Evidence that grey seals (*Halichoerus grypus*) use above-water vision to locate baited buoys

Arne Fjälling[1], Jenny Kleiner[2] and Magdalena Beszczyńska[3]

[1] *Institute of Coastal Research, Swedish Board of Fisheries, S-17893 Drottningholm, Sweden. Corresponding author.*
[2] *Biskop Brasks Gränd 60, S-17676 Järfälle, Sweden*
[3] *Rydsvägen 120, S-58431 Linköping, Sweden*

ABSTRACT

Fishing gear in the Baltic is often raided by grey seals (*Halichoerus grypus*). The seals remove the fish and damage the nets, or entangle themselves and drown. In order to develop ways of mitigating the seals-fisheries conflict, it is important to know exactly how the seals locate the fishing gear. A field experiment was conducted in order to clarify whether seals use their vision above water to do this. Bait (herring; *Clupea harengus*) was attached to the anchor lines of buoys of the type that is commonly used to mark the position of fishing gear. In all, 643 buoys were set. Some of the buoys (210) were also fitted with camera traps. Weather data were collected from official weather stations nearby. Bait loss (mean 18%) was significantly correlated with buoy size (P = 0.002) and wind speed (P = 0.04). There was a significant association between bait loss and seal observations near the buoys (P = 0.05). Five photos of grey seals were obtained from the camera traps. No fish-eating birds, such as cormorants or mergansers, were ever observed near the buoys or caught on camera. It was concluded that a main cause of missing bait was scavenging by grey seals, and that they did use above-water vision to locate the buoys. It was also concluded that wind strength (i.e. wave action) contributed to the bait loss. The camera trap buoys had a somewhat lower bait loss than the other buoys (P = 0.054), which was attributed to a scaring effect. Neither the number of seal observations nor the bait loss differed significantly between the 2 study areas in the experiment (P = 0.43 and P = 0.83, respectively). Bait loss was not affected by the buoy colour (red, white, or grey; P = 0.87). We suggest that the findings of this experiment could be put into practice in a seal-disturbed area by deploying a number of decoy buoys, or by hiding live buoys below the surface of the water. This would increase the cost of foraging for the seals, and hence discourage them from exploiting fishing gear as a feeding place.

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INTRODUCTION

Seals and coastal fisheries

After a severe decline in the grey seal (*Halichoerus grypus*) population of the Baltic Sea to a low point in the 1970´s, the population is presently recovering at a rapid rate (Halkka *et al.* 2005, Härkönen *et al.* 2007, Karlsson and Helander 2005). As a result, the conflict with the coastal fisheries is also increasing (Westerberg *et al.* 2000, Anon 2001, Fig. 1). The grey seal is still listed as an endangered species by the International Union for the Conservation of Nature (IUCN), and the Swedish government has adopted a goal of a maximum fisheries bycatch of less than 1% for all marine mammal populations (Anon 2005). Bycatches of seals are however still common and were estimated at 901 (462 of which were grey seals) in 2001 (Lunneryd *et al.* 2003a). Mitigation methods are presently being developed to reduce the seals-fisheries conflict (Westerberg *et al.* 2007). Modifications of fishing gear such as set traps have been successful in reducing catch losses (Lunneryd *et al.* 2003b) and other mitigation methods have also showed promising results (*i.e.* Acoustic Harassment De-

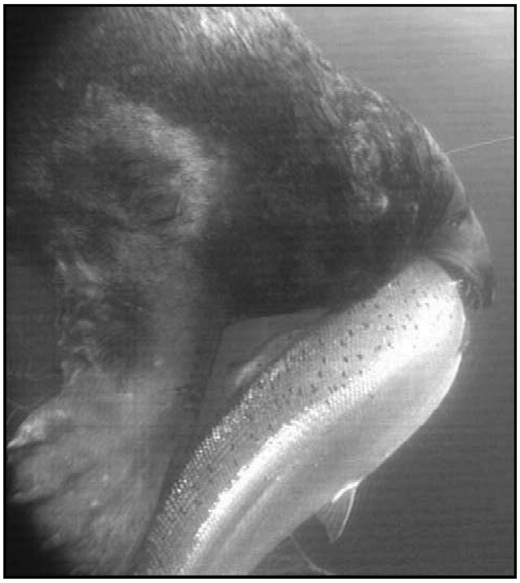


Fig. 1. *Caught in the act: a grey seal removes a salmon from a fish trap. (Photo: Sara Könignson)*

vices; Fjälling *et al.* 2006). Still there is a strong need for the introduction of additional mitigation methods, especially for non-stationary gear such as gillnets and fyke nets. In the development of such methods, detailed knowledge of seal foraging behaviour in general, and of how seals locate and exploit fishing gear in particular, is needed. An obvious visual source of information by which seals might find fishing gear would be the surface buoys that mark the positions of such equipment. Fishermen sometimes tell anecdotes about concealed fishing gear, without buoys at the surface, which suffered less attention from seals. The same is said about nets set during poor visibility conditions. One example of the latter was narrated by Sundfeldt and Johnson (1964), who reported that fishermen experienced less seal-induced losses in nets that were deployed during the hours of darkness, than in nets that were deployed during daylight.

