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# **Spatial patterns in the spring NEFSC survey for Eastern Georges Bank cod, Eastern Georges Bank haddock and Georges Bank yellowtail flounder**

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## **ABSTRACT**

Spatial indicators were used to evaluate potential implications of the delayed 2016 Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey on the observed distribution of Eastern Georges Bank (EGB) cod, EGB haddock and Georges Bank yellowtail flounder. The mean locations of all three stocks in 2016 were within  $\pm 1$  standard deviation of other mean locations over the past decade for the respective stocks. In terms of spatial distribution there should be no impact of the delayed 2016 survey on the assessment.

## Introduction

The objective of this study was to address the Term of Reference “Evaluate potential implications of the delayed 2016 RV spring survey on the 2017 assessment” by providing a spatial distribution analysis for Eastern Georges Bank (EGB) cod, EGB haddock and Georges Bank (GB) yellowtail flounder based on spring Northeast Fisheries Science Center (NEFSC) bottom trawl survey data, 1968–2017.

## Methods/Results

Data were prepared for spatial analysis using the methods described in Adams (2017). Briefly, longitude and latitude for each trawl station were converted to Euclidean space. Geographically referenced longitude and latitude are hereafter referred to as the X- and Y-components of the CG.

The center of gravity (CG) is the bivariate mean location of the population:

$$CG = \frac{\sum_{i=1}^n x_i w_i z_i}{\sum_{i=1}^n w_i z_i} \quad (1)$$

where  $x_i$  is location (XCG or YCG),  $w_i$  is the area of influence, and  $z_i$  is the number of groundfish. In the case of irregular sampling, spatial indicators are weighted with an area of influence (Woillez et al., 2007; 2009). Given the stratified random survey design (as opposed to a grid), a Dirichlet tessellation (Legendre and Legendre, 1998) was used as a non-subjective method to calculate areas of influence, with areas along the edge of the study area clipped to the boundary of the strata.

The inertia (variance) describes how dispersed the population is around its CG:

$$I = \frac{\sum_{i=1}^n (x_i - CG)^2 w_i z_i}{\sum_{i=1}^n w_i z_i} \quad (2)$$

$I$  can be decomposed into two orthogonal axes describing the maximum and the minimum components of the inertia. The square root of  $I$  for a given axis gives the standard deviation of the respective axis. As  $I$  has units of  $\text{km}^2$ , axes of inertia are plotted on CG maps as the standard deviation, which has units of  $\text{km}$  (Woillez et al., 2007; 2009). CG maps by year for each stock are provided in Appendix 1.

There was a late start in 2014 as well as 2016 (Table 1). Both years are considered in the following Results & Conclusions.

Figure 1 shows variation in the CG over the course of the entire time series for EGB cod. Restricting data points to the 10 most recent years (for clarity) shows that the

CGs for both late years (2014 and 2016) were within  $\pm 1$  standard deviation of other CGs over the past decade (Figure 2).

Figure 3 show the time series of CGs for EGB haddock. The 10 most recent years of CGs shows that both late years (2014 and 2016) were within  $\pm 1$  standard deviation of other CGs over the past decade (Figure 4).

The time series of CGs for GB yellowtail flounder are shown in Figure 5. The 10 most recent years of CGs shows that both late years (2014 and 2016) were well within  $\pm 1$  standard deviation of other CGs over the past decade (Figure 6).

### **Conclusions/Summary/Recommendations**

The mean locations of all three stocks in 2016 were within  $\pm 1$  standard deviation of other CGs over the past decade for the respective stocks. A similar result was also found for another recent late year (2014). In terms of spatial distribution there should be no impact of the delayed 2016 survey on the assessment.

### **Literature Cited**

Adams, C. F. 2017. Age-specific differences in the seasonal spatial distribution of butterfish (*Peprilus triacanthus*). ICES Journal of Marine Science 74:170–179.

Legendre, P., Legendre, L. 1998. Numerical Ecology, 2nd edn. Elsevier, Amsterdam. 853 p.

Woillez, M., Poulard, J.-C., Rivoirard, J., Petitgas, P., Bez, N. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake (*Merluccius merluccius*) in the Bay of Biscay. ICES Journal of Marine Science 64:537–550.

Woillez, M., Rivoirard, J., Petitgas, P. 2009. Notes on survey-based spatial indicators for monitoring fish populations. Aquatic. Living Resources. 22:155–164.

## Tables

Table 1. Start and end dates for the 10 most recent years of Northeast Fisheries Science Center spring bottom trawl surveys.

<u>YEAR</u>	<u>STARTDATE</u>	<u>ENDDATE</u>
2008	6-Mar-08	3-May-08
2009	27-Feb-09	11-May-09
2010	22-Feb-10	4-May-10
2011	1-Mar-11	12-May-11
2012	27-Feb-12	10-May-12
2013	4-Mar-13	11-May-13
2014	31-Mar-14	31-May-14
2015	3-Mar-15	10-May-15
2016	8-Apr-16	7-Jun-16
2017	6-Mar-17	14-May-17

## Figures

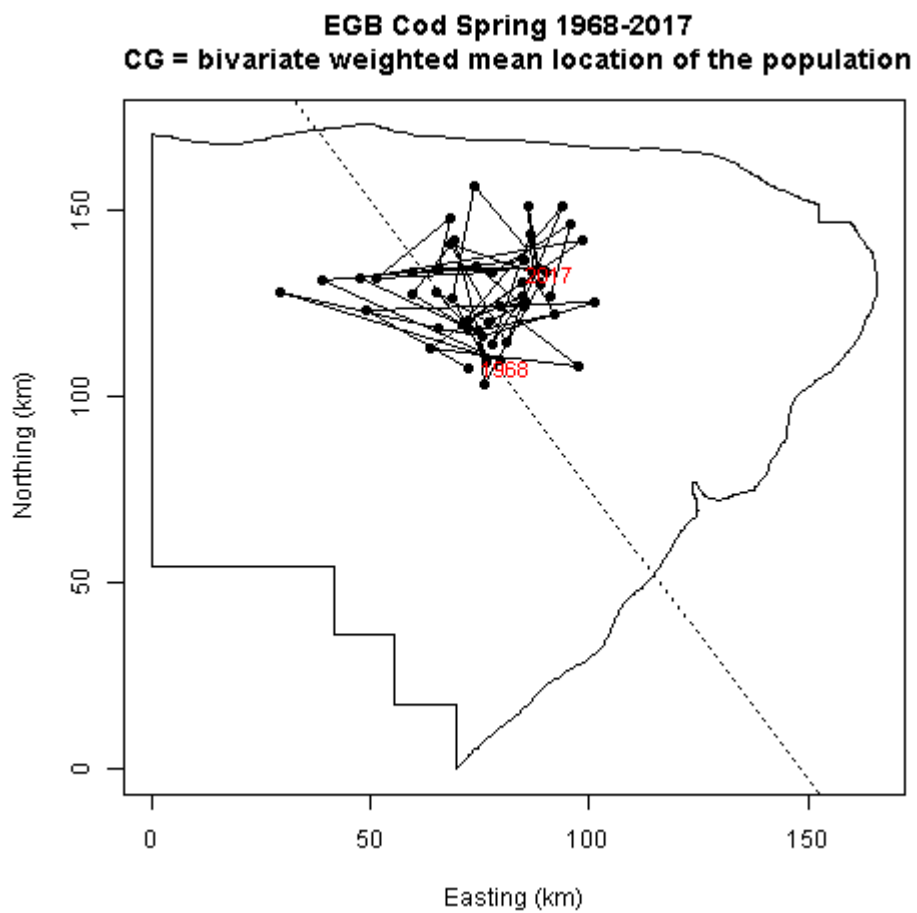


Figure 1. Centers of gravity for Eastern Georges Bank cod, spring 1968–2017.

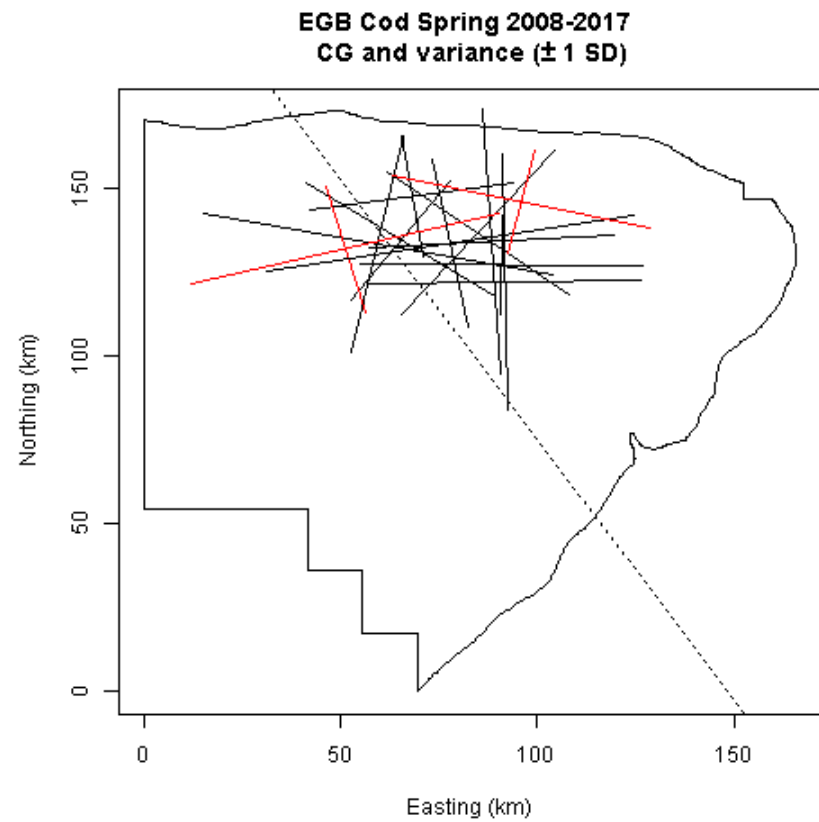
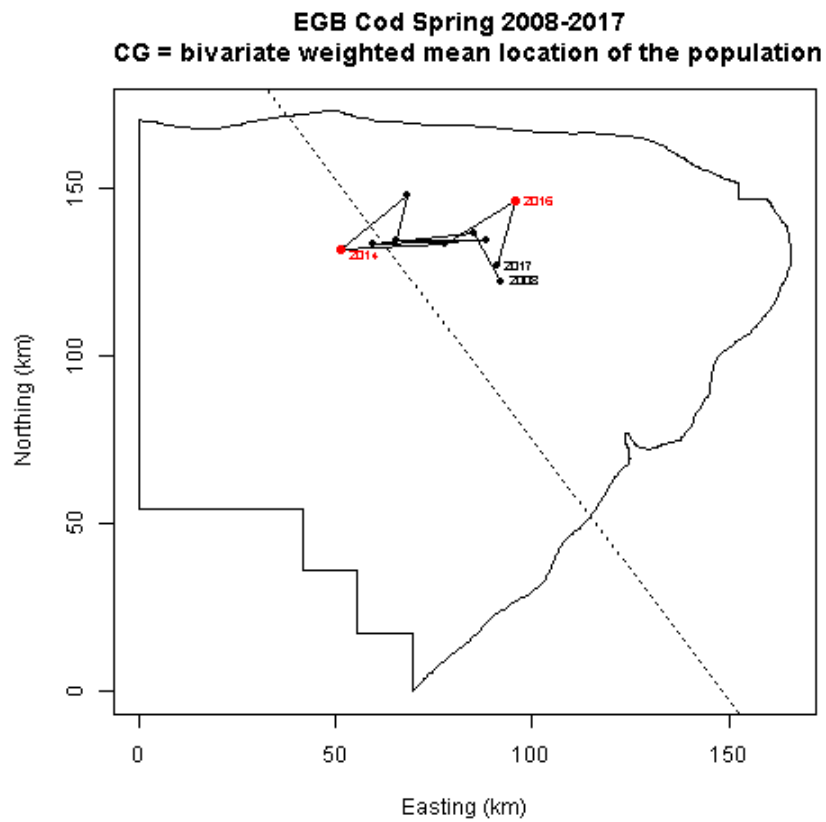


Figure 2. Centers of gravity for Eastern Georges Bank cod, spring 2008–2017 (left), and corresponding axes of inertia (right), shown as  $\pm 1$  standard deviation.



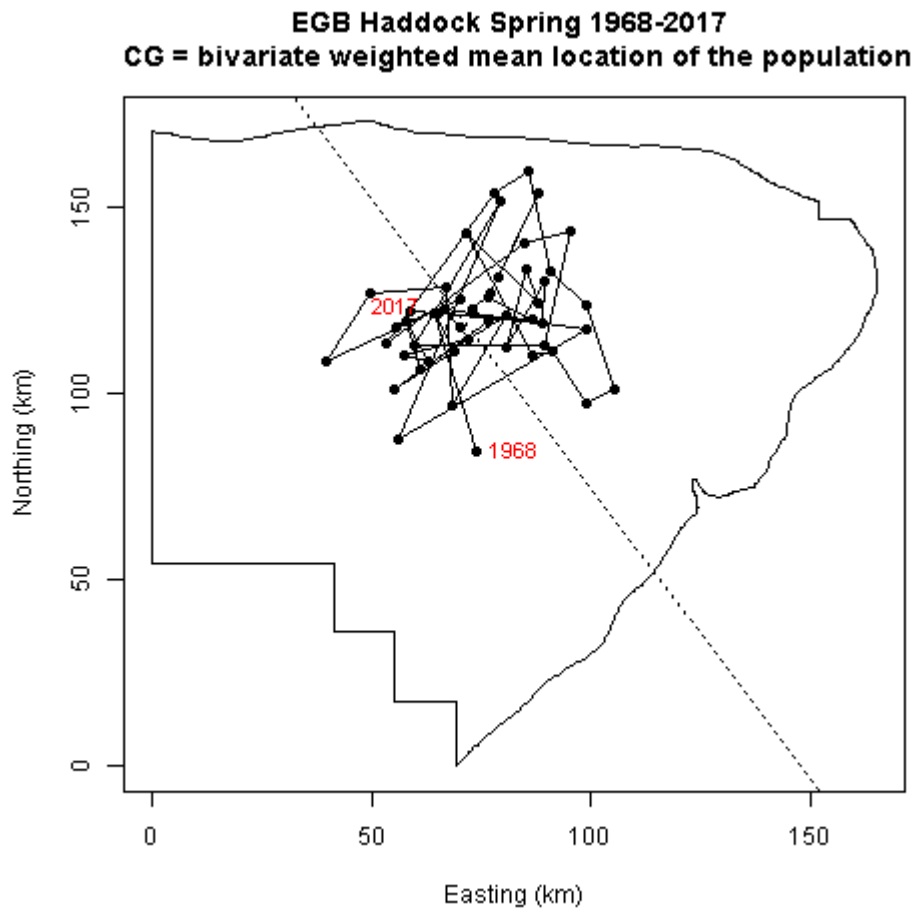


Figure 3. Centers of gravity for Eastern Georges Bank haddock, spring 1968–2017.

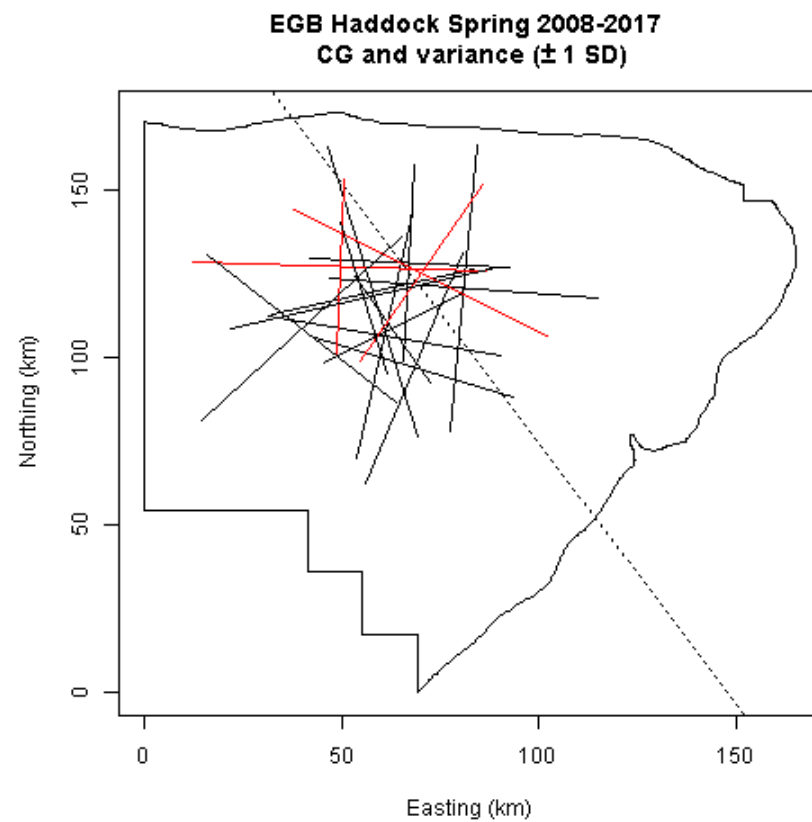
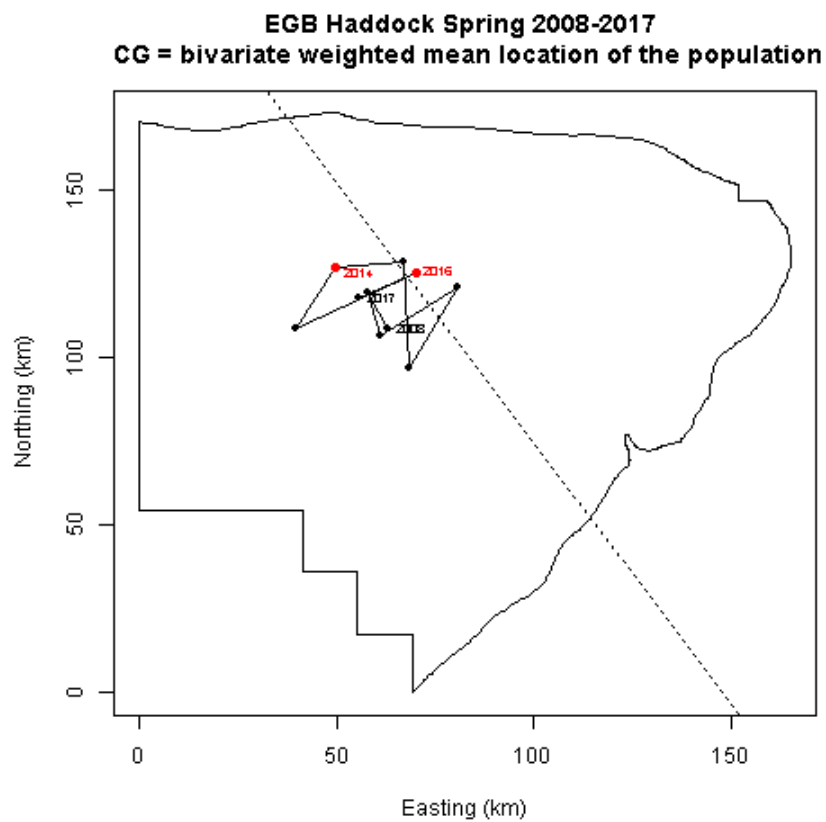


Figure 4. Centers of gravity for Eastern Georges Bank haddock, spring 2008–2017 (left), and corresponding axes of inertia (right), shown as  $\pm 1$  standard deviation.

