Harmful Algae 43 (2015) 13–19

Contents lists available at ScienceDirect

Harmful Algae

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

Assessing the impact of shellfish harvesting area closures on neurotoxic shellfish poisoning (NSP) incidence during red tide (*Karenia brevis*) blooms

Andrew Reich [a,*], Rebecca Lazensky [a], Jeremy Faris [b], Lora E. Fleming [c,d], Barbara Kirkpatrick [d,e], Sharon Watkins [a], Steve Ullmann [d], Kate Kohler [e], Porter Hoagland [f]

[a] Bureau of Epidemiology, Florida Department of Health, Tallahassee, FL, USA
[b] University of Florida, College of Veterinary Medicine, College of Public Health and Health Professions, Gainesville, FL, USA
[c] European Centre for Environment and Human Health, University of Exeter Medical School, Truro, Cornwall, UK
[d] University of Miami, Miami, FL, USA
[e] Environmental Health Program, Mote Marine Laboratory, Sarasota, FL, USA
[f] Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

ARTICLE INFO

Article history:
Received 1 December 2014
Received in revised form 15 December 2014
Accepted 16 December 2014
Available online 4 February 2015

Keywords:
Brevetoxin
Epidemiology
Surveillance
Recreational harvesters
Neurotoxic shellfish poisoning (NSP)
Shellfish harvesting areas (SHAs)

ABSTRACT

Neurotoxic shellfish poisoning (NSP) is caused by the consumption of molluscan shellfish meat contaminated with brevetoxins produced by the dinoflagellate, *Karenia brevis* (*K. brevis*). During a prolonged and intermittent *K. brevis* bloom starting in 2005 lasting through early 2007 in the Gulf of Mexico off southwest Florida coast, there were 24 confirmed cases of NSP linked to the consumption of clams recreationally harvested in, or in close proximity to, regulated shellfish harvesting areas; these shellfish beds had already been officially closed to harvesting due to the presence of the *K. brevis* bloom. The majority of NSP cases (78%) were in "visitors," either non-Florida residents or Florida residents living outside the county of harvest. The number of confirmed NSP cases was likely an underestimate of the actual number of cases.

Current management strategy appears to be effective in limiting the number of NSP cases associated with shellfish harvested *commercially* during red tide events. In contrast, public notification that shellfish beds are closed to harvest, due to red tides or pathogens, is not reaching all *recreational* shellfish harvesters and consumers, particularly visitors from outside the county or state. The constantly changing closure status of shellfish harvesting areas in combination with overlooked notifications may lead to an apparent disregard of harvesting restrictions. It is important, therefore, to provide the general public, including visitors and those with language barriers, with improved access to up-to-date information concerning the daily openings and closings of shellfish harvesting areas. Furthermore, the risks of consuming potentially toxic shellfish should be disseminated more broadly.

1. Introduction

A prolonged *Karenia brevis* (*K. brevis*) bloom began in 2005 in the ocean and along the coast of southwest Florida. Neurotoxic shellfish poisoning (NSP) cases were identified among Florida county residents and visitors who consumed shellfish harvested from or in close proximity to regulated shellfish harvesting areas (SHAs) located off the coasts of the Florida counties of Charlotte, Hillsborough, Lee, Manatee, and Sarasota. This bloom became more widespread along the Florida Gulf Coast, with SHA closures occurring from Okaloosa county to Collier county between January 2005 and January 2006 and between June 2006 and December 2006. NSP outbreaks that occurred in March 2006 appeared to have subsided by August 2006. Nevertheless, additional NSP outbreaks were identified by the Florida Department of Health (DOH) in October and November 2006, and again in December 2006 (Watkins et al., 2008).

These NSP outbreaks occurred even though shellfish beds along the southwest Florida coast were closed to all harvesting. Both commercial and recreational shellfish harvesting were prohibited throughout the affected areas. No published research was found on the relationship between NSP cases and the status of the areas

* Corresponding author at: Bureau of Environmental Health, Florida Department of Health, 4052 Bald Cypress Way Bin A08, Tallahassee, FL 32399-1720, USA. Tel.: +1 850 245 4187.
E-mail address: andy.reich@flhealth.gov (A. Reich).

http://dx.doi.org/10.1016/j.hal.2014.12.003
1568-9883/

where the contaminated shellfish harvesting occurred. The overall objective of this study was to assess the relationship between the location of harvesting by people formally diagnosed with NSP and the management of SHAs during *K. brevis* blooms and other red tide events.

1.1. Neurotoxic shellfish poisoning (NSP)

Neurotoxic shellfish poisoning (NSP) is caused by the consumption of molluscan shellfish meats contaminated with brevetoxins produced by the dinoflagellate, *K. brevis* (Wang, 2008). This marine dinoflagellate is associated with *K. brevis* blooms or harmful algal blooms (HABs), which commonly occur in the Gulf of Mexico. *K. brevis* is present naturally in the Gulf waters at low concentrations. As they feed, molluscan bivalve shellfish (referred to as "shellfish") filter the alga from the water column, thereby accumulating brevetoxins. Brevetoxins can accumulate in shellfish tissues to concentrations that are toxic when consumed by humans, leading to NSP cases (Fleming et al., 2002; Backer et al., 2003, 2005; Dickey et al., 2011). Historically, NSP cases in Florida have been associated only with recreationally harvested shellfish (Watkins et al., 2008). Commercial harvesters are notified of closures and are prohibited from working in closed shellfish beds. This regulation reportedly has been effective in eliminating contaminated shellfish from entering commercial markets.