Vision performance and use in seals

In the published literature there is quite a lot of information available on visual acuity and sensitivity in seals (Schusterman 1972, Renouf 1991, Levenson and Schusterman 1997, Crognale *et al.* 1998, Levenson and Schusterman 1999). There is however scant information on how seals use their vision in everyday life. In unpublished hunting records of the past, there are several observations of seals reacting to visual information, for example to approaching hunters. The seal's eye has a difficult task, having to cope with both the air and the water environment, which offer very different optical conditions. There is an inevitable trade-off which leads to a limited visual acuity in air under low light conditions (Schusterman and Balliet 1971). During daylight however, the seal's vision above water is acute. Schusterman and Balliet (1970) found that trained Californian sea lions (Zalophus californianus) were able to distinguish a grating with 10.3 mm black and white stripes from an even grey surface at a distance of 5.5 m (90% correct responses). This might roughly correspond to being able to spot an object with a diameter of 160 mm at a distance of 85 m and an object of 370 mm at a distance of 200 m, even though figures on resolution are not directly transferable in this way. This can be compared with older accounts, where an expert seal hunter on ice, dressed in white camouflage clothes, lying down and facing the seal, could at the very best come within 100 m in daylight (Hortlander 1927). Visual underwater localization of bait or fishing gear should only be possible at a close range, since the visibility in water is limited (< 5 m).

The ability of pinnipeds to discriminate colour was long uncertain (Renouf 1991), but Crognale *et al.* (1998) found that harbour seals (*Phoca vitulina*) were probably functionally colour-blind. Peichl and Moutairou (1998) found this to be a common feature in 5 species of seals studied, including grey seals; further information is given in Peichl *et al.* (2001). The best sensitivity is in the blue-green range of the spectrum, for harbour seals at wavelengths

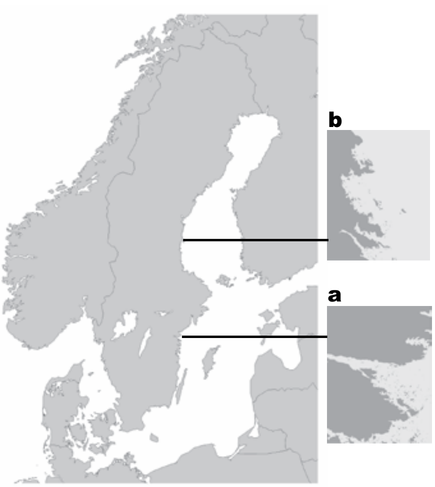


Fig. 2. *Map of the Baltic region and the study areas at (a) Nävekvarn and (b) Skärså.*

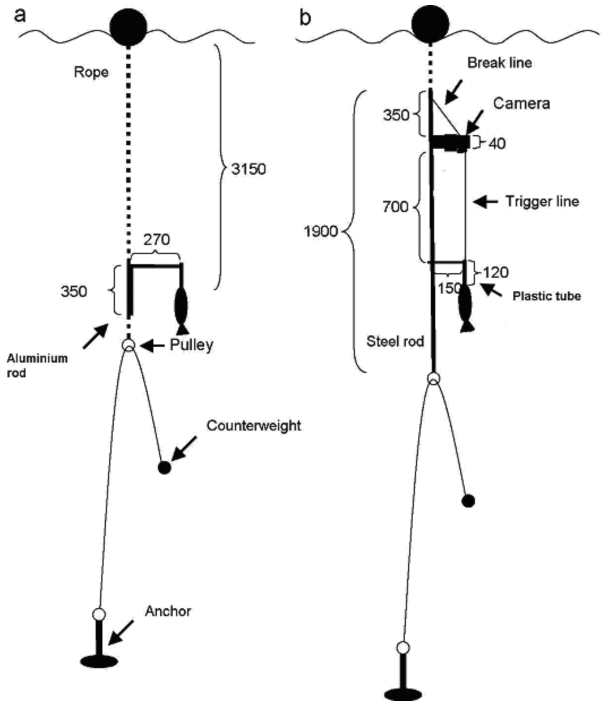


Fig. 3. Experimental setup with (a) a baited buoy and (b) a baited buoy with camera trap.

around 510 nm (Crognale *et al.* 1998). Griebel and Peichl (2003) gives a recent overview of color vision in aquatic mammals, whereas Griebel *et al.* (2006) present detailed data on the spectral sensitivity in harbour seals and in the South American sea lion (*Otaria flavecens*).

