#19a

Additional Correspondence

Joan O'Leary

From: Captain Gary Cannell Tuna Hunter <tunahunter@gmail.com>
Sent: Thursday, November 06, 2014 3:13 PM
To: comments
Subject: Closing Gulf of Maine

RECEIVED
NOV -6 2014
NEW ENGLAND FISHERY
MANAGEMENT COUNCIL

Dear Sir

I can't believe the council wants to close rod and reel recreation and charter boat fishing in the western gulf of Maine.

On Nov. 3rd I was on charter tuna fishing nwc of Stellwagen Bank. I was fishing with three rods three hooks. While tuna fishing I was surrounded by nine 50 to 70 foot bottom draggers killing all bottom life.To the south 6 miles on middle bank there were 10 more draggers killing all the bottom life.

I do not understand how you can consider closing down the hook and line fishing. This closure will close down thousands of jobs and thousands of business !

I would like to know why these important meetings are not near Boston and publicized so thousands of people could find out what's going on !

This is very sad !
Gary Cannell
Tuna Hunter Charters

Sent from my iPad

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026

November 10, 2014

RECEIVED
NOV 10 2014
NEW ENGLAND FISHERY
MANAGEMENT COUNCIL

Jackie Odell
Executive Director
Northeast Seafood Coalition

Vito Giacalone
Executive Director
Gloucester Fishing Community Preservation Fund

Dear Jackie and Vito,

Thank you for your October 17, 2014 letter expressing concerns regarding the Gulf of Maine cod assessment conducted by the Center in August. In your letter, you raise specific concerns about the assessment process and the lack of transparency in the decision-making process that led to this assessment. I recognize the importance of these issues, and appreciate that you took the time to discuss them with us at the recent Northeast Regional Coordinating Council (NRCC) meeting.

As I mentioned during the NRCC meeting, this summer's update of the Gulf of Maine cod assessment was neither planned nor scheduled. I stand behind the quality and integrity of the work that was done on this assessment by our scientists and note that their results were successfully peer reviewed, However, along with excellent science, my commitment is for a process which emphasizes communication, engagement and transparency. In this instance we did not make good on this commitment and this has, unsurprisingly, eroded the trust, which we strive to establish and build. I am accountable for this and I accept full responsibility. I understand that this places an extra burden on us to rebuild trust and this is a very high priority for me.

Unfortunately, the results of the assessment raised serious concerns regarding the declining condition of the stock, and it was essential for us to bring the information forward for consideration by the Council. We acknowledge that this placed a heavy burden on the scientific and management processes, and we greatly appreciate the extraordinary efforts of Council staff, Council members and SSC members to quickly mobilize for the immediate action which enabled the peer review to take place before the September 2014 Council meeting.

We also understand your concerns regarding implications for business planning and management once assessments reveal the occurrence of rapidly changing population. Furthermore, we understand the extent to which the scientific information we bring forward impacts the lives of those who depend on the New England groundfish fishery and we take this very seriously.

We look forward to working with the NRCC and our industry stakeholders as we strive to reform the stock assessment process and improve our communications and transparency.

Please do not hesitate to contact me if you would like to have further discussion of this issue.

Sincerely,

William Karp

William A. Karp, Ph.D.
Science and Research Director
Northeast Fisheries Science Center

cc:

J. Bullard
T. Nies

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
55 Great Republic Drive
Gloucester, MA 01930-2276

RECEIVED
NOV 10 2014
NEW ENGLAND FISHERY
MANAGEMENT COUNCIL

NOV - 6 2014

Richard Beal
42 Beacon St.
Gloucester, MA 01930

Dear Richard:

Thank you for the comments and concerns you raised in your October 14 letter about the history of the New England fishing industry and how some of the regulations have impacted you and others. I appreciate your willingness to share your experiences. It is clear from your letter that it is vitally important that we maintain a vibrant and healthy New England fishing industry. I agree.

I also agree with you that the rapid decline of Gulf of Maine (GOM) cod is not just due to overfishing; there are other factors likely at play, including some of those you mention. The simple truth is that GOM cod is in poor condition under any metric we use to evaluate stock health, and we have not appropriately constrained fishing mortality on the stock.

For GOM cod to recover, additional measures beyond catch reductions will be necessary. The New England Fishery Management Council agrees, and has requested that we develop an emergency action that would put temporary measures in place to protect GOM cod during fishing year 2014. At the same time, the Council is developing permanent measures to end overfishing and to enhance GOM cod rebuilding efforts as part of Framework Adjustment 53, which is scheduled for implementation at the start of fishing year 2015 (May 1, 2015). I encourage you to participate in the upcoming discussions that will be held by the Groundfish Advisory Panel, Groundfish Oversight Committee, and the whole Council.

This is a challenging time for groundfish management in New England. We will continue to work with the Council, members of the fishing industry, and fishing communities, to mitigate the economic impacts of potential catch reductions to the extent that we can. While current management measures will result in short-term economic impacts, sustainably managing our fisheries is expected to result in sustainable businesses in the long-term.

Please feel free to contact my staff in the Sustainable Fisheries Division at (978) 281-9315 if you have any additional questions.

Sincerely,

for John K. Bullard
Regional Administrator

cc: Jackie Odell, Northeast Seafood Coalition
Terry Stockwell, New England Fishery Management Council

3

Joan O'Leary

From: Captain Gary Cannell Tuna Hunter <tunahunter@gmail.com>
Sent: Thursday, November 06, 2014 3:13 PM
To: comments
Subject: Closing Gulf of Maine

RECEIVED
NOV - 6 2014
NEW ENGLAND FISHERY MANAGEMENT COUNCIL

Dear Sir

I can't believe the council wants to close rod and reel recreation and charter boat fishing in the western gulf of Maine.

On Nov. 3rd I was on charter tuna fishing nwc of Stellwagen Bank. I was fishing with three rods three hooks. While tuna fishing I was surrounded by nine 50 to 70 foot bottom draggers killing all bottom life.To the south 6 miles on middle bank there were 10 more draggers killing all the bottom life.

I do not understand how you can consider closing down the hook and line fishing. This closure will close down thousands of jobs and thousands of business !

I would like to know why these important meetings are not near Boston and publicized so thousands of people could find out what's going on !

This is very sad !
Gary Cannell
Tuna Hunter Charters

Sent from my iPad

Greater Atlantic Region Bulletin

NOAA Fisheries, Greater Atlantic Regional Fisheries Office, 55 Great Republic Drive, Gloucester, MA 01930

RECEIVED
NOV 10 2014
NEW ENGLAND FISHERY MANAGEMENT COUNCIL

For Information Contact:
Sustainable Fisheries Division
(978) 281 – 9315

www.greateratlanticfisheries.noaa.gov/
Date Issued: 11/10/2014

GROUNDFISH FISHERMEN

NOAA Fisheries Announces Temporary Gulf of Maine Cod and Haddock Management Measures

Effective Date: November 13, 2014, through May 12, 2015

Gulf of Maine Cod

We are implementing five temporary actions for cod in this action:

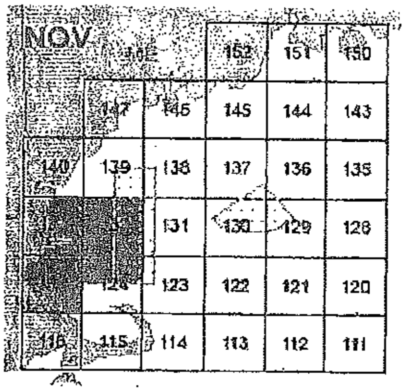
1. Commercial and recreational fishery closure areas: The existing Gulf of Maine (GOM) rolling closures for commercial common pool and sector vessels are replaced with several seasonal 30-minute grids in the GOM Broad Stock Area. Seasonal Interim Closure Areas are closed to vessels using certain commercial and recreational gear capable of catching cod (meaning gear other than "exempted gear," or, gear exempted from current groundfish closed areas, as specified in groundfish regulations). These areas are shown on the next page. Vessels that do not possess a Federal multispecies permit and that fish exclusively in state waters must comply with state measures.
2. Commercial trip limits: A 200-lb trip limit for GOM cod is implemented for all sector and common pool fishing trips taken in the open areas of the GOM Broad Stock Area.
3. Zero recreational possession: Federally permitted recreational vessels, including party and charter vessels, and any other recreational vessel in the Exclusive Economic Zone cannot possess or land recreationally caught GOM cod.
4. Commercial fishery declaration change: Limited access groundfish vessels that declare to fish in the GOM Broad Stock Area may only fish in that broad stock area for the duration of the declared trip, irrespective of whether an at-sea monitor or observer is onboard.
5. Gillnet exemption change: The fishing year 2014 sector exemption that allowed a higher number of gillnets that Day gillnet vessels fishing in the GOM can use is revoked. Vessels that have crossed the vessel monitoring system (VMS) demarcation line and are currently at sea on a groundfish trip may complete the trip under previous rules.

Commercial and recreational fishery closure areas

The seasonal interim closure areas, shown below, are closed to closed to vessels using certain commercial and recreational gear capable of catching cod (meaning gear other than "exempted gear," or, gear exempted from current groundfish closed areas) in the times and areas indicated beginning when this rule is published in the *Federal Register*. These measures temporarily replace and expand on the existing GOM rolling closures. Implementation of these closure areas is effective when the rule publishes; however, we will provide a 2-week period for fixed gear retrieval. This time is intended to allow fixed gear (gillnets, longline) time to remove fishing gear from the November closure areas (i.e., 30-minute squares 132, 133, 125, and the northern half of 124). The portions of the year-round Western Gulf of Maine (WGOM) Closure Area not otherwise closed by the 30-minute squares that overlap the area in this action will continue to remain accessible for federally permitted party and charter vessels through a letter of authorization.

For small entity compliance guides, this bulletin complies with section 212 of the Small Business Regulatory Enforcement and Fairness Act of 1996. This notice is authorized by the Regional Administrator of the National Marine Fisheries Service, Greater Atlantic Region.

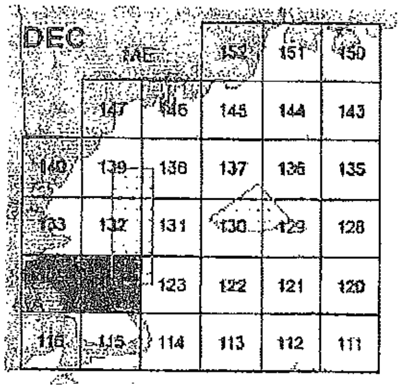
Interim Action Seasonal Commercial and Recreational Fishery Closure Areas, by Month.



POINT	LATITUDE	LONGITUDE
NOV1	43°00'N	(1)
NOV2	43°00'N	70°00'W
NOV3	42°15'N	70°00'W
NOV4	42°15'N	70°30'W
NOV5	42°00'N	70°30'W
NOV6	42°00'N	(2)

[1] The intersection of 43°00' N latitude and the New Hampshire coastline.

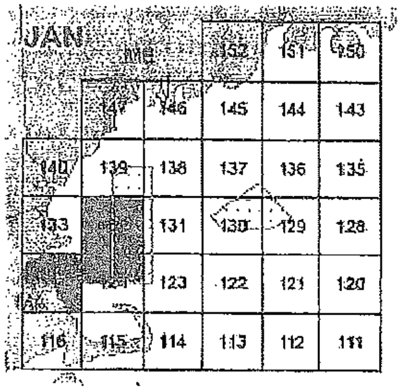
[2] The intersection of 42°00'N latitude and the Massachusetts coastline.



POINT	LATITUDE	LONGITUDE
DEC1	42°30'N	(1)
DEC2	42°30'N	70°00'W
DEC3	42°00'N	70°00'W
DEC4	42°00'N	(2)

[1] The intersection of 42°30' N latitude and the Massachusetts coastline.

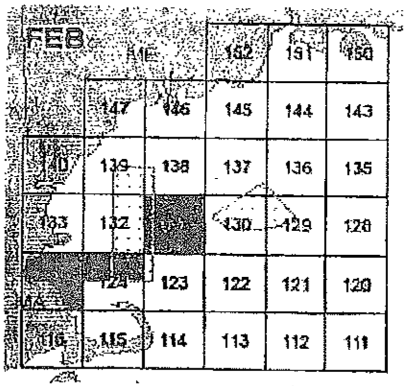
[2] The intersection of 42°00'N latitude and the Kingston, Massachusetts (mainland) coastline.



POINT	LATITUDE	LONGITUDE
JAN1	42°30'N	(1)
JAN2	42°30'N	70°30'W
JAN3	43°00'N	70°30'W
JAN4	43°00'N	70°00'W
JAN5	42°15'N	70°00'W
JAN6	42°15'N	70°30'W
JAN7	42°00'N	70°30'W
JAN8	42°00'N	(2)

[1] The intersection of 42°30'N latitude and the Massachusetts coastline.

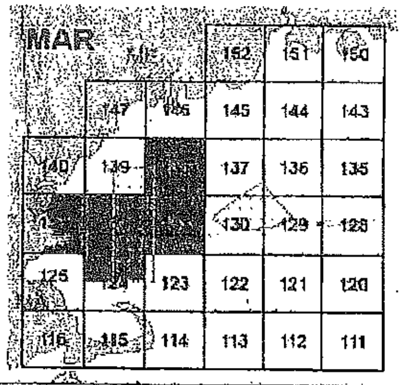
[2] The intersection of 42°00'N latitude and the Massachusetts coastline.



POINT	LATITUDE	LONGITUDE
FEB1	42°30'N	(1)
FEB2	42°30'N	70°00'W
FEB3	43°00'N	70°00'W
FEB4	43°00'N	69°30'W
FEB5	42°30'N	69°30'W
FEB2	42°30'N	70°00'W
FEB7	42°15'N	70°00'W
FEB8	42°15'N	70°30'W
FEB9	42°00'N	70°30'W
FEB10	42°00'N	(2)

[1] The intersection of 42°30'N latitude and the Massachusetts coastline.

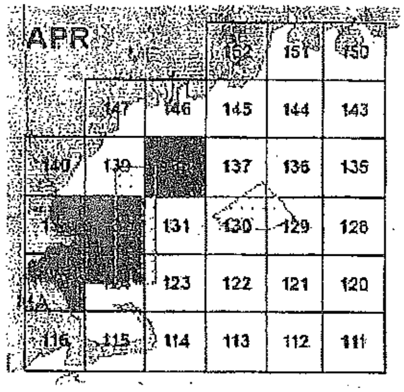
[2] The intersection of 42°00'N latitude and the Massachusetts coastline.



POINT	LATITUDE	LONGITUDE
MAR1	43°00'N	(1)
MAR2	43°00'N	70°00'W
MAR3	43°30'N	70°00'W
MAR4	43°30'N	69°30'W
MAR5	42°30'N	69°30'W
MAR6	42°30'N	70°00'W
MAR7	42°15'N	70°00'W
MAR8	42°15'N	70°30'W
MAR9	42°30'N	70°30'W
MAR10	42°30'N	(2)

[1] The intersection of 43°00'N latitude and the New Hampshire coastline.

[2] The intersection of 42°30'N latitude and the Massachusetts coastline.



POINT	LATITUDE	LONGITUDE
APR1	43°00'N	(1)
APR2	43°00'N	70°00'W
APR3	43°30'N	70°00'W
APR4	43°30'N	69°30'W
APR5	43°00'N	69°30'W
APR2	43°00'N	70°00'W
APR7	42°15'N	70°00'W
APR8	42°15'N	70°30'W
APR9	42°00'N	70°30'W
MAR10	42°0'N	(2)

[1] The intersection of 43°00'N latitude and the New Hampshire coastline.

[2] The intersection of 42°00'N latitude and the Massachusetts coastline

Commercial trip limits

All commercial fishing vessels, regardless of common pool permit category or whether enrolled in sectors, may not possess or land more than 200 lb of cod per trip from the Gulf of Maine. Sector provisions that require all legal-sized cod to be landed are temporarily suspended; meaning vessels that catch more than 200 pounds of cod must discard any overage at sea. Sector Annual Catch Entitlement (ACE) for fishing year 2014 is unchanged by this action and remains in effect. It also remains constraining; once a sector exhausts available ACE, it must cease operations in the Broad Stock Area or secure additional ACE. Cod onboard must be separated from other species of fish and readily available for inspection. The GOM cod stock is in poor condition. For this reason, we strongly encourage fishermen to avoid catching cod to minimize fishing mortality and to avoid the need to discard catch beyond the 200-lb trip limit.

Recreational catch prohibition

Federally permitted recreational vessels, including federally permitted party and charter vessels, and any other recreational vessel in the Exclusive Economic Zone, may not possess or land GOM cod. We encourage recreational fishermen to practice good fish handling and release techniques to minimize post-release stress and mortality. Some preliminary studies indicate a higher survivability for fish taken on baited hooks, in large part because this type of set up more frequently results in mouth hooking. By contrast, jigging tends to hook fish more often in the head or body. Please consider using baited hooks in lieu of unbaited lures/jigs in areas where cod may be found.

