Fisheries Research 208 (2018) 22–33

Contents lists available at ScienceDirect

Fisheries Research

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

Variability of coastal cephalopods in overexploited China Seas under climate change with implications on fisheries management

Yumeng Pang[a,1], Yongjun Tian[a,b,*], Caihong Fu[c], Bin Wang[a], Jianchao Li[a], Yiping Ren[a], Rong Wan[a]

[a] Fisheries College, Ocean University of China, Yushan Road 5, Qingdao, 266003, China
[b] Laboratory for Marine Fisheries Science and Food Production Processes, Qingdao National Laboratory for Marine Science and Technology, Aoshanwei, Qingdao, 266071, China
[c] Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia V9T 6N7, Canada

ARTICLE INFO

Handled by B. Arara

Keywords:
Cephalopod
Chinese coastal area
Population fluctuation
Life history strategy
Climate change

ABSTRACT

Cephalopods (squids, cuttlefish and octopus) have increased globally over the past decades, which may be attributed to their strong phenotypic plasticity, allowing them to adapt quickly to a changing ocean environment. The global proliferation of cephalopods may yield important ecosystem effects worldwide. However, information on cephalopods variability in Chinese waters is still scant. Coastal cephalopods, in spite of chronic overexploitation, form a vital component of the catch composition in China Seas. In this paper, we review the status and trends of coastal cephalopods in China Seas and explore their responses to environmental variability. We focus on four commercially-important coastal cephalopod species, including golden cuttlefish (*Sepia esculenta* Hoyle), Japanese loligo squid (*Loligo japonica* Steenstrup), common Chinese cuttlefish (*Sepiella maindroni* de Rochebrune) and swordtip squid (*Uroteuthis edulis* Hoyle). Even though spatial distributions of these four species partially overlap, their differing life history strategies with respect to factors such as growth, distribution, migration, and spawning patterns, have led to differing population responses to environmental variability. As a result, an overall increasing trend in cephalopod production has been apparent since the 1990s, accompanied by major changes in species composition. Catch trends of the four species show either decadal patterns of significant decline or increase in the late 1980s to mid-1990s. Statistical analysis indicates different responses to environmental warming, with Japanese loligo squid and swordtip squid seeming to benefit from warmer environment while golden cuttlefish and common Chinese cuttlefish seeming to respond negatively. Our study has allowed us to explore the impacts of environmental changes on Chinese coastal cephalopods in the overexploited ecosystems of the China Seas and to conclude that fluctuations of coastal cephalopods are mainly driven by large scale environmental variations associated with climate change and/or marine ecosystem regime shifts.

1. Introduction

Total world catch production by marine fisheries has maintained an unprecedentedly high level in recent decades. This has been facilitated by dramatic increases in the yield of cephalopods (Ye and Cochrane, 2011; FAO, 2016). As shown in Fig. 1, elevated cephalopod catch coincides with a reduction of global fish stocks (Anderson et al., 2011; Pauly and Palomares, 2005). Cephalopods were found contributing to fisheries in 28 marine ecosystems of the world both in terms of their value as commodities and in terms of the ecological support services they render (Hunsicker et al., 2010; Xavier et al., 2015). Recent evidence has shown that cephalopods in both coastal and oceanic areas have taken advantage of changing ocean environments and have increased in abundance (Doubleday et al., 2016). Although some cephalopod stocks have been overexploited (Quetglas et al., 2015; Tang and Wu, 1986), cephalopods in general appear to withstand substantial expansion in fishery landings, and harvests of cephalopods can be expected to meet ongoing exploitation needs for marine fisheries resources (Arkhipkin et al., 2015).

Impacts of climate change over the past decades have been well documented in the North Pacific Ocean (Sugimoto et al., 2001; McGowan et al., 1998). The 1976/77 regime shift in the North Pacific was commonly recognized as a shift from “negative” to “positive” phase in PDO (Pacific Decadal Oscillation), resulting in significant changes in

* Corresponding author at: Fisheries College, Ocean University of China, Yushan Road 5, Qingdao, 266003, China.
E-mail address: yjtian@ouc.edu.cn (Y. Tian).
[1] Present address: Atmosphere and Ocean Research Institute, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8564, Japan.

https://doi.org/10.1016/j.fishres.2018.07.004
Received 28 November 2017; Received in revised form 13 June 2018; Accepted 7 July 2018

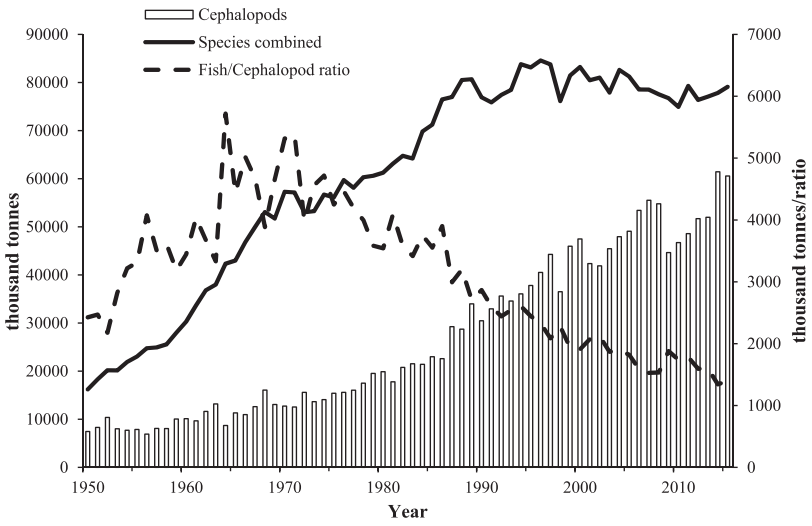

Fig. 1. Global marine catches of species combined (Marine fishes, Crustaceans and Molluscs) (solid line) and cephalopods (squid, cuttlefish and octopus) (bar), and fish to cephalopods catch ratio (100%, dashed line). Global marine catch of species combined was plotted along the first axis, while cephalopods catch and fish/cephalopod ratio along the secondary axis.