The use of visual input by seals in orientating themselves (above and underwater) was suggested by Schusterman (1972) and in foraging (underwater) by Hobson (1966) and Schusterman (1972). Their findings imply that vision is generally important to seals in these contexts. Mauck *et al.* (2005) presented data that imply that harbour seals have the visual capacity to astro-navigate. It has, however, not yet been shown that seals use above-water vision in their search for food. The aim of the present study, then, was to investigate whether grey seals do indeed use their above-water vision to find baited buoys, representing fishing gear.

MATERIALS AND METHODS

Study areas

The field experiment was conducted in 2 areas of the Baltic, at Nävekvarn (58° 38′ N, 16° 48′ E) between 29 June and 25 August 2004, and at Skärså (61° 23′ N, 17° 7′ E) between 25 September and 1 November the same year (Fig. 2). There is a lot of human activity in the first area; a main shipping route crosses in an east-west direction, there are many leisure craft, especially in the summer months, and Nävekvarn has a busy yacht harbour. The second area is remote, with no shipping routes and limited leisure boat traffic. In both areas the small scale coastal fisheries are severely disturbed by seals (Söderlind 2004, Königson *et al.* 2007).

Buoys and bait attachment

Three sizes of buoys of the type (red, inflatable and made of PVC) that is common among coastal fishers in the Baltic were used in the field experiment, and fully submerged buoys were to be used as controls. However, due to technical problems, small buoys painted in a dull grey shade (giving low visual contrast) were used as controls instead of the submerged buoys (Table 1). These control buoys were oval shaped (68 mm x 120 mm), but since they had a vertical long-axis and were riding somewhat low in the water, their functional cross-section was approximately circular. The buoys were baited with fresh herring (*Clupea harengus*) with a length of 150 to 200 mm. If the available fish were too small, which happened on a few occasions, 2 fish were used to make the amount (weight) of bait as equal as possible. The bait was suspended by a double 0.15 mm monofilament nylon fishing line. A bight of the line was pushed through the eye sockets, looped around the nose of the fish and then pulled tight, resulting in a head-up, tail-down position of the bait. The line was then fastened to a bait set-up made from a 3 mm diameter aluminium rod (Fig. 3a). A short plastic tube between the fish and the rod prevented the bait from tangling. Bait was deployed well below the surface (at 3.15 m depth) to prevent seagulls from taking it. Weights of around 2 kg each were used for anchors. The anchor line was run through a pulley fastened to the lower end of the rod, and then provided with a small counterweight (20 g to 200 g depending on the buoy size). This automatically kept the anchor line taut and prevented the buoys from drifting downwind. It also adjusted for varying water depths.

Table 1. Size and colour of the baited experimental buoys in the field trial.

Experimental buoys					
Dia (mm)	**Colour**	**Shape**	**Material**	**Type**	**Comment**
68	grey	oval	PVC	foam	control
156	red	spherical	PVC	inflated	main experiment
156	white	spherical	styrene	foam	from olfaction experiment
232	red	spherical	PVC	inflated	main experiment
369	red	spherical	PVC	inflated	main experiment

Camera traps

Some buoys were fitted with a camera trap. The camera trap was designed to be triggered when an animal took bait, thereby making it possible to identify the animal to species. The camera was a disposable Fuji Film Quick Snap Jeans, 27 exposures, with a built-in flash. This model was chosen since it has the unusual quality (for disposable cameras) of keeping the flash capacitor charged for long periods of time (up to 48 h). The camera was enclosed in a waterproof bag (Aqua Pak, 185 mm x 115 mm; Fig. 4). The camera and trigger mechanism were mounted on a 5 mm diameter stainless steel

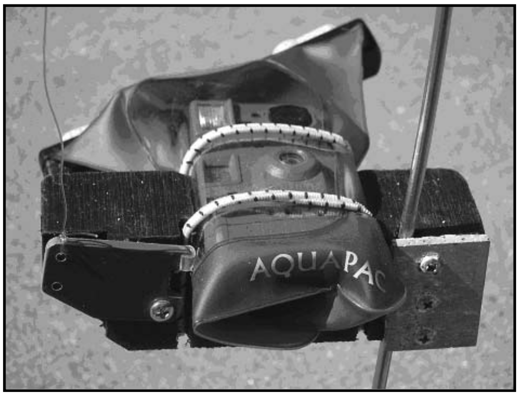


Fig. 4. Experimental set-up with disposable camera in waterproof bag and self-triggering arrangement.

