Journal of Sea Research 142 (2018) 157–166

Contents lists available at ScienceDirect

Journal of Sea Research

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

Occurrence and life history characteristics of tropical flatfishes at the coral reefs of Curaçao, Dutch Caribbean

Henk W. van der Veer[a,*], Joana F.M.F. Cardoso[a], Ivan Mateo[b,1], Johannes IJ. Witte[a], Fleur C. van Duyl[c]

[a] Royal Netherlands Institute for Sea Research, Department of Coastal Systems and Utrecht University, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands
[b] National Research Council Research Associateship Programs, 500 Fifth Street NW (Keck 568), Washington, DC 20001, USA
[c] Royal Netherlands Institute for Sea Research, Department of Marine Microbiology and Biogeochemistry and Utrecht University, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands

ARTICLE INFO

Keywords:
Coral reef
Flatfish
Life history
Bothus spec.
Curaçao

ABSTRACT

In this paper, life history characteristics of tropical flatfishes occurring at the fringing reefs of Curaçao to a depth of 20 m were studied. In total four flatfish species were caught, three common Bothidae species: the eyed flounder *Bothus ocellatus*, the mottled or maculated flounder *B. maculiferus* and the peacock flounder *B. lunatus*, and –in small numbers- the channel flounder *Syacium micrurum*. *B. ocellatus* and *S. micrurum* only occurred in sandy moats on the shallow reef terrace and fore reef and between coral patches on the terrace and fore reef slope. The other species could also be found on coral patches. The depth distribution of the various species overlapped: all species were caught over a depth range from a few meters up to 20 m. All *Bothus* species were carnivores, preying on a variety of mobile benthic animals such as fishes and crustaceans. Reproduction seemed to occur year round in all three *Bothus* species. Growth between the species varied considerably with a maximum age found in *B. maculiferus* and *B. lunatus* of a little over 1 year, and in *B. ocellatus* of about 2 years. Growth was lowest in *B. ocellatus* and highest in *B. lunatus*: after one year *B. ocellatus* was about 10 cm in size, *B. maculiferus* 25 cm and *B. lunatus* about 35 cm. After correction for differences in water temperature, the *Bothus* species showed a similar variability and range in growth rate as some temperate and subtropical flatfish species. These observations do not fit the hypothesis postulated by Pauly (1994) of an increasing importance of food-limitation in juvenile flatfish with decreasing latitude, despite the low densities and biomass of benthic in- and epifauna in the soft sediments in mangroves, seagrass beds and the reefs of Curaçao.

1. Introduction

Temperate coastal systems are often characterized by a substantial benthic community and especially for opportunistic (*epi*)benthic feeders such as juvenile (flat)fishes and crustaceans, food appear to be ample available (see for instance Beukema et al., 1996). Indeed, various juvenile flatfishes such as European plaice, flounder and sole, showed fast growth rates (Zijlstra et al., 1982; van der Veer, 1986) and for a long time these rates were thought to represent the maximum possible rates under the prevailing temperature conditions, summarized by the 'maximum growth-optimal food condition hypothesis' (van der Veer and Witte, 1993). However, on the other hand, growth variability within individuals and among groups was found in a variety of European coastal areas suggesting that in addition to food quantity also food quality is of importance (van der Veer and Witte, 1993; Ciotti et al., 2013a, 2013b, 2014). Even within various nursery areas, also seasonal variations in growth rate were observed, especially indications of some summer growth reduction (van der Veer et al., 2010, 2016; Freitas et al., 2012; Cardoso et al., 2016). A recent analysis also illustrated the importance of environmental variability (water temperature), non-genetic irreversible adaptation and especially sex in inducing variability in growth and hence in sizes (van der Veer et al., 2016). Overall, growth conditions in temperate flatfish species appear to be in the order of 0.5–1.0 mm d^{-1} and observations about stunted growth or starvation are lacking (for review see Ciotti et al., 2014).

It is thought that there is a general trend in food availability with low but relatively constant and uniform productivity at low latitude (Gross et al., 1988). The consideration that flatfishes in general might

* Corresponding author.
E-mail address: henk.van.der.veer@nioz.nl (H.W. van der Veer).
[1] Present adddress: SAI Global Assurance Services LTD, Global Trust Certification LTD, Quayside Business Park, Mill Street, Dundalk, County Louth, Ireland.

https://doi.org/10.1016/j.seares.2018.09.010
Received 25 April 2018; Received in revised form 17 September 2018; Accepted 18 September 2018
Available online 21 September 2018
1385-1101/

be overadapted to feeding on zoobenthic in- and epifauna led Pauly (1994) to the expectation that due to the decreasing importance of the benthic system towards the tropics, this would potentially result in increasing food limitation. So this would imply that reduced growth would become a more general phenomenon towards low latitudes and maybe year round in tropical systems. So far, this suggestion has not been studied and tested in more detail. Few laboratory studies (Reichert and van der Veer, 1991) and field studies (van der Veer et al., 1994a, 1994b, 1995) on juvenile flatfish growth and Von Bertalanffy growth parameters for some commercial flatfish species (Pauly, 1994) both even suggest that growth rates of subtropical flatfishes on soft sediments can be of the same order (between 0.5 and 1.0 mm d^{-1}) as that of temperate flatfish species.

