NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX I:

# 2009 TRAC Status Report and Related ABC Documents

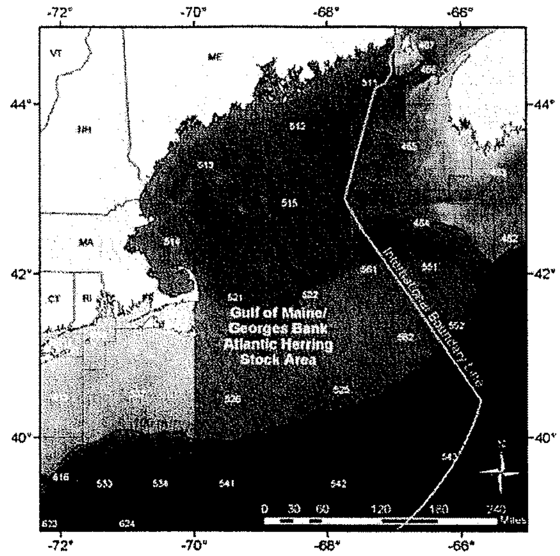
Fisheries and Oceans Canada | Pêches et Océans Canada

NOAA FISHERIES
NATIONAL MARINE FISHERIES SERVICE

**Transboundary Resources Assessment Committee**

**Status Report 2009/04**

# GULF OF MAINE-GEORGES BANK HERRING STOCK COMPLEX





## *Summary*

- Combined Canada and USA herring landings increased from 106,000 mt in 2005 to 116,000 mt in 2006, then declined to 90,000 mt in 2008.

- Stock biomass (2+, January 1) increased steadily from about 111,600 mt in 1982 to almost 830,000 mt in 1997, fluctuated without trend since then, and was estimated to be 652,000 mt at the beginning of 2008. This is below $B_{msy}$ (670,600 mt).

- Recruitment at Age 2 from the 2004 and 2006 year classes appear weaker than the long-term (1967-2005) average of 2.3 billion fish. The 2005 year class abundance estimate is above average abundance at 3.3 billion fish.

- Fishing mortality (Age 2+) declined to 0.14 in 1993 and has remained stable at about 0.16 from 2002 onwards (Figure 1). Estimated fishing mortality in 2008 was 0.14. This is below $F_{msy}$ (0.27).



Ce document est disponible sur l'Internet à : This document is available on the Internet at :
http://www.mar.dfo-mpo.gc.ca/science/TRAC/trac.html

Canada

July 2009
(Revised)

**Landings, 2+ Biomass (thousands mt); Recruits (millions)**

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Avg[1] | Min[1] | Max[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Canada Landed* | 18.6 | 17.1 | 24.8 | 13.4 | 9.0 | 20.6 | 12.6 | 12.9 | 30.9 | 6.4 | 23.1 | 6.4 | 44.1 |
| *USA Landed* | 110.6 | 108.8 | 120.0 | 93.2 | 100.8 | 94.4 | 93.3 | 103.1 | 81.7 | 83.6 | 80.6 | 33.2 | 123.6 |
| *Total Landed* | 129.1 | 125.9 | 144.8 | 106.6 | 109.8 | 115.0 | 105.9 | 116.0 | 112.6 | 90.0 | 103.7 | 44.6 | 144.8 |
| | | | | | | | | | | | | | |
| *2+ Biomass* | 735 | 854 | 790 | 670 | 674 | 711 | 684 | 690 | 697 | 652 | 529 | 112 | 1,294 |
| | | | | | | | | | | | | | |
| *Age 2 Recruits* | 1032 | 3828 | 1033 | 1275 | 2739 | 3775 | 1616 | 1318 | 3252 | 265 | 2268 | 265 | 8758 |
| | | | | | | | | | | | | | |
| *Fishing Mortality* | 0.19 | 0.16 | 0.20 | 0.17 | 0.17 | 0.17 | 0.16 | 0.17 | 0.17 | 0.14 | 0.37 | 0.14 | 0.80 |
| | | | | | | | | | | | | | |
| *Exploitation Rate* | 0.16 | 0.13 | 0.16 | 0.14 | 0.14 | 0.14 | 0.13 | 0.14 | 0.14 | 0.12 | 0.28 | 0.12 | 0.50 |

[1] 1978-2008 for landings (thousands mt)
1967-2008 for 2+ biomass (thousands mt), recruitment (millions) and F(2+)

## *Fishery*

**Combined Canada/USA landings.** Combined Canada/USA landings averaged 90,000 mt during 1978-1994 (Figure 1). Landings increased during 1995-2001, averaging 133,000 mt, and peaking at 145,000 mt in 2001. Landings declined slightly during 2002-2005, and averaged 109,000 mt. During 1978-2005, the USA accounted for about 76% of the total landings, but during the most recent decade, this percentage increased to about 85%.

**Canadian landings.** Landings by Canada averaged about 27,000 mt during 1978-1994, declined to an average of 19,000 mt during 1995-2001, and declined further to 14,000 mt during 2002-2005. Landing from 2006-2008 average 16,800 mt although landings in 2007 peaked at 31,000 mt. Canadian landing have been dominated by the New Brunswick weir fishery.

**USA landings.** Landings by the United States averaged about 62,300 mt during 1978-1994, increased to an average of 103,000 mt during 1995-2001, and declined to an average of 95,000 mt during 2002-2005. Landings since 2005 have averaged 89,000 mt. During 1978-1982, USA landings were about equally split between the weir fisheries and purse seines. During 1983-1992, most USA landings were taken by purse seines but subsequently single mid-water and paired mid-water trawling have dominated the landings, with purse seining accounting for only about 10-15% of the total USA landings during 2000-2005. Since 2005 purse seining has increased while pair and single midwater trawling has decreased with pair trawling accounting for 56%, single midwater trawling 12% and purse seine 26%.

## *Harvest Strategy and Reference Points*

The Atlantic herring 2006 TRAC recommended that a strategy be adopted to maintain a low to neutral risk of exceeding the fishing mortality limit reference point, and that when stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding. A Fox surplus production model estimated $F_{msy} = 0.27$, MSY = 178,374 mt, and $B_{msy}$ = 670,600 mt. Yield per recruit reference points (proxies for $F_{msy}$) were estimated as: $F_{0.1}=0.21$, and $F_{40\%}=0.20$.

## *State of Resource*

The state of the resource was based on results from an age-structured, analytical assessment which used fishery catch statistics and biological samples to characterize the size and age composition of the catches during 1967 to 2008. Even though this was an update assessment, the suite of indices used was re-evaluated. All formulations showed similar trends in stock size but differed in scale. The final formulation was selected, with some difficulty, to balance various data sources and their uncertainty, and was calibrated to trends in abundance from the NMFS spring and fall bottom trawl surveys. In addition, a revised landings at age was applied, as recommended in the benchmark. This resulted in changes to biomass estimates that will be reviewed in more detail at the next benchmark.

Retrospective analyses were used to detect any patterns to overestimate - or underestimate - fishing mortality, biomass and recruitment relative to the terminal year estimates. A significant retrospective pattern was detected in this assessment in overestimating SSB relative to the current estimate (averaging + 42%/year, and ranging between 14-56%) and this is a concern (Figure 2). The pattern has persisted for several years and is expected to continue in the future.

**Stock biomass (2+, January 1)** increased steadily from about 111,600 mt in 1982 to almost 830,000 mt in 1997, fluctuated without trend since then, and was estimated to be 650,700 mt at the beginning of 2008. This is below $B_{msy}$ (670,600 mt). Biomass increases in the late 1990s were due to improved recruitment, especially from two very large year classes, 1994 and 1998 (Figure 3). Weights-at-age in the population declined in the late 1980s but have remained steady since 1995.

**Recruitment** (at Age 2) markedly improved in the late 1980s with several moderate year classes and three large year classes (1994 cohort: 6.3 billion; 1998 cohort: 3.8 billion; and the 2002 cohort: 3.8 billion). Recruitment from the 2004 and 2006 year classes appear weaker than the long-term (1967-2005) average of 2.3 billion fish. The 2005 year class abundance estimate is above average abundance at 3.3 billion fish.

**Fishing mortality (Age 2+)** declined from peak values above 0.7 in the 1970s to an average of 0.4 during the mid-late 1980s (Figure 1). Fishing mortality declined to 0.14 in 1993 and has remained stable at about 0.16 from 2002 onwards (Figure 1). Estimated fishing mortality in 2008 was 0.14. This is below $F_{msy}$ (0.27).

## *Productivity*

Age structure, spatial distribution, and fish growth reflect changes in the productive potential of the stock complex. The **population age structure** shows an increase in abundance of ages 6+ in 1995, remaining relatively constant since then, consistent with lowered exploitation. Increasing abundance of older fish in the landings-at-age and future surveys would help to confirm this pattern. **Spatial distribution** patterns of herring in recent NMFS fall bottom trawl surveys (1998-2008) were similar to patterns observed in the 1960s, prior to the collapse of the offshore stock component. Declines in **weights-at-age** are a factor in limiting increases in the population biomass. On balance, however, the productive potential of the herring stock complex has improved in recent years.

## *Outlook*

An outlook is provided in terms of the consequences on SSB and for landings in 2009, 2010 and 2011 of fishing at the current F=0.14. Additional projections will be run at various Fs as required by management. Although uncertainty in stock size and recruitment generates uncertainty in forecast results, a formal risk analysis was not undertaken due to the significant retrospective pattern in SSB and the difficulty and uncertainty in selecting the final model formulation. Nevertheless, the forecasts are considered useful for general management guidance.

The projections assumed that recruitment of the 2009-2011 year classes was equal to the recent 10-year average (2.0 billion fish at Age 2) (Figures 3 and 4). A fishing mortality of F=0.14 in 2009 generates a landings of 82,403 mt and an SSB in 2009 of 460,343 mt, a decline of about 11%. Continuing to fish at F=0.14 in both 2010 and 2011 produces annual landings of 81,154 mt and 82,625 mt, respectively, and results in a slight decline in SSB in 2011 to 444,532 mt.

| | 2+ Biomass | SSB | Landings | F |
|---|---|---|---|---|
| **2009** | 694.3 | 460.3 | 82.4 | 0.14 |
| **2010** | 683.8 | 440.0 | 81.2 | 0.14 |
| **2011** | 692.2 | 444.5 | 82.6 | 0.14 |

## *Special Considerations*

The 2005 year class dominated landings in 2006 and 2007 at ages 1 and 2 respectively, and landings over the next several years are therefore dependent on the magnitude of the 2005 year class, which still has high uncertainty.

The retrospective pattern in SSB that has persisted in the last several assessments is an issue and will continue to be investigated in the next benchmark. Ignoring the retrospective pattern in biomass could increase the risk of not meeting conservation objectives.

Analysis of predator consumption and mortality, as well as the use of a larval index to estimate SSB, were discussed. It was considered possible to incorporate these into the assessment, and they will be investigated further at the next benchmark.

Ongoing issues with aging will be addressed further to determine the age at which adequate resolution is achieved. Additional otolith exchanges, workshops and development of common protocols are encouraged.

## *Source Documents*

Overholtz, W.J., and J.S. Link. 2007. Consumption Impacts by Marine Mammals, Fish and Seabirds on the Gulf of Maine-Georges Bank Atlantic Herring (*Clupea harengus*) Complex During the Years 1977-2002. ICES Journal of Maine Science, 64:83-96.

Overholtz, W.J., L.D. Jacobson, G.D. Melvin, M. Cieri, M. Power, D. Libby, and K. Clark. 2004. Stock Assessment of the Gulf of Maine-Georges Bank Atlantic Herring Complex, 2003. Northeast Fisheries Science Center Reference Document 04-06, 290 p.

TRAC. 2006. Gulf of Maine-Georges Bank Herring Stock Complex. TRAC Status Report 2006/01.

### *Correct Citation*

TRAC. 2009. Gulf Of Maine-Georges Bank Herring Stock Complex. TRAC Status Report 2009/04.

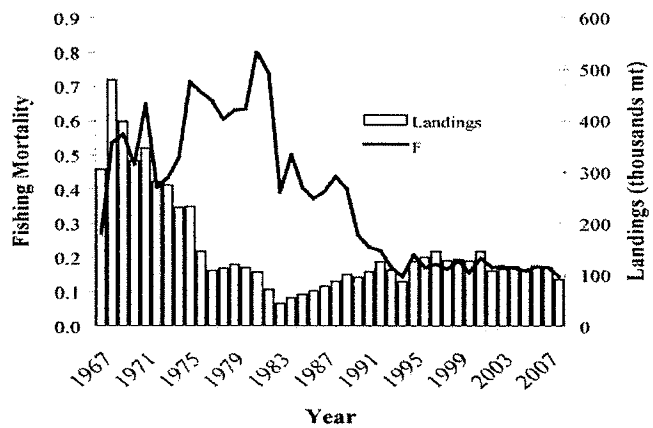



Figure 1. Gulf of Maine/Georges Bank Atlantic herring landings and Age 2+ fishing mortality.

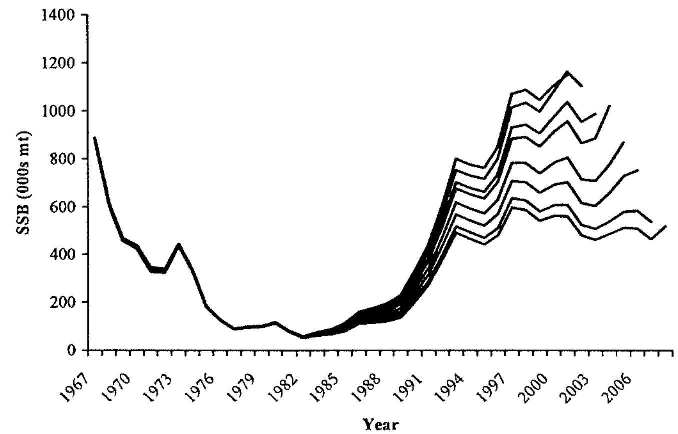



Figure 2. Retrospective pattern of Gulf of Maine/Georges Bank Atlantic herring spawning stock biomass.

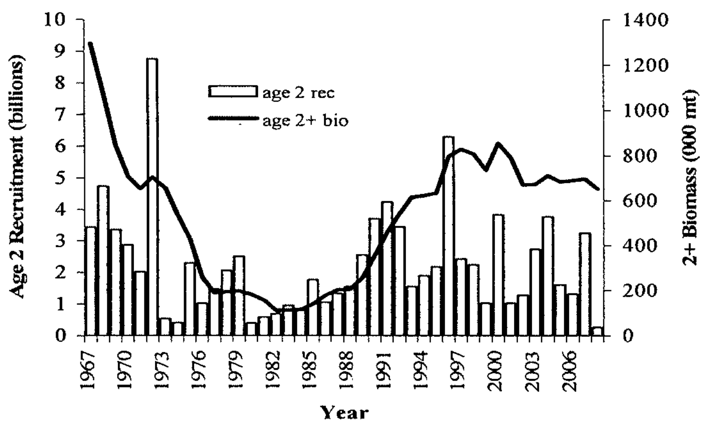



Figure 3. Gulf of Maine/Georges Bank Atlantic herring Age 2+ biomass and Age 2 recruitment.

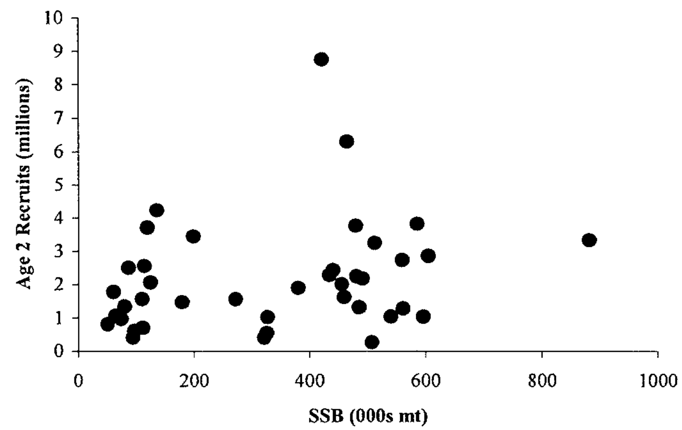



Figure 4. Gulf of Maine/Georges Bank Atlantic herring SSB and Age 2 recruitment.

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# MEMORANDUM

**DATE:** July 28, 2009

**TO:** Scientific and Statistical Committee (SSC) Members

**FROM:** Lori Steele, NEFMC Staff, Herring PDT Chair

**SUBJECT:** **Atlantic Herring Assessment Results and Preliminary Guidance Re. Specification of Allowable Biological Catch (ABC)**

## *Background*

The Transboundary Resource Assessment Committee (TRAC) Atlantic Herring Stock Assessment was conducted in early June 2009 in St. Andrews, New Brunswick, Canada. This assessment served as an update; Atlantic herring for the Gulf of Maine/Georges Bank area were last assessed in a benchmark assessment in May 2006 (O'Boyle and Overholtz 2006). At the 2006 assessment meeting, it was agreed that the Age Structured Assessment Program (ASAP) Base model showed the least retrospective pattern and was the preferred approach amongst all the model formulations. The purpose of the 2009 assessment meeting was to update both independent and dependent data, and use it in the established benchmark formulation to determine the current status of the Atlantic herring resource. The updated assessment model also prompted revision of the biological reference points to reflect the new results.

The TRAC update assessment results estimate that Atlantic herring biomass was 651,700 mt at the beginning of 2008, which is below $B_{MSY}$ (670,600 mt). Estimated fishing mortality in 2008 was 0.14, which is below $F_{MSY}$ (0.27).

The Atlantic herring stock complex is above ½ $B_{MSY}$ and fishing mortality is below $F_{MSY}$, so the stock is not overfished and overfishing is not occurring. The current overfishing definition for Atlantic herring is provided below.

> *If stock biomass is equal or greater than $B_{MSY}$, overfishing occurs when fishing mortality exceeds $F_{MSY}$. If stock biomass is below $B_{MSY}$, overfishing occurs when fishing mortality exceeds the level that has a 50 percent probability to rebuild stock biomass to $B_{MSY}$ in 5 years ($F_{Threshold}$). The stock is in an overfished condition when stock biomass is below ½ $B_{MSY}$ and overfishing occurs when fishing mortality exceeds $F_{Threshold}$. These reference points are thresholds and form the basis for the control rule.*

*The control rule also specifies risk averse fishing mortality targets, accounting for the uncertainty in the estimate of $F_{MSY}$. If stock biomass is equal to or greater than $1/2B_{MSY}$, the target fishing mortality will be the lower level of the 80 percent confidence interval about $F_{MSY}$. When biomass is below $B_{MSY}$, the target fishing mortality will be reduced consistent with the five-year rebuilding schedule used to determine $F_{Threshold}$.*

**Table 1 Current (TRAC 2009) Biomass and Fishing Mortality Status/Reference Points for the Atlantic Herring Stock Complex**

| | BIOMASS | FISHING MORTALITY |
|---|---|---|
| **REFERENCE POINTS**<br>**(MSY = 178,374 mt)** | $B_{MSY}$= 670,600 mt<br>$B_{Threshold}$ = 335,290 mt | $F_{MSY}$ = 0.27<br>$F_{Target}$ = Unknown* |
| **2008 ESTIMATES (TRAC 2009)** | 651,700 mt | 0.14 |

**The methods for calculating reference points in the TRAC assessment do not yield probability distributions, so the 80% confidence interval cannot be calculated.*

Several issues associated with the current overfishing definition for Atlantic herring, which is provided from the original Herring FMP (1999), need attention. The current control rule (with target F) may be inconsistent in light of the new MSRA requirements and associated National Standard Guidelines or have estimation problems (developing confidence limits around $F_{MSY}$). The definition of overfishing is contingent on the relationship of current biomass to $B_{MSY}$. For biomass at or above $B_{MSY}$, overfishing is defined as fishing above $F_{MSY}$. However, when biomass is between ½ $B_{MSY}$ and $B_{MSY}$, overfishing is defined as exceeding the rebuilding F, specified as an F that allows rebuilding within 5 years with 50% probability. Currently, the population does not rebuild to $B_{MSY}$ using long-term projections using $F_{MSY}$ and empirical recruitment model. The inconsistency between the long-term projections (required to develop rebuilding F and time periods and stock determination overfishing criterion when B is below $B_{MSY}$) and the reference points (to define stock status) needs reconciling in order to have a functional control rule.

More importantly, the FMP utilizes target F, defined as the lower bound of the percentile of the confidence limits around $F_{MSY}$. The explicit goal of the Ftarget is to take into account the uncertainty with the $F_{MSY}$ estimate. Two problems with the Ftarget approach are: the current external Fox production model used to define the Fthreshold does not generate 80% confidence limits of the $F_{MSY}$ estimate needed to estimate the Ftarget; and the Ftarget does not explicitly account for other sources of scientific uncertainty such as retrospective pattern in the assessment because confidence intervals are not generated from the model. Without the necessary information, overfishing determinations and target fishing mortality rates cannot be determined. However, given current F (about ½ $F_{MSY}$) and current B (97% of $B_{MSY}$), assuming that overfishing is not occurring is reasonable. An appropriate target F based on the current control rule definition still remains unknown, and whether Ftarget is even necessary under the new approach to specifying an ABC and ABC control rule is unclear. A benchmark stock assessment is needed to resolve the technical issues related to the current overfishing definition, and guidance from the NMFS Regional Office is appropriate regarding the need to specify a target F.

Atlantic herring fishery specifications for the 2007-2009 fishing years are based on the 2006 TRAC assessment results and include a specification of allowable biological catch equivalent to the 2006 MSY value of 194,000 mt (Table 2). Optimum yield for the fishery is currently set at 145,000 mt, and the buffer between MSY and OY accounts for Canadian catch (20,000 mt), the retrospective pattern in the stock assessment, other sources of assessment/scientific uncertainty, and the important role of herring in the Northwest Atlantic ecosystem. The herring fishery specifications for 2010-2012 should be adjusted to ensure compliance with new provisions of the Magnuson-Stevens Reauthorization Act (MSRA) and the National Standard 1 Guidelines published by NOAA Fisheries in January 2009.

**Table 2 Atlantic Herring Fishery Specifications for the 2007-2009 Fishing Years (January 1 – December 31)**

| | 2007 | 2008/2009 |
|---|---|---|
| Allowable Biological Catch (ABC) | 194,000 | 194,000 |
| U.S. Optimum Yield | 145,000 | 145,000 |
| Domestic Annual Harvesting (DAH) | 145,000 | 145,000 |
| Domestic Annual Processing (DAP) | 141,000 | 141,000 |
| Joint Venture Processing Total (JVPt) | 0 | 0 |
| JVP | 0 | 0 |
| Internal Waters Processing (IWP) | 0 | 0 |
| U.S. At-Sea Processing (USAP) | 20,000 (Areas 2 and 3 only) | 20,000 (Areas 2 and 3 only) |
| Border Transfer (BT) | 4,000 | 4,000 |
| Total Allowable Level of Foreign Fishing (TALFF) | 0 | 0 |
| RESERVE | 0 | 0 |
| TAC Area 1A | 50,000 (5,000 Jan-May) | 45,000 (43,650 fishery; 5,000 Jan-May) |
| TAC Area 1B | 10,000 | 10,000 (9,700 fishery) |
| TAC Area 2 | 30,000 | 30,000 (29,100 fishery) |
| TAC Area 3 | 55,000 | 60,000 (58,200 fishery) |
| Research Set-Aside (RSA) | N/A | Area 1A RSA 1,350<br>Area 1B RSA 300<br>Area 2 RSA 900<br>Area 3 RSA 1,800 |

Table 3 provides IVR catches for the 2008 fishing year. Overall, the IVR reports totaled 80,800 mt of herring across all management areas in 2008, which represents about 56% of the OY for the U.S. fishery (145,000 mt) . Consistent with previous years, the majority of the landings were taken from Area 1 (1A and 1B). Part of the reduction in total landings since 2006 is attributable to a 15,000 mt decrease in the TAC for Area 1A. In 2008, the Area 1A fishery closed on November 14, 2008.

Table 4 reports IVR catches to date for the 2009 fishing year (through July 6, 2009). State restrictions (ME, NH, MA) preclude landings from Area 1A until June 1, so the fishery in Area 1A is just beginning, but it is expected that 95% of the 1A TAC will be taken before December 31. There was more activity in the Area 2 winter fishery (Jan-April) in 2009 than 2008, and the majority of the Area 2 TAC has already been taken. It is anticipated that all of the Area 1A quota will be taken during 2009. With the additional catch from Area 2, total 2009 catch is predicted to be about 8,000 mt higher than in 2008.

**Table 3 IVR Herring Catch for 2008 Fishing Year**

| Management Area | IVR Catch (mt) | % of TAC |
|---|---|---|
| Area 1A (Jan 1st – May 31st) | 0 | N/A |
| Area 1A (June 1st – Dec 31st) | 41,640 | N/A |
| Area 1A TOTAL | 41,640 | 92.5% |
| Area 1B | 8,104 | 81% |
| Area 2 | 19,256 | 64.2% |
| Area 3 | 11,800 | 19.7% |
| **Total** | **80,800** | **55.7%** |

**Table 4 2009 IVR Herring Catch (Supplemented with Dealer Data, through July 6, 2009)**

| Management Area | IVR Catch (mt) | % of TAC |
|---|---|---|
| Area 1A (Jan 1st – May 31st) | 0 | N/A |
| Area 1A (June 1st – Dec 31st) | 5,105 | N/A |
| Area 1A TOTAL | 5,105 | 10% |
| Area 1B | 1,589 | 16% |
| Area 2 | 27,087 | 90% |
| Area 3 | 1,296 | 2% |
| **Total** | **35,076** | **24%** |

Amendment 4 to the Atlantic Herring FMP establishes a process for developing annual catch limits (ACLs) and accountability measures (AMs) consistent with the MSRA, including provisions for the SSC to specify an acceptable biological catch (ABC) for the herring fishery. As previously noted, the current overfishing limit for the Atlantic herring fishery is specified as *allowable biological catch*, which is based on the most recent scientifically-accepted estimate of MSY for the stock complex. The current specification of ABC is different from the MSRA's requirement to specify ABC, the *acceptable biological catch*, and changes are proposed in Amendment 4 to reflect the new requirements of the MSRA. The MSRA's interpretation of

ABC includes consideration of biological uncertainty (stock structure, stock mixing, and other stock assessment issues, for example), and recommendations for ABC should come from the SSC.

Several modifications to the specification process are required to bring the Atlantic Herring FMP into compliance with the MSRA, most notably the introduction of new terminology, changes to the ABC specification, the addition of the Council's SSC to the process for setting ABC, and separate consideration of scientific and management uncertainty during the ACL-setting process. Based on the new MSRA requirements, once scientific uncertainty is accounted for and the OFL for Atlantic herring is adjusted accordingly to a level corresponding to *acceptable biological catch* (ABC) based on recommendations from the Council's SSC, an ACL for the stock complex may be established, and the ACL can be divided into TACs or sub-ACLs, which can be specified for each management area. The sub-ACLs (TACs for the management areas) should be set such that the risk of overfishing a stock component is minimized to the extent possible.

### *Overfishing Level*

The overfishing level (OFL) is defined in Amendment 4 as the *catch that results from applying the maximum fishing mortality threshold to a current or projected estimate of stock size.* When the stock is not overfished and overfishing is not occurring, the maximum fishing mortality threshold is $F_{MSY}$ or its proxy. The Atlantic herring stock complex is not overfished, and the current (2009 TRAC) estimate of $F_{MSY}$ is 0.27.

To estimate the 2010 OFL, the Herring PDT applied the 2008 catch to the 2008 biomass estimate for the herring complex to estimate the 2009 starting biomass. The PDT then estimated a fishing mortality rate for 2009 based on the 2008 landings plus an additional 7,800 mt to account for the increased catch in Area 2. The projected F for 2009 is 0.16. Applying 0.16 to the estimated biomass in 2009 yields a projected biomass in 2010. $F_{MSY}$ can then be applied to the 2010 biomass projection to derive an overfishing level ($F_{MSY}$ x B) for 2010. The resulting OFL for 2010 is **143,845 mt** (Table 5).

**Table 5 Projected OFL for 2010**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LANDINGS | (000 mt) | | | | | | | | |
| YEAR | AVG | STD | | | | | | | |
| 2009 | 93.292 | 12.135 | **2009F = 0.16** | | | | | | |
| 2010 | 144.806 | 19.827 | **2010F and 2011F = 0.27** | | | | | | |
| 2011 | 132.512 | 21.913 | | | | | | | |
| | | | | | | | | | |
| PERCENTILES OF LANDINGS | | | (000 MT) | | | | | | |
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2009 | 68.5 | 75.3 | 78.1 | 84.5 | 92.078 | 101.0 | 109.9 | 115.6 | 124.2 |
| 2010 | 104.7 | 114.5 | 119.7 | 130.0 | 143.845 | 158.3 | 171.4 | 178.9 | 193.7 |
| 2011 | 88.7 | 98.3 | 104.0 | 116.0 | 132.019 | 147.3 | 162.2 | 170.3 | 183.7 |

### *Addressing Scientific Uncertainty and Specifying ABC*

Allowable Biological Catch (ABC) is defined in Amendment 4 as the maximum catch that is recommended for harvest, consistent with meeting the biological objectives of the management plan. ABC can equal but never exceed the OFL. While the amendment states that ABC should be based on $F_{MSY}$ or its proxy for the stock if overfishing is not occurring and/or the stock is not in a rebuilding program, the specification of ABC must consider/address scientific uncertainty.

At its September 16, 2009 meeting, the SSC is scheduled to review available information and provide its recommendations regarding the specification of allowable biological catch (ABC) for the 2010-2012 fishing years as well as the ABC control rule. The Herring PDT will provide projections and other information related to the specification of ABC for the Atlantic herring fishery. However, uncertainty related to the recent stock assessment update warrants some initial discussion with the SSC; the Herring PDT is seeking preliminary guidance from the SSC regarding approaches that may be used to account for scientific uncertainty.

The most significant source of uncertainty relates to the **retrospective pattern** that continues to be apparent in the stock assessment and has worsened since the last benchmark (see TRAC Assessment Document). Substantial retrospective patterns persisted in all model variations examined. Generally, fishing mortality estimates behaved better than biomass, biomass estimates averaged + 42%/year, and ranged between 14-56%.

Three primary sources of uncertainty exist within the model applied to the 2009 update: (1) the effects of changing the catch-at-age input; (2) the effects of the model formulation and the variation within the model (input data); and (3) the retrospective pattern. The effects of the estimates of natural mortality are also uncertain. There also appears to be considerable uncertainty regarding the estimation of the biological reference points (BRPs). BRPs for Gulf of Maine/Georges Bank Atlantic herring were calculated using biomass and landing estimates from 1967-2008. The first two years in the time series are highly influential in fitting the Fox surplus production model. Removal of either one or two of these values produce $B_{MSY}$ estimates ranging from 575,700 mt to 707,401 mt. In addition, a 30 year projection of 2008 age 2+ biomass at $F_{MSY}$ (0.27) produces average biomass of 591,000 mt ($\pm$ 1 std dev ranges from 423,100 to 759,400 mt).

While other sources of scientific uncertainty clearly exist, the retrospective pattern is significant enough that the PDT feels that accounting for the retrospective pattern will account for other uncertainty related to the stock assessment. The PDT is seeking preliminary guidance on how to address issues related to the retrospective pattern in the assessment when specifying ABC for 2010-2012.

*Herring PDT Questions*

- Given the scientific uncertainties in this assessment and given time/analysis constraints (documents for the SSC need to be finalized no later than September 3, 2009): What kind(s) of ABC control rule(s) should the Herring PDT evaluate? For example:
    - ABC based on a general approach using a target F (a fraction of $F_{MSY}$ or a percentile of the $F_{MSY}$ estimate)?
    - ABC based on a specified fraction of the OFL?
    - ABC based on a quantitative adjustment (reduction) to account for the retrospective pattern and/or other scientific uncertainty? How could this adjustment be made (direct rho-based adjustment to catch, direct rho-based adjustments to exploitable biomass, rho-adjusted starting number-at-age projections)?
- The herring stock complex is believed to be composed of individual spawning components that mix seasonally in different areas. Considerable uncertainty exists about the mixing rates as well as the exploitation rates on the individual components. This element of scientific uncertainty may play a role when setting the sub-ACLs in order to prevent localized overfishing on the individual spawning components. The stock-wide ABC will be adjusted to a stock-wide ACL (after accounting for management uncertainty), which will be separated into sub-ACLs based on the management areas for the herring fishery. The PDT believes that taking all of the ABC to be taken from one management area is undesirable, as overfishing of a stock subcomponent would likely result. The sub-ACLs are intended to minimize the risk of overfishing on individual stock components while still allowing for full exploitation. In general, should the PDT account for this stock structure uncertainty in setting ABC for a stock complex or should this scientific uncertainty be incorporated in the setting of sub-ACLs (analogous to the previous practice of setting subarea TACs)?

New England Fishery Management Council
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John Pappalardo, *Chairman* | Paul J. Howard, *Executive Director*

# MEMORANDUM

**DATE:** September 8, 2009

**TO:** Scientific and Statistical Committee (SSC) Members

**FROM:** Lori Steele, NEFMC Staff, Herring PDT Chair

**SUBJECT:** **Herring Plan Development Team (PDT) Recommendations for Specifying Atlantic Herring ABC for the 2010-2012 Fishing Years**

- Causes for the retrospective pattern are unknown in the case of Atlantic herring, but general causes can include misspecification of catch, ageing problems, changes in natural mortality (M), changes in survey catchability, differences in fishery selectivity difference among stock components or across time, etc. The range of uncertainty in the retrospective analysis in the final model encompasses the range of uncertainty found in the various model formulations. The Herring PDT concludes that the retrospective adjustment in the projections should provide adequate precaution for these scientific uncertainties.
- The Herring PDT recommends changing the control rule specified in the Herring FMP so that it is more useful and consistent with control rules for other stocks. The proposed modification to the control rule provides a more appropriate approach that recognizes natural variability associated with maintaining a stock at $B_{MSY}$ (see Herring PDT memo: *Atlantic Herring Overfishing Definition – Proposed Modification to Control Rule*).
- Because stock biomass is estimated from the TRAC assessment to be at 97% of $B_{MSY}$ and given the recommended changed to the control rule, the Herring PDT recommends basing overfishing level (OFL) for herring on $F_{MSY}$ for 2010-2012 and applying a retrospective adjustment to the terminal year stock size in order to derive acceptable biological catch (ABC) and account for scientific uncertainty (see Herring PDT Discussion Paper *Projected Landings and Stock Biomass Under Different Fishing Mortality Scenarios for Atlantic Herring*).

**Herring PDT Recommendations for OFL and ABC 2010-2012**

| YEAR | OFL ('000 mt) | ABC ('000 mt) |
|---|---|---|
| 2010 | 144.996 | 92.135 |
| 2011 | 134.493 | 97.690 |
| 2012 | 126.966 | 102.943 |

*OFL is based on $F_{MSY}$ applied to stock biomass projected from the assessment.*
*Projections of ABC incorporate a retrospective adjustment from the AGEPRO projection model.*

- The Atlantic herring stock is a complex composed of several spawning components, which mix at different rates during the year. Annual catch limits (ACLs) will be set for four management areas (1A, 1B, 2, and 3). The risk of these ACLs to the inshore component of the stock will be analyzed by the PDT during the ACL setting process.

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# MEMORANDUM

**DATE:** September 9, 2009

**TO:** Steve Cadrin, Chairman, Scientific and Statistical Committee (SSC)

**FROM:** John Pappalardo, Chairman, NEFMC

**SUBJECT:** **Herring Committee Questions for SSC Consideration**

The Herring Committee met on August 6, 2009 to review and discuss the recent results of the Transboundary Resource Assessment Committee (TRAC) update assessment for the Atlantic herring stock complex. Following a thorough discussion of the TRAC results, the Herring Committee generated the following questions regarding the assessment for the Scientific and Statistical Committee (SSC) to consider at its September 16, 2009 meeting and/or during the SSC report at the upcoming Council meeting. The Herring Committee's discussion centered on the prominent retrospective pattern present in the TRAC assessment, and how to interpret the assessment from data with high margins of error and uncertainty.

