FIRST DATA ON THE DAILY FOOD CONSUMPTION BY ANTARCTIC FISH TREMATOMUS HANSONI (ACTINOPTERYGII: PERCIFORMES: NOTOTHENIIDAE) IN CAPTIVITY

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Abstract. In this study, we present first observations on the feeding behaviour of an Antarctic notothenioid fish, the striped rockcod, Trematomus hansoni Boulenger, 1902. During 13 days of feeding experiment onboard RV Polarstern, the striped rockcod consumed an average of 1.0% BM · day⁻¹ of Loligo reynaudii at the temperature around +1.0°C. The daily food ration of T. hansoni turned out to be lower than predicted by theoretical equations derived for fish living at higher temperatures but was similar to values observed in other Antarctic fish in captivity.

Keywords: daily ration, Nototheniidae, captivity, temperature, Antarctica

INTRODUCTION

The Southern Ocean is a unique environment encompassing the Southern Ocean, one of three major centres of origin of marine biodiversity (Briggs 2003). One of the products of such rich diversification are notothenioid fishes that evolved to live at sub-zero temperatures (Eastman 1993, Bargelloni et al. 2000) and therefore have physiological adaptations very different from fishes in other parts of the world’s oceans (Kock 2005). Notothenioids represent approximately 90% of the fish biomass occurring on the shelf and upper slope down to 500 m depth in the Southern Ocean (Eastman and Clarke 1998).

The ecology of Antarctic fishes has been under intensive study since the end of the 19th century and to date, a sound set of materials on many aspects of their lifestyle has been collected. Their trophic relations have been the focus of prolific studies. Resource partitioning between coexisting species evolved to mitigate competition for food resources (Ross 1986, La Mesa et al. 2015). Every year increasingly more publications describe individual species’ feeding spectra (e.g., Vacchi and La Mesa 1995, Flores et al. 2003, Peck et al. 2008, Vanella et al. 2012).

The information on the daily food requirements of Antarctic fish can be obtained in two ways. One such method would be monitoring stomach fullness and the degree of food digestion in samples collected in the different times of the day with resolution no more than a few hours (La Mesa et al. 1997, Flores et al. 2003, Bushula et al. 2005). In this case, assumptions on temperature (Beers and Jayasundara 2015) and size-dependent digestion rates could be made based on the empirical equations of Elliott and Persson (1978), dos Santos and Jobling (1995), Pennington (1985), and others (Pakhomov and Tseitlin 1991, Pahomov 1993, Olaso et al. 2005).

The second approach is based on direct observations of feeding in captivity (Johnston and Battram 1993, Coggan 1997, Olaso et al. 2004), which requires keeping fish in tanks over extended periods of time, weighing both the delivered food and uneaten leftovers. This method is very difficult technically but provides more reliable results. Because of logistical constraints (experiments having to be done in the Antarctic and involving a closed water circulation system), only a handful of data exists on the actual daily requirements of Antarctic fish. However, in this case, the observed daily rations are likely maximum, because in captivity fish is normally fed ad libitum, whereas in a natural environment the food must be found and hunted.
In order to address the paucity of relevant data, the aim of this study was to estimate the daily rations of fish species inhabiting the high Antarctic ecosystem.

MATERIALS AND METHODS

The Antarctic fish used in this study were captured on board the RV Polarstern (expedition PS117 15 December 2018 to 7 February 2019) in the King Haakon VII Sea, which is located between the Weddell Sea in the West and the Lazarev Sea in the East. The water temperature often drops under zero degrees and the surface is usually ice covered in winter (Spæren et al. 2008). A fish trap of six independent nets (Fig. 1), each baited with defrosted trawl-captured *Loligo reynaudii* (see Roper et al. 1984) freely suspended, was deployed on 11 January 2019 (70°32.14′S, 008°52.25′W, depth 406–420 m) and recovered five days later, on 16 January 2019.

