

Food utilisation by coastal fish assemblages in rocky and soft bottoms on the Swedish west coast: Inference for identification of essential fish habitats

Johan Stål*, Leif Pihl, Håkan Wennhage

Department of Marine Ecology, Göteborg University, Kristineberg Marine Research Station, 566, SE-450 34 Fiskebäckskil, Sweden

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Abstract

The concept of essential fish habitats (EFHs) is widely accepted for conservational and management purposes. EFHs are often considered as high quality habitats for fisheries species and subsequently of high values for society. In this study, fish and Substrate-Associated Prey (SAP) were sampled during the productive summer season 1998 (fish) and 2003 and 2004 (SAP) in shallow coastal rocky- and soft-bottom habitats on the Swedish west coast. The aim was to study the spatial and monthly variation of SAP as well as abundance and biomass of fish, and to examine if food items found in the diet of the fish assemblage were derived from SAP. We also examined if the diet of *Ctenolabrus rupestris*, a resident and abundant fish species in the shallow coastal habitats, and the diet of four seasonally abundant and commercially important fish species (*Gadus morhua*, *Pleuronectes platessa*, *Salmo trutta* and *Scomber scombrus*) were derived from SAP. There were significantly higher mean species number and abundance of the SAP assemblage on rocky compared to soft bottoms and the highest values were found on the rocky bottoms in August and in the shallowest (0–3 m) depth strata. There were no significant differences in number of fish species caught in the two habitats, although mean number of fish and mean biomass were significantly higher on rocky bottoms. Both habitats showed the same seasonal variation and the highest values of number of fish species, abundance and biomass were observed in June. On rocky bottoms, gastropods and amphipods were the most frequent food items in the diet of the entire fish assemblage and these items were also the most abundant SAP in this habitat. The dominant food items of the soft-bottom fish assemblage were decapods and fish, which were not common SAP. However, except for *S. scombrus*, the diet of the selected fish species showed a strong association to the SAP availability. *Gadus morhua* displayed the strongest association to SAP on rocky bottoms and *P. platessa* and *C. rupestris* to SAP on soft bottoms. Further, for *C. rupestris*, multivariate statistical analysis showed a significant association to the SAP assemblage on both rocky and soft bottoms. These results provide vital new information for the management and conservation of Essential Fish Habitats on the Swedish west coast.

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1. Introduction

Coastal marine habitats are highly productive and support high abundances and diversity of fish and invertebrates (Beck et al., 2001). A wide range of marine fish species occupy the coastal zone and may, depending on life stage, utilise

different habitats (Gillanders et al., 2003). Many species occur in coastal waters during their early life stages, as the shallow waters provide nursery areas (Gibson, 1994; Beck et al., 2001), which offer protection against predation and ample food conditions (Choat and Ayling, 1987; Carr, 1994). Additionally, some species live permanently in the coastal zone where both juvenile and adult stages are restricted to a specific habitat. When juveniles and adults of a benthic fish species are dependent on specific coastal habitats for development and growth, the coastal habitats may constitute a bottleneck for

* Corresponding author.

E-mail address: johan.stal@kmf.gu.se (J. Stål).

the population and could accordingly determine the recruitment success of that species. An identification of such “Essential Fish Habitats” (EFHs), defined as “those waters and substrate necessary for fish for spawning, feeding or growth to maturity” (Benaka, 1999), is important for management and conservational purposes. Several studies have investigated the role of seagrass beds and rocky-bottom communities in coastal waters as essential spawning and nursery habitats (Able, 1999; Minello, 1999; Packer and Hoff, 1999) and shallow soft bottoms have been identified as important nursery areas, especially for flatfishes (Modin and Pihl, 1994; van der Veer et al., 2001). Most investigations on EFHs in the coastal zone have focused on differences in abundance, biomass or size distribution of fish, with the aim to evaluate the importance of different habitats on the dynamics of the fish populations under study (Lloret and Planes, 2003), but only a few studies have attempted to link the food availability of habitats to the distribution of the fish assemblages (Kaiser et al., 2004; Hinz et al., 2005; Norderhaug et al., 2005). The food availability in a specific habitat is one indication of habitat quality, reflecting habitat requirements (Wennhage et al., 2006) and will, in combination with the overall distribution pattern for the selected fish species, provide valuable information for the management of sustainable ecosystems and fisheries.