Table 2. Data on primary and secondary variables collected in the field experiment with baited buoys.

Variable name	Unit	Type	Data type	Expected influence on degree of bait loss: Direction	Magnitude	Assumed mechanism	Notes
buoy diameter	mm	primary	continuous	positive	high	visual stimuli (magnitude)	main factor?
buoy colour *		primary	category	uncertain	low	visual stimuli (contrast)	seals have monochromatic vision
time in water	h	primary	continuous	positive	high	accumulated exposure	grey seals are not very sensitive to freshness in baits
camera	yes / no	primary	category	negative	moderate	scaring effect	observed in other studies
study area *		primary	category	uncertain	low		similar disturbance to fisheries in both areas
depth	m	primary	continuous	uncertain	moderate	foraging activity	grey seals prefer certain bathymetric conditions
visibility in water	m	secondary	continuous	positive	low	underwater spotting	very limited underwater visual range
wind speed	m/s	secondary	continuous	uncertain	uncertain	wave action	masking or enhancing vision, mechanical disturbance
visibility in air	m	secondary	continuous	positive	low	direct visual stimuli	usually larger than seals visual range, small variations
seal observation	yes / no	primary	category	-	-	independent measure	observation is a result of a seal visit, not a causative agent

* eliminated before regression

rod of 1,900 mm length (Fig. 3b). A break-line (0.15 mm diameter monofilament nylon fishing line) was tied taut between the steel rod, 300 mm above the camera, and the trigger lever. A second short break-line (0.20 mm) was tied to the fish as above. Finally, a trigger line (1.0 mm) was tied taut between the second break-line and the trigger. When the bait was yanked, the thin upper break-line would break first, allowing the trigger line to operate the trigger lever and thus release the camera shutter. The second break-line would split a moment later and allow the predator to take off with the bait.

Deployment and checking of buoys

Buoys were checked and reset on a daily basis. They were evenly spaced and set further apart than the presumed visual range of seals, *i.e.* at least 300 m apart, and in most cases considerably more. During the early summer, buoys were set and retrieved both in the mornings and the afternoons. In the autumn, they were mainly tended to only once around midday (Fig. 5), due to limited daylight hours. When a pre-determined new position was arrived at, the area was first scanned for seals with binoculars, for 30 seconds in each of the 4 cardinal directions. If 1 or more seals were observed, this position was discarded and another one selected. When an already deployed buoy was checked, scanning for seals was first performed as described. The bait was then inspected and new bait attached. If the old bait was intact, the setup was reset at the same position for another day. If the old bait was damaged or missing, the setup was relocated. This was done to prevent seals from learning and returning to the buoys' positions. Buoys were not set in a water depth of less than 10 m. This was done in order to avoid vegetation masking the bait, or causing the camera trap mechanisms to get jammed. The water depth was measured to the nearest meter using a lead-line. The transparency of the water was measured daily to the nearest 0.1 m with a 250 mm Secchi disc. This was done at a fixed point just outside of the local fishing harbour. A GPS receiver was used for positioning. A small open boat was used for the sea-tours. They were made at maximum speed to reduce the chance of seals following the boat.

Data and data collection

Variables that could be directly attributable to a certain buoy deployment (hereafter referred to as 'primary variables') were: Bait (untouched / damaged / missing), buoy position, diameter of the buoy (mm), colour of the buoy (grey, white or red), setting and retrieval time (month: day: hour: minute), camera (with or without), water depth (m), seal observation (yes or no) and study area (Nävekvarn, Skärså). Variables that were only indirectly attributable to a certain buoy deployment (hereafter referred to as 'secondary variables') were: visibility underwater (m), wind speed (m/s), and visibility above water (m). Those data were common for several buoys and were collected only at fixed points in time. Thus, secondary variables were assumed to have a weaker connection to buoy deployments than primary variables. Variables are presented with subjective estimates of influence on bait loss in Table 2. Data on wind speed and sight were obtained from the Swedish Meteorological and Hydrological Institute (SMHI). Data were available only for certain points in time (0900 and every subsequent 3 hours) and space (regular weather stations). The data point was chosen which was nearest in time to the mid-point between setting and retrieving the buoy.

