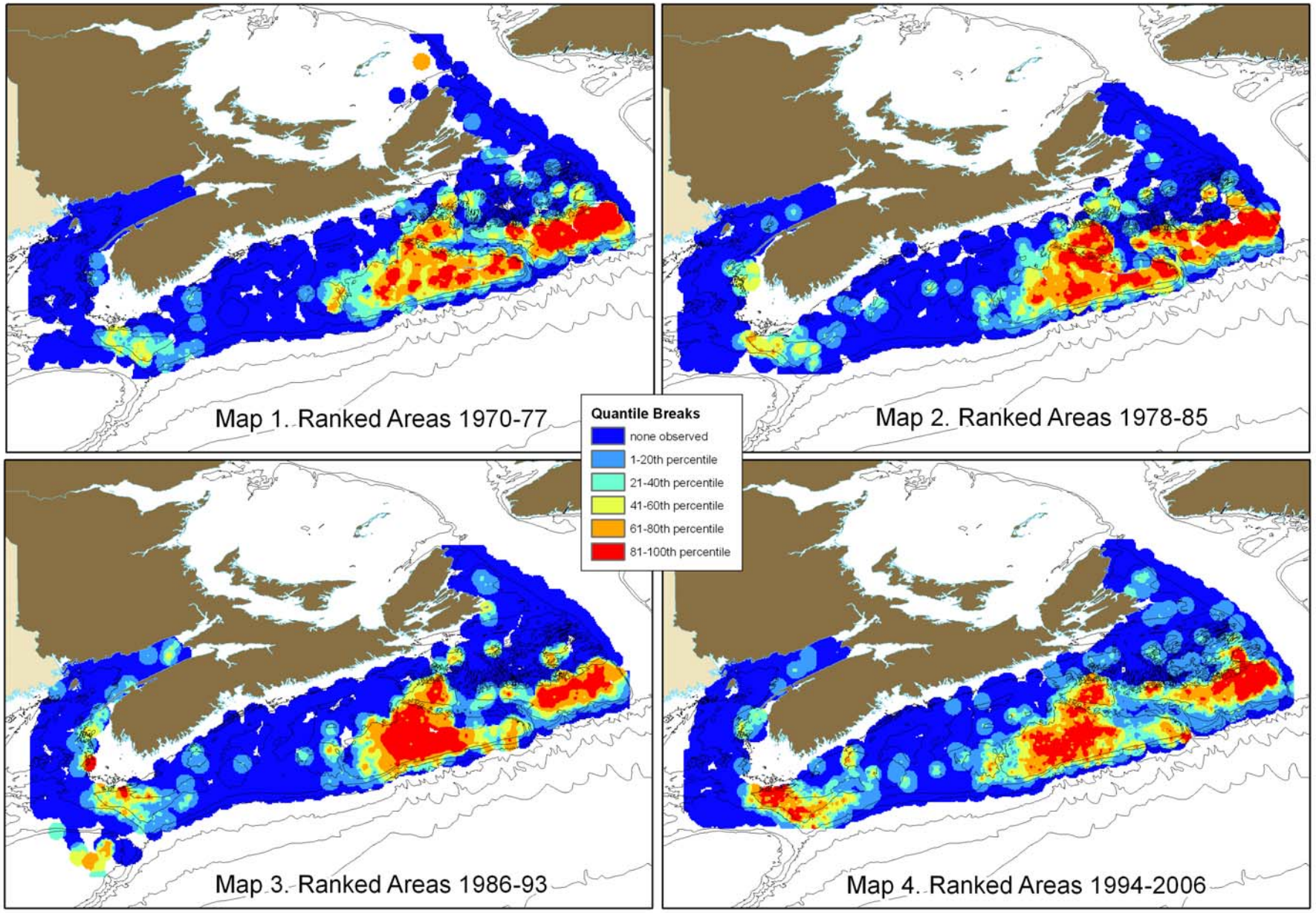


Figure 1. Population Trend





Yellowtail founder (*Limanda ferruginea*)