1. Can the SSC reconcile its guidance to the Herring PDT about accounting for the retrospective pattern in setting the ABC with the recommendation of the Retrospective Working Group in January 2008 that a strong retrospective pattern is grounds to reject the assessment model as an indication of stock status or the basis for management advice? If the assessment is to be used to form the basis of management advice, is it robust enough for a three-year TAC setting process?
2. Is it appropriate to use the age-structured ASAP model when considering the significant disagreement between the three primary labs that age herring?
3. Since the stock is not considered to be overfished and overfishing is not occurring, what value of F would be appropriate to use in 2010?
4. Would it be appropriate to use the TRAC assessment results with a higher M to address previous recommendations, and if so what would be the implications of a higher mortality rate, and would there be an effect on those reference points?
5. Given that the herring resource is composed of smaller spawning components and the mixing ratios and migratory patterns remain somewhat uncertain, how does the Committee prevent double counting scientific uncertainty?

6. What is the impact of the uncertainty related to the 2005 year class? What was the impact of the Canadian catch of the 2005 year class on stock abundance? Would the assessment be improved by adding age 1 fish caught in both the New Brunswick weir fishery and the U.S. fishery?
7. The reasons for eliminating the winter survey from the assessment model appear unclear. Does the SSC agree with the elimination of the winter survey from the updated assessment?

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John Pappalardo, *Chairman* | Paul J. Howard, *Executive Director*

**To:** Paul J. Howard, Executive Director
**From:** Dr. Steve Cadrin, Chairman, Scientific and Statistical Committee
**Date:** September 23, 2009

**Subject:** **Acceptable Biological Catch (ABC) value for the Gulf of Maine / Georges Bank Atlantic herring complex**

The Scientific and Statistical Committee (SSC) was asked to review the available information provided by the Herring Plan Development Team (PDT) and develop recommendations regarding the specification of acceptable biological catch (ABC) for the 2010-2012 fishing years, as well as an ABC control rule. On August 11 and September 16 2009, the SSC reviewed several sources of information and associated presentations by the Herring Plan Development Team (PDT):

1. 2006 TRAC Benchmark Assessment Proceedings
2. 2006 TRAC Benchmark Assessment Status Report
3. 2009 Herring TRAC Update Assessment Document
4. 2009 Herring TRAC Update Assessment Status Report
5. July 28, 2009 Memo from Herring PDT: Atlantic Herring Assessment Results and Preliminary Guidance Re. Specification of Allowable Biological Catch (ABC)
6. Herring PDT Discussion Paper: Projected Landings and Stock Biomass Under Different Fishing Mortality Scenarios for Atlantic Herring
7. Herring PDT Memo: Atlantic Herring Overfishing Definition – Proposed Modification to Control Rule
8. Herring PDT Memo: PDT Recommendations for Specifying Atlantic Herring ABC for the 2010-2012 Fishing Years
9. Report of the Retrospective Working Group (NEFSC Reference Document 09-01)

The SSC endorses the 2009 stock assessment produced by the Transboundary Resources Assessment Committee (TRAC) as a basis for projection, derivation of overfishing limit (OFL) and Acceptable Biological Catch (ABC) but recognizes considerable uncertainty in the assessment. Two aspects of the uncertainty in the assessment influence the derivation of OFL and ABC: 1) The assessment has a strong 'retrospective pattern' in which estimates of stock size are sequentially revised downward as new data are added to the assessment; and 2) Maximum sustainable yield reference points estimated from the biomass dynamics model are inconsistent with the age-based, stochastic projection; such that fishing at the current estimate of $F_{MSY}$ is expected to maintain equilibrium biomass that is less than the current estimate of $B_{MSY}$. Given the magnitude of uncertainty in the herring assessment and reference points, an ABC control rule cannot be derived at this time, and the SSC recommends a new benchmark assessment of herring as soon as possible. The SSC suggests that the next benchmark assessment should revise MSY reference points to be consistent with the assessment method and consider including estimates of consumption and spatial structure in the assessment.

The SSC requires further clarification of the PDT's proposed revision to the overfishing definition before it can recommend a revision to the Council. Therefore, the SSC based its OFL calculation on the existing overfishing definition (The maximum fishing mortality threshold is $F_{MSY}$ when stock size is greater than $B_{MSY}$, and the fishing mortality that allows rebuilding in five years when biomass is less than $B_{MSY}$). The 2008 estimate of biomass is substantially greater than the biomass expected from long-term stochastic projection at $F_{MSY}$. Accordingly, the SSC's calculation of OFL is based on $F_{MSY}$ projections.

Given the substantial uncertainty in the assessment, the SSC based its ABC recommendation on two general approaches that produce consistent catch advice: 1) uncertainty in OFL and 2) a magnitude of removals that appears to sustain a relatively abundant stock. National Standard 1 Guidelines suggest that ABC should be less than OFL, and that the 'buffer' between OFL and ABC should account for scientific uncertainty. The average retrospective inconsistency in the estimate of exploitable biomass is approximately 40%, and according to the 2009 TRAC, "uncertainty due to model configuration is dwarfed by uncertainty due to retrospective bias." Therefore, the SSC considers that the magnitude of retrospective inconsistency accounts for the major sources of uncertainty in the assessment, and the buffer between OFL and ABC should be 40% (approximately 90,000 mt in 2010). Alternatively, the stock assessment suggests that recent catches have maintained a relatively abundant stock size (estimates of stock biomass from 1998 to 2008 have been greater than $B_{MSY}$) and low fishing mortality (estimates 1998 to 2008 fishing mortality have been less than $F_{MSY}$). Total catch of the Gulf of Maine / Georges Bank herring complex by U.S. and Canada in 2008 was 90,000 mt. Given the consistency in catch advice from these two approaches, the SSC's recommendation is that ABC should be 90,000 mt each year until the stock assessment is revised.

**The SSC recommends that:**

1. **The Overfishing Limit (OFL) is 145,000 mt in 2010, 134,000 mt in 2011 and 127,000 mt in 2012 based on projections of fishing at the current estimate of $F_{MSY}$.**
2. **Acceptable Biological Catch (ABC) is 90,000 mt each year for 2010 to 2012.**
3. **Catch recommendations include combined U.S. and Canadian catch of the Gulf of Maine / Georges Bank Atlantic herring complex.**
4. **A new benchmark assessment should be scheduled as soon as possible to address sources of uncertainty, re-estimate MSY reference points and consider including estimates of consumption and spatial structure in the assessment.**

# Commonwealth of Massachusetts

## Division of Marine Fisheries

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**Paul J. Diodati**
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*Secretary*
**Mary B. Griffin**
*Commissioner*


October 5, 2009

Mr. John Pappalardo, Chairman
New England Fishery Management Council
50 Water St.
Newburyport, MA 01950

Dear John:

The Council and ASMFC are being challenged and tested by the absence of a benchmark assessment for sea herring, the 2010-2012 specification process, and our self-imposed drastic reduction in the sea herring quota(s) as a consequence of our apparent belief that a SSC-recommended ABC and Council ACLs must be set beginning next year. At the Council's request and with PDT involvement, we asked the SSC for 2010-12 specification recommendations, and it responded with annual ABCs of 90,000 mt (OFL reduced by 40% in 2010). The SSC noted that total catch of the Gulf of Maine/Georges Bank complex by the U.S. and Canada was 90,000 mt in 2008.

As a result, we all find ourselves in a surreal situation: sea herring is not overfished and overfishing is not occurring yet we will dramatically reduce herring catch next year. In fact, according to the SSC, recent catches have maintained a relatively abundant stock size (estimates of stock biomass from 1998 to 2008 have been greater than $B_{MSY}$) and low fishing mortality (estimates 1998 to 2008 fishing mortality have been less than $F_{MSY}$).

On further reflection about the seriousness of this situation, i.e., (1) a very large decrease in area quotas especially for 2010 in Area 1A (42,000 mt decrease to perhaps 10,000 mt, or thereabouts), (2) a resulting dramatic shortage of bait for the lobster fishery, and (3) Canada having no restrictions on its GOM New Brunswick fishery (e.g., 30,145 mt in 2007) and no need/requirement to cut its catch in 2010 (or any year), it occurred to me that we do not have to set an ABC for 2010. We are not overfishing, and that conclusion is indisputable. The SSC has confirmed this all-important fact and has noted the previous years' long-term stability of the resource and fishery.

I suggest that the Council does not have to set an annual catch limit (ACL) for 2010 because overfishing is not occurring and has not occurred for many years. My argument is supported by NS #1 guidelines regarding Council actions to address overfishing and rebuilding for stocks and stock complexes in the fishery. If overfishing is occurring then ACLs and AM mechanisms must be established in 2010. If not, then ACLs and AMs are to be established in 2011.

Furthermore, ABC can equal OFL. In the Guidelines it states: "...NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year..." With a 2010 ABC of 145,000 mt corresponding to catch at $F_{msy}$ and our expecting that catch still will be at or near status quo of 90,000 mt in 2010, $F_{msy}$ will not be exceeded.

Consequently, I suggest the specification for 2010 can be status quo at 145,000 mt. The 2009 ABC was 194,000 mt reduced to 145,000 mt (OY). To do otherwise will force the Council and the ASMFC Sea Herring Section to set the ABC at 90,000 mt (40% reduction from 145,000 mt) resulting in a one-year drastic decrease in ABC from 194,000 mt in 2009 to 90,000 mt in 2010 – a 54% decrease. This will occur even though stock biomass is just below $B_{msy}$ (652,000 mt versus 670,600 mt).

I understand a benchmark assessment may occur in 2011. Ideally, we would wait until then to adjust the ABC. However, it appears we are required to adopt the SSC's ABC values for 2011 and 2012 that are the OFLs reduced by 40% to account for scientific uncertainty. Even though I believe that adjustment is too high and recent years' retrospective difference (about 15%) should be used instead of the 40% (average) and we await the SSC to revisit this issue (Council vote), for now it appears the 90,000 ABC will be required for 2011 and 2012. These ABCs may have to be adjusted up or down to account for benchmark assessment findings.

I end by emphasizing our need to be sensitive to stock status. We all should be heartened by the SSC acceptance of TRAC findings, i.e., "recent catches have maintained a relatively abundant stock size (estimates of stock biomass from 1998 to 2008 have been greater than $B_{MSY}$) and low fishing mortality (estimates 1998 to 2008 fishing mortality have been less than $F_{MSY}$). Those conclusions justify waiting until 2011 before implementing the SSC's ABCs, unless of course the SSC after revisiting the extent to which the OFL should be reduced, provides a different recommendation.

Sincerely yours,

David E. Pierce, Ph.D.

cc
Paul Diodati
Paul Howard

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX II:

# Simulating Removals of the Inshore Component for the Herring Fishery for Years 1999-2008 Using the Herring PDT's Risk Assessment Methodology

# Simulating Removals of the Inshore Component for the Herring Fishery for Years 1999-2008 Using the Herring PDT's Risk Assessment Methodology

Steven Correia
Massachusetts Division of Marine Fisheries
September 24, 2009

**Introduction**

Atlantic sea herring complex is assessed as a combined Gulf of Maine and Nantucket shoals/Georges Bank unit stock. The inshore Gulf of Maine and offshore Georges Bank stock are segregated during spawning season, but mix during feeding and movement during the year. During the 2006 TRAC assessment three approaches (commercial acoustic survey biomass estimates, NEFSC autumn survey swept biomass ratios, and morphometric) were used to estimate the proportions by spawning component (Table 1). TRAC 2006 concluded that each method was "equally valid and that the overall average be based on the unweighted average of each estimate. The mean of the three estimates is 17.667%.

Table 1. Inshore component as a percentage of total stock by three methods.

| Method | Inshore component as percentage of total biomass |
|---|---|
| Acoustic Survey (biomass) | 10% |
| Morphometrics (numbers) | 13% |
| NEFSC area swept biomass | 30% |

We applied the PDT's risk assessment simulation to historical landings by management age for 1999-2008 to assess removals from the inshore component of the stock.

**Methodology and model inputs**

The PDT's risk analysis uses Monte Carlo simulation to assess the amount of inshore removals, the ratio of inshore removals to inshore biomass and the size of the inshore biomass given uncertainty in the size of the inshore component and the monthly landings by management area. Model inputs include landings by month within each management area. The mixing percentages given as inshore biomass as a percentage of total stock by month and area is shown in Table 2. The pop mixing rate was randomly drawn from a triangular distribution with the minimum set to 0.10, maximum set to 0.30, and the mode set to 0.13. This gives an average percentage of 0.17667 and a median percentage of 0.13. The summer mixing rate was drawn from a uniform distribution with minimum value set at 0.2 and maximum value set at 0.8. This gives a mean and median summer mixing percentage at 0.5.

**Table 2. Mixing percentages (inshore component as percent of total) by month and area.**

| Month | Area 1A | Area 1B | Area 2 | Area 3 |
|---|---|---|---|---|
| January | 100% | Pop mixing | Pop mixing | 0% |
| February | 100% | Pop mixing | Pop mixing | 0% |
| March | 100% | Pop mixing | Pop mixing | 0% |
| April | Summer mix | Pop mixing | 0% | 0% |
| May | Summer mix | Pop mixing | 0% | 0% |
| June | Summer mix | Pop mixing | 0% | 0% |
| July | Summer mix | Pop mixing | 0% | 0% |
| August | 100% | Pop mixing | Pop mixing | 0% |
| September | 100% | Pop mixing | Pop mixing | 0% |
| October | 100% | Pop mixing | Pop mixing | 0% |
| November | 100% | Pop mixing | Pop mixing | 0% |
| December | 100% | Pop mixing | Pop mixing | 0% |
| | | | | |

Year specific total stock biomass (1999-2008) was taken from the 2009 TRAC assessments. The inshore biomass was simulated by applying the population mixing rate value to the total stock biomass.

The risk analysis model also uses monthly landings by management area as a proportion of total landings by management area as an input. Uncertainty is simulated by drawing monthly proportions for each management area from a multinomial distribution. Effective sample size is an input parameter and controls the amount of uncertainty in the monthly proportions. We used year specific observed landings by management area and set the effective sample size to 10,000 so that the distribution of simulated landings by month and area match the observed landings for 1999-2008.

Canadian age 2+ landings are simulated using a random draw from the 1995-2008 time series. In the historical comparisons runs, year specific Canadian landings were used in the simulation and Canadian landings are assumed to be from entirely from the inshore component.

For each simulation, a single value of the population mixing rate is randomly drawn from the triangular distribution and a single value of the summer mixing rate is randomly drawn from the uniform distribution. These mixing rates were applied to landings taken from month-area combination shown in Table 2 to apportion the landings to the inshore and offshore components of the stock. The population mixing rate is also applied to the January 1 2+ stock biomass to provide an estimate of the inshore biomass. A ratio of inshore landings over total January 1 inshore biomass was calculation.

Each year consisted of 5,000 simulations.

**Catch curve analysis**

Total mortality (Z) was estimated on an catch at age developed from catches taken when the inshore component was on the spawning grounds using catch curve analysis. Details are provided in Correia and Cierri (2009). $\text{Log}_e$ catch in number was modeled as a regression of age and cohort (with separate slopes and intercepts for each cohort). Exploratory analysis suggested that ages 6-9 were "fully-selected" and these were the ages selected for the analysis. Note that knife-edge selectivity is set at age 2 in the TRAC assessment.

$\text{Log}_e$ catch (000's) was modeled as multiple regression using cohort and area as factors and age (6-9) as a covariate. Initial models included first and second order interactions. Reference levels was the 1991 cohort in GOM. Stepwise regression using AIC suggested including all interaction. An analysis of variance suggested a simpler model with cohort and age plus an age:cohort interaction. Residual patterns indicated that this model tended to overestimate catch at age 6 and 9 and underestimate catch at ages 7 and 8. Given the improvement in diagnostics and the AIC values, a full model was used. Slopes represent estimates of –Z. F was estimated by subtracting M (0.2) from the absolute value of the slope. For each year, an annual F was estimated using a catch-weighted average of cohort F within each year. These annual F's were converted to exploitation rates using Ricker's formula for a type 2 fishery.

For comparative purposes, catch curve analysis was applied to the total catch at age used in the assessment. Here we used ages 2-5 in the regression. In some years, age 2 appeared to be partially recruited. The final selected model estimated a slope and intercept for each cohort.

**Results**

Summary statistics of inshore biomass, catch from the inshore component and the ratio of inshore catch to inshore biomass, and size of the inshore biomass by year are shown in Table 3. Density plots of the distributions of inshore biomass, ratio inshore landings/inshore biomass and inshore landings are shown in Figures 1-3, respectively.

The simulations indicate that the mean inshore removals peaked at 75,900 tons in 1999 (Table 3), fluctuated around 56,500 tons from 2000-2007, and declined to 42,100 in 2008. The ratio of inshore landings to inshore biomass shows a similar trend with a peak of 0.62 in 1999, fluctuations around 0.47 from 2000-2007 and a decline to 0.39 in 2008. For 1999, approximately 1% of the landings over inshore biomass ratio exceeded 1. This is caused by the combination of a large amount of landings taken out of area 1A, drawing a low value for the inshore biomass (e.g., near 10%) , and drawing a high value for the summer mix (e.g., 80%). From 2006-2007, $F_{msy}$ =0.31, equivalent to an exploitation rate of 0.24 (based on catch in number). The ratio of inshore catch to January 1 inshore biomass can be considered as proxy for the exploitation rate because all ages are fully selected by the fishery. The ratio of catch biomass over January 1 biomass from the assessment is compared with the exploitation rate calculated from the fully recruited F is shown in Table 4. The ratio of inshore catch over inshore biomass deviates from the exploitation rate by not accounting for biomass growth during the year (i.e., the exploitation rate should be calculated as catch biomass over mean biomass, rather than catch in number over January 1 abundance). For 2006-2007, the lower quartile of catch over inshore biomass is higher than 0.24, suggesting that removals on the inshore stock may be result in localized exploitation rates higher than with $F_{msy}$.

Catch curve analysis from catch at age developed from the inshore stock during spawning results in annual catch weighted F that ranged from 1.21 to 0.67. The F and exploitation rate from the cohort analysis is compared with the ratio of inshore catch to inshore biomass in Table 4. Overall, the exploitation rates derived via the catch curve are similar in magnitude to the catch over inshore biomass ratios from the simulations. Although there is not a lot of contrast in the exploitation rates, the highest and lowest exploitation occur in the same year for both methods. The ratio of catch biomass over January 1 biomass from the assessment is compared with the exploitation rate calculated from the fully recruited F in Table 6. These values are similar in magnitude, with the catch curve giving lower values than the assessment. This difference between assessment F and catch curve F is likely related to age 2 appearing to be partially selected relative to older ages used in the catch curve analysis, whereas it is considered fully recruited in the assessment.

**Conclusions**

Comparison of relative exploitation rates (Inshore Catch/ Inshore Biomass) derived from the Monte Carlo simulations are similar in magnitude to exploitation rates derived from catch curve analysis of the inshore spawning catch at age matrix derived under a set of assumptions independent of assumptions used in the Monte Carlo simulations. These results suggest that this simulation tool can be used to compare the removals from the inshore component from various TAC allocation to management areas.

Results from applying the simulation tool to herring catches by management area from 1999 through 2008 suggest that removals from the inshore component have been consistently higher than the exploitation rate associated with current $F_{MSY}$ estimate for the entire stock. Differences in productivity among the individual subcomponents of the stock complex are not known and reference points (and therefore status determination criteria) are only available for the stock complex. Therefore, the OFL catch to total biomass ratio should be taken as an approximate target rather than a hard threshold.

**Table 3. Summary statistics for inshore landings, landings over inshore biomass, and inshore biomass based on 5,000 simulations. CV is the coefficient of variation for the distribution.**

Landings (000's tons)

| year | Minimum | 1st Quartile | Median | Mean | 3rd Quartile | Maximum | Standard deviation | CV |
|---|---|---|---|---|---|---|---|---|
| 1999 | 56.0 | 70.3 | 75.9 | 75.9 | 81.5 | 95.6 | 7.75 | 10.2 |
| 2000 | 38.2 | 52.3 | 58.0 | 58.0 | 63.5 | 77.9 | 7.75 | 13.4 |
| 2001 | 35.6 | 49.2 | 54.4 | 54.4 | 59.6 | 73.3 | 7.37 | 13.5 |
| 2002 | 41.5 | 51.2 | 55.2 | 55.3 | 59.3 | 69.5 | 5.60 | 10.1 |
| 2003 | 45.7 | 53.4 | 56.6 | 56.7 | 59.9 | 68.2 | 4.39 | 7.7 |
| 2004 | 40.9 | 54.2 | 59.6 | 59.6 | 65.1 | 78.6 | 7.51 | 12.6 |
| 2005 | 44.6 | 54.1 | 57.9 | 57.9 | 61.8 | 70.9 | 5.33 | 9.2 |
| 2006 | 39.2 | 50.1 | 54.5 | 54.6 | 59.0 | 69.3 | 5.79 | 10.6 |
| 2007 | 35.5 | 48.4 | 56.0 | 55.9 | 63.4 | 75.9 | 9.22 | 16.5 |
| 2008 | 33.7 | 39.8 | 42.1 | 42.1 | 44.4 | 51.0 | 3.19 | 7.6 |

Landings over inshore biomass

| year | Minimum | 1st Quartile | Median | Mean | 3rd Quartile | Maximum | Standard deviation | CV |
|---|---|---|---|---|---|---|---|---|
| 1999 | 0.30 | 0.50 | 0.61 | 0.62 | 0.73 | 1.14 | 0.16 | 25.3 |
| 2000 | 0.18 | 0.33 | 0.40 | 0.41 | 0.48 | 0.83 | 0.11 | 25.8 |
| 2001 | 0.19 | 0.33 | 0.40 | 0.41 | 0.49 | 0.82 | 0.11 | 26.3 |
| 2002 | 0.23 | 0.39 | 0.48 | 0.49 | 0.58 | 0.90 | 0.12 | 25.3 |
| 2003 | 0.25 | 0.41 | 0.50 | 0.51 | 0.60 | 0.89 | 0.13 | 24.7 |
| 2004 | 0.23 | 0.40 | 0.49 | 0.51 | 0.60 | 0.97 | 0.13 | 26.1 |
| 2005 | 0.25 | 0.41 | 0.50 | 0.51 | 0.60 | 0.96 | 0.13 | 24.7 |
| 2006 | 0.24 | 0.38 | 0.46 | 0.47 | 0.56 | 0.89 | 0.12 | 25.0 |
| 2007 | 0.21 | 0.38 | 0.47 | 0.48 | 0.57 | 0.97 | 0.13 | 27.9 |
| 2008 | 0.21 | 0.31 | 0.38 | 0.39 | 0.45 | 0.66 | 0.09 | 22.9 |

(Jan 1) 2+ inshore biomass (000's tons)

| year | Minimum | 1st Quartile | Median | Mean | 3rd Quartile | Maximum | Standard deviation | CV |
|---|---|---|---|---|---|---|---|---|
| 1999 | 73.8 | 103.0 | 124.8 | 129.9 | 152.6 | 219.7 | 32.9 | 25.3 |
| 2000 | 85.8 | 119.7 | 144.5 | 150.4 | 176.3 | 253.9 | 37.5 | 24.9 |
| 2001 | 80.2 | 110.9 | 134.1 | 139.2 | 163.9 | 235.9 | 34.5 | 24.8 |
| 2002 | 67.7 | 94.6 | 114.2 | 118.7 | 139.3 | 199.3 | 29.3 | 24.6 |
| 2003 | 67.5 | 94.1 | 113.2 | 118.5 | 140.0 | 200.4 | 29.9 | 25.3 |
| 2004 | 71.9 | 99.9 | 120.1 | 124.8 | 145.8 | 212.1 | 30.6 | 24.5 |
| 2005 | 68.6 | 95.8 | 114.9 | 120.5 | 141.6 | 202.3 | 30.0 | 24.9 |
| 2006 | 69.6 | 96.9 | 117.2 | 122.0 | 143.7 | 205.8 | 30.3 | 24.8 |
| 2007 | 70.6 | 96.9 | 117.7 | 122.5 | 143.8 | 205.7 | 30.8 | 25.1 |
| 2008 | 65.6 | 91.1 | 111.3 | 115.4 | 136.0 | 194.3 | 29.1 | 25.2 |

Table 4. Comparison of the ratio of catch biomass over January biomass from stock assessment with exploitation rate calculated from assessment F.

| Year | Assessment catch biomass over January 1 biomass | Exploitation rate based on assessment fully recruited F |
|---|---|---|
| 1999 | 0.18 | 0.16 |
| 2000 | 0.15 | 0.13 |
| 2001 | 0.18 | 0.16 |
| 2002 | 0.16 | 0.14 |
| 2003 | 0.16 | 0.14 |
| 2004 | 0.16 | 0.14 |
| 2005 | 0.16 | 0.13 |
| 2006 | 0.16 | 0.14 |
| 2007 | 0.16 | 0.14 |
| 2008 | 0.14 | 0.12 |

Table 5. Comparison of annual catch weighted F from catch curve analysis of inshore spawning component, exploitation rate and the ratio of inshore catch to inshore biomass.

| year | Catch Curve F | exploitation rate from catch curve F | Simulated ratio inshore catch to inshore biomass |
|---|---|---|---|
| 1999 | 1.21 | 0.65 | 0.62 |
| 2000 | 1.11 | 0.62 | 0.41 |
| 2001 | 0.77 | 0.49 | 0.41 |
| 2002 | 0.75 | 0.48 | 0.49 |
| 2003 | 0.67 | 0.45 | 0.51 |
| 2004 | 0.68 | 0.45 | 0.51 |
| 2005 | 0.66 | 0.44 | 0.51 |
| 2006 | 0.67 | 0.45 | 0.47 |
| 2007 | 0.66 | 0.44 | 0.48 |
| 2008 | 0.67 | 0.45 | 0.39 |

Table 6. Comparison of annual catch weighted F from catch curve analysis on entire stock catch at age and fully recruited F from the assessment.

| year | cohort weighted | F from assessment |
|---|---|---|
| 1992 | 0.20 | 0.22 |
| 1993 | 0.17 | 0.17 |
| 1994 | 0.15 | 0.14 |
| 1995 | 0.11 | 0.21 |
| 1996 | 0.10 | 0.17 |
| 1997 | 0.10 | 0.18 |
| 1998 | 0.10 | 0.17 |
| 1999 | 0.10 | 0.19 |
| 2000 | 0.10 | 0.16 |
| 2001 | 0.09 | 0.20 |
| 2002 | 0.09 | 0.17 |
| 2003 | 0.09 | 0.17 |

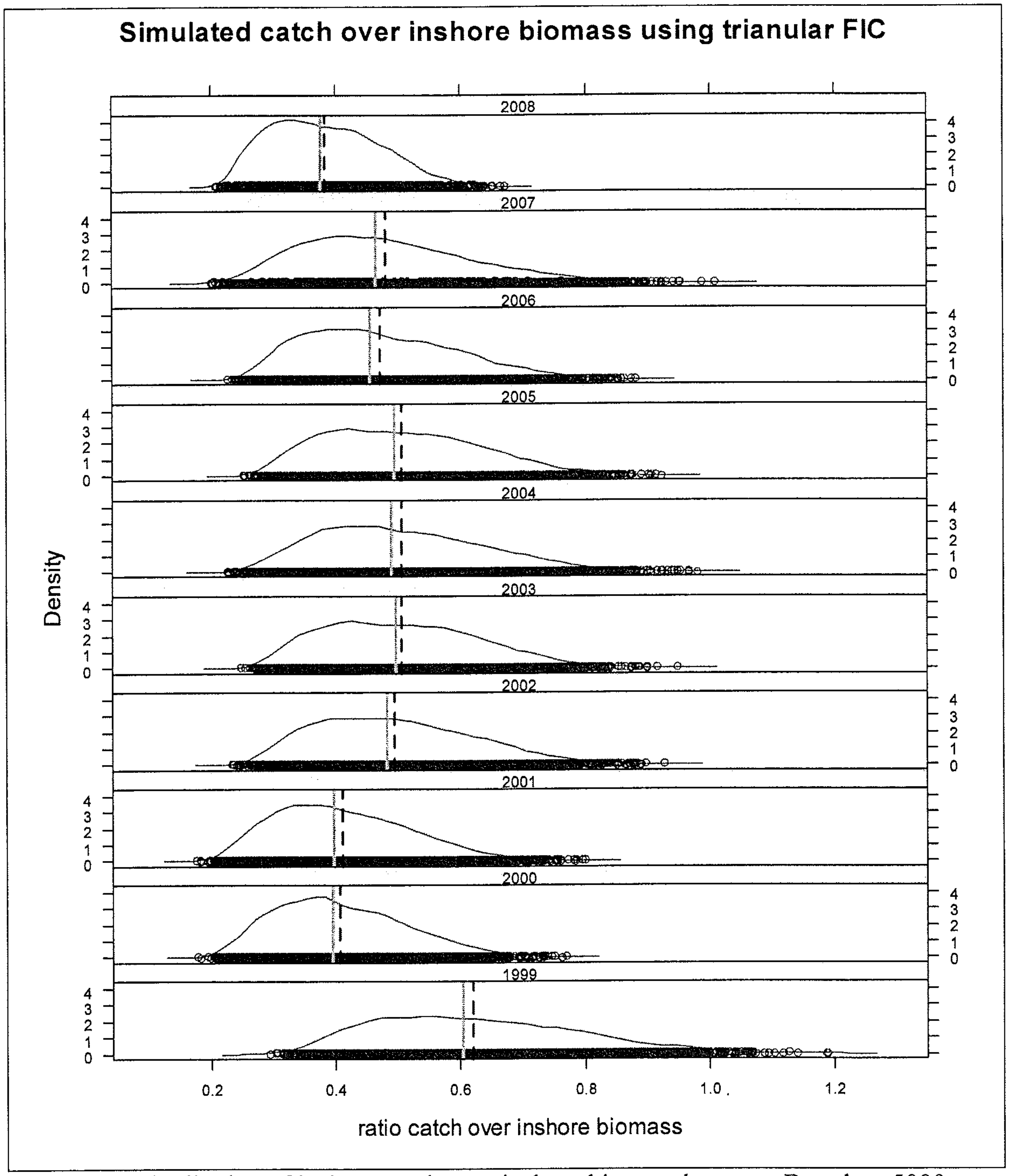


Figure 3. Distribution of inshore catch over inshore biomass by year. Based on 5000 simulations per year. Red dashed line is mean, solid gray line is median.

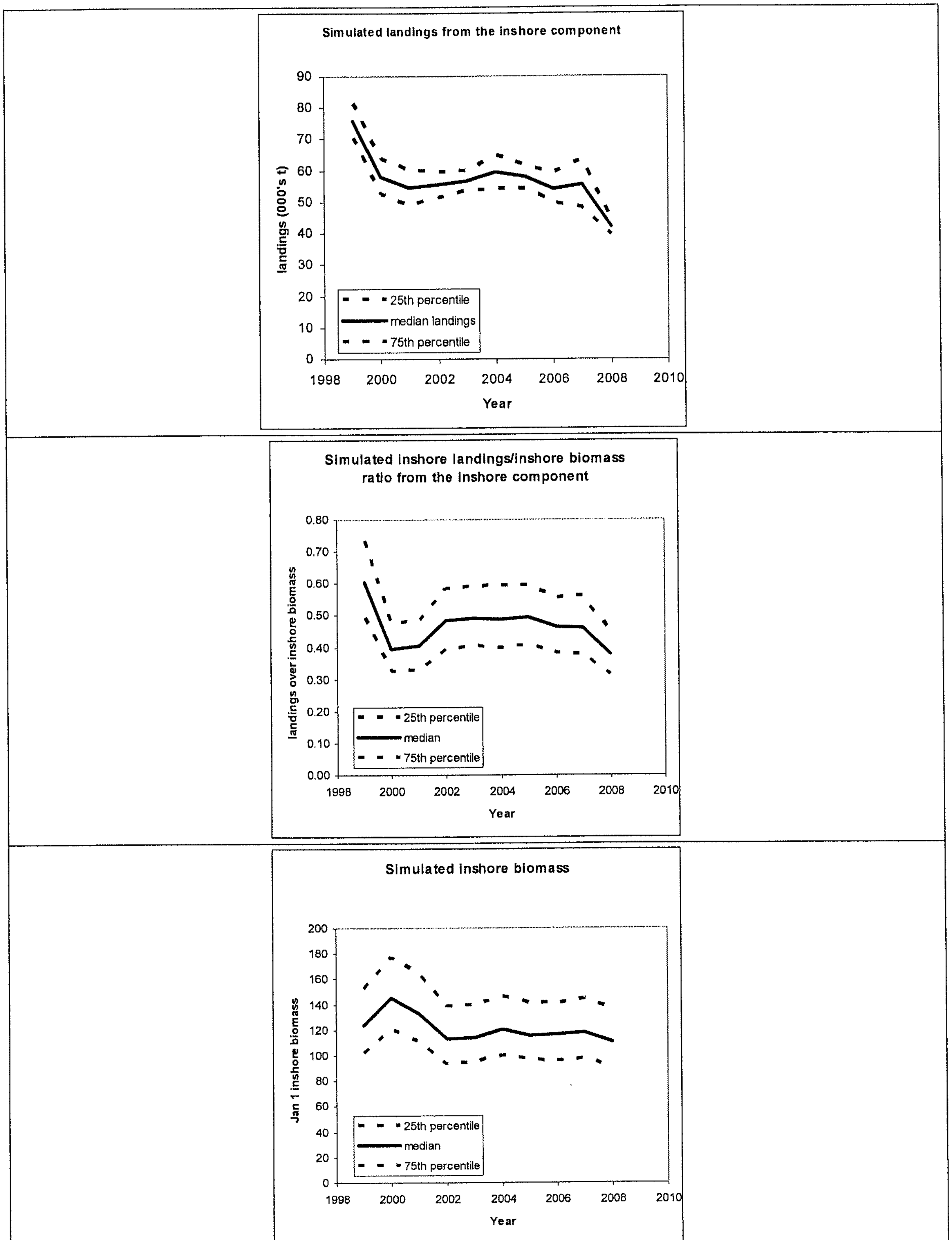


Figure 4. Top panel: trends in landings from inshore component. Middle panel: trends in ratio of inshore landings to inshore biomass. Bottom Panel: trends in inshore biomass. Solid line=median, dashed line interquartile values.

Literature cited.

O' Boyle, R and W. Overholtz. 2006. Proceedings of the Transboundary Resources Assessment Committee (TRAC). Benchmark review of Stock Assessment Models for Gulf of Maine and Georges Bank herring. 2-5 May 2006. Woods Hole, Massachusetts. http://www.mar.dfo-mpo.gc.ca/science/TRAC/trac.htlm.

