



## Dreissenid Mussels – Zebra and Quagga mussels

### Purpose

- To track the status and trends of *Dreissena rostriformis bugensis* (quagga mussel) and *Dreissena polymorpha* (zebra mussel). Instability in dreissenid populations, as measured by abundance and biomass, results in uncertainties in resource management.
- The dreissenid mussels indicator is used in the Great Lakes indicators suite as a Pressure indicator in the Invasive Species top level reporting category.

### Status Justification

**Good** – Populations are not changing, or changing at a slow rate- predictability good

**Fair** – Populations are changing at a moderate rate- predictability fair

**Poor** – Populations are changing at a relatively fast rate-predictability poor

### Overall Assessment

**Status:** Fair

**Trend:** Deteriorating

**Rationale:** Over all the Great Lakes, dreissenid mussels are changing at various rates depending on the particular lake, and the particular area within a lake. Currently, quagga mussels (profunda phenotype) are replacing zebra mussels and reaching high abundances in some shallow, nearshore areas, and are also expanding into deep, offshore areas. In other shallow areas, quagga mussel populations (shallow phenotype) are stable and zebra mussels are still present. The offshore region comprises a relatively large proportion of many lakes where quagga mussels are still expanding at a rapid rate (i.e., Lakes Michigan, Ontario, and Huron). Therefore, the current overall assessment would indicate predictability is deteriorating.

### Lake-by-Lake Assessment

#### Lake Superior

Status: Good

Trend: Unchanging

Rationale: Zebra mussels were first found in Duluth-Superior Harbor in 1989, and quagga mussels were found in the same area in 2005. Since then, spread and population growth of both dreissenid species has been minimal. Both species are most abundant confined in the harbor area or in the immediate vicinity of nearshore Lake Superior. Some zebra mussels, however, were found in 2009 in a bay of Isle Royale, and were also present in Thunder Bay harbor in 2001. Overall, population growth and spread of both species has been slow. It is believed that calcium concentrations in Lake Superior are too low to support high abundances.

#### Lake Michigan

Status: Poor

Trend: Deteriorating

Rationale: A recent survey throughout Lake Michigan (2010) indicated that the quagga mussel population expanded greatly since the last survey (2005), and that zebra mussels are now very rare. Based on yearly sampling just in the southern basin, the quagga mussel population at depths < 90 m has apparently stopped increasing and is beginning to decline, but is still increasing at depths > 90 m (Figure 1). Biomass is presently declining at < 50 m, but still increasing at > 50 m (Figure 2). Maximum biomass at < 50 m reached 45 g m<sup>-2</sup> in 2008.

**Lake Huron**

Status: Poor

Trend: Deteriorating

Rationale: The last lake-wide survey of dreissenid populations in Lake Huron occurred in 2007. This survey indicated abundances of quagga mussels increased between 2003 and 2007, but zebra mussels decreased and were rarely found. Between 2003 and 2007, quagga mussels increased 1.6-4.0-fold at depths between 30 and 90 m in the main lake. Similar increases were found in Georgian Bay, but dreissenids were not found in North Channel.

Biomass was not determined in any of these regions. Surveys in Saginaw Bay in 2008-2010 indicated that mean abundance and biomass had decreased 1.6-1.7 fold compared to 1991-1996. In addition, year-to-year variation in 2008-2010 was minimal, indicating that the population had perhaps stabilized at these lower levels. In 2008-2010 the population in Saginaw Bay consisted of 80% quagga mussels and 20% zebra mussels.

**Lake Erie**

Status: Fair

Trend: Undetermined

Rationale: The last lake wide survey in Lake Erie occurred in 2002. Mean abundances in that year were little changed since 1992 (2,025 m<sup>-2</sup> in 2002 compared to 2,636 m<sup>-2</sup> in 1992), but mean biomass increased 4-fold (24.7 g m<sup>-2</sup> in 2002 compared to 6.8 g m<sup>-2</sup> in 1992). Most dreissenid biomass (90%) occurs in the eastern basin.