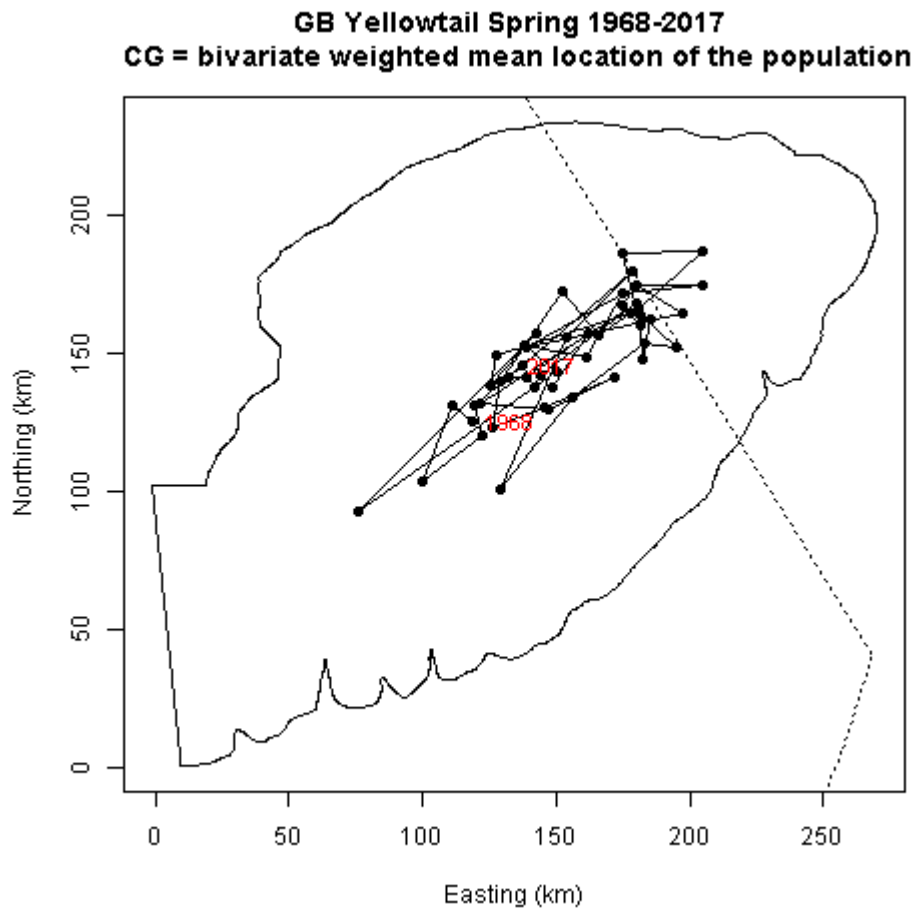


Figure 5. Centers of gravity for Georges Bank yellowtail flounder, spring 1968–2017.

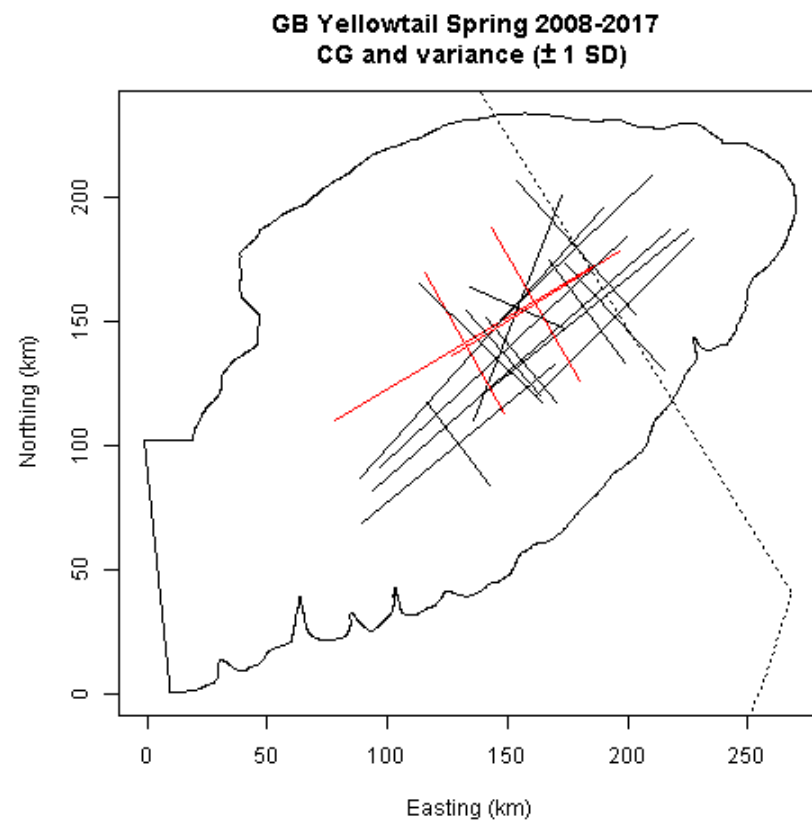
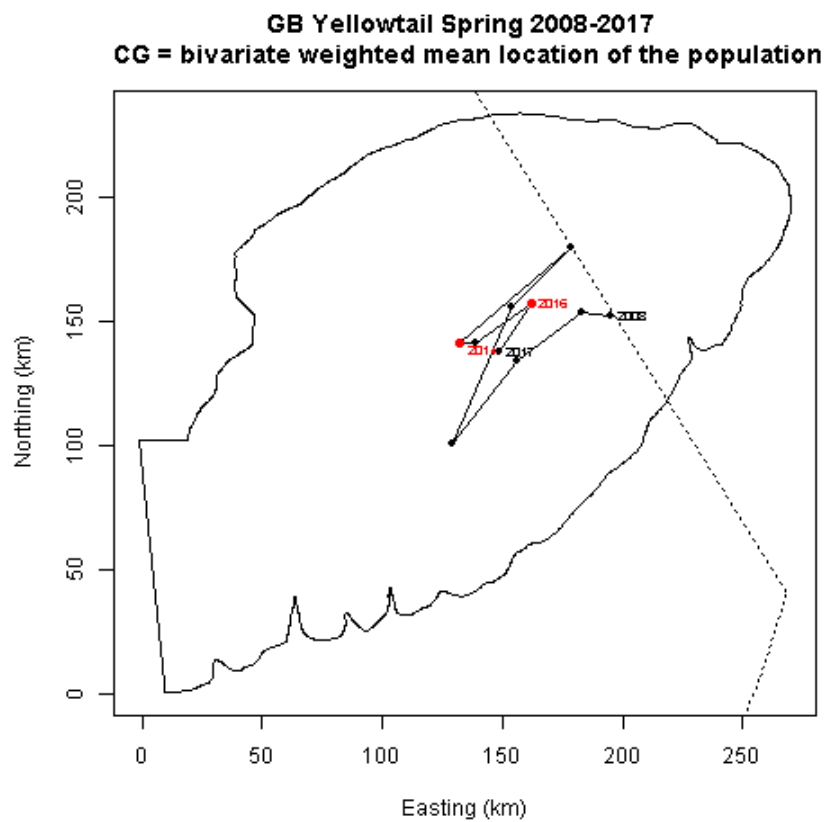


Figure 6. Centers of gravity for Georges Bank yellowtail flounder, spring 2008–2017 (left), and corresponding axes of inertia (right), shown as  $\pm 1$  standard deviation.

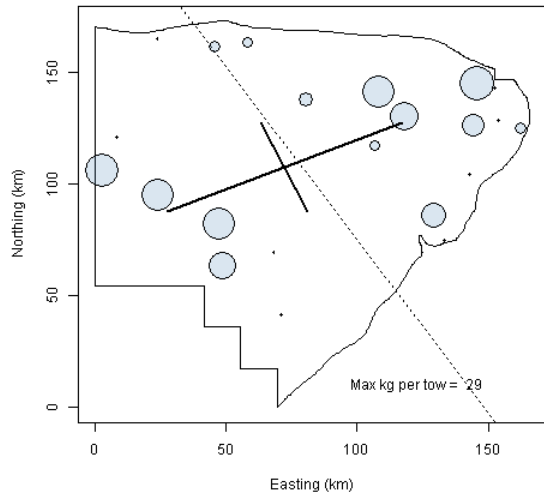
## Appendix

Center of gravity and inertia maps based on spring NEFSC survey data, 1968–2017

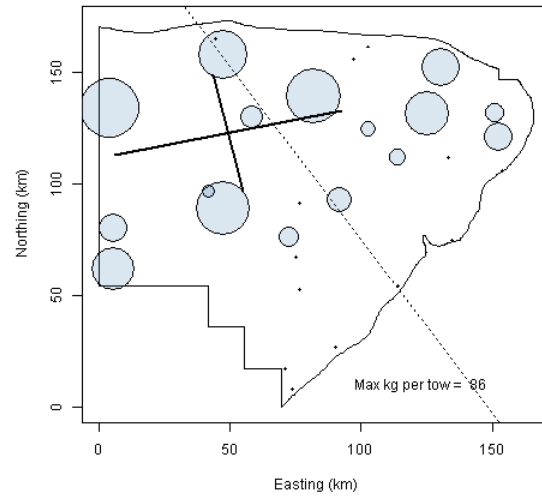
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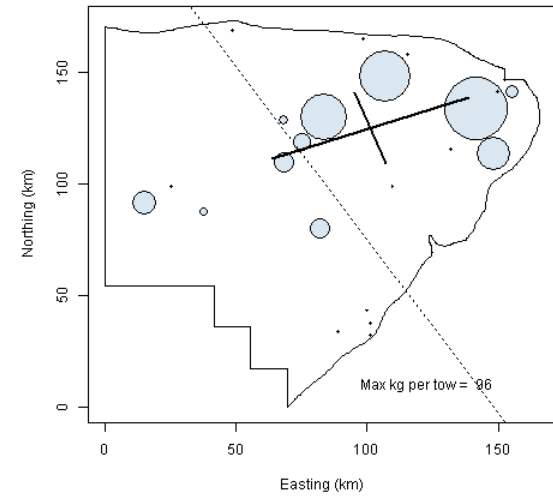
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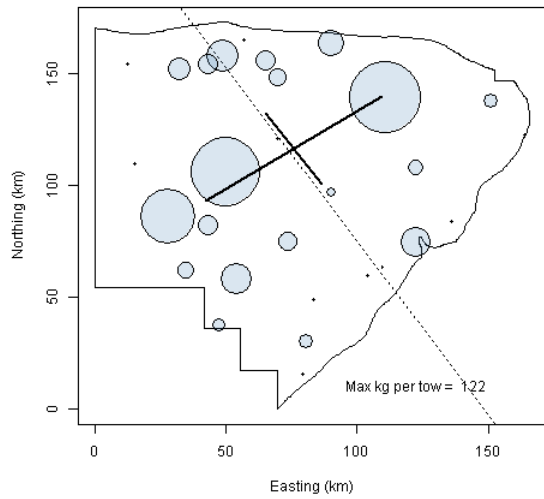
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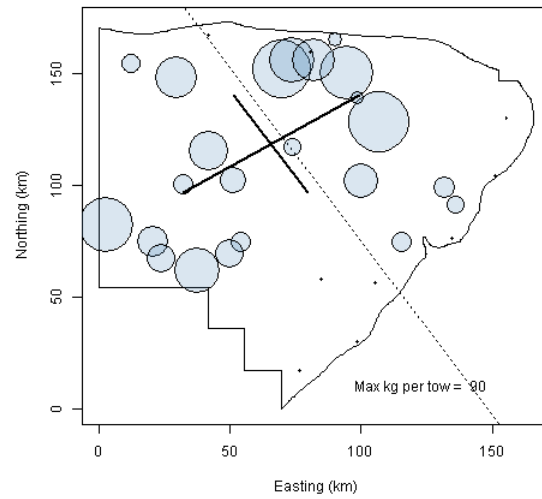
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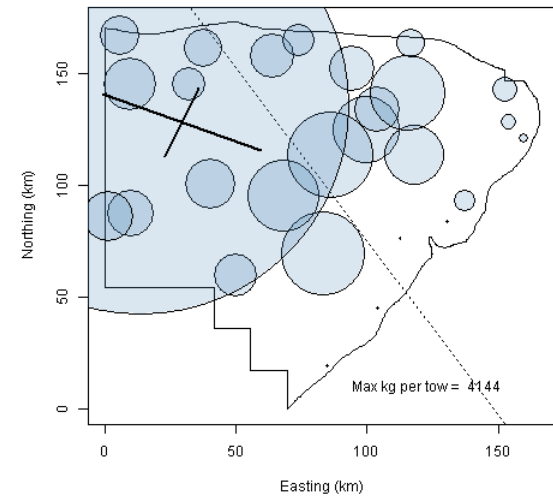
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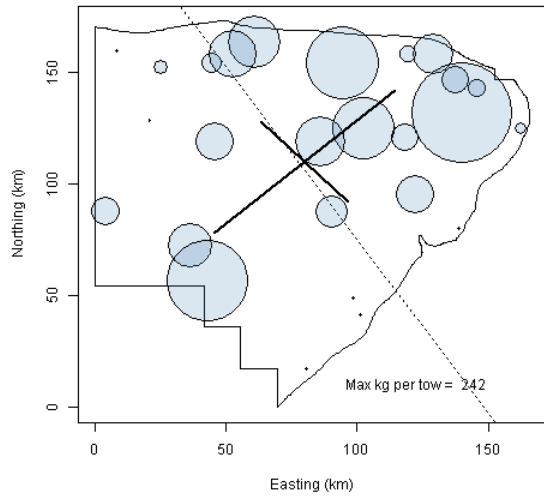
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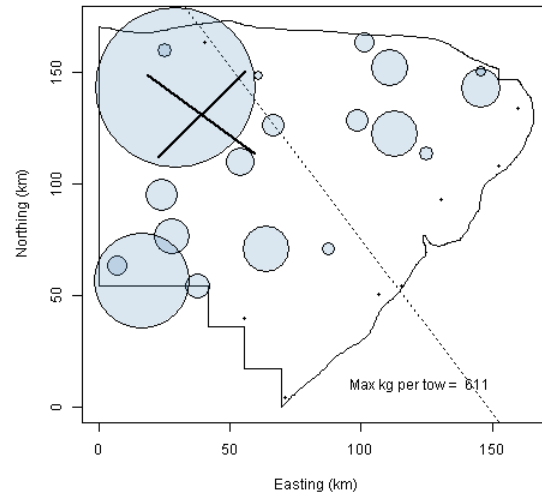
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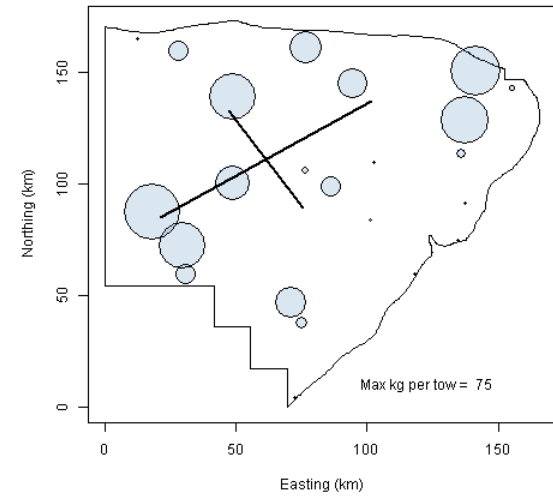
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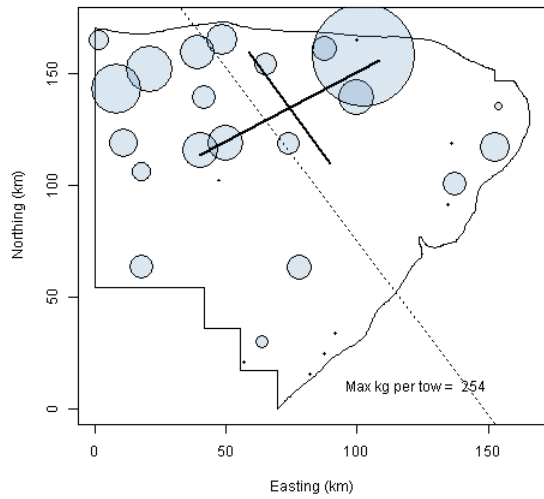
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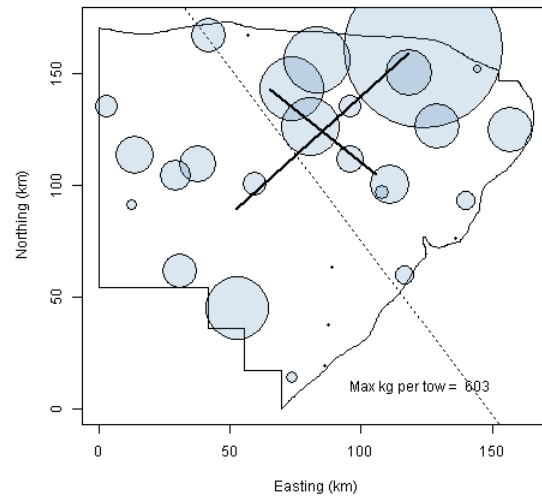
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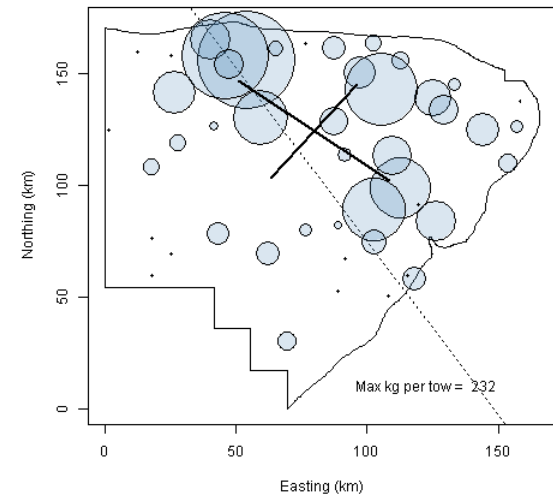
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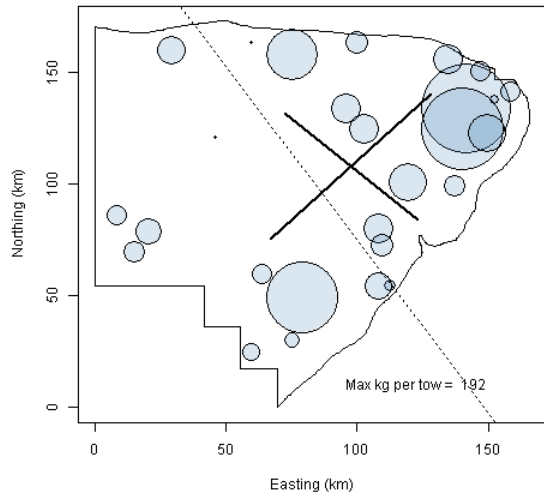
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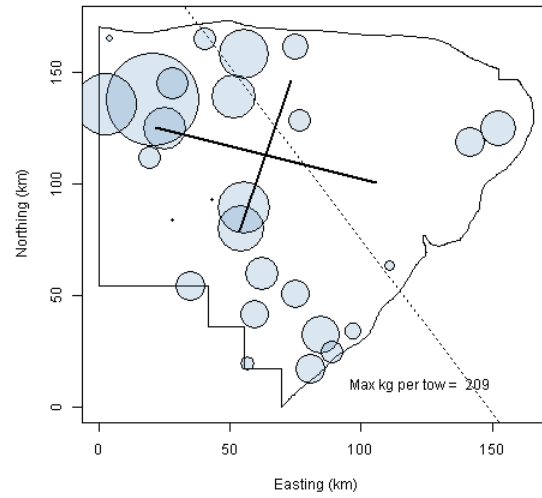
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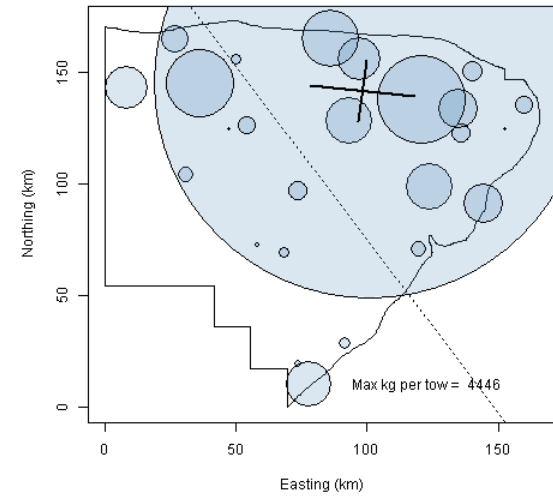
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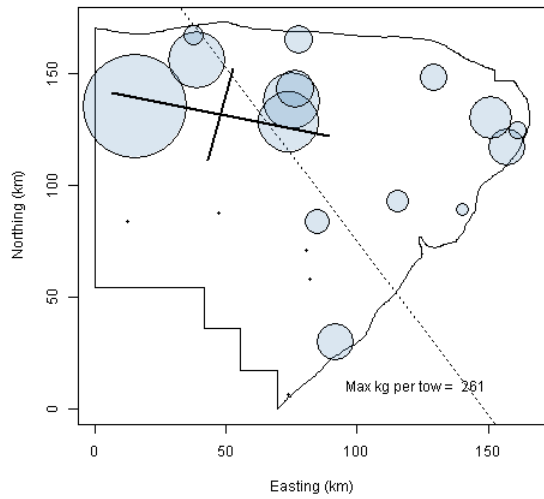
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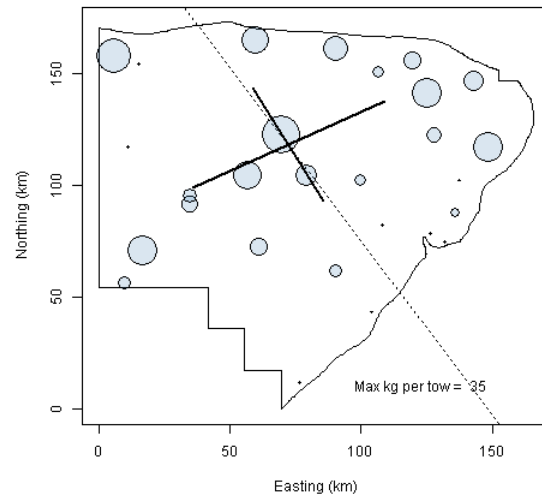
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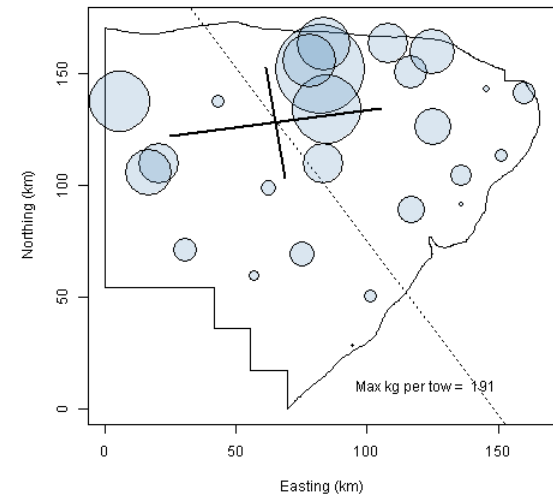
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**EGB Cod Spring 1984**

