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Diets and niche overlap among nine co-occurring demersal fishes in the southern continental shelf of East/Japan Sea, Korea

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ABSTRACT

Dietary niches and food resource partitioning can support the coexistence of many fishes in benthic marine systems, which can lead to the greater abundances of those species that can potentially support their fisheries. Diets and niche overlap among nine demersal fish species were investigated in the southern continental shelf of East/Japan Sea, Korea. Specimens were collected monthly from January to November 2007 on soft bottoms between 40 and 100 m depth using a bottom trawl. A total of 20 prey taxa were found in 1904 stomachs of the nine species. Comparison of the stomach contents among the nine species showed that inter-specific dietary compositions differed significantly. Although all fish species consumed similar types of prey items, their contributions to the diet of different species varied. Among prey taxa, carid shrimps contributed greatly to the diets of *Amblychaeturichthys hexanema*, *Amblychaeturichthys sciistius*, *Coelorinchus multispinulosus*, *Lepidotrigla guentheri*, and *Liparis tanakae*, whereas polychaetes and teleosts contributed to the diets of *Callionymus lunatus* and *Lophius litulon*, respectively. On the other hand, carid shrimps and teleosts together contributed to the diets of *Pseudorhombus pentophthalmus*. Non-metric multivariate analysis of the mass contributions of dietary categories for food resources emphasized visually that the dietary compositions of the nine species differed. Although *C. multispinulosus*, *L. guentheri*, *L. litulon*, and *L. tanakae* showed similar dietary compositions between small and large size classes, ontogenetic diet changes of the remaining six species were evident. Feeding relationships among the nine demersal species were complicated, but inter- and intra-specific differences in dietary composition among the species reduced potential competition for food resources within the fish community in the southern continental shelf of East/Japan Sea, Korea.

1. Introduction

The East/Japan Sea is a marginal sea in the western North Pacific characterized by relatively small size and semi-enclosed geographical features (Naganuma, 2000). The oceanographic structures are largely associated with the Tsushima Warm Current and Liman Cold Current. The variations in water mass between the surface Tsushima warm water and the homogeneous cold deep water are largely associated with the dynamics of a marine ecosystem in the East/Japan Sea (Naganuma, 2000; Lee et al., 2009). Changes in faunal assemblages in the East/Japan Sea have been documented over varying time periods and have been linked to a number of anthropogenic influences including fishing and climate change (Kang et al., 2000; Tian et al., 2006, 2011). The entire East/Japan Sea warmed due to expansion of the Tsushima Warm Current after the 1980s. Thus, biological responses to climate change in the region are expected to have already begun (Kang et al., 2000; Tian et al., 2011). Fisheries have also generated reduction in high trophic level species and consequently decreased the mean trophic level in this area (Rahman and Lee, 2012). The impact on and temporal responses of the biota to change, together with food web structure, appear to be due to influences of climate, as well as the non-climate related past and continuing human impacts. In the absence of a baseline from which to compare future studies, it is impossible to predict effectively the impacts of fishing and climate change on the biodiversity of the area. Indeed, demersal marine communities inhabiting the East/Japan Sea in Korea have been studied little compared with those of the southern Sea and Yellow Sea, Korea.

Marine benthic ecosystems with greater diversity and niche complexity of species show greater resilience to outside pressure and are more easily fished sustainably, because the structures of fish

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assemblage respond to both environmental variables and ecological interactions. Among the different factors that control community structure, partitioning of food resources and habitat separation play a major role in co-existence of different species (Ross, 1986). Intraspecific differences among community members may be attributed to competitive interaction as results of competition for the same resources over evolutionary time scales even though they are taxonomically distant (Connell, 1983; Kido, 1997; Platell and Potter, 2001). The study of food utilization and partitioning among dominant fish species is fundamental to the understanding of marine ecosystems (Duarte and Garcia, 1999; Xue et al., 2005) because knowledge on the trophic ecology of dominant fish species is necessary to understand the functional role of fishes within their ecosystem (Wootton, 1990; Brodeur and Pearcy, 1992; Xue et al., 2005). Understanding feeding relationships is also useful for developing management approaches for conservation and sustainable use of biological diversity (Micheli and Halpern, 2005; Greenstreet and Rogers, 2006).

Several studies have investigated food resource partitioning among demersal fish assemblages, and their diets have revealed a considerable degree of resource segregation among co-occurring species (e.g. Gibson and Ezzi, 1987; Dou, 1995; Fujita et al., 1995; Labropoulou and Papadopoulou-Smith, 1999; Platell and Potter, 2001; Madurell and Cartes, 2006). However, most studies on demersal fish assemblages in the benthic ecosystems of East/Japan Sea, Korea have concentrated on community structure (e.g., Lee, 1999) and the feeding habits of single species (e.g., Huh and Baeck, 2003; Huh et al., 2006; Choi et al., 2011; Baeck et al., 2013). Choi et al. (2009) described the diets of three sympatric deep sea fishes, *Lumpenella longirostris*, *Malacocottus gibber*, and *Bothrocara hollandi*, in the East/Japan Sea at depths of 300–900 m and provided information on differences in their dietary composition and feeding behaviors. Nonetheless, trophic relationships and food partitioning among demersal fishes in the continental shelves of Korea including the East/Japan Sea have not been investigated adequately.

The aim of this study was to investigate the dietary composition and feeding relationships among nine co-occurring demersal fish species, including commercially important fishes and potential prey species of commercially important fish, in the southern continental shelf of the East/Japan Sea, Korea. Our specific objectives were to 1) investigate and describe the diets of nine demersal fish species, 2) identify any size-related changes in dietary composition, and 3) assess any inter- and intra-specific niche overlap among the fishes in this area. The results from this study will contribute to the understanding of feeding relationships of demersal fishes, and serve as an important baseline for future trophic community analyses for fish assemblage in this region.