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

## Herring PDT Risk Assessment: Complete Results for Options Under Consideration for the 2010-2012 Fishery Specifications

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## CURRENT (2009) HERRING FISHERY SPECIFICATIONS

**Table 1 Atlantic Herring Fishery Specifications for the 2007-2009 Fishing Years (January 1 – December 31)**

| | 2007 | 2008/2009 |
|---|---|---|
| Allowable Biological Catch (ABC) | 194,000 | 194,000 |
| U.S. Optimum Yield | 145,000 | 145,000 |
| Domestic Annual Harvesting (DAH) | 145,000 | 145,000 |
| Domestic Annual Processing (DAP) | 141,000 | 141,000 |
| Joint Venture Processing Total (JVPt) | 0 | 0 |
| JVP | 0 | 0 |
| Internal Waters Processing (IWP) | 0 | 0 |
| U.S. At-Sea Processing (USAP) | 20,000 (Areas 2 and 3 only) | 20,000 (Areas 2 and 3 only) |
| Border Transfer (BT) | 4,000 | 4,000 |
| Total Allowable Level of Foreign Fishing (TALFF) | 0 | 0 |
| RESERVE | 0 | 0 |
| TAC Area 1A | 50,000 (5,000 Jan-May) | 45,000 (43,650 fishery; 5,000 Jan-May) |
| TAC Area 1B | 10,000 | 10,000 (9,700 fishery) |
| TAC Area 2 | 30,000 | 30,000 (29,100 fishery) |
| TAC Area 3 | 55,000 | 60,000 (58,200 fishery) |
| Research Set-Aside (RSA) | N/A | Area 1A RSA 1,350<br>Area 1B RSA 300<br>Area 2 RSA 900<br>Area 3 RSA 1,800 |

**Area 2 and 3 RSA was not utilized and was re-allocated to the management area TACs for the remainder of the fishing year.*

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Table 2 2010-2012 OPTIONS UNDER CONSIDERATION

| | | ALTERNATIVE 1 | ALTERNATIVE 2 | ALTERNATIVES 1 and 2 | |
|---|---|---|---|---|---|
| | | 2010 | 2010 | 2011 | 2012 |
| OFL | | 145,000 | 145,000 | 134,000 | 127,000 |
| ABC | | 145,000 | 90,000 | 90,000 | 90,000 |
| Mgmt Uncertainty | | 14,800 | 14,800 | 14,800 | 14,800 |
| Stockwide ACL/OY | | 130,200 | 75,200 | 75,200 | 75,200 |
| Option 1 (historical) | 1A | 76,000 | 43,900 | 40,313 | 37,135 |
| | 1B | 6,500 | 3,700 | 3,398 | 3,130 |
| | 2 | 24,100 | 13,900 | 12,764 | 11,758 |
| | 3 | 23,600 | 13,700 | 18,725 | 23,177 |
| Option 2 (2001 with reserve) | 1A | 31,200 | 18,000 | 16,529 | 15,226 |
| | 1B | 5,200 | 3,000 | 2,755 | 2,538 |
| | 2 | 67,700 | 39,100 | 35,906 | 33,075 |
| | 3 | 26,100 | 15,100 | 20,010 | 24,361 |
| Option 2A (2001 without reserve) | 1A | 45,400 | 26,000 | 23,876 | 21993 |
| | 1B | 7,600 | 4,300 | 3,949 | 3,637 |
| | 2 | 37,800 | 21,700 | 19,927 | 18,356 |
| | 3 | 37,800 | 21,700 | 19,927 | 18,356 |
| Option 3 (2009) | 1A | 40,400 | 23,300 | 21,396 | 19,709 |
| | 1B | 9,000 | 5,200 | 4,775 | 4,399 |
| | 2 | 27,000 | 15,600 | 14,325 | 13,196 |
| | 3 | 53,800 | 31,100 | 34,703 | 37,896 |
| Option 4A (Max 1A) | 1A | 19,771 | 11,419 | 10,486 | 9,659 |
| | 1B | 8,593 | 4,963 | 4,558 | 4,198 |
| | 2 | 7,812 | 4,512 | 4,143 | 3,817 |
| | 3 | 94,024 | 54,306 | 56,013 | 57,526 |
| Option 4B (Max 1A) | 1A | 32,778 | 18,931 | 16,000 | 13,000 |
| | 1B | 8,593 | 4,963 | 4,500 | 3,500 |
| | 2 | 7,812 | 4,512 | 4,000 | 4,000 |
| | 3 | 81,017 | 46,794 | 50,700 | 54,700 |
| Option 5 (Max 2) | 1A | 11,197 | 6,467 | 5,000 | 4,000 |
| | 1B | 8,723 | 5,038 | 4,500 | 4,000 |
| | 2 | 52,080 | 30,080 | 26,000 | 24,000 |
| | 3 | 58,200 | 33,615 | 39,700 | 43,200 |
| Option 6 (Balanced) | 1A | 17,690 | 10,217 | 8,500 | 7,000 |
| | 1B | 8,854 | 5,114 | 4,500 | 3,500 |
| | 2 | 17,707 | 10,227 | 8,500 | 7,000 |
| | 3 | 85,949 | 49,642 | 53,700 | 57,700 |

## Table 3 2010-2012 PROPOSED MONTHLY CATCH PROPORTIONS

| | OPTION 1 (Historical) | OPTION 2 (2001) | OPTION 3 (2009) | OPTION 4A (Max 1A) | OPTION 4B (Max 1A) | OPTION 5 (Max 2) | OPTION 6 (Balanced) |
|---|---|---|---|---|---|---|---|
| | AREA 1A | AREA 1A | AREA 1A | AREA 1A | AREA 1A | AREA 1A | AREA 1A |
| JAN | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FEB | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| MARCH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| APRIL | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| MAY | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 |
| JUNE | 0.09 | 0.09 | 0.09 | 0.00 | 0.33 | 0.00 | 0.00 |
| JULY | 0.23 | 0.23 | 0.23 | 0.33 | 0.33 | 0.40 | 0.33 |
| AUGUST | 0.28 | 0.28 | 0.28 | 0.33 | 0.00 | 0.30 | 0.33 |
| SEPT | 0.02 | 0.02 | 0.02 | 0.33 | 0.00 | 0.30 | 0.33 |
| OCT | 0.19 | 0.19 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| NOV | 0.19 | 0.19 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| DEC | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Note: Options 1-3 (shaded) indicate the catch proportions used in the Herring PDT's risk assessment, which are based on the best available information about 2009 proportion of monthly catches. The catch proportions in Options 1 – 3 are not proposed to be implemented as regulations. The catch proportions in Options 4- 6 would, however, be implemented (i.e., Options 4 – 6 include a seasonal allocation of the 1A quota).*

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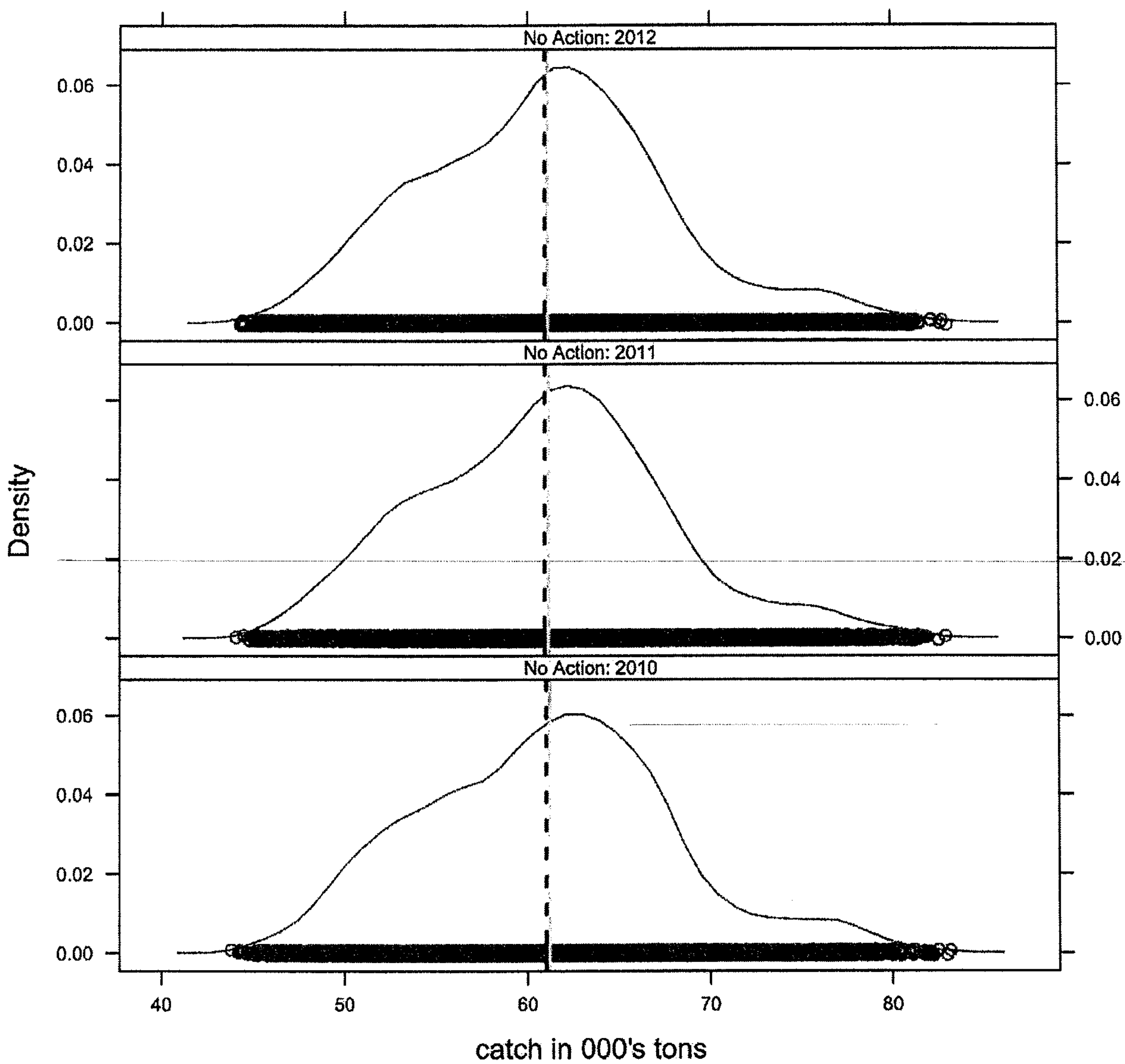
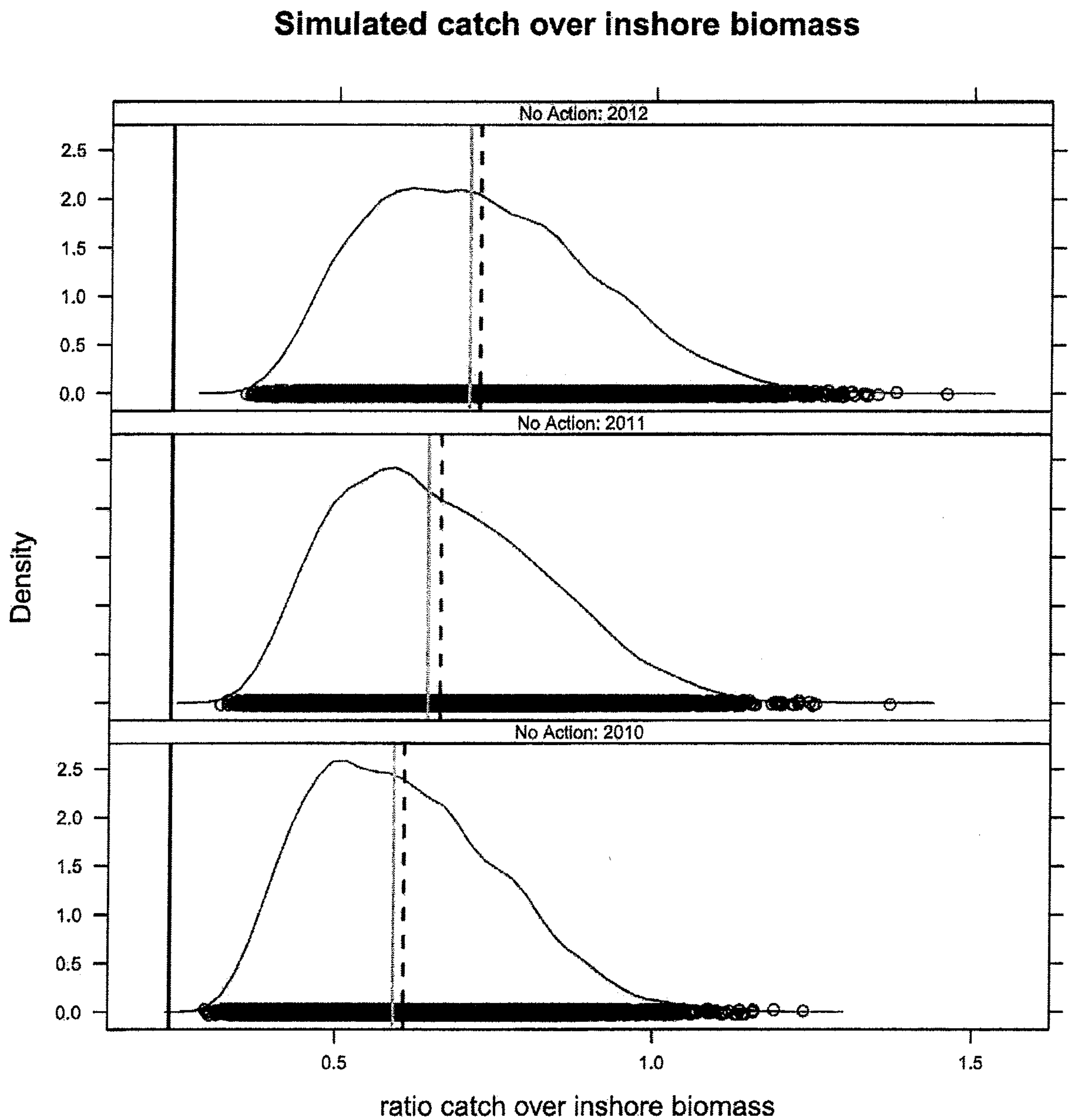
# 2010-2012 Atlantic Herring Fishery Specifications

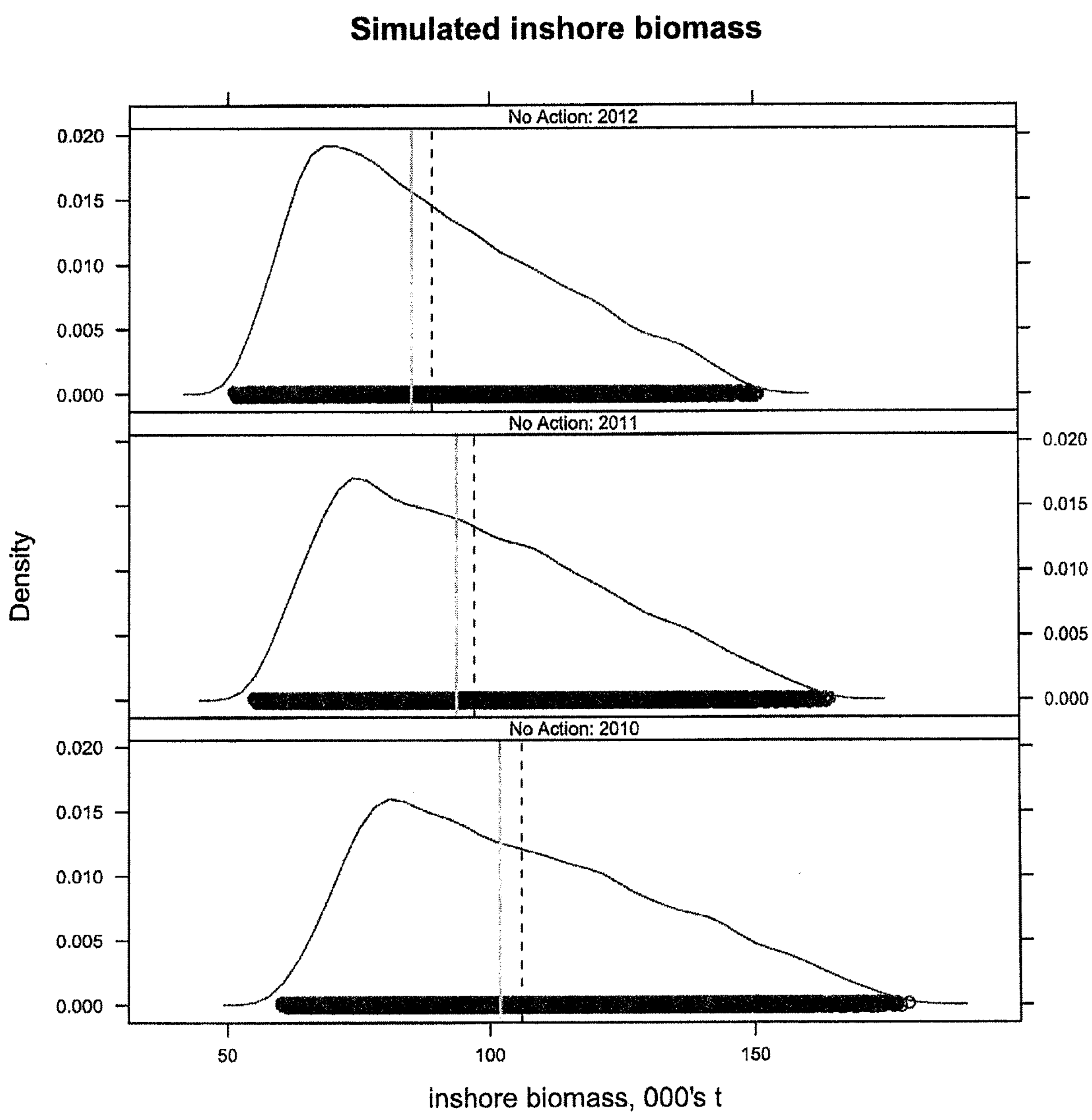
# APPENDIX III:

# NO ACTION ALTERNATIVE

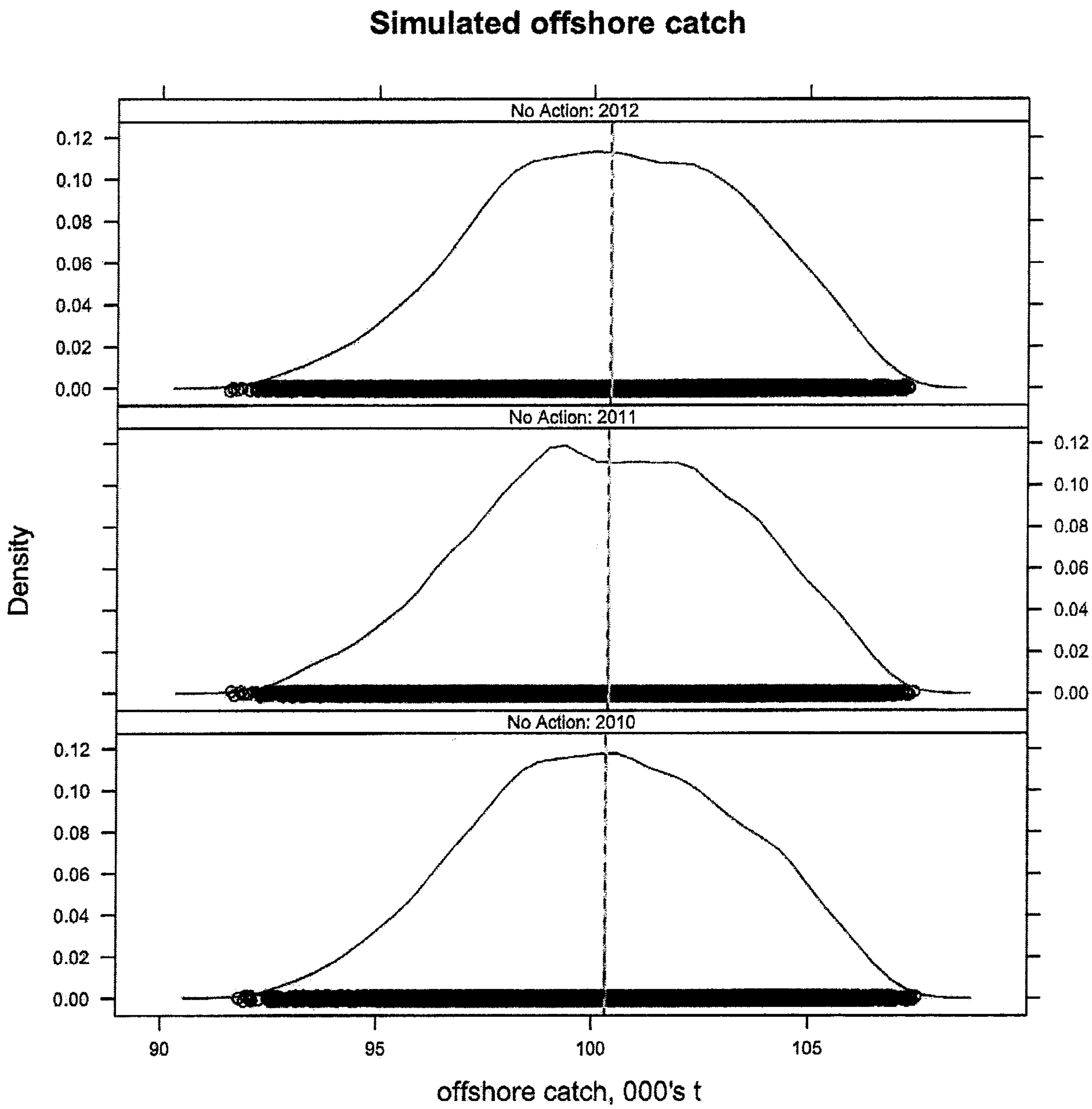
# Simulated inshore removals

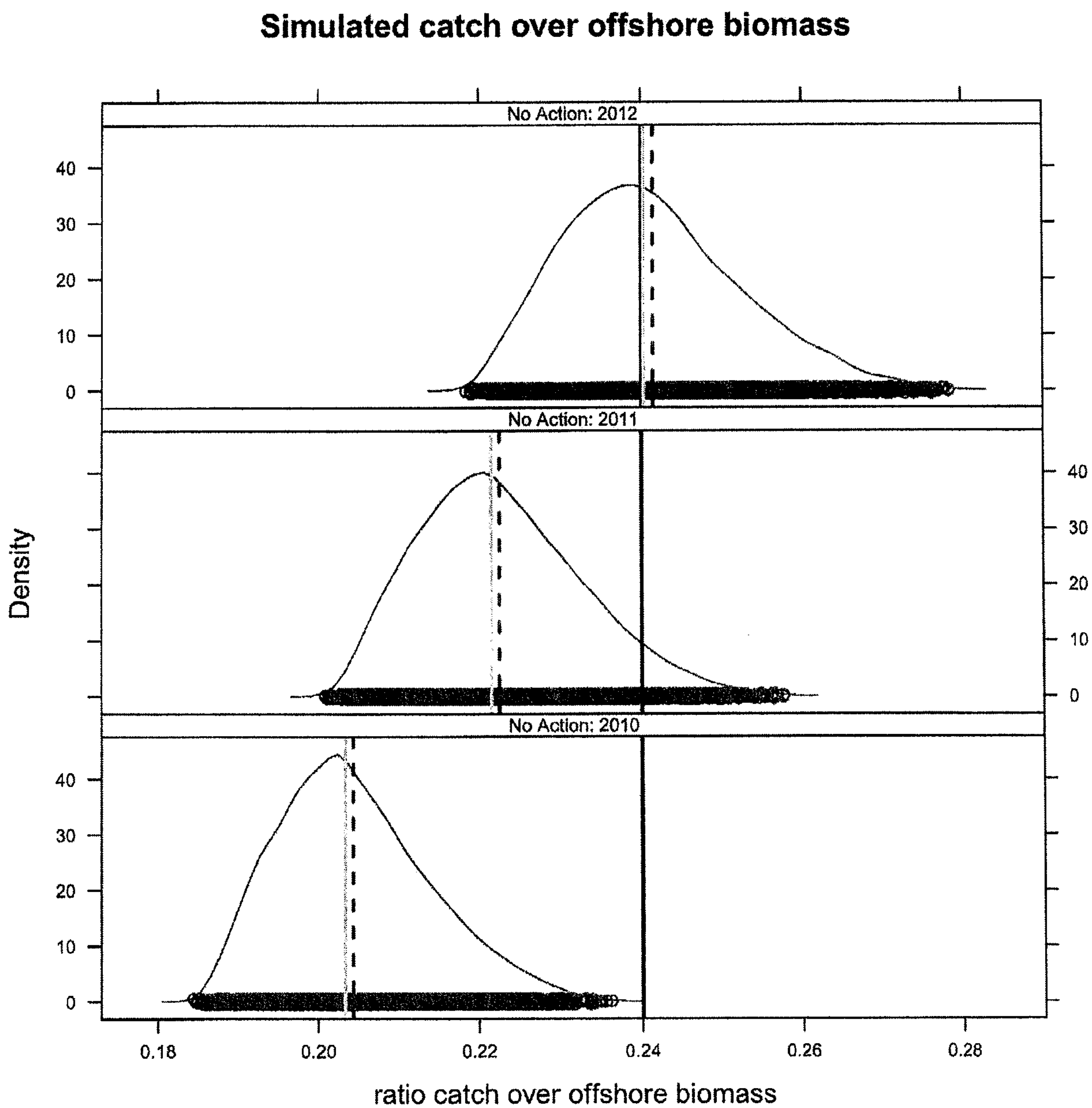



Simulated catch over inshore biomass
No Action: 2012
No Action: 2011
No Action: 2010
Density
2.5
2.0
1.5
1.0
0.5
0.0
0.5
1.0
1.5
ratio catch over inshore biomass



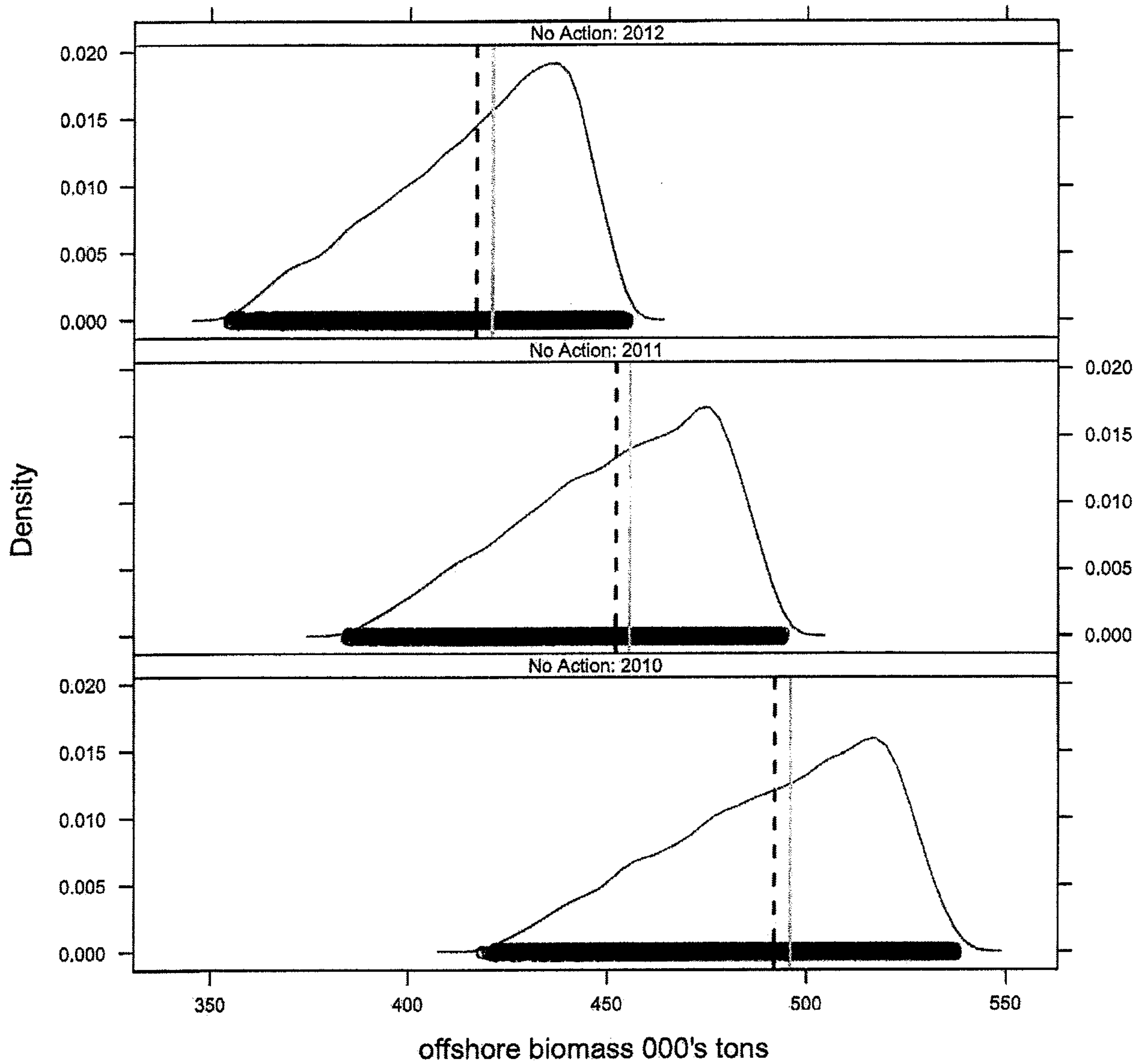
Simulated inshore biomass
No Action: 2012
No Action: 2011
No Action: 2010
0.020
0.015
0.010
0.005
0.000
Density
50
100
150
inshore biomass, 000's t


Simulated offshore catch
No Action: 2012
No Action: 2011
No Action: 2010
Density
0.12
0.10
0.08
0.06
0.04
0.02
0.00
90
95
100
105
offshore catch, 000's t



Simulated catch over offshore biomass
No Action: 2012
No Action: 2011
No Action: 2010
Density
40
30
20
10
0
0.18
0.20
0.22
0.24
0.26
0.28
ratio catch over offshore biomass

## Simulated offshore biomass



NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 1

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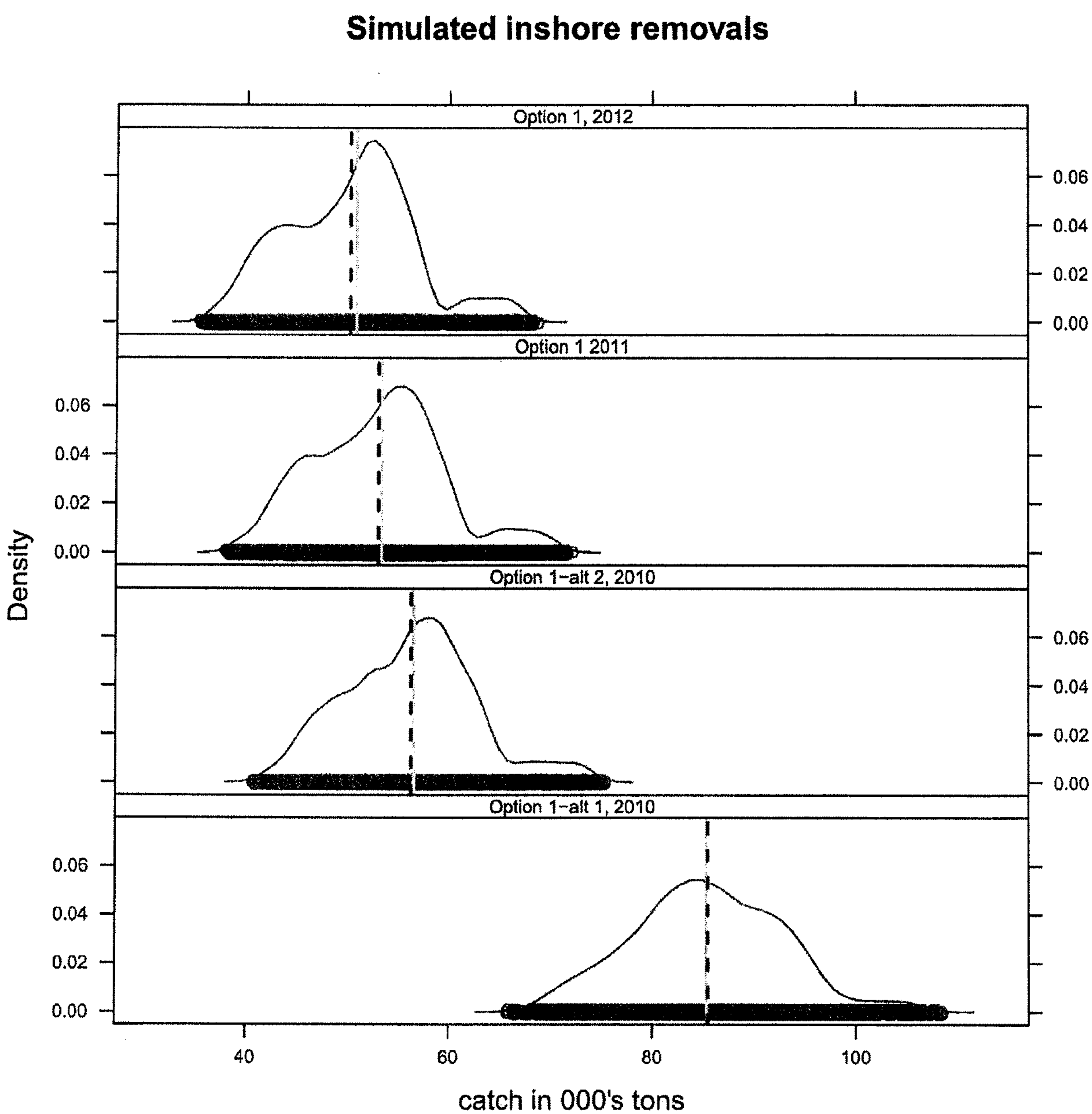
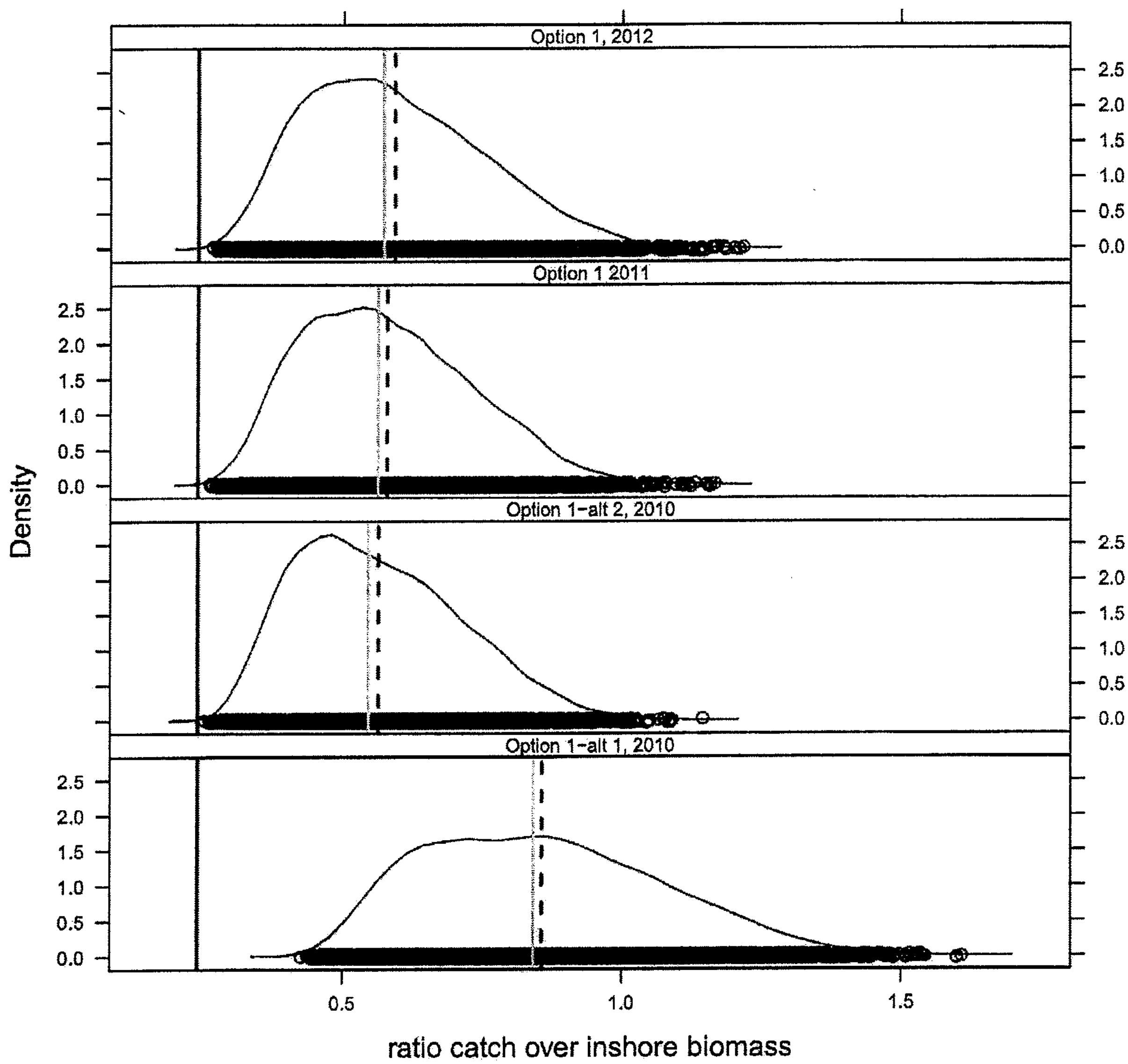
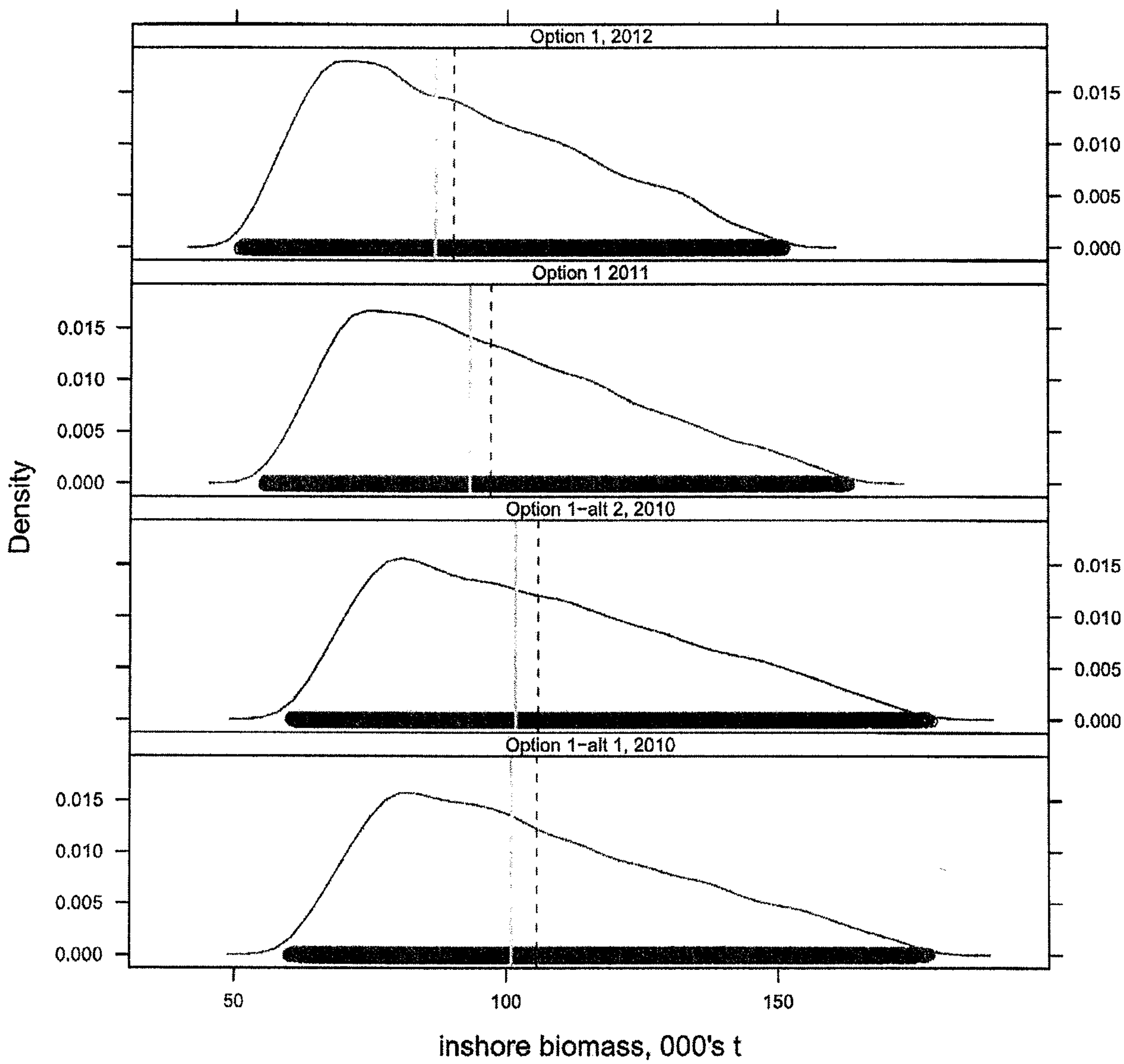

