Journal of Invertebrate Pathology 110 (2012) 201–210

Contents lists available at SciVerse ScienceDirect

Journal of Invertebrate Pathology

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

Minireview

Protistan parasites as mortality drivers in cold water crab fisheries

J. Frank Morado [a,*], M.S.M. Siddeek [b], Darrell R. Mullowney [c], Earl G. Dawe [c]

[a] Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA 98115-0070, USA
[b] Alaska Department of Fish and Game, Division of Commercial Fisheries, PO Box 115526, Juneau, AK 99811, USA
[c] Science Branch, Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, PO Box 5667, 80 East White Hills Road, St. John's, NL, Canada A1C 5X1

ARTICLE INFO

Article history:
Available online 14 March 2012

Keywords:
Coldwater crabs
Disease
Environment
Host
Pathogen
Humans
Epizootiology

ABSTRACT

From a historical perspective, several protistan taxa, including the recently re-aligned Microsporidia, have been associated with or identified as causes of mortalities in crustacean populations. Depending upon the host species, associated protistan prevalences could be as low as 5% or approach 100%. It has generally been assumed that reported prevalences translated directly into significant mortalities that could impact the distribution and abundance of affected populations. However, this assumption may be incorrect especially when the dynamics of host–pathogen–environment interactions are not entirely understood. We will discuss the presumed impact of several protistan pathogens on temperate and cold water commercial crab species. By using selected examples such as a ciliate in the Dungeness crab (*Cancer magister*) and *Hematodinium* sp. infections in North Pacific crabs, we will attempt to contrast differences between prevalence and mortality, acute and chronic infections/mortalities, age or size selectivity of affected population, and geographically restricted and widespread epizootics. We will also briefly discuss the potential impact of environmental changes such as climate change and ocean acidification on both host and protistan pathogen.

Published by Elsevier Inc.

Contents

1. Introduction

Coldwater or high latitude crab fisheries are relatively recent when compared to temperate crab fisheries such as the blue crab (*Callinectes sapidus*), and the American and Norway lobster (*Homarus americanus* and *Nephrops norvegicus*, respectively) fisheries. Coldwater crab fisheries have been in existence since the turn of the 20th century, although, intensive coldwater crab (especially Alaska red king crab) commercial fishing did not begin until shortly after the 1st World War (Otto, 2006). Since that time several other coldwater crab species have been the focus of major crab fisheries, some of which for a time produced some of the largest landings in the world (Orensanz et al., 1998). Currently, members of the family Lithodidae from both the southern and northern hemispheres are highly sought after because of their large size and rich flavor. Other cold water species that are of commercial importance include species of the genera *Chionoecetes*, *Erimacrus*, *Cancer* and *Pseudocarcinus*.

Coldwater or high latitude crab species are generally long-lived taking several years to mature as opposed to temperate or warm water crab species. The Dungeness crab, *Cancer magister*, is found

* Corresponding author. Fax: +1 206 526 6723.
E-mail address: frank.morado@noaa.gov (J. Frank Morado).

0022-2011/$ - see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.jip.2012.03.008

as far south as Pt. Conception, California and as far north as the eastern Aleutian Islands, Alaska, provides an excellent example. In the cold waters of Alaska, the Dungeness crab, reaches sexual maturity at 3-yr, but may live as long as 8–13 years (Woodford, 2008). Age to sexual maturity and life span are shorter for Dungeness crab that inhabit warmer coastal waters of the western continental United States (Leet et al., 2001). Commercial species of the family Lithodidae, and the genus *Chionoecetes* are truly coldwater and tend to mature more slowly. Alaskan red king crab, *Paralithodes camtschaticus*, average age to maturity is 4–5 years, enter the fishery 2–3 years later and may live as long as 20–30 years. Tanner crabs (*Chionoecetes* spp.) mature at 5–6 years of age and may live as long as 14 years (Woodford, 2008).

Parasitic protists have a long history as symbionts of Crustacea (Sprague, 1970; Sprague and Couch, 1971). Some parasitic species such as the gregarines are of little concern because infections appear self-limiting and mortalities are not generally associated with their presence. Other protistan parasites such as coccidians also appear self-limiting and non-lethal, but some species may affect host health and cause changes in host behavior. For example, *Aggregata eberthi* was reported to cause parasitic castration and feminization of males of the intermediate crab host *Inachus dorsellensis* (Smith, 1905). Several infected crabs were noted with milky hemolymph and morphological changes were associated with male feminization. Although Smith did not observe behavioral changes in infected males, feminization of males resulting from parasitism, generally results in modifications of male behavior. Other pathogens such as ciliates and dinoflagellates produce outright morbidity, and mortality that may be acute or chronic in nature.