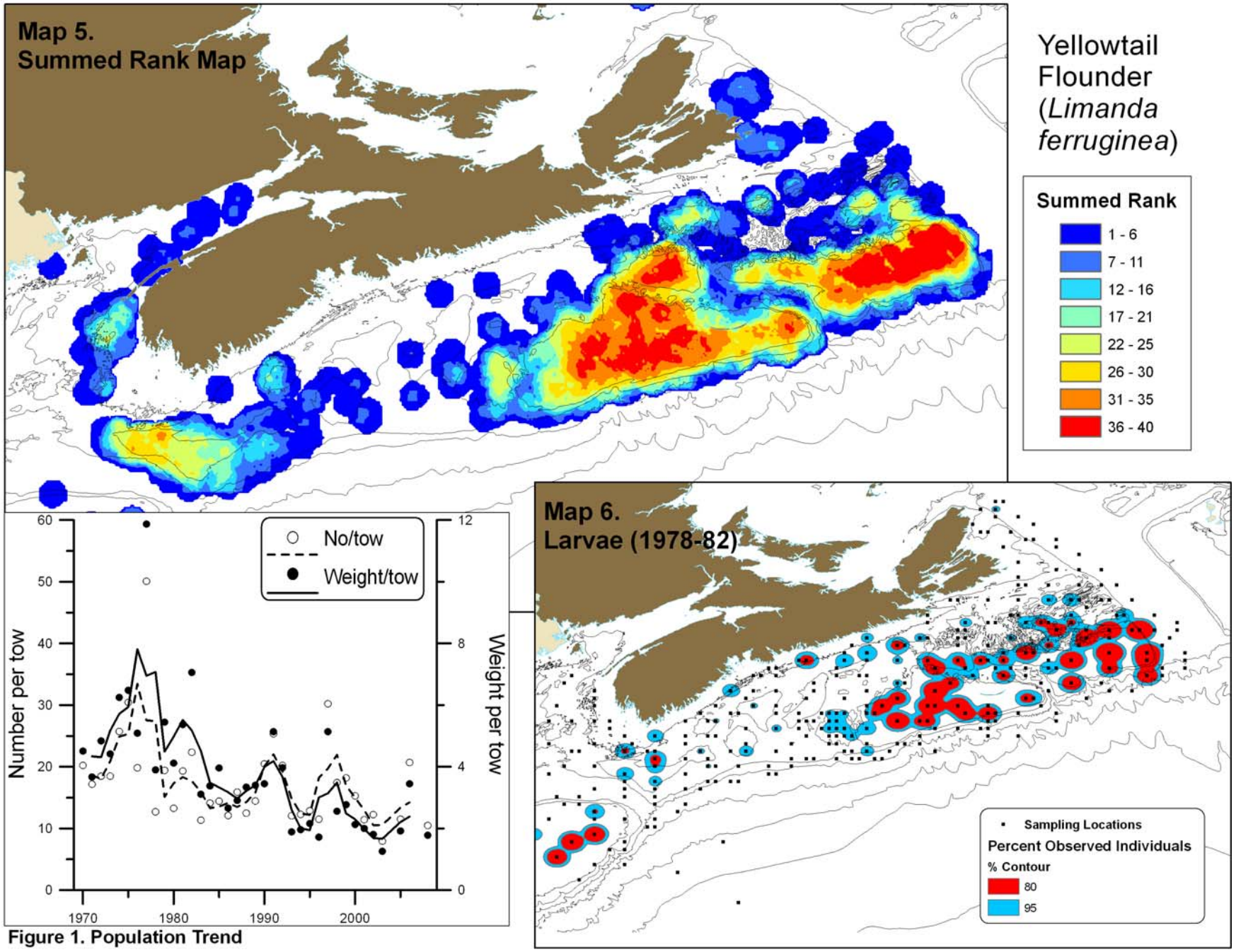
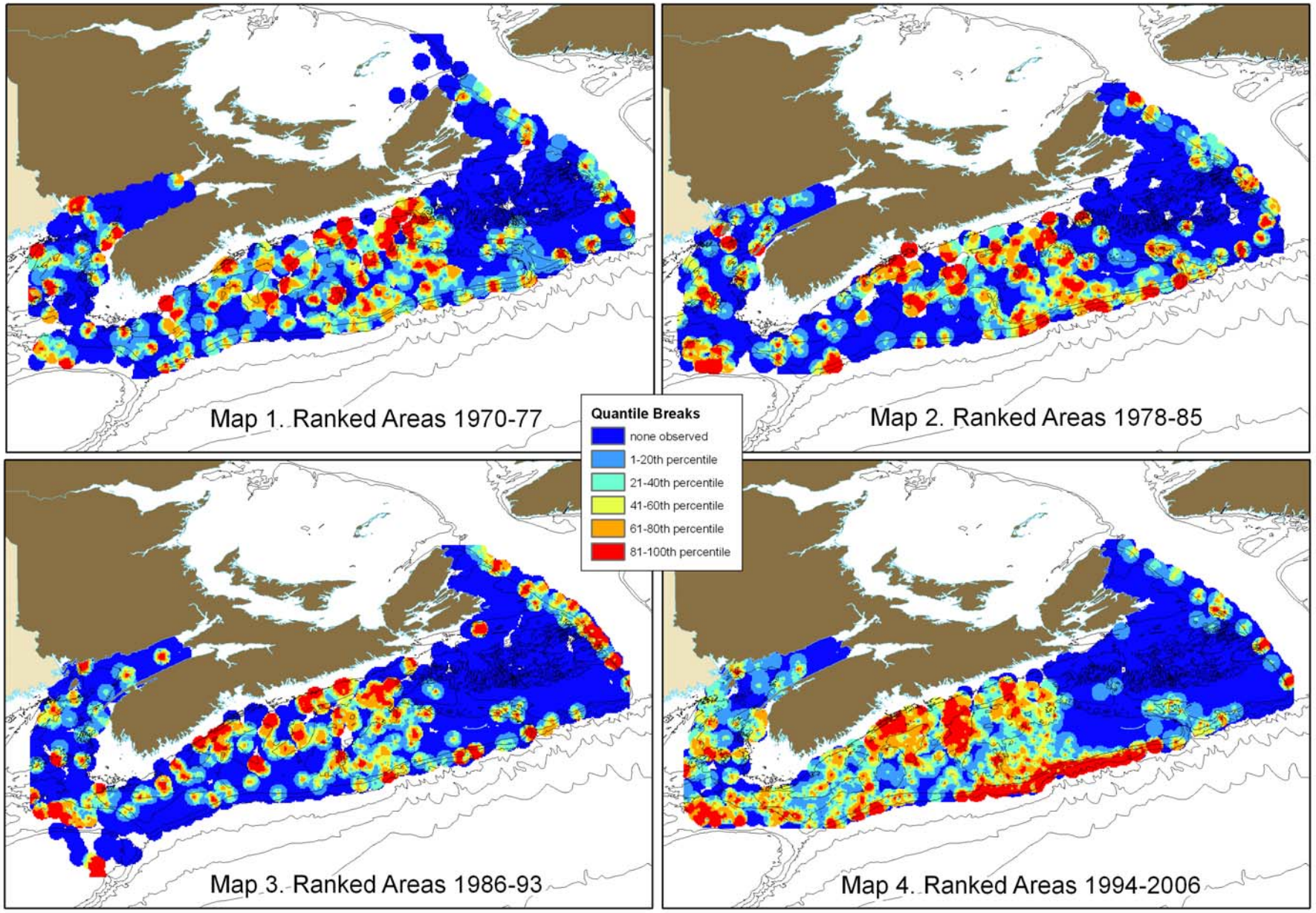
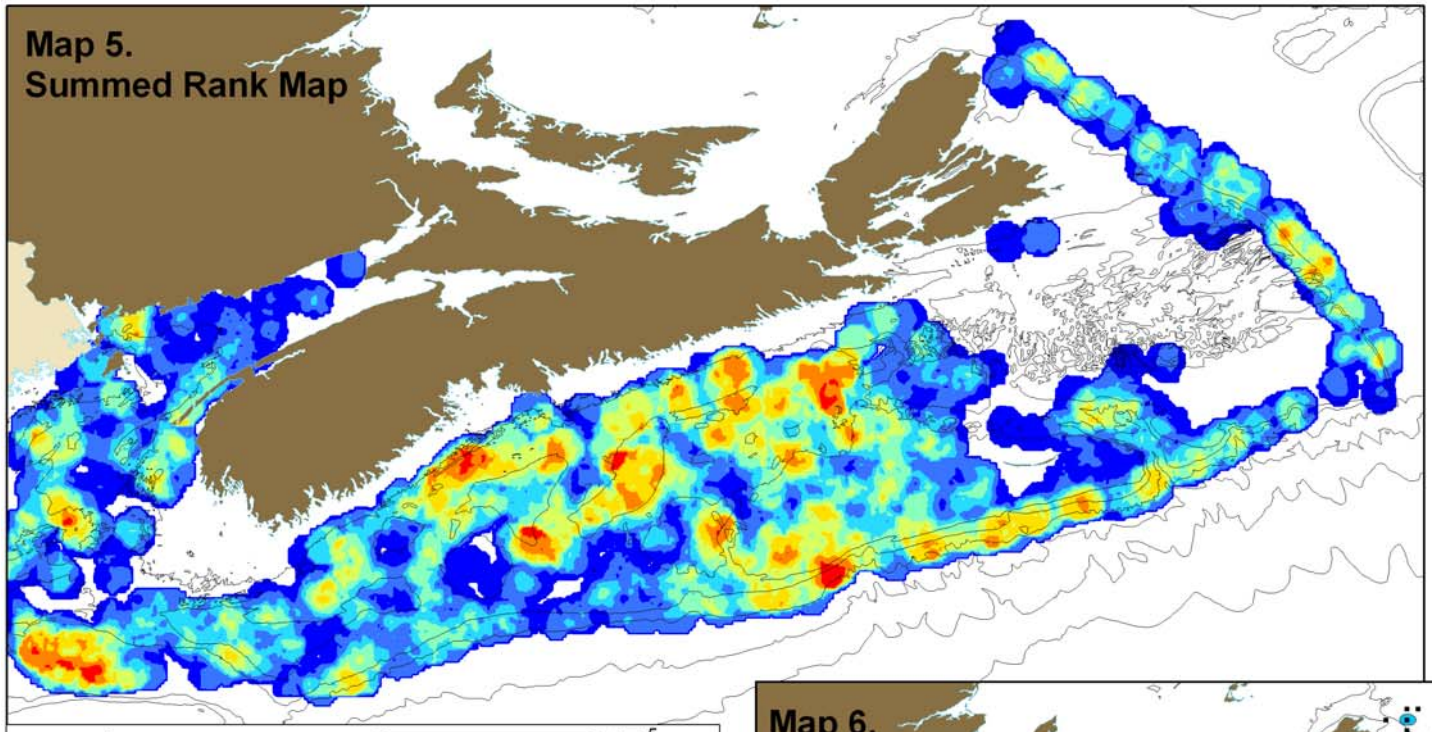