Populations in the central basin are limited because of seasonal hypoxia, and populations in the western basin are limited because of poor food quality (cyanophytes, inorganic particulates). Recent surveys (2005-2010) in the western basin indicate that dreissenid populations have fluctuated from year-to-year with no clear trends, and that quagga mussels have replaced zebra mussels as the dominant species (Figure 3). Recent trends in the eastern basin are unknown.

**Lake Ontario**

Status: Fair

Trend: Deteriorating

Rationale: Since 2007, *Dreissena* abundance has been stable or slowly increasing based on data from offshore surveys at depths beyond 30 m (Figure 4). Since 2000, all mussels collected in the offshore portions of Lake Ontario have been quagga mussels. Zebra mussels are restricted to shallow embayments such as the upper Bay of Quinte and inside Hamilton Harbor. Quagga mussels have slowly increased at depths beyond 100 m. Since 2008, they have been present in the deepest part of the lake (224 m), as well as at the middle of the lake. Densities are greatest nearest the south shore, often exceeding 5000 m<sup>-2</sup>, but are as large as 400 m<sup>-2</sup> at 150 m. The population in the east basin of Lake Ontario near Main Duck Island (35 m) has been stable since 2007, and is composed mostly of large individuals greater than 15 mm in length. There, the wet biomass of their soft tissue has ranged between 300 and 450 g m<sup>-2</sup> (shell-free). Assuming dry weight is about 10% of wet weight, this is equivalent to 30-45 g m<sup>-2</sup> dry weight and hence generally similar to the maximum of 45 g m<sup>-2</sup> found at 31-50 m in southern Lake Michigan.

**Ecosystem Objective**

Dreissenids are actively changing the integrity of Great Lakes ecosystems by altering nutrient and energy cycling, promoting nuisance algal blooms and benthic algae, and negatively impacting native species of invertebrates and fish. Such changes to ecosystem integrity create uncertainty in effective resource management. Thus, the indicator addresses the objective of maintaining healthy and sustainable ecosystems.

**Measure**

Ideally, specific measures to be reported are dreissenid abundances, biomass, size-frequency distributions, and length-weights. The latter two measures are essential for the most efficient determination of biomass, and also provide a basis for assessing the relative status of populations and individuals, respectively. As a minimum indicator, abundances of both zebra and quagga mussels should be reported. Spatial scales should be each lake, and any par-

ticular bay or basin within a lake. Often trends in zebra and quagga mussels can be quite different depending on environmental conditions. The entire suite of measurements listed above will be reported for additional scales.

At the minimum, spatially intensive studies of dreissenid abundance should be conducted once every five years in conjunction with other programs associated with the lake wide intensive monitoring program. More frequent sampling (yearly) is recommended in areas that are newly colonized or subjected to new perturbations, such as a new invader.

## **Endpoint**

A quantitative endpoint has not yet been determined. A proposed endpoint of zero dreissenids is unrealistic. A working qualitative endpoint is the point in time and space in which a dreissenid population becomes stable, or varies within a given range. Such an endpoint will allow for the modeling of dreissenid population dynamics and inputs to predictive ecosystem models. Such models are a necessary precursor to effective resource management.

## **Ecological Condition**

Dreissenid populations in the Great Lakes are presently in various stages of change. In many offshore regions, populations are increasing, but in some near shore regions populations seem to be stable or declining. While some year-to-year variability can be expected, a goal of this indicator is to determine at what level of abundance/biomass populations become stable and at equilibrium with the surrounding environment. Such levels, along with associated degrees of uncertainty, can then be used in predictive models to better manage Great Lakes resources.

