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Short Communication

How harbor seals (*Phoca vitulina*) pursue schooling herring

Meike Kilian, Guido Dehnhardt, Frederike D. Hanke*

University of Rostock, Institute for Biosciences, Sensory and Cognitive Ecology, Albert-Einstein-Str. 3, 18059 Rostock, Germany

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ABSTRACT

Only a few reports have described how pinnipeds hunt schooling fish. However, we had the opportunity to systematically observe captive harbor seals hunting a school of herring in a shallow enclosure during daylight. The seals actively pursued the fish, mostly changing from one side of the school to the other, swimming in a supine position close to the water surface. They were often found swimming rapidly down to the fish out of this position. When hunting in the vertical, the seals mostly adopted a dorsal body posture relative to the school. They swam and attacked the school in a supine orientation when approaching from the water surface and swam in a prone orientation when approaching from below. They even maintained this relative body position during turning movements. These phenomena suggest that the seals were constantly keeping the school in their large dorsal visual field, which favors visual hunting during daylight and in clear waters. When interacting with the school, the school mostly split asymmetrically, and the seals were following preferably a smaller number of fish afterwards. Successful prey catch was only observed, when a small group or a single herring had been separated, thus the seals probably avoided the confusion effect of the school. In conclusion, we provide detailed insight in seals pursuing schooling prey, thereby extending previous reports and confirming speculations as well as brief observations.

Harbor seals hunt benthic as well as pelagic fish individually and in schools (Bowen et al., 2002; Marshall, 1998). From the few studies available, we know that, when hunting schooling fish, harbor seals attack the edges of the school most likely in an attempt to separate single fish or small subunits (Bowen et al., 2002; Zamon, 2001). Seals often seem to be engaged in "active pursuit", during which they constantly keep contact with the school and shift from one side of the school to the other (Bowen et al., 2002). Zamon (Zamon, 2001) document behavioral differences of adults and pups; adult harbor seals ingest a mouthful of fish from the edges of a school whereas pups swim through the school and are seen darting on single fish that were separated from the school. Harbor seals also hunt schooling fish close to the sea floor which seems to constrain fish to escape (Olsen and Bjorge, 1995). The same effect could be achieved by chasing fish towards the water surface as described for separated sand lance (*Ammodytes dubius*) (Bowen et al., 2002).

These few insights in harbor seal foraging behavior were obtained with the help of animal-borne video systems (Bowen and Harrison, 1996; Bowen et al., 2002; Marshall, 1998), developed in the 1990s (Davis et al., 1992, 1999; Marshall, 1998), or by observations from vessels and land (Middlemas et al., 2005; Wright et al., 2007; Yurk and Trites, 2000; Zamon, 2001). However, these documents are rare and allow only glimpses on the foraging behavior. This is due to two main challenges associated with studying foraging in marine mammals. One challenge is that seals hunt under water, an environment, which is still relatively inaccessible to humans despite advances in modern technology. The other challenge refers to seals being highly mobile species. To successfully monitor their foraging behavior thus requires techniques that do not impose spatial constraints and preferably allows observing the seal-school-unit in total.

In the present study, we had the unique opportunity to characterize the foraging behavior of harbor seals hunting schooling fish in greater detail. We could systematically observe a group of nine captive harbor seals (3–27 years), which are kept for scientific reasons under semi-natural conditions in a large seawater enclosure (3–6 m depth, 60 m in length and 30 m in width) separated from the open sea only by a net (mesh size 5 × 5 cm) at the Marine Science Center, Rostock, Germany. All seals were born in zoos and had only come into contact with living fish such as flatfish, eel and herring after moving into the seawater enclosure in summer 2008. In spring 2009, a school of herring (*Clupea harengus*) with more than 1000 fish entered the seals' enclosure and stayed for four weeks from mid-April to May. During this time, the seals were observed

* Corresponding author. Tel.: +49 381 666971914; fax: +49 381 666971935.
E-mail addresses:
meike.kilian@web.de (M. Kilian), guido.dehnhardt@uni-rostock.de (G. Dehnhardt), frederike.hanke@uni-rostock.de (F.D. Hanke).

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Table 1
Ethogram used to analyze the video recordings listing all behaviors documented and their definitions as well as the results listing the frequency with which the behavior occurred as number of total events *N* and in % (within a category).