Figure 1. Population Trend



Monkfish (*Lophius americanus*)



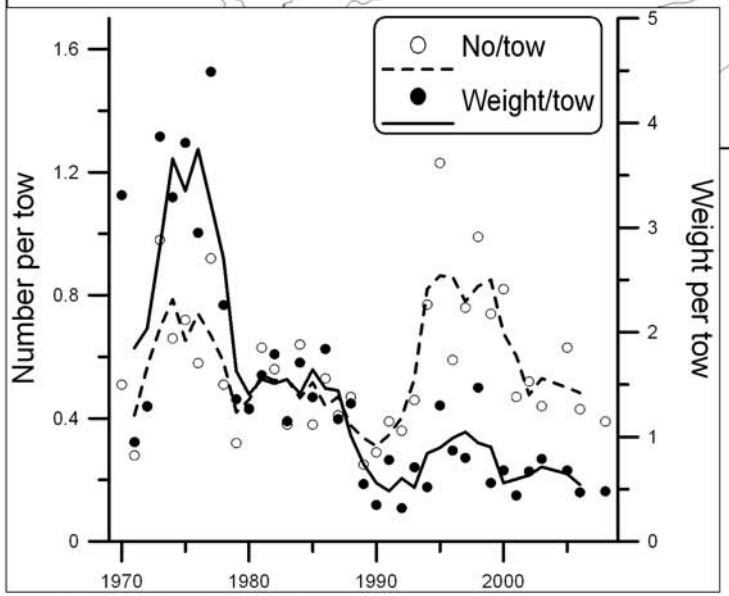
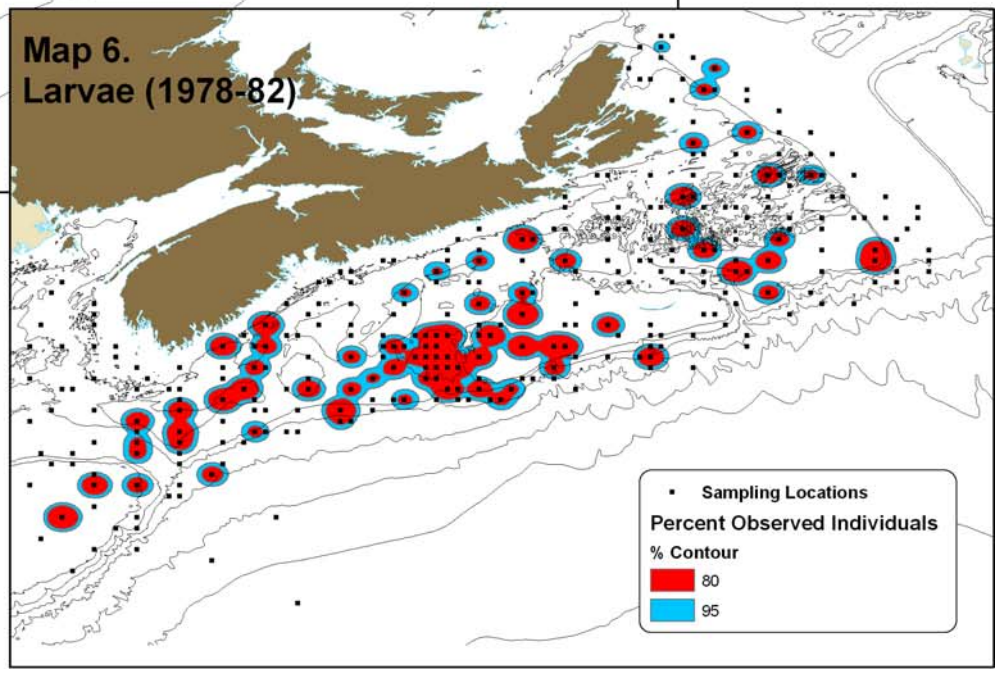
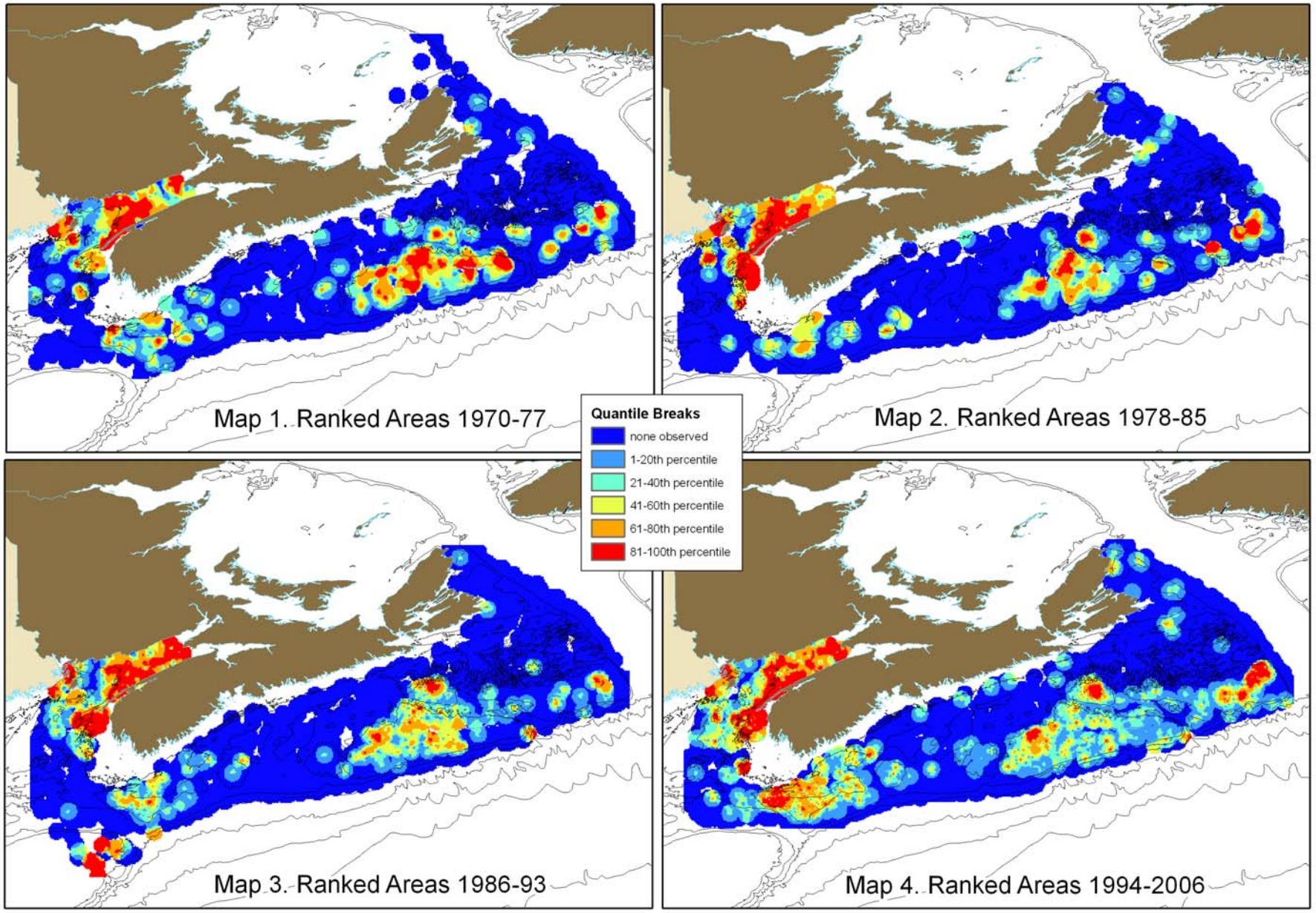


