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Temporal stability of lake whitefish genetic stocks in Lake Michigan

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ABSTRACT

Lake whitefish *Coregonus clupeaformis* are the predominant species in the Lake Michigan commercial fishing industry. Six genetic stocks were identified in Lake Michigan in 2007; however, genetic structure can fluctuate throughout time due to demographic variables and changing environments. Temporally stable genetic units have a higher probability of containing genetically adaptive traits and thus, are integral components of a sustainable stock-based management approach. The objective of this research was to determine if the genetic stock structure of lake whitefish in Lake Michigan has remained temporally stable from the 1970s through early 2007. Archived scale samples collected by state and tribal agencies during annual assessments from the 1970s, 1980s, and 1990s were used as a source of deoxyribonucleic acid (DNA). Samples were genotyped at 11 microsatellite loci consistent with the contemporary genetic stock dataset. Tests of F_{ST}, Jost's D_{EST}, and Nei's genetic distance were used to compare nine historical sample populations to contemporary stocks. Most stocks showed temporal stability for a majority of the three different analysis methods. The only historical samples to not support the trend of temporal stability were located in the Green Bay region, where two genetic stocks are present in close proximity and are known to have relatively high levels of gene flow between the two stocks. The prevalence of temporal stability gives support to the theory that a stock-based management plan is appropriate for lake whitefish in Lake Michigan.

Introduction

The stock concept has become widely recognized as a vital component of fisheries management (Booke, 1981; Begg et al., 1999). To properly manage a fishery for sustainable yield, stock structure must be identified and each stock must be managed individually as the overall productivity and evolutionary potential of a species is dependent on maintaining the abundance and diversity of its component stocks (Grimes et al., 1987; Shaklee and Currens, 2003). The definition of a stock can be a malleable entity; however, in this context we define a stock as a local population or group of populations that maintains recognizable genetic differentiation by separation of spawning place or time (Bailey and Smith, 1981). The recognition of stocks as a crucial component of sustainable fisheries management has led to the utilization of the stock concept in nearly all commercial fisheries management strategies (Berst and Simon, 1981; Booke, 1981).

Lake whitefish *Coregonus clupeaformis* have been an important species of the commercial fishing industry in the Great Lakes since the 1800s and have supported subsistence and recreational fisheries for many decades (Baldwin et al., 2009; Ebener et al., 2008). Starting in the 1850s and culminating in the 1950s, lake whitefish in Lake Michigan experienced a substantial decline due to the combination of overharvesting, pollution, introduction of exotic species, and other anthropogenic factors (Smith, 1968; Wells and McLain, 1973; Fleischer et al., 1992; Ebener et al., 2008). The commercial harvest of lake whitefish from Lake Michigan dropped from one million kg annually to 130,000 kg following the decline in the 1950s (Baldwin et al., 2009). More recently, the population has recovered, and currently represents the largest commercial fishery in Lake Michigan in terms of both economic value and total weight harvested (Schneeberger et al., 2005; USGS, 2014). In 2014, the lake whitefish harvest from Lake Michigan exceeded 1.56 million kg and was valued at 7.84 million USD (USGS, 2014); recent average annual harvest rates are higher than that of any recorded values in history (Baldwin et al., 2009).

Lake whitefish in Lake Michigan currently support a state-licensed and a tribal commercial fishery in Michigan waters and a state-

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licensed commercial fishery in Wisconsin waters. The Wisconsin and Michigan Departments of Natural Resources and the Chippewa Ottawa Resource Authority are the licensing agents. The inter-jurisdictional nature of this fishery complicates management because sustainable harvest must be allocated among multiple user groups with varying seasons and regulations. Due to its economic and cultural importance, managing sustainable populations of lake whitefish is a high priority across the Great Lakes (GLFC, 2010). Currently, quotas are established for commercial management zones (Fig. 1) based on predicted abundance at age from statistical catch-at-age models developed for each zone (Ebener et al., 2008). Zones were developed based on historical spawning locations and political (state) boundaries (Ebener et al., 2008).

Evidence of stock structure was apparent in the Lake Michigan's lake whitefish population before 1980 (Borgeson, 1980). Various methods have been used to assess the stock structure of lake whitefish including vital statistics and tagging (Ebener and Copes, 1985; Scheerer and Taylor, 1985), isozyme genetic analyses (Imhoff et al., 1980), and, more recently, microsatellite markers (VanDeHey et al., 2009). During the spawning seasons of 2005 and 2006, lake whitefish were collected from 11 known spawning locations throughout Lake Michigan. Genetic analyses suggested relatively low levels of differentiation between spawning stocks (F_{ST}: 0.0001 to 0.0231), indicating moderate to high levels of historical gene flow. Based on a suite of genetic stock identification techniques, six distinct genetic stocks were identified within the Lake Michigan population of lake whitefish: Big Bay de Noc (BBN), North and Moonlight Bays (NMB), Northern (NOR), Northeastern (NOE), Elk Rapids (EKR), and Southeastern (SOE; Fig. 1; VanDeHey et al., 2009; VanDeHey et al., 2010). Three of the six genetic stocks identified span across multiple contemporary commercial harvest management zones (NMB: WFM-00 and WI-2, NOE: WFM-04 and WFM-05, SOE: WFM-07 and WFM-08) and one management zone consisted of two separate genetic stocks (WFM-05: NOE and EKR).