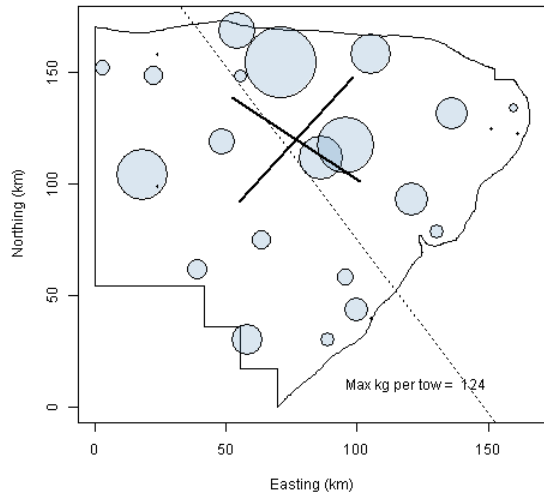


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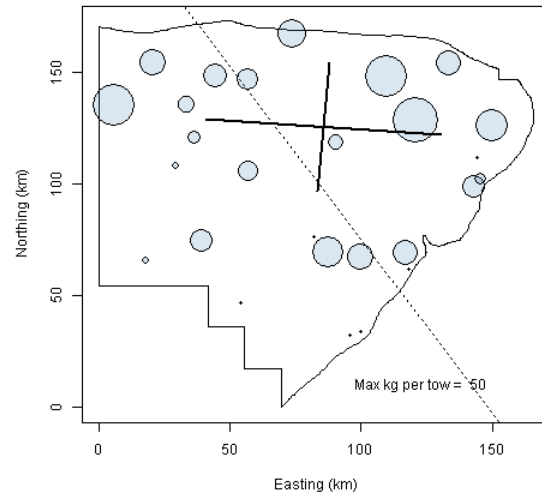