Figure 1. Population Trend





Sea Raven / Sea Sculpin (*Hemitripterus americanus*)

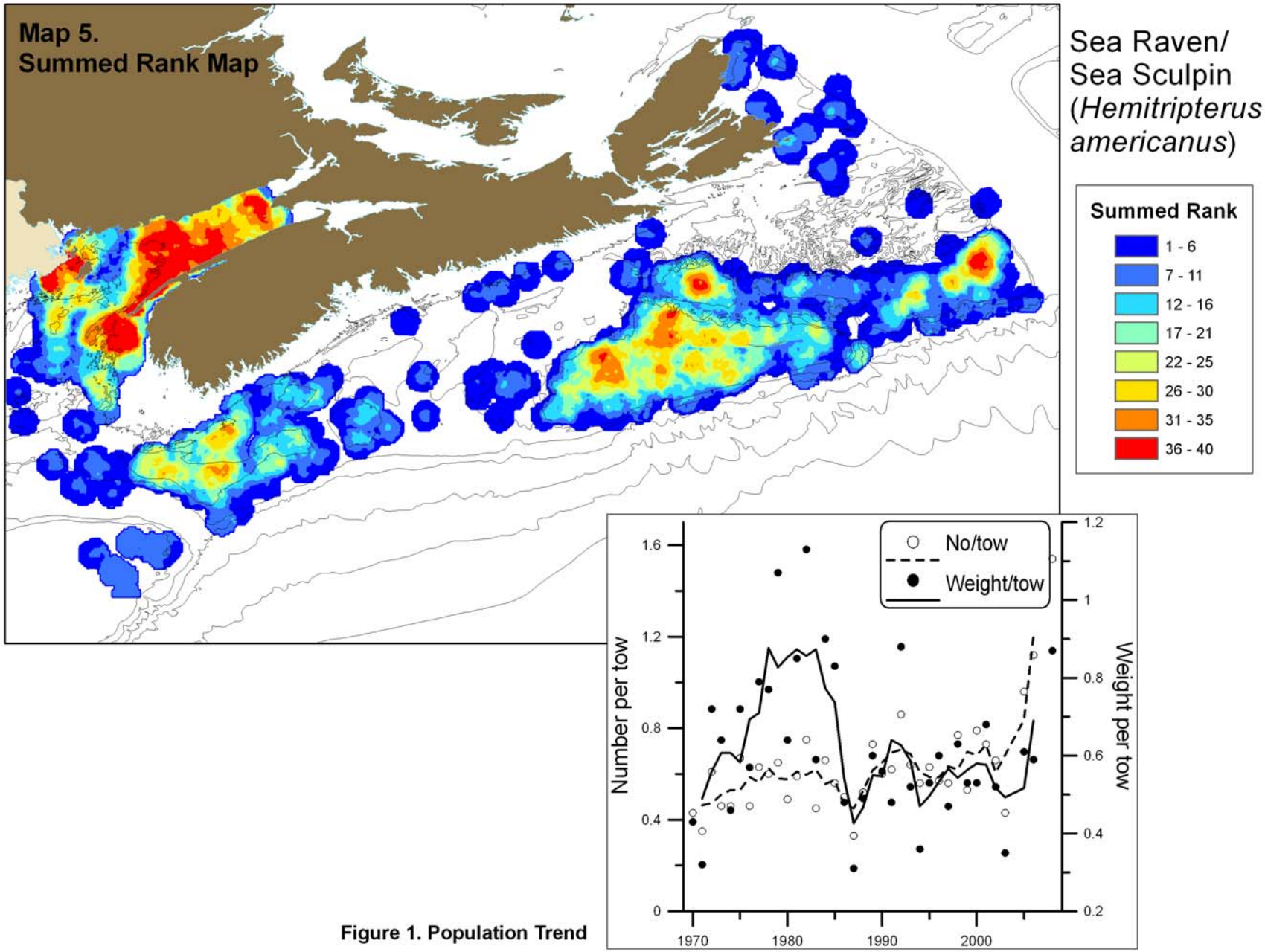
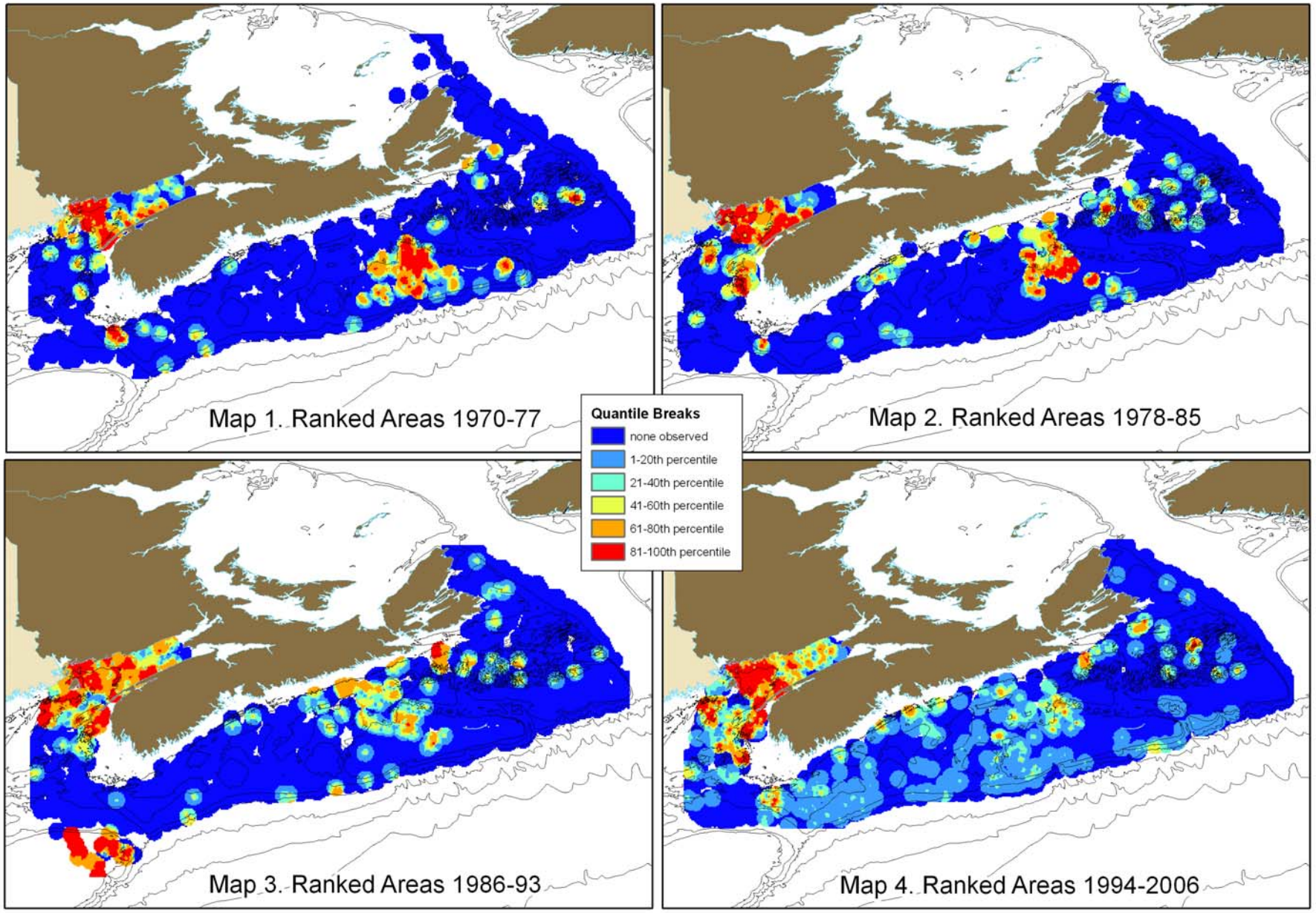