Commercial fishery declaration change

Commercial fishing vessels declaring into the GOM Broad Stock Area may only fish within that area for the duration of the declared trip. You may still fish in any combination of the other broad stock areas (inshore Georges Bank, offshore Georges Bank, and/or Southern New England); however, you may not fish in one of these other areas then flex to the GOM Broad Stock Area.

Gillnet exemption change

Sector day gillnet vessels will be receiving a revised letter of authorization (LOA) revoking the exemption on the number and type of gillnets that may be fished within the GOM Broad Stock Area. Under the revised LOA, day gillnet vessels will be subject to the existing net restrictions in section 648.80: No more than 100 gillnets of 300 feet, or 50 fathoms, in length. Of these 100 gillnets, no more than 50 gillnets may be rigged for roundfish (i.e., gillnets that are constructed with floats on the float line and that have no tie-down twine between the float line and the lead line). Gillnets in the GOM regulated mesh area must be tagged with two tags per net.

Gulf of Maine Haddock

Following a recent GOM haddock assessment, and at the request of the New England Fishery Management Council, NOAA Fisheries has implemented an emergency action to increase GOM haddock catch limits for the duration of fishing year 2014. Table 1 below compares the previous fishing year 2014 catch limits with the revised catch limits. Tables 2 and 3 below show the revised sector and common pool catch limits. Because catch models suggest that the recreational fishery has likely already exceeded the revised catch limit of 173 mt this fishing year, we did not modify recreational management measures for GOM haddock in this action.

Table 1. Revised Fishing Year 2014 GOM Haddock Catch Limits

Catch Level	Previous Fishing Year 2014 Levels (mt)	Revised Fishing Year 2014 Levels (mt)
Overfishing Limit of Catch	440	1085
Acceptable Biological Catch	341	677
Total Annual Catch Limit (ACL)	323	641
Groundfish sub-ACL	307	610
Sector sub-ACL	218	432
Common Pool sub-ACL	2	4
Recreational sub-ACL	87	173
State Waters ACL subcomponent	5	10
Other ACL subcomponent	7	15
Mid-Water Trawl sub-ACL	3	6

Table 2. Preliminary GOM Haddock Annual Catch Entitlement by Sector for Fishing Year 2014 (lb)

Sector Name	Previous Fishing Year 2014 Allocation	Revised Allocation
Fixed Gear Sector	8,922.32	17,520.18
Maine Coast Community Sector	12,375.78	24,301.54
Maine Permit Bank	5,431.97	10,666.42
NEFS 1	12.03	23.63
NEFS 2	79,343.13	155,801.06
NEFS 3	45,030.20	88,422.95
NEFS 4	40,511.81	79,550.47
NEFS 5	1,406.55	2,761.95
NEFS 6	18,660.52	36,642.48
NEFS 7	2,275.42	4,468.11
NEFS 8	974.47	1,913.50
NEFS 9	23,256.90	45,668.10
NEFS 10	12,284.38	24,122.06
NEFS 11	15,567.10	30,568.12
NEFS 13	4,793.20	9,412.10
NCCS	1,744.68	3,425.92
New Hampshire Permit Bank	150.95	296.41
Sustainable Harvest Sector 1	207,161.20	406,789.26
Sustainable Harvest Sector 3	316.08	620.67
Sector Total	480,218.69	942,974.93
Common Pool	4,798.26	9,422.05

NEFS = Northeast Fishery Sector, NCCS = Northeast Coastal Communities Sector

Table 3. GOM Haddock Common Pool Trimester TACs for fishing year 2014 (mt)

Trimester	Trimester Allocations	Previous Fishing Year 2014 Allocation	Revised Allocation
Trimester 1	27%	.51	1.17
Trimester 2	26%	.49	1.12
Trimester 3	47%	.88	2.03

Frequently Asked Questions	
Where can I find additional information?	Because there was a need to develop these actions, including this bulletin, quickly, an abbreviated FAQ is provided. More information can be found in the specific rules and analyses either on Regulations.gov or http://www.greateratlantic.fisheries.noaa.gov/sustainable/species/multispecies/index.html. These documents provide detailed explanations of how the interim measures were derived and why they differ from many of the measures initially discussed by the New England Fishery Management Council. For information by telephone, call the Greater Atlantic Regional Office's Sustainable Fisheries Division at (978) 281-9315.
Can I still recreationally fish in the Western Gulf of Maine Closure (WGOM) Area under the interim measures?	Yes; however, you may not fish in the WGOM Closure Areas that overlap the Seasonal Interim Closure Areas shown on page 2 of this bulletin. For party and charter vessels, a letter of authorization (LOA) is required to do so. Previously issued LOAs are being invalidated and revised LOAs will be sent from the Greater Atlantic Regional Fisheries Office to all federally permitted party and charter vessels. Contact the Permit Office at (978)281-9370 for more information. Note the Rolling Closure LOA is suspended for the duration of the interim action. This is because the rolling closures are temporarily replaced by the Seasonal Interim Closure Areas that prohibit recreational fishing with gear capable of catching cod.
Do the closures and recreational prohibitions apply to state waters?	Yes, if you are operating a federally permitted Northeast multispecies commercial, party, or charter vessel. Individual states may impose restrictions on vessels that are not federally permitted and/or private anglers. Please check with the marine fisheries management agency or agencies for individual states for more information.
How will the single-stock area declaration work?	If you declare multiple areas through your Vessel Monitoring System (VMS) you will be notified that you may only fish in the GOM or in other areas but not both GOM and other areas. This will split the Redfish Exemption Area for sector vessels, so it will be necessary for redfish fishermen to make either GOM or Georges Bank redfish trips. Should you ultimately fish in the GOM and another Broad Stock Area on a trip, you will be in violation and subject to enforcement action. This measure is intended to make sure that the attribution of catch to a stock area is improved while the interim action is in effect.
Can I transit Closure Areas?	Yes, transiting is allowed. The existing provision for area gear stowage and transiting closed areas remain in effect under the interim action. Gear must be stowed and unavailable for use.
Won't commercial trip limits and zero possession for recreational fishery cause fishermen to throw back cod, most of which will die anyway?	The cod stock is in poor shape—the trip limit is intended to dissuade catch of cod. In instances where commercial fishermen catch more than 200 lb, they will have to discard fish and the mortality associated with most commercial gears is high. Recreationally caught fish have a higher survival rate and studies indicate this can be further improved by good handling and release techniques and making use of baited hooks that are more likely to hook cod in the mouth. We encourage fishermen to actively avoid cod whenever possible. Don't catch it, and you won't have to discard it. Possession of, or landing more than, 200 lb of cod on a trip will be subject to enforcement action.
Does this action change existing Harbor Porpoise Take Reduction Closure Areas?	No. In many places there is overlap between the Interim Seasonal Closure Areas and the Harbor Porpoise Take Reduction Areas, but the take reduction closures remain in full force and effect during the interim rule period. For more information on the Harbor Porpoise Take Reduction Closure Areas visit: http://www.greateratlantic.fisheries.noaa.gov/protected/porptrp/ or call the Greater Atlantic Region's Take Reduction Plan Coordinator at (978) 282-8481.

RECEIVED
NOV 10 2014
NEW ENGLAND FISHERY
MANAGEMENT COUNCIL

Marc Stettner
91 Fairview Avenue
Portsmouth NH 30801

November 9, 2014
New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
Thomas A. Nies, *Executive Director*

Dear NEFMC,

I am writing this letter as a recreational fisherman. I fish for striped bass, winter flounder, black seabass and other inshore fish.

I have concerns about the area closures that will affect recreational fishermen, as proposed in Framework 53. It is my understanding individual states set the fishery regulations within their boundaries. The concern I have is regarding the language in FW 53 that states:

Recreational fishing vessels (including party-charter vessels) are subject to the following restrictions:

All recreational fishing vessels using gear capable of catching groundfish are prohibited from fishing in the areas during the dates specified. Only pelagic hook and line gear, as defined in the commercial fishing exempted gear regulations, is allowed for use in the area.

Regulated groundfish such as winter founder, pollock and cod are found inshore in state waters. The language above will create conflicts in state waters since <u>**any**</u> recreational fishing uses "gear capable of catching groundfish.." and would be prohibited.

The regulations need to be clear that the language above does not apply to state waters. In addition and any federally permitted charter/partyboats would also need to be exempt from this requirement when fishing in state waters.

Respectfully,

Marc Stettner

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026

October 9, 2014

Mr. Marc Stettner
91 Fairview Ave
Portsmouth, NH 03801

Dear Mr. Stettner,

Thank you for your August 24, 2014 letter concerning the recent Gulf of Maine Atlantic cod stock assessment. The New England Fishery Management Council's Scientific and Statistical Committee (SSC) reviewed this assessment on August 28-29 and did not find the characteristics of the 2012 and 2013 data anomalous. In your letter, you posed four questions and we asked our scientists at the Northeast Fisheries Science Center to provide additional information.

QUESTION 1: What were the plankton counts for the winter of 2012-2013 compared to previous years?

RESPONSE: The Northeast Fisheries Science Center (NEFSC) conducts Ecosystem Monitoring cruises throughout the Northeast U.S. Continental Shelf. These cruises started in 1977 and occur several times per year to capture the seasonal variation in oceanography and plankton. Data collected in 2014 are still being processed.

Data for the Gulf of Maine from January to April and for the entire year are shown in Figure 1. Zooplankton biomass was below the long-term mean during 2012 and 2013. It's possible that this could lead to less favorable feeding conditions for larval Atlantic cod. However, this would not have directly impacted assessment results since the survey indices used in the assessment include only age-1 and older fish. The winter of 2011/2012 was anomalously warm, and. while temperatures moderated somewhat during the winter of 2012/2013, they were still above the long-term mean.

QUESTION 2: What was the abundance of herring, mackerel, and silver hake for the winter 2012-2013?

RESPONSE: The Northeast Fisheries Science Center conducts annual spring and fall bottom multispecies bottom trawl surveys, but does not currently conduct fishery independent surveys during the winter. The NEFSC spring and fall bottom trawl survey abundance indices for Atlantic herring, Atlantic mackerel and silver hake are shown in Figure 2. Please note the fall survey is uninformative for Atlantic mackerel as the seasonal distribution is typically north of the survey area. Generally, the abundance indices were at, or above the recent (2000-present) time series mean for Atlantic herring and silver hake. Atlantic mackerel were below the recent time series mean in 2012 and 2013. Overall, the abundance indices of herring, mackerel and silver hake were not anomalous during this time period.

If you would like additional information on the results of annual surveys, we encourage you to refer to the research reports the NEFSC generates for each of its surveys. These are posted on our website at:

http://www.nefsc.noaa.gov/femad/ecosurvey/mainpage/
(click on the Resource Surveys Reports tab on the left)

Figures

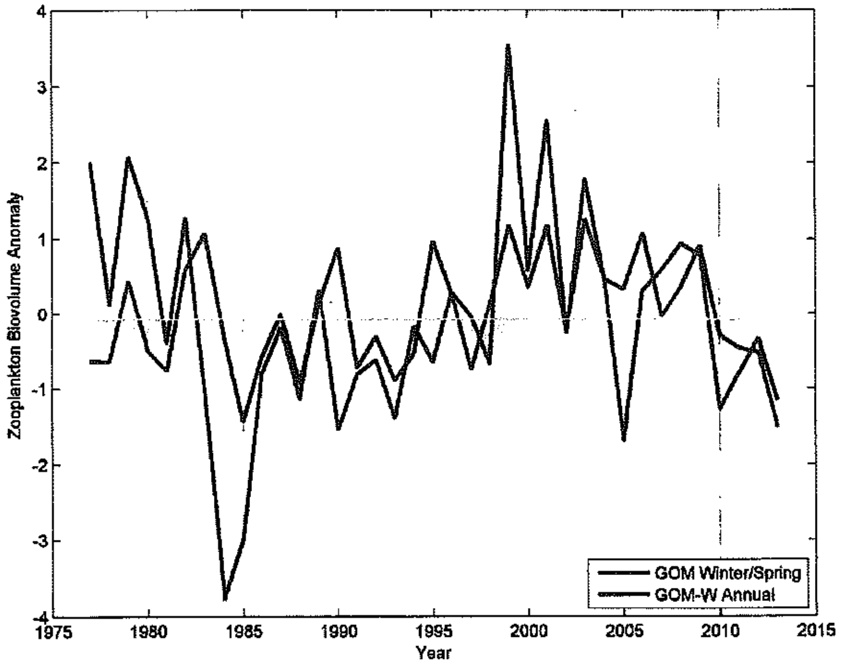


Figure 1. Zooplankton Biovolume Anomalies calculated from data collected by the Northeast Fisheries Science Center Ecosystem Monitoring Group. Anomalies (expressed in standard deviation units) are shown for the January to April period as well as for the entire year.

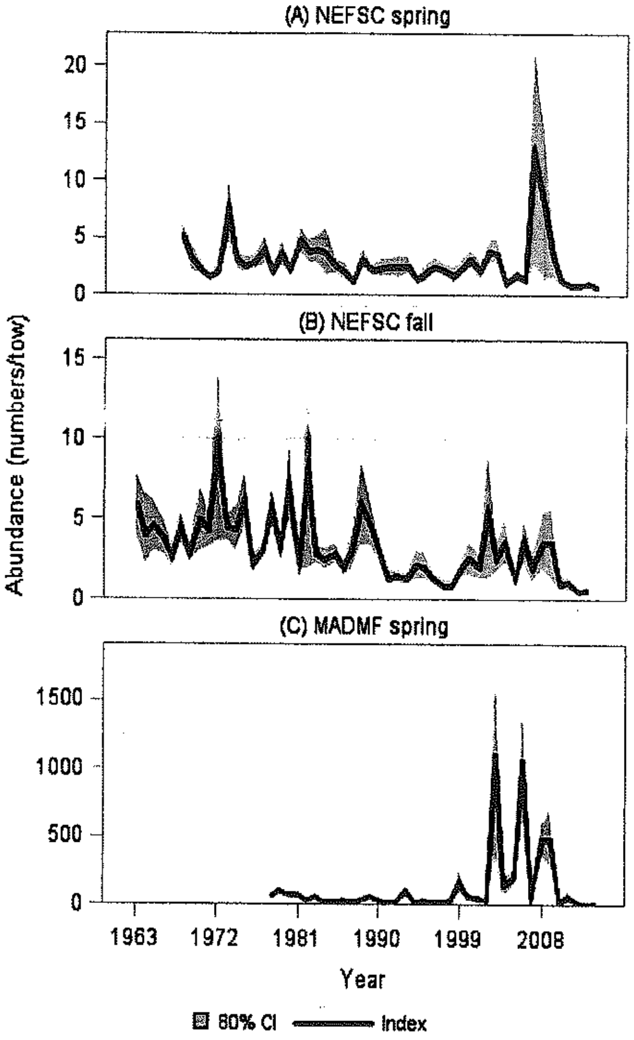
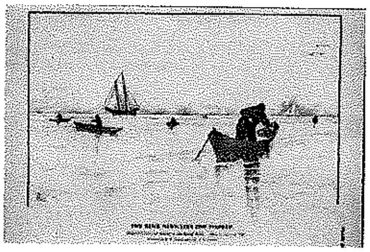


Figure 3. Gulf of Maine Atlantic cod indices of abundance between 1963 and 2014 for the Northeast Fisheries Science Center (NEFSC) spring (A) and fall (B) bottom trawl surveys and the Massachusetts Division of Marine Fisheries (MADMF) spring (C) bottom trawl survey. *Note that the fall 2014 indices are not yet available.*

91 FAIRVIEW AVE
PORSTMOUTH NH 03801

NORTHEAST HOOK FISHERMAN'S ASSOCIATION



November 9, 2014
New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
Thomas A. Nies, *Executive Director*

Dear NEFMC & NMFS:

We represent a small group of Commercial Fishermen with the Limited Access Handgear HA Permits, employing the use rod and reel, handlines or tub trawls to catch Cod, Haddock and Pollock along with small quantities of other regulated and non-regulated marine fish.

We are providing the following for Framework 53 discussions:

"***Fine-scale diel and gender-based patterns in behavior of Atlantic cod (Gadus morhua) on a spawning ground in the Western Gulf of Maine***" by Micah J. Dean1*, William S. Hoffman1, Douglas R. Zemeckis2, and Michael P. Armstrong1

Respectfully,
Marc Stettner /s/

NEHFA MEMBERS: Marc Stettner, Timothy Rider, AJ Orlando, Hilary Dombrowski, Paul Hoffman, Christopher DiPilato, Ed Snell, Scott Rice, Roger Bryson, Brian McDevitt, Anthony Gross, Doug Amorello

ICES Journal of Marine Science Advance Access published March 24, 2014

ICES Journal of Marine Science

ICES Journal of Marine Science; doi:10.1093/icesjms/fsu040

Fine-scale diel and gender-based patterns in behaviour of Atlantic cod (*Gadus morhua*) on a spawning ground in the Western Gulf of Maine

Micah J. Dean[1]*, William S. Hoffman[1], Douglas R. Zemeckis[2], and Michael P. Armstrong[1]

[1] *Massachusetts Division of Marine Fisheries, Annisquam River Marine Fisheries Station, 30 Emerson Avenue, Gloucester, MA 01930, USA*
[2] *School for Marine Science and Technology, University of Massachusetts - Dartmouth, 200 Mill Road, Suite 325, Fairhaven, MA 02719, USA*

**Corresponding author: tel: +1 978 282 0308; fax +1 617 727 3337; e-mail: micah.dean@state.ma.us*

Dean, M. J., Hoffman, W. S., Zemeckis, D. R., and Armstrong, M. P. Fine-scale diel and gender-based patterns in behaviour of Atlantic cod (*Gadus morhua*) on a spawning ground in the Western Gulf of Maine. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu040.