Simulated inshore removals
Option 1, 2012
Option 1 2011
Option 1−alt 2, 2010
Option 1−alt 1, 2010
Density
0.00
0.02
0.04
0.06
40
60
80
100
catch in 000's tons

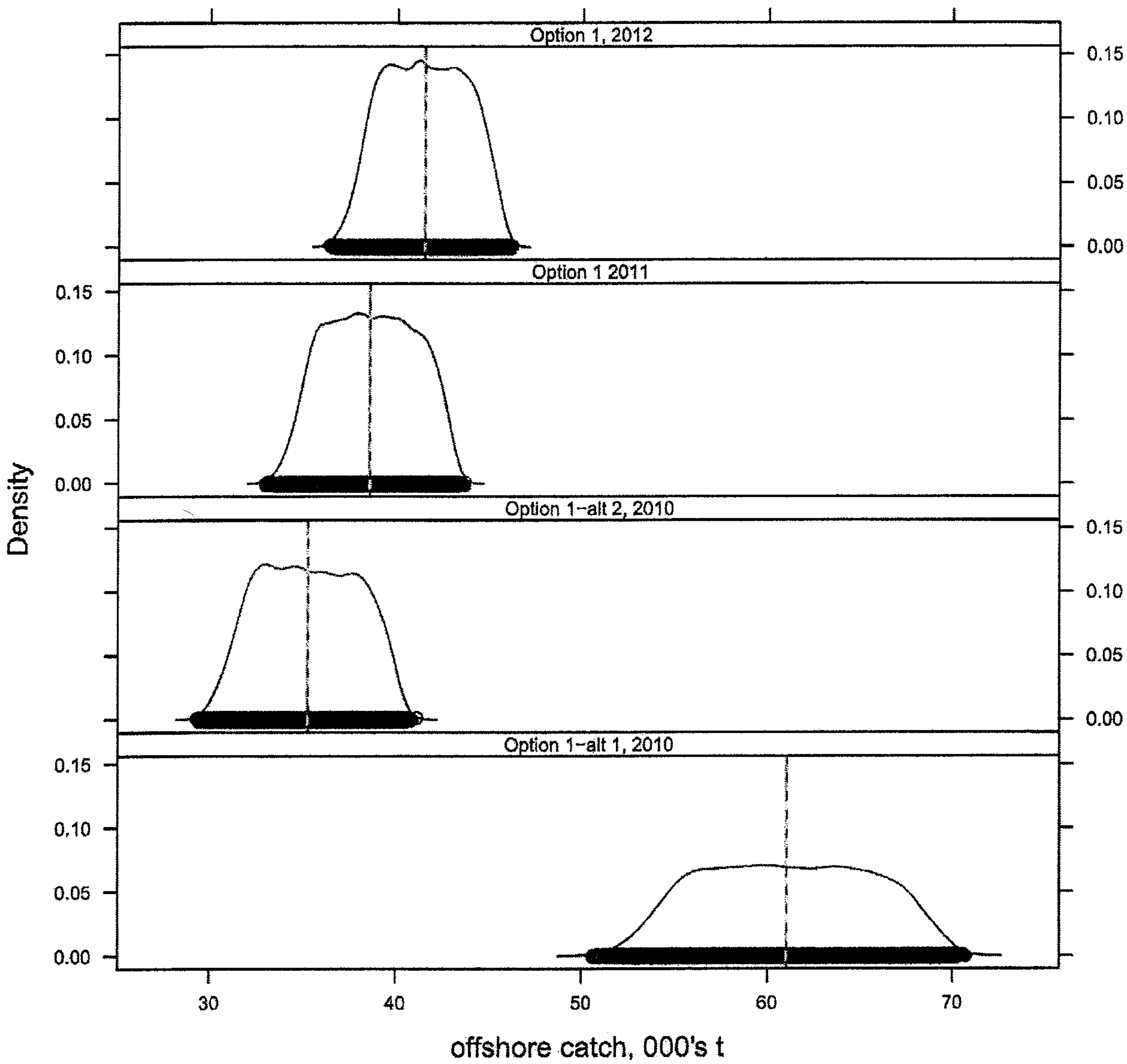
# Simulated catch over inshore biomass

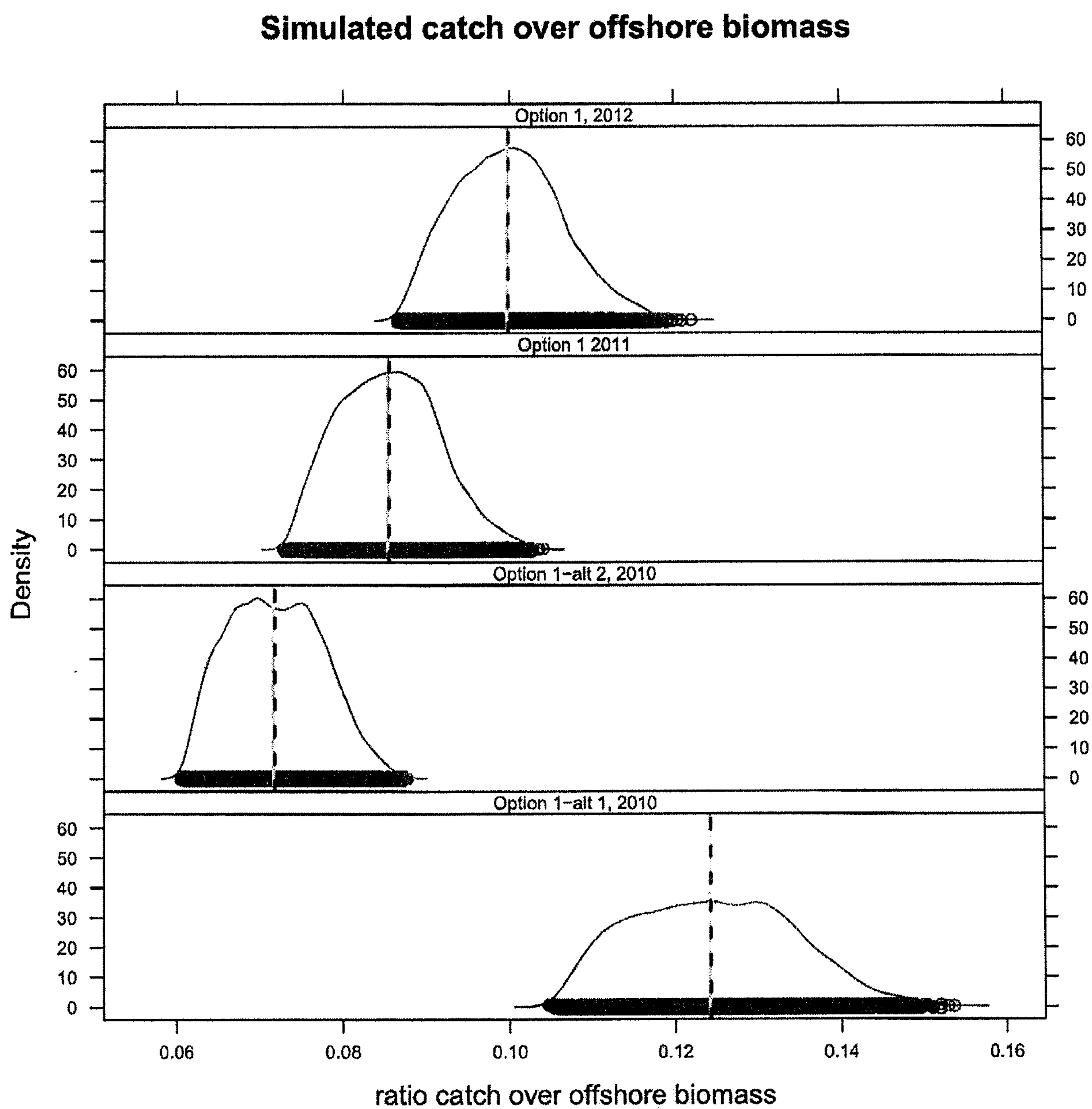


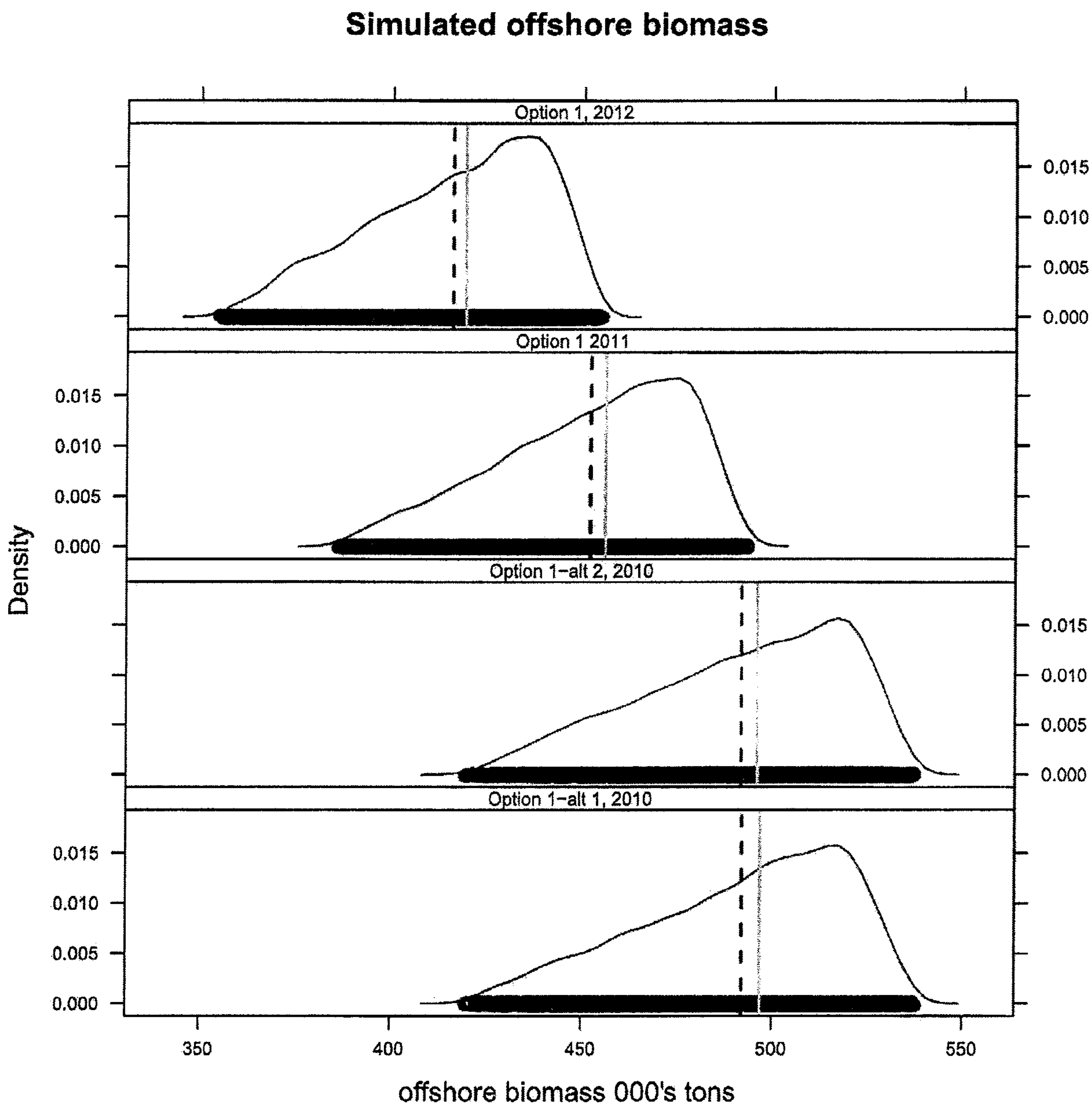
## Simulated inshore biomass



## Simulated offshore catch




Simulated catch over offshore biomass
Option 1, 2012
Option 1 2011
Option 1-alt 2, 2010
Option 1-alt 1, 2010
Density
60
50
40
30
20
10
0
0.06
0.08
0.10
0.12
0.14
0.16
ratio catch over offshore biomass


Simulated offshore biomass
Option 1, 2012
Option 1 2011
Option 1−alt 2, 2010
Option 1−alt 1, 2010
Density
0.000
0.005
0.010
0.015
350
400
450
500
550
offshore biomass 000's tons

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# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 2

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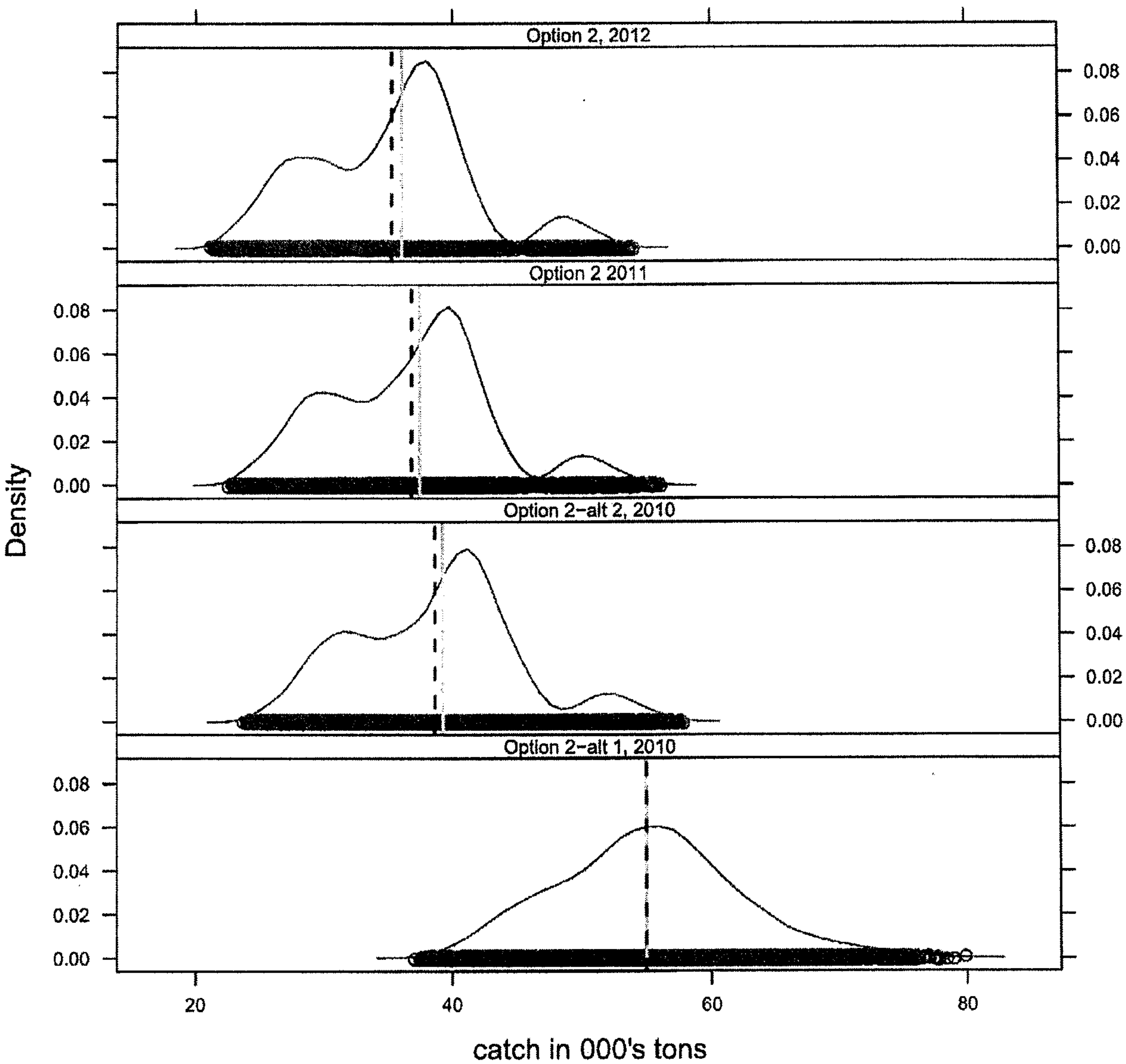
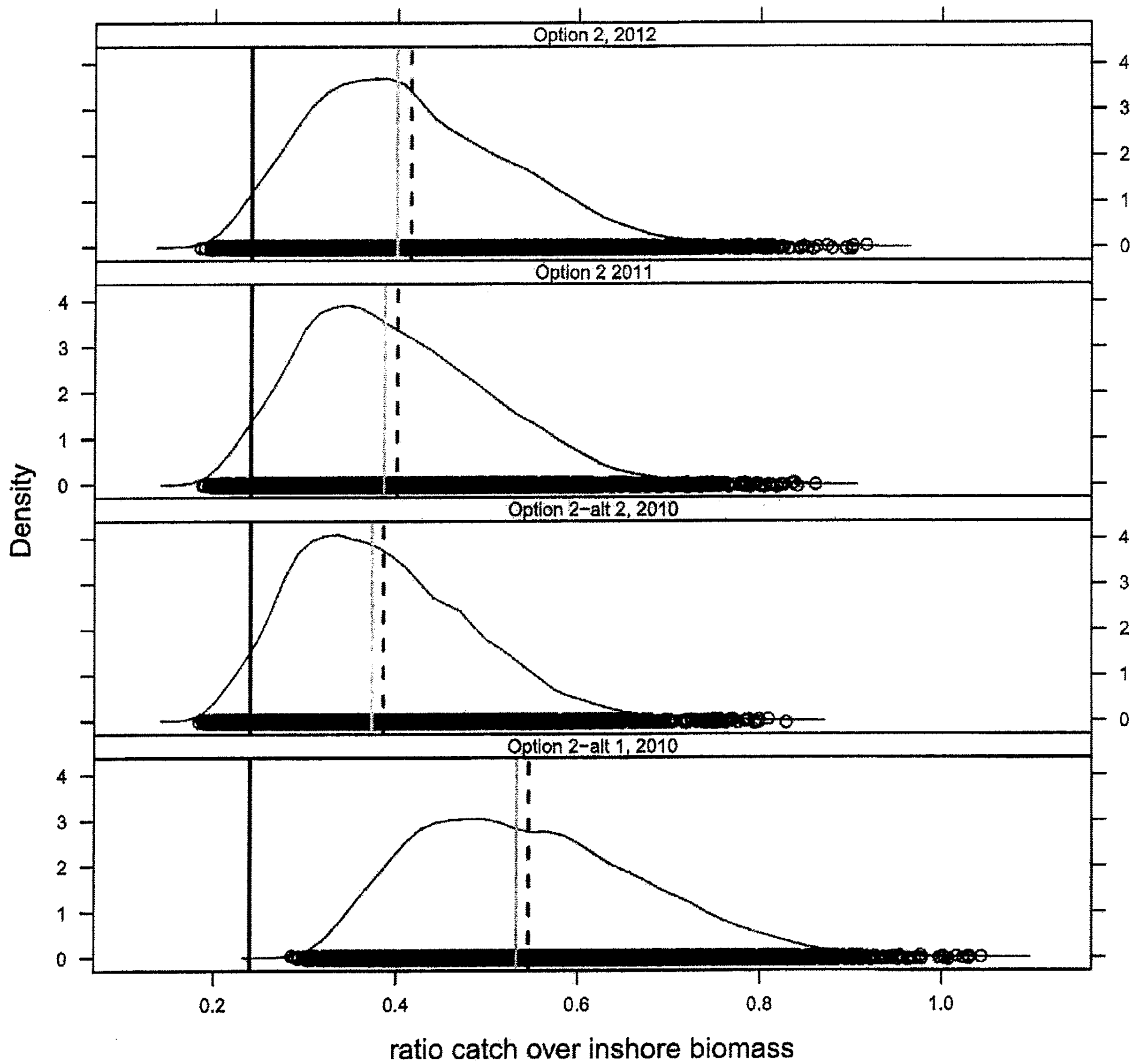
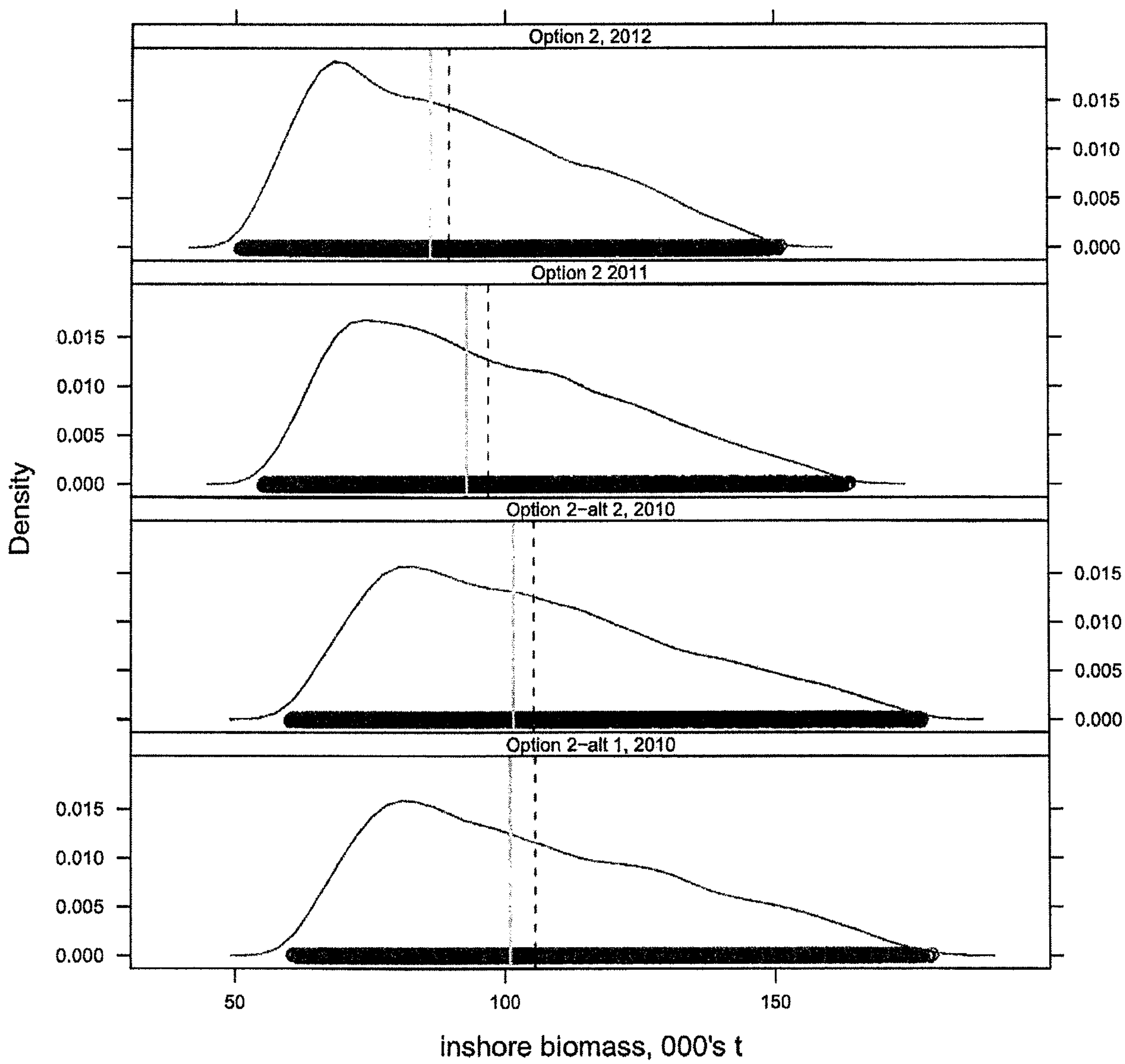
## Simulated inshore removals



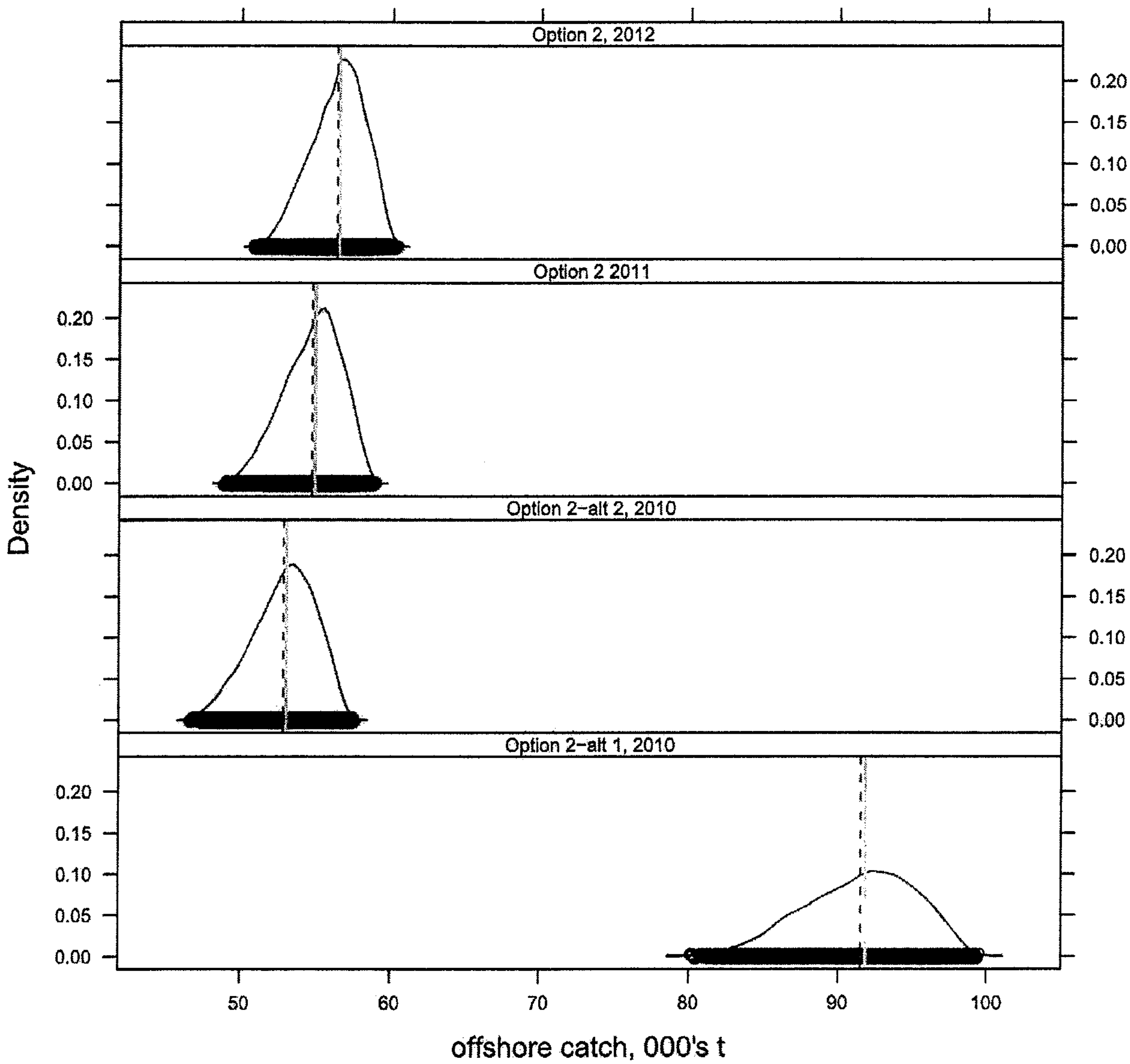
# Simulated catch over inshore biomass



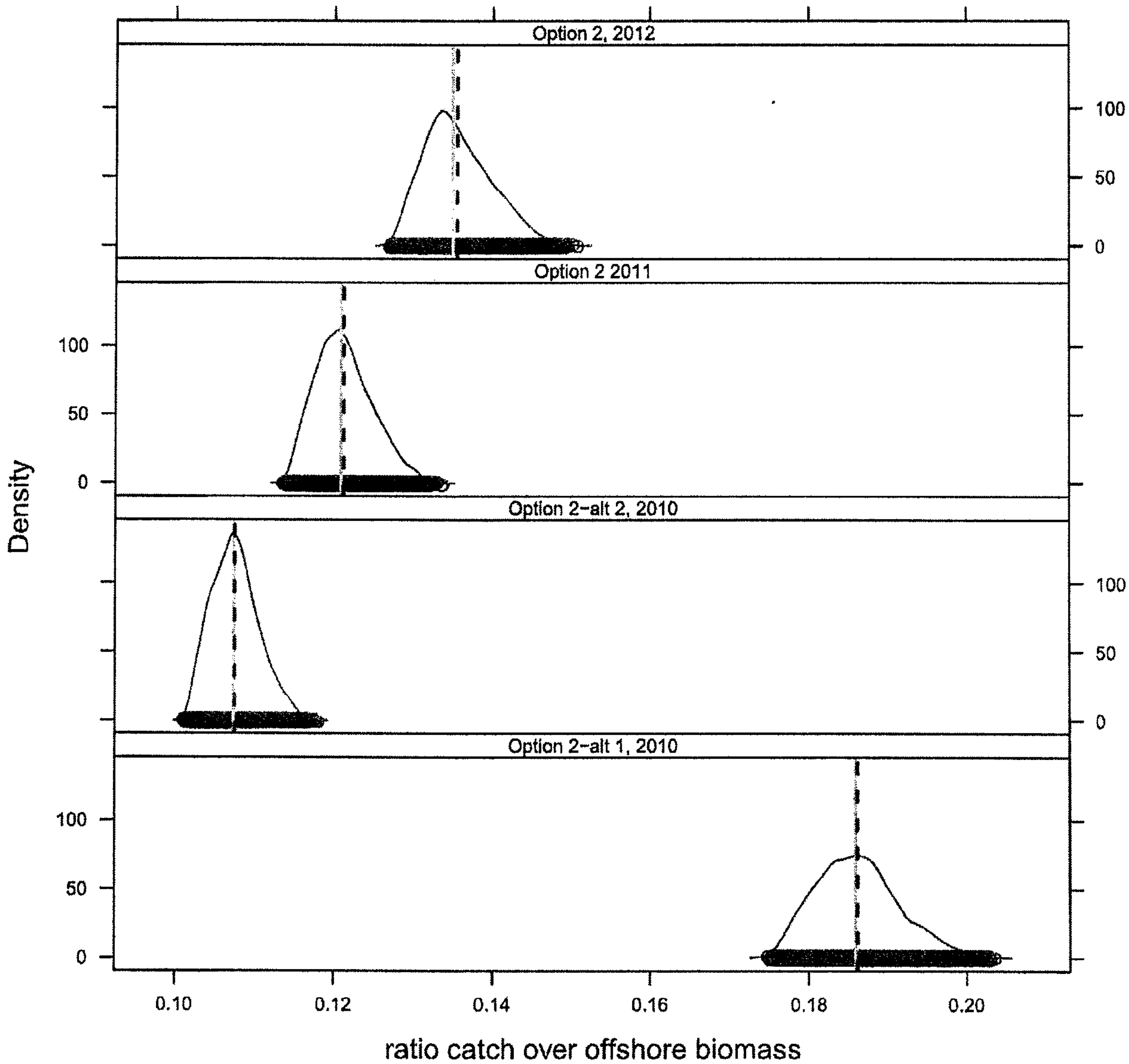
## Simulated inshore biomass

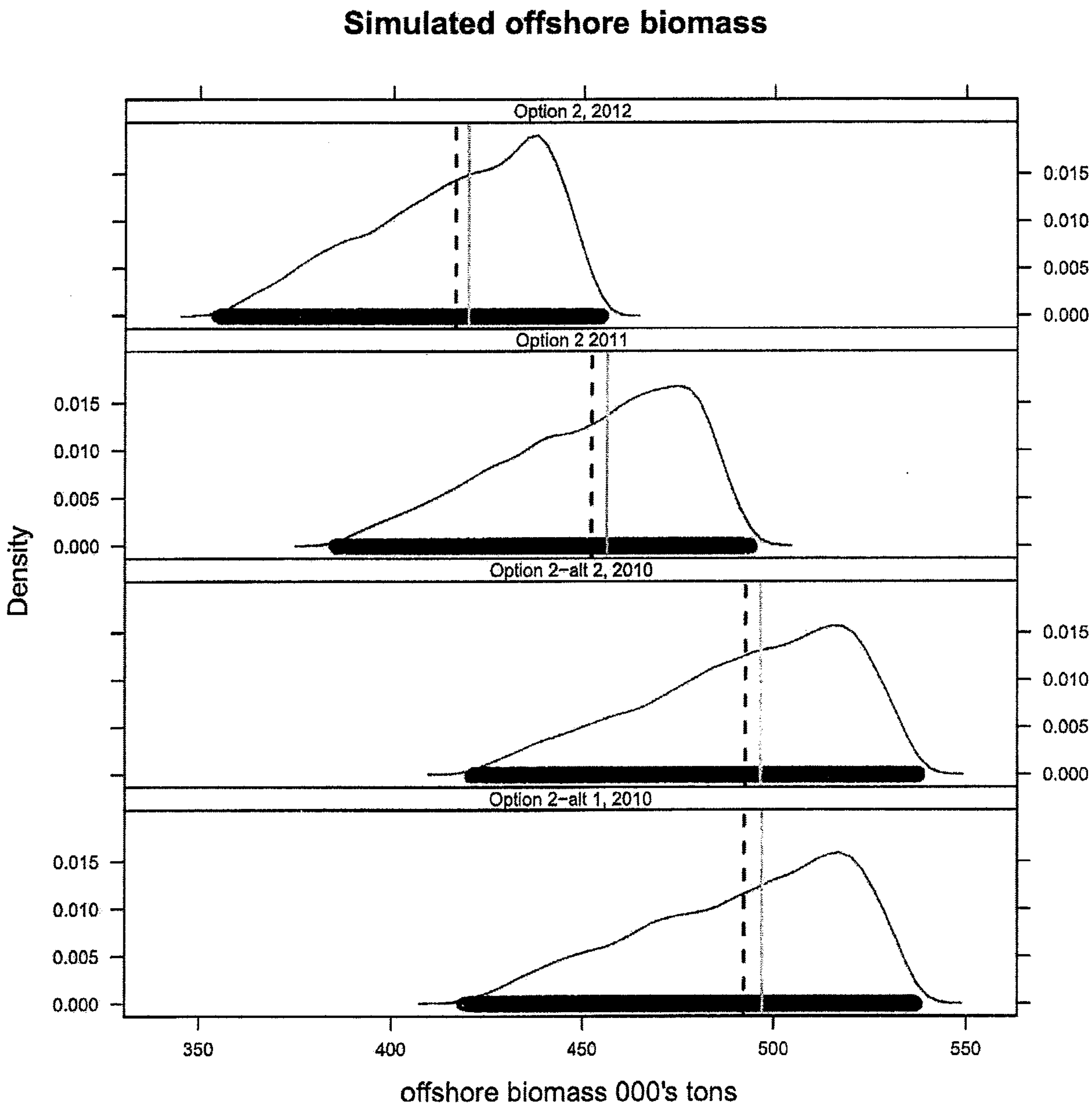


# Simulated offshore catch



# Simulated catch over offshore biomass





Simulated offshore biomass
Option 2, 2012
Option 2 2011
Option 2-alt 2, 2010
Option 2-alt 1, 2010
Density
0.000
0.005
0.010
0.015
350
400
450
500
550
offshore biomass 000's tons