Figure 1. Population Trend



Ocean Pout (*Zoarces americanus*)

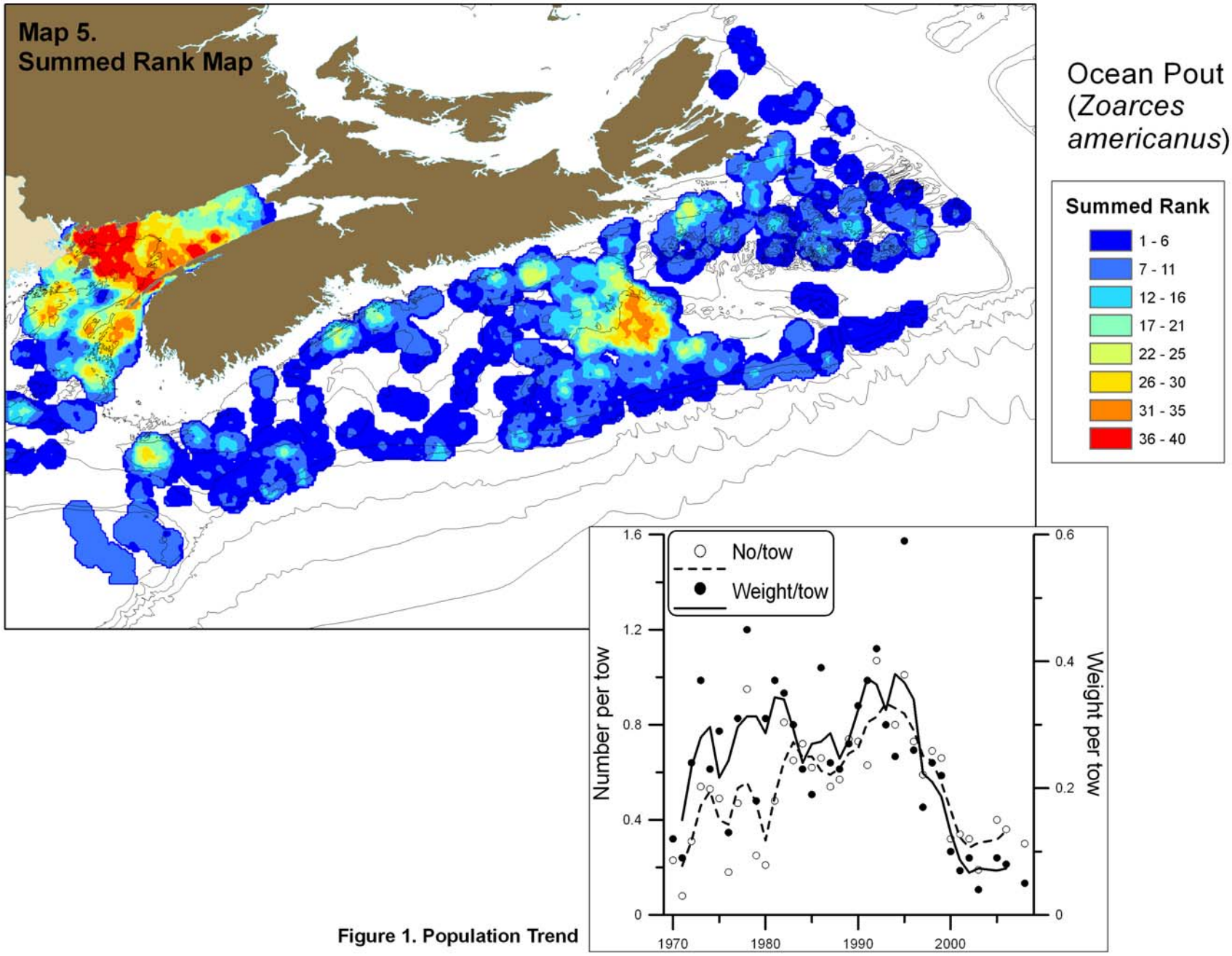
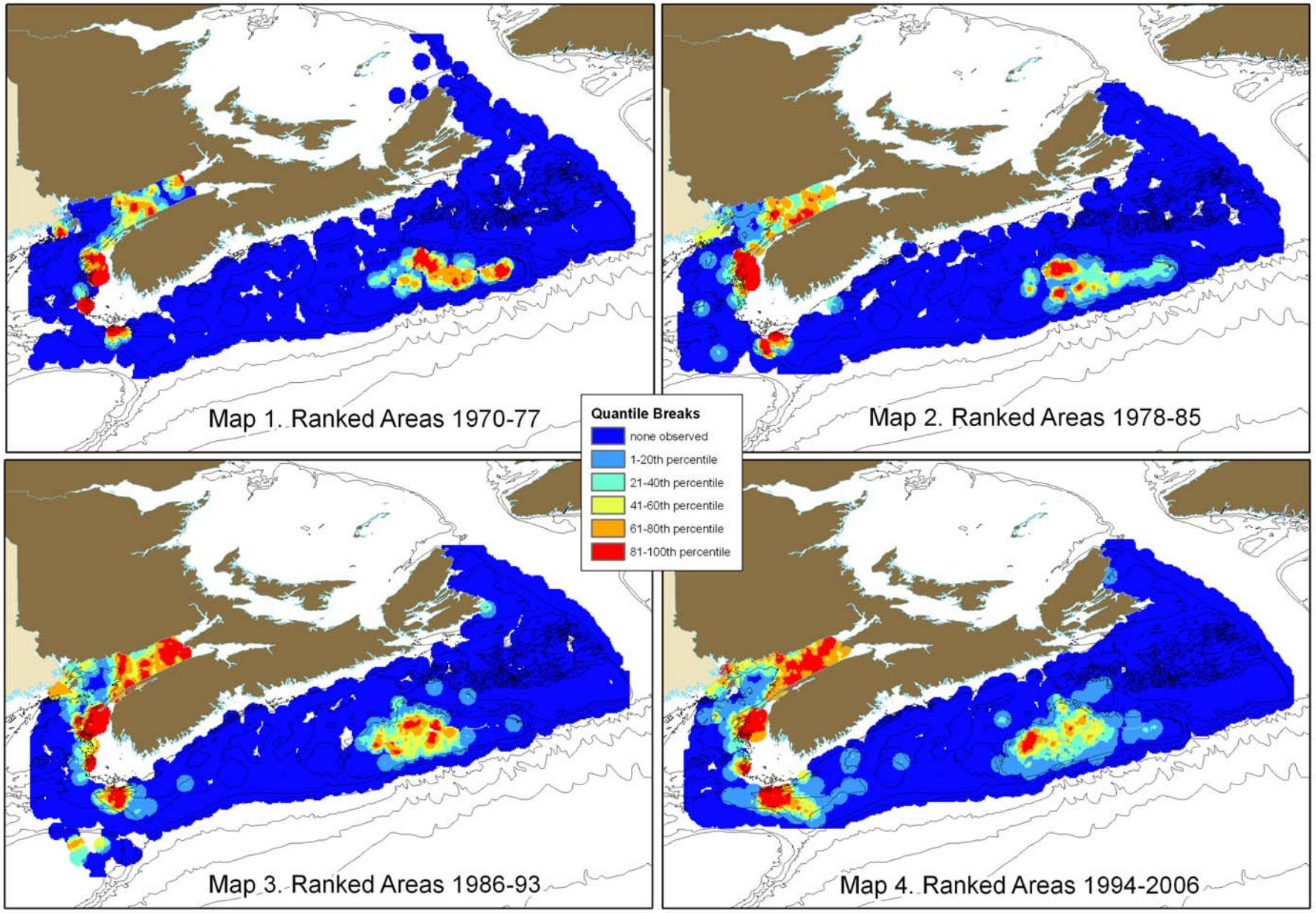