Received 27 November 2013; accepted 18 February 2014.

Understanding the influence of spawning behaviour on the fine-scale distribution of Atlantic cod is essential to the design of effective conservation measures. Laboratory studies suggest that spawning activity occurs primarily at night, yet no field studies have evaluated the influence of diel period on the behaviour of individual wild spawning cod. Using an acoustic telemetry positioning system, the fine-scale movements of spawning cod were observed *in situ* as they returned to the same spawning location over consecutive seasons. The resulting data identify clear gender-based diel patterns in space use and aggregation behaviour among cod on a spawning ground. During the day, females remained aggregated in one small location that varied little within and between years. Males also aggregated during the day, but occupied a much larger adjacent area. At night, individual males sought out separate small territories while females generally remained near their daytime aggregation site, making periodic excursions into the surrounding area. These patterns were surprisingly stable over the 2 years of observation, indicating little interannual variability in spawning behaviour. This study provides an unprecedented examination of the natural spawning behaviour of Atlantic cod, and makes connections between earlier laboratory studies and field observations.

Keywords: acoustic telemetry, Atlantic cod, *Gadus morhua*, Gulf of Maine, spawning behaviour, VEMCO VPS.

Introduction

Atlantic cod (*Gadus morhua*) is one of the most commercially sought after and socio-economically important fish species in the world (Kurlansky, 1998; FAO, 2012). Despite inordinate attention on stock assessment and fishery management, most cod populations have experienced steep declines in abundance with limited success at rebuilding (Lilly *et al.*, 2008). Overfishing has often been cited as the primary culprit (Myers *et al.*, 1996; Shelton *et al.*, 2006), yet it seems unlikely that the blame falls entirely on imperfect stock assessment models or management decisions that are insufficiently precautionary to account for uncertainty. As many have pointed out, environmental variability (e.g. climate change, Atlantic Multidecadal Oscillation, North Atlantic Oscillation) is having an impact on productivity, growth, and recruitment of many stocks (Rose, 2004; Brander, 2005; Drinkwater, 2005; Koster *et al.*, 2005); as are fluctuations in the populations of predators, competitors, and prey species (Swain and Sinclair, 2000; Trzcinski *et al.* 2006; Ames and Lichter 2013).

Still, it appears that there is some element to the population dynamics of this species that is currently being ignored or misunderstood that causes such widespread failure to prevent stock collapse and achieve recovery. Several papers have recently suggested that ignoring fine-scale population structure is a contributing, if not a leading cause (Svedäng *et al.*, 2010; Lindegren *et al.*, 2013; Zemeckis *et al.*, in press). There is ample evidence that many cod stocks function as metapopulations, containing multiple subpopulations made up of semi-discrete spawning components (Smedbol and Wroblewski, 2002; Wright *et al.*, 2006; Rose *et al.*, 2011). By managing stocks as a single homogeneous unit, we ignore this fine-scale population structure and risk the serial depletion of unique sub-components, thereby lowering stock productivity (Frank and Brickman, 2000; Smedbol and Stephenson, 2001).

The strong spawning site fidelity exhibited by cod suggests that once a semi-discrete spawning component is extirpated, the likelihood of rapid re-colonization is low (Robichaud and Rose, 2001; Skjæraasen *et al.*, 2011). Spawning behaviour is at the heart of a metapopulation; it provides not only the mechanism by which population structure is developed and maintained, it also influences whether lost or depleted components will recover. Understanding the "where", "when", and "how" of spawning helps us manage cod stocks more effectively by providing the necessary information to design conservation measures that prevent the loss or depletion of spawning components (Zemeckis *et al.*, in press).

Our knowledge of individual spawning behaviour comes primarily from observations made in captivity. These studies have shown that Atlantic cod employ a mating system known as a lek, with males forming a dense aggregation at specific sites where they perform courtship displays to attract females (Nordeide and Folstad, 2000). The largest, most dominant males are thought to form an individual display territory that they defend from other males through agonistic interactions (Hutchings *et al.*, 1999). Females remain segregated from males and periodically enter a dominant male's territory when ready to spawn (Brawn, 1961). The presence of the female in its territory causes the male to initiate a courtship routine involving circling bouts, fin displays, and vocalizations (Hutchings *et al.*, 1999). Mating is based on female choice; after successful male courtship, a spawning pair rises off the bottom and releases their gametes during a "ventral mount" (Brawn, 1961; Hutchings *et al.*, 1999; Morgan *et al.*, 1999). There is also evidence for an alternative male reproductive strategy where a sub-dominant (or "sneaker") male follows the mounted pair and fertilizes a portion of the eggs released by the female (Bekkevold *et al.*, 2002; Rowe *et al.*, 2008). Although our ability to observe mating behaviour is restricted by light availability, tank experiments suggest that spawning events occur primarily at night (Brawn, 1961; Kjesbu, 1989; Hutchings *et al.*, 1999; Morgan *et al.*, 1999).

While little is known about the spawning behaviour of cod in the wild, there is ample indirect evidence from field studies supporting the findings of tank experiments. Survey and fishery-dependent observations have shown that wild spawning cod form dense aggregations that are spatially and temporally predictable (Nordeide, 1998; Marteinsdóttir *et al.*, 2000; Vitale *et al.*, 2007). Strongly skewed sex ratios are commonly found in catches made on or near a spawning aggregation, corroborating the idea of spatial segregation of the sexes while spawning (Morgan and Trippel, 1996; Lawson and Rose, 2000; Armstrong *et al.*, 2004; Windle and Rose, 2007). Hydroacoustic observations have indicated that vertical movements play a role during spawning, with individuals typically rising in the water column at night (Ouellet *et al.*, 1997; Fudge and Rose, 2009; Knickle and Rose, 2012). Despite these similarities, it is difficult to reconcile some of the behaviours observed among a small group in a tank with the magnitude of a wild spawning aggregation. For instance, how does a socially determined hierarchy persist among thousands (if not millions) of individuals? At what scale do females and males segregate (causing skewed sex ratios), while still maintaining the proximity necessary for the lek mating system to occur? Does the diel influence on behaviour observed in the laboratory affect their space use and habitat utilization in the wild? Resolving these questions will help fill the void of information on the spawning behaviour of wild Atlantic cod and allow us to design more informed conservation measures.

Of the different approaches to studying spawning behaviour, acoustic telemetry alone offers the ability to observe the natural movements of individual fish *in situ*. The first applications of this technology to observe spawning cod demonstrated strong site fidelity and gender-related differences in spawning period (Robichaud and Rose, 2001, 2002, 2003). Recent technological advances now permit increased sample sizes, multiyear observation, and expanded detection areas (DeCelles and Zemeckis, 2014). Greatly improved resolution of reconstructed positions can be achieved by locating acoustic receivers in proximity to each other, allowing for the simultaneous detection of tagged individuals by multiple receivers. This receiver configuration, known as a "positioning system", can provide the precise location of tagged fish within a few metres at intervals of less than a minute (Andrews *et al.*, 2011). However, such systems require a significant investment in resources, in addition to *a priori* knowledge of where tagged fish are likely to go once released. Atlantic cod are an ideal candidate for observation with an acoustic telemetry positioning system, given their strong site fidelity and limited space use while spawning (Siceloff and Howell, 2013). Several researchers have recently used positioning systems to reveal fine-scale detail on the movements and behaviour of wild spawning cod (Espeland *et al.*, 2007; Meager *et al.*, 2010; Dean *et al.*, 2012). However, none have accounted for the effect of diel period, despite strong evidence that spawning activity occurs primarily at night. Furthermore, the use of this technology has been limited to relatively small detection areas (≤ 4 receivers) and a single year of observation. In most telemetry studies, spawning cod have been tagged and released with an unknown portion of the spawning season having already transpired. By collecting telemetry data from individuals returning to a spawning ground over multiple seasons, the full spawning period is observed and their movements are more reflective of natural behaviour. The goal of this research was to describe the influence of gender and diel period on cod spawning behaviour through an unprecedented view of fine-scale individual movements of wild cod over multiple seasons.

Material and methods

Study area

This study was conducted within the boundaries of the Spring Cod Conservation Zone (SCCZ), a seasonal fishery closure located ~5 km south of Gloucester, MA, USA in the western Gulf of Maine (Figure 1) (Armstrong *et al.*, 2013). The size of the closure area changed over the course of the study, increasing from 23 km^2 in 2009–2010 to 46 km^2 in 2011 (Figure 2). Spawning cod typically aggregate from April through July around a gravel/cobble deposit near the centre of the SCCZ, which has ~2 m of relief above a surrounding flat muddy plain that is bordered to the north and east by large outcrops of bedrock that come to within 25 m of the surface. The average depth at low water in the SCCZ is ~50 m, with a 3 m tidal range. Over the course of this study, the mean water temperature in April at a nearby oceanographic monitoring buoy was 4°C at the bottom and 7°C at the surface (NERACOOS Buoy "A"—http://www.neracoos.org). By July, the mean temperature rose to 6°C at the bottom and to 19°C at the surface.

Tagging

Cod were captured from the SCCZ via angling with conventional cod jigs aboard the Massachusetts Division of Marine Fisheries' RV "Alosa". Upon capture, fish were placed in a 500-l tank supplied with continuous seawater flow (a "livewell") for up to 30 min before tagging. Only cod that appeared healthy and vigorous were selected

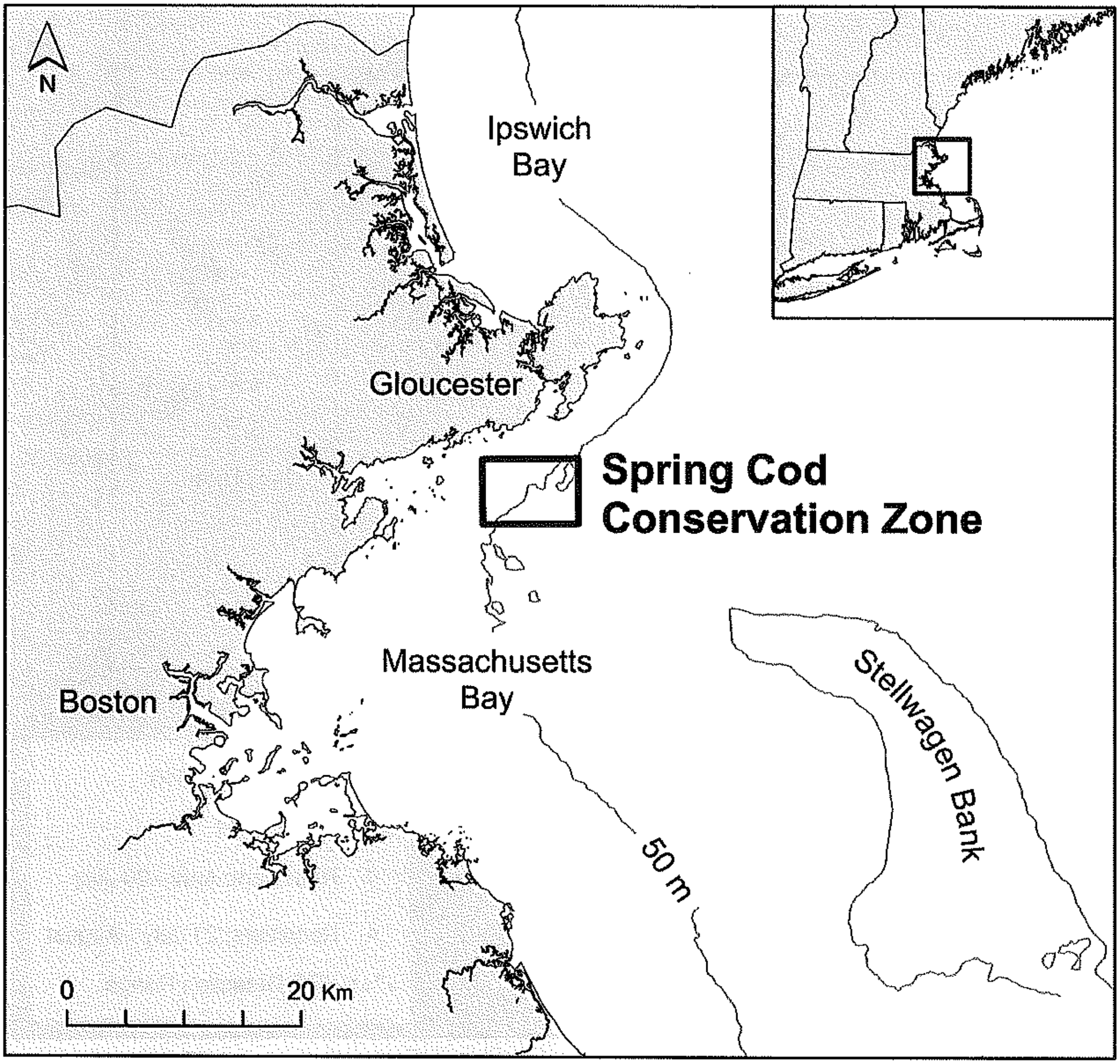


Figure 1. Map of the study area showing the general location in Massachusetts Bay and the western Gulf of Maine. The boundaries of the Spring Cod Conservation Zone in 2011 are shown in bold.

for tagging with acoustic transmitters. In 2009, sex and spawning condition were recorded only when externally apparent (i.e. flowing sperm or eggs); therefore, several individuals of unknown sex and maturity were tagged in that year. In 2010 and 2011, all captured cod were cannulated to determine sex and maturity and only fish in spawning condition were tagged (i.e. males with flowing sperm or females with hydrated eggs). After recording sex, maturity and total length, a wet towel was placed over the eyes of the fish to calm it during the tagging procedure. A small incision (<4 cm) was made in the lower left side of the abdomen, through which the acoustic transmitter was inserted. The incision was then sutured shut with a sterile needle and braided silk thread. The tagging procedure typically lasted <4 min and fish were allowed to recover in the livewell for up to 30 min before release. Handling time was kept as short as possible to reduce stress and minimize any latent effects on spawning behaviour. Consequently, no anaesthesia was used that would have added significantly to the length of time on-board the tagging vessel. The acoustic transmitters (VEMCO Inc., Model V16P-6H, 69 kHz, 16 × 98 mm, 37 g in air) were configured to transmit a unique identifier and pressure (depth) sensor reading at random intervals between 30 and 90 s. Each tag had an expected battery life of over 4 years, which allowed us to track the movements of cod that returned to the spawning site over multiple seasons.

