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Resource partitioning in gurnard species using trophic analyses: The importance of temporal resolution

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ABSTRACT

Dietary habits and intra- and inter-specific trophic ecology of co-occurring *Lepidotrigla mulhalli* and *L. vanessa* from south-eastern Australia were analysed using stomach content and stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$). Both species are bottom-feeding carnivores that consumed mainly benthic crustaceans, but teleosts were also abundant in the diet of larger *L. vanessa*. Non-metric multidimensional scaling (nMDS) ordination and analysis of similarity (ANOSIM) of dietary data revealed significant inter-specific dietary differences; i.e. food resource partitioning. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values were similar between *L. mulhalli* and *L. vanessa*, however, suggesting similar trophic positioning. Ontogenetic changes in diet composition and stable isotope values were evident. As *L. vanessa* grew, they preyed upon larger individuals, such as teleosts and caridean shrmips, but no such trend was observed in the diets of *L. mulhalli*. Adults of both species were significantly enriched in ^{15}N relative to juvenile conspecifics thus supporting these data. Consequently, in this study, both methodologies, i.e. stomach content and stable isotope analyses, provided evidence of inter- and/or intra-specific dietary segregations and trophic niche partitioning between co-occurring *L. mulhalli* and *L. vanessa* off Tasmanian waters.

1. Introduction

Sympatric species in marine habitats often co-exist by sharing resources such as food and habitat (Platell and Potter, 2001; O'Shea et al., 2013). Among the different resource axes that control community structure, food resource partitioning and niche segregation are fundamental processes in community ecology and play a major role in the co-existence of similar species (Ross, 1986; Platell and Potter, 1999). The study of food utilization and partitioning between co-occurring fish species is often the principal mechanism of niche segregation (Gerking, 1994; Duarte and Garcia, 1999), and also useful for developing management approaches for conservation and sustainability (Micheli and Halpern, 2005; Greenstreet and Rogers, 2006), as ecosystems with greater diversity and niche complexity generally show greater resilience to outside pressures (Elmqvist et al., 2003).

Gurnards (Scorpaeniformes: Triglidae) are marine demersal fish commonly found in tropical and temperate waters globally (Richards and Jones, 2002). Triglidae fishes constitute approximately 125 species in 9 genera (Froese and Pauly, 2015) and more than 30 species occur in Australian waters (Rowling et al., 2010). The rough-snouted gurnard *Lepidotrigla mulhalli* (Macleay, 1884) and butterfly gurnard *L. vanessa* (Richardson, 1839) are widely distributed throughout southern Australian waters from southeastern New South Wales to southwestern Western Australia (Gomon et al., 2008), occurring in depths less than 200 m (May and Maxwell, 1986). Although several large-sized gurnards such as the red gurnard (*Chelidonichthys kumu*) and latchets (*Pterygotrigla andertori* and *P. polyommata*) grow large enough to be marketed, the relatively small gurnards (e.g. *Lepidotrigla* spp.) are a major component of trawl-bycatch but not economically valuable per se in Australia (Rowling et al., 2010). *L. mulhalli* have been listed as ecologically important species, however, because of their high abundance and prominence in the diets of other fishes in the south-eastern Australian marine ecosystem (Bulman et al., 2001).

The diet of Triglidae fishes has been studied worldwide (e.g. Ross, 1978; Moreno-Amich, 1992, 1994; Terrats et al., 2000; Boudaya et al., 2007; Huh et al., 2007; Baeck et al., 2011). Partitioning of resources amongst triglid fishes also has been studied in the North-western Atlantic (Ross, 1977), the Mediterranean Sea (Morte et al., 1997), south-western Australia (Platell and Potter, 1999), and the Cantabrian Sea (Lopez-Lopez et al., 2011). Despite their ecological importance, however, little is known about the dietary habits of *Lepidotrigla* species in southern Australia. Two papers have

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described the feeding of guild of these fishes, including *L. mulhalli* and *L. vanessa* in the southeastern Australian waters (Coleman and Mobley, 1984; Bulman et al., 2001), and a paper reported carbon and nitrogen stable isotope values for *Lepidotrigla* species (Devenport and Bax, 2002). However, there is no targeted study on how feeding may change with size and how resources and trophic niche may be partitioned among these species.

Historically, food web interactions have been problematic due to the difficulties associated with stomach content analysis. This technique limits dietary analysis to the very short term, and can be strongly influenced by prey choice (soft vs. hard prey) and regurgitation during capture (Cortés, 1997). More recently, stable isotope analysis has become the technique of choice, with fewer limitations than stomach content analysis and more accurate determination of long-term diet choice (Bearhop et al., 2004). When consuming a prey, a predator integrates the carbon ($\delta^{13}C$, ^{13}C: ^{12}C) and nitrogen ($\delta^{15}N$, ^{15}N: ^{14}N) isotopic ratios of its prey into its own tissues. The consumer's tissue will thus be a time-integrated dietary representation on a scale of weeks to months (e.g., Buchheister and Latour, 2010), unlike stomach contents that only represent a snapshot of diet. Thus, stable isotopes can elucidate the prey groups that are directly responsible for driving tissue growth and production of consumer species (Fry, 2006), and isotopic techniques are useful for identifying broader sources of production and for differentiating between benthic and pelagic trophic pathway (Fry, 2006). However, stable isotope analyses do not attain the same level of taxonomic resolution afforded by stomach content analysis. For example, different prey groups with similar trophic isotopic values are impossible to distinguish from each other by stable isotope analysis. Thus, a combination of stomach contents and stable isotope analysis is increasingly being used to improve interpretation of trophic ecology and aquatic food web (Lin et al., 2007; Cresson et al., 2014; Knickle and Rose, 2014). However, few studies have attempted to describe trophic ecology using both methods in Australian waters.