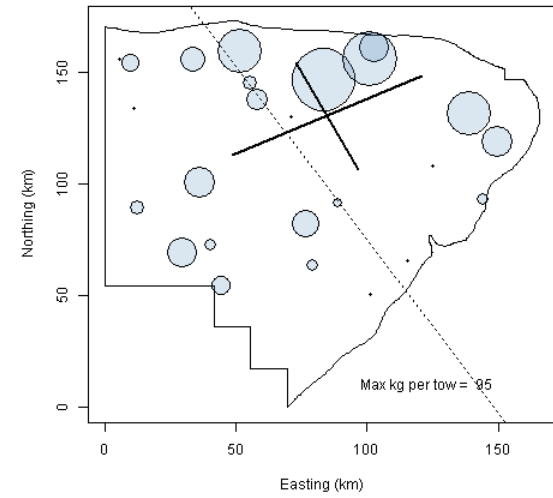
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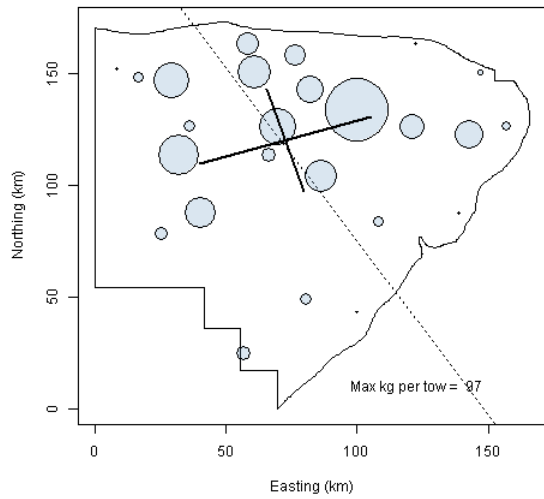
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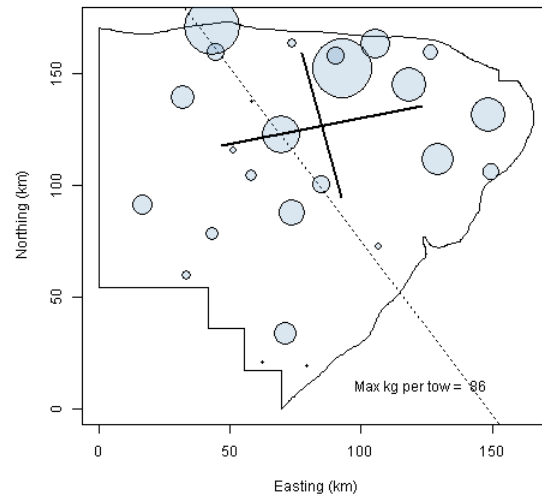
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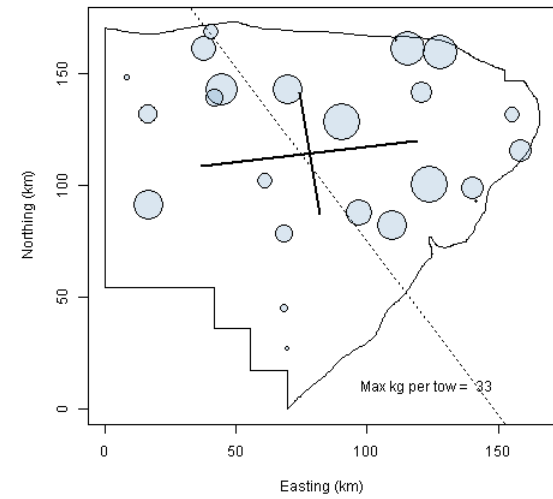
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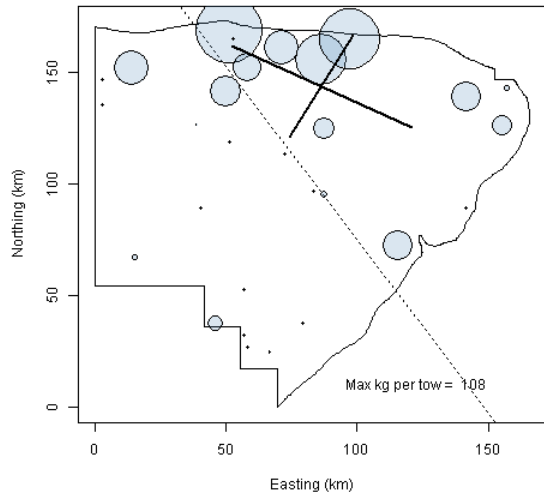
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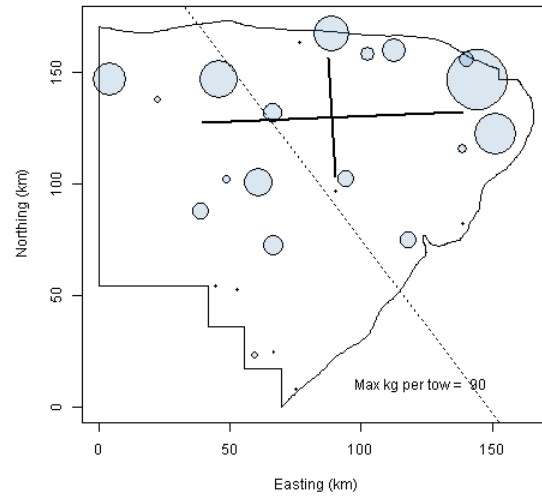
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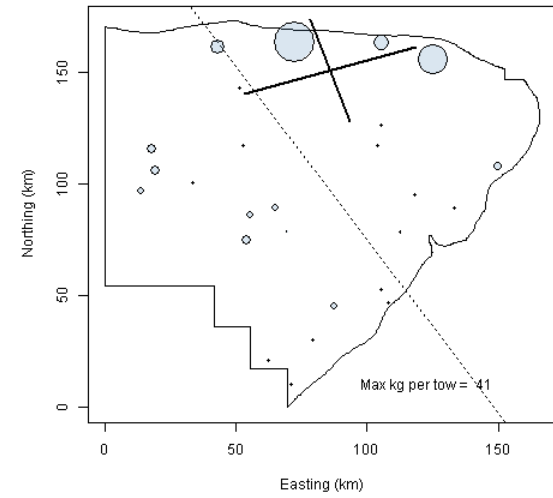
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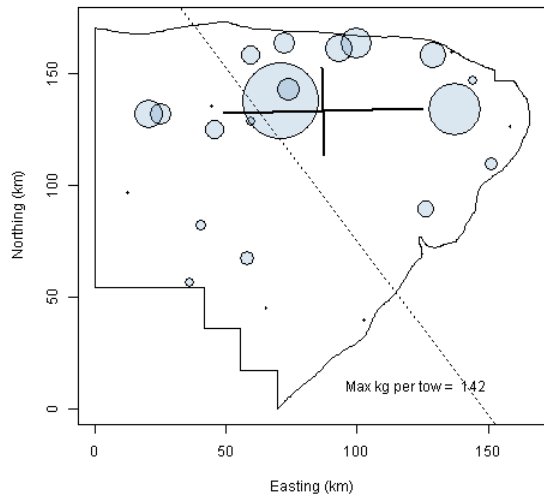
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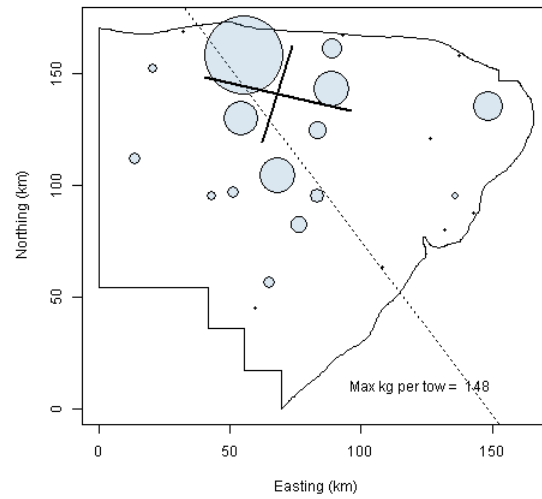
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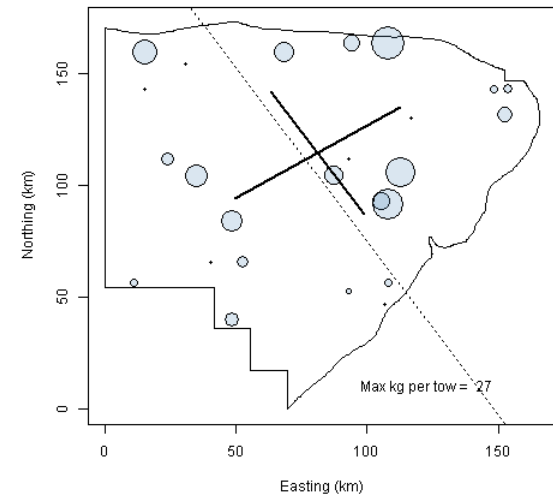
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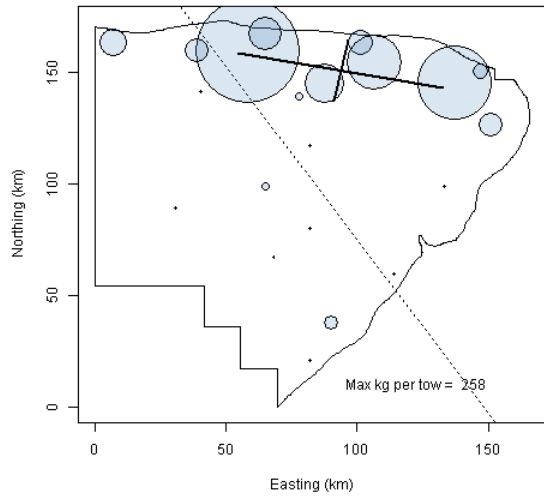
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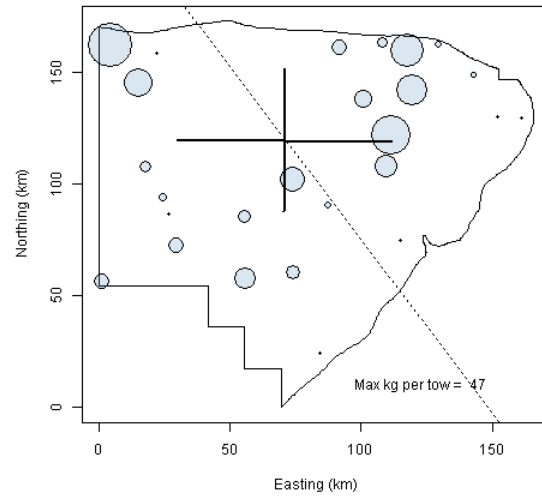
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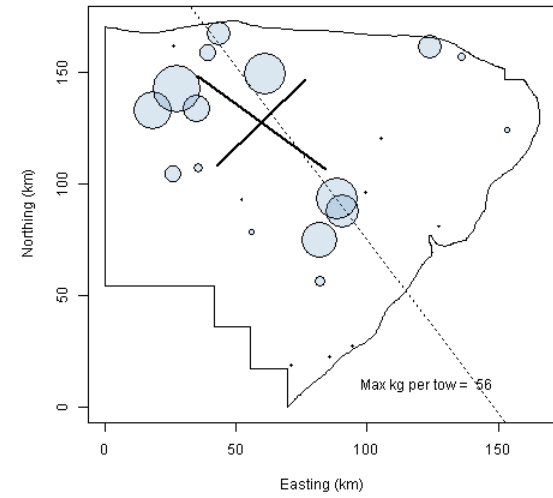
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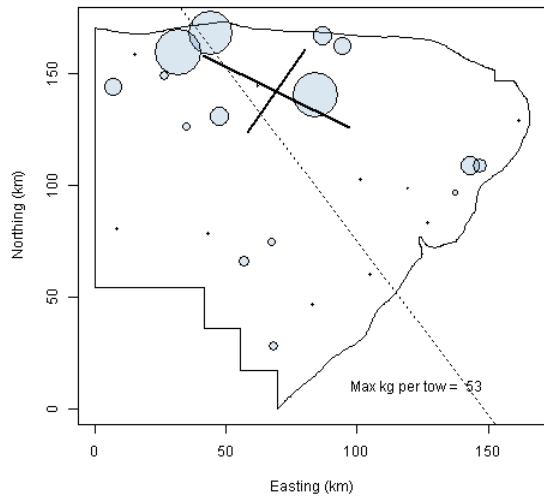
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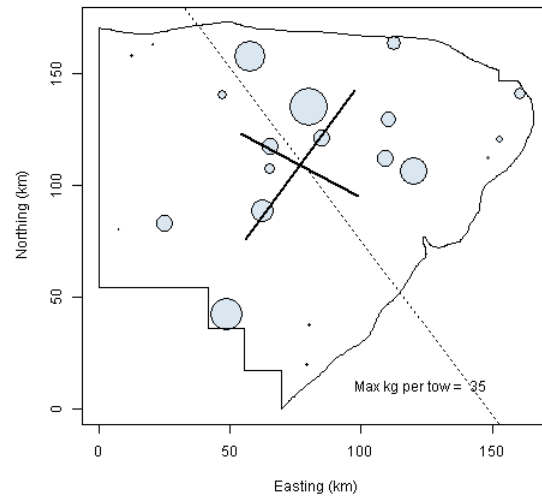
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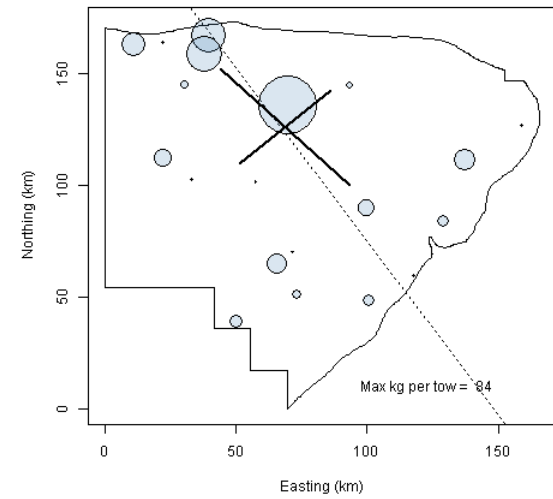
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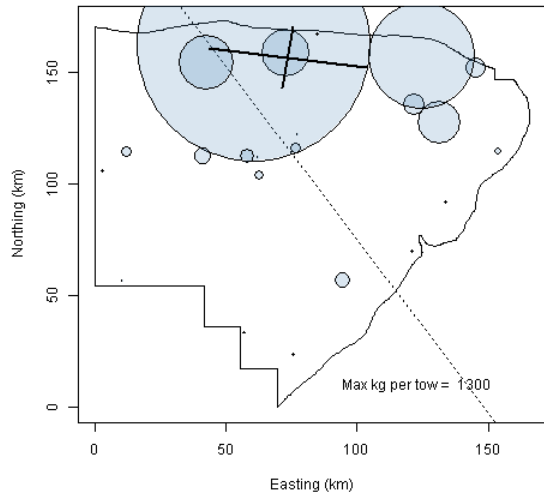
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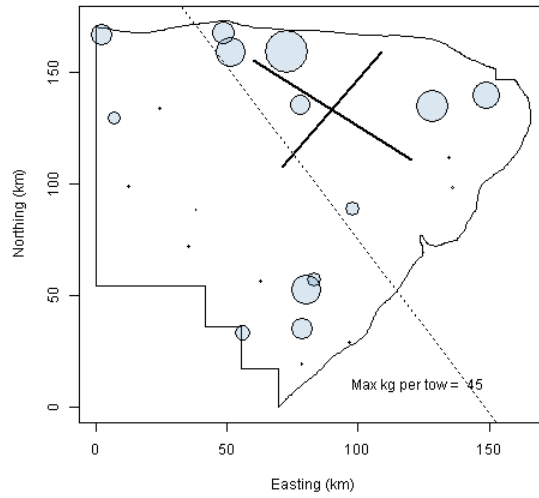
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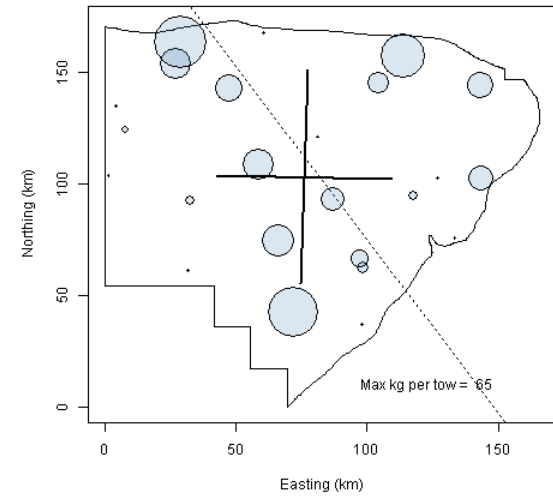
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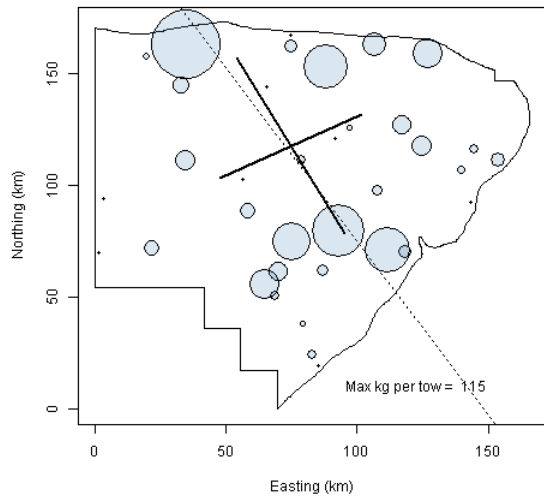
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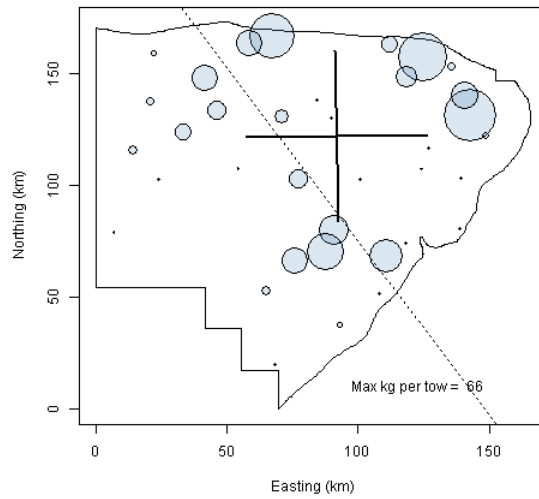
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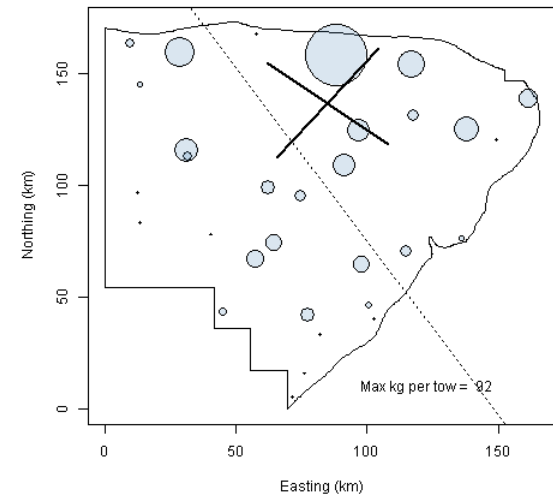
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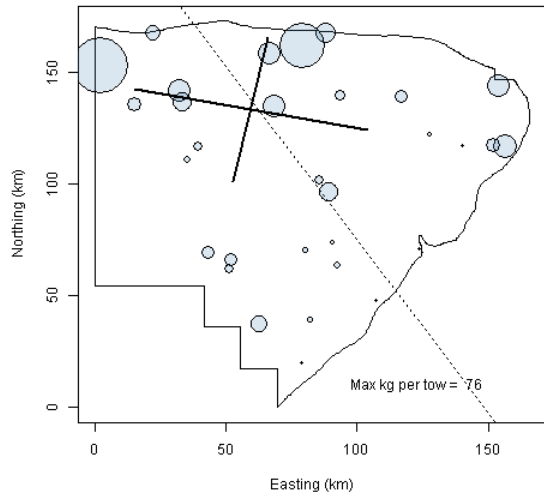
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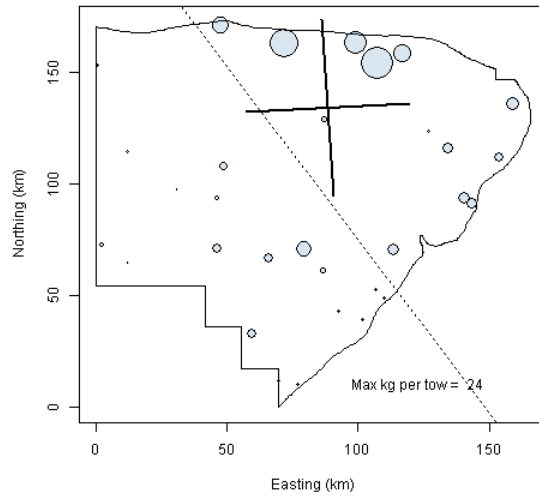
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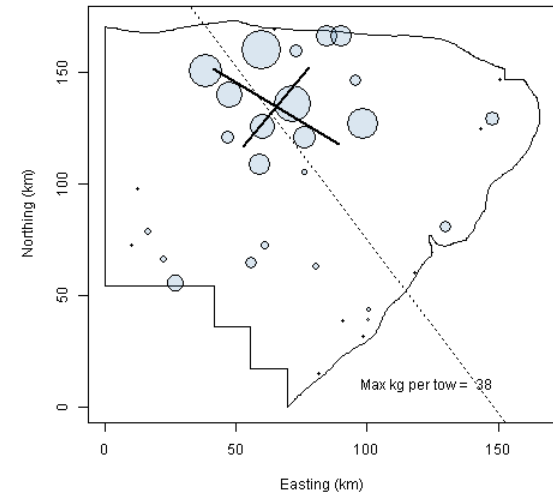
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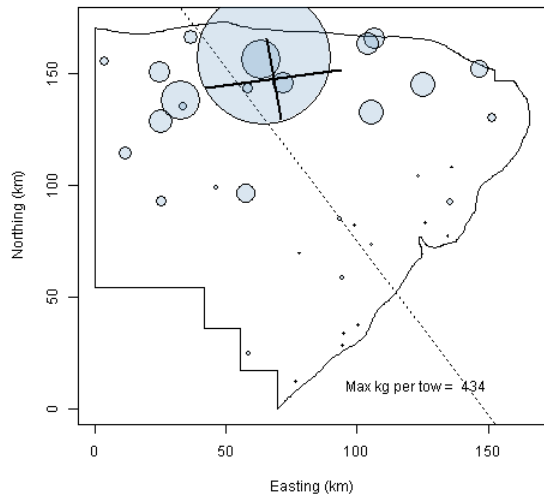
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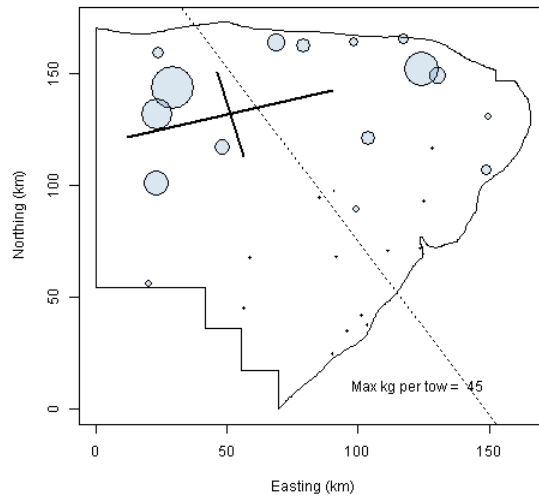
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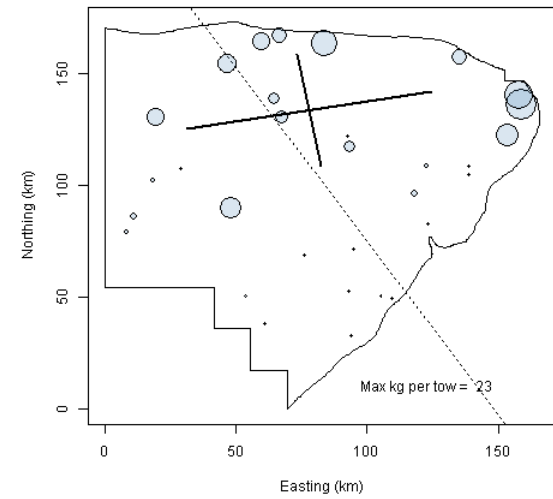
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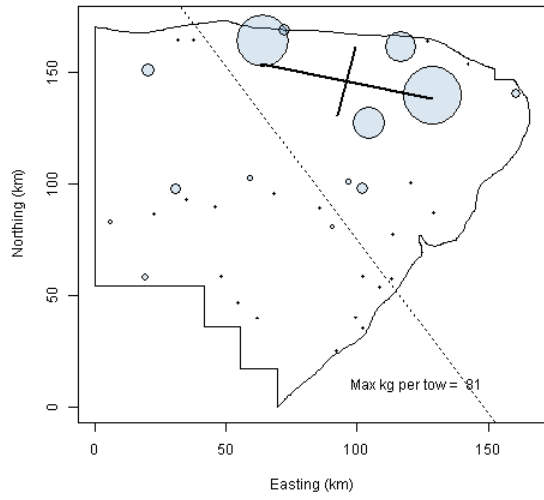
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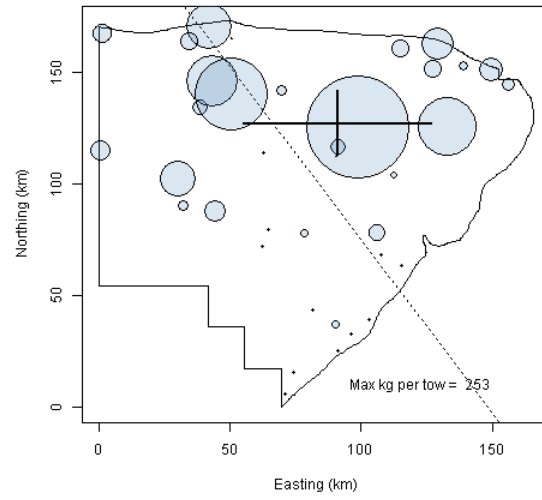
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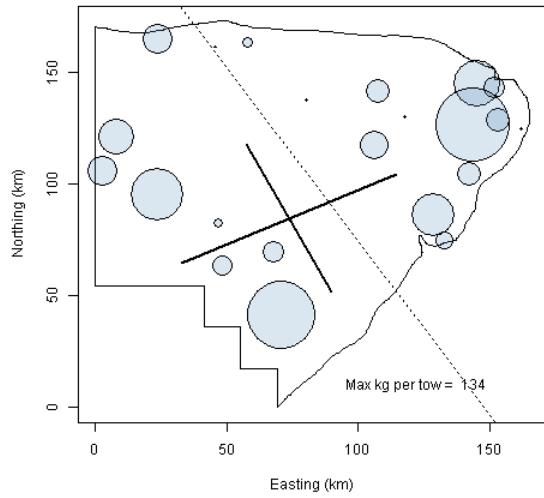
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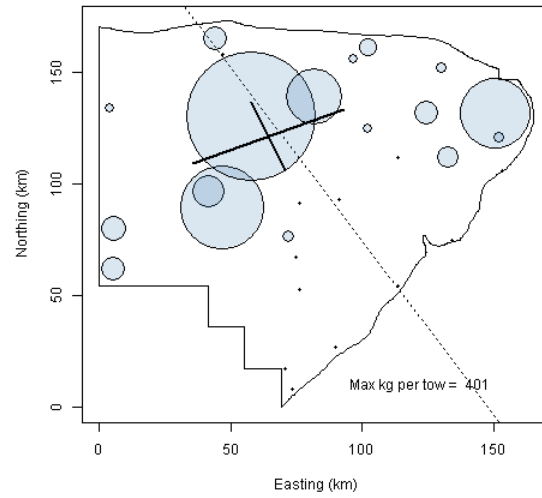
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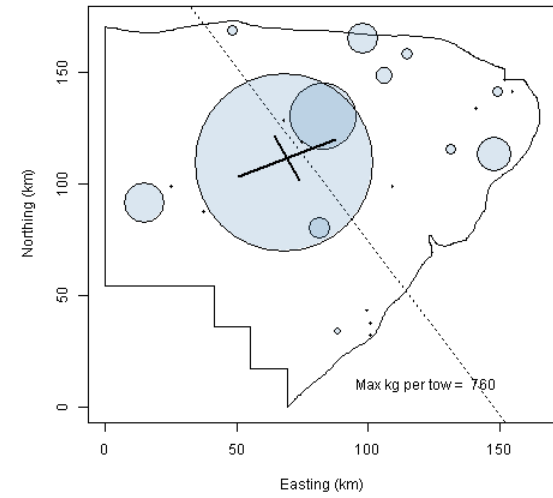
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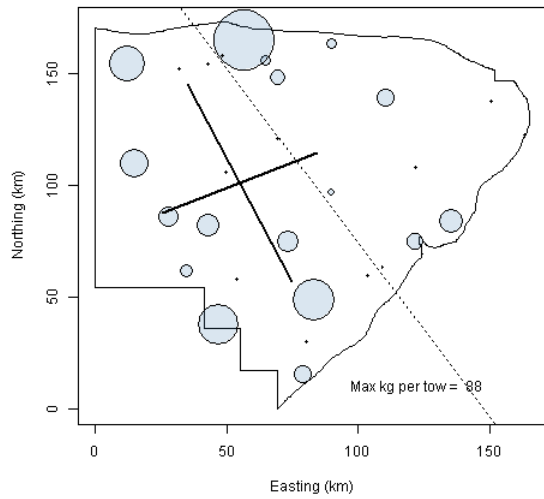
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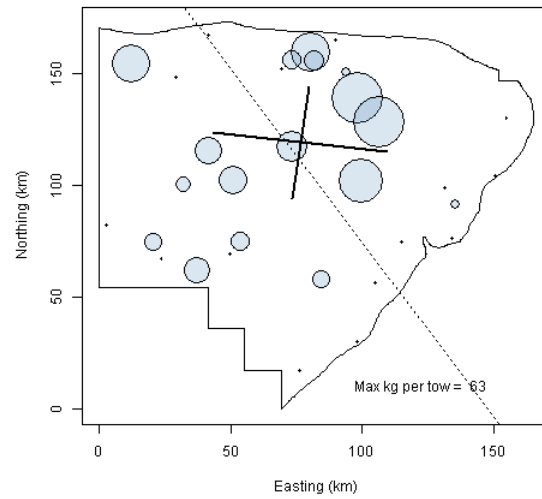
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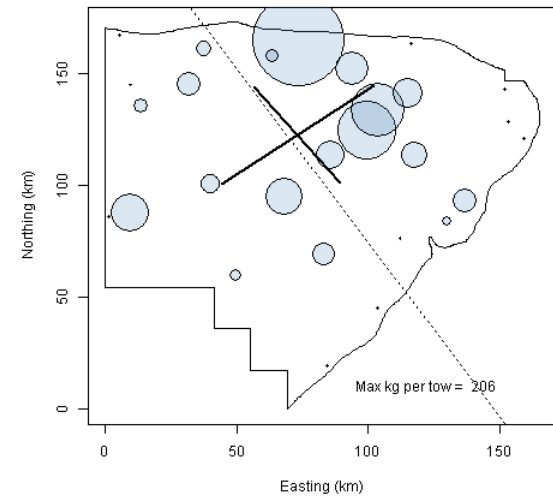
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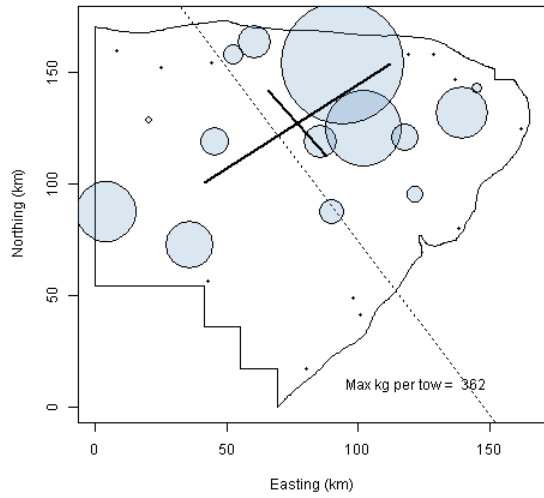
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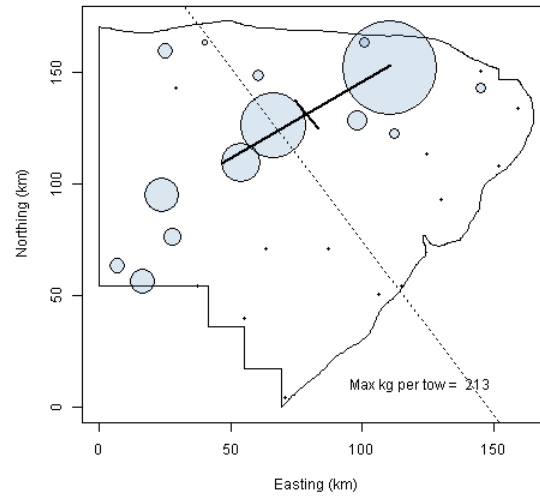
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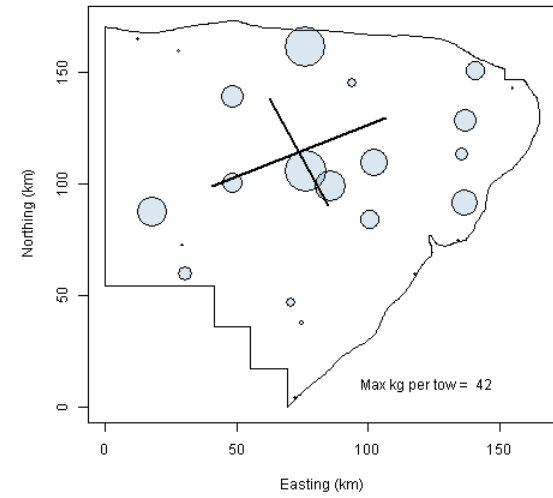
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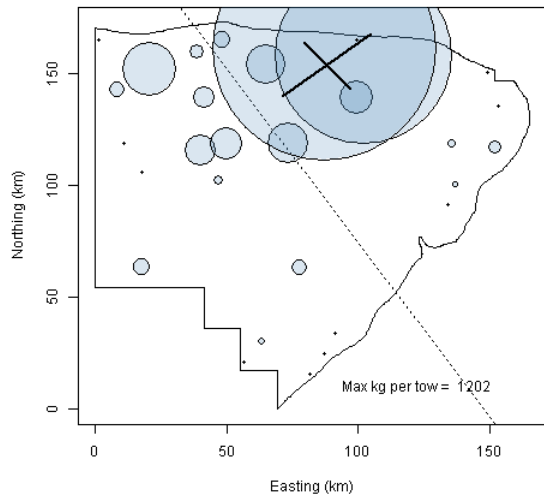
**EGB Haddock Spring 1975**