Acoustic receiver array

To track the movements of tagged fish in 2010 and 2011, an array of 28 acoustic receivers (VEMCO Inc., Model VR2W) was deployed in the form of an isometric grid roughly centred on the main aggregation site (Figure 2). Receivers were attached to vertical lines and

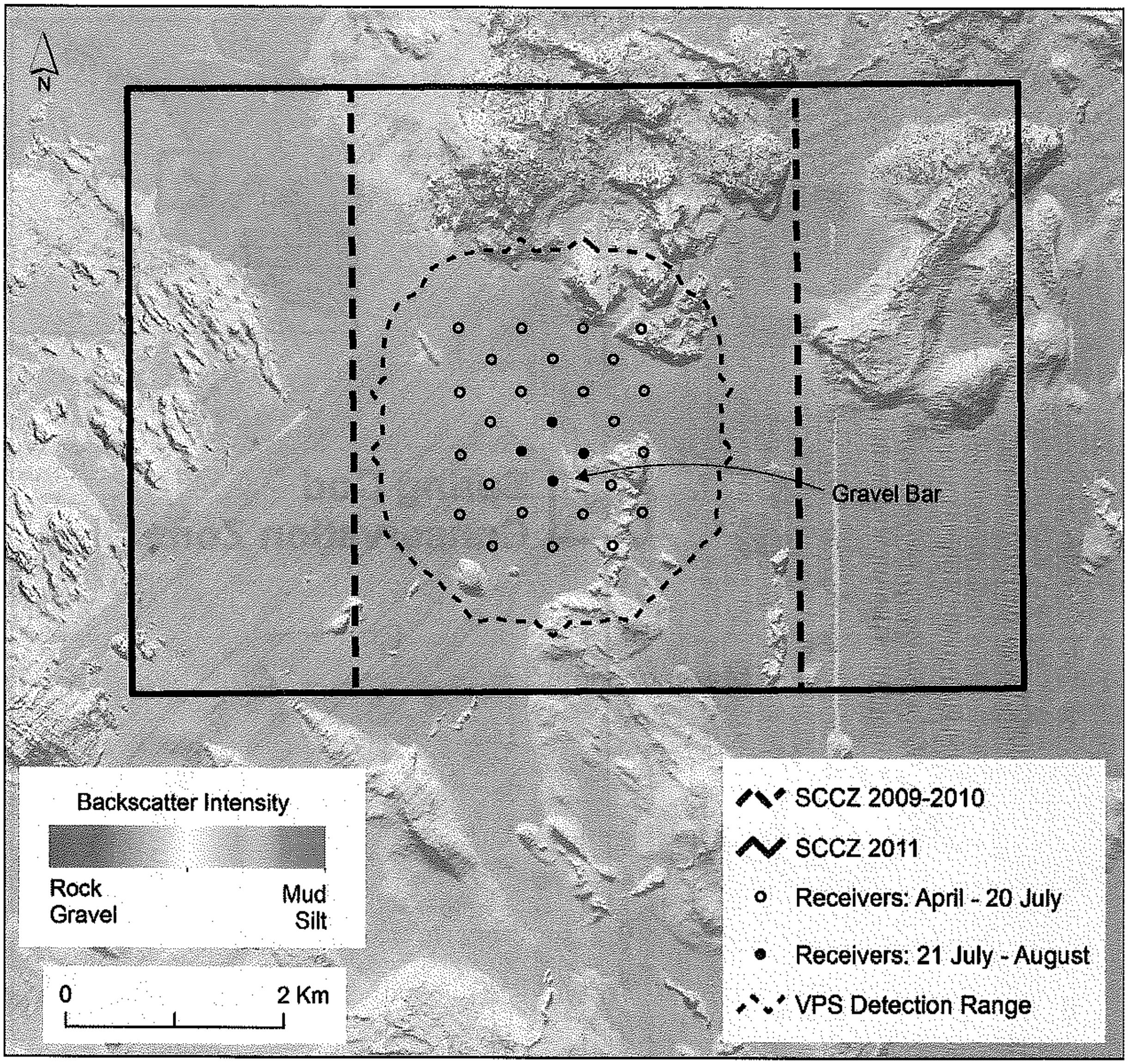


Figure 2. Map of the acoustic receiver array within the Spring Cod Conservation Zone (SCCZ). The width of the SCCZ was expanded in 2011, doubling the size of the closure area. In both 2010 and 2011, all but four receivers (closed circles) were removed on 20 July to minimize conflict with fishers once the SCCZ opened to fishing on 21 July. The background image depicts the bathymetric features of the surrounding area through backscatter intensity and hillshaded topography (Butman *et al.*, 2007). The gravel bar identified at the centre of the array was the focal point of the spawning aggregation in both years.

moored 2 m above the seabed. Reference transmitters ("synctags") were attached to each vertical line to determine the position of receivers in relation to each other. Receivers were spaced 400 m apart, providing substantial overlap in detection areas given the ~1 km detection radius of each receiver. This array was part of a VEMCO Positioning System (VPS), which provided an ~9.5 km^2 area over which the movements of tagged cod could be observed. All 28 receivers were deployed before the formation of the spawning aggregation (21 April 2010; 14 April 2011). Just before the lifting of the SCCZ fishery closure on 21 July, all but the four receivers closest to the main aggregation site were removed to minimize the loss of equipment through entanglement with commercial fishing gear. These remaining receivers were removed once all tagged fish had vacated the area (30 August 2010; 24 August 2011).

Data analysis

Raw detection data were downloaded from the receivers at the end of each season and sent to VEMCO Inc. for processing. This procedure involved using the time-difference-of-arrival (TDOA) among receivers to calculate a precise latitude and longitude for each tag transmission (i.e. hyperbolic positioning) (Smith, 2013). Processed data consisted of tag ID, detection date/time, latitude, longitude, depth, and an estimate of the horizontal position error (HPE) for each relocation. HPE is a unitless error measurement that describes the sensitivity of the positioning system to the variables that affect horizontal accuracy (e.g. array geometry, water temperature, salinity, etc.) (Espinoza *et al.*, 2011). A measure of actual positioning error (HPEm), or the distance separating calculated positions and known locations, is available from the relocated positions of synctag transmissions. Therefore, a linear model was constructed between mean HPEm and HPE (binned in 1 m increments, up to 50 m) for synctag positions (HPEm $\sim 1.3056 + 0.3443 \times$ HPE; d.f. $= 45$, $r^2 = 0.89$, $P < 0.0001$) and applied to the processed dataset of fish tag transmissions to estimate the mean position error in metres (Smith, 2013). Tag positions with an HPE >25 were omitted from all analyses, as they were estimated to have an actual position error of more than 10 m.

Many demersal physoclistous fish, including cod, suffer the effects of barotrauma caused by the change in pressure when brought to the surface from depth (Heffernan *et al.*, 2004; Nichol and Chilton, 2006). Rapid expansion can cause the swimbladder to rupture, releasing gas that can only be replenished through an internal chemical process. Once released, cod with barotrauma often return to the seabed, but then make frequent ascents to shallower depths to achieve neutral buoyancy. The height of these ascents diminishes as the swimbladder heals and the fish replaces lost gas. Van der Kooj *et al.* (2007) examined this process in Atlantic cod from a variety of regions, and found that the equilibrium period lasted 3.8 days on average, but was influenced by depth of capture and water temperature. In the present study, this pattern of vertical behaviour was apparent in several fish, and appeared to cease within 1 week. For this reason, the first 7 days of observations post-release were omitted from all analyses to minimize the influence of the capture and tagging procedure on behaviour metrics.

To examine diel differences in behaviour, the relocated positions were assigned to the following periods, using astronomical data from the US Naval Observatory (http://aa.usno.navy.mil/): Day = 1 h after sunrise to 1 h before sunset; Night = 1 h after sunset to 1 h before sunrise; Dawn/Dusk = the 2-h period surrounding either sunrise or sunset. Night observations after midnight were assigned to the previous date, so that a single contiguous Night period existed for each calendar date. For most analyses of diel patterns, only Day and Night periods were compared, because the Dawn/Dusk period appeared to be a time of transition between two relatively stable behaviour states.

Patterns in space use were described through the creation of utilization distributions (UDs) from the processed dataset. A UD is essentially a map of the probability of locating a tagged animal over a given period (Worton, 1987). Because the detection data were highly autocorrelated, a Brownian bridge movement model (BBMM) was used to construct each UD with the adehabitat package (version 1.8.12; Calenge 2006) of the R statistical software (version 3.0.2; R Development Core Team 2012). This model leverages the information contained in the sequence of observations to obtain a more precise measure of space use than a traditional kernel density estimator, which assumes that observed positions are a random sample of all possible locations along the trajectory of a tagged animal. The BBMM relies on two key parameters: mean position error (δ) and Brownian motion variance (σ_m^2, related to circuitousness of movement), both of which were estimated via the maximum likelihood approach of Horne *et al.* (2007). Because of the expected heterogeneity in movement patterns, δ and σ_m^2 were estimated independently for each fish, date, and diel period. Some tagged fish periodically left the array; as such, UDs were calculated in multiple "bursts" when necessary. A burst was defined as a sequence of observations with no more than 1 h between positions. Burst UDs were then averaged together, weighting by the burst length (hours) to achieve a single UD for each fish, date, and period combination. This step ensured that each UD described the space use of a fish only when it was within the array.

Four measures of individual movement or space use were derived from either the UD or the processed point dataset directly: area occupied, height above bottom, site affinity, and aggregation intensity. These behaviour metrics were then examined for differences between genders, diel periods, or years with a mixed-effect generalized linear model (GLMM), using the R package lme4 (version 1.0–5). Fish ID was defined as a random intercept to account for within-fish variation. For each behaviour metric, error was best represented by the Gamma distribution with a log link function. Before analysis, each dataset was summarized to establish the individual fish as the unit of observation. For example, the mean height above the bottom per individual, diel period, and year were calculated and used as input to the model, as opposed to relying on the raw or daily observations. This step avoids the pitfalls of autocorrelation and pseudoreplication common to acoustic telemetry studies that rely on individual positions as the unit of observation (Rogers and White, 2007). Best fitting models for each behavioural metric were selected using backwards stepwise regression and the Bayesian information criterion.

Area occupied

The area occupied by an individual fish is related to its swimming speed and the directionality of its movement. Both are subject to change as it switches between behaviour modes (i.e. foraging, courtship, spawning, etc.), yet are difficult to measure directly. The estimation of swimming speed is affected by the interval between calculated positions, which in turn is affected by the number of tagged fish simultaneously present in the array. Because receivers can detect only one tag transmission at a time, the more fish that are within range of a single receiver increases the chance that two tags will transmit at the same time and cancel each other out. This leads to longer intervals between positions and a substantial downward bias in estimated swimming speed (Løkkeborg *et al.*, 2002). Determining the directionality of movement is equally problematic, particularly when aggregated fish are making limited movements relative to the level of horizontal position error. The BBMM accounts for both the variability in position intervals and the level of position error in the estimation of the UD. To represent the area occupied by an individual fish, the 95% and 50% probability contours were extracted from each UD, referred to here as the UD_{95} and UD_{50}. In wildlife telemetry studies, these values are commonly referred to as the "home range" and "core area" of a tagged animal, respectively (Downs and Horner, 2008). The former is more inclusive and describes nearly all the areas that a tagged individual might visit over a given period, while the latter is more indicative of just the areas where that individual spent the most time.

Height above bottom

Both laboratory and field studies of cod spawning behaviour have observed some level of vertical movement (Meager *et al.*, 2009; Knickle and Rose, 2012). Measuring the position of spawning cod in the water column provides a third dimension with which to illustrate their patterns of behaviour. However, the raw tag depth data are not inherently informative, given that the study area encompasses water depths of 25–65 m with a tidal range of 3 m. For a demersal species like Atlantic cod, a more relevant measure of vertical behaviour is the position of the tagged fish in relation to the seabed. As such, tag depths from the processed dataset were converted to heights above the bottom according to the following procedure: first, the tidal height from nearby Gloucester Harbor obtained from the National Oceanographic and Atmospheric Administration (http://tidesandcurrents.noaa.gov/) was subtracted from the tag depth to achieve a depth referenced to Mean Lower Low Water. The tag height above the bottom was then calculated by subtracting the depth of the water column at each position, which was obtained from a high-resolution bathymetric survey of the study area (Butman *et al.*, 2007). While the tag depth data were highly precise, as is evident from the clearly defined tidal cycle, each tag appeared to be biased by up to a few metres, a fact acknowledged by the tag manufacturer (i.e. the calculated height of several fish indicated they were several metres *below* the seabed). To correct for this bias, a synthesized "bottom line" was constructed for each tag by subtracting 1 m from a loess smoother (span = 5 days) of each tag's minimum height above the bottom per hour. Tag height data were then adjusted by making this synthesized bottom line the new zero height level. This assumes that when the tidal cycle is evident in the depth data, a fish is ~1 m above the bottom, which appeared to be a reasonable assumption given video observations of the aggregation. Since the tidal cycle was apparent for each fish for some portion of each day, it was possible to use this technique to discern the location of the seabed from the recorded depth data. A loess smoother was used instead of a scalar adjustment, because the amount of sensor bias appeared to drift slightly over the course of a tag's life.

Site affinity

The relationship between spawning fish and their surrounding habitat is of critical importance for their protection and conservation. Describing the affinity for particular locations helps us to understand what constitutes optimal spawning conditions and can help explain potential mechanisms for genotypic divergence. The level of site affinity was measured using a UD overlap index (UDOI) as described in Dean *et al.* (2012), originally adapted from Meager *et al.* (2010). This method calculates the similarity in space use (i.e. per cent overlap between two UD_{95}) from one date to the next for a given fish and diel period. Only periods separated by one calendar day were used to calculate site affinity (e.g. from day_t to day_{t+1}, or from $night_t$ to $night_{t+1}$). A UDOI score of 0 means that a fish occupied completely different areas on consecutive periods; whereas a score of 100 indicates that it returned to the exact same area. A value of 0.01 was added to all UDOI scores to satisfy the assumptions of a Gamma-distributed variable in the GLMM (i.e. no zero values).

Aggregation intensity

Many field studies of spawning cod refer to the formation of dense aggregations, yet observations in captivity have shown that courtship and gamete release occur primarily in pairs. Understanding how these two phenomena function within a single mating system requires measuring the amount of overlap in space use between individuals in an aggregation. We quantified aggregation intensity among fish of the same gender using the same UDOI employed to measure site affinity. However, in this instance we measured the similarity in space use (i.e. per cent overlap in UD_{95}) between all possible inter-fish combinations (within a gender) on a given date and period. A UDOI score of zero indicates complete disaggregation, or no overlap in space use among individuals; larger values indicate more overlap between individual fish, and a higher aggregation intensity. As with site affinity, a value of 0.01 was added to all UDOI scores to satisfy the assumptions of a Gamma-distributed variable in the GLMM.

Aggregation scale and location

Interannual variation in the focal point and extent of an aggregation helps determine the spatial predictability of a spawning event and therefore the appropriate size of a fishery closure. Substantial variation in spawning location from 1 year to the next implies that much larger spatial management measures are necessary to provide meaningful protection. Little interannual variation in aggregation location demonstrates fine-scale spawning site fidelity, which underscores the uniqueness of a spawning component and the need to protect it from overexploitation. The persistence of the aggregation focal point was evaluated by calculating the distance separating the overall average position of individuals and comparing between years, genders, and periods. To measure the average position of a group of individuals, the mean latitude and longitude were first determined for each fish, then the mean of those coordinates was calculated, ensuring that individuals with more detections did not exert undue influence on this measure of aggregation location.

The physical extent of the aggregation as well as the use of space in relation to the surrounding habitat was described through the creation of composite UDs. Composite UDs were constructed by first averaging the UDs from all dates for each individual, diel period, year combination, then averaging across all individuals. Thus, each composite UD represents the probability of locating an average tagged cod of that gender during that diel period over the entire season. The area inside the composite UD_{95} and UD_{50} was used to describe the area occupied by the group.

Results

A total of 2,032 cod were caught in the SCCZ between the months of April and July from 2009 to 2011. These were predominantly large fish in spawning condition, with the majority (60%) being female (Table 1). Males were significantly smaller (two-sample *t*-test; d.f. = 1621.5; $P < 0.0001$) and more likely to be in spawning condition than females (two-sample *z*-test; d.f. = 1; $P < 0.0001$). Despite cannulation, we were unable to determine the sex and maturity of a small number of fish (5% in 2010; 7% in 2011). A total of 70 uninjured cod with a minimum size of 65 cm were tagged with acoustic transmitters, in approximately equal proportions of males and females. Some of these fish were tagged in 2009 and did not return in 2010 or 2011 ($n = 8$), while others were determined to have died soon after release based on depth sensor data ($n = 3$). The remaining 59 fish were tracked in either 2010, 2011 or both years (Figure 3). Only 1 tagged fish (Fish ID = 19) was not in spawning condition when released; data from this transmitter were omitted from all analyses. Most tag releases occurred in 2010 and were distributed over multiple dates to encompass the entire spawning period (Figure 3). On average, tagged cod were tracked for 20 d (range = 1–53 d) in the year of their release. However, 19 tagged fish (29%) returned to the array in subsequent seasons and were tracked for an average of 36 d (range = 3–101 d) in those years. All but four fish tracked in 2011 were released in prior years, providing the best description of the full natural spawning season in that year: the first tagged fish arrived on 18 April and the last fish was detected on 1 August. The peak number of tagged fish simultaneously present in the array (15 fish) in 2011 occurred on 28 May.

Table 1. Number; mean, standard deviation, minimum and maximum total length (cm); and spawning condition of cod caught and tagged with acoustic transmitters in the SCCZ by gender, 2009–2011.

	2009		**2010**		**2011**	
	Caught	**Tagged**	**Caught**	**Tagged**	**Caught**	**Tagged**
Female						
Number	13	3	598	31	519	1
Mean length	67.3	91.3	82.8	94.5	82.6	97.0
SD length	17.3	11.2	14.3	15.1	15.3	–
Min length	46	79	43	68	39	97
Max length	101	101	140	125	122	97
% spawning	69.2	100	67.7	100	59.2	100
Male						
Number	35	1	325	24	417	3
Mean length	60.6	73.0	68.3	80.2	69.1	114.7
SD length	9.6	–	13.8	9.1	14.7	4.2
Min length	31	73	40	65	40	110
Max length	78	73	106	99	118	118
% spawning	91.4	100	94.5	100	96.4	100
Unknown						
Number	7	7	52	–	66	–
Mean length	84.6	84.6	60.1	–	42.4	–
SD length	15.5	15.5	21.0	–	13.4	–
Min length	68	68	31	–	30	–
Max length	107	107	117	–	109	–
% spawning	0%	0%	0%	–	0%	–

Over eight million tag detections were recorded in 2010 and 2011. However, the majority were duplicate detections of tags simultaneously within the range of multiple receivers. Consequently, the VPS processing algorithm yielded a total of 363 272 individual positions with an estimated HPEm below our maximum threshold of 10 m (Table 2). After cropping the dataset for the post-release interval (7 d), a total of 47 fish (23 males; 24 females) had sufficient positions for estimating UDs. The median interval between positions was <3 min in both years, but was slightly higher in 2010 due to the larger number of fish tracked that year. Some fish occasionally left the array during their spawning season, which was defined as the period between the first and last detections in a given year. Any interval between positions more than 1 h was considered a departure from the array. On average, males spent approximately twice as much time outside of the array than females (Table 2; Wilcox rank-sum test, $P = 0.0212$); however, the median departure from the array was <3 h for both sexes.