Two fishes were captured alive, the striped rockcod, *Trematomus hansoni* Boulenger, 1902 (see Dewitt et al. 1990) and the long-fingered icefish, *Cryodraco antarcticus* Dollo, 1900 (see Iwami and Kock 1990). They were immediately transferred into separate tanks situated in a constant room temperature (0–2°C) and enclosed in a circulation system containing 2 m³ of air-saturated seawater. The circulating seawater was pumped through an ultraviolet lamp to eliminate bacteria and a skimmer to remove the proteins. To protect the fishes’ eyes from damage and to avoid stress, that could potentially alter the feeding habit, only dimmed red light was used inside the room during working operations (feeding and cleaning). Otherwise, tanks were kept in complete darkness.

In between capture and start of the experiment the fish had four days for recovery from the strain resulting in the capture.

The fish were fed once a day with common squid, *L. reynaudii* at approximately 0945 h (UTC) *ad libitum*. The defrosted squid was prepared fresh and was weighed with an accuracy of ±0.1 g (“M2000 Series” scales; Marel). Each day tanks were simultaneously checked twice for the presence of uneaten food. The second check took place 12 h after the first at approximately 2145 h (UTC). If the fish had eaten the squid during the day, another portion was dispensed in the evening. Otherwise, uneaten food was replaced with fresh food the next morning.

During the 13 days of observation, *T. hansoni* was offered a total of 192.1 g of food ranging from 7.8 g to 15.2 g per piece, mean 3.0% ± 0.5% drawn to its BM · day⁻¹. *Cryodraco antarcticus* was fed with a total of 162.5 g ranging from 11.7 g to 14.7 g per piece, mean 1.9% ± 0.2% expressed in its BM · day⁻¹. The pieces were small enough to have no doubts that they fit into the fish mouth opening.

The daily check of water parameters consisted of measuring the salinity, the temperature, and the concentration of ammonium. When the ammonium concentration reached the threshold of 0.4 mg · L⁻¹ due to the presence of uneaten food, the water was exchanged immediately. The water was exchanged on a daily basis regardless of the ammonium concentration.

The feeding experiment lasted 13 days. Afterward, the individual fish were anesthetized with MS-222 (0.2 g · L⁻¹). The total length (TL) and standard length (SL) of the fish were measured to the nearest mm and body mass (BM) as

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**Fig. 1.** Fish trap with (1) a hook for deploying and recovering the device and (2) feet, on which a set of weights (350 kg in total) are attached to keep the trap on the seabed after the deployment. Bait was placed into the creels (3) to attract the fish. An acoustic signal induces the detachment of the fish trap from the weights by the releaser (4) and its rise to the surface by means of several floats (5)
well as the gutted mass (GM) were measured to the nearest 0.1 g. Their stomachs were also checked for the presence of undigested food.

**Statistical analysis.** The results of the environmental variability and the biological observations (Table 1) bear the arithmetic mean with its standard deviation (SD), calculated with MS Excel.

**RESULTS**

**Environmental variability.** During the experiment the water temperature in the system ranged from 0.6 to 1.4°C (mean ± SD = 1.0 ± 0.3°C). The salinity varied between 33.2 µS · cm⁻¹ and 34.2 µS · cm⁻¹ (mean ± SD = 33.7 ± 0.3 µS · cm⁻¹) and the ammonium concentration varied between 0.10 mg · L⁻¹ and 0.44 mg · L⁻¹ (mean ± SD = 0.28 ± 0.10 mg · L⁻¹).

**Biological observations.** The total length of *Trematomus hansoni* was TL = 31.5 cm and the standard length, SL = 26 cm. Its body mass was BM = 358.5 g, and gutted mass at the end of the experiment was GM = 295 g. *Trematomus hansoni* was an immature female, the maturity stage II was assessed according to the five-point scale proposed for notothenioids (Kock and Kellermann 1991).

*Trematomus hansoni* began to eat food on the fourth day after capture (20 January 2019) and then took three more portions, the last one on 25 January 2019 (Table 2). Upon dissection, on 31 January 2019, the fish stomach was found to contain two pieces of partially digested squid, indicating that the fish was probably still not hungry and food digestion in the Antarctic waters might take up to a week or even longer. The total mass of eaten food was 46.1 g, which corresponds to 1.0% BM · day⁻¹ for the period of this study.