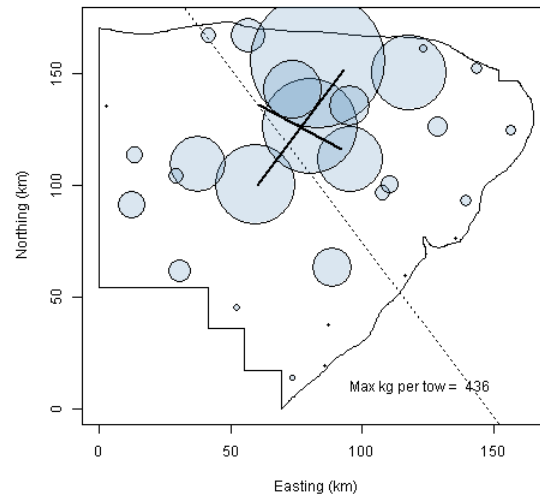
**EGB Haddock Spring 1976**



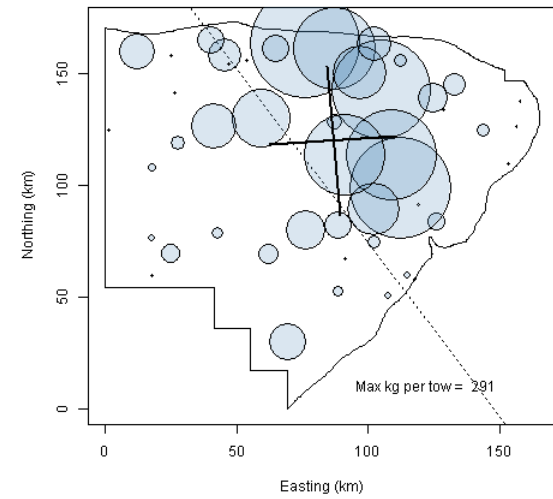
**EGB Haddock Spring 1977**



**EGB Haddock Spring 1978**

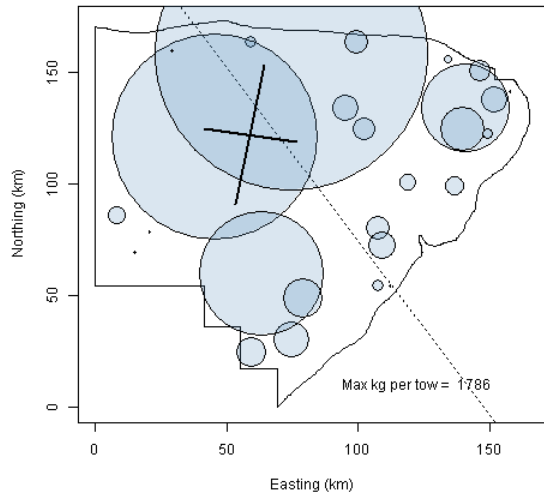


**EGB Haddock Spring 1979**

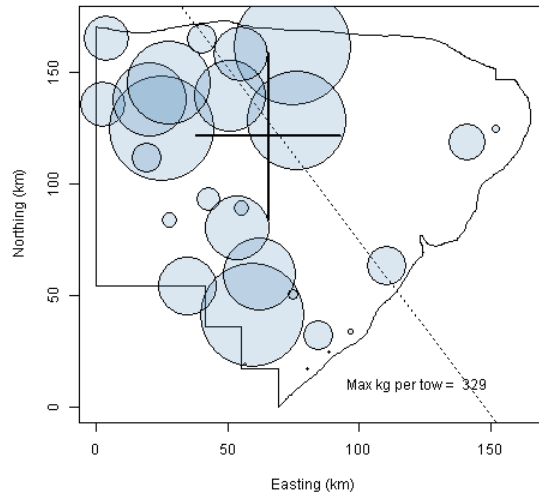




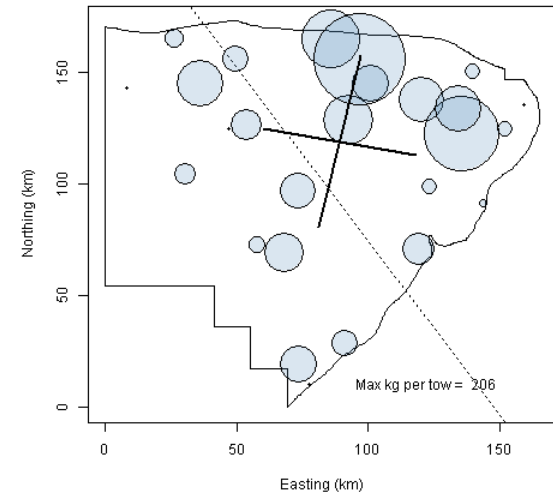
**EGB Haddock Spring 1980**



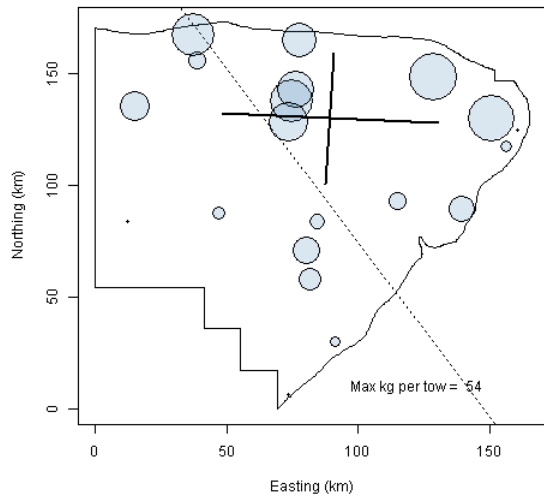
**EGB Haddock Spring 1981**



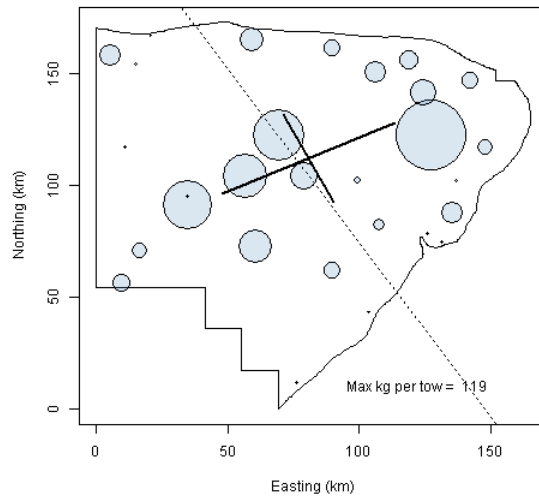
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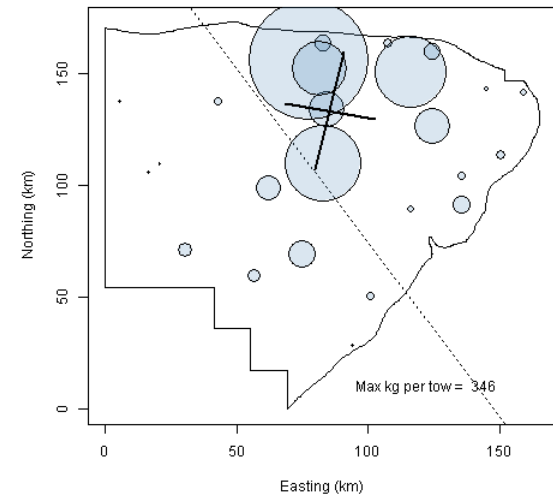
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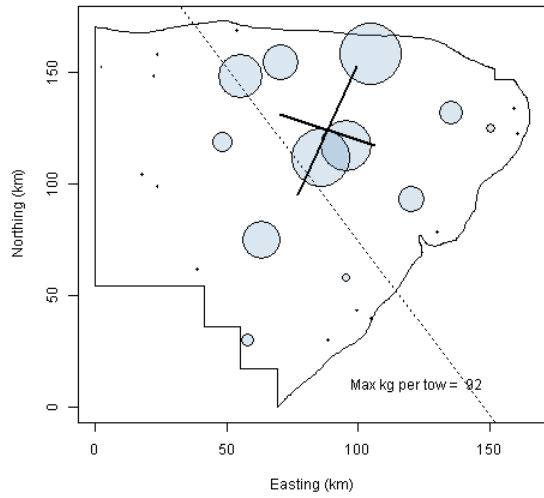
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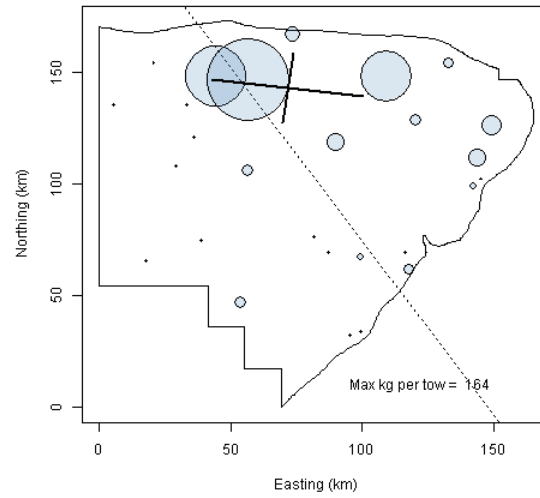
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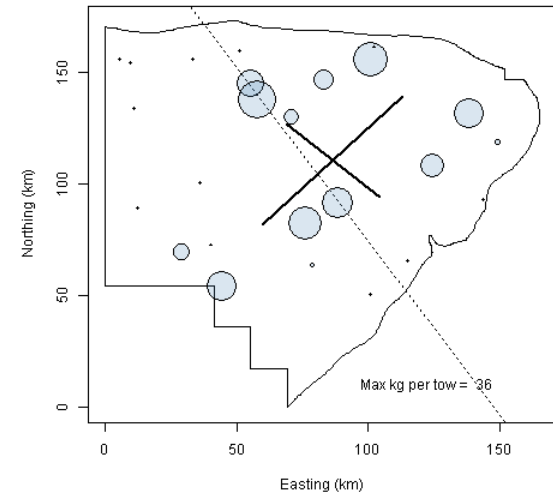
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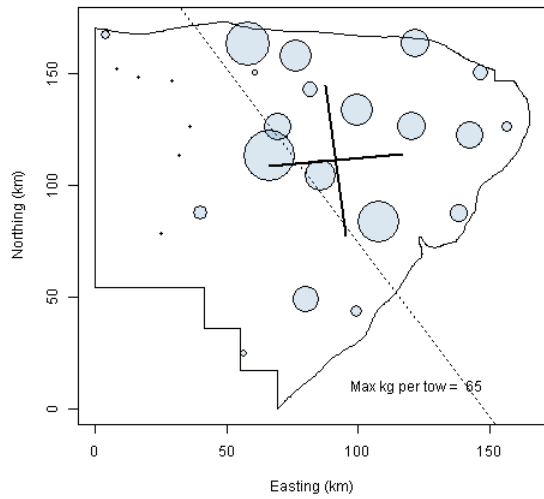
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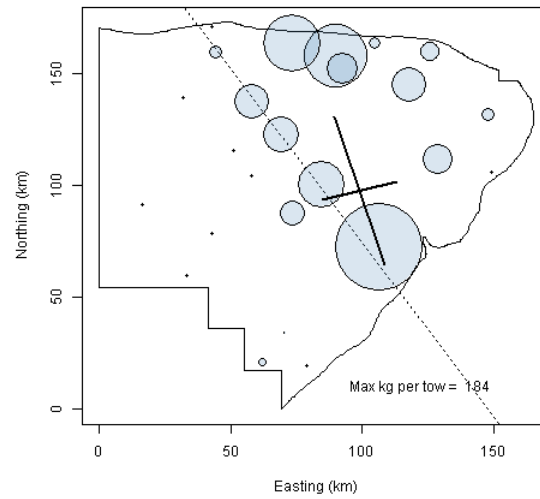
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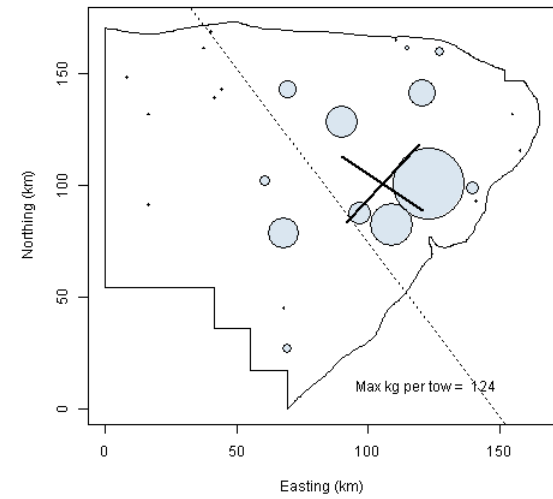
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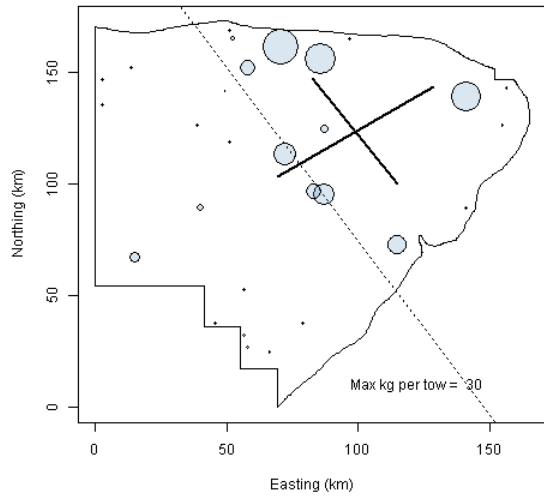
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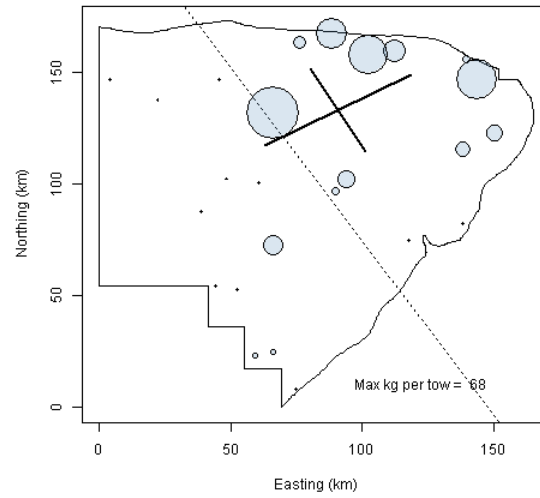
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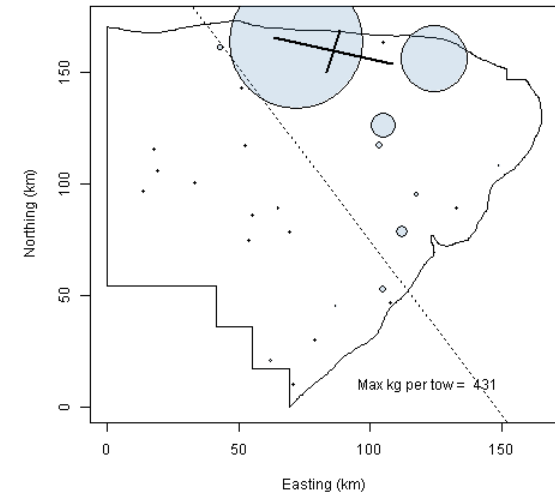
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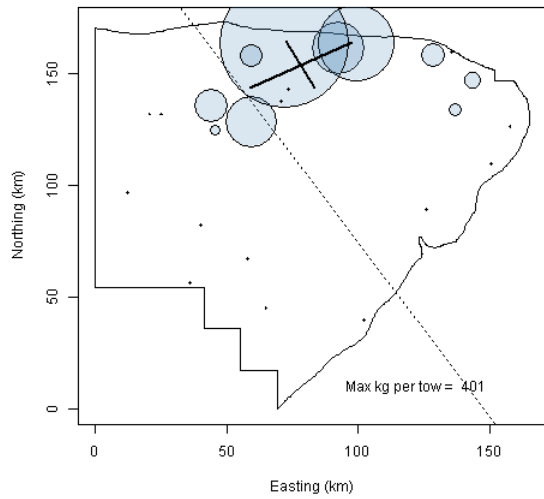
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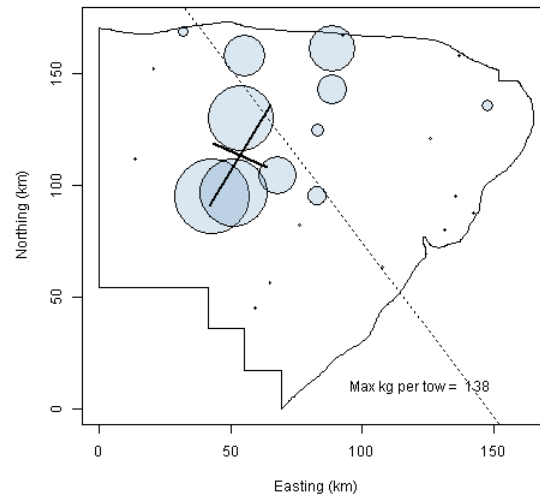
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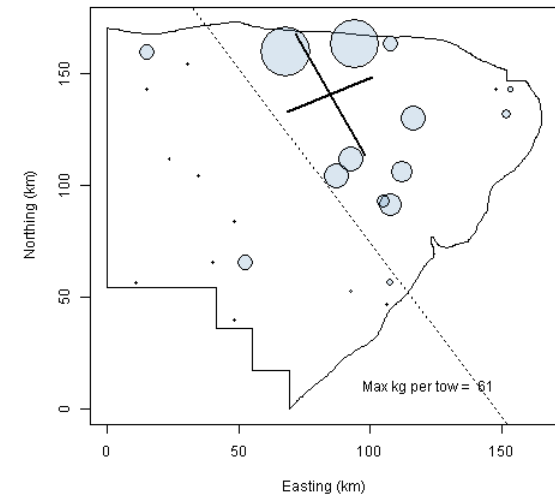
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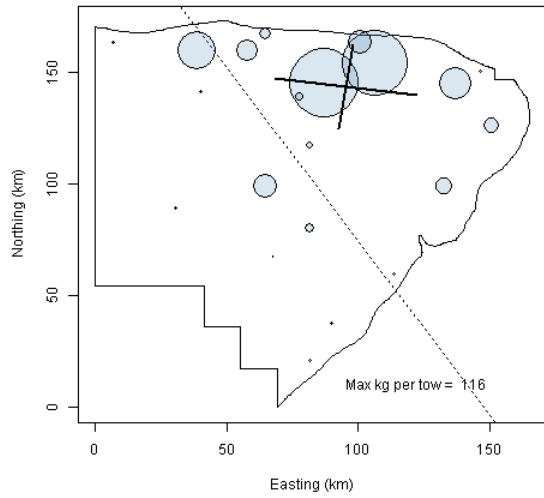
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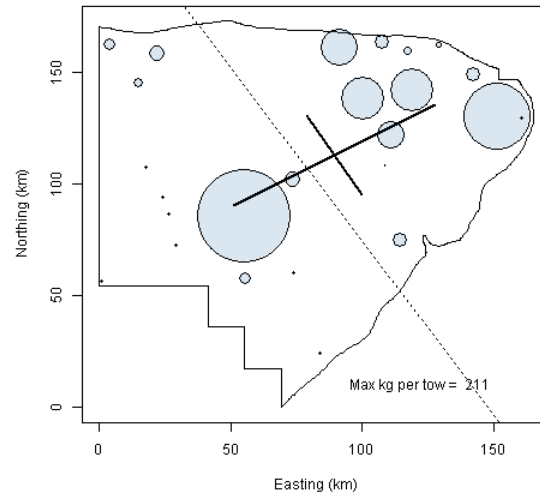
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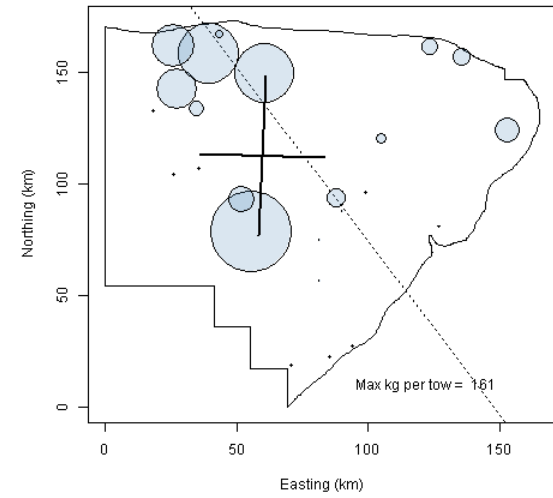
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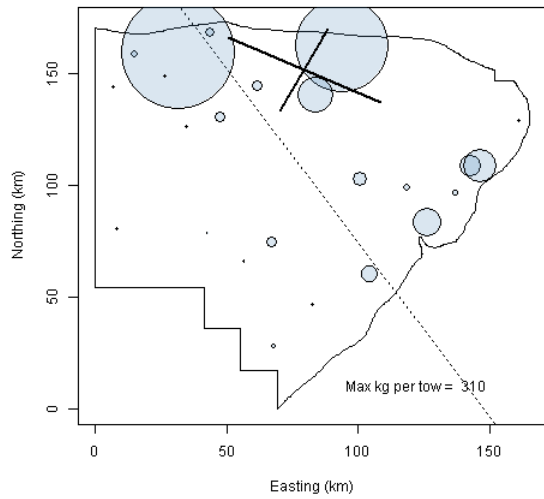
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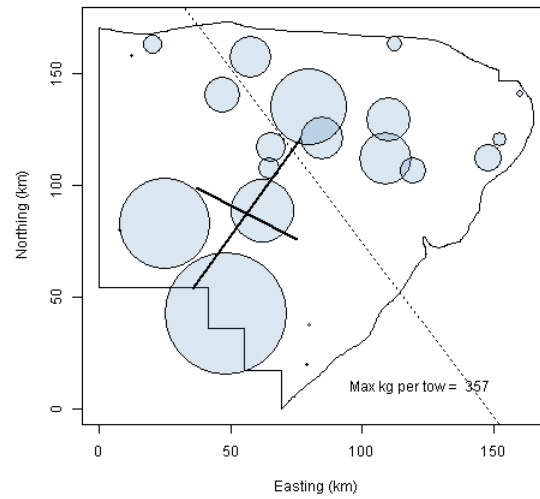
**EGB Haddock Spring 2000**