The receiver array was dramatically reduced in size (from 28 to 4 receivers) upon the opening of the fishery on 21 July. During the closure period, each individual appeared to make daily visits to the area covered by the smaller array. Therefore, it seems reasonable to assume that the smaller array adequately documented the end of the spawning period. However, due to its limited detection area, the smaller array did not prove useful in the creation of UDs. Fortunately, more than 90% of the tagged fish had left the area before the opening of the fishery in both years. Therefore, it appears that the larger VPS array during the closure period captured the majority of the spawning season for most individuals. The GLMM analyses revealed a strong SEX effect in the best fitting model for all behaviour metrics (Table 3). PERIOD or SEX:PERIOD interactions were significant predictors in each model as well, indicating a strong diel influence on behaviour, with each gender responding differently to the change in diel period. A lack of a significant YEAR effect in all metrics indicates little interannual variability in spawning behaviour.

Males exhibited a two- to fourfold diel difference in the core area occupied by individual fish (UD_{50}), ranging from 0. 5 ha at night to 1.4–2.4 ha during the day (Table 4, Figure 4). Females showed less diel change in area occupied, remaining within a UD_{50} of 0.6–0.7 ha at night and 0.9–1.2 ha during the day. A similar pattern was also apparent in the broader measure of home range (UD_{95}). Females showed a higher affinity for a particular location than males, both during the day and at night. Both genders exhibited a three- to eightfold increase in site affinity during the day, indicating that tagged cod tended to seek out new areas each night but returned to the same area each day. On average, females were ~3 m above the bottom during the night, and within a metre of the bottom during the day. Males had less diel difference in depth, typically remaining within 2 m of the bottom both day and night. Both males and females exhibited higher aggregation intensity during the day; however, females were more aggregated than males both day and night.

The location of the spawning aggregation was remarkably consistent between years. The year-to-year change in average position of females was only 9 m at night and 104 m during the day (Table 5). Similarly, the interannual change in average male position was higher during the day (360 m) than at night (75 m). Males tended to move west at night, while females tended to move to the north. Interestingly, the average male position was consistently west of the average female position by several hundred metres in both years, regardless of diel period, suggesting some amount of segregation among the sexes.

The composite UDs of all tagged individuals showed that during the daytime, males were active over a 160–256 ha area (UD_{95}) extending west from the gravel bar out over the muddy plain (Table 6, Figure 5). The core area of male activity (UD_{50}) during the day increased from 5 ha in 2010 to 46 ha in 2011, which is potentially a result of an increase in the size of the fishery closure area. At night, the area occupied by all males either increased (2010) or stayed roughly the same (2011), despite individual males occupying much smaller areas. As a result of male disaggregation at night, the composite UD appears as a patchy pattern resulting from the accumulation of individual territories (Figure 6). Regardless of diel period, males restricted their movements to the muddy plain west of the gravel bar. Female's collective use of space was slightly larger at night (139–170 ha) than during the day (113–125 ha), as measured by the UD_{95}. However, the core area of female activity (UD_{50}) was seven to eight times larger at night than during the day. In both years, all tagged females could be found inside of a 1.6 ha UD_{50} during the day, essentially outlining the limits of the gravel bar at the centre of the SCCZ. The tendency of females to make periodic excursions from the gravel bar at night causes the composite UD to appear as a tangle of linear trajectories radiating from a single core area (Figure 6).

Discussion

Our results identify clear gender-related diel patterns in movement and space use among Atlantic cod on a spawning ground. During the day, females remained aggregated close to the bottom in one small location that varied little within and between years. Males were also aggregated during the day, but occupied a much larger adjacent area to the west. At night, these behaviours changed as both genders disaggregated, males more so than females. Individual males sought

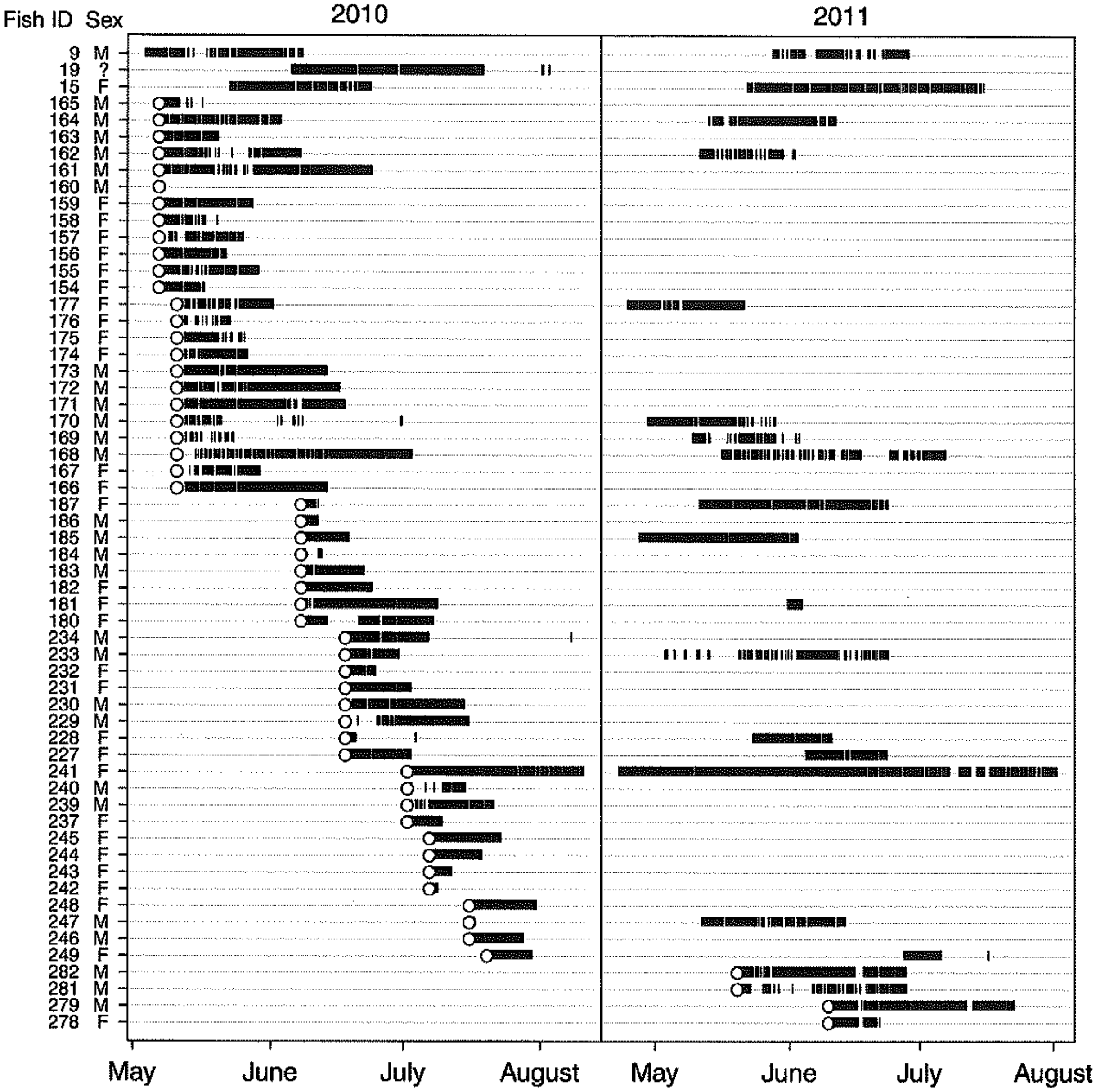


Figure 3. Detection timeline for acoustically tagged cod in the Spring Cod Conservation Zone (SCCZ) in 2010 and 2011. Open circles indicate the release date, whereas black bars indicate detections. Fish IDs 9, 15, and 19 were released in 2009.

out separate small territories each night, while females generally remained near their daytime aggregation site, making periodic excursions into the surrounding area. Females moved higher in the water column at night, while males tended to remain close to the seabed both day and night. These patterns in behaviour were surprisingly stable over the 2 years of observation (Figures 5 and 6).

In many ways, our observations are consistent with the results of tank experiments describing cod spawning behaviour. The limited space use and disaggregation by males at night supports the notion of individual territories for display and courtship (Brawn, 1961; Hutchings *et al.*, 1999). Several studies reported that females were segregated from males during the spawning period (Brawn, 1961; Kjesbu, 1989; Meager *et al.*, 2009). Similarly, we found that males and females favoured different areas, although substantial overlap remained both day and night. Both Brawn (1961) and Kjesbu (1989) found that spawning occurs primarily at night, with most individuals joining a "passive" aggregation during the day. Our results support this concept, as both genders were more aggregated during the day, and spawning-related behaviours (male territories, female excursions, vertical movement) were more common at night.

However, our findings differ from these studies in a few key ways. Both Brawn (1961) and Hutchings *et al.* (1999) support the concept of a dominance hierarchy wherein only the largest, most dominant males form territories that they defend from other males through agonistic interactions. Female cod have been shown to preferentially select dominant males with territories for mating (Brawn, 1961) and paternity analysis of the offspring from captive cod has shown that larger, dominant males achieve the highest reproductive success, a phenomenon known as "mating skew" (Bekkevold *et al.*, 2002; Rowe *et al.*, 2008; Skjæraasen and Hutchings, 2010). Furthermore, male dominance hierarchies have been found to be stable over the course of an entire season (Hutchings *et al.*, 1999), or until the dominant male is depleted of sperm (Bekkevold *et al.*, 2002). Our findings suggest that the presence of these behaviours in captive spawning cod may result from confinement, and extrapolation to wild spawners may be unwarranted. If the natural size of an individual male territory is greater than or equal to the dimensions of a laboratory tank, only one fish would be expected to form a territory. Furthermore, it seems logical that only the largest male would be successful at defending this territory from competitors. In the wild, physical space is not as limited and mature males may choose to establish their own territory, rather than challenge a larger male for his. Our observations indicate that males are not faithful to a specific location when they form individual territories at night. It seems unlikely that a social hierarchy determined through agonistic interactions in defence of a specific territory would persist if a new location is chosen each night, and that location is abandoned during the day; any investment in securing a position in the hierarchy would be lost and have to be re-established each night. Furthermore, it seems somewhat implausible that a social hierarchy would persist within an aggregation of thousands, if not millions of conspecifics. A persistent male dominance hierarchy and strong mating skew are common in avian leks, but they typically contain less than a hundred individuals (Widemo and Owens, 1999), with mating skew increasing as the size of the lek decreases (Widemo and Owens, 1995). While female mate choice is likely a universal component of the cod mating system, the extent to which male dominance hierarchies and mating skew play a role may be amplified by the artificially smaller lek caused by a laboratory tank. However, it should be noted that regional variation in reproductive strategy may exist, and while there is little evidence supporting a male dominance hierarchy in the present study, this may not be the case elsewhere.

Table 2. Summary of tag positions calculated from detections made by the acoustic receiver array in 2010 and 2011.

	Females	Males
2010		
Individuals tracked	25 (1/24/–)	21 (1/20/–)
Relocated positions	78 894	77 485
Median position error (HPEm)	2.8 m	2.9 m
Median position interval	150 s	162 s
Mean % of season outside array	20.7%	37.0%
2011		
Individuals tracked	9 (1/7/1)	12 (1/8/3)
Relocated positions	104 737	102 606
Median position error (HPEm)	3.0 m	3.1 m
Median position interval	116 s	128 s
Mean % of season outside array	20.3%	41.0%

Notes: The number individuals tracked in a given year is provided in total, and by year tagged in parentheses (2009/2010/2011). Position error is the estimated distance (m) separating a calculated position and the true location. Position interval (s) is the amount of time separating consecutive detections for an individual fish. The per cent of a fish's season spent outside the array was calculated as the sum of the detection "gaps" (time between consecutive detections separated by more than 1 h) divided by its "season" (time difference between the first and last detections).

Table 3. *P*-values associated with independent variables of best fitting models for each behaviour metric.

Dependent variables	Independent variables		
	Period	Sex	Period × sex
Area occupied (UD_{50})	0.2055	0.0030	0.0034
Area occupied (UD_{95})	0.0389	0.0027	0.0180
Height above bottom	<0.0001	0.0013	<0.0001
Site affinity	0.0083	<0.0001	–
Aggregation	<0.0001	0.0003	0.0050

The vertical movements of spawning cod have been directly observed in captivity, and remotely described via telemetry and hydroacoustic surveys. Laboratory studies have typically found that females occupy a higher place in the water column than males when not actively engaged in courtship or spawning events

Table 4. Mean values (standard deviation) associated with each individual behaviour metric by year, gender, and diel period.

	Area occupied (ha)		Height above bottom (m)	Site affinity (UDOI)	Aggregation intensity (UDOI)
	UD_{50}	UD_{95}			
2010					
Female					
Day	1.17 (1.7)	5.79 (7.1)	0.90 (0.5)	14.76 (9.9)	5.82 (4.9)
Night	0.61 (0.4)	3.05 (2.1)	3.20 (1.0)	4.28 (3.1)	1.82 (1.7)
Male					
Day	1.43 (1.3)	7.37 (5.6)	1.50 (0.3)	14.05 (11.2)	3.71 (3.2)
Night	0.54 (0.4)	3.09 (2.1)	1.96 (0.8)	1.84 (1.3)	0.35 (0.8)
2011					
Female					
Day	0.91 (0.9)	5.51 (4.3)	1.32 (0.5)	14.65 (6.6)	7.09 (5.1)
Night	0.73 (0.3)	3.59 (1.1)	3.12 (2.0)	3.41 (2.3)	1.67 (1.3)
Male					
Day	2.37 (1.3)	10.96 (5.4)	1.79 (0.3)	7.83 (3.8)	2.74 (2.0)
Night	0.56 (0.2)	3.30 (1.4)	1.48 (0.1)	1.85 (1.7)	0.59 (1.1)

Notes: UD_{50} and UD_{95} represent the area inside the 50th and 95th probability contours of individual fish UDs. Site affinity is measured by the amount of UD_{95} overlap (UDOI) on consecutive dates for a given fish. Aggregation intensity is measure by the average amount of UD_{95} overlap (UDOI) between all possible inter-fish combinations within a group.

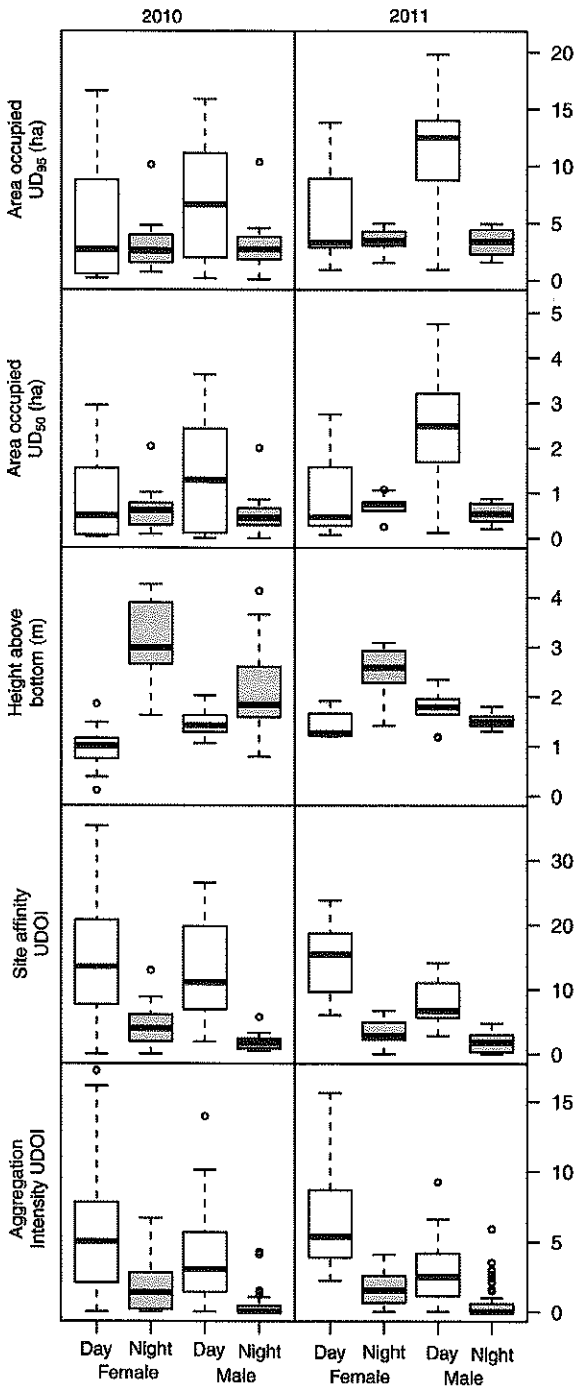


Figure 4. Box plots of mean behaviour metrics, by year, gender, and diel period (from top to bottom): mean area occupied per individual, as measured by the UD 50% and 95% probability contours; mean height above bottom per individual (m); mean site affinity per individual, as measured by the UD overlap index (UDOI) between consecutive periods; aggregation intensity, as measured by the mean UDOI of all possible inter-fish combinations within a group.