A second data set was merged with the data from the red buoys. The latter data set was collected in parallel with (overlapping time and area) the first trial, in an experiment with scented buoys (Beszczyńska 2005). Since there was no difference in bait loss among the scented buoys in the second experiment, the data sets were deemed equal. The reasons for using both data sets were (a) to make use of all available buoy data for greater power and (b) to allow for an analysis of the influence of differing buoy colour on bait loss. All buoys in the second data set had the same diameter as the mid-sized buoys in the first data set and were made from white styrene plastic (Table 1). The experimental methods were the same as in the first trial.

Statistical analysis

Data were first screened to identify outliers. Twenty-one samples were removed, having soak times exceeding 72 h because of storms preventing scheduled checks (all other soak times were less than 36 h). Twenty-seven samples using bait other than herring were also removed. Some combinations of colour and study area (primary variables) were not replicated and thus could not be tested simultaneously. This was an effect of merging the 2 data sets mentioned. Therefore a special procedure was designed and used. As a first step, the variables Colour and Study Area (where an interaction was assumed to be unlikely) were tested independently, using the primary variables and a reduced dataset. If Colour and Study Area were found not to contribute significantly to bait loss, they could then be excluded from the main analysis. As a second step, all other variables (including the secondary variables) were included in a stepwise forward logistic regression to identify the variables that best explained the degree of bait loss. A generalised linear model with binomial distribution and a log-link function was used for this. Finally, a 'Best model' was regressed from these variables. A confidence level of 95% was used throughout. Scaled deviance was used as a goodness of fit measure; a ratio close to 1.0 indicates a good fit. For all statistical tests Statistica 7.0 (Statsoft Inc., 2004) was used. Observation of seals was treated as an independent measure of seal activity since it actually occurred after the buoy deployment period. The association with bait loss was therefore tested in a separate chi-square test.

RESULTS

A total of 643 buoy deployments remained in the dataset after removing the outliers, from which bait went missing in 114 cases (18%; Table 3). In the first test in which the effect of the different colours was tested (Skärså only; 544 samples) there was no significant difference (P = 0.67; Table 4). In the second test in which the effect of the study area was tested (red buoys only; 305 samples) the result was the same (P = 0.83; Table 4). A forward stepwise regression was then made on the remaining primary variables and the secondary variables and a best model was built (Table 5). The variables Diameter and Wind speed were found to have a significant association with bait loss (P = 0.002 and P = 0.04, respectively). The mean bait loss increased with larger buoy size, and with higher wind speed (Fig. 6a, b). Time in water, water depth, underwater and above-water visibility did not contribute significantly to the probability of missing bait.

The proportion of bait missing from the 210 camera trap buoys was lower than from the 431 buoys without cameras (14% and 20% respectively; Table 6), and the association was nearly significant in the calculated 'Best model' (Table 5; P = 0.054). Ten cameras of the 29 where the bait was missing had been triggered. Five usable photographs were obtained, all depicting a grey seal taking bait (Fig. 7). Twenty-five of the 181 camera traps where the bait was retrieved intact and 2 of the cameras where the bait was missing had suffered from technical problems (broken lines, leaking camera bags, entanglement with sea-weed, lost anchors etc.).

The bait loss was significantly higher at buoys where one or more seals had been observed prior to checking (5 of 13 cases), than in the rest of the buoy deployments where seals had not been observed (109 of 630 cases; X2 = 3.94, df =1, P = 0.047). Slightly more seals were sighted near buoys in the Skärså study area (567 buoys, 13 observations) than in the Nävekvarn area (97 buoys, 1 observation; P = 0.43).

Table 3. Number of buoys set and bait that went missing (possibly taken by seals) during the field experiment with baited buoys, in relation to buoy diameter, buoy colour and camera present / ab-

		All areas			Bråviken			Skärså		
Buoy specifics		Deployed	Bait missing		De-ployed	Bait missing		Deployed	Bait missing	
Dia (mm)	Colour	Number	Number	%	Number	Number	%	Number	Number	%
68	grey	41	3	7 %	0	0	-	39	3	8 %
156	red	107	14	13 %	37	3	8 %	70	11	16 %
156	white	297	49	16 %	0	0	-	297	49	16 %
232	red	112	26	23 %	42	13	31 %	70	13	19 %
369	red	86	22	26 %	18	5	28 %	68	17	25 %
Sum		**643**	**114**	**18 %**	**97**	**21**	**22 %**	**544**	**93**	**17 %**

Table 4. Result of logistic regression with primary variables in the buoy experiment, using three different datasets: All areas (Colour excluded), All colours (Study area excluded) and All data (Colour and Study area excluded).