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 2A

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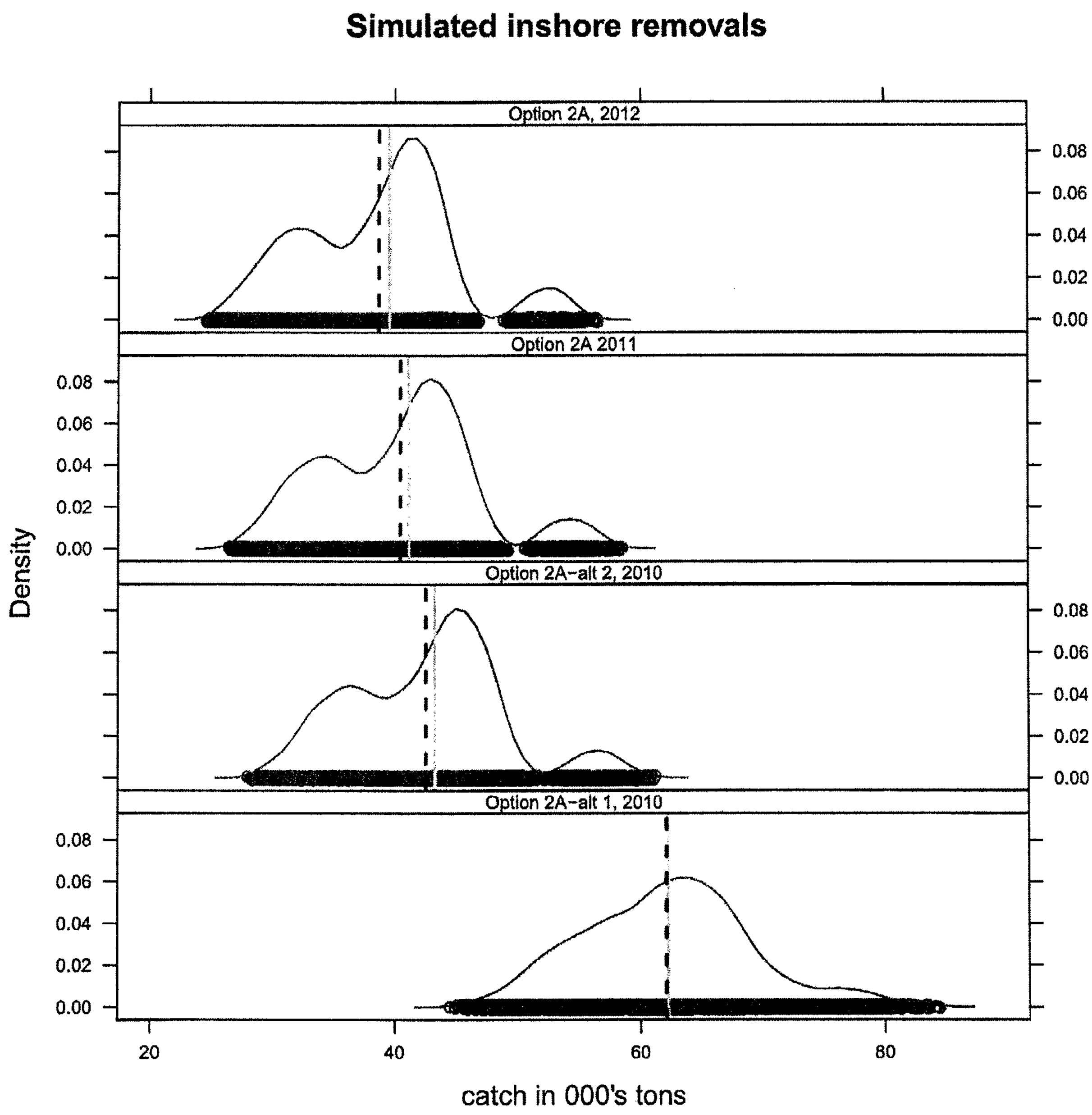
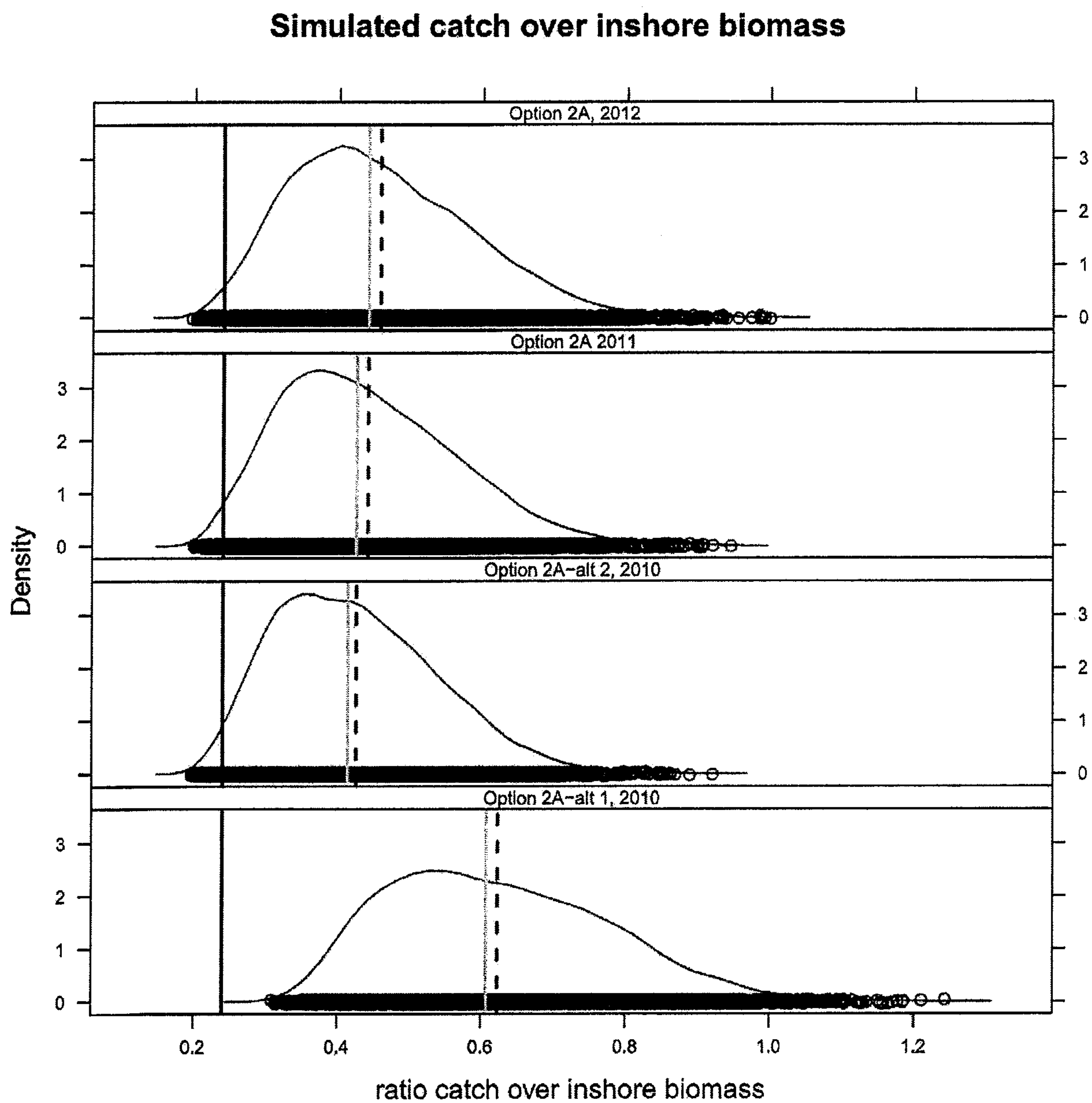
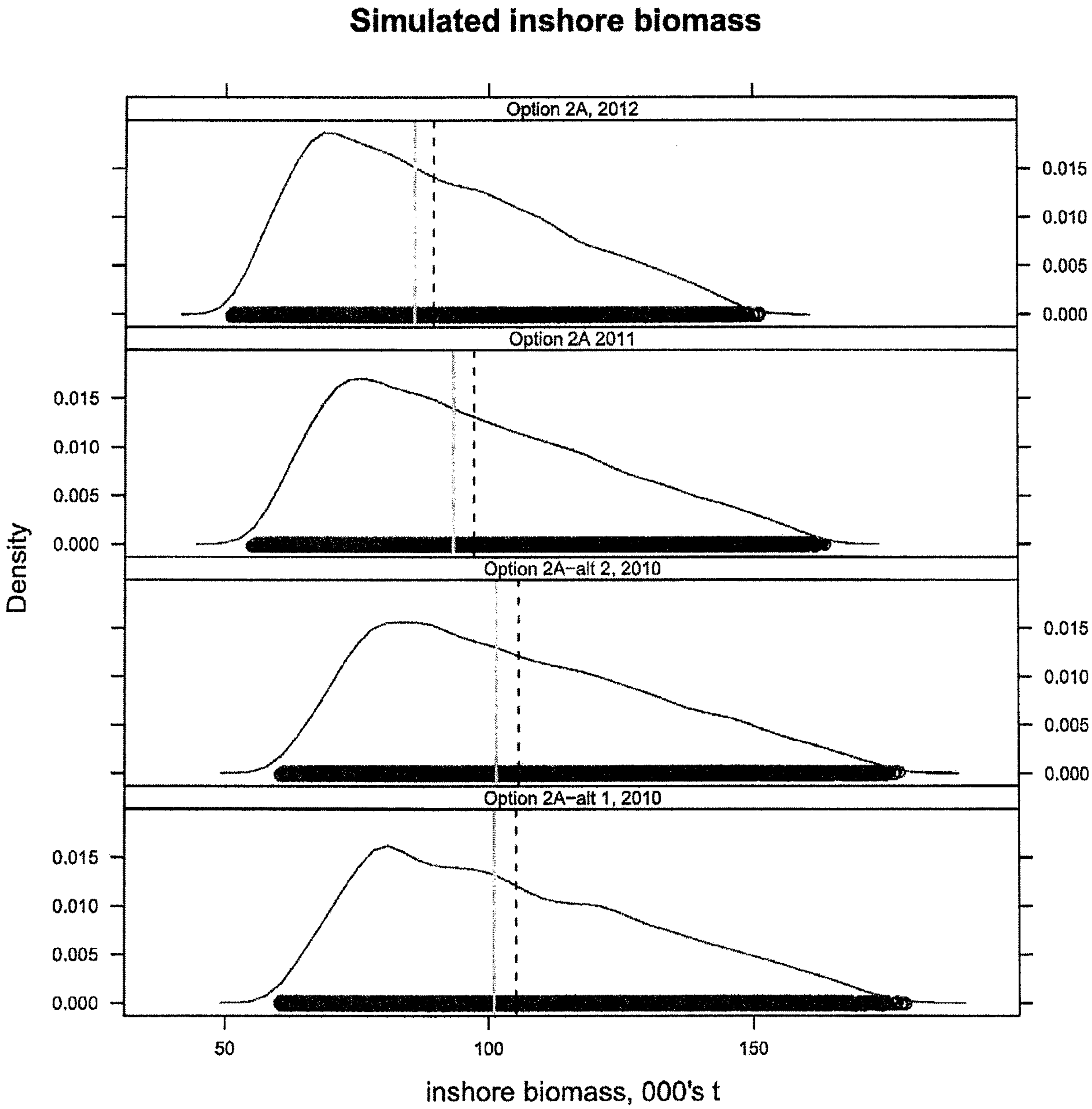
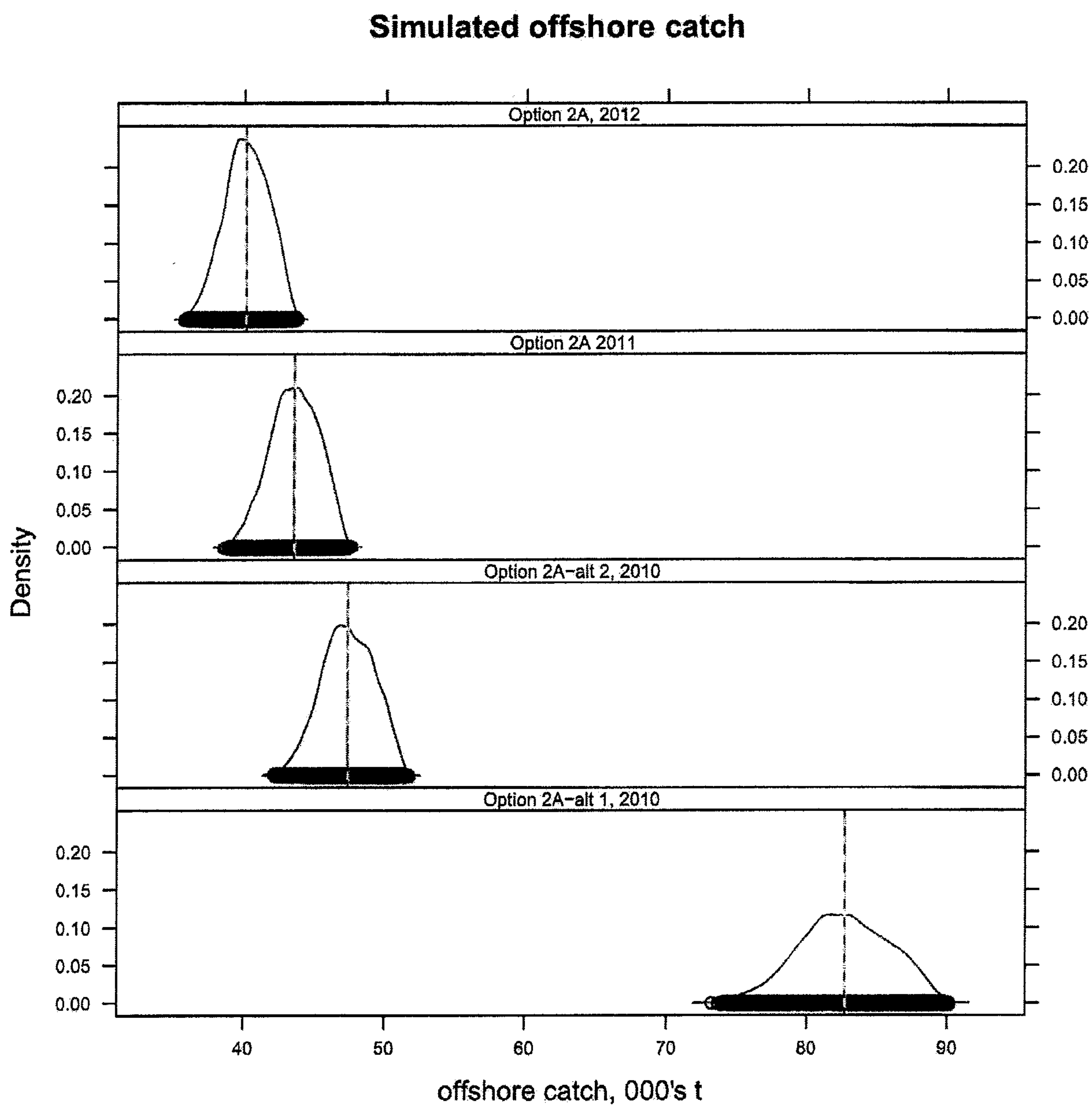


Simulated inshore removals
Option 2A, 2012
Option 2A 2011
Option 2A−alt 2, 2010
Option 2A−alt 1, 2010
Density
0.00
0.02
0.04
0.06
0.08
20
40
60
80
catch in 000's tons



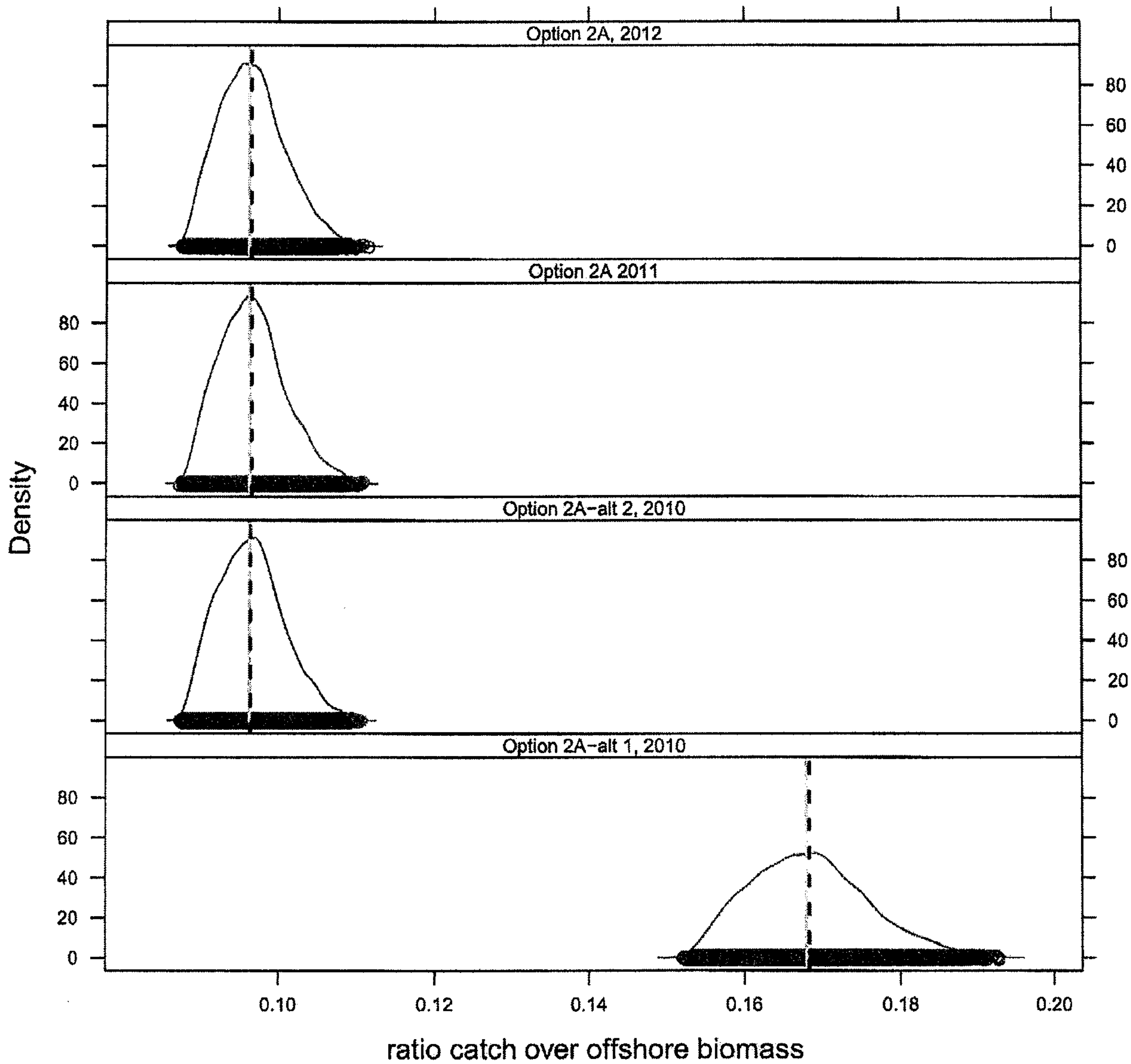
Simulated catch over inshore biomass
Option 2A, 2012
Option 2A 2011
Option 2A-alt 2, 2010
Option 2A-alt 1, 2010
Density
0
1
2
3
0.2
0.4
0.6
0.8
1.0
1.2
ratio catch over inshore biomass


Simulated inshore biomass
Option 2A, 2012
Option 2A 2011
Option 2A−alt 2, 2010
Option 2A−alt 1, 2010
Density
0.000
0.005
0.010
0.015
50
100
150
inshore biomass, 000's t

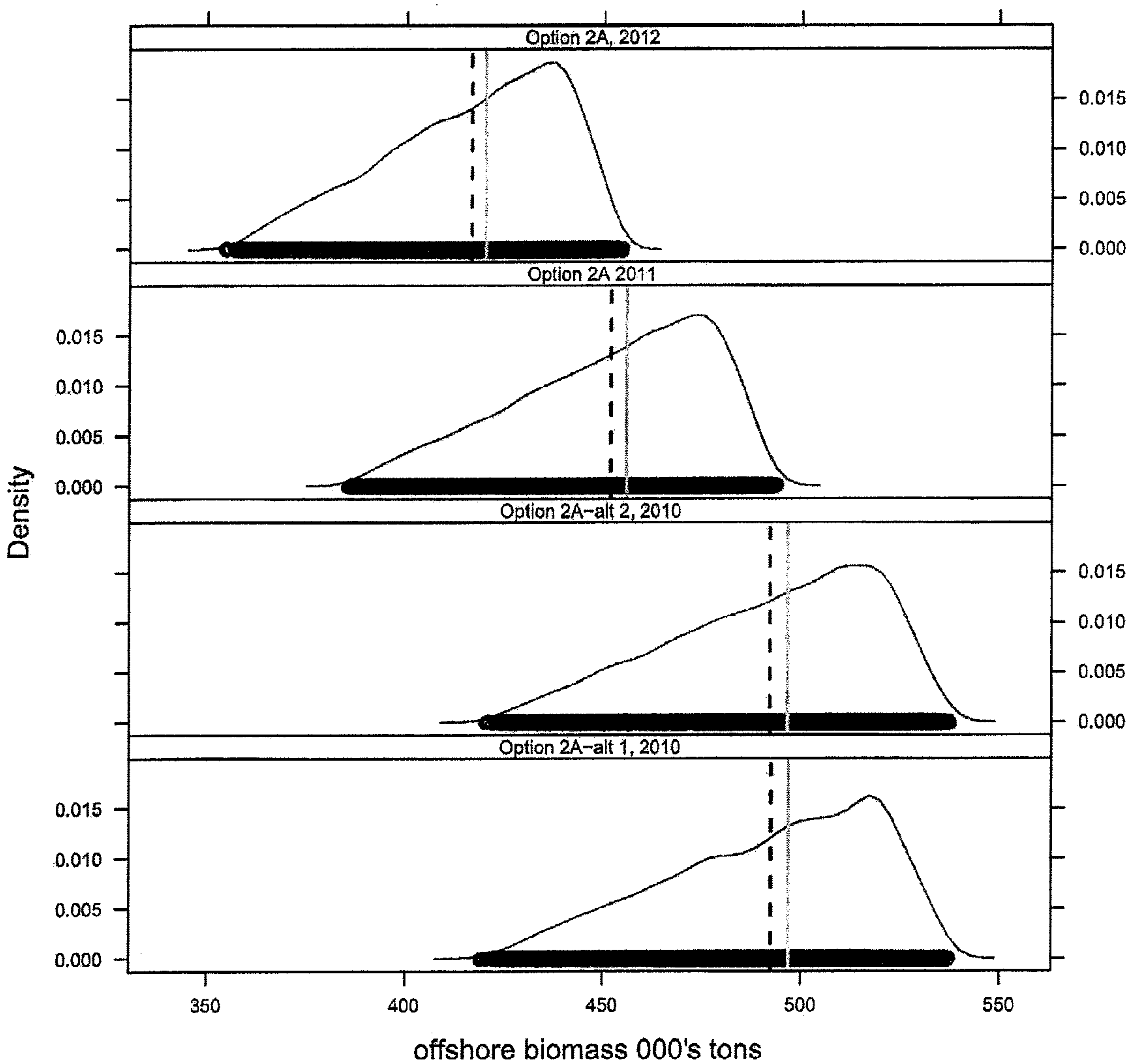


Simulated offshore catch
Option 2A, 2012
Option 2A 2011
Option 2A−alt 2, 2010
Option 2A−alt 1, 2010
Density
0.00
0.05
0.10
0.15
0.20
40
50
60
70
80
90
offshore catch, 000's t

## Simulated catch over offshore biomass



## Simulated offshore biomass



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# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 3

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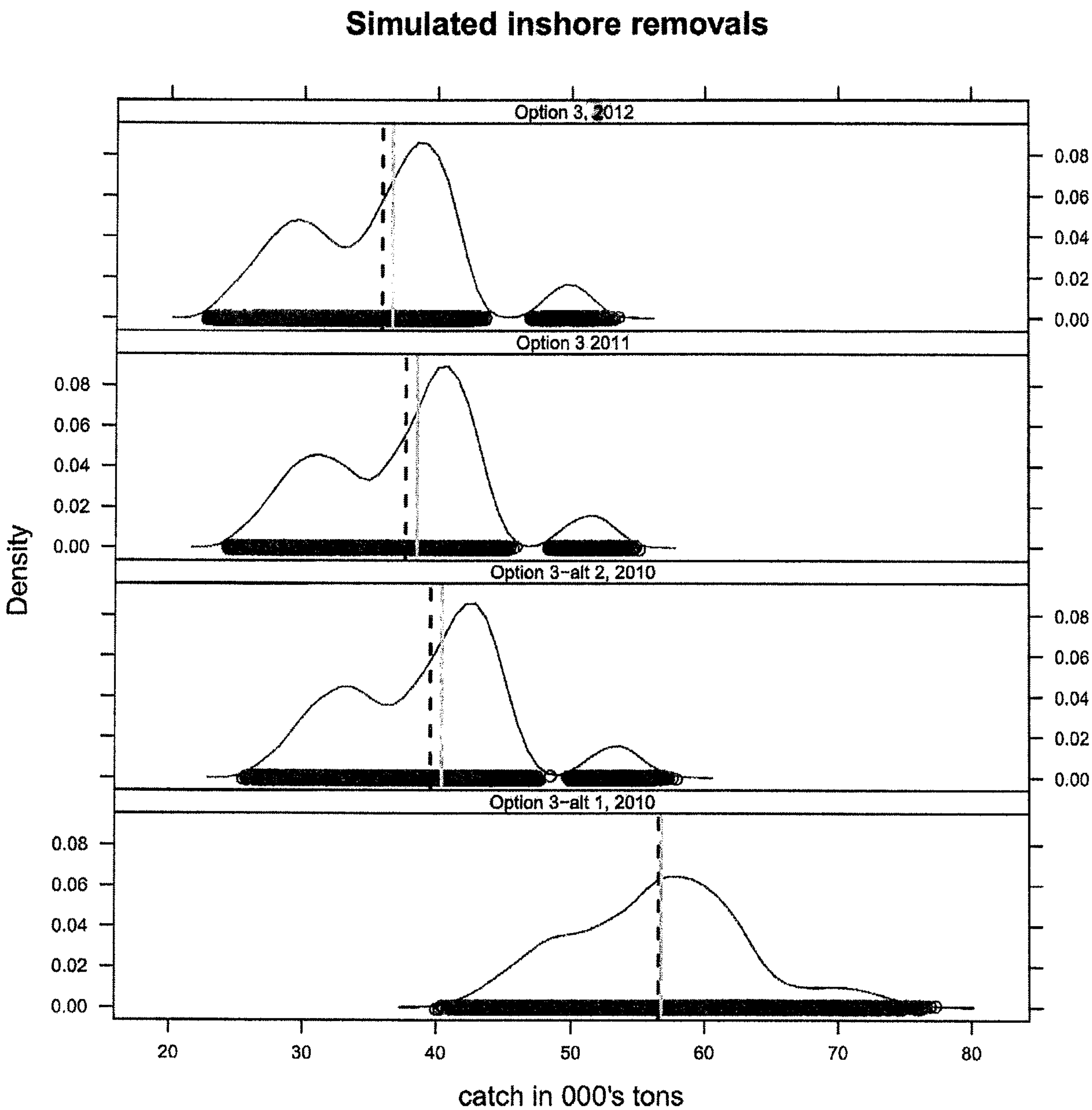
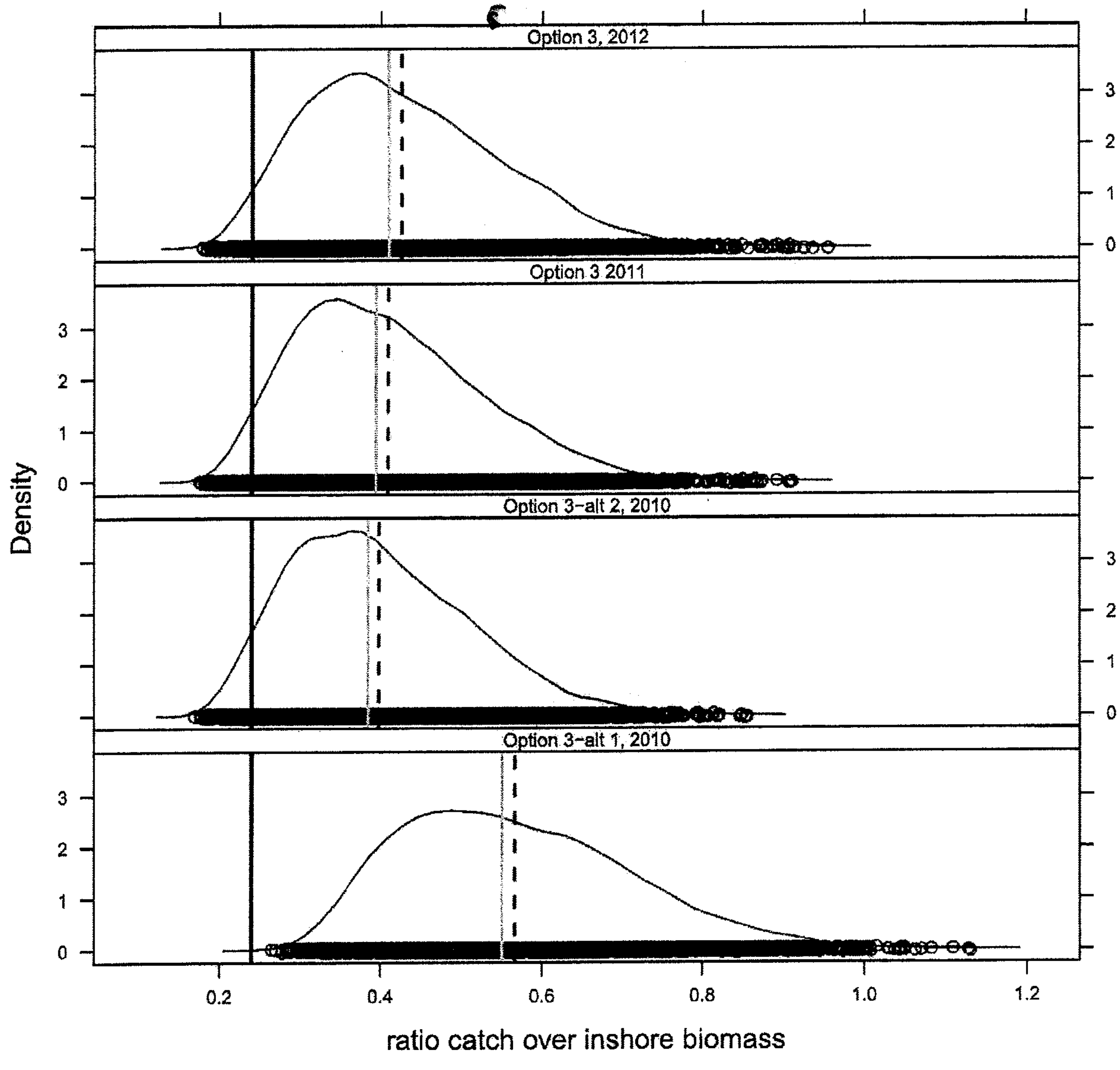
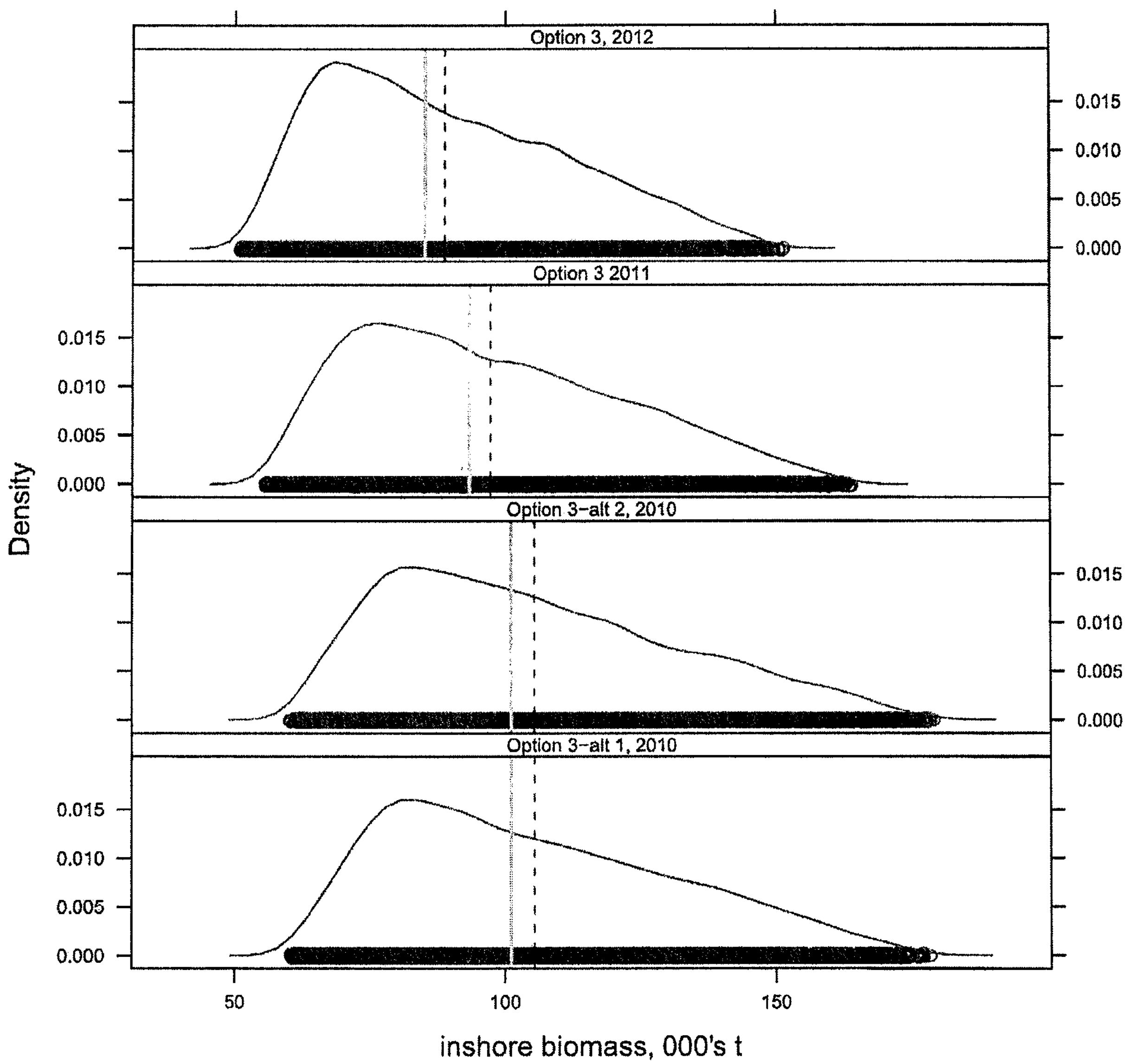
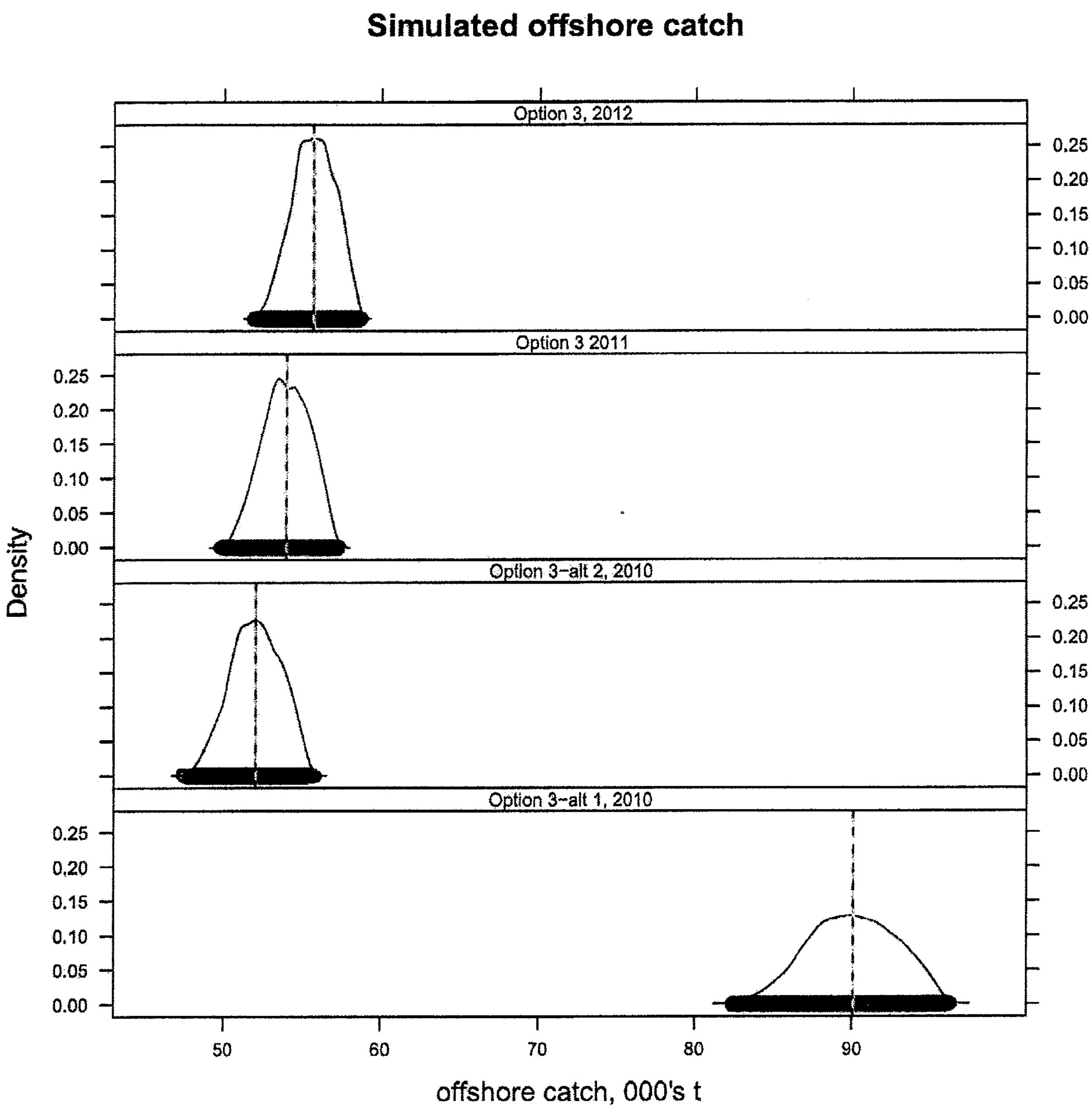