Table 5. Distance (m) between the average position of each gender, diel period, and year combination.

	2010				**2011**			
	Female		**Male**		**Female**		**Male**	
	Day	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
2010								
Female								
Day	0	198	182	768	104	191	542	704
Night		0	247	765	105	9	531	692
Male								
Day			0	586	225	238	360	522
Night				0	794	758	234	75
2011								
Female								
Day					0	101	561	725
Night						0	524	686
Male								
Day							0	164
Night								0

Table 6. Total area occupied by all tagged individuals of a group by year, gender, and diel period.

	Area occupied (ha)	
	UD$_{50}$	**UD$_{95}$**
2010		
Female		
Day	1.6	125.3
Night	11.4	138.8
Male		
Day	4.5	160.0
Night	34.6	215.7
2011		
Female		
Day	1.6	112.9
Night	13.6	169.9
Male		
Day	45.5	255.7
Night	41.6	240.1

Notes: UD$_{50}$ and UD$_{95}$ represent the area inside the 50th and 95th probability contours of a composite UD.

(Hutchings *et al.*, 1999; Meager *et al.*, 2009). Courtship activity appears associated with the seabed, while the ventral mount and actual spawning release occurs near the surface (Brawn, 1961; Hutchings *et al.*, 1999; Meager *et al.*, 2009). However, it should be noted that the vertical dimensions of the experimental tanks in all studies were 3 m or less, limiting their relevance to natural spawning conditions. In our study, we never recorded tagged cod more than 20 m above the seabed, which was still ~35 m below the surface. While reports of the vertical behaviour of spawning cod in captivity are fairly consistent, there appears to be substantial diversity among regions in the wild. In some areas, spawning cod favour a pelagic distribution (Godø, 1989; Nielsen *et al.* 2013), while in other locations they are associated with the seabed (Lawson and Rose, 1999; Meager *et al.*, 2009; Siceloff and Howell, 2013). In Newfoundland, spawning aggregations of cod are typically close to the bottom during the day, yet become pelagic at night (Ouellet *et al.*; 1997, Rose, 2003; Fudge and Rose, 2009). Large pelagic "columns" of cod have been observed via echosounder during the spawning season (Rose, 1993; Knickle and Rose, 2012), yet this behaviour is rarely observed outside of Canada. Despite extensive behavioural plasticity, there are some

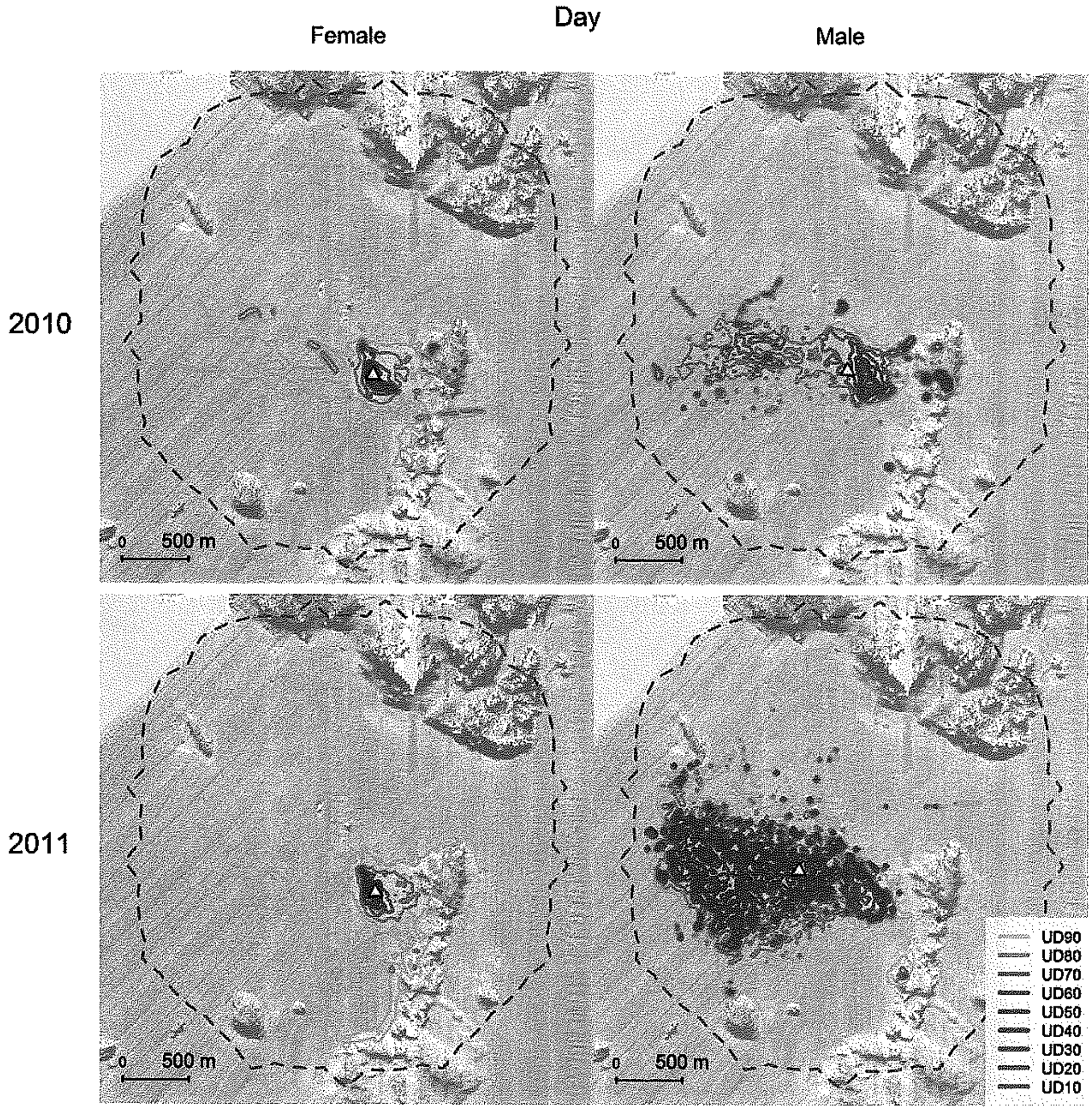


Figure 5. Probability contours extracted from the composite daytime UD of acoustically tagged cod, by year and gender. The dashed grey line represents the approximate detection limit of the acoustic array. The yellow triangle identifies the average daytime position for that gender and year.

common elements to the studies describing individual vertical movements (i.e. laboratory and telemetry observations): females generally occur higher in the water column than males, and females move higher in the water column at night. Our findings are consistent on both these points.

Cod spawning grounds have often been identified by an abundance of ripe fish in survey or fishery catches (Lawson and Rose, 2000). In addition, it is common to find strongly skewed sex ratios on a spawning ground, typically with the majority being male (Morgan and Trippel, 1996; Nordeide, 1998; Jakobsen and Ajiad, 1999; Armstrong *et al.*, 2004). From these observations, it has been inferred that males arrive on the spawning ground first and remain there more consistently than females. Females are believed to be more widely dispersed and less consistently present on the spawning ground. Per the theory, females periodically enter the male-dominated aggregation from the periphery when ready to spawn. However, the idea that sex ratios can be used to infer patterns in distribution is based on the assumption that there is a negligible difference in catchability between the genders. Our results indicate that not only are females more consistently present, they are also more densely aggregated and more faithful to a particular locale. This gender disparity in aggregation behaviour could explain the male-skewed sex ratios commonly found on spawning grounds. While still aggregated, males are far more wide ranging than females, making them more susceptible to encounters with fishing gear. Our experience with angling for cod in the SCCZ supports

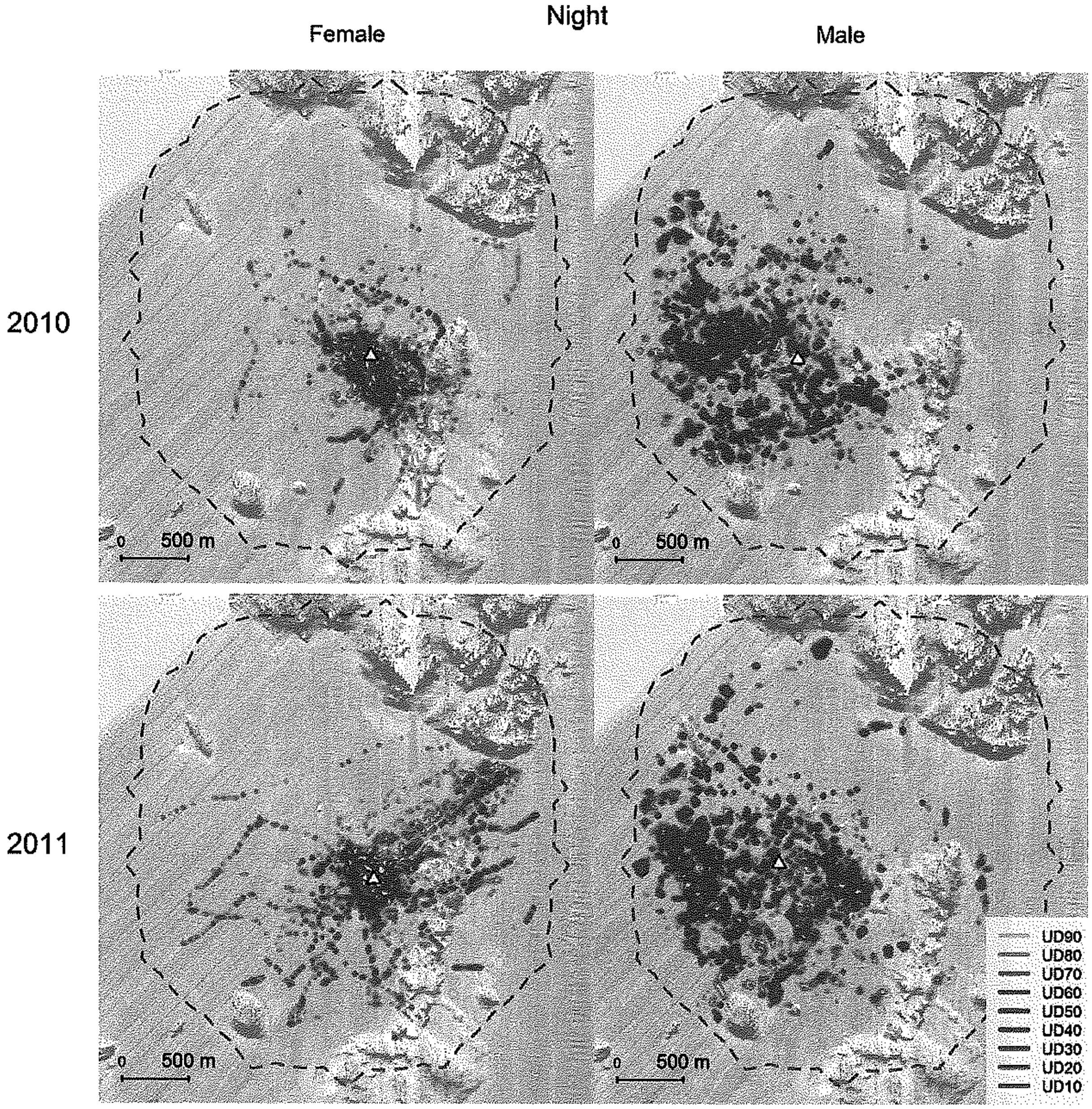


Figure 6. Probability contours extracted from the composite night-time UD of acoustically tagged cod, by year and gender. The dashed grey line represents the approximate detection limit of the acoustic array. The yellow triangle identifies the average daytime position for that gender and year.

this idea. The initial telemetry work in this area in 2009 identified the site of the female-dominated aggregation (Dean *et al.*, 2012). Since this was the most productive fishing location, much of our angling effort was focused here in 2010 and 2011. Consequently, the overall sex ratio of our catches was dominated by females (Table 1). Yet, whenever the research vessel drifted off of this location, the sex ratio of catches quickly became more male-dominated.

The influence of spawning behaviour on the observed sex ratio has important implications for the assessment and management of this species. Stock demographics (e.g. size distribution, fecundity, sex ratio, etc.) can vary dramatically over time; yet, it is common to use spawning-stock biomass (SSB) as a measure of the reproductive potential of the stock, which assumes constancy in the demographic variables that influence egg production and thus recruitment (Marshall *et al.*, 2006). Recently, efforts have been made to incorporate more biological information into assessments, and measures such as female spawning biomass and total egg production have been favoured over SSB (Marshall *et al.*, 2006; Morgan, 2008; Lambert, 2013). The proportion of females in the population (i.e. sex ratio) is an integral component to these alternative measures of stock reproductive capacity. Our findings caution reliance upon sex ratio information collected near known spawning grounds, as these data are likely biased towards males, which would underestimate female-based measures of spawning stock.

The behaviours observed in this study could inform the spatial distribution of cod on spawning grounds elsewhere. Tank studies from both sides of the Atlantic have indicated that spawning occurs mainly at night, and that the sexes are typically segregated during spawning (Brawn, 1961; Kjesbu, 1989; Hutchings *et al.*, 1999). Our observations corroborate both these points, which lead us to believe that there are aspects of the cod mating system that are common to all cod stocks. Yet, the scale on which these spawning behaviours occur remains unclear. The spawning component protected by the SCCZ is a relatively small aggregation within a relatively small cod stock (NEFSC, 2013). In contrast, spawning aggregations in Canada and Norway have been shown to span many kilometres and contain millions of fish (Ouellet *et al.*, 1997; Nordeide and Kjellsby, 1999; Rose, 2003). If these larger groups of fish exhibit comparable diel and gender patterns in behaviour, do they form a single large female aggregation? Or, are there multiple smaller groups of densely aggregated females distributed sporadically throughout the spawning ground? It would seem energetically impractical to have all members of one gender many kilometres apart from the other gender, as was previously suggested from the examination of sex ratios from bottom trawl surveys (Morgan and Trippel, 1996). Interestingly, both Morgan and Trippel (1996) and Nordeide (1998) found a small portion of female-skewed sets scattered among most of the male-dominated sets on the spawning ground, providing evidence of a network of multiple small female-dominated aggregations.

Both Espeland *et al.* (2007) and Meager *et al.* (2010) used an acoustic telemetry positioning system to describe the space use of wild spawning cod in two separate Norwegian fjords. The home ranges (UD_{95}) of individual fish in both studies (Espeland: 3–77 ha; Meager: 2–51 ha) were somewhat larger than our estimates (0.2–27 ha), but this is to be expected given their kernel density approach to estimating the UD. In contrast to our findings, Meager *et al.* (2010) found that males as a group occupied a smaller area than females, and males exhibited more overlapping space use than females. However, with only three receivers, perhaps a significant portion of the movements of their tagged fish went unobserved. In fact, 20 of their 48 tagged fish did not yield sufficient positions to estimate a UD. In the SCCZ, our perception of the aggregation extent was broadened significantly between the 4-receiver array of 2009 (Dean *et al.*, 2012) and the 28-receiver array of 2010–2011. Furthermore, our results identify a strong diel component to cod spawning behaviour, and for this reason it is difficult to make direct comparisons to these earlier studies that did not evaluate day/night differences. Regardless, all acoustic telemetry studies of spawning cod (present study included) confirm the observations made in captivity of sexually dimorphic behaviour.

The dramatic diel difference in behaviour observed in this study has important implications for the monitoring and protection of cod spawning aggregations. The location, intensity, and spatial extent of the spawning aggregation varied significantly from day to night. Ignoring this spatio-temporal pattern in the design of spawning protection measures can have negative consequences. For example, the initial SCCZ fishery closure in 2009 was based around knowledge of the female-dominated daytime aggregation. However, upon reviewing the telemetry observations included in this paper, it was clear that many fish (primarily males) were leaving the closure at night. Consequently, managers doubled the size of the SCCZ in 2011 to ensure the integrity of the spawning aggregation and prevent overexploitation and fishery-induced disruption (Dean *et al.*, 2012; Armstrong *et al.*, 2013). This change in the size of the closure could explain the larger spatial extent of the aggregation in 2011 (Table 5; Figure 5). Spawning cod have been shown to react to and avoid both gillnet and trawl fishing activity (Morgan *et al.*, 1997; Dean *et al.*, 2012). Although speculative, fishing pressure immediately outside of the closure may have caused individual fish to avoid the margins and restrict their movements to the interior. Interestingly, both the closure and aggregation extent expanded in an east–west direction in 2011.