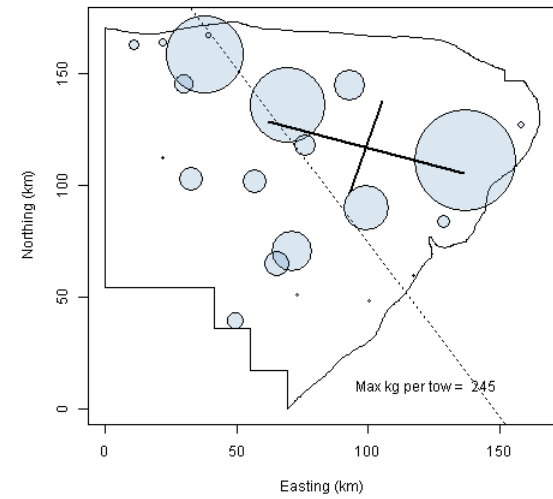
**EGB Haddock Spring 2001**



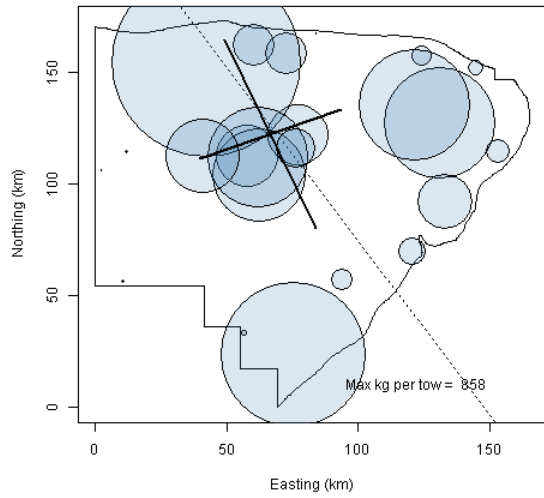
**EGB Haddock Spring 2002**



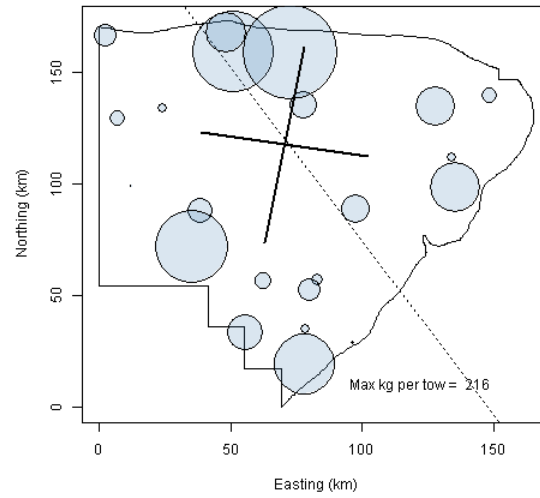
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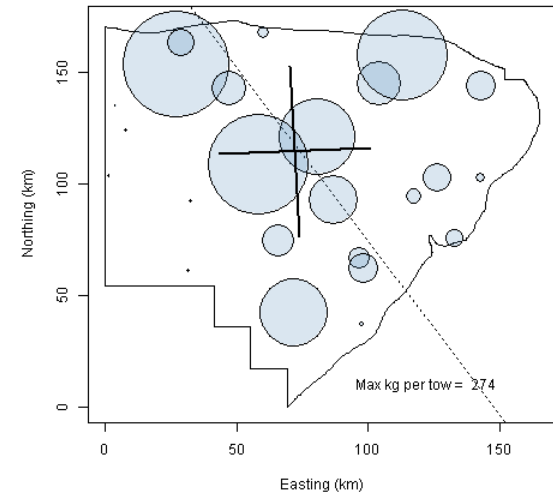
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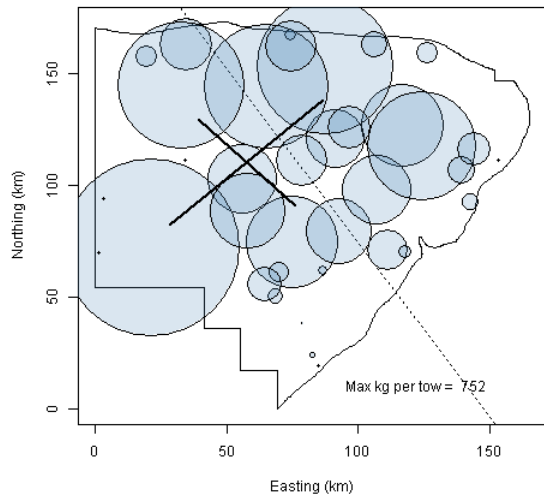
**EGB Haddock Spring 2005**



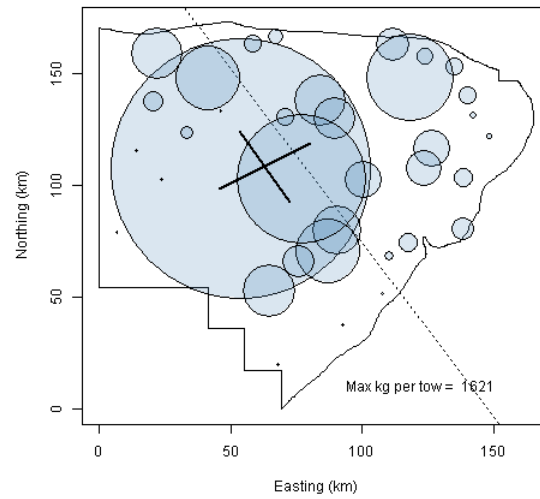
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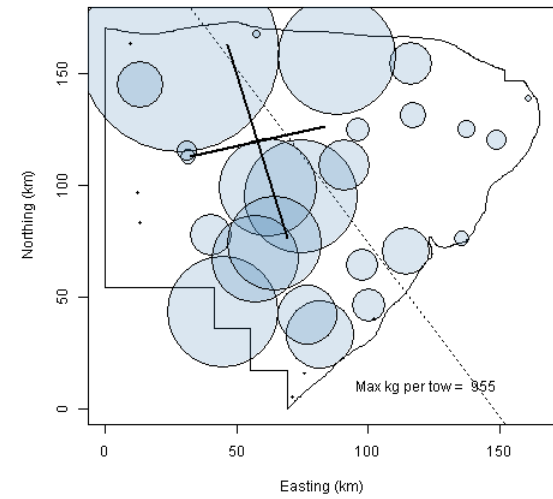
**EGB Haddock Spring 2007**



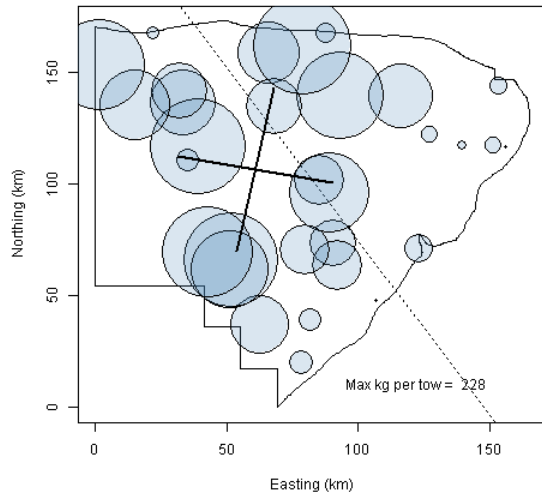
**EGB Haddock Spring 2008**



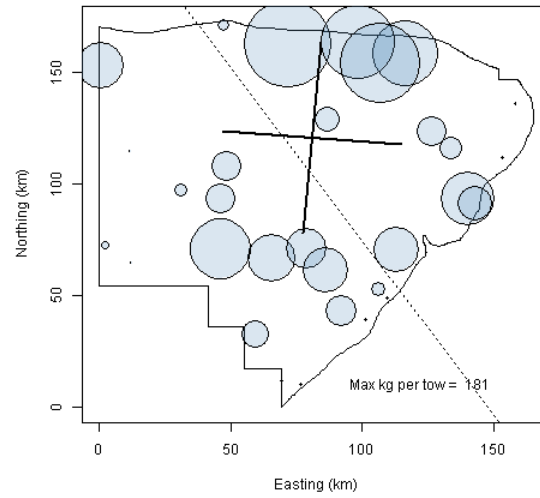
**EGB Haddock Spring 2009**



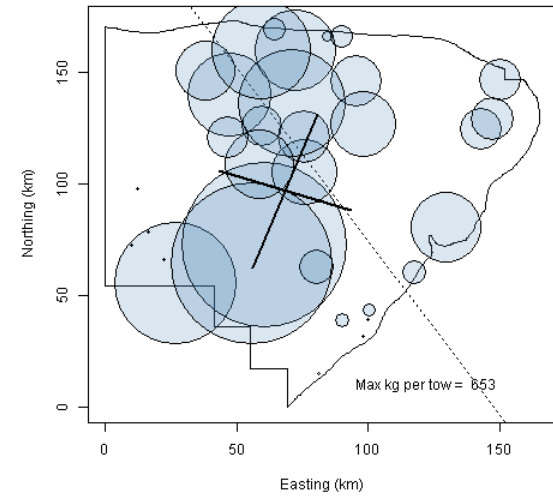
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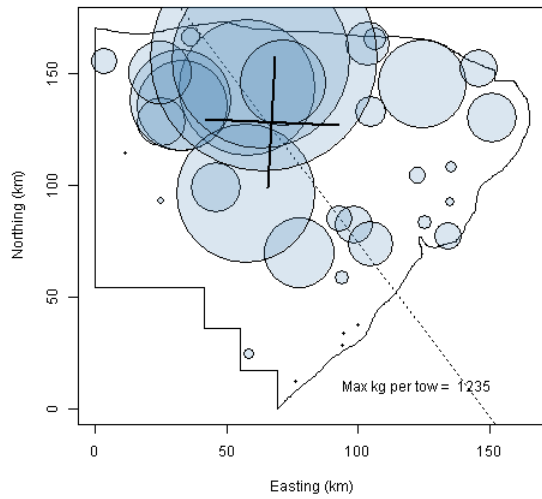
**EGB Haddock Spring 2011**