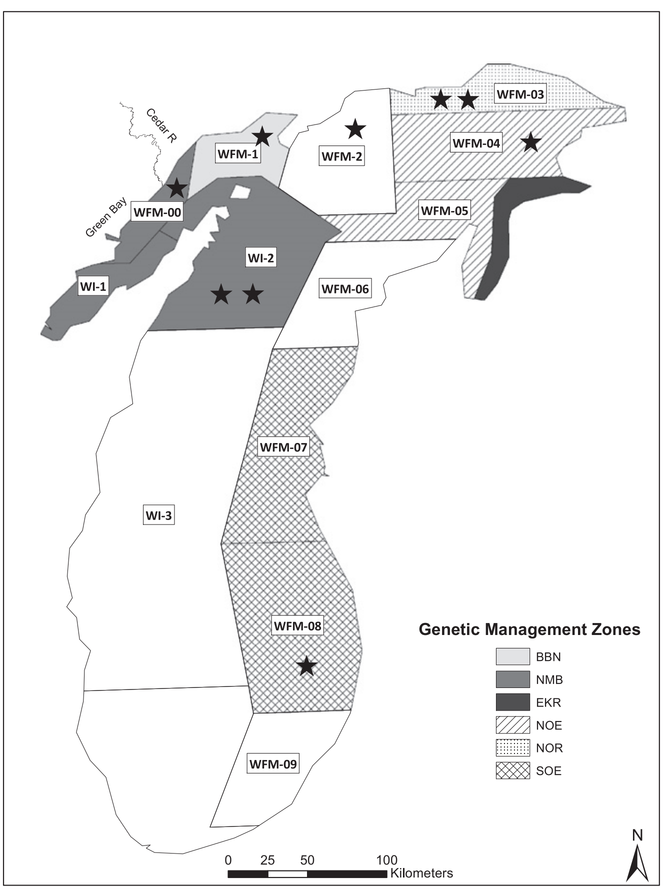

Fig. 1. Lake Michigan lake whitefish commercial fishing management zones of Wisconsin (WI) and Michigan (WFM), with the genetic management zones prescribed by VanDeHey et al. (2009). NMB = North Moonlight Bay stock, BBN = Big Bay de Noc stock, NOR = Northern stock, NOE = Northeastern stock, EKR = Elk Rapids stock, and SOE = Southeastern stock. The number of black stars denotes the number of historical sample populations collected from each commercial management zone.

Individuals from the six genetic stocks mix outside of the spawning season, likely in search of quality habitat (Rennie et al., 2012; Ebener et al., 2010), and multiple stocks are often harvested simultaneously within a single management zone (Andvik et al., in press). The presence of this mixed-stock fishery further emphasizes the need to understand stock-structure dynamics and the temporal stability among the delineated genetic stocks. Further, stocks are a dynamic entity shaped by biological, environmental, and anthropogenic factors and could potentially experience changes in genetic diversity over time (Østergaard et al., 2003; Therkildsen et al., 2010). The contemporary stocks identified by VanDeHey et al. (2009) could be the result of chance re-colonization of spawning sites following the population declines and therefore represent a mere "snapshot" in time of the genetic stock structure present.

A challenge in determining any historical pattern is the availability of quality, historical data. Archived scale samples, collected from historical commercial catches and fishery independent samples, can provide the necessary genetic material to observe past stock structure (Nielsen and Hansen, 2008). The use of archived scale samples has proven to be a viable tool in testing historical genetic trends in fish species including walleye *Sander vitreus* (Franckowiak et al., 2009), Atlantic salmon *Salmo salar* (Nielsen et al., 1997; Tessier and Bernatchez, 1999), and Atlantic cod *Gadus morhua* (Therkildsen et al., 2010). Using archived scale samples, the temporal stability of the lake whitefish stocks can be assessed by comparing historical samples to the contemporary, putative stocks.

Failure of a stock to show temporal stability suggests that the resolved genetic stocks are less relevant in terms of management for sustainability and viability of the resource. Conversely, if the stocks show temporal stability, then genetic-based units should be incorporated as a key component of management to conserve genetic variation, as opposed to the current management units based on jurisdictional boundaries which have been utilized since the 1980s (Ryman, 1991; Ebener et al., 2008; Vähä et al., 2008). Depleting individual stocks could result in reduced genetic variation and lead to lower adaptability of the species as a whole (Shaklee and Currens, 2003). Therefore, the objective of this study was to determine if the Lake Michigan lake whitefish genetic stocks exhibited temporal stability from the 1970s through early 2007.

Methods

Sample collection

We utilized archived scale samples collected by Wisconsin and Michigan commercial fishermen as well as by the Inter-Tribal Fisheries and Assessment program. The collection was assembled by the Great Lakes Fishery Commission Lake Whitefish Task Group and included more than 108,000 samples collected over more than 30 years (Casselman et al., 2001). Samples were collected from both Wisconsin and Michigan lake whitefish management zones (Fig. 1) and were stored in scale envelopes with additional layers of moisture absorbing parchment to improve long-term storage viability. Both spatial and temporal considerations were included during the selection process of historical samples. Samples selected for this study were collected from locations that were (a) known spawning sites for lake whitefish; and (b) locations used as the basis for identification of the contemporary genetic management units of lake whitefish in Lake Michigan (VanDeHey et al., 2009; Fig. 1). Lake whitefish exhibit broad-scale movements and stocks intermingle throughout the year (Ebener and Copes, 1985; Ebener et al., 2010; Andvik et al., in press). VanDeHey et al. (2009)