Continental Shelf Research 92 (2015) 72–86

Contents lists available at ScienceDirect

Continental Shelf Research

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

Processes of physical change to the seabed and bivalve recruitment over a 10-year period following experimental hydraulic clam dredging on Banquereau, Scotian Shelf

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ARTICLE INFO

Article history:
Received 7 June 2013
Received in revised form
14 November 2014
Accepted 17 November 2014
Available online 20 November 2014

Keywords:
Hydraulic clam dredging
Habitat recovery
Bivalve recruitment
Storm sediment transport
Banquereau
Nova Scotia

ABSTRACT

A previous study on the effects of experimental hydraulic clam dredging on seabed habitat and commercial bivalve populations revealed a lack of recovery after a 3-year post-dredging period (1998–2001) on a deep (65–75 m) offshore sandy bank on the Scotian Shelf, Canada. Follow-up sidescan sonar surveys were carried out 5 and 10 years after dredging (2003, 2008) in order to identify long-term processes of seabed recovery. Grab sampling was carried out 10 years after dredging to identify post-dredging commercial bivalve recruitment. Changes in the seafloor, including dredge tracks, were documented with a series of 7 sidescan sonar surveys between 1998 and 2008. A sediment mobility model was constructed based on modeled tidal current and hindcast wave data over this time period to quantify natural seabed disturbance and interpret changes to the dredge tracks mapped by sidescan sonar surveys. The model indicated that tidal currents had minimal effect on sediment mobilization. The main driving force associated with re-working of surficial sediments as evidenced by deterioration of dredge tracks in sonograms was annual fall/winter storms. While the annual frequency of storms and associated wave heights was variable, the observations and sediment mobility calculations suggest that the most influential variable is the magnitude of individual large storms, specifically storms with a significant wave height of ~11 m. These storms are capable of generating mobile sediment layers of 20–30 cm thickness, equivalent to the dredge blade cutting depth. It appears that, with minor exceptions, sediment properties have returned to pre-dredging conditions 10 years after dredging in this habitat. Based on known age-length relationships, the four commercial bivalve species showed very low recruitment at the experimental site over the 10-year post-dredging period. However, this is unlikely due to a dredging effect since a similar pattern was observed in non-dredged areas.

1. Introduction

Determining rates and processes of recovery to seabed habitat and benthic communities following mobile bottom fishing is fundamental to ecosystem based fisheries management. However, due to numerous constraints imposed on those carrying out fishing gear impact studies (e.g. duration of studies limited by funding constraints), documenting complete habitat recovery is not always possible. This includes investigations into the impacts of hydraulic clam dredging on seabed habitat, for which a distinguishing feature of this class of gear is that the tracks or furrows left on the seabed following passage of the dredge typically have substantially greater depths of penetration into the sediment compared to scours left by other bottom fishing gears (e.g. trawls), possibly leading to longer habitat recovery times. The literature on dredge track longevities is largely restricted to shallow water environments (typically < 15 m depth), over very short monitoring periods (hours to weeks) (see Godcharles, 1971; Medcof and Caddy, 1971; Meyer et al., 1981; Hall et al., 1990; Tuck et al., 2000; Gaspar et al., 2003). Methods used to monitor dredge track longevities vary. In the aforementioned studies, visual observations along with dredge track measurements were made, in some cases, by divers. At these shallow depths, track longevities were typically of short duration due to high natural sediment disturbance created by storms and tidal currents. In deep water offshore environments,

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http://dx.doi.org/10.1016/j.csr.2014.11.006
0278-4343/

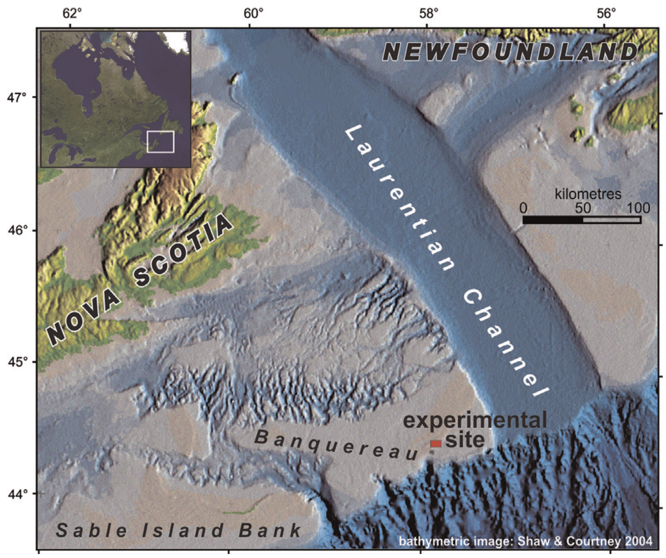

Fig. 1. Regional setting and location of the hydraulic clam dredging experimental site (bathymetry image excerpted from Shaw and Courtney, 2004).

diver observations are not an option. However, in these environments, sidescan sonar imagery provides backscatter intensity which is seabed micro-roughness dependent, and so, commonly applied as a proxy for sediment structure, texture and/or compaction. In the context of dredge tracks, seabed backscatter comparisons between inside, adjacent and well beyond dredge tracks showed both spatial and temporal differences (Gilkinson et al., 2003). This methodology has also been used successfully to document bottom trawl scour marks (Krost et al., 1990; Friedlander et al., 1999; Humborstad et al., 2004; Smith et al., 2007; Lucchetti and Sala, 2012). Overall, sidescan imagery is a sensitive tool for delineating linear seabed features and a key indicator of recovery of previously disturbed seabed is visual assessment of the persistence of dredge tracks and their transformation over time based on sidescan sonar records.