Many sampling efforts have sought to provide data on population abundances and biomass. While abundances are the most common reporting measure of population status, biomass is more valuable for assessing ecological impacts and for input to predictive models. Biomass is calculated from the soft tissue of these organisms. Some protocols call for separating soft tissue from shell and directly determining soft tissue weight, while others determine the size frequency of the populations (shell length) and infer tissue biomass based upon a predetermined relationship between shell length and soft tissue weight. Data used to obtain biomass with the latter protocol can also be used to assess population dynamics and predict the direction of populations over time. For example, a population with a large number of individuals and a size distribution skewed toward smaller individuals demonstrates high recruitment and possibly low survivability (or if survivability is not compromised then it may illustrate recent colonization). In contrast, populations showing a size-frequency distribution skewed towards larger individuals with fewer numbers suggests an aging population with relatively lower recruitment and greater survivability. Traditional population ecology suggests that stable populations move from a size-frequency distribution of low mean biomass towards one of higher mean biomass. As a population colonizes a new area, high resource availability promotes high recruitment. As resources are sequestered into the population, recruitment decreases with decreasing resource availability and mean biomass increases as fewer new (low biomass) individuals are added to the population and surviving members continue to grow.

## **Management Challenges/Opportunities**

The main issue which compromises this indicator is the presence or absence of a commitment by agencies to monitor dreissenids on a regular basis. U.S. EPA Great Lakes National Program Office monitors benthos annually, but the spatial scope emphasizes deeper regions. The regular monitoring of Environment Canada does not include benthos. Sampling by Fisheries and Oceans Canada on Lake Ontario is sporadic. NOAA has supported dreissenid monitoring throughout Lakes Michigan and Huron every five years, and in the southern basin of Lake Michigan every year, but it is uncertain whether this support will continue.

## **Comments from the author(s)**

Because of the rapid rate at which *Dreissena* populations have expanded in many areas, and because of the ability of dreissenids to cause ecosystem-wide changes, agencies committed to documenting trends should report data in a timely manner. Besides abundance, biomass should be routinely monitored. This allows comparisons across lakes and other food web components, and is most useful for predictive models. Since dreissenids are found on hard as well as on soft substrates, various sampling methods may be needed to truly assess population mass in a given lake or lake region.

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## Assessing Data Quality

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources	X					
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin			X			
5. Data obtained from sources within the U.S. are comparable to those from Canada	X					
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report	X					
Clarifying Notes:						

## Acknowledgments

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## Information Sources

Bunnell, D. B., Madenjian, C. P., Holuszko, J. D., Adams, J. V., and French, J. R. P. III. 2009. Expansion of *Dreissena* into offshore waters of Lake Michigan and potential impacts on fish populations. *J. Great Lakes Res.* 35: 74-80.

French, J. R. P. III, Schaeffer, J. S., Roseman, E. F., Kiley, C. C., Fouilleroux. 2009. Abundance and distribution of benthic macroinvertebrates in offshore soft sediments in Western Lake Huron, 2001-2007. *J. Great Lakes Res.* 35: 120-127.

Grigorovich, I. A., Kornushin, A. V., Gray, D. K., Duggan, J. C., Colautti, R. I., and MacIsaac, H. J. 2003. Lake Superior: and invasion coldspot? *Hydrobiology* 499:191-210.

Nalepa, T. F., Fanslow, D. L., Pothoven, S. A., Foley, A. J. III, and Lang, G. A. 2007. Long-term trends in benthic macroinvertebrate populations in Lake Huron over the past four decades. *J. Great Lakes Res.* 33: 421-436.

Nalepa, T. F., Fanslow, D. Pothoven, S. A. 2011. Recent changes in density, biomass, recruitment, size structure, and nutritional state of *Dreissena* populations in southern Lake Michigan. *J. Great Lakes Res.* 36 (Suppl. 3): 5-19.

Patterson, M. R., Ciborowski, J. J. H., and Barton, D. R. 2005. The distribution and abundance of *Dreissena* species (*Dreissenidae*) in Lake Erie, 2002. *J. Great Lakes Res.* 31 (Suppl.2): 223-237.

Soster, F. M., McCall, P. L., and Herrman, K. A. 2011. Decadal changes in the benthic invertebrate community in

western Lake Erie between 1981 and 2004.