	All areas			All colours			All data		
Variable	**D.f.**	**Wald Stat.**	**p**	**D.f.**	**Wald Stat.**	**p**	**D.f.**	**Wald Stat.**	**p**
Study area	1	0.047	0.829	-	-	-	-	-	-
Colour	-	-	-	2	0.786	0.675	-	-	-
Time in water (h)	1	1.025	0.311	1	1.314	0.252	1	1.353	0.245
Diameter (mm)	1	7.868	0.005	1	4.448	0.035	1	8.31	0.004
Depth (m)	1	0.156	0.693	1	0.115	0.734	1	0.136	0.712
Residual	638			637			639		
Scaled deviance	0.927			0.927			0.925		

Table 5. Result of a forward stepwise logistic regression in the buoy experiment, using primary and secondary variables, and a logistic regression based on variables selected by the forward procedure (best model). Values for the last iteration were reached when adding more variables did not improve the model.

	Last iteration				Best model		
Variable	**D.f.**	**Wald Stat.**	**p**		**D.f.**	**Wald Stat.**	**p**
Time in water (h)	1	0.047	0.828	out			
Diameter (mm)	1	9.391	0.002	in	1	9.147	0.002
Depth (m)	1	0.245	0.621	out			
Camera (presense of)	1	3.947	0.047	in	1	3.722	0.054
Visibility in water (m)	1	0.019	0.891	out			
Windspeed (m/s)	1	4.274	0.039	in	1	9.009	0.003
Visibility in air (m)	1	1.017	0.313	out			
Residual	635				639		
Scaled deviance	0.909				0.906		

Table 6. Frequency of missing bait in the buoy experiment in relation to whether a camera trap was fitted or not.

		Buoys without camera traps			Buoys with camera traps		
Buoy specifics		Deployed	Bait missing		Deployed	Bait missing	
Dia (mm)	**Colour**	**Number**	**Number**	**%**	**Number**	**Number**	**%**
68	grey	39	3	8 %	0	0	-
156	red	66	7	11 %	41	7	17 %
156	white	204	37	18 %	93	12	13 %
232	red	73	22	30 %	39	4	10 %
369	red	49	16	33 %	37	6	16 %
		431	**85**	**20 %**	**210**	**29**	**14 %**

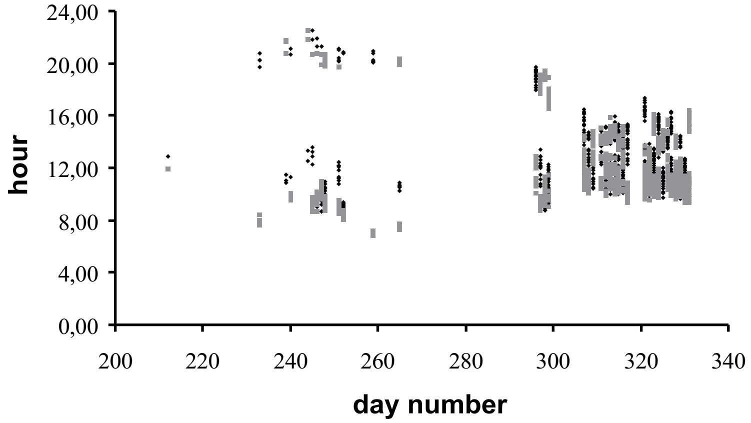
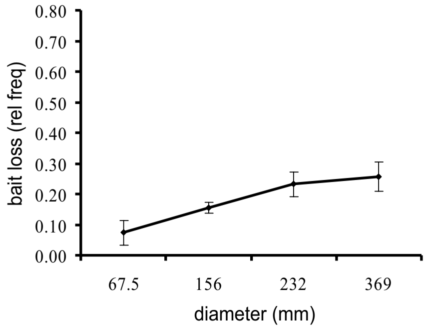


Fig. 5. *Time of day for setting (black) and retrieving (grey) buoys.*



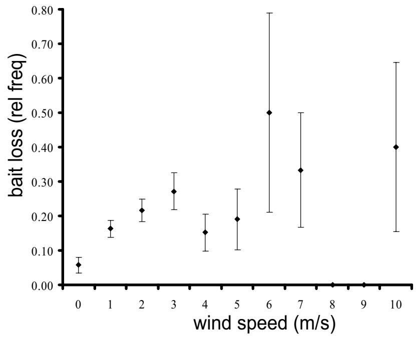


Fig. 6. Relative frequency of missing bait in the buoy experiment in relation to (a) buoy diameter and (b) wind speed (SE indicated by vertical bars).