2. Materials and methods

2.1. Sampling

Fishing grounds located 4–15 km off the southern continental shelf and the eastern coast of East/Japan Sea, Korea (Fig. 1). The study area exhibits environmental and geographical characteristics that distinguish them from the coastal marine ecosystems of adjacent southern Korean seas (Park, 1978). Our study area serves as a habitat for many commercially significant demersal fishes, such as *Doederleinia berycoides*, *Engraulis japonicus*, *Liparis tanakai*, *Lophius litulon,* and *Zeus faber* (Kim et al., 2004). The area also forms a productive nursery with abundant food resources for early stage of fishes (Park, 2010) and provides overwintering and feeding grounds for a variety of commercially important fishes (Kim, 1998; Choo, 2007). Surface temperatures (13.6–26.5 °C) and salinities (28.4–34.3%) remain in the general range of those of the temperate ocean, while water bottom temperatures (40–100 m) range from 9.0 to 22.7 °C (Park, 2010).

Sampling was performed monthly from January to November 2007. Fish samples were collected at depths of 40–100 m using a small bottom trawl (length 20 m, width 4 m, mesh wing and body 3 cm, mesh liner 1 cm). Trawl netting was performed during daylight at neap tide and a speed of approximately 2.0 knots. As a broad range of depths with the demersal trawl was used, we did not examine spatial differences of the diets. A total of 56 fish species have been found in the study area (unpublished data). This study focused on nine abundant demersal fish species during the study periods: *Liparis tanakae* (5.4–37.0 cm standard length [SL], n = 334; Liparidae), *Pseudorhombus pentophthalmus* (7.0–22.5 cm SL, n = 320; Paralichthyidae), *Lophius litulon* (3.9–45.8 cm SL, n = 258; Lophiidae), *Callionymus lunatus* (4.7–13.0 cm SL, n = 217; Callionymidae), *Coelorinchus multispinulosus* (2.6–8.5 cm anal length [AL], n = 178; Macrouridae), *Chelidonichthys kumu* (15.5–33.4 cm SL, n = 185; Triglidae), *Lepidotrigla guentheri* (4.5–14.0 cm SL, n = 172; Triglidae), *Amblychaeturichthys sciistius* (3.4–7.5 cm SL, n = 129; Gobiidae), and *Amblychaeturichthys hexanema* (5.7–12.9 cm SL, n = 124; Gobiidae). Immediately after capture, fish were packed in ice and taken to the laboratory. SL (or AL for *C. multispinulosus*) and wet weight were measured to the nearest millimeter and nearest gram, respectively. Stomachs were removed, and the contents were preserved in 5% formalin and then transferred to 70% isopropanol (for storage) after 24 h.

2.2. Stomach content analyses

The stomach from each individual was cut open, and the contents were examined under a stereomicroscope. Prey items were identified as accurately as possible (species or family level), with any unidentifiable prey items and digested parts being categorized to a higher taxonomic level (class or order levels). The parasites, sediment, gravel, and unidentifiable materials were not recorded as food items. Fresh prey that may have been consumed within a trawl net (an activity known as net feeding) were not used in the analyses, because it appears to be an instinctive reaction and does not necessarily reflect natural feeding or prey selection (Hopkins and Baird, 1975). For example, goosefish including *L. litulon* in this study often engaged in “net feeding”, as prey items were found in the buccal cavity and esophagus or were obviously fresh in the stomach (Armstrong et al., 1996). Most prey items were intact. Some prey fragments were collected and considered to be parts of a single prey item; prey counts included these collected fragmentary items. The number and wet weight of each prey item were recorded. The results of stomach analysis were quantified as the percentage mass:

$$\%M = 100 \times M_i \times M_t^{-1},$$

where M_i is the mass of prey individual *i*, and M_t is the total mass of prey individuals.

Cumulative prey curves were constructed for each species to determine if a sufficient number of stomachs were analyzed to describe their diets (Ferry and Cailliet, 1996). The order of the stomachs was randomized 10 times, and the cumulative number of new prey taxa was counted for each randomization. The mean number of prey taxa was plotted against the number of stomachs analyzed. Attainment of an asymptote indicated that an adequate number of stomachs had been evaluated. A curve was considered to be asymptotic if at least 10 previous values of the total number of prey were in the range of the asymptotic number of prey ± 0.5 (Huveneers et al., 2007).

Size-related variations in diet were examined by dividing the specimens into two size classes (small and large). The lengths of the size classes of each species were as follows: *A. hexanema* (small, 5.7–8.9 cm and large, 9.0–12.9 cm SL), *A. sciistius* (small, 3.4–5.9 cm and large, 6.0–7.5 cm SL), *C. kumu* (small, 15.5–23.9 cm and large, 24.0–33.4 cm SL), *C. lunatus* (small, 4.7–8.9 cm and large, 9.0–13.0 cm SL), *C. multispinulosus* (small, 2.6–4.9 cm and large, 5.0–8.5 cm AL), *L. guentheri* (small, 4.5–9.9 cm and large, 10.0–14.0 cm SL), *L. litulon* (small, 3.9–25.9 cm and large, 26.0–45.8 cm SL), *L. tanakae* (small, 5.4–19.9 cm and large, 20.0–37.0 cm SL), and *P. pentophthalmus* (small, 7.0–15.9 cm and large, 16.0–22.5 cm SL).