Fisheries Research 167 (2015) 260–277

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

The role of spiny dogfish in the northeast United States continental shelf ecosystem: How it has changed over time and potential interspecific competition for resources

Alexia C. Morgan*, James A. Sulikowski

University of New England, Marine Science Center, 11 Hills Beach Rd, Biddeford, ME 04005, United States

ARTICLE INFO

Article history:
Received 21 December 2014
Received in revised form 17 February 2015
Accepted 7 March 2015
Handling Editor George A. Rose
Available online 30 March 2015

Keywords:
Ecosystem modeling
Ecopath
Atlantic cod
Spiny dogfish
PREBAL

ABSTRACT

Ecosystem based modeling was used to determine the ecological role of spiny dogfish (*Squalus acanthias*), an opportunistic predator, in the northeast United States marine environment. Two time periods were modeled; one when spiny dogfish populations were depressed and one after recovery. According to our results, the ecological role of spiny dogfish has changed over time. During the depressed time period, spiny dogfish were not a keystone species and had little impact, positive or negative, on other species/groups in this ecosystem. Spiny dogfish currently have one of the highest trophic levels in this ecosystem and are akeystone species, having a high prey overlap with commercially depleted Atlantic cod (*Gadus morhua*). Spiny dogfish appear to have responded well to changes in this ecosystem caused by fishing and perhaps environmental change or a combination of both, while other species in the region have not. This is important, as spiny dogfish could now be potentially out competing commercially valuable and highly depleted populations of groundfish for resources. Based on our results, we suggest fisheries managers should look toward ecosystem based management measures in the future in order to actively and properly manage the ecosystem as a whole.

1. Introduction

The northeast United States continental shelf is home to a variety of marine species, some of which have supported large commercial fisheries over time, and includes areas such as the Gulf of Maine (GOM) and Georges Bank (GB). A combination of physical and oceanographic features in these two areas (GOM and GB) allows for a large amount of biodiversity to coexist (Fautin et al., 2010). Spiny dogfish (*Squalus acanthias*) are distributed in the western North Atlantic Ocean from Labrador to Florida but are most abundant from Nova Scotia to Cape Hatteras (Burgess, 2002). This species of shark is considered an opportunistic predator that swims in large aggregations (up to tens of thousands of individuals), often targeting schools of relatively small prey throughout the water column (Burgess, 2002). Seasonal migrations are thought to occur northward in the spring and summer toward the GOM and GB, and southward in the fall and winter toward North Carolina (NC) (Stehlik, 2007; Cudney and Rulifson, 2008). Information on their distribution south of here is lacking. Recent satellite tagging studies have suggested that movement patterns may be more spatially limited for a segment of the population, whereby a subset of the population of spiny dogfish may remain in the northeast year round (Sulikowski et al., 2010; Carlson et al., 2014).

Research in the northeast region of the US has shown that many changes have occurred to this ecosystem over time. For example, increases in the biomass of some species groups, changes in trophic structure, diets of individual species, aggregation patterns and changes to the overall distribution have all occurred (Link and Ford, 2006; Zhang and Chen, 2007; Overholtz et al., 2011; Richardson et al., 2014). Zhang and Chen (2007) showed that while populations of several invertebrates and Atlantic herring (*Clupea harengus*) increased between the 1980s and 1990s, groundfish biomass decreased. Changes to the distribution of Gulf of Maine Atlantic cod (*Gadus mohura*), in response to increases in prey abundance, have also occurred (Richardson et al., 2014). Fishing pressure and/or environmental factors have been linked or theorized to be behind many of these observed changes (Fogarty and Mruawski, 1998; Frank et al., 2005; Link, 2007; Zhang et al., 2011; Nye et al., 2014) or projected to influence such factors in the future (Overholtz et al., 2011; Sargarese et al., 2014). For example, Lucey and Nye (2010) suggested that the two main pressures on the Northeast US Continental Shelf Large Marine Ecosystem (NES LME) are

* Corresponding author. Tel.: +1 352 262 3368.
E-mail address: alexia.morgan2@gmail.com (A.C. Morgan).

http://dx.doi.org/10.1016/j.fishres.2015.03.004
0165-7836/

Table 1
(a) and (b) Information on the data sources for both diet and basic parameters used in the (A) depleted and (B) rebuilt models for each species/group.

A.