In the present study, space use did not appear random with respect to local bathymetric features. In both years, the main focal point of the aggregation was a 2 ha gravel bar near the centre of the array with ~2 m of vertical relief (Figure 2). Both males and females frequented the surrounding flat muddy area at night, but appeared to avoid entirely the bedrock ledges to the north and east (Figure 2). This preference for a particular habitat during spawning is similar to observations of spring-spawning cod in nearby Ipswich Bay (Siceloff and Howell, 2013). In that study, spawning cod were active over "muddy flats" in 60–70 m of water, bounded by a series of "rocky humps" with 30 m of vertical relief, and were most frequently observed around a small bathymetric feature (~6 ha) with 4 m of relief. This similarity in habitat utilization between Massachusetts Bay and Ipswich Bay cod suggests a common reproductive strategy among genetically related spring-spawning components (Kovach *et al.*, 2010). It is not evident what distinguishes this particular gravel bar from others in Massachusetts Bay, as there are a number of seemingly similar bathymetric features within a 10 km radius. Presumably, this location is associated with other favourable oceanographic conditions suitable for the survival of early life stages; Massachusetts Bay in general has been shown to be an area that promotes the local retention of cod larvae (Huret *et al.*, 2007; Churchill *et al.*, 2011) and provides suitable habitat for juveniles (Howe *et al.*, 2002).

In many regions, Atlantic cod are a migratory species, often wandering hundreds of kilometres in search of forage or favourable environmental conditions before returning to their spawning ground each year (Robichaud and Rose, 2004). This interannual spawning site fidelity is well documented and has been shown to occur on the scale of <1 km (Robichaud and Rose, 2001; Skjæraasen *et al.*, 2011). The level of homing to a particular site observed in the present study was astonishing, with only 9 m separating the mean night-time position of females in 2010 and 2011 (Table 5). Although not presented here, telemetry observations from 2009 (Dean *et al.*, 2012) and 2012 confirm the persistence of this aggregation focal point in those years as well. Such extreme site fidelity underscores the need to protect spawning aggregations, as their spatial and temporal reliability make them particularly vulnerable to overexploitation and disruption from fishing activity (Sadovy and Domeier, 2005; Dean *et al.*, 2012). Furthermore, the fine scale on which spawning site fidelity occurs suggests a potential mechanism for evolutionary divergence in populations that share adjacent spawning grounds (e.g. Nordeide 1998; Kovach *et al.* 2010; Grabowski *et al.* 2011).

The ability of these spawners to navigate to an exact location each year is particularly intriguing. With individual fish returning to the same fixed location each day of each season, it seems visual cues must play a role in how they orient themselves on the spawning ground. Some species of fish have been shown to use landmarks to return to a particular location (Dodson, 1988). Both field and laboratory experiments have shown that fish have the ability to learn the position of and route to a desirable location (e.g. for feeding or spawning) from more experienced "demonstrators" (Brown and Laland, 2003). Rose (1993) used hydroacoustic observations of migrating cod off Newfoundland to propose that smaller fish followed the lead of larger "scouts". The mere existence of such extreme site fidelity in an open marine system suggests that social learning plays a role in the spatial persistence of spawning aggregations, and that cod may experience diminished recruitment success if the age structure becomes truncated and the evolutionary "knowledge" to spawn at an optimal location is lost.

This study furthers our understanding of cod spawning behaviour by providing critical details that connect the findings of earlier laboratory experiments and field observations. Our results identify strong diel and gender-based differences in the spatial distribution and aggregation behaviour of spawning cod. However, it remains to be seen whether the behaviours observed in this study are a property of spring-spawning Gulf of Maine cod, or of the species in general. Similar investigations made elsewhere in the Gulf of Maine or in other stocks would contribute greatly to answering this question. Regardless, our findings provide an empirical example of how spawning behaviour can influence the fine-scale distribution of Atlantic cod. Acknowledging and understanding these patterns can aid in the design of more effective management measures and help reduce biases in stock assessments.

Supplementary material

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Acknowledgements

We are grateful to Brant McAfee, Brad Schondelmeier, and Nick Buchan for their hard work and dedication in assembling and maintaining the acoustic array. Preliminary findings from this work were presented at the ICES symposium "Gadoid Fisheries: The ecology and management of rebuilding" in St Andrews, New Brunswick in October 2013. Feedback from several individuals at the symposium contributed greatly to the development of this manuscript, including Jon Egil Skjæraasen, Joanne Morgan, and John Brattey. This project was funded in part by the U.S. Fish and Wildlife Service through the Sportfish Restoration Act under grant F-57-R. This paper is contribution 48 of the Massachusetts Division of Marine Fisheries.

References

Ames, E. P., and Lichter, J. 2013. Gadids and Alewives: structure within complexity in the Gulf of Maine. Fisheries Research, 141: 70–78.

Andrews, K. S., Tolimieri, N., Williams, G. D., Samhouri, J. F., Harvey, C. J., and Levin, P. S. 2011. Comparison of fine-scale acoustic monitoring systems using home range size of a demersal fish. Marine Biology, 158: 2377–2387.

Armstrong, M. J., Gerritsen, H. D., Allen, M., McCurdy, W. J., and Peel, J. A. D. 2004. Variability in maturity and growth in a heavily exploited stock: cod (*Gadus morhua* L.) in the Irish Sea. ICES Journal of Marine Science, 61: 98–112.

Armstrong, M. P., Dean, M. J., Hoffman, W. S., Zemeckis, D. R., Nies, T. A., Pierce, T. A., Diodati, P. J., *et al.* 2013. The application of small scale fishery closures to protect Atlantic cod spawning aggregations in the inshore Gulf of Maine. Fisheries Research, 141: 62–69.

Bekkevold, D., Hansen, M. M., and Loeschcke, V. 2002. Male reproductive competition in spawning aggregations of cod (*Gadus morhua*, L.). Molecular Ecology, 11: 91–102.

Brander, K. M. 2005. Cod recruitment is strongly affected by climate when stock biomass is low. ICES Journal of Marine Science, 62: 339–343.

Brawn, V. M. 1961. Reproductive behaviour of the cod (*Gadus callarias* L.). Behaviour, 18: 177–198.

Brown, C., and Laland, K. N. 2003. Social learning in fishes: a review. Fish and Fisheries, 4: 280–288.

Butman, B., Valentine, P. C., Middleton, T. J., and Danforth, W. W. 2007. A GIS Library of multibeam data for Massachusetts Bay and the Stellwagen Bank National Marine Sanctuary, Offshore of Boston, Massachusetts. U.S. Geological Survey, Data Series 99, Woods Hole, MA.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modeling, 197: 516–519.

Churchill, J. H., Runge, J., and Chen, C. 2011. Processes controlling retention of spring-spawned Atlantic cod (*Gadus morhua*) in the western Gulf of Maine and their relationship to an index of recruitment success. Fisheries Oceanography, 20: 32–46.

Dean, M. J., Hoffman, W. S., and Armstrong, M. P. 2012. Disruption of an Atlantic Cod spawning aggregation resulting from the opening of a directed Gill-Net Fishery. North American Journal of Fisheries Management, 32: 124–134.

DeCelles, G., and Zemeckis, D. 2014. Acoustic and radio telemetry. *In* Stock Identification methods, 2nd edn, pp. 397–428. Ed. by S. Cadrin, L. Kerr, and S. Mariano. Elsevier Academic Press, Amsterdam. 588 pp.

Dodson, J. J. 1988. The nature and role of learning in the orientation and migratory behavior of fishes. Environmental Biology of Fishes, 23: 161–182.

Downs, J. A., and Horner, M. W. 2008. Effects of point pattern shape on home-range estimates. Journal of Wildlife Management, 72: 1813–1818.

Drinkwater, K. F. 2005. The response of Atlantic cod (*Gadus morhua*) to future climate change. ICES Journal of Marine Science, 62: 1327–1337.

Espeland, S. H., Gundersen, A. F., Olsen, E. M., Knutsen, H., Gjøsæter, J., and Stenseth, N. C. 2007. Home range and elevated egg densities within an inshore spawning ground of coastal cod. ICES Journal of Marine Science, 64: 920–928.

Espinoza, M., Farrugia, T. J., Webber, D. M., Smith, F., and Lowe, C. G. 2011. Testing a new acoustic telemetry technique to quantify long-term, fine-scale movements of aquatic animals. Fisheries Research, 108: 364–371.

Food and Aquaculture Organization of the United Nations (FAO). 2012. The State of World Fisheries and Aquaculture 2012. Food and Aquaculture Organization of the United Nations (FAO), Rome. 209 pp.

Frank, K. T., and Brickman, D. 2000. Allee effects and compensatory population dynamics within a stock complex. Canadian Journal of Fisheries and Aquatic Sciences, 57: 513–517.

Fudge, S. B., and Rose, G. A. 2009. Passive- and active-acoustic properties of a spawning Atlantic cod (*Gadus morhua*) aggregation. ICES Journal of Marine Science, 66: 1259–1263.

Godø, O. R. 1989. The use of tagging studies to determine the optimal time for estimating acoustic abundance of spawning cod. Fisheries Research, 8: 129–140.

Grabowski, T. B., Thorsteinsson, V., McAdam, B. J., and Marteinsdóttir, G. 2011. Evidence of segregated spawning in a single marine fish stock: sympatric divergence of ecotypes in Icelandic Cod? Progress in Oceanograpy, 6: 1–9.

Heffernan, O., Righton, D., and Michalsen, K. 2004. Use of data storage tags to quantify vertical movements of cod: effects on acoustic measures. ICES Journal of Marine Science, 61: 1062–1070.

Horne, J. S., Garton, E. O., Krone, S. M., and Lewis, J. S. 2007. Analyzing animal movements using Brownian bridges. Ecology, 88: 2354–2363.

Howe, A. B., Correia, S. J., Currier, T. P., King, J., and Johnston, R. 2002. Spatial distribution of ages 0 and 1 Atlantic cod (*Gadus morhua*) off the eastern Massachusetts coast, 1978–1999, relative to 'Habitat Area of Special Concern'. Massachusetts Division of Marine Fisheries. Technical Report TR12. 35 pp.

Huret, M., Runge, J. A., Chen, C., Cowles, G., Xu, Q., and Pringle, J. M. 2007. Dispersal modeling of fish early life stages: sensitivity with application to Atlantic cod in the western Gulf of Maine. Marine Ecology Progress Series, 347: 261–274.

Hutchings, J. A., Bishop, T. D., and McGregor-Shaw, C. R. 1999. Spawning behaviour of Atlantic cod, *Gadus morhua*: evidence of mate competition and mate choice in a broadcast spawner. Canadian Journal of Fisheries and Aquatic Sciences, 56: 97–104.

Jakobsen, T., and Ajiad, A. 1999. Management implications of sexual differences in maturation and spawning mortality of Northeast Arctic Cod. Journal of Northwest Atlantic Fisheries Science, 25: 125–131.

Kjesbu, O. S. 1989. The spawning activity of cod, *Gadus morhua* L. Journal of Fish Biology, 34: 195–206.

Knickle, D. C., and Rose, G. A. 2012. Acoustic markers of Atlantic cod (*Gadus morhua*) spawning in coastal Newfoundland. Fisheries Research, 129–130: 8–16.

Köster, F. W., Möllmann, C., Hinrichsen, H.-H., Wieland, K., Tomkiewicz, J., Kraus, G., Voss, R., *et al.* 2005. Baltic cod recruitment—the impact of climate variability on key processes. ICES Journal of Marine Science, 62: 1408–1425.

Kovach, A. I., Breton, T. S., Berlinsky, D. L., Maceda, L., and Wirgin, I. 2010. Fine-scale spatial and temporal genetic structure of Atlantic cod off the Atlantic coast of the USA. Marine Ecology Progress Series, 410: 177–195.

Kurlansky, M. 1998. Cod: a biography of the fish that changed the world. Penguin Books, New York. 294 pp.

Lambert, Y. 2013. Long-term changes in life history characteristics and reproductive potential of northern Gulf of St. Lawrence cod (*Gadus morhua*) and consequences for the stock productivity. Fisheries Research, 138: 5–13.

Lawson, G. L., and Rose, G. A. 1999. The importance of detectability to acoustic surveys of semi-demersal fish. ICES Journal of Marine Science, 56: 370–380.

Lawson, G. L., and Rose, G. A. 2000. Small-scale spatial and temporal patterns in spawning of Atlantic cod (*Gadus morhua*) in coastal Newfoundland waters. Canadian Journal of Fisheries and Aquatic Sciences, 57: 1011–1024.

Lilly, G. R., Wieland, K., Rothschild, B., Sundby, S., Drinkwater, K., Brander, K., Ottersen, G., *et al.* 2008. Decline and recovery of Atlantic cod (Gadus morhua) stocks throughout the North Atlantic. In Resiliency of Gadid stocks to fishing and climate change, pp. 39–66. Ed. by Kruse, G. H., Drinkwater, K., Ianelli, J. N., Link, J. S., Stram, D. L., Wespestad, V., and Woodby, D. Alaska Sea Grant College Program, Fairbanks. 364 pp.

Lindegren, M., Waldo, S., Nilsson, P. A., Svedäng, H., and Persson, A. 2013. Towards sustainable fisheries of the Öresund cod (*Gadus morhua*) through sub-stock-specific assessment and management recommendations. ICES Journal of Marine Science, 70: 1140–1150.

Løkkeborg, S., Fernö, A., and Jørgensen, T. 2002. Effect of position-fixing interval on estimated swimming speed and movement pattern of fish tracked with a stationary positioning system. Hydrobiologia, 483: 259–264.

Marshall, C. T., Needle, C. L., Thorsen, A., Kjesbu, O. S., and Yaragina, N. A. 2006. Systematic bias in estimates of reproductive potential of an Atlantic cod (*Gadus morhua*) stock: implications for stock–recruit theory and management. Canadian Journal of Fisheries and Aquatic Sciences, 63: 980–994.

Marteinsdóttir, G., Gudmundsdottir, A., Thorsteinsson, V., and Stefansson, G. 2000. Spatial variation in abundance, size composition and viable egg production of spawning cod (*Gadus morhua* L.) in Icelandic waters. ICES Journal of Marine Science, 57: 824–830.

Meager, J. J., Skjæraasen, J. E., Fernö, A., Karlsen, Ø., Løkkeborg, S., Michalsen, K., and Utskot, S. O. 2009. Vertical dynamics and reproductive behaviour of farmed and wild Atlantic cod *Gadus morhua*. Marine Ecology Progress Series, 389: 233–243.

Meager, J. J., Skaeraasen, J. E., Fernö, A., and Løkkeborg, S. 2010. Reproductive interactions between fugitive farmed and wild Atlantic cod (*Gadus morhua*) in the field. Canadian Journal of Fisheries and Aquatic Sciences, 67: 1221–1231.

Morgan, M. J. 2008. Integrating reproductive biology into scientific advice for fisheries management. Journal of Northwest Atlantic Fisheries Science, 41: 37–51.

Morgan, M. J., DeBlois, E. M., and Rose, G. A. 1997. An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. Canadian Journal of Fisheries and Aquatic Sciences, 54: 217–223.

Morgan, M. J., and Trippel, E. A. 1996. Skewed sex ratios in spawning shoals of Atlantic cod (*Gadus morhua*). ICES Journal of Marine Science, 53: 520–526.

Morgan, M. J., Wilson, C. E., and Crim, L. W. 1999. The effect of stress on reproduction in Atlantic cod. Journal of Fish Biology, 54: 477–488.

Myers, R. A., Hutchings, J. A., and Barrowman, N. J. 1996. Hypotheses for the decline of cod in the North Atlantic. Marine Ecology Progress Series, 138: 293–308.

Nichol, D. G., and Chilton, E. A. 2006. Recuperation and behaviour of Pacific cod after barotrauma. ICES Journal of Marine Science, 63: 83–94.

Nielsen, B., Hüssy, K., Neuenfeldt, S., Tomkiewicz, J., Behrens, J. W., and Andersen, K. H. 2013. Individual behaviour of Baltic cod *Gadus morhua* in relation to sex and reproductive state. Animal Behavior, 18: 197–207.

Nordeide, J. T. 1998. Coastal cod and north-east Arctic cod—do they mingle at the spawning grounds in Lofoten? Sarsia, 83: 373–379.

Nordeide, J. T., and Folstad, I. 2000. Is cod lekking or a promiscuous group spawner? Fish and Fisheries, 1: 90–93.

Nordeide, J. T., and Kjellsby, E. 1999. Sound from spawning cod at their spawning grounds. ICES Journal of Marine Science, 56: 326–332.

Northeast Fisheries Science Center (NEFSC). 2013. 55th Northeast Regional Stock Assessment Workshop (55th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 13-11: 845 pp. Woods Hole, Massachusetts, USA.

Ouellet, P., Lambert, Y., and Castonguay, M. 1997. Spawning of Atlantic cod (*Gadus morhua*) in the northern Gulf of St. Lawrence: a study of adult and egg distributions and characteristics. Canadian Journal of Fisheries and Aquatic Sciences, 54: 198–210.

R Development Core Team 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, http://www.R-project.org/.

Robichaud, D., and Rose, G. A. 2001. Multiyear homing of Atlantic cod to a spawning ground. Canadian Journal of Fisheries and Aquatic Sciences, 58: 2325–2329.

Robichaud, D., and Rose, G. A. 2002. Assessing evacuation rates and spawning abundance of marine fishes using coupled telemetric and acoustic surveys. ICES Journal of Marine Science, 59: 254–260.

Robichaud, D., and Rose, G. A. 2003. Sex differences in cod residency on a spawning ground. Fisheries Research, 60: 33–43.

