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Contribution to the Symposium: '*International Eel Symposium 2014*'

Introduction

Understanding the decline in anguillid eels

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This symposium issue of the *ICES Journal of Marine Science* contains 16 contributions from the second International Eels Symposium held during the American Fisheries Society (AFS) Annual Meeting (August 2014, Québec City, Canada). This symposium followed the first International Eels Symposium held in 2003, which emphasized the international scope of the *Anguilla* conservation problem. This second symposium reviewed a decade of research on biology and life history, genetics and genomics, reproduction, oceanic biology, early life history, population dynamics, assessment and management, eel passage at hydroelectric facilities, stocking, and threats, focusing primarily on Atlantic anguillids. The symposium finished with a panel discussion that emphasized the need to develop inter-jurisdictional governance approaches for panmictic eels as a way to promote recovery of the various species.

Keywords: anguilla, assessment and management, decline, Eels, governance, population dynamics.

Introduction

Eels are mysterious and fascinating animals. Despite a century of research, key aspects of their oceanic and continental life history remain shrouded in mystery. In recent decades, many species of the genus *Anguilla* have seen their abundance decline below safe biological levels. The usual anthropogenic suspects have been implicated in this worldwide decline: habitat loss caused by dams, habitat fragmentation, mortality from hydropower turbines, fisheries, chemical contamination, parasites, and climate warming affecting oceanic spawning sites.

The previous AFS symposium in 2003, also held in Québec, led to the Québec Declaration of Concern highlighting the international scope of the *Anguilla* conservation problem (Dekker *et al.*, 2003). Intensified monitoring and international assessment efforts in Europe now yield new insights into overall population dynamics, although major anthropogenic impacts remain largely unquantified. Responsible agencies have taken steps to protect eel stocks. Have these measures provided adequate protection? How do we define a reference level? An understanding of the core processes driving eel populations is needed to answer these questions. We also need to define and implement effective means towards species-wide joint action on eel assessment, management, and conservation of the various species of the genus *Anguilla* worldwide.

In Europe, international integration of eel assessment, management, and protection is underway under the auspices of ICES, while in North America, Asia, and Oceania, only tentative steps have been taken so far. For non-European countries, management is typically only conducted at the regional scale; this is inadequate considering the panmictic nature of anguillids, which calls for inter-jurisdictional management.

Symposium content

This second International Eels Symposium was held in Québec City (Canada) from 18 to 21 August 2014 within the 144th Annual Meeting of the American Fisheries Society. The objective was to obtain an overview of the latest research on eels.

The Eels Symposium was the second largest of the 40 symposia that took place during the 2014 Annual Meeting of the AFS and also probably the largest eel symposium ever convened. It included 99 oral presentations and 10 posters from 21 countries and 5 continents. The symposium covered the following themes: biology and life history including aboriginal traditional knowledge, genetics and genomics, reproduction, oceanic biology, early life history, population dynamics, assessment and management, eel passage at hydroelectric facilities, stocking, and threats. The symposium emphasized Atlantic eel species *Anguilla anguilla* and *Anguilla*

rostrata, but relevant contributions on other eel species were also considered. All symposium abstracts are available as Supplementary material.

Martin Castonguay introduced the symposium and presented a surprise guest: Mr Konrad Sioui, Grand Chief of the Huron-Wendat Nation from Wendake near Québec City. Mr Sioui discussed the historical and current importance of the eel for the Huron people. We then listened to four keynote plenary speakers. Louis Bernatchez (Canada) was the first keynote speaker. He discussed recent contributions of genomics in providing a better understanding of *Anguilla* biology and its relevance for conservation and management. Conservation genetics is the application of genetics to preserve species as dynamic entities capable of coping with environmental change. The goal of this research is to find causal relationships between genetic variation, phenotypes, and environment to predict future dynamics of selectively important variation and potential for adaptation to new conditions. Dr Bernatchez emphasized the progress in this research field with respect to the Atlantic eels. In particular, recent studies provided (i) a detailed view of whole-genome divergence between European and American eels, (ii) definite evidence for panmixia in both species (Als *et al.*, 2011; Côté *et al.*, 2013), (iii) strong support for spatially varying selection associated with temperature, salinity, and habitat use (Côté *et al.*, 2009, 2014, 2015; Gagnaire *et al.*, 2012; Boivin *et al.*, 2015), and (iv) evidence that such selection is responsible for generating genetically based local phenotypic differences between freshwater and brackish water yellow (juvenile) eels (Pavey *et al.*, 2015). He then discussed the relevance of these new findings for eel conservation and management strategies.