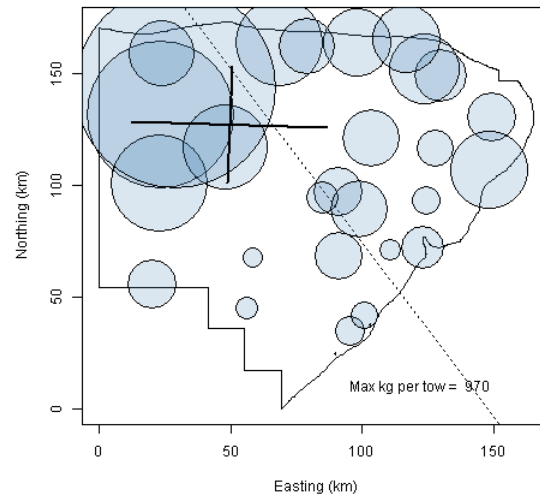
**EGB Haddock Spring 2012**



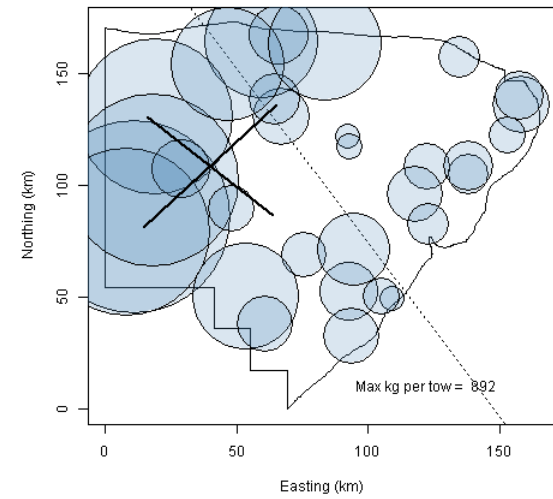
**EGB Haddock Spring 2013**



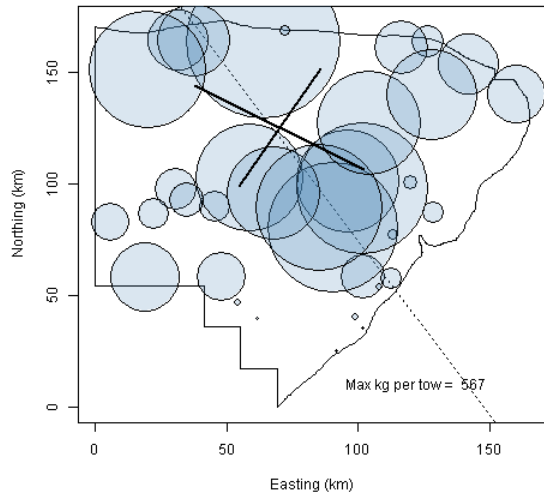
**EGB Haddock Spring 2014**



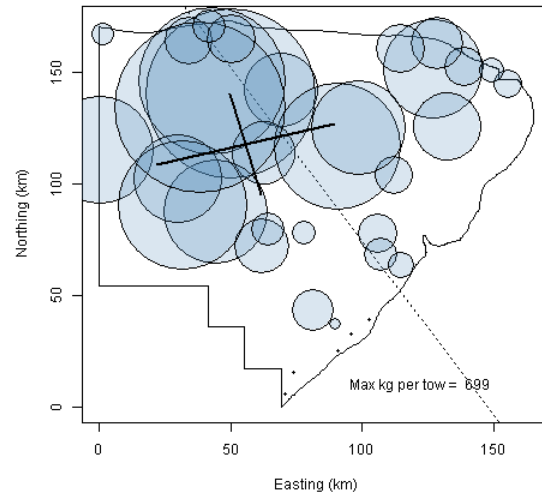
**EGB Haddock Spring 2015**



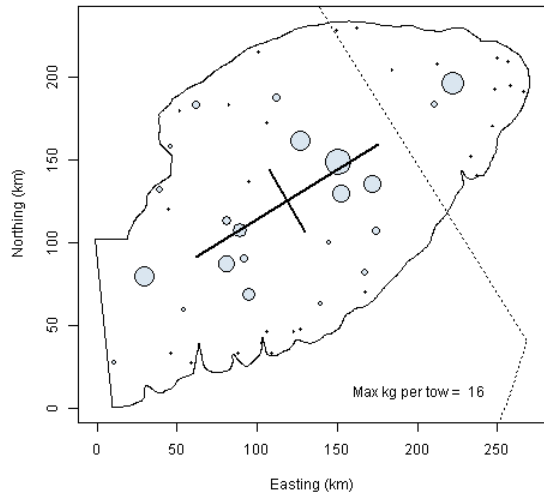
**EGB Haddock Spring 2016**



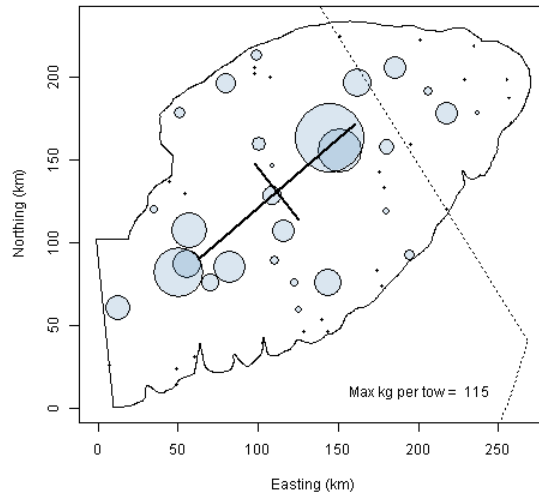
**EGB Haddock Spring 2017**



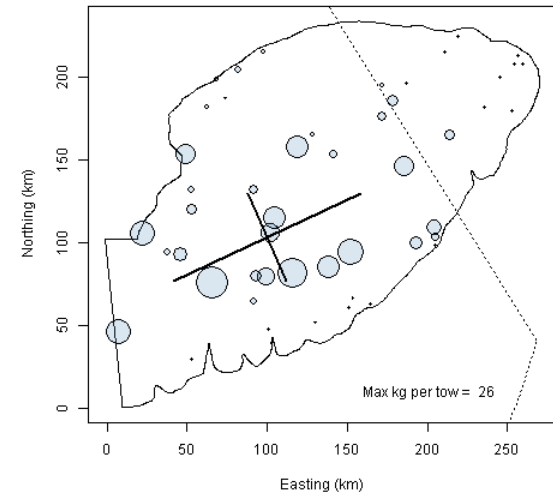
**GB Yellowtail Spring 1968**



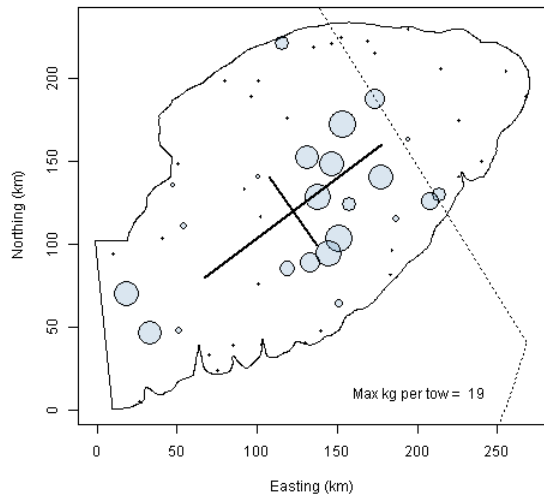
**GB Yellowtail Spring 1969**



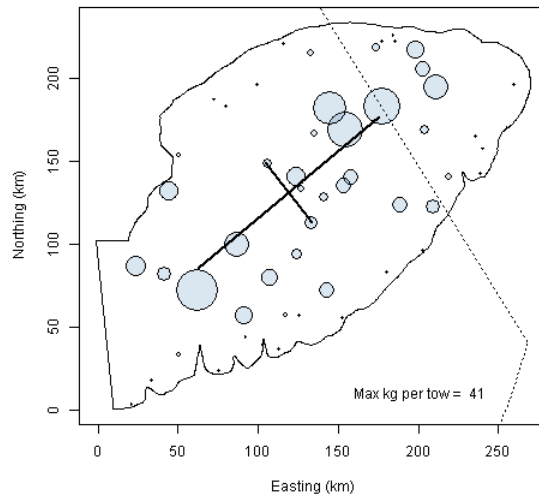
**GB Yellowtail Spring 1970**



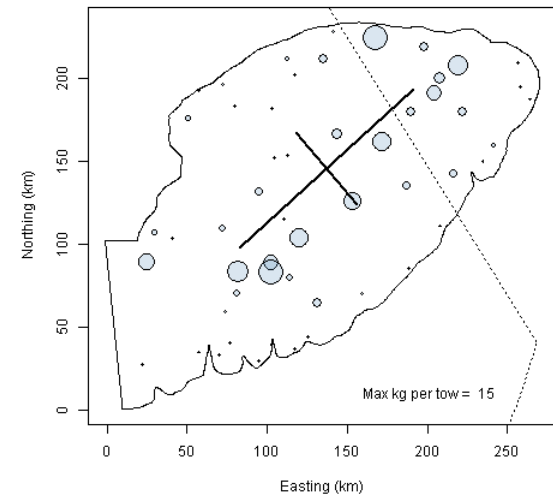
**GB Yellowtail Spring 1971**



**GB Yellowtail Spring 1972**

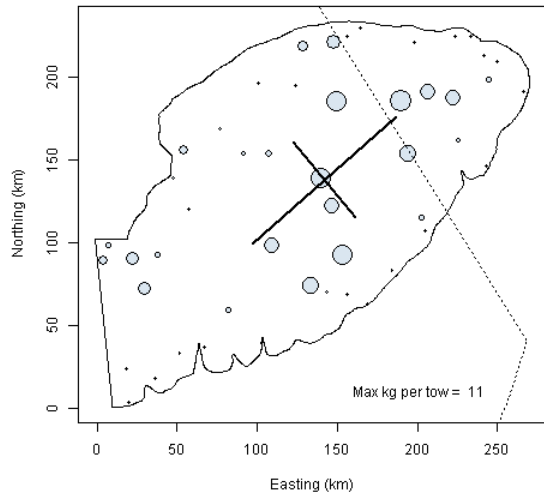


**GB Yellowtail Spring 1973**

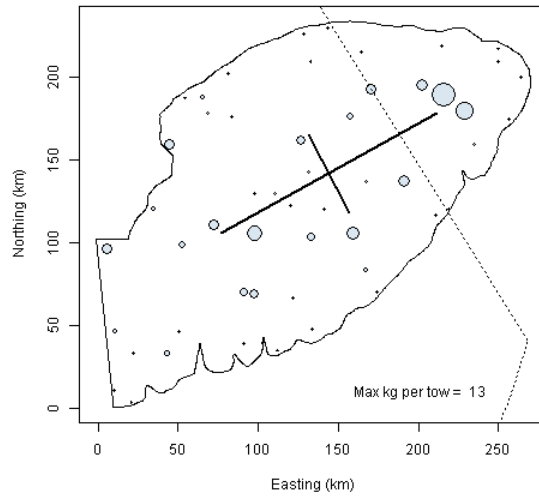




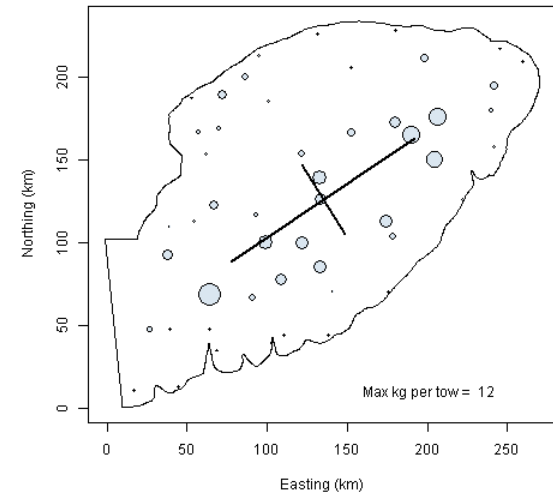
**GB Yellowtail Spring 1974**



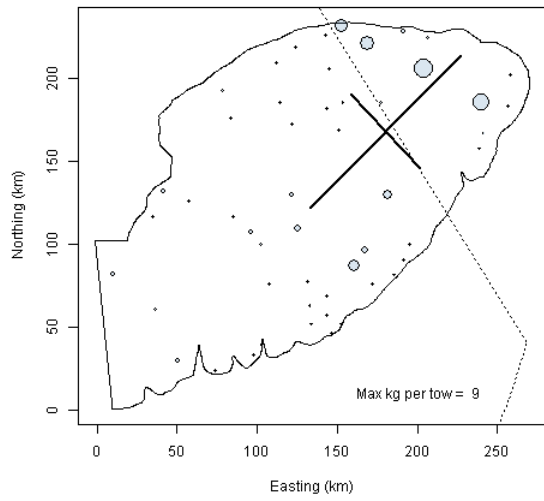
**GB Yellowtail Spring 1975**



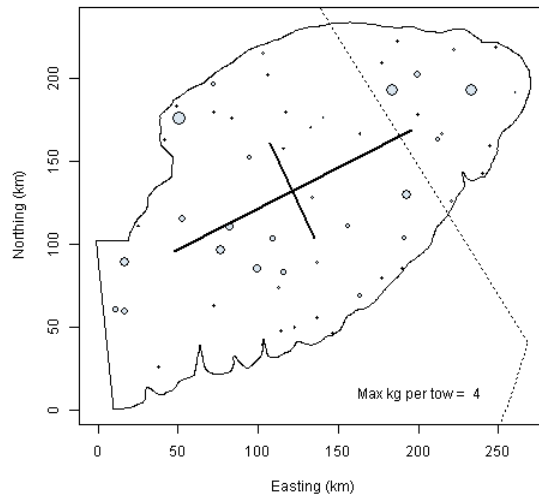
**GB Yellowtail Spring 1976**



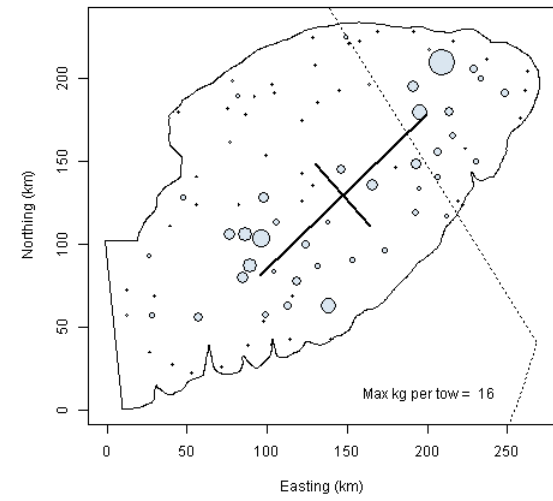
**GB Yellowtail Spring 1977**



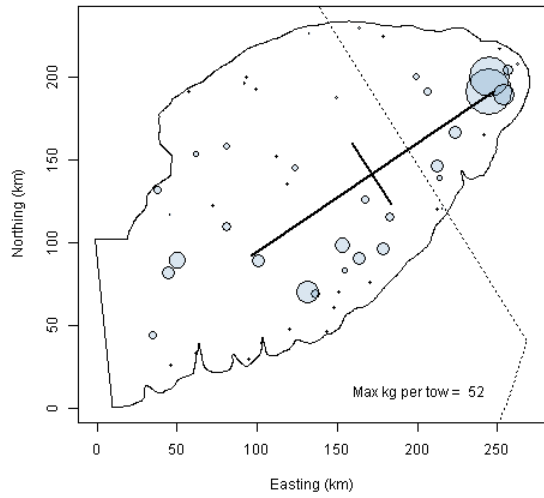
**GB Yellowtail Spring 1978**



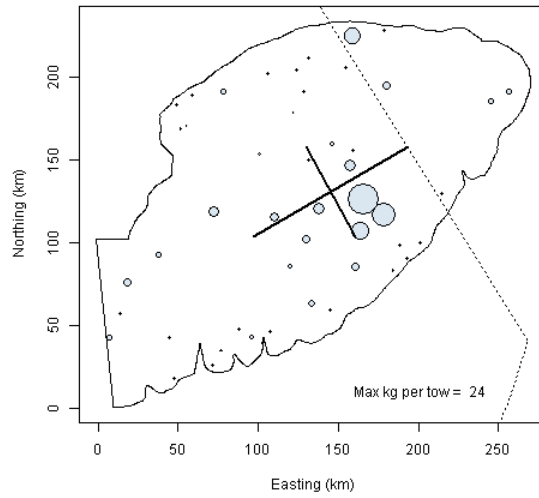
**GB Yellowtail Spring 1979**



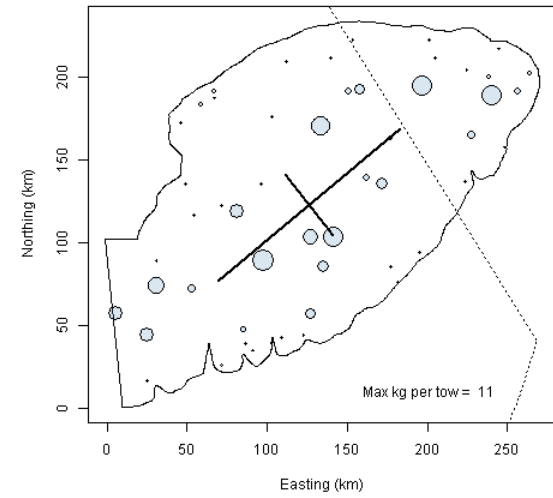
**GB Yellowtail Spring 1980**



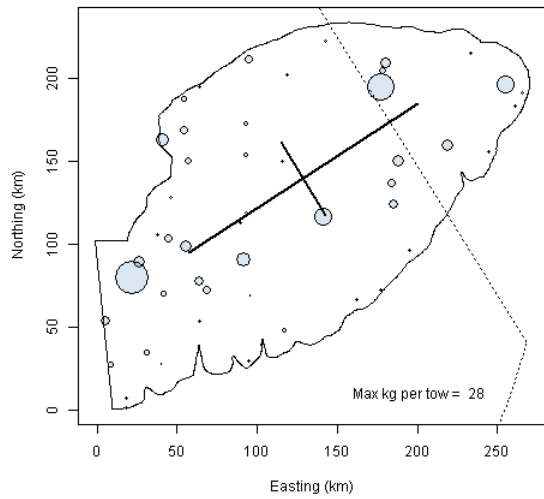
**GB Yellowtail Spring 1981**



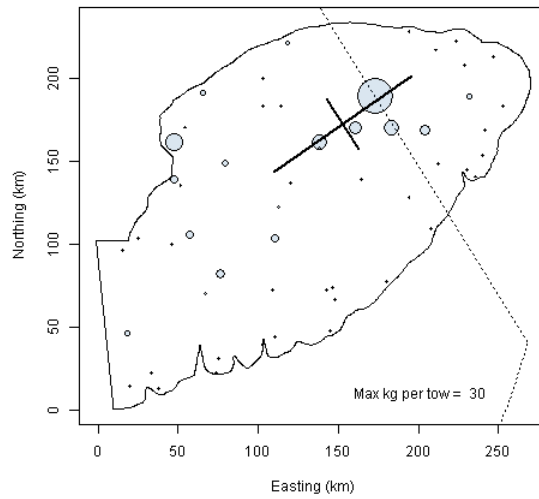
**GB Yellowtail Spring 1982**



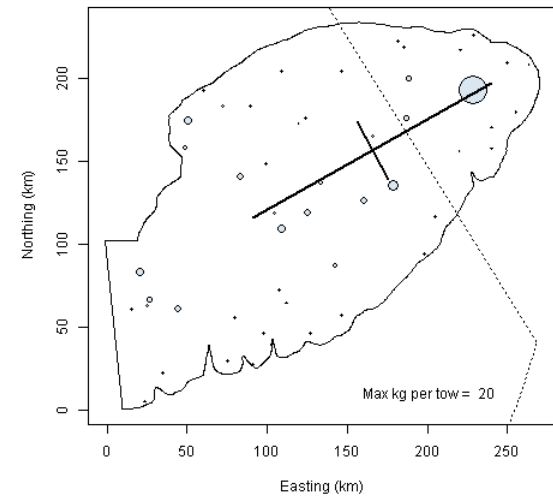
**GB Yellowtail Spring 1983**



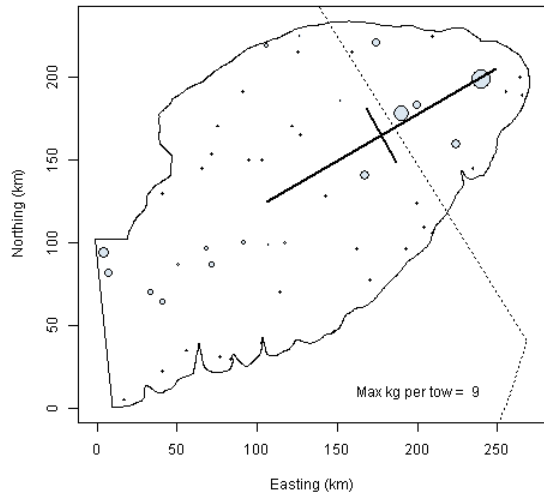
**GB Yellowtail Spring 1984**



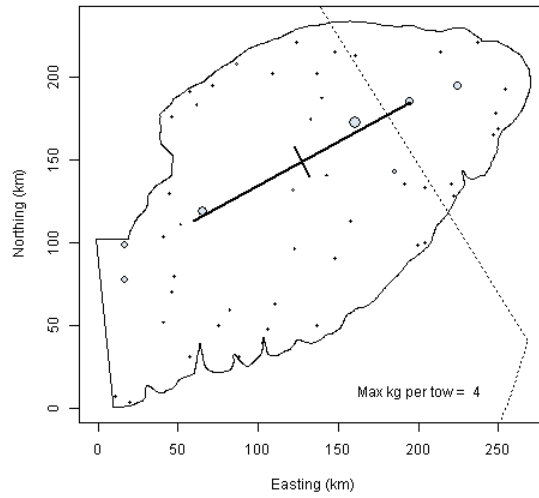
**GB Yellowtail Spring 1985**



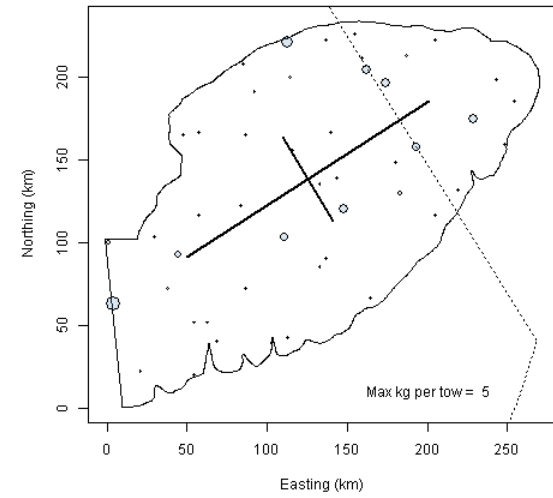
**GB Yellowtail Spring 1986**



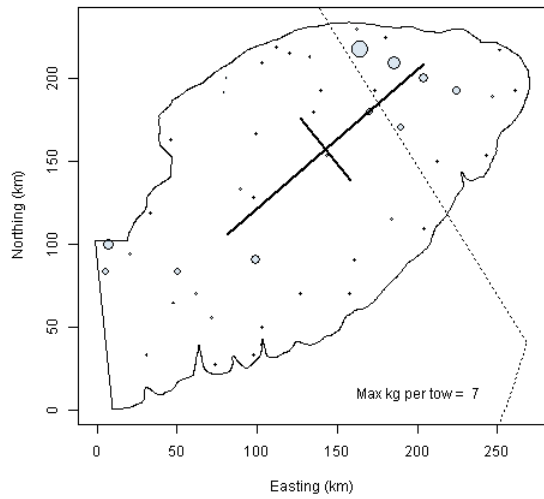
**GB Yellowtail Spring 1987**



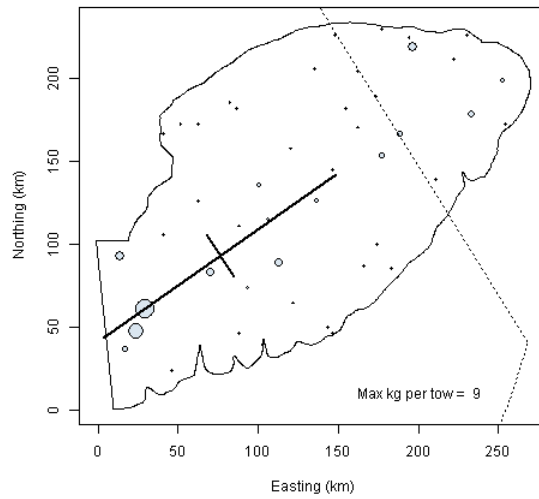
**GB Yellowtail Spring 1988**



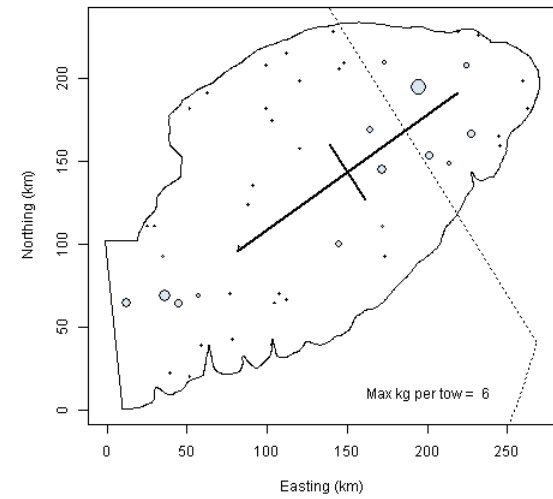