The consumption of the contaminated shellfish may cause neurologic, gastrointestinal, and cardiac symptoms due to the neurotoxic effects of the brevetoxins. Reported NSP symptoms include: diarrhea, vomiting, abdominal discomfort, nausea, dizziness, difficulty with coordination, difficulty breathing, slurred speech, tingling of the tongue and lips, temperature reversal, convulsions, seizures, and partial paralysis. The onset of symptoms can range from a few minutes up to 18 h following the consumption of toxic shellfish (Wang, 2008). The duration of symptoms is typically 24–48 h, although no long-term follow-up studies on NSP patients have been undertaken to evaluate possible chronic health effects (Watkins et al., 2008). No known fatalities have been reported from NSP.

1.2. Management and regulation

Florida statutory law (Ch. 597) stipulates that SHAs are regulated by the Division of Aquaculture in the Florida Department of Agriculture and Consumer Services (FDACS). To prevent NSP and other illnesses associated with shellfish consumption, Florida maintains 38 SHAs, encompassing over 1.4 million acres of its coastal waters. In collaboration with the Florida Fish and Wildlife Conservation Commission (FWC), FDACS monitors *K. brevis* blooms, closing SHAs to harvest when cell counts exceed 5000 cells L^{-1}. FDACS re-opens the SHAs when brevetoxin levels in the shellfish return to acceptable levels of 20 "mouse units" or less. If concentrations are found to exceed this threshold, a "stop sale" order can be issued on the shellfish collected the day of sampling, and the product can be recalled for testing. The destruction or sale of these shellfish is then managed by FDACS on a case-by-case basis (2011).

Before re-opening a SHA after a closure for a *K. brevis* bloom, FWC performs a required mouse bioassay test (FDACS, 2002; APHA, 1970). If the tested shellfish are found to contain less than 20 mouse units of toxin, the shellfish are deemed to be non-toxic. Those SHAs for which samples were deemed non-toxic are re-opened at sunrise the following calendar day. If a *K. brevis* bloom persists in or near open SHAs, water sampling is continued, and the closing/opening procedure is repeated (FDACS, 2011).

The aim of this study was to determine whether confirmed cases of NSP may have been tied to shellfish harvested from closed areas due to *K. brevis* cell counts in excess of 5000 L^{-1}.

2. Methods

2.1. Epidemiology

Neurotoxic shellfish poisoning has been a reportable disease in Florida since 1999, requiring healthcare providers and diagnostic laboratories to report suspected and confirmed cases to the DOH (Fl Stat § 381.0011). The DOH case definition for NSP requires notification for a "... clinically compatible illness that is associated with consumption of shellfish with a positive laboratory finding (brevetoxin), or with consumption of shellfish from areas where other toxic shellfish have been found or where red tide is documented (FDACS SHA closed in region)." An "NSP outbreak" is defined as an event in which two or more cases are temporally linked with a common exposure (DOH, 2013).

The DOH maintains an electronic data repository, *Merlin*, for reportable (also referred to as "notifiable") diseases in Florida. *Merlin* is required to include cases diagnosed only among Florida residents. Nevertheless, *Merlin* does have the capacity to include non-Florida resident cases; whether or not to include non-Florida cases is left to the discretion of the individual county-based DOH facility. Cases that occurred before 2001 were compiled and stored on paper forms at both the local health department and the state health office. With the establishment of *Merlin* in 2001, the majority of historic cases were transcribed into its electronic reporting system. *Merlin* case notes contained information on the location of the shellfish harvests based on interviews by DOH epidemiologists with NSP cases at the time of reporting.

In some instances, non-Florida cases were also documented in the DOH "Food–Water–Vector Borne Illness Surveillance System" *(FWVSS)*. Additional case information was found in county health department epidemiology investigation summary report forms submitted to the Electronic Food Outbreak Reporting System (*eFORS*), a now archaic national reporting system used by the US Centers for Disease Control and Prevention (CDC) to collect national data. Information on these reports included data similar to that found in *Merlin*, with the addition of non-Florida resident cases.

To insure that all reported cases were represented in this analysis and identified, hard-copy county health forms were reviewed for NSP cases reported to the DOH from 1997 to 2009. Because these datasets included personal identifiers and protected information, the analysis was undertaken by DOH staff with subsequent anonymization of the data to protect confidentiality. During the review of cases, it was found that surveillance data before 2004 were incomplete, involving inconsistently used case notes, missing information from extended data, or ambiguously labeled identifications of in-state versus out-of-state cases. Therefore, it was decided that the assessment should be limited to NSP cases identified from 2004 to 2009.

2.2. Environmental

The SHA dataset analyzed in this report was compiled using FDACS Division of Aquaculture SHA opening and closing reports from 2004 to 2009. PDF documents containing all reports related to red tide were extracted into a database, using data querying software. Query terms included "red tide" or "Chapter 5L-1.003(8)" (Rule 5L-1.003(8) of the Florida comprehensive shellfish control code pertains to red tide management, such as closings or openings of shellfish beds). The county data and the type of SHA (oysters, clams, or both oysters and clams) also were identified on the FDACS website (FDACS, 2014).

It was determined if the SHAs associated with each NSP case were open or closed at the time of harvest. The illness onset date and reported harvesting locations for each NSP case were used to