Figure 1. Population Trend



Winter Flounder (*Pseudopleuronectes americanus*)

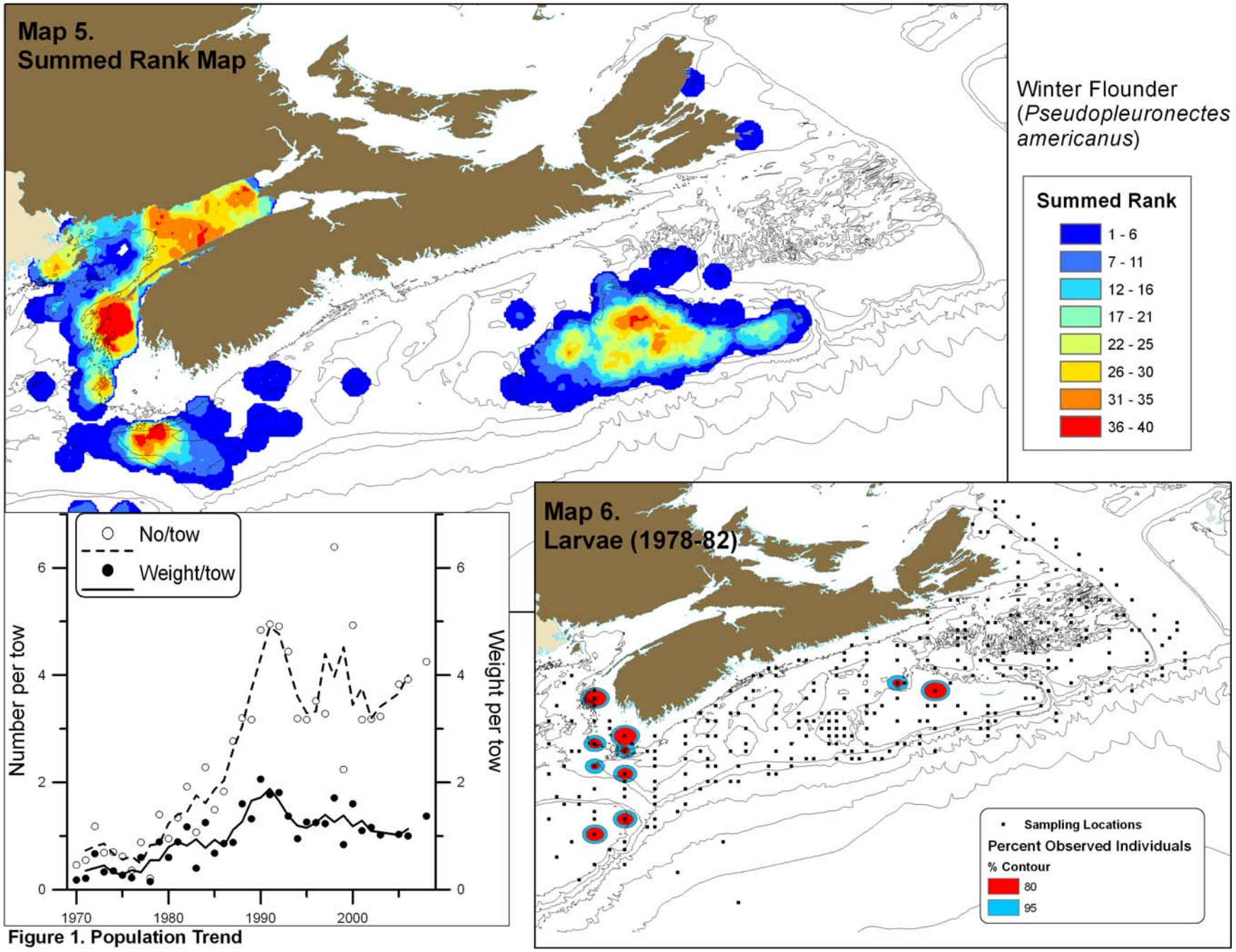
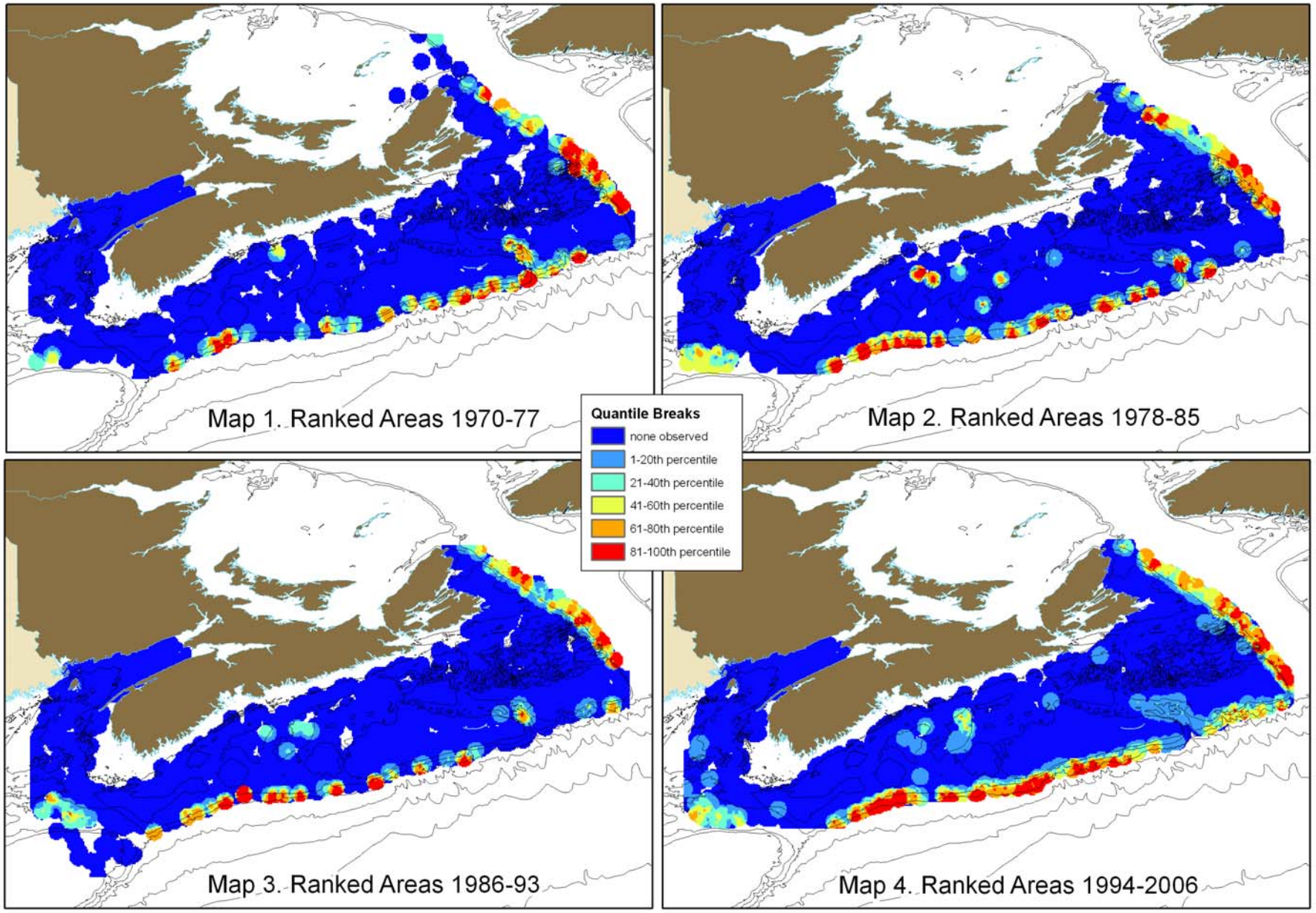
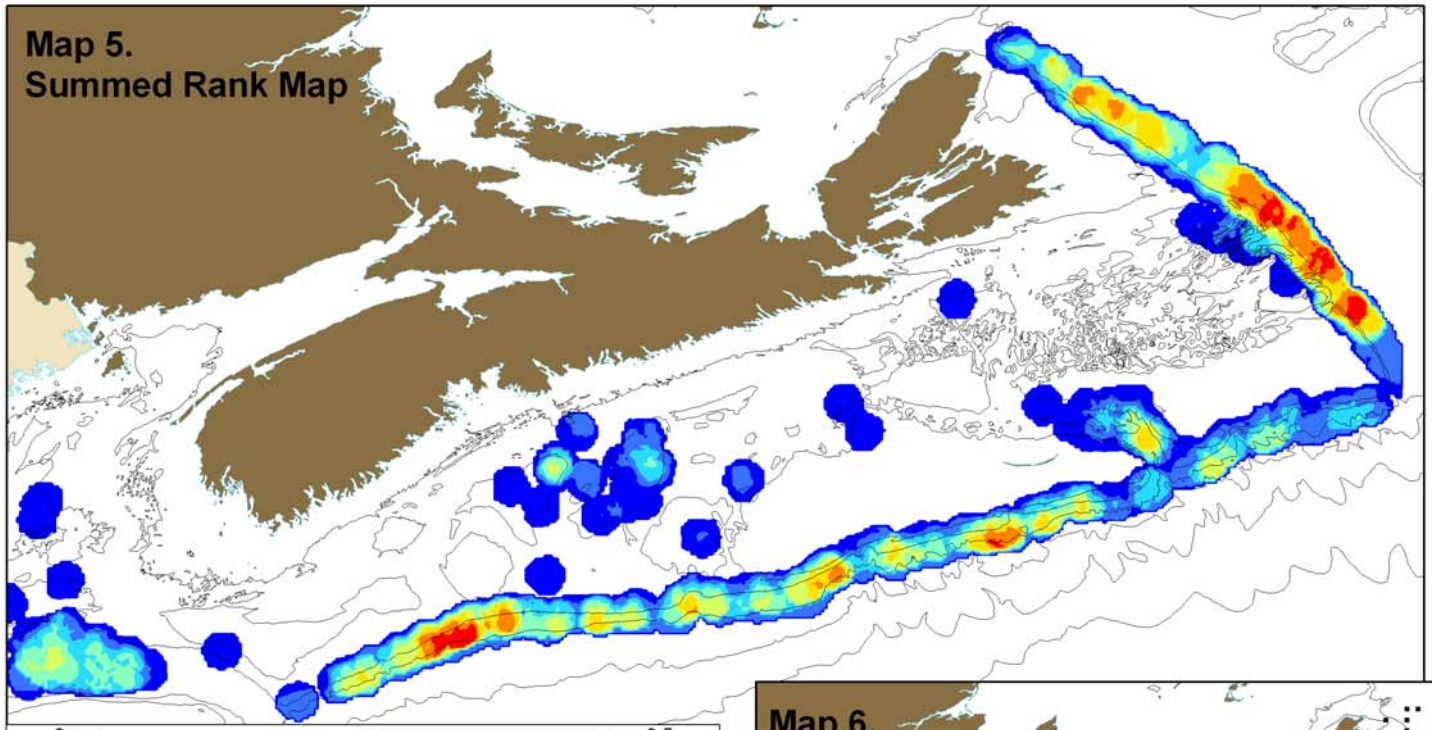