*Cryodraco antarcticus* had a TL = 49 cm and a SL = 47.5 cm. Its body mass was BM = 668 g (GM = 489 g). *Cryodraco antarcticus* was a mature male, stage IV (Kock and Kellermann 1991). During the experiment, it did not eat anything. Its stomach was found to be empty after dissection.

**DISCUSSION**

The maximum daily ration of approximately 1.0% BM · day⁻¹ observed in *Trematomus hansoni* at temperatures of around +1.0°C represents the first observation for this species. This fish is known as an opportunistic feeder (La Mesa et al. 1997), eagerly consuming whatever is available including fishery discards, which represent half as the percentage of fish body mass (BM) .

**Table 1**

| Date         | Temperature [°C] | Salinity [µS · cm⁻¹] | Ammonium [mg · L⁻¹] |
|--------------|-----------------|----------------------|---------------------|
| 19 January 2019 | 1.3             | 34.2                 | 0.10                |
| 19 January 2019 | 1.4             | 34.1                 | 0.10                |
| 20 January 2019 | 1.3             | 34.0                 | 0.20                |
| 21 January 2019 | 1.3             | 34.1                 | 0.22                |
| 22 January 2019 | 1.3             | 33.8                 | 0.30                |
| 23 January 2019 | 1.2             | 33.9                 | 0.30                |
| 24 January 2019 | 1.1             | 33.6                 | 0.44                |
| 25 January 2019 | 0.8             | 33.6                 | 0.28                |
| 26 January 2019 | 0.6             | 33.7                 | 0.38                |
| 27 January 2019 | 0.8             | 33.5                 | 0.32                |
| 28 January 2019 | 0.9             | 33.7                 | 0.36                |
| 29 January 2019 | 1.0             | 33.4                 | 0.26                |
| 30 January 2019 | 1.0             | 33.3                 | 0.38                |
| 31 January 2019 | 0.8             | 33.2                 | 0.24                |
| 1 February 2019  | 0.8             | 33.2                 | 0.32                |

**Table 2**

The relative food consumption of *Trematomus hansoni* during the reported experiment; food amounts expressed as the percentage of fish body mass (BM)

| Date         | Feed ration [%BM] |
|--------------|-------------------|
| 20 January 2019 | 3.1               |
| 20 January 2019 | 2.2               |
| 23 January 2019 | 3.4               |
| 25 January 2019 | 4.2               |
Edward Island’s water, sub-Antarctic, using Baikov’s relation (Bushula et al. 2005). However, these rations are calculated for warm water fish and are not applicable to cold water ones.

The approach of calculating the fish daily food requirement by monitoring stomach fullness and the degree of food digestion would work well only if Antarctic fish would have a strong diurnal feeding activity and digestion time would not exceed 24 h. However, for Antarctic fish, the time intervals between feeding events often exceeded the supposed 36–48 h (Kock 1992). This is even the case in captivity, where fish have constant fresh food access (Pakhomov 1998) what puts the possibility of using these theoretical approaches under doubt. The unreliability of theoretical methods might be caused by the fact that these formulas were derived from using data of fishes living in much warmer latitudes.

The two species that were captured for this study have different hunting methods. Browsers and scavengers (La Mesa et al. 2004), like T. hansoni, do not need their prey moving and therefore could be easily fed in captivity. Bottom icefishes, like Cryodraco antarcticus Dollo, 1990—judging from their body morphology—are ambush predators (Kock and Jones 2002), that detect the prey by its movement. It might be possible that this provoked difficulties regarding the feeding of this specimen. The fact that it entered the trap does not necessarily mean that it was attracted by the bait: the icefish might look for shelter or target small scavengers like amphipods inside the trap.

Assumptions regardless of how well they are backed, are still assumptions and we think that only primary observations might give a clue what occurs in nature. In this respect every single piece of reliable information on actual feeding rates matters, even the observations on single fish.

CONCLUSION

Overall, our results in comparison to other field studies demonstrate that food rations of Antarctic fish are likely overestimated by the traditional formula of Pennington, which derived from data based on relatively warm water species. A new theoretical approach is required to solve this disparity.

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