The littoral zone of the Swedish west coast has a complex structure of islands, fjords and open coast lines but is mainly dominated by two habitat types: vegetated rocky bottoms and shallow soft sediments partially covered by seagrass, *Zostera marina*. Rocky bottoms are characterized either by steep vegetated rock walls or gently sloping bottoms with rocks and boulders covered by algae to various degrees. There is a clear zonation pattern of green, brown and red algae which provide a mosaic of microhabitats for fish and invertebrates. Complex structures of algae are capable of supporting high abundances of epibenthic fauna which is dominated by amphipods and gastropods (Holmlund et al., 1990; Norderhaug, 2004) and large kelp beds on the adjacent Norwegian coast may support 100 000 individuals m^{-2} in the summer (Christie et al., 2003). Soft bottoms are characterized by sandy to silty sediments and are covered to some extent by the seagrass *Z. marina*. Consequently, soft bottoms support a different macrofauna assemblage mainly comprised of sediment-dwelling bivalves and polychaetes. This difference in habitat characteristics between rocky and soft bottoms is reflected in different invertebrate communities, which subsequently may affect the distribution of the fish assemblages.

Around 60 fish species have been identified in shallow (0–10 m depth) rocky- and soft-bottom habitats on the Swedish west coast (Pihl et al., 1994; Pihl and Wennhage, 2002). Among these species, *Gadus morhua*, *Anguilla anguilla*, *Clupea harengus*, *Scomber scombrus*, *Pleuronectes platessa* and *Salmo trutta* are of considerable commercial importance for various fisheries. In the studied area, where abiotic factors are similar among habitats, a fish species' use of a habitat can broadly be related to two major ecological functions, predator avoidance/shelter and food availability. Depending on life

strategy and age, coastal fish may seek food on, or in close proximity to, the benthic habitat; they may forage in the water column above the substratum or they may use a combination of the two feeding strategies (Choat and Ayling, 1987; Anderson, 1994; Wennhage and Pihl, 2002). Knowledge of the community of food organisms and the diet of fish species will provide the information necessary to determine the dependency on a habitat for foraging. Studies on the shelter function would require repeated measures of densities to estimate survival, while controlling for migration. These data will be almost impossible to acquire for an entire fish assemblage. In this study, we define shallow habitats as the physical structure of the benthic habitat (i.e. algae, sediment, rocks, seagrass etc.). We investigate the resource utilisation of the fish assemblage and relate this to the composition of Substrate-Associated Prey (SAP) in shallow (<10 m deep) coastal habitats. This is the first time that the fish assemblage, its diet, and food availability on rocky and soft bottoms have been quantitatively assessed in this area.

The aim of this study was to investigate (a) the spatial and monthly variation in availability of SAP and (b) the spatial and monthly variation in abundance, biomass and diet of fish. These data were then used to examine the consumption of SAP by the total fish assemblage in addition to some selected fish species on rocky and soft bottoms during the productive summer season on the Swedish west coast.

2. Materials and methods

2.1. Study area

Fish and benthic macrofauna were sampled at three rocky- and three soft-bottom locations in the outer archipelago of the Gullmars Fjord on the Swedish west coast (Fig. 1). At each location, a sampling area of approximately 2 ha was designated within the water depth of 0–10 m. The archipelago consists of hundreds of small rocky islands of varying size with a mixture of soft and rocky bottoms. Rocky bottoms are characterized by a high cover of macroalgae from the surface down to around 10 m depth. Soft-bottom habitats consist of sandy to silty sediment that are, to a varying degree, covered by seagrass beds (*Zostera marina*) within the depth range of 1–6 m (Baden et al., 2003). The tidal amplitude on the Swedish west coast is around 0.2 m (Svansson, 1975), and exchange of surface water in the study area is therefore mostly driven by diffuse wind-driven processes. Mean surface water temperatures usually range from 5 to 15 °C in spring and autumn and 15 to 20 °C from June to August (Pihl and Rosenberg, 1982). During winter (December to February), surface temperature is normally <5 °C, and in most years ice occurs during a few weeks. Surface water salinity typically fluctuates between 20 and 25.

2.2. Vegetation

Species composition and vegetation cover of algae and seagrass were estimated at all localities during the fish sampling

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