Documented behaviors	Definition	*N*	In %
Behavioral components of prey pursuit			
Absolute body position	Body position absolute in the water column		
Prone	Back pointing towards the water surface	609	32.8
Supine	Belly pointing towards the water surface	1066	57.5
Side	A flipper pointing towards the water surface	179	9.7
Relative body position	Body position relative to the school		
Dorsal	A seal's back pointing towards the school	329	17.8
Ventral	A seal's belly pointing towards the school	41	2.2
Lateral	A seal pointing with one side, tail or snout towards the school	1484	80.0
Turning movements	A change of absolute and/or relative body position during ascent and descent		
Unchanged	A seal keeping its relative body position during turning	327	70.3
Changed	A seal changing its relative body position during turning	138	29.7
Effect of an approaching seal on school			
Splitting			
Symmetrical	The two resulting parts of the school were approximately the same size	91	19.3
Asymmetrical	A different number of individuals was estimated in two or more subunits	318	80.7
Following	A seal following fish after splitting		
Following smaller subunit	A seal following the smaller fish subunit after splitting	176	55.0
Following larger subunit	A seal following the larger fish subunit after splitting	54	17.0
Following a single fish	A seal following a single fish after splitting	29	9.0
Not following	A seal did not follow fish after splitting	59	19.0
Acceleration	A seal was accelerating		
Acceleration on small subunit	A seal was accelerating when following a small fish subunit	87	41.2
Acceleration in large subunit	A seal was accelerating when following a large fish subunit	43	20.4
Acceleration on single fish	A seal was accelerating when following a single fish	22	10.4
Acceleration when others accelerated	A seal was accelerating when another seal accelerated	9	4.3
Acceleration with no apparent reason	A seal was accelerating with no apparent reason	48	22.7
Prey capture	A seal was successfully catching a fish	0	0

while hunting throughout the day. Two of the seals exclusively fed on herring captured from the school. All other seals occasionally hunted but also participated in the scientific experiments and routine training activity, during which they received fish rewards. The behavior of the hunting seals during daylight hours was recorded from a top view video camcorder (Canon XL1S; Canon Deutschland GmbH, Krefeld, Germany) that captured the seal as well as the school. On the basis of an ethogram (Table 1) that was developed during preparatory observations and that focused on behavioral components of pursuing the fish and on the effect an approaching seal has on the school, we analyzed 75 min of high quality video footage during which six of the altogether nine seals and the school of fish could be observed throughout the entire water column of the enclosure. The depth within the water column, at which a specific behavior occurred, was documented and categorized as "at the water surface" in cases where at least one part of the seal's body was seen out of the water, "down to approximately 1 m depth" when the seal was below the water surface, and "deeper than approximately 1 m". The 1 m transition point was estimated on the basis of the height of a seal and took some uncertainty in the determination of the water depth from above into account.

In contrast to previous studies, we were able to continuously record six of the nine hunting seals during daylight hours and to systematically document the foraging behavior over a large area with full view on the seals and the school together. Our goal was to generally extend the existing knowledge of harbor seals hunting schooling fish and to specifically describe the behavioral sequence occurring during the pursuit of a school of herring. We were interested in how the seals were positioning themselves absolutely in the water column and relatively to the fish, which might allow assessing the sensory modality the seals were predominantly using. Our hypothesis was that the seals mainly hunt visually in the shallow enclosure in which light penetrates up to the bottom. Furthermore we wanted to test the hypothesis that the school breaks into subunits by an approaching seal and that the seals are predominantly following a smaller number of fish afterwards. In this context, we hypothesized that attacks occur mostly on small subunits and single fishes, which would document the adaptive value of breaking a school into subunits or separating single fish.

Our analysis revealed that, during hunting, the six recorded seals were moving through or with the school and only rarely remained stationary. Their absolute body position was significantly correlated with water depth ($\chi^2 = 11{,}770.5$, df = 8, $p < 0.0001$, Fig. 1). Overall, the seals were swimming in a "supine" orientation in 57.7% of the time ($n = 1066$, $\chi^2 = 636.7$, df = 2, $p < 0.0001$). However, when

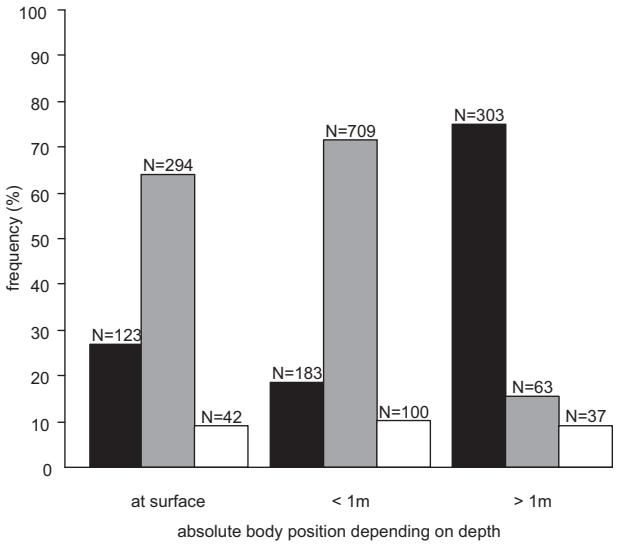

Fig. 1. Orientation of the seals in the water. Absolute body positions adopted by the seals in the water column depending on water depth. The absolute body position ("prone", "supine", or "side") was documented depending on the depth ("at the water surface", "down to approximately 1 m" and "deeper than approximately 1 m"), at which it was performed within the water column. Frequency is plotted as percentage of total events, absolute numbers are indicated at the respective bars. Black bars indicate the frequency of adopting the body position "prone", gray bars the frequency of the position "supine" and white bars the frequency of the position "side".