environmental conditions (Hare and Mantua, 2000). In addition to the 1976/77 regime shift, annual anomalies of climatic indices indicated a changing thermal regime that subsequently impacted large marine ecosystems of the North Pacific in the late 1980s (Tian et al., 2008). These climatic changes have large impacts not only on individual species such as sardine and squid but also on communities and ecosystems (Chavez et al., 2003: Lehodey et al., 2006; Tian, 2009; Tian et al., 2008, 2013).

Because of their typical biological traits of cephalopods, such as rapid growth, short lifespan, high turnover rate and strong phenotypic plasticity, their growth, maturation and distribution are heavily affected by environmental variation (Pecl and Jackson, 2008; Pierce et al., 2008; Pecl et al., 2004). While coastal ecosystems are easily degraded by high fishing pressure and climate change, cephalopods tend to take advantage of changing environmental conditions and may overtake fish species due to their flexible life history strategies (Caddy and Rodhouse, 1998; Pecl and Jackson, 2008). Thus, cephalopod catch fluctuations in overexploited ecosystems might in large part be driven by environmental variation (Caddy and Rodhouse, 1998). Previous studies on various cephalopod species suggested that climate change significantly influenced status and spatial distributions of cephalopods (Pecl and Jackson, 2008; Sakurai et al., 2000). For instance, stock status and spatial distribution of Japanese common squid (*Todarodes pacificus* Steenstrup) appeared to vary under different thermal regimes (Sakurai et al., 2000). The relative abundance of spear squid (*Loligo bleekeri* Keferstein) in Japanese water showed latitudinal differences and appeared to be primarily driven by major ecosystem regime shifts (Tian, 2009; Tian et al., 2013).

China Seas (Fig. 2) represent a set of overexploited coastal ecosystems where commercial fish stocks have largely declined and individual fish tend to be small-sized and of low-quality due to several decades of high fishing pressure (Ren et al., 2005; Watson and Pauly, 2001). In addition, China Seas is one of the most rapidly warming large marine ecosystems in the world ocean. Sea surface temperature (SST) in the East China Sea increased by 1.22 °C between 1982 and 2006 (Belkin, 2009), evidently associated largely with global warming and large-scale climate variability (Cai et al., 2015, 2014). Consequently, fisheries catch composition and the structure of the ecosystem have changed drastically with fish species declining and invertebrates increasing (Jin and Tang, 1996; Jin, 2004; Liu et al., 2015). Extensive research has been carried out to investigate the impacts of environmental changes on population dynamics and spatial distributions of oceanic cephalopods in the northwestern Pacific (Chen et al., 2008; Sakurai et al., 2002; Yu et al., 2015). However, holistic information on the status of Chinese coastal cephalopods including catch trends and species composition is

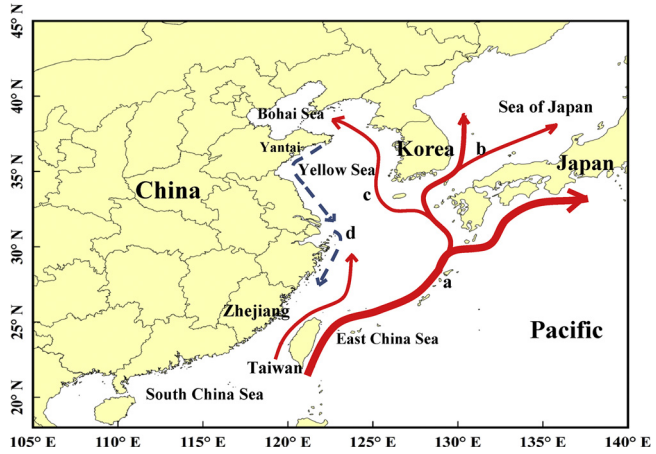

Fig. 2. Map of China Seas (Bohai Sea, Yellow Sea, East China Sea, and South China Sea) and the different currents (a. Kuroshio Current, b. Tsushima warm current, c. Yellow warm current, and d. Mainland coastal current) (Guan, 1994).

scant, and potential influencing factors for population fluctuations are still not well understood.

In this paper, firstly we present a review on the status and variation patterns of Chinese cephalopods over several decades in the context of climate change, with particular focus on four commercially-important, representative coastal species exhibiting different life history strategies: golden cuttlefish (*Sepia esculenta* Hoyle), Japanese loligo squid (*Loligo japonica* Steenstrup), common Chinese cuttlefish (*Sepiella maindroni* de Rochebrune) and swordtip squid (*Uroteuthis edulis* Hoyle). Secondly, we hypothesize that environmental changes have exerted the greatest impacts on coastal cephalopods in the overexploited China Seas and apply statistical analyses to identify oceanographic and climatic factors that influence the dynamics of their populations. Finally, we discuss the relative impacts of environmental changes and human activities on their population fluctuations and attempt to provide useful guidance as to appropriate fisheries management actions under climate change.

2. Materials and methods

2.1. Fishery data and species selection

Data were extracted from various sources at different scales in order to characterize the role of coastal cephalopods through comparisons of cephalopods to fish and oceanic cephalopods to coastal cephalopods