Simulated inshore removals
Option 3, 2012
Option 3 2011
Option 3-alt 2, 2010
Option 3-alt 1, 2010
Density
0.00
0.02
0.04
0.06
0.08
20
30
40
50
60
70
80
catch in 000's tons

## Simulated catch over inshore biomass

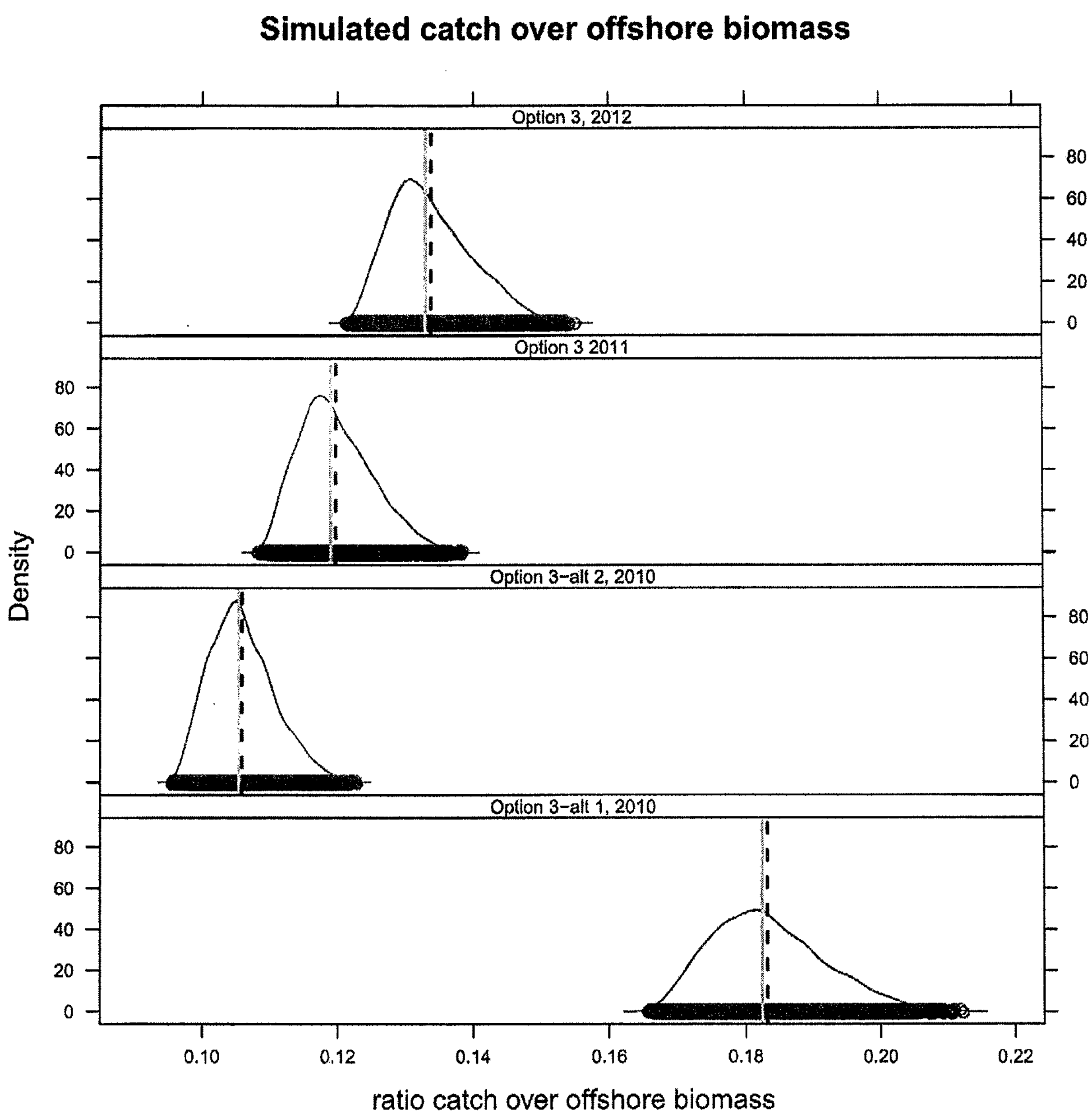


## Simulated inshore biomass

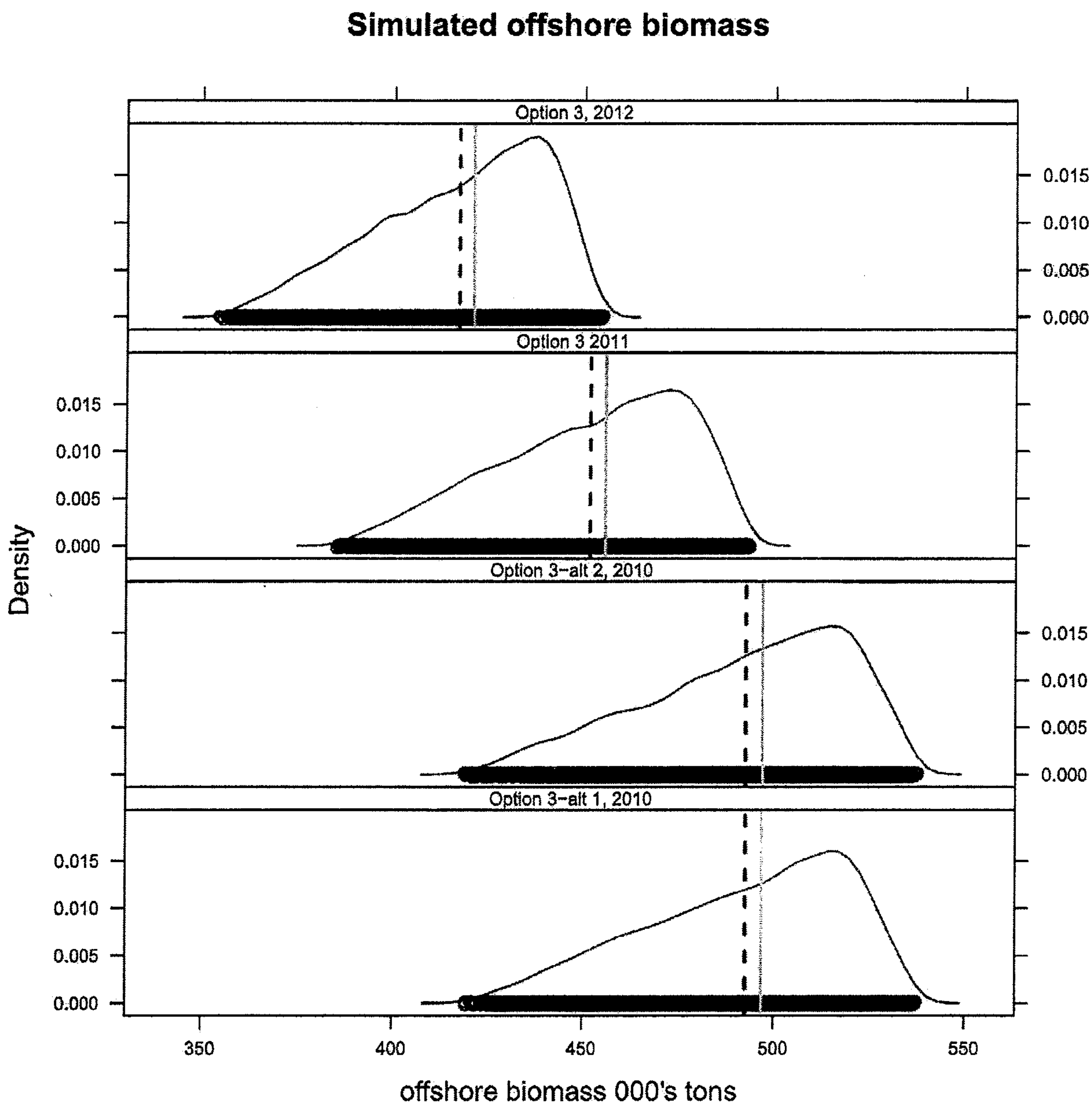




Simulated offshore catch
Option 3, 2012
Option 3 2011
Option 3−alt 2, 2010
Option 3−alt 1, 2010
Density
0.25
0.20
0.15
0.10
0.05
0.00
50
60
70
80
90
offshore catch, 000's t



Simulated catch over offshore biomass
Option 3, 2012
Option 3 2011
Option 3-alt 2, 2010
Option 3-alt 1, 2010
Density
0
20
40
60
80
0.10
0.12
0.14
0.16
0.18
0.20
0.22
ratio catch over offshore biomass


Simulated offshore biomass
Option 3, 2012
Option 3 2011
Option 3-alt 2, 2010
Option 3-alt 1, 2010
0.015
0.010
0.005
0.000
Density
350
400
450
500
550
offshore biomass 000's tons

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# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 4A

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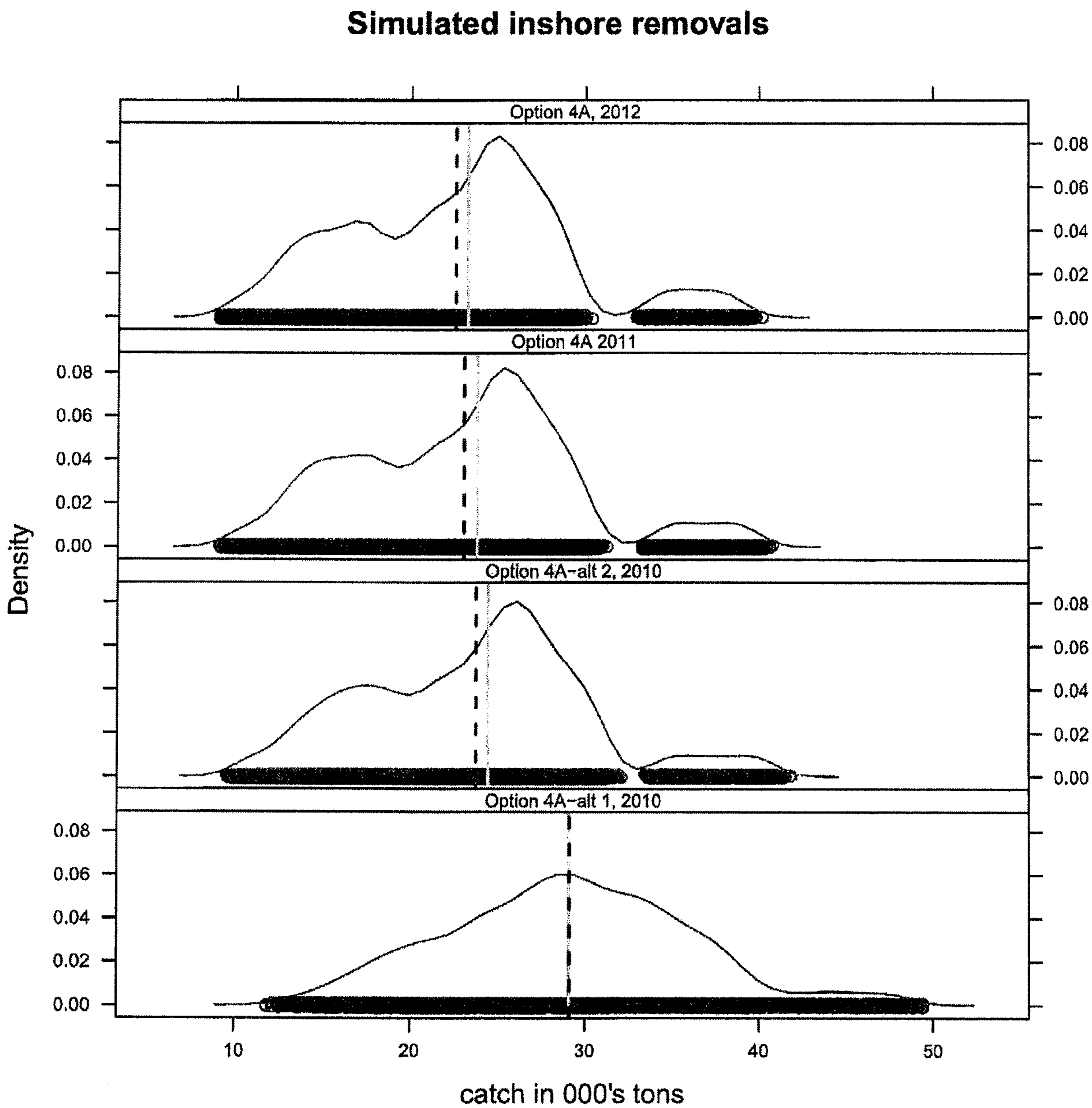
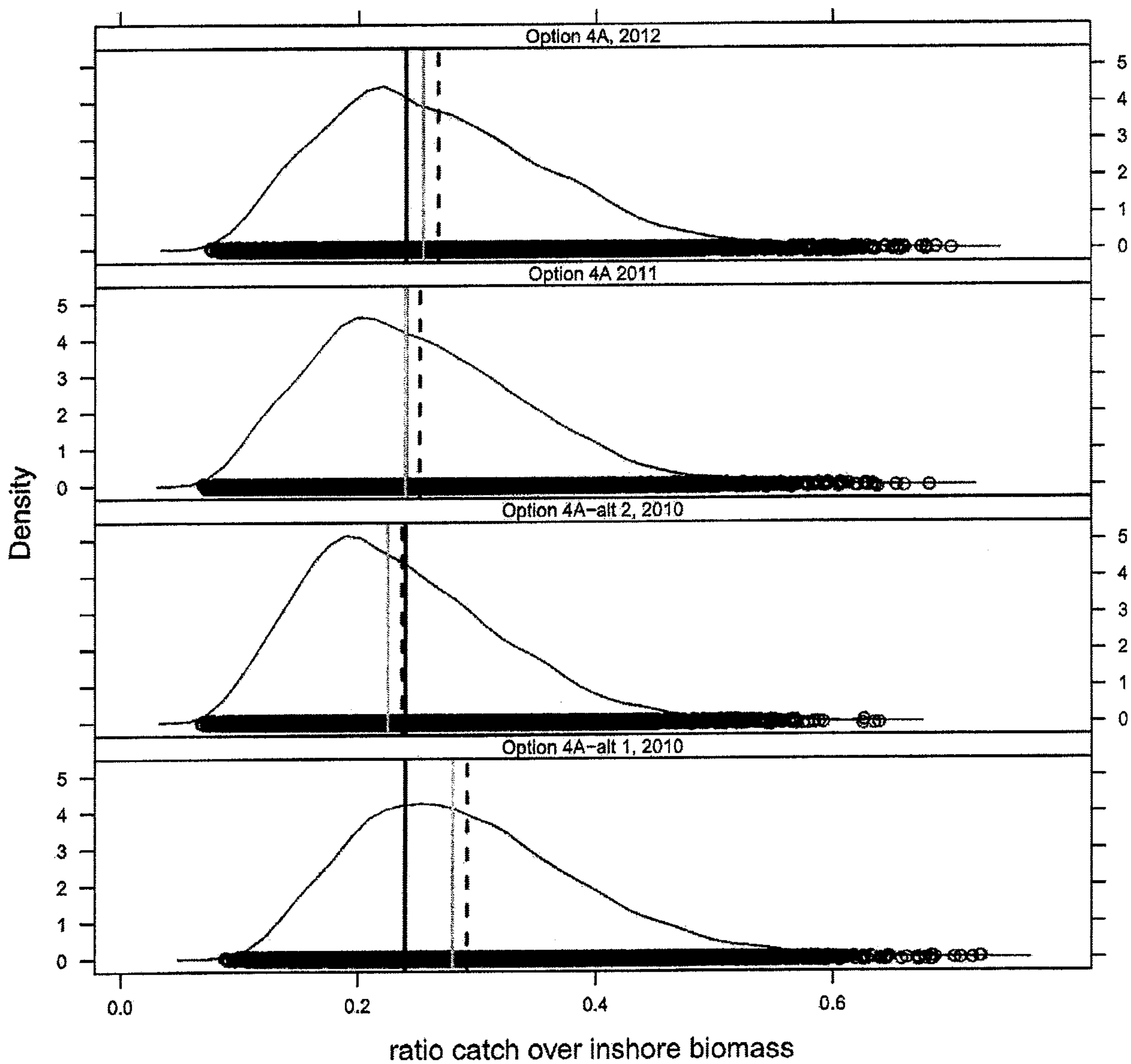
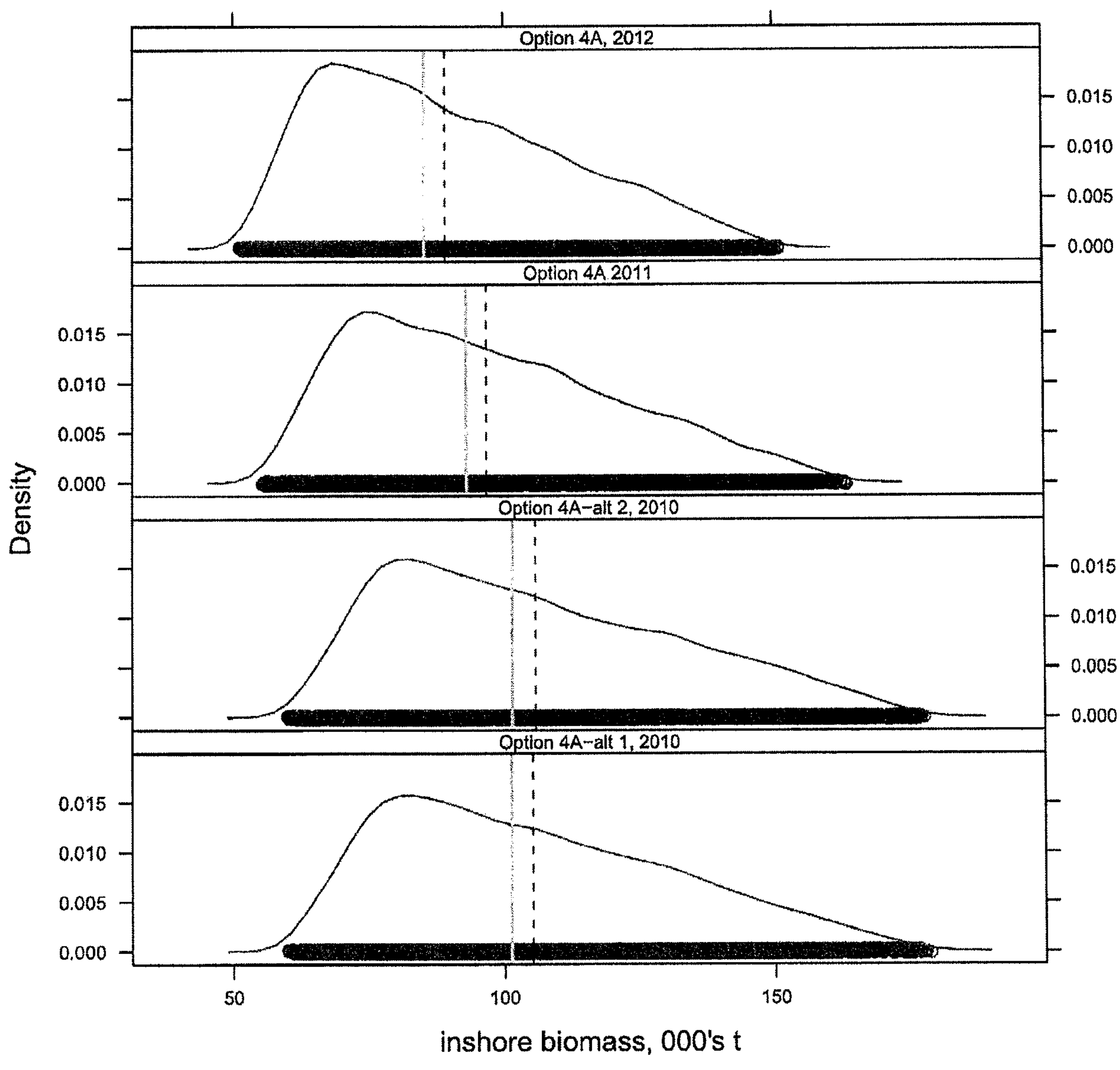
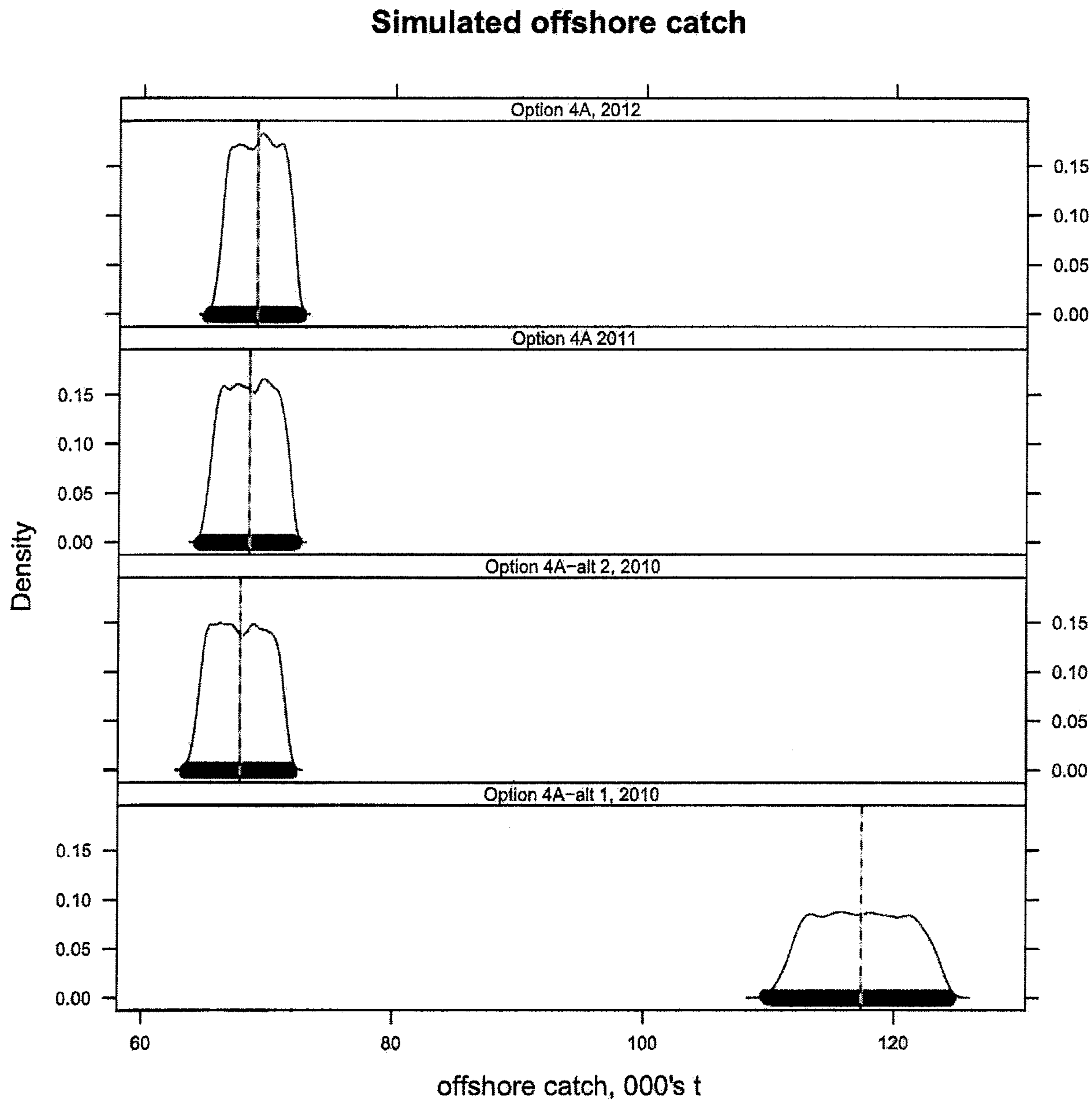

Simulated inshore removals
Option 4A, 2012
Option 4A 2011
Option 4A-alt 2, 2010
Option 4A-alt 1, 2010
0.08
0.06
0.04
0.02
0.00
Density
10
20
30
40
50
catch in 000's tons

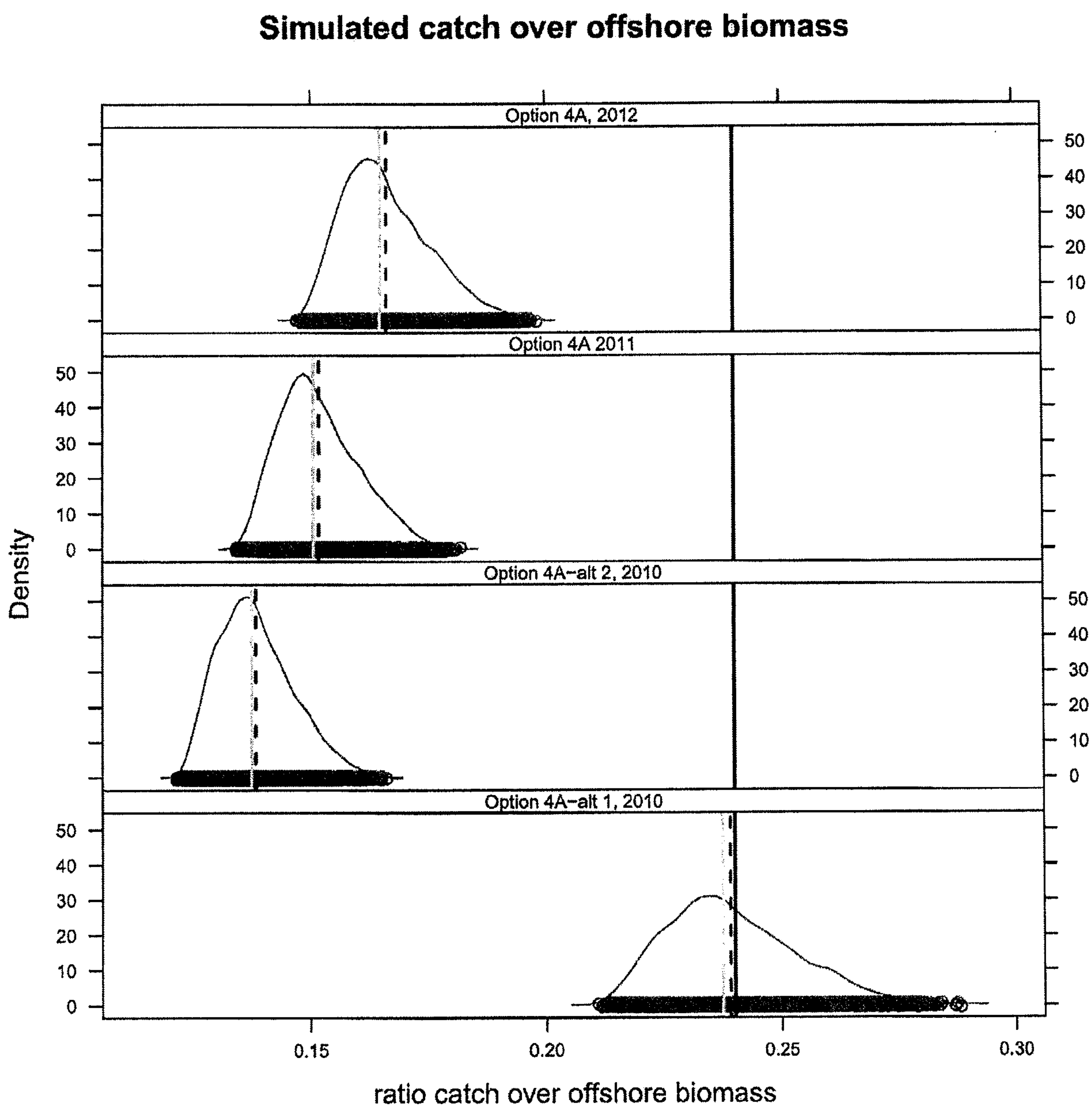
## Simulated catch over inshore biomass

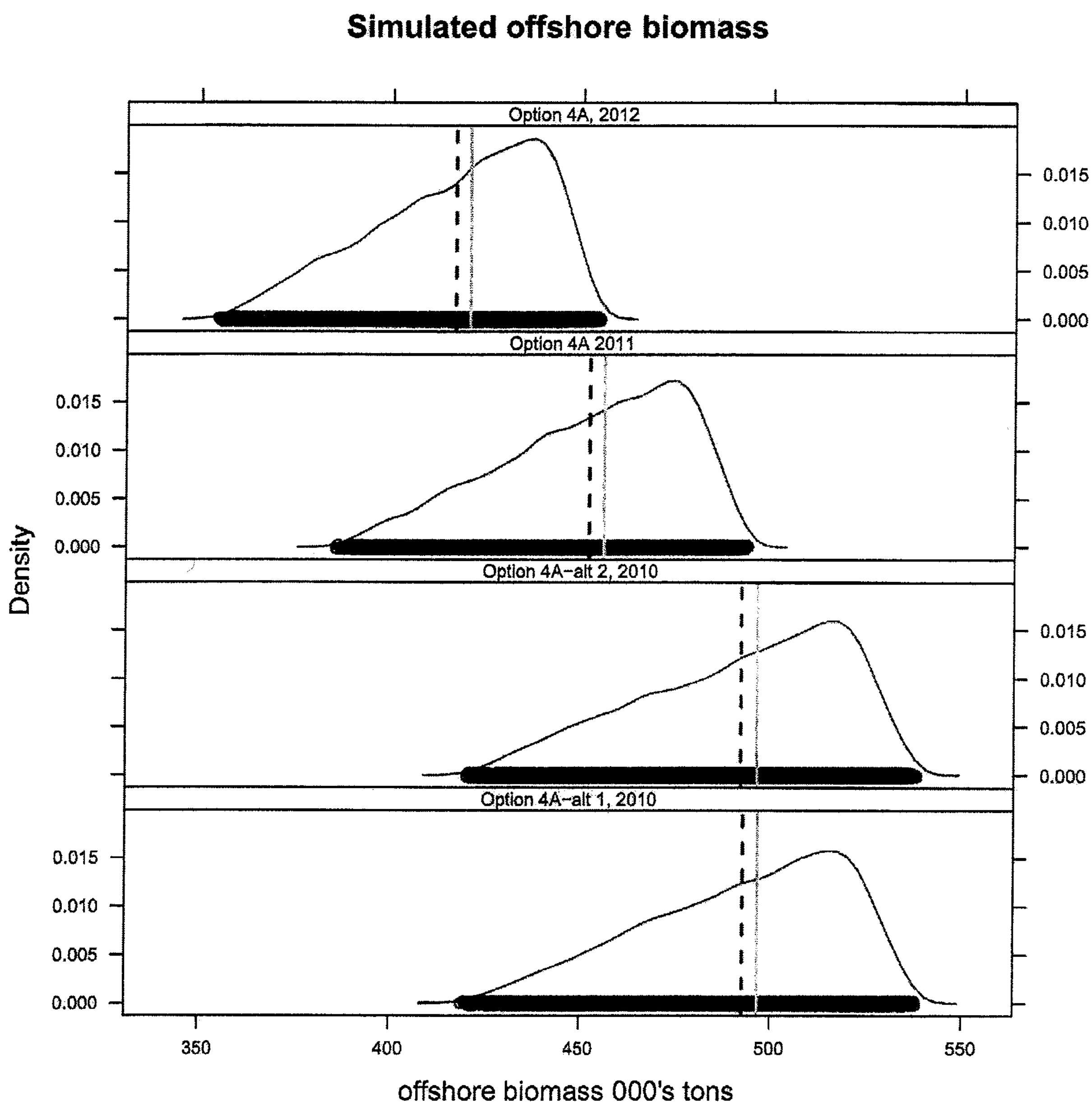


## Simulated inshore biomass




Simulated offshore catch
Option 4A, 2012
Option 4A 2011
Option 4A−alt 2, 2010
Option 4A−alt 1, 2010
Density
0.15
0.10
0.05
0.00
60
80
100
120
offshore catch, 000's t


