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Are condition factors powerful proxies of energy content in wild tropical tunas?

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ABSTRACT

The "condition" is used as an indicator of fish health and is generally equated with the quantity of energy reserves. Biometric condition factors have been widely used and preferred over costly and time-consuming biochemical condition. Here, we investigated the relevance of four common condition factors based on biometric measurements (Le Cren's index, girth-length index, gonado-somatic index and hepato-somatic index) and of size- and weight-based empirical models to describe the physiological condition of tropical tunas. Biometric condition factors of bigeye (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tunas sampled throughout 2013 in the western Indian Ocean region were assessed against benchmark biochemical indices (lipid content, protein content, triacylglycerol:sterol ratio and energy density) estimated in tissues with different physiological functions, i.e. red muscle, white muscle, liver, and gonads. Our findings suggest that tropical tunas do not store lipids in white muscle and that protein content is less variable than lipid content, which largely varies with ontogeny and the seasons according to tissue and species. This variability induced inconsistency between biometric factors, including the empirically adjusted ones, and biochemical indices, with the exception of the gonado-somatic index that fitted well to the composition of the gonads in the three species, and especially in females.

1. Introduction

In animal ecology, the term 'condition' is used to describe the general health or well-being of an individual and usually refers to the quantity of energy reserves (Stevenson and Woods, 2006). Stemming from diet sources, these reserves can be used to meet the energy demands for maintenance, growth, sexual maturation and reproduction (Jakob et al., 1996). In fish, their level directly affects survival and trade-off in energy allocation (Post and Parkinson, 2001). The caloric content and tissue proximate composition analysis are thus the reference methods used to estimate the condition of an individual (e.g. Pangle and Sutton, 2005; Domínguez-Petit et al., 2010). Lipids function primarily as an energy reserve in fish and the level of lipids in an individual generally indicates the energy available for vital functions (Tocher, 2003). On the other hand, proteins will act as an energy source only in extreme case of starvation (McCue, 2010). Derived measures of condition were also developed, such as the lipid reserve index (i.e. triacylglycerol:sterol ratio, which are reserve and structural lipids respectively; Fraser, 1989). However, morphometric measures are generally preferred over costly and time-consuming biochemical analyses to assess fish condition.

Historically used in fisheries research as early as the 1900s (Nash et al., 2006), morphometric condition factors are based on individual plumpness variations, considering that at a same size, a bigger fish is healthier (Ricker, 1975). Among a great number of morphometric factors available, the most commonly used is the relative condition factor (K_n) developed by Le Cren (1951), which is the ratio of a fish weight to its predicted weight as derived from a population-specific length-weight relationship (Bolger and Connolly, 1989). Other anatomical factors based on specific organ and tissue mass variations have been used to investigate reproduction dynamics: e.g. gonado and hepato-somatic indices (GSI and HSI), which relate the weight of gonads and liver to the somatic

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weight of the fish, respectively. Morphometric condition factors have been generally used as proxies of body lipid content (Grande et al., 2014; Zudaire et al., 2014). They have been shown to well reflect energy reserves in cold water species (Lambert and Dutil, 1997; Kaufman et al., 2007) and have been proven to be useful for studying the effects of environmental conditions on mortality (Dutil and Lambert, 2000), growth (Cardinale et al., 2002), recruitment success (Plourde et al., 2015) and fecundity (Marshall et al., 2006). Other studies, however, failed to attempt to correlate morphometric condition factors and body composition in temperate pelagic fish (Goñi and Arrizabalaga, 2010; McPherson et al., 2010). In tropical tunas, Fulton's condition factor (Ricker, 1975), GSI and HSI were related to the reproductive cycle and helped to determine the main periods and areas of reproduction in these species (Grande et al., 2014; Zudaire et al., 2014). Others factors (girth or ratio between girth and size; total lipid content and lipid reserve index) were used to assess the impact of the association to floating objects on tunas' fitness (Hallier and Gaertner, 2008; Robert et al., 2014). However, to the best of our knowledge, the relationships between anatomical or morphometric condition factors and body composition have not been investigated yet in tropical tunas. Taking into account the global fishing pressure on tuna populations that has steadily increased over the last decades (Juan-Jordá et al., 2011), an accurate monitoring of tropical tunas health through individual condition is urgently required. Among the three principal market tropical tunas targeted in the Indian Ocean, i.e *Thunnus albacares* (yellowfin tuna; YFT), *Thunnus obesus* (bigeye tuna; BET) and *Katsuwonus pelamis* (skipjack tuna, SKJ), YFT has been recently classified as overfished (IOTC, 2015).[1]

The present study aimed to shed the light on bioenergetics profiles in wild populations of tropical tunas in the Western Indian Ocean: (i) to determine the main causes of energy variations in the three species through the analysis of proximate composition, and (ii) to test the assumption that morphometric condition factors reflect the energy content in tropical tuna. Four common condition factors and empirical models based on size and weight were assessed monthly in the three tropical tuna species together with the proximate composition of their tissues (i.e. liver, gonads, white and red muscles used during fast- and slow-twitch respectively); the influence of biological and environmental factors on these variables was also investigated.