Coral reef ecosystems are commonly found in tropical regions. Reef fish communities are composed of a variety of different taxa and species, often with complex life cycles, at least partly associated to the coral reef habitat (see for instance Sale, 2002). Among these reef fishes, also some flatfish species can be found, however, densities are often low, which might at least partly for epibenthic flatfish species due to the small amount of suitable habitat in the form of soft sediment (van Duyl, 1985). Apart from a general description of species composition and some information on feeding habits, ecological information about tropical flatfish species on coral reefs is scarce. Based on numerous studies in temperate and subtropical areas (a.o. Kuipers, 1977; Zijlstra, 1972), flatfish species are, except from seasonal migrations, in general considered as being rather sessile, especially during the juvenile stages. The condition and growth of these demersal species is often studied and considered to be an indicator for habitat quality of the benthic system (a.o. Ciotti et al., 2013a, 2013b, 2014; Freitas et al., 2016). However, it is unclear whether Pauly's hypothesis (Pauly, 1994) that tropical flatfishes are (year round) food limited is valid for these systems.

Often, various flatfish species occur in the same reef habitat with no basic information about their growth and reproduction, except for some observations about morphological differences. It is unclear to what extent the various species also differ in their performance despite occupying the same habitat. In this paper, basic population parameters such as abundance, distribution, length-weight, growth, reproductive effort etc. are collected for the common tropical flatfishes occurring on reefs environs in Curaçao, Dutch Caribbean, with the aim to estimate their growth and compare it with that in other systems. Some information is known about aspects of the social and reproductive behaviour of some flatfishes from a nearby island, Bonaire (Konstantinou and Shen, 1995).

2. Material and methods

2.1. Study area

The study was performed on the fringing reef along the SW coast of Curaçao (Dutch Caribbean), situated between 12°02′ and 12°23′ N and 68°12′ and 69°10′W. At Curaçao there is a prevailing trade wind from the north-easterly direction. Therefore, the south, southwest and west coasts are more sheltered than the northeast coast (van Duyl, 1985). Water temperature at the reef varies annually around 27 ± 1 °C.

The atlas of the living reefs of Curaçao and Bonaire (van Duyl, 1985) was used to select suitable shallow sand flats for sampling on the reef terrace. At one station, Porto Marie, a few flatfish were also caught at 20 m depth on a sand flat between the double reef. The dive sites are shown in Fig. 1.

2.2. Sampling

Flatfishes were caught on sandy patches by scuba divers with nets. Two scuba divers swam next to each other carrying a small drift net of 270 cm in length, 75 cm in height and a mesh size of 1.25 * 1.25 cm with a tickler chain below the net and drifters on top. For small flatfish (1–2 cm) a small rectangular gauze net was used of 90 * 45 cm and a mesh size of 1.25 *1.25 cm with underneath a lead rope. In order to spot and catch small fishes the sediment was disturbed softly and the rectangular gauze net was placed over a detected fish. Large flatfish were detected by swimming 0.5–1 m above the bottom, and were caught by circling and closing the net around them. Subsequently the flatfish was taken out of the enclosure by hand and stored in a bag.

All flatfish were kept in a bag with a mesh size of 0.5 * 0.5 cm (Underwater Kenetics®) until the end of a dive. Fishes were put immediately on ice in a cooler, transported to the laboratory and stored individually in sealed plastic bags at −7 °C until further analyses within a week. A subsample was weighted before storing at −7 °C to determine weight loss due to freezing.

Flatfish were collected during the first two weeks of every month in 1995 and irregularly in 1996. Each day, two dives were made during daytime, randomly at various locations. On average, between 0 and 5 flatfishes were caught during each sampling dive on sandy patches on the reef. Diving continued until at least 20 specimens of each flatfish species were collected per monthly sampling period. In some months, fewer individuals were caught.

2.3. Data analysis

All analyses were done within a few days after collection of the fish. Before dissection, fish were defrosted in seawater. All flatfish were identified with the FAO sheets (FAO, 1978), Gutherz (1967) and Top and Hoff Jr (1972). After species identification, standard length (cm), total length (cm) and wet weight (g) was determined. Weight loss due to freezing was low between 1 and 2%, therefore no correction was applied. Subsequently, the guts were removed and the gutted weight (g) was measured. Stomach content was analysed and weighted if possible. Also gonads (> 0.01 g) were weighted (g).

Age was determined by removing from each individual the sagittae otoliths and preparing transverse thin sections of 400 μm with a Buehler low-speed saw. Subsequently, each section was mounted on a microscope petrographic slide with thermoplastic glue and ground to the core in the sagittal plane with lapping film (30, 15, 9 and 3 μm). Otoliths were examined under an Olympus MX-51 transmitted light microscope at 400× at the National Marine Fisheries Services laboratory in Narragansett, Rhode Island, USA. Using Image-Pro image analysis software (Media Cybernetics 1998), increments were enumerated and increments widths along the anterior dorsal section of the otolith from the core to the outer edge following the standard protocol for reading and interpreting the otoliths (Searcy and Sponaugle, 2000, 2001). For reading, first, all unclear, abnormally shaped (nonlinear growth axis) sagittae were discarded. A sagitta from each specimen was read randomly twice independently by the same reader. If the increment counts were within 5% of each other, one measurement was randomly selected for analysis (Searcy and Sponaugle, 2000, 2001). If the increment counts differed by > 5%, the otolith was read again. If the increment counts from the third reading differed from the other readings by > 5%, the otolith was discarded. If the difference on the third count was < 5% of one of the former readings, then one of these two measurements was randomly selected for analysis.

Growth curves were fitted to length-at-age data with the Von Bertalanffy growth model (VBGM) using the traditional version of the model developed by Von Bertalanffy with modifications by Beverton (1954) and Beverton and Holt (1957) in Cailliet et al. (2006):

$$L_t = L_\infty \times (1 - e^{-K \times (t - t_0)})$$

whereby L_∞ is the estimated maximum total length (cm), K is the growth rate constant (y^{-1}), t is age (y), t_0 is the age at length zero and L_t is the observed length at age t.

The investment in total body, somatic and gonadal mass was analysed by means of the body mass index (BMI), the somatic mass index