Simulated catch over offshore biomass
Option 4A, 2012
Option 4A 2011
Option 4A−alt 2, 2010
Option 4A−alt 1, 2010
Density
0
10
20
30
40
50
0.15
0.20
0.25
0.30
ratio catch over offshore biomass


Simulated offshore biomass
Option 4A, 2012
Option 4A 2011
Option 4A−alt 2, 2010
Option 4A−alt 1, 2010
0.015
0.010
0.005
0.000
Density
350
400
450
500
550
offshore biomass 000's tons

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 4B

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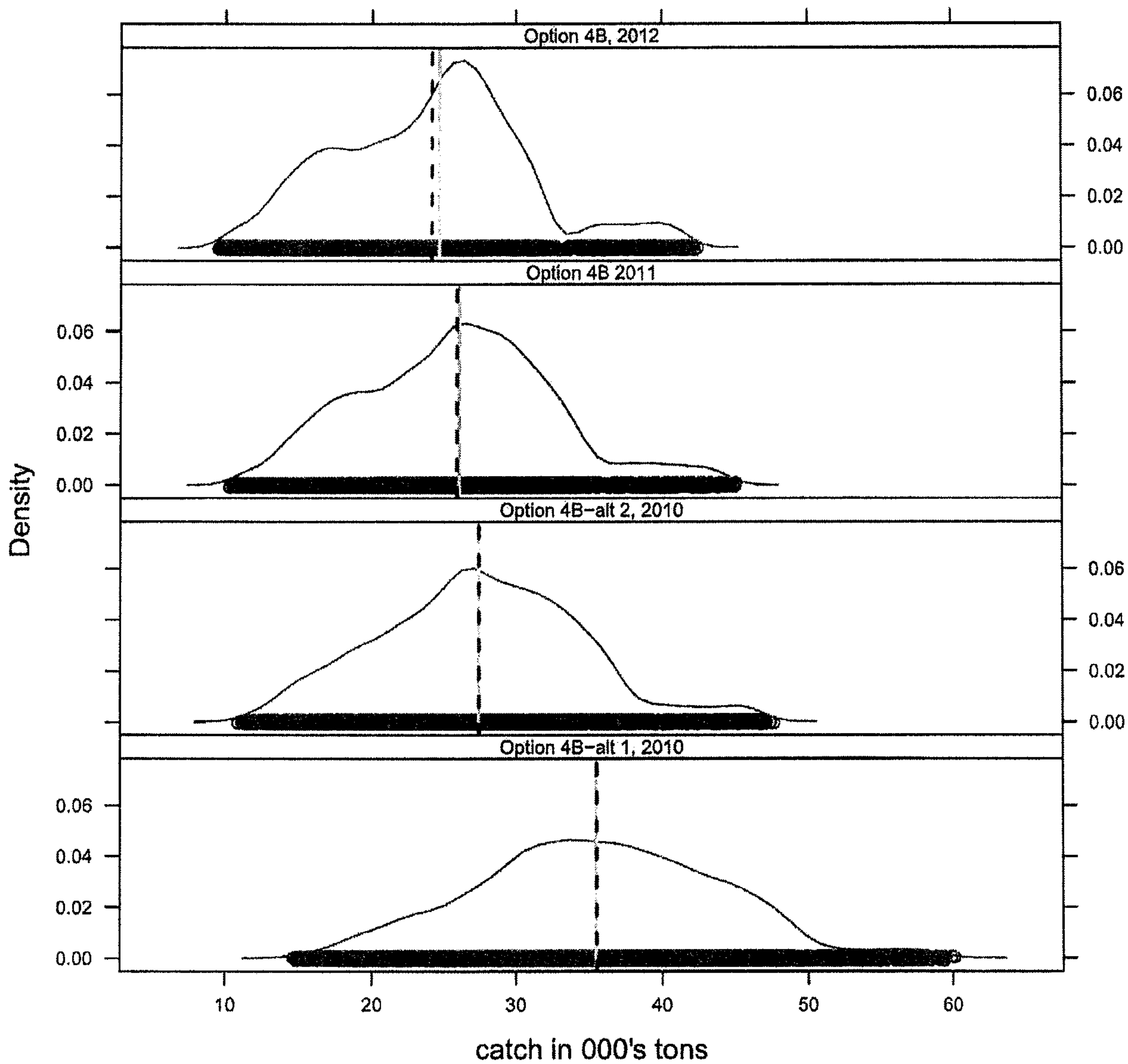
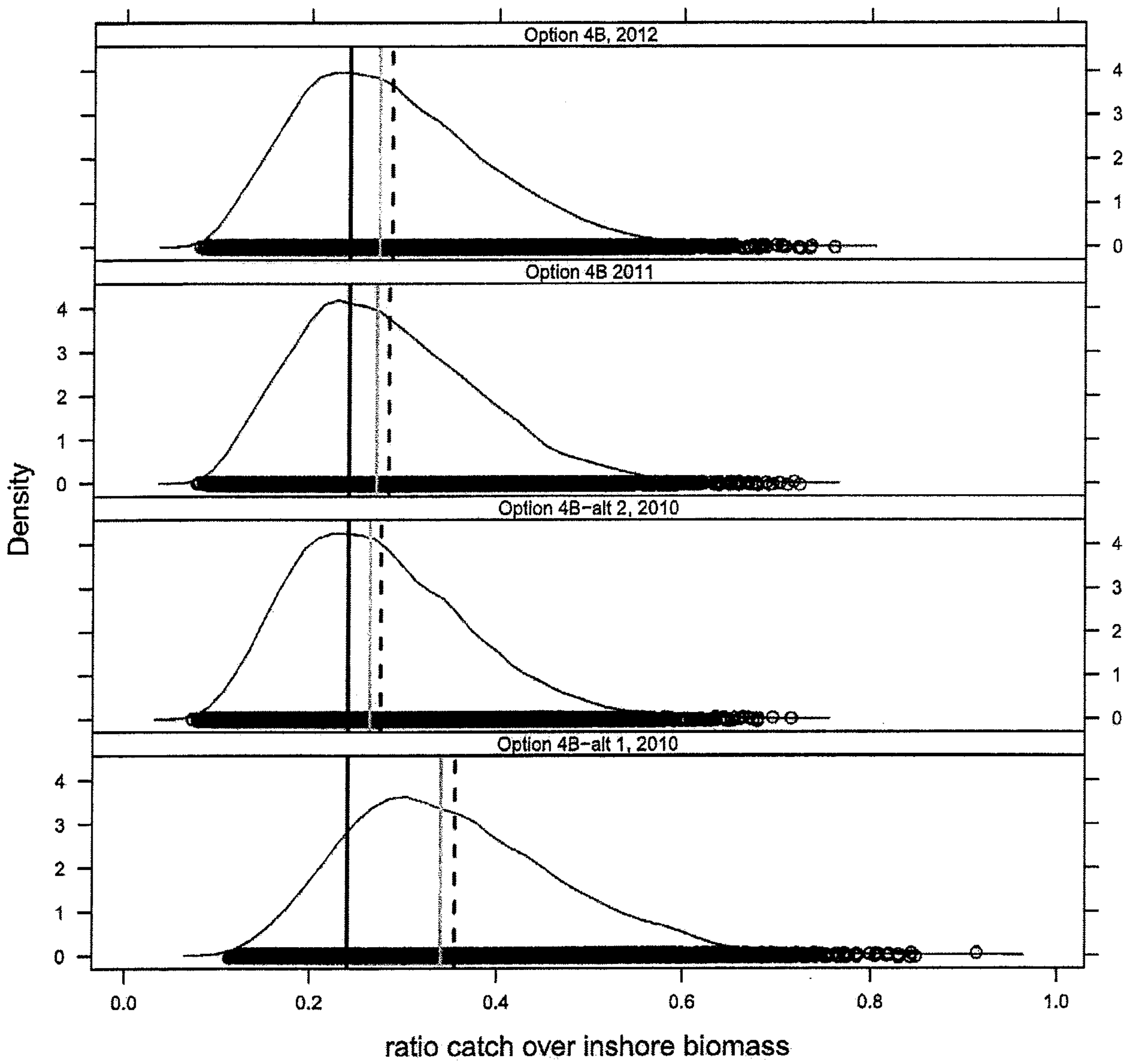
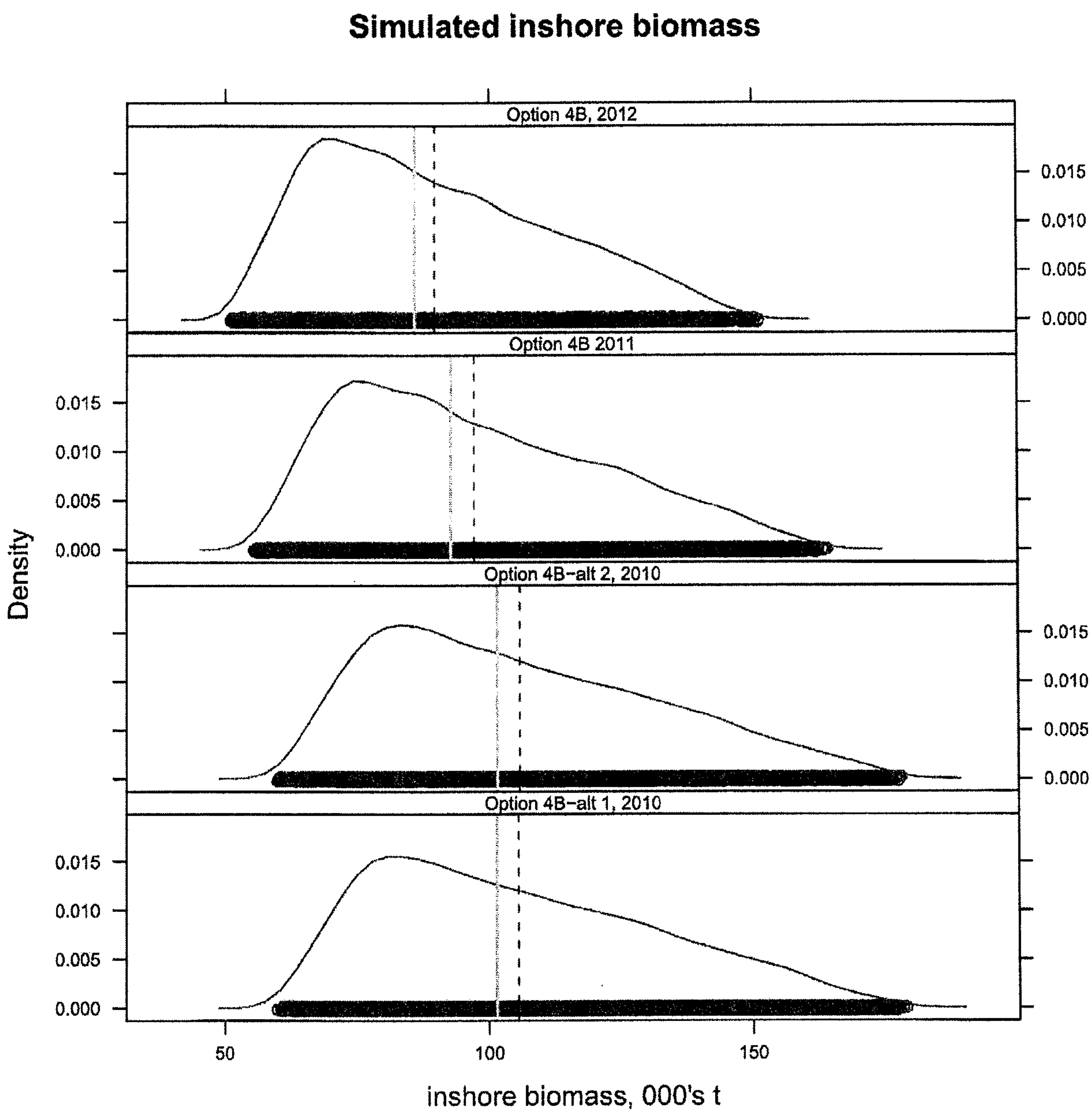
# Simulated inshore removals



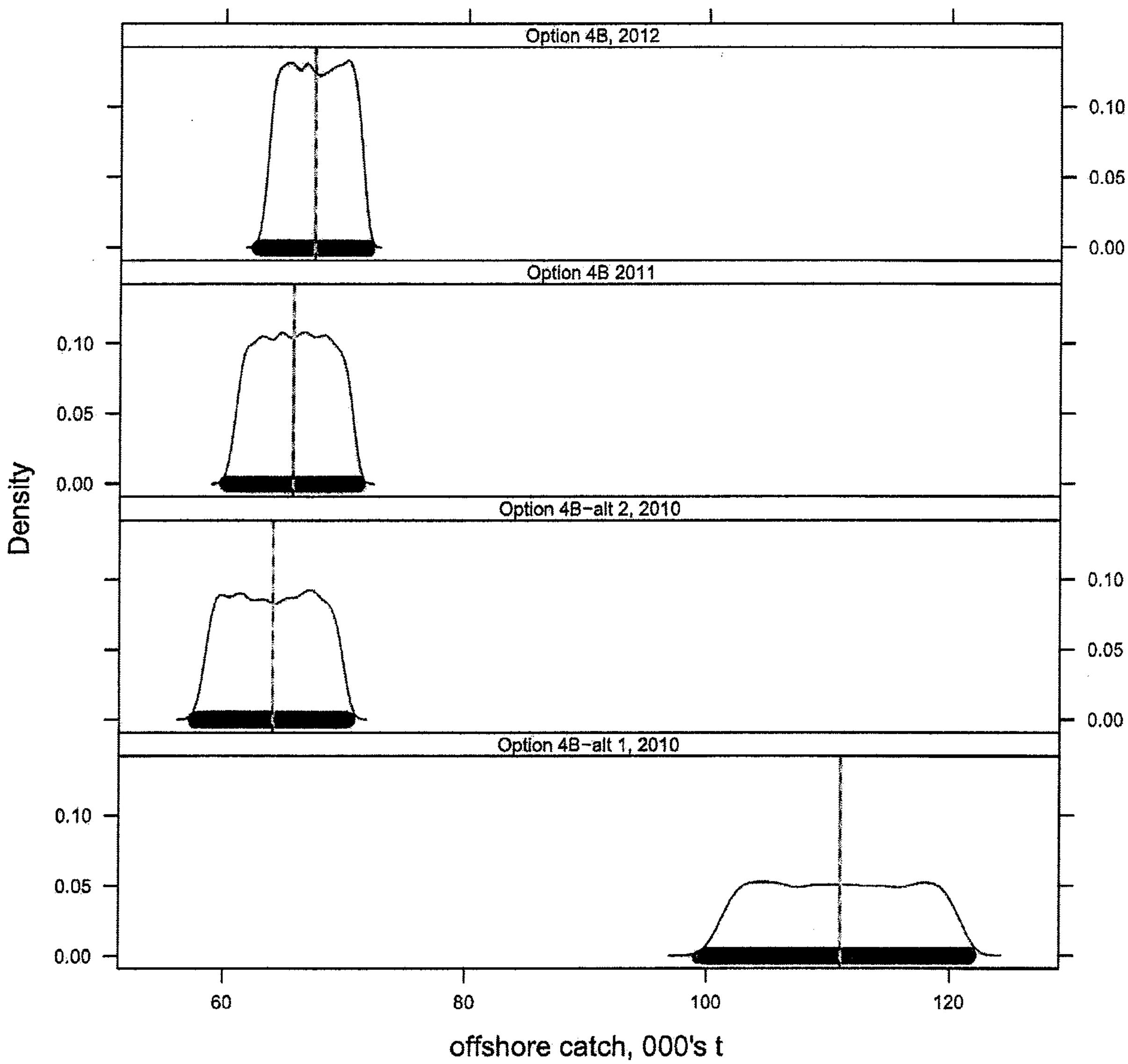
## Simulated catch over inshore biomass



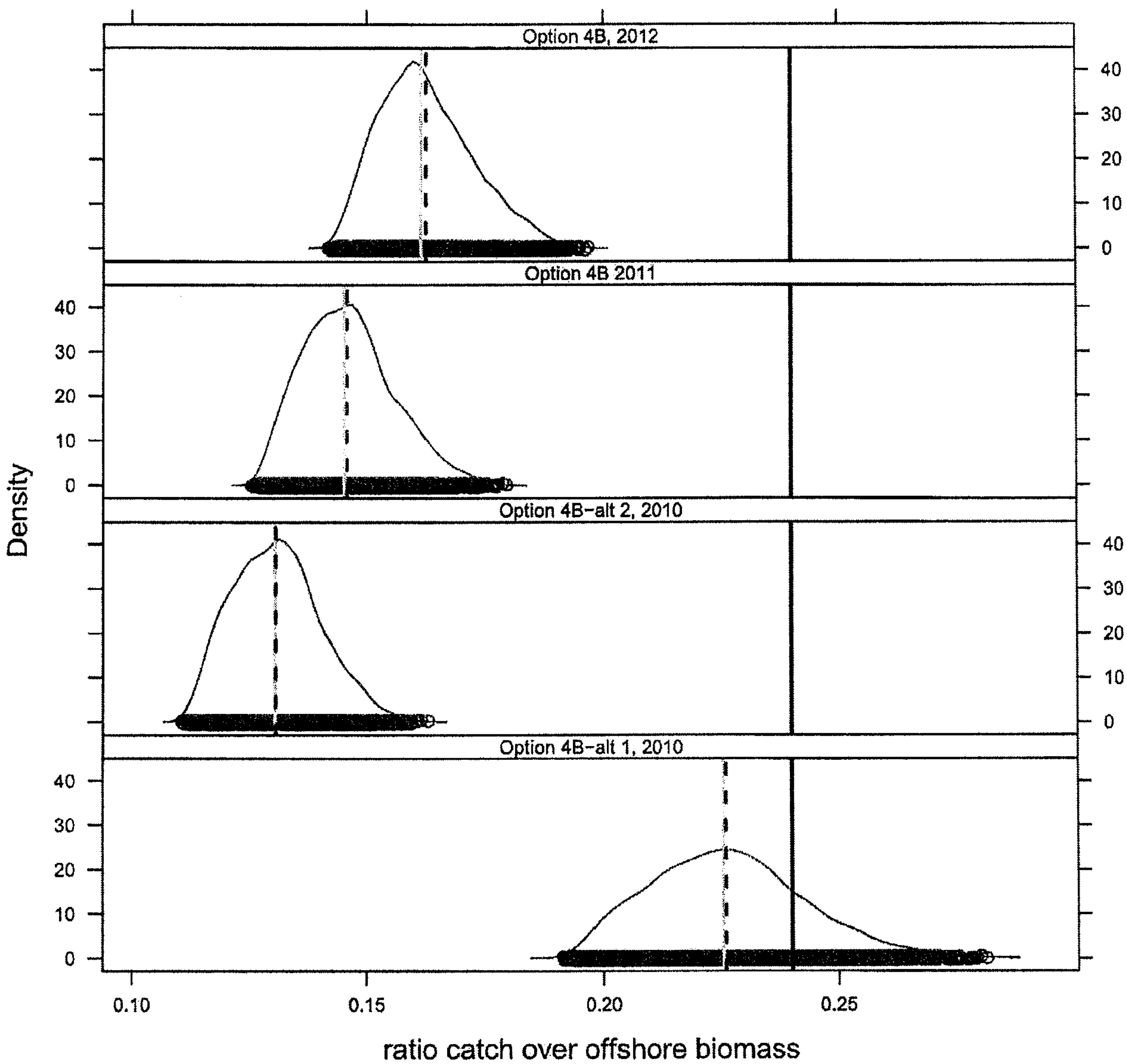


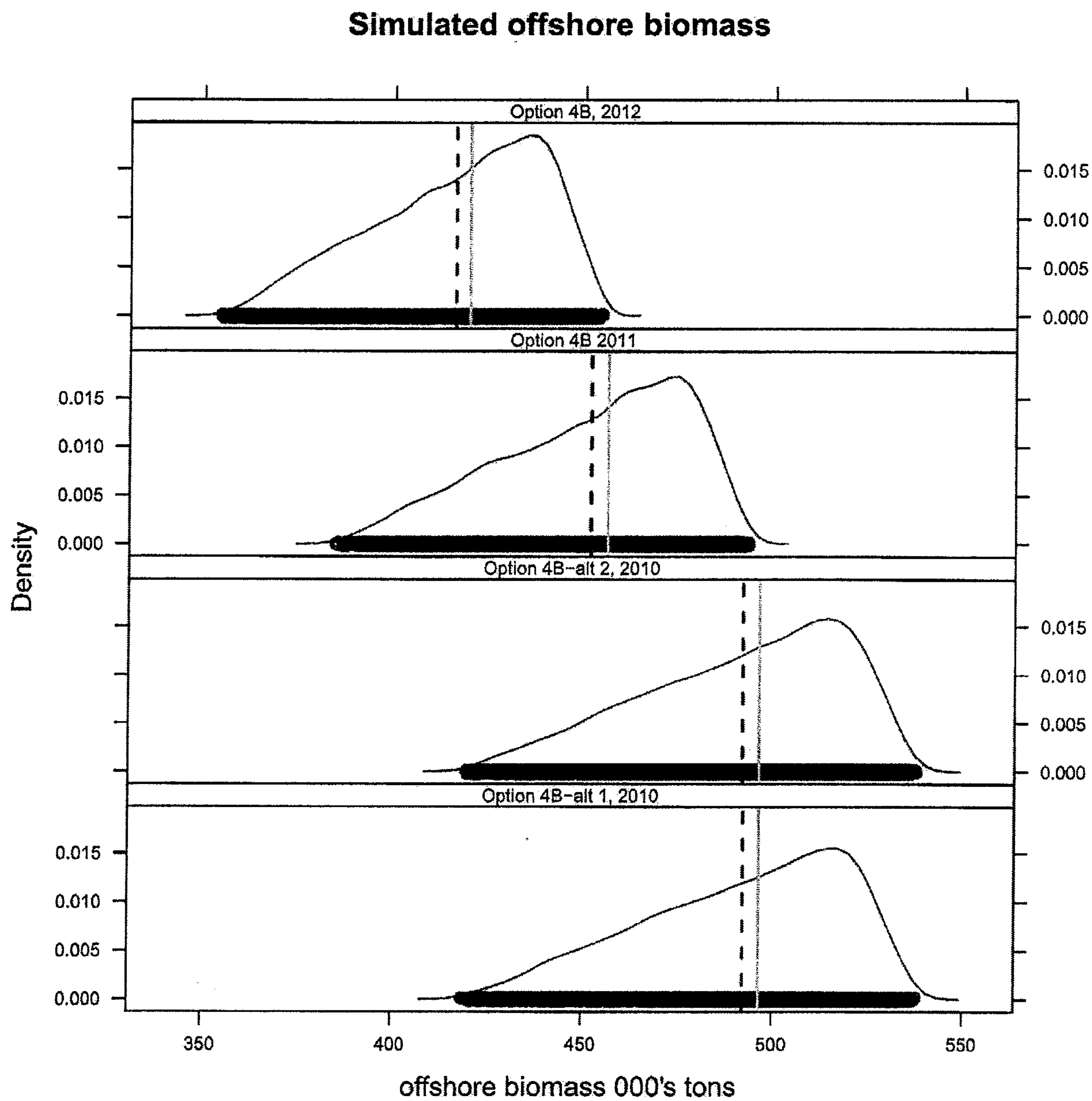
Simulated inshore biomass
Option 4B, 2012
Option 4B 2011
Option 4B-alt 2, 2010
Option 4B-alt 1, 2010
Density
0.000
0.005
0.010
0.015
50
100
150
inshore biomass, 000's t

# Simulated offshore catch



## Simulated catch over offshore biomass





Simulated offshore biomass
Option 4B, 2012
Option 4B 2011
Option 4B-alt 2, 2010
Option 4B-alt 1, 2010
0.015
0.010
0.005
0.000
Density
350
400
450
500
550
offshore biomass 000's tons

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 5

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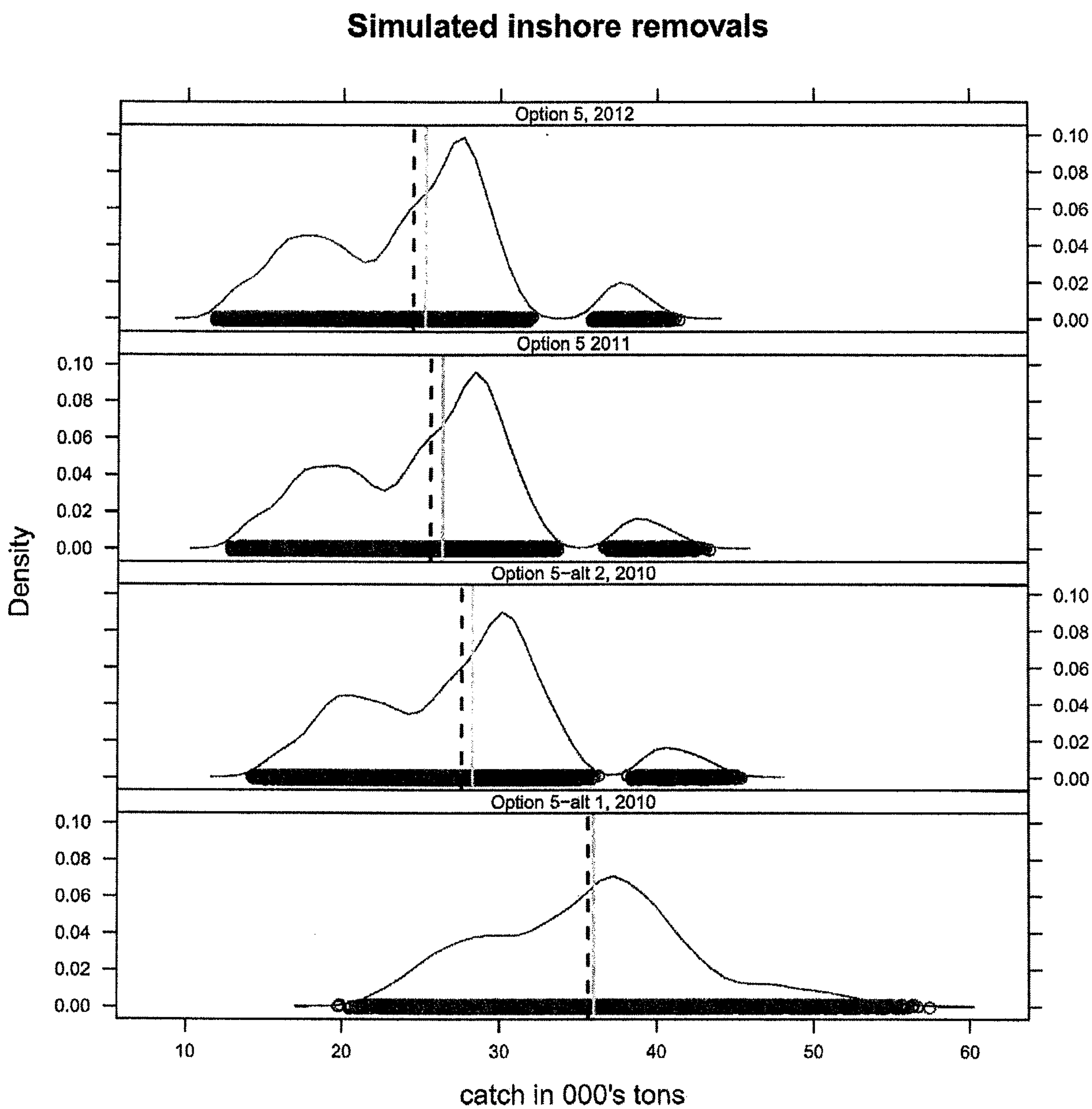
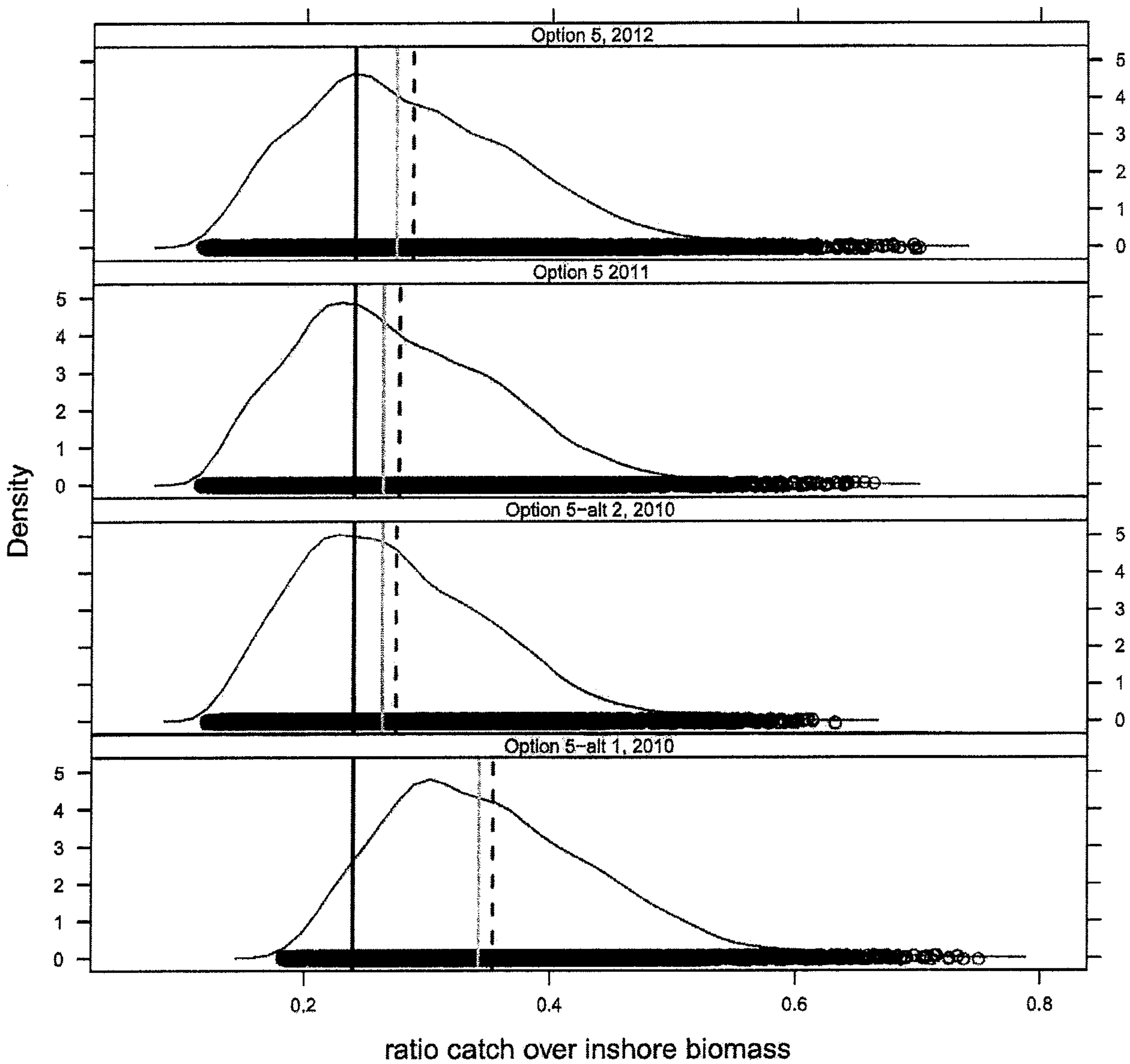
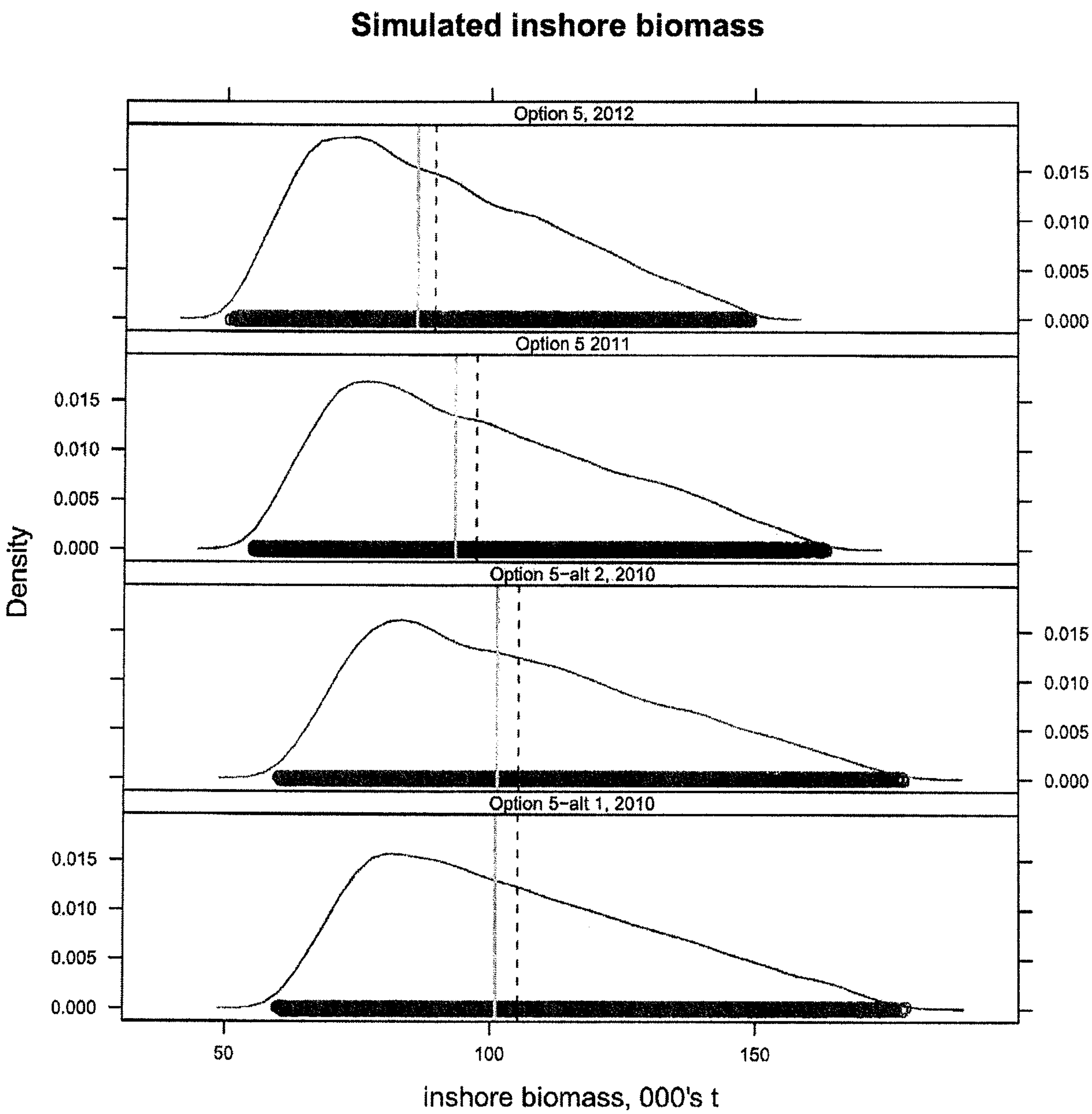