DISCUSSION

Bait did continuously disappear from the experimental buoys. There was a significant association with both buoy size and prevailing wind speed. Two factors causing bait loss were contemplated; wave action shook the bait loose, or predators like seals or diving birds (cormorants, mergansers) took bait. Since bait loss increased with wind speed, there was probably a wave mediated loss of bait. This was also indicated by the high proportion of bait missing (15 out of 21) from buoys that were left out for a prolonged period (73 h – 78 h) during a storm (the buoys could not be checked for safety reasons; these data were excluded from the main analysis). It could be argued that buoys were more easily spotted by seals when they were lifted by high waves and silhouetted against the horizon, but it seems likely that at least some bait did work loose by the wave action. The wind speed (wave action) did possibly also interact with buoy size, as larger buoys should move with more power than small ones. There were however clear signs of predator interaction at the buoys, bait was continually lost also during light winds, and several camera-traps were triggered by the required sharp jerk at the bait. Very few diving birds were seen in the experimental area, and none near the buoys, making it unlikely that birds removed bait. Grey seals, on the other hand, were depicted on pictures from the camera-traps, and there was a significant association between observations of seals near buoys and bait going missing. It was therefore concluded that an important cause of bait going missing was scavenging by seals.

For seals, fishing gear constitutes a substantial foraging resource. In a study by Königson *et al.* (2007) using pre-baited herring gillnets, 14 out of 19 fishing sets were disturbed by seals. When the nets were lifted, 96% of the marked fish were missing and 5% were damaged. Fjälling (2005) likewise found that 47% of all liftings of set traps for salmonids in the Baltic were seal-disturbed, and that at least 43% of the catch was missing during the seal-disturbed days. The higher frequency of seal visits to fishing gear, compared to the experimental buoys, can be explained by the fact that fishing gear generally is marked with several buoys, and that seals are likely to learn the positions of fixed gear.

Which cues might then have led the seals to the baited buoys? Airborne sounds might theoretically emanate from the buoys riding the waves. However, such sounds could not be heard by the experimenters even at extremely short range, and taking into consideration that human aerial hearing is more acute than that of harbour seals in the low frequency range concerned (Møhl 1968), these sounds ought not to be an important long distance detection cue for seals. The pulley which the anchor line was run through may possibly have caused some mechanical under-water sounds in the heave of the seas and under-water sounds may serve as a cue for seals. Møhl (1964) and Terhune (1974) found harbour seals to have directional hearing. The sounds omitted from the pulley, when operated above water, were faint, however, and could not be heard by human ear at a distance of more than 0.2 m. They ought to have been weak compared to the sounds of the background wave action. Seals are sensitive to sounds well above the human hearing range. Such sounds do however have a short range. The low frequency underwater sounds (Aeolian waves) produced by a single buoy line in the water flow (currents, waves) ought also to be negligible at the prevalent low current speeds (Wahlberg 1999). The smell was probably an insignificant factor in this trial since the buoys were plastic and were continually sea-washed; the odour was found unimportant even in buoys provided with a scent of fish (Beszczyńska 2005).

Based on these arguments, and the positive association between buoy diameter and rate of missing bait, it was deemed likely that the grey seals had used their above water vision to locate the buoys, and had not just come across them by chance during patrolling, or upon moving to profitable areas on the basis of multiple sensory cues. Olfactory cues are however potentially important since it has been demonstrated that harbour seals have the olfactory capacity to orient towards productive feeding areas, and that they spontaneously demonstrate a go-response when exposed to a concentrated fish odour (Kowalewsky *et al.* 2005). Davis *et al.* (1999) found that Weddell seals (*Leptonychotes weddellii*) used their vision when hunting beneath the ice, and Hultgren (2003) found that vision was important in underwater prey detection in harbour seals. These findings suggest that vision is important for seals at short distances underwater. The present results imply that vision may also be important at longer distances above water. Naturally occurring situations where long range visual information from above the water surface could be of importance for foraging seals might include, for example, sea-birds swimming above or circling in the air above aggregations of fish. Thompson *et al.* (1991) observed a grey seal tagged with an ultrasonic transmitter repeatedly feeding below dense assemblies of sea-birds, but did not discuss how the seal navigated there.