**GB Yellowtail Spring 1989**



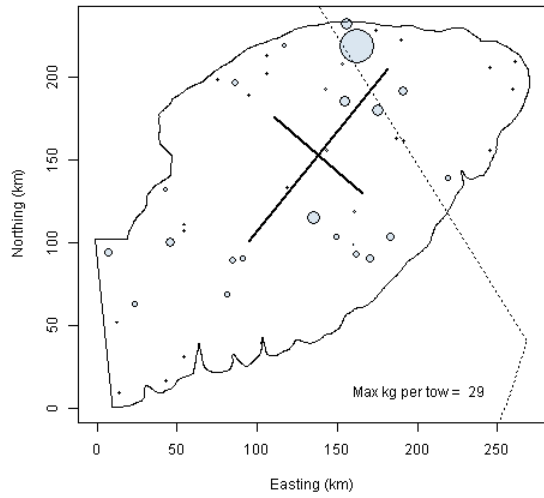
**GB Yellowtail Spring 1990**



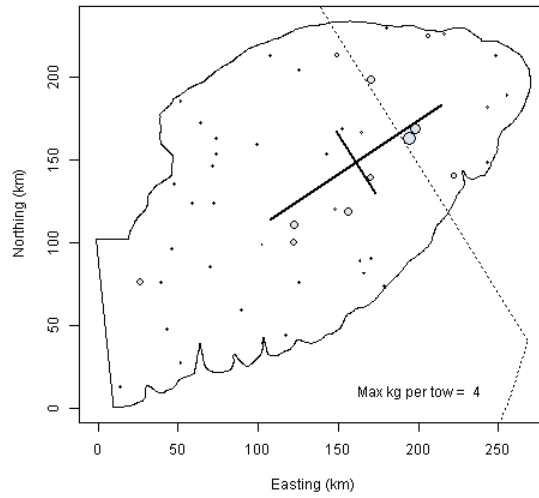
**GB Yellowtail Spring 1991**



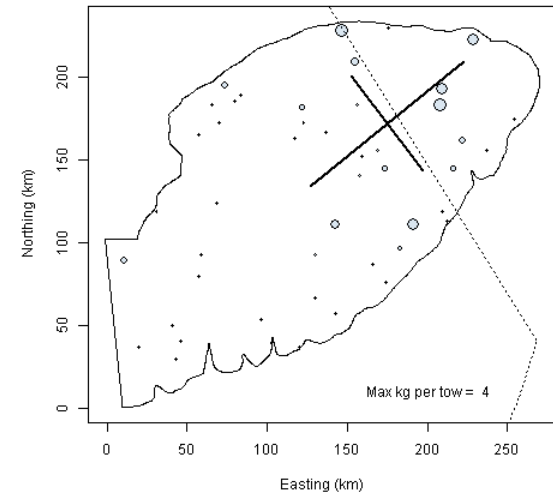
**GB Yellowtail Spring 1992**



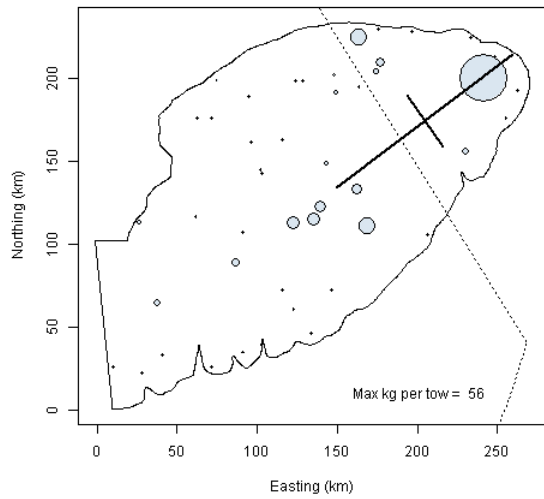
**GB Yellowtail Spring 1993**



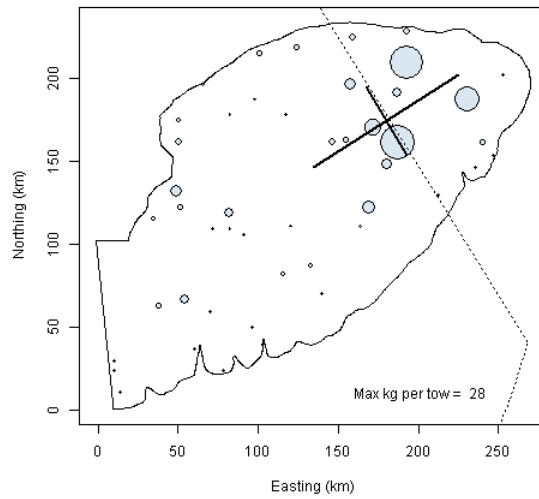
**GB Yellowtail Spring 1994**



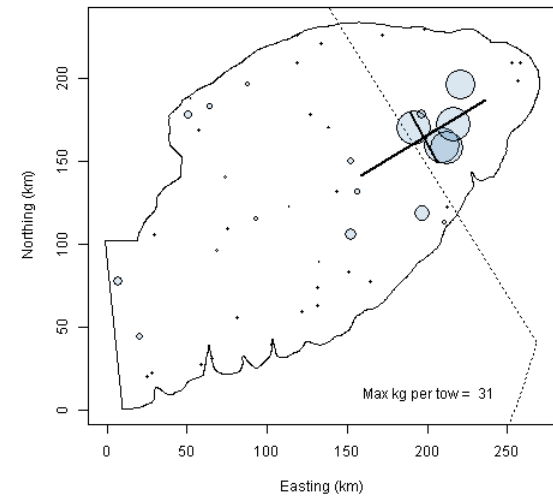
**GB Yellowtail Spring 1995**



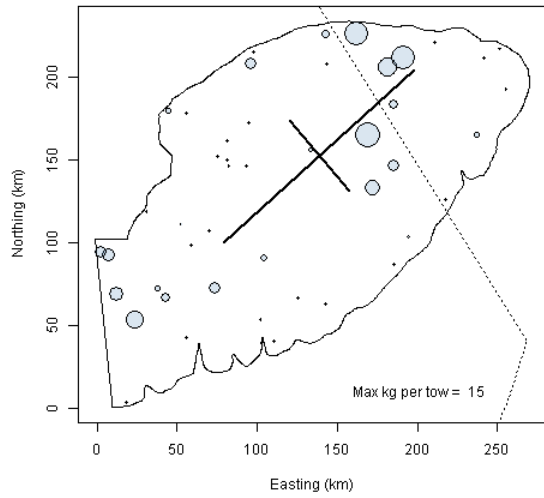
**GB Yellowtail Spring 1996**



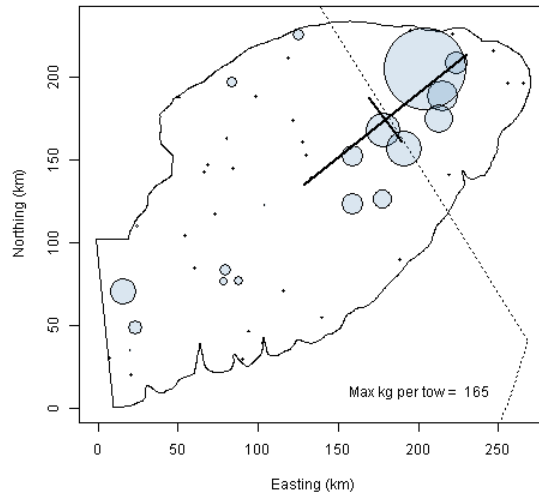
**GB Yellowtail Spring 1997**



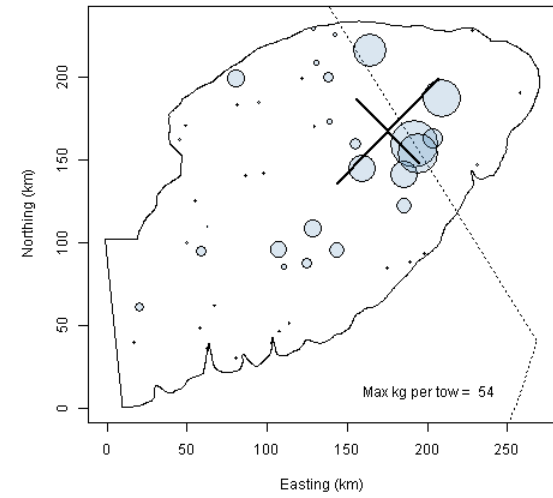
**GB Yellowtail Spring 1998**



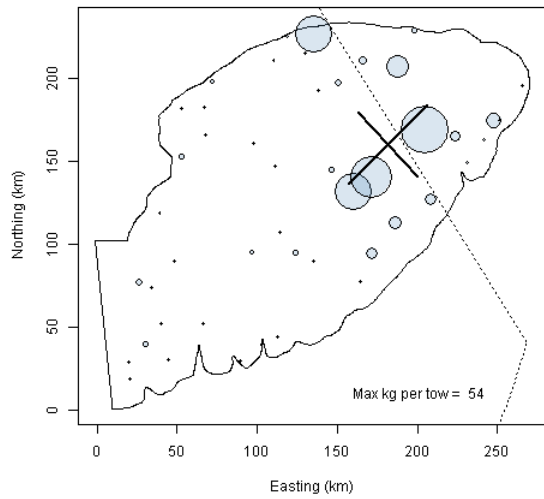
**GB Yellowtail Spring 1999**



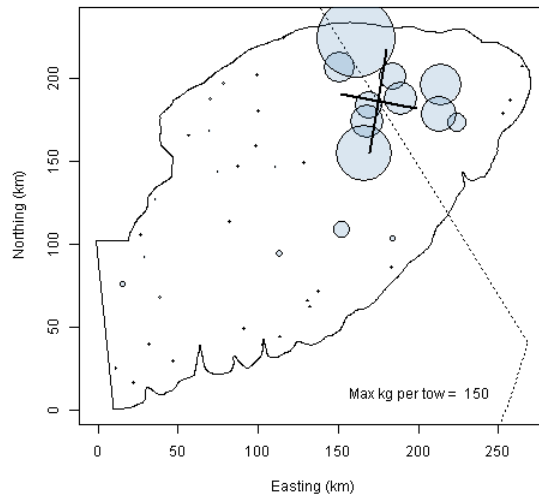
**GB Yellowtail Spring 2000**



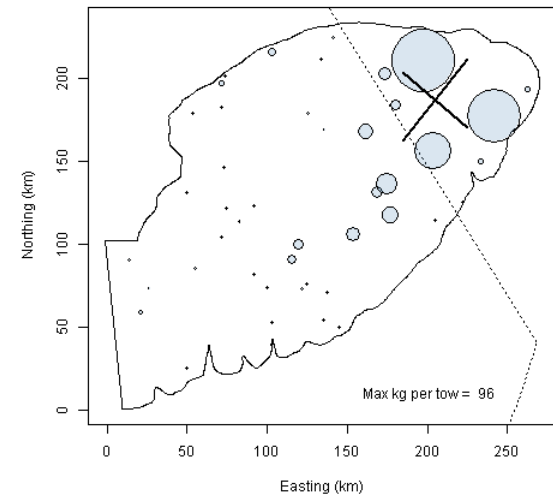
**GB Yellowtail Spring 2001**



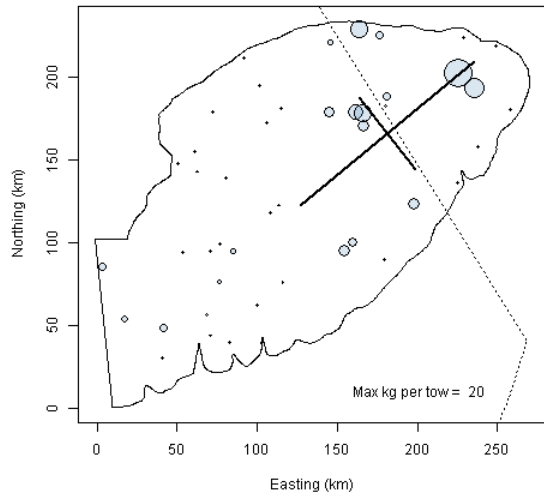
**GB Yellowtail Spring 2002**



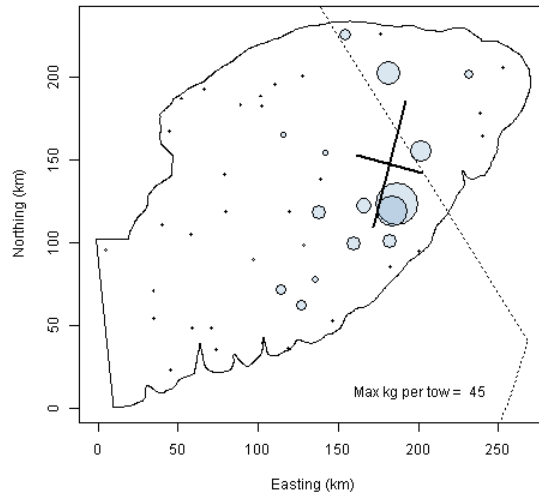
**GB Yellowtail Spring 2003**



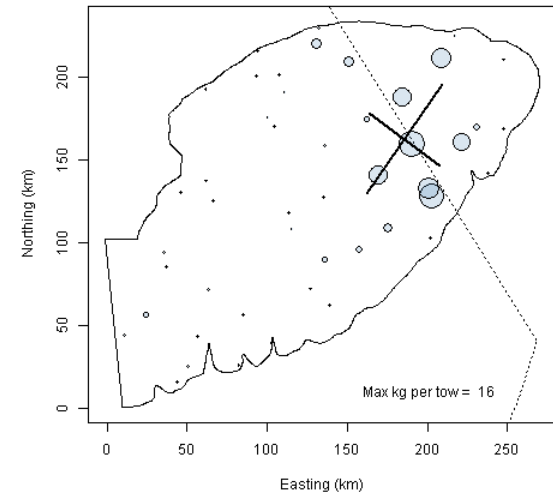
**GB Yellowtail Spring 2004**



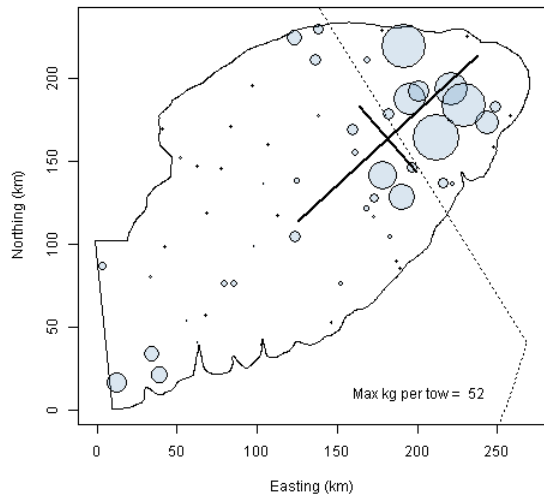
**GB Yellowtail Spring 2005**



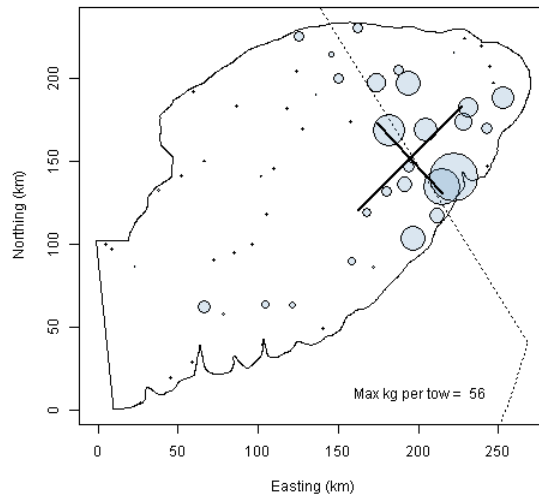
**GB Yellowtail Spring 2006**



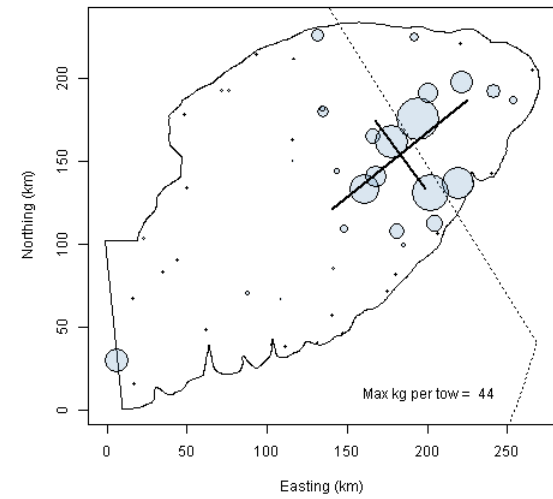
**GB Yellowtail Spring 2007**



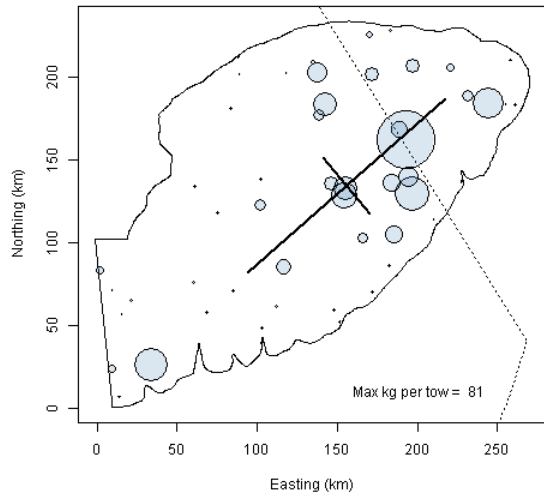
**GB Yellowtail Spring 2008**



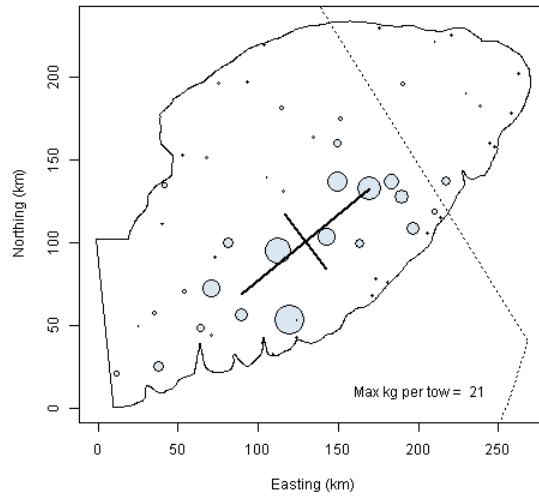
**GB Yellowtail Spring 2009**



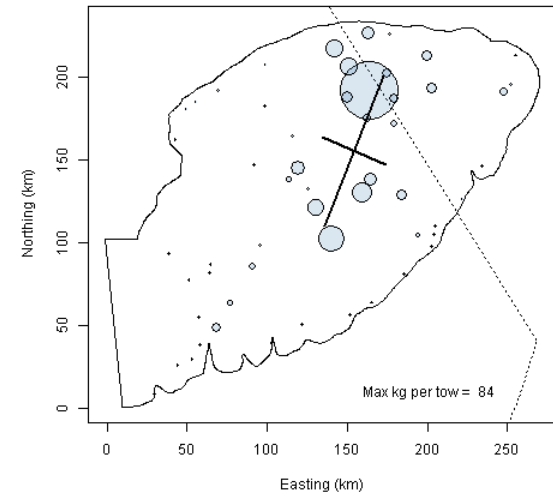
**GB Yellowtail Spring 2010**



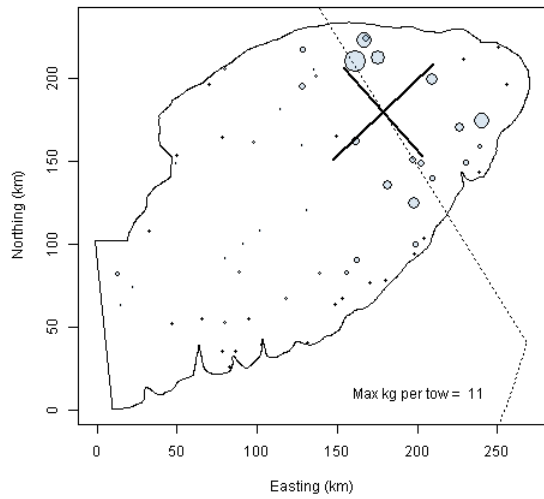
**GB Yellowtail Spring 2011**



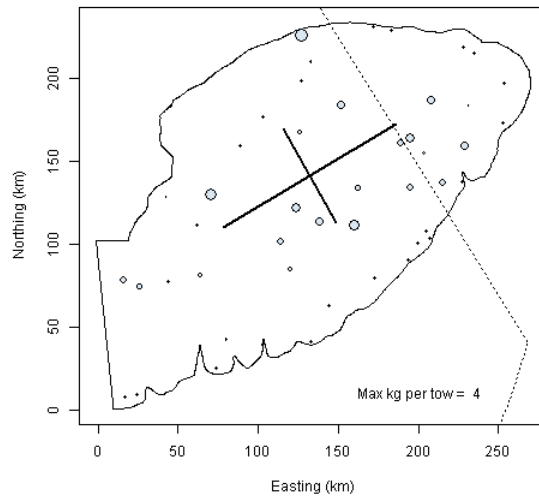
**GB Yellowtail Spring 2012**



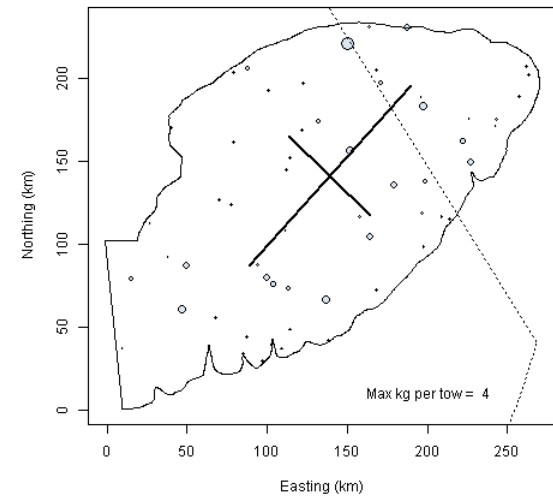
**GB Yellowtail Spring 2013**



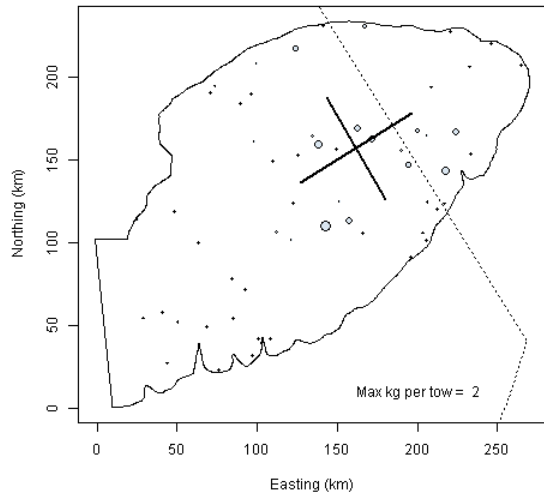
**GB Yellowtail Spring 2014**



**GB Yellowtail Spring 2015**



**GB Yellowtail Spring 2016**



**GB Yellowtail Spring 2017**