Figure 1. Population Trend



Longfin Hake (*Phycis chesteri*)



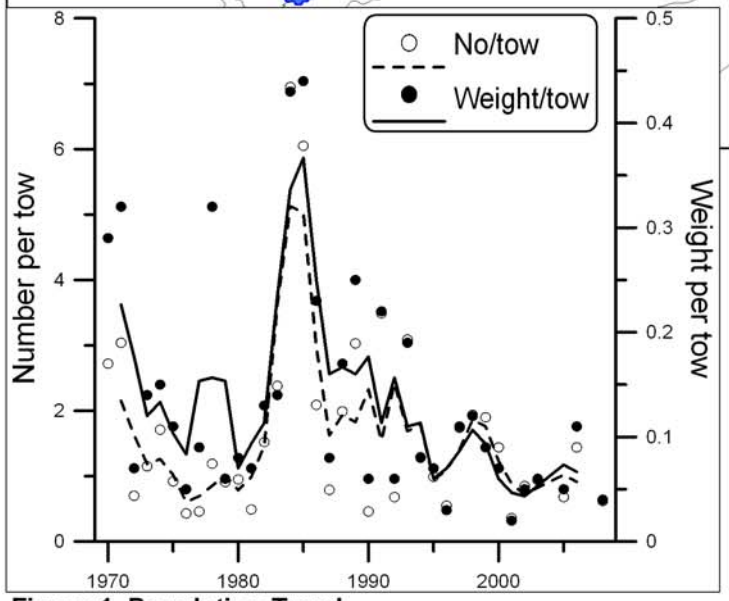
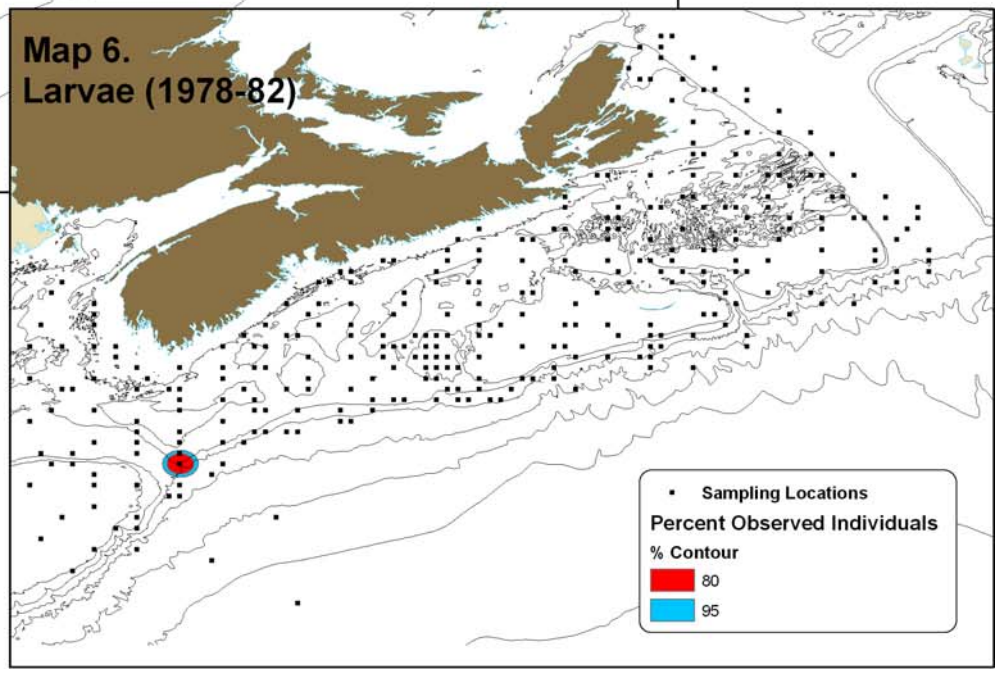