Robichaud, D., and Rose, G. A. 2004. Migratory behaviour and range in Atlantic cod: inference from a century of tagging. Fish and Fisheries, 5: 185–214.

Rogers, K. B., and White, G. C. 2007. Analysis of movement and habitat use from telemetry data. *In* Analysis and interpretation of freshwater fisheries data, pp. 625–676. Ed. by C. S. Guy, and M. L. Brown. American Fisheries Society, Bethesda, MD. 961 pp.

Rose, G. A. 1993. Cod spawning on a migration highway in the north-west Atlantic. Nature, 366: 458–461.

Rose, G. A. 2003. Monitoring coastal northern cod: towards an optimal survey of Smith Sound, Newfoundland. ICES Journal of Marine Science, 60: 453–462.

Rose, G. A. 2004. Reconciling overfishing and climate change with stock dynamics of Atlantic cod (*Gadus morhua*) over 500years. Canadian Journal of Fisheries and Aquatic Sciences, 61: 1553–1557.

Rose, G. A., Nelson, R. J., and Mello, L. G. S. 2011. Isolation or metapopulation: whence and whither the Smith sound cod? Canadian Journal of Fisheries and Aquatic Sciences, 68: 152–169.

Rowe, S., Hutchings, J. A., Skjæraasen, J. E., and Bezanson, L. 2008. Morphological and behavioural correlates of reproductive success in Atlantic cod *Gadus morhua*. Marine Ecology Progress Series, 354: 257–265.

Sadovy, Y., and Domeier, M. 2005. Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs, 24: 254–262.

Shelton, P. A., Sinclair, A. F., Chouinard, G. A., Mohn, R., and Duplisea, D. E. 2006. Fishing under low productivity conditions is further delaying recovery of Northwest Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences, 62: 235–238.

Siceloff, L., and Howell, W. H. 2013. Fine-scale temporal and spatial distributions of Atlantic cod (*Gadus morhua*) on a western Gulf of Maine spawning ground. Fisheries Research, 141: 31–43.

Skjæraasen, J. E., and Hutchings, J. A. 2010. Shifting reproductive success in a shoal of Atlantic Cod, *Gadus morhua* L. Environmental Biology of Fishes, 88: 311–318.

Skjæraasen, J. E., Meager, J. J., Karlsen, Ø., Hutchings, J. A., and Fernö, A. 2011. Extreme spawning-site fidelity in Atlantic cod. ICES Journal of Marine Science, 68: 1472–1477.

Smedbol, R. K., and Stephenson, R. 2001. The importance of managing within-species diversity in cod and herring fisheries of the northwestern Atlantic. Journal of Fish Biology, 59: 109–128.

Smedbol, R. K., and Wroblewski, J. S. 2002. Metapopulation theory and northern cod population structure: interdependency of subpopulations in recovery of a groundfish population. Fisheries Research, 55: 161–174.

Smith, F. 2013. Understanding HPE in the VEMCO Positioning System (VPS) V1.0. VEMCO Document # Doc-005457–07. VEMCO Inc., Halifax. 31 pp.

Svedäng, H., André, C., Jonsson, P., Elfman, M., and Limburg, K. E. 2010. Migratory behaviour and otolith chemistry suggest fine-scale sub-population structure within a genetically homogenous Atlantic Cod population. Environmental Biology of Fishes, 89: 383–397.

Swain, D. P., and Sinclair, A. F. 2000. Pelagic fishes and the cod recruitment dilemma in the Northwest Atlantic. Canadian Journal of Fisheries and Aquatic Sciences, 57: 1321–1325.

Trzcinski, M. K., Mohn, R., and Bowen, W. D. 2006. Continued decline of an Atlantic cod population: how important is gray seal predation? Ecological Applications, 16: 2276–2292.

van der Kooij, J., Righton, D., Strand, E., Michalsen, K., Thorsteinsson, V., Svedäng, H., Neat, F. C., *et al.* 2007. Life under pressure: insights from electronic data-storage tags into cod swimbladder function. ICES Journal of Marine Science, 64: 1293–1301.

Vitale, F., Börjesson, P., Svedäng, H., and Casini, M. 2007. The spatial distribution of cod (*Gadus morhua* L.) spawning grounds in the Kattegat, eastern North Sea. Fisheries Research, 90: 36–44.

Widemo, F., and Owens, I. P. F. 1995. Lek size, male mating skew and the evolution of lekking. Nature, 373: 148–151.

Widemo, F., and Owens, I. P. F. 1999. Size and stability of vertebrate leks. Animal Behavior, 58: 1217–1221.

Windle, M. J. S., and Rose, G. A. 2007. Do cod form spawning leks? Evidence from a Newfoundland spawning ground. Marine Biology, 150: 671–680.

Worton, B. J. 1987. A review of models of home range for animal movement. Ecological Modeling, 38: 277–298.

Wright, P. J., Neat, F. C., Gibb, F. M., Gibb, I. M., and Thordarson, H. 2006. Evidence for metapopulation structuring in cod from the west of Scotland and North Sea. Journal of Fish Biology, 69: 181–199.

Zemeckis, D. R., Dean, M. J., and Cadrin, S. X. In Press. Spawning dynamics and associated management implications for Atlantic cod (*Gadus morhua*). North American Journal of Fisheries Management, doi:10.1080/02755947.2014.882456.

Handling editor: Caroline Durif

November 1, 2014

TO: Ground Fish Committee

FROM: Joshua Wiersma, PhD; Manager, XI Northeast Fishery Sector (New Hampshire Sector) &

Board of Directors, XI Northeast Fishery Sector (New Hampshire Sector)

Re: **Fishery Impacts of Proposed Changes to the Gulf of Maine Cod Fishery Management Plan via Emergency Action and Framework 53**

Dear Senator,

The New England federal ground fish fishery was declared a natural disaster in 2012 after the National Marine Fisheries Service (NMFS) implemented an 80% cut to the Gulf of Maine (GOM) cod catch limit (ACL) and large cuts to other primary species like Gulf of Maine Yellow Tail flounder, Grey Sole, and GOM haddock.

As a result of these cuts, our ground fishing sector in New Hampshire (which encompasses all of NH's ground fish permit holders) has been forced down to one half of its size over the last two years (24 to 12 boats). Furthermore, direct operating revenue to the sector from fish landings has declined by 40% each year, and at the current rate of landings, the sector will be bankrupt in three years.

Next year (May 1, 2015), the Science & Statistical Committee (SSC) is recommending a 70% cut in GOM cod catch limit from our current low allocation—turning GOM cod into a severe choke stock. The council is also considering bringing back many previously eliminated "rolling closed areas"—increasing the likelihood of localized depletion and pulse fishing as the remaining boats directly compete for the remaining fishing areas and times left open. These two actions completely change the management plan for Gulf of Maine cod— back to an effort managed fishery.

Only it's worse. It would effectively be an effort controlled fishery operating within the confines of a sector management system that is based on output controls. The more effort controls placed on top of output controls, the less effective output controlled systems are in maximizing bio-economic efficiency. This new "combination" management system--specifically designed to reduce the Gulf of Maine cod fishery down to a "bycatch only fishery" needs to be studied for the dramatic socio-economic consequences of such an action, and for the bio-economic impacts of what this new plan means for the other regulated ground fish that are caught along with cod.

These consequences have not been adequately addressed using the best available socio-economic science, nor have the cumulative economic impacts been estimated both to fishermen and fishing communities. Given the scope of the bio-economic impacts from such a dramatic change---it is clear that such an analysis requires a full environmental impact statement (EIS) to address, and hence an amendment and not a framework to change the GOM cod management plan. Unless a Fishery Impact Statement (FIS) is conducted through a full Environmental Impact Statement (EIS), we feel strongly that the changes to the GOM Cod Fishery Management Plan are unlawful.

November 1, 2014

NH Sector Background

The reason sectors work is primarily because of the flexibility they afford. If you eliminate flexibility, you reduce the effectiveness of sectors, and thereby eliminate opportunities for fishermen to creatively develop other fisheries—thus diversifying the fleet in the process. But true diversity takes some time to develop. In New Hampshire, we have already started the process by forming our sector fishermen into a marketing and sales cooperative called New Hampshire Community Seafood, where consumer buys underutilized species like dogfish and whiting directly from the local boat—increasing price, traceability, and seafood quality. Other sectors are doing similar things, and the larger vessels have started to effectively re-develop the redfish, hake, and Pollock fisheries. Everyone left in the fishing industry is surviving by targeting other fish besides GOM cod.

Fishermen are avoiding cod because it was too costly to catch at a quota price of $2.00 lbs. In fact, so many people were avoiding it that the cod quota price began falling and is still falling—even at the lowest ACL levels ever. This is because fishermen are selling off cod because it's too costly to target relative to doing something else—GOM cod ACL is already primarily being used for incidental catch. Still, a 70% cut from current levels turns incidental catch into impossible fishing. The fleet could unavoidably catch all of its allocation in the first two months of fishing under the proposed scenario—shutting down the fishery for the rest of the year.

The proposed changes to the Gulf of Maine cod Fishery Management Plan via Framework 53 and Emergency Action would have devastating impacts to New Hampshire fishermen, shore side infrastructure, fishing organizations, and the future prospects of ever having a thriving NH fishery again. New Hampshire fishermen are primarily owner/captains, who fish small "day boat" vessels close to home, and have minimal impact on the environment. The fleet is solely dependent on the Gulf of Maine for its fishery. In terms of our allocation, Gulf of Maine cod PSC% represents 35% of our total PSC% across 16 allocated stocks—but now only accounts for 5 % of our total sector ACE given the suite of dramatic cuts in Gulf of Maine cod ACL over the last four years. We have now been forced to use this 5% Gulf of Maine cod ACE solely for by-catch purposes to target the other 95% of ACE on our portfolio over the last two years.

The 70% proposed cut next year to our already minimal Gulf of Maine cod allocation would leave us with no fishery at all. New Hampshire and all its culture, local knowledge, and ecosystem of fishery services would be eliminated from the historic New England ground fish fishery. The cumulative economic impacts would be irreversible. This brings us to the larger issue of how to properly address these economic impacts?

November 1, 2014

Renewed Importance of Socio-Economic Analysis via 16 U.S.C. § 1853(a)(9))

The Magnuson-Stevens Fishery Conservation and Management Reauthorization of 2006 ("Reauthorization Act") on January 12, 2007, ushered a new and challenging era in fisheries management. The Reauthorization Act was a sweeping piece of legislation, dealing with everything from tsunami warnings and polar bears, to data collection and cooperative research.

While this bill's conservation measure received the most attention, The Reauthorization Act also increased the rigor of the social and economic inquiry into the "importance of fishery resources to fishing communities" by specifying that it be conducted "utilizing economic and social data that meet the requirements of National Standard 2", the best science standard (Reauthorization Act § 101(b), 120 Stat. at 3579 (codified at 16 U.S.C. § 1853(a)(9)).

Congress also expanded the scope of the required "fishery impact statement" (FIS) to accompany every fishery management plan or amendment (Reauthorization Act § 101(b), 120 Stat. at 3579 (codified at 16 U.S.C. § 1853(a)(9)). It is meant to ensure that fishery managers consider the impacts of regulations on "participants in the fisheries and fishing communities". In this respect, an FIS is analogous to an environmental impact statement (EIS) under the National Environmental Policy Act ("NEPA") (42 U.S.C. §§ 4321-4347 (2006)), and is even more so in light of the Reauthorization Act changes.

Specifically, the bill added a requirement that such impact statements "analyze the likely effects, if any, including the cumulative conservation, economic, and social impacts, of the conservation and management measures on, and possible mitigation measures" for regulated fishermen and their communities. Thus, like an environmental impact statement under NEPA, the MSA now requires an assessment of both cumulative impacts and a consideration of alternatives—in the context of impacts on the regulated community.

In terms of The Reauthorization Act's heightened social and economic protections, congress left room for interpretation by the courts regarding the extent of the changes in the law; however, they clearly wanted greater importance and a higher understanding of the bio-economic tradeoffs between conservation measures and the social and economic impacts to fishermen, their families and community.

Since 2007, only one case has made a substantive decision relating to the FIS—Coastal Conservation Association vs. Blank (M.D. Fla. Sept. 29, 2011). This case did not define the scope of the FIS provision in any great detail, but the case is noteworthy for its holding that subsection 1853(a)(9) of MSA, requiring each FMP to contain a "fishery impact statement," "provides an independent basis for [a] challenge" to that FMP. In other words, a councils' or NMFS' failure to comply with either the substantive or procedural requirements in subsection 1853(a)(9) is grounds for finding an FMP unlawful.

In regards to the substantive requirement, the court deferred expertise to NMFS to decide the expertise of the data used for analysis, but now at least that data must meet the heightened requirement of 16 U.S.C. § 1853(a)(9) (National Standard 2 Science). This means that if it can be shown that NMFS did not use the best available information in analyzing socio-economic impacts for the FIS, the FMP could be found to be unlawful.

The scope of the procedural requirements of subsection 1853(a)(9) has yet to be uniformly formalized by the courts, and therefore the legality of an FIS could potentially be decided on a case after case basis. It seems clear that the depth and formality of the FIS analysis should be on par with the magnitude of the cumulative socio-economic impacts of an FMP. It should also be on par with the type of analysis used for full EIS.

Economic Analysis to Consider

Specifically, for Environmental Impact Statements (EIS), the CEQ regulations (40 CFR §§ 1500 - 1508) define the impacts and effects that must be addressed and considered by Federal agencies in satisfying the requirements of the NEPA process. This includes direct, indirect and cumulative impacts. These are the same impacts that should be addressed by a full FIS.

- Direct effects are caused by the action and occur at the same time and place. (40 CFR § 1508.8)
- Indirect effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. (40 CFR § 1508.8)
- Cumulative impact is the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. (40 CFR § 1508.7)

Input-Output models, like the ones developed by the Northeast Fisheries Science Center to look specifically at the supply chain linkages in New England small fishing communities "can satisfy part of the requirements of National Environmental Policy Act (NEPA), Executive Order 12866, and National Standard 8" (Steinbeck and Thunberg 2006). This type of analysis has not been done for the current proposed changes to GOM Fishery Management Plan, but because the changes to GOM management plan would have such dramatic disproportionately cumulative impacts across harbors, states, regions, and gear types—it is critically important to know ahead of time what those impacts are likely to be.

But Input-output models only tell half the story. To see the dynamic impact (future impact), we must first know the change in behavior of the fishing fleet relative to the change in environment from the proposed action. So, for example, if one area of the ocean is closed, where and what will fishermen likely chose to fish—and what is the resulting loss in revenue and change in fish abundance? Fisheries Economists use bio-economic models that incorporate both the biological growth function of the stock with a cost function of fishermen. Spatial utility models that incorporate previous fishing location choices with catch can then be used to predict fishing behavior in light of changes to fishing opportunity.

This bio-economic impact is extremely important to consider given the change in likely species catch composition from changes in fishing location and allowable catch. This changes both the supply of fish available on the market and the stock of fish available to catch in the ocean. Only after controlling for these changes can the true net present value of the fishery be estimated from a proposed change in management. Fortunately, researchers from the Gulf of Maine Research Institute, the Northeast Fishery Science Center, and the Northwest Fishery Science center have started to look at the bio-economic decision making of fishermen in response to both changes in management and changes in quota price. This best available information is important to help the public understand the socio-economic and cumulative impacts of the proposed changes to GOM cod management.

Conclusion

The Reauthorization Act 2006 requires a much higher level of analysis and scrutiny of cumulative socio-economic impacts to satisfy 16 U.S.C. § 1853(a)(9). This higher level of scrutiny was needed because the other changes proposed in The Reauthorization Act (primarily shifting from input to output controls) were so dramatic that it was predicted future economic impacts would also be more dramatic. The EIS for Amendment 16 was also more thorough, and examined in detail the potential impacts from a switch from effort controlled fishing to output controlled fishing. A hybrid management system is evolving now through the council process, and promoted by NMFS, that layers effort controls on top of the output controlled system. This hybrid system is clearly different than what was analyzed through the EIS for Amendment 16.

In terms of the Reauthorization Act's heightened social and economic protections, no court decisions have thoroughly examined the meaning or extent of the changes in the law. But, Coastal Conservation Association vs. Blank (M.D. Fla. Sept. 29, 2011) did hold that subsection 1853(a)(9) of MSA, requiring each FMP to contain a "fishery impact statement," "provides an independent basis for [a] challenge" to that FMP. This challenge seems eminent in the case of GOM cod given that the cumulative socio-economic and human impacts have not adequately been addressed using the best available socio-economic science.

It is also clear, this management action disproportionally affects the smaller inshore dayboat fishery, and could completely eliminate entire regions and states commercial fisheries. Unless a Fishery Impact Statement (FIS) is conducted through a full Environmental Impact Statement (EIS), we feel strongly that the changes to the GOM Cod Fishery Management Plan via Framework 53 and Emergency Action are unlawful. On behalf of all New Hampshire ground fishermen, we thank you for seriously considering our concerns.

Sincerely,

Joshua Wiersma, PhD
Manager, XI Northeast Fishery Sector Inc.

James Hayward, F/V Heidi and Elisabeth
President, XI Northeast Fishery Sector Inc.