Group Name	Diet Source	Basic parameter source
Toothed whale	Overholtz and Waring (1991), Pauly et al. (1998)	Waring et al. (2003), Link et al. (2006), Froese and Pauly (2012)
Baleen whale	Link et al. (2006)	
Large shark	Smith and Link (2010)	Kitchell et al. (2002), Link et al. (2006), Froese and Pauly (2012)
Pinnipeds	Payne and Selzer (1989), Lawson et al. (1994), Wood (2001)	Waring et al. (2003), Link et al. (2006), Froese and Pauly (2012)
Tuna	Froese and Pauly (2012)	Link et al. (2006), Froese and Pauly (2012)
Spiny dogfish (*Squalas acanthias*)	Smith and Link (2010)	NEFSC (2003a), Link et al. (2006), Froese and Pauly (2012)
Skates	Smith and Link (2010)	Savenkoff et al. (2001), Link et al. (2006), Froese and Pauly (2012)
Atlantic cod (*Gadus morhua*)	Smith and Link (2010)	NEFSC (1998b), Link et al. (2006), Froese and Pauly (2012)
Haddock (*Melanogrammus aeglefinus*)	Smith and Link (2010)	NEFSC (1998b), NEFSC (2001a), Link et al. (2006), Froese and Pauly (2012)
Mackerel (*Scomber scrombrus*)	Smith and Link (2010)	NEFSC (2000a), Link et al. (2006), Froese and Pauly (2012)
Flatfish	Smith and Link (2010)	NEFSC (2002), NEFSC (2003a,b), Link et al. (2006), Froese and Pauly (2012)
Silver hake (*Merluccius bilinearis*)	Smith and Link (2010)	NEFSC (2001a), Froese and Pauly (2012)
Bluefish (*Pomatomus saltatrix*)	Smith and Link (2010)	NEFSC (1997), Link et al. (2006), Froese and Pauly (2012)
Northern searobin (*Prionotus cavrolinus*)	Smith and Link (2010)	Christensen et al. (2004), Link et al. (2006), Froese and Pauly (2012)
Atlantic herring (*Clupea harengus*)	Mauer and Bowman (1975)	NEFSC (1998b), Zhang and Chen (2007), Froese and Pauly (2012)
Sand lance (*Ammodytes dubius*)	Smith and Link (2010)	Link et al. (2006)
Atlantic butterfish (*Peprilus triacanthus*)	Smith and Link (2010)	NEFSC (2004), Link et al. (2006), Froese and Pauly (2012)
American eel (*Anguilla rostrata*)	Gray and Andrews (1971)	Froese and Pauly (2012)
Squid	Smith and Link (2010)	NEFSC (2001b), Kitchell et al. (2002), Link et al. (2006), Zhang and Chen (2007), Froese and Pauly (2012)
Crustaceans	Laughlin (1982), Elner and Campbell (1987)	Zhang and Chen (2007), Link et al. (2006), Froese and Pauly (2012)
Shrimp	Savenkoff et al. (2006)	NEFSC (2003b), Walters et al. (2006), Zhang and Chen (2007), Overholtz and Link (2009)
Other fish	Smith and Link (2010)	Sissenwine (1987), Zhang and Chen (2007)
Bivalves	NEFSC (2010a,b)	NEFSC (1997), NEFSC (2000a), NEFSC (2000b), Link et al. (2006)
Benthic invert	Link et al. (2006)	Link et al. (2006)
Polycheates	Feder and Jewitt (1988)	Savenkoff et al. (2001), Link et al. (2006)
Gelatinous zooplankton	Link et al. (2006)	Link et al. (2006)
Macro zooplankton	Link et al. (2006)	Overholtz and Link (2009)
Micro zooplankton	Link et al. (2006)	Zhang and Chen (2007)
Phytoplankton	Cahoon and Cooke (1992)	Zhang and Chen (2007)
Detritus		Heymans (2001), Link et al. (2006)

B.

Group Name	Diet Source	Basic Parameters Source
Toothed whale	Link et al. (2006)	Link et al. (2006,Waring et al. (2014)
Baleen whale	Link et al. (2006)	Link et al. (2006,Waring et al. (2014)
Large shark	Joyce et al. (2002), McCord and Campana (2003), Wood et al. (2007)	Kitchell et al. (2002), ICCAT (2012a)
Pinnipeds	Wood (2001), Ampela and Ferland (2006), Beck et al. (2007)	Waring et al. (2014)
Tuna	Logan (2009), Froese and Pauly (2012)	ICCAT (2010), ICCAT (2011), ICCAT (2012b)
Spiny dogfish (*Squalas acanthias*)	Smith and Link (2010)	NEFSC (1998a), TRAC (2010a), Rago and Sosebee (2013)
Skates	Ebert and Bizzarro (2007)	Savenkoff et al. (2001), Zhang and Chen (2007), NEFSC (2009a)
Atlantic cod (*Gadus morhua*)	Smith and Link (2010)	NEFSC (2013a)
Haddock (*Melanogrammus aeglefinus*)	Smith and Link (2010)	Froese and Pauly (2012), NEFSC (2014a)
Mackerel (*Scomber scrombrus*)	Smith and Link (2010)	TRAC (2010b), Byron et al. (2011), Froese and Pauly (2012)
Flatfish	Smith and Link (2010)	NEFSC (2011b), NEFSC (2012), NEFSC (2013b), Froese and Pauly (2012)
Silver hake (*Merluccius bilinearis*)	Smith and Link (2010)	NEFSC (2011a), Froese and Pauly (2012)
Bluefish (*Pomatomus saltatrix*)	Smith and Link (2010	NEFSC (2005), Froese and Pauly (2012)
Northern searobin (*Prionotus cavrolinus*)	Byron and Link (2010)	Christensen et al. (2004), Froese and Pauly (2012)
Atlantic herring (*Clupea harengus*)	Smith and Link (2010)	Shepherd et al. (2009), Froese and Pauly (2012)
Sand lance (*Ammodytes dubius*)	Smith and Link (2010	Link et al. (2006)
Atlantic butterfish (*Peprilus triacanthus*)	Smith and Link (2010)	NEFSC (2014b)
American eel (*Anguilla rostrata*)	Gray and Andrews (1971)	ASMFC (2012), Froese and Pauly (2012)
Squid	Smith and Link (2010)	Kitchell et al. (2002), NEFSC (2011a)
Crustaceans	Laughlin (1982), Elner and Campbell (1987)	Link et al. (2006), Walters et al. (2006), ASMFC (2009), DEM (2011)