The second keynote speaker was Willem Dekker (Sweden). He examined population dynamics and management of European eel from a historical perspective going back 200 years (Noël, 1815; Yarrell, 1836; Radcliffe, 1921; Koch, 1925; Dekker and Beaulaton, 2016). Few fish stocks have been as impacted by humans (intentionally and inadvertently) as the European eel, all across the continent. However, the dynamics of the European eel population is poorly understood. Rather than focusing on the causes of the historically low abundance or on the minimal protection levels required, his talk went back in time—two centuries—unravelling time-series and distribution patterns, reviewing historical actions and objectives, and discussing technical developments and scientific advice. Picturing the slippery slope that the eel stock has come down from, Dr Dekker evaluated hypotheses on the causes of stock decline and discussed the adequacy of protective actions. The first claim that the continental stock was in decline dates back to the early 1800s, and stock-enhancement actions were initiated shortly thereafter. Diffuse objectives, technical innovations, eternal optimism, and—above all—the lack of quantification impede the evaluation of historical reports. After 1950, when quantification improved, a slow but consistent decline was observed. But it is only two decades after the crash in recruitment from the ocean (1980) that protection plans addressed the depleted status of the stock.

The third keynote speaker was Laurent Beaulaton (France), who discussed a decade of science and management for European eel in the context of an eel management plan that requires member states to implement measures to preserve and restore eel stocks within their borders (ICES, 2014). The 2003 symposium in Québec issued the "Québec Declaration of Concern" on *Anguilla* species, marking the onset of a period of political decisions in Europe. Returning to Québec in 2014, we review a decade of protective actions on European eel. In 2007, the European eel was listed by CITES (Appendix II); at the same time, the European Union adopted a regulation "establishing measures for the recovery of the [eel] stock". This "Eel Regulation" sets objectives in terms of silver (i.e. maturing) eel escapement. Much work has been done to assess/model silver eel escapement at the basin level and to compare these models. Additional work is in progress to develop eel-specific biological reference points. These include assessment of recruitment at the population level, spawner biomass, and the relationship between them. The first reporting by EU Member States in 2012 enabled post-evaluation of management measures, for which a unique post-evaluation framework has been developed. Dr Beaulaton concluded by discussing the interaction between science and management, and made suggestions for further developments.

The fourth and last keynote speaker was Katsumi Tsukamato (Japan). He examined aquaculture production of glass eels as a possible conservation measure for eels. Japan consumes 70% of the freshwater eels eaten worldwide, but is also striving to conserve the Japanese eel in East Asia. Artificial production of Japanese eels is one unique effort now being intensively conducted. If trials succeed in mass production of glass eels, the human impact on wild glass eels can be reduced to help its future population recovery. The first larvae were obtained from artificially matured adults in 1973, and the first glass eels were produced artificially in 2003 (e.g. Tanaka *et al.*, 2003). Second-generation eels were produced in 2010 and the resulting juveniles are now being reared for further breeding to produce domestic strains (Tanaka, 2015). At present, one experimental hatchery in Japan can produce ~1000 glass eels per year, possibly 2000 at most, which cost tens of dollars each to produce. Although recent nitrogen isotopic ratio analyses indicate that food for wild eel leptocephali in the ocean primarily consists of abundant midwater marine snow, the problem in the aquaculture process is that the semi-liquid slurry-type diet for larvae mainly includes spiny dogfish (*Squalus acanthias*) egg yolk, which pollutes rearing tanks. Dr Tsukamoto concluded his talk by emphasizing that intensive research is currently developing a new type of larval diet to minimize tank pollution to achieve high-density culture and mass production of glass eels.

After the plenary keynote speaker session, the symposium was split in two concurrent sessions for the rest of the week until the plenary panel discussion that concluded the symposium. The panel discussion was chaired by Bob Lambe (Great Lakes Fishery Commission) and included the following panelists: Brad Chase (USA), Reinhold Hanel (Germany), Larry McDermott (Canada), Guy Verreault (Canada), and Alan Walker (UK). Questions for the panel included the following:

(i) How do we ensure that eels climb back up the slippery slope? Therefore, what effective science and conservation actions can we take to improve eel status?

(ii) Have these measures provided adequate protection? What is adequate? What insights have we gained from this symposium?

Minutes of the panel discussions can be found on the Great Lakes Fishery Commission website (www.glfc.int).

A subset of symposium participants subsequently published a 2014 Québec Eel Declaration entitled "The 2003 Québec Declaration of Concern about eel declines—11 years later: Are eels climbing back the slippery slope?" (Dekker and Casselman [coordinators], 2014).