## List of Figures

Figure 1. Mean ( $\pm$  SE) abundance (number per square meter) of the *Dreissena* population in each of four depth intervals at 40 stations in the southern basin of Lake Michigan between 1980 and 2010. The number of stations in each depth interval was 16-30 m = 12, 31-50 = 10, 51-90 m = 12, > 90 m = 6. solid circle/solid line = zebra mussel; open circle/dashed line = quagga mussel. Source: Great Lakes Environmental Research Lab, NOAA

Figure 2. Mean ( $\pm$  SE) biomass (grams per square meter) of the *Dreissena* population in each of four depth intervals at 40 stations in the southern basin of Lake Michigan between 1980 and 2010. Biomass is given as shell-free dry weight. The number of stations in each depth interval was 16-30 m = 12, 31-50 = 10, 51-90 m = 12, > 90 m = 6. solid circle/solid line = zebra mussel; open circle/dashed line = quagga mussel. Source: Great Lakes Environmental Research Lab, NOAA

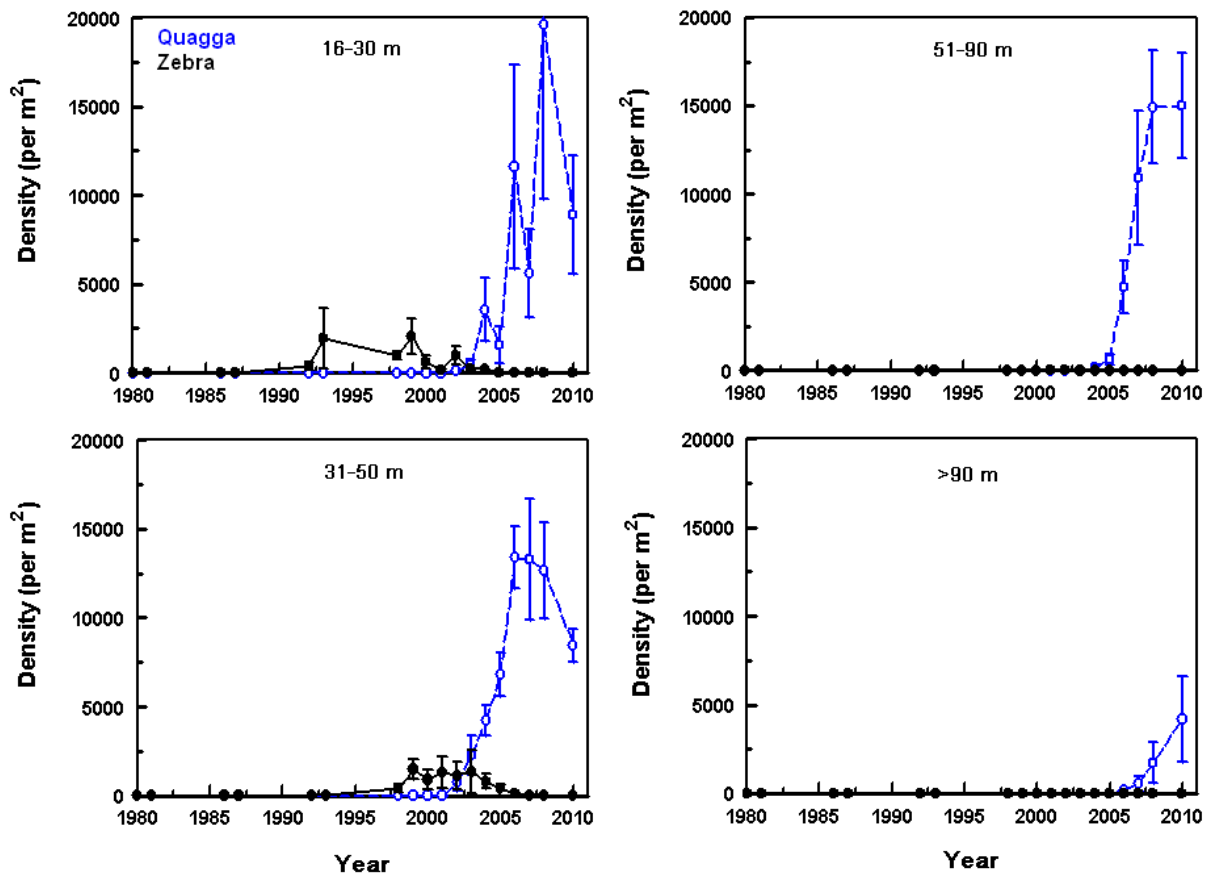
Figure 3. Percentage of sites with *Dreissena* (top panel) and mean abundance of *Dreissena* (number per square meter) (bottom panel) in western Lake Erie between 1991 and 2010; n=30. Source: Great Lakes Science Center, USGS