In this study, dietary habits and the intra- and inter-specific trophic niche partitioning between two species of gurnards in the Tasmanian waters, Australia were assessed. Our specific objectives were to 1) investigate the diets of *L. mulhalli* and *L. vanessa*; 2) identify any size-related change in dietary composition based on maturity; and 3) assess any inter- and intra-specific dietary overlap and stable isotope signatures between the two species in this area. The results would be highly beneficial both for management purposes and future trophic community analyses locally and globally.

2. Materials and methods

2.1. Study area and sampling

Field sampling was conducted in waters off northeastern Tasmania, Australia (40°15′S–42°20′S, 147°05′E–148°35′E; Fig. 1).

Samples were collected as by-catch from repeated research trawls on board the Australian Maritime College vessel *RV Bluefin* in the Australian spring 2014 (September and November). Fish were collected at depths between 30 and 40 m using a 70 mm mesh demersal trawl of 16 m headline length towed at 3 knots. Immediately after capture, individuals were identified to species, snap frozen at −20 °C and transported to the Marine Ecology Laboratory at Macquarie University. Fish were held frozen until processing, which occurred immediately after thawing in the laboratory. This method of preservation did not influence the ability to identify prey or to estimate the gravimetric contributions of the various prey items.

2.2. Stomach contents analysis

In the laboratory, total length (TL, ± 1.0 mm) and wet weight (± 1.0 g) were measured for each specimen. Stomachs were removed and preserved in 70% isopropanol for at least 24 h, and then the contents were analysed using a stereo microscope. Stomach contents were identified to the lowest taxonomic level and the prevalence of each prey item was quantified (numbers and wet weights [±0.001 g] of each prey item were recorded). Cumulative prey curves were constructed for each species to determine if a sufficient number of stomachs were analysed to describe their diets (Ferry and Cailliet, 1996). The order of stomachs was randomized 10 times and the cumulative number of new prey taxa was counted for each randomization. Mean number of prey taxa against the number of stomachs analysed were plotted. Attainment of an asymptote indicated that an adequate number of stomachs were studied. A curve was considered to asymptote if at least ten previous values of the total number of prey taxa were in the range of the asymptotic number of prey ± 0.5 (Huveneers et al., 2007).

Diet was quantified by frequency of occurrence ($\%F = 100 \times A_i \times N^{-1}$), as a numerical percentage ($\%N = 100 \times N_i \times N_T{}^{-1}$), and as a mass percentage ($\%M = 100 \times M_i \times M_T{}^{-1}$), where A_i was the number of fish preying on species i, N was the total number of fish examined (excluding those with empty stomachs), N_i (M_i) was the number (mass) of prey individuals i, and N_T (M_T) was the total number (mass) of prey individuals. Next, the index of relative importance (IRI) (Pinkas et al., 1971) was calculated for each prey item as follows: IRI = (%N +%M) × %F, and expressed as a percentage (%IRI).

To infer ontogenetic trends, individuals were categorised into two size classes (juvenile and adult) based on their gonadosomatic index (GSI = gonad weight/body weight × 100). GSI values of females were plotted against their TL (Fig. S1). The TL with a dramatic increase in GSI was considered to be the minimum maturity size (Tuuli et al., 2011), i.e. criteria to divide between juvenile (immature) and adult (mature). Juveniles were defined as 105–154 mm (n = 13) for *L. mulhalli* and 119–201 mm (n = 89) for *L. vanessa*, and adults 155–218 mm (n = 155) for *L. mulhalli* and 202–248 mm (n = 73) for *L. vanessa*.

Diet diversity and niche breadth were calculated from number of the lowest possible taxonomical level using the Shannon–Wiener diversity index (H′) and Levin's standardized niche breadth (B_N) (Krebs, 1989).

2.3. Multivariate analysis-Stomach contents

Stomach content data were analysed using non-metric multidimensional scaling (nMDS), permutational multivariate analysis of variance (PERMANOVA), analysis of similarity (ANOSIM) and similarity percentages (SIMPER) to make intra- and inter- specific comparisons between these two species based on percentage mass (%M) data between two species (Clarke and Gorley, 2006; Anderson et al., 2008).

To examine the relative extent to which the dietary composition of fish differed between species, and between size classes, stomachs were randomly sorted into groups of five or six (depending on the sample size). The proportion of mass for each of the major prey categories were determined for each group for dietary composition analyses. Randomization and subsequent grouping of mass data were designed to reduce the number of prey categories in the samples with zero values, thus increasing the effectiveness of multivariate analysis (White et al., 2004; Marshall et al., 2008). Mass data were square root transformed to avoid any tendency for the main dietary components to be excessively dominant and Bray–Curtis similarity matrices were constructed for each of the three gurnards (Platell and Potter, 2001). The Bray–Curtis