Both the panel discussions and the 2014 Québec Eel Declaration focused on the need to develop inter-jurisdictional governance approaches for panmictic anguillids as a way to promote recovery of the various species, which could possibly be inspired by the European experience with the European eel. For example, governance remains to be developed for the American eel. Although there is a certain level of concerted efforts within each country, there is no formal agreement between Canada and the United States for this species, which is made up of a single population. Moreover, in Canada, eel is a provincial jurisdiction in the provinces of Québec and Ontario, while it is a federal jurisdiction in the four provinces of Atlantic Canada. The Canadian Eel Science Working Group does conduct regular meetings where scientists from all jurisdictions exchange information and coordinate monitoring and research (e.g. DFO, 2013), but there is little coordination of management actions on eels throughout Eastern Canada.

Emerging themes

Investigating the causes of the decline of eels remains a major preoccupation among eel scientists. Dekker and Beaulaton (2016) examined population dynamics and management of European eel from a historical perspective going back 200 years to provide an overview of the decline in the eel population. The swimbladder parasite *Anguillicola crassus* is still believed to have contributed to the decline by impairing the swimming abilities of eels. Its distribution is now widespread in American and European eels. Hein *et al.* (2016) showed that it was found at an early glass eel stage of *A. rostrata*. Dam construction in freshwater systems has also greatly reduced eel habitat and is most likely involved in the decline of eels. A detailed description of 5600 dams in tributaries to the St Lawrence River in Québec (Canada) is provided by Tremblay *et al.* (2016). This is an important step towards restoring access to potential eel habitats. Welsh *et al.* (2016) monitored upstream dam passage of yellow-phase eels in the Shenandoah River (USA). This is quite new information since most research on upstream passage has been conducted on younger glass eels or elvers. High river discharge and dark periods around the new moon were favourable for upstream migration.

Miller *et al.* (2016) highlighted the fact that the three northern hemisphere anguillid species experienced recruitment declines at similar times and that this implies common causes of the declines. The authors discussed the cumulative and simultaneous effects of (i) anthropogenic impacts on eel growth habitats, introduction of parasites, and overfishing combined with (ii) shifts in ocean–atmospheric conditions that could have reduced feeding success of larvae or disrupted larval transport. Knowledge of orientation mechanisms helps us understand how the physical marine environment, such as oceanic currents, affect the reproductive migration of eels. Béguer-Pon *et al.* (2016) used a biophysical particle-tracking model to simulate migratory pathways of virtual silver *A. rostrata* and *A. anguilla* eels and found that compass orientation (vs. true navigation) could be sufficient for eels to reach their spawning sites.

Stock assessment and generating management advice remains a basic topic of eel research. Westerberg and Wickström (2016) assessed trends in recruitment and escapement to and from the Baltic based on scientific surveys. One of the challenges associated with this task was to include stocked and translocated eels from the rest of Europe to the Baltic. Estonia is one of the countries that also receive a large proportion of stocked eels. Trends in professional landings, scientific eel monitoring, and recreational catches were analysed by Bernotas *et al.* (2016). A decline in eels was also evident in these data, with the steepest catch-per-unit-effort decline occurring in the last 5 years. Silver eel escapement values were assessed on the other side of the Baltic, in Germany (Brämick *et al.*, 2016). The authors concluded that stocking was necessary to reach current escapement targets set by European eel management plans. Aalto *et al.* (2016) examined the declining trends of Mediterranean eel stocks. An analysis of eel fisheries in coastal lagoons and a population dynamics model provide a preliminary estimate of pristine, potential, and actual escapement of spawning adults (silver eels) across the Mediterranean basin under historical and current conditions. The Bay of Biscay receives the largest glass eel recruitment in Europe. Aranburu *et al.* (2016) estimated glass eel density in an estuary using scientific and commercial eel fishery time-series as they relate to ocean currents and water depths to obtain a recruitment index and density predictions.

Better stock assessment relies on knowledge of the species distribution. Benchetrit and McCleave (2016) examined the historical and current distribution of American eel in the Caribbean and South America. They based this first comprehensive description of the species in this region on quantitative and qualitative information from the literature, museum records, and personal contacts. The results of this investigation confirm that the American eel was historically—and continues to be—widely distributed throughout the wider Caribbean region, extending all the way to eastern Venezuela and the island of Trinidad.

Fecundity estimates of silver eels are useful for evaluating the reproductive capacities of eels migrating back to the Sargasso Sea. MacNamara *et al.* (2016) showed that geographical location explained more variation in eel fecundity than did their different salinity environments. Quantitative estimates of future spawners migrating from the southern part of its distribution area in Tunisia were given by Derouiche *et al.* (2016).

Stocking of juvenile eels (glass eels or elvers) is implemented by many countries in recovery plans. In their study, Josset *et al.* (2016) estimated short-term mortality of glass eels after their release. They highlighted which handling factors are likely to increase the efficiency of stocking protocols. Pedersen and Rasmussen (2016) evaluated the yield from stocking two different sizes of glass eels from aquaculture and found no advantage in using larger glass eels compared with smaller glass eels for stocking.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

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