Figure 1. Population Trend



4.0 Discussion

4.1 Interpretation of the maps

The time period maps are intended to provide a better understanding about the areas of importance for many of the significant fish species on the Scotian Shelf. The four time period maps (Maps 1-4 for each species) provide information about the relative distribution of species during the summer months when the surveys are conducted. The summer survey reflects distribution during a rapid growth/feeding phase for northern temperate marine species. The distribution may, or may not change throughout the rest of the year, dependent on the species. The associated figures of population trends (Figure 1 for each species) are intended to provide the reader with insight about how the stratified mean numbers and biomass per tow have changed since the beginning of the RV survey. It is important to examine the pattern between the population trends and the ranked maps. In some cases top ranking areas expand while the population trend shows decreases in numbers and/or weight (e.g. Northern Shortfin Squid) while in other cases the areas expand with increases in population (*e.g.* Herring, Sandlance).

The time periods selected for the maps roughly correspond to changes in fishery management. These maps illustrate how the relative biomass of the species changed from one period to another. In some cases localized declines in relative biomass can be observed from these maps (e.g., Atlantic Cod , Thorny Skate, Winter Skate and Atlantic Wolffish). In other cases expansion of high ranking areas of biomass appears to be occurring (e.g., red hake) despite a stable population trend. As explained in the introduction, directed fishing on an area of high density could deplete that area if it were not replenished. For species that may have been highly targeted and are now highly depleted, the resultant array of preferred habitat (map 5) may not reflect the true array. For that reason, the maps should be interpreted in the context of the status of the population and any other pertinent knowledge (e.g., historical fishing patterns). We emphasize that for species at risk, maps that represent habitat before significant population declines should be used to identify preferred habitat.

Maps of important habitat (Map 5 for each species) indicate areas that consistently remained important summer habitat for the species. Areas that receive a score of 36 or higher (darkest red on the maps) have been important habitat for that species since the trawl surveys began despite changes in population, management and environmental conditions.

The larval distribution maps allow the reader to judge the level of spatial consistency between larval and adult distributions.

4.2 Application of the maps

It is anticipated that these maps will provide important and relevant information to many of the initiatives for sustainable development and ecosystem-based management, including marine protected area planning, by providing managers and stakeholders with information about important habitat for the significant fish species of the Scotian Shelf.

5.0 Acknowledgements

We would like to thank Jim Simon and Peter Koeller for reviewing an earlier draft. We are grateful to Bob Branton and Jerry Black for their expertise in organizing the information and for providing the data.

6.0 References

Beyer, H. 2008. Hawth's Analysis Tools for ArcGIS. 20 August 2008. http://www.spatialecology.com/htools/kde.php

Breeze H., D.G. Fenton, R.J. Rutherford, and M.A. Silva. 2002. The Scotian Shelf: an ecological overview for ocean planning. Can Tech Rep Fish Aquat Sci 2393

Bundy A. 2005. Structure and functioning of the eastern Scotian Shelf ecosystem before and after the collapse of groundfish stocks in the early 1990s. Can. J. Fish. Aquat. Sci. **62**: 1453–1473

DFO. 2005. Canada's Oceans Action Plan. Communications Branch. DFO/ 2005-348.

DFO. 2006. Identification of Ecologically Significant Species and Community Properties. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/041.

DFO. 2007a. Eastern Scotian Shelf Integrated Ocean Management Plan. DFO Maritimes Region, Oceans and Habitat Branch. DFO/2007-1229.

DFO. 2007b. Guidance Document on Identifying Conservation Priorities and Phrasing Conservation Objectives for Large Ocean Management Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/010.

Fisher, J.A.D., and K.T. Frank. 2004. Changes in finfish community structure associated with an offshore fishery closed area on the Scotian Shelf. Mar. Ecol. Prog. Ser. 240: 249–265**.**

Fretwell, S. D., and H. L. Lucas. 1970. On territorial behaviour and other factors influencing the habitat distribution of birds. I. Theoretical development. Acta Biotheoretica **19**:16–36.

Gaston, K. J., and T. M. Blackburn. 2000. Pattern and process in macroecology. Blackwell Science, London, UK

Keith, C.M. 2005. GIS Modeling of Potential Marine Protected Areas in the Northwest Atlantic via Biological and Socioeconomic Parameters. Master of Science Thesis. Oregon State University.

MacCall, A. D. 1990. Dynamic geography of marine fish populations. University of Washington Press, Seattle, Washington, USA.

Mahon, R., S.K. Brown, K.C.T. Zwanenburg, D.B. Atkinson, K.R. Buja, L. Claflin, G.D. Howell, M.E. Monaco, R.N. O'Boyle, and M. Sinclair. 1998. Assemblages and biogeography of demersal fishes of the east coast of North America. Can. J. Fish. Aquat. Sci. **55**: 1704.1738.

Marshall, C. T., and K. T. Frank. 1994. Density-dependent habitat selection by juvenile Haddock (*Melanogrammus aeglefinus*) on the southwestern Scotian Shelf. Canadian Journal of Fisheries and Aquatic Sciences **52**:1007–1017.

Myers, R. A., and K. Stokes. 1989. Density-dependent habitat utilization of groundfish and the improvement of research surveys. ICES C.M. 1989/D:15. International Council for the Exploration of the Sea, Charlottenlund, Denmark.

O'Boyle, R.N., M. Sinclair, R.J. Conover, K.H. Mann, and A.C. Kohler. 1984. Temporal and spatial distribution of ichthyplankton communities of the Scotian Shelf in relation to biological, hydrological and physiographic features. Rapp. P.-v. Réun. Cons. Int. Explor. Mer, **183**: 27–40.

Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p

Shackell, N.L. and K.T. Frank. 2000. Larval fish diversity on the Scotian Shelf Can. J. Fish. Aquat. Sci. **57**: 1747–1760

Shackell, N.L., K.T. Frank and D.W. Brickman. 2005. Range contraction may not always predict core areas: an example from marine fish. Ecological Applications. **15**: 1440-1449.

Simon, J.E., Biologist, Population Ecology Division, Maritimes Region, Fisheries and Oceans Canada. Personal communication on April 8, 2009.

Simon, J.E., and P.A. Comeau. 1994 Summer distribution and abundance trends of species caught on the Scotian Shelf from 1970–92 by the research vessel groundfish survey. Can Tech Rep Fish Aquat Sci 1953, 145 pp.

Swain, D. P., and R. Morin. 1996. Relationships between geographic distribution and abundance of American Plaice (Hippoglossoides platessoides) in the southern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences **53**:106–119.

Swain, D. P., and A. F. Sinclair. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Canadian Journal of Fisheries and Aquatic Sciences **51**:1046–1054.