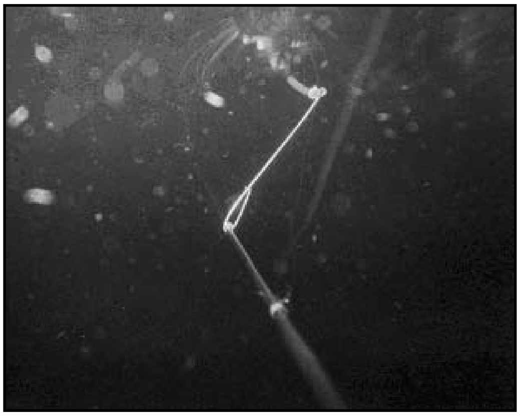


***Fig.** 7. Photo from camera trap; grey seal taking bait (top of picture).*

The lower proportion of bait taken from the camera equipped buoys than the buoys without (*P* = 0.054) was expected since there are previous observations suggesting that animals avoid camera traps (Séquin *et al.* 2003). The low number of seal observations in the Bråviken area is in agreement with what the local fishermen say, and the result that the bait loss did not differ between the areas is in agreement with Söderlind (2004) and Königson *et al.* (2007) who reported intense seal interaction in each area. Why do the seals appear to be less visible in one area than the other? Hunting is known to induce shyness in seals (Ling 1915), but is not known to take place in either area. The difference in the number of seal observations may instead be due to the much higher, and more disturbing, day-time boat traffic in the Bråviken area than in the Skärså area.

There was no significant difference found in the frequency of bait loss in relation to buoy colour (P = 0.67). This was expected since pinnipeds are not able to discriminate between red and grey (Griebel and Schmid 1992). There was however a distinct possibility that the brightness of the different buoys (grey, red and white) would contrast differently against the background, and so affect their visibility. The brightness of the sea is extremely variable, however, from the series of grey targets used by Griebel and Schmid (1997) to test manatees, one gets the impression that the buoys should have contrasted fairly well.

The probability of bait going missing did not increase with time (P = 0.83) as might have been logically expected (due to increased exposure time to possible seal predation and wave action). The ageing of the bait itself was not *a priori* expected to have a negative influence. During a pilot trial to this study, even rotten bait was taken by seals, and in a previous preference study by Lunneryd (2001), the time-related condition of the bait did not markedly affect the consumption rate. The small bait fish used in the present experiment may possibly have decayed more quickly to a non-edible point than the larger fish used in the earlier trials, but we do not consider this a sufficient explanation. A possible cue for the seals finding the buoys might have been the sight or sound of the research boat on the way to check the buoys. Checking buoys was however not done in any special order, *i.e.* in relation to buoy type, and movements between positions were carried out as rapidly as possible to minimize this risk.

All data on wind speed and visibility were from instantaneous readings. Since it was not known when the seals took bait, a direct connection to these data did not exist. Also, the data were obtained from weather stations some distance away from the study areas. However, wind speed and visibility were considered potentially important and were expected to be reasonably stable over intervals of several hours, and were therefore included. Environmental variations may have influenced the seal induced bait loss also in other ways, either through optic conditions (visual range), or through an influence on seal behaviour (activity).

Finally, when considering other factors which might have affected our results, during the last weeks of the field study at Skärså, an independent experiment was carried out that may have influenced the present study. A feeding station close to the study area was set up where seals could freely consume herring. The feeding station was stocked with up to 40 kg per day, and one seal consumed up to 16 kg in one day, confirmed by video recordings. During the last week of the buoy experiment, the seals did not eat much from the feeding station. The bait loss from the buoys during this period was 22 out of 180 (12%), as opposed to the mean 17% in this area, suggesting a drop in the seals' foraging activity.

The findings of this study, that seals do use above-water vision for finding fishing gear, could be used by the fishing industry to reduce the seals-fisheries conflict. Buoys marking fishing gear could be surrounded by decoy buoys not attached to any fishing gear. This would increase the cost for seals hoping to find the nets, and thus decrease the value of the fishing gear as a feeding resource. Alternatively, the buoys could be hidden by submersion until hauling, although this might cause some practical problems and would require a modification of the regulations concerning the marking of fishing gear (Fiskeriverket 1994). More information on the efficiency of the suggested methods and on how seals search out buoys and fishing gear could be gained by means of a new experiment involving both baited buoys and fishing gear. It would then be important to record the explicit environmental factors (wind speed, wave height, visibility, light conditions, etc.) at precisely the time when the bait was taken or the gear visited. This could be accomplished with an electronic recording weather station positioned in the study area, and a timer device with each bait arrangement. Ideally, bait would be dispensed in such a way as to ensure that it was unaffected by wave action. Cameras would be used as in the present trial, but aimed upwards. Seals would then be silhouetted against the bright water surface during the daylight hours, and the cameras would be camouflaged by the dark background of the deep.

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