A number of studies suggest that protistan parasites are major drivers of crustacean mortality (see reviews by Sparks (1985), Meyers (1990), Sindermann (1990), and Stentiford and Shields (2005)). We will provide a brief overview of current information on protistan parasites as causes of disease and mortality in high latitude crab species. We propose that the data are not clear in some circumstances, in particular, prevalence may not be indicative of an epizootic, or translate directly into mortalities because of lack of baseline prevalence data, and death of the host from a specific parasitic infection may not be confirmed. Furthermore, the data may be complicated by factors associated with the epidemiological triad (Fig. 1), in addition to other factors previously discussed (Morado, 2011). Each triad factor is composed of complex features that are dynamic and interactive (synergistic or otherwise) and, thus, predisposing events may vary between epizootics. As a result, we acknowledge that the scope of this topic is much larger than can be presented in this paper so we will only briefly touch upon relevant topics as a means to generate discussion on disease dynamics in wild coldwater crab (and other crustacean) species. The influence of the human factor will also be briefly discussed as human activities have the potential to shape or destabilize ecosystems, and cause shifts in animal and pathogen distribution and abundance.

2. Environmental factors/stressors

Earth has experienced considerable changes in climate throughout its past. Within the more recent 2000 years, warm and cold eras have been documented (Fig. 2). On a finer scale, warm and cold periods have occurred throughout the past century, often continuing for decades with interspersed periods of divergent episodes (Fig. 3). Most recently in the Bering Sea, an extraordinarily warm period (2002–2005) was followed by a particularly cold period (2006–2009, Hunt et al., 2010). The ecological significance of this and other short-term trends are uncertain because ecosystem change, as reflected by species composition and distribution, is not often immediate (Litzow, 2006).

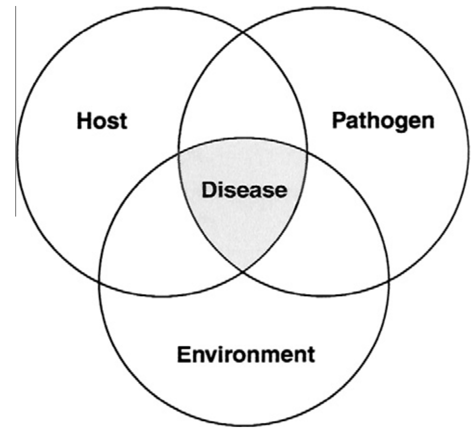

Fig. 1. An overt infectious disease occurs when a susceptible host is exposed to a virulent pathogen under proper environmental conditions (with permission from Snieszko, 1974).

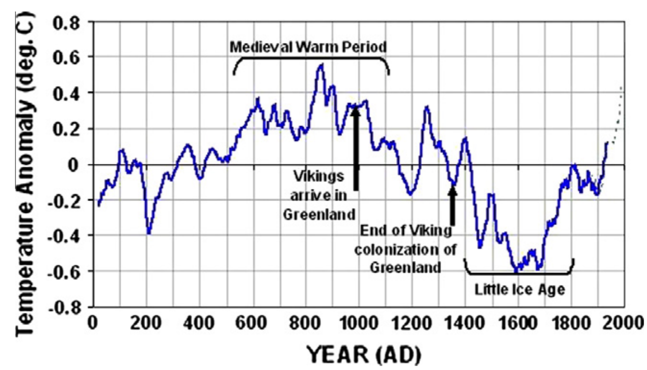

Fig. 2. This graph shows the average of 18 non-tree ring proxies of temperature from 12 locations around the Northern Hemisphere (with permission from Loehle, 2007). It clearly shows that natural climate variability happens, and these proxies coincide with known events in human history.

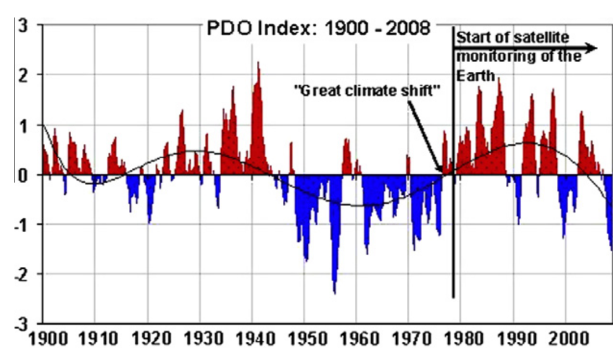

Fig. 3. The Pacific Decadal Oscillation (PDO) is an internal switch between two slightly different circulation patterns that occurs every 30 years or so in the North Pacific Ocean. It was originally described in 1997 in the context of salmon production. It has a positive (warm) phase that tends to warm the land masses of the Northern Hemisphere, as well as a negative (cool) phase. (with permission from www.drroyspencer.com/global-warming-background-articles/the-pacific-decadal-oscillation).

In association with chronic climate shifts, marked changes have been reported in marine species composition (Grebmeier et al., 2006; Lindley et al., 2010; Mollmann et al., 2011) and distribution (Orensanz et al., 2004). Following the late-1970s climate shift in the Gulf of Alaska, a marked change in species composition from