Figure 4. Distribution and mean abundance (number per square meter) of the *Dreissena* population (zebra and quagga mussels) in Lake Ontario between 1995 and 2009. Small crosses indicate stations not visited. Ave. = average abundance for all stations sampled that year. Source: Great Lakes Lab. for Fisheries & Aquatic Sciences, DFO

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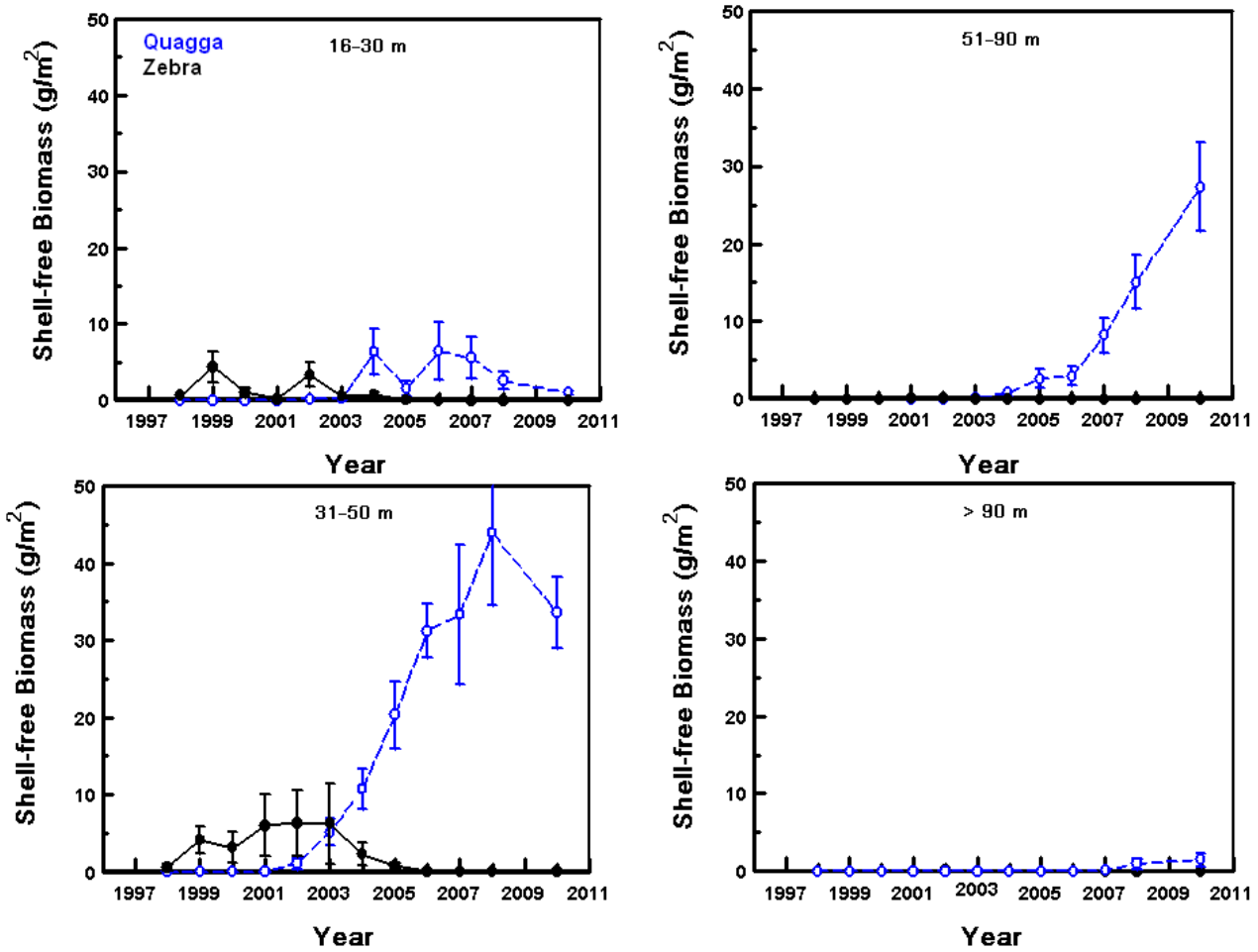