In the present study, processes and rates of recovery to seabed habitat following hydraulic clam dredging were followed over a long time period (10 years) on Banquereau, Scotian Shelf, eastern Canada (Fig. 1). Following single pulse dredging in 1998, biological and geophysical surveys were carried out at the site over a three-year period. Details of the experimental design, sampling, and assessment of impacts to seabed habitat and biological communities over this time period are provided in Gilkinson et al. (2003, 2005) and Harris et al. (2009). Subsequent sidescan sonar surveys in 2003 and 2008 provided a time series for recovery processes 5 and 10 years following dredging. In addition, wider areas of Banquereau were surveyed in order to place the results observed at the experimental site in a larger, regional context.

The present study represents the first long-term monitoring of the evolution of clam hydraulic dredge tracks in a deep water environment (65–75 m) using sidescan sonograms. An important mechanism of seabed recovery following dredging in continental shelf environments should be a re-working of dredged sediments through natural physical processes of sediment mobility. This was also a focus of our study.

The clam fishing industry operating on Banquereau has used, as a general benchmark, a return period of approximately 10 years to resume dredging on previously dredged sites although this is not part of the formal management plan. The target species is the Arctic Surfclam (*Mactromeris polynyma*), a long-lived (> 60 years) bivalve. Profitable fishing at a previously dredged site is dependent on both growth of clams left behind (i.e. not captured) and new recruitment and growth. The 10-year time frame is based on an estimate of the recovery time for the exploited bivalve populations such that resumption of fishing operations is commercially viable (i.e. yielding suitable quantities of market-size clams). Given this, and the fact that recovery of commercial bivalve populations and physical seabed habitat was incomplete three years after experimental dredging (Gilkinson et al., 2005), grab sampling was carried out in 2008, 10 years after experimental hydraulic clam dredging in order to identify recruitment of commercial species of bivalves within the dredged and reference areas.

1.1. *Objectives*

The primary objectives of the 10-year post-dredging study are outlined below.

1.1.1. *Status of recovery of seabed habitat*

The state of recovery of physical seabed habitat at the experimental site was assessed based on sidescan sonograms which provided a 10-year (1998–2001, 2003, 2008) time series of dredge furrow appearance. These were compared with sonograms of known-age commercial dredge tracks from other sites on Banquereau.

1.1.2. *Assessment of natural processes and rates of sediment movement*

The seabed shear stresses and sediment mobilization by tidal currents and storm waves play important roles in determining the rates and processes of dredge track recovery. The relative severity of the impact of hydraulic clam dredging on the habitat also should be evaluated against the magnitude and frequency of seabed disturbance by natural processes such as waves and tidal currents (see DeAlteris et al., 1999). This was assessed to address the following questions: (1) How strongly do tidal currents and storms affect the bottom sediment at the study site? (2) Are there correlations between winter storm intensities and the dredge track changes mapped by repeat sidescan surveys? and (3) What is the magnitude of storms required to cause significant degradation of dredge tracks at the experimental site and what is the frequency of passage of storms of this magnitude through the study area?

1.1.3. *Recruitment of commercial bivalve species*

Patterns of recruitment, inside and outside the dredged areas over the 10-year period, were assessed for the four commercial bivalve species (Arctic Surfclam, *M. polynyma*; Northern Propellerclam, *Cyrtodaria siliqua*; Ocean Quahog, *Arctica islandica*; and Greenland Smoothcockle, *Serripes groenlandicus*). However, presently, only *M. polynyma* has a directed commercial fishery on Banquereau although marketing potential for the other species has been examined. Based on industry practices, which typically allows for a 10-year fallow period before return-dredging, we predict that recovery of these species (i.e. recruitment to the fishery) to pre-disturbance levels will be achieved. As recruitment of bivalves is temporally and spatially highly variable, this will be measured by comparing recruitment in dredged and reference areas.

1.2. *Geologic and bathymetric setting*

The experimental site is located on Banquereau, the easternmost outer shelf bank on the Scotian Shelf, southeast Atlantic Canada (Fig. 1). The setting and geology are described in Gilkinson et al. (2003) and summarized here. Banquereau is a sandy, storm-dominated bank with clean, well-rounded and well-sorted, primarily medium grained, quartz-rich sand. The experimental site is located near the base of Eastern Shoal, a comparatively flat,