2. Material and methods

2.1. Data collection

A total of 223 BET, 178 SKJ and 230 YFT were sampled throughout 2013, on a basis of 15–20 individuals per month, at the unloading of purse seiners at Victoria, Seychelles. Fishing date and accurate GPS[2] fishing location from purse seiners' logbooks allowed for the distinction of two main capture areas that differed according to their oceanographic specificities: Mozambique Channel (MOZ) and Western-central Indian Ocean (WCIO) (Fig. 1). Four seasons were considered to account for the monsoon regime that strongly affects the oceanographic conditions in the Indian Ocean: North-Eastern Monsoon (NEM) from mid-November to mid-March, Spring Inter-Monsoon (SIM) from mid-March to mid-May, South Western Monsoon (SWM) from mid-May to mid-September, and Autumn Inter-Monsoon (AIM) from mid-September to mid-November (Schott and McCreary, 2001). All sampled fish were weighed (kg to the nearest 0.1 kg), measured in fork length, which refers to the length from the tip of the snout to the fork of the tail (F_L, cm to the nearest 0.5 cm) and measured in thorax girth (T_G, cm to the nearest 0.5 cm), which refers to the girth under the pectoral fins beneath the first dorsal spine. Weights of the gonads (W_G) and liver (W_L) were determined to the nearest g. Somatic weight (Ws) was then computed to the nearest 0.1 kg as the total fish weight minus the weight of all internal organs and remaining viscera. Sex was determined from macroscopic exam, except for individuals not developed enough for which it was recorded as "indeterminate" (*I*). These fish were considered immature. Maturity was determined from visual inspection of the gonads and split between developing (Dev, i.e. immature to developing fish) and spawning stage (Spa, i.e. spawning capable to resting fish) (Brown-Peterson et al., 2011). Among the 631 tuna processed, 81 BET, 79 SKJ and 80 YFT were selected for biochemical analyses, based on their length, sex and sampling origin to cover most of the life cycle and main environmental conditions encountered. Samples of approximately 2 g (wet weight) of gonads (G) and liver (L), white muscle (W) and red muscle (R) were collected and stored at −80 °C until biochemical analysis. For consistency, white muscle was systematically sampled under the dorsal spine on the left side and red muscle under the pectoral fin.

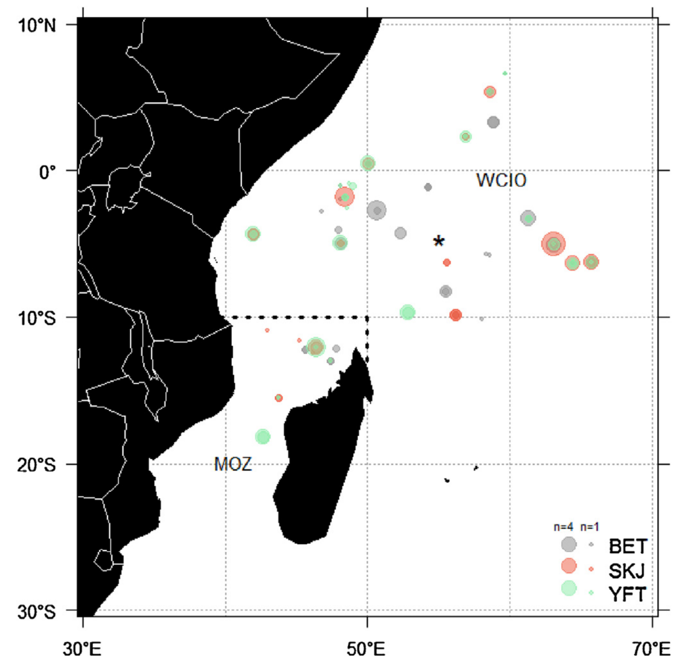

Fig. 1. Location of bigeye (BET), skipjack (SKJ) and yellowfin (YFT) caught in the Western Indian Ocean throughout 2013 and analyzed for biochemical content. The limit of the two study areas, Mozambique Channel (MOZ) and Western-Central Indian Ocean (WCIO) is indicated with dashed line. Star indicates Victoria port, Seychelles.

2.2. Biochemical analyses

Only lipid and protein contents were determined in the present study since glycogen levels are very low in fish, e.g. 0.36% in the wet white muscle of *T. alalunga* (Vlieg and Murray, 1988). In addition, glycogen is generally rapidly consumed because of the stress experienced during fishing operation (Black and Love, 1988).

2.2.1. Lipid content and composition

Approximately 250 ± 50 mg of 908 wet samples (231 W, 233 L, 229 R and 196 G) were weighed to the nearest mg, then crushed using a FastPrep System® (MP Biomedicals) and extracted with 2 ml of dichloromethane:methanol (2:1, v/v). After centrifu-

[1] Indian Ocean Tuna Commission.
[2] Global Positioning System.