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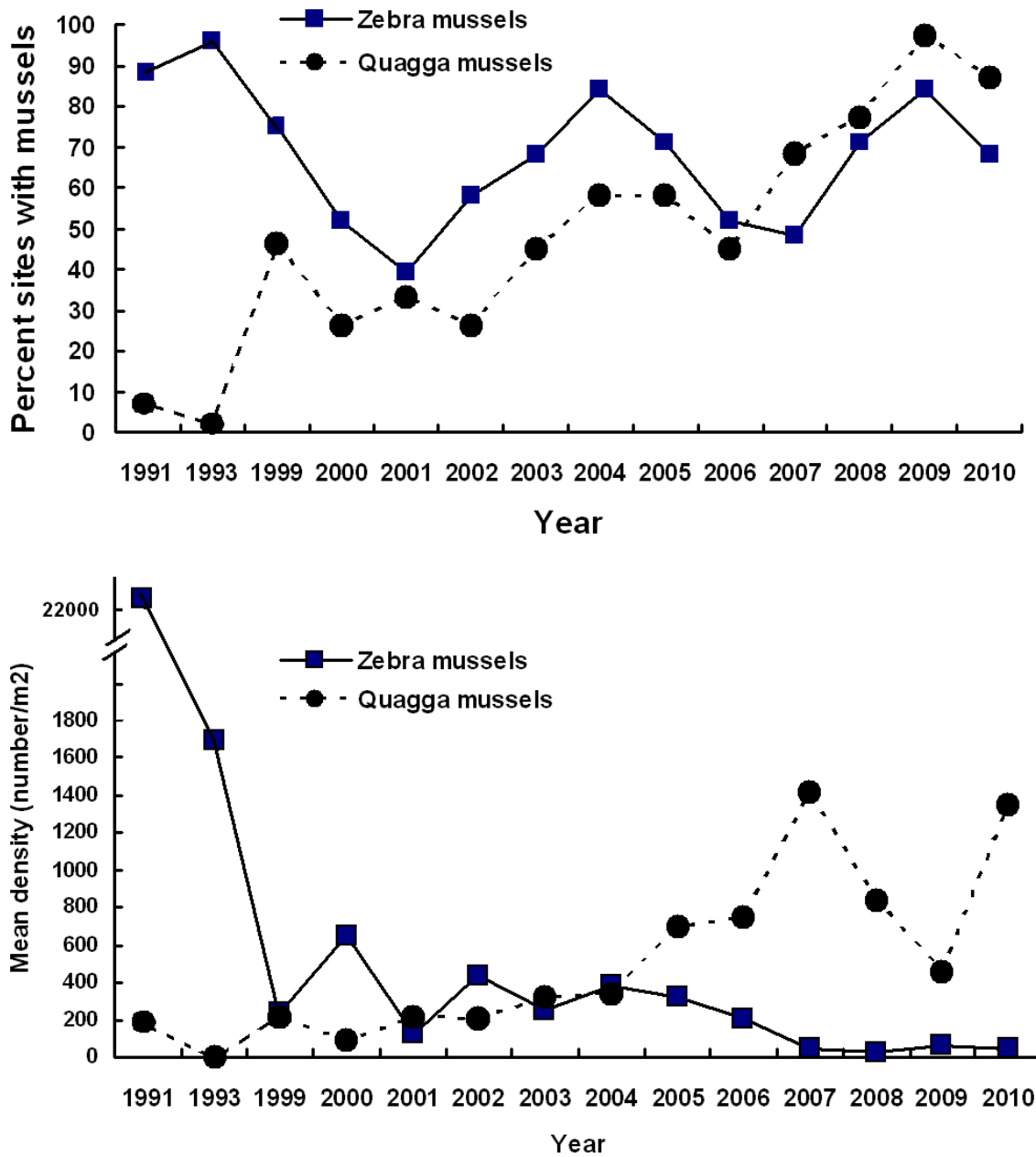
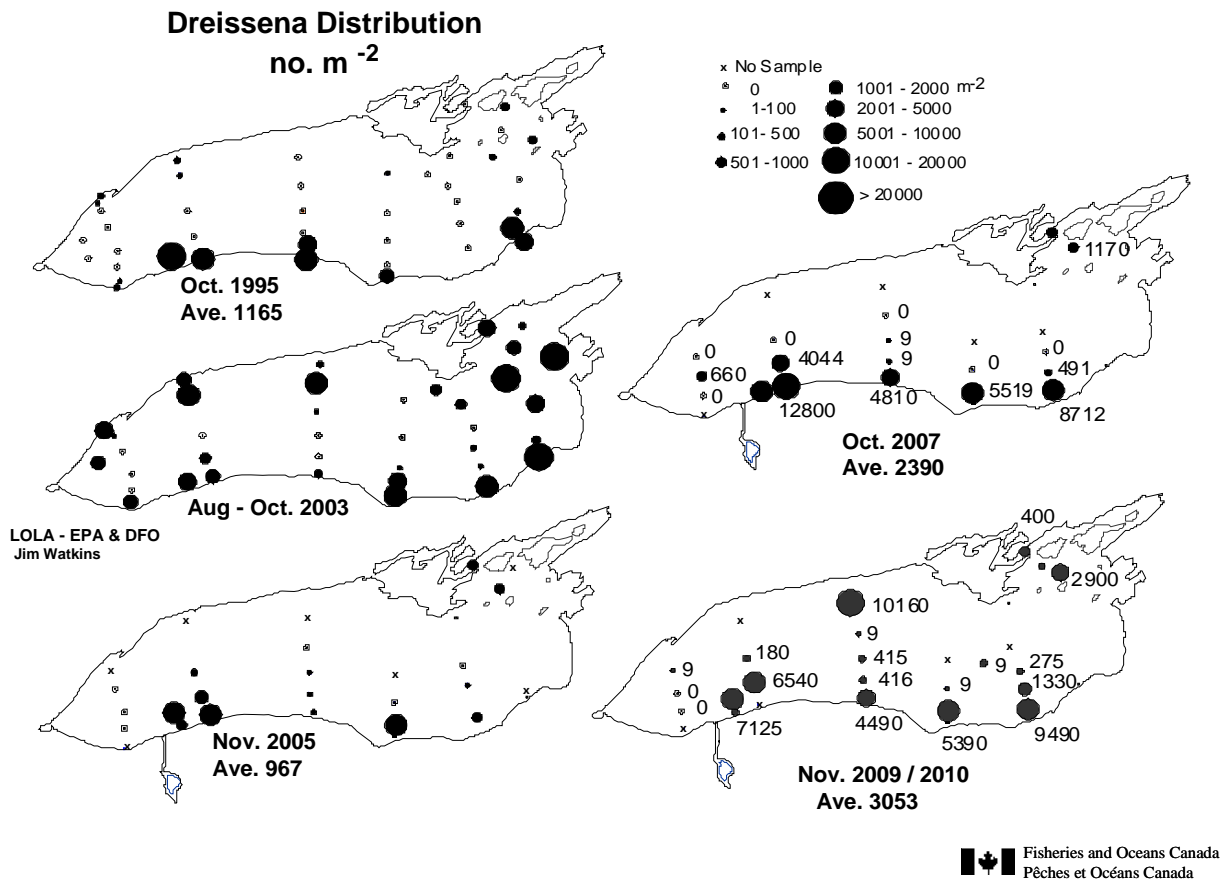


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