Simulated inshore removals
Option 5, 2012
Option 5 2011
Option 5−alt 2, 2010
Option 5−alt 1, 2010
Density
0.00
0.02
0.04
0.06
0.08
0.10
10
20
30
40
50
60
catch in 000's tons

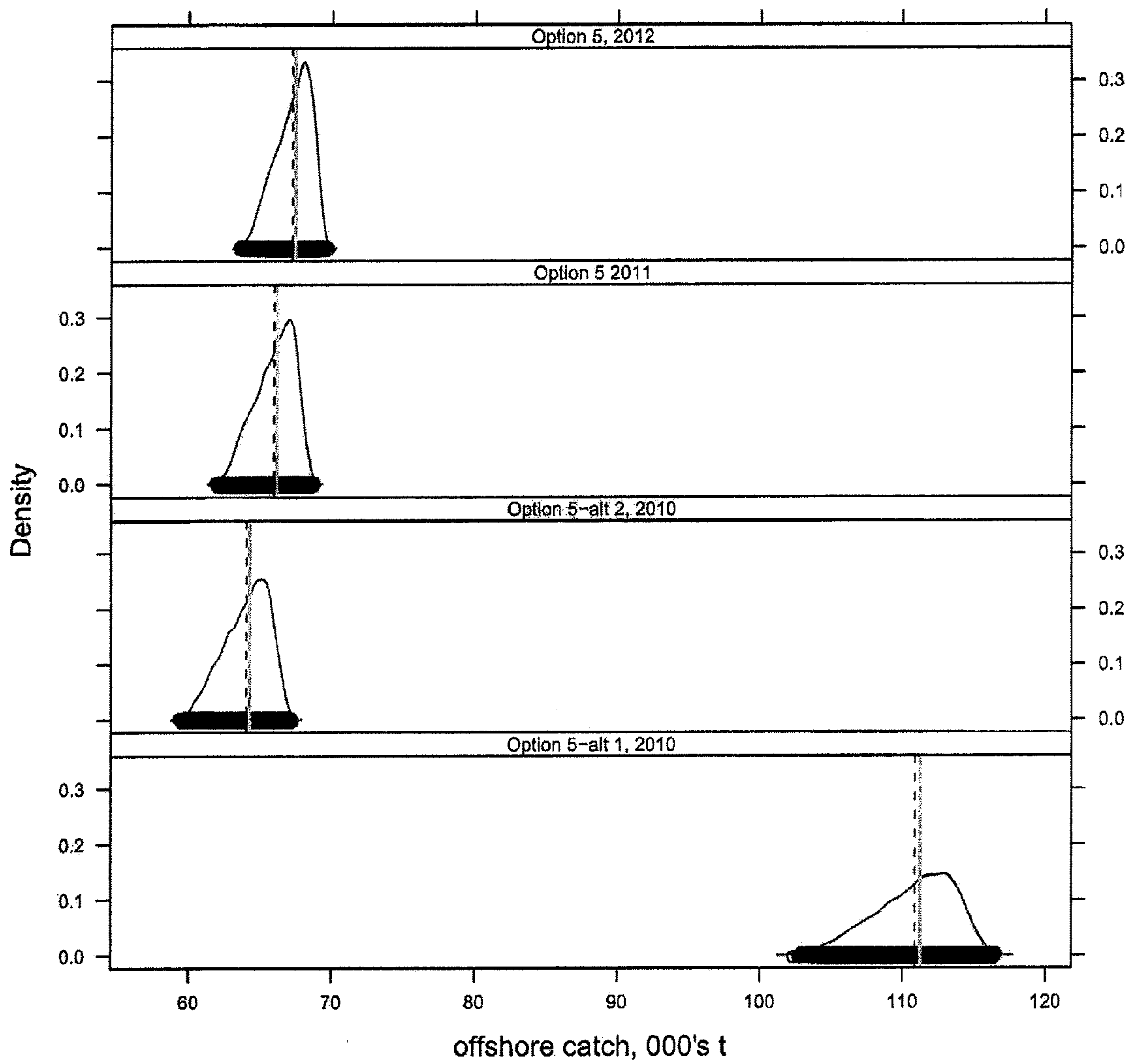
## Simulated catch over inshore biomass

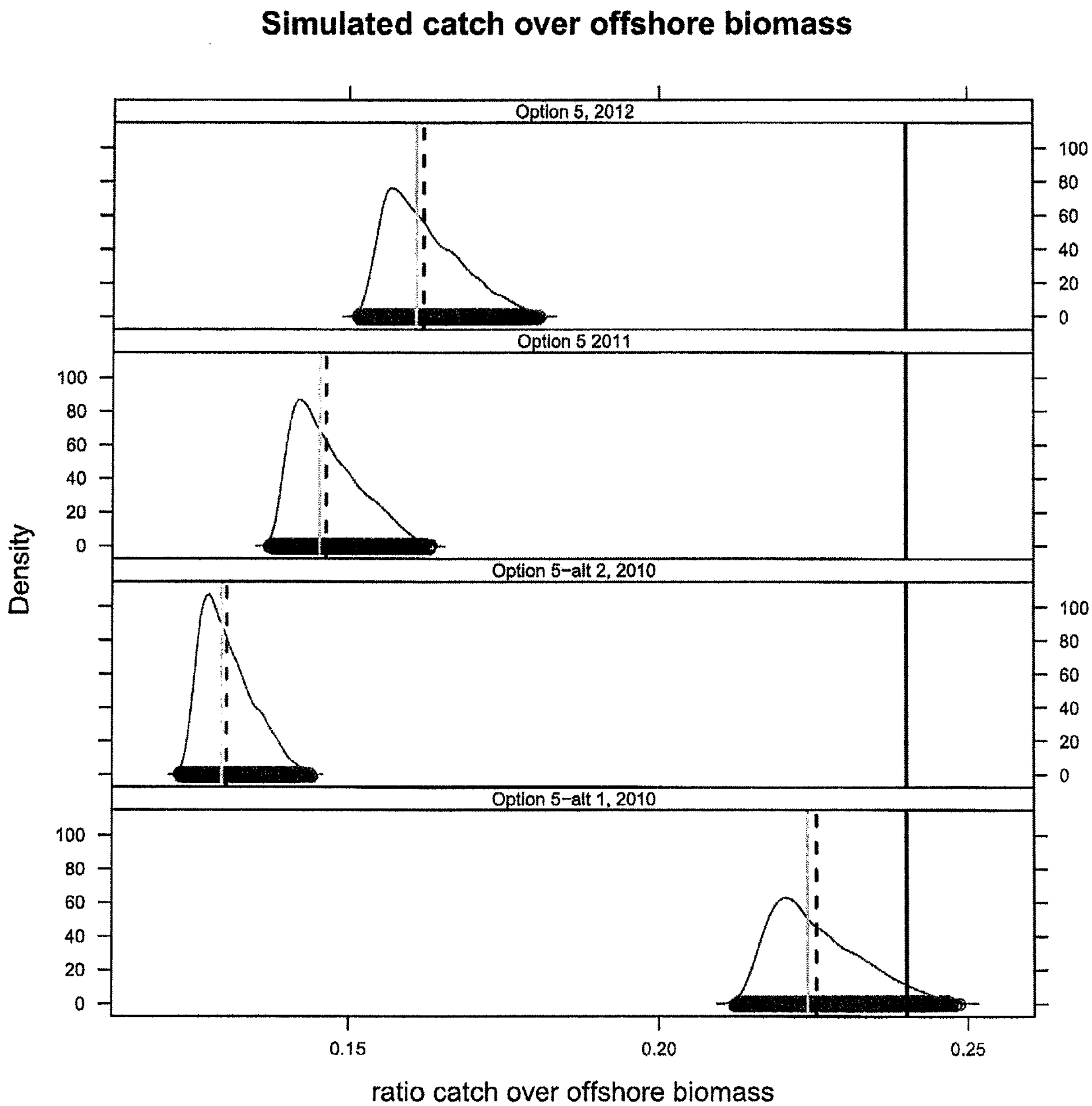




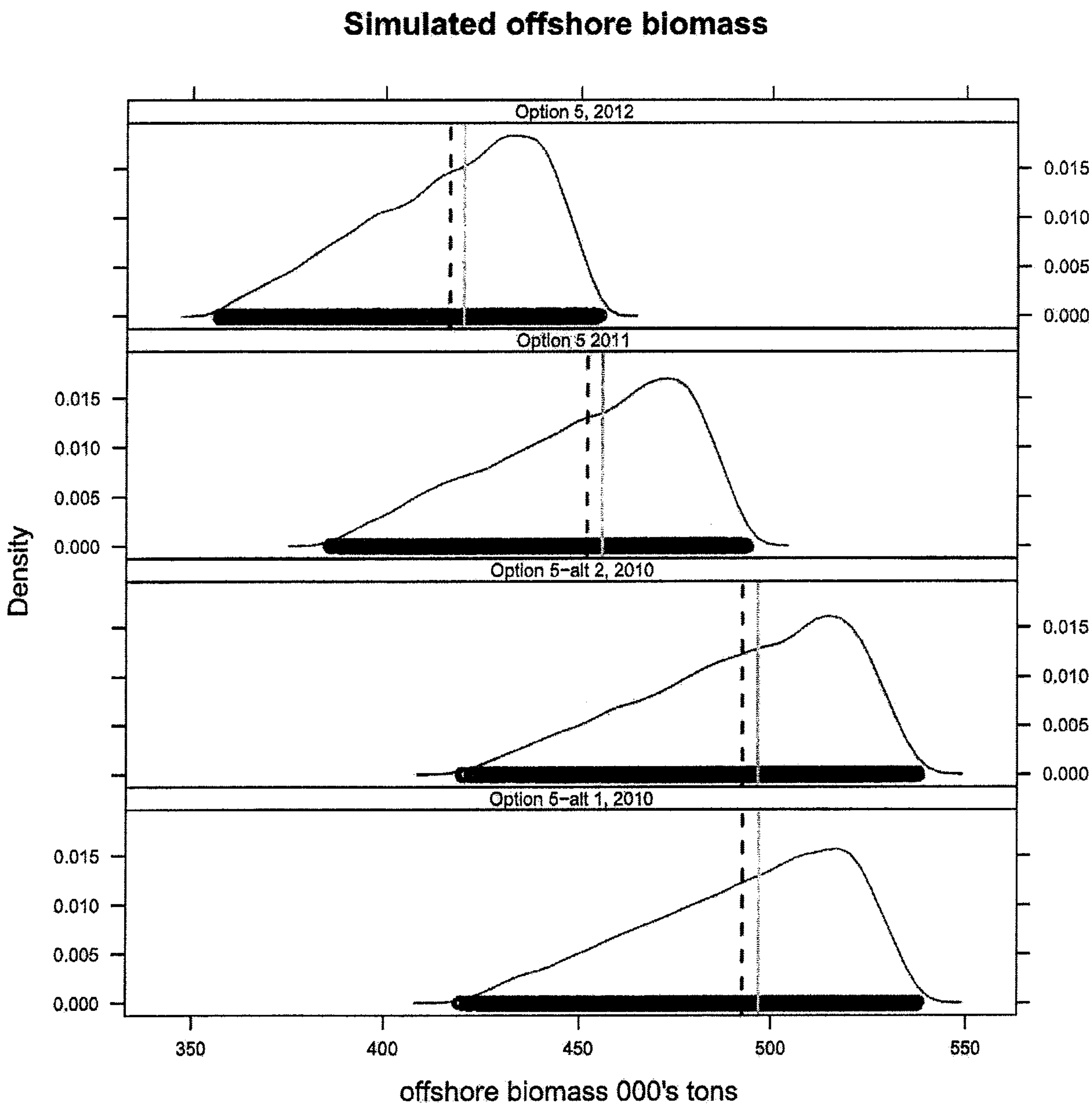
Simulated inshore biomass
Option 5, 2012
Option 5 2011
Option 5-alt 2, 2010
Option 5-alt 1, 2010
0.015
0.010
0.005
0.000
Density
50
100
150
inshore biomass, 000's t

## Simulated offshore catch





Simulated catch over offshore biomass
Option 5, 2012
Option 5 2011
Option 5-alt 2, 2010
Option 5-alt 1, 2010
Density
100
80
60
40
20
0
0.15
0.20
0.25
ratio catch over offshore biomass



Simulated offshore biomass
Option 5, 2012
Option 5 2011
Option 5-alt 2, 2010
Option 5-alt 1, 2010
0.015
0.010
0.005
0.000
Density
350
400
450
500
550
offshore biomass 000's tons

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

# 2010-2012 Atlantic Herring Fishery Specifications

# APPENDIX III:

# OPTION 6

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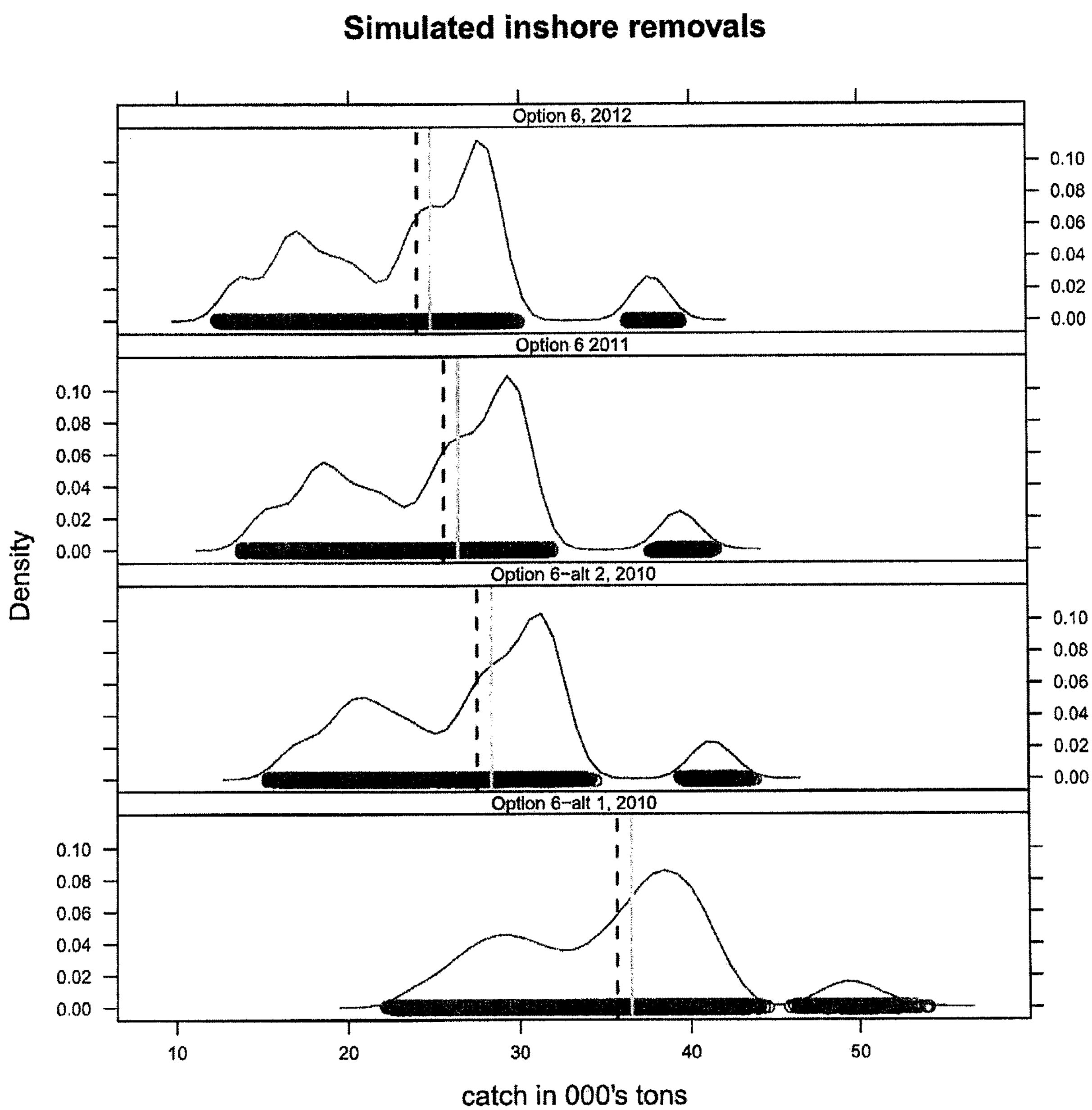
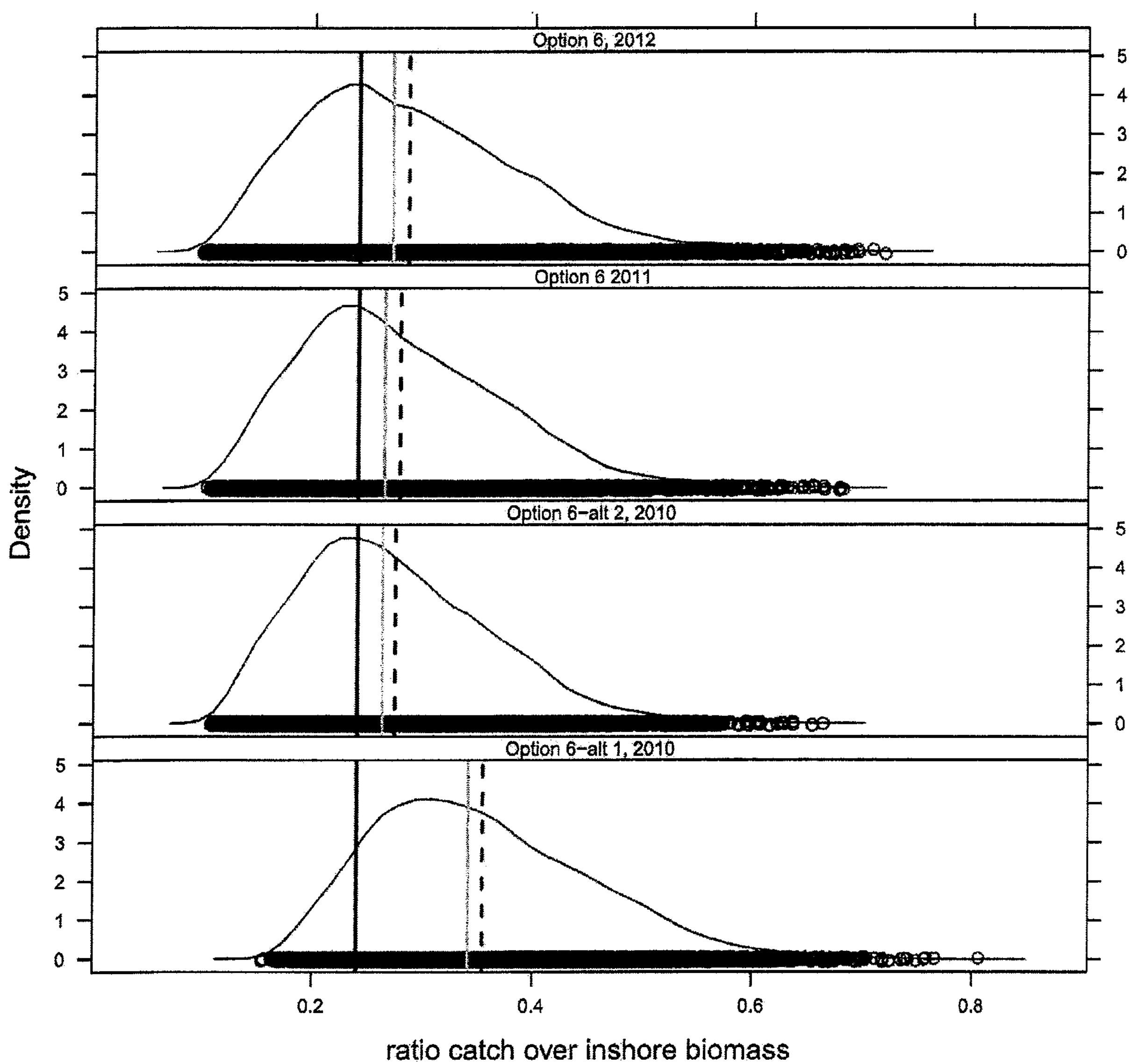
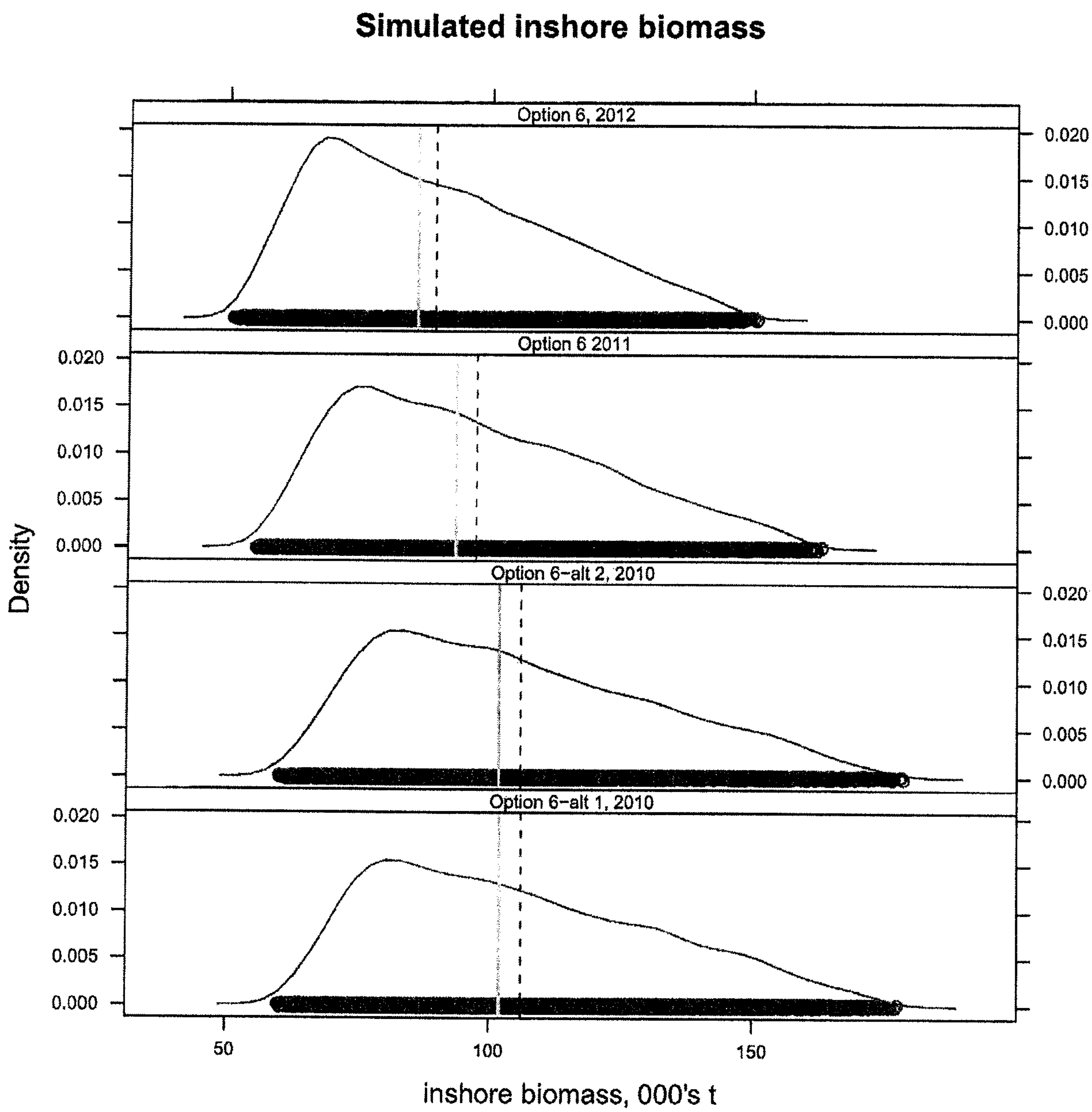
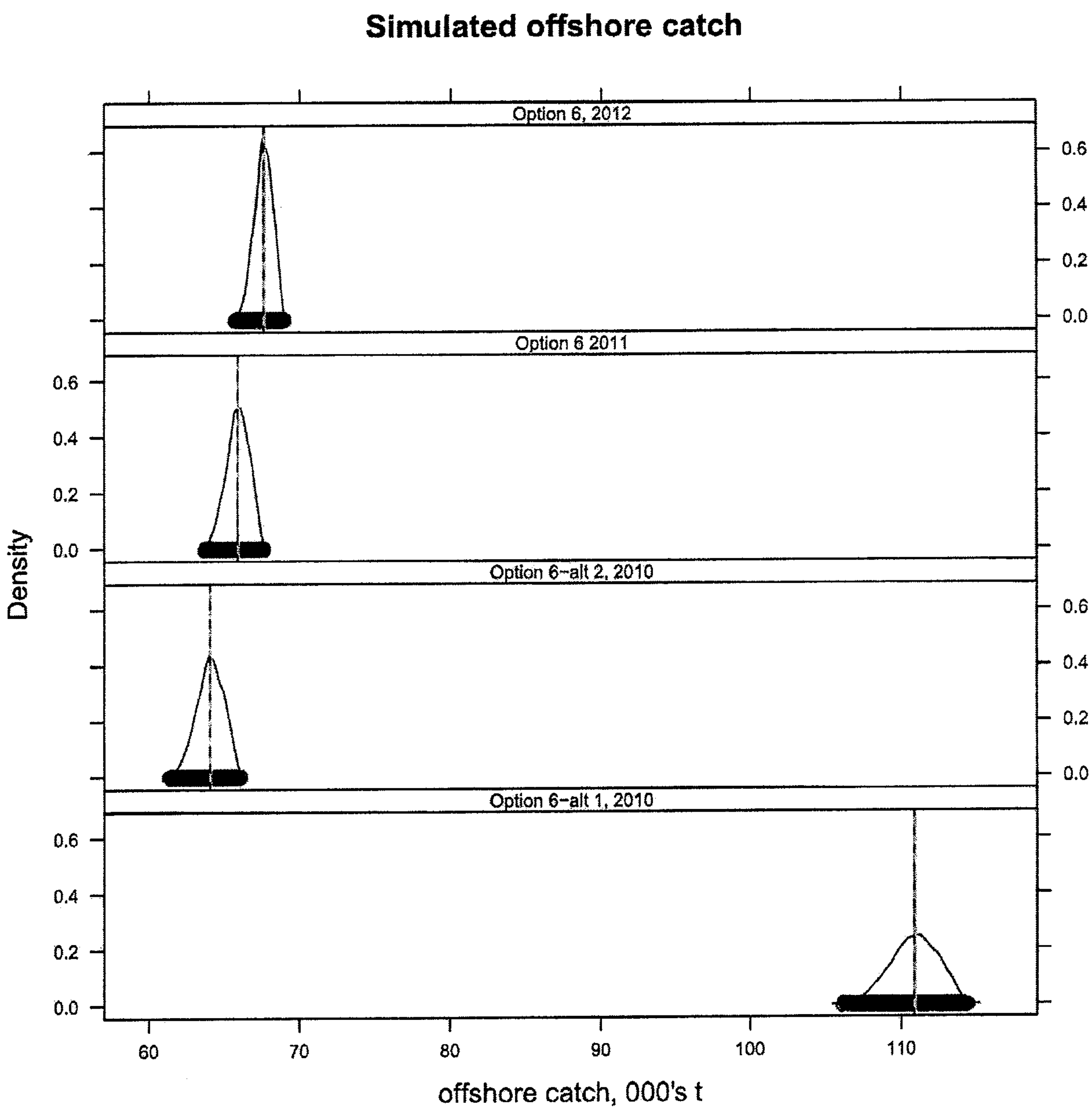

Simulated inshore removals
Option 6, 2012
Option 6 2011
Option 6-alt 2, 2010
Option 6-alt 1, 2010
Density
0.00
0.02
0.04
0.06
0.08
0.10
10
20
30
40
50
catch in 000's tons

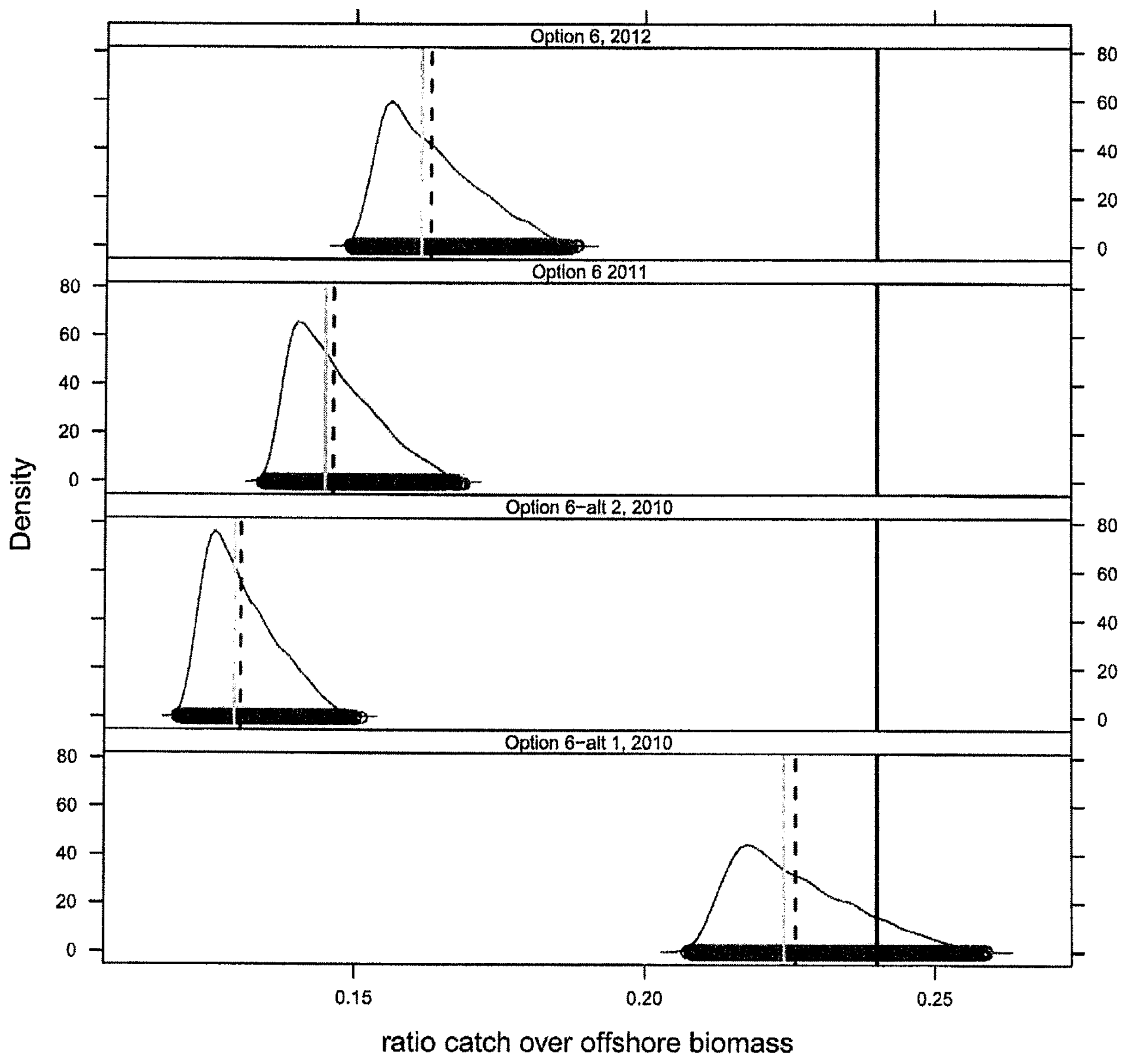
## Simulated catch over inshore biomass

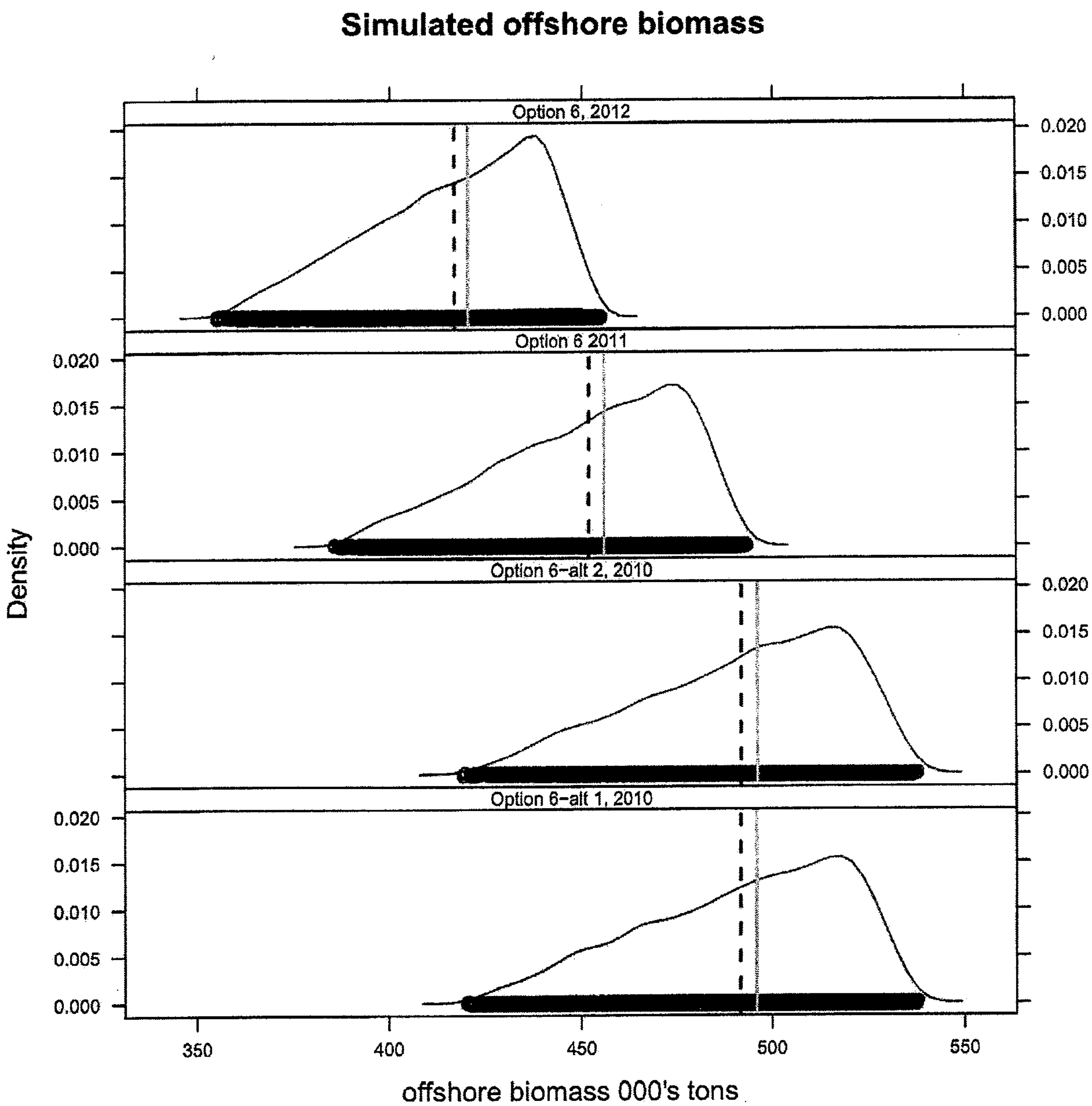



Simulated inshore biomass
Option 6, 2012
Option 6 2011
Option 6-alt 2, 2010
Option 6-alt 1, 2010
Density
0.000
0.005
0.010
0.015
0.020
50
100
150
inshore biomass, 000's t


Simulated offshore catch
Option 6, 2012
Option 6 2011
Option 6-alt 2, 2010
Option 6-alt 1, 2010
Density
0.0
0.2
0.4
0.6
60
70
80
90
100
110
offshore catch, 000's t

## Simulated catch over offshore biomass




Simulated offshore biomass
Option 6, 2012
Option 6 2011
Option 6-alt 2, 2010
Option 6-alt 1, 2010
Density
0.000
0.005
0.010
0.015
0.020
350
400
450
500
550
offshore biomass 000's tons